Observations of radio-emitting magnetars: current status and possible application of high-frequency VLBI

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Introduction

After 50 years from the first serendipitous discovery of pulsars, there have been unexpected applications and exciting discoveries about pulsars. Among magnetars, one of the small family within the pulsar population, 4 sources are found as radio-emitting magnetars. The flat spectra of the magnetars make themselves be observed at high-frequencies, providing lots of information about their emission properties.

Pulsars

Pulsars are fast rotating neutron stars which show strong magnetic field. After proposed their existence by Baade & Zwicky (1934) and discovered by Bell & Hewish on 1967, pulsars are still one of the hot topics in astronomy.

The basic theoretical model of pulsar is the neutron star that has magnetic axis misaligned with rotating axis, which means that strong pulses can be observed when the magnetic axis faces the line of sight to the Earth.

Because the beam radiated by charged particles is very strong to be observed in broad band from radio to X-ray and γ-ray.

There are several types including not only normal pulsars consistent with basic pulsar model but also giant radio bursts (GRBs), magnetars, etc.

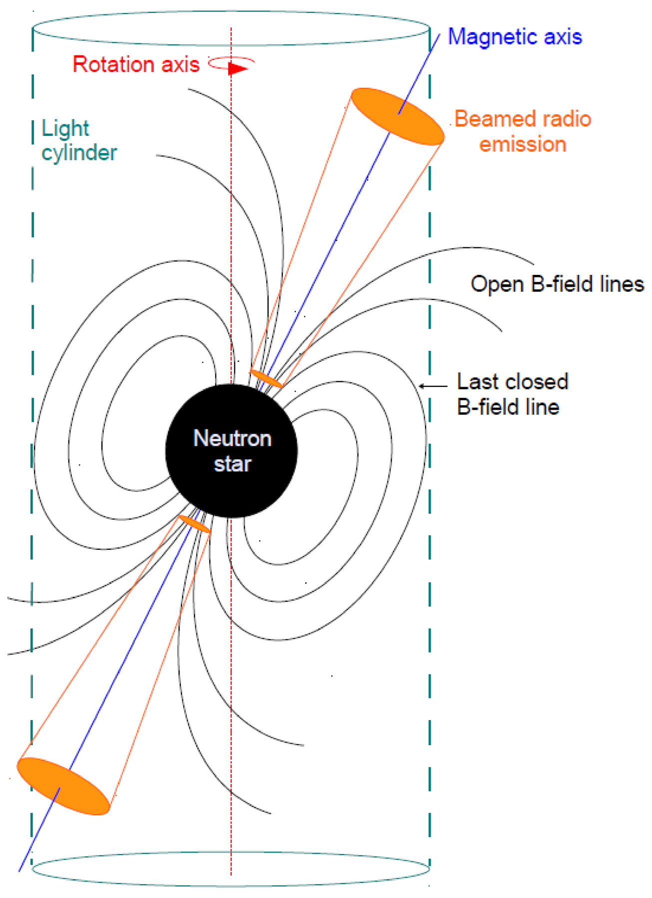

Figure 1. Basic model of pulsar

Possibilities of VERA and KaVA

The spectra of radio-emitting magnetars are flat compared to ordinary pulsars, which enables them to be observable in high radio frequencies. And to reduce the effect of the scatter broadening, high-frequency observations are important to detect fast-spinning pulsars.[6]

But still high sensitivity is needed for high-frequencies because the fluxes are much lower than at low-frequencies, therefore VLBI with wide collecting area and bandwidth can be a necessity.

Observation in GHz band using VERA and KaVA can play a big role in understanding their emission mechanism in radio band.

In addition, measuring proper motions of pulsars precisely, with high angular resolution, i.e. using VLBI, can elucidate their birth sites in massive stellar clusters[7].

Magnetars

Magnetars are young and highly magnetized neutron stars which get energy for emission from the decay of enormous internal magnetic fields.

Until now, only ~29 sources are known as magnetars, but they account for at least 10% of the young neutron star population[1].

The relevance of magnetars to gamma-ray bursts (GRBs), fast radio bursts (FRBs), super-luminous supernovae or gravitational waves is still under debate.

Table 1. Known radio-emitting magnetars[1]

Name	Period (s)	B field (10^{14} G)	Age (kyr)	Distance (kpc)	Observable band
XTE J1810-197	5.54	2.1	11	3.5	OIR / radio
1E 1547.0-5408	2.07	3.0	0.69	4.5	radio / hard X-ray
PSR J1622-4950	4.33	2.7	4.0	~ 9	radio
SGR J1745-2900	3.76	2.3	4.3	8.3	radio / hard X-ray

Radio-emitting magnetars

XTE J1810-197 [PSR J1809-1943]

As the first radio-detected magnetar (Halpern et al. 2005, Camilo et al. 2006), XTE J1810-197 was detected up to 144 GHz[2]. It was caught in an outburst in 2003 and observed to the decay on the timescale of a year.

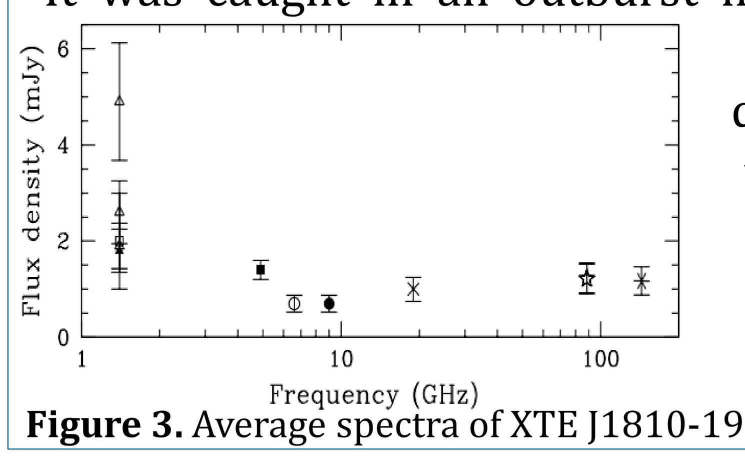

Figure 3. Average spectra of XTE J1810-197[2]

1E 1547.0-5408 [PSR J1550-5418]

1E 1547.0-5408 is the second magnetar discovered in radio-band (Camilo et al. 2007) and it is suggested as a candidates for pulsars with gigahertz-peak spectra (GPS)[3].

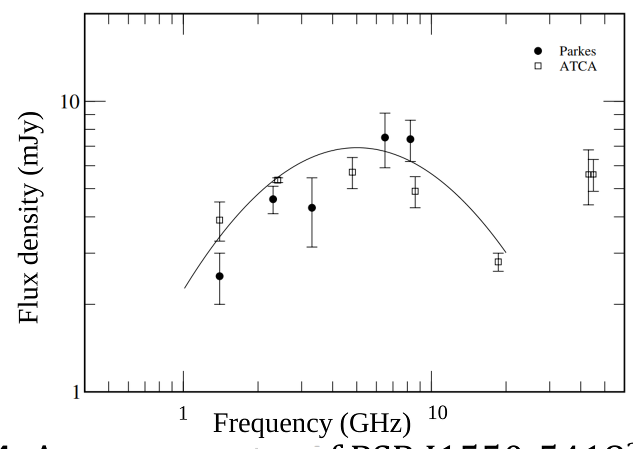

Figure 4. Average spectra of PSR J1550-5418[3]

SGR J1745-2900

After discovered in 2013, SGR J1745-2900 is one of the noticeable pulsar because of its closeness to the galactic center. With offset of ~3 arcsec from Sgr A*, it orbits a black hole in the system.

Torne et al. (2015, 2017) observed this source twice in 2014 and 2015 up to 291 GHz[4,5]. It wasn't detected at 296-472 GHz in 2014. In 2015, the spectral index was slightly inverted to $\langle\alpha\rangle = +0.4 \pm 0.2$ from $\langle\alpha\rangle = -0.4 \pm 0.2$ in 2014. But for same source, Pennucci et al. (2015) reported steeper spectral index (-1.4) between 2 to 9 GHz. It can be inferred that the radio spectra of magnetars may not be well described by a single spectral index though they are approximately flat overall. In regarding to Torn et al. (2017)'s data, observations between 8.35 and 87 GHz are needed to verify whether there is a turn-up in the emission.

Bower et al. (2015) suggests the galactic center pulsars will originate from the stellar disk and deepen the mystery regarding the small number of detected Galactic center pulsars.

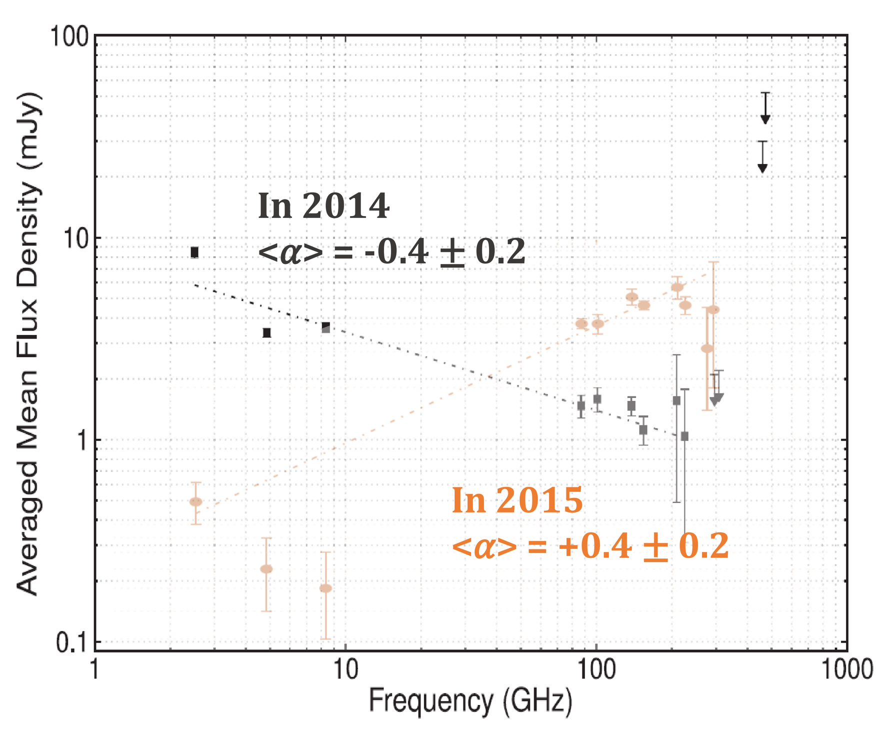

Figure 6. Average spectra of SGR J1745-2900[4,5]

PSR J1622-4950

With 1E 1547.0-5408, PSR J1622-4950 shows characteristic features of GPS. It was detected at 3 and 1.4 GHz until 2014 but has not detected from 2015 to 2016 (Scholz et al. 2017).

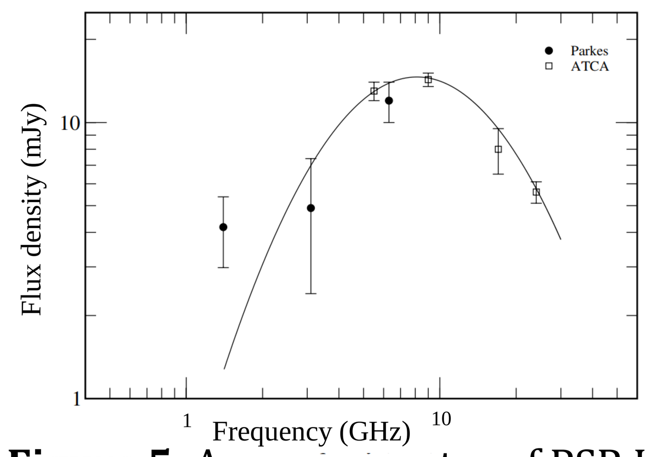

Figure 5. Average spectra of PSR J1622-4950[3]

Summary and future work

- Radio-emitting magnetars are spectrally flat, which means they can be observed above a few GHz.
- High-frequency radio observations of magnetars can let us to understand (and if combined with previous observational data at low-frequencies) magnetar formation, radio emission mechanism of magnetars, etc.
- Observing and processing data of other types of pulsars with VERA and KaVA can be applied to observation of magnetars.

Literature cited

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