中国科学院新疆天文台
XINJIANG ASTRONOMICAL OBSERVATORY, CAS

Rotational evolution of the slowest radio pulsar PSR J0250+5854：

contrasting different spin-down mechanisms

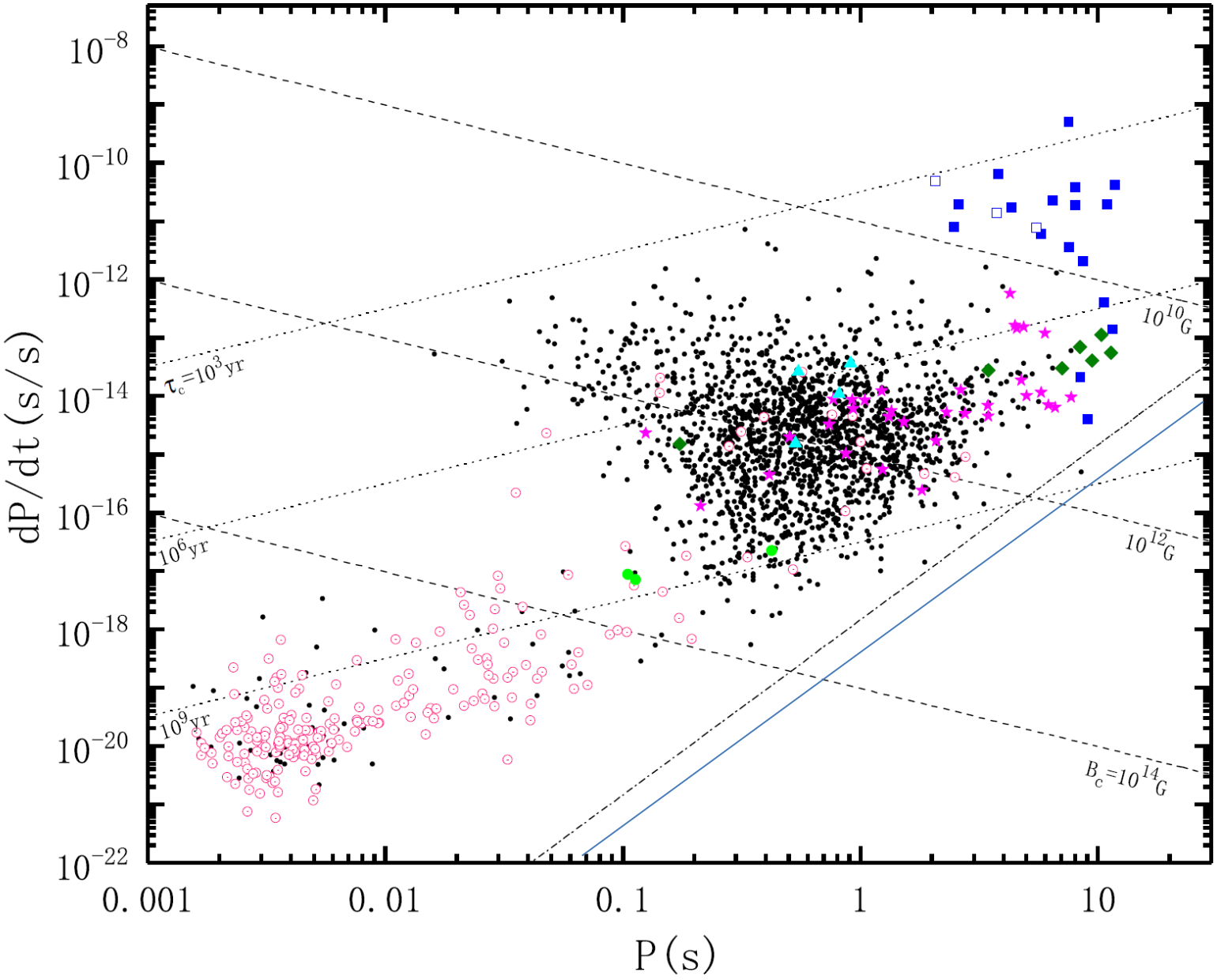
Xia ZHOU(周霞)
20190510@CCNU
Xinjiang Astronomical Observatory, CAS

zhouxia@xao.ac.cn

Outline

- P-$\dot{P}$ diagram
- Slowest radio pulsar PSR J0250+5854
- Different spin-down mechanisms
- Conclusions and discussion

P-$\dot{P}$ diagram adapted from Zhou et al., 2017, MNRAS



23.5s Radio Pulsar

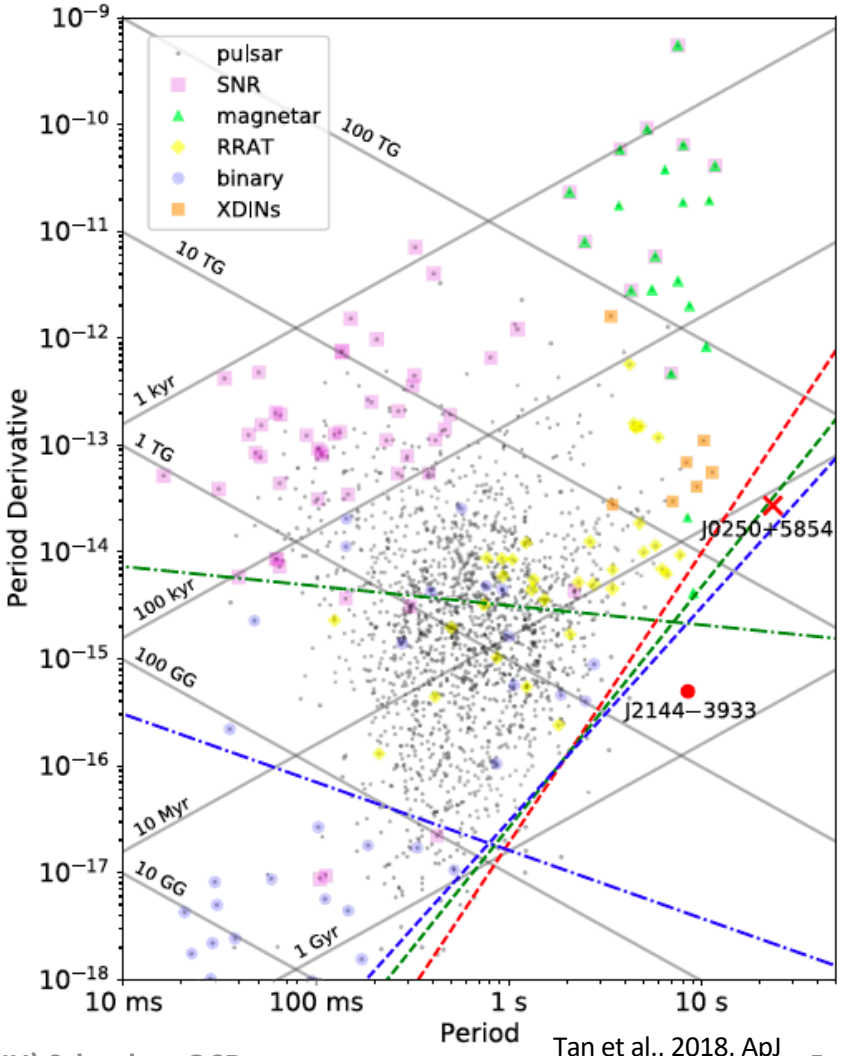
Tan et al., 2018, ApJ

- PSR J0250+5854, a radio pulsar with a spin period of 23.5 s, was discovered using LOFAR(the Low Frequency Array), slower than any known radio pulsar, magnetar, or XDINS.
  - $\dot{P} = 2.7\times10^{-14}\mathrm{s}\ s^{-1}$
  - a dipole magnetic field of 5.1×10^{13} G at the pole
  - characteristic age of 13.7 Myr
  - LOFAR, 135 MHz/ GBT, 350 MHz

23.5s Radio Pulsar

Tan et al., 2018, ApJ

- not detected by the Swift/X-Ray Telescope in the energy band of 0.3–10 keV
- a bolometric luminosity limit of 1.5×10^{32} erg s^{-1} for an assumed $N_H = 1.35 \times 10^{21}$ cm^{-2} and a temperature of 85 eV
- PSR J0250+5854 place it at the right end of the P-$\dot{P}$ diagram
- the more recent death line models are able to explain the presence of PSR J0250+5854



Tan et al., 2018, ApJ

Spin-down torque

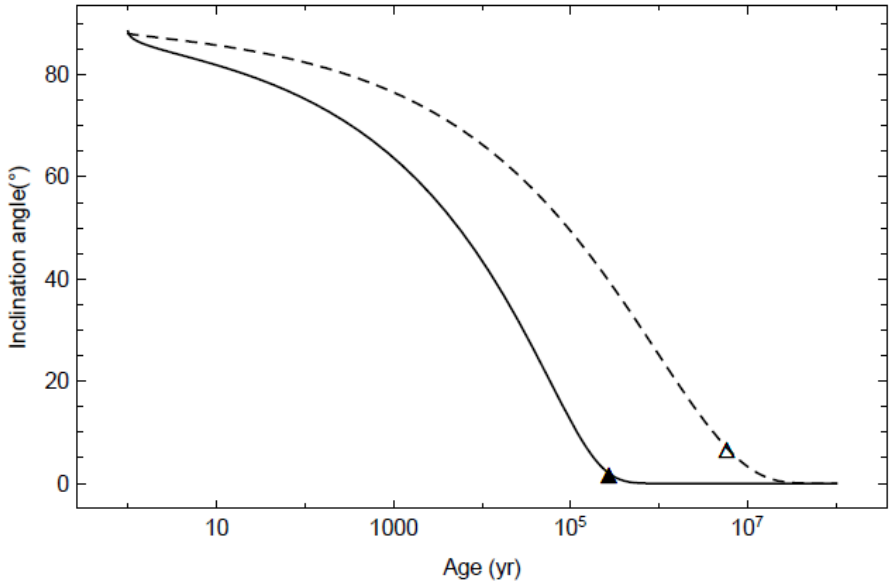
To investigate the link between PSR J0250+5854 and other neutron stars

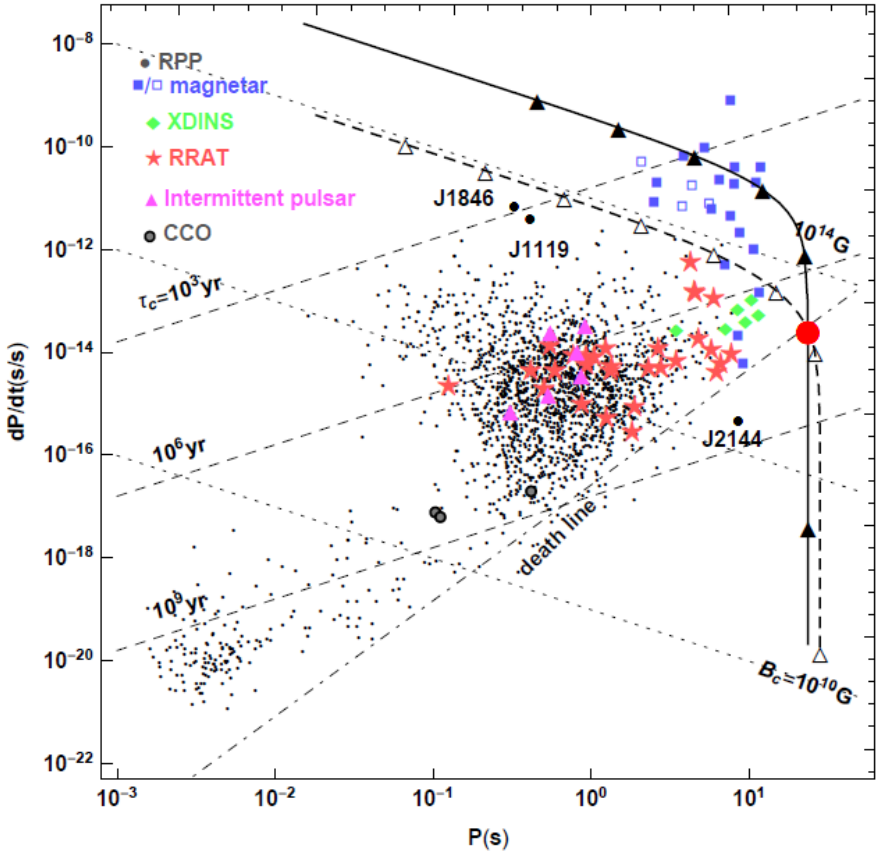
- Magnetospheric evolution
- Magnetic field decay
- ……

Kou et al., arXiv:1901.00300, to be appeared in ApJ

Rotational evolution in the case of magnetospheric evolution

$$K_{\rm spinning} = -k_0 \frac{\mu^2 \Omega^3}{c^3} (\sin^2 \alpha + k_1)$$



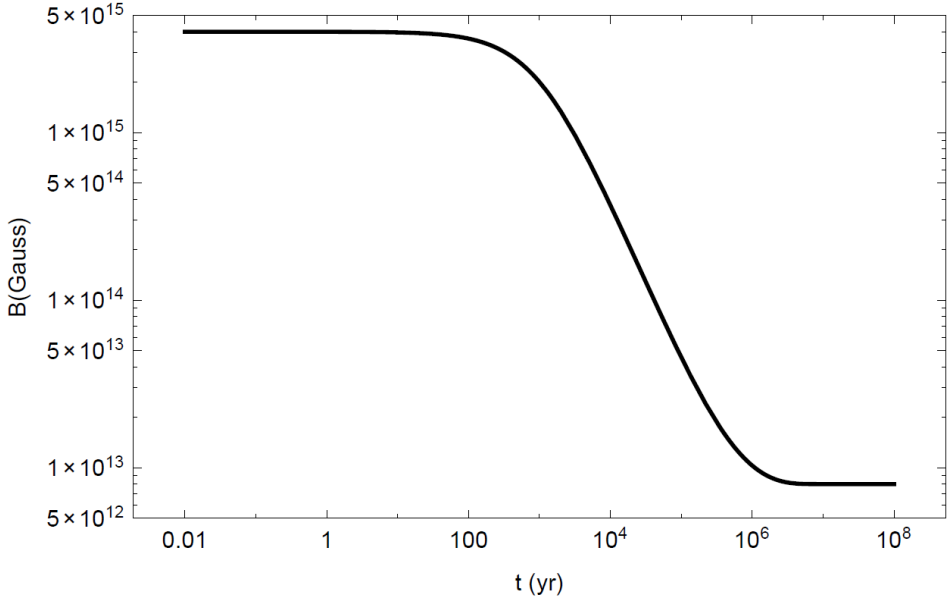


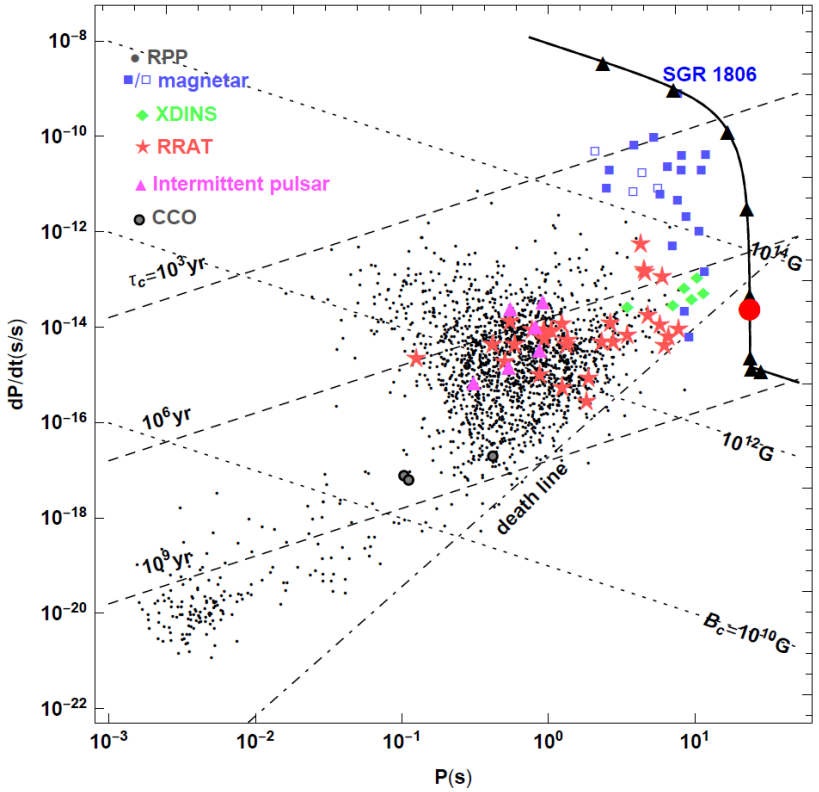
Similarly long-period pulsars, most of them should have a relatively small period derivative $\dot{P}$<10^{-15} s s^{-1}

Kou et al., arXiv:1901.00300, to be appeared in ApJ

Rotational evolution in the case of magnetic field decay

$$B(t) = \frac{B_0 \exp(-t/\tau_o)}{1 + (\tau_o/\tau_H)[1 - \exp(-t/\tau_o)]} + B_{fin}$$



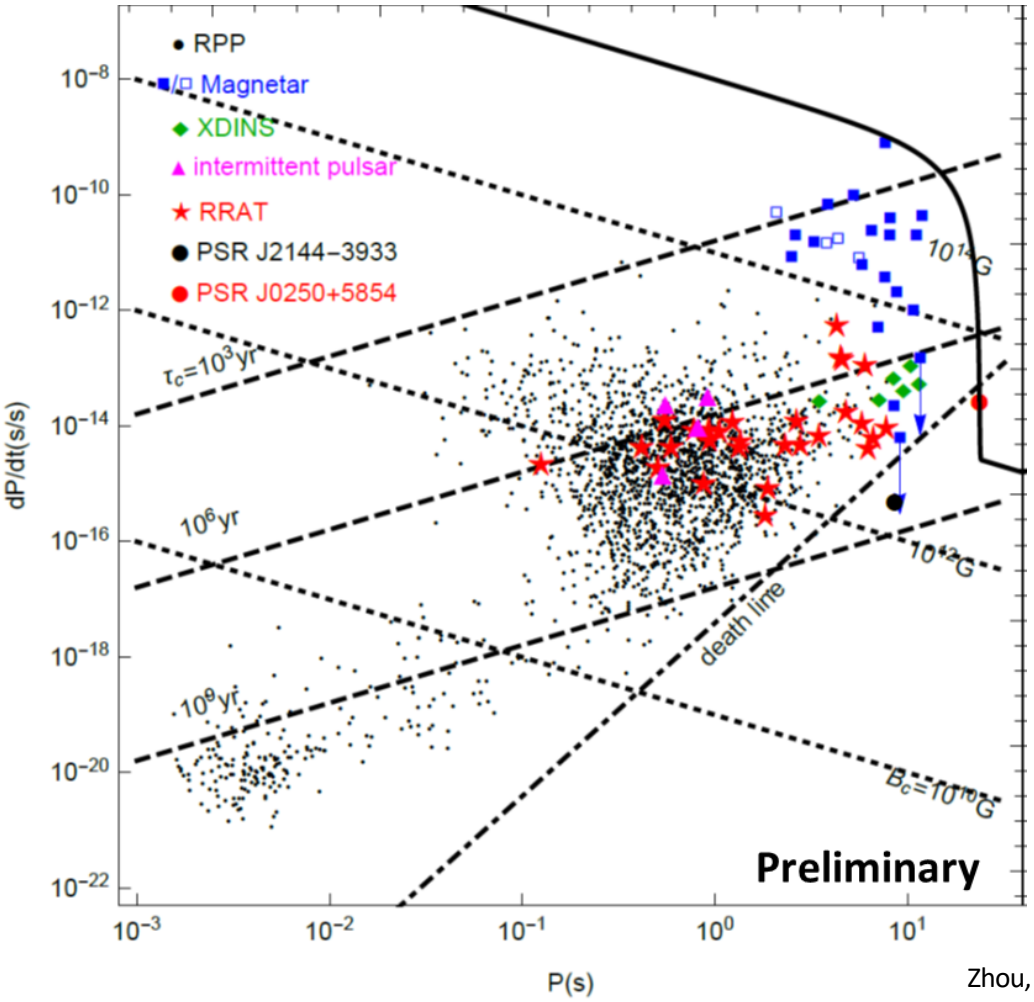


similarly long-period pulsars, most of them should have relatively higher period derivatives $\dot{P} \sim 10^{-15}$ s s^{-1}

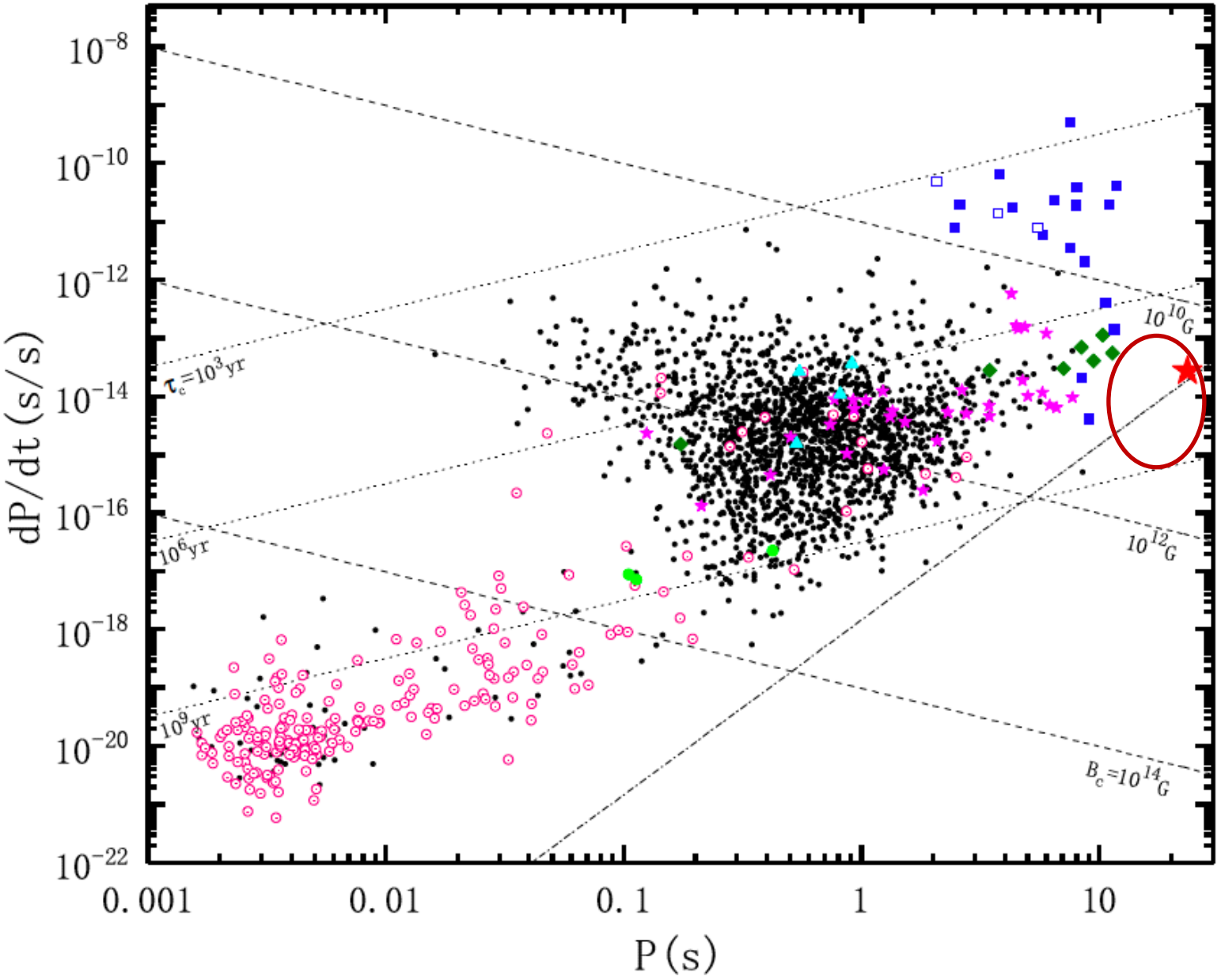
Kou et al., arXiv:1901.00300, to be appeared in ApJ

Rotational evolution in the case of r-mode instability

$$\frac{d\Omega}{dt} = -\frac{\Omega}{\tau_m}\frac{1}{1-\kappa Q} - \frac{2\Omega}{\tau_g}\frac{\kappa Q}{1-\kappa Q}$$



Zhou, unpublished


dP/dt (s/s)
P (s)
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
10^{-18}
10^{-20}
10^{-22}
0.001
0.01
0.1
1
10
$\tau_c=10^3$yr
10^6yr
10^9yr
10^{10}G
10^{12}G
$B_c=10^{14}$G

contrasting different spin-down mechanisms

Just discussion

- a bolometric luminosity limit of 1.5×10^{32} erg s^{-1} for an assumed NH = 1.35×10^{21} cm^{-2} and a temperature of 85 eV

$$L = 4\pi R^2 \sigma T_s^4 \sim \frac{E_B}{t} \sim \frac{4\pi R^3}{3} \frac{\langle B^2 \rangle}{8\pi} \frac{1}{t} \qquad \sim 10^{29} \text{erg s}^{-1}$$

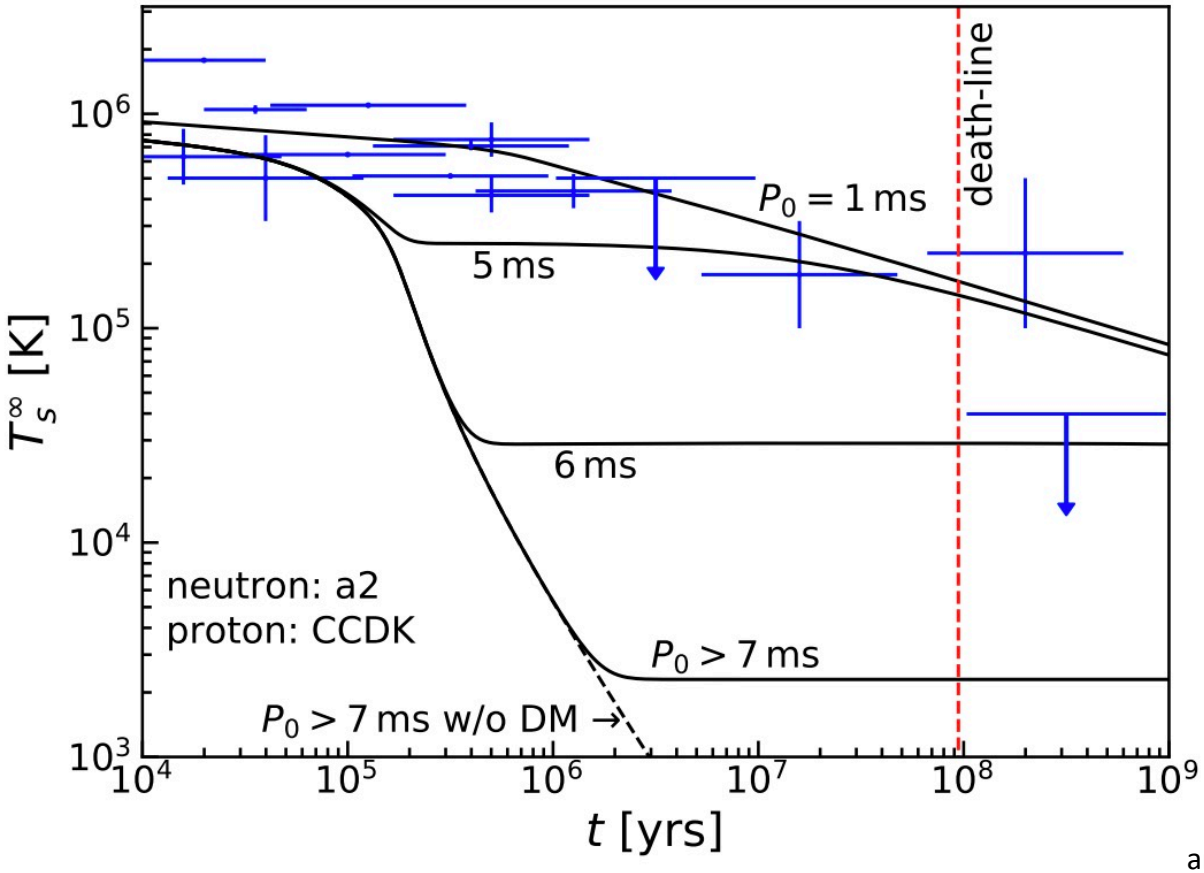
- The energy from the decay of magnetic field is not enough for PSR J0250+5854(XDINSs)

contrasting different spin-down mechanisms

– We need other energetic internal heating source..
rotochemical heating/deconfinement heating

contrasting different spin-down mechanisms

– We need other energetic heating source..



arXiv：1905.02991

Conclusions

- A few numbers of spin-down mechanisms could simulate the possible evolution of the slowest rotation pulsar(PSR J0250+5854)
- Future observations of more long period pulsars can give a constraint on the models of spin-down and cooling of pulsars, and thus on its interior
- Multi-band observational data could help us to know more about pulsars