Onsala Space Observatory (OSO)

Swedish National Infrastructure for Radio Astronomy

Annual Report to VR 2024

OSO Director, John Conway, 11th April 2025

1 Summary - This document briefly describes the VR funded activities of the Onsala Space Observatory (OSO) national infrastructure for radio astronomy during 2024. These activities comprise several components: first, radio telescope observations, both at Onsala and at APEX[1] in Chile, secondly the provision of radio astronomy user support (currently primarily toward Swedish users of ALMA and SKA pathfinders such as LOFAR), and finally the development of hardware/software deliveries for local and international radio telescopes (VLBI, ALMA, SKA etc). The OSO VR grant during 2024 also funded the Swedish share of the annual SKA Observatory office/construction administration costs ('SKA operations').

The present OSO VR grant (2019-00208) covering 2021-2026 is linked to a proposal submitted by OSO in February 2019 for Swedish participation in the SKA project. The VR special conditions of this grant reference the *OSO Strategy 2020- 2030* as defining the OSO workplan over the grant period. The modules used for financial and other reporting to VR are carried over from OSO's previous VR contract and comprise: *1- Management, 2- Interferometry User Support, 3- APEX, 4- Astronomical VLBI, 5- LOFAR, 8- mm Receiver Development, 9-cm Receiver Development* and *10- General Costs.* SKA operations costs are taken under Module 10. Note that Module 6 - Outreach is not supported by the VR infrastructure grant while *Module 7- Geoscience* has since January 2021 been financed by Lantmäteriet, the Swedish National Land Survey organization. This report only gives a brief overview of the OSO activities funded by VR. A more extensive OSO 2024 'Activity Report' is under preparation and will be placed on the Annual OSO Reports webpage when completed, latest by end of April 2025. This larger report describes all OSO activities during 2024, including activities in geoscience as well as in astronomy.

2 Popular Science Description- Onsala rymdobservatorium har sedan 1990 utgjort en nationell infrastruktur för radioastronomi. Dess huvudsakliga uppgift är att stödja svenska forskare som vill genomföra och utnyttja observationer vid radiovåglängder inom astronomi (finansierat av Vetenskapsrådet) samt att samla in geovetenskapliga data (finansierat av Lantmäteriet). Inom radioastronomin tillhandahåller observatoriet både avancerad utrustning och specialistkompetens för forskare som undersöker några av de mest grundläggande frågorna inom astronomin – om universums fysikaliska lagar och om förutsättningarna för liv. Observatoriet driver idag flera teleskop vid anläggningen i Onsala och ger samtidigt svenska forskare tillgång till världsledande teleskop och internationella teleskopnätverk, såsom ALMA (Atacama Large Millimetre/Submillimetre Array) och det kommande SKA (Square Kilometre Array). Teleskopen vid Onsala används ofta i kombination med motsvarande teleskop i andra länder genom tekniken långbasinterferometri (VLBI), vilket möjliggör observationer med mycket hög upplösning. Ett framstående exempel är LOFAR, vars svenska station är placerad i Onsala. LOFAR är ett banbrytande radioteleskop för de lägsta radiofrekvenserna och har introducerat nya metoder för att hantera stora mängder mätdata. Det har tjänat som ett pilotprojekt och vägvisare för SKA, och uppgraderas nu till LOFAR 2.0 – en ny generation som kommer att

[1] This report contains a large number of acronyms; definitions can be found on pages 39 to 41 of the 2023 OSO Activity Report at the OSO reports web page and also within the full 2024 Activity Report when completed.

komplettera det kommande SKA-low-teleskopet med längre baslinjer och observationer vid låga frekvenser.

3. Description of Activities

3.1 Timeplan –The OSO Strategic Plan 2020-2030 contains a diagram (Fig 3 in that document) showing the then planned OSO developments this decade. Fig 1 below presents a revised version of this diagram. The main differences to the original plan lie within the astronomical VLBI area (Module 4, i.e. blue boxes in Fig 1). The VLBI triband receiver for the 20 m telescope within that plan has been much delayed due to limited staff and financial resources but a fully costed design for the receiver was completed during 2024. Given that if Triband construction started in 2025 this project would stretch into the next OSO funding period (2027-2030), and because of its large component costs (10 Mkr), it has been decided to pause this project pending the outcome of OSO's new VR proposal. A funding request for a second planned 20 m telescope receiver covering 4 GHz – 15 GHz VLBI is also included in the VR proposal request; work on this second receiver is scheduled to begin only after the Triband receiver is completed. Another delayed project relative to the 2020-2030 strategy is the upgrade of Onsala LOFAR station to the new LOFAR 2.0 standard. This project has been affected by delays beyond OSO's control related to the design and procurement of the new LOFAR 2.0 electronics. At the time of writing the LOFAR 2.0 roll-out in the Netherlands has begun with the Onsala station scheduled to be upgraded in September 2025.

The construction of SKA in Australia and South Africa continued apace during 2024 following the timeline shown in Fig 1. During 2024 two Swedish companies that were successful in the SKA procurement process, i.e. Omnisys AB supplying the SKA-mid Band 1 receiver and Quamcom AB supplying the SKA-mid Band 1, 2 digitizers, started work on building equipment for the SKA. During 2024 OSO supported both companies through contracts signed with SKAO. Also, during 2024 the Swedish part of the SKA Regional Centre Network (SRCNet), which will collectively store and process SKA data, continued to ramp-up its activities, including executing a procurement for compute nodes to be delivered in early 2025.

Other differences between Fig.1 below and the original timeline within the 2020 -2030 strategy document are the absence of a mm wave space mission, since none not been selected by space agencies, and the addition of more details within Fig 1 on APEX current and future plans.

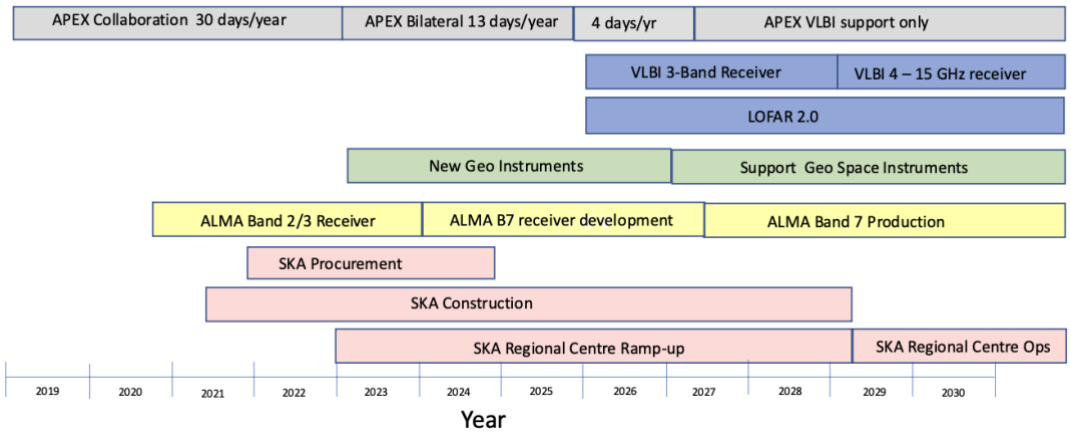

Fig 1 Observatory Development Timeline updated from original version in the 2020-2030 strategy document. Colours represent development areas i.e. Red-SKA, Yellow- ALMA, Green-Geo (Note not funded by VR but included for completeness), Blue-Astro VLBI and Grey – APEX.

3.2 Construction, Development and Operation of the infrastructure – All the planned OSO radio astronomy ´observations involving OSO telescopes that were scheduled during 2024 occurred without major disruptions. Construction and Development highlights were as follows;

Module *2* Observational Support - The ALMA Regional Centre (ARC) node continued with its primary tasks of face-to-face and other user support, with specialization in supporting polarization observations. The node also organized proposal preparation meetings for potential ALMA users before the April deadline and supplied teachers to the European ALMA school in the UK. The Swedish node of the global SRCNet, which collectively supports SKA data handling, installed the control plane processor for the new Science cloud at Chalmers and procured compute nodes to be delivered in 2025. The Swedish SRC hosted the SRCNet-wide Programme Increment (PI) planning meeting in Gothenburg in June and arranged the 2nd SKA Swedish Days meeting in September, which was well attended, both by Swedish scientists and by industry partners. ***Module 3-APEX*** – The OSO supplied Band 7 receiver was used successfully for the first time for VLBI at 345 GHz as part of the Event Horizon Telescope (EHT). Subsequently a fault occurred which caused instability in one of that receiver's two polarization channels (identical to a problem with the Band 9 receiver the year earlier). A repair was initiated by shipping the malfunctioning receiver subsystem to the US. ***Module 4 - Astro VLBI and RFI –*** Design work continued toward a Triband receiver for the 20 m telescope with a final architecture defined that fitted all requirements. On the radio interference front there were during the year several important contacts with PTS, the national body responsible for frequency allocations, including obtaining protection from a powerful nearby radar operating around 8 GHz. In December in collaboration with SKAO and the SpaceX company experiments were conducted using the OSO telescopes to investigate collaborative methods to reduce the impact on satellite constellations on radio astronomy, both in general and for SKA in particular. ***Module 5 - LOFAR*** – The original plastic fence surrounding the LOFAR antennas installed in 2011, having become brittle due to UV light exposure, was damaged in several places by deer who then got into the LOFAR enclosure causing damage to some Low Band antennas. The fence was patched and a projected started to install a new metal fence, to be completed in 2025. ***Module 8 - mm Receiver*** **development** – Work continued toward completing the ESO-funded Band 6+7 receiver project including demonstrating the goal of 16 GHz per sideband, with Double Sideband (DSB) measurements showing quantum-limited noise. ***Module 9 – cm Receiver Development*** –Commercial off the shelf (COTS) technology digitizer boards were used to implement correlation between OSO telescopes with multiple applications for antenna calibration and source flux-density monitoring.

3.3 Cooperation with other infrastructures – Virtually all OSO's activities include operating as part of international telescope arrays or contributing user support, hardware, and software to international radio telescopes; there are therefore very tight collaborations with multiple international infrastructures. In some cases, the OSO Director John Conway serves on the governing bodies of these international telescopes; for example, on the boards of the European VLBI Network (EVN) and the JIV-ERIC and LOFAR-ERIC councils.

3.4 Data management and need for supporting e-infrastructure – The radio telescopes at Onsala collect large amounts of raw data as part of their participation in VLBI but this data, with week or month-long latency, is transferred to international correlator centres and is not permanently stored at OSO. In the other direction processed data from VLBI, ALMA, LOFAR and other SKA precursors like MeerKAT, is brought to OSO for analysis by users. A major new capability being led by OSO is the establishment of the Swedish node of the SKA Regional Centre network, a node which eventually will be required to permanently store 15 Pb/year of SKA data in Sweden. The same science cloud facility will also be used to support the increased data rate coming from ALMA after its Wideband Sensitivity Upgrade. Work on developing this node is being carried out by OSO in close collaboration with the Chalmers e-commons organization which provides its experience in High Performance Computing plus offering a complete spectrum of centrally coordinated digital support services at Chalmers.

4. Changes in organization/staffing – A new position of OSO Deputy Director was established in 2024. After an internal Chalmers recruitment process Wouter Vlemmings from the Chalmers Astronomy and Plasma group was appointed to serve in this position at the 40% level. The

existing position of OSO Division head operates in parallel to the OSO Director and has formal line responsibilities for the staff in the OSO Division that hosts the OSO infrastructure. Eva Wirström stepped down in November 2024, at the end of her second three-year term. After an internal Chalmers recruitment process Vincent Desmaris was appointed to this 50% position from the beginning of December 2024.

5. Steering group activities – The Onsala Steering Committee (OSC) had three meetings during the year. The first meeting on 6th May was the last meeting of the outgoing OSC at the end of its three-year term. On 15th May 2024 the newly constituted OSC with revised membership held its first meeting. Continuing as OSC members into a second term are its Chair Jan-Eric Sundgren plus Olga Botner (Uppsala Univ), Garrelt Mellema (Stockholm Univ), Daniella Thaller (BKG, Germany), and Kirsten Kraiberg Knudsen (Chalmers), with the latter stepping down in November 2024 leaving a vacancy to be filled. Two new members appointed to the OSC were Michiel van Haarlem (ASTRON, Netherlands) and Per Eric Opseth (Kartverket, Norway). The first meeting of the new OSC was held face-to-face on 28th August, with the main agenda point being discussion of strategy toward the upcoming VR infrastructure proposal for OSO's funding 2027-2030. The final OSC meeting of the year was held via Zoom on 16th October. Amongst other things this meeting approved the 2025 budget and held a further discussion on the VR proposal strategy.

6. Financial outcome - As reported in the financial submissions to VR the income to OSO from VR during 2024 was 36.55 Mkr, calculated as 38 Mkr less the cost of the JIV-ERIC annual costs, which was paid directly by VR. There was a significant increase in personnel costs charged to VR between 2023 and 2024 despite the number of the total personnel effort in the radio astronomy infrastructure (24.5 FTE versus 25.3 FTE) being almost identical. This higher personnel cost arises because the reported FTE numbers measure the total personnel involved in the OSO radio astronomy infrastructure, whatever their funding source; between 2023 and 2024 however several personnel moved from external project funding (ESO ALMA receiver development) to VR funding, increasing the latter's cost. Total costs to the VR grant were 40.49 Mkr resulting in an annual loss of -3.96 Mkr. This is the first annual loss during the present contract period (2021-2026) and gives an OSO VR project balance of 8.861 Mkr at the end of 2024. Planned losses in the last two years of -2.9 and -6.0 Mkr (rising into 2026 due to SKA operations costs ramping up to their final level of 1.5 M€/yr) will combine to give a zero VR project balance by the end of the project. The 2026 projected total loss (VR project plus Chalmers funding) for OSO's radio astronomy activities will be more than double the VR loss in that year, reflecting high salary and other costs due to accumulated inflation.

7. Comment on the key numbers - The submitted excel file *OSO_Nyckeltal_2024.xlsx* contains staff information on the OSO infrastructure plus detailed information on observing proposals/users. Note within the latter section some information relating to LOFAR is marked as not being available (n/a) because information could not be supplied by the LOFAR-ERIC. The small number of proposed and executed LOFAR projects during 2024 relate to the ramp down of LOFAR 1.0 operations, during which existing observing commitments were fulfilled rather than new observing programmes started; before the final switching off of LOFAR 1.0 network operations in mid-2024 in preparation for the LOFAR 2.0 upgrade. The number of Swedish PI led proposals[2] to the OSO supported international telescopes (ALMA/ARC, APEX, VLBI and LOFAR) was 76 in 2024 compared to 70 in 2023. The number of executed proposals led by Swedish PI's was 19 in 2024 compared to 20 in 2023 and the number of Swedish Co-I's

[2] As in last year's report the submitted excel file does not divide between male and female users. All the OSO supported instruments, except for APEX Swedish time, are run by international organizations that either do not collect gender information or who are extremely cautious, based on privacy concerns, about sharing such statistics.

on executed proposals was 63 in 2024 compared to 66 in 2023. None of the small changes within these reported user metrics are considered statistically significant.

8. Comment on the publication list - The submitted *OSO_publications_2024.xlsx* excel file gives a list of papers in refereed journals published in 2024. The table below gives summary statistics for each of the four international telescopes (ALMA/ARC, APEX, Astro VLBI and LOFAR) which is supported by OSO. For each instrument two numbers are given; the first is the total number of telescope-related publications while the second is the number of publications with at least one Swedish author. Within the first line of figures below relating to ALMA only those papers that received explicit support from the ALMA Nordic ARC node are counted,

• ALMA/Nordic ARC node - dedicated support	36/22	*(Nordic/Swedish)*
• ALMA/Band 5	20/6	(*Total/Swedish*)
• APEX	66/11	*(Total/Swedish)*
• Astronomical VLBI	38/13	*(Total/Swedish)*
• LOFAR	131/6	*(Total/Swedish)*

New for this year is the reporting of ALMA papers that make use of the Band 5 receivers built for ALMA by OSO's GARD unit (given in the second ALMA related line above). Considering all the papers that OSO supports (less than the sum of Nordic/Total numbers in each category above because some papers are in multiple categories) there were 287(269) papers in 2024 compared to 241 papers in 2023, where the bracketed first figure excludes the newly reported category of ALMA Band 5 papers to facilitate inter-year comparison. Concerning OSO supported publications that have at least one Swedish author the 2024 total was 55(52) papers compared to 45 in 2023. While there is an increase in both statistics considering the typical size of year-to-year variations these small increases are not statistically significant.

9. Equality - The OSO infrastructure currently has a very male-dominated workforce; addressing this inequality requires systematic work sustained over a long period. The OSO leadership group has regular meetings specifically focusing on improving equality and diversity. OSO has a policy that seminar speakers invited by OSO staff should be gender balanced, with this balance being achieved during 2024. Much attention is also given when recruiting at reaching good female candidates. There was an incremental improvement in staff gender balance during 2024 with the recruitment of a female research engineer to the OSO Technical Support Group unit.

10. Risk analysis - The highest likelihood/impact strategic risks during 2024 included: (1) Difficulties in recruitment and retention of specialist Research Engineers and Support Scientists within a host university (Chalmers) employment structure not optimized for a national infrastructure. (2) Increasing threats from Radio Frequency Interference requiring the dedication of increasing staff time to frequency protection issues. (4) Uncertainties in future VR and Chalmers funding combined with inflationary cost increases.

11. Educational efforts and Outreach – OSO runs a significant outreach operation toward both the general public and schools**.** The OSO site with its telescopes and other instruments combined with the new visitor centre ('Rymdrum') provides a very attractive resource to reach schoolchildren and other visitor groups the importance of science and technology. The outreach effort at Onsala is funded by Chalmers in combination with donations from private bodies such as the Hasselblad Foundation. Full use is made of the new OSO Visitor Centre (financed by Chalmers and inaugurated by the Chalmers Rektor in October 2022), with its exhibition being continually developed. During 2024 a new OSO exhibition and school outreach coordinator was recruited, funded by Chalmers and working 50% at Onsala. This addition increases the total Chalmers funded outreach support activity to approximately 2 FTE.