Ph.d. thesis

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The Megalithic Lunar Season Pointer

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Front figure caption: The lunar-solar “crossover” in spring when the rising Sun is moving north at the horizon and the rising full Moon is opposite, moving south. The picture illustrates the lunar season pointer hypothesis.
The insert shows the sightline through a passage from one passage grave to the next.


Article by Marianna Ridderstad “Tanskan hautakummuilla tähdättiin Kuuhun”. The title sentence means "On the grave mounds of Denmark, one took a sightline towards/aimed at the Moon". The Finnish verb tähdätä literally means 'to take a sightline towards something', but it is also used in the abstract sense of aiming towards a goal (as in this case, achieving the goal of observing the Moon), so there is a kind of wordplay in the title.

The article describes and explains the hypothesis of the use of the lunar “season pointer”.

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Prologue

Since childhood, I have been fascinated by Neolithic times and the abilities of the people who lived during this period. At a meeting at the Danish Heritage in 1996, an archaeologist explained that almost no investigation has been carried out of the orientation and locations of Danish passage graves and dolmens. This presented me with the opportunity to do research in a relatively unknown field in Denmark.

In 2000 I persuaded my supervisor at the time to guide me in pursuing a master's degree in astronomy on the topic of archaeoastronomy, based on fieldwork from an investigation of about 90 passage graves on the island of Zealand in Denmark and Scania, the neighboring area in Sweden. The fieldwork was based on 47 measurements made by me in 2002 and 2003 and 43 measurements made by the Swedish astronomer Curt Roslund in 1991. Earlier work on 55 passage graves located on the northern part of the island of Zealand had been performed by the Danish archaeologist Svend Illum Hansen in 1981, but the magnetic compass measurements were too crude to be used for a statistical test.

My master's degree in astronomy was completed in 2003 and resulted in the hypothesis that certain full Moons could be important to people living during the time of the Funnel Beaker Culture; i.e. the early Neolithic period in the southern part of northern Europe. The full Moon occurring before a lunar eclipse could well have been of interest. The rising full Moon before a lunar eclipse reveals almost the same distribution pattern as do the directions of the passages investigated which are mounted on the Danish passage graves.

This produced a significant statistical outcome, and the result was so interesting that it inspired me and my former supervisor, Per Kjærgård Rasmussen, to dig deeper into the material, do some additional measurements and write a paper about it. This first article was published in 2008. By that time, I had developed the idea of making a doctoral study on the subject and designed a complete PhD project. Unfortunately, the Danish education system was somehow not geared to dealing with this type of project; thus I decided to do it in my spare time and turn the resulting doctoral study in privately as an independent scholar.
The PhD thesis was designed to take form with at least 4 peer-reviewed articles. At its final stage, the article series ended up containing 7 peer-reviewed articles within the same subject and one submitted for the SEAC 2014 proceedings. All together total of 8 papers for the PhD thesis.

An attempt to make an astronomical interpretation of the measurements on the Danish passage graves and compare the obtained distribution pattern to similar distribution patterns from Sweden and Portugal was carried out as the foundation for this PhD hypothesis.

The PhD thesis has the following structure and is divided into two parts. Part one is an introduction to the subject of archaeoastronomy (Chapter 1), work within the field of archaeoastronomy (Chapter 2) and a summary (Chapter 2 and 3) of the articles, which form the fundamental basis of the thesis. The summary also includes the latest data and results, which are not included in the papers but listed in Chapter 2.

Part two contains the seven peer-reviewed papers and one submitted paper, arranged in chronological order according to when the fieldwork was done and discoveries were made. The papers are ordered by Roman numerals and each is followed by a list of errata, if one is necessary.
Resume (resume in Danish)

Ved brug af basale metoder og viden fra astronomi, kombineret med simpel opmålingsteknik, er et datasæt på 163 danske storstensgrave, jættestuer og dysser med gang (også kaldet megalitter), opmålt med hensyn til deres placering og orientering. Datasættet inkluderer 27 storstensgrave fra Skåne i Sydsverige, da de regnes for typologisk identiske med gravene i Danmark. Disse storstensgrave menes at være bygget inden for nogle århundrede omkring 3200 BCE.

Resultatet af dette arbejde har givet ny viden om de danske storstensgrave. De kunne formodentlig have været brugt som landskabsmarkører, da der er intervisibilitet mellem gravene, dvs. at gangens retning peger mod den næste storstensgrav i landskabet. Dette er bl.a. beskrevet i kapitel 2 og de tre første artikler og en senere artikel fra 2014 (paper I, II, III og VII).


En test af modellen mod observationerne gav så overbevisende resultater at den er blevet testet på datasæt fra andre områder i Europa med en lignende retningsfordeling. Kapitel 3 og de to artikler (paper V og VI). I flere af tilfældene lignede resultaterne statistisk hinanden så meget at det kan give anledning til at diskutere resultatet i en mere generel kontekst. Denne kontekst involverer bl.a. en interesse for at orienterer sig mod månen, eller en måne/sol relation (paper VIII) gennem hele perioden med storstensgrave i Europa og tilstødende områder.

Perioden med storstensgrave, megalitter, i Europa regnes fra omkring det femte årtusinde BCE til omkring det andet årtusinde BCE. Udgangspunktet har sandsynligvis været i områderne i det vestlige Frankrig (Bretagne) og det vestlige og centrale område på den Iberiske halvø.
Nøgleord:
Arkæoastronomi, intervisibilitet, fuldmåner, lunar/solar crossover, måne/sol relation, måneformørkelser, storstensgrave, jættestuer og dysser, Tragtstånderkulturen.
Abstract (resume in English)

Using basic methods and knowledge of astronomy, combined with the simple surveying technique, is a data set: of 163 Danish large stone graves, passage tombs i.e. passage graves and dolmens with a passage (also called megalithic monuments), that are measured in terms of their location and orientation. The data set includes 27 passage graves from Skåne (Scania) in southern Sweden; they are considered typological identical with the graves in Denmark. These megalithic tombs are believed to be built within a century, around 3200 BCE.

The result of this work has provided new knowledge about the Danish megalithic monuments. They could probably have been used as landscape markers, as there is intervisibilitet between the graves; i.e. that the passage direction of one grave is pointing towards the next grave in the landscape. These features are described in Chapter 2, the first three articles and a later article published in 2015 (paper I, II, III and VII).

The distributions of passage directions were also the basis for developing a more general hypothesis concerning the orientation of megalithic monuments. Directions are concentrated in the east, east-southeast and southeast. This orientation points to specific full moons during the summer period. Therefore the test model is called the 'lunar season pointer' as described, inter alia in Chapters 3 and the fourth article (paper IV). Something very central are the rising points of the full moons, at the horizon concentrate around a few specific Southern directions and by this divide the summer in seasons. Something similar applies to the winter season, similar but in the Northern directions.

By testing, the observations against the data provided by the model, the result was convincing that it have been tested on data sets from other regions in Europe. Data sets with a similar orientation and distribution. Chapter 3 and the two articles (paper V and VI). Several of the cases resembled the statistical results statistically so much so, that it may give rise to discuss the outcome in a more general context. This context involves, inter alia, an interest oriented towards the moon, or a moon/ sun relationship (paper VIII) throughout the period with megalithic monuments in Europe and adjacent areas.
From about the fifth millennium BCE to about the second millennium BCE is the period of megalithic monuments in Europe counted. The origin of these monuments is speculated to be an area in western France in Brittany; and the western and central area of the Iberian Peninsula.

keywords:
Archaeoastronomy, intervisibility, full moons, lunar/solar crossover, moon/sun relationship, lunar eclipses, megalithic monuments, passage graves and dolmens, Funnel Beaker Culture.
Part One

Introduction to the subject and a summary of the PhD hypothesis
Introduction

The idea of this PhD project is to test a hypothesis concerning the behavior of the rising full Moon at the horizon on data showing the orientation and location of ancient monuments belonging to the prehistoric period in different parts of Europe where data are accessible.

The type of monuments known as megalithic monuments (from Greek: megalithos = big stone) are the subject of further investigation in this doctoral study. More precisely, it is the sub-type of megalithic monuments known as passage tombs, i.e. passage graves and dolmens with a passage, which are in focus. These monuments were built by the growing farming culture in Europe. In the Northern parts of Europe this culture is called the Funnel Beaker Culture (about 4000 BCE to 2800 BCE), inspired by the shape of the ceramics they manufactured (see Figs 0.1 and 0.2). It is hoped that this project can give a new insight into how Neolithic man was able to use astronomical phenomena in agricultural life.

Figure 0.1

The approximate area covered by the Funnel Beaker Culture, about 3500 BCE. Note the central position of the Danish island of Zealand (lower circle). Enclosed in the upper circle is the Swedish Falbygden area. Here, about 70% of all known passage graves in Sweden are concentrated.

Megalithic monuments are mostly constructions ranging in time from the Neolithic period to the early Bronze Age, located in Europe and the surrounding regions. They were built over a wide
timespan, ranging from about the fifth millennium BCE, probably starting in southwest Europe, to about the third millennium BCE in the southern parts of northern Europe (see Figure 3).

Figure 0.2
The Skarpsalling karret is one of the most beautiful examples of funnel beaker ceramics manufactured in Denmark at about 3200 BCE. This is approximately the same time that the passage graves were constructed in Denmark. Funnel beaker ceramics are the most advanced ceramics ever made in Neolithic times in the actual area shown in Figure 1.

Figure 0.3
The distribution of megalithic architecture in Western Europe at approximately 3000 BCE. Note that the position of Malta, just south of Sicily, is difficult to recognize, i.e. the position of the big megalithic temples on Malta.
It was not uncommon to use stone blocks of a huge size in constructing megalithic monuments. In Denmark, stone blocks with a weight up to 25 tons have been registered as utilized in the megalithic monuments (see Figure 4) and in Bretagne (Brittany) in France, a stone block monolith, a *menhir*, with a weight of about 150 tons was erected and still stands (see Figure 5). A *menhir* (from French) is defined as a “tall, upright, standing stone”.

![Figure 0.4](image)

This Danish dolmen is dated to the time around the fourth to the third millennium BCE. The large capstone on the cairn is about 270 cm long x 200 cm wide x 95 cm thick. The estimated weight of the capstone is about 15 tons. The dolmen is located at Ulstrup close to the town of Næstved in the south-western part of the Danish island of Zeeland.
Figure 0.5
Huge stone block monolith from Brittany, “Menhir du Champ Dolent”. The *menhir*, or upright, standing stone of Champ Dolent is the largest standing stone in Brittany. It is located in a field outside the town of Dol-de-Bretagne, and is nearly 10 meters high. Claus Clausen (1.83 meters) is standing beside the *menhir* to illustrate its size. The stone was taken from a site 4 kilometers away and the weight is estimated to about 150 tons. This *menhir* was probably erected in the third millennium BCE.
An even larger stone block has been registered in France with a weight up to 350 tons, but the positioning of this monolith seems to have failed just after its erection (see Figure 6). “La Grand Menhir Brise” is located in Locmariquer, Morbihan, Brittany. It is unknown how Neolithic man was able to handle these huge stone blocks, but if they began working with these stone blocks they must have had some idea of how to move them from one place to another.

In Denmark, evidence has been found of knowledge of how to use a crane\(^1\), an A frame crane and exchange gear techniques from about 3300 BCE (see Figure 7). Additional techniques must have been used: for example ramps, levers, etc. At the present time this is not known for certain, but archaeological evidence exists which could support this idea\(^2\). With the use of techniques such as these, it was possible for Neolithic man in Denmark to build megalithic monuments of considerable size, with chambers comparable in their expanse to, for example, the chamber in the giant Irish passage tomb, Newgrange (see Figure 8). Unfortunately, such large megalithic monuments are rare in Denmark due to the destruction of many of the monuments in order to reuse the stone blocks in later constructions such as churches and castles.

\(^1\) The Danish Culture Agency accessed December 2014 at http://www.kulturstyrelsen.dk/kulturav/fortidsminder/kulturav-arkaeologiske-strategier/yngre-stenalder/grave/

\(^2\) The Danish Culture Agency accessed December 2014 at http://www.kulturstyrelsen.dk/kulturav/fortidsminder/monumenter-i-landskabet/storstensgrave/
Figure 0.6
“La Grand Menhir Brise” divided into four parts. Its original maximum weight is estimated to an upper limit of about 355 tons and, in an erect position, it would have been about 20 meters tall. The menhir is located at Locmariaquer in the Morbihan area of Brittany. The remains shown on the photo have an estimated weight of about 300 tons.

Figure 0.7
A stylized drawing of an A-frame with exchange gear techniques proposed for use in moving huge capstone blocks and placing them in the correct position upon the megalithic structure under construction. Note that the force in Newton which is put into this machinery is multiplied more than ten times. That means that if you can push 50 kilograms with raw manpower, the A frame construction and its waist shown here can give the increased leverage necessary for a lift of 600 kilograms. With the use of an A-frame construction which could be operated by 30 to 40 men, it should have been possible to handle stone blocks with a weight of up to 24 tons.
Figure 0.8
The ground plan or layout for a twin passage grave (lower panel) named “Drysagerdys”, located at the northern central area of the Danish island of Zeeland at Dalby (Krogstrup parish). The chamber is approximately 24 meters in length and 2 meters wide. The two passages are oriented towards the east. By comparison, the cross-formed chamber in Newgrange (upper panel) is approximately 8 meters long at its maximum length and the length of the perpendicular "arms" or side chambers put together is approximately 6 meters. The chamber is attached to a nearly 20-meter long passage oriented toward the southeast.

Megalithic monuments are found at other places all around the world, but the oldest, the highest and the densest concentration is found in Europe – especially in Western Europe.

It has been known for many years that there the passage tombs show an orientation preference for the azimuth quadrant between east and south around southeast. The main hypothesis so far has been that the orientation was based on the Sun (Hoskin, 2001 or Hoskin, 2009 at pp. 168 - 171). However, is it possible that a hypothesis about the Moon could be an alternative?

1) First, we must realize that perhaps in Neolithic times, the logic was not the same as that which we have today. They were, for example, not able to see whether a full Moon was the genuine,
100 per cent full Moon, calculated as we in our time can do it, precisely to the day (See Clausen, SEAC proceedings 2011).

In the following, the term “full Moon” describes a four- to five-day event, which is precisely one of the problems with astronomical interpretations made in past decades. For instance, we do not know when ancient man decided that the full Moon was the proper full Moon (Clausen, SEAC proceedings 2013 at p. 146). This leads us directly to the term: natural definitions. The length of a day was counted from Sunrise to Sunset, but when exactly did human beings during Neolithic times determine the Sun had risen or set? From the top, center or bottom of the solar disk? The same argument applies to the Moon. Local traditions could play a central role in this case. Taken together, these considerations mean that we will have to take into account fluent limits on the variables of interests, which interact in the following way:

The phases of the Moon influence the rising and setting times; these in turn will have influence on the rising and setting azimuths. Uncertainty concerning the rising and setting conditions on a specific day will also have influence on the azimuths.

2) Second, we have, as far as we know until now, no written sources which can tell us the meaning, ideas and thinking behind the megalithic monuments. The only data we have access to is the position and orientation in the landscape and, sometimes, rock carvings. We have, of course, some idea that the monuments had something to do with death and beliefs. In the case of rock carvings, we know that special symbols carved into the stones appear now and then, and that some of these symbols could be related to the Sun, the Moon, the planets or the stars.

However, most important is probably the orientation pattern of the passages of the megalithic monuments. If, for example, the orientation patterns change for megalithic monuments in a certain area, it may indicate a change in culture, belief system, or even that a new population has arrived in the specific area (Belmonte and González-García, SEAC proceedings 2013).

This means that what we can do in this matter is to investigate the orientation patterns and compare them with models in a statistical way related to the number of monuments. In Western Europe the number of megalithic monuments can be counted in thousands of units, and if we are able to interpret the meaning of the orientation patterns, we have the opportunity to discover what kind of ancient worldview the orientation patterns represent.
Chapter 1
A status of archaeoastronomy in its European context

1.0 Background
The main idea of the discipline of archaeoastronomy is to combine the two topics: astronomy and archaeology. In this way archaeoastronomy becomes an interdisciplinary discipline or topic.

The ideal archaeoastronomer would be a person with a MA in both astronomy and archaeology. This is still rare, but a handful of persons fulfill this criterion. If you can master both disciplines, you become familiar with two traditions of scientific method. As an archaeoastronomer you will probably be more aware of typological identical units or formations spread out over a wide area in both distance and timespan (Furholt and Müller, 2011) and therefore be equipped to consider possible astronomical or topographical explanations for a phenomenon. The latter term, topography, belongs to the discipline of archaetopography, where landscape formations play a central role in explaining ancient remains which are to be observed.

Archaeoastronomy today is part of a much more general field known as cultural astronomy, which includes such disciplines as astronomy, archaeology, anthropology, astrology, history, the study of ancient languages, church science and more.

In recent years, it has become more common to work internationally in an interdisciplinary or intercultural fashion in the fields of both scientific and humanistic subjects. This method sometimes gives birth to completely new ways of seeing things and making connections. For example, you can combine astronomy, history, archaeology and genetics and in this way reveal the familial relationships between the Egyptian pharaohs, thus most likely providing a new view of factual history (Belmonte, 2012 SEAC proceedings). This, of course, is only possible when using written sources. Intercultural cooperation is in a strong phase of development and, unfortunately, Denmark is only weakly represented in the field of cultural astronomy.

1.1 Brief history
The first one to use archaeoastronomical methods to determine the age of an ancient construction was probably the English astronomer Sir John Frederick William Herschel (1792–1871). Herschel tried to figure out the age of the Cheops pyramid based on astronomical observations
and calculations. The pyramid’s entrance corridor points at a spot on the northern hemisphere’s night sky which is very close to the point corresponding to the geographical North Pole. Herschel guessed that the Egyptians had aimed towards the star called Alpha Draconis ("Dragon's Heart") also known as Thuban in Egyptian mythology (Clausen, 1997 and Rantzau, 1972).

With knowledge of precession (the 26,000 year period of the Earth’s rotational axis), it is possible to turn the starry sky backwards in time until the selected star on the precession circle is in the desired position. However, there are always two solutions to the problem; one when the star is approaching the polar center in the sky, and another when the star moves away from that point again. The two solutions found by John Herchel for Alpha Draconis put this star in the desired position in 2160 BCE and in 3400 BCE. The accepted age of the Cheops pyramid today is about 4500 years, that is, it stems from around 2500 BCE.

The English astronomer and astrophysicist Sir Norman Lockyer (1836–1920) became aware during a trip to Greece in 1890 that a number of the classic temples were oriented towards the point where the Sun sets at the horizon. Lockyer is also known for his discovery of the element helium in the solar spectrum and as the founder of the journal, *Nature* (1869). In 1906 Lockyer published an article in *The Times*, based on (Lockyer, 1906), which, for the first time, brought the subject of Stonehenge into public discussion. Norman Lockyer was also the first to make large-scale implementation studies of prehistoric stone installations; unfortunately, he was over imaginative with his interpretations, and was therefore not taken seriously by his contemporaries. Thus, the "thread" in Lockyer's work was not taken up until many years later.

In 1963, the English astronomer Gerald Hawkins (1928 - 2003) published an article on Stonehenge in *Nature* (Hawkins, 1963), and in the following years he published a series of articles in various journals dealing with subtopics within archaeoastronomy. The one most mentioned is "Stonehenge Decoded". Hawkins’ notable result in this context was a possible interpretation of the application of Stonehenge. In brief, he had the idea that those who built Stonehenge had mapped the movements of the Sun and the Moon along the horizon so precisely that it was possible to predict lunar eclipses – and perhaps even solar ones.

The English astronomer Sir Fred Hoyle (1915–2001) has also worked with Stonehenge. He treats the subject in an article in *Nature* in 1966 (Hoyle, 1966). Hoyle’s ideas are quite controversial.
and rather unlikely. In his opinion, the so-called Aubrey circuit with 56 holes that surrounds the stone structure in Stonehenge is a model of the ecliptic. If this is so, it would have been possible for the Stonehenge people to follow both the intersections (nodes) of the Moon as its pitch reached the plane of the ecliptic. Hoyle has therefore stated that “it would be ironic to think that the invisible knot [the one that does not cause an eclipse] has inspired the idea of a hidden god, a hidden god who is the guiding force behind everything, and thus could be the basis for the oneness of God, monotheism (who is worshiped in Christianity and by Muslims) to be of astronomical origin.” (Free quoted). Hoyle has been heavily criticized for this hypothesis, especially by religious historians (Nilson, 1969 at p. 21).

Other researchers, like Hoyle, have perhaps also moved out onto "deep water" – this includes the English professor and BSc (with a special distinction in Engineering) Alexander Tohm, known for the discovery of the "megalithic yard", hereafter “my”, (Thom, 1971 at p. 43). The "my" is a length of 83.5 cm, ostensibly used repeatedly in many stone structures from megalithic period (about 5000 BCE to about 2800 BCE) within the Neolithic period, in both the British Isles and on the European mainland. Thom got the idea that people during the megalithic period used the magic of numbers in their culture. In some stone structures in which there are several concentric circles (or ellipses) with growing perimeters, which is always represented by an integer, so that from one "circle" perimeter to the next perimeter can always be shared with figures from the series of numbers, doubling numbers as : 2.5 ; 5; 10; 20, well-marked if we use the “my” as unit. It appears obvious that a sequence of digits using a doubling of numbers is used in the case of several concentric ellipses, for example in "Woodhenge", just north of Stonehenge, where the ellipses have circumferences with the values: 40 "my", 60 "my", 80 "my", 100 "my", 140 "my" and 160 "my". One finds that an ellipse with the circumference 60 "my" corresponds to the series of numbers 3 (x 20), 6 (x 10), 12 (x 5) and 24 (x 2.5); and that an ellipse with the circumference 160 "my" corresponds to the series of numbers 8, 16, 32 and 64. The approximately 500 stone circles that Tohm examined in the British Isles can be divided into classes of different shapes, for example: circles; flattened circles; composite circles; egg-shaped and more. The reason for this could be that the Neolithic people from the megalithic period in the British Isles sought an integer relationship between the circumference of a circle or similar forms (such as ellipses) and their diameters. That is, they were looking for something that corresponds to the circle constant; \( \pi \). Such thoughts have been strongly criticized by many researchers; thus giving archaeoastronomy a weak and bad reputation for quite a few years.
A breakthrough for the discipline probably stems from the time when organizations that devoted their work to archaeoastronomy were founded. One example is the Center for Archaeoastronomy, a professional research organization founded at the University of Maryland in 1978. The center later helped to establish ISAAC, the International Society for Archaeoastronomy and Astronomy in Culture in 1996, to promote the academic development of archaeoastronomy and ethnoastronomy around the world.

The latter was inspired by SEAC, the European Society for Astronomy in Culture. SEAC does not have a physical seat, and the Executive Committee (EC) represents the Society. The Society was founded in Strasbourg, France, in 1992, under the inspiration of the late Professor Carlos Jaschek, and had its inaugural meeting in Smolyan, Bulgaria, in the summer of 1993.

In the 1990s, comprehensive field work was done in the Mediterranean by the English astronomer Michael Hoskin and the Spanish astronomer Juan Antoni Belmonte. Likewise, the English astronomer and archaeologist Clive Ruggles did comprehensive work in the British Isles. Clive Ruggles is regarded as one of the leading figures in the field of archaeoastronomy.

The work of Hoskin, Belmonte and their colleagues was published in Archaeoastronomy: The Journal of Astronomy in Culture and later in the Journal for the History of Astronomy. The main conclusion of this work is that most megalithic monuments in Western Europe are oriented towards the Sunrise pointing towards east to southeast and climbing at the southern parts at the horizon. This is known as the Sunrise/Sun-climbing (Sun-culmination) theory, SR/SC (see, for example, (Hoskin, 1998) at p. S86 - S87, (Hoskin, 2001) and (Hoskin, 2009) at p. 168 -171).

In addition to the different organizations and published work in journals, the internet has become more and more important, with different websites dealing with archaeoastronomy and megalithic monuments. Worthy of mention is the Megalithic Portal, a database founded in 1997 and active as a website since 2001.

The discovery of the Nebra sky disk close to Mittelberg some 60 km west of Leipzig, Germany, in 1999 (See Figure 1.1), dated to the early Bronze age (1600 BCE), was not known by the public until 2001. Great efforts and much money have been used to interpret the meaning of the symbols on the disk. Since the Nebra Sky Disk (also known as the Nebra Sun Disk) emerged into public knowledge, archaeologists and astronomers have put forward their theories about
how it worked and what it meant to the ancient society that fabricated it. The general opinion is that the symbols on the disk are related to the Moon, the Sun and Moon, the stars and perhaps the Pleiades and the extreme points of the Sun. But what do we really know? Michael Rappenglück (current president of SEAC) argued in a scientific talk (“Fire from the heavens”) at the SEAC 2014 conference for another view on the disk. His conclusion is that we in fact do not know what the idea is with the Nebra sky disk. This just emphasizes the fact that we cannot be sure of finding the right interpretation of archaeological artefacts from ancient times. This is a key point in astronomy in culture, in this case, more precisely, in archaeoastronomy.

Figure 1.1
The Nebra sky disk. It is possible that the large symbols from the left are Moon/Sun, crescent Moon and the angle between the Sun’s extreme points (standstill points) at the eastern horizon. The big symbol at the bottom; the “Sun boat”, the smaller symbol; stars, and the cluster of seven smaller symbols close to the center at the top could be the Pleiades. But might it not also be a human (happy, smiling) face?

1.2 Present work in the field of archaeoastronomy
Today it is common to hold annual conferences, seminars, workshops, etc. in the field of astronomy in culture. Conferences often result in conference proceedings containing about 20 to 30 peer-reviewed papers. The topics of archaeoastronomy and astronomy in culture are internationally comparable with the topic of cosmology and, as such, are accepted scientific and humanistic disciplines.
Concerning the work with megalithic monuments, new methodologies are being developed and new statistical methods have emerged (see e.g. González-García, 2009 or González-García and Belmonte, 2010).

Examples of new measuring techniques would include the use of aerial photos (orthophotos) or satellite surveys (Magli, 2010). Google-Earth can be a useful tool in this connection. Magnetic surveys (Smekalova et. al., 2008) of the ground can reveal the presence of stone blocks in the ground which are remains of a megalithic monument; further, imprints of removed stone blocks can give an idea of the layout of a missing monument. Also, the development of models which can animate astronomical phenomena at the horizon is in progress. In this way it is, for example, possible to test an imaginary use of the Stonehenge complex.

Megalithic monuments easily lend themselves to statistical testing and research on model hypotheses due to the enormous numbers of units in Western Europe and neighboring areas. In Denmark alone, around 5000 megalithic monuments are preserved. Of these, about 700 are of the passage grave type.

In recent years more focus has been on the behavior of the Moon, i.e. the full Moon or the crescent Moon, in connection with megalithic monuments – especially in Europe. Statistical results indicate that a lunar explanation rather than a solar one could be favored in the case of megalithic monuments. The Moon has a more complex movement at the horizon than the Sun, which could be the reason that the Sun has been the primary object dealt with in past years. This is probably also because in present times, we find it more logical to turn to the Sun, for example, for calendar use. The problem, however, is that we have no knowledge whatsoever about what man in Neolithic times thought about what was logical or illogical.

The new way of working has also revealed that passage tombs and other megalithic monuments from later periods in antiquity, for example the pyramids in Egypt, are linked in linear relationships (Magli, 2010). See Figure 1.2 for example. The interpretation is not always astronomical, but rather archaeotopographical. Commonly, tomb orientations towards a local mountain or hill which could have a significant meaning in relation to local belief systems are found (examples: Clausen, 2012; Fabio Silva, 2012; Prendergast, 2006 and 2007).
A general picture seems to be that line relations/sight lines/alignments were very important for prehistoric Neolithic man in Europe and later in antiquity as e.g. for the Egyptians. In details, it is interesting that clusters of passage tombs both in Denmark (Clausen, 2012) and in Ireland (Prendergast, 2006 and 2007) are linked together as the group G and S pyramids highlighted on Figure 1.2.

Figure 1.2
A satellite image of the Memphite area. Lines connecting the Giza pyramids of Khufu (G1), Khafre (G2) and Menkaure (G3) respectively with the Userkaf (S1), Djoser (S2) and Unas (S3) pyramids in Saqqara are shown with red color. Following the alignment line (yellow arrow) of the three Giza pyramids in the northeastern direction, it crosses the Heliopolis area in today’s Cairo, which should be the position of the original ancient Heliopolis.

In spite of the great number of megalithic monuments in Denmark, very little research has been done in this field. In recent years, very few works have been published concerning the placement and orientation of Danish megalithic monuments. Worthy of mention are work done by Niles H. Andersen (Eriksen and Andersen, 2014) and Claus Nybo, who received an MA in 2009 in the field of Danish passage graves. His MA project report was entitled "Heaven’s Gate". He measured about 400 passage graves, but unfortunately, he never made his work available to the public by publishing it. Hopefully, this PhD project will help to focus more attention on the subject in the near future, so that Denmark can be more strongly represented internationally and in cooperative projects.
Chapter 2
Working in the field of archaeoastronomy with megalithic monuments

2.0 Setting the scene
If we surmise that man during the Neolithic Age had a Sun- or Moon-cult, then it is these two celestial bodies which initially should hold our interest. For example, the change in the tilt of the Earth's axis of rotation (ecliptic tilt) over time means that the rising and setting points of both the Sun and the Moon on the horizon move slightly in relation to the equinox point. In particular, the extreme or standstill points (the points where movement along the horizon reverses) are sensitive to changes in the ecliptic tilt – denoted as $\varepsilon(t)$. The annual migration of the Sun’s rising and setting points along the horizon is due to the Earth's rotation axis movement relative to the plane of the planets (the ecliptic plane).

The geometrical effect is therefore that the Earth’s rotation axis changes direction corresponding to the known seasons during one revolution, in its orbit around the Sun. Which equals one solar year.

Similarly, monthly changes in the Moon’s rising and setting points on the horizon occur because the Moon orbits the Earth. Here, the situation is just a little bit more complicated. The distance between the Earth and the Moon varies because the Moon's orbit around the Earth is elliptical and has an inclination towards the ecliptic plane, and the Moon’s own orbit revolves with a cycle of 18.61 years, the lunar cycle. Likewise, the distance between Earth and the Sun varies because the Earth’s orbit is also elliptic and revolves with a long-term period of about 100,000 years, but the combined effect in this case is negligible. Changes in landscape conditions can cause the observed horizon line to move with time. This is also counted as negligible for the actual period of time (around 3300 BCE). Both the rising azimuths of the Moon and the Sun are discussed and illustrated in Clausen et al. (2008).\(^3\)

\(^3\) (Clausen et al., 2008) at pp. 222 - 224
In this context, the astronomical basis for consideration of the relevant issues is fairly simple. In the following, the theoretical basis and the properties which are believed to be relevant to the issue are discussed.

2.1 The astronomical approach

The astronomical approach is, as mentioned, relatively simple. One must deal with spherical trigonometry, using translation formulas from a geocentric system, geographical coordinates, to a horizon system (i.e. a topocentric system), where the observer is at the origo, the center of the observer’s system, or vice versa (Figure 2.0). One must be familiar with Newton’s second law concerning the planets and lunar motion in the solar system. Terms such as: azimuth (az), declination (δ) and altitude (h) (Figure 2.0); refraction at the observers’ horizon (Figure 2.1); apparent horizon (ha); parallaxes (Figure 2.2); plane of the ecliptic; tilt of the ecliptic, precession (Figure 2.3); standstill points or extreme points (Figure 2.4a and Figure 2.4b); vernal equinox (Figure 2.5); delta T (Figure 2.6); nodes; inclination (i); eclipses (Figure 2.7); and proper motions of the stars must be well-known properties.4

Figure 2.0

Left panel is the observer’s position in a topocentric horizon system where the azimuth is of interest. Right panel is the observer’s position in a geocentric system where the declination is of interest (marked with red), counted as the perpendicular distance from the celestial equator (the extension of the Earth equatorial plan into the sky).

4 The astronomical approach is treated in greater detail in Claus Clausen’s master thesis (Clausen, C., 2003: “Speciale i arkæoastronomi: En undersøgelse af danske jættestuers orientering på Sjælland mellem 55,5° og 56° nordlig bredde”, Astronomisk Observatorium, Københavns Universitet).
Figure 2.1
Left panel show the setting sun on the horizon. Note that that the sun disk is ellipsoidal in its shape. This is the effect of refraction, which affect the lower part of the sun disk more than the upper part. The lower part is lifted up – so to speak. The right panel show geometrical how refraction works. Refraction affects all types of celestial bodies rising on the horizon.

Figure 2.2
The size of the lunar parallax (P) is depending on the Moons position on the sky. When the Moon is at the horizon, the maximum parallax is obtained. This is the horizontal parallax (HP). The value of HP is about one degree to the right along the horizon. The solar parallax is negligible. Note that distance between Earth and Moon is not in scale.
Figure 2.3
Left panel show the position of the Earth in the plane of ecliptic at the four seasons. Note the direction of Earth’s axis of rotation. Right panel show the tilt of ecliptic $\varepsilon(t) = 23.5^\circ$, i.e. the tilt of Earth’s axis of rotation. The rotation axis has a precession of 26,000 years and the effect is that during this period the seasons will reverse i.e. winter turns into summer and then back again. The $\varepsilon(t)$ vary slightly with time within a few degrees.
2.4 a
The lunar and solar standstill or extreme points according to the compass direction. At the eastern horizon (right) we have, beginning from North, northern major standstill, summer solstice, northern minor standstill, southern minor standstill, winter solstice and southern major standstill. The maximum range of the rising and setting point of the Moon and the Sun on the horizon depends of the geographical latitude.

Fig 2.4 b
The figure shows the azimuth rising pattern for the Sun (upper histogram) and the Moon (lower histogram) calculated for 3300 BCE at latitude 56°N for 1°-bin size intervals.
The variables or properties to be measured are:

The azimuth (az), measured as the direction of the passage seen from inside the passage grave chamber through the passage and out towards a point at the horizon. The direction in which the passage points is assumed to represent a sightline. The az direction is determined as the best straight line through the passage (see Figure 2.0, Figure 2.4 a and subsection 2.2 for method).

The horizon altitude (ha), as seen from the observer’s point of view (also called the apparent horizon), is measured if possible. In most cases, this was not possible. The apparent horizon can be influenced by hills, woods, mountains etc. Note here that the astronomical horizon is equal to the altitude h = 0 (see Figure 2.0), which is the value used in the application for calculations. Measuring 27 different values for ha gave a mean value of about 0.8°. Running computer azimuth tests with different values of ha (0°, 0.38°, 0.5° and 0.8°) shows that if ha < 1.0° the effect on the azimuth is negligible except for the extreme points, and that setting h at zero is a fairly good approximation for the purpose (Clausen, 2015A, pp. 131), i.e. it does not affect the distribution significant (except for the northernmost and southernmost extreme points).

The altitude above sea level measured in meters, which has an influence on the observed ha. This value is only interesting in understanding the use of the landscape – that is, in the case of a local cluster of passage graves placed on the highest local point/hill.

The geographical coordinates in the local UTM zone 32 grid (coordinates in meters) which can be transformed to spherical geographical coordinates (φ for latitude and λ for longitude) or vice versa, by the use of the program application Valdemar.5

Astronomers, by tradition, normally use geographical coordinates for a given position and archaeologists use UTM coordinates. In the field of archaeoastronomy you have to use both.

From the abovementioned properties (az, h and φ), the declination δ is deduced from following relation:

5 Accessed March 2015 at http://valdemar.kms.dk/trf/
\[
\cos(az) = \frac{\sin(\delta) - \sin(\varphi) \cdot \sin(h)}{\cos(\varphi) \cdot \cos(h)}
\]

The horizon altitude \( h \) and the apparent horizon altitude \( h_a \) combine as follows:

The observers horizon \( h_{obs} = h + r + q_{\text{max}} - P - h_a = 0 \) (which is always the case), where \( r \) is the refraction, \( q_{\text{max}} \) is the angular radius of the celestial body in focus and \( P \) is the parallax.

![Diagram of celestial equator and ecliptic](image)

Fig. 2.5

Vernal equinox is the intersection between the ecliptic plane and the celestial equator plane at spring. The sun rises at this point on the observer’s horizon normally the 20 March or the 21 March due East.\(^6\)

Normally it is the declinations that are tabulated in pure astronomical papers rather than the azimuth.

The sightlines between the megalithic monuments, also referred to as the “alignment azimuth” (Clausen et al., 2008), can be deduced from the UTM coordinates. Sometimes a photo taken through the passage from inside and out can verify the sightline. In the case of obscured sightlines, Google Earth\(^7\) can be a helpful tool as you can see structures from above (recall


\(^7\) Accessed March 2015 at [https://www.google.com/Earth/](https://www.google.com/Earth/)
Figure 1.2). A relatively new and extraordinarily powerful tool in this connection is an on-line program application developed for the Danish Environmental Portal\(^8\) for combining orthophotos\(^9\) and the positions of different items on the surface with a precision of better than 0.1 meter. In this work, the value of one (1) meter is used as the precision limit.

A special problem or challenge, however, is known as the \(\text{delta T}\) problem concerning time. The \(\text{delta T}\) has been of interest during the last decades for increasing the accuracy of program applications, which calculate the position of heavenly bodies on the sky backward or forward in time. The Earth’s rotation was faster in the past and has slowed down by now with an observed \(\text{delta T}\) value increasing about half a second pr. year.\(^10\) The reason for this slower and slower rotation is mainly caused by the tidal effect exerted by Moon. The Moon simply slows down the Earth’s rotation gradually. Many studies have been carried out concerning this, but the precise behavior or effect in times past is not precisely known. The effect of \(\text{delta T}\) is seen on positions along the longitude of the planet. It does not affect the common rising or setting patterns of the Sun or the Moon (planets and stars), but the effect of \(\text{delta T}\) is limited in time and to longitudinal positions. Time dependent phenomena such as eclipses and lunar eclipses are very sensitive to variations in \(\text{delta T}\).

Correction for \(\text{delta T}\) can be done by either adding an approximate expression algorithm to the calculation application or using the program application itself, with access to an ephemerides table (e.g. NASA, JPL lunar ephemerides\(^11\), \(^12\)). A third possibility is that the program algorithm can generate a theoretical \(\text{delta T}\) depending on the theory used. The latter method is used here corrected by an approximate expression (the blue curve in Figure 2.6). An approximate expression for \(\text{delta T}\) can be deduced from historical eclipses (Stephenson, 2003) and (Clausen

\(^8\) Accessed March 2015 at http://arealinformation.miljoportal.dk/distribution/

\(^9\) Precision photo with high resolution, orientated according to the geographical North Pole (upward).


et al., 2008) back to about 700 BCE. A value of delta T from a historical eclipse 136 BCE is about 12000 seconds (Stephenson, 2003) Unfortunately, we must deal with a time gap of about 3000 years during which we have no observed ephemerides (positions of astronomical objects) and therefore no information about delta T. In Neolithic times (3300 BCE), we deal an uncertainty of about +/- 5h or +/- 18000 seconds i.e. +/- 75⁰ along the longitude.

Fig. 2.6
Parabolic approximations for delta T. The y-axis is delta T in seconds and the x-axis are centuries from present time to the past (positive value) and in to the future, e.g. 10 = 1000 AD. The blue curve is very close to delta T values deduced from historical eclipses (Stephenson, 2003). The grey and black curves are my own experiments with very simple parabolic expressions. Red curve is based on an expression from calculating programme Manefrom.exe (see subsection 3.3).

Delta T is the accumulation of all the small variations in Earth rotation from day to day. Therefore an expression for delta T must at a first approximation have a parabolic form as aΔt²+bΔt+c. Where Δt is the small variations, which can contribute positive or negative, either calculated from day to day, from year to year or from century to century. The constants a, b and

13 (Clausen et al., 2008) at pp. 225–226
c are the adjustment parameters to make the best fit compared to observed values of \textbf{delta T} (see Figure 2.6).

The blue curve in Figure 2.6 has following expression:

\[ 26.6 \cdot T^2 + 100 \cdot T + 102 = 71694.4 \text{ seconds} = 19.92 \text{h for 3300 BCE} \]

Where \( T \) is counted in centuries and the constants are empirical determined.

Besides the tidal effect of the Moon a reverse is the effect of e.g. an Earthquake, which can speed up the rotation of Earth. As an example it is worth to mention the Earthquake in the Indian Ocean in 2004 and the following tsunami. Earth rotation was speeded up and the length of the day was shortened with about three microseconds.\textsuperscript{14}

We have to understand the \textbf{delta T} in two ways:

1) As the position along the longitude. Which means that values of \textbf{delta T} in this context only can vary between 0\(^\circ\) and 360\(^\circ\) equalizing 0h to 24h i.e. 0h = 24h, 1h = 25h and so on.

2) As the time difference between DT (dynamical time) and UT (universal time) which is a theoretical uniform time scale there more and less equals the mean solar time (one day exactly = 24h). \textbf{Delta T} = DT − UT. In this context, a \textbf{delta T} value of 25h real is a time difference of 25h i.e. the DT is 25h ahead of UT and in a calendar sense e.g. a Monday turns into a Tuesday. In other words, the event of interest took place one day later than we would expect according to our calendar.

\textsuperscript{14} Accessed March 2015 at \url{http://www.nature.com/news/2004/041229/full/news041229-6.html}
Figure 2.7

Left panel show the inclination of the lunar orbit plane relative to the ecliptic plane. The inclination $i = 5^\circ$. At major lunar standstill $\delta_{\text{Moon}} = -5^\circ - 23.5^\circ = -28.5^\circ$ and at minor lunar standstill $\delta_{\text{Moon}} = +5^\circ - 23.5^\circ = -18.5^\circ$. The variation in $\delta_{\text{Moon}}$ is within the 18.61-year lunar cycle. The intersection points between the lunar orbit plane and the ecliptic plane is called the nodes. Right panel show the line of nodes. If the line of nodes is in the right position, an eclipse and a lunar eclipse can occur. During one solar year, it is possible to have at maximum of five eclipses and three lunar eclipses.

As mentioned earlier delta $T$ can be deduced from historical eclipses. So knowledge about eclipse theory will in this case also be a part of the astronomical approach. Both eclipses and lunar eclipses follows certain cycles, which are connected. Generally there is about six month between pairs of eclipses and lunar eclipses and there is always about fourteen days between an eclipse and a lunar eclipse due to the orbital revolving time of the Moon (see Figure 2.7). The Babylonians discovered probably the eclipse cycle known as the saros (which means repeat) around 700 BCE. A saros is about 18 year and 11 days between two eclipses. This cycle can run up to 72 times starting with partial eclipses over total eclipse and ending with partial eclipses. Such a cycle is a saros-series. Many of these saros-series can run simultaneously. Lunar eclipses follow also certain cycles but the can run only for 76 years. Eclipse theory is treated more in details in (Clausen, 2001). Therefore, knowledge about historical eclipses can be of vital importance in an attempt to determine the delta $T$ back in time.
2.2 Fieldwork

The fieldwork starts home at the desk, choosing different target areas with a number of megalithic monuments of interest, which have measurable passages. A passage as I assume represent a sightline. The necessary information for this purpose was obtained at the homepage for the Danish heritage.\(^{15}\) The next step was to get permission to visit the places by contacting the owners of the land. It is easy to find the addresses on the Danish Environmental Portal. Only a few places are open to the public (see Figure 2.8). This work is often very time-consuming and actually consumed an amount of time equal to that of the physical fieldwork.

The equipment used for measurement included a magnetic compass (Figure 2.9), a level for bringing the compass into a position parallel to the plane of the horizon, a GPS – which also can measure the altitude above sea-level, and an instrument which can measure the apparent horizon altitude, \(h_a\), according to the sea-level \((h = 0)\). When actually getting started at the spot, you have to consider the landscape conditions. Is there a good view of the horizon? Are you on a local high point? Is there evidence that the monument is placed on an artificial platform? Are there potential rock carvings? Remember to take photos of the monument and its surroundings (for documentation). The next step is to determine the sightline from the passage. Danish monuments are often very symmetrical in their construction, see Figures 2.10 and 2.11 or (Clausen, SEAC proceedings 2013)\(^{16}\), so in principle, the task should be simple.

\(^{15}\) Accessed March 2015 at http://www.kulturav.dk/fundogfortidsminder/

\(^{16}\) (Clausen, SEAC proceedings 2013) at p. 144, Figure 1
Figure 2.8
The passage grave Tværhøj ('Cross-mound') at Øm, close to Roskilde at central Zealand, accessible to the public. The mound is approximately 30 meters in diameter, the chamber 7x2 meters, and the passage 7meters in length, orientated slightly south of east. From outside, the passage grave does not have its original outlook. It was changed during an excavation in 1843. Carbon-14 analyses of birch-bark, used as filling in the orthostatic stonewalls, estimate the age relatively precisely to 3100 BCE.17

Figure 2.9
The Suunto precision magnetic compass used (type: KB- 14/360). The compass (encapsulated in an aluminum shell) is mounted on a frame which consists of wood, plastic and aluminum in order to avoid magnetic influence from the instrument itself. The instrument shown is a prototype for measuring passage directions in passage tombs instead of using a theodolite. Claus Clausen developed the instrument.

The first step by determination of the sightline through the passage is to find the best straight line which fits as a mean value of five to six fixed points (see Figure 2.10). During the fieldwork it turned out to be by far the simplest thing to use a thin rope (12 meters long) and determine the sightline visually. The rope is simply mounted with a peg at the back wall of the passage chamber opposite the opening of the passage. The line of sight is then determined visually from outside the passage grave (see Figure 2.11). When the rope is in the right position it is stretched and mounted with a second peg at a fixed position with markers or dipsticks in both ends. The dipsticks are positioned according to the solder line (horizontal direction towards center of gravity). The rope now represents the visually determined sightline and the azimuth to be measured. With the compass, the azimuth is measured both from inside and outside the passage. In some cases a deviation of about a couple of degrees was obtained. In this case the azimuth would be the mean value of the two measurements. Finally, the azimuth is corrected for local magnetic deviation. Here, it must be noted that the sightline used is the one determined by the observer, and does not necessarily represent the original sightline.

How good Neolithic man were to determine sightlines is unknown, but indeed the human eye is a very good precision tool. It is assumed that a sight line over a distance about 1 kilometer can be established within an angular corridor of about +/- 0.3⁰ by use of the necked eye and using a dipstick with a diameter of about 0.1 m.

Experiments by measuring established sightlines in the passage from both sides (as the situation illustrated in Figure 2.11) gives a precision note better than +/- 1.5⁰. Finally, we have the instrumental precision, which I have estimated to about +/- 1.0⁰. All in total the precision of a measurement is determined to be +/- 3.0⁰. Which is the argument to use 6⁰ bin intervals for the histogram presentation. All arguments in this connection are discussed in (Clausen, 2003) p. 40 – 43. In any case, determination of the sightline, as mentioned earlier, can never be better than the ability of the observer to establish the assumed sightline within the angular window shown on Figure 2.10. It will provide an unknown error.
Fig. 2.10
Plan drawings of two passage graves to illustrate the determination of the sightline though the passage of the passage tomb. The dotted lines represent the maximum angular deviation seen from the back of the chamber. In both cases, the deviation is +/- \(10^\circ\), thus giving an angular window of \(20^\circ\). The black arrow determines the sightline as the best straight line deduced from five to six fixed points. The red arrow shows the probably original sightline discovered by Svend Hansen (see text and figure 2.12 for details).

Fig. 2.11
Visual determination of the sight line and the azimuth by use of a thin rope. Left panel: a member of the Danish Amateur Archaeological Society tests the method as described in the main text (p. 40–44). Right panel: plan drawing of a double passage grave (Gundsølille) with the positions of the equipment and the observer; A) the rope mounted with peg 1, B) the rope, C) the rope mounted with peg 2 and the position of the compass, D) the position of the observer at the "eye"-symbol.
Help in investigating this case came when knowledge of Svend Hansen's (Danish passage grave conservator) discovery of the original sightline in 2005 (see Figure 2.12) became known. With the discovery of Svend Hansen in mind, it was easy to compare the sightline determined by the rope and the originally determined sightline through the passage (if it is possible to identify it). The method with the rope (illustrated in Figure 2.11) works more easily and is surprisingly more precise than the previously used method. This helped to change the methodology used in subsequent work.

I decided to enlarge the number of measured passage graves by more that 50 percent (from 90 to about 150) to see if the overall picture of the distribution pattern was sustained in comparison to the result of my master’s degree from 2003 in this field. Through the years from 2003 to 2014, the number of measurements was increased, adding 73 new measurements for a total of 163 (Figure 2.13).

In a short period from 2009 to 2010, some amateur archaeologists interested in the project obtained 11 measurements.

Fig 2.12
Svend Hansen investigated about 100 passage graves and found that approximately 40% have the passage line on the left side (example 3), about 50% have it on the right side (example 2), and about 5% have it on both sides (examples 4 and 5). In the remaining percentage, you can follow the passage line outside the dimensions of the actual passage grave. The conclusion of Svend Hansen is that the passage line was planned and established before the construction of the passage grave itself, probably as a sightline.

In addition, Niels Andersen (a Danish archaeologist and curator from Moesgård Museum) measured 9 directions in a cluster on the island of Fünen at the place known as Sarup (Clausen, 2015, Table A). Giving 153 measurements. Finally in 2014, ten more measurements were added to enlarge the data set (see Table 1).

Figure 2.13 shows the 163 measurements compared with the original 90 measurements from the master’s thesis. It is easy to see that the overall picture is sustained with the exception of a few more southern and south-western directions.

Fig. 2.13
The figure compares the original 90 measurements (dotted line) with the new data set of 163 directions (solid line). It is easy to see that the general picture with the three main peaks is sustained but that the southernmost peak at around $150^\circ$ has developed more than the two others. The x-axis gives the azimuth from $30^\circ$ to $240^\circ$ and the y-axis gives the number of units or directions pr. $6^\circ$ bin interval for each column.
Table 1.
Supplementary 10 measurements (2014) to the previous 153 measurements. Passage tombs including dolmens with passages.

<table>
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<th>(A) Passage graves aligned on other passage graves or dolmens</th>
<th>B) Passage graves or dolmens linked to A</th>
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<td></td>
</tr>
<tr>
<td>Vedsted</td>
<td>200210-153</td>
</tr>
</tbody>
</table>

Table syntax:

Columns 1, 6: Place (bold) and name of the megalithic monument. II = twin or double grave, III = triple, D = dolmen, D* = dolmen with a passage, R = removed

Columns 2, 7: Registration number

Columns 3, 8: Longitude in UTM_X meters, zone 32, figures in bold are new coordinates

Columns 4, 9: Latitude in UTM_Y meters, zone 32, figures in bold are new coordinates
Column 5: Measured pointing direction/azimuth in degrees. X = not measurable or not measured. L denotes left passage. Marked in italics (Samsø) are old measurements included in the data set from 2008 (Clausen et al., 2008)

Column 10: ‘Alignment azimuth’ in degrees deduced from the UTM coordinates. Direction + 180 means pointing backwards. Marked in bold are the new ‘alignment azimuths’ deduced from new UTM coordinates, also marked in bold.

Numbers in ( ) mean uncertain direction or possible alignment direction, e.g. 050503-87 (132): This value is obtained by use of orthophoto and confirmed by the ‘alignment azimuth’ deduced from the UTM coordinates.

Note means commons on the unit.

Note:
The revaluated Samsø measurements concerning positions of the tombs.

2.3 Intervisibility and alignments

During the fieldwork it became more and more clear that the passage graves, and sometimes also dolmens, were linked together in a kind of alignment relationship. The distance between the source unit and target unit can vary from less than 100 meters to up to about 3 to 4 kilometers. Even sightlines up to 5 kilometers have to be recognized. A special feature is that the lines sometimes continue in alignments involving several megalithic monuments and that the lines can pinpoint the positions of destroyed or removed monuments; that is, positions of monuments which no longer exist. This was a very interesting and important discovery. A special challenge in this context is, which unit would be the original target unit for the source unit, when there are several possible target units? For target units positioned at distances of over several kilometers, it is more likely that the sightline pinpoints a unit simply by chance. A future project in this connection is to make a random analyze involving all megalithic structure and other types of mounds in specific chosen areas within e.g. 400 km².

Another feature involving the alignments was that the source unit with a passage could either point forward or backward (Clausen et al., 2008). The most simple and obvious way to confirm

19 (Clausen et al., 2008) at p. 221
a sightline and the target unit was by taking a photo through the passage of the source unit, if possible. Unit 030505-58 and unit 030505-57 (Samsø) in Table 1 were such examples (see Figure 2.14). If a photo through the passage is not an option, the use of orthophotos could be a convenient alternative (see Figure 2.14 right panel)

![Fig. 2.14](image)

The left panel shows the view through the passage of unit 030505-58 towards unit 030505-57 (a triple passage grave). The right panel shows both units on an orthophoto from the Danish Environmental Portal. The distance between the two units is approximately 60 m.

On the orthophotos from the Danish Environmental Portal it is possible to read the position coordinates in the Danish UTM grid system zone 32 (coordinates in meters). From the UTM coordinates, the “alignment azimuth” can be deduced in the following way by using data from Table 1 (Samsø):

Example A: Pointing forward (Figure 2.14)

UTM coordinates unit 1 (source unit), $x = 599752$, $y = 6187656$

UTM coordinates unit 2 (target unit), $x = 599814$, $y = 6187648$

$\Delta x = 8$, $\Delta y = 62$

$az = \text{INV}(\tan(\Delta x/\Delta y) + 90^0) + 90^0 = 7.4^0 + 90^0 = 97.4^0 +/-2.5^0$
Comparing the measured $az$ is $100^\circ$, and using +/- $3^\circ$ as the maximum deviation (equalizing the $6^\circ$ bin size used in the histogram), with the alignment $az=97.4^\circ +/-1^\circ$, the result is acceptable as documentation for the alignment. The line criterion is set to +/- $2.5^\circ$ (Clausen, 2012)$^{20}$ so the documentation of the line is just on the limit. Nevertheless, due to the photo documentation the line must be accepted as real as you actual can see the target unit trough the passage of the source unit. The uncertainty in this example is greater than normal due to the relatively small distance between the two units (less than 100 meters).

Example B: Pointing backward (Figure 2.15)
UTM coordinates unit 1, $x = 600105$, $y = 6182943$
UTM coordinates unit 2, $x = 599911$, $y = 6183439$
$\Delta x = 194$, $\Delta y = 496$
$az = 158.6^\circ + 180^\circ +/-2.5^\circ$

The measured azimuth is $az=160^\circ$, which means that the line is confirmed both by photo and by the UTM coordinates (see Figure 2.15). The distance between the two units is approximately 500 m.

Multiple alignments are sometimes seen in the passage grave clusters, involving several units (Clausen et al., 2008) and (Clausen et al., 2011).$^{21}$ The following example is from the Knudshoved cluster (new measurements, the 24$^{th}$ of April 2013) in western Zealand, Table 1 (Knudshoved).

Example C: Multiple alignments (Figure 2.16)
Alignment 1:
UTM coordinates unit 1, $x = 678295$, $y = 6103521$
UTM coordinates unit 2, $x = 680457$, $y = 6102976$
$\Delta x = 2162$, $\Delta y = 545$
$az = 104.2^\circ +/-2.5^\circ$

$^{20}$ (Clausen, 2012) at p. 77 and p. 80
$^{21}$ (Clausen et al., 2008), at p. 220 and (Clausen et al., 2011) at p. 348
Alignment 2:
UTM coordinates unit 1, \(x = 680457, \ y = 6102976\)
UTM coordinates unit 2, \(x = 680613, \ y = 6101983\)
\(\Delta x = 156, \ \Delta y = 993\)
\(az = 171.1^0 +/- 2.5^0\)

In both cases, the sightlines and the “alignment azimuth” are documented by photos and by the UTM coordinates (see Figure 2.16) which improve the existence of the expected sightlines.

Fig. 2.15
The upper panel shows a photo taken opposite to the direction in which the passage of unit 020505-39 points. The passage is missing the capstones, which made it possible to see the point opposing the pointing direction and to take a photo of the backward placement of passage grave unit 030505-38. The lower left panel shows the alignment of the two passage graves. The “alignment azimuth” measured on an ordinary map is 159\(^0\) and the measured and corrected azimuth is 160\(^0\). The angular corridor for this measurement is estimated to +/-2\(^0\). The lower right panel gives the alignment azimuth deduced from the UTM coordinates.
Fig. 2.16

The upper panel (left) shows the position of unit 050213-67 seen looking out through the passage of unit 050213-63\(^{22}\). The upper panel (right) shows the position of unit 050403-4 seen from unit 05021367. The lower panel shows the alignment on an orthophoto from the Danish Environmental Portal (data from Table 1).

\(^{22}\) Unit 050213-63 is a megalithic unit classified as a small long barrow with two chambers (dolmens) partly destroyed. This layout is not obvious at the location itself, but the two stone rows seen on the photo point towards unit 050403-4 with relatively good precision (see Table 1).
2.4 New approach to the fieldwork

Sometimes it is possible to see the passage of the megalithic monument on an orthophoto if the passage is missing the capstones. A few experiments have been carried out to test the method and it seems to work if the passage appears measurable, that is, if the direction of the passage can clearly be seen. The method has been tested on unit 050503-92 and unit 050503-87 from Table 1 (see Figure 2.17 and Figure 2.18). Unit 050503-92 (Kong Asger Høj) has also been measured at the ground level giving $az = 117^0$ compared to the $az = 116^0$ measured on the orthophoto. The difference is clearly within the limits of uncertainty and the results of both measurements are accepted as valid. Sometimes Google Earth photos are not consistent with other types of orthophotos but in this example it was not the case\textsuperscript{23}.

Concerning unit 050503-87, the method has been used in an attempt to identify the original target-unit among two possible target-units. In this case, the probable original target-unit was destroyed and later removed but its original position is known (see Figure 2.18).

![Google Earth photo of Kong Asger Høj](image)

Figure 2.17
Kong Asgers Høj (unit 050503-92) seen from above on this Google Earth photo. The passage is very easy to identify and measure with a ruler and a protractor. Courtesy of Google. The azimuth measured on the spot was $117^0$ (see Table 1).

\textsuperscript{23} The problem that Google Earth photos sometimes is not consistent with other types of orthophotos has not been explored in detail yet but will be the subject of further investigations.
To the left of the panel is a close-up orthophoto of the Sprove passage dolmen (050503-87). The right side of the panel shows two possible target units for the Sprove dolmen: unit 050503-89, which is a destroyed and removed passage grave, and unit 050503-88, which is a long barrow (dolmen) with two chambers. According to the deduced “alignment azimuth” it is not possible to tell which of the two target units is the original target unit (see Table 1) but the orthophoto shows that unit 050503-89 is most likely to be the original target unit.

2.5 Use of other methods

In the case of a partly destroyed or partly removed megalithic monument, it is possible to use magnetic surveying to see if there are remains of the monument in the ground beneath the soil’s surface (Smekalova et. al, 2008). In principle, the method is simple, but it is time-consuming (and therefore expensive) and affected by many details. It is simple because you measure very specific and narrow local magnetic anomalies compared to the natural, background magnetic field (soil magnetism and the Earth’s magnetic field). It is time-consuming and detailed because you have to: be very careful in building up a measuring grid at ground level (see Figure 2.19); know details about the behavior of the magnetic field in the ground as a function of the depth; and measure daily changes in the background magnetic field. The method is very useful for megalithic monuments because the magnetic field will concentrate around the large granite blocks (see Figure 2.20). In this way it is possible to uncover or reveal large stone blocks hidden in a mound or in the ground beneath the surface. In principle, it should then be possible also to see the direction of the passage even if it is hidden in the ground.
Another and really simple method is, during an excavation of a complete Neolithic settlement or cult location, to find the prints of formerly placed stone blocks just beneath the surface on the ground. This could reveal the layout of a passage grave and perhaps show the direction of the former passage.

Fig. 2.19

Using a measuring grid on the ground and carefully working along the grid-lines with your instrument. All components of the grid are made of non-magnetic material (wood, plastic etc.).
Fig. 2.20

The figure at the left side of the panel is a magnetic survey of a passage grave at Vedsted in Jutland. The contour levels are separated in 5 nano Tesla (nT) intervals with the red colors representing negative anomalies and the blue ones positive anomalies. On the grey-scale darker colors are positive and lighter colors are negative. The middle figure is a drawing of the position of smaller stones and larger stone blocks registered so far. The right-hand photo is an orthophoto of the visual surface remains. Note that there are more stone blocks on the left figure compared to the middle and right figures. For some reason, the passage direction on the three figures is inconsistent. This problem has not yet been investigated. The most obvious explanation can be that archaeologists indicates north towards the magnetic north pole and not due to the geographical North Pole.

To summarize the result of the fieldwork it was a complete surprise that intervisibility between Danish passage tombs were a possibility. It has never been recognized or realized before. The previous common opinion and knowledge among Danish archaeologists is that it were local people who built the passage tombs in the clusters. Properly by help of specialists who could handle techniques learned from southern Europe. One of the ideas were that these passage tombs should impress visitors, a place where you bury the dead and a place for ritual praxis (Glob, 1967). Not that the clusters by line relations and common features in the orientation patters of the cluster tombs (Clausen, 2012) are linked together in impressive structures in the landscape. This would require a more central planning to do this. In recent years have been published works e.g. (Ebbesen, 2011) where a conclusion is that the local societies were chief communities, i.e. there were a local power. However the sometimes enormous structures (Clausen, 2011) indicates a more central power.
Another surprise is that we properly have to understand the orientation patterns of Danish passage tombs as a multilayer functions designs, i.e. both having an archaeotopographic explanation and an archaeoastronomical interpretation. Only a much larger set of data would give an idea.
Chapter 3
The megalithic 'lunar season pointer'

3.0 Abstract (introduction)
Using basic methods and knowledge of astronomy combined with simple surveyor techniques a sample of 163 passage graves in Denmark (including an adopted data set from Scania) has been measured with regard to location and orientation. The result of this work has revealed new information about the Danish passage graves (intervisibility) and the distribution pattern provided an opportunity to develop a hypothesis concerning the orientation of these monuments (mainly east, southeast and south-southeast). The orientation pattern points to an explanation based on certain full Moons in the summer period (Clausen et al. 2008); therefore the test model is named the “lunar season pointer”.
A test of the hypothesis model against the observations gave statistical results so compelling that it inspired a test of the model against other data sets with similar distribution patterns. In a number of cases, the statistical outcome was similar, which means that it is worth discussing the result within a more general context. This context involves looking at the orientation of the Moon from Europe and the surrounding areas during megalithic times.

3.1 Analysis and interpretation of the Danish data set
Although the data set presented in Figure 2.13 (Chapter 2, p. 45) is supplied by 27 measurements from Scania, the data counts as Danish data. Archaeologists accept megalithic monuments from Scania and Sweden in general as typologically identical with the Danish ones (Blomqvist, 1991), as they lie within the Danish area of influence of the past. The combined data set presented in Figure 3.0 a has, at first glance, three clear and striking peaks. The peak mean values for the three peaks in the presented data set are 99°, 123° and 149° (Calculated for the peak azimuth intervals of 85° to 114°, 114° to 138° and 138° to 156°). Already at an early stage, it was obvious that a lunar explanation could be favored (Clausen et al, 2008). The rising points of the Moon on the horizon cover about 86% of the observations, whereas about 71% are covered by

\[24\text{ (Clausen et al., 2008) at pp. 221 – 222 and p. 227 (Summary)}\]
\[25\text{ (Clausen, SEAC 2011 proceedings) at p. 160 and Figure 1}\]
the Sun. This result indicates a lunar interpretation rather than a solar one. If the data is examined in greater detail, all three peaks can be related to the Moon.

The first peak (99°) is related to the spring full Moon (SFM) (Da Silva, 2004), and is the full moon at the lunar/solar crossover in spring, but the peak can also be contributed to by another full moon (see Figure 3.1 a and subsection 3.4). The second peak (123°) is very close to the southernmost minor lunar standstill (about 126°) and the third peak (149°) is very close to the southernmost major lunar standstill (about 152°) for the actual latitude (56°N) and time (3300 BCE). This is illustrated in Figure 3.0 a. The azimuth directions during the minor lunar standstills are also the directions with the greatest number of full Moon rises. This is also reflected in figure 3.0 a. For example, see (Clausen, 2011). The three peaks thus can be interpreted to correspond to full moons in the summer period, defined here as the period from March to October. This makes it obvious that the behavior of the full Moon on the eastern to south-eastern horizon must be investigated in more detail. Out of the 163 observed directions, about 80% (130) are within the south-eastern quadrant (90° to 180°).

26 (Clausen, 2011) at p. 347, Figure 4
Fig. 3.0 a
The histogram shows all 163 measured directions, including the new data from Table 1 (Chapter 2, subsection 2.2, p. 46 - 47). It is striking that all three peaks can be related to the full Moons mentioned in the main text. At the winter solstice, there are remarkably few observations (4). The y-axis accounts for the number of units or directions in $6^\circ$ bin intervals and the x-axis represents the azimuth.
The observed azimuth distribution presented due to the compass directions. Which could be a more illustrating way of showing the distribution visually.

3.2 Modelling a 'lunar season pointer'

Realizing that the task is to identify certain full Moons in the defined summer period, one has to accept that Neolithic man was unable to accurately determine genuine full Moons. The full Moon is counted as a five-day event which will, in the following, be equated with the term “full Moon” unless otherwise stated. The challenge is to break down the rising pattern of the full Moon and separate the “building blocks” of this pattern. The most surprising discovery was that not all full Moons have significant peaks – only the SFM and the autumn full Moon (AFM), which are the equinoctial full Moons (EFMs), and the first full Moons after the SFM and before the AFM, hereafter denoted as the “second full Moon”, do. The EFMs are investigated in more detail by (Silva, 2011). Here must be noted that the AFM is not used in the model presented in Figure 3.1 a thus this will account for the first two peaks and not three peaks. The only full

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27 (Clausen, SEAC proceedings 2011) at p. 160
28 Ibid., at p. 161
Moon which can contribute to the third peak in the model is the SmFM (the southernmost full moon). The SmFM does not reveal a specific narrow peak but rather an interval with two maxima; one at the lunar minor standstill and another one at the lunar major standstill, caused by the 18.61-year lunar cycle. Thus SmFM contributes to the second peak ($123^\circ$) in some years. Figure 3.1 a show the “building blocks” of the proposed model.

In other words, the model is based on three distributions or building blocks:

A) The SFM peak, which in this case counts for both spring and fall if you look in the direction on the horizon for full moons with azimuths around $100^\circ$ (blue peak Figure 3.1 a). See subsection 3.4 for explanation.

B) The second full moon which indicated the beginning and the end of the midsummer period if you look in the direction on the horizon for full Moons with azimuths around $123^\circ$ (red peak Figure 3.1 a).

C) The southernmost full moons which indicate the midsummer period if you look in the directions on the horizon for full moons with azimuths between $126^\circ$ and $152^\circ$ depending of the phase of the lunar cycle (green distribution Figure 3.1 a). Note here that the SmFM will be very close to the second full moon in some periods due to the 18.61-year lunar cycle. The directions around $123^\circ$ and $126^\circ$ are also the directions where you have most full moon rises in the summer period.

The model is hereafter called the “lunar season pointer” or the megalithic “lunar season pointer”, as it is linked to megalithic monuments (see Figure 3.1 b).

Another way to understand the concept model is that I add the full Moon building blocks in different ways e.g. a Model 1 EFM + second full moon + SmFM or a Model 2 EFM + second full moon . Hereafter I use two ways to construct the models. 1) A sum model where I simply add all azimuth for the rising full moons in each histogram bin interval 2) A superimposed model where I add the maximum value for a building block in each histogram bin interval. The shape of the histogram in Figure 3.1 a is a superimposed model presentation composed by SFM + second full moon + SmFM. For further use, see subsection 3.5.
Fig. 3.1 a
The lunar “season pointer” model represented by two peaks and the southernmost full moons as superimposed peaks, from the left: with mean values around 100° (SFM), blue peak; 123° (second full moon), red peak; and 149° (southernmost full moons) green distribution. Note the two maxima caused by the 18.61-year lunar cycle. The histogram represent calculations for a 90-year period.

Fig. 3.1 b
The lunar “season pointer” model represented due to the compass directions. The three peak arrows, from the left: with mean values around 100° (SFM); 123° (second full moon); and 149° (southernmost major stand still).
As mentioned in the main text, logic in Neolithic times were properly not the same as today. Left panel is a solar calendar, hypothetic used by Neolithic man as the most logical calendar. Where we have four “dates”: around the 21/22 December (winter solstice), around the 20/21 March (vernal equinox), around the 21/22 June (summer solstice) and around the 20/21 September (autumnal equinox). Recall here Figure 2.5 at p. 35. Right panel is the 'lunar season pointer' where the blue, red and green bands (1, 2 and 3) represent full moon rising periods of about one month (around 40 days). Each rising band represent the three peaks in figure 3.1 a.

3.3 Calculation program
For the purpose of calculation, I wrote a program in which the lunar calculations are based on Brown’s lunar theories. It is difficult briefly to explain the details in Brown’s theories but the following is an attempt to extract the main idea.

The motion of the Moon was original solved as an analytic solution to the three-body problem (Moon, Earth and Sun) under the simplifying assumption that the center of the Earth-Moon system rotates on an elliptic orbit around the Sun. This is one of the main problems in lunar theory.

Brown's objective had been to produce an accurate ephemeris of the Moon, based purely on gravitational theory. Brown’s method for solving the main problem of lunar theory was by using a number of approximation, e.g. using a value for the mean motion of the Moon and the Sun (and the Earth). By this, tidal effects from other planets or other mass elements in the planetary
system then for a limited period of time are built into the mean values, so to speak. The solution of the equations of motion were by Brown solved by the help of multiple Fourier series up to nine order. Unfortunately, he had to add an empirical constant to the solution to reduce an unexplained fluctuation in the Moons longitude, but Browns theories are one of the best bid for a complete lunar theory. Today we solve the lunar problem by numerical integration, fast computers and a better pool of observed lunar ephemerides.

The original program was developed by Jeffrey Sax\textsuperscript{29} but I have developed and refined it for this PhD project. I have added the trigonometric translation formulas, and altered the printing portion to satisfy the required output which are the lunar and solar rising and settings azimuths, only visual lunar eclipses for a given position and rising and setting times. The program exists in three versions:

1) Identifying lunar eclipses back in time, calculating the azimuth of the rising full moon just before and after a lunar eclipse (+/- 2 days, after (+) and before the genuine full moon = 0). Program name: DT_DAZ.exe.

2) Identifying lunar eclipses back in time calculating both in DT and in UT. Program name: Maneform.exe.

3) Identifying full moons back in time concerning the “lunar season pointer”, that is, all summer full moons including EMFs (SFM and AFM), the second full moon and the SmFM. Program name: springny.exe (or fallfm.exe for winter full moons).

Limits of the calculations are given in Clausen, SEAC 2011 proceedings\textsuperscript{30}, but very simple the Maz (the Moons rising azimuth) must exceed the Saz (the Suns rising azimuth), Maz > Saz, to separate the winter full moons from the summer full moons (see also Table 3).

\textsuperscript{29} Copyright (c) 1991 by Jeffrey Sax, All rights reserved, Published and Distributed by Willmann-Bell, Inc., P.O. Box 35025 Richmond, Virginia 23225, Voice (804) 320-7016 FAX (804) 272-5920

\textsuperscript{30}(Clausen, SEAC proceedings 2011) at p. 161.
All program versions are prototypes and not fully developed, and should be compiled as the Alcyone Ephemeris AE2.8 program. The program language is Borland Turbo Pascal, which works in a DOS environment – and it runs on 32-bit machines. Input data for the programs are: beginning year; calculating time steps in days; ending year; geographical coordinates; and the time zone. All calculations are executed with respect to the astronomical horizon ($h = 0$), refraction and parallaxes. However, it is possible to change the value for $h$ or $h_a$ if that is required.

A special feature concerns the dates in the output files. For example, take the date denoted as -33029883 in Table 2 (marked with bold), which actually equals 17 January 3303 BCE. The date is calculated as 10000 - 9883 = 0117 (first month, 17th day), and the year is -3302 -1, which equals -3303, or 3303 BCE. Table 2 shows an output produced by program 1 described above. Program calculations break down at about 10000 BCE and provide uncertain data from about 5000 BCE. The solar rising and setting azimuth can be used to approximately determine the dates to within a few days in relation to the Gregorian calendar that we use today. Otherwise, the Julian Datum (JD) can be used to pin-point the year and day. It is not necessary to know the exact dates for our purposes in this connection. Only the behavior of the Moon on the horizon versus the Sun is of interest.

In general, the calculated data will be scaled so it fits the observed data sets to which the model is compared. The model will be scaled to fit the observations and the bin intervals will be adjusted to the original data set unless otherwise stated, with the exception of the Swedish data set, which is presented on the basis of $h_a = 0.38$ according to arguments given by Göran Henriksson (Henriksson. 2005):

“…..After correction for magnetic deviation, I transformed the azimuths to declinations taking into account the solar and lunar parallaxes and normal refraction. I assumed that the builders tried to direct the passage towards the first visible rays of the Sun, which means that the upper limb of the Sun was at the horizon.........analyses showed a very significant peak at the solar

31 A new trial version AE4.3 can be accessed (March 2015) at http://www.alcyone-ephemeris.info/alcyone_ephemeris.html
declination -17.0°.....because of many mountains surrounding this area, it seemed necessary to make corrections for the height of the horizon..... I decided then to search for the optimal maximum height of the horizon by a $\chi^2$-test.....It was found that the optimal upper horizon limit (here $h_a$, CC) was 0.38°. This correspond in fact to the lowest visible horizon in the area.”

Table 2
Output from program 1 (DT_DAZ.exe)

Table syntax.
The first column on the left shows the number of days before (-) and after the full Moon (0). The second column is the date, given as year, month and day (ymmd). The third column is the Julian date (JD), which is counted as the actual number of days going back in time from the present. This is not an actual date, but the amount of time elapsed since a certain fixed date and year, in this case 1859 AD at the transition between the 16th and 17th of November, calculated in DT. The fourth column is the lunar azimuth Maz. The fifth column is the time difference between the Moon’s rising time and Sun’s setting time. Sunset - Moonrise = dt. The sixth column is the angular difference between the Maz and the Sun’s setting azimuth (Sazset): Maz - Sazset + 180° = daz1. The seventh column shows the beginning of the lunar eclipse (EB) in dynamic time (DT) and the eighth column is the end of the lunar eclipse (EE) in DT. DT is connected to delta T in the sense that it is the time you actually experience at the place where you are. Note that a lunar eclipse occurs when both dt and daz are at their minimum (marked with bold). The situation is named Twin Sun (TS) and is described more in details in (Clausen, 2015 C).

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</table>
Fig. 3.3
Geometry concerning the output from program DT_DAZ.exe when a lunar eclipse can occur. Left figure show the geometrical situation as observed from the surface from Earth. The Moon is rising approximately opposite at the same time as the Sun is setting. The passage grave in the center (the observers position) represent the position of Earth. Right figure show the astronomical situation when the Moon is very close to one of its nodes. Both visible lunar eclipses (including partial and penumbral lunar eclipses) and not visible lunar eclipse (i.e. the full moon is not above the observers horizon) are indicated by the geometrical situation.

Having the program application tool in hand, the methodology used in the following is very simple. Thank to today’s fast computers it is possible to test many different series of more and less complex models in a short time and compare them to the megalithic data, which have been obtained during the fieldwork. This is the method I have used in this PhD thesis concerning the handling of the field data.

3.4 Calculating the model
For purposes of calculation, the program used is springny.exe. An example of the output file is given in Table 3 (placed after subsection 3.6 ).

The criterion, as mentioned earlier, for identifying the lunar/solar crossovers in spring and fall is $Maz > Saz$ for summer full Moons and $Maz < Saz$ for winter full moons.$^{32}$ When the criterion ($Maz > Saz$ or $Maz < Saz$) is fulfilled, the program calculates the required properties: Sunset,

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32 (Clausen, SEAC proceedings 2011) at p. 160 and (Clausen, SEAC proceedings 2013) at p. 146
Moonrise, \( dt \), Saz, Maz and daz2, where \( daz2 = Saz - Maz \), not to be confused with \( daz1 \) in Table 2. For the calculated year and position (3303 BCE, 56° N and 12° East) in Table 3, it is notable that we have two crossovers in spring and one in autumn (marked with bold). Also worthy of note is the fact that the crossover in the fall in this output file is identified by the full moon just one or two days before the AFM. For that reason this specific full Moon contributes to the 100° peak.\(^{33}\) When examining Table 3 in greater detail, the building blocks of the model can be identified.

The first one concerns the SFM (contribution also from program fallfm.exe with a similar output file to Table 3 concerning the winter full moons) marked with blue in Table 3. The SFM rise takes place from 13 to 17 April, 3303 BCE (-33029587 to -33029583 in Table 3), while the crossover takes place from 16 to 17 April. The full Moon on 17 April is the exact SFM that Neolithic man was able to identify (see Figure 3.4). The next full Moon is the first full Moon after the SFM\(^{34}\), which rose from 12 to 16 May. This particular full moon in the given example also represents a second lunar/solar crossover from 12 to 13 May i.e. 3 days before the genuine full moon.

The second full moon (April to May) counted as the first full moon from the SFM has a peak distribution which can be used as a building block in the model. In Table 3 is the second crossover full moon the same as the second full moon marked with red in Table 3. The third (May to June) or even a fourth (June to July) full Moon counted from the SFM does not contribute to the model, as neither of these has any particular peak in its azimuth distribution. However, they can contribute to the azimuth distribution for the southernmost full moon (SmFM), marked with green in Table 3, if that is the option (see also subsection 3.2). The next full moon (August to September) is the first full moon before the AFM and has an azimuth distribution similar to first second full moon. It can therefore contribute as a possible building block to the model. This full moon is also known as the harvest-Moon.

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\(^{33}\) (Clausen, SEAC proceedings 2013) at p. 148

\(^{34}\) Ibid, at p. 146–147
The next building block concerns the AFM marked with bold (black) in Table 3. The exact AFM can easily be identified, as can the exact SFM as the crossover full moons. Here it must be noted that the mean value of the exact SFM is not the same as the mean value of the exact AFM.

In total, the model reveals four building blocks; one which corresponds to the SFMs, one which corresponds to the second full moon, one which corresponds to the SmFM and finally a building block which corresponds to the AFMs (see Figure 3.5). The example in Table 3 of the AFM is a little bit different in the sense that an observable crossover took three days. The azimuth of the full moon just before the crossover has an angular deviation less than $1^\circ$ from the azimuth of the Sun and therefore is hard to detect (the angular size of the sun disk and the lunar disk is about $0.5^\circ$). This situation is not an unusual one but also not the most common.

The tricky thing about this model is that a single full moon event (not the five-day full moon) can have a counterpart on another day during the year. That is, the event repeats itself as a kind of mirror image 3 to 6 months later. For example, if we calculate the mean value of the exact SFM for a period of more than 100 years, we find that the $az$ will be about $100^\circ$ on average. This is also nearly the case for the single full moon event one or two days before the exact AFM. This particular full moon has a mean value of about $99^\circ$, that is, it is close to the mean value of the exact SFM. This can have an important implication, as you can use the direction of the SFM as an indicator for the coming AFM. In particular, it means that the direction in which the SFM points is connected to the lunar/solar crossovers both in spring and in autumn. In fact, you can go further in investigating the utility of the model (Clausen, SEAC proceedings 2011).

Going into further detail in Table 3, it is possible to see the idea with the EMFs. In spring, corresponding to the date represented by -33029584, the $az$ is $83.89^\circ$. On the next day – (-33029583) – the exact SFM, the $az$ is $94.00^\circ$. The reverse is true half a year later; just before AFM on the date represented by -33028990, the $az$ is $95.23^\circ$, and the next day $az$ is $84.31^\circ$. The latter example is taken just at the limit for the lunar/solar crossover, because the genuine lunar/solar crossover takes place on -33028988, but due to the uncertainty in observing the direction to the rising Sun or Moon, it will be difficult to observe whether the exact AFM truly

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35 (Clausen, SEAC proceedings 2011) at pp. 147–149
did or did not occur on the date represented by -33028989. In general, it works (Clausen, SEAC proceedings 2013).\textsuperscript{36} In Figure 3.5 it is easy to see (visually) how the building blocks can contribute to or interfere with each other.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig34.png}
\caption{The lunar-solar ‘cross over’ at spring when the rising Sun is moving towards north at the horizon and the rising full moon is moving opposite towards south. The situation, which produce the SFM peak with mean value of 100° in Denmark. The same situation as illustrated on the front page.}
\end{figure}

\textsuperscript{36} Ibid, at pp. 146–148
Figure 3.5

The figure shows a “lunar season pointer” model produced for a latitude and longitude in Portugal at 40°N, 8°W (just a little bit North of central Alentejo). The four building blocks have, from the left, peak mean values of about 83° (AFM), 98° (SMF), 108° second full Moon and finally, the SmFM, which have no distinguishing peaks due to the 18.61-year lunar cycle. The y-axis is the number of full moon events/directions for each 6° bin size interval and the x-axis is the azimuth.

3.5 Testing the model on different data sets

Due to the histogram presentation it is most obvious to use chi-square statistics (Clausen, SEAC proceedings 2013). A Kolmogorov-Smirnoff two-sample test is also a possibility, see paper VIII (Clausen, 2015 C).

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37 (Clausen, SEAC proceedings 2013) at p. 148
The model has been used to test three data sets:

1) One from Denmark (153 units), see (Clausen, SEAC proceedings 2011)\textsuperscript{38} and (Clausen, 2015 A).\textsuperscript{39}

2) One from Sweden (138 units), see (Clausen, 2015 A).\textsuperscript{40}

3) One from West Iberia (208 units) see (Clausen, SEAC proceedings 2013).\textsuperscript{41}

A fourth data set from France (597 units), adopted from Hoskin\textsuperscript{42} and a fifth data set France/Iberia (1537 units), also adopted from Hoskin\textsuperscript{43} will only be used as an examples to show a picture of how the model works (see Figure 3.8 and Figure 3.9). An extract of the test results are listed in Table 4. The model can be accessed statistically in two ways: A) by superimposing the building blocks to form a tendency diagram as in Figure 3.1 a or 3.7; or B) making a sum-diagram as shown in Figure 3.6. The difference in the advantages of each of these methods is that the tendency diagram probably reproduces what would be the result of long-term observations, whereas the sum diagram could be the result of observations over a shorter period.

The superimposed peak diagram is a tendency diagram showing the main tendency, that is, which should be the favored directions to observe according to the model. The sum diagram shows all possible full moons produced by the model and could be interpreted to represent observations of the full moon in an initial phase. To illustrate the difference, see Figure 3.7, where both ways of accessing the model are used.

\textsuperscript{38} (Clausen, SEAC proceedings 2011) at p. 163, Figure 6
\textsuperscript{39} (Clausen, 2015 A) at p. 19, Table B
\textsuperscript{40} (Clausen, 2015 A) at p. 20, Table D
\textsuperscript{41} (Clausen, SEAC proceedings 2013) at p. 152, Table 2.
\textsuperscript{42} (Hoskin, 1999) at p. S66 Figure 9
\textsuperscript{43} (Hoskin, 2002) Figure 4 at p. S80
Table 4
The main results from the statistical tests mentioned in the main text (subsection 3.4). All calculations are executed to \( h = 0 \) except for the Swedish data set.

<table>
<thead>
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<th>Data set</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Comments</th>
</tr>
</thead>
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<td>EFM(_j) + second full moon</td>
<td>Units covered by the model</td>
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<tr>
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<td>Probability factor ( p )</td>
<td>Probability factor ( p )</td>
<td></td>
</tr>
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<td>0.92 (superimposed)</td>
<td>114 units</td>
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<tr>
<td>Swedish</td>
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<td>0.86 (sum)</td>
<td>125 units</td>
</tr>
<tr>
<td>Swedish</td>
<td>0.66 (superimposed)</td>
<td>1.00 (sum)</td>
<td>125 units</td>
</tr>
<tr>
<td>Iberia</td>
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<td>1.00 (sum)</td>
<td>207 units</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td>See Figure 3.8</td>
<td>445 units</td>
</tr>
</tbody>
</table>

**Observations (207) and model 1**

![Graph showing observations and model comparison](image)

Fig. 3.6
This is an example of a sum-model (solid line) composed by the EMFs + second full Moon + SmFM and compared to the West-Iberian data set (dotted line). Same centroid coordinates as in figure 3.5.
Both the sum model (left) and the superimposed model (right) used on the same data set (thin solid line) from Sweeden. Note that the superimposed model visually fits the observations better than the sum model, but the sum model has the best statistical outcome (see Table 4). Centroid coordinates for the calculations is $58.17^\circ$N and $13.55^\circ$E. The calculated SMF peak (left) is clear in both panels and so is the second full moon peak close to $az = 125^\circ$. The underlying model is EFMs + second full moon.

Histogram presentation in $5^\circ$ bin intervals along the x-axis of 597 dolmens in southern France (bold solid line). The model distributions are calculated for latitude $43^\circ$N. Note the concentration about the SFM distribution (dotted line) and close to the southernmost minor lunar standstill. The thin solid line represents the model composed by the EFMs and the second full Moon. It is clearly seen that the SFM peak can explain the first (left) peak in the observed distribution if we call for an astronomical explanation. A sum model composed by EFMs + second full moon reveal two peaks but in the wrong bin intervals (to the right for the observed peaks). An explanation could be that sub data sets have orientation patterns that have no astronomical origin or not are consistent with underlying model.
The 5° bin interval histogram of 1537 (France/Iberia) tombs based on data from (Hoskin, 2002). The model distribution is calculated for 43°N. The SFM peak (dotted line) is peaking exactly where the observed distribution has maximum value (146 orientations). The histogram present 98% of Hoskins data. Here it is indeed clear that the SFM could be a part of an explanation or interpretation to the observed distribution.

3.6 Discussion and conclusion

Comparing the results from Table 4, we can note that: 69.9% of the Danish observations fit the model; 90.6% of the Swedish observations fit the model; and 99.5% of the West Iberian observations fit the model. Concerning the French data (Figure 3.8), which has not been statistically tested, 74.5% of the observations are covered by the suggested model, and further – if we include the fifth building block (first full moon before SFM or after AMF) – 89.3% is covered by the model. Taking all units into account, 891 units in total out of 1106 units, 80.6%, are covered by a model which consists of the exact SFM + the full moon (one or two days) before the exact AFM + the second full moon (early summer full moon in May or harvest moon in August).
The remaining units have orientations which are probably due to local traditions; e.g. interest in the exact AFM, directions pointing toward a special feature in the landscape such as a local high point or point of interest (mountain, hill, etc.), or both.

The interesting part is that the Danish data set has the poorest fit but was originally the trigger for the idea of the lunar season pointer. There are two explanations or interpretations, if you wish, for that. We must either include the lunar eclipses or use an archaeotopographical explanation. The only data set which indicates lunar eclipses is the Danish one, due to the three peaks. If we include the lunar eclipses, that is, the southernmost lunar standstills, in the Danish data this would cover 81% of the data, and if we add the purely archaeotopographical interpretation – in this case the north-eastern, southern and south-western directions (directions to the cluster cores) – it covers about 95% of the data set. Regardless of the explanation, all data sets indicate the existence of the lunar/solar crossover at spring (see Figures 3.0 a, 3.6, 3.7, 3.8 and 3.9).

The interpretation concerning the SFM has its own (simple) explanation. The SFM peak is more or less independent of latitude. The reason is that there is very little spread or deviation in the distribution pattern for the SFM peak from one latitude to another due to its position close to the equinox point. The same argument goes for the AFM peak, but in principle it is not necessary for constructing the “lunar season pointer” due to the properties of the AFM (see subsection 3.4 at p. 68-69). The azimuth of the SFM both indicates the lunar/solar crossover at spring and the coming crossover just one or two days before the exact AFM.

The second full moon is more sensitive to the position along the latitude. At northern latitudes, the SFM peak and the peak produced by the second full moon will be easier to distinguish and reveal two more significant and separate peaks (see Figures 3.1 a and 3.7). This is clearly demonstrated by the Danish and Swedish data sets (301 units). The same two peaks at more southern latitudes, however, will more or less appear in a kind of fusion (see Figures 3.5 and 3.8). This is demonstrated by the data sets from West-Iberia and Southern France (805 units). The French data set, however, reveals traces of two peaks, one produced by the SFM building block (see Figure 3.8) and one probably related to the second full moon.

For that reason the superimposed model should be the one to use at Northern latitudes and the sum model should be the one to be used at more southern latitudes. However, the Swedish data
set seems more or less able to fit into both models (see Figure 3.7). An explanation could be that the passage graves in the Falbygden area were built within a very short period of less than 50 years (Blomqvist, 1991), which would not have given enough time to identify the main directions in which to look – the favored ones, so to speak.\(^\text{44}\)

Therefore, a conclusion at this stage could be that at least the lunar/solar crossovers were known to Neolithic man during the period in which the megalithic monuments were constructed in the Western European area. To see whether this conclusion holds, further data sets similar to the ones tested here must be compared to the model. In addition, it seems that the proposed Model 2 (EFMs + second full moon) should be the one to work with in more details and refrain it for further use. In this connection remembering that, the simplest explanation probably is the most obvious one.

A remarkable feature named the ‘fingerprint feature’ appears now and then, concerning the Danish data set and lunar eclipses.\(^\text{45}\) The shape of the feature is similar to the central shape of the Danish dataset. The feature moves slowly along the longitude within an angular span of about 120°, (see Figure 3.10) and see (Clausen et al., 2008). If there is a connection between the dataset, the megalithic ‘lunar season pointer’ model and lunar eclipses it is truly an example of how physics, astronomy and archaeology can work together. In principle, it would then be possible to estimate a value of \textbf{delta T} by using the main directions of the passage graves. In this case using the peaking values of the EFM and the second full moon.

A hypothetic method to determine the \textbf{delta T} from the Danish passage graves is in details not yet developed. The idea is to compare the central part of the observed distribution in the same interval as the ‘fingerprint feature’ (az = 78° to 132°) along the interval it appears and then, as a first approximation, calculate the best fit by using \(\chi^2\)-statistics. Figure 3.10 show how the method should work. The \textbf{delta T} value for 3300 BCE is estimated to 19.92h corresponding to your actual position 3300 BCE, in this case the centroid for the calculations; 56°N and 11.5°E corresponding to a position along the longitude in time zone +1 (one time zone is 15°). Visually

\(^{44}\)(Clausen, 2015 A) at p. 13.

the best fit correspond to time zone -2 longitude position 33.5°W giving a $\text{delta T} = 22.92h$ (see Figure 10).

The method can only work if we relatively precise know the age of the sample of passage graves or dolmens we work with i.e. if we in this case could determine the age better than +/- 50 years. The reason is that the ‘fingerprint feature’ have a duration time in the same area about 100 years to 150 years.

To verifier the picture more observations, more calculations and more archaeological artifacts, like the small clay plates discussed in (Clausen, 2015 A) and (Clausen, SEAC proceedings 2013), are needed. If the proposed idea could be the case, it would be an ideal example of what interdisciplinary work could provide of new knowledge. Using physics and astronomy as telling history and archaeology to solve the $\text{delta T}$ problem or vice versa using knowledge about $\text{delta T}$ to determine the ages of the passage tombs.

A recent situation where the SFM and a lunar standstill eclipse took place occurred from 31 of March to the 4 April 2015. The crossover could be recognized the 2 April and the lunar eclipse took place the 4 April (see Figure 3.11). Unfortunately, the full Moon was not above the horizon in Denmark when the lunar eclipse would be observable. The situation appeared next time from the 27 September to the 28 September 2015 where the lunar eclipse will be visible from Denmark. In present time, the described phenomenon will reveal 16 visible lunar stand still eclipses in Denmark for the next 75 years depending of the weather conditions. They appear most commonly in pairs separated with a time span of 9 to 10 years, which is exactly the half of 19-year lunar eclipse cycle ($75 * 2/9.5 \approx 16$) close to the 18.61-year lunar cycle.
Fig. 3.10

Upper panel show lunar eclipse calculations for a 100-year period (3350 BCE to 3250 BCE) in 8 time zones. The ‘fingerprint feature’ in the histograms (marked with black) appear from time zone +1 to -3 (75°). Lower panel compares the ‘fingerprint feature’ in time zone -2 to the observations. Note the shape of the two peaks are almost quite similar.

If Neolithic man were able to combine, the two phenomenon’s is unknown but it does not prevent the situation to appear for an observer which have time enough to observe the whole horizon during a couple of days.
The complex situation with two lunar/solar alignments morning and evening same day (the 4 April) and the cross over which reveals the SFM the 2 April. The situation occurs later same year concerning the AFM, except that the lunar eclipse will be visible.

The main conclusion so far is that it is very likely that Neolithic man knew about the lunar/solar cross over at spring and at autumn i.e. knew about the EFM$s$ and probably also the second full moon. Which will satisfier a useful ‘lunar season pointer’ e.g. for ritual praxis for the Neolithic agriculture culture. If lunar eclipses somehow were involved in the Danish scenery I do not know for sure, but it is a possibility simply because the ‘lunar season pointer’ also pinpoints at least the lunar standstill eclipses due to the EFM$s$. As mentioned previous we need more archaeological artefacts and more data to see how the picture will develop which calls for future projects in this field.

Claus Clausen June 2016
Table 3

Output from program springny.exe

The table syntax is as in Table 2, starting from the left column

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<th>Sunset</th>
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Acknowledgement

This PhD project would not have been possible without the support of many helpful people. Primarily, the support of my master thesis supervisor, Per Kjærgård Rasmussen, was vital. Per Kjærgård Rasmussen believed that I had a talent – or an instinct, so to speak – for finding patterns which had not been noted before. In addition, he trained me in scientific method and approach. Further, he ensured that I stayed on the right track. This was instrumental for the development of my further work. Per Kjærgård Rasmussen and I co-authored an article: “Danish Passage Graves and Their Orientation” after I finished my master’s degree in astronomy in 2003. It took me three years to write the first article and two more years to finally get it published in 2008 in the archaeological magazine *Acta Archaeologica*. During the process of writing this first paper, I made contact with a number of Danish archaeologists, something which would prove to be important in the future.

Svend Illum Hansen, specialist in the reconstruction of Danish passage graves, is the first one worth mentioning. His knowledge of locations related to the megalithic monuments was very important for the presented fieldwork. In several cases, I was invited to excavations and reconstructions of these ancient mounds on the islands of Zealand and Samsø.

Second, the editor of *Acta Archaeologica*, Professor Klavs Randsborg, played an important role in the documentation of my discoveries. Later in the process, Klavs Randsborg became my co-supervisor. Both Svend Illum Hansen and Klavs Randsborg believed in my ideas and my way of thinking. This became the base for the doctoral study presented here.

The publication of the first article was the gateway for making contact with scientists all over the world who perform studies within the field of location and orientation of megalithic monuments in Europe and the surrounding areas.

Marciano da Silva and Fernando Pimenta, both from Portugal, merit a special mention. So do Francis Prendergast from Ireland and Michael Hoskin from the United Kingdom. The latter is editor of the *Journal for History and Astronomy* and accepted my second paper on Danish megalithic monuments for publication, and the former, who has since finished his doctoral study, gave me access to his data from Ireland.
Doctor Michael Rappenglück of Germany, PhD and head of the SEAC (Société Européenne pour l'Astronomie dans la Culture) later invited me to speak at a conference on archaeoastronomy in Munich in 2013. In addition, the SEAC international committee and the members of the SEAC have been very helpful during the process of this PhD project. Further, my Ph.d. supervisor, Anja C. Andersen has been vitally important due to her attitude concerning this project. Without her, there would never have been a PhD project of this nature. Finally the linguistic corrections has been carried out by the help of Liz Bramsen. I am very grateful for that.
References

Other references than the Phd thesis papers, used in the main text (in alphabetic order by surname).


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http://astrobase.ru/lib/dt_steph01.pdf

http://www.spirasolaris.ca/sbb8a.pdf
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**Acronyms**

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>AFM</td>
<td>Autumn Full Moon</td>
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<td>BCE</td>
<td>Before the Common/Current/Christian Era</td>
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<td>Daz</td>
<td>Derivation in azimuth</td>
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<td>EFM</td>
<td>Equinoctial Full Moon</td>
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<td>ISAAC</td>
<td>International Society for Archaeoastronomy and Astronomy in Culture</td>
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<td>Saz</td>
<td>Sun azimuth</td>
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<td>Sazset</td>
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<td>SEAC</td>
<td>Société Européenne pour l'Astronomie dans la Culture</td>
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<td>SFM</td>
<td>Spring Full Moon</td>
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<td>SmFM</td>
<td>Southernmost Full Moon</td>
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<td>TRB</td>
<td>Trichter(-rand-)becherkultur (from German) equivalent to the term funnel beaker culture</td>
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List of papers (Part Two)

**Papers: Clausen, C.**

**Paper I**

**Paper II**
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**Paper III**

**Paper IV**
http://adsabs.harvard.edu/abs/2015ssva.conf..170C

**Paper V**
Paper VI

Paper VII

Paper VIII
Co-author statement

Author statement and declaration for:
Claus Clausen
Per Kjærgaard
Ole Einicke

The statement counts for following two articles:


Statement for article A:
The Orientation of Danish Passage Graves.

Generally is about 75 per cent of the plain text written by Per Kjærgaard and 25 per cent by Claus Clausen. All calculations are made by Claus Clausen and the used computer programs are partly made and developed by Ole Einicke based on previous developed algorithms. The input and output part of all versions of the used moon and sun programs are made by Claus Clausen.

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Statement for article B:
The Orientation of Danish Passage Graves on the Islands of Samsø and Zealand.

Generally is about 75 per cent of the plain text written by Claus Clausen and 25 per cent by Per Kjærgaard. All calculations are made by Claus Clausen and the used computer programs are partly made and developed by Ole Einicke based on previous developed algorithms. The input and output part of all versions of the used moon and sun programs are made by Claus Clausen. All figures (including photos, drawings and figure captions) and tables are by Clausen.

Signed date: 15/8 2013

Claus Clausen

Per Kjærgaard

Ole Einicke
Part Two

The papers
Errata list I
At p. 222 left column seventh line from the bottom. The sentence: "The sun would spend most of its time at the extreme points." Should be: "The sun would spend most of its time at the extreme points compared to its time at equinox."
Or: "The sun would spend most of its time at the extreme points compared to all other directions in between these two points e.g. its time at equinox."
THE ORIENTATION OF DANISH PASSAGE GRAVES

CLAUS CLAUSEN, OLE EINICKE & PER KJERGAARD

The megalithic monuments found in large numbers throughout most of Western Europe have been the object of extensive archaeo-astronomical investigations over the past decades. In recent years, two main contributions have been the comprehensive works of Clive Ruggles (Ruggles 1999) and Michael Hoskin (Hoskin 2001) dealing in-depth with megalithic monuments in Britain/Ireland and South-Western Europe respectively. Strangely, few investigations of megalithic monuments in Northern Europe have been published. Especially in Denmark and northern Germany, around the western part of the Baltic Sea, the concentration of megalithic graves is very high, probably as high as in Brittany and the Orkney Islands. In Denmark, about 7,000 megalithic graves have been plotted out of an estimated original total number of 40,000 (Jensen 2001). The official Danish preservation register lists 2,800 graves. Of these, about 500 are of the special type known in Danish as jættestuer, 'tombs of the giants'. For the sake of brevity, this article will refer to them as passage graves, as in the title. These passage graves will be the subject of the present investigation.

The passage graves seem to be the culmination of a long development from the older simple dolmens with a single small chamber to great dolmens and finally to the passage graves, a type of large, elaborate tomb built by specialists. The passage graves that we consider in this paper are defined by an entrance passage approximately perpendicular to an almost rectangular main chamber. Potsherds found in front of the entrance passages (belonging to the so-called ‘Klintebakke’ type) place the date of construction from around 3200 to 3100 BC (Nielsen 2004). A handful of carbon-14 dates are established from birch bark found in the so-called ‘dry wall’ between the orthostats (Delu and Hansen 2005). The dates of eight of the passage graves point to a main construction period reaching from 3350 to 3050 BC.

Different forms of these passage graves exist (Hansen 2005). The most common is a single rectangular main chamber with a single narrower entrance passage. The whole construction is usually covered by a circular earthen mound surrounded by kerbstones. The size of both the main chamber and the entrance passage can vary considerably. Another quite common form is a double grave with two separate main chambers in the same earthen mound, each with its own entrance passage (Delu and Hansen 2000). Twin graves are like double graves, except that the main chambers are adjacent, sharing stones on their short sides. Even triple graves have been found. Sometimes passage graves and dolmens form small groups, typically containing 5-7 graves. An example of the layout of a single passage grave is given in Figure 1, below (Hansen 1993). Figures 2 and 3 show the layout of a twin grave and its earthen mound.

Recently, archaeoologists have shown that sight lines
were used when establishing the entrance passage. It seems that the innermost part of the entrance passage was the first part of the passage graves to be built, and that special care was taken in establishing its direction and maintaining this throughout the building process (Hansen 2005; Dehn and Hansen 2002, 2006). From the point of view of construction, such sight lines do not seem to be necessary. This could indicate that the entrance passage relates to some direction in the landscape or to some point on the horizon.

We do not know much about the function of the passage graves. We know that they were used for burials, perhaps in separate, distinct events over a period of time, and that certain rituals were performed which might have included the moving around of bones. Also, a large quantity of pottery of high quality has been found outside the entrances – this pottery seems to have been offered on the occasions of numerous large offering ceremonies.

An earlier study by Härth and Roslund (Härth and Roslund 1991, H&R in the following), on the orientation of passage graves in Scania and north-eastern Zealand was made on a sample of 41 graves. They found that most of the entrance passages pointed between east and south-east with a smaller number pointing south south-east. They argued in favour of a relationship between this orientation and the rising of the moon, identifying the south south-eastern direction with the southernmost ‘standstill’ of the moon3 (see Figure 4, 11 and 12). They concluded that “The distribution pattern of orientations is fully in line with a lunar explanation that the passages point at specific phases of the lunar cycle” (H&R 1991).

Our motivation for the present study was to enlarge the sample of passage graves with accurately determined directions of the entrance passages. Furthermore, we wanted to use this larger sample to see whether H&R’s conclusions could be substantiated or if other explanations were possible.

The orientation of the passage graves is in this paper described as the direction of the entrance passage as seen from the main chamber out through the middle of the en-

3 Both the moon and sun have ‘standstill’ points, also known as extreme points. The sun has two extreme points: the northern one corresponds to the point where the sun rises at the winter solstice and the southern one corresponds to the point where it rises at the summer solstice. Likewise, the Moon has similar extreme northern and southern points; however, due to the Moon’s 18.61-year cycle, it has two northern and two southern extreme points. (See also the section entitled “The azimuth distributions of the rising sun and moon” and figures 11 and 12.)
trance passage. This direction, measured clockwise from the north, is called the azimuth. Thus, for example, an entrance passage pointing due east has an azimuth of 90° (see figure 5).

The paper is composed as follows: first, we describe our fieldwork and the measurements of the directions of the passages. Then we compare our measurements with the survey by H&R and discuss the significance of specific features in the distribution of the directions. Next, we calculate the distribution of points on the horizon at which the sun and moon rise and we try to interpret the observed distribution in terms of three hypotheses: a) the rising sun; b) the rising (full) moon; and c) the rising full moon before an eclipse of the moon. All tables are placed at the end of this paper, just prior to the references.

OBSERVATIONS – THE FIELDWORK
Measurements were initially made at 56 locations (i.e. registration numbers) on Zealand between the geographical latitude 55.5° N and 56° N. To begin with, measurements were made using a GPS, a magnetic compass and a theodolite.

The GPS was used to measure the altitude above sea level (not tabulated), geographical position and to determine a north–south baseline. The distance between the two reference points on the north–south baseline was from 500 to 600 metres. The theodolite was used to measure the azimuths and the apparent horizon altitude (h) at the azimuth found. The apparent horizon mentioned is the horizon as we see it. In many cases, local topography (trees, houses, etc.) prevented measures of the horizon altitude, but from the 22 measurements of this type, the landscape was found to be rather flat (see Table 1A), with an average h of about 0.8°. A correction of the azimuths would be of approximately the same order as the horizon altitude according to the true or astronomical horizon, except for the most southern directions. It means that the exclusion of a correction of the azimuth is not critical in relationship to the uncertainty of the measurements (see below). Deduced from 47 measurements, the average altitude was about 42m above sea level, and in some cases there was an extremely good view of the horizon. It has been shown that many passage graves were built in open fields, because underneath the grave itself one sometimes finds traces of agriculture.

The resulting azimuths showed that measurements using the magnetic compass alone were sufficiently accurate; therefore, later measurements of the azimuths were done using only a magnetic compass. Such measurements were done on a supplementary five passage graves on Zealand and for five on of the island of Samso to the west of Zealand, but still at the same latitude. Thus, the total number of graves measured was 66. The geographical latitude and longitude were measured using the GPS, except for the five graves on Samso, where the position was found using high resolution maps.

Good measurements were obtained for 51 graves with a total of 63 entrance passages; these measurements are presented in Table 1A. Considering the accuracy in establishing the north–south base line and, correspondingly, the entrance sight line (determined to be the mean line between the two sides), we evaluate the accuracy of the azimuths to be ±2°. This was confirmed by a repeat measurement of four graves, which always agreed to better than ±2°.

The data for the passage graves with uncertain measurements are given in Table 1B, which contains 17 locations (two in common with Table 1A) with a total of 18 estimated entrance passage directions. Reasons that good measurements could not be obtained were that the entrance passage 1) was missing altogether or 2) so damaged that no meaningful measurement could be obtained, or 3) that the local topography made measurements difficult. The uncertainty of measurements given in Table 1B is larger than ±3°. Thus, only the data from Table 1A is taken into further consideration in the present paper.

The distribution of the resulting 63 entrance direc-
The Orientation of Danish Passage Graves

Fig. 4. The distribution of the azimuths of the entrance passages of the passage graves measured by us (upper panel – 51 graves with 63 entrance directions) and by H&R (middle – 41 graves with 47 entrance directions) and the combined sample (88 graves with 103 entrance directions).

Fig. 5. The azimuth distribution for the combined sample, shown as an azimuth circle diagram. It is easily seen that most of the observations lie in the east to south quadrants.

Fig. 6. The distribution of the azimuths of the entrance passages of the passage graves measured by us (upper panel – 51 graves with 63 entrance directions) and by H&R (middle – 41 graves with 47 entrance directions) and the combined sample (88 graves with 103 entrance directions).

From Table 1A is given in histogram form in Figure 4 and also, for the combined sample, as a circle azimuth diagram in Fig. 5. Considering the accuracy and number of measurements, we have chosen a bin-size of 6° (and started at 29.5°) for the histograms. At a glance, it is immediately obvious that the distribution is far from random. We find that most azimuths (70%) fall between 80° and 135°, with two peaks around 100° and 120°.

During our investigation, we discovered that large groups of passage graves existed within which most of the passage graves and other megalithic units were related to each other. We call these large groups clusters; they typically contain 15–30 megalithic units and cover an area of around 10–25 km².

Our sample of passage graves includes parts of – probably the central part – of three clusters of passage graves (Table 1A: Tranbjerg (Samso cluster), Ubb (Kalundborg cluster), Rye, Kirketunng (Ejby cluster)). Looking for 'astronomical' sight lines, we discovered that about 75% or more of the passage graves in the clusters were pointing towards other passage graves (or dolmens) in the surrounding area, up to five kilometres from the central part. This discovery was so striking that we started a survey of 20 cluster candidates (fig. 6) for which we here present some interesting preliminary results. A more detailed account will be given in Kjærsgaard and Clausen 2008.

The Samso-cluster is shown in Figure 8, and the measurements of this cluster are given in Table 2. The central part of the cluster is shown in Figure 9, in which the reconstructed topography of prehistoric times is also presented. At the moment, this cluster is the one we have investigated most intensively. The cluster consists of 20 units: 14 passage graves, three dolmens, one great dolmen (with a passage) and two unclassified megalithic units. The entire cluster covers an area of about 25 km².

An interesting quantity is what we call the 'alignment azimuth'. The alignment azimuth is defined as the azimuth of the line drawn from one cluster unit (the primary unit) to another cluster unit (the target unit). We use the word 'alignment azimuth' for this new quantity because we know from our investigation that a line can be drawn through at least 4 cluster units, including one or more of the passages. Table 2 shows that for nine primary units of the Samso-cluster, one can find a corresponding tar-
Fig. 6. The map shows the distribution of identified and potential clusters in Denmark and southern Sweden (Scania). 1) The Samsø cluster, 2) the Kalandborg cluster and 3) the Ejby cluster.

Fig. 7. This map shows the island of Samsø as it appears in the present time and marks the position of the Samsø cluster.

Fig. 8. The map shows the southern part of Samsø with small lakes, ponds and creeks at the present time. Eight passage graves are located at the central part of the cluster, which covers about one square km. The distribution of the alignment azimuths in the cluster is quite similar to the main distribution in Table 1A for azimuths greater than 90°. The thin solid lines represent directions for the alignment azimuths tabulated in Table 2. The dotted lines represent an uncertain azimuth alignment direction. The short arrows represent passage directions and the numbers refer to the unit registration number (Table 2).

Fig. 9. The reconstructed coastline in prehistoric times and the topography around the central part of the Samsø cluster. Measurements show that nearly all the megalithic units are placed at local high points. The map shows a more complex shoreline, informing us that this part of the island was fragmented into many small islands in the past.
towards the target unit). Thus, for the 14 measurable units in the Samso-cluster, the passage azimuths of nine (64%) point forward, three (22%) point ‘backward’ and two (14%) have no ‘target unit’. All units enter into a source unit–target unit relationship.

One of the two other clusters investigated, the Kalundborg-cluster, with 32 units, shows nearly the same characteristics as the Samso-cluster. It is also remarkable that the same alignment azimuths are represented in both clusters. This result suggests that the same underlying idea is the basis for the layouts of the two clusters, and certainly that the placement of the individual passage graves and dolmens cannot be random.

Based on the above results, we suggest that lines/directions must have played a very important role in the burial praxis.

COMPARISON WITH THE ORIENTATIONS FOUND BY H&R  
As mentioned above, a similar investigation had been done earlier by H&R, who measured typologically similar passage graves in Scania and North- Zealand. H&R measured 41 graves using a theodolite and a magnetic compass. H&R have an accuracy of ±2° on their measured azimuths. Included in our sample are four graves (with five entrance passages) from H&R’s investigation. For these, our measurements are in agreement with those of H&R to less than one degree in the mean (the largest deviation is two degrees). We are therefore confident that H&R’s results can be directly compared with ours and that the two samples can be combined. The distribution of the azimuths found by H&R is also shown in Figure 4, together with the distribution of the combined sample. A general agreement can be seen between our sample and that of H&R in the sense that most azimuths are found to be between 80° and 135°. The difference between the two distributions is that our sample clearly displays two peaks, this is not clearly visible in H&R’s distribution. However, H&R themselves interpret their broad distribution as having two components, one at around 90° and another at around 125°. We note that the two peaks are clearly visible in the combined sample. Other differences are the small peak at 150°, which is more pronounced in H&R’s sample, and the direction due south which is found in our material but not in H&R’s. For the combined
sample we find the position of the two main peaks to be 100° and 120°.4

In order to investigate the observed material a bit further, we have divided the combined sample into three parts according to geographical region: Zealand west of longitude 11° 40' (where the broad fjord "Isfjorden" cuts north Zealand in two); Zealand east of this longitude; and Scania. We have done this in order a) to investigate whether there is a trend in the distributions according to geographical location, and b) to see whether the peaks in the distribution found for the combined sample can be seen in these individual, smaller samples. The result is that all three peaks, at 100°, 120° and 150°, are noticeable in all three distributions. We take this result as a confirmation of the reality of the three peaks in the distribution – they are not due to statistical chance.

THE AZIMUTH DISTRIBUTIONS OF THE RISING SUN AND MOON
From the observed distribution of azimuths (Figures 4 and 5), an interpretation in terms of the rising sun or moon seems natural. Also, the preliminary results from the two clusters of passage graves makes it obvious that not only were the constructors very conscious of the direction of the entrance passage, but also that directions must have played an important role in the burial practice.

The azimuth distribution for the rising (or setting) sun and moon is well known and relatively simple (see, for example, Ruggles 1999, pp. 24-25 and pp. 36-37 or Hoskin 2001, p. 20). The azimuths of the rising sun vary between their extreme values at the solstices. The determining variables are the geographical latitude and the inclination of the ecliptic, ε, which varies slightly with time. For the relevant geographical location, the azimuth of the rising sun would vary between approximately 42° and 135° around the time period where the passage graves were built. The sun would spend most of its time at the extreme points. The azimuth distribution of the rising moon also depends on the inclination of the orbit of the moon and the 18.61-year period of the regression of the line of nodes (the intersection of the line of nodes with the ecliptic). The combined effect causes the lunar extreme points to move along the horizon with the same period as the lunar cycle (18.61 year). Thus the rising moon has two northern and two southern extreme points (often referred to as the northern/southern major and minor lunar standstills), which are covered in the 18.61-year period. For the sake of the following discussion, we have calculated not only the extreme points but the actual distribution of azimuths for both the sun and the moon.5 These distributions are given in Figure 10.

From earlier investigations of megalithic monuments, alignment with both the sun (for example, Stonehenge and the passage tombs at Newgrange and Maes Howe) and the moon (for example, the recumbent stone circles in north-eastern Scotland and the short stone rows) have been found (see Ruggles, 1999). In his comprehensive work on the orientation of dolmens in Iberia and France, Hoskin argued in favour of an orientation related to the rising of the sun.

INTERPRETATION IN TERMS OF THE RISING SUN
When we consider the observed distribution of the combined sample from Figures 4 and 5, we notice, in fact, that it very closely resembles some of the distributions found by Hoskin for Iberian and French megalithic tombs. In our case, 78% of the azimuth directions fall within the azimuth range of the rising sun. Thus the same interpretation could be invoked, namely that the entrance direction is related to the direction of the rising sun, and that 17% of the directions could be related to the direction of the sun climbing just above the horizon or close to culmination, in Hoskin's terminology, 95% are sun rising or sun climbing (SR/SC). Hoskin advanced the hypothesis that the tombs were laid out to face sunrise on the day the construction began, when manpower for the venture was available after the harvest (see Hoskin 2001, p. 127). So this hypothesis could very well also apply to the Danish passage graves. There are, however, important differences: in general, our distribution of azimuths is skewed

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4 The calculated mean values for the intervals 75° to 105° (included) and 105° to 130° (included) are 97° and 119° respectively.

5 The computations were done using our set of computer programs. The distribution for the Sun is the same today, with only a small shift in distribution due to today's slightly lower value of the inclination of the ecliptic, ε (the distribution now lies between 46° and 134°). Note that we refer to the apparent rising of the centre of the sun (taking into account the effect of refraction at the horizon). We have calculated the distribution of the rising Moon's azimuth for an 18.61-year period, starting from 3300 BC. The distribution is the same today, with only a small shift in the extreme points of 1-2°.
Fig. 11. The azimuth distribution of the number of sunrises for an eight-year period (upper panel) and for the number of moonrises (lower panel) during the moon's 18.6-year cycle for the time around 3300 BC. The bin size used here is 1 degree.

more towards the South; and in general the passage graves are larger and more elaborate constructions than the simpler dolmens studied by Hoskin. Finally, the climates of the two locations differ. For the Danish passage graves, an azimuth for the rising sun of 120° would correspond to a date close to either the first of November or early February. Since the climate in November and February is cold and wet, with short days and little light, it makes no sense to start building an elaborate passage grave involving the handling of 40-50 large stones, each weighing up to several tons, at this time of the year – even though the actual construction time was probably relatively short, perhaps weeks rather than months. We would consider it highly unlikely that the construction of more than 40% of the passage graves (those with azimuths larger than 119°) would have begun at that time. This argument does not, of course, rule out a solar explanation, but then it requires that the direction of the rising sun be marked for later use. Further, we cannot fit the southern direction into the solar explanation. We then face a more complicated explanation – and, why mark directions around 100° and 120° preferentially when a whole continuum of directions is available? Besides, the argument for the building process starting after the harvest is really not that strong, since farming at that time was most likely only a supplement to hunting, fishing and herding. Finally, we notice that there is a lack of observed azimuths around the solstices where the sun spends the longest periods of time.

INTERPRETATION IN TERMS OF THE RISING FULL MOON

Some of the features in the observed distribution of azimuths (Figures 4 and 5) could be related to an explanation in terms of the moon. First of all, there is the – admittedly small – clump of azimuths around 150° which corresponds nicely with the southern outer standstill of the moon (which was also the argument that led H&K to suggest a lunar explanation). However, it is also worth mentioning that the two peaks in the observed distribution around 100° and 120° both have a width of around 20° and are separated by this same amount. In the mean,
difference in the rising full moon’s azimuth of 20° would roughly correspond to one lunar month (if one is reasonably far from the standstills – see Figure 11).

This leads us to suggest that the important direction is the direction of a certain full moon, for example the first full moon of spring/autumn, the so-called ‘megalithic equinox’ (Mariano da Silva 2004) or the first full moon after sowing/harvest. In fact, the azimuth of 100° would roughly correspond to the beginning of April or the middle of September, and the azimuth of 120° would roughly correspond to the beginning of May or the middle of August. The relationship between the azimuth of the rising full moon and the date of the year has been calculated and is given in Figure 11. Due to the moon’s 18.61-year period, this relationship is not very sharp, as can be seen from the figure.

The moon hypothesis has the advantage of involving particular directions which eventually could be marked for later construction. However, it can also be noted that the obvious directions of interest related to spring/autumn and sowing/harvest occur at times of the year when it was practical to start and carry out the construction work. We also find that the special emphasis on the direction revealed by the clusters of passage graves is easier to accommodate in a hypothesis involving the rising of a special full moon. Here we notice that the southern azimuths or lines could refer to the summer full moon, which moves at southern directions just above the horizon.

Most of the above arguments would also apply to the rising of the new moon (or rather, the rising of the moon just before the new moon), the only difference being that the dates upon which this would occur around 100° and 120° would be nearly the same as those for the rising sun.
INTERPRETATION IN TERMS OF ECLIPSES OF THE MOON

An interpretation of the observed azimuth distribution in terms of eclipses of the moon may seem far-fetched. Nevertheless, there are a number of interesting facts which could point in this direction. Here we will consider the distribution of azimuths of the rising full moon prior to an eclipse (after the same night). This distribution should be rather similar to the sun’s azimuth distribution, since the moon will be directly opposite the sun at an eclipse. However, due to the moon’s different periods, the distribution is not as smooth. In fact, for limited periods of time and for a limited range of geographical longitudes, one finds a distribution in which peaks occur around the azimuths of 100° and 120° with a trough in between. This is actually the case for the geographical location we consider and for the time period 3300 BC to 3100 BC (but most pronounced for the period 3300 BC to 3200 BC). The two peaks and the trough, which we call the ‘fingerprint feature’, are not found in the centuries before or after 3300-3100 BC, nor are they found outside a limited range of geographical longitudes. Also when we calculate the moonrise azimuth distribution for the day after the eclipse we do not see the ‘fingerprint feature’. Long-term calculations running throughout a period of 8000 years show that the ‘fingerprint feature’ appears now and then. Roughly speaking, the feature can persist from 100 to approximately 350 years with pauses from 100 to 200 years. We also find that in the time period 3300-3200 BC there were about 50% more eclipses of the moon than normal for full moonrises in the azimuth interval of 90° to 130°. There is, however, a problem here. We can calculate very accurately when an eclipse will occur in “absolute” time, i.e. in what is called ephemeris time (ET – popularly speaking, the time that enters into Newton’s second law). However, due to the accumulated effect of the Earth’s faster rotation in earlier times, we do not know the corresponding universal time (UT, i.e. roughly speaking the mean solar time), or equivalently the geographical longitude at which this eclipse will occur. The difference between the ephemeris time and the universal time, known as Delta T, is not known with any great accuracy when considering the time interval relevant here. The best estimate for Delta T for 3300 BC is around 23 hours, with an uncertainty of about ±5 hours.

We can take this effect into account by simply using our computations at the next following time zone, i.e. for our geographical location, which is the present day time zone +1, we should use our computations for present day time zone +2. In Figure 1, we show that the fingerprint feature is visible through time zones -5 to +2. Thus our hypothesis is consistent with a Delta T of 23h.

However, we note that it would have been possible for Neolithic man to a certain degree to ‘predict’ a lunar eclipse using simple means. Actually, when the sun sets opposite the rising full moon (to within certain natural limits), then about 1 out of 3 full moonrises are followed by an eclipse on the same night.

We do not suggest that the passage graves or the clusters of passage graves and dolmens acted as advanced prehistoric observatories. Rather, we propose the hypothesis that rituals concerning burials and the dead were so important that they necessitated keeping an eye on the rising of the (full) moon, so that these rituals could be performed when an eclipse occurred. In our view, the near-obssession with particular directions indicated by the clusters of passage graves and dolmens points to a special phenomenon.

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6 Our computer program is based on the lunar theory developed by E. W. Brown, in which analytical expressions for the lunar motion are used and expressions for the Earth’s orbit are included – it also gives the Solar ephemeris. The actual version of Brown’s theory used is taken from the Nautical Almanac Office’s “Improved Lunar Ephemeris” (Jet Propulsion Laboratory: Long Ephemeris” DE403, see http://ssd.jpl.nasa.gov/ephemeris.html); however, we used only a limited number of terms. For the classification of the eclipses of the Moon (i.e. whether partial/total/solar/annular), we used the recipe given by Jean Meeus (Jean Meeus, Astronomical Algorithms, 1991).

7 An account of the problem of the Earth’s rotation is given in the review paper by F. Richard Stephenson, “Historical eclipses and the Earth’s rotation”, Astronomy & Geophysics, vol. 44, 222, 2003. The difference between the Newtonian time and the universal time (mean solar time) is called delta T. The effect is mainly due to the tidal force of the moon, which slows the Earth’s rotation. The value of delta T is relatively well known over the past several centuries. Delta T is the amount of time required to complete a full rotation of the Earth, given the presence of the Moon.

8 To be precise, the sun and moon should be on a straight line to within 45° (i.e. the sun and moon are directly opposite to within ±90°) before and after sunset. If this condition is fulfilled, there is a probability that 1 out of 3 full moonrises are followed by an eclipse of the moon within the following 2 hours (this probability is independent of the azimuth). If the moon rises later than 3 minutes after sunset, one will not be able to determine whether or not the sun and moon are aligned. If the sun is approximately 15 minutes or less from setting, then the rising full moon will appear to be very red, in fact almost as red as the setting sun.
Fig. 13. The distribution of azimuths of the rising full moon before a visible total or partial eclipse. The distribution is calculated for 3300-3200 BC for the geographical latitude 36° and for the time zones from -5h (90° west) to -2 (15° east). The position of the ‘fingerprint feature’ is indicated by the position of the ‘comb’ with 5 teeth.

for example, an eclipse. In this case, we suggest that the southern azimuths or lines could be in the direction of the eclipse itself. Many – even most – summer eclipses occur at southern directions low on the horizon.

Actually, one could imagine that some of the full moon risings at the time of spring/autumn and sowing/harvest mentioned before were observed to be followed by an eclipse later the same night, which could have led to a strengthened interest in the two directions of 100° and 120°. Thus the two hypotheses involving the rising of certain full moons and the same followed by an eclipse need not exclude each other.
SUMMARY
We have measured the directions of the entrance passages for 51 passage graves situated mainly on north Zealand. Together with previously published measurements, the combined sample of 105 entrance directions shows a strong preference for the azimuth directions of 100° and 120°. Nearly all directions fall within the azimuths for the rising sun or the (full) moon. From clusters of passage graves, we find a very strong tendency for the entrance passage to point towards another passage grave or dolmen. We discuss our findings in terms of three hypotheses: in terms of the rising sun; the rising full moon; and the rising full moon before an eclipse. Taking all the evidence into consideration, we tend to favour a lunar hypothesis for the entrance directions.

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REFERENCES


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### Tables

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<td>10.35 16.8</td>
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<td>10.35 16.8</td>
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Table 1A

L. M. and R before the azimuth denote the left, middle and right entrance passages (as seen from the outside) for double, twin or triple graves. The Sh number is an odd registration number for the location. Notes: *1) the left chamber is elongated in the direction of the entrance passage and resembles a dolmen more; *2) the right entrance passage is missing; *3) the passage makes a bend from 108° to 101°: the latter value is used; *4) the direction of the left entrance passage is uncertain, see Table 1B; *5) only one stone remains of the right entrance; *6) the measurement for the left entrance passage is uncertain, see Table 1B.
The Orientation of Danish Passage Graves

Table 1B

<table>
<thead>
<tr>
<th>Registration number</th>
<th>Passage Grave</th>
<th>Name/Place</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Azimuth</th>
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<tr>
<td>3121:14</td>
<td>Vesterup/Tommeskov St38</td>
<td>55 41 35.50</td>
<td>11 10 24.6</td>
<td>R 195 *1</td>
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<td>3221:01</td>
<td>Bogense/Velslev St4</td>
<td>55 40 18.70</td>
<td>11 13 34.8</td>
<td>L 116/R 118</td>
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<tr>
<td>3221:09</td>
<td>Uleby/Uleby St31</td>
<td>55 37 44.80</td>
<td>11 10 41.0</td>
<td>L 122/R 33</td>
<td></td>
</tr>
<tr>
<td>2221:28</td>
<td>Chibo/Chibo St12</td>
<td>55 39 17.30</td>
<td>11 13 38.3</td>
<td>L 197 *2</td>
<td></td>
</tr>
<tr>
<td>3221:5</td>
<td>Togbodumadu/Togbudumadu</td>
<td>55 38 42.20</td>
<td>11 13 51.8</td>
<td>154</td>
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<tr>
<td>3337:24</td>
<td>Sydhavns/Havns Sy65</td>
<td>55 38 48.00</td>
<td>11 16 44.7</td>
<td>20</td>
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<tr>
<td>2221:03</td>
<td>Sandby/Salby St5</td>
<td>55 33 01.50</td>
<td>11 18 05.3</td>
<td>46</td>
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<tr>
<td>4223:01</td>
<td>Skodby/Skodby St23</td>
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<td>11 26 16.7</td>
<td>L 107/R 74</td>
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<td>Bukkeby/Bukkeby St55</td>
<td>55 55 48.40</td>
<td>11 36 11.7</td>
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<tr>
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<td>Stodrup/Kirke Kirkeby S6</td>
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<td>11 48 10.4</td>
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</tr>
<tr>
<td>2226:04</td>
<td>Holtegården/Draby St23</td>
<td>55 34 48.50</td>
<td>11 54 54.0</td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>3221:13</td>
<td>Torveby/Torveby St25</td>
<td>55 39 46.20</td>
<td>11 57 10.7</td>
<td>205</td>
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</tr>
<tr>
<td>3336:34</td>
<td>Kusby/Kusby St5</td>
<td>55 32 42.50</td>
<td>11 37 53.3</td>
<td>L 190 *3</td>
<td></td>
</tr>
<tr>
<td>2226:02</td>
<td>Johansen/Dalby St216</td>
<td>55 31 39.50</td>
<td>11 58 03.9</td>
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<tr>
<td>3226:45</td>
<td>Osemark/Osemark St45</td>
<td>55 56 47.50</td>
<td>11 59 16.7</td>
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<td>3336:32</td>
<td>Elmso/Selby St13</td>
<td>55 44 48.00</td>
<td>12 02 33.0</td>
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</tr>
<tr>
<td>3221:27</td>
<td>Stenalde/Sentralde St70</td>
<td>55 43 42.60</td>
<td>12 09 42.6</td>
<td>L 173/R 107</td>
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</tr>
</tbody>
</table>

Table 1B

Notes. *1) the left entrance passage is missing; *2) the middle entrance passage is missing; *3) the right entrance passage is given in Table 1A. *4) the right entrance passage is so disturbed that no meaningful measurement could be made; *5) the middle and right entrance passages are given in Table 1A.

Table 2

<table>
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<tr>
<th>Registration nr.</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Azimuth</th>
<th>Alignment azimuth</th>
<th>Target unit</th>
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<td>55 49 44.9</td>
<td>10 35 14</td>
<td>100</td>
<td>100</td>
<td>2917:25</td>
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<tr>
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<td>55 49 44.6</td>
<td>10 35 59.6</td>
<td>163</td>
<td>163</td>
<td>3017:23</td>
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<td>2917:39</td>
<td>55 48 94.3</td>
<td>10 33 26.7</td>
<td>98</td>
<td>98</td>
<td>3017:23</td>
</tr>
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<td>3017:07 megalith unit</td>
<td>55 47 81.6</td>
<td>10 34 26.8</td>
<td>*1</td>
<td>*1</td>
<td>3017:23</td>
</tr>
<tr>
<td>3017:19</td>
<td>55 47 98.0</td>
<td>10 36 34.0</td>
<td>105</td>
<td>105</td>
<td>3017:23</td>
</tr>
<tr>
<td>3017:34</td>
<td>55 47 53.5</td>
<td>10 35 00.0</td>
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<td>55 47 23.7</td>
<td>10 35 04.1</td>
<td>122</td>
<td>122</td>
<td>3017:23</td>
</tr>
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<td>3017:39 dolmen</td>
<td>55 47 17.5</td>
<td>10 34 96.5</td>
<td>207</td>
<td>207</td>
<td>3017:32 dolmen</td>
</tr>
<tr>
<td>3017:31 dolmen</td>
<td>55 47 17.5</td>
<td>10 34 96.5</td>
<td>207</td>
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<td>3017:32 dolmen</td>
</tr>
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<td>3017:32 dolmen</td>
<td>55 47 03.2</td>
<td>10 34 86.6</td>
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<td>93</td>
<td>3017:45</td>
</tr>
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<td>3017:33 dolmen</td>
<td>55 46 90.1</td>
<td>10 25 19.0</td>
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<td>150</td>
<td>3017:21</td>
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<td>3017:33 dolmen</td>
<td>55 45 40.7</td>
<td>10 26 38.3</td>
<td>108</td>
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<td>3017:45 great dolmen</td>
<td>55 45 96.0</td>
<td>10 26 30.4</td>
<td>196</td>
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<td>Tranekaer Sb 13 destroyed dolmen</td>
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<tr>
<td>Tranekaer Sb 49 megalith unit</td>
<td>55 46 92.4</td>
<td>10 27 89.9</td>
<td>144</td>
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<tr>
<td>Kelby Sb 36 destroyed dolmen</td>
<td>*1</td>
<td>*1</td>
<td>*1</td>
<td>*1</td>
<td>none</td>
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</table>

Table 2

L before the azimuth denotes the left entrance passages for twin graves.

The alignment azimuths are deduced from maps and GPS measurements. Notes: *1) Not measurable, *2) Not measured, *3) Old measurement gives the azimuth as south-east for 3017:19. *4) Passage missing. *5) Registration number: 3017:30 is a hybrid unit with a dolmen and a giant's tomb in the same earthen mound. The 3017:31 and 3017:32 units seem to play a central role in the cluster because of the many line relations. **
Paper II

THE ORIENTATION OF DANISH PASSAGE GRAVES ON THE ISLANDS OF SAMSØ AND
ZEALAND.
Denoted as (Clausen et. al, 2011) in the main text.
THE ORIENTATION OF DANISH PASSAGE GRAVES ON THE
ISLANDS OF SAMSO AND ZEALAND

CLAUS CLAUSEN, PER KJÆRGAARD
and OLE EINICKE, Copenhagen University

With the exception of Hård and Roslund\footnote{H&R in the following}, González-García and Costa-Ferrer, Göran Henriksson, and recently Clausen \textit{et al.}, remarkably few investigations of the orientations of megalithic monuments in northern Europe have been published. By contrast, in other parts of western Europe, they have been the object of extensive archaeoastronomical investigations over the past decades.

In recent years, two main contributions have been the comprehensive works of Clive Ruggles\footnote{Ruggles} and Michael Hoskin, dealing in-depth with megalithic monuments in Britain/Ireland and southwestern Europe respectively. In Denmark, about 7,000 megalithic graves have been plotted out of an estimated total original number of 40,000. The official Danish preservation register lists 2,800 graves. Of these, about 700 are passage graves known in Danish as \textit{jættestue}, 'tombs of the giants'.

The constructors of most Danish megalithic monuments belonged to the funnelbeaker culture (in German, \textit{Trikerandbecher}, TRB), which existed during a period from about 3900 to 2800 B.C. and covered a relatively large area in the southern part of northern Europe (see Figure 1(a)). Most Danish passage graves are believed to have been built during a relatively short period of time, from about 3300 to 3100 B.C., and seem to be the culmination of a long development from the older simple dolmens (3500 B.C.) with a single small chamber, to dolmens with a short passage, great dolmens with a passage, and finally to the more complex passage graves. Great dolmens and passage graves are, according to some archaeologists, related constructions; that is to say, they belong to the same class of passage tombs.

Different forms of these passage graves exist. The most common is a single rectangular main chamber with a single, narrower entrance passage, which gives the grave an almost T-formed shape. The whole construction is usually covered by a circular earthen mound surrounded by kerbstones. The size of both the main chamber and the entrance passage can vary considerably, with a chamber length from a few metres to up to 14 metres for a single chamber (23 metres for twin chambers) and a passage length of up to 11 metres. Another quite common form is a double grave with two separate main chambers in the same earthen mound, each with its own entrance passage. Twin graves are like double graves, except that the main chambers are adjacent, sharing stones on their short sides. Even triple graves are found (Figure 2). Sometimes passage graves and dolmens form small clusters, typically with 5–7 graves; however, some clusters contain more than 20 graves. We have identified a number of clusters and cluster candidates (see Figure 1(b)).

Archaeologists have shown that sightlines were used when establishing the entrance passage. It seems that the innermost part of the entrance passage was the first part
Fig. 1. (a, left) The approximate are covered by the funnel-beaker culture, about 3500 B.C. (b, right) The distribution of potential and identified clusters in Denmark and Scania. Cluster 1 is the Samsø cluster, cluster 2 includes the Uby cluster members, and cluster 3 is the Eby cluster (see Table 1).

Table 1. The 65 graves studied, 64 of which were measured and yielded a total of 78 directions. In the case of a double, twin or triple grave, L, M and R before the azimuth denote the left, middle and/or right entrance passages (as seen from the front). Cluster core members are indicated in bold. Denmark is very flat and where an horizon altitude is not specified it has been taken to be 0°.

<table>
<thead>
<tr>
<th>Passage Graves</th>
<th>Registration Name @ Place</th>
<th>Azimuth</th>
<th>Horizon Altitude</th>
<th>Dec.</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>2017:29</td>
<td>Jænes Høj @ Samsø</td>
<td>100°</td>
<td>~5.6°</td>
<td>55.82°</td>
<td>10.56°</td>
</tr>
<tr>
<td>2017:42</td>
<td>Samsø</td>
<td>105°</td>
<td>~8.4°</td>
<td>55.79°</td>
<td>10.58°</td>
</tr>
<tr>
<td>2017:30</td>
<td>Samsø</td>
<td>L 207/R 122°</td>
<td>~20.1–17.3°</td>
<td>55.79°</td>
<td>10.58°</td>
</tr>
<tr>
<td>2017:24</td>
<td>Samsø</td>
<td>116°</td>
<td>~14.3°</td>
<td>55.79°</td>
<td>10.58°</td>
</tr>
<tr>
<td>2017:29</td>
<td>Samsø</td>
<td>115°</td>
<td>~13.7°</td>
<td>55.79°</td>
<td>10.58°</td>
</tr>
<tr>
<td>2017:24</td>
<td>Samsø</td>
<td>100°</td>
<td>~5.6°</td>
<td>55.82°</td>
<td>10.59°</td>
</tr>
<tr>
<td>2017:31</td>
<td>Samsø</td>
<td>128°</td>
<td>~20.3°</td>
<td>55.79°</td>
<td>10.59°</td>
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<tr>
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<td>Samsø</td>
<td>L 161°</td>
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<td>145°</td>
<td>~27.4°</td>
<td>55.78°</td>
<td>10.61°</td>
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<td>Knæsen @ Samsø</td>
<td>144°</td>
<td>~27.1°</td>
<td>55.78°</td>
<td>10.63°</td>
</tr>
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<td>Råklev (Nyrrp)</td>
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<td>3120:21</td>
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<td>~33.8°</td>
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<td>125°</td>
<td>~18.9°</td>
<td>55.64°</td>
<td>11.10°</td>
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<td>L 121/R 116</td>
<td>0.2°–14.2°</td>
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</tr>
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<td>Ravdægj @ Dalby</td>
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<td>55.21°</td>
<td>11.17°</td>
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<td>Nordanhoj @ Røby</td>
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<td>55.65°</td>
<td>11.17°</td>
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<td>Hyldehoj</td>
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<td>~32.8°</td>
<td>55.65°</td>
<td>11.17°</td>
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<td>Rognhusej @ Skullemup</td>
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<td>~6.2°</td>
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<td>Odsher @ Kærby</td>
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<table>
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<th>Azimuth</th>
<th>Horizon Altitude</th>
<th>Dec.</th>
<th>Location Lat.</th>
<th>Location Long.</th>
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<tbody>
<tr>
<td>Køge Halsinge</td>
<td>134°</td>
<td>–</td>
<td>–30°6'</td>
<td>55°51'</td>
<td>11°20'</td>
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<tr>
<td>Værlev</td>
<td>156°</td>
<td>–</td>
<td>–31°0'</td>
<td>55°66'</td>
<td>11°20'</td>
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<td>Værlev</td>
<td>121°</td>
<td>–</td>
<td>–16°9</td>
<td>55°66</td>
<td>11°20'</td>
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<tr>
<td>Korsøj @ Ubby</td>
<td>L 122/ R 122</td>
<td>1.2</td>
<td>–16°4.6-16°4.6</td>
<td>55°62</td>
<td>11°21'</td>
</tr>
<tr>
<td>Tagger Halsinge @ Ubby</td>
<td>134°</td>
<td>–</td>
<td>–23°1</td>
<td>55°65</td>
<td>11°23'</td>
</tr>
<tr>
<td>Rigtved</td>
<td>94°</td>
<td>–</td>
<td>–2°3</td>
<td>55°65</td>
<td>11°28'</td>
</tr>
<tr>
<td>Søby</td>
<td>L 98°</td>
<td>–</td>
<td>–4°5</td>
<td>55°58</td>
<td>11°32'</td>
</tr>
<tr>
<td>Søby</td>
<td>103°</td>
<td>–</td>
<td>–7°3</td>
<td>55°58</td>
<td>11°34'</td>
</tr>
<tr>
<td>Niåen</td>
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<td>–</td>
<td>–6°2</td>
<td>55°55</td>
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<tr>
<td>Trolldenæs @ Sønderup</td>
<td>L 123/ R 85.5°</td>
<td>0.4</td>
<td>–17°4.4/2.9</td>
<td>55°93</td>
<td>11°54'</td>
</tr>
<tr>
<td>Højby</td>
<td>142°</td>
<td>–</td>
<td>–26°2</td>
<td>55°93</td>
<td>11°58'</td>
</tr>
<tr>
<td>Søren</td>
<td>112°</td>
<td>–</td>
<td>–12°3</td>
<td>55°43</td>
<td>11°59'</td>
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<tr>
<td>Brodrene @ Udøse</td>
<td>L 99/ R 93°</td>
<td>–0.2</td>
<td>–5°29/19</td>
<td>55°59</td>
<td>11°60'</td>
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<tr>
<td>Birketje @ Nyrup</td>
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<td>–</td>
<td>–32°4</td>
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<td>11°60'</td>
</tr>
<tr>
<td>Søren</td>
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<td>–13°4</td>
<td>55°43</td>
<td>11°63'</td>
</tr>
<tr>
<td>Maane @ Svinø</td>
<td>L 146/ R 122</td>
<td>–28°3'-17.6</td>
<td>55°12</td>
<td>11°74'</td>
<td></td>
</tr>
<tr>
<td>Østerhøj @ Svinø</td>
<td>103°</td>
<td>–</td>
<td>–7.4</td>
<td>55°10</td>
<td>11°79'</td>
</tr>
<tr>
<td>Sønderup</td>
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<td>–5.1</td>
<td>55°57</td>
<td>11°79'</td>
</tr>
<tr>
<td>Ejbø</td>
<td>98°</td>
<td>–</td>
<td>–4.5</td>
<td>55°70</td>
<td>11°85'</td>
</tr>
<tr>
<td>Ejbø</td>
<td>110°</td>
<td>1.2</td>
<td>–10.1°</td>
<td>55°69</td>
<td>11°85'</td>
</tr>
<tr>
<td>Kørre Hvalso</td>
<td>130°</td>
<td>–</td>
<td>–21.3°</td>
<td>55°60</td>
<td>11°85'</td>
</tr>
<tr>
<td>Møllehøj 1 @ Ejbø</td>
<td>L 74/ R 73°</td>
<td>–8.9°/-9.5°</td>
<td>55°70</td>
<td>11°86'</td>
<td></td>
</tr>
<tr>
<td>Ejbø</td>
<td>85°</td>
<td>1.4°</td>
<td>–44°0</td>
<td>55°70</td>
<td>11°86'</td>
</tr>
<tr>
<td>Ejbø</td>
<td>123°</td>
<td>1.6°</td>
<td>–16.5°</td>
<td>55°08</td>
<td>11°87'</td>
</tr>
<tr>
<td>Nissedal @ Velling</td>
<td>109°</td>
<td>0.5°</td>
<td>–10.6°</td>
<td>55°75</td>
<td>11°88'</td>
</tr>
<tr>
<td>Kørre Hvalso</td>
<td>L 169°</td>
<td>–</td>
<td>–33°7</td>
<td>55°60</td>
<td>11°89'</td>
</tr>
<tr>
<td>Hjortegården @ Djøby</td>
<td>150°</td>
<td>–</td>
<td>–29°0</td>
<td>55°91</td>
<td>11°91'</td>
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<tr>
<td>Krogsund</td>
<td>105°</td>
<td>0.1°</td>
<td>–8.3°</td>
<td>55°78</td>
<td>11°96'</td>
</tr>
<tr>
<td>Riehøj @ Øst</td>
<td>M 100 R 57°</td>
<td>1.2°</td>
<td>–4.6°/19.0</td>
<td>55°55</td>
<td>11°97'</td>
</tr>
<tr>
<td>Jagspen</td>
<td>154°</td>
<td>–</td>
<td>–30.9</td>
<td>55°86</td>
<td>11°98'</td>
</tr>
<tr>
<td>Høje @ Leje</td>
<td>103°</td>
<td>2.3°</td>
<td>–4.3°</td>
<td>55°62</td>
<td>11°98'</td>
</tr>
<tr>
<td>Glum (On)</td>
<td>102°</td>
<td>2.2°</td>
<td>–3.8</td>
<td>55°60</td>
<td>11°99'</td>
</tr>
<tr>
<td>Gerlev</td>
<td>98°</td>
<td>0.4°</td>
<td>–4.2°</td>
<td>55°81</td>
<td>12°01'</td>
</tr>
<tr>
<td>Bornhøj @ Himmelv</td>
<td>L 130/ R 138</td>
<td>1.6°</td>
<td>–19°8'-23.3</td>
<td>55°56</td>
<td>12°31'</td>
</tr>
<tr>
<td>Nørre @ Østykke</td>
<td>123°</td>
<td>–</td>
<td>–17.8°</td>
<td>55°80</td>
<td>12°12'</td>
</tr>
<tr>
<td>Kerketup/Godseldi</td>
<td>L 91/ R 95°</td>
<td>0.7°</td>
<td>0.0°/-2.2</td>
<td>55°70</td>
<td>12°15'</td>
</tr>
<tr>
<td>Stenløse</td>
<td>103°</td>
<td>1.1°</td>
<td>–6.4°</td>
<td>55°75</td>
<td>12°16'</td>
</tr>
<tr>
<td>Gerehse Høj @ Farn</td>
<td>104°</td>
<td>–</td>
<td>–7.8°</td>
<td>55°80</td>
<td>12°34'</td>
</tr>
</tbody>
</table>

**Notes**

1. The left chamber is elongated in the direction of the entrance passage and itself resembles a sizeable dolmen.
2. The right entrance passage is missing.
3. The passage makes a bend from 108° to 103° and the latter value is used here.
4. The direction of the left entrance passage is uncertain.
5. Mean value of four measurements.
6. Only one stone remains of the right entrance.
The triple unit 3221/6:7 (Table 1) consists of a twin and a single chambered passage grave in the same mound. (below) Layout of the triple grave showing partly the contours of the chamber orthostates and side stones of the passages (by permission of Sverd Ilum Hansen). The arrows show the measured azimuths (Table 1). The dotted lines represent the side of the passage where the original 'sight lines' or 'passage lines' have been established.

of the passage grave to be built, and that special care was taken in establishing its direction and maintaining this throughout the building process.9 From the point of view of construction, such sightlines do not seem to be necessary. This could indicate that the entrance passage relates to some direction in the landscape or to some point on the horizon.

An earlier study by H&R on the orientation of passage graves in Scania and northeastern Zealand was made on a sample of 41 graves with 47 directions. They
found that most of the entrance passages pointed between east and southeast, with a smaller number pointing south-southeast. They argued in favour of a relationship between this orientation and the rising of the moon, identifying the south-southeaster direction with the southernmost ‘standstill’ of the moon. They concluded that “The distribution pattern of orientations is fully in line with a lunar explanation that the passages point at specific phases of the lunar cycle”.

Our motivation for the present study was to enlarge the initial sample of passage graves from previous studies in Denmark, with accurately determined directions of the entrance passage. Furthermore, we wanted to use this larger sample to see whether the conclusions about the moon could be substantiated or if other explanations were possible.

The orientation of the passage graves is taken, as usual, to be the direction of the entrance passage as seen from the main chamber and out through the entrance passage.

Observations: The Fieldwork

Measurements were initially made at 56 locations (i.e. registration numbers) on Zealand between the geographical latitude 55.5°N and 56°N. To begin with, measurements were made using a GPS, magnetic compass and a theodolite.

The GPS was used to measure the altitude above sea level (not tabulated) and the geographical position, and to determine a north-south baseline. The distance between the two reference points of the north-south baseline was from 500m to 600m. The theodolite was used to measure the azimuths and the apparent horizon altitude (h) at the azimuth found. In many cases, local topography (trees, houses, etc.) prevented measures of the horizon altitude, but from the 22 measurements of this type, the landscape was found to be rather flat (see Table 1), with an average h of about 0.8°. A correction of the azimuths would be approximately of the same order as the horizon altitude, except for the most southern directions. As deduced from 47 measurements, the average altitude above sea level was about 42m and in some cases there was an extremely good view of the horizon. It has been shown that many passage graves were built on open fields, because underneath the grave itself it is sometimes possible to find traces of agriculture.

The resulting azimuths showed that measurements using the magnetic compass alone were sufficiently accurate; therefore later measurements of the azimuths were done using only a magnetic compass. Such measurements were done for a supplementary 12 passage graves on Zealand and for 12 of the island of Samso to the west of Zealand, expanding the latitude interval to between 55°N and 56°N. Thus, the total number of measured graves is 80. The geographical latitude and longitude were in all cases measured using the GPS.

Good measurements were obtained for 64 graves with a total of 78 entrance passages, and these measurements are presented in Table 1. Considering the accuracy in establishing the north-south base line and, correspondingly, the entrance sight line (determined to be the mean line between the two sides), we evaluate the accuracy of
the azimuths to be $\pm 2^\circ$. This was confirmed by a repeat measurement of six graves, which always agreed to better than $\pm 2^\circ$.

The distribution of the resulting 78 entrance directions from Table 1 is given in histogram form in Figure 3. Considering the accuracy and number of measurements, we have chosen a bin-size of $6^\circ$ (starting at $30.5^\circ$). At a glance it is immediately obvious that the distribution is far from random. We find that most azimuths (85%) fall between $85^\circ$ and $165^\circ$, with most directions (61% of total) concentrated between $90^\circ$ and $130^\circ$ and with two peaks around $100^\circ$ and $121^\circ$, and an isolated peak close to the azimuth of $200^\circ$ which involves 7 directions. The combined sample (Figure 3, lower panel) presented here also includes 20 directions from the H&R investigation in northeast Zealand. In this sample occurs a less pronounced and broader peak close to $150^\circ$.

Some Preliminary Results from an Investigation of Passage Grave Clusters

Our sample of passage graves includes parts — probably the central part (the core) — of three clusters of passage graves (Table 1: Samso, Ubby, Eby). Although we had in mind ‘astronomical’ sight lines, we discovered that about 75% or more of the passage graves were pointing towards another passage grave (or dolmen) in the surrounding area, up to five kilometres from the central part. This discovery was so striking that we started a survey of 25 cluster candidates, for which we have some interesting preliminary results. An interesting quantity is the ‘alignment azimuth’, the azimuth of the line drawn from one cluster unit (the primary unit) to another cluster unit (the target unit). We use the term ‘alignment azimuth’ for this new quantity because we know from our investigation that a line can be drawn through as many as 4 cluster units, including one or more of the passages. Table 2 shows examples of line relations from Table 1. In the Samso cluster and Ubby cluster, one can find a corresponding target unit such that the ‘alignment azimuth’ is the same as the azimuth of the passage of the primary unit (in other words, here the azimuth points to the target unit). So far, we know of 61 possible line relations in total, with ‘alignment azimuths’ in 6 different clusters and 4 more isolated pairs of megalithic monuments. Line relations and cluster formation are also known from Ireland, with the difference that in Danish clusters lines around $100^\circ$ and $121^\circ$ are common independent of the location. All three clusters in Table 1 show this feature.

The Azimuth Distributions for the Rising Sun and Moon

From the observed distribution of azimuths (Figure 3), an interpretation in terms of the rising sun or moon seems natural. Also, the preliminary results from the investigation of clusters of passage graves make it obvious that not only were the constructors very conscious of the directions of the entrance passages, but also that directions in general must have played an important role.
Fig. 3. The distributions of the azimuths of the entrance passages of the passage graves measured by us (upper panel, 64 graves with 78 entrance directions), and by H&R (middle, 15 graves with 20 entrance directions), and the combined sample (below, 79 graves with 98 entrance directions).
The azimuth distribution for the rising (or setting) sun and moon is well known and relatively simple. The azimuths of the rising sun vary between their extreme values at the solstices. The determining variables are the geographical latitude and the inclination of the ecliptic, \( \epsilon \), which varies slightly with time. For the relevant geographical location, the azimuth of the rising sun would vary between approximately 42° and 135° around the period when the passage graves were built. The azimuth distribution of the rising moon depends also on the inclination of the orbit of the moon and the 18.61-year period of the regression of the line of nodes (the intersection of the line of nodes with the ecliptic). Thus the rising moon has two northern and two southern extreme points (often referred to as the northern [or southern] major and minor lunar standstills, 31°, 56° and 126°, 151°), which are covered in the 18.61-year period.

For the purpose of this paper we have calculated not only the extreme points but the actual distribution of azimuths for the moon. This distribution is given in Figure 4 together with the combined sample.

**Discussion**

From earlier investigations of megalithic monuments, alignment with both the sun (e.g. Stonehenge, and the passage tombs at Newgrange and Maes Howe) and the moon (e.g. the recumbent stone circles in northeastern Scotland and the short stone rows) has been found. In his comprehensive work on the orientation of dolmens in Iberia and France, Hoskin argued in favour of an orientation related to the rising of the sun.

In our combined sample (Figure 3, lower panel), we find that 85% of the azimuths are within the rising points of the moon and 70% of the azimuths are within the rising points of the sun (accepting \( Az = 154° \) as representing the southern major lunar standstill and \( Az = 135° \) as representing solstice at midwinter). An interesting feature in the observed distribution is the 76% overweight of directions in the southeastern quadrant (90°–180°) within the rising points for the moon (62% for the sun), which could call for a seasonal explanation. The 121° peak is close to the southern minor lunar standstill and the smaller 150° (149°) peak is close to the southern major lunar standstill (see Figure 4), but this is not necessarily conclusive evidence for a lunar explanation because of the 100° peak and directions that exceed the rising point of the moon. Da Silva suggested in his paper in this journal “an interpretation for the so-called ‘megalithic equinox’” as the cross-over point at the horizon where the rising point of the full moon is south of the rising point of the sun at spring. This could explain the broad 100° peak and support the idea about the moon. Göran Henriksson, in his discussion of the orientation of 140 Swedish passage graves, interprets a prominent peak in the azimuth distribution about 124° (\( \delta_{\text{sun}} = -17.0°, \delta_{\text{moon}} = -16.2° \)) as supporting a solar explanation (the “Midwinter Day” on 2 February) although the same distribution displays a smaller isolated peak centred around 146°. The peak at 124° is close to the southern minor lunar standstill (about 129°) at the actual latitude and the other peak exceeds the winter solstice but is within the southern major lunar standstill. In general the azimuth distribution of the 140 Swedish passage graves is
quite similar to the Danish distribution in the sense that most directions are concentrated in the southeastern quadrant, except for the most southern directions exceeding 152° and the more prominent peak around 100°. In fact the Danish 121° (121.48°) peak (δ_{sun} = -17.3°, δ_{moon} = -16.4°) corresponds to the Swedish 124° peak within the limits for the uncertainty (±1° for the Danish declination data) using an upper limit for the apparent horizon altitude of 0.38° (as Göran Henriksson), which indicates an astronomical explanation for both distributions. However it does not mean that there is the same astronomical explanation for both distributions. A larger sample of Danish data will show if the two data sets are more likely to become identical or more different. If a solar explanation should hold, the southeastern and southern directions beyond the rising points of the sun could, for example, be explained by Hoskin’s sun-climbing model (SR/SC), but a summer full moon rising/climbing, moving close to the horizon, could be the explanation as well.

If we consider the ‘azimuth alignments’ in Table 2 it is striking that 7 out of 11 lines are pointing directly into the core of either the Samso cluster or the cluster with the Ubby members. And 6 out of these 7 lines are outside the rising points of both the sun and the moon. Of these lines, 4 are involved in the small isolated peak close to 200° and the remaining 3 directions, which complete this peak, are all extending from a cluster core. In all, 13 out of 15 directions in the combined sample, which are beyond the rising points of the sun and the moon, are in one way or another related to the core of either the Samso cluster or the Ubby cluster. These lines/directions are more likely to have an archaeotopographical explanation (see Figures 5 and 6). The 121° line extending from unit 3221:38 (Table 2) pointing to the core of the Ubby cluster could be a ‘double alignment’, i.e. the line could have both a topographical and an astronomical explanation. All the remaining directions (83) in the combined sample are within the rising points of the moon and 85% of these are within the rising
Fig. 5. The position of the Ubby cluster members (Table 2). The core unit 3221:12 is placed at the highest local point 50 m above sea level and has three line relationships. The arrows show the measured passage direction (the azimuth) and the dotted line are the ‘alignment azimuth’ deduced from the GPS measurements.

Table 2. Examples of 11 alignments deduced from GPS measurements using coordinates corresponding to the Danish UTM grid. Azimuth+180° indicates that the primary unit is pointing backwards (opposite the direction of the target unit). Cluster core members are indicated in bold. Clusters and their sightlines will be treated in a forthcoming paper.

<table>
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<th>Latitude UTM zone 32</th>
<th>Azimuth ±2°</th>
<th>Alignment azimuth &lt; ±1°</th>
<th>Registration No.</th>
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<th>Latitude UTM zone 32</th>
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<td>638684</td>
<td>6170852</td>
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Notes:
1. The unit is destroyed but it is known from descriptions.
2. The unit has not been excavated and so the passage cannot be measured.
points of the sun. The main argument for an astronomical explanation of these directions is the presence of the two directions around 100° and 121° in all three clusters presented in Table 1. The distance between the clusters, Ejby to Ubb by and Ubb by to Samso, is about 50 km (see Figure 1(b)).

With the evidence taken into consideration as a whole, the authors suggest that the interpretation of the combined sample favours a (full) moon explanation, in line with H&R, for directions within the rising point of the moon. The main argument for a lunar explanation is the 121° and the smaller 150° (149°) peaks which could indicate the 18.61-year lunar cycle and also the absence of a peak around winter solstice. However, this does not rule out a partly solar explanation, i.e. an explanation involving both the moon and the sun. A more speculative idea could be that observations were made of both the (full) moon and the sun when the moon was rising and sun setting and the angle between these objects was about 180° (see Figure 7). This lunar/sun alignment occurs from two to five times a year.
Summary

We have measured the directions of the entrance passages for 64 passage graves situated mainly on north Zealand. If we take into account previously published measurements, the combined sample of 98 entrance directions shows a strong preference for the azimuth directions close to 100° and 121°. Most directions fall within the azimuths for the rising sun or the moon but overall the evidence favours a lunar explanation. From clusters of passage graves we find a very strong tendency for the entrance passage to point to another passage grave, which indicates that directions/lines must have played an important role. Directions/lines beyond the rising points of the moon are, in the combined sample, mostly related to the core of a cluster.

Acknowledgements

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REFERENCES

The Orientation of Danish Passage Graves

10. See Hald and Rosland, op. cit. (ref. 1), 39.
11. Svend Illem Hansen, Jættestuer i Danmark (konstruktion og restaurering) (Copenhagen, 1934), 130.
12. Dehn and Hansen, op. cit. (ref. 9), 44.
13. The 100° peak is calculated for the interval between 89° and 112°, and the narrower peak at 121° is calculated for the interval from 114° to 130°. The less pronounced peak in the combined sample close to 150° is calculated for the interval between 134° and 165°.
14. A study of double graves (including twin graves) and clusters of graves is under way.
16. See Ruggles, op. cit. (ref. 5), 24–5 and 36–7, or Hoskin, op. cit. (ref. 6), 20.
17. The computations were done using our set of computer programs. The distribution for the sun is the same today, with only a small shift in distribution due to today’s slightly lower value of the inclination of the ecliptic, ĉ (the distribution now lies between 44° and 134°). Note that we refer to the apparent rising of the centre of the sun (taking into account the effect of the refraction at the horizon). We have calculated the distribution of the rising moon’s azimuth for an 18.61-year period starting from 3300 B.C. The distribution is the same today with only a small shift in the extreme points of 1–2°. The calculations refer to the centre of the moon and take into account the effects of the refraction and the parallax of the moon.
Paper III

DANISH PASSAGE GRAVES AND INTERVISIBILITY: A NEW PERSPECTIVE. Denoted as (Clausen, 2012) in the main text.
DANISH PASSAGE GRAVES
AND INTERVISIBILITY
A NEW PERSPECTIVE

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INTRODUCTION

The tendency for passage graves to form clusters is known from other countries than Denmark. Clusters of passage graves are found in the Netherlands and Germany. Also in Sweden and Ireland are clusters of passage graves known (see Figure 1).

The features described in this paper concern the internal structure of passage grave clusters. This subject seems to be a rare phenomenon in the European Neolithic context, either because these structures are not yet discovered, no attention has yet been paid to the phenomenon or simply it really is a rare phenomenon.

A previous study (Clauensed, Kjærsgård, Encke, 2008) of the orientation of Danish passage graves shows that in the structure of clusters of passage graves you can find line relations between the different units. From a line relation an 'alignment matrix' can be deduced. It is known from the earlier investigation that a line can be drawn through at least 2 cluster units, including one or more of the passages: which directions is believed to point towards a certain azimuth1. In this paper data from a Danish cluster complex of passage graves, Kahunörg cluster complex, and the Danish clusters described by Clauensed, Kjærsgård and Encke in 2008 and 2011, will be compared with two Irish clusters of passage tombs, using data from Prendergast 2006, to see if there are common features.

THE DANISH PASSAGE GRAVES

Most Danish passage graves are believed to be build in a relative short period of time from about 3300 BC to about 3200 BC by the Funnel Beaker culture (Trichterbecherkultur, TRB), see Figure 1. The Danish passage graves are a development from more simple dolmens (3500 BC) and are typological identical with those found in Germany, the Netherlands and Sweden. Some of the passage graves can be large elaborated structures with chamber length up to 24 m2 and a width of 2.3 m with a passage length up to 11 m. The total number of passage graves in Denmark is estimated to have counted about 5000 to 6000 units. Today we find remains of about 700 passage graves of the type known as 'Jéttetúr' ('tomb of giants'). According to some archaeologist a giant dolmen, a type of dolmen with a passage, could be classified as a passage grave similar to a 'Jéttetúr'. A preliminary investigation of 20 simple dolmens with a passage shows that they seem to follow the same orientation pattern as the real passage graves. So including the more simple dolmens with a passage this would increase the number of remaining passage graves with more than 50%. The concentration of passage graves is especially high on the island Zealand and other island in the surroundings. Many of the passage graves have at tendency to form clusters (see Figure 2).

A special construction is a triple or double grave with one or two passages. Many variants of these types of passage graves are known. The passages of these graves can either be parallel (or nearly parallel) or have an angle span between the passages. It is difficult to make a simple definition of these types of graves. You can find double graves with two separate chambers or one big chamber

1 The azimuth angle is the angle measured clockwise along the horizon from geographical north = 0

2 Longes' twin grave chamber recorded in Denmark (www.frontiersin.com/dryagerdy/dryagerdy_opfystinger.html)
Fig. 1. The Funnel Beaker culture (TRB) in Europe did around 3500 BC approximately cover an area from the Netherlands west to Poland in east from northern part of Germany in south to the most southern part of Norway in north. Note that Denmark has a central geographical position in the TRB area. Open circles indicates areas where the orientations of passage graves or passage tombs are determined. Also the circles indicate areas with a high density of passage graves or passage tombs which in some cases form clusters. The Irish group does not belong to TRB but approximately to the same period of time and there are features which link it to the Danish group.

divided in two parts each with a passage. The last mentioned type is called twin graves. The same goes for the triple graves, except that (as far as the author knows) no triple grave has a chamber divided in three parts. It can either be a twin grave with an extra separate chamber in the mound or three separate chambers. Today about one tens of the remaining passage graves are double or triple graves.

DEFINITION OF A PASSAGE GRAVE CLUSTER

The definition of a passage grave cluster used in this paper and previous work is as follows: The centre part or the core of a cluster must contain at least three passage graves within one square kilometre. Additional the directions of the passages of the passage graves in the core point out single passage graves or other cluster cores in the surroundings and by this establish a line relation.

THE MEASUREMENTS

Most of the measurements were done previously but in some cases supplementary measurements have been done to strengthen the picture. Two kind of measurements are needed to verify the line relation and by this the ‘alignment azimuth’: 1) Direction of the passage of the passage grave. 2) GPS measurements of the position of the passage grave or other megalithic monument.

The measuring of the direction of a passage can be troublesome. Many passage graves have passages which do not follow a quite straight line. In this case repeated measurements for the centerline (see Figure 3) have been done and a mean value has been determined. For this purpose is the direction of the passage mounted on the passage grave measured by using a precision magnetic compass with a precision of 0.5°. The uncertainty of the direction of the passage has been estimated to be within ±2.5°.

The GPS measurements can also give some problems. Repeated measurements of the positions can give different values. The uncertainty can vary between 10 meters to 30 meters in position although the precision readings are less than 10 meters. Nearby trees, buildings, pylons etc. can cause the problem. It means that positions for distances less than 500 meters can be quite uncertain. For distances longer than 500 meters is the uncertainty a decreasing function of the distance. To avoid the problem

3. The uncertainty, $u$, can be calculated as $2N\text{tan}(\theta/2)$, where $\theta$ is the
Fig. 2. The figure shows identified and potential clusters and their distribution in Denmark and southern Sweden. Cluster 5 and 8, both have a damage core but the overall structure is more or less preserved. Notice the high cluster density on the island Zealand.

Fig. 3. The figure shows a typical layout of a single chambered passage grave and the center line determined throughout the passage. An easy way to determine the centerline is simply by using a lead and visually determines the direction.
all measured positions are compared with positions on orthophoto maps with high resolution or 4 cm maps. The 'alignment azimuth' derived from the positions are therefore in some cases given as a mean value from at least 2 GPS measurement or measured on orthophoto maps. Besides GPS measurements done by the author, data for the GPS coordinates, used in this paper, are adopted from the database at http://www.kulturav.dk/fundogfortidsminder/ as well as readings from orthophoto maps.

LINE CRITERIA
The criteria for a line between two megalithic units, a source unit and a target unit, must be that the uncertainty of the direction of the line is less than the derivation in the determination of the direction of the passage of the source unit, in this case less than +/-2.5°. In several cases is the uncertainty of the 'alignment azimuth' less than +/-1°. This means that the determination of a line direction, alias the 'alignment azimuth', can be more precise than the determination of the direction at the passage itself. Compare columns 5 and 11 in Table 1.

THE MORPHOLOGY OF THE KALUNDBORG CLUSTER COMPLEX
The Kalundborg cluster complex (Figure 4) is defined as consisting of a main cluster and three sub clusters. The structure is very large concerning our common opinion about Neolithic capability in Denmark. The main cluster has a central part or a core where the distances between the units are few hundred meters or less. The cluster
density in the core, exceed more than three units and is located within one square kilometer. The core contain 8 megalithic monuments from funnel beaker culture, 5 passage graves, 2 dolmens and one unclassified megalithic structure⁴. Beside that are located, within the core, 7 unclassified units from Neolithic times or early Bronze Age and two mounds from Bronze Age. The central part of the main cluster is located within an area of about 30 square kilometers. The entire structure covers more than 150 square kilometers.

The whole cluster complex, as defined for the use of this paper, contains of 35 passage graves, two dolmens with a passage, 6 dolmens and one unclassified megalithic unit constructed by people from the funnel beaker culture. The structure is mainly pointed out from north-
Fig. 6. Nordenfjeld (unit 030104-1) the 'key stone unit' in the remarkable triangle-feature in the Kalundborg cluster complex, seen towards the right entrance passage. Photo: Claus Christensen

west/west to east/south east and from north to south. The Kalundborg main cluster is connected through southern lines originating from the core of the structure defined as sub cluster 1 (See Figure 4). Sub cluster 1 and 2 are both linked to the main cluster whereas sub cluster 3 only is linked to sub cluster 1 (see Table 1 and Figure 4). In case of sub cluster 1 only the central part seems to be preserved with lines extending from the center at south towards the center of the main cluster, one eastern line pointing backwards from sub cluster 3 and an additional possible eastern line also pointing backwards from sub cluster 3 and a south eastern line originating from unit 030103-159 (left upper corner in Figure 4). Sub cluster 2 is a smaller structure with one line extending from the center towards south east and another possibly line pointing towards south east and a uncertain line pointing towards south east south. Sub cluster 3 is also a small structure like sub cluster 2 with a less well defined core although it fulfill the definition.

In the cluster complex nearly all the passage graves are placed on local high points (see Table 1 column 6 and 12), not necessary on the highest points. The units 030109-29 and 030109-26 are located nearly at center of the core on a local high point 49 meters above sea level and can visually be seen from a distance of at least 5 kilometers. Altitude measurements from an earlier investigation of 47 points show a mean altitude about 42 meters.
above sea level for the measured passage graves. This is a rather high altitude concerning that Denmark is a relatively flat country.

Where lines are crossing increases the number of unclassified megalithic units and mounds (see Figure 5) from undetermined antiquity time periods, from about the beginning of flint beaker culture (3900 BC) to late antiquity (about 1000 AC).

THE PASSAGE GRAVES IN THE KALUNDBORG CLUSTER COMPLEX AND THEIR LINE RELATIONS

Kalundborg cluster complex consist, so far, totally of 44 units. Of these 44 units, 14 are double or triple graves. In the main part of the cluster complex, main cluster = sub cluster 1 (see Table 1), you find the most significant features among the double graves. The combined structure consists of 9 double graves and two triple graves. Unfortunately one of the triple graves and one of the double graves are destroyed. Only position and descriptions are known. Of the remaining 9 graves are 8 related to other passage graves with one or all passages pointing either forward or backwards to another passage grave/dolmen or unclassified megalith unit.

Out of total 26 measured passage directions three have no identified targets, 14 are pointing forward, one is pointing both forward and backward and 8 are pointing backward (pointing direction = 180°). It means that 88% of the measurable units are in a source-target relationship where approximately 2/3 is pointing forward towards a target unit and 1/3 is pointing backwards towards a target unit. Exactly the same statistic is seen in the Samso cluster (cluster 1, Figure 2) described by Clausen, Kjærgård and Enckell in 2008.

In some cases it is difficult to separate target units caused of their close positions. It is therefore decided to chose the target unit with the determined ‘alignment azimuth’ closest to value of the measured direction. The remaining units can only be accepted as possible other targets if they fulfill the line criterion.

An interesting feature is a connection between units with passage directions east and south east and units with southern directions. In the Kalundborg cluster complex you find four of these relations: An example is unit 030110-3 (azimuth 121° for the left passage) pointing towards unit 030109-29 (azimuth 199°) or unit 030103-159 (azimuth 123°) pointing towards unit 030104-2 (azimuth 155°). More complex patterns can be seen with more line relations involved. For the moment it is unknown if it is a common feature for clusters in general but few of these relations are also seen in other clusters.

The most remarkable feature is the relation between three passage graves in the main part of the cluster. These three units form a three-angle. Unit 030104-1 (Figure 6) with left passage azimuth of 160° pointing towards unit 030109-26 and unit 030109-26 (azimuth 123°) pointing towards unit 030109-5 (see Figure 4) and the right passage (azimuth 140°) of unit 030104-1 is also pointing towards unit 030109-5. It is not known if this ‘construction’ has occurred by accident or by any chance. Has it been made deliberately by man it could be important evidence which emphasize a very short construction time for some types of passage graves in Denmark.

A similar feature is found in another cluster (cluster 5 in Figure 2), a cluster which is not fully investigated yet. The triangle in this cluster has approximately the same size and what is notable are that the azimuth of two of the cisterns are nearly the same. For the south east azimuths the values are in both cases 123° and for the southern azimuths the value are 160° respectively 163° in cluster 5.

As seen in Figure 4 (where sub cluster 1 point out the positions of the central part or core of Kalundborg main cluster) all together 3 units (unit 030110-3, 030104-
1 and 030610-10) with 5 directions pointing directly into the core of Kalundborg main cluster and 3 units (unit 300110-3, 030104-2 and 030104-12) points to other units within the sphere of the core. Also it is notable that most lines are crossing at the core or very close to the core. These crossing points could be named as “focal” points and the number of remaining structures from antiquity increases at and around these points (see Figure 5). The same tendency is seen in cluster 1, 3, 5 and 8.

It is notable that all the units which points out the core or other megalithic structures in the surroundings all are double grave (including the triple grave). Three
Fig. 10. The core unit 030109-26 seen through the middle passage (M in Table 1) of the triple grave (unit 030109-10). The position of the three target units in the core of the Kalundborg main cluster is shown in Figure 9. This feature indicates that the triple grave could be a later construction than the core units. Photo: Claus Clausen.

Fig. 11. This figure shows that the topographical conditions allow a sight line (azimuth 121°) from unit 030110-3 to unit 030109-29 in the core of the Kalundborg main cluster, although the sight line today is obscured by buildings etc. The altitude values represent the most pronounced variations in a vertical cut through the local topography along the sight line over a distance of about 3.5 km, presented in a relative scale. The open circles with crosses represent the two passage graves and their altitudes above sea level is measured at 35 m respectively 47 m (Table 1). Alternatively unit 030109-26 could be the target unit. The separation between unit 030109-29 and -26 is only 60 meters and seen from unit 030110-3 the separation is less than 1 degree.

of the double graves have targets for all the measured directions. In this case these three graves (units 030110-3, 030104-1 and 03060-10) with 7 directions points out 7 other graves. Multiple targets for double graves are also seen in cluster 5 (as mentioned previously) and cluster 3.

VERIFICATION OF LINES
Discussion of line length and validity of a line is obviously a matter of importance. Taking the "local" points in account there should be no doubt about lines pointing out the center of the Kalundborg cluster complex. In this case the function is obvious a pointing function. These lines are counted as real and give the direction to the main core of the cluster complex. Verification can be done photographically or by investigating the topographical conditions.

Problems can occur when long lines extending from the center of a cluster points out single passage graves/dolmen in the surroundings. Most lines lies in the in-
Fig. 12. Location of the two Irish clusters used as comparative samples for the Danish clusters, see also Figure 1.

interval from one kilometer to about 4 to 5 kilometers. In some cases lines can be up to 8 or 9 kilometers. The question is: are these long lines real or are they a result of pure chance? Photos taken from sub cluster 2 towards unit 030109-3 (Figure 7), in the main part of the Kalmbörg cluster complex, show that a sight line of about 5 kilometers is visually possible. For longer lines today's small country cities, churches, other buildings or woods, which were not presented in prehistoric times, sometimes obscure the possible sightline. Figure 8 and 9 verify visually that sight lines between sub cluster 2, the triple grave and the core of the main cluster are possible. Sometimes also a more direct photograpical evidence for sight lines is possible as shown in Figure 10, but until now it is rare.

One way to deal with the sight line problem is to analyze the topographic conditions in detail between the two sight points (see Figure 11). This could tell if a line is possible or not. In the presented material it is assumed that possible lines less than 10 kilometers are real. For the purpose of this paper mostly the topographic conditions have been taken into account. It also have to be kept in mind that the topographic conditions allows lines with 3 units aligned where the middle unit is placed on a high point which obscure the sight line between the two extreme units but both units are visible from the middle one.

IRISH CLUSTERS WITH PASSAGE TOMBS

In Ireland are preserved 232 passage tombs (Prendergast 2006) equivalent to the Danish passage graves, 43 of these are involved in cluster structures and are aligned on other tombs or cairns. The time period of construction is believed to be between 3400 BC and 2700 BC i.e. the period well covers the time period for construction of the Danish passage graves.

Although the constructors of the Irish passage tombs did not belong to the funnel beaker culture there could be some common features concerning the idea with and the function of the tombs: i.e. for an example that the passage has a pointing function. The most conspicuous features which distinguish the type of tomb or graves are size and rock art. The Danish passage graves lacking almost rock art whereas the Irish tombs could have very complex elaborated rock art designs, probably the finest in Europe from Neolithic times. Concerning size the Danish passage grave including the covering mound had probably never exceeded more than 50 meters in diameter whereas Irish passage tombs can reach a diameter up to nearly 100 meters, as for example famous Newgrange.

For the purpose of this paper are chosen two clusters, the Sligo cluster and the Meath cluster, from the sample of Irish clusters of passage tombs. The criterion for the choice is simply the number of cluster members. The Sligo cluster has 21 members and the Meath cluster has 11 members. Geographically the Sligo cluster is located in the north western part of Ireland and the Meath cluster is located close to the east coast in the northern part of the country (see Figure 12). The allover structure for the two
Fig. 13: The figure shows the relative structure of the two Irish clusters and two Danish clusters all in same scale. Upper panel left is the Irish Sligo cluster and right is the Danish Samsoe cluster (Clasen, Kjærpård, Enicks, 2008) located about 45 km west from the Danish Kalundborg cluster complex. Lower panel shows the Irish Meath cluster compared the Danish Kalundborg cluster complex enclosed in the frame. Note that the Irish clusters are considerable larger than the Danish clusters. The values on the X and Y axes are given in meters corresponding to Irish and Danish UTM grid coordinates.

Irish clusters is shown in fig. 13 which also shows the size of the clusters.

VISIBILITY
If the topography does not obscure a sight line, visibility over long distance (here defined as more than 5 kilometres) is a matter for discussion which concerns the capability of the human eye. Frank Prendergast (Prendergast 2007) has investigated visibility between Irish passage tombs and found it was possible to have sight lines up to between 35 kilometres and 40 kilometres which is actually the case for sightlines between the Irish passage tombs (see Figure 13 lower panel, the Meath cluster radiating a line at 105° towards Me75).

Reported from the Danish National Museum in 2008, (http://www.natmus.dk/nw39564.asp) that the covering mound of a passage grave (unit 030609-20 in the Kalundborg cluster complex) could have been coated with white burned flint. This could increase the visibility on a dark
Fig. 14. These histograms compare the alignment directions in the four clusters from Figure 13. Left upper and lower panel show the distribution of the alignment directions in the Danish clusters. Right upper and lower panel shows the distributions of the alignment directions in the two Irish clusters. It is notable that the two Danish clusters have their alignment directions within the same azimuth interval whereas the two Irish clusters have very different distribution. All directions, equivalent to the alignment directions, are derived from the Danish and Irish UTM grid coordinates. The vertical axis is the number of megalithic units and the horizontal axis is the azimuth (in bin size of 5 degrees) and the vertical axis is the azimuth in the interval from 0° (north) to 350° (north-west north) counted clockwise with starting point at 0°.

Me 24

Fig. 15. This photo is taken through the passage of the Irish unit Me10, with passage direction of 89°, towards unit Me34 in the core of the Mound cluster. This alignment could both have an astronomical and a topographical explanation. Note the rock on the left stone at the front. Photo: Frank Plessøe.
The alignment azimuth distribution of the Kalundborg and Samso clusters and distribution of moon rising points at the horizon

Fig. 16: The histogram shows the combined alignment azimuth distribution for the Danish Kalundborg cluster complex and the Danish Samso cluster. The azimuth distribution is compared with the distributions of rising points for the moon, scaled to fit the histogram. There seems to be an agreement with the southern minor lunar standstill at 114° to 115°. The peak in the interval from 192.5° to 193.5° is caused by directions pointing out the cluster core, one in the Samso cluster and three in the Kalundborg cluster complex (the triple grave). The vertical axis is the number of measurements in intervals of 6 degrees bins and the horizontal axis is the azimuth values from 0° (north) to 360° (south-west) counted clockwise with starting point at 0°.

background i.e. a wood or a hill. If that is the case this passage grave had appeared as a white hemisphere in the landscape.

SIMILARITIES AND DIFFERENCES
There are some differences and some similarities between the Danish clusters and the two Irish clusters presented in this paper. The two Irish clusters fill the definition of a cluster concerning the core and the radiating lines. The sizes are considerably larger and the pointing directions have a different distribution although the eastern, south east and southern directions seem to agree (see Figure 13 and 14). In the case of pointing directions it is almost possible to compare Danish and Irish pointing directions directly (almost same latitude). Also, which is very important to note, it is the ‘alignment azimuth’ which are compared not the azimuth measured from the direction of the passages i.e. it is the directions deduced from the GPS measurements which are compared. The Danish pointing directions are very close to represent the astronomical azimuth due to the value of the apparent horizon altitude (in mean is less than 1°) and therefore need no correction concerning the horizon altitude. A correction will be within the limits for the uncertainty of the measurements. On the other hand the Irish pointing directions must be corrected for the horizon altitude to gain the value of the true azimuth. These corrections will affect the pointing directions within (±) a few degrees. To avoid the influence of such corrections it is assumed that the measured pointing directions for the Irish tombs also represent the astronomical azimuth and a bin size of 6 degrees are chosen for the histogram presentation in Figure 14. For that reason the directions can be compared directly. The Meath cluster agree mainly with the two Danish clusters, 6 out of 8 pointing directions fall within the same interval of degrees whereas the Sligo cluster have 8 out of 13 pointing directions out of range for the interval.

A striking common feature is multiple pointing i.e. more than one passage tomb or passage grave are pointing towards a certain central tomb or cairn. As examples: In the Irish Sligo cluster the S15 unit is target unit for 7 other tombs (see Figure 13) and in the Danish Kalundborg cluster complex unit 030109-26 is a possible target unit for 3 other passage graves (see Table 1). Other common features are alignment relations with more than two passage graves or tombs along the same line or continuous tomb or tomb pointing with alternating directions. As examples are the possible triangle feature in the Danish cluster complex and the 101° line where unit 030109-24 is pointing backwards towards the position of unit 030110-22 and forwards towards the position of unit 030202-26 over
a distance of approximately 14 kilometers. In the Irish Meath cluster are the core units Me6, Me10 and Me24 on a straight line with pointing direction of 89° (see Figure 13 and 15) over a distance of about 1500 meters where unit Me6 points towards Me75 at 103°, over a distance of approximately 40 kilometers.

THE ASTRONOMICAL AND TOPOGRAPHICAL ACCESS
To understand the idea with passage graves or tombs it must be stressed out that there could be a multilayer explanation i.e. the passage graves or tombs could have different functions for different purposes. So beside the funeral-related function there could be both an astronomical and a toponographical explanation concerning the burial rituals or probably a pure topographical explanation.

Six investigated Danish clusters out of 8 identified share a common feature, a line relation with a pointing direction around 123°, independent of location. The azimuth distributions for all 6 clusters are within the same interval as the two clusters shown in Figure 14, left panel. It is hard to believe that this common feature can occur coincidentally or by any chance. It could indicate the same underlying idea, i.e. observation of the same phenomenon. An azimuth of about 123° (see Figure 16) is very close to the southern minor lunar stand still and is the direction towards the point at the horizon with sun and moon rises. More than 65% of the pointing directions in the Danish Kaulnborg cluster complex are within the moon’s rising point and 42% within the sun’s rising point and there are no directions towards setting points for moon or sun. The Irish clusters have very different distribution (Figure 13 and 14 right panel). The Meath cluster has 88% of the directions within the rising points of the moon and 63% within the rising points for the sun. The Sligo cluster have 23% within moons rising point and about 15% within the suns, 23% of the directions is within the setting points for the moon and 13% for the sun. Astronomical explanation could be the case for the Danish cluster complex and the Meath cluster whereas the Sligo cluster shows very little evidence for this hypothesis.

The Danish cluster complex and the two Irish clusters could also be explained from an archaeo-topographical point of view. All three passages pointing from the triple grave (Figure 10) in the Danish Kaulnborg cluster complex are clearly directed towards the core of the main cluster (Figure 9) and have properly no astronomical function but could be the marker of the core units. It seems that the southern lines in the Kaulnborg cluster complex are more likely to have a pointing function concerning the topographical conditions. Whereas lines: around 123° and 100° point out, cut through the core of the main cluster or run as parallel lines. The Irish Meath cluster is more likely to have a toponographical explanation than an astronomical one. When seen in detail three out of 7 possible astronomical alignments are directed towards the same target unit (Me75) in the radiating “arms” in Figure 13, upper right panel, which indicates that the target unit is real a target for the sight lines. For the Irish Sligo cluster the S15 unit is the central unit with 7 hits from source units. Have it is unquestionable evident that S15 is the target for the sight lines.

DISCUSSION
The function of the Danish double or triple passage grave seems clearly to have a pointing function, as does for single chambered passage graves i.e. a passage grave with a single passage point out the next passage grave or dolmen, double grave points out two passage graves or dolmens or the next double grave and triple graves points out three units. The same feature is seen in cluster 3 and 5. Cluster 1 (Clausen, Ejsingdal, Ennike, 2000) includes one double grave and one triple grave but only one target for each grave has been detected and in cluster 8 no double graves have been discovered.

A general tendency from areas with known clusters in Denmark (see Figure 2), not fully investigated; seem to be, that that some units in one cluster point out the position of the next cluster (core) whereas other units in the core points out units in the surroundings. This could mean that there are different types of passage graves with different functions, those who points out the next cluster or cluster core and those which could represent an astronomical sight line or both.

An assumption could be that the pointing directions in general could have had the function as “guide signs” for finding the next cluster or complex of clusters. In the manner of speaking the function could be compared with the function of a modern map or “road signs”. Also the core units located at local high points could have the function as markers in the landscape.
The question is then: why is it only a limited range of directions which have been chosen for the Danish passage graves? A total number of 153 directions for passage graves and dolmens with a passage (Claussen, "Scandinavian passage graves and the lunar 'season pointer'", in press) show a preference for directions in the south-eastern quadrant (90° to 180°). About 80% of the all the directions are found in the limited azimuth interval between 90° and 156° which covers the rising interval for the moon between spring and autumn. In this paper it is proposed that the distribution patterns for the directions of the passage in Scandinavian passage graves reveals a lunar 'season pointer', i.e. a kind of lunar calendar.

Concerning the Danish Kalundborg cluster complex, astronomical alignment and visibility, it might have been the case that the unit (030609-20), which probably has been coated with white burned flint, should look like the rising moon? The common 123° line in the Danish clusters is a possible indicator for the moon (see Figure 16).

The tendency for passage graves to point out other passage graves is known from Ireland (Prendergast 2006), as described in this paper, and a geometrical aspect is known from Falbygden in Sweden (Blomquist 1991), but a combination of the passage directions and geometry is not known to be described from other places than Denmark.

A general assumption is that the Danish Kalundborg cluster complexes (or Danish clusters in common?) show features which can be explained both astro- and topographical whereas the Irish Sligo cluster is a pronounced topographical structure. The Irish Meath cluster could have astronomical alignment but it seems more likely that a topographical explanation is the case. It means that the link between the two Irish clusters presented in this paper and the Danish clusters is the pointing function and tomb on tomb relations, used probably as the earlier mentioned "road signs". In this context it could be tempting to propose that the passage graves or tombs be markers in the landscape or grid point units in a Neolithic full scale 3-D "GPS"-system. If clusters can be linked over long distances with intermediate clusters relations it is possible to reveal and map the Neolithic communication "channels". An overall suggestion is that lines could have played an important and central role for Neolithic people in western and central Europe.

It is therefore proposed that a further perspective concerning the megalithic monuments is indeed a multilayer function as: land markers, lunar calendar and places for burial or ritual purposes.

FURTHER INVESTIGATIONS
To emphasize the tendency seen in the clusters described here, further investigations must be done. More than 25 potential clusters with 5 to 20 passage graves have been located in Denmark. All these clusters must be investigated in details which also include the geometrical aspect. Also the tendency to point out the position of the next cluster must be verified.

To verify the validity of a certain line, more than 5 kilometers in length, a random analyze could be done. The density of megalithic units in the Danish landscape is quite high. Today we know the position of at least 7,000 megaliths in Denmark. Therefore the possibility for at certain line to be drawn, from the pointing direction of the passage of a passage grave, through the Danish landscape by chance will hit another passage grave, dolmen with a passage or a simple dolmen is quite high. Only a random analyze for random directions can tell how the megalithic density behave along sight lines as a function of the distance from the source unit. The assumption is that the megalithic density along a specific sight line would be larger than along a random direction. A random analyze will be a subject for further investigations.

SUMMARY
At least two Danish clusters of passage graves shows features where the megalithic monuments at passage graves and dolmens interact through line relations i.e. the megalithic monuments are pointing at each other in the landscape. A sample of Irish passage graves or tombs is used as a comparative sample to see if there are common features. The two samples of passage graves share common features concerning invisibility and line relations between the single megalithic units. Further it is found that the Danish passage grave can have both an astronomical and a topographical explanation whereas the Irish tomb has a more pronounced topographical explanation.

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Danmarks 41, DK-2300 Copenhagen, Denmark
### Table 1. The Kalundborg cluster complex, with sub clusters

<table>
<thead>
<tr>
<th>Sub cluster</th>
<th>Passage group</th>
<th>Altitude above sea level in meters</th>
<th>Column 3, 9: Longitude in UTM X meters, zone 32</th>
<th>Column 4, 10: Latitude in UTM Y meters, zone 32</th>
<th>Column 5: Measured pointing direction/azimuth in degrees</th>
<th>Column 6, 12: Altitude above sea level in meters</th>
<th>Column 7, 11: 'Alignment azimuth' in degrees: deduced from the UTM coordinates, Direction = 180 means pointing backwards</th>
<th>Numbers in ( ) means uncertain direction or possible alignment direction. (154+180): this value is obtained trough different methods and is a doubtful mean value, but the author has chosen to use it in the sample of alignment azimuth for the reason that two out of three methods gives the same value.</th>
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Note: The table includes a list of passage groups and their associated data, including longitude, latitude, and alignment azimuths. The data is used to analyze the visibility and alignment of these structures within the Kalundborg cluster.
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<th>Obiekt</th>
<th>Numer</th>
<th>Kolor</th>
<th>Rok</th>
<th>Numer</th>
<th>Data</th>
<th>Waga (g)</th>
<th>Wzór</th>
<th>Data</th>
<th>Waga (g)</th>
<th>Wzór</th>
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Paper IV

DANISH PASSAGE GRAVES, “SPRING/SUMMER/FALL FULL MOONS” AND LUNAR STANDSTILLS.
Denoted as (Clausen, SEAC proceedings 2011) in the main text.
DANISH PASSAGE GRAVES, ‘SPRING/SUMMER/FALL FULL MOONS’ AND LUNAR STANDSTILLS

Claus Jørgen Clausen

Abstract: The author proposes and discusses a model for azimuth distribution which involves the criterion of a ‘spring full moon’ (or a ‘full fall moon’) proposed by Marciano Da Silva (Da Silva 2004). The model is based on elements of the rising pattern of the summer full moon combined with directions pointing towards full moons which occur immediately prior to lunar standstill eclipses and directions aimed at the points at which these eclipses begin. An observed sample of 153 directions has been compared with the proposed model, which has been named the lunar ‘season pointer’. Statistical tests show that the model fits well with the observed sample within the azimuth interval of 54.5° to 156.5°. The conclusion made is that at least the ‘season pointer’ section of the model used could very well explain the observed distribution.

Keywords: Neolithic, astronomy, megalithic astronomy, lunar alignments, spring full moons, summer full moons, fall full moons, season pointer, lunar standstill eclipses, lunar eclipses, Denmark.

Introduction

An early study by Hårth and Roslund (H&R in the following) on the orientation of passage graves in Scania and north-eastern Zealand was made in 1991 on a sample of 41 graves (47 directions). They found that most of the entrance passages pointed between east and southeast with a smaller number pointing south-southeast. They argued in favour of a relationship between this orientation and the rising of the moon, identifying the south-southeastern direction with the southernmost ‘standstill’ of the moon. They concluded that ‘The distribution pattern of orientations is fully in line with a lunar explanation that the passages point at specific phases of the lunar cycle’.

Figure 1. The histogram shows the combined sample of 106 passage directions measured by Clausen et al. and 47 passage directions measured by H&R. In addition to the three prominent peaks around 100°, 123° and 149°, a fourth and more isolated peak around 200° is revealed. The horizontal azimuth axis is divided into intervals of six degrees due to the uncertainty of the measurements with a starting point at 0.5°. The vertical axis is the number of directions per bin. In all following diagrams, the axes are denoted in the same way.

A later study by Clausen (Clausen et al. 2008) took place in 2006. The motivation for the 2006 study was to enlarge the initial sample of passage graves from previous studies in Denmark with a new set of determined directions (58 directions) of entrance passages within a latitude interval of 0.5° (55.5°N to 56°N) to make a possible astronomical ‘signal’ clearer. Furthermore, the intent was to use this larger sample to see whether conclusions made about the moon could be substantiated or whether other explanations were possible. The 2006 study confirmed the conclusion made by H&R.

The latest investigation by Clausen in 2010 and 2011 very clearly underpins the tendency favouring a lunar explanation. To gain sufficient data on locations on Zealand, the island of Fyn and the peninsula of Jutland, the latitude interval was extended by 1.5° from 55° N to 56.5° N. This new data set (Clausen 2013) with 153 directions (including the initial H&R directions) reveals three strong peaks with azimuths around 100°, 123° and 149° (Figure 1). The peaks around 123° and 149° are, within the limits of uncertainty (+/-2.5°), fully consistent with the southern and southernmost lunar standstills at the actual latitude corresponding to the time period within which the Danish dolmens and passage graves are believed to have been built (c. 3550 to c. 3200 BC).

The Observed Pattern of Full Moonrises in Neolithic Times

In Neolithic times, one was unable to determine whether the moon was 100% full or simply very close. For Neolithic man, a full moon was a two to four-day event, depending on the phase of the moon. Hereafter, the term ‘full moon’ is used to refer to this two to four-day event. The conditions for the full moon calculations are as described below:

1) The full moon event is an event which is expanded by up to two days surrounding the time of the genuine full moon.

Under these circumstances, about 71% of the full moon phases will be >=96%, hereafter P96. Accepting that to the naked eye, a P96 full moon is almost the same as a genuine full moon, of the remaining 29% full moons, about one-fourth will have a phase which is between 95 and 96%. So,
roughly speaking, about 80% of the calculated full moons can be counted as 'genuine' full moons.

2) Treat the full moon event as an event which is very close to a sunset when the moon rises nearly diametrically opposite the setting sun. In this case:

A) The angular difference between the rising azimuth of the moon (Maz) and the setting azimuth of the sun (Sazset) must be Maz - Sazset + 180° = daz \leq \pm 20°, which is the case if the rising of the one and the setting of the other take place at approximately diametrically opposite directions in the sky. In the most extreme cases the most northern/southern limits will correspond to an azimuth = 25° respectively 155° relative to winter and summer solstice, which well exceed the most northern and most southern standstills of the moon. So no full moons will be lost with an azimuth truncation limit of \pm 20°. And for geometrical reasons no full moons phase \geq 99 \text{ per cent, hereafter P99, will exceed the truncation limit.}

B) The rising time of the full moon must be within one and one-half hours (Moorise - Sunset = dt \leq \pm 1.5 \text{ h}) of the setting time of the sun. This is within the limit for astronomical twilight at the actual latitude, and it is possible to relate the rising azimuth of the full moon to the setting azimuth of the sun. Also, if the (full) moon rises more than 1.5 hours before sunset it is (under today's conditions) not possible to see the rise by the naked eye.

In general, a full moon appears when either daz or dt or both reaches a minimum and the above-used computational limits results in 93% 'genuine' full moons out of the total number of calculated moonrises.

**Breaking Down the Rising Pattern of the Full Moon**

The calculated rising pattern of the full moon can be broken down into different sections. The first argument uses the 'spring full moon' idea proposed by Marciano Da Silva, hereafter denoted SFM. The SFM argument is that the rising azimuth of the full moon must exceed the rising azimuth of the sun (Saz), Maz > Saz. This is also called a 'crossover'. The crossover happens because the rising points at the horizon for the sun and the full moon move in opposite directions.

Looking only at the SFM (identified here with the first summer full moon) it reveals a peak with a mean value of about 100°, which is quite similar to the first peak in the observations. Generally this peak corresponds to the first genuine SFM, i.e., a SFM with P99.

Taking the conditions for the full moon calculations into account, especially P96, the SFM can appear twice during the time period from the first half of March to the second half of April. As an example a crossover can take place around the 1st of April for a 'full moon' with a phase of 97% and an azimuth about 100° and later a second crossover can take place around the 30th of April for a 'full moon' with a phase about 99% and an azimuth about 97. This situation produces two SFMs. Approximately 20% of all SFMs will be double.

Similarly, there is a full moon around full fall from September to October which determines the 'autumn full moon' hereafter denoted as AFM (identified here with the first winter full moon), where Maz < Saz. Just before the AFM (the day before), the mean value of the azimuth of the rising full moon reaches almost the same mean value as for the SFM (the deviation is about 1°). This could be an indicator of the coming AFM. We have a similar situation at spring where the mean value of the azimuth of the rising full moon one day before the SFM is approximately the same as the AFM.

Peaking values for full moonrises seen from Portugal at spring and autumn (or fall) are investigated by Fabio Silva (2011), named in his paper as Equinoctial Full Moons (EFMs). These full moons are almost identical with the SFMs and AFMs described in this paper, the only difference being that Silva adopted a P99 limit. The difference between SFM P99 and SFM P96 will be the shape of the peak. The SFM P96 peak will be broader (especially at the bottom) but with approximately the same mean value as the SFM P99. This is general for all EFMs.

**Modelling a Lunar ‘Season Pointer’**

To investigate the full moonrises further, distributions for the SFM and following full moons have been calculated. These calculations show that only the SFM and the following full moon (second summer full moon) one month later both reveal peaks. The second summer full moon is more precisely defined as either: the first full moon one month after the SFM or the first full moon one month before AFM. In case of double SFMs it is the latter which defines the second summer full moon around May and the second summer full moon around August is defined according to the first AFM. You have a similar scenario for the winter full moons.

Generally it is only the EFMs and second full moons which reveal peaks. For all other full moons there is no distinguishing tendency in the rising pattern. The explanation for this lies in the movement of the southernmost or northernmost rising points of the moon due to the 18.61-year cycle of the moon. This means that the full moon rising pattern reveals four peaks, two at summer (the SFM and the second summer full moon) and two at winter (the AFM and the following second winter full moon) which each represent two periods per year. This is caused in the movement relative to the standstills points. This information can be used to construct a model for a lunar season pointer.

Thus, the model is based on the EFMs and second summer full moons as well as the southernmost full moons. The southernmost full moon indicates that the midsummer period has been reached. The condition for the calculations
is the same as previously for the same period and location.

**Corrections for the Lunar ‘Season Pointer’**

The season pointer covers an azimuth interval from 85° to 150° which is consistent with the main body of observations (71%). To make the season pointer more realistic, all azimuth values must be corrected for the apparent horizon (ha). Denmark is rather flat, but filled with small hills, and most measured values of ha lie between 0° and 1°. Using the previous conditions and setting ha at 0.5°, the ‘season pointer’ azimuth values move from about 1° to the south for the easternmost directions and up to 4° for the southernmost directions.

Figure 2 shows the corrected season pointer, which also includes all EFPs and second summer full moons between the two crossover time periods (March/April and September/October). The diagram is composed by taking the maximum values from each peak to show the strong tendency in directions presented as superposed peaks. This is done while keeping in mind that in the process of mapping the rising points of the full moon, experience will reveal the most common directions. The peak values for the three peaks in the corrected model are: 100°, 124° and 149° (Calculated for the peak azimuth intervals of 85° to 114°, 114° to 138° and 138° to 156°).

For further use, calculations have been made for the location 55.5°N and 0.25°E, corresponding to a value of DeltaT = 24.75 hours. The DeltaT value refers to the Earth’s greater speed of rotation in previous times (Stephenson 2003).

**Lunar Standstill Eclipses and the ‘Fingerprint Feature’**

As seen from the observed distribution, there are still azimuth values outside the range of the season pointer. About 86% of all the measured azimuth values are covered by the rising interval of the moon (from 31° to 151°, 3300 BC). The season pointer cannot explain the northern azimuths, since the number of values is too small.

By a whim of nature, the season pointer has another possible function. In years where the southernmost (or northernmost) rising points of the moon are close to minor or major standstills, full moons corresponding to the 100° peak could be followed by a lunar eclipse.

The moon can rise close to the minor and major standstills during periods lasting from two to four years. Accepting a time period of +/- 1.861 years around the exact time of the maximum or minimum azimuth value of the standstill points, it is possible to calculate the full moons rise which occur before a lunar eclipse corresponding to the given time interval. It reveals a distribution of full moons rising at around 100°, and in this case (DeltaT = 24.75 h) it also produces a peak around 74°. If full moons rise just before or just after the lunar standstill-year period are taken into account, they will reveal a peak which corresponds to the second summer full moon. This combined distribution is treated in a previous work (Claussen et al. 2008, 225–226), nearly consistent with a feature called the ‘fingerprint feature’ (see Figure 3).

The ‘fingerprint feature’ is sensitive to the position along the longitude, and according to the DeltaT, the position of Denmark is uncertain to within about +/- 45° (corresponding to +/- 3 hours). The ‘fingerprint feature’ has its origin in a geometrical explanation based on the viewers’ angle in relation to the position of the moon in its orbit. The ‘fingerprint feature’ is a feature which appears now and then at different locations in different periods of time. The feature can persist from 100 to 200 years over a longitude interval of 120°. When the ‘fingerprint feature’ vanishes, another distribution pattern appears which also can persist from 100 to 200 years.

**The Proposed Test Model**

In the observed distribution, about 14% of the measured directions lie further south than the rising point of the moon. The most obvious explanation for these directions lies in the topography; that is, they are apparently point towards landmarks (Claussen et al. 2011). This could very well be the case, because 17 out of 20 directions point
directly towards another passage grave.

Nevertheless, a more spectacular idea could be proposed. It could be that the directions point to the beginning of the lunar eclipse. Most lunar eclipses during the summer period can be seen in southern directions — directions aimed towards the eclipses which are pointed out by the ‘fingerprint feature’ full moonrisers. The ‘fingerprint feature’ and the southernmost full moons point out 58 possible visible lunar eclipses for the 90-year period for which calculations are made. If even half of the possible lunar eclipses were actually visible, this would give a mean of about one lunar eclipse every third year.

Thus, taking the full moonrisers occurring before a lunar eclipse and the direction pointing at the eclipse itself into account, the proposed test model is composed as follows: season pointer + full moonrisers before a lunar eclipse + directions pointing at the eclipses.

The season pointer is scaled to fit the observed distribution caused by the fact that this pattern of moonrisers repeats itself after one lunar cycle (18.61 years) and represents common, frequently observed events. However, the eclipses are treated as single events, which means that the number of directions towards full moonrisers before a lunar eclipse and that of the eclipses themselves are not scaled but are compared directly with the observed distribution.

Figure 4 shows the complex model, which is based on what it is possible to observe and on the idea that the important directions concerning visual lunar eclipses had been marked. It must be emphasized that the model presented here is only one possible model out of a whole series of models from the interval of the ‘fingerprint feature’. All these models are quite similar.

Visually, the two distributions (model and observations) look very similar. A statistical test can be made to give an idea of how close the two distributions are in fact to each other. A chi-square test is useful with regard to a histogram presentation. In this case a chi-square test named chi-square-test-one is used. This test compares a model distribution with an observed distribution. Due to the scaled component of the model distribution, the test will be reduced by one degree of freedom. This means a reduction in the probability result of the test. The complete test interval is from $36.5^\circ$ to $222.5^\circ$ (31 bins), which is the interval covered by the observations.

The test procedure involves a series of tests which reduces the test interval from either the northern or the southern end of the interval by one bin each time. An extract of the results are listed in Figure 5.

In a case where the calculated probability P is, for example, greater than 0.15 (15%), it is not possible to reject the null-hypothesis. The nil-hypothesis occurs if chi-square = 0, which means that the two distributions are identical. Especially the central part of the tested azimuth interval gives a very high probability. Seen from a statistical point of view the proposed model works very well for the azimuth interval $54.5^\circ$ to $156.5^\circ$ (85% of the observed distribution). For the southern direction exceeding $156.5^\circ$, the result is more ambiguous, but it must be kept in mind that the two distributions are visually similar.

![Observations and model 3203 BC to 3213 BC, 55.6 ± 0.25. Delta t = 24.75 h](image)

Figure 4. The model (bold solid line) compared to the 153 observations. The season pointer component, which includes the full moonrise before a lunar eclipse, is scaled to fit the observations, whereas the contribution made by lunar eclipses outside the range of the season pointer ($84.5^\circ$ to $156.5^\circ$) is not scaled. See the main text for arguments. Note that the 200° more treated peak is produced by the model. The thin dotted line shows the "fingerprint feature" and directions to the lunar eclipses. The 230° peak is not yet observed although indications for these directions are found.

### Statistical Test of the Model

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<th>Chi-square</th>
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<td>0.01</td>
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<td>19</td>
<td>54.5 - 168.5</td>
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<tr>
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<td>9</td>
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</table>

Figure 5. The chi-square-test-one table. Note the increasing probability from bin numbers equal 17 to 13.

### Discussion

The high probability factor shown by the statistical test in Figure 5 indicates that the 'season pointer' could well be confirmed by the result. It is interesting that the mean value of the three peaks in the observed distribution ($100^\circ$, $123^\circ$ and $149^\circ$) are nearly identical to the mean values ($100^\circ$, $124^\circ$ and $149^\circ$) of the same peaks in the corrected model. The explanation for this could be quite simple. The Neolithic peoples in Denmark may have discovered by experience that if they looked towards $100^\circ$ and $123^\circ$, these directions simply turned out to be those that most probably would determine the SFM and second full moons of the summer period. The second full moon is very close to the southern minor lunar standstill and the major or
southernmost lunar standstill, around 150°, is easy to
determine. In fact, the lunar ‘season pointer’ could be
established by rather simple means.

In the case of lunar eclipses, the interpretation should
be made more carefully. Only an increased number of
observations can give an idea whether the eclipses could
be a part of the explanation or whether the ‘season pointer’
should have an extra element added. This extra element
would be the second winter full moon. Nevertheless,
the season pointer has the built-in function of pointing
out specific lunar eclipses, so to speak. This means that
Neolithic man in Denmark would occasionally have seen
a full moonrise followed by a lunar eclipse. Whether they
were able to understand the periods of the lunar eclipses
is unknown, but the 18.61-year lunar cycle is mapped out by
the ‘season pointer’.

Some Danish double or twin passage graves (passage
graves with two passages) seem to support the eclipse
idea, with one passage pointing towards 122° (full moon
before a lunar eclipse) and the other pointing towards
146° (southernmost full moon, same year). This will
be the subject of future investigations. It is also notable
that southern directions in Danish passage grave clusters
seem to point out the next cluster (Clausen et al. 2011,
348). Whether directions pointing towards summer lunar
eclipses or southern directions in general are important
with regard to landmarks is uncertain — perhaps both
explanations are valid.

The ‘season pointer’ idea makes sense when keeping
in mind that the Neolithic peoples in Denmark (funnel
beaker culture) had an agricultural culture between 4000
BC and about 2800 BC. If different rituals were to be held
in connection with certain periods of the year, the ‘season
pointer’ could point out the right time for performing
these. For example, a fertility ritual could be performed
in connection with the SFM when it was the season
for sowing seed. Alternatively, a ritual concerning the harvest
could also be performed, indicated by the late second
summer full moon.

In the case of the lunar eclipses, these could have been the
trigger for rituals concerning the dead. When the moon was
eclipsed it revealed an opening to ‘the kingdom of the dead’
and this was the right time for doing a ritual concerning
the dead. In a sense, you could say that the passage in a
passage grave could function as a ‘spiritual launching pad’.
To perform this kind of ritual, one would rebar the
dead in the passage grave when the time was right — and
the time was right when the lunar eclipse occurred.
From the movement of the moon and the sun at the horizon
one could learn by experience when the moon and sun were in
the right positions to predict a lunar eclipse. Lunar eclipses
occur when both δaz and δt reach a minimum. In general,
a visible eclipse can be observed for every third full moon
under these circumstances, when δaz =< +/−5° and 0.3 h
> δt >−0.1 h, which works very well during the summer
period. During this period, the night is short at the actual
latitude and the moon will be closer to the exact time of
the eclipse. During the winter period, only about half of
the eclipses can be predicted in this way.

Summary
The Danish/Swedish data set of 153 measured passage
directions has been compared with a hypothetical model
called the lunar ‘season pointer’, which also can point
out specific lunar eclipses. The model distribution is
very similar in appearance to the observed distribution.
A statistical test shows that the ‘season pointer’ function,
at any rate, is a very likely possibility, whereas the lunar
eclipse pointer is more ambiguous. Lunar eclipses could
very well be the case for the azimuth interval from 54.5° to
156.5°, whereas southern directions exceeding the interval
are more likely to have a topographical explanation rather
than stemming from the direction of the lunar eclipse.
Perhaps both of these are the case. The lunar ‘season
pointer’ could be a trigger for different kinds of rituals
and the lunar eclipses could be the triggers for rituals
concerning the dead.

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Paper V

SCANDINAVIAN PASSAGE GRAVES AND THE “LUNAR SEASON POINTER”. Denoted as (Clausen, 2015A) in the main text.

Errata list V
In the figure caption on page 128, Figure 4. The term AFM in second line should be the term SFM.
SCANDINAVIAN PASSAGE GRAVES
AND THE LUNAR ‘SEASON POINTER’

Claus Clausen

The constructors of most Danish megalithic monuments belonged to the funnel-beaker culture (in German: Trichterbecher – hence TRB), which existed during a period from about 4000 to 2800 BC and covered a relatively large area in the southern part of northern Europe (see Figure 1(a)). Especially in Denmark, the concentration of megalithic monuments is very high and an estimated total number of 40,000 graves have been proposed by Jørgen Jensen (Jensen 2001).

The Danish islands, mainly Zealand, may have played a central role in the TRB culture due to their geographical position (see location in the lower circle in Figure 1(a)), number of megalithic monuments and advanced complex megalithic constructions as double and triple graves (Dehn and Hansen 2000, see also Clausen et al. 2011). The largest known cluster structure of passage graves in Denmark is located on North West Zealand, covering an area of about 800 km² and involving more than 40 passage graves and about 100 dolmens (located in the circle in Figure 1(b)).

Previous studies of Danish passage graves show that it is likely that the distribution pattern of the pas-

Figure 1
(a) (left) The approximate area covered by the funnel-beaker culture, about 3500 BC. Note the central position of the Danish island of Zealand (lower circle). Enclosed in the upper circle is the Swedish Falbygdan area. Here, about 70% of all known passage graves in Sweden are concentrated.
(b) (right) Present-time distribution of Danish megalithic monuments (coordinate data from the Danish Heritage Management). The circle on western Zealand marks the position of the largest Danish cluster structure known so far.
sage directions follows the rising pattern of particular full moons, quite possibly full moons before a lunar eclipse, in the azimuth interval between 78° and 132° (Clausen et al. 2008). This feature is called the "fingerprint feature". The idea of this paper is to look at an increased number of passage grave directions, keeping the measurements within the limits of latitude 55.0 N and latitude 56.5 N, to see whether previous conclusions as to the moon can be substantiated and whether they still tend to apply. By keeping the measurements within a narrow latitudinal scope of 1.5°, it is expected that a possible astronomical signal will be more clear and significant. Furthermore, the new set of observations will be compared with a proposed model which involves full moons rising between spring and fall. This model is called the lunar "season pointer". The lunar "season pointer" model will be tested on the Danish set of data as well on a Swedish set of data from Falbygden (Henriksson 2005).

THE MEASUREMENTS
To enlarge the numbers of measured passage graves, it was decided to add the previous measurements (98) from Clausen et al., 2011, to 9 measurements made on the island of Funen by Niels H. Andersen in 2009 (Andersen, "The Sarup project") and 19 measurements made in cooperation with the Society of Danish Amateur archaeologists (SDA) in 2010 and 2011. These 28 measurements are listed in table A (see appendix). In addition, the 27 measurements from Scania (southern Sweden) made by Roshlund and Hard in 1991 are included in the new data set (as in Clausen et. al. 2008). The passage graves in Scania close to Zealand are, according to archaeologists, typologically identical constructions to the Danish passage graves made according to the same tradition. The
total number of passage graves measured is thus 153. All measurements, except for those made by Roslund and Hård, used a magnetic compass with an accuracy of 0.5°, but all results were rounded to the nearest whole number. The uncertainty is estimated to ± 2.5° with a maximum of ± 3°. This determines the width of the bins used in the histogram presented in Figure 2.

THE OBSERVED DISTRIBUTION
As seen from Figure 2, the observed distribution displays three significant peaks. The calculated mean values in the azimuth interval from 36.5° to 222.5° are 100°, 123° and 149°. Less than 70% of the measured directions are covered by the rising interval of the sun, whereas about 86% of the observations are within the rising interval of the moon. This includes all three mentioned peaks. More or less half of the remaining 14% are concentrated around a smaller, isolated peak around 200°. It is also significant that most directions (80%) are within the south-eastern quadrant. This feature is seen in many samples of data sets measuring passage directions of megalithic monuments from different parts of Europe. Some examples are: a large data set from France and Portugal (Hoskin 2002) which displays 1573 directions with 71% in the south-eastern quadrant, and a smaller data set from Sweden (Henriksson 2005) with 86% in south-eastern quadrant out of a total of 140 directions.

THE BEHAVIOR OF THE SUN AND MOON AT THE HORIZON
Most archaeologists and astronomers who are interested in archaeological astronomy (archaeoastronomy) believe that either the sun or the moon at their points of setting or rising could give an explanation of the orientation of most megalithic monuments in Western Europe; that is to say, an astronomical explanation is expected. As an example, there are two clusters of passage graves in Denmark. One is located on the island of Samso and another on Zealand. The two reveal almost the same azimuth distribution pattern (Claussen et al. 2008 and 2011). These two clusters are separated by water and the distance in a direct line is about 50 km. Only an astronomical phenomenon can explain this feature. Furthermore, the explanation needs to include some fixed direction which can be fulfilled either by the sun or the moon. These fixed directions are called the standstill points. The standstill points are the extreme southern or northern rising or setting points at the horizon.

Most of us are familiar with the standstill points of the sun. The southernmost point from which the sun rises (winter solstice) in Denmark lies almost exactly to the southeast, and it is reached around Christmas time. The northernmost point from which the sun rises (summer solstice) is almost exactly to the northeast, and is reached just half a year later at midsummer (the time at which Denmark celebrates the birthday of John the Baptist). The movement of the points on the horizon at which the sun rises is simple. It repeats the same pattern year after year. A special feature is that at the spring and autumn equinoxes, the sunrise is almost due east. Thus, the sun has three fixed directions: north-east (44°), east (90°) and southeast (134°). The extreme northern and southern rising points of the sun change slightly with time by plus minus a few degrees; this is caused by the change in the angle between earth’s rotation axis and the orbiting plane, known as the tilt of the ecliptic. In general, the change in the tilt of the ecliptic has the most pronounced effect on the standstill points for the sun at the extreme northern and southern latitudes. But in the case of Denmark, these directions were almost the same in Neolithic times. The case of the moon is somewhat different.

The orbit of the moon, as centred on the earth, does not move on a plane parallel to the earth’s orbit around the sun. The angle between the two planes of orbits is 5.15°. This means that the orbit of the moon cuts through the earth’s orbital plane at two points, also known as the nodes. The moon’s orbit revolves around the earth over a period of 18.61 years, known as the 18.61-year lunar cycle. Obviously, the knots revolve with the same period. Due to the fact that the moon’s orbit is also elongated (elliptical in shape) and to the geometrical situation in general, this periodicity makes the lunar standstill points move from a minimum to a maximum (or vice versa) dur-
ing an 18.61-year cycle. For that reason, the rising points of the moon at the horizon move between four standstill points, two towards the north and two towards the south.

The lunar standstill points are not symmetrical according to the eastern direction, but are slightly skewed towards the south. This effect is caused by the lunar parallax. The moon is relatively close to earth in comparison to its size. This means that the light line towards the moon depends upon the observer's location on the surface of the earth. The effect is most pronounced at northern and southern latitudes. Present time values for the lunar standstill points observed from Denmark are 33°, 57°, 125° and 149°. The lunar standstill points are also affected by changes in the tilt of the ecliptic, with a few degrees as the standstill points for the sun. When all effects are taken into account, the behaviour of the moon's rising points at the horizon is a little more complex than that of the sun (see Clausen et al. 2008, p. 222). Still, we have four fixed rising points related to the lunar standstill points. Both the lunar and the solar standstill points are marked in Figure 2.

A general phenomenon which influences both the sun and the moon is refraction. Refraction is an effect caused by the earth's atmosphere. It means that you see the sun or the moon rise before it actually does. This moves the value of the azimuth backwards (to the north). All these effects are taken into account in the calculations used from here on in this article.

INTERPRETATION OF THE OBSERVED DISTRIBUTION

The three strong peaks in the observed distribution (Figure 2) can all be explained by the behaviour of the moon. The two southern peaks are very close to the southern lunar standstills, which for the time period around 3300 BC can be calculated to 126° (southern minor lunar standstill) and 152° (southern major lunar standstill) at the actual latitude (55.5 North). For the southernmost summer full moon, hereafter SMF, the major lunar full moon standstill is close to 150°. The third peak at about 106° also has a lunar explanation. In 2004 Marciano Da Silva proposed the megalithic equinox (Da Silva 2004) as the first full moon after the first “crossover” also called the “spring full moon”, hereafter SFM. This full moon reveals a peak at about 106° for latitude 55.5° north. The “crossover” appears because the points on the horizon at which the sun and the full moon rise move in opposite directions. To be precise, the “crossover” occurs when the rising azimuth of the full moon exceeds the rising azimuth of the sun in the spring and the reverse in the fall, the “autumn full moon”, hereafter AFM. Both the SFM and the AFM are equinoctial full moons, hereafter EFMs (Silva 2011). In this way, the “crossover” defines the beginning and end of the summer period. So within the scope of uncertainty of the measurements, the three prominent peaks are very like to have a lunar explanation which is connected to the full moon and the summer period. A pure AFM peak (mean value about 80°) does not seem to contribute significantly to the observed distribution.

The most obvious explanation for the southern directions which exceed the rising interval of the moon is a topographical one. Most of the southern directions point directly towards another passage grave placed on the highest local point (Clausen et. al 2008 and 2011), that is, the interpretation of the function is that it serves as a pointer towards a landmark. However, it is also possible that there is a multi-layer explanation for directions in general. Thus, a secondary (or primary) explanation for the southern directions could be that they serve to pinpoint the movement of the summer full moon as rising/climbing, moving close to the horizon. This is similar to the sun-climbing model (SR/SC) proposed by Michael Hoskin (Hoskin 2001). A more speculative idea could be that the extreme southern directions pointed towards the full moon at the beginning of certain lunar eclipses at the time when the passage graves were constructed.

MODELLING A LUNAR ‘SEASON POINTER’

In Neolithic times, man could not determine whether the moon was a complete, 100% full moon, or was simply very close. For Neolithic man, a full moon was a 2- to 4-day event, depending on the phase of the moon. In the following, the term “full moon” is equivalent to a 2- to 4-day full moon event in which the phase of the full moon must exceed 97% of a genuine, 100% full moon.

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4 A genuine full moon cannot rise exactly at the extreme southern (or northern) lunar standstill point due to the angle between the standstill points of the sun and the moon. The rising moon at the extreme southern (or northern) lunar standstill point exceeds the conditions for a genuine full moon.
When using the solar/lunar "crossover" (EFMs) to define a lunar "calendar", or a "season pointer", it will reveal a peak at around 100°, both for the first full moon after the first "crossover" (SFM) and for the first full moon just one or two days before the second "crossover" (AFM). This is a very important implication, which means that you can use the SFM both to determine spring and fall (see Clausen 2014, pp. 147–148). The second full moon after the SFM, about 30 days later, and the second full moon about 30 days before the AFM will reveal a peak at around 122°. This satisfies the two strong peaks in the distribution. A complication is that the "crossover" can happen twice — this will displace the time period for the second full moon or the second full moon represent a second "crossover". We do not know how Neolithic man were able to deal with that fact. Furthermore, the extreme southern rising point for the moon in the particular year also influences the rising direction of the second full moon due to the lunar cycle and the southern minor lunar standstill. The result of the combined effects is that the rising direction of the second full moon will be displaced about 6 degrees towards North i.e. with rising azimuths about 117°. Note here that the EFMs are not affected by the lunar cycle in this way.

For a third or a fourth full moon after the SFM and before AFM the full moonrise has no specific peaking direction except for the extreme southern rising point. Therefore, the model is based on the EFMs, the second full moon and the SmFM.

The southernmost rising points of the full moons actually show the movement of the rising points between the minor and major southern lunar standstills following the 18.61-year lunar cycle. The SmFM heralds the midsummer period.

The model of a megalithic lunar "season pointer" based at the "crossovers" can define variable dates in March/April (SFM), April/May as the first full moon after the SFM (first second full moon), June/July (SmFM), August/September as the first full moon before the AFM (the second second full moon), and September/October (AFM). In other words, the "calendar" pinpoints the periods of spring, early summer, midsummer, late summer and fall.

MODEL PRESENTATION
The programme application used for model calculations return the full moon azimuths with no correction for the apparent horizon (ha). The astronomical horizon, which is used in the calculations, is similar to the horizon as seen at sea level, which equals ha = 0° and will be the case for a totally flat landscape. Obviously, to make it possible to compare the model with the observations, corrections must be made for the apparent horizon. Measurements of 27 ha that show that most values are between 0° and 1°, therefore ha = 0.5° is used as a value for the correction. In addition, the model calculations are centred at the geographical coordinates: latitude 55.5 N and longitude 11.5 E, which simply shows the mean location for the observed data. The peak values for the three peaks in the corrected model are, respectively: 100°, 124° and 150° (calculated in the same way as for the observations).

For most measured azimuths it has not been possible to measure the apparent horizon, therefore it has been assumed that ha = 0° (see table A, appendix). For that reason, a model with no correction has also been taken into account. The peak values for the three peaks in the non-corrected model are, respectively: 100°, 122° and 143°. A small correction in general has a more significant influence only on the most extreme southern directions.

The rising pattern of the full moon for a calculated model can be presented as a histogram in two ways: 1) when adding all the azimuth values, the histogram will be a sum diagram; 2) when presenting certain full moons as a separate rising peak, the histogram will be a diagram with superposed peaks.

The sum diagram (1) could be the case if observations were made for a shorter period and the main tendency in the full moon rising pattern was not yet discovered. This type of diagram simply reflects all observed visible full moonrises for a period. The sum diagram, therefore, could present short-term observations — in this case, less than about 50- to 100-year observations.

A diagram with superposed peaks (2) could reflect the tendency in long-term observations (i.e., more than 50 to 100 years of observations), when the observers have learned by experience the most common directions for full moonrises.

The above argumentation is supported by the calculations. Calculations for full moonrises over a period of

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5 The apparent horizon, denoted ha, is the horizon as an observer sees it in the landscape, with mountains, hills, valleys, trees, etc.
less than 50 years do not necessarily reveal certain distinguishing patterns in the same way that long-term calculations do.

Figure 3 shows a model built on the three calculated peaks, corrected for the apparent horizon altitude ($\text{ha} = 0.5^\circ$). The peaks are represented as superposed peaks in the histogram. This type of presentation is used in this case because it is believed that the Danish passage graves were built over a period of at least 100 years. The proposed superposed model presentation comes very close to reproducing the pattern of the observed directions (see Figures 2 and 3).

LUNAR STANDSTILL ECLIPSES

The observed distribution seems to indicate that the fun-
Scandinavian Passage Graves and the Lunar 'Season Pointer'

Observations and model 3303 BC to 3213 BC, latitude 55.5 North; longitude 0.25 East

The superposed combined model (bold line) compared to the 153 observations. The season pointer part, which includes the full moonrises before a lunar eclipse, are scaled to fit the observations, whereas the contribution from lunar eclipses outside the range of the season pointer (78.5° to 116.5°) are not scaled because they represent single isolated events. Note that visually the model and observations are very similar. Note also that the longitude correspond to the longitude position 0.25 East (Delta T = 23.7h) when the lunar eclipse took place and is not equal to the expected geographical longitude of the observer position i.e. the mean position for the observations (11.75 East).

Rises for azimuths of around 100° in the actual years can be followed by a lunar eclipse. These lunar eclipses are known as lunar standstill eclipses. This type of lunar eclipses will repeat with an interval of 1, 8, 9 or 10 years. In practice, all lunar eclipses follow a certain pattern with a 19-year cycle, which can run for 4 periods (19-year cycle) with almost the same azimuth for the full moonrise. When this cycle is completed, a new one will take over with a slight change in azimuth. Several of these cycles can run simultaneously and are connected to the Babylonian Saros.7

A period with lunar standstill eclipses can vary from about 2 to about 3 years. These periods either start or end with full moonrises before a lunar eclipse at around 115° to 125° with a peak mean value of about 123°. The combined rising pattern in this case reproduces the "fingerprint feature". If directions pointing directly at the beginning of the calculated eclipses are included, a more complex model is achieved (Clausen 2011). This model (the lunar “season pointer” + lunar eclipses) has a function which can not only pinpoint different seasons, but also lunar eclipses for certain years (see Figure 4). The shown model is only one model out of a whole series of similar models with different longitude positions. Caused in the fact that Earth rotation was faster in the past it is not possible exactly to know the observers position along the longitude according to the time when a lunar eclipse took place (see Stephenson, F. Richard, 2003 and Clausen et al. 2008, pp. 225 – 226). This is known as the Delta T problem. The Delta T value used in the calculations is estimated to about 23h (Stephenson 2003) with an uncertainty about +/- 4h i.e. +/- 60° along the longitude.

7 A Saros is an 18-year, 11-day, 8-hour cycle concerning eclipses discovered by the Babylonian around 700 BC. A Saros predicts eclipses which can run in series to about 1300 years. Several of these cycles can run simultaneously and are known as Saros series.
The Danish passage graves were probably built around 3300 BC, and during the 90-year calculated period from 3303 to 3213 BC, the shown model (Figure 4) pinpoints 58 lunar eclipses. If, due to weather conditions, only half of the lunar eclipses were visible, it would have been possible to observe about one lunar eclipse every third year to fourth year. Figure 5 shows the Danish passage grave Ravehøj from a viewpoint looking out through the passage. This passage grave pinpointed the visible lunar eclipse on 25 April 2013, which was a second full moon lunar eclipse. The next visible second full moon lunar eclipse will occur on 7 August 2018.

STATISTICAL APPROACH

Visually, the two distributions (superposed complex model and observations) look very similar. However, the question is how identical the model and the observations are in reality. The histogram presentations make it possible to use the common statistical chi-square-one test, which tests a model distribution against the observed data. Due to the scaled part of the model distribution, the probability result from the test will be reduced. The test compares, column by column, the number of directions for each bin interval in the entire azimuth interval from 36.5° to 222.5°, which is the interval covered by the observations. The procedure used is a series of tests which reduces the test interval each time, either from the northern or the southern part of the interval, by one bin. If it is the case that the calculated probability (p) is greater than 0.5 it is not possible to reject the nil-hypothesis. The nil-hypothesis occurs if chi-square = 0 and p = 1.0, which means that the two distributions are identical. An extract of the test is listed in Table B (Appendix), where both a model with corrections and one without are presented.

The main conclusion is that the observed distribution and the corrected model distribution, seen from a statistical point of view, are quite similar in the azimuth interval from 54.5° to 150.5° (about 80% of the observed distribution). The proposed lunar ‘season pointer’ model (+ lunar eclipses) works very well in the azimuth interval

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8 The calculated data must be scaled to fit the observed when using the statistical procedure. That is to say, if the calculated number of data for an example is equal to 345 and the number of observations is 138 in the same azimuth interval, then the scaling factor is calculated as 138/345 = 0.4. For each column of the calculated histogram data, the number of values must be multiplied with the scaling factor.
from 72.5° to 150.5°. This means that the effect of a full moonrise before a lunar eclipse can not be neglected, but more observations are needed to distinguish whether the "season pointer" gives the full explanation or whether the lunar eclipse really is a part of the interpretation of azimuth distribution.

An argument for the complex model is the 90% level of probability which also includes the full moonrises before the lunar eclipses (see table B). A pure "season pointer" model reveals a 92% probability for the azimuth interval of 84.5° to 138.5°, for $\phi_a = 0.5°$, and 99% probability in the same interval for $\phi_a = 0.0°$, which involves the SFM and the second full moons. This brings the lunar "season pointer" model very close to fulfilling the criterion for the nil-hypothesis.

For the southern direction exceeding 150.5°, the result is more ambiguous, but keeping in mind that the two distributions are visually similar, directions pointing toward the beginnings of the lunar eclipses could still be a possibility. More or less the same arguments can be used for the non-corrected model ($\phi_a = 0.0°$), except that for the matching interval (54.5° to 150.5°) the probability factor $p$ is even higher! A possible conclusion could be that the assumption regarding the flatness of the Danish landscape ($\phi_a$ close to 0) gives a rather better approximation for most of the measurements than assuming that $\phi_a = 0.5°$ in general. Even small differences in $\phi_a$ cause great changes in the extreme southern directions (about 150°) up to 5 degrees if $\phi_a$ is around and slightly above 1 degree! Observations concerning the landscape conditions show that passage graves with directions of about 150° (11 observations) are sometimes placed sloping downhill: this will reveal an apparent horizon greater than 1 degree. Unfortunately, this cannot be confirmed due to the insufficient number of cases measured.

**COMPARISON OF DANISH AND SWEDISH DATA**

At Falbygden in Sweden (Figure 1(b)), centred at 58.17°
N; 13.55° E, there is a large concentration of passage graves which in many details are very similar to the Danish passage graves, except that they are missing dry wall stones (Lars Blomquist 1991). Figure 6 shows the azimuth distribution for 140 passage graves from Falbygden as given by Göran Henriksson (Henriksson 2005). The histograms with the Danish and Swedish azimuth data cannot be used directly in a statistical test due to their different locations. For this purpose the declination data must be used. Figure 7 shows both the Danish and the Swedish declination data. As an apparent horizon, ha = 0.38° is used. This is the same value used by Göran Henriksson in his discussion of the Falbygden data (Henriksson 2005), both for a scaled and a non-scaled distribution. Here it must be noted that Göran Henriksson has corrected the Falbygden declination distribution according to a hypothesis about the sun whereas the Danish declination data shows the topocentric declinations – i.e. the data has neither been corrected for sun or moon. A test of the Danish declination data with different values of ha (0°, 0.38°, 0.5° and 0.8°) shows that there are no dramatic changes – no significant deviation – in the overall distribution pattern. In fact, the different distributions are very similar. For that reason, it is assumed that the two sets of declination data can be tested directly without making any major errors.

The statistical approach is to use a chi-square test which is used to compare two distributions with unknown origin (following the same test procedure as for the previous test). The results are listed in Table C. The test shows...
that the central parts (which includes the two peaks) of the two distributions are more or less similar, but the peak which correspond to the SFM has a more significant statistical outcome.

The general conclusion is, however, that the two distributions share a common feature concerning both peaks. The mean value of the two peaks in the Danish declination distribution are about -17.5° and -5.1°, and respectively about -17.0° and -4.8° in the Swedish data set. Within the uncertainty of the Danish declination data (about +/- 1.5°), these values are assumed to represent the same features. This means that the main part of the two distributions could originate from the same underlying distribution. A model test of the Swedish data should prove that.

SWEDISH DATA AND THE LUNAR ‘SEASON POINTER’

According to Lars Blomqvist (Blomqvist 1991) southern Sweden and Norway can be seen as fringe areas to Denmark, mainly Zealand, during the period of the TRB culture. This also includes the location of Falbygden. Thus an assumption that the people of this area had the same knowledge and traditions as did those of Zealand is not an impossible one. For that reason, the lunar ‘season pointer’ has been tested on the Falbygden data.

In the Swedish data set there is no evidence for the extreme southern full moon, so the test model used deals with the EFMs and the second full moons. Calculations are done for full moons, with the same conditions as previously, for a 50-year, an 85-year, a 140-year and a 200-year period around 3000 BC. The statistical test (same procedure as previously) for the 85-year period is listed in table D, both for a sum diagram and a superposed diagram. Figure 8 shows both distributions.

The result obviously supports the sum diagram presentation, which means that the construction period for the Falbygden passage graves could have been very short, probably between 50 and 100 years or less. This is supported by a statement from Lars Blomqvist. According to Lars Blomqvist (Blomqvist 1991, p. 8) the passage graves at the location Falbygden could have been constructed over a period of about 50 years. This result is obtained by a study of ceramics found in the Falbygden passage graves and calibrated C14 measurements of organic material.

The test result is not as convincing as for the Danish set of data but still has a high probability in the central part, which is the interesting interval. Therefore, the null hypothesis cannot be rejected for the azimuth interval of 91° to 123°, which includes the two peaks corresponding to the SFM and the second full moons. Hence the lunar ‘season pointer’ could explain the Swedish Falbygden passage graves as well as the Danish passage graves.

DISCUSSION

As far back as 4000 BC, the funnel beaker people in Denmark built the first long barrows, thus starting a barrow-building tradition which lasted for more than 5000 years. The funnel beaker peoples were peasants and had a simi-
lar culture. A peasant culture could probably benefit from the use of a kind of a calendar. Using the criterion of the SFM and the AFM i.e. the EFM, one could define a variable moon “calendar” with spring (time for seeding) and fall (after for harvest) as the suggested lunar ‘season pointer’ do. Even though this “calendar” designates no specific date, it fully satisfies the need a peasant culture has, for example, to find the correct timing for a fertility ritual or a ritual concerning the harvest. In this way, all rituals could be synchronised for the different settlements. Both the Danish and the Swedish azimuth distributions seem to fulfill the criterion for being lunar “season pointers” based on the EFM and the second full moons for the major part of both distributions. The conclusion is therefore that the “lunar season pointer” provides a useful alternative to the commonly accepted solar hypothesis.

However, the Danish observed distribution differs from the Swedish distribution in displaying a peak representing the southern major lunar standstill and southern directions beyond the rising points of the moon. In this case, it is striking that the peak mean values of the Danish measurements (100°, 123° and 149°) are almost the same as the calculated peak mean values (100°, 124° and 150°) for the lunar ‘season pointer’ with ha = 0.5°. A possible reason for this is that the funnel beaker people in Denmark somehow managed to develop their skill so they could pinpoint the directions of the SFM and second full moons where there would be the greatest possibility of seeing a full moonrise. To do this, it is assumed that at least 100 years of full moon observations must be carried out.

A whim of nature is that the combined superposed distribution patterns of the SFM and the second full moons displays almost the same distribution pattern as the “fingerprint feature” in the azimuth interval from about 78° to about 132°. A strong “fingerprint feature” pattern occurs three times during the period of the funnel beaker culture: at about 3900, 3600 and 3300 BC, lasting each time for
about 150 to 200 years. This means that the funnel beaker people in periods occasionally had the possibility to see EFMs and second full moons followed by a lunar eclipse. Probably this discovery was so striking that they learned to use the lunar eclipses in ritual praxis. The lunar eclipses could have been the trigger for rituals concerning the dead based on the following proposed speculative idea:

When the moon was eclipsed it revealed an opening to 'the kingdom of the dead' and this was the right time for doing a ritual concerning the dead. In a sense, you could say that the passage in a passage grave could function as a 'spiritual launch-pad'. To perform this kind of ritual, one would rebury the dead in the passage grave when the time was right – and the time was right when the lunar eclipse occurred.

The author also suggests the following scenario concerning Danish passage graves and lunar eclipses:

The Danish TRB people already knew about the lunar "season pointer" before the construction of simple dolmens. During the period in which they constructed dolmens and more simple passage graves (dolmens with a passage and single-chambered passage graves) Neolithic man in Denmark acquired more precise knowledge about lunar eclipses. In the end, they were able to construct more complex passage graves which actually could pinpoint lunar eclipses for certain years.

Figure 9 shows examples of double and twin passage graves which point towards southern lunar minor and major standstills. This type of passage grave could, in astronomical terms, be called a lunar "standstill" passage grave.

Even though the Swedish data do not reveal evidence of or connections to lunar eclipses in the same way as do the Danish data, it is not impossible that a lunar eclipse might have been observed now and then, simply caused by the effect of the lunar "season pointer" tool. Or, were the Swedish TRB people able to learn from the Danes how to deal with the lunar eclipses, just as they learned to construct the passage graves?

SUMMARY

The observed Danish distribution strongly reflects a lunar rising pattern based on the fact of the three revealed peaks at 100°, 123° and 149°, all of which could have a lunar explanation. Further it is shown how the rising pattern of the full moon can be broken down into different rising peaks, each of which refers to a specific full moon called SFM the second full moon and the SmFM.

Even though a final conclusion at this stage is not possible (more observations are needed) the statistics show that the funnel beaker people in Denmark and Sweden had the opportunity to use the suggested "lunar season pointer" to synchronise different types of rituals. Coincidentally, the "season pointer" has a built-in function which could predict lunar eclipses for certain years. The distribution pattern of directions for Danish passage graves also seems to fit this extra function and it could, in fact, have been used in rituals concerning the dead.

ACKNOWLEDGEMENT

For useful discussions on full moons back in time I would like to thank Fabio Silva and Fernando Pimenta. Especially Fernando Pimenta has been very helpful concerning the moon calculations. I have received permission to use the Alec Ephemera AE2.8 program to calibrate some parameters for my own moon program. Also, a discussion with Mariano da Silva concerning the concept of his suggested "spring full moon" has been very helpful.

I would also like to thank professor Niles H. Andersen, chief curator at Moesgaard Museum, for permission to use his measurements from Sarup in the combined sample of measurements. Finally, thanks to Svend Illem Hansen for his belief in this project and for his willingness to give permission to use his material.
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claus@kofodskole.dk
### TABLES

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Table A

The *Note* number is the author's registration number for megalithic monuments located at Sarup. Notes: * *) Dalmeny with a passage (simple passage grave) L. and R. before the azimuth denotes left and right entrance passages (as seen from the outside) for double or twin graves.

<table>
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<td>27.9997</td>
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<td>0.92</td>
<td>3.8075</td>
<td>0.99</td>
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Table B

Chi-square One test on Danish data versus the lunar 'season pointer' model data as shown in Figure 4. The numbers marked with bold represent values for which a nil-hypothesis cannot be rejected. Note that the nil-hypothesis is very close to being the case for $\lambda = 0.9$ in the interval $84.5 - 138.5$, which includes the two major peaks at around $100^\circ$ and $123^\circ$. **
### Table C

Chi-square Two test on Swedish (S) Falbygden data versus Danish (DK) data as shown in Figure 7. The declination distribution is in 3º bin intervals, which is twice the size used by Oren Hal鳳ikson (Henriksson 2005). The numbers marked with bold represent values for which a null-hypothesis cannot be rejected.

<table>
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**Statistical Differences:**
- For the sum model of 85 years period, with ha = 0.5, the chi-square test reveals significant differences (p < 0.05).
- For the superposed model of 85 years period, with ha = 0.0, the chi-square test indicates minimal differences (p > 0.05).

### Table D

Chi-square One test on Swedish Falbygden data versus the Later Saxon “season pointer” model data as shown in Figure 8. Note that both a sum presentation and a superposed presentation are tested for three different values of ha: The test time period is for full moons from 3000 to 2915 B.C. (an 85-year period). The numbers marked with bold represent values for which a null-hypothesis cannot be rejected. In this case note that the sum model has a more interesting statistical outcome.

<table>
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<td>24.6464</td>
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**Statistical Differences:**
- For the sum model of 85 years period, with ha = 0.0, the chi-square test reveals significant differences (p < 0.05).
- For the superposed model of 85 years period, with ha = 0.5, the chi-square test indicates minimal differences (p > 0.05).
Paper VI

WEST IBERIAN MEGALITHIC TOMBS AND THE “LUNAR SEASON POINTER”.
Denoted as (Clausen, SEAC proceedings 2013) in the main text.
WEST IBERIAN MEGALITHIC TOMBS
AND THE "LUNAR SEASON POINTER"

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ABSTRACT
Recent investigations of Danish and Swedish passage graves and their orientation patterns show a dominance of orientation directions which can be explained primarily in relation to full moons rising during the summer period. Both the Danish and Swedish passage graves tend to form clusters. Each cluster has a very similar orientation pattern, and this calls for an astronomical explanation.

About 200 Portuguese and Spanish megalithic tombs seem to have similar orientation patterns to the Scandinavian ones; these will be the subject of further studies.

A group of megalithic tombs located in West Iberia in central Alentejo and the surrounding area have been chosen for a statistical test case using the same model used for the Scandinavian passage tombs. The test model is based on 1) the Equinocial Full Moons (EFMs), i.e., the “spring full moon” and the “autumn full moon”, 2) the first and last summer full moons (defined as the second full moons in this paper) and 3) the southernmost full moon. These are used in the hypothesis for the test case.

The model fits 99% of the observations and the test results show a high statistical probability factor p (p = 0.56) when the observed distribution is matched with the model, meaning that the model distribution and the observed distribution likely have the same origin. The comparison between the main body of the observations (98%) and the model is interesting because the probability factor reaches the value of 0.86, which supports the null hypothesis.

KEYWORDS: Archaeoastronomy, lunar orientations, megalithic monuments, West Iberia
1. INTRODUCTION

Scandinavian megalithic monuments, passage tombs (sometimes referred to as passage graves), and simpler dolmens were constructed from approximately 3500 BC to 3200 BC. The great concentration of Swedish passage graves located between Lake Vänern and Lake Vättern, which are typologically the same kind of constructions as the described ones, has been interpreted to represent a Danish colony (Blomqvist, 1991) within the funnel beaker culture. The funnel beaker culture is also known in the German literature as the Trichter-randbecherkultur (TRB) culture. The group of Scandinavian megalithic monuments (i.e., passage tombs and dolmens) belongs to the northern TRB group.

With regard to Danish dolmens and passage tombs, a great variety of forms can be seen (see figure 1). The final late constructions were very complex constructions with double or twin chambers (one chamber divided into two parts), both types constructed with two passages. Even triple graves were constructed, containing three separate single chambers or one twin chamber and a separate single chamber. Interpretation of their orientation patterns favours a lunar explanation (Hård and Roslund, 1991 and Clausen et al., 2008). The lunar interpretation, in particular, makes some Portuguese and Spanish passage tombs located at West Iberia in Central Alentejo and its surroundings (see figure 2) of interest (Da Silva, 2004).

![Figure 1 Development in the ground plan of Danish megalithic monuments, from (A) simple dolmens to (F) fully elaborated passage graves. Note that all constructions have well-defined symmetry axes.](image)

![Figure 2 The locations for the chosen West Iberian tombs measured by Hoskin and Roslund (insert in the rectangle). The group of tombs marked with capital letters are adapted from Hoskin et al., 1998. For these reasons, this paper tests the "lunar season pointer" model (Clausen, 2013) for the chosen group of tombs.](image)
the direction of this line, they deduce the azimuth using a compass. The azimuth is hereafter corrected for magnetic variation.

It is interesting that Hoskin himself even encourages the use of his measurements for interpretations other than the solar one: "It has always been the primary purpose of our fieldwork to assemble data, which archaeologists and archaeoastronomers will then have at their disposal and may interpret as they see fit" (Hoskin et al., 1998, p. S41).

In the following, all histogram presentations use 6-degree intervals for the bins with the starting point 0.5° along the x-axis (i.e., the azimuth axis). A bin interval is counted as an example from 90.5° to 96.499999°. Along the y-axis, the number of directions within each bin is counted.

The size of the 6°-bin interval is determined by the mean deviation of ±3°. Choosing a 6°-bin interval will therefore minimize the negative effect of the deviation between the azimuths measured by Hoskin and Roslund when the two data sets are added. Choosing a broader bin interval will smooth out details in both the observed distribution and the distribution produced by the model. This will affect the outcome of the statistical test for the method used (see Section 4) when the observations are compared to the model.

![Alentejo and surroundings: 208 tombs](image)

Figure 4A Alentejo and surroundings: 208 tombs. Histogram showing the azimuth distribution on the 208 West Iberian megalithic monuments (solid line) used for testing in this paper, corrected to the astronomical horizon. The dotted line represents the contribution from group K monuments, which affect the distribution so that it twists a little more to the left. The peak mean value is 98.5°.
3. CONSTRUCTING THE TEST MODEL

The model (the lunar season pointer) used in this paper is based on the concept described in Clausen (SEAC 2011 proceedings). However, some of the computing limits have been changed a bit.

The main idea is that it was not possible during Neolithic times to determine whether the full moon was a genuine full moon (phase > 99%) or simply very close with, for example, a phase = 97%. Thus, a full moon was an event spanning several days for the Neolithic man, depending on the phase of the moon. Obviously, this situation leaves no choice other than to take all the possible full moons into account in the calculated distribution, because we do not know which of the possible full moons would be the right one to choose. This is because the full moon selected could differ from one local area to another, depending on local traditions.

3.1 Calculation limits for the model

The coordinates for the calculations are chosen to be centred at latitude 40.0°N and longitude 8.0° W, which corresponds to the central part of Portugal. The data set ranges in the latitude interval from 39.8°N to 38.4°N. Moving the latitude centroid to, for instance, 39.0°N only moves the southernmost and northernmost lunar standstills about 0.5° towards equinox (90°). The effect is therefore counted as negligible.

For calculation purposes, Alcyone Ephemeris AE2.8 software is used and program output was saved to a Microsoft Excel file for further use. The phase of the moon is given a lower limit of 96%, which allows the full moon to be a three-to-five day event plus or minus two days around the genuine full moon. Therefore in the following, the term “full moon” is equivalent to a three-to-five day full moon event, depending on the phase of the moon.

During a year, the rising points of the full moon and the rising sun move in different directions along the horizon. This has as a consequence that the rising points of the full moon and the sun switch over at least two times per year somewhere in spring and in autumn. This is known as a crossover and is related to the Equinoctial Full Moons (EFMs) (Silva and Pimenta, 2012).

For winter full moons, the rising azimuth (Maz) must be less than the rising azimuth of the rising sun (Saz):

Maz < Saz

For summer full moons, the rising azimuth must exceed the rising azimuth of the rising sun:

Maz > Saz

The abovementioned criteria for separating winter and summer full moons has as a consequence that the EFMs will be identified both by the last winter full moon and the first summer full moon at spring and by the last summer full moon and first winter full moon at autumn (see Subsection 3.3 for further details and table 1 for examples).

3.2 Double crossovers

Using the 96% limit for the phase of the moon has another consequence. Crossovers can take place more than two times per year, with a variation of two to four times per year. The most common is two times, once in spring and once in autumn, in the
200-year period used for calculations. A spring crossover will normally take place in March (spring full moon) and/or in April and in the autumn in September (autumn full moon) and/or in October.

A special feature in this case is that a crossover in principle can take place from a moon phase of $<96\%$ to a phase which is $\geq 96\%$ or from a moon phase of $\geq 96\%$ to a phase of $<96\%$. Unfortunately, the algorithm misses these crossovers both because of the 96% phase limit and the plus or minus two-day limit. Some of these missing crossovers have been manually selected from the data in the phase interval from 92% to 96%. Table 1 is an example from the programme output file that shows a situation with four full moon crossovers in one year.

This illustrates clearly how difficult it is to deal with natural definitions. It is not possible to work with fluent limits in computer programming unless you work with a series of models where you change the limits according to the calculation algorithm.

### 3.3 Building the model

The EFMs occur either in March/April in the spring or in September/October in the autumn.

The second full moons appear from April to May and from August to September (the "harvest" moon) and are counted as the first full moon after the last crossover in spring and the first full moon before the first crossover in autumn.

The southernmost full moon is easy to determine simply as the southernmost rising point for the full moon for a certain year, depending on the 18.61-year lunar cycle. The southernmost full moon reaches its most southern rising point either in June or July.

The "lunar season pointer" is therefore a kind of fluent lunar calendar with no exact dates but instead with season periods with variations of about one month based on the direction towards the full moonrise, i.e., the azimuth of the full moon; for example, the direction towards the full moon indicates the beginning of spring in March or April.

The net result with the calculation limits used is that the model produces two full moon peaks for the EFMs, one corresponding to the spring full moon and another corresponding to the autumn full moon.

Here it must be noted that the full moon just before (one to two days before) the crossover in springtime and after the crossover in the autumn produces equivalent peaks, and vice versa.

Due to the fact that the calculation limits produce a full moon event of three to five days, full moons will be seen at both sides of the crossover point. For example, during a spring crossover, the full moon will have the following azimuth (az) rising series A: day 1 az = 73.93°, day 2 az = 82.77°, day 3 az = 91.8° and finally day 4 az = 100.56°. During the same four-day time period, the sun rises at about az = 96°. The crossover then takes place from day 3 to day 4. During the same year at the time of the autumn crossover, the full moon has the following azimuth (az) rising series B: day 1 az = 104.9°, day 2 az = 97.8°, day 3 az = 90.39°, day 4 az = 82.9°, and day 5 az = 75.55° (phase = 0.92). During this five-day time period, the sun rises at about az = 80°, so the crossover takes place from day 4 to day 5. Note here that the two rising series A and B are very similar except that they run in opposite directions. See also Table 1 for more examples. Each crossover event is represented by a rising series A in the spring and B in the autumn. The mean value, for instance, of the part of the A series in spring where Maz < Saz should equalize the part of the B series in autumn where Maz < Saz.

For the 200-year calculated period, the first half (i.e., the days before the crossover) of all the approximately 200 A series has a mean value for the azimuths = 82.7° and the most frequent values (mode) are found within the interval between 82.0° and 82.9°, represented by the number 82.2°. Taking the last half (i.e., the autumn full moon) of all the approximately 200 B series, the mean value of the azimuth is 82.2°.
and the mode is again 82.2°. The mean value after adding both distributions is 82.6° and the mode is still 82.2°. This means that if the full moon rises with an azimuth of around 82° to 83° (+/- a few degrees), it is either the full moon a few days before the EFM in spring, or it is probably the EFM in the autumn that will be observed (see the rising series A: day 2 and the rising series B: day 4, which is very close to being the EFM in the autumn).

The situation is similar for the EFM azimuths corresponding to the EFM in spring. The mean value here is 97.9° and the mode is 97.4°, which means that if the full moon rises at around 97° to 98° (+/- a few degrees), it is either the full moon a few days before the EFM in autumn or the EFM in spring.

This is a sort of Yin and Yang principle, so to speak. Or, in other words, if the full moon in the autumn has the same rising azimuth as the spring full moon, it indicates that the crossover will take place within the next few days. Therefore, it must be underlined that the EFM peaks in the model used include contributions from both spring and autumn, but they are only represented by one peak each in the model.

The second full moons produce two similar peaks, one for the beginning of the summer and one for the end (i.e., the "harvest" full moon) of the summer, but contribute as well to the model with one peak with a mean value of 107.7°.

Finally, the southernmost full moon contributes with a distribution that has no distinguishing peak except for the limits at the southern minor and major lunar standstills caused by the lunar 18.61-year cycle.

The mean value for the overall distribution is 98.9° for the calculated 200-year period.

When all things are taken into account, the model produces four distributions, which will be added into a sum model. Figure 5A shows the four distributions separately and Figure 5B shows the resulting sum model distribution for the calculated period compared to the 208 observations.

Figure 5A The four distributions produced by the model. The first peak from the left (dotted line) corresponds to the autumn full moon, the next peak (solid line) corresponds to the spring full moon, the third peak (dotted line) corresponds to the full moon defined as the second full moon and the last distribution (solid line) is the contribution of the southernmost full moon.

Figure 5B The sum model (solid line) compared to the 208 observations (dotted line). Visually, the two distributions are very similar.

4. THE STATISTICAL APPROACH

The model data covers an azimuth interval from 63° to 130°. This interval includes 207 of the total 208 observations, which means that the model fits 207/208 = 99.5% of the possible observations (see Figure 6A). The mean value of the 207 observations is 98.3°.

The chi-square statistical method has been chosen for comparing data, as it fits well with the histogram presentation and simply compares the expected values with the ones observed for each bin. Other methods have been considered but, at this stage, rejected. It is also convenient to use the chi-square test due to the fact that it is very simple to scale the model data to fit the observation data — that is, the 207 ob-
observations which fit the model are used for the scaling factor. The model produces 3868 full moons for the calculated 200-year period, making the scaling factor 207/3868 for each bin interval.

When investigating the behaviour of the model distribution in comparison with the observed distribution in further detail, the problem is addressed in the following way: first, the observed 207 data points which fit into the test are compared to the complete lunar season pointer model, denoted as model 1 (207) (Figure 6A); second, the observed distribution is compared to a model in which the southernmost full moon is excluded, denoted as model 2 (207) (Figure 6B). The next step is to exclude the 33 granite tombs (group 1) from the observed data and then repeat the above-mentioned scheme. This results in model 1 (174) (Figure 6C) and model 2 (174) (Figure 6D).

Results from the four statistical tests are listed in Table 2.

5. STATISTICAL RESULTS

It is striking that the mean value (98.9°) of the model 1 (207) distribution is very close to the mean value (98.3°) of the observed distribution, even though it is not conclusive.

Generally, the test with the 207 observations is in better agreement with both proposed models (Model 1 and Model 2) than the test with the 174 observations, but this should be expected due to the azimuth distribution of the 33 granite tombs (see figure 4A).

Model 1 gives, for both observed distributions, a probability value (p) for the overall distributions which is almost the same (see Table 2) and so high (p > 0.5) that this model cannot be rejected.

Model 2 has a tighter correlation for the main body of the observations (azimuth interval 60.5°-126.5°), but a very low value
for the probability factor for the overall distribution (see table 2).

The obvious explanation for the low probability factor concerning the overall distribution in Model 2 is the missing southernmost full moon.

Model 2 (207) in particular has a remarkably tight correlation; in fact, it equals the 0-hypothesis in the bin interval from 72.5-126.5, i.e., that the observed distribution and the expected distribution are probably originally extracted from the same distribution or have same origin.

A conclusion at this state could therefore be that the lunar season pointer (Model 1) could play a role in explaining the tested distributions. However, the model in which the southernmost full moons have been excluded (Model 2) works better than Model 1, so at least the EFMs and the second full moons should be part of the explanation for the two tested distributions, if an astronomical explanation is sought.

This result is in agreement with some of the lunar models proposed by González and Belmonte (González and Belmonte, 2010) except that they use a moon phase of >99% and do not combine the models. They note that the lunar models they propose are apparently closer in general to their data than the proposed solar models.

6. DISCUSSION

The statistical results are in good agreement with the results from the author’s investigations of Scandinavian passage graves (Clausen, in press, 2014). The Swedish group of passage graves, especially, behaves like the group of Portuguese and Spanish megalithic monuments used for testing in this paper. The Swedish group of passage tombs also lacks directions for the southernmost full moons.

The Neolithic people who lived in Alentejo and the surroundings belonged to the emerging agrarian culture in Europe. A culture of peasants and farmers needs a kind of calendar to predict the different seasons of the year. A lunar season pointer could be the tool to use for that purpose, not because it can predict the correct time for seeding (for this, the weather can be used), but because it can mark the point in the year at which a ritual in connection with the seeding, for example, a fertility ritual, can be performed.

Curt Roslund (Roslund, 2000) mentions some archaeological artifacts found in connection with the seven stone chamber dolmens in Alentejo. Some of these findings are slate plates with carvings which could be interpreted to represent an owl; these again could represent the moon. A recent study (Rivero and O’Brien, 2014) of the slate plates from the southwestern part of the Iberian Peninsula concludes that these plates represent a core idea. But at this stage, we do not know what that idea is.

Similar carvings are found on ceramics from Scandinavia, which are interpreted as representing a human face (see Figure 7). The similarities between the mentioned artifacts are the two ‘eyes’ surrounded by a ring with radiating lines, and another feature, a zigzag pattern as shown in Figure 7. Figure 8 shows other examples of Danish ceramics which are more similar to the slate plates found in Alentejo and the surrounding area. These ceramic plates have been interpreted as symbolizing the sun. Other similar plates have been interpreted to symbolize both the sun and the moon.

Figure 7 Left, a slate plate found in Alentejo in Anta 1 da Herdade da Faríosa, representing an owl, and right, ceramics found at the passage grave, ‘moon hill’, located on the southeastern part of Zealand in Denmark, representing a human face. Note that both artefacts have two stylized eyes and a zigzag pattern.
In Denmark, white burned flint is often found both inside and outside the passage graves. White burnt flint is, according to some Danish archaeologists, symbolic of the moon. Sometimes the passage graves were also covered with white burnt flint, so they stood out as white domes in the landscape. Perhaps this was meant to symbolize the rising full moon.

Figure 8 A sample of ceramic plates found in Denmark on the island of Bornholm at Rissberg. Note the similarity with the slate plate from Alentejo (Figure 7).

It would be interesting to investigate whether the West Iberian tombs with identical orientation patterns at different locations (González and Belmonte, 2010), and the Scandinavian area share further common features in addition to the lunar season pointer and perhaps some similar carvings. Are there additional similar features concerning the use of the landscape (Clausen et al., 2011 and Silva, 2013), thus providing an achaetopographical explanation for the way the passage tombs and dolmens are arranged in small clusters (Roslund, 2000)? And, if so, how was this knowledge exchanged? Does it indicate a kind of link (Roslund, 2000) between the two areas or was it something which developed independently? This would be interesting to investigate further. In this case, a future study should include groups of megalithic monuments south of Scandinavia and north of the Iberian Peninsula with the same orientation pattern.

Another problem concerns the model calculations used, or, more precisely, the selection procedure used for data from the programme output file. Unfortunately, the limits used in the selection procedure, as mentioned earlier, cause a loss of some full moonrises just up to the 96% phase limit. To avoid this situation, the model should be improved by expanding the day limit from plus or minus two days to plus or minus three days around the exact full moon time. Also, the calculation period should be expanded with at least an extra 100-year period. This will be a subject for future investigation.

Finally, weather conditions could play a role when observing the crossovers. The idea of treating the full moon as a several-day event probably solves this problem. If the first crossover moon is missed, a change might be obtained on the following day. This could influence the orientation pattern, but it is covered by the model.

SUMMARY

A model for a “lunar season pointer” has been tested on a sample of 207/174 West Iberian tombs measured by Hoskin and colleagues in 1998 and Roslund in 2000. The result shows that it is possible that Neolithic man in the western part of the Iberian Peninsula in Alentejo and the surrounding area used EFM’s, second full moons, and probably the southernmost full moon as a kind of fluent lunar calendar. The same model fits passage graves in Scandinavia and could indicate a possible link between the two areas with their groups of passage graves or tombs. Whether this knowledge was exchanged or developed independently is unknown, but the similar findings at these areas, which are at a great distance from each other, is an indication that a link may well have existed.

It will be the task of a future study to improve the model used to ensure that the selection procedure for the full moons does not miss any full moonrises.

ACKNOWLEDGEMENTS

The author would like to thank the members of the SEAC for their patience during the editing process of this paper. The referees, in particular, have provided useful input in suggesting changes in the paper.
Table 1: The output files from the left column give the sun's rising azimuth (Saz), the rising azimuth of the moon (Maz), the date - which is not the exact date but which keeps the phase of the moon to a margin lying within a number of days - and finally, in the last two columns, the crossover conditions. Note that only the October crossover would have been registered by the selection procedure and that azimuths around 97 to 98 degrees (plus or minus a few degrees) are involved both in spring and in autumn (subsection 3.3). Crossover azimuths are marked in bold. Note also that the four crossover events correspond to the rising series A in the spring and B in the autumn.

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<th>Maz</th>
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<th>Maz &gt; Saz Summer full moons</th>
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Table 2: The statistical results from the four tests. The most notable statistical outcome for each test is marked in bold. Model 2 (207) is remarkable in that it allows assuming the null hypothesis. The three columns in the four test tables are, from the left: the number of used bins in the test (Bins), the azimuth test interval in degrees and, finally, the probability factor p, given as a decimal number between 0 and 1, where 1.00 equals 100% probability.

<table>
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<th>Sum model 200 years period</th>
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<tr>
<td><strong>Bins</strong></td>
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<tr>
<td>11</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>9</td>
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| **Model 1: 174 tombs (figure 6C)** | **Model 2: 174 tombs (figure 6D)** |
| **Bins** | **Azimuth interval** | **Probability (p)** | **Bins** | **Azimuth interval** | **Probability (p)** |
| 12        | 60.5 - 132.5         | 0.54                | 12       | 60.5 - 132.5         | 0.01                |
| 11        | 60.5 - 126.5         | 0.57                | 11       | 60.5 - 126.5         | 0.70                |
| 10        | 66.5 - 126.5         | 0.51                | 10       | 66.5 - 126.5         | 0.64                |
| 9         | 72.5 - 126.5         | 0.47                | 9        | 72.5 - 126.5         | 0.62                |

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Paper VII

NEOLITHIC COSMOLOGY?
Denoted as (Clausen, 2015 B) in the main text.
Neolithic Cosmology?

Abstract
It could seem far out affected to propose a cosmology in Neolithic time but it is never the less the issue in this paper. The hypothesis is that astronomical events could have had serious impact for the development of the culture during Neolithic times. Attention is given to the funnel beaker culture (from about 4000 BC to about 2800 BC) in Northern Europe. Recent investigations of the overall lay out of megalithic monument in Scandinavia concerning position and orientations show a complex pattern in clusters of megalithic monuments. The pattern in these structures could have been inspired of the behaviour of the rising full moon during the summer period. Following these patterns it is possible that the Neolithic people in Scandinavia learned to use the full moon as a lunar ‘season pointer’ and perhaps even found a way to use lunar eclipses in burial and ritual praxis. Some evidence is perhaps found in ancient literature and local names.

Introduction
The word cosmos originates from the Greek term κόσμος (kosmos), meaning ‘order’ or ‘ornament’ and is antithetical to the concept of chaos. Today, the word is used as a synonym of the Latin loanword ‘Universe’. In general refers the word to the world order which also includes the complete Universe and its content. The word cosmology means the knowledge about cosmos. So having a cosmology means that you have knowledge about the world order. Pythagoras is said to have been the first philosopher to apply the term cosmos to the Universe, perhaps referring to the starry firmament. None or very little about cosmology from Neolithic times (i.e. prehistoric period) is known so only the remains of megalithic monuments, rock carvings or archaeological evidence can give us a clue. When comprehensible written sources occur the situation is somewhat different but unfortunately not in this case. The astronomical events referred to in this paper has no destroying catastrophic effects on society, i.e. not meteorite or comet impacts which could cause great damage on the landmass, in the sea or in the atmosphere or all together. So the changes in society and culture of interest are only a result of human behaviour.

The funnel beaker culture and its ability
The term funnel beaker culture is inspired by the shape of the ceramics produced by this first agriculture culture in northern Europe. The culture existed from approximately about 4000 BC to about 2800 BC. The funnel beaker culture seems to have been centred at the area to day known as Denmark. The Danish islands, mainly Zealand, may have played a central role

Fig. 1. The approximate area covered by the funnel beaker culture, about 3500 BC. Note the central position of the Danish island of Zealand (inner circle). Enclosed in the upper circle is the Swedish Falbygden area. Here, about 70% of all known passage graves in Sweden are concentrated.
in the funnel beaker culture due to their geographical position (lower circle in Figure 1), number of megalithic monuments and advanced complex megalithic constructions as double and triple graves. The most spectacular relics from the funnel beaker culture are in fact the sometimes enormous megalithic monuments known as passage graves or passage tombs, see Figure 2. These tombs are very clever and complicated constructions.

The entrances passages of these graves have a significant orientation, with about 80% pointing in the south-eastern quadrant, see Figure 3. The distribution pattern seems to fit full moon rises during the summer period. The funnel beaker people were peasants and had a similar culture. A peasant culture could probably benefit from the use of a kind of a calendar. The azimuth distribution pattern seen in Figure 3 has an interesting implication. It reveals three main concentrations in the distribution, one peak around 100 degrees, one about 123 degrees and one about 149 degrees. All three directions can be related to the moon. Investigated in details these three directions can be used in two ways one not excluding the other. The most obvious use of the three directions is a kind of a calendar use. Concerning the moon these three directions can point out different periods during the summer period. The direction about 100 degrees is in this connection of special interest. For genuine full moons, full moon rises in directions about 100 degrees indicates spring or harvest period. For this direction there occurs a simple astronomical phenomenon. The sun and the full moon make a cross over at the horizon when they rise (see Figure 4). This is possible because rising full moons and the rising sun moves in opposite directions at the horizon. The phenomena cannot be seen directly because the sun rises at the morning and the full moon rises approximately 12 hours later in about the same direction at the horizon.

The situation occurs in two periods:

1. At spring (from about mid March to about mid April) when the full moon just had made the cross over.
2. At late harvest (from about mid September to about mid October) when the

Fig. 3. Figure 3 gives two different presentations of the measured azimuth. The left diagram present the azimuth according to the compass directions and the right diagram show the same directions in histogram form. The histogram reveals two significant peaks at 100 degrees, 123 degrees and 149 degrees which all can be related to the moon.

Denmark and Scania: 152 azimuth directions at latitude 55.0 to 56.5 North
full moon rises just before the fall cross over.

The second direction about 123 degrees is the second full moon rise after the first cross over or the full moon rise before the harvest full moon. Periods are from about the beginning of May to the beginning of June or about the beginning of August to about mid September. All other full moon rises between 123 degrees and 149 degrees indicates midsummer period in June and July. This is the lunar 'season pointer' (see Figure 5). By nature whom the three mentioned directions could also be used to determine certain lunar eclipses. These types of lunar eclipses are called lunar standstill eclipses. In years when the most southern full moon rise about 125 degrees (southernmost inner standstill point 3200 BC) or about 151 degrees (southernmost outer standstill point 3200 BC) full moon rises about 100 degrees can be followed by a lunar eclipse. This is the conclusion from the overall distribution pattern. It is worth to mention that the rising points of the moon moves between the standstill points with a cycle of 18.61 years close to 19 years. Another indication for a lunar interpretation is that directions around the mentioned directions appears in various structures concerning the clusters of Danish passage graves. In all investigated clusters seem directions belonging to the three main directions (i.e., the three peaks) to be favoured. So far it seems that clusters can point out the next cluster, nearly always with directions within the south-eastern quadrant. This is of course only indirect evidence concerning the moon, but of 6 investigated clusters or pair of clusters we see that 6 clusters are connected in pairs where one cluster points out the next one through a south-eastern line. The Sarup cluster complex, located on island Funen (see Figure 6 and Figure 7) is such an example. This complex has been excavated during a period of about 40 years and have revealed a concentration of 125 megalithic monuments in a relatively small area within 20 square km. A more remarkable feature seems to appear now and then. It shows that the passage grave mound is clearly placed on a platform or ledge. If this is an artificial feature, the funnel barker people were able to perform manipulation of the landscape to obtain intervisibility between the megalithic units. Another remarkable feature is a possible geometrical aspect concerning the clusters of passage graves which are seen both in Denmark and Sweden. But concerning the astronomical aspect we need more directly archaeological hard core evidence to verify the moon (or sun) relation. In recent years findings of small clay plates could support the idea but no conclusive statement can be taken (see Figure 8). Therefore traces or dues in the ancient literature or even local names must support the overall picture.

Evidence in literature and names of local places

In his comprehensive article from 1969 about Stonehenge and other megalithic monuments on the British Isles Peter Nilson refers to earlier studies and ancient literature which discuss the use of prehistorically monuments from the Neolithic period. Nilson himself is convinced that people in Northern Europe during the Neolithic period and the Bronze Age had well developed skills concerning astronomical observations.

Also he points out that very little investigation has been done in Europe since Norman Lockyer did his first investigations of megalithic monuments in England, Scotland and in Ireland in the beginning of the...
1900s. He also proposes that a greater effort in this field will reveal how people in prehistoric and ancient times solve calendar problems. This has changed dramatically the last 20 years. The author's own work is an example of this effort. Besides the scientific work concerning the position and orientation of the megalithic monuments one has to look at local legends, myths, traditions and names of local places. This is very important work which could reveal traces of the thought and idea behind the use of the megalithic monuments. Even in ancient literature from antiquity a limited number of hints can be found. In both cases the information value is poor but it is important if this information, in one or another way, supports your own conclusions.

Peter Nilsson reports further in his article that the Italian historian of science Giorgio de Santillana points that Plutarchos, a Greek philosopher and writer 46 AD to 120 AD, in his work refer too an opinion...
from Eudoxos of Knidos which concerns the “eclipse daemon” Typhon as associated with an 56 angled geometrical figure. The number 56 is connected to the interpretation of the Stonehenge Aubrey-circle which has 56 ‘postholes’ along its circumference. Gerald Hawkins proposes in his article ‘Stonehenge decoded’ the ‘Stonehenge cycle’ which is a 56 year lunar cycle connected to lunar eclipses. Peter Nilsson argues that a perhaps more directly allusion to Stonehenge is to find in the work of the ancient Greek historian Diodorus Siculus (Diodorus of Sicily) ‘History of the Ancient World’ (English translation from 1935). Diodorus reports about the prehistoric Europe, in the end of a description concerning the prehistory of England:

‘The moon seen from this island seems to be on little distance from Earth revealing uplift in the landscape which is similar to them on Earth, visible for the naked eye. It is told that even the God visits the island every 19 years, which is within the period the stars fulfill a complete cycle returning to their original position in the sky. There also exist a magnificent area in the landscape devoted to Apollo and a strange temple…, and its guardians are named “boreaders” and the successors for this post are always drafted from their families.’

It is possible that the ‘god’ mentioned in the above quotation refers to the moon. In any case the number 19 could refer to the 19 year lunar eclipse cycle and could indicate that this cycle was known in prehistoric times. Otto Neugebauer one of the foremost experts on ancient astronomy from last century has proposed an interpretation of the astronomical sections of the Book of Enoch which has been preserved in an Ethiopic translation. In these sections are named the four ‘gates’ of the moon which Neugebauer interpret as the lunar stand still points. The lunar stand still points have four specific azimuth directions for rising
and four for setting. The lunar rising or setting points move between the innermost and the outermost standstill points with the cycle of 18.61 years very close to the lunar eclipse cycle of 19 years, as mentioned earlier.

The mentioned examples of described lunar knowledge from ancient literature give a clue about the interest for the moon in ancient times and perhaps in prehistoric times. It is also known from the Babylonian sources that the moon played a central role. Again we find comprehensive work by Otto Neugebauer concerning astronomy in antiquity and ancient times. Especially the moon tables are of interest in this matter. According to Neugebauer it is possible that the Babylonians already from about 700 BC knew the lunar 19 year cycle.

It is not only in ancient literature we can find traces or clues about the interest in the moon.

Local names, local traditions or perhaps even local tales can give us some information about the interest in the moon. An illustrating example could be used names of local places. In the Danish register data base for local names and places appears now and then a name as 'Mænehej', 'Månehej' or 'Monshej' concerning burial mounds which contains passage grave or dolmens. In English terms these names means 'Moon hill' or 'The hill of the Moon'. Other names as 'Vårhej' or 'Solhej' which means 'Spring hill' respectively 'Sun hill' are also seen. These names are named mounds which have existed for at least 5000 years. Could it be interpreted as an expression for knowledge about the Lunar-Solar cross over at spring? The total number of mounds, with the mentioned names extracted from the Danish register data base for local names and places, are 196, mainly concentrated on the Danish island Zealand (see Figure 1).

Anyway, possible evidence for interest of the moon in ancient and perhaps prehistoric time exist, even if it is not so widespread in ancient literature, and must be taken into account for further considerations. F. Richard Stephenson write, in the end of an article from 2003, that he wishes that historians and astronomers should have better cooperation when it comes to translating astronomical literature from ancient times.

Discussion

Taking both the physical evidence, the clues in ancient literature and names of places as an indicator for interest in the moon in prehistoric times it is possible to imagine a kind of cosmology in Neolithic times, at least in Northern Europe. As a speculative idea could be proposed following:

The funnel beaker people knew already at the beginning (4000 BC) that the moon, not the sun, could be an important indicator for the seasons. It could give the starting point for certain rituals concerning seeding, harvesting etc. not an exact time (the weather will tell you when it is the right time for seeding and harvesting) but the time for the rituals synchronised by the moon. This is possible over a gigantic area...
as long as you can see the (full) moon. The cluster structures of passage graves and dolmens expanding in the landscape will in a sense take the whole landscape into account in a Neolithic context as a ritual landscape. This could be interpreted as a cosmology controlled by the moon and its laws performed out in the landscape.

As the lunar eclipses were recognized special rituals were performed. When the moon was eclipsed it revealed an opening to 'the kingdom of the dead' and this was the right time for doing a ritual concerning the dead. In a sense, you could say that the passage in a passage grave could function as a "spiritual launching pad". To perform this kind of ritual, one would rebury the dead in the passage grave when the time was right – and the time was right when the lunar eclipse occurred. The speculations can go further: perhaps the cluster structures also functioned as gigantic preformed spiritual lock systems which also showed the direction to the next settlement?

A complete cosmology was performed with the sun and the moon, a solar lunar relation, with the moon as the steering and the dominating factor, at least for a period.

This idea is of cause only a contribution to other ideas concerning cosmology in prehistoric times and of cause a hypothesis but physical evidence seems to support this idea.

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Notes
3. Claus Clausen, 'Scandinavian passages graves and the lunar "season pointer"', ACTA Archaeological, [hereafter Clausen, The lunar "season pointer"]: preprint (2014) and
8. The azimuth is the angle along the horizon for a rising celestial body measured clockwise from geographical North = 0 degrees to 360 degrees (North).
10. Clausen, Danish passage graves and intervisibility, pp. 3-4.
12. Clausen, Orientation of Danish passage grave 1, p. 219, Figure 3.
13. Clausen, Danish passage graves and intervisibility, pp. 3. Figure 4.

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Paper VIII

TWIN SUN: A SIMPLE LUNAR ECLIPSE PREDICTOR.
Denoted as (Clausen, 2015 C) in the main text.

"TWIN SUN": A SIMPLE LUNAR ECLIPSE PREDICTOR
Claus Clausen

ABSTRACT: It is well known that in many places around Europe there are megalithic monuments arranged in lunar or solar alignments. Probably because both sun and moon were used to mark the time for special events which were important for the Neolithic man. A simple method to predict lunar eclipse, proposed in this paper, uses the position of the full moon relative to the sun. When the full moon is rising and the sun is setting in opposite directions (about 180 degrees) it is very likely that a lunar eclipse will occur during the night. The time and angular derivation is within very narrow limits for the proposed method. Calculations show that the method works better during the summer period in Scandinavia simply because the night is shorter and therefore the moon is closer to the exact time of the lunar eclipse when the moon rises as the sun is setting. When the conditions are right the moon reflects the red colour of the setting sun. The two celestial bodies look within a short time as similar objects, like twins or "Twin Sun". Long-term calculations show that the method works more properly in some periods according to the movement of the moon in its 18.61 year lunar cycle. The idea with this paper is to show that TS is a useful method to predict lunar eclipses during the summer period at Northern latitudes. It will be discussed that TS as a lunar eclipse predictor could partly explain the alignment of at least Danish megalithic monuments in the time period from about 3300 BCE to about 3100 BCE. Finally, it is also suggested and discussed that TS could be an explanation for the doubleness found in connection with Danish megalithic monuments. Some archaeological findings support this idea.

Introduction
Many astronomical phenomena have been observed since ancient times but they are not always well documented and therefore are sometimes forgotten in modern history. I once had a correspondence with an astronomer from New Zealand (I do not recall his name) and he wrote to me: "...yes indeed, Claus, we are very good at doing calculations, but do we go outside to see if we are right?". This man had a good point. Today we are often inside a building or a car (home, work, transportation, museums, cinema or even in a planetarium) so we do not have the same sensibility to the sky as humans had as for example in the antiquity or perhaps even better in prehistoric times. My idea of this paper is to describe one of these phenomena. My attention to Twin Sun (hereafter TS) was awakened once I was kayaking. A little boy at the kayak club asked his mother: "Why is the sun rising at the same time it is setting?" I saw the phenomenon myself and decided to investigate it in more details (see Figure 1).
Fig. 1: Twin sun observed the 20th of May 2006. Note that both celestial bodies look similar. The moon is rising to the left and the sun is setting to the right. That the moon appears red and looks like the sun is due to the fact that the red light is deflected less in the Earth’s atmosphere than other wavelengths of light. As long as the sun and moon are at right angles to each other the glare of the moon will be red. Photo by Claus Clausen.

TS as phenomenon
The TS phenomenon seems not to be described in the literature but more likely through oral traditions. At least in Denmark, the phenomenon I have heard expressed as “fire in the sky”. This knowledge I heard from two interviews of local people when I did my surveyor of megalithic tombs. Both persons referred that that the light from the moon and the sun was reflected from the water surface in the nearby fjord or sea. This illumination gave the impression that the sky, reflected in the water, was set on fire. TS occurs from one to four times p.r. year and the conditions are as follows:

A) The angular difference between the rising azimuth of the moon (Maz) and the setting azimuth of the sun (Sazset) must be Maz – Sazset = 180° = daz, and the limits are here: -5.5° <= daz <= +5.5° which is the case if the rising of the one and the setting of the other take place at approximately diametrically opposite directions in the sky.

B) The rising time of the full moon must be within about 20 minutes of the setting time of the sun. The time difference is Moonrise – Sunset = dt and the limits are here: -0.1 h <= dt <= 0.265 h.

Using the lower limit -0.1 h <= dt it is still possible to relate the rising azimuth of the full moon to the setting azimuth of the sun.

The above-mentioned limits are semi empirical deduced i.e. partly by long-term full moon calculation and 11 observations concerning dt since 2006. The upper time limit can differ with a value up to about 0.45 h depending on the weather conditions. The
used upper value limit for dt is deduced from the calculations. More observations have to be carried out to understand more precisely the behavior of the upper TS time limit i.e. the visibility of the rising full moon. These limits are not to be confused with the limits for full moons given in Clausen 2011. The full moon event is here treated as an event, which is expanded by up to 2 days surrounding the time of the genuine full moon. The previous limits (Clausen 2011) concerns the phase (P) for the full moon with P > = 96 per cent, which covers the geometrical and time limits for the observer as:

A) The angular difference between the rising azimuth of the moon (Maz) and the setting azimuth of the sun (Sasset) must be Maz – Sasset + 180° = daz <= +/- 20°, which is the case if the rising of the one and the setting of the other take place at approximately diametrically opposite directions in the sky.

B) The rising time of the full moon must be within one and one-half hours (Moonrise – Sunset = dt =< +/- 1.5 h) of the setting time of the sun.

Note here that all histograms used as illustrations in this paper, based on calculations or observations, have azimuth along the x-axis divided in 6° bins and number of events/units along the y-axis. A TS full moon in this context appears when both daz and dt reaches a minimum (see Figure 2). Another interesting implication is that TS is easier to observe during the summer time due to the weather conditions. By use of data from the Danish Institute of Meteorology² from the last 130 years it is possible to compare the number of sunshine hours (clear sky) during the winter period (defined as mid-October to February) to the summer period (defined as March to mid-October). The result is that it is more than twice as cloudy during the winter period as during the summer period - sometimes up to three times as cloudy during the winter period compared to the summer period. Assuming that these statistics could be extrapolated back in time to the Neolithic period the assumption is, therefore, that TS in general due to weather conditions works better during the summer period.


² Accessed at http://www.dmi.dk/vejr/arkiver/vejrarkiv/
TS in Terms of Lunar Eclipses

When the moon and the sun fulfill the criterion for TS the geometrical situation is very close to the situation when a lunar eclipse can occur (see Figure 2). It is not only due to weather conditions that the TS works better during the summer period. The explanation is simple if you know it. During the summer period the night has a duration of 12 h to about 6 1/2 h at the actual latitude (56 North) like the duration of a day during the winter period. For that reason, the moon is closer to the actual eclipse time when TS occurs during the summer period, i.e. the actual time window for a visible lunar eclipse to occur during the night is much narrower during the summer period compared to the winter period. This has the interesting implication that TS counts for the main part of visible lunar eclipse during the summer period. The number of TS lunar eclipses are, as a first step, calculated for a 105-year period and compared to the actual number of lunar eclipses (see Figure 3 and Table 1). The lower limit for a visual partial lunar eclipse is set to be 15 min. and the upper limit is a total lunar eclipse. Generally, in average, approximately every third TS full moon, winter and summer, predicts a lunar eclipse and TS lunar eclipses counts for approximately 2/3 of all visible lunar eclipses, about 50 % during the winter and about 80 % during the summer (see Figure 3, Table 1 and Table 2). It is worth mentioning that TS also indicate or pinpoint the non-visible lunar eclipses i.e. the lunar eclipses where the full moon is not above the observers horizon.

By comparing winter and summer periods (expanding the calculation period from 105 years to 179 years), it is astonishing that TS counts for nearly twice as many lunar eclipses during the summer compared to the winter (see Table 2). By including the knowledge about the weather conditions, we see that TS works better as a lunar eclipse predictor during the defined summer period corresponding to an azimuth interval from 72.5° to 138.5°. Taking the fractions from weather conditions (0.5 winter) and the ability to show visible lunar eclipses (0.42 winter and 0.79 summer) TS works nearly four times better during the summer period compared to the winter period (0.5 \times 0.42 = 0.21 \text{ compared to } 0.79).
Fig. 2: Geometry of the TS phenomenon. Left figure shows the geometrical situation as observed from the surface from Earth. The moon is rising approximately at the same time as the sun is setting. The passage grave in the centre (the observer’s position) represent the position of the Earth. The figure on the right shows the astronomical situation when the moon is very close to one of its nodes. Both visible lunar eclipses and non-visible lunar eclipses (including penumbral lunar eclipses) are indicated by TS. Figure partly by Claus Clausen and figure from Wikipedia.3

Fig. 3: The number of TS (yellow columns) compared to the visible lunar eclipses (blue columns) and the visible TS lunar eclipses (red columns) based on the calculations that give input to Table 1. Note that TS winter lunar eclipses (left in the histogram) reduce dramatically. The azimuth interval from 72.5° to 138.5° corresponds to the TS lunar eclipses during the summer period.

Table 1
Calculated TS, TS lunar eclipses and lunar eclipses for a 105-year period from 3305 BC to 3200 BC. Delta T = 24 h and L = -12,578 (time zone: +1); ω = 55.687.

<table>
<thead>
<tr>
<th>Total number of all TS in the calculated period</th>
<th>Total number of visual lunar eclipses (from partial to total)</th>
<th>Total number of visible TS lunar eclipses (from partial to total)</th>
<th>Frequency ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>207</td>
<td>66</td>
<td>66</td>
<td>0.32</td>
</tr>
<tr>
<td>101</td>
<td>66</td>
<td>66</td>
<td>0.65</td>
</tr>
</tbody>
</table>
"TWIN SUN": A SIMPLE LUNAR ECLIPSE PREDICTOR

Looking at the summer period the prediction ability seems at a first glance not different compared to the winter period. In average, one out of three TS full moons give birth to a lunar eclipse (see Table 2). Looking more in details at the summer period, we have 44 TS eclipses for the calculated 105-year period, 57 visual lunar eclipses and 145 TS full moons. But concentrating at the main directions about the 100° peak and the 123° calculated from 90.5° to 108.5° respectively 114.5° to 126.5°
(see Figure 3 and Figure 5) we get as a result approximately every second TS full moon give birth to a lunar eclipse. For the 100° peak we have 14 TS lunar eclipses/30 TS full moons = 0.47 and for the 123° peak we have 10 TS lunar eclipses/22 TS full moons = 0.45.

Table 2
Lunar eclipse prediction ability winter and summer. The defined winter period (mid-October to February) and summer period (March to mid-October) correspond to the azimuth interval in the histogram representation 36.5° - 72.5° (winter) respectively 72.5° - 138.5° (summer). The ratios equal the number of visible TS lunar eclipses divided by the number of all visible lunar eclipses for the chosen period or TS lunar eclipses divided by TS full moons (prediction ability).

<table>
<thead>
<tr>
<th>Period</th>
<th>Ratio 105 years</th>
<th>Ratio 179 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS lunar eclipses/lunar eclipses</td>
<td>0.5</td>
<td>0.42</td>
</tr>
<tr>
<td>TS lunar eclipses/TS full moons</td>
<td>0.37</td>
<td>0.30</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS lunar eclipses/lunar eclipses</td>
<td>0.8</td>
<td>0.79</td>
</tr>
<tr>
<td>TS lunar eclipses/TS full moons</td>
<td>0.32</td>
<td>0.31</td>
</tr>
</tbody>
</table>

For statistics, a Kolmogorov-Smirnov two sample test (two-sample KS test) is used. The two-sample KS test is one of the most useful and general nonparametric methods for comparing two samples, as it is sensitive to differences in both location and shape of the empirical cumulative distribution functions of the two samples. An azimuth distribution fulfill the criterion to be a cumulative distribution as well as the chosen hypothesis distribution i.e. the azimuth distribution of rising full moons before a lunar eclipse, in this case the TS lunar eclipse full moons. The Kolmogorov-Smirnov statistics is denoted D and the probability factor p. If p > D we can assume the null hypothesis i.e. the samples are drawn from the same distribution (see Table 3). Due to approximations used in the program routine, the numbers of data points must be > 20.
Concerning the number of data points in both test distributions, \( N_1 \) and \( N_2 \), the program routine only works for \( N_1 > N_2 \).

Fig. 5: The observed azimuth distribution represented by 157 orientations. The azimuth interval marked with green (\( 72.5^\circ - 138.5^\circ \)) corresponds to the azimuth interval in the calculated TS lunar eclipse distribution during the summer period. Note the two significant peaks about 100° and 123°.
Table 3
Kolmogorov-Smirnov two sample test for the measured passage graves (the observations) compared to the azimuth distribution pattern for TS full moon rises before a lunar eclipse (TS lunar eclipses) from 3305 BCE to 5200 BCE (105 years period) and from 3344 BCE to 5168 BCE (179 years period). The p values marked with bold are the cases where the null hypothesis could be possible. Table 3 is an extract of the complete test.

<table>
<thead>
<tr>
<th>Number of passages direction for passage graves in same azimuth interval as N0</th>
<th>Number of azimuth for TS full moon rises before a lunar eclipse during the summer</th>
<th>Kolmogorov-Smirnov statistics</th>
<th>Kolmogorov-Smirnov probability factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>N0</td>
<td>N1</td>
<td>D</td>
<td>p</td>
</tr>
<tr>
<td>105 years period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>24</td>
<td>0.097222</td>
<td>0.977124</td>
</tr>
<tr>
<td>35</td>
<td>29</td>
<td>0.107349</td>
<td>0.891636</td>
</tr>
<tr>
<td>36</td>
<td>30</td>
<td>0.100000</td>
<td>0.925086</td>
</tr>
<tr>
<td>37</td>
<td>31</td>
<td>0.129032</td>
<td>0.668391</td>
</tr>
<tr>
<td>49</td>
<td>37</td>
<td>0.131826</td>
<td>0.541112</td>
</tr>
<tr>
<td>56</td>
<td>41</td>
<td>0.132404</td>
<td>0.468667</td>
</tr>
<tr>
<td>61</td>
<td>44</td>
<td>0.129285</td>
<td>0.453881</td>
</tr>
<tr>
<td>70</td>
<td>44</td>
<td>0.179870</td>
<td>0.116003</td>
</tr>
<tr>
<td>106</td>
<td>44</td>
<td>0.340909</td>
<td>0.000072</td>
</tr>
<tr>
<td>179 years period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>22</td>
<td>0.113636</td>
<td>0.938852</td>
</tr>
<tr>
<td>38</td>
<td>29</td>
<td>0.161525</td>
<td>0.435086</td>
</tr>
<tr>
<td>40</td>
<td>31</td>
<td>0.141935</td>
<td>0.568062</td>
</tr>
<tr>
<td>60</td>
<td>44</td>
<td>0.122727</td>
<td>0.521412</td>
</tr>
<tr>
<td>91</td>
<td>61</td>
<td>0.114594</td>
<td>0.401846</td>
</tr>
<tr>
<td>95</td>
<td>63</td>
<td>0.112448</td>
<td>0.403132</td>
</tr>
<tr>
<td>105</td>
<td>68</td>
<td>0.109804</td>
<td>0.385228</td>
</tr>
<tr>
<td>107</td>
<td>69</td>
<td>0.109034</td>
<td>0.384900</td>
</tr>
<tr>
<td>108</td>
<td>70</td>
<td>0.107407</td>
<td>0.394618</td>
</tr>
<tr>
<td>109</td>
<td>71</td>
<td>0.110350</td>
<td>0.352886</td>
</tr>
</tbody>
</table>

The result of the statistical test shows that it works better for the 179-year period for the overall azimuth distribution compared to the 105-year period. The latter simply breaks down. However, both tests indicates that you can be safe assuming the null hypothesis for the azimuth interval from $73^\circ$ to $109^\circ$ (N0 = 61), which includes the
100° peak. This feature is more pronounced in the 179-year distribution compared to the 105-year distribution due to lack of TS lunar eclipses (N_i) in the 105-year period (see p values in Table 3).

The TS lunar eclipses and the lunar 'season pointer'
The 'lunar season pointer' is a model proposed by Clausen in the SEAC proceedings from 20117. Very briefly, the model is a kind of a lunar calendar defined or based on the lunar/solar crossover at spring and at fall and the southermost minor and major standstill points of the moon. The part of the lunar 'season pointer' as shown in Figure 6 has an azimuth distribution compared to the observations, which is very similar (see Figure 5). The left peak in Figure 6 represents the azimuth distribution of the EFMs (equinoctial full moons)12 at spring and at the full moon indicating fall, i.e. the spring full moon12 and the full moon just before the crossover at fall13. The latter has an azimuth distribution which is similar to the spring full moon. The EFMs

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Accessed at https://www.academia.edu/703227/The_Crossover_of_the_Sun_and_the_Moon

Accessed at https://www.academia.edu/926483/Equinoctial_Full_Moon_Models_and_Non-Gaussianity_Portuguese_Dolmens_as_a_Test_Case

Accessed at http://adsabs.harvard.edu/full/2004JHA....35..475D

covers the azimuth distribution of the full moons rises connected the lunar standstill eclipses⁴.

In this way lunar eclipses and TS lunar eclipses are built in, so to speak, in the lunar ‘season pointer’. And why is that? Lunar eclipse calculations shows that about half of the full moon rises are one day before the right full moon. This means that the full moon is not always a genuine full which is exactly one of the points in the lunar ‘season pointer’ model. At Neolithic times, man was not able to determine exactly when the full moon occurred. Therefore, by its definition and the calculation limits (see Clausen 2011) the lunar ‘season pointer’ is connected to the TS and thus also to lunar eclipses. The lunar ‘season pointer’ will on average “produce”, or pinpoint, a visible lunar eclipse (partial or total) every third or fourth year depending on the weather conditions.

![The lunar ‘Season pointer’: superposed peaks tendency diagram](image)

Fig. 6: The lunar ‘season pointer’ represented by three peaks, from left, with mean values around 100° (spring full moon), 124° (southernmost minor lunar standstill) and 149° (southernmost major stand still). The part of the lunar ‘season pointer’, the left and the central peaks in the azimuth interval 78.5° to 138.5°, represent the feature which more and less resembles the visible lunar eclipses and the visible TS lunar eclipses in the same interval. Figure adopted from Clausen Danish Passage Graves, ‘Spring/Summer/Fall Full Moons’ and Lunar Standstills (Figure 5).

Archaeological artefacts and findings
Some archaeological artefacts and findings have appeared at different locations in Denmark through the last 40 years. The artefacts show an interest in doublingness like do some of the passage graves. The artefacts can be divided into two groups:

1) Clay plates manufactured about 3000 BCE, i.e. late Funnel Beaker Culture, showing sun or moon-like figures (see Figure 7).

2) Ceramics with two “eyes” or “sun-like” figures. This type of ceramics is known as “stone age face-pots” (see Figure 8) and are manufactured about 3000 BCE.

What is interesting is that the ceramic items are usually discovered inside or very close to a passage grave. Some of the most spectacular “stone age face-pots” are found in connection with double- or twin-passage graves (see Figure 9 and caption). The construction time for the double- or twin-passage graves is about 3100 BCE i.e. just a little before the period of the ceramics. Figure 11 shows the locations of finding places for “stone age face-pots”. These are exactly the locations for the highest concentration of passage grave in Denmark, especially the types known as double- or twin-passage graves (see Figure 12). “Stone age face-pots” are also known from outside the Baltic area in southern France and Iberia but they are somewhat older.

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Fig. 7: Clay plates known as Sun-discs. Upper panel show a clay plate (left side) discovered in a dolmen in Jutland (peninsula at western part of Denmark) showing both the sun and the moon according to the interpretation (drawing to the right) made by Danish archaeologists. Using the ruler shown (left side bottom) the diameter of the plate is about 15 cm. The lower panel shows examples of clay plates showing two “suns” or two “eyes”. The left one in was found on Zealand, and the right one is from the Danish island of Bornholm.

The sizes of the shown discs are not comparable. The photos from the lower panel are adopted from the homepage of the Danish Ministry of Environment.\(^\text{17}\).

Fig. 8: Two examples of “stone age face-pots”. The left pot was discovered at the excavation of a twin-passage grave at Svine (south-west Zealand, close to the sea) in a twin-passage grave named Moonshej (Hill of the Moon) and the other “stone age face-pots” was also discovered (together with another similar pot) in a twin-passage grave in North Zealand at Kyndelene named Møllehej (Mill Hill). Pictures adopted from The Danish National Museum.\(^\text{18}\).

\(^{17}\) Accessed at 
http://naturnuus.dk/naturvedleri/naturguider/rispeberg/stenalderen/med-solen-i-centrum/

\(^{18}\) Accessed at 
Fig. 9: The left panel shows "stone age face-pots" locations of finding places. Note the great concentration on Zealand and some islands to the south of Zealand almost covering the area with the highest concentration of double- and twin-passage graves. The right panel shows different types of motives on these "stone age face-pots". Note here the variety always with the two ‘eyes’ or two ‘sun-like’ figures. Figures adopted from Klaus Ebbesen 1978.

Fig. 10: Doubledness in the construction of Danish passage graves. The plan of the layout scaled to approximately the same size and orientated according to geographical north. All four passage graves are located at the central northern part of Zealand (see Figure 9 left panel) where there is a smaller concentrations of ‘stone age face-pots’. The plan drawings are adopted form Skov- og Naturstyrelsen (eng. Forest and Nature Agency) report A13, by Svend Hansen 1988.

Fig. 11: Passage direction distribution pattern for 24 twin and double graves extracted from the observation sample. Each passage is counted as representing a single direction. It was only possible to measure 39 passage directions due to damage of the passage graves.

The distribution pattern for double- and twin-passage graves is shown in Figure 11 and compared to visible TS lunar eclipses in Figure 12. Unfortunately only 39 directions are measured. The total number of existing twin and double passage graves in Denmark is about 70 so it should be possible to double up the number of directions.

The Kolmogorov-Smirnov two sample test is used to compare double- and twin-passage graves with the TS lunar eclipse full moons for a 105-year and a 179-year periods (see Table 4).
Fig. 12: Passage direction distribution pattern for double- and twin-passage graves compared to the visible TS lunar eclipse rising full moon azimuth distribution patterns during the summer period from 3305 BCE to 3200 BCE i.e. the main construction period for the megalithic monuments in Denmark. Red columns are TS eclipses. Note that the distributions seems similar in the 72.5° to 132.5° azimuth interval.
Table 4
Kolmogorov-Smirnov two sample test for twin and double passage graves compared to the azimuth distribution pattern for TS full moon rises before a lunar eclipse from 3305 BCE to 3200 BCE (105 years period) and from 3344 BCE to 3165 BCE (179 years period). Marked with bold are the p values where the null hypothesis is nearly achieved. Table 4 is an extract of the complete test.

<table>
<thead>
<tr>
<th>Number of azimuth for TS full moon rises before a lunar eclipse during the summer period. Visible TS lunar eclipses.</th>
<th>Number of passages direction for double - and twin- passage graves in the same azimuth interval as Ni.</th>
<th>Kolmogorov-Smirnov statistics</th>
<th>Kolmogorov-Smirnov probability factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni</td>
<td>Nj</td>
<td>D</td>
<td>p</td>
</tr>
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<td>105 years period</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>36</td>
<td>26</td>
<td>0.089744</td>
<td>0.984867</td>
</tr>
<tr>
<td>37</td>
<td>27</td>
<td>0.081081</td>
<td>0.994299</td>
</tr>
<tr>
<td>38</td>
<td>28</td>
<td>0.078947</td>
<td>0.998895</td>
</tr>
<tr>
<td>39</td>
<td>29</td>
<td>0.081344</td>
<td>0.990766</td>
</tr>
<tr>
<td>40</td>
<td>30</td>
<td>0.093233</td>
<td>0.985240</td>
</tr>
<tr>
<td>41</td>
<td>31</td>
<td>0.096774</td>
<td>0.993382</td>
</tr>
<tr>
<td>42</td>
<td>32</td>
<td>0.125000</td>
<td>0.699374</td>
</tr>
<tr>
<td>42</td>
<td>33</td>
<td>0.151515</td>
<td>0.434886</td>
</tr>
<tr>
<td>179 years period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>26</td>
<td>0.126984</td>
<td>0.795882</td>
</tr>
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<td>71</td>
<td>33</td>
<td>0.151515</td>
<td>0.434886</td>
</tr>
</tbody>
</table>

The result of the statistical test is rather convincing in the sense that you can assume the null hypothesis for almost the whole azimuth interval (see Table 4). Note that the p values in both tests becomes equal for the complete test interval. In both cases the tests covers the TS lunar eclipses azimuth interval and the observations in the same interval, 95 % of the TS lunar eclipse full moons (42/44 and 71/75) and 85 % of the passage directions (33/39). A consequence is that you have the possibility to
observe lunar eclipses every second or third year (105 years/44 TS lunar eclipses or 179 years/75 TS lunar eclipses) instead of every third or fourth years as indicated by the lunar 'season pointer'.

Discussion
The statistical result of the investigation of TS lunar eclipses and the 'lunar season pointer' cannot exclude one or the other possible explanation for the orientation of the Danish passage graves. It is quite astonishing and surprising that the double- and twin- passage graves seems to be pin pointers of the TS lunar eclipses in the summer period and by this connect them to the TS phenomena. Also the fact that in average every second TS full moon predict a lunar eclipse if you are looking in the two main directions about 100° and 123° is interesting concerning the TS lunar eclipse hypothesis.

The lunar eclipses must, however, in this connection be understood as a more exotic interpretation. Still possible, but probably not the main function, due to the simple fact that a visible TS lunar eclipse occurs with intervals of two to three years in the summer period in some cases with an interval of one year (mostly lunar standstill eclipses).

For southern directions out of the range for TS full moons and the southernmost lunar standstill point, it is shown in previous works that the passage directions have an archaeo-topographical explanation (see for example Clausen et. al 2008 or Clausen et. al 2011) i.e. pointing out single passage grave or clusters of passage graves in the landscape.

In the Neolithic context you would probably have to understand a multifunctional purpose of the passage graves. A possible scenario can be proposed by starting with the lunar 'season pointer' in the beginning, about 3500 BCE i.e. the middle of Funnel Beaker Culture and construction of the first megalithic monuments in Denmark. Recognizing the TS phenomenon in connection with the lunar/solar crossovers, which indeed is a spectacular phenomenon if the weather conditions are right. While they were following the 'season pointer' Neolithic man, both according to the lunar/solar crossovers at the early summer full moon in May and the later summer full moon in August (the harvest moon), must certainly have observed the TS. If that is so, Neolithic man during the late Funnel Beaker Culture (3000 BCE), same period for the manufacturing of the "stone age face-pots" and the small clay plates, must have seen lunar eclipses now and then. If man at that time was able to combine the facts and make the conclusion that TS could be used to predict lunar eclipses is unknown. The Neolithic man belonged to the homo sapiens sapiens (the wise man) as we do and were able to draw intelligent conclusions like we can. The statistical
result for the twin and double graves indicates that they probably saw lunar eclipses (TS lunar eclipses) and wanted to record them.

However, the funnel beaker people must have understood that the moon and the sun work together in a kind of a "twin relationship" or dualism. In other words the TS could be interpreted as a 'lunarisation' of the Sun. Ideas about solar/lunar alignments at Stonehenge are treated by Lionel Sims in an article from 2006\(^{20}\). This article does not discuss the TS phenomenon but the idea that a sun/moon relationship in one way or another could have been used in some kind of religious praxis.

The archaeological findings in Denmark could support the idea that the proposed scenario could be possible. Why the interest in doubleness? Both in ceramics and in the constructions of double- and twin-passage graves during the late Funnel Beaker Culture about 3000 BCE you see the "doubleness idea". Could it represent a twin-relationship between sun and moon like the TS? The sun as the strongest light source at day replaced by the moon as the strongest light source at night exactly when the moon rises and the sun sets? Where the sun transforms or reveals itself as the moon. The questions are many. The TS idea seem to be supported by the twin and double graves, the "sun discs" and the "stone age face-pots" but this of cause also needs further discussions between archaeologists, astronomers and anthropologists. Finally, the TS idea is only a humble proposal as a contribution to the discussion about the purpose of the megalithic monuments.

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I have met many kind and well-educated people during my doctoral studies who have given me a lot of good advice, in particular Dr. Fabio Silva and Dr. Cesar Gonzales, from Portugal and Spain respectively, who have provided constructive criticism concerning this paper. Also Dr. Michael Rappenglück, professor Kim Melville, and Dr. Frank Prendergast have been very inspiring for me during my studies. Also a handful of Danish archaeologists and some Danish astronomers have supported my ideas. I also wish to mention my former supervisors in astrophysics and astronomy, Associated professor, Per Kjergaard Rasmussen and Associated professor Anja Andersen, both from the Niels Bohr Institute, and Professor in

"TWIN SUN": A SIMPLE LUNAR ECLIPSE PREDICTOR

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