Using QTT to Observe Magnetars' Supernova Remanants

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Outline of presentation

- *Introduction of Supernova Remnants (SNRs).*
- *Magnetars and their SNRs.*
- *Our recent work on magnetars and their SNRs.*
- *Observation results of 79 SNRs with Urumqi 25m telescope .*
- *Using QTT to observe magnetars' SNRs.*
- *Conclusions.*

Introduction of Supernova Remnants (SNRs)

◆When a star explodes in a supernova explosion, the gaseous remainders will form a rapidly expanding and slowly fading cloud, mixing with the interstellar matter These nebulae are called supernova remnants (SNRs).

◆Depending on the type of the supernova, there may also be a central compact remnant in the form of a neutron star.

Supernovae Events

- So far more than 272 Galactic supernova remnants (SNRs) have been identified in the radio range. Supernovae (SN) release an enormous amount of energy into interstellar medium.

- Supernovae (SN) are classified by their optical spectra: type-I with Balmer lines and type-II without Balmer lines.

- A core collapse needs a more massive star (I-b/c, II-P) than SN from thermo-nuclear burning star (I-a,II-L).

- Core collapse events leave a neutron star, while thermo-nuclear burning events do probably not leave a stellar remnant (W. Reich 2002).

Importance of radio observations of SNRs

- Radio observations of SNRs can probe the process of particle acceleration and synchrotron radiation.

  (Note, to reveal this process, multiband observations are needed to make images of the spectral index distribution.)

- Radio observations of SNRs can probe the magnetic field structure of SNRs.

  (Specifically, Faraday rotation can be used to get the intrinsic polarization angle of radio emission, so that the intrinsic magnetic field structure of SNRs can be revealed.)

Magnetars and their SNRs

Magnetars have surface magnetic field $(B \sim 10^{14-15}\mathrm{G})$, about two order of magnitude higher than those of most normal pulsars,and as young as young radio pulsars (1-100 kyr).

- Anomalous X-ray pulsars (AXPs) and soft gamma-ray repeaters (SGRs).
- So far, only 26 magnetar candidates (20 confirmed) are detected,
- Seeing from McGill SGR/AXP Online Catalog, 11 magnetars candidates have their associated SNRs .
- Most of 15 magnetars show various degree of associations with Large Magellanic Cloud(LMC), Small Magellanic Cloud(SMC), and Pulsar Wind Nebulae (PWNe) and so on.

Magnetars and their SNRs

Table 1 Observed parameters of magnetars and their SNRs. .

Sources	P (s)	$\dot{P}$ (10^{-11}s s^{-1})	B_{sur} (10^{14} G)	τ_C (kyr)	SNR	t_{SNR} (kyr)	Ref.‡
SGR 0526-66	8.0544(2)	3.8(1)	5.6	3.4	N49	10 ± 5	[1, 2]
SGR 1806-20	7.6022(7)	75(4)	24	0.16	G10.0–0.3	17 ± 13	[3, 4]
SGR 1627-41ł	2.594578(6)	1.9(4)	2.2	2.20	G33.70–0.1	16.3 ± 13.7	[5, 6]
SGR 1900+14	5.19987(7)	9.2(4)	7.0	0.90	G42.8+0.6	19.8 ± 10.2	[7, 8]
Swift J1834	2.4823018(1)	0.796(12)	1.4	4.9	W41	150 ± 50	[7, 8]
SGR 0501+4516	5.7620953(3)	0.582(3)	1.9	16	HB9(G160.2+2.6)	15 ± 5	[9, 10]
1E 2259+586	6.9789484460(39)	0.048430(8)	0.59	230	CTB109	12 ± 3	[9, 10]
1E 1841–045	11.7828977(10)	3.93(1)	6.9	4.8	Kes73	1.5 ± 1.0	[11, 12]
1E 1547ł	2.0721255(1)	4.7	3.2	0.70	G327.24–0.13	3.2 ± 1.8	[13, 14]
CXOU J1714†	3.82535(5)	6.40(14)	5.0	0.95	CTB37B	3.2 ± 1.7	[15-17]
AX J1845†	6.97127(28)	–	–	–	G29.6+0.1	15.3 ± 14.7	[18, 19]

Note: All data are from the McGill AXP/SGR online catalog of 1 January 2013 (http://www.physics.mcgill.ca/ pulsar/magnetar/main.html). The surface dipole magnetic field $B_{dip} = 3.2\times10^{32}\sqrt{P\dot{P}}$ G, and canonical spin-down age $\tau_C = P/2\dot{P}$, here P and $\dot{P}$ are the pulsar period and period derivative, respectively.The sign 'ł' denotes:A transient AXP. The sign '†' denotes:This candidate is unconfirmed. The sign '‡' denotes: cited from [1]: Kulkarni 2003; [2]: Klose 2004; [3]: Kulkarni 1993; [4]: Marsden 2001; [5]: Corbel 1999; [6]: Wachter 2004; [7]:Hurley 1999; [8]:Mazets 1999; [9]: Green 1989; [10]: Rho 1997; [11]: Sanbonmatsu 1992; [12]:Vasisht 1997; [13]: Camilo 2007; [14]: Gelfand 2007; [15]: Aharonian 2008; [16]: Halpern 2010; [17]: Horvath 2011; [18]: Gaensler 1999; [19]: Vasisht 2000.

Our recent work on magnetars and their SNRs.

- We have studied the relation between the characteristic ages and the ages of SNRs, and explained why some magnetars become older (or younger) than they appear to be.

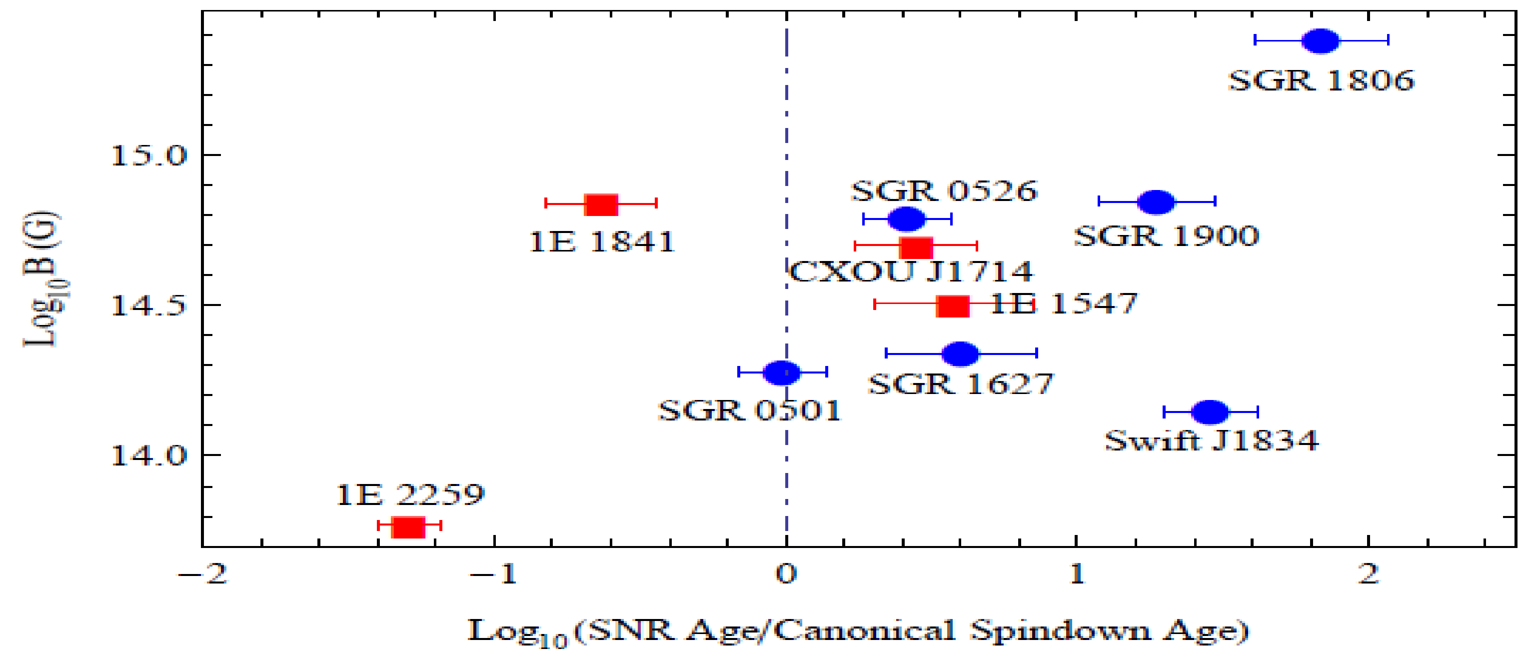


Fig. 1 Log_{10}(SNR(Age)/Canonical Spindown(Age)) vs. $\mathrm{Log}_{10}B$. The dot-dashed line corresponds to $t_{\mathrm{SNR}} = t_{\mathrm{Spin}}$. Circles and squares are for SGRs and AXPs, respectively.

(From Z.F. Gao , Q.H.Peng, N.Wang et~al *Astrophys. Space Sci*. **342**, 55, 2012)

Our recent work on magnetars and their SNRs.

- Based on the assumption that the real ages of magnetars are the ages of their associated SNRs, we compute d the values of magnetar average braking indexes for 10 candidates with SNRs. We also discuss the quantum electrodynamic (QED) effects on EOSs of magnetars.

Table 2 Braking indexes and frequency parameters of magentars' associated SNRs. .

Sources	ν(Hz)	$\dot{\nu}$(s^{-2})	$\ddot{\nu}$ (s^{-3})	$\tilde{n}$
SGR 0526–66	0.124155(1)	-5.85(15)$\times 10^{-13}$	$(5.259 \pm 1.301) \times 10^{-24}$	1.908 ± 0.472
SGR 1806–20	0.131533(3)	-1.30(7)$\times 10^{-11}$	$(1.3459 \pm 1.2735) \times 10^{-21}$	1.048 ± 0.038
SGR 1627–41	0.385419(1)	-3.32(9)$\times 10^{-12}$	$(5.3207 \pm 2.0633) \times 10^{-23}$	1.861 ± 0.722
SGR 1900+14	0.192312(3)	-3.40(15)$\times 10^{-12}$	$(6.7684 \pm 0.4147) \times 10^{-24}$	1.126 ± 0.069
Swift J1834.9–0846	0.40285190(1)	-1.29(2)$\times 10^{-12}$	$(7.2310 \pm 1.0678) \times 10^{-24}$	1.751 ± 0.258
SGR 0501+4516[a]	0.173547980(9)	-1.753(9)$\times 10^{-13}$	$(5.9321 \pm 1.4027) \times 10^{-25}$	3.354 ± 0.785
1E 1547.0–5408	0.482596252(23)	-1.0946259(1)$\times 10^{-11}$	$(4.0695 \pm 0.8926) \times 10^{-25}$	1.639 ± 0.359
1E 2259+586	0.14328729765(1)	-9.9433(2)$\times 10^{-15}$	$(2.6962 \pm 0.526) \times 10^{-26}$	39.082 ± 7.618
1E 1841–045	0.08486867(7)	-2.830(7)$\times 10^{-13}$	$(1.6373 \pm 0.8728) \times 10^{-23}$	17.351 ± 9.249
CXOU J171405.7–381031	0.2614140(34)	-4.37(9)$\times 10^{-12}$	$(1.4172 \pm 0.8728) \times 10^{-22}$	1.94 ± 0.35

(From Z.F. Gao , N.Wang , Q.H.Peng, et~al, Moden Phys. Letter. A. 2013, Accepeted)

Unfortunate and fortunate

Unfortunate:

- Up to now, only 4 magnetars have radio emission:XTE J 1810-197, PSR J 1622-4950 (SNR ---G333.9+0.0), 1E 1547.0-5408 (SNR---G327.24-0.13) and SGR J 1745-2900 (Galactic Center. Sgr A).
- we cannot measure magnetars' braking indexes observationally due to strong timing noise and the lack of long-term radio emission.

Fortunate:

- In future, FAST of Guizhou, China and QTT of Xinjiang,China will make radio observations of magnetars and their SNRs available.

Observation results of 79 SNRs with Urumqi 25m telescope

Urumqi 25 m telescope

- Since August. 2004, Urumqi 25 m radio telescope has been used for the Sino-German 6 cm polarization survey of the Galactic plane in the region of $10^0 \le l \le 230^0$ and $|b| \le 5^o$ (X.H. Sun et al. 2007,X.Y.Gao et al. 2010, X.H.Sun et al. 2010)

- By using the single band polarization system of the Urumqi 25 m radio telescope, many large SNRs are scanned at 6 cm wavelength.

Polarization Observations of Large SNRs

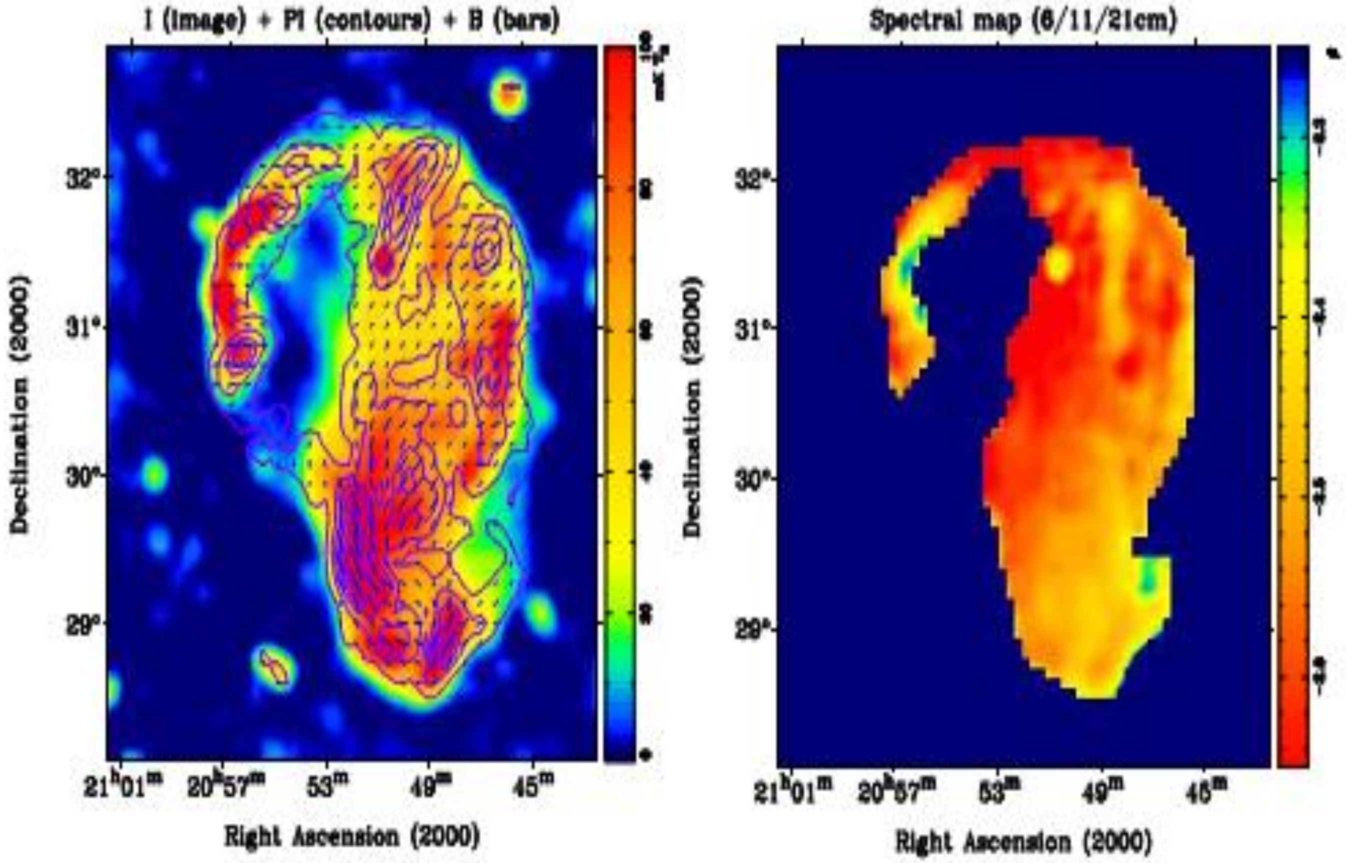
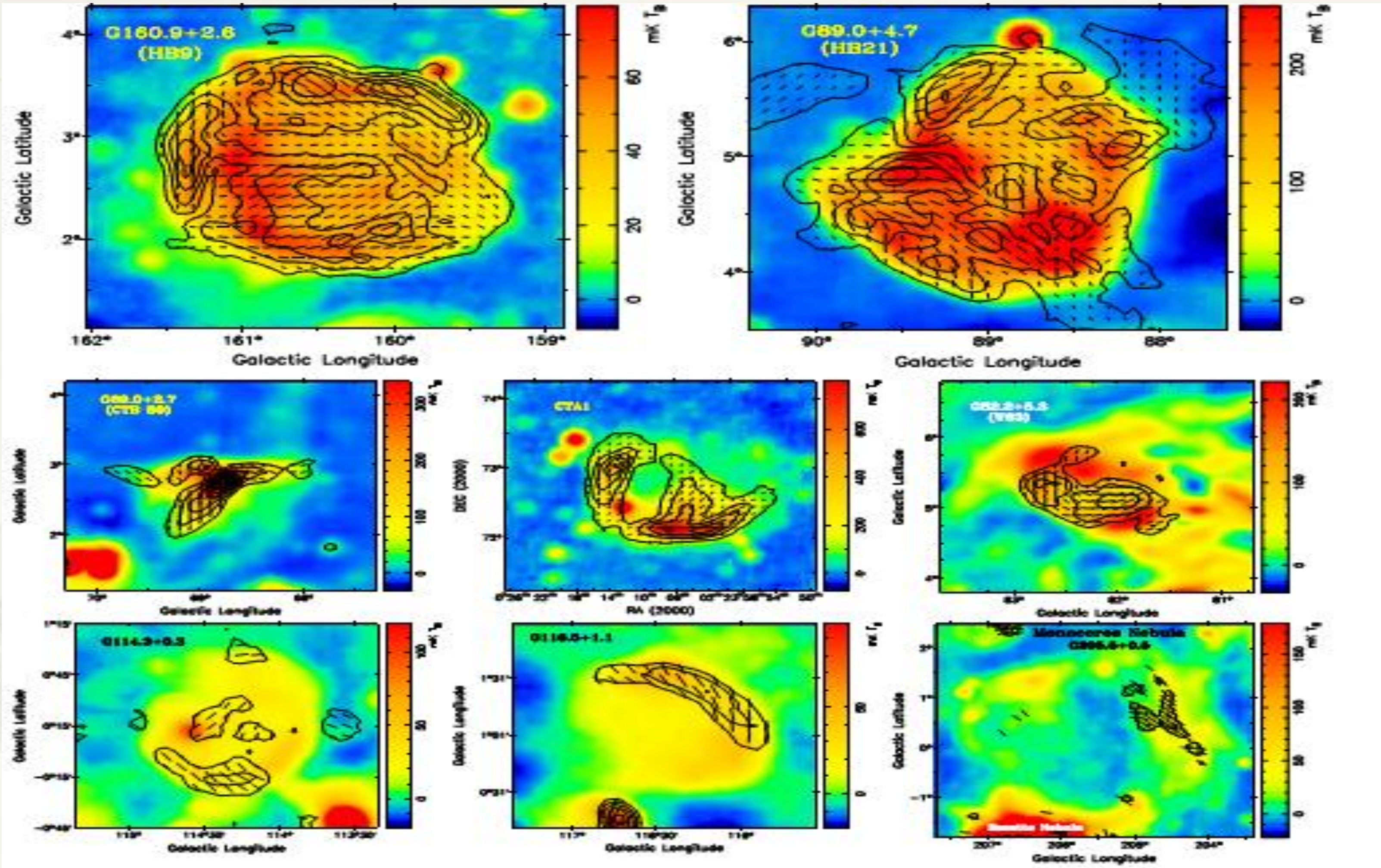


Figure 1. The first polarization map *(left)* was made for the Cygnus loop using the λ6 cm system. Combining our map with λ11 cm and λ21 cm maps from Effelsberg observations, we calculated a spectral index map *(right)*.

(**From IAUS 296,2013, J.L.Han et al .2013,arXiv:1304.1949v2[astro-ph.GA]**)

New Polarization Maps of Some SNRs



(Note: Color image for total intensity, contours for the polarization intensity and vectors for **B** orientation, cited from arXiv:1304.1949v2[astro-ph.GA])

Main Observational Results

- The first polarization image of 6 cm system:Cygnus loop,
- New flux density measurements for integrated spectra,
- Spectral index maps of large SNRs,
- New polarization maps,
- Rotation measures in SNRs,
- Discovery of two large SNRs:G178.2-4.2 and G25.1-2.3,
- Disapproved "SNRs": OA184, G192.8-1.1,G16.8-1.1 and Half of the Origem loop.

***However, magnetars' SNRs have not been observed in this Sino-German cooperation*.**

Effelsberg 100 m radio telescope

Using QTT to Observe Magnetars' SNRs

- Qitai Radio Telescope (QTT) has been proposed to be constructed in Qitai County of Xinjiang province, China.
- QTT will be the largest fully steerable single-dish radio telescope (diameter 110 m) with a range of observation frequency much higher than FAST, possible up to 3 mm.
- QTT and Urumqi 25 m telescope can be mutual benefit, and mutual complementarity, which allows Xinjiang Astronomical Observatory to conduct astronomical observations ,including observations of magnetars' SNRs, under distinctive geography and feasible weather conditions.

Using QTT to Observe Magnetars' SNRs

Because of its large field of view , unprecedented high sensitivity in total power and linear polarization, QTT will be used to:

- **Observe known magnetars' SNRs (or PWNe)**
- **Discover more new magnetars' SNRs**

  (This is due to a nominal sum of known magnetars' SNRs)
- **Probe the B-field in magnetars' SNRs (or PWNe)**

  (This might help reveal the mystery of magnetars' projenitors)
- **Study the magneto-ioic medium between us and magnetars' SNRs**

Highly Evolved Magnetars’ SNRs

- Highly evolved magnetars’ SNRs should be faint and large.
- At some point the impact of B-field inside magnetars’ SNRs on the background polarization should become stronger than its actual emission.
- Specifically old SNRs could be sources to faint to be seen at any wavelength, but still producing high Faraday Rotation.

Special Emphasis!

Faraday Rotation in Magnetars' SNRs

- To investigate B-fields inside magnetars' SNRs (or PMNe) with maps of Faraday rotation measure.
- To probe the magnetic field in large magnetars' SNRs with polarized background sources.
- The magnetic field structure inside shell-type SNRs can be used to study the local interstellar magnetic field.

Special Emphasis!

Conclusions

In summary, in China there are several experienced teams of radio observations and some researchers investigating magnetars' supernova remnants. QTT possessing powerful hardware designs and software functions will provide a potential feasibility for the observations of magnetars' SNRs.

Thank you for your attention!