Um Zoológico de Pulsares

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FAPESP 2013/15088-0
Temático: Dense Matter in the Universe 2013/26258-4

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Workshop PG - Astrofísica/DAS: May 03, 2016

Overview

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3. On the rotation-power nature of SGRs and AXPs
   - Jaziel G. Coelho, Jorge A. Rueda and R. Ruffini
4. GWs from pulsars with measured braking index
   - J. C. N. de Araujo, Jaziel G. Coelho and C. Costa
5. The influence of QVF on pulsars
   - Jaziel G. Coelho, Jonas P. Pereira and J. C. N. de Araujo
6. Neutron stars or quark stars?
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7. In progress...
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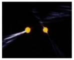
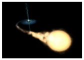
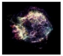
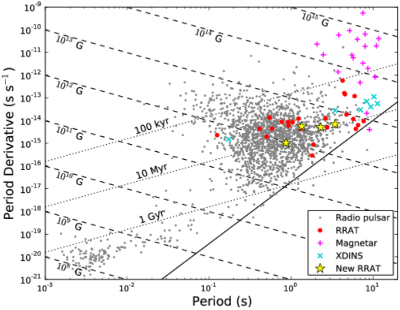
The Pulsar Zoo

- Radio Pulsar: ∼2000
- X-ray binary NSs: ∼1000
- X-ray Isolated NSs: ∼9
- RRATs:∼70
- CCOs:∼5
- SGRs/AXPs (magnetars):∼23



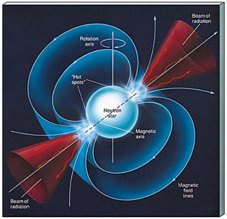



Pulsar Theory

Standard magnetic dipole model	
Pulsar Period	P
Age of a Pulsar	$t_c = P/2\dot{P}$
Energy Release	$\dot{E}_{rot} = -4\pi^2 I\dot{P}/P^3$
Dipole	$\dot{E}_{dip} = \frac{2\lvert\overrightarrow{m}\rvert^2}{3c^3}\Omega^4 \sin^2\alpha$
Magnetic Field	$B = \sqrt{\frac{3Ic^3}{8\pi^2 R^6}P\dot{P}}$

Canonical Neutron Star

$$B_{NS} = 3.2 \times 10^{19}(P\dot{P})^{1/2}\ G$$
$$|\dot{E}_{rot}|_{NS} = 3.9 \times 10^{46}\dot{P}/P^3\ erg/s$$



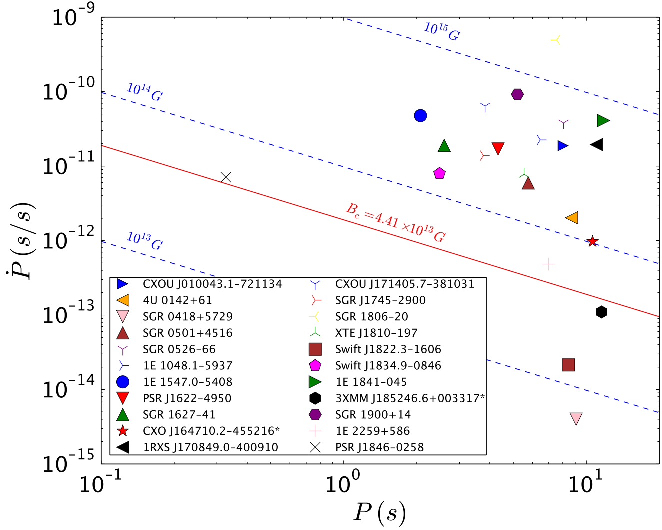
SGRs/AXPs - The Sources

SGRs - Soft Gamma Repearters.
AXPs - Anomalous X-ray Pulsars.

Particular class of pulsars:

Pulsars		
	Ordinary Pulsars	SGRs/AXPs
P	$\approx 10^{-3}s$	$(2-12)s$
$\dot{P}$	$\approx 10^{-15}\ s/s$	$\approx (10^{-10}-10^{-13})s/s$
L_X	$\approx 10^{30}\ erg/s$	$\approx (10^{34}-10^{36})erg/s$
t_c	$> 10^{6}\ yr$	$\approx 10^{3}\ yr$

Our sample, $P - \dot{P}$



SGRs/AXPs - What are they?

Understood as:

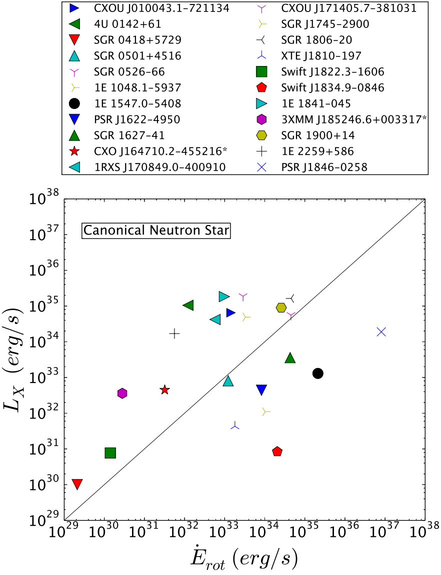
- Slowly rotating Neutron Stars - $P \approx (2-12)$s:
  Canonical Neutron Star
  - $M = 1.4 M_\odot$
  - $R = 10\ km$
  - $I \approx 10^{45} g\ cm^2$
- Large x-ray luminosity - $L_X >> \dot{E}_{rot}$.
- Their persistent X-ray luminosity, as well as the bursts and flares typical of these sources, are believed to be powered by the decay of their ultra strong B.
- Powered by strong magnetic fields - $B > 10^{14}$G.

Difficulties of the magnetar model

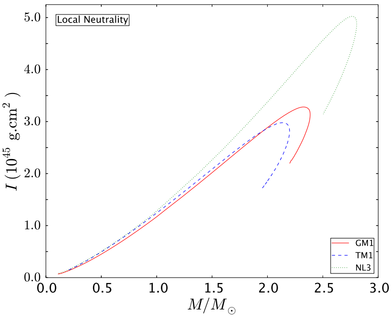
- up to now, attempts to estimate the magnetic field strength through the measurement of cyclotron resonance features, as successfully done for accreting pulsars, have been inconclusive.
- SGRs with low-B, 4 radio sources[1].

[1] alternative models - Malheiro et al. 2012, Coelho & Malheiro 2014

$L_X / \dot{E}_{rot}$


CXOU J010043.1-721134
4U 0142+61
SGR 0418+5729
SGR 0501+4516
SGR 0526-66
1E 1048.1-5937
1E 1547.0-5408
PSR J1622-4950
SGR 1627-41
CXO J164710.2-455216*
1RXS J170849.0-400910
CXOU J171405.7-381031
SGR J1745-2900
SGR 1806-20
XTE J1810-197
Swift J1822.3-1606
Swift J1834.9-0846
1E 1841-045
3XMM J185246.6+003317*
SGR 1900+14
1E 2259+586
PSR J1846-0258
Canonical Neutron Star
L_X (erg/s)
$\dot{E}_{rot}$ (erg/s)
10^{29} 10^{30} 10^{31} 10^{32} 10^{33} 10^{34} 10^{35} 10^{36} 10^{37} 10^{38}

I *versus* M



Local Neutrality
$I\,(10^{45}\ \mathrm{g.cm^2})$
$M/M_\odot$
GM1
TM1
NL3
Global Neutrality
$I\,(10^{45}\ \mathrm{g.cm^2})$
$M/M_\odot$
GM1
TM1
NL3

GR Magnetic Field

$$f = -\frac{3}{8}\left(\frac{R}{M_0}\right)^3\left[\ln(N^2) + \frac{2M_0}{R}\left(1 + \frac{M_0}{R}\right)\right], \quad (1)$$

$$N = \sqrt{1 - \frac{2M_0}{R}}, \quad (2)$$

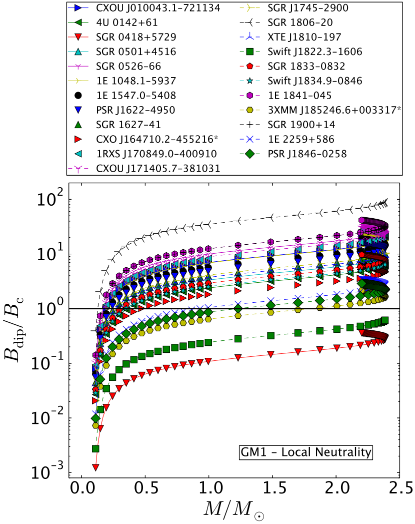
$$B \sin\chi = \frac{N^2}{f}\left(\frac{3c^3}{8\pi^2}\frac{I}{R^6}P\dot{P}\right)^{1/2}. \quad (3)$$

1 Rezzolla and Ahmedov, **MNRAS 352, 1161 (2004)**.

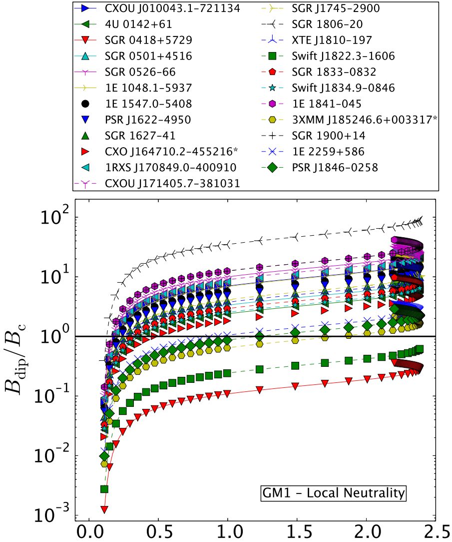
Dipolar Magnetic Field

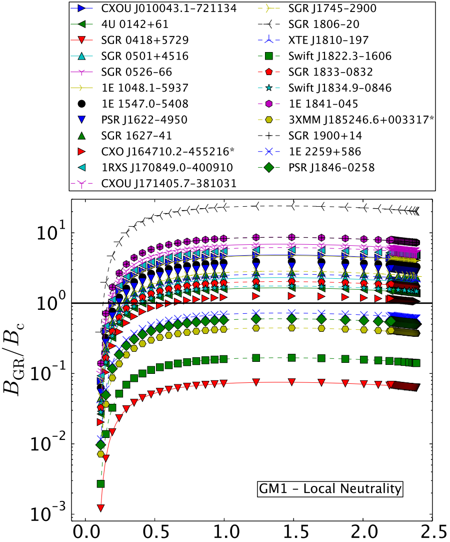
Canonical NS

Source	B_{NS}/B_c
CXOU J010043.1-721134	8.9
4U 0142+61	3.0
SGR 0418+5729	0.1
SGR 0501+4516	4.2
SGR 0526-66	12.6
1E 1048.1-5937	8.7
1E 1547.0-5408	7.2
PSR J1622-4950	6.2
SGR 1627-41	5.0
CXO J164710.2-455216*	2.3
1RXS J170849.0-400910	10.6
CXOU J171405.7-381031	11.3
SGR J1745-2900	5.2
SGR 1806-20	44.3
XTE J1810-197	4.7
Swift J1822.3-1606	0.3
Swift J1834.9-0846	3.2
1E 1841-045	15.9
3XMM J185246.6+003317*	0.8
SGR 1900+14	15.8
1E 2259+586	1.3
PSR J1846-0258	1.1

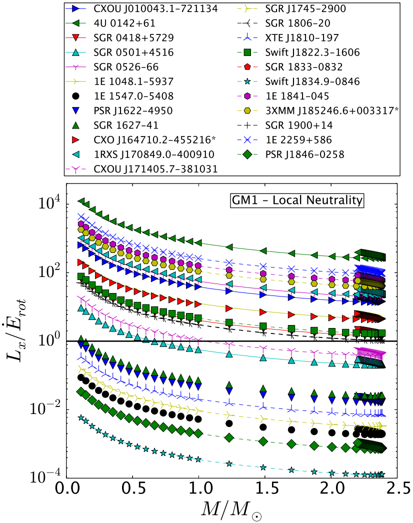


GR Magnetic Field





$L_X / \dot{E}_{rot}$ - Efficiency

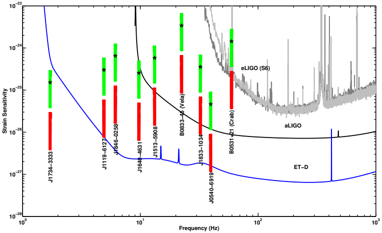


GWs from pulsars with measured braking index - papers submitted to PRD RC and EPJ C

- GWs + magnetic dipole brakes can naturally explain the measured braking index.
- PSR J1640 ($n = 3.15$): the amplitude h of the GW is around a factor four lower than the h modeled exclusively by GW energy loss.
- aLIGO and ET Telescope.

Table 1 Periods (P) and their first derivatives ($\dot{P}$) for Pulsars with known braking indices (n).

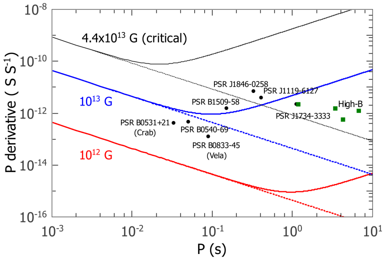
Pulsar	P (s)	$\dot{P}$ (10^{-13} s/s)	n
PSR J1734-3333	1.17	22.8	0.9 ± 0.2
PSR B0833-45 (Vela)	0.089	1.25	1.4 ± 0.2
PSR J1833-1034	0.062	2.02	1.8569 ± 0.0006
PSR J0540-6919	0.050	4.79	2.140 ± 0.009
PSR J1846-0258	0.324	71	2.19 ± 0.03
PSR B0531+21 (Crab)	0.033	4.21	2.51 ± 0.01
PSR J1119-6127	0.408	40.2	2.684 ± 0.002
PSR J1513-5908	0.151	15.3	2.839 ± 0.001
PSR J1640-4631	0.207	9.72	3.15 ± 0.03



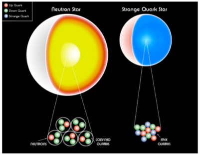
The influence of QVF on pulsars (Coelho, Pereira and Araujo - ApJ 2016)

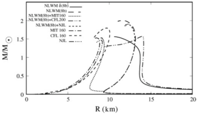
- when the magnetic field of a given system is close to B_c, quantum effects should play a noteworthy role there...

$$\dot{P} = \frac{4\pi^2 B_0^2 R^6 \sin^2\phi}{3IPc^3} + \frac{\alpha B_0^4 R^4 P \sin^2\phi}{75 I\pi c B_c^2}$$



Neutron stars or quark stars?)





- radius of a neutron or quark star dependent on the equation of state of the nucleon/quark matter
- phase transition changing the energy content of the star

$$E_{\rm grav} \sim \frac{GM^2}{R}$$

$$\Rightarrow \Delta E_{\rm grav} \sim -\frac{GM^2}{R}\left(\frac{\Delta R}{R}\right)$$

for $M = 1.5\ \mathrm{M}_\odot$ and $\Delta R/R \sim 0.2$

$$\Delta E_{\rm grav} \sim -10^{53}\ \mathrm{erg}$$

In progress...

- Magnetic and Thermal evolution of XDINs - *(Negreiros, Bernal, Coelho, Malheiro and Rueda) submitted to MNRAS*
- AE Aqr, RX J0648.0 and X-ray modeling of polars (CYCLOPS-X) (w/ Claudia e JC)
- Optical Counterpart of SGRs/AXPs (Sarah Villanova)

Publications 2015-2016

- Lobato, R V ; COELHO, JAZIEL ; Malheiro, M . Particle acceleration and radio emission for SGRs/AXPs as white dwarf pulsars. Journal of Physics (Online), v. 630, p. 012015, 2015.
- Otoniel, E ; Malheiro, M ; COELHO, J G . Fermionic matter under the effects of high magnetic fields and its consequences in white dwarfs. Journal of Physics (Print), v. 630, p. 012039, 2015.
- Pereira, Jonas P. ; COELHO, JAZIEL G. ; Rueda, Jorge A. Physical Review. D. Particles, Fields, Gravitation, and Cosmology (Online), v. 91, p. 069901, 2015.
- Rafael C. R. de Lima ; Coelho, J.G. et al. Analysis of the properties of SGRs and AXPs with realistic neutron star configurations. AIP Conference Proceedings, v. 1693, p. 030009, 2015.
- Lobato, R V ; COELHO, J G ; Malheiro, M . Radio pulsar death lines to SGRs/AXPs and white dwarfs pulsars. AIP Conference Proceedings, v. 1693, p. 030003, 2015.

Publications 2015-2016

- Jaziel G. COELHO, Jonas P. Pereira, Jose C. N. de Araujo, The influence of QVF on Pulsars, ApJ 2016
- M. Malheiro, R. M. Marinho, R. V. Lobato, J. G. COELHO, Ultra-Magnetized White Dwarfs are Stable?, IJMPC 2016
- R. V. Lobato, M. Malheiro, J. G. COELHO, SGRs as white dwarf pulsars: sources of ultra-high energetic photons with $E \sim 10^{21}$ eV, IJMPC 2016
- Rafael C. R. de Lima ; COELHO, J.G. et al., IJMPC 2016
- Magnetars and White Dwarf Pulsars, Ronaldo V. Lobato, Manuel Malheiro, Jaziel G. COELHO, to appear in a Special Issue of the IJMPD 2016
- D. L. Caceres, J. G. COELHO, J. Rueda and R. Ruffini, submitted to MNRAS 2016
- R. Lobato, J. G. COELHO, M. Malheiro, *Model of radio emition for SGRs/AXPs as white dwarfs pulsars*, to be submitted 2016