What makes pulsars and magnetars radio laud?

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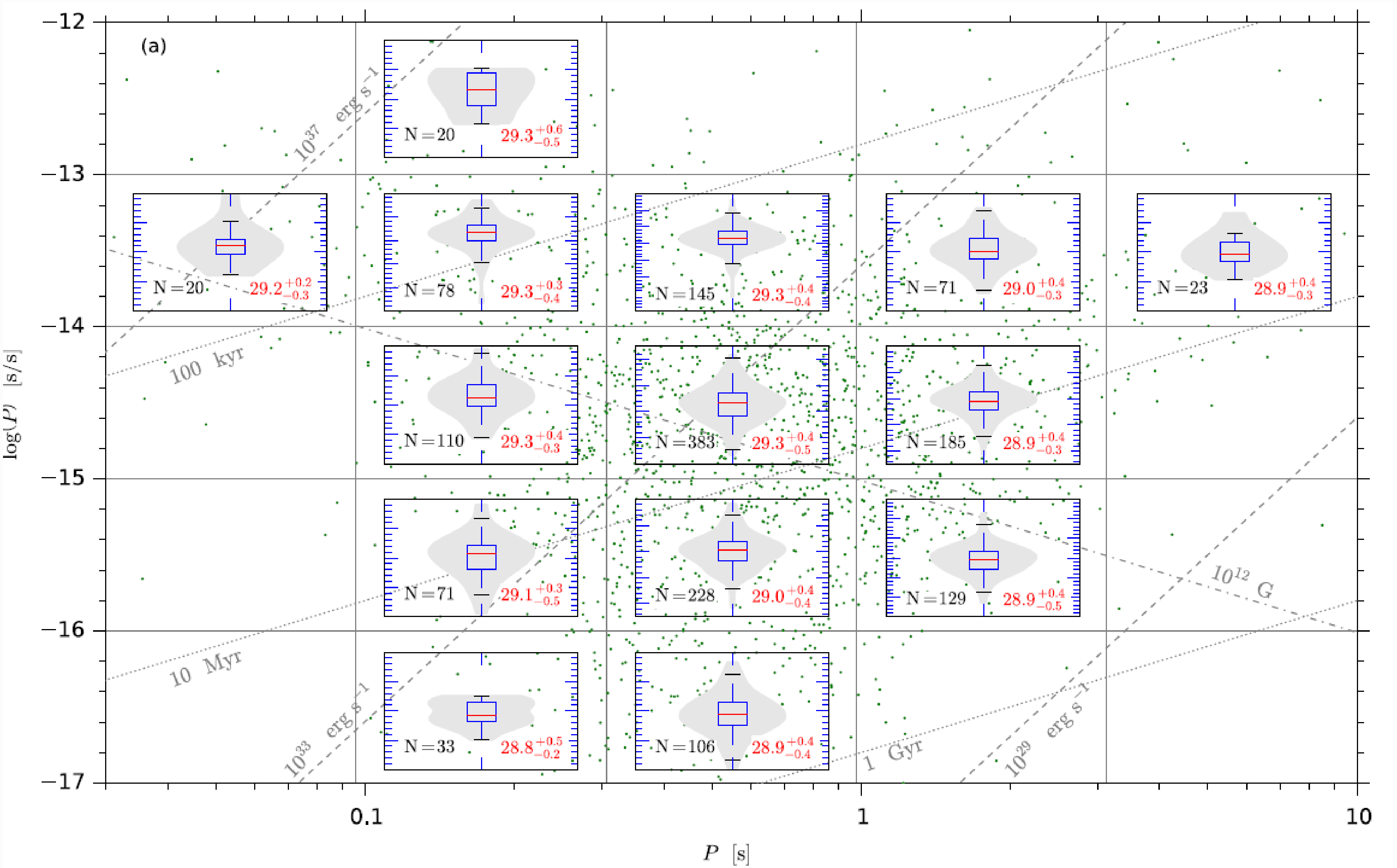
Partially Screened Gap (PSG model)

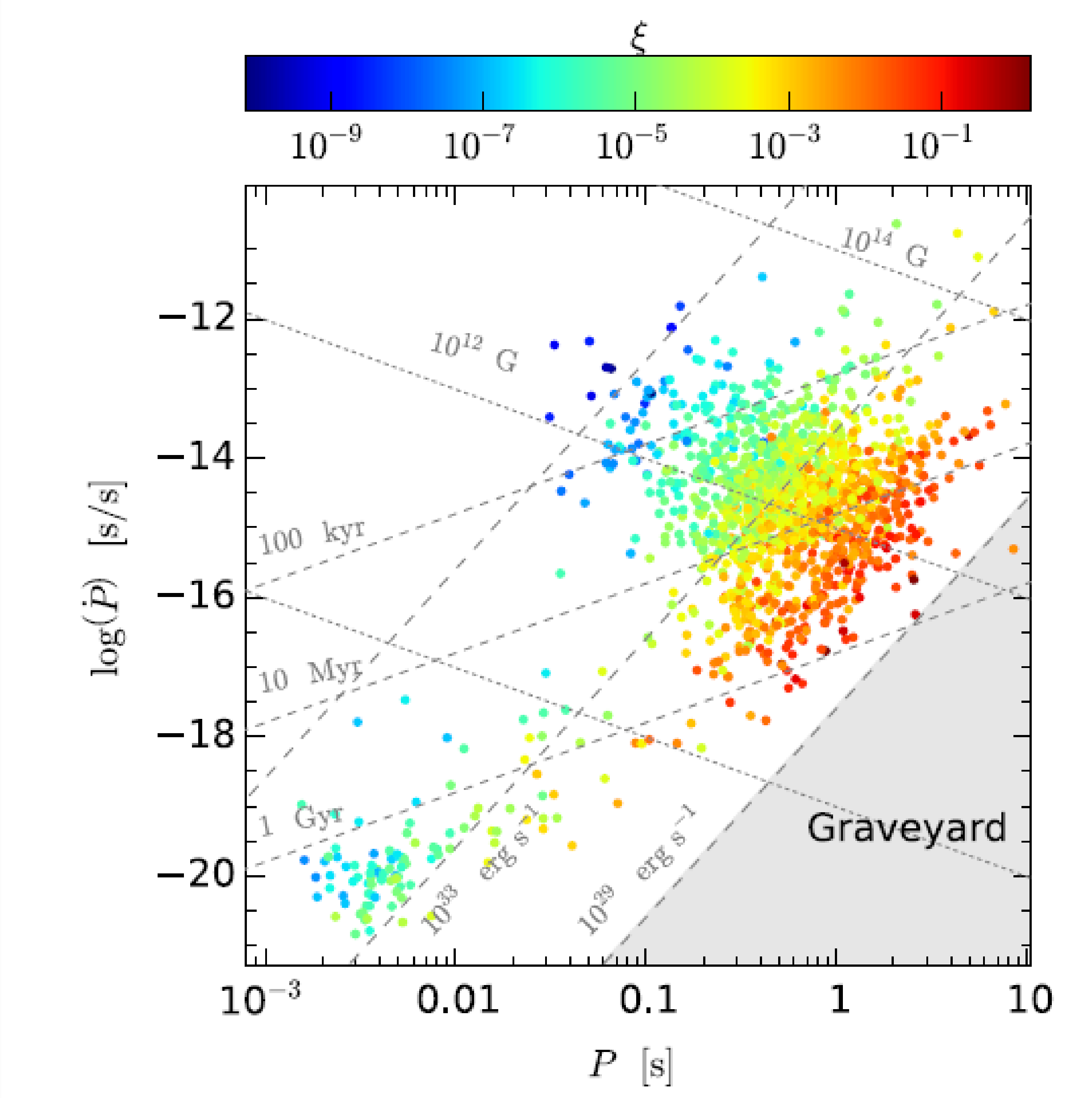
1. Positive charges cannot be supplied at the rate that would compensate the inertial outflow through the light cylinder. As a result, significant potential drop develops above the polar.
2. Back-flow of electrons heats the surface to temperature above 10^6 K.
3. Thermal ejection of iron ions causes a partial screening of the acceleration potential drop.
4. Consequently, backflow heating decreases as well.
5. Thus heating leads to cooling – this is a classical thermostat.
6. Surface temperature T_s is thermostatically regulated to retain its value close to critical temperature T_i above which thermal ion flow reaches co-rotation limited level (Goldreich-Julian charge density)
7. According to calculations of cohesive energy by Medin-Lai (2007), this can occur if the surface magnetic field is close to 10^{14} G. In majority of radio pulsars this has to be highly non-dipolar crust anchored field.

Does the radio-luminosity really depend on P and $\dot{P}$?



A. Szary et al. 2014 ApJ

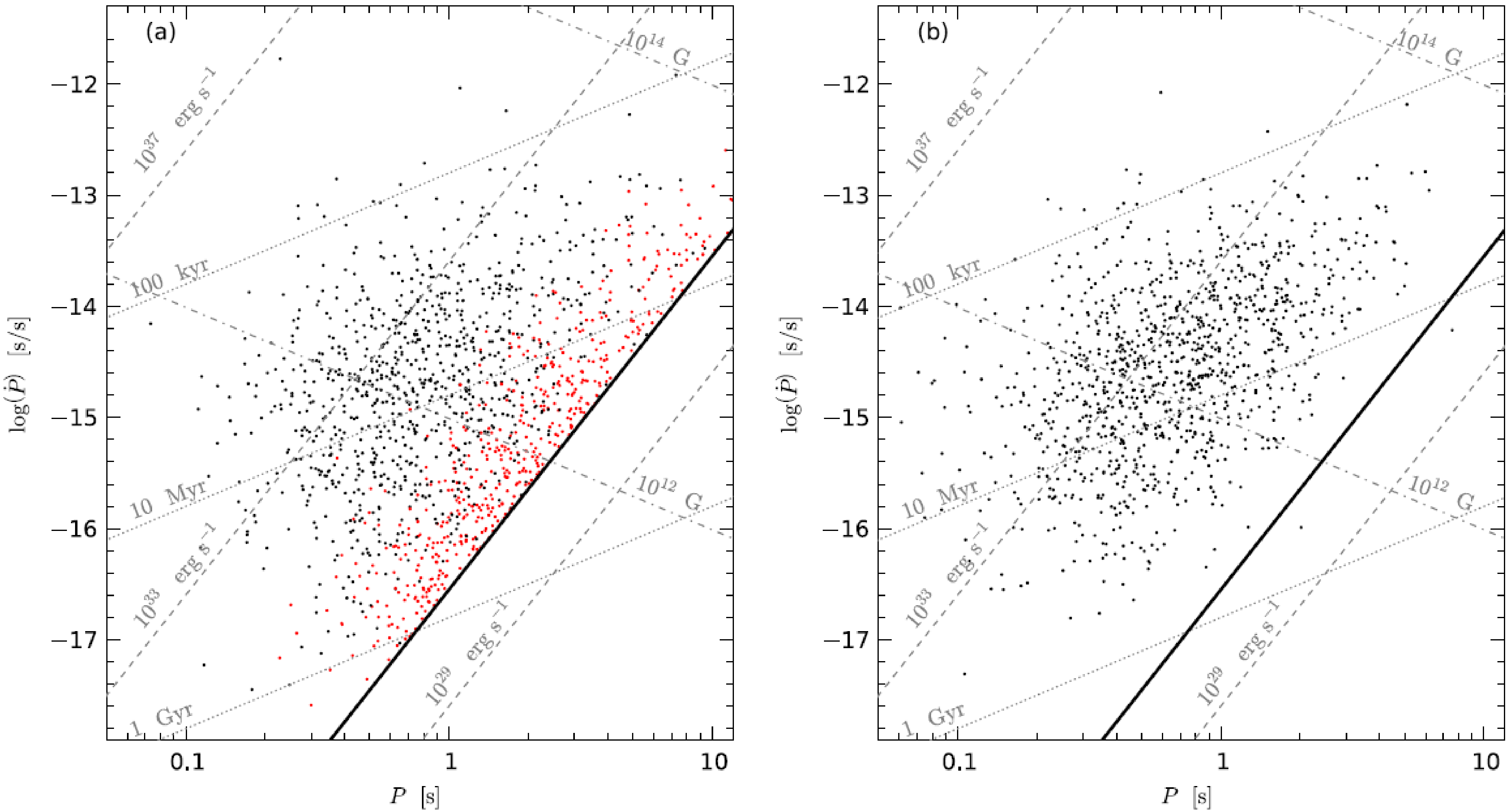
$P - \dot{P}$ diagram shown for a sample of the 1436 pulsars used in the analysis of radio efficiency. Colors correspond to different values of radio efficiency.



$P - \dot{P}$ diagram for a typical MC realization.

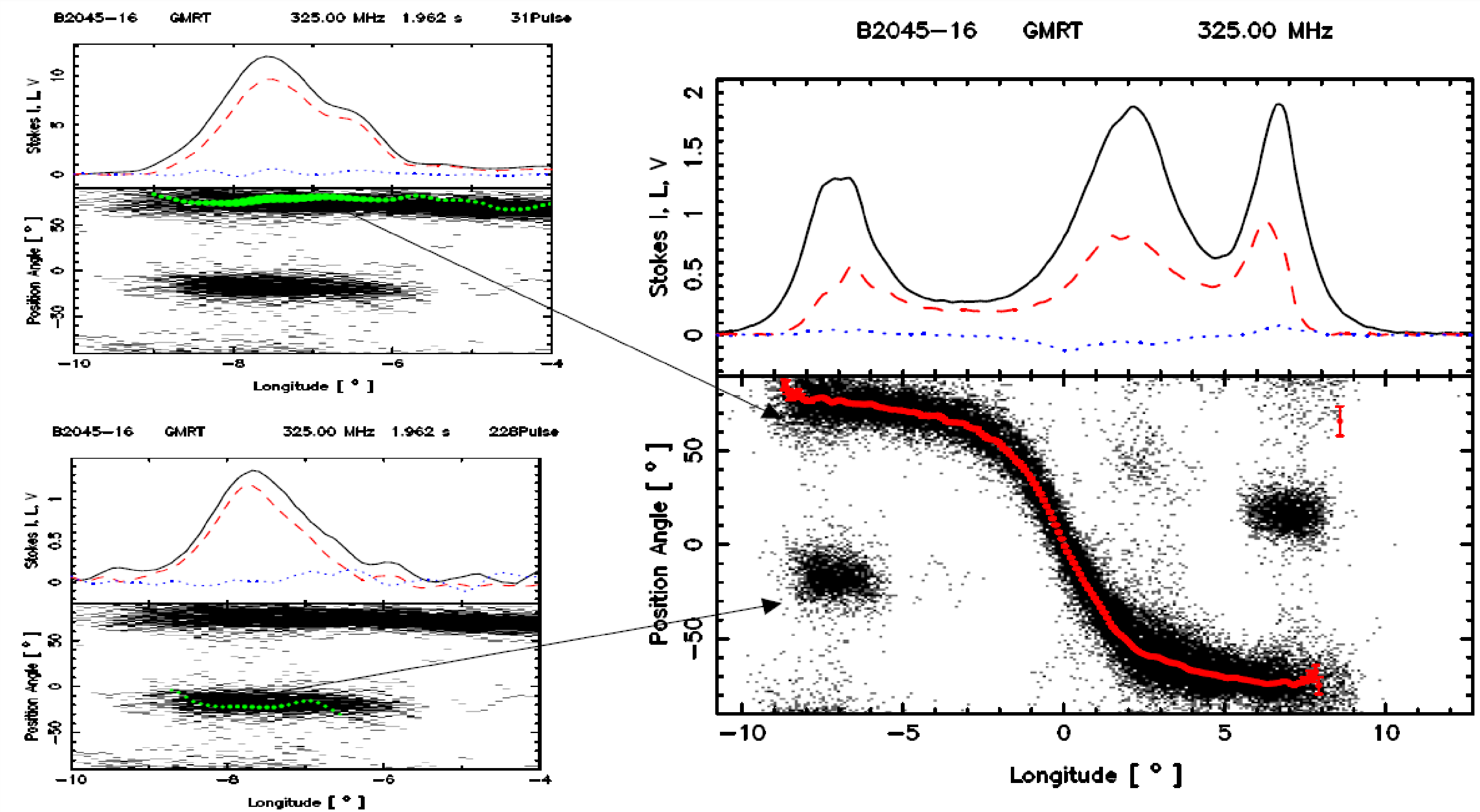
In panel (a) pulsars were rejected based on the modeled death line (Bhattacharya et al. 1992) – the thick solid line, while in panel (b), pulsars were rejected based on the radio efficiency limit $\xi < 0.01$.

Red dots correspond to pulsars with radio efficiency greater than 1%.



But where does the radio emission comes from?

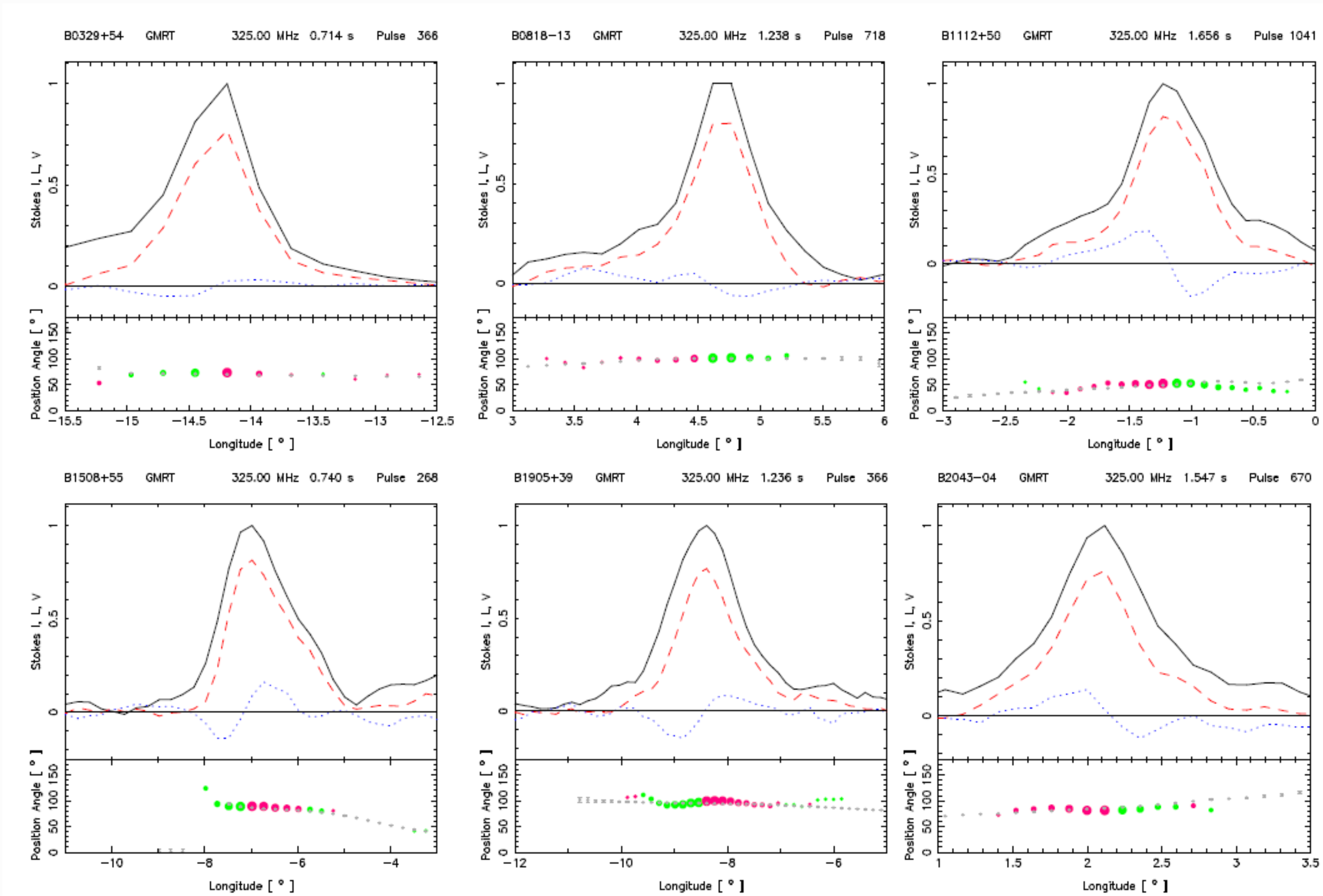
The crucial information comes from the observations of highly polarized subpulses into single pulses



D. Mitra et al. in preparation

But where does the radio emission comes from?

Radio observations show:

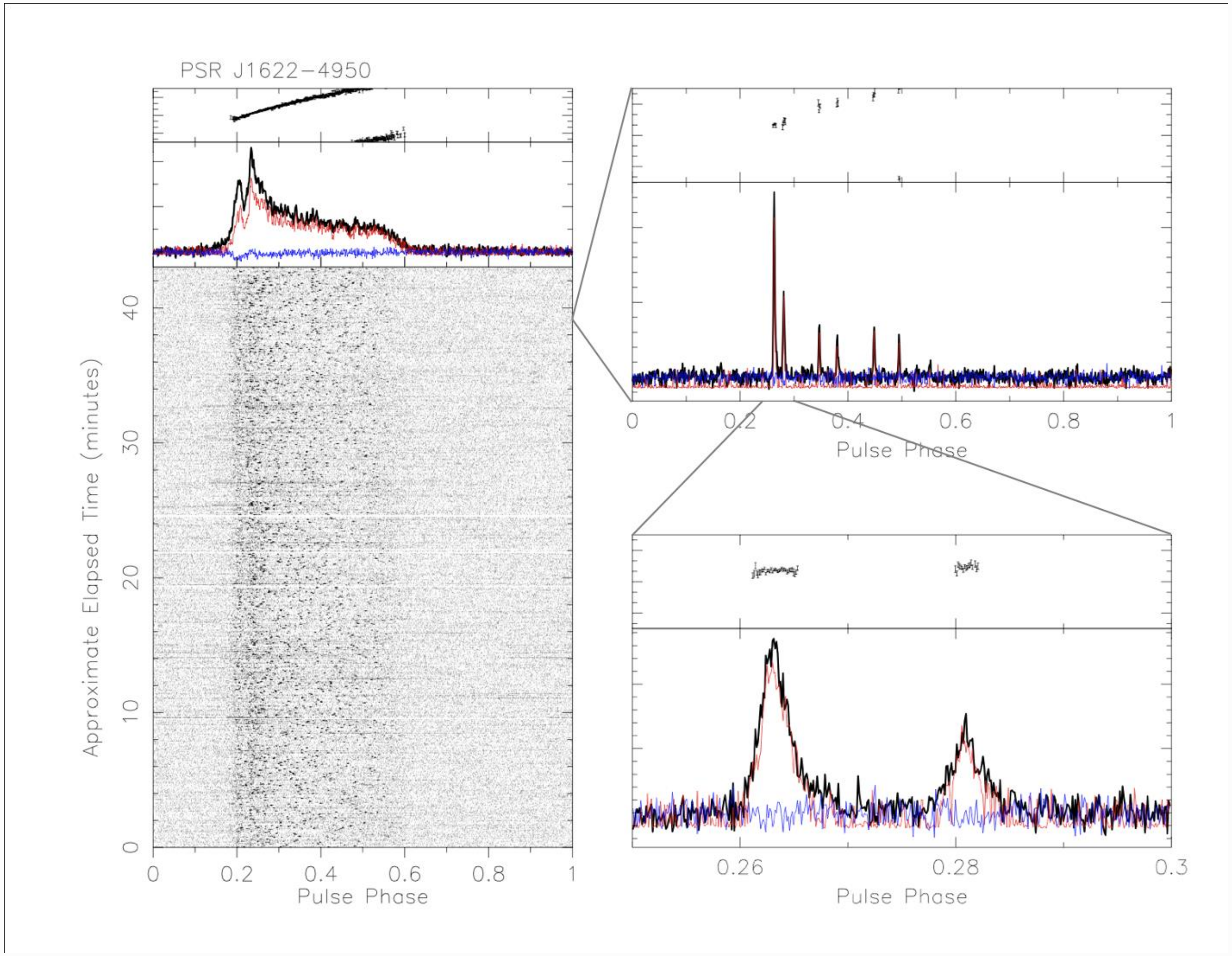


Radio pulsars

Mitra, Gil & Melikidze, 2009, ApJ

But where does the radio emission comes from?

Radio observations show:



Radio magnetar PSR J1622–4950

L. Levin, M. Bailes, S. D. Bates, et al. MNRAS, 2012

But where does the radio emission comes from?

Radio observations show:

Johnston et al. (2005), Rankin (2007), Noutsos (2012 and 2013).

The proper motion direction

The absolute value of polarization position angle at the steepest gradient point.

The bimodal distribution of
Ψ=(PM, PA)
is centered around 0◦ and 90◦.

Mitra, D, Rankin, J. M. & Gupta, Y., 2007, MNRAS

PA should be parallel or perpendicular to the fiducial plane.

The (Coherent) Curvature Radiation

is the only mechanism which is sensitive to the plane of curved magnetic field lines

The Coherent Curvature Radiation

$$n^{-1/3} = \lambda_c$$

If the lengths of generated waves are less than λc we can treat the radiating particle as a free particle. Otherwise, the process should be treated as a collective effect.

$$L_1 \propto q^2$$

Radiation power of a particle possessing a charge q is proportional to q^2.

$$L_{\mathrm{ncoh}} = NL_1 \propto Nq^2$$

The non-coherent sum of N particle radiation.

$$L_{\mathrm{coh}} \propto (Nq)^2 = N^2 q^2$$

The Coherent Curvature Radiation

The first attempt – Coherent curvature radiation by the linear plasma waves (RS75)

Unsuccessful

The timescale of the radiative process must be significantly shorter than the plasma oscillation period

$$\omega_r > \omega_0$$

The linear characteristic dimension of bunches must be shorter than the wavelength of radiated wave

$$k_r < k_0$$

But $\omega_r \approx k_r c$ *and* $\omega_0 \approx k_0 c$

It is impossible to satisfy simultaneously the above two conditions!

The Coherent Curvature Radiation

The coherent radio emission of pulsars should be generated by means of some instabilities in the strongly magnetized relativistic electron-positron plasma

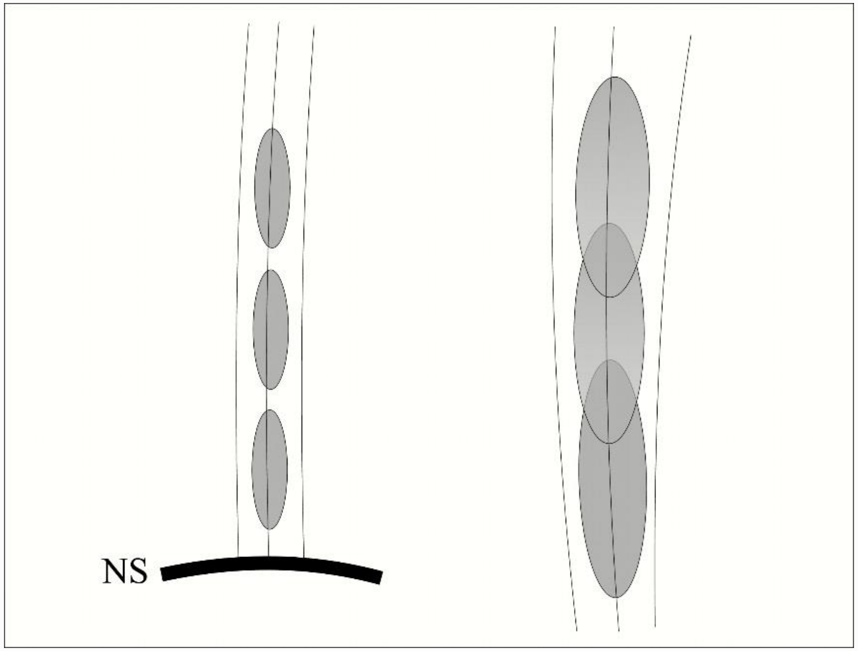
At the altitudes about 100 stellar radii or less the only instability that can arise in the magnetospheric plasma is the two-stream instability.

The two-stream instability triggered by the relative motion of two species of particles.

The Coherent Curvature Radiation

The two-stream instability:

Due to the non-stationary sparking discharge.



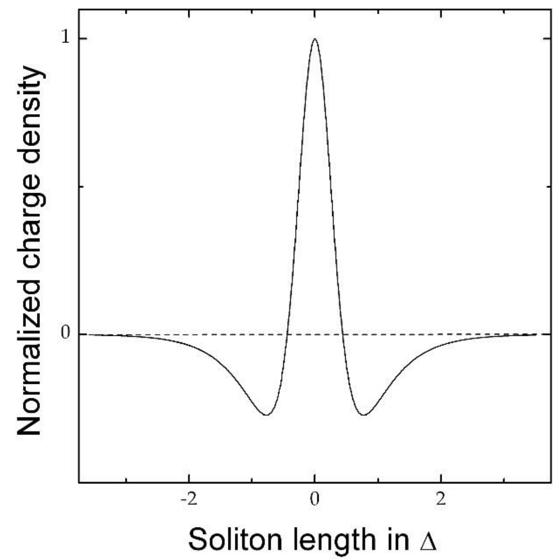
Usov, 1987, ApJ, 320, 333

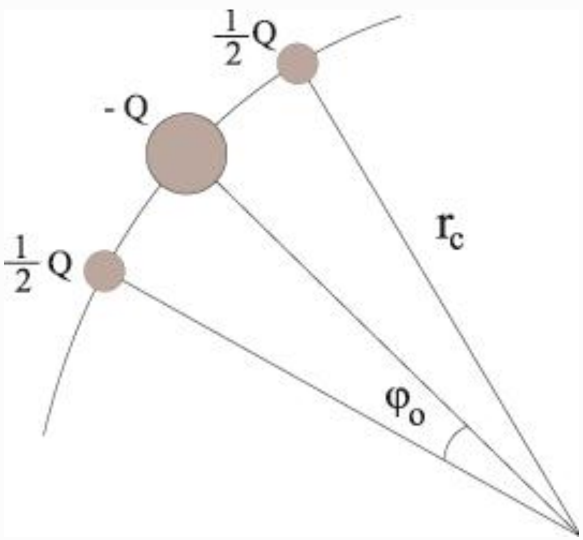
Asseo & Melikidze , 1998, MNRAS, 299, 51.

The Coherent Curvature Radiation

The Soliton Model for Coherent Curvature Radio Emission

Melikidze & Pataraya, 1980, Astrofizika
Melikidze, Gil & Pataraya , 2000, ApJ
Gil, J., Lyubarsky, Y., & Melikidze, G. I. 2004, ApJ

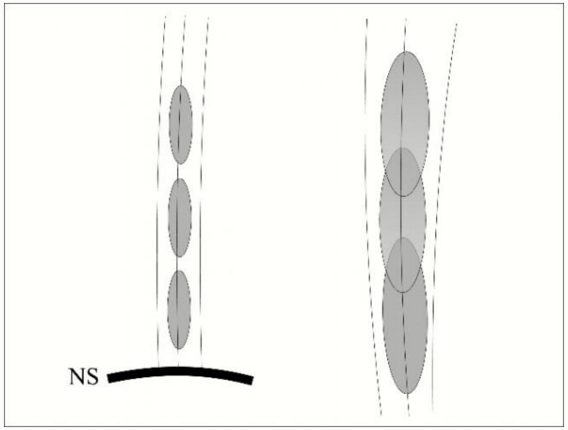


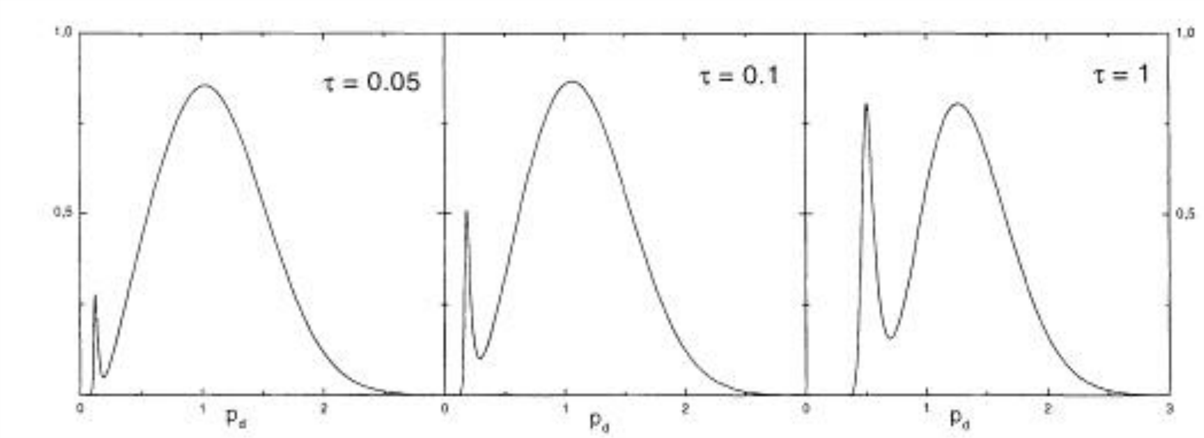


$$\rho' = \frac{\sum_\alpha e_\alpha \omega_{p\alpha}^2 \oint \frac{1}{(v-v_g)} \frac{d}{dp} \left(\frac{(v-v_g)}{(\omega_l - k_l v)^2} \frac{df_\alpha}{dp} \right) dp}{4\pi \sum_\alpha \omega_{p\alpha}^2 \oint \frac{1}{(v-v_g)} \frac{df_\alpha}{dp} dp} \times \frac{\partial^2}{\partial \xi^2} \mid E_\parallel^{(1)} \mid^2$$

The Coherent Curvature Radiation

The sparking discharge provides the necessary conditions for the two stream instability.



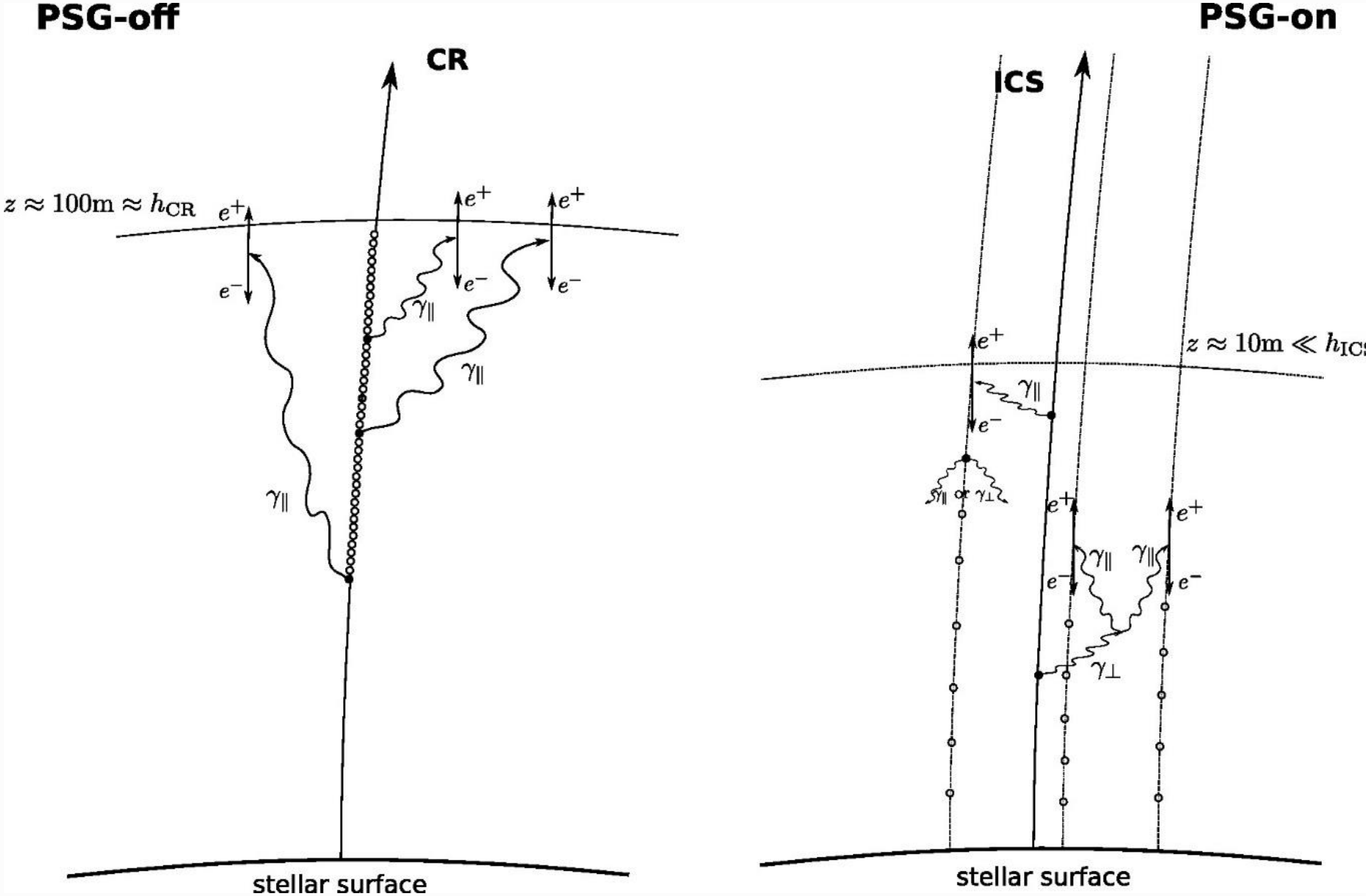


R_{em} ***The altitudes of the radio emission***

$$R_{\mathrm{em}} \approx 2\gamma_s^2 z$$

z ***The distance between two successive clouds***

Two different scenarios of gap breakdown.
A. Szary



Mode changing – Chameleon Pulsar

Conclusions

1. The sparking discharge provides the necessary conditions for the two stream instability.

2. ICS – dominated gap.
   a) PSG in Normal pulsars - the strong crust ancored magnetic Field.
   b) Magnetars – during the active phase with strong thermal x-ray emission.

3. The Langmuir turbulence creates and supports charged bunches.

4. Features of the coherent curvature radiation in the magnetized electron-positron plasma naturally explains the observed features of the radio emission.

The end.