

VERA follow-up for possible IceCube counterpart TXS 0506+056

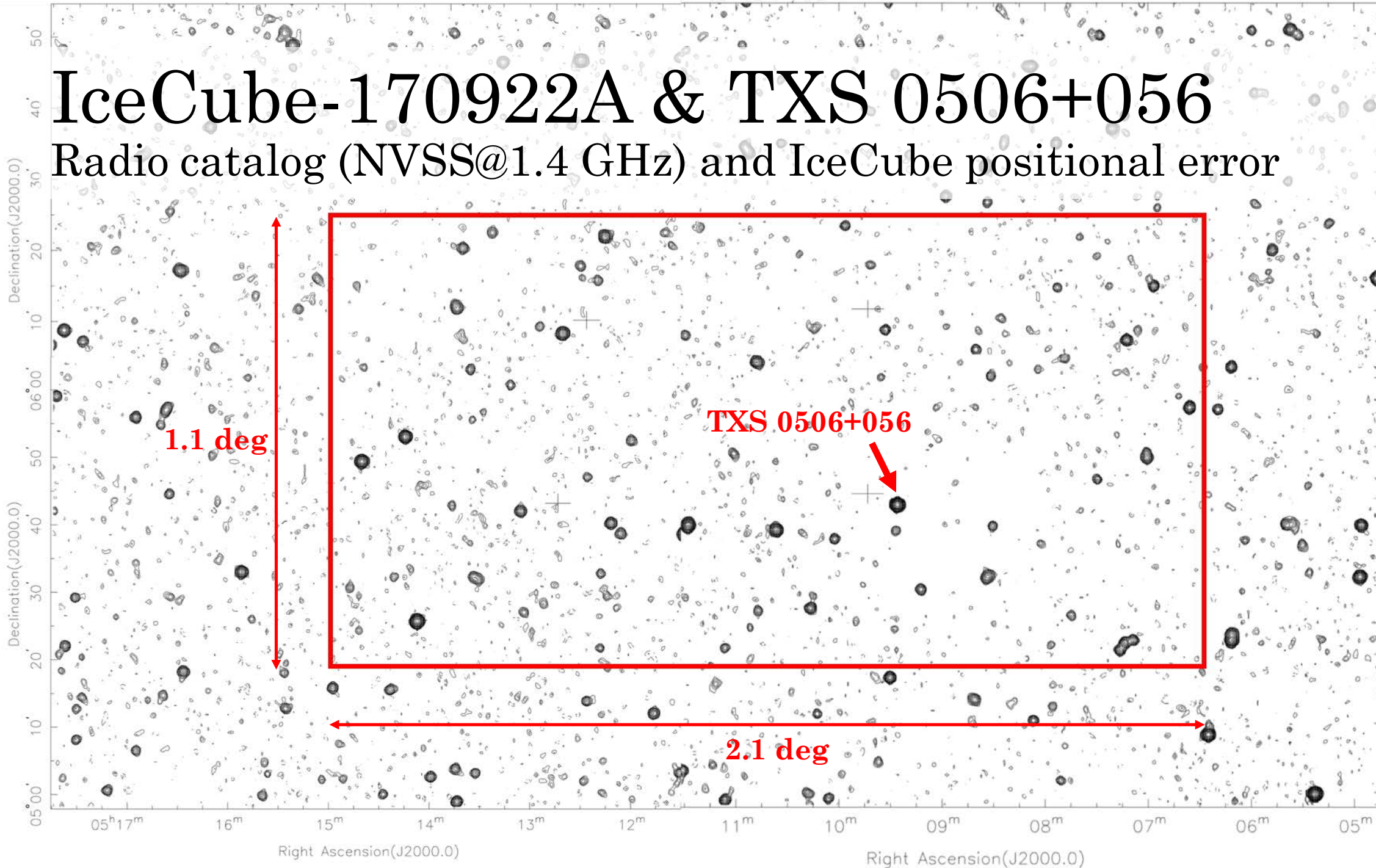
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and S. Yoshida (Chiba Univ.)

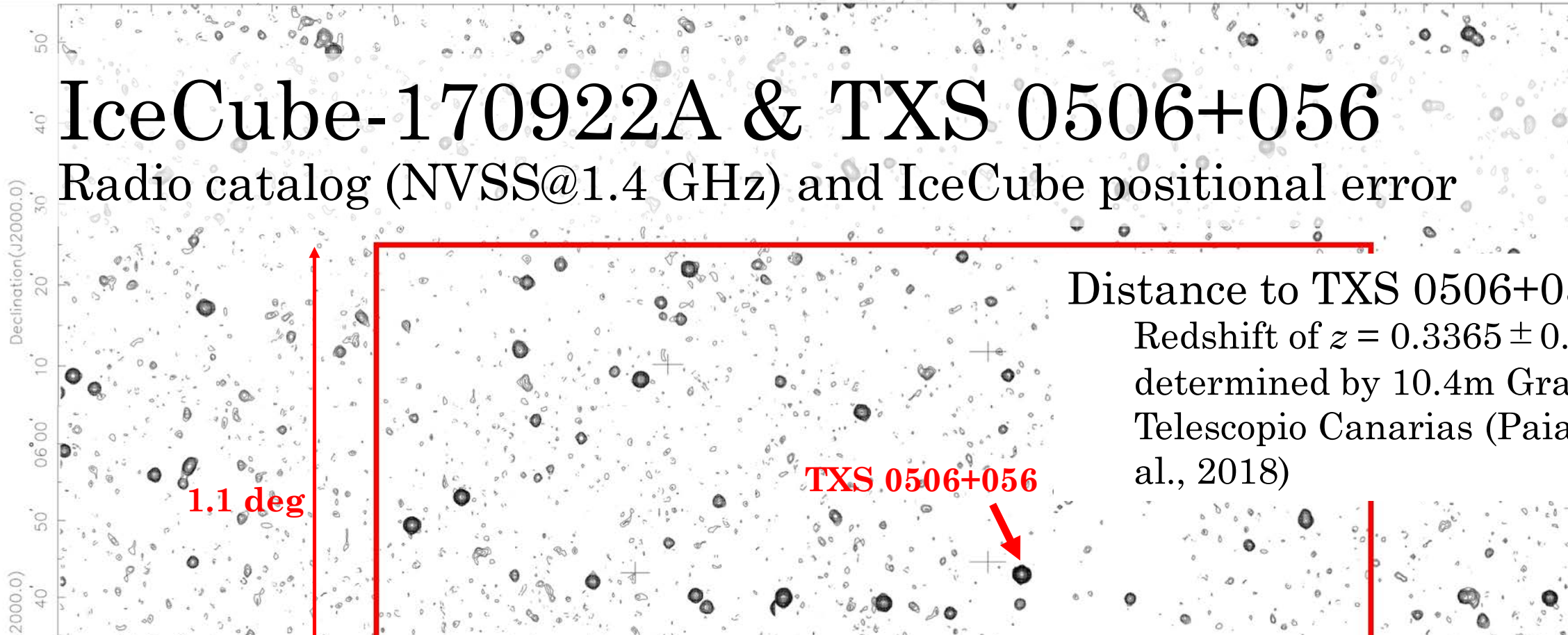
IceCube-170922A & TXS 0506+056

Radio catalog (NVSS@1.4 GHz) and IceCube positional error

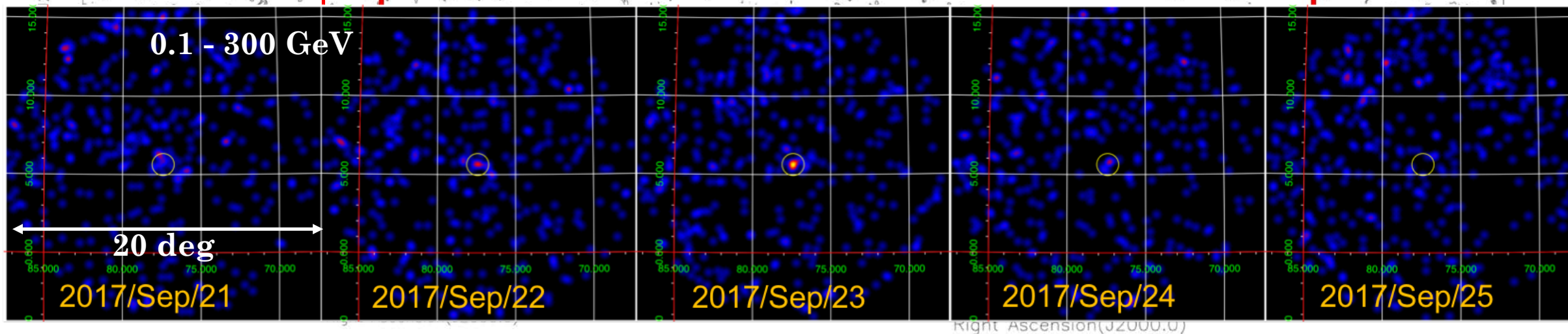


IceCube-170922A & TXS 0506+056

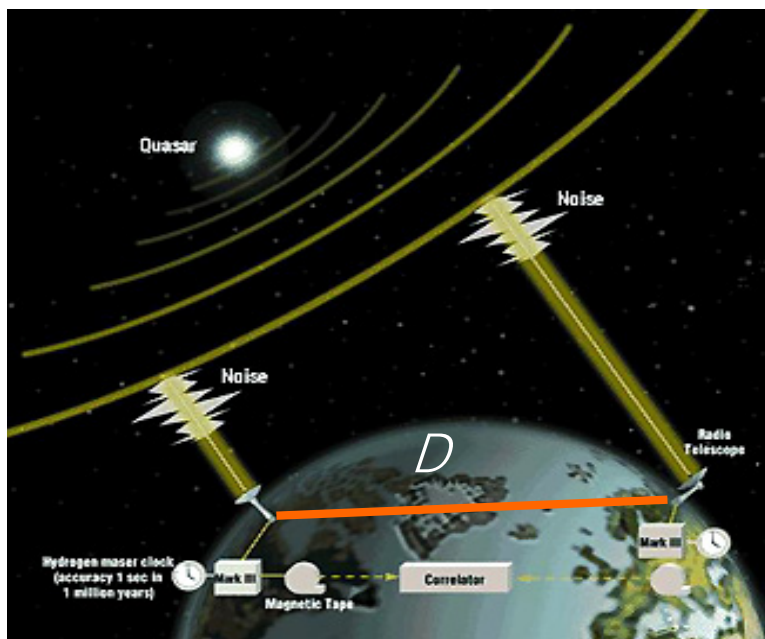
Radio catalog (NVSS@1.4 GHz) and IceCube positional error



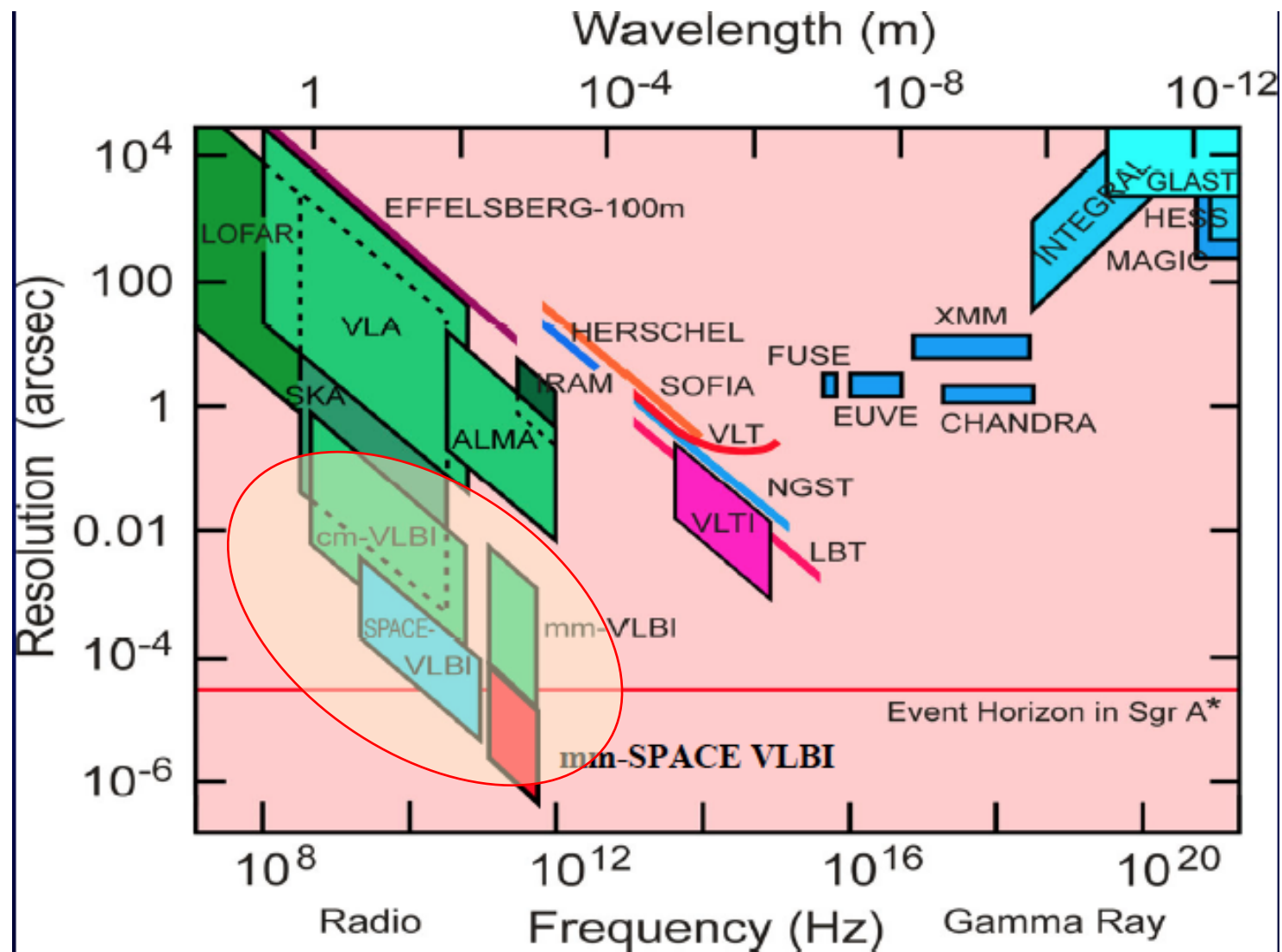
Distance to TXS 0506+056:
Redshift of $z = 0.3365 \pm 0.0010$
determined by 10.4m Gran
Telescopio Canarias (Paiano et
al., 2018)



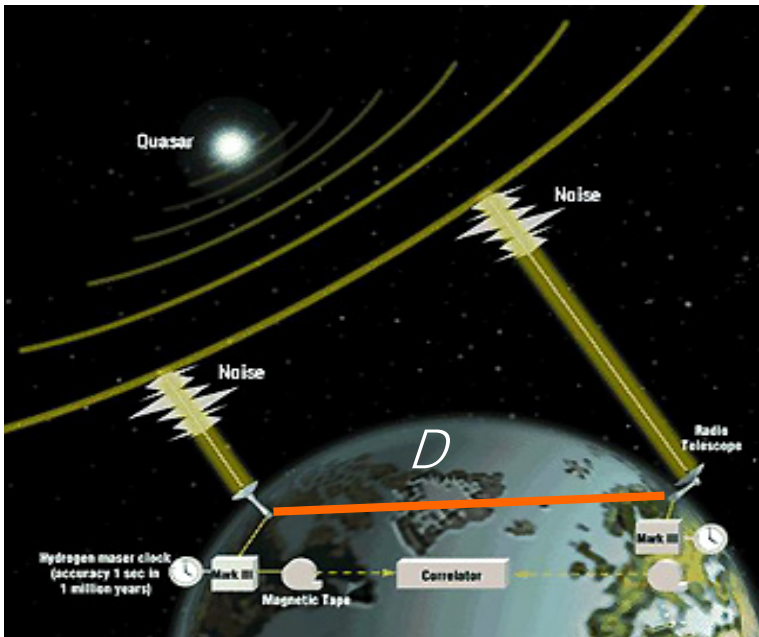
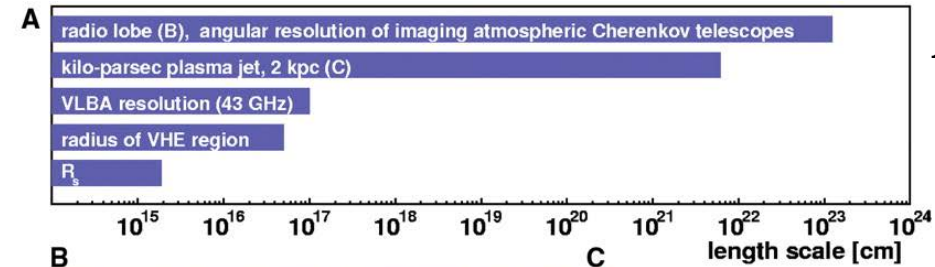
Very Long Baseline Interferometry



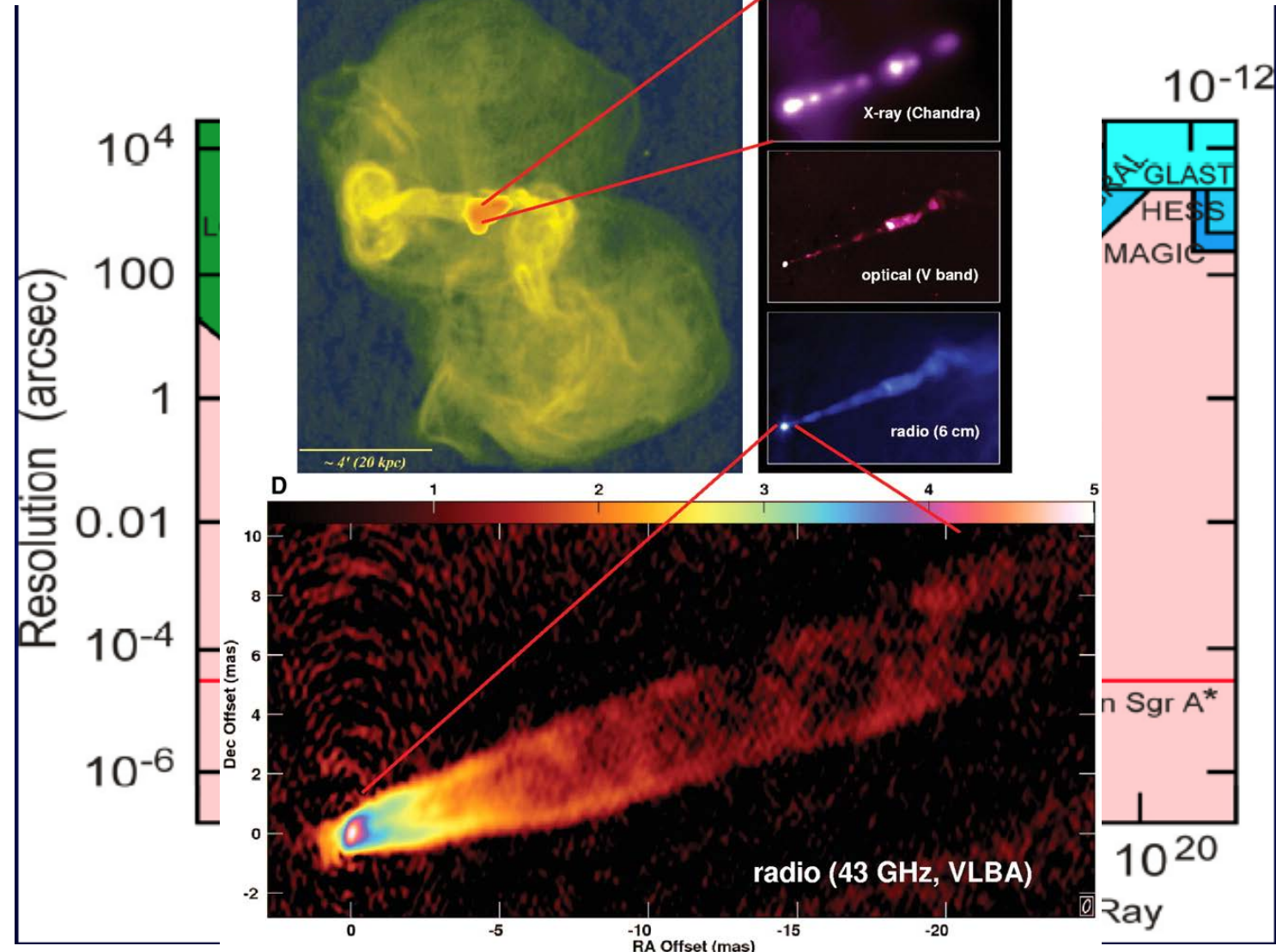
- Angular resolution
 $\theta \sim \lambda / D$ (baseline length)
- $\theta < 1$ mas



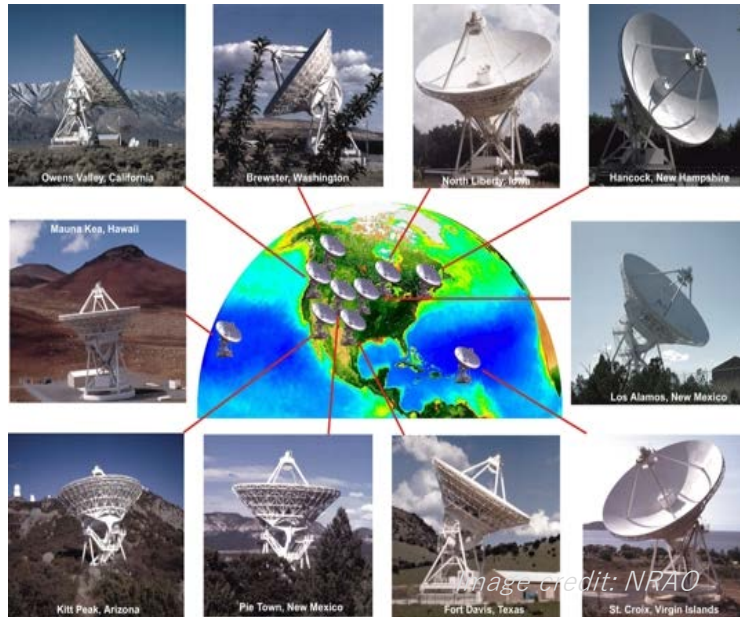
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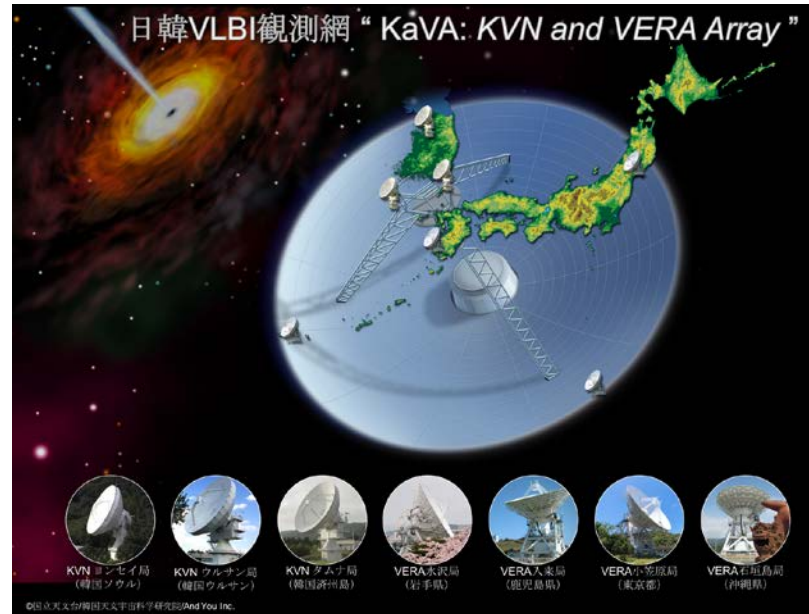


VLBI array in the world



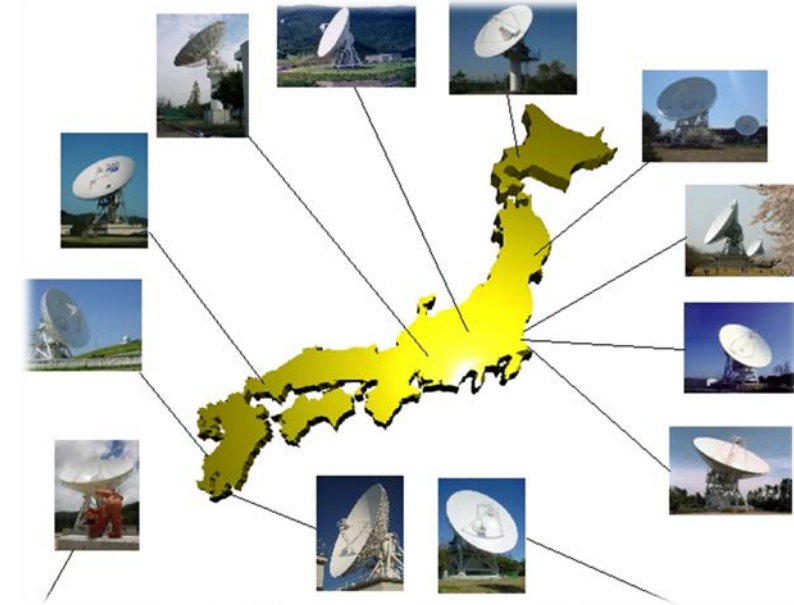
Very Long Baseline Array (VLBA)

- D: ~8,000 km
- Frq.: 330 MHz - 86 GHz
- NRAO



日韓VLBI観測網 (KaVA)

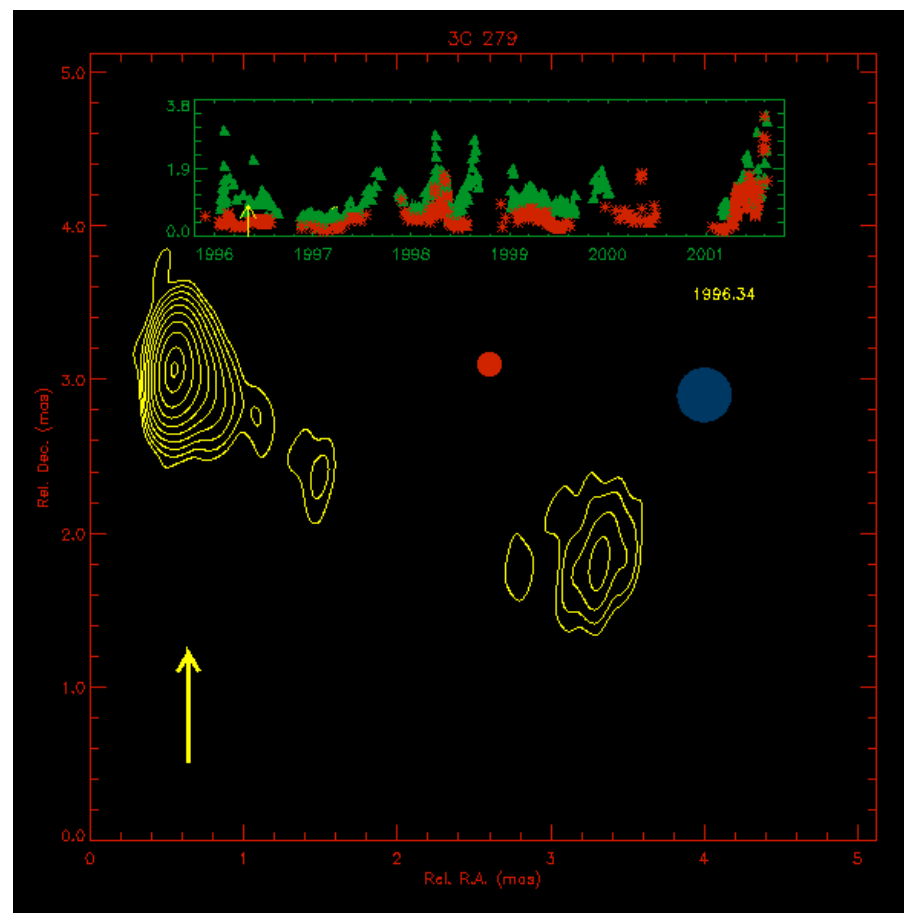
- D: ~3,000 km
- Frq.: 22/43 GHz
- NAOJ/KASI



Japanese VLBI Network (JVN)

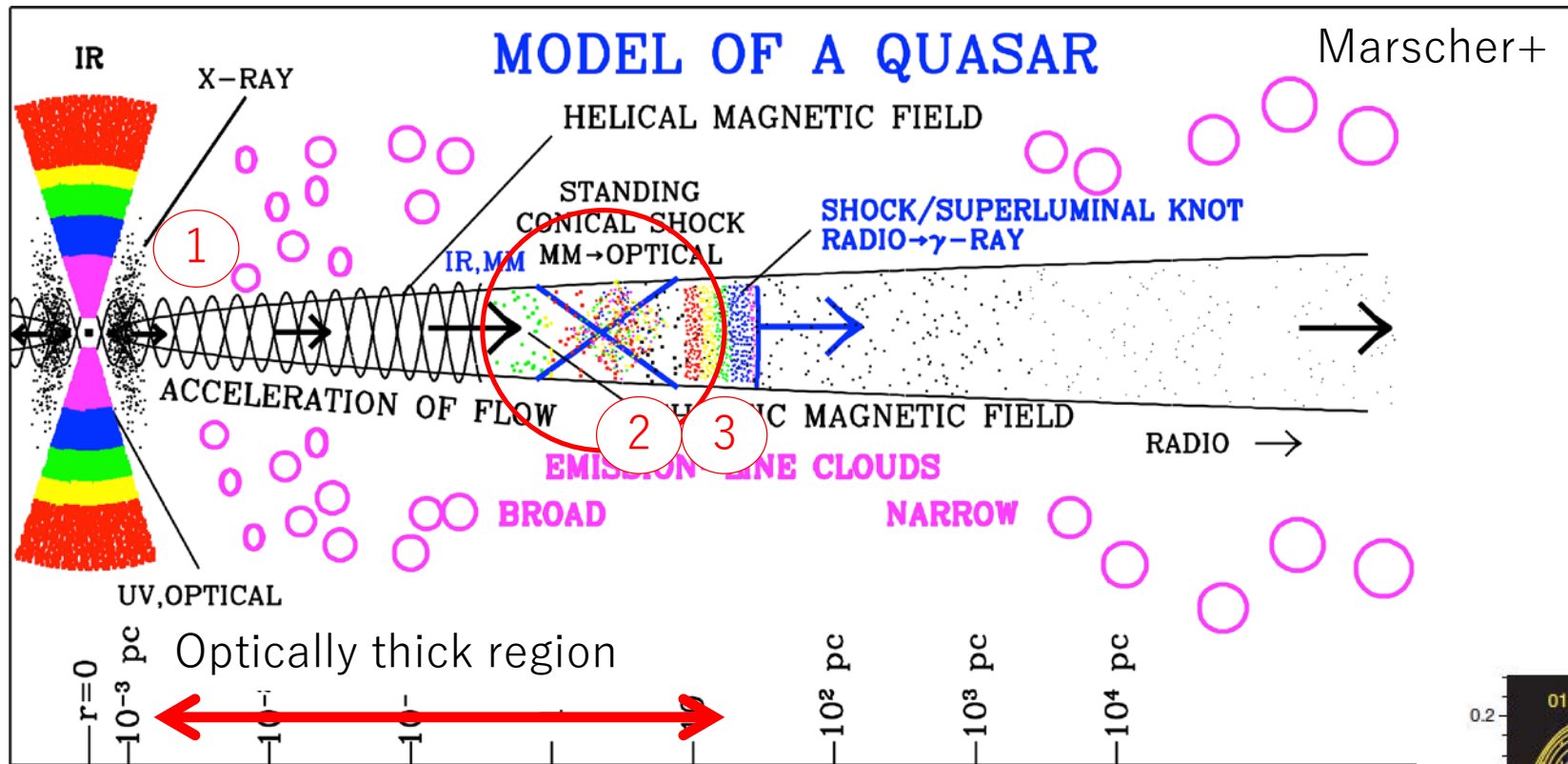
- D: ~2,270 km
- Frq.: 6/8/22 GHz
- Universities (茨城、筑波、岐阜、大阪府立、山口、鹿児島) + NICT、NAOJ、JAXA

VLBI observation of Blazars



43 GHz VLBA monitor of Blazar 3C279
(Boston U. blazar monitor)

VLBI observation of Blazars

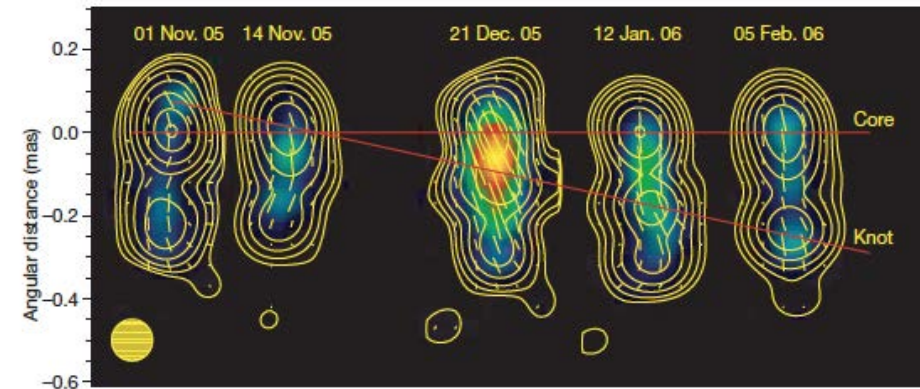
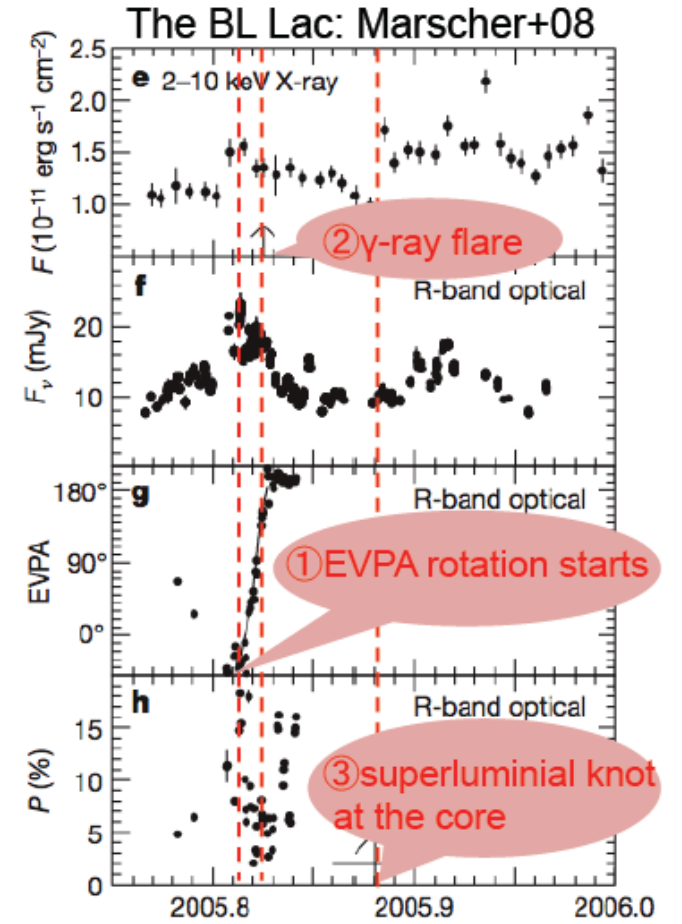


Blazar core is ~ 10 pc ($\sim 10^5 R_s$) far from BH

Estimated by indirect way (time-lag of LC, EVPA rotation)

BL Lac, PKS 1510-089, AO 0235+164, OJ 287 (Marscher+08, 10, Agudo+12)

*Radio core at mm wavelength is a standing shock region



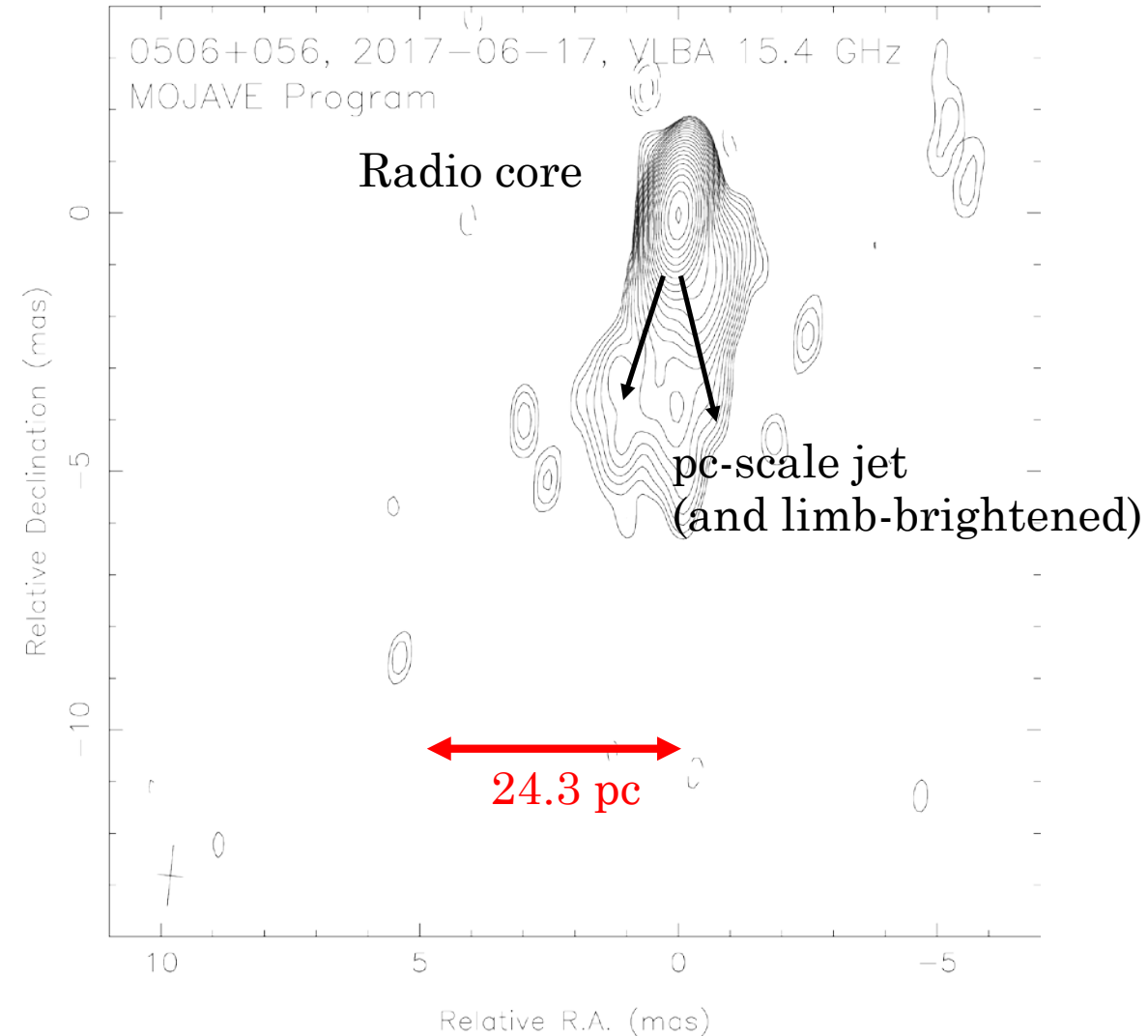
Radio (VLBI) property of TXS 0506+056

Common Name:	TXS 0506+056
B1950 Name:	0506+056
J2000 Name:	J0509+0541
R.A. and Dec. (J2000):	5h9m25.964s +5d41'35.334"
AGN Class:	ISP BL Lac
Redshift:	
Luminosity Distance:	Unknown
Radio Spectrum:	Flat
Gamma-ray Association	LAT: Y, EGRET: Y, TeV: Y
Kpc-scale morphology:	Core
Jet Speed:	Maximum: $332 \pm 82 \mu\text{as/y}$; Median: ; based on 4 moving features Lister et al. 2013,AJ,146,120

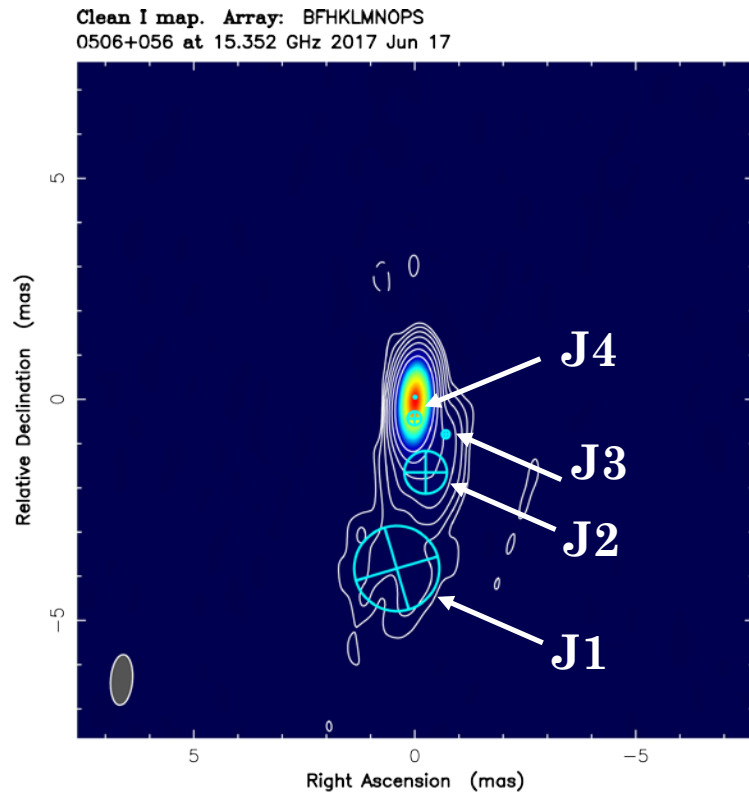
“VLBA-MOJAVE project”

<http://www.physics.purdue.edu/astro/MOJAVE/sourcepages/0506+056.shtml>

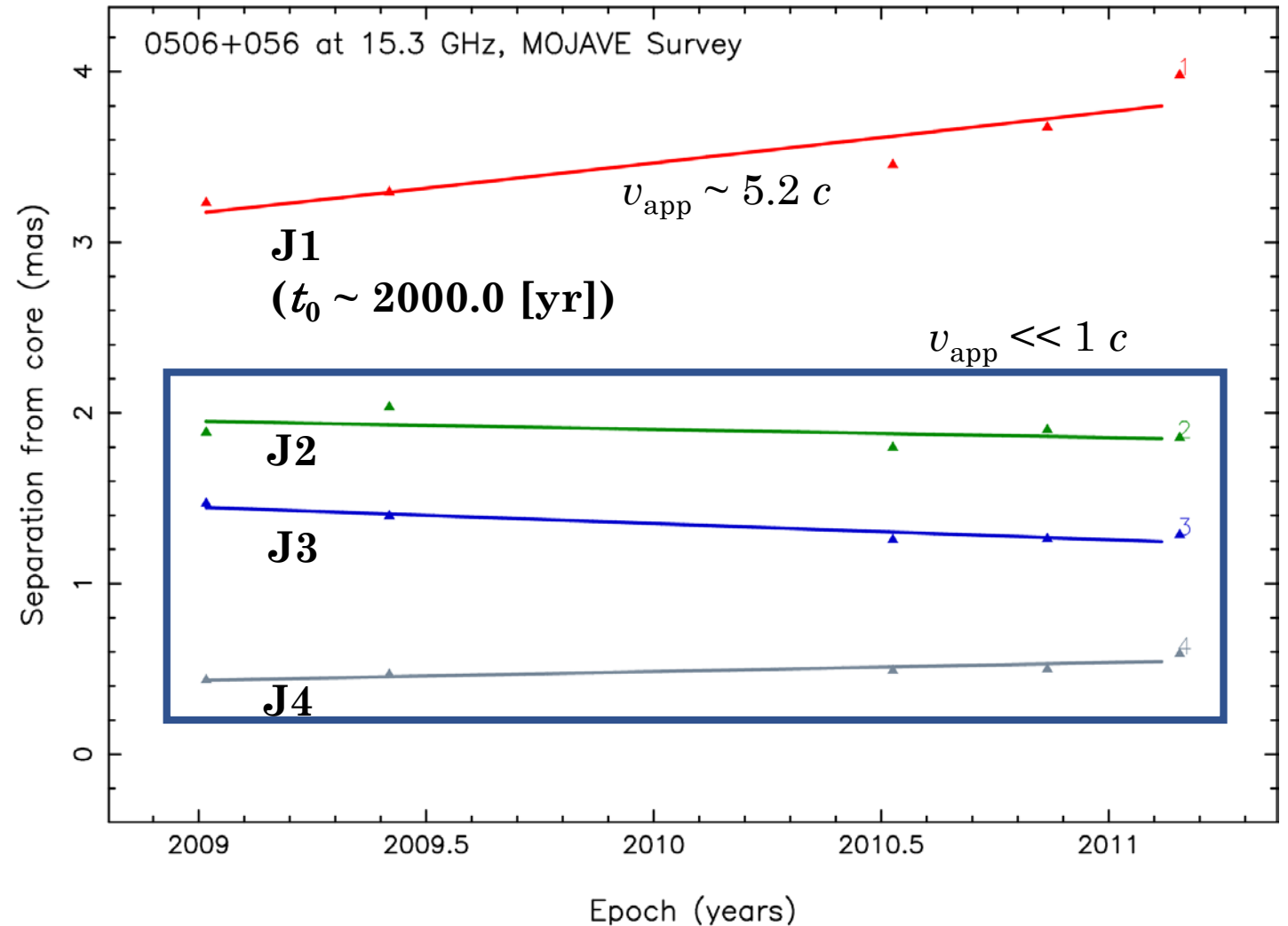
Peak: 454.0, Contours: $0.30 \times \sqrt{2}$, RMS: 0.09 mJy/beam
Beam: 1.18 x 0.50 mas at -5.9 deg., Nat. Wgt. (no taper)



Proper Motion of Blazar Jet

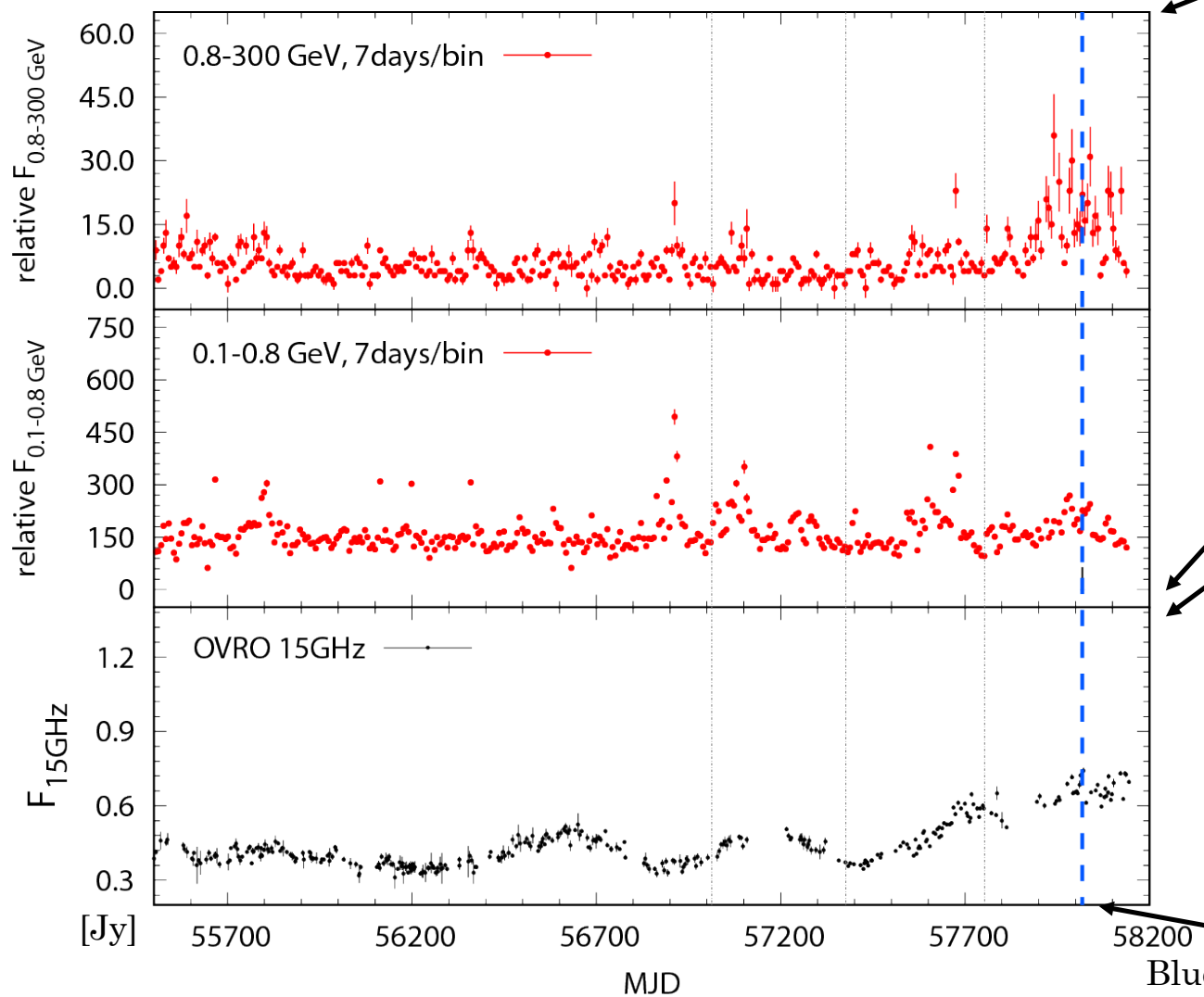


Modeling the jet structure using 2-D Gaussians



GeV γ -ray & Radio light curve

2015 2016 2017



Fermi All-sky Variability Analysis (FAVA)



The OVRO 40-Meter Telescope Monitoring Program

Blue line: IceCube-170922A

Intensive VERA observation of TXS 0506+056

What is the VERA?

□ One of Japanese VLBI arrays

□ Baseline length

- Longest : 2,270 km (Mizusawa-Ishigaki)
- Shortest : 1,000 km (Iriki-Ishigaki)

□ Frequency (angular resolution)

- 22GHz (~1.2 mas)
- 43GHz (~0.6 mas)

VERA = VLBI Exploration of Radio Astrometry

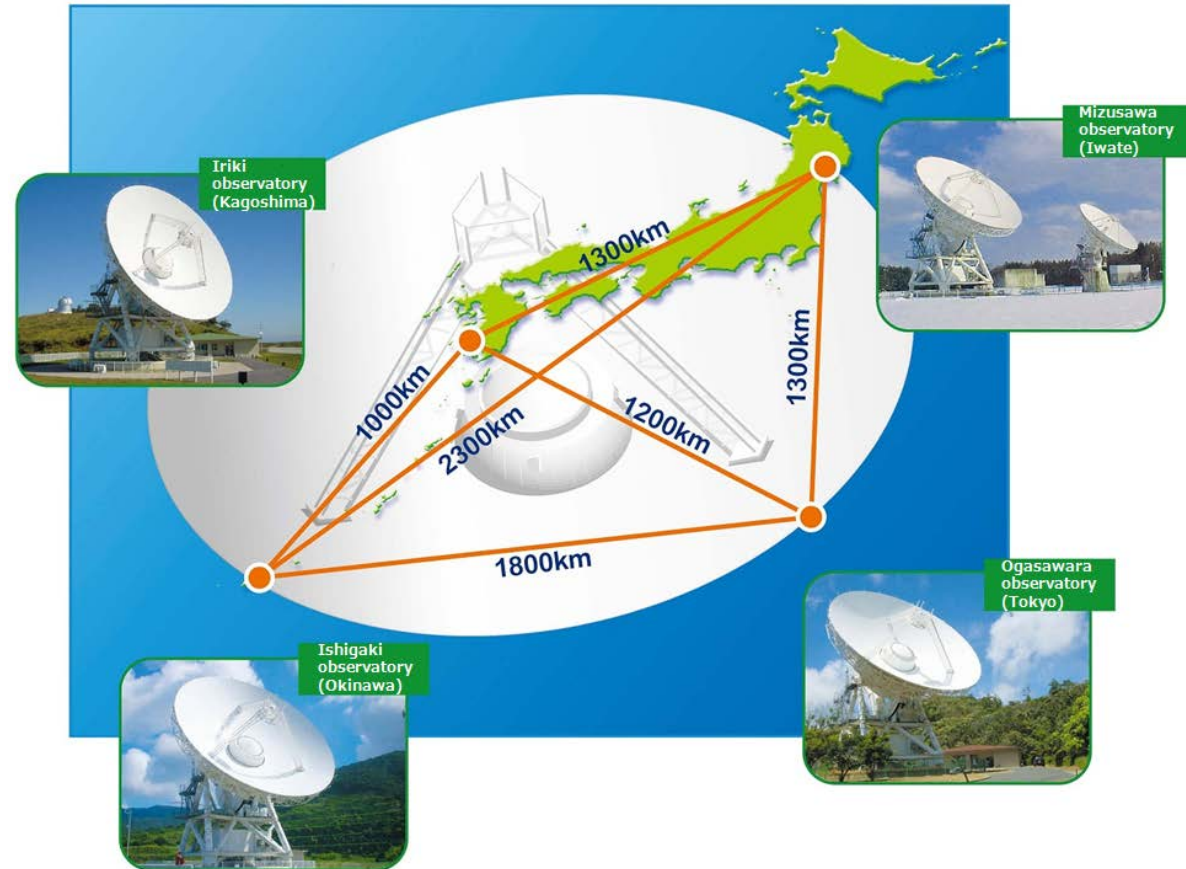


図. 国内4カ所（岩手県奥州市、東京都小笠原村、鹿児島県薩摩川内市、沖縄県石垣市）に1基ずつ電波望遠鏡が置かれている。

VERA observation of TXS 0506+056

▣ Observations

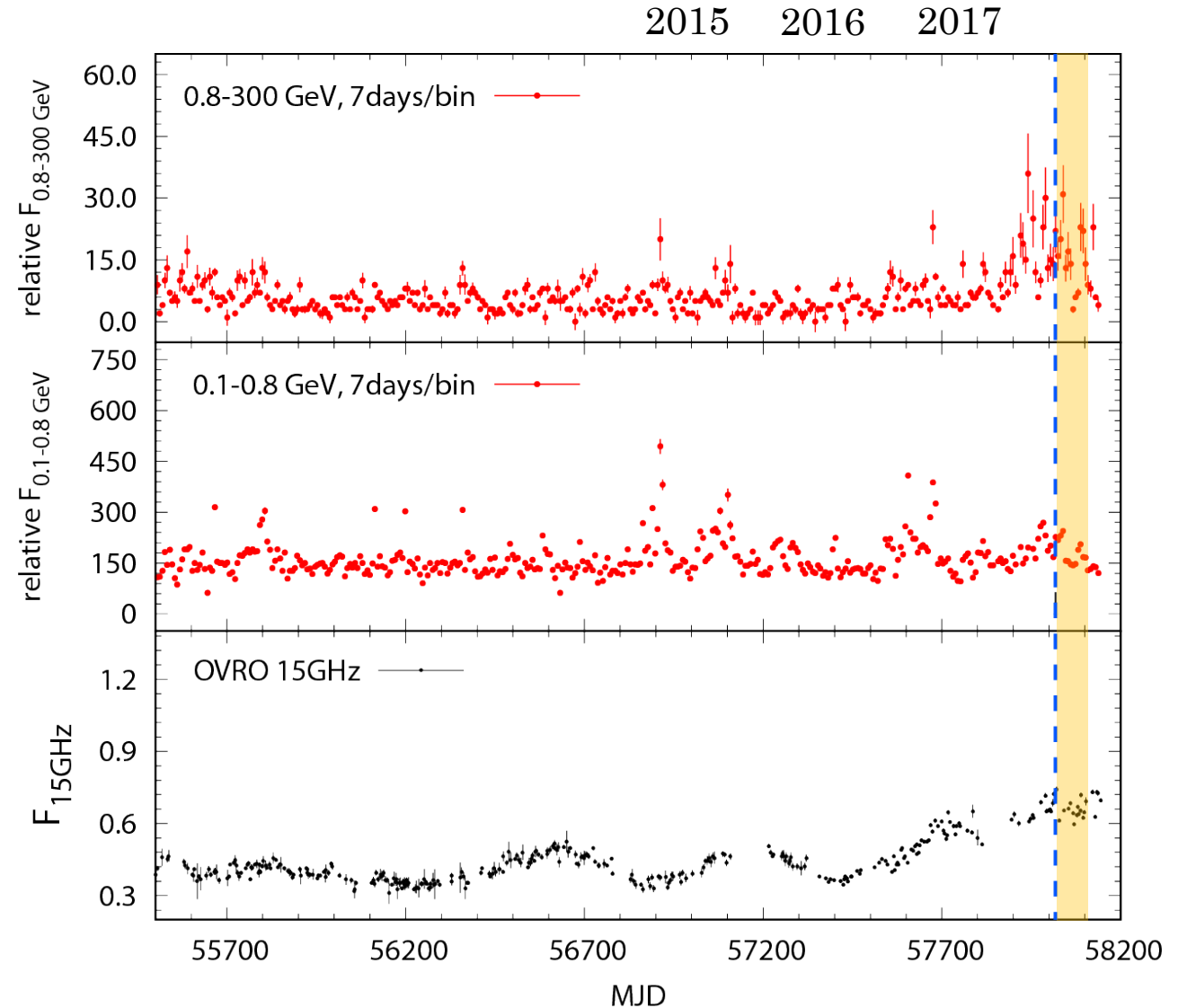
- 2017/Sep/30, Oct/13, Nov/1,
Nov/14 (4 epochs)

▣ Frequency

- 22 GHz

▣ Beam size

- 1.2×0.8 (mas²)

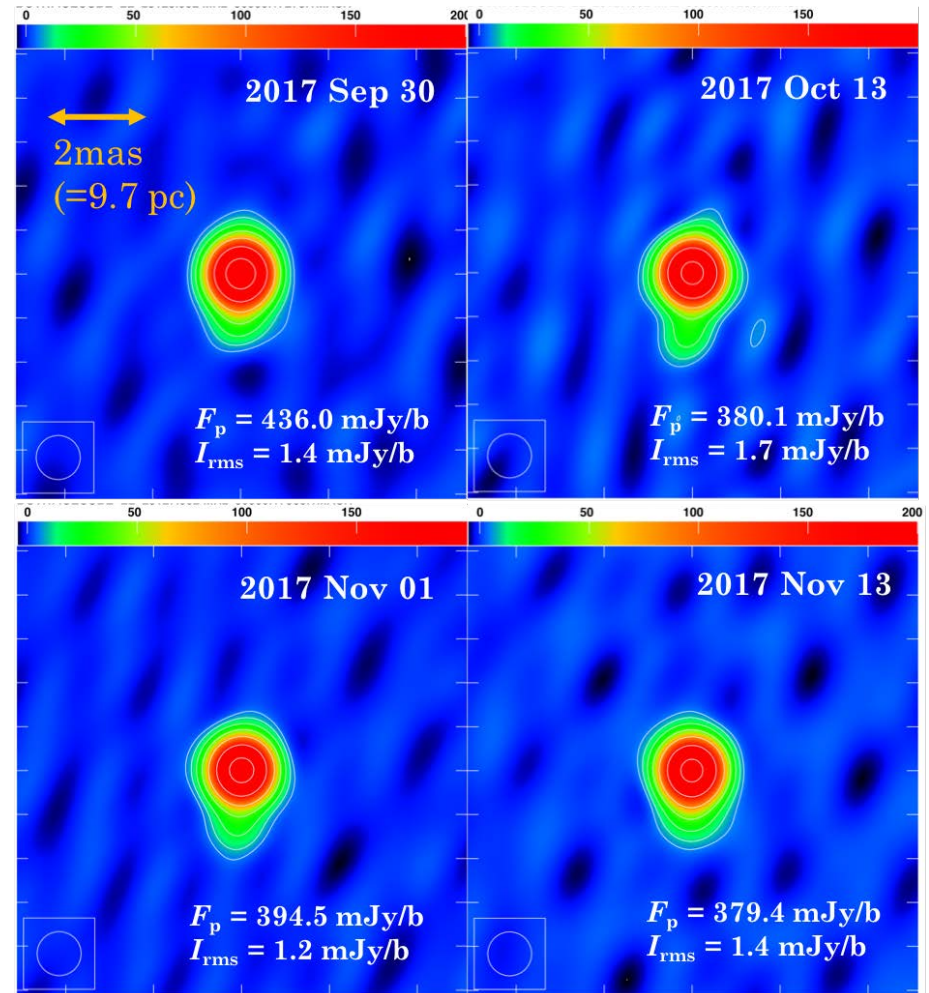


VERA observations - Images

□ $S_{\text{core}} \sim 0.4$ Jy/b throughout 4 epochs

□ Core + compact jet in south direction

- Consistent with previous images in the VLBA archive



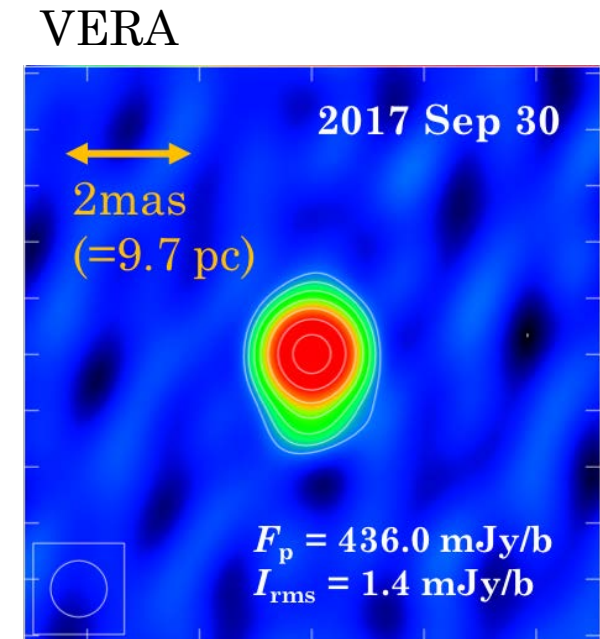
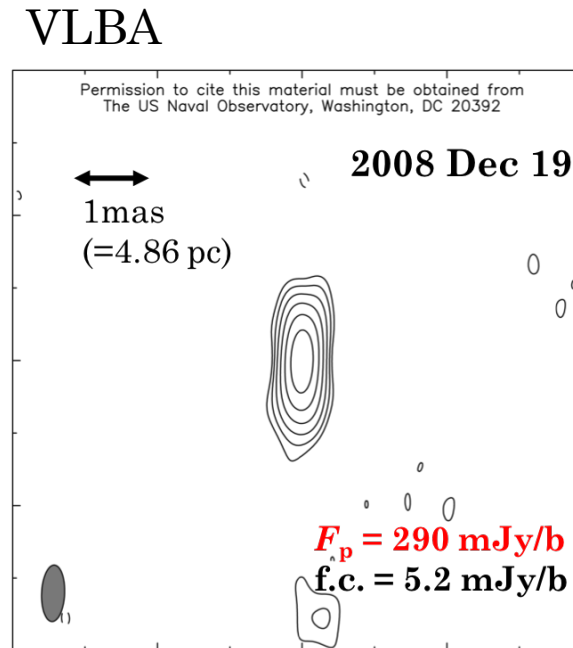
Preliminary

Comparison with previous works

□ Core flux density shows an increase as compared to that in 2008, which is consistent with the trend seen in the single dish light curve (OVRO)

□ No major change in flux (>15%) among 4 epochs of the VERA observations

- Consistent with the single dish light curve (OVRO)



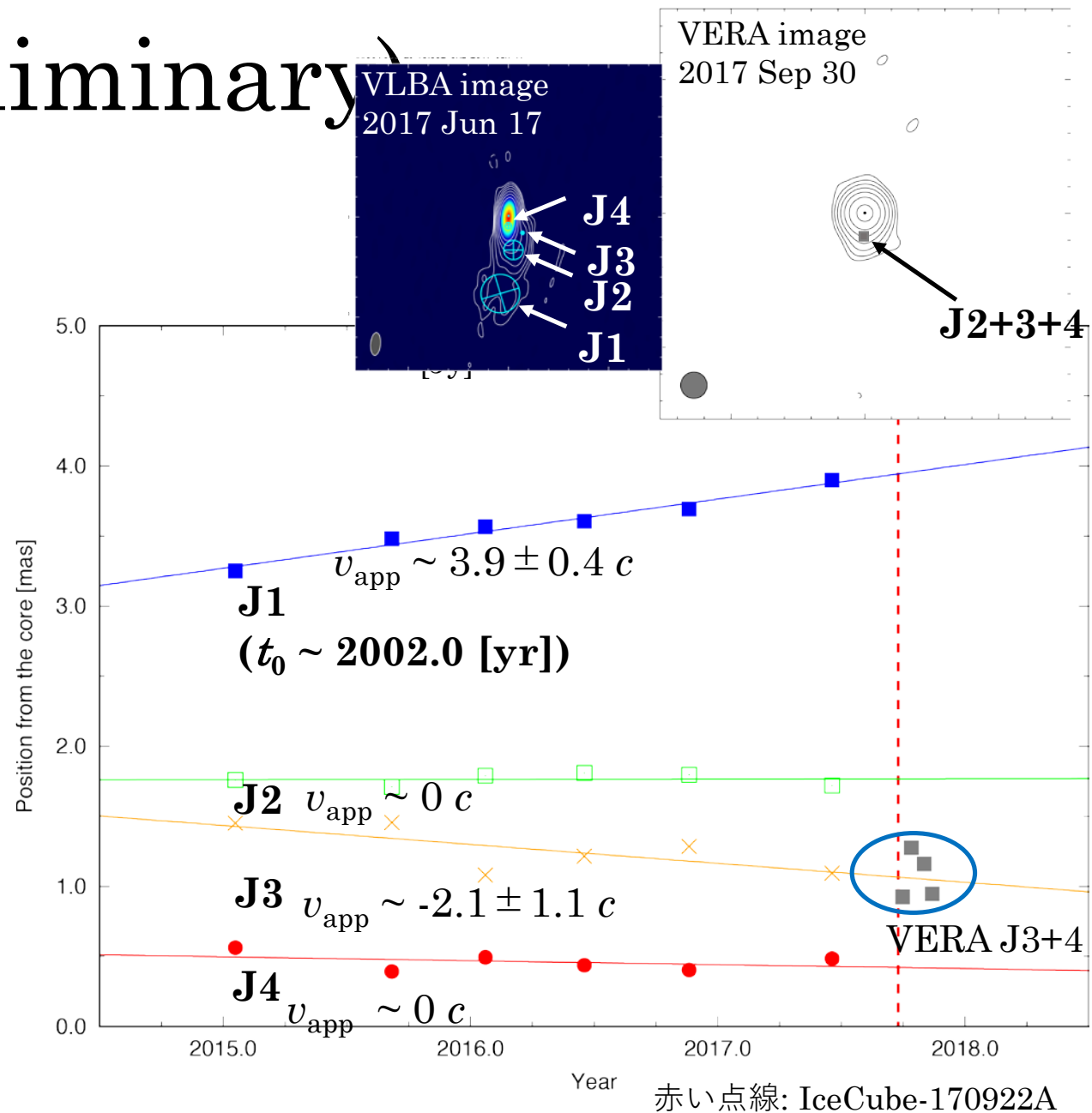
Proper Motion (Preliminary)

□ Jet component seen in the VERA image is a mixture of J2, J3, and J4

- No clear motion of J2+3+4 within 4 epochs of VERA observations

□ No new-born component is observed in the VERA image

- $v_{\text{jet}} < 55c$ if a new component was ejected with IceCube-170922A
 - No distance information was available when the observations were triggered, so monitoring interval was not optimal.



Discussion & Summary

- No major flux increase nor emergence of new moving component 8-44 days after IceCube-170922A
- Upper limit on the velocity of a possible moving component associated with this event ($<55c$)
- Continuing VLBI observations is essential to hunt a possible emergence of new component
 - 2-3 years

ALMA

□ Shall we do ToO observations with ALMA next time?

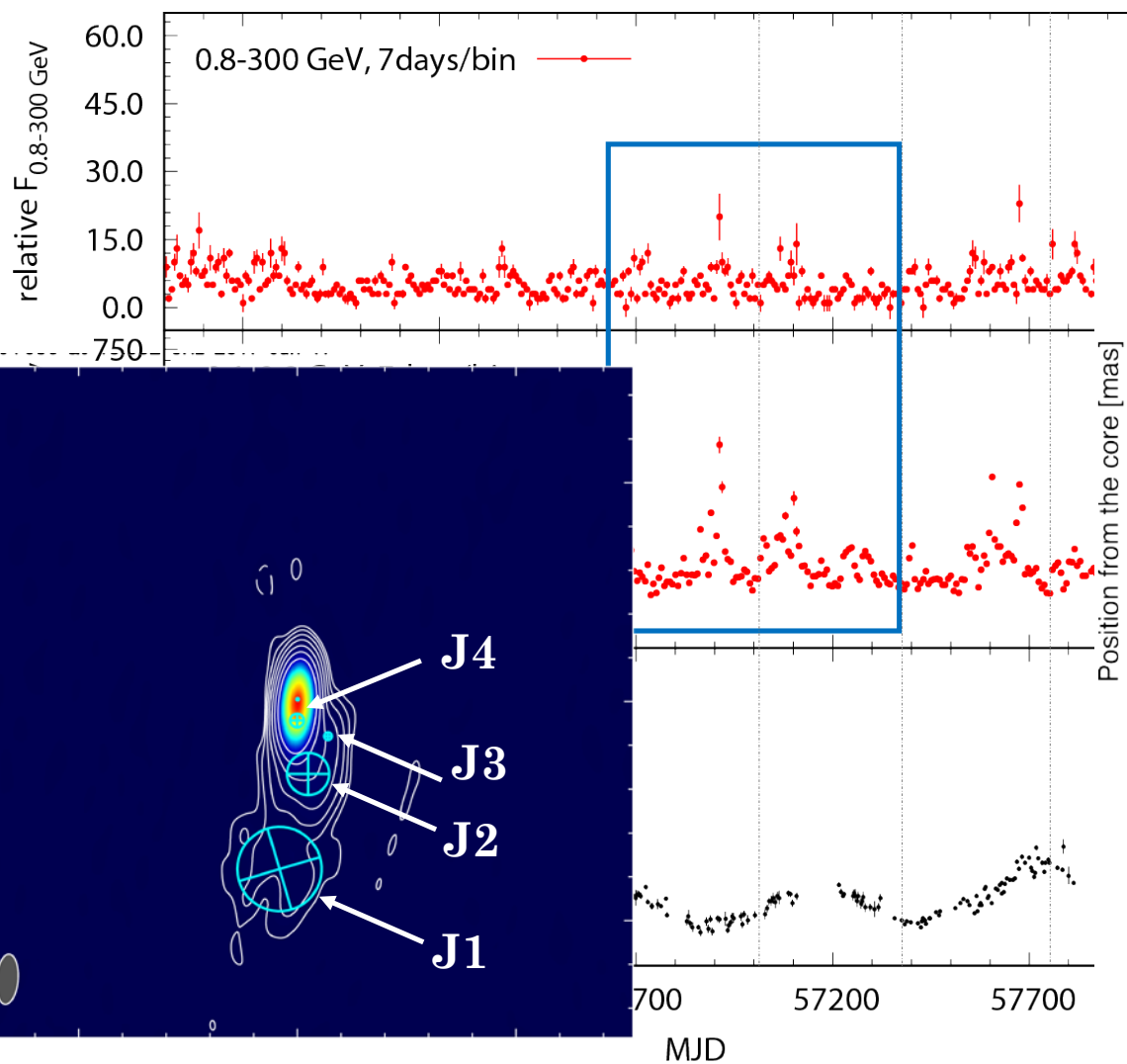
- Now ALMA allows quick follow-up (<1 d) after the triggering.
- Resolution is poorer than VLBI, but mm/submm observations can probe optically thinner part of jets.
- Anyone interested in submitting proposals for Cycle 6 (Deadline: April 19)?



backup

GeV γ -ray & Radio light curve

2015 2016 2017



No jet ejection associated with the activities in 2015 (from MOJAVE data)

