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Greatings from the Director

Happy New Year, 2019!

Time flies. It seems like yesterday, when I wrote the greetings for 2018. However, a lot has happened, also in Effelsberg - a glimpse of which was given in last year's newsletters.

Whether there are technical enhancements, like the new Q-band receiver, or scientific results like the detection of large magneto-ionic variations toward the Galactic Center Magnetar, or results from successful collaboration work - old and new - like with EVN or FAST, there is always a large diversity in activities and results. Moreover, despite being used to these diverse actions, there is always another surprise or something unusual.

For instance, on November 26, Effelsberg and GBT were tracking the signals of the InSight lander on Mars, relaying the signals to Mission Control at JPL and engineers at Lockheed Martin Space in Denver. Then a little later still, magnetar XTE J1810-197 decided to become visible in the radio again, after about 12 years being silent. Effelsberg observed the magnetar then, 12 years ago, together with the Lovell telescope at Jodrell Bank, and it did so again this time.

I want to use the occasion to highlight that such flexibility and motivation for constant change and improvement would not be possible without the fantastic staff that works in Effelsberg and Bonn, preparing the telescope and its infrastructure, the receivers, the backends and all the other little things that are important but that observers don't even notice.

In this spirit, I want to thank all the staff, but also all the observers, who use the telescope, produce interesting results and give us valuable feedback! Let's see what 2019 will bring!

Happy New Year, and happy observing!

Michael Kramer

Call for proposals – Deadline February 4, 2019, UT 15:00

by Alex Kraus

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 and the Program Committee can be found at https://www.mpifr-bonn.mpg.de/effelsberg/astronomers (potential observers are especially encouraged to visit 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 Mk6 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.

Currently, we are gauging community interest for shared-risk observations with the **Phased-Array-Feed**. Observers that are interested should contact us via effsched@mpifr.de .

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 February, the next deadline will be on June 4, 2019, 15:00 UT.

RadioNet Transnational Access Programme

by Alex Kraus

RadioNet (http://www.radionet-org.eu) includes a coherent set of Transnational Access (TA) programs 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.

Astronomers who are based in the EU and the Associated States but are not affiliated to a German astronomical institute, may also receive additional aid from the Transnational Access (TA) Program of 'RadioNet'. This will entail free access to the telescope, as well as financial support of travel and accommodation expenses for one of the proposal team members to visit the Effelsberg telescope for observations.

The Transnational Access program is one of the activities of "RadioNet“, an Integrated Infrastructure Initiative (I3) funded under the ECs Framework Program Horizon2020, that has pulled together all of Europe's leading astronomy facilities to produce a focused, coherent and integrated project that will significantly enhance the quality and quantity of science performed by European astronomers.

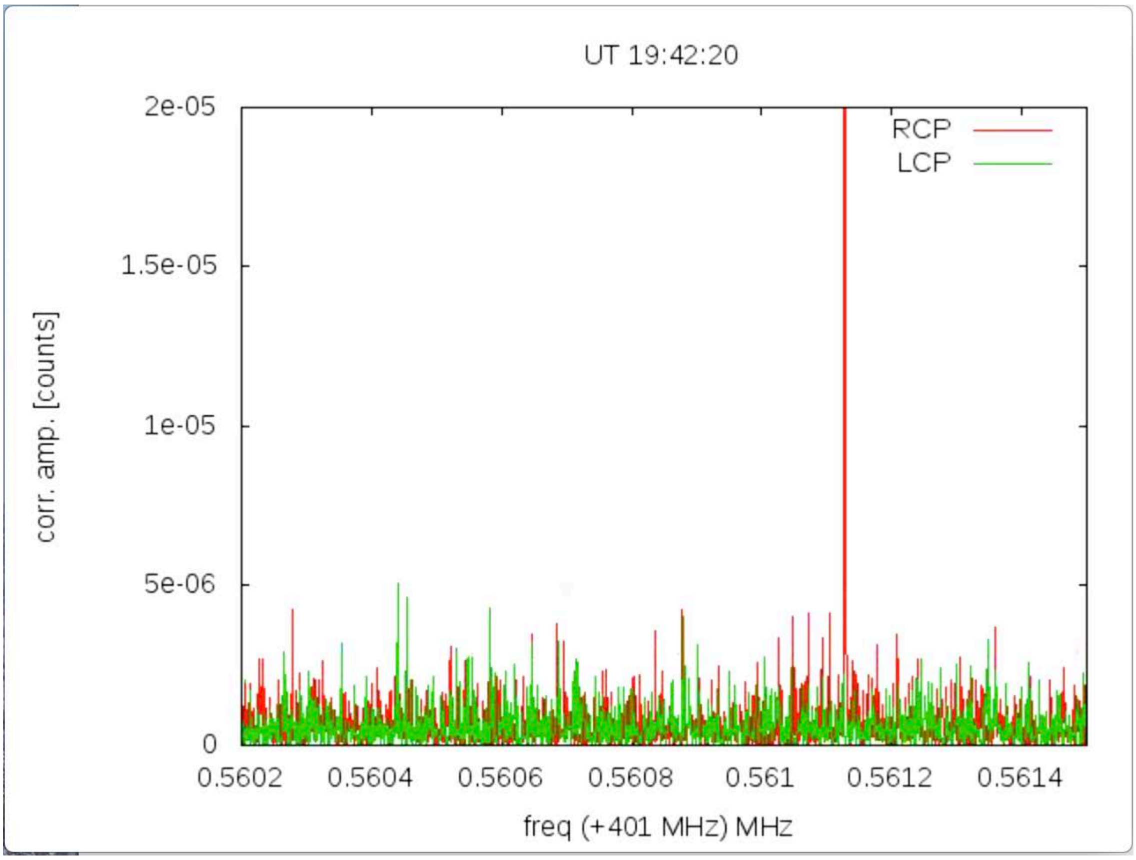
One - in exceptional cases more - scientists who are going to Effelsberg for observations can be supported, if the User Group Leader (i.e., the PI - a User Group is a team of one or more researchers) and the majority of the users work in (a) country(ies) other than the country where the installation is located. Only user groups that are allowed to disseminate the results they have generated under this program may benefit from the access.
After completion of their observations, TNA supported scientists are required to submit their feedback through the TNA web pages.

The 100-m telescope supported NASA during the landing of the InSight spacecraft on Mars

by Alex Kraus

On November 26, 2018, NASA's InSight spacecraft (https://mars.nasa.gov/insight/) successfully landed on Mars. During the EDL (Entry, Descend and Landing) phase, the 100-m telescope (as well as the Green Bank telescope in West Virginia, USA) observed the UHF carrier with telemetry modulation of the lander to confirm that the last minutes of InSight's six month-trip to the Martian surface proceeded as planned.
Despite the weakness of the signal (just 10 W in about 1 AU distance), the signal could be acquired at the expected time. The data were processed and recorded with JPL's radio science receiver and with the Digital Baseband converter of the Effelsberg's VLBI equipment.

The Doppler drift of the signal as well as the loss of it due to the plasma blackout in the Martian atmosphere occurred as expected confirming the descent of InSight according to its schedule.



Observation of InSight's beacon at 401.56 MHz with Effelsberg's Digital Baseband Converter (by Uwe Bach)

Happy faces in the control room after the successful observation and touch-down of InSight (by Norbert Tacken).

High-precision linear and circular polarimetry with the Effelsberg telescope and the case study of OJ 287

by Ioannis Myserlis

Introduction

Linear and circular polarimetry are powerful tools for the study of physical conditions and variability processes in astrophysical sources. As a defining property of the emission mechanism, its polarization state is directly related to the intrinsic physical conditions of the radiating region, such as the magnetic field strength and topology or the plasma particle composition and energetics. Furthermore, birefringent material along the line of sight – such as the intergalactic and interstellar medium – can modify or even eliminate the polarized component of the propagated radiation. Consequently, processes that induce variability in the emitting or transmitting regions can be traced by variations in the observed polarization parameters.

However, the reliable detection of the polarization states — especially the circular one — is usually a challenging endeavor. This is due to the fact that many astrophysical sources show low polarization levels, either intrinsically or as a result of de-polarizing effects like disorder of their magnetic fields or Faraday rotation induced by magnetized plasma regions along the line of sight. For example, single-dish measurements of extragalactic jets are usually at the level of 3%–5% for linear and 0.5%–1% for circular polarization. In addition, many sources show pronounced variability which can further decrease their polarization level. Moreover, the observing systems usually modify the polarization state of the incident radiation (instrumental polarization) and favor one of the two polarization states by design, e.g. radio telescopes with *circularly* polarized feeds are more sensitive to *linear* polarization measurements and vice versa.

We have recently developed an end-to-end data analysis pipeline to enable the recovery of all four Stokes parameters with high precision. It is designed to minimize the effect of instrumental polarization, allowing the detection of linear and circular polarization degrees as low as 0.3%. Among several applications, the pipeline is used routinely to recover the polarization parameters of the blazar OJ 287, which has been monitored intensely with the Effelsberg telescope since December 2015 over a wide range of frequencies (2.64 GHz — 43 GHz). As shown below, the combined analysis of our single-dish radio data with concurrent VLBI and optical polarization data provided evidence for the jet structure and magnetic field geometry.

The new polarimetric data analysis pipeline

As expected, the new pipeline contains several well-known procedures aimed to reconstruct the incident radiation outside the Earth's atmosphere, such as the corrections for pointing offset, atmospheric opacity and elevation-dependent gain of the telescope. However, its main scope is to maximize the efficiency of linear and circular polarization measurements through the careful treatment of all relevant instrumental effects. The final uncertainty reached is as low as 0.1% for linear polarization degree, 1° for polarization angle and 0.2% for circular polarization degree measurements. Although it has beed designed for systems with circularly polarized feeds, it can easily be generalized for linearly polarized feeds as well.

The polarimetric efficiency is maximized through the following correction steps:

Instrumental linear polarization correction

The instrumental linear polarization is manifested in the form of spurious signals in the receiver channels responsible for the Stokes *Q* and *U* measurements. Those signals are caused by a cross-talk between the left- and right-handed circularly polarized feeds and their amplitudes can be up to ~0.5% of the total flux density. Those signals can also be interpreted as "slices" of the polarized beam patterns over the corresponding scanning directions.

The instrumental polarization profile is modeled using a set of smooth functions to describe the telescope response (Stokes *Q* and *U*) to linearly unpolarized sources, such as planetary nebulae. The modeled profile is then used to correct the underlying spurious instrumental polarization signal for each measurement individually. The above approach has made it possible to recover significant Stokes *Q* and *U* detections even when the recorded signals are severely corrupted by the instrumental component (Fig. 1).

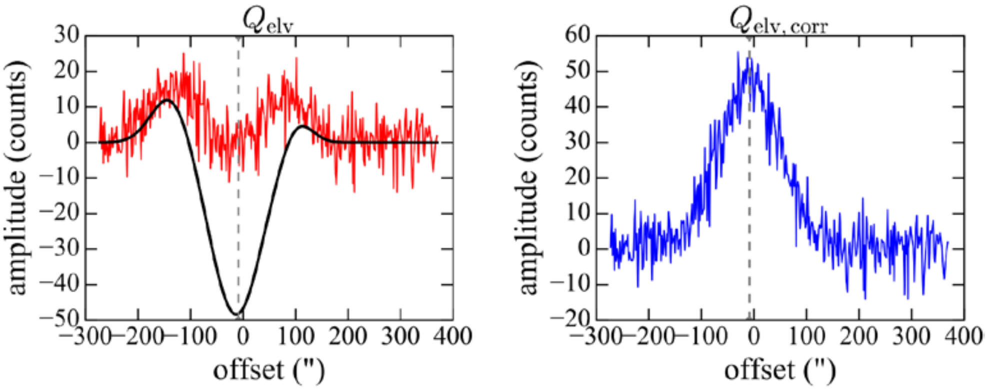


Fig. 1: Instrumental linear polarization correction example. The observed Stokes *Q* signal — severely corrupted by instrumental effects — is shown on the left by the noisy red line, while the smooth black line shows the expected instrumental polarization signal that was generated by the modeled profile for the given scan. The corrected signal, which is merely the subtraction of the latter two, is shown on the right with blue.

Instrumental polarization angle rotation correction

A possible sensitivity imbalance between the linearly polarized channels (Stokes *Q* and *U*) can lead to a rotation of the measured polarization angle. To quantify this effect we conducted lunar observations, since the Moon has a well understood polarization configuration. Its polarization degree maximizes towards the limb and its polarization angle has an almost perfect radial configuration. A direct comparison between the observed and the expected polarization angle values along the lunar limb (Fig. 2) revealed a slight instrumental rotation of about 1º, which was then subtracted from the measurements.

Instrumental circular polarization correction

Finally, a possible sensitivity imbalance between the circularly polarized channels (left and right) can introduce instrumental circular polarization, manifested by a systematic offset of the Stokes *V* measurements. This offset can be as high as 0.5%—1% of the total flux density, which is in most cases comparable to the circular polarization level to be detected. The pipeline includes two independent methods to correct for the above sensitivity imbalance. One is based on the observation of circularly unpolarized sources and the other assumes a subset of sources with stable circular polarization and is based on an application of the singular value decomposition (SVD) method. As an ultimate test, the corrected circular polarization data were compared against concurrent observations of the UMRAO monitoring program. There is a very good agreement between the measurements with a median discrepancy of only 0.2%, i.e. comparable to the uncertainty.

An interesting spinoff result of the pipeline development was the identification of several sources with stable linear and circular polarization parameters, at least over the 4.5 years that were examined (July 2010 — January 2015). Such sources are sparse in the available literature but needed to calibrate polarization observations accurately. A detailed description of the polarimetric data analysis pipeline along with the complete list of sources with stable linear and circular polarization is published in *Astronomy & Astrophysics*, see https://www.aanda.org/articles/aa/abs/2018/01/aa30301-16/aa30301-16.html.

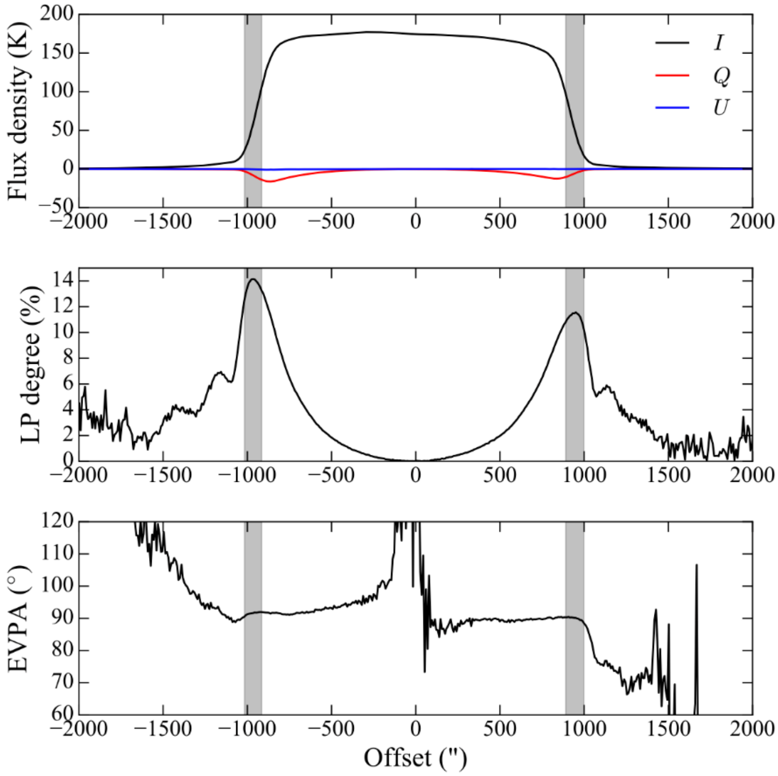


Fig. 2: Lunar observation example. Stokes parameters *I*, *Q* and *U* at 4.85 GHz (top panel), linear polarization degree (middle panel) and polarization angle (bottom panel) across the lunar surface, scanned over the azimuth direction. Along the Moon's limb (grey-shaded areas) the polarization degree is maximized and the polarization angle follows a radial configuration (±90º in the case of horizontal scans).

The case study of OJ 287: helical magnetic field within a bent jet

The new polarimetric pipeline is used routinely to recover the polarization parameters for observations conducted with the Effelsberg telescope. One example is the multifrequency, dense radio monitoring program of the blazar OJ 287 that was initiated in December 2015. The program was designed to investigate different aspects of the binary supermassive black hole (SMBH) scenario and study the physical conditions in its jet. The total flux is measured approximately every ten days over a wide frequency range (2.64 GHz — 43 GHz), using most of the secondary focus receivers. The linear polarization parameters are recovered at four bands between 2.64 GHz and 10.45 GHz, and the circular polarization at two bands, namely 4.85 GHz and 8.35 GHz.

The source showed flaring activity and significant polarization variability between December 2015 and January 2017. The high cadence monitoring in Effelsberg proved to be essential for detecting a long polarization angle rotation of about 340º during that period (Fig. 3). The analysis of concurrent VLBI polarization data at 15 GHz and 43 GHz revealed that the rotation originated within the jet core region. Furthermore, optical polarization data showed a similar rotation, superposed with shorter but much faster rotations.

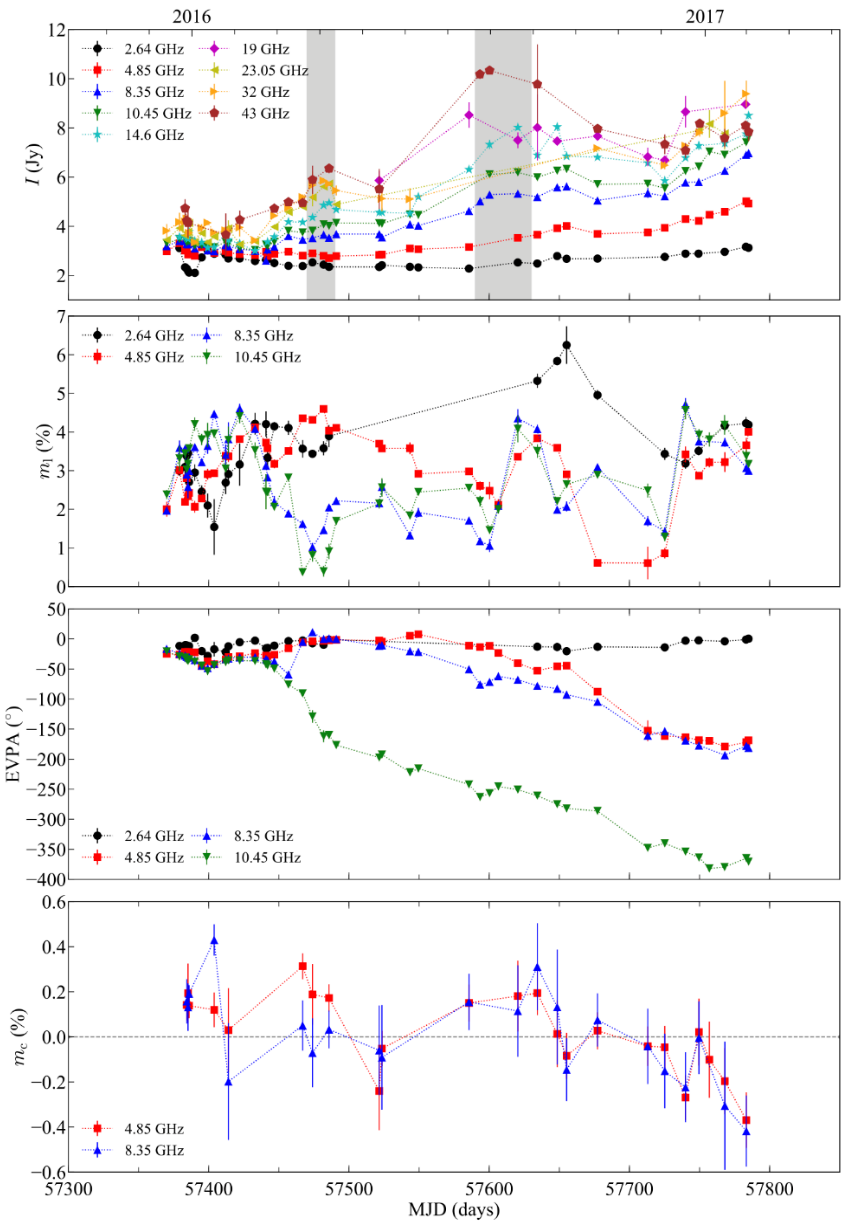


Fig. 3: Flux density and polarization curves of OJ287. From top to bottom: Stokes *I*, linear polarization degree, polarization angle and circular polarization degree. The long polarization angle rotation that was detected owing to the intense Effelsberg monitoring is shown by the 10.45 GHz data in the third panel (green line).

The complex polarization variability of OJ 287 can be interpreted by a polarized emission component that propagates on a helical trajectory within a bent jet. The observables were used to constrain the arc length and radius of the helical path to 0.26 pc and ≤0.04 pc, respectively. Moreover, the jet bending arc length was estimated to ≤1.9–7.6 pc, i.e. in agreement with recent ultra-high angular resolution VLBI observations by RadioAstron. The helical trajectory seems to cover a small part of the jet width, possibly its spine. Finally, the results revealed also the presence of a stable polarized emission component at an angle of −10º, which is perpendicular to the large-scale jet, suggesting the dominance of the poloidal magnetic field component. The complete analysis is published in *Astronomy & Astrophysics*, see https://www.aanda.org/articles/aa/abs/2018/11/aa32273-17/aa32273-17.html.

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