

Evidence for an evolving cyclotron line energy in 4U 1538–522

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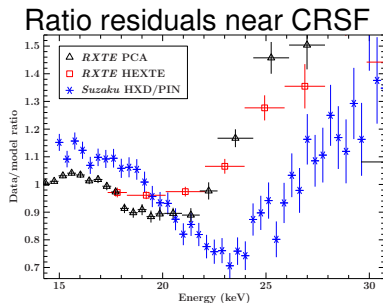
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4U 1538–522: Vital statistics

4U 1538–522 is a moderately-luminous ($\sim 5 \times 10^{36} \text{ erg}^{-1}$) wind-accreting X-ray pulsar

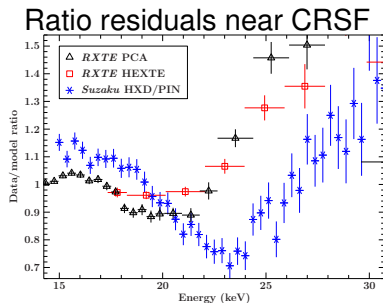
- *RXTE* (Coburn+ 2001, Rodes-Roca+ 2009) and *BeppoSAX* (Robba+ 2001) find CRSF at $\sim 20 \text{ keV}$
- *Suzaku* (Hemphill+ 2014) finds CRSF at $\sim 22 \text{ keV}$



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- **Is this due to some other physical factor, e.g. a correlation with luminosity?**
- **Or is this because of model choice and/or instrumental differences?**

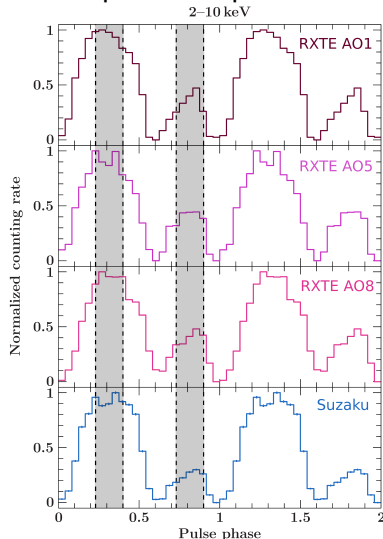


Analysis strategy

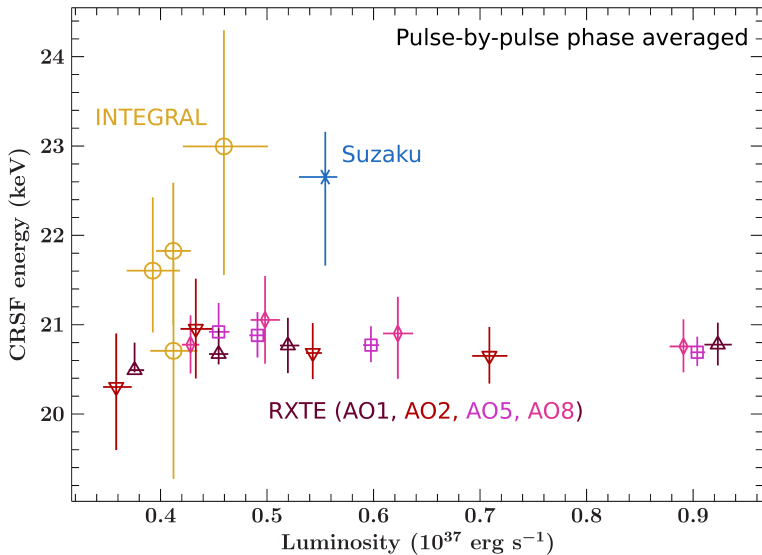
We analyze all *RXTE* (~ 50 observations) and *Suzaku* data (1 observation), and some *INTEGRAL*.

- Three data selections:
 - ▶ *Pulse-by-pulse*, luminosity-resolved (phase-averaged)
 - ▶ Peak of primary pulse (phase-resolved)
 - ▶ Peak of secondary pulse (phase-resolved)
- Use same model for all data:
 - ▶ Powerlaw-HighEcut continuum
 - ▶ Gaussian-profile CRSFs at ~ 21 and ~ 50 keV

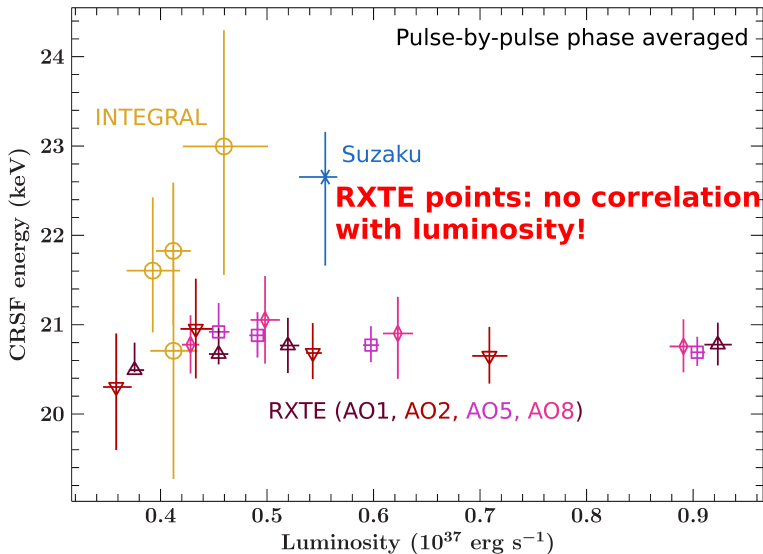
Pulse profiles & phase bins



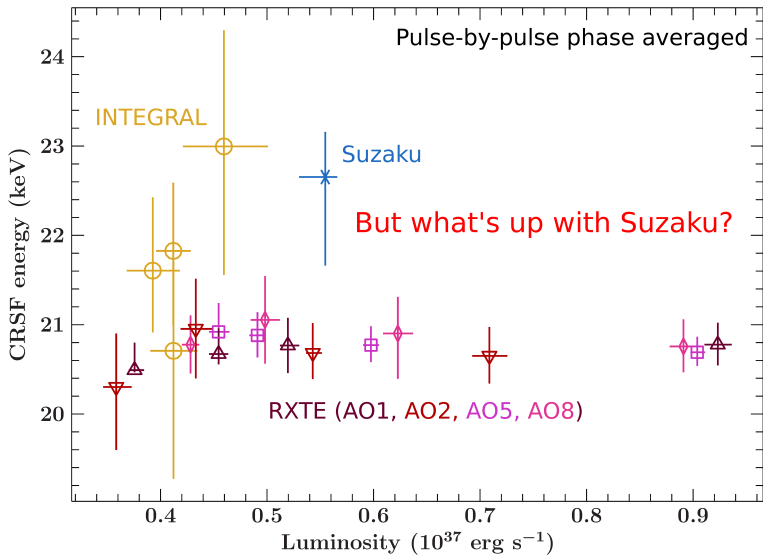
E_{cyc} vs. luminosity



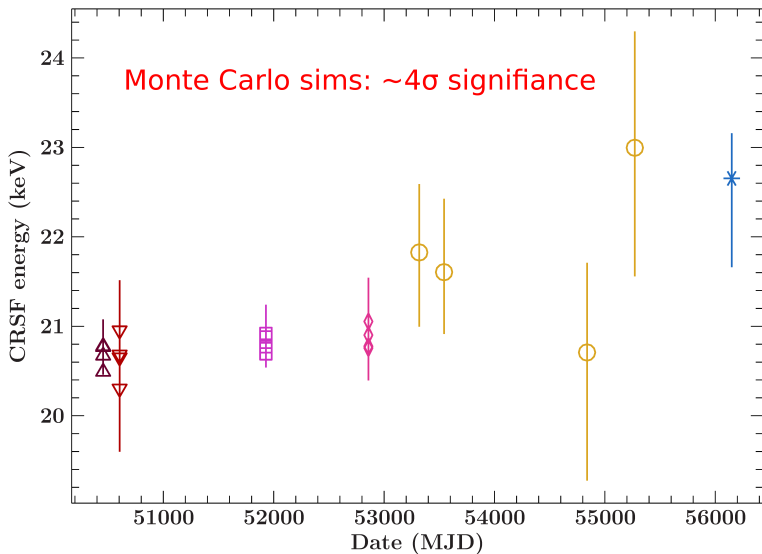
E_{cyc} vs. luminosity



E_{cyc} vs. luminosity



Change in E_{cyc} with time



Discussion: How can we get this change in E_{cyc} ?

Probably not simply a change in scattering region altitude:

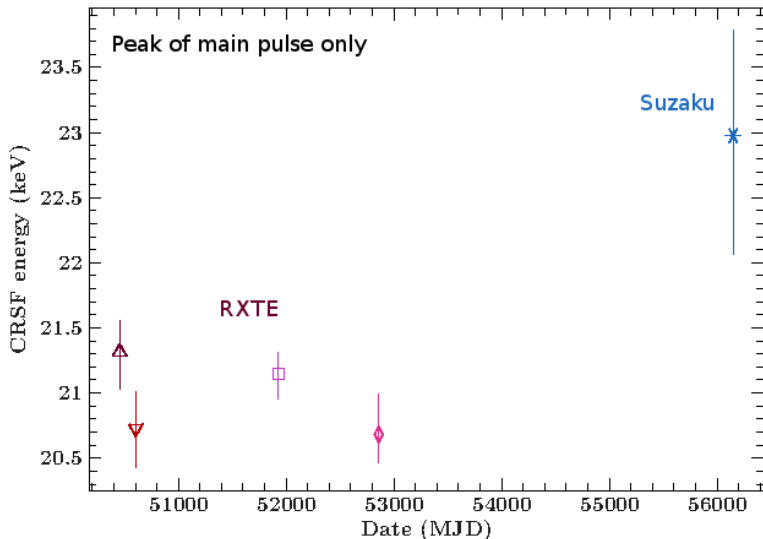
- Dipole field? 5% increase in $|\vec{B}|$ means **1.5 km** decrease in scattering region altitude
- But constant E_{cyc} implies we're close ($\lesssim 100$ m) to the surface (see, e.g., Becker+ 2012)

However, simulations (Mukherjee+ 2012) show $\sim 15\%$ deviations from dipolar fields in accretion mounds

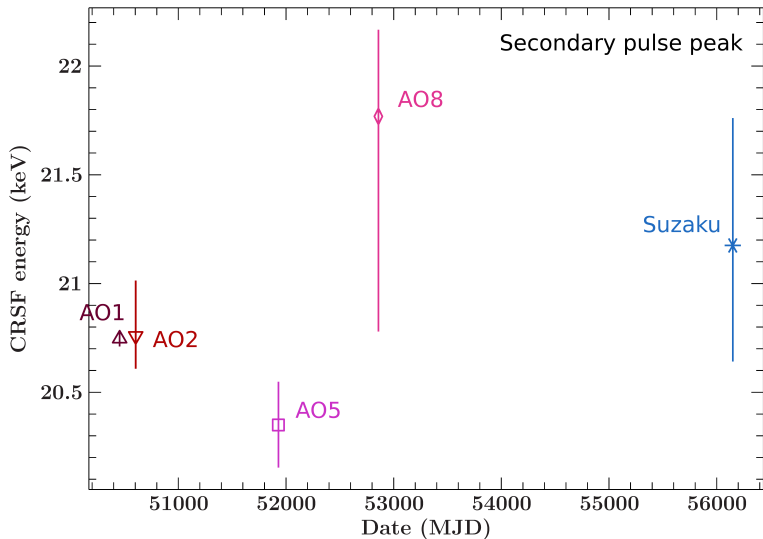
- Could a reconfigured/collapsed accretion mound increase E_{cyc} ?

One last thing to think about...

Primary pulse only — E_{cyc} still increases



Secondary pulse only — no significant change



Conclusions

- 4U 1538–522's CRSF is uncorrelated with luminosity
- However, *Suzaku* spectra show ~ 1 keV **higher-energy CRSF** compared to *RXTE* data
- Shift is significant at $\sim 4\sigma$ **level** in both phase-averaged and pulse-peak data

However...

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However...

- It's only one point!
- Shift is *not* detected in data from secondary pulse

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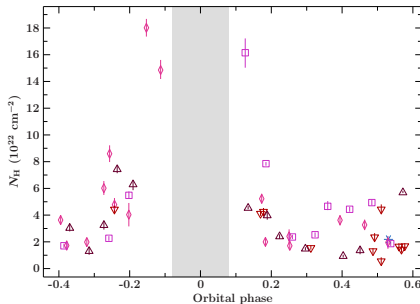
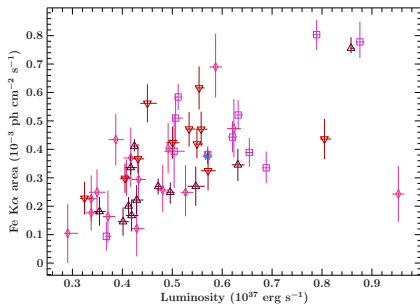
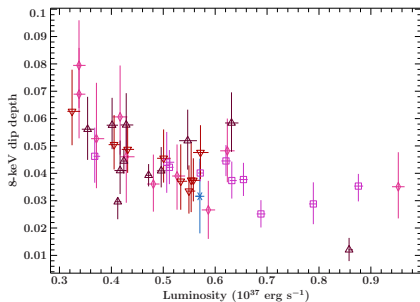
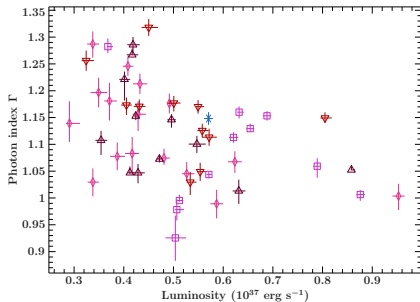
Remaining questions:

- **Is this a long-term or short-term effect?**
- **Is this a change in only one magnetic pole?**

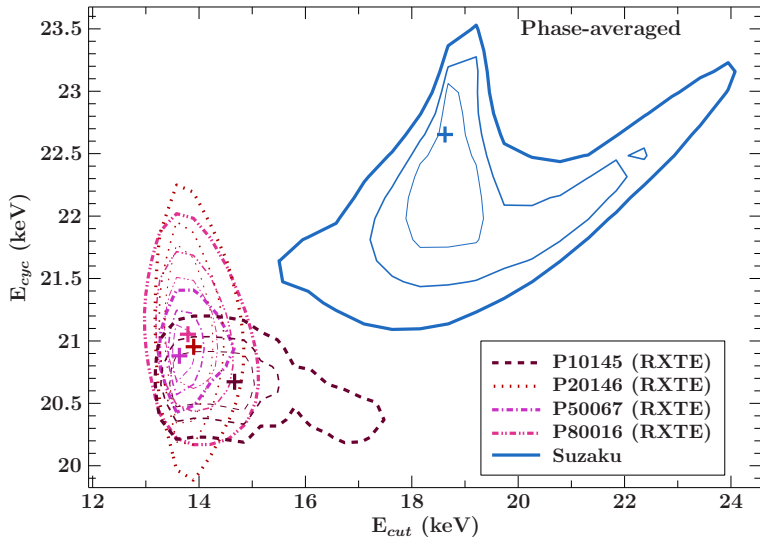
NuSTAR and *INTEGRAL* observations this AO! Physical models are under development (see other talks in this session, also posters by Gottlieb+ [120.09], Rothschild+ [120.21], Wolff+ [120.24])

Backup slides

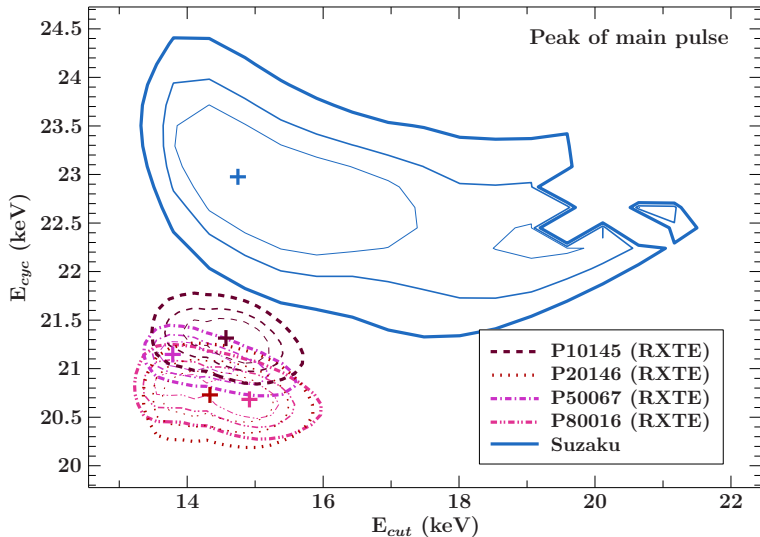
Other parameters



Confidence contour — phase-averaged



Confidence contour — pulse peak



Comparison — *RXTE* and *Suzaku*

