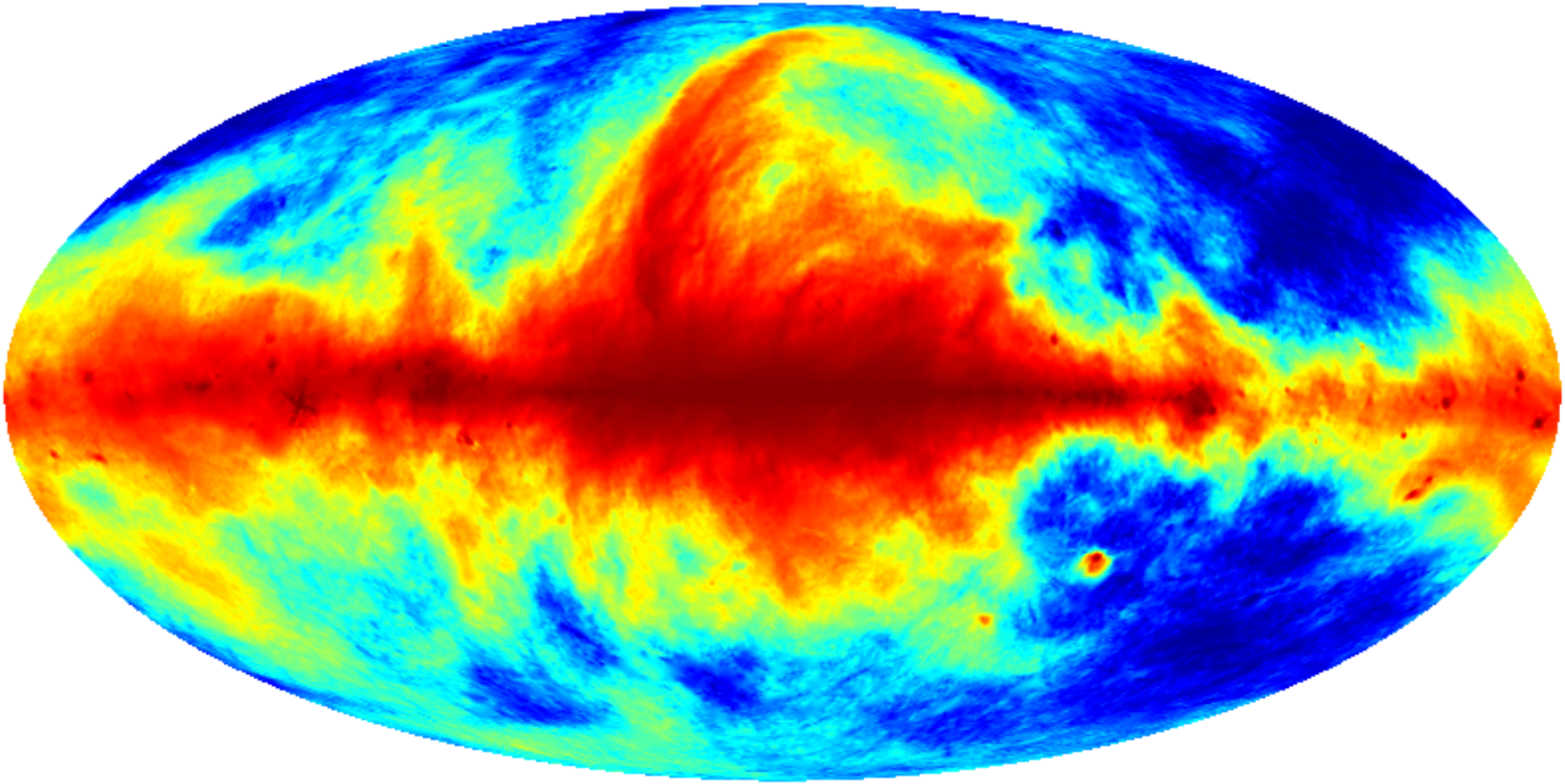
EVN transients

Zsolt Paragi et al.
Joint Institute for VLBI ERIC (JIVE)

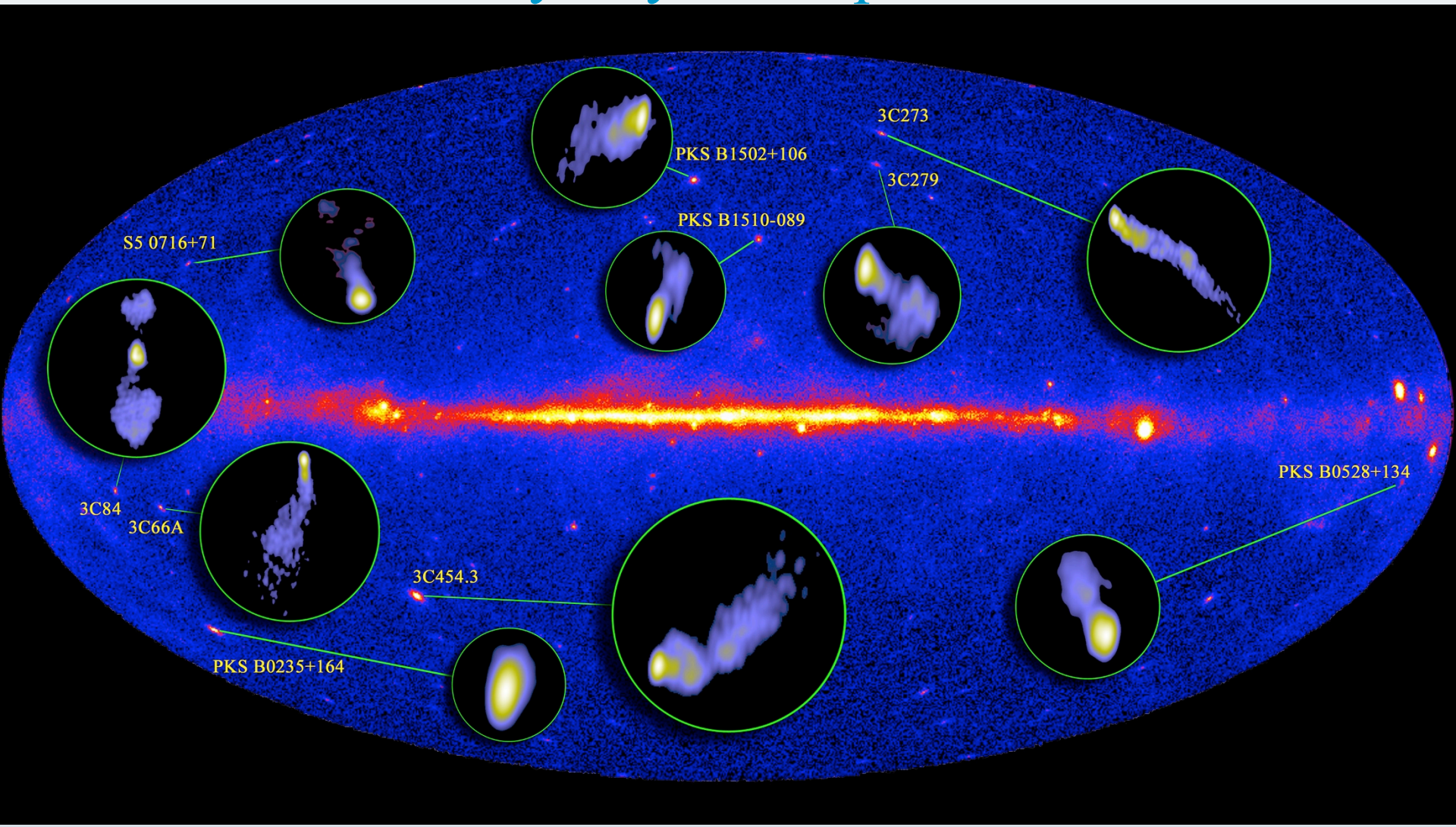
The Radio Sky at 408 MHz



Combined data from the Jodrell Bank, Effelsberg & Parkes radio telescopes

Haslam et al. (1982);
Re-processed by *Remaezilles et al. 2014*
http://www.jb.man.ac.uk/news/2014/RadioLoops/

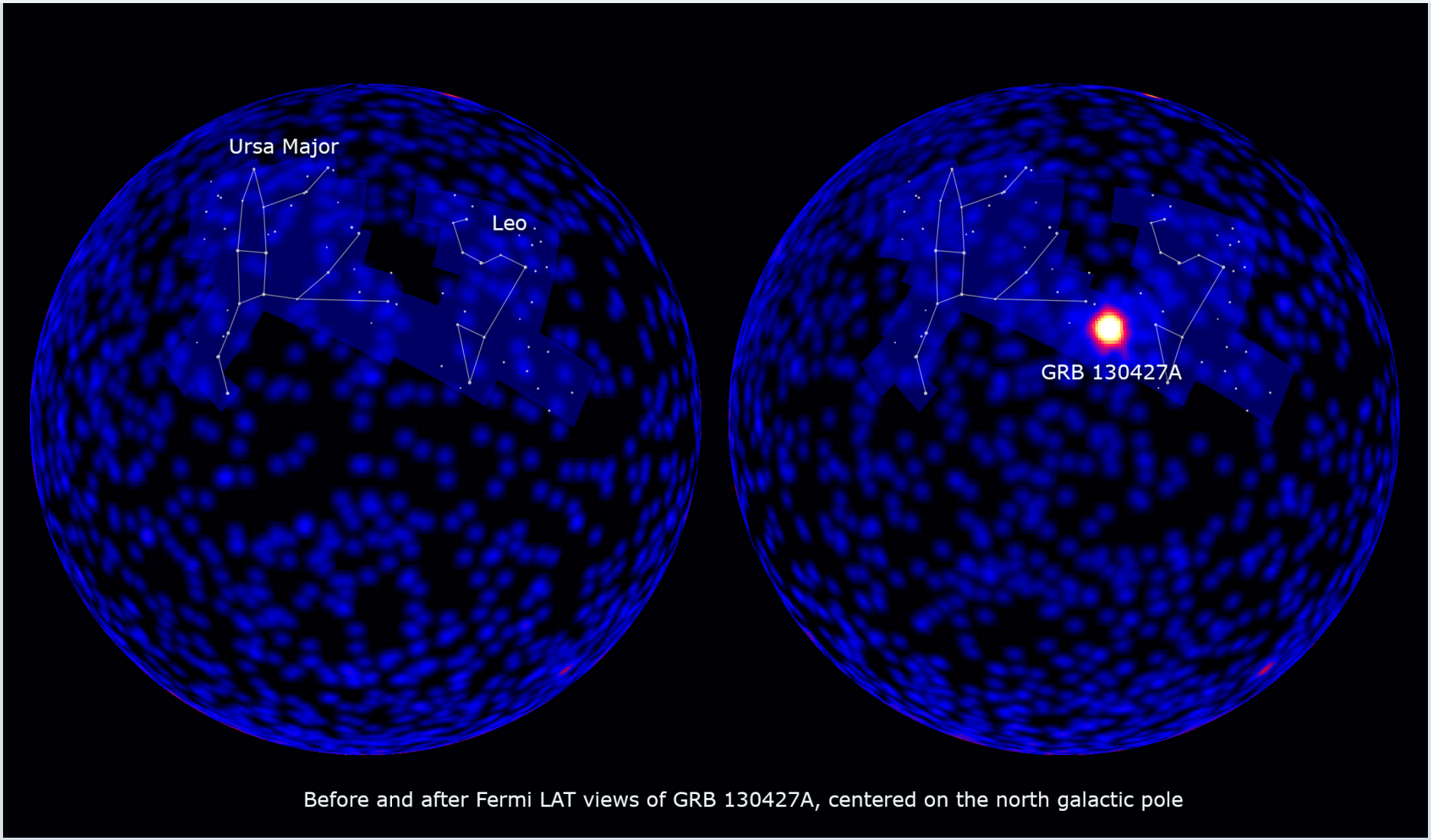
The Gamma-ray Sky / Compact radio sources



Gamma-rays: Fermi; Radio: VLBA (MOJAVE Survey)

Credit: NASA/DOE/Fermi LAT Collaboration and NRAO/AUI/MOJAVE Team/M. Kadler

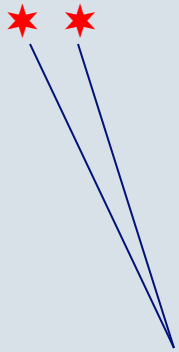
Transients



http://i0.wp.com/www.techweez.com/wp-content/uploads/2013/11/gamma_ray_burst.jpg

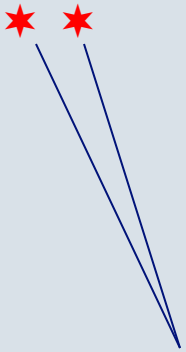
Field of view / resolution in the radio

~1 arcmintes

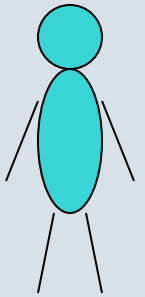


RESOLUTION:

$\alpha \sim 1.22\ \lambda/D$

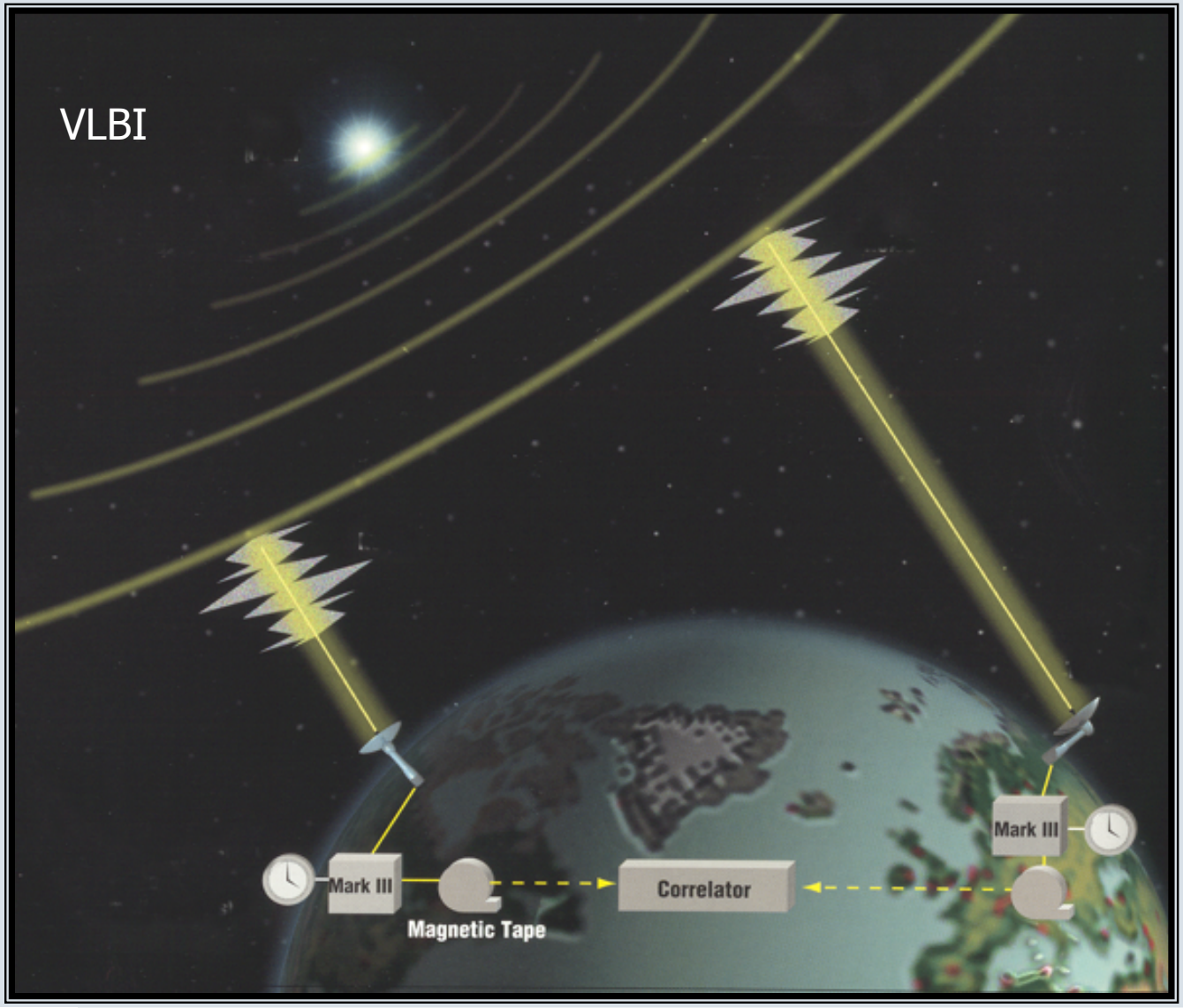


One of the greatest radio telescopes



One of the greatest optical astronomers, without the aid of a telescope

Combine telescopes!



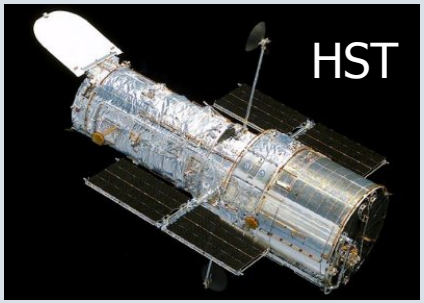
Interferometry is a way to increase the resolution.

Connecting the most powerful radio telescopes over thousands of km:

Very Long Baseline Interferometry

Angular scales

	1.6 GHz	5 GHz	22 GHz
10^0 km	45″	15″	3.4″
10^1 km	4.5″	1.5″	340 mas
10^2 km	450 mas	150 mas	34 mas
10^3 km	45 mas	15 mas	3.4 mas
10^4 km	4.5 mas	1.5 mas	340 μas



The European VLBI Network

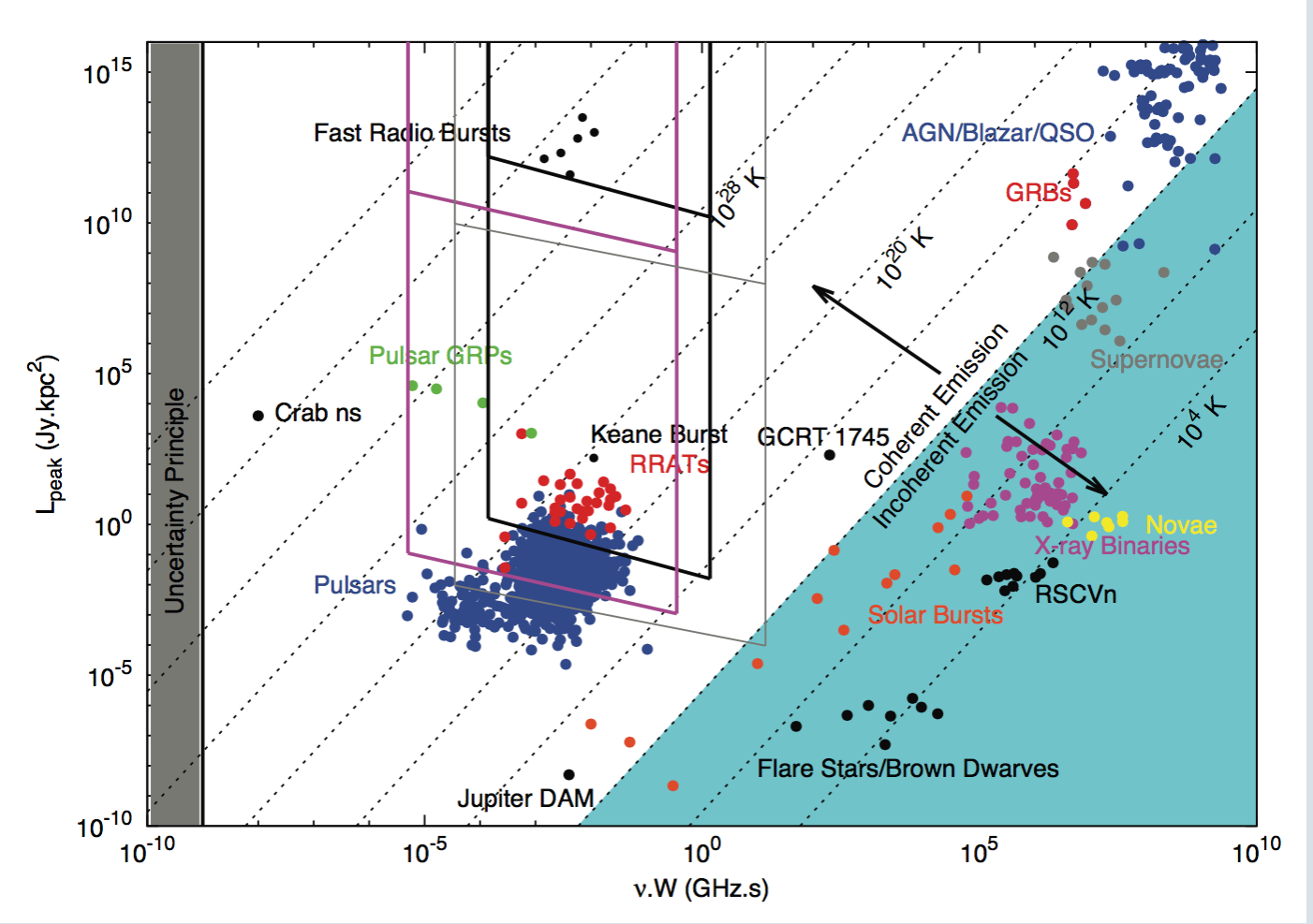
Radio transients parameter space

(Beam-formed) sensitivities at 1 kpc and 1 Gpc for:

Parkes (black lines)

SKA1-LOW (pink)

SKA1-MID (grey)



Specific luminosity vs. product of observing frequency and transient duration

SKA Transient WG - Macquart et al. (2015); update of *Cordes, Lazio & McLaughlin 2004*

A historical fast transient search

- Evaporating primordial BH smaller than 10^{12} kg will produce short flashes in gamma rays

Hawking (1974), Nature, 248, 30

- Radio waves predicted from e^- and e^+ interacting with magnetic fields; detectable at least out to 10 kpc

Rees (1977), Nature, 266, 333

- Radio limits on explosive primordial BH e.g. by the Dwingeloo Radio Telescope

O'Sullivan, Ekers, Shaver (1978), Nature, 590, 591

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Wikipedia:

"**John O'Sullivan** is an Australian electrical engineer whose work in the application of Fourier transforms to radio astronomy[1] led to his invention with colleagues of a core technology that made wireless LAN fast and reliable…"

Fast Radio Bursts (FRB)

- Highly dispersed, non-repeating ms-transient signals, indicating cosmological origin, >1 Jy

Lorimer et al. (2007), Science, 318, 777
Keane et al. (2011), MNRAS, 415, 3065 - Galactic???
Thornton et al. (2013), Science, 241, 53 – 4 FRBs; +1 in PhD thesis
Spitler et al. (2014), ApJ, 790, 101 – Arecibo!
Bourke-Spolaor & Bannister (2014), ApJ, 792, 19
Petroff et al. (2015), MNRAS, 447, 246 – real-time
Ravi, Shannon, Jameson (2015) – real-time (Carina Dwarf gx?)
Masui et al. (2015), Nature, 528, 523 – GBT!
Keane et al. (2016), Nature, 530, 453 – "real-time", follow-up
Spitler et al. (2016), Nature, 531, 202 – repeating FRB

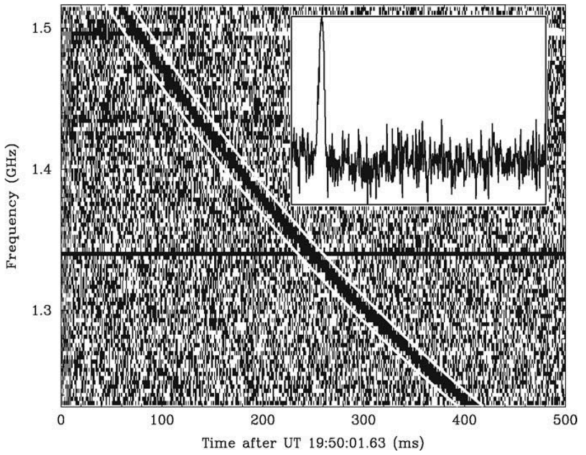
- Not to be confused with *Perytons*, dispersed signals of local origin

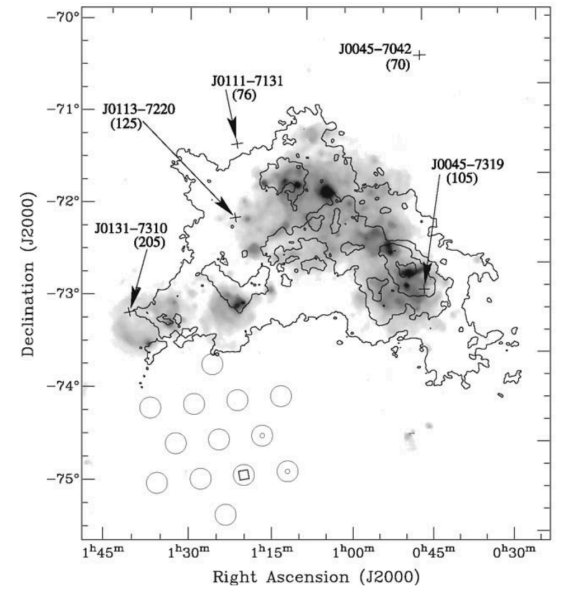
Bourke-Spolaor et. al. (2011), ApJ, 727, 18
Petroff et al. (2015), MNRAS, 451, 3933

- Initial even rate of ~>10^4/sky/day recently reconsidered to ~10^{3-4}/sky/day

Rane et al. (2016), MNRAS, 455, 2207

To date, there is still no LOFAR, MWA or VLA detection!





The origin of FRBs

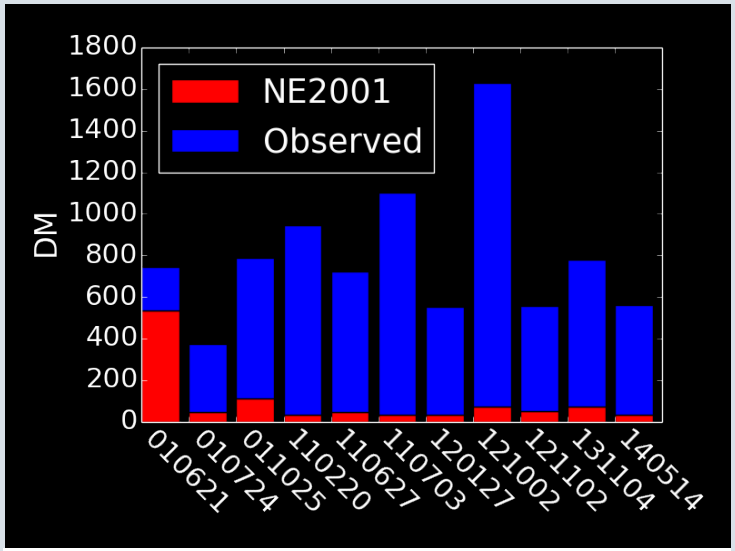
Dispersion measures well in excess of Galactic values.
Proposed explanations include:

- 'Blitzar': collapsing supramassive neutron stars

Falcke & Rezzola et. al. (2011), A&A, 562, A137

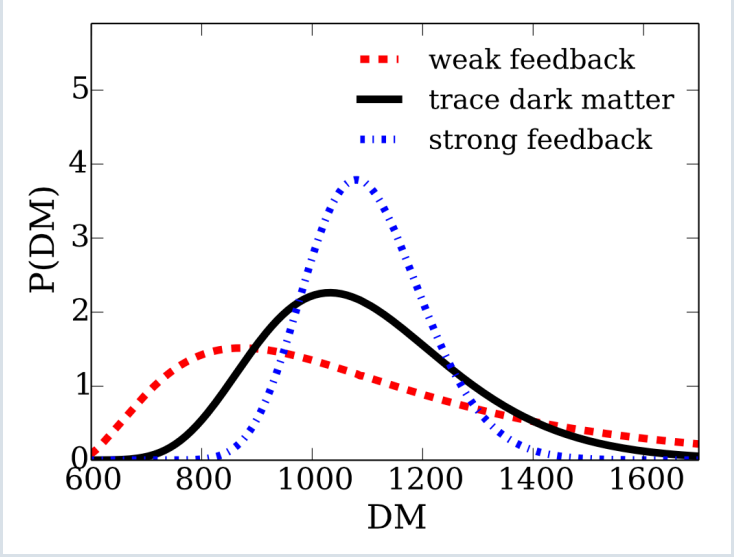
- Nearby flare stars; DM due to coronal plasma effects

Loeb, Shvartzvald, Maoz *(2014), MNRAS, 439, L46*
Maoz et al. (2015), MNRAS, 454, 2183



If extragalactic, they are important for cosmology:

- To weigh the missing barions *(McQuinn 2014)*
- To measure intergalactic magnetic field and determine dark energy equation of state *(Gao, Li & Zhang 2014; Zhou et al. 2014)*



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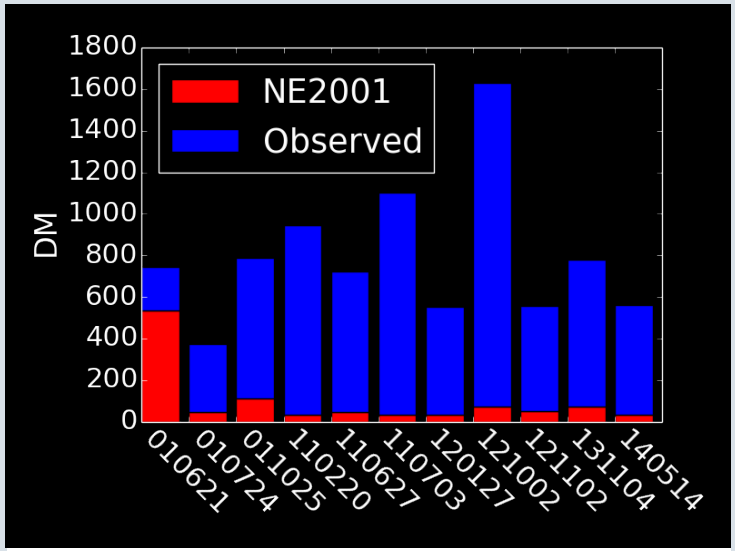

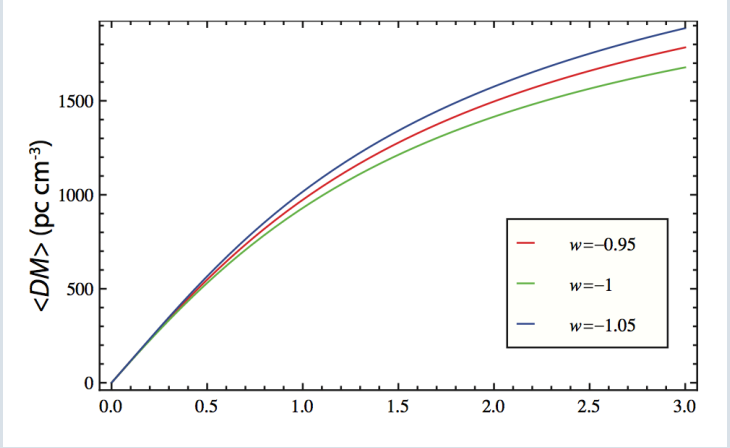

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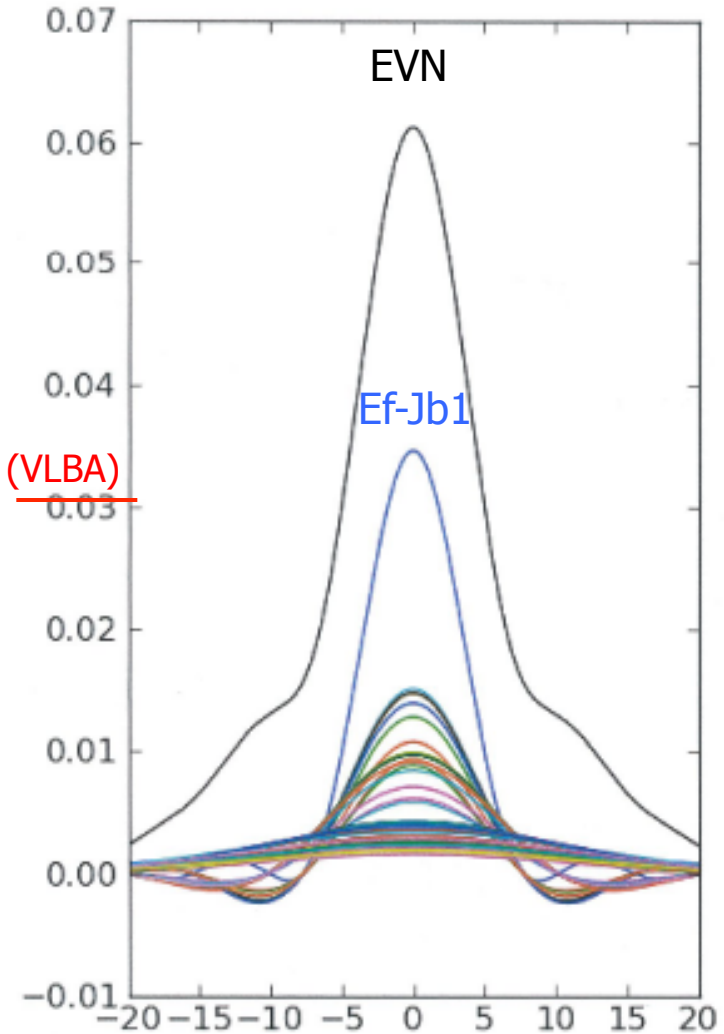
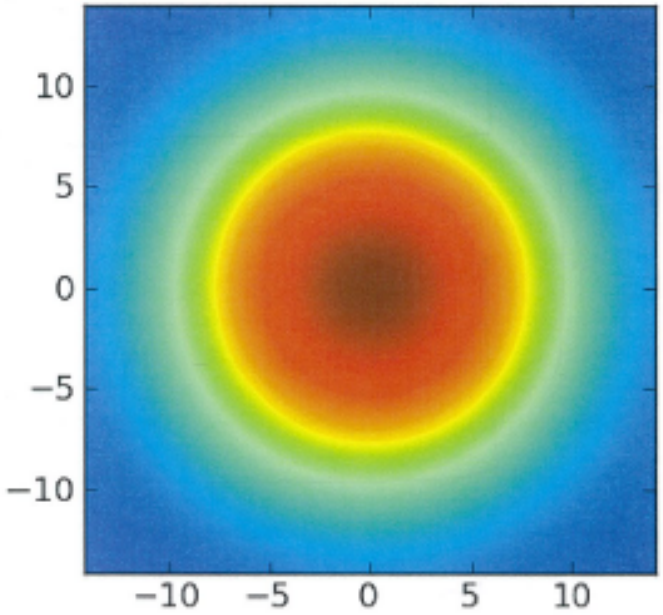
Localization needed to prove extragalactic origin!

Feasible with the EVN FoV?



1/SEFD* [Jy]



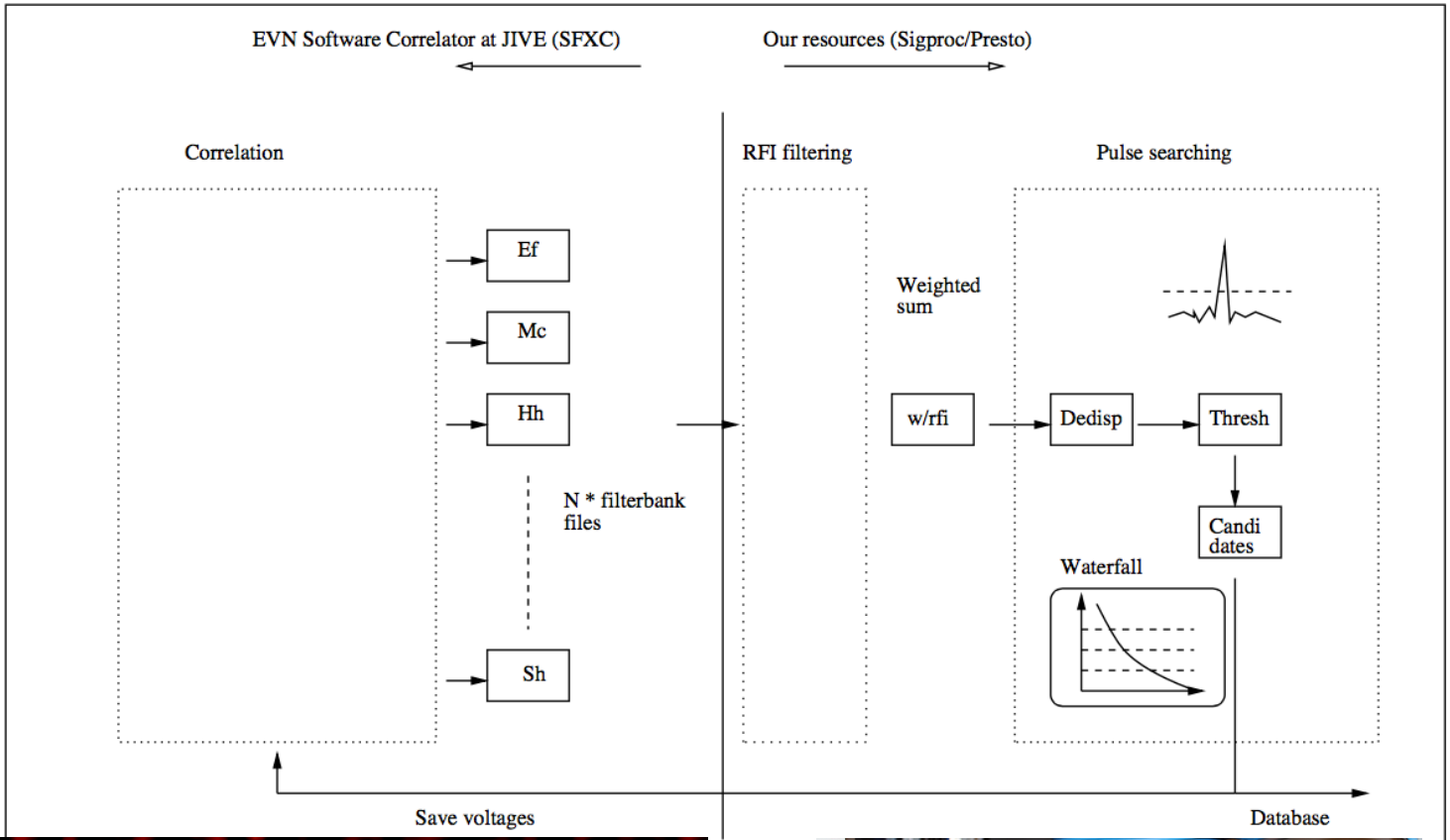
Radius [arcmin]:

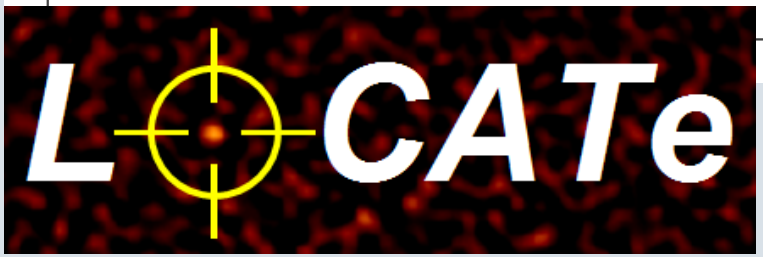
<5′ → ~0.1-0.3 Jy

5-10′ → ~0.3-1 Jy

>10′ → >1 Jy

The idea of an EVN commensal project



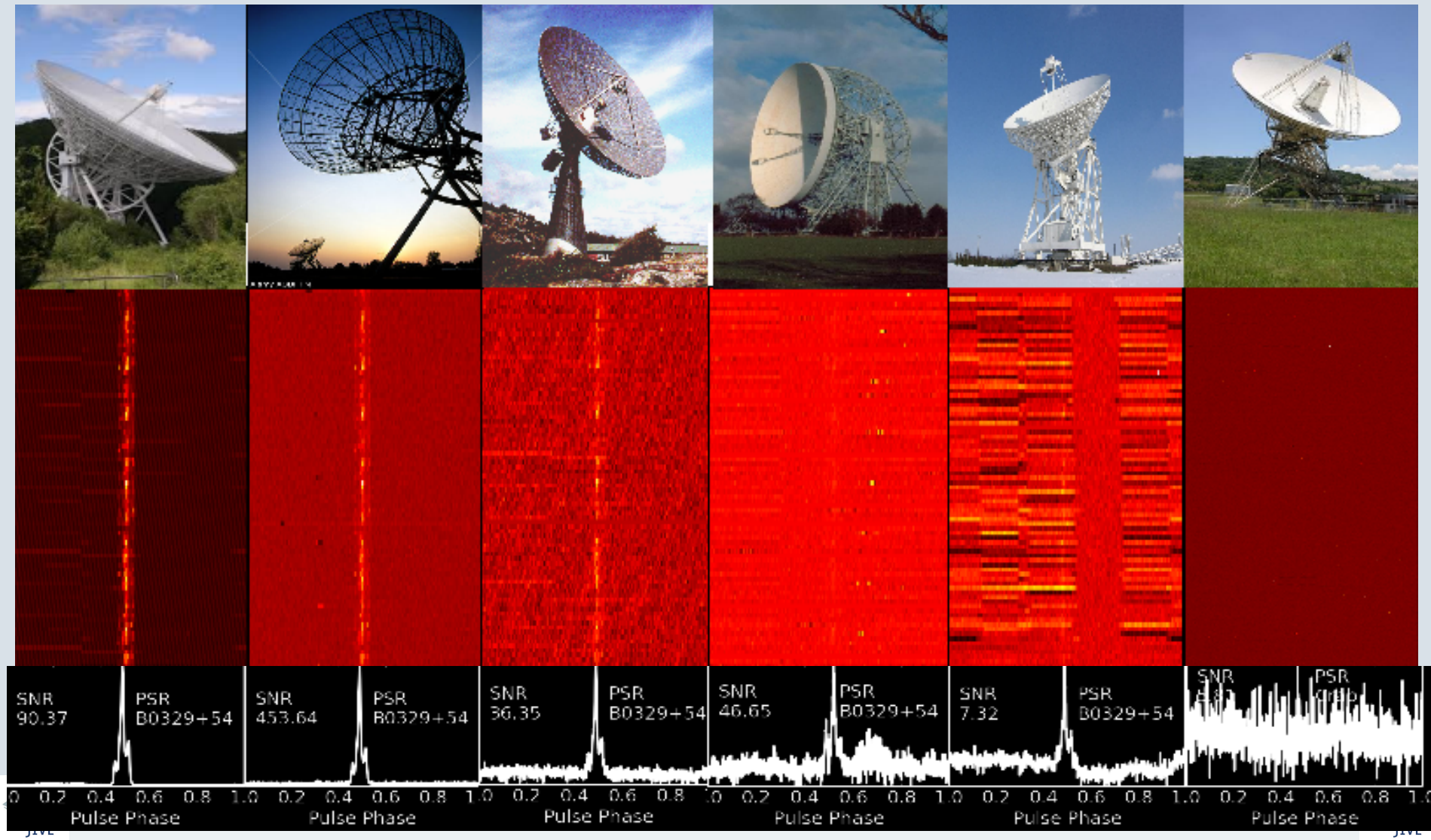


A feasibility study (summer project)

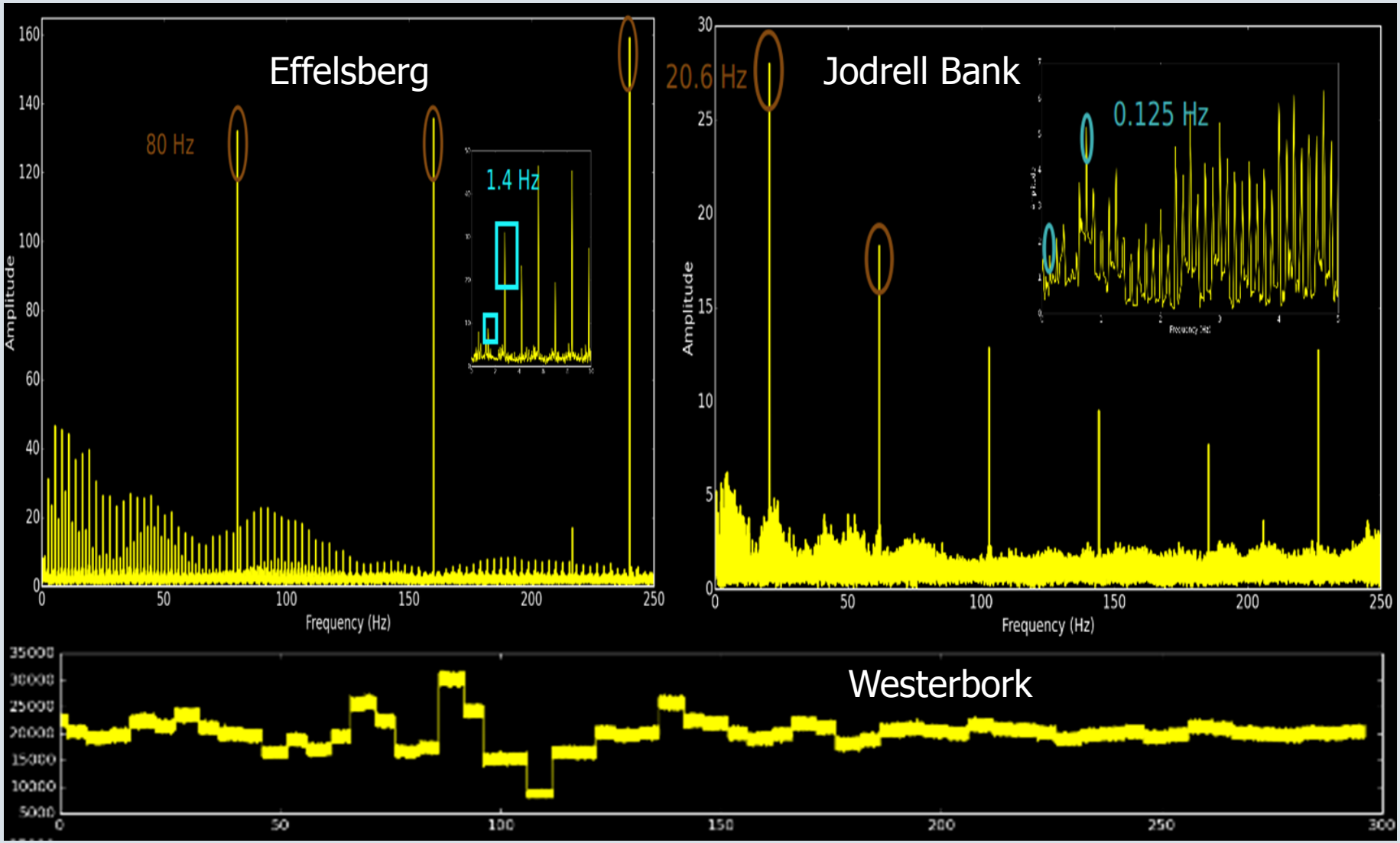
Supervisor delivering
Wb test data on pulsars

The team (not complete): Sander ter Veen (Astron), **Zhigang Wen** (Urumqi Obs.), Anne Archibald (Astron), Aard Keimpema (JIVE)

First EVN test observations

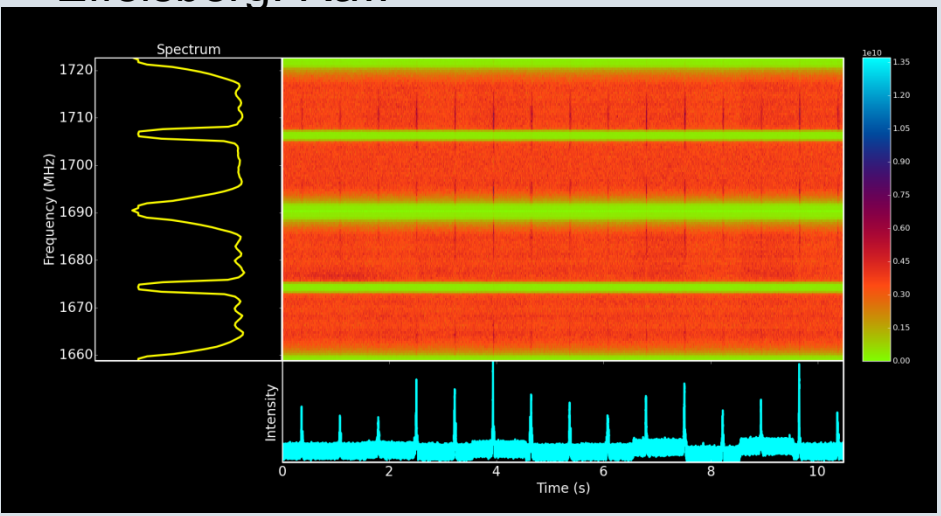


The ‘real EVN’ – RFI, calibration, gain control…

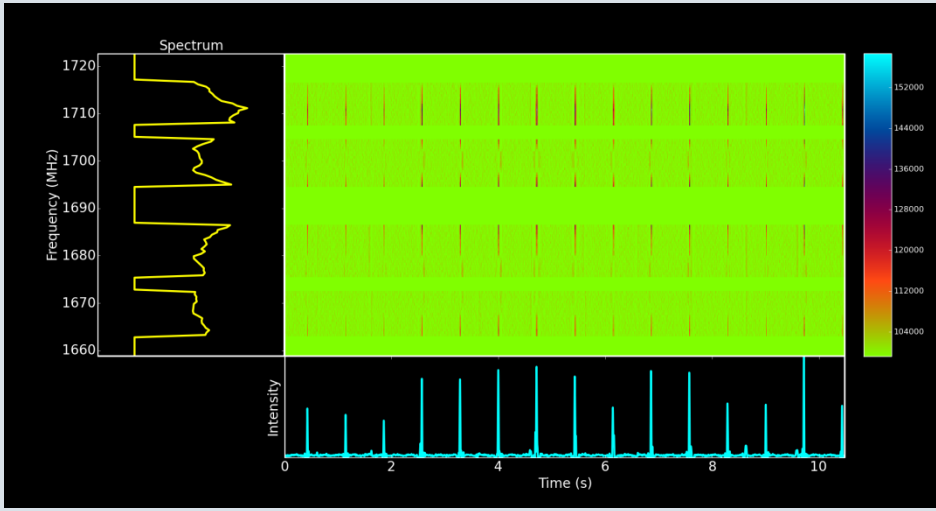


The dynamic spectrum before/after ‘cleaning’

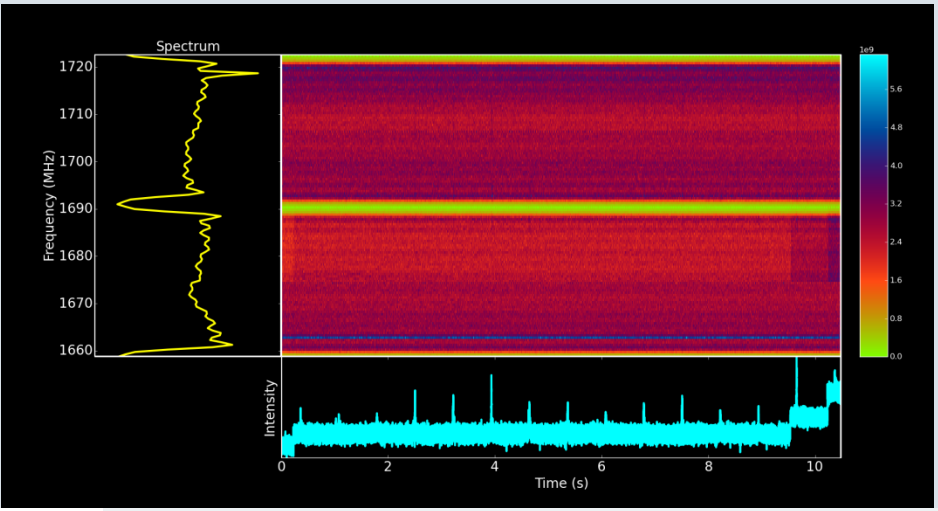
Effelsberg: Raw



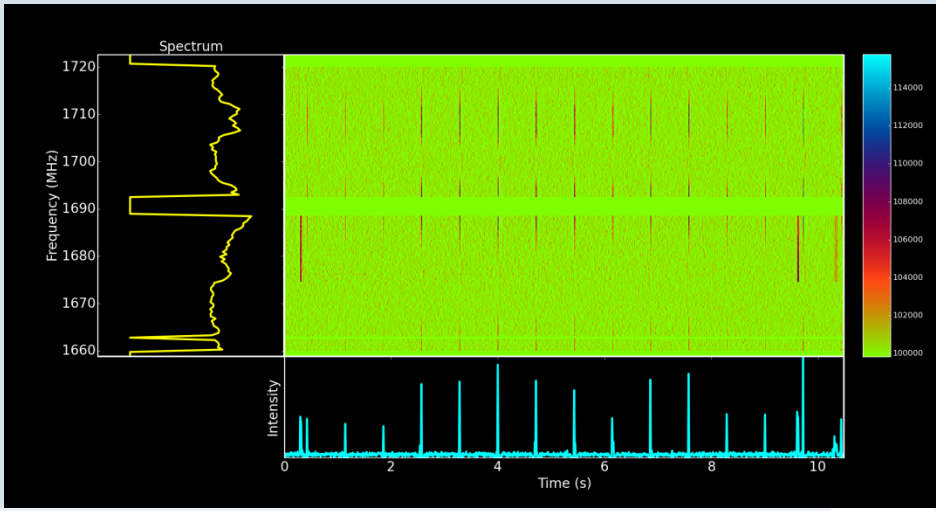
Clean



Westerbork: Raw



Clean

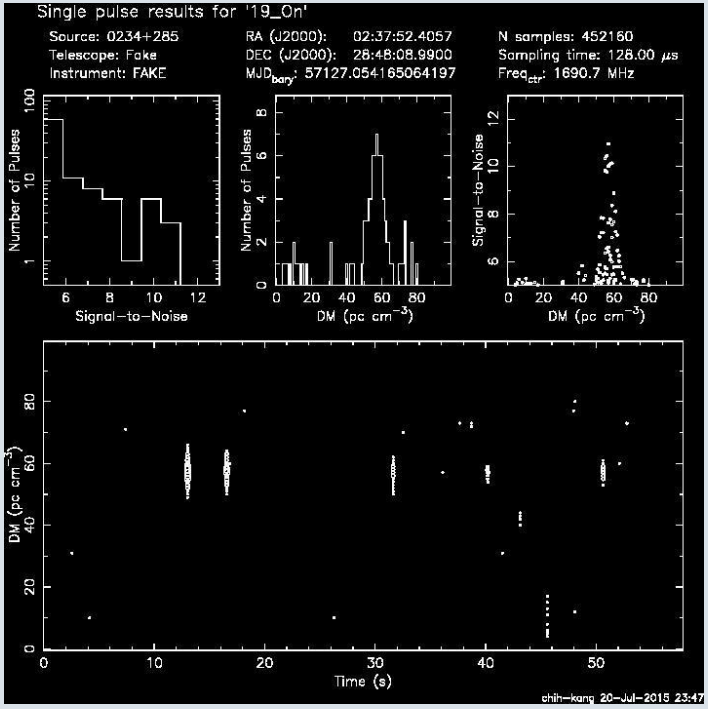


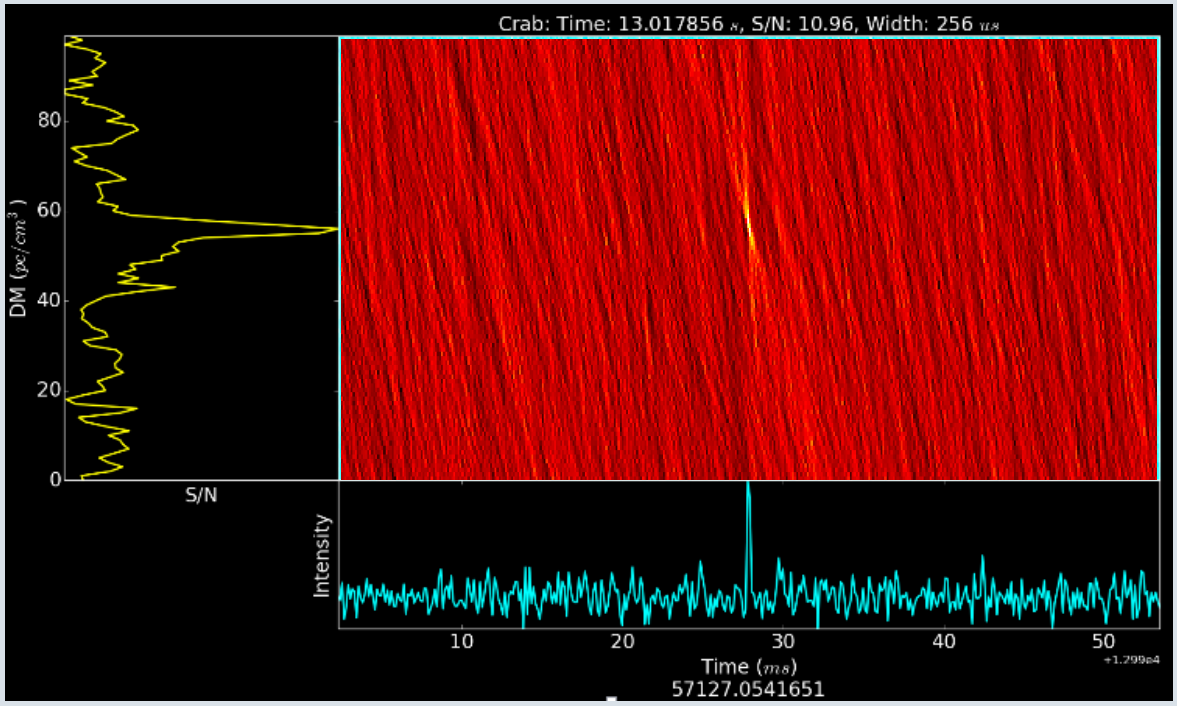
Processing steps

1. De-dispersion (Loop over DM trails)
2. Matched filtering (Loop over boxcar filter widths)

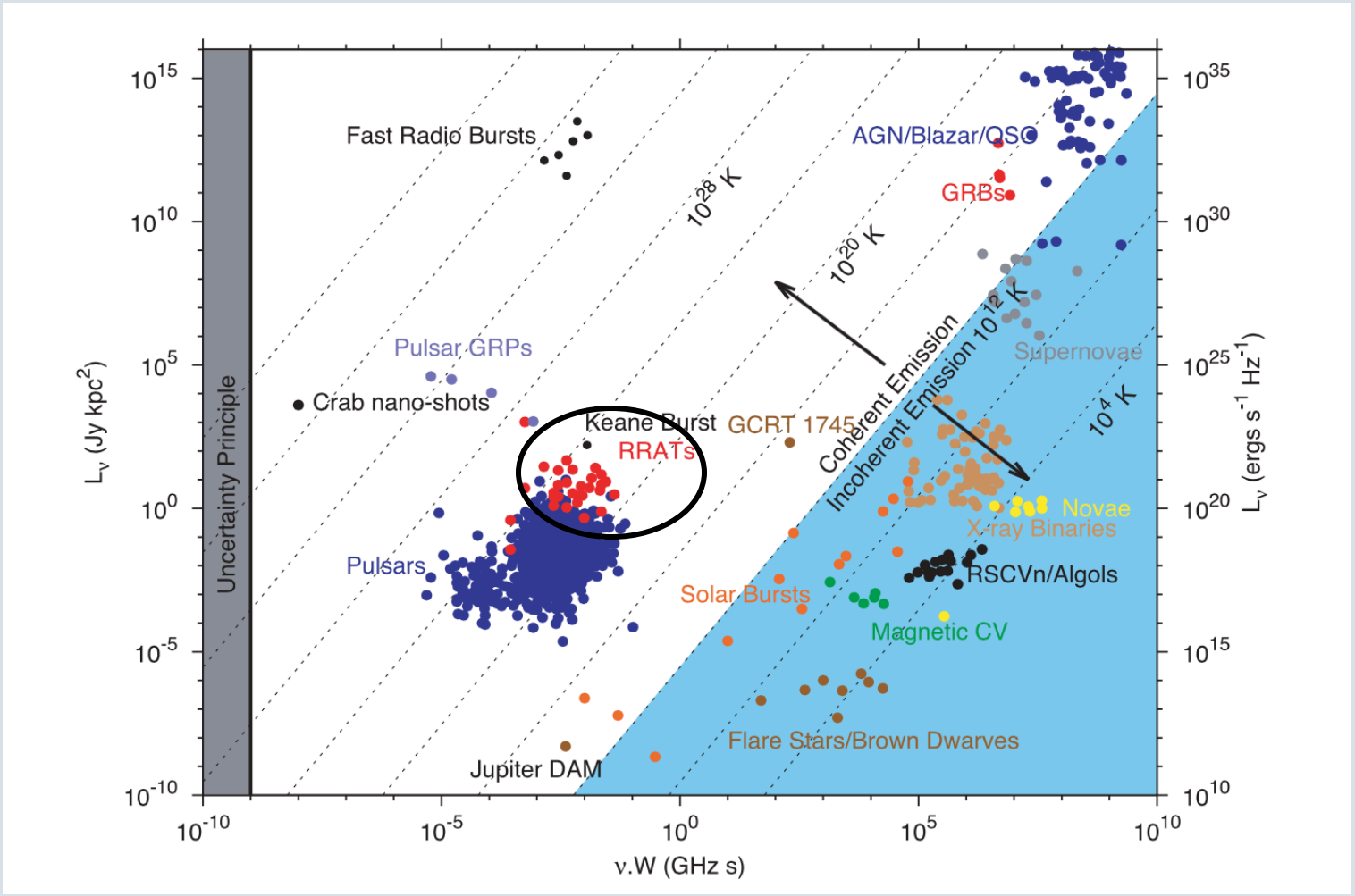
3. Peak detection and clustering

Crab giant pulses in 1m data (left); DM vs. time for one of these (right)

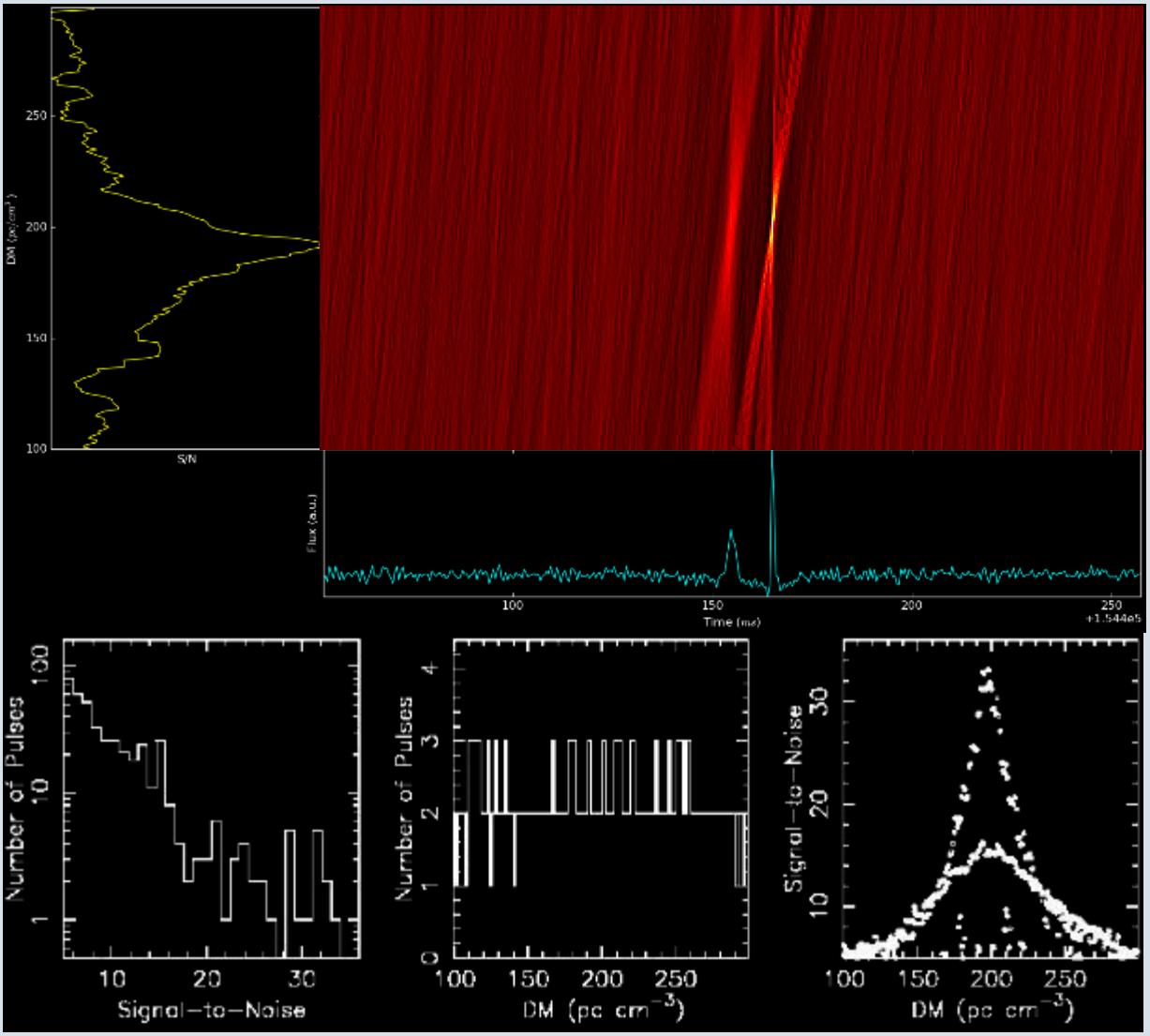


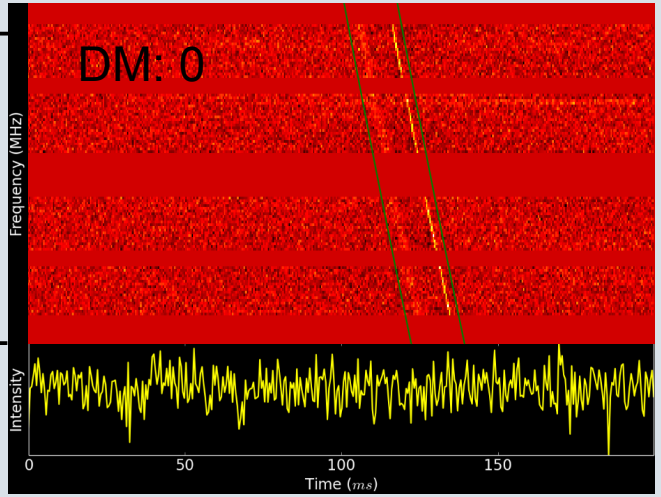


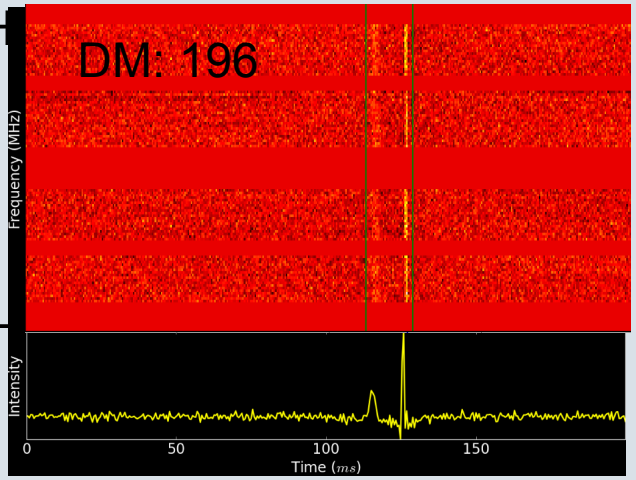
Find and image pulses of unknown position!



RRAT J1819-1458







Go to the VLBI data products…

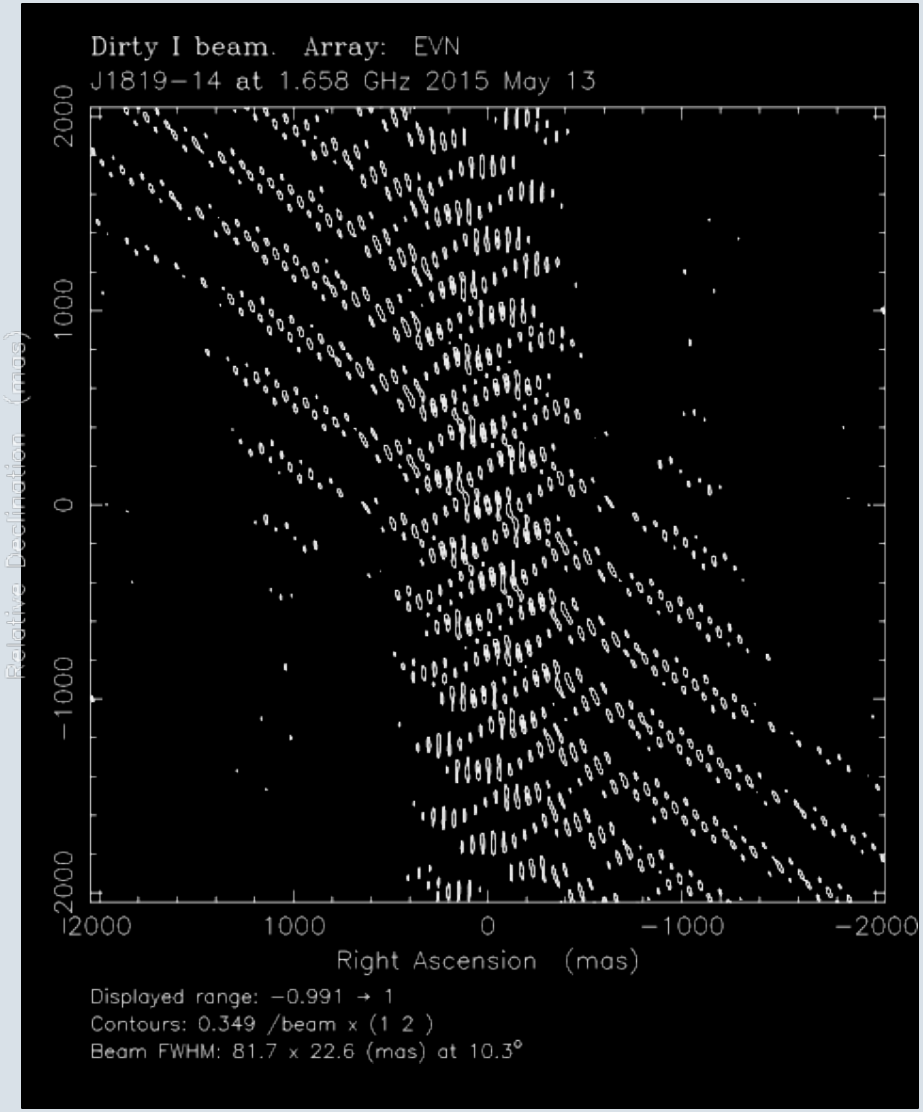
1. Pipeline calibrate the phase-referencing experiment (normal correlation)

2. De-disperse and re-correlate a few seconds of data around the burst time with high spectral and time resolution (~5ms)

3. Pass the calibration tables from the Pipeline

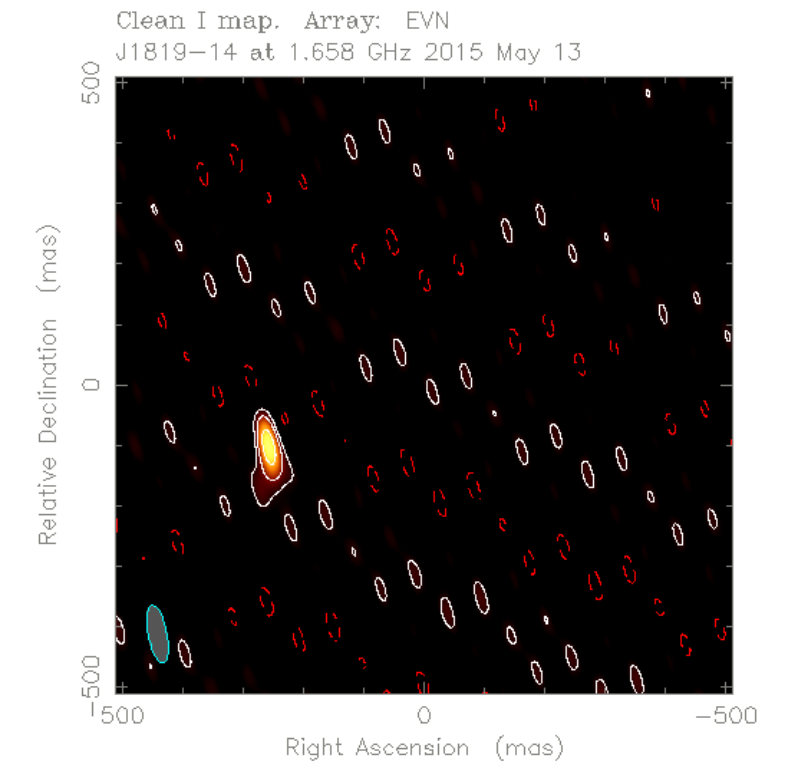
4. Make an image around a-priori position of RRAT J1819-1458

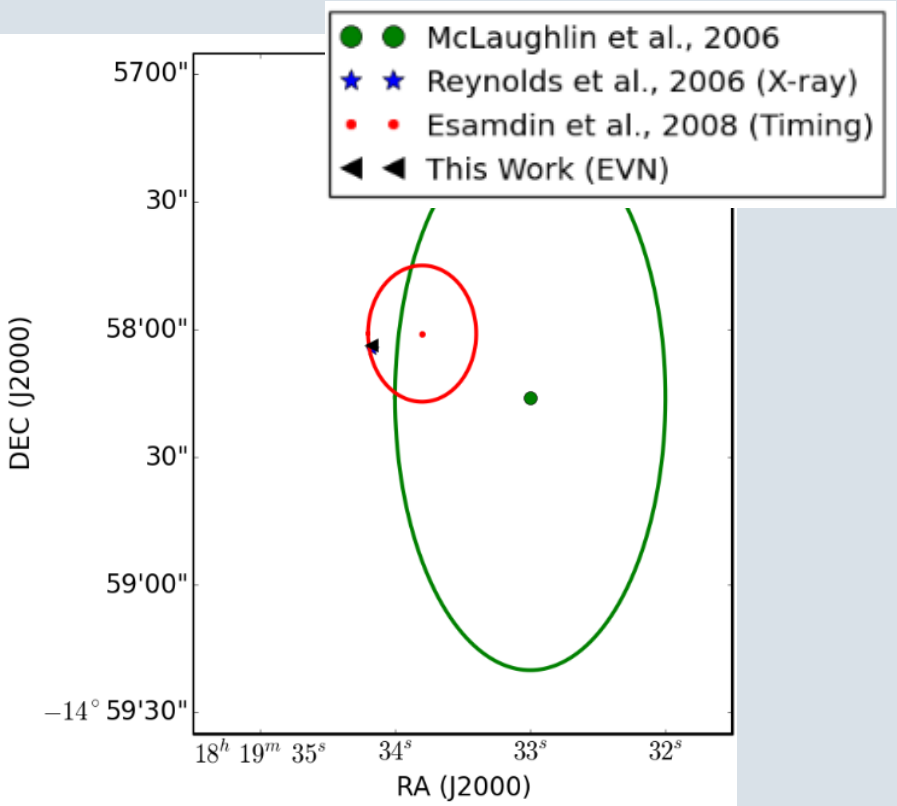
For a few-ms data (poor u-v sampling), the dirty beam is indeed dirty!



Successful EVN localization!

Single pulse e-EVN image of RRAT J1819-1458
(note this mode of observation requires buffering/recording VLBI voltage data)





Paragi/Wen/Keimpema/Siemion et al.; preliminary)

I. e-EVN follow-up of FRB150418

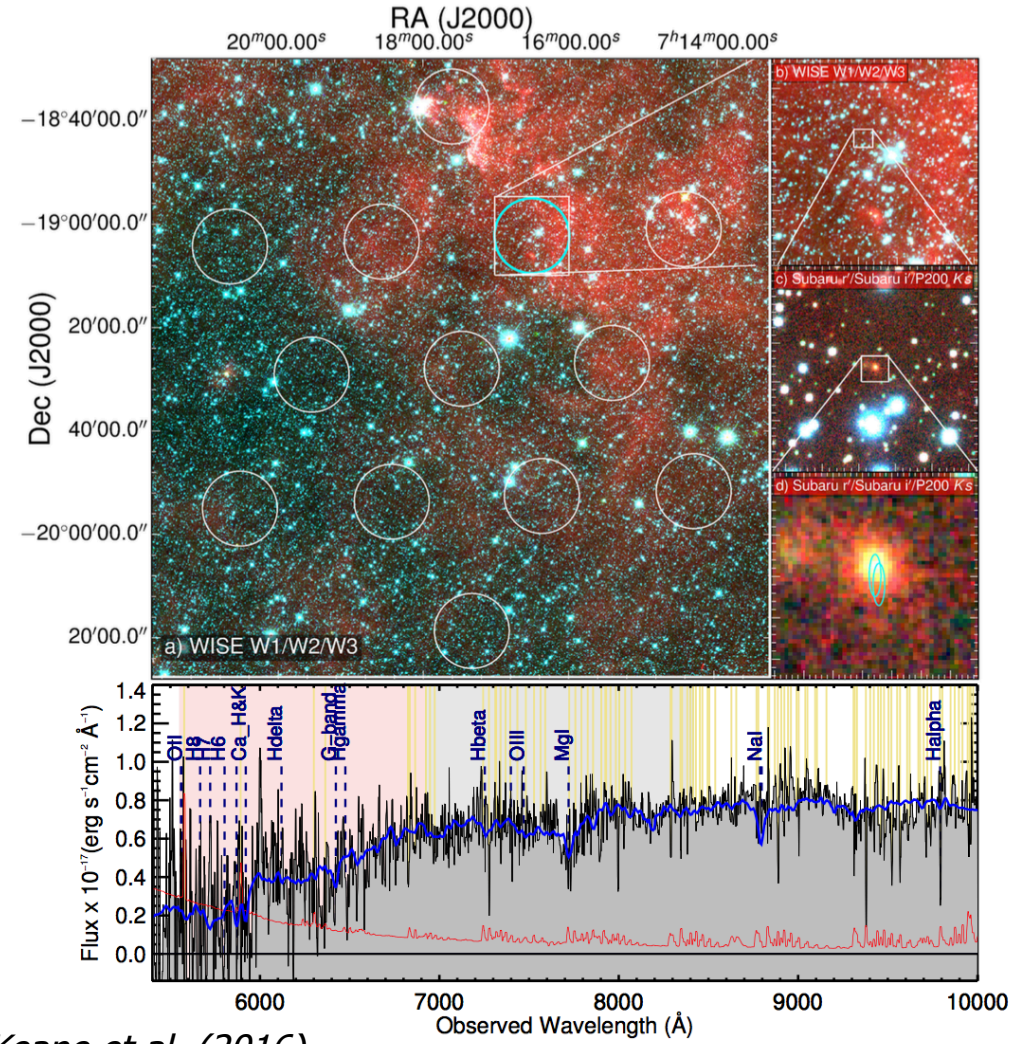
Claimed localization of an FRB host Galaxy based on finding a fading continuum transient source in the FoV of FRB150418.

Alternatively, the transient might be related to an AGN.

Williams, Berger & Chornock (2016)
Atel #8752

Williams & Berger (2016)
arXiv160208434

e-EVN observations to verify this start this afternoon: data are being streamed from radio telescopes to the EVN/JIVE correlator in the basement right now (PI Garrett).



Keane et al. (2016)

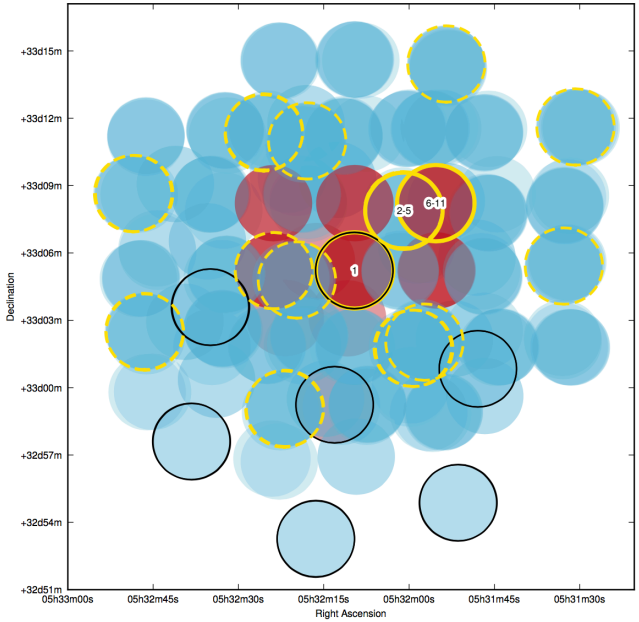
II. e-EVN hunt for the repeating FRB121102

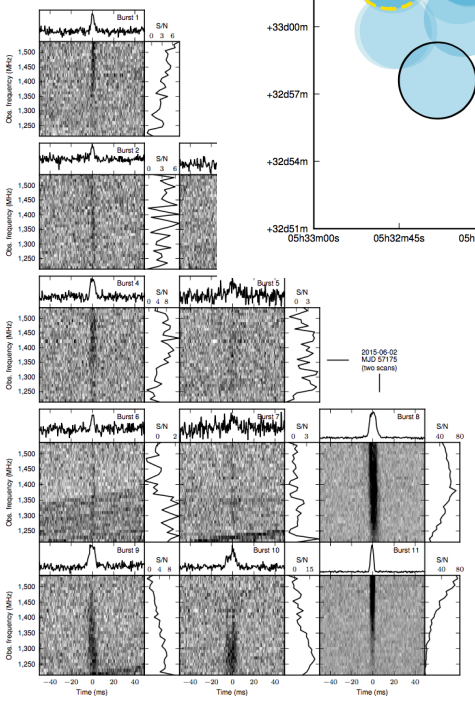
First FRB that repeats, and shows similarity to RRATs/magnetars.

Spitler et al. (2016)

e-EVN observations using our new tools to find an FRB burst directly in VLBI data and do first direct localization.
(PIs Hessels/Paragi)

Three epochs observed in February 2016 with e-EVN +Arecibo, more to come!





Future: use these techniques for SETI?

1. Combining the largest dishes is increasing our sensitivity and potentilally can reduce the effect of RFI significantly
2. Downside: search field of view is still limited by the largest dish size
3. Advantage: very accurate localization of a transient signal is possible
4. Even planetary motion around a star in a nearby system could be detected with VLBI
5. A similar project (not for SETI) is already going on at the EVN: RICHARD (PI Gawronski)