ASTRON building finished
LOFAR studies famous mode-switching pulsar B0943+10
Over 300 engineers and scientists gather in Western Australia to advance the SKA telescope
The spiral galaxy M101 belongs to a small and select group of galaxies that are the HI icons of the WSRT. M101 is one of the largest nearby late-type galaxies and, because it is seen fairly face-on, offers one of the most detailed views of the complex structure and kinematics of spiral galaxies.

The latest observations were done last year. Twenty days of observation were used to cover the entire extent of the galaxy (about 1 degree). Compared to the observations of the early 70's, the new data reveal features that are about hundred times fainter than the weakest HI clouds in the first observations. The main aim of the observations is to study, in the greatest possible detail, the effects of star formation and of gas accretion on the disk of a spiral galaxy. For this purpose, these HI data will be combined with WSRT and LOFAR observations of the (polarised) continuum emission of M101.

*Credits cover image: Tom Oosterloo*
## CONTENTS

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Director’s corner</td>
</tr>
<tr>
<td>6</td>
<td>Supermassive black hole trio shakes spacetime</td>
</tr>
<tr>
<td>7</td>
<td>The first lowfrequency limit on Fast Radio Bursts</td>
</tr>
<tr>
<td>8</td>
<td>The LOFAR longbaseline snapshot calibrator survey</td>
</tr>
<tr>
<td>9</td>
<td>Optical link technology for LFAA</td>
</tr>
<tr>
<td>10</td>
<td>New Postdoc at ASTRON</td>
</tr>
<tr>
<td>11</td>
<td>LOFAR Multifrequency Snapshot Sky Survey</td>
</tr>
<tr>
<td>12</td>
<td>DOME project: Steroids for the SKA</td>
</tr>
<tr>
<td>13</td>
<td>LOFAR studies famous modeswitching pulsar B0943+10</td>
</tr>
<tr>
<td>14</td>
<td>The Low Frequency Aperture Array</td>
</tr>
<tr>
<td>16</td>
<td>SKA1-LOW architecture team visits ASTRON</td>
</tr>
<tr>
<td>17</td>
<td>New Postdoc at ASTRON</td>
</tr>
<tr>
<td>18</td>
<td>Over 300 engineers and scientists gather in Western Australia to advance the SKA telescope</td>
</tr>
<tr>
<td>20</td>
<td>New Postdoc at ASTRON</td>
</tr>
<tr>
<td>21</td>
<td>Polarimetry of the IGM: astrophysics at 1 rad/m²</td>
</tr>
<tr>
<td>22</td>
<td>Peculiar Galactic ‘fog’</td>
</tr>
<tr>
<td>23</td>
<td>A team for the success of RadioLife</td>
</tr>
<tr>
<td>24</td>
<td>Discovery of a hydrogen cloud near the spiral galaxy NGC 2403</td>
</tr>
<tr>
<td>25</td>
<td>New Postdoc at ASTRON</td>
</tr>
<tr>
<td>26</td>
<td>LOFAR zooms in on millisecond pulsar scintillation</td>
</tr>
<tr>
<td>27</td>
<td>Astronomy Pretty Poster Pageant 2014</td>
</tr>
<tr>
<td>28</td>
<td>New Postdoc at ASTRON</td>
</tr>
<tr>
<td>29</td>
<td>Lunar hide and seek</td>
</tr>
<tr>
<td>30</td>
<td>ASTRON and SETI PC at IAC 2014</td>
</tr>
<tr>
<td>32</td>
<td>Good night sweet, princely MFFE…</td>
</tr>
<tr>
<td>33</td>
<td>Delegations from South Africa and NWO-EW visit ASTRON</td>
</tr>
<tr>
<td>34</td>
<td>SPHERE-ZIMPOL on sky</td>
</tr>
<tr>
<td>35</td>
<td>New PhD student at ASTRON</td>
</tr>
<tr>
<td>36</td>
<td>APERTIF successfully passed its Critical Design Review</td>
</tr>
<tr>
<td>38</td>
<td>Outreach and media</td>
</tr>
<tr>
<td>39</td>
<td>New Polish ILT stations update</td>
</tr>
<tr>
<td>40</td>
<td>New PhD student at ASTRON</td>
</tr>
<tr>
<td>41</td>
<td>Sharp radio images unravel the mystery of gamma rays in stellar explosions</td>
</tr>
<tr>
<td>42</td>
<td>The third operational cycle for LOFAR (LC2)</td>
</tr>
<tr>
<td>44</td>
<td>Connecting with Portugal for developments in energy and the SKA</td>
</tr>
<tr>
<td>45</td>
<td>New PhD student at ASTRON</td>
</tr>
<tr>
<td>46</td>
<td>SKA Board visiting FAST</td>
</tr>
<tr>
<td>48</td>
<td>Calibration &amp; Imaging Tiger Team</td>
</tr>
<tr>
<td>49</td>
<td>The ASTRON/JIVE Summer Student Programme 2014</td>
</tr>
<tr>
<td>50</td>
<td>Building process finished</td>
</tr>
</tbody>
</table>
There has been a lot going on at ASTRON since the summer! We hope you will enjoy reading about some of the highlights from the past few months in the Winter 2014 edition of the ASTRON news.

This edition is full of interesting scientific results from the ASTRON, JIVE, and NOVA-Optical groups, including discoveries of a hydrogen cloud associated with a spiral galaxy approximately ten million lightyears away, and a triple supermassive black hole system. An instrument for exoplanet-hunting, developed by NOVA and collaborators, was commissioned for the VLT and already shows impressive images. The third LOFAR operational cycle has been completed, and the fourth operational cycle is underway. The high-band antenna observations for LOFAR’s first imaging survey (MSSS) have also been completed, and a journal publication with an initial mini-catalogue will be available soon. You can also find details about developing technologies for the SKA, and other exciting events.

ASTRON always strives to do as much public outreach as possible. This year we organised the ‘Girlsday’, to introduce girls to radio astronomy and associated technologies. We have also been working on a novel for children called ‘het Logboek’ that introduces them to the exciting world of radio astronomy. We are also very proud of the extensive media attention ASTRON has garnered, and you can read more about this in this edition of the ASTRON news.

The new ASTRON office building has also been finalised, so the next time you come to visit, you will be welcomed into the newly renovated space!

From everyone at ASTRON, we wish you happy holidays and all the best for the New Year!

The Editorial Team
As 2014 draws to a close, we reflect on a year of tremendous success for ASTRON and its partners. The recent award of 12M€ of National Roadmap money covering part of the Netherlands contribution to the SKA Design Phase is one of a number of important successes.

The resulting establishment of the NL SKA Consortium is also a very welcome development. The consortium will oversee the management of the Roadmap project and the distribution of funds. Meanwhile, the international SKA project is also taking great strides forwards.

A major task for the community and the SKA Office is to understand how the various re-baselining scenarios can fit within the stated 650M€ cost-cap. The expectation is that a range of scenarios will be presented to the SKA Board at their meeting in March 2015 and a decision on the final design of Phase 1 will be made.

Another major goal of the project is to engage with the various SKA members at government level – a Letter of Intent has been distributed to the members with the aim of seeing these signed by ministries early next year – the letter requests ministry level engagement to kick-start discussions on topics such as the future governance model for the SKA and possible funding scenarios/contributions. And finally, the location of the SKA Office HQ in the construction phase also needs to be decided in 2015.

As the SKA moves towards the construction phase, ASTRON is also beginning to see how it positions itself towards contributing to the operational phase of the project. It is now clear that the SKA’s operational phase will require support from national and regional Science, Engineering and Data Centres. For some time, we have been looking towards a Science Data Centre that would ensure optimal exploitation of not only the SKA but also other facilities, in particular LOFAR. The headline goals of such a centre would include the generation of Science Ready Data Products (SRDP), distributed (possibly Cloud-based) access to the SRDP repository, improved pipeline heuristics, advanced algorithm development, interactive portal-based reprocessing, and the development of new science-enabling tools (especially in the area of visualisation and Big data analytics). End-to-end astronomer support, including a 24/7 help desk and face-to-face user assistance will also be an important aspect of the centre’s mission.

In October, the APERTIF CDR (Critical Design Review) took place. APERTIF is a PAF (Phased Array Feed) based system that would increase the survey speed of the Westerbork Synthesis Radio Telescope (WSRT) by more than an order of magnitude. We are pleased to report that APERTIF passed the CDR with flying colours, a testimony to the huge effort that staff at ASTRON have invested in the project over the last months and indeed years. The CDR report will be an important input on the “Go/No-go” decision that also needs to take into account the available remaining capital costs and the longer-term operational costs. We will be taking advice from many parties, including our own Scientific Advisory Committee – we expect to make a decision on the future of APERTIF before the end of the year.

Finally, we have received a favourable assessment of our mid-term self-evaluation report by the NWO Board. This is an important step in preparing for our next full and independent evaluation expected to take place in 2017. We expect that one of the outcomes of the acceptance of the mid-term report will be the continuation of ASTRON’s base-budget at its current level.

In the meantime, on behalf of the ASTRON Management Team, I wish you a merry Christmas and a very productive 2015.

Prof. Michael A. Garrett (garrett@astron.nl)
General & Scientific Director of ASTRON
Supermassive black hole trio shakes space-time

Zsolt Paragi (zparagi@jive.nl)

Finding dual, and even multiple, supermassive black holes is of great importance because these systems have played an important role in forming galaxies in the early Universe, and they are also a potential source of gravitational wave radiation.

Networks of radio telescopes like the European VLBI Network (EVN) are particularly well suited for this quest because the unprecedented angular resolution allows us to resolve the closest pairs of supermassive black hole (SMBH) candidates. In a paper published in the 3 July 2014 issue of Nature, Roger Deane (UCT), and collaborators, report the detection of a small-separation compact double source within the system J1502+1115, that was already known to host a wider separation dual-SMBH, using the EVN, see Figure 1. The compact structures and the observed flat spectra point to the presence of an inner dual active galactic nucleus (AGN) in a rare type of triple-SMBH system (there are currently only a handful of suspected candidates), with a separation of only 140 parsec for the inner pair.

This finding needs to be confirmed by further observations because another group has claimed that the VLBI structure might instead indicate a peculiar Compact Symmetric Object (CSO): a pair of compact radio lobes from a single, young active galactic nucleus. In any case, J1502+1115 remains a high-profile target for sensitive VLBI observations.

Deane et al. also predict that the orbital motion of very small separation ‘binary’ black holes will be imprinted onto their large-scale jets, twisting them into a helical or corkscrew-like shape, see background image. Therefore, even though some black holes may be too close together for our telescopes to resolve them, their twisted jets may help in locating these systems in the future, using sensitive instruments like the Square Kilometre Array (SKA).

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Zsolt Paragi is the head of User Support at the Joint Institute for VLBI in Europe.
The first low-frequency limit on Fast Radio Bursts

Joeri van Leeuwen, Thijs Coenen
(leeuwen@astron.nl)

In 2007, a millisecond-duration radio burst was detected, whose high dispersion strongly suggested an extra-galactic origin. Since then, a handful more of such bright Fast Radio Bursts (FRBs) have been detected from other directions. None of these have ever been seen to repeat. The origin of the bursts remains unclear, but the brightness and distance suggests that a highly energetic process must be involved. Given their extremely short observable lifetime (a few milliseconds) detecting more FRBs is challenging. The LOFAR Pilot Pulsar Survey (LPPS) was the first low-frequency survey with enough sky coverage to detect an FRB.

The first pilot survey for radio pulsars and fast transients with LOFAR, LPPS, was set up to use the ‘incoherent sum’ mode of as many high-band antenna stations as possible. LPPS covered a large fraction of the northern sky: about 14,000 square degrees, using one-hour dwell times (see left panel of Figure 1).

Due to the long dwell times and the large field of view provided by LPPS, the survey data can be used to either detect or limit FRBs at low radio frequencies. FRBs have previously only been detected at 1.4 GHz using the Parkes and Arecibo radio telescopes. After searching LPPS for bursts originating from outside our Galaxy, no FRBs were detected. Thus, we derived a limit on the occurrence of FRBs at 142 MHz: less than 150 per day across the entire sky. This number is consistent with the rate derived from the Parkes detections for a range of spectral indices (see right panel of Figure 1).

Ongoing LOFAR transient searches will either soon find FRBs or show that the 1.4 GHz window is optimal for their detection.

For further information, see Coenen et al. 2014, A&A 570, A60.

Joeri van Leeuwen is a Staff Astronomer in the Astronomy Group at ASTRON. Thijs Coenen graduated from the University of Amsterdam in 2013 with a PhD thesis entitled ‘Searching for Pulsars with LOFAR’ and the work described here was a significant part of his thesis.
The LOFAR long-baseline snapshot calibrator survey

Javier Moldón, Adam Deller
(moldon@astron.nl)

True sub-arcsecond imaging at frequencies below 300 MHz is now possible after the commissioning of the International LOFAR Telescope. To make full use of this new capability, astronomers needed to understand the population of compact sources that could be used to calibrate International LOFAR. We find that at ~140 MHz, the density of suitable long-baseline calibrators is approximately one per square degree: high enough that a suitable calibrator should be found virtually anywhere in the sky.

The majority of the LOFAR stations are distributed over an area that is roughly 180 km in diameter. Currently, the array also includes eight international LOFAR stations across Europe that provide baselines up to 1300 km. The calibration of these stations requires specialised data reduction techniques borrowed from Very Long Baseline Interferometry (VLBI), and the use of compact, nearby calibrators. Therefore, we studied the population of compact sources at low frequencies and their suitability as calibrators.

We used the multi-beaming capability of LOFAR to conduct a fast and computationally inexpensive survey using the full international LOFAR array. We inspected 630 sources in two hours to determine whether they possess a sufficiently bright and compact component to be used as LOFAR delay calibrators.

Three main conclusions can be derived from our work. Firstly, with a survey speed of approximately 30 targets in five minutes in ‘snapshot’ mode, identifying the optimal calibrator for a LOFAR observation using the full international array can be quickly performed before the main observation.

Secondly, the density of suitable long-baseline calibrators at around 140 MHz is approximately one per square degree: high enough that a suitable calibrator should be found virtually anywhere in the sky (excluding regions of high scattering, such as the Galactic plane), see Figure 1.

Thirdly, we have identified the key parameters from low-frequency catalogues to select potential suitable calibrators. Useful predictors that a source will be suitable as a calibrator include: a high flux density, a flat low-frequency spectrum, and that it is compact on arcsecond scales at GHz frequencies. However, the spectral index at higher frequencies is a poor predictor.

The details of the observational strategies used for the International LOFAR Telescope, the calibration techniques for metre-wavelength VLBI, and the expected distribution of compact calibrators on the sky and their suitability will be published by Moldón et al. (A&A, accepted, see http://arxiv.org/abs/1411.2743).

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Javier Moldón is a Postdoc in the Astronomy Group at ASTRON. Adam Deller is a Staff Astronomer in the Astronomy Group at ASTRON.
Optical link technology for LFAA

Peter Maat (maat@astron.nl) on behalf of the Photonics/LFAA team

The signals from the 250,000 antenna elements in SKA’s Low Frequency Aperture Array (LFAA) will be transferred to a signal processor via low cost optical links. The required optical link technology has been developed by ASTRON, and is currently being tested in an Aperture Array Verification System (AAVS) demonstrator system in Western Australia.

The current concept for the LFAA system consists of 250,000 antenna elements. A big challenge during the development of the LFAA technology is to keep the costs of the technologies, which are needed for the transfer and processing of the large number of signals received, to an acceptable level. A novel approach to realising these low costs is to transfer the signals from the antenna elements directly to a central signal processor, without any signal processing in the harsh environment at the antenna locations. The long distance signal transport that is needed for this approach can only be provided by optical analogue link technologies.

In the past years, a low cost optical analogue link has been developed at the ASTRON R&D lab, which complies with the requirements of the LFAA system.

The ASTRON optical link is a custom made system with a low cost DFB laser at the transmitter and a photo diode at the receiver. Both modules are equipped with a custom-designed low-power impedance matching/amplifier stage, and they are combined with the optical modules on a PCB. The transmitter and receiver modules have a low cost USB-A connector as an RF and power interface.

The optical links made by ASTRON are currently being demonstrated and tested in a demonstrator system for the AAVS project. The demonstrator consists of 16 antennas, each of which is connected to a receiver via an optical link.

The optical modules are combined in a box on a PCB, which is shown in Figure 1.

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Peter Maat is the project leader of Optical Signal Processing and Transport in the Research and Development Group at ASTRON.

Figure 1: The PCB with 16 optical link modules.
Hi! I am André Offringa and I am happy to have started working as a Postdoc at ASTRON since 1 October. About two and a half years ago I finished my PhD at the Kapteyn Astronomical Institute in Groningen, on the subject of radio-frequency interference mitigation for LOFAR and the Epoch of Reionisation (EoR) project. After that, I have been in Australia to work as a Postdoc on the Murchison Widefield Array (MWA). I was involved in calibration and imaging for the MWA EoR and survey projects.

Now that I’m back in the Netherlands, I will be working on LOFAR data, and I am (again) a member of the LOFAR EoR group. One specific project I will undertake is surveying the LOFAR EoR fields for sources with redshifted 21-cm HI absorption.

Besides astronomy, I am a big fan of all kinds of dancing. I like ballroom dancing in particular, for which I am also a teacher. I also like playing instruments, especially piano. I live in Groningen and work two days per week at the Kapteyn Astronomical Institute and three days per week at ASTRON. My work involves a lot of interaction with colleagues both within and outside ASTRON, which I enjoy a lot.

In my free time I enjoy sailing on the beautiful Waddenzee, windsurfing and playing classical guitar.
LOFAR Multi-frequency Snapshot Sky Survey

George Heald (heald@astron.nl)

LOFAR’s first imaging survey has made great strides and is poised for its first data release.

LOFAR’s first imaging survey, the Multi-frequency Snapshot Sky Survey (MSSS), is mapping the northern radio sky in two frequency ranges: 30-75 MHz, using the low-band antennas (LBAs); and 120-160 MHz, using the high-band antennas (HBAs).

Observations using the HBAs have been completed and used to create image mosaics of the entire survey area. The creation of the first HBA source catalogue is underway and expected to contain a quarter of a million extragalactic radio sources.

A journal publication describing the full MSSS survey, along with a representative mini-catalogue in a verification region, has been completed and will be available to the international community soon! Early science results from MSSS data are also in progress and will start to appear throughout the next year.

The next steps will include: further progress on the LBA portion of the survey; efforts toward a higher angular resolution MSSS-HBA survey product; and cooperative work with the counterpart radio survey in the southern sky (GLEAM) using the Murchison Widefield Array (MWA). Ultimately, MSSS and GLEAM together will produce a uniform low-frequency radio catalogue covering the entire sky.

George Heald is a Staff Astronomer in the Astronomy Group at ASTRON.

Figure 1: A large MSSS-HBA mosaic, 29 degrees across, near the celestial equator. The image rms is around 12 mJy/beam with 2.5’ resolution.
DOME project: Steroids for the SKA

Erik Vermij, Bram Veenboer & John Romein (erik.vermij@nl.ibm.com, veenboer@astron.nl, romein@astron.nl)

The upcoming Square Kilometre Array (SKA) radio telescope will offer scientists great opportunities for research. However, huge compute capabilities are needed to support this.

The SKA will deploy hundreds of dishes, and several hundreds of thousands of antennas. Although all of these must be designed and built with great care, the final research product will also be provided by software. The requirements for the software processing steps in the SKA are huge. To put these requirements in perspective:

- 150,000 x more incoming data than Facebook's photo service,
- 5 x more data in ‘hot’ storage than an entire year of Facebook photos,
- 5 x more compute power than today’s fastest supercomputer.

To make the SKA a reality, we will need to come up with fast and efficient solutions for the most demanding steps in the processing pipeline for the SKA. Here is where the so called ‘accelerator package’ of the DOME project comes in.

Track 1: Optimising algorithms for existing and upcoming hardware algorithms required for, e.g. creating sky images.
These are very specific, and often the result of years of research. When algorithms have proven themselves, it is time to optimise them to run very efficiently on modern hardware. This is a non-trivial task, but reaching high hardware utilisation is critical for the feasibility of the SKA.

We implement and optimise some of the key algorithms, e.g., a filter, correlator, and imager, on a wide variety of accelerator platforms, such as GPUs, the Xeon Phi, and a DSP. We compare their performance, energy efficiency (see Figure 1), and programming models.

Track 2: Developing novel hardware.
It has been shown that workload-optimised systems can beat existing hardware in speed and energy efficiency. Therefore, research has to be conducted into the design and possible realisation of SKA-optimised systems and devices.

Currently, our efforts are focussed on minimising data transport, and reducing unnecessary overhead. Both of which can limit performance and drain energy.

Erik Vermij and Bram Veenboer are PhD students in the Computing Group at ASTRON, and John Romein is a Senior Researcher in the Computing Group at ASTRON.

Figure 1: A custom-built energy meter measures the power consumption of a GPU at millisecond time resolution.
LOFAR studies famous mode-switching pulsar B0943+10

Anya Bilous, Jason Hessels & Vlad Kondratiev
(a.bilous@astro.ru.nl)

PSR B0943+10 is famous for its two stable modes of radio and X-ray emission. Using the LOFAR LBAs we have discovered a new phenomenon we hope can shed light on the physical mechanism.

PSR B0943+10 has two personalities: it switches rapidly, and apparently unpredictably, between a `Bright' and `Quiet' radio mode. Recently, a combined LOFAR/GMRT/XMM-Newton observing campaign showed that the observed X-ray emission properties also change at the same time (Hermsen et al. 2013, Science, 339, 436). Frustratingly, we still don’t understand why this happens.

In Bilous et al. 2014 (A&A, in press) we decided to delve deeper into these mysteries by observing PSR B0943+10 at the lowest possible radio frequencies. Since this pulsar has a particularly steep spectrum (it is also famous for that quality), it is very well observed using the LOFAR low-band antennas (LBAs).

Using 15 hours of Cycle 0 LOFAR data, we studied the frequency evolution of the pulsar’s pulse shape in order to constrain how the location of the radio emission region might change between the Bright and Quiet modes. We found that in both modes the profile evolution with frequency can be well explained by ‘radius-to-frequency mapping’ (i.e. the emission height grows towards lower emission frequency) at altitudes within a few hundred kilometres of the stellar surface. Also, despite the seemingly different behaviour of the profiles, we find that radio emission comes from virtually the same range of heights, if both modes originate at the same magnetic latitude.

We also carefully studied the timing properties during the two modes. Quite surprisingly, we also discovered that during the Bright mode the average profile shifts gradually towards later rotational phase, and then resets its position at the next Quiet-to-Bright transition, illustrated in Figure 1. Such a delay is puzzling because it is frequency-independent and much too large to be due to changing spin-down rate. One possible explanation for the delay is a variation of the accelerating potential inside the polar gap, which then causes changes in the corotation velocity of the plasma in the open field line region. This explanation connects the observed profile delay to the gradually evolving subpulse drift rate, which depends on the gradient of the potential across the field lines. The observed effect sheds more light on the pulsar’s Bright mode, which, unlike the Quiet mode, is not completely static, but evolves in a systematic and reproducible way before suddenly switching back to the Quiet mode. We hope that this added piece in the puzzle will help us gain a better understanding of the underlying physical mechanism behind pulsar emission modes.

Figure 1: PSR B0943+10’s simulated pulse profile versus time (vertical axis). The pulsar switches between Bright and Quiet modes. LOFAR LBA data shows that the profile systematically drifts by a few milliseconds in each Bright mode (here the effect is exaggerated by four times for clarity).
The Low Frequency Aperture Array

ASTRON participates in the SKA1-LOW telescope at various levels, from the antenna array up to the image processing. Part of the contribution is the ASTRON leadership of the Low Frequency Aperture Array (LFAA) Element.

LFAA Element of SKA1-LOW deals with the antenna array stations and station signal processing. The output signals of the ‘LFAA’, the station beams, are connected to the correlator and, subsequently, the image processing.

The Aperture Array Design and Construction (AADC) Consortium executing the LFAA work consists of teams from University of Oxford, University of Cambridge, INAF (Italy), ICRAR (Australia), KLAASA (China), JIVE, and ASTRON. The AADC Consortium completed two major milestones in Q3 2014 and finished a series of studies. The first of the two milestones was the re-baseline submission.

This milestone facilitates the process of re-baselining SKA1 with two main documents: an overall design report, and a detailed cost assessment.

The LFAA cost assessment was created using a bottom-up process, starting with resistors, nuts and bolts, and building the complete system up to large units. The outcome of this process led to a cost very close to the cost cap set by the SKA office.

The Preliminary Design Review (PDR) documents have been submitted: a set of more than 40 original documents describing the details of the system, including the antenna design, radio frequency-over-fiber (RFoF) link performance, the receiver, and the signal processing. The LFAA design follows the SKA1 baseline design closely: a telescope with 250,000 antennas, installed in 1024 stations, with 95% of these stations located in an area with a three kilometre diameter (the core). This system will be optimal for Epoch of Reionisation observations, pulsar searching and timing, and detecting transients.

As illustrated by the system diagram shown in Figure 1, all antennas in the core of SKA1-LOW are connected to the central processing facility. This creates a very flexible system; changes or upgrades to the signal processing only require a hardware (ex)change in the facility, allowing performance enhancements when they become available.

Key to the concept with a central processing facility is the RFoF technology, which allows long-range transmission of the signal before digitisation. ASTRON delivered one of the solutions for the RFoF link.
The photograph in Figure 2 shows a zoom-in of the RFoF receiver units. It is a compact, low-cost design that will be tested with a 16-antenna test array in the Murchison Radio Observatory, close to the SKA site in Australia.

The next step of the LFAA work package, after the completion of the PDR, is the realisation of a verification system. The verification system, envisioned to be three or four stations including one full-size station with 256 antennas, will be the final test for the LFAA technology. The system will be located close to the Murchison Widefield Array (MWA). The MWA will provide an initial test environment for the verification system.

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Jan Geralt Bij de Vaate is the SKA-AADC Consortium Manager in the Research & Development Group at ASTRON.
The SKA1-LOW architecture team consisting of Mark Waterson, Tim Cornwell, and Maria Grazia Labate visited ASTRON on 18 and 19 September 2014 to learn more about calibration options for the SKA1-LOW system.

Calibration plays a pivotal role in using current and future observations from radio telescopes. This is particularly true for the Square Kilometre Array (SKA), with its unprecedented sensitivity. Calibration issues are therefore steadily moving upwards on the priority list of the SKA architecture team. On 18 and 19 September 2014, three members of the SKA architecture group visited ASTRON to learn more from the experts working here.

George Heald and Ger de Bruyn presented the current state-of-the-art in LOFAR calibration. These talks gave clear insights into the practicalities of calibration of low-frequency instruments with clear ideas to be implemented for the SKA-LOW. The team were quite impressed by the progress made by the EoR team, as demonstrated by some very deep images of the NCP region (see Figure 1).

After the presentations about the experience gained from LOFAR, Stefan Wijnholds discussed the calibratability of the new generation of radio telescopes. He stressed that even with perfect imaging and calibration software, these instruments might not work as advertised if the wrong design decisions are made. This started an interesting and constructive discussion, which will be continued.

The team from SKA1-LOW was clearly impressed by the practical experience built up around LOFAR, and by the amount of thought ASTRON has invested into the design of radio telescopes – LOFAR and the SKA in particular.

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*Stefan Wijnholds is a Researcher in the Research and Development Group at ASTRON.*
My name is Kristina Nyland, and I recently joined the Astronomy Group at ASTRON as a postdoc in September 2014. I earned my undergraduate degree at the University of Michigan in 2007 (go blue!). In 2014 I completed my Ph.D. in Physics from New Mexico Tech in Socorro, NM.

My primary research interests revolve around the broad topic of galaxy evolution, and I’m especially interested in the impact and underlying physics of energetic active galactic nucleus (AGN)-driven feedback and outflows. My observational tool of choice during my PhD thesis was radio interferometry, and I have extensively observed with the Karl G. Jansky Very Large Array (VLA). I have also led very long baseline interferometric (VLBI) projects with the Very Long Baseline Array on its own as well as combined with the phased VLA.

I am very excited to extend the research I began during my PhD with the new observational tools available to me at ASTRON, such as LOFAR and the European VLBI network. My postdoctoral research will support the RadioLife project led by Raffaella Morganti. This project aims to provide critical insights into the typical life cycles of radio AGNs and the role they play in shaping the evolution of galaxies.

When I’m not doing research, I enjoy martial arts (Muay Thai and Brazilian Jiu-Jitsu), playing music (piano and saxophone), and practicing the Italian language.
Over 300 engineers and scientists from 15 countries recently travelled to Freemantle, Western Australia, to take part in an engineering meeting about the status, recent developments, and future progress of the Square Kilometre Array. This meeting had the largest number of participants who work on the SKA, to date.

The official proceedings were opened by Colin Barnett, Premier of Western Australia, in the presence of the SKA Organisation Director General, Professor Philip Diamond, the U.S. Consul General, and representatives from the Dutch and UK governments.

Updates on all aspects of the project were presented: from governance to precursor telescopes’ progress, design of the various elements of the SKA, and science priorities. This set the stage for two days of working meetings to discuss detailed aspects of the SKA’s design. Figure 1 shows the large number of attendees.
The SKA project is now in the pre-construction phase with 11 teams, called consortia, carrying out design work to enable the project to enter the construction phase in 2017-2018. These consortia consist of people from a variety of institutes and commercial companies from all over the world. Each consortium has been tasked with designing a specific element of the SKA telescope, for example, computing, infrastructure, and antenna design.

Over the next two days of the meeting, there was much discussion about an important upcoming period for the SKA: the preliminary design review. The review will look closely at the designs presented by the various consortia for each element of the telescope that they are responsible for. The review will also scrutinise the detailed cost estimates calculated by the consortia for the SKA’s first phase of construction. The 650 million Euros allocated for phase 1, while also ensuring that the telescope delivers groundbreaking science, should cover these costs.

The re-baselining process will optimise the phases of deployment of the SKA, before the critical design review in 2016. The science priorities of the SKA, which are currently being refined, will also be taken into account to help decide which instruments should be built first and what their specific design should be.

The ASTRON team was well equipped to participate in all of the different levels of the meeting. The team included a mix of engineers, scientists, and management.

Besides manpower, we were also able to transport the Radio Frequency over Fibre (RFoF) hardware to the meeting. This will be tested and evaluated on site in the coming months by the local team.

An interactive workshop on the re-baselining was also organised, to brainstorm the possible options. It was a very fruitful meeting, with lots of interesting suggestions on overall cost reduction, system design improvements, power reduction, and process enhancements. The attendees were divided into smaller groups and, after a two-hour brainstorming session, each group presented their ideas. Although the two-hour timeframe was short, the session was effective. A few of the suggestions are illustrated in Figure 2.

On the last day of the meeting, a number of delegates used the opportunity to visit the Australian SKA site, many of them for the first time due to the remoteness of the location. Despite the tight schedule, the visit was a great experience, see Figure 3.

Pieter Benthem is the project leader of Phased Array Systems in the Research and Development Group at ASTRON.
My name is Ioannis (Yiannis) Bagetakos, and I am a joint ASTRON-Kapteyn Postdoc. I originally come from Athens, Greece, but I have spent the last 15 years in the UK studying astronomy and software engineering and teaching undergraduate students. I completed my PhD in 2012 at the University of Hertfordshire working with Prof. Elias Brinks on the porosity of the interstellar medium in nearby galaxies, as well as on the development of a method to compare multi-wavelength images.

While at ASTRON, I will mainly be involved with the preparation for the upcoming MHONGOOSE survey (MeerKAT HI observations of nearby galactic objects: observing southern emitters, P.I. Prof. Erwin de Blok), in particular the target selection and science goals. In addition, I aim to continue the work of my PhD and increase my expertise on radio data reduction in light of APERTIF. Other projects include the determination of the gas scale height in galaxies and the gas porosity of LITTLE THINGS galaxies.

In the free time I have outside of astronomy, I enjoy listening to, and playing, music and learning to play new musical instruments. I also have an interest in team games, especially board and role playing games.
Polarimetry of the IGM: astrophysics at 1 rad/m²

Ger de Bruyn (ger@astron.nl), V.N. Pandey, Vibor Jelic and Michiel Brentjens.

Radio galaxies are often highly polarised at high frequencies. The object has to be Faraday thin to allow polarised emission to propagate. At very long wavelengths, where LOFAR operates, this requires an extremely tenuous emitting plasma. The lobes of giant radio galaxies occasionally provide such conditions. Therefore, these objects provide a unique probe of the (magnetised) intergalactic medium.

In a companion article in this issue, Vibor Jelic describes the very complex diffuse Galactic polarised foreground seen in the 3C196 field, a primary EoR window. Here, we draw attention to one of the many discrete polarised sources found in the same dataset, J0808+4928: a (giant) radio galaxy of about 90 arcseconds in angular size. Both lobes of this radio source have been detected, and are shown in the left panel of Figure 1.

The observed Faraday rotation measure (RM) has four contributions due to: the radio source itself; the intergalactic medium (IGM); the Galactic interstellar medium; and the ionosphere. Each of these four components brings challenges in either the interpretation or the calibration of the data.

To learn about the Faraday rotation caused by the IGM, which thus far has not been unambiguously detected, we need to worry mostly about the Galactic contribution, which can vary by several rad/m² on angular scales of one degree. Ideally, we would like to find sources very close together, but at different redshifts. Such a ‘differential’ experiment would carry sensitive information on the IGM magnetic field (and electron density) because the Galactic contributions would cancel. Such pairs, however, will be hard to find at the current sensitivity. Nevertheless, our final stacked RM cube using LOFAR observations of the 3C196 field will reach a sensitivity of 10-15 μJy, which should result in a much higher density of polarised sources at resolutions down to sub-arcseconds.

In the meantime, we can use the two sightlines towards the lobes of a double radio source to learn about the IGM magnetic field. They carry information on the spatial structure function of the IGM magneto-ionic medium on linear scales of several hundreds of kpc to one Mpc. In the source J0808+4928, the RM difference is approximately only 1.0 rad/m², with an estimated uncertainty of 0.05 rad/m². Several other sources with small RM differences have been detected and a statistical study of these sources is underway.

Ger de Bruyn is a Staff Astronomer in the Astronomy Group at ASTRON.

Figure 1: Left: Image of polarised emission in the radio galaxy J0808+4928 at 30-arcsec resolution. The image displays one frame of an RM-cube produced using RM-synthesis. The RM of this frame is -2.5 rad/m², where the fainter northern lobe of the radio galaxy peaks. Right: Faraday spectra at the locations of the northern and southern lobes. Note the exquisite resolution of 1.0 rad/m² in Faraday depth (phi).
Peculiar Galactic ‘fog’

Vibor Jelic (jelic@astron.nl)

The complicated polarised radio emission from our own Galaxy obscures the view towards the first ‘stars’ in the Universe. Astronomers from the LOFAR-EoR team have studied this Galactic ‘fog’ and have discovered a very peculiar filament, probably located in the solar neighborhood.

The LOFAR-EoR team is working towards detecting the cosmological radiation emitted billions of years ago, from the time of the first ‘stars’. However, detection of this weak emission is difficult. Emission from our own Galaxy intervenes, like fog on an autumn morning. To clear the view towards the early childhood of the Universe, we need to study the emission from our Galaxy in great detail.

Using LOFAR, the LOFAR-EoR team has discovered peculiar diffuse polarised emission from our Galaxy, with a brightness temperature of several Kelvin. This emission is the result of the interaction between fast moving charged particles and the magnetic field of our Galaxy.

The polarised emission also provides information about the distribution of the intervening plasma along the line of sight.

The most interesting morphological feature of this emission is shown in Figure 1. This large-scale filamentary structure represents intervening magneto-ionic material, located in front of the diffuse polarised background. It is likely that the background emission has been built up over a path of several hundreds of parsecs from us. This means that the filamentary structure is likely in the Solar neighborhood, and possibly within a few tens of parsecs.

By comparing observations carried out over many years, we will attempt to measure the structure’s proper motion. For example, assuming a distance of 30 parsecs, we should be sensitive to radial velocities larger than 30 km/s.

Vibor Jelic is a Postdoc at the University of Groningen and ASTRON, supported by an NWO-VENI grant.

Figure 1: The polarised, complex filamentary structure illustrated in the Stokes Q parameter, showing an excess of only 1.5 rad/m² in Faraday depth (Φ). The structure is at least four degrees long and 30 arcminutes wide, running from North to South across a very bright source in the 3C196 field (Jelic et al., 2015).
A team for the success of RadioLife

Raffaella Morganti (morganti@astron.nl)

The ERC Advanced Grant ‘Exploiting new radio telescopes to understand the role of active galactic nuclei (AGN) in galaxy evolution’, better known as ‘RadioLife’, has been up and running for one and a half years. The project has been awarded 2.5 million Euros to set up a science team dedicated to explore the impact of radio-loud AGN on galaxy evolution using LOFAR and Apertif. The RadioLife team is now complete!

Figure 1 shows the great team of students, postdocs, and a software engineer that the principle investigator, Raffaella Morganti, has put together. She expects many great things from the group.

Indeed, several exciting results have already been obtained in this initial period: the self-calibration pipeline for LOFAR data; the identification and characterization of HI absorption; and the identification of jet-driven molecular outflows, to name a few. This is a very promising start, and we look forward to many more results.

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Raffaella Morganti is the head of the Astronomy Group at ASTRON.
Discovery of a hydrogen cloud near the spiral galaxy NGC 2403

Erwin de Blok (blok@astron.nl)

One of the unanswered questions about galaxies is how they acquire their gas. When galaxies form stars, they consume their gas, and measurements show that they do not contain enough gas to sustain star formation over their lifetime.

ASTRON astronomer Erwin de Blok is part of an international team (led by D.J. Pisano from West Virginia University, USA) that uses the Green Bank Telescope (GBT) to search for very faint gas around nearby galaxies to investigate whether they are acquiring gas from their environment. One of the galaxies studied is NGC 2403.

Using the GBT, the faint signal of a hitherto unknown neutral hydrogen (HI) cloud was discovered outside the main gas disk of NGC 2403. Comparison with deep HI data obtained a number of years ago with the Very Large Array radio telescope showed that the cloud is most likely associated with a filament of gas in the inner disk that shows peculiar velocities. The cloud and filament probably form one single complex.

There are several possible explanations for this cloud/filament complex. The most likely two are that we are seeing gas being accreted by the galaxy, or that we are looking at gas drawn out from the disk due to the passage of a smaller galaxy. A study of the rest of the survey should show how frequent these events are, and help to explain them.

Erwin de Blok is a Staff Astronomer in the Astronomy Group at ASTRON.
My name is Natasha Maddox, and I joined the Astronomy Group at ASTRON as a postdoctoral research fellow in August 2014. Before coming to ASTRON, I was an SKA South Africa postdoctoral fellow at the University of Cape Town. I am originally from a small town in western Canada, but I moved to the UK for my PhD at Cambridge University.

My research is focused on galaxy evolution, and spans many wavelengths and redshifts. At optical and infrared wavelengths, I look at the relationship between galaxies and the supermassive black holes located at their centres. For this work, I collaborate with the AGN group at ASTRON. I also investigate the neutral hydrogen content of large samples of relatively local galaxies, working within the Nearby Galaxies group. The upcoming SKA and precursor telescopes will allow HI observations at greater distances and better sensitivity than are currently possible, extending our knowledge of the neutral gas reservoirs of galaxies beyond the nearby Universe.

During my time in Cape Town, I became involved in two large surveys to be undertaken with the South African SKA precursor telescope, MeerKAT. There are strong research links between the Netherlands and South Africa, and I hope to continue collaborating with South African-based researchers to help build their astronomy community.
LOFAR zooms in on millisecond pulsar scintillation

Anne Archibald, Vlad Kondratiev, Jason Hessels & Dan Stinebring
(archibald@astron.nl)

Pulsars are nature’s near-perfect clocks. By better modelling of the propagation effects through the interstellar medium, we hope to achieve even higher timing precision and accuracy.

While travelling through the ionised and magnetised interstellar medium, radio signals from pulsars are affected by propagation effects such as dispersion, scintillation, and scattering. The magnitude of these effects varies strongly with frequency, and they can become extreme at LOFAR's low observing frequencies. Moreover, these propagation effects are time variable, as our line-of-sight to the pulsar changes because of the relatively high velocities of pulsars in our Galaxy. All of these issues degrade our ability to use pulsars as precision clocks for testing fundamental physical theories or for directly detecting gravitational waves.

In Archibald et al. 2014 (ApJL, 790, 22) we used the advanced technique of ‘cyclic spectroscopy’ to measure the scintillation features from three millisecond pulsars. LOFAR’s observing frequencies are not optimal for precision pulsar timing, but they provide a strong handle on scattering effects that would be too subtle to study at higher frequencies.

Figure 1 illustrates how the pulse profile of PSR J1810+1744 is progressively more scattered towards lower frequencies (upper panel) and shows extremely narrow scintillation structures (lower panel). By performing an auto-correlation analysis on the dynamic spectra, we were able to trace the frequency dependence of the scattering time using a single, five-minute LOFAR observation.

It is important to note that without using cyclic spectroscopy (this is one of the first times this has been applied for such an analysis), it would be impossible to resolve the extremely narrow kilohertz scintillation structures, while also detecting the very short, 1.7 millisecond pulse period (you would hit the Nyquist limit!).

We are continuing this work with a much larger monitoring campaign in LOFAR’s observing Cycle 2.

Anne Archibald is a Postdoc in the Astronomy Group at ASTRON and is funded by an NWO Vrije Competitie grant to Jason Hessels. Jason Hessels is a Staff Astronomer at ASTRON and Associate Professor at the University of Amsterdam. Vlad Kondratiev is a Postdoc in the ASTRON Astronomy Group, funded by ERC Starting Grant ‘DRAGNET’ (PI Hessels). Dan Stinebring is a Professor at Oberlin College, U.S.A., and this work was done during a 6-month visit to ASTRON funded by an NWO Bezoekersbeurs (PI Hessels).

Figure 1: Analysis of the frequency structure of PSR J1810+1744’s emission. The pulsar’s pulse profile becomes increasingly scattered towards lower observing frequencies (upper panel). Zooming in to a tiny fraction of the observed dynamic spectrum, we see kilohertz-wide scintillation structures (lower panel), which are only possible to resolve for this pulsar by using cyclic spectroscopy.
Astronomy Pretty Poster Pageant 2014

To celebrate and decorate our renovated wing of the building, the Astronomy Group recently organised the Astronomy Pretty Poster Pageant 2014.

Out of the impressive number of entries (46!), the judges decided on the top three winners. 1st place: Tom Oosterloo with ‘M101 – a new image from the last deep observation of the pre-APERTIF WSRT’. 2nd place: John McKean with ‘Global

VLBI imaging of the gravitational lens MG J0751+2716’. 3rd place: Charlotte Sobey with ‘PSR B0823+26: Emission modes in single pulses’.

Joeri van Leeuwen is a Staff Astronomer in the Astronomy Group at ASTRON.
My name is Jeremy Harwood and I am from London, UK. I have recently taken up a position as a research fellow here at ASTRON after finishing my PhD thesis on the dynamics and energetics of radio-loud active galaxies.

After graduating from the University of Hertfordshire, I started on a PhD programme with Prof. Martin Hardcastle extending my undergraduate work into the properties of extragalactic radio sources. After initially using X-ray observations, I moved to radio wavelengths, specifically the new generation of broadband interferometers such as the JVLA, e-MERLIN and LOFAR. My time at Hertfordshire also involved working as a coordinator and visiting lecturer for undergraduate practicals at Bayfordbury observatory, observatory outreach coordinator and trainer, and I was the founder of Ask an Astronomer UK.

After the submission of my PhD thesis, I was awarded a short-term position funded under the STFC STEP programme working on the physics of radio-loud active galaxies, before moving to my present position here at ASTRON in September 2014.

My research at ASTRON continues my study into the physics of radio galaxies and models of spectral ageing in extragalactic sources, along with joining the ERC RadioLife project team lead by Prof. Raffaella Morganti. I also have a strong interest in radio relics and I am the developer of the Broadband Radio Astronomy Tools (BRATS) for the spectral analysis of radio sources (see http://www.askanastronomer.co.uk/brats). I am also involved in various international collaborations including the LOFAR Multifrequency Snapshot Sky Survey (MSSS), the LOFAR nearby AGN key science project and the e-MERLIN legacy project to resolve key questions in extragalactic jet physics.
Lunar hide and seek

Harish Vedantham (harish@astro.rug.nl)

We have all witnessed the Moon hiding the Sun, but can an eclipse by the Moon reveal something otherwise hidden? Astronomers from the LOFAR-EoR group have demonstrated a technique of measuring the cosmic radio background by observing its occultation (eclipse) by the Moon: a new observational pathway to measure the elusive 21-cm signal from the Cosmic Dawn.

Observing the epoch of the formation of the first stars in the Universe (Cosmic Dawn) is one of the unexplored frontiers in astronomy. The LOFAR-EoR group is working towards detecting the faint 21-cm signal from this epoch. Interferometers like LOFAR measure spatial fluctuations, leaving us in the dark as far as the mean value of the 21-cm signal is concerned. However, the mean value carries important information about the global properties of the Universe from this epoch.

We recently showed that interferometers are sensitive to the eclipse of the mean signal, and can measure the brightness of the mean-signal with the eclipsing object (the Moon in this case) as a reference. This technique was conjectured by Ger de Bruyn, ASTRON staff astronomer, in 1999. Fifteen years later, the LOFAR-EoR team has provided the first observational evidence to confirm the practical merits of this technique.

We also found a ‘spot’ at the centre of the Moon at some frequencies, see Figure 1. At LOFAR wavelengths, the Moon essentially looks like a polished mirror, and the spot is a reflection of the man-made radio frequency interference generated on Earth. The brightness of the spot is a measurement of the interference levels on the Moon - a critical input to future astronomy missions to the Moon. The spot also tells us how bright our planet might look for an outside observer.

As the excitement of seeing our nearest neighbour with radio eyes subsides, we are focussing on refining the technique. With new LOFAR data, we expect to apply the lessons learnt to determine the background spectrum to better than a few Kelvin accuracy throughout the LOFAR band.

Detecting the sub-Kelvin level Cosmic Dawn signal with any technique will be challenging, but with the new data, cutting-edge lunar science is already within our reach! Lunar thermal emission comes from deeper inside the Moon towards lower frequencies. LOFAR can probe the lunar regolith at unprecedented depths (up to 1 km). Very little is known about lunar composition and temperature at these depths, and in the near future we may learn something very interesting about our Moon from LOFAR observations.

Harish Vedantham is a PhD student at Kapteyn Astronomical Institute, University of Groningen.
ASTRON and SETI
PC at IAC 2014

ASTRON was well represented at the IAC 2014 (International Astronautical Congress). The IAC is the largest meeting of space experts in the world, with Ronald Halfwerk forming part of the Dutch delegation.

ASTRON was very visible in the Dutch exhibition stand, with our various space-related programmes highlighted, including the PAASAR (Phased Array Antenna for Search and Rescue) project, OLFAR (Orbiting Low Frequency Antennas for Radio Astronomy) and the GNSS Signal In Space Monitoring facility at the WSRT.

The IAC programme also included two SETI sessions sponsored by the IAA (International Academy of Astronautics). In the early 1970’s, the IAA formally established a committee for SETI known as the IAA SETI Permanent →
Committee (SETI PC). The Permanent Committee currently operates under the auspices of the IAA Commission on Space Physical Sciences, developing international SETI policy in areas such as the SETI post-detection protocols, and discussing good practice in related activities, including more controversial topics such as METI (active SETI).

This year, in Toronto, Mike Garrett was elected as a Corresponding Member of the IAA Basic Sciences section and a few days later was also elected to the position of vice-chair of the SETI PC.

*The images show the IAC 2014 exhibition area and the SETI PC meeting.*
As commissioning and considerations for the WSRT upgrade to APERTIF progress, a supplemental call for WSRT MFFE proposals was issued in the autumn of 2014.

As one author phrased it, ‘the halcyon days of the MFFEs will soon pass, but in their waning months…’ further time was made available for projects to use the existing MFFE and DZB system, mostly in the under-subscribed 16:00-09:00 LST range. The supplemental call with a deadline of 6 October 2014 attracted 15 proposals, for a total of 1442 hours, for both existing and new projects. These will be observed, next to the remainder of the currently allocated projects, until the projected end of operations in late spring 2015.

Currently, observations from the last regular WSRT call are being observed (close to 4900 hours will be observed by the end of 2014). Three of the dishes have already had APERTIF frontends installed, and maintenance and refurbishment of the remaining dishes has been taking place throughout 2014. Hence, the number of available MFFE dishes has varied between 8 and 11. Later in 2015, this number may be further reduced to 6.

Antonis Polatidis is an Observatory Astronomer in the Radio Observatory Group at ASTRON.
Delegations from South Africa and NWO-EW visit ASTRON

Mike Garrett (garrett@astron.nl)

A few months ago, ASTRON welcomed a high-level delegation from South Africa and NWO. The respective delegations were led by Dr. Thomas Auf der Heyde (Deputy Director-General: Research Development and Support, Department of Science and Technology) and Louis Vertegaal (Director of NWO-EW).

The visitors toured the facilities at ASTRON, including an excursion to the WSRT. Of particular interest to all parties was ASTRON’s work in the area of Big Data, and in particular the ASTRON-IBM DOME project. South Africa is already involved in DOME, and the discussions included some interesting ideas about how we might expand this very successful collaboration still further. The highlight of the day was a 'team-building' visit to the focus box of one of the WSRT telescopes - an APERTIF Phased Array Feed (PAF) system was opened for inspection by the team.
SPHERE-ZIMPOL on sky

Ronald Roelfsema & Johan Pragt (roelfsema@astron.nl, pragt@astron.nl)

SPHERE is one of the first instruments dedicated to the direct detection of light from extra-solar planets. The instrument has just finished its commissioning phase at the VLT and will be offered to the community in early 2015.

SPHERE (Spectro Polarimetric High Contrast Exoplanet Research) is equipped with three focal plane instruments. One of them is the ZIMPOL polarimeter that is developed by NOVA in collaboration with ETH-Zurich in Switzerland. ZIMPOL (Zurich Imaging Polarimeter) will search for polarised reflected light from old planets in or close to the ‘habitable zone’. The search for reflected light from extra-solar planets is very demanding. For a Jupiter-sized object, and a separation of a few Astronomical Units, the planet-star contrast required for a successful detection is on the order of $10^{-7}$ to $10^{-8}$ magnitudes. SPHERE-ZIMPOL uses a combination of Extreme Adaptive Optics, coronagraphy, and polarimetry to achieve such contrasts.

SPHERE was installed on the VLT (see Figure 1) early this year and was successfully commissioned during four intense commissioning runs from May to October 2014. During commissioning, the instrument already showed impressive performance and spectacular images of Titan, Neptune, and proto-planetary disks.

Figure 1: SPHERE installed at Unit Telescope 3 of the VLT, ready for first light.

Figure 2 shows an H-Alpha image of Alpha Eridani that demonstrates the best performance achieved on any space/ground-based telescope, in terms of resolution at this wavelength, to date. Using ZIMPOL, a contrast of $5 \times 10^{-8}$ magnitudes was already achieved in a relatively short technical observing run. This is a very promising start, and very encouraging for when we start planet-hunting in early 2015.


Ronald Roelfsema is a System Engineer in the NOVA Group at ASTRON. Johan Pragt is the head of Mechanics in the Research and Development Group at ASTRON.
Hi! I am Samayra Straal and I started my PhD at UvA/ASTRON in September 2014. I was born and raised in Amsterdam. I also obtained my Bachelors and Masters degree in Astronomy at the University of Amsterdam.

For my Masters thesis, I investigated the nature of the rare Oxygen Wolf-Rayet stars (only nine of which are known to date) using optical spectra obtained with the X-Shooter instrument at the VLT. From the stellar parameters obtained we found that they are possibly post core helium burning. One of the objects I analysed is expected to explode as a type Ic supernova within approximately 2000 years!

For my PhD project, I will work on objects that are left over after supernovae, namely pulsars, and also on fast radio bursts (FRBs). I was just awarded time to observe known supernova remnants and pulsar wind nebulae using LOFAR in order to find (high-velocity) pulsars. Working with Dr. Joeri van Leeuwen and colleagues, we will also conduct an all-sky survey to search for FRBs and pulsars using APERTIF. Being my optimistic self, discovering the nature of FRBs is a goal for my PhD!

Next to finding pulsars and FRBs, I enjoy doing sports. I have played national level Softball for a couple of years; unfortunately we were recently relegated to the recreational division. In the coming year we will travel around the country to try to be promoted back to the national-level. I also like to spend time with family and friends.
APERTIF successfully passed its Critical Design Review

Wim van Cappellen (cappellen@astron.nl)

The APERTIF project passed an important milestone last October. APERTIF aims to greatly boost the survey speed of the Westerbork Synthesis Radio Telescope (WSRT) by replacing the current horn feeds by Phased Array Feed (PAF) technology. The key advantage of this new system is that it is capable of surveying the sky with 37 beams simultaneously, compared to one beam using the current horn feeds! At the same time, the instantaneous bandwidth is almost doubled.

Over the last couple of years, APERTIF has been designed in detail. Several challenges have been overcome, such as the design of very low-noise room-temperature amplifiers, the hostile RFI environment at the WSRT, and the massive amount of digital data (9.8 Tbps!) that must be processed in real-time. To validate the design, prototypes have been built and installed in three WSRT dishes. This prototype system, known as ALPHA-3, confirmed the expected performance of APERTIF.

To independently assess the system and to minimise the risk that something had been overlooked, a Critical Design Review (CDR) was organised. A strong, international panel of experts was invited to review whether the APERTIF system fulfills the science and system requirements and whether all major risks were identified. The review panel consisted of the following members: Mark Bowen (CSIRO, chair), Erwin de Blok (ASTRON), Hans van der Marel (ASTRON), Lister Staveley-Smith (UWA/ICRAR), Ravi Subrahmanyan (Raman Research Institute),

Figure 1: Presentation session during the Critical Design Review.

Figure 2: Members of the review panel listening carefully.
Gundolf Wieching (MPIfR) and Victor Pankratius (MIT Haystack Observatory). The APERTIF team supplied them with an extensive set of documentation, describing every detail of the design and initial commissioning results. During the face-to-face meeting the highlights and issues were discussed. And, of course, the panel went for a tour to the WSRT to see the ALPHA-3 system in action, see Figure 3.

We are excited to report that the panel was very impressed by the quality of the documentation and the presentations and was unable to identify any significant risk that was not already reflected in the risk register. The panel concluded that, as designed, APERTIF promises to make the WSRT a world-class facility for the next decade. We are eagerly looking forward to start rolling out APERTIF in the coming year.

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*Wim van Cappellen is the head of the Radio Group in the Research and Development Group at ASTRON.*
Outreach and media

Roy van der Werp (werp@astron.nl)

There have been lots of exciting activities at ASTRON and media attention over the last six months. Here, we highlight a few of these.

In cooperation with Anke den Duyn, the youth novel ‘Het Logboek’ was created, see Figure 1. This was a great experience for us. The novel is aimed at children and introduces them to the world of astronomy.

Following on from the novel, children from nearby schools can participate in a project to introduce them to the world of technology and astronomy. Through this project, we hope to reach out to future scientists.

ASTRON, JIVE, NOVA, and CAMRAS also organised the annual Girl’s Day. The main purpose of this event is to immerse girls in their early teens in science- and technology-related professions. Every year girls leave with a more positive image of the work undertaken here, and they discover more about how science and technology change the world around them. We hope that this will encourage more of them to choose a more technical career path.

We also use social media as part of our outreach activities. Since last summer we have been trying to use social media outlets a lot more. For example, we have recently updated our Facebook page, and we are keeping it up-to-date with all kinds of interesting facts and news. So, don’t forget to ‘like’ our Facebook page to keep up to date with the latest ASTRON news.

ASTRON had a busy media month throughout October. In the Dutch paper ‘De Volkskrant’, an article was published about the search for extra-terrestrial intelligence. This article created a lot of interest from the Dutch media about our research. Joeri van Leeuwen also gave a radio interview and a television interview for RTV Drenthe.

You can also look forward to more great events coming soon. We can’t reveal too much yet, but it will be big! You can read all about it in the next edition of ASTRON News.
New Polish ILT stations update

Ronald Halfwerk (halfwerk@astron.nl)

The POLFAR consortium has started the groundwork for the new Polish international LOFAR stations at each of the locations in Borówiec, Bałdy, and Łazy. This includes some sophisticated drainage systems for the antenna fields. ASTRON is now working to conclude the Station Layout Design, in which the exact positions of the antenna fields will be determined.

A large amount of hardware is now being procured, in production, or even shipped already to Poland. Since the previous production run to manufacture the components was several years ago, we have to deal with obsolete components. The logistics of shipping the components to the three different destinations requires very careful collaboration with our Polish partners. At the end of November 2014, nearly 2000 m³ of high-band antenna equipment should be delivered to its destination!

Ronald Halfwerk is the Technology Transfer Officer in the Research and Development Group at ASTRON.
Hello, I am Klim Mikhailov, a new PhD student working on pulsars and radio transients.

Originally, I am 75% physicist and 25% computational scientist from the Northern Capital of Russia, Saint Petersburg. I did my bachelor’s degree at Saint Petersburg State University in high energy and elementary particle physics. After that, I moved on to computational science in order to perform more multidisciplinary research. This led me to a double-degree programme from Saint Petersburg National Research University ITMO and the University of Amsterdam, from which I graduated with a master’s degree in computational astrophysics.

Now, I am a first year PhD student. I am going to search for the traces of ‘fast radio bursts’ using cutting edge hardware and software technologies, mainly WSRT APERTIF FPA and GPU programming, working under the supervision of Dr. Joeri van Leeuwen. To get familiar with radio techniques, I will first be doing an intensive search for pulsars, as well as other transients, in nearby galaxies. That is a hot topic at the moment due to a recent X-ray pulsar discovery in another galaxy. I have already been awarded LOFAR Cycle 3 observing time to conduct such a search. My working schedule includes four days per week in Amsterdam (API, UvA) and one day per week at ASTRON.

My main non-research interests include playing with digital sound, listening to music, learning about new technologies, spinning, and swimming.
Sharp radio images unravel the mystery of gamma rays in stellar explosions

Zsolt Paragi (zparagi@jive.nl)

Highly detailed radio-telescope images have pinpointed the locations of where a stellar explosion, called a nova, emits gamma rays (the most energetic form of electromagnetic waves).

The discovery revealed a probable mechanism for the gamma-ray emission, which mystified astronomers who first observed this in 2012.

A nova occurs when a dense white dwarf star pulls material onto itself from a companion star, triggering a thermonuclear explosion that blows debris into interstellar space. Astronomers did not expect this scenario to produce high-energy gamma rays. However, in June 2012, NASA's Fermi spacecraft detected gamma rays coming from a classical nova called V959 Mon, some 6500 light-years from Earth. Radio emission was discovered by the Karl G. Jansky Very Large Array (VLA), which was further studied by the European VLBI Network (EVN), at very high resolution. The EVN images revealed compact emission regions of relativistic particles that moved away from each other in a direction that did not line up with the orientation of thermal ejecta observed with the VLA at various phases of the explosion.

This observation, supported by data obtained by e-MERLIN in the UK and the Very Long Baseline Array in the US, allowed our group to form a coherent picture of how these emitting regions and the gamma rays were produced. In the first stage of this scenario, the white dwarf and its companion give up orbital energy to boost some of the explosion material, making the ejected material move outward faster in the plane of the binary's orbit. Later, the white dwarf blows off a faster wind of particles moving mostly outward along the poles of the orbital plane. When the faster-moving polar flow hits the slower-moving material, the shock accelerates particles up to the speeds needed to produce gamma rays, and the compact radio emission seen by the EVN.

The results were published in the 16 October 2014 issue of Nature.

Zsolt Paragi is the head of User Support at the Joint Institute for VLBI in Europe.

Figure 1: The upper panels show radio images of V959 Mon. The EVN images 91 and 113 days after the nova explosion are shown in contours and colour, respectively. The expanding thermal ejecta seen by the VLA are shown in the top middle and right panels. The lower panels explain the various stages of the explosion. Left: the nova envelope expands and interacts with the binary system, yielding dense material in the equatorial plane. Middle: the white dwarf powers a fast wind that is funnelled towards the low-density poles, causing shocks. Right: at late times, the slower-expanding equatorial material will dominate the emission.

The third operational cycle for LOFAR (LC2)

Roberto Pizzo (pizzo@astron.nl)

The third LOFAR operational cycle is almost completed. Successful operations progressed side-by-side with software development, which is pushing new functionality in the observing system that will be available for users during the next observing cycles.

LOFAR’s third operational cycle (Cycle 2) started on 15 May 2014 and will finish on 14 November 2014.

All 45 proposals that applied for Cycle 2 observing time were accepted. In total, 1612 observing and 1702 CEP2 processing hours were allocated. In parallel with the operational cycle, commissioning of COBALT, the new correlator, and the remainder of observations for the HBA segment of the commissioning MSSS survey also took place.

At the time of writing (31 October 2014), 27 Cycle 2 projects have been completed. This corresponds to 1300 hours of observations performed successfully (81% of the time allocated). An additional 150 observing hours are scheduled before the end of the cycle, while the rest will be completed during the following semester at second priority, with respect to the new Cycle 3 allocations. The observing efficiency (defined as the percentage of calendar hours during which successful observations were produced for both allocated PC projects and MSSS) during Cycle 2 is shown in Figure 1. As with previous cycles, Cycle 2 has also been an important learning experience for the Radio Observatory. Despite some operational issues, important progress was made in both procedures and techniques. This represents a significant achievement for all of the people who are working hard on the still developing system.

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**Observing efficiency since the start of Cycle 2**

LOFAR’s third operational cycle (Cycle 2) started on 15 May 2014 and finished on 14 November 2014.
So far, LOFAR has delivered more than 11 PB of scientific data to its users, who are also working side-by-side with the Radio Observatory to further improve the overall output of the telescope.

As of the deadline for the LOFAR Cycle 3 (LC3) call for proposals, 10 September 2014, 35 regular proposals and one long-term proposal were submitted. The affiliation of the primary author of the proposals by country, shown in Figure 2, follows a pattern similar to that for previous cycles. The proposals requested the full spectrum of observing modes offered by LOFAR and proposed for a broad range of science areas: EoR, extragalactic objects, transients, solar, planets and exoplanets, ISM, stars, and cosmic rays.

At the meeting on 28 and 29 October 2014, the LOFAR Programme Committee accepted 32 projects and awarded 1600 observing hours and 1326 processing hours, in total. Observations for LC3 will be performed from 15 November 2014 until 14 May 2015.

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Roberto Pizzo is the head of Science Support in the Radio Observatory Group at ASTRON.
Connecting with Portugal for developments in energy and the SKA

Arnold van Ardenne (ardenne@astron.nl)

Some time ago, I paid a visit to the impressive, huge solar-voltaic power plant in Moura, Portugal. Its large area of 300,000 square metres gave me an impression of the size of a future SKA aperture array. It was also evident that the use of renewable energies could not only accommodate the SKA’s operational power bill, but could also visibly contribute to a sustainable society.

Many of the advancements required for the SKA have motivated the investigation into sustainable development in radio astronomy. Ultimately, this contributes to and increases the visibility of radio astronomy as a societally relevant and necessary endeavour. This is illustrated, for example, by research and development into low-power algorithms and green computing as part of the DOME programme.

In light of the continuing SKA activities, and initiatives to investigate solar power for LOFAR, a small team from IT Portugal visited ASTRON on 7 and 8 July 2014 to re-

establish connections. The group included industrial partners Martifer-Solar and AST-
Portugal/Netherlands. Also present were officials from the province of Drenthe, with responsibilities for renewable energies, and EnTranCe, the Dutch enabler of energy products and services.

The meeting was made even more relevant in view of the Portuguese intention to become an (associate) member of the SKA, facilitated by the release of national funds. This will strengthen the Portuguese position in the SKA consortia, in particular those that are concerned with aperture arrays (LFAA and MFAA).

Arnold van Ardenne is an Adjunct Professor at Chalmers University of Technology. He was the coordinator of the ASTRON SKA Programme Office from 2009 to 2013 and is currently an advisor to ASTRON.
My name is Amruta Jaodand. I come from India. I studied for my master’s degree at Birla Institute of Technology and Science, and simultaneously obtained a Bachelor in Electronics and Communication Engineering.

During my master’s thesis I explored the statistical properties of the Cosmic Microwave Background. After I completed my master’s, I started working with Prof. Parmeswaran Ajith at the International Centre for Theoretical Sciences, Bangalore. My work there focussed on the statistical estimation of uncertainties in parameter estimation for gravitational waves and applying these estimates to formulate tests of General Relativity.

I started my PhD with Prof. Jason Hessels in September, and I am being hosted at the Anton Pannekoek Institute for Astronomy, University of Amsterdam. During the course of my PhD, I will be involved in exploring the transient properties of radio pulsars with LOFAR. I will also be working on pulsar timing arrays.

My hobbies include dancing, reading, and travelling.
SKA Board visiting FAST

Mike Garrett (garrett@astron.nl)

In October, the SKA Board met in the city of Guiyang, in South West China. At the end of the Board meeting, our Chinese hosts organised a very special visit to the Five hundred meter Aperture Spherical Telescope (FAST), a new radio telescope now under construction and located in a natural hollow (karst) in Pingtang County, Guizhou Province.

Despite the Board being ferried to FAST via a VIP police convoy, it still took almost five hours to reach the telescope from Guiyang.

Negotiating some very bumpy roads and some perilous overhanging mountain dirt tracks, the SKA Board were enthusiastic (and perhaps a little relieved) to see the impressive progress now being made on the telescope structure. The view of the current support ring and suspension towers is breathtaking, even though the surface is not yet installed. Already the scale of the telescope is clearly visible for all to see.

The visit to FAST also included a stop off in a traditional village and dinner with regional dignitaries and leaders.

Due to the active surface (some 4600 panels, providing a total effective
aperture of ~ 70000 square metres), the telescope is able to cover quite a large fraction of sky - within 40 degrees of zenith. Operating at a frequency of 0.3 – 3 GHz, one of the key science programmes will include studying, and searching for, pulsars. The telescope is expected to be operational complete in two years’ time – we wish our Chinese colleagues every possible success with the project.

The images show the SKA Board and Chinese colleagues visiting the FAST telescope and nearby area.
Calibration & Imaging Tiger Team

George Heald & Tammo Jan Dijkema
(heald@astron.nl, dijkema@astron.nl)

About a year ago, ASTRON's first Tiger Team kicked off to make necessary fundamental improvements to calibration and imaging of LOFAR data. A lot has happened since then.

The highly focused Calibration & Imaging Tiger Team (CITT) consists of seven experts from all three of ASTRON's departments, as well as members from outside ASTRON.

A major result of the CITT is that a new, automatic self-calibration pipeline will be rolled out soon. This will enable the LOFAR observatory to automatically process visibility data and produce images with improved scientific potential.

Other CITT efforts are focused on improving the calibration and imaging tools that form the foundation of the imaging pipeline: BBS, NDPPP and the awimager. The improvements to these tools have been made available to the community immediately.

The CITT has enjoyed fantastic assistance from all of the LOFAR commissioners, who help us test and improve our software. Particular highlights are the ‘Imaging Busy Weeks’, during which up to twenty skilled experts locked themselves up in one room for a week to make major steps forward in imaging capability.

The success of the CITT has led to the formation of several new Tiger Teams within ASTRON.

We are now working hard to pull all improvements together into a new ‘selfcal v3.0’, which should be available in the beginning of 2015.

The background image has been processed using the selfcal pipeline developed by the CITT. Image credit: S.S. Sridhar et al (in prep).

George Heald is a Staff Astronomer in the Astronomy Group at ASTRON. Tammo Jan Dijkema is a Scientific Software Engineer in the Research and Development Group at ASTRON.

A diagram of the LOFAR imaging pipelines with CITT improvements.
The ASTRON/JIVE Summer Student Programme 2014

Vibor Jelic & Anne Archibald
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The ASTRON/JIVE Summer Student Programme enables advanced undergraduate or graduate students to spend the summer (10-12 weeks) conducting astronomical research. The programme has a long tradition and is a collaborative effort between ASTRON and JIVE.

This year we had a group of six enthusiastic summer students from all over the world: Laura Driessen (Monash University, Australia), Tarraneh Eftekhari (University of New Mexico, USA), Luke Pratley (Victoria University of Wellington, New Zealand), Kamlesh Rajpurohit (Friedrich-Schiller-University of Jena, Germany), Naomi Robertson (University of Edinburgh, UK), and Susan Schmitz (University of Iowa, USA).

The topics of their projects were varied: Laura studied interstellar scattering using WSRT observations of the Crab Pulsar; Tarraneh studied heliospheric Faraday rotation towards the Crab Pulsar using LOFAR observations; Luke studied an initial sample of galaxy clusters from LOFAR MSSS data; Kamlesh studied scintillation of radio emission from AGN and from planetary spacecraft; Naomi studied star-formation in gravitationally magnified quasars; and Susan studied O-type star formation using EVN observations of methanol at 6.7 GHz.

As usual, the students followed lectures on radio interferometry, the LOFAR telescope, and other areas of scientific research conducted at ASTRON and JIVE. They also visited the LOFAR ‘Superterp’ in Exloo, the WSRT, and the European Space Research and Technology Centre in Noordwijk. Besides the scientific work they were conducting, supervised by ASTRON and/or JIVE employees, the students explored the surroundings by bike, enjoyed BBQs, and other social activities organised for them, see Figure 1.

More information about the Summer Student Programme can be found on our website:


Please do have a look if you are interested in the Summer Student Programme 2015.

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Vibor Jelic is a Postdoc at the University of Groningen and ASTRON. Anne Archibald is a Postdoc in the Astronomy Group at ASTRON.
ASTRON building finished

Diana Verweij (verweij@astron.nl)

After a lengthy process (which started in 2006/2007 with the first ideas and plans) the building process of ASTRON was finished.

Already in 2006/2007 the first ideas were launched about the building at the Oude Hoogeveensedijk in Dwingeloo, the Netherlands. It took a lot of effort and time of a number of people to actually start on April 11, 2012. First the new wing was build. In January 2013 everybody moved in. Then the next phase was the thorough renovation of the 1980 wing. With the new façade and the new kitchen/canteen area as well as the refurbishments of several labs, the process has come to an end. We have included a collage of photos from throughout the process.
ASTRON is part of the Netherlands Organisation for Scientific Research (NWO).

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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