JVN observations toward the Galactic center magnetar, PSR J1745-2900

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Introduction

Observed as pulsars with moderately long periods (~ seconds) and fast periodic changes, magnetars are thought of as being young neutron stars with extremely strong magnetic fields[1]. Among the known ~29 magnetars, only four of them have ever identified in the radio band[2], providing additional hints for unsolved mysteries about their origin and emission mechanism. Unlike ordinary pulsars, their radio spectra are flat leading to the relatively stronger radio pulsations at high frequencies. In addition, the radio pulses vary in short and long timescales with regard to the flux density, the shape of pulse profiles, spectral densities and polarization properties, etc.[3] These unique properties enable us to utilize Japanese radio telescopes combined with high frequency receivers for magnetar observations.

Japanese VLBI Network (JVN)

As a collaborative project of institutes and universities in Japan, Japanese VLBI Network (JVN) manages radio antennas for VLBI observations. They are members of East Asia VLBI Network (EAVN), mainly for AGN/ black hole and star formation/ evolution studies[4]. If an antenna cover the region where a pulsar is, the raw VLBI data can be used also for pulsar research.

Figure 1. Japanese VLBI Network
(credit: JVN official website)

Target: PSR J1745-2900 (Galactic center magnetar)

PSR J1745-2900 is one of only four radio-loud magnetars. The proximity to the supermassive black hole in the Sagittarius A* (Sgr A*) system not only gives its another famous name, Galactic center (GC) magnetar, but makes it have an important role in explaining the environmental effects to the formation/evolution of magnetars and in relating magnetars to fast radio bursts.

With the rotational period of 3.76 s and the surface magnetic field of 2×10^{14} G which are comparable to those of other radio-emitting magnetars, PSR J1745-2900 has been observed in the radio and hard X-ray bands [2].

Its radio pulses were detected by Torne et al. (2015, 2017) from 2.54 GHz to 291 GHz, which is recorded as the highest radio frequency detection of pulses from a neutron star so far [5,6]. Their studies imply the need for the mm-wavelengths observations to explain the magnetar's emission in the frequency gap.

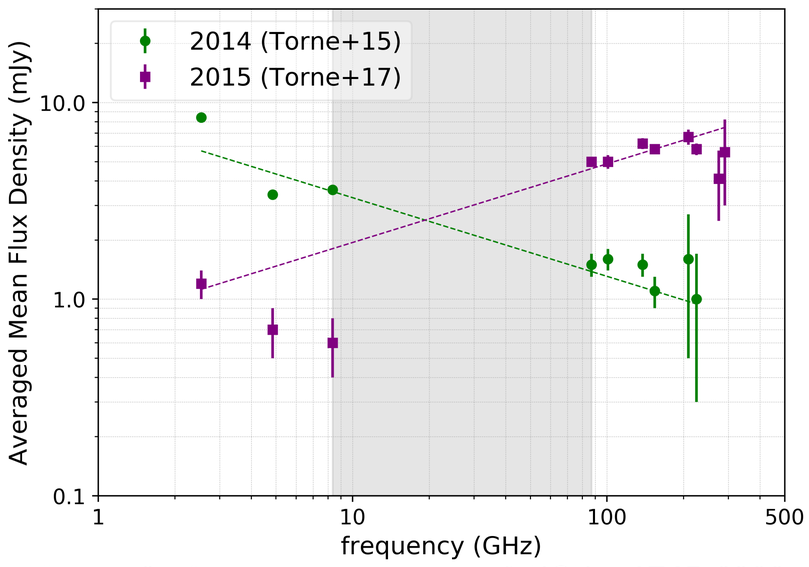


Figure 2. Average spectrum of PSR J1745-2900 (Replotted from data of Torne et al. 2015, 2017). The region between 8.35 and 87 GHz that their observations do not cover is shaded with gray color. The data in this band could give us additional noteworthy information to explain GHz-emission.

Observations

The raw data of Sgr A* were mainly obtained from KaVA (KVN and VERA Array) / EAVN observations led by KaVA and EAVN AGN science working group (PI: K. Hada). They are VLBI observations done in 2017 and 2018. Additionally, 1 hour of single dish data by Ibaraki University's telescope (PI: Y. Yonekura) was obtained in 2018. The data list we are working on is shown in Table 1.

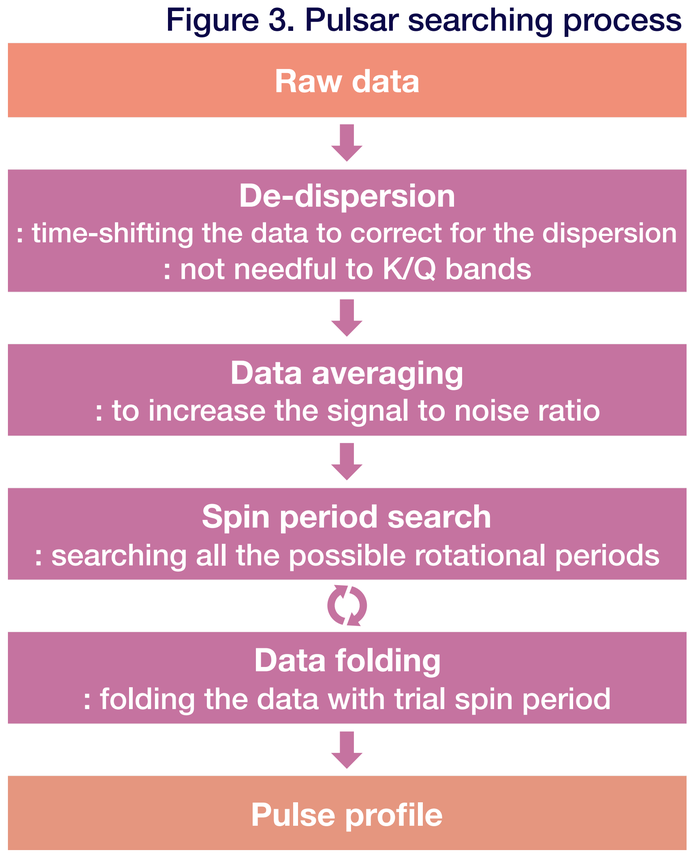
Table 1. Observational data

Obs ID	Facility (diameter)	Band	VLBI?	PI	Exposure time (Sgr A* part)
a17093a	Takahagi (32m)	K	O	K. Hada	3658 s
a17099a	Nobeyama (45m)	Q	O	K. Hada	9360 s
a18110a	Nobeyama (45m) Takahagi (32m) Hitachi (32m)	K	O	K. Hada	7260 s 7800 s 7800 s
a18117a	Nobeyama (45m)	Q	O	K. Hada	in process
a18118a	Takahagi (32m) Hitachi (32m)	K	O	K. Hada	in process
a18128a	Takahagi (32m) Hitachi (32m)	K	O	K. Hada	in process
u18179e	Takahagi (32m)	K	X	Y. Yonekura	3600 s

Pulsar searching procedures and current status

Figure 3 shows the steps for pulsar searching. The data for VLBI observations need an additional step of extracting the Sgr A* parts from the whole raw data. Examining and removing the trends due to the change in the elevation of Galactic center is also necessary. Five of the eleven datasets in the Table 1 are processed to the step of averaging data and have been done for searching the spin period to obtain the pulsed emission of the GC magnetar.

Figure 3. Pulsar searching process



Summary and Next steps

- PSR J1745-2900, the Galactic center magnetar, is one of the radio-emitting magnetars and has shown relatively flat, highly-variable spectra.
- High-frequency radio observations of magnetars can provide the unique information about magnetar formation, radio emission mechanism, etc.
- Previous/future data observed by Japanese radio telescopes toward the Galactic center can be used for studying the GC magnetar.
- Data processing for the detection of radio pulsation with Japanese telescopes is ongoing.

Literature cited

1. Duncan & Thompson, 1992, ApJ, 392, L9
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3. Lynch et al. 2015, ApJ, 806, 266
4. An et al. 2018, NatAs, 2, 118A
5. Torne et al. 2015, MNRAS 451, L50
6. Torne et al. 2017, MNRAS, 465, 242

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