Effelsberg Newsletter

January 2017

Credit: Norbert Tacken

Happy New Year 2017 !

Greetings from the Director

A Happy New Year 2017!

Dear Colleagues,

as usual in a new year, I use the January edition of the newsletter to wish everyone a good, successful and, especially, healthy new year. This new year will bring a lot of changes for many people around the world, and let us hope that they will be good. We, the staff at MPIfR and particular the technical divisions working for and in Effelsberg, will continue to work hard to bring the best possible equipment and observing conditions to you as an observer at the observatory. The telescope has been extremely successful last year. The publication rate continues to be very high, including the usual large number of publications in high-impact journals. Of course, we look forward to keeping this high level, in particular with the new PAF that will arrive next month. That is only one example of the things to arrive, so look forward to the coming editions of the newsletter, where we will be delighted to keep you informed.

Happy New Year, Michael Kramer

Call for Proposals

Deadline: February 6, 2017, 15:00 UT

Observing proposals are invited for the Effelsberg 100-meter Radio Telescope of the Max Planck Institute for Radio Astronomy (MPIfR).

The Effelsberg telescope is one of the World's largest fully steerable instruments. This extreme-precision antenna is used exclusively for research in radio astronomy, both as a stand-alone instrument as well as for Very Long Baseline Interferometry (VLBI) experiments.

Access to the telescope is open to all qualified astronomers. Use of the instrument by scientists from outside the MPIfR is strongly encouraged. The institute can provide support and advice on project preparation, observation, and data analysis.

The directors of the institute make observing time available to applicants based on the recommendations of the Program Committee for Effelsberg (PKE), which judges the scientific merit (and technical feasibility) of the observing requests.

Information about the telescope, its receivers and backends, the Program Committee and selection process can be found at the observatories web pages:

http://www.mpifr-bonn.mpg.de/effelsberg/astronomers/

(potential observers are especially encouraged tovisit the wiki pages!).

Observing modes

Possible observing modes include spectral line, continuum, and pulsar observations as well as VLBI. Available backends are several FFT spectrometers (with up to 65536 channels per subband/polarization), a digital continuum backend, a number of polarimeters, several pulsar systems (coherent and incoherent dedispersion), and two VLBI terminals (dBBC and RDBE type with MK5 recorders).

Receiving systems cover the frequency range from 0.3 to 96 GHz. The actual availability of the receivers depends on technical circumstances and proposal pressure. For a description of the receivers see the web pages.

How to submit

Applicants should use the NorthStar proposal tool for preparation and submission of their observing requests. North Star is reachable at https://northstar.mpifr-bonn.mpg.de .

For VLBI proposals special rules apply. For proposals which request Effelsberg as part of the European VLBI Network (EVN) see:

http://www.evlbi.org/proposals/

Information on proposals for the Global mm-VLBI network can be found at

http://www3.mpifr-bonn.mpg.de/div/vlbi/globalmm/index.html

Other proposals which ask for Effelsberg plus (an)other antenna(s) should be submitted twice, one to the MPIfR and a second to the institute(s) operating the other telescope(s) (eg. to NRAO for the VLBA).

After October, the next deadline will be on Jun 7 2017, 15.00 UT.

by Alex Kraus

Meeting postponed: Science with the 100-m telescope

The workshop „Science with the Effelsberg 100-m telescope“ which was scheduled for Apr 4 & 5, 2017, has to be postponed for organizational reasons. It will be held on

November 6-7, 2017 at the MPIfR in Bonn.

This meeting is intended to bring together various user groups of the 100-m telescope with the support staff of the observatory and the technical developers. We are looking forward to the opportunity to discuss recent observational results and technical developments with the users of the 100-m telescope. Furthermore, this meeting will give us the possibility to learn about new ideas for observing projects allowing us to plan the technical and software development for the next years.

More information about the meeting will be published in the next issue of this newsletter as well as on the webpages of the MPIfR soon - stay tuned!

TECHNICAL NEWS

The MPIfR S-Band System for MeerKAT

by Olaf Wucknitz & Gundolf Wieching
on behalf of MPIfR's MeerKAT S-Band Receiver Development Team

The MeerKAT array, one of the precursors for the Square Kilometer Array, is currently being built in the Northern Cape province of South Africa. The final array will consist of 64 antennas, each with 13.5m diameter, spread over an area of several kilometers. The total collecting area corresponds to a single dish slightly larger than the 100m Effelsberg telescope, which will make this one of the most sensitive radio telescopes in the world.

To complement the originally planned MeerKAT receivers covering the UHF range (0.58-1.015 GHz), the L-band (0.9-1.67 GHz) and the X-band (8-14.5 GHz), S-band receivers are provided by the MPIfR. These will cover the range 1.75-3.5 GHz, which is essential for many fields of research.

Our electronics division invented and implemented a novel receiver design within only one year. The analog signal is digitized without down-conversion in the second Nyquist zone with a sampling rate of 3.5 GHz directly at the receiver system. One half of the total band can be selected to be processed by the MeerKAT correlator system, and the second half is available for future extensions, including beamforming. At this point the signals are transported digitally via two 40 Gbps Ethernet links. The entire receiver system is contained in a metal casing of less than 65 kg total. This compact and self-contained design (see Figs. 1 and 2) allows for very easy and cost-effective production, installation and maintenance. This direct digitization near the focus is also considered as an option to unify the Effelsberg receiver and backend suite in the future.

Fig. 1: The S-band receiver installed in the indexer of one of the MeerKAT dishes. A second dish can be seen in the background.

Fig. 2: The S-band receiver with its feed horn.

Two prototypes were produced in 2016 and brought to the array site for first commissioning tests in September and October. They were installed on antennas 07 and 08 with a baseline length of 132 m. The installation went smoothly and test observations were possible after a preliminary integration into the MeerKAT correlator system. Aims of these tests were the characterization of the system and the identification of potential problems in order to optimize the design.

Interferometric tests consisted of scans and raster-scans of a number of sources with recording of channelized autocorrelations and visibilities. Geometric delays had to be corrected off-line. With these observations we measured the beamshape and sensitivity as function of frequency. Figure 3 shows the system noise in Jy over the upper half of the band.

Phase stability is essential for imaging and beamforming, and a first assessment is possible from our tests (see Fig. 4). Finally we recorded a few minutes of raw digitizer output data from one receiver while pointing at the Vela pulsar. The target was detected clearly even with just one antenna and one polarization (Figure 5). These data also revealed subtle artifacts caused by the power supply, which will now be modified accordingly.

The receiver design is currently being optimized, and commissioning will continue in 2017. Eight receivers are expected to be installed by the end of the year and the full number of 64 by the end of 2018.

In addition to the S-band receivers our institute together with The University of Manchester (PI Stappers) also provides a beamformer that will be able to coherently add up the signals from the MeerKAT dishes for up to 400 pointings simultaneously. This capability will be mostly used for pulsar searches and to find and localize fast radio bursts (FRBs). We look forward to using some of the developed technology for Effelsberg.

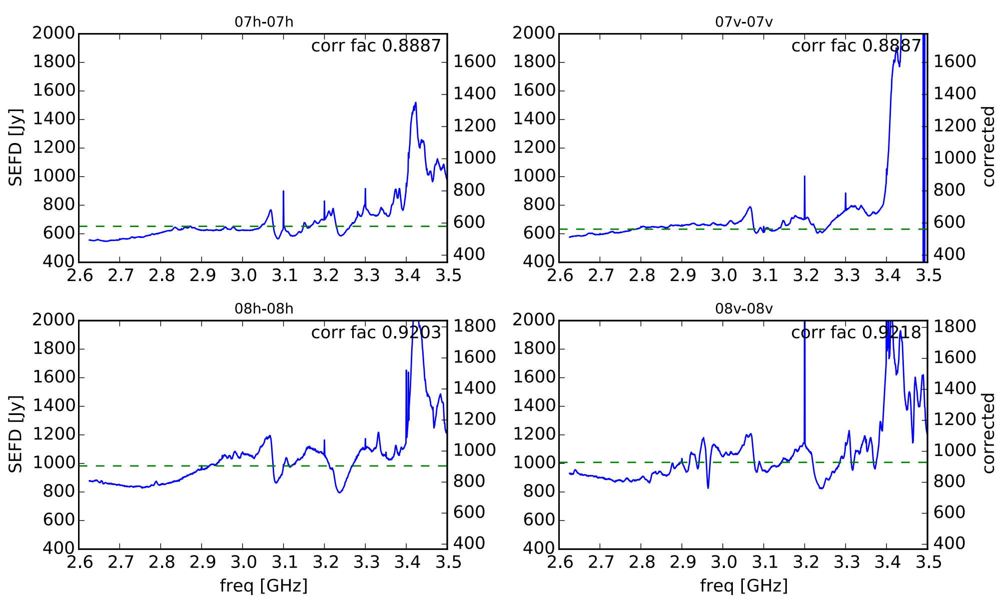


Fig. 3: System noise (SEFD) as function of frequency for both receivers and polarisations. The scale on the left is the nominal measurement, the one on the right is corrected for the low elevation of the observation. The cause of the "ripples" at higher frequencies is understood and will be taken care of in the next version of the receiver. The horizontal lines are averaged over all frequencies. With an assumed efficiency of 0.65, these values correspond to 19 K (better than the design goal!) for antenna 07 and 30 K for antenna 08. At lower frequencies the noise is even lower.

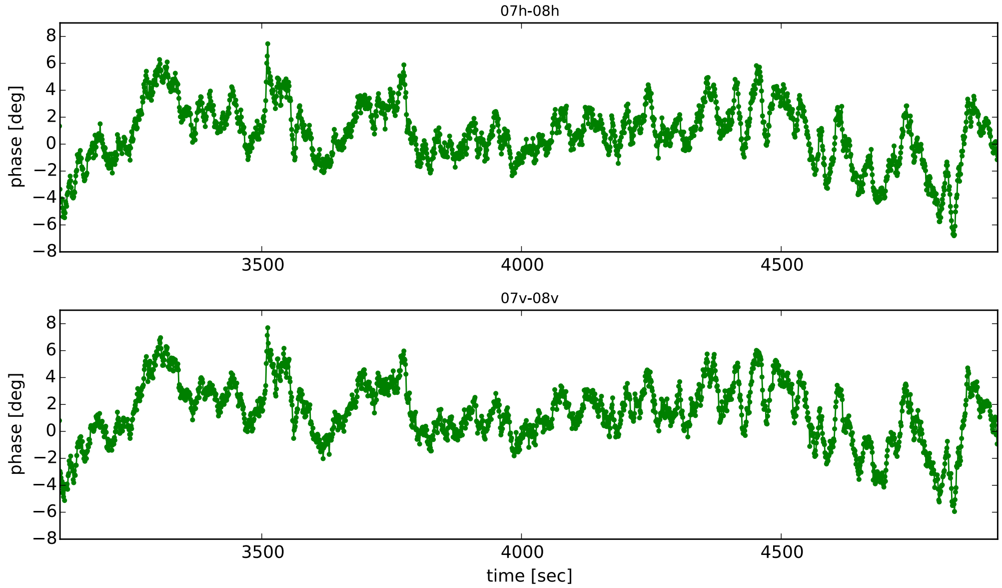


Fig. 4: Interferometric phases on the 132-m baseline over 30 min on the source PKS B1921-293 after correction for the predicted geometric delay. Phases are constant within a few degrees. These tiny fluctuations are the sum of atmospheric effects and possible residual variations of instrumental delays. They are so small that constant beamforming weights can be used without measurable sensitivity losses. One degree corresponds to less than one picosecond of time difference, the time that radio waves need to move by less than 0.3 mm! On the sky this is a shift of 0.4 arcsec, much less than the fringe spacing of 2.5 arcmin on this baseline.

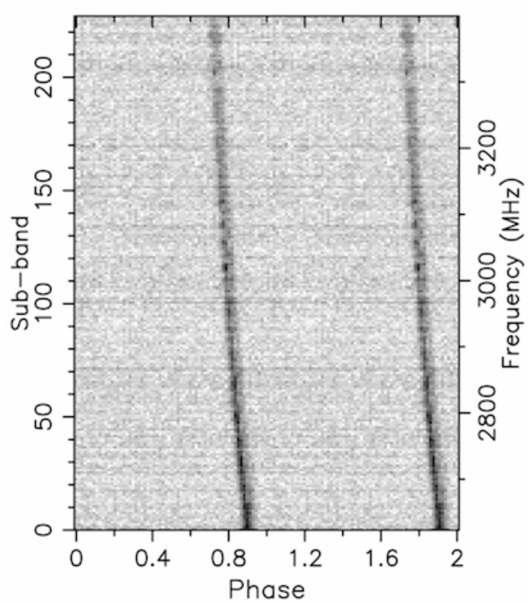


Fig. 5: Folded signal (two periods shown) of the Vela pulsar in the upper part of the band using only 90 sec of one polarization from one antenna. The interstellar dispersion has not been removed here.

First VLBI Fringes with the new C+ Broad Band receiver

By Uwe Bach

At the end of 2015 a new broad band receiver covering a frequency range of 4 GHz to 9.3 GHz was installed in the 100m Effelsberg telescope (see also Effelsberg Newsletter May 2015). Primarily, the receiver has been build for high sensitivity continuum observations and spectroscopy of molecule transitions, like Formaldehyde and Methanol. With its two linear polarizations it is not naturally the first choice for VLBI observations as most stations in VLBI record left and right circular polarization (LCP and RCP) signals. With linear polarization signals the gain and polarization properties of each widely separated antenna will vary with the parallactic angle which makes it difficult to calibrate the correlated data. Therefore, the 4.6 GHz to 6.8 GHz C-band for VLBI observations at Effelsberg is covered by two additional individual circular polarized receivers with narrower bandwidth.

In December 2016, the regular real time eVLBI observations were scheduled at 6.65 GHz, but the standard VLBI 6 GHz prime focus receiver box at Effelsberg was not available due to maintenance. To support the observations it was decided to use new the C+ receiver. Since the PI was interested in the total power information only, the disadvantage of the linear polarization would be just a sqrt(2) loss in sensitivity. However, since the new receiver has a lower system temperature the loss is compensated by the better sensitivity of the C+ receiver and the observations went perfectly well. In contrast to our normal IF distribution with IF frequencies between 500 and 1000 MHz, the C+ receiver provides a 2.5 GHz wide IF over optical fiber. To reach the VLBI target frequencies an additional set of IF filters covering 1024 MHz to 1536 MHz had to be installed in the DBBC VLBI backend.

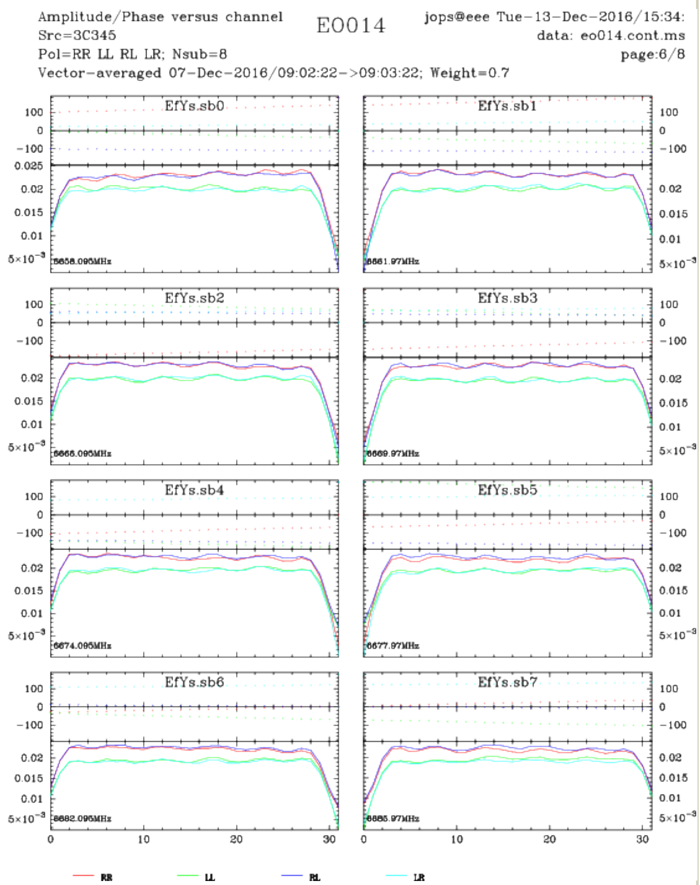


Fig. 1: Plots of correlated amplitude and phase for each sub-band of the correlation between linear polarization data from Effelsberg and RCP and LCP data from Yebes.

During eVLBI observations the data is directly streamed to the JIVE software correlator in Dwingeloo and Effelsberg showed good and stable fringes from the start of the experiment. The correlation and calibration of the Effelsberg data was successful and Figure 1 shows the Effelsberg data correlated against the RCP and LCP data from Yebes for all 8 sub-bands. The plot shows the correlated phase and amplitude of the 4 MHz wide base band channels between 6658 MHz and 6690 MHz on one of the calibration sources. The high amplitudes of the cross-polarized terms (LR and RL) are due to the linear polarization being a mixture of RCP and LCP.

Because circular polarization receivers are difficult to build for very wide bandwidth some of the modern instruments, like ALMA, provide linear polarization signals only as well. To enable VLBI observations with such instruments a recent study developed an algorithm to properly calibrate data from mixed polarization VLBI data (Marti-Vidal et al. 2016, A&A, 587, p. 143). The software from this study will be tested by the JIVE VLBI support group to calibrate and convert the Effelsberg linear polarization data within the next weeks. Depending on the results of future test for full polarization continuum calibration, the new receiver might be an option for all regular C-band observations.

Track repair at the 100-m telescope

In spring this year, some major repair work at the track of the 100-m telescope will be necessary which will cause operational restrictions.

The reason for this activity goes back to 2009. After the second fissure of the track in that year, we decided not to do the “standard” repair procedure (removing the concrete, cutting the track around the break, welding the two parts together and rebuild the concrete) as this would have caused another 5-6 weeks of downtime. Instead, a ~20 x 20 cm^2 part was milled out of the track (at the position of the crack) and a fitting piece was inserted which was connected to one side of the track only (see picture).

Over the years this provisional repair worked well, but we noticed that the foundation did sink at the place of the fissure (due to one-sided loads) by up to few tenths of a mm. That was corrected three times by the insertion of some special resin underneath.

However, recently, we measured not only that the subsidence of the foundation reached another high value (~0.8 mm), but also a significant level difference between both sides of the crack.

Furthermore, a small part of the fitting piece was broken and became loose. Hence, after seven years living with the provisional repair, a more permanent overhaul is necessary. That will be done starting on April 5. From that time on, only restricted observations will be possible. We expect that the work will be completed around May 15, so that regular observations could re-start at that date.

Science Highlights

Finding the Home of a Fast Radio Burst

By Laura Spitler

Fast Radio Bursts (FRBs) are millisecond-duration radio pulses that were discovered a decade ago. Their astrophysical origin is still a mystery, but their large observed dispersion measures (DM) imply distances of order 100 Mpc to a few Gpc. Eighteen FRB sources are currently in the literature, all of which have been discovered by large, single-dish radio telescopes. One hurdle in solving the puzzle is the poor spatial resolution of single dish detections. A localization on the order of an arcsecond is needed to associate the burst source with a host galaxy and obtain an independent measure of distance. This measurement is important for a number of reasons. First, it would confirm or refute the assumptions underlying the DM-based distance estimate. Second, it would constrain the energy budget of these pulses, which is important for origin models.

All but one FRB discovered so far has been a one-off event despite extensive follow-up observations of known sources searching for repeat bursts. The single exception is FRB 121102, which was discovered by the 305-m Arecibo Observatory (and first detected on 2 November 2012). FRB 121102 exhibits phases of high burst activity, during which several to 10s of pulses can be detected with the Arecibo Observatory during a two hour session. One such active phase occurred during September 2016. Coincidentally, a large collaboration of astronomers at institutes throughout Europe and North America planned a

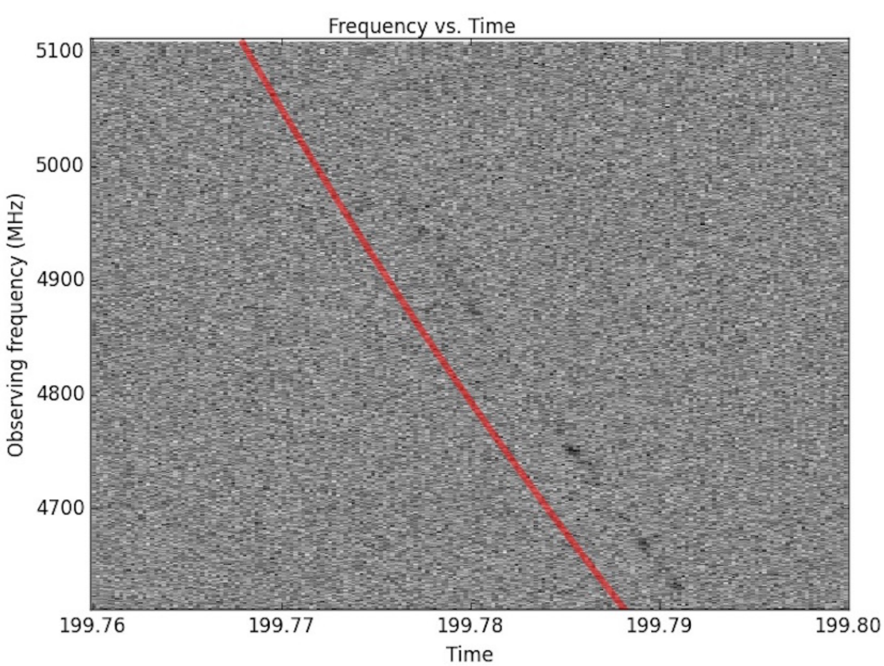


Fig. 1: A burst from FRB 121102 observed with Effelsberg using the 6cm receiver. This was the first detection of the repeating FRB at 5 GHz. The structure in the spectrum may be interstellar scintillations caused by the burst traveling through the ISM.

high-cadence, multi-telescope campaign of FRB 121102. Simultaneous observations were done daily for three weeks with the Arecibo observatory at 1.4 GHz, the Jansky Very Large Array (VLA) in New Mexico, USA at 3 GHz, and the Effelsberg telescope at 5 GHz (from Friday to Sunday).

Arecibo detected over 100 bursts during this three week campaign, including many with multiple pulse sub-components. The VLA detected a total of nine radio bursts from FRB 121102. This determined its sky position to a fraction of an arc second, over 200 times more precise than the previous measurements with Arecibo. Unfortunately Effelsberg did not detect any bursts during this campaign, but these non-detection will help provide constraints on the broadband spectrum of the source. The VLA localization of the radio bursts is spatially coincident with a compact, persistent radio source with a flux density of 0.2 mJy at 3 GHz. Also, a faint optical source was found at the position in archival Keck images. No high-energy counterpart has been seen. The initial characterization of the persistent radio source and multi-wavelength archival studies were presented in a paper in Nature published in January 2017 (Chatterjee et al. 2017). The evidence suggests two possible origin scenarios: a young neutron star in a supernova remnant or an active galactic nuclei (AGN).

We obtained a spectrum of the optical counterpart using the Gemini North Telescope, which showed a number of strong spectral lines (OIII, H-alpha and H-beta). The redshift of the host galaxy is 0.1927(1), which corresponds to a luminosity distance of 972 Mpc. This redshift is perfectly consistent with the estimates based on the DM. Interestingly, the host is a dwarf galaxy similar to the Small Magellanic Cloud with a diameter of ~4 kpc, a stellar mass of ~4-7 x 10^7 solar masses, and high rate of star formation (0.4 solar masses per year). This discovery strongly favors the neutron star in a supernova remnant model, because these galaxies are efficient at producing the massive stars needed for neutron stars and AGNs are extremely rare in dwarf galaxies.

With the European VLBI Network (EVN) we measured both the persistent radio source and detected four bursts from FRB 121102. Because the bursts from FRB 121102 are generally weak, the Effelsberg-Arecibo baselines were essential to have sufficient signal-to-noise. The size of the persistent radio source is ~3 mas at 1.4 GHz and ~0.3 mas at 5 GHz, consistent with angular broadening from the interstellar scattering. The upper limit to the projected physical size of the persistent source is < 0.7 pc. The position of the bursts and the persistent source are spatially coincident to within the measurement errors (~ 1 mas), which suggests the two sources are physically related. These results would support either model. On one hand, it is currently unclear whether an AGN is capable of producing fast radio bursts. On the other hand, the implied luminosity of the persistent source is significantly larger than any known supernova remnant.

In the near future we will be working on more in-depth analyses of the bursts from FRB 121102 in the hopes of further understanding the underlying source. For example, if we could determine a periodicity from the large number of Arecibo detections, it would immediately prove the neutron star model. Furthermore, I will be working on publishing three bursts from FRB 121102 detected with the Effelsberg telescope at 5 GHz (just before the simultaneous campaign began). During these detections we were also observing with the German LOFAR stations and the Stockert 25-meter telescope; neither made a detection. Finally, one of the open questions is whether all FRBs can in principle repeat and FRB 121102 simply does so more often, or if there are multiple classes of astrophysical sources capable of producing FRBs. To this end we are are regularly monitoring the known FRBs with Effelsberg in the hopes of detecting a second repeater.

HI4PI - a new full-sky HI line survey of the Milky Way

By Benjamin Winkel and Juergen Kerp on behalf of the HI4PI collaboration

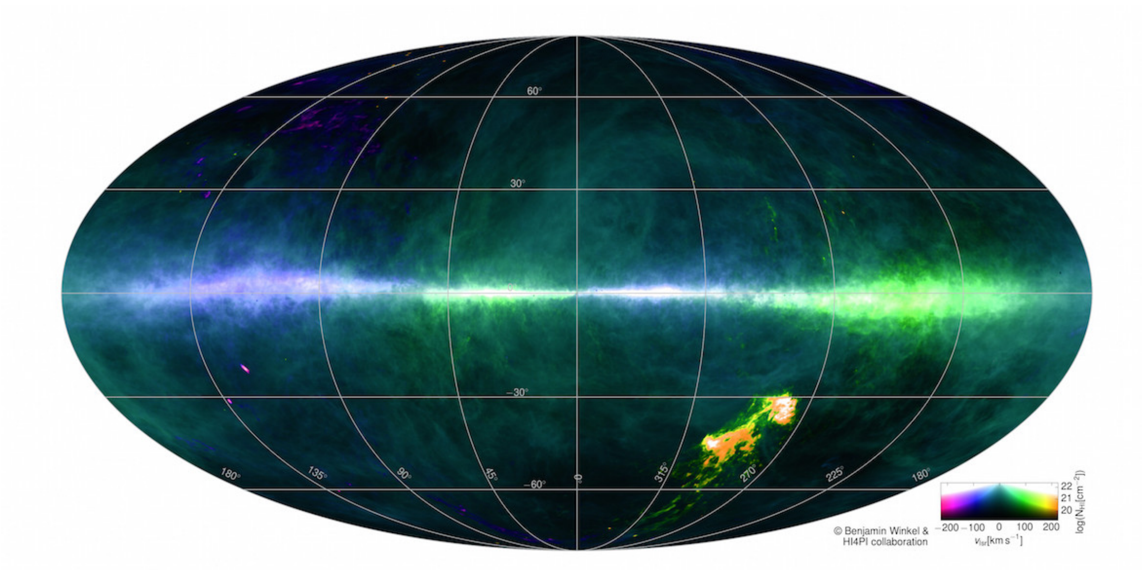


Fig. 1: The entire sky in the light of neutral atomic hydrogen (HI) as seen by the Parkes and Effelsberg radio telescope. Our host galaxy, the Milky Way, appears as a luminous band across the sky with the Galactic Center in the middle. The Magellanic Clouds (Large and Small Magellanic Cloud) are prominently visible in orange colors below the Galactic plane. They are surrounded by huge amounts of gas, which was forcefully disrupted from their hosts by gravitational interaction. The HI emission of the Andromeda galaxy (M31) and its neighbor, Triangulum (M33), is also easy to spot as bright purple ellipses in the South-western part of the map. The gas motion is color coded with different hue values, and the visual brightness in the image denotes the intensity of the received HI radiation.

As a faithful reader of the Effelsberg newsletter, you recall that about a year ago we released the Milky Way (MW) portion of the Effelsberg-Bonn HI Survey (EBHIS). In 2006, a comparable HI Survey has been made with the 64-m Parkes telescope in Australia - the Galactic All-Sky Survey (GASS). Consequently, it was only a matter of time before the EBHIS and GASS teams made the effort to combine both data sets, to establish a state-of-the-art complete full-sky database of our Milky Way galaxy.

In the October issue of Astronomy & Astrophysics, we report on this new and truly unique endeavor, the first HI spectral line survey ever made with 100-m class telescopes that covers 4-Pi sterad of the celestial sphere: the HI4PI Survey (HI4PI collaboration, A&A 594, A116, 2016). During the first two months after publication, the full-text paper has already been downloaded more than 3000 times, probably because a nice eye-catchy image (cf. Fig. 1) appeared also as "Astronomy picture of the day". This figure displays a composite of the HI column density and first Moment (intensity-weighted average radial velocity), which nicely reveals the differential rotation of Milky Way disk material. Furthermore, the Magellanic Cloud System is prominently visible, with its huge amounts of neutral gas being obviously disrupted from the Small- and Large Magellanic Cloud by tidal interaction.

But the beautiful map in Fig. 1 is only a visualization of a tiny fraction of the HI4PI data, as it marginalizes over the spectral axis of our data.

Owing to the high spectral resolution of the involved spectrometers, we could produce a data cube with almost 1000 channels, covering the radial velocity interval between -600 and +600 km/s. This cube a size of about 25 GBytes, and is accessible for your research via the Strasbourg data center (CDS, http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/594/A116) in various sky projections. Of course, to allow the data to be viewed and used on personal computers, smaller sub-sets of the data are provided, as well. However, if you would like to get an impression on how the full spectral data looks like, check out a video we have uploaded to YouTube (https://youtu.be/Q2mgpsTFuV8). It shows the brightness temperature for selected velocity slices of the all-sky data cube (Mollweide projection, Galactic coordinates).

HI4PI will serve as a major resource for researchers working with observational data at all wavelengths. As an example, X-ray and Gamma ray photons interact with the baryonic matter traced by the HI distribution. They are scattered and/or re-emitted at lower wavelengths by Milky Way hydrogen during their journey from outer space to our telescopes. Therefore, the distribution of HI in the Milky Way significantly alters the incoming signal observed by high-energy telescopes. The HI4PI data set allows the scientists to correct for these disturbing effects, cleaning our window to the distant universe.

Today astronomers often make use of the Leiden/Argentine/Bonn (LAB) survey data for such purposes. HI4PI provides a huge improvement over the LAB data in terms of sensitivity and angular resolution. Moreover, it has full spatial sampling and thus overcomes a major drawback of LAB, which severely undersamples the sky. HI4PI will eventually serve as a highly improved substitute to the LAB. Have fun and exciting insights with HI4PI.

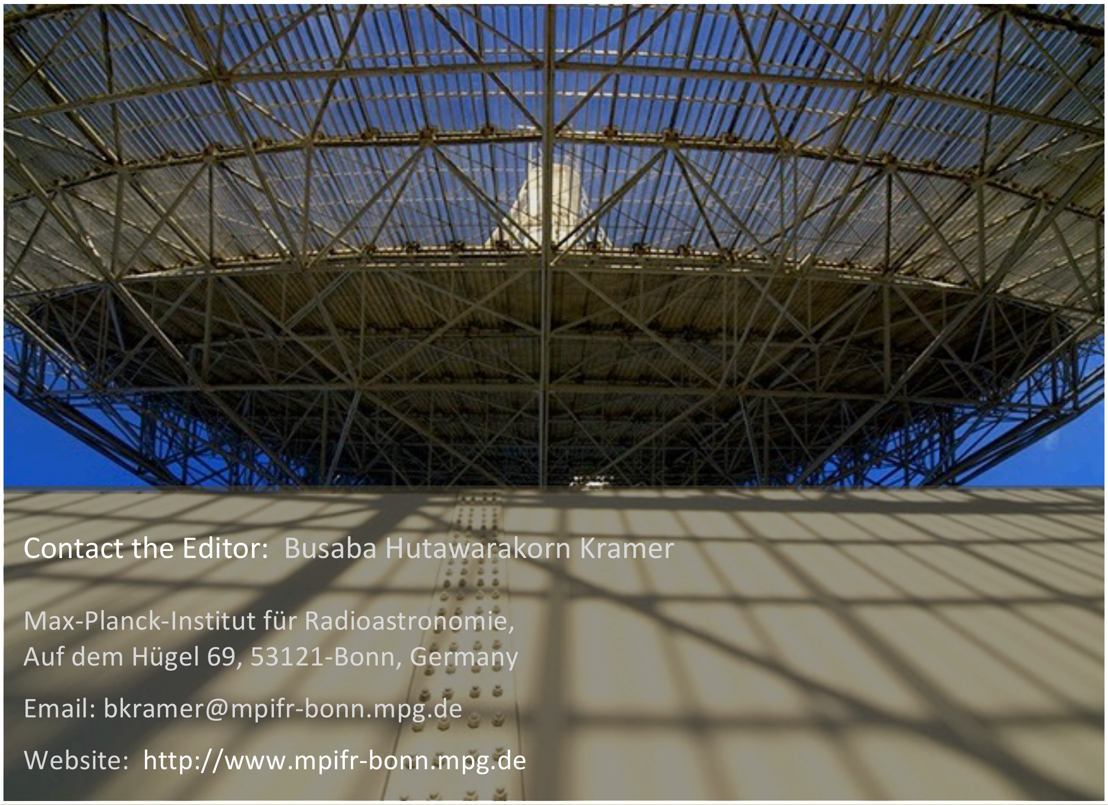
Who is Who in Effelsberg?

In 1971 Holger was born in a small village north of the Teutoburg Forest, a rather famous place in history since the Germanic tribes defeated here a remarkable part of the Roman Empire in the year 9 AD. After school and 15 month of civilian service where he helped and instructed delinquent minors to fulfill their imposed social working hours he started to study Electrical Engeneering at the RWTH Aachen and later on at the university of Genoa (Italy). In his diploma thesis he focused on the development of a magnetic levitation control for a luggage conveyor vehicle. For almost 15 years Holger has been working in the automotive supplier industry.

He focused on programming and electrical planning for car body painting systems and worldwide industrialization of steering systems for passenger cars. During his employment with Thyssen-Krupp Holger worked internationally in Slovakia, Mexico, Italy and China.

Holger started to work at the radio observatory on Oct 1, 2016 and is very glad about joining the Max Planck Institute. He likes the idea of supporting a professional team of scientists in his role as team leader of the electric department.

In his spare time Holger likes reading, cinema, going out with friends and watching football matches of his favourite team Borussia Dortmund. Additionally he is registered as a part-time student for mathematics at the FernUniversität Hagen (a distance university in Germany).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