



# *Annual Report*

2018



UNIVERSITY OF  
COPENHAGEN



Danmarks  
Grundforskningsfond  
Danish National  
Research Foundation



**Cosmic DAWN Center, Center of Excellence: Host the first Annual Site Visit with members of the  
Danish National Research Foundation (DNRF)**



**ABOUT COSMIC DAWN CENTER**

The Cosmic Dawn Center (DAWN) is a new international basic research center supported by the Danish National Research Foundation. DAWN is located in Copenhagen at the Niels Bohr Institute, University of Copenhagen, and at the Space division of the Technical University of Denmark (DTU-Space). The center is dedicated to uncovering how and when the first galaxies, stars and black holes formed, through observations with the prime telescopes of the next decade (ALMA, JWST, Euclid, E-ELT, HST) as well as through theory and simulations.

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# Annual Highlights

It has been exciting and eventful first year for the Cosmic Dawn Center. Shortly before the center's official start, NASA announced to a surprised community that the launch of the James Webb Space Telescope (JWST) was to be postponed until March 2021. This has slightly modified our research plan, since the involvement of DAWN staff in Guaranteed Time Observations (GTO) planned on JWST instruments is at the heart of our research. Taking advantage of this unexpected delay we have initiated a number of new activities that will maximize our scientific return from JWST once it launches. We are leading several new ground-breaking surveys that will increase by orders of magnitude the number of cosmic dawn galaxies to point the JWST at once it flies. Also, we have built a strong theory group to simulate early galaxy formation, which will greatly aid us in the design and interpretation of JWST observations. DAWN astronomers in Denmark and abroad published a total of 143 peer reviewed papers in 2018, on diverse aspects of the evolution of galaxies over the last 13 billion years of cosmic time, both from an observational and theoretical point of view. Here we highlight two studies, one theoretical [100] and one observational [27].

**Theory:** State-of-the-art models for the Universe when it was only a billion years old consistently underestimate the amount of ultraviolet light that circulated between infant galaxies. By dispersing the light from bright quasars, astronomers can detect faint shadows indicating atoms of hydrogen and heavier elements that happen to lie between the Earth and the quasar. Ultraviolet light is energetic enough to strip electrons from those atoms and change their shadows. Through detailed comparisons between observations and models, DAWN scientist **Kristian Finlator** from New Mexico State University found that some of the shadows were not dark enough and some were too dark. Both problems indicate that the young universe was brighter than scientists expect [100]. Where did the missing light come from? Was it from very faint galaxies, quasars, or from some other source? This mystery is spurring further investigations and improvements to models.

**Observation:** Forming stars at a leisurely rate it took our Galaxy 10 billion years to assemble its current stellar mass. DAWN has discovered the most distant known examples of a mysterious type of red compact galaxies, which appears to have formed as many stars as our Galaxy already 12 billion years ago [130], and with the stars packed 100× closer together [44]. The galaxies appear to have formed 1.3 billion years after the big bang. DAWN PhD student **Carlos Gomez-Guijarro** studied in detail the dust and stars of starburst galaxies at this early epoch and found them to be the likely progenitors of the red compact galaxies seen at later times [27]. These progenitor galaxies form stars 1000× faster than our Galaxy today, but within in a very small volume. The stars are formed under a blanket of dust so thick that all visible light is blocked, only thermal radiation from dust heated by young stars reveals the star formation. The high star formation activity is likely being induced by gas inflows and a constant bombardment of smaller galaxies.

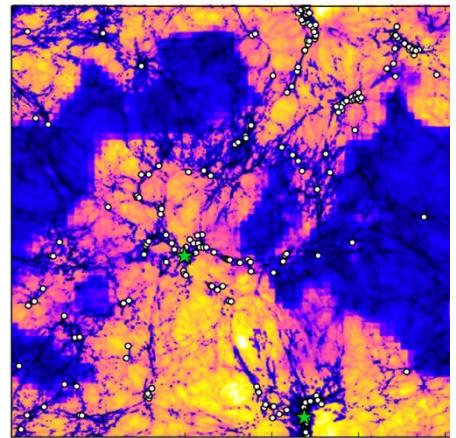


Figure 1 A simulation showing the line-of-sight density of neutral hydrogen at time when the Universe was only 5% of its current age (13.7 billion years). Bright colours indicate regions where the hydrogen has been ionised by the ultraviolet light. These regions are lined by dense filaments of neutral gas (dark colors) along which the galaxies are seen to form (indicated by circles).

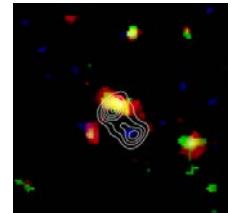


Figure 2: An extremely star forming galaxy observed 1.3 Billion years after the big bang. The color image shows starlight. The white contours show emission from dust heated by young stars. Thousands of new stars are being born every year under a thick layer of dust that blocks the starlight. The extreme star formation is likely driven by collisions with the small surrounding galaxies.

## The Organization

### Housing of the Center

The delay of the Niels Bohr Building (current estimated move in date 2021) and the termination of the lease for the Rockefeller building meant that it was not possible to find a home for the NBI part of DAWN until half a year after the start of the center. In October, we moved to Vibenshuset, a “temporary” space anticipated to be our home for several years. Several compromises had to be made during this process. The most important is that we had to accept that the center is broken up into two pieces (on the same floor), where most of the team is working in a large open plan office. This is sub-optimal for academic work, and the limited space is already filled, leaving very little room for the planned expansion of DAWN in the coming years. Housing at DTU went more smoothly, and the center moved into allocated space in July 2018.

### **Launch of James Webb Space Telescope Delayed to 2021**

In March 2018, NASA announced that the launch of James Webb Space Telescope (JWST) was to be postponed from October 2018 until March 2021. This was announced to a surprised community less than two weeks before the first deadline for General Observer (GO) proposals.

This 29-month delay has resulted in several changes in our planning, since the active involvement of DAWN staff in Guaranteed Time Observations (GTO) on multiple JWST instruments is a central component of many of our major goals. Although the significant investment and data access in JWST remain unaffected, the first data from JWST GTO programs can now only be expected in the second half of 2021 following commissioning of the observatory in orbit. In the meantime, detailed GTO observations are scheduled to be finalized and frozen by mid-2019 in order that they can be called out in the general JWST Call for Proposals, which is presently foreseen to be issued at the beginning of 2020.

**H Nørgaard-Nielsen, L Colina, T Greves and A Hornstrup** lead the High-z Universe Working Group for the MIRI instrument GTO team. In particular, DAWN is leading the MIRI Deep Imaging Survey, expected to be the most sensitive mid infrared survey of the early universe for several years after JWSTs launch. Current work is focused on a detailed understanding of the instrument’s performance, which is crucial to push MIRI to its limit.

Critical support for the NIRSpec instrument has been provided by **P Jakobsen** and **N Bonaventura**, who are developing the algorithms and software needed to employ the ~250.000 individually-addressable shutters of NIRSpec’s slit selection device in an optimal manner during the all-important multi-object spectroscopic surveys of the most remote galaxies planned for the instrument. **G Brammer** has been leading the effort to prepare a software analysis pipeline for processing the NIRISS GTO and Early Release Science (ERS) observations, building on unique expertise from the Hubble Space Telescope (HST). The pipeline also produces high-fidelity simulations of the planned observations, and a first generation of these simulations was used to refine the target list and calculate realistic sensitivity limits for the NIRISS GTO survey plan.

### **DAWN Prior to JWST**

We will use the unexpected extra preparation time for JWST to do two additional things which we believe will make DAWN a world leading institute for Cosmic Dawn studies even before the launch of JWST:

1. *Build a world leading simulation group in Copenhagen, to make detailed theoretical predictions for JWST, and set up infrastructure for speedy physical interpretation of the first observations*

This was achieved by hiring **Daniel Ceverino** as one of our first DAWN fellows. Daniel is a world leading theoretical astrophysicist and the PI of the FIRSTLIGHT project [13]; to date the largest and most detailed simulation of early galaxy formation. A cornerstone of the project is a publicly available database of realistic simulated JWST observations, which is already a major resource for the whole community (<http://www.ita.uni-heidelberg.de/~ceverino/FirstLight/>).

2. *Start new major observational surveys with existing telescopes to identify large numbers of early galaxies to be studied in detail by JWST, ALMA and E-ELT.*

Presently, only a few handfuls of galaxies in the Cosmic Dawn Epoch are known, most selected from very deep so-called pencil beam surveys with the Hubble Space Telescope. These are prime targets for JWST, but to make efficient use of its capabilities in its limited lifetime it is critical to identify larger samples of candidate Cosmic Dawn galaxies.

DAWN is taking advantage of the delay to lead a number of new large survey initiatives with this goal in mind. The most prominent of these include:

**ALPINE** (ALMA Large program to Investigate CII at Early Times) (**P Capak** Co-PI, **S Toft**, **P Oesch**, **D Narayanan** Cols): A large ALMA program to study gas and dust in the inter stellar medium of 122 galaxies 0.9-1.5 billion years after the big bang. ALPINE increases the number of galaxies with such measurements with an order of magnitudes and is expected to have a major impact on the field in the coming years (<https://cesam.lam.fr/a2c2s/>)

**SMUVS** (The Spitzer Matching Survey of the Ultra-VISTA Deep Stripes) (**K Caputi** PI, **B Milvang-Jensen**, **J Fynbo** Co-Is): SMUVS [16] is the deepest current wide area mid infrared survey, focusing on the addition of mid-infrared observations to parts of the COSMOS field, in which there is a wealth of existing observations at other wavelengths. DAWN is also co-leading COSMOS near-infrared UltraVISTA survey (**J Fynbo** Co-PI, **B Milvang-Jensen**, **S Toft** core members), and is heavily involved in the COSMOS collaboration, where many of the discoveries highlighted below were obtained using COSMOS data (<http://cosmos.astro.caltech.edu>).

**HUDV** (Hubble Deep UV Legacy Survey) (**P Oesch** PI): HUDV [122] is the widest and deepest current high-resolution UV survey to date. It is designed to add Hubble Space Telescope ultraviolet observations to fields which have already been the sources of the highest-redshift galaxies yet found. HUDV covers an area 14 times larger than its predecessor, allowing a major improvement in our ability to track the birth of new stars in early galaxies (<http://www.astro.yale.edu/hduv/>).

**BUFFALO** (Beyond Ultra –Deep Frontier Fields and Legacy Observations) (**C Steinhardt** PI): A new Hubble Space Telescope large treasury program targeting a wide area around six of the most powerful known gravitational telescopes (clusters of galaxies). The team of 100 international astronomers is led from DAWN. The survey is expected to double the number of massive bright cosmic dawn galaxies, and provide new insight in the properties of the mysterious Dark Matter in the clusters (<https://buffalo.ipac.caltech.edu/>).

**CHARGE** (**G Brammer** PI): All known Cosmic Dawn galaxies are selected from a relatively small area ( $0.25 \text{ deg}^2$ ) covered in named extragalactic Hubble surveys. Over its >25 years lifetime, Hubble has collected many times that area with observations from a broad array of science programs focusing on more nearby objects. DAWN is leading the “Complete Hubble Archive for Galaxy Evolution” (CHARGE) program to automatically process all data ever taken by Hubble and systematically search for Cosmic Dawn Galaxies. Furthermore, in support of the archival Hubble observations we have just won a large allocation of 600 hours with the Spitzer Space Telescope to cover the fields that are missing infrared data, which is crucial for finding Cosmic Dawn Galaxies.

**Cosmic Dawn Survey (S Toft, P Capak Co-PIs):** The Euclid mission is a ground-breaking facility for finding Cosmic Dawn galaxies, a hundred times more efficient than Hubble. DAWN is leading Euclid's Deep Field program, and in preparation for launch in 2021 we have started the Cosmic Dawn Survey, which combines 30 nights of deep optical data from the Japanese Subaru Telescope in Hawaii, with nearly a year of observations with the Spitzer Space Telescope. When combined with Euclid data, the Cosmic Dawn Survey will be >100 times larger than any existing survey and is expected to find thousands of Cosmic Dawn Galaxies. Most importantly, the wide area will find the rare high-density regions of the early Universe which are expected to be the formation sites of the first galaxies (<http://dawn.ipac.caltech.edu>)

## Status of the Hiring Plan

The DAWN postdoctoral and PhD fellowship programs are off to a good start. We are advertising them internationally and follow the academic cycle of major US institutions and received 80 PD and 45 PhD highly competitive applications. In late 2018, we hired two outstanding fellows, and three talented PhD students. The embedment positions which should have started by September 1<sup>st</sup>, 2018 have been delayed. The DTU position is progressing (in the interview stage), while the NBI position has still not been advertised.

## Recruitment and Gender Strategy

DAWN recruits internationally at all levels, participating in the international calendar for postdoctoral and PhD recruitment. In the first year of our center, DAWN hired two postdoctoral fellows, competing successfully against offers from strong groups in both Europe and North America. We also chose to participate in the international calendar for graduate recruitment, which had not been done before at NBI nor DTU, issuing one call with a January deadline. This resulted in a much stronger pool of applicants than previous individual calls, and DAWN hired three PhD students in 2018 from the United States and United Kingdom.

DAWN has made improving gender balance a priority and is actively focusing on recruiting upper-level female staff and associates. In 2018, our first two postdoctoral offers were both to women, although they ultimately declined. We have been more successful in achieving a good gender balance with PhD hiring as well as two undergraduate summer programs, one (<https://dawn.nbi.ku.dk/research/surfdawn/>) funded by Caltech (PI: **C Steinhardt**) and another (<https://dawn.uconn.edu/>) recently awarded through the United States National Science Foundation (PI: **K Whitaker**). This will continue to be a focus of our recruitment efforts in 2019, and as part of this effort, we require that assessment, interview, and hiring committees have a diverse makeup.

## Research Integrity

The Cosmic Dawn Center of Excellence (DAWN) was created as a highly international basis for research in astronomy and assembled a team of experts spanning several continents. Due to a high number of international collaborators, communication practices between different entities have to be carefully monitored so that a high standard of research ethics can be achieved. The DAWN Center therefore is fully committed to the guidelines outlined in the Vancouver Convention and also adopts its core principles from the Danish Code of Conduct for Research Integrity. Adherence to both of these sets of recommendations ensures transparency, honesty and accountability that pervades all aspects of work that is being conducted at the center. DAWN also ensures that communication channels are always kept open between collaborating institutions to avoid any clash between the content of publications from taking place.

To encourage the validation of scientific methods, increase the impact of research and to ensure new collaborations, the data and the data analysing tools either become available publicly immediately following a publication, or soon thereafter, after a proprietary period has elapsed.

## Science and Research Plan Update

### Scientific Progress in 2018

DAWN is primarily focused on six main science themes, which are interdependent and at the core of the design of our center. Some of these involve problems which must wait for the launch of JWST, while others have been able to make progress immediately at the start of the center. A longer description of each of these problems can be found in the initial proposal. We update the status of each of these working groups below.

#### Opaque to Transparent (Cosmic Reionization)

In 2018, DAWN members played leading roles in efforts to discover the stars and galaxies that had already formed when the universe was less than one billion years old. A key goal is to understand how galaxies contributed to the last major phase transition of the universe from a neutral to an ionized state (the so-called reionization). **S Toft** and **P Capak** participated in a study [30] that found faint, young galaxies might generate the ultraviolet light that is needed to drive reionization very efficiently. Similarly, **P Oesch** contributed to the detailed study of the gas of ten early galaxies [129], finding extreme physical conditions that might lead to reionization. DAWN studied explosions of massive stars as well as galaxies. **D Watson** helped study light from a star that exploded when the Universe was less than 700 million years old [71]. It is widely-assumed that such stars packed enough punch to drive reionization to completion.

DAWN astronomers are leading the interpretation of observations of this epoch. These efforts are anchored in detailed measurements of the timing of reionization from the Planck satellite, which **H Nørgaard** is involved in [54]. In recognition of this work he was the co-recipient of 2018 Gruber price (shared with the rest of the Planck team). **C Steinhardt** supervised an effort predicting that early galaxies made much heavier stars than the Milky Way, heating their environments and forging heavy elements [37]. **K Finlator** used large-scale computer simulations to find that young galaxies were vigorous enough to heat the early Universe and enrich it with heavy elements [100].

#### The First Galaxies

One of the key goals of DAWN is to discover the first galaxies and explain the details of their formation. Solving these problems will ultimately require JWST, which was recently delayed. Therefore, in 2018 we focused on two major goals: leading the largest and deepest surveys which can be conducted prior to launch and developing novel statistical methods to learn new things from the best datasets which already exist.

In 2018, DAWN members were PIs of programs at several different stages of development and execution. **G Brammer** is the PI of CHARGE, an archival Hubble program which will bring together a wide range of Hubble and associated observations which are already complete. **C Steinhardt** is the PI of BUFFALO, a new large Hubble program which took its first data in July 2018 and will run through 2020. Finally, **S Toft, P Capak (co-PIs), P Oesch, C Steinhardt, G Brammer, G Magdis and T Greve** are running the Cosmic Dawn Survey, which will take place over the next several years and be over 100 times larger than any existing survey.

DAWN has also become a leader in novel methodology for analysing these large datasets. **P Capak**'s group showed that there is sufficient information in galaxy photometry to predict the results of much more expensive and time-consuming follow-up observations [117]. The template-fitting code written by **G Brammer** to estimate the distance to galaxies remains a leading technique.

### Protogalaxies Become Galaxies (Galaxy Evolution)

A general challenge in galaxy evolution is combining disparate measurements and analysis techniques to connect the earliest galaxies with the more organized, stately structures observed in the local universe. Although a detailed characterization of galaxies at Cosmic Dawn must await JWST and future facilities, both in terms of sensitivity and wavelength coverage, galaxies at “Cosmic Noon” are often much brighter than their distant ancestors and their physical properties can be characterized by current telescope facilities on the ground and in space. This epoch is a time of rapid evolution containing the peak of both star formation and supermassive black hole growth, when the organized structures which exist today begin to emerge.

DAWN members contributed to spectroscopic studies of Cosmic Noon galaxies which are relatively rare at Cosmic Noon, but thought to be more analogous to their more distant ancestors. **K Nakajima** discovered correlations between Lyman-alpha and CIII] emission in the ultraviolet spectra of starburst galaxies [53]. In a related study, Berg, **G Brammer** et al. found that the extreme star-forming conditions of one of the most metal-poor galaxies known at redshift 2 can't be explained by current photoionization models [8].

DAWN also worked to develop a more complete characterization of stars and gas in and around galaxies that is often otherwise invisible. **J Fynbo** detected CO emission from a member of a galaxy group at  $z=2.5$  [25]. Ma, **Brammer** et al. discovered the massive optical counterpart to a metal-rich system at  $z=2.1$  [46]. **J Selsing** determined the redshift of the star-forming host galaxy of the most distant short duration gamma ray burst known ( $z=2.2$ , [64]), objects thought to be bright signposts of early production of heavy elements. These studies discover galaxies in unique ways, finding different populations than established selection techniques.

### Galaxies Die (Exploring and Understanding Quenching)

The majority of stars in the local Universe belong to massive, red, dead elliptical galaxies that ceased converting gas into new stars already billions of years ago. Studies suggest that they formed and died very early in the history of the Universe. How the most massive galaxies in the Universe could form so quickly, and how they stop forming stars at a time when young galaxies were bombarded with fresh reservoirs of gas from their surroundings is not currently understood.

DAWN members are 4 leaders on multiple fronts to shed light on these issues even before JWST. We are using a combination of Hubble, ALMA and the largest ground-based telescopes to track down the earliest dead galaxies, to try to catch them as close as possible to the epoch when they formed and died. **P Oesch** took part in a study that for the first time spectroscopically confirmed the existence of a substantial population of massive, dead galaxies at  $3 < z < 3.7$  [130]. At this time, just 1.7 billion years after the big bang, these galaxies had already been dead for 0.5 billion years, suggesting even more distant examples must exist. DAWN is co-leading a program to find these galaxies. The first results show that candidates exist already at  $z > 4$ , 1.5 Billion years after the big bang, with stellar densities that are higher than in any known objects, close to theoretical limits in current models of star formation (Kubo, **Toft**, Stockmann, **Gomez-Guijarro**, [44]).

## Dust and Molecules Form (Interstellar Medium Studies)

The formation, growth and subsequent death of the galaxies largely relies on the interplay between the three major components of their Interstellar medium (ISM) that also make up most of the baryonic matter in a galaxy; the stars the gas and the dust. A concurrent study of these three components is essential in order to understand the processes that lead to the formation, the growth and eventually the death of the galaxies.

A major discovery, published in *Science*, was the detection of a remarkable molecular outflow launched from a dust-rich star-forming galaxy 1 billion years after the Big Bang, uncovering feedback mechanisms powered by radiation pressure, supernovae, or supermassive black hole accretion (Spilker, Narayanan et al. [131]). A second major result, published in *Nature* (Miller, Greve Narayanan et al. [51]), discovered a large structure in the early Universe consisting of 14 gas rich galaxies when the Universe was just 10% of its current age. This discovery finds structure growth which challenges our current theoretical models of galaxy assembly and evolution.

DAWN is also a leader in ground-breaking studies using ALMA, with discoveries including the largest and most detailed surveys of atomic and single ionised atomic carbon in the early Universe (**G Magdis, F Valentino, T Greve, S Toft**) as well as the most complete dust continuum survey with ALMA (**G Magdis**). By detecting infrared emission from dust particles, we have published a series of breakthrough papers that build an alternative view of the ISM in the distant galaxies (**Valentino** et al. [73], Zanella, **Magdis, Valentino, Walter** et al. [80]), present a full 3D tomography of the structure of baryonic matter in distant galaxies (Gómez-Guijarro et al.[27], Jimenez-Andrade, **Magdis** et al. [38], Silverman, **Magdis** et al. [67], Calistro-Rivera, **Greve** et al. [12]) and have revealed the puzzling population the HST dark sources, that are bright in the infrared but completely undetected in the optical (Franco, **Magdis** et al. [23]).

## Putting it All Together (Theory)

Ultimately, the goal of our observational efforts is to use them to build a theoretical understanding of the processes by which galaxies assemble and grow. Cosmological hydrodynamical simulations have become an important theoretical tool for understanding the formation and evolution of the first galaxies during Cosmic Dawn. They are making predictions that will be tested for the first time in future deep fields with JWST and other new facilities in the next decade. This was a major focus of our efforts in 2018, as we hired simulators in Denmark to join our three associates.

Daniel Ceverino, newly hired as an assistant professor at DAWN, is leading the FirstLight project and public repository of simulated data. These simulations allow us to link the physical conditions of the gas around first stars with observables, such as the recombination lines of doubly-ionized Oxygen and Hydrogen (**Ceverino, Klessen & Glover** [13]). These calculations agree well with current observations (**Ceverino, Glover & Klessen** 2017) and the database enables detailed predictions about the origin and evolution of star-forming galaxies during the first billion years [13]. **C Lagos** has been a leader in results from the EAGLE simulations, including predictions about the formation and evolution of the first galaxies [111]. She has also published *Shark* [112] a new open-source semi-analytical model simulating galaxy evolution. DAWNs future plans involve the generation of realistic mock JWST observations that will help us to prepare and design new strategies for JWST observations.

# Public Outreach

## Social Media

DR2 Dagen interview with Center Leader Sune Toft regarding a Nature paper about distant galaxies

BUFFALO Facebook interview with Center Leader Sune Toft promoting the BUFFALO Project

COSMOS Facebook interview with Center Leader Sune Toft promoting the COSMOS activities

TV2 Go' Morgen Danmark interview with Professor Johan Fynbo on Parker Solar Probe

DK4 Søstrene Bishop På Jagt Efter Gud: Conversation with Bishop Trine Lindhardt and Professor Johan Fynbo on Science and Faith

## Lectures and Presentations

Lecture Open University	29/1/2018	The Dark Universe	Johan Fynbo
Lecture Open University	8/2/2018	Astronomy	Johan Fynbo
Lecture at Korsør kirke	20/2/2018	Science and Faith	Johan Fynbo
Lecture Open University	26/2/2018	Cosmology	Johan Fynbo
Lecture Trinitatis Church, Fredericia	1/3/2018	Beauty in Science	Johan Fynbo
Lecturur for High School Teachers	14/3/2018	Galaxy formation	Johan Fynbo
Lecture at Herlev Church	14/3/2018	Science and Faith	Johan Fynbo
Lecture at UNF, COpenhagen	22/3/2018	Gravitational waves	Johan Fynbo
Lecture Open University, Løgstør	12/4/2018	Science and Faith	Johan Fynbo
Lecture Open University	23/4/2018	Gamma-Ray Bursts	Johan Fynbo
Lecture at Islev Kirke,	27/6/2018	Science and Faith	Johan Fynbo
Lecture at Herlev Babtist Church	5/9/2018	Science and Faith	Johan Fynbo
Lectureeet Sorø Akademi / Talent Program	11/9/2018	Cosmology	Johan Fynbo
Lecture at Skt. Hans Torv	12/9/2018	Science and Faith	Johan Fynbo
Lecture for Physics Students Annual "Hyttetur"	22/9/2018	Astronomy	Johan Fynbo
Lecure at Odense Sitfts Landemøde	29/9/2018	Science and Faith	Johan Fynbo
Lecture at Tycho Planetarium	9/10/2018	Large Scale Structure	Johan Fynbo
Lecture Open University Aarhus	11/10/2018	Gamma-Ray Bursts	Johan Fynbo
Lecture at Nyborgmødet	15/10/2018	Science and Faith	Johan Fynbo
Lecture Svogerslev kirke	25/10/2018	Science and Faith	Johan Fynbo
Lecture Open Universityh Esbjerg	27/10/2018	The physics of time	Johan Fynbo
Lecture Lundtofte Kirke	30/10/2018	Science and Faith	Johan Fynbo
Lecture Open University	31/10/2018	The Big Questions In Astronomy	Johan Fynbo
Lecture Brorfelde	28/11/2018	Modern telescopes	Johan Fynbo
Lecture for Copenhagen Sceptics	10/12/2018	Science and Faith	Johan Fynbo
Lecture for Visiting High School Class	10/12/2018	Galaxy formation	Johan Fynbo
Lecture Open Unviversity	12/12/2018	The Big questions In Astronomy	Johan Fynbo
Fredericia Gymnasium	5/04/2018	Det ModerneAstronomiske Verdenbillede Peter Jakobsen	

Hørsholm Bibliotek	23/04/2018	Det Moderne Astronomiske Verdenbillede Peter Jakobsen
Ørslev Landsbylaug	24 /04/2018	Det Moderne Astronomiske Verdenbillede Peter Jakobsen
Ingrid Jespersens Gymnasium	19 /11/2018	Det Moderne Astronomiske Verdenbillede Peter Jakobsen
Sognegården Sengeløse	12 /02/2018	Har Naturvidenskaben Svar på det Hele? Peter Jakobsen
Nyborg Provsti, Tycho Brahe Planetariet	11/09/2018 En række naturvidenskabelige erkendelser om os selv	Peter Jakobsen
Public lecture at the Tyco Brahe Planetarium	8/11/2018	Galaxies at Cosmic Dawn Gabriel Brammer
NASA Presentation "Universe of Learning" Program for Educators and Museum Professionals	19/09/2018	Distant galaxies with Hubble and JWST Gabriel Brammer

## Awards

Senior Scientist Hans Ulrik Nørgaard–Nielsen and his fellow Plank Team members received the Gruber Foundation Cosmology Prize, 20 August 2018.

Peter Laursen, postdoc, Institute of Theoretical Astrophysics, University of Oslo, Norway, and the Cosmic Dawn Center, University of Copenhagen, Denmark received the Best Outreach 2018 on Videnskab.dk.

## Collaborations with Industry and Public

European Space Agency: The purpose of the collaboration was to provide expertise on the development and operation of the NIRSpec instrument onboard the James Webb Space Telescope. (JWST)

## Conferences

Meeting of the NIRSpec Instrument Science Team, Carlsberg Academy: Copenhagen, Denmark

COSMOS Team Meeting 2018: Copenhagen, Denmark

Cosmic Dust: origin, Applications & Implications (Chair: Darach Watson)

Hawaii-Two-0 Meeting: Copenhagen Denmark

Euclid Consortium Meeting: Primeval Universe Splinter Session, Bonn Germany

Ultravista Meeting: Copenhagen, Denmark

# Invited Talks

COSMOS Team Meeting 2018	Geological Museum, Copenhagen, Denmark	Sune Toft, Francesco Valentino, Georgios Magdis, Carlos Gomez, Isabella Cortzen
Walking the Line; Simulating line emission from Galaxies	Arizona State University - Phoenix	Georgios Magdis
8th KIAS Workshop on Cosmology and Structure Formation	Korean Institute of Advanced Studies	Georgios Magdis
Origins Space Telescope; From First Stars to Life	University of Oxford	Georgios Magdis
Subaru Users Committee Meeting 2019	National Astronomical Observatory Japan (NAOJ)	Sune Toft
WFIRST/LSST Deep Fields Workshop,	Princeton University, New Jersey	Sune Toft
Niels Bohr International Academy Colloquium	Niels Bohr International Academy, Copenhagen	Sune Toft
Seminar	Kavli Institute for the Physics and Mathematics of the Universe (IPMU), Tokyo	Sune Toft
Linking galaxies from the epoch of star formation to today (talk: Probing the molecular gas in star-forming galaxies using PAHs and [CI])	Rydges World Square Center, Sydney, Australia	Isabella Cortzen
Galaxy formation through cosmic time: synergizing theory and observations in the era of large facilities (European Week of Astronomy & Space Science S3)	Arena & Convention Centre (ACC), Liverpool, United Kingdom	Darach Watson
The interstellar medium as a window onto galaxy evolution (EWASS S9)	Arena & Convention Centre (ACC), Liverpool, United Kingdom	Darach Watson

# Publications list

The compiled list includes one or more authors from the Cosmic Dawn Center and its international associates. These are items limited to publication dates from 1 Apr 2018 through 31 Dec 2018. All of the publications listed here have been peer reviewed and have been published by the journals indicated in the bibliographic entries. The journals indicated have a variety of Open Access (OA) policies; a query on these paper DOIs at <http://apps.webofknowledge.com> indicates that 56 articles are currently available with Open Access.

Some summary statistics of the Dawn publications extracted from ADS are as follows:

- 143** = Total number of refereed journal articles with contributions from Cosmic Dawn Center members
- 80** = Articles from Dawn members in Copenhagen
- 19** = Articles including collaboration between both our local members and international associates
- 15** = Primary (i.e., first) author publications from Dawn members (local and associates)
- 5** = Publications in the prestigious cross-disciplinary journals *Nature* (1), *Nature Astronomy* (3), and *Science* (1)
- 14** = Citation *h*-index
- 39** = Number of articles already with ten or more citations (*i10*-index)
- 1121** = Number of unique articles citing the 143 Dawn papers

Often-used journal names are abbreviated below as:

- AJ* – The Astronomical Journal
- ApJ* – The Astrophysical Journal
- ApJSS* – The Astrophysical Journal Supplements Series
- A&A* – Astronomy & Astrophysics
- MNRAS* – Monthly Notices of the Royal Astronomical Society
- PASA* – Publications of the Astronomical Society of Australia
- PASJ* – Publications of the Astronomical Society of Japan
- PASP* – Publications of the Astronomical Society of the Pacific

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