Danish National Research Foundation’s
Dark Cosmology Centre at the Niels Bohr Institute,
University of Copenhagen

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Front Cover Image:
Illustration shows a star exploding as a gamma-ray burst in the early Universe. Artistic rendering: European Southern Observatory (ESO)
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1. Highlights of the Year

Most distant object in the Universe

Researchers at the Centre were involved in the discovery of the most distant object known in the Universe, a gamma-ray burst which exploded just 600 million years after the Big Bang. The ten-second gamma-ray burst was detected by NASA’s Swift satellite in the morning of Thursday, 23 April, and was then followed by a series of telescopes on Earth, both the Nordic Optical Telescope, NOT on La Palma and ESO’s Very Large Telescope, VLT in Chile. In related work, a study of spectra of no less than 77 gamma-ray burst afterglows, was published.

Landmarks

Researchers affiliated to the Centre published a record number of 81 papers in refereed, international journals. The Faculty of Science granted the PhD degree to four students from Centre who subsequently moved on to take up postdoctoral positions at the Weizmann Institute, University College London, University of Queensland, and at the Royal Observatory, Edinburgh.

Disappearing stars

Brahe Fellow Justyn Maund showed in a Science paper that our notion of the origin of supernovae is correct: he showed that two supernovae originated from stars seen in pre-explosion images which are now gone. In a highly cited review he laid out what we know about progenitors of supernova. In related work, other researchers published the first results from the Sloan Digital Sky Survey II supernova survey and imposed new constraints on cosmological parameters.

The geometry of the Universe from gravitationally lensed quasars

Massive galaxies can deflect the light from distant sources, in some cases leading to double or quadruple images of the same quasar. Scientists at the Centre devised new methods for determining cosmological parameters using the differences in arrival times for the light of the different images. New constraints on the scale of the Universe was obtained, whereas measurement of the geometry and content of dark energy requires future observations.

The collisionless nature of dark matter

Normal matter such as a gas of particles achieves equilibrium through energy exchange via collisions between the particles. It is widely believed that dark matter does not behave in this way. This was explicitly demonstrated for the first time through the measurement of dark matter velocity anisotropy in a sample of clusters of galaxies, showing that dark matter particles have a slight preference for moving along radial orbits over tangential orbits.

Understanding dust

The Centre held a conference on 'Current Problems in Extragalactic Dust', which brought together most experts in the world on one of the Centre’s main themes. The meeting, held at the Niels Bohr International Academy at the end of June, very successfully met its principal aim of addressing outstanding questions in understanding extragalactic dust, and allowing DARK researchers to set up new collaborations. Many important findings on cosmic dust were published.
in 2009, including theoretical work on the sources of early dust formation (AGB stars and supernovae), the detection of the 2175 Å feature at the highest redshift so far, and work to derive dust masses and estimate the sources of dust in high-redshift sub-mm galaxies.

**Space Science Centre**

In 2008, the University of Copenhagen Faculty of Science named DARK associate professor, Kristian Pedersen, leader of a new initiative. The Space Science Center encompasses more than 100 researchers at the Faculty of Science who are using space as a platform for science. DARK is a member of the Centre.

Evaluation panel:
"...the DARK Cosmology Centre has rapidly established itself as a leading, world-class group working at the forefront of cosmology. The Centre has carried out an impressively wide variety of cutting-edge research, has taken the lead in several fields of central current interest, has created a dynamic group of great importance to Danish Science, and has led the field in innovative, effective, management and education."

**Looking ahead...**

The Centre was successfully evaluated and granted a second 5-year period (2010-2015). Both new core scientific staff (Sune Toft on a Lundbeck Junior Group Leader grant from the Lundbeck Foundation and Marianne Vestergaard, Freja Fellow and associate professor) and administrative staff (centre coordinator Michelle Cumming Løkkegaard, administrative assistant Corinne Toulouse-Aastrup, and office assistant Sarah Pearson) arrived.

The group of postdoctoral researchers was expanded by the arrivals of Andrew Zirm and Berian James.

2. **Organization**

Due to an increase in external funding the need for additional and more professional administrative staff was acted upon, resulting in the hiring of a Centre coordinator, Michelle Cumming Løkkegaard, and additional secretarial staff, Sarah Pearson and Corinne Toulouse-Aastrup. Major decisions continue to be discussed and made at weekly faculty meetings, and the Centre coordinator has taken over many responsibilities, allowing the senior researchers to focus more on research.

The intranet and weekly newsletter function as the Centre’s main internal communications vehicles, and all staff also share information and events using the Centre’s shared calendar system. Organised discussion of recent arXiv preprints occurs every morning Monday–Thursday over coffee at 11 o’clock in the Centre’s lounge; on Fridays, the discussions are reserved for coffee and interaction with the other astrophysics research groups at Niels Bohr Institute. The PhD students run a popular weekly DARK Cake Meeting, which is a seminar series enjoyed with cake and coffee.

The second Sophie and Tycho Brahe Fellow, Berian James, joined the Centre in September. During his fellowship, he will maintain a strong interaction with University of California at Berkeley, where he will work for the third year of his fellowship. Marie Curie Fellow Paul Vreeswijk extended his stay at the Centre at the end of his fellowship term.

The Centre is now a major training site for young researchers, and many of the PhD students who started at the beginning of the Centre’s funding period are finishing, with four graduating in 2009. One new PhD student, Stefan Geier (German) started in December 2009, and the Centre launched a major search for new PhD students who will begin their studies in 2010.
3. Research 2009

In this section we briefly address progress on the 2009 milestones (see boxes). We next provide some supplementary comments on the key projects, and finally we list 2010 milestones.

### 2009 Research Goals and Milestones

#### Probing the end of the dark ages

1. Completion of major work on spectroscopy of GRB afterglows using data accumulated over the past several years.
   A major paper reporting low-resolution spectroscopy of a large sample of GRB afterglows was published (Fynbo et al. 2009). The discovery of the most distant known object was announced (Tanvir et al. 2009).

2. Submit the first four survey papers based on the GRB host program for publication in refereed journals.
   This goal was not met. Progress was made and the intention is to submit the four papers in 2010.

3. Approval of the JANUS mission for launch.
   JANUS was not selected for launch. The collaboration is still alive and JANUS will be submitted for the next NASA announcement of opportunity.

#### Supernova cosmology

4. Submission of paper on the final dataset from ESSENCE (almost 200 supernovae), which will conclude this major endeavour.
   The paper is now in preparation and will be submitted in the 1st half of 2010

5. Submission of paper on the first-year data (71 SNe Ia at intermediate redshifts) from the SDSS II search.
   This will include a cosmological analysis, and a DARK XMM-shooter discussion more exotic cosmological models.
   This work was submitted and published (Sollerman et al. 2009).

6. Investigate how much of the dust budget in the early universe can be contributed by intermediate mass stars.
   One paper was published (Valiante et al. 2009), one was submitted for publication and included in a PhD thesis (Michalowski et al. 2009). A comprehensive study is underway and will be part of Gall's PhD thesis.

#### The nature of dark matter

7. Initiate a thorough statistical analysis of a set of X-ray observed galaxy clusters, with the purpose of distinguishing between various predicted dark matter profiles.
   This thorough statistical analysis was performed, and a paper (Hoel & Hansen) was submitted.

8. Use high-resolution numerically simulated data to test to which extent one can predict the shape of the velocity distribution function, with the purpose of deriving the velocity anisotropy.
   This study was performed, and the answer was affirmative. The results were published (Hansen 2009).

9. Use the XMM-Newton pipeline to study biases and scatter in X-ray methods for measuring cluster mass profiles.
   This study is on-going and results will be presented as part of Ferreira's PhD thesis.

#### Smaller and more risky projects

10. Produce the extinction curve of one of the most distant GRBs, 050904. Produce the absolute extinction curve using the data from the Spitzer target of opportunity observation triggered in 2008. Re-examine the evidence for unusual extinction curves at high redshift, publishing our results in 2009.
    A paper on the extinction curve on GRB 050904 was submitted and accepted for publication and will be published in 2010 (Zafar et al. 2010). No progress has been made on deriving absolute extinction curves using Spitzer data. The data on the high-redshift QSO extinction curves has been re-examined. A strategy has been devised using further observations to determine this question once and for all, with observing proposals to be submitted this year.

11. The first mid-infrared spectrum and the first observationally complete SED of a GRB host galaxy (HG031203) will be published in 2009. Publish modelling of a sample of sub-mm–selected galaxies.
    The data on HG 031203 were not published and are still being worked on. An X-shooter spectrum on the same galaxy has been acquired and will allow a more comprehensive analysis of the spectral energy distribution to be made in combination with the Spitzer spectra. Two comprehensive papers on SED modeling of sub-mm galaxies were accepted for publication and included in the PhD thesis of Michalowski.

12. Obtain a first measure of the temperature, density, gas mass and total mass fraction at large cluster-centric distances of at least one cluster by combining X-ray, SZ, and gravitational lensing data.
    The data analysis procedures have been set up and qualified on data from numerical simulations. Combined X-ray and gravitational lensing studies of two clusters will be published in 2010.

13. Study the feasibility of using time delays and lens velocity dispersions to determine cosmological parameters. Measure time delays and prepare for measurement of velocity dispersions.
    This work was published (Paraficz & Hjorth 2009). One time delay was measured (Paraficz et al. 2009). An observing proposal for X-shooter measurement of the velocity dispersion of a high-redshift gravitational lens was accepted but canceled due to technical problems. It will be re-proposed in 2010.

14. Prepare for future lensing programs, leading up to the proposed second period, through a small lensing thinkshop or extended visits by collaborators.
    Several lensing experts visited the Centre and collaborations were established on HST, JWST, and X-shooter observations of cluster lensing.
Key Project 1: Probing the End of the Dark Ages

Studying the dark ages is a very challenging task and will continue to be so for the coming decade. At the Centre, we investigate the sources that ended the dark ages by studying distant gamma-ray bursts (GRBs) and distant Lyman-α emitting galaxies. Lyman-α emission is the result of hydrogen gas that recombinates after having been ionized by hot stars. The first galaxies were full of hydrogen gas and hot stars, so the Lyman-α emission line is expected to be very strong from these objects.

On April 23, the most distant GRB and the most distant object known in the Universe to date was detected (redshift 8.2) and DARK played an important role in this pioneering work. Dark staff members Fynbo, Hjorth, Maund, Sollerman, and Watson co-authored the work, which was published in Nature.

Unfortunately, the proposed NASA SMEX mission called JANUS (Joint Astrophysics Nacent Universe Satellite) was not selected for launch, but we are now working on improving the mission for a future launch opportunity. The purpose of JANUS is to detect the most distant GRBs and quasars.

The UltraVISTA survey will detect Lyman-α galaxies at redshift \( z = 8.8 \). The survey is co-led by DARK faculty member Johan Fynbo. As anticipated in our latest annual report, the UltraVISTA survey started in December 2009. The survey is progressing according to plan and will be completed in 2014/15. The X-shooter spectrograph at the ESO VLT is functioning within specifications. DARK has access to 33 guaranteed nights (GTO) with X-shooter 2009–2012, and at least a third of those nights will be used on projects that advance the science of the dark ages.

Key Project 2: Supernova Cosmology

The year was spectacular in many respects for supernova science. The most exciting result was the discovery by Maund et al. (2009a) and Smartt et al. of the missing link between red supergiant stars and their supernovae, providing a deeper understanding of how massive stars die. But the 2009 papers by Leloudas et al., Patat et al., Maund et al. (2009b), Pastorello et al., Kotak et al., Malesani et al., and Hunter et al. also added to the understanding of the formation and evolution of supernova.

To determine the expansion history of the Universe three major supernova surveys, ESSENCE, SDSS II and SNLS have been initiated. The aim of the surveys is to determine the relationship between the light-curve shape and luminosity of a particular type of supernova (type SN Ia), used to establish the luminosity distance as a function of redshift. The first four years of the ESSENCE survey was presented in Foley et al. and included a total sample of 329 spectra of 274 objects and the first year of the SDSS II survey presenting measurements of the Hubble diagram for 103 supernovae. The importance of the SDSS II survey is that these data fill in the redshift "desert", between low- and high-redshift supernova surveys (Kessler et al. 2009). The results from both surveys were used (Sollerman et al. 2009) together with observation of the cosmic microwave background and baryon acoustic oscillations to constrain cosmological models.

To do initial investigations of whether stellar sources can account for the more than 100 million solar masses of dust inferred from mm/sub-mm observations of samples of \( 5 < z < 6.4 \) quasars, Valiante et al. 2009 developed a chemical evolution model to follow the evolution of metals and...
dust on the stellar characteristic lifetimes, taking into account dust destruction mechanisms. This first rough estimate gave a clear indication that stars with masses in the range too low to become supernovae, can contribute at these high redshifts, disproving previous assumptions. Gall is currently investigating this in much more detail as part of her PhD thesis.

Elíasdóttir et al. (2009) reported for the first time the clear detection of the 2175 Å dust absorption feature in the optical afterglow spectrum of the gamma-ray burst GRB 070802 at a redshift of $z = 2.45$. This is the highest redshift 2175 Å dust bump detected to date, and it is the first clear detection of the 2175 Å bump in a GRB host galaxy, while several tens of optical afterglow spectra without the bump have been recorded in the past decade. To find what essentially looks like a Milky Way twin galaxy in the young Universe was rather surprising and indicates that the general assumption about how metallicity develops with redshift might be more complex than generally assumed.

**Key Project 3: The Nature of Dark Matter**

Numerical simulations have for the last 15 years found that the dark matter velocity anisotropy is non-zero, indicating that the equilibration of dark matter structures proceeds in a fashion very different from normal gasses. We have successfully observed the radial profile of the velocity anistropy in galaxy clusters for the first time (Host et al. 2009), and our observations are in excellent agreement with numerical predictions. We have also presented the first analytically-derived velocity anisotropy (Hansen 2009), which provides physical insight into the origin of this counter-intuitive behaviour of dark matter.

The gas profile in galaxy clusters has been observed for many years; however, no accurate analytical prediction exists. We have presented a derivation of the gas profiles (Frederiksen et al. 2009), which is in nice agreement with observations, suggesting that all gas properties are derivable directly from the gravitationally dominating dark matter profiles.

The particle nature of dark matter was investigated by performing the first X-ray analysis of a dwarf galaxy (Riemer-Sørensen & Hansen 2009). Such dwarf galaxies are totally dark matter dominated and very nearby, which makes them excellent sites for searching for an X-ray signature of decaying dark matter particles.

The discrepancy between masses of clusters derived from X-ray observations and gravitational lensing was investigated using the cluster Abell 1689 as a case study (Riemer-Sørensen et al. 2009). Based on the excellent data for this cluster some new substructures were identified, and when excluding these, the X-ray-derived and lensing-masses agree.

Work is ongoing to unveil the three-dimensional structure of galaxy clusters, which could potentially resolve the discrepancy between X-ray and lensing masses. We are also working towards a detailed statistical analysis of dark matter mass profiles for a full sample of equilibrated galaxy clusters.

**Smaller/Risky Projects**

An analysis of the spectral energy distributions of sub-mm galaxies was completed, including an assessment of the dominant dust-sources in the highest-redshift sub-mm-selected galaxies. This work resulted in two papers to be published in 2010, and the PhD thesis of Michalowski on the modelling of sub-mm galaxies.

Gravitational lensing came strongly to the fore in 2009, with the publication of many papers related to understanding dark matter haloes using strong-lensing in galaxy clusters (Limousin et al. 2009a,b; Richard et al. 2009), and the exciting prospect of measuring cosmological parameters using galaxy-lenses (Paraficz et al. 2009; Paraficz & Hjorth 2009, Dobke et al. 2009), which resulted in the successful conclusion of the PhD thesis of Paraficz. An automated search for the rare disk-galaxy lenses was developed and applied to the SDSS, finding two new examples of these systems.
Cosmological simulations of Lyα radiative transfer in galaxies came to fruition this year with two papers. The first showing the escape fraction and effects of scattering of the line on the emission properties of the galaxy and the Lyα line (Laursen et al. 2009a). The second taking into account the effects of dust in such galaxies (Laursen et al. 2009b).

X-ray observations of two, massive Milky Way-like galaxies were re-analyzed (with the newest calibrations) in order to search for a hot corona around these galaxies (Rasmussen et al. 2009). No hot coronae were found and based on the upper limits on the coronal X-ray emission constraints on galaxy formation scenarios were derived by comparison to detailed numerical simulations of galaxy formation an evolution.

**2010 Research Goals and Milestones**

| 1. | Continue 100 GRB X-shooter survey |
| 2. | Attempt first redshift determination of z > 7 galaxies with X-shooter |
| 3. | Finalize four survey papers on GRB host galaxies |
| 4. | Obtain and reduce the first UltraVISTA data |
| 5. | Establish membership of international collaborations on space missions JANUS (new proposal) and/or EUCLID |
| 6. | Prepare for ALMA observations of the high-redshift universe |
| 7. | Propose deep HST and JWST observations of clusters as gravitational telescopes |
| 8. | Investigate the effects of modeling galaxy cluster dark matter and gas distribution as triaxial structures |
| 9. | Study the effects of including non-thermal pressure of the hot gas in the analysis of galaxy cluster data |
| 10. | Analyze XMM-Newton X-ray observations of a few clusters and compare the derived properties to results from Chandra X-ray Observatory observations of the same clusters |
| 11. | Propose new theory for the structure of dark-matter halos and the origin of their central cusps |
| 12. | Perform an extensive analysis of the detectability of sterile neutrinos as dark matter |
| 13. | Perform an extensive analysis of the detectability of sterile neutrinos as dark matter |
| 14. | Investigate the possibility of measuring the dark matter velocity anisotropy in elliptical galaxies |
| 15. | Initiate an investigation of of measuring non-sphericity of clusters using X-rays |
| 16. | Produce a large spectroscopic sample of extinction curves using GRBs |
| 17. | Obtain X-shooter observations of high-redshift supernovae |
| 18. | Conduct a feasibility of using UltraVISTA data for near-infrared monitoring of intermediate-redshift supernovae |
| 19. | Determine velocity dispersion of a compact quiescent massive z~2 galaxy with X-shooter |
| 20. | Submit proposals to search for and characterise compact quiescent massive z~2 galaxies |
| 21. | Study the existence of hot dust in high-redshift QSOs and the correlation with the mass of the central black hole |
| 22. | Setup, prepare for, and start the modeling and analysis of the Sloan Digital Sky Survey quasar catalog of ~77,000 quasars |
| 23. | Establish the intrinsic mass function of accreting supermassive black hole |

**4A. External relations**

The research conducted at the Centre is highly international, as evidenced by the fact that the refereed papers published in 2009 have authors affiliated to over a hundred institutions from dozens of countries worldwide. These papers are the result of established networks and consortia, but 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.

The Centre is engaged in several high-profile international collaborations. The Centre is one of the founding institutions for the UltraVISTA survey, which is a collaboration within the European Southern Observatory between University of Edinburgh, Leiden Observatory, University of Marseilles, and the Centre. The Sophie and Tycho Brahe Fellowship programme launched by the Centre currently hosts a joint fellow with University of California, Santa Cruz and one with the of California, Berkeley. Another fellow has just been identified for the third year of the program starting in 2010, jointly with the Yale University.
Two Centre staff members are leading Nordic networks: Jesper Sollerman is leading the Nordic Network of Astrophysics and Cosmology, a network of centres of excellence facilitating interaction between members across the Nordic countries. Steen H. Hansen is heading the network Particle Physics and Cosmology: From the Smallest Scales to the Largest, giving young Nordic researchers more frequent possibilities to exchange ideas and results.

The Centre has an extensive visitor programme, including collaborations with its associates. The programme includes everything from very short visits (people passing through or quick collaboration meetings) to longer-term visits, of order weeks up to several months. For example, Prof. Lillya Williams from the University of Minnesota spent part of her sabbatical at the Centre in 2009. The visitor programme is also used to invite speakers for local collaborative meetings. Past, current, and future visitors are listed on the Centre’s website (http://www.dark-cosmology.dk/visitors/).

4B. Conferences

The most significant of the five events organized by the centre in 2009, is certainly the dust workshop. It took place from June 29th to July 3rd and was co-funded by the Niels Bohr International Academy, the Instrument Center for Danish Astrophysics and the Nordic Network for Astrophysics and Cosmology. It gathered 43 scientists from all over the world to work on Intergalactic cosmic dust and its influence on the observations of dark energy.

Participation in international workshops and conferences also rates high on the Centre’s agenda, with 54 seminar/conferences/workshops attended by staff or students in 11 countries. At these events, 40 talks were given by centre members, 24 of which were invited.

4C. Educational activities

The aim of the Centre’s training activities is to train original and independent researchers at an internationally competitive level. 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. There is a lively and informal contact between PhD students and supervisor on a daily basis in the Centre’s international environment. Other research training foci for the Centre include recruiting the best international students, maintaining a high fraction of international MSc and PhD students, and having a balanced MSc and PhD student gender profile.

As we near the end of the first funding period, the Centre’s PhD students are finishing and moving on, and a new cohort is starting. We enrolled one new student in 2009, and have plans to enroll as many as 10 in 2010. Of the four PhD students who graduated from the Centre in 2009, all have taken up international postdoctoral positions (Weizmann Institute of Science in Israel, University of Queensland in Australia, University College London England, and University of Edinburgh in Scotland). An additional student, who was co-supervised by DARK Faculty and was a resident at DARK on a special internationalization grant, also finished her PhD and is now teaching astrophysics at a university in Paris.

All PhD students at the Centre are automatically associated with the Danish Astrophysics Research School (DARS), which organizes courses and meetings for Danish astrophysics PhD students. The Centre is one of three founding institutions behind DARS. DARK faculty members contributed to the organization of DARS, as well as the planning and giving of DARS courses for PhD students; particularly in connection with the annual DARS meeting in Ebeltoft, January 2009.

In 2009, 6 MSc theses and 10 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 the Centre’s research themes as well as running a major share of the undergraduate teaching in
astronomy at University of Copenhagen. In addition, DARK co-hosted a Faculty of Science elite PhD course in October 2009, called Advanced Methods in Statistics.

4E. External funding

The Centre continues to energetically seek additional funding from external sources. The Centre was awarded 12,000,000 DKK for 5 full Ph.D. stipends (2010–2014), for which recruitment and selection has begun. The Centre supported the successful application for 1,171,544 DKK to the Carlsberg Foundation of Jesper Rasmussen, who will start at the Centre in October 2010 to work on “Characterising the hot baryons in the Universe using ALMA”. The Centre supported the successful 2,000,000 DKK application to the Instrument Centre for Danish Astrophysics by Thomas Greve, who will co-lead national initiatives using ALMA 2010-2012. Margrethe Wold was awarded a two-year Marie Curie Fellowship from the European Union FP7 programme and will take up her position at the Centre in 2010.

Funding for the Instrument Centre for Danish Astrophysics (IDA) funding was renewed with 8,400,000 DKK, 2010–2012, which will be administered from the Centre.

4F. Awards and recognitions

DARK scientists were awarded several prizes this year. Tamara Davis received the L’Oréal Australia prize for "Women in Science" for her groundbreaking research on the Universe’s dark energy. The Svend Bergsøe Foundation awarded their Mediation Award to Anja C. Andersen for her unparalleled dissemination of knowledge about the universe to children, young people and the general public. Anja C. Andersen was also awarded the Mathilde Prize by Dansk Kvindersamfund. Kristian Pedersen received the Tycho Brahe medal in silver for launching the national "Børn af Galileo" project during the International Year of Astronomy.

4G. Public outreach

The Centre is engaged in a highly public and comprehensive outreach programme and has established itself in the Danish community and media as a widely known research centre. Our website, the Centre’s window on the world, was redesigned and enhanced in a desire to share the many activities as well as a dynamic and productive day to day life. In the fall, DARK initiated a fan page on Facebook, attracting more than 300 fans following and commenting on postings and links.

On top of the Centre’s own public outreach programme, DARK contributes to public outreach at the Niels Bohr Institute at the same level as the Institute’s other research groups. The Centre received wide national and international media coverage from a press release and an advanced publication issued in 2009:

- Discovery of the most distant object in the Universe (ESO press release)
- Identifying red giants as supernova progenitors (Science Express)

Three news stories were issued through the Niels Bohr Institute communications office. Members of the DARK staff made significant public outreach contributions via books published for the Danish market in 2009:

- Interviews of Anja C. Andersen to contribute to the books: “Dømt Til At Skabe” and “Lykkelig I Nørdland”
- An article by Kristian Pedersen in the Danish Almanac

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Nine popular articles were published. Anja C. Andersen has been a regular columnist for Weekendavisen. Centre staff appeared 27 times in electronic media (TV, radio, web) productions, and gave 53 popular talks to school classes or the general public.

The Centre is heavily involved in influencing communication of science nationally, with faculty serving on several public committees. In 2009, Anja C. Andersen served as a member of the Council for the Danish Technical University, on the Advisory Board for DTU Space, as a board member for Dansk Naturvidenskabsformdling, and as member of the præsidium for the Experimentarium. Kristian Pedersen was a member of the Niels Bohr Institute board for communications and he was the national coordinator for the International Year of Astronomy 2009.

41. Publications

The Centre’s scientific output is focused on the most prestigious and highest impact publication avenues in the astrophysical community: the major international peer-reviewed journals. DARK also produces a large number of community-service bulletins—CBET circulars and GCN notices—that are highly valued as tools of the trade. All preprints are posted prior to publication to the arXiv Open Source preprint archive (http://www.arxiv.org). On the Centre website a daily-updated list of published papers sorted by year (all hyperlinked) is maintained, as well as a list of all, as yet unpublished, preprints (http://www.dark-cosmology.dk/research/publications).

The Centre has increased its already high rate of scientific productivity, publishing on average more than one and a half papers every week in 2009 (81 peer-reviewed papers). The citation rate also increased, with an impact factor 50% higher than the community average in these high-impact journals (ApJ, A&A, MNRAS, AJ, JCAP). As of 29 March 2008, the 81 papers published in international refereed journals have received a total of 709 citations. It is worth noting that the Centre targets publication in the high-impact journals: the citation rate for papers in these journals is almost twice the average of peer-reviewed articles in astrophysics. All statistics are derived from the NASA Astrophysics Data Service (ADS).