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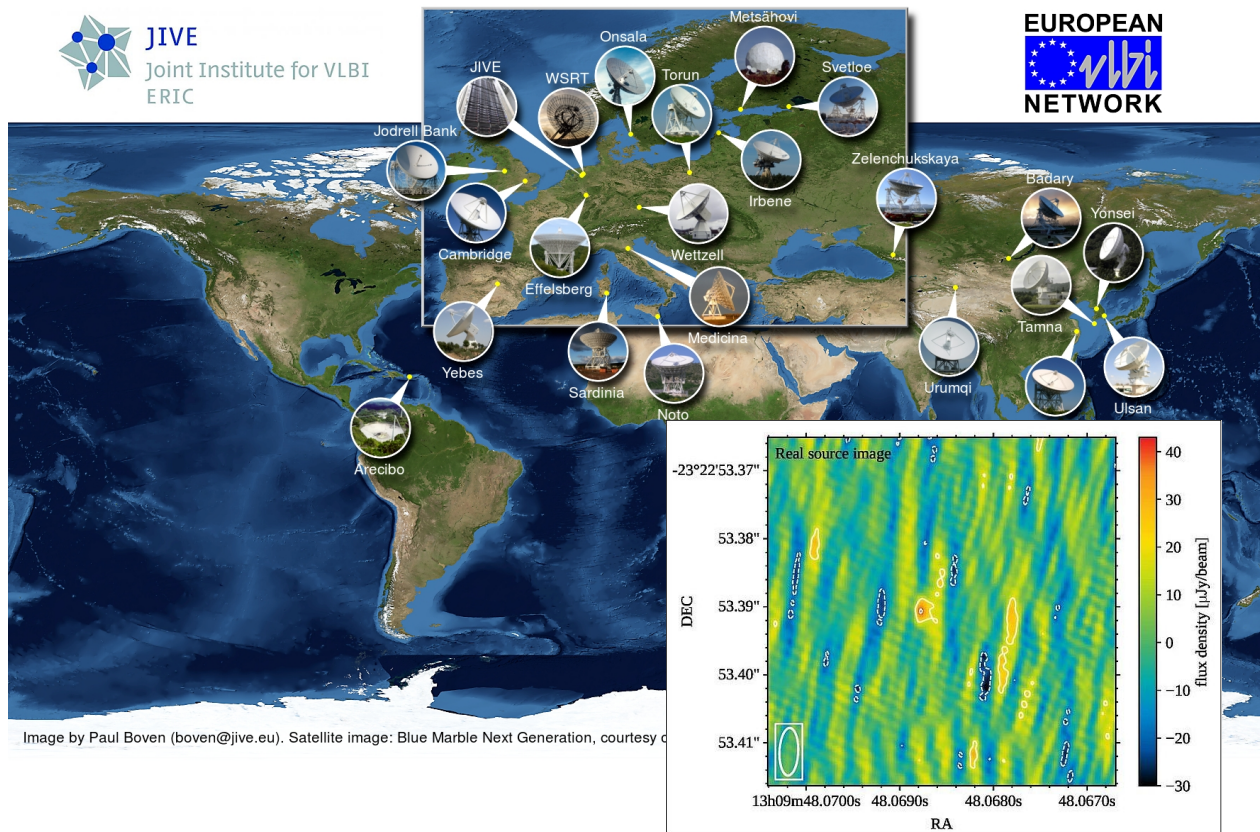
Radio observations in the era of time-domain astronomy



JIVE

Joint Institute for VLBI
ERIC

EUROPEAN
VLBI
NETWORK



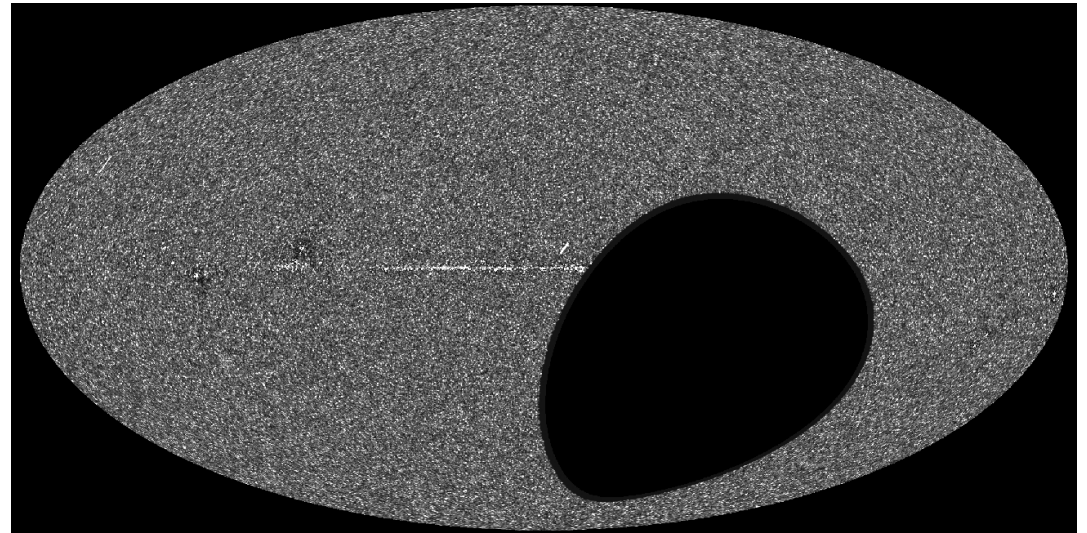
Marcin Gawroński & Magdalena Kunert-Bajraszewska

Radio catalogs:

NVSS - NRAO VLA Sky Survey Catalog

- NVSS

- NVSS Catalog covers the sky north of the J2000.0 Dec of -40 deg at 1.4 GHz (Condon+98)
- restoring beam 45"
- rms ~0.45 mJy/beam, ~2mln sources with $S > 2.5$ mJy/beam



Radio catalogs:

The Green Bank 4.85 GHz northern sky survey

- NVSS

- observations Nov 1986 – Oct 1987 by 91m transit telescope (Gregory+96)

- **GB6**

- 4.85 GHz, Dec 0 deg → 75 deg

- 75162 sources with $S > 18$ mJy/beam, restoring beam $\sim 10'$

Radio catalogs:

WENSS - Westerbork Northern Sky Survey

- NVSS

- low-frequency sky survey at 325 MHz (92 cm) (Rengeling+97)

- GB6

- restoring beam 54', Dec > 28 deg

- **WENSS**

- 292420 sources, S > 18 mJy/beam

Radio catalogs:

VLSS - VLA Low-Frequency Sky Survey Discrete Source Catalog

- NVSS

- low-frequency sky survey at 74 MHz (4m) (Cohen+07)

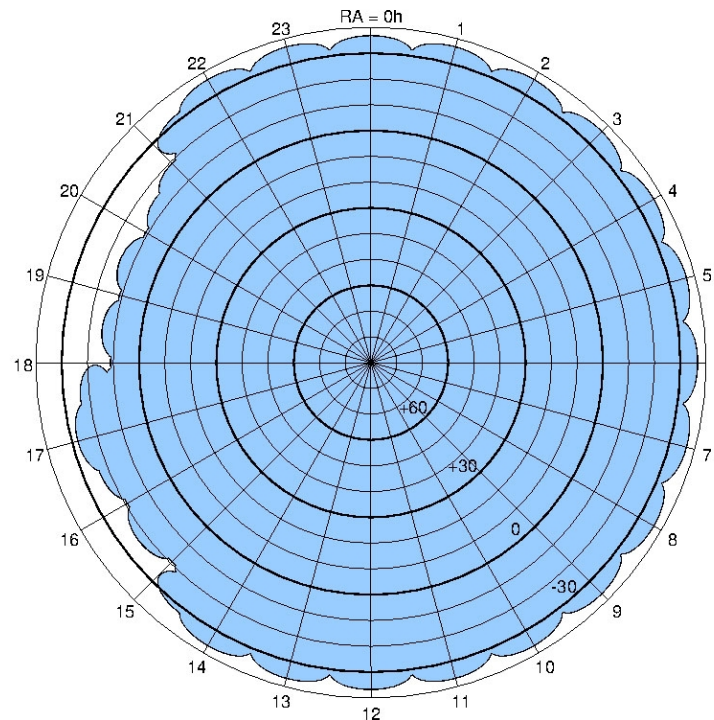
- GB6

- restoring beam $\sim 80''$, Dec $> \sim 30^\circ$

- WENSS

- ~ 70000 sources, $S > 0.1$ Jy/beam

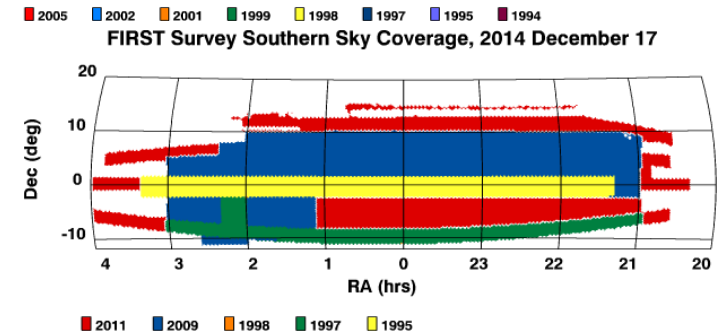
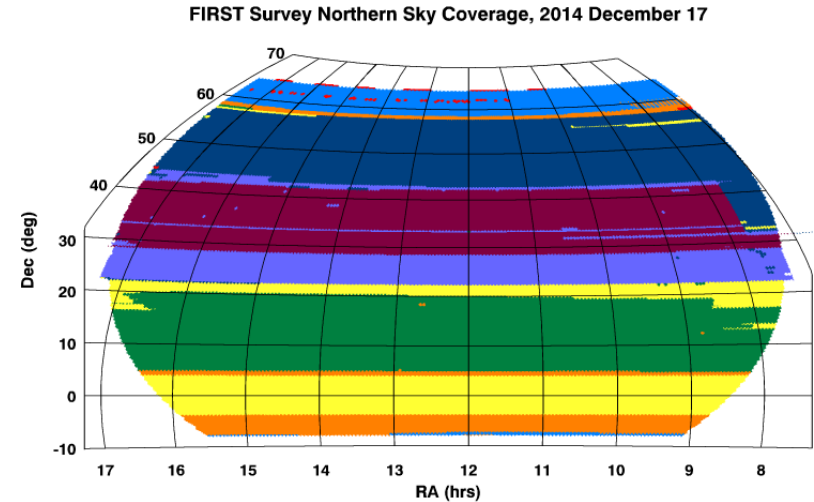
- **VLSS**



Radio catalogs:

Faint Images of the Radio Sky at Twenty-Centimeters

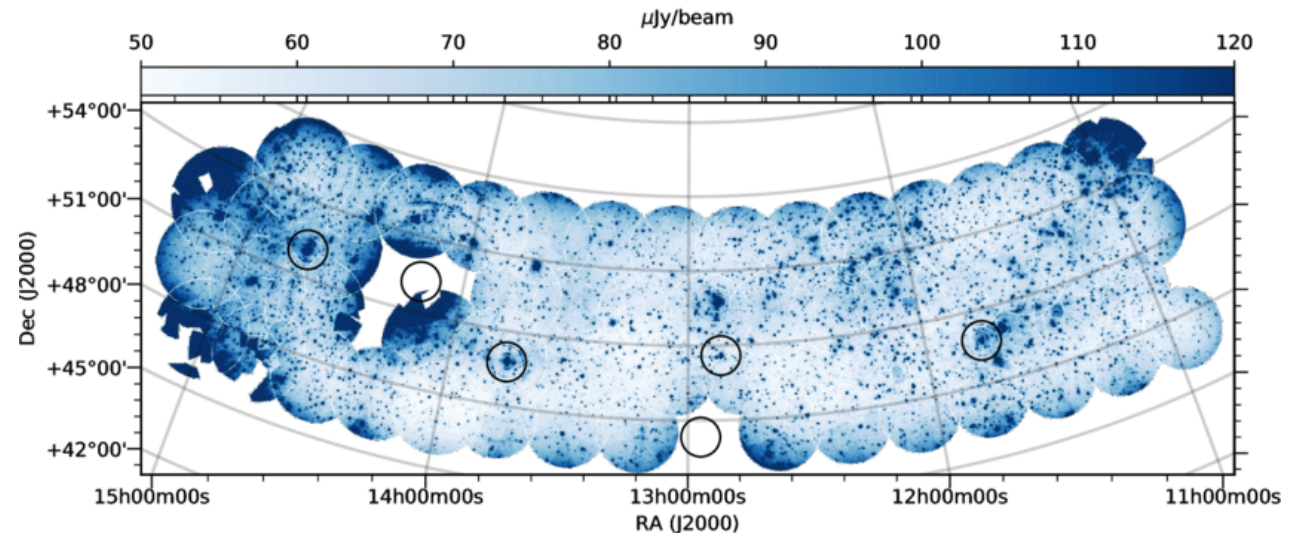
- NVSS
 - radio equivalent of the Palomar Observatory Sky Survey (Becker+94)
- GB6
 - 1.4 GHz, restoring beam 5"
- WENSS
 - ~946000 sources, ~10600 deg²
 - $S > 1$ mJy/beam, ~35% sources have resolved structures
- VLSS
- **FIRST**



Radio catalogs:

The Low Frequency Array (LOFAR) Two-metre Sky Survey

- NVSS
 - deep 128-168 MHz image survey, Dec > 0 deg (Shimwell+17)
- GB6
 - restoring beam $\sim 25''$, S > 0.3 mJy/beam
- WENSS
 - DR1: ~ 44000 sources
 - ongoing observations
- VLSS
- FIRST
- **LoTSS**



Radio catalogs:

The Very Large Array Sky Survey

- NVSS
 - started in 2017, Dec > 40 deg, 2 – 4 GHz, beam ~2".5, S > 70 μ Jy/beam (Lacy+19)
- GB6
 - significant improvement in sensitivity, ~10 mln sources catalog.

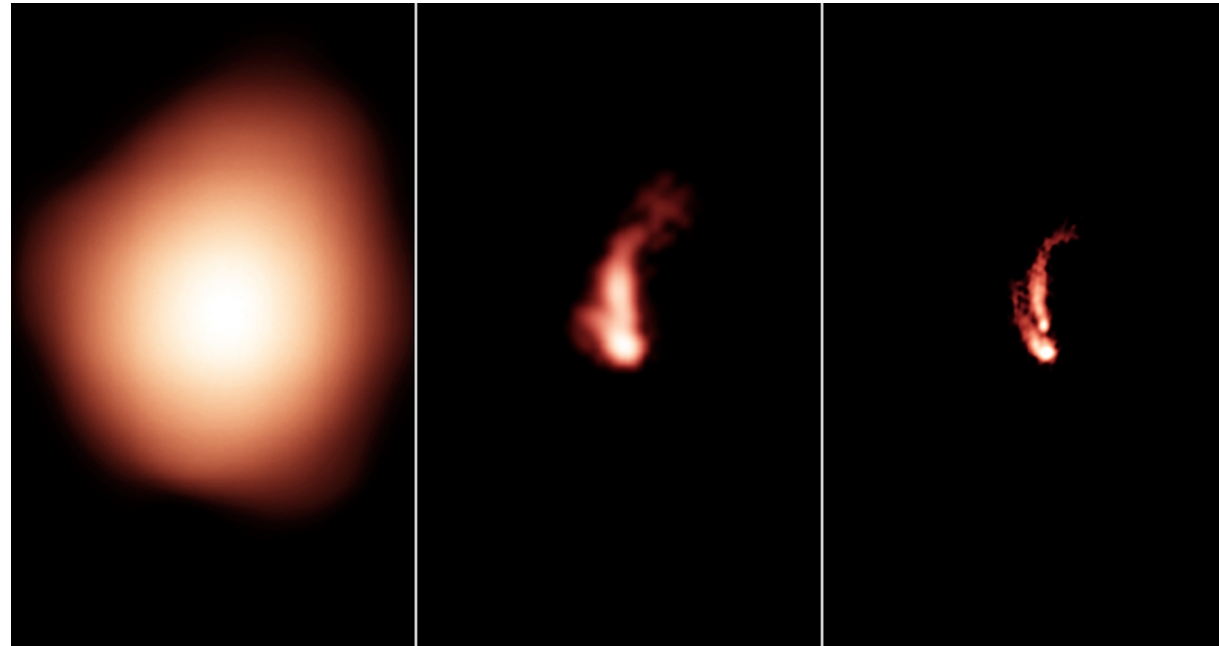
- WENSS

- VLSS

- FIRST

- LoTSS

- **VLASS**



NVSS

FIRST

VLASS

Radio catalogs:

- NVSS
 - precise positions with mas accuracy
- GB6
 - correlated fluxes at ~5000km baselines (VLBA, EVN, ATCA)
- WENSS

- VLSS

- FIRST

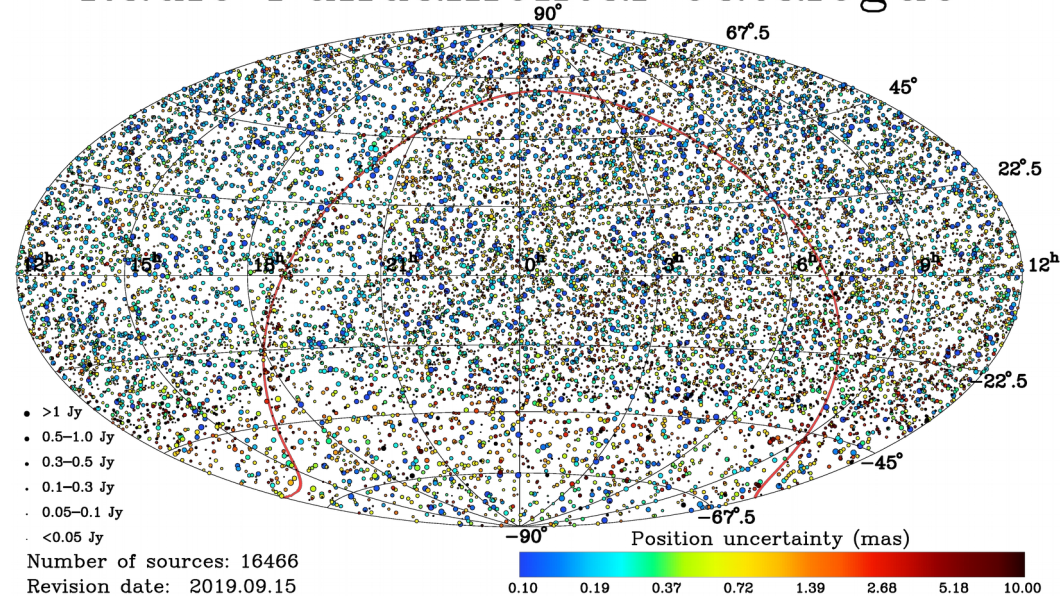
- LoTSS

- VLASS

- **RFC**

Radio Fundamental Catalog

Radio Fundamental Catalogue

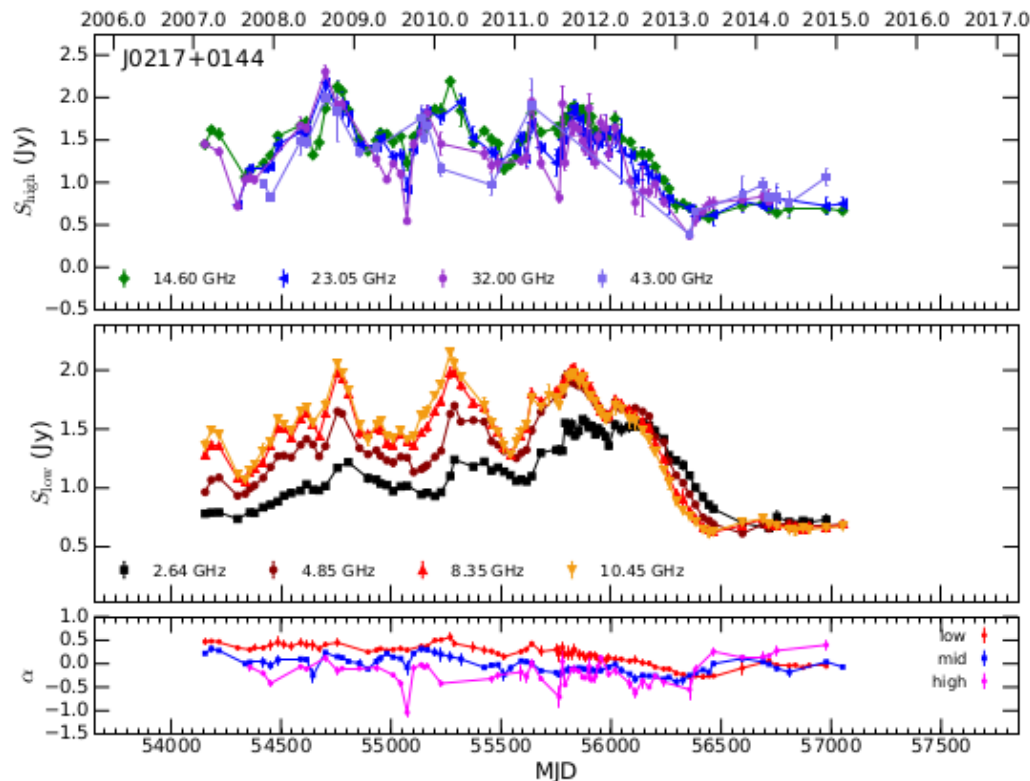


Variable radio sources:

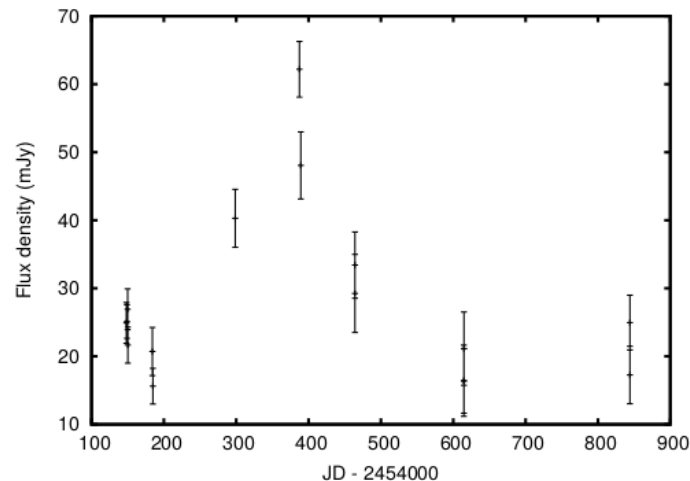
AGN central engine activity

- quasars (days – years)

- physical processes (shock/new blobs in the jet structures)



F-GAMMA (Angelakis+19)



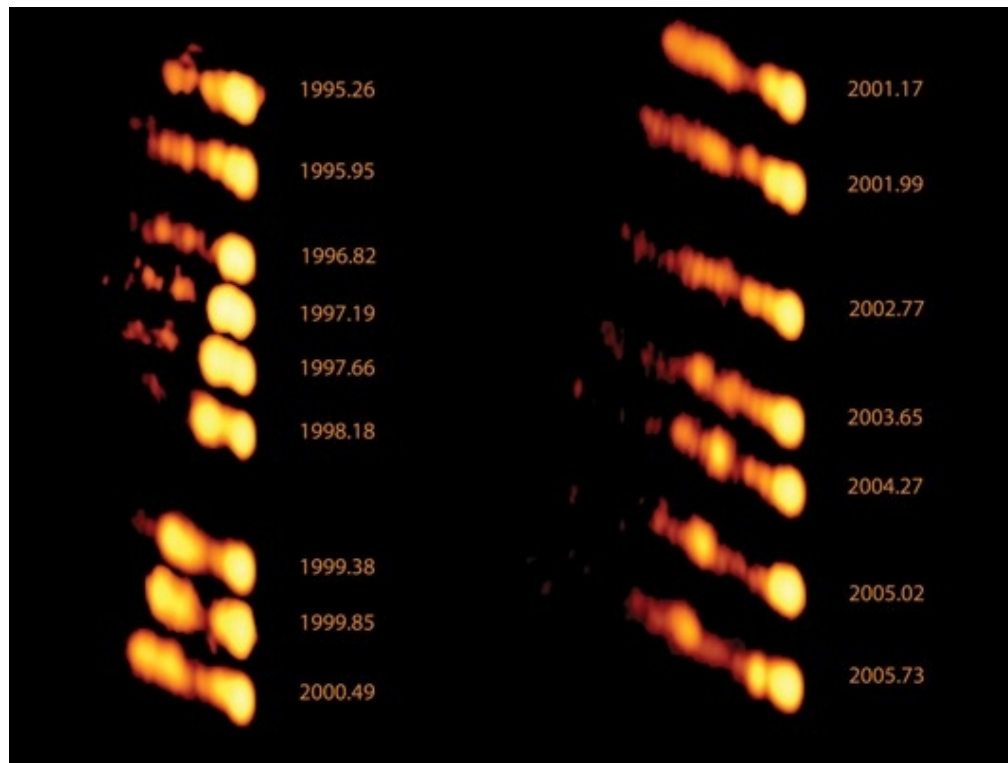
OCRA-p survey at 30 GHz
(Gawroński+09)

Variable radio sources:

AGN central engine activity

- **quasars (days – years)**

- physical processes (shock/new blobs in the jet structures)



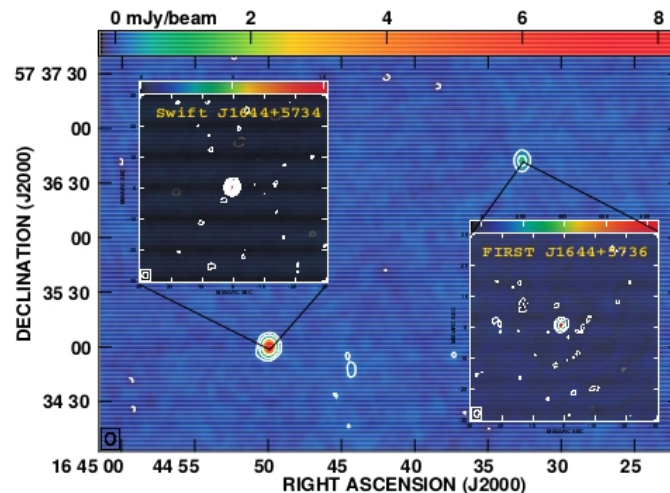
Jet evolution in 3c 111 (Kadler+07)

Variable radio sources:

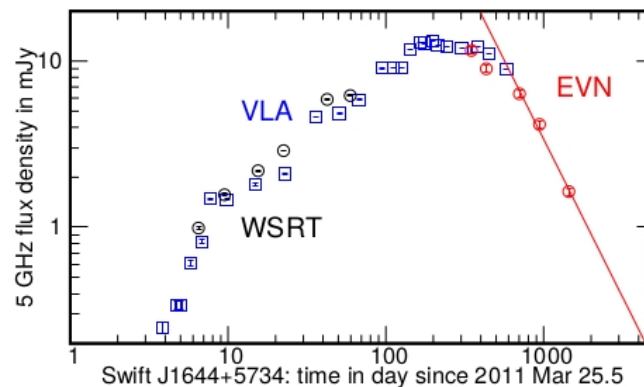
- quasars (days – years)

- **TDE** (days – years)

Radio emission in Swift J1644+5734



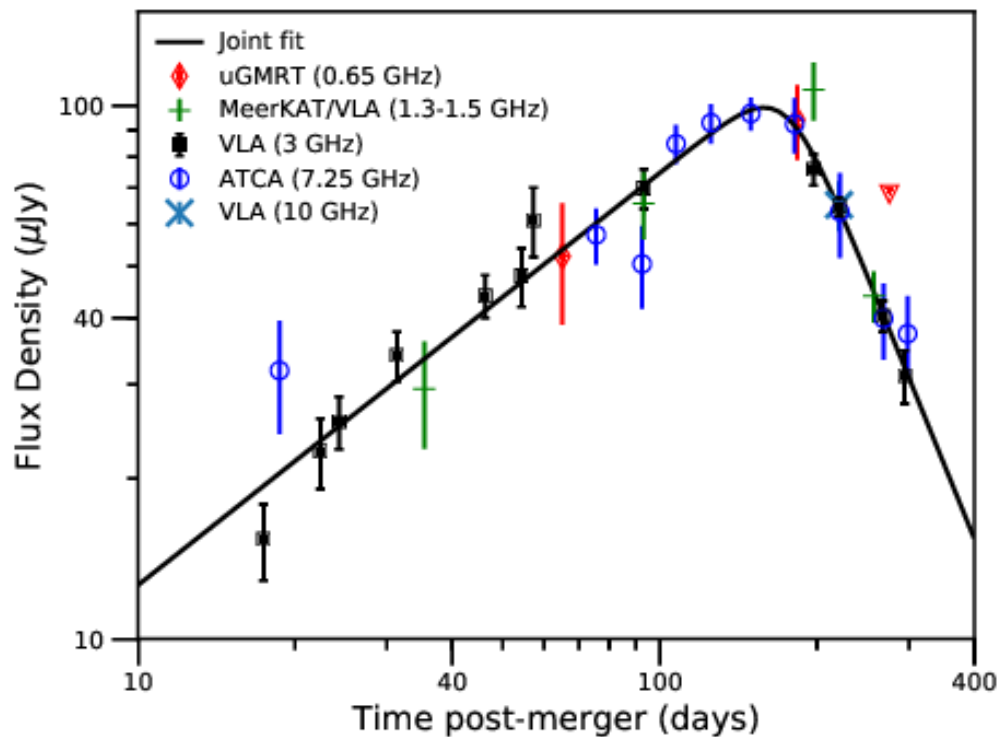
EVN image at 5cm
(Yang+18)



Variable radio sources:

- quasars (days – years)
- TDE (days – years)
- **BNS mergers (days – years)**

SSS 17a radio light curve

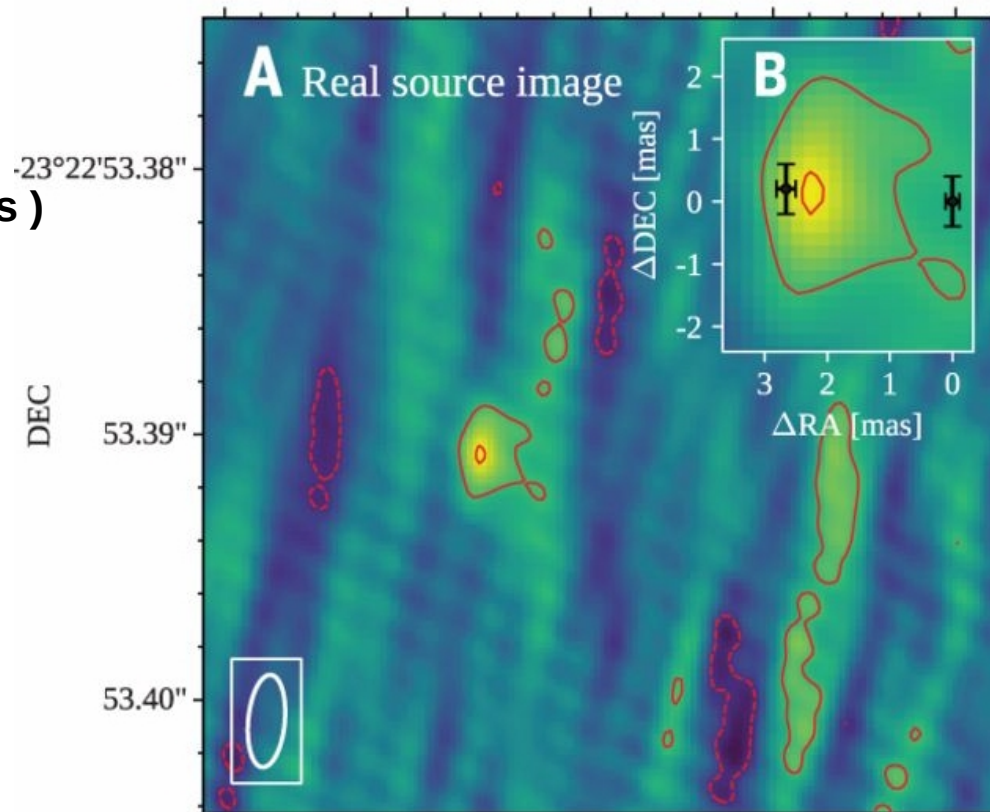


Mooley+18

Variable radio sources:

- quasars (days – years)
- TDE (days – years)
- **BNS mergers (days – years)**

Superluminal motion in SSS 17a



$$\beta_{\text{app}} = 4.1 \pm 0.5 \text{ c}$$

(Mooley+18)

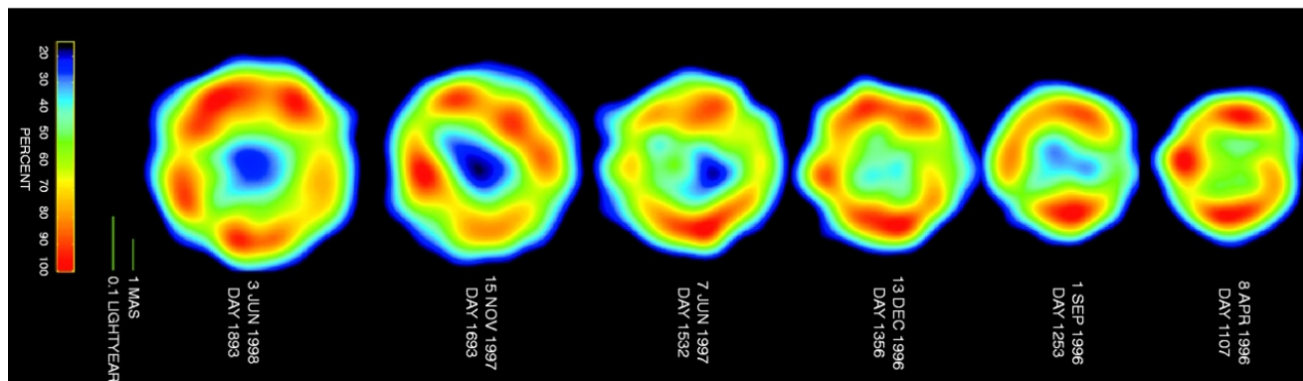
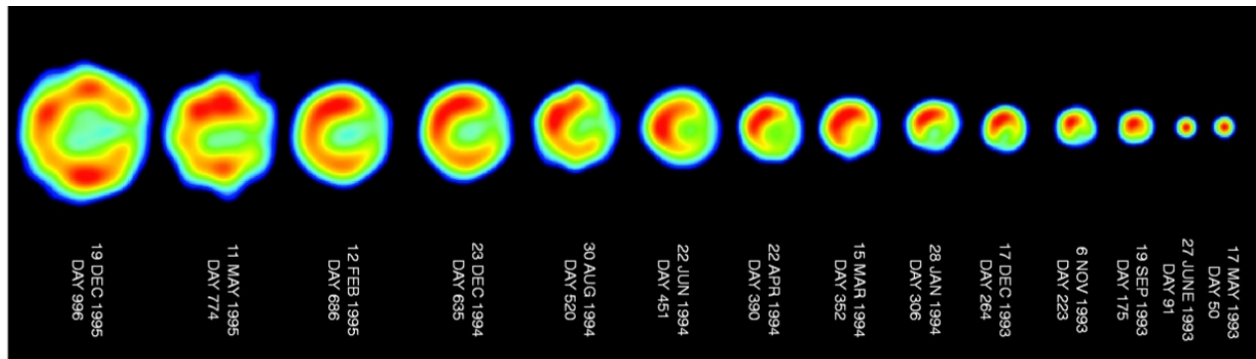
Global VLBI map at 6cm (Ghirlanda+19)

Variable radio sources:

- quasars (days – years)
- TDE (days – years)
- BNS mergers (days – years)
- **supernovae (days – years)**

Radio emission in SN (mostly type IIIn)

- evolution of the supernovae remnants



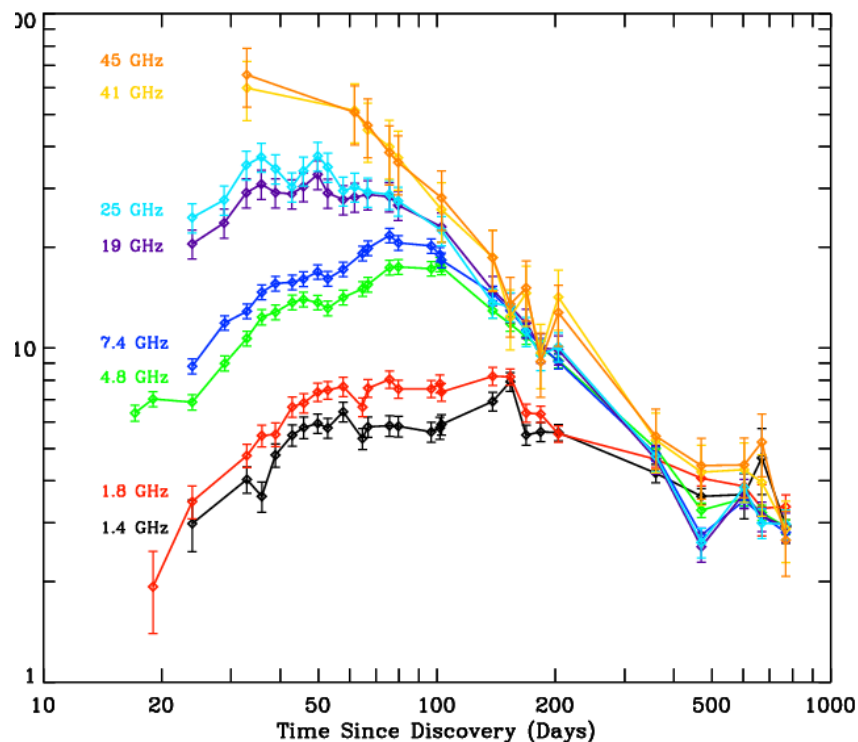
SN 1993J in M81 (Bartel+00)

Variable radio sources:

- quasars (days – years)
- TDE (days – years)
- BNS mergers (days – years)
- supernovae (days – years)
- **novae (days – years)**

Radio emission in nova stars

- shocks moving through the envelope



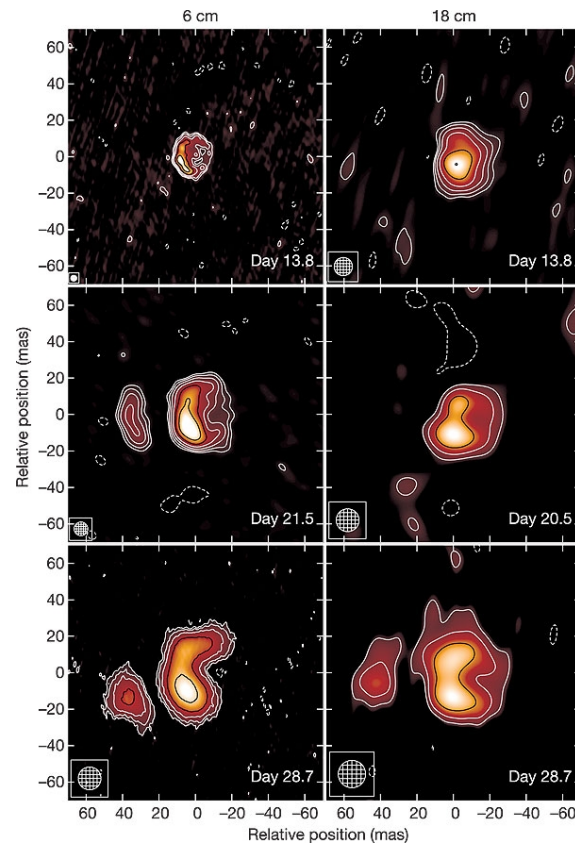
V407 Cyg – VLA (Chomiuk+12)

Variable radio sources:

- quasars (days – years)
- TDE (days – years)
- BNS mergers (days – years)
- supernovae (days – years)
- **novae (days – years)**

Radio emission in nova stars

- shocks moving through the envelope



VLBA images of RS Oph
(Eyres+06)

Variable radio sources:

- quasars (days – years)

- TDE (days – years)

- BNS mergers (days – years)

- supernovae (days – years)

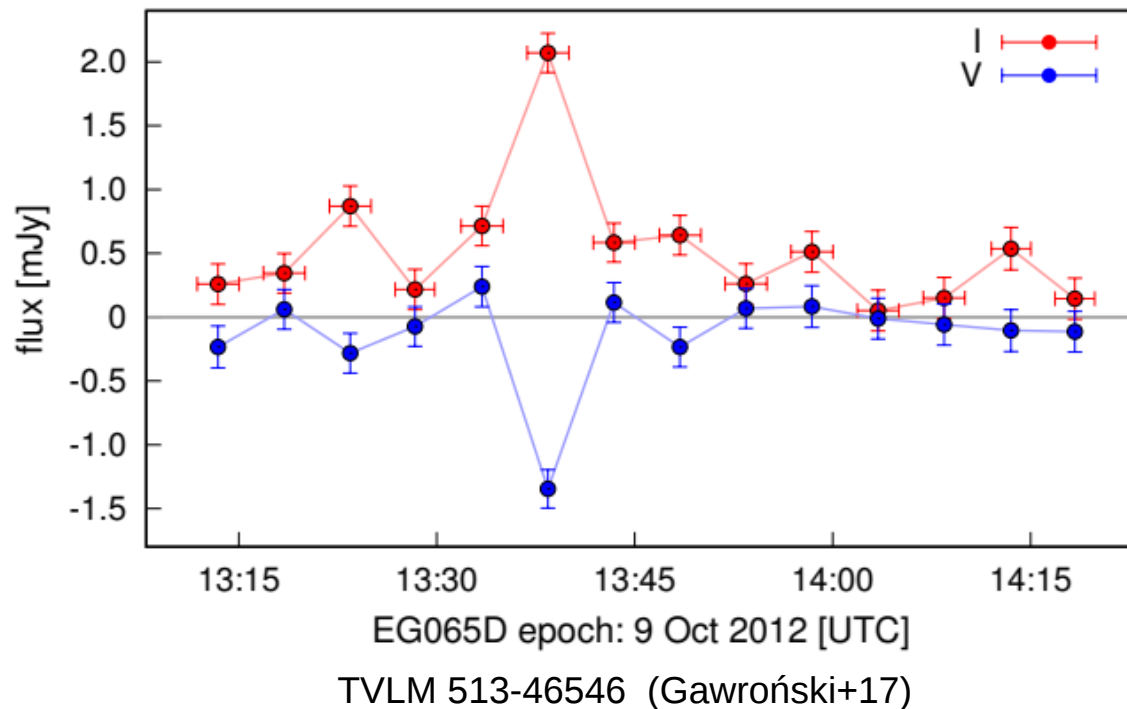
- novae (days – years)

- **flare stars (min - days)**

Radio emission from young, magnetically active red dwarfs

- radio flares due to magnetic reconnection and electron cyclotron maser instability

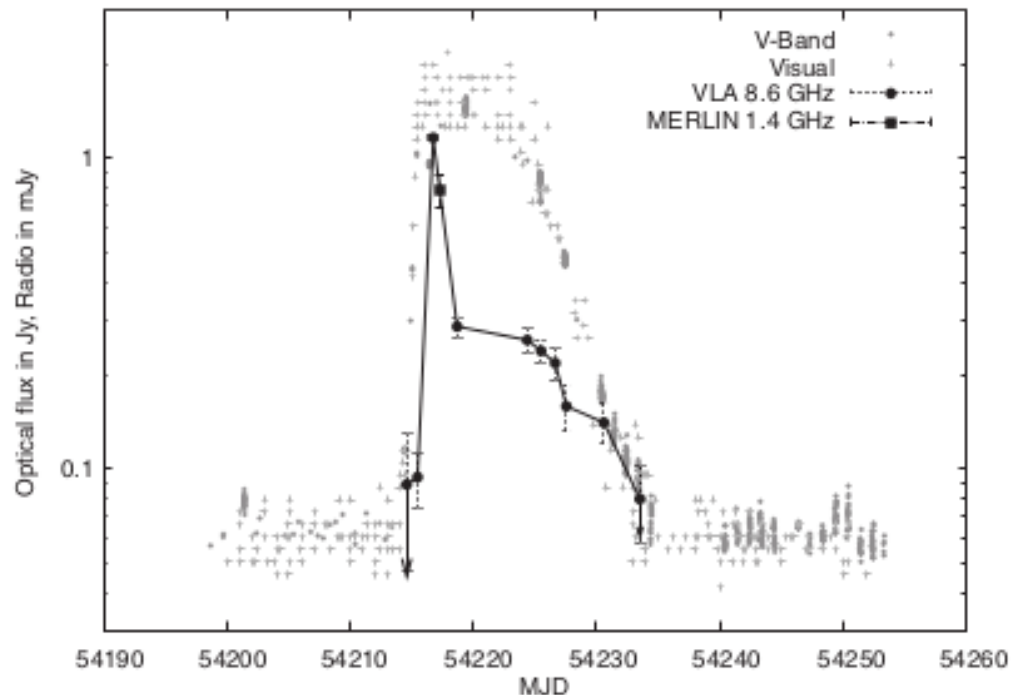
- quiescent emission due to gyrosynchrotron radiation in large scale kG fields



Variable radio sources:

- quasars (days – years)
- TDE (days – years)
- BNS mergers (days – years)
- supernovae (days – years)
- novae (days – years)
- flare stars (min – days)
- **CV systems (hours – days)**

CV stars produce transient jets during outbursts



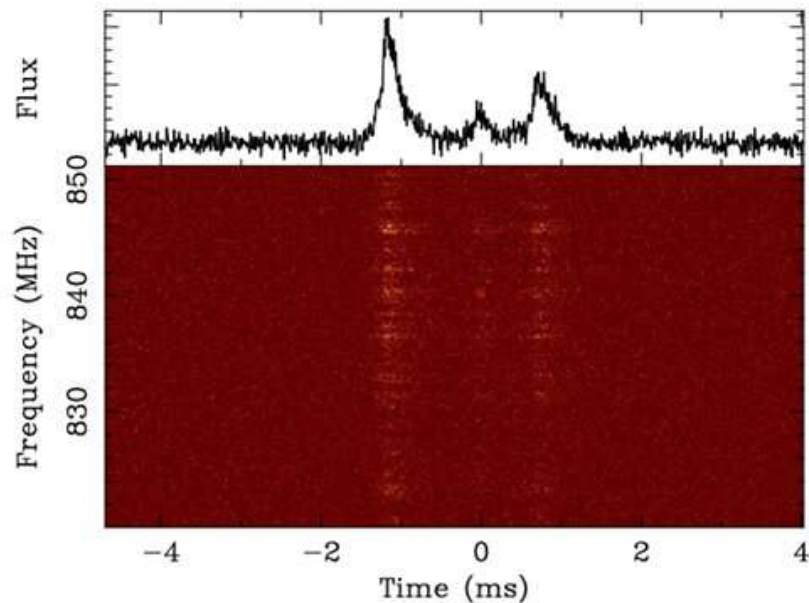
SS Cyg (Kording+08)

Variable radio sources:

- quasars (days – years)
- TDE (days – years)
- BNS mergers (days – years)
- supernovae (days – years)
- novae (days – years)
- flare stars (min – days)
- CV systems (hours – days)
- **Fast Radio Bursts (~millisec)**

FRB – new phenomenon discovered in the radio domain
(Lorimer+07)

- cosmological sources
- origin(?), evolution (?), physical processes (??)



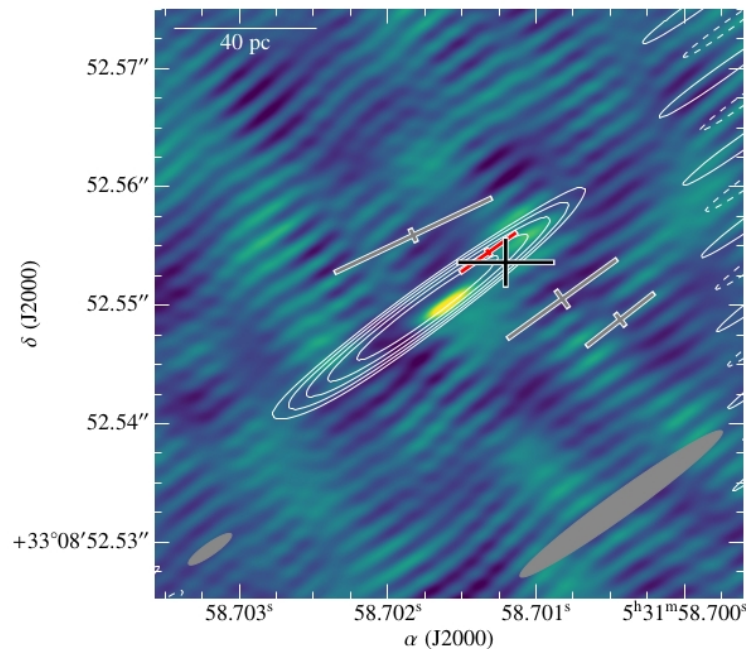
FRB profile (Farah+19)

Variable radio sources:

- quasars (days – years)
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- novae (days – years)
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FRB – new phenomenon discovered in the radio domain
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- using VLBI astrometry it is possible to estimate the FRB position with submas accuracy



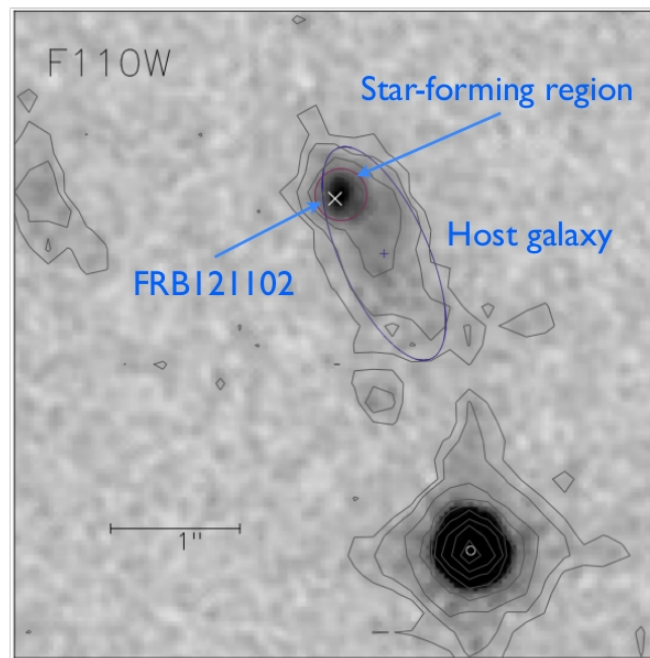
EVN map of FRB 121102 (Marcote+17)

Variable radio sources:

- quasars (days – years)
- TDE (days – years)
- BNS mergers (days – years)
- supernovae (days – years)
- novae (days – years)
- flare stars (min – days)
- CV systems (hours – days)
- **Fast Radio Bursts (~millisec)**

FRB – new phenomenon discovered in the radio domain
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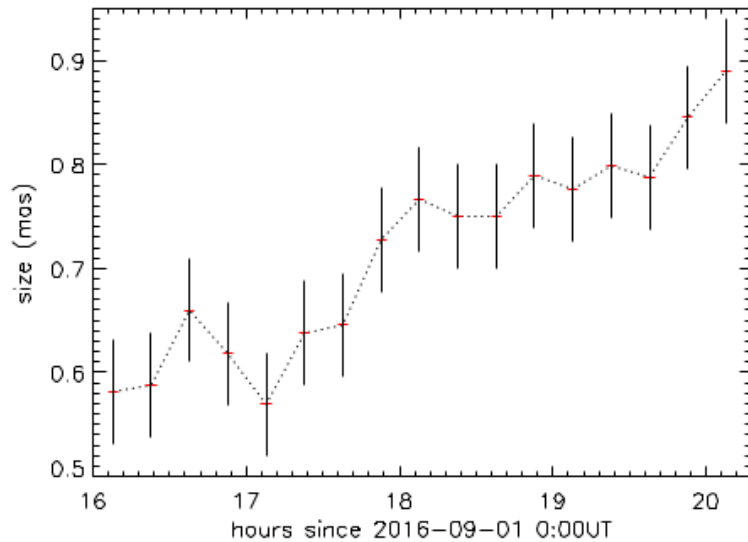
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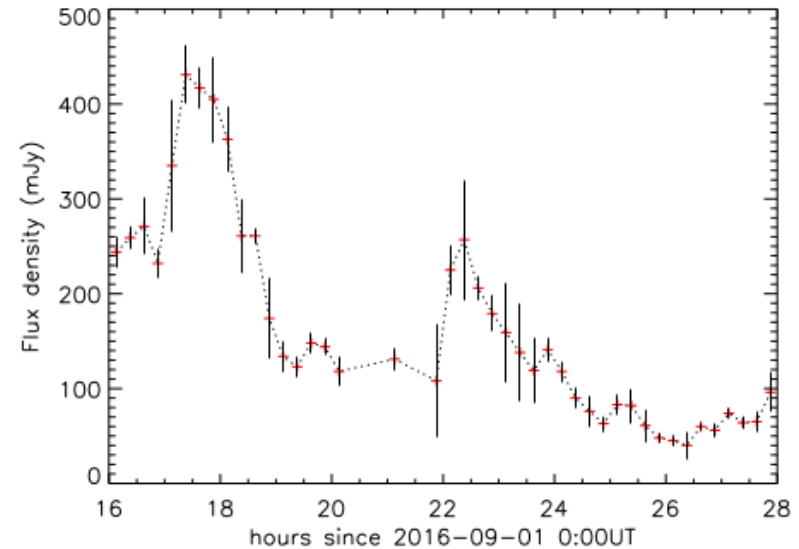
Bassa+17

New possibilities with VLBI observations

- rapid improvement in sensitivity → shorter integration time → more targets to observe
- due to software correlators it is possible to organize smaller networks inside the EVN structure
- Cyg X-3 giant flare episode in 2016 – five antennas network at 22 GHz (Sr – Mc – No – Tr – Ys)



Expansion of the emitting region

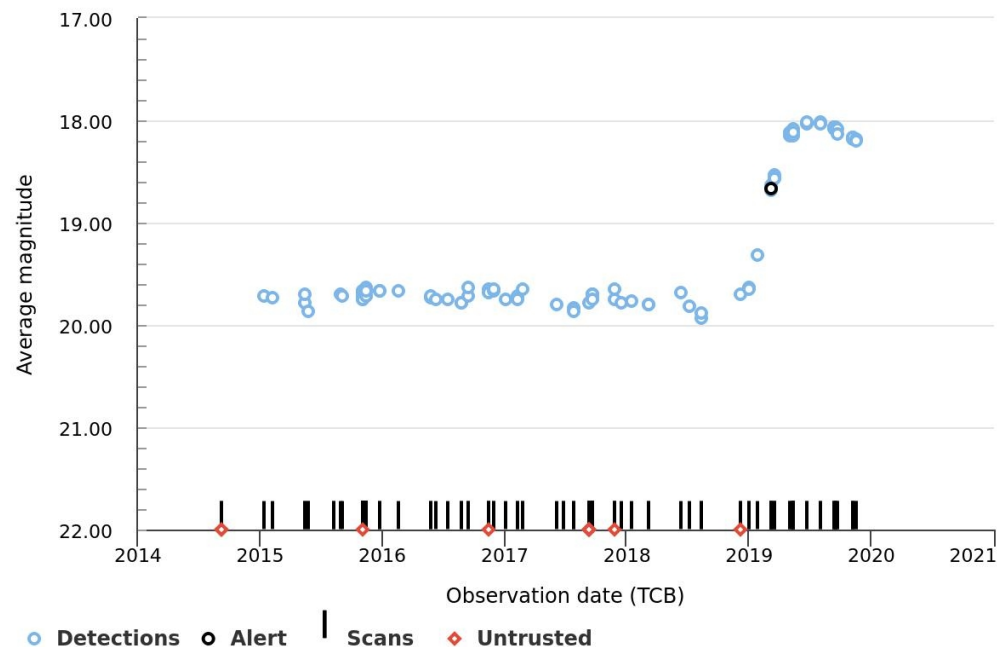


VLBI radio light curve

Egron+17

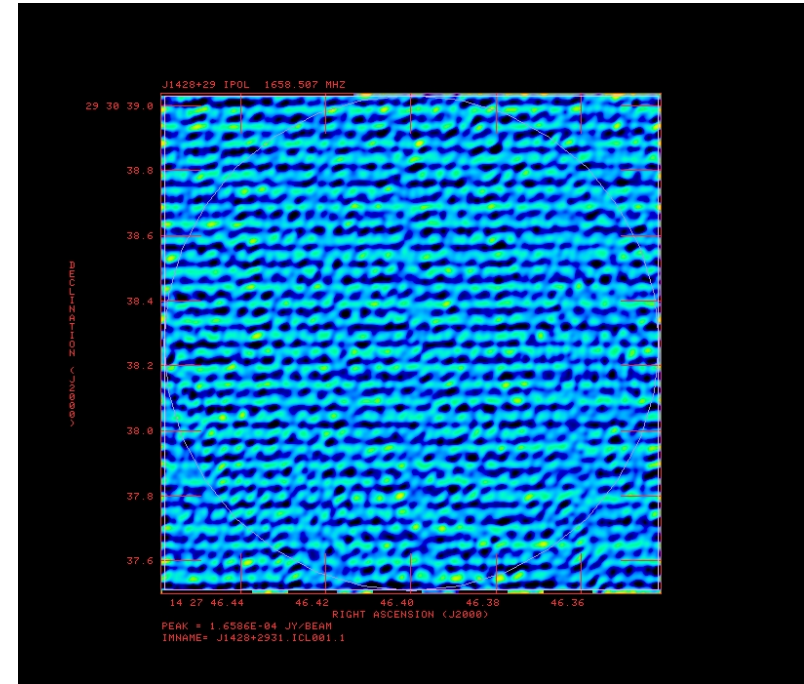
GAIA transient Gaia19axp

- alerting date 2019-03-10
- bluish QSO at $z=0.373$
- no detection in available radio catalogs
- changes in the optical spectrum after the alert
- changes in accretion rate/accretion mode?
- the origin of the radio loud/radio quiet AGN dichotomy
- do we observe the birth of radio structures?



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- do we observe the birth of radio structures?
- short e-VLBI 2hrs observations 2019-06-18 at 1.6 GHz



No detection with upper limit of 110 μ Jy :(
Probable worth to check again...



Thanks for your attention