
Radio astronomy in Finland: a fine balance of astronomy and high-tech engineering

Tuomas Savolainen

Aalto University Metsähovi Radio Observatory

Early years 1951-1966

– Radio Astronomy Station of the University of Helsinki

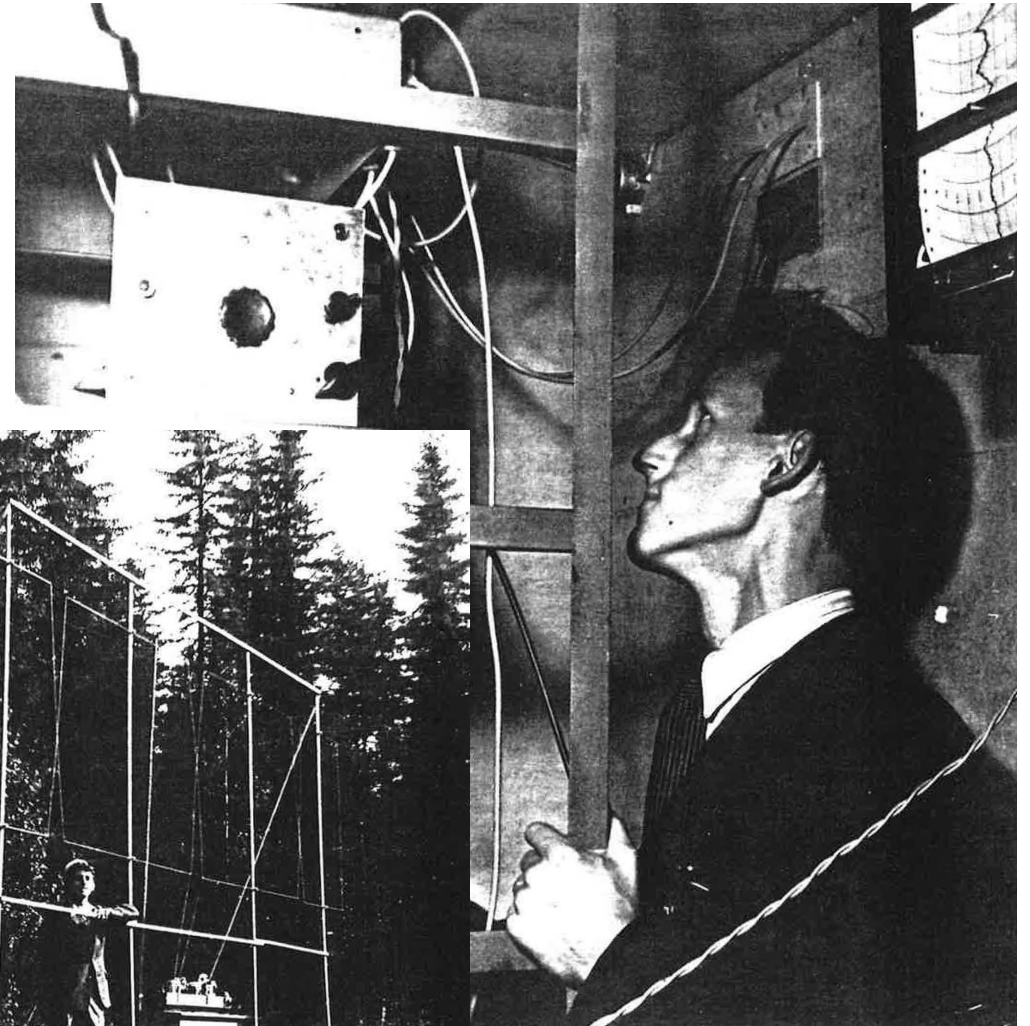
“Primus motor”: Jaakko Tuominen (1909-1989)

- Theorist who had spent long periods abroad, and brought modern astrophysical research to Finland
- Extraordinary professor in University of Helsinki (UH) from 1951
- Got interested in radio astronomy and wanted to start experimental work in Finland; had blue prints of radio astronomical receivers from NL
- Contacted the Helsinki University of Technology (HUT) to recruit an engineering student for building radio astronomical equipment – the kick-off meeting was held on 12.9.1951



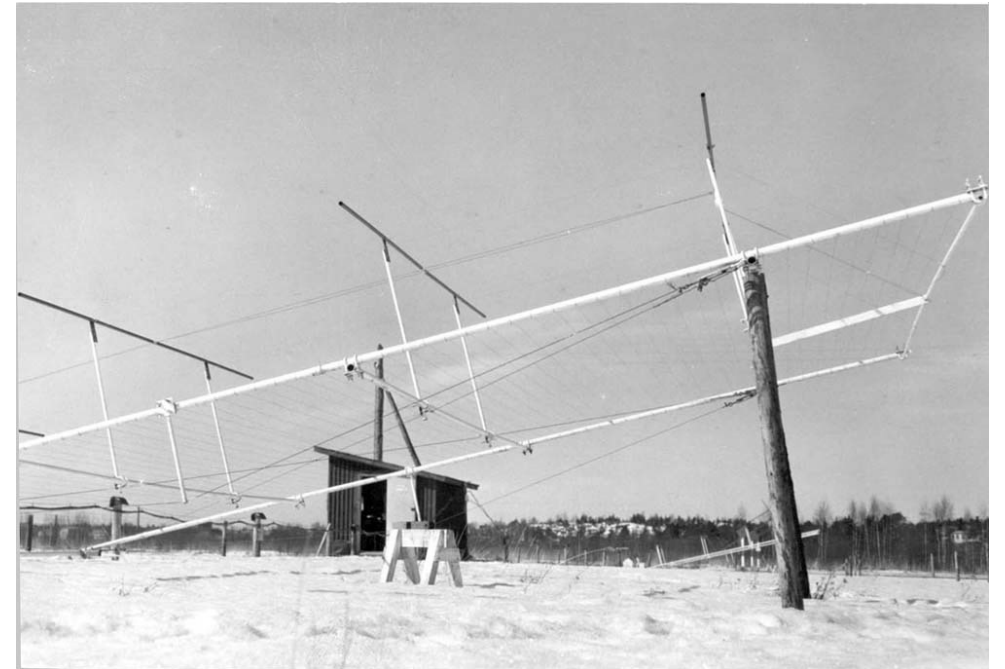
The dynamo: Jorma Riihimaa (1929-2011)

- Engineering student recruited by Tuominen. A very talented instrument builder.
- Interested in radio astronomy already in 1948 after reading about Seeger's detection of Solar radio emission
 - Correspondence with Charles Seeger, Martin Ryle and Jaakko Tuominen
 - Built the first radio telescope in Finland in 1949
- Studies in the USA in 1958-1960
- PhD from HUT on Jupiter decametric burst spectra in 1966



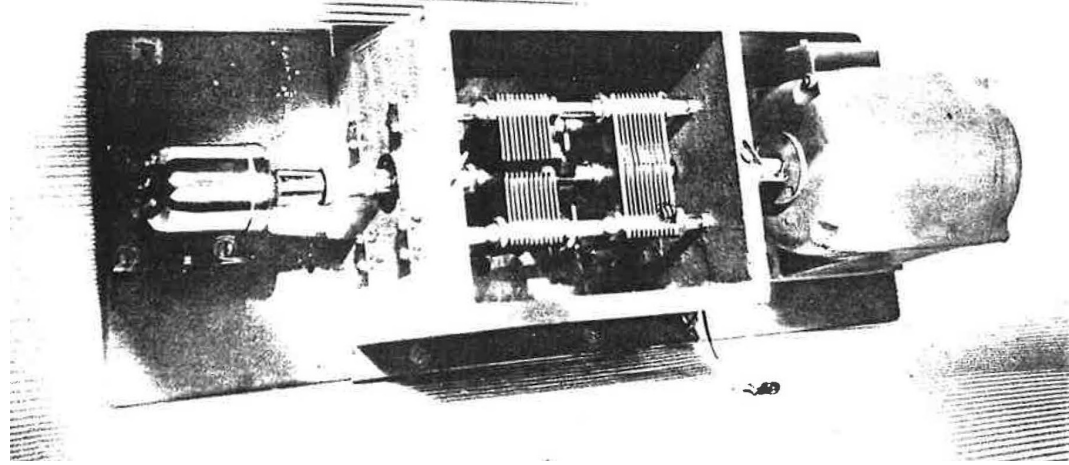
Radio Astronomy Station (1952-1966)

- University of Helsinki founded a radio astronomy station in 1952 with the first field station was on a research farm in Viikki
- First observing frequencies were 81.5, 79 and 45 MHz; all the equipment were built in-house
- In the 1950s, observations were made of radio source occultations, solar eclipses, and the scintillation of Cas A.

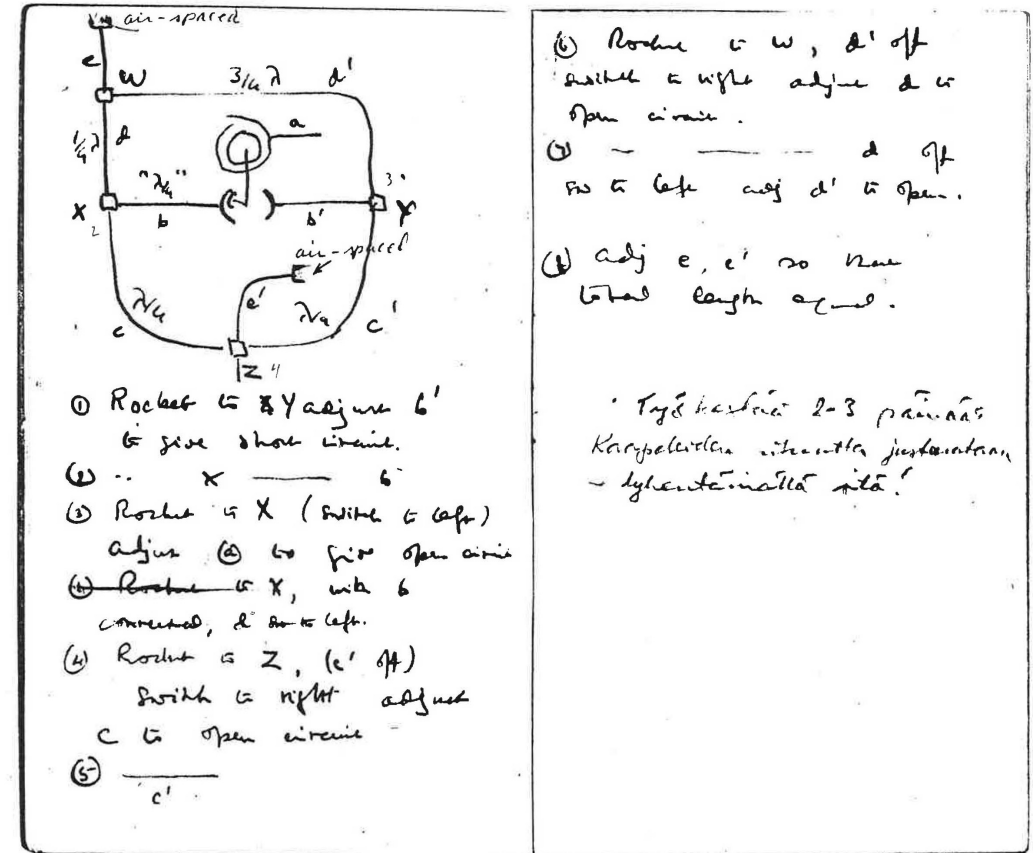


Connections to Cambridge, UK

- Both Tuominen and Riihimaa visited Ryle in Cambridge in different occasions in 1951-1952
- Ryle introduced Riihimaa to the new phase-switching interferometer, which was then built by Riihimaa in Helsinki
- According to Riihimaa, this was the only such unit outside of UK and Australia



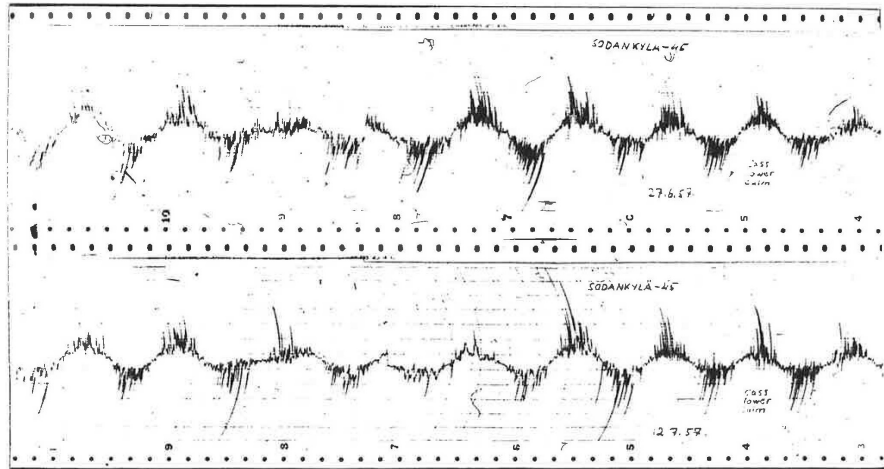
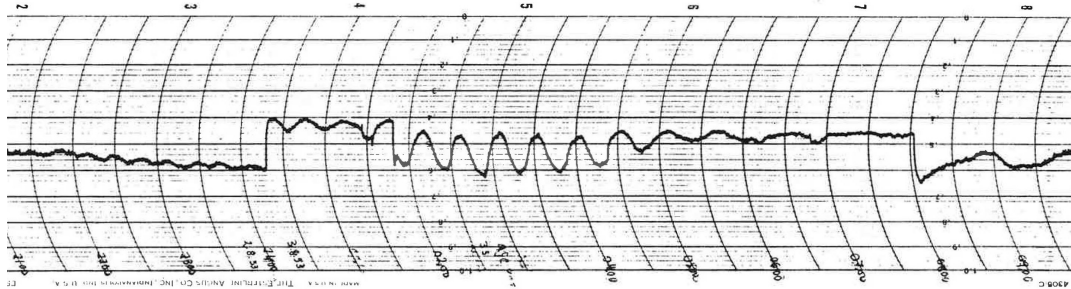
First phase-switch unit built by Riihimaa



Ryle's handwritten tuning instructions for the phase-switch (from Riihimaa's notebook)

Observations with the 81.5, 79 and 45 MHz phase-switching interferometers (1953-1959)

First detection of Cas A at 81.5 MHz



Scintillation of Cas A at 45 MHz

ANNALES D'ASTROPHYSIQUE
18^e ANNÉE - N° 3
MAI-JUIN 1955

THE SOLAR ECLIPSE OF JUNE 30, 1954
AS OBSERVED IN HELSINKI ON WAVE-LENGTH 3.7 METERS
by J. TUOMINEN, J. RIIHIMAA and K. TUORI.

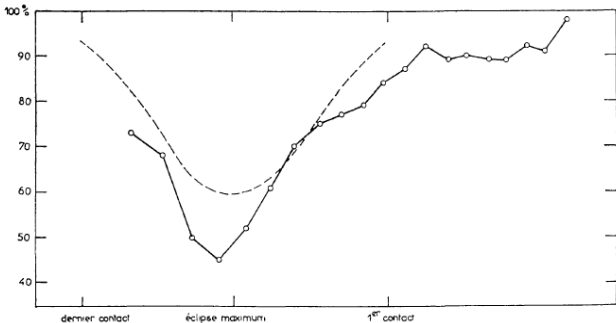


FIG. 2. — Percentage of solar radiation received during the eclipse as a function of time.
——— Observed values.
----- O'Brien's values (based on circular symmetry).

Spectroscopy of solar radio bursts and Jupiter decametric radio bursts (1960-1966)

No. 5021 January 22, 1966 NATURE 387

LETTERS TO THE EDITOR

RADIO ASTRONOMY

High-resolution Spectra of Decametric Radio Bursts from Jupiter

A previous experiment relating to the fine structure in the dynamic spectra of decametric radiation from Jupiter^{1,2} was repeated during the 1964 apparition of the planet, but using different techniques of observation. The main instrument was a high-resolution multi-channel spectrograph. The centre channel was tuned to 19.0 Mc/s and the others at 50-ke/s intervals on both sides of it—their 3 and 40 dB band-widths being 5 and 50 ke/s, respectively. The number of channels varied from 10 to 14. The dynamic spectra were recorded photographically from intensity-modulated indicators, the time constant of integration being 30 msec. The aerial was a two-element collinear array with driven reflectors.

Two phase-switching interferometers were used to identify the Jovian radio bursts. One was of a panoramic type sweeping, repeatedly every 6 sec, the range 20–15 Mc/s. The dynamic spectra with phase were recorded on colour film from an intensity-modulated white-phosphor cathode-ray tube display, in front of which a colour disk with red and green segments was synchronized to rotate with the broad-band phase-switch. The other interferometer was of a single-frequency type (working at 19.3 Mc/s) driving a pen recorder. The aerials consisted respectively of two horizontal biconical dipoles with reflecting screens, and two three-element Yagi aerials, the baselines extending a few wave-lengths in the east-west direction.

The multi-channel spectrograph was operated for 4–5 h each night from September 1 to December 15, 1964, and the other receivers continuously over the same period. Almost no local interference was experienced at either of the two isolated sites of observation and the low night-time values of the ionospheric critical penetration frequency resulted in the absence of long-range interference during the Jovian transits.

Only the strongest bursts were recorded with the high-resolution equipment, the total number of nights with activity being 35. Most of the recordings showed roughly similar variations of intensity with time from channel to channel, indicating radiation band-widths of the order of 500 ke/s or more, the durations ranging from a few seconds to a few tens of seconds. On 14 nights recordings were obtained in which the variations were not similar at all, indicating fine structure composed of pulses with band-widths of the order of 50 ke/s or less. The duration of pulses varied from the time resolution of the instrument to a few seconds. A typical spectrum is reproduced in Fig. 1.

Fig. 1. A Jovian radio burst recorded with a multi-channel spectrograph showing a different variation of intensity with time in each of the channels, tuned at 50-ke/s intervals. System III longitude is 122°.

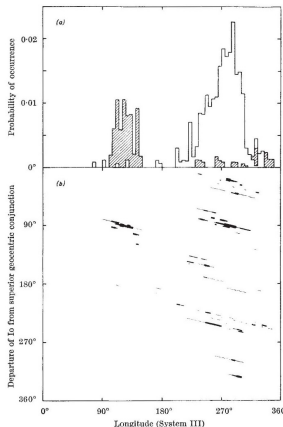


Fig. 2. (a) Probability of occurrence plotted against System III longitude. Recordings that are dissimilar from channel to channel are denoted by shaded areas and those that are on average similar by unshaded areas. (b) The radio storms observed in high resolution, plotted on System III longitude and the position of the satellite Io.

The probability of occurrence as a function of System III central meridian longitude³ is shown in Fig. 2a, the shaded profile denoting narrow-band structure. The relatively low over-all gain of the multi-channel installation results in low values of probabilities. Following the precedence of Bigg⁴ the storms are plotted in Fig. 2b on the co-ordinate system of the longitude of the Jovian satellite Io in its orbit, measured from superior geocentric conjunction⁵, and the radio longitude. Here the width of the lines is closely related to the total duration of the bursts in equal intervals of observing time.

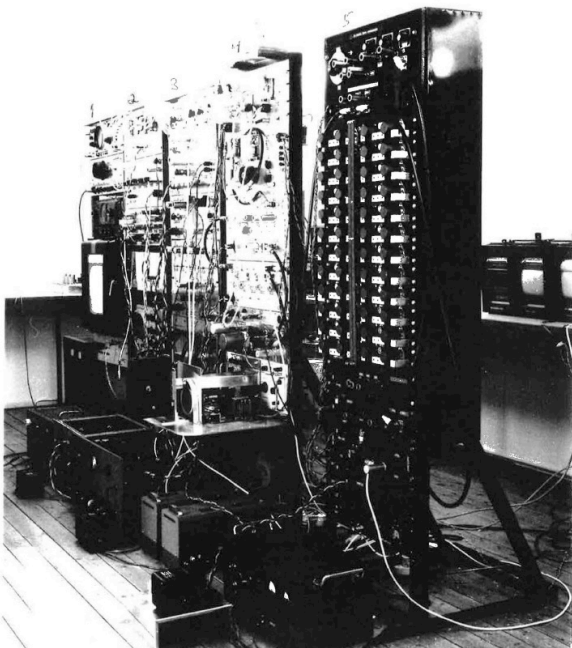
It is worth noting that the trains of short-duration pulses observed in 1963 (refs. 1 and 2), which occurred at radio longitudes of the central meridian of 140°–190° and Io's position of 55°–75°, seem to be a different spectral phenomenon, although they were not recorded with certainty in 1964.

It is possible that these observations indicate some variations in the spectral fine structure depending on the positions of the radio system and the satellite Io. Various authors^{6,7} have discussed the Jovian decametric emissions presuming some kind of exospheric disturbances; the extension of the present experiment to weaker radio storms would probably have some interest in studying the nature of the disturbances produced by the satellite.

J. J. RIIHIMAA

Radio Astronomy Station,
University of Helsinki,
Finland.

- ¹ Riihimaa, J. J., *Nature*, **200**, 476 (1964).
- ² Riihimaa, J. J., *Ann. Acad. Sci. Fenn. A VI*, **156** (1964).
- ³ *Intern. Astro. Union Inform. Bull.*, No. 8 (March 1962).
- ⁴ Bigg, E. K., *Nature*, **193**, 1008 (1964).
- ⁵ *The Astronomical Ephemeris* (1964).
- ⁶ Stille, G. H. A., and McCulloch, P. M., *Austral. J. Phys.*, **10**, 380 (1963).
- ⁷ Warwick, J. W., *Ann. Roy. Astr. Soc.*, **2**, 1 (1964).



- In DTM in 1960, Riihimaa designed the first 20-30 MHz voltage-tuned swept-frequency spectrograph. One copy was sent to Finland and used for solar radio burst observations
- In Finland, Riihimaa designed and built a swept-frequency inteferometer for Jupiter decametric burst observations. The observations were made in Metsähovi.
- Jupiter work resulted in **3 Nature papers** in 1964-1966 describing spectra of different burst classes

Radio astronomy in the Helsinki University of Technology (1962-)

Martti Tiuri (1925-2016)



- PhD (1960) on radio reflections from satellite-produced ion trails
- Visiting professor in Ohio State University (1961-1962); develops radio astronomical receivers and later writes a chapter on receivers in the book "Radio Astronomy" by John D. Kraus
- Professor of radio technology in HUT from 1962
- Metsähovi 14-m mm-telescope was Tiuri's idea (likely influenced by Kraus) and he organized funding for it

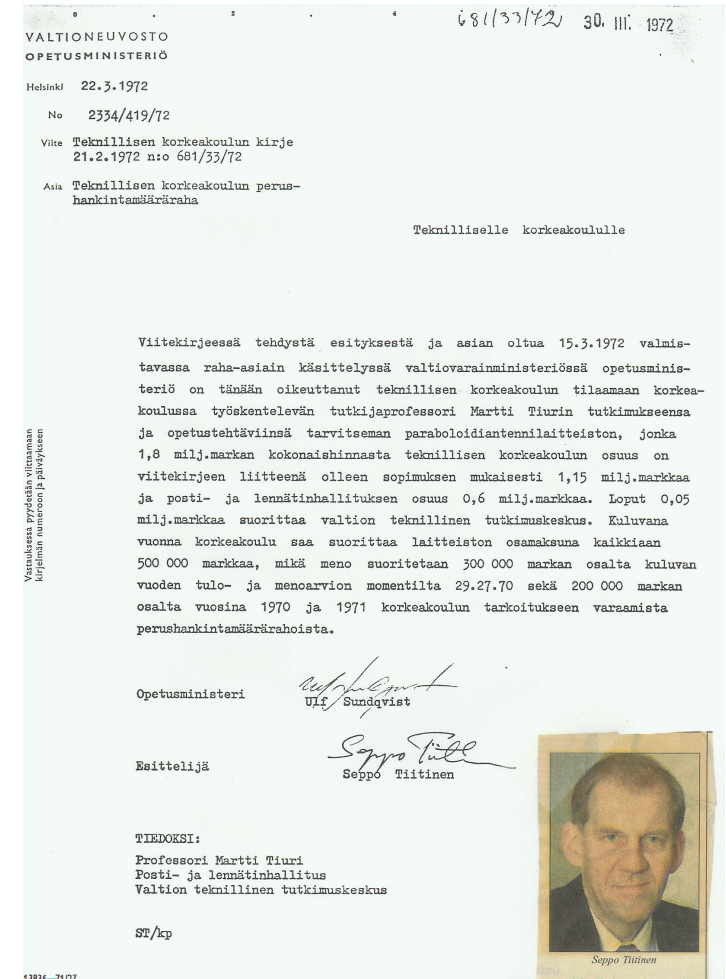
Seppo Urpo (1941-2005)



- Tiuri's student, who led the construction of the 14-m radio telescope in Metsähovi and later became professor and the director of the observatory (1988-2004)
- PhD (1982) on mm-wavelength observing methods; later research focused on Solar mm-wave observations

mm-wavelength radio telescope – a big dream

- After returning from Ohio in 1962, Tiuri has the idea of building a mm-wavelength radio telescope in Finland. It takes a decade to gather funding.
- Funding comes from several sources: HUT, Finnish National Broadcasting Corporation, Post and Telegraph Office, and Technical Research Centre of Finland.
- Telescope was ordered from Electronic Space Systems Corporation (ESSCO; USA) in 1972.

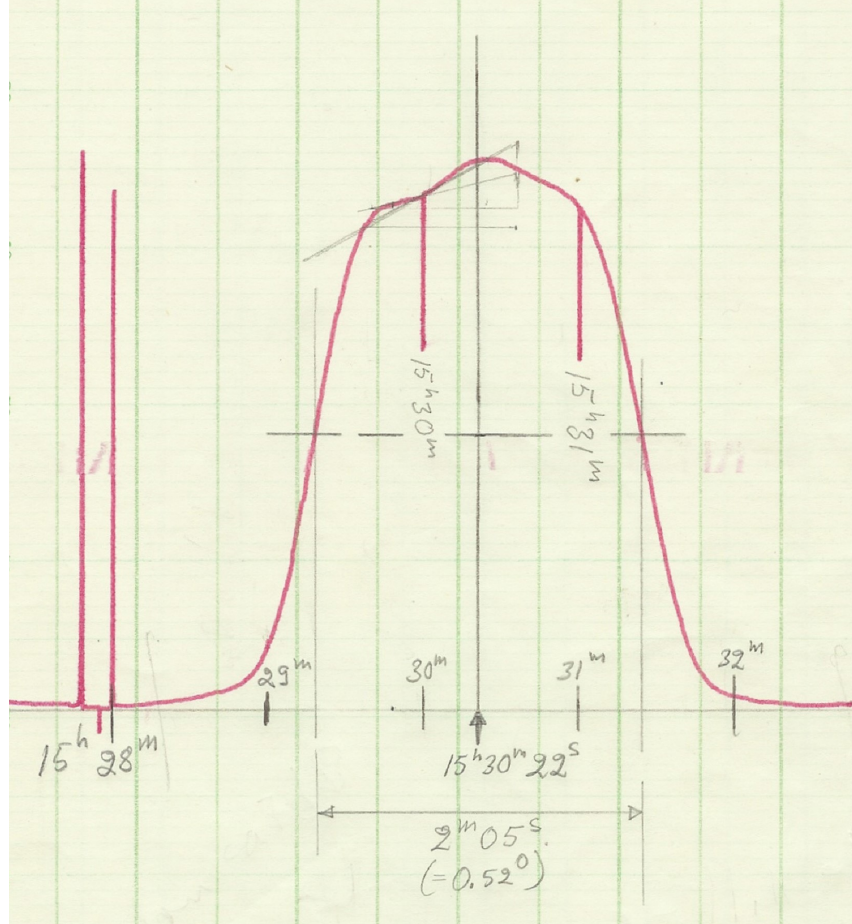


Decision letter from the ministry of education giving HUT a permission to order a radio telescope (1972)

Building “The Great Pumpkin” in Metsähovi (1973-1974)



First light on the 11th of April 1974 – Sun at 11 GHz



Astronomical use of Metsähovi starts (late 1970s – early 1980s)

Astron. Astrophys. 71, 198—204 (1979)

ASTRONOMY
AND
ASTROPHYSICS

Continuum Observations of the H II Regions W 51 A, W 3 (Main), W 49 A and DR 21 at 3.9 mm

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Received December 21, 1977; revised April 10, 1978

Summary. The 13.7-m radio telescope at the Metsähovi Radio Research Station equipped with a 76 GHz mixer receiver has been used to observe the continuum emission of the H II regions W 51 A, W 3 (Main), W 49 A, and W 75/DR 21. The 3.9 mm flux densities for W 3 (Main), W 49 A, and W 75/DR 21 are in good agreement with previous observations and are consistent with pure free-free emission. For W 51 A we have detected an excess emission. It has been interpreted as thermal emission by heated dust associated with the dense molecular cloud.

Key words: H II regions — dust — radio radiation

In the present paper we report the observations at 3.9 mm of the H II regions W 51 A, W 49 A, W 3 (Main) and W 75/DR 21, carried out with the 13.7-m telescope at the Metsähovi Radio Research Station. For W 51 A an excess emission above the expected free-free radiation has been detected, and it is interpreted in terms of thermal emission from heated dust grains.

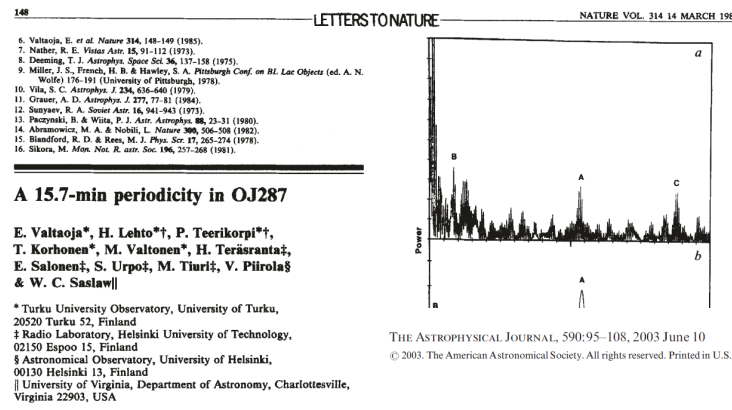
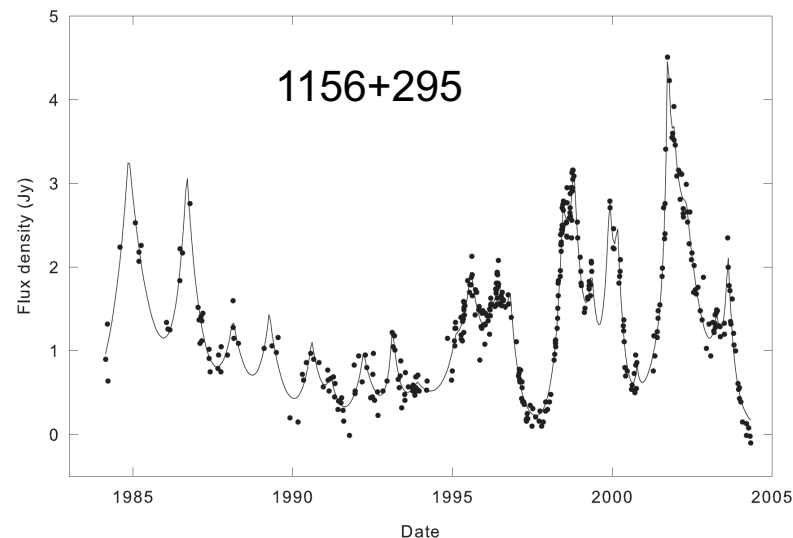
II. Instrumentation

a) Antenna

Astronomical use of Metsähovi starts (late 1970s – early 1980s)

Collaboration with University of Turku on observing quasar variability at mm-wavelengths

- Long-term monitoring at 22/37/87 GHz which is still ongoing
- Established shocks in the jet as the main driver of radio-mm variability in blazars
- Major contribution to understanding the radio-gamma-ray connection in blazars



Mauri Valtonen



Esko Valtaoja

Astron. Astrophys. 203, 1–20 (1988)

Five years monitoring of extragalactic radio sources II. Quiescent spectra and the evolution of outbursts

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TESTING OF INVERSE COMPTON MODELS FOR ACTIVE GALACTIC NUCLEI WITH GAMMA-RAY AND RADIO OBSERVATIONS

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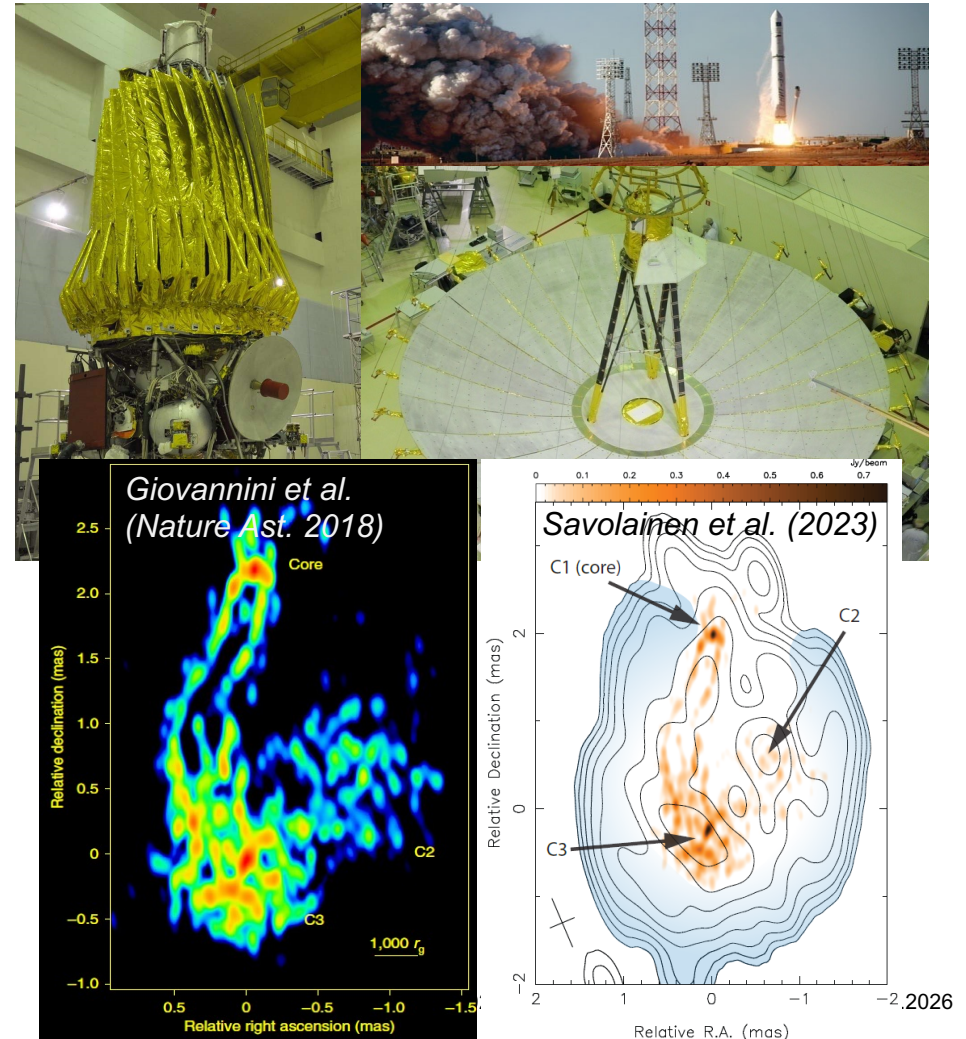
Received 2002 April 19; accepted 2003 February 18

RadioAstron 22 GHz receiver project

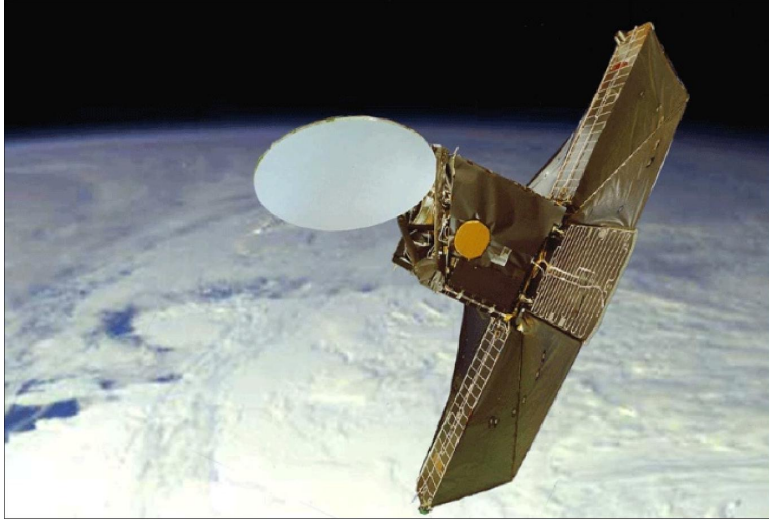
Soviet *RadioAstron* space-VLBI mission

- After NRAO had to back out from building a 22 GHz receiver for RadioAstron, HUT radio lab seized the opportunity in 1987
- Finland built the original K-band receiver for the spacecraft and Metsähovi was supposed to work as a ground station in space-VLBI experiments – **start of the VLBI activities in Metsähovi**
- Launch of *RadioAstron* delayed until 2011 – still, one of the key science programs was led from Metsähovi!

A!

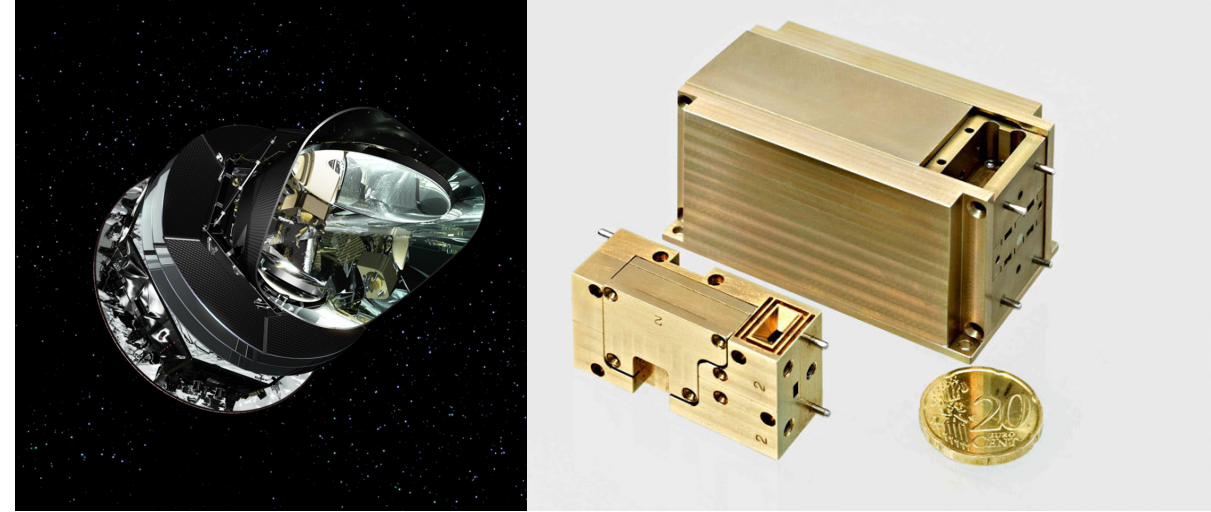


Space projects: *Odin* and *Planck*



Odin (Sweden-Canada-Finland-France)

- Combined Earth Observation and Astrophysics mission operating radiometers in mm- and sub-mm bands
- Finland built the 119 GHz receiver
- Odin was 25 years in space – launched in 2001 and the mission ended on August 3 2026



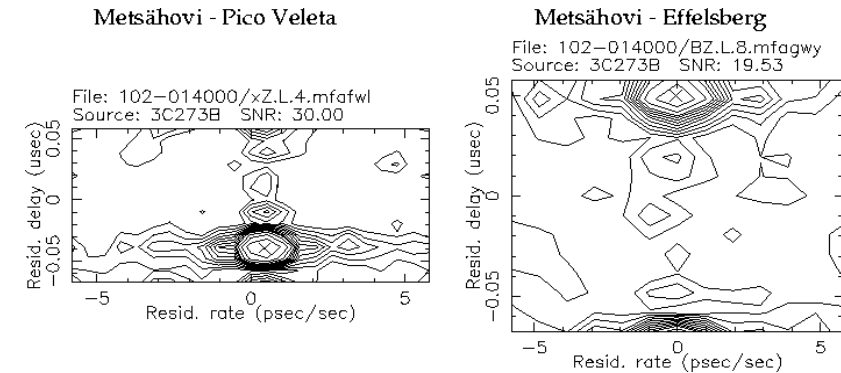
Planck (ESA)

- Cosmic microwave background mission
- Finland built the 70 GHz receiver and HUT/Aalto, UH and UT participated in the science program; Metsähovi developed a quick-look system for flare alerts
- Launched in 2009, mission completed in 2013

Start of VLBI observations in Finland

Metsähovi VLBI activities

- H-maser and Mk2 terminal in 1990, first VLBI observations in 1991 (2 global sessions at 22 GHz)
- Associate member of the European VLBI Network since 1991
- In-house built VLBA terminal completed in 1993
- First 3 mm VLBI fringes in 1997 and first 7 mm fringes in 1998
- Successful 2 mm VLBI experiment between MRO and IRAM 30-m in 2001
- Regular geodetic S/X VLBI observations since 2004



First 3mm fringes to Metsähovi in April 1997.

A&A 390, L19–L22 (2002)
DOI: 10.1051/0004-6361:20020893
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**Astronomy
&
Astrophysics**



147 GHz VLBI observations: Detection of 3C 273 and 3C 279 on the 3100 km baseline Metsähovi – Pico Veleta

A. Greve¹, P. Könönen², D. A. Graham³, K. Wiik^{4,2}, T. P. Krichbaum³, J. Conway⁵, F. Rantakyro⁶, S. Urpo², M. Grewing¹, R. S. Booth⁵, J. A. Zensus³, D. John⁷, S. Navarro⁷, A. Mujunen², J. Ristakari², J. Peltonen², P. Sjöman², E. Oinaskallio², and M. Berton¹

VLBI recorders and data transfer records

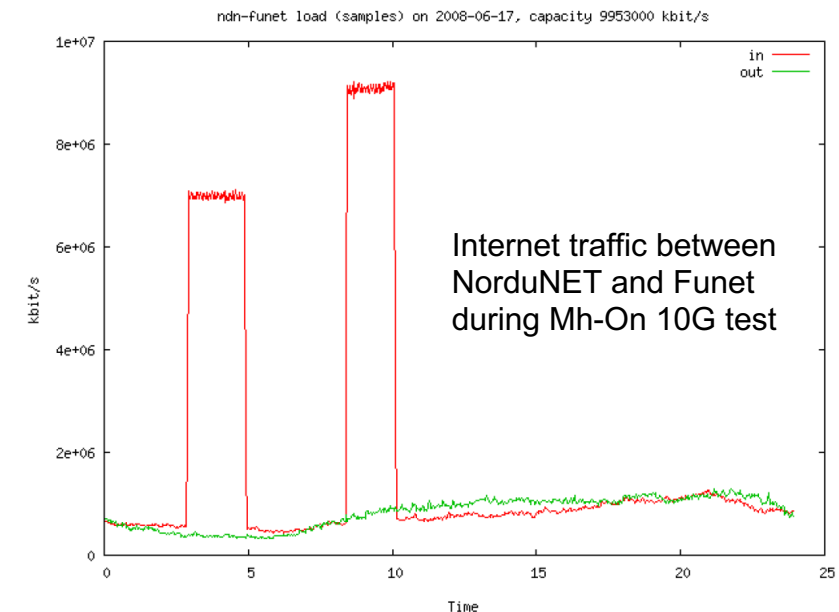
VLBI recording systems developed at Metsähovi

- 1994-2000: 1 Gbps EMU-EVN MarkIV upgrade (new MarkIV compatible read/write electronics to many EVN stations, DSN and geodetic stations)
- Early 2002-2006: PC-EVN – a VSI-standard based recording system using COTS PC hardware
- 2010-12: Flexbuff, a widely used disk-based VLBI recording system

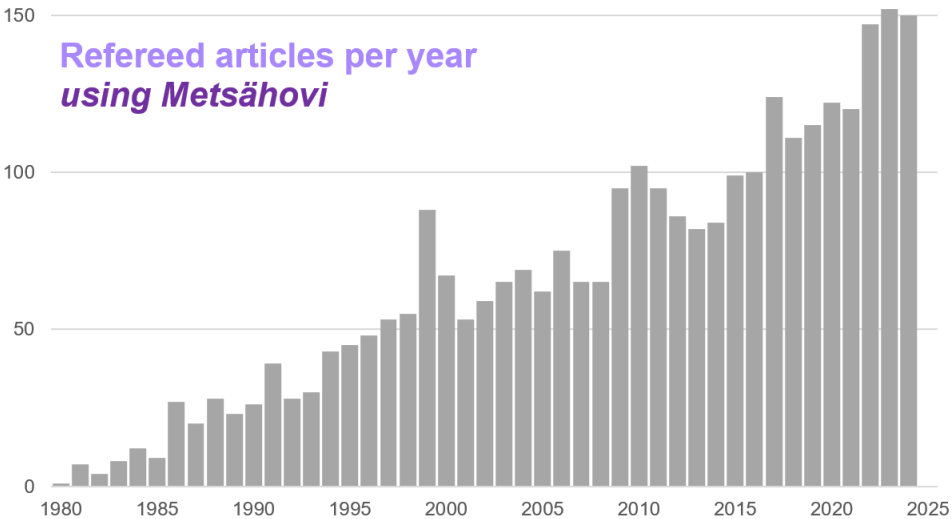
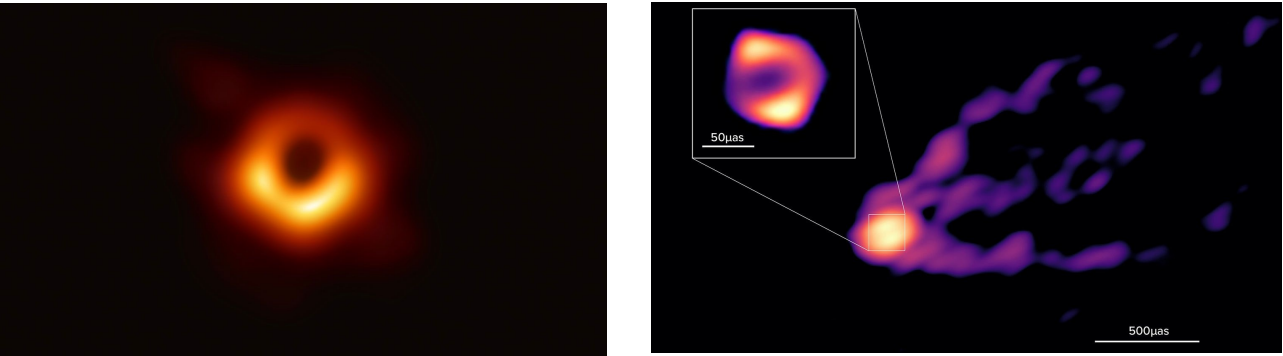


VLBI data transfer developments

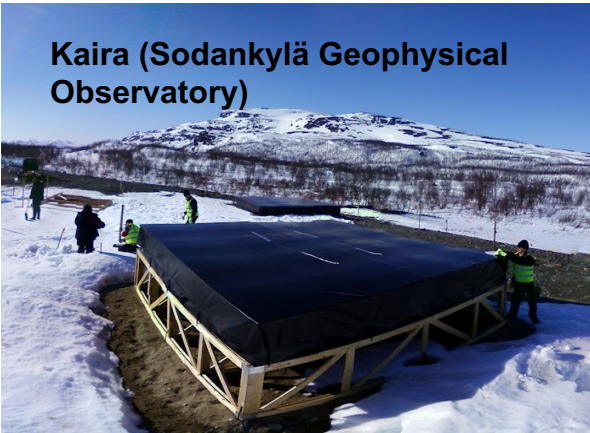
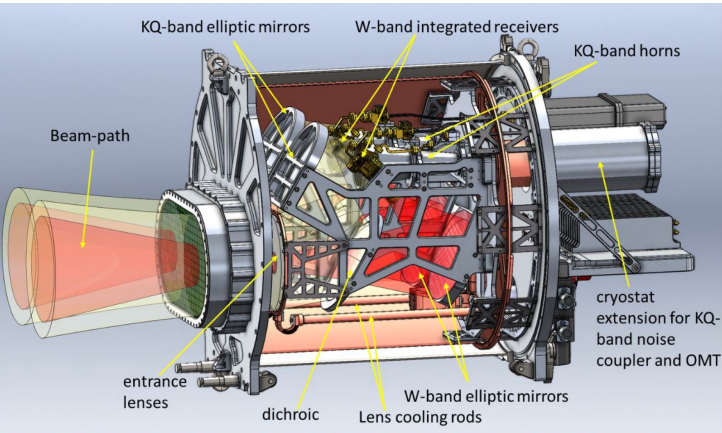
- Modified Tsunami protocol – e-transfer at 512 Mbps (2005; lab test), 1 Gbps (2006) and 7 Gbps (2008)
- A real-time radio signal streaming between Onsala and Metsähovi at 4-8 Gbps in 2008



Radio Astronomy in Finland today



New or upcoming capabilities after 2010





Kiitos aalto.fi

Sources:

- Memoirs of Jorma Riihimaa (“Radioastronomian vaiheita suomessa 1949-1966”, unpublished, 1995)
- Memoirs of Seppo Urpo (“Hajatarinoita Kurpitsan historiasta 1”, unpublished, 2004)
- Memoirs of Antti Räisänen (“Radiolaboratorion maratoonari”, 2019)
- Metsähovi Radio Observatory Annual Reports 1988-2011

Special thanks to Ari Mujunen, Joni Tammi, and Ahto Apajalahti

Backup

Science in Finland after the second world war

– scarce resources

- Science funding by the Finnish state reached the level of 1938 only in the early 1960s
- It was difficult to get components: no transistors were available, and the availability of especially miniature tubes was limited
- Help from the US (both official programs and Tuominen's personal contacts)
 - Tuominen's contacts (including multi-millionaire Waino Hoover) sent components and even instruments
 - ASLA-Fulbright funding for instruments and Riihimaa's stipend to Colorado and Washington DC
 - Many American astrophysicists visited the Radio astronomy station, including Donald Menzel, Allen Hynek, and Nancy Roman