The long-term post-outburst spin down of low magnetic field magnetar Swift J1822.3-1606

Scholz et al 2014, ApJ, accepted, arXiv:1401.6965

Paul Scholz
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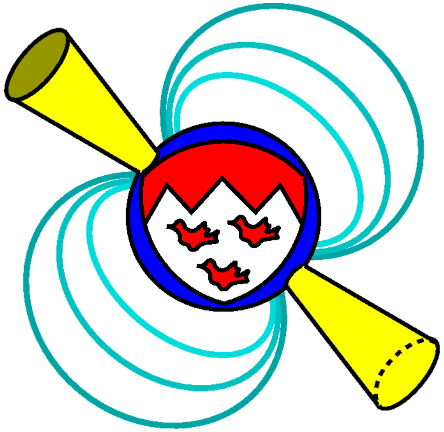


Collaborators: Vicky Kaspi, Andrew Cumming,
Robert Archibald, C.-Y. Ng, Margaret Livingstone

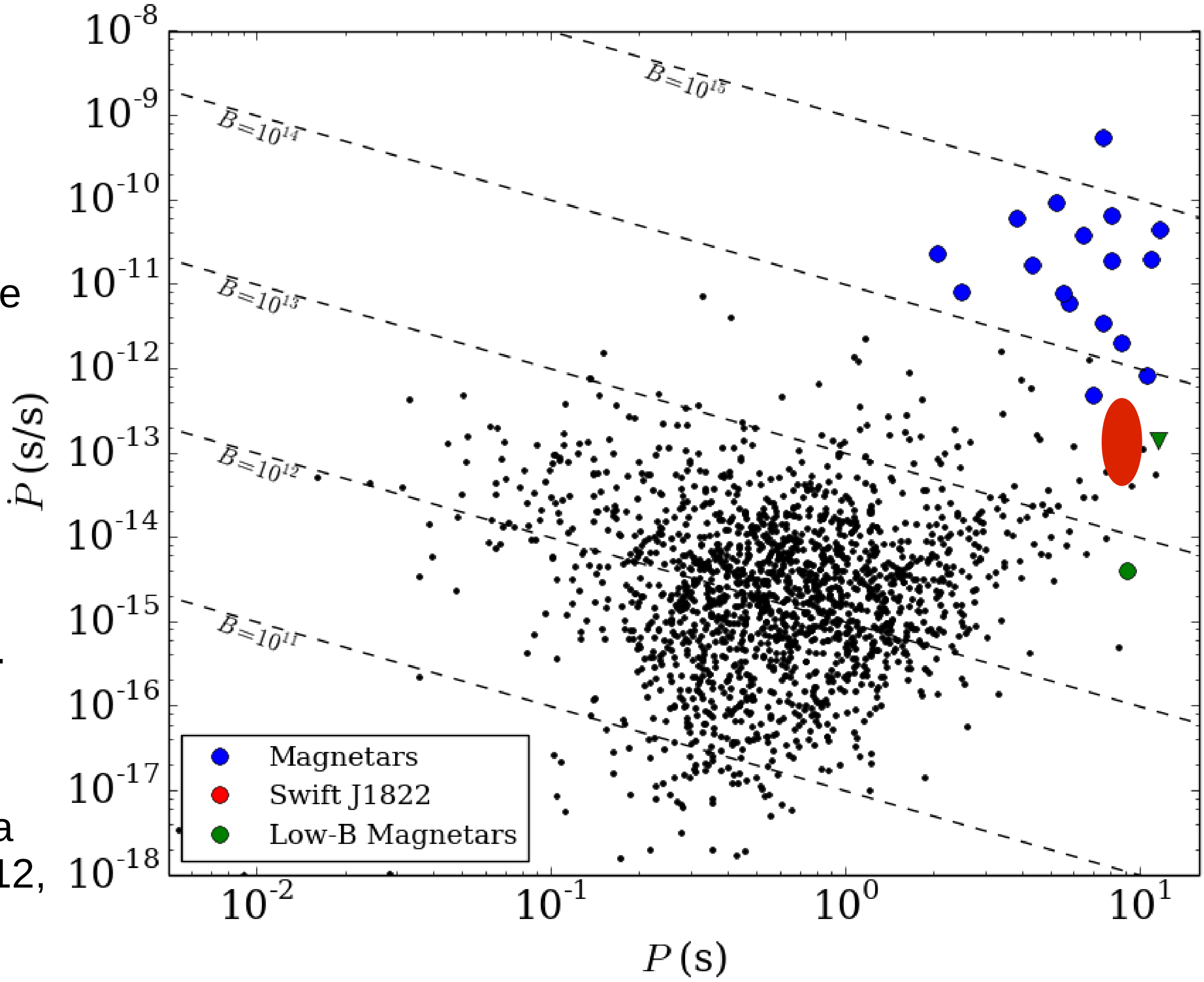
Magnetars: Properties

- Bright X-ray pulsars with $L_x = 10^{32}$-10^{36} ergs/s
- Periods from 2-12s
- B-fields ~10^{13}-10^{15}
- Often have glitches (and sometimes anti-glitches)
- High amounts of timing noise
- Several found near SNRs → Young
- Spectra: Thermal surface photons scattered by currents in magnetosphere
  - Often modelled by BB + Power-law

Magnetars: Low B magnetars

- Previously:
  - Magnetars need high dipole B-field
  - B~10^{14} G rough lower limit
  - Thought magnetars separate from pulsar population
- Recently several “low-B” magnetars discovered:
  - SGR 0418+5729 (Rea et al. 2009,2013)
  - 3XMM J1852+00 (Rea et al. 2014)
  - Swift J1822.3-1606

    (Livingstone et al. 2011, Rea et al. 2012, Scholz et al. 2012, this talk)



Magnetars

How does low field work with magnetar model?

- Hidden B-field?
  - True magnetic fields could be higher if significant toroidal component
  - If toroidal component can be ~100x larger than dipole, SGR 0418 could have magnetar-sized true B-field
  - Pulsars with 'low' dipolar fields could have hidden magnetar-sized B-fields
- Can have magnetar properties and activity from low B-field?

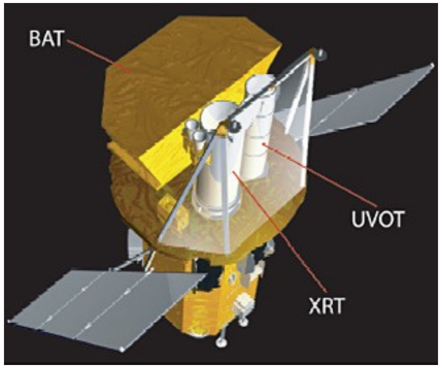
Swift J1822.3-1606

- Detected by the Swift Burst Alert Telescope (BAT) on 14 July 2011 (Cummings et al. 2011)
- Emitted several short (~10ms bursts)
- Reached a peak 1-10 keV flux of >2×10^{-10} ergs cm^{-2} s^{-1}
- 8.4 s pulsar
- Found in archival ROSAT observation with a 1-10 keV flux of ~1×10^{-13} ergs cm^{-2} s^{-1} (Esposito et al. 2011)

→ **Flux increased by ~3 orders of magnitude at outburst onset**

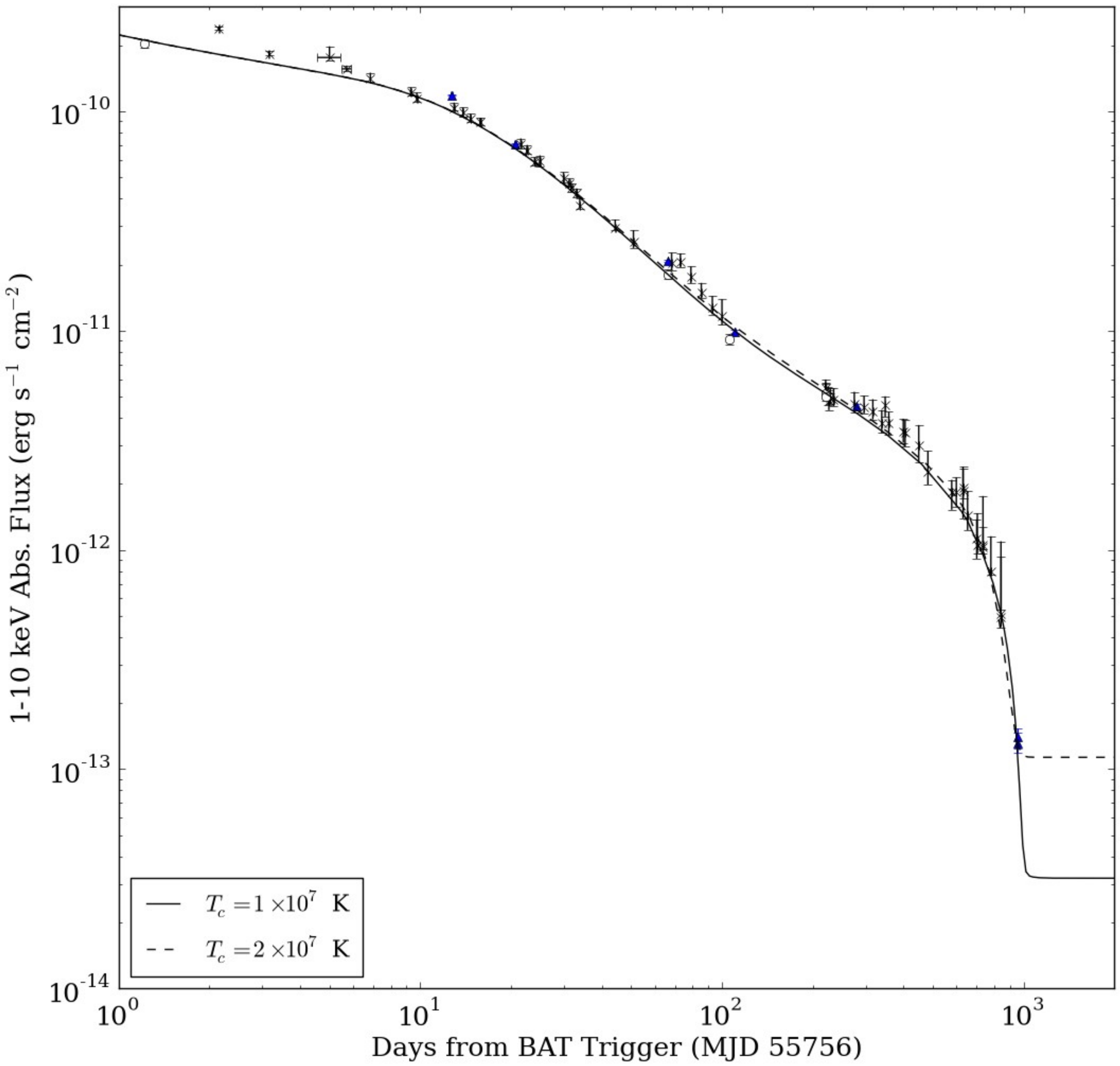
Swift J1822.3-1606: Follow-up

- X-ray observations using:
    - Swift
    - RXTE
    - Chandra



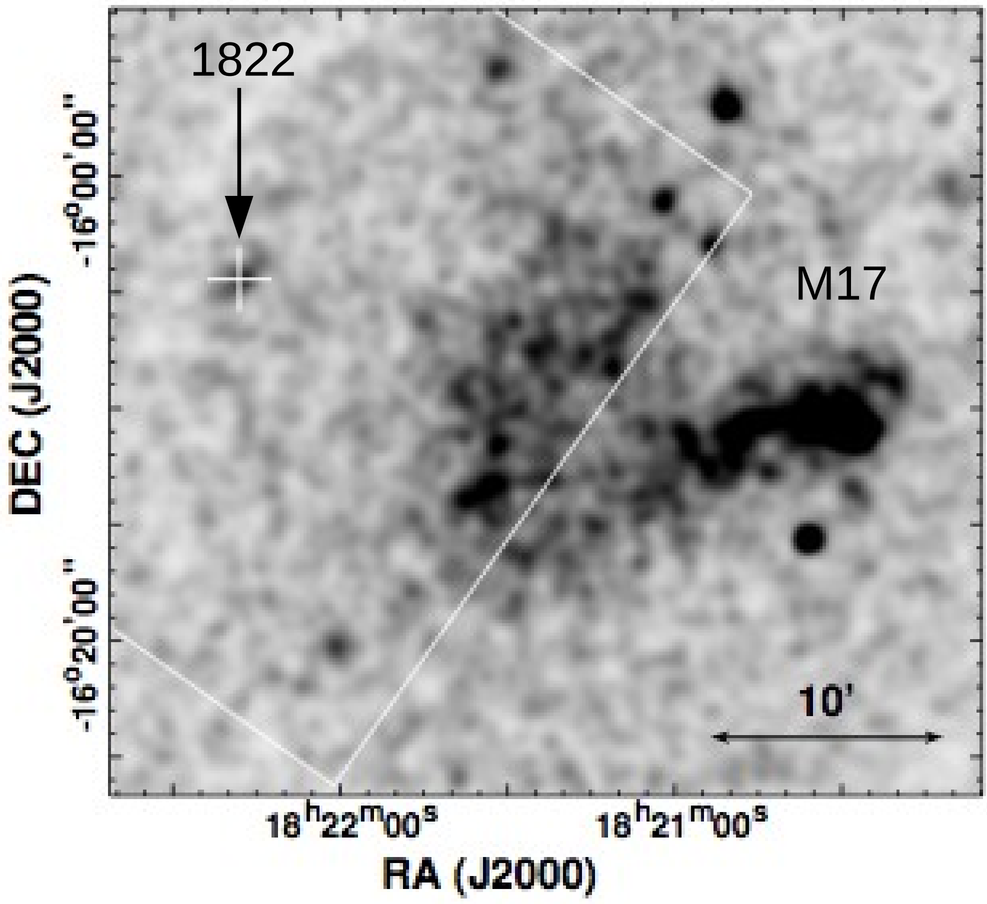
Images Credit: NASA

Swift J1822: Flux evolution



Swift J1822: Closest Magnetar?

- M17 and Swift 1822 have similar N_H (~4×10^{21} cm^{-2})
- **Similar N_H suggests similar distance even if not directly associated**
- Distance to M17 is 1.6+/-0.3 kpc
- Magnetars SGR J0418+5729 and SGR J0501+4516 have estimated distances of ~2 kpc



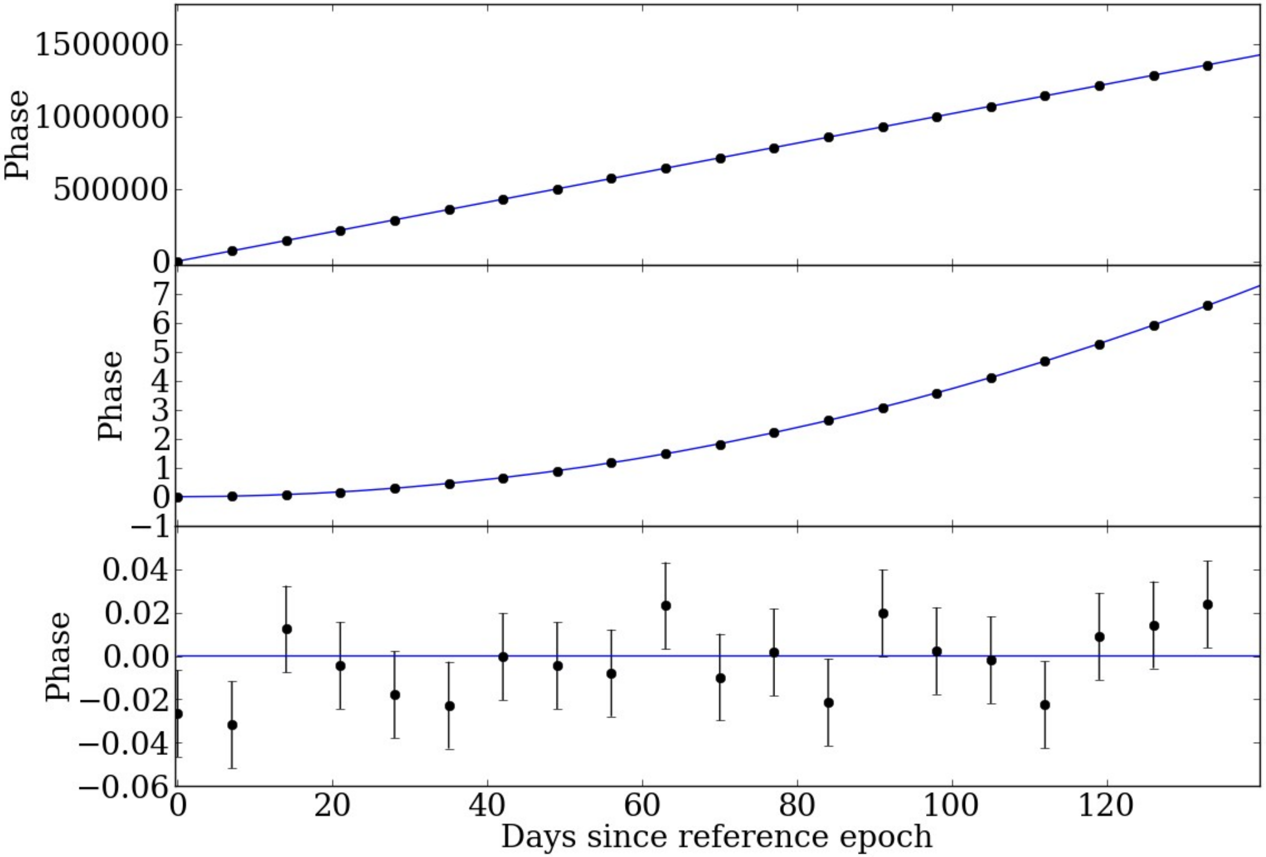
Scholz et al. 2012

- All other known magnetars have estimated distances > 2 kpc

→ **Swift J1822.3-1606 is one of the nearest known magnetars**

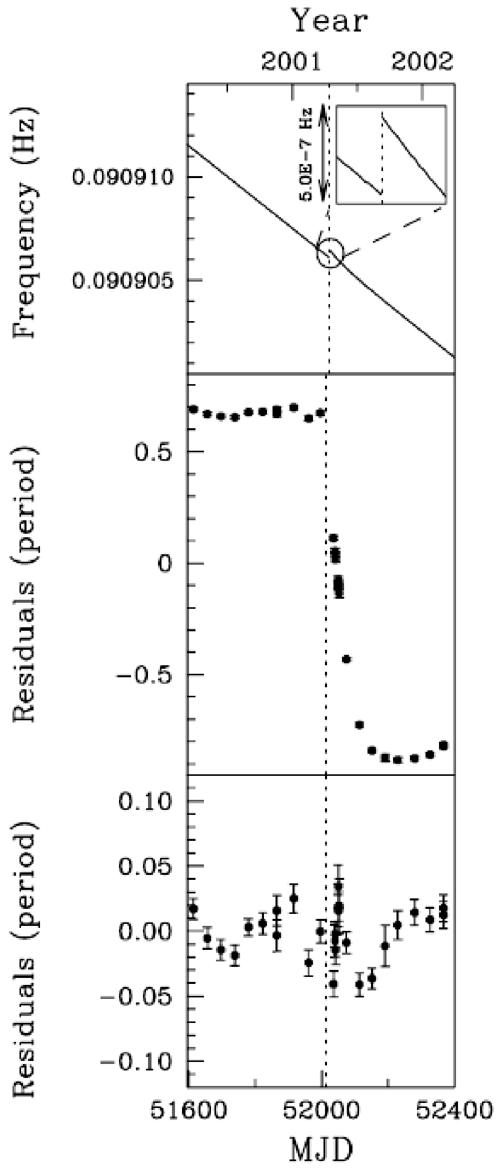
Pulsar Timing

$$\phi(t) = \phi_0 + \dot{\phi}_0(t - t_0) + \frac{1}{2}\ddot{\phi}_0(t - t_0)^2 + \ldots$$



Glitches in magnetars

- 16 years of magnetar monitoring with RXTE (Dib & Kaspi 2014)
  - 22 glitches in 5 magnetars
  - Every radiative event (flux increase etc) in magnetars accompanied by timing change (increase in timing noise, glitch etc)
  - 3 of them showed exponential recoveries
- Glitches are common in magnetars
  - Sometimes see exponential recoveries

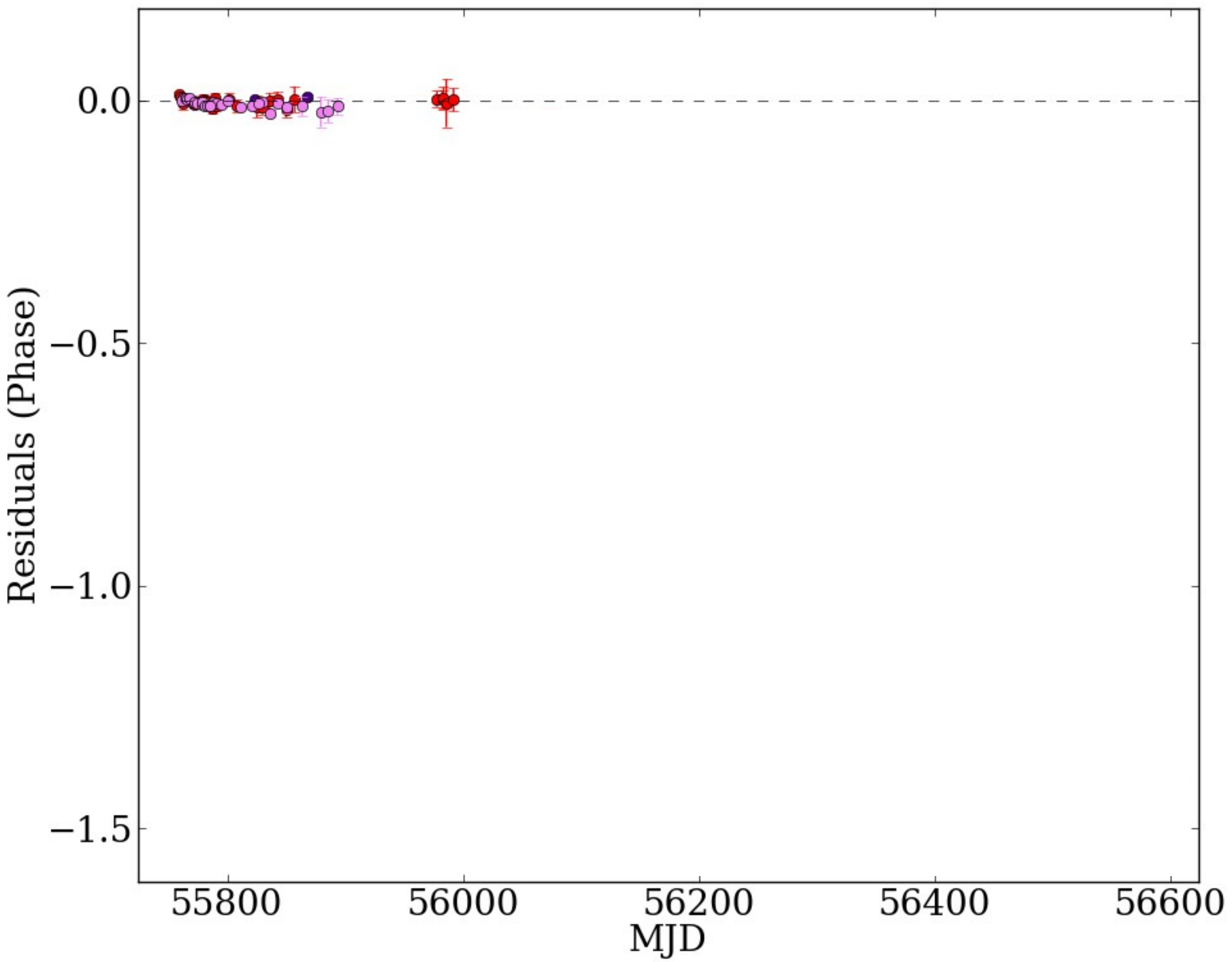


1RXS J170849.0-400910; Dib et al. 2009

Swift J1822: Timing

- Rea et al. 2012 find B = 2.7x10^{13} G
- Solution 1 of Scholz et al. 2012 gave B = 2.4x10^{13} G
- Both noted that not statistically good fits (reduced χ^2 = 2.2, 5.0)

Early single-derivative (Rea et al 2012, Scholz et al 2012)



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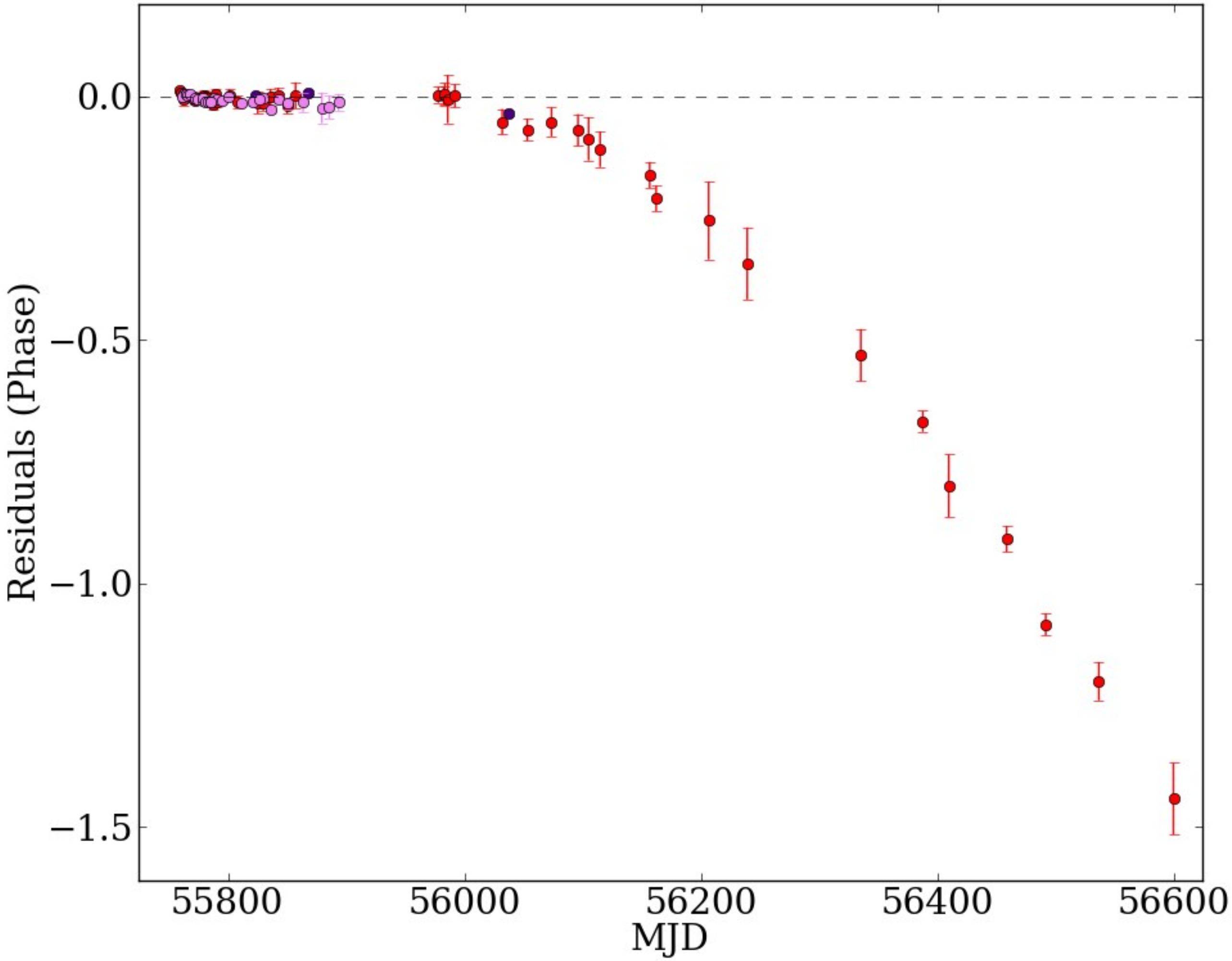

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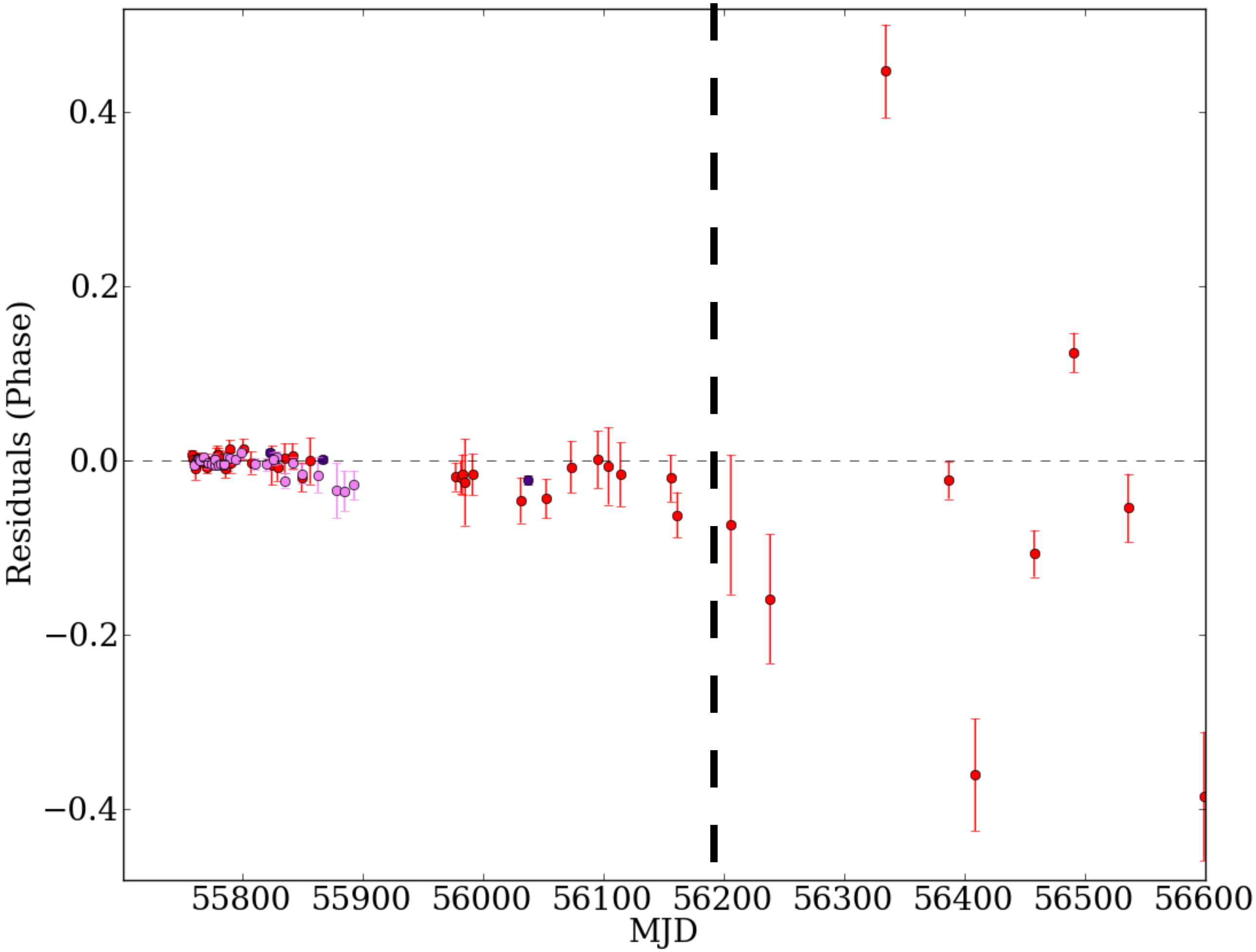
Three period derivatives (Solution 3 of Scholz et al 2012)



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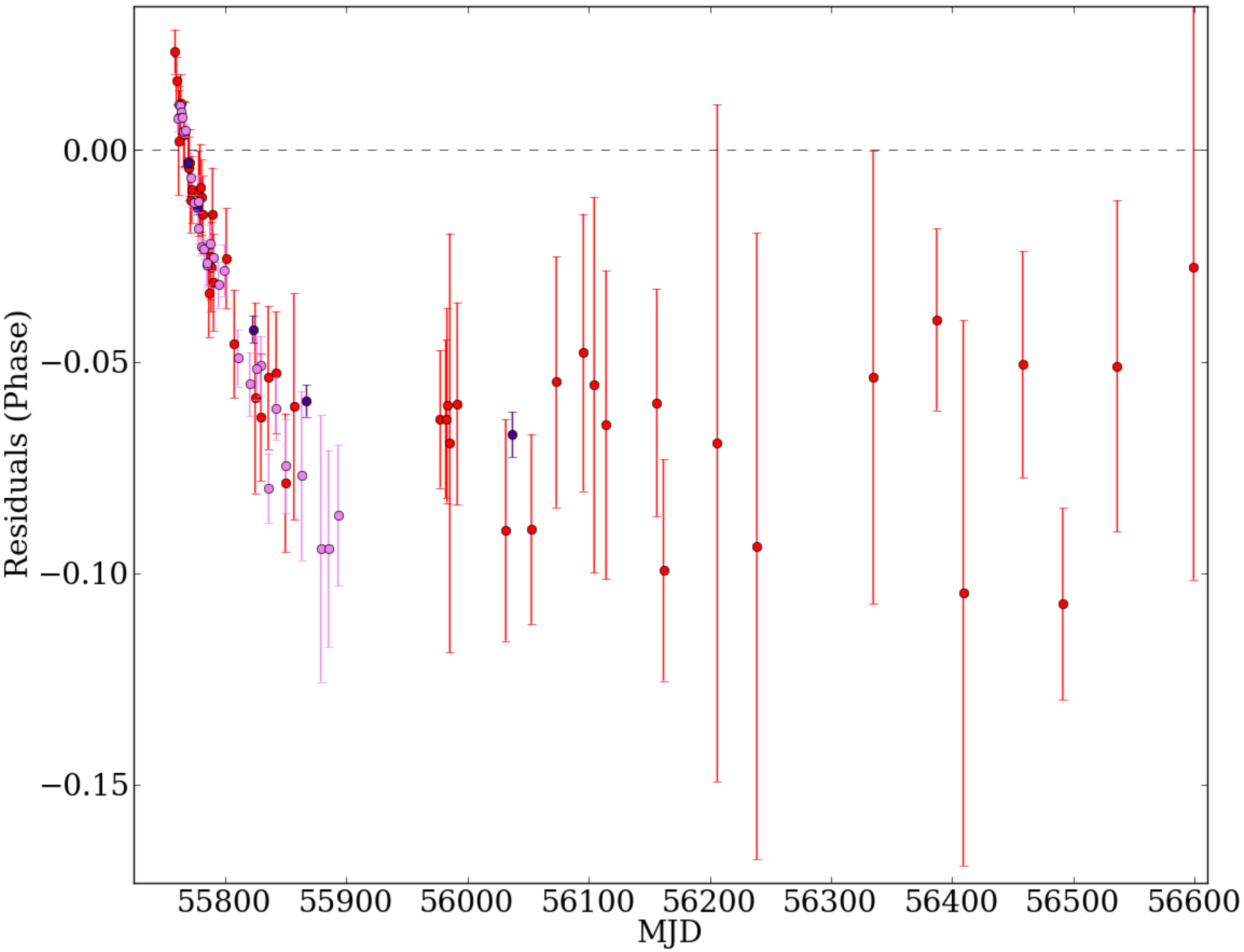
- Long-term timing shows that B=1.35x10^{13} G fits well
- But: spinning down more rapidly in initial ~50-100 days

Single-derivative with all data (Scholz et al. 2014)



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- **Fit with exponential glitch recovery**

$$\phi_{\rm exp}(t) = \begin{cases} \phi(t) + \Delta\nu_d\tau_d\left(1 - e^{-\frac{t-t_g}{\tau_d}}\right) & t \geq t_g \\ \phi(t) & t < t_g \end{cases}$$

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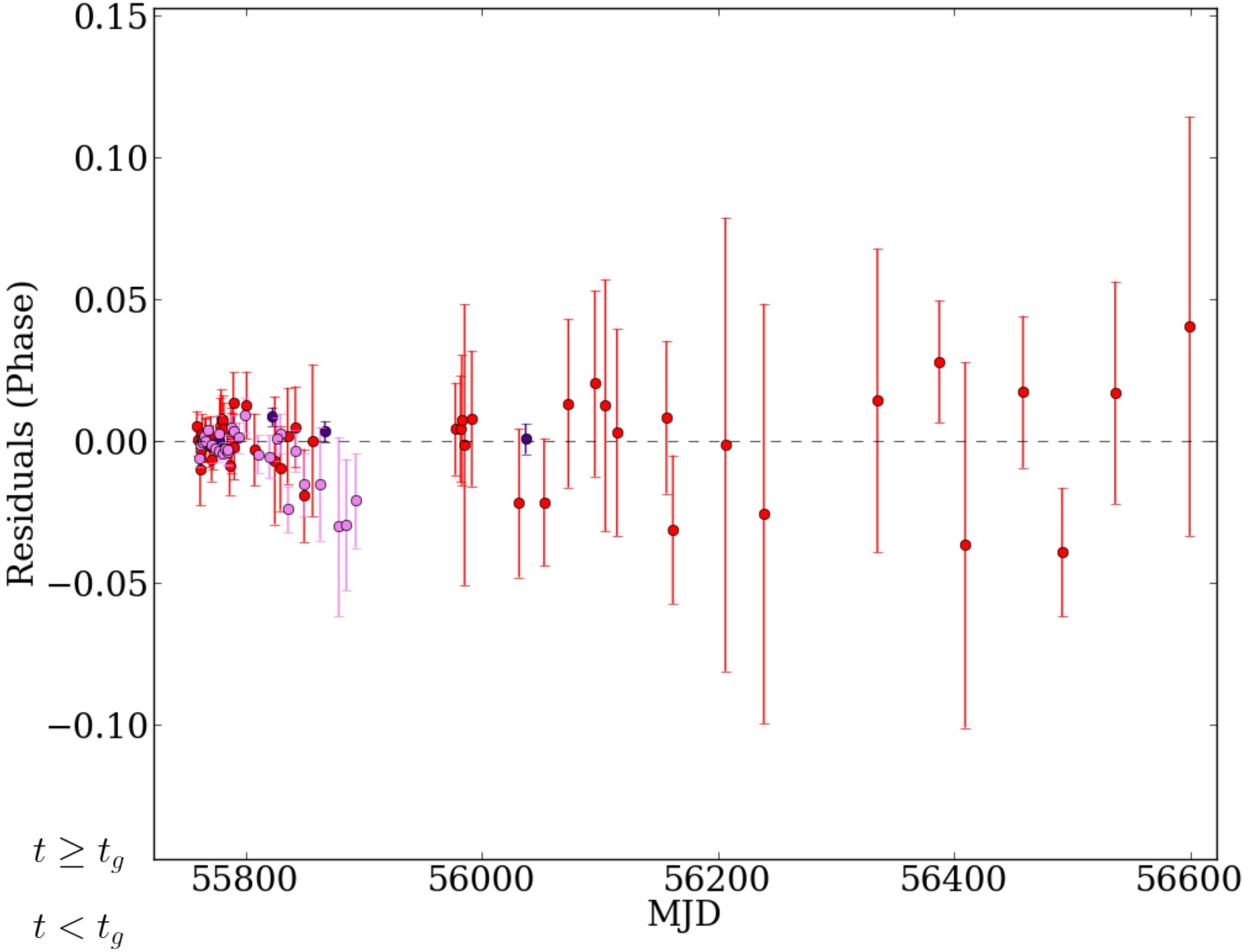

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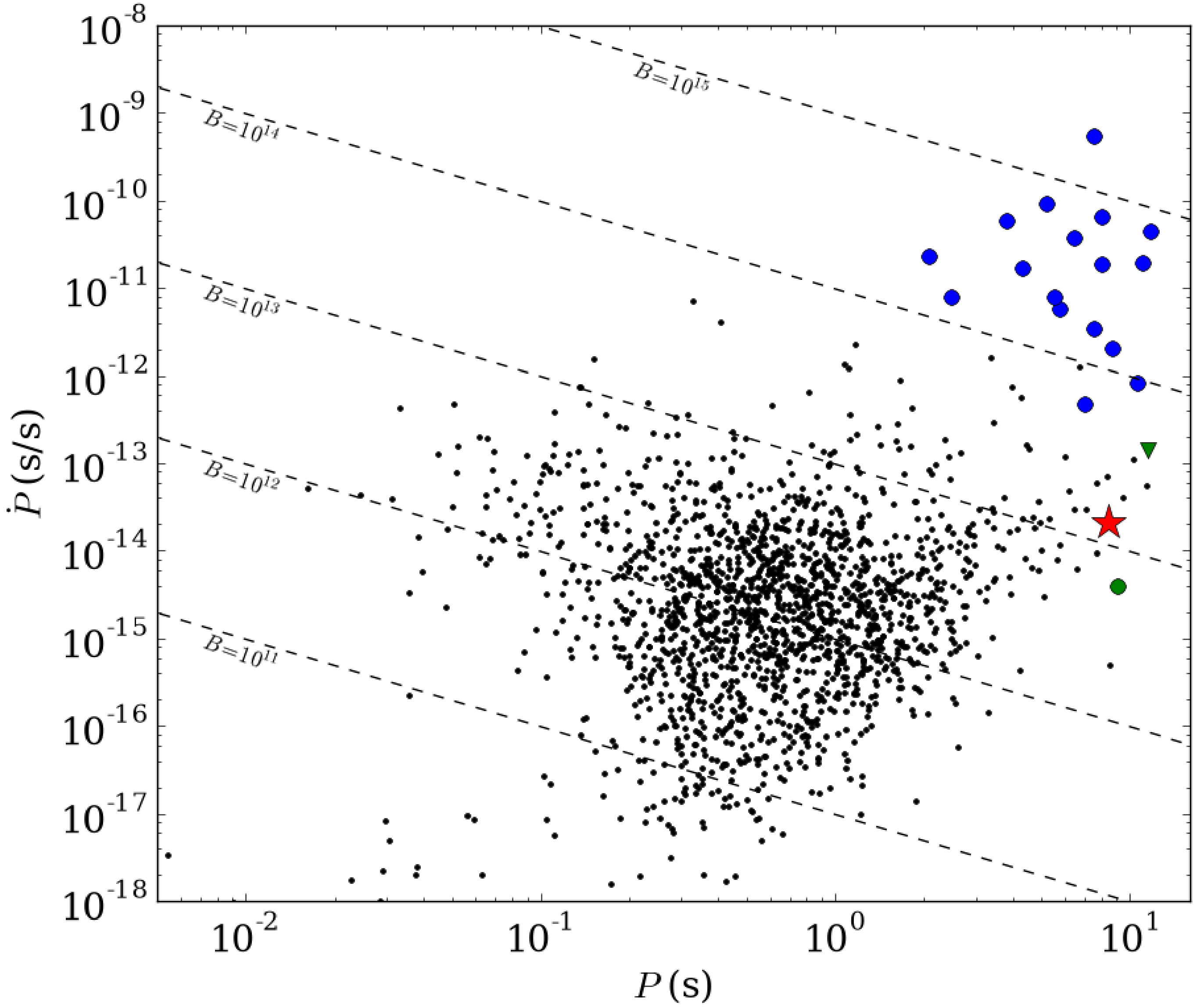

Glitches in magnetars

- Likely that Swift J1822 had a glitch at or near outburst epoch
- **But**: Don't actually see the glitch, so strictly exponentially decreasing spin-down
  - Requires exponentially decreasing torque on neutron star
  - Could be due to internal process (vortex unpinning) or external process (wind, magnetosphere)
- Some glitches in other magnetars have been observed to be radiatively quiet (Dib & Kaspi 2013, Scholz et al 2014)
  - Assume a single mechanism for magnetar glitches
  - Assume external process would cause observable radiative changes
  - ➔ **Internal process favored for magnetar glitches**

Summary

- Previous measurements of the spin-down of Swift J1822 were 'contaminated' by the exponential recovery
- Swift J1822 likely had a glitch at or near the outburst epoch
- The spin-inferred dipolar B-field of Swift J1822 is 1.35×10^{13} G, the second lowest B-field for a magnetar

- Leads to questions:
    - Do we expect activity from all pulsars, just less frequent with lower B-field? (See Perna & Pons 2011)
    - How low (dipolar) B-field can magnetars have?
    - (How) are magnetars evolutionarily linked to rotation-powered pulsars?