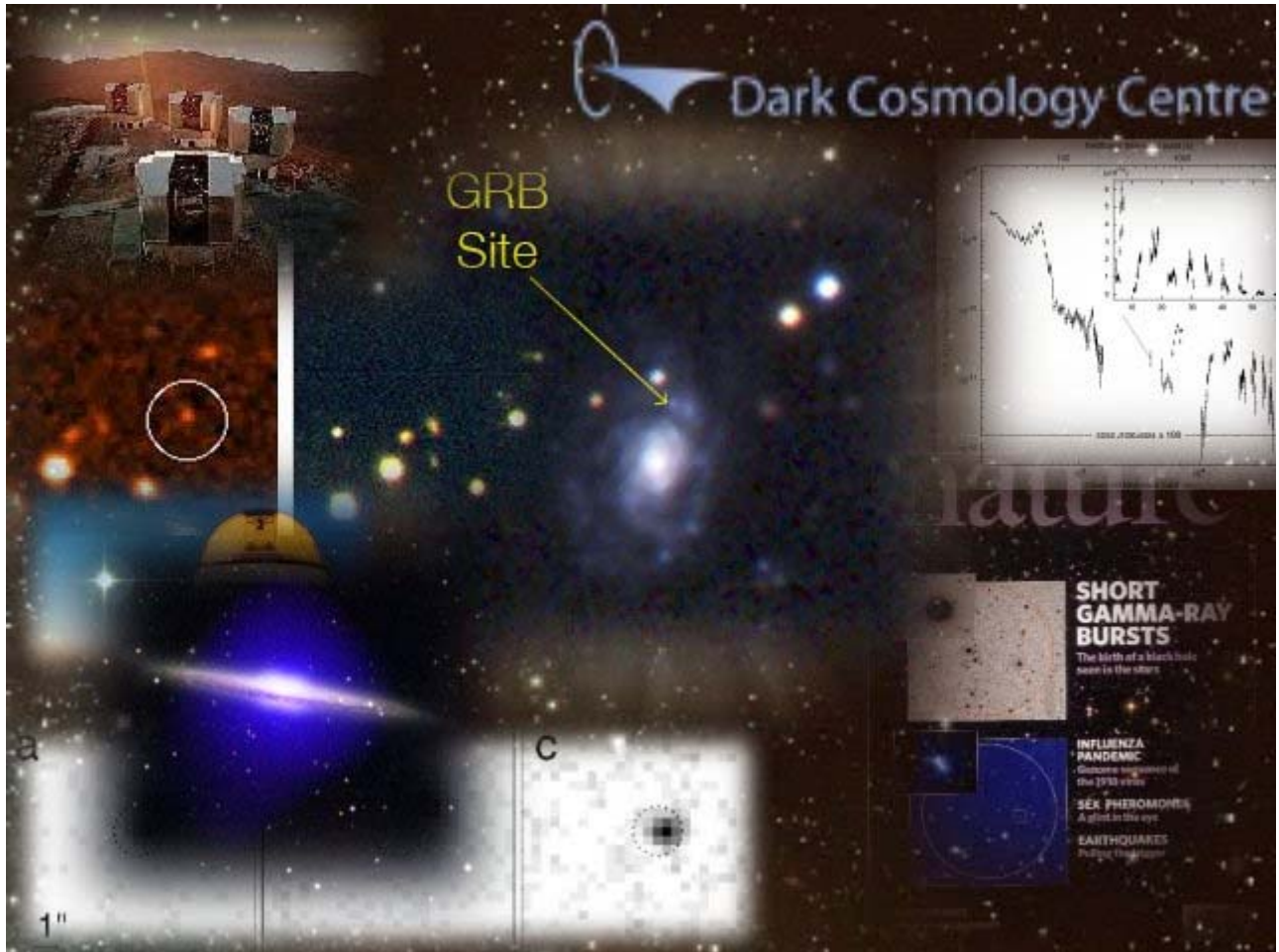


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# Dark Cosmology Centre

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Danmarks Grundforskningsfonds Center for  
Kosmologi ved Københavns Universitet

ANNUAL REPORT 2006 (1 JAN – 31 DEC)

Produced Monday, April 2, 2007, Copenhagen

Description of the cover image: Prominent images from the highlights of the year are added to the previous year's images to make a visual tableau of science from the start of the Centre. Highlighted results from 2006 include (clockwise from left) the linking of X-ray flashes and supernovae, hot galaxy haloes, the most distant X-ray source, and (centre) a new type of silent stellar death.

## 1. Highlights of the Year

### *Gamma-ray bursts as probes of cosmic structure formation*

The study of gamma-ray bursts, exploding stars visible to extremely large distances, continued to be a major activity at the Centre in 2006. Notably, one Article and two Letters were published in the journal *Nature*, one of which was led by staff member Fynbo, uncovering a type of long-duration gamma-ray burst without an associated supernova—a major and unexpected discovery. These studies concentrated on the gamma-ray burst phenomenon itself and on the galaxies hosting them. Other work made important inroads into the use of gamma-ray bursts as probes of the distant universe. In particular, staff member Watson reported the X-ray properties of the most distant gamma-ray burst observed to date, which outshone quasars by many orders of magnitude, thus constituting a potentially powerful probe of the end of the dark ages, one of the main themes of the Centre. In related work, postdoc Jakobsson published a careful study of the redshift distribution of gamma-ray bursts, showing that their mean distance is higher than other known populations of galaxies tracing the star-formation rate in the universe. Gamma-ray bursts have long been sought to be used as probes of the star-forming regions of distant galaxies, and in 2006 the immediate environments of gamma-ray bursts were the subject of papers led by Fynbo, which discussed how gamma-ray bursts may shed light on the so-called missing metals problem, and by Watson, which reported the largest gas column ever observed in a star-forming galaxy, and showed how the gas, metal and dust properties of galaxies or star forming regions may be probed *in situ* via gamma-ray bursts.

### *Constraints on the nature of dark matter*

Several studies advanced our understanding of the nature of dark matter. Using NASA's Chandra X-ray Observatory an extensive halo of hot gas around a quiescent spiral galaxy was detected in a study led by staff member Pedersen. This discovery independently proves that galaxies like our Milky Way are dominated by dark matter, binding the hot halo. Furthermore, this discovery is the long awaited evidence that massive galaxies are still accumulating matter for star formation from the gradual inflow of intergalactic gas. This result was backed by high-resolution N-body/gas-dynamical galaxy formation simulations reported by associate scientist Sommer-Larsen, showing that for a galaxy like the Milky Way, most of the baryonic mass should in fact reside around the galaxy in the form of hot gas.

One well-motivated dark matter candidate is the sterile neutrino which should decay into an observable photon, presumably in the X-ray regime. MSc/PhD student Riemer-Sørensen published a study using Chandra data to look out through the Milky Way halo to search for X-rays from decaying sterile neutrinos. Albeit no signal from sterile neutrinos was detected, a broad band in parameter space is still open, leaving the sterile neutrino as a viable dark matter candidate.

### *Awards and recognitions*

Anja C. Andersen received the Lektor, dr.phil. Fru Kirstine Meyer, f. Bjerrums Mindelegat.

Anja C. Andersen was awarded the Junior Chamber's prize, Outstanding Young Person, in the category "academic achievement and leadership".

Anja C. Andersen received Danmarks Radio's Rosenkjærpris.

Tamara M. Davis received the UNSW U Committee Award for Research Excellence (best Science PhD of 2004—AUS\$10,000).

Árdís Elíasdóttir received “Minningarsjóður Helgu Jónsdóttur og Sigurliða Kristjánssonar til styrktar stúdentum í raunvísindanámi” (500,000 ISK).

Steen H. Hansen was offered an assistant professorship (from the Swiss National Science Foundation) in Zurich and a lectureship at the Niels Bohr Institute. Fortunately for the Centre he accepted the NBI job (funded until 2010 by the Centre).

Jens Hjorth was elected a member of the Royal Danish Academy of Sciences.

Jesper Sollerman received a 5-year award from the Royal Swedish Academy of Sciences.

Jesper Sollerman was a finalist for the European Young Investigator Awards.

#### *Internal review*

The Centre conducted an internal review in September, one year after the start of the Centre. The review consisted of five parts: (i) review of Centre organization (core staff) (ii) review of science (core staff) (iii) an open discussion (all Centre members) (iv) yearly visit by the DNRF (Chairman of the Board Klaus Bock, Director Ole Fejerskov, Research Advisor Klaus Robert Svendsen) (v) decision meeting (core staff). Based on the discussions and input a list of action items were drawn up and are being put into action. The Centre plans to conduct yearly internal reviews.

#### *Other important landmarks*

Steen H. Hansen joined the Centre as a staff member in September. Upon obtaining his PhD degree, Páll Jakobsson left for a postdoctoral position in Hertfordshire where he has now been awarded a permanent position. Jesper Sommer-Larsen is taking up a research position at a new center for computational astrophysics in Munich but will keep close ties to the Centre as a regular visitor. The staffing profile of the Centre is international with a fairly balanced gender representation. Of a total of 34 staff, PhD, and MSc students, the Centre has 18 international members and 14 female members. The number of PhD students rose to 12 at the end of 2006, representing 9 different nationalities. The majority of these are women.

The Centre organized a Nordic Summer school on Observational Astrophysics for 16 PhD students at the Nordic Optical Telescope and was a founding partner of the new national PhD school, Danish Astrophysics Research School. Several scientific meetings were organized and took place at the Centre's premises, including the mid-term review for the EU network ANGLES and the 'Dust Day'.

The Centre continued its extensive outreach program targeting the general public, most notably the popular talk by Nobel laureate (Physics, 2002), Prof. Giacconi, in relation to his visit in Copenhagen where he was awarded an honorary Doctorate from the University of Copenhagen. More than 50 public talks were given to audiences ranging from primary school classes to government ministers.

## 2. Research 2006

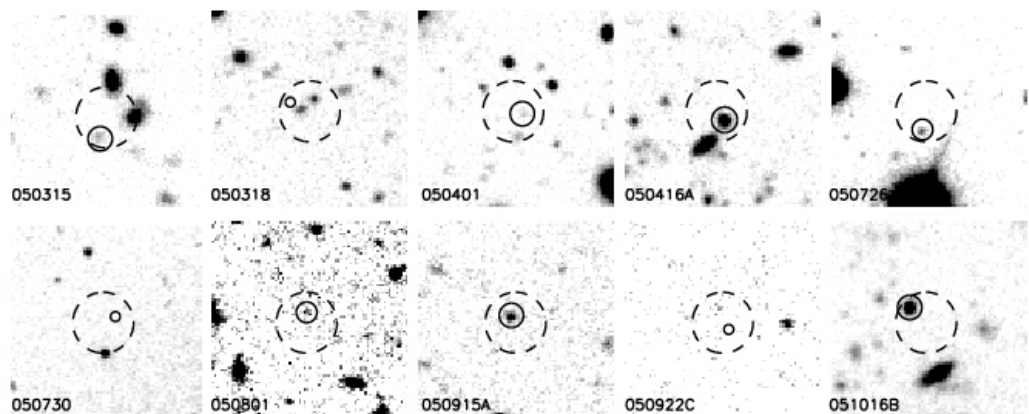
As described in the research plan, the Centre's projects revolve around using cosmic lighthouses like supernovae and gamma-ray bursts (GRBs) for constraining cosmological parameters and studying distant galaxies. The Centre operates around four scientific themes (dark energy, dark matter, dark ages, cosmic dust) expressed as three key projects and a series of smaller or more risky projects.

### *Key Project 1: Probing the end of the dark ages*

The technical complication in studying the end of the dark ages is that at optical wavelengths, the Universe is opaque to the light emitted at that time. This is because of the cosmological redshift: emission that we can observe at optical wavelengths was emitted as ultraviolet light, and the ultraviolet light is absorbed by intervening hydrogen gas before reaching Earth (so called Lyman- $\alpha$  blanketing). Therefore, the sources that ended the dark ages must be studied at near-infrared wavelengths. On top of this, these sources are immensely faint due to their extreme distance. We currently follow two main strategies to probe star formation in the early Universe from redshifts  $z \approx 2$  back to the end of the dark ages, and for both we have had good progress in 2006.

The first strategy is using the powerful GRBs as cosmic lighthouses. They can easily be detected at great distances, and as well as studying the GRBs directly, we are using GRBs to pinpoint the most distant galaxies. A great effort is being made to build up a sample with simple and well-understood selection criteria, suitable for statistical analysis. Using this approach we published a good estimate of the true GRB redshift distribution, finding a very high mean redshift. This has also led to work on finding the most distant GRBs, pushing towards the dark ages. We have studied (and taken part in the discoveries of) the three most distant GRBs known: In the beginning of 2006 we published at Letter in the Astrophysical Journal on the X-ray afterglow of the most distant GRB known – the burst of September 4, 2005. We have also detected the afterglows of the 2nd and 3rd most distant Gamma-Ray Bursts (these bursts were detected on August 14 2005 and September 27 2006). The host galaxies are studied primarily as part of a VLT Large Programme, initiated in February 2006 and running for two years. This project has already observed  $\sim 30$  new GRB host galaxies and has produced several new redshifts. A mosaic of the first 10 targets observed at optical and near-infrared wavelengths is shown in the figure. Towards the end of 2006, postdoc Daniele Malesani

was hired to strengthen the effort on this project. December saw the first collaboration meeting on the Large Programme, held at the Centre.



The second main strategy we follow to study the end of the dark ages, is to search for very distant Lyman- $\alpha$  emitting galaxies. In previous years we have had success in studying Lyman- $\alpha$  emitting galaxies at 2–3 billion years after the Big Bang, but we are now using this method to push back to within the first billion years. For this, we ordered in 2005 a special narrow-band filter tuned to



search for Lyman- $\alpha$  emitting galaxies at an optimal dark region of the near-infrared background corresponding to a redshift at the end of the dark ages. We have now become leading members of a consortium that will use the new VISTA near-infrared survey telescope (see picture) to study galaxies at the end of the dark ages. Our survey, called UltraVISTA, was the highest ranked among the proposed VISTA surveys. The survey is currently in its final design phase. Data taking is expected to start in 2008 and the survey will run for 3 years.

### *Key Project 2: Supernova cosmology*

The supernova cosmology focus team (Sollerman, Stritzinger, Davis) was enlarged with PhD student Giorgos Leloudas at the end of year 2006. During 2006, much effort was put into the ESSENCE project, the aim of which has been to use supernovae to measure the cosmological parameters that define the structure of the universe. Both Davis and Sollerman went to Chile to observe with the VLT for this project. Several papers based on this comprehensive supernova survey were started during this period.

The group also initiated a collaboration with the large Sloan Digital Sky Survey (SDSS-II) supernova survey group. As part of a new European node for this project, the Centre won observing time at the Nordic Optical Telescope (observers Stritzinger and Leloudas) and also obtained observations at ESO's NTT in Chile (Sollerman, Stritzinger). A number of international circulars (CBET messages) were issued based on the obtained classifications of SDSS-II supernovae. At the end of the year, the Centre applied for full external partnership in SDSS-II.

Two papers were published on the properties of nearby Type Ia supernovae aiming to understand the physics of the supernovae used for cosmological measurements, as well as an investigation of the best observational setup for future supernova satellites. Both Stritzinger and Davis presented these results at a conference in Sicily in the summer. Several important studies on the connection between supernovae and gamma-ray bursts were also published throughout the year.

As part of the initiative to model dust formation in supernovae the Centre is part of an international collaboration to investigate the hypothesis that core-collapse supernovae are, or have been, major producers of cosmic dust. This has resulted in a study of the infrared echo of typical core-collapse supernovae, identifying dust from the progenitor of the core-collapse supernovae, indicating that the supernova progenitors could be contributors to the universal dust content. The first ever detection of the SiO molecule in a Type II supernova was also reported. This is an exciting finding as it may signal the onset of dust condensation in the ejecta.

### *Key Project 3: The nature of dark matter*

Recent observations using the technique of weak lensing have shown unambiguously that merging clusters have a spatial separation between the gravitationally dominating dark matter, and the X-ray-emitting hot baryonic gas. This is the long-awaited, definite proof of the existence of dark matter and permits the identification of spatial regions (dark matter blobs) with remarkably high dark matter abundance, which are excellent for direct dark matter searches.

One well-motivated dark matter candidate is the sterile neutrino. The minimal standard model including sterile neutrinos can explain the masses of the active neutrinos, the baryon asymmetry of the Universe and the abundance of the dark matter. The decay products of these sterile neutrinos include an observable photon. We have considered the possibility of constraining decaying dark matter by looking out through the Milky Way halo. Specifically, *Chandra X-ray Observatory* blank sky observations were used to constrain the parameter space of sterile neutrinos. A broad band in parameter space remains, leaving the sterile neutrino as a potential dark matter candidate.

Hot gaseous haloes surrounding galaxies and extending well beyond the distribution of stars are a ubiquitous prediction of galaxy formation scenarios. The haloes are believed to consist of gravitationally trapped gas with a temperature of millions of Kelvin. Using data from *Chandra* we have detected the first hot, large-scale gaseous halo surrounding a normal, quiescent galaxy, NGC 5746, alleviating a long-standing problem for galaxy formation models. The presence and extent of this halo provides independent proof that substantial amounts of dark matter must be present in Milky Way-like galaxies, in order to bind the gas. Based on high-resolution N-body/gas dynamical galaxy formation simulations we showed that for a galaxy like the Milky Way, in addition to the baryonic mass of the galaxy itself, about 70% extra baryonic mass should reside around the galaxy in the form of hot gas. Averaging over the entire field galaxy population, this ‘external’ component amounts to more than two thirds of the baryonic mass of the population itself. These findings are entirely consistent with the properties of the hot halo around NGC 5746.



On the theoretical side, we have studied the gas haloes around galaxies. Extended gas haloes around galaxies are a ubiquitous prediction of galaxy formation scenarios. However, the density profile of this hot halo gas was previously unknown, although various profiles have been suggested on theoretical grounds. We have solved the underlying gas equations, including the effect of the gravitationally dominating dark matter, finding that the gas profile has a non-trivial dependence of the total mass profile. Comparison to galaxies from direct cosmological simulations with these analytical solutions leads to remarkable agreement.

An important steps in the Centre’s theoretical efforts in the field of dark matter and the link to astroparticle physics was taken with the hiring of Steen H. Hansen for a permanent position in theoretical cosmology.

### *Smaller or more risky projects*

We have completed and published a survey of the extinction properties of ten lensing galaxies, in the redshift range  $z = 0.04\text{--}1.01$ , using multiply lensed quasars imaged with the ESO VLT in the optical and near infrared. The multiple images act as 'standard light sources' shining through different parts of the lensing galaxy, allowing for extinction studies by comparison of pairs of images. Given the similar redshift distribution of Type Ia supernova host galaxies and lensing galaxies, we suggest that a large, space-based study of multiply imaged quasars would be a useful complement to future dark energy Type Ia supernova surveys, providing independent constraints on the statistical extinction properties of galaxies up to  $z\sim 1$ .

In a search for microlensing variability in the light curves of five gravitationally lensed quasars with well-determined time delays significant long-term (years) and short-term (100 days) brightness variations were detected. The MSc thesis of Paraficz on this subject was also completed. Taking advantage of Paraficz's stay at the NOT, a project to measure accurate time delays of four bright double quasars, recently discovered in the SDSS, was initiated. The continued build-up of time delays will eventually lead to important constraints on the distribution of dark matter in galaxies as well as direct constraints on the Hubble constant and other cosmological parameters.

Simulating galaxies, galaxy groups and clusters: Using a Lagrangian, particle based TreeSPH (gravitational/gas-dynamical; SPH: smoothed particle hydrodynamics) code we have performed cosmological simulations of the formation and evolution of galaxies as well as galaxy groups and clusters. Moreover, an AMR (adaptive mesh refinement) code, invoking full radiation-hydrodynamics, is used to study the first phases of galaxy formation, as well as various radiative transfer problems. Recent work, much of which was initiated in 2005 has been bearing important fruit. Results published this year include the reproduction of the galaxy cluster 'red sequence', predictions of the properties of 'intra-cluster' stars, a solution to the so-called 'missing galactic baryons' problem, predictions of the evolution of the spiral galaxy 'Tully-Fisher' relation with age of the Universe, the effects of Lyman- $\alpha$  resonant scattering in young galaxies on their observational properties and the distribution of hot gas in galaxy haloes. Moreover we have started to quantify the amount of H and He ionizing radiation that escapes from young galaxies and hence will be available for cosmological re-ionization, using radiative transfer calculations.

Measurement of extinction curves using afterglows of GRBs: A very dusty intervening system was discovered along the line of sight toward a GRB. In this system we made the first detection of the 2175Å bump in the extinction curve of an intervening absorber to a GRB, one of the few non-local detections of this dust feature. An analysis of metallic X-ray absorption in comparison to neutral hydrogen absorption in GRB afterglows was begun. Limits on the extinction curve in GRB050401 (work reported last year) were published.

Obscured star formation: Analysis of data from the *Spitzer Space Telescope* in combination with UV, optical, near-infrared and sub-mm data as a probe of the obscured star formation in GRB host galaxies at redshift  $z\sim 1$  has been published. We discovered the first GRB host galaxy that is an extremely red object (ERO) and analysed the very red afterglow of the GRB itself, a result with important implications for the use of GRBs as probes of star formation in the early universe. Analysis of galaxies at other redshifts and full spectral energy distribution modelling is ongoing. The MSc thesis of Michalowski on the modelling of spectral energy distributions of GRB host galaxies was completed.



### 3. Cooperation and collaboration

#### *Scientific collaboration with research groups in Denmark and abroad*

The research conducted at the Centre is highly international, as evidenced by the fact that the 47 refereed papers published in 2006 have authors affiliated to a total of about 160 institutions from 31 countries worldwide. This comes from established networks and consortia but is also often formed on a case-by-case basis, especially where observational data from many facilities around the world are combined in a collaborative work. There is also collaboration with all Danish astrophysics research institutes.

#### *Participation in EU framework programs*

The Centre continued its participation as a node in two EU framework Research Training Networks:

FP5: Research Training Network “Gamma-Ray Bursts – An Enigma and a Tool”. The network activities formally ended in September 2006. Darach Watson ended his contract in February 2006. Node members participated in a network meeting in Antalya, Turkey in March. Network members visited the Centre on several occasions and collaboration is ongoing beyond the network funding.

FP6: Marie Curie Research Training Network “Astrophysics Network on Galaxy Lens Systems – ANGLES”. The network has partially funded PhD students Árdís Elíasdóttir and Chloé Féron. The network arranged several meetings and schools, in which the students were heavily involved. The mid-term review was hosted by the Centre in Copenhagen in December.

Dr. Paul Vreeswijk applied for and won a Marie Curie Fellowship in 2006. He will take up his position at the Centre in mid-2007. Our associate and former postdoc, Páll Jakobsson, also obtained a Marie Curie intra-European fellowship in 2006 to work in the UK.

#### *Exchange of researchers*

The Centre has continued its visitor program, including collaboration with its associates. The visitor program is also used to invite speakers for local collaboration meetings. The program includes everything from very short visits (people passing through or quick collaboration meetings) to longer term visits, of order weeks up to a month. The total cost of the visitor program amounts to about one person-year. The 2006 list of visiting scientists is given in Appendix 1. Lists of past, current, and future visitors is also maintained at the Centre web site. A list of research visits and participation in conferences by researchers at the Centre is given in Appendix 2. A list of talks given at the Centre is provided in Appendix 3.

#### *Workshops and meetings*

No major conferences were arranged for 2006, but many collaboration and network meetings and workshops were organised, including a one-day meeting to kick-start the Centre’s dust theme (Appendix 4), a Marie Curie FP6 Research Training Network mid-term review and meeting (Appendix 4), and a collaboration meeting related to the VLT Large Programme on GRB host galaxies. The Centre submitted an application for hosting the 2007 Niels Bohr Summer Institute, which was approved.

### *Advisory committee*

The Centre maintained informal contact with its Advisory Committee in 2006 and plans a site visit by the committee in 2007.

### *Coordination with the host institution*

Interaction and coordination with the host institution, notably through the Niels Bohr Institute, is generally smooth and satisfactory, through the organizational setup described in the contract. Significant steps have been taken to solve the accounting problems mentioned in the 2005 report. As a result, the Centre's overview of its finances and its ability to make financial transactions is improving.

## **4. Relations with industry and society**

The research of the Centre, by its fundamental character, precludes the commercialization of its scientific results. The Centre also does not receive financial support from private companies. However, it is one of the Centre's outstanding strengths that it is engaged in a highly public and wide-ranging outreach program (Appendix 5) and, with Centre staff serving on many public committees, we are deeply involved in the development of science nationally and locally. As mentioned in Section 1, several prizes were awarded to the Centre's staff for their communication skills.

During the Centre's first year it has established itself in the Danish community as a widely known research centre. On top of the Centre's own communications activities, it received during 2006 a broad range of enquiries about outreach activities; many more than could be accommodated given the Centre's manpower. The Centre has defined a communications strategy which serves as a guide when deciding whether or not to engage in each specific activity—this is done on a case-by-case basis by the person responsible for communications, who also serves as the single point of contact regarding all communications enquiries and issues.

Three major press releases were issued in 2006, resulting in wide media coverage in Denmark and internationally:

- The discovery of a 'hot atmosphere' around Milky Way like galaxy (*Chandra* NASA press release)
- Observations of hydrogen falling into heavy dark matter clump early in the universe (ESO press release)
- Discovery of long gamma-ray bursts without accompanying supernovae (NBI press release, ESO press release)

The Centre made significant contributions to the Tycho Brahe exhibition at the National Museum by setting up and running a workshop for high school and primary school classes.

A public talk by the Nobel Laureate, Prof. Riccardo Giacconi (2002, Physics), was organized in collaboration with the Tycho Brahe Planetarium. More than 250 people attended the event in the Planetarium's space theatre.

A dozen popular articles were published on topics ranging from cosmic dust to dark energy. Anja C. Andersen and Kristian Pedersen were engaged as permanent column writers in the weekly science section of the national newspaper "Politiken".

The Centre was engaged in numerous TV, radio, newspaper, and magazine interviews, and popular talks to school classes as well as the general public. See Appendix 5 for a full list of the Centre's outreach activities in 2006.

The Centre hosted a visit of the Danish Parliament's Research Committee on 13 June.

In 2006 Anja C. Andersen served on the following committees: Board member of Dansk Naturvidenskabsformidling, member of Albrightgruppen.dk, Expert Panel Member for the European Commission's Descartes Science Communication Prize, member of the presidium for Experimentarium, member of the Danish Academy of Technical Sciences Think Tank. Kristian Pedersen was member of the Niels Bohr Institute board for communications, member of the board of the Danish Physical Society, and was appointed national coordinator for the International Year of Astronomy 2009.

Finally, other research centres and organizations have approached the Centre in order to learn about its experiences and ideas on communications strategies.

## **5. Research training**

The aim is to educate original and independent researchers at an internationally competitive level. The Centre strives to achieve this by lively and informal contact between PhD student and supervisor on a daily basis in the Centre's international environment. All PhD students are involved in on-going international collaborations, in particular by spending part of their PhD abroad working in associated research groups and by attending international conferences. Other research training foci for the Centre include recruiting the best international students, maintaining a high fraction of international MSc and PhD students, and to have a balanced MSc and PhD student gender profile.

The Centre has experienced a dramatic increase in the number of PhD students, from 6 in 2005 to 12 at the end of 2006. They represent 9 different nationalities, and the majority (7) are females. With the present supervisor capacity, this is near the maximum number of PhD students which can be accommodated and while ensuring a sufficiently high quality of the supervision. The Centre is a founding partner in the new national PhD school, Danish Astrophysics Research School, providing co-funding for PhD stipends and organizing courses and meetings for astrophysics PhD students in Denmark.

The Centre (by Jesper Sollerman) organized a Nordic Summer school on Observational Astrophysics for 16 PhD students June 27-July 8 2006 at the Nordic Optical Telescope (Roque de los Muchachos, La Palma, Spain). The aim of the school was to train the PhD students in how to prepare, carry out, and analyze observations at both the Nordic Optical Telescope and the Swedish solar telescope on the mountain. The school was mainly financed by NordForsk.

Staff at the Centre is offering KU students MSc and BSc projects within cosmology in order to attract the most talented students. In 2006, 4 MSc theses and 4 BSc theses were awarded under the supervision of the Centre's staff. Also, the Centre is offering a number of graduate courses in the

fields covered by our research plan (dark matter, dark energy, and to some degree galaxy formation) as well as running a major share of the undergraduate teaching in astronomy.

## 6. Economy

External funding in 2006, excluding contributions from the host institution, exceeded that foreseen in the contract. The value of the external funding for salary, 3.5 MDKK, is equivalent to nearly 50% of the funding received from the DNRF in 2006.

Appendix 6 contains a list of all active grants held by Centre members.

## 7. Publications

The main scientific production of the Centre consists of scientific papers published in major international (peer-reviewed) journals. In this report we list only research papers published in peer reviewed, international journals in 2006 (Appendix 7). On the Centre website we maintain a daily updated list of published papers by year (all hyperlinked) as well as a list of all, as yet unpublished, preprints, posted at the arXiv archive (as of 31 March 2007 there are 32 unpublished papers). All preprints are posted prior to publication to the arXiv Open Source preprint archive (<http://www.arxiv.org>). In Appendix 7 we also list major publications not directly related to the research plan. These include several papers popularizing our research in Danish.

Any newly-initiated research centre would be expected to take some lead-in time to reach a high level of scientific output given considerations such as time taken to construct and hone an administrative set-up and to hire researchers and other staff. In this regard, however, the Centre has hit the ground running: its first half-year of operation were, by any standards, remarkably successful. 2006 continued to be marked by very high output of scientific papers and very high citation rate. Through ADS, CITEBASE or SLAC/SPIRES there is ready access to citation statistics for the Centre publications. As of 31 March 2007 the 47 papers have received a total of 578 citations according to ADS, 240% the average citation rate in this period for the journals in which the Centre published. It is worth noting that the Centre publishes predominantly in the high-impact journals: the citation rate for Centre papers is in fact nearly five times the average of the *total* peer-reviewed astrophysics literature in 2006—the Centre was responsible for 0.24% of the peer-reviewed astrophysics papers published worldwide and 1.2% of the citations. (To date, the 10 papers listed in the 2005 annual report have received 415 citations). More detailed and experimental publication statistics are reviewed in Appendix 8.

Ved underskriften bekræftes det, at beretning og regnskab med tilhørende noter og oversigter indeholder alle oplysninger, som vedrører årets aktiviteter i Danmarks Grundforskningscenter for Kosmologi ved Københavns Universitet.

Jens Hjorth

København 2. april 2007

## Appendix 1: Visiting scientists 2006

Dr. Marianne Vestergaard (Steward Observatory, USA)	01–04 Jan 06
Prof. Javier Gorosabel (IAA, Granada, Spain)	03–15 Feb 06
Dr. Stephen Holland (GSFC, USA)	06–24 Feb 06
Dr. Michael Weidinger (U. Aarhus, DK)	20–21 Feb 06
Dr. Palle Møller (ESO, Germany)	20–24 Feb 06
Dr. Steen H. Hansen (U. Zurich, Switzerland)	27 Feb–10 Mar 06
Dr. Edvard Mörtzell (U. Stockholm, S)	28 Feb–1 Mar 06
Dr. Elena D’Onghia (Münich, Germany)	05–08 Mar 06
Dr. Nicola Napolitano (Napoli, Italy)	05–08 Mar 06
Dr. Laura Portinari (U. Turku, Finland)	05–08 Mar 06
Dr. Alesio Romeo (Napoli, Italy)	05–08 Mar 06
Prof. Steen Hannestad (U. Aarhus, DK)	07–08 Mar 06
Ms. Kim Nilsson (ESO, Germany)	07–10 Mar 06
Dr. Monica Pozzo (UCL, UK)	13–14 Mar 06
Dr. Rhaana Starling (U. Amsterdam, Netherlands)	13–16 Mar 06
Ms. Danuta Paraficz (Nordic Optical Telescope, ES)	13–18 Mar 06
Dr. Andrew Levan (U. Hertfordshire, UK)	05 Apr 06
Mr. Johan Richard (Caltech, USA)	17–24 Apr 06
Prof. Gunnlaugur Björnsson (U. Iceland, IS)	01–05 May 06
Dr. Erik Zackarrison (U. Uppsala, S)	02–30 May 06
Dr. Frank Grundahl (U. Aarhus, DK)	03 May 06
Dr. Palle Møller (ESO, Germany)	08–09 May 06
Prof. Susanne Höfner (U. Uppsala, S)	21–28 May 06
Ms. Kim Nilsson (ESO, Germany)	22–26 May 06
Dr. Ole Møller (MPA, Germany)	22–26 May 06
Prof. Gunnlaugur Björnsson (U. Iceland, IS)	09 Jun 06
Dr. Enrico Ramirez-Ruiz (Princeton, USA)	11–25 Jun 06
Dr. Thomas Greve (Caltech, USA)	13–14 Jun 06
Prof. Garrelt Mellema (U. Stockholm, S)	20–21 Jun 06
Ms. Danuta Paraficz (Nordic Optical Telescope, ES)	26–30 Jun 06
Prof. Joshua Bloom (Berkeley, USA)	25–28 Jun 06
Dr. Christophe Benoist (U. Nice, France)	03–14 Jul 06
Dr. Tomás Verdugo González (UNAM, Mexico)	09–30 Jul 06
Dr. Luc Binette (UNAM, Mexico)	25–28 Jul 06
Dr. Páll Jakobsson (U. Hertfordshire, UK)	29 Jul–3 Aug 06
Prof. Priyamvada Natarajan (Yale, USA)	01–04 Aug 06
Ms. Danuta Paraficz (Nordic Optical Telescope, ES)	04 Aug 06
Dr. Roberto Mainini (U. Milan-Biococca, Italy)	09–12 Aug 06
Ms. Suzanne Foley (U. Dublin, Ireland)	13 Aug–20 Sep 06
Prof. Paul Davies (Sydney, Australia)	17 Aug 06
Mr. Daniele Malesani (Trieste, Italy)	20–21 Aug 06
Ms. Josefine Selj (U. Oslo, Norway)	28 Aug–1 Sep 06
Prof. Eric Linder (Berkeley, USA)	29 Aug–2 Sep 06
Dr. Alex Razoumov (U. Saint Mary, Halifax, Canada)	02–15 Sep 06
Prof. Sara Ellison (U. Victoria, Canada)	18–30 Sep 06
Dr. Peter Johansson (Münich, Germany)	25–29 Sep 06
Ms. Taia Kronborg (LPNHE, Paris)	26–27 Sep 06
Dr. Reynald Pain (LPNHE, Paris)	26–27 Sep 06

Dr. Julien Guy (LPNHE, Paris)	26–27 Sep 06
Prof. A. Kusenko (U. California, USA)	27 Sep 06
Mr. Atish P. Kamble (RRI, India)	22–25 Oct 06
Prof. J Vergados (U. Ioannini, Greece)	27 Oct 06
Dr. Michael I Andersen (AIP, Germany)	06–10 Nov 06
Dr. Constantin Zioutas (U. Frankfurt, Germany)	19–20 Nov 06
Dr. Sune Toft (ESO, Germany)	20–21 Nov 06
Dr. Mia Schelke (U. Stockholm, S)	22–24 Nov 06
Ms. Christa Rainer (Vienna, Austria)	27–28 Nov 06
Dr. Marianne Vestergaard (Steward Observatory, USA)	27 Nov–15 Dec 06
Dr. Joan-Marc Miralles (ESO, Germany)	03–14 Dec 06
Dr. Håkon Dahle (U. Oslo, N)	05–06 Dec 06
Dr. Rhaana Starling (U. Leicester, UK)	09–13 Dec 06
Mr. Klaas Wiersema (U. Amsterdam, Netherlands)	09–15 Dec 06
Prof. Nial Tanvir (U. Leicester, UK)	10–13 Dec 06
Prof. Javier Gorosabel (IAA, Granada, Spain)	10–14 Dec 06
Dr. Christophe Benoist (U. Nice, France)	11–20 Dec 06
Dr. Palle Møller (ESO, Germany)	11–13 Dec 06
Dr. Andreas O. Jaunsen (U. Oslo, N)	11–12 Dec 06
Dr. Thomas Greve (Caltech, USA)	11–15 Dec 06
Dr. Troels Haugbølle (Aarhus, DK)	21–22 Dec 06
Dr. Sune Toft (ESO, Germany)	21 Dec 06

## Appendix 2: Travel, talks and visits

- 19 January 2006, NBI, Copenhagen, “NBI Kick-off meeting”, Tamara Davis (talk).
- 6–9 February 2006, Yllas, Finland, “ANGLES workshop”, Árdís Elíasdóttir (organizer).
- 7 February 2006, NBI, Copenhagen, “Astrobiology Seminar”, Tamara Davis (talk).
- 27 February 2006, Uppsala University, Sweden, Anja Andersen (visit).
- 5–20 March 2006, La Silla, Chile, “Observations”, Chloé Féron, Christina Thöne (visit).
- 12 March 2006, La Thuile, Italy, “XXVIth Astrophysics Moriond Meeting”, Lisbeth Fogh Grove (talk).
- 13 March 2006, Stockholm, Sweden, “Stockholm University”, Tamara Davis (visit).
- 13 March 2006, Moriond, Italy, “Moriond Conference”, Marceau Limousin (talk).
- 14 March 2006, DARK, “DARK Dust Day”, Tamara Davis, José María Castro Cerón (talks).
- 24 March 2006, Brisbane, Australia, “University of Queensland Colloquium”, Tamara Davis (talk).
- 25–29 March 2006, Crans-Montona, Switzerland, “SNAC 06”, Steen H. Hansen, Signe Riemer-Sørensen (2 talks).
- 29 March 2006, Canberra, ACT, Australia, “Australian National University, Mount Stomlo Observatory”, Tamara Davis (visit).
- 29 March–1 April 2006, Antalya, Turkey, “GRBs – an enigma and a tool”, Christina Thöne, Jesper Sollerman (talks).
- 31 March 2006, University of New South Wales, Sydney, Australia, “Graduation Ceremony”, Tamara Davis (visit).
- 3 April 2006, Vejle, Denmark, “FNU meeting”, Jens Hjorth (presentation).
- 6 April 2006, Stockholm Observatory, Sweden, Anja Andersen (visit).
- 18 April 2006, Nice, France, Lisbeth Fogh Grove (visit).
- 22–26 April 2006, Nordic Optical Telescope, Spain, Kim Nilsson (observations).
- 1–3 May 2006, Padova, Italy “EDisCS collaboration”, Bo Milvang-Jensen (visit).
- 3 May 2006, Copenhagen, Denmark, “Cosmic rays, aerosols, clouds and climate”, Anja Andersen (talk).
- 8 May 2006, Aarhus, Denmark “Complex molecules in Space”, Anja Andersen (talk).
- 24 May 2006, Copenhagen, Denmark, “Kandidatfrokostklub NBI”, Signe Riemer-Sørensen (talk).
- 31 May–2 June 2006, Nyborg, Denmark “Danish Physical Society yearly meeting”, Anja Andersen, Chloé Féron, Lisbeth Fogh Grove, Jens Hjorth, Peter Laursen, Bo Milvang-Jensen, Kristian Pedersen, Signe Riemer-Sørensen, Christina Thöne (4 talks).
- June 2006, Dublin, Ireland, Darach Watson (visit).
- June 2006, Stockholm University, Maximilian Stritzinger (visit).
- 1–3 June 2006, Lawrence Berkeley Laboratory, Berkeley, USA, “SNAP collaboration meeting”, Tamara Davis (talk).

6–10 June 2006, Penn State, State College, USA., “Summer School in Statistics for Astronomers and Physicists”, Tamara Davis, Árdís Elíasdóttir (talk/visit).

11–24 June 2006, Cefalu, Italy, “The Multicoloured Landscape of Compact Objects and their Explosive Origins”, Michal Michalowski, Tamara Davis, Maximilian Stritzinger (3 talks).

15–16 June 2006, Reykjavik, Iceland, Jens Hjorth (PhD defence).

19 June 2006, Reykjavik, Iceland, Anja Andersen (3 talks).

20–22 June 2006, Edinburgh, UK, VISTA public surveys meeting, Kim Nilsson (visit).

21–25 June 2006, Center for Astrophysics, Harvard, USA, ESSENCE collaboration meeting, Tamara Davis (talk).

26 June – 9 July 2006, “NOT Summer School”, Christina Thöne, Dong Xu (talk + poster).

3 July 2006, Brussels, Belgium, Anja Andersen (evaluator for science communication Descartes Prize).

23–29 July 2006, Berlin, Germany, “11th Marcel Grossman Meeting”, Signe Riemer-Sørensen, Johan Fynbo (talks).

31 July–4 August 2006, Durham, UK, “Cosmic Frontiers”, Kim Nilsson (visit).

7 August 2006, Vienna, Austria, “Why Galaxies Care About AGB Stars”, Anja Andersen (review talk).

13 August 2006, Prague, Czech Republic, “Galaxy evolution across the Hubble time”, Lisbeth Fogh Grove (poster).

14 August 2006, Prague, Czech Republic, IAU XXVIth “General Assembly”, Anja Andersen (Co-chair).

23 August - 1 September 2006, La Silla, Christina Thöne (observing).

9 September–5 November 2006, KITIP at UCSB, USA, “Applications Of Gravitational Lensing”, Árdís Elíasdóttir (talk).

12 September 2006, Dark Cosmology Centre, Copenhagen, “Danish National Research Foundation visit”, Jens Hjorth, Kristian Pedersen, Johan Fynbo, Anja Andersen, Darach Watson, Tamara Davis, Signe Riemer-Sørensen, Michal Michalowski (8 talks).

September 2006, Stockholm, Sweden, “GLAST GRB symposium”, Jesper Sollerman (talk).

18–20 September 2006, London, UK, “Royal Society Discussion Meeting on GRBs”, Darach Watson (talk).

20–23 September 2006, Nordic Optical Telescope, La Palma, Spain, Christina Thöne (observing).

25–29 September 2006, Heidelberg, Germany, “IMPRS Summer School on Interstellar Matter”, Christina Thöne (visit).

26–29 September 2006, Torun, Poland, “8th EVN Symposium 2006”, Michal Michalowski (visit).

26 September 2006, Heidelberg, Germany, Anja Andersen (visit).

October 2006, La Silla, Chile, Maximilian Stritzinger (observing).

2 October 2006, Stockholm, Sweden, “Institute for future studies”, Jesper Sollerman (arranged seminar).

2 October 2006, Niels Bohr Institute, Copenhagen, “Folkeuniversitetet i København”, Tamara Davis (talk).



2 October 2006, Aarhus University, Denmark, “Folkeuniversitet i Aarhus”, Tamara Davis (talk).

3–10 October 2006, KITP at UCSB, USA, “Applications Of Gravitational Lensing”, Árdís Elíasdóttir (poster).

5–6 October 2006, Stockholm, Sweden, “Stockholm University”, Tamara Davis (visit).

9–13 October 2006, Sintra, Portugal, “At the Edge of the Universe”, Lisbeth Fogh Grove, Kim Nilsson (poster/talk).

10 October, Copenhagen, Denmark, “Kulturnatten” Signe Riemer-Sørensen, Peter Laursen, Steen H. Hansen (talks/demonstration).

23 October 2006, UC Berkeley and LBL, USA, Árdís Elíasdóttir (talk).

November 2006, Nordic Optical Telescope, La Palma, Spain, Maximilian Stritzinger (observing).

6 November 2006, Brorfelde, Denmark, “ASF weekend-tur”, Signe Riemer-Sørensen (talk).

7–11 November 2006, Yale Univ., USA, Árdís Elíasdóttir (visit).

8–10 November 2006, Marseille, France, Kim Nilsson (talk).

9 November 2006, Bergen, Norway, “Nordic conference”, Steen H. Hansen, Alma Ruiz Velasco (talks).

12–15 November 2006, Copenhagen Denmark “ANGLES meeting”, Árdís Elíasdóttir, Chloé Féron, Signe Riemer-Sørensen, Steen H. Hansen (4 talks).

13–17 November 2006, Madrid, Spain, “Science with ALMA”, Michal Michalowski (visit).

21 November 2006, ESO, Garching, Germany, Anja Andersen (evaluator) .

22 November 2006, DTU, Denmark, “General Physics Talk”, Steen H. Hansen (talk).

24 November, 2006, ESO, Santiago, Chile, Marceau Limousin (talk).

November 2006, PUC, Santiago, Chile, Marceau Limousin (talk).

December 2006, Valparaiso, Chile, Marceau Limousin (talk).

November 2006, Brisbane, Queensland, Australia, Tamara Davis (visit).

09 December 2006, Brorfelde, Denmark, “Astronomy Symposium”, Steen H. Hansen (talk).

10 December 2006, Paris, France, “TPC conference”, Steen H. Hansen, Ole Høst (visit).

11–15 December 2006, Melbourne, Australia, “XXIII Texas Symposium on Relativistic Astrophysics”, Tamara Davis, Chloé Féron, Árdís Elíasdóttir, Christina Thöne (talks/posters).

18–19 December 2006, Dublin, Ireland, “Colloquium in honour of Brian McBreen”, Darach Watson (talk).

20 December 2006, Granada, Spain, “Instituto de Astrofísica de Andalucía”, José María Castro Cerón (talk).

### Appendix 3: Seminars given at the Centre

Date	Speaker	Title
Jan 12	Dong Xu (DARK)	“Optical emission from GRB 050709: a short/hard GRB in a star forming galaxy”
Feb 15	Troels Haugbølle (DARK)	“The scientific computing infrastructure in Denmark”
Feb 22	Desiree D. M. Ferreira (DARK)	“XMM observations of real and simulated clusters of galaxies”
Mar 01	Marceau Limousin (DARK)	“Strong lensing analysis of the galaxy cluster Abell 68 with the Keck and the VLT”
Mar 07	Elena D’Onghia (USM, Munich)	“Open questions in the formation of fossil systems in the hierarchical Universe”
Mar 08	Laura Portinari (Tuorla)	“The Tully-Fisher relation: zero-point and evolution”
Mar 08	Nicola Napolitano (Napoli)	“Diffuse light in galaxy cluster”
Mar 29	Michal Michalowski (DARK)	“Spectral energy distributions of GRB host galaxies”
Apr 05	Max Stritzinger (DARK)	“On the explosion mechanism of Type Ia SNe”
Apr 05	Pavel Naselsky (NBI)	“WMAP third year data release”
Apr 19	Johan Richard (CalTech)	“Looking for very high redshift galaxies with gravitational telescopes”
Apr 27	Dong Xu (DARK)	“The early afterglow of the short GRB 060313”
May 04	Tamara Davis (DARK)	“The universe is a very strange place”
May 16	Eric Zackrisson (Tuorla)	“The red halos of galaxies”
May 23	Ole Möller (ESO)	“Not all that glitters is gold: the search for the golden lens and why it failed”
May 24	Kim Nilsson (ESO/DARK)	“High redshift Ly $\alpha$ emitters”
May 24	Susanne Höfner (Uppsala)	“The dark side of dust grains”
Jun 12	Christina Thöne (DARK)	“A lonely mountain in the desert – observing at the Danish 1.54m on La Silla”
Jun 21	Garreht Mellema (Stockholm)	“Simulating Reionization on Large Scales for LOFAR”
Jun 29	Tamara Davis (DARK)	“An off the bench, last minute substitution talk”
Jul 06	Árdís Elíasdóttir (DARK)	“Report on the Second Summer School in Statistics for Astronomers and Physicists at Penn State”
Jul 24	Luc Binette (UNAM, Mexico)	“Quasar update”
Aug 03	Priyamvada Natarajan (Yale)	“Mapping clusters and the geometry of the Universe with gravitational lensing”

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Aug 10	Roberto Mainini (INFN, Turin)	“Structure formation in coupled dark energy model”
Aug 17	Paul Davies (Macquarie U.)	“Cosmological horizons and information”
Aug 21	Daniele Malesani (Brera, Milan)	“GRB afterglow SEDs constrain their physics and environments”
Aug 30	Eric Linder (Berkeley)	“Concepts and Challenges in Dark Energy”
Sep 06	Árdís Elíasdóttir (DARK)	“Comparison of the lensing properties of the Navarro, Frenk & White and the Sérsic dark matter halo density profiles”
Sep 13	Alexei Razoumov (Halifax)	“Escape of ionizing photons from star-forming regions in high-redshift galaxies”
Sep 20	Sara Ellison (Victoria)	“Dust, Metals and Diffuse Interstellar Bands in Damped Lyman Alpha Systems”
Sep 26	Arto Järvinen (NOT)	“GRB spectroscopy with FIES”
Sep 27	Brian Niebergal (Calgary)	“SGRs and AXPs within the Quark-Nova Scenario”
Sep 27	Jan Staff (Calgary)	“GRBs within the quark-nova scenario”
Sep 29	Peter Johansson (Cambridge)	“Where Are the Missing Cosmic Metals?”
Oct 03	Isabelle Gavignaud (AIP)	“The faint end of AGN luminosity function”
Oct 04	Desiree D. M. Ferreira (DARK)	“Observations at La Silla”
Oct 11	Bo Milvang-Jensen (DARK)	“Spectroscopy of clusters in the ESO Distant Cluster Survey (EDisCS)”
Oct 18	Christina Thöne (DARK)	“Heidelberg ISM Summer School”
Oct 25	Atish Kamble (RRI, Bangalore)	“Multiband Modeling of GRB Afterglows”
Nov 01	Michal Michalowski (DARK)	“Report on The 8th European VLBI Network Symposium, Torun, Poland”
Nov 08	Lisbeth Fogh Grove (DARK)	“Building the Bridge Survey - work in progress”
Nov 16	Peter Laursen (DARK)	“Super computational cosmology”
Nov 22	Mia Schelke (INFN, Turin)	“Supersymmetric Dark Matter - constraints from relic density and astrophysics detectors”
Nov 23	Chloé Féron (DARK)	“Disk-galaxy lens candidates”
Nov 23	Johan Fynbo (DARK)	“The future of the NOT”
Nov 30	Ole Høst (DARK)	“Neutrino Masses in Cosmology and in the Lab”
Dec 08	Joan-Marc Miralles (ON, Brazil)	“Technical challenges for the next generation of imaging surveys”
Dec 14	Christophe Benoist (Nice)	“Galaxy clusters in the CFHTLS”

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## Appendix 4: “DARK Dust Day” and “ANGLES Mid-term Review Meeting”

This appendix includes the program and participants list for the DARK Dust Day 14 March 2006 and the ANGLES Mid-term Review Meeting 13 – 15 November 2006.

*DARK Dust Day 14 March 2006 (Tuesday)*

### Program

09.00-09.15	DARK and DUST, the director’s introduction Professor Jens Hjorth
09.15-09.45	Dust-to-gas ratios from lensed X-ray QSOs Dr. Kristian Pedersen
09.45-10.30	Type II Supernova and dust Dr. Monica Pozzo
10.30-11.00	Coffee Break
11.00-11.30	Dust and supernova cosmology Dr. Tamara Davis
11.30-12.00	Extinction curves from multiply imaged QSOs Ms. Árdís Elíasdóttir
12.00-13.15	Lunch
13.15-14.15	The microphysics of dust Dr. Anja C. Andersen
14.15-14.45	Tracing dust-driven winds of AGB stars Dr. Walter Nowotny
14.45-15.15	Coffee
15.15-15.45	Dust metallicity and column densities from X-ray and optical spectroscopy Dr. Darach Watson
15.45-16.00	Spitzer observations of GRB host galaxies at $z \sim 1$ Mr. José María Castro Cerón
16.00-16.30	Extinction curve fits to GRB afterglows Dr. Pall Jakobsson
16.30-17.30	Discussion

### Participants

All DARK staff  
Dr. Monica Pozzo (UCL, UK)  
Dr. Walter Nowotny (U. Vienna, Austria)  
Dr. Rhaana Starling (U. Leicester, UK)

## *ANGLES Mid-term Review Meeting 13 November 2006*

### **Administrative program**

- 09:15 Introduction by Erno Vandeweert representing the Commission  
09:30 Coordinator's report
- 10:45 Coffee break
- 11:15 Brief presentations by the ESR/ERs
- 13:00 Lunch
- 14:00 Meeting between ESRs/ERs and Erno Vandeweert  
15:15 Meeting between the coordinator, scientists in charge and Erno Vandeweert.
- 16:15 Tea
- 16:30 Open discussion  
17:30 Presentation by Erno Vandeweert on the FP7 People Program.  
18:15 Meeting ends

### **Participants**

Timo Anguita	Heidelberg (ESR)
Alicia Berciano Alba	JIVE (ESR)
Edward Boyce	JBO (ER)
Ian Browne	JBO (Coordinator)
Árdís Elíasdóttir	Copenhagen (ESR)
Wyn Evans	Cambridge (PI)
Chris Fannacht	UC Davis (PI)
Michael Garrett	JIVE (PI)
Jens Hjorth	Copenhagen (PI)
Christophe Jean	Valencia (ER)
John McKean	Bonn (ER)
Anupreet More	Bonn (ESR)
Ana Mosquera	Valencia (ESR)
Jose Munoz	Valencia (PI)
Richard Porcas	Bonn (PI)
Joachim Wambsganss	Heidelberg (PI)
Olaf Wucknitz	JIVE (ER)
Lukasz Wyrzykowski	Cambridge (ER)
Ming Zhang	JBO (ESR)

*ANGLES Mid-term Review Meeting 14 November 2006*

**Scientific Program**

	09:00 – 10:30	Session 1: Surveys -past and present Chair: John McKean
09:00	Neal Jackson	After CLASS: uses of radio lenses and future prospects
09:30	Leon Koopmans	The latest result from the SLACS survey
10:00	Oliver Czoske	Integral Field Spectroscopy of SLACS lenses
10:20	Chloé Féron	Finding disk – galaxy lenses in the SDSS
		Coffee break, DARK Lounge 10:30 – 11:00
	11:00 – 12:40	Session 2: Time delays Chair: Lukasz Wyrzykowski
11:00	Andy Biggs	Refining measurement of the time delay in B0218+357
11:20	Danuta Paraficz	Time delay of doubly lensed quasar SDSS J0903+502
11:40	Aurora Ullan	New magnification ratios of the gravitational lens system SBS 0909+532 and possible interpretations
12:00	Olaf Wucknitz	Image coherence of gravitational lenses
12:20	Ben Dobke	Density profiles from lensing time delays and tidal interactions of lens galaxies
		Lunch, DARK Lounge 12:40 – 14:00
	14:00 – 15:40	Session 3: Density profiles and third images Chair: Andy Biggs
14:00	Edward Boyce	The Extragalactic Lens VLBI Imaging Survey (ELVIS): searching for central images
14:20	Ming Zhang	A search for the third lensed image in B1030+074
14:40	Matteo Barnabe	Joint gravitational lensing & stellar dynamics analysis of elliptical galaxies: a novel method
		Miscellaneous topics
15:00	Alicia Berciano Alba	A parseltongue pipeline for VLA data analysis of B1600+434
15:20	Sanhita Joshi	Search for Aligned Radio Polarization of quasars
		Coffee break, DARK Lounge 15:40 – 16:10
	16:10 – 17:45	Session 4: Groups and clusters Chair: Edward Boyce
16:10	Chris Fassnacht	The environments of lensing galaxies
16:30	Matt Auger	The galaxy group – gravitational lens connection
16:50	Aleksi Halkola	The sizes of galaxy haloes in Abell 1689 with strong lensing
17:10	Signe Riemer-Sørensen	Direct dark matter detection from dark clumps identified through lensing
17:25	Anupreeta More	Multi-frequency observations of two wide gravitational lens systems: B2016+112 and B2108+213
	19:15 – 20:15	Public lecture in the Tycho Brahe Planetarium

19:15 Riccardo Giacconi Gammel Kongevej 10, 1610 Copenhagen V  
Astronomy in a Flat World

20:30 Dinner in the Cassiopeia Restaurant (at the Planetarium)

*ANGLES Mid-term Review Meeting 15 November 2006 (Wednesday)*

**Scientific Program**

09:00 – 10:10 Session 5: Substructure Chair: Christophe Jean

09:00 Wyn Evans Substructure and lensing.  
09:20 Edward Shin Lensing by spiral galaxies.  
09:40 John McKean The flux-ratio anomaly of B2045+265: dark or luminous satellites?

10:10 – 12:20 Session 6: Microlensing Chair: Olaf Wucknitz

10:10 Alex Wood Microlensing optical depth as a function of source apparent magnitude

Coffee break, DARK Lounge 10:30 – 11:00

11:00 Lukasz Wyrzykowski OGLE-II microlensing survey towards the LMC -indication of low optical depth.  
11:20 Martin Smith Blending in Galactic bulge microlensing experiments.  
11:40 Nick Rattenbury Planetary microlensing: past results, future prospects.  
12:00 Timo Anguita VIMOS IFU observations of gravitationally lensed quasars HE0230–2130 and RXJ 0911+0551

Lunch, DARK Lounge 12:20 – 13:30

13:30 – 14:40 Session 7: Lensing galaxies Chair: Martin Smith

13:30 Árdís Elíasdóttir Extinction curves of lensing galaxies.  
13:50 Ana Mosquera Chromaticity studies in the gravitational lens systems SDSS J1650+4251 and Q2237+0305

14:20 Christophe Jean Redshift estimate and classification of an extinction law in a distant galaxy

Coffee break, DARK Lounge 14:40 – 15:10

15:15 – 16:15 Inaugural Lecture, Associate Professorship Niels Bohr Institute Colloquium  
Aud. 3, H. C. Ørsted Institutet, Universitetsparken 5

15:15 Steen H. Hansen The Behaviour of Dark Matter

16:30 – 17:30 Concluding Session

## Participants

Neal Jackson	JB	Wyn Evans	Cambridge
Michael Garrett	JIVE	Alex Wood	JB
Sanhita Joshi	JB	Martin Smith	JIVE
Ming Zhang	ESR, JB	Matteo Barnabe	JIVE
Chris Fassnacht	USA	Jose Munoz	Valencia
Matt Auger	USA	Andy Biggs	JB
Edward Boyce	ER, JB	Erno Vandeweert	Brussels, EU
Satoru Sakai	JB	Benjamin Dobke	Cambridge
Richard Porcas	MPI	Oliver Czoske	JIVE
Aurora Ullan	Valencia	Aleksi Halkola	MPI
Nicholas Rattenbury	JB	Leon Koopmans	JIVE
Christophe Jean	Valencia	Simona Vegetti	JIVE
Lukasz Wyrzykowski	ER, Cambridge	Chloé Ferón	DARK
Timo Anguita	ESR, ARI	Signe Riemer-Sørensen	DARK
Olaf Wucknitz	ER, JIVE	Árdís Elíasdóttir	DARK
Joachim Wamsganss	ARI	Steen H. Hansen	DARK
Alicia Berciano Alba	ESR, JIVE	Dong Xu	DARK
Anupreeta More	ESR, MPI	Christina Thöene	DARK
Ana Mosquera	ESR, Valencia	Jens Hjorth	DARK
Danuta Paraficz	DARK	Kristian Pedersen	DARK
John McKean	ER, MPI	Darach Watson	DARK
Ian Browne	JB	Riccardo Giacconi	Johns Hopkins
Edward Shin	Cambridge		



## Appendix 5: Public outreach activities

Date	Activity	Place	DARK persons
Jan	Contribution to Foreign Ministry's web-portal denmark.dk (Science & research)	—	Kristian Anja
Jan	Article in "Studier på Naturvidenskab 2006" by KU	—	Anja
Jan	Article in "Universitetsliv 2005": "Stjernernes formidler"	—	Anja
Jan	Article in "Den Svenska Almanackan" 2006: "Gammablixlar"	—	Jesper S.
Jan	Article in "Forskning och Framsted", vol. 1: "Rymdens magnetiska fyrar"	—	Jesper S.
Jan	Article in "Populär Astronomi", vol. 1: "Farväl til en trotjänere"	—	Jesper S.
Jan 4	Interview by Information on lack of equal opportunities for women in university "udviklingskontrakter"	—	Anja
Jan 9	Talk: "Stjerners fødsel, liv og død" for gymnasium class	Rockefeller	Peter
Jan 12	Talk: "Cosmology" for gymnasium class	Rockefeller	Peter
Jan 12	Interview in "Go'morgen Danmark", TV2, about Stardust mission return to Earth	TV2 København	Anja
Jan 13	Talk: "Spectroscopy" for 2.g Himmelev Gymnasium	Rockefeller	Peter
Jan 15	Expert on Stardust mission return to Earth arrangement	Tycho Brahe Planetarium	Anja
Jan 15	Interview in "TV Avisen" 12.00 about Stardust landing	Tycho Brahe Planetarium	Anja
Jan 14	Supervision of 3.g project on gamma-ray bursts	Rockefeller (1 student)	Johan
Jan 17	Supervision of 3.g project on gamma-ray bursts	Rockefeller (1 student)	Johan, Kristian
Jan 23	"Science and society communicate", talk at the European Commissions Consultation Seminar: Science in Society... and YOU?	(150 people)	Anja
Jan 25	Talk: "Astronomi og spektroskopi" for gymnasium class	Rockefeller	Peter
Jan 27	Talk: "Nyt lys over det mørke Univers" for 3.g fysik højniveau, Århus Katedralskole	Rockefeller	Kristian

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Jan 23– Feb 3	Erhvervspraktikant from Sindal	Rockefeller	Johan
Jan 27	Talk: “Mørkt stof og kernesyntese” for 3.g højniveau from Århus Katedralskole	Rockefeller	Kristian
Jan 28	Article in “Weekendavisen” about dark energy	—	Kristian
Jan 31	Interview in ”Viden Om” about discovery of most Earth—like planet	TV Byen	Anja
Feb	Article in “Illustreret Videnskab”: ”Gåden bag et gammaglimt”	—	Jesper Sollerman
Feb 1	Talk: “Stellar evolution” for gymnasium class	Rockefeller	Peter
Feb 1	Phone interview about dark matter to ”Dagens Industri”	—	Kristian
Feb 2	Popular talk: ”Nyt lys over det mørke Univers” for UNF Odense	SDU (100 people)	Kristian
Feb 6	Talk: “Det mørke univers” at “Videnskabernes Selskab” on	Videnskabernes Selskab (100 people)	Jens
Feb 6	Interview by DR P1 Morgen on discovery of ‘hot atmosphere’ around Milky Way like galaxy	Rockefeller	Kristian
Feb 7	UTV recording of talk on astrobiology	Nordita	Tamara
Feb 7	Talk: “Det mørke univers” for astro gymnasium class, Herlev Gym.	Rockefeller	Kristian
Feb 8	Talk: “Spectroscopy” for 2.g gymnasium class from Midtfyns Gymnasium	Rockefeller	Peter
Feb 12	Article in “Politiken” on discovery of “hot atmosphere” around Milky Way like galaxy	—	Kristian, Jesper S-L
Feb 13	Portrait article of Anja in “Ugebladet Søndag”	—	Anja
Feb 14	Guest in ”Viden Om” about black holes etc.	TV Byen	Anja
Feb 20–24	Erhvervspraktikanter from Himmelev and Frederikssund	Rockefeller	Anja
Feb 23	DARK session at NBI “Åbent Hus”	Rockefeller	Johan
Feb 23	Popular talk: “Saturn sonder” for UNF Odense	SDU	Anja
Feb 20	Article in “Frederiksborg Amts Avis”	—	Anja
Mar	Article in “Illustrerad Vetenskap”, vol. 3: “Gåtan bakom de korta gammablixtarna”	—	Jesper S.
Mar 4	Interview by “Videnskabens Verden” DR P1 about discovery of hot atmosphere around galaxy	Rockefeller	Kristian

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Mar 8	Talk: "Liv I Universet", fællestime at Ribe Seminarium & HF	Ribe (350 people)	Anja
Mar 8	Interview til ESA website on lack of women in space science	—	Anja
Mar 9	Erhvervspraktikanter at NBI: "Astro day"	Rockefeller (5 people)	Kristian
Mar 10	Popular talk for "Forskerspirer"	Rockefeller	Kristian
Mar 15	Talk: "Nyt lys over det mørke univers" for 2.g physics class from Vejen Gymnasium	Rockefeller	Kristian Anja
Mar 16	Recording of radio program: "Sommergæsten", DR P1	Café Hovedtelegraf	Anja Kristian
Mar 20	Interview in "P1 Morgen" "Pølsefabrik eller fjumreår?"	Radiohuset	Anja
Mar 20	Talk: "Kosmologi og relativitetsteori" for 2.g, Sorø Akademi	Rockefeller	Peter
Mar 21	Talk: "Spectroscopy for "gymnasium" class	Rockefeller	Peter
Mar 22	Talk: "Astrobiology" for 1.g from Haslev Gymnasium	Rockefeller	Anja
Mar 28—29	Expert on trip to total solar eclipse	Antalya, Turkey (210 people)	Kristian
Mar 30	Naturfaglig temadag: "Drenge og piger i naturfagene"	Odense (50 people)	Anja
Mar 30	"Forskning og formidling", talk for PhD students, Herbert Pris 2006,	SDU, (40 people)	Anja
Apr	Article in "Populär Astronomi", vol. 4: "Nobelpriset i Astronomi"	—	Jesper S.
Apr	Interview in magazine "Science & Devenir" about Anja and her research and public outreach	—	Anja
Apr 3	Talk: "Spektroskopi" for 3.g VUC Nord	Rockefeller (15 people)	Peter
Apr 4	Article about "Rymdens magnetiska fyrar" in "Forskning & Framsteg"	—	Jesper Sollerman
Apr 4	Article about Jesper Sollerman in "Forskning & Framsteg"	—	Jesper Sollerman
Apr 6	Popular talk: "Nyt lys over det mørke Univers"	Orion Planetarium (30 people)	Kristian
Apr 7	Article in "NBI Nyt" about total solar eclipse tour to Egypt	—	Janaki
Apr 17	Talk: "Spektroskopi" for gymnasium class	Rockefeller	Peter
Apr 25	Popular talk: "Nyt lys over det mørke Univers"	Astronomisk Forening for Køge Bugt	Kristian

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Apr 25	Participant in popular youth science TV program "Nørd" on the total eclipse March 29	Antalya, Turkey	Kristian
May 5	Talk: "Udforskning af Mars" ved "Forskningens Døgn"	Lyngby Rådhus	Anja
May 8	Talk: "Spektroskopi" for gymnasium class	Rockefeller	Peter
May 17	Participating in film about research, aiming at "gymnasiet"	Feldballe Film	Anja
May 24	Tamara Davis receives award for best PhD thesis of 2004 at University of New South Wales, Australia	University of New South Wales	Tamara
Jun 8	Talk: "Kvinder i academia"	Århus	Anja
Jun 16	Interview by "Ingeniøren" on women in permanent positions	—	Anja
Jun 15–16	Interview by national Icelandic radio on the lack of women in science and Árdís' PhD project	Rockefeller	Árdís Anja
Jun 20	Talk: "Cosmic dust – the source of life"	Reykjavik	Anja
Jun 21	Talk: "The lack of women in academia"	Reykjavik	Anja
Jul 11	Radio program DR P1, "Sommergæsten", 1.5h	Café Hovedtelegrafen	Anja Kristian
Jul 12	Talk: "Stardust missionen"	Silkeborg Højskole	Anja
Aug	Article in "FoF", vol. 8: "Tycho Brahe lever kvar"	—	Jesper S.
Aug 15	Interview about "Pluto: Planet eller ej?" Go'Morgen P3	Radiohuset	Kristian
Aug 20	Interview about "Pluto: Planet eller ej?" Berlingske	—	Kristian
Aug 22	Talk: "Astronomy at NBI" for new first year physics students	HC Ørsted Institutet	Kristian
Aug 25	Guest in DR P1 radio program "Ugen på spidsen", on IAU resolution on planet definition	Radiohuset	Anja
Aug 29	Participants in TV program "Viden Om" about dark matter	Rockefeller	Kristian Jesper S-L
Sep	Contribution to article in "Aktuel Naturvidenskab" on the 10 most significant science achievements	—	Kristian
Sep	Article in "Gamma", vol 142, physics journal on "Homochirality — The problem of left handed amino acids"	—	Anja

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Sep 1	Principal speech at opening of "Kunstakademiets Arkitektskole"	Kunstakademiets Arkitektskole (400 people)	Anja
Sep 6	Talk: "Det mørke Univers", for association of physics and chemistry teachers in Copenhagen	Rockefeller	Kristian
Sep 7	"Inspiration day" at Rørvig Kommune, talk for 8.–9. Class	Rørvig (150 pupils)	Anja
Sep 13	Talk: "Kosmologi" for 3.g. gymnasium class from Gl. Hellerup Gymnasium	Rockefeller	Peter
Sep 14	Talk: "Spektroskopi"	Dansk Naturhistorisk Forening	Peter
Sep 18	Talk for "Forskerspirer"	Krogerup Højskole (40 people)	Anja
Sep 20	Talk: "The dark Universe" for high school class from Rome	Rockefeller	Kristian Peter
Sep 20	Fællestime talk: "Life in the universe"	Ishøj Gymnasium (500 people)	Anja
Sep 21	Portrait of Anja C. Andersen in Euronews	—	Anja
Sep 21	Fællestime talk: "Life in the universe"	Varde Gymnasium (150 people)	Anja
Sep 27	Talk: "Spektroskopi" for gymnasium class	Rockefeller	Peter
Oct	Article in Biozoom: "Homochirality and the moment when life came about"	—	Anja
Oct	Article in "Geologisk Nyt": "Fra altings oprindelse – til livets opståen"	—	Anja
Oct 1–14	Contributions to exhibition at "Nationalmuseet": Tycho Brahes Verden. Workshop for Folkeskole—and Gymnasie classes	Nationalmuseet	Signe Camilla Peter Desiree Johan
Oct 1	Klumme i Politiken: "Er tyre aggressive?"	—	Anja
Oct 2	Talk: "Cosmic lighthouses and expanding horizons: How supernovae have expanded our knowledge and limited our view" at Folkeuniversitetet	Rockefeller	Tamara
Oct 7	Anja awarded TOYP 2006 prize	Haderslev	Anja
Oct 9	Talk: "Cosmic lighthouses and expanding horizons: How supernovae have expanded our knowledge and limited our view" at Folkeuniversitetet:	Matematisk Institute, AU	Tamara
Oct 9	Anja awarded Kirstine Meyers legat	Geologisk Museum	Anja
Oct 12	Artikle in "Metro": "Svensk Supernova"	—	Jesper
Oct 13	"Fysik*" lecture for 1st yr physics students: "Astronomy"	H.C. Ørsted Institute (80 students)	Anja

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Oct 16–17	”H.C.Ø. Dage” spectroscopy lab. Exercise, 13 gymnasieelever	Rockefeller	Johan
Oct 19	Talk: ”Spektroskopi” for gymnasium class	Rockefeller	Peter
Oct 23	Talks: ”Liv i Universet” and ”Det mørke Univers” for two classes from Jægerspris skole	Rockefeller (60 pupils)	Anja Kristian
Oct 23	Co-organizer of seminar on threats from space: ”Hotet från rymden”	Institut för Framtidsstudier, Stockholm (100 participants)	Jesper S.
Oct 24–26	”Fortællerum fra himlen”, 9 shows	Odense (600 pupils)	Anja
Oct 26	Popular talk: ”The dark universe”	Københavns Laborantforening	Kristian
Oct 27	NBI news story: ”Første ’svenske’ supernova”	—	Jesper S. Johan
Nov	Article in ”Folkevirke” vol. 4: ”Kosmisk støv – livets kilde	—	Anja
Nov	Portrait article in ”Ud & Se” of Anja	—	Anja
Nov 2	Talk for ”Naturfags konsulenter”	(50 people)	Anja
Nov 2	Talk: ”Kosmologi” for 3.g højniveau fysik klasse, Silkeborg Amtsgymnasium	Rockefeller	Peter
Nov 5	Klumme in Politiken on international students at DK universities	—	Kristian
Nov 9	Talk: ”Det mørke Univers” for astro gymnasium teachers	Skt. Knuds Gymnasium, Odense	Johan
Nov 10	Talk: ”Spektroskopi” for 2.g gymnasium class	Rockefeller	Peter
Nov 14	Popular talk: ”Astronomy in a flat world”, by Nobel Prize winner 2002, Riccardo Giacconi	Tycho Brahe Planetarium	Kristian
Nov 15	Talk about research at DARK and NBI gymnasium related activities for gymnasium teachers	Rockefeller	Anja Kristian
Nov 20	Talk: ”Kosmologi” for gymnasium class	Rockefeller	Peter
Nov 21	DARK lounge used for TV recording for DR2 ”Temalørdag” on time	Rockefeller	Kristian
Nov 22	Talk: ”Kosmologi” for astronomy gymnasium class from Kalundborg Gymnasium	Rockefeller	Signe
Nov 23	Expert in nanophysics at ”Eksperimentarium” arrangement	Eksperimentarium	Anja
Nov 28	TV2 interview of Anja about receiving the DR ”Rosenkjærpris”	TV2 København	Anja
Nov 30	Interview in ”Dagens Danmark” about Anja receiving ”Rosenkjærprisen”	DR TV studies Århus	Anja

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Dec 1	Anja receives the prestigious "Rosenkjær Pris" from DR	DR Byen	Anja
Dec 7	Talk: "Spektroskopi" for gymnasium class	Rockefeller	Peter
Dec 11	Talk: "Nyt lys over det mørke univers" for 3.g physics class from Det Frie Gymnasium	Rockefeller	Kristian
Dec 12	Phone interview about black hole seen "eating" star by Berlingske	—	Kristian
Dec 17	Column in Politiken: "Skal vi være de bedste i verden – eller bare i Danmark?"	—	Anja
Dec 22	Press releases from NBI, ESO, and NASA on discovery of GRBs without SNe – on occasion of Johan's Nature paper	—	Johan Jens Jesper S. Kristian
Dec 24	Column in Politiken: "Kuk i julekalenderen"	—	Kristian
Dec 30	Interview in Politiken: "Hvad er meningen?"	—	Anja

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## Appendix 6: External funding

Below we list the currently active grants held by Centre members. Amounts are in MDKK. Grants marked by a \* are not directly related to the Centre, but relevant for its activities. PIs of these grants who are not Centre members are marked by a \*.

Amount	Activity/grant type	Source	Period	Grant holder
0.7	Descartes Prize	EC	2002–08	Jens Hjorth
1.8	FP5 RTN: GRBs	EC	2002–06	Jens Hjorth
1.8	FP6 MC RTN: ANGLES	EC	2004–08	Jens Hjorth
1.0	FP6 Marie Curie Fellowship	EC	2007–09	Paul M. Vreeswijk
1.0	IDA manager: K. Pedersen	IDA	2004–07	Jens Hjorth
1.6	Steno Fellowship: L. F. Grove	FNU	2006–08	Lisbeth F. Grove
0.7	Postdoc: T. M. Davis	VKR	2005–07	Jens Hjorth
0.4	Postdoc: D. Malesani	IDA	2006–07	Jens Hjorth
0.4	Postdoc: B. Milvang–Jensen	VKR	2006–07	Bo Milvang–Jensen
2.5	Fellowship: J. Sollerman	KVA	2007–12	Jesper Sollerman
0.3	NOT Summerschool	NordForsk	2006	Jesper Sollerman
0.15	Niels Bohr Summer Institute	NBIA	2007	Steen H. Hansen
0.8	PhD stipend: K. K. Madsen	IDA+DNSC	2004–07	*Finn E. Christensen
0.4	PhD stipend: J. M. C. Cerón	FUR	2004–07	José María Castro Cerón
0.8	PhD stipend: J. M. C. Cerón	IDA	2004–07	Jens Hjorth
1.3	PhD stipend: M. Michalowski	KU	2006–09	Michal Michalowski
0.8	PhD stipend: P. Laursen	IDA/DARS	2007–10	Peter Laursen
0.4	PhD stipend: K. Nilsson	IDA	2004–07	Johan Fynbo
0.8	ESO studentship: K. Nilsson	ESO	2005–07	Kim Nilsson
0.4	NOT studentship: D. Paraficz	NOT	2006–07	Danuta Paraficz
0.1	VISTA filter	IDA	2007	Johan Fynbo
15.0	*Instrument Center: IDA	FNU	2004–07	Jens Hjorth
6.9	*PhD school: DARS	FUU	2006–11	*Steen Hannestad
5.6	*X–shooter construction	Carlsberg	2004–08	*Per K. Rasmussen

Centre members applied for the following grants in 2006 which were not awarded:

Kristian Pedersen applied for co-funding of a postdoc from a space science call under the Danish Natural Sciences Research Council (value ~600 kDKK; 2006–2007). The application was rejected on grounds that “there has already been allocated sufficient funds to this area”.

Bo Milvang-Jensen’s applications to the Carlsberg Foundation and the Danish Natural Sciences Research Council for 2–3 year postdoc positions starting in 2007 were rejected.

Jesper Sollerman and Johan Fynbo applied for 5-year European Young Investigator Awards (1.2 MEuro, starting in 2007). Jesper Sollerman made it to the final, but none were funded.



## Appendix 7: Publications 2006

### Refereed papers:

We here provide a list of the research articles that appeared in international journals in 2006. *All of these papers are peer-reviewed.* All are directly related to the main themes of the Centre. Centre affiliates are indicated in bold face. A hyperlinked version (with links to the source paper and bibliographic/bibliometric information) of this list is available at the Centre website (<http://www.dark-cosmology.dk>) along with lists of preprints, conference proceedings, circulars etc.

1. **K. Pedersen**, K. Hurley, **J. Hjorth**, D. A. Smith, M. I. Andersen, L. Christensen, T. Cline, **J. P. U. Fynbo**, J. Goldsten, S. Golenetskii, J. Gorosabel, **P. Jakobsson**, **B. L. Jensen**, B. Milvang-Jensen, T. McClanahan, P. Møller, V. Palshin, N. Scharrel, J. Trombka, M. Ulanov, and **D. Watson**: “Multiwavelength Studies of the Optically Dark Gamma-Ray Burst 001025A”, *Astrophysical Journal* **636**, 381–390 (2006).
2. **D. Watson**, S. A. Vaughan, R. Willingale, **J. Hjorth**, S. Foley, **J. P. U. Fynbo**, **P. Jakobsson**, A. Levan, P. T. O'Brien, J. P. Osborne, **K. Pedersen**, J. N. Reeves, J. A. Tedds, and M. G. Watson: “The Soft X-Ray Blast in the Apparently Subluminous GRB 031203”, *Astrophysical Journal* **636**, 967–970 (2006).
3. P. M. Vreeswijk, A. Smette, A. S. Fruchter, E. Palazzi, E. Rol, R. A. M. J. Wijers, C. Kouveliotou, L. Kaper, E. Pian, N. Masetti, F. Frontera, **J. Hjorth**, J. Gorosabel, L. Piro, **J. P. U. Fynbo**, **P. Jakobsson**, **D. Watson**, P. T. O'Brien, and C. Ledoux: “Low-resolution VLT spectroscopy of GRBs 991216, 011211 and 021211”, *Astronomy and Astrophysics* **447**, 145–156 (2006).
4. **D. Watson**, J. N. Reeves, **J. Hjorth**, **J. P. U. Fynbo**, **P. Jakobsson**, **K. Pedersen**, **J. Sollerman**, **J. M. Castro Cerón**, S. McBreen, and S. Foley: “Outshining the Quasars at Reionization: The X-Ray Spectrum and Light Curve of the Redshift 6.29 Gamma-Ray Burst GRB 050904”, *Astrophysical Journal* **637**, L69–L72 (2006).
5. S. Foley, **D. Watson**, J. Gorosabel, **J. P. U. Fynbo**, **J. Sollerman**, S. McGlynn, B. McBreen, and **J. Hjorth**: “The galaxies in the field of the nearby GRB 980425/SN 1998bw”, *Astronomy and Astrophysics* **447**, 891–895 (2006).
6. **P. Jakobsson**, A. Levan, **J. P. U. Fynbo**, R. Priddey, **J. Hjorth**, N. Tanvir, **D. Watson**, **B. L. Jensen**, **J. Sollerman**, P. Natarajan, J. Gorosabel, **J. M. Castro Cerón**, **K. Pedersen**, T. Pursimo, A. S. Árnadóttir, A. J. Castro-Tirado, C. J. Davis, H. J. Deeg, D. A. Fiuza, S. Mykolaitis, and S. G. Sousa: “A mean redshift of 2.8 for Swift gamma-ray bursts”, *Astronomy and Astrophysics* **447**, 897–903 (2006).
7. K. I. Nishikawa, P. E. Hardee, **C. B. Hededal**, and G. J. Fishman: “Acceleration Mechanics in Relativistic Shocks by the Weibel Instability”, *Astrophysical Journal* **642**, 1267–1274 (2006).
8. D. Bersier, A. S. Fruchter, L.-G. Strolger, J. Gorosabel, A. Levan, I. Burud, J. E. Rhoads, A. C. Becker, A. Cassan, R. Chornock, S. Covino, R. S. de Jong, D. Dominis, A. V. Filippenko, **J. Hjorth**, J. Holmberg, D. Malesani, B. Mobasher, K. A. G. Olsen, M. Stefanon, **J. M. Castro Cerón**, **J. P. U. Fynbo**, S. T. Holland, C. Kouveliotou, H. Pedersen, N. R. Tanvir, and S. E. Woosley: “Evidence for a Supernova Associated with the X-Ray Flash 020903”, *Astrophysical Journal* **643**, 284–291 (2006).
9. M. Pozzo, W. P. S. Meikle, J. T. Rayner, R. D. Joseph, A. V. Filippenko, R. J. Foley, W. Li, S. Mattila, and **J. Sollerman**: “Optical and infrared observations of the Type IIP SN2002hh from days 3 to 397”, *Monthly Notices of the Royal Astronomical Society* **368**, 1169–1195 (2006).
10. A. S. Fruchter, A. J. Levan, L. Strolger, P. M. Vreeswijk, S. E. Thorsett, D. Bersier, I. Burud, **J. M. Castro Cerón**, A. J. Castro-Tirado, C. Conselice, T. Dahlen, H. C. Ferguson, **J. P. U. Fynbo**, P. M. Garnavich, R. A. Gibbons, J. Gorosabel, T. R. Gull, **J. Hjorth**, S. T. Holland, C. Kouveliotou, Z. Levay, M. Livio, M. R. Metzger, P. E. Nugent, L. Petro, E. Pian, J. E. Rhoads, A. G. Riess, K. C. Sahu, A. Smette, N. R. Tanvir, R. A. M. J. Wijers, and S. E. Woosley: “Long  $\gamma$ -ray bursts and core-collapse supernovae have different environments”, *Nature* **441**, 463–468 (2006).

11. **K. Pedersen**, J. Rasmussen, **J. Sommer-Larsen**, S. Toft, A. J. Benson, and R. G. Bower: “Discovery of a very extended X-ray halo around a quiescent spiral galaxy – The “missing link” of galaxy formation”, *New Astronomy* **11**, 465–470 (2006).
12. **J. P. U. Fynbo**, R. L. C. Starling, C. Ledoux, K. Wiersema, **C. C. Thöne**, **J. Sollerman**, **P. Jakobsson**, **J. Hjorth**, **D. Watson**, P. M. Vreeswijk, P. Möller, E. Rol, J. Gorosabel, J. Näränen, R. A. M. J. Wijers, G. Björnsson, **J. M. Castro Cerón**, P. Curran, D. H. Hartmann, S. T. Holland, **B. L. Jensen**, A. J. Levan, **M. Limousin**, C. Kouveliotou, G. Nelemans, **K. Pedersen**, R. S. Priddey, and N. R. Tanvir: “Probing cosmic chemical evolution with gamma-ray bursts: GRB 060206 at  $z = 4.048$ ”, *Astronomy and Astrophysics* **451**, L47–L50 (2006).
13. **L. F. Olsen**, J.-M. Miralles, L. da Costa, C. Benoist, B. Vandame, R. Rengelink, C. Rité, M. Scodreggio, R. Slijkhuis, A. Wicenec, and S. Zaggia: “ESO imaging survey: infrared observations of CDF-S and HDF-S”, *Astronomy and Astrophysics* **452**, 119–129 (2006).
14. **K. K. Nilsson**, **J. P. U. Fynbo**, P. Möller, **J. Sommer-Larsen**, and C. Ledoux: “A Lyman- $\alpha$  blob in the GOODS South field: evidence for cold accretion onto a dark matter halo”, *Astronomy and Astrophysics* **452**, L23–L26 (2006).
15. K. Heng, R. McCray, S. A. Zhekov, P. M. Challis, R. A. Chevalier, A. P. S. Crotts, C. Fransson, P. Garnavich, R. P. Kirshner, S. S. Lawrence, P. Lundqvist, N. Panagia, C. S. J. Pun, N. Smith, **J. Sollerman**, and L. Wang: “Evolution of the Reverse Shock Emission from SNR 1987A”, *Astrophysical Journal* **644**, 959–970 (2006).
16. **J. Sommer-Larsen**: “Where Are the ‘Missing’ Galactic Baryons?”, *Astrophysical Journal* **644**, L1–L4 (2006).
17. **S. Riemer-Sørensen**, S. H. Hansen, and **K. Pedersen**: “Sterile Neutrinos in the Milky Way: Observational Constraints”, *Astrophysical Journal* **644**, L33–L36 (2006).
18. **J. Sommer-Larsen**: “Properties of intra-group stars and galaxies in galaxy groups: ‘normal’ versus ‘fossil’ groups”, *Monthly Notices of the Royal Astronomical Society* **369**, 958–968 (2006).
19. S. I. Blinnikov, F. K. Röpkke, E. I. Sorokina, M. Gieseler, M. Reinecke, C. Travaglio, W. Hillebrandt, and **M. Stritzinger**: “Theoretical light curves for deflagration models of type Ia supernova”, *Astronomy and Astrophysics* **453**, 229–240 (2006).
20. **A. C. Andersen**, H. Mutschke, T. Posch, M. Min, and A. Tamanai: “Infrared extinction by homogeneous particle aggregates of SiC, FeO and SiO<sub>2</sub>: Comparison of different theoretical approaches”, *Journal of Quantitative Spectroscopy and Radiative Transfer* **100**, 4–15 (2006).
21. **J. Sollerman**, A. O. Jaunsen, **J. P. U. Fynbo**, **J. Hjorth**, **P. Jakobsson**, **M. Stritzinger**, **C. Féron**, **P. Laursen**, J.-E. Ovaldsen, J. Selj, **C. C. Thöne**, **D. Xu**, **T. Davis**, J. Gorosabel, **D. Watson**, R. Duro, I. Ilyin, **B. L. Jensen**, N. Lysfjord, T. Marquart, T. B. Nielsen, J. Näränen, H. E. Schwarz, S. Walch, M. Wold, and G. Östlin: “Supernova 2006aj and the associated X-Ray Flash 060218”, *Astronomy and Astrophysics* **454**, 503–509 (2006).
22. **D. Watson**, **J. Hjorth**, **P. Jakobsson**, **D. Xu**, **J. P. U. Fynbo**, **J. Sollerman**, **C. C. Thöne**, and **K. Pedersen**: “Are short gamma-ray bursts collimated? GRB 050709, a flare but no break”, *Astronomy and Astrophysics* **454**, L123–L126 (2006).
23. E. Maiorano, N. Masetti, E. Palazzi, S. Savaglio, E. Rol, P. M. Vreeswijk, E. Pian, P. A. Price, B. A. Peterson, M. Jelínek, L. Amati, M. I. Andersen, A. J. Castro-Tirado, **J. M. Castro Cerón**, A. de Ugarte Postigo, F. Frontera, A. S. Fruchter, **J. P. U. Fynbo**, J. Gorosabel, A. A. Henden, **J. Hjorth**, **B. L. Jensen**, S. Klose, C. Kouveliotou, G. Masi, P. Möller, L. Nicastro, E. O. Ofek, S. B. Pandey, J. Rhoads, N. R. Tanvir, R. A. M. J. Wijers, and E. P. J. van den Heuvel: “Physics of the GRB 030328 afterglow and its environment”, *Astronomy and Astrophysics* **455**, 423–431 (2006).
24. **D. Paraficz**, **J. Hjorth**, I. Burud, **P. Jakobsson**, and **Á. Elíasdóttir**: “Microlensing variability in time-delay quasars”, *Astronomy and Astrophysics* **455**, L1–L4 (2006).
25. A. Levan, A. Fruchter, J. Rhoads, B. Mobasher, N. Tanvir, J. Gorosabel, E. Rol, C. Kouveliotou, I. Dell’Antonio, M. Merrill, E. Bergeron, **J. M. Castro Cerón**, N. Masetti, P. Vreeswijk, A. Antonelli, D. Bersier, A. Castro-Tirado, **J. Fynbo**, P. Garnavich, S. Holland, **J. Hjorth**, P. Nugent, E. Pian, A. Smette, B. Thomsen, S. E. Thorsett, and R. Wijers: “Infrared and Optical Observations of GRB 030115 and its Extremely Red Host Galaxy: Implications for Dark Bursts”, *Astrophysical Journal* **647**, 471–482 (2006).

26. J. B. James, **T. M. Davis**, B. P. Schmidt, and A. G. Kim: “Spectral diversity of Type Ia supernovae”, *Monthly Notices of the Royal Astronomical Society* **370**, 933–940 (2006).
27. E. Pian, P. A. Mazzali, N. Masetti, P. Ferrero, S. Klose, E. Palazzi, E. Ramirez-Ruiz, S. E. Woosley, C. Kouveliotou, J. Deng, A. V. Filippenko, R. J. Foley, **J. P. U. Fynbo**, D. A. Kann, W. Li, **J. Hjorth**, K. Nomoto, F. Patat, D. N. Sauer, **J. Sollerman**, P. M. Vreeswijk, E. W. Guenther, A. Levan, P. O’Brien, N. R. Tanvir, R. A. M. J. Wijers, C. Dumas, O. Hainaut, D. S. Wong, D. Baade, L. Wang, L. Amati, E. Cappellaro, A. J. Castro-Tirado, S. Ellison, F. Frontera, A. S. Fruchter, J. Greiner, K. Kawabata, C. Ledoux, K. Maeda, P. Møller, L. Nicastro, E. Rol, and R. Starling: “An optical supernova associated with the X-ray flash XRF 060218”, *Nature* **442**, 1011–1013 (2006).
28. **L. F. Olsen**, J.-M. Miralles, L. da Costa, R. Madejsky, H. E. Jensen, A. Mignano, S. Arnouts, C. Benoist, J. P. Dietrich, R. Slijkhuis, and S. Zaggia: “ESO imaging survey: infrared deep public survey”, *Astronomy and Astrophysics* **456**, 881–893 (2006).
29. A. J. Levan, N. R. Tanvir, A. S. Fruchter, E. Rol, **J. P. U. Fynbo**, **J. Hjorth**, G. Williams, E. Bergeron, D. Bersier, M. Bremer, T. Grav, **P. Jakobsson**, K. Nilsson, E. Olszewski, R. S. Priddey, D. Rafferty, and J. Rhoads: “The Faint Afterglow and Host Galaxy of the Short-Hard GRB 060121”, *Astrophysical Journal* **648**, L9–L12 (2006).
30. W. P. S. Meikle, S. Mattila, C. L. Gerardy, R. Kotak, M. Pozzo, S. D. van Dyk, D. Farrah, R. A. Fesen, A. V. Filippenko, C. Fransson, P. Lundqvist, **J. Sollerman**, and J. C. Wheeler: “A Spitzer Space Telescope Study of SN 2002hh: An Infrared Echo from a Type IIP Supernova”, *Astrophysical Journal* **649**, 332–344 (2006).
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- \*16. **Kristian Pedersen:** “Alma kan gavne Danmark – hvis hun da får en chance”, column in *Politiken*, 5 Nov. (2006).
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## Appendix 8: Quantitative measures and bibliometric analysis

It is interesting to contrast the aims of a research centre and what it considers its benchmarks: is it quality, quantity and overall impact of the centre compared to national research groups, the international scientific community (i.e. is the centre competitive with groups in other countries publishing in high-impact international journals), or a comparison to the top research groups at the world's best institutions (a comparison that may be unreasonable given the historical prestige advantage and large financial weight of such institutions)? Data for such benchmarks and performance assessments are easier to obtain in some fields than others, though the results are almost always subject to controversy. In astrophysics, data on citation rates and numbers of articles are relatively easy to obtain and so the Centre can and does analyse its own performance in this regard. For instance, we have produced a comparison between the citation rates of papers by the Centre and some of the major astronomical institutes normalized by the international average (Fig. 8.1)

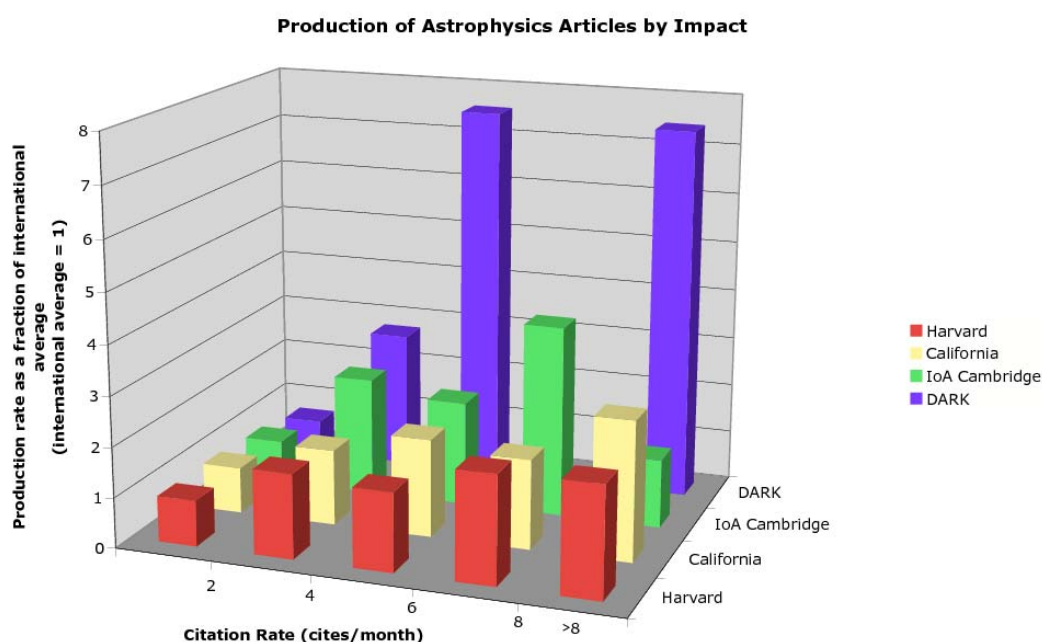


Figure 8.1 Production rate of articles as a function of citation rate normalized by the international average. The top institutions in the world have clearly outperformed the international average (rates greater than 1). The Centre (DARK) has had a striking first eighteen months with an enormously high production of very highly cited papers

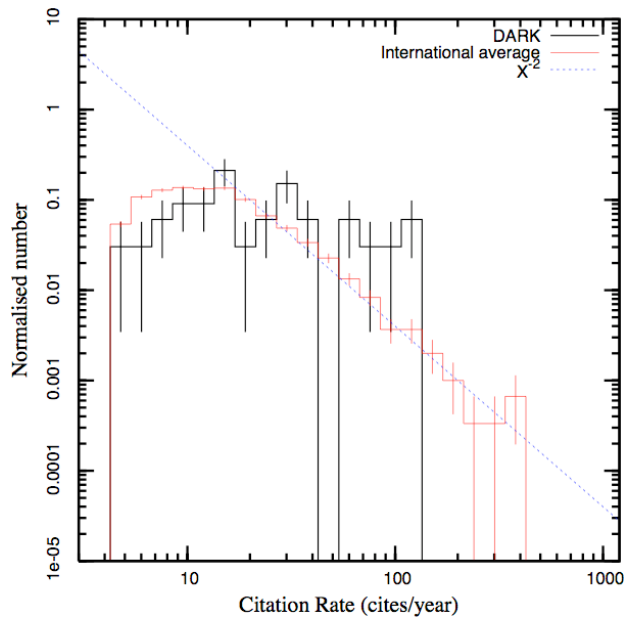
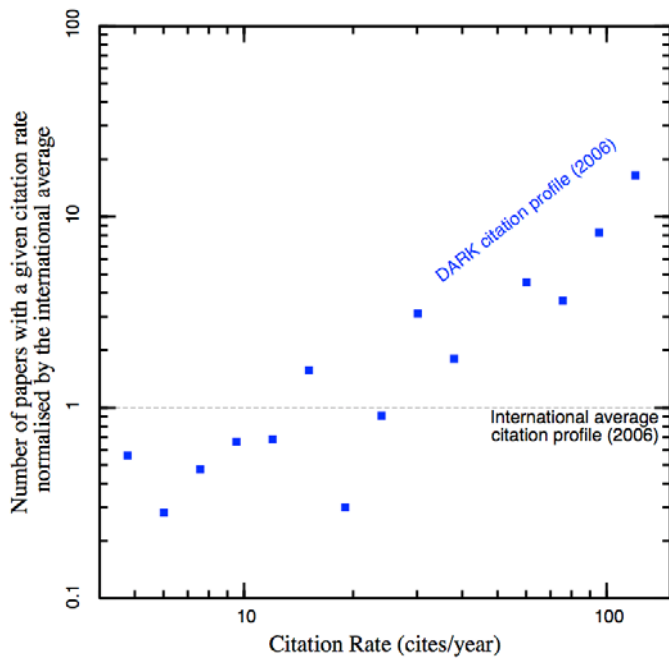


Figure 8.2 Distribution of papers by citation rate for the international astronomical community and DARK. A flatter slope suggests higher quality publications.

So far our thinking on statistics related to scientific performance has led us to consider different indicators. One of these is the h-index as proposed by Jorge Hirsch (*PNAS* **102**, 16569, 2005). This indicator is easy to obtain and is designed simultaneously as a measure of both quality and quantity, since a small number of very highly cited works (e.g. methods papers) may skew mean citation rates, and a large number of papers indicates only a lot of (possibly mundane) publications. A “first author h-index” may be produced by looking only at papers where the author is the principle (first) author, thus eliminating bias introduced by papers with many authors. For groups, a h-index of the group as a whole may be produced, eliminating inflation of statistics by having every group member on every paper. This can then be relatively easily normalized by the number of group members or by the investment made in the group (whichever quantity is the most relevant in terms of value).

A more sophisticated analysis of citation statistics leads to the fact that each group or individual has a number of papers with a distribution of citations. Often this is believed to be a power-law ( $n \propto c^{-\alpha}$ ), with many low-cited papers and very, very few papers with a high citation rate. The normalization of such a power-law would then be an indicator of productivity and the slope would be a measure of quality, with a flatter slope suggesting more highly-cited papers, and a steep slope indicating that the distribution is more dominated by papers with low citation rates. We have produced such a plot for DARK papers and for all papers published in the journals in which the Centre has published this year (to establish a benchmark based on the international, peer-reviewed literature) as an example (Fig. 8.2). We have normalized the absolute values so that the plots are comparable in this case. In general however, groups with similar funding profiles may be compared in this way in terms of normalization (quantity) as well as slope (quality). It is worth noting that the h-index is roughly the pivot point of these power-laws, showing that it gives a similar, though less detailed, result. For the time being this plot indicates that such an analysis may be attempted after only a year, though the statistics are clearly not excellent.

Of course, different disciplines are not readily comparable in this way since citation statistics and number of papers are very different in different areas of science. However, by normalizing by the papers published in that field to obtain an international benchmark in each case, a version of this analysis may be obtained which should be comparable since it shows 1) what fraction of the total papers in the field are produced by the group or individual in question and 2) what the quality profile of the group/individual in question is relative to the international average in that field. We have produced such a plot below (Fig. 8.3), though it is normalized, so in this preliminary study we only get information on the relative slope (quality). It is clear in this case that the slope is steeply positive, indicating a much higher rate of highly cited papers than the international peer-reviewed average for DARK publications in 2006.



The ideas expressed above are thoughts on the most effective way to use citation statistics to try to measure scientific output in an increasingly demanding and competitive environment and as yet are still incomplete.

Figure 8.3 Distribution of DARK papers by citation rate normalised by the international average. A positive slope (as shown) indicates a higher impact than the international average.