Implications for Compact Star Matter State from Radio Pulsar Observation

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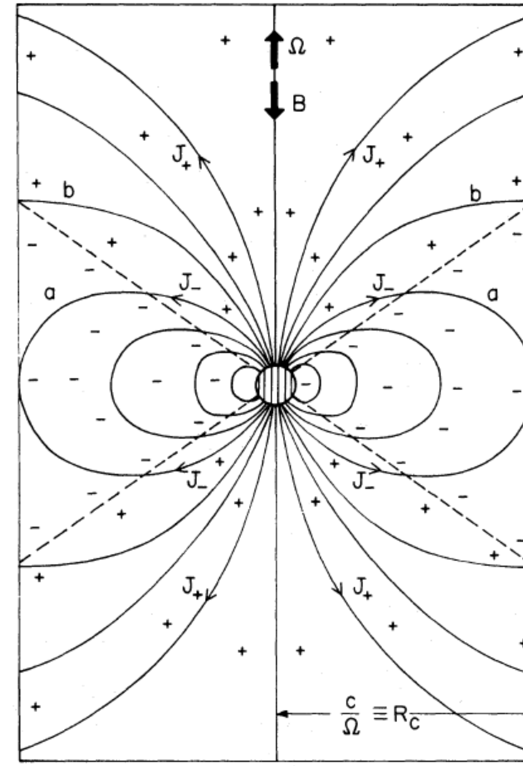
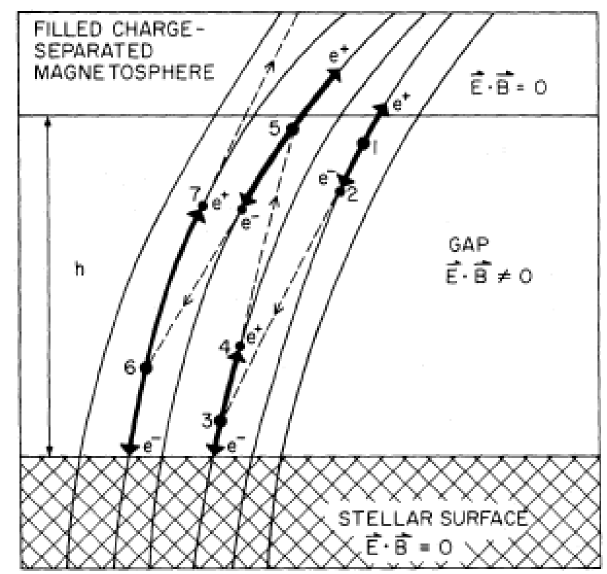
Polar gap model for radio radiation from pulsar

- The charged particles in magnetosphere moving outwards and the **high binding energy** of particles on stellar surface form the polar gap.
- Deviation from the equilibrium charge distribution lead to high electric field $\overrightarrow{\boldsymbol{E}_{\parallel}}$ in the gap.

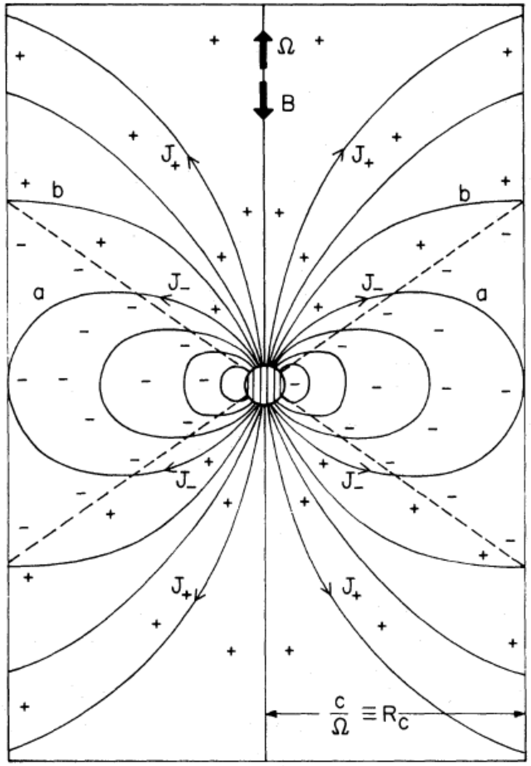


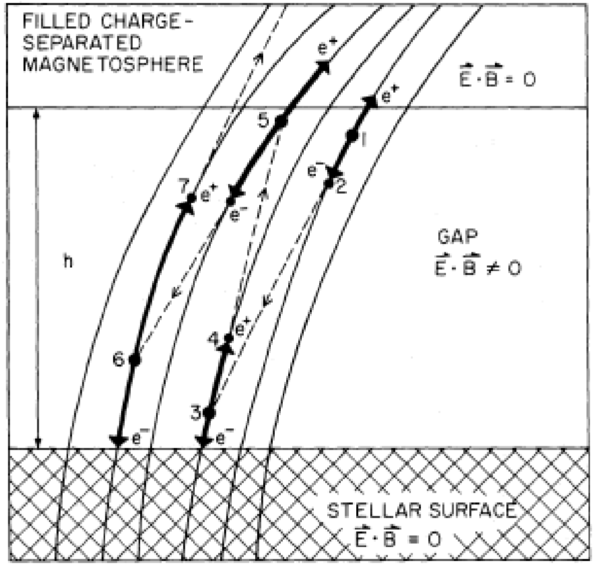


Ruderman & Sutherland (1975)

Polar gap model for radio radiation from pulsar

- Strong electric field $\overrightarrow{\boldsymbol{E}_{\parallel}}$ in polar gap accelerates charged particles to high energy to generate radio radiation.
- Electron-positron pairs and γ photon pairs cascading forms sparks in polar gap.

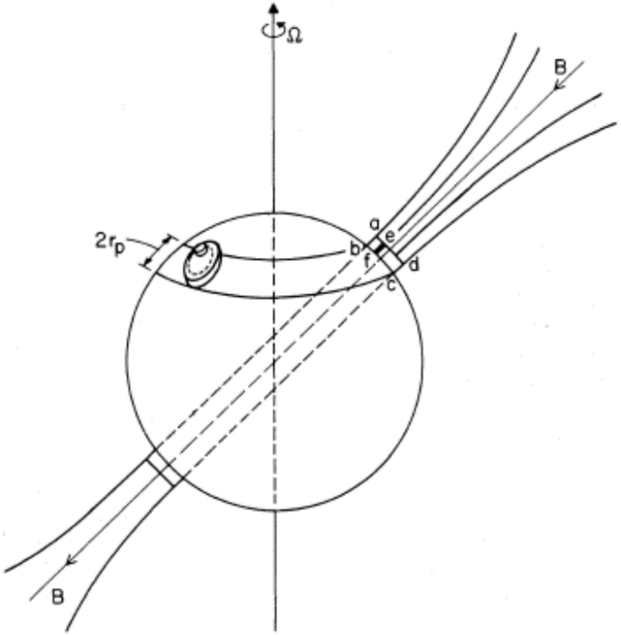


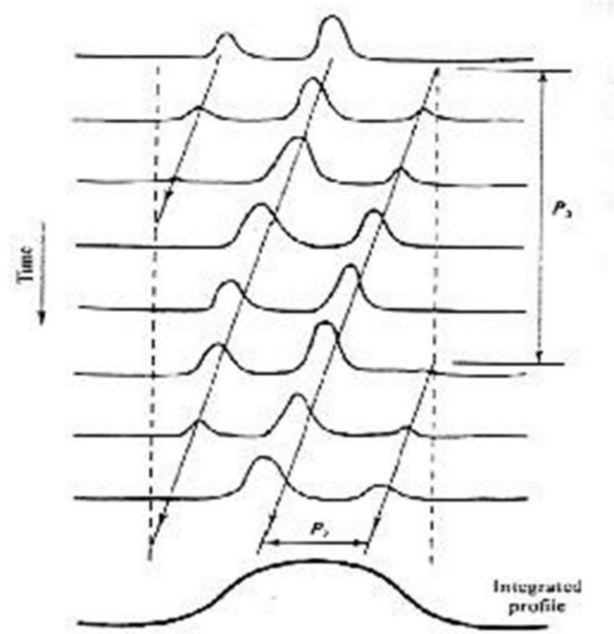


Ruderman & Sutherland (1975)

Sub-pulse drift in polar gap model

- The sparks move towards the direction of $\overrightarrow{E_\perp} \times \vec{B}$ in the gap.
- It could explain the sub-pulse drift phenomenon (P_2 & P_3) in the observed single pulse trains at radio frequency.
- **high binding energy of particles on stellar surface $\Longrightarrow$ self-bound surface**

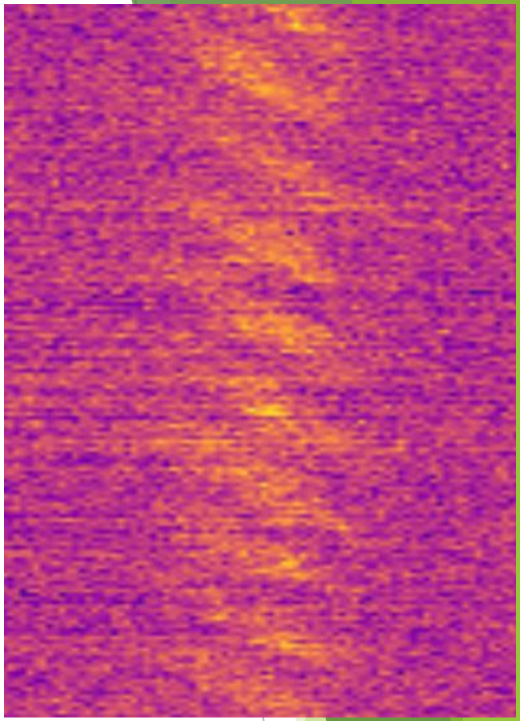


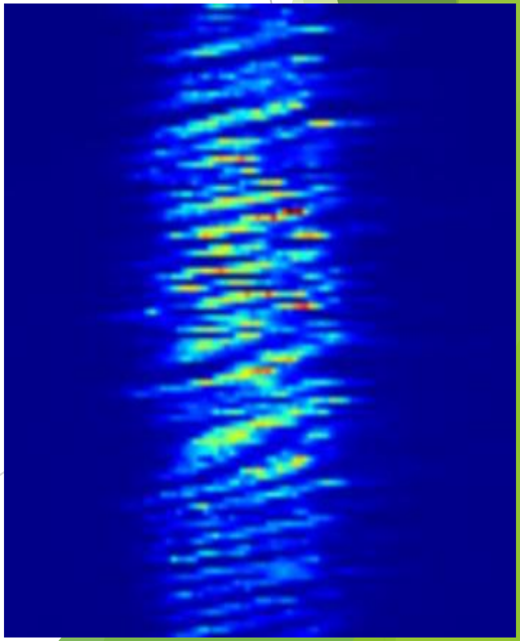


Ruderman & Sutherland (1975)

Other properties of drifting sub-pulse

- coherent drifter and diffused drifter
- diffused drifter ⟹ different electric field near the spark ⟹ spark may happen at different place in polar gap
- point discharge from coarse stellar surface?
- **coarse stellar surface ⟹ solid stellar surface ⟹ solid star?**





Physical prediction

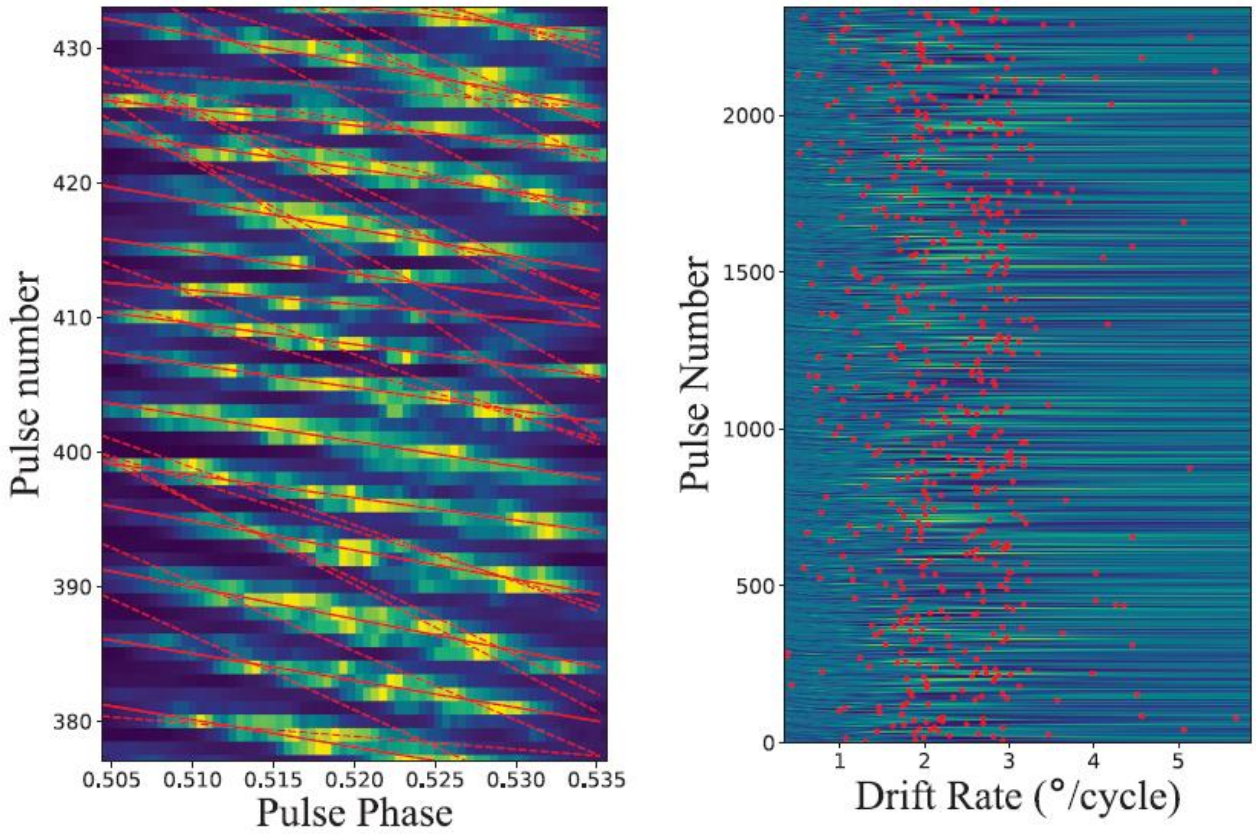
- Ruderman & Sutherland (1975) pointed that in polar gap there is a positive relation between $\boldsymbol{E}_{\perp}$ and $\boldsymbol{E}_{\parallel}$.
- Thus, for diffused drifters, larger P_2 $\Longrightarrow$ sparser sparks $\Longrightarrow$ lower $\boldsymbol{E}_{\parallel}$ $\Longrightarrow$ lower $\boldsymbol{E}_{\perp}$ $\Longrightarrow$ smaller drift speed $\frac{\overrightarrow{\boldsymbol{E}_{\perp}} \times \overrightarrow{\boldsymbol{B}}}{\left|\overrightarrow{\boldsymbol{B}}\right|^{2}}$.

Sub-pulse drift study with FAST

- Single pulse study need large telescope.
- FAST (Five-hundred-meter Aperture Spherical radio Telescope) could be used to study the relation between P_2 and drift speed of diffused drifters.

Drifting sub-pulse: drift rate

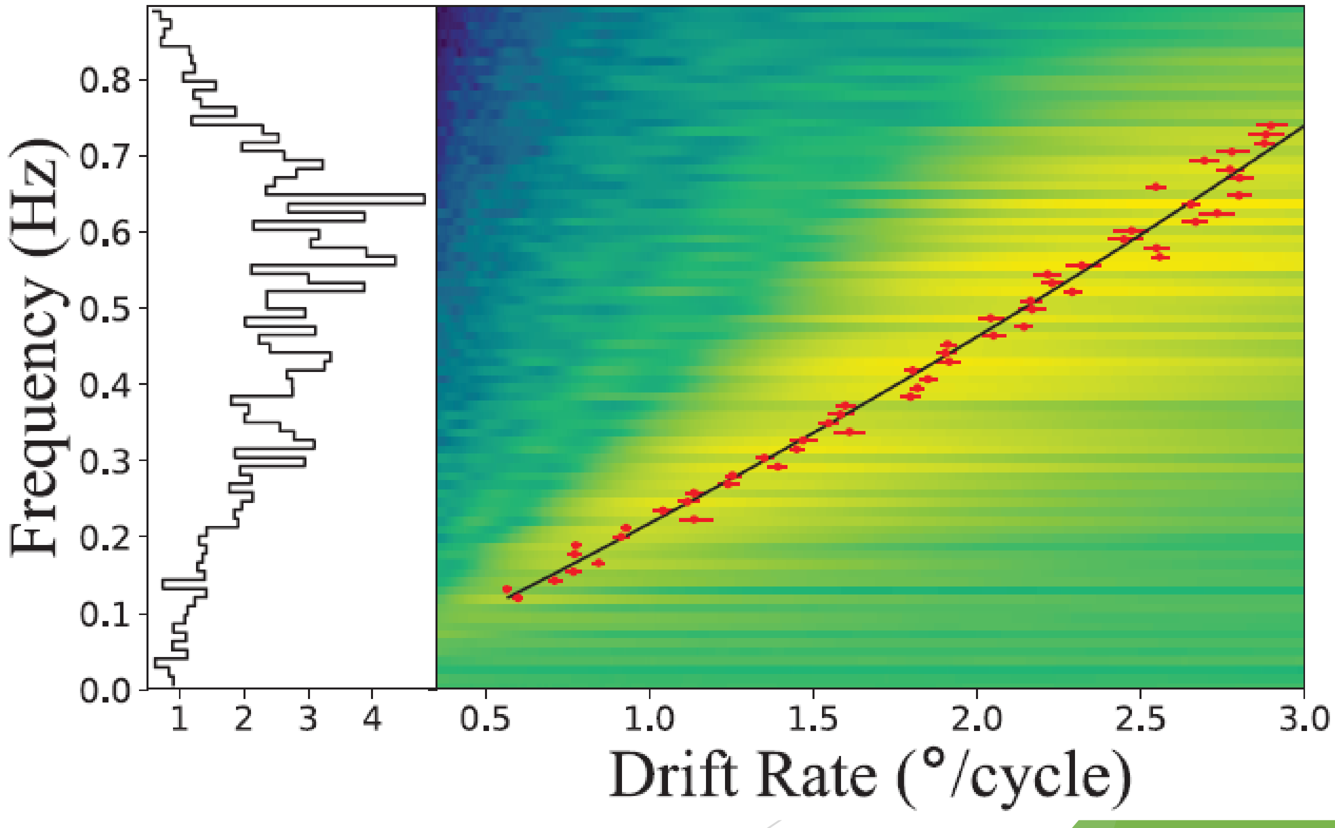
- diffused drifter PSR B2016+28
- Drift rate fluctuates with time.



Drift rate and F_3; P_2 & P_3

- P_3 evolves with drift rate.

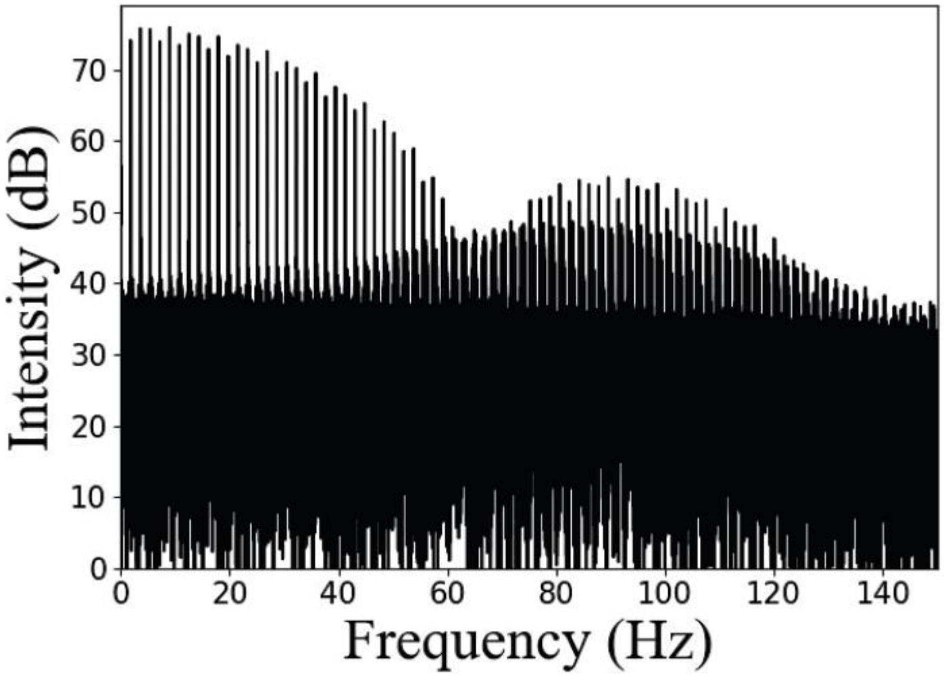
$$D = \frac{F_3}{k_d F_3 + b_d}$$

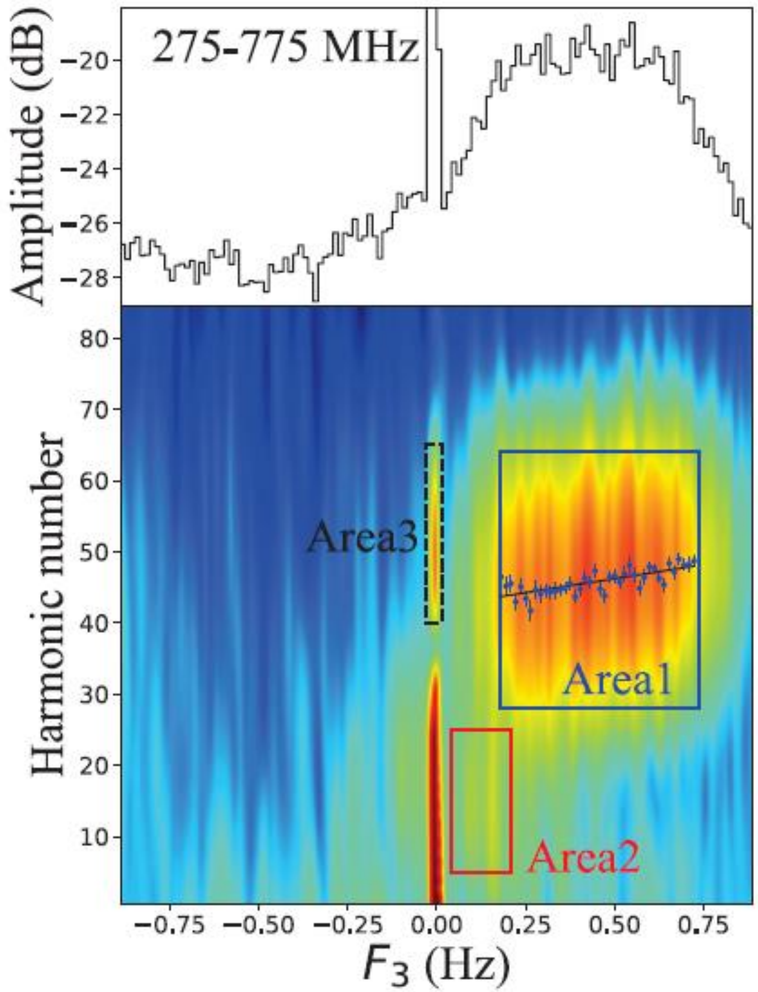


Harmonic analysis for drifting sub-pulse

- P_3 evolves with P_2.

$$H = k_h F_3 + b_h$$

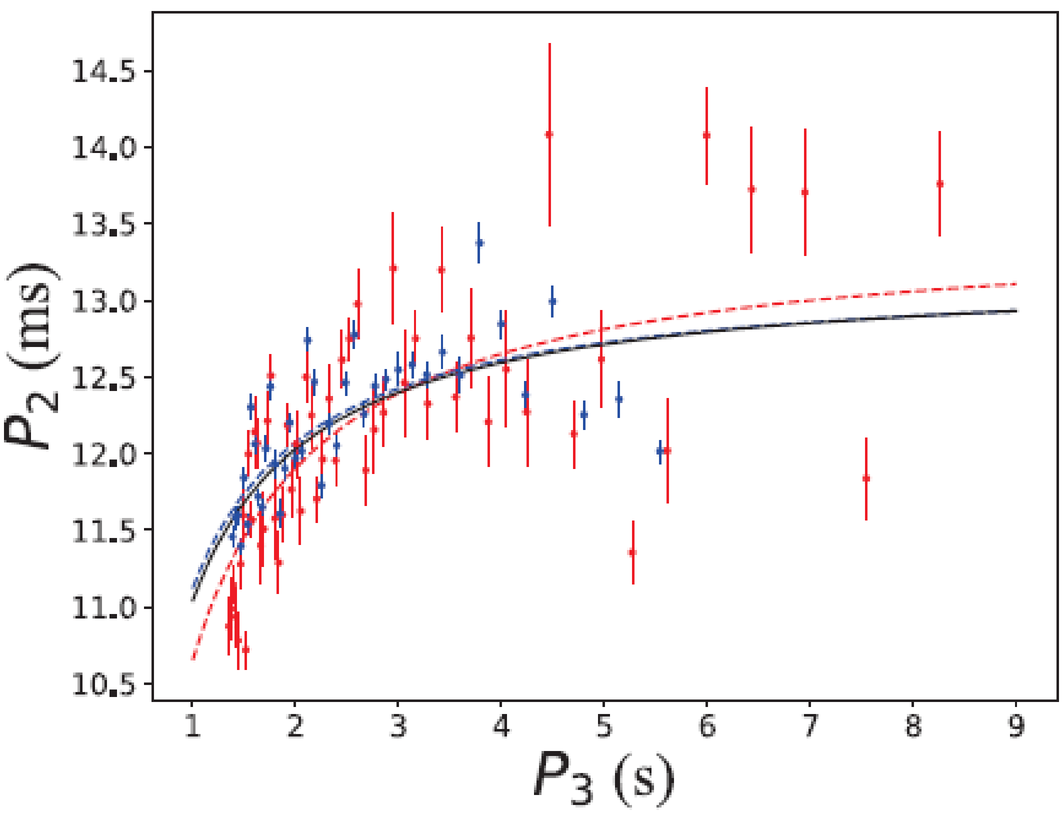




Relation between P_2 & P_3

- P_3 evolves with P_2.
- larger P_2 $\Leftrightarrow$ larger P_3 $\Leftrightarrow$ smaller drift speed
- spark happen at different position of polar gap
- point discharge from solid coarse stellar surface? $\Longrightarrow$ strangeon star?

$$P_2 = \frac{P_3}{\gamma P_3 + \beta}$$



SUMMARY

- The drifting sub-pulse phenomenon implicates **high binding energy** of pulsar surface.
- The positive relation between P_2 and sub-pulse drift rate suggests a **solid coarse surface of pulsar**.

Thanks!