A Stable Super-orbital Clock in NGC 5907 ULX1

Lense-Thirring versus Neutron Star Free Precession

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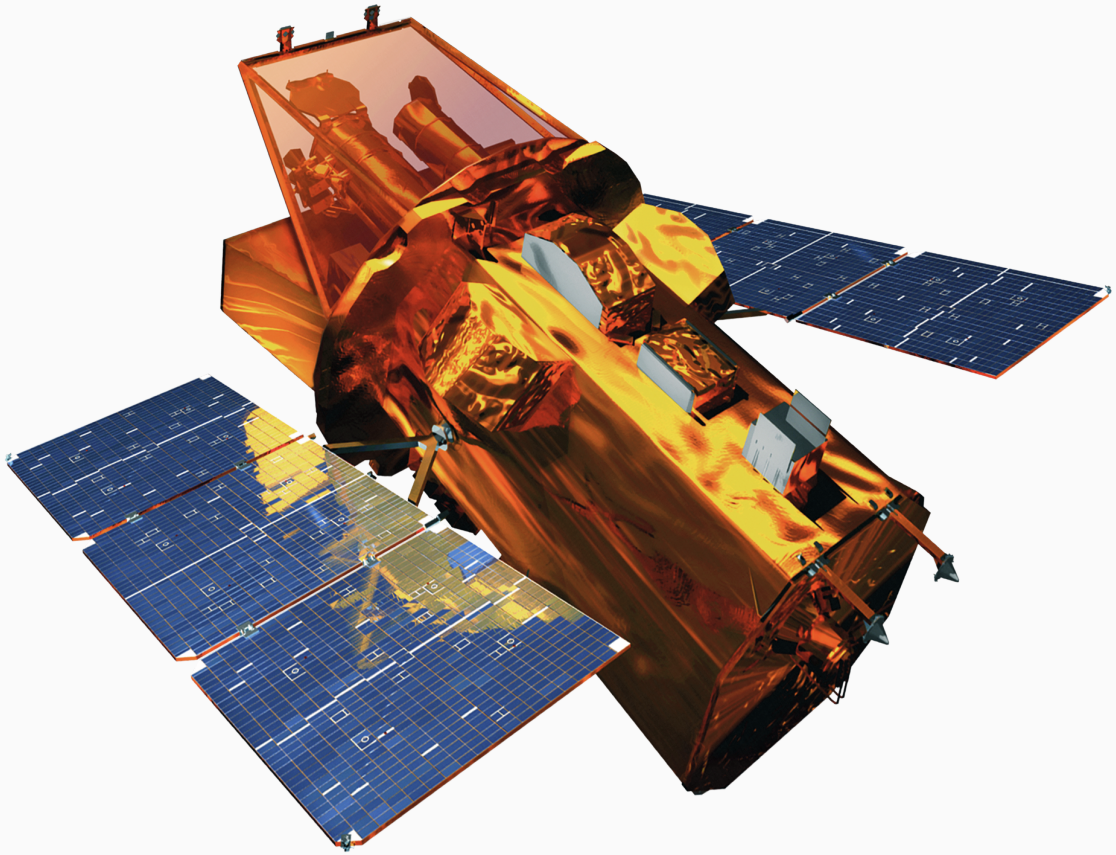
NewAthena Rising 2026

Long-Term Monitoring with Swift XRT



What drives the super-orbital modulations in ULX(P)s?

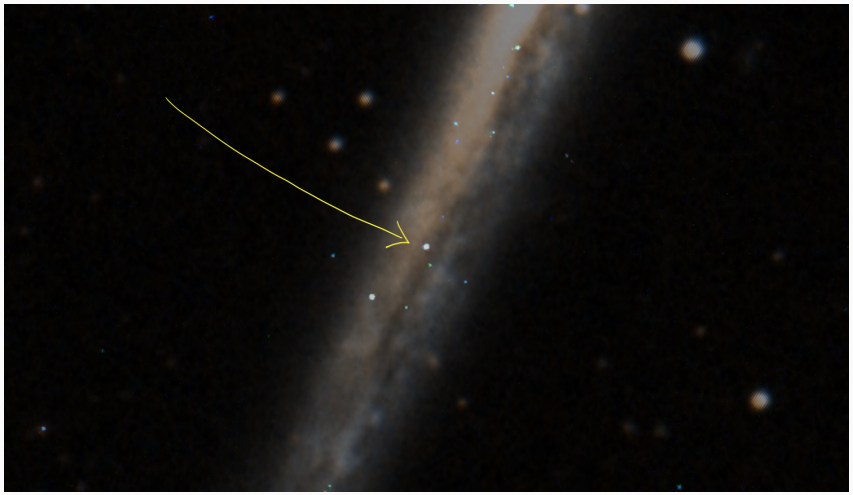
10–100 d modulations in ULXPs are super-orbital: precession.
Candidate drivers depend differently to accretion rate ($\dot{m}_0$) and $P_{\rm spin}$:

Drivers	resp. $\dot{m}_0$?	resp. $P_{\rm spin}$?
Lense–Thirring (Middleton+18)	yes ($\propto \dot{m}_0^3$)	yes
NS free precession (Vasilopoulos+20)	no	yes
Donor precession	no	no

Discriminant: do signal properties change with $\dot{m}_0$, or $P_{\rm spin}$?

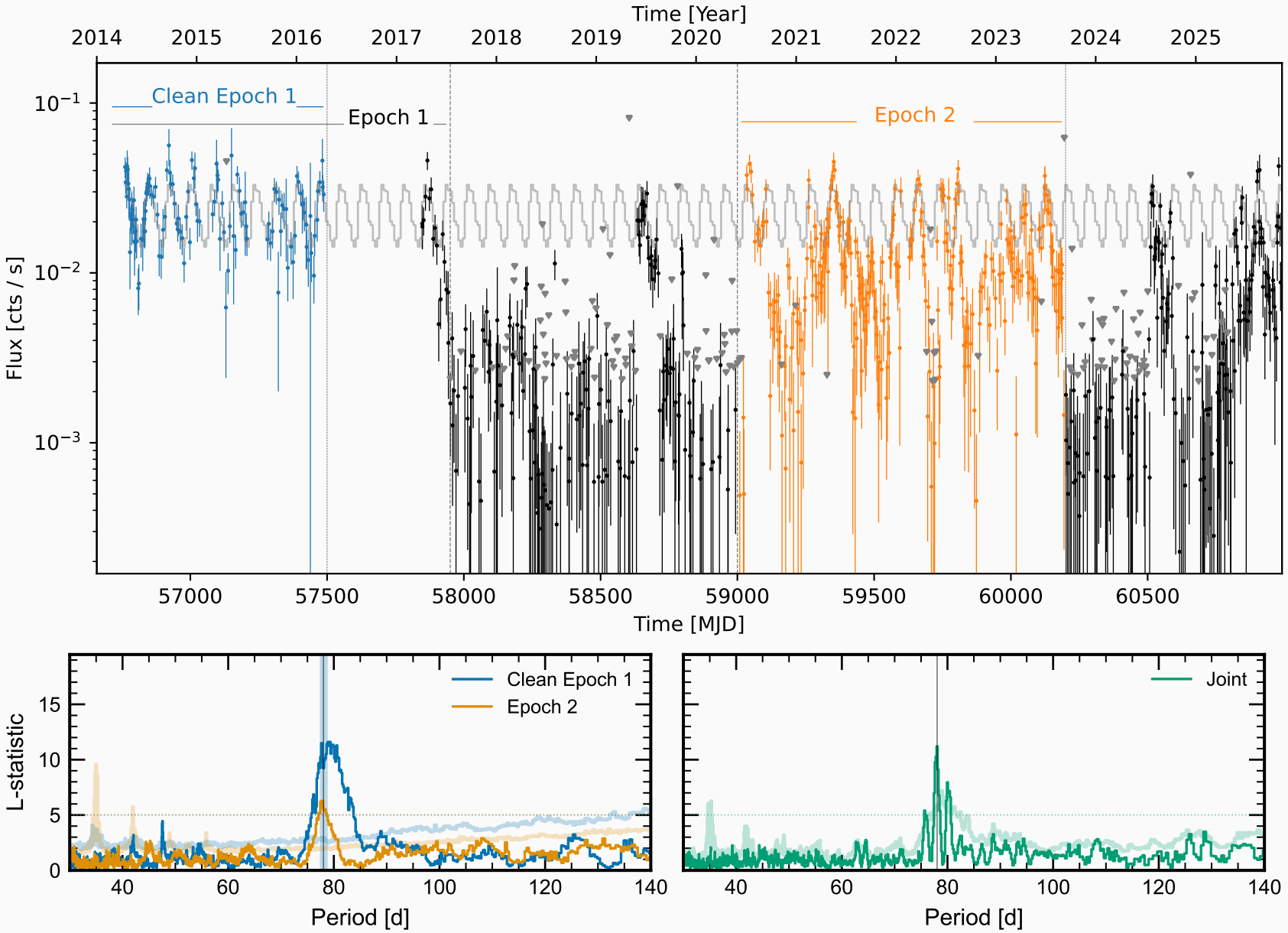
Test Subject: NGC 5907 ULX-1

- Most extreme ULXP:
  $L_{\rm peak} \sim 500 \times L_{\rm Edd}(M_{\rm NS})$
- $P_{\rm spin} \sim 1$s (Israel+17),
  $P_{\rm orb} \sim 5$d (Belfiore+24),
  $P_{\rm sup} \sim 78$d (Walton+16)
- Propeller off-state
  ($\sim$2017–2020) *between* two
  high-flux epochs (Fürst+23)



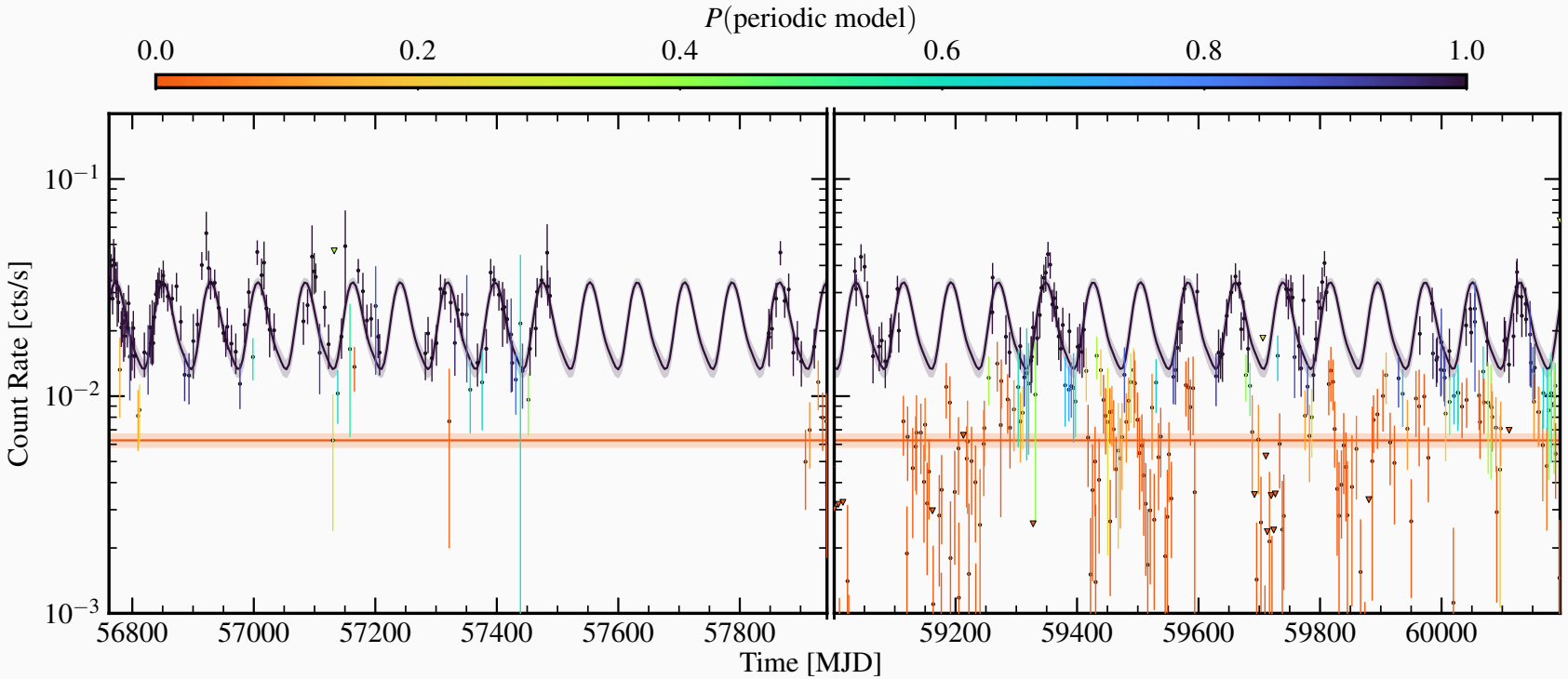
Experiment: in the propeller, $\dot{m}_0$ must have changed.
Does the clock persist, period and phase?

11+ years of Swift XRT Monitoring



Characterising the signal

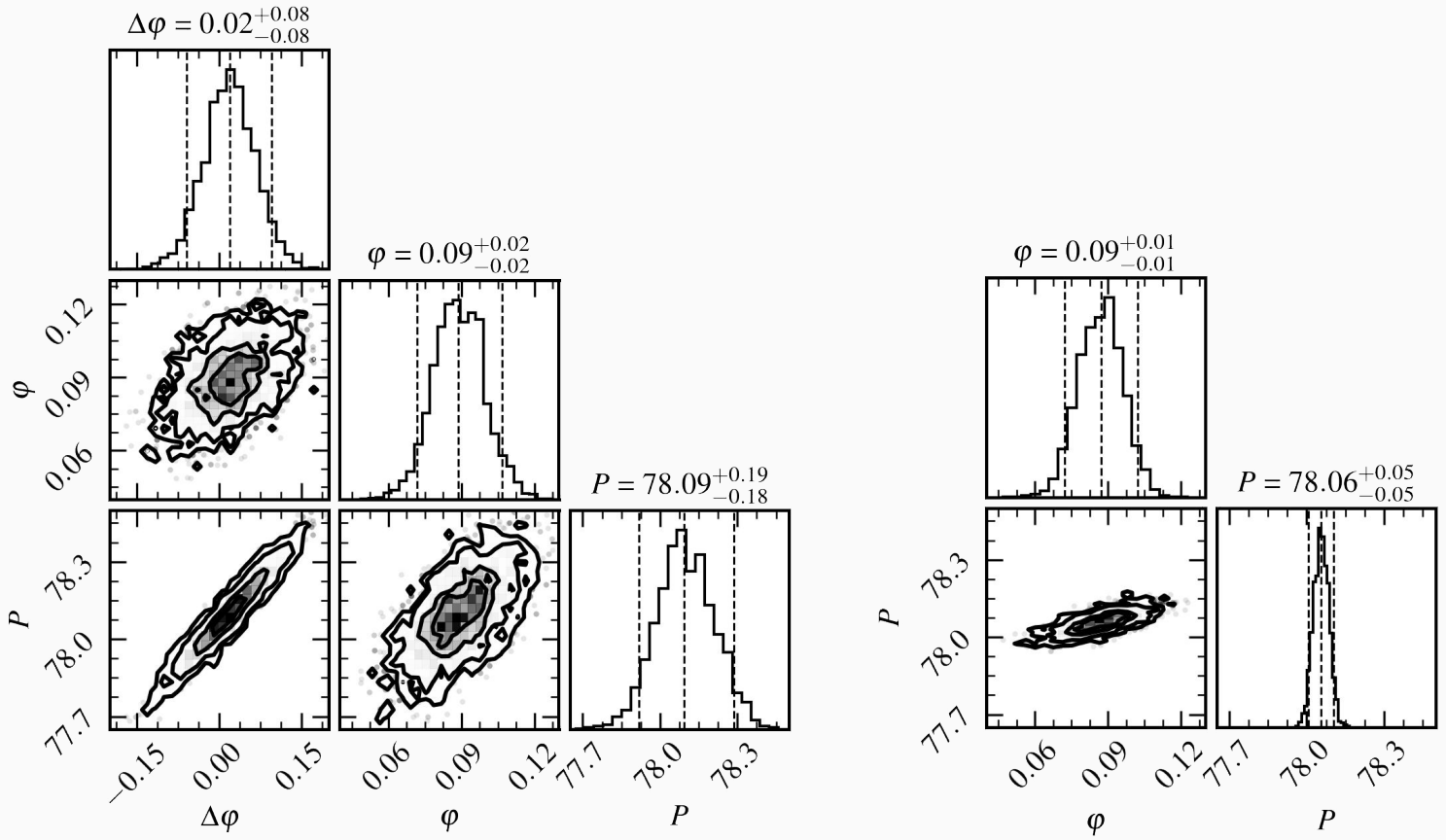
Bayesian mixture model (Hogg+10): periodic + constant-rate outlier, Poisson likelihood, nested sampling (`UltraNest`; Buchner 21).



- Second-harmonic model (FRED-like; Walton+16) favoured
- Mixture recovers intermediate flux state *self-consistently*

Takeaway Result: stable clock that keeps phase

Posteriors: phase-jump $\Delta\varphi$ model vs. joint phase φ model (P always shared)



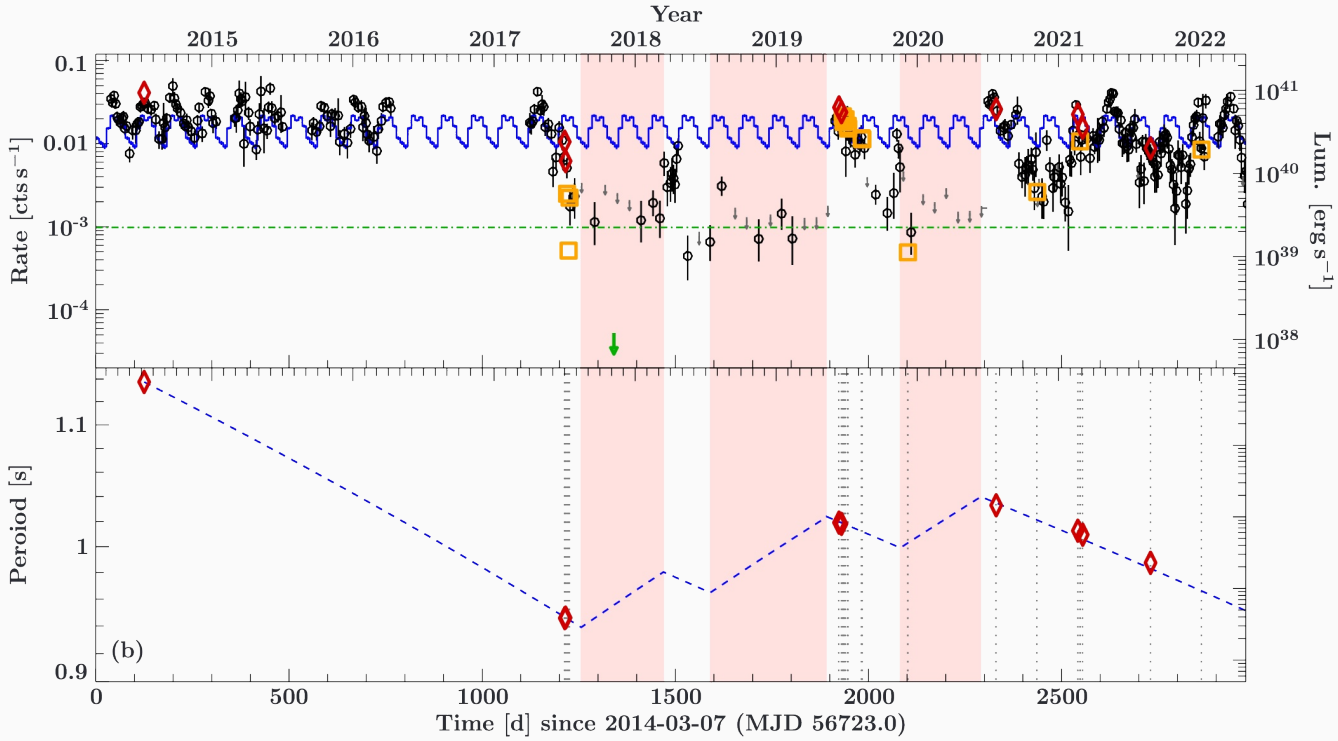
Phase preserved across propeller state.

Implications

- L-T struggles with persisting clock across a propeller state $P_{\mathrm{sup}} \propto \dot{m}_0^3$
- NS Free Precession is stable
- Donor Precession is stable

Revealing a spin up problem from deep observations

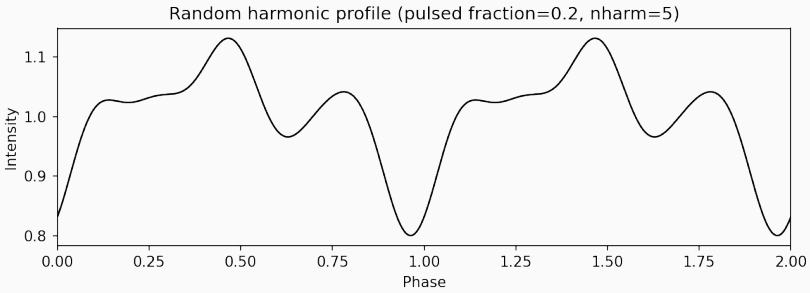
NS free precession $P_{\rm sup} \propto P_{\rm spin}$. From Fürst+23:

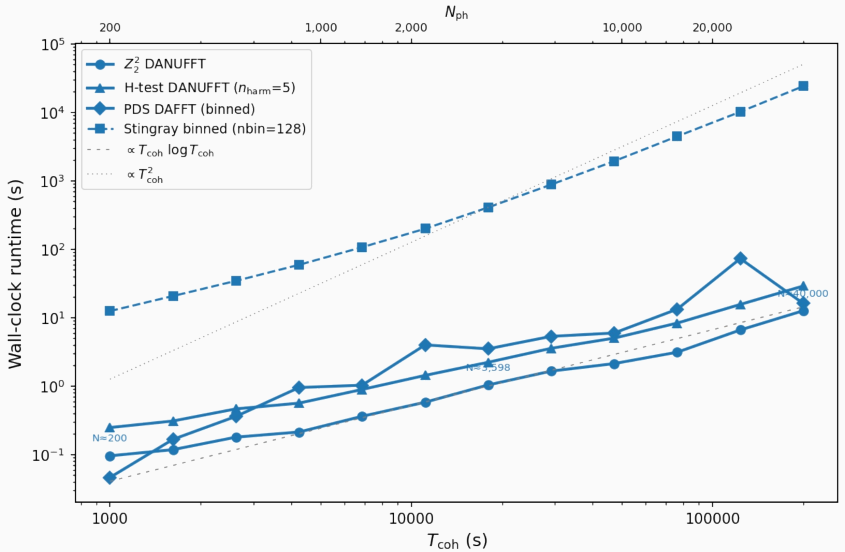


Linear tracking predicts 78.9d $\rightarrow$ 63.1d but the posterior for P is too narrow. Is there a resolution?

Super-Orbital Phase-Resolved Timing

- To test: NS Free Precession (even in super-critical disc) likely to show PF% evolution with super-orbital phase.
- PF% does change across observations (also in NGC 7793 P13)... limitations (photon statistics[1], computational cost of search)
- To improve upon computational cost and sensitivity: new Z_n^2-search method[2] *(TEAZ)*



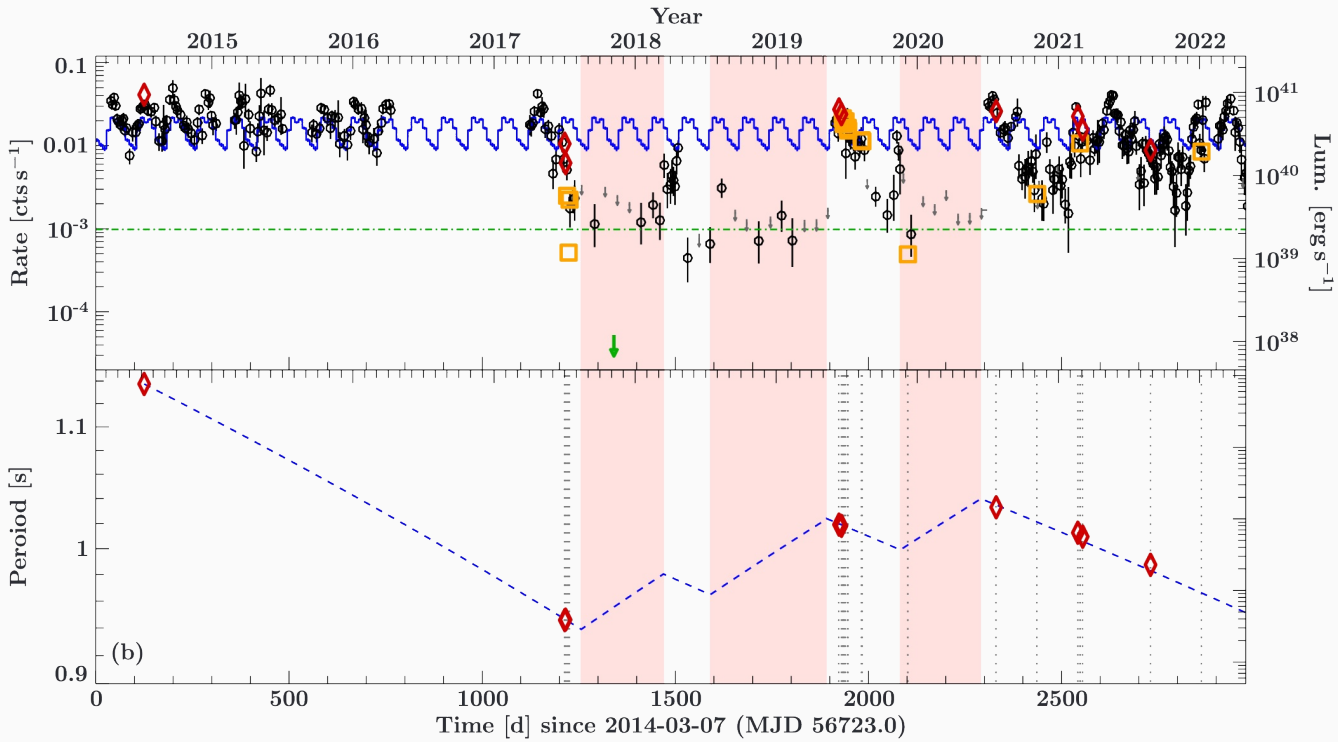


[1] NewAthena will help!

[2] NewAthena should benefit too!

Outlook

Next up: see if we can associate continuum components with geometry super-orbital phase-resolved spectroscopy



Thanks!