Isolated Radioquiet Neutron Stars: Astrophysical Perspective

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Astrophysical appearance of INSs

Astronomy — is the only purely observational natural science!
We have just emission ...

Number of NSs in the Galaxy:

$$10^8 < N_{NS} < 10^9$$

Main parameters, which determine astrophysical appearance:

- Spin period, p
- Magnetic field, B
- Mass, M
- Spatial velocity, v
- Surface temperature, T
- Angle between spin and magnetic axes, α

...plus parameters of the ISM ...

1. Radio pulsars
2. AXPs
3. SGRs
4. CCO in SNRs
5. Geminga+
6. The "Magnificent seven"

+lensing
+unidentified EGRET sources
+unidentified ROSAT sources

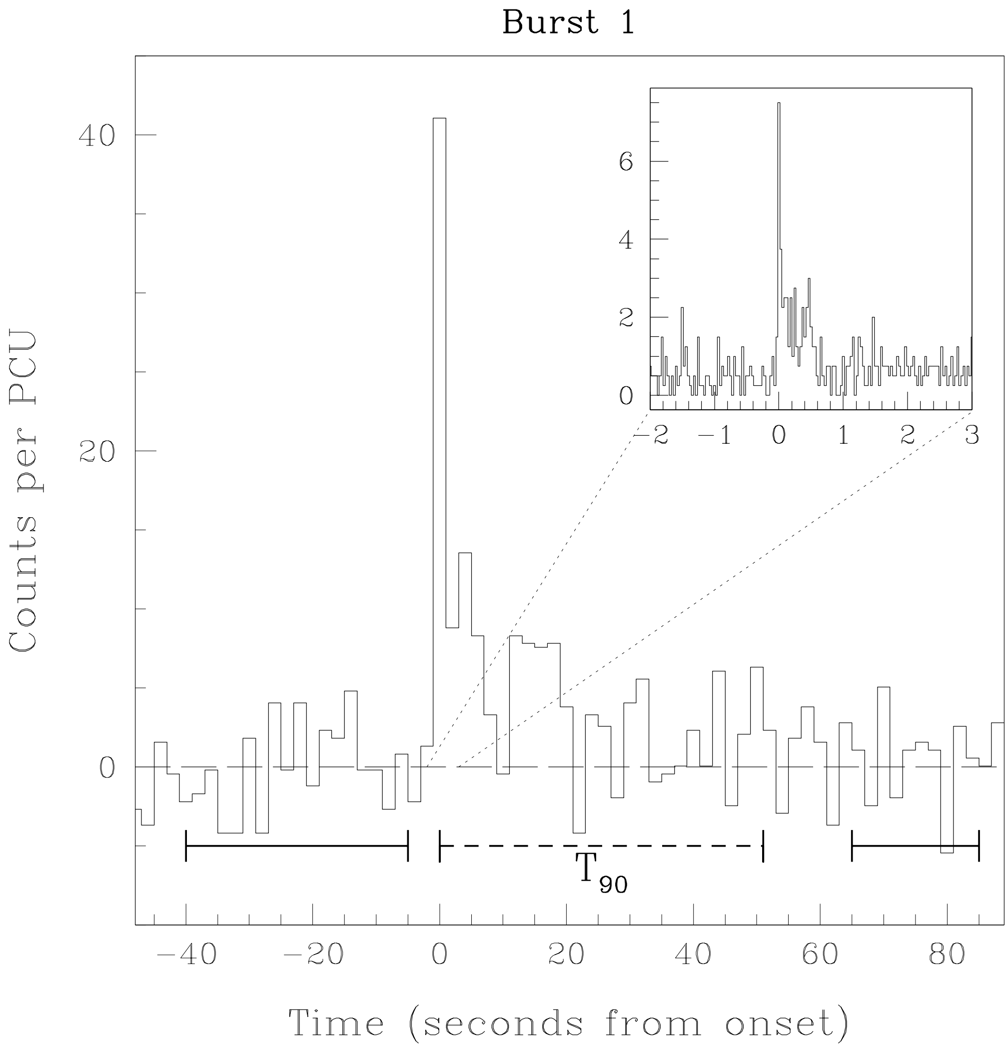
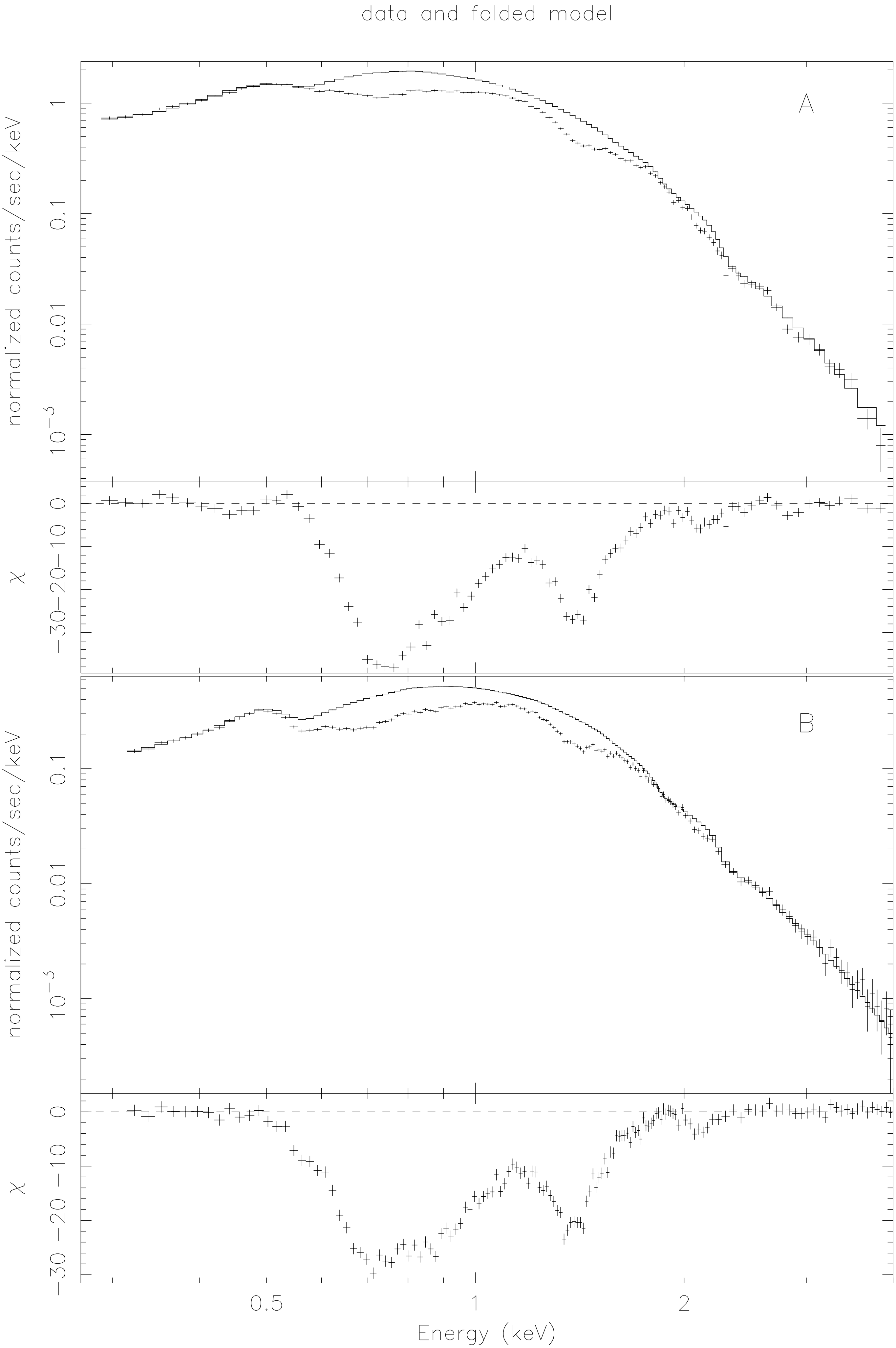


Figure 1: AXP 1E 1048-5937 burst. From Gavriil et al. 2002 (astro-ph/0209202).


data and folded model
A
normalized counts/sec/keV
1
0.1
0.01
10^−3
χ
0
−10
−20
−30
B
normalized counts/sec/keV
0.1
0.01
10^−3
χ
0
−10
−20
−30
0.5
1
2
Energy (keV)

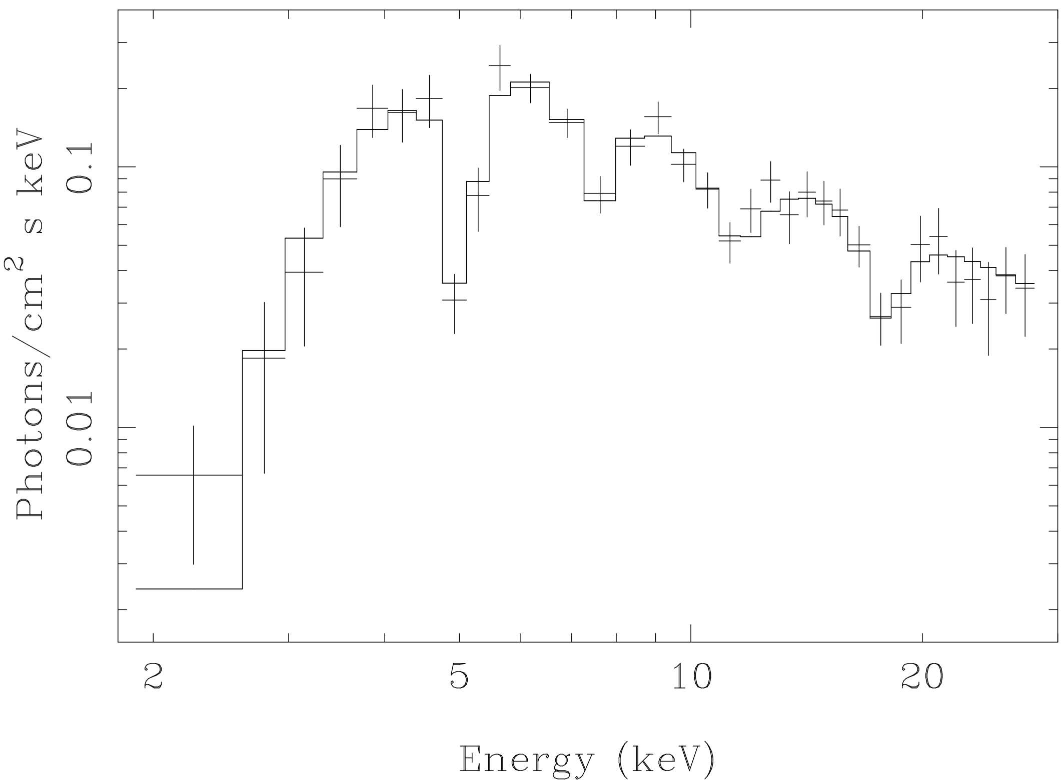


Figure 2: Spectrum of SGR 1806-20. From Ibrahim et al. 2002 (astro-ph/0210523).

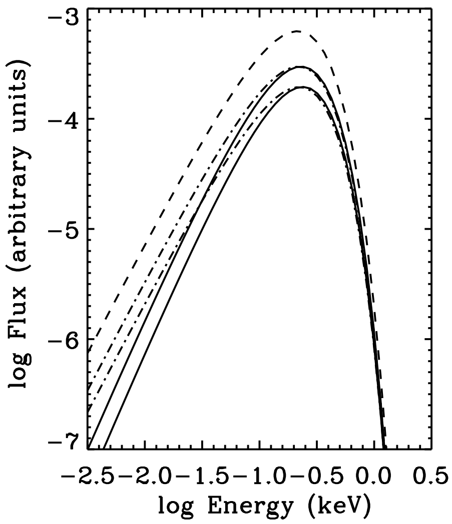


Figure 3: Model spectra of a naked neutron star. The emitted spectrum in the cold plasma limit for $B_p = 3 \times 10^{13}$ G and $T_{surf} = 75$ eV. Left panel: uniform surface temperature; right panel: meridional temperature variation. The dashed line is the blackbody at T_{surf} and the dash-dotted line the blackbody which best-fits the calculated spectrum in the 0.1–2 keV range. The two models shown in each panel are computed for $\omega_p = \omega_{p,0}$ (upper solid curve) and $2.45\omega_{p,0}$ (lower solid curve). Spectra are at the star surface and no red-shift correction has been applied. From Turolla et al. 2002 (astro-ph/0308326).

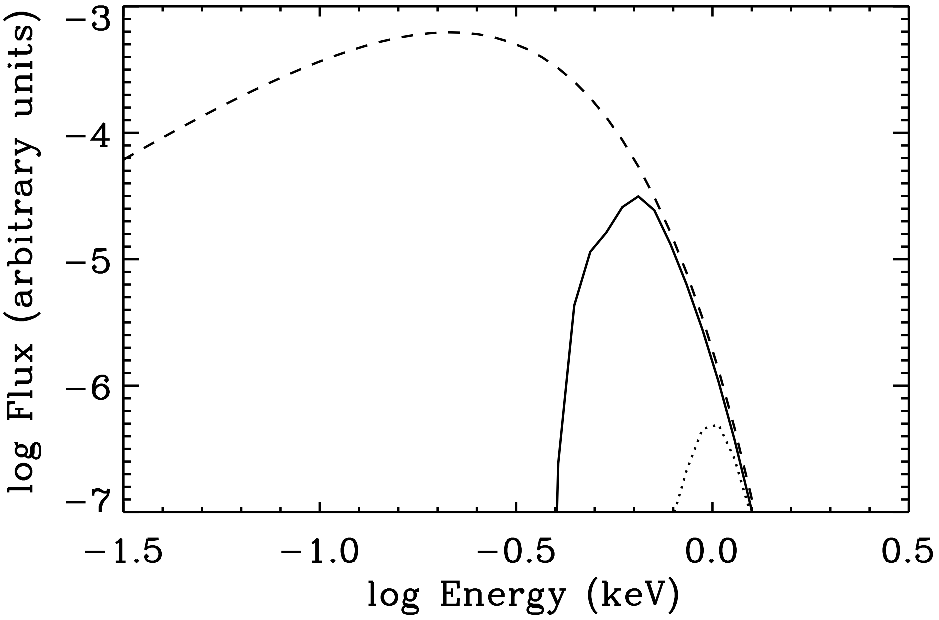


Figure 4: Model spectra of a naked neutron star. The emitted spectrum computed with electron-phonon damping. The dotted and solid lines are for $B_p = 10^{13}$ G $B_p = 5 \times 10^{13}$ G respectively. Only the uniform surface temperature case is shown ($T_{surf} = 75$ eV) and no best-fit with a blackbody was attempted. The two models are computed for $\omega_p = \omega_{p,0}$. From Turolla et al. 2002 (astro-ph/0308326).

WHAT'S NEW? (2002-2003: Observations I.)

1. Magnetic field determination

- AXP 1E 1048-5937. $B \sim 1.2 \cdot 10^{12}$ G or $B \sim 2.4 \cdot 10^{15}$ G (Gavriil et al. 2002, 2003). Not very clear.... Not consistent with spin-down.
- 1E 1207.4-5209. CCO in SNR. $B \sim 8 \cdot 10^{10}$ G or $\sim 1.6 \cdot 10^{14}$ G (Bignami et al. 2003). From spin-down $B \sim (2-3) \cdot 10^{13}$ G.
- SGR 1806-20. $B \sim 10^{15}$ G (Ibrahim et al. 2002).
- AXP 1RXS J170849-400910. $B \sim 9 \cdot 10^{11}$ G or $1.6 \cdot 10^{15}$ G (Rea et al. 2003).
- RBS 1223. "Magnificent seven". $B \sim (2-6) \cdot 10^{13}$ G (Haberl et al. 2003).
- RX J0720.4-3125. "Magnificent seven". $B \sim 5 \cdot 10^{13}$ G (Haberl et al., private comm.).

2. Relations between AXPs and SGRs

X-ray burst very similar to the ones from SGRs.

- AXP 1E1048-5937 (Gavriil et al. 2002, 2003).
- AXP 1E 2259+586 (Kaspi, Gavriil 2002).

3. More radiopulsars.

- ATNF catalogue (Hobbs et al. 2003).
- Parkes survey (Morris et al. 2002).

WHAT'S NEW? (2002-2003: Observations II.)

4. NS velocity distribution

- Two components: 90 km/s and 500 km/s (Arzoumanian et al. 2002).
- New pulsar proper motions (Brisken et al. 2003).
- New Model for the Galactic Distribution of Free Electrons (Cordes, Lazio 2002).

5. Proper motions of RINSs

- RX 1856.5-3754. $d = 117$ pc, $v_T = 185$ km/s (Walter, Lattimer 2002; Kaplan et al. 2002).
- RX 0720.4-3125. $v_T = 50(d/100\mathrm{pc})$ km/s (Motch et al. 2003).

6. Geminga-like object

- 3EG 1835+5918. EGRET source (Halpern et al. 2002).

7. $\dot{p}$ for RINS.

- RX 0720.4-3125. $\dot{p} \sim (3-6) \cdot 10^{-14}$ (Zane et al. Haberl et al 2002).
- RX 1308.6+2127. $\dot{p} < 10^{-11}$ (Hambaryan et al. 2002).

8. IR from AXPs

- 1E 2259+586 (Halleman et al. 2001).
- 1E 1048.1-5937 (Wang, Chakrabarty 2002).
  Variability (Israel et al. 2002).
- 1RXS J1708.9-400910 (Israel et al. 2003).

WHAT'S NEW? (2002-2003: Observations III.)

9. Pulsars jets and toruses

- Variable Jet of the Vela Pulsar (Pavlov et al. 2003)

10. NS masses

- Vela X-1 $M \approx 2\,M_\odot$ (Quaintrell et al. 2003).

11. Precession of isolated NSs

- Review (Link 2002).
- Crab (Vidri et al. 2003).

12. Pulsars with magnetar parameters

- $p = 6.7$ s, $B \approx 9.4 \cdot 10^{13}$ G (McLaughlin et al. 2003).

13. 3C 58

- X-ray (Murray et al. (2002).
- Radio (Camilo et al. 2002).
- Cooling (Yakovlev et al. 2002).

14. Gravitationaly redshifted line from an accreting NS

- EXO 0748-676. z=0.35 (Cottam et al. 2002).

WHAT'S NEW? (2002-2003: Observations IV.)

15. $\dot{p}$ for CCO in SNRs

- Kes 75. $p = 0.325$ s, $\dot{p} = 7.1 \cdot 10^{-12}$ (Mereghetti et al. 2002).
- G296.5+10. $p = 0.424$ s, $\dot{p} = (0.7 - 3) \cdot 10^{-14}$ (Pavlov et al. 2002).

16. Pulsar wind nebulae: new data

- X-rays. Correlation between the X-ray spectra of pulsars and their PWN (Gotthelf 2003).

17. BHs in microlensing

- Agol et al. 2002; Bennet et al. 2002.

WHAT'S NEW? (2002-2003: Theory I.)

1. SN explosions

- 3-Dimensional core-collapse (Fryer, Warren 2003).
- Nucleosynthesis, dynamics (Heger, Woosley et al. 2002).
- Jets, GRB, X-ray flashes [HETE-2 data] (Lamb et al. 2003).

2. Gould Belt in population synthesis

- EGRET sources (Grenier, Perrot 2003).
- RINS (Popov et al. 2003).

3. Spectra of strongly magnetized NSs

- Lines for high magnetic field (Turolla, Zane; Ho, Lai; Özel).
- Naked neutron star emission (Turolla et al. 2002).
- Atmospheres + Spectrum for high magnetic field (Potekhin, Chabrier et al.).

4. Accretion

- CDAF (Igumenschev 2002)
- Low angular momentum accretion (Proga, Begelman 2003).
- INS (Toropina et al., Romanova et al. 2003).

5. Cooling curves

- Superfluidity (Kaminker, Yakovlev, Gnedin et al. 2002).

WHAT'S NEW? (2002-2003: Theory II.)

6. Fossil discs

- It can be! (Alpar 2003).
- It can't be! (Francischelli, Wijers 2002).

7. Electrodynamics of magnetars

- SGR (Thompson et al. 2002).

8. Magnetic field decay

- Nonlinear decay (Geppert, Rheinhardt 2002).

9. Gravitational waves

- GW from newborn NSs (Ferrari et al. 2002).

10. Propeller regime

- Subsonic propeller (Ikhsanov 2003).

WHAT DO WE (Astrophysicists) WANT?

We have troubles even without quark stars!

We want initial parameters + evolutionary laws:

- Initial spin period, magnetic field, mass, radius etc.
  + ... correlations between them ...
- "Ejectorability" — ability to produce relativistic wind
- Cooling curves
- Field decay