Flickering of the Vela pulsar during its 2016 glitch

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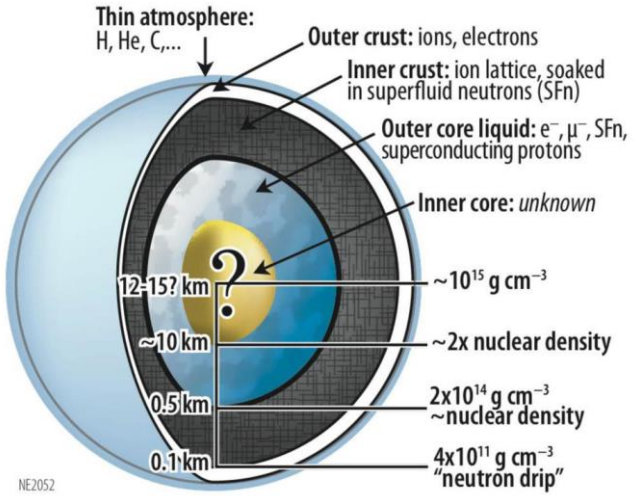
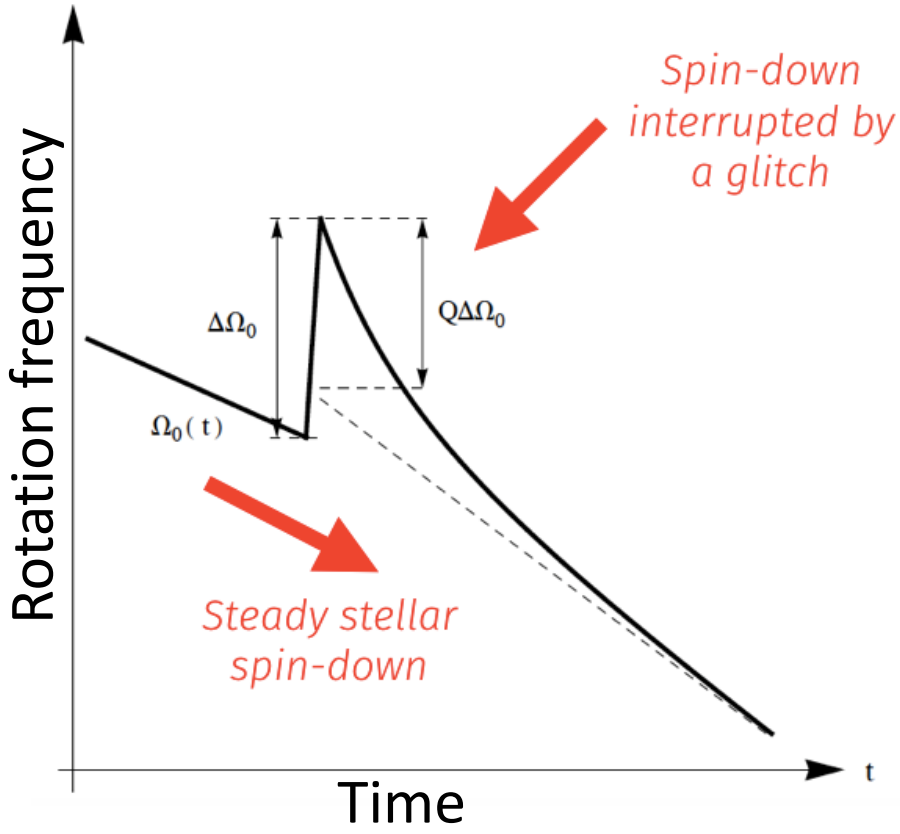
Radio pulsar glitches

- Sudden spin-up event
- Coupling of the inner and outer crust
- Insights into the interior
- See Haskell & Melatos (2015)

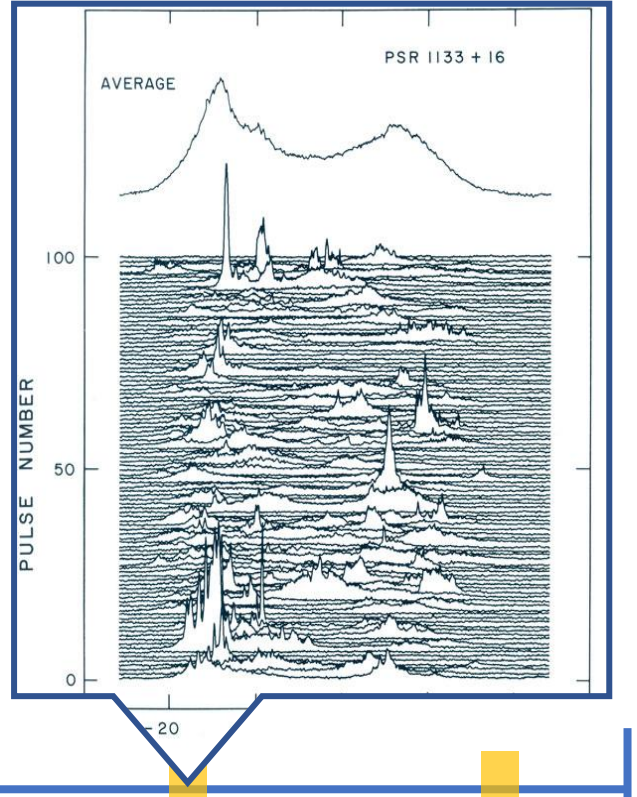


NASA / GSFC / NICER



Middleditch et al. (2018)

Traditional pulsar timing



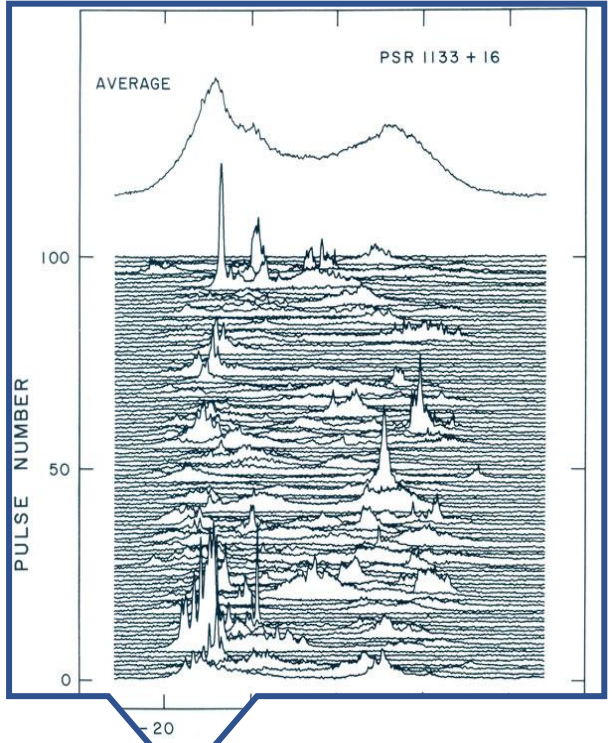
Observations

TOA_1 TOA_2 TOA_3 TOA_4 TOA_5 TOA_6 TOA_7

Time of arrivals

Timing model

Traditional pulsar timing



Observations

Glitch

TOA_1 TOA_2 TOA_3 TOA_4 TOA_5 TOA_6 TOA_7

Time of arrivals

Timing model

Traditional timing approaches are unlikely to observe a glitch directly

The 2016 Vela radio-pulsar glitch

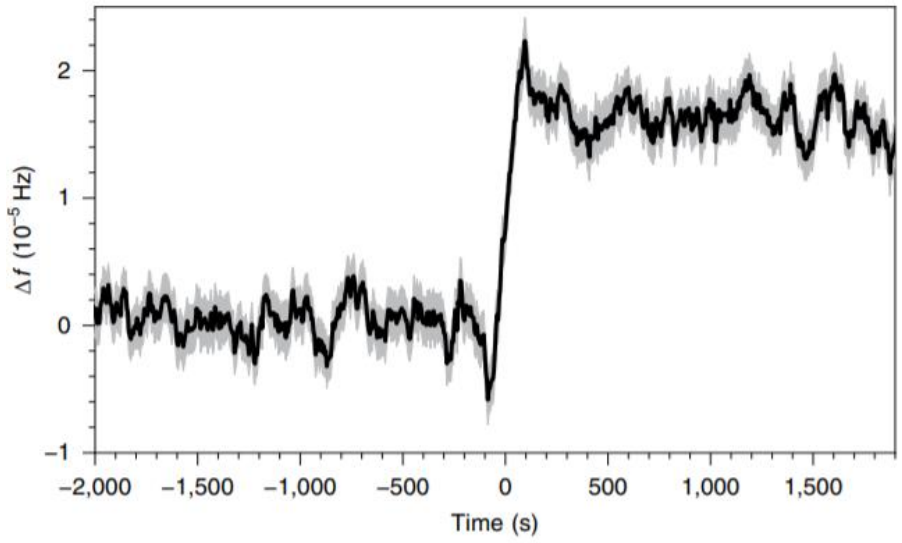
- Mt Pleasant Observatory Tasmania
- Constantly surveilling the Vela pulsar
- In 2016 it caught a glitch in real time:

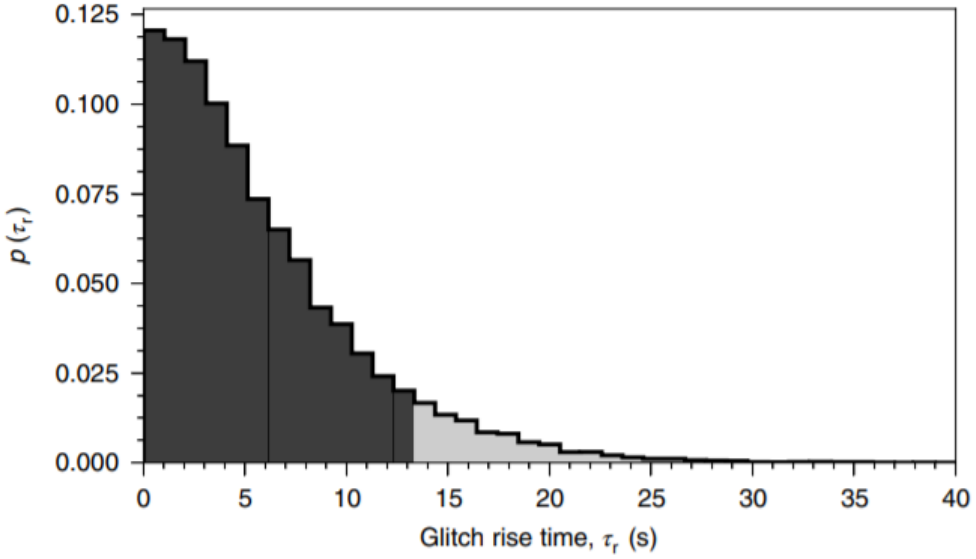
  “Pulse-to-pulse observations”

- Palfreyman et al. (2018)

Seeing the spin-up

- The data allowed us to see the spin-up itself, for the first time:

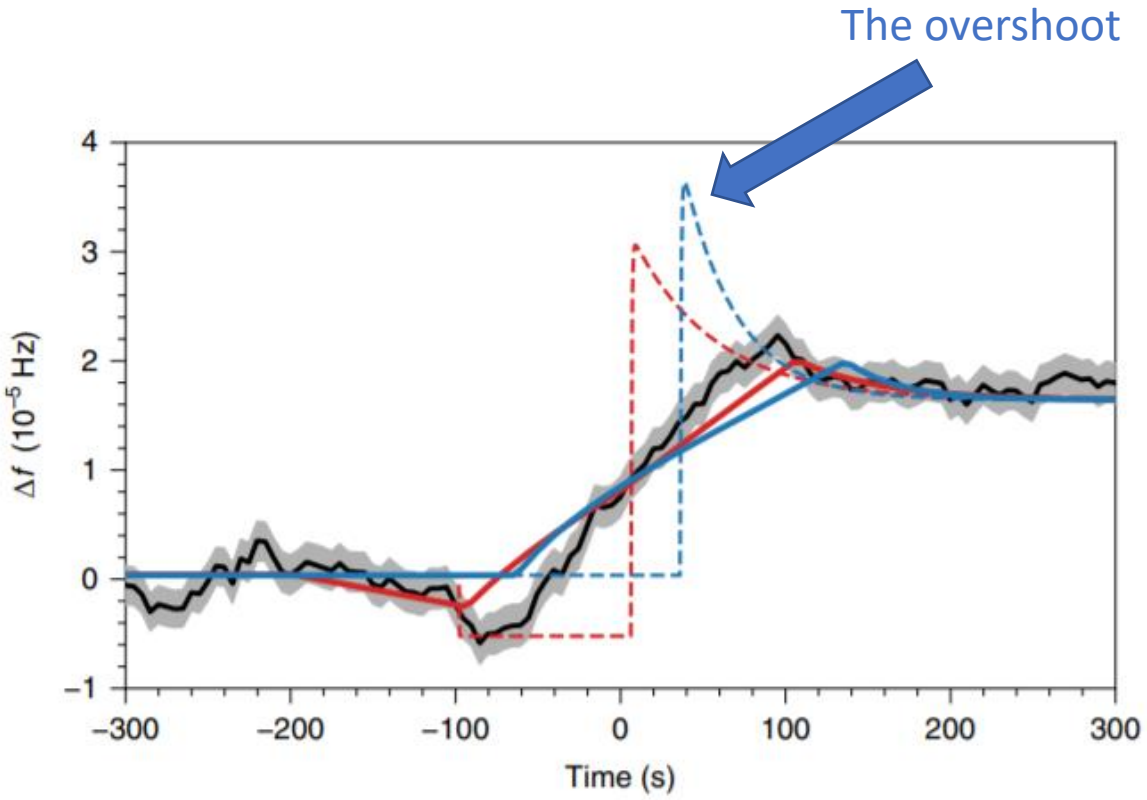




Ashton et al. (2019)

Using the dynamics to probe the physics

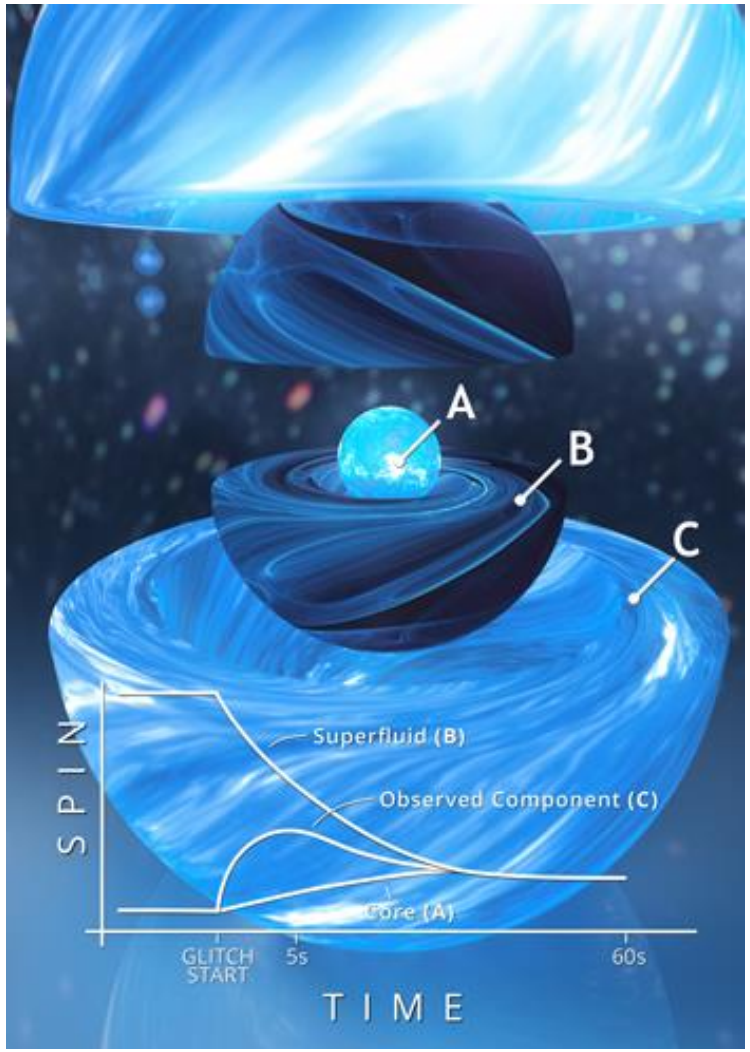
- We fit phenological models to infer the glitch properties
- We find overwhelming evidence for an “overshoot”



Evidence for three-components

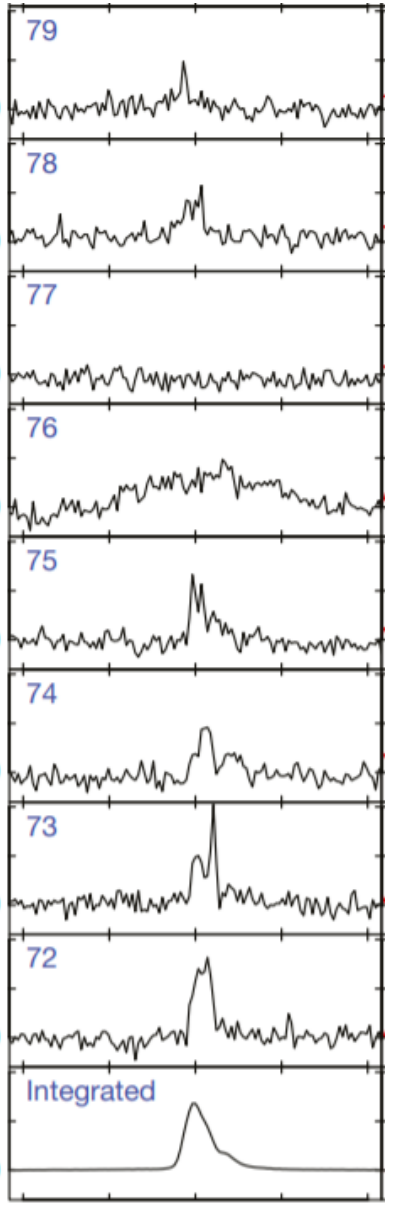
- The overshoot suggests the existence of three separate components

- This allows direct measurements of the Moment of Inertia and coupling between components:
  - Pizzochero et al. (2020)
  - Gügercinoğlu et al. (2020)
  - Montoli et al (2020)



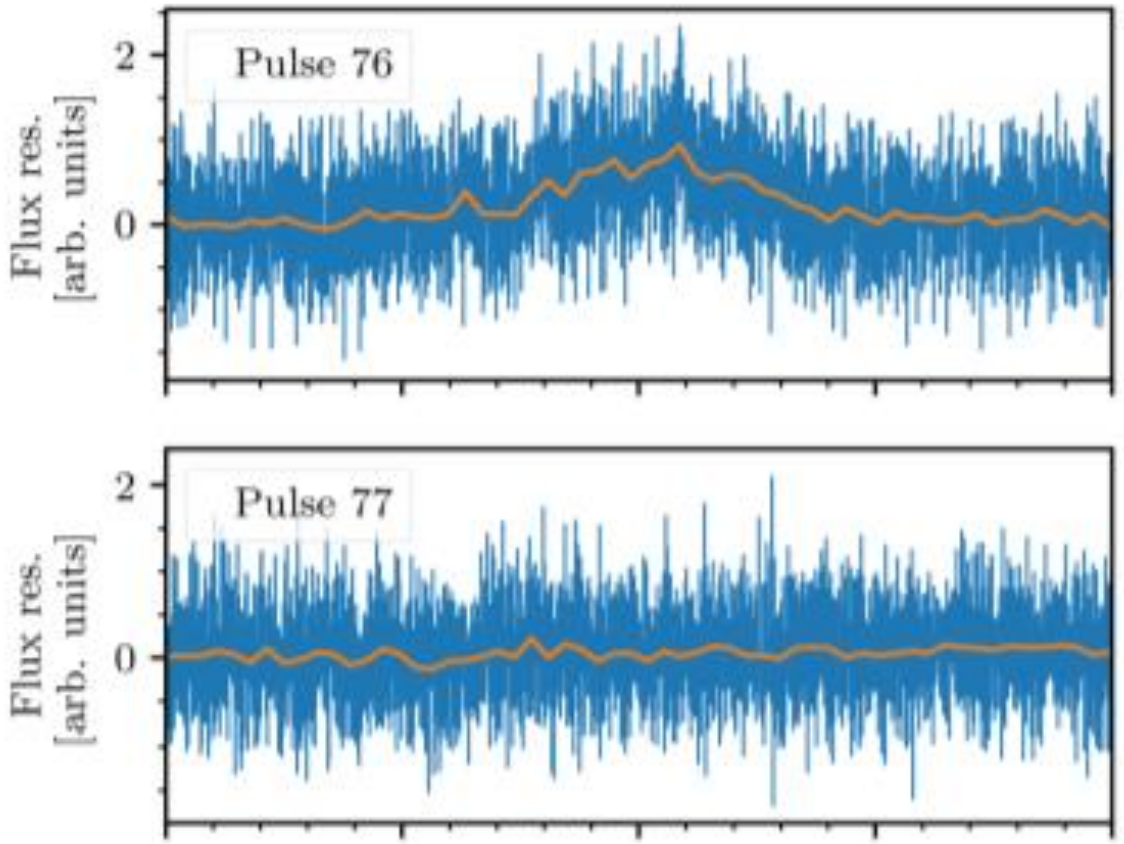
A null just prior to the glitch

- This data allowed Palfreyman to analyze individual pulses during the glitch.
- While **integrated pulses are stable**: pulsars are known to exhibit significant **jitter**.
- A null, **pulse 77**, occurred just before the glitch.
- This is the first recorded null in the Vela pulsar



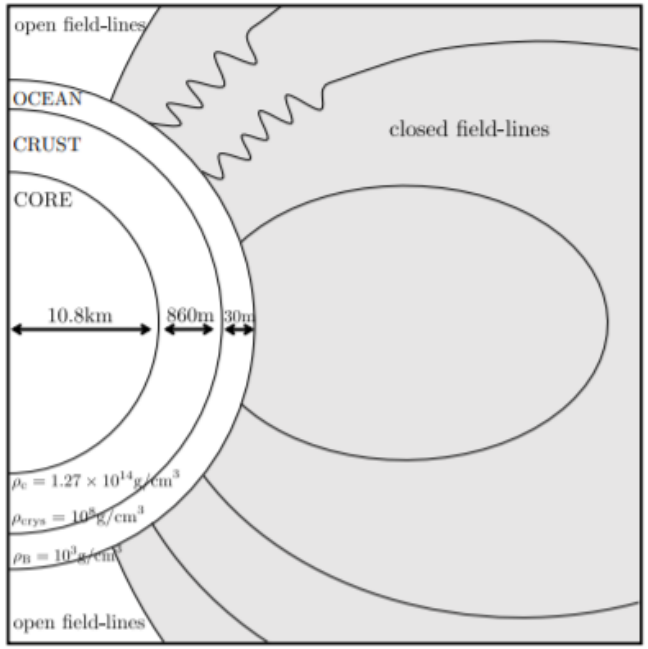
Palfreyman et al (2018)

The broad pulse and null pulse in more detail



Implications of the null

- Bransgrove et al. (2020) develop a model connecting the glitch and null:



Bransgrove et al. (2020)

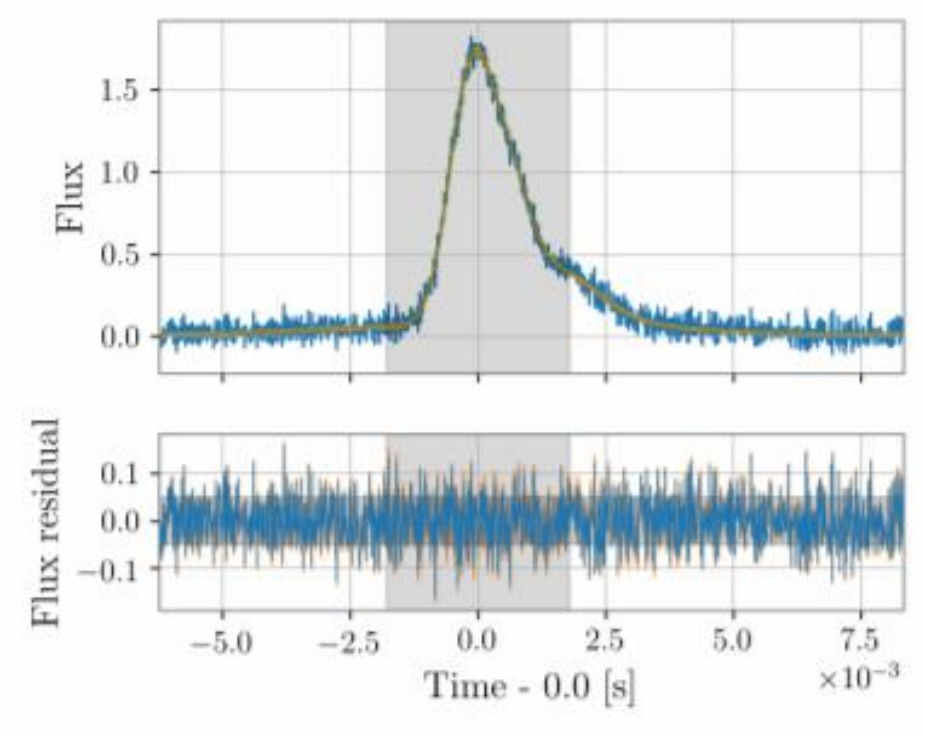
Stress builds up in the crust: reason unknown → Critical stress causes quake in the crust → Crustquake triggers superfluid-unpinning → Observed glitch

Critical stress causes quake in the crust → Oscillations disrupt the magnetosphere (damped over a single rotation) → Observed null

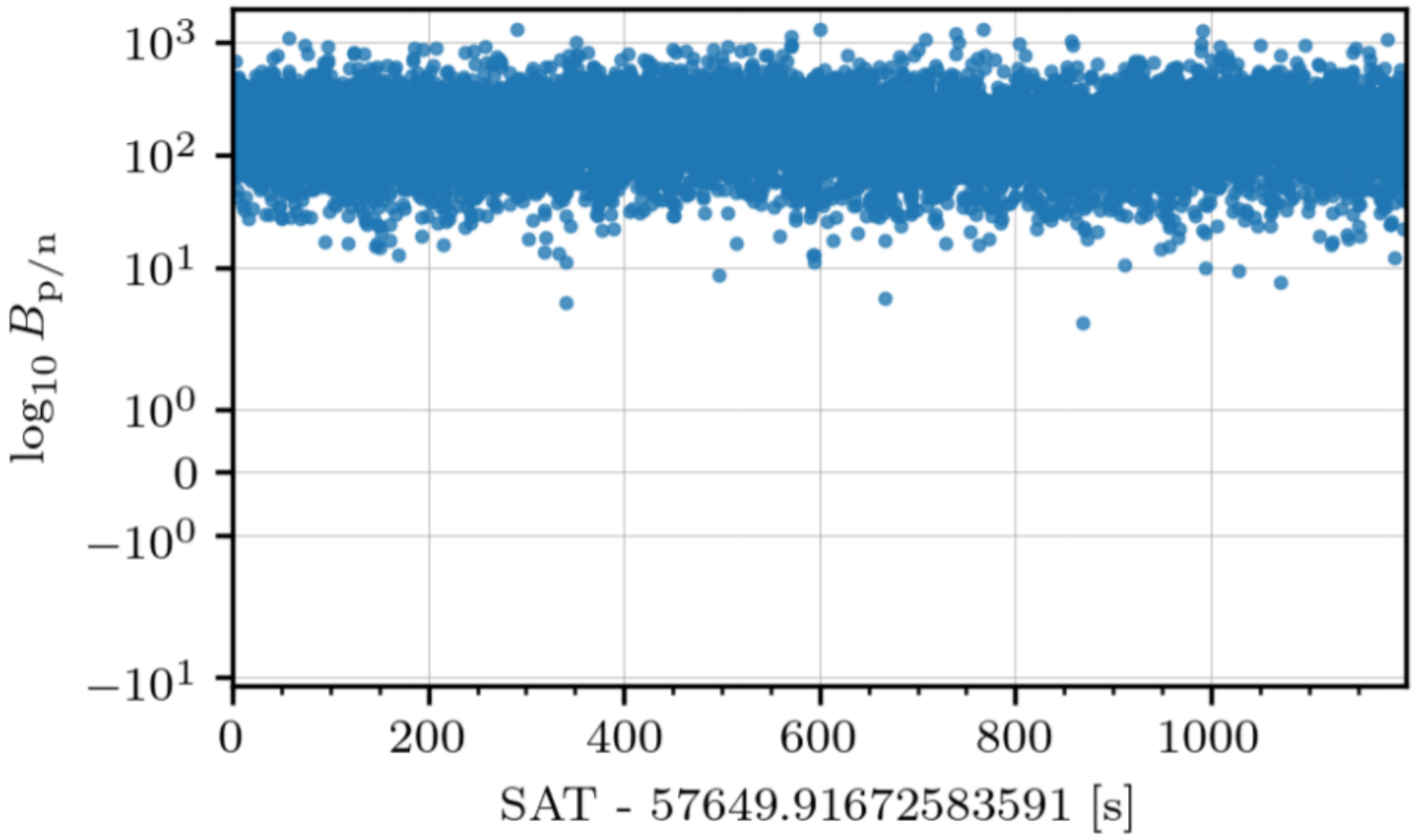
Reanalyze the raw data

- Ashton et al. (2020)
- We fit phenomological flux models to the raw data of each individual pulse
- Use the open-source kookaburra package
- Can calculate a Bayes factor

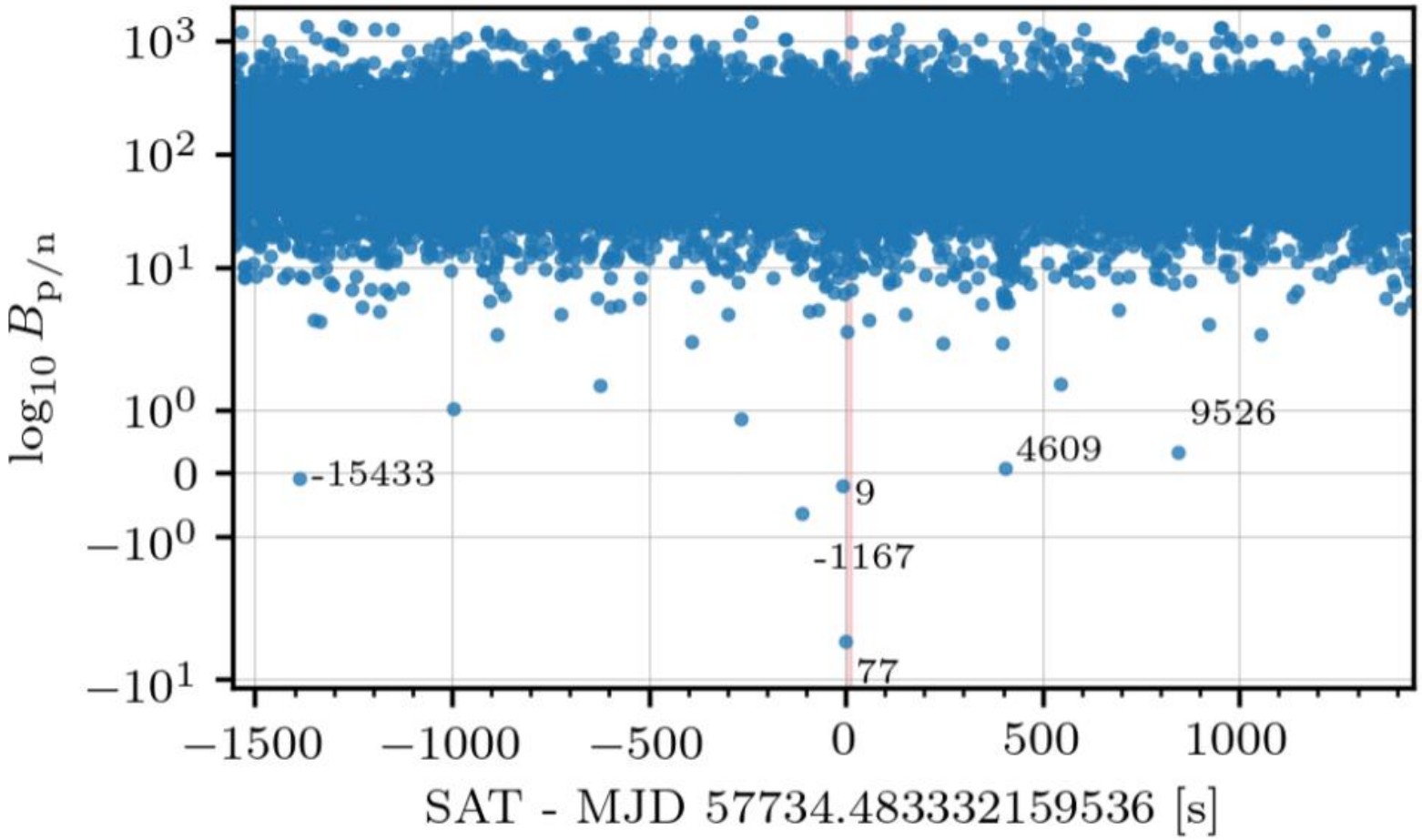
$$B_{\mathrm{p/n}} = \frac{P(\,\mathrm{pulse}\,|\,\mathrm{data}\,)}{P(\,\mathrm{null}\,|\,\mathrm{data}\,)}$$



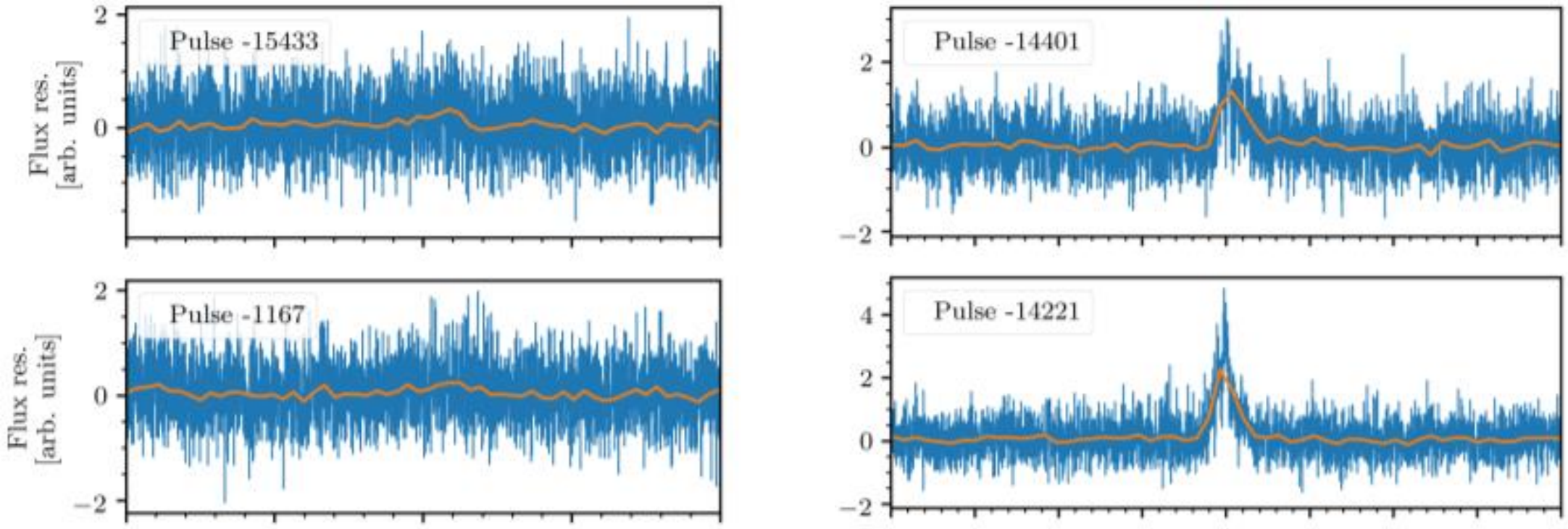
20 minutes of data away from the glitch



50 minutes of data around the glitch



Quasi pulses: what do they look like?



Conclusions

- Re can re-affirm the existence of the null
- We also find evidence of the existence of “quasi-nulls”
  - What does this mean for the Bransgrove et al interpretation?
  - Could the null + quasi-nulls instead be explained by a “magnetospheric storm”
- Currently analyzing a larger quantity of data
- Extended activity could be used as an early-warning system