Annual Report 2013

BIRKELAND CENTRE
FOR SPACE SCIENCE

From the Centre Leader

The Birkeland Centre for Space Science (BCSS) was the first of the third generation Centres of Excellence to open and had its kick-off meeting 7-8 March 2013. The Centre is lead from the Department of Physics and Technology at the University of Bergen with nodes at NTNU and UNIS. The overarching scientific objective of the BCSS is to understand "How the Earth is coupled to space". Under this title we have formulated four main questions where we have identified fundamental gaps in our knowledge:

Q1. When and why is the aurora in the two hemispheres asymmetric?

The occurrence of asymmetric aurora probably means that the two polar caps are not connected similarly to space

Q2. How do we get beyond the static large-scale picture of the ionosphere?

Today, static large-scale models of the ionospheric electric current systems are widely used as input to modelling the Earth's electro-magnetic environment. In reality, the system works on all scales and is highly dynamic.

Q3. What are the effects of particle precipitation on the atmospheric system?

This precipitation affects both temperature and chemistry in our atmosphere. Collaboration with climate researchers has been initiated to find out how important this is.

Q4. What is the role of energetic particles from thunderstorms in geospace?

During the last twenty years it has been discovered that relativistic electrons and positrons, as well as gamma-ray flashes, are produced by lightning. A new scientific field of high-energy radiation and particles has been born, opening a zoo of unresolved questions.

The BCSS is organised in scientific groups focusing on these four questions. In addition we have two groups to design, build and operate state-of-the art instrumentation, one for space and one for ground-based instrumentation. We also have a group for education and public outreach that makes our results available to the public.

During the first year of our existence we have hired, or are in the process of hiring, almost all the personnel that were in our budget. All groups are up and going, and the scientific production has been extensive. In 2013 we have published 31 papers in peer-reviewed journals and another 7 are submitted—our target was a total of 40. A highlight was our latest paper on terrestrial gamma-ray flashes (Østgaard et al. 2013). The American Geophysical Union (AGU) did a special press release of the results from this paper in *Geophysical Research Letters* on April 23, 2013. An animation of the results on YouTube has been viewed more than 5000 times. Another highlight from 2013 was the 24 hour experiment performed at the Arecibo radar, which is the world's greatest radar with a dish diameter of 300 m. A new and innovative experiment was awarded with 24 hour continuous operation of the radar to explore how temporal and spatial scales of ionospheric parameters can be resolved. A third highlight is that the BCSS team at UNIS is organizing the next superDARN international workshop—May 2014.

The BCSS has been highly visible on the international scene: At the AGU fall meeting in San Francisco in December 2013, which is the largest yearly meeting in Geophysics, we organised four sessions, gave two invited talks, three contributed talks, presented nine posters and contributed to another five presentations. One PhD thesis has been produced and our students have won the Meltzer prize, EGU and AGU student awards. The BCSS is represented in several international organizations and networks (e.g., SCOSTEP, TEA-IS etc.) as well as the advisory group (SSEWG) for future satellite missions funded by European Space Agency. The instrumentation group for ground-based instruments has been running several campaigns and is building a new superDARN radar at Svalbard. Main activity in the space instrumentation group is building an X- and gamma-ray detector for the International Space Station to be launched in 2016. BCSS is continuously attracting new students and at UIB, at the moment, there are 11 Master students.

In the following sections you will find reports on the activity in the seven groups of BCSS. As planned, two workshops were held in 2013. The one-year old centre is healthy and is doing pretty well.

Nikolai Østgaard,
Leader of BCSS

Photo: Hilde Kristin Strand

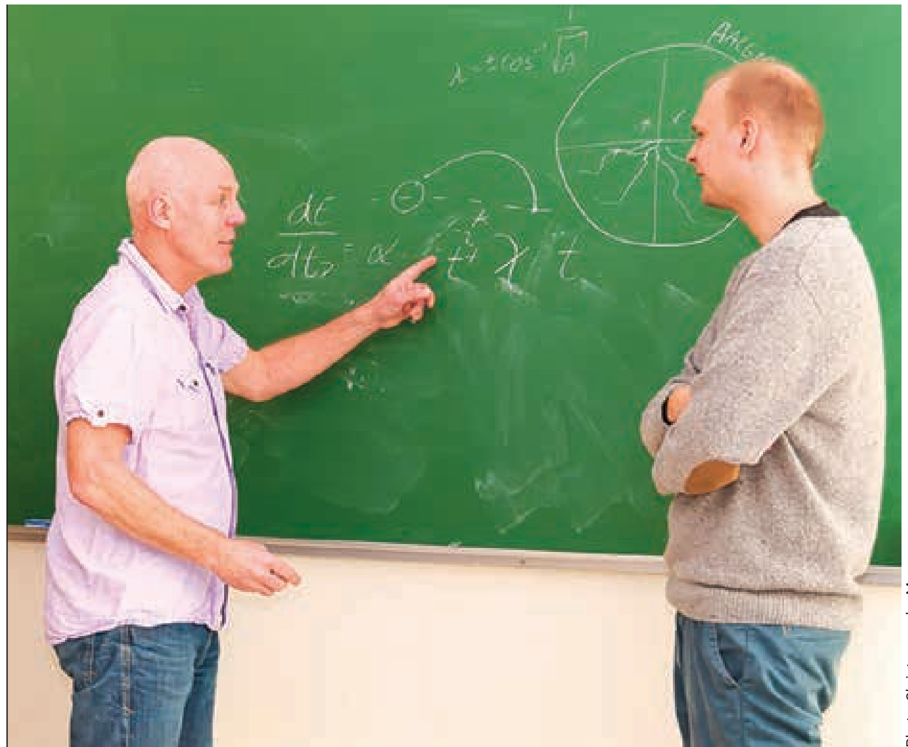


Photo: Christer van der Meeren

Q1

When and why are the auroras in a the two hemispheres asymmetrical?

L to R: Prof. Nikolai Østgaard and Dr. Carl M. Laundal, UIB

The aurora is a manifestation of the coupling between the solar wind, the Earth's magnetic field and our atmosphere. Understanding this coupling is a key issue in space physics. Aurora is one of the few parameters that can be observed routinely on a global scale. So far, space scientists have more or less assumed that auroral observations made in one hemisphere are mirror images of the opposite hemisphere. The reason that we might expect symmetry is that most of the processes that are believed to be responsible for the aurora map along magnetic field lines to both hemispheres. However, this is not always the case.

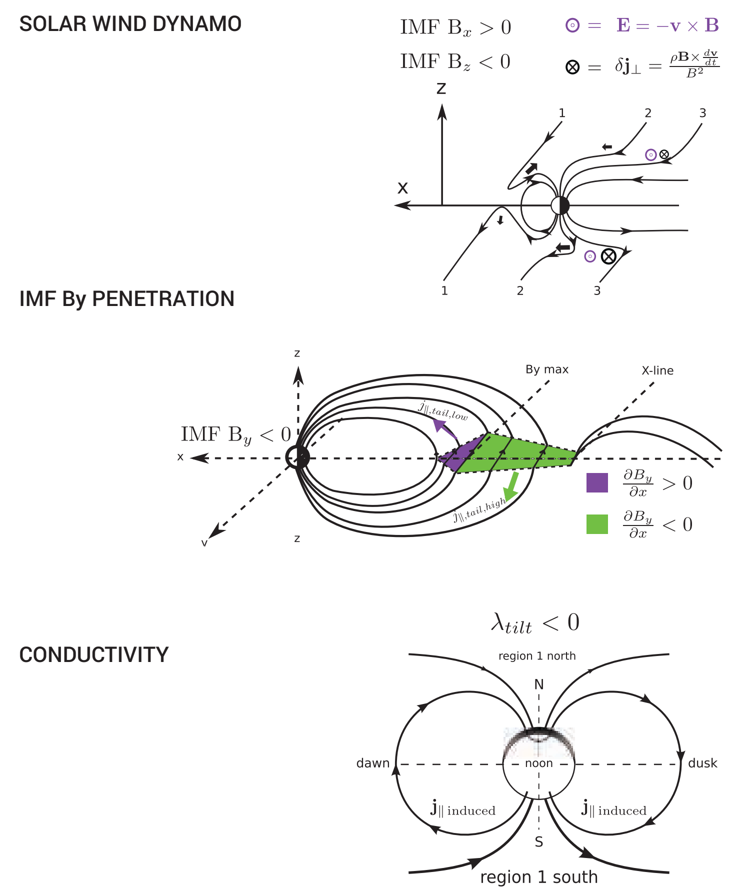
In 2009, we published a spectacular example of non-conjugate auroras (Laundal and Østgaard, 2009) and suggested they were a signature of interhemispheric and asymmetric electric currents. Østgaard and Laundal (2011) summarized our findings over the last 10 years and suggested three mechanisms that can produce such interhemispheric and/or asymmetric currents. Two of these mechanisms are related to the orientation of the Sun's magnetic field as it encounters the Earth's magnetic field. If this field has a strong component along the Sun-Earth axis, it will create twists in the field-region where the Sun's and the Earth's magnetic fields connect. This will affect the Birkeland currents (magnetic field-aligned currents) differently in the two hemispheres. This is known as the solar wind dynamo mechanism. The second mechanism is related to the component of the interplanetary magnetic field that is perpendicular to the Sun-Earth axis and to the Earth's dipole axis. When this magnetic field component penetrates the Earth's magnetic field, a dawn-dusk twist is created in the nightside magnetosphere that will also produce interhemispheric currents. This is known as the interplanetary magnetic field (IMF) By penetration mechanism.

The third mechanism is related to seasons, that is, when one polar cap is more illuminated (local summer) than the other (local winter), interhemispheric currents will be set up at the terminator. This is known as the conductivity mechanism. The main objective for this group is to investigate the three proposed causes for non-conjugate aurora and interhemispheric or asymmetric currents.

In 2013, BCSS PhD candidate, Jone P. Reistad and co-workers (Reistad et al., 2013) published a paper in *Journal of Geophysical Research*, testing the relative importance of these mechanisms. From the 10 events that were studied (19 hours in total), 15 features were characterized as non-conjugate. This study shows that such features are more common than many researchers anticipated. They found that 7 of the features could be explained by the solar wind dynamo mechanism, 5 by IMF By penetration and 3 by the conductivity mechanism.

At the AGU fall meeting we gave an invited talk where the three mechanisms were presented and discussed, which we hope will encourage the international community to attack these problems.

In addition to this main focus of the group we have published some important papers on related topics. Tenfjord and Østgaard (2013) addressed the energy transfer from the solar wind to the magnetosphere. They compared the available energy in the solar wind with the main energy sinks in the magnetosphere and ionosphere. Combined with theoretical considerations based on first principles of physics, they used 13 years of data to develop a dynamic energy transfer function, which is the first to take into account that the area where energy is transferred is dynamic. Søraas et al. (2013) presented observations of proton aurora that appeared well equatorward of the main auroral oval. By lucky coincidence, a low-altitude NOAA spacecraft traversed a small spot of proton aurora (~100 km) imaged by IMAGE at the same time. Such a spot has never been reported in this location before. The precipitating protons were suggested to originate in the magnetospheric ring current.



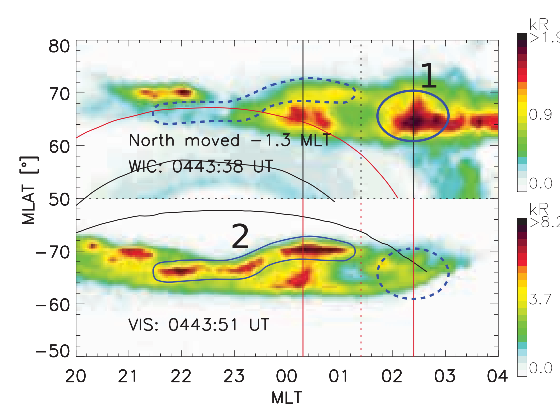


Figure 1: **Top:** The three mechanisms for generating asymmetric or interhemispheric currents (Østgaard and Laundal, 2011).

Bottom: Asymmetric auroral features caused by solar wind dynamo (marked 1) and IMF By penetration (marked 2), from Reistad et al., 2013.

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Photos: Christer van der Meeren

Top: PhD candidate Paul Tenfjord and Dr. Kristian Snekvik
Bottom: Drs. Karl M. Laundal and Stein Haaland

Q2

How do we get beyond the large-scale static picture of the ionosphere?

Photo: Eva Therese Jenssen, UNIS

L to R: Profs. Dag Lorentzen and Lisa Baddeley, and PhD candidate Xiangcai Chen, UNIS

Much of our understanding of the coupling between the Earth and near space has been crippled by the inherent observational shortcomings of single satellite missions. The large-scale and static picture of ionospheric parameters has been established, but to address the dynamics and time-space relationship, new approaches are needed. Recent and future satellite missions (e.g. ESA SWARM, THEMIS and Cluster) provide multi-point measurements allowing a separation of spatial gradients and temporal variability of measured electromagnetic parameters. The limitations lead to the commonly used assumption that observed variations are due to spatial gradients or that the system is static.

The highlight of the efforts in Q2 was the 24 hour experiment performed at the Arecibo radar. This is the world's greatest radar with a dish diameter of 300 m. Dr Gjerloev proposed a new and innovative experiment and was awarded 24 hour continuous operation of the radar. A satellite in orbit around the Earth provides measurements that are separated in both space and time. For a ground based radar the Earth rotation results in measurements that are likewise separated in both space and time. Gjerloev proposed a mode in which the Earth rotation is counteracted by continuously redirecting the beam direction (Figure 2). This allows for 6 minutes of continuous monitoring of the ionospheric plasma properties in a very small volume (~1 km by ~4 km). The surprising findings showed rapid plasma density growth rates not expected and unaccounted for in state-of-the-art models and simulations.

In a recent study (Gjerloev et al., 2103) we analyzed a movie of aurora to determine the scale size dependent variability of auroral emissions by using a simple, yet robust, 2D Fourier transform technique. When plotting the correlation pattern as a function of scale size and time separation we find a pattern with distinct regions of high and low correlation. This remarkable result is interpreted as an indication of a magnetosphere-ionosphere system that uses repeatable solutions to transfer energy and momentum from the magnetosphere to the ionosphere. We compared our average result with a large statistical study of field-aligned currents (Gjerloev et al., 2011). Despite the differences in e.g. parameter and technique between the two studies we conclude that the characteristics of field-aligned currents and auroral emissions are in excellent agreement.

We further performed several studies revealing the spatial morphology and temporal behaviour of the ring current as revealed by precipitating protons/ENA, ground based SuperMAG observations and Cluster measurements. As an example, Haaland and Gjerloev (2013) found that the dawn-dusk asymmetry seen in the ring current has its counterpart in the magnetopause currents and becomes more pronounced during disturbed magnetospheric conditions.

Baddeley and Lorentzen are currently planning and organizing the 2014 SuperDARN workshop which will be held at UNIS. Østgaard is an invited speaker to the workshop to present the work and the goals of the BCSS. A special session was organised at the Fall AGU conference in San Francisco with a focus on separating time and space for which Gjerloev was the lead convener. Another session has been approved for the AOGS meeting to be held in Sapporo, Japan in July 2014.

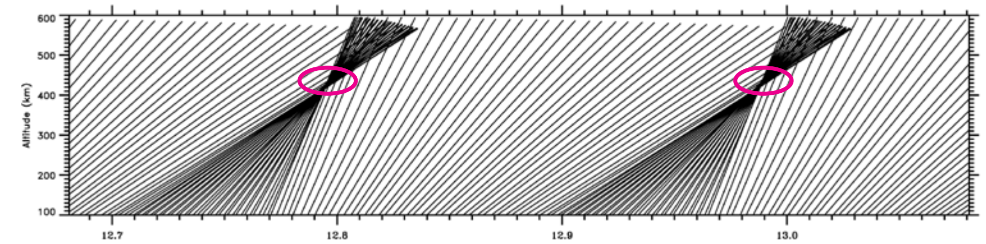
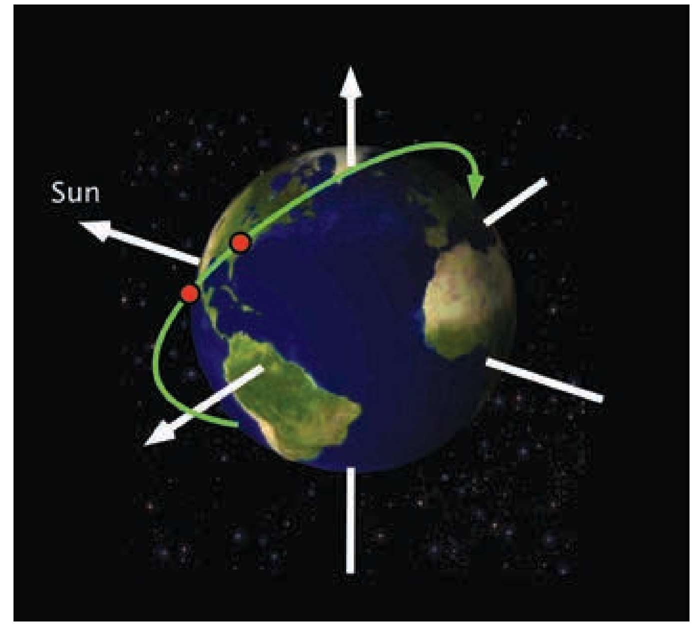


Figure 2: **Above:** 14 minutes of operation showing two focusing points



Left: Single satellite observations mix space and time.

Left: World's greatest radar Arecibo in Puerto Rico used for the experiment

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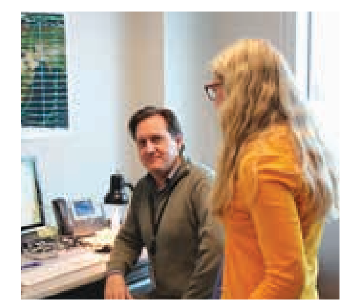
Photo: Eva Therese Jenssen, UNIS



Top: PhD candidate Xiangcai Chen, UNIS
Bottom: Prof. Jesper Gjerloev, Johns Hopkins University and PhD candidate Beate Humberset, UIB

Q3

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

Throughout the first year the group has more than doubled and is still growing. As we are the most geographically diverse group, we intend to ensure that all nodes, NTNU, UNIS and UIB have both a post-doctoral fellow and at least one PhD student associated with the BCSS. In addition, we now have a number of Master students with advisors and co-advisors from more than one institute. We are working together to quantify the effects of particle precipitation on the atmospheric system.

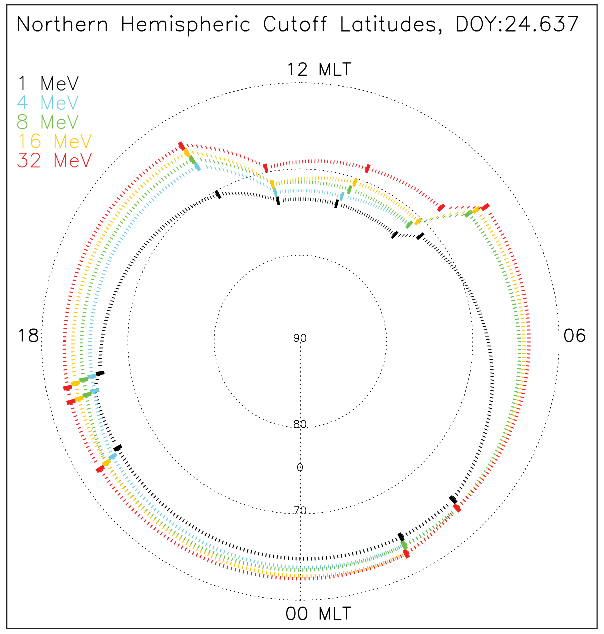
Traditionally, atmospheric studies have been carried out within specific altitude regimes: thermosphere, mesosphere, stratosphere and troposphere. However, the effects of energetic particle precipitation cross these traditional boundaries, and a new cross-disciplinary approach is required to make further progress on the open questions. Solar proton events associated with large coronal mass ejections from the Sun have been widely studied in relation to the production of reactive species such as NOx and HOx in the middle atmosphere. However, frequently-used models oversimplify the nature of the proton energy deposition to the extent that they may overestimate the energy being deposited in the middle atmosphere. In a recent paper focusing on the large solar proton event in January 2012 we showed strong day-night asymmetry in the cutoff latitudes and thereby in the energy being deposited (Nesse Tyssøy et al., 2013).

However, quantifying the influence of energetic particle precipitation energy deposition into the middle atmosphere during January 2012 requires a detailed understanding of the background dynamics. The January 2012 solar proton event coincided with a major stratospheric warming strongly impacting the entire middle atmosphere. During these events the products of energetic particle precipitation are transported horizontally to new latitudes both northward and southward depending on the time and location, as we showed in the paper by Kleinknecht et al. (2014). In addition, we have reported (Tweedy et al., 2013, De Wit et al., 2014) that there is a strong vertical movement, turbulence and gravity wave energy deposition influencing the chemistry.

Even, during less extreme conditions, the dynamics of the middle atmosphere has

Photo: Christer van der Meeren

L to R: Dr. Hilde Tyssøy, UIB, Profs. Robert Hibbins and Patrick Espy, NTNU



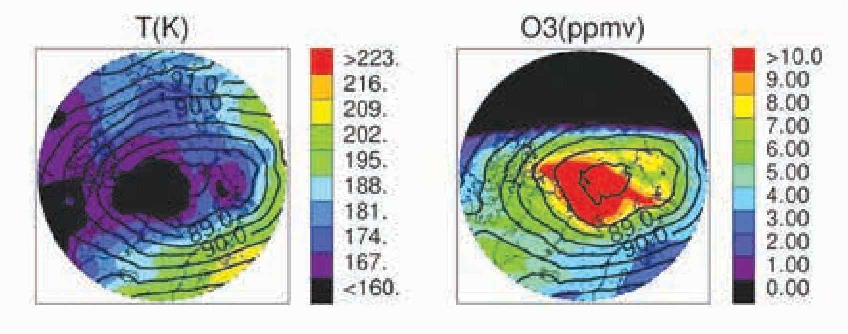


Figure 3: **Left:** Nesse Tyssøy et al. (2013) found a clear day-night asymmetry in the cutoff latitudes during Solar Proton Events. Quantifying the effects of energetic particle precipitation requires an understanding of the background atmosphere which can be influenced by a stratospheric warming

Below: The effect of a sudden stratospheric warming illustrated at 97 km for ozone and temperature (Tweedy et al., JGR, 2013).

to be taken into account. Middle atmosphere dynamics, in particular at polar latitudes, is not a mature research field. In several papers (Holmen et al., 2013; de Wit et al., 2013, Demissie et al., 2013a,b, 2014) we have focused on the dynamic processes driving the background middle atmosphere in an effort to achieve a picture of the unperturbed middle atmosphere. This was also the topic for our first PhD dissertation, Demissie (2013). A current Master student project applies these background winds to particular air parcels exposed to energetic particle precipitation to trace their trajectories. This work is vital for understanding the effective photochemical lifetime of NOx gasses which strongly depends on sun light exposure.

The leadership of the BCSS, in defining the role of energetic particle precipitation perturbations to the middle atmosphere, has been recognized within the peer community through a number of publications. In addition, a student paper was giving an Outstanding Student Paper Award at the American Geophysical Union in December 2013. This work has also generated interest by the Norwegian and international media with a number of newspaper articles and a TV feature on the state-of-the-art Momentum Flux Meteor Radar at Trondheim *(Schrødingers Katt)*.

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Photos: Christer van der Meeren

Top: Postdocs Venkateswara Rao and Marit Sandanger
Bottom: PhD candidate Linn-Kristine Ødegaard

Q4

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

It is now 20 years since it was discovered that thunderclouds emit very energetic particles into the near space environment. The energetic gamma bursts are called Terrestrial Gamma-ray Flashes (TGFs) and they are the most energetic natural photon phenomenon in our atmosphere. Since then, it has also been found that energetic electrons and positrons are emitted from thunderstorms to space. The origin of these newly discovered phenomenon, and their effects on the near space environment is the main science objective for our group. In 2013 we have published two papers, given two invited talks and contributed to eight other presentations at international meetings, directly related this main science question. We have arranged special sessions at both the EGU and AGU meetings and we have several public outreach contributions. We are represented in the steering committee of a European network "Thunderstorm Effects on the Atmosphere-Ionosphere System" funded by ESF, and take part in organizing the summer school for this network in 2014.

A significant step in understanding the relation between lightning and TGFs was published by Østgaard et al. (2013). This paper presented the very first simultaneous observation of a TGF and optical lightning. By fortunate coincidence, two independent satellites, traveling at 7 km/s, passed right above the same thunderstorm when a TGF, lasting only 70µs, occurred. One satellite (RHESSI) carried a gamma-ray instrument and the other satellite (TRMM) carried an optical lightning detector. In addition we had simultaneous measurements from the Duke VLF radio receiver and the World Wide Lightning Location Network, which measures radio waves from the currents produced by the TGF and the lightning. Figure 4 shows the sequence of events. A weak radio signal is seen at the initiation of the leader. The TGF is produced just before the leader reaches the positive charge layer and emits a strong radio signal, and finally the optical lightning occurs when the leader short-cuts the two charge layers. AGU produced a press release when our study was published in Geophysical Research Letters. This press release caught the attention by the worldwide media. An animation of the observations posted on YouTube received nearly five thousand hits.

Important characteristic of TGFs are their occurrence frequency, production altitude, spatial extent of its source region and spectral/spatial distribution of photons in a TGF. One important parameter is the number of initial photons in a TGF. In a paper by Hansen et al. (2013) we investigated this number based on observations and simulations. The number of initial photons in a TGF spans over several orders of magnitude, depending mostly on the production altitude of the TGF. Assuming 10 km production altitude, 1018 initial photons are needed for a TGF to escape atmospheric attenuation and be detected in space. In an on-going study of three TGFs occurring over the Mediterranean basin we use meteorological data to show that TGFs may be produced down to 10 km altitude and therefore must be initially very bright.

In 2013 we undertook electrical discharge experiments in the laboratory at the Technical University of Eindhoven with a 1 MV Marx generator. One spark is shown in Figure 5. Data from about 1000 sparks were obtained with detectors arranged in different geometries. The goal of this campaign is to determine the spatial characteristics of the X-rays that are produced in these sparks and to see if there are traces of electrons as well in the data. The analysis of the data is on-going and is also the topic for a Master project.

Photo: Christer van der Meeren

L to R: Drs. Martino Marisaldi and Thomas Gjesteland

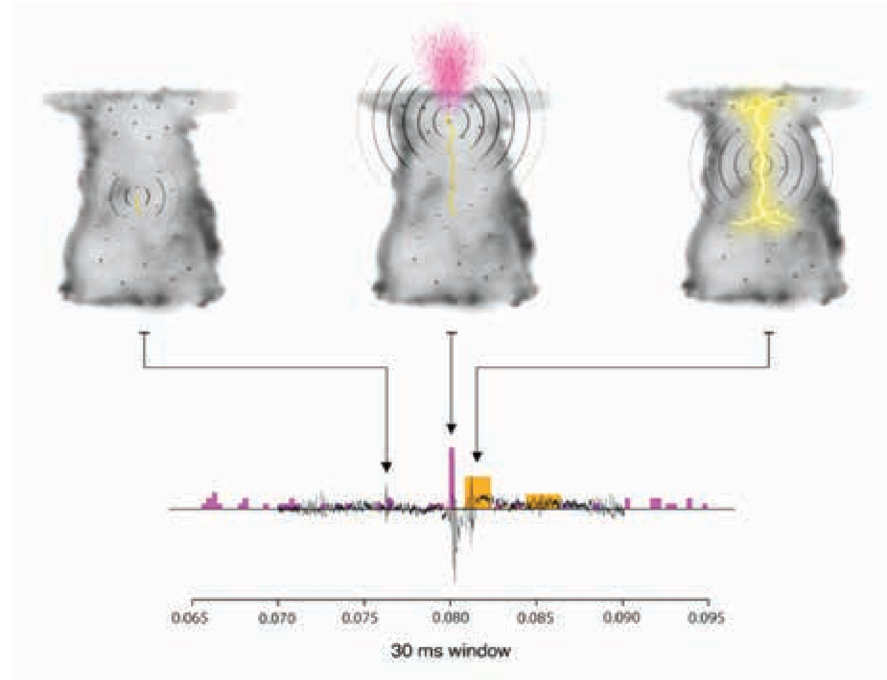

Image: Fabian Schnuer Gode

Figure 4: **Above** A leader forms and produces a weak radio pulse. (middle): Electrons with speed of light produce gamma-rays (pink), electric current and a strong radio pulse.(right): The leader short-cuts the two charge layers, strong electric current, radio pulse and bright lightning are produced.

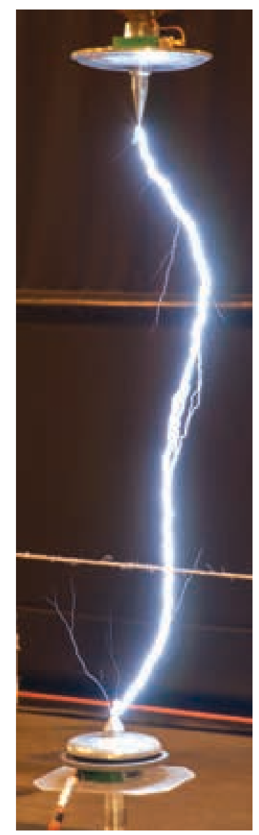

Figure 5: Spark in the laboratory

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Photo: Kavitha Becker

Photo: Georgi Genov

Top: PhD candidate Alexander Broberg Skeltved
Bottom: Master students Vegard Askøy and Anders Ohma

Space Instrumentation Group

The main task for the space instrumentation-group in 2013 has been to develop the electronics and mechanical structure for the Modular X-ray and Gamma Sensor (MXGS) instrument of the Atmosphere-Space Interactions Monitor (ASIM).

The ASIM payload is an instrument suite to be mounted on an external platform of Columbus laboratory on the International Space Station (ISS, location shown in Figure 6). ASIM will study the coupling of thunderstorm processes to the upper atmosphere, ionosphere and radiation belts. ASIM is a spectroscopic mission, measuring optical (Transient Luminous Events: TLEs and lightning) and X- and gamma-ray emissions (Terrestrial Gamma-ray Flashes: TGFs). ASIM will be able to correlate, in space and time, the lightning, the TLEs and the TGFs by means of precise internal triggering and synchronisation between optical instrumentation and the MXGS.

University of Bergen is responsible for developing and building the two X- and gamma-ray detectors that comprise the MXGS sensor. The low energy detector is a detector array of 8 x 8 (64) Cadmium Zink Telluride (CZT) detector modules (DM) with dedicated read out electronics. This detector layer is pixelated and with a detection area of 1024 cm2 it will measure energies in the range of 15keV up to 400 keV and enable imaging of the TGFs. The high energy detector is 900 cm2 and consists of 12 Bismuth Germanate (BGO) crystals coupled to photomultiplier tubes with its dedicated read out electronics. It will cover energies extending up to 20 MeV. Both detector layers are built based on a modular structure; the LED is comprised of 4 identical CZT Detector Assembly Units (CZT DAUs) while the high energy detector layer is comprised of 4 identical BGO DAUs.

The group been working on testing and debugging the early prototypes of the CZT and BGO DAU electronics, first the breadboards and then the "elegant breadboards". Based on the result of this debugging, an updated revision of the electronics design was built—the engineering model. The purpose of this model is to verify the functionality of the electronics design before building the actual Flight Model.

In the same timeframe we have been working on testing and verifying the thermal and mechanical design of the CZT and BGO DAUs, using dummies of the CZT and BGO DAUs. These dummies were thermally and mechanically representative of the Flight Models and were tested and verified in Spain.

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Photo: Christer van der Meeren

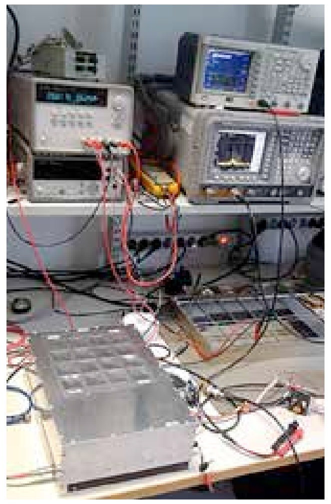
Below: L to R: Prof. Kjetil Ullaland, Shiming Yang and Georgi Genov

We have also had the task of inspecting and checking all incoming flight parts for their integrity and functionality. For example the team has been performing "burn-in" testing of the CZT detectors over the last months. This is a test designed to stress the detectors with applied voltage at elevated temperatures over a calculated time period. The goal is to exclude defect detectors.

It has also been a major task of the group to put together the documentation package for the Critical Design Review (CDR), a milestone in the ASIM project life time which is aimed at freezing the design of the instrument.

In addition to ASIM, we have also started the preparations for the balloon project COBRAT (Coupled Observations from Balloon related to ASIM and TARANIS). TARANIS (Tool for the Analysis of RAdiations from lightNIng and Sprites) is a French microsatellite mission to be launched the same year as ASIM in 2016. The main objective of COBRAT is to provide complementary measurements to the ASIM and TARANIS missions, but closer to the source. Through long duration flights of about one week COBRAT will fly at ~30 km altitude and make observations of runaway electrons and gamma-rays from lightning and to potentially detect the NOx and aerosol enhancements. We have adapted a design for the COBRAT instrument based on the design of the HED detector from ASIM. The work has so far resulted in a preliminary 3D mechanical structure for the detector (see Figure 8). The procurement of parts and materials for the detector has also started.

We are also responsible for a radio receiver, which is connected to the VLF/LF lightning detection network (LINET) run by the University of Munich.



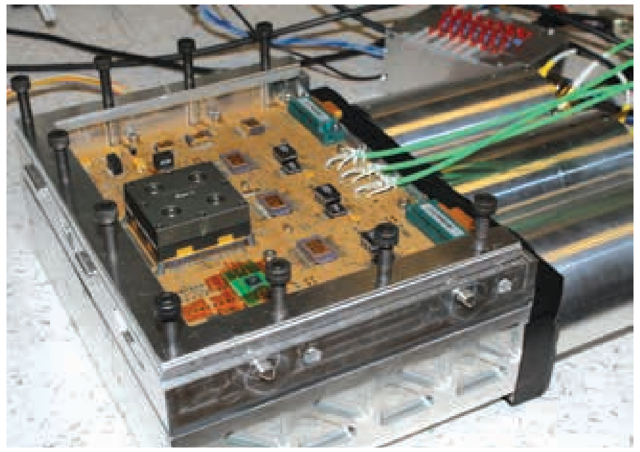


Figure 7: **Above** CZT DAU EM
Below BGO DAU EM

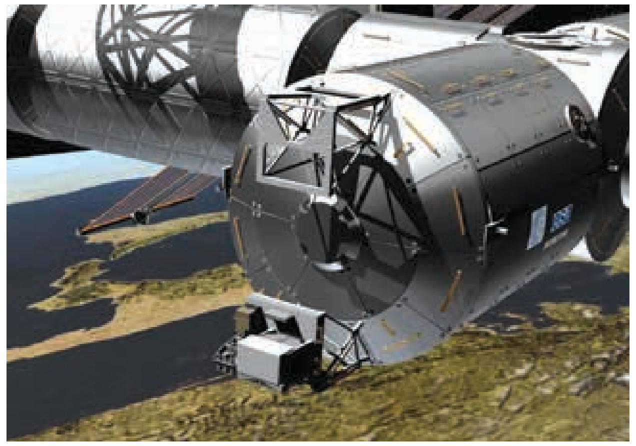


Figure 6: **Above** An illustration of the ASIM payload outside the Columbus module (lower left)
Courtesy, Danish Technical University

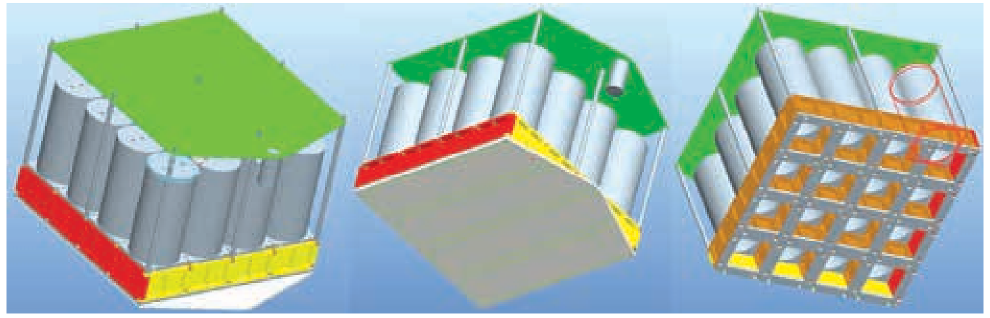


Figure 8: **Above** Illustration of the latest mechanical design of COBRAT

Ground-based Instrumentation Group

The ground-based instrumentation group is running and maintaining the research infrastructure (KHO, SPEAR and the new SuperDARN radar). This considerable effort includes a long duration campaign of 5 months every year. This section reports on the main activity in 2013 at The Kjell Henriksen Observatory (KHO), the new node to the Super Dual Auroral Radar Network (SuperDARN) and The BCSS Scintillation and Total Electron Content (TEC) network during 2013.

The activity at the Kjell Henriksen Observatory has been high in 2013. The season has been good with lots of clear nights and aurora. On the 1st of February, her Royal Majesty Queen Sonja of Norway visited KHO with friends. Together with Sysselmannen (the Governor) she inspected key instruments and learned about the dayside aurora and airglow.

There are now 17 instrumental groups at the observatory. In 2013, MARINTEK joined with instruments to study service loss for the Iridium and GPS systems, and the Finnish Meteorological Institute (FMI) installed a Beacon satellite receiver. The plans for a new Chinese magnetometer have started. 21 different institutions from 9 nations were present at KHO in the time period 2006-2013. KHO is now more or less fully automated. In addition, all the 77 rooms of KHO are now secured by an automatic fire extinguishing system based on the INERGEN gas.

During the auroral winter season from November to the end of February, 25 optical instruments operate 24 hours a day. The 10 non-optical instruments run all-year-round 24 hours a day.

The instruments at KHO are grouped into six main categories:

A. All-sky cameras and narrow field-of-view imagers,

B. Meridian scanning photometers,

C. Spectrometers / spectrographs

D. Scanning / imaging interferometers

E. Radio or non-optical instruments

F. Active optical instruments (lasers)

Our mobile phone Auroral forecast has reached over 10 000+ downloads on Google Play. The latter numbers are not known for iPhone and Windows.

A new narrow field of view sCMOS camera has been installed on an azimuth/elevation mount at KHO. This camera records the night sky at a very high spatial resolution of 14 m per pixel at 130 km altitude. In addition, the calibration laboratory at UNIS has been upgraded with 1 m diameter integrating sphere system for absolute calibration purposes. The integrating sphere can be used by visiting scientists for calibration of their instruments before employment at the observation site.

A low cost all-sky EMCCD camera has been assembled and tested. The camera is able to automatically detect aurora based on color matching at high frame rates.

In 2013 BCSS installed four new scintillation and total electron content receivers in Svalbard. One unit is located in Longyearbyen at KHO, and the other three units at Ny-Ålesund, Hopen and Bjørnøya. Each receiver stores detailed information about the signal amplitude and phase, in order to study how navigation signals from GPS, GLONASS and GALILEO are affected by plasma irregularities on their way through the ionosphere.

The new SuperDARN project sponsored through the ConocoPhillips / Lundin High North research program is making excellent progress. Below is a summary of the important milestones achieved in 2013 along with ongoing work:

A. Design and location of radar antennas and transmitters confirmed.

B. Documentation process on-going with the local government regarding the planning permission for the system.

C. Signing of a contract with the University of Leicester (UoL) regarding the building of the transmitters.

D. Signing of the contract with the University of Saskatoon (UoS) regarding the building, design and deployment of the antenna masts.

E. Site survey completed with UoS and UoL engineers.

Ground-based observational facilities running during 2013 in support of BCSS activities at NTNU's Dragvoll campus in Trondheim include a new generation 30 kW Skiymet meteor radar system, a near-IR Andor spectrometer and an all-sky airglow imager run in collaboration with the University of Illinois (G. Swenson). Data from these instruments have been used in seven Masters projects and two bachelor projects at NTNU during 2013 together with three papers currently in preparation as part of an ongoing PhD programme at NTNU (R.J. de Wit).

TEAM

Fred Sigernes
Team Leader
Professor, UNIS

Dag Lorentzen
Professor, UNIS

Lisa Baddeley
Associate Professor, UNIS

Robert Hibbins
Professor, NTNU

L to R: Profs. Dag Lorentzen and Lisa Baddeley

Figure 9: **Above** The domes of the Kjell Henriksen Observatory

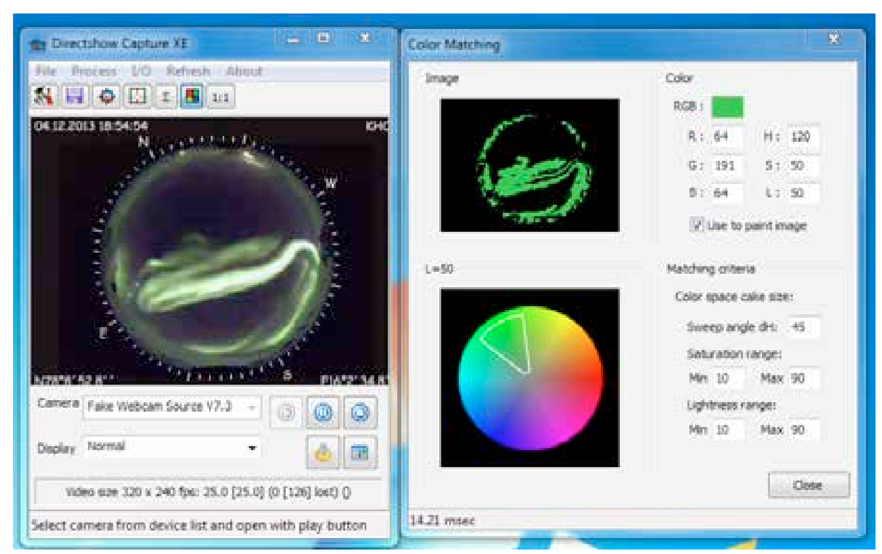


Figure 10: **Left** Real time colour segmentation of aurora by a Colour all-sky EMCCD camera at the Kjell Henriksen Observatory (KHO)

Education and Public Outreach

This group is responsible for making research results accessible to interested members of the public. The first step to doing this was to develop the brand identity of the Centre. During the first months of 2013, the logo of the BCSS was developed. It was presented at the kick-off meeting for the Centre on March 7, 2013.

BIRKELAND CENTRE FOR SPACE SCIENCE

In May 2013, a temporary homepage for BCSS was made within the framework of the web system at the University of Bergen. At the same time, the process of designing a permanent BCSS website started. After deciding on the site-map and designing the layout of the website, a cooperation with the IT department at UIB was initiated to ensure a successful implementation of the webpage. The new webpage was launched on the first birthday of BCSS (March 7, 2014).

An important role of EPO is to assist researchers to highlight their science in the media. During 2013, 70 media articles involving the BCSS were produced. The most discussed case took place in April, when the American Geophysical Union (AGU) published a press release entitled "Scientists detect dark lightning linked to visible lightning". This press release was based on a paper in *Geophysical Research Letters* (GRL) by Østgaard et al. (2013) and resulted in 38 news articles around the world.

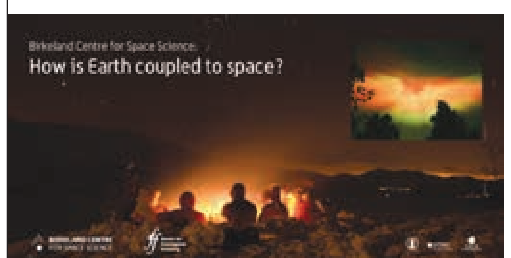
Below is an article by Thomas Gjesteland in *Bergens Tidende* from April 2013 about the enigmatic gamma-ray flash.

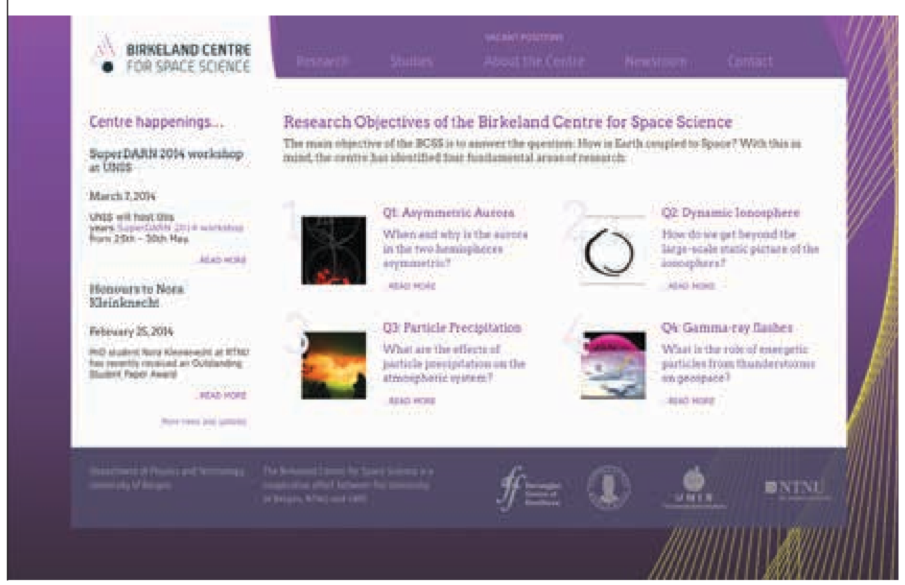
The EPO group has developed various brand identity materials for BCSS including business papers, a Power Point presentation template and roll-ups for use at conferences.

Below is a poster that was made for the BCSS participation at the Christie Conference in Bergen on the 25th of April. This poster is 2m x 4m and is now found on the wall in the BCSS building in Bergen.

Photo: Christer van der Meeren

L to R: Prof. Kjartan Olafsson, Brage Førland and Dr. Arve Aksnes





Top: Article, *Bergens Tidende*
Left: Christie Conference poster
Below: new BCSS homepage

TEAM

Arve Aksnes
Team Leader
Advisor, The Faculty of Mathematics and Natural Sciences, UIB

Kjartan Olafsson
Associate Professor, UIB

Brage Førland
Chief Engineer, UIB

Kavitha Becker
Graphic Designer, UIB

Projects supporting BCSS 2013

Birkeland Centre for Space Science: SFF Funding 160 MNOK; Total Funding over ten years 440 MNOK

	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	P.I. Nikolai Østgaard
2010-2016	**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.	2.85 MEUR
	Strategic Core Activities for the Space Physics group at the University of Bergen (SCASP-UIB) | Project nr: 216872/F50–NFR/Program for Space Research	P.I. Nikolai Østgaard
2012-2015	A project to support TGF research and Cluster studies – one PhD student	3 MNOK
	Norwegian Research Council Program for Space Research | Project nr: 208028/F50	P.I. Nikolai Østgaard
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	4.86 MNOK
	Norwegian Research Council Program for Space Research | Project nr: 230956/F50	P.I. Nikolai Østgaard
2014-2016	**The Norwegian Cluster studies** A small project to support the Norwegian collaboration using Cluster data	600 KNOK
	Norwegian Research Council Program for Space Research | Project nr: 212014/F50	P.I. Kjellmar Oksavik
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 campaigns at Svalbard	1.3 MNOK
	Norwegian Research Council Program for Space Research | Project nr: 195385/F50	P.I. Dag Lorentzen
2010-2015	**Infrastructure for space physics related research on Svalbard** A project to develop new space related infrastructure on Svalbard	8.2 MNOK
	Norwegian Research Council Program for Space Research | Project nr: 191747/V30	P.I. Patrick J. Espy
Dec. 2009 - Feb. 2013	**Gravity-wave sources and scales in the Polar Regions and their effect on Polar Mesospheric Clouds**	2.523 MNOK full cost
	Norwegian Polar Institute Researcher | Project-NARE	P.I. Patrick J. Espy
2011-2013	**Observation of carbon monoxide and ozone in the Antarctic and Arctic:** Implications for the inter-hemispheric coupling of vertical motions	2.566 MNOK full cost
	UK Natural Environment Research Council standard grant | NE/G018707/1	P.I. Steve Milan, Co-I: Robert Hibbins
Aug. 2009- July 2013	**A new radar for integrated atmospheric science in the southern hemisphere** British Antarctic Survey / University of Leicester	Full economic cost £686K
	UK Natural Environment Research Council standard grant | NE/H009760/1	P.I. Robert Hibbins
April 2010- Mar. 2013	**Wave dynamics of the mesosphere** British Antarctic Survey / University of Bath	Full economic cost £588K
	UK Natural Environment Research Council standard grant | NE/I010173/1	Co-I. Robert Hibbins
April 2011- Mar. 2014	**Solar wind connection to regional climate** British Antarctic Survey	Full economic cost £457K
	Norwegian Research Council FRINAT Program | Project nr: 191628	P.I. Lisa Baddeley
2009-2014	**SPEAR – a high power ionospheric modification facility for Svalbard**	6617 KNOK

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Personnel 2013

Summary

	TOTAL	UIB	NTNU	UNIS	MEN	WOMEN
Professor	11	6	2	3	10	1
Scientists / Postdocs	8	7	-	1	6	2
PhD Candidates	10	7	1	2	5	5
Technicians	9	9	-	-	6	3
Master Students	19	12	7	0	12	7

BCSS Team

Centre Leader	Nikolai Østgaard	UIB
Adm. Coordinator	Anja Hegen	UIB
Centre Board	Jarl Giske, *Vice-Dean* , *Faculty of Math. & Natural Sciences*	UIB
	Bjørn Åge Tømmerås, *Dir. of Faculty, Faculty of Math. & Natural Sciences*	UIB
	Geir Anton Johansen, *Head, Department of Physics and Technology*	UIB
	Mikael Lindgren, *Head, Department of Physics*	NTNU
	Ole Arve Misund, *Managing Director*	UNIS
	Nikolai Østgaard, *Leader, BCSS*	UIB
	Anja Hegen, *Administrative Coordinator, BCSS*	UIB

Engineering Team

Lisa Baddeley	UNIS
Margit Dyrland	UNIS
Georgi Genov	UIB
Dominik Fehlker (until July 2013)	UIB
Robert Hibbins	NTNU
Geir Anton Johansen	UIB
Dag Lorentzen	UNIS
Kåre Njøten	UIB
Fred Sigernes	UNIS
Maja Rostad	UIB
Kjetil Ullaland	UIB
Shiming Yang	UIB

Education and Public Outreach Team

Arve Aksnes	UIB
Kavitha Becker	UIB
Brage Førland	UIB
Kjartan Olafsson	UIB

Science Advisory Board (SAB)

Margaret Chen, *Aerospace Cooperation, Los Angeles*	USA
Alan Rodger, *Former Director of British Antarctic Survey*	UK
Asgeir Brekke, *Professor Emeritus, University of Tromsø*	NOR

Scientific Team

Lisa Baddeley	Associate Professor	UNIS
Patrick Espy	Professor	NTNU
Jesper Gjerloev	Professor *20% UIB*/JHAPL	USA
Robert Hibbins	Professor	NTNU
Dag Lorentzen	Professor	UNIS
Kjellmar Oksavik	Professor	UIB
Johan Stadsnes	Professor *Emeritus*	UIB
Finn Søraas	Professor *Emeritus*	UIB
Nikolai Østgaard	Professor	UIB
Brant Carlson	Sr. Researcher *20% UIB*/Carthage Coll.	USA
Margit Dyrland	Postdoc	UNIS
Thomas Gjesteland	Researcher	UIB
Stein Haaland	Researcher *20% UIB*/ISSI	CH
Karl Laundal	Researcher	UIB
Martino Marisaldi	Visiting scientist, Univ. of Bologna	IT
Yvan Orsolini	Senior scientist *20% UIB*/NILU	NOR
Hilde Nesse Tyssøy	Researcher	UIB
Xiangcai Chen	PhD candidate	UNIS
Marianne Daae	PhD candidate	NTNU
Ragnhild Hansen	PhD candidate	UIB
Silje Eriksen Holmen	PhD candidate	UNIS
Beate Humberset	PhD candidate	UIB
Jone Reistad	PhD candidate	UIB
Alexander Skeltved	PhD candidate	UIB
Paul Tenfjord	PhD candidate	UIB
Christer van der Meeren	PhD candidate	UIB
Linn Kristine Ødegaard	PhD candidate	UIB

Major Achievements

March 2014	UNIS will host this year's SuperDARN 2014 workshop from 25th - 30th May. Nikolai Østgaard will give an invited talk about BCSS, and the workshop will be attended by members from all three institutions (UIB, NTNU, UNIS).
February 2014	BCSS research group Q2 will be responsible for a special session at the AOGS conference in Sapporo, Japan.
February 2014	Initiating the collaboration with the Bjerknes Centre for Climate Research, first meeting April 2014.
January 2014	Delivery of ASIM ground model. The purpose of this model is to verify the functionality of the electronics design before building the actual Flight Model.
2014-2016	Nikolai Østgaard becomes member of the Solar System Exploration Working Group (ESA).
December 2013	Outstanding Student Paper Award given to Nora Kleinknecht, NTNU, for her poster presentation at the AGU Fall Meeting 2013.
Fall 2013	Impressive presence at AGU Meeting 2013: • 4 sessions • 9 poster presentations • 3 contributed talks • 2 invited talks • Contributed to 5 other presentations
October-November 2013	Nikolai Østgaard lectures at SCOSTEP/ISWI, Nairobi, Kenya.
20 October 2013	The newspaper *Bergens Tidende* presents 47 of the most promising leader talents under the age of 35 years in the Bergen region. Among the talents we find Thomas Gjesteland, who is portrayed on the front page. Beate Krøvel Humberset is also highlighted in the runners-up group of 70 talents.
August 2013	Jesper Gjerloev was awarded observation time at the Arecibo radar, famously featured in movies like *Golden Eye* (James Bond) and *Contact*. The Arecibo radar will now be used by BCSS to get beyond the large-scale static picture of the ionosphere.
May 2013	PhD candidate Beate Krøvel Humberset was awarded an EGU Outstanding Student Poster (OSP) award for her poster presentation "Untangling the space-time ambiguity of pulsating aurora", abstract N° EGU2013-833 in session ST3.2.
April 2013	A press release entitled "Scientists detect dark lightning linked to visible lightning" was published by AGU, based on a GRL-paper by Nikolai Østgaard, Thomas Gjesteland and Brant Carlson from the Birkeland Centre for Space Science. Other authors include A. B. Collier, S. A. Cummer, G. Lu, and H. J. Christian. A video was also uploaded to the AGU YouTube site. The press release resulted in many news articles around the world.