Dependence of Pulsar death line on the equation of state

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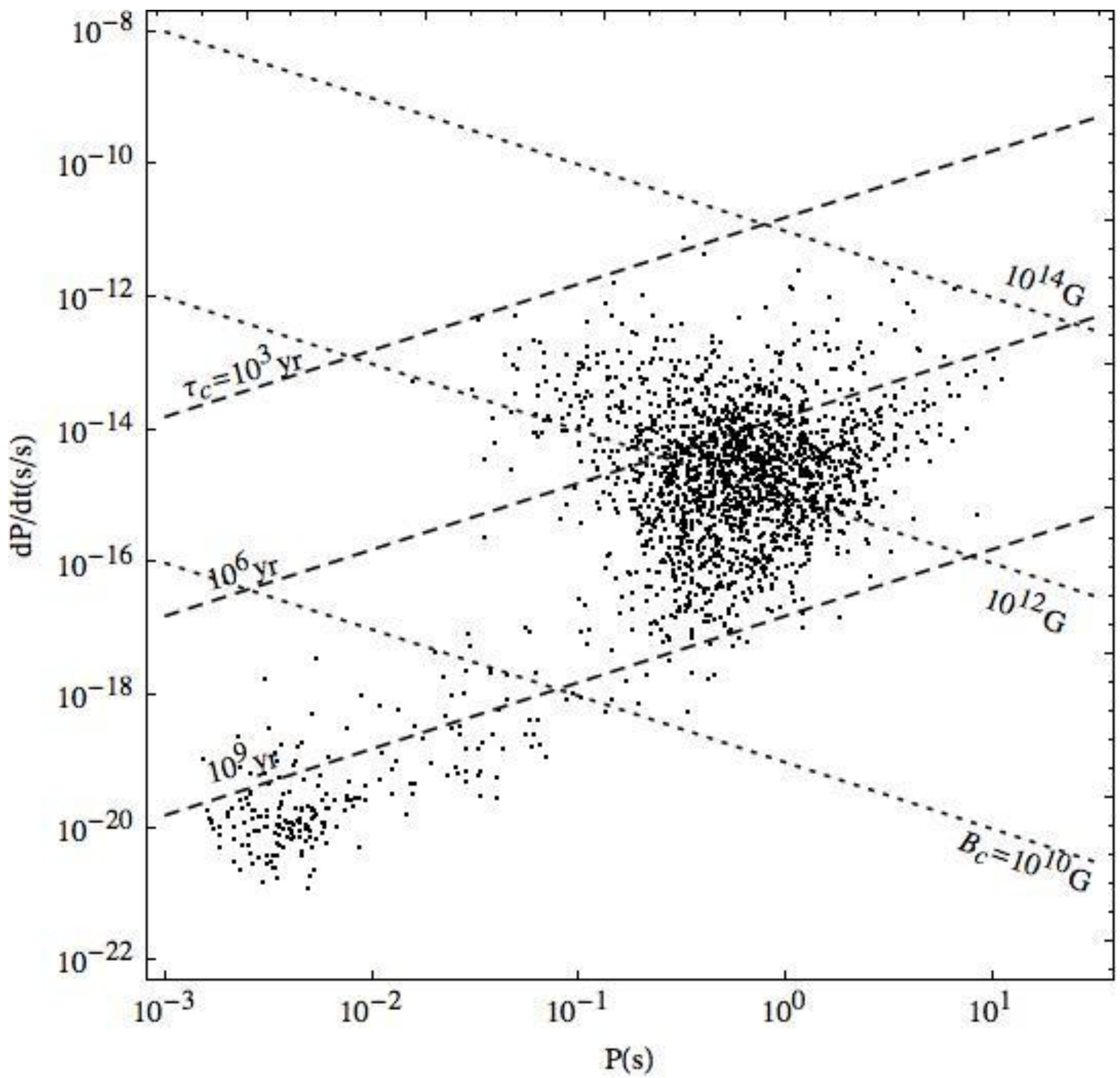
Outlines

- Motivations and backgrounds
- Pulsar death line and Equation of state
- Summary

Motivations

- Radio pulsars identified as neutron stars
- Spin period P and spin down rate $\dot{P}$ can be obtained through timing measurement.
- The pulsars could be placed on the P $-\dot{P}$ plane
- Radio pulsar death line is defined as a line in the P $-\dot{P}$ diagram



Motivations

- Pulsar death line

separates the pulsars that can produce radio emission from those that can not

$$\Delta V = \Phi_{max}$$

potential drop across the accelerator ΔV
the maximum potential drop Φ_{max}

Ruderman, M. A., & Sutherland, P. G. 1975, ApJ, 196, 51,Zhang et al. 2000, Xu &Qiao 2001

Motivations

- Pulsar death line

separates the pulsars that can produce radio emission from those that can not

$$\Delta V = \Phi_{max}$$

maximum acceleration potential $\Phi_{max} = \frac{BR^3\Omega^2}{2c^2}$

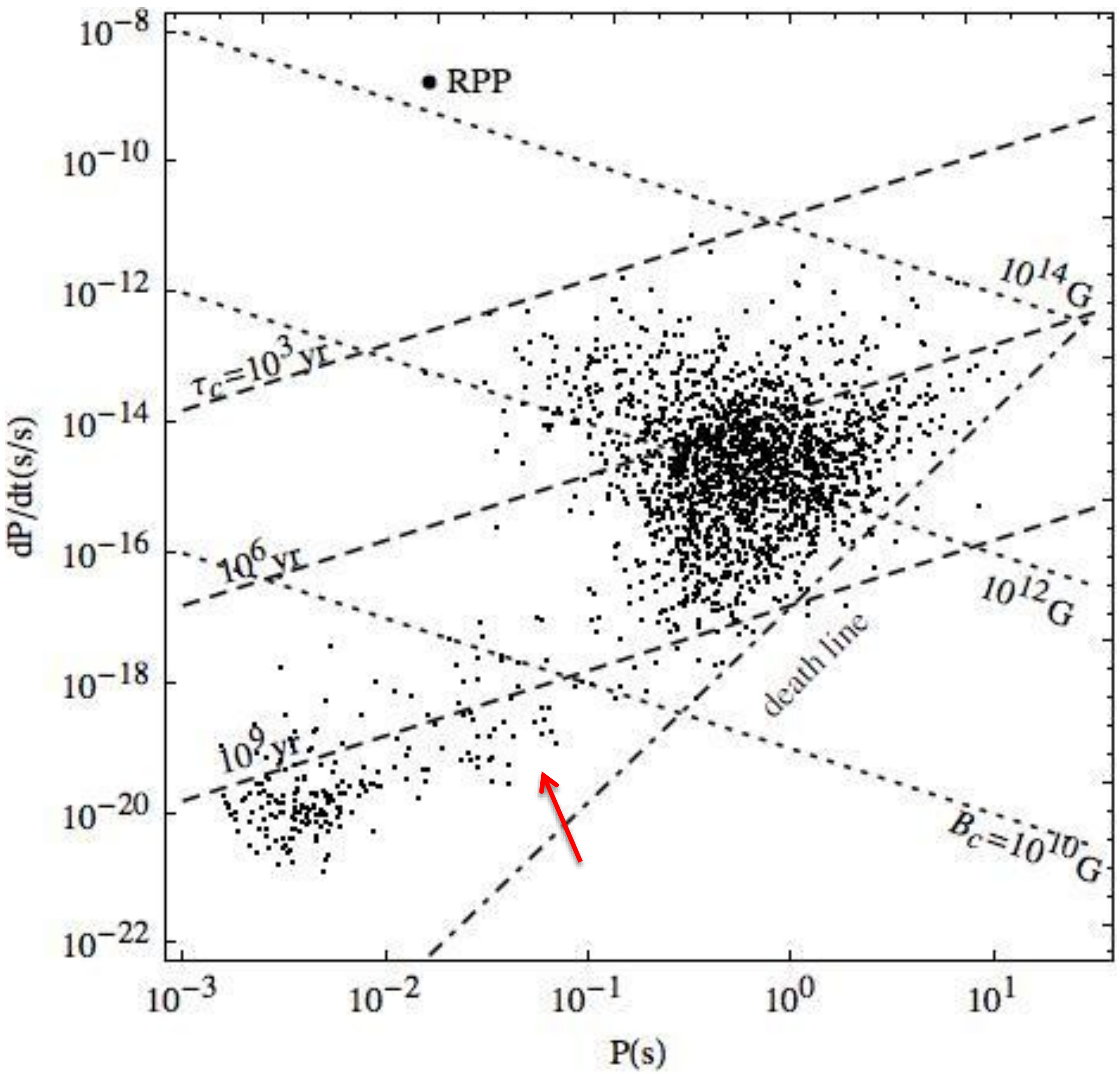
surface dipolar magnetic field $B = \sqrt{\frac{3Ic^3P\dot{P}}{8\pi^2R^6\sin\theta^2}}$

Ruderman, M. A., & Sutherland, P. G. 1975, ApJ, 196, 51,Zhang et al. 2000, Xu &Qiao 2001

Motivations

Radio pulsars are just one observational manifestation of neutron stars. we have identified multiple other classes

- RRATs, Intermittent pulsars
- Magnetars
- XDINS
- CCOs



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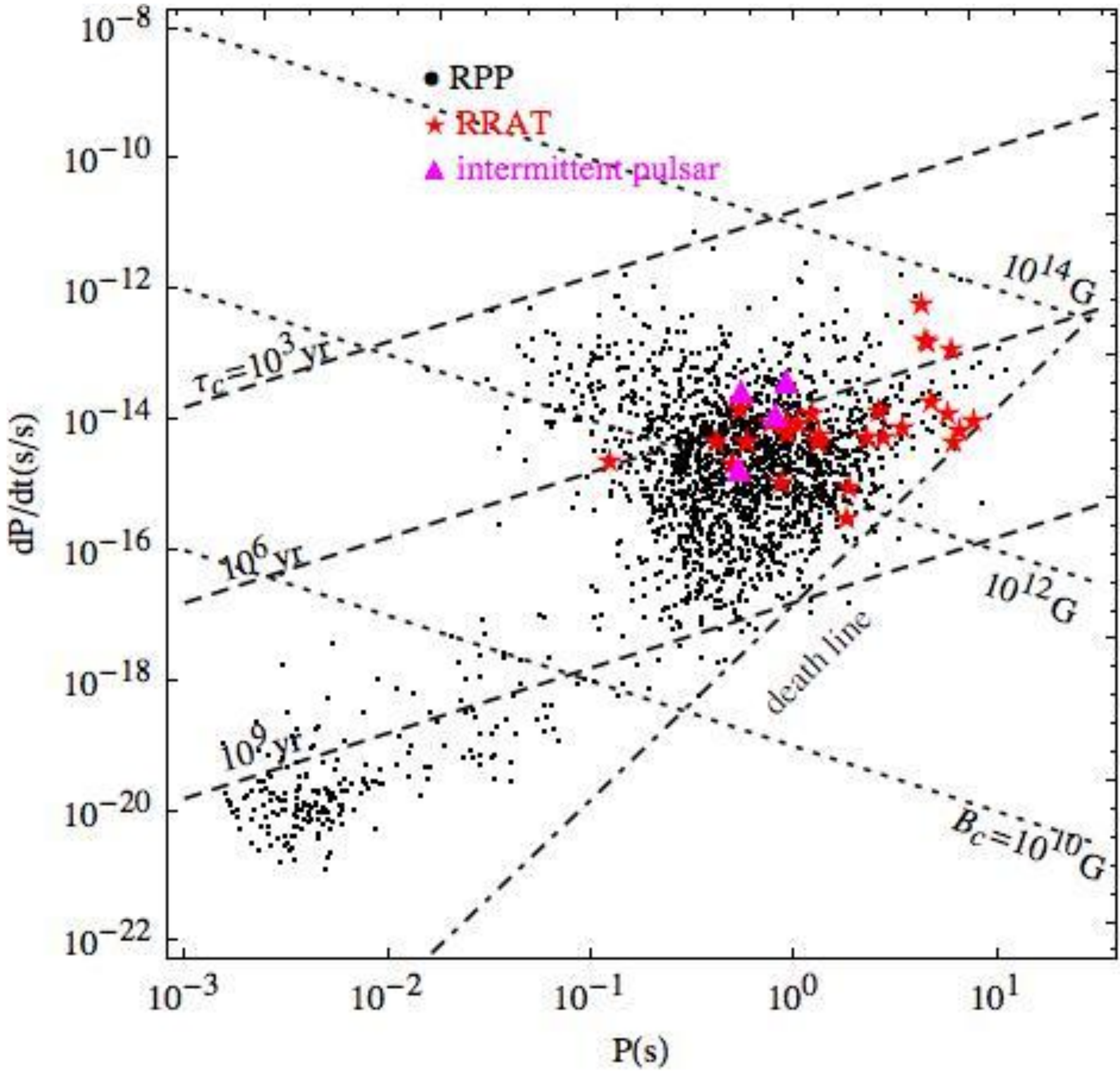
Rotating Radio Transients(RRATs)

RRATs

- neutron stars which emit short (2-30 ms) radio pulses at intervals of minutes to hours
- have larger magnetic fields and spin periods

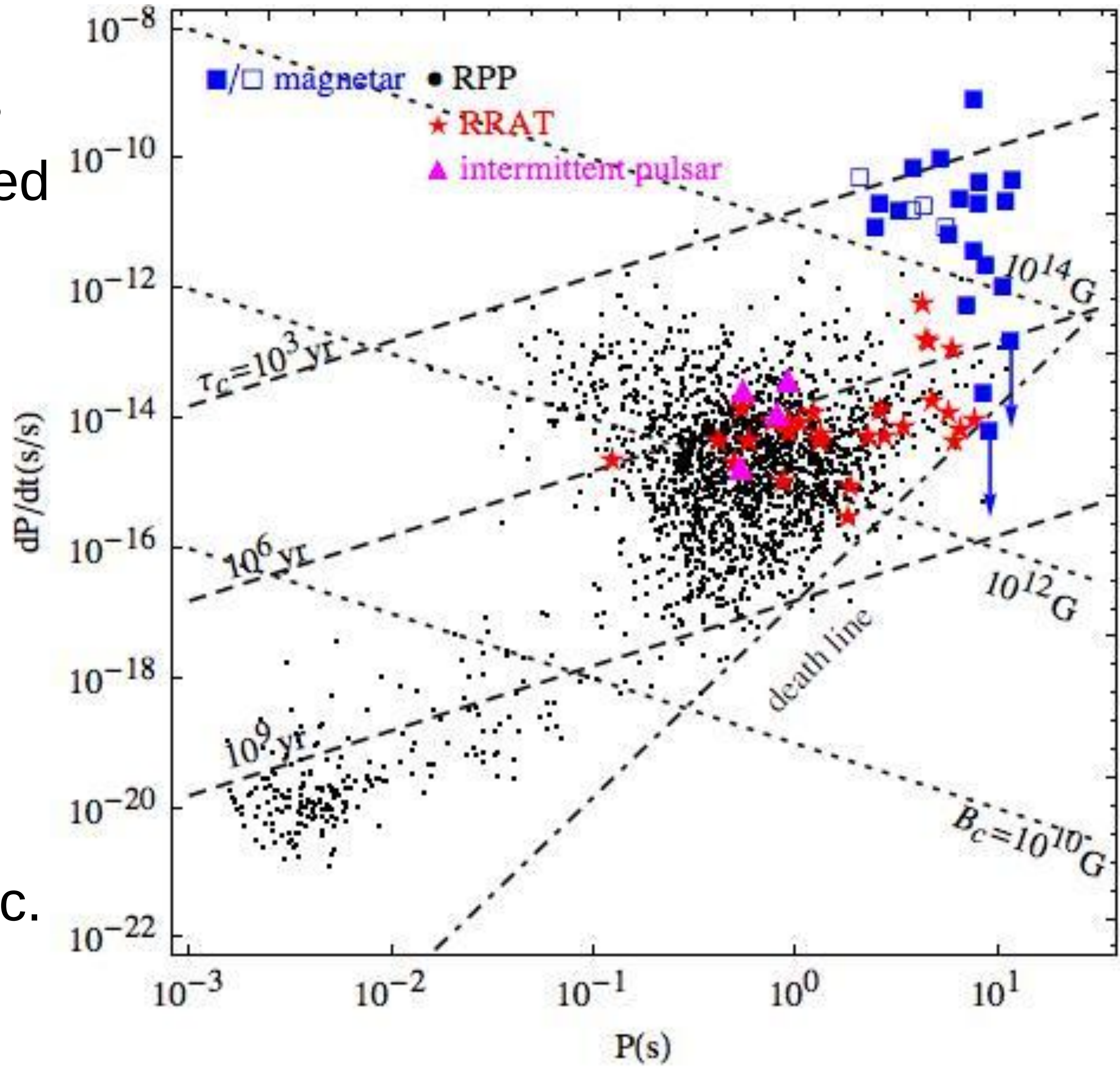
Intermittent pulsars

- part-time radio pulsars
- radio-loud/ radio-quiet



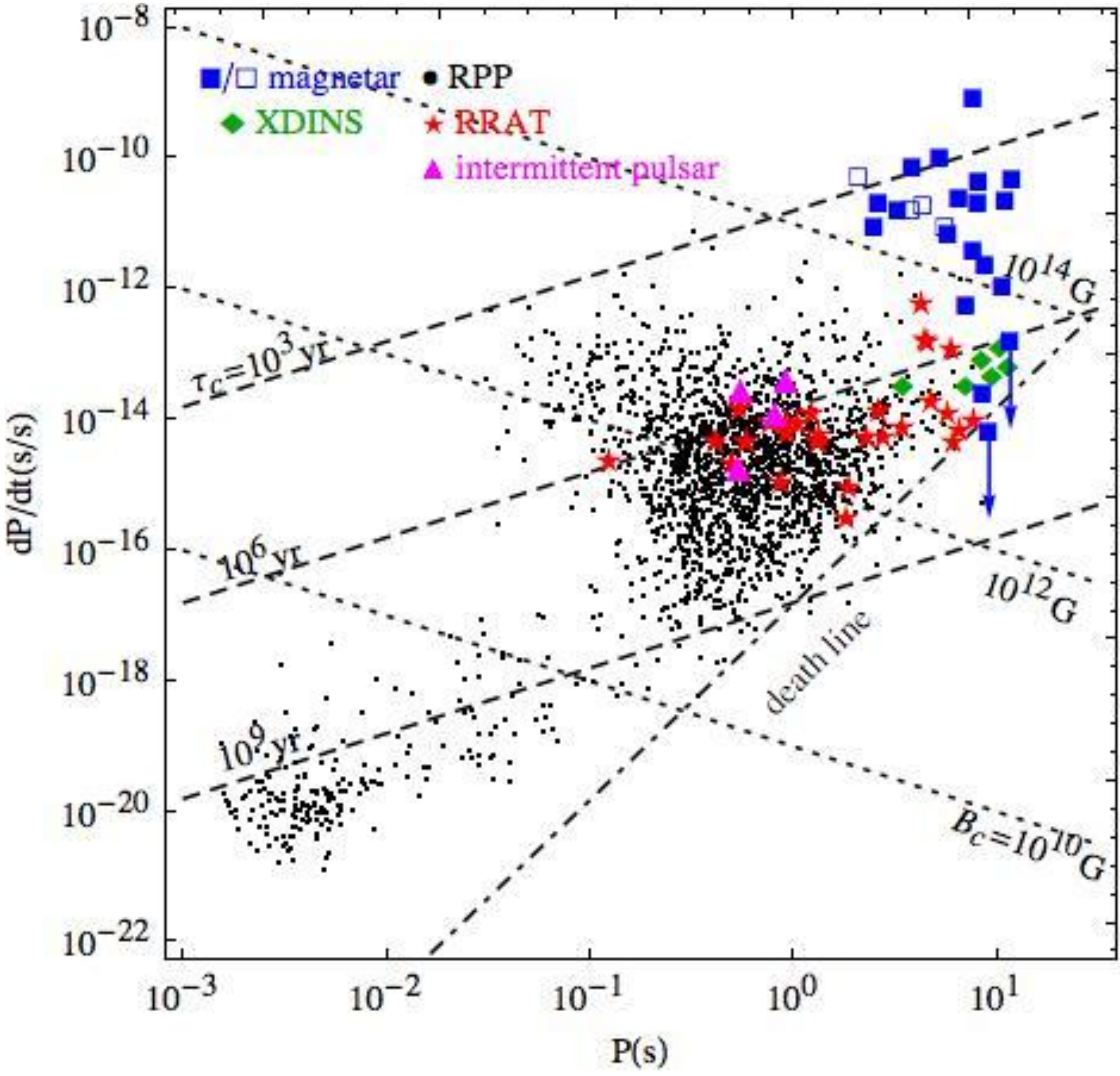
Magnetars

- Observationally, AXPs and SGRs are assumed to be magnetars
- Dipolar fields ~ 10^{14} – 10^{15} G.
- ages ~ 10^3 –10^5 yrs
- Release of magnetic energy in all wavelength, including radio, optical/infrared, soft and hard X-ray etc.



X-ray dim isolated neutron star(XDINS)

- nearby sources with high surface dipole field~ 10^{13} G
- quasi-thermal X-ray emission with relatively low X-ray luminosity
- relatively long periodicities (P =3–11 s)
- no radio emission



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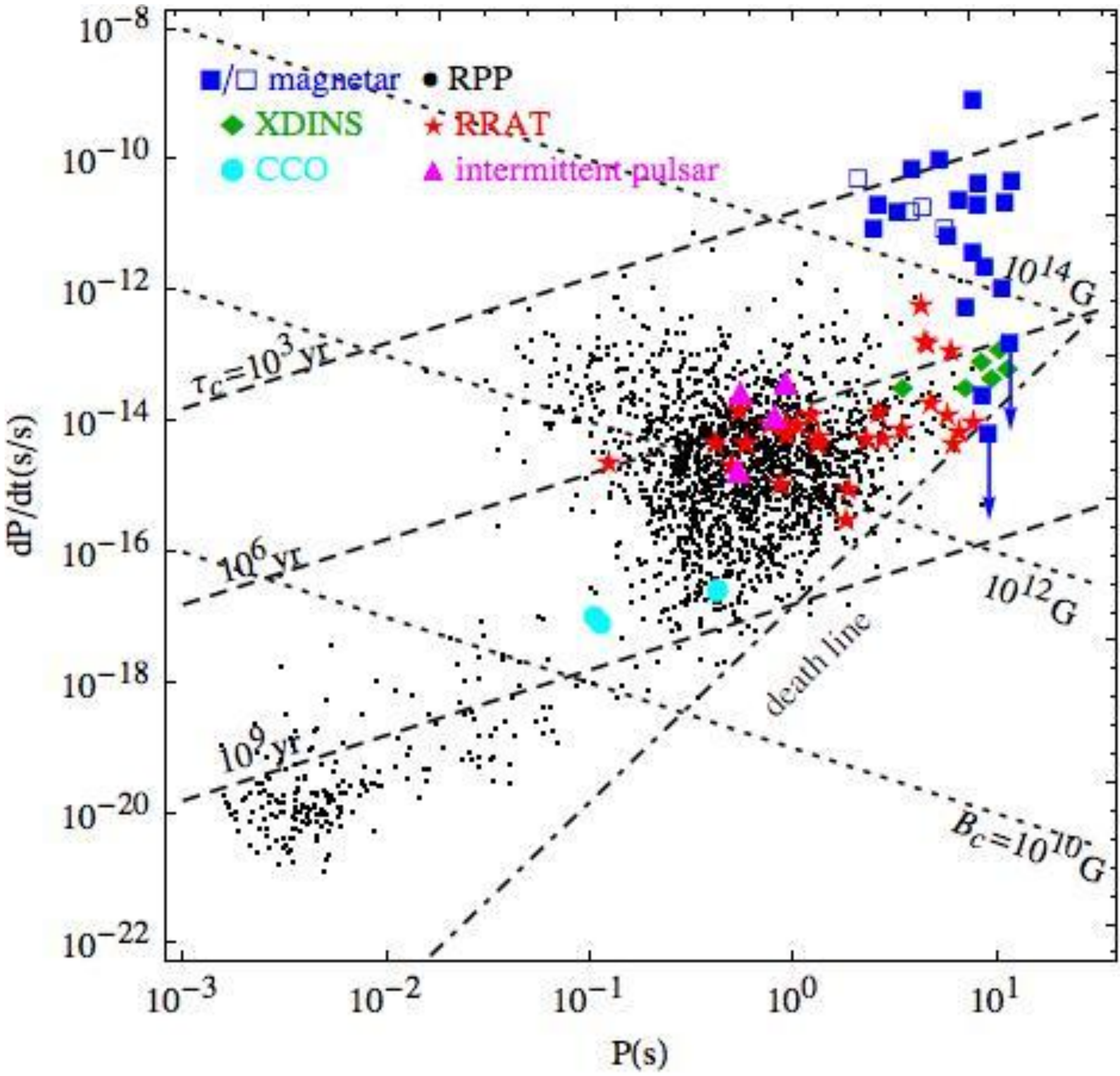
Central Compact Objects (CCO)

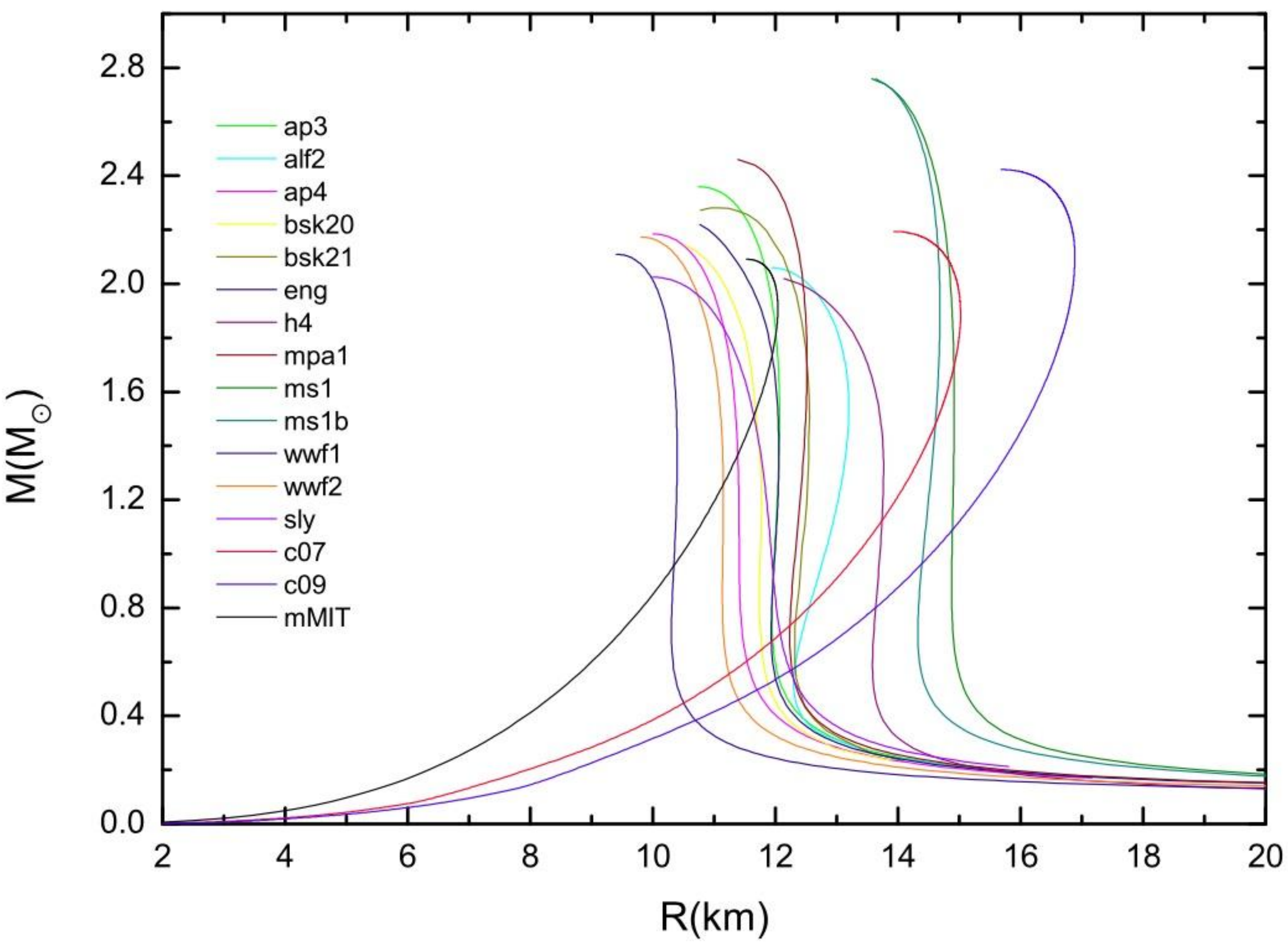
- compact stars lying at the center of the supernova remnant
- small hot spot in X-rays
- timing observations only find a very small surface dipole field
- no radio emission

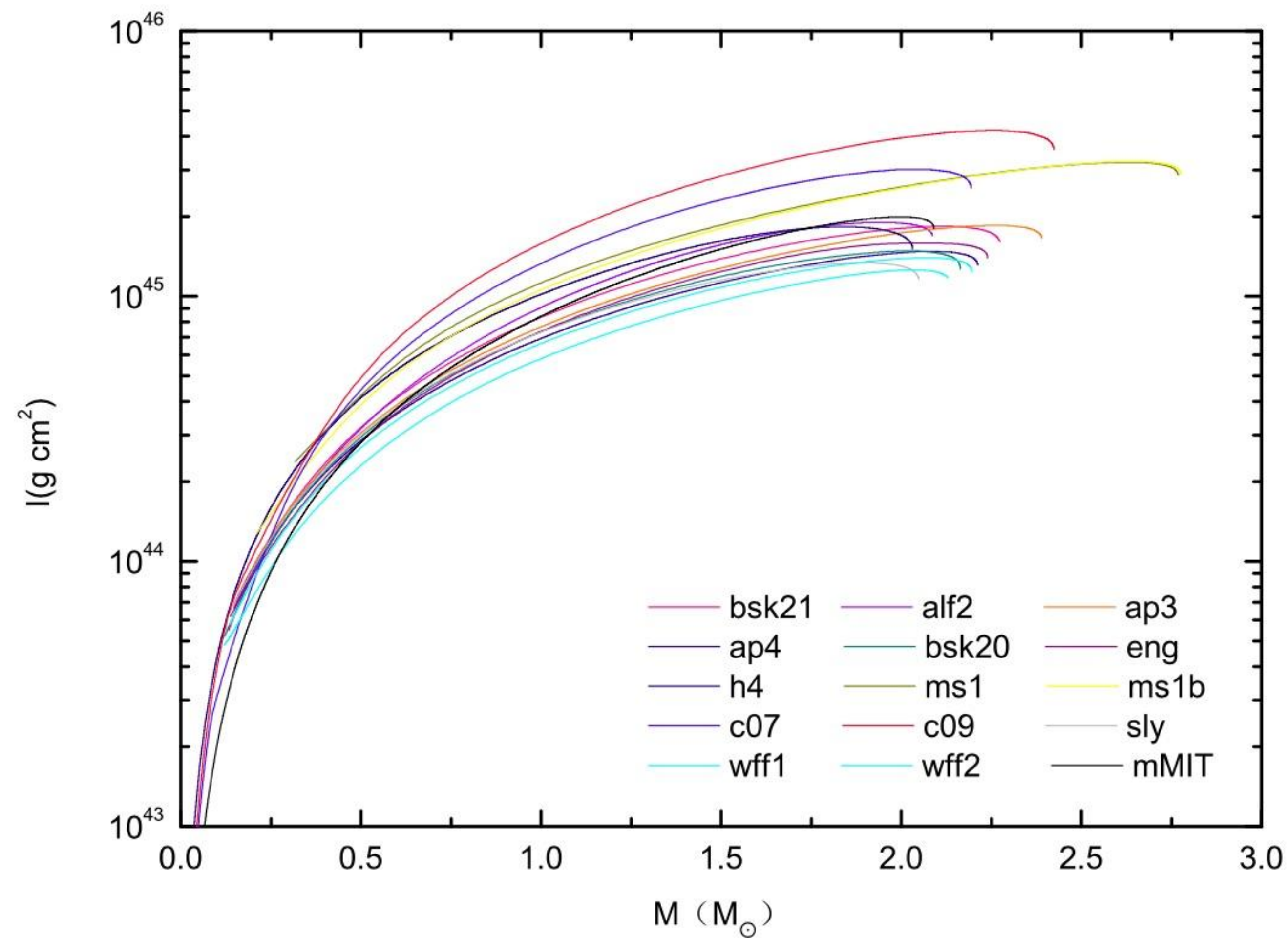


Equation of state

$$\Phi_{max} = \frac{BR^3\Omega^2}{2c^2}$$

$$B = \sqrt{\frac{3Ic^3P\dot{P}}{8\pi^2R^6\sin\theta^2}}$$





Özel et al. 2015,2016; 2016,Bhattacharyya et al. 2016, MNRAS, 457, 3101; Li Ang et al, 2015

Equation of state

- The maximum mass: observational data 2.01(4)$M_{\odot}$
- The smallest mass

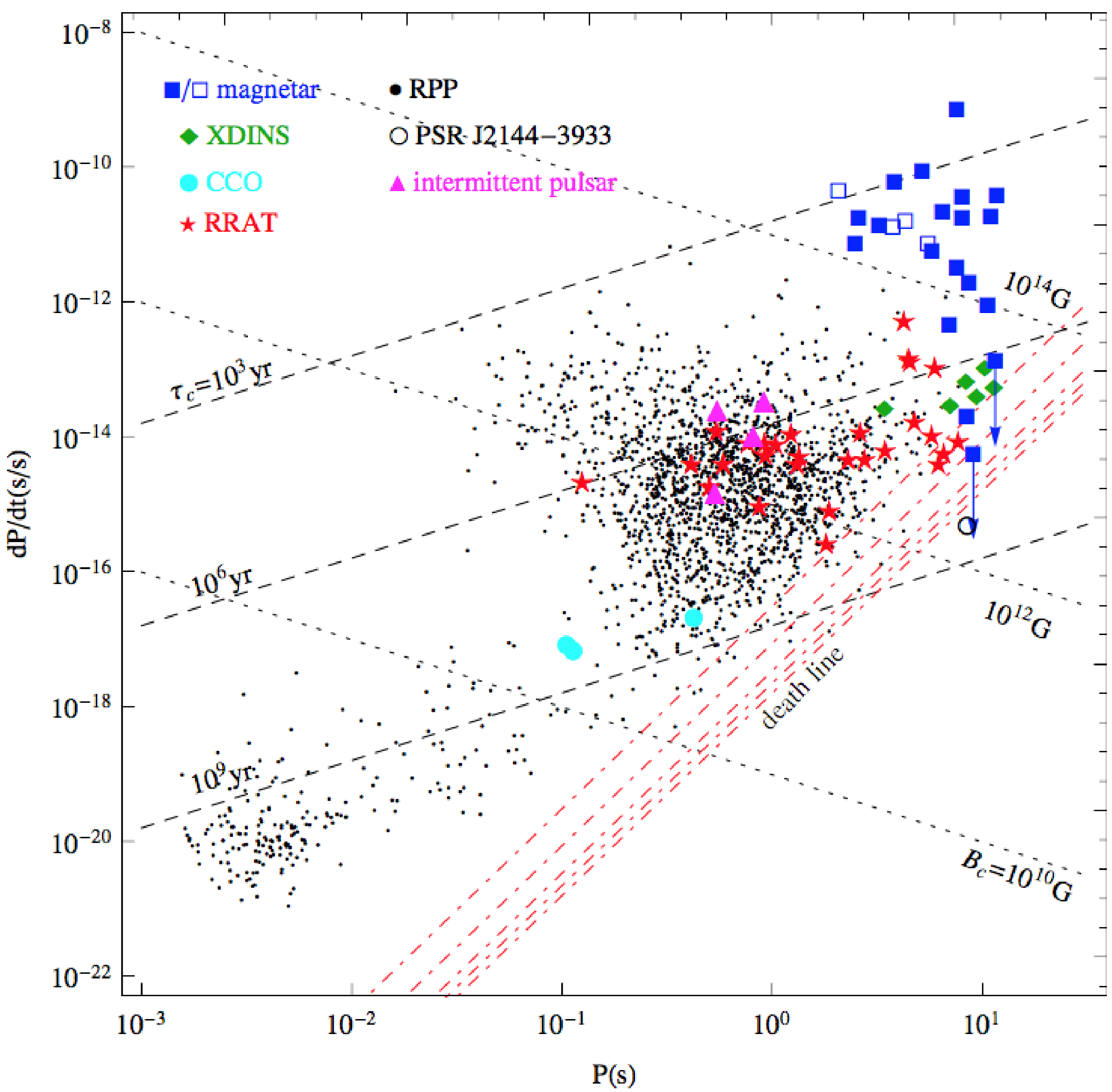
  neutron star:0.2$M_{\odot}$ (eos, bsk21)

  strange star: 0.037$M_{\odot}$ (eos, mMIT, R_{small} =4km, CCO)

In order to compare the effect of equation of state on the pulsar death line, we choose different mass of neutron stars and quark stars. Corresponding moment of inertia are calculated through the ToV equation.

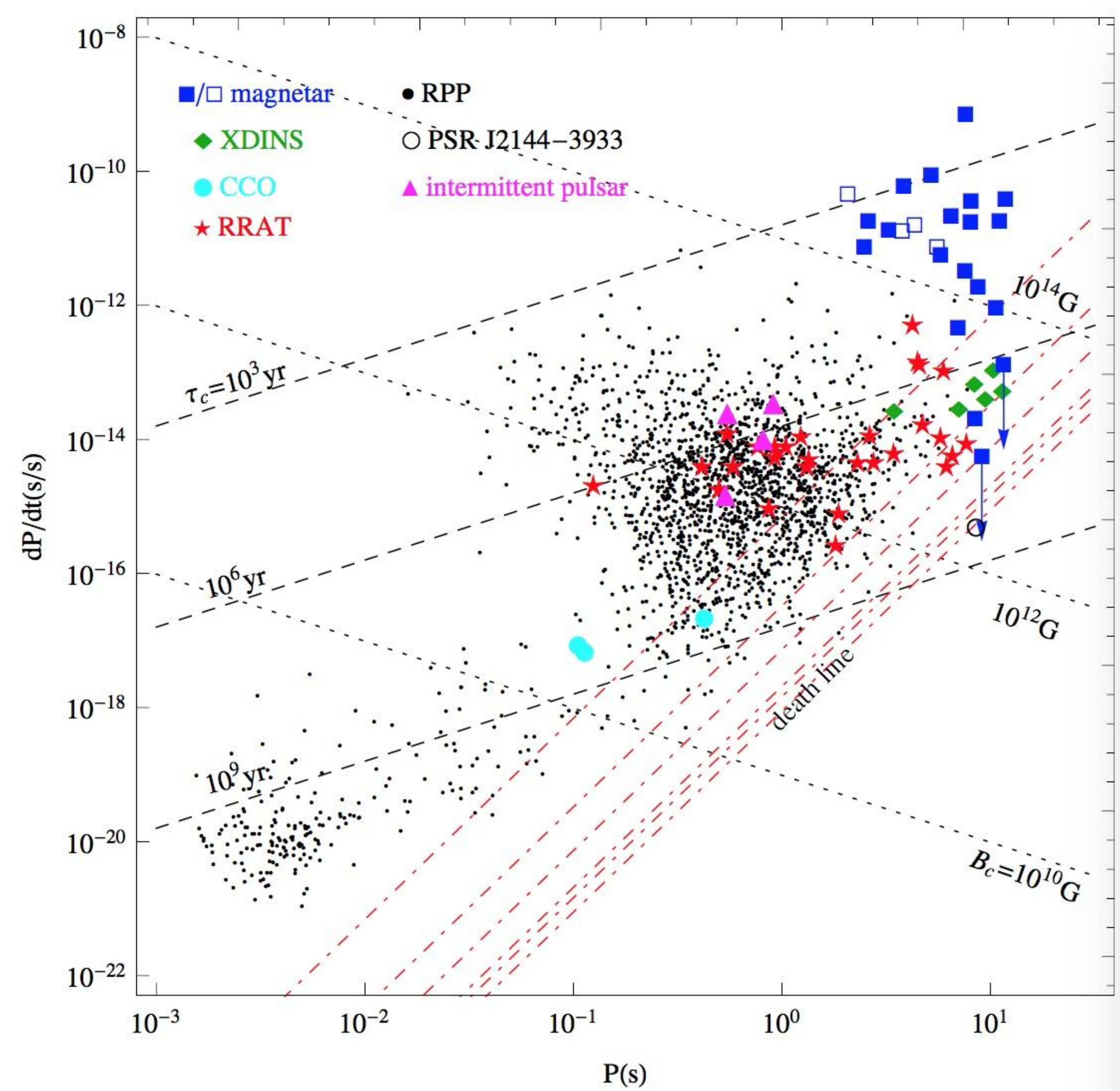
Ozel et al. 2016,Bhattacharyya et al. 2016, MNRAS, 457, 3101

Equation of state



Neutron stars

M=0.2,0.5,1.0,1.4,2.0 $M_\odot$



Quark stars

M=0.032,0.2,0.5,1.0,1.4,2.0 $M_\odot$

Summary

- We offer a another point of view to understand the pulsar death line
- Central Compact Objects would be small mass of self-bound strange stars
- Rotating Radio Transients might be old pulsars on the verge of death
- PSR J2144-3933 would be a large mass pulsar, which would be larger than $2.0M_\odot$
- Multiple observational facts would help us to reveal the nature of pulsars



Thank you for your attention!