

Onsala new dish private funding exploration

John Conway
Director: Onsala Space Observatory
Version 2



Slides based on presentation at preliminary discussion meeting held 2026-9-25 with Teppo Heiskanen, Lars Bern, of Chalmers office for attracting private funding (John Conway and Elvire De Beck in attendance); presenting a case for seeking funding for a new high frequency dish at Onsala.

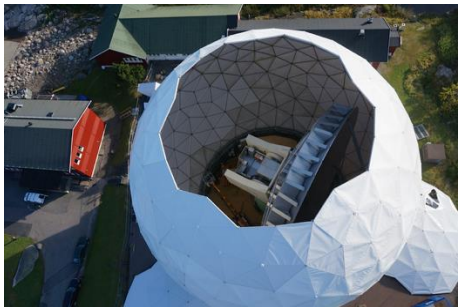
Current OSO National Facility Telescopes



25m telescope cm



Onsala Twin Telescope (OTT)
cm-geo



20m telescope cm/mm wave



Meeting concerns possible fund-raising for a new dish to replace 25 m telescope (built 1964) and eventually 20 m telescope (built 1976). New dish lifetime 40+ years.



LOFAR station – m -wave

Possible Pitch

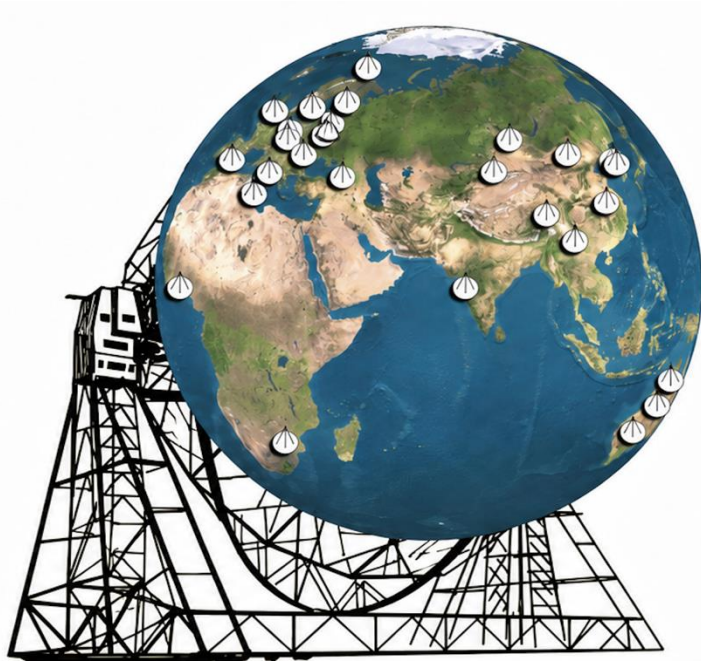
A new dish for the new space age

The 25 m telescope was inaugurated in 1964 at the start of the first space age, relaying the first live intercontinental TV satellite pictures directly to Sweden via the earliest telecommunications satellites. We now stand on the brink of a new space age realized by fully re-usable rockets and new US and Chinese led manned and robotic moon missions, demanding increased capacity for communications, tracking and co-observing with space assets; for instance observations related to Earth and Space navigation.

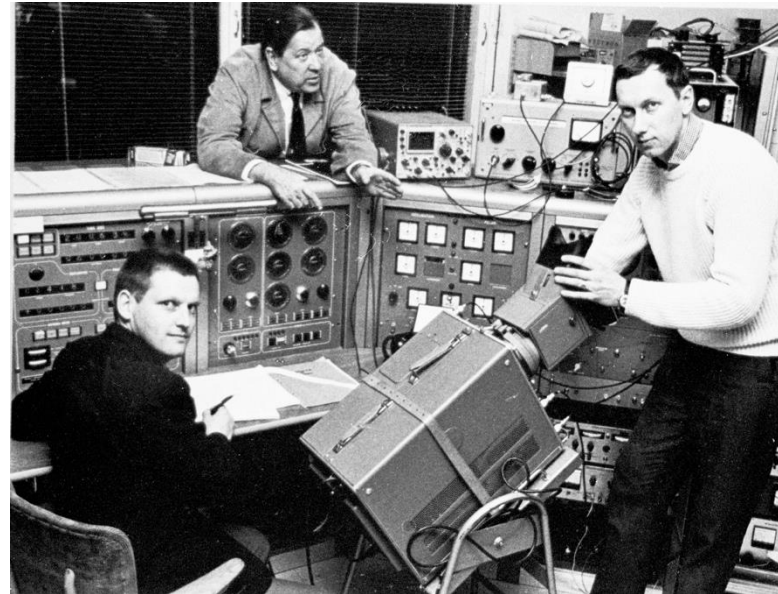
On the ground, related to space activities, we are also within a new era of radio telescope construction for both astronomy and for strategic space access applications; including measuring critical society and defence Earth orientation parameters. Chalmers possess a rare and valuable strategic asset amongst universities worldwide by having via Onsala its own in-house connection to space.

A new state-of-the-art dish at Onsala, replacing the observatory's two oldest dishes, will simultaneously reduce running costs while also greatly increasing capability. This investment will allow Chalmers to expand its already leading global positions in both radio astronomy and in multi-disciplinary Space-Earth applications.

VLBI Onsala creates a global radio telescope - 1968



Very Long Baseline Interferometry (VLBI) – technique that combines signals to form a virtual radio telescope the size of the Earth - Allows very sharp images + Also gives location of telescopes to up to mm accuracy



Control room of 25 m telescope Onsala in 1968. First Transatlantic VLBI to Westford Massachusetts

Today OSO's telescopes take part in state-of-the-art **mm**, **cm** and **m** wave VLBI arrays for both astronomy and geodetic applications. In geodesy we are one of the most active sites worldwide. In astronomy the strategic NS baselines from the OSO telescopes are made more sensitive and scientifically productive via the inclusion of the huge ALMA array and (in future) SKA.

Two possible new antenna types



SKA dish, Karoo, South Africa

Produced in China. 15m diameter equivalent dish Operates 0.3 – 15 (43) GHz. Quotation last year for structure, transport and Installation at Onsala was only 1.3 M€ (does not include foundation or receivers).



ngVLA dish New Mexico, USA

Part of the US ngVLA project (SKA-high) Antennas made in Germany. Uses ball bearings from SKF in Gothenburg, These 18 m equivalent diameter dishes operate 1.0 – 115 GHz Structure and installation approx.4 M€ (receivers cost 1 – 4 M€ ?)

Why ngVLA dish is preferred over SKA dish

- The dish is larger (18m versus 15 m effective diameter plus better surface).
- It goes to higher frequency (115 GHz rather than 15-22 (43?) GHz. This means we can first replace the 25 m (via equipping with low frequency receivers first) and the later add high frequency receivers and decommission the 20 m (avoiding the need to replace the 20 m radome in 10 + years). Consolidating around one new radio astronomy dish rather than two old dishes at Onsala has the potential to reduce operations costs.
- The dish is made in Germany and not China.
- Germany is building a high frequency enhanced version in the Bavarian Alps, the Wetterstein Millimetre Telescope (WMT, funding secured, construction to start soon) and has plans for more dishes in Germany. Netherlands is also considering seeking money for a ngVLA dish, NRAO in the US announced in July that it is building the first 10 ngVLA dishes scattered around the US financed by US Naval Observatory for Earth Orientation Parameter (EoP) measurements + radio astronomy. The ngVLA dish is becoming the de facto standard dish for future Northern hemisphere VLBI
- Unlike the SKA dish the ngVLA dish does not have pointing limit at low elevations which greatly reduces co-observing with Southern hemisphere telescopes (such as ALMA in Chile, and ironically SKA in South Africa).
- Good connections exist to the ngVLA project via ex-Onsala employees working in both the US ngVLA project and for the WMT in Germany.



I am attending week after next the Third Workshop on German Science Opportunities for the ngVLA 5 Oct 2026, 07:00 → 6 Oct 2026 – at future WMT site at **Umweltforschungsstation Schneefernerhaus, Zugspitze** – Highest point in Germany at 2650 m altitude and future site of the WMT. Place is said to be like a James Bond villain's lair... but for real. Meeting programme at

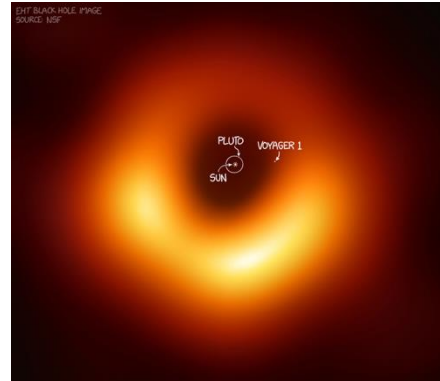
https://indico.astro.uni-wuerzburg.de/event/3/timetable/?view=standard_numbered_inline_minutes

OSO mid-century Vision

With a renewed complement of fewer but more modern and capable radio telescopes, OSO's future three telescopes will consist of the new ngEHT high frequency dish for astronomy/geodesy/space applications, our operational VGOS OTT telescope for space geodesy and our LOFAR station for metre wave astronomy, space weather, radar and ionosphere research. OSO will by the 2030's have a new complement of top-modern telescopes covering from millimetre to decametre wavelength, all of which will have been constructed 2012 or after.

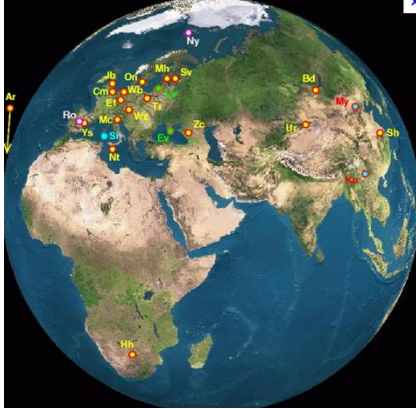
The above set of three telescopes (plus multiple new lower cost geoscience sensors to be installed) will serve Onsala over the next 40 years or more for astronomy and Earth-Space societal applications, via operational data collection, research and teaching. Via the installation of a new dish OSO will expand its existing role as a concrete realization of West Sweden's connection to the ever-expanding space activities that are envisioned throughout this century. The renewed OSO observatory will also be a unique facility for Chalmers in Europe for the education of students and the research needed to support the success of West Sweden's companies in the coming new space age.

1. Radio astronomy example use cases for new dish

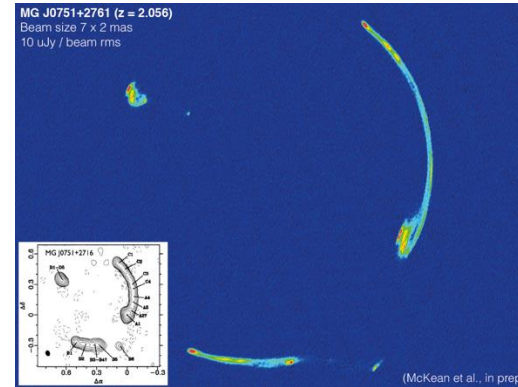


3mm wavelength GMVA image of M87 black hole and jet launching region - Kim et al 2025 – using **Onsala 20 m telescope** in GMVA network

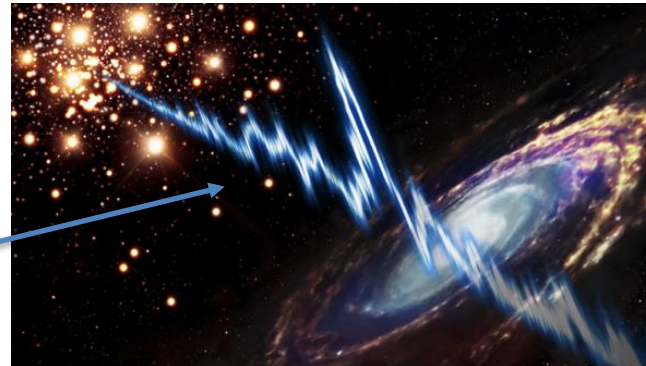
Centimetre VLBI Results made using 20m/25m telescopes-example applications



European VLBI Network (EVN)



Gravitational Lens Observations, constrains dark matter



An artist's depiction of fast radio bursts coming from galaxy M81. (Image credit: Chalmers University of Technology/Daniëlle Futselaar, artsources.nl)

Fast Radio Bursts (FRB) - Mysterious flashes of radio radiation lasting $< 10\text{ms}$ – first precise location and identification to a galaxy at $z=0.3$ in 2017. Detection and precise location using VLBI of the nearest FRB in galaxy M81 – led by Chalmers PI Kirsten et al 2022. **New telescope needed to continue myriad science goals of cm VLBI (25m may reach mechanical lifetime soon) and expand by combining via VLBI with SKA and ngVLA for much higher sensitivity**

SKA will revolutionize cm–VLBI

- The breakthrough allowing Black Hole imaging via 1.3 mm and 3mm wavelength VLBI was made possible by the addition of ALMA, as a huge sensitive anchor station, to global VLBI arrays.
- The creation of SKA-mid in South Africa as a similar anchor station at 2cm – 30 cm wavelength is expected to similarly revolutionize cm wavelength VLBI.
- **The SKA with its internal <100km baselines does different core science than VLBI - so does not replace the science that Onsala does via astronomical VLBI. SKA instead greatly increases the science value of a new telescope at Onsala via SKA being included as single large element in global VLBI increasing array sensitivity to the Onsala dish at a strategic northern location giving the longest North-South baselines.**
- A new modern telescope provides a platform allowing innovation toward increased bandwidth receivers and other new techniques (going well beyond the technology on SKA, whose design was frozen 10 years ago) – This technology can then be deployed for future SKA upgrades and give new industrial return to Sweden beyond the 31 M€ so far returned for contracts or SKA initial construction.

2. Multi-disciplinary space related
uses of a new dish

1) Space Geodesy and Space navigation

Ground based VLBI of artificial beacons in orbit or Moon for geoscience (i.e. Genesis mission, Novamoon) and future similar missions. Also, standard geo-VLBI of natural sources for Earth Orientation Parameters vital for operation of Galileo GNSS satellites etc.

We already have 12 m diameter OTT VGOS telescopes operating to 14 GHz for space-geodesy but a larger higher frequency dish can be used also to define celestial reference frame, correct for source structure in VGOS observations (big argument for WMT) and co-observe for space geodesy with US ngVLA dishes. Additionally can do VLBI of satellites and probes for their navigation and for setting up reference frames on the moon and in space.

2) Planetary science

Use ground-based VLBI of planetary probes for accurate position, range rate, PRIDE (Huygens probe, Mars express Phobos flybys. Coming JUICE grand tour, see following slides) + atmosphere occultation.

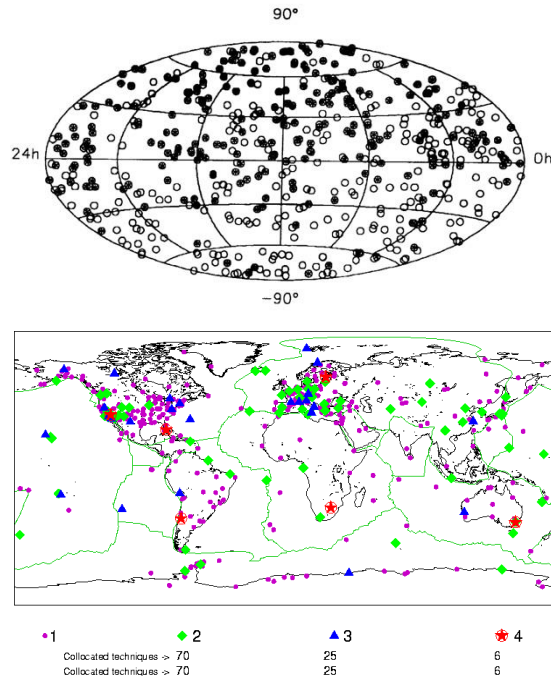
3) Space VLBI (longer baselines than Earth diameter)

Use Ground-Space VLBI of natural objects combined with a radio telescope in space to give longer baselines and hence higher spatial resolution. Previous mission VSOP (Japan), Radioastron (Russia) and recent Chinese LOVELL lunar orbiter space VLBI observations with Onsala. New dish can support future Earth-Space VLBI at 100 GHz for Black Hole imaging.

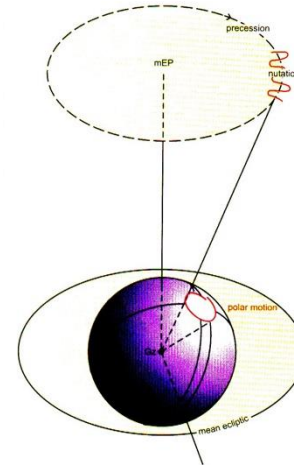
1) Geodetic VLBI observations – (a) Ground-based VLBI of natural sources to maintain space infrastructure

ICRF
International
Celestial
Reference
Frame

ITRF –
International
Terrestrial
Reference
Frame



EOP Earth
Orientation
Parameters



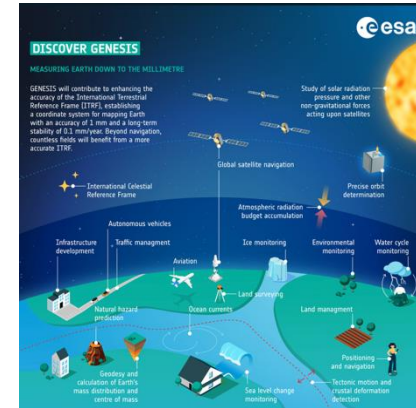
- **ICRF:**
 - Radio Source Positions
- **ITRF:**
 - Station Positions
 - Velocities
- **EOP's:**
 - Celestial Pole ($d\epsilon$, $d\psi$)
 - Polar Motion (x_P , y_P)
 - UT1-UTC (DUT1)
- Importance documented: coming up IAG Project **IGGOS** with demand for
 - mm-accuracy
 - consistent for decades
 -

Ground based observation of natural radio sources provide fundamental information for Geoscience and give important practical input for **navigation services** (GPS, phone location) and **Geophysics**. Geo-location service worth worldwide 10's Billions of Euro (NOTE a practical use of black holes !). Also defines celestial reference frame for astronomers. Of strategic importance for Europe to independently measure Earth orientation Parameters to calibrate Galileo satellites

Use Onsala OTT is our workhorse for EOP etc but a larger high frequency dish is needed to correct for source structure to achieve the highest geodetic accuracy and for defining the International Celestial Reference Frame and for receiving signals from space assets

1)– Geodetic VLBI Observations - (b) including artificial space transmitters

ESA Genesis probe.



ESA genesis satellite due to be launched 2028 (likely first of others) carries four space geodetic techniques including a beacon observable by ground VLBI (Science leader Rudiger Haas, FA, Chalmers - to link Earth and Space coordinate systems).

ESA Novamoon beacon

Work ongoing to establish lunar reference system and link to earth including Novamoon beacon observable by ground VLBI

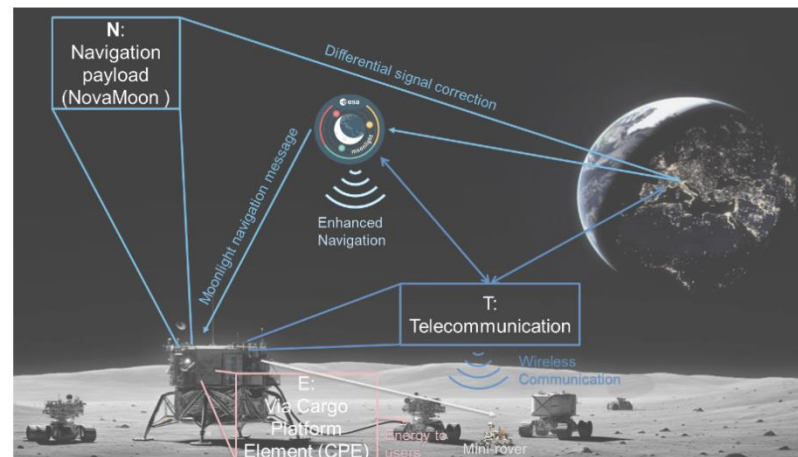
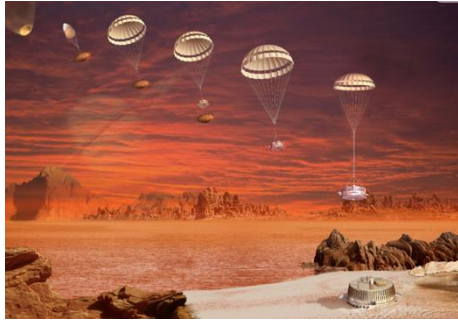


FIGURE 2 ArgoNET Mission concept including the NovaMoon payload.

2)- VLBI for Planetary science – Ground based VLBI of space probes

PRIDE (Planetary Radio Interferometry and Doppler Experiment) - Examples

Huygens, Titan 2005



Mars Express 2013

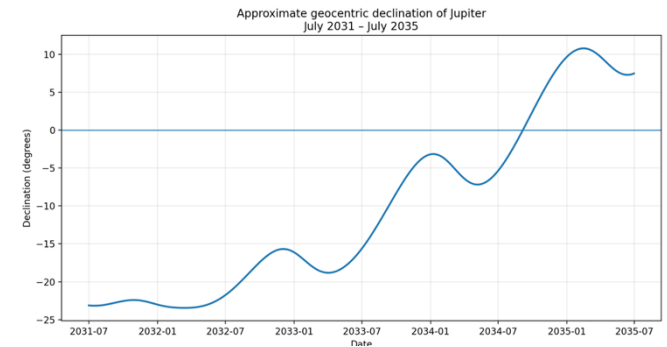
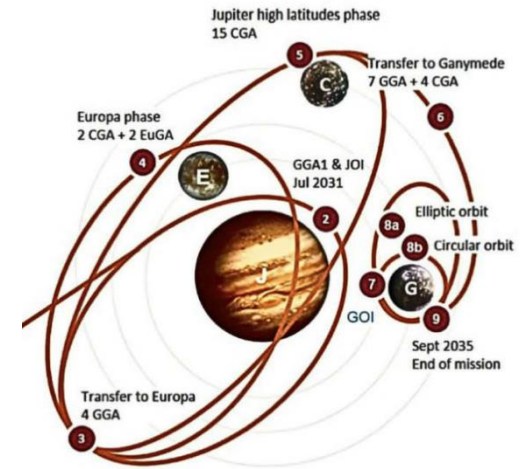
Planetary Radio Interferometry and Doppler Experiment (PRIDE) technique: A test case of the Mars Express Phobos fly-by

D. A. Duev^{1,2,3}, S. V. Pogrebenko², G. Cimò^{2,4}, G. Molera Calvés^{5,2}, T. M. Bocanegra Bahamón^{6,2,7}, L. I. Gurbits², M. M. Kettenis², J. Kania^{8,2}, V. Tudose⁹, P. Rosenblatt¹⁰, J.-C. Marty¹¹, V. Lainey¹², P. de Vicente¹³, J. Quick¹⁴, M. Nickola¹⁴, A. Neidhardt¹⁵, G. Kronschnabl¹⁵, C. Ploetz¹⁵, R. Haas¹⁶, M. Lindqvist¹⁶, A. Orlati¹⁷, A. V. Ipatov¹¹, M. A. Kharinov¹⁸, A. G. Mikhailov¹⁸, J. E. J. Lovell¹⁹, J. N. McCallum¹⁹, J. Stevens²⁰, S. A. Gulyaev²¹, T. Natush², S. Weston²¹, W. H. Wang⁷, B. Xia⁷, W. J. Yang²², L.-F. Hao²³, J. Kallunki²⁴, and O. Witasse²⁵

(Affiliations can be found after the references)

Received 7 May 2016 / Accepted 31 May 2016

JUICE 2031- 2035



Onsala can be part of ground VLBI array for later phases when Jupiter higher Declination

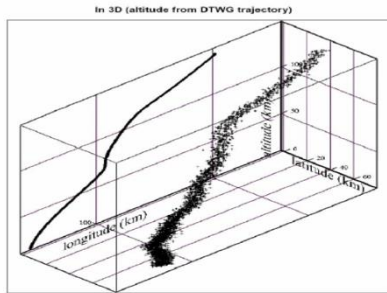
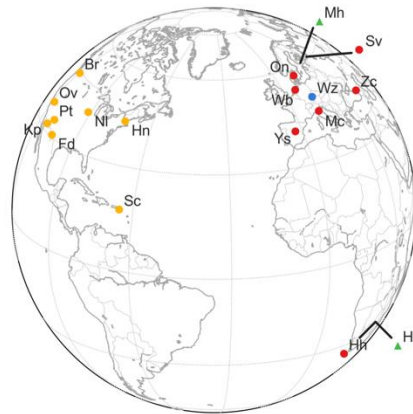
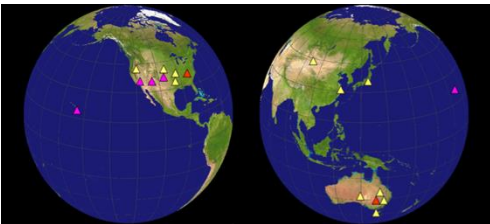
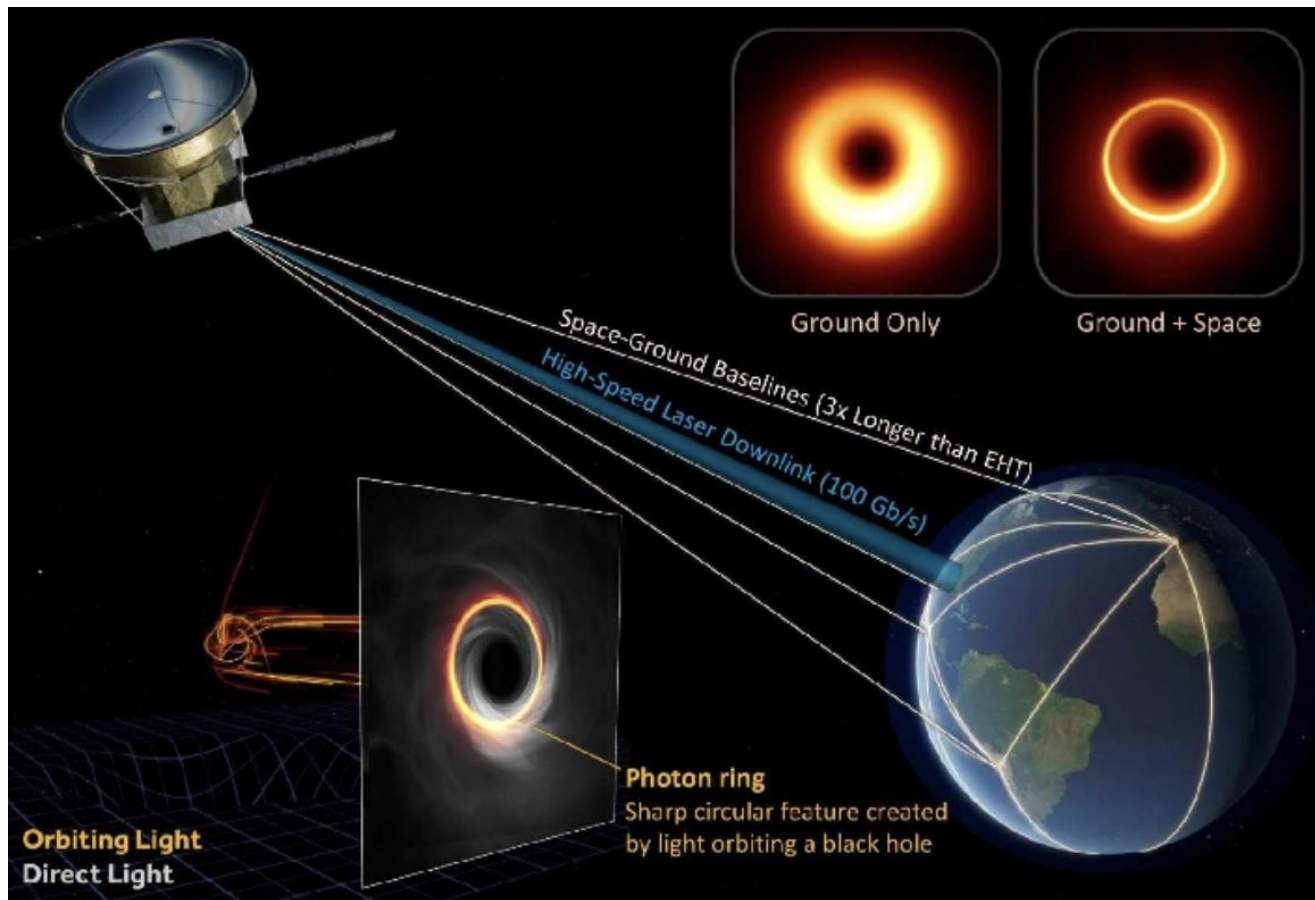


Figure 1: A 3D reconstruction of the descent trajectory of the Huygens Probe.

Onsala took part extensively in these Mars Express observations

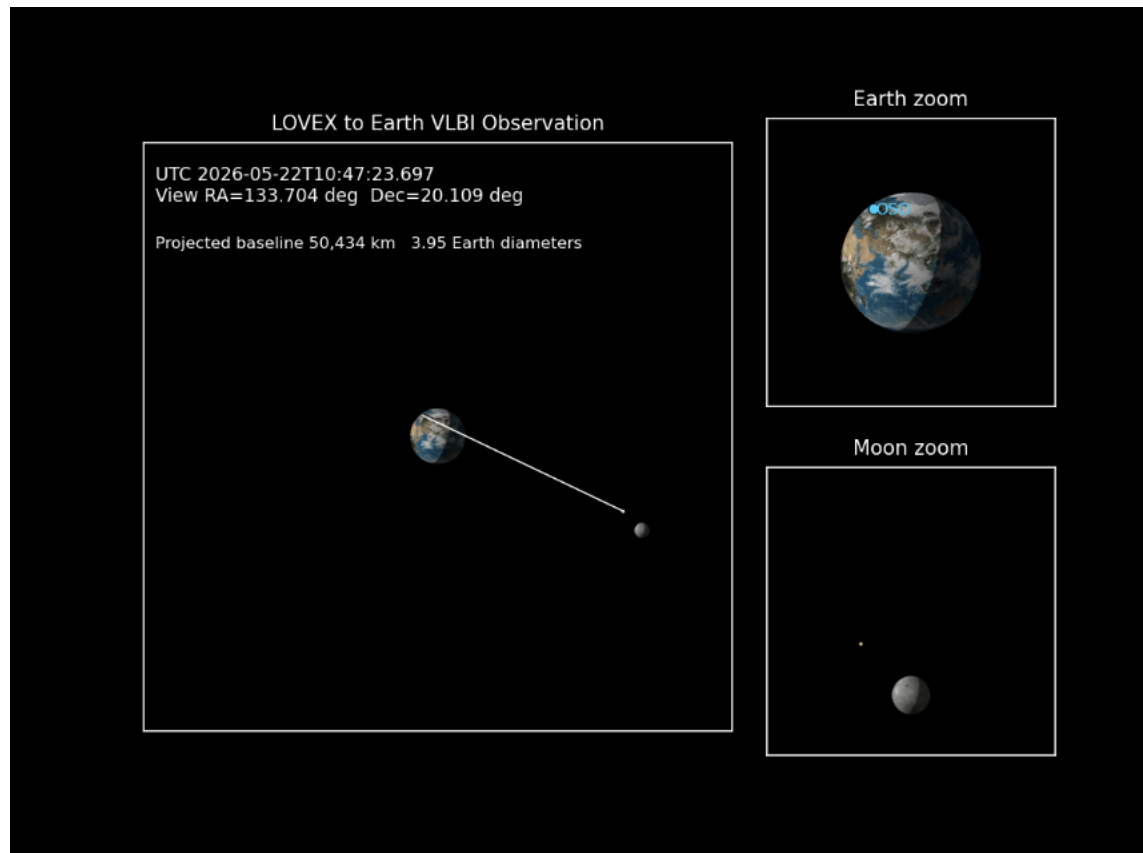
Wrong Earth longitude for OSO participation

3) Space-Earth Very Long Baseline Interferometry



Unlike previous examples using ground VLBI of natural sources or transmitting space assets in Space-VLBI the space asset forms part of the VLBI array, giving baselines longer than an Earth diameter and higher resolution. Follow up previous space-VLBI via example participating via new dish in the proposed Black Hole Explorer (BHEX) mission.

Recent OSO Space-Earth VLBI 20m Telescope Chinese LOVEX satellite 21/22 May 2026



Recent space VLBI observations involving Onsala - out to 4 Earth diameters

5) Space Weather

Carry out measurements of Space Weather, via Interplanetary Scintillation, Faraday rotation and using new dish at high frequency Solar imaging

6) Space Situational Awareness (SSA)

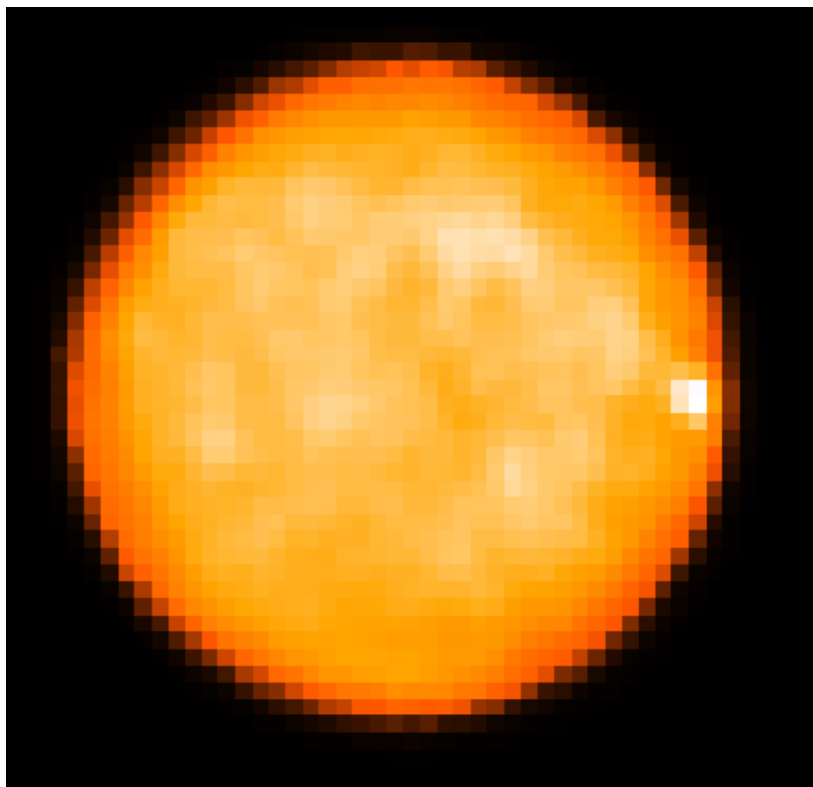
Ground based cm wavelength dishes carrying out imaging/position finding or orbiting objects via bistatic radar for Space Situational Awareness (SSA). Will be possible with new telescope up to 100 GHz

7) Space Communications

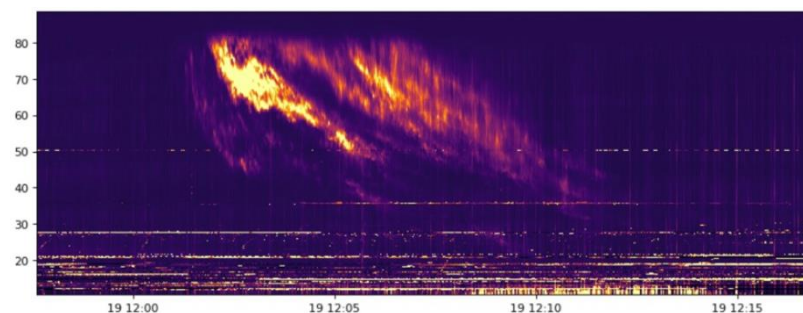
Radio telescopes are very sensitive for communications; we can use a new dish for communicating with very small probes to the moon and asteroid. Possibility of carrying out data transport from small Chalmers probes to the moon or asteroids.

8) Teaching and Outreach -A new dish will open up many opportunities for Chalmers students to get involved in all of the above areas. The renewed telescope suite will act as a magnet for students studying in Chalmers new space masters programme amongst universities in Europe Chalmers will have a unique facility for hand-on training for space-geodesy and other space applications such as Space Situation Awareness and Space Weather and will also expand OSO's already significant Outreach presence as a symbol of West Sweden's participation in the New Space Age-

5) Space Weather – observations to track Coronal Mass ejections affecting Earth

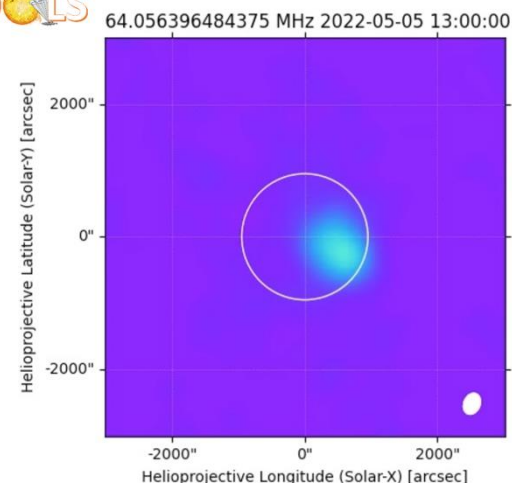


Example solar imaging using a 20 m class telescope operating at 24 GHz in single dish mode scanning across sun . Shows results possible with new telescope which can image Sun to higher frequencies up to 100 GHz and so detect coronal mass ejection forming on sun.



Synergy with 

solar
monitoring at
low frequency
with Onsala
LOFAR
station, and
imaging by
LOFAR array



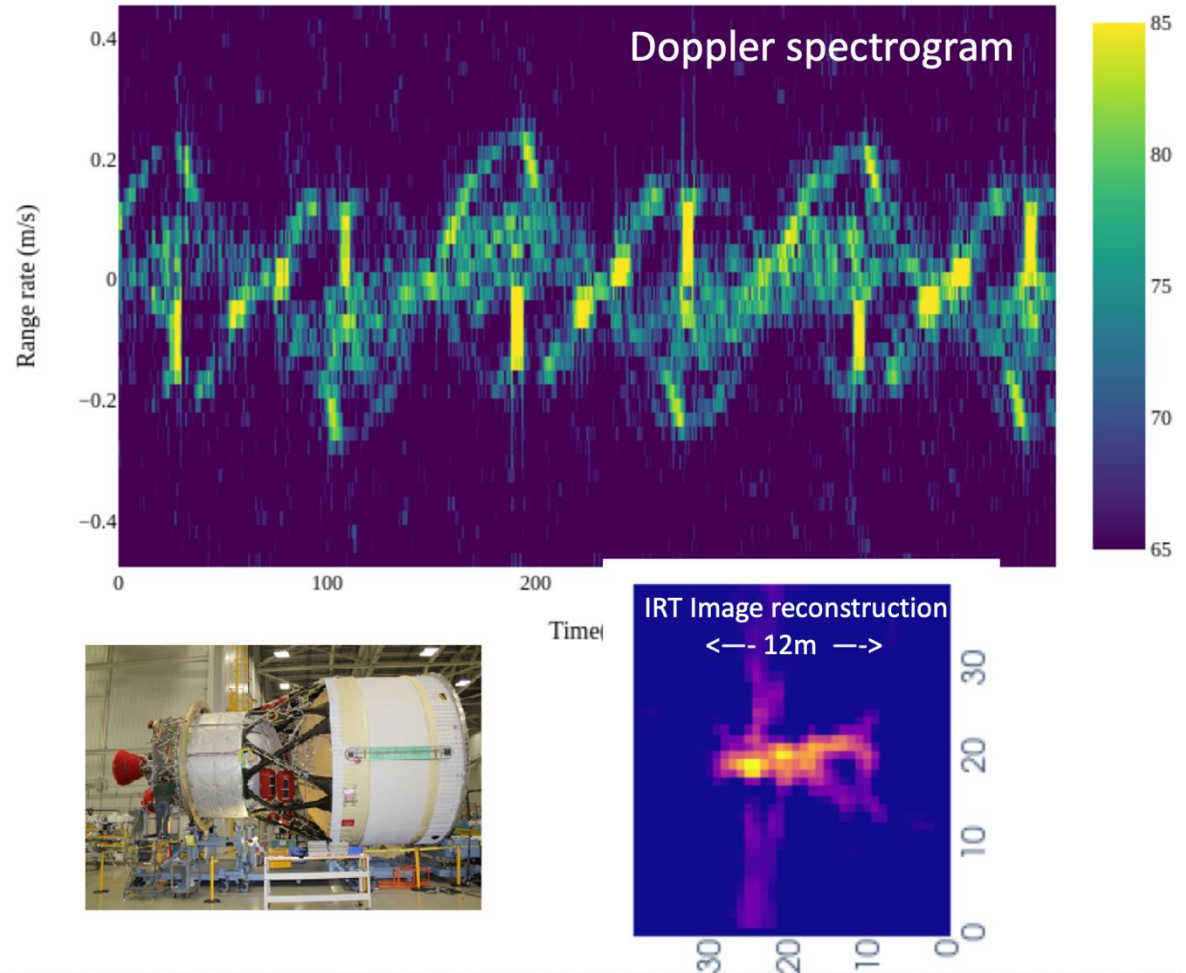
6) Space Situational Awareness

Tumbling Delta 4 rocket
Body, illuminated by cooperating
Pulsed radar and using radio
Telescope to receive (Garrington
et al 2023), The range-Doppler
signal shown to right, below is
image reconstruction

Combine with correlating signals
over a VLBI Array and apply
PRIDE to Measure direction and
distance from wavefront

Curvature giving cm 3D positions.
Follow on from Haas et al 2014
Wetzell-Onsala GLONASS
(transmit, non-radar)
observations)

Both accurate orbits and detailed
imaging possible for Rotating
objects Potential OSO
involvement in NATO based
technical study projects.



New dish at OSO can be used for such experiments up to 100 GHz frequency giving centimetre resolution images of satellites and via, using ground VLBI, to get accurate orbit determination.

7- Space communications

- For LEO satellites the current fast tracking OTT dishes can be used for data download from say a Chalmers student satellite.
- Hundreds of universities have launched student satellites but so far none launched **toward moon or Near-Earth asteroids, biggest problem is the data communications which is far too expensive using commercial rates but could be achieved with a new OSO dish.** OSO was approached 10 years ago by a wealthy businessman in Sweden thinking of financing a small mission to a near Earth asteroid, but biggest problem was access to communication and therefore asked for OSO collaboration.

Strategic overview

Recognising and supporting the multidisciplinary use of radio astronomy facilities is something Sweden could do better. Unlike China which takes a holistic view and is building radio telescope all over the world in support of its Space aims in Sweden/Europe we are in part hampered by having different funding agencies, VR, Lantmäteriet, Defence, SNSA etc potentially involved and not recognizing the large potential synergy savings that exist.

Cut through the above problem by accessing private infrastructure funding?