Suzaku Studies of the Supernova Remnant CTB109 and its Central Magnetar 1E 2259+586

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1.Introduction

Today, "Anomalous X-ray Pulsars" (AXPs) and "Soft Gamma Repeaters" (SGRs) are generally understood as magnetars, which are neutron stars with unusually high magnetic fields[1]. One of the most interesting topics of magnetars is their origin. Although neutron stars, including magnetars, are believed to be a result of supernovae (SNe), it is not yet clear what kind of SNe produce magnetars. Supernova remnants (SNRs) with assciated magnetars can be clue of magnetars formation[2]. We decided to study such SNRs associated with magnetars.

2. CTB109/1E 2259+586

CTB109 is a good target for the above objective sample, because it includes the magnetar 1E 2259+586 inside it, and has the largest diameter (~30') among the known SNR/magnetar pairs, together with bright externals. Therefore, *Suzaku* moderate angular resolution can easily resolve-out the SNR X-ray emission from that of the AXP.

3. Previous study

AXP 1E 2259+586

Pulse period : 6.9 s
P-dot : $(3 - 6) \times 10^{-13}$ ss^{-1} [3]
Magnetic Fild : 5.9×10^{13} G
Chractic age : 2.2 × × 10 ky

CTB109

Diameter : 28 arcmin (30 pc@4 kpc)
Morphology : Semi circular shell
Association : HII regions (Kothes et al.2002)
Plasma model : kT = 4-5 keV
Abundance : mostly ~1 Solar
Explosion energy : 0.7 × 1051 erg
Sedov-age : 8.8 ky (Sasaki et al. 2004) [4]

Distance : 3.2+/- 0.8 kpc [5]

1E 2259+586 and CTB109 have a huge age discrepancy.

4. Suzaku Studies (This work)

Suzaku observation of 1E 2259+586/CTB 109 was made on two occasions.

2009/5/25 (AO4 Key Project) [6]
Target : 1E 2259+586
Instrument : XIS 1/4-win mode

2011/12/15 (AO6)
Target : CTB109 4-pointings
- NorthWest (NW)
- SouthWest (SW)
- North East (NE)
- South East (SE)

Instrument : XIS Full-win mode

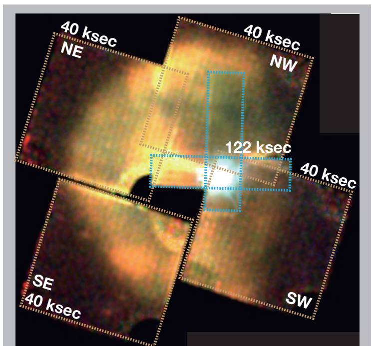

Fig1. False colour X-ray Image. Red (0.5-0.9 keV), Green (0.9-1.7 keV), Blue (1.7-5.0 keV)

Spectral analysis

We applied non- equilibrium model(NEI) and variable-abundance non-equilibrium model(VNEI) to explain with two different temperatures. (See Fig.2) We assumed lower (kT_1) and higher (kT_2) temperature plasma are interstellar medium(ISM) and ejecta respectively. Abundance profile is explained by theoritycal model of core-colapse supernova[7]. (See Fig.3)

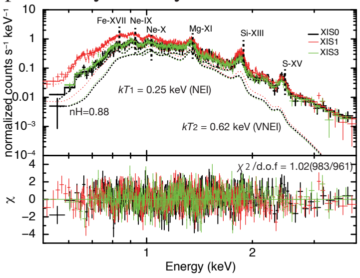

Fig 2

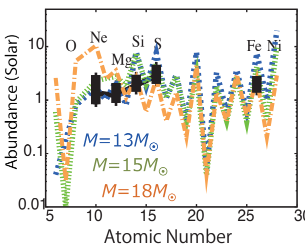

Fig 3

Age estimation with Sedov solution

Using the Sedov similarity solution and the fitting parameters, we estimated the explosion energy E and the SNR age T as

$E = (1.7\text{-}7.0) \times 10^{51}$ erg

$T = (1.3\text{-}1.7) \times 10^{4}$ year We cofirmed the age discrepancy

5. Solving Age Discrepancy with B-decay

Usually characteristic age is calculated assuming a constant magnetic field. But magnetars are thought that they consume their magnetic field. Then we have to recaluculate their characteristic ages considering field decay. We use simple decay model [8][9].

Const B : $$\frac{dB}{dt} = 0 \quad \Rightarrow \quad \tau_c \equiv \frac{P}{2\dot{P}} \simeq t_{\rm real}$$

Variable B : $$\frac{dB}{dt} = -aB^{1+\alpha}$$
$$B(t) = B_0/(1+\alpha t/\tau_d)^{1/\alpha} \quad \Rightarrow \tau_c \gg t_{\rm real}$$
$$\tau_d = 1/(aB_0^\alpha)$$

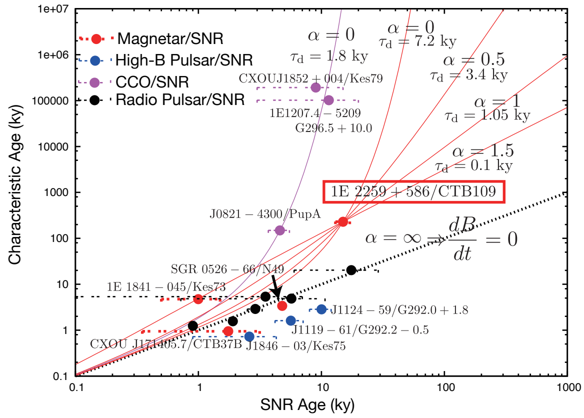

Fig 4. Relation between SNR ages and characteristic ages. (ATNF [10] and McGill [11])

Magnetic field decay can explain overestimation of Characteristic ages of magnetar. Magnetars are younger than we thought so far.

6. Spatial Distribution of Magnetars

We compared galactic spatial distribution of magnetars with that of other pulsars. Neutron stars get away from the galactic plane gradually. In spite of characteristic age, the distribution of magnetars is narrower than other pulsars. This also implies that magnetars are younger than other pulsars.

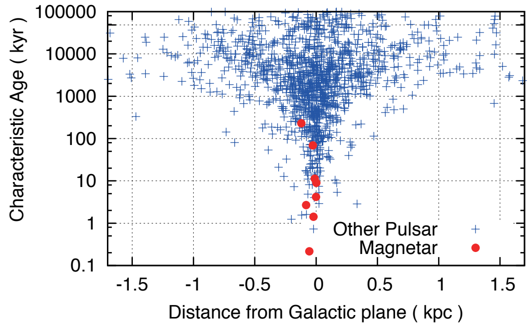

Fig 5. Spatial distribution of pulsars.

7. Conclusion

We analyzed Suzaku data of CTB109 and reconfirmed overestimation of characteristic age of 1E 2259. This age discrepancy can be solved considering magnetic field decay. Thus, true age of magnetars are younger than their characteristic ages. The distribution from galactic plane of magnetars also supports the overestimations of characteristic ages.

Refferences

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