K-band VLBI Observation of Magnetar Radio Outburst

Contents

1. Why Magnetar Astrometry?
2. Observation and Analysis
3. Future Prospect

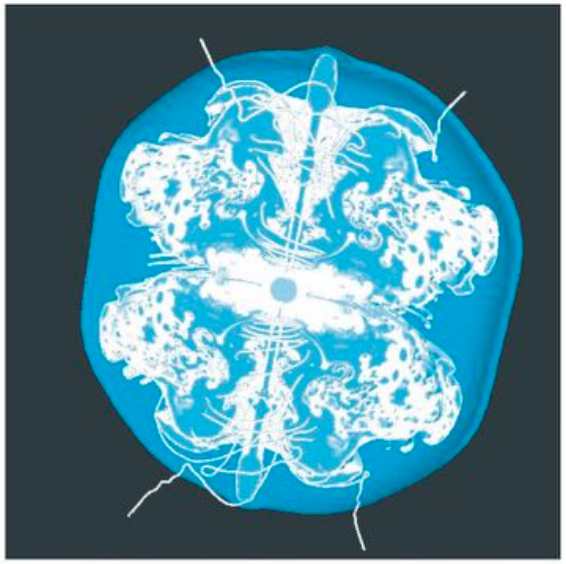
NAOJ SKA1 STUDY GROUP
国立天文台SKA1検討グループ

Takuya Akahori

Group Scientist / Manager

Issues on Magnetar Hypothesis

■The magnetar hypothesis explains AXP and SGR well, but...



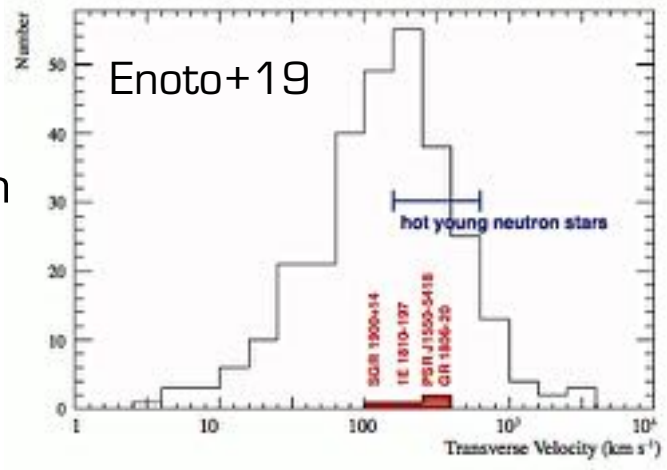
Takiwaki-san's Geppou

1. What is the origin of strong B?

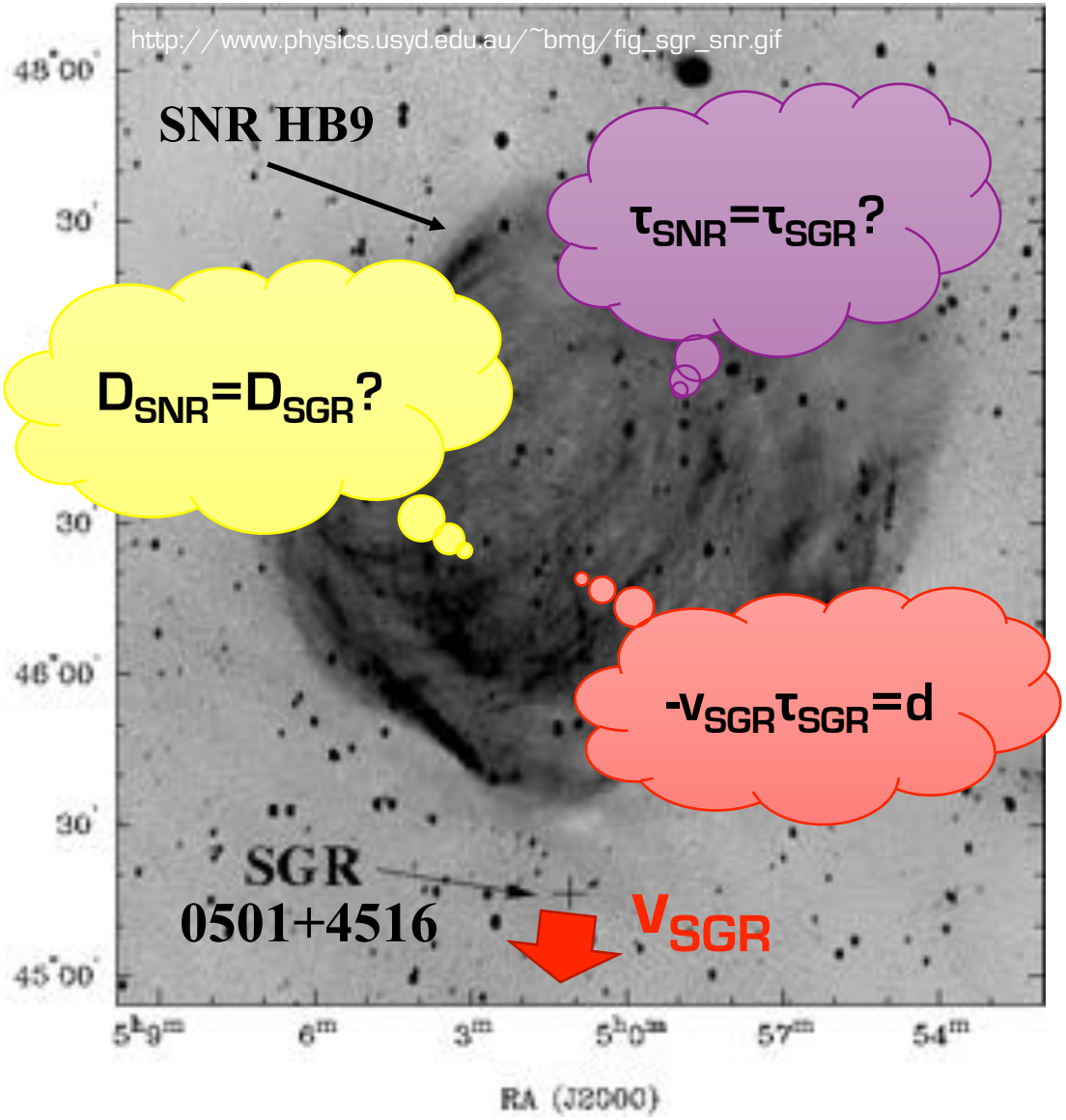
- The standing accretion shock instability (SASI) can induce **dynamo** at a supernova explosion
- Hypothesis: SNR has a **peculiar morphology**?
- Method: Identify the progenitor SNR → Measure the magnetar's location and velocity

2. What is the trigger of outburst?

- Supernovae "kick" neutron stars
- Violent (v = several x 100km/s) interaction with the ISM may induce **Alfvenic waves** and impact onto the magnetosphere
- Hypothesis: Magnetars have **higher velocity**?
- Method: Measure the magnetar's velocity



1. Why Magnetar Astrometry?
Quiz

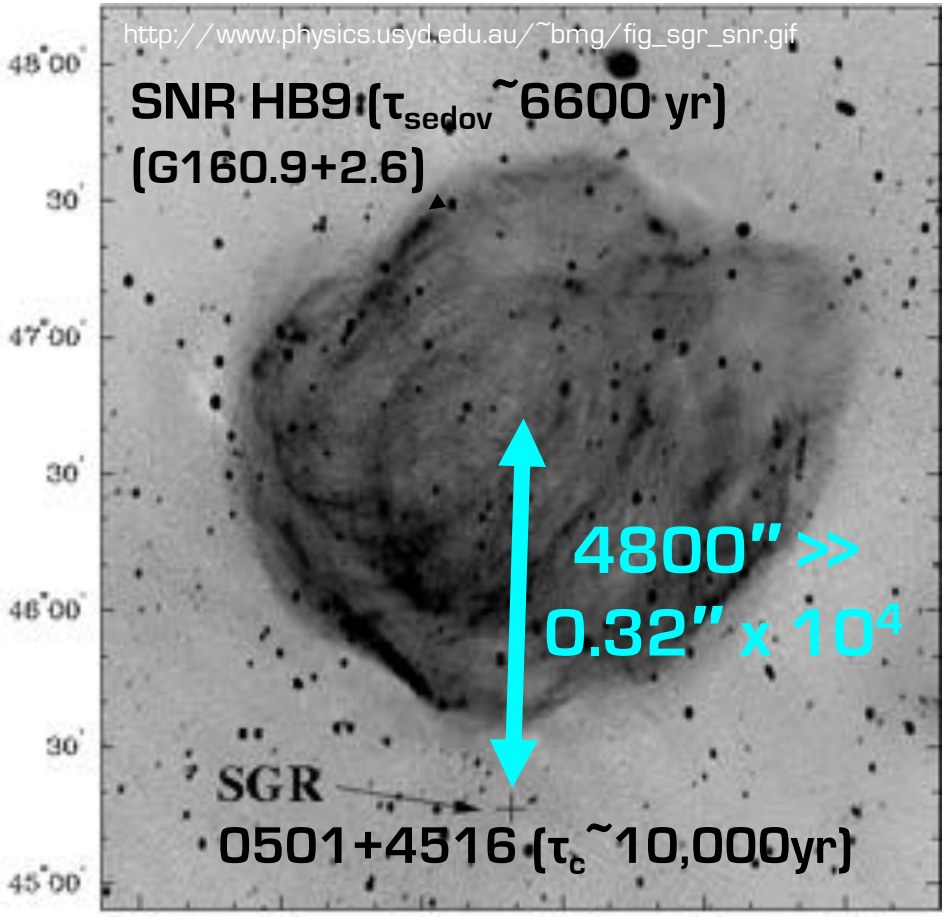


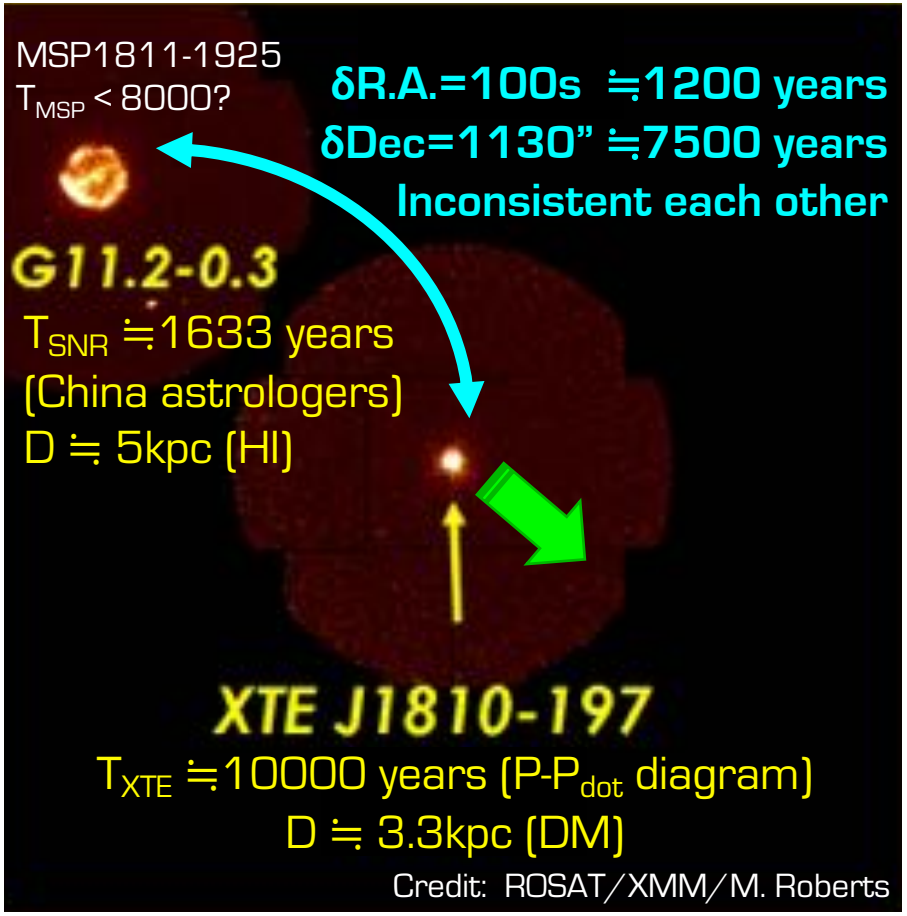
Q: Is HB9 the progenitor of SGR0501?

1. Yes
2. No
3. Uncertain

Which physical parameters are needed to conclude?

Missing Link: Magnetar and SNR



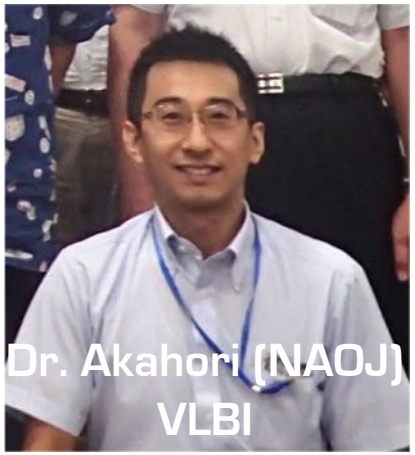


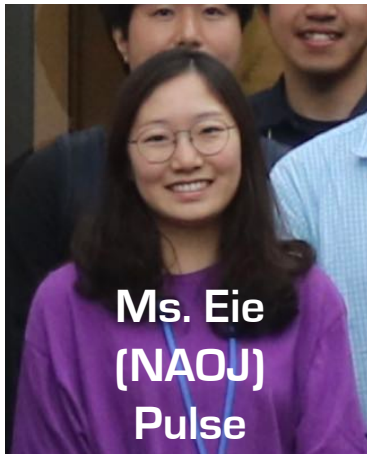
Chandra upper limit of **0.32"/yr** may **reject** this progenitor (Mong & Ng 18, assuming D=5kpc)

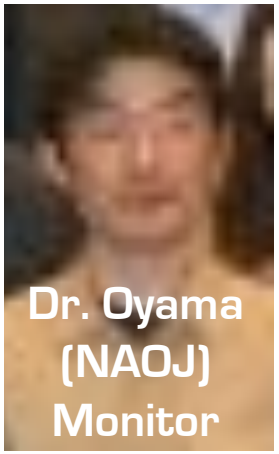
VLBA astrometry of v= **212 km/s** toward **SW** may **reject** this progenitor (Helfand+07)

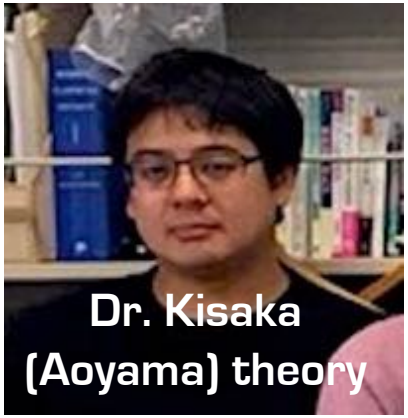
Magnetar Observation Team of VERA

■ **MOT VERA: Developing our VLBI experience of observing neutron stars (and FRBs) toward the SKA**









Prof. Terasawa
(NAOJ) Pulse

Prof. Honma
(NAOJ) Advisor

More Contributors

Prof. Yonekura
(Ibaraki)
Prof. Misawa, Dr.
Tsuchiya [Tohoku]
Dr. Sekido, Dr. Takefuji
(NICT)

Observing Strategy with VERA

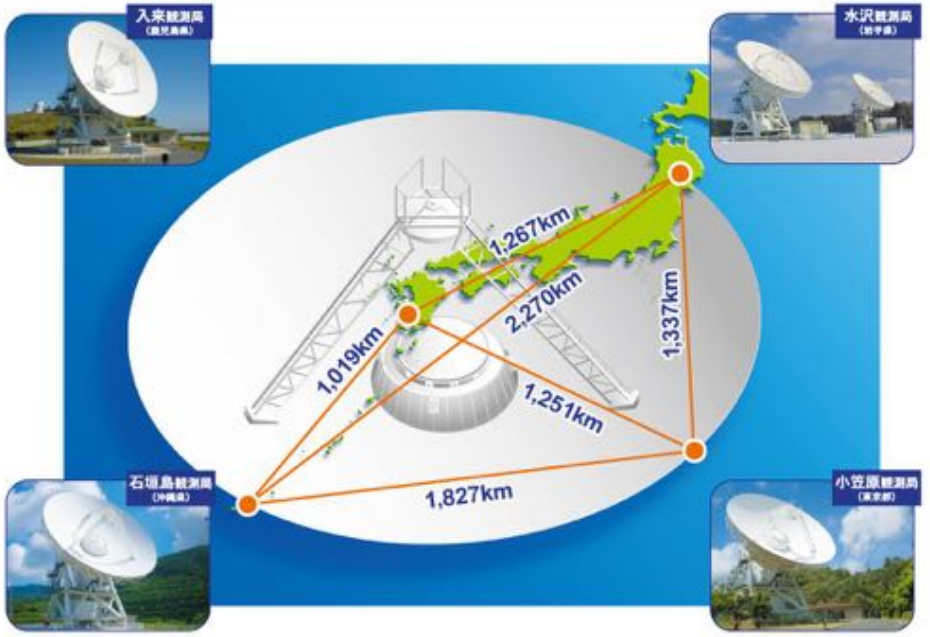
Why VERA 22 GHz?

1. **Resolution = 1.2 mas!**
   - Can capture 1.7 mas/month for 200 km/s @ 2 kpc
2. **Sensitivity = 0.2mJy!**
   - per 8hr per 128MHz (open use)
   - Note: 2048MHz for SWG

Target selection criteria

1. At anti-galactic center to meet low DM & low time pressure.
2. With phase calibrators
   - Ideal: d < 2°, S > 300mJy
   - OK: d < 3°, S > 60mJy

■Exception = outburst (ToO) →



Name	P (sec)	D (kpc)	Flux (mJy)	SNR
SGR0501+452	5.76	1-5?	300?	HB9?
4U 0142+61	8.69	3.6?	???	?
1E 2259+586	6.98	3.2?	???	CTB 109?
XTE1810-197	5.54	3-5?	10?	G11.2 -0.3?

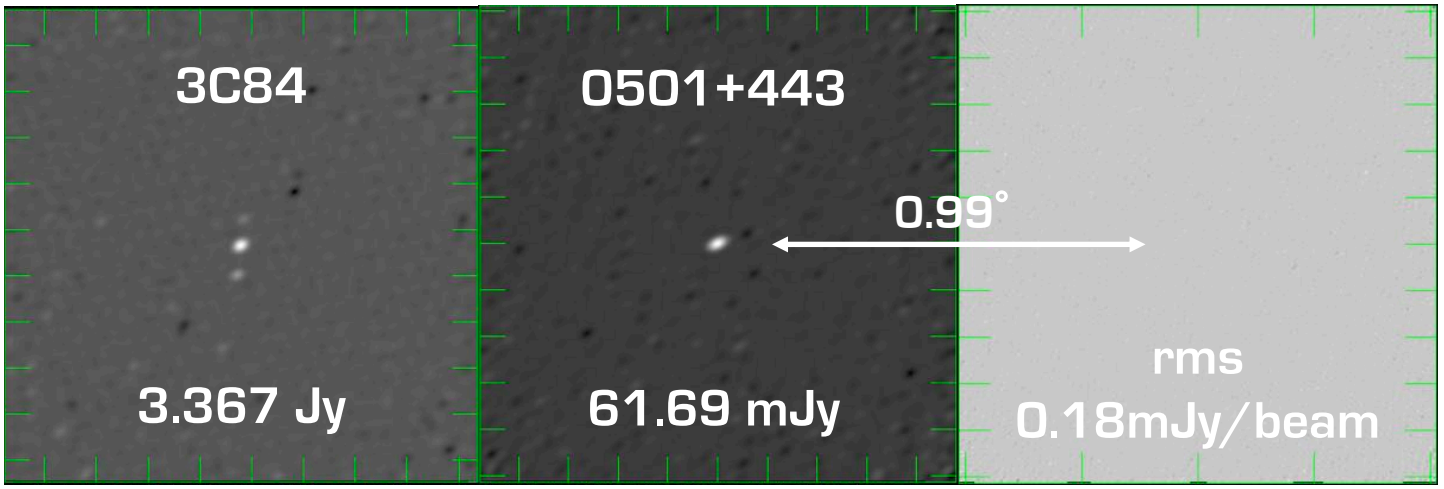
Result of SGR0501 VLBI Imaging

Sta	τ_0	T_{rx}	T_{sys}
MIZ	0.12	83	121
IRK	0.09	93	135
OGA	0.11	86	131
ISG	0.20	97	186

10hr

End	τ_0	T_{rx}	T_{sys}
MIZ	0.14	85	142
IRK	0.08	96	142
OGA	0.10	89	135
ISG	0.18	110	189

R18093A(2018/4/3)

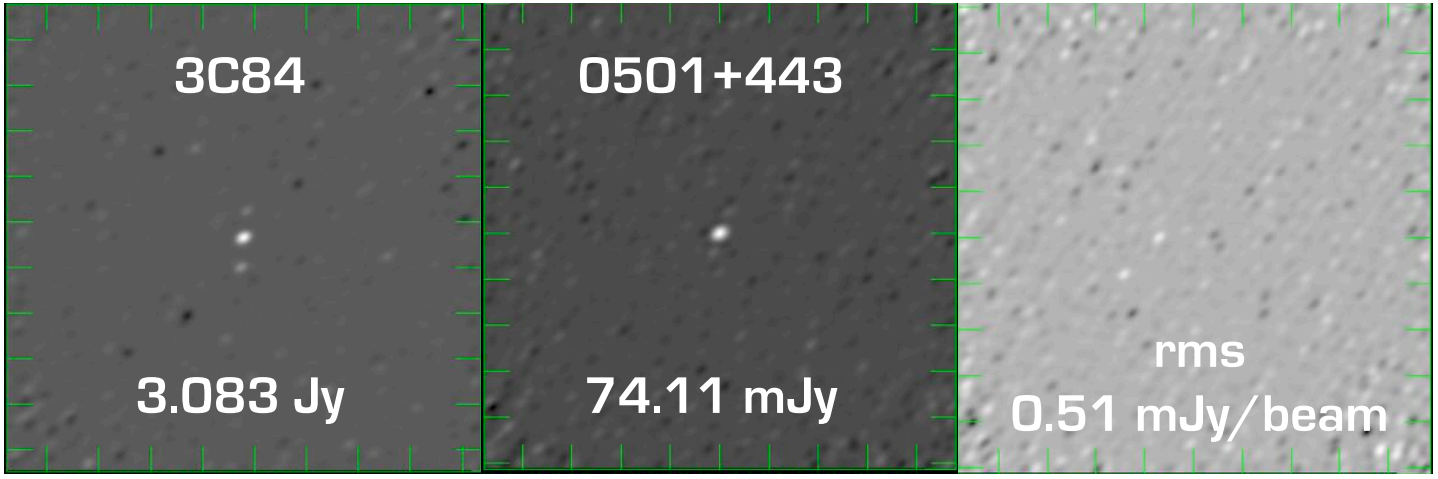


Sta	τ_0	T_{rx}	T_{sys}
MIZ	0.15	71	132
IRK	0.25	119	232
OGA	0.19	117	203
ISG	0.26	176	310

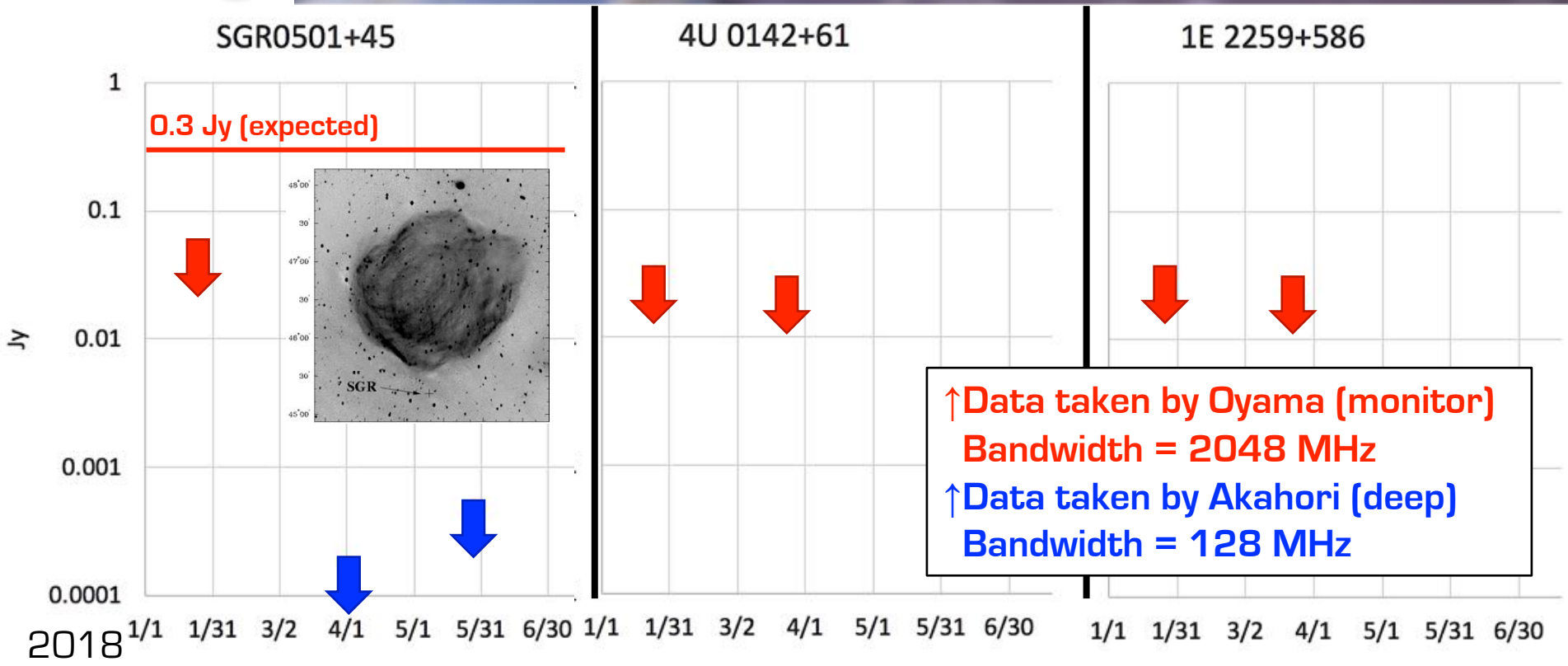
10hr

End	τ_0	T_{rx}	T_{sys}
MIZ	0.17	88	157
IRK	0.21	124	229
OGA	0.29	143	278
ISG	0.23	114	216

R18148B(2018/5/29, 55days)



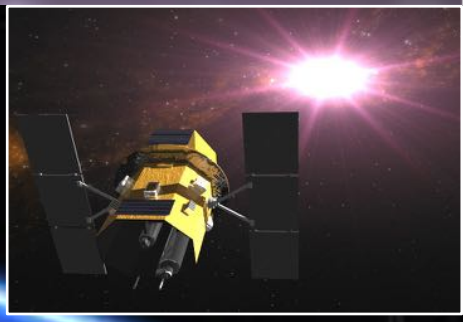
Result of SGR0501 VLBI Imaging



- No radio emission was detected
- An upper limit of 0.2-0.5 mJy → top 20% of known normal radio pulsars are excluded

2. Observation and Analysis

Revival of XTE1810 Radio Outburst



litate 31m (0.3 GHz), Kashima 34-m (2 GHz), Hitachi 32-m (7/8 GHz), four VERA 20m (22 GHz), and NICER and Swift

18.12.18
19.01.07
19.01.21
19.02.15

18.12.14
18.12.18
19.01.07
19.02.15
19.04.23
19.06.12

18.12.18
19.01.07
19.01.21
19.02.15

VERA

18.12.18
19.01.07
19.01.21
19.02.15

18.12.18
19.01.07
19.01.21
19.02.15

18.12.14
19.01.07
19.02.15
19.03.04
19.04.23
19.06.12

18.12.13
18.12.18
19.01.07
19.01.09
19.02.15
19.03.04
19.03.31
19.04.23
19.06.12

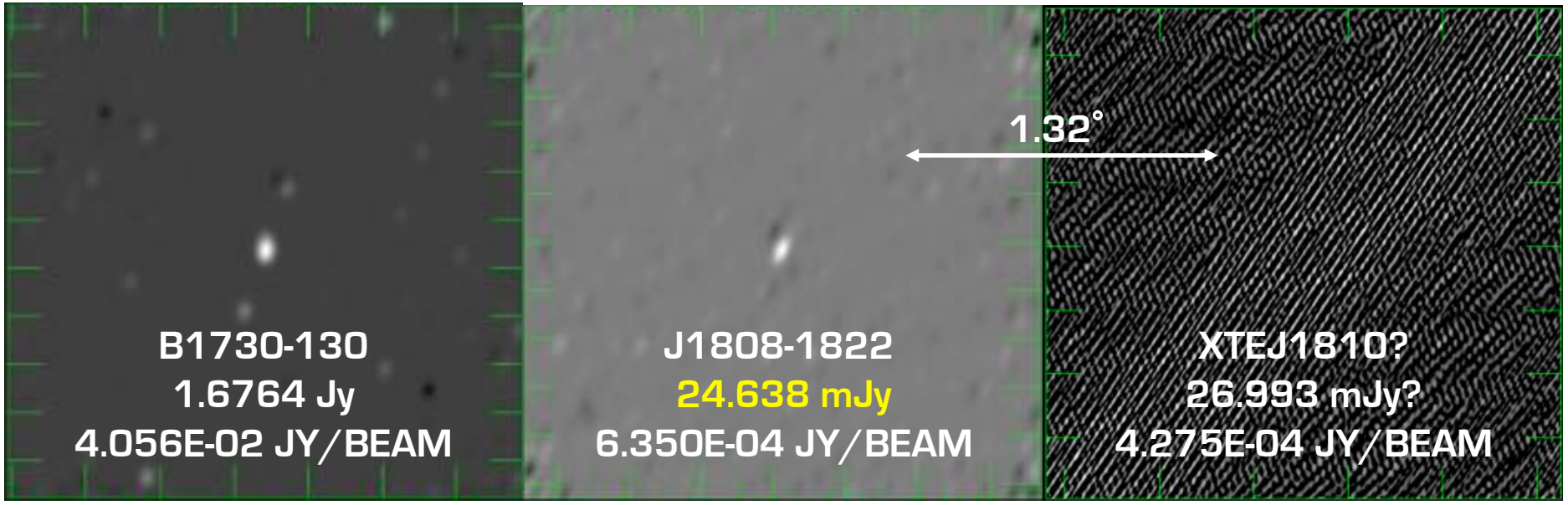
JVN

Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, CEBCO

Google Earth

Result of XTE1810 VLBI Imaging

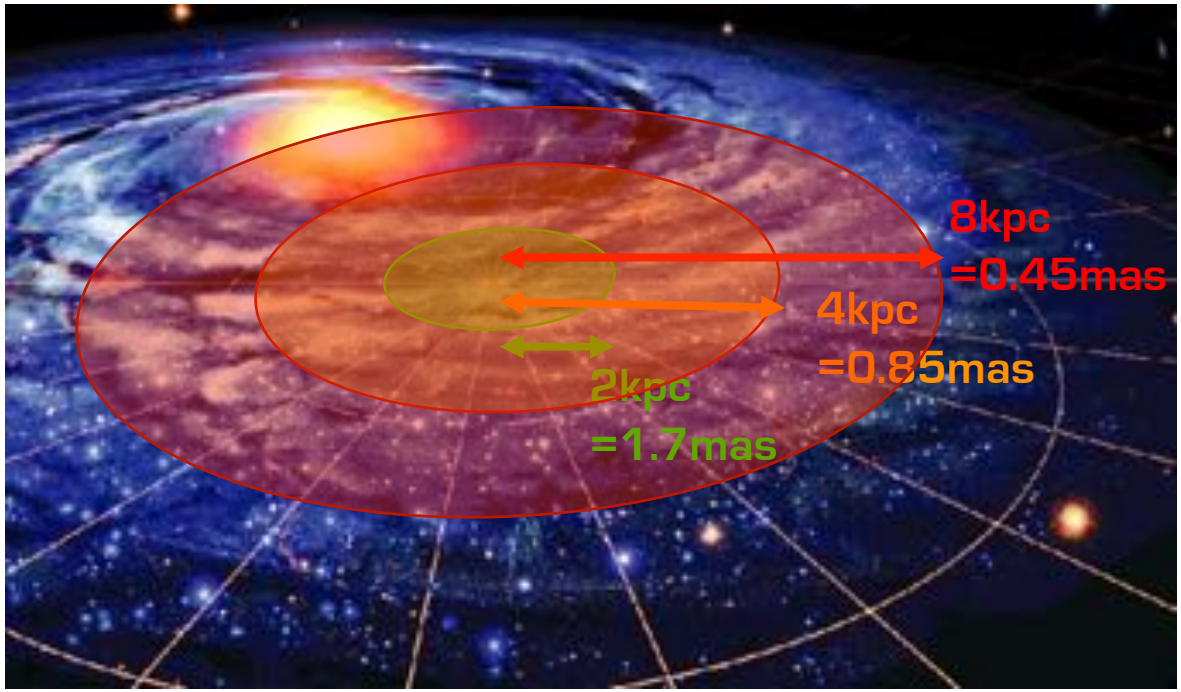
R18352A(2018/12/18)



- No radio emission was detected
- Data taken in January 7 would be more promising

3. Future Prospect

K-band VLBI of Magnetars (ToO)



■**Resolving the proper motion of 200 km/s in a month**

MOT-VERA

Magnetar Observation Team of VERA

Local arm, Perseus arm

VERA 3000 km = 1.2 mas

MUAY-THAI (2023-)

Magnetar Unprecedented Astrometry Yielded by Thailand

MOT-VERA + inter-arm, halo

Super EAVN 6000km = 0.6 mas

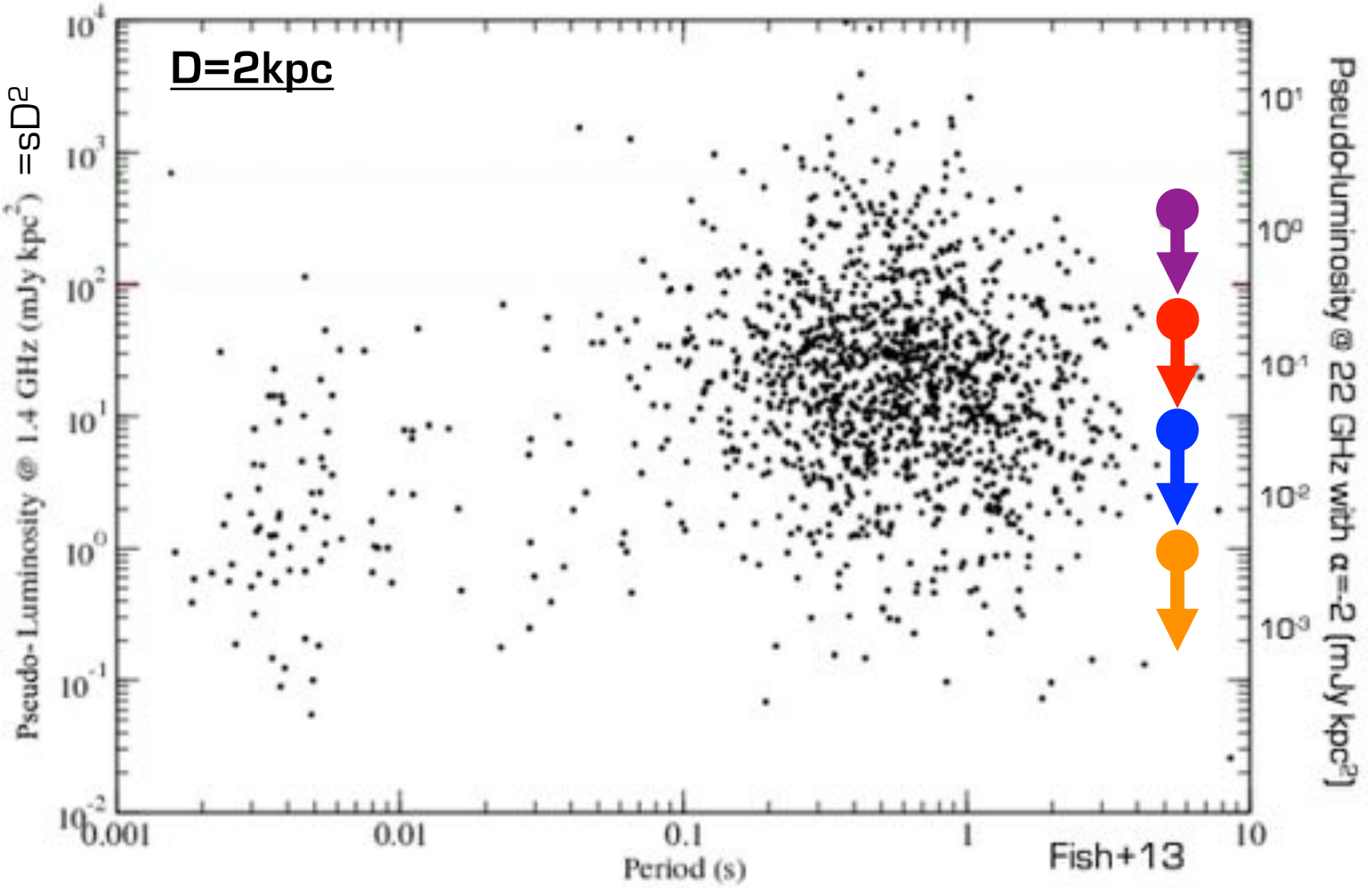
KAIRAKUEN (2030-)

Key Alliance of International Radio Astrometry at K-band for Ultimate Exploration of NSs

MUAY-THAI + arms + galactic center

SKA-VLBI with EAVN 12000 km = 0.3 mas

Neutron stars will be your interests



K-band!

VERA 18A130

VERA 12Gbps

Super-EAVN Case4

SKA VLBI Band 5c

- Persistent radio pulses enable us to perform astrometry
- No detection gives some clues for the emission mechanism

Summary

■Magnetars Radio Outburst

- There is so far no solid identification of progenitor SNRs of magnetars
- The trigger of radio outburst is fully unknown

■MOT VERA Project

- Four magnetars have been observed
- SGR0501: no detection, XTE1810: no, work in progress
- We have established the procedures of magnetar VLBI observation and analysis through our activity in the last 2 years
- We are waiting for magnetar radio bursts

■Future Prospects

- **MOT-VERA → MUAY-THAI → KAIRAKUEN!**
  - ✓ Key Alliance of International Radio Astrometry at K-band for Ultimate Exploration of NSs
- Is the origin of FRB (e.g., 121102) a young magnetar's giant pulse?