Timing Events (and the associated outbursts) in Anomalous X-ray Pulsars

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Part I:
Introduction

How to recognize a magnetar?

- X-ray Pulsars in the top-right corner of the p-$\dot{p}$ diagram (p~5s, $\dot{p}$~10^{-11}, $\dot{\nu}$~$10^{-13}s^{-2}$).

- Luminosity (~10^{35}erg/s) > spindown luminosity.

- X-ray spectra traditionally fit to a BB+PL model (SGR photon index < AXP photon index).

- Exhibit X-ray bursts. SGRs: several forests of bursts during active periods. AXPs: a few isolated bursts, forests seen in 2 sources.

- Located in the galactic plane (except 2 sources in the LMC/SMC). 3 AXPs and 1 SGR are associated with SNRs.

List of Known Magnetars

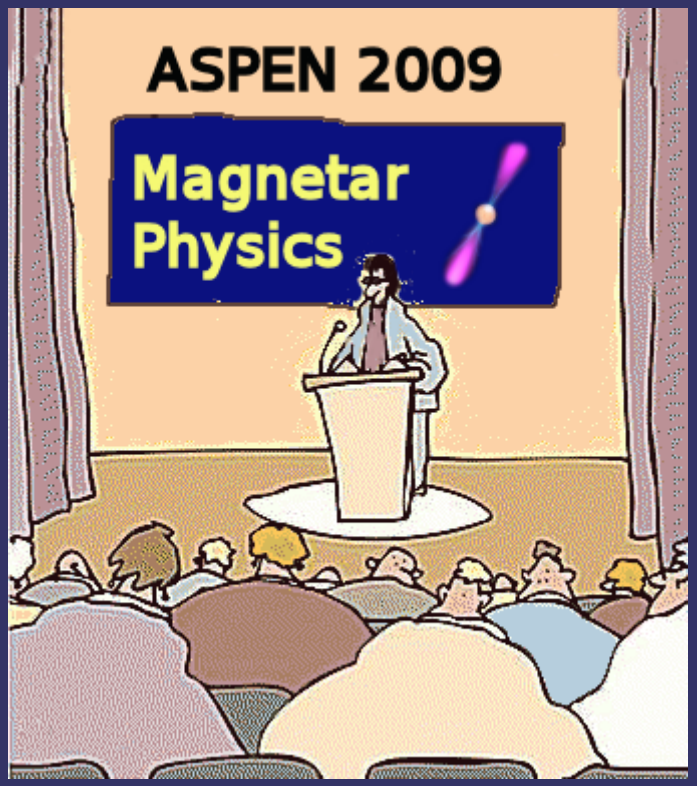
Magnetar	$\dot{\nu}_{(X10^{-13})}s^{-2}$	Activity
1E 2259+586*	**-0.10**	**(P)♦ 1 Major Outburst** *(+glitch/burst forest)* **♦ 1 Glitch**
4U 0142+61	**-0.27**	**(P)♦ 1 Glitch? ♦ 1 Timing anomaly** *(+bursts)*
RXS J170849	**-1.58**	**(P)♦ Several glitches**
1E 1841-045*	**-2.96**	**(P)♦ Several glitches**
1E 1048-5937	**-5.43**	**(P)♦ 2 Slow flares** *(+timing anomalies/bursts)* **♦ 1 Outburst** *(+glitch/burst)* **♦ Extreme torque noise**
XTE J1810-197	**-2.6** *(2003)*	**(T)♦ 2003 brightening** *(+radio pulses/bursts while fading).*
1E 1547-5408*	**-50** *(2007)* **-250** *(2008)*	**(T)♦1980→2006 dimming ♦ 2007 brightening** *(+radio pulses)* **♦ 2008,2009 outbursts** *(+bursts/fast increase in $\lvert\dot{\nu}\rvert$)*
CXO J164710	**-0.2** *(2006)*	**2005 discovery ♦ 2006 outburst** *(+glitch/burst)*
CXOU J010043	**-2.9** *(2004)*	**Far (SMC)**
SGR 0501+4516	**-4.5** *(2008)*	**Active in: 2008** *(bursts)*
SGR 0526-66*	**-10** *(2000)*	**Active in: 1979-1983** *(giant flare, bursts)* **♦ Far (LMC)**
SGR 1900+14	**-18 to -45**	**Active in: several periods** *(giant flare, flares, bursts, timing anomaly in 1998)*
SGR 1806-20	**-15 to -96**	**Active in: several periods** *(giant flare, flares, bursts)*
SGR 1627-41	**?**	**Active in: 1998** *(bursts)***, 2008** *(bursts)*

Not included: Candidate AXP J1845-0258 (1993) & candidate SGR 1801-23 (1997).

To constrain the physics of magnetars (*internal structure, magnetospheric structure, how they form, origin of their variability, etc. etc.*), long-term monitoring helps.

It allows the discovery of correlations/patterns in the variability (timing, flux, spectra).

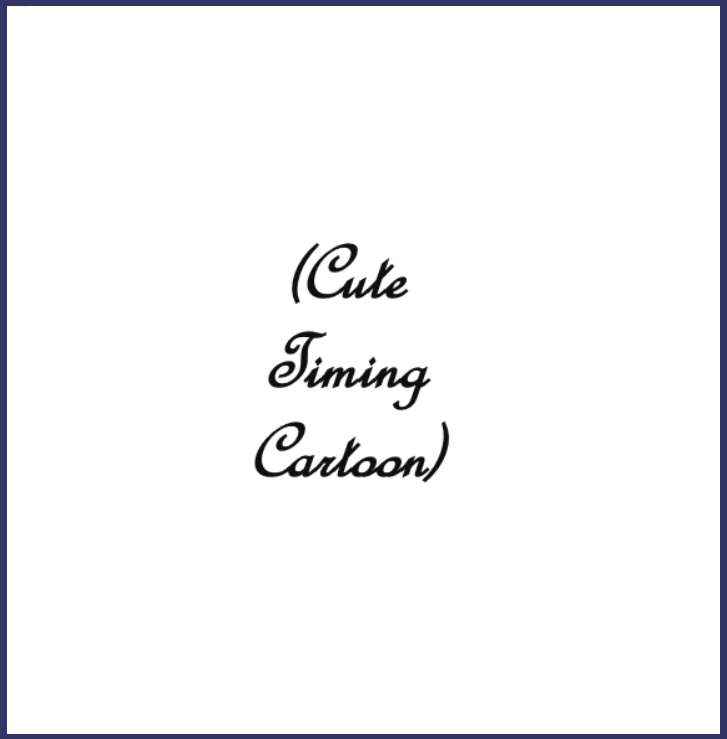
It facilitates comparisons between magnetars and rotation-powered pulsars.



adapted from a cartoon found on cartoonstock.com

The AXP Monitoring Program: weekly RXTE observations of the AXPs which can be used to

1- Do pulsar timing



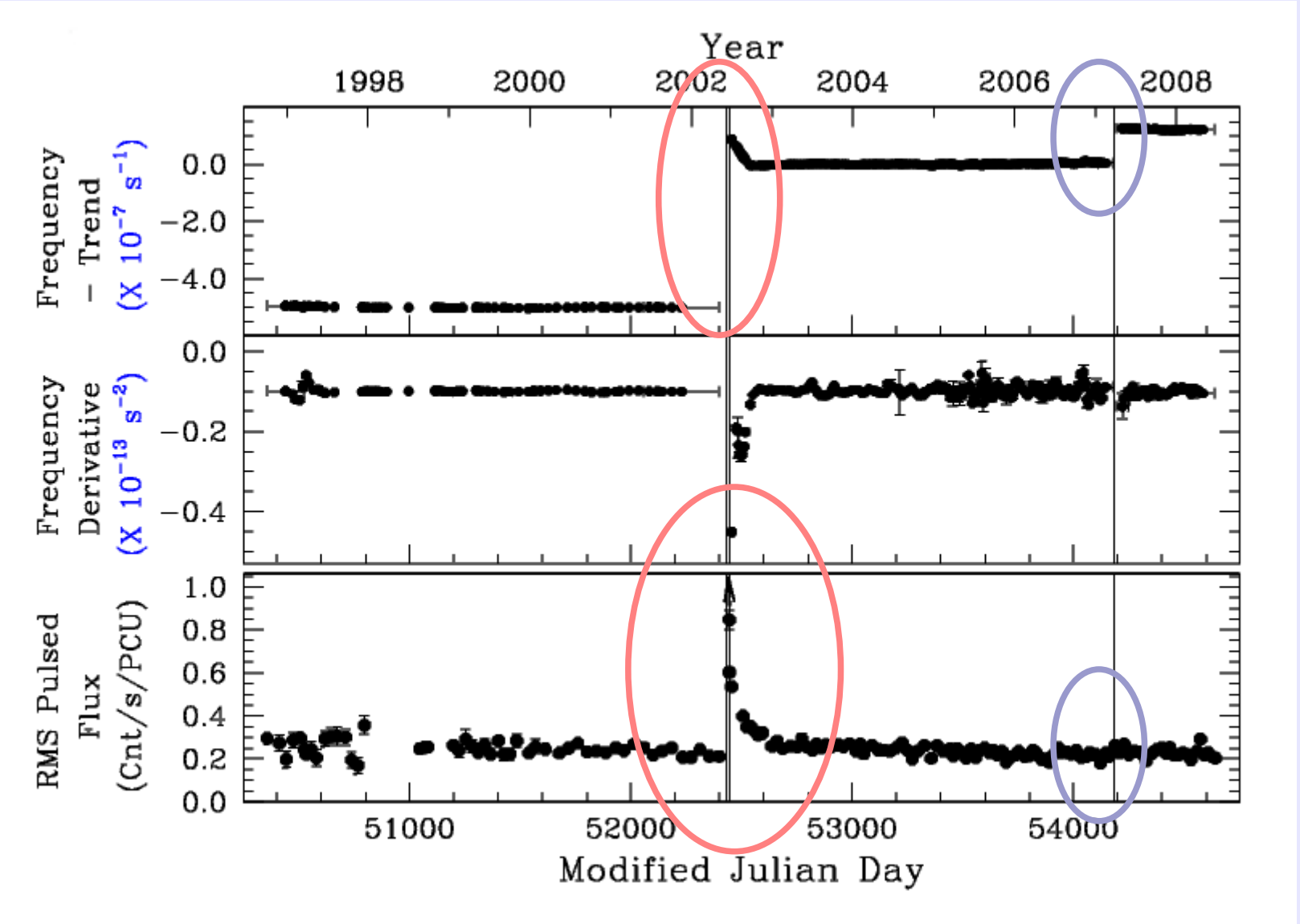
2- Look for pulsed flux changes.
3- Look for pulse profile changes.
4- Look for short bursts.

Part II:
Quick summary of AXP activity

AXP 1E 2259+586 (in SNR CTB109)

p~7s, ν~0.14s^{-1}, $\dot{\nu}$~-0.1x10$^{-13}s^{-2}$, B~0.6x10^{14}G

2 Events in 12 yr of monitoring

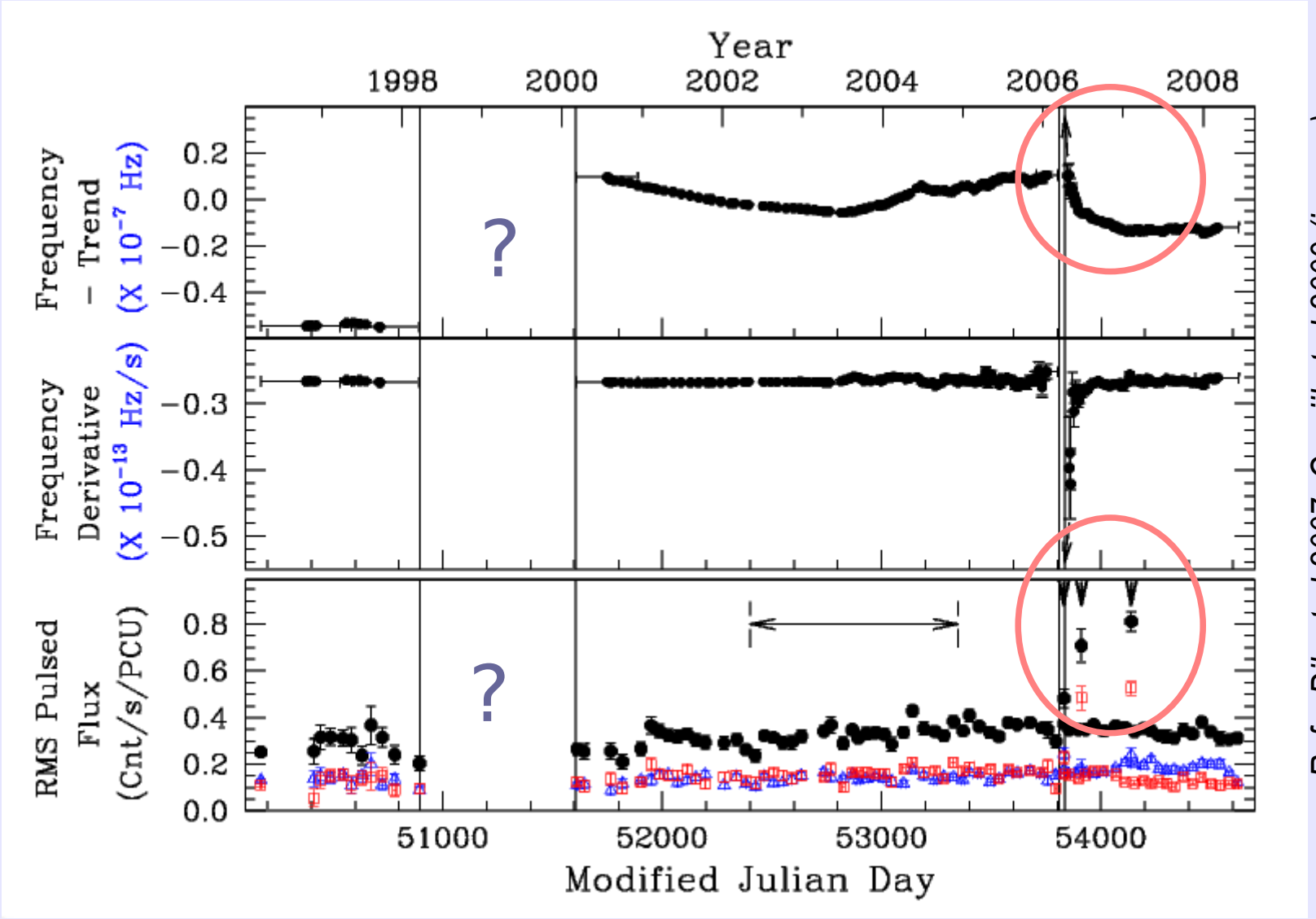


Refs Kaspi et al 03, Woods et al 04, Dib et al 08 (proceedings).

AXP 4U 0142+61:

p~8.7s, ν~0.12s^{-1}, $\dot{\nu}$~-0.27x10^{-13}s^{-2}, B~0.9x10^{14}G

2? Events in 2+8 yr of monitoring

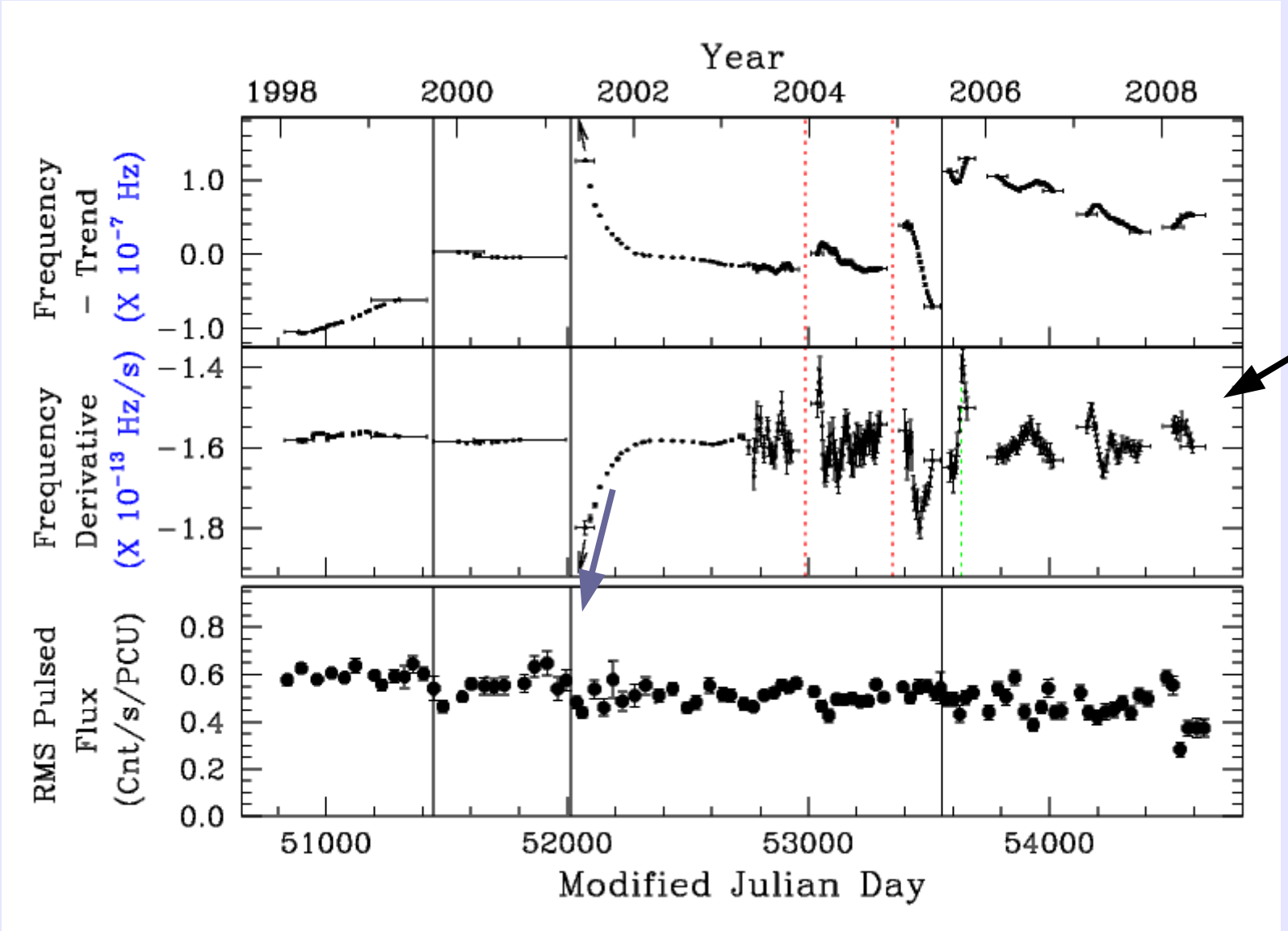


Refs Dib et al 2007, Gavriil et al 2009 (in prep).

AXP RXS J170849.0-400910:

p~11s, ν~0.09s^{-1}, $\dot{\nu}$~-1.58x10$^{-13}s^{-2}$, B~3.2x10^{14}G

3-5 Events in 11 yr of monitoring



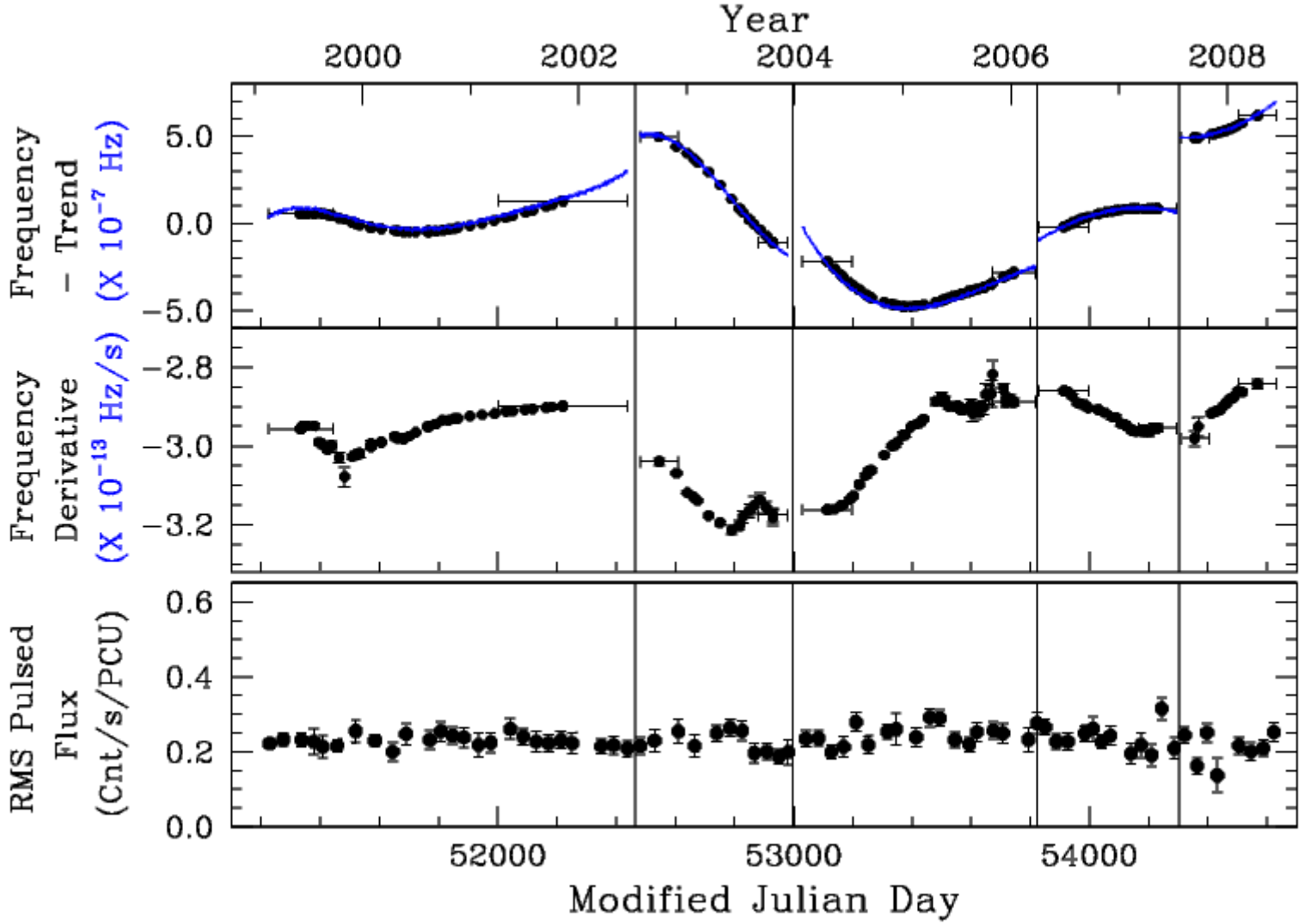
noise

Refs Kaspi et al 00&03, Dall'Osso 03, Dib et al 08, Israel et al 08.

AXP 1E 1841+045 (in SNR Kes73)

p~12s, ν~0.09s^{-1}, $\dot{\nu}$~-2.96x10$^{-13}s^{-2}$, B~4.8x10^{14}G

4 “silent” Glitches in 10 yr of monitoring

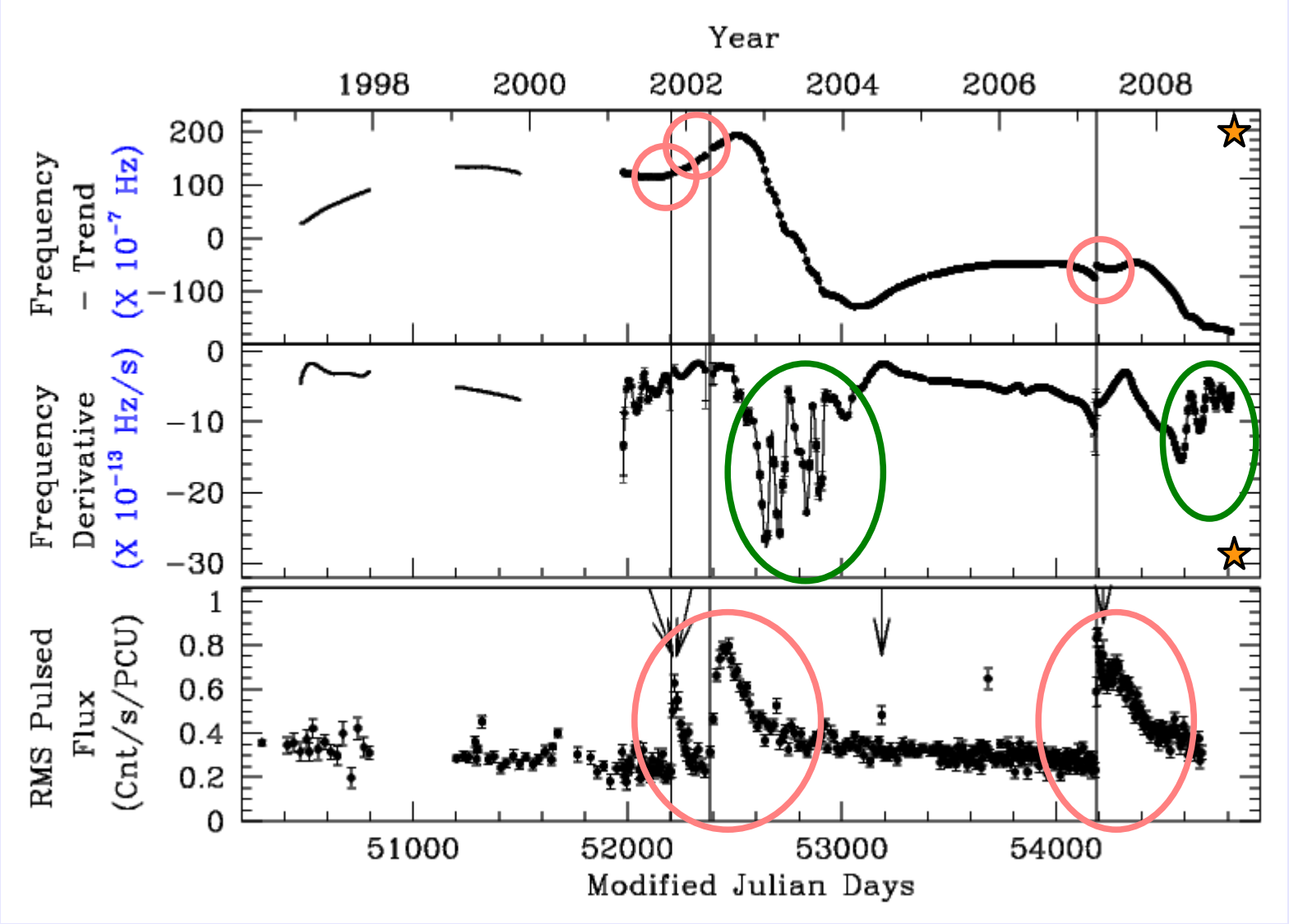


Refs: Dib et al, 2008 (paper+proceedings).

AXP 1E 1048-5937:

p~7s, ν~0.15s^{-1}, $\dot{\nu}$~-5.4x$10^{-13}s^{-2}$, B~2.7x10^{14}G

3 Events and 2 "noise episodes" in 2+12 yr of monitoring



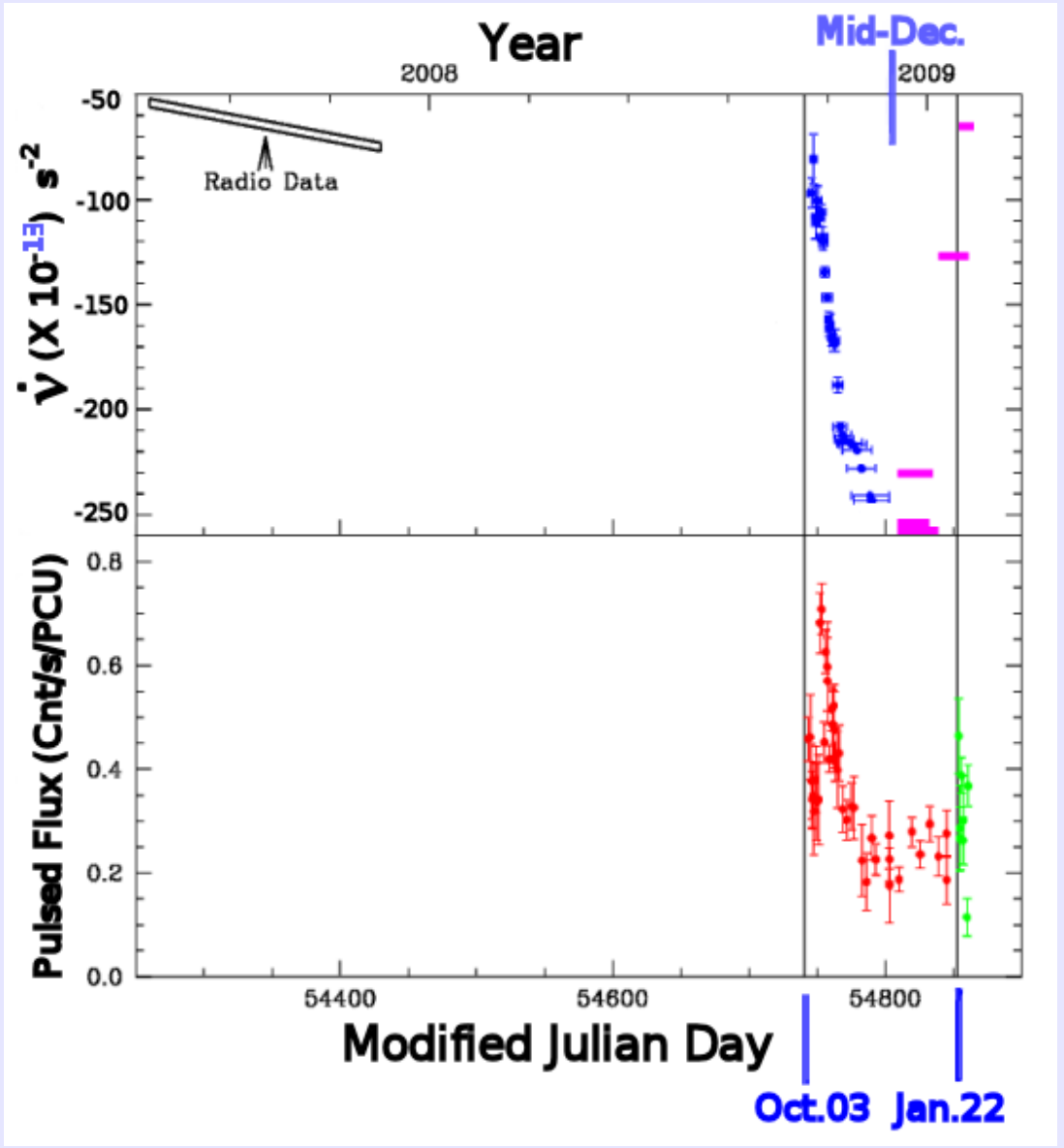
Refs Gavriil & Kaspi 2004, Dib et al 2008 (submitted).

★ *Timing parameters fit using splines.*

AXP 1E 1547.0-5408 (in SNR G327.24-0.13)

p~2.07s, ν~0.483s^{-1}, $\dot{\nu}$~-70X$10^{-13}s^{-2}$, B~2.5x10^{14}G

Preliminary Results



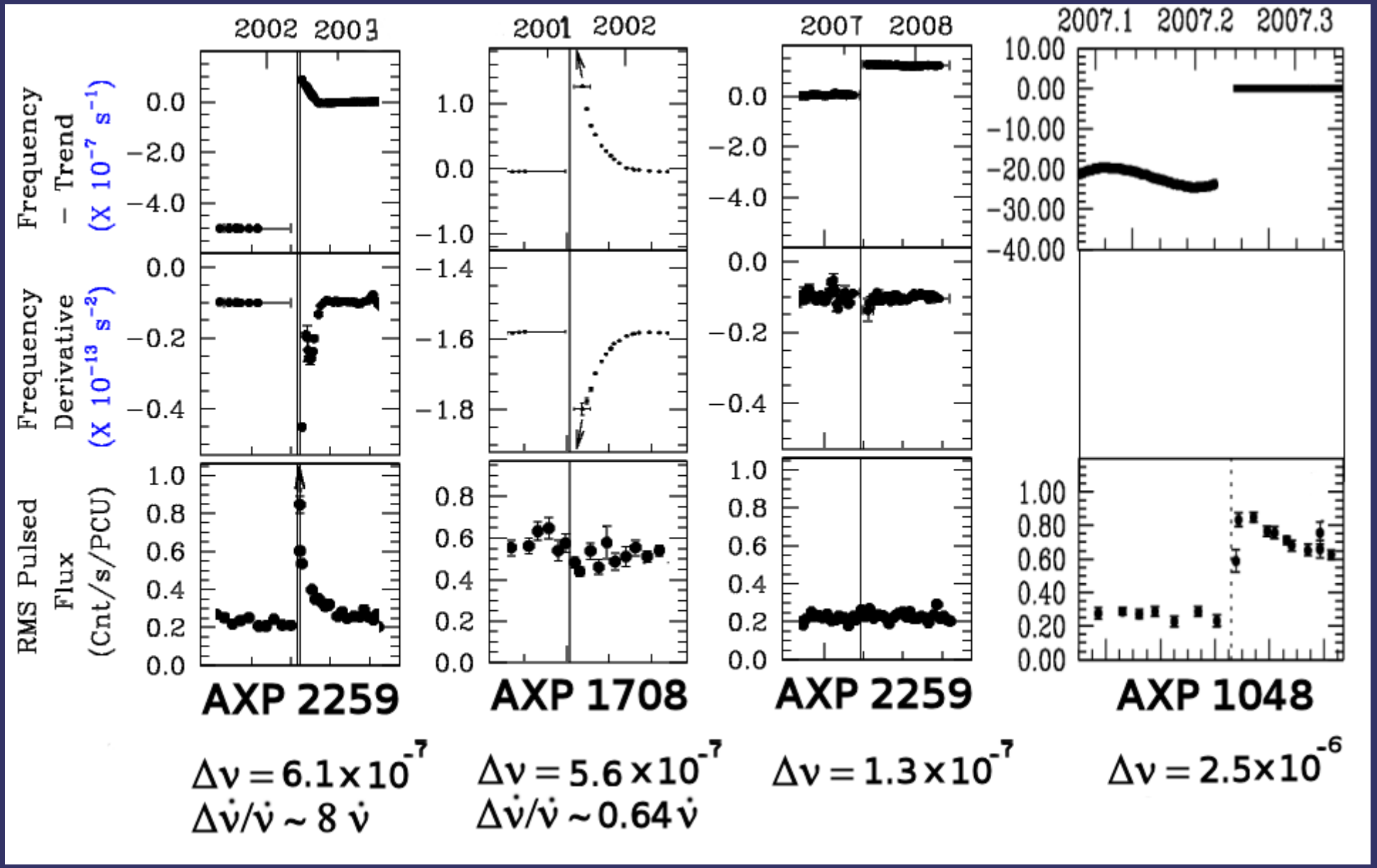
Refs Radio: Camilo et al, 2008. RXTE: Dib et al, in prep.

Part III:

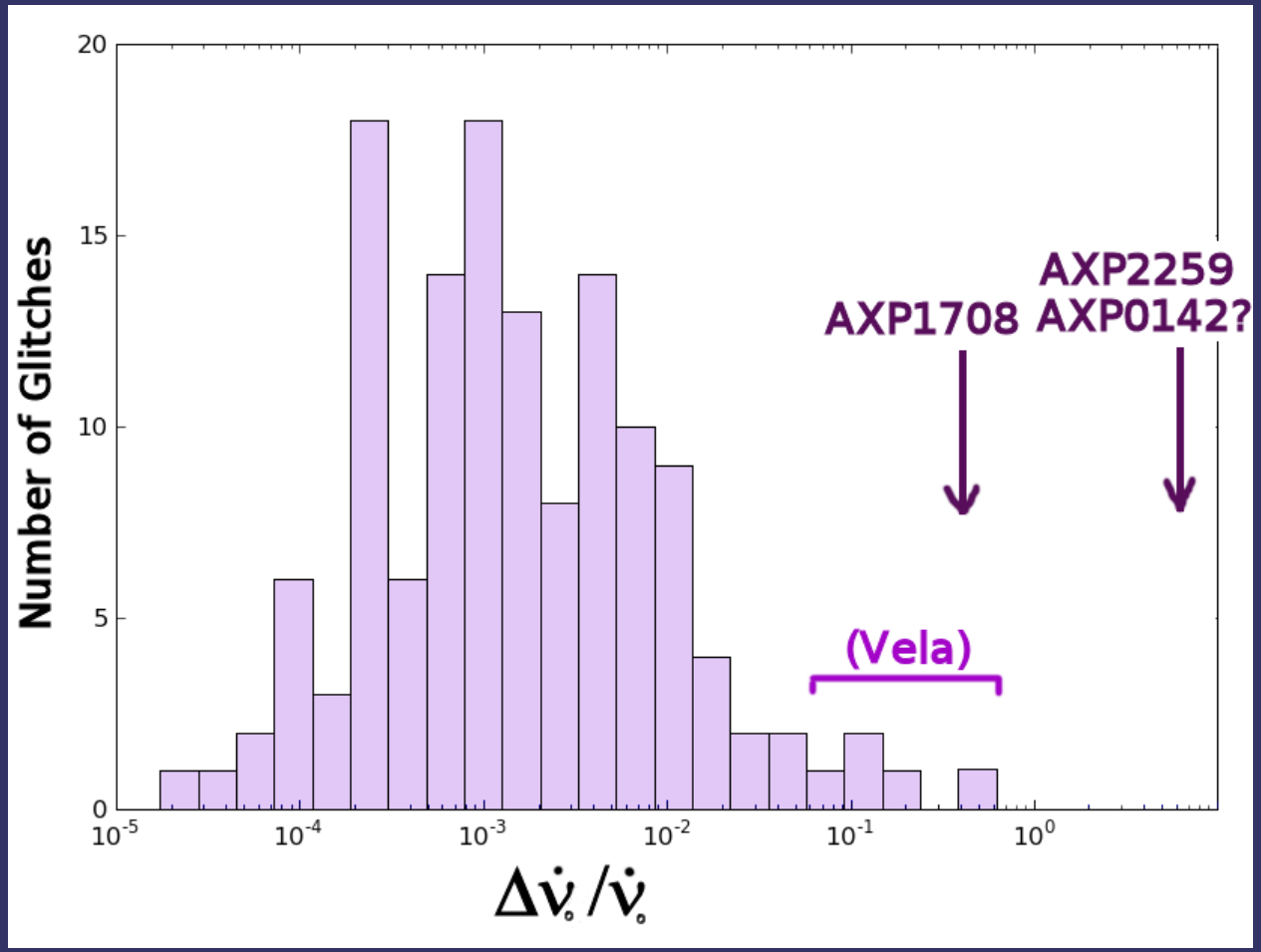
Timing Puzzles:

(in other words, “here is what we would like future/ existing theories to be able to explain”)

Puzzle #1: Why do some AXP glitches have a recovery and other AXP glitches do not?



Puzzle #1 (contin.): Why do some AXP glitches have a recovery and other AXP glitches do not?



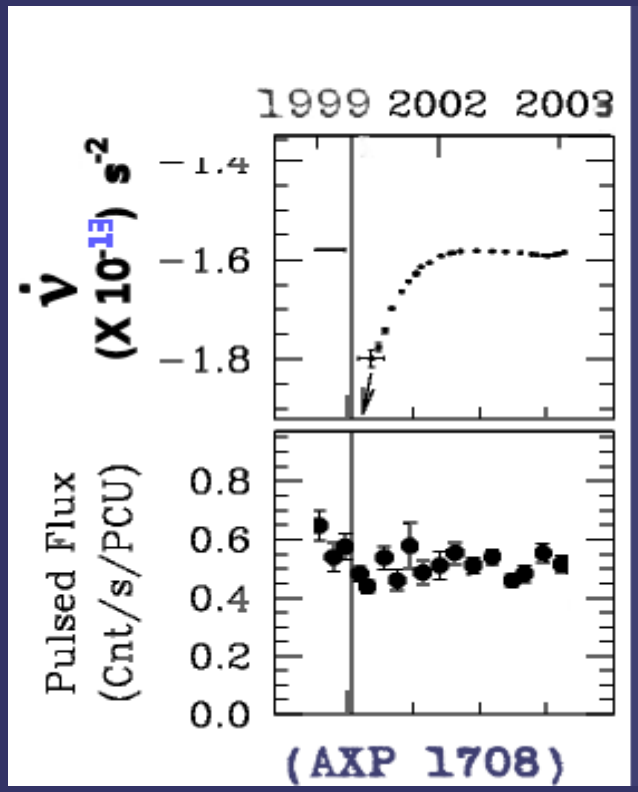
AXP Glitch recoveries have unusually large $\Delta\dot{\nu}/\dot{\nu}$!

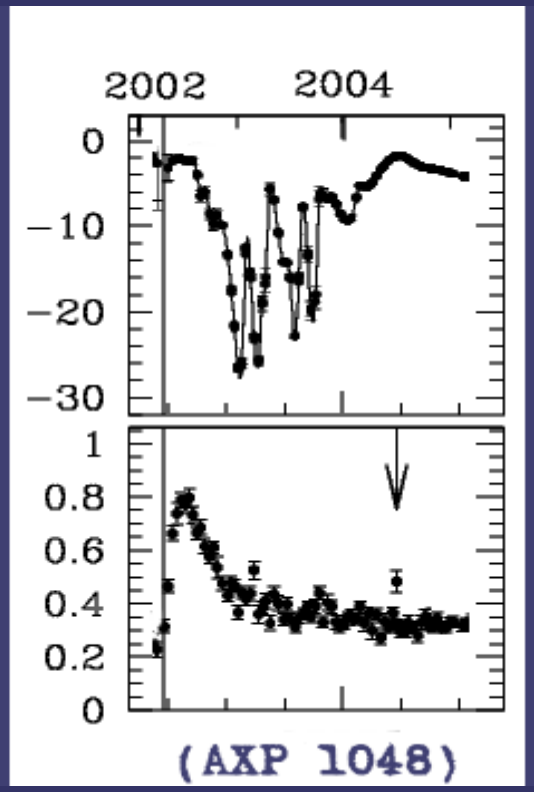
Puzzle #2: What causes the episodes of large (65%–900%) and rapid (< 2 months) changes in $\dot{\nu}$?

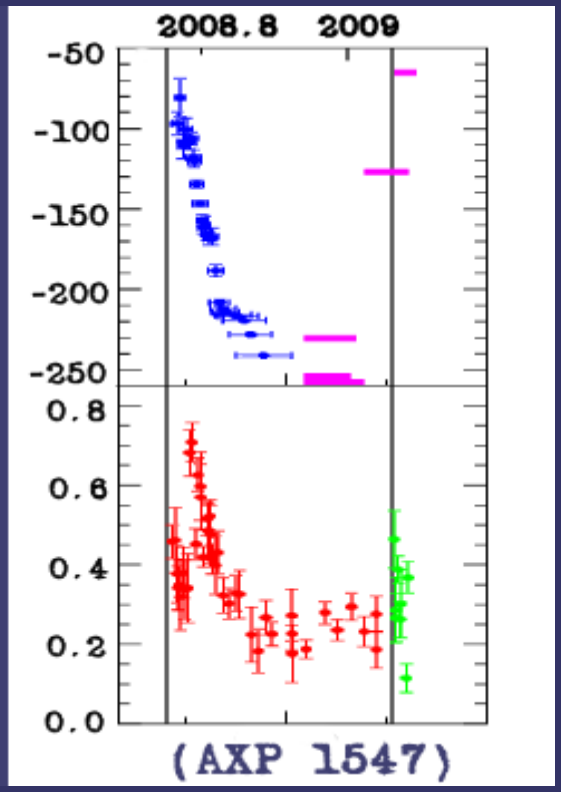
$|\dot{\nu}|$ decrease

$|\dot{\nu}|$ "oscillations"

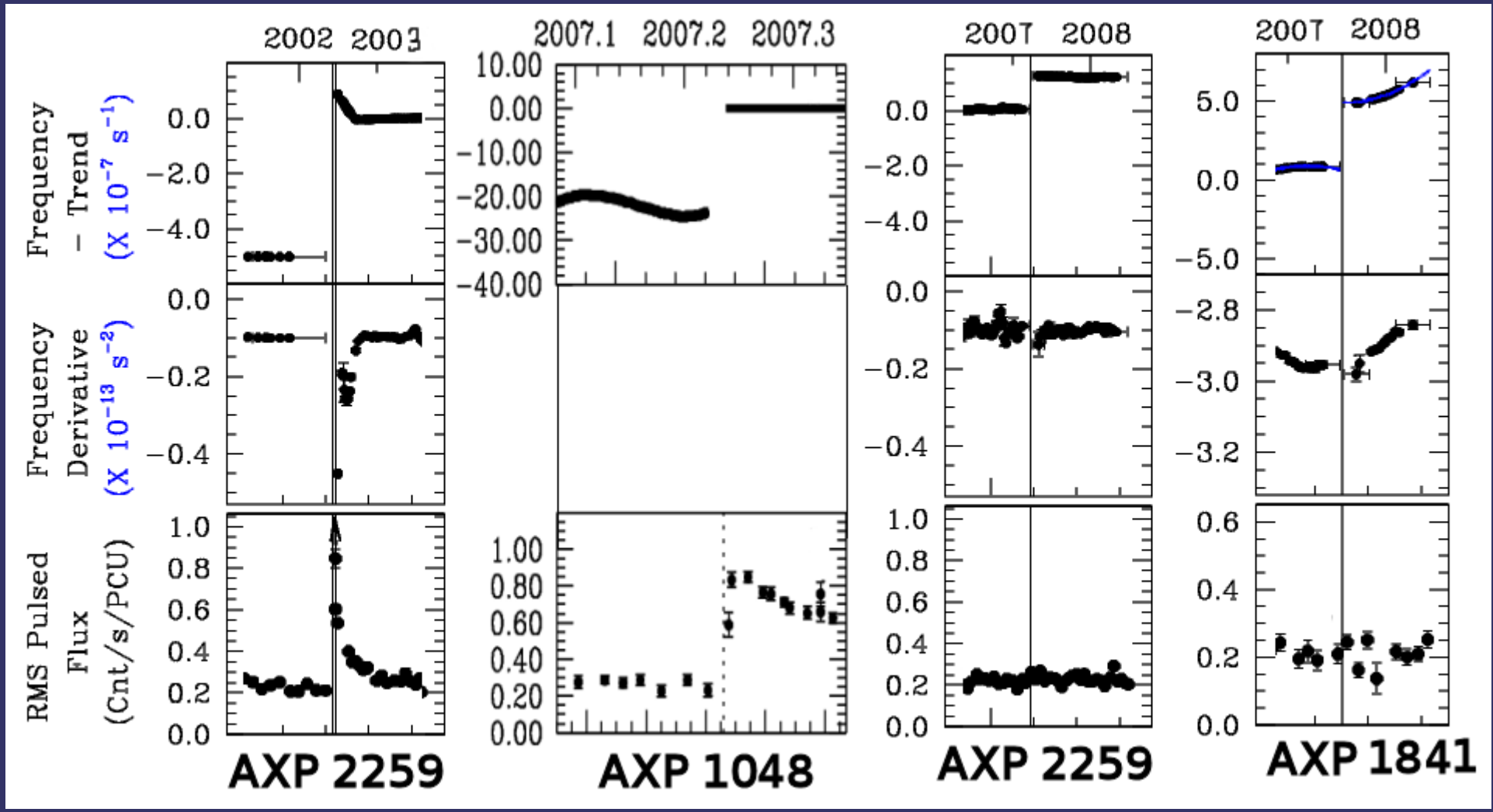
$|\dot{\nu}|$ increase





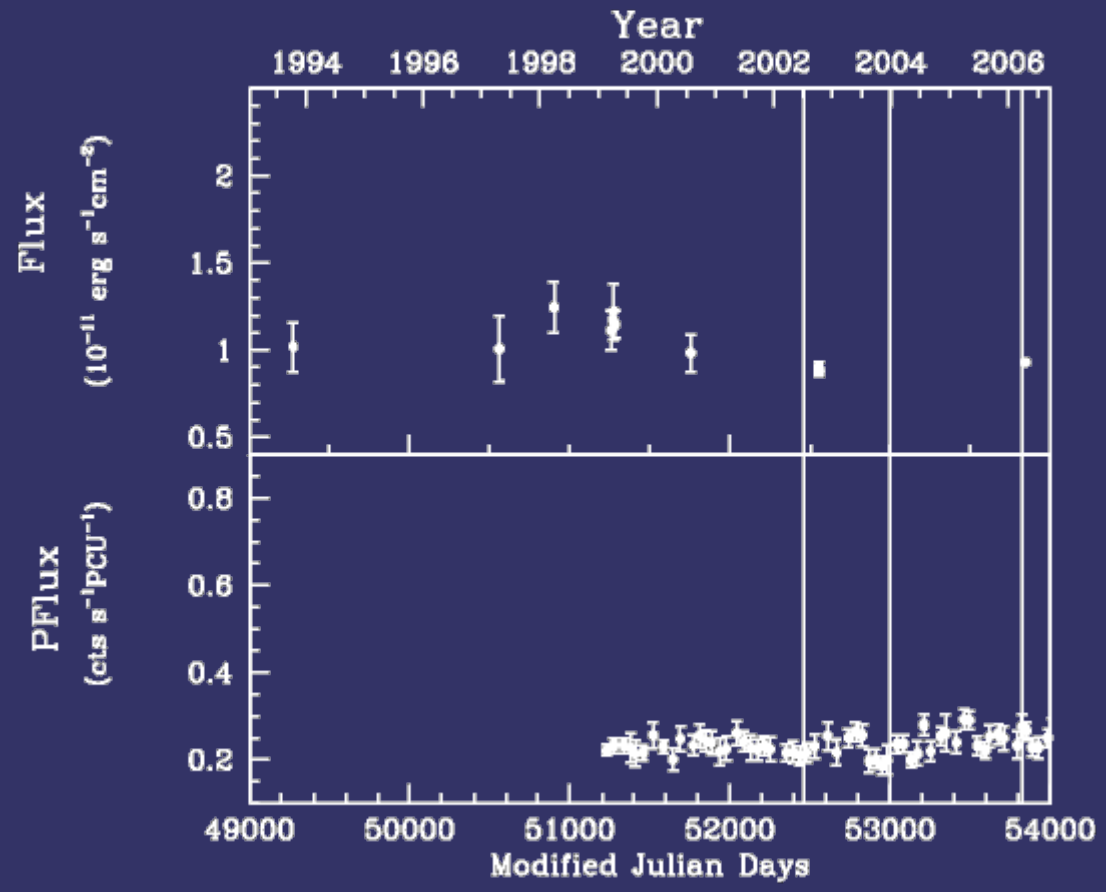


Puzzle #3: Why are some AXP glitches “radiatively silent” and other AXP glitches are not?



Puzzle #3 (contin.): Why are some AXP glitches "radiatively silent" and other AXP glitches are not?

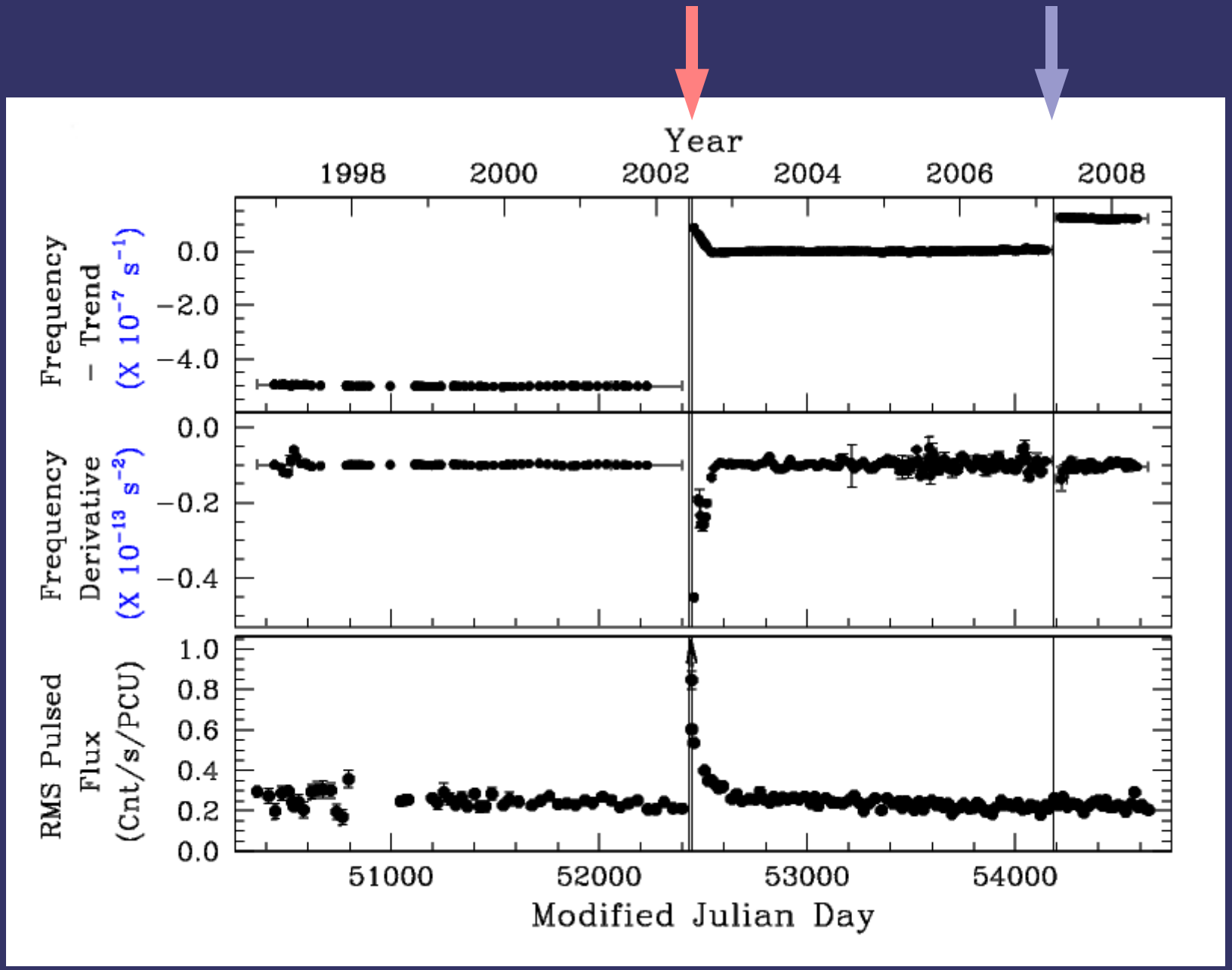
AXP 1841 (Zhu et al., preliminary result)



Note: This slide was shown as a response to the question: "does a quiet pulsed flux necessarily imply a quiet total phase-averaged flux?"

Puzzle #4: Why does every radiative outburst seem to be associated with a timing event (glitch/timing anomaly)? And why is the converse not true?

Example: AXP 2259



Summary

- AXP Timing: AXPs glitch 2–3 times per decade. Sometimes, they exhibit episodes of extreme timing noise.

- AXP Outbursts: AXPs exhibit a variety of sudden outbursts, roughly once per decade.

Some Unanswerred Timing-Related Questions:

- Why do some AXP glitches have a recovery and other AXP glitches do not? (and why are the recoveries different from those of rotation-powered pulsars?)

- What causes the episodes of large and fast changes in $\dot{\nu}$?

- Why are some AXP glitches radiatively silent and other AXP glitches are not?

- Every radiative outburst is accompanied by a timing event but the converse is not true. Why?