

# Onsala Space Observatory astronomy newsletter



October, 2020 — Volume 12

## From the Director:

The COVID-19 virus has had an enormous impact on all of our lives during 2020. While at Onsala, despite the virus, most observations have continued, at the APEX and ALMA telescopes in Chile observations ceased in the Spring. APEX observations have restarted since mid-September and ALMA has also recently begun a process of array recovery. The ALMA deadline scheduled for April 2020 was cancelled, but there are now plans for a new deadline in Spring 2021. There was also no APEX/Onsala Call for Proposals this April; details of the upcoming APEX/Onsala proposal deadline on November 18th are given in this newsletter.

Despite the hiatus in ALMA observations technical development continues. The OSO/Chalmers Group for Advanced Receiver Development (GARD) is playing a leading role in the design and production of the new Band 2 (+3) receivers for ALMA. Together with the earlier delivered Band 5 receivers we can be proud that two of the ALMA receiver bands have been substantially supplied by Sweden.

In the last edition of this newsletter published a year ago the positive VR review of the Swedish proposal for involvement in the SKA's construction/operations phase was presented. During the last year there has been significant progress in securing SKA industrial work-packages to Sweden, including the Digitiser system for SKA1-mid in South Africa, which you can read about in this newsletter. We are eagerly awaiting a final government decision on Sweden joining the SKA Observatory, and hope it will be made before the end of 2020.

Sincerely, John Conway



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Editor: [Michael Lindqvist](#)

## Call for Proposals

Proposals are invited for observations with the **APEX** telescope and the Onsala Space Observatory **20 m telescope** in the observing period April–August 2021 (APEX) and January–April 2021 (20 m telescope). **Deadline for proposals: Wednesday 18 November 2020.** 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** (SEPIA180, **159-211 GHz**; SEPIA345, **272-376 GHz**; SEPIA660, **578-738 GHz**) and nFLASH (nFLASH230, **200-270 GHz**; and nFLASH460, **385-500 GHz**), and the bolometer arrays ArTeMiS (**350** and **450  $\mu\text{m}$** ). 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). We welcome proposals for **Large programmes**, i.e. spanning more than one semester and/or require a large number of hours ( $> 500$  h). Starting from this deadline proposals for the Onsala 20 m telescope must have **at least one co-I with a Chalmers affiliation**. ***This change of policy is caused by re-prioritisation of OSO staff toward other duties requiring a local contact at Chalmers to support the single dish observations of the 20m which are Chalmers university funded.*** It also planned to have in future only a single 20 m proposal deadline per year in the Autumn.

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 February 2021.](#)

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

## Support at OSO

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, [SALSA](#), 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](#).

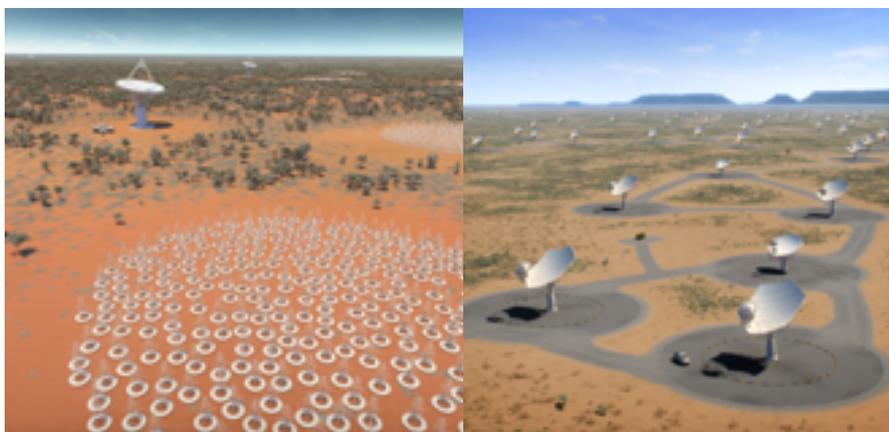
**More Information:** Contact [Michael Lindqvist](#), Head of Astronomy User Support.

# Science News

Below we describe recent project and science highlights related to telescopes operated or supported by, OSO. We welcome short contributions by our users of our telescopes, so please do not hesitate to contact us if you have results you would like to share in future newsletters.

## SKA Project

At the SKA Organisation Board meeting on 18th/19th September 2020 (held via zoom) the board formally endorsed a set of documents that collectively describe the construction and operations phase of the SKA. This Construction Proposal is expected to be formally approved and put into effect at the first formal meeting of the council of the new SKA Observatory Intergovernmental Organisation (IGO) – leading to the start of construction for SKA during 2021 (Fig. 1). The SKA Observatory IGO will come into existence once the SKA convention is signed and ratified by at least five countries. This threshold is expect to be reached by late 2020. It is planned that during 2021 the assets of the current SKA Organisation company will be transferred to the new SKA Observatory IGO and then the SKA Organisation company wound up.

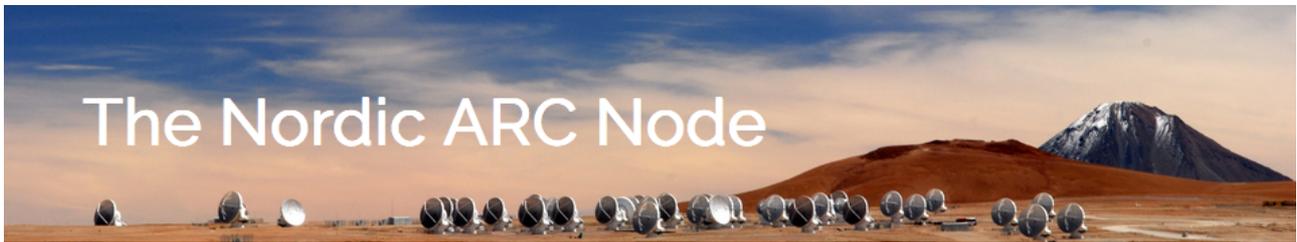


*Figure 1. Left - Simulated image of SKA1-low in Australia showing in the foreground one its 512 dipole stations, with other stations in the background (and dishes of the ASKAP SKA precursor array). Right: Simulated image showing a small fraction of the 197 dishes that will comprise SKA1-mid in South Africa.*

*John Conway, Chalmers*

**Interested in SKA/LOFAR news?** Please sign up to the Swedish [LOFAR/SKA mailing list](#).

## ALMA operations and Cycle 8 suspension due to the COVID-19 pandemic



Due to the COVID-19 outbreak, ALMA operations and Cycle 8 Call for Proposals were suspended last spring and postponed until 2021. If the situation allows, it is anticipated that the Cycle 8 Call for Proposals will open again in March 2021 and the start of Cycle 8 will take place in October 2021. ALMA Cycle 7 will continue through September 2021, with currently non-completed projects ranked A, B and C remaining in the observing queue.

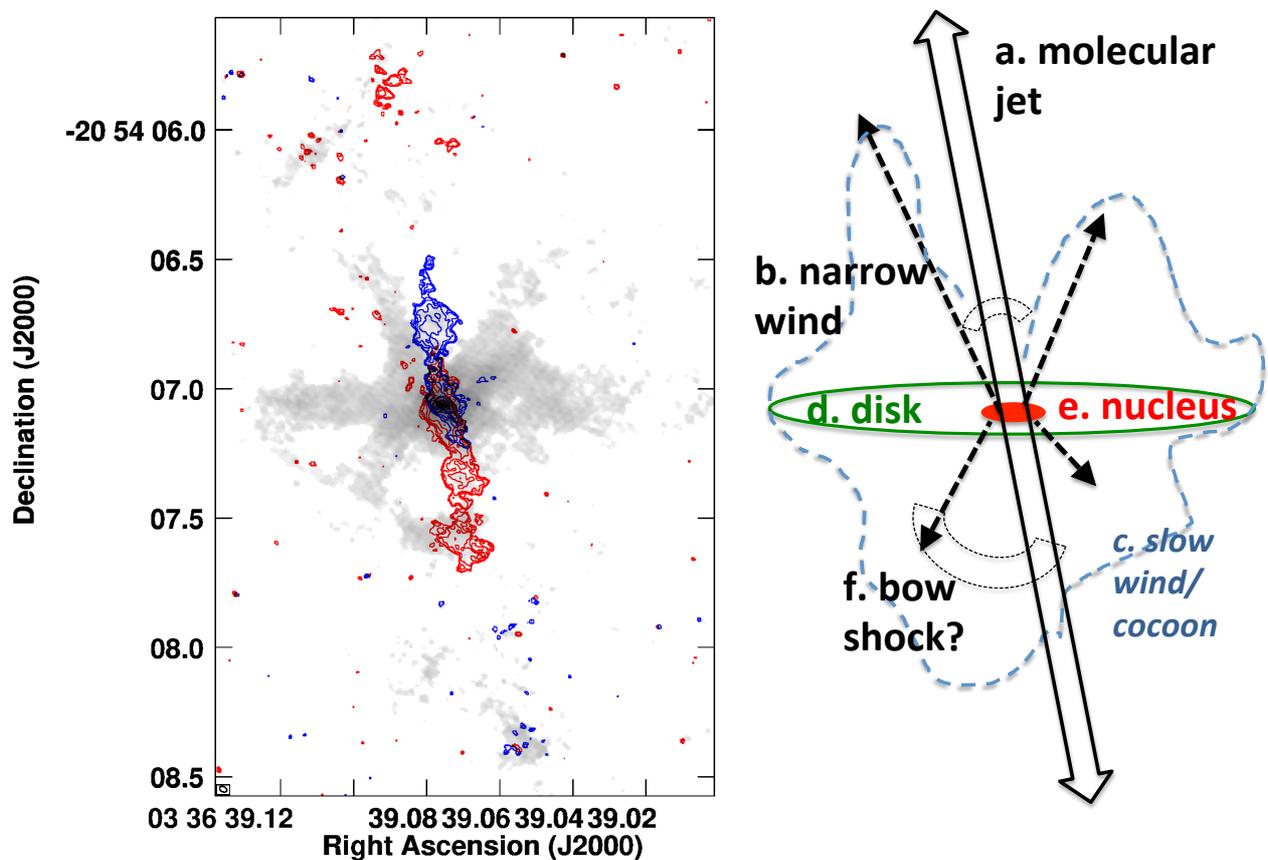
On October 1st, 2020, ALMA started the long process of recovering the telescope array, focusing on the safe return of staff and contractors to the ALMA Operations Support Facility (OSF) at 2900 m as a first priority, before beginning the process of restarting the Array Operations Site (AOS) at 5000 m. The ALMA Observatory has developed an extensive set of enhanced safety protocols related to managing the risk posed by the virus, covering all activities as the recovery of operations progresses. The current restart plan requires about 80 days to reach the antenna power-up milestone, assuming there are no major repairs, or changes in the schedule due to impacts of the pandemic. The time needed to recover sufficient antennas for science observations is highly uncertain. Nevertheless, the plan is to have antennas collecting data and verifying the observing systems after approximately 100 days. *This implies that January 2021 is the earliest there may be enough functional antennas and cooled receivers to attempt the first science observations.* In addition, the regular February infrastructure maintenance is scheduled. The ultimate goal is to be in a position to perform PI science observations no later than mid-March 2021. Status updates will continue to be provided, as the recovery of operations progresses.

As always, the Nordic ARC node will continue supporting the ALMA user community in proposal preparation, data reduction, advanced analysis and archival research. We strongly encourage users to contact the Node to get support. In the current situation, we can particularly assist you through virtual face-to-face support of your PI or archival data projects. You can contact us at [contact@nordic-alma.se](mailto:contact@nordic-alma.se) or visit [nordic-alma.se](http://nordic-alma.se).

*Carmen Toribio, Chalmers*

## ALMA resolves the remarkable molecular jet and rotating wind in the extremely radio-quiet galaxy NGC 1377

Studying outflows, winds, jets and other mechanical feedback processes is important to our understanding of how galaxies evolve both in the local and distant Universe. Feedback from active galactic nuclei (AGN) and starbursts may, for example, help prevent overgrowth of massive galaxies and regulate the growth of supermassive black holes (SMBHs).



**Figure 2.** Left panel: CO (3–2) integrated intensity image where emission close to systemic is shown in grey scale. The high-velocity ( $\pm 80$  to  $\pm 160$  km s $^{-1}$ ) emission from the molecular jet is shown in contours, with the red and blue showing the velocity reversals. Right panel: Chart of the various components of the molecular structure of NGC 1377: the molecular jet and narrow wind, the slow wind and the suggested bow shocks.

With very high-resolution (20 by 30 mas ( $2 \times 3$  pc)) ALMA observations of CO (3–2), HCO $^+$  (4–3), vibrationally excited HCN (4–3)  $v_2=1f$ , and continuum, [Aalto et al. \(2020\)](#) have studied the remarkable, extremely radio-quiet, molecular jet and wind of the lenticular galaxy NGC 1377

(Fig. 2). The outflow structure is resolved, revealing a 150 pc long, clumpy, high-velocity ( $\sim 600 \text{ km s}^{-1}$ ), collimated molecular jet where the molecular emission is emerging from the spine of the jet with an average diameter of 3-7 pc. A narrow-angle ( $50^\circ$ - $70^\circ$ ), misaligned and rotating molecular wind surrounds the jet, and both are enveloped by a larger-scale CO-emitting structure at near-systemic velocity. The jet and narrow wind have steep radial gas excitation gradients and appear turbulent with high gas dispersion ( $\sigma > 40 \text{ km s}^{-1}$ ). The jet shows velocity reversals that [Aalto et al. \(2020\)](#) propose are caused by precession, or more episodic directional changes. [Aalto et al. \(2020\)](#) further suggest that an important process for the molecular jet and narrow wind is likely magneto-centrifugal driving. An asymmetric, nuclear  $r \sim 2$  pc dust structure with a high inferred molecular column density  $N(\text{H}_2) > 10^{24} \text{ cm}^{-2}$  is detected in continuum and vibrationally excited HCN. The nuclear dust emission is hot ( $T_d > 180 \text{ K}$ ) and its luminosity is likely powered by a buried AGN. [Aalto et al. \(2020\)](#) suggest that the SMBH of NGC 1377 is at the end of an intense phase of accretion and evolving from a state of more extreme nuclear obscuration. The nuclear growth may be fuelled by low-angular momentum gas inflowing from the gas ejected in the molecular jet and wind. Such a feedback-loop of cyclic outflows and central accretion would be an effective process in growing the nuclear SMBH and thus would constitute an important phase in the evolution of NGC 1377. This also invites new questions as to SMBH growth processes in obscured, dusty galaxies.

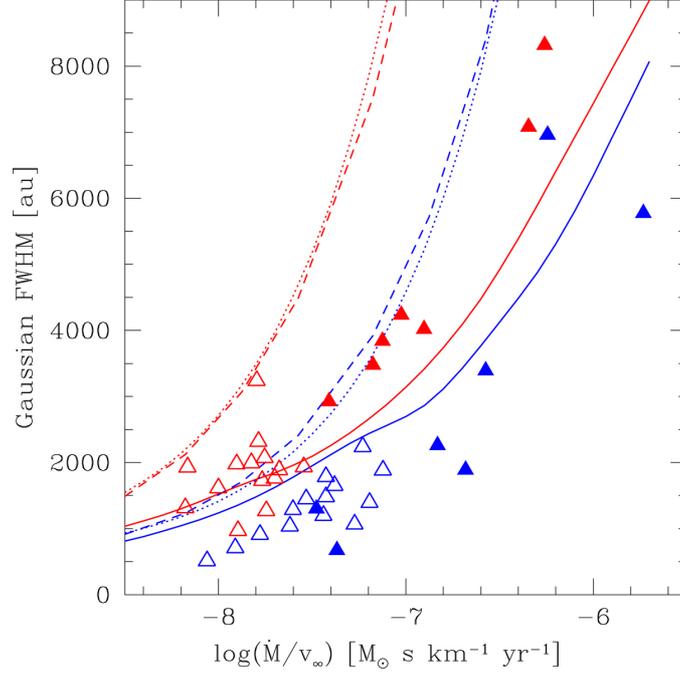
*Susanne Aalto, Chalmers*

*The above result is published in A&A, see [Aalto et al. \(2020\)](#).*

## **DEATHSTAR, first results: CO envelope sizes and asymmetries**

When solar-like stars reach the end of their lives they develop massive winds. Over time, the wind will remove the entire stellar atmosphere and lead to the death of the star. Material that is enriched with new elements formed inside the star is thereby recycled in the galaxy and will make up new stars and planets. This process is well established, but the accuracy of current measurements is insufficient to properly constrain stellar wind and evolutionary models.

DEATHSTAR is a large project aimed at improving the accuracy of stellar wind-parameter measurements. Significant uncertainty is related to assumptions made regarding the size and shape of the circumstellar envelope created by the wind. By mapping the envelopes, this uncertainty is reduced or even removed. The DEATHSTAR sample consists of 180 nearby ( $< 1 \text{ kpc}$ ) stars on the asymptotic giant branch (AGB). In a recent paper by [Ramstedt et al. \(2020\)](#), the circumstellar envelopes of 42 southern stars have been mapped in two CO transitions,  $J=2-1$  and  $3-2$  with ALMA ACA.



**Figure 3.** Comparison between measured CO(2-1) envelope sizes (triangles) and expected sizes (lines) from photodissociation models plotted against a measure of the circumstellar density. Carbon stars are red. M-type stars are blue. Filled symbols are Mira variables. The dashed and dotted lines show the predicted full photodissociation diameter from models ([Mamon et al. 1988](#); [Saberri et al. 2019](#)). The solid lines show the expected Gaussian full-width half-maximum (FWHM) of the CO(2-1) emission determined from radiative transfer modeling of the recent photodissociation from [Saberri et al. \(2019\)](#). See [Ramstedt et al. \(2020\)](#) for a further explanation.

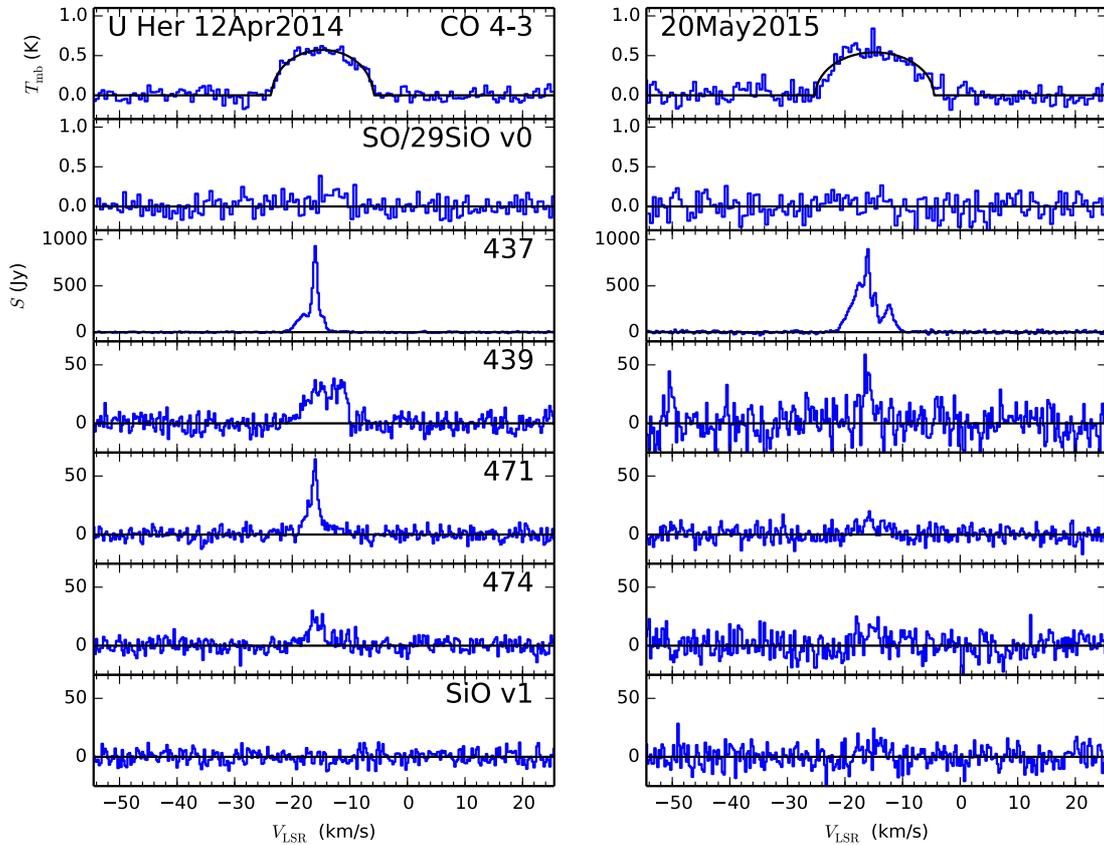
First results include that about one third of the envelopes show strong signs of anisotropy and cannot have been created by a smooth wind. Furthermore, the envelope sizes are significantly different from what has previously been assumed, probably mainly due to discrepancies in the CO abundance. For carbon stars ( $C/O > 1$ ), the envelopes can be up to a factor of 2 larger and for M-type stars ( $C/O < 1$ ), the maps show the opposite trend (see Fig. 3). To a first approximation, this will translate into the opposite change in mass-loss rate, i.e., current mass-loss rate estimates for carbon and M-type stars could be too large and too small by up to a factor of 2, respectively. The CO-abundance of circumstellar envelopes of different spectral types are estimated from chemical models, but this is the first time it can be constrained observationally.

Additional results from ALMA ACA will be presented in an upcoming paper ([Andriantsaralaza et al. 2021, in prep.](#)) with close to 30 additional stars, including S-type sources. Improved wind-parameter estimates from detailed radiative transfer models will be presented in future publications

*Sofia Ramstedt, Uppsala University, The above result is published in A&A, see [Ramstedt et al. \(2020\)](#)*

## High-frequency water masers towards evolved stars

The Atacama Pathfinder EXperiment (APEX) radio telescope is located at 5100 m altitude in the Chilean Andes. The very arid location, together with the high altitude, make it possible to observe submillimetre spectral lines from water in the envelopes of evolved stars. This study focuses on water lines in the 400 GHz regime that are previously known to exhibit maser action. As an example, spectra toward the star U Her are shown in Fig. 4 from two different epochs about 1 year apart. As indicated, the top spectra are from CO which reveal the smooth wind expansion of the envelope and is the same at both epochs. The four water spectra (at 437, 439, 471, and 474 GHz) clearly show time variations. The water maser at 437 GHz can be very strong and highly variable.



**Figure 4.** APEX observations in the 400 GHz regime toward the evolved star U Her (a Mira type variable star) on two different epochs. Top spectra are from CO while the water maser lines are indicated by their frequencies (437, 439, 471, and 474 GHz). Also some SiO lines are shown (but not detected in this source).

The variability of the maser lines is likely to be related to the stellar pulsation and the lines emerge from the inner part of the stellar atmosphere and not in the outer smoothly expanding envelope. Maser activity is a highly non-linear phenomenon and thus inherently difficult to model. The modelling results by [Bergman & Humphreys \(2020\)](#) confirm the conclusion that these water maser

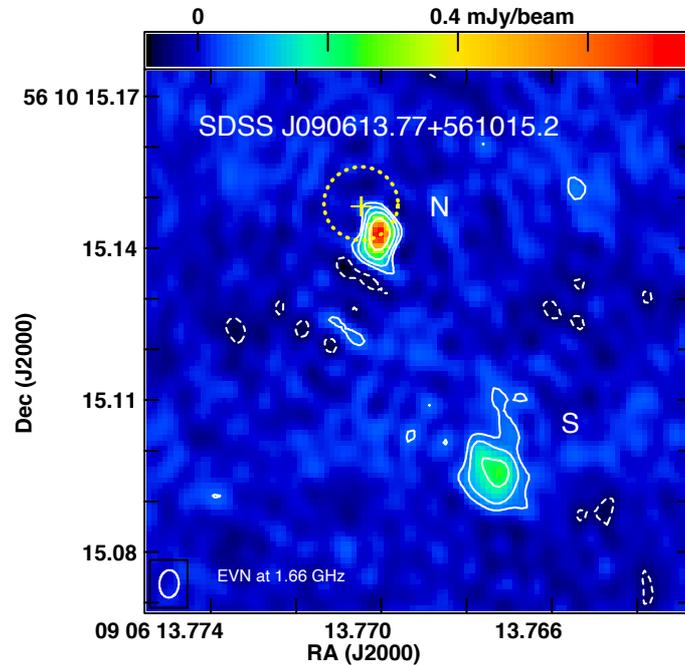
lines form in the inner part of the envelope where strong shocks maybe pivotal of creating the necessary physical conditions. From the modelling it is also evident that dust properties play an important role to create strong water masers.

*Per Bergman, Chalmers*

*The above result is published in A&A, see [Bergman & Humphreys \(2020\)](#).*

## Accreting intermediate-mass black holes: more jets could be detectable in dwarf galaxies

Nuclei in optically faint dwarf galaxies may host relatively light black holes with masses less than one million times of solar masses ( $<10^6 M_{\odot}$ ), i.e. intermediate mass black holes (IMBHs). With VLBI observations, including the Onsala 25 meter radio telescope, [Yang et al. \(2020\)](#) have discovered a rarely-seen powerful IMBH jet in the dwarf galaxy J0906+5610, Fig. 5. This finding indicates that more IMBH jets could be detectable in particular in nearby dwarf galaxies with the existing radio facilities.



**Figure 5.** A two-component brightness distribution found by the EVN at 1.66 GHz in the dwarf galaxy SDSS J0906+5610 hosting an accreting IMBH. The yellow cross and circle mark the optical (Gaia DR2) centroid and the error circle. The contours start from 3 and increase by factors of two.

IMBHs are very rare objects in the local Universe because of the rapid growth of galaxies and black holes. Finding these nearby faint “leftover” objects would shed light on the formation and growth of seed black holes and jet activity in the very early Universe.

To date, jetted radio-emitting outflows compact on sub-pc scales have been revealed in only one dwarf galaxy, NGC 4395. The dwarf elliptical galaxy J0906+5610 host an IMBH with a mass of about  $400\,000 M_{\odot}$  at  $\sim 193$  Mpc. The recent VLBI observations of J0906+5610 reveal two 1 mJy extended jet components. Compared to the first IMBH jet in NGC 4395, the second IMBH jet in J0906+5610 has  $\sim 160$  times larger structure and  $\sim 100\,000$  times higher radio luminosity.

In Fig. 5, the yellow cross and circle mark the central position and the error circle of the optical counterpart. The northern feature in the top region is located in the yellow circle and most likely represents the inner jet base or emerging jet component launched by the accreting IMBH. The southern elongated feature might be a dying jet component ejected in the early time. Owing to no significant stellar activity in the host galaxy, the observed radio structure can only result from the central IMBH jet activity.

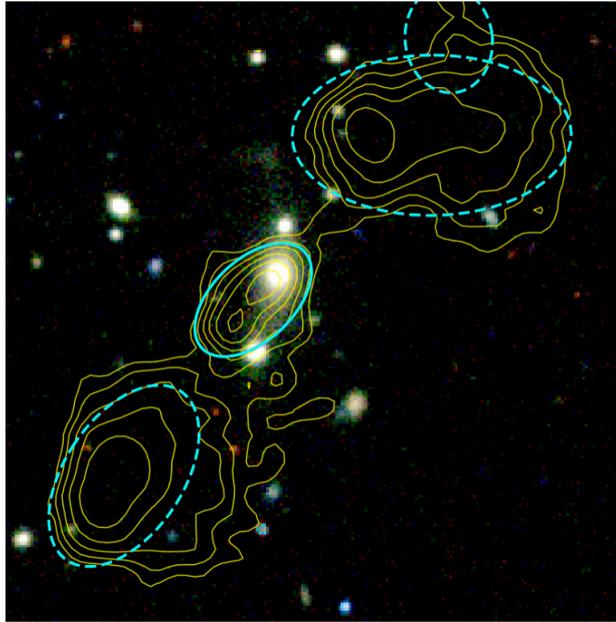
*Jun Yang, Chalmers*

*The above result is published in MNRAS, see [Yang et al. \(2020\)](#).*

## Radio Galaxy Zoo: LOFAR

The Radio Galaxy Zoo: LOFAR (<http://lofargalaxyzoo.nl>) is looking for more volunteers to identify the host galaxies of radio galaxies found in the LOFAR survey of the northern sky! This is one of the many exciting citizen-science global projects hosted at the Zooniverse website (<https://www.zooniverse.org>), and the temptation is great to get involved in all kinds of projects, from helping to monitor the population of seals across the world to transcribing the groundbreaking work of early women astronomers, or searching for mitochondria (the powerhouses of our cells) in images taken by electron microscopes!

But let us focus on the amazing LOFAR images taken at frequency of 150 MHz (wavelength of about 2 meters). LOFAR is in the process of mapping the entire northern sky at a resolution of 6 arcseconds, which is expected to lead to the detection of over 10 million radio sources. Obviously it won't be possible to look at each and one of them by eye, and computers need to be trained to identify features common to a same radio source and to compare radio images with images at other wavelengths, especially in the optical and infrared.



*Figure 6. Example from the LOFAR radio galaxy zoo. LOFAR isocontours of the brightness distribution of a large radio galaxy are overlaid on an optical image. The solid ellipse shows the location of the main radio component, which is very likely associated with the massive elliptical galaxy seen in the optical. The dashed ellipses mark the locations of other nearby areas of radio emission that, in this case, are likely to be associated radio lobes.*

Batches of about 5000 optical and LOFAR images are uploaded at a time for inspection by volunteers, and each image needs to be looked at by five pairs of eyeballs before it can be “retired”. Some radio sources are obviously trickier than others: for distant point-like radio sources it will hopefully be possible to find a red dot in the optical image that will be the host galaxy. But in many cases, extended radio emission may come from diffuse lobes located at some distance from a central supermassive black hole, produced by collimated jets from the galaxy's active nucleus. The images come with dashed ellipses overlaid on the radio features, and your job will be not only to find the optical host galaxy, but also to judge whether those radio features are associated or not to the component marked by a solid ellipse (see Fig. 6). There is a good tutorial and, in case of doubt, it is strongly encouraged to write in the comments box. All this information will help produce LOFAR valued-added catalogs with information on the host galaxies (and eventually their redshifts) and also on the morphology of the radio sources.

This is an excellent way to get some insight into radio galaxies and to contribute to ongoing European research. LOFAR, the LOW Frequency ARray, is centred in the Netherlands with stations in several European countries, including Sweden. Radio Galaxy Zoo: LOFAR is available in many languages, among them Swedish.

*Cathy Horellou, Chalmers*

## VLBI20-30: a scientific roadmap for the next decade – The future of the European VLBI Network

The roadmap describes the science case for Very Long Baseline Interferometry (VLBI) and provides suggestions towards upgrade paths for the European VLBI Network (EVN). The EVN is a distributed long-baseline radio interferometric array, that operates at the very forefront of astronomical research. Recent results, together with the new science possibilities outlined in this vision document, demonstrate the EVN's potential to generate new and exciting results that will transform our view of the cosmos. Together with e-MERLIN in the UK, the EVN provides a range of baseline lengths that permit unique studies of faint radio sources to be made over a wide range of spatial scales.

The science cases are reviewed in six chapters that cover the following broad areas: cosmology, galaxy formation and evolution, innermost regions of active galactic nuclei, explosive phenomena and transients, stars and stellar masers in the Milky Way, celestial reference frames and space applications. The document concludes with identifying the synergies with other radio, as well as multi-band/multi-messenger instruments, and provide the recommendations for future improvements.

As described in [Newsletter 5](#), Onsala Space Observatory is involved in the VLBI related H2020 project [JUMPING JIVE](#) where the roadmap is the main deliverable of work package 7, WP7, The VLBI future.



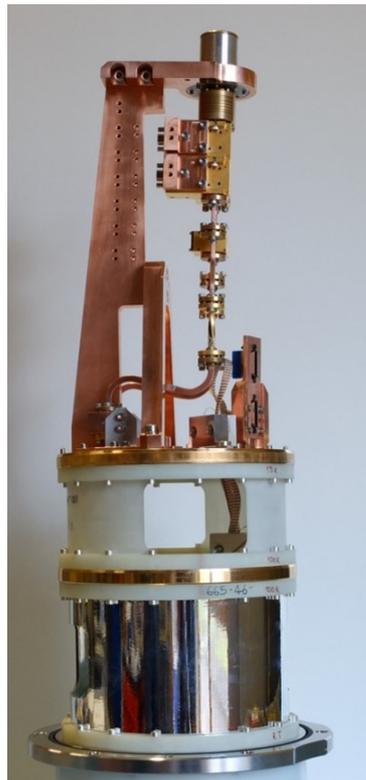
*Michael Lindqvist, Chalmers*

*The above result is published in [Venturi et al. \(2020\)](#).*

# Technical News

## GARD/OSO and ALMA band 2

In May 2020, after almost 3 years of discussions and negotiations, the European Southern Observatory and a consortium of institutions from Sweden, Italy, and the Netherlands had the formal kick-off of the project that will complete the ALMA Observatory's suite of receivers and patch the gap in the frequency band 67-86 GHz. In fact, the ALMA Band 2 Project has bigger ambitions and aims not only deliver the ALMA Band 2 receiver but also upgrade the ALMA Band 3, 86-116 GHz. The new receiver should cover 67-116 GHz in one band. The cryogenic part of the receiver, the cold cartridge assembly (CCA, Fig. 7), will receive two polarisations and employ HEMT amplifiers, while the warm cartridge assembly will perform sideband separation with IF bandwidth 4-12 GHz for the two polarisations and two sidebands providing simultaneously  $4 \times 8 \text{ GHz} = 32 \text{ GHz}$ ; a total bandwidth twice as great as any other ALMA receiver band.



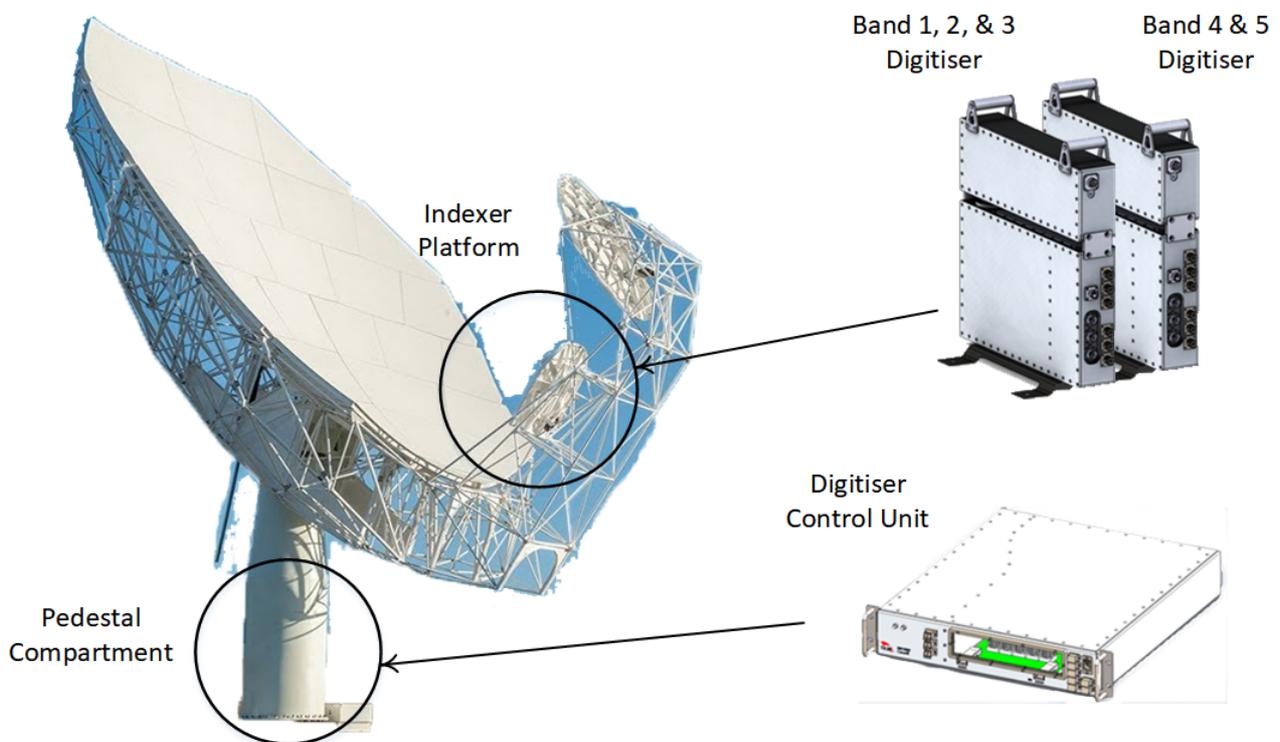
*Figure 7. Early ALMA Band 2 (+3) cold cartridge prototype*

The consortium responsible for technology development, design and construction of the prototype ALMA Band 2(+3) receiver consists of [INAF \(Italy\)](#), NOVA (Groningen, Netherlands) ([NOVA \(Groningen, Netherlands\)](#)) and the Group for Advanced Receiver Development (GARD) at OSO/Chalmers [[GARD \(OSO, Chalmers\)](#)]. GARD and INAF have been involved in the ALMA Band 2(+3) project from an earlier stage in which different combinations of optics, amplifiers, orthomode transducers were designed, evaluated and tested as part of demonstration receiver. The exciting science planned for the new ALMA receiver, plus a description of technical developments and test results is presented in [Yagoubov et al. \(2020\)](#) and provides strong motivation for the new phase of the project where GARD leads the Cold Cartridge Assembly (CCA) development work. The new ALMA Band 2(+3) project will make a first prototype of the new receiver and demonstrate that it meets specifications. Thereafter, the Consortium will built a pre-production series of 6 receivers for testing at the ALMA Observatory in Chile. By end of the project a full set of receivers will be delivered to equip all ALMA 66 antennas with the new Band 2(+3) capability covering 67-116 GHz.

*Victor Belitsky, GARD/OSO, Chalmers*

## Sweden to lead delivery of the digitiser system for SKA-mid

Sweden's industrial contributions to the SKA have recently been expanded beyond delivery of the Band 1 (350 MHz - 105 MHz) receiver and Low Noise Amplifiers for multiple bands to also encompass the digitiser system for SKA-mid, Fig. 8. Sweden will now complete the development and construction of the overall digitiser system for SKA1-mid, as well as lead and co-ordinate the digitiser sub-system contributions from Canada, France and South Africa. The work (worth ~55 million SEK, to be completed by mid-2025) is being spread over several phases and will be carried out by Swedish Industry. It is an excellent opportunity for the Swedish aerospace and telecom industries to apply their skills to the development of state-of-the-art sampling technology that will digitise all five SKA-mid observing bands collectively spanning from 350 MHz to 15 GHz.



**Figure 8.** The main parts of the digitiser and their location on SKA-mid dish.

Gary Hovey, Chalmers

**Interested in SKA/LOFAR news?** Please sign up to the Swedish [LOFAR/SKA mailing list](#).