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Polish contribution to the research of the Universe at radio waves

Krzysztof Katarzyński
Institute of Astronomy, NCU

Polish Astronomical Society Meeting 2023

14.09.2023

Beginnings of Polish Radio Astronomy

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Krakow - former capital city of Poland.

First Polish radio telescope

First Polish radio telescope was build in **1954** in “Fort Rock” – currently Astronomical Observatory of the Jagiellonian University in **Kakow** (director **T. Banachewicz**).

The instrument was designed and constructed by **L. Kowalski, A. Strzałko-wski, O. Czyżewski, J. de Mezer** and many others…

It was 5 m parabolic dish designed to work at ~1 m wavelength. The telescope was used for the first time on 30 of June 1954 for observations of the solar eclipse. In following years the instrument was used for regular monitoring of solar activity at 47 and 94 cm (**J. Masłowski, J. Machalski, S. Zięba, A. Michalec, A. Kułak** and others…)

Second radio telescope in Krakow

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15 m dish formally commissioned in 1965. It was intended to replace the old seven-meter radio telescope in radio observations of the Sun. It was used for example for precise measurements of radio background emission at 1300 MHz (Machalski 1973).

Third radio telescope in Krakow

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In October 1995, a new, **8-meter** radio telescope was commissioned in Krakow. This instrument with full automation and a new system for conducting observations and collecting data, without the participation and presence of an observer in the cabin, was dedicated for observations of the Sun. New observations were carried out simultaneously in 10 bands (at 10 wavelengths) ranging from 10 cm to over 1 meter.

Other radio astronomical project in Krakow

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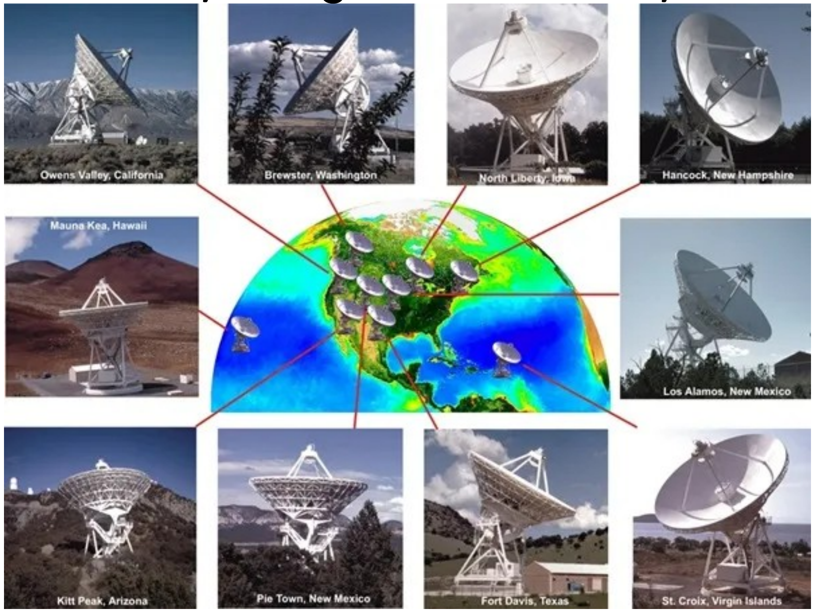
Green Bank 300 ft RT

Effelsberg 100 m RT

VLA – Very Large Array

Very Long Baseline Array



From the 1970s Krakow radio astronomers also began to intensively use world's best radio astronomy instruments.

Structure of magnetic fields in the Universe

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Weżgowiec et al. 2022

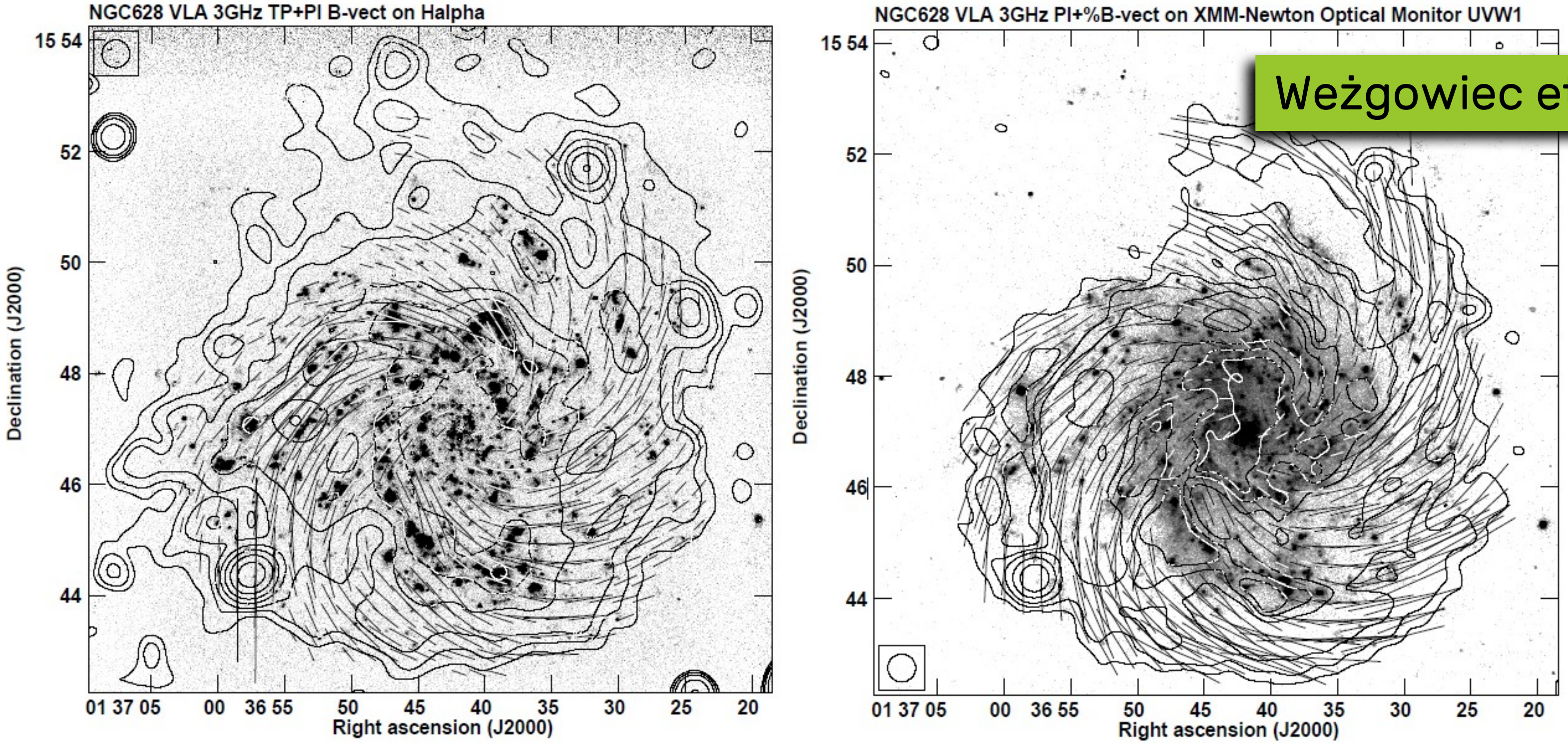

Fig. 1. Map of the total (*left*) and polarised (*right*) radio intensity at 3 GHz (λ 10 cm) of NGC 628 overlaid on an Hα and *XMM-Newton* Optical Monitor in UVW1 filter map, respectively. The contour levels are 3, 5, 8, 16, 32, 64, 128, 256, and 512 × 24 μJy (*left*) or 10 μJy (*right*). The lines show the orientation of the magnetic fields, and their lengths of 1′ are proportional to the polarised intensity of 150 μJy (*left*) or to a degree of polarisation of 36% (*right*). The angular resolution is 30″.

Structures of radio galaxies

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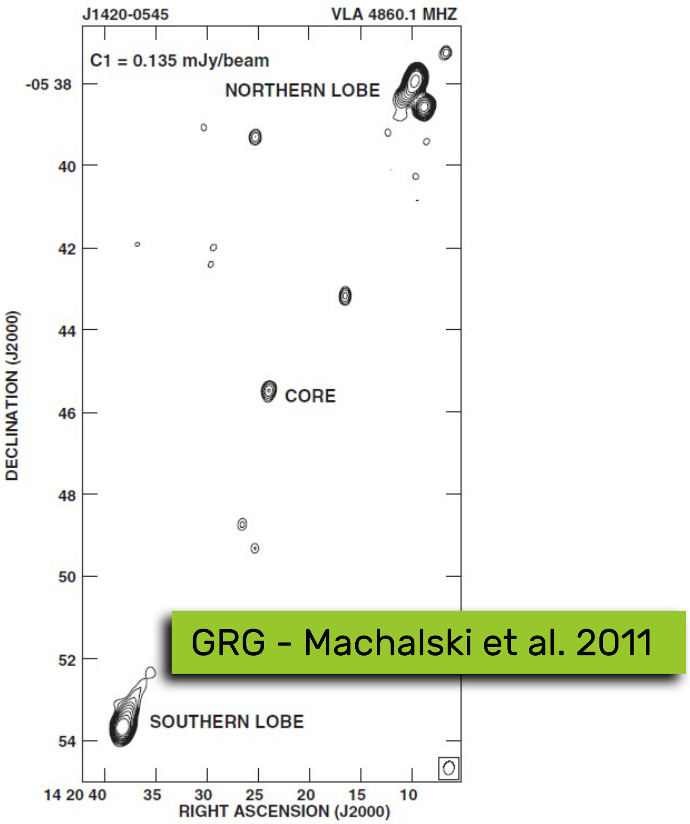

Figure 1. VLA image of J1420−0545 at 4860.1 MHz with an angular resolution convolved to 15″ × 20″, shown as an ellipse in the bottom right-hand corner. The position of the radio core, as well as the northern and southern lobes, are also marked. The contours spaced by a factor of $\sqrt{2}$ in brightness are plotted starting with a value of 0.135 mJy beam^{-1}.

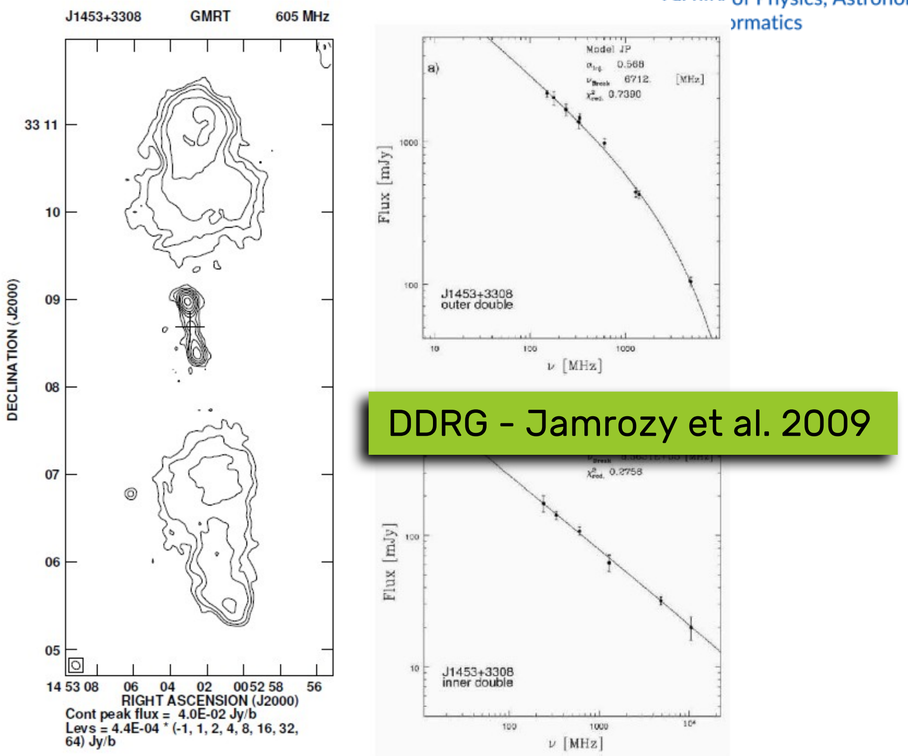

Figure 1. Left: The GMRT image of the DDRG J1453+3308 at 605 MHz with an angular resolution of ~5.4 arcsec. Spectra of the outer and inner doubles fitted with the models of radiative losses. Upper right panel: the outer double fitted with the Jaffe-Perola model. Lower right panel: the inner double fitted with the continuous-injection model (Konar et al. 2006).

POLFAR Polish part of LOFAR

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- Jagiellonian University (coordinator),
- University of Warmia and Mazury in Olsztyn,
- Space Research Centre of PAS,
- University of Zielona Góra,
- Nicolaus Copernicus University in Toruń,
- Nicolaus Copernicus Astronomical Center of PAN,
- University of Szczecin,
- Wrocław University of Environmental and Life Sciences,
- Poznan Supercomputing and Networking Center

Beginnings of the radio astronomy in Toruń

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Toruń – “Kraków of the North”

First radio telescope in the Piwnice Observatory

RT-1

parabolic-cylindrical antenna **12x26 m**, built in the second half of 1957. In 1958 the instrument was used to monitor solar activity. Main constructors: **H. Iwaniszewski, S. Gorgolewski, H. Wiśniewski, J. Hanasz** and many others...

Second radio telescope in the Observatory

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RT-2

1958 - a hand-operated parabolic antenna, **12 m** in diameter, sensitive enough to measure the emission of a quiet Sun. It was used for daily observations during the Geophysical Year (1957/58) and for the following years. It was also used to observe the solar eclipse on February 15, 1961. Persons identified on the photo: **S. Gorgolewski, A. Buchholz, H. Wiśniewski and J. Hanasz.**

Third radio telescope in the Observatory

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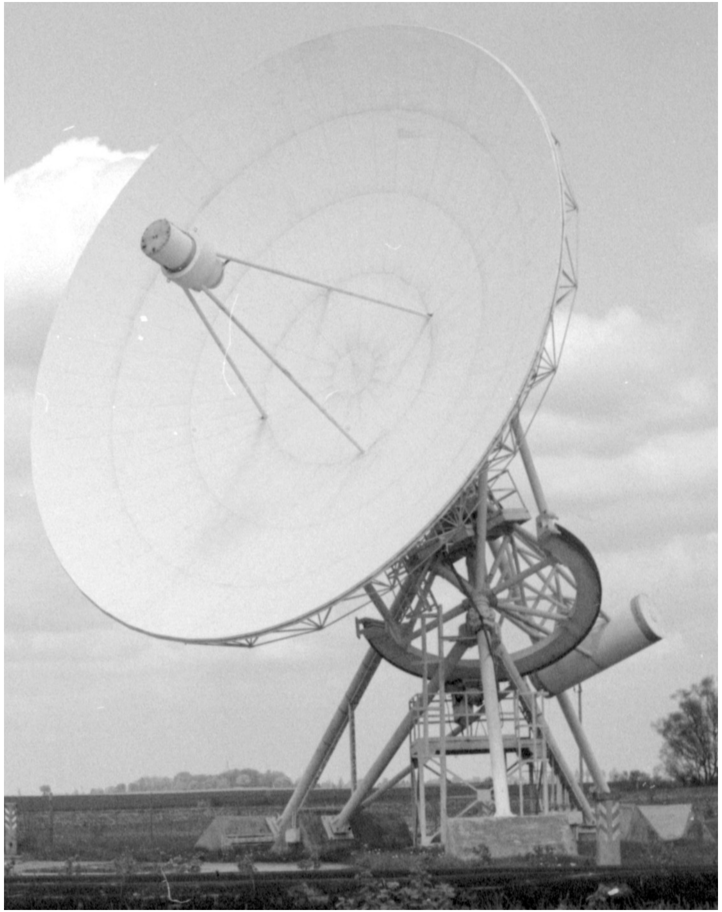

RT-3

This instrument has a paraboloidal surface with a diameter of **15 m**. The construction of this telescope lasted from spring to autumn **1976** (project by **E. Śledziewski** and **Z. Bujakowski**). The radio telescope has an equatorial mount. In the early eighties of the twentieth century, the radio telescope was equipped with a number of receivers that allowed to record radio radiation at 2.8, 6, 18, 21, 49 and 92 cm wavelengths.

In 1981, the so-called interference fringes between the signal recorded by RT-3 and the 100-meter radio telescope in Effelsberg, Germany were obtained for the first time. It was the **beginning of Very Long-Baseline Interferometry (VLBI)** at the Observatory in Piwnice.

Fourth radio telescope in the Observatory

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RT-4 named after **Nicolaus Copernicus**

32-meter precise parabolic antenna, designed (**Z. Bujakowski** and co-workers) and built in Poland in **1994**, is a fully steerable telescope with a classic azimuth-elevation mount. The main mirror consists of 336 panels, each made with an accuracy of 0.35 mm. The 32-meter antenna with high-quality instrumentation is a unique tool for Polish astronomers in space research. The telescope is part of the European and worldwide VLBI interferometric network.

Fourth radio telescope in the Observatory

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RT-4 a few parameters

• Optic:	Cassegrain system
• Mount:	azimuth-elevation
• Elevation range:	+2 to +95 deg
• Azimuth range:	+-270 deg (South = 0)
• Diameter:	32 m
• Max height:	37.6 m
• Weight:	~620 tons

• L-band receiver:	1.4-1.8 GHz	Tsys ~35 K
• C1-band receiver:	4.3-5.3 GHz	Tsys ~35 K
• C2-band receiver:	5.9-6.9 GHz	Tsys ~25 K
• X-band receiver:	8-12 GHz	Tsys ~55 K
• K-band receiver:	21-25 GHz	Tsys ~100 K
• Ka-band receiver:	27-33 GHz	Tsys ~40 K

- **Single dish:** total power radiometry, spectroscopy, polarimetry.
- **VLBI network:** high resolution imaging, radio-astrometry, spectroscopy, polarimetry.

Renovation of RT-4 in 2020

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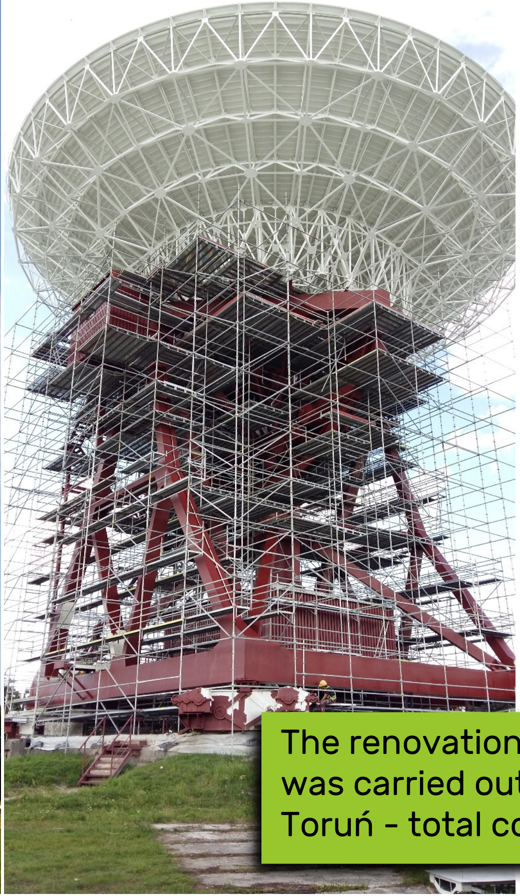

The renovation, which took 4.5 months, was carried out by ENERGON S.A. from Toruń – total cost **PLN 2 300 000**.

Pulsar timing program with the 32 m RT

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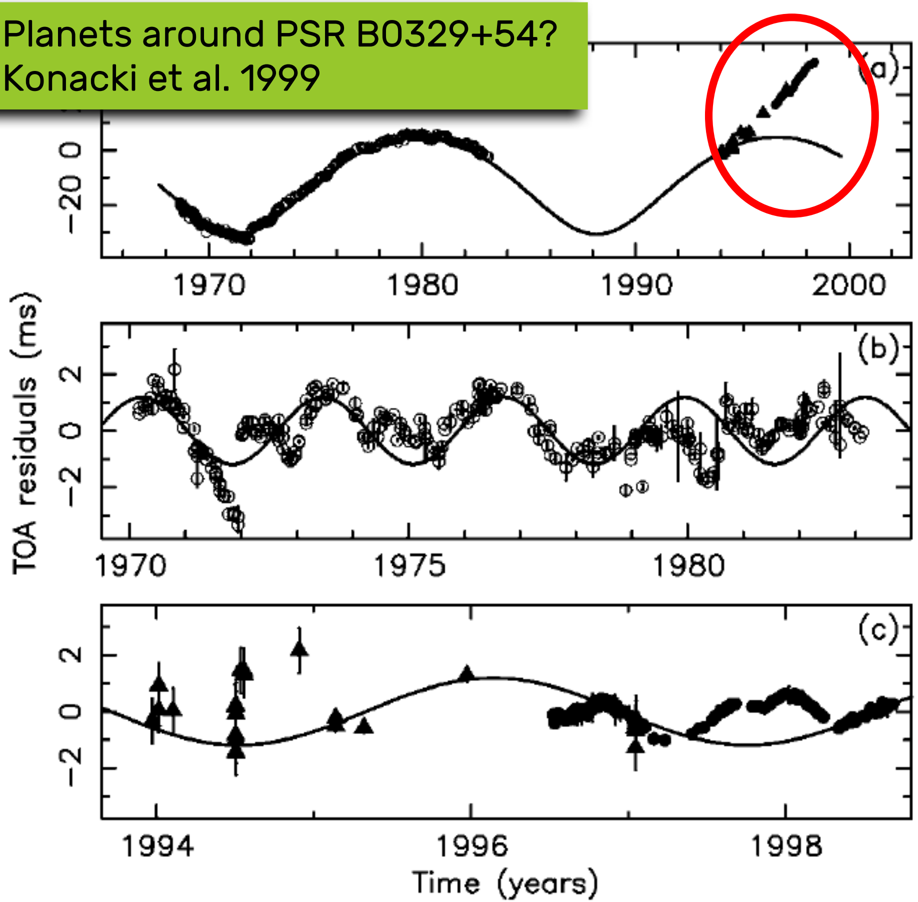
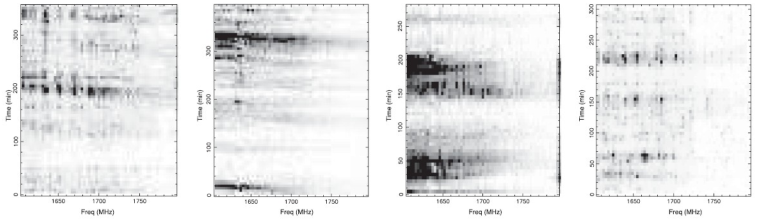
Planets around PSR B0329+54?
Konacki et al. 1999



Regular monitoring (a measurement every few days) of about **100** strong pulsars at 1.7 GHz with the **Penn State Pulsar Machine 2** - 2 x 64 x 3 MHz channels (A. Wolszczan, M. Konacki, W. Lewandowski and many others…



Scintilations of PSR B0823+26 – Daszuta et al. 2013.

Search for methanol maser emission

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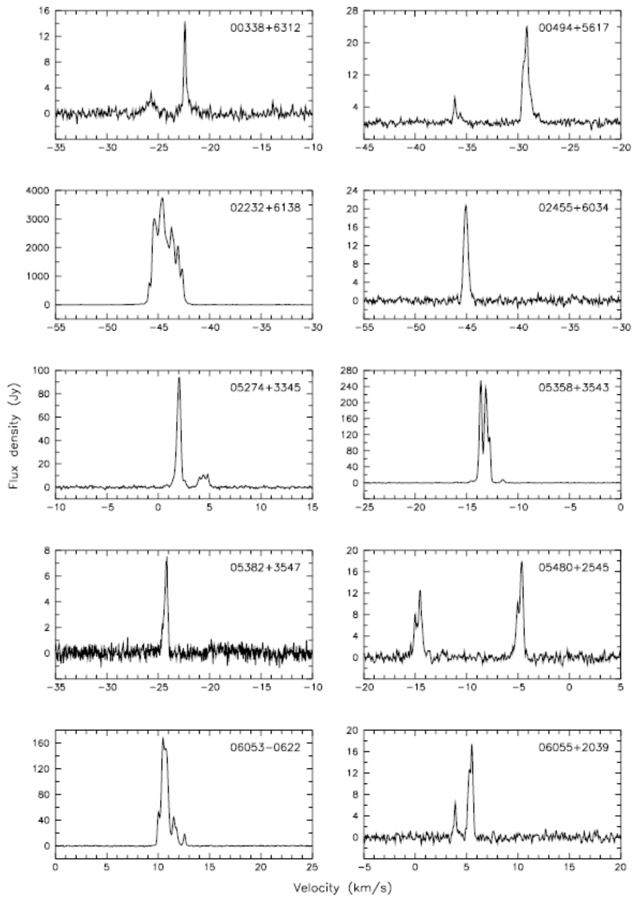

- Search of **1399 IRAS** objects north of declination -20 deg at 6.7 GHz.
- Maser emission **was found in 182 sources**, including **70 new detections**.
- **32 new sources** were identified with objects of radio emission associated with **star-forming regions**.
- Results suggested that about 65% of methanol masers exhibit moderate or strong variations on time-scales of about 4 and 8 years.

(Szymczak et al. 2000)

Blind survey of the Galactic plane

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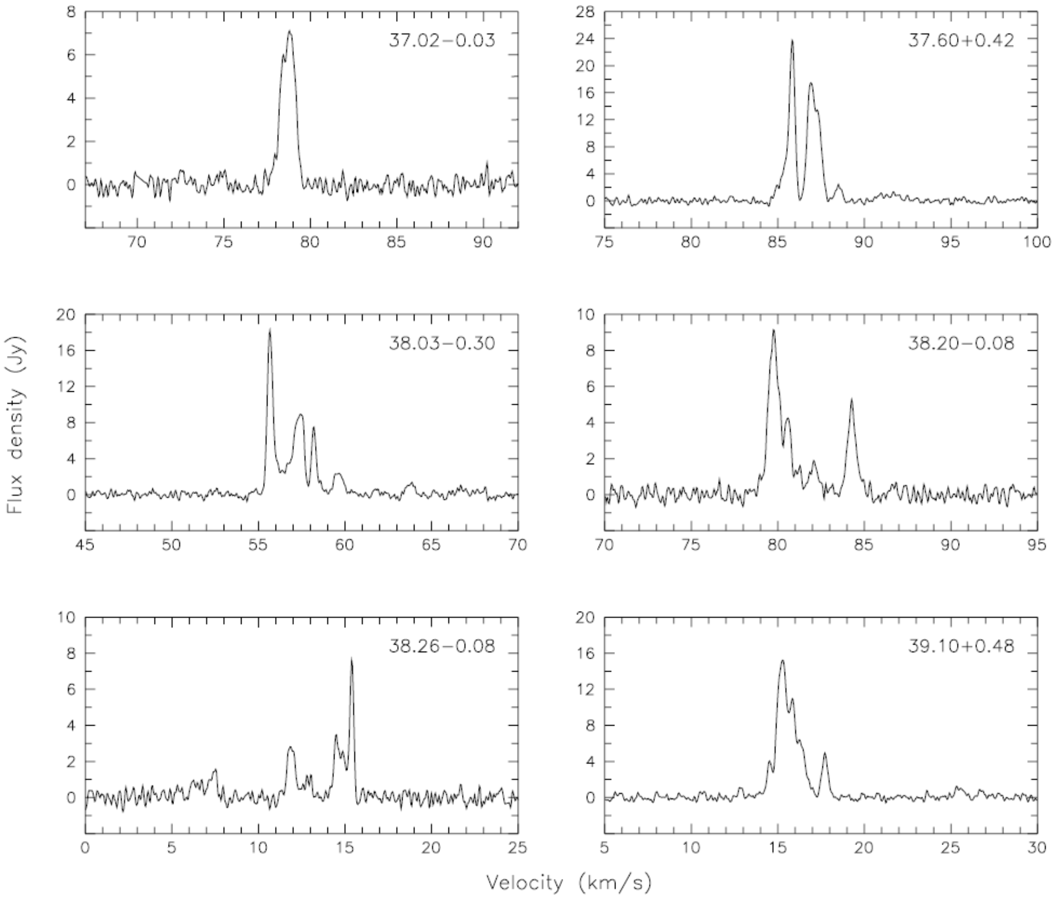

A blind search for methanol masers sources in a strip of the Galactic plane (20 to 40 deg in longitude and +- 0.52 deg in latitude).

100 sources were detected in total, where **26 objects were detected for the first time**.

(Szymczak et al. 2002)

Periodic variability of methanol masers

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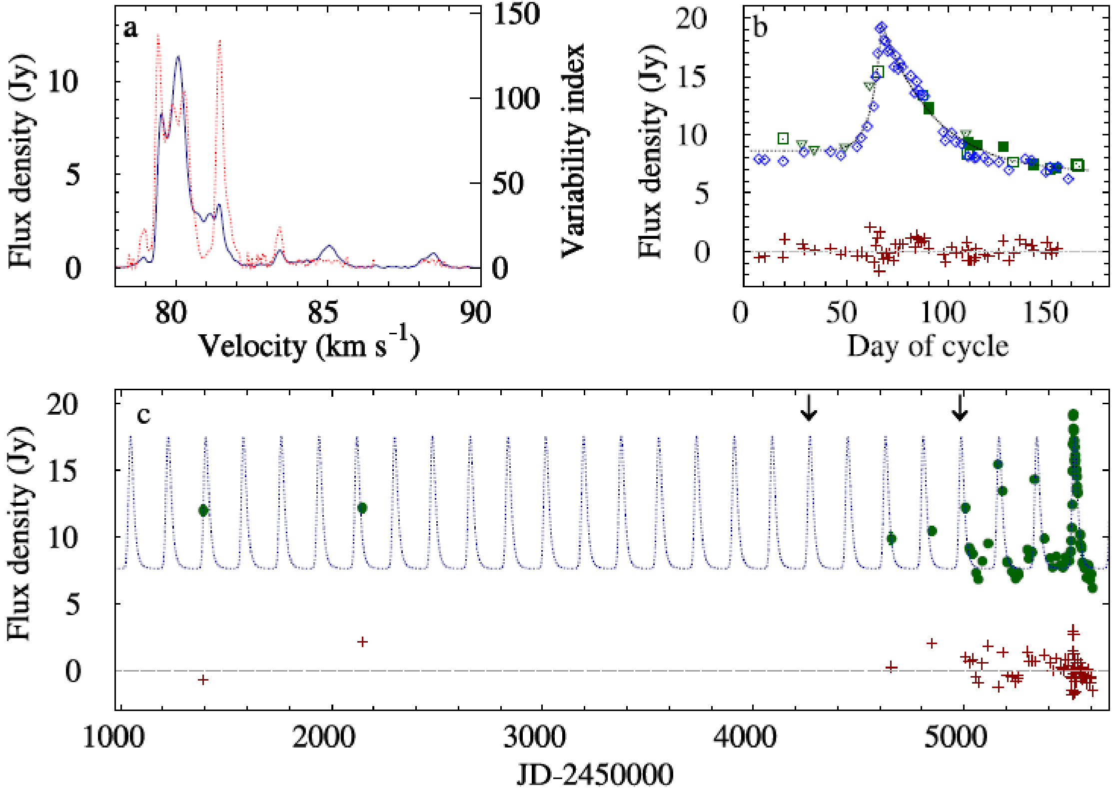

Periodic variability of methanol masers in G22.357+0.066. The period of the variations is about 179 days and seems to be stable in last 12 years.

(Szymczak et al. 2011)

Alternating flares of the methanol masers

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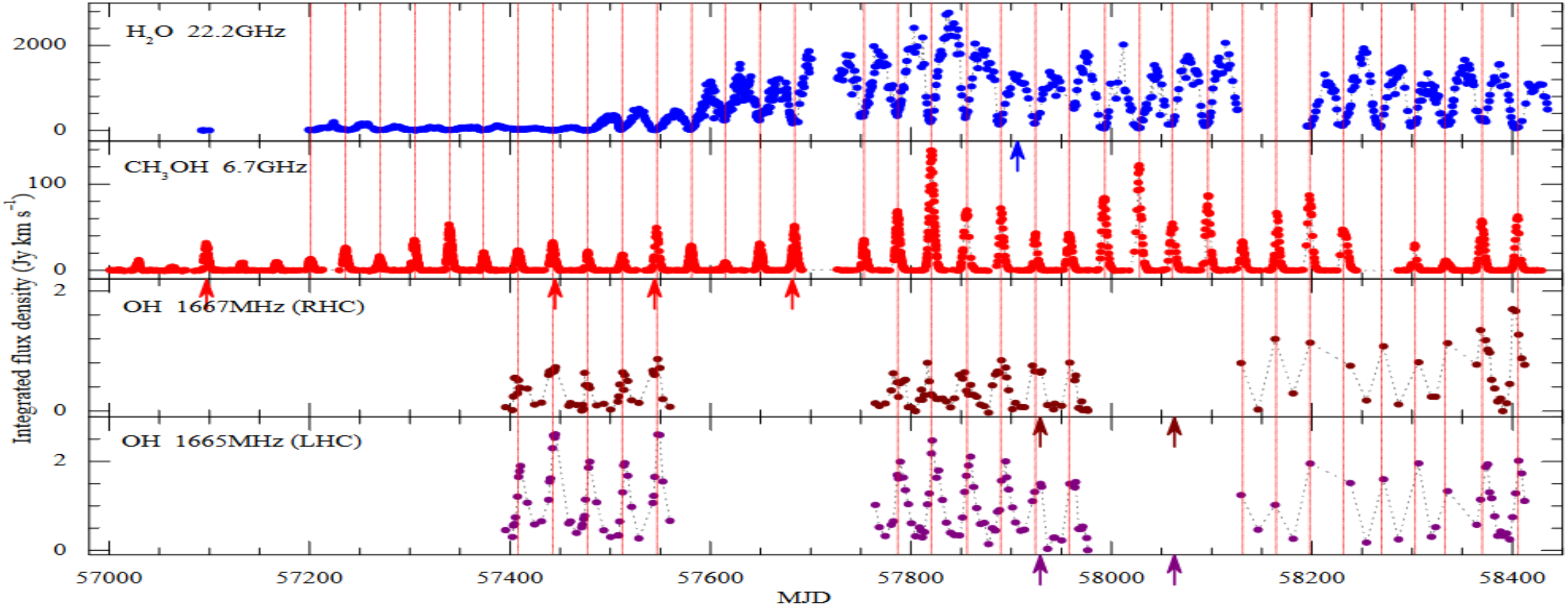

G107.298+5.639 - alternating flares of the **methanol (6.7 GHz)** and **water (22.2 GHz)** masers with a period of **34.4 days**. Periodic flares of maser emission are thought to be induced either by variations of the seed photon flux in young binary systems or the pump rate regulated by stellar and accretion luminosities (Olech at al. 2020)

Number of known periodic maser sources

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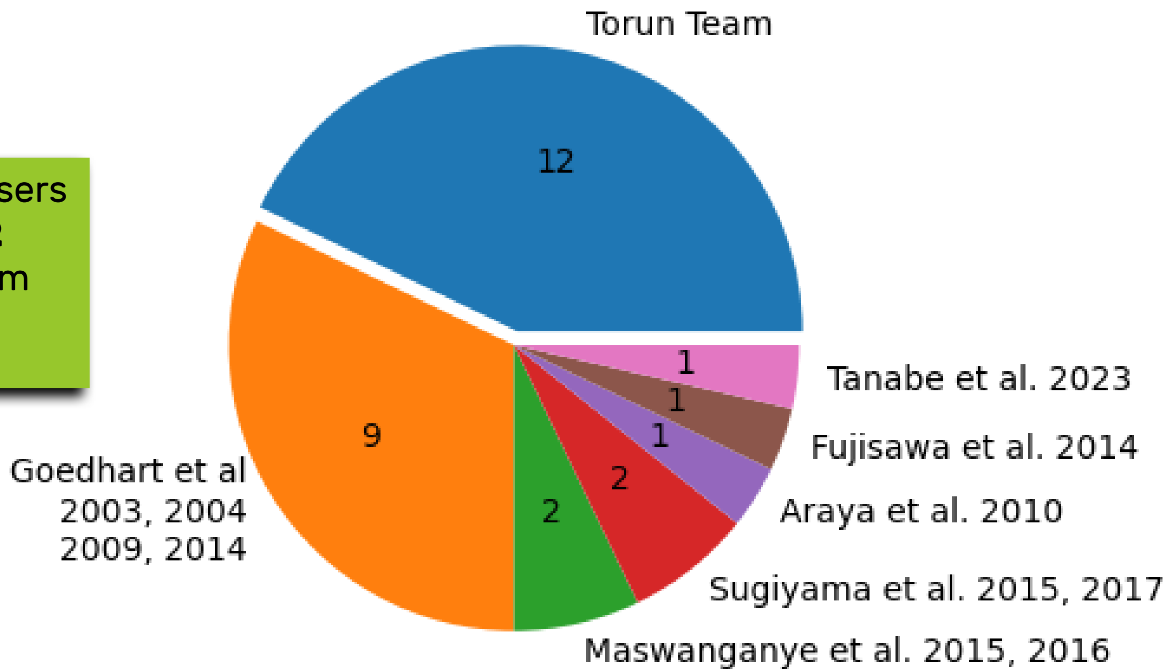
So far only **28** periodic masers were discovered, where **12** sources were found by 32 m radio telescope in Toruń.



Fast Radio Bursts

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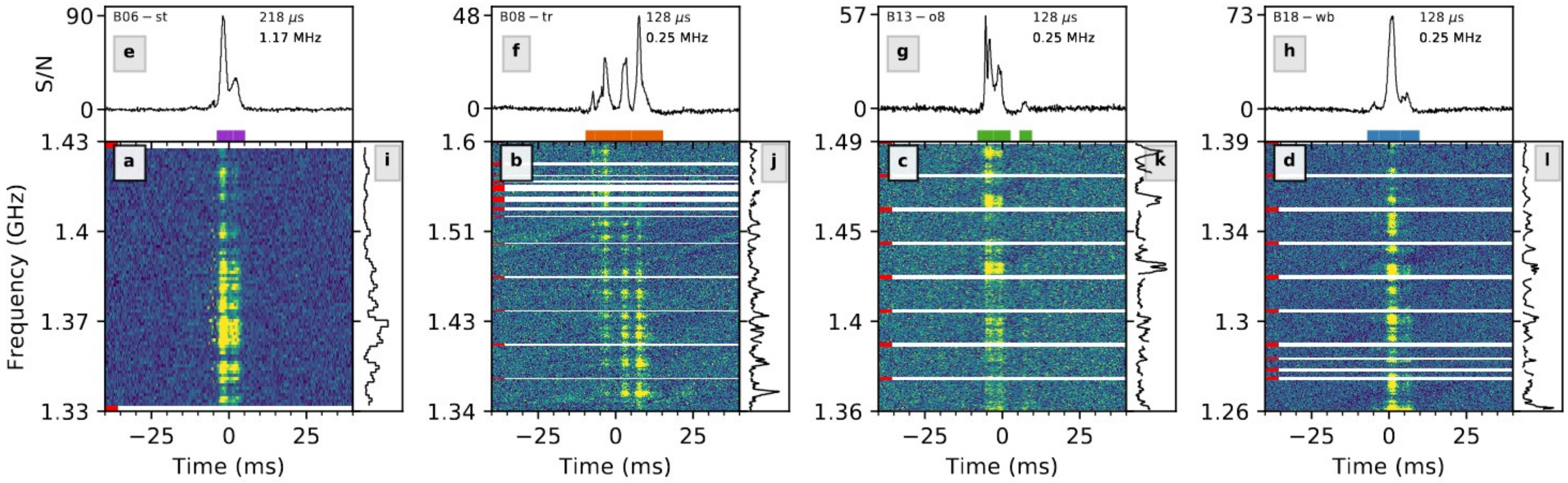

FRB 20201124A - observed between April 2021 and March 2022 by: 25 m telescope in Stockert, Germany; 32 m dish in Toruń, Poland; 25 m dish in Onsala, Sweden; 25 m dish in Westerbork, The Netherlands (Kirsten et al. Accepted for Nature Astronomy).

EVN and JIVE

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JIVE
Joint Institute for VLBI ERIC

EUROPEAN vlbi NETWORK

Agnieszka Słowikowska
a new Director of JIVE

Radio-loud Active Galactic Nuclei

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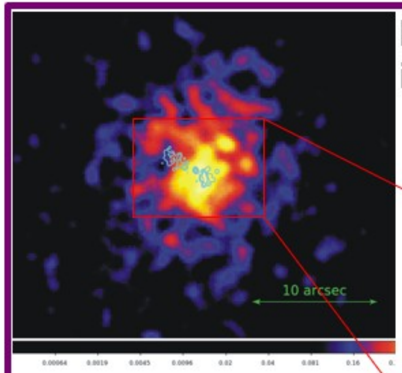
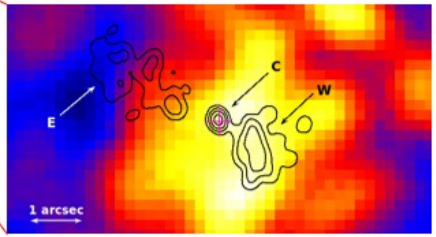
Radio galaxy in the center of X-ray cluster

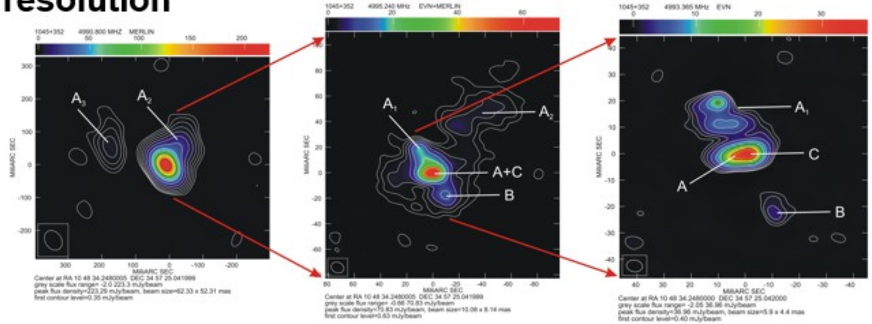
Chandra X-ray image in 0.5-7 keV energy range overlayed with the grey radio contours from the MERLIN 1.6 GHz observations.





Kunert-Bajraszewska et al. 2013, ApJ,772, L7

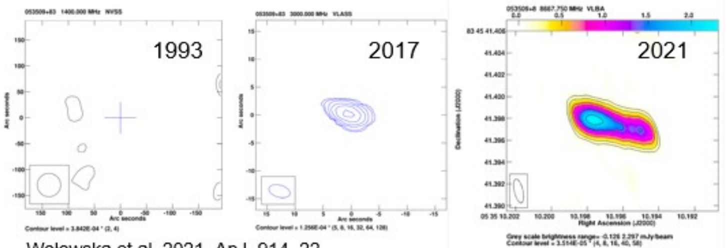
Looking inside a compact radio galaxy with high resolution



Kunert-Bajraszewska et al. 2010, ApJ,718, 1345

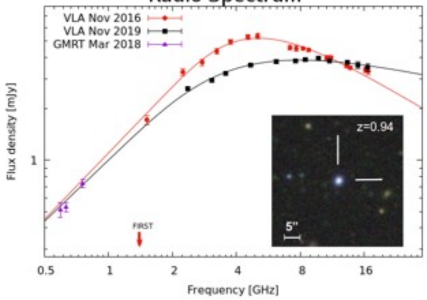
Discovery of slow radio transients

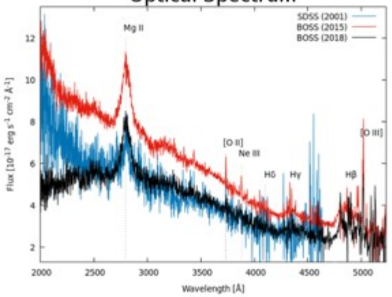
The discovered radio sources transitioned from a radio-quiet to radio-loud state after > 5–25 years of absence.



Wołowska et al. 2021, ApJ, 914, 22

During the transition they show changes in radio spectrum and UV-optical continuum.





Kunert-Bajraszewska et al. 2020, ApJ,897, 128

Morphology of radio galaxies

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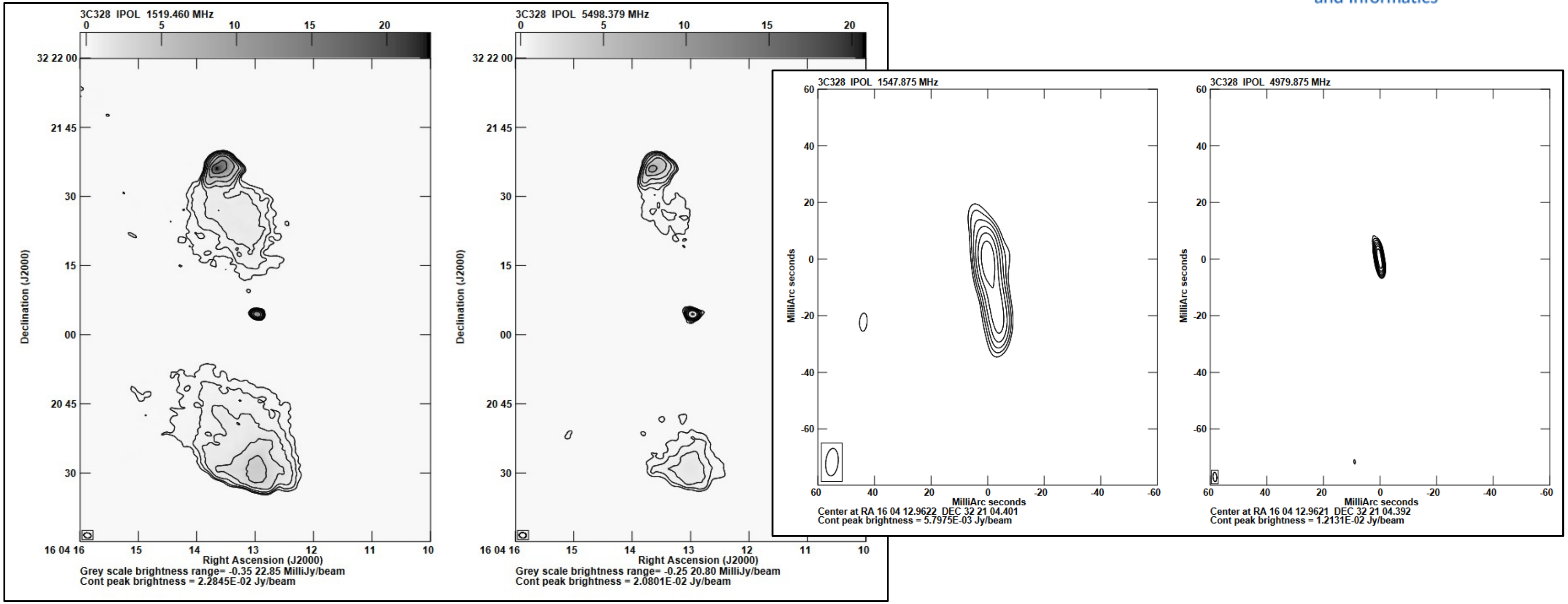

Zoom into the center of 3C 328 shows a new jets, so the source restarted activity (Marecki 2021).

Structured jet in kilonova GW170817

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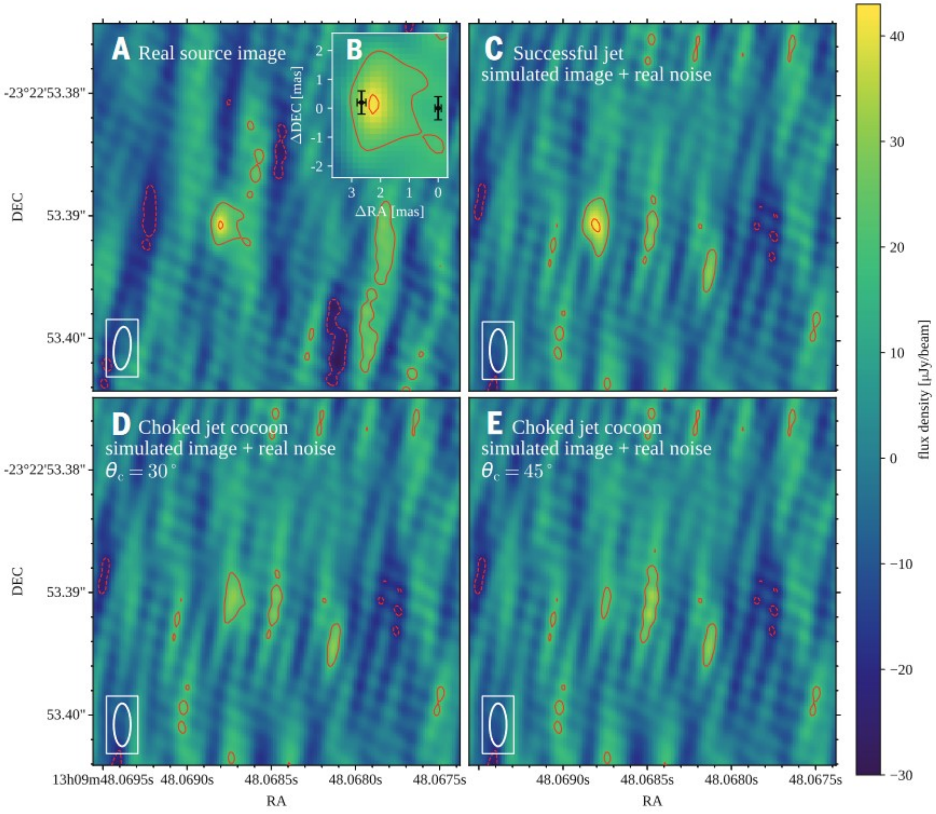

The binary neutron star merger event GW170817 was detected through both electromagnetic radiation and gravitational waves. Its afterglow emission may have been produced by either a narrow relativistic jet or an isotropic outflow.

The apparent source size is constrained to be smaller than 2.5 milliarcseconds at the 90% confidence level. This excludes the isotropic outflow scenario, which would have produced a larger apparent size, indicating that GW170817 produced a structured relativistic jet.

(Ghirlanda et al. Science 2019)

Annual parallaxes with EVN

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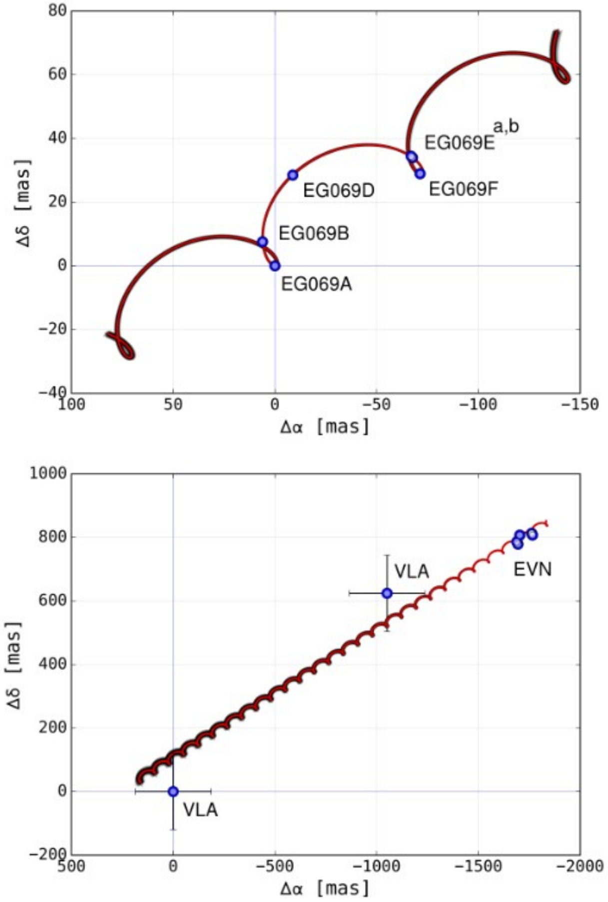

Sky-projected paralactic motion of **AM-Herculis** - binary cataclysmic system. This particular system is formed by the magnetic white dwarf (primary) and the red dwarf (secondary) - a prototype of so-called **polars**.

A new EVN observations allowed to update the annual parallax for this system with the best precision to date **(π = 11.29 ± 0.08 mas)**, equivalent to the distance of **88.6 ± 0.6 pc** (Gawroński et al. 2018).

Previous estimations of this distance where in the range from **71** to **108** pc.

Discovery of a ring of maser emission

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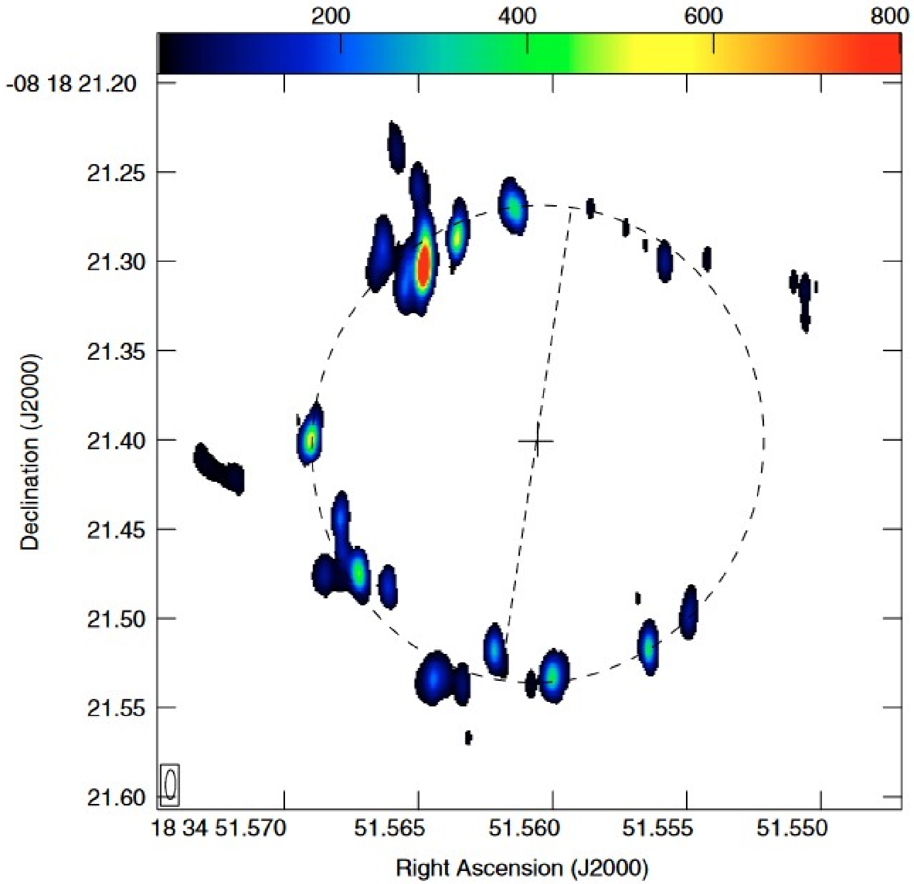
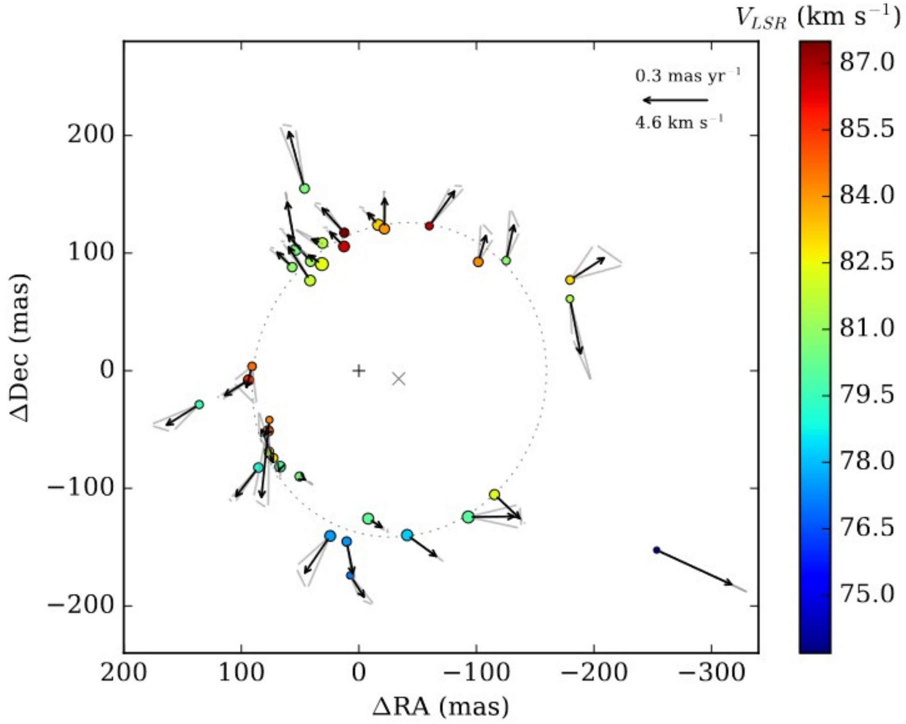


6.7 GHz methanol maser emission from the candidate **high-mass protostar** G23.657-0.127.

Spherical bubble or rotating disc seen nearly face-on?

(Bartkiewicz et al. 2005)

Further investigation of the maser ring



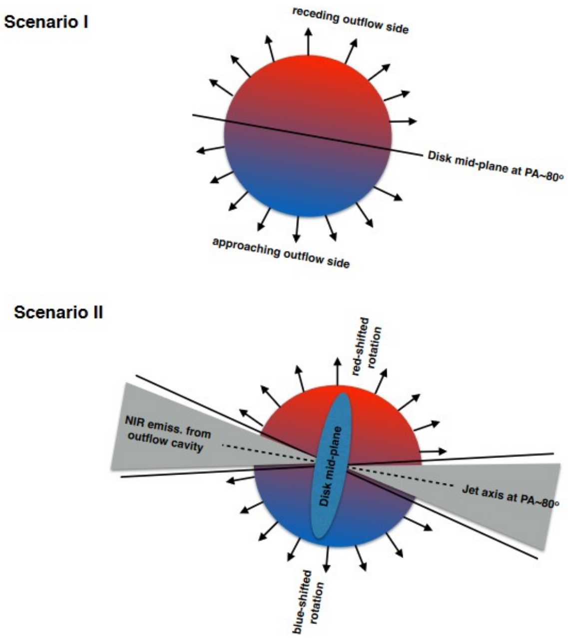


Fig. 7. Schematic models of maser expansion related to a sphere-like outflow (Scenario I) or tracing a wide angle wind at the base of the protostellar jet (Scenario II).

Two possible scenarios: spherical outflow or a wide angle wind (Bartkiewicz et al 2020).

Statistic of the publications

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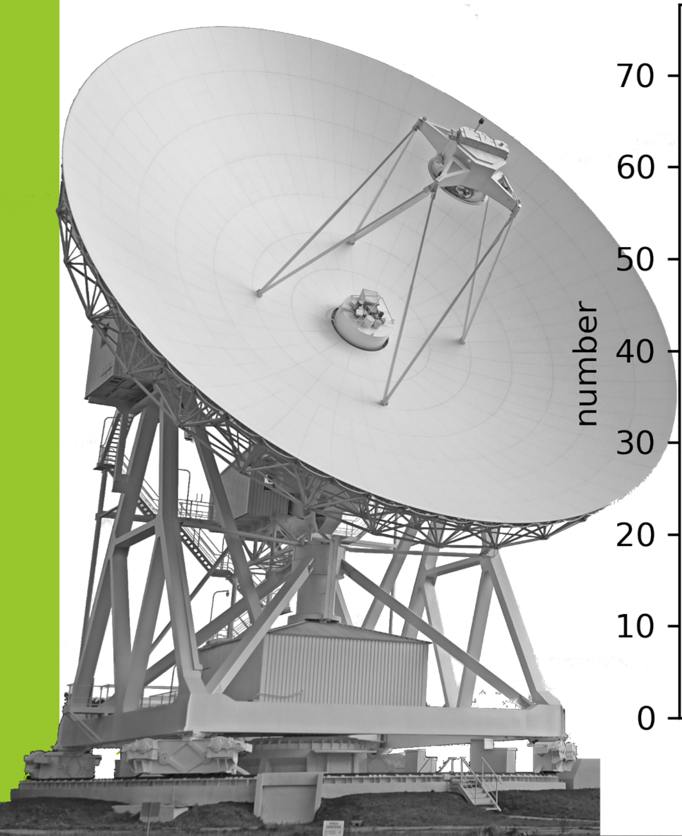

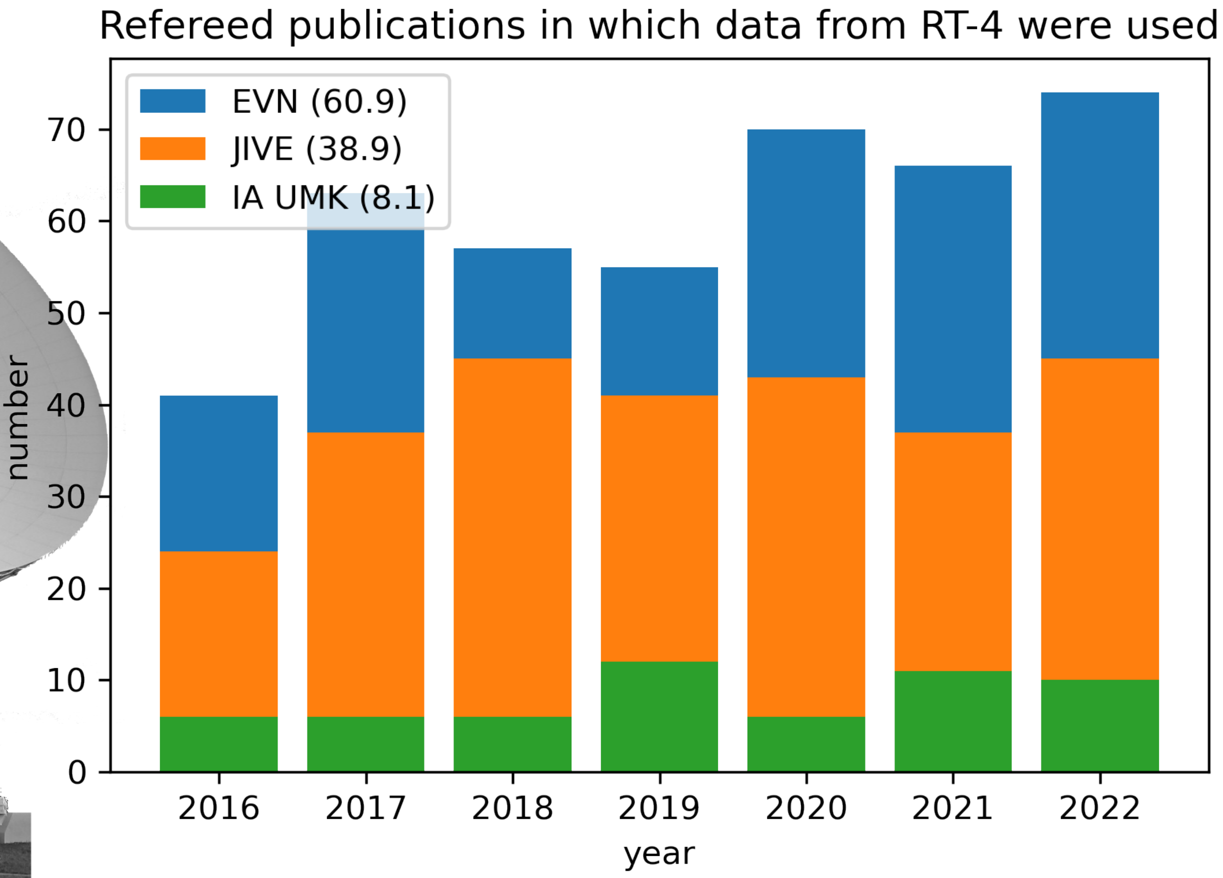

The End

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Thank you!