Do we understand glitches yet?

1. What is the mechanism that causes glitches? Starquakes? Vortex line unpinning in crust? Flux tube migration?
2. Flux creep, repinning, recovery times? (Ekman layers with squshy crust and varying shear modulus; pasta, lasagna, pizza?)
3. Coupling of multiple regions? (e.g. crust and core)
4. Implications for nuclear physics? Connections to gaps via coherence lengths/vortex sizes and interactions with nuclear lattice (crust).
5. Quark? Solid core?
6. Magnetar glitches?

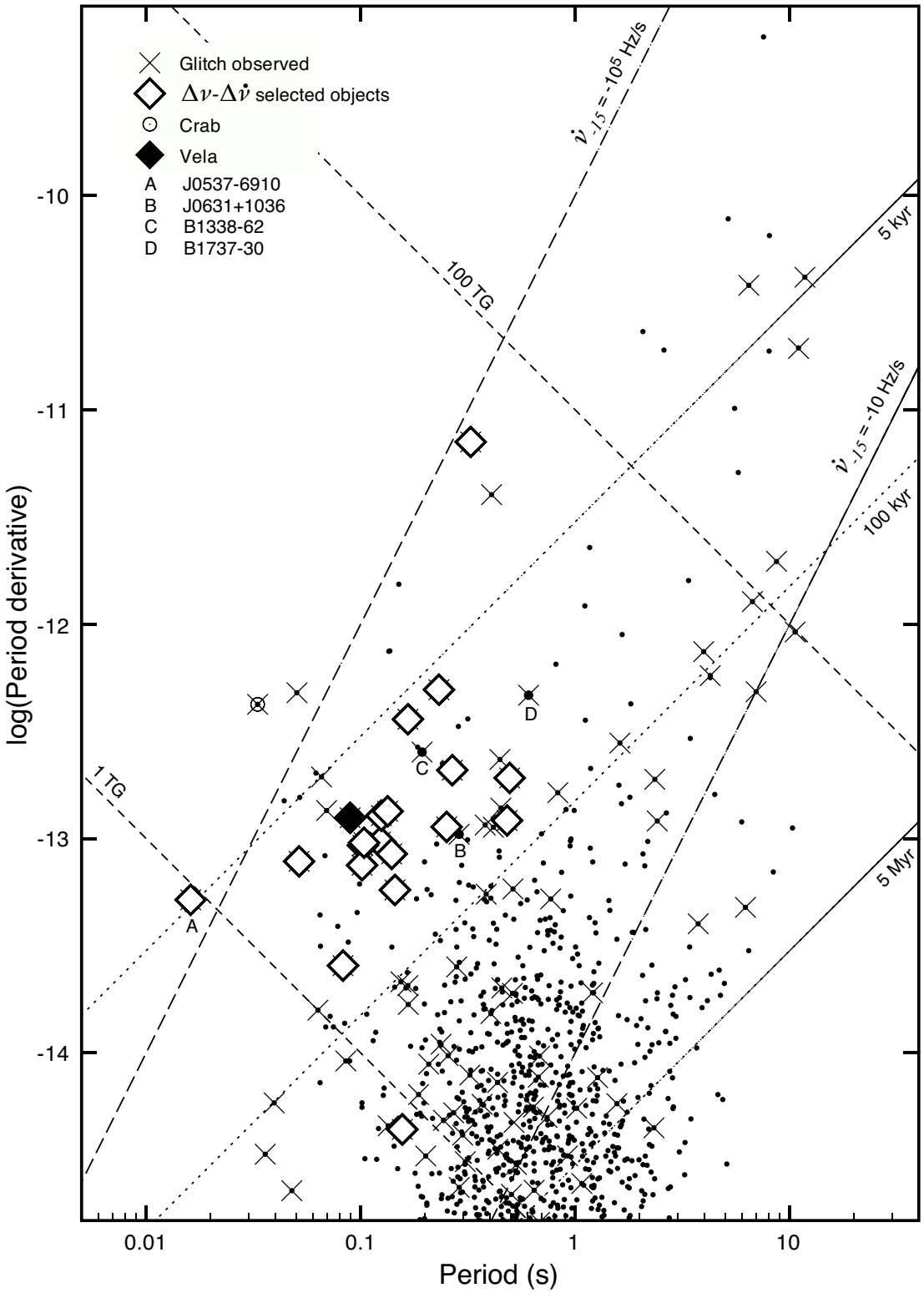

Fig. 1.—: From Espinoza et al., MNRAS, 414, 1679 [2011]. Shows glitching pulsars in $P - \dot{P}$ diagram (X). 315 glitches seen from 102 pulsars.

What causes slow variations?

- Context: timescale $\sim$ years for 1 second "day" equivalent to $\sim$ 10Myr for Earth.
- Magnetospheric mode switching? (e.g. from one spindown state to another, as favored by Lyne et al.) If so, of no interest to this audience...but why years? Also: magnetospheric fluctuation $\Rightarrow$ stellar response.
- Other slow timescales?
  1. "Solid body" precession: timescale $\sim P_{\rm rot}/\epsilon$ requires $\epsilon \sim 10^{-7}$. Plausible? Impossible (Shaham; Sedrakian, IW, Cordes)? Possible (Cutler and Link)?
  2. "$B - \Omega$" precession: two distortions (rotational and magnetic) perhaps (definitely?) misaligned (Spitzer, Mestel...ancient texts). Magnetic distortion $\sim BHR^4/GM^2 \approx 10^{-12}(BH/10^{24}{\rm G})$; fluid precession about magnetic axis; slow internal velocity fields.
  3. "$\mathbf{E} \times \mathbf{B}$" Drift: Frequency $\sim m_p cGM/R^3 eB \approx 10^{-8} B_{12}^{-1} {\rm s}^{-1}$. Might be magnetospheric (Ruderman) might be internal.
  4. Vortex lattice waves?
  5. Instabilities?

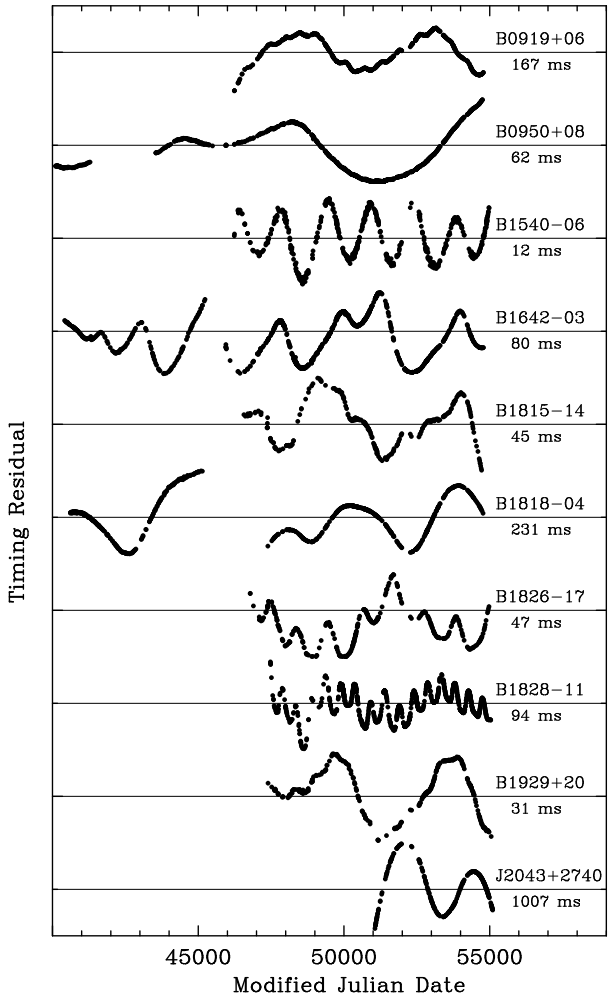

Figure 1:

Fig. 2.—: From Lyne et al., Science 329, 408 [2010]. Timing residuals for 10 pulsars relative to model up to $\dot{\nu}$ ($\ddot{\nu}$ for 0919-06, 1540-06, 1828-11) 4

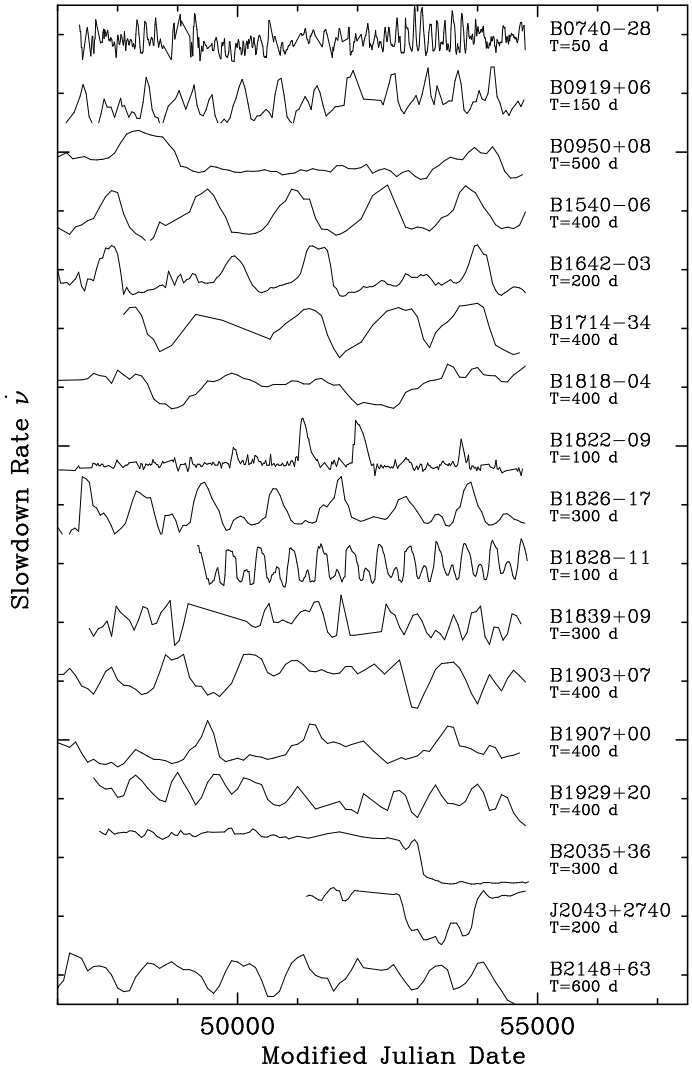

Figure 2:

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Fig. 3.—: From Lyne et al. $\dot{\nu}$ variations for 17 pulsars over 20 years.

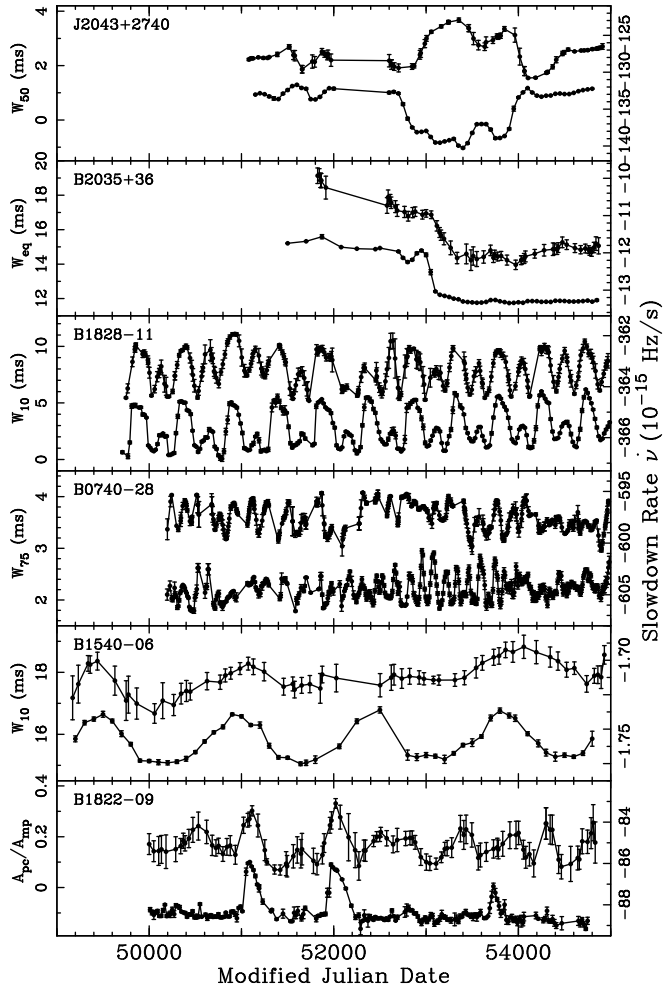

Figure 4:

Fig. 4.—: From Lyne et al. Various measures of pulse shape variations for six pulsars over $\gtrsim 10$ years.