VLBI activity in Japan and future pulsar study in SKA era

Mareki Honma

Director of Mizusawa VLBI Observatory, NAOJ

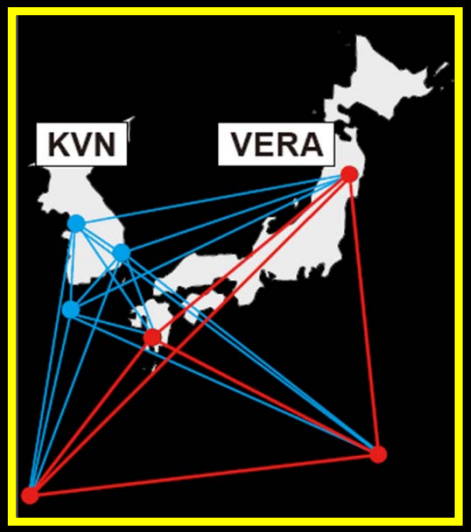
Contents

- Introduction of our VLBI activity
- Preparatory works for FRB/pulsar studies

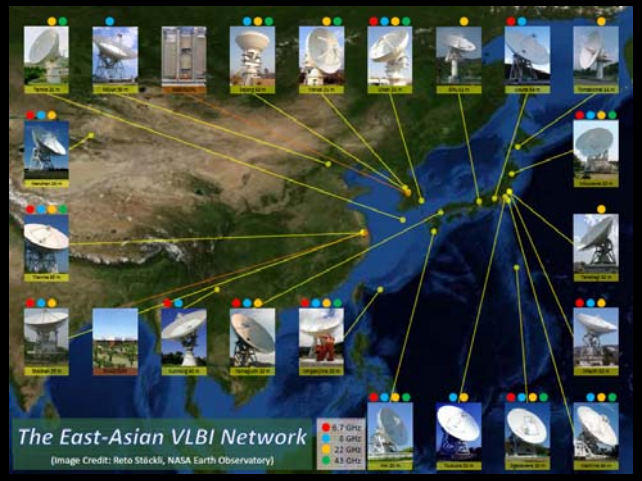
Facilities related to our observatory

VERA

KaVA



EAVN



EHT

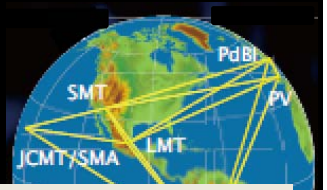
Brief history of radio astronomy in Japan

mm wave (thermal)

6m mm-wave telescope (1970's)

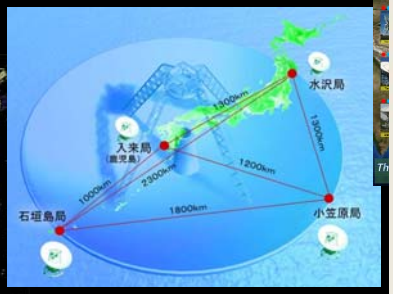
Nobeyama 45m and NMA (1980's~)

ALMA (2011~)



cm and longer λ (non-thermal)

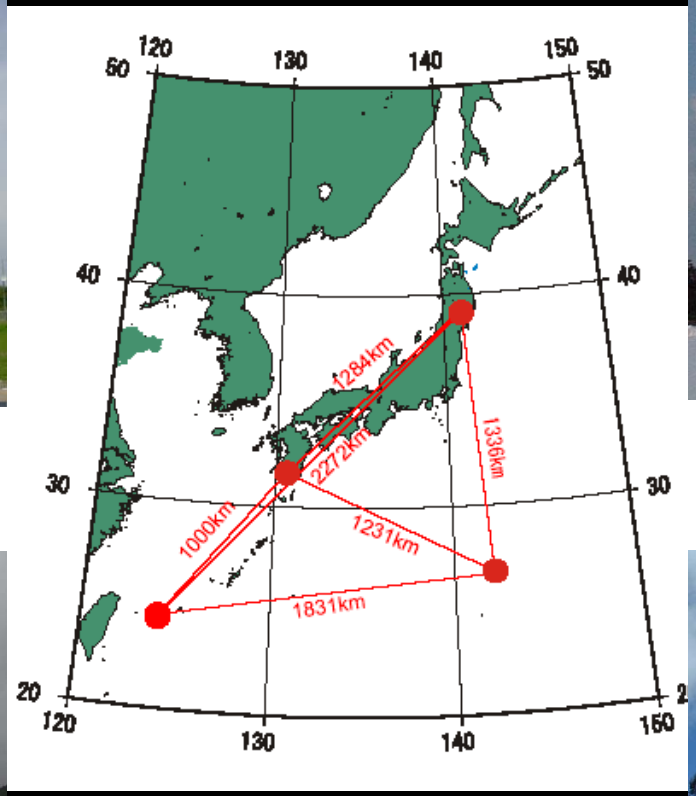
VSOP (1997~2005)

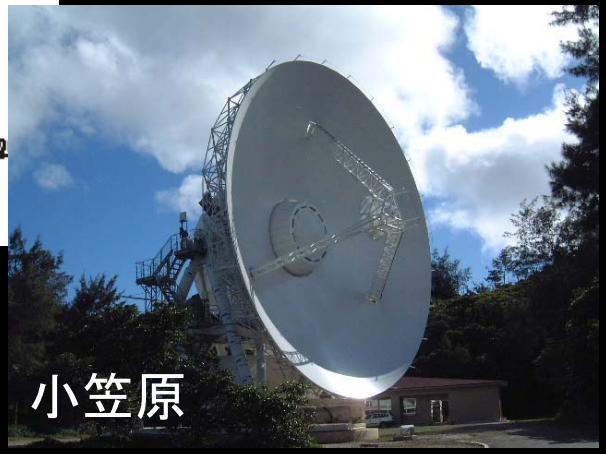


VERA (2002~)

VERA: VLBI Exploration of Radio Astrometry

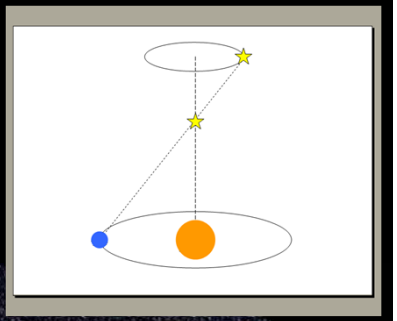
VLBI dedicated to maser astrometry
H2O maser (22GHz) + SiO (43G), CH3OH (6.7G)

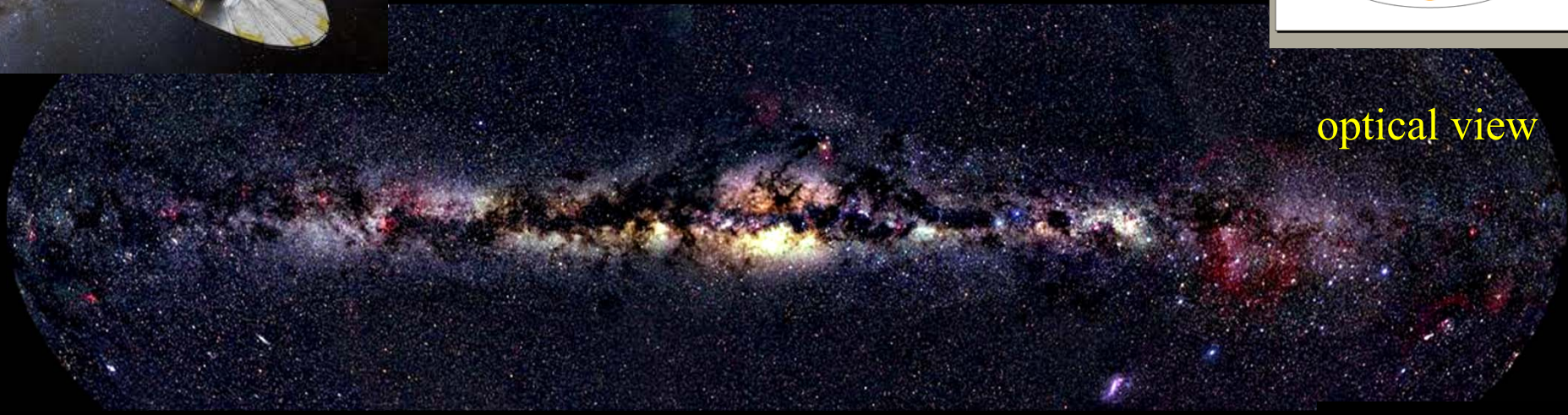




Galactic astrometry

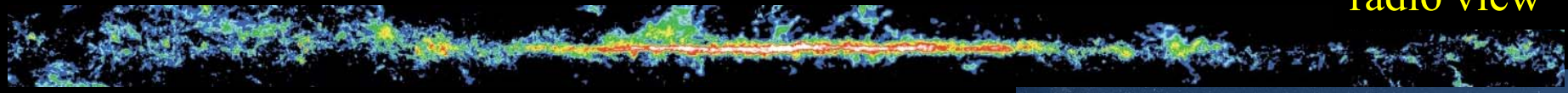
Parallax ~ 100 uas
for 10 kpc distance





optical view

radio view

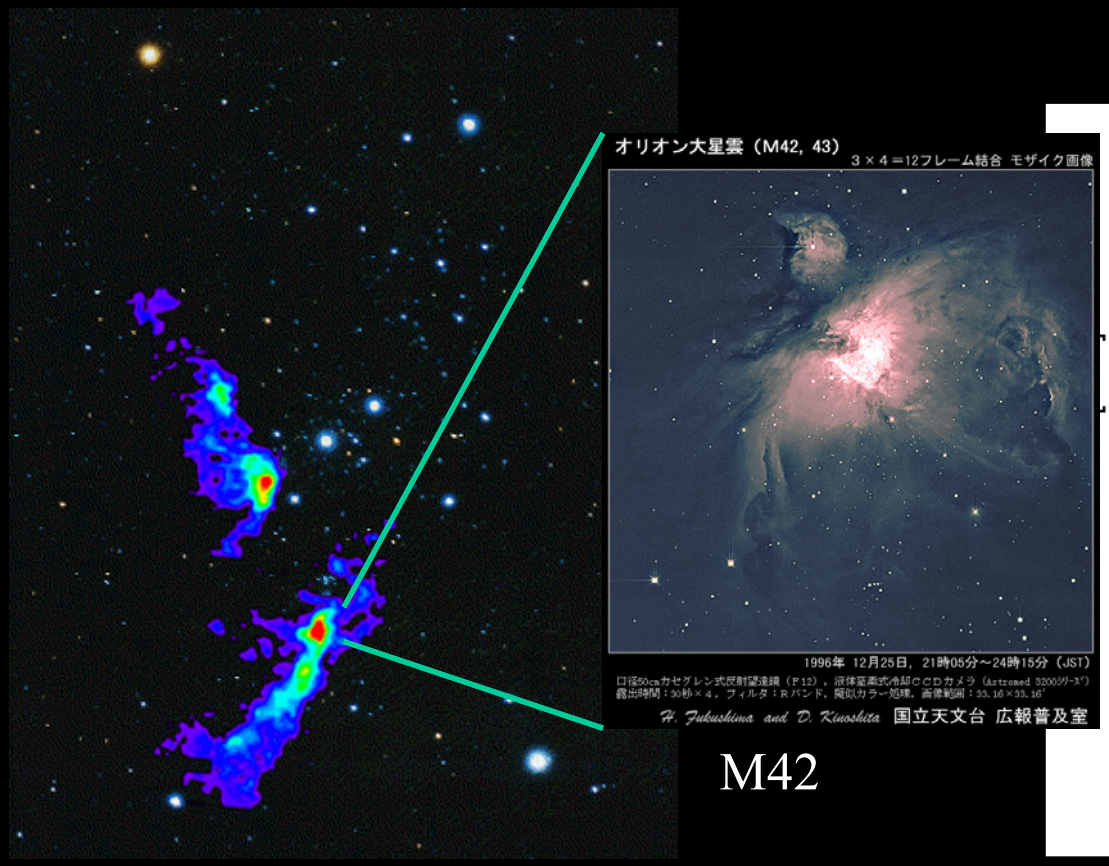


GAIA and VLBI are complementary
to each other

Example of Astrometric results

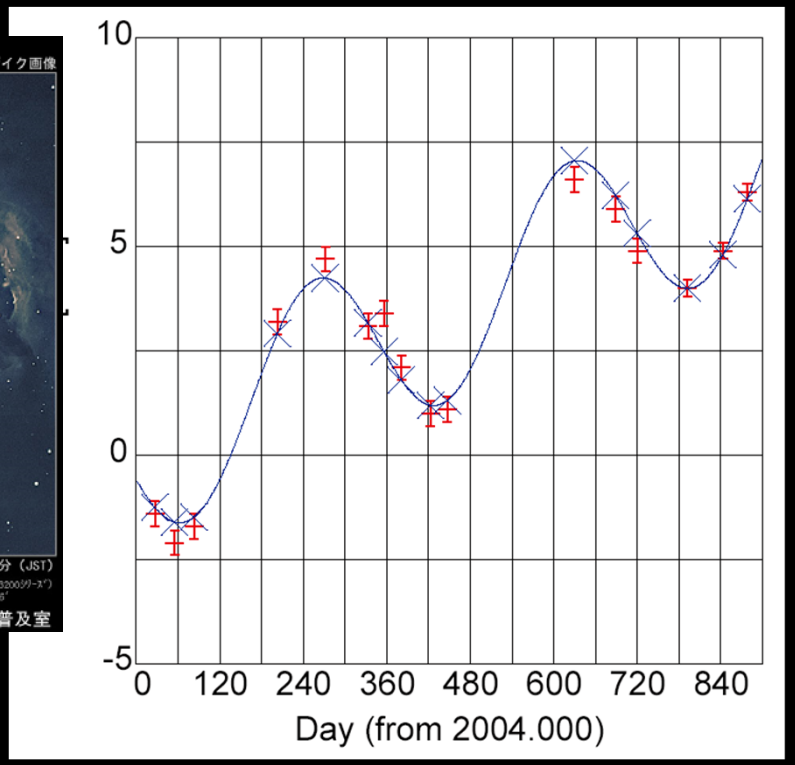
H2O maser in Orion

D =440 pc



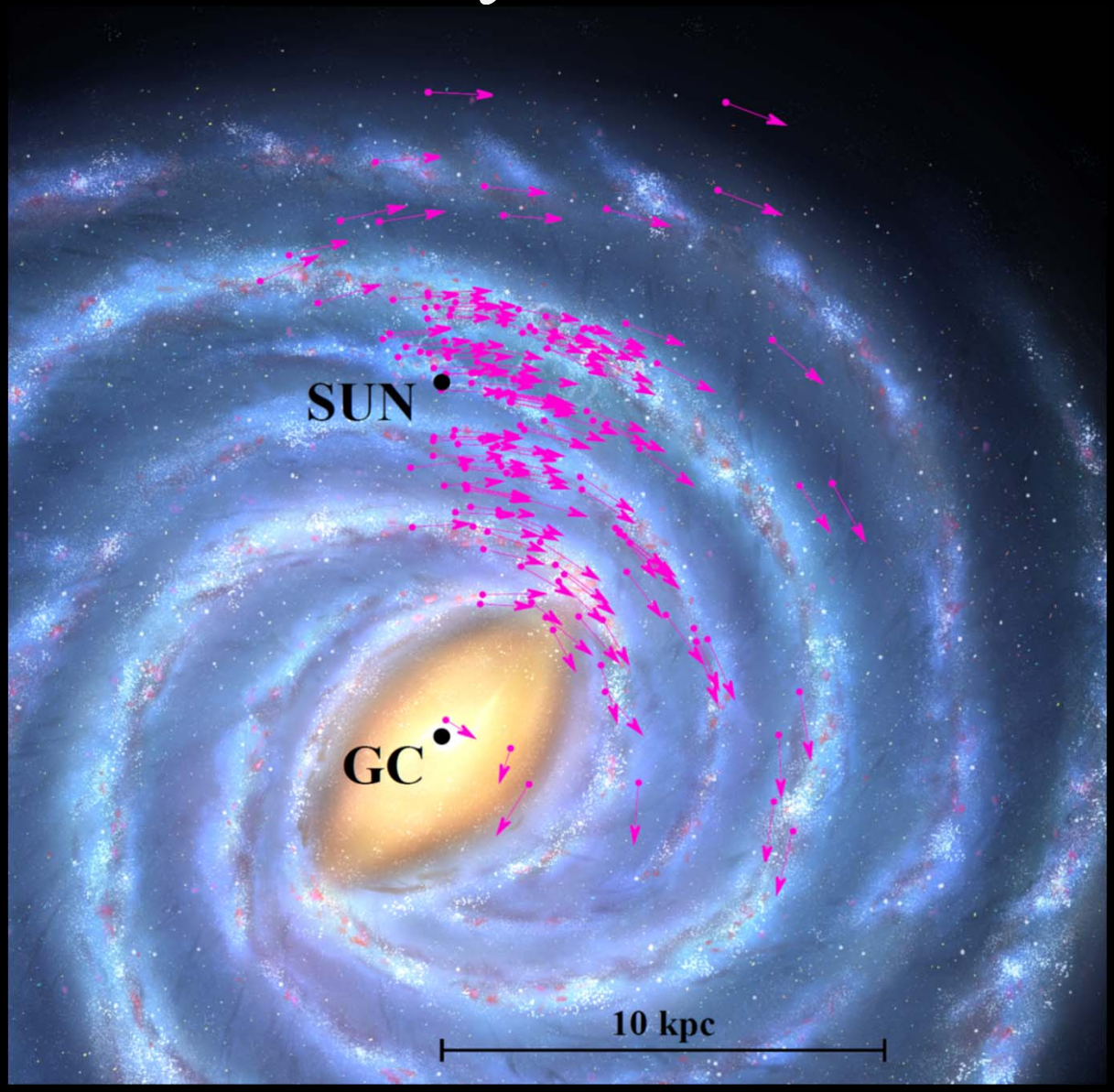
M42

Constellation Orion



H2O maser motion against QSO

Galaxy rotation

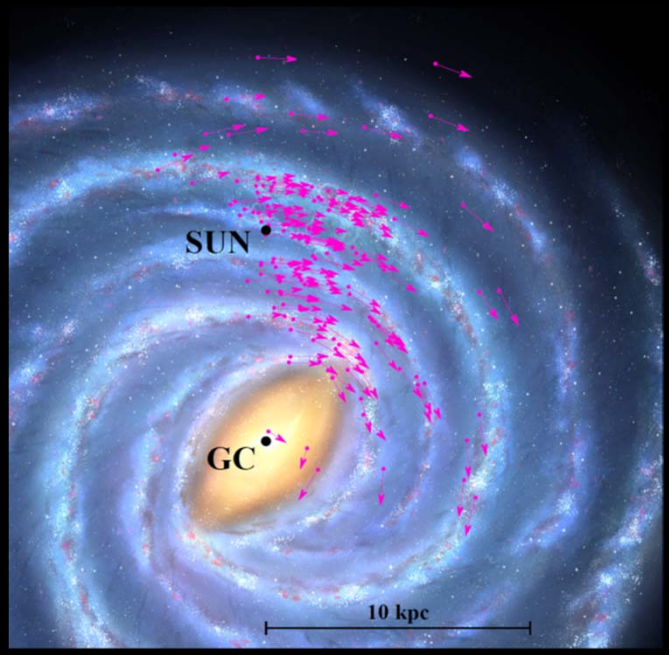


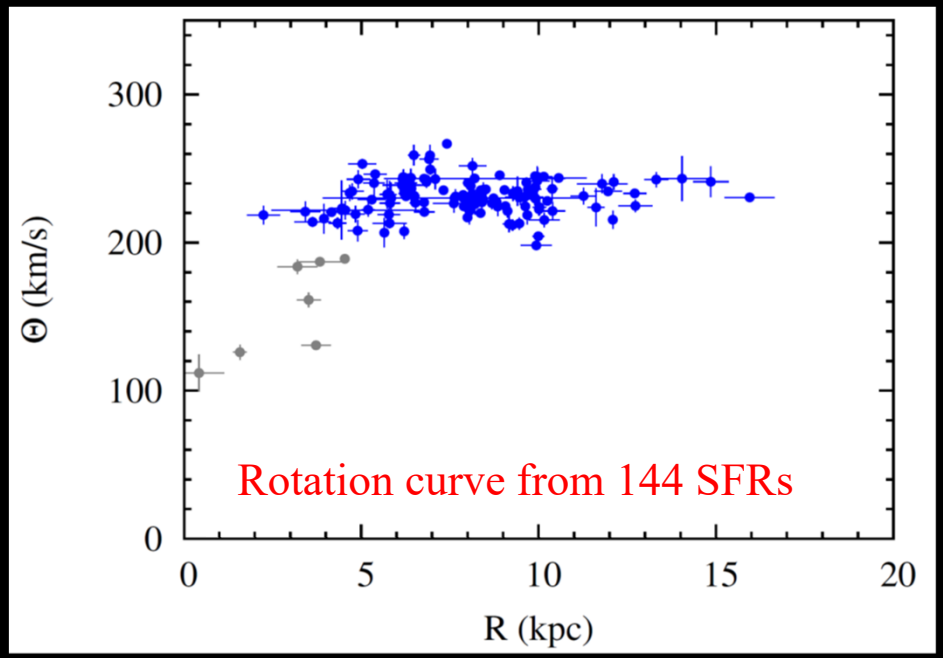
~150 sources with VERA/VLBA/EVN

Galactic constants

As of 2017 (preliminary)	Honma+ (2012)
144 SFRs	52 SFRs
$R_0 = 8.16 \pm 0.26$ kpc	$R_0 = 8.05 \pm 0.45$ kpc
$\Theta_0 = 237 \pm 8$ km/s	$\Theta_0 = 238 \pm 14$ km/s
$\Omega_0 = 28.99 \pm 0.39$ km/s/kpc	$\Omega_0 = 29.57 \pm 0.78$ km/s/kpc

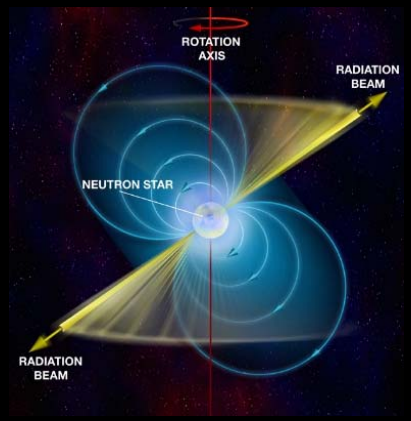
$(U_\odot, V_\odot, W_\odot) = (11.10, 12.24, 7.25)$ km/s (Schorich, Binney, Dehnen 2012) assumed

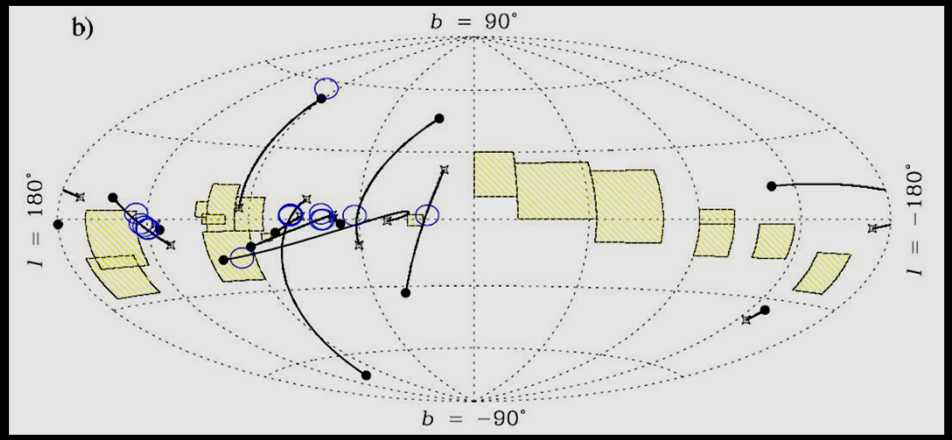




Note on astrometry impact on pulsars

- Pulsar parallax:
  - required for physical parameter determination
  - Also important for GW detection by PTA
- Proper motion:
  - Pulsar kick velocity (SN explosion, pulsar formation)
  - Shklovski effect (2nd-order effect on pulse period by PM)

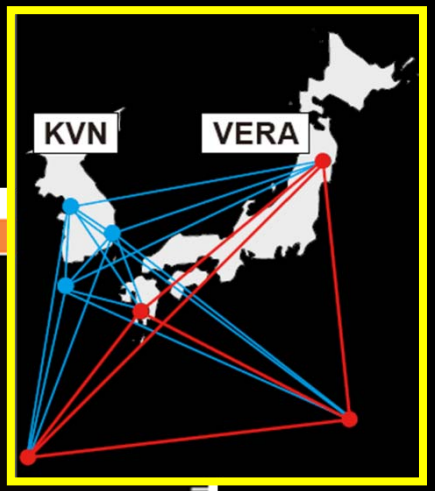


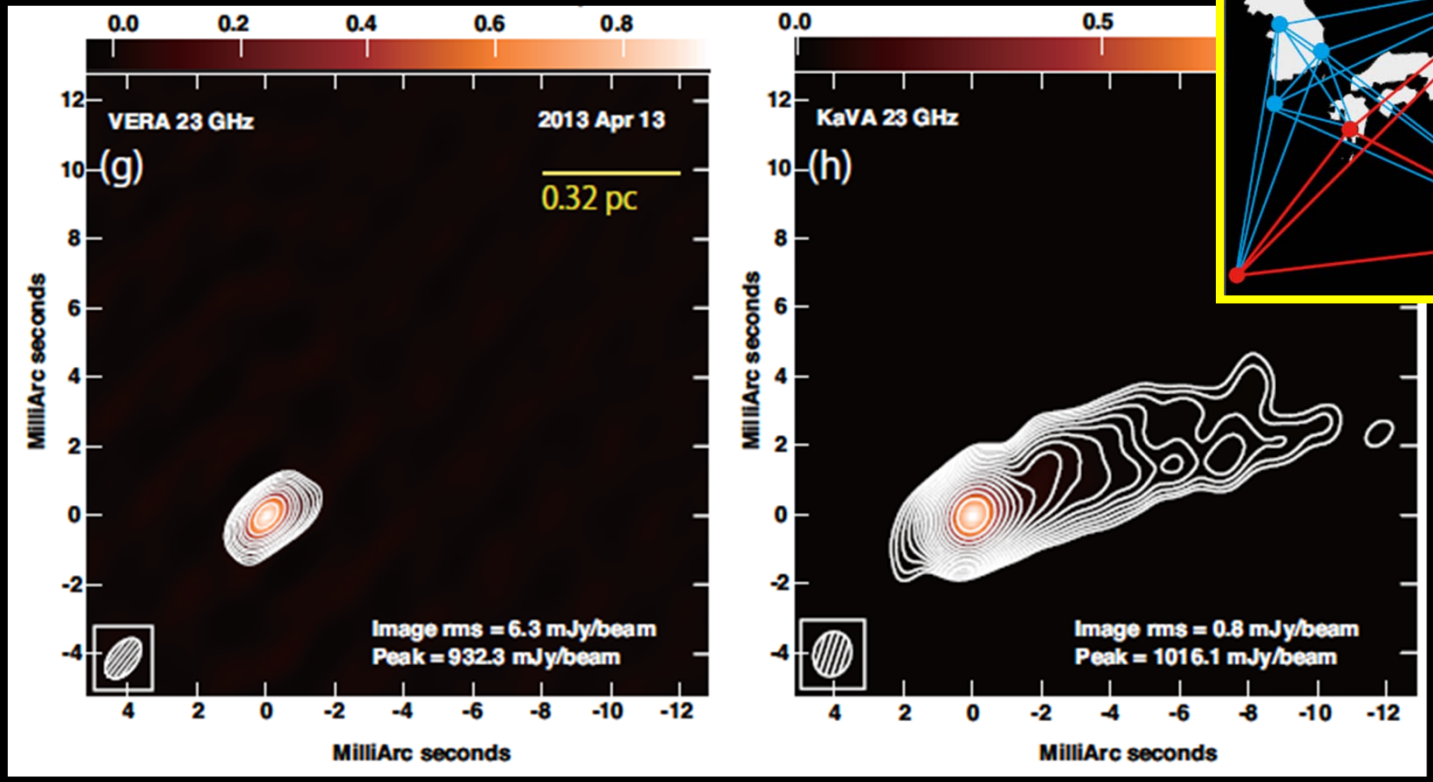


Chaterjee+(2009)

KaVA (KVN and VERA Array)

- KaVA: KVN and VERA Array, 7station 21 baselines
- Open-use started since 2014
- KaVA Large Project starts in 2015

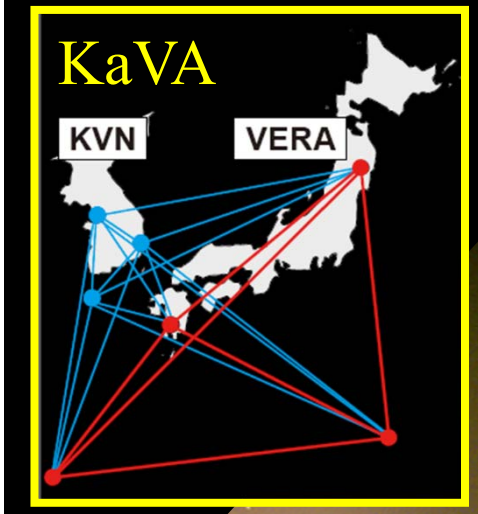


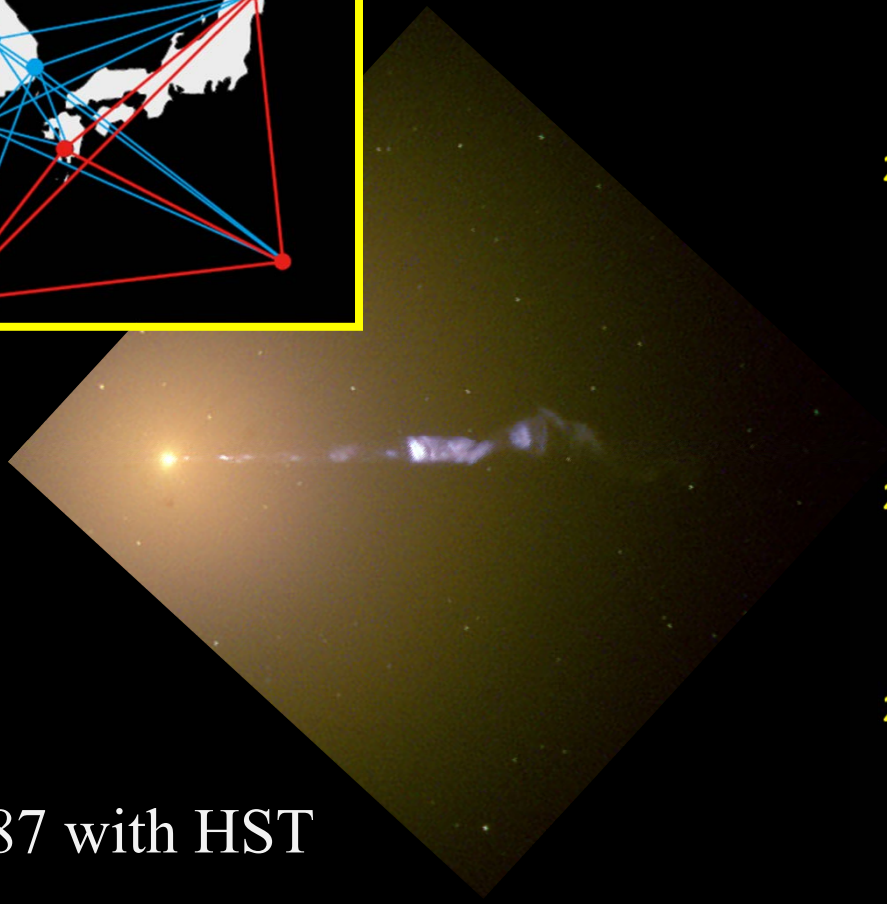


M87 jet with VERA KaVA

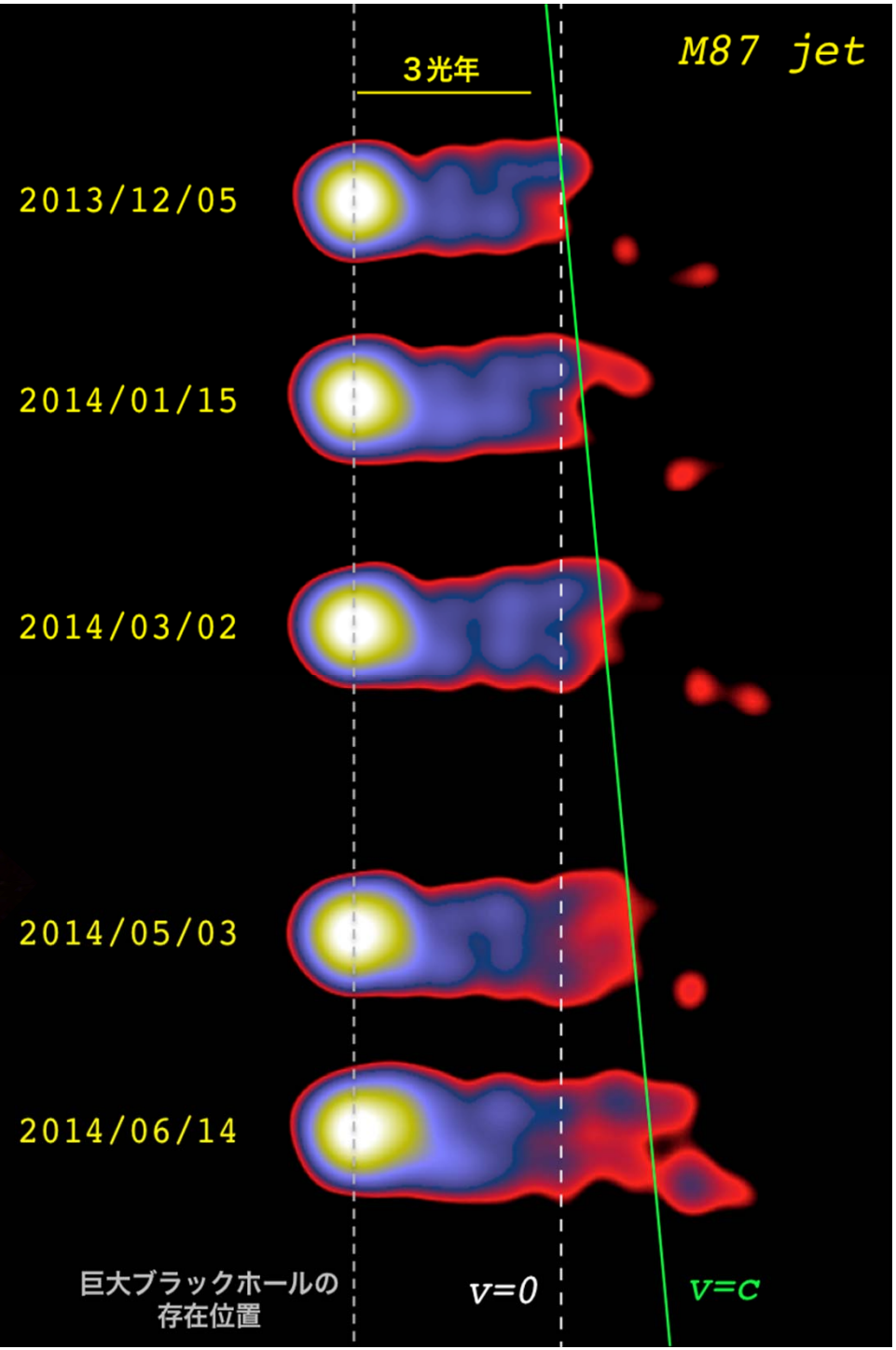
Demonstration of KaVA's capability: Niinuma et al.(2014)

KaVA:
KVN and VERA Array

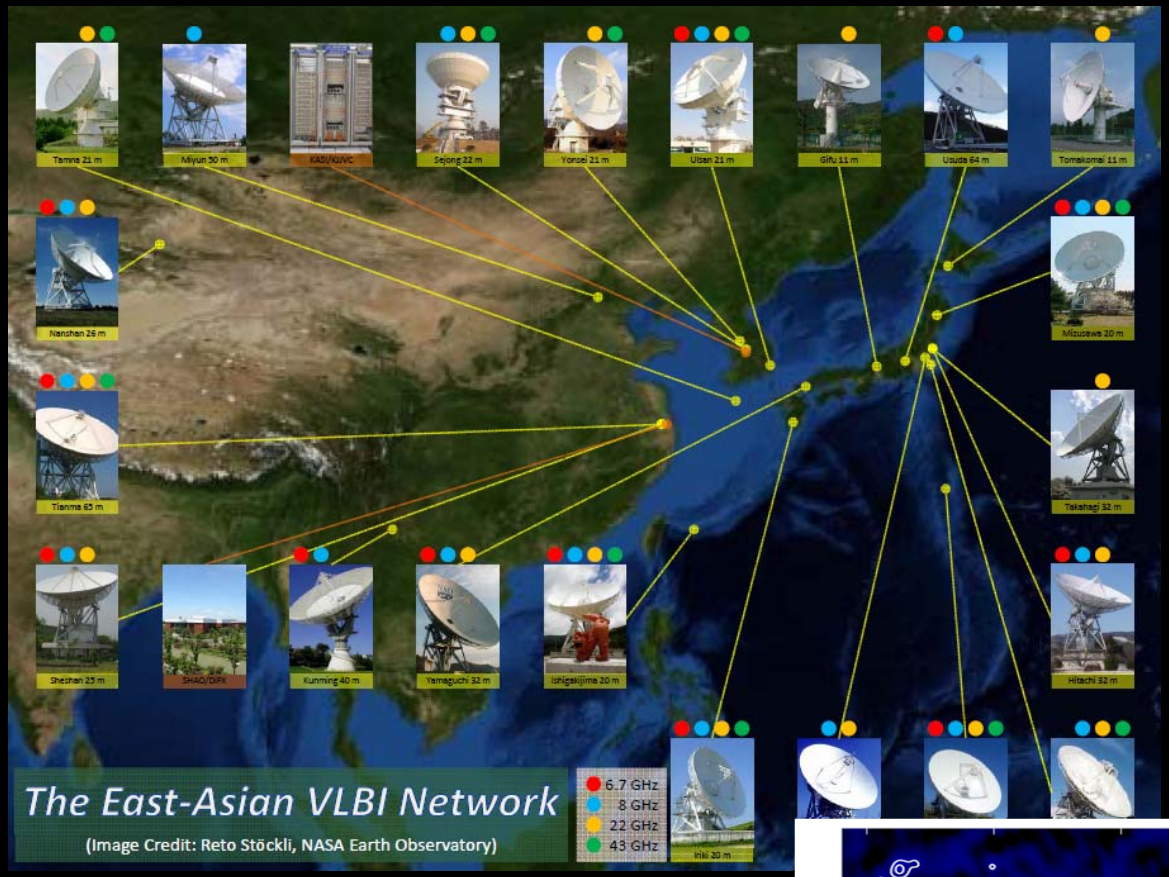




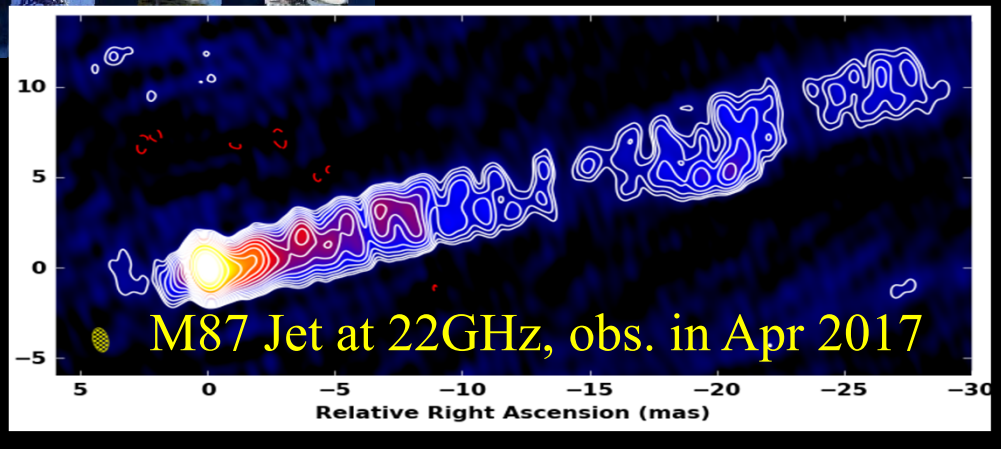
M87 with HST



EAVN: East Asian VLBI Network



KaVA+Tianma+Nanshan mode will start regular operation in 2018 fall.



EHT (Event Horizon Telescope)

mm-wave VLBI to resolve the black hole shadows

GLT

PdBI

CARMA

SMT/ARO

IRAM

LMT

SMA,
JCMT

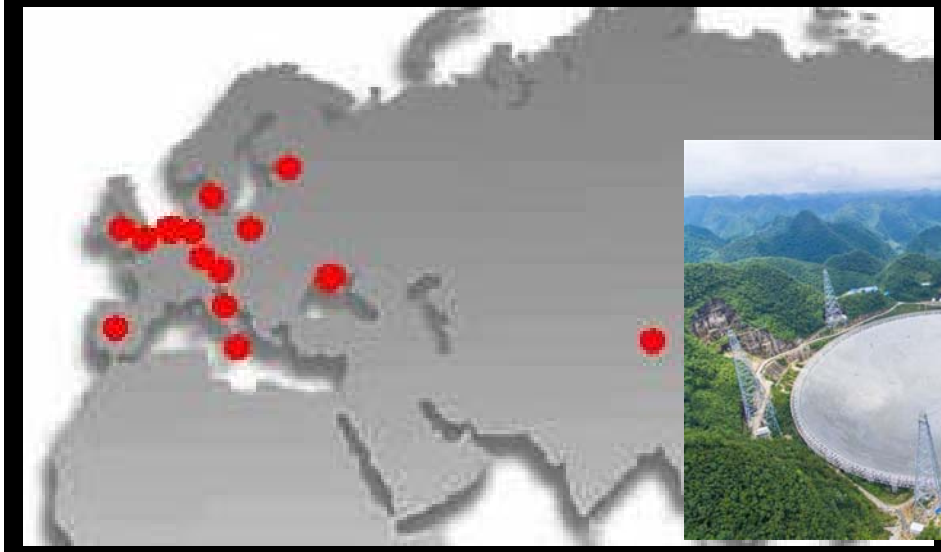
APEX, ALMA

South Pole (SPT)

First obs. with ALMA conducted in 2017

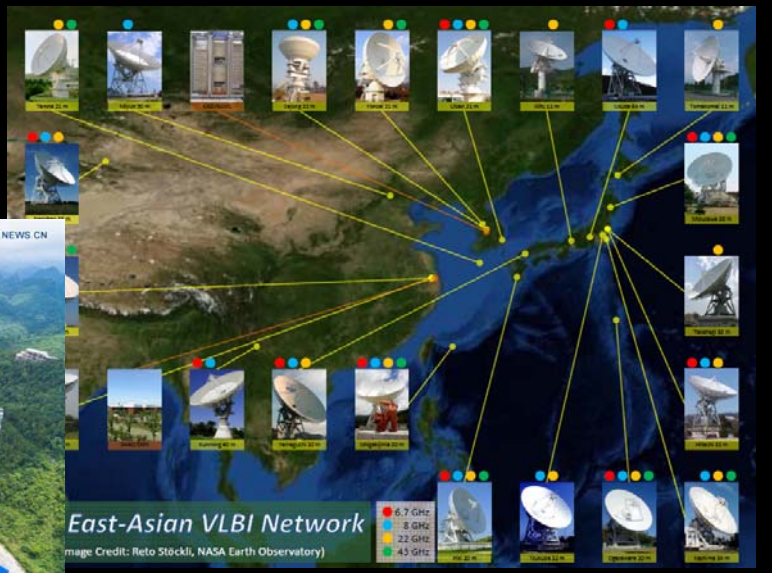
Future: global VLBI in cm wave

EVN

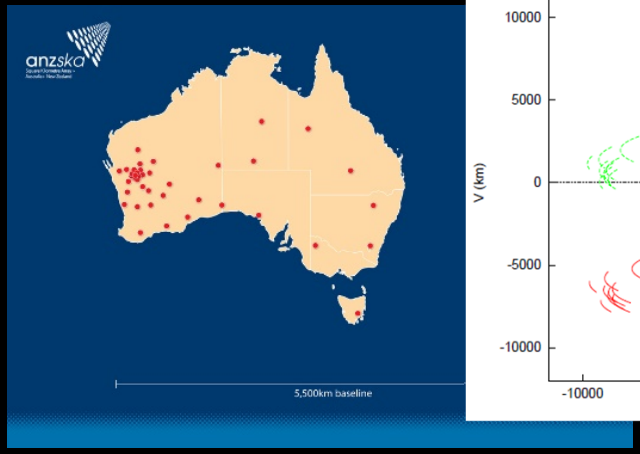


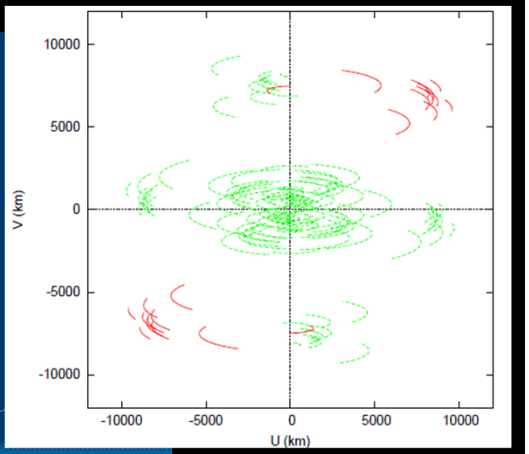
FAST

EAVN



SKA





From VERA to SKA

	VERA	KaVA	EAVN	EAVN+ QTT110 m	Global VLBI (EA/Eu/ US)	SKA-1 (mid)	SKA-2 (mid)
Operation start	2004	2014	2018?	2022?	?	2027?	2032??
Max baseline (km)	2300	2300	5000	5000	10000	150	3000
Collecting area (m^2)	**1250**	**2300**	**15000**	**23000**	**70000**	**32600**	**440000**

VERA/KaVA/EAVN → SKA (+global VLBI)

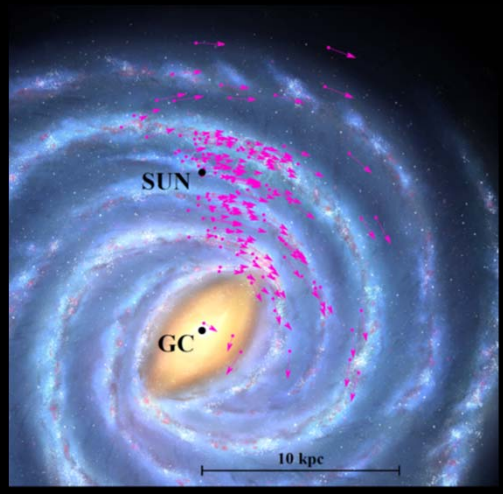
Science cases

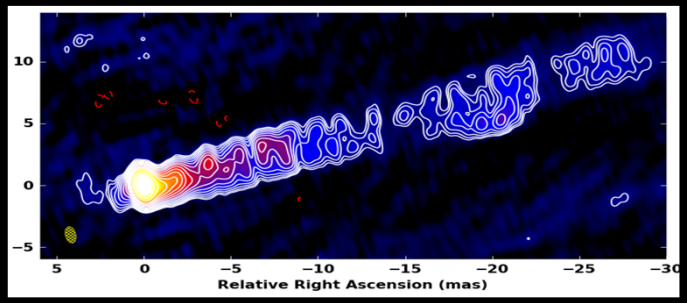
- Galactic structure
- AGNs
- Maser

+

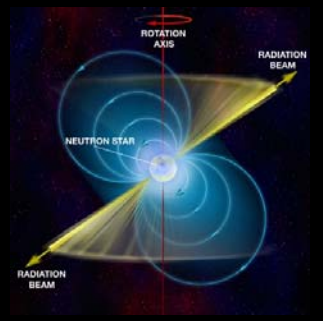
- Pulsars
- Radio transients
- SETI (!?)

and hopefully more



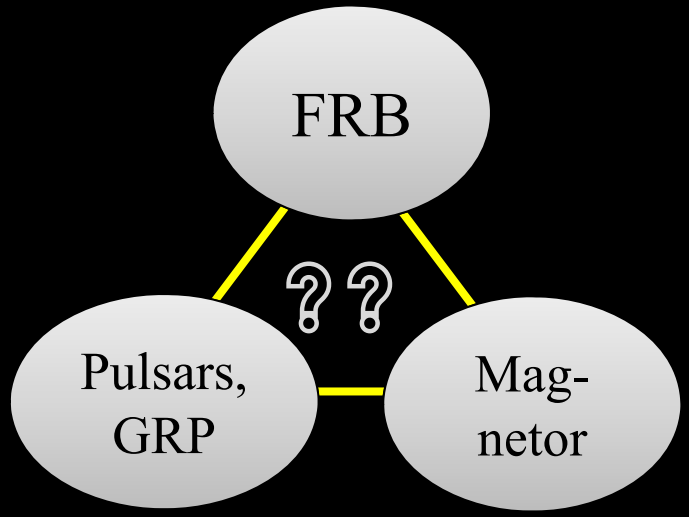


Pulsars, magnetars, FRBs



Pulsars, Magentars, FRBs are attractive targets in SKA era

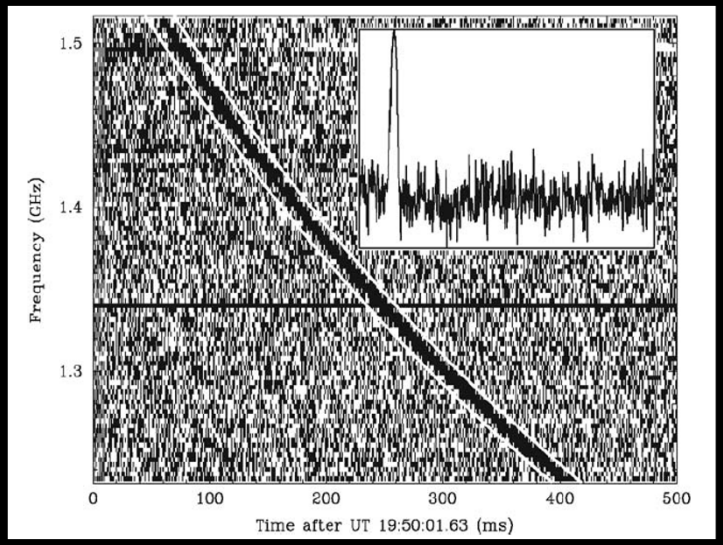
- They may be physically related ?



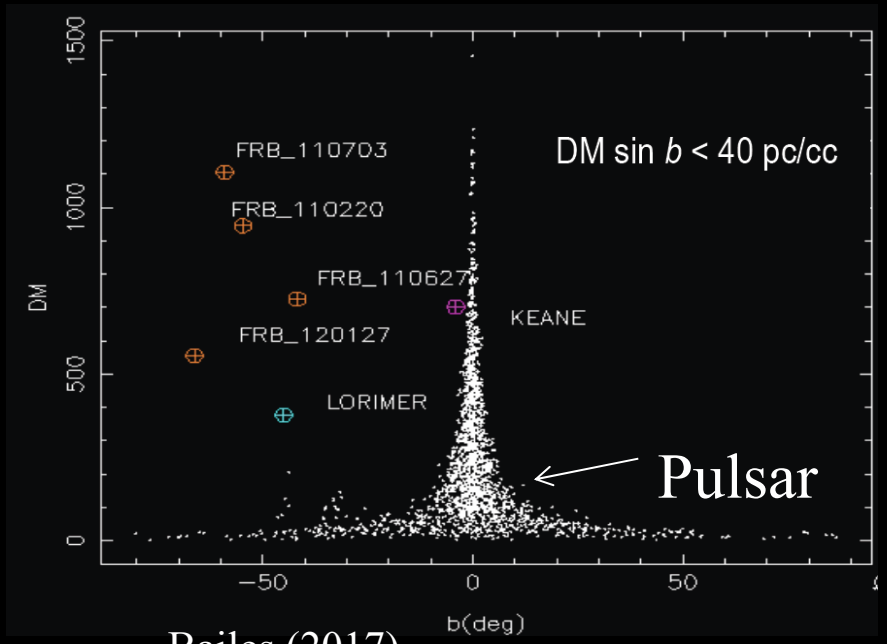
- Observationally they are closely related (time domain analysis, unpredictable bursts, …)

FRB: Fast Radio Burst

- Mysterious single radio pulse with large DM, likely to be extra-galactic.
- A few tens of events detected, with only one repeater



Lorimer burst



Bailes (2017)

LETTER

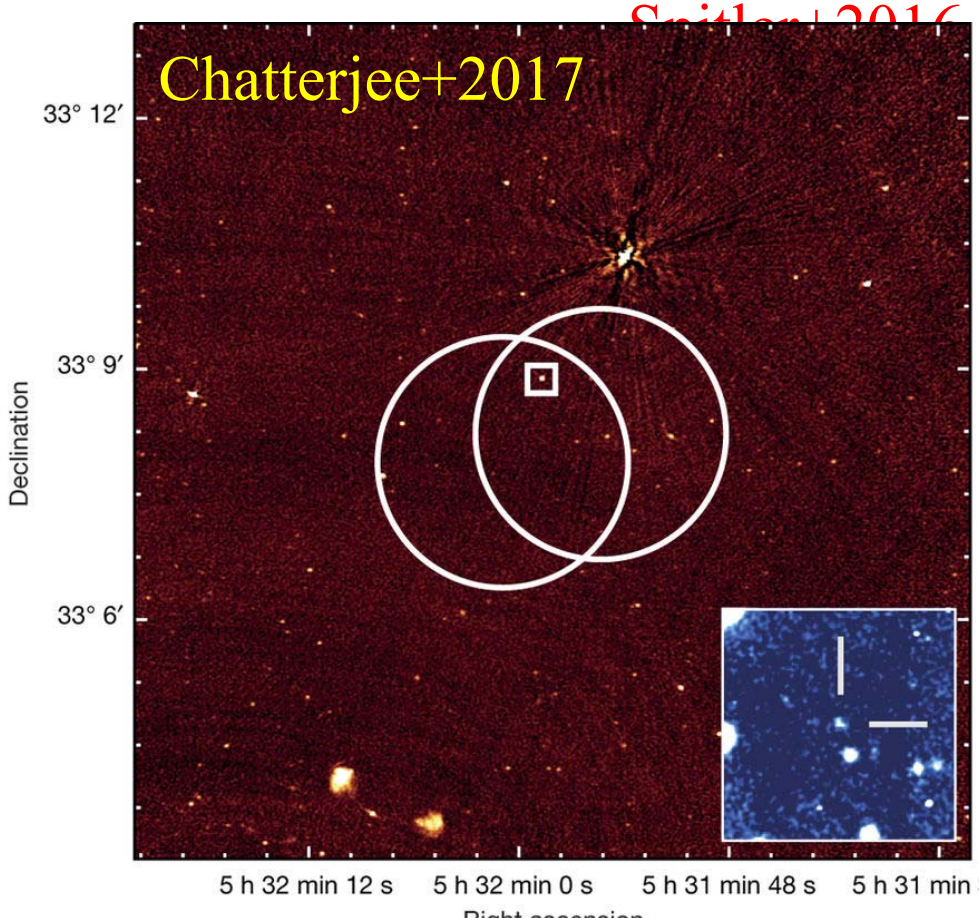
a

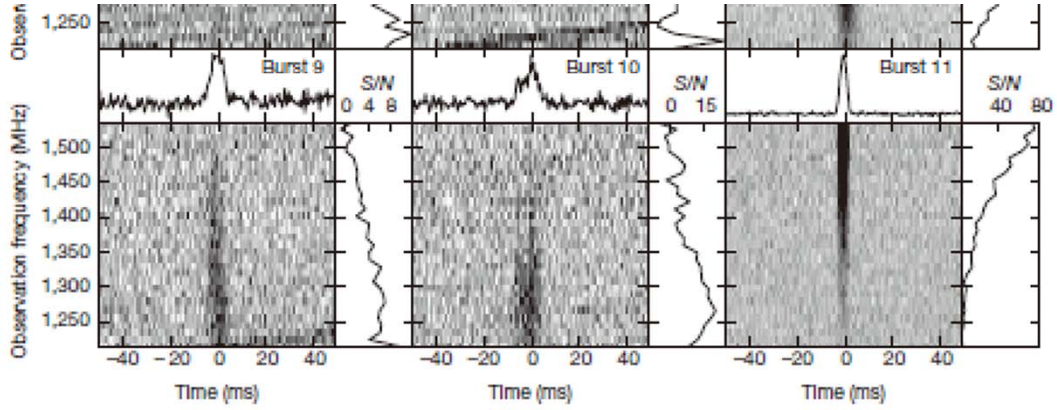
A repeating fast radio

L. G. Spitler[1], P. Scholz[2], J. W. T. Hessels[3,4], S. Bogdan
J. Deneva[10], R. D. Ferdman[2], P. C. C. Freire[1], V. M. Kas
S. M. Ransom[13], A. Seymour[14], I. H. Stairs[2,15], B. W. S

Spitler+2016

Chatterjee+2017





Repeating FRB
(the only one)

The host galaxy
identified

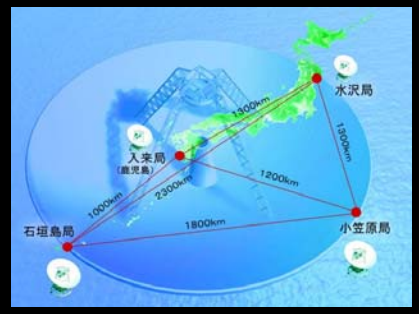
Opening of FRB
cosmology

FRB studies possibility in Japan

- Strength
  - Large machine time (our own telescope)
  - possibility of accurate localization (VLBI)

- Weakness
  - small dishes (low sensitivity)
  - telescopes/RX not optimized to low frequency
  - -> Low detection rate

  Different approaches needed …



RX status of our radio telescopes

NAOJ radio telescopes

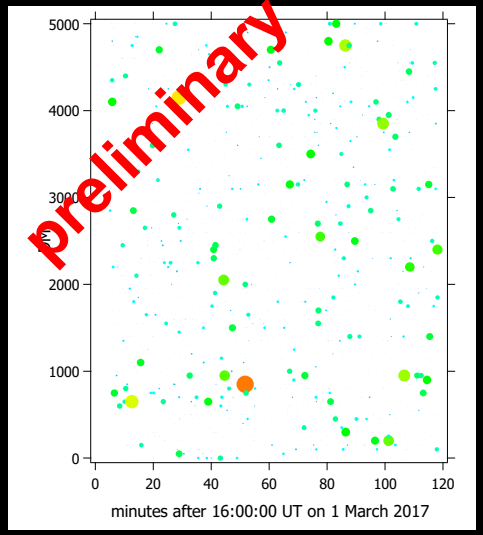
Station	L (1.4 GHz)	S (2 GHz)	C/X (5-8 GHz)	K (22 GHz)	Q (43 GHz)
VERA 20m x 4	NA	Room Temp.	Room Temp	Cooled, dual	Cooled, dual
KaVA 21m x 3	NA	NA	NA	Cooled, Multi-λ	Cooled, Multi-λ
Yamaguchi 32m	NA	NA	Cooled	NA	NA
Ibaraki 32m x 2	NA	NA	Cooled	Cooled	NA
Nobeyama 45m	NA	NA	NA	Cooled	Cooled
Kashima 34m	Cooled	Cooled	Cooled	Cooled	NA
Usuda 64m	Cooled	Cooled	Cooled	NA	NA

← Pulsars/FRBs → ← Masers, AGN →

FRB studies with VERA (1)

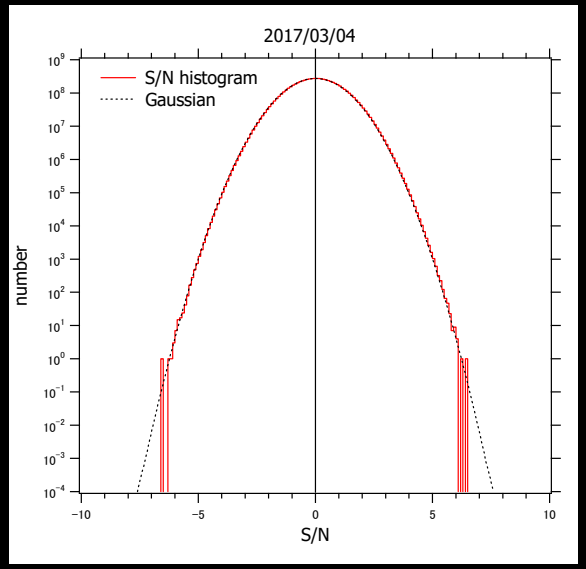
- Targeted FRB search at high-frequency
  - repeating FRB may be a very young pulsar?
  - look for FRB events toward nearby young SN.
  - High-frequency may be better (optical depth effect)
- Test observations conducted on Mar 2017 toward a young SN (PTF10iam) at 22 GHz

DM →



Time →

occurrence



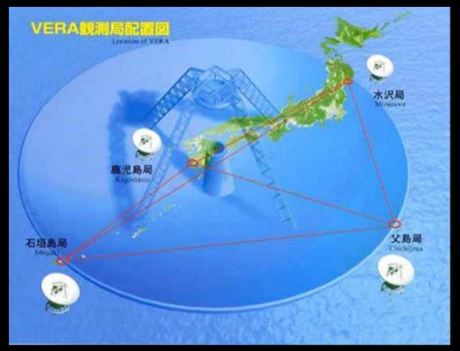
Log S/N

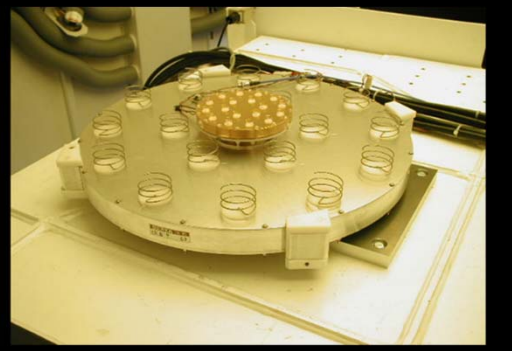
by Terasawa-sa

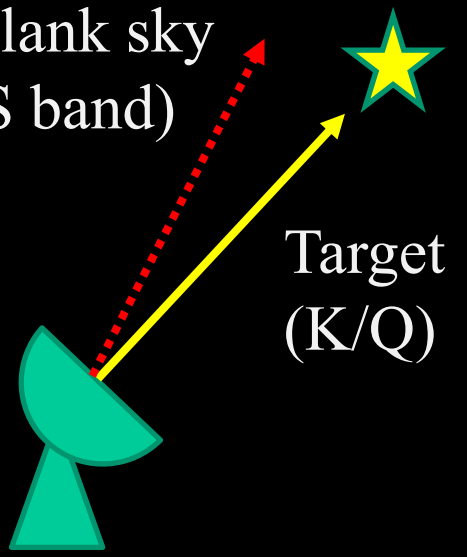
FRB study with VERA (2)

- Blind search with VERA
- VERA operates for 2000 hr/yr
  for project observations.
  (K or Q band)
- Commensal search with S-band RX
- Expected # of FRB
  - one per a few years with current RX
  - more that one per year with new cooled RX

VERA and S-band RX



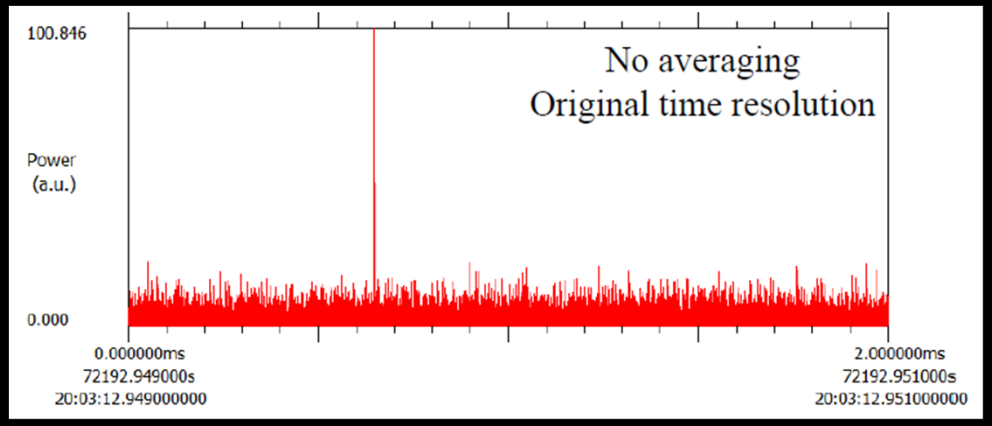




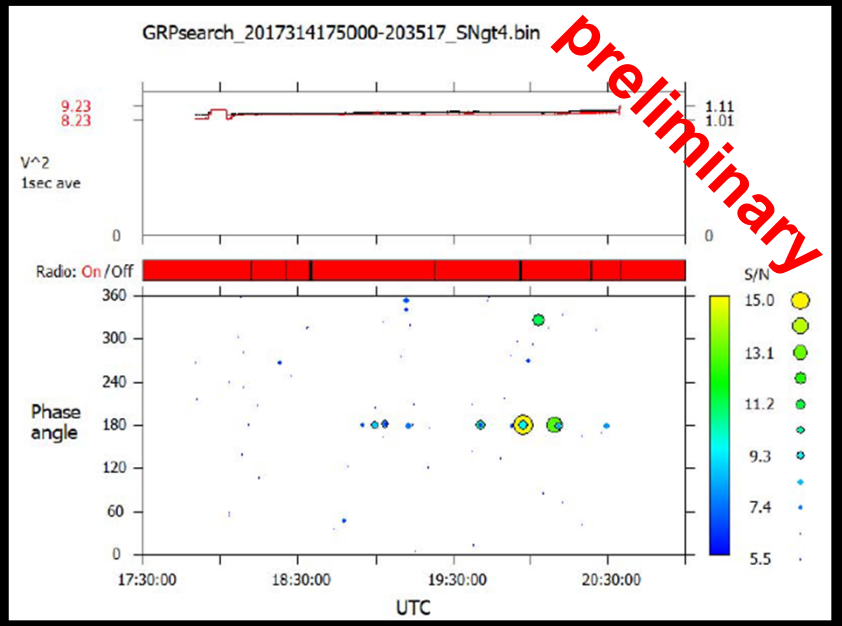
If detected with multiple stations, it should provide an accurate position.

Test obs: Crab GRP with VERA

- Crab GRP(Giant Radio Pulse) detection with VERA at S-band (thanks to Terasawa-san)



An example of GRP
Observed in Nov. 2017



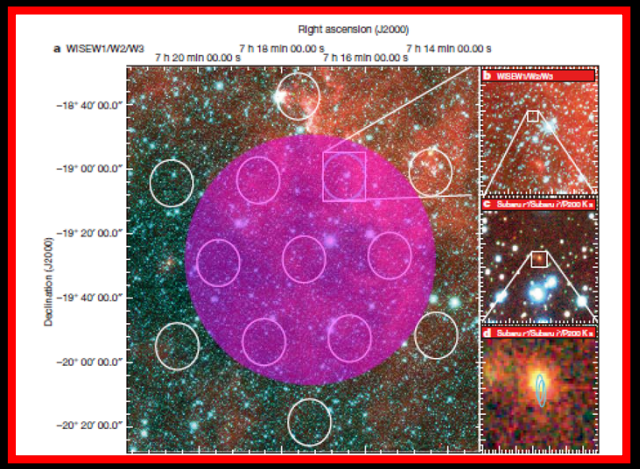
Pulse search for 4 hours

This confirms that both hardware & software work well.

Another proposal – shadowing obs. with Mizusawa 10m dish

- Mizusawa 10m: not much operated nowadays
- We are planning to install L-band RX for Pulsar/FRB studies

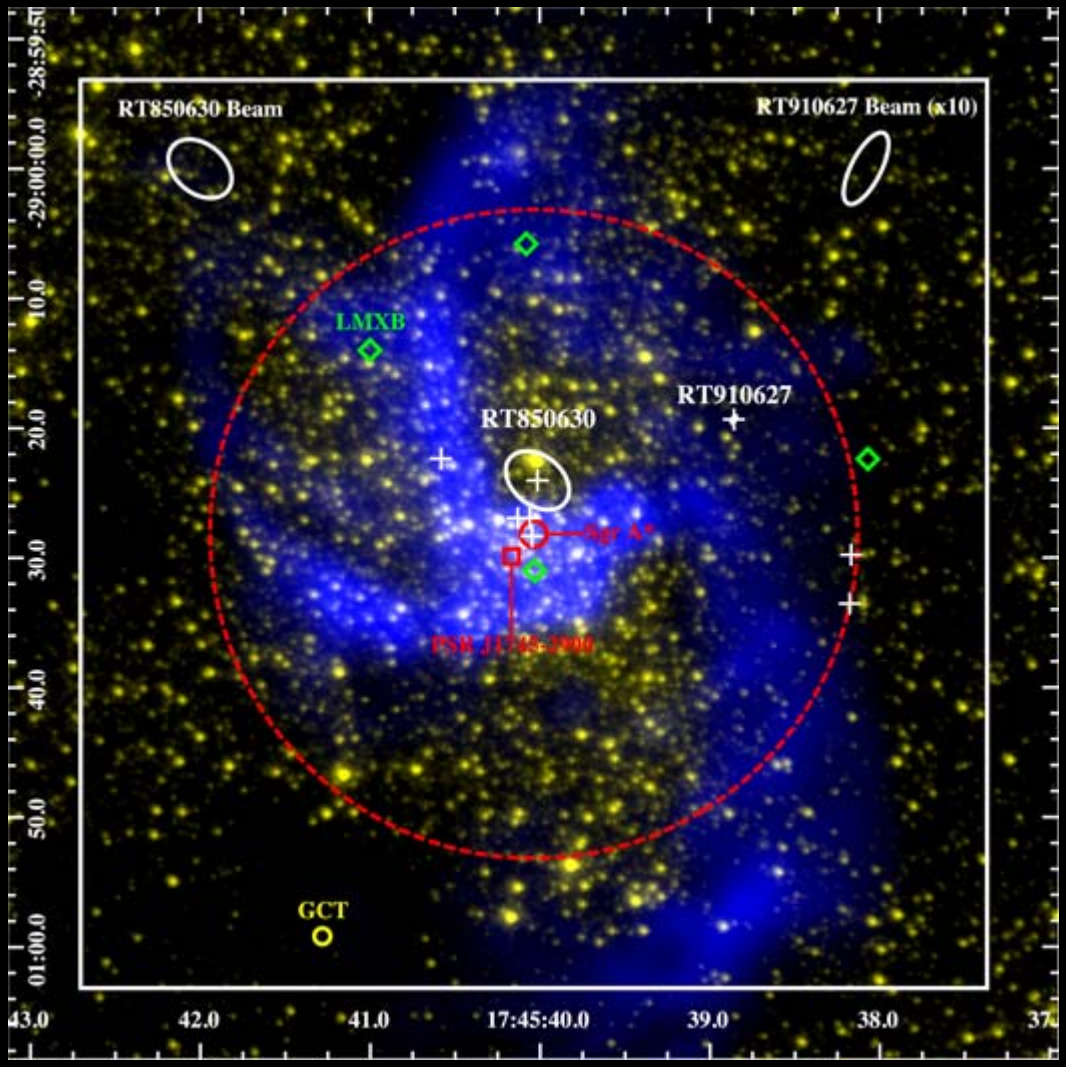
- What about shadowing with a bigger telescope such as Parkes, FAST? Simultaneous detection directly leads to a good localization.



FoV: 1.2 deg @ 1.4G

Magnetars

- Only small number of magnetars are observable in radio
- GC magnetar J1745-2900 discovered in 2013
- Close to Sgr A*

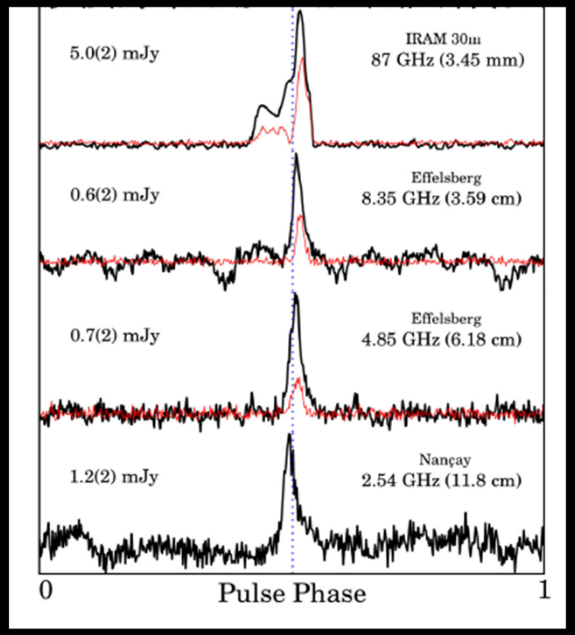


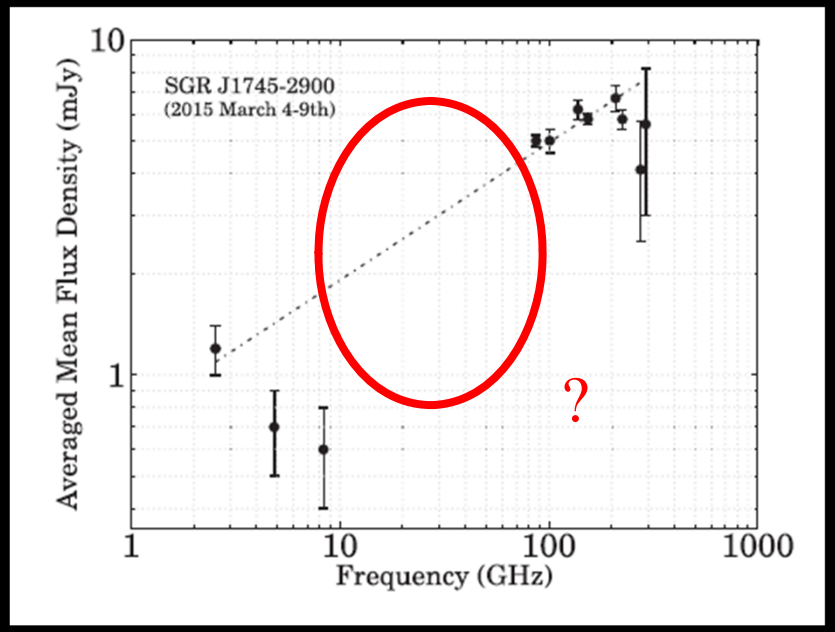
Chiti+2016

The GC magnetar

- GC magnetar has a inverted spectra

Torne+2017





K/Q VLBI observations will be unique to measure spectrum, pulse shapes, motions etc.

GC magnetars with EAVN

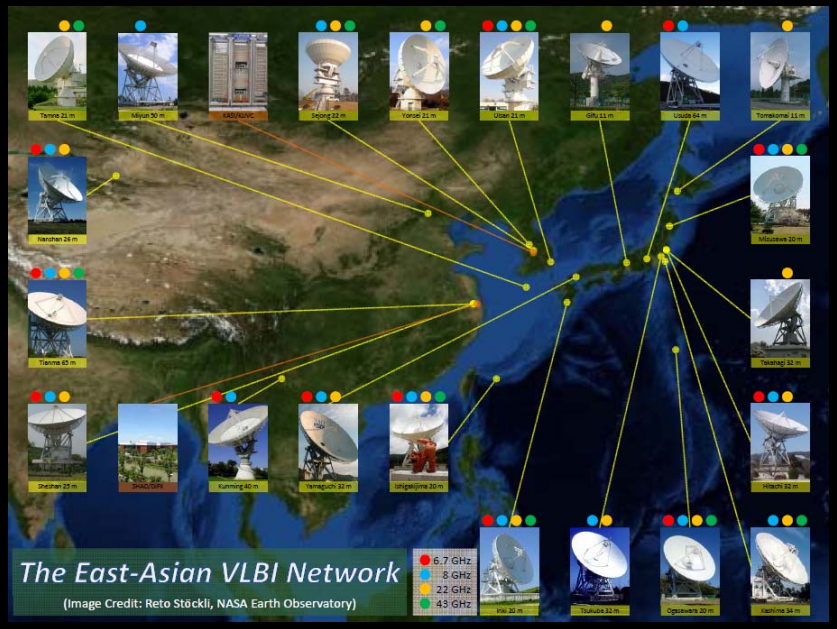
- Already observed in EHT campaign in Apr 2017

  17 epochs with EAVN (13/7 mm)

  5 epochs with EHT (1.3 mm)

- There will be another big campaign in 2018 April.

  Multi-λ observations welcome !



Summary

Several preparatory works on-going

- Targeted/commensal search for FRBs
- Giant Radio Pulse observations
- Multi-λ observations of GC magnetars

Collaborations/suggestions are welcome!