Magnetic fields of neutron stars: very low and very high

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Abstract

Estimations of magnetic fields of neutron stars, observed as radio and X-ray pulsars, are discussed. It is shown, that theoretical and observational values for different types of radiopulsars are in good correspondence. Magnetic fields of X-ray pulsars are estimated from the cyclotron line energy. In the case of Her X-1 this estimation exceeds considerably the value of its magnetic field obtained from long term observational data related to the beam structure evolution. Another interpretation of the cyclotron feature, based on the relativistic dipole radiation mechanism, could remove this discrepancy. Observational data about soft gamma repeators and their interpretation as magnetars are critically analyzed.

1 Introduction

First theoretical estimations of neutron star magnetic fields have been obtained from the condition of the magnetic flux conservation during contraction of a normal star to a neutron star (Ginzburg, 1964):

$$B_{ns} = B_s \left(\frac{R_s}{R_{ns}}\right)^2. \tag{1}$$

For main sequence stellar magnetic field $B_s = 10 \div 100$ Gs, and stellar radius $R_s = (3 \div 10)R_\odot \approx (2 \div 7)10^{11}$ cm, we get $B_{ns} \approx 4 \times 10^{11} \div 5 \times 10^{13}$ Gs, for a neutron star radius $R_{ns} = 10^6$ cm. As shown below, this simple estimation occurs to be in a good correspondence with most observational data.

2 Radio pulsars

It is now commonly accepted that radio pulsars are rotating neutron stars with inclined magnetic axes. For rotating with angular velocity Ω dipole, the rotational energy losses (Landau & Lifshitz, 1962; Pacini, 1963) are determined as

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$\dot{E} = AB^2\Omega^4$. The rotational energy is $E = \frac{1}{2}I\Omega^2$, I is an inertia momentum of the neutron star. By measuring of $P = 2\pi/\Omega$ and $\dot{P}$, we obtain the observational estimation of the neutron star magnetic field as

$$B^2 = \frac{IP\dot{P}}{4\pi^2 A}. \qquad (2)$$

It was shown by Goldreich and Julian (1969) that energy losses by a pulsar relativistic wind are important also when the magnetic and rotational axes coincide, and one may use (2) with $A = \frac{R_{ns}^6}{6c^3}$, and B_{ns} corresponding to the magnetic pole, at any inclination angle. Magnetic fields of radio pulsars estimated using (2) with observational values of P and $\dot{P}$ lay in a wide region between 10^8 and 10^{13} Gs (Lyne, Smith, 1997). There are two distinctly different groups: single radiopulsars with periods exceeding 0.033 sec, and magnetic fields between 10^{11} and 10^{13} Gs, and recycled pulsars (RP), present or former members of close binary systems with millisecond periods and low magnetic fields between 10^8 and 10^{10} Gs. Low magnetic field of recycled pulsars is probably a result of its damping during preceding accretion stage (Bisnovatyi-Kogan, Komberg, 1974, 1976).

3 X-ray binaries

There are several ways to estimate observationally magnetic field of an X-ray pulsar. During accretion matter is stopped by the magnetic field at the alfvenic surface, where gaseous and magnetic pressures are in a balance. At stationary state Keplerian angular velocity of the accretion disk at the alfvenic surface is equal to the stellar angular velocity (Pringle, Rees, 1972) $\Omega_K = \Omega_s = \Omega_A$. Otherwise neutron star would be accelerated due to absorption of matter with large angular momentum, or decelerated due to throwing away matter with additional angular momentum (Ilarionov, Sunyaev, 1975). X-ray pulsars may have spin-up and spin-down stages (Bildsten et al., 1997), but most of them show average spin-up, what indicate to their angular velocity being less than the equilibrium one. This is observed in the best studied X-ray pulsar Hex X-1 (Sheffer et al., 1992; Deeter et al., 1998). Analysis of spin-up/down phenomena in the X-ray pulsars indicate to important role of the mass loss (Lovelace et al., 1995), and to stochastic origin of spin-up/down transitions (Lovelace et al., 1999).

For a given luminosity $L_{36} = L/(10^{36}\text{ergs/s})$ and dipole magnetic field at stellar equator $B_{12} = B/(10^{12}\text{Gs})$ we get the following value of the equilibrium period (Lipunov, 1992), for the neutron star mass $M_s = 1.4M_\odot$

$$P_{eq} \approx 2.6\, B_{12}^{6/7}\, L_{36}^{3/7}\text{s}. \qquad (3)$$

For Her X-1 parameters $L_{36} = 10,\ P = 1.24$ s, we get a magnetic field corresponding to the equilibrium rotation $B_{12}^{eq} = 0.9$. Taking into account the average spin-up of the pulsar in Her X-1, we may consider this value as an upper limit of its magnetic field. Even more rough estimations of the magnetic field in X-ray pulsars follow from the average spin-up rate under condition $\dot{J}_{rot} = \dot{M}\,\Omega_A$, or restrictions on the polar magnetic field value following from the observed beam structure and condition of local luminosity not exceeding the critical Eddington one. These conditions lead to smaller values of the magnetic field of Her X-1 on the level $10^9 - 10^{10}$ Gs (Bisnovatyi-Kogan and Komberg, 1974, 1975: Bisnovatyi-Kogan, 1974).

Observations of low mass X-ray binaries (LMXB) indicate to very low values of their magnetic fields due to absence of X-ray pulsar phenomena. Modulation of X-ray flux permitted to reveal the rotational period of the neutron star in the LMXB SAX J1808.4-3658 corresponding to the frequency 401 Hz, due to RXTE observations (see review of van der Klis, 1998). This observations fill a gap and form a long-waiting link between LBXB and recycled millisecond pulsars (Ruderman, Shaham, 1983), as neutron stars with very low magnetic field (up to 10^8 Gs).

The most reliable estimation of the magnetic field of the X-pulsar Her X-1 comes from detailed observations of the beam variation in this pulsar on different stages, made on the satellites ASTRON (Sheffer et al., 1992), and GINGA (Deeter et al., 1998). This pulsar, in addition to 1.24 s period of the neutron star rotation, is in a binary system with an orbital period 1.7 days, and shows a 35 day cycle, where during only 12 days its luminosity is high. During other 23 days its X-ray luminosity strongly decreases, but small changes in the optical luminosity and remaining strong reflection effect indicate, that the X-ray luminosity remains almost the same during all 35 day cycle. Visible decrease of the X-ray flux is due to an occultation phenomena. The model which explains satisfactory the phenomenon of the 35 day cycle is based on the precession of the accretion disc with the 35 day period, and occultation of the X-ray beam during 23 days. Analysis of the beam structure during high and low X-ray states lead to the conclusion, that during the low state we observe not the direct X-ray flux from the neutron star, but the flux, reflected from the inner edge of the accretion disc. This conclusion is based on the 180 deg phase shift between the X-ray beams in high and low states (Sheffer et al., 1992; Deeter et al., 1998). In order to observe the X-ray flux reflected from the inner edge, situated near the Alfven radius of the accretion disc, it cannot be very far away from the neutron star. The estimations give the upper limit to the ratio of the Alfven and stellar radiuses

$$\frac{r_A}{r_s} \leq 20. \tag{4}$$

The schematic picture of the accretion disc and its inner edge orientation around the neutron star at different stages of the 35 day cycle is shown in Fig.1, taken from Sheffer et al. (1992). As was indicated above, the value of the Alfven radius is determined by the neutron star mass ($M_s = 1.4M_s$), mass flux $\dot{M} = 3 \times 10^16$ g/s, corresponding to the luminosity $L = 10^{37}$ ergs/s, and the value of the magnetic field. Taking dipole radial dependence of the magnetic field $B = B_s(r_s/r)^3$, and neutron star radius $r_s = 10^6$ cm, we obtain the ratio in the form $r_A/r_s \approx 300B_{12}^{4/7}$. To have this ratio not exceeding 20 we get an inequality $B \leq 3 \times 10^{10}$ Gs.

Trümper et al. (1978) had found a feature in the spectrum of Her X-1 at energies between 50 and 60 keV. Interpreting it as a cyclotron line feature according to $E_X = \frac{\hbar eB}{m_e c}$ leads to the value of the magnetic field $B_{cycl} = (5 - 6) \times 10^{12}$ Gs, what is much higher than any other above mentioned estimations. Spectral features had been observed also in other X-ray sources. Recent observations on RXTE (Heindl et al., 1999), and Beppo-SAX (Santangelo et al., 1999) of the pulsating transient 4U 0115+63 had shown a presence of 3 and 4 cyclotron harmonics features, corresponding to the magnetic field strength of 1.3×10^{12} Gs. A comparison of the shapes of the beam in cyclotron harmonics may be used for testing the nature of these features. Cyclotron features had been observed in several X-ray sources (Mihara et al., 1997), and they always had corresponded to large values of magnetic fields $B_{cycl} > 10^{12}$ Gs. Such situation was not in good accordance with a well established observational fact, that all recycled pulsars, going through a stage of an X-ray source, have much smaller magnetic fields, usually not exceeding 10^{10} Gs. Particularly, for the Her X-1 the value of its magnetic field, following from the cyclotron interpretation of the spectral feature, was in contradiction with all other observations, including the most reliable, based on the beam shape variability during 35 day cycle.

4 Relativistic dipole interpretation of the spectral feature in Her X-1

It seems likely that this conflict is created by using the non-relativistic formula connecting cyclotron frequency with a value of the magnetic field. According to Bisnovatyi-Kogan and Fridman (1969), ultrarelativistic electrons with a temperature $\sim 10^{11}K$, may be formed in the non-collisional shock during accretion, emitting a relativistic dipole line. The mean energy of this line is broadened and shifted relativistically, in comparison with the cyclotron line, by a factor of $\gamma \simeq \frac{kT}{mc^2}$. The spectrum profile of the relativistic dipole line is calculated by Baushev and Bisnovatyi-Kogan (1999) for various electron distributions, where the model of the hot spot of Her X-1 is considered, and it is shown that the overall observed X-ray spectrum (from 0.2 to 120 KeV) can arise under the fields near $5 \cdot 10^{10}$ Gs which are well below B_{cycl}, and are not in the conflict with other observations.

According to Gnedin and Sunyaev (1973), and Bisnovatyi-Kogan (1973), in the magnetic field near the pulsar the cross component of a momentum of electrons is emitting rapidly, while the parallel velocity remains constant. Hence the momentum distribution of the electrons is anisotropic $p_\perp^2 \ll p_\parallel^2$, with $p_\perp \ll mc$, $p_\parallel \gg mc$. Assume for simplicity that the transverse electron distribution is two-dimensional Maxwellian $dn = \frac{N}{T_1}\exp\left(-\frac{mu^2}{2T_1}\right) d\frac{mu^2}{2}$, $T_1 \ll mc^2$.

In the relativistic dipole regime of radiation the electron is non-relativistic in the coordinate system, connected with the Larmor circle. In the laboratory system, where the electron is moving with a velocity V, the angle between the magnetic field and electron momentum vectors is smaller than the angle of the emitting beam. In this conditions we may consider that all radiation is emitted along the magnetic field with an intensity $J(0)$, after integration over du, at frequency ω_{md} as (Baushev and Bisnovatyi-Kogan, 1999)

$$J(0) = \frac{2Ne^4B^2T_1}{\pi c^5 m^3(1-\frac{V}{c})}, \qquad \omega_{md} = \omega_{cycl}\sqrt{\frac{1+\frac{V}{c}}{1-\frac{V}{c}}} \approx 2\omega_{cycl}\frac{E_\parallel}{m_e c^2}, \tag{5}$$

where $\omega_{cycl} = \frac{eB}{mc}$. That gives $1 - \frac{V}{c} = \frac{2\omega_{cycl}^2}{\omega^2}$. Let us consider the parallel momentum distribution of the electrons as: $dn = f(p_\parallel)\,dp_\parallel$. Substituting of dn for N and using $p_\parallel = \frac{mc}{2}\frac{\omega}{\omega_{cycl}}$, we obtain for the spectral density

$$J_\omega = \frac{e^2T_1}{2\pi c^2\omega_{cycl}}\omega^2 f\left(\frac{mc}{2}\frac{\omega}{\omega_{cycl}}\right) d\omega. \tag{6}$$

Let us consider two cases. The first is a relativistic Maxwell $f = \frac{n_0 c}{T_2}\exp\left(-\frac{p_\parallel c}{T_2}\right)$, where n_0 is a number of emitting electrons. The spectrum is

$$J_\omega = \frac{n_0 e^2}{2\pi c\omega_{cycl}}\frac{T_1}{T_2}\omega^2 \exp\left(-\frac{mc^2\omega}{2\omega_{cycl}T_2}\right) d\omega. \tag{7}$$

It has a single maximum at $\frac{\omega}{\omega_{cycl}} = \frac{4T_2}{mc^2}$. In the second case $f = \frac{n_0}{\sqrt{\pi}\sigma}\exp\left[-\frac{(p_\parallel - a)^2}{\sigma^2}\right]$. The spectrum of radiation is

$$J_\omega = \frac{n_0 e^2 T_1}{2\pi^{3/2}c^2\omega_{cycl}\sqrt{\sigma}}\omega^2 \exp\left(-\frac{(\frac{mc}{2}\frac{\omega}{\omega_{cycl}} - a)^2}{\sigma^2}\right) d\omega. \tag{8}$$

When $\sigma \ll a$ this spectrum has a single maximum at $\omega \simeq \frac{2a}{mc}\omega_{cycl}$. Baushev and Bisnovatyi-Kogan (1999) had approximated experimental spectra taken from Mihara et al. (1990), and McCray et al. (1982). The last spectrum (solid line) and its fitting (dashed line) are shown in Fig.2. It was taken in accordance with Bisnovatyi-Kogan and Fridman (1969), $a = 7\cdot 10^{-4}\ \frac{\text{eV}\cdot\text{s}}{\text{cm}}$, corresponding to average electron energy $E_\parallel = ac \approx 20$ MeV, and the best fit for the line shape was obtained at the magnetic field strength $B = 4\cdot 10^{10}$ Gs. In this model the beam of the "cyclotron" feature is determined by the number distribution of the emitting relativistic electrons, moving predominantly along the magnetic field, over the polar cap.

In order to obtain the whole experimental spectrum of the Her X-1 the following model of the hot spot (Fig.3) was considered by Baushev and Bisnovatyi-Kogan (1999). A collisionless shock wave is generated in the accretion flow near the surface on the magnetic pole of a neutron star. In it's front the ultrarelativistic electrons are generated. Under the shock there is a hot turbulent zone with a temperature T_e, and optical depth τ_e, situated over a heated spot with a smaller temperature on the surface of the neutron star.

The whole X-ray spectrum of pulsar Her X-1 from McCray et al. (1982) is represented in Fig.3 by the solid line. There are three main regions in it: a quasi-Planckian spectrum between 0,3 and 0,6 KeV, that is generated (re-radiated) near the magnetosphere of the X-ray pulsar; power-law spectrum $(0.6 \div 20)$ KeV with a rapid decrease at 20 KeV, and the "cyclotron" feature. The power-law spectrum is a result of comptonization in the corona of a black-body spectrum emitted by the stellar surface. The comptonized spectrum has been calculated according to Sunyaev and Titarchuk (1980). Setting the neutron star radius equal to 10 km, distance to the X-ray pulsar 6 Kps, hot spot area $S = 2 \cdot 10^{12}$ cm^2, the best fit was found at $T_s = 1$ KeV, $T_e = 8$ KeV, $\tau_e = 14$, which is represented in Fig.3 by the dashed line.

The observations of the variability of the "cyclotron" lines are reported by Mihara et al. (1997). Ginga detected the changes of the cyclotron energies in 4 pulsars. The change is as much as 40 % in the case of 4U 0115+63. Larger luminosity of the source corresponds to smaller average energy of the cyclotron feature. These changes might be easily explained in our model. The velocity of the accretion flow decreases with increasing of the pulsar luminosity because locally the luminosity is close to the Eddington limit. As a result the shock wave intensity drops as well as the energy of the ultrarelativistic electrons in it's front, leading to decrease of the relativistic dipole line energy.

5 Magnetars

Among more than 2000 cosmic gamma ray bursts (GRB) 4 recurrent sources had been discovered, and were related to a separate class of GRB, called soft gamma repeators (SGR). Besides observations of short, soft, faint recurrent bursts, three of them had given giant bursts, most powerful among all GRB. All four SGR are situated close or inside SNR, three of them show long periodic pulsations. These properties had separated SGR, situated in our or nearby galaxies, in a quite special class, very different from other GRB, which are believed to have a cosmologilal origin at red shifts $z \sim 1$. One SGR 1627-41 had been discovered by BATSE (Woods et al., 1999a) and three other had been discovered in KONUS experiment in 1979 (Mazets et al., 1979, 1981; Golenetskii et al., 1984). Three of SGR show regular pulsations, and for two of them $\dot{P}$ had been estimated, indicating to very high values of the magnetic fields, up to 10^{15} Gs, and small age of these objects. SGR have the following properties (Feroci et al., 1999; Hurley et al., 1999a-e; Kouveliotou et al., 1998, 1999; Mazets et al., 1979, 1999a-c; Murakami et al., 1999; Woods et al., 1999b)

1. SGR0526-66 (Mazets et al., 1979, 1999c)

It was discovered due to a giant burst of 5 March 1979, projected to the edge of the SNR N49 in LMC. Accepting the distance 55 kpc to LMC, the peak luminosity in the region $E_\gamma > 30$ keV is equal to $L_p = 3.6 \times 10^{45}$ ergs/s, the total energy release in the peak $Q_p = 1.6 \times 10^{44}$ ergs, in the subsequent tail $Q_t = 3.6 \times 10^{44}$ ergs. The short recurrent bursts have peak luminosities in this region $L_p^{rec} = 3 \times 10^{41} - 3 \times 10^{42}$ ergs/s, and energy release $Q^{rec} = 5 \times 10^{40} - 7 \times 10^{42}$ ergs. The tail was observed about 3 minutes and had regular pulsations with the period $P \approx 8$ s. There was not a chance to measure $\dot{P}$ in this object.

2. SGR1900+14 (Mazets et al., 1999c,d; Kouveliotou et al., 1999; Woods et al., 1999b)

It was discovered first due to its recurrent bursts, the giant burst was observed 27 August, 1998. The source lies close to the less than 10^4 year old SNR G42.8+0.6, situated at distance ~ 10 kpc. Pulsations had been observed in the giant burst, as well as in the X-ray emission observed in this source in quiescence by RXTE and ASCA. $\dot{P}$ was measured, being strongly variable. Accepting the distance 10 kpc, this source had in the region $E_\gamma > 15$ keV: $L_p > 3.7 \times 10^{44}$ ergs/s, $Q_p > 6.8 \times 10^{43}$ ergs, $Q_t = 5.2 \times 10^{43}$ ergs, $L_p^{rec} = 2 \times 10^{40} - 4 \times 10^{41}$ ergs/s, $Q^{rec} = 2 \times 10^{39} - 6 \times 10^{41}$ ergs, $P = 5.16$ s, $\dot{P} = 5 \times 10^{-11} - 1.5 \times 10^{-10}$ s/s. This source was discovered at frequency 111 MHz as a faint, $L_r^{max} = 50$ mJy, radiopulsar (Shitov, 1999) with the same P and variable $\dot{P}$ good corresponding to X-ray and gamma-ray observations. These values of P and average $\dot{P}$, according to (2) correspond to the rate of a loss of rotational energy $\dot{E}_{rot} = 3.5 \times 10^{34}$ ergs/s, and magnetic field $B = 8 \times 10^{14}$ Gs. The age of the pulsar estimated as $\tau_p = P/2\dot{P} = 700$ years is much less than the estimated age of the close nearby SNR. Note that the X-ray luminosity of this object $L_x = 2 \times 10^{35} - 2 \times 10^{36}$ ergs/s is much higher, than rate of a loss of rotational energy, what means that rotation cannot be a source of energy in these objects. It was suggested that the main source of energy comes from a magnetic field annihilation, and such objects had been called as magnetars (Duncan, Thompson, 1992).

3. SGR1806-20 (Kouveliotou, 1998; Hurley et al., 1999e)

This source was observed only by recurrent bursts. Connection with the Galactic radio SNR G10.0-03 was found. The source has a small but significant displacement from that of the non-thermal core of this SNR. The distance to SNR is estimated as 14.5 kpc. The X-ray source observed by ASCA and RXTE in this object shows regular pulsations with a period $P = 7.47$ s, and average $\dot{P} = 8.3 \times 10^{-11}$ s/s. As in the previous case, it leads to the pulsar age $\tau_p \sim 1500$

years, much smaller that the age of SNR, estimated by 10^4 years. These values of P and $\dot{P}$ correspond to $B = 8 \times 10^{14}$ Gs. $\dot{P}$ is not constant, uniform set of observations by RXTE gave much smaller and less definite value $\dot{P} = 2.8(1.4) \times 10^{-11}$ s/s, the value in brackets gives 1σ error. The peak luminosity in the burst reaches $L_p^{rec} \sim 10^{41}$ ergs/s in the region 25-60 keV, the X-ray luminosity in 2-10 keV band is $L_x \approx 2 \times 10^{35}$ ergs/s is also much higher than the rate of the loss of rotational energy (for average $\dot{P}$) $\dot{E}_{rot} \approx 10^{33}$ ergs/s.

4. SRG1627-41 (Mazets et al., 1999a; Woods et al., 1999a)

Here the giant burst was observed 18 June 1998, in addition to numerous soft recurrent bursts. Its position coincides with the SNR G337.0-0.1, assuming 5.8 kpc distance. Some evidences was obtained for a possible periodicity of 6.7 s, but giant burst does not show any periodic signal (Mazets et al., 1999a), contrary to two other giant burst in SGR. The following characteristics had been observed with a time resolution 2 ms at photon energy $E_\gamma > 15$ keV: $L_p \sim 8 \times 10^{43}$ ergs/s, $Q_p \sim 3 \times 10^{42}$ ergs, no tail of the giant burst had been observed. $L_p^{rec} = 4 \times 10^{40} - 4 \times 10^{41}$ ergs/s, $Q^{rec} = 10^{39} - 3 \times 10^{40}$ ergs. Periodicity in this source is not certain, so there is no $\dot{P}$.

To measure $\dot{P}$ the peaks of the beam are compared during long period of time. Both SRG with measured $\dot{P}$ have highly variable beam shapes, what implies systematic errors in the result. Another source of systematic error comes from the barycenter correction of the arriving signal in the source with an essential error in angular coordinates. This effect is especially significant for determination of $\ddot{P}$ (Bisnovatyi-Kogan, Postnov, 1993), but when observational shifts are short the error in the coordinates could not be extracted easily. Earth motion around the Sun, as well as the satellite motion around the Earth may influence the results. Nevertheless, independent measurements of P and $\dot{P}$ in such different spectral bands as radio and X-rays gave similar results for SGR1900+14.

The physical connection between SGR and related SNR is not perfectly established: SNR ages are much larger, than ages of SNR estimated by P and $\dot{P}$ measurements, and all four SGR are situated at the very edge of the corresponding SNR, or well outside them. Using the pulsar age estimation we come to conclusion of a very high speed of the neutron star at several thousands km/s, exceeding strongly all measured speeds of radiopulsars. Physical properties of the pulsars observed in SGR are very unusual. If the connection with SNR is real, and the distances to SGR are the same then the pulsar luminosity during giant bursts is much larger than the critical Eddington luminosity. As follows from simple physical reasons, when the radiation force is much larger than the force of gravity, the matter would be expelled at large speed, forming strong outflow and dense envelope around the neutron star which could screen pulsations. No outflowing envelope around SGR have been found. The large difference between $\dot{E}_{rot}$ and average $L_x + L_\gamma$ luminosity needs to suggest a source of energy, much larger than the one coming from the rotational losses. It is suggested that in magnetars the energy comes from the magnetic field annihilation (Duncan, Thompson, 1992). It is rather surprising to observe the field annihilation without formation of relativistic particles, where considerable part of the released energy should go. Radio emitting nebula should be formed around the SGR, but had not been found. So, it is not possible to exclude that there is no physical connection between SNR and SGR, that SGR are much closer objects, their pulsar luminosity is less than the Eddington one, and their magnetic fields are not so extremely high.

There is a striking similarity between SGR and special class of X-ray pulsars called anomalous X-ray pulsars (AXP). Both have periods in the interval 6 - 12 seconds, binarity was not found, spin-down of the pulsar corresponding to small age ~ 1000 years, observed irregularities in $\dot{P}$ (see e.g. Melatos, 1999). The main difference is an absence of any visible bursts in AXP, characteristic for SGR. Suggestions had been made about their common origin as magnetars (Kouveliotou et al., 1998, Melatos, 1999). Other models of AXP had been discussed (see e.g. Mereghetti et al., 1998). We may expect that establishing of the nature of AXP would help strongly for the determination of the nature of SGR.

6 Conclusions

1. Magnetic fields of radiopulsars are in good correspondence with theoretical estimations.
2. RP and LMXB have small magnetic fields, which very probably had been decreased by damping or screening during accretion stage.
3. Contradiction between high B_{cycl} and other observational estimations of B in the LMXB Her X-1 may be removed in the model of relativistic dipole mechanism of the formation of a hard spectral feature by strongly anisortopic relativistic electrons, leading to conventional value of $B \approx 5 \times 10^{10}$ Gs.
4. Very high magnetic fields in magnetar model of SGR needs farther confirmation and investigation.

7 Questioning, Answering, and Checking magnetars

1. **Q**. Is it possible to observe an influence of a giant burst on the related SNR ?
   A. May be.

C. Radio observations of SNR, search for changes, wisps like in the Crab nebula.

2. **Q**.What could we see if SGR would be 10 times farther ?
   A. Ordinary short GRB.

3. **Q**. Why observed short GRB has larger hardness among GRB, opposite to SGR (Cline et al., 1999)?
   A. We could see only the main peak which is rather hard.

4. **Q**. How many "SGR" we should have seen in neighboring galaxies (Andromeda) by their giant busts?
   A. ~ 30 in Andromeda.
   C. Better statistical estimation and search in BATSE/KONUS data.

5. **Q**. Are short GRB identical with distant SGR?
   A. May be yes.

6. **Q**. How many SGR remnants should be in the Galaxy if SGR-SNR connection is real?
   A. About 10^8 neutron stars.

7. **Q**. Is it possible to provide γ-radiation by magnetic field annihilation without appearance of large number of ultra-relativistic particles and strong nonthermal emission in other spectral bands?
   A. Solar flashes produced by field annihilation are characterized by very broad spectrum, from radio to gamma.

8. **Q**. Is it possible to use pulsar-like formula for age estimation of SGR and its magnetic field from P and $\dot{P}$ measurements, when $L_{tot} \gg \dot{E}_{rot}$?
   A. Probably not (Marsden et al., 1999).

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Figure captions

Fig.1 Configuration of the inner edge of the disk and the neutron star; neutron star and the disk in the "high-on" state (left top box), and in the "low-on" state (right bottom box).

Fig.2 Comparison of the observational and computational X-ray spectra of Her X-1. The solid curve is the observational results taken from McCray et al. (1982), the dot curve is the approximation with $T_s = 0.9$ KeV, $T_e = 8$ KeV, $\tau_e = 14$, $a = 7 \cdot 10^{-4}\ \frac{\mathrm{eV \cdot s}}{\mathrm{cm}}$, $\sigma = 10^{-4}\ \frac{\mathrm{eV \cdot s}}{\mathrm{cm}}$, $B = 4 \times 10^{10}$ Gs.

Fig.3 Schematic structure of the accretion column near the magnetic pole of the neutron star (top), and its radiation spectrum (bottom).