Dear Reader,

This is the one and only final annual report from the department of Earth and Space Sciences. From 1 May 2017 we will have a new name, namely the Department of Space, Earth, and Environment, and the number of staff will roughly double.

It is a strange feeling to say thank you and goodbye although we know from experiences in life, as well as from our research, that nothing is forever. For a while I was thinking of summarising the most remarkable experiences, both the good and the bad ones, but it would take up too much space. Instead I would like to make a short statement that the 17 years as head of department, with its outstanding personnel, have been fantastic. But hey, wait a minute, isn’t this a typical statement from a retiring person? So what else can be added to make you the reader believe it?

What was produced by the department during 2016? More than 160 reviewed papers were published in scientific journals, including three in the high-status journal Nature. That is indeed remarkable, but is it good or bad? In these days it is rather common to hear statements about how measure quality. What does that mean? In order to do so we need a unique link from quality to quantity. It is not at all clear that these links exist for all areas where we want to assess quality. In fact I have only heard of one such link that I easily accept. I cite, in my own words, our chairman of the department’s advisory board, Göran Netzler. “The quality of your work is inversely proportional to the number of complaints you receive related to what you produce”. In research we produce scientific papers. The complaints you get can be found through citations. Hm, there must be a misunderstanding here, because I once heard someone saying that a very good scientist receive many citations ... academic life is obviously complicated.

As tradition requires the annual report is also introduced by some highlights from the year. A highlight could be anything that I have found special.

– The Odin satellite celebrated 15 years in space
– The radar remote sensing group built an experimental tower (see the front page)
– Sebastien Muller was given the competence of associate professor (docent) in Radio Astronomy and Astrophysics on 26 April
– Lars Ulander was appointed Director of the master’s program Wireless, Photonics, and Space Engineering. He also became an IEEE Fellow (both effectively from 1 January 2017, but decided in 2016)
– Pär Strand was appointed ITER Science Fellow
– The twin telescopes at the observatory were installed and at the end of 2016 they were ready for the receivers to be mounted
– Two “Massive Open Online Courses (MOOCs)” were given: Sensing Planet Earth – From Core to Outer Space, and Sensing Planet Earth – Water and Ice

There are also many additional individual highlights in the form of thesis works. They are presented on pages 10-11.

Finally, I am pretty sure that the staff in today’s department will continue, in the new department, to produce highly interesting research as well as to teach and motivate our students in order to prepare them for interesting lives.

Gunnar Elgered, Head of Department

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Copies: 500
A new research station, BorealScat, was established during 2016 in an experimental forest at Remningstorp, located between Skara and Skövde in southern Sweden. It consists of a 50 m high tower with radar and meteorological instruments. The antenna array with 20 ultra-wideband elements at the top of the tower allows tomographic and polarimetric radar imaging of the forest below. The objective is to acquire long-term time series of radar and meteorological measurements to investigate variations of electromagnetic scattering from the vegetation.

The project is motivated by a research effort, led by the European Space Agency (ESA), to map global forest biomass using data from synthetic aperture radar (SAR) satellites. The biomass estimates are affected by changes in the forest due to season, weather and other environmental conditions. Measurements from BorealScat will give a better understanding of electromagnetic scattering from boreal forests and will improve the accuracy of forest biomass maps. The station is operating since December 2016.

Photo: Albert Monteith
Public Outreach

In our outreach programme we engage with the public in order to communicate the excitement and importance of science to people of all ages.

Our first two Chalmers MOOCs (massive open online courses), titled Sensing Planet Earth were a great success. The two courses, From Core to Outer Space and Water and Ice, each attracted over 3000 students from 129 countries, most from the US, India and Sweden, and achieved the highest completion rates yet for Chalmers MOOCs.

We communicated news from Onsala facilities and research by Chalmers scientists to the media in collaboration with Chalmers press office and partner organisations. News reports from Sweden and around the world featured the Band 1 feed for SKA, the precessing black hole jet in galaxy NGC 1377, a tidal disruption event observed by the EVN, and ALMA observations of disk winds from a young star, and a forming triple-star system. Astronomers Susanne Aalto and Hans Olofsson also contributed to the 16-part radio series Bildningsbyråns: Rymden produced by UR (the Swedish Educational Broadcasting Company).

Onsala Space Observatory was the focus of a programme on Swedish national public radio (Vetandets värld) about radio astronomy and China’s FAST telescope.

During the year 1900 people visited Onsala Space Observatory, its telescopes and exhibition. Most came as part of a total of 65 guided tours, of which school groups of all ages accounted for 25 of the tours. Many visitors to Onsala came as part of two public open days, during the Gothenburg Science Festival and on the Mothers’ day in May.

Department scientists gave a number of public talks during the year. On the Physics day during Gothenburg Scientific Festival Santiago Arellano held a lecture on how general physics can help us understand volcanic eruptions through models, experiments and observations. Several talks were given on Sweden’s Day and Night of Astronomy on October 8, at events in Gothenburg, Växjö, Trollhättan, Stenungsund and Fjärås. In November Eva Wirström talked about the science of planets with 550 schoolchildren at Härlanda/Örgryte library, Gothenburg, in conjunction with National Children’s Book Week.

Our SALSA radio telescopes were booked for an average of 21 hours per week, on average 3.5 h per booking, by students, teachers and amateur astronomers from ten countries. This includes Sweden but also from as far away as the US, Israel and Ecuador. Most users study the movements of interstellar gas in the Milky Way. We provided supervision for Swedish high school projects using SALSA. The SALSA telescopes are used to demonstrate and teach radio astronomy to the general public in multiple outreach activities, both in Onsala and elsewhere.

In December 2016, (from left to right) Ludvig och Oliver Norman and Thea och Tyra Lillhage, all from Onsala Montessoriskola, became the first twins to visit the Onsala Twin Telescopes. Photo: Anna Sterning
Press Clippings

Three projects could be Sweden’s next science satellite
Space missions SIW and DICE are two of three possible successors to national climate satellite MATS.
Populär Astronomi, Dec.

Telescopes have millimeter-precision tabs on the Earth’s distances
Two identical telescopes are being built in Onsala. Soon they’ll measure distances across the Earth - to the millimetre.
Sveriges radio Vetenskapsradion, June

Odin celebrates 15 years in space - working overtime
For 15 years, seven times its expected lifetime, the Swedish satellite has circled earth.
Rymdkanalen, Feb.

LA-area refineries emit up to 12 times more toxic chemicals than reported
Refineries in greater Los Angeles are emitting up to 12 times more toxic chemicals than previously reported, according to a new study by Swedish researchers and the South Coast Air Quality Management District.
89.3 KPCC Southern California Public Radio, Nov.

China Fighting Air Pollution in Air, Land, and Sea
China is keen to learn best practices for marine fuel enforcement regulation from Chalmers scientists.
Huffington Post, May.

Triple star caught in unique image
An international team of scientists has taken a picture that could make the world’s hobby photographers feel pretty small.
SVT Vetenskap, Oct.

Susanne Aalto was interviewed by SVT Väst on 31 July about ALMA’s observations of a swirling black hole jet.
Credit: SVT

The research satellite Odin has circled earth 81,942 times in 15 years!
Photo: Sara Sällström SR

Their technology makes the world’s biggest telescope work
Miroslav Pantaleev and Jonas Flygare are part of the Swedish team developing cutting-edge tech for the international telescope project SKA.
DN, Aug.

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DN, Aug.
First Degree and Master’s Studies

The department is active at several levels of teaching: we give courses for students at Chalmers’ Foundation Year, the three-year engineering programme in Electrical Engineering and five-year master of engineering programmes in Electrical Engineering, Automation and Mechatronics Engineering, and Engineering Physics. Most of our courses are at the master’s level, and many of them are also open for students at the University of Gothenburg (GU). We also cooperate with the Department of Physics at GU by giving courses at bachelor’s level in basic astronomy.

In 2016, the department was responsible for more than 20 courses at Chalmers, plus thesis projects on bachelor’s and master’s level. Our teachers also participated in courses given by other departments. The subjects range from basic electrical engineering to courses closely related to our research in, e.g., astrophysics, remote sensing, receiver development, and plasma physics. An important subject is measurement techniques. We have our own laboratory, which is used exclusively for teaching and where students get hands-on experience with measurement instruments. Also the instruments at Onsala Space Observatory are used in several courses. One example is the small radio telescope SALSAL, which astronomy students use to observe atomic hydrogen gas in the Milky Way.

We have long strived to increase the department’s teaching, in particular on the bachelor’s level. In 2016, we were given the responsibility for the course Circuit analysis for first year electrical engineering students.

The department is involved in two master’s programmes: Physics and Astronomy (together with the Department of Fundamental Physics) and Wireless, Photonics and Space Engineering (together with the Department of Microtechnology and Nanoscience).

Two of the department’s teachers are also responsible for education programmes as Chalmers: Cathy Horellou is Director of the Master’s Programme in Physics and Astronomy, and Arto Heikkilä is Head of the Programme in Electrical Engineering. In addition, Lars Ulander was appointed Director of the Master’s programme Wireless, Photonics, and Space Engineering in 2016, but his actual work as Director of the programme will start 1 January 2017.

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Chalmers courses given during 2016
(NB: many of the master’s courses were also open to students at the University of Gothenburg)

**A Foundation Year**
- Physics, part B
- Physics project (parts of the course)

**Engineering programmes**
- Electrical engineering
- Electrical engineering project
- Telecommunication

**Master of Engineering programmes, year 1–3**
- Bachelor’s thesis in Earth and Space Sciences
- Circuit analysis
- Electric circuits and electric power (part of the course)
- Engineering measurements (for Automation and Mechatronics Engineering)
- Engineering measurements (for Electrical Engineering)
- Environmental measurement techniques
- High frequency electromagnetic waves
- Planetary sciences

**Master’s courses and equivalent**
- Active microwave circuits (parts of the course)
- Electromagnetic waves and components
- Experimental physics: spectroscopic methods (parts of the course)
- Galaxies and observational cosmology
- Image processing
- Master’s thesis in Earth and Space Sciences
- Microwave engineering (parts of the course)
- Millimetre wave and THz technology
- Modern astrophysics
- Plasma physics with applications
- Remote sensing
- Radar systems and applications
- Radioastronomical techniques and interferometry
- Satellite positioning
- Satellite communications
- Space science and techniques
- Stellar physics
- The interstellar medium and star formation
Bachelor’s Thesis Reports

Erik Börjesson, Julia Jansson, Carl von Rosen Johansson
Test and implementation of a laser based sea level sensor
Supervisor: Gunnar Elgered

Master’s Thesis Reports

Mariana Alves David
The gravitationally lensed blazar PKS 1830-211 seen by ALMA determination of the time delay between the lensed images
Supervisors: Sebastien Muller and Ivan Martí-Vidal

Torbjörn Rathsman
A software toolkit for generating ice and snow particle shape data
Supervisor: Patrick Eriksson

Madeleine Yttergren
Gravitational instabilities in nearby star-forming galaxies
Supervisor: Alessandro Romeo

Katarina Raaholt Larsson
Retrieval of descent rates in the polar vortex during the arctic winter 2012/2013
Supervisor: Kristell Pérot

Simon Pfreundschuh
invlib: A generic implementation of bayesian methods for inverse problems in remote sensing
Supervisor: Patrick Eriksson

Jonathan Arvidsson
GPS based flight motion capture
Supervisors: Patrik Dammert (Saab) and Thomas Hobiger

Justin Salér Ramberg
The outflow of the Boomerang nebula: the coldest object in the universe
Supervisors: Wouter Vlemmings and Theo Khouri

Anton Nilsson
Probing galactic haloes using background polarized radio sources
Supervisor: Cathy Horellou

Jonas Flygare
A wideband quad-ridge flared horn feed design for the Square Kilometre Array band 1
Supervisors: Miroslav Pantaleev and Bhushan Billade

Sven Eriksson
Real-time kinematic positioning of UAS - possibilities and restrictions
Supervisors: Thomas Hobiger and Rüdiger Haas

Paul Gnilsen
Scheduling for VGOS twin telescopes
Supervisors: Rüdiger Haas and Johannes Böhm (Vienna University)

Christos Drosinos Eleftherios
GNSS signal reflections off sea ice
Supervisor: Thomas Hobiger

The SKA Band 1 feed horn mounted on the DVA1 dish at the CNRC-DRAO facility near Penticton, British Columbia, Canada, seen here with Onsala Space Observatory engineers. Jonas Flygare (left) and Magnus Dahlgren. (Photo: Onsala Space Observatory/CNRC-DRAO/J. Flygare)
Master's programme

PHYSICS AND ASTRONOMY

From elementary particles to a complex universe

Understanding the basic laws of physics has been a fascinating problem since the birth of modern science. It is of great intrinsic interest and also forms the basis of other branches of science. Trying to probe the smallest structures of matter and the largest structures of the Universe also drives the development of new technologies.

Physics and Astronomy is intended for students with a keen interest in either the theoretical or experimental aspects of front-line physics and astronomy.

CAREER OPPORTUNITIES

The skills in problem solving and advanced experimental techniques, as well as collaboration and presentation skills, acquired in this program are highly valued both in the academic world and on the job market.

Previous students have found positions in for example industrial research, consulting, product and production development, management and administration, financial analysis.

The interested student will also be well prepared to enter a doctoral programme at Chalmers or at another university in both Sweden and worldwide.

UNIQUE FEATURES

Close connections to leading research laboratories like the accelerator facilities at CERN and GSI, and the Swedish National Facility for Radio Astronomy: Onsala Space Observatory.

SPECIALIZATION

Through the choice of elective courses it is possible to specialize in theoretical and/or experimental aspects of particle physics, subatomic physics or astrophysics.

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<tr>
<th>Year 1</th>
<th>Year 2</th>
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<tr>
<td>Autumn</td>
<td>Spring</td>
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<tr>
<td>Quantum Mechanics</td>
<td>Advanced Quantum Field Theory</td>
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<td>Electro-dynamics</td>
<td>Experimental Physics: Spectroscopic Methods</td>
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<td>Advanced Quantum Mechanics</td>
<td>Modern Astrophysics</td>
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<td>Gravitation and Cosmology</td>
<td>Interstellar Medium &amp; Star Formation</td>
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<td>Elective courses</td>
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<tr>
<td>Autumn</td>
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<tr>
<td>Elective courses</td>
<td>Master's Thesis (30 or 60 Credits)</td>
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Semico- compulsory courses, select 4–8 of 12 courses. The order of the courses might be changed.
Master’s programme

WIRELESS, PHOTONICS AND SPACE ENGINEERING

Electromagnetic waves in research and everyday life

Wireless, Photonics and Space Engineering with their many applications are large industries and strong research fields both in Sweden and worldwide.

The master’s programme will prepare you for a career in this field through studies of wireless and optical communication components and systems, RF and microwave engineering, photonics (phenomena and applications utilizing photons), and space science and techniques.

CAREER OPPORTUNITIES

The programme provides a master’s education for a future career in engineering branches that rely heavily on electromagnetic waves, e.g. telecommunication, automotive electronics, space engineering, medical applications of microwaves and photonics, remote sensing, solid state lighting, environmental monitoring, navigation, and radio astronomy.

You will find career opportunities in industry, at universities, or at research institutes.

UNIQUE FEATURES

The programme offers a unique opportunity to study a combination of subjects where Chalmers has world class facilities: Onsala Space Observatory with radio telescopes and equipment to study the Earth and its atmosphere, the Nanofabrication Laboratory with a clean room for micro and nanotechnology, and state of the art photonics and microwave measurement equipment in research laboratories.

COURSES

The programme starts with five compulsory courses. Through semi-compulsory courses, students can specialize in wireless, photonics or space engineering, or a combination thereof. To provide opportunities to study related fields, there is also a wide range of elective courses.
Doctoral Programme

The doctoral programme is organised as the research school Radio and Space Science. One of the three specialisations; Astronomy, Environmental Science, and Electrical Engineering may be added to reflecting the diversity of the research carried out at the department. The school strives to give the students a thorough understanding of the research area they have chosen with in depth studies in a particular subject. The students should also take part in some teaching activities as well at other departmental work with the aim of achieving Chalmers goals for postgraduate education. There are currently about 26 research students in the programme — most of whom are employed by the department, although a few have positions in industry or at other institutes. During the past year 7 PhD degrees and 5 licentiate degrees have been awarded, while 3 new post-graduate students were recruited. We also strive to engage the PhD students in the department and have organised PhD student fora once per year. This years was a full day in May. Here we discussed such subjects as the results of the introduction of new students, the personnel questionnaire, generic and transferable skills courses and how to spread knowledge, such as good programming, among each other.

Licentiates

Niko Petteri Kareinen
Geodetic analysis for the very long baseline interferometry global observing system
February
Supervisor: Rüdiger Haas

Carsten Rieck
Real-time time metrology using space geodetic methods
June
Supervisor: Rüdiger Haas

Sascha Krause
Ultra-thin niobium nitride films for hot electron bolometer and THz applications
February
Supervisor: Vincent Desmaris

Judit Fogasy
The environment of high-redshift AGN
June
Supervisor: Kirsten Kraiberg Knudsen

Frida Eriksson
Nonlinear dynamics of frequency sweeping energetic particle modes in tokamaks
March
Supervisor: Hans Nordman
Doctoral Dissertations

**John Johansson**
Optical remote sensing of industrial gas emission fluxes
February
Supervisor: Johan Mellqvist

**Sagi Kazutoshi**
Decadal analysis of stratospheric ozone depletion using data assimilation and Odin/SMR measurements
May
Supervisor: Donal Murtagh

**Taissa Danilovich**
Mass loss and molecules: studies of galactic AGB stars
February
Supervisor: Kay Justtanont

**Lukas Lindroos**
Stacking of interferometric data- a submillimetre and radio view on the evolution of distant galaxies
August
Supervisor: Kirsten Kraiberg Knudsen

**Sofia Wallström**
The death throes of massive stars
April
Supervisor: Sebastien Muller

**Joachim Wiegert**
Circumstellar dust emission from nearby solar-type stars
September
Supervisor: René Liseau

**Hawal Marouf Rashid**
Towards ultimate performance of THz heterodyne receivers: SIS frequency multiplier and wideband passive components
April
Supervisor: Vincent Desmaris

**Eskil Varenius**
Investigating the origin of radio emission in nearby starburst galaxies via high-resolution metre and centimetre observations
October
Supervisor: John Conway
The Group for Advanced Receiver Development (GARD) is a research and engineering group working on Terahertz technologies and instrumentation. GARD research activities are focused on superconducting electronics, material science and thin-film processing. The results and experience from the research facilitate development and building of state-of-the-art instruments used in radio astronomy and environmental science.

**Academic Activities**
GARD participated actively in teaching within the Chalmers Master Program “Wireless, Photonics and Space Engineering” and at the undergraduate level (a total of five different courses). S. Krause has presented his Licentiate thesis in February 2016 and H. Rashid defended his PhD thesis in April 2016. GARD has produced 13 publications during the year.

**ALMA Band 5 Full Production Project**
At the beginning of 2013, GARD has been awarded the contract to build Band 5 receivers for the entire Atacama Large Millimeter/submillimeter Array (ALMA). The Project aims to produce 75 receiver cartridges in collaboration with the Nederlandse Onderzoekschool Voor Astronomie (NOVA), Netherlands, and is funded by the European Southern Observatory (ESO) at the level of about 13 ME for 5 years. The ALMA Band 5 European Consortium collaborates with the National Radio Astronomy Observatory (NRAO), USA, providing the local oscillator system and warm cartridge assembly. By the end of 2016, more than 37 Band 5 receiver cartridges have been delivered to the ALMA Project. The installed Band 5 receivers have passed scientific commissioning and the ALMA Band 5 receivers will be offered for observations during cycle 5 (2018).

**APEX Project**
GARD has performed four missions to APEX telescope, which included the de-installation and re-installation of the new SEPIA receiver (Swedish-ESO PI Instrument for APEX) to a share position at the telescope with other PI instruments. The SEPIA receiver is a completely new instrument that allows using ALMA receiver cartridges (up to 3) and consisted, at the start, of a cryostat and a pre-production ALMA Band 5 receiver cartridge that covers the frequency range 158 GHz - 211 GHz, built under EC FP6 funded project, and upgraded by GARD. ESO has contributed to the SEPIA with the hardware (including LO/WCA purchased from NRAO) and commissioning. During 2016, GARD in collaboration with NOVA added a new receiver cartridge: the ALMA Band 9 receiver covers the 600 GHz – 720 GHz RF band. SEPIA is actively used by astronomers of all APEX partners and through ESO by the entire astronomy community, while SEPIA Band 5 receiver is in big demand as a pathfinder for coming use of ALMA Band 5 observations starting in 2018.

The first superconducting tunnel junction based frequency multiplier chip designed by Hawal Rashid. This frequency multiplier has demonstrated to produce sufficient power for practical use by generating about 50 nW of power around 190 GHz. This work was published in IEEE Terahertz Science and Technology magazine and has been nominated by reviewers as “The best publication of the year”. Credit: H. Rashid.
MATS, SIW and DICE

During the past year we have been looking to the future. As always this is guided by the opportunities that present themselves. Sweden’s National Space Board issued a call for new small innovative satellite ideas as a follow-up on MATS (Mesospheric Aerosol/Airglow Tomography Satellite) to which we submitted two ideas: SIW (Stratospheric Inferred Winds) and DICE (Dual-band Ice Cloud Explorer) both of which were selected in December to go forward together with a proposal from KTH Royal Institute of Technology to a pre-study that is intended to ensure that the technical and financial risks are well understood before a final selection toward the end of 2017.

The group has been working on the simulation waves in the oxygen airglow which is one of the phenomena that will be observed by MATS. DICE builds on current work within the group in preparation for the ICI (Ice Cloud Imager)

of frequencies information on the amount of water tied up in ice particles as well as some information about the size can be obtained. The idea with DICE is to perform similar measurements but with a higher horizontal resolution that better matches the types of structures seen in ice clouds and to do this from an orbit that is not fixed in local time so that the evolution of the cloud structures can be followed throughout the day. Such data will provide important tests of climate and weather prediction models.

SIW also uses microwave spectroscopy but in this case we are interested in the shifts in the frequency of the emission lines cause by the wind field though the phenomenon known as the Doppler effect. Using data from the SMILES instrument that functioned on the International Space Station between Oct. 2009 and March 2010 we were able to demonstrate that stratospheric and mesospheric winds can be measured with an accuracy of 5-10 ms⁻¹. SIW is designed to allow us to measure full vector winds over the height range 30-80 km and will also provide profiles of ozone and other related compounds, such as HCl and HNO₃, that will continue these important observations after the current satellite instrument has ceased to function.

The figure shows how the SIW instrument will in turn observe first in the backward direction observe the cold sky as part of the calibration method then in the forward direction and finally the warm calibration target. Credit:Omnisys

An example of a large tropical ice cloud of the type that can be investigated by DICE. Photo: © NASA
Optical Remote Sensing

The optical remote sensing group is working with development and application of ground-based optical remote sensing methods for atmospheric measurements. We focus on tailoring instruments and measurement strategies to address specific measurement problems related to environmental research and monitoring needs. The work is very international and field-oriented, and spans a large variety of disciplines.

**Volcanic gas measurements**
Since 2001 we are strongly involved in developing methods to quantify gas emission from active volcanoes. The EU-project NOVAC (Network for Observation of Volcanic and Atmospheric Change), coordinated by Chalmers, was initiated in late 2005. This project aims at establishing a network of instruments for gas measurements and today comprises 41 of the most active volcanoes in the world. In 2013 a new project DECADE (Deep Earth Carbon Degassing) was initiated, aiming at improving the knowledge on CO₂ emission from volcanoes as part of a large scale international effort DCO, Deep Carbon Observatory. During September 2016 a field campaign was carried out in Papua New Guinea with the aim to quantify the gas emission, SO₂ and CO₂, from the Bagana, Tavurvur and Ulawun volcanoes. There we tested for the first time performing measurements using a drone system. Successful measurements of plume composition were made up to an altitude of 1800 m above the ground.

**Gas emissions from industry and transport**
Unique optical methods have been developed for the quantification of emissions of volatile hydrocarbons, NO₂ and SO₂. We are using these techniques worldwide for bottom-up and top-down studies of gas emissions from various sources. This includes gas measurements in north China during 2016 to assess industrial emissions and gas fluxes from Beijing (VR project Photosmog-China), measurements of volatile hydrocarbons in Los Angeles from fossil fuel related activities and standardization of remote optical techniques for the quantification of gas emissions (CEN WG 38).

**Gas and particle emissions from shipping**
Several methods, including both optical and sniffer technology, have been developed for remote airborne and ground based measurements of gas and particle exhaust emissions from ships. The aim with the systems is to control whether ships comply with new environmental regulation and to quantify emissions per fuel burnt. The work is funded by several EU projects (CompMon, EnviSum), the Danish environmental authorities and Chalmers Transport area of advance. During the period 2014-2016, measurements were carried out from fixed stations at the harbor of Göteborg, the Öresund Bridge, the Great Belt bridge and the port of Los Angeles. In addition airborne measurements of ships were carried out around Denmark and at the entrance of the English channel.

**Stratospheric ozone depletion and satellite validation**
Since 1994 we have operated a high resolution FTIR spectrometer for solar measurements at Harestua in southern Norway. The instrument is part of NDACC (Network for the Detection of Atmospheric Composition Change), and its main purpose is to study the composition of the atmosphere in relation to climate gases and to gases that induce stratospheric ozone loss. During 2016 regular measurements have been carried out, financed by the Swedish Environmental Protection Agency.
Instabilities and transport in fusion plasmas

The strong gradients in temperature present in magnetically confined fusion plasmas drive instabilities and turbulence in the plasma. This in turn leads to large transport of heat and particles across the confining magnetic field. The large turbulent transport crucially affects the size and performance of a fusion device. Our current work in this area is focused on modelling of experiments at the largest tokamak in operation, the Joint European Torus (JET, UK), using both large scale gyrokinetic turbulence simulations (see picture) and predictive simulations of density and temperature profiles using reduced fluid models of turbulent transport.

While turbulence is responsible for most of the transport in a fusion plasma, collisions of the plasma particles and the curvature of the magnetic field also drive the usually weaker neoclassical transport. A better understanding of synergy between the two transport phenomena in gyrokinetic simulations is an ongoing effort in the fusion research community. In our current work we study the role of this interaction for energy transport and how it is influenced by the plasma parameters.

One important objective for the next generation tokamak ITER is the study of alpha particle transport and associated heating. The fast alpha particles produced in the fusion reactions are prone to excite wave instabilities which may subsequently lead to severely degraded alpha particle confinement and reduced heating of the plasma. Within this field, our research activity focuses on theory development and modeling of the effects of alpha particles on plasma instabilities and transport.

Computational modelling of plasmas

Computational modelling of turbulent transport is very demanding, requiring the use of supercomputers. Modelling larger plasmas, for example in ITER, with sufficient detail, and approaching the goal of predictive simulations, pushes computational demand even further. To meet these challenges, the group is also involved in developing the simulation code GENE to be able to utilize current and future supercomputers. A significant portion of the computation power of these supercomputers is provided by non-conventional processing units such as GPUs (graphics processing units), and more recently, in the form of MICs (many integrated core architectures). The recent tier-0 European supercomputer, Marconi, includes a partition with 3600 Intel KNL chips, with 68 cores each. These 244800 cores provide for a peak performance of 11 Pflops, or roughly five times the peak performance of the partition with conventional CPUs. Ongoing work focuses on efficiently utilizing these resources in GENE, as well as creating a foundation to move to new architectures more easily in the future.
Radar Remote Sensing

The objective of our research is to investigate and develop advanced radar methods and their applications. Current application domains include forestry, glaciology and oceanography. The group specialises in synthetic aperture radar (SAR) and algorithms for image formation, autofocus and information extraction. Large-scale forest mapping is an important application motivated by the need for improved climate change prediction, storm-damage assessment and sustainable management in commercial forestry. Ocean surface winds and currents, and sea ice are other applications with importance for the climate system, but also for supporting ship routing and other maritime activities.

Radar tower for time series measurements

The European Space Agency is funding and developing the BIOMASS satellite to be launched into low-Earth orbit in 2021. The payload is a SAR instrument which will be the first of its kind operating at a centre frequency of 435 MHz and will be dedicated to global forest mapping. The radar remote sensing group is part of the research team developing the mission. As part of the preparations, the 50 m high BorealScat tower has been erected at the Remningstorp forest test site between Skara and Skövde in southern Sweden. Equipped with an array of 5 x 4 ultra-wideband antenna elements and a 20-channel radar, the system provides fully polarimetric, tomographic electromagnetic imaging of the forest every 5 minutes. The research station is also equipped with meteorological and moisture sensors. This will provide much needed information about how the radar response of boreal forests changes throughout the diurnal cycle, seasons and in the weather conditions at northern latitudes. The BorealScat experiment aims to improve the understanding and accuracy of parameter estimation such as forest biomass and vertical canopy structure using SAR satellites. These satellites perform multiple imaging passes, separated by fractions of a second to months, over a forest site in order to collect the data needed for parameter retrieval. Understanding how the radar polarimetric response changes during observation intervals is necessary for improving retrieval algorithms. The system currently operates in five frequency bands from 420 MHz to 1375 MHz.

Satellite data for ship navigation support

During the past three years, the research group has participated in the SpaceNav project. The objective has been to use satellite data to derive information about wind, waves and ocean currents and to use this information to compute a ship route that minimizes fuel consumption and gas emissions. The optimum route is transmitted to the ship via a satellite link and presented in a graphical user interface developed in the project. Algorithms for ingestion, processing and merging of satellite and model data from a large number of external sources have been developed by the radar remote sensing group, while models for fuel consumption and route optimization have been implemented at Chalmers’ Department of Shipping and Marine Technology. The project has been funded by the EU seventh framework program and was concluded in November 2016 with a demonstration of a navigation support system installed on a large cruiseferry. The work continues in the EO-Nav project, where the goals are to increase the number of ships that use the navigation service, test the service globally and build up a spin-off company that brings the service to the market.
Space Geodesy and Geodynamics

Our main interests are geodynamic phenomena and atmospheric processes. We study e.g. deformations of the Earth’s crust due to mass redistribution, inter- and intra-plate tectonics, loading effects, and variations in the Earth’s orientation and rotation. We also study spatial and temporal variations of water vapour in the atmosphere. We address these research topics using a variety of observational techniques together with theoretical modelling.

Sea level measurements from inverse modeling of GNSS-R data

We developed an advanced method to derive sea surface height from reflected Global Navigation Satellite System (GNSS) data. It is based on inverse modelling of signal to noise data recorded by coastal GNSS equipment. The temporal variations of the sea surface are represented as B-splines in order to account for its continuity. A non-linear least-squares analysis of the signal to noise data with a consistent choice of model parameters enables the combination of multiple GNSS in one single inversion process. Compared to previous analysis approaches using spectral analysis, the new method leads to a significant increase in precision of the sea level retrievals due to a better spatial and temporal sampling of the reflecting surface. The method was tested with data from the coastal GNSS sites at Onsala, Sweden, and Spring Bay, Tasmania. It leads to a significant improvement with respect to previous studies, in terms of accuracy, precision and coherence, when comparing against independent sea level observations from co-located tide gauges.

Robust ambiguity estimation for the analysis of geodetic VLBI observations

We developed a strategy to improve the automated analysis of geodetic Very Long Baseline Interferometry (VLBI) observations. This is achieved by implementing a robust estimation procedure to determine the delay ambiguities in the VLBI data. Compared to the traditional analysis strategy, the new strategy leads to a significantly higher number of good quality earth rotation solutions and lower post-fit residuals.

Ultra-rapid earth rotation determination during continuous VLBI campaigns

We investigated the quality of the ultra-rapid results for the difference between astronomical and atomic time, usually described as UT1-UTC, that were derived on the baseline Onsala – Tsukuba during the continuous VLBI campaigns CONT11 and CONT14 using an automated near-real time analysis strategy. The ultra-rapid results were compared to corresponding results from post-processing of the complete CONT networks and the results from dedicated intensive VLBI sessions on other single baselines. The accuracies of the ultra-rapid results showed to be roughly a factor of three worse than results from the dedicated single-baseline sessions and/or the results from complete network analysis. The reason is that the CONT sessions were not optimized for earth rotation determination on just a single baseline.
Our research covers a wide range of topics from star formation and spiral structure in nearby galaxies, the growth of supermassive black holes in galaxy nuclei to the evolution of galaxies and clusters in the early universe. We carry out observations, theoretical research and develop numerical simulations. We also help to develop future telescopes on the ground and in space. Here we present a few examples of the group’s very recent results.

**Galaxies, star formation and active galactic nuclei**

We have explored the role that gravitational instability plays in NGC 1068, a nearby Seyfert galaxy that exhibits unusually vigorous starburst activity. Our results show that the starburst disk is subject to unusually powerful instabilities. Seyfert galaxies have nuclei that are powered by accreting supermassive black holes – a so-called AGN (Active Galactic Nucleus). AGNs often have powerful jets. We have modelled the broadband emission of our own Galaxy nucleus with a new improved version of a jet code to probe to what extent black hole accretion and growth processes are similar and independent of black hole mass.

Using the ALMA telescope, we have discovered a jet-like molecular outflow in the lenticular galaxy NGC1377. The jet seems to be swirling which may be very unusual. We have detected radio continuum and X-ray emission for the first time in this extremely radio-quiet galaxy. We found that star formation alone cannot drive the observed molecular outflow and that this is likely associated with a peculiar, faint radio jet from a hidden AGN.

We have recently mapped emission from multiple molecular species in NGC5195, a small disturbed companion galaxy to the large spiral M51, with the CARMA interferometer and the Onsala 20 m telescope. We find that NGC5195 is forming stars at a normal rate and that the filling factor of dense gas is rather low. Surprisingly, the luminosity of the CN radical is abnormally high which may be due to a buried AGN.

**Clusters of galaxies and the high-redshift Universe**

The first results of the XXL survey (a deep extragalactic survey of 50 square degrees of the sky carried out with the X-ray space observatory XMM-Newton) have been published. XXL is sensitive to clusters of galaxies and AGN out to cosmological distances. Catalogues of the brightest 100 galaxy clusters and 1000 AGNs were released. In addition, five superclusters (clusters of clusters of galaxies) were discovered and one of them, which is likely in the process of merging, was studied in detail. We have also observed 42 massive clusters with a bolometer camera installed on the APEX telescope in Chile.

Using ALMA, significant progress has been made in the studies of some of the most distant galaxies that have been seen so far. Deep observations have revealed a faint detection of ionized carbon in the galaxy A383-5.1, while the dust emission of the A1689-zD1 has been resolved revealing sub-kpc scale structure. Exploring the recently developed interferometric stacking code, statistical studies have been conducted of distant galaxies that are very faint at radio and mm wavelengths. The studies focused on the sizes and size evolution for galaxies that are normally evolving. The methodology and algorithm is continuously been improved and new features are now being investigated, among them the possibility of stacking spectral line data.
Galactic Astrophysics

Our research focuses on our own galaxy and its various constituents, including planetary atmospheres, the physics and chemistry of the interstellar medium and the evolution of stars, from star formation to stellar end products. We use a wide variety of observational tools covering a large wavelength range and perform detailed theoretical work and numerical simulations. Here we present a few examples of our recent work.

The interstellar medium, star- and planet formation
The general lack of oxygen in molecular clouds is an enigma in astrochemistry which, if resolved, could shed light on many other poorly understood issues. By observing very dense, cold cores with the HIFI instrument of the Herschel Space Observatory it has been possible to refute a proposed theory for how oxygen atoms and molecules bind to grain surfaces. Other Herschel and Spitzer Space Telescope observations, in the infrared, have solved the puzzle of the massive star IRAS 19312+1950. This star shows conflicting signs of being both extremely old and extremely young. Based on an analysis of the new data we have revealed that it is indeed an embedded protostar, rather than a late-stage star shedding its outer layers.

ALMA has also been used to make the first observations how an outflow is launched from the rotating disc of gas and dust surrounding a young low mass star. These observations provide the first direct evidence of the disk-wind mechanism, where material is flung from the disk along magnetic field lines. With other ALMA observations, we have also been able to catch a young multiple-star system in the act of forming. The observations directly support the idea of forming close multiple systems through fragmentation of circumstellar disks.

Evolved stars
We have also continued the study of the dust and molecules in, and the morphology of, the circumstellar envelopes of asymptotic giant branch stars. The sulphur compounds SO and SO$_2$ have not been widely studied in these envelopes. By modeling a large number of SO and SO$_2$ lines, we determined for the first time their circumstellar abundances and distributions for stars of different mass-loss rates. We concluded that the observations are consistent with current chemical models for neither SO nor SO$_2$. In a further study of seven evolved stars we find signatures of gaseous aluminum monoxide (AlO) close to the stellar surface. This gas reservoir likely serves as the feeding grounds for the first dust seeds around these stars, which are essential for propelling the stellar wind. It has also been possible to set new constraints on the abundances of H$_2$O in the circumstellar envelope. For this, we used an advanced radiative transfer code to model Herschel data of molecular lines in the far infrared.

Our ALMA studies of evolved stars also continued. New ALMA observations were used to investigate the detached shell around the evolved star R Sculptoris, and constrained the most recent thermal pulse. The total amount of mass lost in this process may be significantly higher, constraining the amount of new elements it can produce.

ALMA observations of the red- and blue-shifted molecular outflow from the protostar TMC1A. Dust in the disk from where the outflow is launched is shown in green.

We also reported detections with ALMA of the pure-rotational $J=3$-2 transition of CO within its first vibrationally-excited state from five AGB stars. This transition had been detected in only one AGB star previously. We show it to be a good probe of the gas in the poorly-understood region where AGB winds are accelerated.

We also studied the inner dust envelope of the asymptotic giant branch star R Dor using the new extreme adaptive optics polarimeter, SPHERE, on the very large telescope (VLT). The observations were modeled to investigate the dust distribution close to the star and its role in driving the outflow of R Dor.

Research group leader
Wouter Vlemmings

Staff
Per Bjerkeli
John Black (-May) (Jun-Emeritus)
Elvire De Beck (Sep-)
Malcolm Fridlund (Affiliated)
Arto Heikkilä
Theo Khouri
Kay Justtannont
René Liseau (-Oct) (Nov-Emeritus)
Robin Lombaert (-Oct)
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Sofia Wallström (-Apr)
Joachim Wiegert (-Sep)
Onsala Space Observatory

Onsala Space Observatory (OSO) is the Swedish National Facility for Radio Astronomy. In Onsala, the observatory operates two parabolic radio telescopes, a 25 m diameter cm-wave dish and a 20 m diameter mm-wave dish, and the Swedish LOFAR (Low Frequency Array) station. The observatory is also one of three partners in the Atacama Pathfinder Experiment (APEX), a 12 m diameter submillimetre-wave telescope in Chile, and provides the channel through which Sweden is involved in large international radio astronomy projects, such as EVN (European VLBI Network), LOFAR, ALMA (Atacama Large Millimetre/submillimetre Array), and SKA (Square Kilometre Array). The Nordic ARC node, which provides ALMA support services to Nordic and Baltic astronomers, is based at OSO.

In addition to radio astronomy, geoscience activities are an official part of the mission of the observatory. The geoscience equipment consists of receivers for GNSS (Global Navigation Satellite Systems), several tide gauge sensors, a superconducting gravimeter, a seismometer (owned by Uppsala University), and radiometers for aeronomy. The 20 m telescope is partly used for geodetic VLBI (Very Long Baseline Interferometry). The observatory also contributes to establishing the official Swedish maser clocks and one cesium clock.

APEX

A celebration of APEX’s 10 years of operation was held at the APEX base in Sequitor, Chile, in late January. The celebration coincided in time with an international evaluation of the APEX project. The report noted the high current scientific productivity of APEX and innovative plans for future instrumentation. The report enthusiastically recommended the continuation of the APEX project through the 2018–2022 period. In February of 2016, an ALMA Band 9 receiver for the frequency band 600–722 GHz was installed into the SEPIA cartridge on the APEX telescope. The installation was a joint effort by teams from NOVA and OSO’s Group for Advanced Receiver Development (GARD). Science verification observations of the Band 9 receiver on Swedish time took place in June and August, and the first regular observations on Swedish time were successfully carried out in August.

ALMA Band 5 and archive mining

The Group for Advanced Receiver Development (GARD) has continued to deliver Band 5 receivers to the ALMA telescopes, in cooperation with NOVA (NL) and NRAO (US). Band 5 (157–212 GHz) includes a spectral line from the important water molecule. In 2016, the first ALMA observations in Band 5 were made. The observed objects include the colliding galaxies Arp 220, a massive region of star formation close to the centre of the Milky Way, and a dusty red supergiant star approaching the supernova explosion that will end its life. To process the data and check its quality, astronomers and technical specialists gathered at the Nordic ARC node in Onsala for a “Band 5 Busy Week”. The final results were made freely available to the astronomical community worldwide.

ALMA has now observed the sky for more than five years, and has produced large amounts of data accessible to the entire astronomical community. The Nordic ARC node in Onsala now supports the Nordic community in archive searches, data retrieval, calibration, and imaging, and advanced analysis of the results.

VLBI

Astronomers using the European VLBI Network (EVN), and the Arecibo Observatory, have for the first time pinpointed the location of a so-called fast radio burst (FRB 121102) – a type of short-duration radio flash of enigmatic origin. The observations revealed that the galaxy hosting the FRB is surprisingly small, a so-called dwarf galaxy located at a distance of over 3 billion light-years. The physical nature of FRBs is not known, but the location of FRB 121102 in a dwarf galaxy might be a clue to their origin.

SKA

A feed horn for the Square Kilometre Array (SKA) Band 1 (350–1050 MHz), developed and built at OSO, was delivered for testing in Canada in June 2016.
It will eventually be fitted on each of the 133 dish antennas at the SKA’s South African site in the first phase of deployment of the SKA. The feed horn has a so-called quadridge design, with four ridges on the inside, and an opening almost one metre across. The horn is combined with an advanced low-noise amplifier (developed by the Gothenburg-based company Low Noise Factory in collaboration with OSO and the Gigahertz Centre at Chalmers).

The Onsala twin telescopes
During June and July the equipment was installed in the cabins and the telescope foundation towers, and the reflectors were attached to the elevation cabins. An important milestone was reached on 18 August when the reflectors were mounted on top of the towers. The work continued with further installation, adjustment of the reflector panels and commissioning of the telescope drive systems. In parallel, the electronics lab at OSO worked on the production of two VGOS-compatible receiver systems, one with a quadridge feed and one with an Eleven feed, covering a common frequency range of 3–14 GHz. The site acceptance test for the two telescopes was conducted in early December. After that the work continued with fine-tuning of the drive systems and the installation of the signal chains, including the time-and-frequency distribution and the receivers. The goal is to achieve “first light” in early 2017 and to celebrate the official inauguration on 18 May 2017.

Aeronomy
The first simultaneous measurements of mesospheric O$_3$ at 110.8 GHz and CO at 115.3 GHz made by a ground-based, double-sideband, and frequency-switched radiometer system operated at OSO was presented in 2016. The figure shows the retrieved vertical profiles of CO and O$_3$ from October 2014 until April 2015. The general structure of the CO distribution is seen in the upper plot with a sharp increase in volume mixing in the upper mesosphere. The time series mainly covers the winter period when the general circulation brings down air from the thermosphere into the mesosphere, which increases the mesospheric CO abundance. This down-welling is strongest inside the polar vortex, and the variation of CO seen from day to day is mainly explained by movement of the polar vortex. The time series of O$_3$ in the lower plot both show the upper part of the stratospheric peak and a nighttime peak at altitudes above 70 km. The observed mesospheric diurnal peak is a mixture of both “the secondary ozone peak” at 90 km and “the tertiary ozone peak”, located at 72 km.

OSO in Horizon 2020 projects
OSO is part of three Horizon 2020 projects funded by the EU (proposals submitted and accepted in 2016): RadioNet, AENEAS and Jumping JIVE.

RadioNet joins together 28 radio astronomy institutes. OSO will be part of the Transnational Access program via APEX and EVN, participate in the Networking Activities, and will play a major role in all of the Joint Research Activities which includes both software and hardware development.

The large scale, rate, and complexity of the data that the Square Kilometre Array (SKA) will generate, present challenges in data management, computing, and networking. The AENEAS project will develop a concept and design for a distributed European Science Data Centre to support the astronomical community in achieving the scientific goals of the SKA.

Jumping JIVE aims to prepare and position European Very Long Baseline Interferometry (VLBI) for the SKA era, and to plan the role of JIVE, as well as the EVN, in the future European and global landscape of research infrastructures.
The list contains peer reviewed journal publications that were actually published during 2016. The publications are presented for each research group and in alphabetical order based on the first author’s last name. A few publications with authors from more than one research group are listed in each group. In order to have a list of a reasonable size, we have chosen to only include peer reviewed journal publications on these pages. PhD and licentiate theses are presented on pages 10 and 11. A complete list for 2016, and in most cases also links to the full papers, can be found at: publications.lib.chalmers.se/cpl/lists/publications/departments.

**Advanced Receiver Development**

Humphreys, E.M.L.; Vlemmings, W.; Impellizzeri, C.M.V.; ... ; Olberg, M.; Conway, J.; Belitsky, V.; et al. (2016).


**Global Environmental Measurements and Modelling**


Christensen, O.M.; Benze, S.; Eriksson, P.; ... ; Murtagh, D.P.; et al. (2016). The relationship between polar mesospheric clouds and their background atmosphere as observed by Odin-SMR and Odin-OSIRIS. Atmos. Chem. Phys., 16, 12587-12600.


Optical Remote Sensing

Long-term monitoring of SO2 quiescent degassing from Nyiragongo's lava lake.

Multi-component gas emission measurements of the active lava lake of Nyiragongo, DR Congo.

Linking SO2 emission rates and seismicity by continuous wavelet transform: implications for volcanic surveillance at San Cristabal volcano, Nicaragua.

Turmoil at Turrialba Volcano (Costa Rica): Degassing and eruptive processes inferred from high-frequency gas monitoring.

Seasonal and diurnal patterns in the dispersion of SO2 from Mt. Nyiragongo.

Photochemical Smog in China: Scientific challenges and implications for air quality policies.

 Retrieval of absolute SO2 column amounts from scattered-light spectra: implications for the evaluation of data from automated DOAS networks.

First results of the Piton de la Fournaise STRAP 2015 experiment: multidisciplinary tracking of a volcanic gas and aerosol plume.
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The least uncomfortable journey from A to B.
Am. J. Phys., 84, 690.

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Nucl. Fusion, 56.

He, Y.; Liu, Y.; Liang, Y.; et al. (2016).
Combined effects of trapped energetic ions and resistive layer damping on the stability of the resistive wall mode.
Phys. Plasmas, 23.

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Nucl. Fusion, 56, 126007.

Li, L.; Liu, Y.; Liang, Y.; et al. (2016).
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Nucl. Fusion, 56.

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Liu, Y.; Akaslompolo, S.; Cavinato, M.; et al. (2016).
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Nucl. Fusion, 56, 066001.

Multimachine Data-Based Prediction of High-Frequency Sensor Signal Noise for Resistive Wall Mode Control in ITER.

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Nucl. Fusion, 56.

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Phys. Plasmas, 23.

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Interaction between neoclassical effects and ion temperature gradient turbulence in gradient- and flux-driven gyrokinetic simulations.
Phys. Plasmas, 23.

Comparative gyrokinetic analysis of JET baseline H-mode core plasmas with carbon wall and ITER-like wall.


Radio Remote Sensing


Radio Astronomy and Astrophysics and the Swedish National Facility for Radio Astronomy


Cordiner, M.A.; Boogert, A.C.A; Charney, S; Justtanont, K.; ...; Wirstöm, E.; et al. (2016).
On the Nature of the Enigmatic Object IRAS 19212+1950: A Rare Phase of Massive Star Formation?

Radio continuum and X-ray emission from the most extreme far-IR-excess galaxy NGC 1577: An extremely obscured AGN revealed.

The ALMA-PILS survey: First detections of deuterated formamide and deuterated isocyanic acid in the interstellar medium.

Sulphur molecules in the circumstellar envelopes of M-type AGB stars.

ALMA-resolved salt emission traces the chemical footprint and inner wind morphology of VY Canis Majoris.
Astron. Astrophys., 592, A76.

NIBLES: an HI census of stellar mass selected SDSS galaxies I. The Nancay HI survey.

Drouart, G.; Rocca-Volmerange, B.; De Breuck, C.; et al. (2016).
Disentangling star formation and AGN activity in powerful infrared luminous radio galaxies at 1 < z < 4.

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Astron. Astrophys., 593, A34.

Eigmuller, P.; Eisloffel, J.; Csizmadia, S.; ...; Fridlund, M.; et al. (2016).
An M Dwarf Companion to an F-Type Star in a Young Main-Sequence Binary.

On the properties of dust and gas in the environs of V838 Monocerotis.

Infrared Spectral Energy Distribution Decomposition of Wise-Selected, Hyperluminous Hot Dust-Obscured Galaxies.

Forkman, P.; Christensen, O.M.; Eriksson, P.; Billade, B.; et al. (2016).
A compact receiver system for simultaneous measurements of mesospheric CO and O3.

The XXL Survey VI. The 1000 brightest X-ray point sources.

The Way Forward.

Water, methanol and dense gas tracers in the local ULIRG Arp 220: results from the new SEPIA Band 5 Science Verification campaign.

ALMA resolves the torus of NGC 1068: Continuum and molecular line emission.

Dense gas in the Galactic central molecular zone is warm and heated by turbulence.

Disk Dispersal: Theoretical Understanding and Observational Constraints.
Space Sci. Rev., 205, 125-152.

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K2-31B, a Grazing Transiting Hot Jupiter on a 1.26-Day Orbit Around a Bright G7v Star.
Astron. J., 152.

The mysterious morphology of MRC0943-242 as revealed by ALMA and MUSE.

ALMA finds dew drops in the dusty spider’s web.

On the accretion process in a high-mass star forming region - A multitransitional THz Herschel-HIFI study of ammonia toward G34.26+0.15.


Software-Defined Radio Direct Correlation GNSS Reflectometry by Means of GLONASS.

Kiloparsec-Scale Dust Disks in High-Redshift Luminous Submillimeter Galaxies.

Detection of 183 GHz H2O megamaser emission towards NGC 4945.
NAOJ/NRAO, NRAO/AUI/NSF. Credit: Bill Saxton, ALMA (ESO/NAOJ/NRAO), NRAO/AUI/NSF.


## Facts and Figures

### Income (SEK 1,000)

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### Used grants (SEK 1,000)

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### External funding (SEK 1,000)

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<td>VINNOVA (Swedish Govt. Agency for Innovation Systems)</td>
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<td>1,817</td>
<td>2,547</td>
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<td><strong>Total</strong></td>
<td>100,667</td>
<td>100,736</td>
<td>95,318</td>
<td>92,365</td>
<td>88,429</td>
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### Personell (31 Dec)

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<td><strong>Total</strong></td>
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</table>
Departmental Advisory Group

The advisory team’s task is to identify and take a standpoint on overall strategic issues that are of relevance to the long-term development of the department, and to support the department’s steering group in other matters that may arise. The team met three times during 2016.

External representatives 2016
- Göran Netzler, Chairman
- Göran Berndes, Chalmers’ President’s representative
- Thomas Lewin, Ericsson Research
- Sven Grahn, Swedish Space Corporation
- Marie Rådbo, University of Gothenburg

Management Group

The management group handles strategic as well as operational matters for the department as a whole. It meets every third week. The group consists of: the Head of Department, the Deputy Head, the Vice Head, a Secretary, the Head of Administration and Finance, the Personnel Officer, the Director of the Onsala Space Observatory and our seven research group leaders.

Teaching Staff

The teaching staff had on the average over 2016 approximately 24 members. Alessandro Romeo was the Chairman and Hans-Georg Scherneck was the Vice Chairman up to the summer. The group has an advisory function on research and educational issues and met 3 times during the year.

Local Collaboration Group

The Local Collaboration Group is a forum for discussing all issues concerning the management of the department: appointment of staff members, matters related to the premises and general working conditions, including the work environment (physical as well as psychosocial) and gender equality.

The group consist of the Head of Department, the Head of Administration and Finance, the Personnel Officer, three representatives from our unions, a work environment ombudsman and an equality ombudsman, and meets every sixth week.

* In August 2016 the Radio Astronomy and Astrophysics research group was divided into two research groups: Extragalactic Astrophysics with Susanne Aalto as group leader and Galactic Astrophysics with Wouter Vlemmings as group leader.
Administration and Finance

The group works with organisational and financial planning and follow-up, accounting, study administration, HR administration, purchasing, web and other forms of communication, as well as any other services needed by the research and teaching staff. On December 31 the group consisted of:

- Sofie Halldén  
  *Head of Administration/Communications Officer*

- Maria Karlsson  
  *Department Financial Officer*

- Katarina Norheim  
  *Financial Officer*

- Camilla Andersson  
  *Administrator*

- Paula Rosell  
  *Administrator*

- Paulina Sjögren  
  *Administrator*

Eva Wirström and Jana Mendrol were happy winners of the Shuffleboard competition at the yearly department day in September.  
*Photo: Leif Eriksson*

November sunset at Onsala Space Observatory with the twin telescopes to the left and the 25 m telescope to the right.  
*Photo: Sofie Halldén*