Effelsberg Newsletter

September 2012

Science & Technology News:

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Call for Proposals:

Deadline October 9, 2012, 13.00 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.

Content

Icon Images: Norbert Tacken

Information about the telescope, its receivers and backends and the Program Committee can be found at

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

Observing modes

Possible observing modes include spectral line, continuum, pulsar, and VLBI. Available backends are a FFT spectrometer (with 32768 channels), a digital continuum backend, a pulsar system (coherent and incoherent dedispersion), and two VLBI terminals (MK4/5 and VLBA/RDBE type).

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 new 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/proposals.html

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

http://www.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 February 6, 2013, 13.00 UT.

by Alex Kraus

RadioNet Transnational Access Programme

RadioNet (see http://www.radionet-eu.org) includes a coherent set of Transnational Access programmes aimed at significantly improving the access of European astronomers to the major radio astronomical infrastructures that exist in, or are owned and run by, European organizations. Observing time at Effelsberg is available to astronomers from EU Member States (except Germany) and Associated States that meet certain criteria of eligibility. For more information:

http://www.radionet-eu.org/transnational-access

Time on these facilities is awarded following standard selection procedures for each TNA site, mainly based on scientific merits and feasibility. New users, young researchers and users from countries with no similar research infrastructure, are specially encouraged to apply. User groups who are awarded observing time under this contract, following the selection procedures and meeting the criteria of eligibility, will gain free access to the awarded facility, including infrastructure and logistical support, scientific and technical support usually provided to internal users and travel and subsistence grants for one of the members of the research team.

by Alex Kraus

Science & Technology News

The Ultra-Broadband Receiver - Motivation, Funding and Current Status

Paulo Freire

The base of our current scientific understanding of the universe at large scales is general relativity (henceforth GR), formulated by Albert Einstein in 1915. This theory describes gravity as an effect of the geometry of space-time, which becomes noticeably curved in the presence of large masses, like those of astronomical objects. This explains several long-standing mysteries in Newtonian gravity, like "action at a distance" (and its "solution", the idea of a gravitational potential) and the universality of free fall: unlike for other forces in nature, all objects accelerate in the same way under the same gravitational field. It also makes a large number of predictions, like, for instance, the bending of light near the Sun. The verification of this prediction in 1919 by Eddington and collaborators made Einstein world famous overnight and started the process of rigorous testing the theory.

Fig. 1. The UBB receiver, as seen at the end of June, shortly before being sent to Effelsberg.

Almost 100 years later, GR has passed all experimental tests. In the first phase of this process, the Solar System was used as a natural laboratory to test this theory, a process that continues to this day. A second phase started in 1974 with the discovery of the first binary pulsar, PSR B1913+16. In this new phase GR is being tested where no one had tested it before: for gravitational fields immensely stronger than what we can find in the Solar System. Pulsars are essentially giant atomic nuclei with 400000 times the Earth's mass packed in a sphere the size of Cologne; this results in densities of hundreds of millions of tons per cubic centimetre and gravitational fields at their surfaces hundreds of billions of times stronger than at the Earth's surface.

Testing GR in binary pulsars has allowed the detection of phenomena that simply cannot be detected in the Solar System, like the emission of gravitational waves, which were originally predicted by Einstein himself in 1916. Confirming the existence of gravitational radiation opened up an entirely new field of research in physics and astronomy, with detectors like LIGO, VIRGO and, interestingly, Pulsar Timing Arrays (a current topic of research at Effelsberg) now attempting a direct detection of gravitational waves. Furthermore, this experiment showed that GR, formulated at a time where only weak fields were observable, continues being valid in a completely unforeseen regime. No wonder the discoverers of PSR B1913+16, Russell Hulse and Joe Taylor, earned the Nobel Prize in Physics in 1993.

Since then, the discovery of the double pulsar system J0737-3039 (Lyne et al. 2004, Science, 303, 1153) has allowed five tests of GR in that system alone - and, despite the unprecedented precision of some of these tests, the theory passes all of them with flying colours! (Kramer et al. 2006, Science, 314, 97).

Looking beyond general relativity

Despite these successes, the present understanding of gravity cannot be reconciled with the quantum-mechanical standard model of particle physics, which describes the three other fundamental forces of Nature.

A fundamental ingredient of the standard model are scalar fields generated by spin-0 particles. Such scalar fields are thought to be the force that drove the formation of our Universe through cosmic inflation (e.g Caldwell & Kamionkowski, Ann. Rev. of Nuclear and Particle Science, 59, 397). Furthermore Dark Energy (which now accounts for 70% of the mass of the Universe and fully controls its expansion) could also arise from scalar fields (idem), in a scenario known as "quintessence". A recurring theoretical prediction of the proposed unification theories is that some of these scalar fields will couple with gravity. If this is the case then our current understanding of gravity needs a complete revision. Incidentally, the coupling of gravity with a scalar field is at the basis of the most viable and well-understood alternatives to GR.

What is important to us is that these alternative theories gravity would have two main observable consequences, both of them appearing as very small and apparently unimportant perturbations in the orbits of distant millisecond pulsar - white dwarf (MSP-WD) binaries. This is one of the things that makes pulsar timing so exciting: the unique precision of this technique might make these minute, hypothetical perturbations detectable with radio telescopes here on Earth!

The first perturbation is the emission of dipolar gravitational waves (DGW). This would appear as a slightly larger than expected rate of decay of the orbit of a binary pulsar, caused by the emission of gravitational waves. Until now the most sensitive pulsar timing experiments have not detected it (Freire et al. 2012, MNRAS, 423, 3328). These experiments have made innovative use of optical observations, which provide important information absent in the radio signal (Antoniadis et al. 2012, MNRAS, 423, 3316). The second effect would be a violation of the strong equivalence principle (SEP). This could in principle be detected by a small change in the orbital eccentricity of a MSP-WD binary with a wide orbit (see Freire, Kramer & Wex, 2012, Classical and Quantum Gravity, 29, Issue 18, pp. 184007 for a review).

Although none of these effects have been detected at our current level of experimental precision, that does not imply that they do not occur. Therefore, in order to attempt to detect them, we need to improve the precision of the pulsar timing technique.

What we need to do

The precision of pulsar timing is presently limited by two factors. The first is statistical: pulsars are exceedingly faint radio sources, requiring the use of the world's largest radio telescopes. The second is systematic: as the Earth and the pulsar move, their line of sight is always sampling different regions of the interstellar medium which always have slightly differing electron densities. These unpredictable variations introduce an extra source of uncertainty in the measurement of the times of arrival of the radio pulses.

The solution to both problems is the use of an ultra-broadband receiver (UBB), with corresponding broadband back-ends. Since pulsars are broadband sources, increasing the bandwidth should increase the signal-to-noise ratio of the detection and therefore contribute to improve the precision of the timing. More importantly, the large band allows a great improvement in the measurement of the daily variations of the electron column density between the Earth and the pulsar, therefore mitigating the main systematic effect in our measurements.

With such a system, we will be able to do even more precise tests of general relativity. What is new is that our precision is becoming so high that if we do not falsify GR, we will start falsifying other alternative theories of gravity, an example being a family of theories based on Bekenstein's Tensor-Vector-Scalar theories of gravity. Excluding these theories would have important implications for our understanding of the Universe: these theories attempt to explain the gravitational phenomena we believe to be caused by Dark Matter (like the flat rotation curves of Galaxies) as an incompleteness in our knowledge of gravity at low accelerations. Therefore, if we exclude these theories, we might - provisionally - conclude that Dark Matter really is some form of matter.

This observing system could potentially have vast implications in other areas of research, like the detection of gravitational waves using pulsar timing arrays. Furthermore, to do these precise tests of GR, we need to measure precisely the masses of the millisecond pulsars we are using to do these tests. If we measure a high NS mass, that will be of great importance to the study of nuclear physics (see, for instance, Demorest et al. 2010, Nature, 467, 1081).

Beacons in the dark

The BEACON project, submitted by P. Freire to the European Research Council (ERC) in October 2010, requested a total of 1.9 million euro for the construction of an ultra broadband receiver with a frequency between 0.6 and 3 GHz - the optimal frequencies for pulsar timing. The grant also covered the construction of the associated back-ends (also of unprecedented bandwidth, never built before) and their installation, maintenance and operation at the Effelsberg 100-m telescope for a period of 5 years. Recognizing the scientific importance of the project and its potential scientific impacts (marked with top grade of all proposals in Europe!), the ERC decided to fund the project in June 2011.

Implementation started in September 2011 - one year ago! Soon, the MPIfR workshops started cutting metal, and the electronics labs, under guidance from Christoph Kasemann and Reinhard Keller started building the electronics components. Meanwhile, Gunter Knittel started work on the main back-end system. This consists of a high-speed (12.5 GHz!) Tektronix ADC, capable of

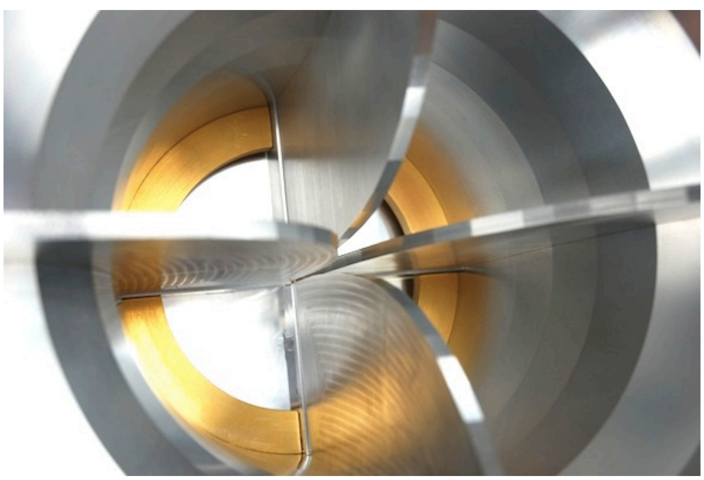

Fig. 2. The unique quad ridge design of the horn, which makes the receiver sensitive to frequencies between 0.6 and 3 GHz.

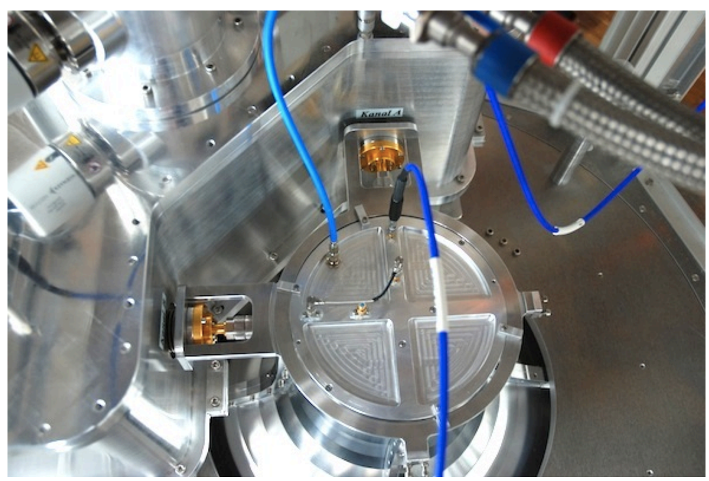

Fig. 3. Top view, illustrating the connection between the horn and the dewar, where the cryogenic low-noise amplifiers are installed.

fully Nyquist sampling two 3.125 GHz polarization channels, supported by a complex and challenging interface module he is designing. When finished, this system will send the data to a polyphase spectrometer, to be implemented in a FPGA-based Uniboard 1 computer by Gianni Comoretto and Antonietta Russo at INAF/Arcetri, our Italian partner institution in the BEACON project. The discrete bands are then coherently dedispersed by a GPU cluster, also being designed (and programmed) by Guenter Knittel. More recently, Ramesh Karuppusamy, now also working on the BEACON project, started increasing the bandwidth of the existing pulsar timing system (based on ROACH boards and conventional CPU coherent dedispersion). This provides important redundancy, mitigating risk and allowing a very important cross-verification of the timing accuracy of the more innovative GPU-based approach.

In June 2012, the receiver had already taken form (Fig. 1) and was being tested in the lab. In Fig. 2 we look down into the quad-ridge horn, designed by Sander Weinreb at the Jet Propulsion Labs within the US Technology Development Project (TDP). The feed is one of the innovative features of this receiver, machining it was a major task, requiring inputs from all parts of the electronic division and many man-months from the technicians at the MPIfR workshop. In Fig. 3 we look down on the back of the horn and we can see how it is connected to the dewar. These connectors are of a new design by Christoph and they lower the receiver noise significantly - a very important quantity for pulsar experiments. The preliminary tests indicate at extremely low system temperature of < 25 K - twice as good as our initial estimate!

At the start of July the receiver was hoisted into the focus cabin of the Effelsberg telescope and started undergoing pointing and focusing tests. This was one of the shortest development times ever for a receiver at Effelsberg, a consequence both of the ERC funding and of the high priority attached to the project by the directors.

On July 18, the first pulsar observations were made by Ramesh, Paulo, David Champion and Patrick Lazarus, using the current ROACH board/Asterix pulsar timing system. Amazingly, everything worked very well: we pointed the receiver at a pulsar and bright pulsar detections appeared on the screen (fig. 4)!

These observations show what we expected: radio interference is and will continue being our great enemy. Because of it, substantial parts of the band have to be deleted, with filters and later when reducing data, thus reducing our sensitivity. Nevertheless, in the future our back-ends will take full advantage of the receiver bandwidth, greatly increasing

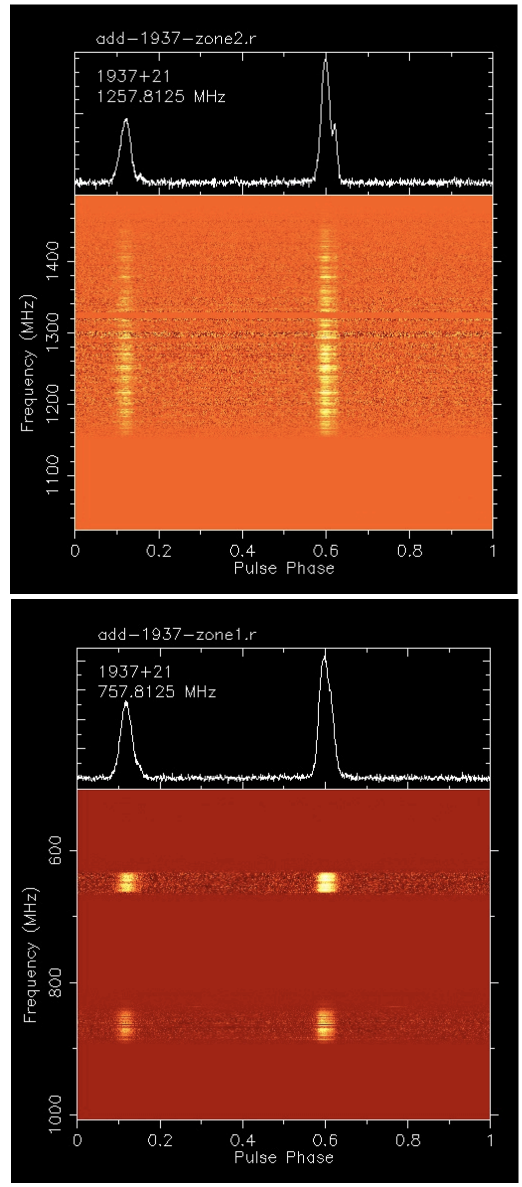

Fig. 4. PSR B1937+21 was the first millisecond pulsar we observed with the new system. The observations gave us a preliminary indication of the sensitivity of the system, which at the moment is still severely constrained by very strong radio frequency. In the vertical axis is displayed the radio frequency and in the horizontal axis the pulse phase - one full cycle is equivalent to one pulsar rotation, 1.57 ms.

the S/N of the detections. Furthermore, we are studying ways of combating radio interference; one full engineering position funded by the BEACON project (to be filled in January by Laura Spitler) for the next 4 years will be largely devoted to this task.

We are therefore well on our way to having the best pulsar timing system in the world. Many other groups have expressed great interest in this receiver for other non-pulsar scientific purposes, where unprecedented studies of radio emission can now be carried out. Furthermore, virtually all other pulsar groups in the world, recognizing the obvious scientific usefulness of this system, are pursuing or are investigating the possibilities to have similar UBBs installed at Jodrell Bank, Parkes, Green Bank, Arecibo and other telescopes. Meanwhile, we will be advancing with our own UBB system, being once again the pioneers both in radio instrumentation, digital electronics and in the fundamental business of checking whether Einstein really has the last word.

Who is Who in Effelsberg ?

Thomas Wedel

Thomas Wedel started his job as a telescope operator at the MPIfR in December 2011.

After his apprenticeship as an electrician and the completion of the advanced technical college for electrical engineering, his main concern was the progressively growing era of IBM compatible personal computers. Thus he decided to start his career in a local trading company in Bonn, which is building personal computers for customers, specialized dealers and public authorities.

In this long lasting employment he was first building personal computers, later he was getting more and more responsible for the computer environment. Finally, after an off-the-job training as a microsoft certified systems engineer, he was the primarily responsible system administrator in this company.

After 16 years working with computers, a bigger and much more interesting challenge was calling for him – the 100 meter radio telescope in Effelsberg!

Thomas lives with his wife in his homelike domicile in a small village near Euskirchen. In his spare time he likes to do trips in the nature, meeting good old friends, of course working with computers or simply relaxing in the garden.

Public Outreach

40 Years of Effelsberg Radio Telescope

Norbert Junkes

The 40th anniversary of the Effelsberg radio telescope is enclosed by two specific dates. The telescope was officially opened on May 12, 1971 and the full commencement of observations started on August 01, 1972. The time from May 2011 to August 2012 has shown a series of celebrations and public outreach activities in the context of the anniversary.

We report here on three particular events, a concert at the Effelsberg radio observatory and two visits of radio and newspaper teams on site which were connected with quiz contests where people could win the participation on two very specific talks and guided tours at the Effelsberg radio telescope.

The concert took place on Sunday, June 24. The symphonic wind orchestra "Orchesterverein Hilgen 1912 e.V." performed "The Planets", an orchestral suite composed by Gustav Holst about 100 years ago, followed by John Williams "Star Wars" theme, both with astronomical aspects:

http://www3.mpifr-bonn.mpg.de/div/effelsberg/40years/Konzert_web.pdf

The poor weather conditions did not allow for an open-air event, but the public could still enjoy the orchestral performance as well as an entertaining talk by Michael Kramer about the "sounds of the universe" under a big tent built in front of the telescope for the occasion.

Fig. 1-3 give some impressions of the concert, visitors listening to the music, the orchestra performing in the tent and Michael Kramer, director at MPIfR, together with Johannes Stert, the conductor of the orchestra.

Fig. 1-3: Anniversary concert at Effelsberg radio observatory on Sunday, June 24, 2012.
Photo: MPIfR/N. Junkes.

Fig. 5: Winners of the “Rheinische Post” quiz contest on the elevation platform of the Effelsberg telescope with Norbert Junkes (August 02, 2012). Photo: Alois Chiandetti.

The Düsseldorf newspaper “Rheinische Post” presented the Effelsberg telescope in its July 11 issue:

http://nachrichten.rp-online.de/wissen/radio-weltall-aus-effelsberg-1.2905375

It was the second part in a series with direct reports from mystic places in Northrhine-Westfalia (“Geheimnisvolle Orte in NRW”). The article was connected with a quiz contest where readers of the newspaper could win the participation in a special talk at the visitors’ pavilion and a following guided tour to the radio observatory and the 100m radio telescope. Fig. 5 shows the winners on the elevation platform of the telescope.

The science magazine “Leonardo” of the Cologne based WDR radio visited the Effelsberg radio telescope on August 02. They accompanied the first mounting of the new UWB receiver in the primary focus of the 100m radio telescope:

http://www.wdr.de/Fotostrecken/wdr5/sendungen/2012/leonardo/Effelsberg.jsp

The radio report was also accompanied by a quiz contest where people could win the participation in a special tour to the radio observatory with a presentation by Hermann-Michael Hahn and a guided tour to the telescope (see Fig. 6, 7).

Both tours for small groups of winners could only be enabled in the context of the 40th anniversary of the Effelsberg radio telescopes. For technical reasons and last but not least for security regulations it is not possible to visit the interior of the Observatory and the telescope itself (with the exception of “Open Days” at the observatory).

Fig. 6: Visit of a German radio team (WDR5 – Leonardo) at the Effelsberg radio telescope. The picture shows two journalists, Michael Lange and Martin Winkelheide, talking to Karl Grypstra from the Effelsberg staff on the telescope 50 m above ground. Photo: MPIfR/N. Junkes.

Fig. 7: Winners of a WDR2 radio quiz contest on the elevation platform of the Effelsberg telescope with Hermann-Michael Hahn and Norbert Junkes (August 23, 2012). Photo: Jan Friese/WDR.

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