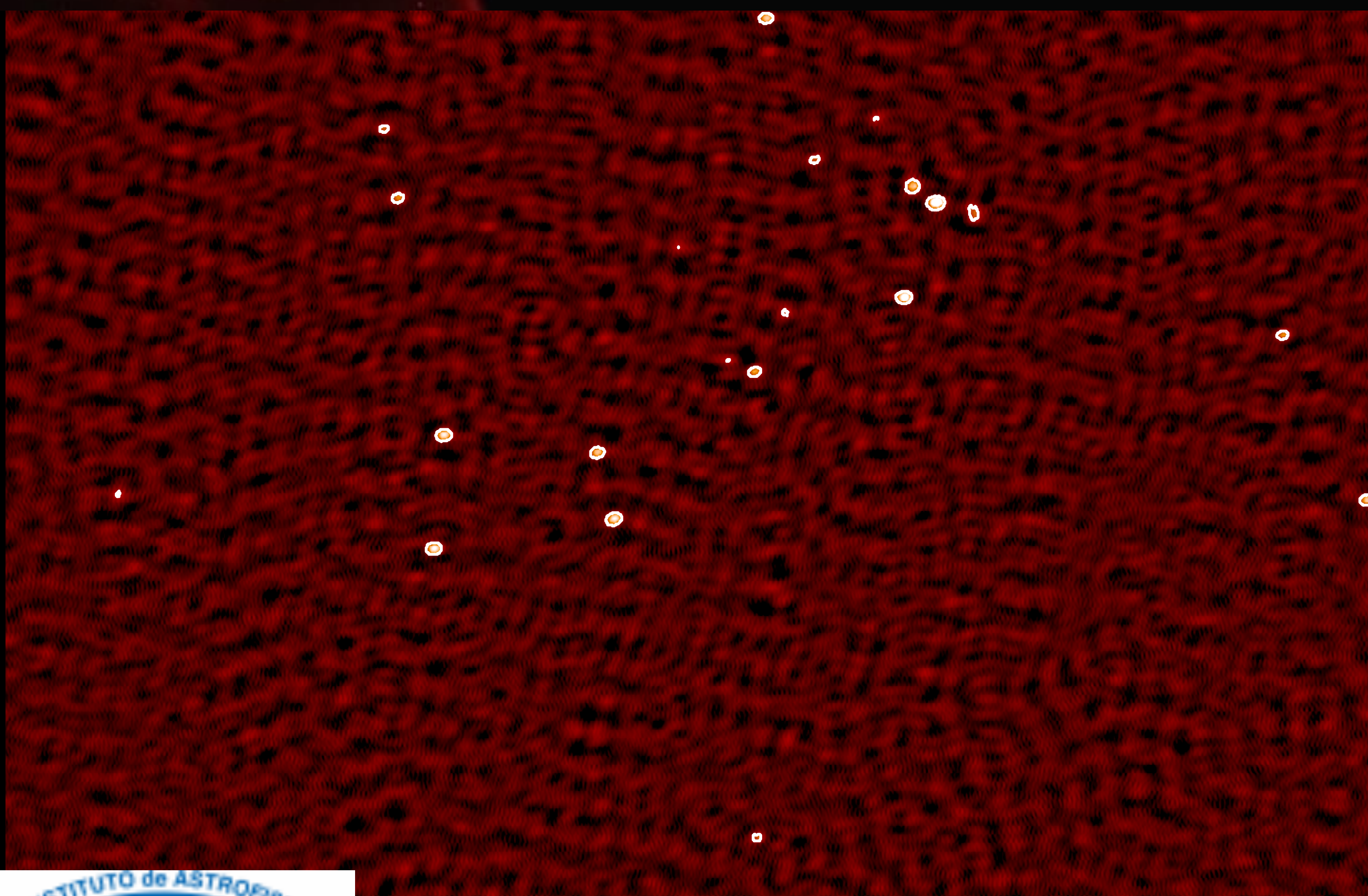
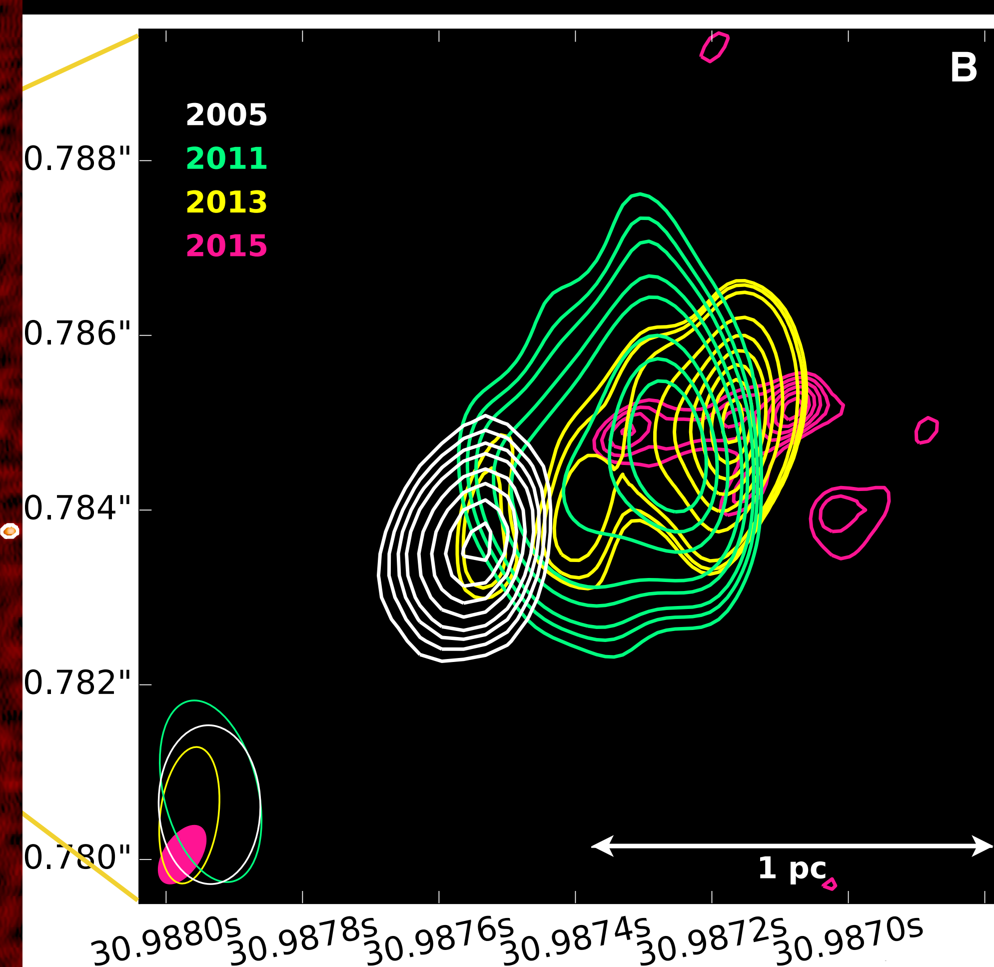
Transient phenomena

Miguel Pérez-Torres (IAA-CSIC,Granada)

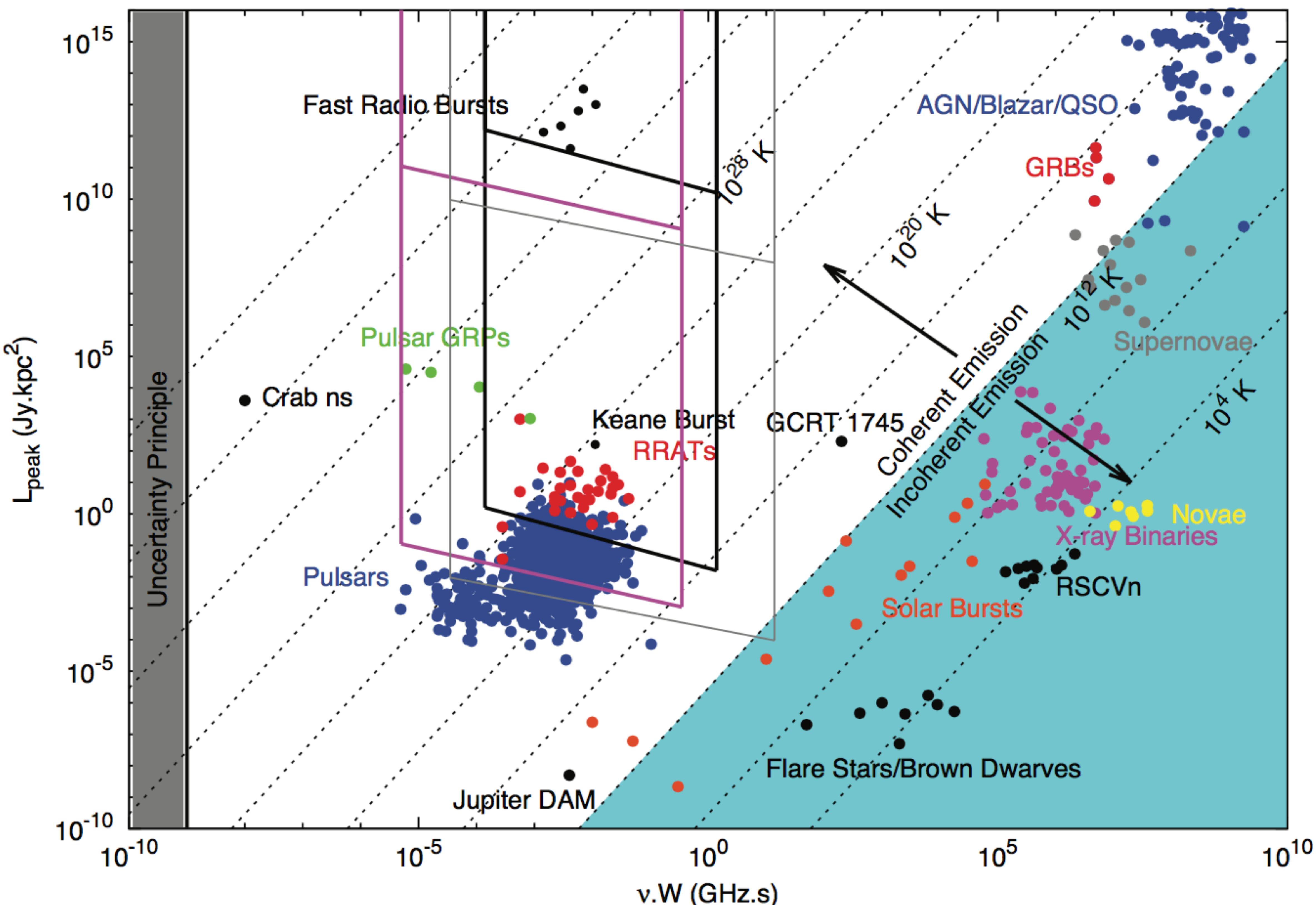
(includes also contributions from
G. Ghirlanda, M. Giroletti, J. Miller-Jones,
T. O'Brien, Z. Paragi, A. Possenti)



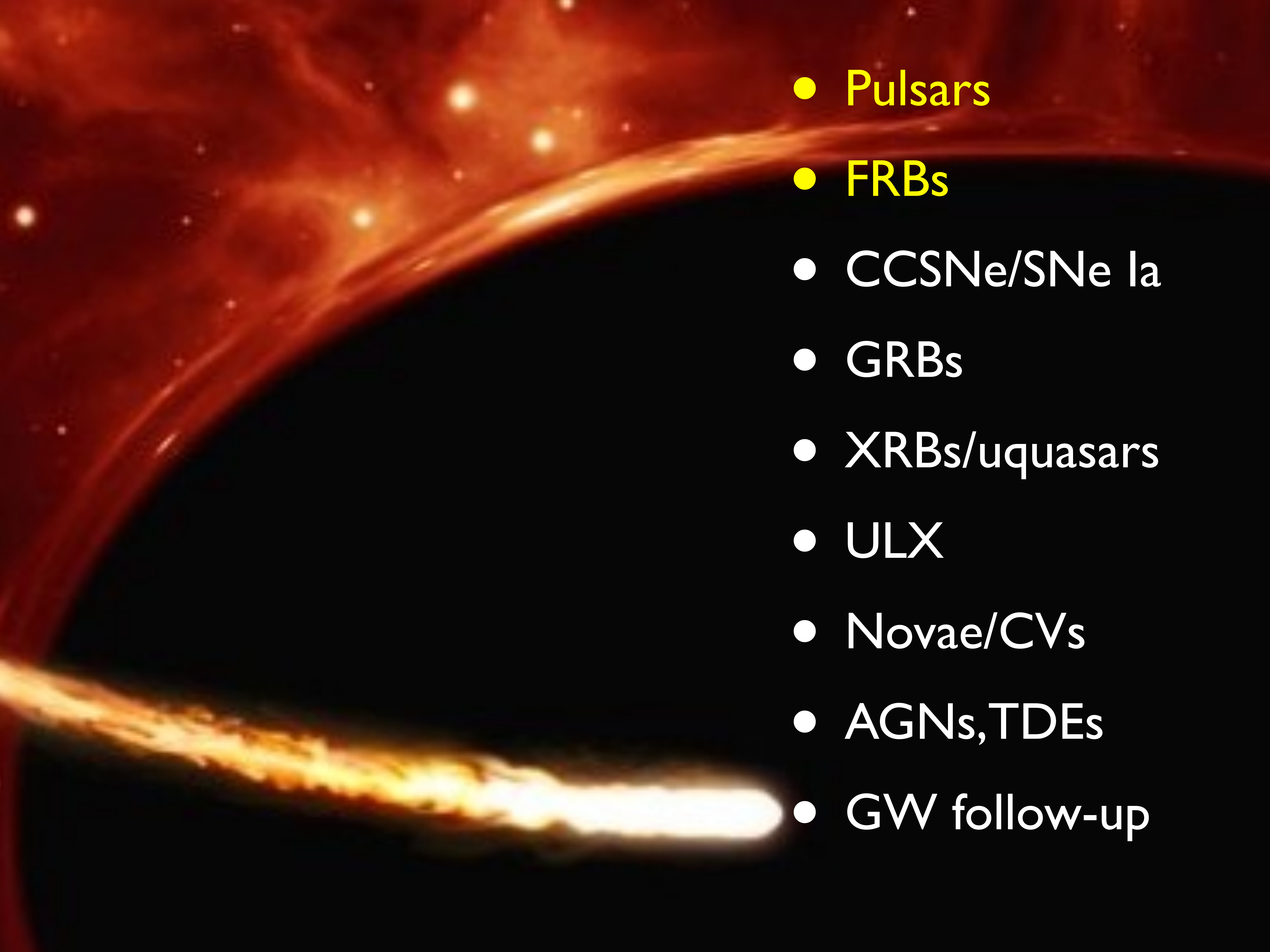


EVN Vision f2f meeting, March 1st, 2018, Zaandam

The transient parameter space



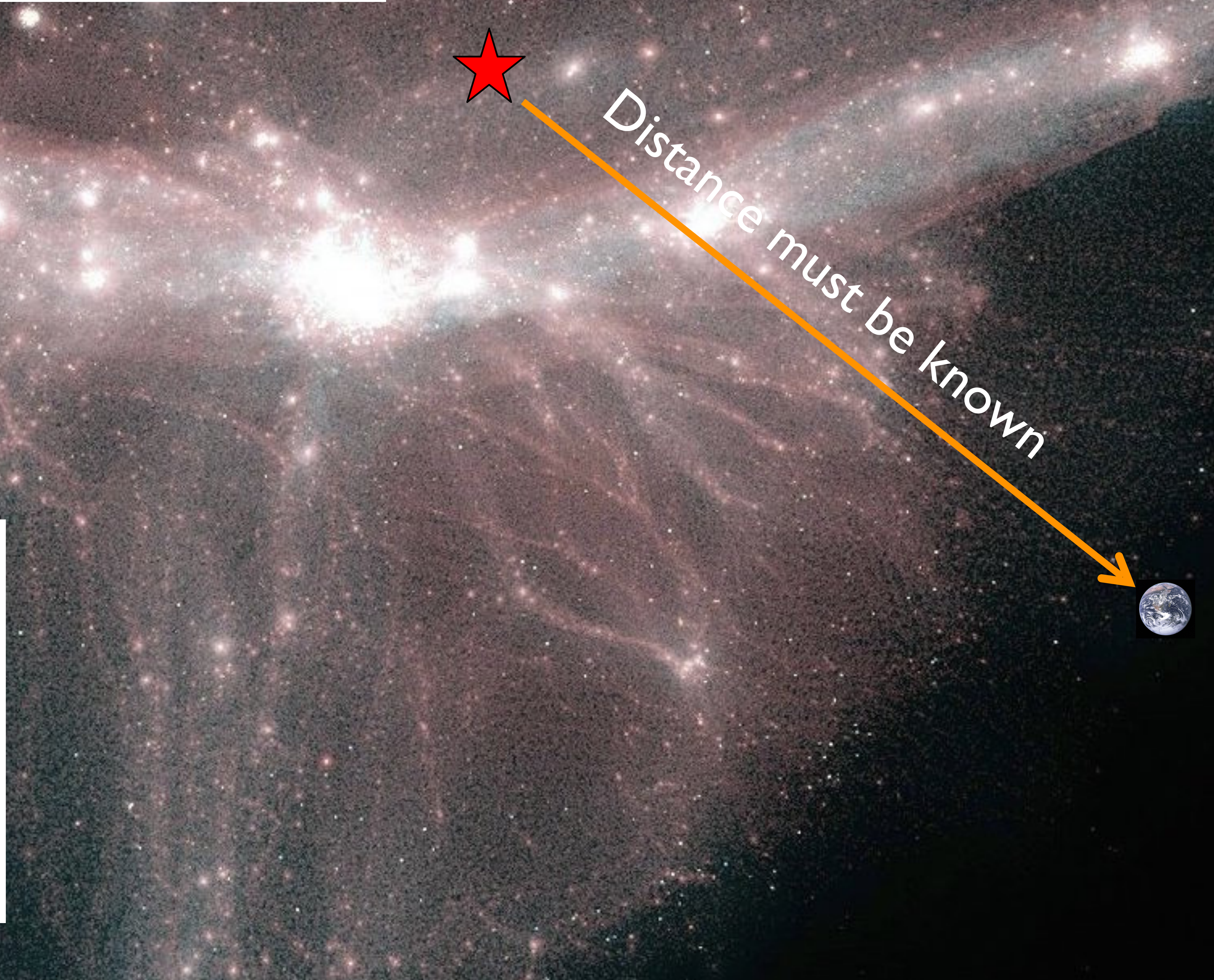
Updated plot of Cordes+2004

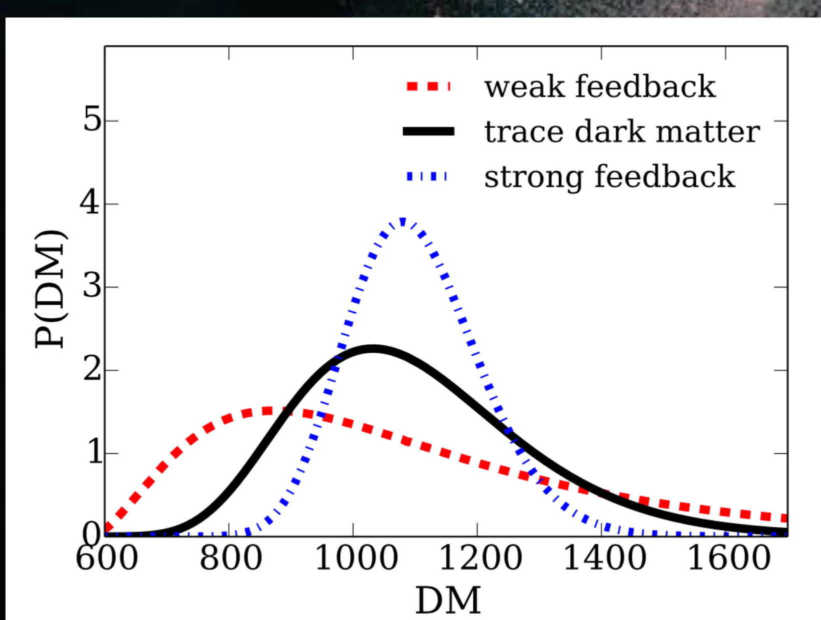


- Pulsars
- FRBs
- CCSNe/SNe Ia
- GRBs
- XRBs/uquasars
- ULX
- Novae/CVs
- AGNs, TDEs
- GW follow-up

FRBs

- ➢ A tool to study the cosmic web: the distribution of matter in the Universe
- ➢ Most of this matter within the galaxies is invisible otherwise

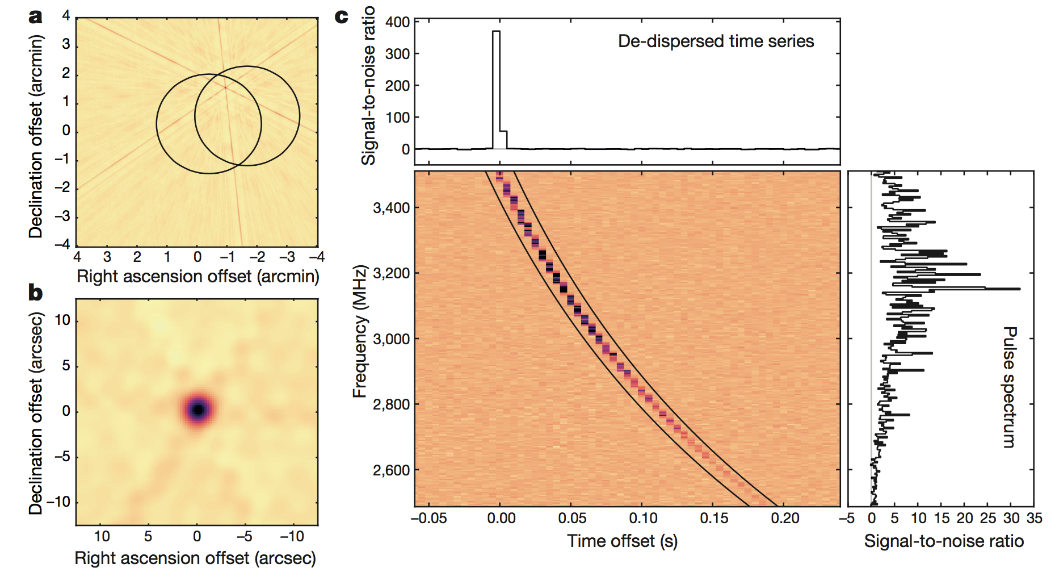




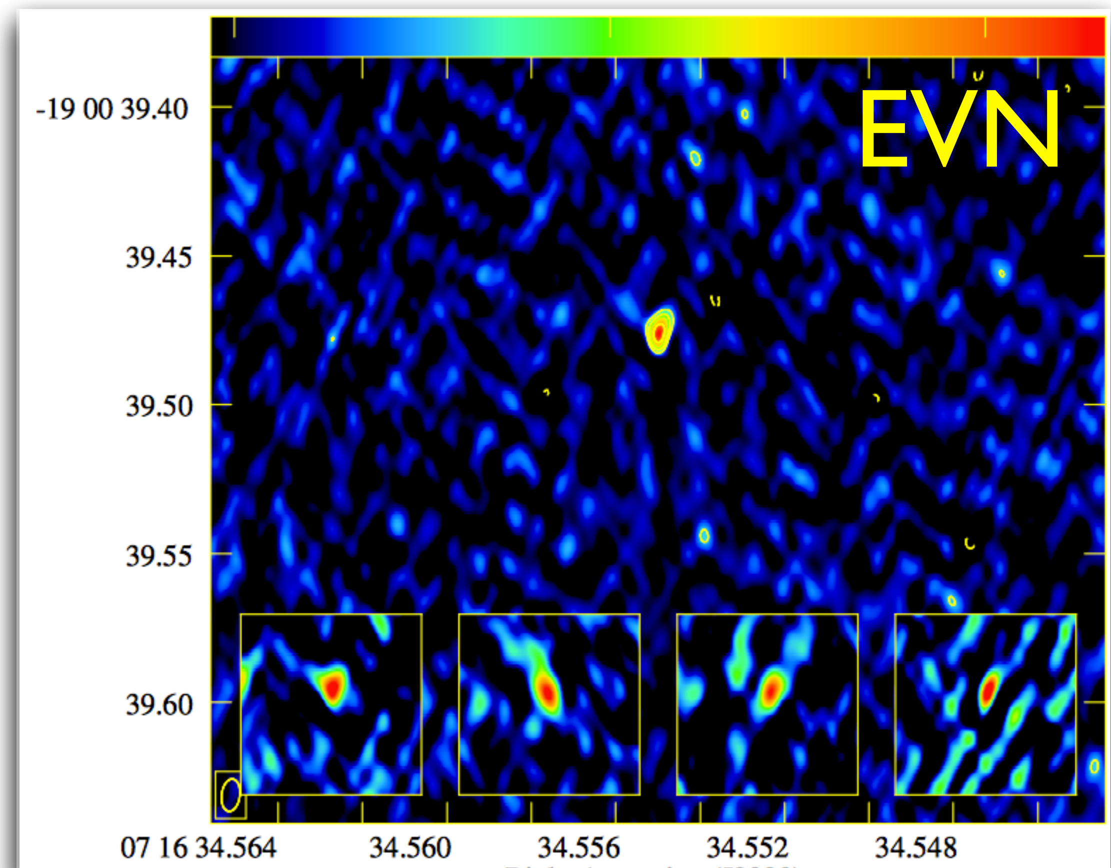
Bourke, Crain and Duffy

Fast Radio Bursts (FRBs)

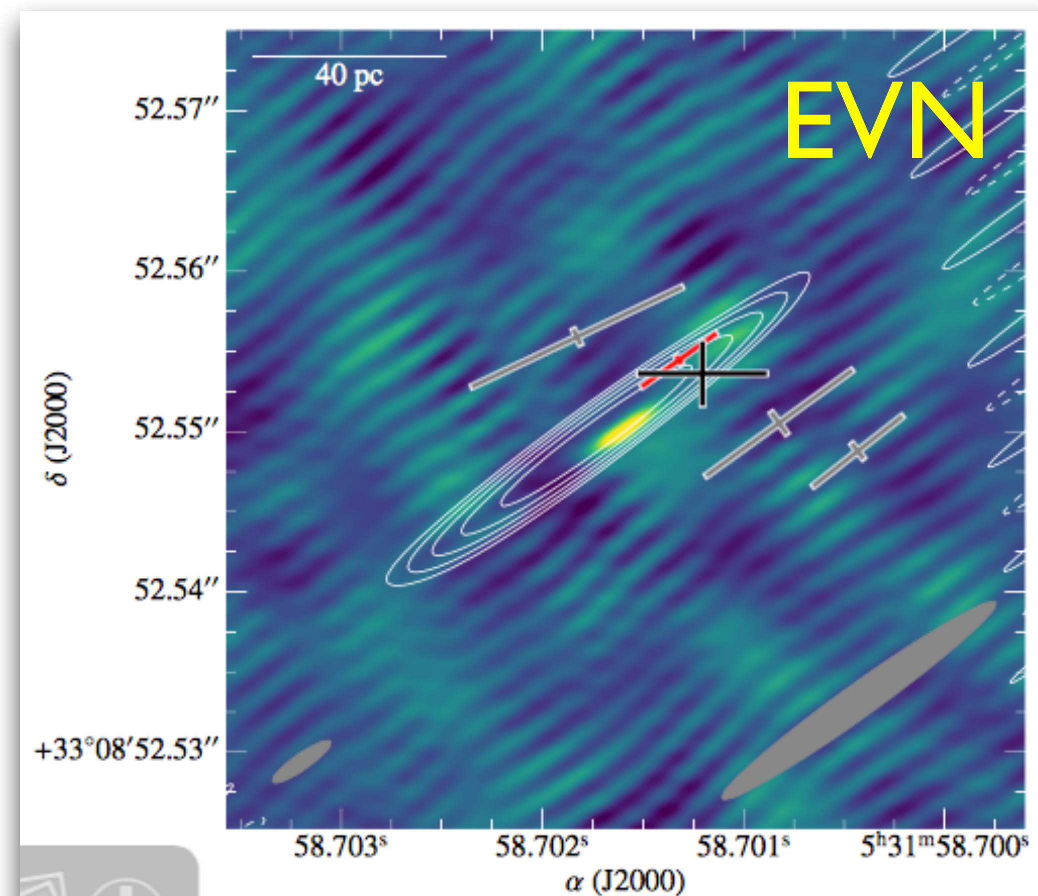
FRB localization is key



5-ms image (dispersion corrected) of one burst.



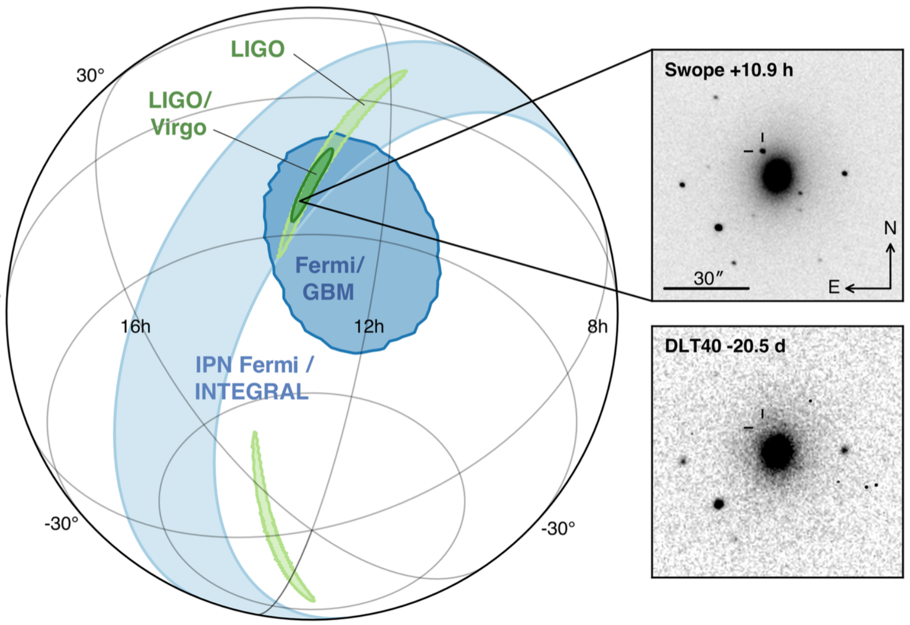
Variable steady source associated to FRB 150418 (Giroletti+16)

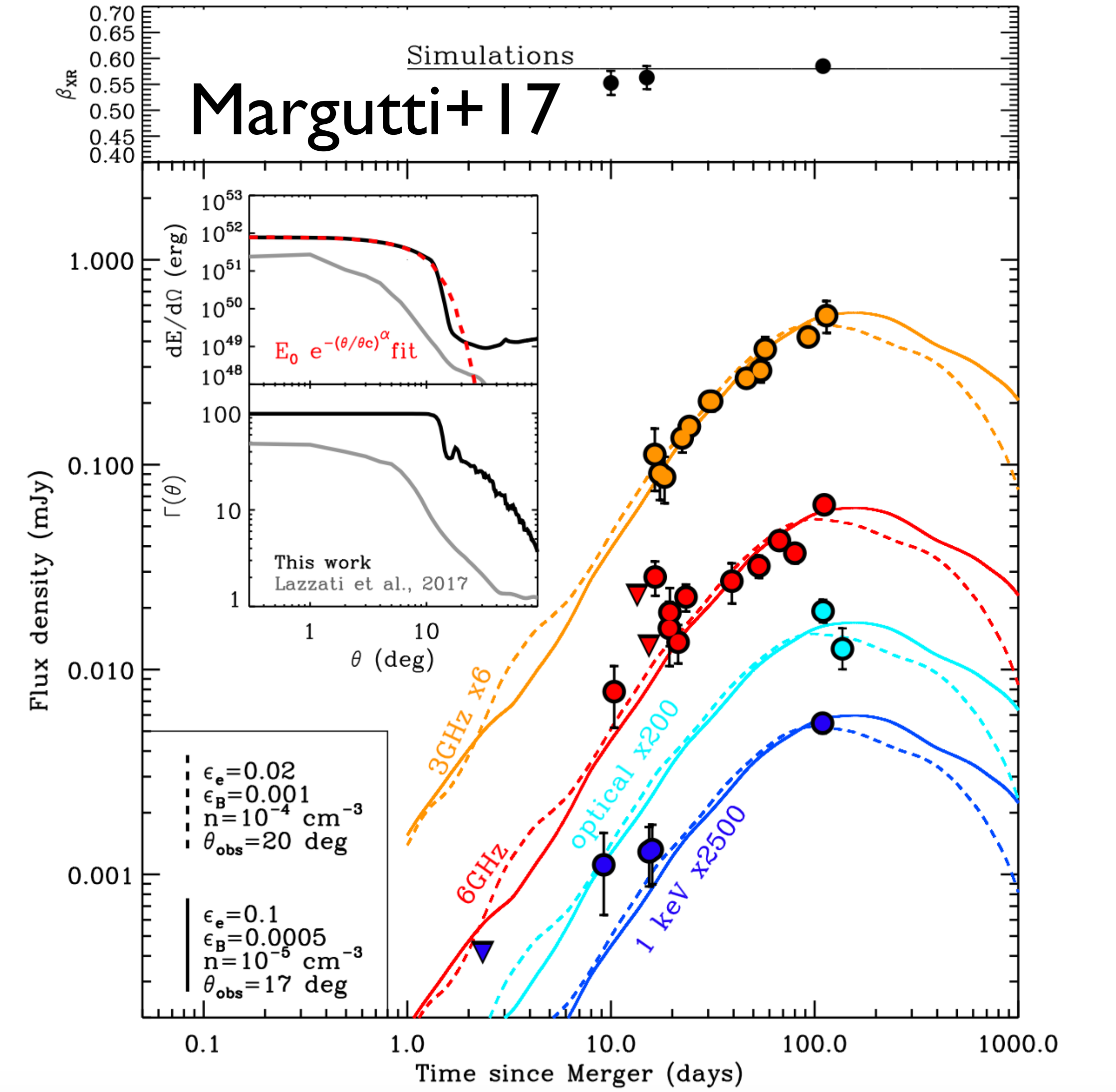


Localisation of the repeating FRB121102 (Marcote+17)

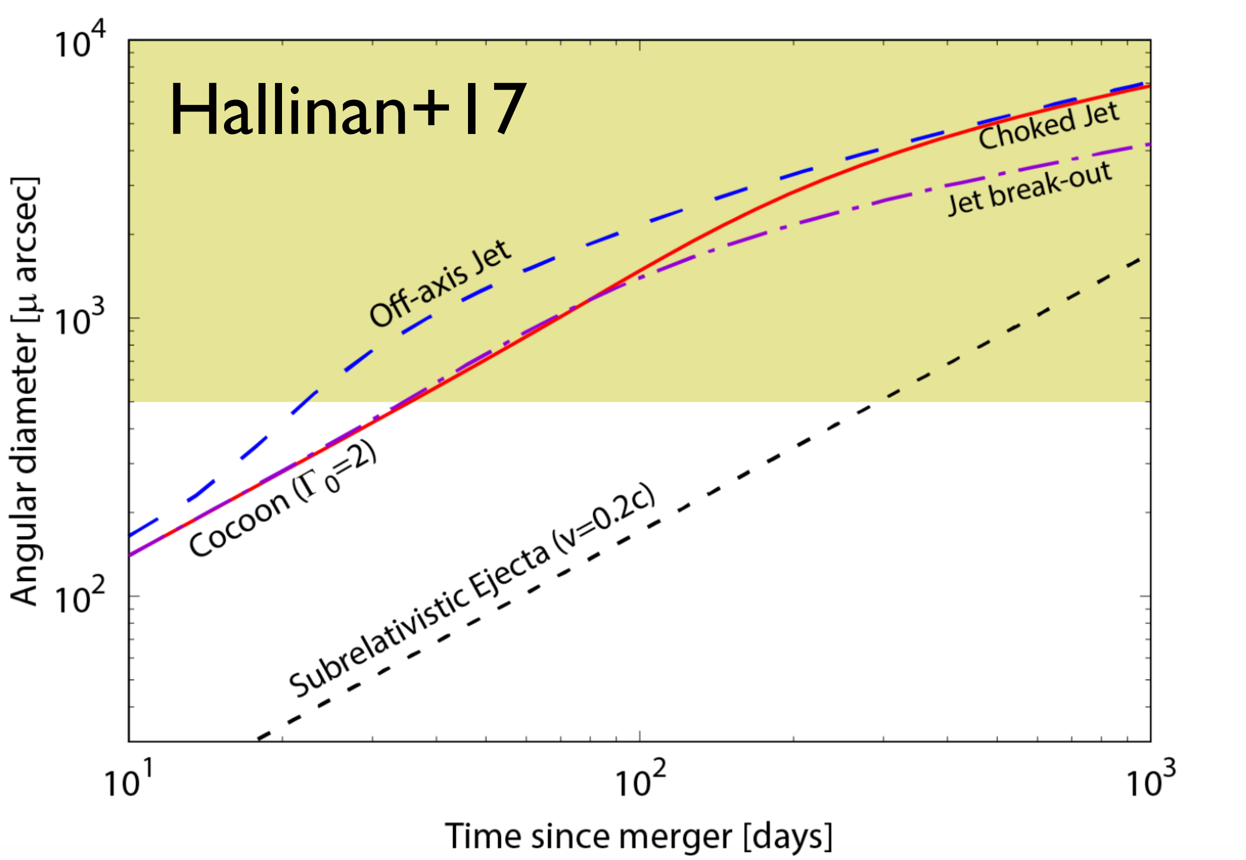
GW170817 EM counterpart

Abbott+17



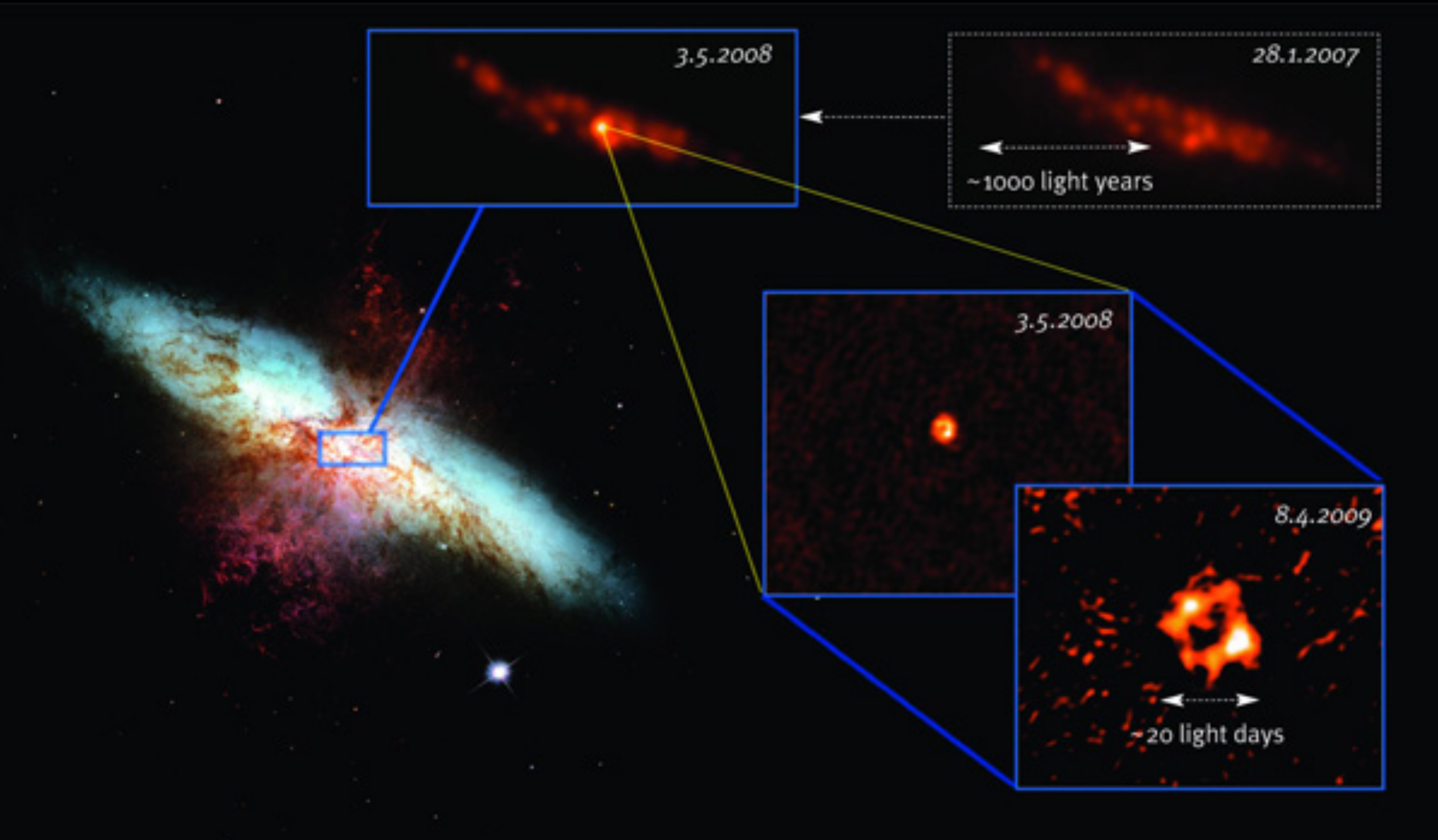


Structured jet and cocoon models tested via light curve modelling



VLBI obs-ns can measure expansion of ejecta

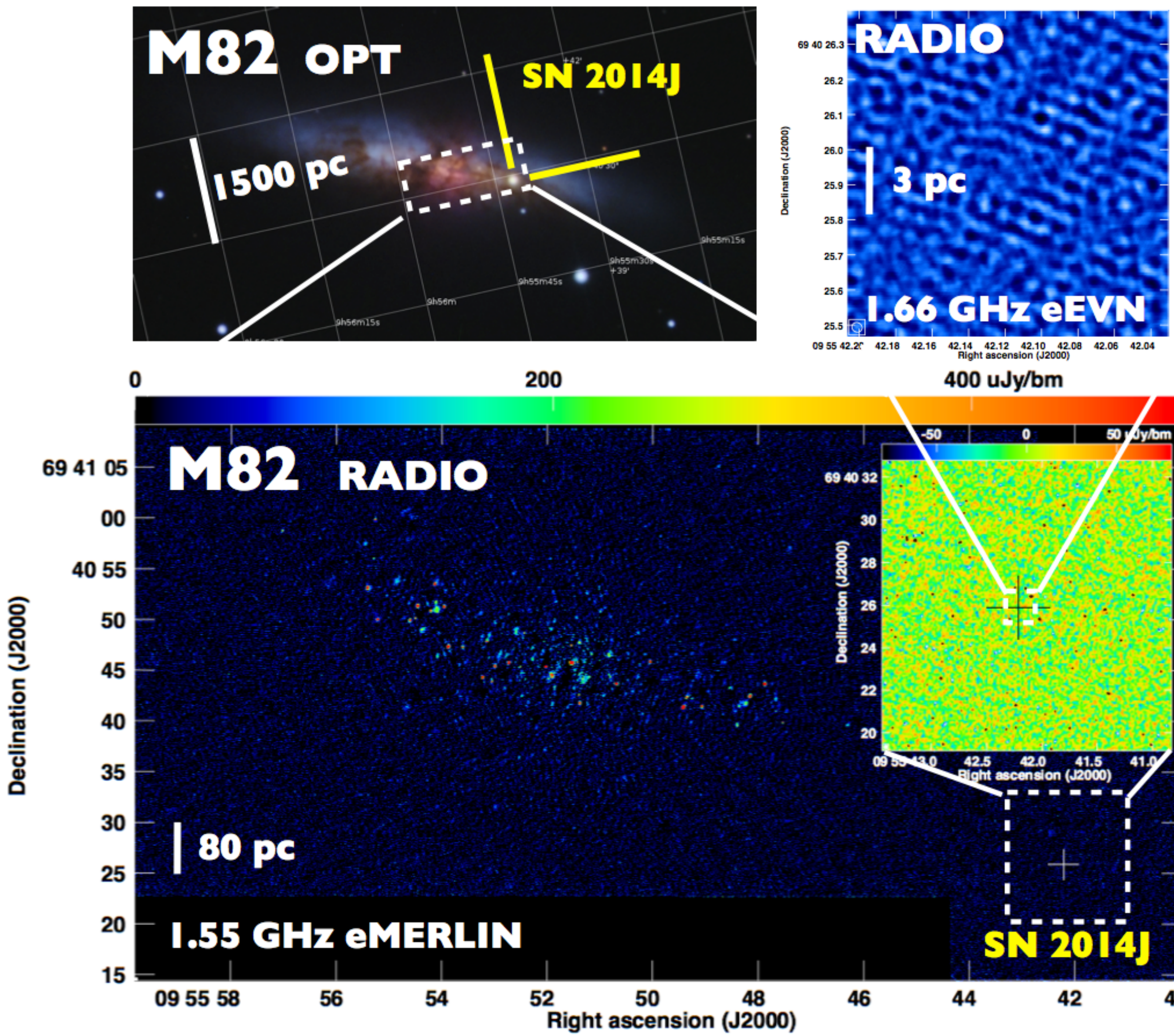
CCSNe



Expansion of SN2008iz in M82 imaged with VLBI (Brunthaler+2010)

Type Ia SNe

- What are their progenitors?
  - Single degenerate (SD) channel=> Prompt radio emission
  - Double-Degenerate (DD) channel => No prompt radio emission



(Pérez-Torres+2015)

Type Ia SNe

5.0 GHz Continuum MERLIN Observations of the Type Ia SN 2013dy

ATel #5619; *M. Perez-Torres (IAA-CSIC/CEFCA, Spain), M. Argo (JBCA, Manchester), P.*
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EVN measurements show no evidence for radio emission from the Type Ia SN 2014J

ATel #6153; *M. Perez-Torres (IAA-CSIC, Granada; CEFCA, Teruel), P. Lundqvist (Dept. of*
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Astronomy
Alber
Manchest
Mart&iacu
(Max-Planc

Subjects: Ra

Referred to

Tweet

We report d
2014J, whic
http://www.
CBET #379
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We find no
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published in

We thank
observations
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research lea
Framework Programme (FP/2007-

Tight constraints on the mass-loss rate of the Type Ia SN 2016coj with e-MERLIN

ATel #10168; *M. Perez-Torres (IAA-CSIC), P. Lundqvist, E. Kundu (Stockholm), J. Moldon*
(JBC

C

Subjects: Supernov

Referred to by ATel

Tweet Reco

We report e-MERL
on 28.18 May 201
#9095). Our observ
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(Cambridge, Pickm
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Torres et al. (2014,
very stringent uppe
masses per year (3-
this model, our dat
MERLIN staff for
supernovae, aimed

Radio constraints on the mass-loss rate of the Type Ia SN 2018gv

ATel #11211; *S. D. Ryder (AAO), P. Lundqvist (Stockholm University), M. A. Perez-Torres (IAA-*
CSIC), E. Kundu (Stockholm Un
Bjornsson (Stockholm U
on
Credential Certif

Subjects: Radio, Supernovae, Transient

Referred to by ATel #: 11324

Tweet Recommend 4

The young Type Ia SN 2018gv (ATel #
with the Australia Telescope Compact
radio emission was detected at the rep
(5.5 GHz) and 30 microJy/beam (9.0
(2013, AJ, 146, 86) of 16.8 Mpc, this
erg/s/Hz. Using the same model as in
SN 2018gv 12 days after explosion, thi
the supernova progenitor of 1.9e-8 sol
100 km/s. We would like to extend ou
The Australia Telescope Compact Arra

Mass-loss rate constraints on the Type Ia SN 2018pv from e-MERLIN observations

ATel #11324; *M. Perez-Torres (IAA-CSIC, Granada), P. Lundqvist (Stockholm University), J. Moldon (JBCA, Manchester), S. Ryder (Maccquarie University/AAO), E. Kundu (Stockholm University), E. Varenius (JBCA, Manchester), A. Alberdi (IAA-CSIC, Granada), R. Beswick (JBCA, Manchester), C.-I. Bjornsson (Stockholm University), C. Fransson (Stockholm University)*

on ***20 Feb 2018; 14:34 UT***

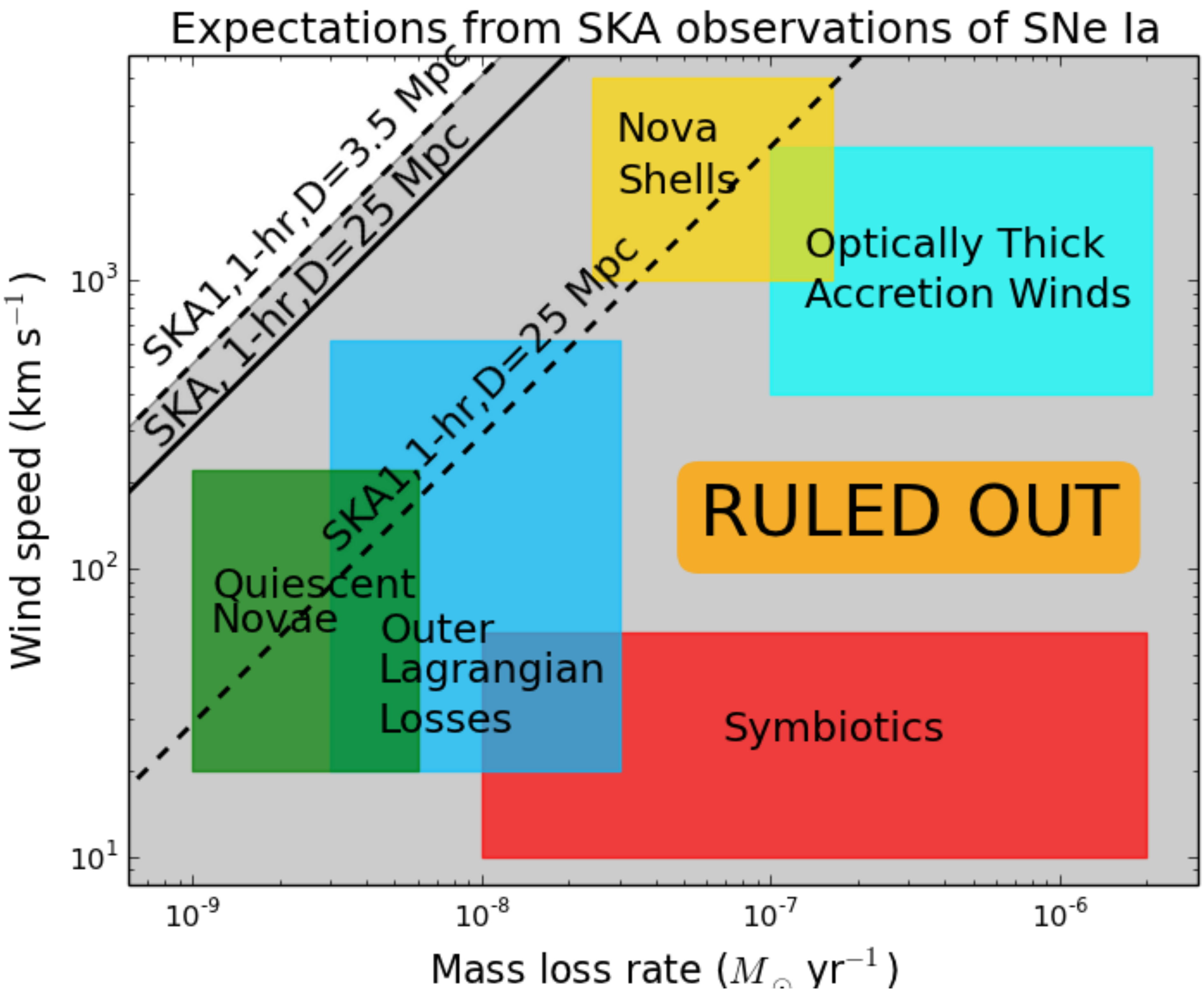
Credential Certification: Miguel A. Perez-Torres (torres@iaa.es)

Subjects: Radio, Supernovae

Tweet Recommend 1

We observed the young Type Ia supernova 2018pv with the electronic Multi-Element Radio Linked Interferometer Network (e-MERLIN) at 5.1 GHz. SN 2018pv was discovered on 3.63 February 2018 UT (MJD 58153.13) in the nearby (z=0.0031) galaxy NGC3941 (Tsuboi, TNS discovery report #16800), and a spectrum on 8.78 February 2018 (MJD 58158.78) confirmed the SN as a Type Ia event a few days before maximum (Yamanaka, TNS classification report #1712). Our observations were carried out on 9-10 February 2018 UT (MJD 58159.08), six days after the SN discovery. We centered our observations at the position of the optical discovery (J2000.0

Type Ia SN progenitors - SD channel



SKA chapter on SNe (Pérez-Torres+2015).
Plot adapted from Pérez-Torres+2014

GRBs

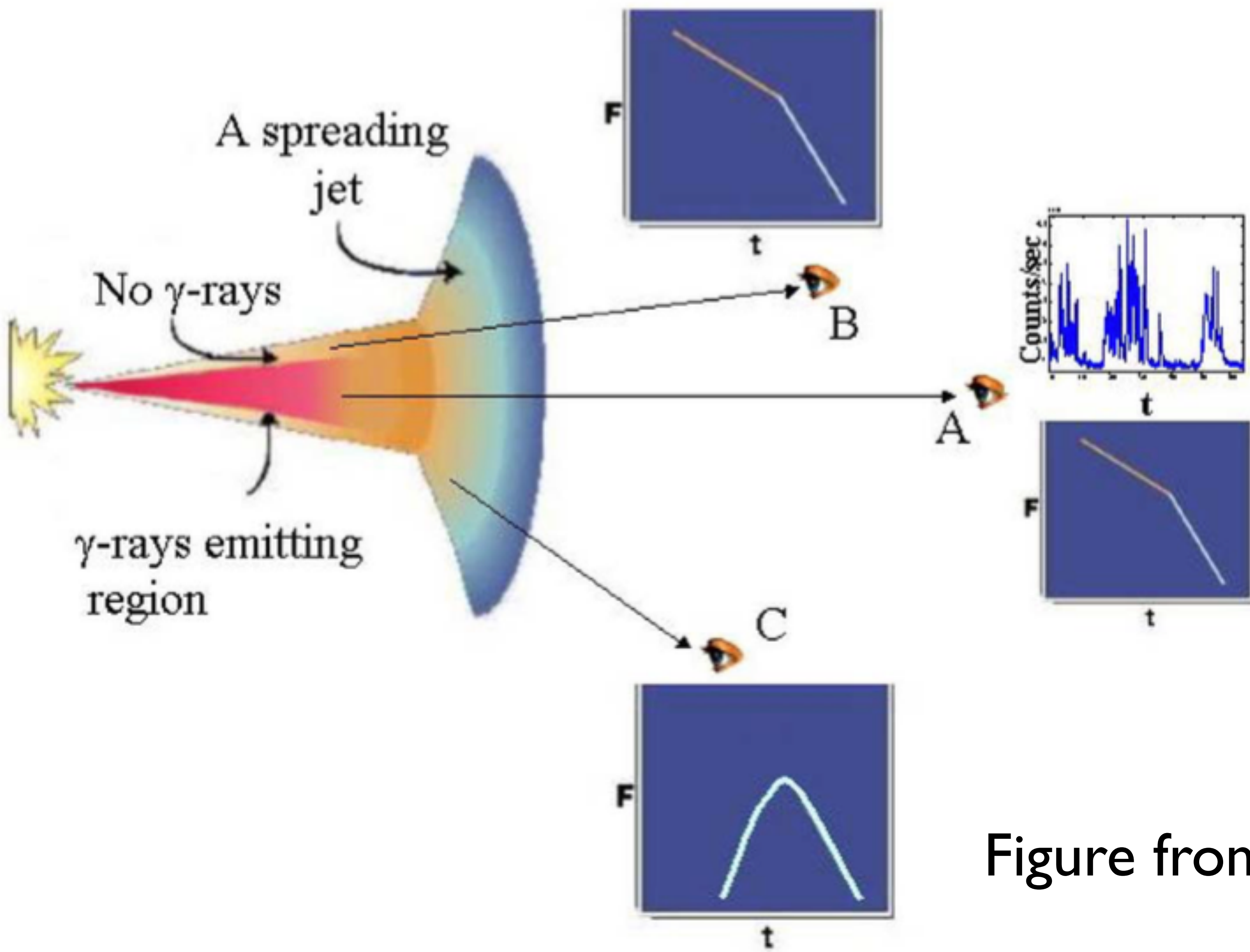


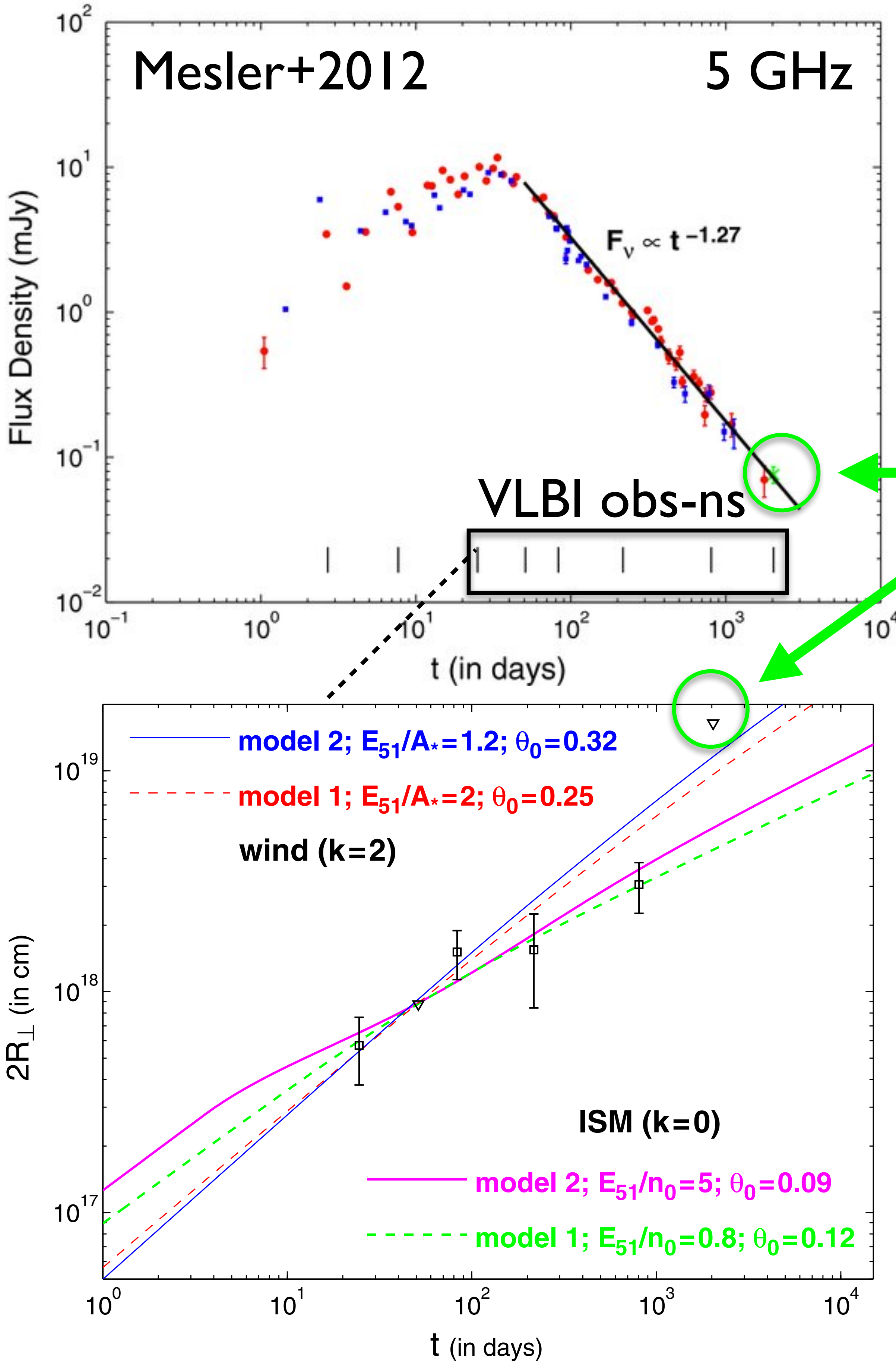
Figure from Nakar & Piran (1993)

VLBI obs-ns extremely useful

=> Deep flux measurements + resolution

- Jet properties (structure, dynamics, orientation)
- Shock properties (e.g. energy spectrum of e-),
- Environment (ISM, wind)

GRBs



GRB 030329: the best ever radio characterization (bright and close)

VLBI observations crucial to disentangle GRB environment

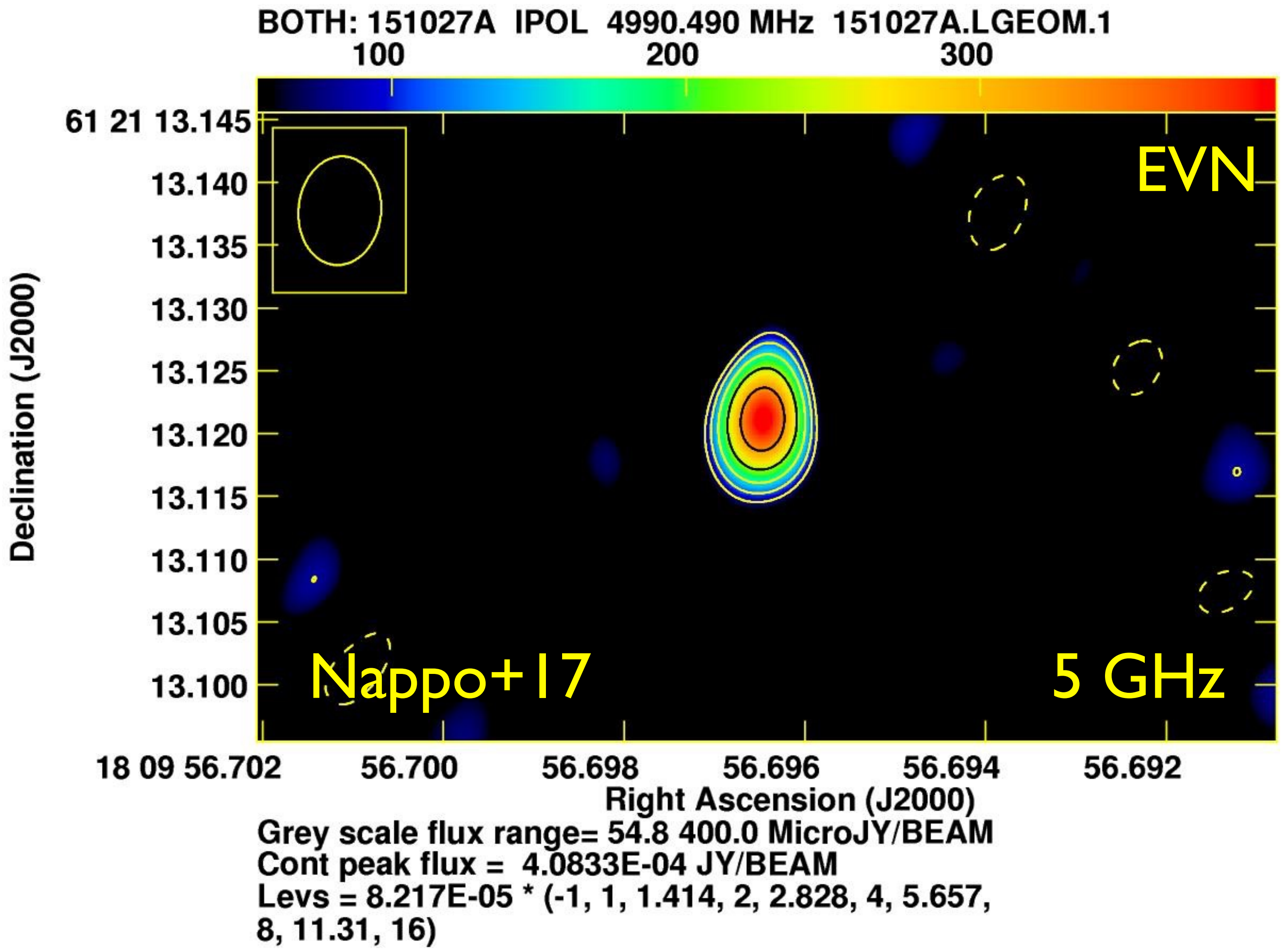
Global VLBI obs-ns (t=5.5 yr!)

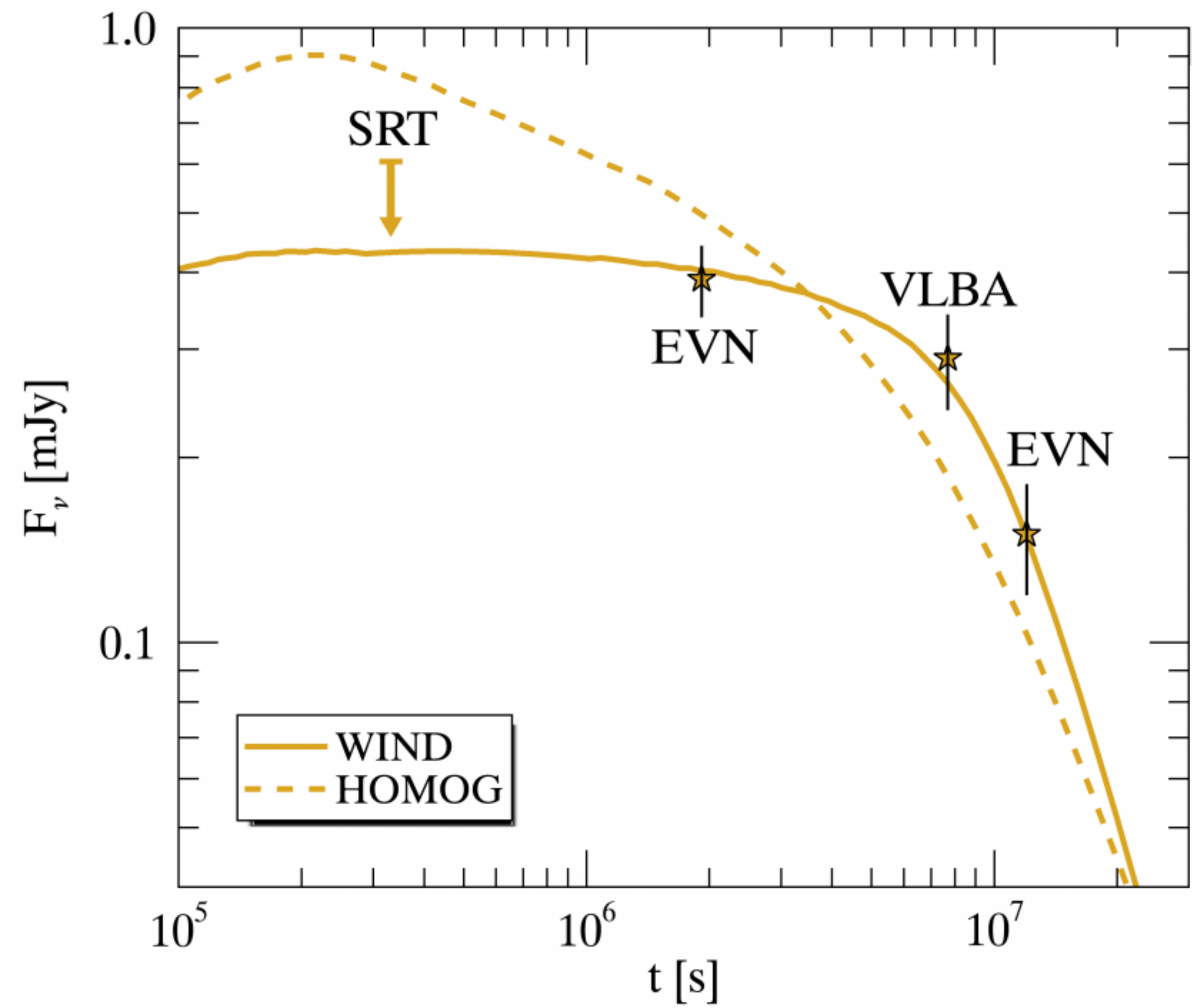
- Single power-law decay ($t^{-1.27}$)
- Proper motion < 0.067 mas yr^{-1}
- Size evolution

- Jet seen close to the LOS
- Expansion in the ISM
- Emission due to external shock, accelerated electrons (p=2.5)

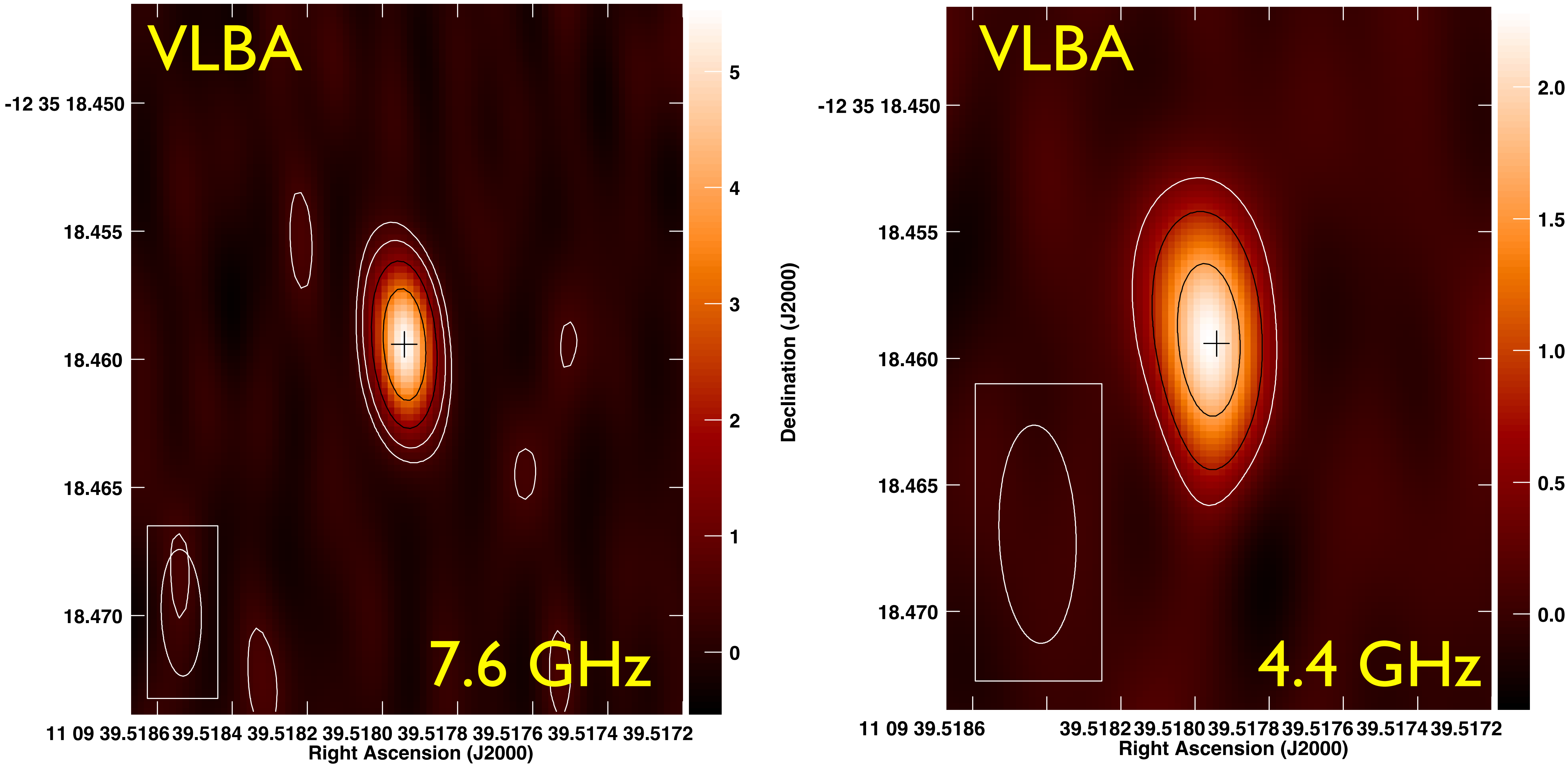
GRBs

GRB151027A





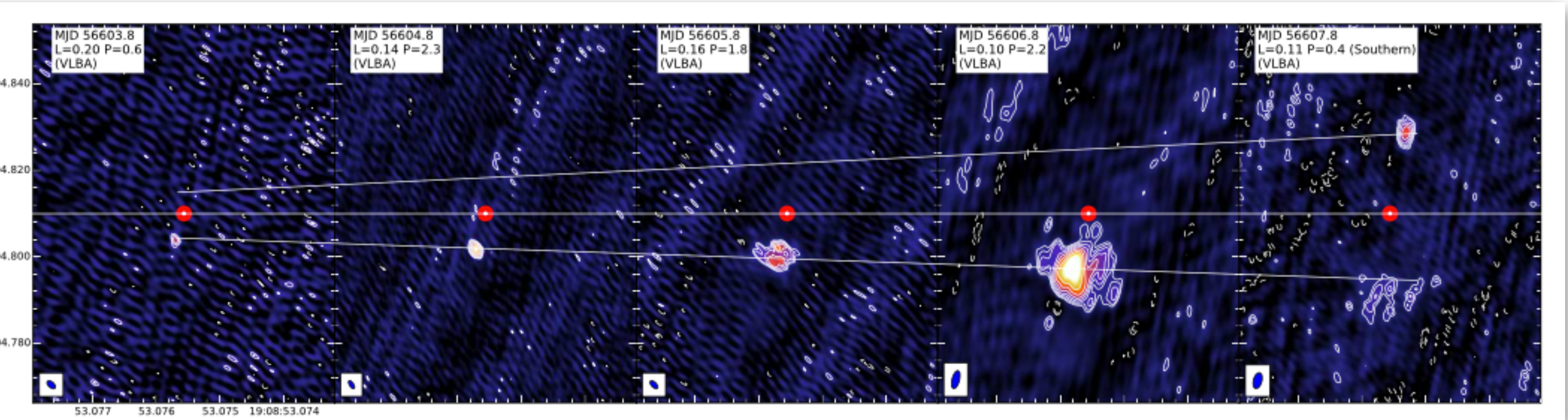
GRBs - GRB171205A



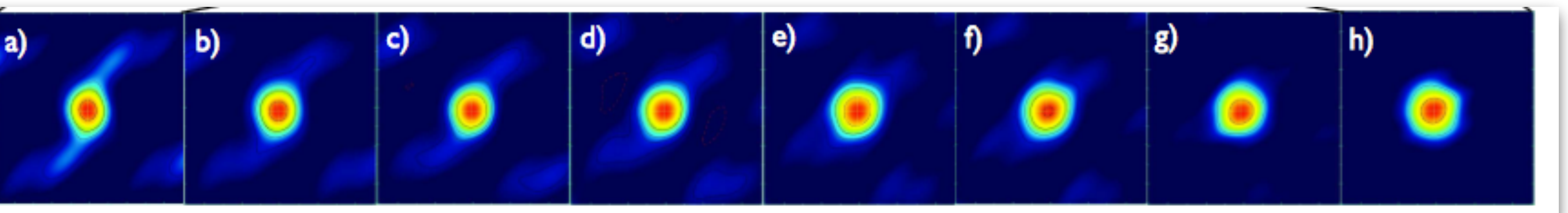
- VLBA, EVN, and eMERLIN obs-ns
- Discern Cannonball/Fireball model
- Discern ISM/wind interaction

Pérez-Torres+ (in prep.)

X-ray binaries



XTE J1908+094 expanding jet (Rushton+17)



Cyg X-3 giant flare (Egron+17)

Novae

White dwarf + Main Sequence/Red Giant companion

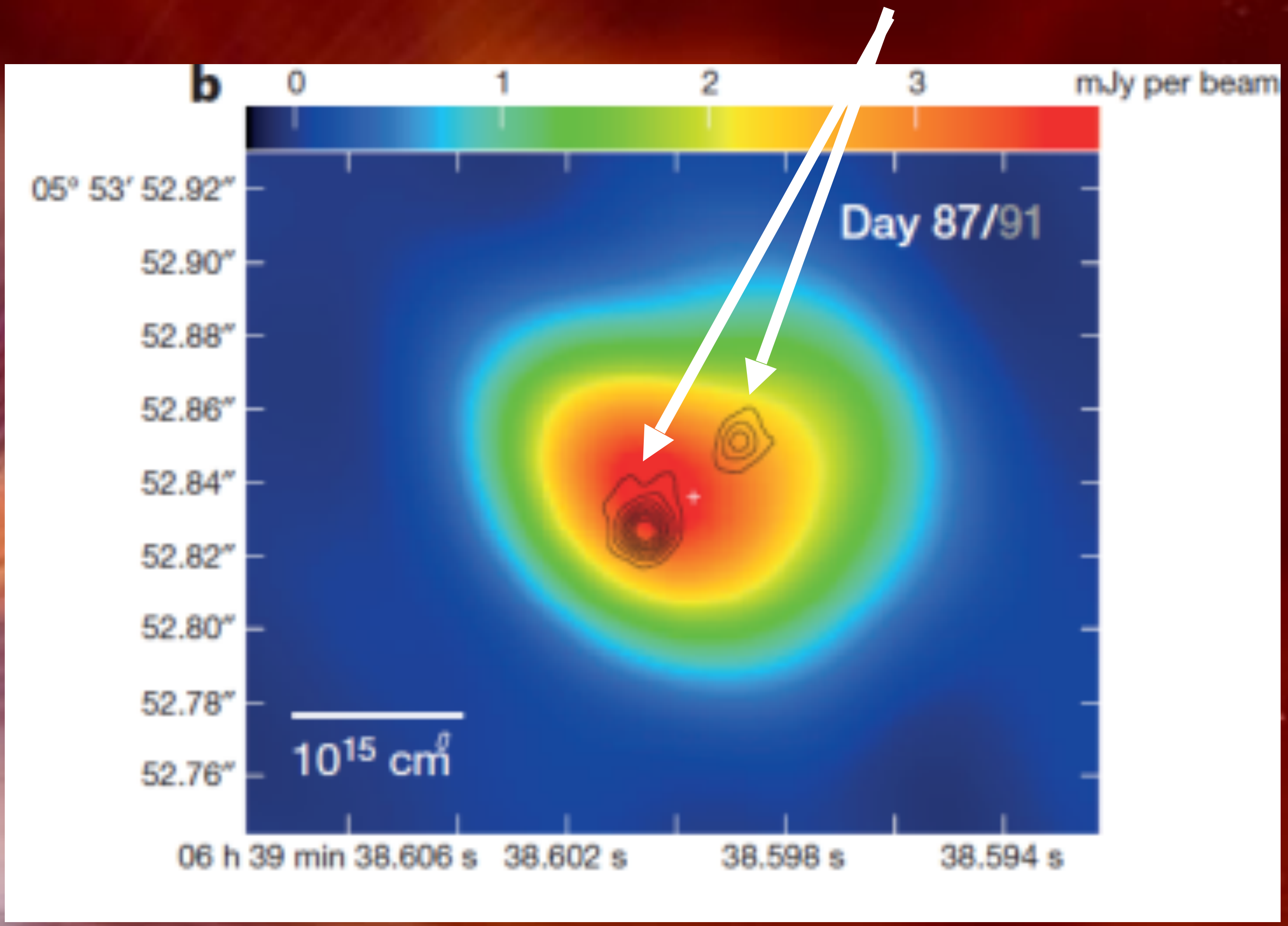
- Outbursts due to thermonuclear runaway in accreted material on WD surface.
- The white dwarf is not destroyed and another nova outburst may occur ~1 to 1000's of years later.

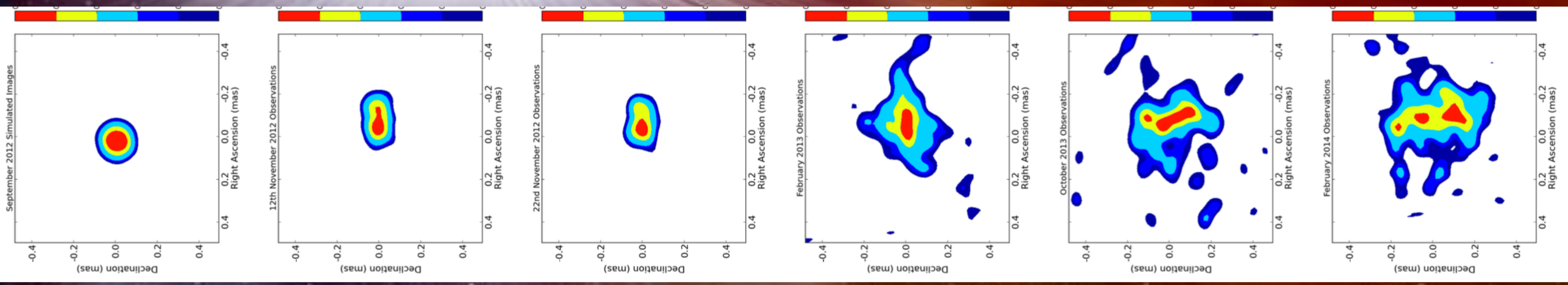
Novae

Gamma-ray nova V959 Mon (Chomiuk et al 2014)

Expanding non-thermal components seen with EVN

- High-resolution radio imaging of their expanding aspherical remnants to understand their ejection geometry, including jets
- Combining radio, X-ray and gamma-ray observations to understand role of shocks in particle acceleration
- Understanding explosions on massive WDs and their link to Type Ia SNe



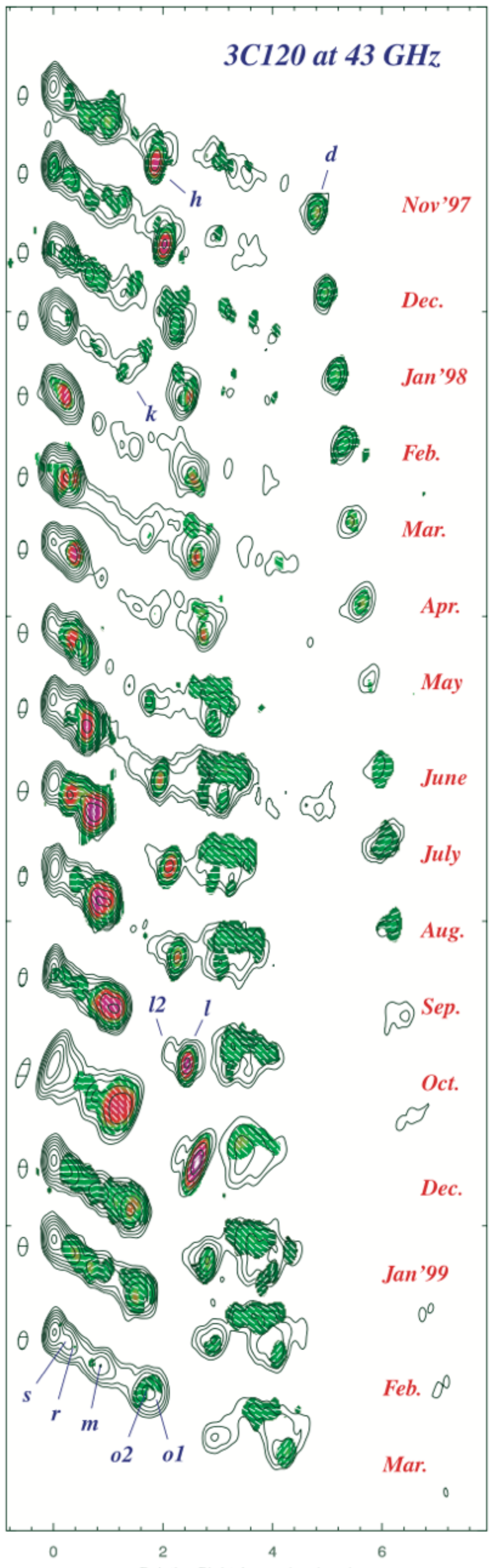


e-MERLIN imaging of V959 Mon (Healy et al 2017)

Microquasars: AGN for the impatient

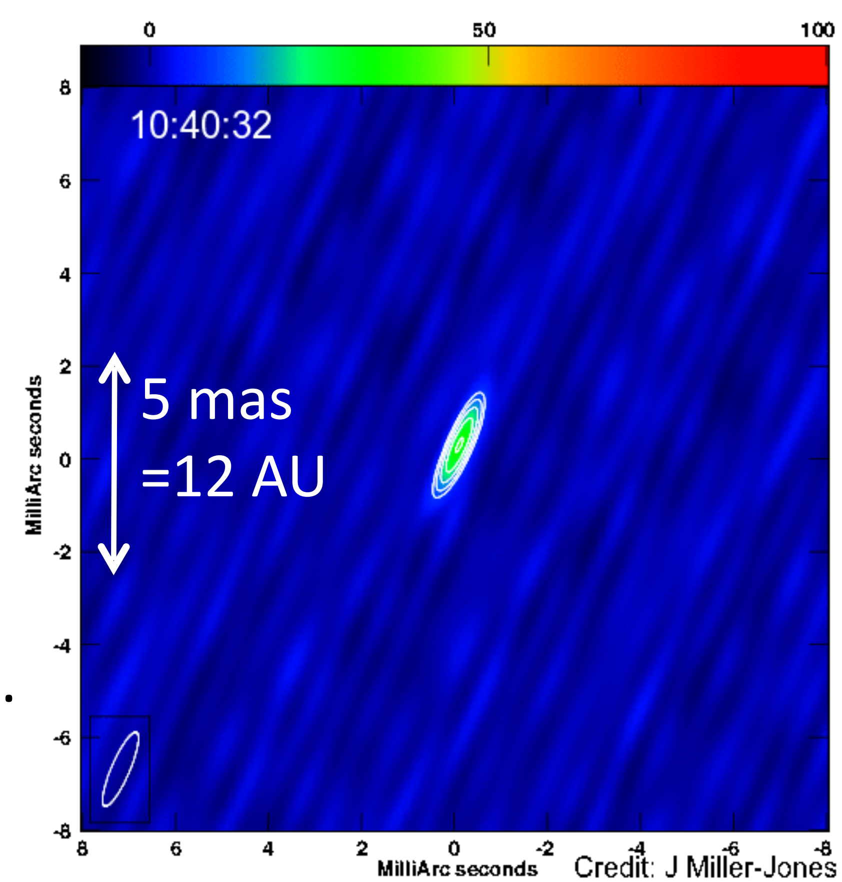
Real-time jet evolution

- ***How relativistic are XRB jets?***
  - Accurate distances essential
- ***How do jets couple to accretion flow?***
  - VLBI proper motions give ejection time
  - Tie to X-ray spectral / timing signatures



18 months

Gomez et al. (2001)

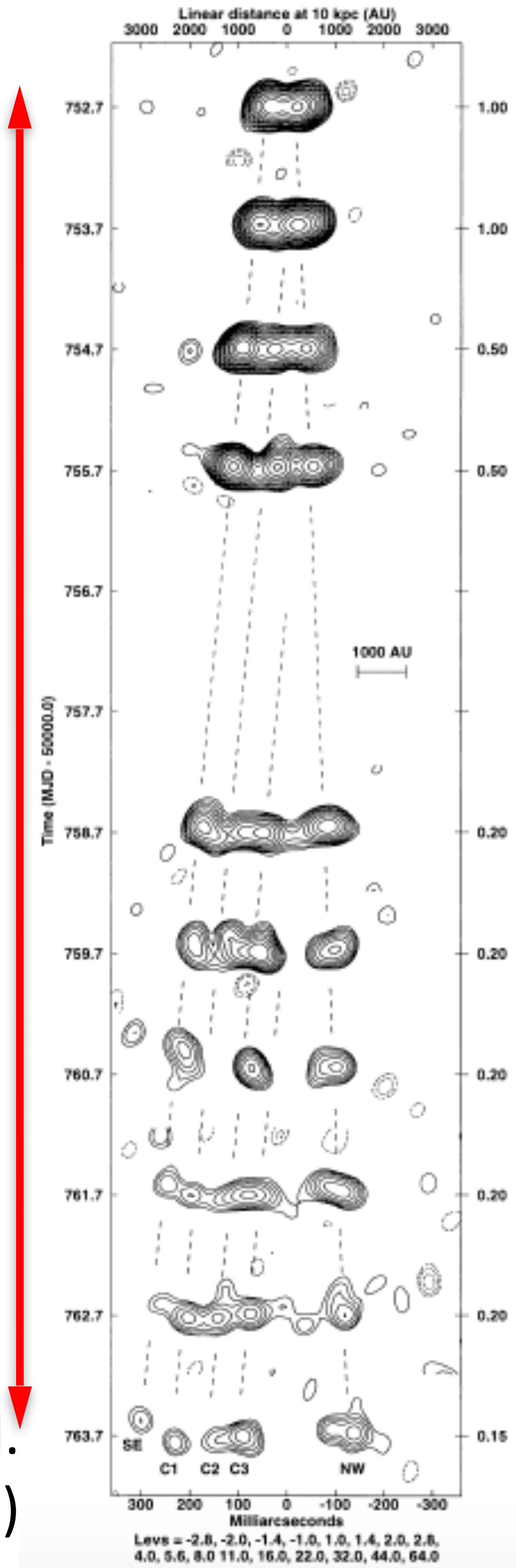


4 hours

Miller-Jones et al. (2018)

11 days

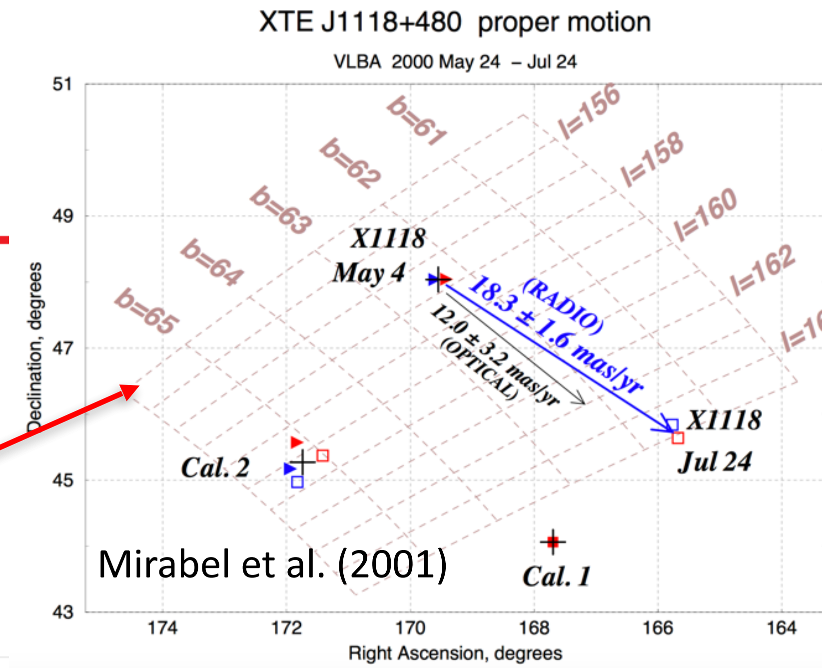
Fender et al. (1999)

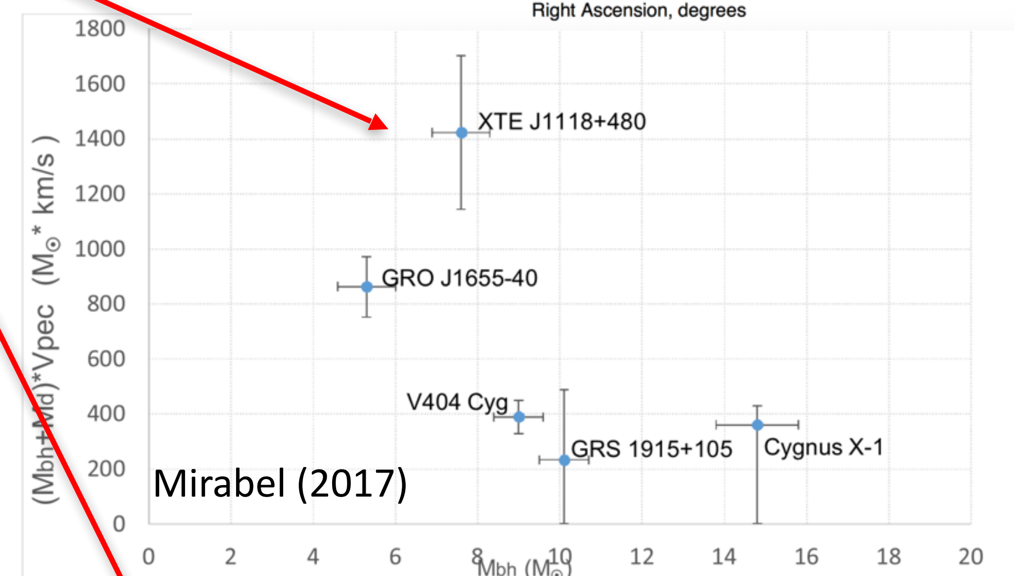


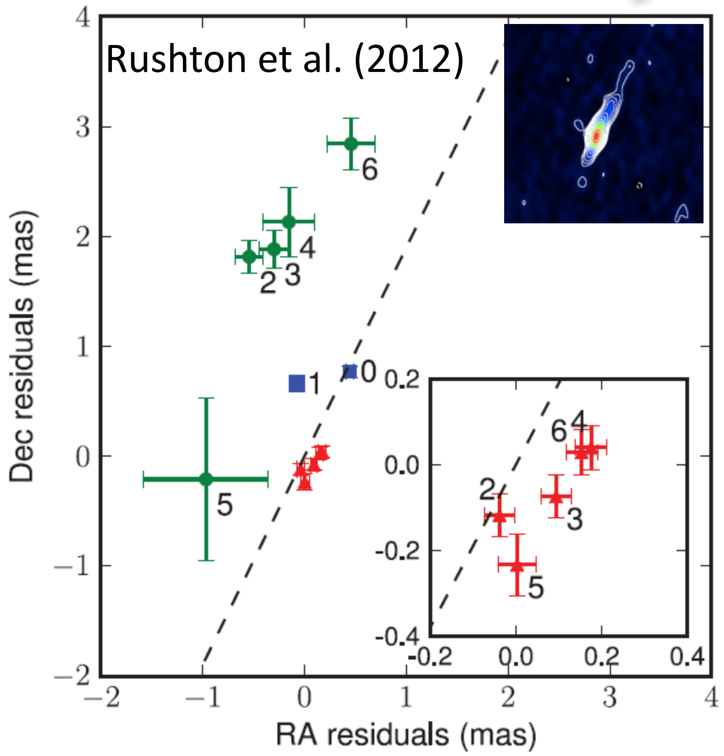
Precision astrometry

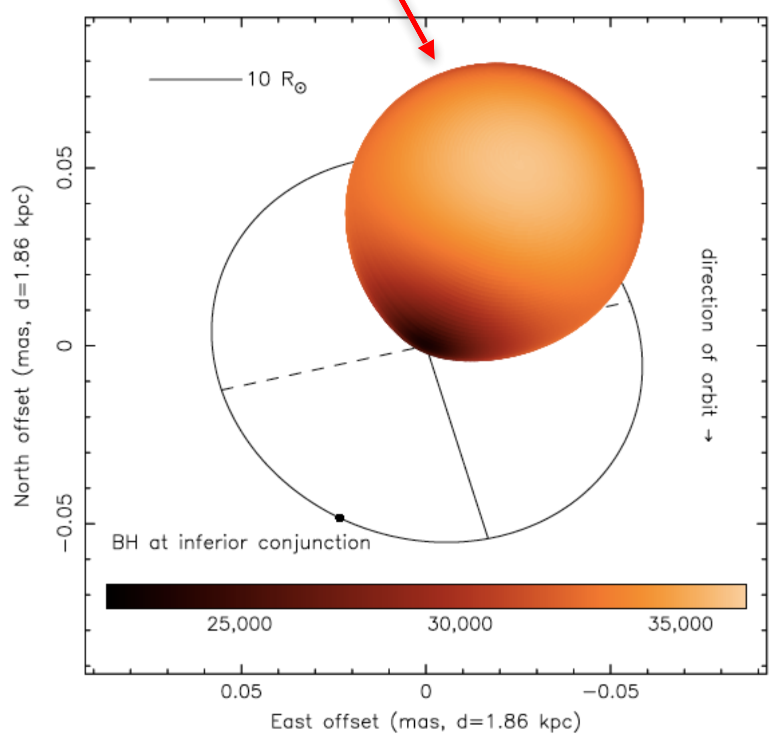
Fundamental physical parameters

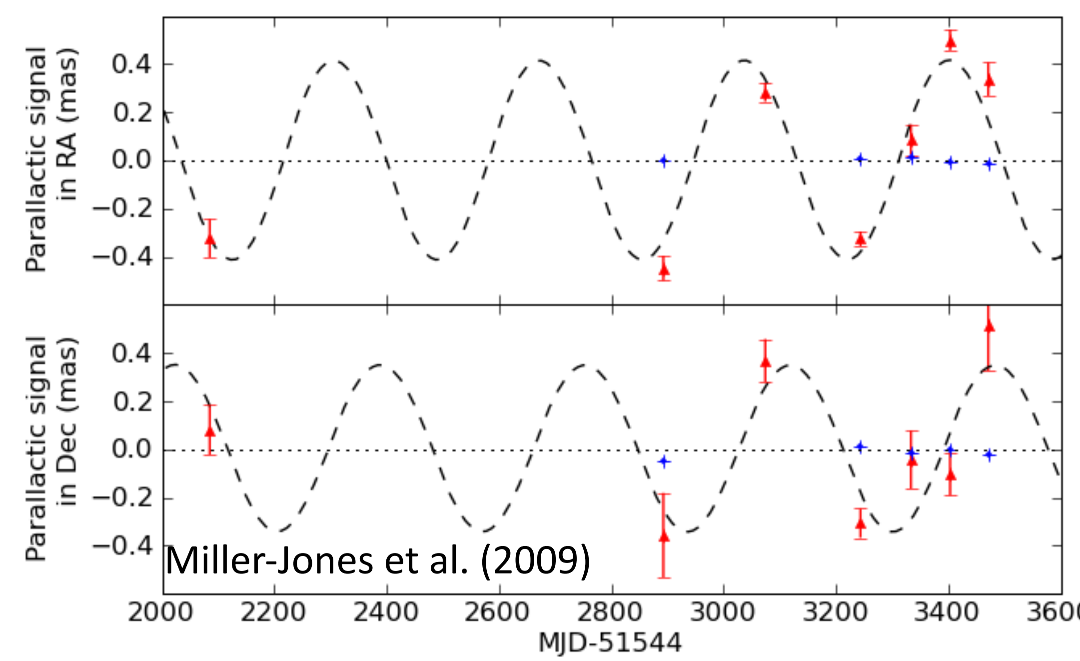
- XRB jet cores provide astrometric targets
  - *Proper motion*: Natal kicks and BH formation
  - *Parallax*: Model-independent distances
  - *Residuals*: Jet size scales
  - *Orbital motion*: Component masses











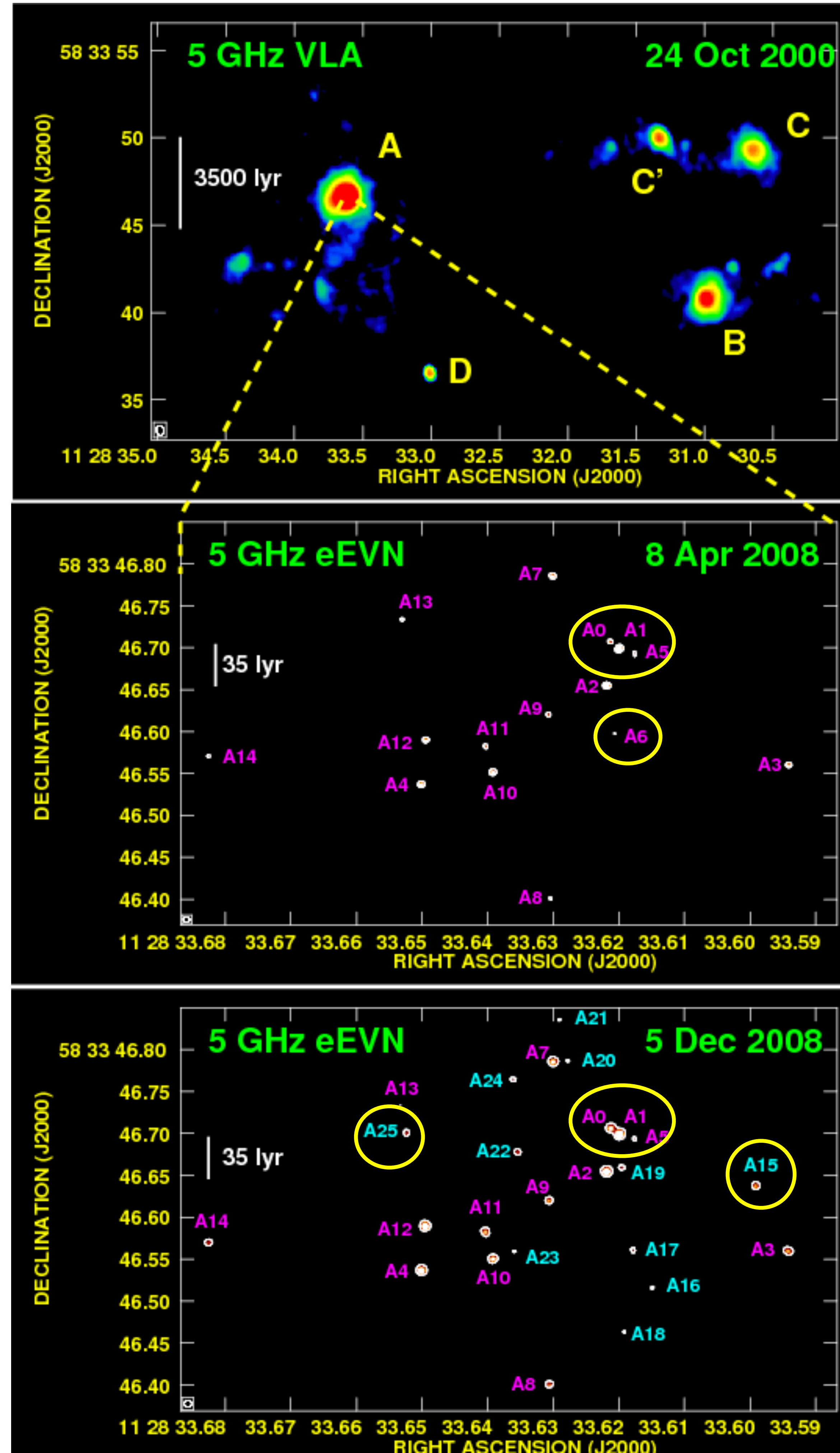
BH natal kick distribution needed to simulate LIGO merger progenitors

Nuclear Transients

An extremely prolific SN factory in Arp 299-A revealed with the eEVN

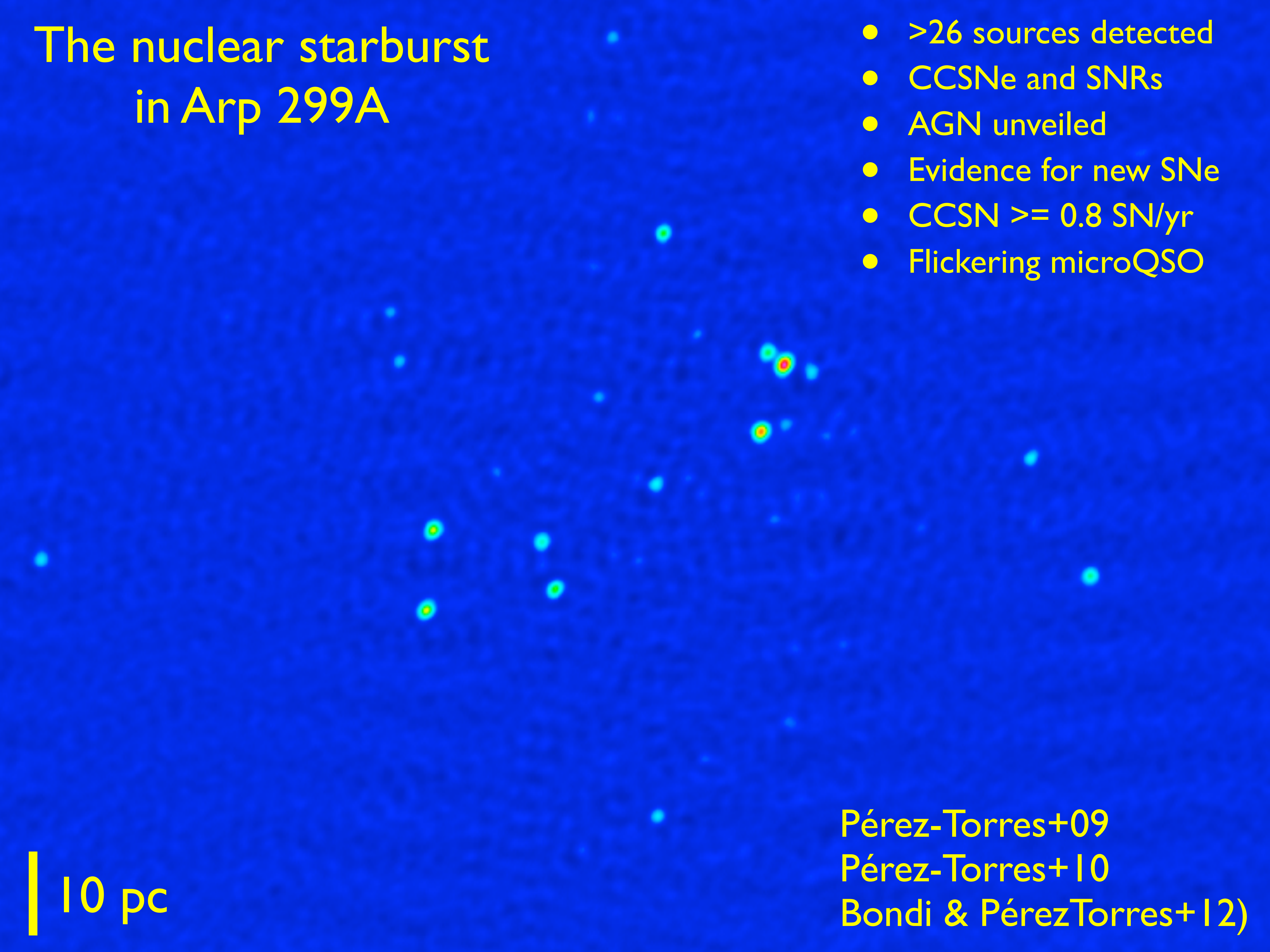
- Rich cluster of compact radio sources in the nuclear region of Arp299A
- SNe and/or SNRs, likely embedded in SSCs.
- Evidence of recent RSNe
- Radio emission levels typical of Type II SNe

(Pérez-Torres+2009, A&A Letters)



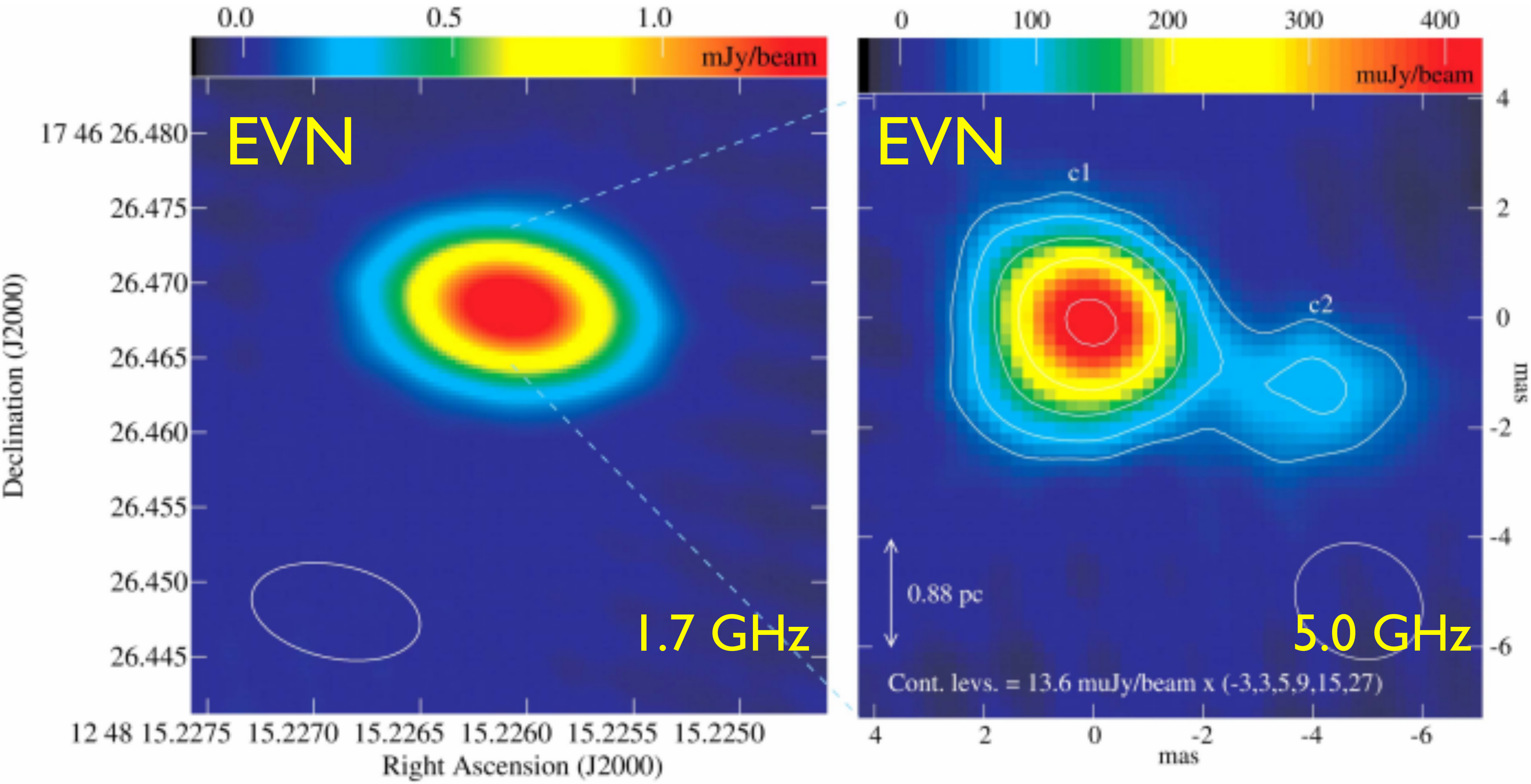
The nuclear starburst in Arp 299A

- >26 sources detected
- CCSNe and SNRs
- AGN unveiled
- Evidence for new SNe
- CCSN >= 0.8 SN/yr
- Flickering microQSO



Pérez-Torres+09
Pérez-Torres+10
Bondi & PérezTorres+12)

Tidal Disruption Events (TDEs)

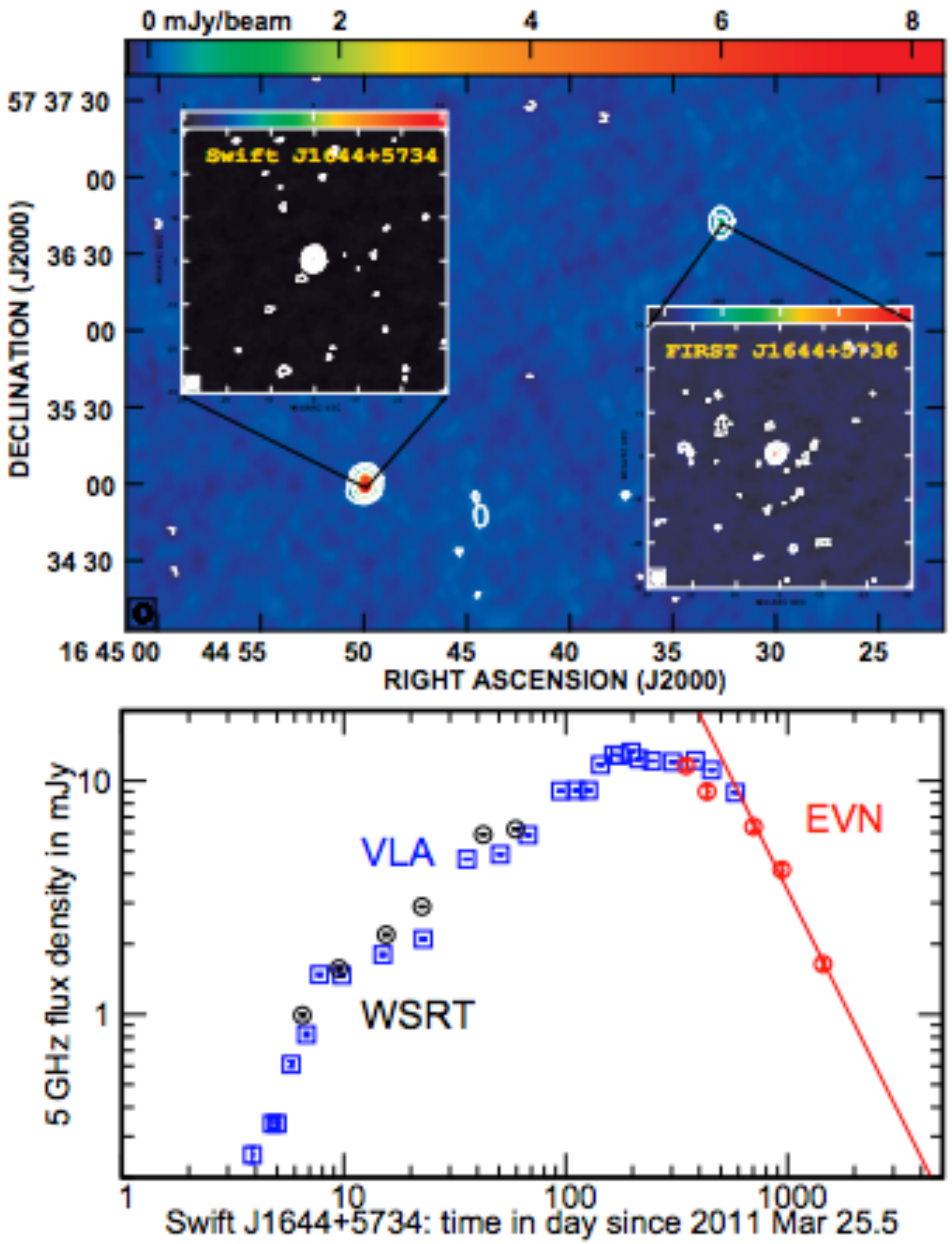


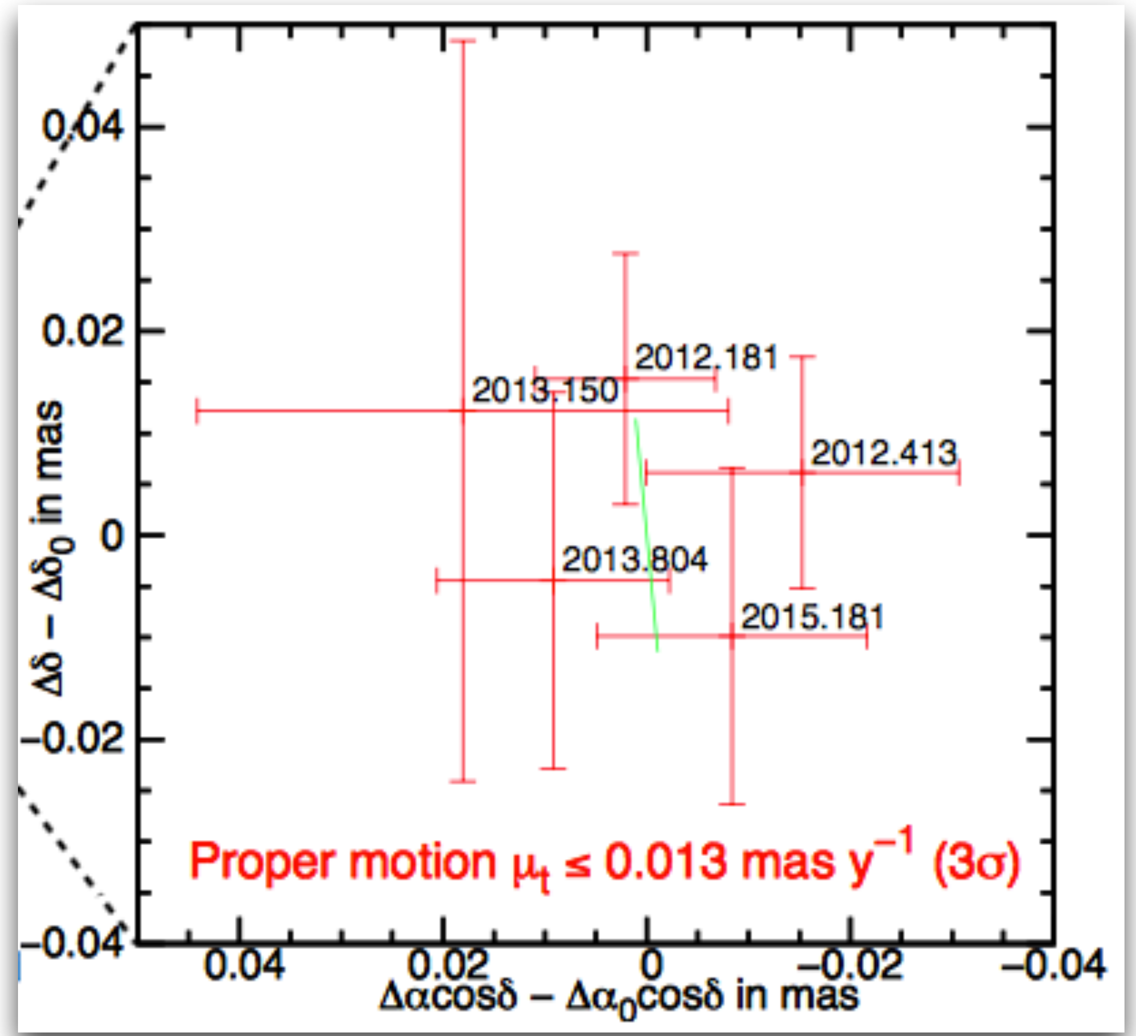
ASSASN-14li resolved at pc-scales with the EVN (Romero-Cañizales+2016)

Source nature unclear:

- Core-relativistic jet?
- Core-non-relativistic jet?
- BBH?

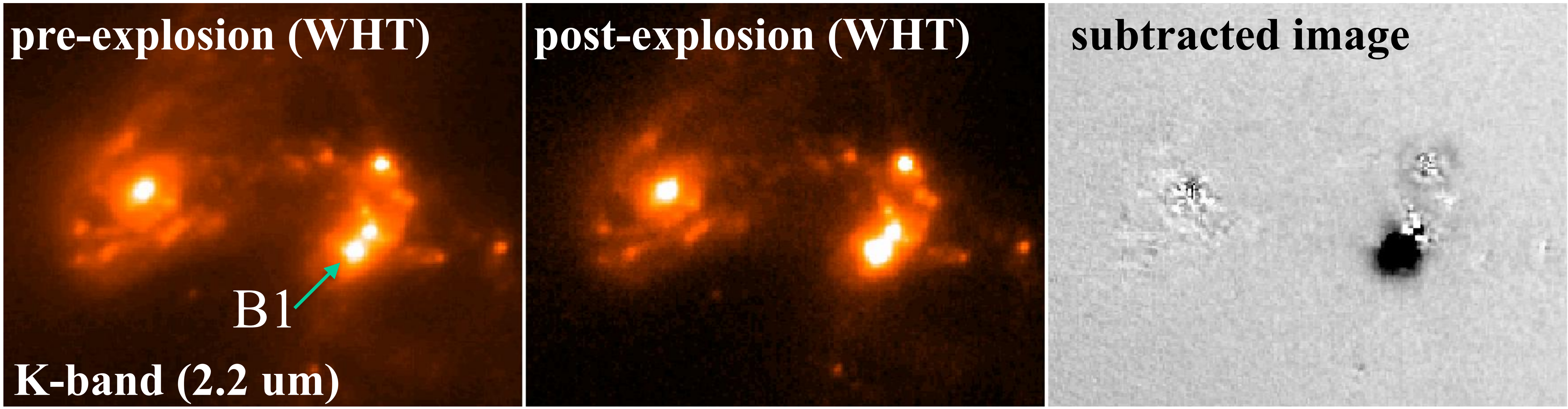
Tidal Disruption Events (TDEs)





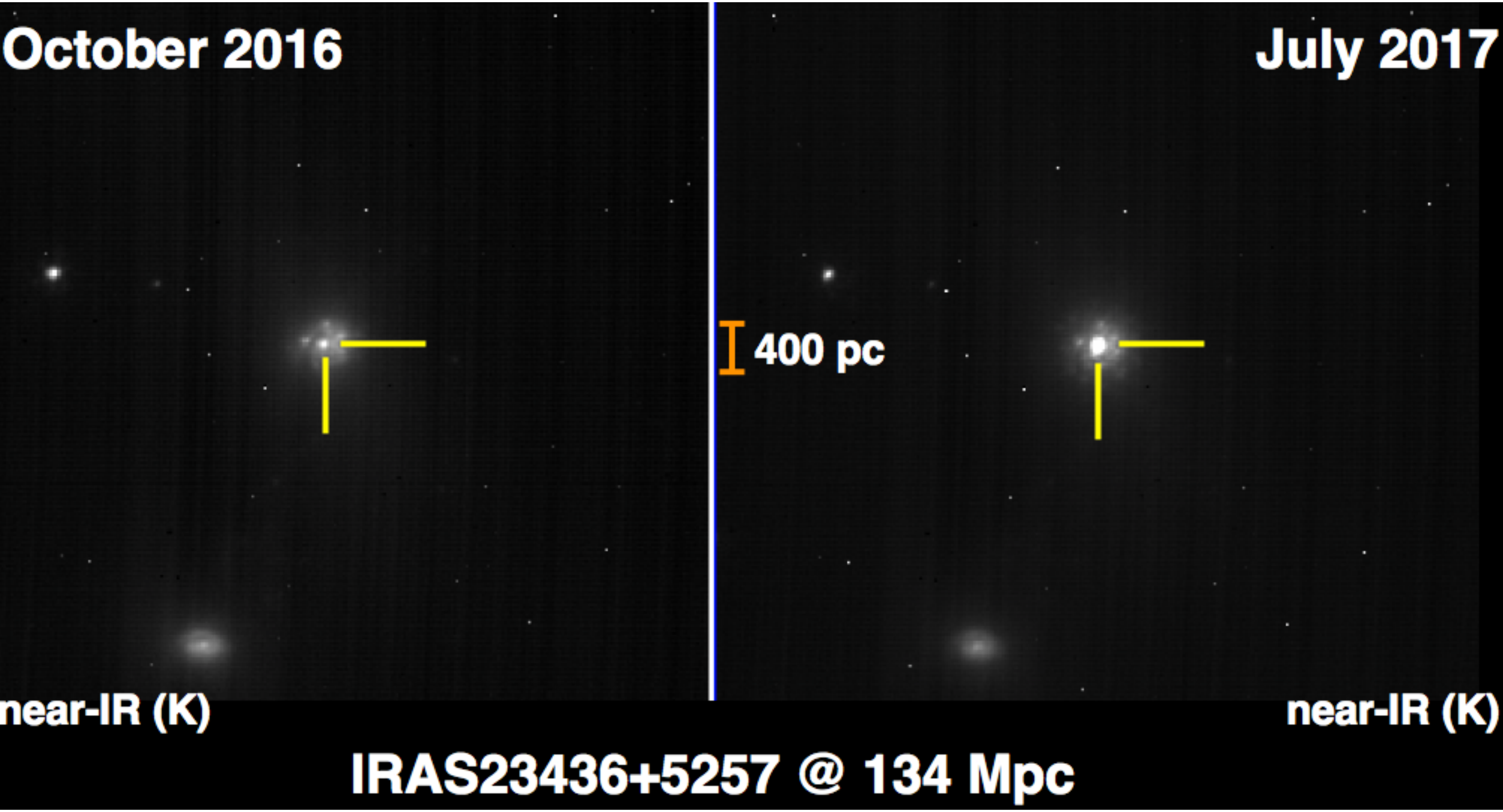
No apparent superluminal motion in Sw J1644+5734 unveiled with the EVN (Yang+2016)

Discovery of an extremely luminous nuclear outburst in Arp 299B1



- Systematic near-IR search for nuclear SNe in starburst galaxies using the WHT
- Discovery of an extremely luminous nuclear outburst in the near-IR in Jan. 2005
- Only detected in the IR, in optical completely obscured by interstellar dust
- Near-IR (JHKs) follow-up from the WHT, NOT, Gemini-N, mid-IR from Spitzer

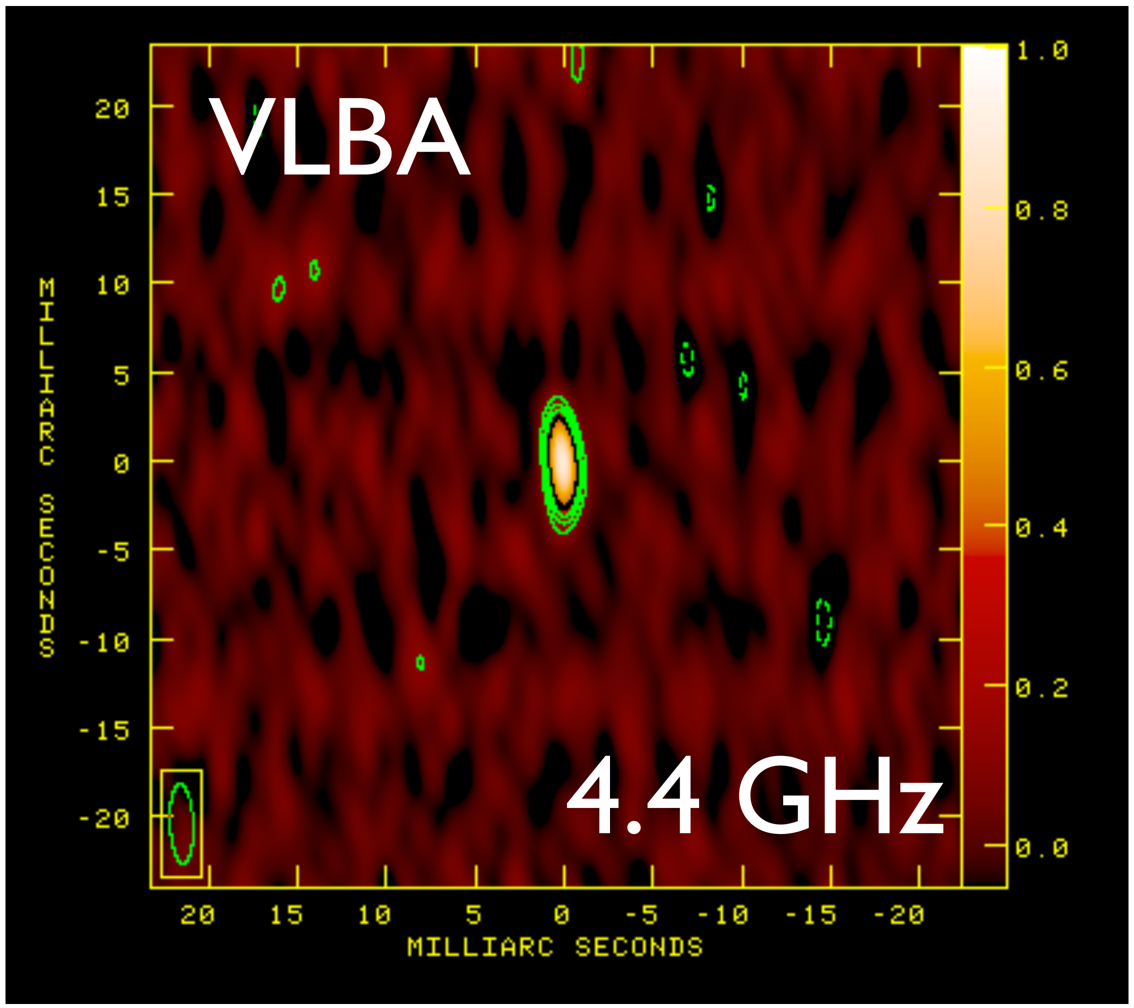
AT 2017gbl in IRAS 23436+5257



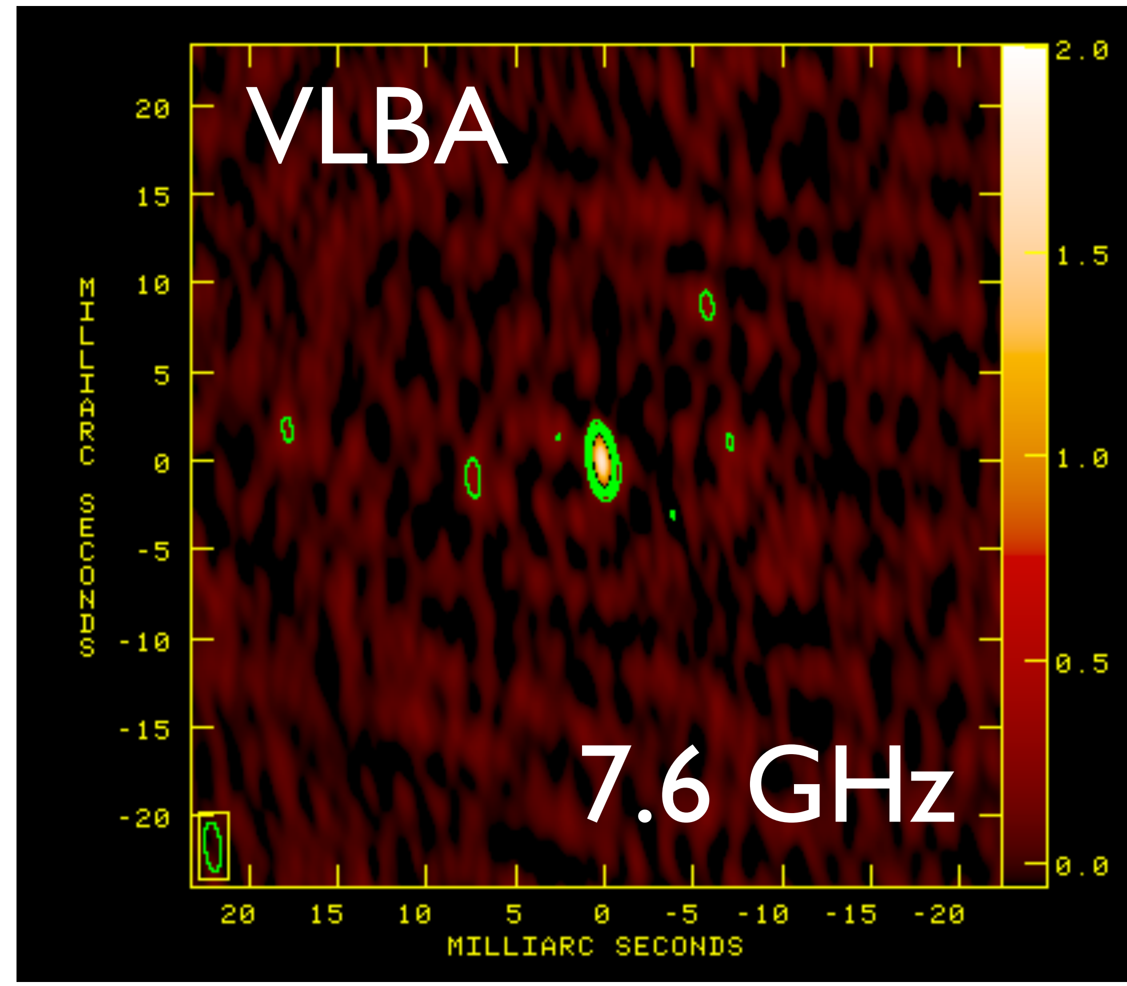
- Near-IR nuclear burst detected in July 2017
- IR properties similar to the Arp299B-AT1 event

Kool et al. (2017)

VLBI obs-ns of AT 2017gbl in the nuclear region of IRAS 23436+5257



Peak = 880 uJy/beam



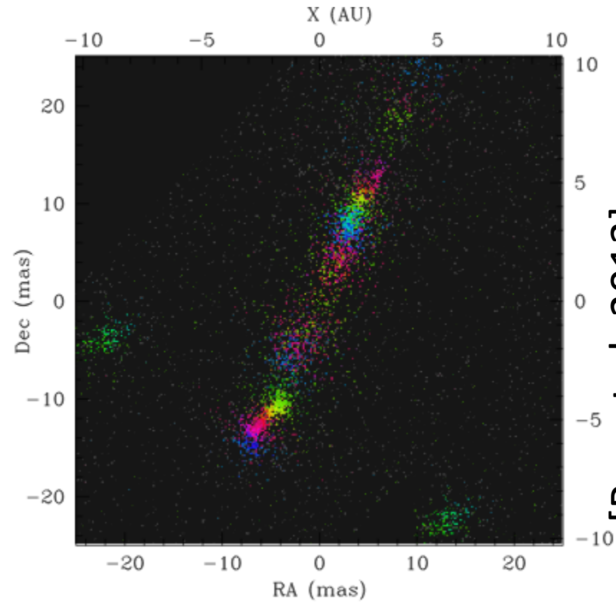
Peak = 1720 uJy/beam

- L_radio ~ 3.2e38 erg/s
- Inverted spectral index (alpha = 1.1; S_nu ~ nu^alpha)
- Compatible with a LLAGN. It could also be AT 2017gbl

Pérez-Torres et al. (2017, ATel)

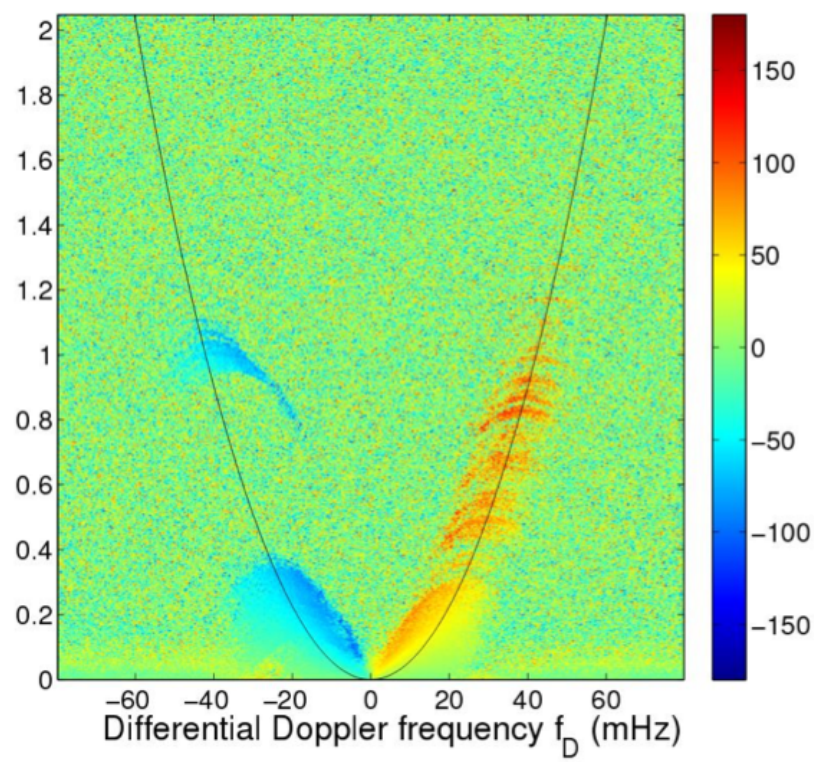
Pulsars

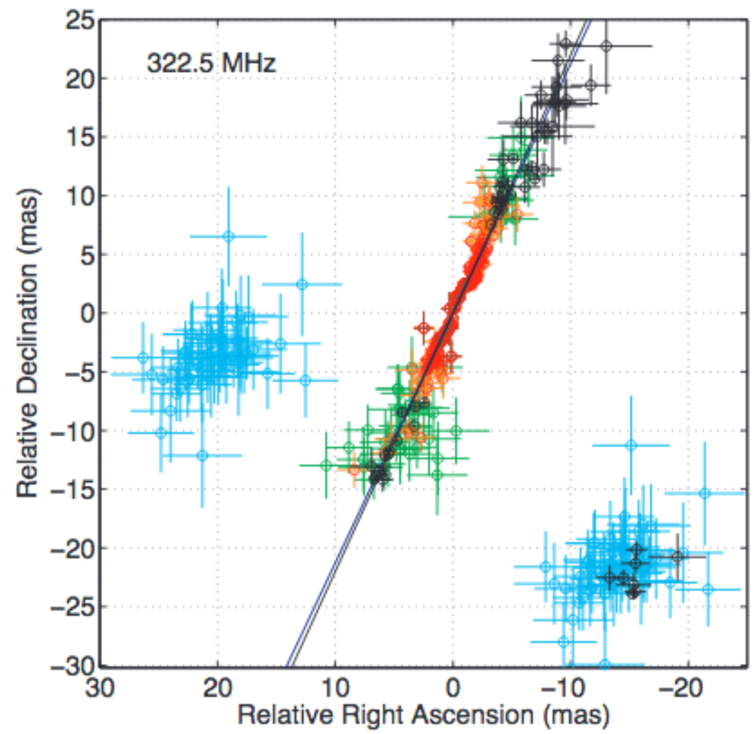
VLBI imaging of the interstellar scattering speckle pattern associated with a very bright pulsar can led to measure the motion of the pulsar emission with nanoarcsec accuracy



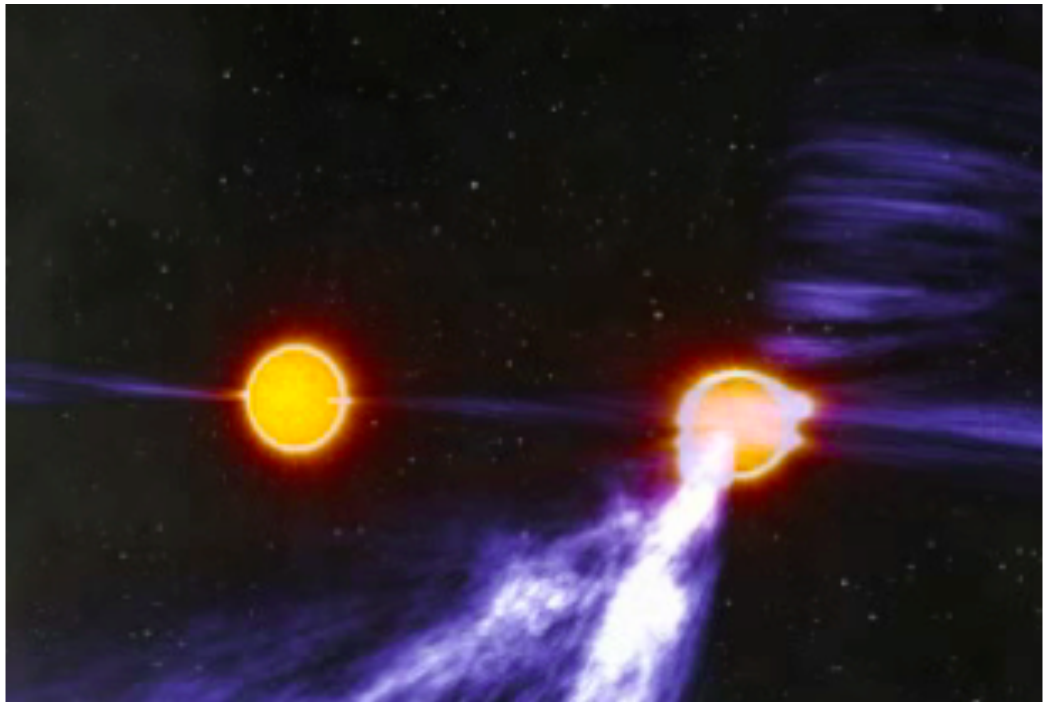
[Pen et al. 2013]

[Brixen et al. 2010]

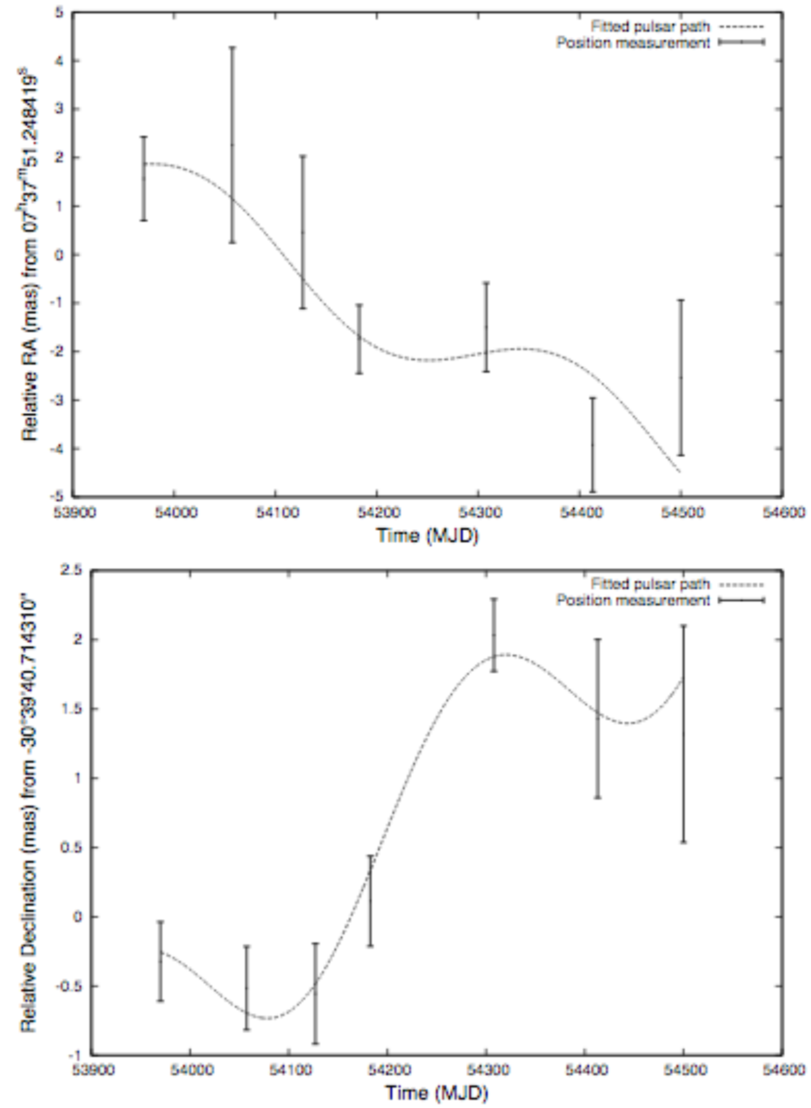




VLBI data on the "secondary spectrum" parabolic arcs [Stinebring et al. 2001] due to the effects of ISM can lead to map the scattered brightness of a pulsar with much higher resolution than the diffractive limit of the interferometer, shedding light on ISM on “mas” scale



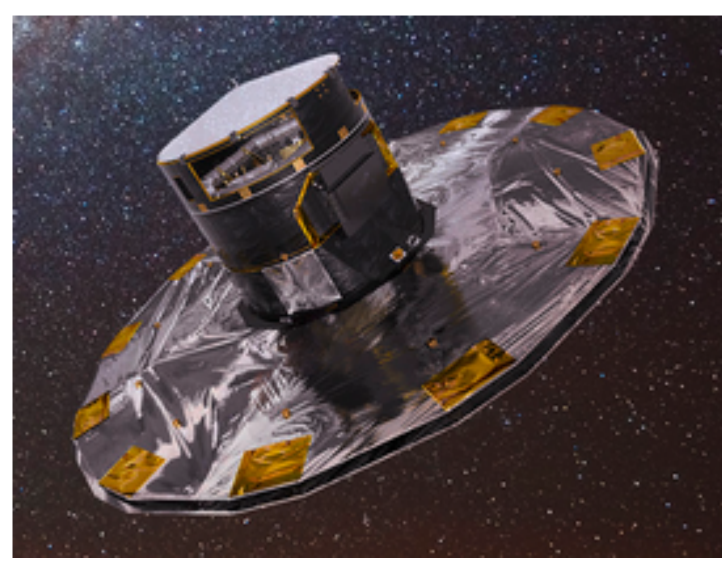
[@ Howe, CSIRO]



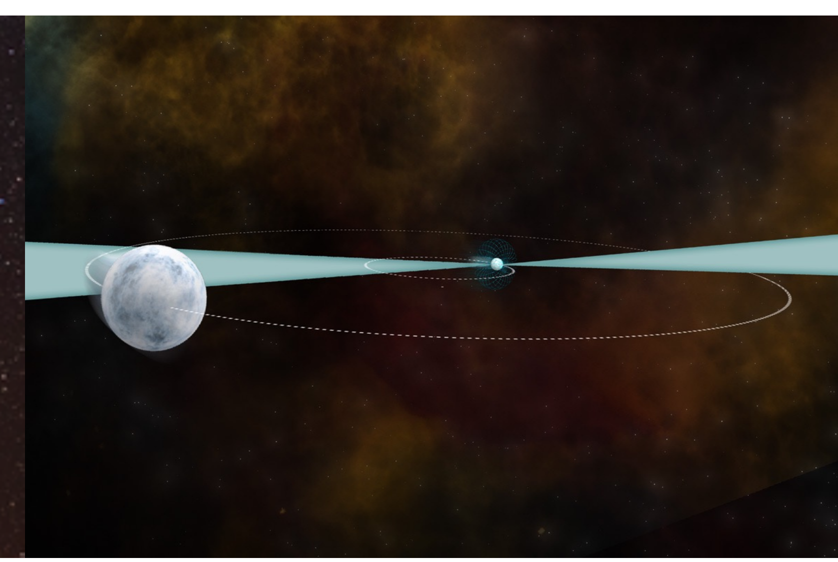
[Deller, Bailes, Tingay 2009]

DOUBLE PULSAR (and future additional relativistic pulsar binaries): combined with few decades of pulsar timing, parallax distance from VLBI will allow tests of gravitational radiation emission theories at the 0.01% level

By combining positions of pulsar-white dwarf binaries derived from a) pulsar timing b) Gaia c) VLBI the three reference frames will be tied with better than 10 μas precision [Paragi et al 2015]



[@ESA/ATG]



[@ Saxton, NRAO/AUI/NSF]

VLBI prospects for transients

- Target localization: mas-precision and accuracy is a must
- Target imaging: Images at mas-scales much needed
- Ultra-high sensitivity: Needed both for imaging and localization purposes, as well as for detection of faint, diffuse emission. Currently a few microJy/b. Should aim at ~1 microJy/b sensitivity, i.e., equal to SKA1-MID
- Astrometric capabilities of VLBI currently experience a renaissance, with strong implications in many fields

VLBI prospects/issues for transients

- Spectral index information: Frequency agility. EVN still lacks it, whether as EVN-regular, or as eEVN
- Target follow-up => Multiple frequencies, multiple visits; VLBA often better suited than EVN; eEVN mitigates this issue
- Need to image simultaneously at different angular scales: => EVN+eMERLIN, VLA=eVLA(=VLA+VLBA),…
- Calibration uncertainties must go down: overall performance and reliability of arrays must get better, esp. the EVN.

VLBI prospects/issues for transients

- Alert/triggering procedures - not straightforward to trigger fast repointing on different sites, particularly if not dedicated/full time arrays
  - Different transients require different triggers (from space or ground, photometry or spectrum) and different reaction times
- Disk availability and shipping, correlation time can cause delays - real-time VLBI is still a relatively scarce resource
- Arrays - Small, flexible arrays for prompt observations; full/global arrays for follow up of truly interesting events?

Challenge for the EVN

Towards a 1 microJy/b sensitivity,
frequency-agile,
flexible, multi-scale VLBI array
for the next decade