

# Giant outburst of EXO 2030+375 I: Spectral and pulse profile evolution

Reconstructing pulse profiles with NICER & IXPE

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K. Pottschmidt,   J. Wilms   & many others ...

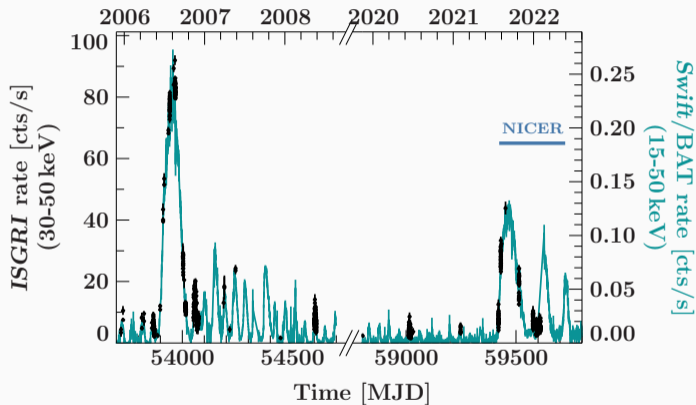
Dr. Karl Remeis-Observatory

ECAP / FAU

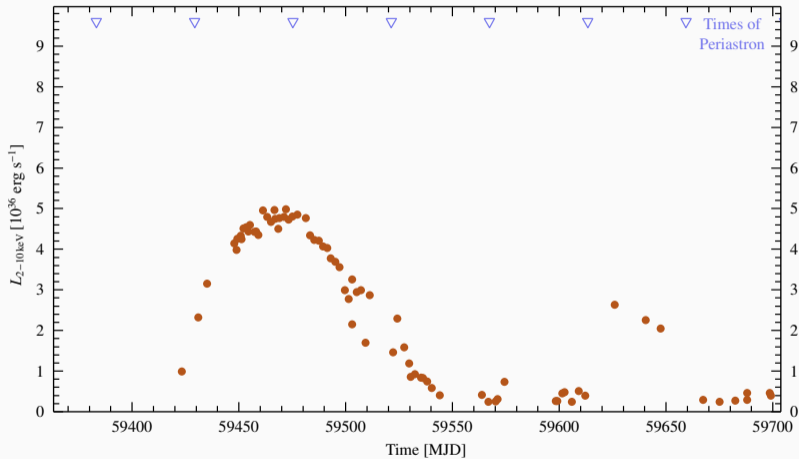


# The prototypical BeXRB EXO 2030+375

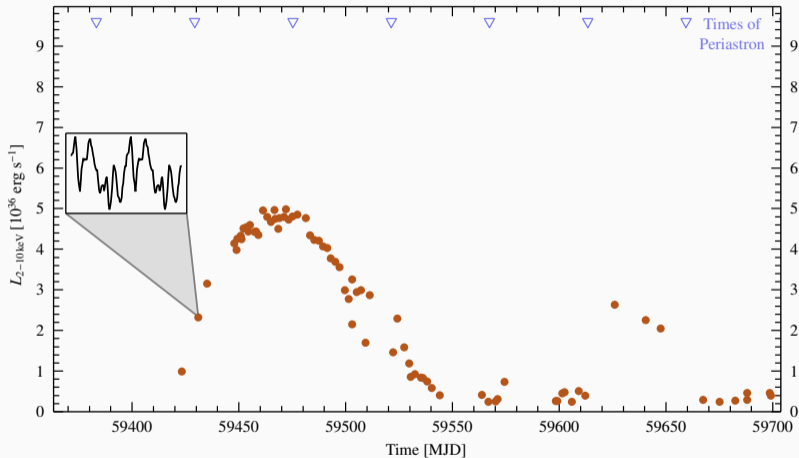
- Giant outbursts in 1986 & 2006
- 2021 outburst monitored by *NICER*
- No accepted cyclotron line (claims between 10 – 64 keV)
- Pulse profile modeling attempted in the past, see Parmer et al. (1989)



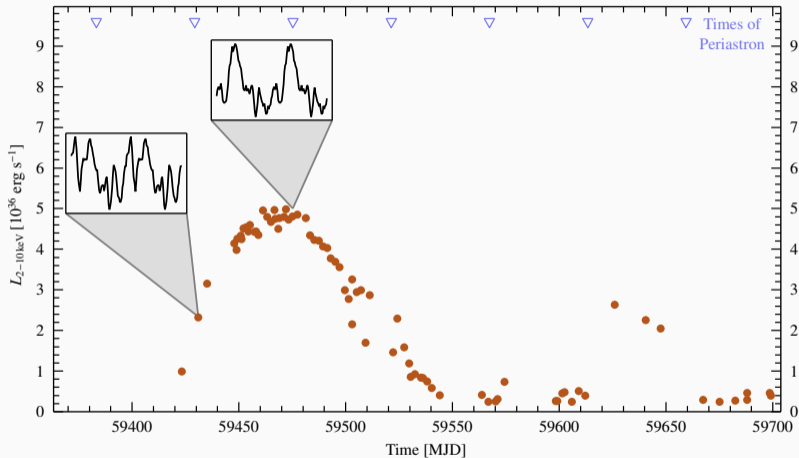
# NICER monitoring of 2021 outburst



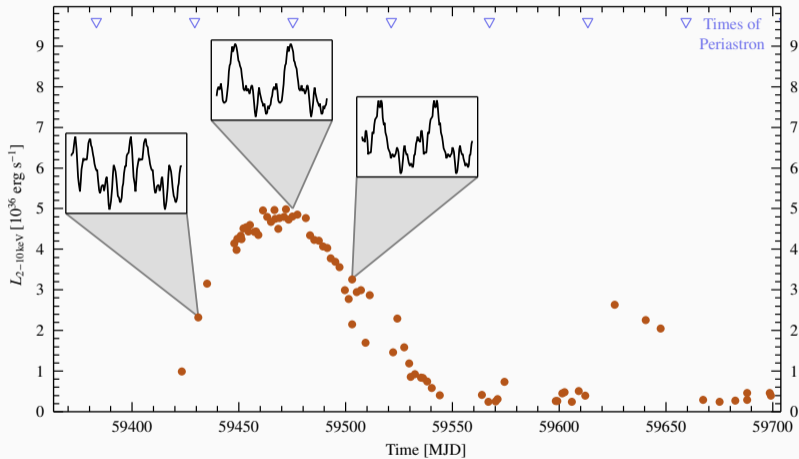
# EXO 2030+375: NICER monitoring of 2021 outburst



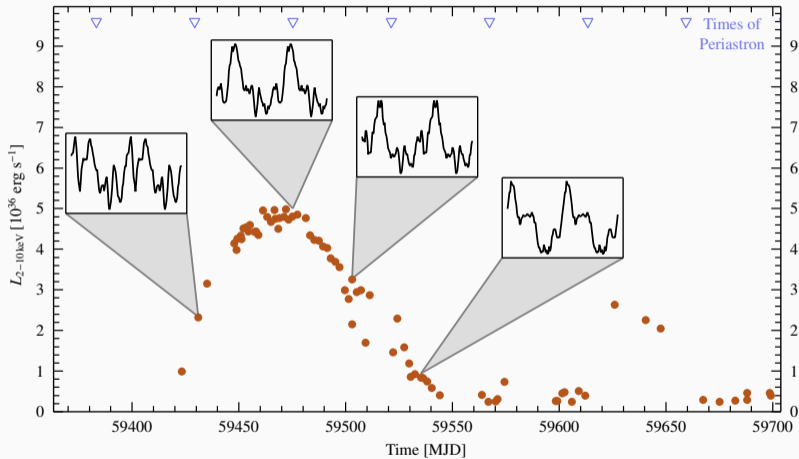
# EXO 2030+375: NICER monitoring of 2021 outburst



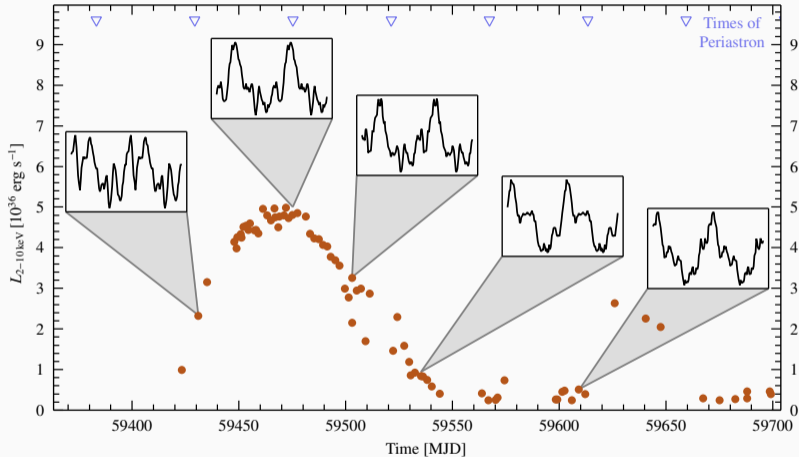
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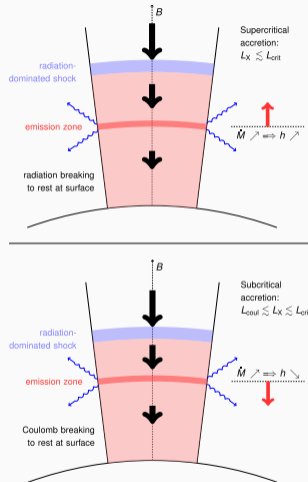
Why are profiles so complex and what changes with luminosity?



# Reminder: Cause of transition?

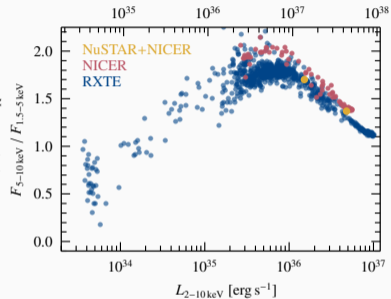
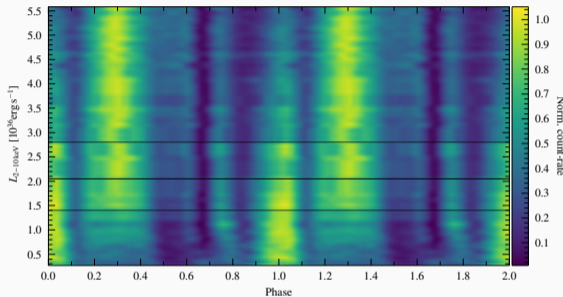
- Mode of deceleration changes
- Radiation pressure affects shock- & emission height
- Changes in the emission pattern & geometry

→ Can we compare  $L_{\text{crit}}$  to theory and measure these changes?



Adapted by Wilms after Becker et al. (2012)

# EXO 2030+375: Transition in Pulse Profiles and Spectrum

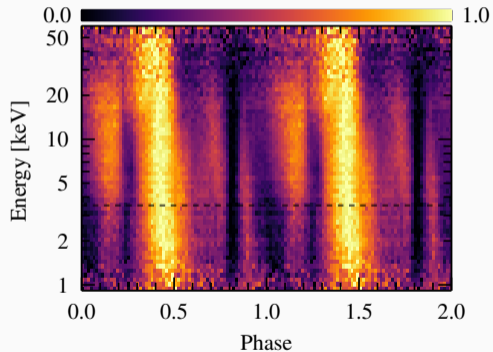


Transition observed  $\sim 2.0 \times 10^{36}$  erg s<sup>-1</sup> and  $\sim 0.5 \times 10^{36}$  erg s<sup>-1</sup>

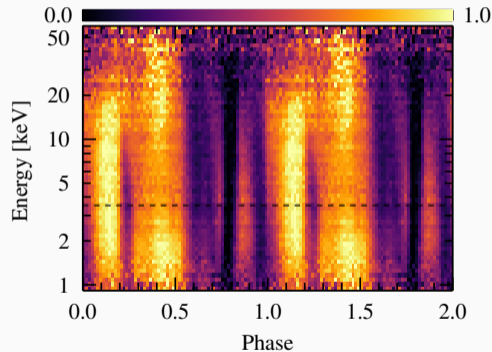
→ **Spectrum-luminosity correlation changes first**

# Energy dependence of pulse profiles: NuSTAR & NICER

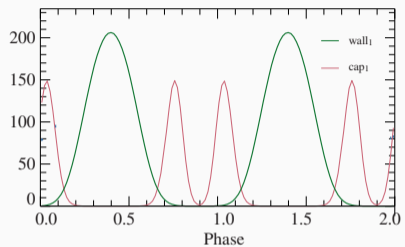
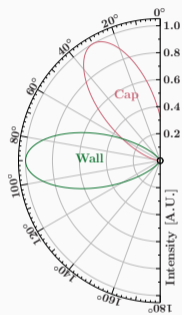
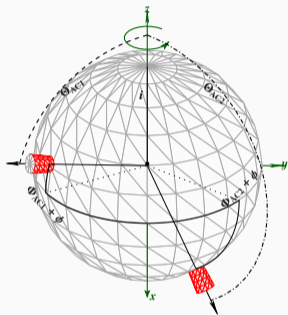
High-Luminosity



Low-Luminosity

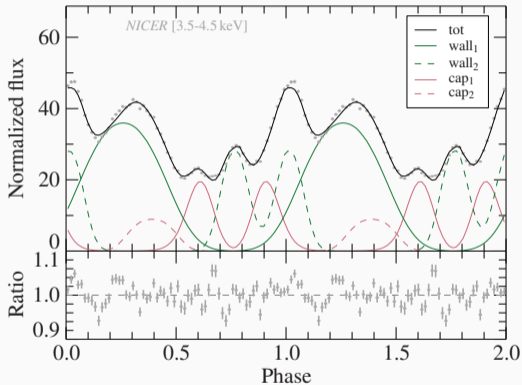
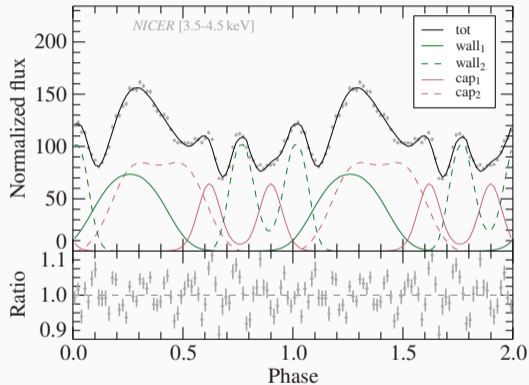


# Step-by-Step: Modeling profiles with light-bending

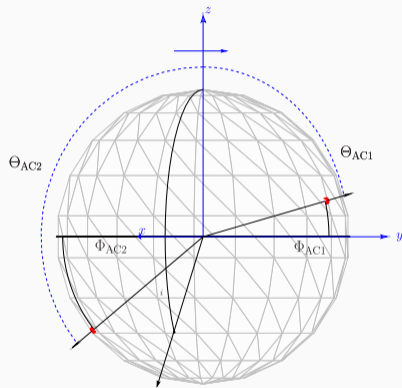


Place accretion columns  $\rightarrow$  Assume emission profile  $\rightarrow$  Get Pulse Profile by rotating NS

# Modeled pulse profiles of EXO 2030+375



## Discussion: Geometry



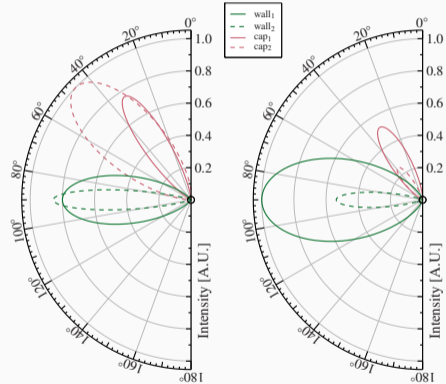
Does that make sense?

- $130^\circ$  observer inclination used from **IXPE** results
- $132^\circ$  between columns  $\rightarrow$  fits previous estimated of  $110\text{-}140^\circ$
- Inclination of columns  $80^\circ$  &  $60^\circ$  fits **IXPE** result of  $59^\circ.8^{+4.6}_{-5.8}$   
 $\rightarrow$  reasonable geometry

# Discussion: Emission profiles

Does the emission pattern make sense?

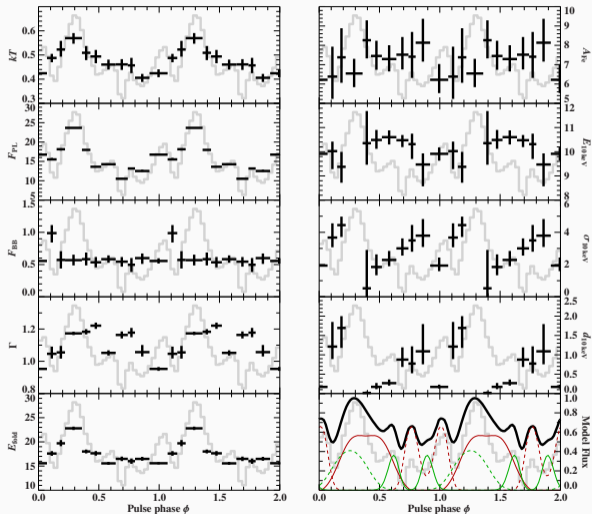
- **Cap** emission seems stronger at higher flux
- **Wall** emission changes differently for the two columns  
→ Less clear picture that goes against expectations



## Paper II: Phase-resolved spectra (by Ralf Ballhausen)

- Using two NuSTAR observation (with NICER) for phase-resolved fits
- 10 keV CRSF absorption signature
- Can we associate spectral and pulse profile components?

→ Not straightforward





## What did we find?

- **IXPE** great for profile modelling
- Two columns and **simple emission profiles** are sufficient to describe the pulse profiles
- **Transition luminosity** in spectrum lower than in pulse-profiles
- Emission profiles deviates from expectation  
→ **other solution possible!**

## What did we find?

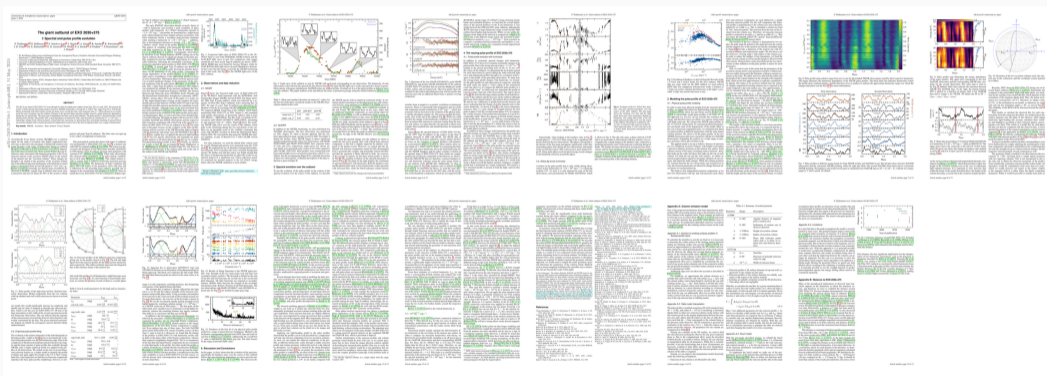
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## What needs to be done

- **Combine spectral & timing** information (see MSP studies)
- **Include all the available data**, i.e., all energies and luminosities
- Another IXPE observation helpful (Doroshenko et al. 2023)

# Thanks for listening!

You can find both papers on arXiv: 2405.20734 & 2406.13029



# Quick look at spectral evolution

