2013
2023

BIRKELAND CENTRE
FOR SPACE SCIENCE

CONTENTS

OUR MISSION

The Birkeland Centre for Space Science (BCSS) was established in March 2013 with a 10 year funding and will end by August 31, 2023. It has been led from the Department of Physics at the University of Bergen, with nodes at NTNU and UNIS. The overarching scientific objective of the BCSS has been to understand "How the Earth is coupled to space." BCSS has been organized into four research groups the first 6 years and in three research groups since 2019:

– Dynamics of Asymmetric Geospace
– Particle Precipitation
– Hard Radiation from Thunderstorms

BCSS has additionally housed two instrumentation groups that design, build, and operate state-of-the art space- and ground-based instrumentation, and a group dedicated to education and public outreach.

FROM THE CENTRE LEADER

This report covers the years 2013 to 2023.

Unlike the nine previous annual reports (from 2013 to 2021), this report will cover the entire life of Birkeland Centre for Space Science (BCSS). We will present what we consider the main achievements regarding:

1. Scientific breakthroughs and highlights
2. The promotion of these breakthroughs and highlights to the general public
3. Scientific leadership nationally and internationally
4. Instrument development both for space and on ground
5. New generation of space scientists

The main ideas for BCSS were born during a brain-storming session between Jesper Gjerløv, Kjellmar Oksavik, and myself on a weekend in early 2011. Both Jesper and Kjellmar had just been hired to join the space physics group at the University of Bergen (UiB). The hiring of the two new professors was a strategic decision made by the then institute leader (Geir Anton Johansen) in response to the very good outcome for our group in the decadal evaluation of all physics groups in Norway the year before. In that evaluation, our group came out at the very top due to its well-defined scientific strategy, many excellent students and decades of heritage in designing and building space instruments at UiB. Important people for this heritage are Professors Emiriti Johan Stadsnes and Finn Søraas, who have also been active members of BCSS. Based on the existing strategy at the time, plus input from the new professors, we defined the main scientific questions for BCSS during that weekend, identified the expertise we needed for resolving these questions, and the people that we needed to get on board. The next move was to involve the collaboration that was already established a few years earlier between UiB (Hilde Tyssøy) and the Norwegian University of Science and Technology (NTNU, Patrick Espy) and finally, to get the space group at The University Centre on Svalbard (UNIS) on board with all the ground-based instrumentation they operate at Svalbard.

With this team, we formulated the brave vision of BCSS and claimed that we would be a Centre of Excellence (CoE) if we received the long-term funding that was offered by the Research Council of Norway (RCN). As we all know, we made it and were one among the thirteen new centres that were awarded the ten-year funding from NRC with a start-up in 2013. Including the in-kind contributions from UIB, NTNU and UNIS, BCSS has had a budget of about 500 million NOK from 2013-2023.

The purpose of the Centre of Excellence program is to give long-term, predictable funding which will enable scientists to work strategically to answer important scientific questions with large impact for the scientific community as a whole. By doing this, one can also make discoveries and present new ways of understanding scientific problems and present paradigm shifts if needed. All the scientific questions presented in the BCSS application focused on important, unresolved questions regarding nature and would potentially result in groundbreaking science.

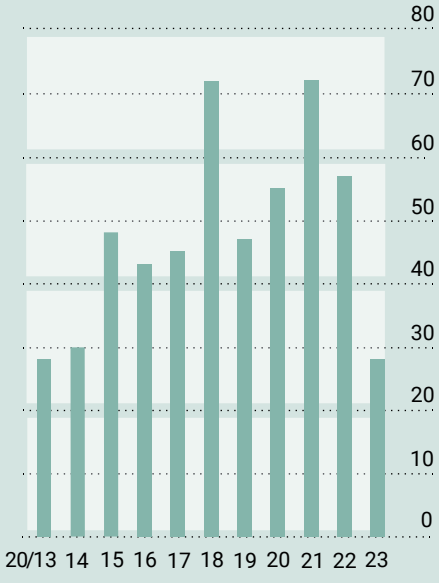
Already during the first few years, BCSS was doing pretty well, but as the head of our Science Advisory Board, Alan Rodger (deceased 2019) pointed out in 2015: we had not yet reached the rank of "excellence"; the Centre was still only "outstanding" at that time. He changed his mind a few years later when we managed to make some real scientific breakthroughs. The report you are now about to read is our documentation of what we have achieved in science, leadership, outreach, education, etc, during these ten years. Then, you can judge for yourself if Alan Rodger was right when he concluded that we finally reached the goal of being "excellent", and if we deserved to have the long-term funding of a CoE.

Although clear leadership for such a big project as BCSS is important, the achievements of BCSS are not the results of just one or a few people's efforts, but the effort of all the people involved in BCSS. So, for the last time, I thank all the members of BCSS for your good hard work during all these ten exceptional years. I also hope that what we have achieved during these ten years have created a good foundation and momentum for the continuation of scientific excellence in Norwegian Space Physics.

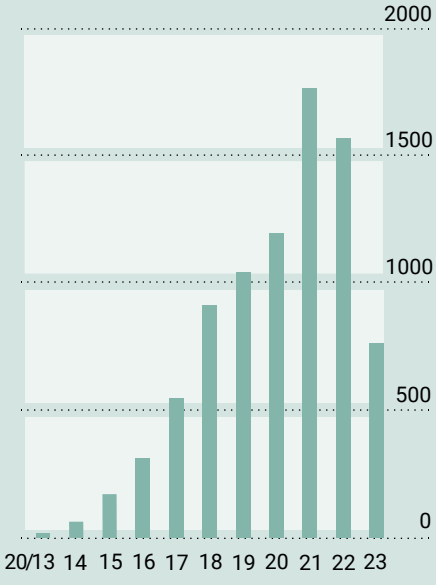
Nikolai Østgaard,
Leader of BCSS (2013-2023)

DISSEMINATION DATA

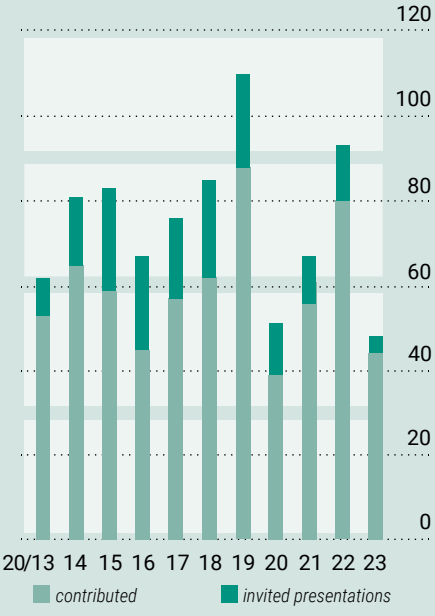
PUBLICATIONS



CITATIONS



PRESENTATIONS



H-index for BCSS: 41 (as of July 5, 2023)

HIGHLIGHTS IN IMAGES

ILLUSTRATION OF MAGNETAR DETECTED BY ASIM

Illustration: BCSS / Mount Visual / Daniel Schmelling

TROND MOHN FOUNDATION STARTING GRANT

Taken from video, UiB

Karl M. Laundal, BCSS group leader, winner – Trond Mohn Foundation Starting Grant

YOUNG CAS AWARD

Photo: Camilla K. Elmar / CAS

Hilde Nesse (right), BCSS group leader, winner – Young CAS Award

NASA ER-2 AIRCRAFT COMISSIONED FOR ALOFT

SCIENCE COVER

Illustration: BCSS / Mount Visual / Daniel Schmelling

January 10, 2020 *Science* cover featuring ASIM results

ALOFT: MOUNTING OF INSTRUMENTS ON THE ER-2 AIRCRAFT

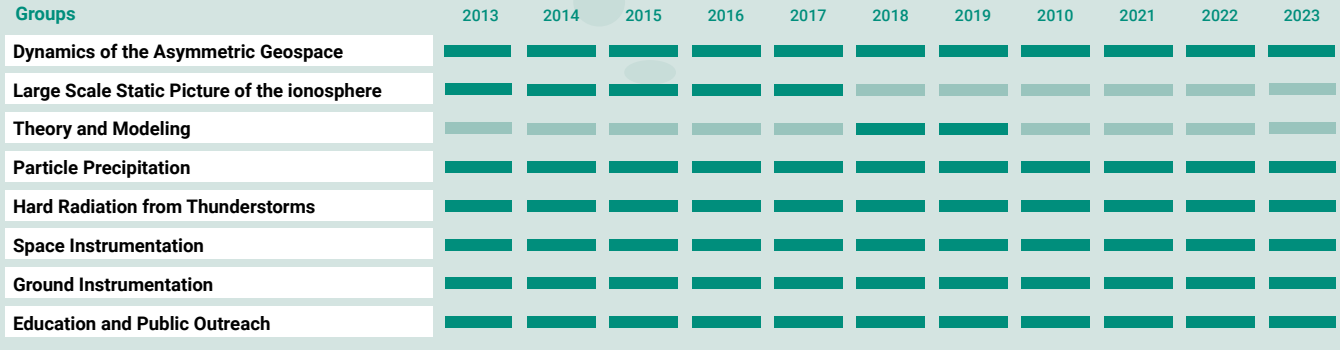
Image: NASA

RELOCATION OF ASIM ON ISS

Images: Courtesy ASIM/DTU, Denmark

GROUPS AND LEADERS

The group structures as well as their names have changed during the ten years of BCSS. Here, we give an overview of the scientific research groups, the instrument groups and the public outreach group and their respective leaders. Some groups have existed all ten years while others have changed.



> Dynamics of the Asymmetric Geospace (DAG): 2013-2023

Why and when is the aurora in the two hemispheres asymmetric?

YEARS	LEADER	CO-LEADER
2013 – 2017	Nikolai Østgaard	Karl Magnus Laundal
2017 – 2019	Therese M. Jørgensen	Karl Magnus Laundal
2019 – 2023	Karl Magnus Laundal	Kjellmar Oksavik

Nikolai Østgaard

Karl M. Laundal

Therese M. Jørgensen

Kjellmar Oksavik

> One of the main goals of the DAG group is to understand how interhemispheric asymmetries in the magnetosphere are created and removed. We know from past years that the interplanetary magnetic field plays a central role in setting up asymmetries. We also know from observations of auroras in the two hemispheres – a visible manifestation of the ionospheric "ends" of magnetospheric magnetic field lines – that asymmetries are reduced during very active times.

The DAG group uses a vast array of different datasets to understand global geospace dynamics: Multi-wavelength images of the aurora from ground and space: radar observations of plasma flow, plasma measurements from satellites, and magnetometer measurements from ground and space. A lot of these data are from the polar ionosphere, which is strongly affected by magnetospheric dynamics. The DAG group has dedicated considerable work to increase our understanding of how these very different data sources should be interpreted with respect to each other, and with respect to magnetospheric dynamics. Different tools and models have been developed for combining datasets, and to map ionospheric electrodynamics.

> How do we get beyond the large-scale static picture of the ionosphere: 2013-2018

YEARS	LEADER	CO-LEADER
2013 – 2015	Jesper Gjerloev	Dag Lorentzen
2015 – 2017	Kjellmar Oksavik	Dag Lorentzen
2017 – 2018 (May)	Therese M. Jørgensen	Kjellmar Oksavik

Jesper Gjerloev

Dag Lorentzen

Therese M. Jørgensen

Kjellmar Oksavik

> The science target for this group is an acknowledgement that the magnetosphere-ionosphere system is highly dynamic including processes with scale sizes from hundreds of meters to thousands of kilometers (at ionospheric altitudes). Despite this well-known fact, most published models assume that observed variations are solely due to spatial gradients or, in other words, that the system is static. This crippling assumption is largely due to the inherent observational shortcomings of single satellite missions, which cannot separate spatial and temporal variations of a measured electromagnetic parameter. Progress, however, has been made possible by the recent launch of multi-point satellite missions (e.g. ESA SWARM, THEMIS and Cluster). These missions as well as some ground-based observations finally provide us the observational basis needed to advance our understanding of the coupling between the Earth and near space.

> Theory and Modeling (TM): 2018-2019

YEARS	LEADER
2018 (May) – 2019* (September)	Michael Hesse

Michael Hesse

> The Theory and Modeling group at the Birkeland Centre for Space Science is engaged in forefront, theory and modeling-based, research of magnetospheric dynamics on large and small scales. Research methodologies range from analytical theory to, for large scales, magnetohydrodynamic modeling and comparisons to spacecraft observations. The group's specific research foci include the kinetic physics foundations of magnetic reconnection, the generation of currents in the magnetosphere, and the mechanisms behind asymmetries of auroral patterns of the northern and southern hemispheres.

** The TM group was established as an independent group at the Department of Physics and Technology from September 1, 2019.*

> Particle Precipitation (PP): 2013-2023

What are the effects of particle precipitation on the atmospheric system?)

YEARS	LEADER	CO-LEADER
2013 – 2023	Hilde Nesse	Patrick Espy

Hilde Nesse

Patrick Espy

> Near-Earth space is a stormy place where the magnetosphere is constantly being ripped and torn by the solar wind. Guided by the Earth's magnetic field, part of this energy is deposited into the atmosphere as energetic particle precipitation. The subsequent ionization of the neutral atmosphere initiates chemical reactions leading to the production of odd nitrogen (NO_x: N, NO, NO_2) and odd hydrogen (HO_x: H, OH, HO_2) species. In the polar winter darkness, odd nitrogen has a long lifetime, allowing the seasonal downwelling to bring excess NO_x into the upper stratosphere. Here it can reduce the ozone concentration in catalytical reactions. Ozone is critically important in the energy budget, which implies that changes in ozone can impact temperature and winds which link to our weather system. The PP group brings together space and atmospheric scientists with the expertise to unravel the complex relationship between EPP and its atmospheric effects by applying both observations and models.

> Hard radiation from thunderstorms (HRT): 2013-2023

What is the role of energetic particles from thunderstorms in geospace?

YEARS	LEADER	CO-LEADER
2013 – 2015	Nikolai Østgaard	Thomas Gjesteland
2016 – 2023	Nikolai Østgaard	Martino Marisaldi

Nikolai Østgaard

Thomas Gjesteland

Martino Marisaldi

> To answer the overarching question about the role of energetic particles from thunderstorms in the atmosphere and geospace, we need to understand several sub-questions: How common are TGFs? How and at what altitude are TGFs produced? How intense can they be? To address these questions we have used satellite observations from RHESSI, AGILE, Fermi and ASIM, and lightning data from aircraft as well as data from laboratory experiments of electric discharges we performed in Eindhoven in 2013. To explore the mechanism as well as the type of lightning that can produce TGFs, we have developed several models of streamers and leaders. We have explored the micro-physics of X-ray production from streamers in laboratory experiments. We have searched for close observation of TGFs and gamma-ray glows with aircraft campaigns in 2017 and 2023. We believe these are the important building blocks of understanding how relativistic electrons and gamma-photons are produced in the natural discharge process.

> Space Instrumentation: 2013-2023

YEARS	LEADER
2013 – 2023	Maja Elise Rostad

Maja Elise Rostad

> The main tasks of the space instrumentation group from 2013-2023 have been to finalize the Modular X-ray and Gamma Sensor (MXGS) instrument of the Atmosphere-Space Interactions Monitor (ASIM) and build detectors for two ER-2 aircraft campaigns: Fly's Eye GLM Simulator (FEGS, 2017) and Airborne Lightning Observatory for FEGS and TGFs (ALOFT, 2023). From 2016 to 2023, the group has designed and built the door mechanism to protect the Charge Coupled Devices in the X-ray telescope on the Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) mission. The group has also developed a particle detector: Distribution of Energetic Electrons and Protons (DEEP).

> Ground Instrumentation: 2013-2023

YEARS	LEADER
2013 – 2023	Fred Sigernes

Fred Sigernes

> The ground-based instrumentation group is running and maintaining the research infrastructure. This includes the Kjell Henriksen Observatory (KHO), the Super Dual Auroral Network (SuperDARN) radar at Svalbard and, during the first years, also SPEAR. The BCSS Scintillation and Total Electron Content (TEC) network, Lightning detection NETwork (LINET) receiver, NTNU's meteor radar with optics at the Dragvoll campus in Trondheim, and the SuperMAG worldwide magnetometer chain have also been part of the BCSS portfolio.

> Education and Public Outreach: 2013-2023

YEARS	LEADER
2013 – 2016	Arve Aksnes
2017 – 2019	Therese M. Jørgensen
2019 – 2023	Kjellmar Oksavik

Arve Aksnes

Therese Jørgensen

Kjellmar Oksavik

> The key currency of dissemination of the BCSS research findings is through publication in top, peer-reviewed journals and through presentations to other researchers in the space science community. Participation in international meetings is also essential to creating opportunities for exchange of ideas and collaborations with top-notch scientists in the field.

To strengthen the public outreach work, BCSS has established, from the beginning, an Education and Public Outreach group. The work of this group has been guided by the following goals, in order of priority:

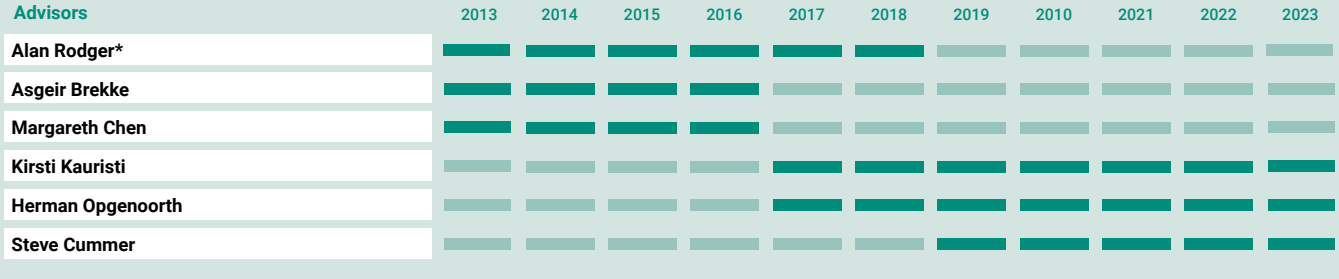
1.To present BCSS research results to the general public

2.To promote the Centre's major achievements (funding, large hardware, stipends etc.) to the general public

3.To create a feeling of pride, ownership, and a sense of belonging within the Birkeland Centre for Space Science in order to create a more cohesive community

4.To recruit bachelor's students to our Master's program and to recruit high school students to higher education (university level) in physics

> Scientific Advisory Board: 2013-2023



* *Alan Rodger passed away in December 2019 after an extended illness. With his vast experience in leadership in our field, Alan played a crucial role in shaping BCSS from an early stage. He took us from a merely "outstanding" centre to a true centre of "excellence".*

SCIENTIFIC BREAKTHROUGHS AND HIGHLIGHTS

As a Center of Excellence (CoE), the Birkeland Centre for Space Science (BCSS) was expected to deliver breakthroughs in science, both through discoveries and theoretical understanding. With the longtime predictable funding that the CoE program provides with the additional in-kind support from the three nodes, BCSS has been able to hire many excellent scientists, both seniors and early career scientists. With this critical mass of expertise over ten years, BCSS has delivered results that have made a large academic impact at an international level, and a societal impact at the national level by bringing space science closer to the general public and fostering and supporting local space industry.

> BCSS has been dedicated to fundamental research in space physics, and has been a unique powerhouse for scientific discoveries, development of space instrumentation, and the education of a highly skilled workforce and the next generation of space scientists since 2013.

BCSS has contributed to more than 480 scientific papers over the last ten years, has reached an H-index of 41, and has been highly visible in all international meetings (AGU, EGU, IAGA, COSPAR, AOGS, etc.) all these years, giving ~800 presentations, of which >150 have been invited.

BCSS has taken full advantage of stable, long-term funding, showing that the 'Center of Excellence' funding scheme pays off. Proof of this can be seen, for example, in the ASIM project–started in 2004 and supported until 2025–and in the work on hemispheric asymmetries–started in 2001 and leading to breakthrough results in 2018-2019. These long-term efforts would have hardly been achievable with short-term grants only.

Here, we focus on three lines of research which contributed to the largest academic impact during the lifetime of BCSS, and an overview of a large number of other achievements that should be highlighted in a report like this. A more detailed overview of achievements of the BCSS can be found in the nine yearly reports from 2013 to 2021.

> A paradigm shift in the understanding of the asymmetry of geospace

> Characterizing and understanding how and why the auroras in the northern and southern hemispheres are not similar has been the focus of researchers from University of Bergen since 2004. It started with a couple of papers describing that auroras were indeed displaced in the two hemispheres (Østgaard et al., 2004, 2005). Another milestone in this research was a paper by Laundal and Østgaard (*Nature,* 2009) that found that the auroras could be not only displaced but completely different in the north and south. This result made it to the front page of *Nature* in July, 2009. A breakthrough in understanding how the asymmetries are created was presented in three papers by Tenfjord et al. (2015, 2016 and 2018). Here, it was shown that it is the asymmetric loading of magnetic pressure and not tail reconnection that is the source of asymmetries. Several features that this new understanding predicts – like asymmetric plasma flows in the ionosphere – were shown by Reistad et al., (2016, 2018). The asymmetric current patterns in the two hemispheres were presented by Laundal et al., 2018. The two last papers (Ohma et al., 2018 and Østgaard et al. 2018) have applied this understanding and also explained how the asymmetries are removed by tail reconnection, contrary to what many in the research community have thought. Since 2004, this research has led to 4 PhDs, 11 Master's and 22 publications. This research has been a truly group effort at BCSS and represents a paradigm-shift in understanding the asymmetric geospace. It has placed Norway in an international leading role in space physics.

Our work on hemispheric asymmetries inspired and supported large international initiatives: a dedicated focus group in the US NSF's Geospace Environment Modeling program, the Community for the Unified Study of Interhemispheric Asymmetries at the University of Texas, Arlington, and two international teams at the International Space Science Institute in Switzerland. A coming NASA flagship mission, Geospace Dynamics Constellation, has the exploration of interhemispheric asymmetries as one of its science goals, highlighting our work in the final report.

- Final report of the NASA Geospace Dynamics Constellation, indicating the study of the hemispheric asymmetry as one of its main science goals[1]
- In the *New York Times*[2]
- AGU press release on BCSS results on hemispheric asymmetries[3]

Publications

Tenfjord, Østgaard, Snekvik, et al. (2015), How the IMF B-y induces a B-y component in the closed magnetosphere and how it leads to asymmetric currents and convection patterns in the two hemispheres, *J. Geophys. Res. – Space Physics*, DOI: 10.1002/2015JA021579

Laundal, Cnossen, **Milan**, et al. (2017), North-South Asymmetries in Earth's Magnetic Field, Space Science Reviews, DOI: 10.1007/s11214-016-0273-0

Ohma, Østgaard, Reistad, et al. (2018), Evolution of Asymmetrically Displaced Footpoints During Substorms, *J. Geophys. Res. – Space Physics*, DOI:10.1029/2018JA025869

1. 2. 3.

Still from the video showing the asymmetric nature of the aurora

BCSS / Mount Visual

> The ASIM instrument onboard the International Space Station as a new benchmark in the field of energetic radiation from thunderstorms and lightning

> ASIM onboard the International Space Station is a mission of the European Space Agency, the first one specifically designed for the observation of short bright bursts of gamma-rays from thunderstorms and lightning, termed terrestrial gamma-ray flashes (TGF). The scientific payload consists of an X- and gamma-ray instrument (MXGS) and an optical instrument (MMIA). The MXGS detector was designed and built at the Department of Physics and Technology at UiB in collaboration with national and international space industries and represents the most complex space instrument realized by Norwegian academia to date. The design and development of the instrument started in 2004 and continued within the premises of the BCSS to the launch in 2018 followed by the scientific operations which are still ongoing. The novelty of the payload is in the simultaneous observation in gamma-ray and optical bands, a process never attempted before. This makes ASIM the current benchmark in this field of research, providing breakthroughs in our understanding of the intimate relationship between TGFs and lightning. In 2019 we reported the simultaneous observation of a TGF and ultraviolet emission associated to perturbations in the ionosphere known as ELVE. This was theoretically predicted a few years earlier but never observed previously. The results were published in the prestigious journal Science (Neubert et al., 2019) and were also graced the cover page of the issue.

The impact of the ASIM mission has been judged so positively by ESA that the mission has been extended and will be supported until at least up to 2025. Two relocations of the payload are involved; one had already taken place in 2022 and one is planned in 2023. BCSS' unique connection with the microelectronics group, and our leading roles in the design and delivery of space instrumentation, has helped Norwegian industry to enter international space projects.

- AGU press release on TGFs[1]
- AGU press releases on ASIM results[2]
- Interview by the journal *Nature* with the BCSS leader regarding ASIM results[3]

Publications

Østgaard et al. (2019), The Modular X- and Gamma-Ray Sensor (MXGS) of the ASIM Payload on the International Space Station, *Space Sci. Rev.* 215:23, DOI: 10.1007. s11214-108-1573-7

Neubert, **Østgaard**, Reglero, Chanrion, Heumesser, Dimitriadou, Christiansen, Budtz-Jørgensen, Kuvvetli, Lundgaard Rasmussen, **Mezentsev**, **Marisaldi**, **Ullaland**, **Genov**, **Yang**, **Kochkin**, Navarro-Gonzalez, Connell, Eyles (2020), A terrestrial gamma-ray flash and ionospheric ultraviolet emissions powered by lightning, *Science*, DOI: 10.1126/science. aax3872. Awarded cover page of issue[4]

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View of the ASIM instrument on the Columbus module of the International Space Station

Image: ESA

> Interdisciplinary branching towards high-energy astrophysics: the ASIM instrument shed light on the intimate structure of highly magnetized neutron stars

> On 15th April 2020, a very short and bright gamma-ray burst triggered many space missions equipped with gamma-ray detectors, including ASIM. Soon, the burst turned out to be the giant-flare of a highly magnetized neutron star (magnetar) in a nearby galaxy 11-million light-years away from our galaxy. The photon flux was so large that most of the instruments were heavily affected by instrumental effects, which suppressed photon detection during the brightest phase of the event. MXGS onboard ASIM did not suffer from significant instrumental effects, thanks to its architecture which was designed to record TGFs, which can be much brighter on shorter time scales. This allowed us a detailed timing analysis of the few milliseconds of the main burst phase, evidencing the presence of Quasi-Periodic Oscillations (QPO) at about 2 and 4 kHz, the first observation of this kind in these objects. These observations are consistent with plasma / wave interaction in the neutron star's strong magnetic field, shedding light to the generation mechanism of these rare giant flares. To obtain these results, we set up a fruitful collaboration with international high-energy astrophysics experts, expanding the academic impact of the ASIM mission to neighbouring fields. The results were published in the prestigious journal Nature (Castro-Tirado et al., 2021).

- Coverage of the ASIM results on the giant magnetar flare: more than 635 media outlets[1]
- "Picture-of-the-week" on the NASA HEASARC website[2]
- June 2023: First Prize for Excellent Research Works published by a team led by University of Malaga (UMA) in Spain researchers

Publications

Castro-Tirado, A.J., **Østgaard, N.**, Gogus, E., Sánchez-Gil, C., Pascual-Granado, J., Reglero, V., **Mezentsev, A.,** Gabler, M., **Marisaldi, M.**, Neubert, T., Budtz-Jørgensen, C., **Lindanger, A.**, **Sarria, D.**, et al. (2021), Very-high-frequency oscillations in the main peak of a magnetar giant flare, *Nature*, DOI: 10.1038/s41586-021-04101-1

1.

2.

ACHIEVEMENTS

> Recognition

EGU Student Award

Beate K. Humberset
2013

Christer v. der Meeren
2015

Christoph Franzen
2016

Josephine Salice
2022

Ingrid Bjørge-Engeland
2022

Fulbright Scholarship | Norway

Beate K. Humberset
9 months, JHU/APL
2013

Paul Tenfjord
9 months, UCLA
2015

Martino Marisaldi
6 months, Duke University
2015

Kjellmar Oksavik
Arctic Chair
Virginia Tech, USA
2017

Hilde Nesse
Univ.of Colorado, Boulder
2018

Peder Sather Grant | UC Berkeley

Jone Reistad
2014

Martino Marisaldi
2023

AGU Student Award

Nora Stray
2013

Beate K. Humberset
2013

ESA Highlight

Karl M. Laundal
SWARM data
2013

Yara's Birkeland Prize

Thomas Gjesteland
2014

ERC Grants

Nikolai Østgaard
Advanced Grant
2013

Karl M. Laundal
Consolidator Grant
2019

Covers of *Journal of Geophysical Research*

Xiancai Chen
Han et al., 2015

Christer v. der Meeren
V.d. Meeren, et al.
2014

> Recognition

Image of the Week

Pavlo Kochkin
Kochkin et al.
J. of Physics, 2016

AGU Press Release

Nikolai Østgaard
Østgaard et al.
GRL, 2013

Anders Ohma
Ohma et al.
2018

Young CAS Award

Hilde Nesse
2019

Trond Mohn Starting Grant

Karl M. Laundal
2019

> Most Cited Papers with BCSS First Authors

> The following is a list of the most cited papers (2013-2023) with BCSS members as first authors; their papers have contributed to an H-index of 41 (Web of Science).

FIRST AUTHOR	PAPER	CITATIONS
K.M. Laundal et al.	Magnetic Coordinate Systems (2017), *Space Sci Rev*, DOI: 10.1007/s11214-016-0275-y	155
S.E. Milan et al.	Overview of Solar Wind–Magnetosphere–Ionosphere–Atmosphere Coupling and the Generation of Magnetospheric Currents (2017), *Space Sci Rev*, DOI: 10.1007/s11214-017-0333-0	90
P. Tenfjord et al.	How the IMF By induces a By component in the closed magnetosphere and how it leads to asymmetric currents and convection patterns in the two hemispheres (2015), *JGR*, DOI: 10.1002/2015JA021579	77
K.M. Laundal et al.	North–South Asymmetries in Earth's Magnetic Field (2016), *Space Sci Rev*, DOI: 10.1007/s11214-016-0273-0	73
M. Marisaldi et al.	Properties of terrestrial gamma ray flashes detected by AGILE MCAL below 30 MeV (2013), *JGR–Space Phys.*, DOI: 10.1002/2013JA019301	63
C. van der Meeren et al.	GPS scintillation and irregularities at the front of an ionization tongue in the nightside polar ionosphere (2014), *JGR–Space Phys.*, DOI: 10.1002/2014JA020114	53
N. Østgaard et al.	Simultaneous observations of optical lightning and terrestrial gamma ray flash from space (2014), *Geophys. Res. Ltrs.*, DOI: 10.1002/grl.50466	51
K.M. Laundal et al.	Solar Wind and Seasonal Influence on Ionospheric Currents From Swarm and CHAMP Measurements (2014), *JGR–Space Phys.*, DOI: 10.1029/2018JA025387	44
R. de Wit et al.	Observations of gravity wave forcing of the mesopause region during the January 2013 major Sudden Stratospheric Warming (2014), *Geophys. Res. Ltrs.*, DOI: 10.1002/2014GL060501	47
N.H. Stray et al.	Observations of planetary waves in the mesosphere-lower thermosphere during stratospheric warming events (2015), *Atm. Chem. Phys.*, DOI: 10.5194/acp-15-4997-2015	45
H.N. Tyssøy et al.	Energetic electron precipitation into the middle atmosphere-Constructing the loss cone fluxes from MEPED POES (2016), *Atm. Chem. Phys.*, DOI: 10.5194/acp-15-4997-2015	44
N. Østgaard et al.	Energetic electron precipitation into the middle atmosphere-Constructing the loss cone fluxes from MEPED POES (2016), *Atm. Chem. Phys.*, DOI: 10.5194/acp-15-4997-2015	42
C. van der Meeren et al.	Severe and localized GNSS scintillation at the poleward edge of the nightside auroral oval during intense substorm aurora (2015), *JGR–Space Phys.*, DOI: 10.1002/2015JA021819	42
M. Marisaldi et al.	Enhanced detection of terrestrial gamma-ray flashes by AGILE (2015), *Geophys. Res. Ltrs.*, DOI: 10.1002/2015GL066100	42
K. Oksavik et al.	Scintillation and loss of signal lock from poleward moving auroral forms in the cusp ionosphere (2015), *Geophys. Res. Ltrs.*, DOI: 10.1002/2015JA021528	42

> Promotion of Science and Public Outreach Events

Still from video: BCSS / Mount Visual

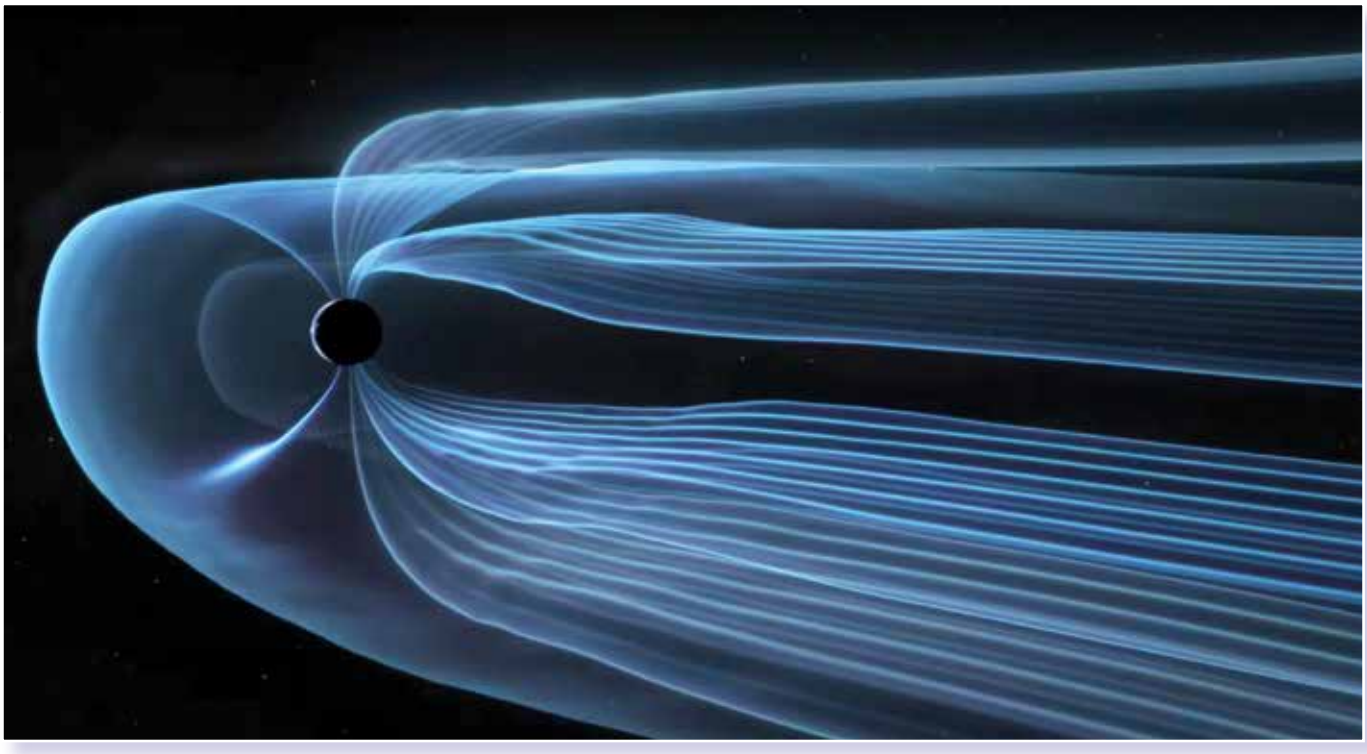


Figure 1: A still image from the video "An Introduction to Asymmetric Geospace". *Credit: BCSS / Mount Visual*

Figure 2: (below) Coverage of "Asymmetry" research findings in the *New York Times*

> During the ten years as a Centre of Excellence, a great many exciting and important papers have been produced by researchers at the Birkeland Centre for Space Science (BCSS).

In order to highlight new findings (as a general rule), we have actively used the Centre homepage, as well as social media (Facebook and Twitter). We have also contacted journalists when we thought that new research results may be of interest for a particular group of readers/viewers.

However, when our researchers have made a substantial scientific breakthrough, we have explored various ways of ensuring the best promotion of the science product possible, e.g., making animations, illustrations, videos, press releases etc. Below, we will present some of the breakthrough science at BCSS, with emphasis on what was done to promote the results. We will also present highlights from a variety of public outreach events during the years.

ASYMMETRIC AURORA

One of the greatest scientific achievements at BCSS is undoubtedly the understanding of the dynamical behavior of our near-Earth geospace, which may be attributed to more than a decade of hard work from numerous BCSS researchers.

With the publication of two papers by the end of 2018 (Ohma et al., 2018 and Østgaard et al., 2018), BCSS decided it was time to promote the new paradigm shift in how we view the asymmetric geospace. To quote Mike Liemohn, former editor-in-chief of *JGR-Space Physics*: "This … explains both how asymmetries are created and how they are removed and it is exactly the opposite of what I and many researchers have thought. (…) Therefore, this result is kind of a big deal".

In order to ensure that the general public would better understand our scientific findings, an animation lasting 2 minutes and 40 seconds *(Figure 1)* was produced through a collaboration with Mount Visual, a digital design agency. This video can be seen on the AGU YouTube channel, and has so far been viewed more than 27,200 times.

Due to the high importance of this scientific breakthrough, a joint press release created by AGU and BCSS was published on the 24th of January 2019, followed by a press release by the University of Bergen. A detailed article was also published on our BCSS webpage, where all the important findings throughout the last 15 years were acknowledged.

This new understanding of our near-Earth neighborhood generated much media

The New York Times

The Northern and Southern Lights Are Asymmetric Dancers in the Dark

Our planet's auroras do not mirror one another, and their varying shapes result from the interplay of the sun and Earth's magnetic fields.

attention, including the article in none other than the *New York Times (Figure 2)*!

ASIM: A TRUE SUCCESS STORY!

When it comes to public outreach, ASIM became a success story even before the instrument began transmitting data from its location outside the International Space Station to Earth. This is indeed what happens when a scientific instrument is exposed by the legendary «T minus 10 seconds and counting». Around the memorable launch date of April 2, 2018, more than 400 media articles from all over the world were written about ASIM.

Since it was installed and mounted outside the International Space Station (ISS) in 2018, the ASIM instrument has led to many exciting discoveries when it comes to TGFs and other lightning events. E.g. ,18 months after the successful ASIM-launch, a slew of new discoveries about the mysterious gamma-ray flashes that come from Earth's thunderclouds were ready to be unveiled. In order to draw as much attention as possible, we launched the new findings on four different platforms at the same time:

a. Press release by AGU entitled "Scientists unveil new discoveries about gamma ray flashes coming from thunderstorms"

b. Press release by University of Bergen entitled "Avslører lynets hemmeligheter"

c. Disclosure of three new publications in *Science* (Neubert et al., 2019) and *Journal of Geophysical Research* (Østgaard et al, 2019; Sarria et al, 2019)

d. Talk given by BCSS-leader Nikolai Østgaard at the AGU Fall Meeting 2019 in San Francisco

In addition, in partnership with Mount Visual, we designed an illustration that was accepted and put on the front page of *Science* a few weeks later (*Figure 3*). The new results generated more than hundred media articles all over the world, including the one in the Spanish edition of *National Geographic* (*Figure 4*).

One year later, history "almost" repeated itself: Centre leader Nikolai Østgaard was co-author on a paper by Torsten Neubert revealing the nature of Blue jets. Once more, we partnered with Mount Visual (as well as DTU Space and Daniel Schmeling) and the resulting illustration appeared on the cover of *Nature (Figure 5)*. A press release was made by University of Bergen entitled "Nye resultater fra romstasjonen", and during the next weeks, more than 600 media articles were produced all over the world!

DETECTING A GAMMA RAY BURST FROM A MAGNETAR

One of the most exciting findings was undoubtedly when ASIM data was able to unveil some of the secrets surrounding magnetars.

In order to promote these spectacular observations, we made a video lasting 6-7 minutes, in which the main researchers doing the study explained magnetars in general and what made this particular ASIM discovery so important.

Additionally, an illustration of the extraordinary shakings of a distant magnetar was made in cooperation with Mount Visual *(Figure 6)*. This illustration was chosen as NASA's "Picture of the Week" in the beginning of January 2022.

Illustration: Mount Visual / Daniel Schmelling

Figure 3: Cover of *Science* (January 2020)

Illustration: BCSS / Mount Visual / Daniel Schmelling

Figure 4: (above) Article in *National Geographic* Spain (December 2019)
Figure 5: (left) Cover of *Nature* (January 2021).

Illustration: BCSS / Mount Visual / Daniel Schmelling

Figure 6: (left) Illustration of a magnetar chosen as NASA's "Picture of the Week"
Figure 7: (below) Centre leader interviewed on NRK news

Vestlandsnytt, Photo: Eva Therese Jenssen/UNIS

Kjellmar frå Fosnavåg oppdaga rom-orkan

Figure 8: (left) Interview with Kjellmar Oksavik regarding the space hurricane in *Vestlandsnytt*
Figure 9: (above) *National Geographic* article on the space hurricane

We also participated with University of Bergen in producing two articles (a Norwegian one entitled "Gigantisk stråling-sutbrudd i verdensrommet fanget opp av UiB-instrument" and an English one entitled "Extraordinary shakings of a distant magnetar"). Finally, a press release was made and distributed as usual by University of Bergen.

The results were immediately picked up by the media, and already the same evening, NRK Vestlandsrevyen was running with the ASIM news item as their top story. This clip was later put on national TV (NRK kveldsnytt) *(Figure 7)*.

Once again, the new findings revealing the true nature of a magnetar led to articles in media all over the world. During a period of only a few weeks the total number of articles reached 635!

THE FIRST OBSERVATION OF A SPACE HURRICANE

In addition to the scientific breakthroughs mentioned above, we should also include the first observation of a space hurricane. The groundbreaking result was published in *Nature Communications* on February 22th 2021 by Zhang et al. (2021), with professor Kjellmar Oksavik of BCSS as a co-author. The phenomenon of a space hurricane really caught the interest of journalists, and Kjellmar was interviewed by "everyone". This includes his local paper *Vestlandsnytt (Figure 8)*, a radio interview on NRK (where Kjellmar explained the space hurricane in more detail), as well as an excellent article in *National Geographic (Figure 9)* entitled "Scientists spot a space hurricane for the first time". Almost 400 media articles throughout the world were finally made about the space hurricane.

INVITED TALK AT UN MEETING

A different type of public outreach activity took place in 2017, when Centre Leader Nikolai Østgaard *(Figure 10)* had the honour of attending the UN-COPUOS (United Nation Committee on the Peaceful Uses of Outer Space) meeting in Vienna, Austria. Østgaard had been invited by the SCOSTEP President Nat Gopalswamy and gave a talk entitled "Norwegian contribution to SCOSTEP/VarSITI.

TOTAL SOLAR ECLIPSE

A most memorable public outreach activity took place in 2015 during the solar eclipse event on March 20. On Svalbard, weather conditions were excellent for enjoying a total solar eclipse. Several researchers from BCSS participated in the TV broadcast that was aired both nationally and internationally. Among the BCSS participants was Ragnhild Schrøder Nisi *(Figure 11)*, to whom the national TV network NRK referred as "their solar eclipse expert." Another public outreach contributor during the solar eclipse was Kjellmar Oksavik. In the image *(Figure 12)* he uses an instrument known as a "sunspotter" to capture the historic event .

UNITING SCIENCE AND ART

In 2019, BCSS became part of a concert series named "Next Step". This was a collaborative effort between the Bergen Philharmonic Orchestra and the University of Bergen seeking to unite science and art through the themes of space, ocean, climate and humanity.

On the evening of September 12, the first concert of the series, "Space", was hosted by Birkeland Centre's Arve Aksnes and UiB doctoral student Susanne Fløe Spinnangr. The two gave a brief introduction to space science with accompanying visuals on a big screen behind them. The presentation ended with a surprise greeting from astronaut Luca Parmitano from aboard the International Space Station *(Figure 13)*.

RESEARCH DAYS IN BERGEN

"Research Days" has been an annual event since 1994 which has been led by the Research council of Norway. The purpose of the event is to promote science to the general public, and every year BCSS has participated in different activities. Associate Professor Kjartan Olafsson has played a major role in these exciting outreach events, alongside (for the most part) several Master's and PhD students from our Centre *(Figure 14)*.

Figure 10: Nikolai Østgaard at the COPUOS meeting

Image: TU, Photo: Sindre Skrede

Photo: forskning.no

Figure 11: (topmost) Ragnhild Nisi
Figure 12: (above) Kjellmar Oksavik demonstrates a sunspotter

Still from video: European Space Agency

Figure 12: (top) "Space" concert presenters Arve Aksnes and Susanne Flø Spinnangr
Figure 13: (left) Astronaut Luca Parmitano surprises concert goers with a "visit" from space.

Figure 14: (right) "Research Days" with students from BCSS engaging with an eager public
Figure 15: (below) PhD student Josephine Salice wins the 2023 "Researcher Grand Prix".

Image: UiB / Øyvind Ganesh Eknes

Image: Kjartan Olafsson

JOSEPHINE SALICE: WINNER OF RESEARCHER'S GRAND PRIX

A new competition has been developed in recent years – Researcher's Grand Prix– in excellence in public presentation. The contest is for PhD students and gives each contestant four minutes to enthrall the audience with a presentation on their science. The top three contenders then make it to the final for the ultimate outreach fight!

After an unnerving and impressive competition among ten PhD candidates, BCSS Phd student Josephine Salice *(Figure 15)* became the winner of the prestigious Researcher's Grand Prix 2022. "When they (ref: judges) announced my name as the winner, I was initially surprised, and then I just became very happy, feeling a big smile spread across my face," says Josephine.

> Scientific Leadership Nationally and Internationally

BCSS Workshops
From 2013 to 2023, we have organized 16 workshops for all BCSS members and guests. Representatives from all the Norwegian space groups have been invited to each workshop. In addition, we have had at least two international guests at each workshop.

Committee on Space Research (COSPAR)
Yvan Orsolini: National Representative (2014-2019), and Main or Deputy Session Organiser for C23 (C22 in 2022): "Advances in External Forcing Studies for the Middle Atmosphere and Lower Ionosphere" at COSPAR General Assemblies (2010-2022)

International Association of Geomagnetism & Aeronomy (IAGA)
Hilde Nesse: Deputy National Representative (2015-2019)

Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)
Nikolai Østgaard (National Representative in the steering committee since 2013): Presentations about Norwegian Space Research have been provided at the SCOSTEP meetings. In 2017, he was invited to give a presentation at the UN Committee on Peaceful Uses of Outer Space (COPUOS).

Hilde Nesse: Science Discipline Representative in SCOSTEP (2021-2022)

Lisa Baddeley: Science Discipline Representative in SCOSTEP (2022-)

International Space Weather Initiative (ISWI):
Nikolai Østgaard, member since 2013

Magnetosphere Multi-Satellite (MMS)
Michael Hesse : Organized meeting in Bergen (2018) with more than 80 international attendees

High Energy Particle Precipitation in the Atmosphere (HEPPA)
Hilde Nesse: Chair of the scientific organizing committee and leader between 2017 and 2022

Heppa-Solaris
Hilde Nesse: Organized and hosted the 8th International HEPPA-SOLARIS Meeting in Bergen in 2022.

Hilde Nesse: Co-Leader of the SOLARIS-HEPPA Working Group (Medium Energy Electrons Model Measurement Intercomparison)

Young Center for Advanced Study Network
Hilde Nesse: Leader of "Unravelling the drivers of energetic electron precipitation" (2019-2021)

International Union of Radio Science (URSI)
Kjellmar Oksavik: National Representative in Commission G since 2020

World Meteorological Organization (WMO)
Martino Marisaldi: Weather and Climate Extremes – evaluation committee for lightning extremes (2021-2022)

International Space Science Institute (ISSI)
Karl Magnus Laundal: led "Understanding Mesoscale Ionospheric Electrodynamics Using Regional Data Assimilation," in 2020

Martino Marisaldi : led the project "Understanding the Properties of the Terrestrial Gamma-ray Flash population" (2019-2022)

Both projects were extended by one year. (see report 2021)

Solar System Exploration Working Group (SSEWG)
Nikolai Østgaard: (2013-2016) SSWEG is an advisory group for ESA which makes recommendations about future and current satellite missions in the ESA scheme of L(arge), M(edium) and S(mall) missions. During the time the centre leader served at SSEWG, SMILE was selected as an ESA – Chinese Academy of Science (CAS) mission, and continuation of Cluster mission was secured

EISCAT 3D
Kjellmar Oksavik (Co-Investigator), *Patrick Espy, Lisa Baddeley* (Norwegian Representative to the EISCAT Science Oversight/Advisory Board) (from 2017)

EGU and AGU
Thomas Gjesteland, Martino Marisaldi, David Sarria, Brant Carlsson: each has taken a turn at organizing sessions at both meetings all ten years

Norwegian Physical Society
Thomas Gjesteland: board member and leader of the division for space-, plasma- and climate physics (2014-2016)

Hilde Nesse: vice-president (2022 -)

> Atmosphere-Space Interaction Monitor (ASIM): 2005-2018

> ASIM is an ESA mission to the International Space Station that started in 2004. Launched in April 2018 *(Figure1)*, it will continue its operation at least throughout 2025. The various instruments that constitute the ASIM payload are designed to measure optical (Transient Luminous Events: TLEs and lightning) and X -and gamma-ray emissions (TGFs). The goal of ASIM is to be able to correlate, in space and time, lightning, the TLEs and the TGFs.

The space group at UiB (BCSS as of 2013) was invited to join ASIM in 2004. During the first 5 years of the project, we were mainly doing the necessary political work to secure support and funding for all the involved partners. Since the beginning, ASIM has been led by Denmark (Danish Technological University (DTU) and TERMA), and the two main partners have been Norway (University of Bergen) and Spain (University of Valencia). During this time, breadboard models of the instruments were designed and built (Phase A and B). ASIM is a complex project requiring expertise on Product Assurance requirements, procurement, ITAR regulations and formal documentation. During this project, the space instrumentation group at BCSS has enhanced its expertise significantly, which was important for getting involved in new space missions such as SMILE.

Our responsibility has been to develop the detector and readout electronics for MXGS, which consists of two X- and Gamma-ray detectors *(Figure 2)*. The Low Energy Detector (LED) is a 1024 cm^2 pixelated detector of CZT (Cadmium Zink Telluride) with dedicated fast read-out electronics. LED measures energies in the range of 50 keV up to 400 keV. With a coded mask, the LED is enabled to perform imaging of the TGFs. The High Energy Detector (HED) is 900 cm^2 of BGO (Bismuth Germanate) crystals coupled to photomultiplier tubes with dedicated fast read-out electronics. It extends the energy range from 300 keV up to more than 30 MeV.

We have developed three models of the instrument and for each step there have been extensive review processes. From 2013 to 2016, we passed the following milestones: 1) Finalizing and testing the Engineering Model of LED and HED and delivering the document package for the Critical Design Review (2013-2014). For such a project, this is a major milestone; after delivery of the package, no design changes can be made. 2) Delivery of the

Photo: Gunnar Mæhlum, IDEAS

Figure 1: (left) A SpaceX rocket carrying the ASIM instrument in a Dragon capsule launches to ISS (2018).
Figure 2: (below) The ASIM instrument mounted on CEPA. MXGS is on the right (silver cover), MMIA is on the left.

> **ASIM** (cont.)

Ground Models (2014), which were electrically representative for the Flight Models (FM), and will be used on-ground to understand problems during operation in space. 3) The building, testing and calibration stages of the Flight Model started immediately after the delivery of ground models and were completed in late 2015. In 2016 we delivered the final HED and LED Data Package – adding up to more than 440 documents – for the Preliminary Acceptance Review. All tests of MXGS were successfully performed.

After that, MXGS was integrated on the CEPA platform together with all other subsystems of ASIM. Following all system testing, ASIM was ready for launch in April 2018 *(Figures 3 & 4)*. ASIM has been the largest space instrumentation project ever undertaken by Norwegian academia. The total budget for our involvement (including in-kind contribution) has been about 70 MNOK.

Since launch, ASIM has delivered unprecedented data on terrestrial gamma-ray flashes (TGFs), galactic gamma-ray bursts (GRBs), lightning strokes and other exotic phenomena like blue jets and elves. Following the success of simultaneous depictions of TGF and Elve on the front page of *Science* at the beginning of the year (Neubert & Østgaard et al. 2020), ASIM results were also featured on the front page of *Nature* in January 2021 (Neubert et al., 2021) – this time with a blue jet and an Elve during the same lightning flash.

ASIM was planned for a two-year mission ending in summer 2020, but due to its success, the project was first extended through 2021, and later further extended until the end of 2025.

In 2021 we got yet another paper published in a top-notch journal: Castro-Tirado, Østgaard, Göğüş et al., 2021 in Nature. This was a 160 ms long signal from a magnetar 11 million lightyears away. ASIM´s superior time resolution made it possible to identify very high frequency oscillations in the very first phase (3 ms) of the burst for the first time.

In early 2022 ASIM was moved to a different location on the Columbus module and will stay there for ~2.5 year. The plan is then to move ASIM back (early 2024) to its original location for another 1.5 years. This means that ASIM will be a 7-year mission, which is much longer than the nominal mission of 2.5 year that was initially planned. Thanks to all the wonderful results from ASIM, both ESA and the national funding agencies have been pro-active in getting this extension funded.

Since 2018 (and until the mission is terminated) BCSS has supported the ASIM Science Data Center with a dedicated programmer/researcher funded through ESA-PRODEX.

Figure 3: From left, former UiB Rector Dag Rune Olsen, Centre Leader Nikolai Østgaard, BCSS Senior Consultant Kavitha Østgaard, Sr. Manager at the Norwegian Space Centre Marianne Vinje Tantillo, Monica Ullaland and BCSS Prof. Kjetil Ullaland, and CEO at IDEAS Gunnar Mæhlum. Sitting: Sr. Engineer at BCSS, Georgi Genov

Figure 4: Center Leader Nikolai Østgaard and then UiB Rector Dag Rune Olsen watch the launch from Cape Canaveral, Florida

Figure 5: ALOFT team posing in front of the ER-2 aircraft at the MacDill Air Force Base in Tampa, Florida. From left: Shiming Yang (UiB-BGO), Nikolai Østgaard (ALOFT PI, UiB-BGO), Gerald Heymsfield (CRS-EXRAD), Christopher Schultz (Deputy Mission Scientist ALOFT & LIP), Corey Amiot (weather foreaster and AMPR), Kelly Carmer (weather forecaster), Sarah Stough (mission planner), Richard Blakeslee (FEGS), David Robles (CoSSIR) and Zachary Khan (iSTORM)

> Aircraft Campaigns

> BCSS has been part of two NASA's ER-2 aircraft campaigns searching for Terrestrial Gamma-ray Flashes and gamma-ray glows from thunderclouds from 20 km altitude; FEGS (2017) and ALOFT (2023).

FLY'S EYE GLM SIMULATOR (FEGS)

For the first campaign in 2017, we were invited by the University of Alabama in Huntsville to join the FEGS campaign. The main target of FEGS was to calibrate the Global Lightning Monitor which is flying on a geostationary satellite. BCSS was flying a spare BGO detector (225 cm^2) from ASIM on the ER-2 aircraft. New read-out electronics, including power supply and a data processing unit, were built for this instrument. As TGF research was not the main target of this campaign, we were not flying in regions that were optimal for TGF detection, but during the campaign, we made high quality observations of gamma-ray glowing clouds, which resulted in two papers.

AIRBORNE LIGHTNING OBSERVATORY FOR FEGS AND TGFS (ALOFT)

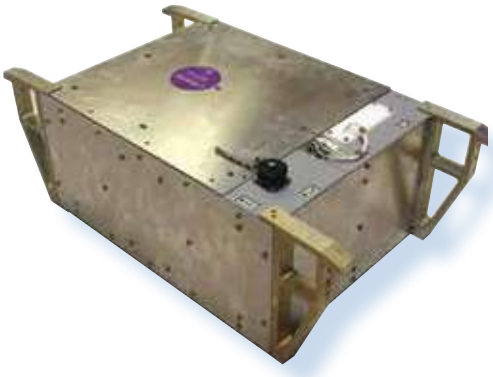
ALOFT is led by BCSS and will fly in July 2023 in one of the most TGF-intense regions on the planet. Since 2021 we have worked with NASA headquarters on a contract to rent the ER-2 aircraft in July 2023; the contract was finally signed in the summer of 2022. The plan is to fly at 20 km altitude over Central America, the Caribbean, and northwest South America. These regions are hotspots for TGF production and July is the best part of the year to observe the short-lived TGFs (microseconds) related to lightning strokes and long-lasting gamma-ray glows (minutes to hours) from the large area of a thundercloud cell. ALOFT will make high-resolution measurements of both the gamma-rays, optical signals, and E-field. The main objective is to measure TGFs from an optimal venue point but the aircraft will also spend 1/3 of the flight time to search for and follow the long-lasting gamma-ray glows from thunderclouds.

ALOFT is a collaboration between BCSS at the University of Bergen and NASA Marshall Space Flight Center *(Figure 5)*. BCSS will fly one of the units from ASIM High Energy Detector, which consist of 3 pairs of BGO/PMT. In addition, we have built three smaller LYSO-detectors to prepare for extremely high gamma-ray fluxes, covering a dynamical range of 4-5 orders of magnitude.

ALOFT will also have the FEGS package with optical instruments, electric field measurements (fast and slow, as well as three vector fields) and several radars to monitor the characteristics of the thunderclouds *(Figures 6 & 7)*.

Read more about ALOFT:

Figure 6: (left) Dr. Mason Quick, NASA Instrument Scientist, supervising the mounting of the FEGS instrument onto the ER-2 aircraft (ALOFT)
Figure 7: (below) FEGS instrument



> Solar wind Magnetosphere Ionosphere Link Explorer (SMILE): 2016-2023

> The Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE) mission is a joint mission of the European Space Agency (ESA) and the Chinese Academy of Science (CAS). Launch is planned in 2025.

One instrument onboard SMILE is the Soft X-ray Imager (SXI), which will provide unprecedented images of the entry of plasma from the Solar Wind into the Earth's magnetosphere. The SXI project is a collaboration between several European universities, research institutes, and industrial partners. BCSS will deliver a Radiation Shutter *(Figures 8 and 9)* to protect the SXI instrument against fatal exposure during spacecraft maneuvers and crossings of the Earth's radiation belt. The Radiation Shutter is comprised of the Radiation Shutter Mechanism (RSM) and Electronics (RSE).

Prototype testing of the RSM was completed in 2021, but changes in US export regulations forced a new European launch lock to be introduced (and major structural redesign of the RSM). It was also discovered that some door position indicator switches were unstable, so a full screening and acceptance test were carried out in our Thermal Vacuum Chamber (TVAC) to eliminate switches with unreliable behavior. Testing of switches was completed in the spring of 2022.

Parts for the RSM Engineering Qualification Model (EQM) were procured in the autumn of 2021, followed by dedicated surface treatments at multiple locations across Europe and a thorough qualification campaign. Vibration tests were completed at ESTEC in April 2022. Thermal cycling and a life test were completed in June 2022, where the door mechanism was successfully operated more than 3370 times in our TVAC at temperatures ranging from -145 to -65 °C.

Procurement of parts for the RSM Flight Model (FM) and Flight Spare (FS) and surface treatments were completed in January 2023. The FM unit was assembled, followed by a full acceptance test campaign. Vibration tests were completed at ESTEC in March 2023, followed by thermal cycling in our TVAC. The RSM FM magnetic field was characterized at ESTEC, and the RSM FM was delivered to University of Leicester in June 2023.

The RSE design also involved multiple design loops driven by to a change of controller from MCU to FPGA and changing US export regulations. The RSE EQM was assembled in 2021, tested at BCSS, and integrated into the SXI EQM electronics box at Institut für Weltraumforschung (IWF) in Austria in 2022 for full qualification testing.

The RSE FM and FS were assembled in 2023 and tested at BCSS. The RSE FM was delivered to IWF for integration into the SXI FM electronics box in June 2023.

Significant work has gone into updates of design and manufacturing documents, including various analyses and data packs needed for various SXI instrument level reviews: System Requirement Review (2017-2018), Preliminary Design Review (2019), and Critical Design Review (2022-2023).

In 2022 there was a sudden loss of key personnel at BCSS in the critical final stage of the project, but the Norwegian Space Centre quickly found a solution. Supplementary funding of 500k EUR from the ESA CTP GeoReturn Special Measures fund allowed BCSS to get quick help from external consultants. STM Maskinering AS in Bergen arrived on-site and provided excellent support in 2022-2023.

The total BCSS involvement in SMILE adds up to over 40 MNOK, including in-kind assistance from UiB and an ESA PRODEX contract of 1515 kEUR. In addition, STM has a 330k EUR contract via ESA to support BCSS activities.

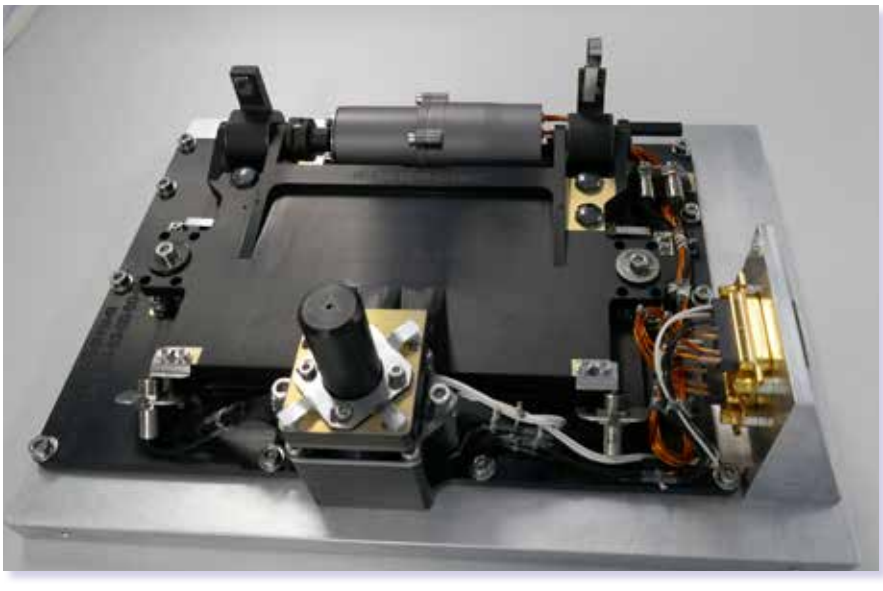
> Electrojet Zeeman Imaging Explorer (EZIE): 2019-

> The Electrojet Zeeman Imaging Explorer (EZIE) is a new NASA mission that will be launched in the fall of 2024 or in early 2025. It will be comprised of three satellites that measure microwave emissions from the mesosphere. Using the Zeeman effect, these emissions allow the derivation of the vector magnetic field at mesospheric altitudes. This is the first mission dedicated to making Zeeman magnetic field measurements on Earth. Jesper Gjerloev, Professor-II at BCSS, is the project scientist. Karl Laundal leads the team that develops the algorithm which will be used to derive maps of the ionospheric currents that produce the mesospheric magnetic field. The unique nature of the EZIE measurements calls for new ways of utilizing the data, and Laundal et al. [2021] have developed a technique that can be used to discover meso-scale structures in the auroral electrojet which have so far not been possible to resolve.

> Distribution of Energetic Electron and Proton Instrument (DEEP): 2019-

> Accurately quantifying the effect of energetic particle precipitation requires a good estimate of the energy deposited in the atmosphere and how the energy is distributed globally. The design and/or orbits of current particle detectors in space are inadequate for determining the amount of particles precipitating into the atmosphere. In particular, the electrons often have a strong anisotropic pitch angle distribution, which is essential in determining the particle loss to the atmosphere. DEEP is composed of three electron (30-500 keV) - and three proton-pixelated (30 keV-10 MeV) detectors in separate housings, covering a field of view of 180°. This makes it possible to determine the electron fluxes absorbed by the atmosphere, as well as the fluxes backscattered from the atmosphere.

The DEEP prototype was first launched in 2019.



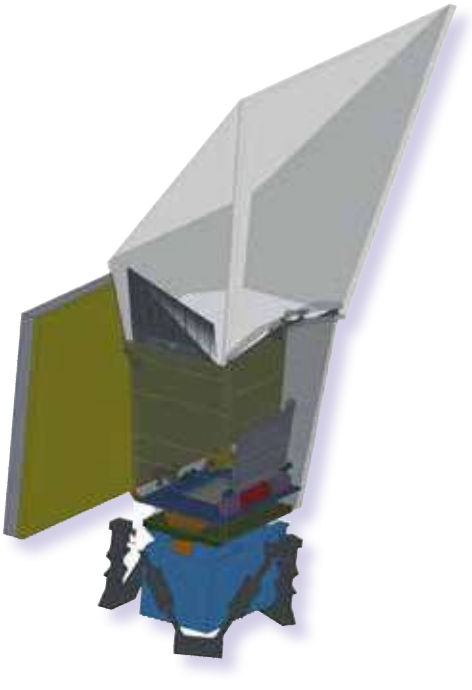


Figure 8: (above) Part of the radiation shutter mechanism for the SMILE project developed at UiB/BCSS
Figure 9: (right) 3D drawing of the mechanism

GROUND-BASED INSTRUMENTS

> The ground-based instrumentation group is running and maintaining already existing research infrastructure that the BCSS is granted access to. This includes the Kjell Henriksen Observatory (KHO), NTNU's meteor radar and optical instrumentation at Dragvoll campus in Trondheim, and the LINET receiver in Bergen. The Scintillation and Total Electron Content (TEC) network of BCSS and SuperDARN are also included in the infrastructure. In the first years of BCSS, both SPEAR and SuperMAG were part of this infrastructure. BCSS is also playing an important role in the new EISCAT 3D radar project.

This section reports on the main activity in 2013 - 2023.

> Kjell Henriksen Observatory (KHO)

> The activity at the Kjell Henriksen Observatory *(Figure 10)* has been high the last decade except for the pandemic year of 2020. Even though the observatory was in full operation, no rocket campaigns were carried out and no visits from our instrumental partners occurred. On the other hand, the situation gave us more time to focus on upgrades, instrumental work, and new constellations. We also managed to keep in contact with our students through Teams or Zoom, and they all finished their courses and degrees successfully.

In total, 32 students have finished their degrees under the supervision of the observatory crew in the last decade. The latter personnel are five full-time permanent scientific positions at the Department of Geophysics at UNIS known as the Space Group. This group has increased its manpower from two to five PhD candidates and two postdocs in 2014 – 2023. In the same period, the group published 108 scientific publications and gave 124 presentations on conferences. Note that the crew is living in Longyearbyen all year round, contributing to the local society.

KHO serves as the main laboratory for hands-on training and teaching of students in the Space physics group at UNIS. The number of courses has increased from four to six with 45 ECTS (European Credit Transfer and Accumulation System) to 75 ECTS of teaching load. The focus is observational techniques, instrument development and remote sensing of the aurora / airglow.

The number of optical instruments that operate during the auroral winter season from November to the end of February has increased from 25 to 31. 22 different institutions from ten nations are now present at the observatory. The number of non-optical instruments that run all-year-round 24 hours a day has risen from ten to sixteen. In 2022, a boost of four new collaborators joined with two high end interferometers, an all-sky camera, a Near-InfraRed (NIR) camera with spectrograph and a GNSS (Global Navigation Satellite System) test receiver. The instrumental activity is now high.

On the instrumental development side, we are pleased to announce that the SuperDARN radar initially constructed back in 2015, is now up and running again after the total breakdown in 2018 due to heavy weather and icing conditions. Additional supporting steel poles have been put into the ground at each end of the two mast arrays. The masts are now made more sturdy with solid aluminum.

Another highlight is that we were able to transfer our knowledge of spectroscopy out into space. Our hyperspectral prototype design was used onboard NTNU's HYPSO-1 (HYPer-spectral Smallsat for ocean Observation no. 1) that was launched on 13 January 2022 by a SpaceX Falcon-9 rocket from Kennedy Space Center in Florida. It is Norway's first scientific satellite. It is one of the smallest of its kind performing ocean spectral mapping with high signal-to-noise characteristics. Two more satellites are planned with our designs.

Both before and after the COVID-19 pandemic, KHO has been used as the main launch decision site for numerous (ten) rocket launches both from mainland Andøya Space Centre and SvalRak in Ny-Ålesund, Svalbard. The extensive battery of optical instruments was used to identify dayside aurora and optimal launch conditions. KHO was an essential partner in the Grand Challenge Initiative – CUSP, which was a successful large-scale international collaboration effort to study multi-scale physics and charged particle precipitation in the geomagnetic cusp region by sounding rockets.

Detailed yearly reports can be found on the observatory's website:

Vincent Fournier/Gallery Stock

Figure 10: Domes of the Kjell Henriksen Observatory

> NTNU Ground-Based Instruments

> NTNU's ground-based program consists of recording continuous middle atmosphere winds, temperatures and gravity-wave momentum flux from the group's Skiymet meteor radar system, and hydroxyl temperatures and radiances recorded with a compact near-infrared spectrometer together with collaborative projects with a large number of international groups.

In addition to the local cluster of instrumentation at Trondheim, the NTNU group has pioneered the development of a novel analysis of the SuperDARN meteor radar array. As published in a series of papers, this analysis has enabled global measurements of tidal and planetary-wave motions, which represent the largest source of wind variability in the middle atmosphere. Due to the high temporal resolution of this analysis technique, it has been possible to observe tidal changes induced during impulsive perturbations such as stratospheric warming and particle precipitation events. This has resulted in four publications since 2020, where the Trondheim meteor radar observations have been combined with the SuperDARN analysis to characterize the natural variability of the atmospheric dynamics in order to better observe the perturbations caused by energetic particle precipitation.

Accompanying these observational techniques, BCSS PhD student Wim van Caspel has developed a sophisticated primitive-equation model of atmospheric tides. Using this model, he has been able to attribute the causes of the tidal variability, and to separate the effects of changes in the background atmosphere from those caused by perturbations in the atmospheric chemistry. Understanding how these large tidal amplitudes and phases change in time is critical to understanding how perturbations caused by particle precipitation, a key goal of the BCSS, can be quantified in the face of these much larger background variations.

Results from NTNU's instrumentation have been presented at international meetings run by the AGU, EGU, AOGS and JpGU during 2021 and have formed a core component of three Master's student theses and three specialization project reports submitted during the past year.

> Scintillation and Total Electron Content (TEC) Network

> In 2013 BCSS installed four scintillation and total electron content receivers that record signals from navigation satellites over Svalbard and the Barents Sea. One unit is in Longyearbyen at KHO, and the other three units are at Ny-Ålesund, Hopen and Bjørnøya, respectively. Each receiver stores detailed information about the signal amplitude and phase to study how navigation signals from GPS, GLONASS and GALILEO are affected by plasma irregularities on their way through the ionosphere. The 60 second time resolution data have been published in the repository DataverseNO (click on following QR-code). This collection currently contains 81 sub data sets for the years 2013-2022. In addition, it is possible to extract raw data (50 Hz) and high-resolution total electron content data (1 second). These data have resulted in a series of publications and a follow-up research project at UiT (PI: Andres Spicher) that will investigate the spatio-temporal characteristics of plasma turbulence.

> LIghtning detection NETwork – LINET

> Since 2017 BCSS has maintained the Bergen LINET station, which is a VLF/LF radio receiver that is part of the lightning detection network LINET. The LINET network was developed by the University of Munich and is now managed by Nowcast GmbH. The combined use of ASIM and LINET data is included in a PhD project at BCSS, part of the SAINT project, that started December 2017. SAINT is a Marie Curie network with ten partners funding fifteen PhD students in Europe.

> SuperMag

> SuperMag is a worldwide collaboration of organizations and national agencies that currently operates some 600 ground-based magnetometers. SuperMAG provides easy access to validated ground magnetic field perturbations in the same coordinate system, identical time resolution, and with a common baseline removal approach. SuperMAG has established its position as the single point of access of ground-based magnetometer data *(Figure 11)*. The ~4000 registered users utilize SuperMAG products to publish ~200 peer-reviewed papers per year. SuperMag is a USA National Science Foundation facility. It has become an integrated part of the worldwide heliophysics science community. SuperMAG provides a long list of tools for easy data access and publication quality plots, over 50 years of data, and the inclusion of satellite footprints (ESA SWARM and NASA RBSP satellites). Figure 4 shows examples of some of the SuperMAG capabilities. SuperMAG provides key observational support for the research performed at BCSS. SuperMAG's enables simultaneous observations in both hemispheres and global and continuous coverage allowing for monitoring large scale current systems. The long duration uninterrupted indices also provide information on the solar wind-magnetospheric driving of the thermosphere. From 2013 to 2016 the lead programmer of SuperMAG was Mr. Brage Foerland (from BCSS) and the PI has been Dr. Jesper W Gjerloev, also a member of BCSS.

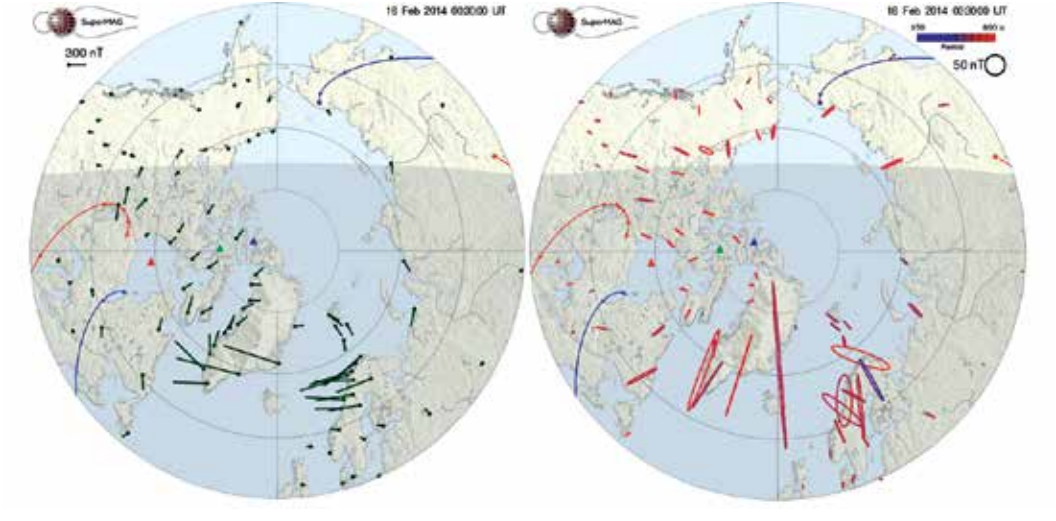


Figure 11: Polar plots of ground level equivalent current vectors (left) and ULF activity. Note the NASA RBSP footprints (red and blue lines) and the ESA SWARM footprints (red, green, blue triangles). Plots downloaded from SuperMAG.

> Super Dual Auroral Radar Network (SuperDARN), HF Radar

> The Svalbard SuperDARN radar *(Figures 12 & 13)* is part of a global network of more than 35 HF radars used for studying the structure and dynamics of the Earth's upper atmosphere. The Svalbard radar, the only Norwegian SuperDARN radar, started routine operations in autumn 2016. It sustained storm damage in autumn 2018, and, after a re-building project phase, new masts, antennas, and feedlines were installed during 2021-2022 The radar became operational again spring 2023. The radar is configured with stereo capabilities, meaning that it can operate two channels simultaneously with different frequencies. It also has an interferometer array, which is used to calculate the elevation angle of the received signal. The field of view of the Svalbard SuperDARN radar is North-East of Svalbard, covering an area of more than 3 million square kilometers. Data from the radar are stored near-real-time at a data server at the British Antarctic Survey, UK. One of the key data products made from the network of SuperDARN radars are the global ionospheric convection maps, which manifests the coupling between the solar wind and the Earth's magnetosphere.

Photo: Mikko Syrjäsuo/UNIS

Figure 12: The SuperDARN radar under construction

> Space Plasma Exploration by Active Radar (SPEAR)

> The SPEAR system was located on Svalbard and was in operation in operation during 2004 - 2013. The facility worked by emitting an electromagnetic beam (which operates at radio wave frequencies of between 4–6 Mhz) into the ionosphere where it interacts with the plasma environment. These interactions reproduce some of the naturally occurring plasma dynamics in the ionosphere (such as electric currents and turbulence), allowing the ionosphere to function as a plasma laboratory. Using a variety of scientific instruments, from Earth-orbiting satellites to ground-based radars, the interactions were then studied under controlled conditions. The experiments conducted in 2013 included researchers from Russia, Norway, and Canada and investigated plasma turbulence using the EISCAT Svalbard Radar, the SuperDARN radar, the ePoP satellite and HF receivers located on Svalbard.

> European Incoherent SCATter 3D (EISCAT 3D)

> The new EISCAT 3D system will be a state of the art, multi-static phased array incoherent scatter radar. The system will be located in Northern Scandinavia with a field of view extending over the entire region. It will be the world's first multi-static phased array capable of delivering volumetric imaging of a wide variety of ionospheric parameters such as temperatures, conductivities, densities and electric fields. First light is due at the end of 2023 although the system has been years in planning for over 15 years. BCSS members have been involved in putting forward the scientific case for the system as well as being active in the EISCAT 3D Norway project board and serving as the Norwegian representatives on the EISCAT Science Advisory Committee. Current and future projects will make use of the new data product as inputs to and corroboration for the new ionospheric models being worked upon within the group.

The current EISCAT radar systems, located in Tromsø and on Svalbard, have been operational during the entirety of the BCSS lifetime. The systems use a dish antenna so while they can deliver the same parameters, they do not have the full volumetric imaging capabilities of the new system. The radars have been used extensively by group members throughout the lifetime of the BCSS for a variety of different ionospheric datasets. A group member is also in charge of the Norwegian scheduling time for the radar systems.

NEW GENERATION OF BCSS SCIENTISTS

> We had originally proposed for the CoE funding that we expected "a minimum of 80 Master students and more than 20 PhD students to graduate from the BCSS during its lifetime." As can be seen from the overviews (below), we have exceeded these expectations significantly. The total numbers 105 Master's and 33 PhD students.

> Overview of Master's Students (UiB, NTNU and UNIS)

NAME	YEAR	THESIS	INST.	M/F
C. van der Meeren	2013	A multi-instrument study of GPS scintillation in the nightside polar cap over Svalbard	UiB	M
L.-K. G. Ødegaard	2013	Recalibration of the MEPED Proton Detectors Onboard NOAA POES Satellites	UiB	F
A.B. Skeltved	2013	A study of the relativistic runaway electron avalanche and the feedback theory to explain terrestrial gamma-ray flashes	UiB	M
T.R. Bjørnsen	2013	Development of Electronic Ground System Equipment for the ASIM Project	UiB	M
A. Pithalice	2013	ASIM-Detector Tests and Analysis	UiB	F
E.A. Hennum	2013	A new algorithm for remote sensing meso-pause temperatures using the hydroxyl airlgow	NTNU	M
K. Nærø	2013	Gravity Wave Refraction in the Atmosphere: Ray tracing versus Geometric Location from a Single Image	NTNU	F
M. Hatlen	2013	On-board, Fourier-Based Image-Analysis System for Satellite Observation of Gravity Waves	NTNU	M
N. Kolnes	2013	Gravity wave Climatology for Trondheim using a Meteor Radar	NTNU	M
K. Albert	2014	SvalPoint: A Multipoint Optical Tracking System	UNIS	F
E.A. Zawedde	2014	Weak to Moderate Recurrent Storms and their Influence on the Middle Atmosphere Composition in 2008	UiB	F
T. V. Fiskerstrand	2014	Magnetosphere-Ionosphere response to changes in the solar wind driver	UiB	F
H. S. Fadnes	2014	Are substorms required to intensify I thinkthe ring current?	UiB	F
E.M. Tjelle	2014	Mesoscale gravity wave activity in the Mesosphere over Northern-Norway	NTNU	M
K. Backer-Owe	2014	Behaviour of the S1 and S2 Components of the Semidiurnal Tide in the MLT	NTNU	M
K.L. Ekern	2014	Velocity error induced by unevenly sampling wind radars	NTNU	M
M. Marcer B. Vandecrux	2015	Snow Distribution Statistical Modelling and UAV-borne remote Sensing of Snow Reflectance in the Arctic	UNIS / DTU	M/M
E.Cimoli	2015	Determining Snow Depth Distribution from Unmanned Aerial Vehicles and Digital Photogrammetry	UNIS / DTU	M
S. Coyle	2015	Statistical Search for Terrestrial Gamma-ray flashes based on RHESSI and LIS data	UiB	M
K. Albrechtsen	2015	Search for unidentified Terrestrial Gamma-ray Flashes	UiB	M
V. Aamodt	2015	Search for Terrestrial Electron Beams in SAMPEX HILT datas	UiB	M
N. K. Kwagala	2015	Dayside 630.0 nm emissions due to Thermally excited O(1D) in the cusp region ionosphere over Longyearbyen, Svalbard	UiB	F
M. A. Marszalek	2015	The Horizontal Transport and Dynamics of NOx Produced by Energetic Particle Precipitation in the Upper Atmosphere	UiB	M
T. Rexer	2015	Current systems associated with Non-Conjugate Aurora	UiB	F
M.D. Risberg	2015	Development of gamma-ray detector for use in ER-2 aircraft	UiB	M
Ø. Grøndahl	2015	High voltage electrical discharges in the laboratory	UiB	M
I. Bakken	2015	A comparison of Gravity Wave Parameters derived from the Analysis of a Three-Field Photometer with Imagers	NTNU	F
C. Franzen	2015	Using Background OH Airglow from astronomical Observations for atmospheric Research: A Proof of Concept	NTNU	M
M. Nordhagen	2015	NAO-Influence on Temperature Trends in Norway and Canada for the last 50 Yearst	NTNU	M
H. Linde	2015	Drivers of the high frequency variability of gravity wave forcing in the mesosphere and lower thermosphere	NTNU	F
D. Jozwicka	2016	Energy input to atmosphere during pulsating aurora	UNIS	F
A. Ohma	2016	A Statistical Study of Field-Aligned Birkeland Currents Using Cluster FGM Data	UNIS	M

NAME	YEAR	THESIS	INST.	M/F
A. Amundsen	2016	Transporterer atmosfæriske bølger polarlysprodusert NO ned til den midtre atmosfæren	NTNU	M
F.R.L. Fritsch	2016	What causes the mid-winter cooling?	NTNU	F
N. Forseth	2017	The Structuring of High Latitude Aurora	UNIS	F
J.K. Osland	2017	Energetic particle precipitation and polar surface air temperature variability	UiB	M
K. Bolmgren	2017	Time dependence of average structure size and precipitation energy in pulsating aurora	UNIS / KTH	M
K. Reed	2017	Study of meso-scale reversed flow events in the polar ionosphere by SuperDARN radars	UiB	M
B. Rosland	2017	Asymmetric Ionospheric Equivalent Currents at Magnetic Conjugate Points	UiB	M
R. Torkelsen	2017	High frequency current oscillations measured in high voltage electrical discharge experiments in the laboratory	UiB	M
N.L. Berge	2017	A new population of Terrestrial Gamma-ray flashes	UiB	F
A.K. Nes	2017	Evaluation and design of readout electronics for electron and proton detectors	UiB	M
C.A. Skeie	2018	Aircraft interaction with electric field of thundercloud and observations of hard radiation	UiB	M
A. Lindanger	2018	Search for Terrestrial Gamma-ray Flashes in AGILE data by correlation with ground-based lightning measurements	UiB	M
M. Isaksen	2018	Dynamic processes in the mesopause region from OH-airglow and meteor echoes above Longyearbyen	UNIS	M
A. Haderlein	2018	Optimization, evaluation and application of EEP measurements in the presence of contaminating protons	UiB	F
A. Fjeldstad	2018	Developing an analysis technique for identification of wave structures in MATS data	NTNU	M
H. Borge	2018	Påvirkningen av temperaturgradienter for tolkningen av rotasjonstemperaturer	NTNU	M
H. Andersen	2018	Design and Simulation of Pixel Layout and Data Processing Algorithms for the DEEP Instrument	UiB	M
M.F. Heigre	2018	Design of an Embedded Readout System for the ALOFT Gamma-Ray Detector Instrument	UiB	M
O. Lylund	2018	Design and Development of the SMILE SXI Radiation Shutter Control System	UiB	M
A.N. Nesse	2018	SoC Design of Electronic Readout System for ALOFT	UiB	M
E.S. Simonsen	2019	An empirical study of the correlation between the Hall and Pedersen ionospheric conductivities and the field-aligned currents at high latitudes	UiB	M
E.W. Knutsen	2019	Dynamical-Chemical Coupling in the Polar Middle Atmosphere: Effects of Energetic Particle Precipitation on the Middle Mesospheric Maximum	NTNU	F
S. Gasparini	2019	Statistical properties of backscatter from the Longyearbyen SuperDARN radar	NTNU	F
J. Dreyer	2019	A detailed study of auroral fragments	UNIS	M
F. Enengl	2019	On the relationship between energetic electron precipitation and mesospheric temperature	UNIS	F
M.B. Henriksen	2019	Hyperspectral Imager Calibration Characterization and Image Correction	UNIS	F
B. Engegård	2019	Extracting OH airglow intensity from the background of the Nordic Optical Telescope	NTNU	M
A.L. Alme	2019	FW implementation of SMILE SXI Radiation Shutter Control System	UiB	M
L. Luque	2020	Multi-Instrument Investigations of Spectral Width in the Polar Ionosphere	UNIS / NTNU	F
S.J. Walker	2020	A novel application of Spherical Elementary Currents with Ground Magnetometers–Analysis of By effects on the auroral electrojets	UiB	M
O.M. Kringlebotn	2020	Climatology of gravity wave activity in Antarctica	NTNU	M
S. Heimly	2020	Tropospheric measurements using the ALOMAR RMR-lidar	NTNU	M
I. Bjørge-Engeland	2020	Time sequence of TGFs and optical pulses detected by ASIM and a comparison of TGFs observed by different spacecrafts	UiB	F
J.Ø. Edvartsen	2020	Impact of space weather on the polar atmosphere	UiB	M
J.A. Salice	2020	Solar wind drivers of energetic electron precipitation	UiB	F
M.J. Breedveld	2020	Predicting the Auroral Oval Boundaries by Means of Polar Operational Environmental Satellite Particle Precipitation Data	UNIS / UiB	M
A.E. Oudijk	2020	Hyperspectral Data Cube Compression Techniques and Quality Assessments	UNIS	F
R. Balfour	2020	The detection of meteoric smoke particles with rocketborne sensors, a feasibility study	NTNU	M
E. Kallelid	2020	Evolution in Cosmic Noise Absorption during Periodic Events	NTNU / UNIS	M
O.M. Borge	2020	Atmospheric Correction over Coastal Waters Based on Machine Learning Models	NTNU	M
K.S.Y. Skarvang	2020	Meteor Radar Observations of the Atmospheric Tides	NTNU	F
H.D.Z. López	2021	The impact of medium energy electrons on mesospheric chemistry and dynamics	UiB	M
B. Husa	2021	Design of Readout Electronics for the DEEP Particle Detector	UiB	M
A. Goertz	2021	Poleward Moving Auroral Forms and Dayside Flow Channels	UNIS	M
I. Svendsen	2021	Correlation between the mean wind in the mesosphere and lower thermosphere and solar cycles	NTNU	F
A.L. Kvernhaug	2021	Empirical Relationship between Nightside Reconnection Rate and Solar Wind / Geomagnetic Measurements	UiB	M
A. Kvamsdal	2021	En undersøkelse av hvordan substormer påvirker konveksjon målt med Swarm-satellitter	UiB	F
A.Ø. Hovland	2021	Mesoskala-konveksjon assosiert med en Polar Cap Arc-hendelse: Resultater for multi-instrument studie og regional dataassimilering	UiB	F
J.K. Slapgaard	2021	Solar Forcing of Planetary Waves	UiB	M
G.E. Granstedt	2021	Polar Cycle Influence on the Semi-Diurnal Tide in the Mesosphere-Lower Thermosphere	NTNU	F

NAME	YEAR	THESIS	INST.	M/F
C. Noaillac	2022	Waves in the ionosphere detected using the Polar Research Ionospheric Doppler Experiment (PRIDE)	UNIS	F
T. Mirzaamin	2022	Eastward-Propagating Planetary Waves in SuperDARN Radar Wind Observations(PRIDE)	NTNU	F
S.H. Seltveit	2022	Auroral Dunes: Bores or Boring? Airglow Imaging of Gravity Wave-Aurora Interaction in the Mesosphere-Lower Thermosphere	NTNU / UNIS	M
K.K.B. Mohr	2022	Temperatures in the mesosphere and lower thermosphere and the viability of using non-continuous time series to derive tides	NTNU	F
S.N. Andresen	2022	Planetary Waves over Antarctica	NTNU	M
L.E. Murberg	2022	The secondary ozone layer and energetic particle precipitation	NTNU	F
H. Alexandersen	2022	Resolved gravity waves in a high-resolution model: The interaction of gravity waves with planetary waves	NTNU	M
V. Dahle	2022	Methods for FPGA pre-processing of data for the ALOFT readout system	UiB	M
H.D. Eide	2022	What is the flux of low energy electron precipitation in the lower thermosphere?	UiB	M
V. Teissier	2022	Automatic morphological classification of auroral structures	UNIS	M
A. Tachet	2022	Auroral detection in coloured all-sky image	UNIS	F
R. Deirmendjian	2022	Silver Bullet Calibration	UNIS	M
L.A.K. Ramdal	2022	Characterization of Silicon Photomultiplier and Design of Front-End Electronics for ALOFT	UiB	F
R. Landet	2022	Modeling of Gamma-Ray Glows from Thunderstorms with GEANT4	UiB	M
T. Løvset	2022	The secondary ozone layer and energetic particle precipitation	NTNU	F
A. Thorell	2023	Sporadic E-layers in the polar cap ionosphere	UNIS	M
B. Dol	2023	Viability of using images classified by an unsupervised AI for determining patterns in the evolution of auroral morphology	UNIS	M
A.L. Ramsli	2023	Observation of cosmic gamma-ray bursts with the ASIM mission onboard the International Space Station	UiB	M
A Fuglestad	2023	Multi Pulse Terrestrial Gamma-ray Flashes and optical pulses of lightning observed by ASIM	UiB	M
T.E. Knutsen	2023	Development of FPGA design and test structures for the updated ALOFT instrument	UiB	M
J.E.L. Cimen	2023	Observation of precipitating auroral electrons in the lower thermosphere	UiB	M
K. Moen	2023	Role of Planetary Waves in Gravity Wave Activity in the Middle Atmosphere During Northern Hemisphere Winter: A High-Resolution General Circulation Model Approach	NTNU	M
J. Salvesen	2023	Design, test and implementation of a UV 355 nm LIDAR depolarization channel to characterize particles in the atmosphere above ALOMAR	NTNU	M

> Overview of PhDs (UiB, NTNU and UNIS)

NAME	YEAR	THESIS	INST	M/F
T.D. Demissie	2013	The vertical structure and source regions of large- and small-scale waves in the middle atmosphere	NTNU	M
R.(S.H) Nisi	2014	Constraining the properties of Terrestrial Gamma-ray Flashes	UiB	F
N. Kleinknecht	2014	Planetary waves in the northern MLT: Vertical coupling and effects	NTNU	F
S.H. Eriksen	2016	Trends and variability of polar mesopause region temperatures attributed to atmospheric dynamics	UNIS/UiT	F
C. van der Meeren	2016	Mesoscale ionosphereic plasma irregularities and scintillation over Svalbard	UiB	M
L.-K. Ødegaard	2016	Energetic particle precipitation into the middle atmosphere	UiB	F
J.P. Reistad	2016	Mechanisms responsible for asymmetric aurora between the conjugate hemispheres	UiB	M
X. Chen	2017	Mechanisms responsible for asymmetric aurora between the conjugate hemispheres	UiB	M
B.K. Humberset	2017	Scale size-dependent characteristics of the magnetosphere-ionosphere system using auroral imaging	UiB	F
P. Tenfjord	2017	Solar wind energy transfer and the asymmetric geospace	UiB	M
A.E. Zawedde	2018	The Impact of Energetic Electron Precipitation on Mesospheric Hydroxyl Radical	UiB	F
N.K. Kwagala	2018	Thermally excited 630.0 nm emissions in the polar Ionosphere	UiB	F
A.B. Skeltved	2018	Evaluating the production scenarios of terrestrial gamma-ray flashes	UiB	M
A.Ohma	2019	How Asymmetries in Geospace Evolve During Increased Tail Reconnection	UiB	M
C. Franzen	2019	Aeronomy of hydroxyl airglow variability by means of high-resolution telescope observations and gravity wave simulations	NTNU	M
F.T. Kebede	2021	Energetic electron precipitation of pulsating aurorae and their mesospheric effects	UNIS	M
C. Maiorana	2021	Geographical Characteristics and Meteorological Environment of Terrestrial Gamma-ray Flashes	UiB	F
K. Herlingshaw	2021	Characterising Mesoscale Fast Flow Channels in the Polar Cap Ionosphere	UNIS	F

NAME	YEAR	THESIS	INST.	M/F
A. Lindanger	2022	Spectral Analysis of Terrestrial Gamma-ray Flashes and Their Connection to Lightning Discharges	UiB	M
W. van Caspel	2022	Atmospheric Tides in the Mesosphere and Lower Thermosphere: Meteor Wind Observations and Mechanistic Tidal Model Simulations	NTNU	M
C.A.K. Skeie	2022	Aircraft and spacecraft observations of high-energy radiation associated with lightning leaders	UiB	M
E. Vorobeva	2023	Exploiting infrasound to probe the dynamics of the middle atmosphere	NTNU	F
J.Ø. Edvartsen	2023	TBD	UiB	M
E.M. Babu	2023	TBD	UiB	M
J.A. Salice	2023	TBD	UiB	F
I. Bjørge-Engeland	2024	TBD	UiB	F
R. Elhawary	TBD	TBD	UiB	F
M. Madelaire	TBD	TBD	UiB	M
S. Gasparini	TBD	TBD	UiB	F
M. Decotte	TBD	TBD	UiB	F
S. Walker	TBD	TBD	UiB	M
C. van Hazendonk	TBD	TBD	UiB	F
N.C. Eriksen	TBD	TBD	UiB	F

> International Lectures and Educational Projects

SCOSTEP/ISWI (2013-2016)
UN Space Science regional schools: Nikolai Østgaard gave lectures at this school in Nairobi, Kenya (2013), Lima, Peru (2014) and Sanglia, India (2016).

TEA-IS (2011-2016)
European network for studying Thunderstorm Effects on the Atmosphere-Ionosphere System: Summer schools (2012 and 2014)

SAINT (2017-2020)
15 PhD students in Europe were funded to study atmospheric electricity and support the ASIM mission. Carolina Maiorana received her PhD at BCSS in 2020 through this program.

Poster for the "Solar Impact on the Winter Polar Atmosphere" Research School

> BCSS Research Schools

> The Birkeland Centre has developed two international research schools for students (Master's, PhD) and postdocs.

SOLAR IMPACT ON THE WINTER POLAR ATMOSPHERE

The first school "Solar Impact on the Winter Polar Atmosphere – from space to surface," was held in March 2019. It brought together lecturers with different, but complementary expertise in space, atmospheric and climate research. The school gave students knowledge of solar variability – both radiation and particles – and its potential role in vertical coupling mechanisms in the atmosphere. It gave the students an introduction to an interdisciplinary field where an understanding of both important atmospheric dynamics- and space physics-terms are necessary tools. This will improve the students' ability to read and work with material in scientific fields adjacent to their own with necessary prudence. This was demonstrated in the final project which was to be completed after the conclusion of the school. A positive evaluation was awarded 5 ETC points. Seventeen Master's students and early career scientists attended.

This school was a follow-up on "Solar effects on natural climate variability in the North Atlantic and Arctic" as part of the Norwegian Research School in Climate Dynamics held in 2015 and 2017. It was a result of the collaboration initiated by BCSS already in 2014 with the Bjerknes Centre.

ATMOSPHERIC ELECTRICITY & HARD RADIATION FROM THUNDERCLOUDS

The other school was "Atmospheric Electricity and Hard Radiation from Thunderclouds," which was held in May 2019. Lectures were given by experts in the field. Professor Vernon Cooray (Uppsala University, Sweden), an expert and author/editor of the textbook "The Lightning Flash," gave lectures about the micro-physics of lightning. Professor Joseph Dwyer (University of New Hampshire, USA), who has been in the forefront of the international research on "Terrestrial Gamma-ray Flashes," lectured on TGF theories. Other lectures were given by BCSS members on ASIM results, laboratory experiments, etc. The assigned project, which required about one month of work, focused on characteristics of TGF observational distributions. For attending the school and receiving a positive evaluation on their project, the students were awarded with 10 ECTS study points. This school was attended by 32 students from 22 institutions in 14 countries.

Attendees and instructors of the "Atmospheric Electricity and Hard Radiation from Thunderclouds" Research School, May 2019

Photo: Georgi Genov

> BCSS Members (2013-2023)

LEADERSHIP

Nikolai Østgaard, *Centre Leader*
Anja Hegen, *Admin. Coordinator*
Katarzyna Kosela, *Admin. Coordinator*
Massara Chaari, *Admin. Coordinator*

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Annet Eva Zawedde, *Phd Cand., UiB*
Linn-Kristine Ødegaard, *Phd Cand., UiB*

> Project Funding

Birkeland Centre for Space Science: CoE Funding 160 MNOK; Total Funding over ten years 440 MNOK. Additional 20 MNOK from UiB.

European Research Council Advanced Grant | Grant Agreement Nr. 320839

P.I. Nikolai Østgaard

2013-2018 **Terrestrial Gamma Flashes–the Most Energetic Photon Phenomenon in our Atmosphere**
A 5 year project to support TGF research. The project comprises both data analysis, modeling and experiments. The goal is to understand what processes are involved in the TGF production. The experiments will be performed from space, balloons, aircraft and in the laboratory.

2.49 MEUR
Additional 623 kEUR (25%) funding was given by the University of Bergen

Atmosphere-Space Interaction Monitor (ASIM) | ESTEC Contract Ref. 40000101107/10/NL/BJ | Terma-DTU Contract TER-SPACE-CON-DTU_SPACE-002_rev2

2010-2019 **Phase C and D, sub-sub-contract between DTU Space and University of Bergen**
This project started September 2010 and is an ESA contract to design and build the front-end electronics and detector arrays for Modular X- and Gamma-ray Monitor (MXGS). ASIM is a payload for the International Space Station and is planned for launch in 2016.

P.I. Nikolai Østgaard
3.75 MEUR

Strategic Core Activities for the Space Physics group at the University of Bergen (SCASP-UIB) | Project nr: 216872/F50–RCN/Program for Space Research

2012-2015 A project to support TGF research and Cluster studies – one PhD student

P.I. Nikolai Østgaard
3 MNOK

Norwegian Research Council Program for Space Research | Project nr: 208028/F50

2010-2016 **Terrestrial Gamma Flashes—the Most Energetic Photon Phenomenon in our Atmosphere**
Project to support TGF research, PhD student, engineer and balloon instruments/campaigns

P.I. Nikolai Østgaard
4.86 MNOK

Norwegian Research Council Program for Space Research | Project nr: 230956/F50

2014-2017 **The Norwegian Cluster studies**
A small project to support the Norwegian collaboration using Cluster data

P.I. Nikolai Østgaard
600 KNOK

Norwegian Research Council Program for Space Research | Project nr: 212014/F50

2012-2014 **Space weather effects in the upper atmosphere on navigation signals**
A small project to investigate how the upper atmosphere affects satellite communication and navigation signals using a set of GNSS scintillation receivers and EISCAT ca**mpaigns at Svalbard**

P.I. Kjellmar Oksavik
1.3 MNOK

Norwegian Research Council Program for Space Research | Project nr: 195385/F50

2010-2015 **Infrastructure for space physics related research on Svalbard**
A project to develop new space related infrastructure on Svalbard

P.I. Dag Lorentzen
8.2 MNOK

Norwegian Research Council Program for Space Research | Project nr: 191747/V30

Dec. 2009 - Feb. 2013 **Gravity-wave sources and scales in the Polar Regions and their effect on Polar Mesospheric Clouds**

P.I. Patrick J. Espy
2.523 MNOK full cost

Norwegian Polar Institute Researcher | Project-NARE

2011-2013 **Observation of carbon monoxide and ozone in the Antarctic and Arctic:**
Implications for the inter-hemispheric coupling of vertical motions

P.I. Patrick J. Espy
2.566 MNOK full cost

UK Natural Environment Research Council standard grant | NE/G018707/1

Aug. 2009-July 2013 **A new radar for integrated atmospheric science in the southern hemisphere**
British Antarctic Survey / University of Leicester

P.I. Steve Milan, **Co-I**: Robert Hibbins
Full economic cost £686K

UK Natural Environment Research Council standard grant | NE/H009760/1

April 2010-Mar. 2013 **Wave dynamics of the mesosphere**
British Antarctic Survey / University of Bath

P.I. Robert Hibbins
Full economic cost £588K

UK Natural Environment Research Council standard grant | NE/I010173/1

April 2011-Mar. 2016 **Solar wind connection to regional climate**
British Antarctic Survey

Co-I. Robert Hibbins
Full economic cost £457K

Norwegian Research Council FRINAT Program | Project nr: 191628

2009-2014 **SPEAR – a high power ionospheric modification facility for Svalbard**

P.I. Lisa Baddeley
6617 KNOK

Norwegian Research Council Program for Space Research | Project: 255276/E10

2016-2019 **SOLENA** – Solar effects on natural climate variability in the North Atlantic and Arctic. Collaboration between the Bjerknes Centre for Climate Research, the Dept. of Geosciences, UiO, and the Geophysical Institute, UiB.

P.I. Yvan Orsolini
11374 KNOK

SuperMAG | ESA PRODEX funding | Contract: 4000104152

P.I. Jesper Gjerloev

2012-2014 **SuperMAG** – is a worldwide collaboration of organizations and national agencies that currently operate more than 300 ground-based magnetometers.

160 KEUR

Tech. Support for ESA SWARM SuperMAG Activity | ESA PRODEX funding | Contract: 4000114432/15/NL/FF/ah

P.I.s Jesper Gjerloev, Nikolai Østgaard

2015-2016 **SuperMAG** – is a worldwide collaboration of organizations and national agencies that currently operate more than 300 ground-based magnetometers.

120 KEUR

> Project Funding (cont.)

EU-MCSA SAINT | Grant: 722337 — SAINT (Science and Innovation with Thunderstorms) | **P.I.** Nikolai Østgaard

2017-2021	**SAINT** – project with a multidisciplinary and inter-sectorial training platform for 15 ESRs. The platform brings together satellite and ground observations with modelling and lab experiments.	**286 KEUR**

Research Council of Norway | FREPPIMA | Project: 263008/F50

2017-2020	Full Range Energetic Particle Precipitation Impacting the Middle Atmosphere	**P.I.** Hilde Nesse **3.52 MNOK**

European Space Agency | ASDC | Project: 4000123438

2018-2025	ASIM Science Data Centre (project extended, funding increased)	**P.I.** Nikolai Østgaard **808 KEUR**

European Space Agency | Testing MHD | Project: 4000124903

2018-2019	**Testing** – MHD (Magnetohydrodynamics) model for geomagnetic applications	**P.I.** Michael Hesse **200 KEUR**

Research Council of Norway Program for Space Research | Project: 246725/E10

2015-2019	Multi-Instrument Studies of High Latitude Atmospheric Turbulence and Wave Processes	**P.I.** Lisa Baddeley **1,5 MNOK**

European Space Agency | SMILE Phase 1 | Project: 4000123238

2018-2023	Radiation Shutter for SXI on SMILE (project extended, funding increased)	**P.I.** Nikolai Østgaard **1,515 KEUR**

European Space Agency | STM for SMILE Project

2018-2023	Direct contract between STM Laksevåg (mechanical engineering) and ESA	**P.I.** Nikolai Østgaard **330 KEUR**

Research Council of Norway | Program for Space Research | Project: 195385

2010-2021	Infrastructure for space physics-related research on Svalbard	**P.I.** Dag Lorentzen **9,1 MNOK**

European Space Agency | Swarm+Coupling High-Low Atmosphere Interactions | Project: 4000126731

2019-2022	Info from Swarm and other satellites will be used to fill knowledge gaps related to "energetic ion outflow"	**P.I.** Spencer Hatch **150 KEUR**

Norwegian Space Agency | DEEP | Project: VIT.02.19.7

2019-2020	DEEP – Electron and Proton Detector	**P.I.** Hilde N. Tyssøy **400 KNOK**

Research Council of Norway | Which types of particle precipitation matter in the middle atmosphere? | Project: 287427

2019-2022	Which types of particle precipitation are important for the chemistry of the atmosphere?	**P.I.** Noora Partamies **7 MNOK**

BTO / Research Council of Norway | Project: 295963

2019-2019	**ARAE - FORNY project** to explore the use of global models of ionospheric currents for navigation purposes	**P.I.** Karl Magnus Laundal **300 KNOK**

Research Council of Norway | Magnetic pulsations and transients: the Sun-Earth connection and impact on the high latitude ionosphere | Project: 309135

2020-2024	INTPART Coordination and Support Activity Support for Network-related Activities	**P.I.** Lisa Baddeley **2,118 MNOK**

Research Council of Norway | Unravelling the Drivers of EEP – Revealing the Imprint of Space on Earth (DEEP - RISE) | Project: 302040

2020-2023	The main objective is to quantify the radiation belt loss of energetic electrons into the atmosphere.	**P.I.** Hilde Nesse Tyssøy **4,936 MNOK**

Research Council of Norway | Ionospheric Impact Response Analysis by Regional Information Integration | Project: 300844

2020-2025	The primary project objective is to determine how ionospheric conditions affect transient geospace phenomena like substorms and rapid changes in dynamic solar wind pressure.	**P.I.** Karl Magnus Laundal **11,055 MNOK**

Research Council of Norway | Effects of Energetic Electron Precipitation In a Changing climate | Project: 300724

2020-2023	The primary project objective is to determine how ionospheric conditions affect transient geospace phenomena like substorms and rapid changes in dynamic solar wind pressure.	**P.I.** Ville Maliniemi **5,826 MNOK**

Research Council of Norway | Charged Cloud Generator (VIS project owner) | Project: 310774

2020-2020	The objectives of this project are: to verify Charge Cloud Generator as a system that can be used between 1500-2000kV, to secure IP and design CCG a modular and scalable solution, and to get industry partnership to help realize CCG in the market.	**P.I.** Pavlo Kochkin **275 KNOK**

> Project Funding (cont.)

Trond Mohn Foundation | What Shapes Space? | Project: TMS2020STG02

2020-2024	The project investigates the time scales of large-scale changes in geospace, and how these time scales differ between hemispheres.	**P.I.** Karl Magnus Laundal **9,247 MNOK**

Research Council of Norway | Understanding the link between lightning, terrestrial gamma-ray flashes and gamma-ray glows | Project: 325582

2021-2025	Primary objective: Understanding the connection between lightning, TGF, and gamma-ray glows	**P.I.** Martino Marisaldi **11,964 MNOK**

European Research Council | DynaMIT | Project: 101086985

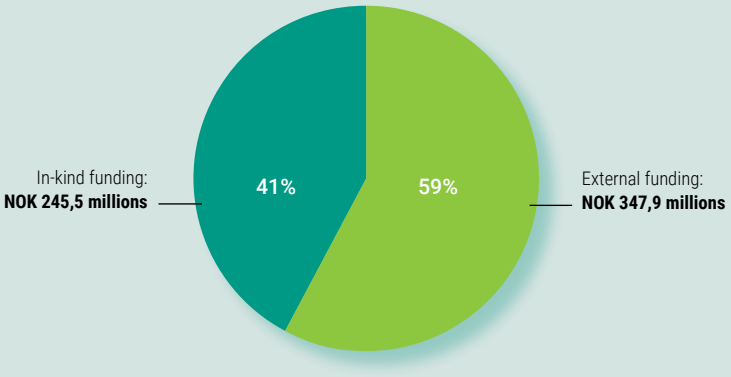
2023-2028	Dynamic Magnetosphere Ionosphere Thermosphere coupling. The goal is to understand and explain, for the first time and from first principles, how Earth's atmosphere is dynamically coupled to space.	**P.I.** Karl Magnus Laundal **2 MEURO**

Norwegian Research Council Program for Space Research | Project nr: 335162

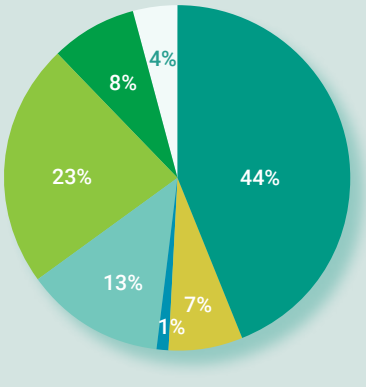
2023-2026	Gamma-ray-glow Effects on Atmospheric Electricity and Chemistry	**P.I.** Nikolai Lehtinen **7,483 MNOK**

> Funding Overview

FINANCE PLAN

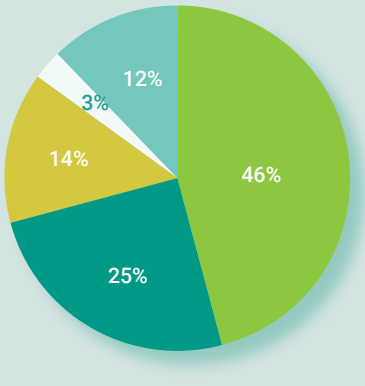


IN-KIND FUNDING



- **44%:** UiB salary/NOK 109,3
- **7%:** NTNU salary/NOK 16,7 millions
- **1%:** NTNU equipment & running costs/NOK 1,8 millions
- **13%:** UNIS salary/NOK 32,1 millions
- **23%:** UNIS equipment & running costs/NOK 55,5
- **8%:** Supplemental funding CoE-UiB/NOK 20,0 millions
- **4%:** Supplemental funding EU/NOK 10,1 millions

EXTERNAL FUNDING



- **46%**: CoE/NOK 160 millions
- **25%**: RCN/NOK 86,3 millions
- **14%:** ESA/NOK 47,5 millions
- **3%:** Other/NOK 10,5 millions
- **12%:** EU/NOK 43,6 millions

> Glossary

A – C

AGILE	Astrorivelatore Gamma a Immagini Leggero
AGU	American Geophysical Union
ALOFT	Airborne Lightning Observatory for FEGS and TGFs
AMPERE	Active Magnetosphere and Planetary Electrodynamics Response Experiment
AOGS	Asia Oceania Geosciences Society
ARISE2	Atmospheric dynamics Research InfraStructure in Europe
ASIM	Atmosphere-Space Interactions Monitor
BAS	British Antarctic Survey
BCSS	Birkeland Centre for Space Science
BGO	Bismuth Germanate Oxide
C-REX	Cusp Region EXperiment
CAS	Chinese Academy of Science
CCD	Charge-Coupled Device
CEPA	Columbus External Payload Adapter
CGM	Corrected GeoMagnetic
CHAMOS	Chemical Aeronomy in the Mesosphere and Ozone in the Stratosphere
CoE	Centre of Excellence
COPUOS	Committee on the Peaceful Uses of Outer Space
COSPAR	Committee for Space Research
CZT	Cadmium Zinc Telluride

D – F

DEEP	Distribution of Energetic Electron and Proton
DTU	Technical University of Denmark
ECTS	European Credit Transfer and Accumulation System
EGU	European Geosciences Union
EISCAT	European Incoherent Scatter Scientific Association
EISCAT_3D	EISCAT three-dimensional imaging radar project
EPO	Education and Public Outreach
EPP	Energetic Particle Precipitation
ERC	European Research Council
ESA	European Space Agency
ESF	European Science Foundation
EU	European Union
EZIE	Electrojet Zeeman Imaging Explorer
FEGS	Fly's Eye GLM Simulator
FM	Flight Model
FMI	Finnish Meteorological Institute
FREPPIMA	Full Range Energetic Particle Precipitation Impacting the Middle Atmosphere

G – I

GALILEO	European global navigation satellite system
GLM	Geostationary Lightning Mapper
GLONASS	Russian global navigation satellite system
GNSS	Global Satellite Navigation System
GPS	Global Positioning System
HED	High-Energy Detector
HEPPA	High-Energy Particle Precipitation in the Atmosphere
HF	High frequency
HOx	Hydroxides
IAGA	International Association of Geomagnetism and Aeronomy
ICMA	International Commission on the Middle Atmosphere
IMF	Interplanetary Magnetic Field
ISS	International Space Station
ISSI	International Space Science Institute
ISWI	International Space Weather Initiative
ITAR	International Traffic in Arms Regulations
ITN	Innovative Training Networks

J – M

JGR	Journal of Geophysical Research
JHUAPL	Johns Hopkins University Applied Physics Laboratory
KHO	Kjell Henriksen Observatory
LED	Low-Energy Detector
LINET	LIgtning detection NETwork
LF	Low Frequency
M-I	Magnetosphere and Ionosphere
MEE	Medium Energy Electrons
MEPED	Medium Energy Proton and Electron Detector
MEPPA	Most Energetic Photon Phenomenon in our Atmosphere
MLT	Mesosphere and Lower Thermosphere
MMIA	Modular Multi-Imaging Assembly
MN-faculty	Faculty of Mathematics and Natural Sciences
MXGS	Modular X- and Gamma-ray Sensor

N – Q

NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NFR	Norges Forskningsråd
NO	Nitric Oxide
NOx	Nitrogen Oxides
NOAA	National Oceanic and Atmospheric Administration
NTNU	Norwegian University of Science and Technology
OH	Hydroxide
OSP	Outstanding Student Poster
PhD	Philosophiae Doctor
PI	Principal Investigator
PMAFs	Poleward Moving Auroral Forms
POES	Polar Orbiting Environmental Satellites

R – S

RBSP	Radiation Belt Storm Probes
RCN	Research Council of Norway
RENU2	Rocket Experiment for Neutral Upwelling 2
ResClim	Research School in Climate Dynamics
RHESSI	Reuven Ramaty High Energy Solar Spectroscopic Image
RREA	Relativistic Run-away Electron Avalanche
SAINT	Science And INnovation with Thunderstorms
SCOSTEP	Scientific Committee on Solar Terrestrial Physics
SFF	Senter for Fremragende Forskning
SMILE	Solar Wind Magnetosphere Ionosphere Link Explorer
SOLARIS	Solar Influences
SOLENA	Solar effects on natural climate variability in the North Atlantic and Artic
SPARC	Stratospheric-tropospheric Processes And their Role in Climate
SPEAR	Space Plasma Exploration by Active Radar
SSL	Space Sciences Laboratory
SSUSI	Special Sensor Ultraviolet Spectrographic Imager
ST	Solar-Terrestrial Sciences
SuperDARN	Super Dual Auroral Radar Network
SuperMAG	Observations of the global magnetic field
SWARM	European satellite mission to study the Earth's magnetic field
SXI	Soft X-ray Imager

T – W

TEA-IS	Thunderstorm Effects on the Atmosphere-Ionosphere System
TEC	Total Electron Content
THEMIS	Time History of Events and Macroscale
TLEs	Transient Luminous Events
TOI	Tongue of Ionization
TGF	Terrestrial Gamma-ray Flash
UC Berkeley	University of California, Berkeley
UCLA	University of California, Los Angeles
UiB	University of Bergen
UiT	UiT – Arctic University of Norway
UK	United Kingdom
UN	United Nations
UNIS	University Centre in Svalbard
UNOOSA	United Nations Office of Outer Space Affairs
US	United States
VarSITI	Variability of the Sun and Its Terrestrial Impact
VLF	Very Low Frequency
WACCM	Whole Atmosphere Community Climate Model
WWLLN	World Wide Lightning Location Network


n/s