Aspen Center for Physics

Physical Applications of Millisecond Pulsars

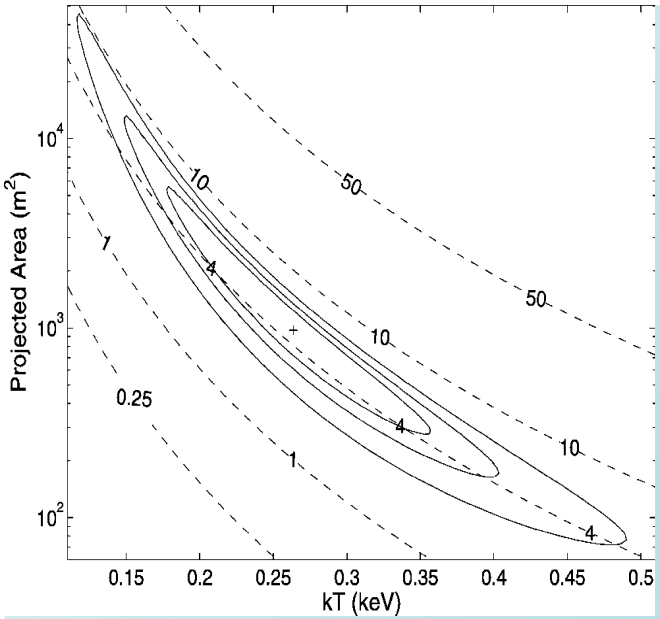
The Partially Screened Gap Model for MSPs

George Melikidze

In collaboration with

Janusz Gil and Andrzej Szary

J. Kepler Institute of Astronomy,
University of Zielona Góra

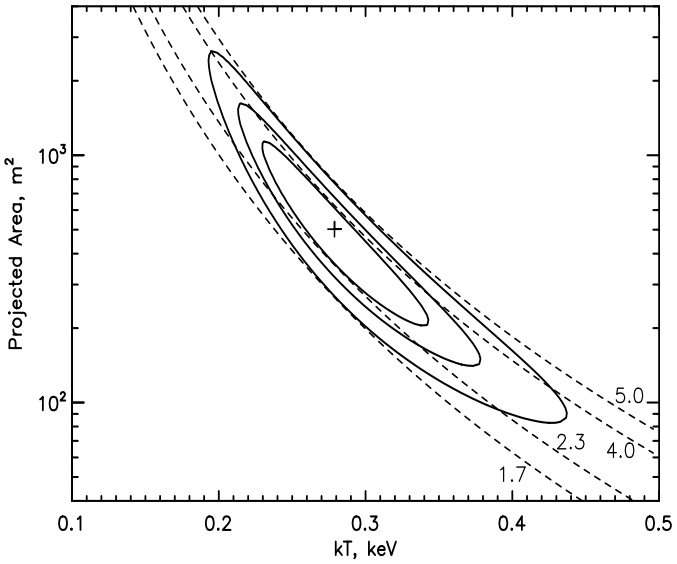


PSR B0943+10

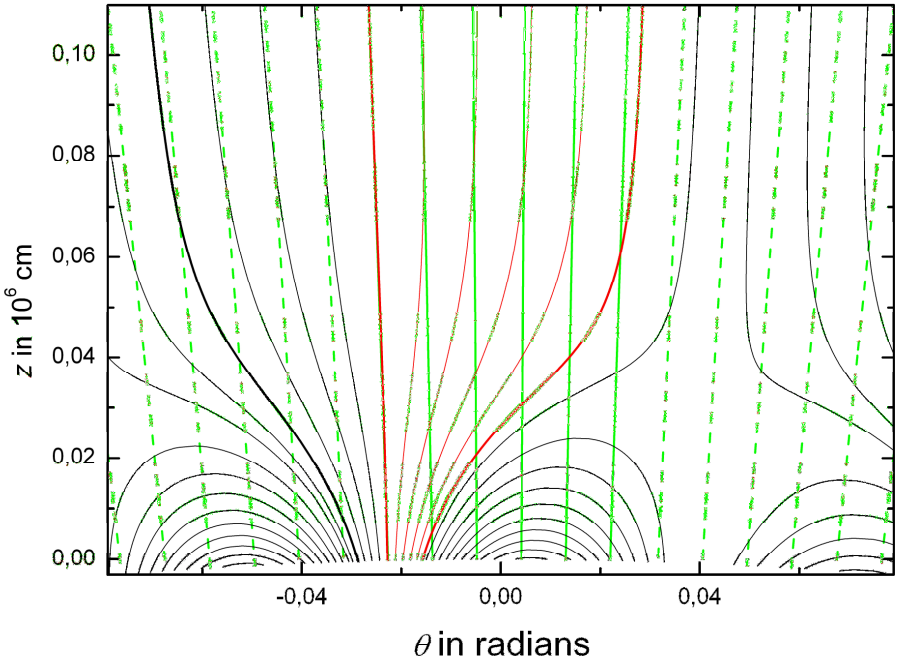
$$b = \frac{A_{\rm PC}}{A_{\rm BB}} \approx 50$$

PSR B1133+16

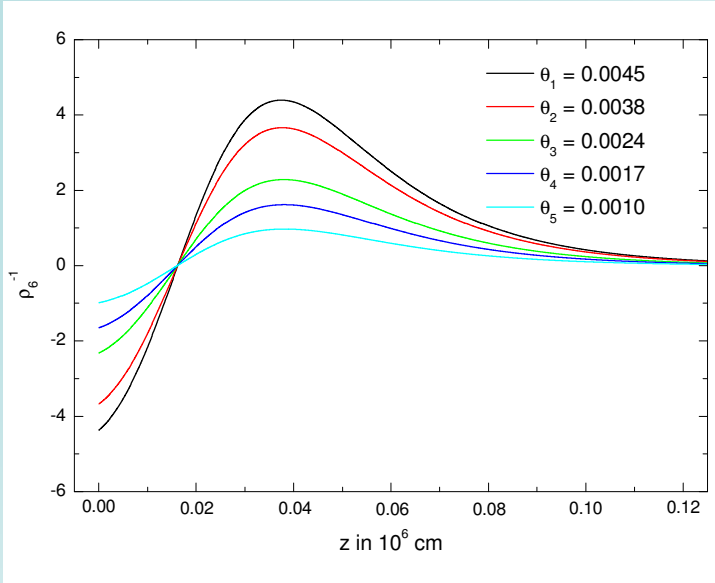
$b \approx 60$



Zhang, Sanwal & Pavlov, ApJ, 624, L109, 2005

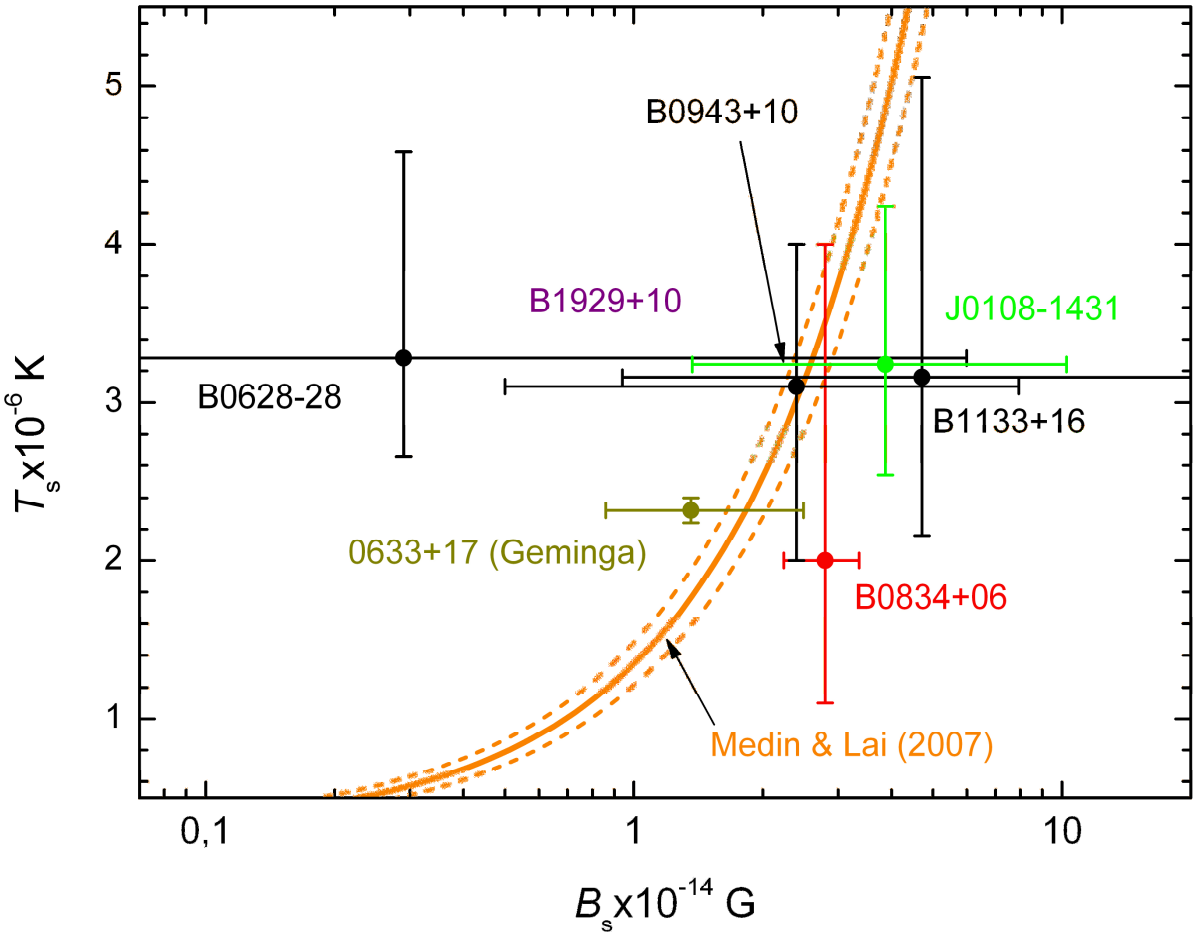


Kargaltsev, Pavlov, & Garmire, ApJ, 636, 406, 2006



Partially Screened Gap model

See the poster for details



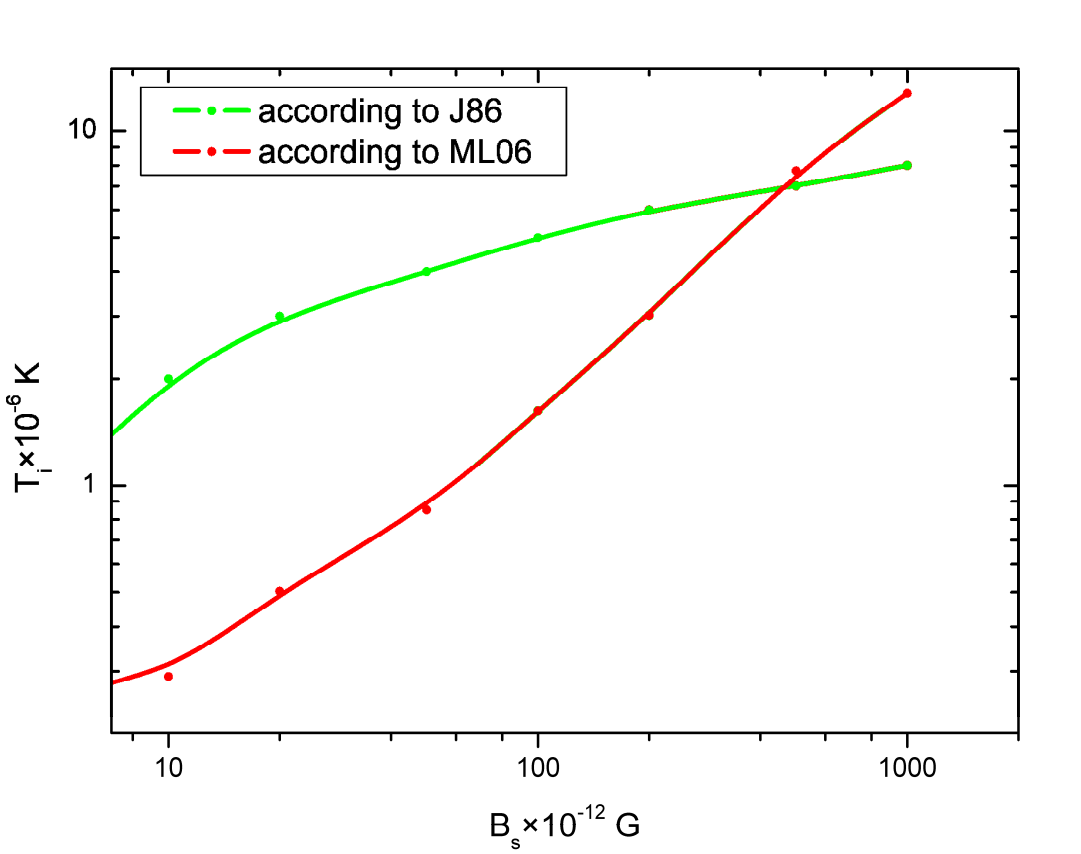
1. Back-flow of electrons heats the surface to temperature above 10^6 K.
2. Thermal ejection of iron ions causes a partial screening of the acceleration potential drop.
3. Consequently, backflow heating decreases as well.
4. Thus heating leads to cooling – this is a classical thermostat.

Partially Screened Gap model

$$b = \frac{A_{\rm PC}}{A_{\rm BB}} = \frac{R_{\rm PC}^2}{R_{\rm BB}^2} = \frac{B_{\rm s}}{B_{\rm d}^{(\rm s)}}$$

$$B_{\rm s} \Rightarrow T_{\rm i}$$

$$T_{\rm s} \approx T_{\rm i}$$



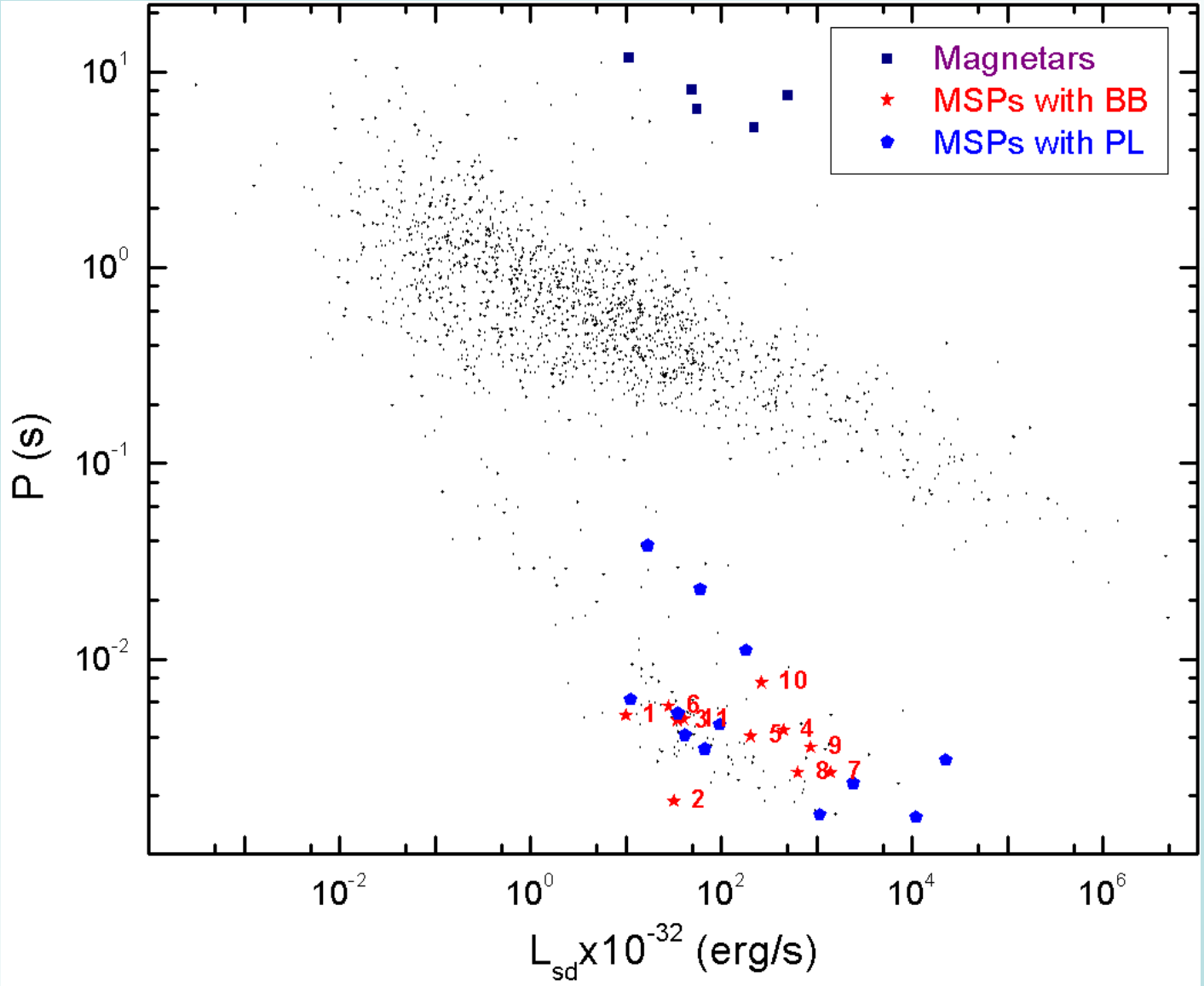
Jones, P.B. 1986, MNRAS.

Medin Z., Lai D., 2006, Phys. Rev. A.

$P - L_{sd}$ diagram for pulsars

MSPs with thermal X-ray

1 J1024-0719
2 J0034-0534
3 J0030+0451
4 J0024-7204U
5 J0024-7204Q
6 J0437-4715
7 J0024-7204F
8 J0024-7204O
9 J0024-7204E
10 J0024-7204T
11 J2124-3358



The fitting parameters of the BB components

1 J1024-0719
2 J0034-0534
3 J0030+0451
4 J0024-7204U
5 J0024-7204Q
6 J0437-4715
7 J0024-7204F
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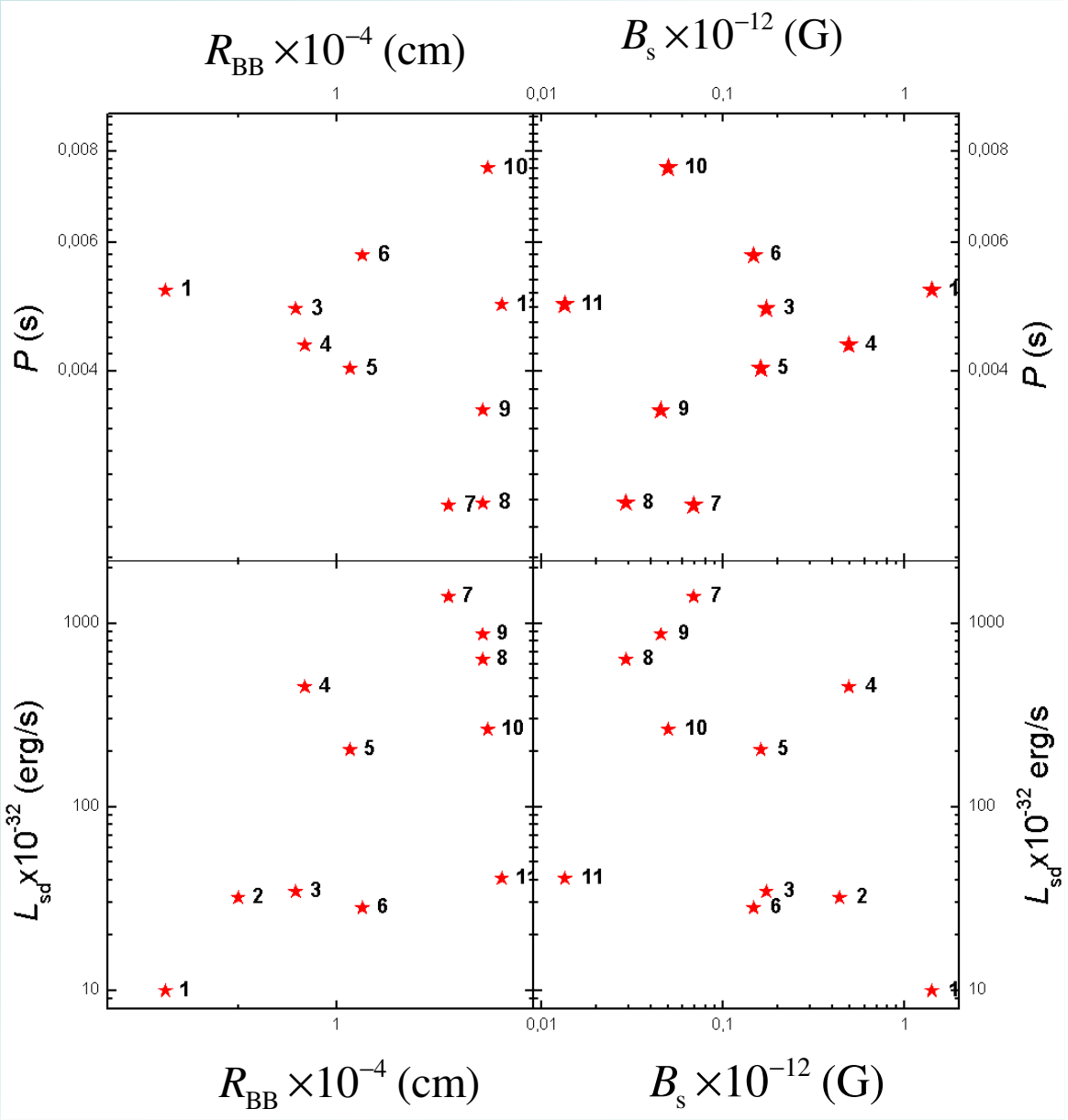
9 J0024-7204E
10 J0024-7204T
11 J2124-3358

Becker, ASSL, 2009;
Blagoev, ApJ, 2013;
etc.

$$T_{\mathrm{BB}} = 1 \div 3 \ \mathrm{MK}$$



$P - L_{\rm sd}$ diagram for pulsars

1 J1024-0719
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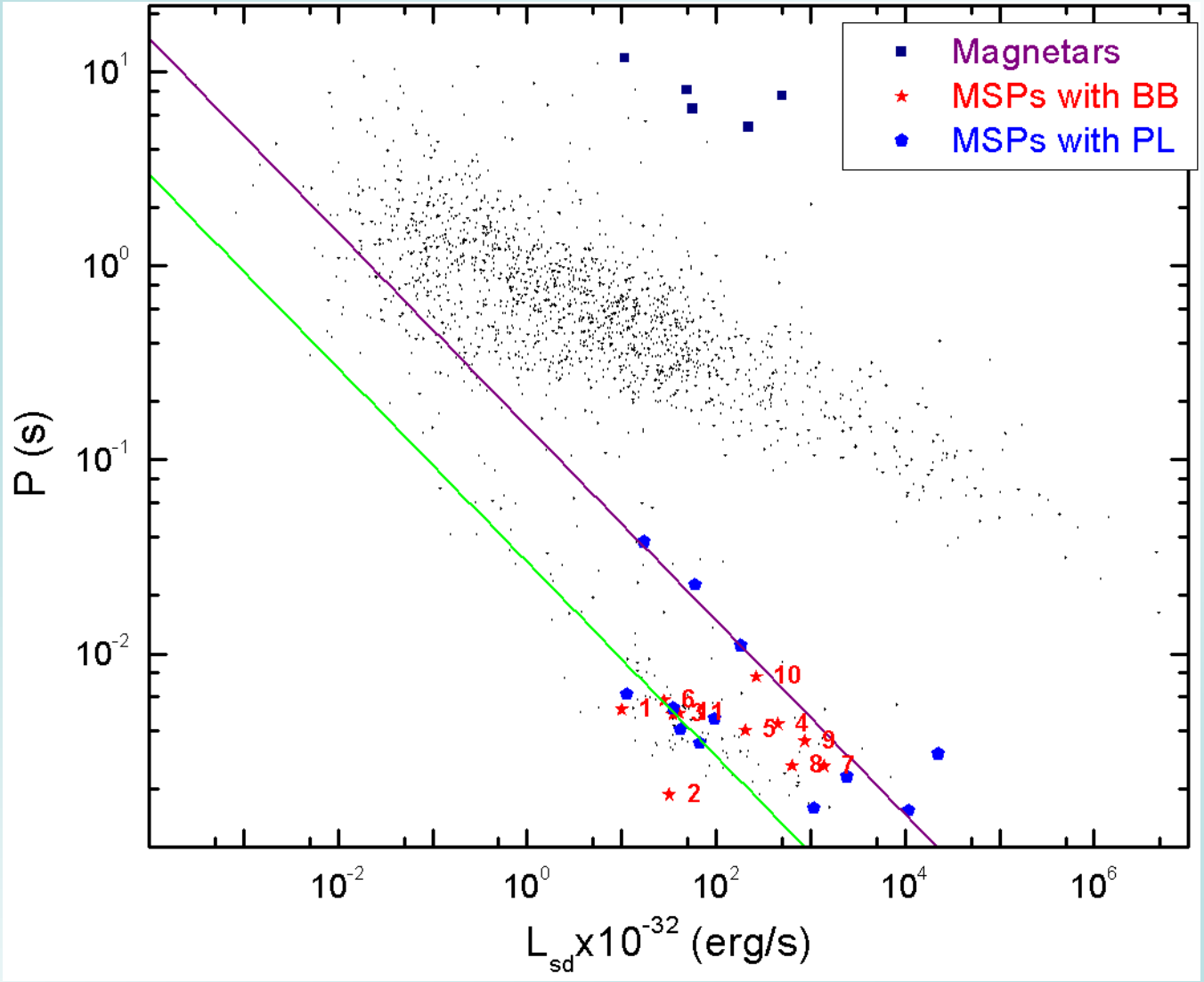


Green line:

$R_{\rm BB} = 10^4$ cm,

$B_{12}^{(s)} = 0.1;$

Purple line:

$R_{\rm BB} = 10^4$ cm,

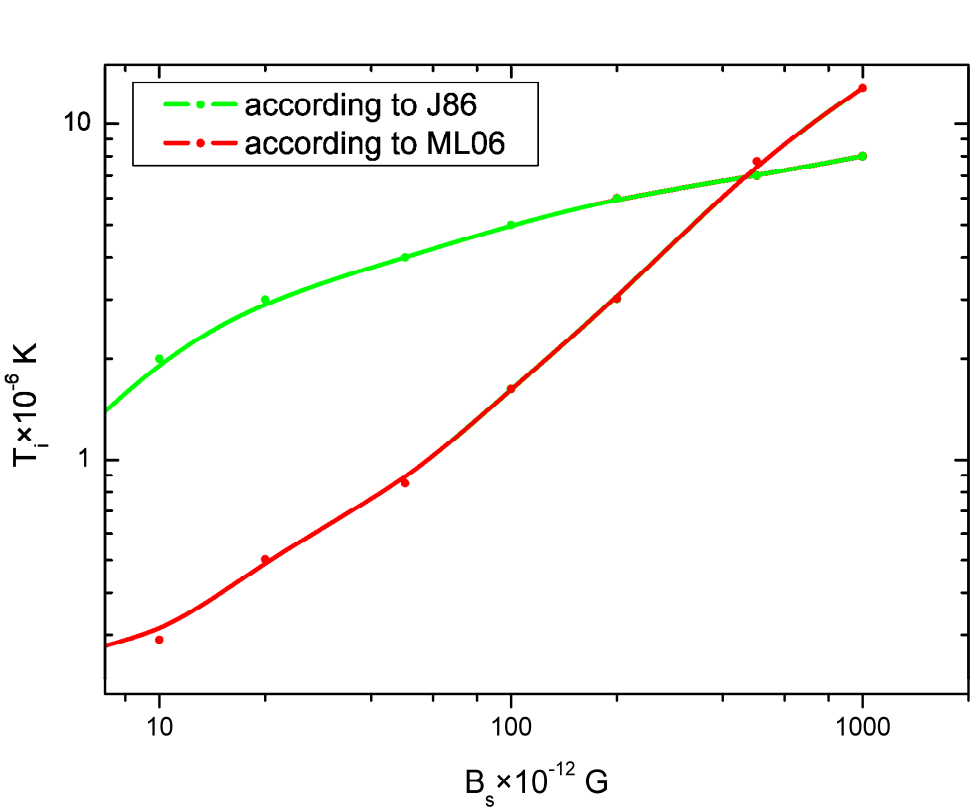
$B_{12}^{(s)} = 0.5;$

For MSPs

$$B_s \sim 10^{11}$$

$$T_i << 10^6 \text{ K}$$

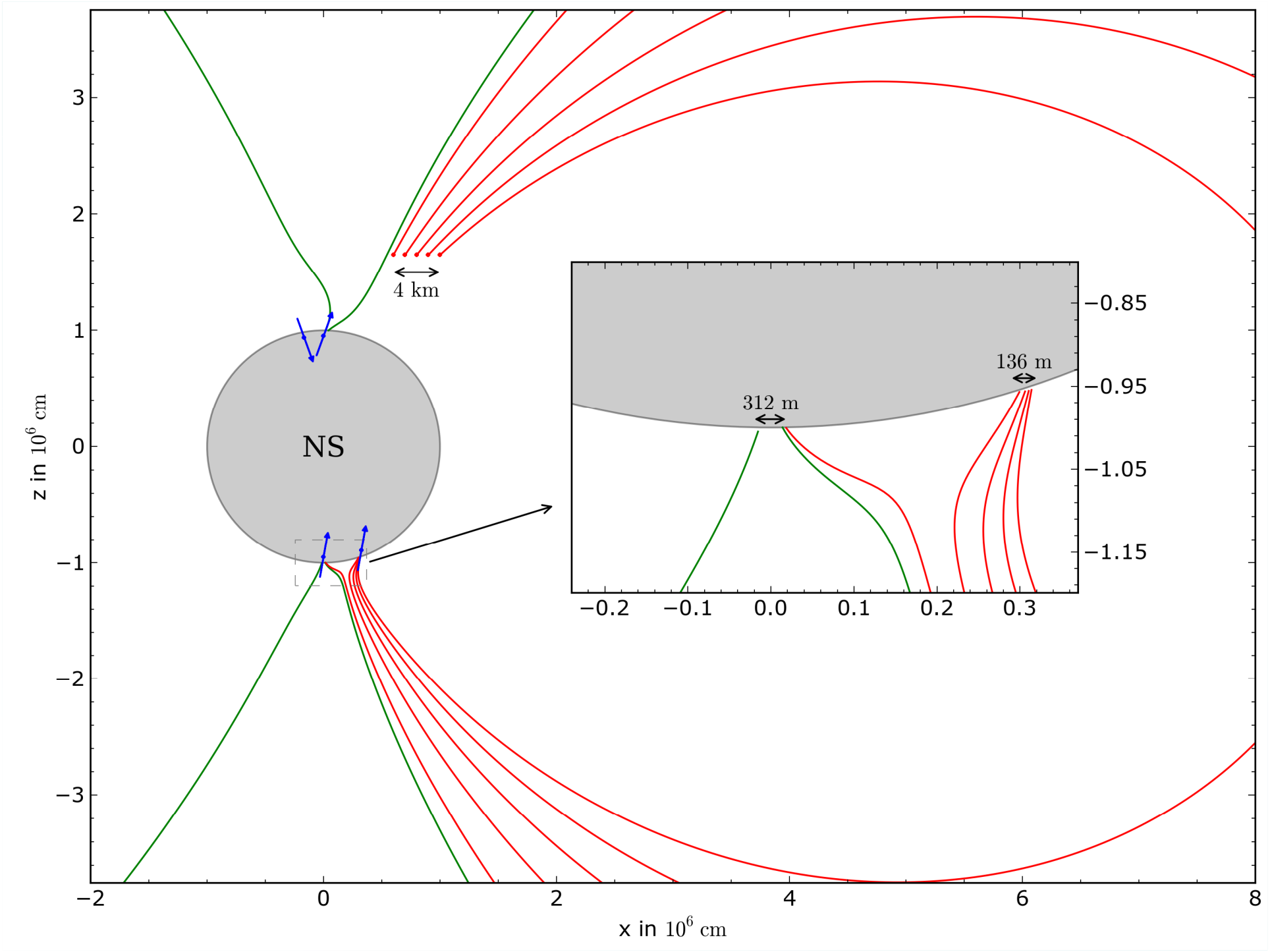
$$T << T_s$$

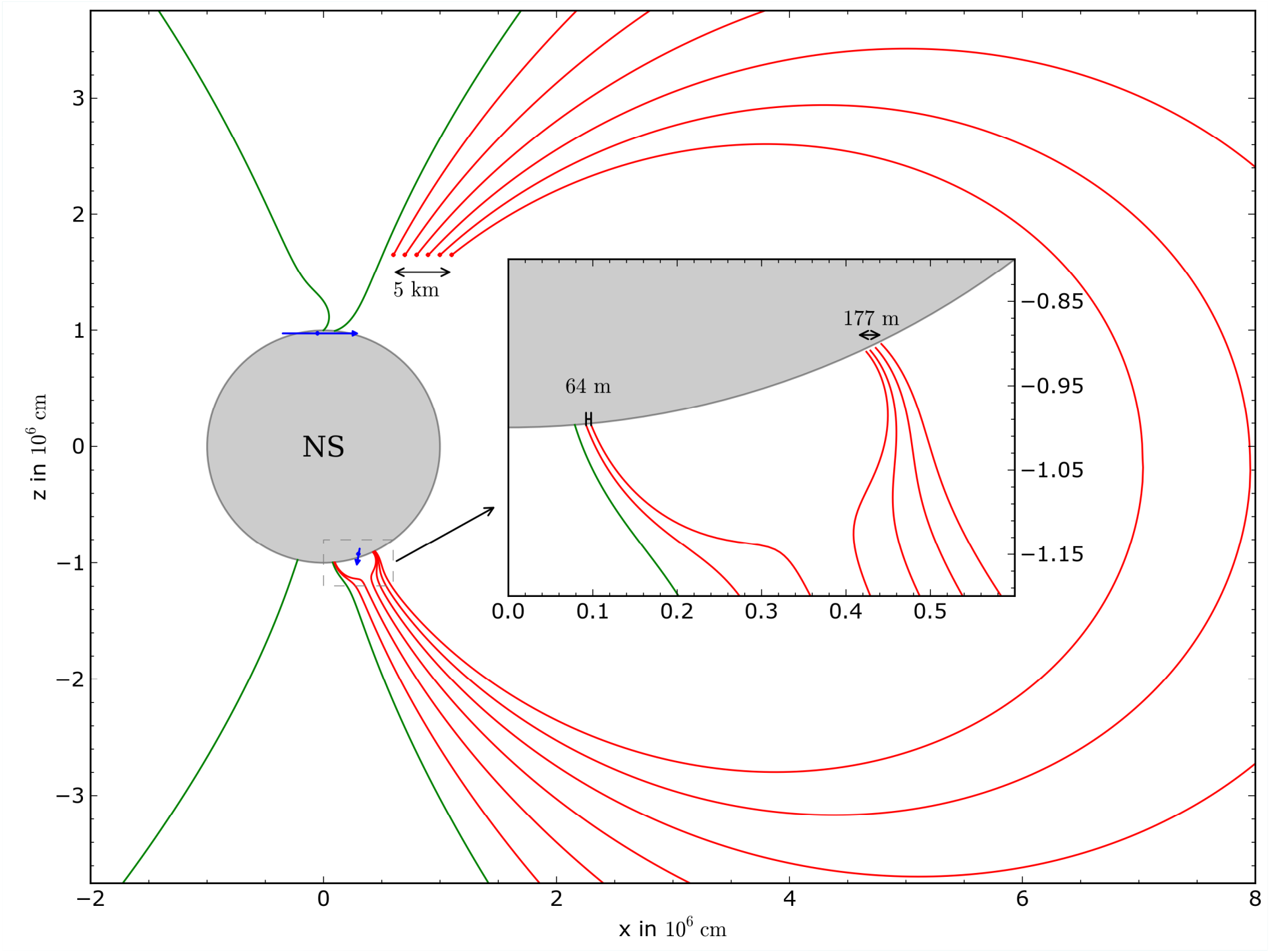


Thus particles cannot be accelerated along the bunch of field lines above the hot spot.

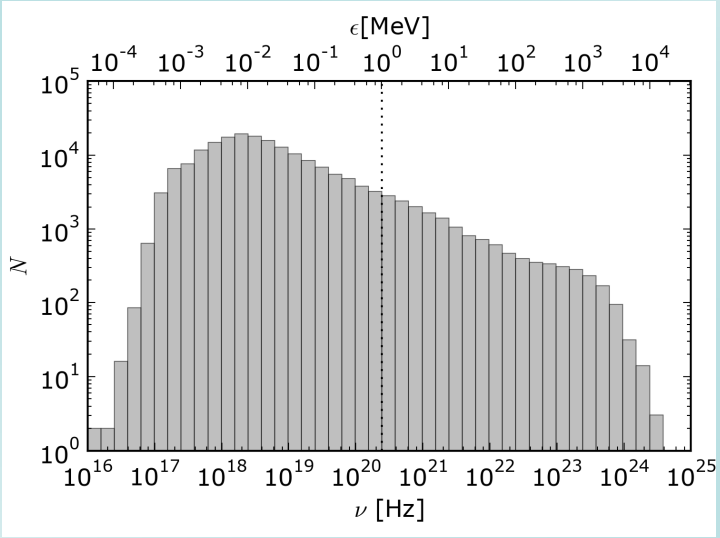
On the other hand the hot spot can be defined by the footprints of the closed field lines!

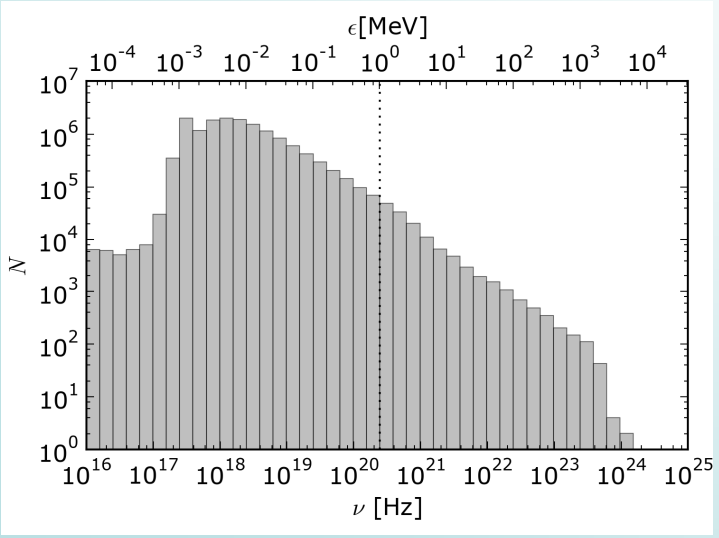
How? It's natural!

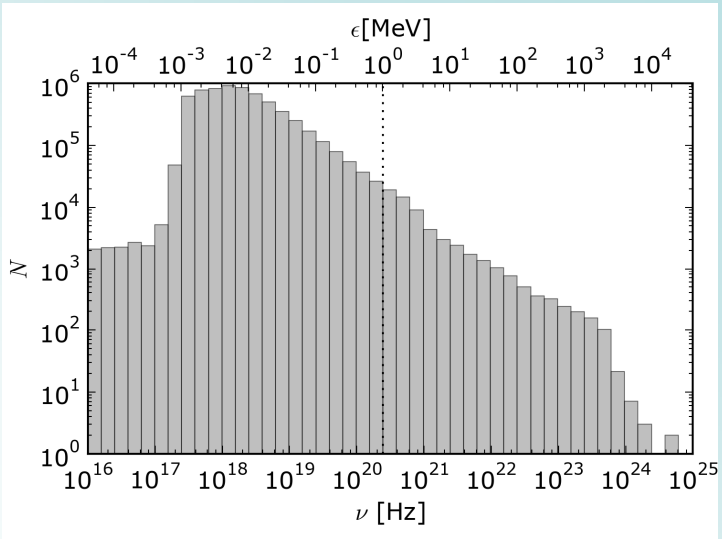

4 km
NS
312 m
136 m
z in 10^6 cm
x in 10^6 cm
3
2
1
0
−1
−2
−3
−2
0
2
4
6
8
−0.85
−0.95
−1.05
−1.15
−0.2
−0.1
0.0
0.1
0.2
0.3

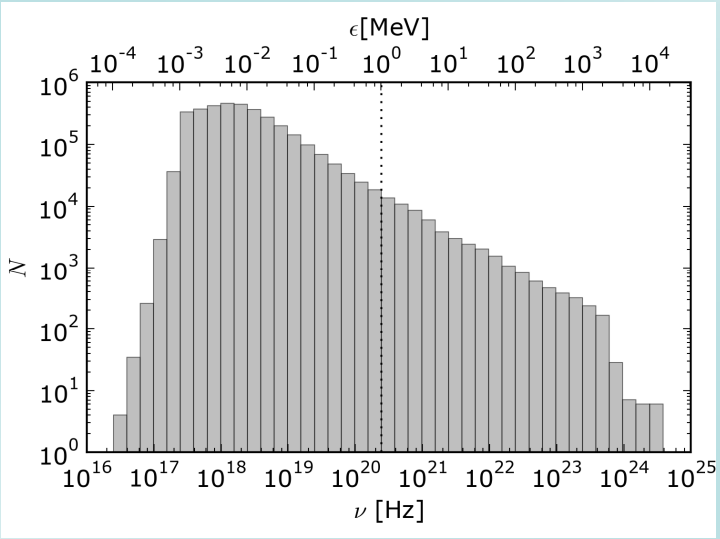

NS
5 km
177 m
64 m
z in 10^6 cm
x in 10^6 cm
3
2
1
0
−1
−2
−3
−2
0
2
4
6
8
−0.85
−0.95
−1.05
−1.15
0.0
0.1
0.2
0.3
0.4
0.5

Sample spectra of photons generated by the electron/positron moving along the different open field lines with $\gamma = 6\times10^{6}$

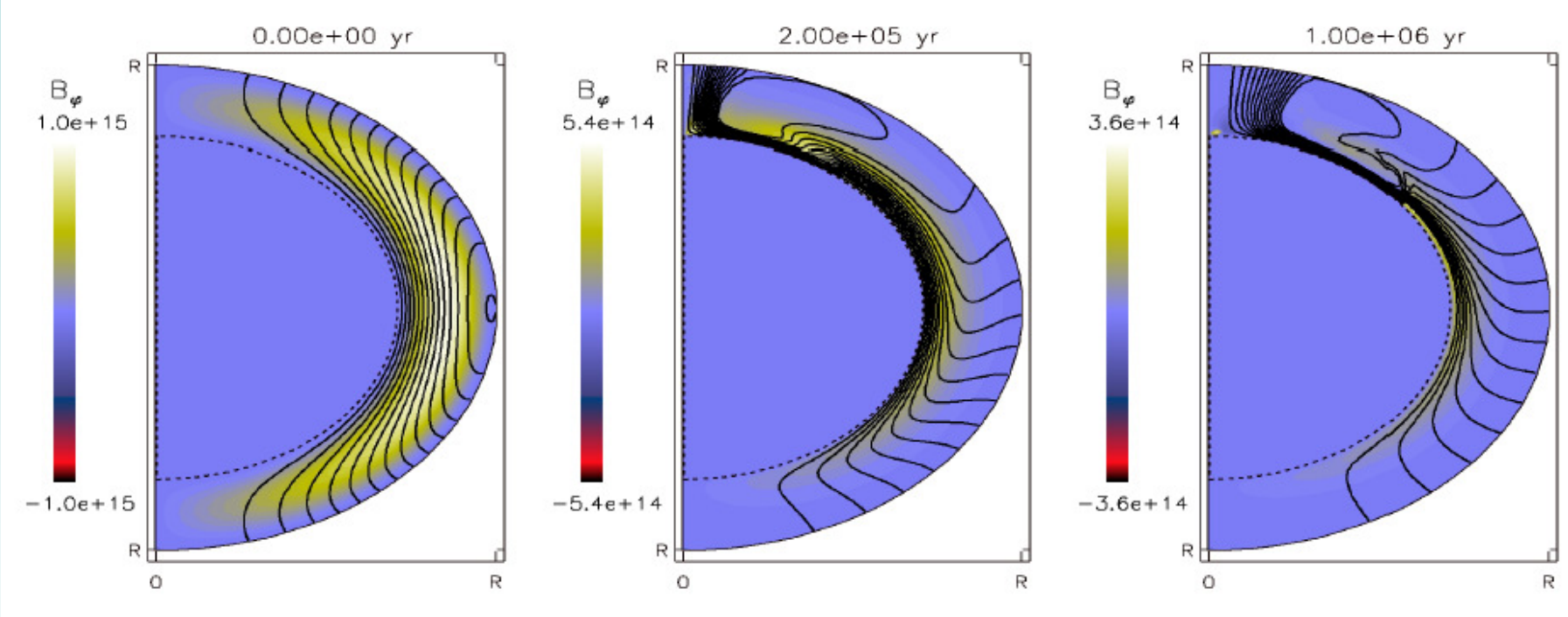








Hall drift in the crust of neutron stars



J. Pons & U. Geppert, A&A (2007, 2010)

Conclusions:

In MSPs the PSG inner acceleration region exists, but it is closer to a vacuum gap than in normal pulsars.

There are two pillars of the PSG model:

a. The magnetic field at the stellar surface differs essentially from the pure dipole structure.

b. The surface temperature is almost equal to the critical (ion) temperature.

In the case of MSPs we cannot observe the hot spot under the open field lines. The temperature is too low.

Conclusions:

Close to the star (few hundred meters) the curvature photons create pairs at such high Landau levels that most of the energy is radiated away as synchrotron radiation in the range of gamma and X-rays.

Relatively less number of photons create pairs at much larger distances (from a kilometer or more) in the area of closed field lines. These particles move along the closed field lines and heat the stellar surface creating the hot spots.

The End!

Thank you for your attention!