Orthogonal pulsar statistics as a test of the evolution model

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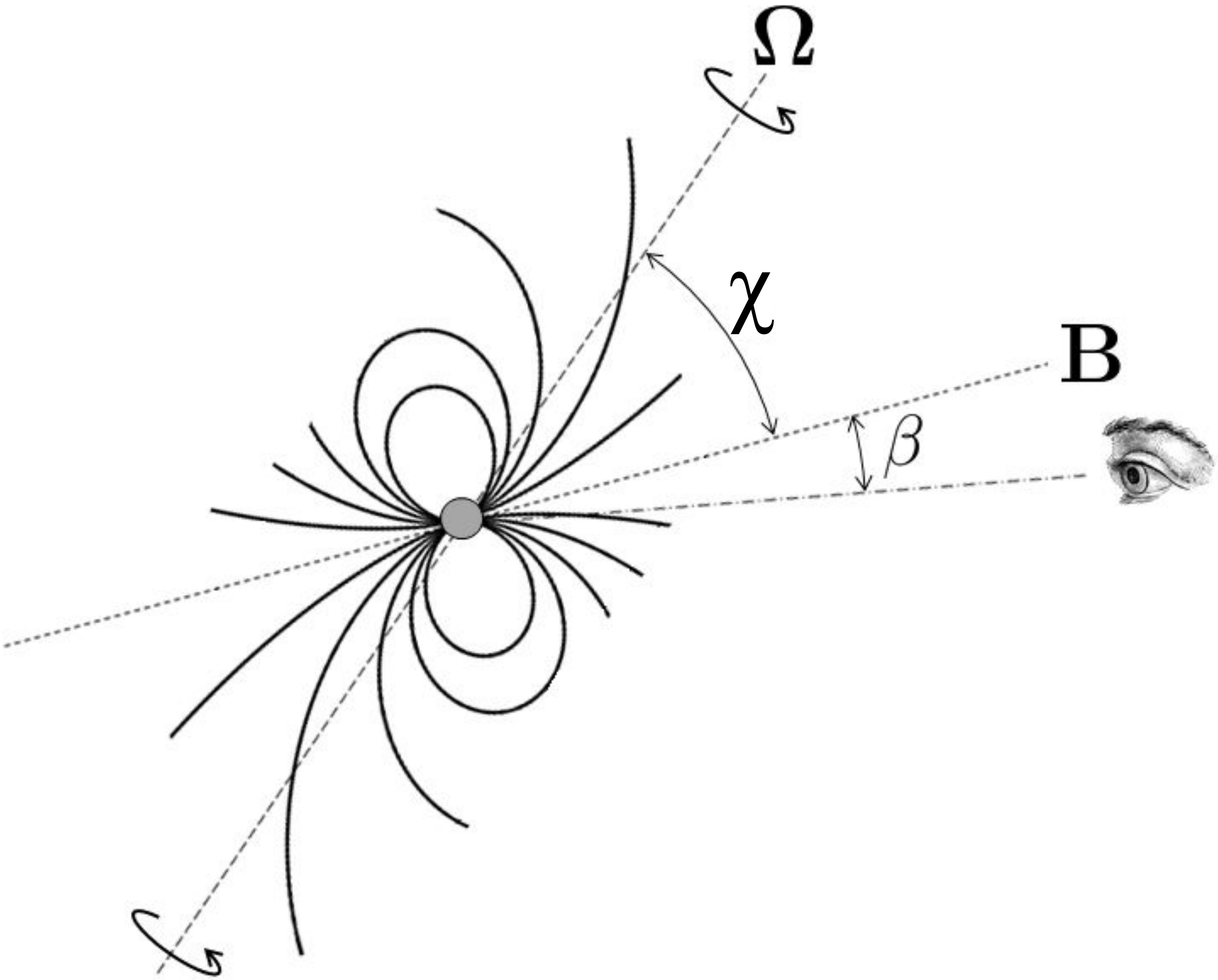
Pulsar



Four key parameter:

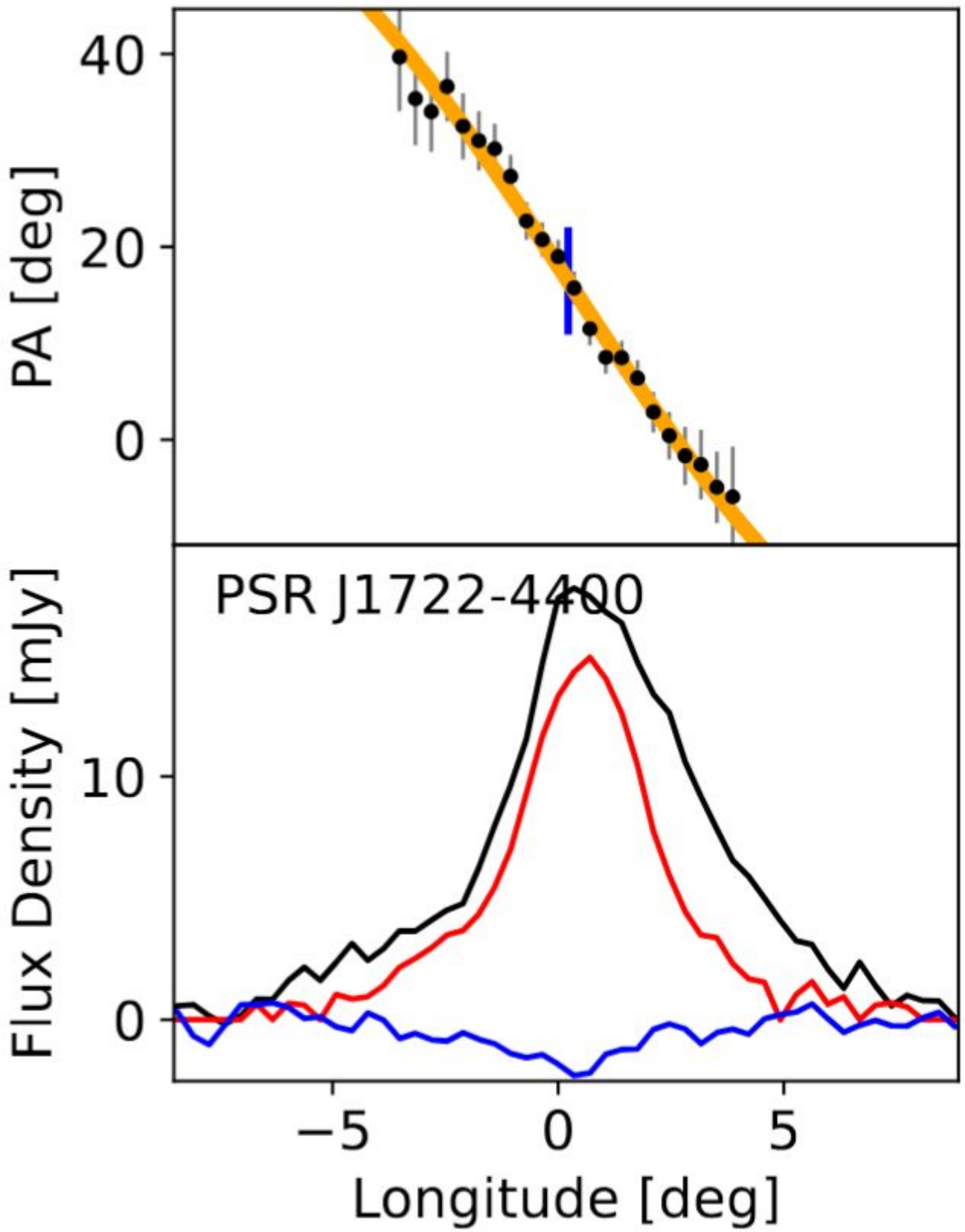
1) Period (P)

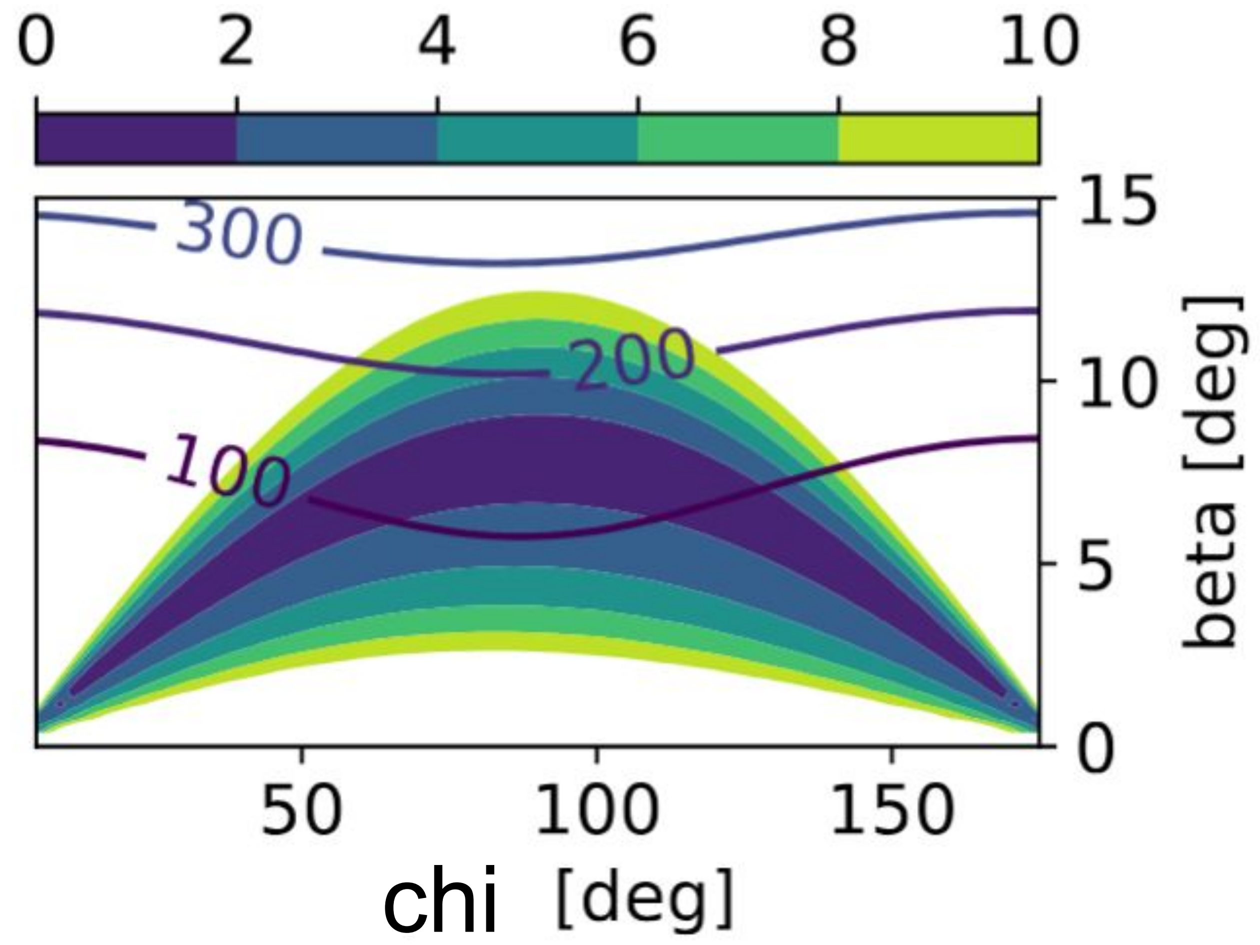
2) Magnetic Field (B)

3) Inclination angle (χ)

4) Impact angle (β)

Inclination angle (RVM)



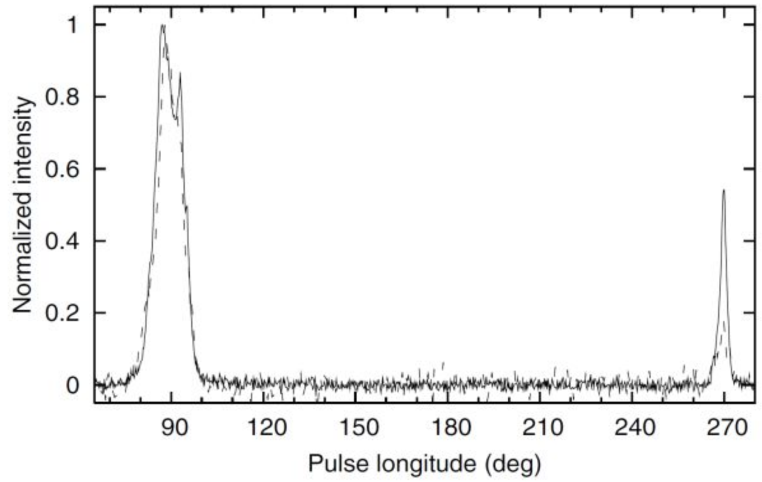


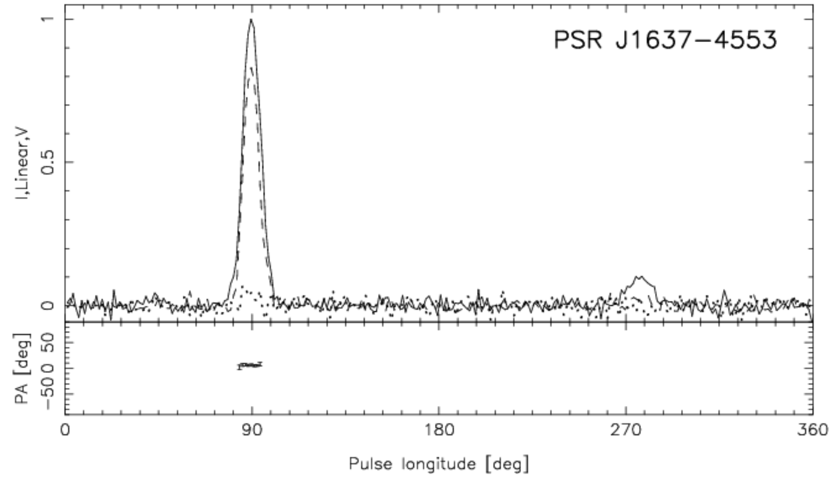
S Johnston, M Kramer, A Karastergiou, M J Keith, L S Oswald, A Parthasarathy, P Weltevrede, Volume 520, Issue 4, April 2023, Pages 4801–4814

Observations

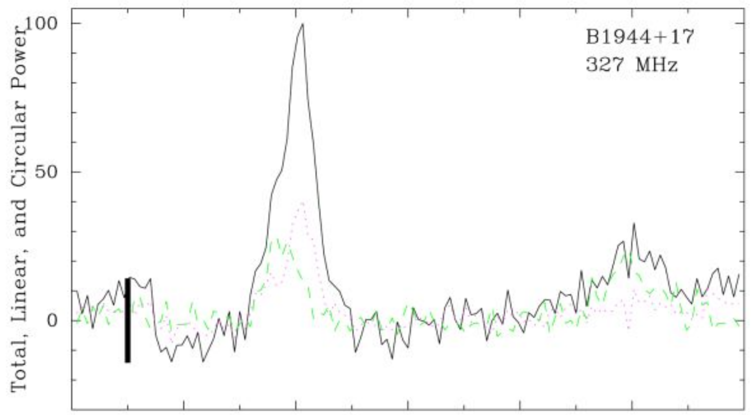
Inter-pulse pulsars

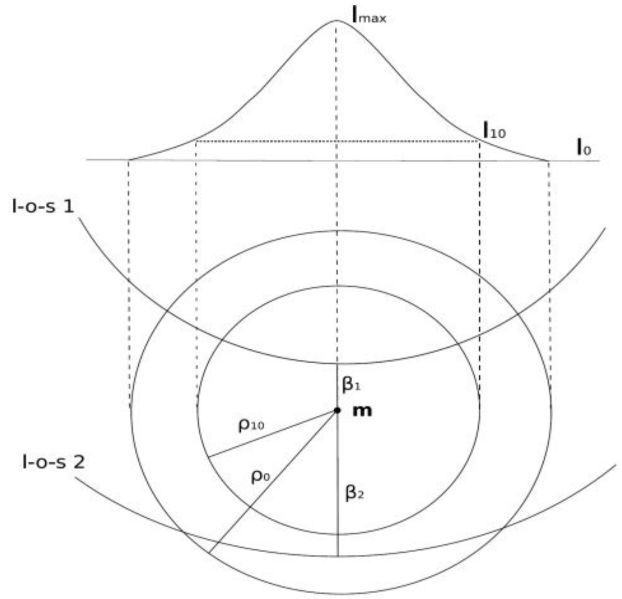
Orthogonal (~ 180^o)





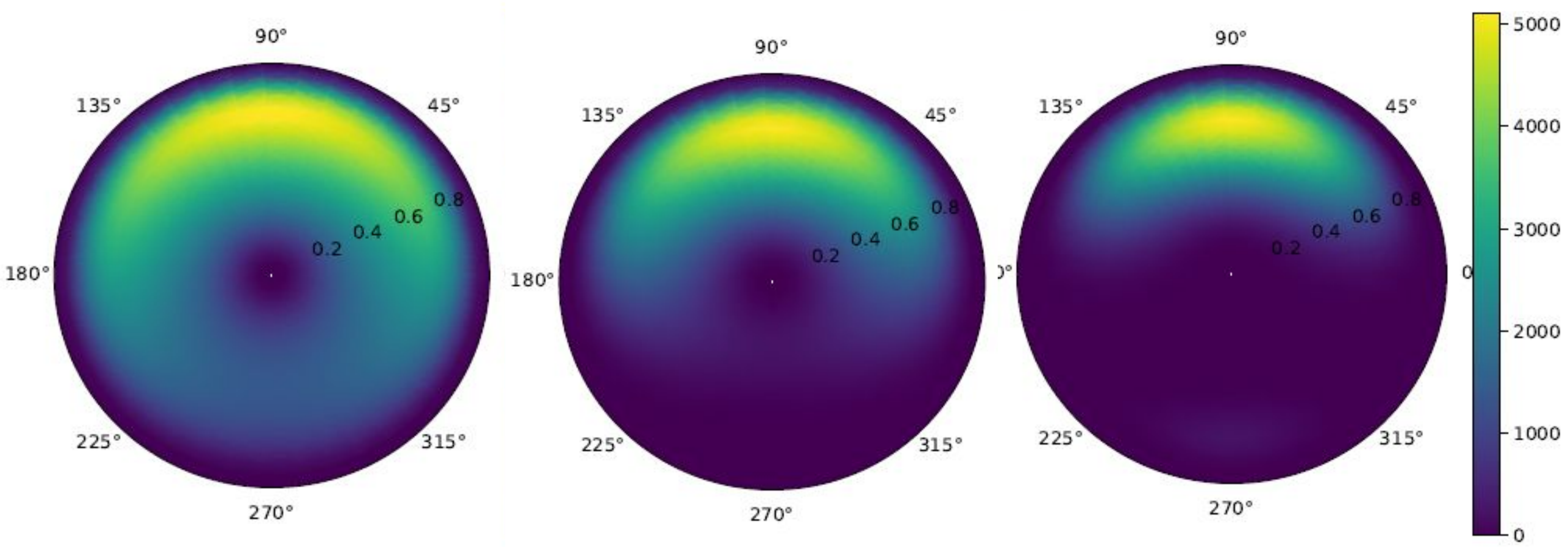
Coaxial (not only 180^o)





Patrick Weltevrede, Simon Johnston, Mon. Not. Roy. Astron. Soc. 391 (2008), 1210

Emission beam of orthogonal pulsar



Istomin, A.Y., Kniazev, F.A. & Beskin, V.S. Acceleration Potential and Density Profile of Secondary Plasma in the Magnetosphere of Orthogonal Pulsars. Astron. Rep. 68, 1271–1285 (2024).

Spin-down models

The MHD model

The magnetohydrodynamic solution continues indefinitely

The current flowing along the power lines is fixed

The current for orthogonal pulsars is of the same order as for coaxial pulsars.

The model of evolution:

$$B_{12}^{\mathrm{MHD}} \approx \frac{\dot{P}_{-15}^{1/2} P^{1/2}}{\sqrt{1+\sin^2\chi}}$$

The BGI model

The solution can be continued only up to the light surface (then a sharp acceleration of particles)

The current flowing along the lines of force is determined by the physics of particle generation

The current for orthogonal pulsars is much less than the current for coaxial pulsars.

The model of evolution:

$$B_{12}^{\mathrm{BGI}} \approx \frac{\dot{P}_{-15}^{1/2} P^{1/2}}{\sqrt{\cos^2\chi + \mathcal{C}}}$$

$$\mathcal{C} \sim \sqrt{\Omega R/c} \ll 1$$

FAST – 682

Research in Astronomy and Astrophysics, 23:104002 (105pp), 2023 October
https://doi.org/10.1088/1674-4527/acea1f

FAST Pulsar Database. I. Polarization Profiles of 682 Pulsars

P. F. Wang[1,2], J. L. Han[1,2], J. Xu[1,2], C. Wang[1,2], Y. Yan[1,2], W. C. Jing[1,2], W. Q. Su[1,2], D. J. Zhou[1,2], and T. Wang[1,2]
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MeerKAT – 1170

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https://doi.org/10.1093/mnras/stac3383

The Thousand Pulsar Array program on MeerKAT – IX. The time-averaged properties of the observed pulsar population

B. Posselt,[1,2★] A. Karastergiou,[1,3★] S. Johnston,[4] A. Parthasarathy,[5] L. S. Oswald,[1,6] R. A. Main,[5] A. Basu,[7] M. J. Keith,[7] X. Song,[7] P. Weltevrede,[7] C. Tiburzi,[8] M. Bailes,[9,10] S. Buchner, M. Geyer,[11,12] M. Kramer,[5,7] R. Spiewak[7,9,10] and V. Venkatraman Krishnan[5]

RS deathline paradigme

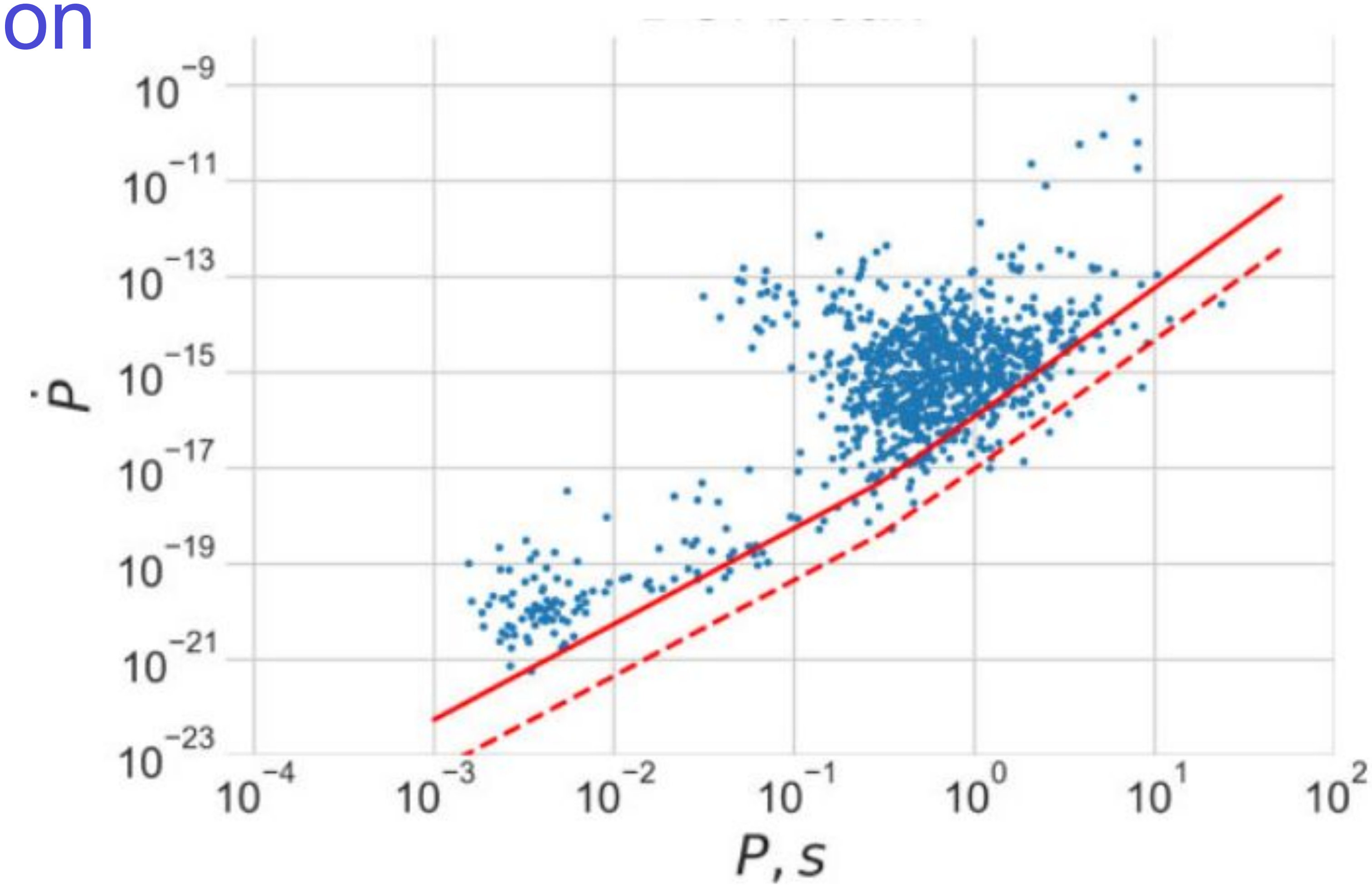
Ruderman-Sutherland deathline paradigme (1975)

It is impossible to make the potential drop greater than the vacuum one (which strongly depends on the inclination angle)

Observational confirmation

2. P-Pdot diagram

$$\cos\chi > k\, P^{15/7}\, B_{12}^{-8/7},$$



V.S. Beskin, A.Yu.Istomin
MNRAS, **516**, 5084 (2022)

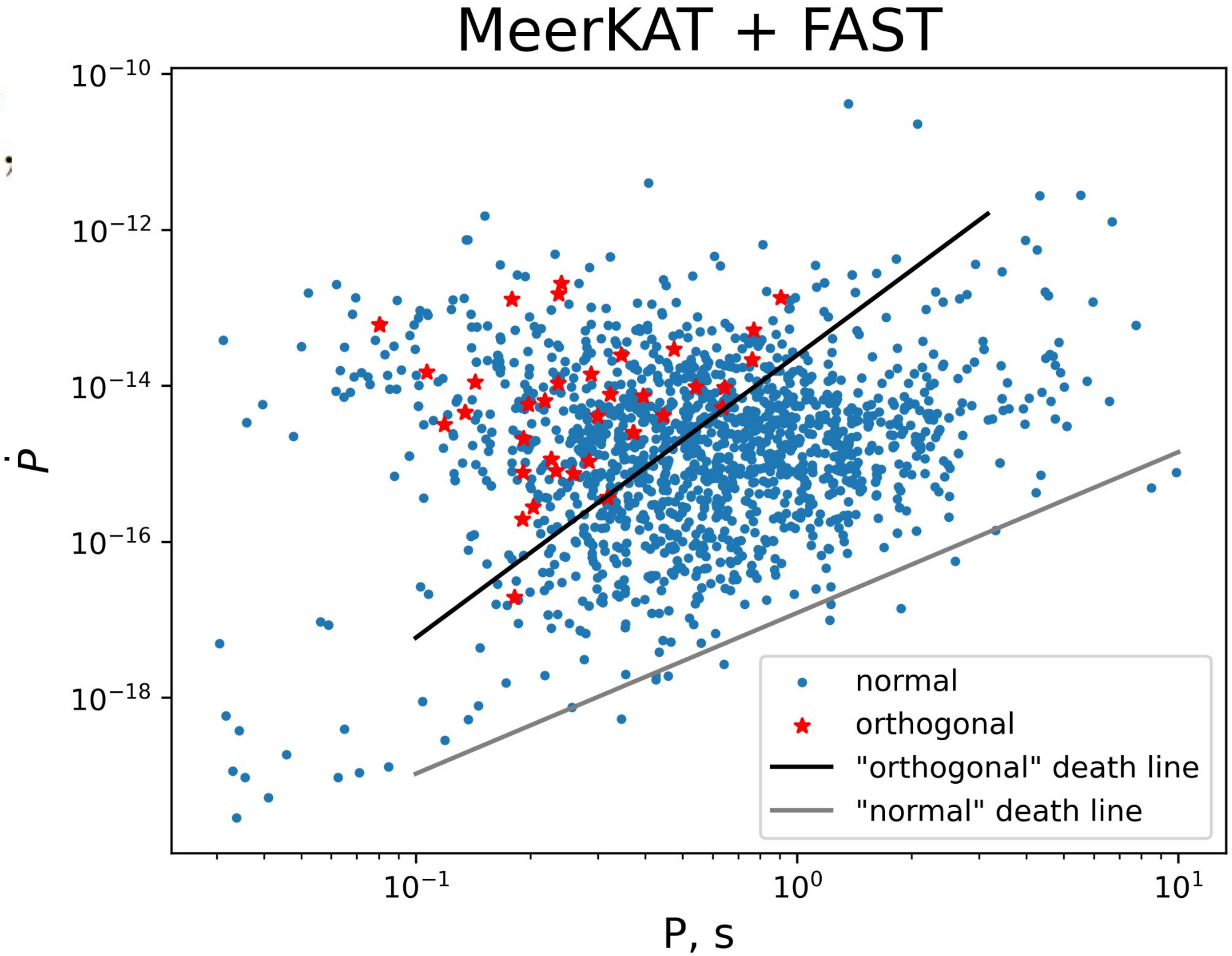
RS deathline paradigme

Ruderman-Sutherland deathline paradigme (1975)
For orthogonal interpulse pulsars

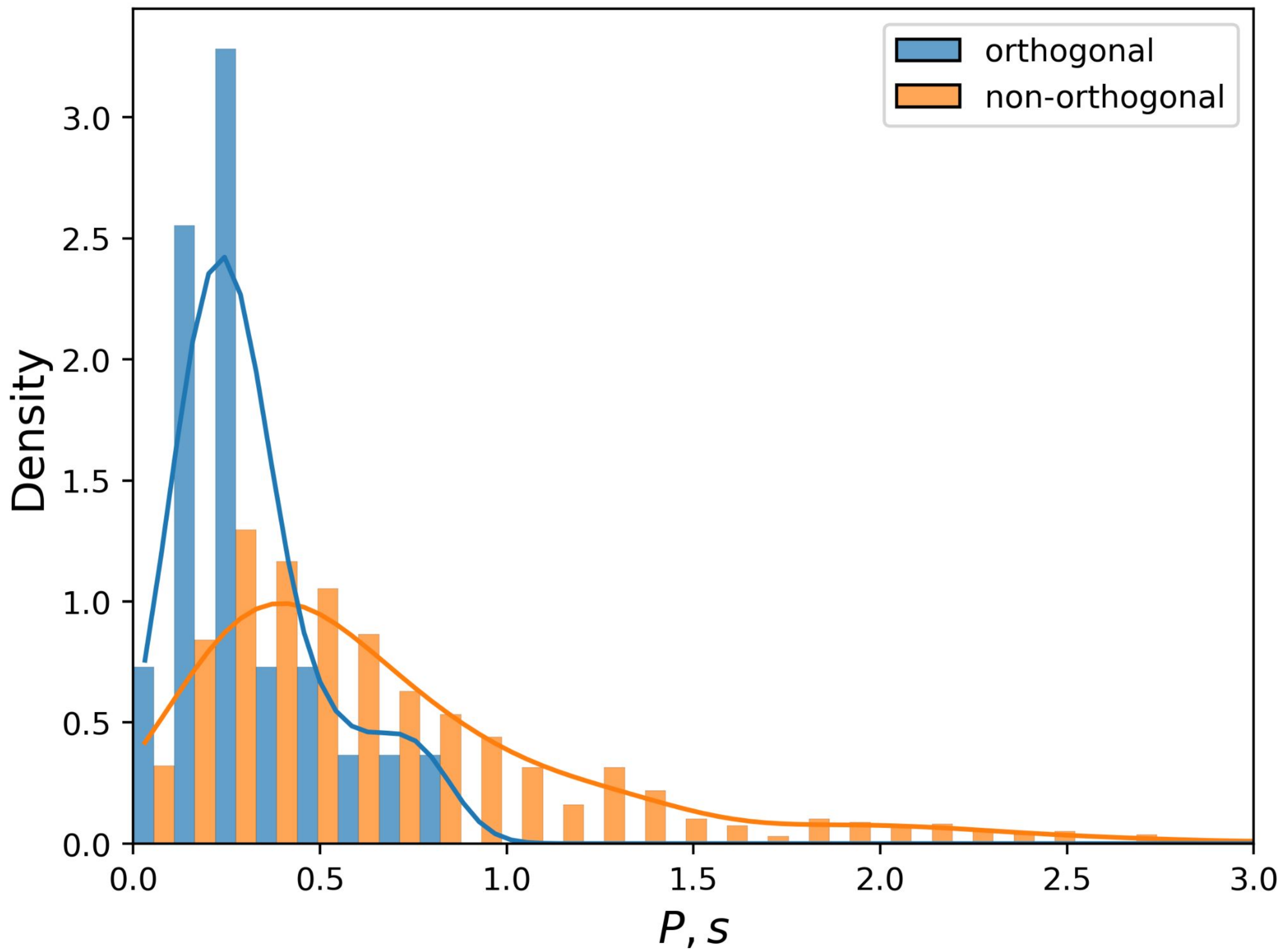
$$\cos\chi > k\, P^{15/7}\, B_{12}^{-8/7},$$

$$\cos\chi = (\Omega R/c)^{1/2}$$

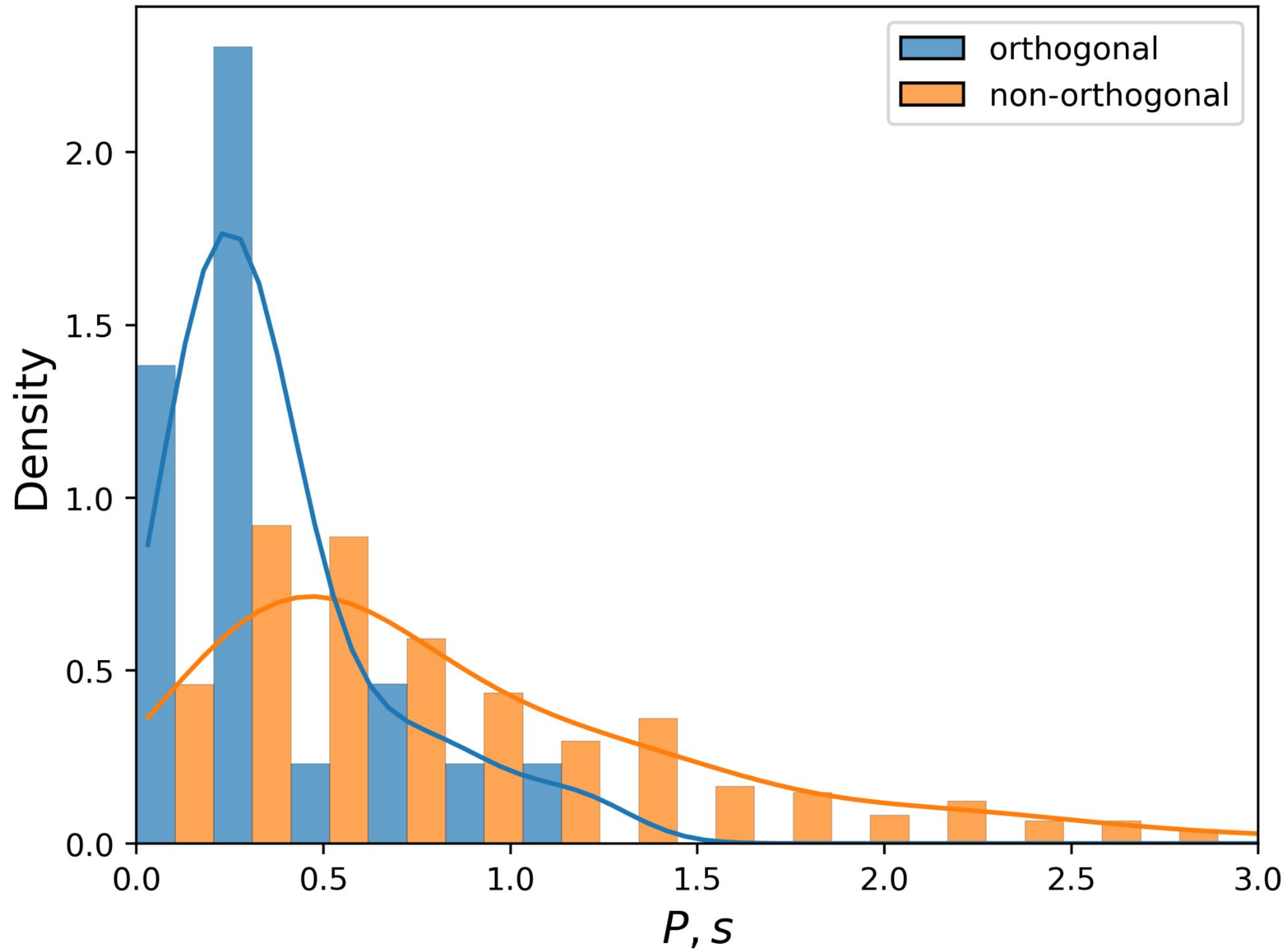
$$P < 0.2\, B_{12}^{28/37}\ \mathrm{s}$$



The evolution of the inclination angle



MeerKAt



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Conclusions

The statistics of orthogonal inter-pulse pulsars can serve as a key test for the pulsar evolution model.

The absence of orthogonal interpulse pulsars at long periods is not consistent with the MHD model, but it is consistent with the BGI model.