‘LOFAR goes deeper than ever before’
‘Imaging the youngest radio supernova’
‘A pilot survey for pulsars with LOFAR’
Welcome to a new winter edition of the ASTRON Newsletter. The second half of 2011 was dominated by big developments, of which the evaluation of the institute in October was the main highlight. Statements from the evaluation panel such as “re-inventing radio astronomy” and “world leading research” made everyone at ASTRON very proud of all the work that has been done in the past years, and the detailed evaluation report will help us with everything that lies ahead.

Furthermore, in September the first LOFAR science results started to be reported in the workshop “First science with LOFAR”. The participants of the workshop, that brought together over 100 members of the LOFAR collaboration from all over Europe, reported on first results from the full range of LOFAR’s key science projects.

More science results can be seen in the report of Raymond Dants on his thesis about cool gas in brightest cluster galaxies. For the ATLAS 3D team (25 European and North American astronomers), Paolo Serra reports on the importance of galaxy environment. For the APERTIF correlator, as well as for the APERTIF digital beam former and the multifunctional Uniboard.

On behalf of the UniBoard development team, André Gunst and Gijs Schoonderbeek inform us on integrating UniBoards, complex and high density boards that will be used for the APERTIF digital beam former and the APERTIF correlator, as well as for the correlation of all 576 dipoles on the central LOFAR superterp. This challenging project promises to be a beneficial design for the SKA. In their article, Gunst and Schoonderbeek describe the workings of this multifunctional UniBoard.

Happy reading!

Femke Boekhorst, Raffaella Morganti, Mike Garrett

The big news for all of us here at ASTRON was the fantastic outcome of the recent evaluation of the institute by a high-level panel headed-up by Prof. C. Cesarsky. We were thrilled for the institute to be awarded top marks - a 5 or excellent - also defined as “research that is internationally leading”. The panel’s findings are an important vindication of the path we have taken over the last 5 years - strengthening our fundamental research in astronomy, commissioning and operating front-line radio astronomy facilities, in particular LOFAR and the WSRT-APERTIF, and investing in the technical, scientific and political development of the Square Kilometre Array. The panel agreed with earlier comments, that ASTRON had practically re-invented radio astronomy over the last few years - with our novel approach to deploying aperture array technology on the ground as sparse and dense arrays, and at the focus of traditional paraboloids. It’s a statement we’re happy to identify with, and we’re looking forward to digesting the panel’s written report and to start implementing any recommendations that might appear there.
Michel’s appointment reminds me of another big event appearing soon on our horizon - “RTS 2012” - Resolving The Sky - Radio Interferometry: Past, Present and Future. This meeting will be held on the 18-20 April, marking the retirement of Prof. Richard T. Schildzus as director of the SPDO. Richard has been a part of the field of radio astronomy over the last three decades, and the efforts he has made most recently in getting the SKA ready for the pre-construction phase and at the same time placing the project directly on the agenda of national funding agencies around the world is a remarkable achievement. I’m looking forward to this meeting and encouraging all of you to register soon - places are limited and will be allocated on a first-come, first-served basis.

Talking of meetings, it would be impossible not to mention the very successful ILT (International LOFAR Telescope) Science Workshop, recently held here in the Netherlands. It’s clear that the telescope is now on the verge of producing publication quality images, and we expect several refereed papers to start appearing in 2012. It’s important to get the first scientific results out soon - as the evaluation panel reminded us, there are many expectations for LOFAR in the community and delivering on past promises is an important responsibility of ASTRON and our international partners. From 2013 onwards, we intend to develop and advertise LOFAR’s science capabilities in a highly staged fashion. We want to ensure our community is clearly aware of what the telescope can and cannot do, and how this will develop over the next few years. A staged approach is also being implemented in the development and later commissioning of LOFAR-APERTIF. It’s essential that the two projects mesh together in a way that optimally maximises the overall return to both communities. In the short term, we aim to have APERTIF’s PANs installed on the WSRT by mid-March 2013 but this will only be a single channel system (12.5 MHz wide) used mainly for commissioning work - in particular, the development of calibration and imaging software, together with various pipeline systems. Meanwhile the other six telescopes of the WSRT will continue to operate with the current multi-frequency front-ends - the aim is to ensure continuity of pulsar timing observations and at the same time maintain some limited VLBI array-aperture capability for as long as possible. At some point, PAFs will be installed on all the telescopes but this will require the commissioning stage of the first six to have been fully proven.

As you can see there is a lot going on at the moment. Hopefully, we can all enjoy a little bit of a breather as the holiday period beckons. In any case, I wish you and yours a Merry Christmas and a very prosperous New Year!

Prof. Mike Garrett
General Director, ASTRON.

One of the most exciting projects to be undertaken with LOFAR is the search for redshifted 21 cm signals from the Epoch of Reionization (EoR). It is currently believed that the Dark Ages, the period after recombination when the Universe turned neutral, lasted until around the Universe was 400,000 years old. During this time, objects started to form and produce the “first” photons, which were energetic enough to ionize the neutral hydrogen surrounding them, carving holes in the neutral primordial gas and creating a pattern that resembles the holes in Swiss cheese.

However, the sensitivity required to achieve this scientific goal, essentially translates to accumulating large amounts of data by repeating observations of the same fields for several nights. Furthermore, the data have to be corrected for instrumental and atmospheric distortions to an unprecedented level in order to detect the weak cosmological signal.

The EoR project team, based at ASTRON and the Kapteyn Institute of the University of Groningen, has been working towards this goal for about 7 years now. During this period, three PhD-theses were completed and a large number of papers have dealt with a wide range of topics ranging from cosmological signal simulations, foreground simulations and the removal, calibration and imaging of the data, but till recently there was a lack of real LOFAR data. With the completion, at the end of 2010, of about 20 split core stations, 7 remote stations in the Netherlands, and 5 stations in Europe, serious commissioning observations of LOFAR commenced. An additional 4 core stations and 2 Dutch remote stations, at distances of up to 60 km from the core of the array were added by September 2011. The latter will be required to make high-resolution (4" PSF) images. Before regular observations can start, a few system components still need to be commissioned.

The LOFAR EoR group is heavily involved in the commissioning of LOFAR and has been taking bi-weekly data on a couple of fields: the 3C 196 Field (Figure 1) and the North Celestial Pole (Figure 2). By October 2011 we have collected and processed 17, 6-hour long repeat observations of the same fields. These are the deepest and highest resolution (1" PSF) images produced up until then at frequencies below 150 MHz. However, these images showed the expected direction dependent corrections due to the different station beams and ionospheric errors. In May 2011, the first deep images of the two fields were made demonstrating a dynamic range of 250,000:1 for the case of the 3C 196 Field. These are the deepest and highest dynamic range images produced until then at frequencies below 150 MHz. However, from 115 to 163 MHz at relatively high time and frequency resolution. The goals of these commissioning observations are to monitor the long-term performance, assess the quality of the data, understand subtle errors in the data, investigate wide-field ionospheric calibration approaches and to test the standard imaging and EoR pipelines on actual data.
Since September 2011 an instrument wide repair program for the failing HBA tiles has begun. With the new station calibration tables, we should collect better quality raw data, which we expect to lead to a better noise behavior as a function of frequency, which is crucial for the EoR KSP. This coupled with other fixes and enhancements in the various software components, will definitely lead to an even higher imaging quality, which is vital for all of the imaging key science programmes.

http://www.astro.ru.nl/~LoFAREff

Figure 1: A small region of the NCP field with the WSRT (left) and LOFAR before (center) and after (right) calibration with SAGECAL.

Figure 2: A small region of the 3C 196 field after calibration and source extraction with SAGECAL.

Cool gas in Brightest Cluster Galaxies

Raymond Oonk (oonk@astron.nl)

Clusters of galaxies are the most massive, gravitationally bound structures in the known universe. They are used to study many astrophysical phenomena, such as large-scale structure formation, galaxy evolution and dark matter. The majority of all local galaxy clusters (z < 0.3) are in a quasi-relaxed state and about half of these have central regions showing hot X-ray emitting gas that is dense enough to cool from its own radiation within a Hubble time. We call these objects cool-core clusters. However, the mass deposition rates inferred from X-ray observations are much larger than those observed at lower energies. A very efficient feedback mechanism to reheat this gas is therefore required.

The centres of cool-core clusters are particularly well suited to study the feedback processes that are thought to inhibit gas cooling. At the very heart of the cool-core one finds the centrally dominant (cD) galaxy. These BCGs are the most massive galaxies known and their proximity makes them ideal laboratories where feedback processes can be studied in great detail.

Since the discovery of cool gas in Abell 2597 in 1989, the ionised and warm molecular gas surrounding cool core BCGs in nearby cool-core clusters. Using the integral-field spectrograph “SINFONI” on the Very Large Telescope (VLT) we map, for the first time, the ionized and warm molecular gas in Abell 2597 in three dimensions. This gas is concentrated in filamentary structures extending out to 20 kpc from the nucleus. The ionized and molecular phases are strongly coupled in distribution, intensity and dynamics (Fig.1). The AB 2597 AGN is observed to stir up this gas in the central few kpc of the BCG, but beyond this region the gas is dynamically cold. If the molecular gas in the filaments is dense then its support remains to be explained.

The excitation of the cool gas in Abell 2597 cannot be explained by either a central AGN or young stars and these can thus be ruled out as the feedback mechanism. The hot X-ray emitting gas can provide the necessary energy to heat the cool gas either by, ultrafast X-ray radiation, or particle heating.

Observations do show the presence of cool, less than 1000 K, gas nebule surrounding cool-core BCGs. These nebulae are only found in cool-cored and not in other galaxy clusters. This cooler gas also requires reheating. It is thought to require an amount of energy similar to that needed to keep the hot X-ray emitting phase from cooling. The origin of the cool gas is unknown, but the correlation between this gas and the presence of a cool-core in a cluster implies a link between the two. By investigating the cool gas, which is rich in diagnostics, we hope to not only gain insight into the feedback mechanism for the cool gas but also for the hot X-ray emitting gas.

During the summer months, the next step was taken: addressing the direction dependent effects. For that a new, fast and robust calibration package that uses Graphics Processing Units to accelerate the computation was developed, SAGECAL. It is now possible to solve for and correct directional errors in more than 100 directions in 15 hours processing time. This enabled us to reach the thermal noise and demonstrate that LOFAR performs up to its specifications. Moreover, the imaging dynamic range has been pushed to 420,000:1 for a single 6 hour observation of the 3C 196 field. This is the first time this has been achieved with an Aperture Array system and shows that LOFAR performs up to its specifications. Once the commissioning data have been fully processed by the end of 2011, these have central regions showing hot X-ray emitting gas that is dense enough to cool from its own radiation within a Hubble time. We call these objects cool-core clusters. However, the mass deposition rates inferred from X-ray observations are much larger than those observed at lower energies. A very efficient feedback mechanism to reheat this gas is therefore required.

The centres of cool-core clusters are particularly well suited to study the feedback processes that are thought to inhibit gas cooling. At the very heart of the cool-core one finds the centrally dominant (cD) galaxy. These BCGs are the most massive galaxies known and their proximity makes them ideal laboratories where feedback processes can be studied in great detail. The cooling of hot gas to form stars is essential for the growth of massive galaxies. At the same time, simulations show that these galaxies require an efficient feedback mechanism to halt gas cooling at early times, preventing them from becoming too massive and too blue.

The cooling of hot gas in Abell 2597 cannot be explained by either a central AGN or young stars and these can thus be ruled out as the feedback mechanism. The hot X-ray emitting gas can provide the necessary energy to heat the cool gas either by, ultrafast X-ray radiation, or particle heating.
Gas cooling is not the only problem in these systems. It has long been known that cool-gases are very luminous in the far-ultraviolet (FUV). Previous investigations associate this light with a dusty star formation. Combining optical and far-ultraviolet (FUV) imaging, we find that in Abell 2597 this requires very hot stars and unusual gas and dust conditions (Fig. 2). This result implies that a purely stellar interpretation for the FUV emission is unlikely. Follow-up, deep spectroscopic investigations with the Hubble Space Telescope are underway and we hope to publish the results soon.

About Raymond Oonk

Raymond Oonk joined the Astronomy Group at ASTRON as a Post-doc in April. He has recently obtained his PhD at the University of Leiden under the supervision of Walter Jaffe. His thesis focused on the thermal balance of the intra-cluster medium in relaxed Galaxy Clusters (also known as “cool-core” clusters). He has used data from both ground-based and space-based telescopes, such as the Very Large Telescope in Chile and the Hubble Space Telescope, for his thesis. He enjoys observing and modeling cool-cores at all available wavelengths to try to piece together a global framework for the heating and cooling of gas in these systems. At ASTRON he hopes to continue this work and, in particular, to further study the link between the cool gas and the central radio source in the Brightest Cluster Galaxy. The LOLA and APERTIF projects, developed by ASTRON, will be key for carrying out these investigations.

The Aperture Tile-in-Focus (APERTIF) system will increase the survey speed of the Westerbork Synthesis Radio Telescope (WSRT) by a factor 30. This will be realized by replacing the current feeds by dual-polarized phased array feeds to enlarge the field-of-view (FoV) of the individual dishes (Figure 1). Phased arrays do not only increase the FoV, but also provide flexible beam forming (a weighted addition of signals from individual antennas), which can be exploited to improve the polarimetric performance, suppress radio frequency interference or adjust the sensitivity of the system while providing perfect reconstruction of the polarization state of the incoming signals. Although this beam-forming scheme that maximizes the performance limits of phased array feeds and to develop the calibration algorithms needed to tune the APERTIF beam former.

After a full week of intense brainstorming at BYU in April 2010, Karl Warnick, Marianna Ivashina, Rob Maaskant and Stefan Wijnholds managed to define an optimal beam-forming scheme that maximizes the sensitivity of the system while providing perfect reconstruction of the polarization state of the incoming signals. Although this beam-forming scheme only works in a measurement setup typically found in an anechoic chamber, which is a bit unpractical for calibrating a WSRT dish, it provides a nice performance benchmark for more realistic beam-forming schemes. To see how this works out for the APERTIF system, we use an end-to-end simulation of the APERTIF system developed by Marianna Ivashina. This simulation takes into account the propagation of radio waves through the optical path of the WSRT dishes as well as the electromagnetic description of the APERTIF front-ends.

The APERTIF front-ends will consist of two sets of feeds with a mutually orthogonal orientation. In the real APERTIF feed signals of each set will be treated separately, while the aforementioned optimal beam-forming scheme combines all of the feed signals to ensure an optimal reception in each polarization. We would therefore like to know how much performance is sacrificed by treating the two feed sets separately.

The simulations indicate that the sensitivity loss will be about 4.5%. This sacrifice is deemed acceptable given the simplification of the digital beam former design. However, we do not only strive for high sensitivity, but also for reliable polarimetry. Figure 2 shows the polarimetric behavior of the FoV measured as the cross-correlation between the two polarizations observed on an unpolarized source. This cross-correlation is zero for an ideal instrument. For the APERTIF system, the performance in the centre of the FoV is very good (less than -30 dB or 0.1% of the power in the peak of the beam), but it deteriorates to -20 dB or 1% towards the edges of the FoV.
Fortunately, this is still acceptable to allow an accurate reconstruction of the polarization state of the incoming signals without too much sensitivity loss. The latter is estimated to be less than 1% in the beam centres.

Another concern for the APERTIF system is the impact of the front-end electronics on the beam stability. We want the relative beam errors to be less than 1% at the half power contour. Fortunately, the framework developed to derive the beam forming algorithms provides an excellent starting point for beam error analysis.

Figure 3 shows the impact of drifts in the beam former parameters for a beam at the edge of the field-of-view. We assumed that the parameters have drifted by 2% from their nominal value measured during a calibration observation. With these errors, the system just satisfies the beam quality requirement. If we allow a 2% RMS error in the beam forming parameters, stability measurements indicate that we need to recalibrate the current front-end electronics approximately every 10 minutes. This can be done using a reference source in the apex of the telescope. This 10-minute update rate is very good news, since it implies that only a very limited fraction of the observing time needs to be spent on the recalibration of the system.

It is nice to see how these results provide a solid foundation for the design choices made for the APERTIF system. This research collaboration has been very fruitful so far and we are looking forward to applying these results to actual data!

New NWO director visits ASTRON

Mike Garrett (garrett@astron.nl)

In October, we were happy to welcome the new General Director of NWO, Hans de Groene, to ASTRON. Hans was appointed in May 2011, and this was an opportunity for him to become better acquainted with ASTRON, our staff and our mission. Hans met with the ASTRON management team and also the OR (Worker’s council). This was followed by a short, whirlwind tour of our facilities in Dwingeloo - the labs, JIVE and the NOVA Optical/IR Group. The new director seemed to enjoy the visit and he did not leave empty handed - some ASTRON outreach goodies accompanied him to the Hague, including an ASTRON mug which I can tell you is now seeing good use in Hans’ office at NWO!
Sound artists perform at Dwingeloo telescope

Femke Boekhorst (boekhorst@astron.nl)

This summer, visitors to the Dwingeloo telescope got to see something very special. Sound artist Andreas Hirsch from Germany gave a light concert with his ‘Solar Sound Ensemble’. The concert was a composition of sounds and images, based on recent observations carried out with the Dwingeloo Telescope. Science and art came together in the beautiful nature area around the telescope, creating an unforgettable night under the stars.

Students from the Stad & Esch School in Diever, Drenthe, made a video production under the supervision of video artist Rosa van Hofwegen, which was shown prior to the concert.

The Dwingeloo Telescope, centre stage of the performance, was open for visits before the concert. CAMRAS, the volunteers who are restoring the telescope and putting it back in business for science and education, provided guided tours of the working telescope.

“First Science with LOFAR” workshop showcases initial science results

Michael Wise (wise@astron.nl)

Over the past year, we have seen an impressive increase in the quality of the scientific data from LOFAR. The continued rollout of the remaining stations, steady improvements in the operational and processing software, and the efforts of a small army of commissioners have resulted in data that is increasingly ready for publication. This quality was on display recently at the First Science with LOFAR workshop held September 14-15 at the Mooirivier Conference Centre in Dalfsen, the Netherlands. This workshop brought together over 100 members of the LOFAR collaboration from all over Europe. Participants reported on first results from the full range of LOFAR’s key science projects.

This workshop represented the first full gathering of the LOFAR collaboration since the previous meeting in Hamburg, Germany, three years ago. The amount of progress in that time has been striking. The majority of the presentations were given by younger staff, postdocs, and graduate students actively involved in the LOFAR development and commissioning. These results include high quality maps of galaxies and clusters, record-breaking 127 simultaneous beam observations of pulsars, discovery of LOFAR’s first possible transient radio source, the first detection of CR events with LOFAR, and dynamic imaging of solar flares. A montage of only a small set of the many impressive results is collected on the right, most of which are expected to produce scientific publications early in the coming year. Judging by the impressive results shown in Dalfsen, this next year is going to be a huge success for LOFAR scientifically.
Hi, my name is Harm Jan Pepping. In August 2011, I started at ASTRON as a digital design engineer. I started my career as an engineer at ASTRON in 2001 when I did my graduating project on the THEA project. Fortunately, I was asked to work for ASTRON after my graduation period and during the next four years, I developed myself as a thorough hardware engineer. After THEA, I continued working on the TIM (Two Input Memory Module) board which can be regarded as a data acquisition board that was used to collect data in the ITS (Initial Test Station of LOFAR). After TIM, I worked with Maaike Damen on the RSP (Remote Station Processing) board that can be considered as the ancestor of the current Uniboard. Both TIM and RSP boards can still be admired on the first floor near the digital lab.

In 2001, I decided to leave ASTRON to try my luck at a company called Chess. There I worked on several projects varying from a prototype ADSL modem to high-end broadcasting cameras. At Chess, I slowly moved from the hardware into the firmware domain, firmware development then involved programming of FPAGAs (Field Programmable Gated Arrays), which are the non-electronic model programmable chips that can do an enormous amount of mathematical operations in parallel. It took about three years of work in this commercial environment to find out that a scientific environment suited me better.

So in 2005, I joined SRON (Netherlands Institute for Space Research) in Utrecht as a digital design engineer. At SRON, I worked predominantly on the Trapez (Transportable Radio Astronomy Preprocessing) project, which is an instrument that will monitor the amounts of methane and carbon monoxide in the earth's atmosphere. It was a fantastic experience to work on an instrument that will eventually be orbiting the Earth in space. Although the work and colleagues at SRON were great, my girlfriend and I decided to go back to Drenthe and now I am back at ASTRON where they are exhibiting in the showcases on the first floor.

Over the last few months, the SKA has made several steps forward as the Founding Board focused on the establishment of a new SKA legal entity for the project. NWO have been leading this difficult process via Patricia Vogel, ably supported by colleagues Miriam Roodlofs and Maaike Damen. On the 23rd of November, the new legal entity, the “SKA Organisation” was established as a limited company in the UK - a major step forward for the Board and the project as a whole. Several other major items have been on the board’s agenda, including the recruitment of an interim director of the SPO (SKA Project Office), resourcing the Pre-construction Phase and the transition of the SPDO to SPO staff transition. I’m very pleased to report that Michiel van Haarlem was recently appointed as the interim director of the SPO - Michiel brings a huge amount of expertise to the project via his experience in the construction and roll-out of LOFAR - we wish him all the best in his new challenge.

SKA Ltd.!

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Ladies and Gentlemen... Introducing LOFAR!

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In the coming year, LOFAR will move into an exciting new operational phase as it matures into a full-fledged astronomical observatory. Early in 2012, we will finish the rollout of the final stations, release a stable version of the operational system deploying the first set of science modes, and complete LOFAR’s initial commissioning survey, the Multi-frequency Snapshot Sky Survey (MSSS). At this stage, LOFAR will open its doors to the international astronomical community with a first open call for observing proposals. This announcement of opportunity will include a mixture of continued commissioning observations, initial components of the Key Science programs, and for the first time ever true “open sky” observing projects. To advertise this opportunity and educate the astronomy community about LOFAR’s unique capabilities, several special presentations have been arranged at a number of major upcoming astronomy conferences.

This LOFAR promotional tour will kick off in January 2012 when a group of astronomers from ASTRON and the KSP’s will travel to Austin, Texas in the US for the American Astronomical Society (AAS) meeting. The winter meeting of the AAS is the primary meeting of the American astronomical community and an excellent opportunity to reach the widest possible audience in the US routinely attracting thousands of astronomers. A Special Session has been organized, focusing specifically on LOFAR. In this session, we intend to present the community with an update on the status of the array and its current scientific capabilities as well as the upcoming opportunities for general, open sky observing. The session will also feature a number of short talks highlighting some initial science results obtained during the past year of commissioning and showcasing LOFAR’s scientific potential. ASTRON will also host a booth during the meeting to advertise not only LOFAR, but also APERTIF and other ASTRON initiatives.

This advertising campaign will continue a few months later in Europe where a similarly focused session on LOFAR has recently been approved for the upcoming 2012 National Astronomy Meeting (NAM) of the Royal Astronomical Society (RAS) that will take place at the University of Manchester, March 27–30, 2012. Finally, we anticipate having at least one plenary talk at the forthcoming European Week of Astronomy and Space Science (EWASS, formerly known as JENAM) to be held in Rome, Italy in July. Keep an eye on ASTRON’s media channels for updates as we introduce LOFAR to the astronomical world!
In October, a panel of independent experts (Profs. C. Cesarsky, R. Blandford, M. Urry, M. Bode, A. Lawrence and A. Roederer) were charged with evaluating ASTRON over the last 6 years (2005-2010).

After spending two days with us, the panel awarded us the highest possible rating: a 5 = excellent - also formally defined as “Research that is world leading”. Naturally we are extremely pleased with the panel’s finding and we are looking forward to receiving the formal report. We’d like to take this opportunity to thank all our students, telescope users, industrial and regional partners, Science advisory Committee and the ASTRON Board, all of whom played an important role in the panel’s decision. Last but not least, we also wish to recognise the fantastic efforts of all of ASTRON staff in achieving this super result - well done to all concerned!

ASTRON evaluated as excellent!
Mike Garrett (garrett@astron.nl)

ASTRON has successfully finished its part of the UniBoard project for RadioNet FP7. A board that is integrated in an actively cooled housing, with out of the box test firmware, was delivered to all of the partner institutes (University of Manchester, INAF, University of Bordeaux, University of Orléans, KASI, Shanghai Observatory, JIVE, that has the overall project lead and ASTRON). The board, shown in Figure 1, was shipped with documentation and test firmware, which tests all of the board interfaces. The firmware has been written in a modular way, so that any issue in re-using each other’s firmware is minimized.

The UniBoard is a complex and a high density board, as is shown in Figure 2. 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 and cost. JIVE=leading UniBoard

Integrating UniBoards: bridging the gap towards SKA size signal processing
Andre Gunst and Gijs Schoonderbeek, on behalf of the ASTRON UniBoard development team for APERTIF and AARTFAAC (gunst@astron.nl, schoonderbeek@astron.nl)

The targeted applications for UniBoard all have three common functionalities:
• Antenna based processing, like a filter bank, delay tracking, fringe stopping, etc.
• Data routing to transport a part of the bandwidth (subband) for all antennas to the next stage processing.
• Subband based processing for all antennas, like a beam-former or a correlator.
The architecture of the board has been designed such that these functionalities can be optimally mapped on one or multiple boards. Therefore, two columns of four FPGAs (Field Programmable Gate Arrays) have been used as shown in Figure 2. Each of the functionalities is realized in the front node FPGA (indicated as FN in Figure 2), back node FPGAs (indicated as BN in Figure 2) or the mesh routing on the board between the front node and back node FPGAs. All of the interfaces on the board are bi-directional. This enables the board to be used in both directions, in whatever direction is more appropriate.

The architecture of the UniBoard is designed so that multiple UniBoards can be integrated in a subrack for building large complex digital processing systems (funded by ExBox). All of the boards can be connected to each other via a backplane. The other side of the backplane can be used to plug in receiver boards, including analog-to-digital converters. This architecture is adopted from the design used for LOFAR, but with a number of significant improvements. Amongst them are the integration of the clock, power and test functionality onto one single board and the integration of both the LOFAR RSP (Remote Station Processing) board and the TBB (Transient Buffer Board) functionality on one board. In Table 1 the analogy between the LOFAR subrack and the state of the art UniBoard subrack is shown.

ASTRON will use the UniBoard for both the APERTIF digital beam-former and the APERTIF correlator. For the beam-former, four UniBoards will be integrated with 64 receivers into one subrack, as is shown in Table 1. The APERTIF receiver and the UniBoard have been integrated already. A test of the UniBoard-APERTIF integrated system is shown in Figure 3. For the APERTIF correlator, a total of 8 UniBoards will be integrated into a single subrack, boosting the processing per subrack by a factor of two. Furthermore, the UniBoards will be used in AARTFAAC. The challenging aim of this project is to correlate all of the 576 dipoles on the LOFAR superterp. This will be a major step towards what is required for the Square Kilometre Array (SKA). JIVE, leader of the UniBoard project, will use the boards for the new EVN correlator.

The trend from LOFAR technology to UniBoard technology will be continued towards what is needed for the SKA. Although the technology itself changes significantly, the philosophy used for designing UniBoard and how to build a scalable and dense system with multiple UniBoards is definitely an approach from which the SKA can benefit.

The ASTRON UniBoard development team for APERTIF and AARTFAAC consists of: André Gunst, Eric Kooistra, Harm-Jan Pepping, Gijs Schoonderbeek, Daniel van der Schuur, Sjouke Zwier.

**Figure 2 - The UniBoard design.**

**Figure 3 - Test result of ADU-UniBoard integration, showing the time domain data (top) and frequency spectrum (bottom) of a single tone at 742 MHz under-sampled with an 800 MHz clock frequency.**

### Table 1 - Comparison of LOFAR and UniBoard subrack parameters

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<thead>
<tr>
<th>Parameter</th>
<th>LOFAR subrack</th>
<th>UniBoard subrack</th>
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<tr>
<td>Receivers</td>
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<td>64</td>
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<td>Bandwidth (MHz)</td>
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<td>400</td>
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<tr>
<td>Beams</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Input bandwidth (Gbps)</td>
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</tr>
<tr>
<td>Output bandwidth (Gbps)</td>
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<td>96 (max. 480)</td>
</tr>
<tr>
<td>Memory (Gbyte)</td>
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</tr>
<tr>
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<td>2009</td>
</tr>
<tr>
<td>Boards</td>
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<td>14</td>
</tr>
<tr>
<td>FPGAs</td>
<td>30</td>
<td>14</td>
</tr>
</tbody>
</table>

(TMAC/s is a Tera Multiply and Accumulate per second.)
The aperture array (AA) telescope development for SKA is aimed at frequencies below the FM band, up to frequencies covering the rest-frame frequency of neutral hydrogen – 1.4 GHz. Because this wide frequency range covers two different sky noise regimes, AA developments are split into AA-Low for the lower part, covering 70 to 450 MHz and AA-mid for the upper part. The technologies used in the LOFAR and EMBRACE aperture arrays will be used as a basis for development of AA-Low and AA-mid, however, they need to be developed still further in order to meet the requirements of SKA.

The AA-mid research for the SKA is working under the umbrella of the Aperture Array Verification Programme (AAVP) which is closely engaged with the international SKA project office in Manchester. The research focus is on system design and hardware development. Furthermore, the possible sharing of subsystems and infrastructure, like processing back-ends and station sites, is also being considered. The EMBRACE stations ready for deployment and design iteration. A major aim of AAVP is to ensure that the results are to be incorporated into the next generation of AA-Mid concept.

The group in Nançay has recently developed a new beam former chip. This chip is undergoing testing and if the results are as expected, it will be implemented in the next board design. The chip will sum multiple single antenna elements together and take care of the needed phase shifting. Further improvements on performance and cost are expected in order to meet the final specifications. Both the Nançay group and ASTRON are working on crucial components of the signal chain: a partially integrated low noise amplifier (LNA) and a low power consumption front-end chip. The design of this LNA includes a sensitivity improvement and a reduction of the power consumption. Both components are being developed and produced in collaboration with chip manufacturer NXP.

The mechanical group at ASTRON is also working on thermal, environmental and industrialization aspects. The goal of the AAVP is to create the first part of an AA-Mid instrument. A preliminary science plan is already available, describing the goals and requirements for such a multi-station AA-Mid instrument. Together with four industrial partners, we are developing cutting edge technology, including new cost, mass production techniques under the SKA-NL banner.

dummy tiles. During these measurements, we will also be able to gather information on other aspects and conditions, such as UV irradiation, the effect of animals (small and big), storms, dust and rain.

We are working towards the assembly of the first set of AA-Mid proto-antenna-tile hardware (Q1 2012) and connect at least one tile to the operational EMBRACE array. The goal is to build multiple stations at the selected SKA site, in order to create the first part of an AA-mid array, leading to a science capable instrument. A preliminary science plan is already available, describing the goals and requirements for such a multi-station AA-Mid instrument.

Up to 2013, the ASTRON part of the AA-Mid project is financially supported by SKA-NL (SKA – Noord-Nederland), a programme covering aperture array R&D ranging from software development to RF component development and the realization of AA-Mid antenna tiles. Together with four industrial partners, we are developing cutting edge technology, including new cost, mass production techniques under the SKA-NL banner.

• The AA-Mid team consists of teams within ASTRON, Nançay/ODPAR, University of Manchester and industrial partners: Major, Neways, S&T, SItrina, NXP and several other contributors.

R&D groups at ASTRON in the Netherlands and Nançay/Observatoire de Paris in France. Industry participates as well, and links exist with other research groups also working on AA-Mid technologies, for example Manchester University working on ORA antennas.

To be able to obtain valuable information from EMBRACE, one of the AA-mid activities is getting both EMBRACE stations fully operational, commissioned and tested. In the previous AAVP newsletter, the potential of EMBRACE was presented in the form of a successful dual-beam experiment - a pulsar was tracked, while simultaneously neutral hydrogen was scanned across the galaxy. Recently, the Nançay group made a similar step forwards by observing a pulsar with their EMBRACE station. These successful experiments are a clear demonstration of the progress being made on AA-mid technology. Besides the EMBRACE evaluation activity, the development strategy is to move from EMBRACE to next generation AA-mid technology. Important topics are dual polarization capability and low power consumption for SKA like RF environments.

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Addressing the issues together: the 2nd “3GC-II” workshop

J.E. Noordam (noordam@astron.nl)

From 18-30 September, the 3GC workshop took place in Albufeira, Portugal. This was the 2nd workshop in a series that is devoted to the development of 3rd Generation Calibration (3GC). The latter is needed for the new giant radio telescopes, including LOFAR, WSRT/APERTIF, MeerKat, ASKAP and the SKA. But it also improves the performance of existing radio telescopes, especially those that have been recently upgraded, like the EVLA.

3GC concerns itself with direction-dependent instrumental effects (DDE). The most important are the station beam shapes and the ionosphere. They will limit the performance of the much more sensitive radio telescopes of the future. However, the most popular 2GC data-reduction packages (AIPS, MIRIAD, NEWSTAR, DIFMAP) cannot be easily adapted to deal with DDEs, and it is not a high priority for CASA. This workshop limited itself to beam shapes, partly to provide a sharper focus, and partly because it is the most urgent issue.

Like its predecessor in Nancay (October 2009), the format of the 3GC-II workshop was a bit unusual in the sense that it took two full weeks, and “required” a considerable amount of preparation from the participants. This kind of experimentation is encouraged by funding agencies like SKADS and RadioNet, who seek to increase the yield of the workshops they fund.

VENI award for Adam Deller

Following the success of Jason Hessels and Paolo Serra, this year Adam Deller has been awarded one of the prestigious VENI grants from the Netherlands Organization for Scientific Research (NWO). This is a great achievement for Adam, who only recently joined the Astronomy Group at ASTRON as a postdoc. This type of grant is aimed at promoting the innovative and exciting research projects of young and talented researchers who have recently been awarded their PhD, and to allow them to continue to develop their ideas. It is therefore, an implicit recognition of the high level of astronomical research carried out at ASTRON. With this grant (of about 250,000 euro), Adam will continue and expand his work on precision astrometry of pulsars using VLBI.

Historically, calibration difficulties have hindered precision VLBI astrometry at the lowest radio frequencies, where most pulsars are brightest. However, Adam is planning to take advantage of new and upgraded instruments such as the International LOFAR Telescope, the EVN and the VLBA to extend his astrometric observations to a large sample of the pulsar population, and to determine how to obtain the highest accuracy astrometry with the Square Kilometre Array. Congratulations Adam and success with your project!

Precision astrometry, where the angular positions of objects on the sky are established with an accuracy of better than a millionth of a degree, can establish the relative motion of the target and its distance from the Solar System. These measurements provide model-independent distance and velocity information that is of great importance in the study of pulsars, giving some insight into their formation and evolution, and also the physics that powers their emission across the electromagnetic spectrum.

Like before, two full weeks was rather exhausting for all involved, but greatly increased their ability and inclination to continue in the field of 3GC afterwards. The main purpose of these workshops is to formulate the questions, and to foment the personal ties that will generate and sustain widely distributed collaborations throughout the 3GC community. The world of the SKA needs answers, and it needs them quickly.

As in Nancay, the 39 participants represented all the major radio telescopes, with a particularly strong South African presence (apart from ASTRON, of course). The fact that they were somewhat more expert this time might be connected with the increased urgency of the beam shape problem, worldwide. In any case, the 3GC software tools were in a much better state than before, and more pertinent data-sets were available. The preparation by participants was also much better than before, but remains a difficult aspect. Hopefully these trends can be sustained in the next workshop(s) in the 3GC series, starting in South Africa next year.
The workshop topic of station beam shapes was sub-divided into three sub-topics:

1) Beam shape modeling:
It is now clear that, for the best results, theoretical beam models will not be accurate enough. So the station beam shapes will have to be measured individually, perhaps even during the observations. To this end, parametrized multi-term expressions are needed for all 4 elements of the 2x2 Jones matrices. A range of suitable basis functions was proposed by various experts, who also indicated how physical constraints could be included. Progress indeed!

2) Beam shape measurement:
It has recently been demonstrated that a typical 21 cm field contains sufficiently bright sources to allow the measurement of the actual voltage beams of the WSRT antennas, as a function of time and frequency. This technique has now been applied to the EVLA as well. The measured “differential gains” were somewhat puzzling, but they were quickly explained by on-the-spot simulations (see also below). Various workshop participants are now in a position to use this technique with other radio telescopes as well.

3) Beam shape application:
Even when the DDEs are known, it is not enough. So the station beam shapes will have to be measured individually, perhaps even during the observations. To this end, parametrized multi-term expressions are needed for all 4 elements of the 2x2 Jones matrices. A range of suitable basis functions was proposed by various experts, who also indicated how physical constraints could be included. Progress indeed!

Finally, one of the two corner-stones of the 3GC community is the available software for rapid experimentation and the easy sharing of detailed results. (The other one is the common language of the Radio Interferometric Measurement Equation, RIME). As mentioned above, the somewhat puzzling EVLA results were quickly explained by on-the-spot simulation. But the most impressive moment came when the understanding of imaging with off-axis Gregorians (an important contender for SKA stations) was sub-divided into three sub-topics:

3) Beam shape application:
Even when the DDEs are known, it is not trivial to apply them to the uv-data, since the latter can only be corrected for a single point in the sky. One possibility is to make many small images with different corrections, but that is prohibitively expensive. Fortunately, it seems possible to apply DDE corrections by convolution during the gridding stage of the imaging process. Several of the participants are actively involved in the development (and implementation, and testing) of this “Alluv-projection” technique, in both forward and backward directions. They were urged on to investigate the limitations of this technique.

An essential “reality check” was provided by the presence of some highly experienced and active astronomers, often with a strong instrumental background.

A potentially important result of the workshop is the realization that “breaking the degeneracy” between instrumental and source model parameters could well be essential for measuring beam shapes in practice. This is achieved by allowing the beams to wander or rotate on the sky in known patterns during the observations. Obviously, this will have a considerable impact on calibration, and the design of SKA stations. All the more reason to pursue it quickly.

Since this was a gathering of people with many different backgrounds, we took the opportunity to have discussions about more peripheral issues, like the future of data reduction systems in our field. Somewhat surprisingly, the most urgent concern was with a fast, scalable, reliable uv-data format, well suited for data access, visualization, flagging, splitting, combining, etc.

Altogether it was a good workshop, even though we measure real success by the continuation of the 3GC work by the participants afterwards. We gratefully acknowledge the support of RadioNet, and of our Portuguese hosts. The latter have been extraordinarily helpful and generous, and we hope that this workshop may lead to one or more active Portuguese nodes in the 3GC community. They will be most welcome.

LOFAR in a cube
Between 18 and 28 August 2011, the LOFAR telescope was part of a show at the famous Noorderzon Performing Arts Festival in Groningen, the Netherlands. This festival is an annual 11-day international, cultural event with a huge number of crossover productions that includes music, dance, circus, theatre, mime, and science. In previous years, over 135,000 people visited the festival.

More than 5,000 people visited Q3, a huge cube exhibition with Einstein on front (see also www.q3.nl). One of the floors in this cube was reserved for an astronomy show called “God is an e²”. A scale model of a LOFAR station and an HBA antenna featured in the show, which was organized by the Kapteyn Institute of the University of Groningen.

LOFAR on tour
Models of the LOFAR antennas are part of exhibitions throughout different locations within the Netherlands. Check them out at:

• 27 May 2011 to 23 January 2012: A scale model of a LOFAR station can be seen in the University Museum of the University of Groningen at the exhibition “Beyond the Stars”; http://www.rug.nl/museum/tentoonstellingen/ beyondthestars.

• The Leiden observatory: A LOFAR set up, including antennas and a LOFAR screen, are installed at the observatory of Leiden in a permanent exhibition.

• Public observatory in Zwolle: A LOFAR LBA and HBA antennas are part of the permanent exhibition of the public observatory of Zwolle.
The ASTRON/JIVE Summer students of 2011

Vibor Jelic (jelic@astron.nl)

The ASTRON/JIVE Summer student programme enables advanced undergraduate or graduate students to spend the summer (10-12 weeks) conducting astronomical research in the middle of the National Park in Dwingeloo. The programme has a long tradition and is a collaborative effort of JIVE and the ASTRON departments: Astronomy Group, Radio Observatory, and R&D.

This year we had a group of eight enthusiastic students from all over the world. You can see them in the picture, from left to right: Dyas Utomo, Institute Teknologi Bandung, Indonesia; Lars Floer, Argelander Institute for Astronomy, University of Bonn, Germany; Sarolta Zahorécz, Eötvös University Department of Astronomy, Hungary; Claire Gilpin, Franklin & Marshall College, USA; Djana Vrbanec, Department of Physics, University of Zagreb, Croatia; Mark Aartsen, University of Adelaide, Australia; Fang Wu, Shanghai Astronomical Observatory, Peoples Republic of China; and Roman Murphy, University College Cork, Ireland.

The topics of their projects varied: testing the new VLT mid-infrared instrument (VISIR), source finding and parameterisation in large HI surveys, atomic hydrogen in galaxy cluster cores, imaging of a rotating-wind detected quasar, and rotation measure gradient reversals as a test of magnetic tower models. Three projects involved LOFAR commissioning observations: the LOFAR pilot survey for nearby radio pulsars, characterization of the earth’s ionosphere using LOFAR, and Galactic foreground simulations/observations for the LOFAR Epoch of Re-ionization project.

As usual, the students followed lectures on radio interferometry, the LOFAR telescope and other scientific topics of research at ASTRON and JIVE. They also visited the LOFAR site at Exloo and the Westerbork radio telescope. Apart from the scientific work they were doing with their supervisors, the students explored the surroundings by bike, enjoyed BBQs and other social activities organized for them.

More information about the summer student programme can be found at http://www.astron.nl/astronomy-group/summer-school/astronjive-international-summer-school. See the ASTRON website if you are interested in the Summer Student Programme 2012.

A pilot survey for pulsars with LOFAR

Thuij Coenen on behalf of the LOFAR Pulsar Working Group

During the commissioning period, the LOFAR Pulsar Working Group (PWG) is performing several pilot surveys to exercise different aspects of the telescope. The first such survey is the LOFAR Pulsar Survey (LPPS).

Ultimately, LOFAR’s sensitivity will top that of any other telescope in the world; for the first time completely mapping the local pulsar population, and possibly finding nearby, dim, exotic pulsar systems. Detections, and even non-detections, of known pulsars in the LOFAR band will illuminate the low-frequency end of the pulsar spectral energy distribution, potentially constraining pulsar emission mechanisms.

The aims of LPPS are more commissioning oriented. Likely science results are the first LOFAR pulsar discoveries and a good upper limit (if not a detection) on the rate of (rare) fast bright transients.

The first goal for LPPS is determining the merit of the “incoherent” beam-forming technique for pulsar surveying. For pulsar surveys, imaging modes cannot provide sufficient fast time sampling (< 0.5 ms) and so-called “beam-formed” modes are used instead. In these modes, antenna signals can be combined in two basic ways. In the “coherent” mode the station signals are summed in phase. This comes at the cost of the field of view for the resulting “tied-array” beams. In the second, called the “incoherent” mode, the phases are ignored and the station powers are summed. This preserves the huge LOFAR field of view, yet at the cost of sensitivity. Nonetheless, it turns out that in some cases it is efficient to perform a survey in this incoherent mode. For example, after a discovery is made using the incoherent mode, the pulsar position can be quickly constrained by switching to the coherent mode. Thus, the combination of a large instantaneous field of view, large sensitivity, and capability to form small beams on the sky for follow-up, makes LOFAR well-suited to performing pulsar surveys.
LPPS used all of the High Band Antennas of the stations that were available in December 2010 to do a fast survey of the northern celestial hemisphere. Each pointing in LPPS consists of 7 simultaneous beams, formed by incoherently combining the station beam data. In this setup, bandwidth is traded for sky coverage; each of the 7 station beams has 1/7th the total 48 MHz bandwidth, but the full sky coverage of 1 station beam. The LPPS pointings cover 167 square degrees each and have an integration time of 57 minutes. In total, 246 observations were taken for this survey, covering almost the entire northern sky. Even though the LOFAR stations were not yet fully calibrated during LPPS the data was already of high quality, as many pulsar re-detections during preliminary processing have shown. Figure 1 shows an actual LPPS pointing and several pulsar detections in it.

The second commissioning goal of LPPS is to test and optimize the LOFAR pulsar search pipeline. The LPPS data is searched for both periodic pulsar signals, and for fast radio transients, i.e. short, bright, dispersed radio bursts. Searching through even a pilot survey such as LPPS takes significant computing resources: these are provided by the Hydra compute cluster at the University of Manchester. To process LPPS, and following pulsar surveys, we adapted existing and proven pulsar search software, and wrote scripts to automate this processing on Hydra. We have made an initial processing pass through much of LPPS. With the pipeline improvements from that testing, we are now reprocessing the entire data set, and look forward to the pulsars that LPPS will turn up. Already we have independently discovered one new pulsar (see Figure 2), which was also found recently in a GBT survey of the northern sky at 350 MHz. After calibration and with better station monitoring, the current-day LOFAR is significantly more sensitive than last December’s LPPS LOFAR. The future is bright for new LOFAR pulsar surveys: we are working on several and hope to share more results soon!

Another step in the completion of the LOFAR telescope was set with the opening of the final two planned international stations. On September 26 the Swedish LOFAR station in Onsala was opened and on October 5 the opening of the last German station in Jülich completed the full set of eight international LOFAR stations. In addition to that, the network connection was upgraded to 2 x 10 Gbit/s links between Aachen/Jülich and Amsterdam and to 3 x 10 Gbit/s links between Amsterdam and Groningen, enabling all eight international LOFAR stations to operate simultaneously at full bandwidth.

In the Netherlands RS508 and RS509 in the northern part of the province of Groningen were added to the array. With these stations, the Dutch part of LOFAR now has baselines of up to 80 kilometres. The inclusion of these stations has increased the resolution of the Dutch array, but not without the expense of needing a more complicated calibration: on these long baselines ionospheric effects are serious and have to be taken into account. Furthermore, four additional core stations, CS011, CS013, CS028 and CS031 are now included in the array.

ASTRON summer student Mark Aartsen from the University of Adelaide in Australia made the first detection of an ionospheric wave over the LOFAR array. Using baselines of up to 40 kilometres to observe the 80 Jy source 3C196, Mark was able to derive a wave velocity of approximately 250 km/s and a wavelength of approximately 120 km, similar to previous detections of ionospheric waves over other low-frequency radio arrays. Not only should the LOFAR calibration scheme be able to deal with these disturbances, but LOFAR might also be able to generate data on the ionosphere with an unprecedented quality!

In addition to the ionosphere, dealing with the different station primary beams that vary in both time and frequency is another challenge for the LOFAR data processing.
The pulsar group recently was able to make their first detection of a cosmic ray in combination with the LORA detectors. This is a major step forward in LOFAR's ability to carry out wide field of view observing and data processing.

The primary beams that LOFAR was effectively using were severely affected by malfunctions affecting the stations within the Core. Action was taken over the summer to address this issue. The origin of the problem was found, measures were taken to drain the water from the stations, the HBA modems were redesigned and most of the malfunctioning modems were temporarily replaced. Thanks to the great work by the roll-out team, the whole repair process took only a few weeks and the stations are back to their original sensitivity.

The single clock in the superterp has been a huge success that it is now being proposed to bring all of the 24 core stations onto a single clock. This will allow the coherent addition of these stations, resulting in even more sensitive tied array beams. Moreover, the real time calibration of the primary beams that LOFAR was used to carry out wide field of view observing and data processing.

Galaxies do not live in isolation. Instead, they are constantly interacting with one another and with the gaseous medium around them. This idea is supported by a vast amount of observational and theoretical studies. It is at the very core of our understanding of galaxy formation and evolution.

Data collected for the Atlas3D project confirm that galaxies' morphological mix (the fraction of early- vs. late-type galaxies) depends strongly on the environmental density. Also, they allow us to study the morphology-density relation from a novel point of view by looking at the way stars move within galaxies.

Within the Atlas3D project we find hints that such a morphology-density relation is driven by the "local" environment of a galaxy -- what really matters is the number of neighbours within a few 100 kpc from it. One of these results comes from a large amount of Westerbork data taken in order to study the neutral-hydrogen (HI) gas content of early-type galaxies.

We find that early-type galaxies in poor "local" environments host typically giant HI discs with radii of up to many tens of kpc. At the edge of these discs the orbital time can be as long as 1 Gyr.
These gaseous systems are very regular, indicating that the host galaxy has enjoyed a quiet life for a very long time (for example, it has not had recent close encounters with other galaxies of similar size). The situation is very different in richer environments like galaxy groups and the outskirts of galaxy clusters. Here HI exhibits typically a very disturbed morphology. Gas discs are also found at these densities, but they are less regular than those in poor environments because of the interaction with nearby galaxies. In many cases long HI tails stretch from the host galaxy into the surrounding space. These tails demonstrate that some gas may have recently been removed from (or accreted onto) the galaxy. In this environment things are happening now and early-type galaxies are evolving because of the interaction with what is around them. Finally, in the very centre of clusters, where many slow rotators live, 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. These and many more results are described in the first dozen Atlas3D papers, recently published or submitted for publication. Check them out and stay tuned for new results at http://purl.org/atlas3d!

Figure 2: 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. Credit Serra et al. (2011, MNRAS, arXiv:1111.4241) submitted, based on WSRT data.

The JWST mission aims at supplementing the HST mission by focusing on objects farther away and thus deeper into the history of the universe. Therefore, the primary mirror of this telescope has a diameter of 6.5 meters (almost 3 x HST) and the science instrument suite programmed on the JWST focuses on longer wavelengths: NIRCAM (imager) and NIRSPEC (spectrometer), covering the wavelength range between 0.6 and 5 μm, and MIRI (imager and spectrometer), covering the wavelength range between 5 and 28 μm. This summer, the Flight Model (FM) of MIRI, built by a huge European-led consortium including the NOVA Optical/Infrared group at ASTRON (responsible for the spectrometer optics), has completed very successfully its final pre-delivery test campaign. The test results should prove that MIRI is ready for acceptance by both ESA and NASA. This first of the instrument acceptance reviews is upgraded to what ESA calls a 'Category 1 level', demonstrating its importance. After the acceptance, the instrument can be shipped to the US to be integrated into the instrument module of the JWST.

The full cryogenic tests (at an environment temperature of 30 K) took place at the Rutherford Appleton Laboratories (RAL) in the UK. The FM, visible in the Figure (covered fully in the shiny metallic foil), was placed in a large cryostat and tested thoroughly during a performance test period of almost 1600 hours (24 hours a day). The recent test campaign including functional testing lasted over 113 days. During this period the whole test program was completed without flaws and interruptions.

More information can be found on http://www.jwst.nasa.gov/miri.html.

Figure 1: The Flight Model of MIRI, fully covered in multi-layer insulation (MLI) foil, is mounted with its simulating arms to a laboratory mounting frame. This instrument will be cooled to 4 K. Credit: Rutherford Appleton Laboratory, MIRI European Consortium and JPL.

Figure 2: Without MLI the real hardware of MIRI becomes visible. The black rods from a carbon fibre insulation mount keep the instrument accurately at its position (even after launch). The bottom consists of the imager of MIRI and the pick off optics. The upper part of the instrument is the spectrometer. Credit: Rutherford Appleton Laboratory, MIRI European Consortium and JPL.

Recent excitement over the serious budget overrun by the prestigious successor of the Hubble Space Telescope (HST) put the James Webb Space Telescope (JWST) high on the political agenda with a severe risk that the project could be cancelled. Notwithstanding these big forces outside the project, developments within the project need to continue. With an original scheduling of launch in 2013, the three science instruments for the JWST are close to completion.

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Currently, there are several cosmological experiments (planned and ongoing) that use low frequency radiation to study the structure, evolution, and origin of our Universe. Among those are cosmic microwave background radiation experiments (e.g. Planck satellite) and cosmological 21 cm experiments (e.g. LOFAR, MWA and SKA). In addition to the main scientific goals of each experiment, they all have one more thing in common: interesting and exciting field in its own right.

At the Joint Institute for VLBI in Europe (JIVE), major efforts are focused on further enhancing the operational capabilities of e-VLBI. Besides incorporating additional telescopes and collaborating with network providers on allocating more bandwidth more flexibly, the project focuses on large bandwidth storage. This will offer the option of buffering data streams en route from the telescopes and on arrival at the correlator, giving e-VLBI the robustness and flexibility to provide the best possible science. Most of this work is done within the FP7 funded programme NEXPReS. In September the project successfully passed its first period review, and the development work is in full swing at all NEXPReS partners, including both JIVE and ASTRON.

An important milestone of e-VLBI developments was the deployment of the EVN software correlator at JIVE (SFXC) for e-VLBI. During a test on August 26, real-time correlation of up to 9 stations at a data rate of 1 Gbps was possible in real-time. This wonderful result was then superseded on 11 October when the same system used the CDAS and Mk5 units in parallel, and 3 Gbps fringes were detected at JIVE between Seshan, Kunming and Urumqi. Hopefully the various systems under development around the world will soon allow user experiments for EVN users, because the greater flexibility and higher accuracy it offers is much in demand.

One reason for concentrating on the software correlator is its use for recording more bandwidth and achieving higher sensitivity. Since the EVN Mk4 data processor is based on custom chips operating at 32 MHz, its individual bandwidth per channel is limited to 16 MHz. To reach beyond its limitation of 16 x 16 MHz channels and data rates of 1 Gbps, new recording equipment and new correlator hardware is necessary. On July 7 the software correlator upgrade is good news for EVN users, because the greater flexibility and higher accuracy it offers is much in demand.

NEXPReS results for e-VLBI!

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An important milestone of e-VLBI developments was the deployment of the EVN software correlator at JIVE (SFXC) for e-VLBI. During a test on August 26, real-time correlation of up to 9 stations at a data rate of 1 Gbps was possible in real-time. This wonderful result was then superseded on 11 October when the same system used the CDAS and Mk5 units in parallel, and 3 Gbps fringes were detected at JIVE between Seshan, Kunming and Urumqi. Hopefully the various systems under development around the world will soon allow user experiments for EVN users, because the greater flexibility and higher accuracy it offers is much in demand.

One reason for concentrating on the software correlator is its use for recording more bandwidth and achieving higher sensitivity. Since the EVN Mk4 data processor is based on custom chips operating at 32 MHz, its individual bandwidth per channel is limited to 16 MHz. To reach beyond its limitation of 16 x 16 MHz channels and data rates of 1 Gbps, new recording equipment and new correlator hardware is necessary. On July 7 the software correlator upgrade is good news for EVN users, because the greater flexibility and higher accuracy it offers is much in demand.
Besides demonstrating the capabilities of the telescope backends and the correlator, such tests are of course also showing the compatibility between international VLBI systems. And in this category there was another highlight, namely the first observations of EVN antennas together with elements in the Korean VLBI Network. The common frequency between the arrays is at 22 GHz, a frequency at which tropospheric effects (like rain!) are expected to seriously affect the phase stability on long baselines. Nevertheless, the fringes were found easily in an e-VLBI test on October 19, between 3 European and 2 Korean antennas. This demonstrated that there are very good network connections between Korea and Europe, as well as compatibility between the different recording systems. It is clear that there are no borders to start running e-VLBI in an even more global setup than we have had so far.

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Imaging the youngest radio supernova

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Only about one fourth of the observed core-collapsed supernovae are detected at radio wavelengths. In the last 30 years only about two dozen supernovae have been detected in the radio domain and around 100 additional upper limits have been established. Out of these, those resolved at milliarcsecond-scales can be counted on the fingers of one hand.

On 1 June 2011, a new Type II supernova, dubbed SN2011dh, was discovered by the Palomar Transient Factory (PTF) in the nearby galaxy M51, at a distance of about 7 Mpc. Just 3 days after the discovery, the radio emission from the supernova was detected by the Combined Array for Research in Millimeter-wave Astronomy (CARMA) at 107 GHz, and monitoring with the Expanded Very Large Array (EVLA) started.

Jumping on the opportunity to observe a supernova at high-resolution so early in its evolution, two independent groups (one including M. Argo, M. Garrett, V. Tudose from ASTRON, and Z. Paragi, J. Yang from JIVE), applied for observing time with the European VLBI Network (EVN) via Target of Opportunity requests. Given the rarity of the occasion, the observing time was granted, and the two teams joined forces in an attempt to make the best out of the observations.

SN2011dh was observed on 14 June 2011 at 22 GHz for about 11 hours with the following telescopes within the EVN: Effelsberg (Germany), Robledo and Yebes (Spain), Onsala (Sweden), Metsahovi (Finland), and Jodrell Bank (UK). The object was detected with a flux density of 2.5 +/- 0.5 mJy (the identification of the target has been confirmed by independent VLBI observations in August). Obtained just 2 weeks after the initiation of the event, the associated radio map (Figure 1) represents the earliest high-resolution image of a radio-loud supernova so far.

During a supernova event the matter is ejected at velocities of thousands of km/s. Shocks are formed that emit at radio frequencies. This radiation is of synchrotron origin and its spectrum shifts towards lower frequencies over timescales of hundreds of days. In fact, observations with the Westerbork Synthesis Radio Telescope (WSRT) on 6 June 2011 at 5 GHz showed no sign of the supernova, as expected.
The VLBI observations are one of the few direct probes of the evolution of a supernova in the relatively early stages (the first couple of years). The rate of the expansion of the ejecta can directly be measured. By modeling the decay rate of the flux density and the variation of the size of the radio emitting region over time, other information can be obtained, related, for instance, to the energetics of the event, the density profile of the circum-stellar medium, etc. Beyond the wealth of information on the individual events, the VLBI data are also useful in a broader, statistical sense. For instance, the VLBI-measured expansion velocities of the few Type II supernovae observed so far show a relatively wide range of values, from 10,000 up to 50,000 km/s. Most of these are about one order of magnitude higher than the predicted theoretical values. If this result holds with the increasing size of the sample then some common assumptions about the properties of the interstellar medium will have to be amended.

The EVN detection of SN2011dh is just the first step in a long-term monitoring campaign. At this early stage the object was compact and only an unconstrained upper-limit to the expansion velocity could be established. Intriguingly, the flux recovered at the VLBI scale was smaller than that detected in the same day, at the same frequency, by the EVLA. This suggests a contribution of extended emission in the EVLA measurements or calibration issues in the EVN and/or the EVLA observations.

The results are presented by Marti-Vidal, Tudose, Paragi et al., “VLBI observations of SN 2011dh: imaging of the youngest radio supernova”, accepted for publication in Astronomy & Astrophysics.

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SPHERE-ZIMPOL towards the mountain

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Direct detection and spectral characterisation of extra-solar planets is one of the most exciting but also one of the most challenging areas in modern astronomy. For the second-generation instrumentation on the VLT of ESO, a unique instrument is being developed: SPHERE combines a powerful adaptive optics system (SAXO), various coronagraphs, an infrared differential imaging camera (IRDIS), an infrared integral field spectrograph (IFS) and a visible differential polarimeter (ZIMPOL).

The ZIMPOL focal plane instrument is a technology development from the group of ETH in Zurich (Switzerland), the NOVA Optical/Infrared group at ASTRON in Dwingeloo, the UvA and UU.

ZIMPOL is a complex system that can only be built with the support from several other high level groups (e.g. instrument software by INAF in Padova (Italy), data reduction software by MPA in Heidelberg and the detector system by ESO in Garching (Germany)). Besides the NOVA group at ASTRON, two other groups from ASTRON contributed significantly: the electronics department gave support for electronics, integration and testing and the ICT group who installed linux servers and supported the connection of external collaborators to the ZIMPOL systems.

In June 2011 the SPHERE collaboration came to Dwingeloo for the review of ZIMPOL and accepted the instrument. Finalizing the remaining action items will require shipment in December 2011 to Grenoble for the final integration in SPHERE, and in 2012, shipment of the full instrument to Paranal (VLT site, Chile).

ZIMPOL is a high-precision imaging polarimeter working in the visual range, covering at least 600 to 900 nm. The ZIMPOL instrument principle is based on a differential comparison of the two polarisation images by fast modulation with a Ferro-electric Liquid Crystal, creating a contrast of $10^{-7}$ to $10^{-8}$ by using a coronagraph with clever calibration and dither procedures. Planets with atmospheres are revealed, because their reflected light is polarized, while starlight is not polarized. Also, proto-planetary disks and debris disks will be observed with this polarization technique.
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Our mission is to make discoveries in radio astronomy happen, via the development of novel and innovative technologies, the operation of world-class radio astronomy facilities, and the pursuit of fundamental astronomical research.

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