ASTRON

Annual report 2011

Facts and figures of 2011

3 Awards or grants

112 refereed articles

157 employees

9 press releases

Funding: € 30.446.230
Expenditure: € 30.482.073
Balance: € -35.843

Contents

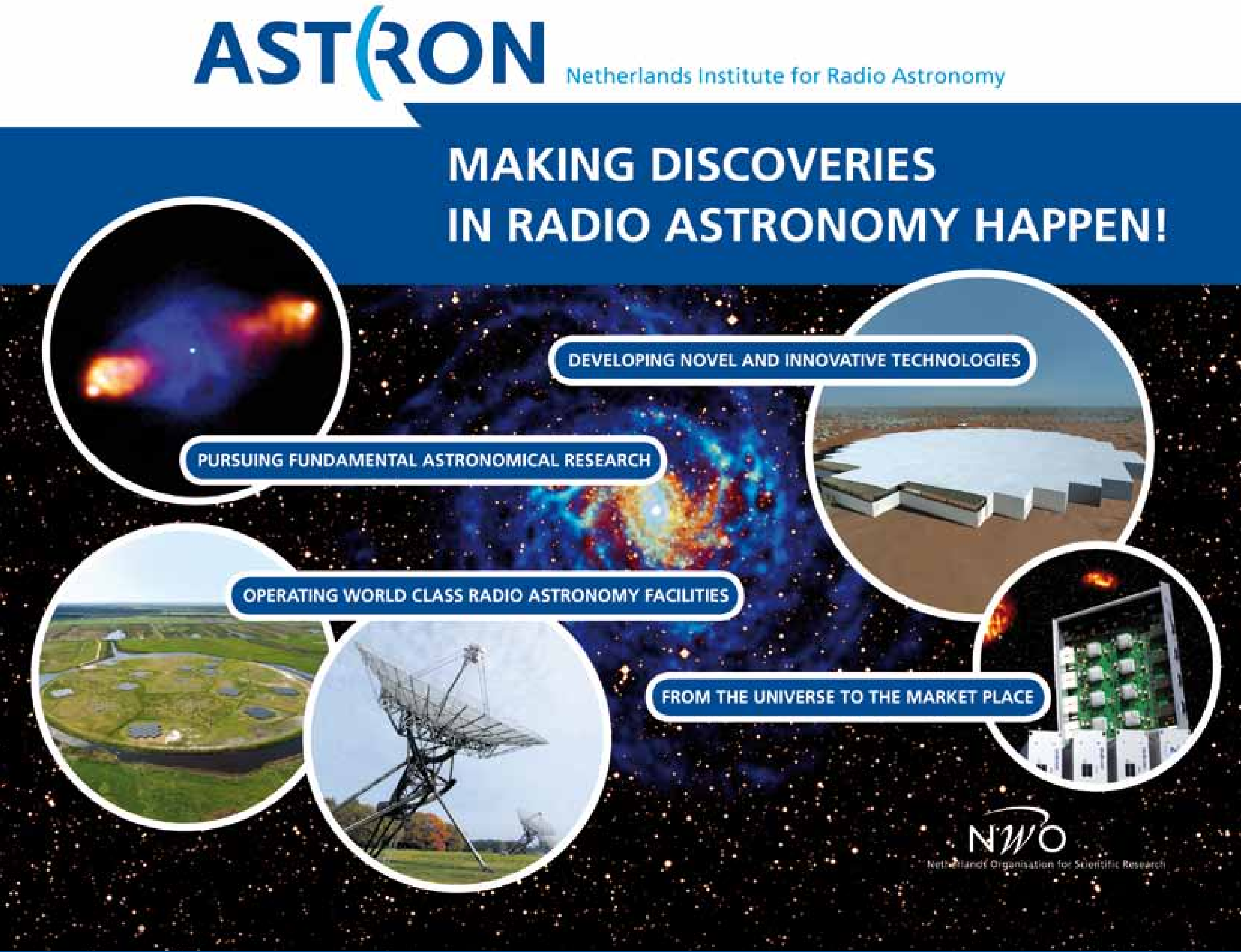
Cover photo: impression of the dense aperture arrays for the Square Kilometre Array (SKA).
Credits: Swinburne Astronomy Productions.

Director's Report

2011 was another great year for ASTRON.
The highlight was undoubtedly the evaluation of the institute by a panel of international experts, chaired by Prof. Catherine Cesarsky. The panel judged ASTRON to be excellent in all possible categories - at the overall institute level and in each of our departments - Astronomy Group, Radio Observatory and Research &Development.

In this year, the output in astronomy research continued to grow - not only in terms of publications and impact, but also in connecting ASTRON to the outside world, and in particular NOVA and the university groups in the Netherlands. LOFAR began to produce its first scientific results and preparations for the APERTIF upgrade to the WSRT began to ramp up. With LOFAR, APERTIF and EMBRACE, ASTRON clearly demonstrated the application and relevance of aperture array technology for radio astronomy - in the words of the chair of our evaluation panel: 'ASTRON is re-inventing radio astronomy'. That statement has become something of a motto for the institute, and its is one that we maintain via the synergy we enjoy between our fundamental science, our operations of world-class facilities and our strong technical R&D programme. Through this combination, ASTRON aims to also make a significant contribution to the governments Topsector Roadmaps for High Tech Systems & Materials and ICT. ASTRON has implemented this strategy within tight financial boundary conditions - in particular, the institute has continued its enviable track-record in doubling the base budget received from NWO through competitive grants and contracts - maintaining this approach will be key to ASTRON's future success, especially in the coming years. Outwith ASTRON, the SKA project made progress with leaps and bounds. The SKA Organisation was established as a company under UK law with the Netherlands, UK, Italy, China, Canada, South Africa, Australia and New Zealand all signing up. In addition, the SKA Site Advisory Committee started its work with the expectation of reporting in early next year. 2012 already looks to be as exciting a year as this one!

Prof. Mike Garrett
General Director



ASTRON in brief

ASTRON is the Netherlands Institute for Radio Astronomy. Its main mission is to make discoveries in radio astronomy happen, via the development of new and innovative technologies, the operation of world-class radio astronomy facilities (the Westerbork Synthesis Radio Telescope and the LOFAR telescope), and the pursuit of fundamental astronomical research. Engineers and astronomers at ASTRON have an outstanding international reputation for novel technology development, and fundamental research in galactic and extra-galactic astronomy. ASTRON hosts the Joint Institute for VLBI in Europe (JIVE) and the Optical/Infrared instrumentation group of NOVA, the Netherlands Research School for Astronomy.

ASTRON is an institute of the Netherlands Organisation for Scientific Research, NWO.

Organisation & Governance

ASTRON is a Foundation under Dutch Law with an oversight Board. Executive authority is vested in the directorate consisting of Prof. dr. Michael Garrett, Scientific Director and Director General, and dr. Marco de Vos, Managing Director and Deputy DG. They report to both the ASTRON Board and the Director of NWO. NWO is also the formal employer of ASTRON staff.

The ASTRON Director General is advised by an international Science Advisory Committee (SAC) on all aspects of the institute's programme. A telescope Programme Committee sets priorities for allocating observing time on ASTRON's telescopes.

The ASTRON Management Team consist of the directorate and department heads.

The International LOFAR Telescope

ASTRON designed and built the LOFAR telescope. LOFAR, the Low Frequency Array, operates at the lowest frequencies that can be observed from Earth. With LOFAR astronomers can look back billions of years to a time before the first stars and galaxies were formed, the so-called 'Dark Ages'. Much of the infrastructure that was needed to build this new radio telescope can also be used by other applications. The common theme throughout is the collection, transport and real-time processing of enormous quantities of data from sensors distributed over a large area.

The superterp which houses six LOFAR stations. *Credits: Top-Foto, Assen.*

LOFAR will address some of the most important questions in modern astronomy and astrophysics. The key science projects are:

- The Epoch of Reionization
- Deep tragalactic survey
- Transient sources and pulsars
- Ultra high energy cosmic rays
- Solar science and space weather
- Cosmic magnetism

The Westerbork Synthesis Radio Telescope

ASTRON operates the Westerbork Synthesis Radio Telescope (WSRT). The WSRT has been built in 1969-1970 and had a major upgrade in 1990-2003. The WSRT is one of the most sensitive radio telescopes in the world and offers astronomers the chance to study a wide variety of astrophysics problems. The telescope consists of fourteen parabolic (dish) antennas of 25-metre in diameter.

In the APERTIF project, advanced receiver technology is developed for the WSRT, creating a two-dimensional radio 'camera' in the focal point of twelve of the dishes. This will increase the field of view of all the antennas by a factor of almost forty. Astronomers can thus quickly survey large parts of the sky, leading to a dramatic increase of the discovery space. With APERTIF, the WSRT will be once more brought to the forefront of radio-astronomical facilities.

Astronomy Group

The Astronomy Group is engaged in many frontline research areas. Hydrogen is studied both nearby and in the most distant parts of the Universe. The Transient Universe is characterized at the shortest possible time-scales. The Magnetic Universe is studied from galaxies to clusters. ➔

The Westerbork Synthesis Radio Telescope.

The group is involved in the commissioning of LOFAR and in all LOFAR key science projects, as well as in the development of other new instruments like the pulsar machine PuMa-II and the APERTIF system mentioned above.

Research & Development laboratories

The ASTRON Research & Development (R&D) laboratories focus on innovative instruments for existing telescopes, such as the Westerbork telescope and LOFAR, as well as on developing technologies for future observing facilities, such as the Square Kilometre Array. The technical laboratory has several unique facilities at its disposal, such as an anechoic chamber, a clean room facility, and an outdoor antenna test location. These serve both research, development of astronomical instruments and other product development.

Target areas in R&D for the Square Kilometre Array are Smart Antennas (Aperture Arrays and Phased Array Feeds) and Science Data Processing (Calibration and Data Intensive Computing).

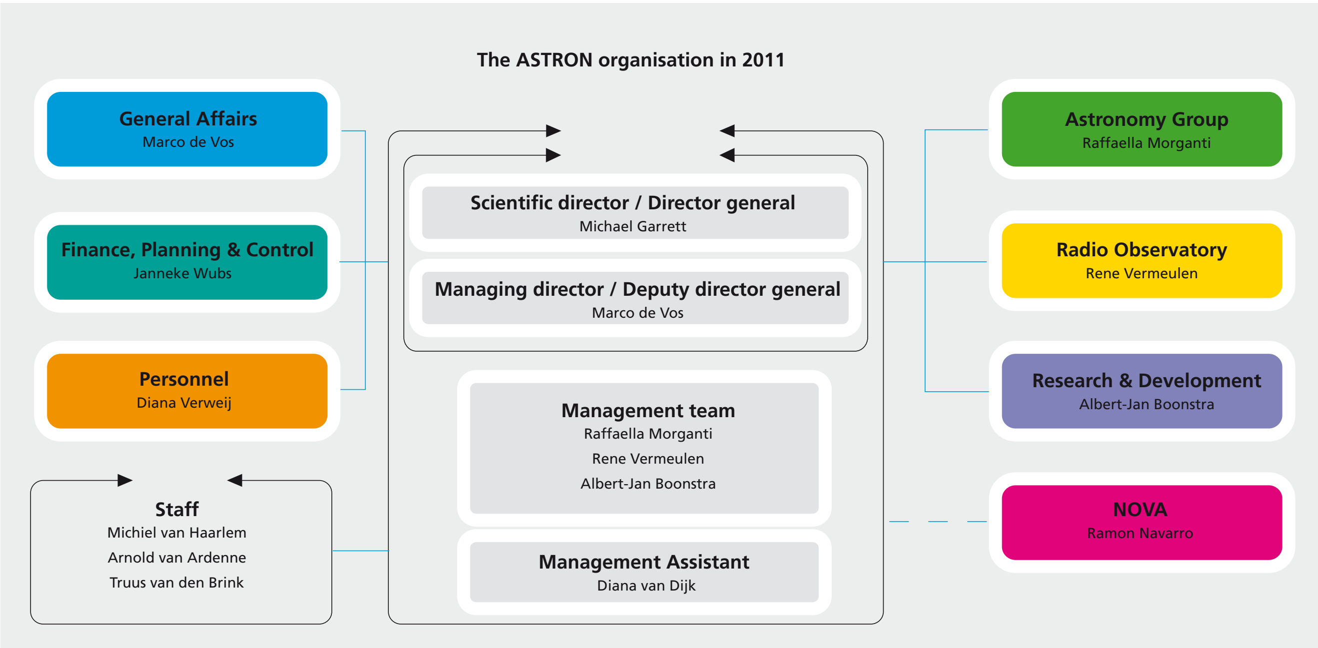
The R&D department is organized along the main disciplines: antennas, low noise systems, digital and embedded signal processing, computing, mechanics and system design and integration.

Array of small antennas in the EMBRACE demonstrator to replace moving dishes.

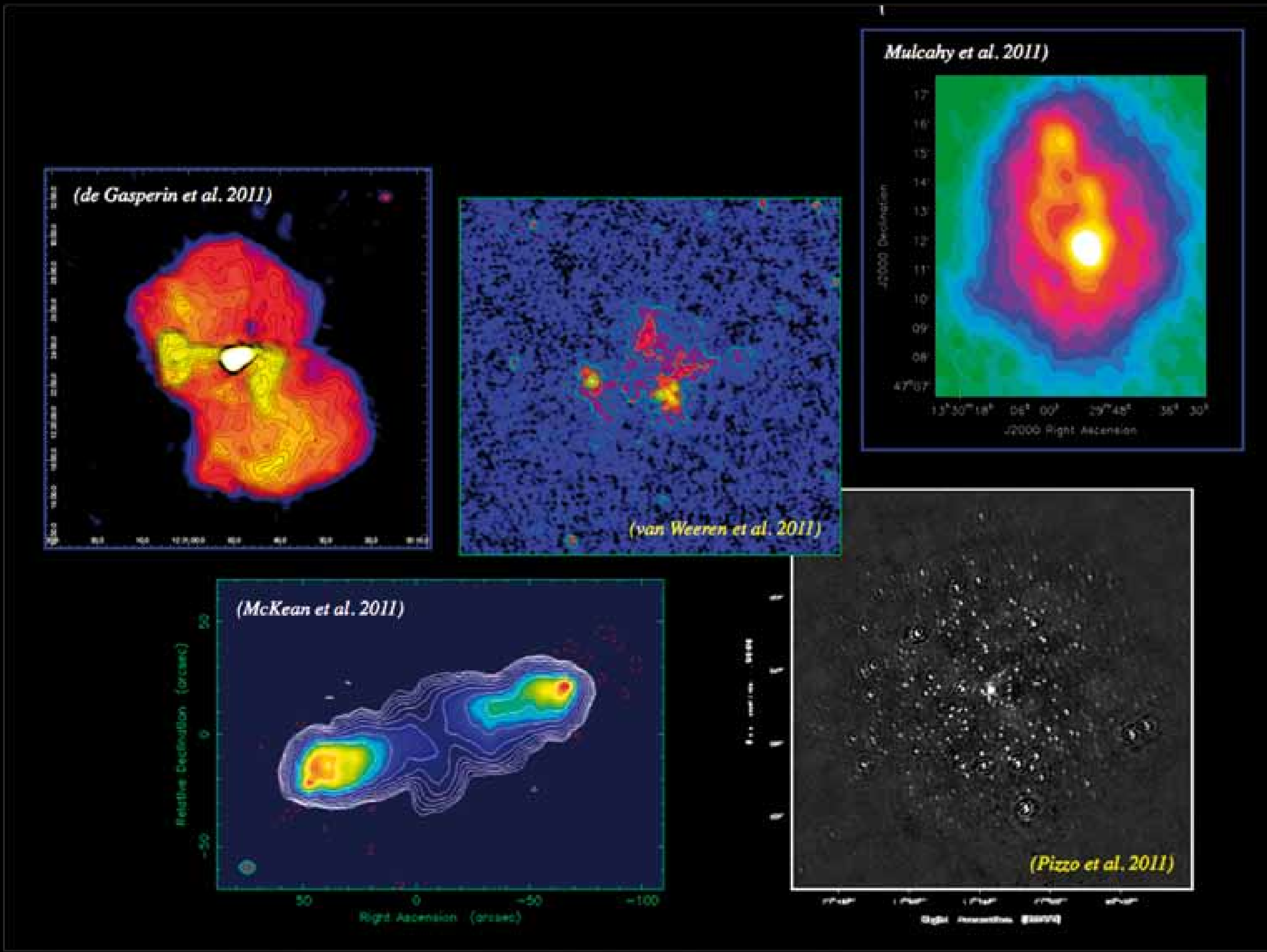
Technology Transfer

ASTRON implements its mission in such a way that the benefit for industry and society is maximised. Partnerships in large development projects are a key aspect of ASTRON's Technology Transfer strategy. ASTRON is a top international research institute and as such offers its partners access to knowledge, expertise and networks.

From the perspective of the Top sectors in the Netherlands a project such as the Square Kilometre Array (SKA) is primarily an international technology programme based on a challenging case: a global consortium to build the world's largest and most sensitive radio telescope. Such a 'Big Science PPP' (Public-Private Partnership) offers unique possibilities for technology development and human capital development.



The ASTRON organisation in 2011.



Some of the first LOFAR science results, presented at the LOFAR Early science workshop on 14 and 15 September 2011.

Performance indicators

Publications

The chart shows the number of publications, refereed journals and other output in 2011.

Legend:

Refereed articles: Articles published in scientific journals that use an anonymous peer review system, which is separate from the editors.

Conference proceedings: Publications in journals that are not refereed, but which are considered important by the field.

Other research output: abstracts, editorships, inaugural lectures, designs and prototypes (e.g. engineering) and media appearances.

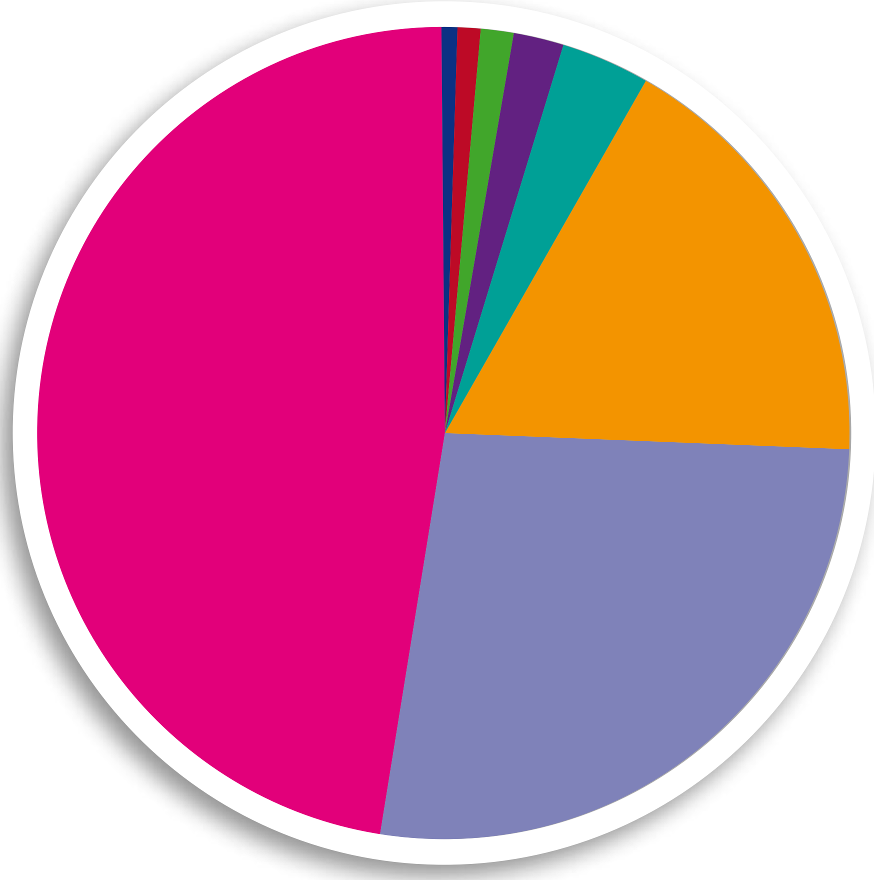
Professional publications: publications intended for professionals in the public and private sectors (i.e. professional publications) including annotations (i.e. legal).

Contracts: number of contracts in which intellectual property rights are transferred or where a license is granted to these rights.

Theses: publications in which the doctorate was obtained.

Chapters in books: contributions to scientific books aimed at an audience of scientists and researchers.

Publications for a wide audience: popular publications on results of scientific research.



- Other research output; 198; 48%
- Refereed articles; 112; 27%
- Conference proceedings; 72; 17%
- Professional publications ; 14; 3%
- Contracts ; 9; 2%
- Theses; 5; 1%
- Chapters in books; 2; 1%
- Publications for a wide audience ; 4; 1%

The Westerbork telescope as seen from the sky.

The Low Band Antenna's of the LOFAR telescope. *Credits Hans Hordijk.*

Observing time

The Westerbork Synthesis Radio Telescope (WSRT) spent a very satisfactory 6166 hours (70% of the year) observing on net 'science time', excluding all overheads. Only 36 hours needed to be repeated because of failures. An additional 1660 telescope hours were spent on general calibration, tuning, regular maintenance, and limited software development work; the remaining 987 hours were unallocated due to inevitable gaps related to scheduling mostly 12-hour full synthesis observations on this east-west array. Of the science time, 1002 hours were for participation in (e)EVN and Global VLBI projects (759 disk-recorded, 243 e-VLBI).

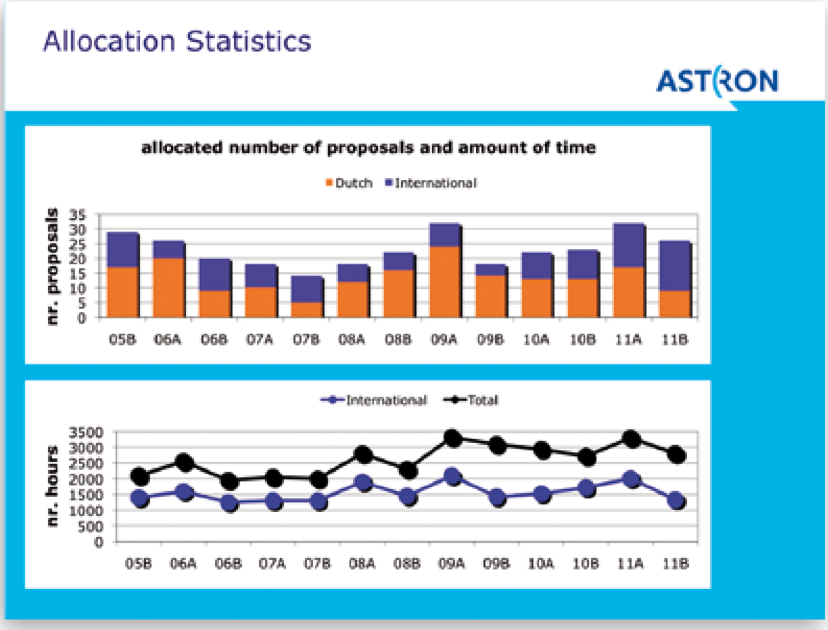
The LOFAR Telescope

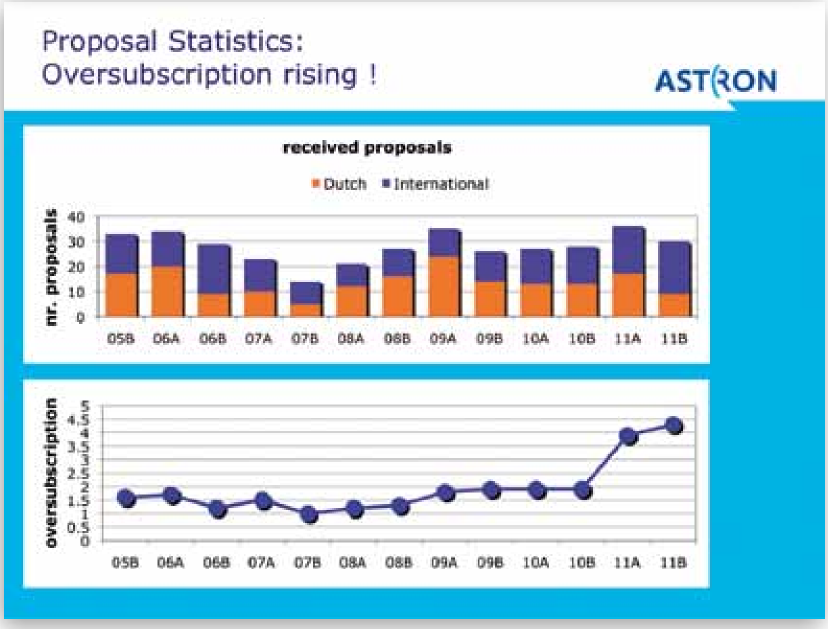
Most of the LOFAR time in 2011 was spent on coordinated system development tests and general commissioning, of which no sub-divided records were kept. However, there were 2661 hours in total on 28 early- science projects, up significantly from 1876 hours in 2010. Most of these served the dual purpose of generating first science results while commissioning specific operations modes and pipelines. In the last couple of months, 424 hours were spent on the initial phases of MSSS, the Multifrequency Snapshot Sky Survey, that will continue into 2012. →

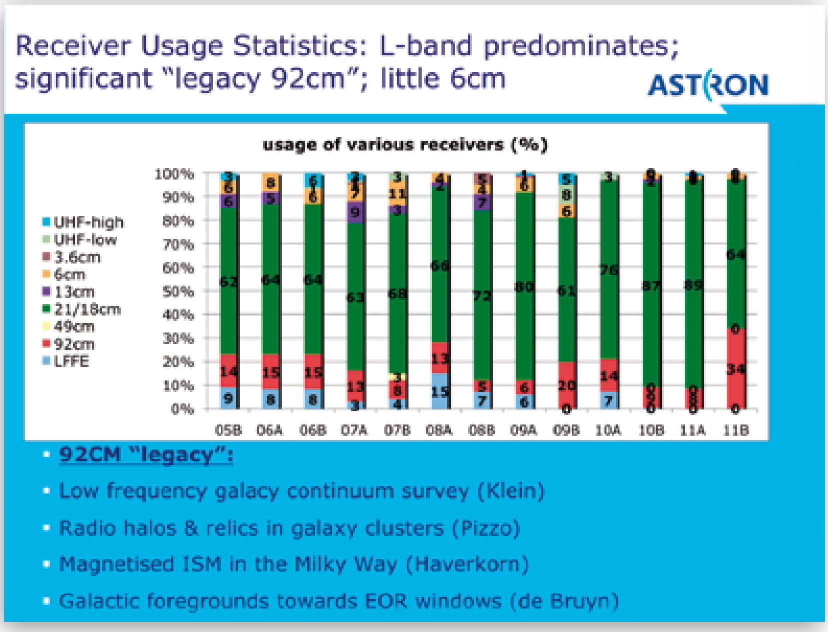
Time allocation on the Westerbork telescoop and LOFAR

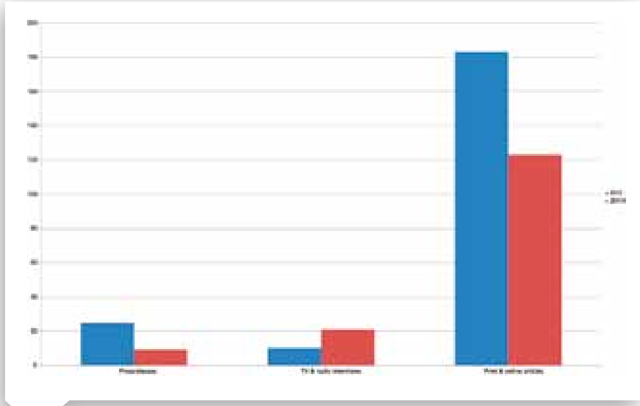
The Westerbork telescope followed the customary semi-annual observing proposal cycle. As illustrated in the first two diagrams, the WSRT continued to see a steady flow of around 30 proposals per semester. However, the total observing time requested by these proposals was up around 8000 hours per semester, or an oversubscription factor of 3-4, whereas this used to be closer to a factor 2 in previous years. This is attributable almost entirely to the desire to carry out large surveys in both the 21cm band and also in the 92cm band, before the planned replacement of the current generation of multi-frequency frontend receivers by Apertif (which will not operate at 92cm, and offer an extended 21cm band with vastly superior at large-area survey capability but at the expense of some instantaneous pointed sensitivity). The added emphasis on 92cm projects, that will lead to a 'WSRT legacy' of data in the archive, can be seen in the third diagram.

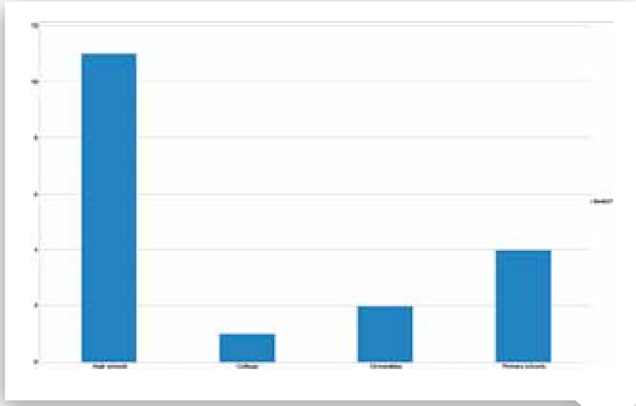
LOFAR early access proposals, submitted in 2010, continued to serve as the basis for the early-science observing programme in 2011. The Technical Advisory Group (TAG) and the LOFAR Commissioning Coordination Group (LCCG), which also met regularly with the PIs of the LOFAR Key Science Projects, carefully monitored the commissioning needs, and the specifications of the observations to be conducted at any stage. A new proposal cycle, for full production capability, is expected for 2012. →











Public Relations activities

ASTRON appeared in print (newspapers and magazines, among which Science and Nature) and online articles 123 times, ten times in TV and radio interviews and issued nine press releases in 2011. A comparison is made with 2010, when the International LOFAR Telescope was opened by Queen Beatrix of the Netherlands, which generated a lot of media action.

The year 2011 was dominated by the evaluation of the institute by a high-level panel headed-up by Prof. C. Cesarsky. ASTRON was awarded top marks – a 5 or excellent – and defined as 'research that is internationally leading'. This in combination with the first amazing science results from the LOFAR telescope, and many other things, resulted in many media appearances, as can be seen above.

Education

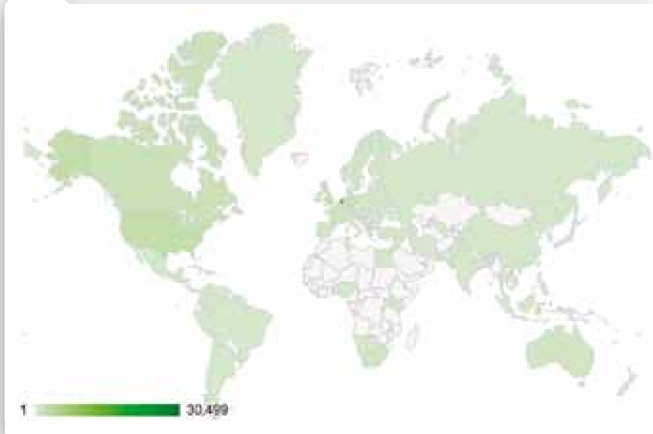
Number of PostDocs in 2011:19.
Number of PhD students in 2011: 3.

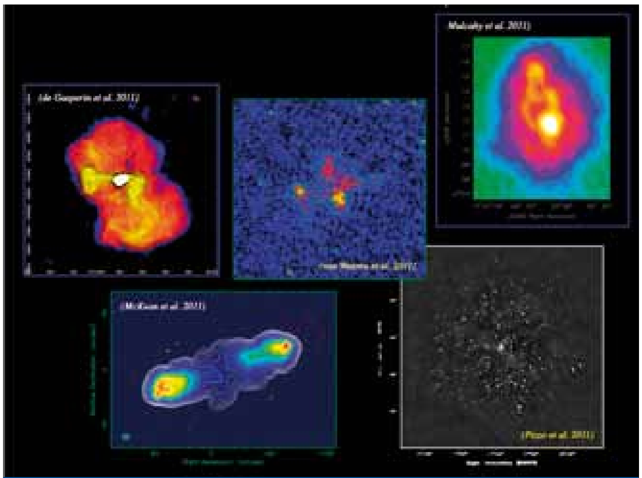
ASTRON/ JIVE Daily Image

In 2011, the ASTRON/JIVE Daily Image, which shows a different ASTRON-related image each day, counted 45,779 visits of which 11,315 are unique. The total number of page views is 313,994. The visitors came from 94 countries. Most visits are from the Netherlands, the UK, US, Germany, Canada, France, South Africa and Australia. The map below shows the division of people all over the world visiting the daily image. Compared to 2010, visits have increased by about 10%.

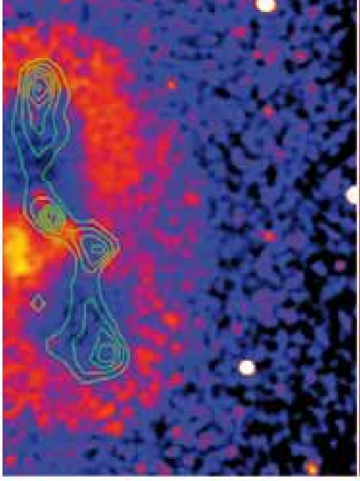
Number of school visits

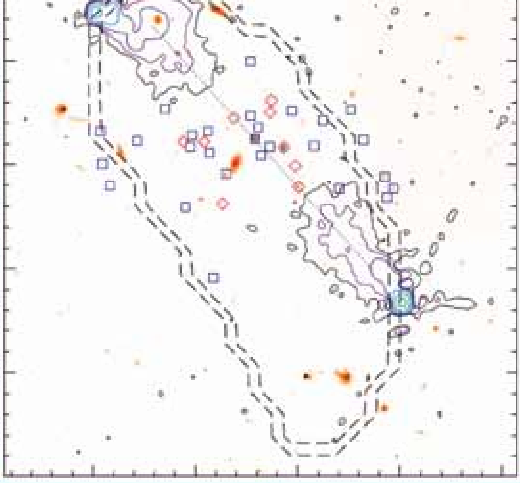
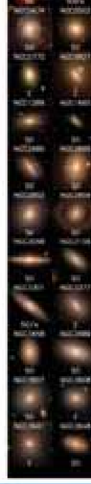
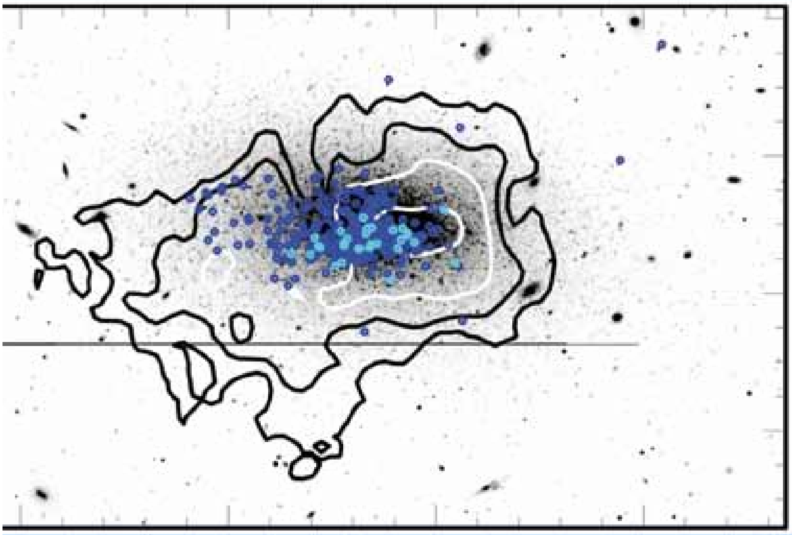
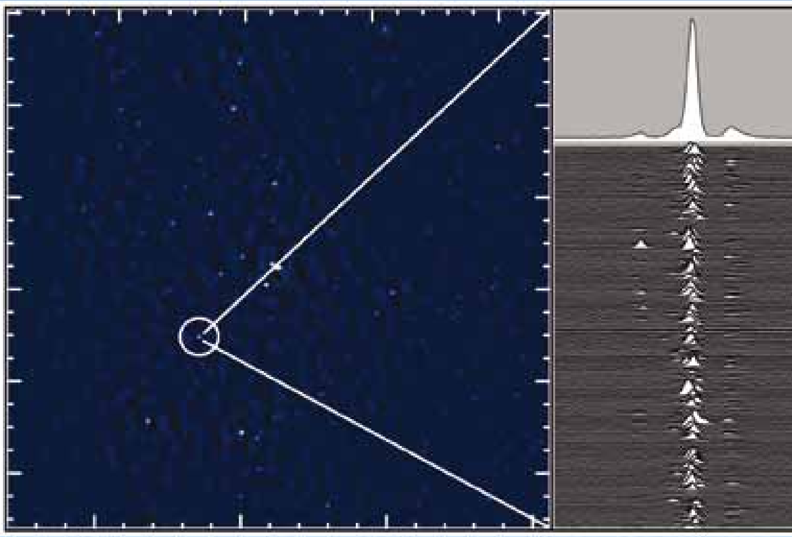
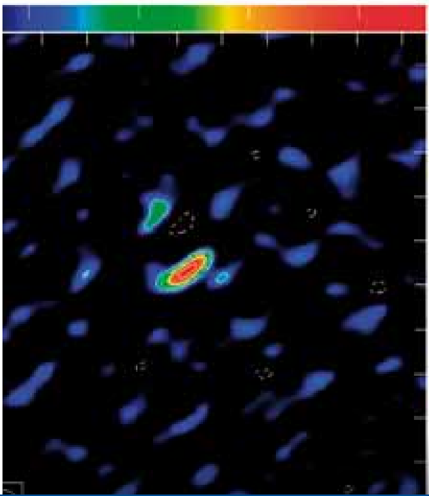
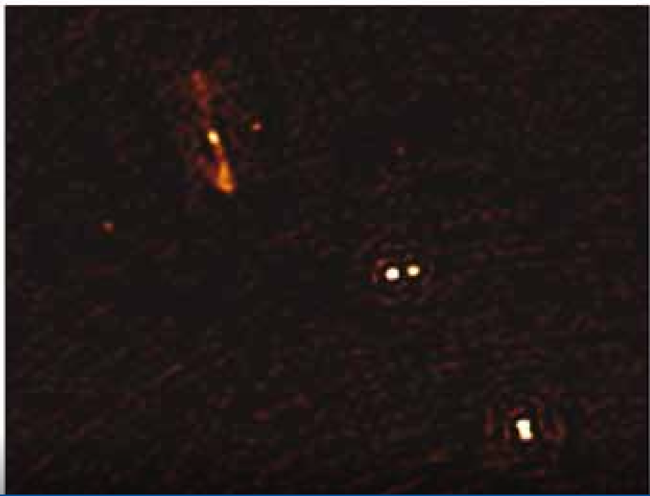
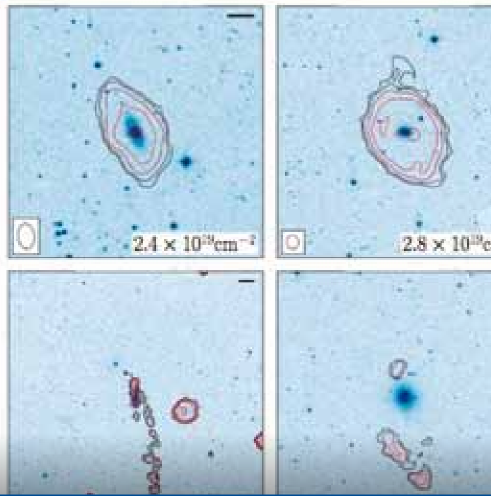
In 2010, ASTRON started a structural activity to stimulate visits of schools as part of our outreach program. The table shows the success of this activity in the period from November 2010 until December 2011.





Some of the first LOFAR science results, presented at the LOFAR Early Science workshop on 14 and 15 September 2011.



Astronomy Group

Science

The astronomy group published 95 refereed papers in 2011, setting a record high for the third year in a row. These studies were accepted for high-impact journals: 1 in Nature (impact factor 36.1), 2 in Science (31.3), 22 in ApJ/ApJL (6.1), 29 in MNRAS (4.9) and 18 in A&A (4.4). The highlights of the research are:

Observing pulsars and fast transients with LOFAR

A large team, including fifteen astronomers from ASTRON, published the first refereed LOFAR paper 'Observing pulsars and fast transients with LOFAR'. Led by the LOFAR pulsar working group, of which Hessels, Kondratiev and van Leeuwen are part, the paper discusses the motivation for low-frequency pulsar observations in general and the potential of LOFAR in addressing these science goals. LOFAR is presented as it is designed to perform high-time-resolution observations of pulsars and other fast transients, and the various relevant observing modes and data reduction pipelines that are already or will soon be implemented to facilitate these observations are outlined. A number of results obtained from commissioning observations are presented to demonstrate the exciting potential of the telescope. The paper outlines the case for low frequency pulsar observations and is intended to serve as a reference for upcoming pulsar/fast transient science papers with LOFAR. (Paper: Stappers et al. 2011, A&A 530, 80).

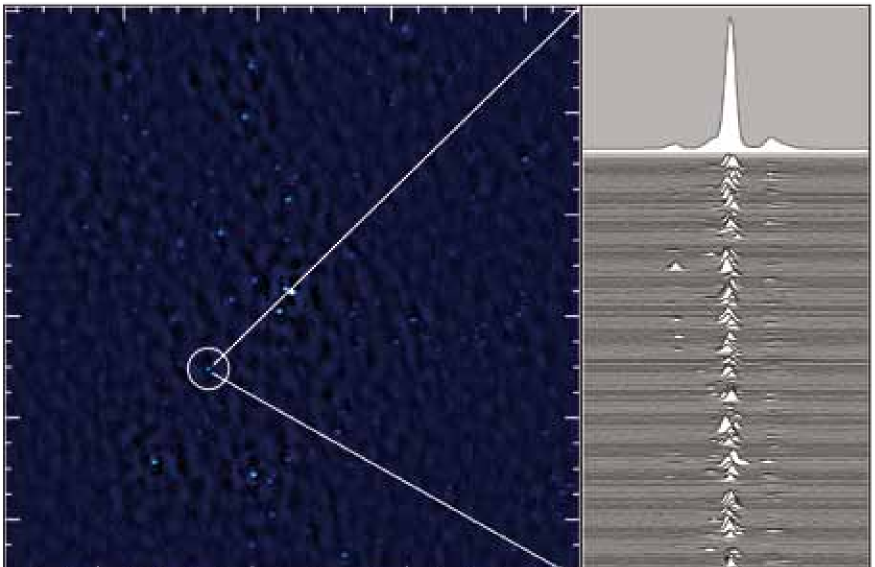
Multiwavelengths study of a new sample of early-type galaxies

Early-type galaxies are generally perceived to be quite boring. At first glance, nothing is really happening, they do not show any interesting structure or features and they all sort of look the same. Nevertheless, a large international team, also involving ASTRON astronomers, is performing a detailed study of a large sample (called the ATLAS3D sample) of galaxies of this type. The team has collected not only optical integral-field data (using the SAURON instrument at the WHT), but also deep optical images (MegaCam at the CFH telescope), CO data (IRAM 30m followed by PdBI and CARMA) and, last but not least, HI (using the WSRT, of course!). The team involves people from Oxford University, ESO, Saclay, UC, Berkeley, Lyon, Hertfordshire, Gemini, MPIA and Toronto. Paolo Serra, Tom Oosterloo and Raffaella Morganti are members of this collaboration and, in particular, they are taking care of the HI data. The paper describing the sample can be found in Cappellari et al. (2011). A total of 11 papers came out of the survey in 2011!

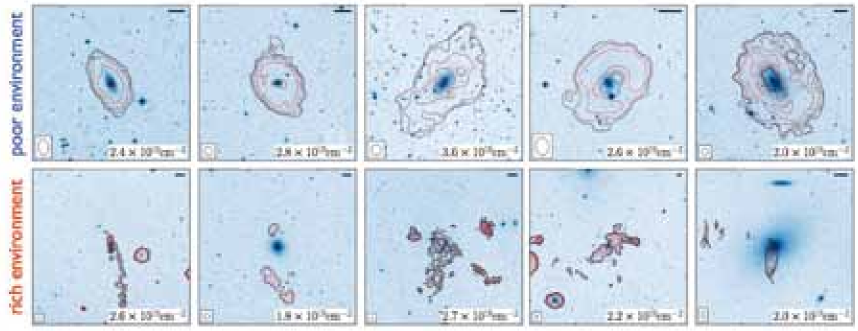
As a result of the Atlas 3D study, the picture people have of early-type galaxies will change

It turns out that, if you really look well, early-type galaxies are a highly varied family of objects; suggesting that their origin and evolution is much more complex than initially thought. One of the main contributions of the WSRT data is that, unexpectedly, many galaxies show very interesting gas structures (about 50% are detected in HI) that indicate a still active assembly. Many of the early-type galaxies studied appear to be in the process of acquiring gas from outside and to form regular (disk) structures. The results of this HI survey are described in Serra et al. 2012.

That paper finds that early-type galaxies in poor 'local' environments typically host giant HI discs with radii of up to many tens of kpc. These systems are very regular, indicating that the host galaxy has enjoyed a quiet life for a very long time. ➔



Simultaneous LOFAR imaging and tied-array observation of PSR B0329+54.

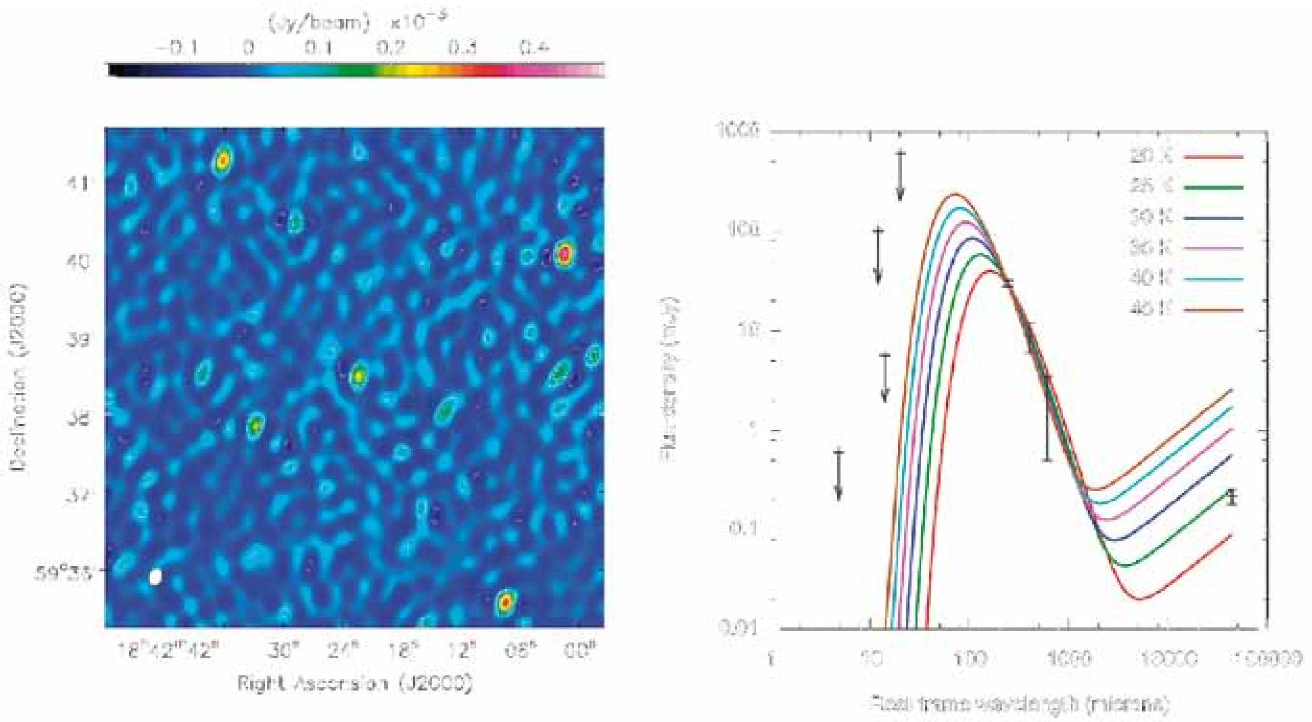


HI constant-column-density contours on top of optical images for galaxies living in a poor environment (top row) and in a rich environment (bottom row). The first contour level is indicated on the bottom-right. The column density increases by a factor of 2 at each step. Contour colour is black to red, faint to bright. The beam is shown on the bottom-left. The top-right bar indicates 10 kpc. Figure taken from Serra et al. (2011, MNRAS, arXiv:1111.4241), based on WSRT data.

The situation is very different in richer environments like galaxy groups and at the outskirts of galaxy clusters. Here the HI typically exhibits a very disturbed morphology. In many cases long HI tails stretch from the host galaxy into the surrounding space, demonstrating that some gas may have recently been removed from (or accreted onto) the galaxy. Early-type galaxies in these environments are evolving because of the interaction with what is around them. At even denser environment densities, in the very centre of clusters, hardly any HI is found. Galaxies live close to each other and are immersed in a hot medium, which makes it very easy for them to lose their HI and very hard to re-accrete some. All this demonstrates that the evolution of early-type galaxies is far from finished and that environment plays a key role driving it.

Star-forming and dust properties of sub-mm galaxies

The lensing group at ASTRON has continued to study high redshift sub-mm galaxies at radio and far infra-red (FIR) wavelengths. The bright sub-mm galaxy MM 18423+5938 at redshift 3.9296 was observed at 1.4 GHz with the WSRT. The galaxy was detected at the 11-sigma level, and the radio emission was used to determine a radio-derived total IR luminosity via the well-established radio-FIR correlation. →

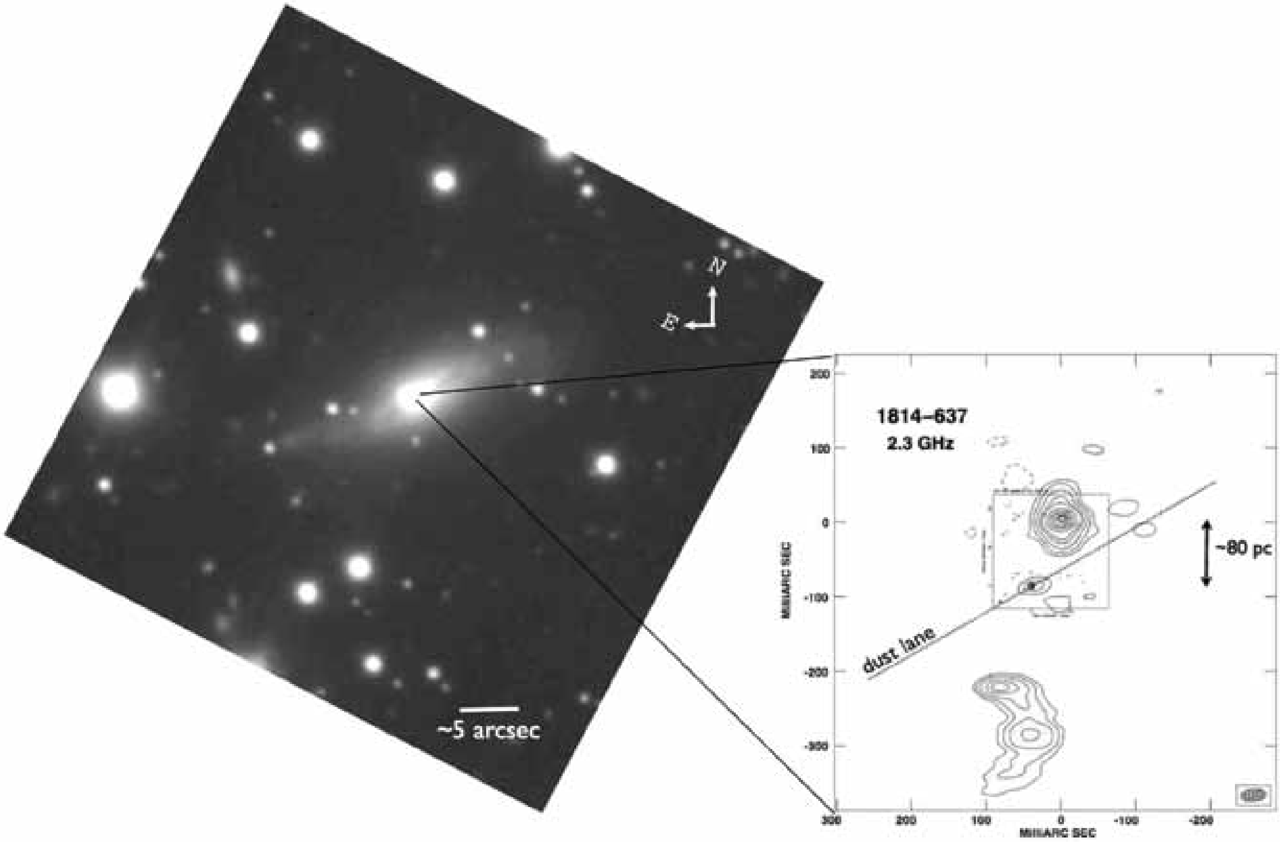


The 1.4 GHz radio emission and spectral energy distribution of the sub-mm galaxy MM 18423+5938.

The radio-derived total IR luminosity and star formation rate are $L_{8-1000\,\mu m} = 5.6^{+4.1}_{-2.4} \times 10^{13}\,\mu^{-1}\,L_{sol}$ and $SFR = 9.4^{+7.4}_{-4.9} \times 10^{3}\,\mu^{-1}\,M_{sol}\,yr^{-1}$, respectively, which are ~9 times smaller than those previously reported for this system, based on an incomplete spectral energy distribution. Using the radio-derived total IR luminosity and the photometric data that are available for this system, the cold dust component was found to have a temperature of $T_d \sim 24^{+7}_{-5}$ K. For typical lensing magnifications (10–50), the de-lensed properties of this galaxy are similar to the z ~ 2 galaxies discovered by SCUBA. The details of this work were reported by McKean et al. (2011, MNRAS, 414, L11) and are part of a pilot study that aims to demonstrate what can be achieved with the large continuum surveys to be carried out with APERTIF.

PKS 1814-637: a powerful radio AGN in a disk

Raffaella Morganti and collaborators (including Tom Oosterloo) have studied a rare case of a powerful radio source, PKS 1814-637, hosted by a disk galaxy. Optical images have been used to model the host galaxy morphology confirming it to be dominated by a strong (and warped) disk component. At radio wavelengths, PKS 1814-637 is about 400 pc in size and it is classified as a compact steep spectrum (CSS) source; such sources are usually considered to be young radio sources observed in the early stages of their evolution. Optical, near and mid-IR and the Australian VLBI network (LBA) HI observations show that the radio source is located in a rich ISM. The properties of the ISM are similar to what is found in Seyfert galaxies. The interaction between the radio plasma and the ISM may actually have boosted the radio emission. Thus, PKS 1814-637 may represent a kind of 'imposter': an intrinsically low power object that is selected in the sample because of the unusually efficient conversion of jet power into radio emission. This would make PKS 1814-637 an extreme example of the effects of ISM in galaxies originated by a gas-rich major merger and perhaps a missing link between radio galaxies and radio-loud Seyfert galaxies. Objects like PKS 1814-637 would, therefore, more easily enter flux limited samples of radio sources and this could explain the relatively large number of CSS sources in those samples. The rarity of strong radio sources hosted by disk galaxies suggests that these objects may be characterised by a short lifetime, likely due to the disruption of the collimated jet in the interaction and/or by instabilities in the accretion disk. (Paper: Morganti et al. 2011, A&A 535, 97). ➔



Optical image obtained from the Gemini South (left) and 2.3 GHz VLBI image (right, Tzioumis et al. 2002) of PKS 1814-637.

First detection of water line emission at z=3.9 in a lensed QSO

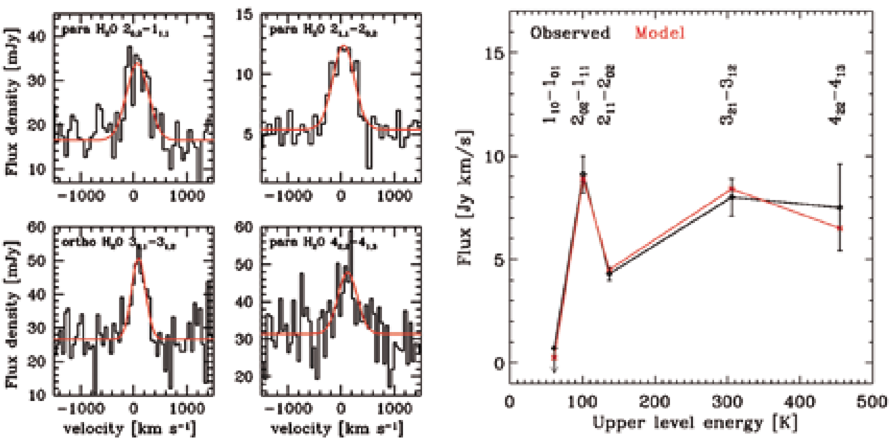
Water is expected to be one of the most abundant molecules in molecular clouds in galaxies, and to play an important role in the hot (T > 230K) gas-phase chemistry, hence influencing the overall chemical composition of the gas. In addition, theoretical studies suggest that water is the dominant cooling agent at high densities and high temperatures, facilitating the gravitational collapse of molecular cloud cores which is required to form stars. Until now, (single) water lines at high-z were only found in two gravitationally lensed systems at z=2.3 and 2.6. The new record holder is the (also gravitationally lensed) QSO host galaxy APM08279+5255 at z=3.9, in which water line emission has been recently reported by our group (van der Werf, Berciano Alba et al. 2011) and two other teams (Lis et al. 2011, Bradford et al. 2011). We used the Plateau de Bure millimeter interferometer to obtain high resolution (40 MHz), 3.6 GHz bandwidth spectra of four rotational water lines in APM08279+5255. This unprecedented detection of multiple water lines in a high-z object has allowed us, for the first time, to explore the use of water as a tracer of the physical properties of the ISM at high-z. (van der Werf, Berciano Alba et al., 2011, ApJ, 741L, 38V). Spectra of the four water lines detected in APM08279 (left), and a comparison between the observed and modeled water line fluxes (right).

The LOFAR Epoch of Reionization project

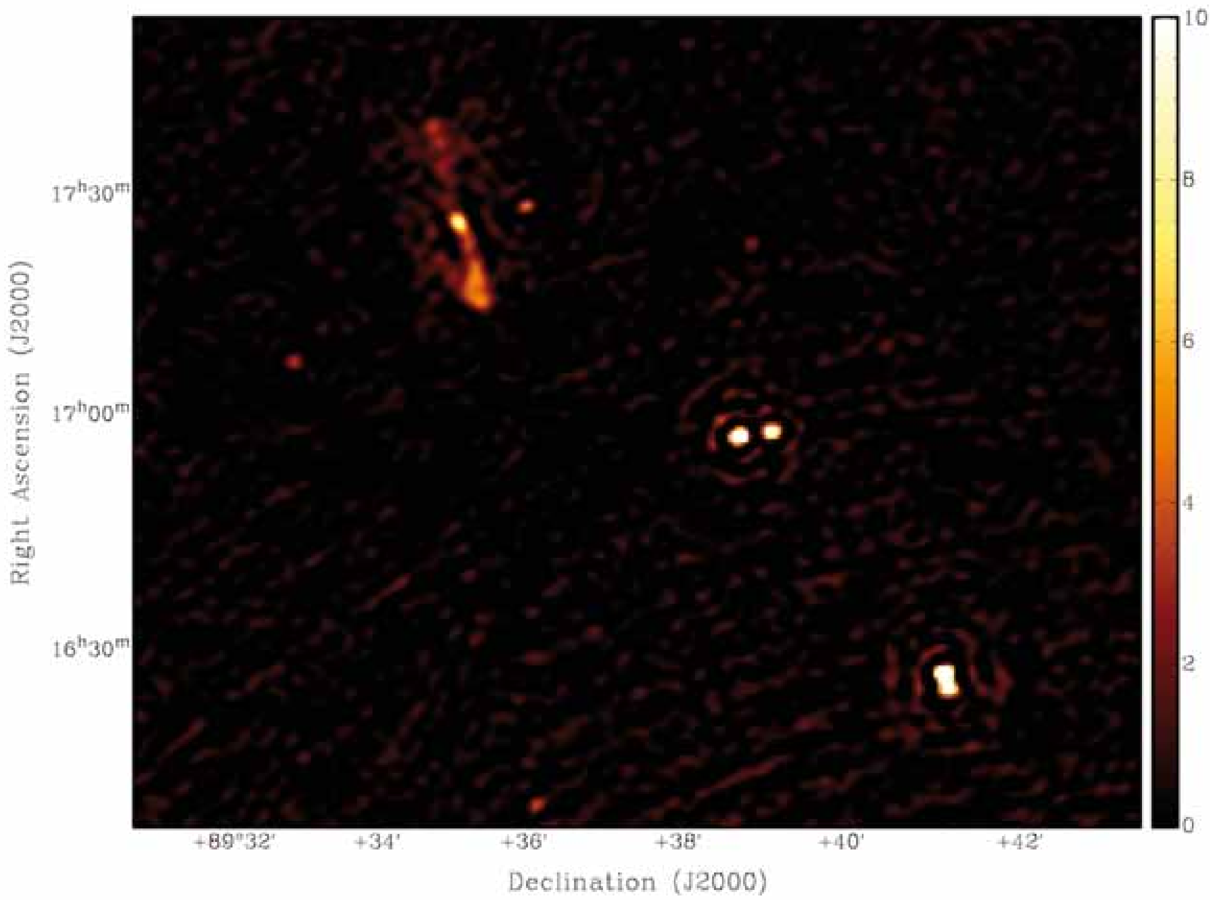
The LOFAR-EoR key science project will use the LOFAR telescope to detect the redshifted 21cm line of neutral hydrogen coming from the Epoch of Reionization (EoR). The EoR is a pivotal period in the history of the Universe during which the all-pervasive hydrogen gas was transformed from neutral to the ionized state. It holds the key to structure formation and evolution, but also represents a missing piece of the puzzle in our current knowledge of the Universe. At the end of 2010, LOFAR started to acquire commissioning data to monitor performance, and as pilot work for deep EoR observations. During the first four months of 2011, about fifteen nights of data (6 hours on each of two fields: 3C196 and the NCP) were collected in the HBA band (115-163 MHz). De Bruyn, Labropoulos and Yatawatta processed several nights of data; these were presented at the Zadar EoR meeting, and as a press release. In each field, in a single 6-hour synthesis using most or all subbands, sub-mJy noise levels were achieved. The images have a resolution of about 8” at an average frequency of about 140 MHz. In the 3C196 field we achieved a formal Dynamic Range of 80 Jy /0.4 mJy or 200,000:1! We are still a significant factor away from the thermal noise and expect in 2012 to achieve improved images when we turn on beam correction during the imaging and start to uv-subtract more sources and deconvolve images.

The nature and evolution of the unique binary pulsar J1903+0327

Two teams published complementary papers (one more observational, one more theoretical) on this system. J1903+0327 is a millisecond pulsar in an eccentric (e = 0.44) 95-day orbit with a (~1M_{sun}) companion, posing a challenge to our understanding of stellar evolution in binary and multiple-star systems. Jason Hessels and colleagues describe optical and radio observations which rule out most of the scenarios proposed to explain formation of this system. They present the most precise measurement of the mass of a millisecond pulsar to date: 1.667 +/- 0.021 solar masses (99.7% confidence limit) (Freire et al. 2011, MNRAS 412, 2763). →

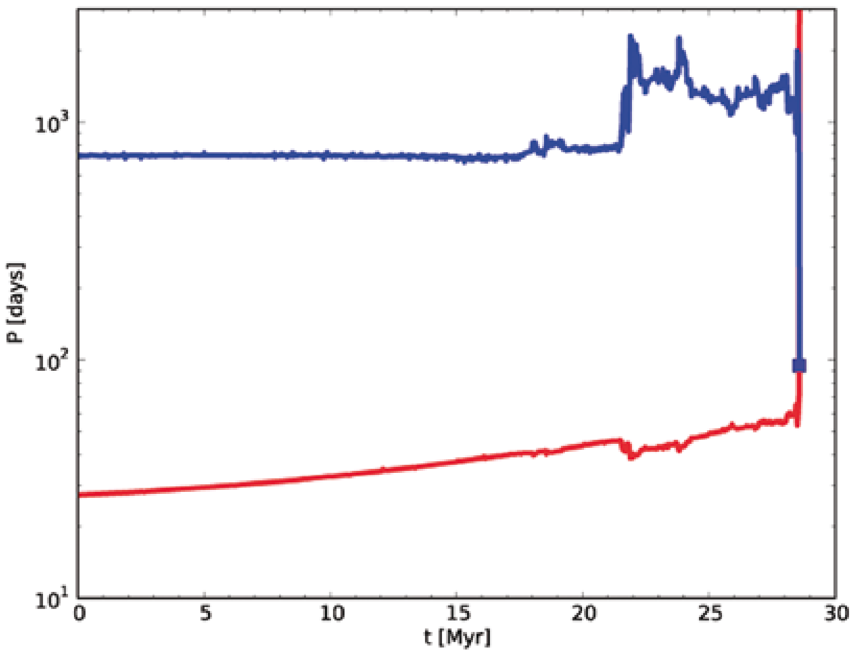


Spectra of the four water lines detected in APM08279 (left), and a comparison between the observed and modeled water line fluxes (right).

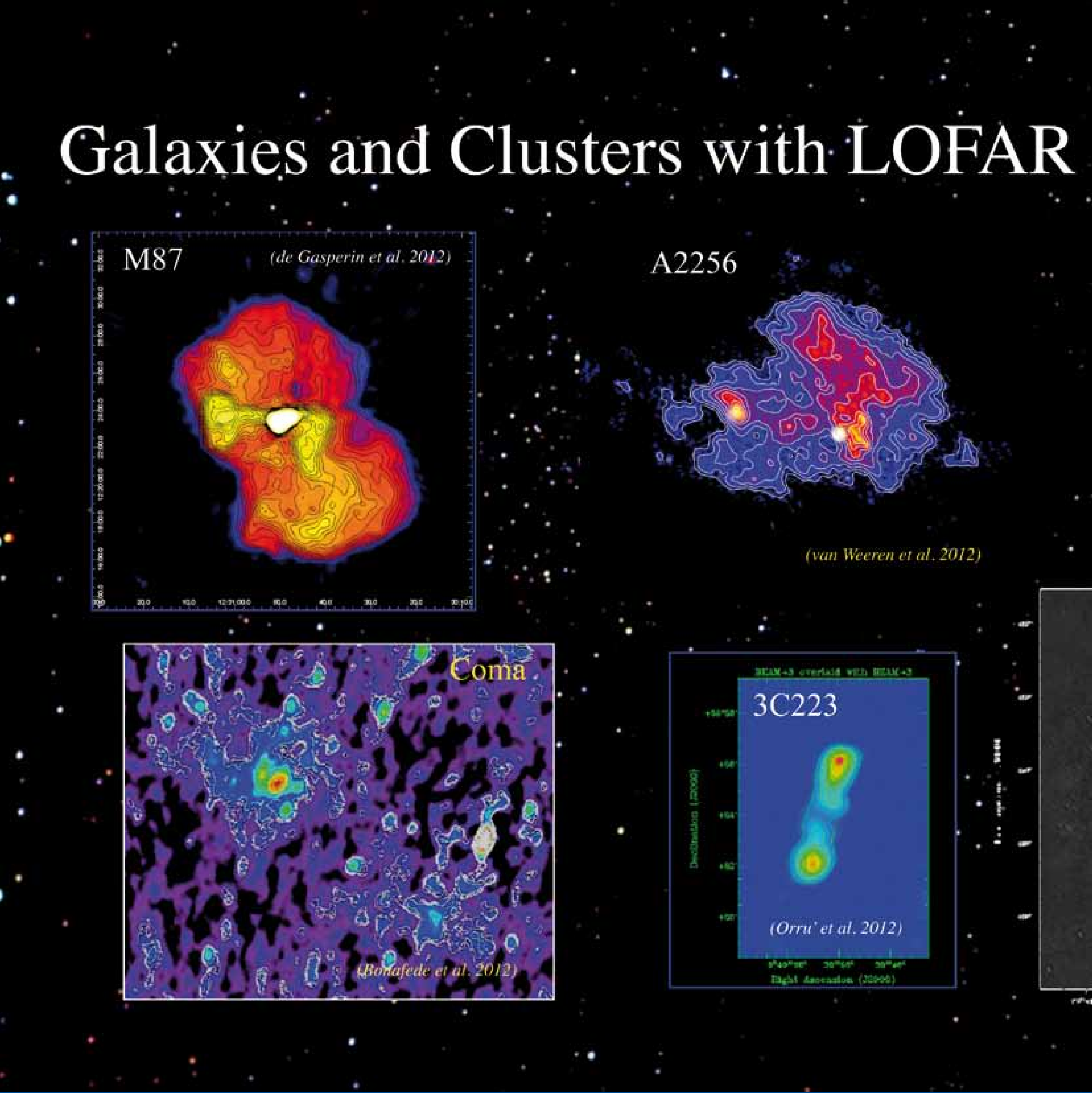


A tiny part of the LOFAR image of the field centered on the North Celestial Pole. It shows at least 7 discrete sources, some of them double or complex. The faintest source has a flux density of only a few mJy at 150 MHz. The image has an angular resolution of 8 arcseconds but still needs to be deconvolved. The data was processed by Dr. Sarod Yatawatta on the EoR-cluster at the University of Groningen.

Joeri van Leeuwen and team present a triple-star model and population synthesis where the expansion of the orbit of the LMXB, driven by the mass transfer from the evolving donor star to its neutron star companion, causes the triple eventually to become dynamically unstable. If the donor star of the LMXB is ejected, a system resembling J1903 will result. If the neutron star is ejected a single MSP results. This model therefore also provides a straightforward mechanism for forming single MSP in the Galactic disk (Portegies Zwart et al. 2011, ApJ 734, 55).



The evolution of the inner and outer orbit for a system producing J1903+0327.



Radio Observatory

Operations with the Westerbork Synthesis Radio Telescope

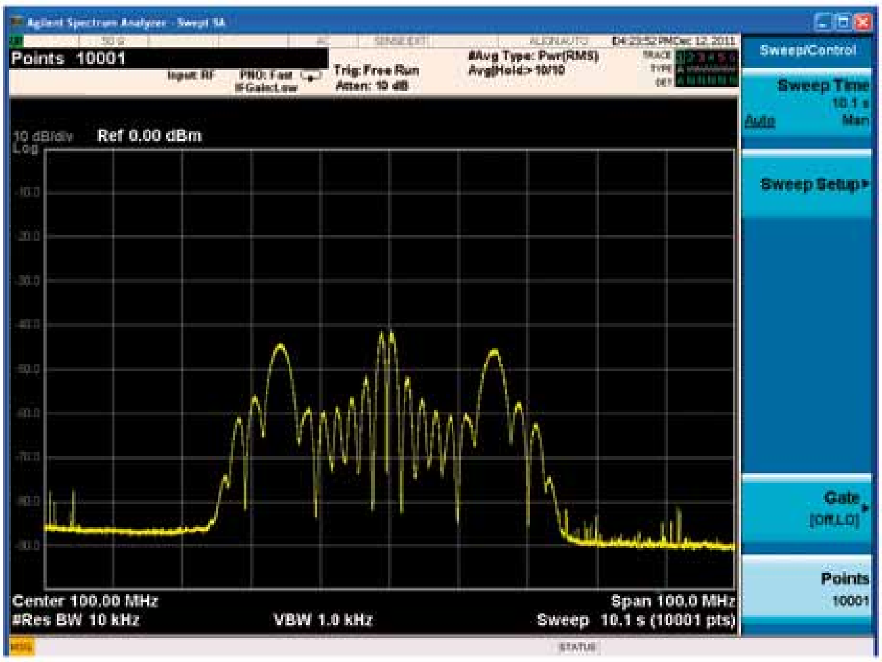
The Westerbork Synthesis Radio Telescope (WSRT) has continued in its highly efficient science production mode, with the staff spending just the required effort to keep the telescope at its current performance level. This currently allows a last generation of deep 92cm and 21cm WSRT Legacy synthesis observations to proceed smoothly, with data flowing steadily into the archive. The continued 'low-maintenance / high-production mode' on the WSRT has allowed the staff of the ASTRON Radio Observatory division to direct most of their efforts in 2011 towards LOFAR.

A crew of 7 persons, spending a total of 3 FTE, was in charge of WSRT hardware maintenance: 3 mechanical engineers, 3 electronic engineers and 1 cryogenics engineer; a temporary worker was hired for 12 days during the summer. On average, the WSRT was in planned maintenance mode for one working day a week. Only five mechanical failures on the telescopes and twenty-one issues related to electronics required corrective maintenance in the entire year. The displacers in the cryogenic pumps of the cooling system began to show an increasing number of failures in 2010, well before their nominal end-of-life expectancy. After some consultation, research, and negotiation with the manufacturer, free delivery of a partial batch of improved displacers was agreed for 2012. In July 2011, deterioration of the electrical cabling of the motors of the movable telescopes caused short circuits; this was replaced with urgency. Larger-scale electrical and mechanical maintenance, to keep the WSRT up-to-date, is being deferred to coincide with the period of transition to the Apertif frontends.

Two WSRT software maintenance weeks were planned for the year, but the second one was cancelled as there was no need for it. The calibration procedure for VLBI observations, which involved a large number of manual steps, was automated, reducing the required effort per VLBI observing period from several hours to several minutes. Apart from some extensions for the Galileo SMF system, the rest of the WSRT software system continued in its stable condition.

WSRT Galileo Signal-in-Space Monitoring Facility

The Signal-in-Space Monitoring Facility (SMF) was realized at the WSRT by a consortium headed by ASTRON, with S&T, Delft University of Technology, and TNO. SMF uses one of the 25-meter WSRT dishes to receive the navigation signals from the Galileo satellites with a high signal-to-noise ratio, and analyses these signals both with respect to their RF and modulation properties and quality and to determine the behaviour of the satellites in their orbits. The facility for the In-Orbit Validation (IOV) of the first four Galileo satellite passed its Qualification Review, and was then delivered to Thales Alenia Space, Italy, on April 6 to start nominal operation. During this event a demonstration and a short training about the use of SMF were given. In the framework of the In-Orbit Test (the phase before the actual IOV) the SMF performed measurements on the 11th, 15th, 18th and 19th of December on the unmodulated and modulated signals of the PFM satellite. The figure below shows the modulated signal in the L1 band of the PFM satellite as measured with the spectrum analyzer of the SMF set-up. ➔



LOFAR Operations

The entire year saw prodigious LOFAR commissioning and early science activities (statistics given on the right). Operations for these were carried out with the observing system in a preliminary and strongly evolving state, that took major personnel effort to support. Most of the Observatory staff devoted their efforts to a mixture of the various ongoing LOFAR development, rollout, commissioning, and early science observing. The Heads of Technical Operations and of Science Support both participated in the central coordination of these efforts via the ASTRON-wide LOFAR Commissioning Coordination Group (LCCG).

The Observatory hardware maintenance staff were engaged in the continued station rollout, both nationally and internationally. The last of the originally ordered batch of eight international stations, SE607, in Onsala, Sweden, was completed and dedicated in September.

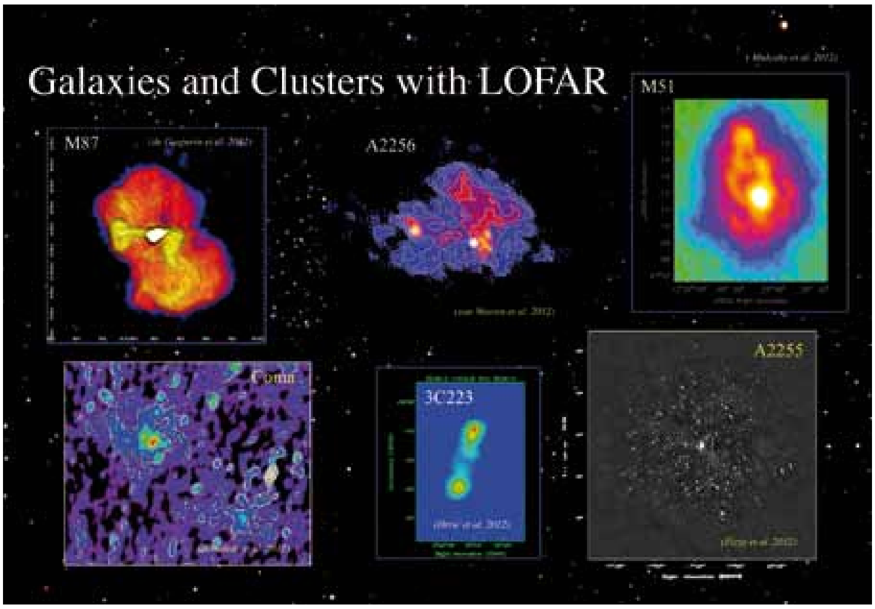
There was a vigorous retrofitting campaign in the autumn to improve the robustness against moisture of the High Band Antenna tiles in NL LOFAR stations. On some of these, field drainage was improved by digging of additional trenches. Also, importantly, a potted design of the tile antenna summator was designed, manufactured, and taken into use to replace all faulty summators henceforth. The measures taken have led to a sharp decline in the incidence of modem faults.

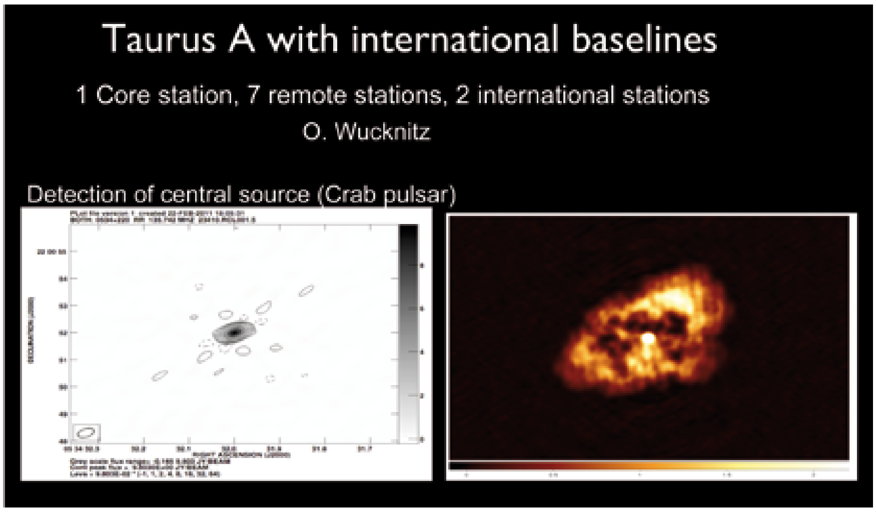
As the year drew to a close, the software development was directed by the LCCG in a very focused way towards a package of capabilities called LOFAR Version 1. This package includes correlated as well as multi-station beam-formed and direct station data dumping modes, that feed into several post-observing pipelines, chiefly for synthesis imaging and known pulsar observing. LOFAR Version 1 encompasses end-to-end operational capabilities, from proposal entry to archived data retrieval. The system is planned to come into operational use following an open call for proposals in 2012. Further packages of functionality for later development (LOFAR Versions 2, and 3), have been defined at top-level by the LCCG and endorsed by the ILT Board.

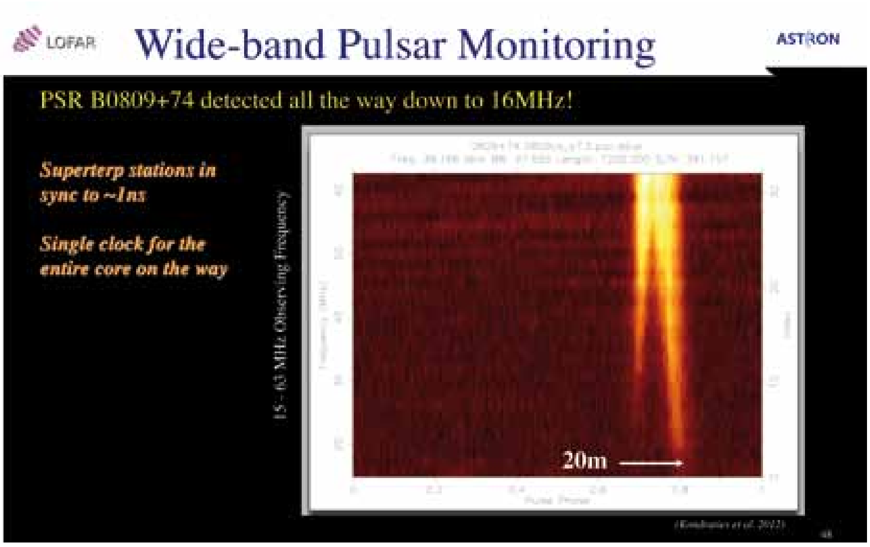
In order to achieve optimal coordination and a tight planning cycle, the LCCG adopted a software planning method called Agile/Scrum. It is well suited to the relatively small team of developers with diverse skills, mostly located at ASTRON but with participation of people from Key Science groups and international LOFAR consortia. Important parts of the development work delivering functionality for LOFAR is also being carried out in multi-party collaborative projects such as NexPress, BigGrid, and Target. The picture below shows vividly the Agile/Scrum method in use mid-way through a Sprint cycle. →

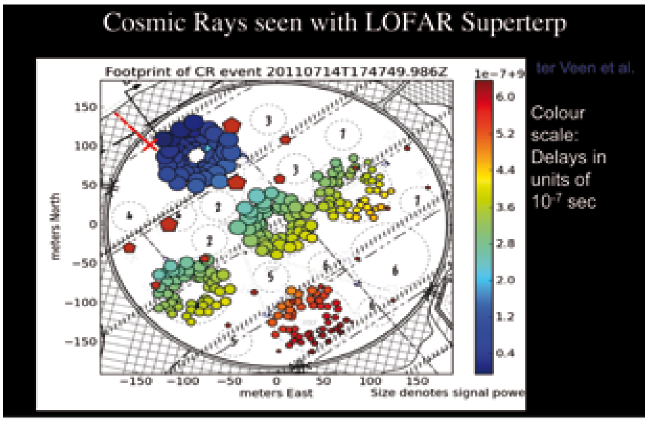
LOFAR Early Science Workshop

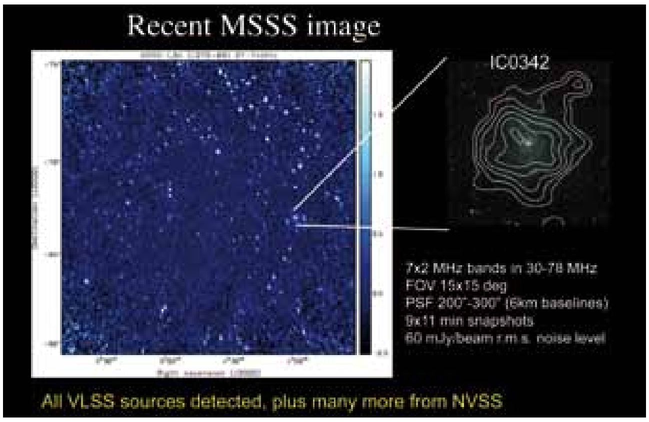
Highly encouraging evidence of the maturing state of LOFAR was given at the 'LOFAR Early Science' meeting organised by the Observatory science support group in Dalfsen, the Netherlands, on September 14 and 15. It was attended by about 110 people from the community engaged in commissioning activities, many of whom are students and postdoctoral researchers, who will assure a bright, young, and lively user community for the future! Some self-explanatory early science summary sheets either presented at the Dalfsen meeting, or obtained around the same time are shown below. →







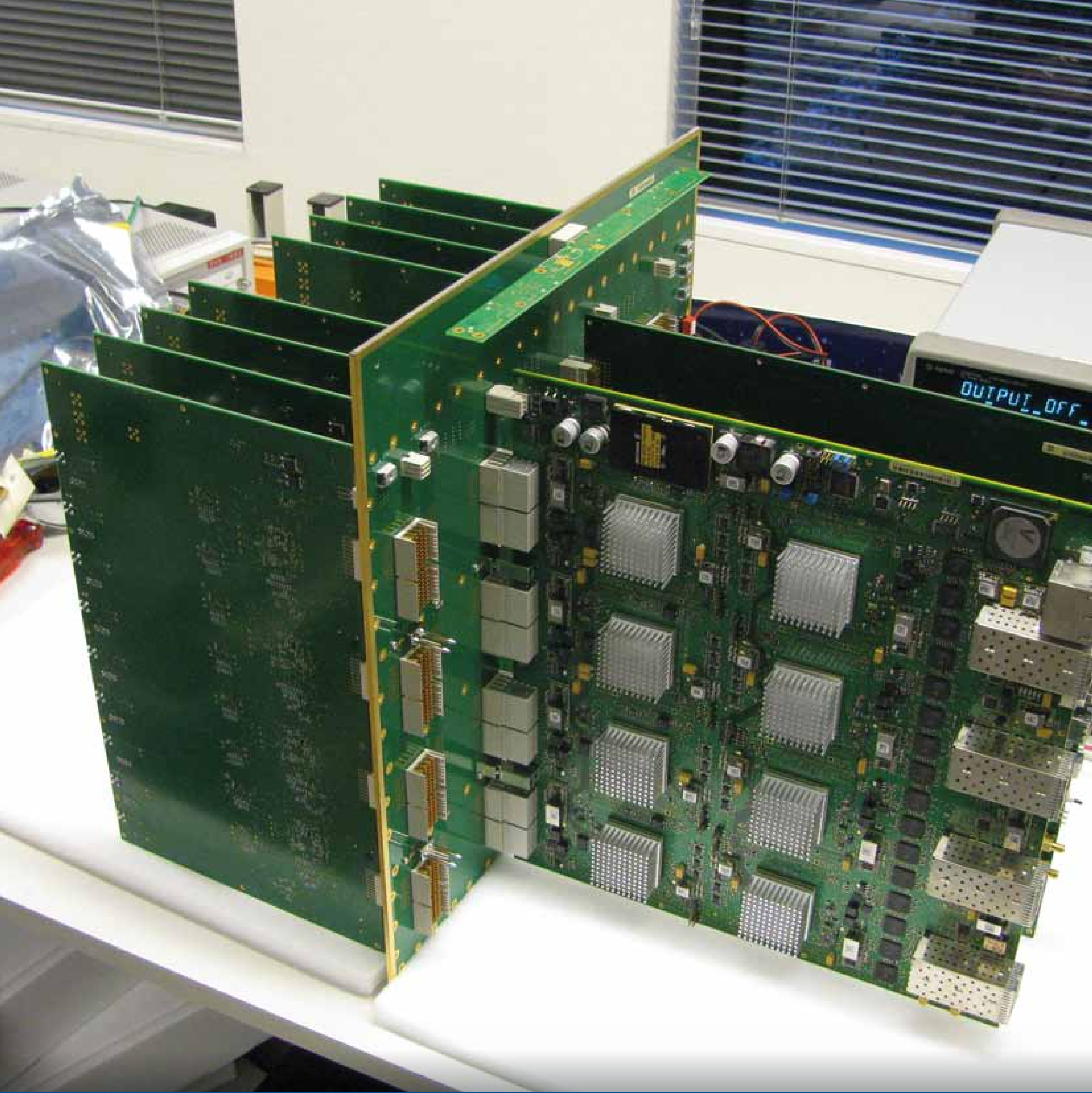




In November, the Low Band part of the LOFAR Multi-Snapshot Sky Survey (MSSS) was started. This will be the first time that LOFAR covers the sky in a uniform way. MSSS is an important step to ensure the availability of calibrator information across the sky. MSSS, continuing in 2012, also serves as a major driver for developing and debugging end-to-end operational functionality of the system. A recent sky image is shown in the figure on the top right.

Development of the International LOFAR Telescope Foundation

Having been formally established by ASTRON and the NL LOFAR consortium in 2010, the ILT blossomed in 2011. Quarterly Board meetings were held. The highlight, on 22 June, was the formal entry of the LOFAR consortia from France, Germany, Sweden, and the United Kingdom (GLOW, FLOW, LOFAR-Sweden, and LOFAR-UK), shown below. The multiple simultaneous entry was enabled by the signing of uniform agreements regulating the usage by the ILT of a first set of international LOFAR stations from all countries involved, as well as, reciprocally, the usage of the ILT by the station owners, and the contribution of these station owners to the central operations of the ILT. These arrangements were subsequently extended to all stations, culminating with the ILT Board approval on 16 September of a GLOW-coordinated package of cash and in-kind contributions to ILT operations, lasting through 2013, and involving both the availability of two software developers for LCCG work, and the provision of archive facilities at Juelich.



R&D Laboratory

APERTIF

The ASTRON R&D department, in close collaboration with the Astronomy Group and the University of Groningen, is world-leading in developing focal plane array technology for radio astronomy. APERTIF 'APERture Tile In Focus' aims to substantially increase the survey speed of the WSRT using Phased Array Feed (PAF) technology enabling new kinds of radio astronomy. Currently, the detailed design of APERTIF is being finalized. Activities include antenna and LNA design, environmental testing of coaxial RF cables, receiver design, digital processing design (beam-former and correlator) and firmware development (see the paragraph about UniBoard), investigation of post-processing pipelines, integration and studies, calibration and beamforming studies. The APERTIF prototype PAF system, called DIGESTIF, has been installed in one of the WSRT dishes and has demonstrated the feasibility of the new system. Some major results include the demonstration of a 68 K system temperature which is intended to be further reduced for production systems. DIGESTIF also demonstrated much improved illumination of the WSRT antenna surface, increasing the efficiency of the telescope system and significantly reducing standing wave effects.

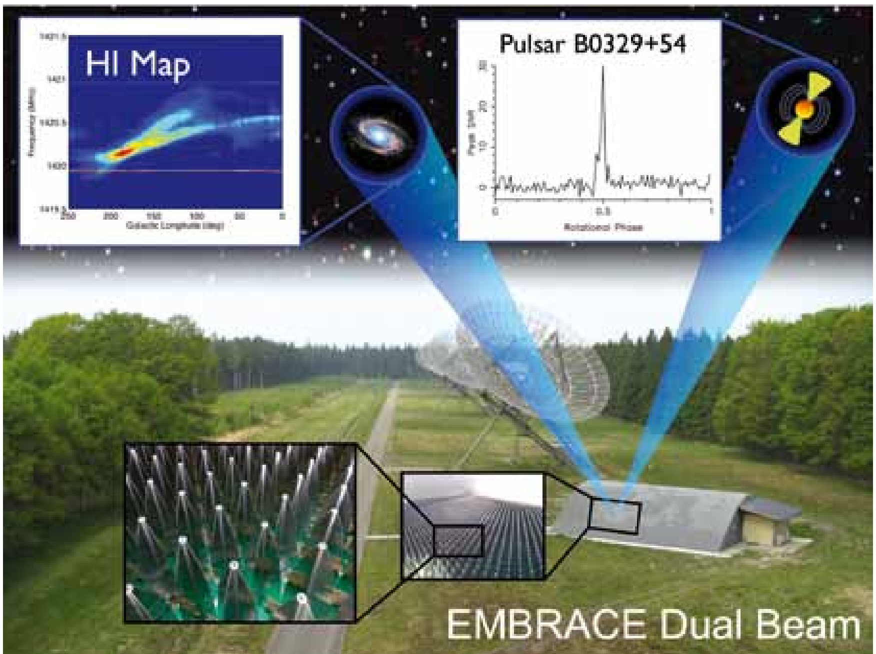
In the week before Christmas the backplane for the APERTIF beamformer arrived. The image shows one backplane, including boards plugged in at both sides of the backplane. In total two of those subracks are required for the APERTIF beamformer for each telescope. On the boards multiple beams are formed from all antenna elements of the phased array feed in the telescope. In a single AUB (ADU UniBoard backplane) four UniBoards (digital beamformer boards), eight ADU (ADC converter units), and a PAC (Power And Clock distribution) board are plugged. Since it now has been proven that all boards fit mechanically in the backplane, the boards are ready for integration in a mechanical subrack housing.

APERTIF beamformer subrack.

EMBRACE

Within the context of the EC FP6 SKADS project, ASTRON designed and built EMBRACE (Electronic Multi-Beam Radio Astronomy ConcEpt). Two of these SKA technology demonstrators have been constructed – one is located alongside the WSRT in the Netherlands, and the other is located in France, at the Nancay Observatory. The goal of the project is to show that a cm-wavelength Aperture Array system can be manufactured at low cost via the development of advanced production technology. The EMBRACE system is also used as a test-bed for instrumental and astronomical validation. An important concept in the array is that of a logical tile. One such logical tile consists of 2×72 antenna elements and is slightly bigger than 1 square metre. The 144 elements are organised in a dual polarisation configuration, however only the signals from one polarisation can currently be processed at any one time. The 72 antenna signals are beam formed into two, fully independent, steerable beams at RF level. The resulting beams are transported over coaxial cables to a small building near the array where the remainder of the signal processing is taken care of. EMBRACE operates at frequencies of up to 1.7 GHz.

The ability of the array to conduct two different measurements simultaneously was demonstrated early 2011. The figure below shows two observations near 1.4 GHz simultaneously by phasing the EMBRACE aperture array elements in such a way to form two beams on the sky at the same time. One beam was used to track a pulsar (right) while the other beam was scanning over the sky to image the neutral hydrogen along the Milky Way (left). →



Dual beams of EMBRACE detecting a pulsar and Galactic HI.

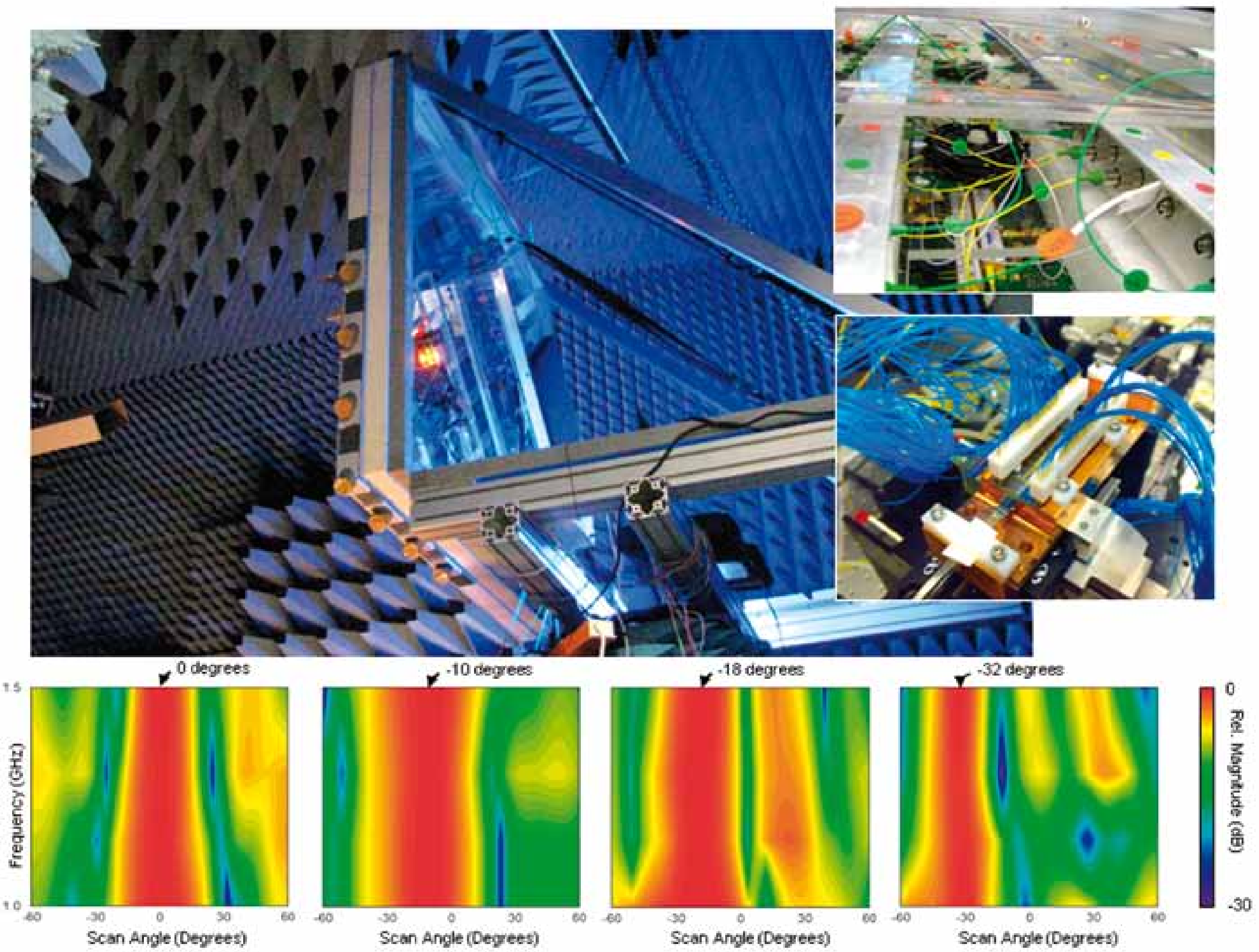
The figure shows the results of these observations: the pulse profile of the pulsar detected and the longitude-velocity diagram of the neutral hydrogen along the Galactic plane (with the double structure indicating spiral arms of the Galaxy). These results show the great potential of multi-beaming for radio telescopes: multiple simultaneous observing modes (in this case recording a time series of a single source and at the same time scanning the sky to do imaging spectroscopy). They also mark the important progress which is being made at ASTRON in developing the technology for the radio telescopes of the future, in particular the Square Kilometre Array.

High-Performance Computing on Streaming Data

The LOFAR telescope is producing huge amounts of data. The real-time part of the central processing of the data stream is implemented on an IBM Blue Gene supercomputer. In order to have the correlator application run at 96% (!) of the peak performance the supercomputer had to be optimized. This involved programming on assembly level, optimizing the network protocol, and adapting the operating system. In doing so we were also able to have the data transpose run on the Blue Gene instead of on a separate input cluster as originally planned, in this way saving the project 1 million Euros. In addition to that all the optimizations also allowed us to process more data (i.e. more instantaneous bandwidth) and to have additional pipelines for pulsar and cosmic ray data processing running.

DAS-4 experimental computer at ASTRON.

In the AstroStream project we are investigating with the TU Delft and the Free University of Amsterdam the possibilities of doing even more advanced streaming astronomical processing. Correlator software was rewritten for running on a IBM Cell processor and on a ATI GPU card. We now have correlator implementations on both NVIDIA and ATI GPUs, the Cell/B.E. processor, Intel/SSE and the BG/P. The gridding part of imaging software was ported to the Cell and GPU and compared to CPU performance. ➔



First photonic tile demonstrator.

The imaging code was parallelized on Intel multi-core machines with multi-threading and SSE3 vector parallelism. Also part of calibration software was considered for running on the Cell. Finally, tied array beamforming and asynchronous transpose on the Blue Gene / P were looked into.

The picture on page 24 (top) shows the latest acquisition of the DAS-4 experimental computer cluster. This system hosts eight of the fastest Graphical Processing Units (GPUs), one of which is shown here. It is absolutely a number-crunching monster, handling 1300 TFLOPS at only 2400 Watt.

Photonic Tile

The ASTRON technical laboratory plays a leading role in the global R&D of technology for aperture arrays and focal-plane arrays for radio astronomy. At this moment, the receptor tiles used in major projects such as EMBRACE and APERTIF (both related to SKA) are still entirely electronic, but photonic technology is also being explored. The latter is very attractive for application in future radio astronomy systems because of its excellent broadband and high-frequency properties and also its RFI immunity, low weight and small space envelope.

The picture shows our first photonic demonstrator phased-array tile, which was constructed and characterised last year and finalized early this year. By equipping this tile with optical analogue links and an integrated photonic beamformer, broadband signal reception and broadband, true time delay beamforming between 0.5 GHz and 1.5 GHz was realised and demonstrated.

While optical technology holds great promise, it also presents its own challenges. In this first demonstrator tile we had to deal with pronounced optical phase instabilities in the signal paths (i.e. fibres). This was overcome by careful and clever measuring by Klaas Dijkstra. By increasing the integration level in the next generation photonic tile, only well-controlled on-chip optical signal paths will be present in the system. As a result, optical phase instabilities will not occur. In addition, a wider and higher frequency band from 2 GHz to 5 GHz will be used. The photonic technology R&D for this first tile and the next generation photonic tile takes place in the Innovation Subsidy-BPB, the SmartMix-MEMPHIS and the PointOne-SATRAX projects, in collaboration with groups at all Dutch technical universities, TNO, and Lionix BV.

UniBoards ready for shipping.

UniBoard

This year ASTRON successfully finished their part of the UniBoard project for RadioNet FP7 by delivering a digital signal processing board integrated in an active cooled housing with out of the box test firmware for all partners: University of Manchester, INAF, University of Bordeaux, University of Orléans, KASI, Shanghai Observatory, JIVE (overall project lead), and ASTRON.

This board provides as much computing power as will reasonably fit on a printed circuit board (PCB), in the form of a large number of state-of-the-art FPGAs yielding a peak performance of up to 4 Tops (Tera-operations per second). The board communicates with the external world using a large number of high-speed links. UniBoard will serve the online data processing needs of many new RadioNet facilities – in particular it is destined to be a crucial component of future correlators and beamformers required for the WSRT-APERTIF and EVN (JIVE). In addition, it will serve as a Peta-operations test bench for SKA research developments.

The boards as shown in the figure were accompanied with documentation and test firmware which can tests all board interfaces. The written firmware has been setup in a modular way, such that the hurdle for reusing firmware is minimized.

The UniBoard is a complex and high density board. In order to guarantee a high yield board production in large volumes a close cooperation has been setup with Neways in Leeuwarden. By using an iterative process the board design has been improved significantly for production, test and cost. Part of this work was funded by SNN (the Northern Netherlands Provinces). The architecture of UniBoard is designed to enable multiple UniBoards integrated in a subrack for building large complex digital processing systems (funded via ExBox). All boards can be connected to each other via a backplane. The other side of the backplane can be used to plug in receivers boards including A/D converters. In this year the receiver board, backplane and clock board have been designed, produced, tested and integrated. Early October an important milestone was achieved by capturing two analogue input signals from the Analogue-Digital Unit (ADU) board into the 4 GByte (DDR3) memory on the UniBoard. This demo showed that the hardware and the program code (the VHDL) of UniBoard works correctly. This milestone is an important intermediate step in the development of the APERTIF beamformer. →

Applied Radio-Frequency Technology course.

250th student for the ASTRON RF-course

In November, ASTRON welcomed the 250th student for its 3-day course on Applied Radio-Frequency Technology. For several years now, ASTRON/ATH has offered this course to B.Sc. & M.Sc. engineers, most of whom are employed by Dutch SMEs. The course is given by ASTRON engineers, and includes theory and hands-on training. During a small ceremony, ASTRON's director of R&D Dr. Albert-Jan Boonstra memorized the history of the course. It started in March 2002 and is offered twice a year. The lucky 250th participant, Mr Rémon Wilms from Agentschap Telecom, was 'distinguished' with some typical ASTRON-style goodies. The picture shows the ceremony, as well as some moments during the hands-on training, where students are exercising the lessons learned about the Smith-chart, IP2 IP3 and noise figures from an example LNA.

Of course, the success of the course critically depends on the commitment and dedication of ASTRON staff Laurens Bakker (teaching RF fundamentals), Bert Woestenburg (RF-systems), Jan-Wim Eikenbroek (Communication Systems), Wim van Cappellen (Antennas), Jürgen Morawietz and Mark Ruiter (hands-on training), Harm-Jan Stiepel (guided tour to the WSRT, an ultimate RF-system) and Renate van Dalen (administrative support).

LOFAR CEP 2.0 Cluster

In April the LOFAR phase II cluster became operational. Shortly after installation in Groningen the first observations were stored and reduced on the new hardware. We've added some 100 hybrid compute and storage nodes, containing 2448 cores, 6.4 terabyte of main memory and just over 2 petabyte of disk storage to our already impressive list of hardware. The entire cluster is in theory capable of performing just over 20.5x1012 floating point operations very second, four times that of the previous cluster.

This new cluster is designed to handle far greater bandwidths than the previous cluster. With this hardware we should (eventually) be able to handle up to 80 Gbps of data streaming from the Blue Gene/P supercomputer, allowing us to observe with more beams, at higher time resolution and with more frequency bands than previously possible.

The installation of this powerful new cluster has been a vital prerequisite to starting an observing project as big as MSSS, the first LOFAR all-sky servey.

The picture shows the (rather noisy) cluster of 100+ nodes. What can't be shown in pictures is the tremendous amount of work that was done, by personnel from both the University of Groningen and ASTRON, to get the operating system and software working in record time.

LOFAR CEP 2.0 Cluster.

Connected legal entities

ASTRON has three connected legal entities: AstroTec Holding B.V. (ATH), the LOFAR Foundation/Limited Partnership and the International LOFAR Telescope Foundation (ILT).

AstroTec Holding B.V.

ATH is a wholly owned subsidiary of ASTRON to facilitate commercial activities that require a joint venture or private partner. ATH is governed by a small Board of Commissioners who report to the shareholder, ASTRON. In 2011, ATH participated in four companies, all start-ups that originated from ASTRON or LOFAR developments. Unfortunately NoFIQ, developing sensor networked fire fighting systems, had to stop business activities. The company was later restarted with new investors. Filitron, developing RF-ID technology was largely dormant in 2011. DySI, developing software for dynamic system intelligence, has grown considerably in 2011 and closed the year with positive results. Dutch Sigma, developing an optical precision scanner, proceeded well towards a first prototype. ASTRON could make additional investments in Dutch Sigma through a grant from NWO.

In 2011, two RF Courses were given, which were again evaluated very positively by the participants.

In the near future, ATH will be made responsible for the handling of the export and installation of international LOFAR stations, as this is more efficiently done under a private entity.

LOFAR Foundation/Limited Partnership

To develop, operate and exploit the LOFAR sensor network, a Limited Partnership (Dutch: Commanditaire Vennootschap) was established by the partners. The LOFAR Foundation is the sole general partner ('beherend vennoot').

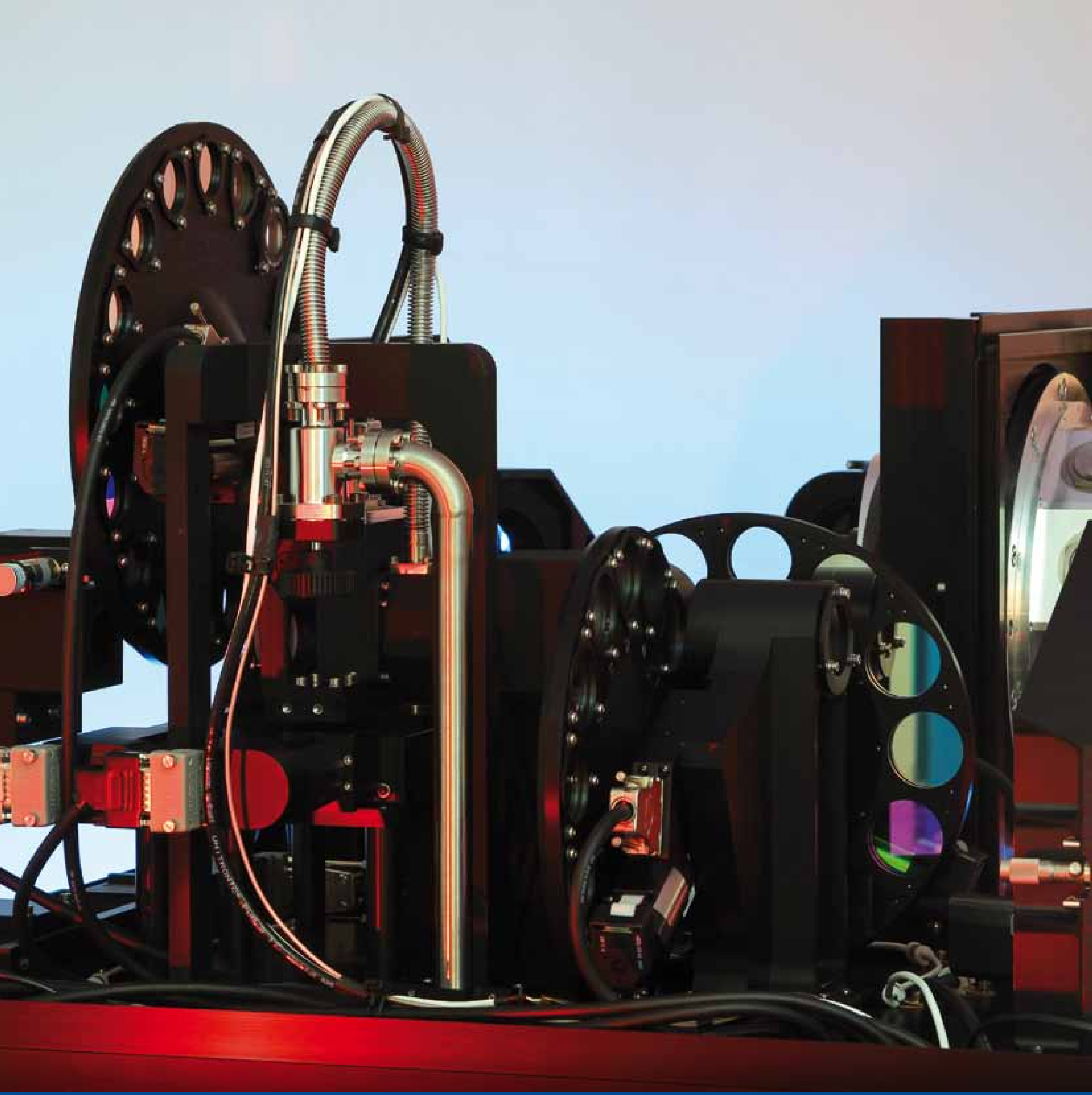
The LOFAR BSIK grant was closed according to plan in 2010. A major task for the LOFAR Foundation was to finalize this grant administratively. This was successfully completed in September. With LOFAR now being an operational entity, the role of the LOFAR Foundation changed. The LOFAR infrastructure will be rented out to commercially to various users, including the ILT. The LOFAR Foundation will handle these contracts, and search for new potential users of the infrastructure. New applications will be developed through the technology transfer offices of the partners.

At the end of 2011, dr. Michiel van Haarlem accepted the position of Interim Director General of the SKA Organisation and stepped back as Managing Director of the LOFAR Foundation. His role was provisionally taken over by dr. Marco de Vos.

International LOFAR Telescope Foundation

The ILT has been established for the operation of LOFAR as a radio telescope. The ILT was founded in November 2010 as a Foundation under Dutch law. International partners joined in June 2011: the German GLOW consortium, the French FLOW consortium, LOFAR-Sweden and LOFAR-UK. All these consortia own one or more LOFAR stations, that are used in connection with the 40 LOFAR stations in the Netherlands and the central computing facilities. The partners share the cost of the central functions in an agreed ratio and support their national stations. ASTRON provides the staff for the central support. The General Director of ASTRON is member of the ILT Board. The ILT Director is seconded from ASTRON, the current Director is dr. René Vermeulen.

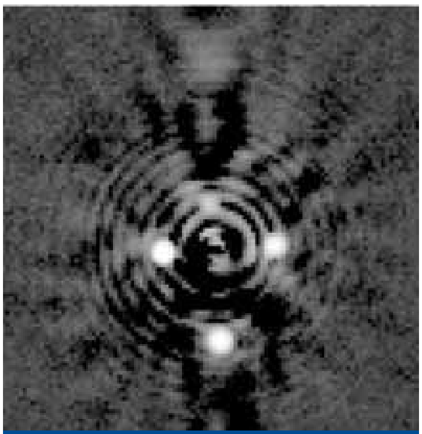
ASTRON headquarters in Dwingeloo, the Netherlands.



NOVA Optical/ Infrared Instrumentation Group

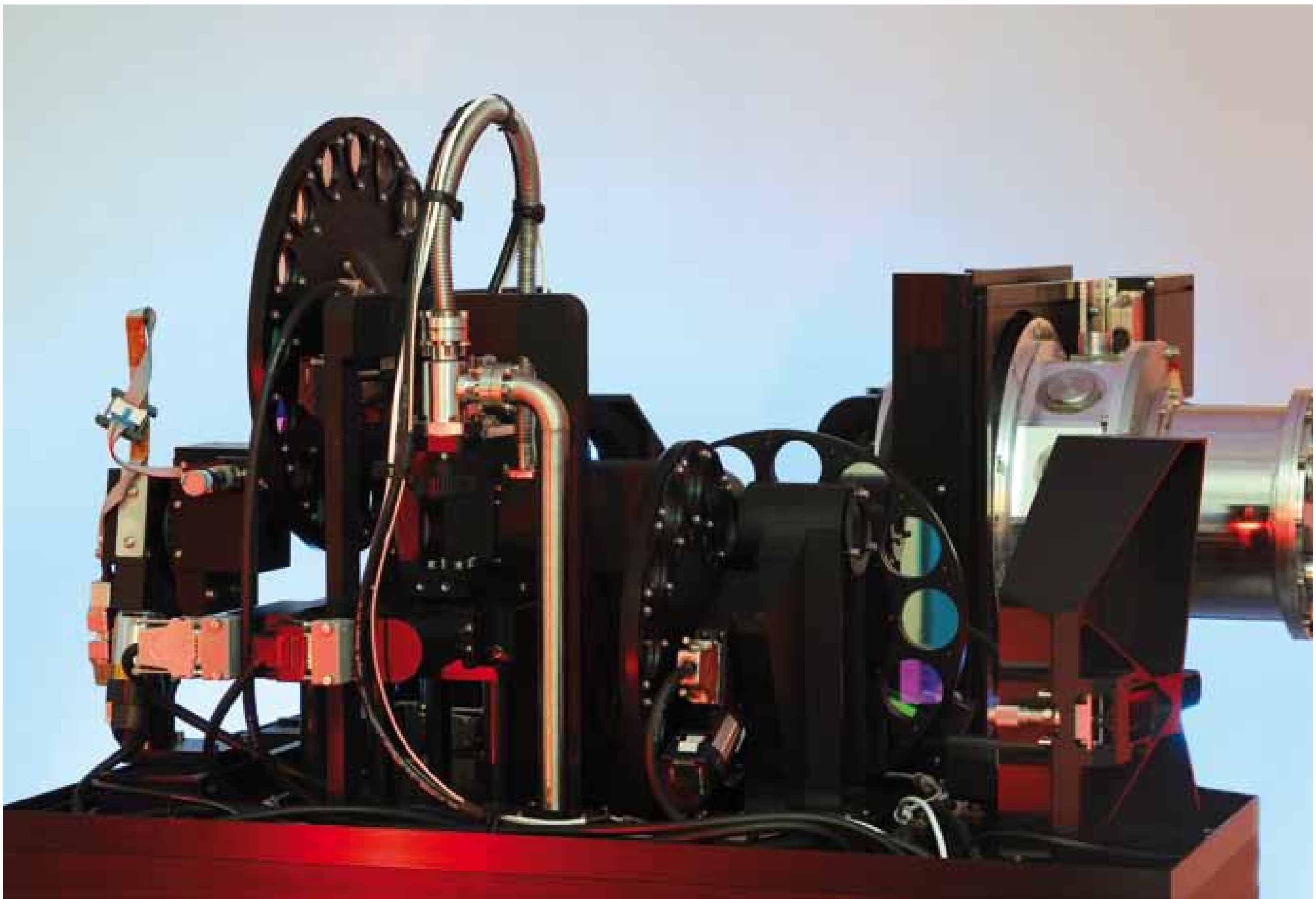
The NOVA Optical / Infrared Instrumentation Group was involved in four of the ten scientific instrumentation concept design studies for the ESO European Extremely Large Telescope. In 2011, six instruments have been formally selected and this includes at least three, possibly all four, of the instruments with Dutch involvement. METIS, the NOVA led Mid Infrared Instrument, is selected as the 3rd scientific instrument on the telescope. At this moment we are still waiting for a formal decision on the construction of the telescope before the instrument projects move to the Preliminary Design Phase. During this period the technology development for METIS continues in a collaboration with several Dutch high tech companies.

NOVA is involved in several Multi Object Spectrographs projects. MOONS and 4MOST were selected by ESO for a concept design study. MOONS is a near infrared expansion or replacement of the VLT Flames-Giraffe multi object spectrograph. 4MOST is an optical all sky survey instrument for either the NTT on La Silla or the VISTA telescope on Paranal. In addition we work on the preliminary design of the WEAVE optical multi object spectrograph for the ING William Hershel Telescope on La Palma.



Differential polarization image of a simulated star-planet system, measured with ZIMPOL system. The simulator uses fiberoptics to insert the image of a star and four planets into the fore optics. In the centre the un-polarized 'star' is suppressed by both the coronagraph and the differential polarization technique of ZIMPOL. The four weak planets, the light of which is polarized, are clearly visible, despite the strong star signal. The 'star' has an intensity of about 107 higher than the four 'planets'. Sky separation of the 'star' to its 'planets' is 70 to 150 mas.

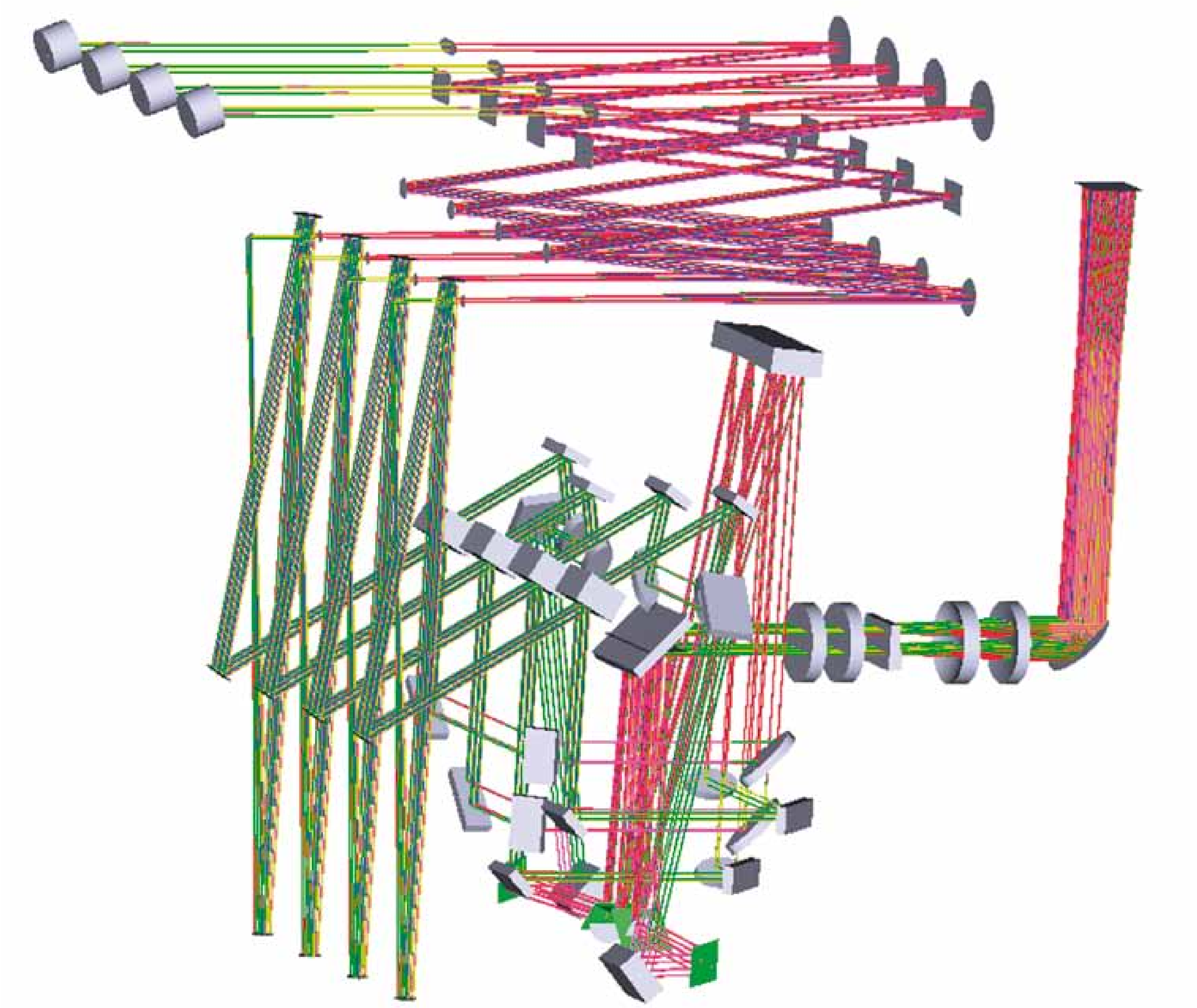
MATISSE is the mid infrared interferometer for the ESO VLTI, combining the light of all four Very Large Telescopes at the same time, creating six baselines and micro-arcsecond angular accuracy. NOVA is responsible for the MATISSE Cryogenic Optics, MPIA (Heidelberg) for the Cryostats, MPIfR (Bonn) for the detectors and data reduction and OCA (Nice) for the warm optics, integration and overall management. →



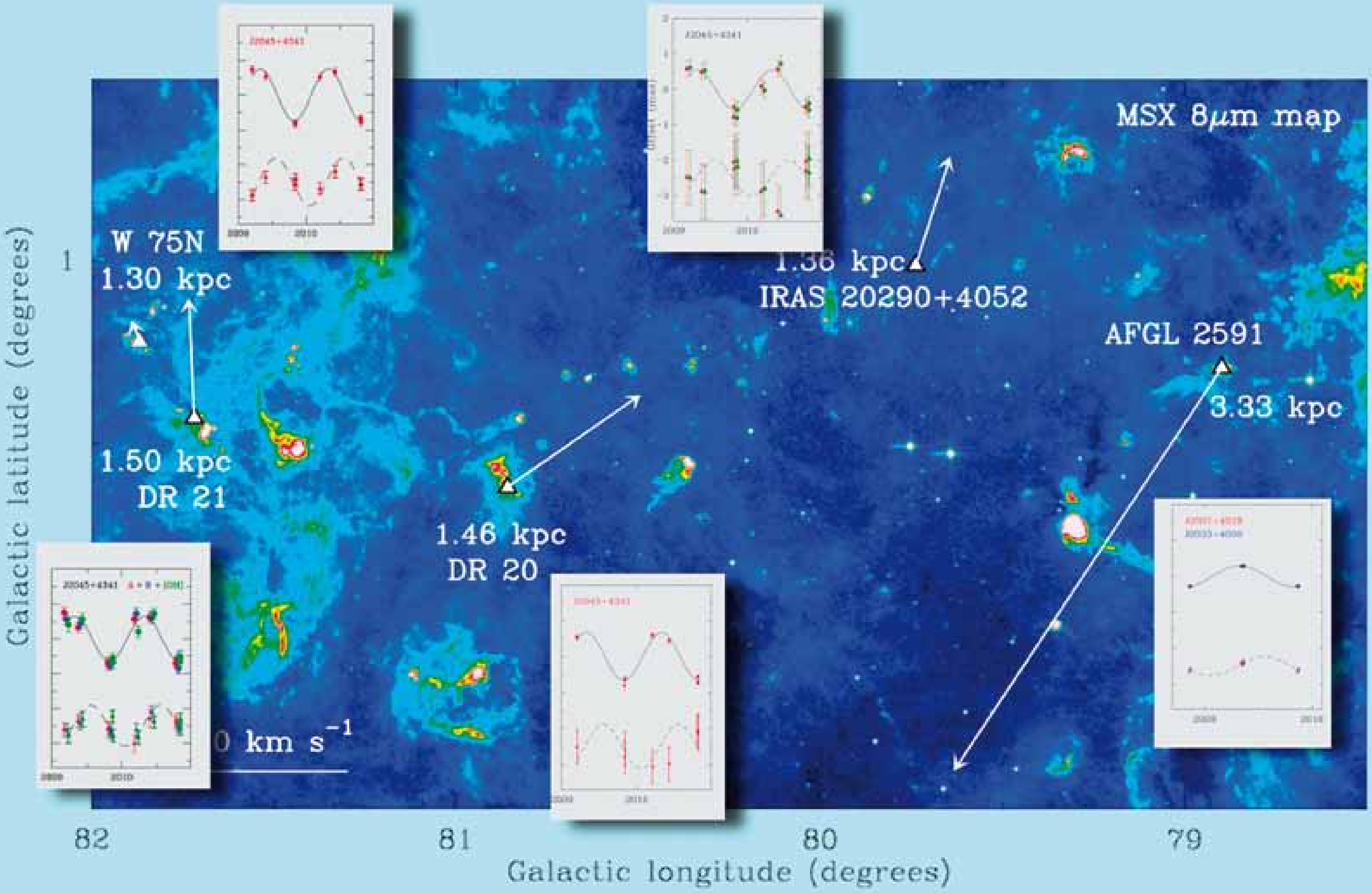
The ZIMPOL instrument without cover, located in the cleanroom at ASTRON for a last overhaul before shipment to Grenoble. Light will enter the instrument from the left, provided by the general optics of SPHERE. Clearly visible are the wheels for filter and polarization components. In the middle a vacuum tube is leading to the FLC, the hart of the instrument. On the right hand side, the cryostat is visible. The two detector CCDs are located in the cryostat.

The MATISSE Cold Optics is a challenging design with hundreds of optical components, ten mechanism for observation modes and dozens of alignment mechanisms all with extreme stability and accuracy requirements situated in a vacuum cryogenic environment. The optical and cryostat final design review is successfully passed in October 2011. A lot of mechanical design effort is now targeted to finalize the design, while procurement of the optics is in full swing and manufacturing of mechanical components has started. This is why MATISSE is the most important project in 2011 in terms of staff effort.

ZIMPOL is a high-precision imaging polarimeter for the SPHERE instrument on the ESO VLT. ZIMPOL operates in the visual range and is based on a differential comparison of the two images by fast modulation with a Ferro-electric Liquid Crystal. Two different polarization directions are measured on the same pixel, allowing for a star-planet contrast of 10-7 to 10-8. Because of this accuracy planets with atmospheres are revealed, as their reflected light is polarized, while starlight is not polarized. The main partners in development of ZIMPOL are ETH (Zürich) and NOVA. In June 2011 the SPHERE management team came to Dwingeloo for review of ZIMPOL and accepted the instrument. In Januari 2012, ZIMPOL was shipped to Grenoble for integration onto the SPHERE platform where it is now being tested in the full system. The instrument will be shipped to the VLT site on Paranal in Chile before the end of 2012 and first light is expected early in 2013.



3D optical layout for the set of four telescope beams inside the MATISSE cold optics. There are two such systems in MATISSE, one for L&M band and one for N band. The four light beams enter the cold optics at the top left corner and end up at the detector in the top right corner.



MSX 8μm map
W 75N
1.30 kpc
1.50 kpc
DR 21
1.46 kpc
DR 20
1.36 kpc
IRAS 20290+4052
AFGL 2591
3.33 kpc
km s^{-1}
Galactic latitude (degrees)
Galactic longitude (degrees)
82
81
80
79
1

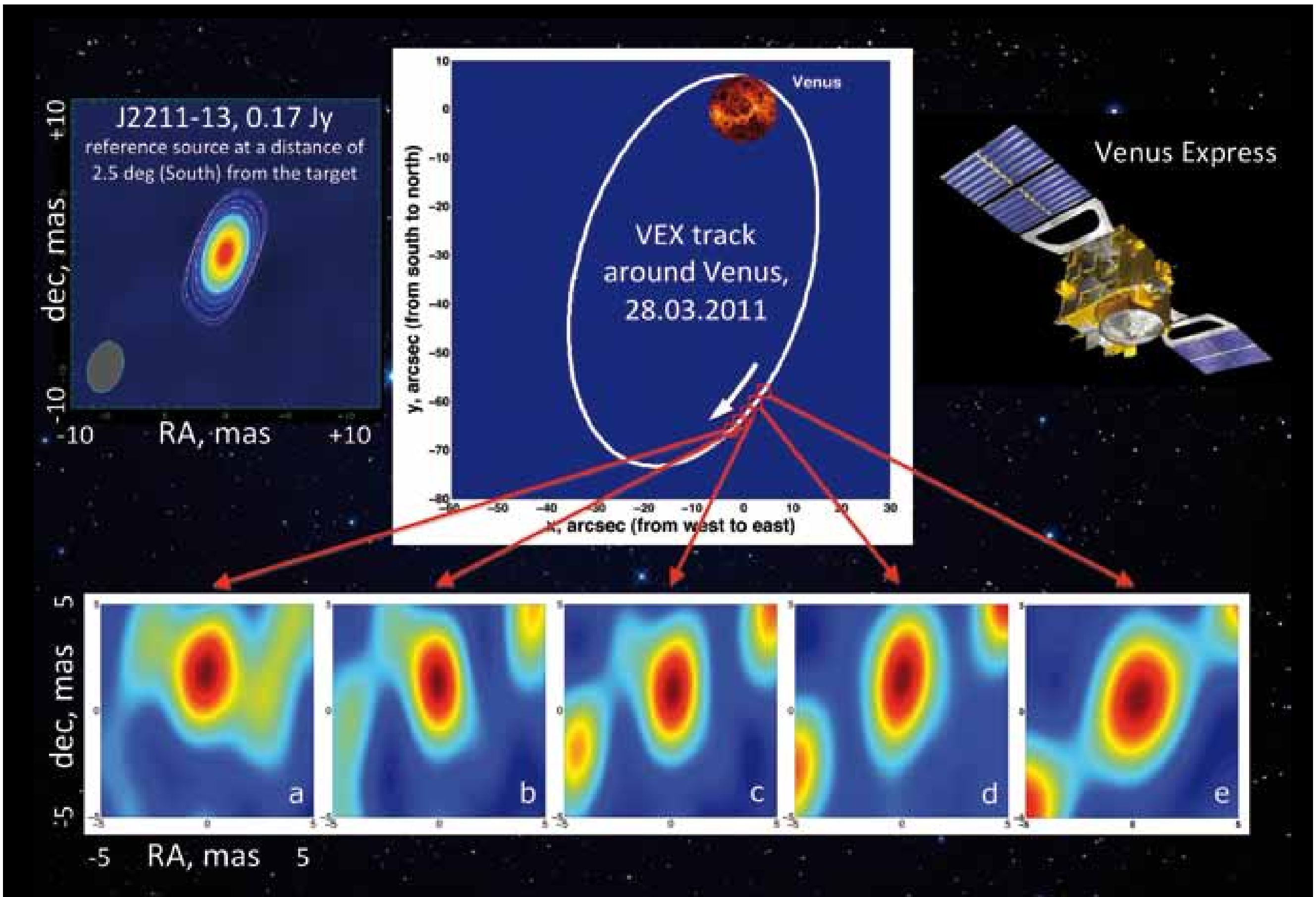
JIVE

The most noticeable change in 2011 at the Joint Institute for VLBI in Europe (JIVE) was the increasing role of the EVN software correlator at JIVE (SFXC) in VLBI operations. Originating from the JIVE spacecraft observing effort, this platform was initially introduced to accommodate special projects that could not be done easily on the MkIV hardware processor. And indeed, there has been quite an interest to do wide-field-of-view imaging, pulsar binning and high spectral resolution processing on the SFXC. Additionally, the results of the first tests of new VLBI equipment at the telescopes were obtained on the SFXC, considerably improving the sensitivity by capturing data at 2 and 3 Gbps. Moreover, it has accommodated an increasing variety of near-field VLBI observations of planetary spacecraft. JIVE collaborates with international partners to facilitate such experiments in order to enhance the science return of current and future space missions, like the BepiColombo mission to Mercury or possible missions to the Jovian system or near-Earth asteroids. The same technique can also be used to get accurate orbital parameters of the RadioAstron space telescope, which was successfully launched into orbit in July 2011.

In addition to such special projects, the flexibility and the robustness of the software correlator proved to be an important asset for dealing with regular operations. After doubling of the hardware configuration, the SFXC platform started to be the correlator of choice for the majority of experiments correlated at JIVE.

In the longer term, JIVE plans to commission a correlator based on the UniBoard concept, developed through a JIVE-led RadioNet research activity. In 2011, the first prototype was delivered. As part of the follow-up EC FP7 RadioNet3 programme, UniBoard2 will investigate even more powerful and energy efficient solutions for future correlator and beam-forming applications, for example in the SKA.

These correlator initiatives have a strong synergy with JIVE's on-going push to make e-VLBI a more robust, flexible and sensitive technique. This effort is subsidised by the EC through the FP7 NEXPReS project that had its first successful yearly review in mid-2011. A highlight for the NEXPReS participants and all e-VLBI operators around the world was the global e-VLBI meeting in South Africa. The meeting and its location were particularly suitable in view of the local ambitions to develop an African VLBI Network based on decommissioned communication dishes in various African countries. ➔



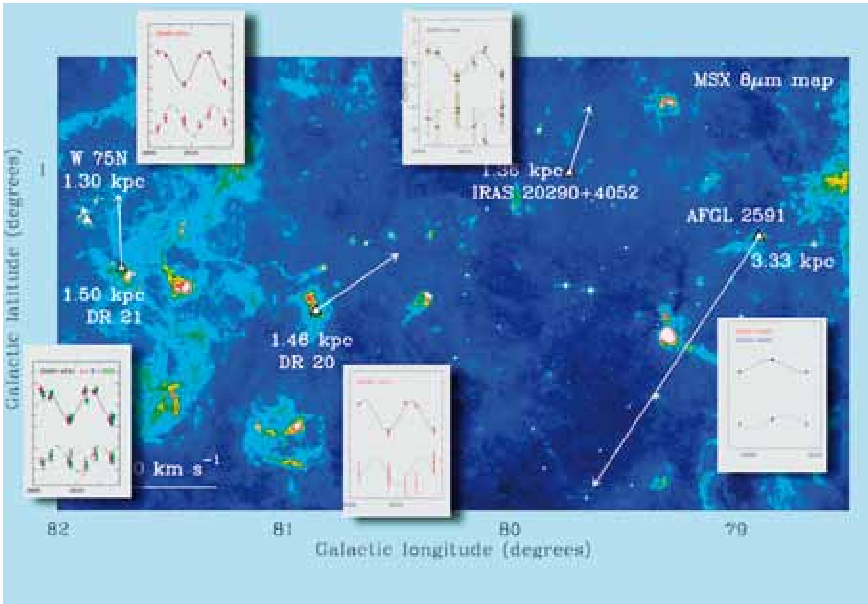
Accurate VLBI observations of the Venus Express spacecraft X-band radio signal demonstrate the capabilities of obtaining spacecraft state-vectors with unsurpassed accuracy (Duev et al. 2012, accepted by A&A).

Participants at the 10th international e-VLBI workshop at Amanzingwe near Johannesburg, South Africa.

All these technological advances are important ingredients of JIVE's view on the future of VLBI. In anticipation of the planned review by external experts in early 2012, JIVE management focused on drafting its vision for the next 5-year funding cycle and beyond. The most important element in this is the specific science programme, addressing fundamental astronomical questions at the highest possible resolution, particularly in synergy with other SKA pathfinders. The JIVE partners have discussed in 2011 how the success of JIVE can contribute to the structuring of European radio astronomy.

The review panel was of course also presented with the science output of the EVN and the JIVE staff. The productivity of the JIVE staff was very tangible in 2011 with three JIVE students (Nikta Amiri – Leiden; Linjie Chen – Bejing; Kalle Torstensson – Leiden) receiving their PhD. But of course it is really the science output of the EVN users that counts, as it is JIVE's primary mission to deliver the best possible data, ready for further astronomical analysis. In 2011 JIVE processed 95 user experiments. Through the advent of e-VLBI this number has been steadily increasing over the last few years. And, although the operations team is faced with an increasing operational complexity, it maintains a perfect track record in delivering flawless data.

It was particularly pleasing to see that EVN results in the literature cover a very wide range of astronomical topics: from the sub-parsec dynamics and magnetic fields around high-mass young stars to the distance scales in our Galaxy, stellar black holes and neutron stars, supernovae in local galaxies, AGN throughout the universe and gravitational lensing at cosmological distances.



Parallaxes of methanol masers in the Cygnus X region demonstrate that notably AFGL2591 is not at the same distance. Therefore it is demonstrated that these star forming regions do not belong to the same large-scale structure in the local spiral arm (Rygl et al. 2012, A&A 539 79).

Outreach and Education

At the end of 2010, a coordinator for education and diversity joined ASTRON. A new programme was set up for high schools and primary schools, which allowed students to visit ASTRON and get to know the institute inside and out. The coordinator also helped shape our diversity strategy and in the process made the committee itself more diverse. Many educational activities took place in 2011, and of course the larger public wasn't left out either.

The summer students of 2011.

Visitors

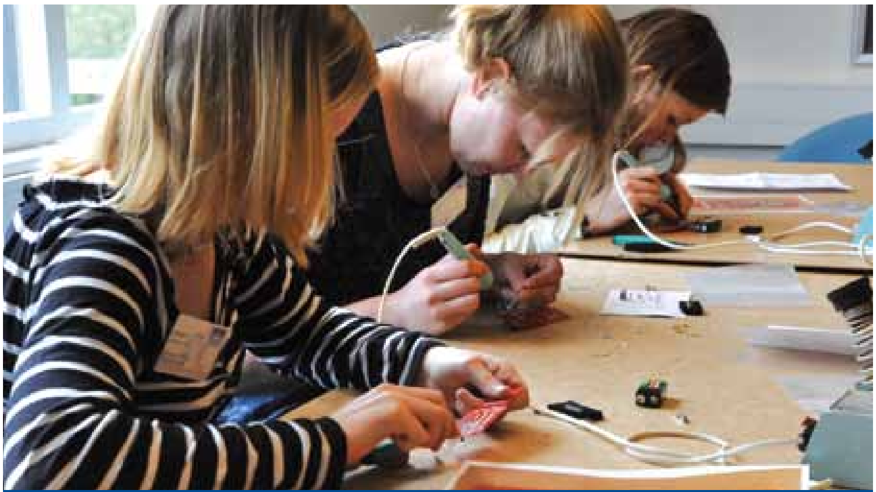
In 2011, six students participated in our International Summer Student Programme (photo on the top right). This was a truly multicultural mix of students, with participants from Croatia, Ireland, Germany, Hungary, Indonesia, Australia and China.

Many other astronomers have visited ASTRON for a variety of activities, in particular connected with LOFAR commissioning. In addition, Dr. Tao An from Shanghai Astronomical Observatory, has spent one year sabbatical at ASTRON. We also had three long-term visits as part of the Helena Kluyver female visitor programme; two of them (Prof. Renee Kraan-Korteweg and Dr. Lakshmi Saripalli) have spent their time at ASTRON as part of their sabbatical.

Tom Oosterloo (on the left, senior astronomer) shows people what hides inside the black boxes on the LOFAR field, during the open day of the EU with the theme 'Europe around the corner'.

Outreach activities

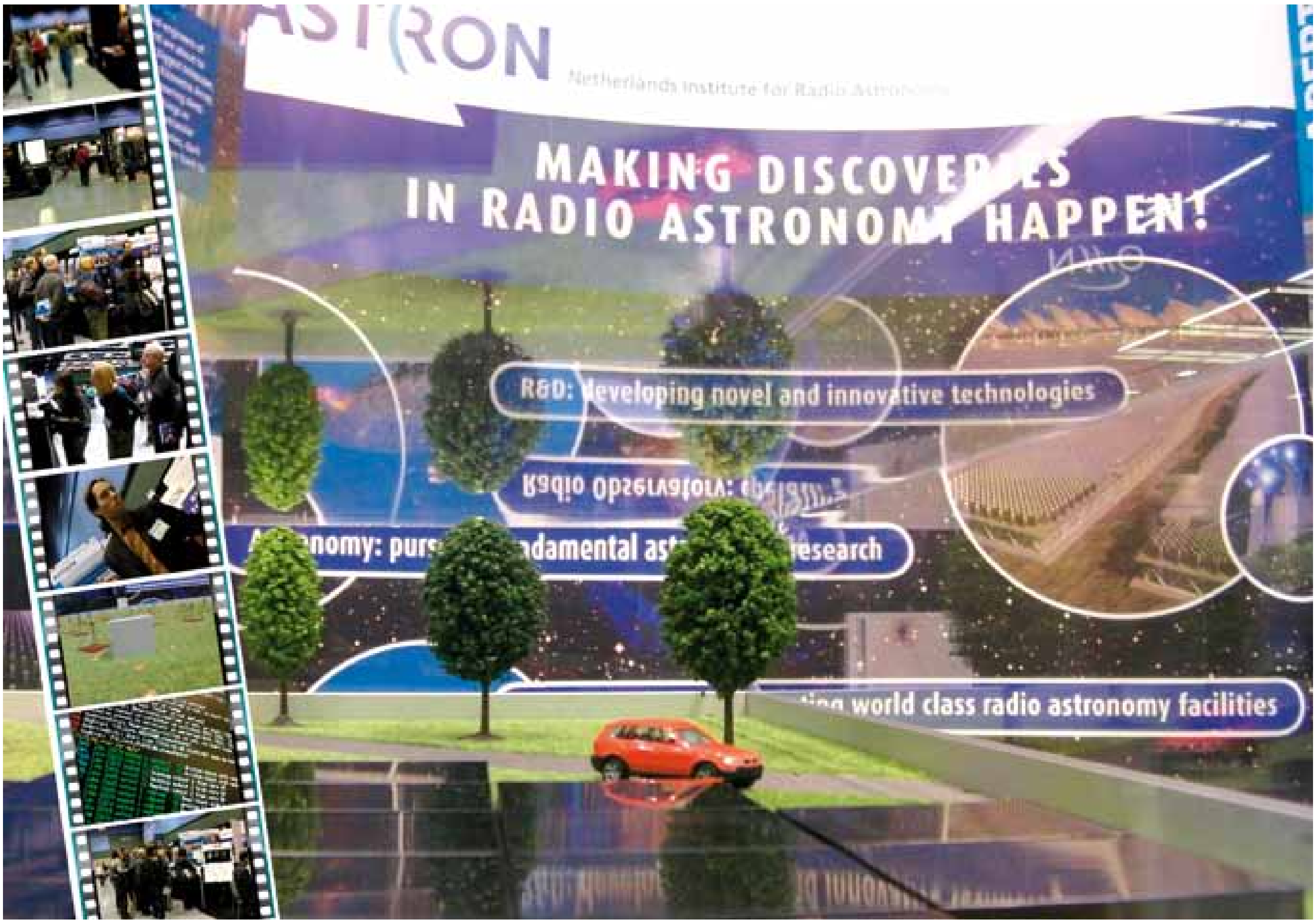
On the 10th of July, the LofarTafel (www.lofarzone.nl) organised 'LOFARdag'- an opportunity to explain the various aspects of the LOFAR project to the local community around Exloo, Borger and the surrounding area. ASTRON was well represented with Albert-Jan Boonstra, Peter Benemma talking to the 600+ people that visited the LOFAR fields, and Roy Smits bravely manning the hugely popular NOVA planetarium show.



Girls soldering LOFAR lights at the Girlsday.

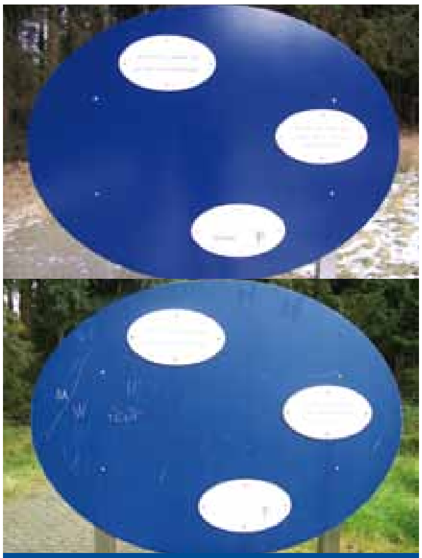
The ASTRON booth (photo below) at the 2011 Seattle AAS meeting not only showcased the LOFAR scale model, it even featured live LOFAR observing. The meeting of the American Astronomical Society is the largest annual astronomy meeting in the world, with about 3000 participants.

Many of those checked out or stopped by the ASTRON booth. We provided information on the R&D and astronomy at ASTRON and on the current status of LOFAR, APERTIF and SKA related work. The LOFAR scale model and the information on our summer student programme especially drew a lot of interest.



Albert-Jan Boonstra, director of the R&D department a.i., explains visitors about the LOFAR telescope.

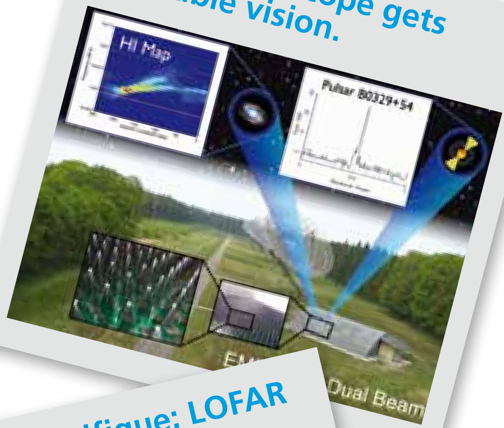
In 2011, the Milky Way path, a 2 km long scale model of the Solar System with its planets, that leads up to the Westerbork Synthesis Radio Telescope, was renewed. The differences between the old and new blue signs are clearly visible as can be seen on the photo's below! All the windows of the glass cabinets have been replaced as well.



Below: one of the old damaged boards on the Milky Way path. Above: the same board, renewed.

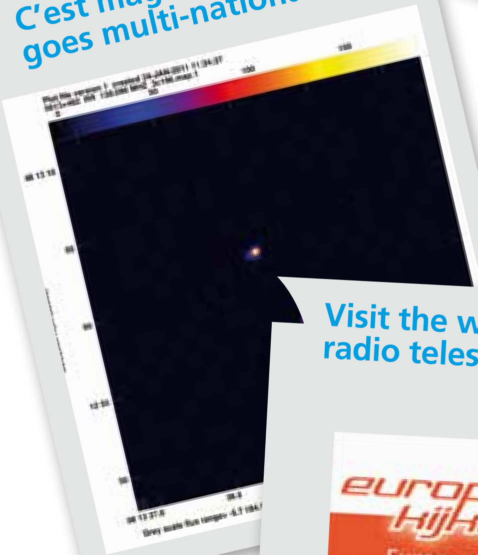
New glass was placed on the cabinets on the Milky Way path.

Radio telescope gets double vision.



New monitoring facility ready for European navigation system.

C'est magnifique: LOFAR goes multi-national.

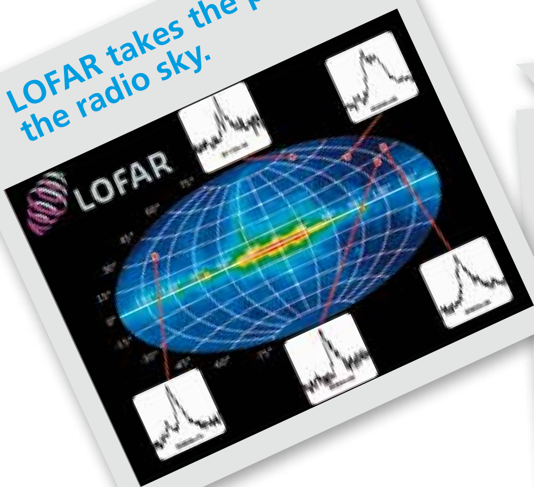


LOFAR makes deeper images of Universe than ever before.

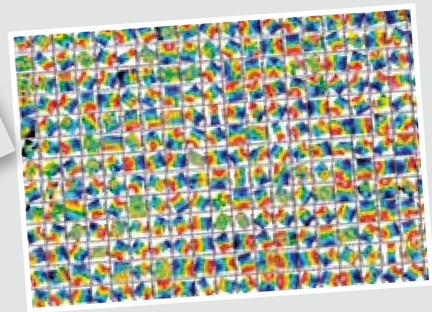
Visit the world's biggest radio telescope on 15 May.

International partners join forces for SKA telescope.

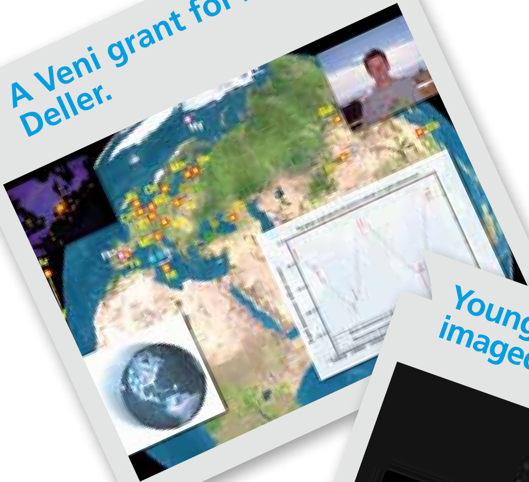
LOFAR takes the pulse of the radio sky.



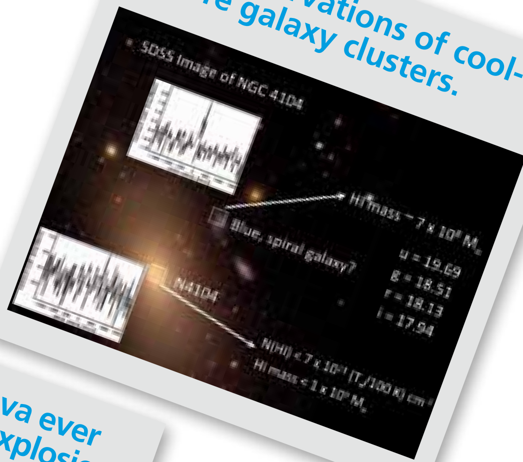
The ATLAS3D project: Replacing handle of Hubble's tuning fork.



A Veni grant for Adam Deller.

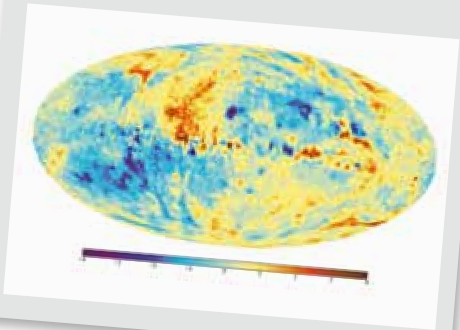


HI observations of cool-core galaxy clusters.

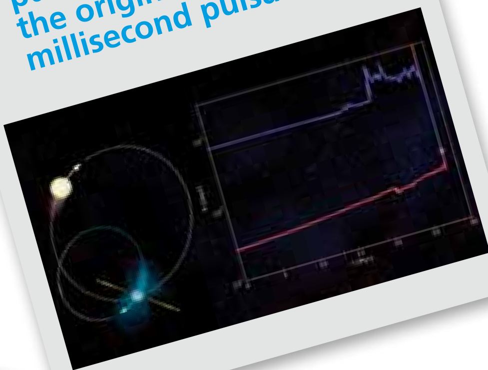


Youngest supernova ever imaged just after explosion.

New all-sky map shows magnetic fields at highest precision.

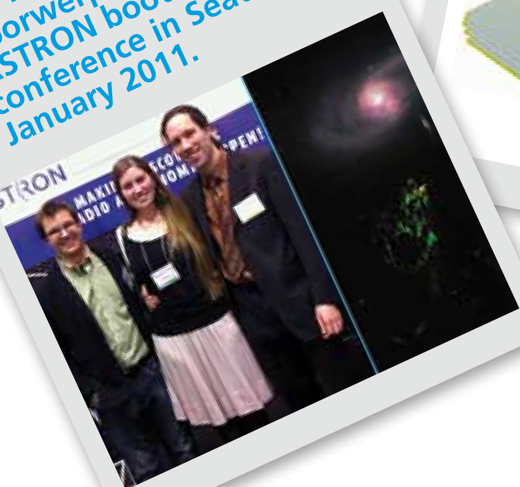


The formation of the eccentric-orbit millisecond pulsar J1903+0327 and the origin of single millisecond pulsars.

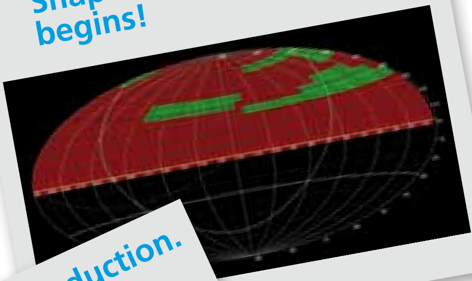


Meet EMMA (Embrace multiple for astronomy), the next generation Aperture Array for the SKA-MID-frequencies.

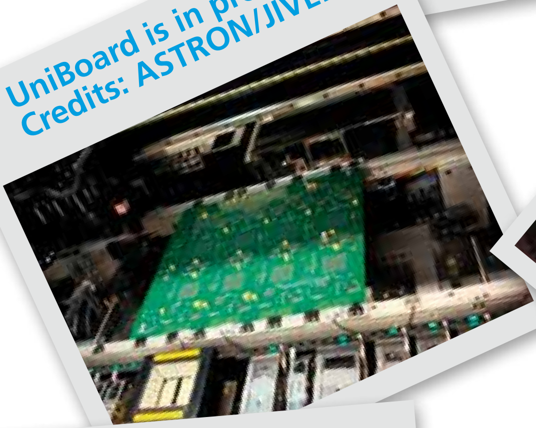
Hanny van Arkel, the teacher who discovered the mysterious Hanny's Voorwerp, visited the ASTRON booth at the AAS conference in Seattle, January 2011.



MSSS (Multifrequency Snapshot Sky Survey) begins!



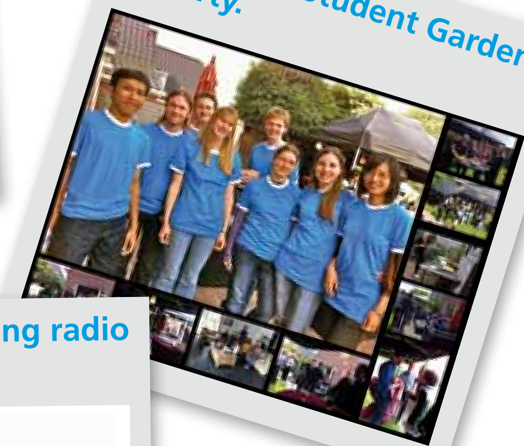
UniBoard is in production. Credits: ASTRON/JIVE.



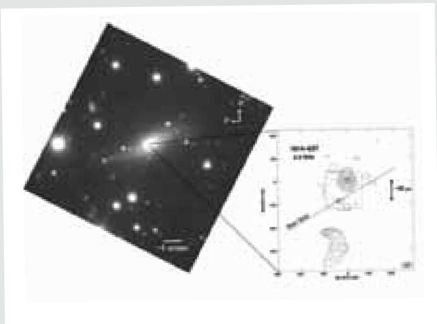
Water vapour reveals how stars form around black hole.

The Netherlands signs up for SKA.

Summer Student Garden Party.



An impostor among radio galaxies.



In alle stilte speuren naar het heelal

Botsende sterrenstelsels maken schokgolf aan straling zichtbaar
Sync 27-01-2011
Voor het eerst hebben sterrenkundigen de straling waargenomen die vrijkomt wanneer enorme clusters van sterrenstelsels tegen elkaar botsen. Reinout van Weeren, promovendus aan de Universiteit Leiden, publiceerde er onlangs over in Science. Het leven van een sterrenkundige gaat niet altijd over rozen. Je zit in een vliegtuig op weg naar een bergtop in een uithoek van de wereld, om daar wekenlang 's nachts observaties te doen.
Syne

Groningse megatelescoop actief
OOG Radio en Televisie 02-02-2011
2 februari 2011 15:26 Sterrenkundigen van de Rijksuniversiteit Groningen hebben voor het eerst gebruik kunnen maken van hun nieuwste speelgoed, de supertelescoop LOFAR. LOFAR is een revolutionaire radiotelescoop die bestaat uit vele duizenden kleine antennes, die verspreid staan opgesteld in heel Noord-Nederland. De antennes zijn gekoppeld aan een supercomputer die op het Zernikecomplex staat.
OOG Radio en Televisie

'Concert is ode aan de stilte in het heelal'

EXASCALE
JÜLICH
Superrechner ermöglicht digitales Radioteleskop

Geschenk valt uit de hemel

The 1000-Kilometer Wide Telescope That'll Look Back at the Beginning of Time

De livegeboorte van een radiopulsar

Astron: 'Windmolenpark funest voor LOFAR'

Astron vreest invloed windpark op radiotelescoop

January

26 January 2011
SKA-NL Industry Day

Representatives of large industry like IBM, Siemens and NXP and SMI's like Neways and many others visited the SKA-NL industry day at ASTRON.

27 January 2011
Society for Physics Teachers

February

03 February 2011
Hondsrug College, Emmen (high school)

17 February 2011
HBO students Technical Physics, Enschede

March

15 March 2011
Mayor and aldermen, Westerveld

16 March 2011
Astronomy students and LappTop students (University of Leiden)

28 March 2011
Pleinschool Helder, Eindhoven

31 March 2011
Primary school 'de Kloostertuin', Assen (Leonardo department)

April

07 April 2011
Northern Netherlands Provinces (SNN) and ambassadors from Estonia, Latvia, Poland, Germany, Denmark, Sweden

14 April 2011
Girlsday

Group photo of the girls and ASTRON staff who participated in girlsday 2011.

18 April 2011
Primary school 'de Kloostertuin', Assen (Leonardo department)

18 April 2011
Drenthe Club of 100 of the political party VVD

20 April 2011
Astrophysics & Cosmology class (Amsterdam University College)

21 April 2011
Gymnasium, Kurgan & Nieuwe Veste, Coevorden. Exchange project for high school students with Dutch and Russian schools

One of the students 'carrying' a Westerbork dish!

May

09 May 2011
Presentation high school 'RSG', Ter Apel. Exchange project for high school students with Dutch and German students. →

The high school students listen to Peter Bennema, LOFAR Nature project leader, explaining about the LOFAR antennas in the field near Exloo.

27 May 2011
Physics and astronomy students (University of Nijmegen)


Technology Transfer Officer Ronald Halfwerk (right) explains the students about aperture array technology.

June

08 June 2011
Final round of the Dutch Physics Olympiad (University of Groningen/High school students)

17 June 2011
City of Emmen

August

19 August 2011
Delegation Committee of Wise Men Knowledge and Innovation

29 August 2011

September

27 September 2011
Visit Society Industry Press


Albert-Jan Boonstra, director of the R&D department, explains the Society for Industry Press about the LOFAR telescope.

October

3-7 October 2011
NOVA fall school

26 October 2011
De Maatschappij

November

02 November 2011
State Committee Province of Drenthe

Appendix 1:
Financial summary

Financial report 2011

Financial report 2011 compared with 2010

		2011 Budget	2011 Actual	2011 Difference	2010 Actual
REVENUES					
Government Grants-Ministry of Education, Culture & Science		11.988.896	11.190.309	798.587	10.858.446
Subsidies / Contributions		4.938.678	18.013.218	-13.074.540	6.758.684
Release to provision		0	412.370	-412.370	591.707
Other Income		337.000	487.381	-150.381	447.021
Cash management		20.000	114.992	-94.992	42.824
	Subtotal	*17.284.574*	*30.218.270*	*-12.933.696*	*18.698.682*
Results Subsidiaries					
Subsidiary ATH		0	10.954	-10.954	0
	Subtotal	*0*	*10.954*	*-10.954*	*0*
Special Income					
Special Income		0	217.006	-217.006	149.304
	Subtotal	*0*	*217.006*	*-217.006*	*149.304*
Total Income		**17.284.574**	**30.446.230**	**-13.161.656**	**18.847.986**
EXPENDITURES					
Grants / Expenditures					
Operations		16.005.922	14.826.316	-1.179.606	15.195.447
Allocation to Projects		pm	-7.281.282	-7.281.282	-7.870.304
Projectcosts		1.211.000	22.896.109	21.685.109	10.472.704
	Subtotal	*17.216.922*	*30.441.143*	*13.224.221*	*17.797.847*
Results Subsidiaries					
Subsidiary ATH		0	0	0	7.448
	Subtotal	*0*	*0*	*0*	*7.448*
Other Expenditures					
Other Expenditures		0	40.930	40.930	37.393
	Subtotal	*0*	*40.930*	*40.930*	*37.393*
Total Expenditures		**17.216.922**	**30.482.073**	**13.265.151**	**17.842.688**
BALANCE		**67.652**	**-35.843**	**103.495**	**1.005.298**

Appendix 2: Personnel highlights

The Helena Kluyver programme for female visitors continued to be successful. In 2011 an additional programme was started to enable young people with work disabilities to build up experience.

Sharing staff

In 2011 we intensified our efforts to get staff collaborations with other institutes and universities. ASTRON wants to actively connect to university groups, and to participate in international projects like the SKA. This is also important to broaden the view and increase the experience of our staff. Several shared appointments and secondments were realized, both on national and international level.

Increasing diversity

As an institute of NWO, ASTRON is fully committed to the charter 'Talent to the Top', with the ambition to increase the number of female employees and the female participation in committees and boards. In 2011, the procedures for hiring processes were updated accordingly. Finding female candidates especially for technical functions remains an issue though. By organizing girls-days and school visits, we interest girls for technical and scientific careers. However, this does not improve our gender balance on the short term!

A healthy organisation

In 2011, the absenteeism was 2,8%. This is a further decrease compared to 2010 (3,6%) and 2009 (3,7%).

The evaluation panel congratulated ASTRON with the level of openness and communication in the organization. Nevertheless ASTRON continues to work on improving communication, in particular in giving and receiving feedback.

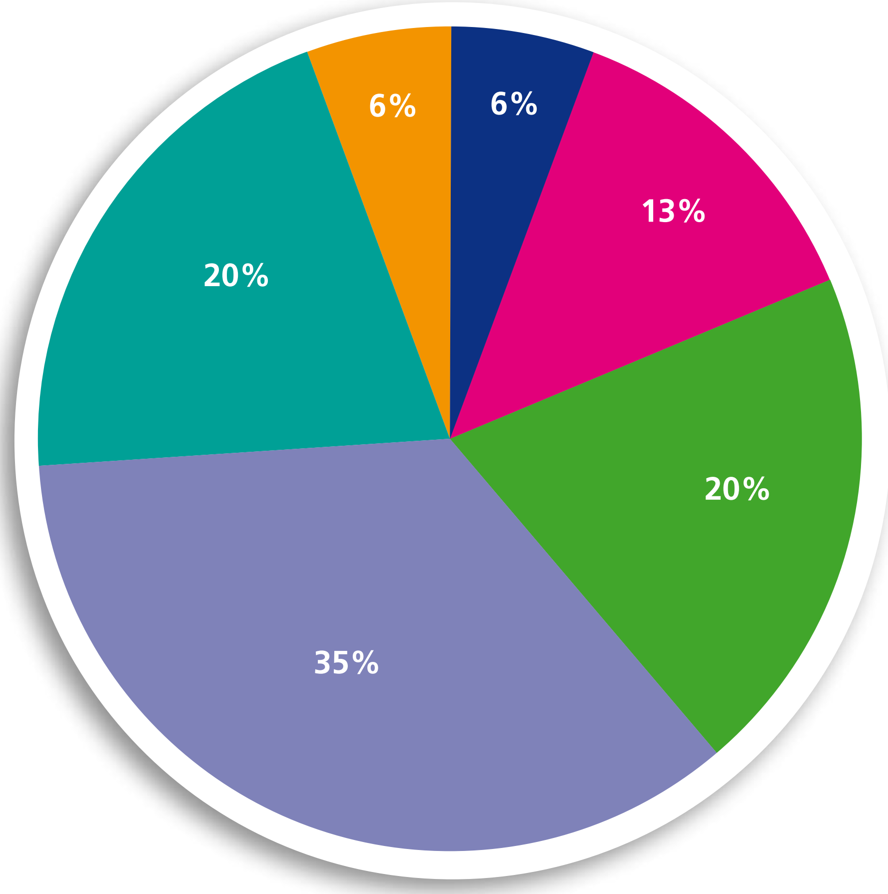
Number of employees

Department	Number of people
Directorate and Staff	9
Astronomy	21
Radio Observatory	31
Research & Development	55
General affairs	32
NOVA*	9
Total	157

*NOVA, the Dutch research school for astronomy, is a separate entity but all personnel of the NOVA/ Infrared group is employed by ASTRON (NWO).

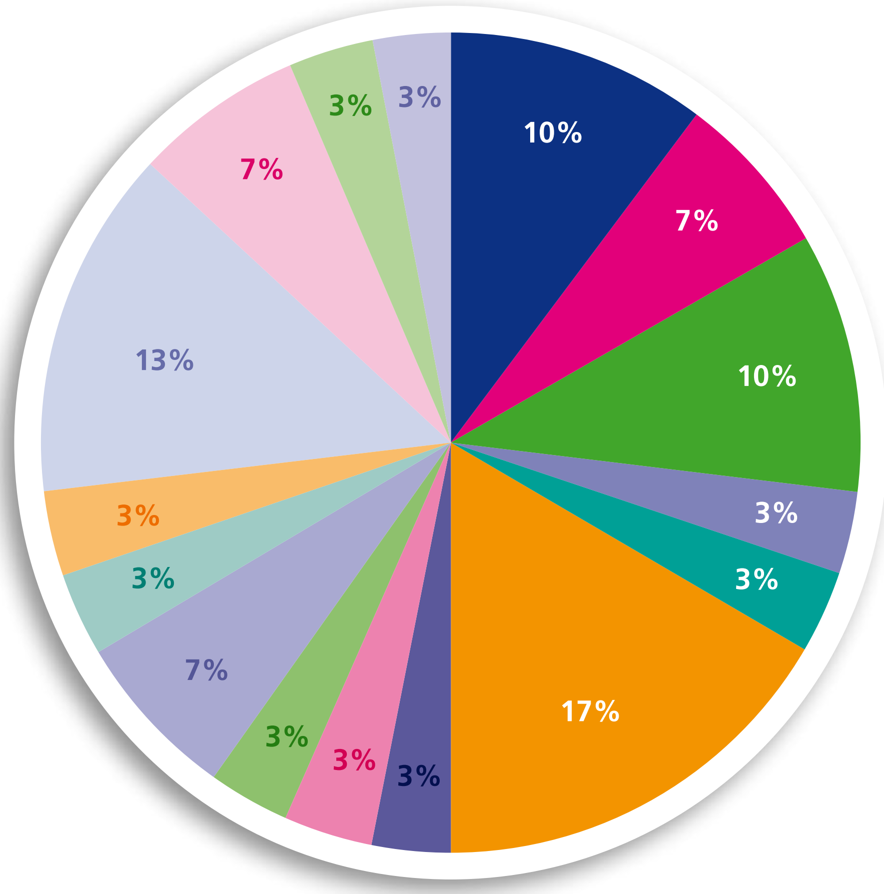
Personnel per department 2011

- Management and Staff
- Astronomy Group
- Radio Observatory
- Research & Development
- General Affairs
- NOVA*



Nationalities at ASTRON 2011

- American
- Australian
- British
- Canadian
- Iranian
- Italian
- Croatian
- Romanian
- Chinese
- German
- Greek
- Hungarian
- Indian
- Russian
- Spanish
- Sri lankan



Appendix 3: Board, Committees and Staff

Board members

Prof. K. Gaemers *(chair)*
Prof. dr. ir. J.A.M. Bleeker, *Wassenaar*
Prof. dr. J.T.M. de Hosson, *University of Groningen*
Drs. S.B. Swierstra, *Assen*
Mw. Prof. dr. J.C.M. van Eijndhoven, *The Hague*
Mw. Drs. J.P. Rijsdijk, *Leiderdorp*

Members of the Science Advisory Committee

Prof. dr. J.H. van Gorkom, *Columbia University*
Dr. D.R. DeBoer, *CSIRO-ATNF*
Dr. L.V.E. Koopmans, *Kapteyn Institute*
Dr. J. Ulvestad, *NRAO*
Prof. dr. J.L. Jonas, *Rhodes University*
Prof. dr. H.J.A. Röttgering, *Radio Observatory Leiden*
Dr. J. Vink, *University Utrecht*
Prof. dr. R.A.M.J. Wijers, *University of Amsterdam*

Members of the WSRT Program Committee

Prof. P. Biermann
Dr. D. Gabuzda
Dr. J. Kaastra
Dr. U. Klein
Prof. dr. M. Kramer
Dr. T. Oosterloo
Dr. I. Prandoni
Prof.dr. T. van der Hulst
Prof.dr. G Woan

Directorate

Michael Garrett, *Scientific director/ Director General*
Marco de Vos, *Managing director/Deputy Director General*

Staff functions

Diana van Dijk, *Management assistant*
Truus van den Brink-Havinga, *Office manager*
Michiel van Haarlem, *Interim Director General SKA Organisation*
Arnold van Ardenne, *Coordinator ASTRON SKA Program Office*
Femke Boekhorst, *PR & Communications officer*
Marja Carnal – v.d. Spek, *Secretary*
André van Es, *Project manager European projects*
Arno Gregoor, *Employee general affairs*

Human Resources and Internal Communications

Diana Verweij, *Head HR&IC*
Carin Lubbers, *HR assistant*
Erika Timmerman, *HR officer*
Marianne Wielink-Strating, *HR assistant*

Finance, Planning & Control

Janneke Wubs-Komdeur, *Head FP&C*
Ingrid Arling, *Assistant FP&C*
Emmy Boerma, *Project controller*
Anne Doek, *Assistant FP&C*
Roelof Kiers, *Support assistant technical documents*
Bertine Kok-Winters, *Financial administrative assistant*
Anno Koster, *Purchasing administrative assistant*
Karin Spijkerman-Hogenkamp, *Project controller*

ICT support

Roelof Boesenkool, *Head of ICT*
Marc Luichjes, *System and network support*
Merijn Martens, *ICT assistant*
Jan Slagter, *System and network support*
Klaas Stuurwold, *Senior officer ICT*

Facilities

Anne Veendijk, *Head of Facilities*
Alex Benjamins, *Technical support*
Henk Bokhorst, *Security*
Pieter Jager, *Warehouse keeper*
Roelie Kremers, *Telephone operator/ receptionist*
Derk Kuipers, *Building and terrain*
Ina Lenten-Streutker, *Secretary*
Fritz Möller, *Facilities coordinator*
Miranda Vos, *Telephone operator/ receptionist*
Henk Vosmeijer, *Application and system administrator*
Albert Wieringh, *Security*

Astronomy Group

Raffaella Morganti, *Head of Astronomy*
Megan Argo, *Research assistant**
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Ilse van Bemmel, *PostDoc*
Alicia Berciano Alba, *PostDoc*
Annette de Boer-Arts, *Coordinator Education and Diversity*
Ger de Bruyn, *Senior astronomer*
Adam Deller, *Staff astronomer**
Liesbet Elpenhof, *Secretary*
Neeraj Gupta, *PostDoc*
George Heald, *Junior scientist*
Jason Hessels, *Staff astronomer*
Vibor Jelic, *PostDoc*
Vlad Kondratiev, *Pulsar PostDoc*
Joeri van Leeuwen, *Staff astronomer*
John McKean, *PostDoc*
Raymond Oonk, *PostDoc**
Tom Oosterloo, *Senior scientist*
Maura Pilia, *PostDoc Pulsar & transient science**
Paolo Serra, *PostDoc*
Mike Sipior, *Astronomical software support coordinator*
Marjan Tibbe, *Office manager*
Valeriu Tudose, *PostDoc*
Michael Wise, *Associate scientist* →

Research and Development

Albert-Jan Boonstra, *Head of R&D a.i.*
Alexander van Amesfoort, *HPC software engineer**
Michel Arts, *Antenna Researcher*
Laurens Bakker, *RF System engineer*
Pieter Benthem, *Instrument engineer*
Mark Bentum, *Senior scientist DESP*
Jan Geralt Bij de Vaate, *Senior Project Manager*
Patricia Breman, *Office manager*
Raymond van den Brink, *Instrument engineer Mechanics*
Chris Broekema, *HPC Researcher*
Wim van Cappellen, *Head Antenna Group*
Arthur Coolen, *Software Design engineer*
Renate van Dalen-Bremer, *Secretary*
Sieds Damstra, *Design engineer*
Ger van Diepen, *Software System engineer*
Marco Drost, *Instrument engineer mechanics*
Albert van Duin, *Support engineer*
Nico Ebbendorf, *Head of Technical support*
Benedetta Fiorelli, *Antenna Design Engineer**
Marchel Gerbers, *Reliability engineer*
André Gunst, *System engineer*
Ronald Halfwerk, *Technology Transfer Officer*
Hiddo Hanenburg, *Instrument engineer mechanics*
Jan Idserda, *Head Mechanics Workshop*
Dion Kant, *Head System design & integration*
Koos Kegel, *Senior RF engineer*
Eric Kooistra, *System engineer DESP*
Anne Koster, *Project support engineer*
Sjouke Kuindersma, *Support engineer Mechanics*
Marcel Loose, *Software System engineer*
Peter Maat, *System researcher Photonics*
Jürgen Morawietz, *RF Instrument engineer*
Eim Mulder, *Support engineer*
Jan Nijboer, *Project support engineer*
Ronald Nijboer, *Head of Computing*
Jan Noordam, *Senior software engineer*
Ruud Overeem, *Instrument engineer software*
Arash Owrang, *PHD researcher**
Vishambhar Nath Pandey, *Researcher**
Harm-Jan Pepping, *Design engineer DESP**
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Raj Thilak Rajan, *Digital signal processing engineer*
John Romein, *System researcher Software*
Mark Ruiter, *RF Instrument engineer*
Gijs Schoonderbeek, *Instrument engineer DESP*
Oleg Smirnov, *Researcher Software*
Niels Tromp, *Instrument engineer Mechanics*
Lars Venema, *Senior researcher*
Klaas Visser, *RF Instrument engineer*
Erik van der Wal, *RF Instrument engineer*
Stefan Wijnholds, *Researcher*
Ronald de Wild, *Instrument engineer DESP*
Roel Witvers, *RF Instrument engineer*
Bert Woestenburg, *Head of RF & low noise systems*
Sarod Yatawatta, *Researcher Software**
Sjouke Zwier, *Design engineer DESP*

Radio Observatory

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Ashish Asgekar, *Support scientist*
Michiel Brentjens, *Researcher Science support*
Pieter Donker, *ICT/Software engineer*
Liesbet Elpenhof, *Secretary*
Wilfred Frieswijk, *Support scientist**
Teun Grit, *ICT/Software engineer*
Peter Gruppen, *Support engineer electronics*
Hanno Holties, *System engineer*
Alwin de Jong, *ICT/Software engineer*
Gyula Józsa, *Support scientist*
Wouter Klijn, *Software engineer**
Geert Kuper, *Operator*
Hans van der Marel, *System engineer*
Rebecca McFadden, *Support scientist*
Henri Meulman, *Hardware engineer*
Rob Millenaar, *System engineer (SKA Project Office)*
Jan David Mol, *ICT/Sofware engineer*
Harm Munk, *Head of Technical Operations*
Menno Norden, *System engineer*
Roberto Pizzo, *Support scientist*
Antonis Polatidis, *Head of Science Support*
Jan-Pieter de Reijer, *Hardware engineer*
Adriaan Renting, *ICT/Sofware engineer*
Arno Schoenmakers, *ICT/Software engineer*
Jurjen Sluman, *Operator*
Roy Smits, *Support scientist**
Harm-Jan Stiepel, *Hardware engineer*
Jan Stolt, *Cryogenic support engineer*
Yuan Tang, *Operator*
Marjan Tibbe, *Office manager*
Nico Vermaas, *ICT/Software engineer*

NOVA Optical/IR Instrumentation Group

Ramon Navarro Y Koren, *Groupleader*
Tibor Agócs, *Instrument engineer**
Eddy Elswijk, *Hardware engineer*
Menno de Haan, *Support engineer*
Rik ter Horst, *Instrument engineer*
Jan Kragt, *Design engineer*
Gabby Kroes, *Instrument engineer*
Ronald Roelfsema, *System engineer*
Menno Schuil, *Support engineer*

**New employee in 2011*

Appendix 4: Publications

Astronomy Group and Radio Observatory

Astronomical publications in refereed journals 2011

1. P. Abreu, ..[128 authors collapsed].., **H. Falcke** and [372 authors collapsed] : *Search for ultrahigh energy neutrinos in highly inclined events at the Pierre Auger Observatory*, 2011, Physical Review D, 84, 122005

2. R. Mittal, C. P. O'Dea, G. Ferland, **J. B. R. Oonk**, A. C. Edge, R. E. A. Canning, H. Russell, S. A. Baum, H. Böhringer, F. Combes, M. Donahue, A. C. Fabian, N. A. Hatch, A. Hoffer, R. Johnstone, B. R. McNamara, P. Salomé, G. Tremblay: *Herschel observations of the Centaurus cluster - the dynamics of cold gas in a cool core*, 2011, Monthly Notices of the Royal Astronomical Society, 418, 2386-2402

3. Slavko Bogdanov, Anne M. Archibald, **Jason W. T. Hessels**, Victoria M. Kaspi, Duncan Lorimer, Maura A. McLaughlin, Scott M. Ransom, Ingrid H. Stairs: *A Chandra X-Ray Observation of the Binary Millisecond Pulsar PSR J1023+0038*, 2011, The Astrophysical Journal, 742, 97

4. P. Abreu, ..[127 authors collapsed].., **H. Falcke** and [364 authors collapsed] : *The Lateral Trigger Probability function for the Ultra-High Energy Cosmic Ray showers detected by the Pierre Auger Observatory*, 2011, Astroparticle Physics, 35, 266-276

5. M. Cappellari, E. Emsellem, D. Krajnovic, R. M. McDermid, N. Scott, G. A. Verdoes Kleijn, L. M. Young, K. Alatalo, R. Bacon, L. Blitz, M. Bois, F. Bournaud, M. Bureau, R. L. Davies, T. A. Davis, P. T. de Zeeuw, P.-A. Duc, S. Khochfar, H. Kuntschner, P.-Y. Lablanche, **R. Morganti**, T. Naab, **T. Oosterloo**, M. Sarzi, **P. Serra**, A.-M. Weijmans: *ATLAS3D project. I. (Cappellari+, 2011)*, 2011, VizieR Online Data Catalog, 741, 30813

6. J. Aleksic, ..[101 authors collapsed].., **M. Pilia** and [55 authors collapsed] : *Observations of the Crab Pulsar between 25 and 100 GeV with the MAGIC I Telescope*, 2011, The Astrophysical Journal, 742, 43

7. Paul P. van der Werf, **A. Berciano Alba**, M. Spaans, A. F. Loenen, R. Meijerink, D. A. Riechers, P. Cox, A. Weiß, F. Walter: Water Vapor Emission Reveals a Highly Obscured, Star-forming Nuclear Region in the QSO Host Galaxy APM 08279+5255 at z = 3.9, 2011, The Astrophysical Journal Letters, 741, L38

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Richard M. McDermid, Maxime Bois, Frédéric Bournaud, Michele Cappellari, Roger L. Davies, Pierre-Alain Duc, P. Tim de Zeeuw, Eric Emsellem, Sadegh Khochfar, Harald Kuntschner, Pierre-Yves Lablanche, **Raffaella Morganti**, Thorsten Naab, **Tom Oosterloo**, Nicholas Scott, Anne-Marie Weijmans: The ATLAS3D project - X. On the origin of the molecular and ionized gas in early-type galaxies, 2011, Monthly Notices of the Royal Astronomical Society, 417, 882-899

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J. Blümer, H. Bozdog, I. M. Brancus, P. Buchholz, S. Buitink, E. Cantoni, A. Chiavassa, K. Daumiller, V. de Souza, P. Doll, R. Engel, **H. Falcke** and [41 authors collapsed]: *New measurements of cosmic ray air showers with the digital radio interferometer LOPES*, 2011, Astrophysics and Space Sciences Transactions, 7, 303-306

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31. B. H. C. Emonts, R. P. Norris, I. Feain, G. Miley, E. M. Sadler, M. Villar-Martín, M. Y. Mao, **T. A. Oosterloo**, R. D. Ekers, J. B. Stevens, M. H. Wieringa, K. E. K. Coppin, C. N. Tadhunter: *CO observations of high-z radio galaxies MRC 2104-242 and MRC 0943-242: spectral-line performance of the Compact Array Broadband Backend*, 2011, Monthly Notices of the Royal Astronomical Society, 415, 655-664

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A. Bulgarelli, F. Gianotti, M. Trifoglio, A. Chen, A. Giuliani, S. Mereghetti, P. Caraveo, F. Perotti, F. D'Ammando, E. Del Monte, Y. Evangelista, M. Feroci, F. Lazzarotto, L. Pacciani, P. Soffitta, E. Costa, I. Lapshov, M. Rapisarda, A. Argan, G. Pucella, S. Sabatini, A. Trois, V. Vittorini, F. Fuschino, M. Galli, C. Labanti, M. Marisaldi, G. Di Cocco, A. Pellizzoni, **M. Pilia**, G. Barbiellini, F. Longo, E. Moretti, E. Vallazza, A. Morselli, P. Picozza, M. Prest, P. Lipari, D. Zanello, P. W. Cattaneo, A. Rappoldi, C. Pittori, P. Santolamazza, P. Giommi, L. Salotti, G. Valentini: *Gamma-ray activity of the blazar PKS 0402-362 detected by AGILE*, 2011, The Astronomer's Telegram, 3658, 1

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2. **Gyula I. G. Józsa**, François Combes, Ken C. Freeman: *Warps and Accretion*, 2011, IAU Symposium, 277, 71-74

3. **George Heald**, John Allan, Laura Zschaechner, Peter Kamphuis, Rich Rand, **Gyula Józsa**, Gianfranco Gentile, François Combes, Ken C. Freeman: *The Westerbork HALOGAS Survey: Status and Early Results*, 2011, IAU Symposium, 277, 59-62

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Publications for a wide audience:

Ger de Bruyn, contribution to Govert Schilling's article on 'The Epoch of Reionization', in Sky and Telescope

Other research output:

1. Joeri van Leeuwen, radio show 'Spijkers met Koppen', 16 April
2. Raffaella Morganti, Astronomy & Astrophysics Review Board of Editors.

Research & Development

Refereed journal publications 2011

1. Hellbourg, G., Weber, R., Capdessus, C., Boonstra, A.J., "Cyclostationary approaches for spatial RFI mitigation in radio astronomy", Comptes Rendus Physique, Vol. 13, Issue 1, pp. 71-79

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(*): on Thomson Reuters list

Appendix 5: Earning capacity

The long-term strategy of ASTRON assumes that the base-budget received from NWO can be doubled by attracting additional grants, contracts and subsidies.

In the period of 2005-2011, ASTRON has been executing several large subsidies that were secured before 2005, in particular the 52M€ BSIK grant (2003-2010) and 22M€ SNN grant (2004-2009) for LOFAR development and roll-out, plus the Optical/IR instruments MIRI (3.8M€) and XShooter (1.7M€).

During the period of of 2005-2010, ASTRON secured 34,7M€ of new funding. In 2011, ASTRON secured 3,9M€ of new funding. These contracts were generated through investment subsidies, innovation subsidies, EC programmes, research grants and (semi-) commercial contracts. The average contract duration is three years.

Investment grants

Two large investment subsidies (NWO-G program) were granted, both for Phased Array Feed systems for the WSRT. APERTIF covered the actual front-end systems, APROPOS the correlator, archive and e-Science environment. Three smaller investment subsidies (NWO-M) were granted for the installation of a well-founded photonics lab, for the development of a fast signal processing board, ExBox (PI JIVE) and for the DAS-4 computer cluster (PI VU Amsterdam).
In addition to the LOFAR BSIK and SNN grants, funding was secured from various sources to turn the LOFAR Core area into a Nature Reserve, which contributed also to the acquisition and preparation of the fields. International LOFAR partners raised funding for the acquisition of their own national LOFAR stations.

Innovation subsidies

Two large innovation subsidies were granted from regional funding (the so-called 'Peaks in the Delta' programme, implemented by the collaboration of the Northern provinces, SNN). One of these, SKA North-Netherlands (SKA-NN) develops Smart Antennas (Aperture Arrays) for the SKA and permits the Netherlands to continue to play a leading role in this field. The other project, Target (PI University of Groningen) studies innovative approaches to storage and archiving, and will permit further development of the LOFAR Long Term Archive, properly integrating it in the Virtual Observatory and the Grid. Several smaller grants funded activities on antenna production techniques and photonic beam-forming.

In all these programmes there is a close collaboration with industrial partners. These activities are of mutual benefit for all concerned: the companies are exposed to and are involved in innovative technologies and designs, ASTRON staff are exposed to industrial methods and mass-manufacturing.

European programmes

ASTRON coordinated the EC FP6 SKA Design Study (SKADS) and the EC FP7 RadioNet Integrating Activity. SKADS permitted Europe to organise itself for the SKA in developing technology demonstrators, in particular, EMBRACE. RadioNet is the de facto European network for radio astronomical institutes and university departments. It has proven so successful that it was one of the few integrating activities that was awarded a follow-up grant also under the latest FP7 follow-up round. ASTRON participates in this RadioNet3 project through networking activities, trans-national access to the WSRT and LOFAR, and three Joint Research Activities.

ASTRON is a major partner in the EC FP7 Preparatory Action for the SKA (PrepSKA), which is primarily used to fund the SKA Project Development Office (hosted by the U. of Manchester). ASTRON is a partner in the FP6 EXPReS and FP7 NEXPReS integrating activities led by JIVE – these have realized real-time VLBI observations over glass fibre and studied innovative storage and correlation techniques. ASTRON is also a major partner in the ERC Advanced Researcher fellowship granted to Prof. R. Weijers (University of Amsterdam).

Research grants

Particular attention has been spent in attracting to ASTRON young talented astronomers that could compete for individual grants like the NWO Innovational Research Incentives Scheme (Vernieuwingsimpuls, VENI, VIDI, VICI) and the ERC grants. This has turned out to be spectacularly successful with three VENI and one VIDI grant acquired by members of the group in the last 3 years, as well as two Marie-Curie reintegration grants. These grants permitted the activities of the Astronomy Group to ramp-up more quickly than we could have hoped for, and this has enabled us to achieve the critical-mass that has been crucial in pushing forward the scientific exploitation of LOFAR.
R&D staff secured an NWO STARE grant (ASTROStream), a NWO Rubicon grant and a Swedish VINMER grant (antenna technology), and participated in four STW research proposals in the past six years. These research grants permitted the institute to enhance its impact in the area of fundamental and applied research. In addition, these initiatives further embed ASTRON in several key national and international research networks. In 2011, two VENI grants were secured and the TOP program from prof. Ger de Bruyn started up.

(Semi-)Commercial activities.

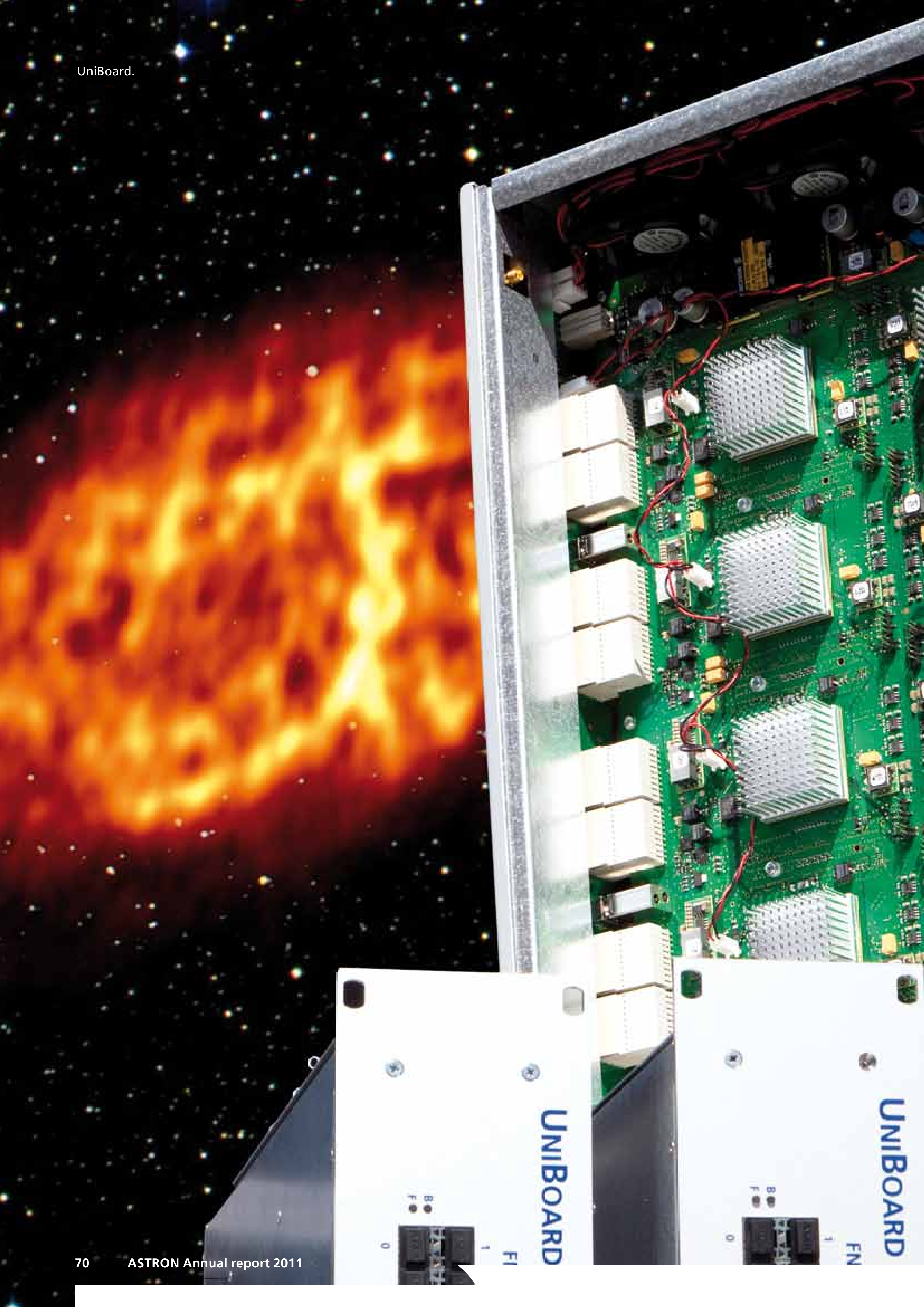
After NOVA took over responsibility of the Optical/IR Instrumentation group, any additional ASTRON involvement in NOVA projects has to be considered as a semi-commercial activity. Since NOVA was involved in four E-ELT instrument studies, additional FTEs were made available by ASTRON. The ASTRON involvement in SPHERE (a pre-2007 commitment) has also been included under work for NOVA. ASTRON and industrial partners secured a contract for Galileo monitoring using the WSRT telescope (GALSEE SMF). ➔

This gave the prospect of making one of the WSRT dishes available on a commercial basis. Unfortunately, the Netherlands gave insufficient priority to the contract for monitoring in the operational phase, which accordingly was granted to a German party. ASTRON is still negotiating with ESTEC and the Netherlands Space Office for a bilateral contract. ESA contracts are both an important component of the technology transfer strategy of the institute, and a way of increasing the critical mass in the technology program.

Over 2005-2011, ASTRON was involved in more than 35 small-scale contracts with industrial partners. These activities provide a small but welcome addition to the institute's budget. However, their main purpose is to facilitate the transfer of technology and knowledge from the ASTRON laboratories to the market place and society at large. Other mechanisms are available to facilitate these kinds of valorization efforts, especially the formation of strategic collaborations associated with large development projects. However, small commercial collaborations and contracts allow ASTRON to serve a large number of SME companies that benefit from brief interactions with our experts and facilities.

Appendix 6: Abbreviations

A&A Astronomy & Astrophysics
AA Aperture Array
AAS American Astronomical Society
AAVP Aperture Array Verification Programme
ADC Analog to Digital Converter
AG Astronomy Group
AGN Active Galactic Nuclei
APERTIF APERture Tiles In Focus, a focal plane array upgrade project for the WSRT
APROPOS A back-end (correlator) project complementing APERTIF
ASTRON Netherlands Institute for Radio Astronomy
ATH ASTROTEC Holding Company
BSIK Decision Subsidies Investment Knowledge Infrastructure
DAS-4 The Distributed ASCI Supercomputer 4
DIGESTIF An APERTIF focal plane array demonstrator project
EC European Commission
E-ELT European Extremely Large Telescope
EMBRACE European Multi-Beam Radio Astronomy Concept - a dense aperture array
demonstrator
EoR Epoch of Reionisation
ESA European Space Agency
ESO European Southern Observatory
ESTEC European Space Research and Technology Centre
EVN European VLBI Network
EXPReS Express Production Reliable e-VLBI Services
FERMI LAT: FERMI Large Area Telescope
FP6 The Sixth Framework Programme of the European Commission
FP7 The Seventh Framework Programme of the European Commision
FPGA Field Programmable Gate Array
FTE Full Time Equivalent; the effort expended by one full time employee
GALSEE SMF Galileo satellite monitoring with the WSRT telescope
GPU Graphical Processing Unit
GRB Gamma-ray bursts
HI Neutral Hydrogen
IAC International Astronautical Congress
IAU International Astronomical Union
ICT Information and Communication Technology
IEEE Institute of Electrical and Electronics Engineers
ILT International LOFAR Telescope
IR InfraRed
ISM Interstellar Matter
JIVE Joint Institute for VLBI in Europe
LMXB Low Mass X-ray Binary
LNA Low-noise amplifier
LOFAR Low Frequency Array
MEMPHIS Merging Electronics and Micro and nano-Photonics
MFFE Multi-Frequency Front-End
MHz Megahertz
MIRI Infrared camera and spectrometer for the James Webb Space Telescope
MNRAS Monthly Notices of the Royal Astronomical Society
MSP Millisecond Pulsar
NEXPReS Novel EXplorations Pushing Robust e-VLBI Services
NL The Netherlands
NOVA Netherlands Research School for Astronomy (collaboration of five Dutch universities)
NWO Netherlands Organisation for Scientific Research
NWO-G NWO Large investment programme
NWO-M NWO Medium investment programme
OCW Ministry of Education, Culture and Science
PAF Phased Array Feed
PCB Printed Circuit Board
PEP Pre-Execution Plan
PhD Doctor of Philosophy
PrepSKA International project for the SKA preparatory phase funded by the EC (FP7)
PSR Pulsar
R&D Research and Development
RadioNet EC integrating activity bringing together radio observatories in Europe (FP7)
RF Radio Frequency
RF course
RFI Radio Frequency Interference
SAC Science Advisory Committee
SKA Square Kilometre Array
SKADS SKA Design Study
SME Small and Medium Enterprises
SNN Joint Collaboration Northern Netherlands
SPDO SKA Program Development Office
SPHERE Spectro-Polarimetric High-contrast Exoplanet Research
SPIE International society for optics and photonics
STW Foundation for Technical Science
URSI International Union of Radio Science
VINMER Swedish Individual Researcher Grant
VLBA Very Long Baseline Array
VLBI Very Long Baseline Interferometry
VLT Very Large Telescope
VLTI VLT Interferometer
WHT William Herschel Telescope
WSRT Westerbork Synthesis Radio Telescope



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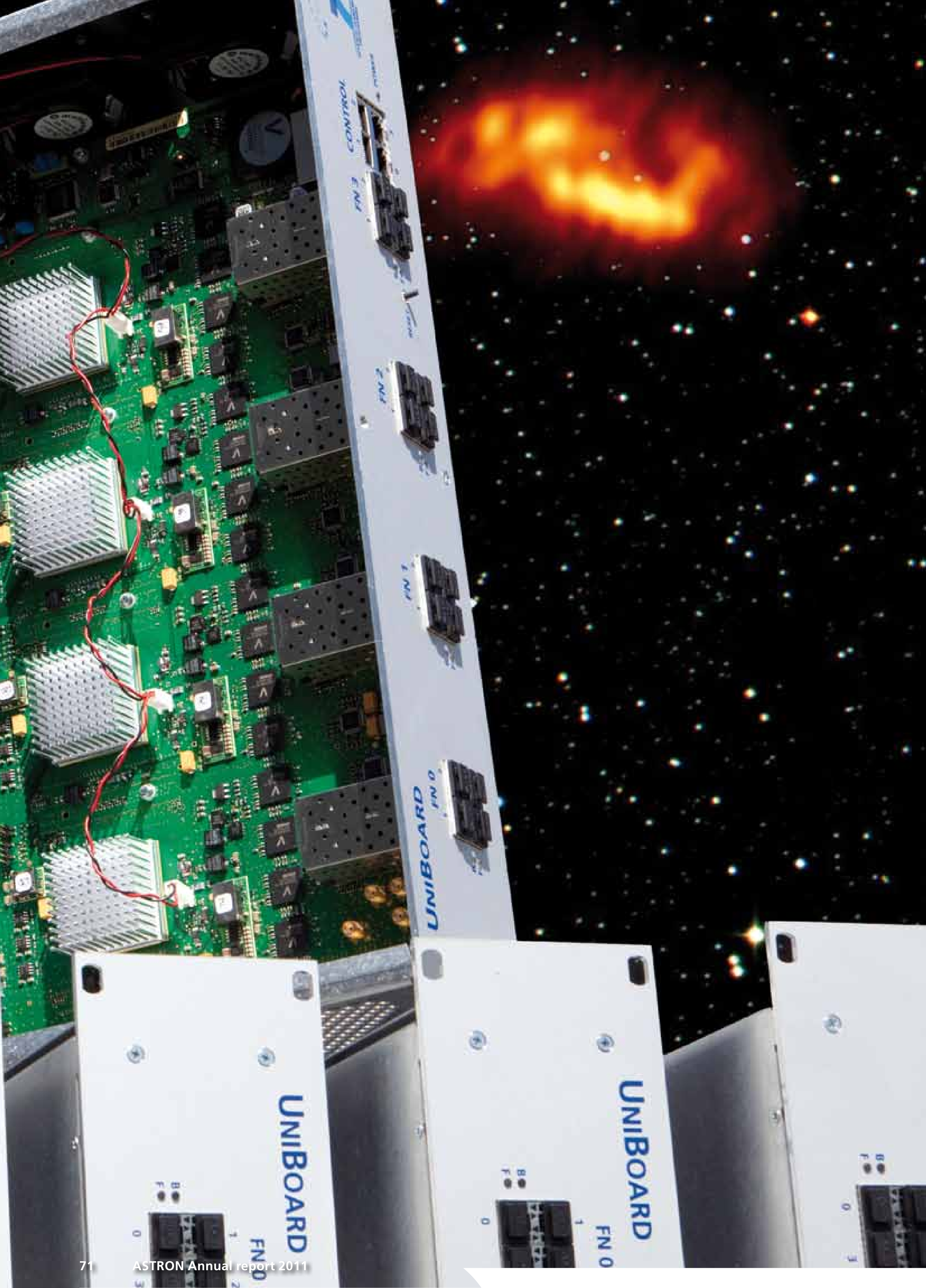
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Cygnus A radio galaxy, image made with the LOFAR telescope. *Image credits: J. McKean and M. Wise, ASTRON.*