From the Director:
The radio/mm infrastructures needed for making today’s most significant astronomy breakthroughs are built by complex global networks. These networks involve individual astronomers, instrument developers (see p 9) and organisations such as Onsala Space Observatory closely working together. This month saw the publication of the first results from the Event Horizon Telescope on the black hole shadow in M87 (p 3). The OSO national infrastructure is proud to be involved in these observations via its contribution to the construction and operation of APEX and our contributions to the construction and calibration of ALMA.

A second featured VLBI science result in this newsletter, this time involving the Onsala 25 m telescope, concerns radio high resolution imaging of the Gravitational Wave source GW170817 (p 4). Also included in this issue are the results of very high resolution ALMA observations of a forming massive binary star (p 6) constraining massive star formation models.

As well as ‘zooming-in’ to achieve the highest spatial resolution radio observations are also uniquely suited to ‘zoom-out’ to execute wide-area surveys - as shown by the first public release of LOFAR survey data (p 5). The SKA, which recently passed an important political milestone with the signing of the SKA treaty (p 7), is designed to be both an outstanding survey instrument and, just like ALMA for EHT observations, have a phased-up mode. This latter mode will allow SKA to participate as a sensitive element of the global cm-VLBI networks together with the Onsala telescopes as important elements.

Sincerely, John Conway
**Call for Proposals**

Proposals are invited for observations with the APEX telescope, the Onsala Space Observatory 20 m telescope, and the Swedish LOFAR station in stand-alone mode. **Deadline for proposals: Friday 10 May 2019.** There is also a coming deadline for the **European VLBI Network (EVN)** - **Deadline 1st June 2019.** More details on these instruments are given below.

**APEX**, the Atacama Pathfinder EXperiment, is a 12 m diameter submillimetre telescope at 5100 m altitude on Llano Chajnantor in Chile. The **receivers** offered in this Call are the heterodyne receivers **SEPIA (band 5, 159-211 GHz)**, and **band 9, 581-727 GHz)**, **PI230** (band 6, 200-270 GHz), **FLASH•345** (band 7, 268-374 GHz), and the bolometer arrays **ArTeMiS** (350 and 450 µm) and **LABOCA** (870 µm). In general, proposals for Swedish time on APEX must have at least one co-I with a Swedish affiliation; however a maximum of 20 % of the observing time will be open to international proposals (i.e. those without a PI or co-I with a Swedish affiliation) - to be scheduled based purely on scientific merit.

The **Onsala 20 m** diameter telescope in Sweden is equipped with receivers which provide continuous frequency coverage in the ranges 18-50, 67-87 and 85-116 GHz with 4 GHz IF bandpass, dual polarisations and full mutual sideband rejection (<−13 dB). For the first time we welcome proposals for **Large programmes**, i.e. spanning more than one semester and/or require a large number of hours (> 500 h).

The **Swedish LOFAR station** at OSO is an array of antennas for the frequency bands 10–90 MHz and 110–240 MHz. It is part of the International LOFAR Telescope (ILT), but is offered here in stand-alone mode.

The **European VLBI Network (EVN)** is a collaboration of the major radio astronomical institutes in Europe (including OSO), Asia and South Africa. **The next deadline for EVN proposals is 1 June 2019.**

For more detailed information: see [OSO web page](#).

The National Facility offers a wide variety of support to Swedish astronomers. For example, we host one of the European ALMA regional nodes, supporting ALMA users throughout the Nordic region. We also offer support in several other areas.

**Data Reduction:** We support the reduction of all types of radio/(sub-)mm interferometric and single-dish observations. We welcome visitors who need reduction support and offer them the use of our National Facility Computing Infrastructure (NaFCI) for reduction of large data sets.

**Specialised Courses:** We will be able to assist with specialised lectures on for example, interferometry, radio/(sub-)mm data analysis and/or the use of National Facility instruments.

**Student projects:** We also encourage visits by students who want to learn how to reduce and analyse their radio/(sub-)mm observations.

**Workshop/School support:** Similarly, we can assist in planning and lecturing at schools or workshops, when these include topics related to National Facility activities and instruments. This includes but is not limited to, for example, radio/(sub-)mm interferometry and single dish observing and analysis, ALMA, APEX, LOFAR, SKA and EVN.

**Seminars:** National facility staff are also available for scientific and technical seminars on the aforementioned instruments.

**Interested in SKA/LOFAR news?** Please sign up to the LOFAR/SKA mailing list.

**More Information:** Contact [Michael Lindqvist](#), Head of Astronomy User Support.
Science News

We would like to introduce you to a few of the recent science highlights produced using the instruments at, and supported by, OSO. We especially welcome short contributions by you, the users of our telescopes, so please do not hesitate to contact us if you have results you would like to share in future newsletters.

First M87 Event Horizon Telescope results

On 10th April 2019, the Event Horizon Telescope (EHT) collaboration, a global VLBI array operating at a wavelength of 1.3 mm, presented its first results - an image of the shadow of the supermassive black hole in galaxy M87, see Fig. 1. The EHT collaboration involves more than 200 scientists and engineers, from 19 countries. The OSO national infrastructure is involved in the EHT as one of the three institutional partners involved in the construction and operation of the APEX telescope which participated in the observations. In addition, three scientists from Chalmers are members of the EHT collaboration and are coauthors on the papers. The published image is dominated by a ring structure of $42 \pm 3 \mu$as diameter that is brighter in the south. The brightness excess is explained as relativistic beaming of material rotating around the black hole, with gas to the South approaching the observer. The structure has a central brightness depression with a contrast of $>10:1$, which matches the expected signature of the black hole shadow. The observations give an estimated black hole mass of $M = 6.5 \pm 0.7 \times 10^9 M_\odot$. Further details can be found in a series of six papers in a special issue of *The Astrophysical Journal Letters*.

The telescopes contributing to this result were ALMA (Chile), APEX (Chile), the IRAM 30 m telescope (Spain), the James Clerk Maxwell Telescope (Hawaii), the Submillimeter Array (Hawaii, USA), the Large Millimeter Telescope Alfonso Serrano (Mexico), and the Submillimeter Telescope (Arizona, USA).

![Figure 1](image-url). *EHT images of M87 on four different observing nights in 2017. The indicated beam is 20 µas. From the EHT collaboration (2019, Paper IV).*
VLBI exposes the aftermath of a violent merger of neutron stars

The binary neutron star merger event GW170817 was detected through both gravitational waves and electromagnetic radiation. The early optical observations located its host galaxy as NGC 4993 and found temporal and spectral properties consistent with a source powered by the radioactive decay of material ejected during and after the merger. Later afterglow emission detected at radio wavelengths is theorised to have been produced by either a narrow relativistic jet or an isotropic outflow interacting with surrounding material.

A group of international astronomers, led by G. Ghirlanda (Italy), has recently presented the imaging results of VLBI observations with 32 radio telescopes including the Onsala 25 m radio telescope. The apparent source size, 207 days after the merger, is constrained to be smaller than 2.5 milli–arc seconds at the 90 % confidence level. The compact structure indicates that GW170817 produced a structured relativistic jet instead of an isotropic outflow scenario, which would have produced a larger apparent size.

![Figure 2](image)

*Figure 2. The global VLBI imaging and simulation results of GW170817. The inset shows real and simulated pseudo-colour images (top), obtained in observations as well as based on model image distributions (bottom) for various scenarios (collimated jet, jet-cocoon with different opening angles). The background artist's impression represents the jet braking through the dense gas ejecta, which was produced during the merger of neutron stars that caused the gravitational waves recorded as GW170817.*

The above results are published in Ghirlanda et al. (2019).
The LOFAR Two-metre Sky Survey-II. First data release

LOFAR (the LOw Frequency ARray) is a radio interferometer centred in the Netherlands with outrigger stations in several European countries, including Sweden. In February 2019 a special issue was published in A&A entitled “LOFAR Surveys: a new window on the Universe”. The publication of 25 papers was accompanied by the first data release of the LOFAR Two-meter Sky Survey (LoTSS). The data release includes mosaicked images at 6” resolution from a region of 425 square degrees at 150 MHz, and a catalog of more than 325 000 radio sources, complete to a point-source sensitivity 0.35 mJy. In addition, optical counterparts and photometric redshifts are provided for 70 % of the sources. This first data release corresponds only to 2 % of the final Survey dataset but gives a taste of what LOFAR can achieve. In the coming five years, LoTSS will cover the entire northern sky and be the most sensitive wide-area radio survey ever made.

The published papers cover a wide range of extragalactic astronomy, from nearby star-forming galaxies (see Fig. 3), galaxy groups and clusters, radio-loud active galactic nuclei, magnetized giant radio galaxies, to distant blazars.

Figure 3. From Miskolczi et al. (2019). Detection of a large halo of synchrotron emission around the nearby (14 Mpc) edge-on star-forming galaxy NGC 3556. The scale height of the radio emission seen by LOFAR at 144 MHz is about 6 kpc, significantly larger than what is inferred from observations at higher frequencies with the Very Large Array (VLA). The combination of the LOFAR image with VLA images makes it possible to constrain models of cosmic-ray propagation, taking into account the ageing of the cosmic-ray electrons that produce the synchrotron emission. The authors showed that the LOFAR observations require an accelerating galactic wind, possibly driven by cosmic rays. This model is further supported by observations of extended X-ray emission from this galaxy and of vertical filaments at the disk-halo interface seen in Hα and in radio continuum.
Spiralling giants: ALMA witnesses the birth of a massive binary star

A recent paper by Zhang, Tan et al. (2019) in Nature Astronomy presents very high angular resolution observations with ALMA at 1.3 mm of a massive protostar, IRAS 07299-1651, Fig. 4. The system is revealed to be a binary, with the components separated by 180 AU on the sky. Importantly, the radial velocity of the components can be estimated from radio recombination lines (H30α), which allows dynamical constraints to be placed on the orbits and the total mass. The stars orbit each other about once every 600 years and they have a combined mass of at least 18 times that of our sun. This is the first time that dynamical constraints have been placed on a forming massive binary. The mass estimate is consistent with independent estimates from the total and ionising luminosities and from the kinematics of in-falling streams seen on larger scales. The results favour a scenario of disk fragmentation to form the binary, and thus the study provides important information for testing theoretical models of massive star formation.

Figure 4. ALMA’s view of the IRAS-07299 star-forming region and the massive binary system at its centre. The background image shows dense, dusty streams of gas (shown in green) that appear to be flowing towards the centre. Gas motions, as traced by the methanol molecule, that are towards us are shown in blue; motions away from us in red. The inset image shows a zoom-in view of the massive forming binary, with the brighter, primary protostar moving toward us shown in blue and the fainter, secondary protostar moving away from us shown in red. The blue and red dotted lines show an example of orbits of the primary and secondary spiralling around their centre of mass (marked by the cross).

The above results are published in Zhang, Tan et al. (2019).
Other News

Signing of SKA Observatory treaty and Swedish SKA proposal.

An important milestone in the development of the Square Kilometre Array (SKA) project was passed on 12th March 2019 in Rome with the signing by seven countries of the international treaty establishing the SKA Observatory as an international organisation. The treaty must now be ratified by the parliaments of the signatory countries with the expectation that the SKA international organisation will start operations during the first half of 2020. During that year the international organisation will take over the roles and assets of present SKA Company. Soon after its first meeting the SKA Observatory’s council it is expected to make the formal decision to start construction of SKA which is then expected to start in early 2021.

A decision on Swedish membership of the SKA Observatory and full participation by Sweden in SKA construction and operations awaits the evaluation of a proposal submitted to VR’s Council for Infrastructures in February. This proposal was officially sponsored by Stockholm University, Uppsala University and Chalmers University of Technology. The proposal listed 53 astronomers and physicists from a wide range of institutions in Sweden expressing their support for Swedish membership of the SKA Observatory.

Figure 5. The 7 initial signatories of the SKA Observatory Convention (UK, China, Portugal, South Africa, the Netherlands, Australia, Italy). Credit: SKA Organisation.

Interested in SKA/LOFAR news? Please sign up to the [LOFAR/SKA mailing list](#).
The Eighth European Radio Interferometry School (ERIS) will take place in Gothenburg during the week 7-11 October 2019. ERIS will provide a week of lectures and tutorials on how to achieve scientific results from radio interferometry. The topics covered by the lectures/tutorials will include:

- Calibration and imaging of continuum, spectral line, and polarization data;
- Observing techniques for low frequencies (e.g. LOFAR), intermediate frequencies (e.g. VLA and e-MERLIN), high frequencies (e.g. ALMA and NOEMA), and VLBI (e.g. EVN);
- Extracting the information from astronomical data and interpreting the results;
- Choosing the most suitable array and observing plan for your project.

For registration (deadline 3 May) and more details see:


**SOC:** Arancha Castro-Carrizo (IRAM, NOEMA), Liz Humphreys (ESO, Garching), Katharine Johnston (University of Leeds), Robert Laing (SKA, Jodrell Bank Observatory), Michael Lindqvist (Chalmers, Chair), Matthias Maercker (Chalmers), John McKean (ASTRON), Monica Orienti (INAF), Anita Richards (JBCA), Eduardo Ros (MPIfR, Bonn), Ilse van Bemmel (JIVE), Wouter Vlemmings (Chalmers).

**LOC:** Stephen Bourke, Michael Lindqvist, Matthias Maercker (Chair), Magnus Thomasson

**Contact:** The SOC and the LOC have a common email address: eris2019@chalmers.se.

*This event has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730562 [RadioNet].* [https://www.radionet-org.eu/radionet/](https://www.radionet-org.eu/radionet/)
The 30th International Symposium on Space Terahertz Technology (ISSTT, [https://www.isstt2019.com/](https://www.isstt2019.com/)) took place on April 15-17, 2019 at Chalmers Campus Lindholmen, Gothenburg. The annual conference is the premier international meeting for instrumentation scientists around the world building astronomy/remote sensing receivers from 100 GHz - 10 THz for both space (and notwithstanding the name of the conference) also ground based facilities.

About 140 registered participants from 15 countries world-wide attended, Fig. 6. The meeting was organised by the Group for Advanced Receiver Development (GARD) within the Onsala Space Observatory Division at Chalmers. This was the second time the ISSTT was arranged at Chalmers. Discussions relevant to future astronomy projects included quantum noise limited, ultra-wideband receivers with relevance to future astronomy projects such as the planned ALMA2030 upgrade, enhancing the Event Horizon Telescope for improved images of black holes, for future Space-VLBI and future and planned THz/Far-IR mission such as the Origins Space Telescope and Millimetron satellites.

![Conference group picture from the ISSTT meeting, Chalmers Lindholmen.](image-url)

*Figure 6. Conference group picture from the ISSTT meeting, Chalmers Lindholmen.*