

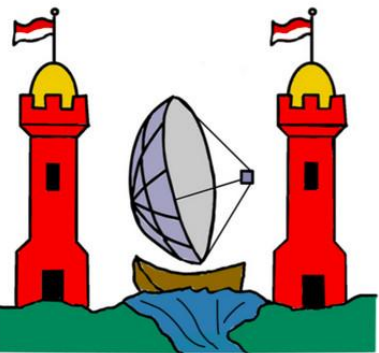
J2102+6015

*An intriguing radio-loud
AGN in the
early Universe*

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***15th EVN Symposium & Users Meeting:
Providing the Sharpest View of the Universe***

***University College Cork, Ireland
July 11-15, 2022***



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Fengchun **Shu** (*SHAO, CN*)

Oleg **Titov** (*GA, AU*)

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Yingkang **Zhang** (*SHAO, CN*)

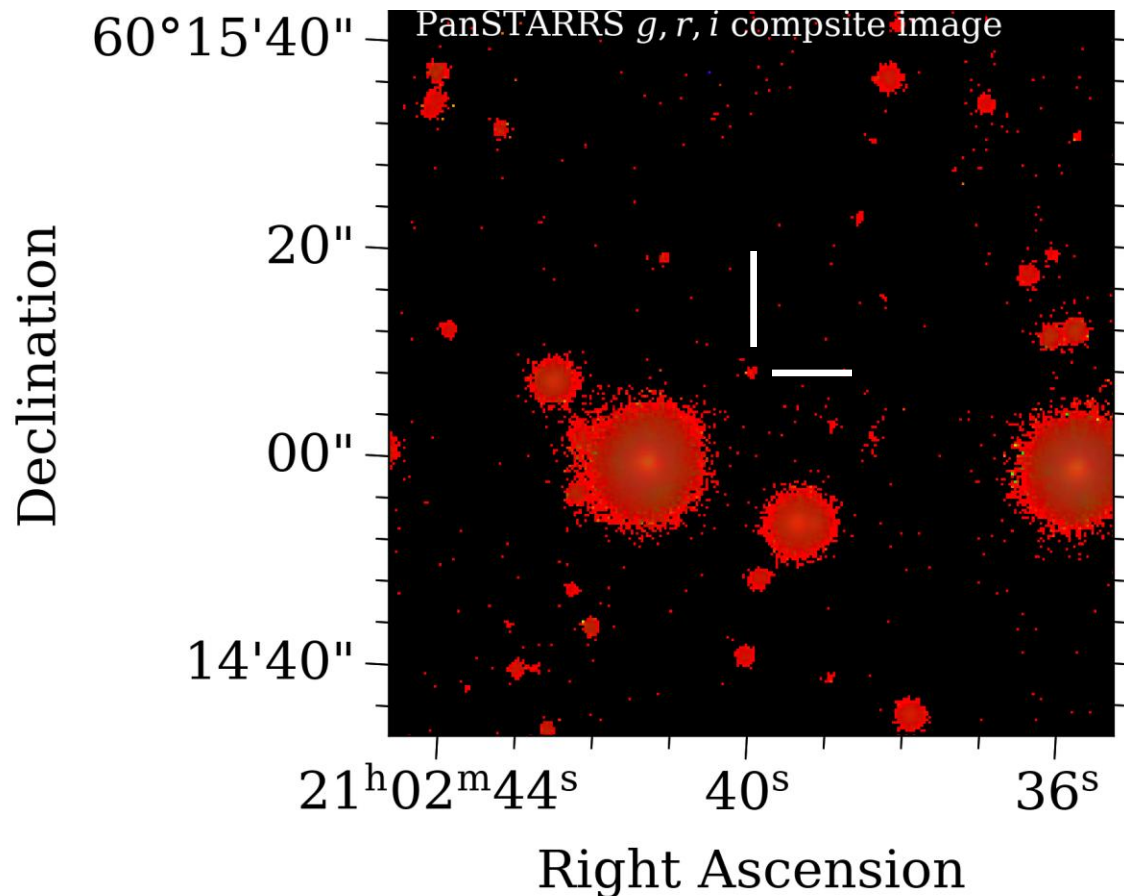
EVN project:
EF029

J2102+6015: a short professional CV

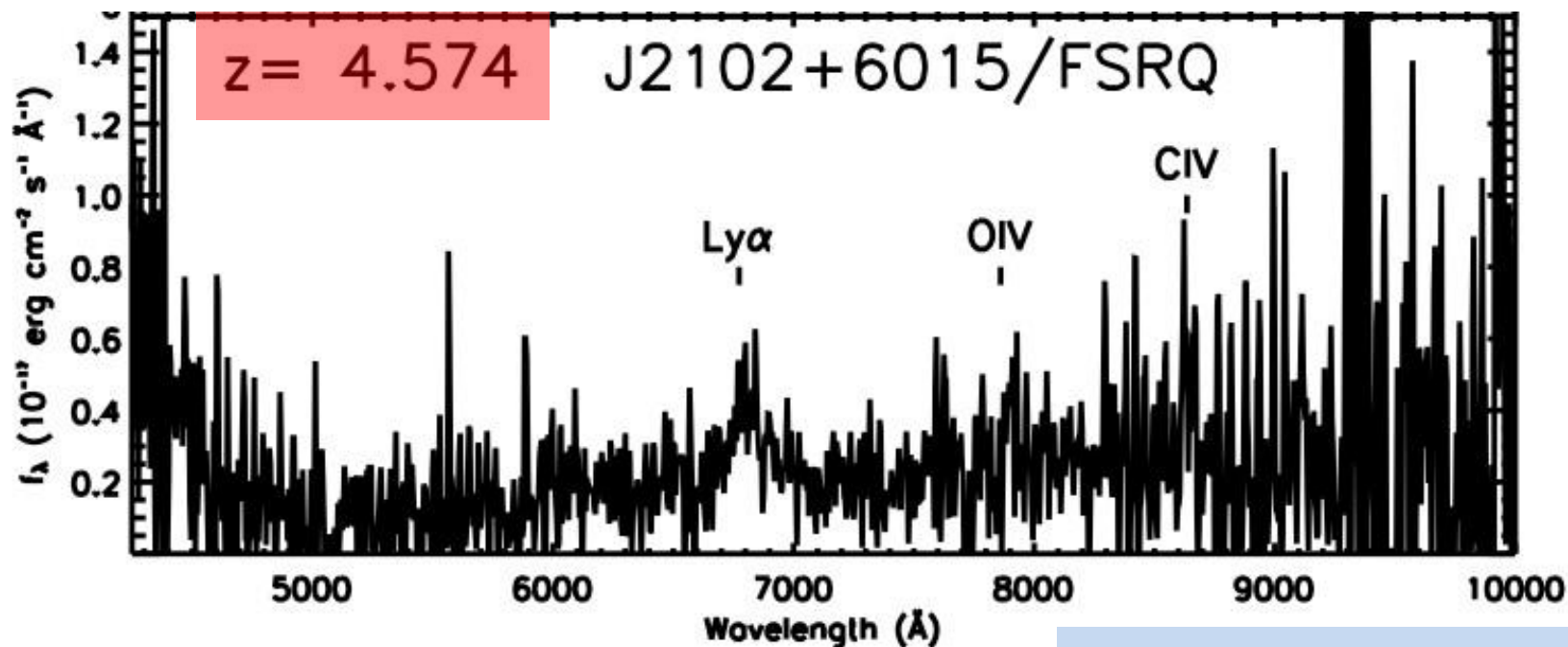
- I started my astronomical career in the early 1990's as a few 100 mJy source in cm-wavelength **radio surveys**
- I became a **candidate** for a radio counterpart of a *CGRO*/EGRET **gamma-ray source**
- I had my **spectroscopic redshift** measured in the early 2000's
- I have a compact radio structure and serve as a **VLBI calibrator** and **astrometric reference** source
- My current position is a member of the exclusive **high-redshift ($z>4$) radio** AGN club

J2102+6015: pictures for the CV

Well, I don't look very impressive in visible and infrared lights...
you can't even find me in the *WISE*, *SDSS*, *Gaia* catalogues



What about my redshift then?



Sowards-Emmerd+ 2004, *ApJ*

TABLE 4
HET SPECTROSCOPY: NORTHERN FOLLOW-UP

Name	FoM	R.A. (J2000.0)	Decl. (J2000.0)	R2 ^a	B2 ^a	<i>z</i>	Type
J0205+1444.....	2.58	02 05 13.12	+14 44 32.4	2.8504	f
J1226+4340.....	0.95	12 26 57.91	+43 40 58.4	19.2	19.3	2.0023	f
J1322+2148.....	0.29	13 22 11.40	+21 48 12.3	19.4	19.3	1.6803	f
J2102+6015.....	0.41	21 02 40.22	+60 15 09.8	4.5749:	f

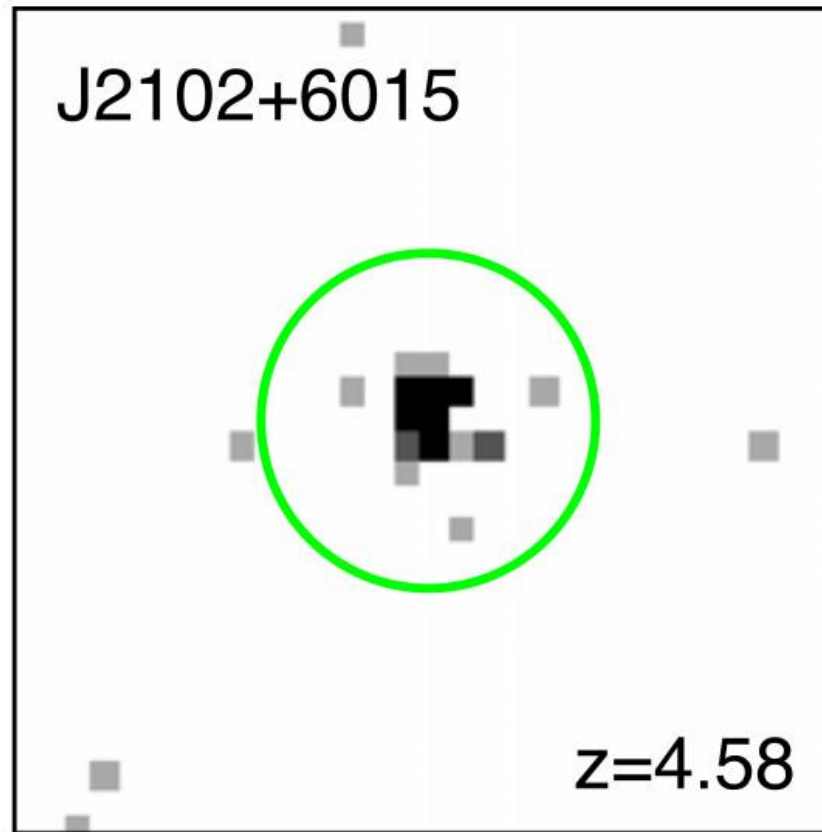
NOTE.—Marginal (e.g., single line or low S/N) redshift estimates are denoted by a colon.

^a R2 and B2 are USNO B1.0 optical magnitudes (Monet et al. 2003).

^b Classification: f = FSRQ.

J2102+6015: pictures for the CV

I look better (?) in the invisible...

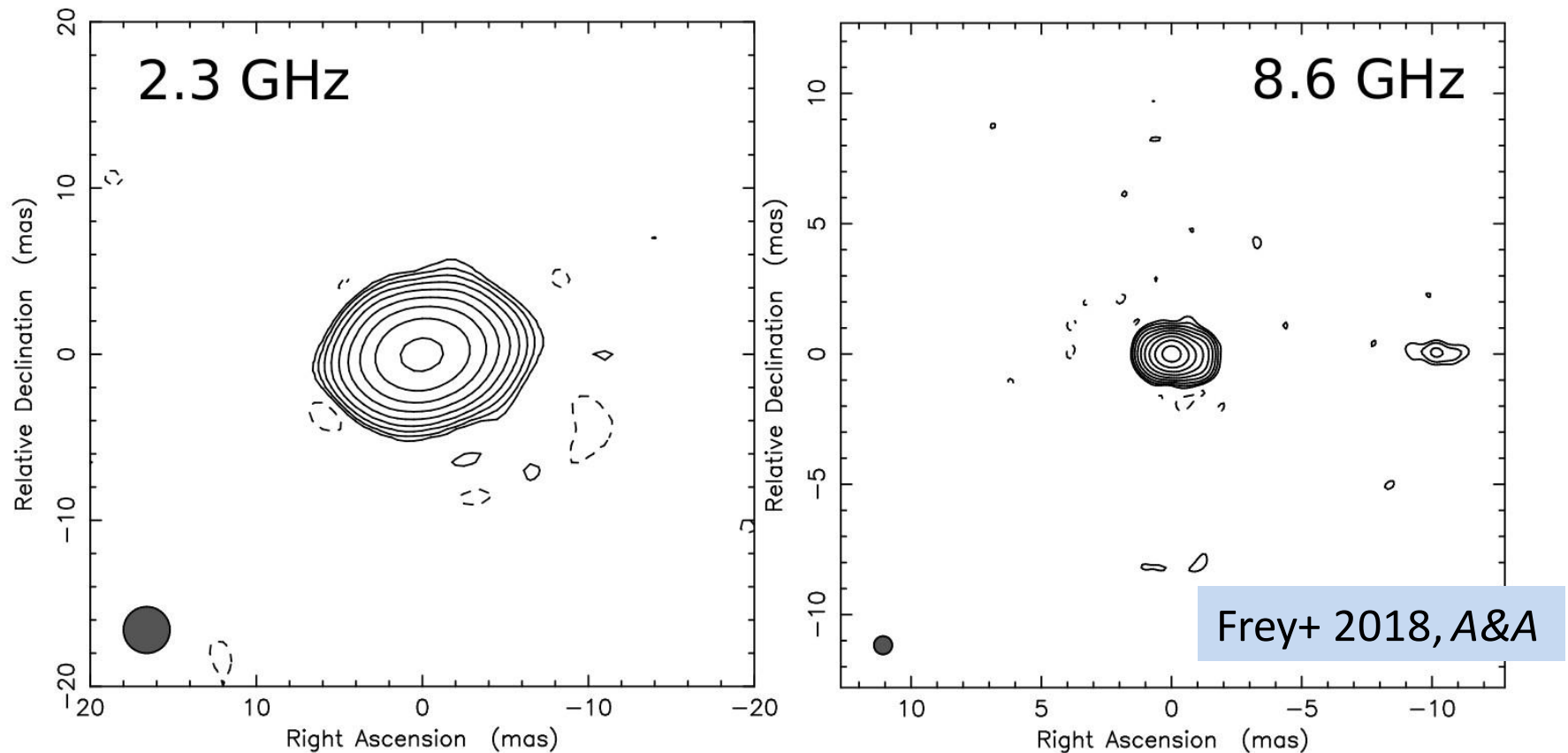


Chandra X-rays

Snios+ 2020, *ApJ*

J2102+6015: pictures for the CV

...but certainly nicer in the radio!

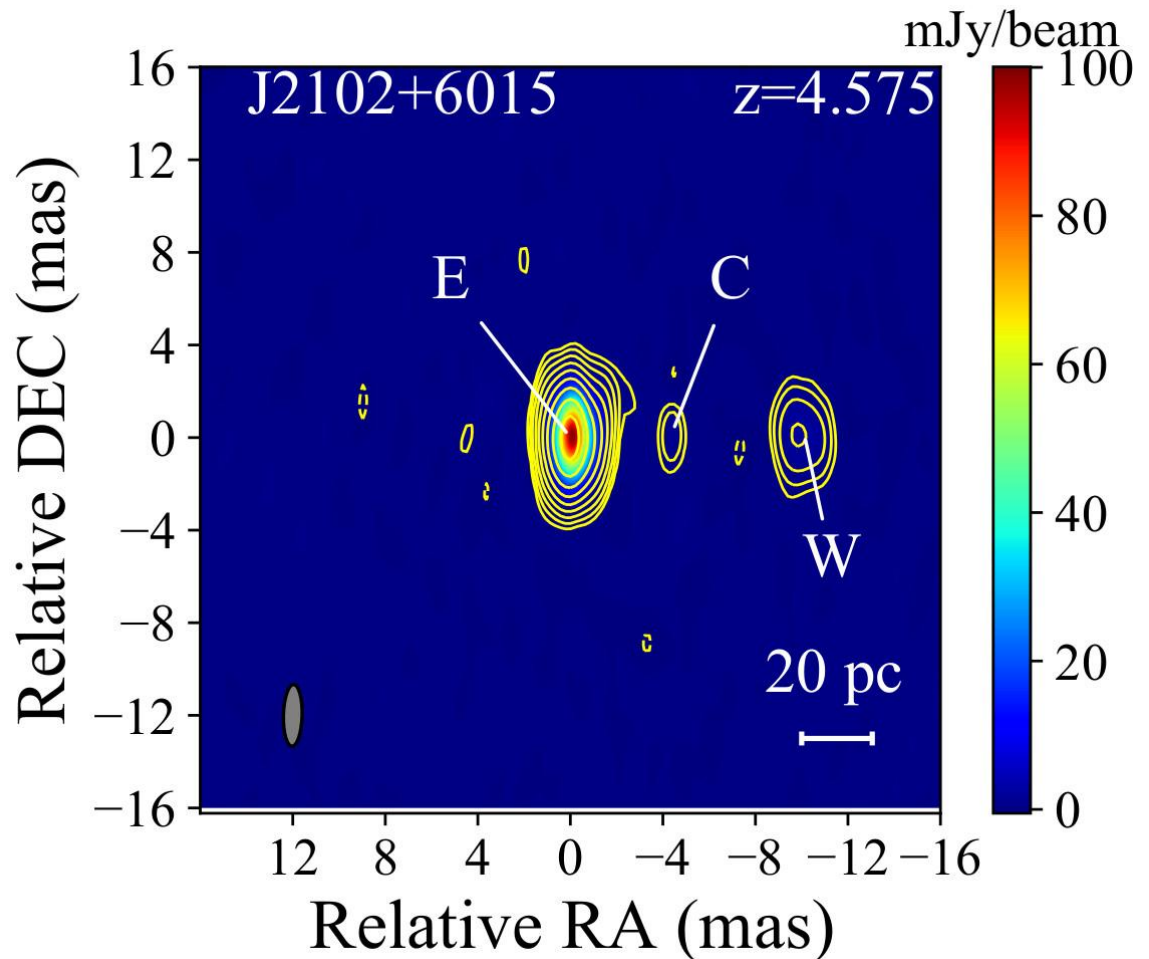


ad-hoc VLBI array (Bd, Sv, Zc, Ys, Sh) – 5 epochs in 2017 combined

A detailed multi-epoch VLBI study

Analysis of archival
X-band VLBI data +
a new sensitive
VLBA observation
(2017 Feb)

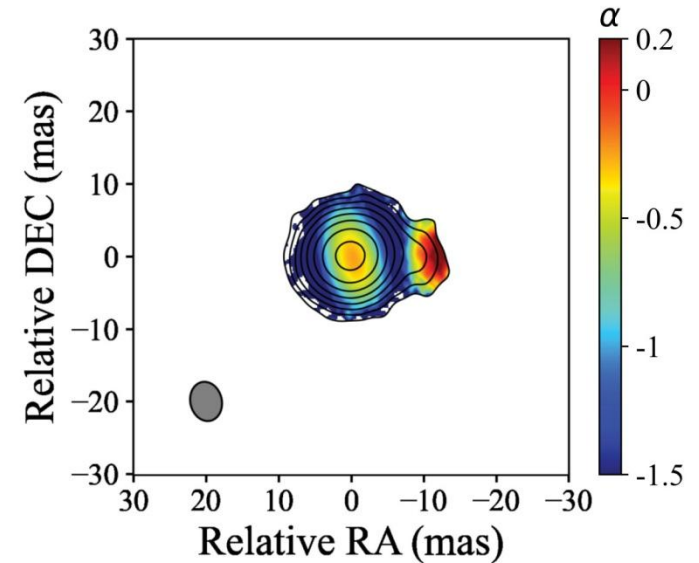
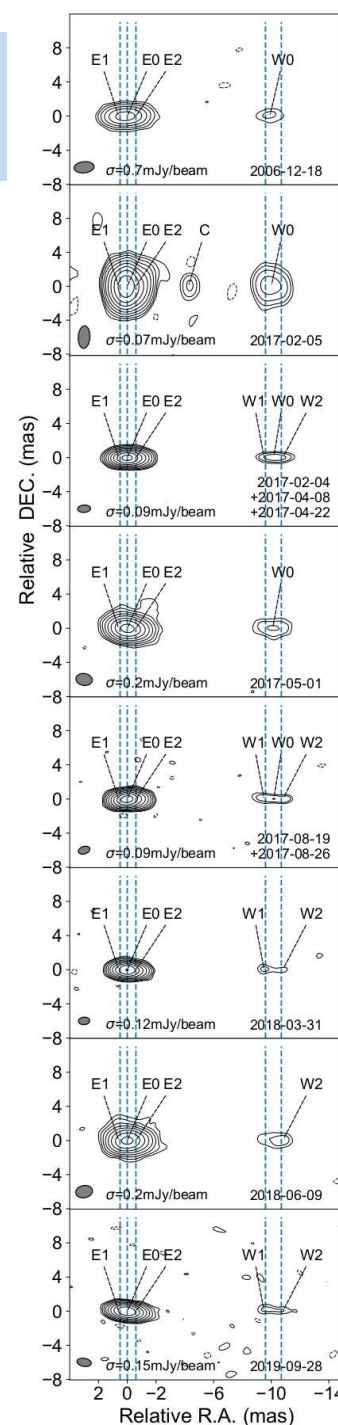
Zhang+ 2021, *MNRAS*



incl. VLBA Calibrator Surveys,
astrogeo.org

The first indication
of a central
component C

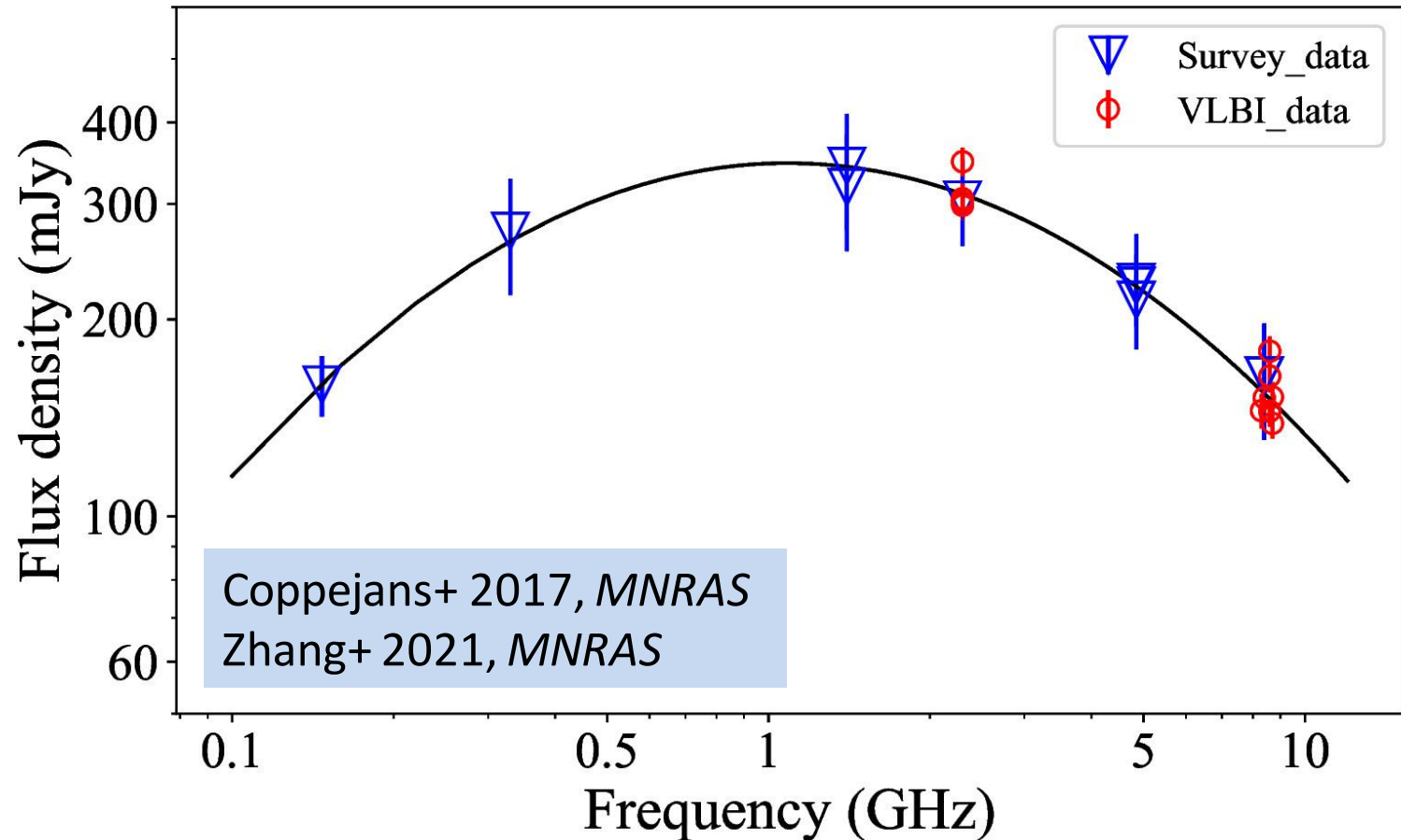
E–W **separation**
speed < 0.04 mas/yr
over ~ 13 yr



Both E and W have
flat/inverted spectra
between S and X
bands

Zhang+ 2021, *MNRAS*

The overall radio spectrum



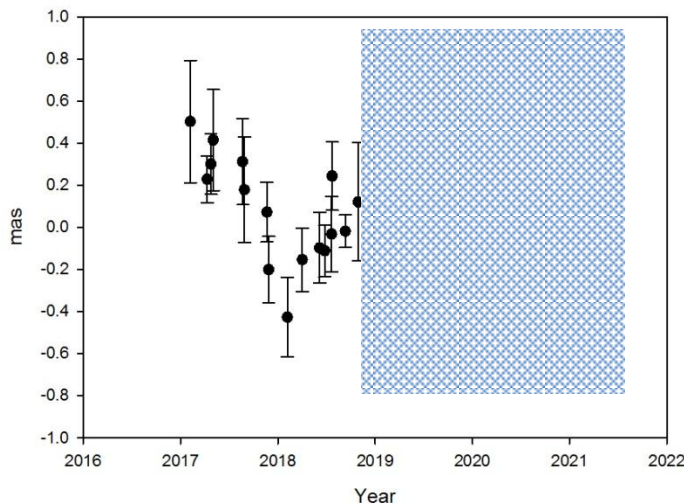
Peaked spectrum, resolved E and W features, central component: is it a **compact symmetric object** (CSO)?

Astrometric behaviour

There are very few $z > 3$ radio AGN that are compact and powerful enough to become a VLBI **astrometric reference source**

How do they change their positions compared to low- z sources?

This was a subject of another EVN project, and the sample included J2102+6015 as well (ET036, PI: Oleg Titov)

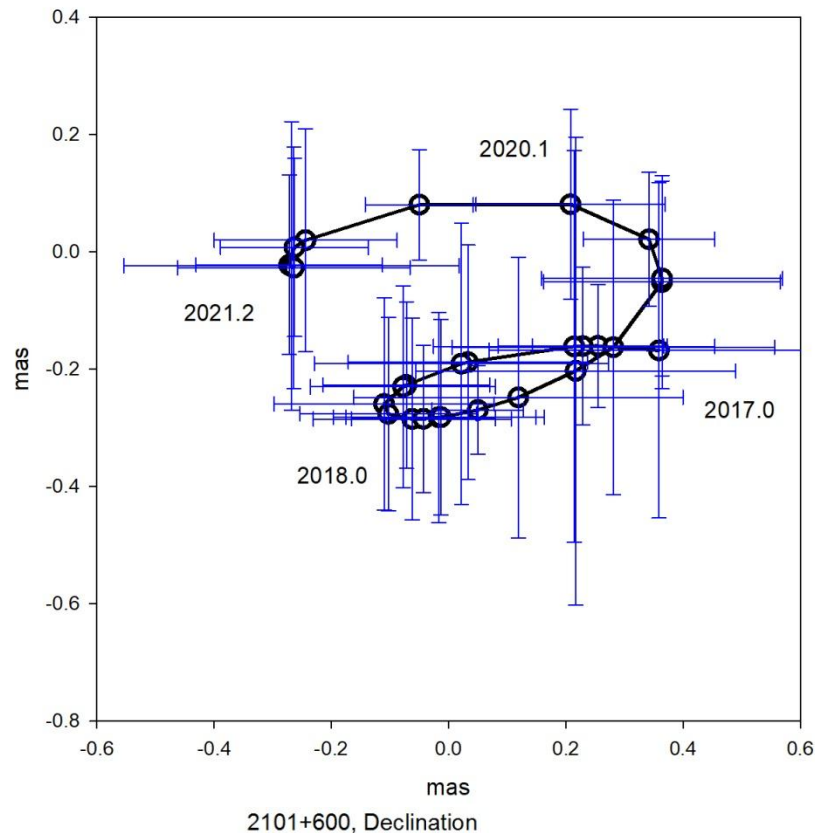


J2102+6015 right ascension as known before the time of the EF029 proposal submission (early 2020)

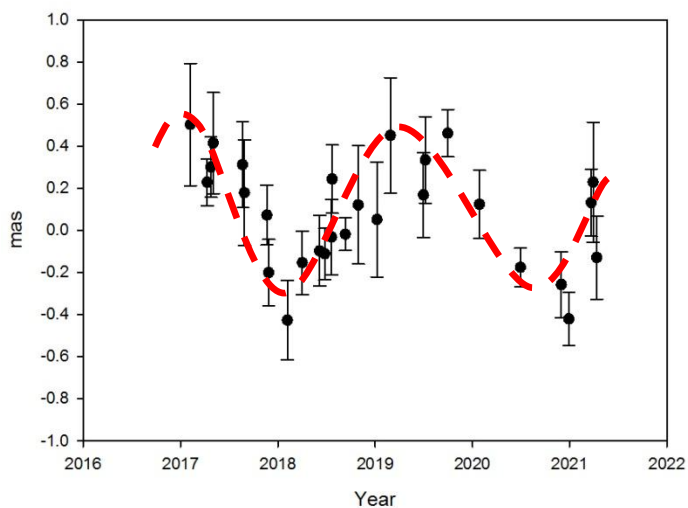
What is happening with this source?

A hint on a ~ 3 -yr period positional variation

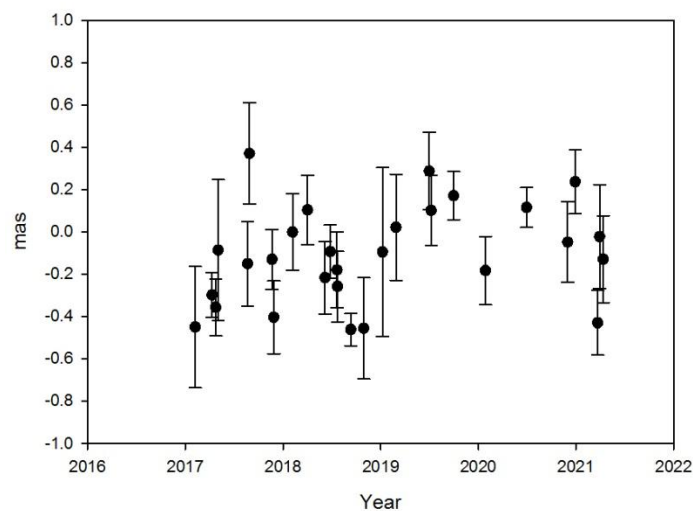
Titov+ 2022, *submitted*



2101+600, Right ascension



2101+600, Declination

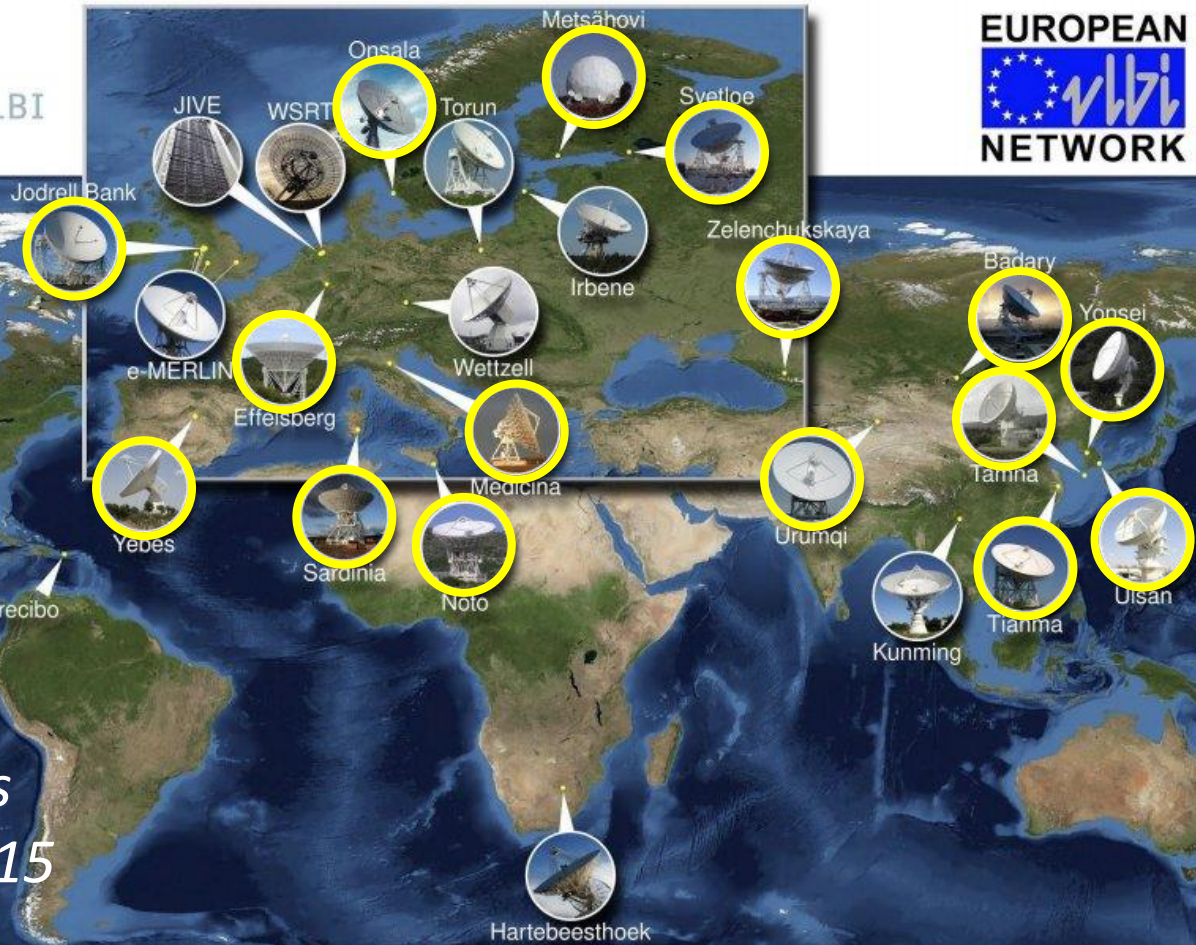


EF029A: 22 GHz, 2021 Jun 7/8



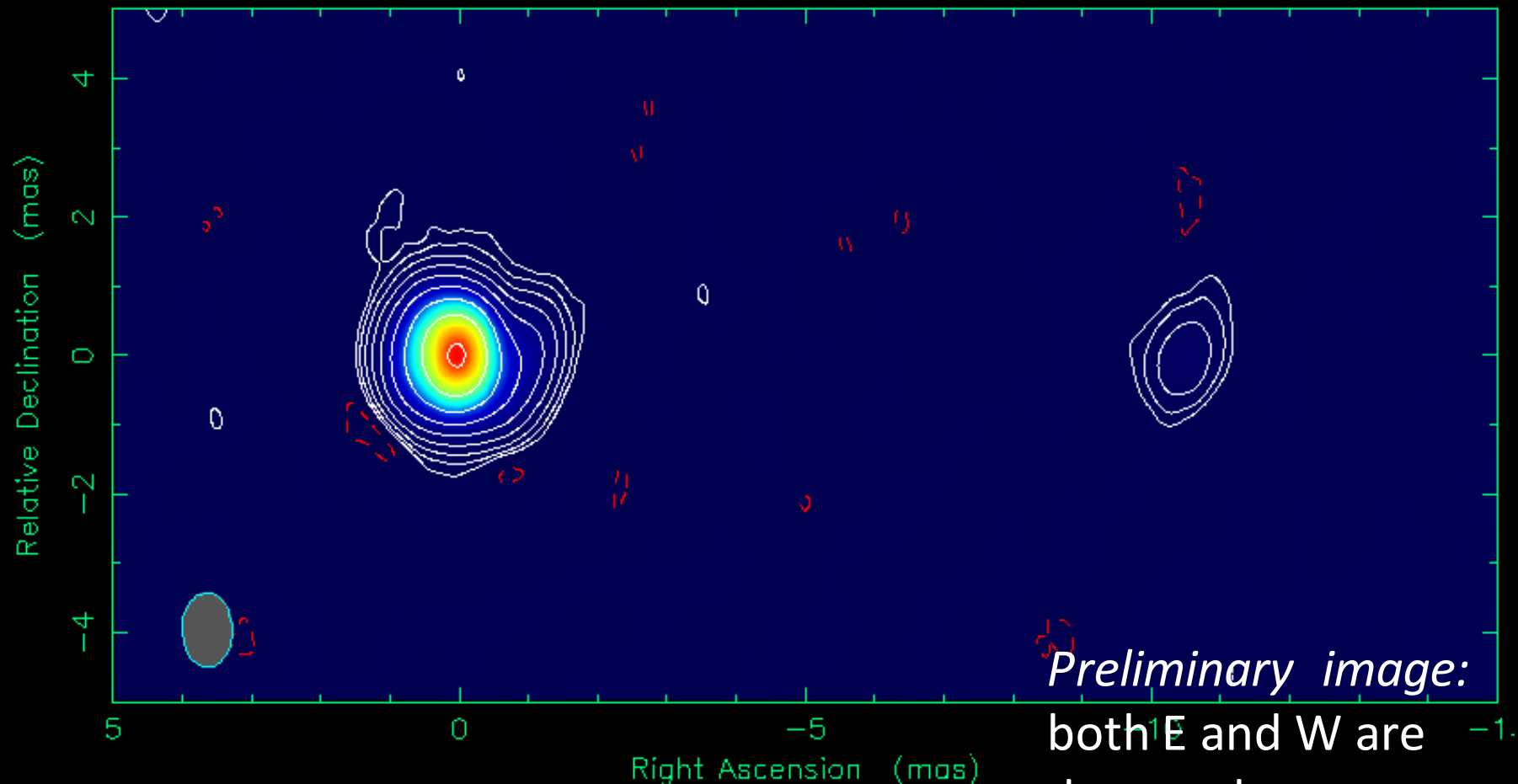
JIVE

Joint Institute for VLBI
ERIC



*at VLBI frequencies
used for J2102+6015
for the first time*

Clean I map. Array: EVN
J2102+60 at 22.235 GHz 2021 Jun 07



Preliminary image:

both E and W are
detected,
resolved emission

Map center: RA: 21 02 40.219, Dec: +60 15 09.836 (2000.0)

Map peak: 0.0294 Jy/beam

Contours: 0.000109 Jy/beam \times { -1 1 2 4 8 16 32 64

Contours: 128 256}

Beam FWHM: 1.08 \times 0.72 (mas) at 1.42°



EF029A: 22 GHz, 2021 Jun 7/8



JIVE

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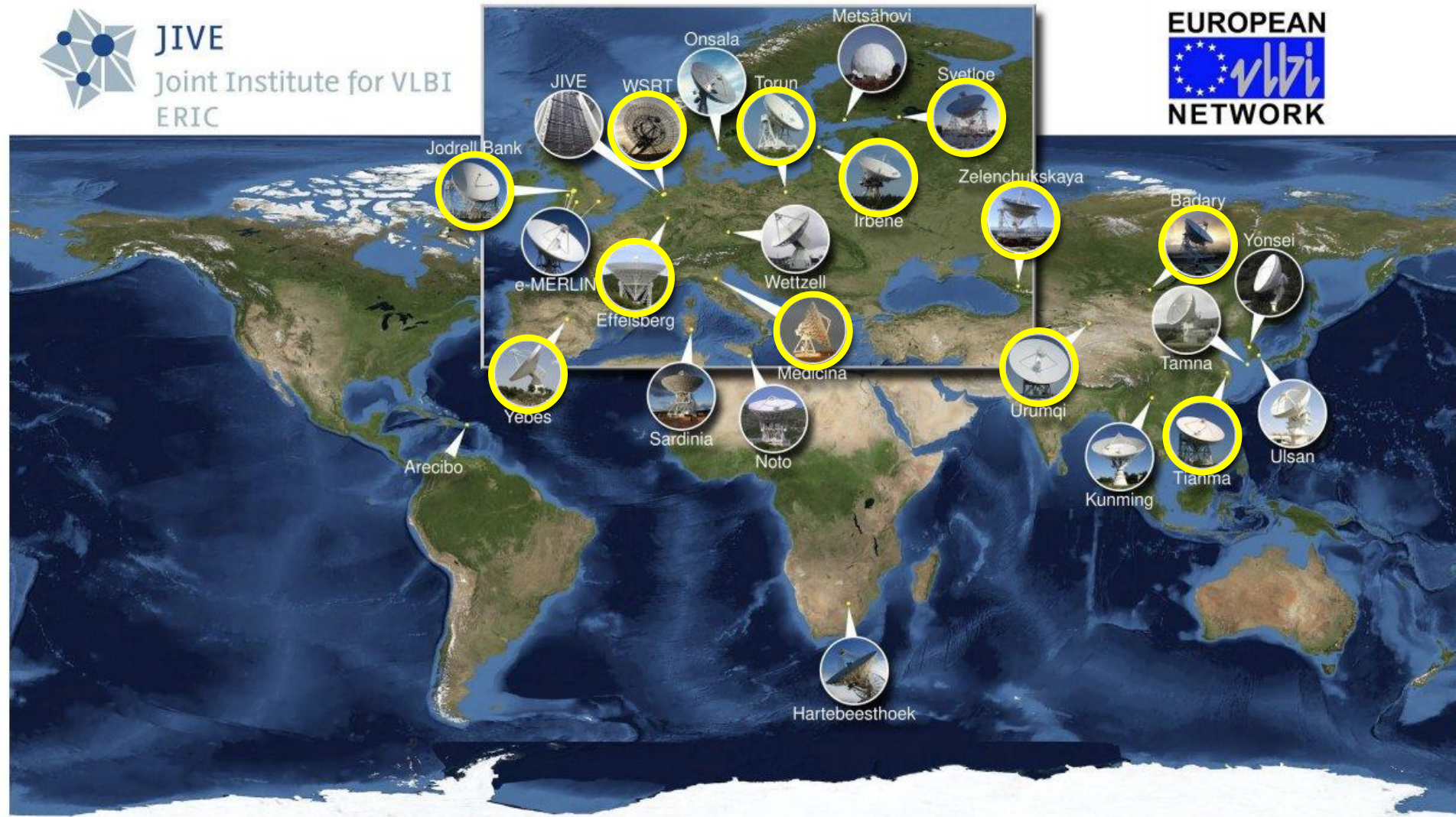
Subarray #1
centred on EF

Subarray #2
centred on T6

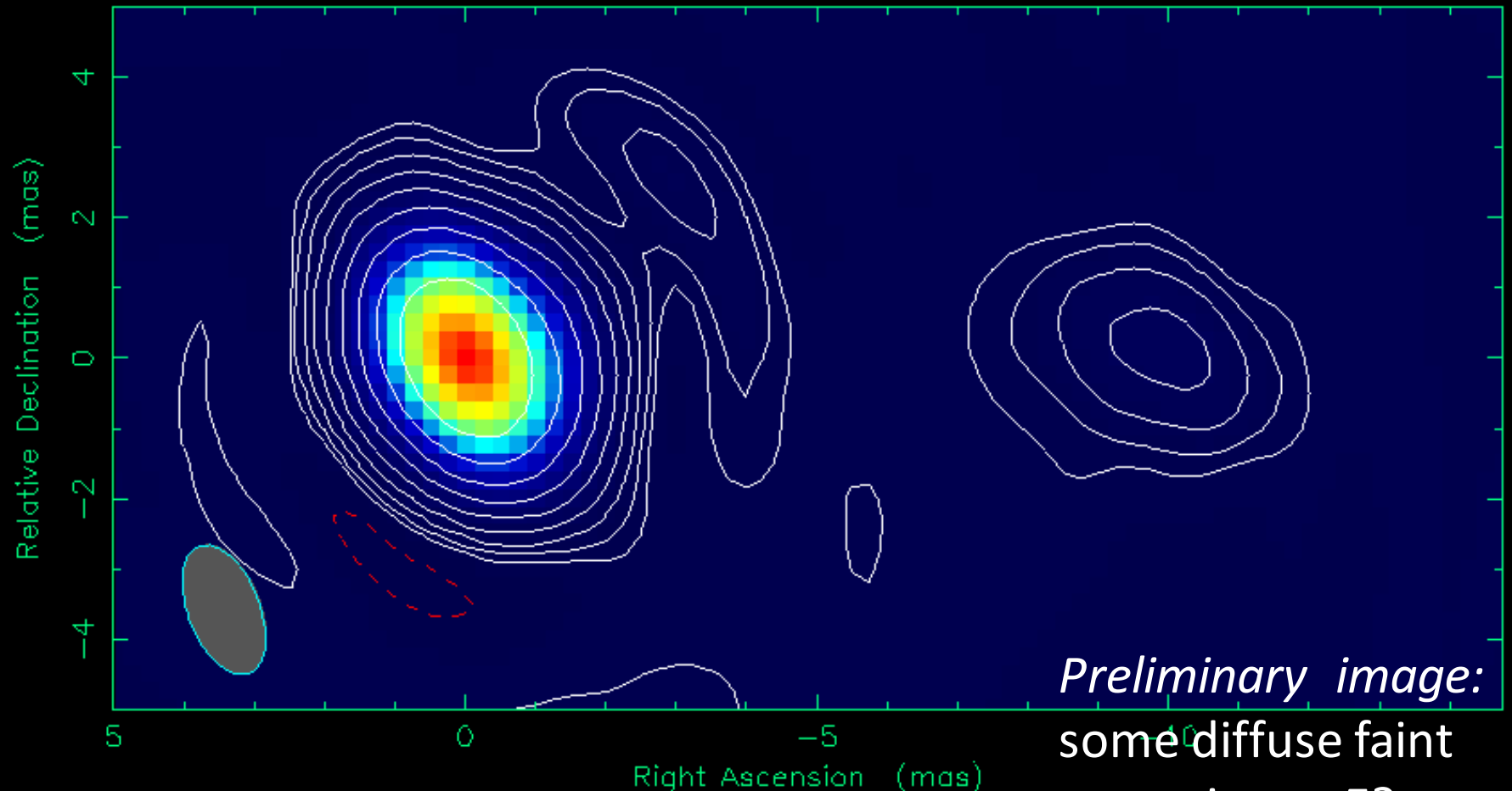
EF029A: 5 GHz, 2021 Jun 14/15



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Clean I map. Array: EVN
J2102+60 at 4.926 GHz 2021 Jun 14



Map center: RA: 21 02 40.219, Dec: +60 15 09.836 (2000.0)
Map peak: 0.124 Jy/beam
Contours: 0.0002 Jy/beam \times (-1 1 2 4 8 16 32 64
Contours: 128 256)
Beam FWHM: 1.94 \times 1.02 (mas) at 21.3°

Preliminary image:
some diffuse faint
extension to E?;
no trace of C



J2102+6015: questions rather than answers

- **Is it indeed at $z=4.57$?**
very faint optical source, marginal redshift determination
high ($>10^{38}$ W/Hz) monochromatic power at GHz frequencies
22 GHz EVN data would correspond to ~ 120 GHz in rest frame
- **How to interpret the ~ 10 -mas scale radio structure?**
not beamed (non-blazar) source with GHz-peaked radio spectrum
small apparent separation speed
- **How to interpret the periodic pattern in the absolute position?**
is it real at all? (only <2 suspected periods observed)

“More observations are needed” (*Unknown astronomer*)



Stay tuned!

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