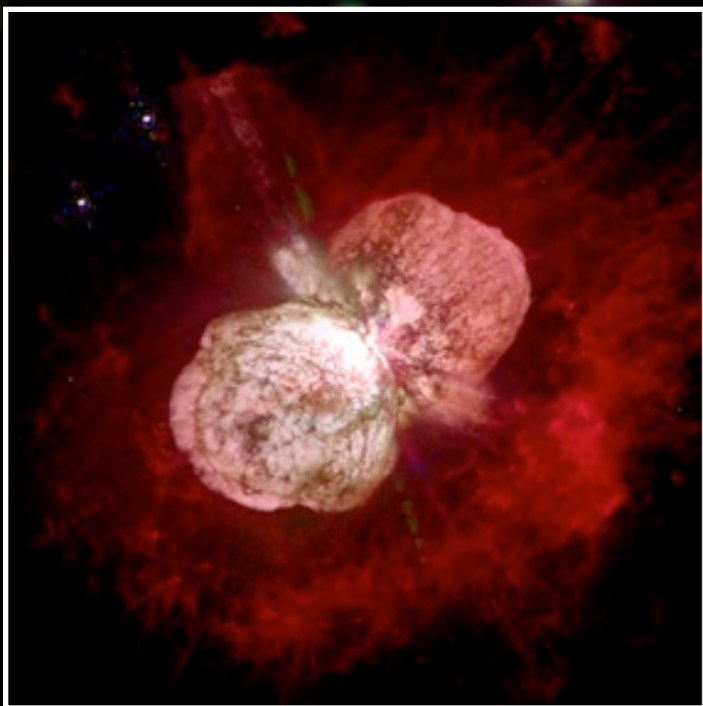


The Orbital Variation of Non-Thermal X-ray Emission from eta Carinae

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Eta Carinae Team





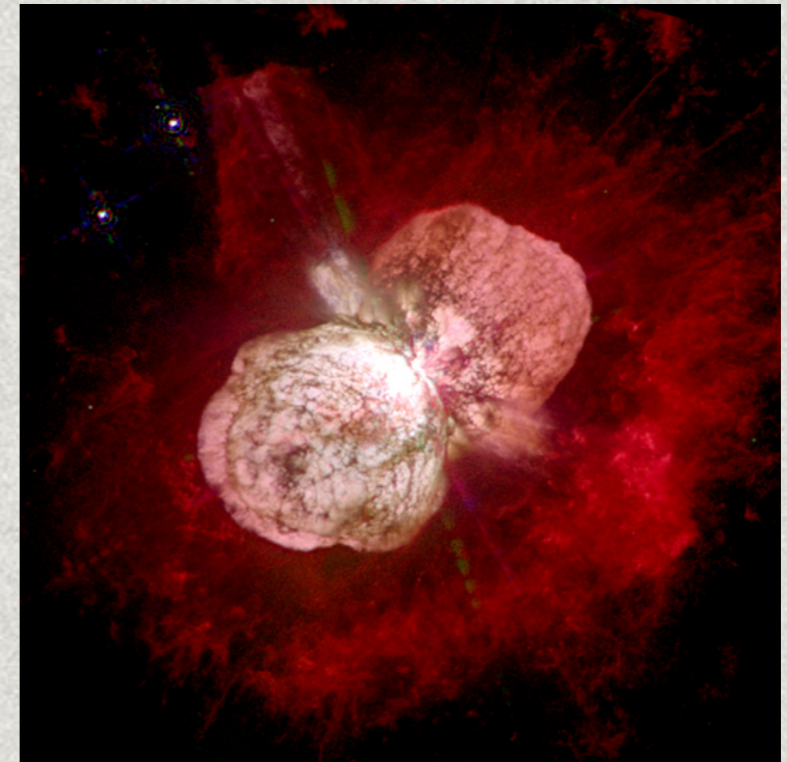
Extended Emission
X-ray Homunculus Nebula
Outer Debris Field
Central Point Source
Wind-wind Colliding (WWC) Emission
Central Constant Emission

10"
23 kAU

Chandra Observatory
X-ray True Color Image

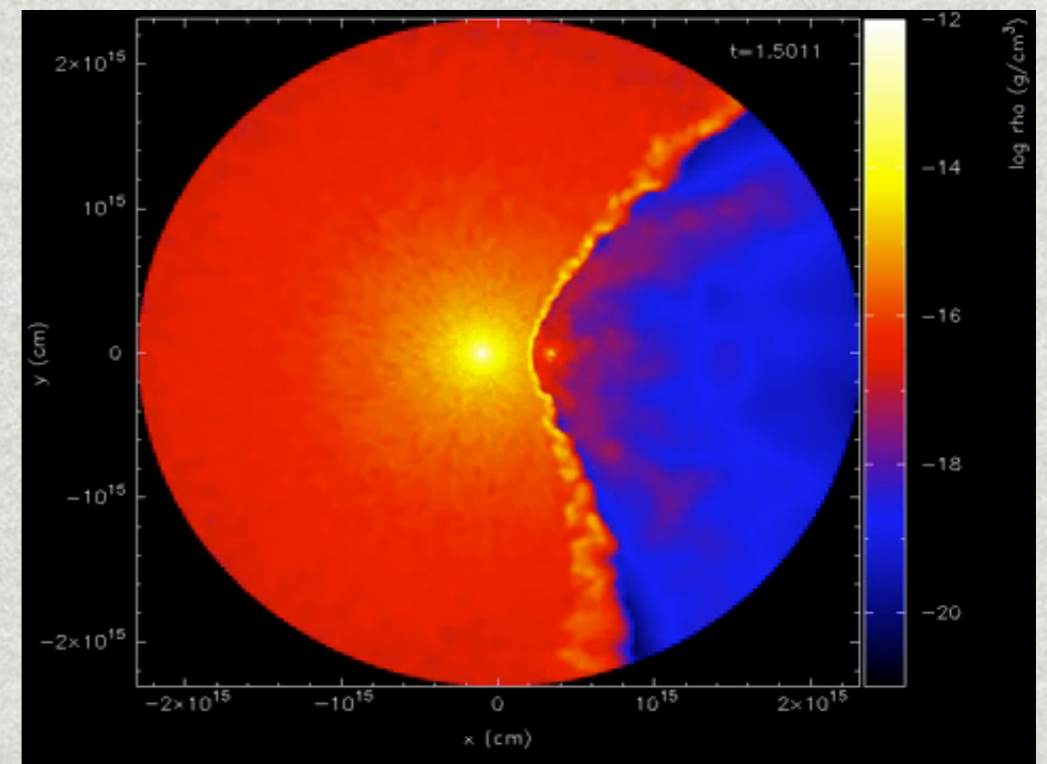
Eta Carinae

- * Evolved supermassive star at 2.3 kpc
 - * Hypernova progenitor?
 - * Future γ -ray burst?
- * Strong mass loss
 - * Great eruption in ~ 1840
- * Embedded binary system
 - * $P \sim 2023$ days (~ 5.5 years)
 - * $e \sim 0.9$
 - * companion hasn't been seen directly.



HST image of η Car

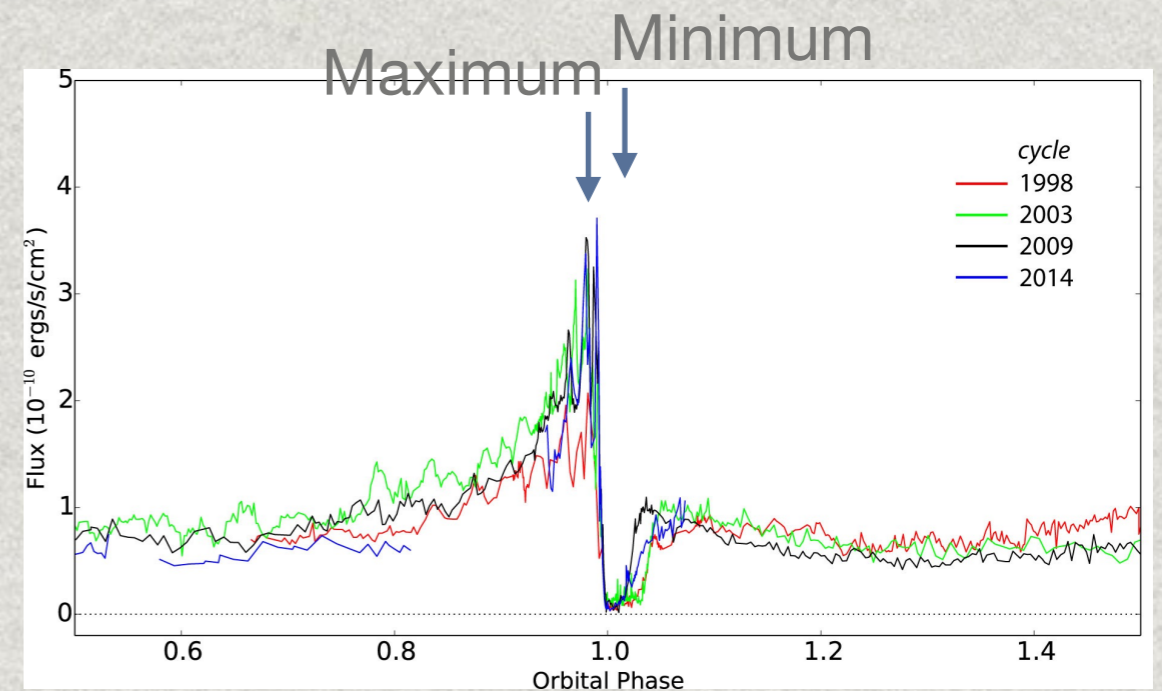
	Type	Mass	\dot{M}	V_{wind}
		M_{\odot}	$10^{-4} M_{\odot} \text{ yr}^{-1}$	km s^{-1}
A	LBV	90	8.5	420
B	O, WN?	30	0.1	3000



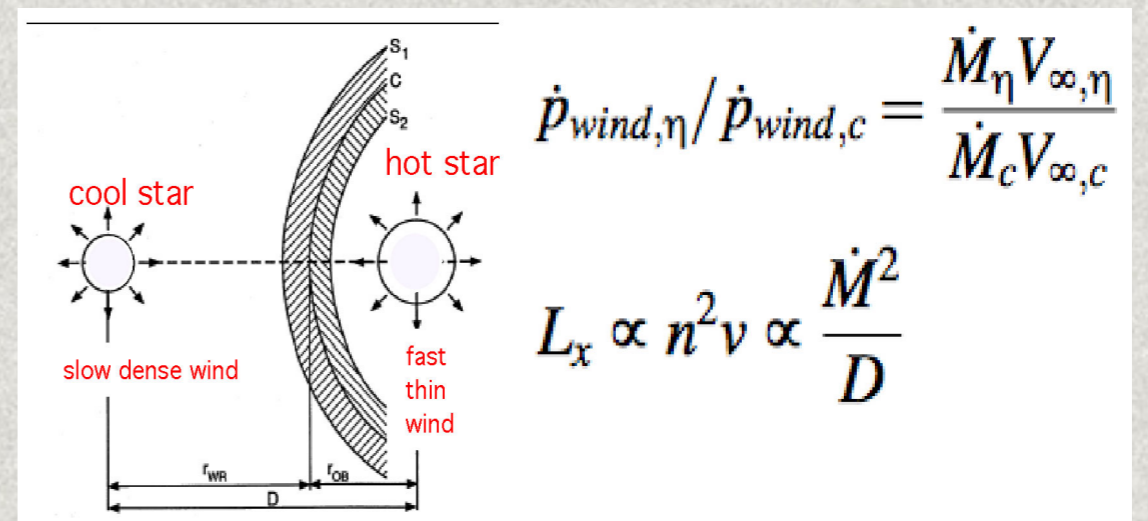
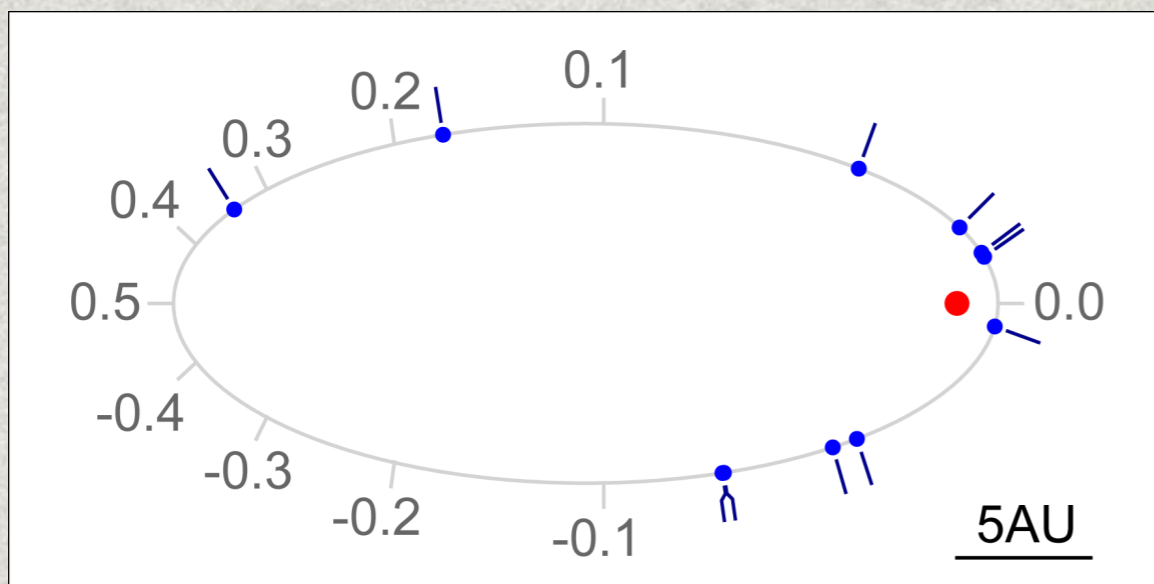
SPH simulation of the wind collision
Russell+2016

Wind-wind Colliding Activity

- * Hot plasma emission
 - * $kT \sim 4-5$ keV
 - * L_x increase toward periastron
- * Plasma heating by wind-wind collision
- * X-ray Minimum
 - * Eclipse
 - * Activity decay



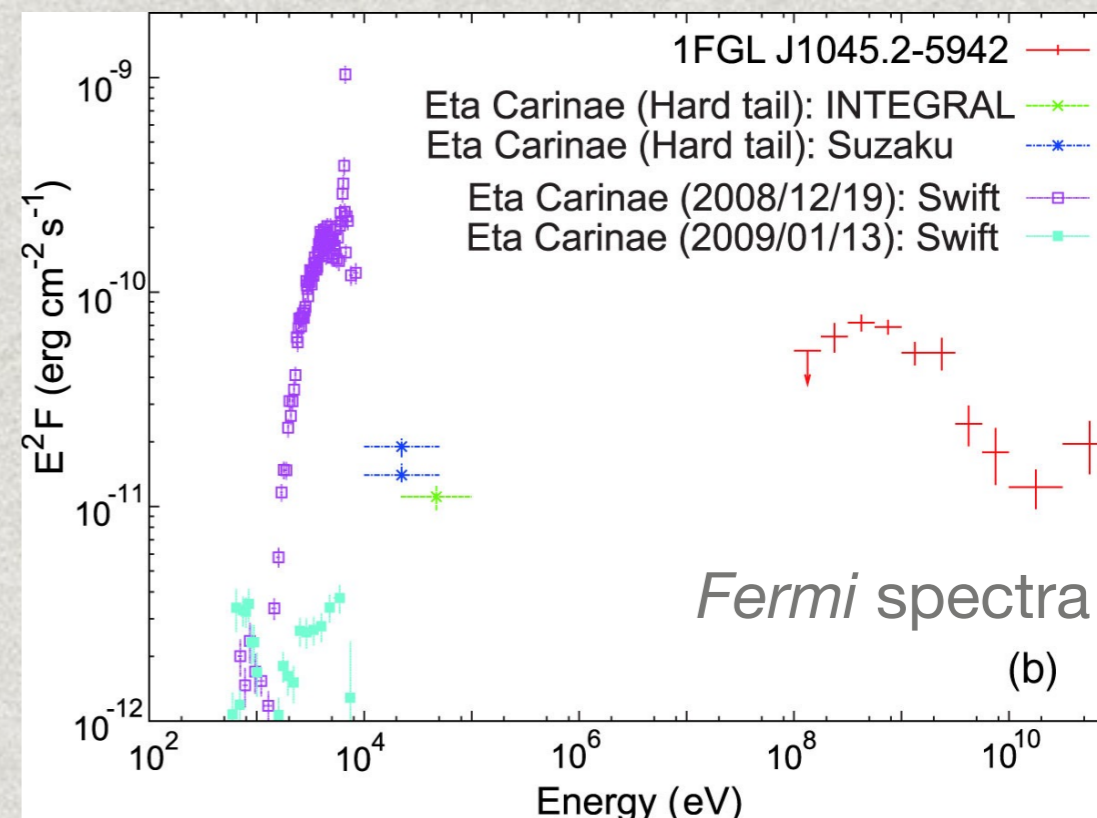
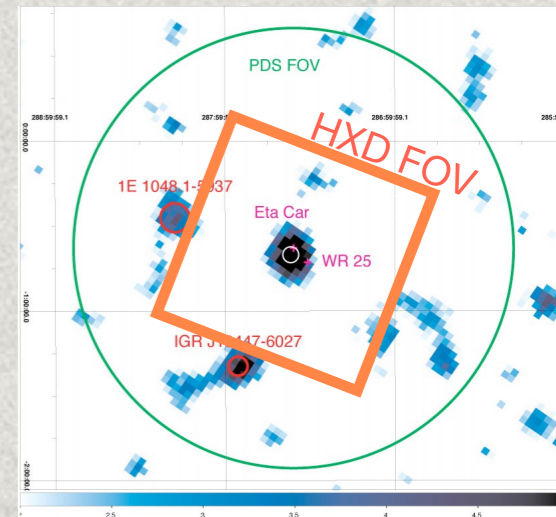
RXTE/Swift phase folded light curves




Extremely high- E Comp.?

- * X-rays (20-100 keV)
 - * stable?
- * γ -rays (GeV, TeV)
 - * as powerful as a pulsar
 - * orbital variation?
- * Non-thermal?
 - * Inverse-Compton?
 - * Pion decay?

**22-100 KEV
W/INTEGRAL**



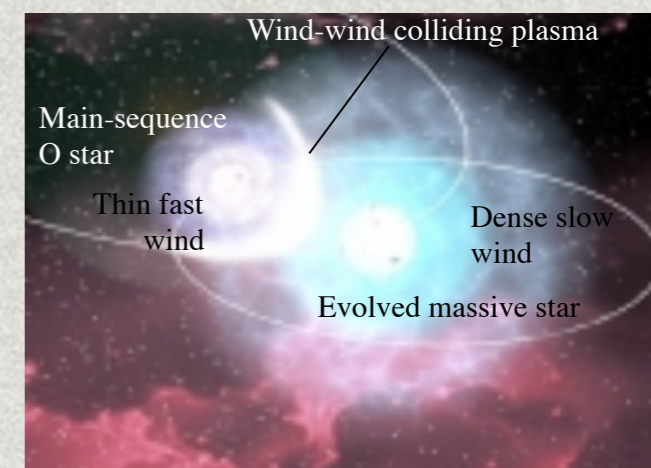
 Is it originated from η Car?

 $> \sim 1'$ position uncertainty

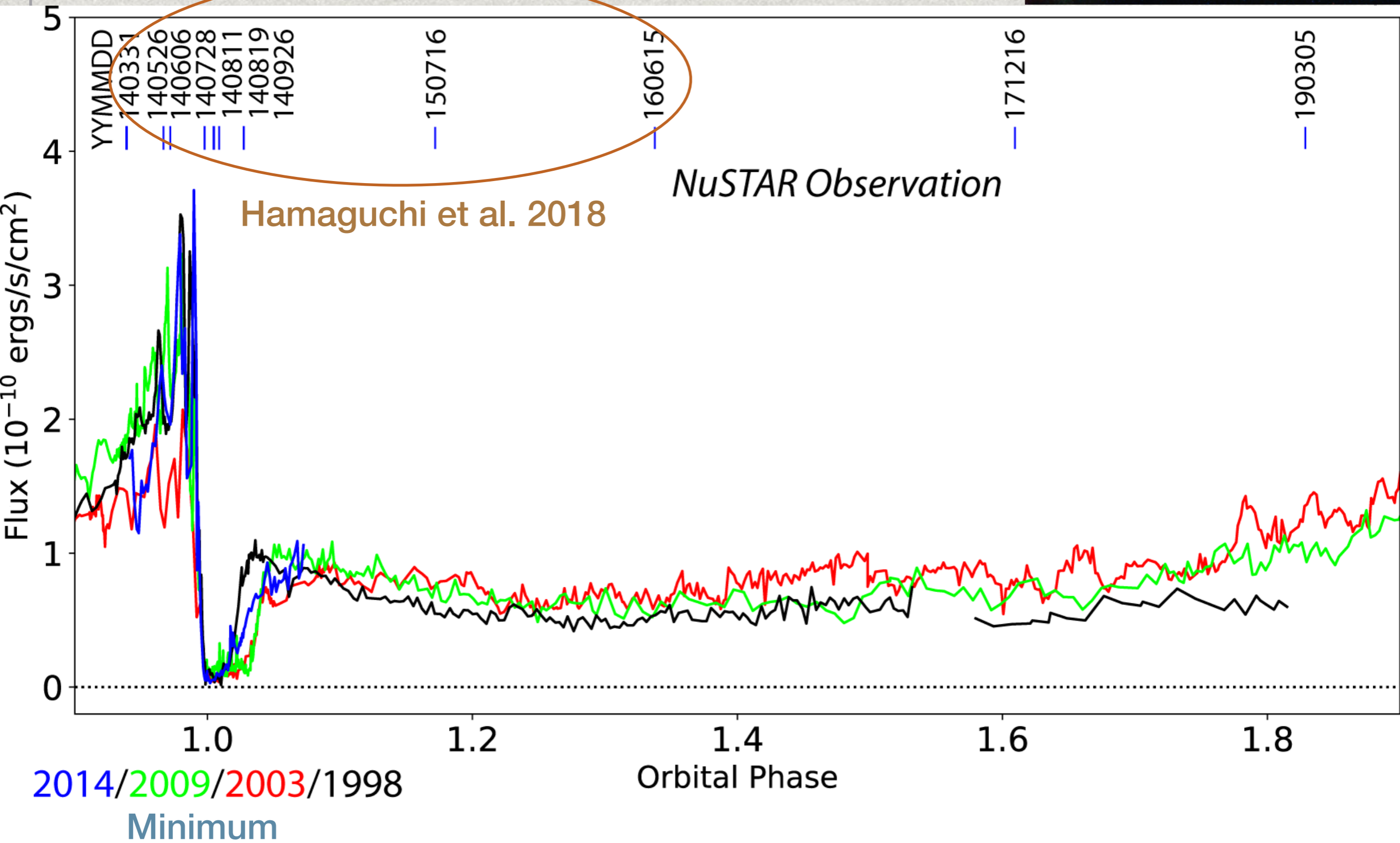
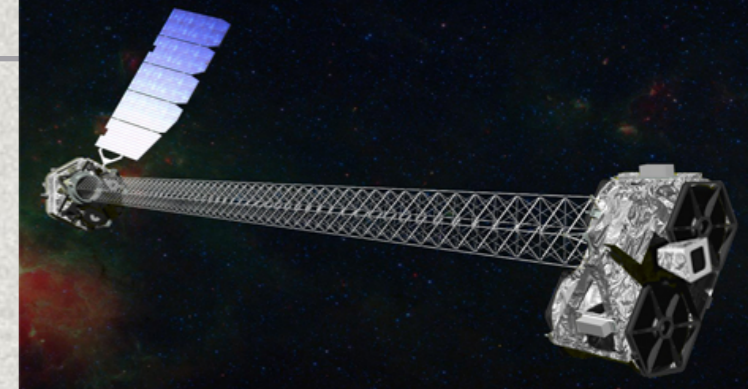
 How are the orbital variation?

20-100 keV X-rays: Leyder+2008,2010, Sekiguchi+2009, Hamaguchi+2014, Hamaguchi+2016

GeV gamma-rays: Tavani+2009, Abdo+2010, Reitberger+2012,2015

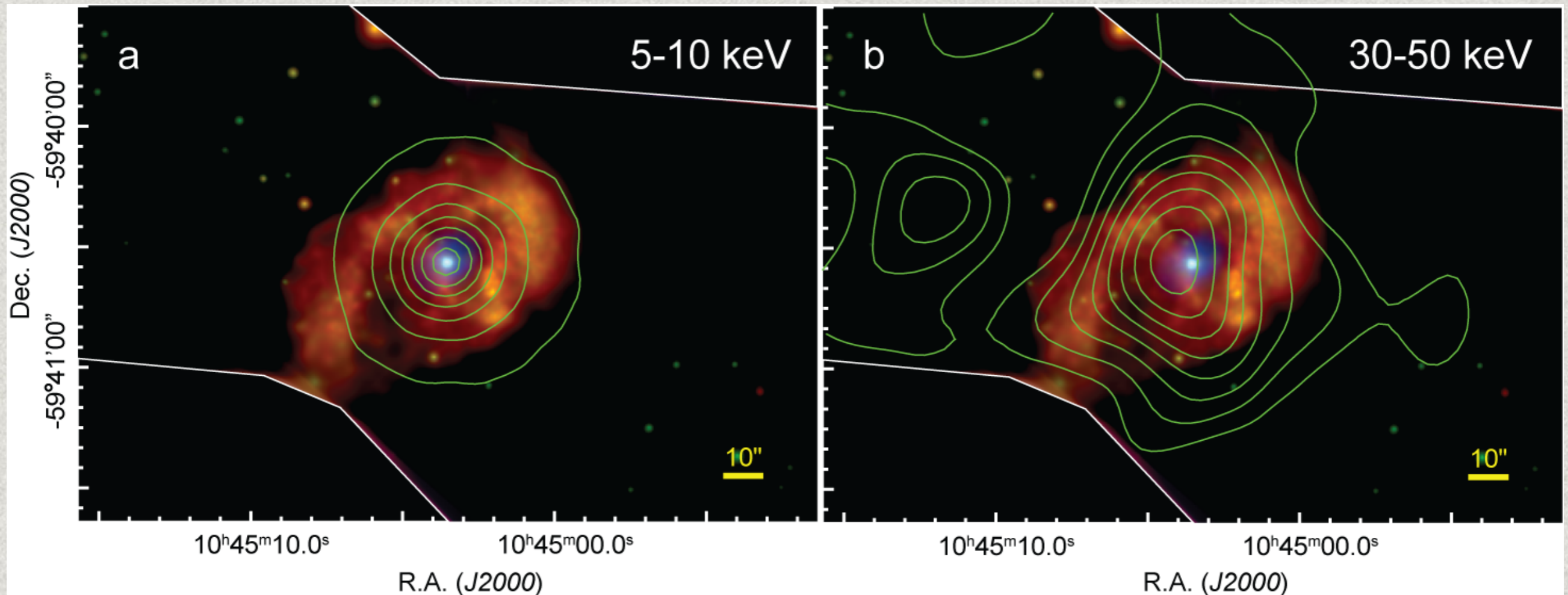


NuSTAR Observations



X-ray Images

- * *NuSTAR* Image Contour on a *Chandra* true color image
- * Combination of two observing data after periastron (2015+2016)

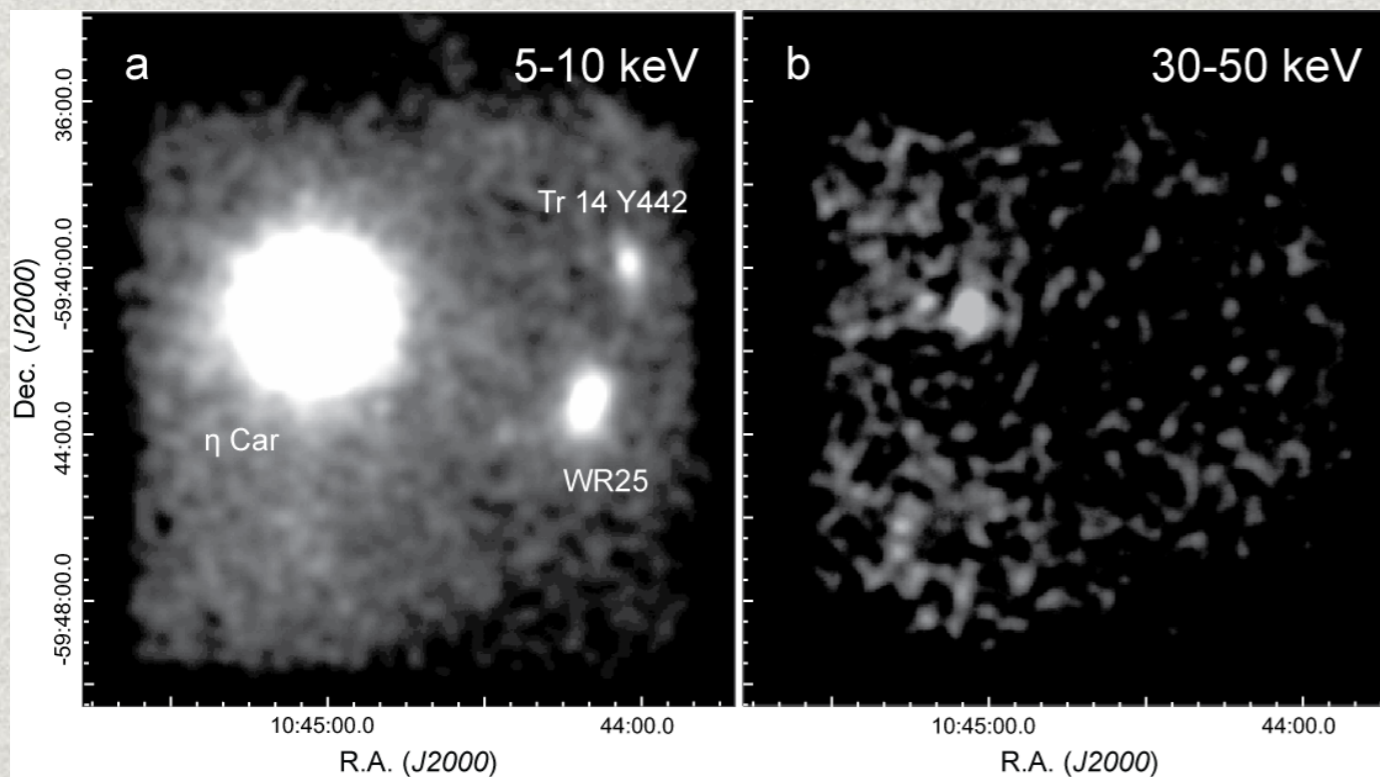


- * The extremely hard X-ray source is located within 5'' from the central binary system.

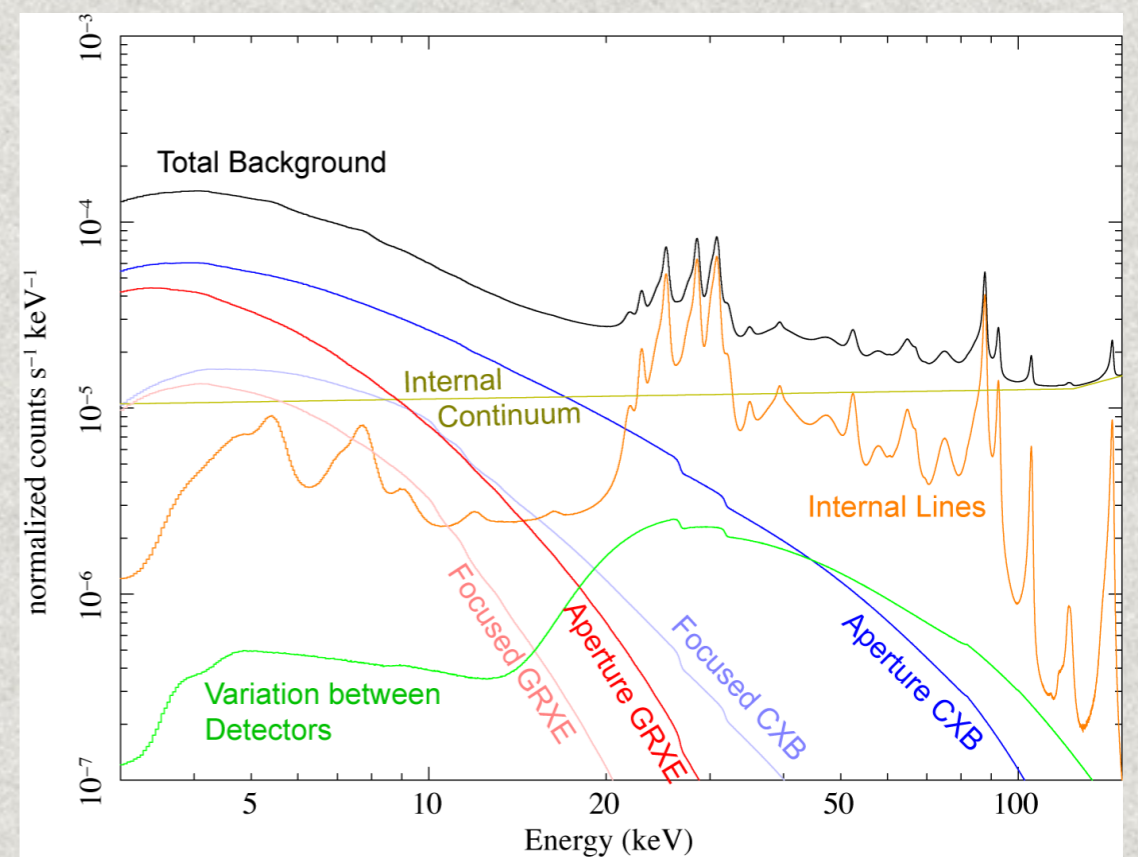
NuSTAR Background Reduction

- ✱ Remove the high background intervals
- ✱ Take a small ($r = 30''$) source region
- ✱ Estimate remaining background with Nuskybgd
 - ✱ Wik et al. 2014

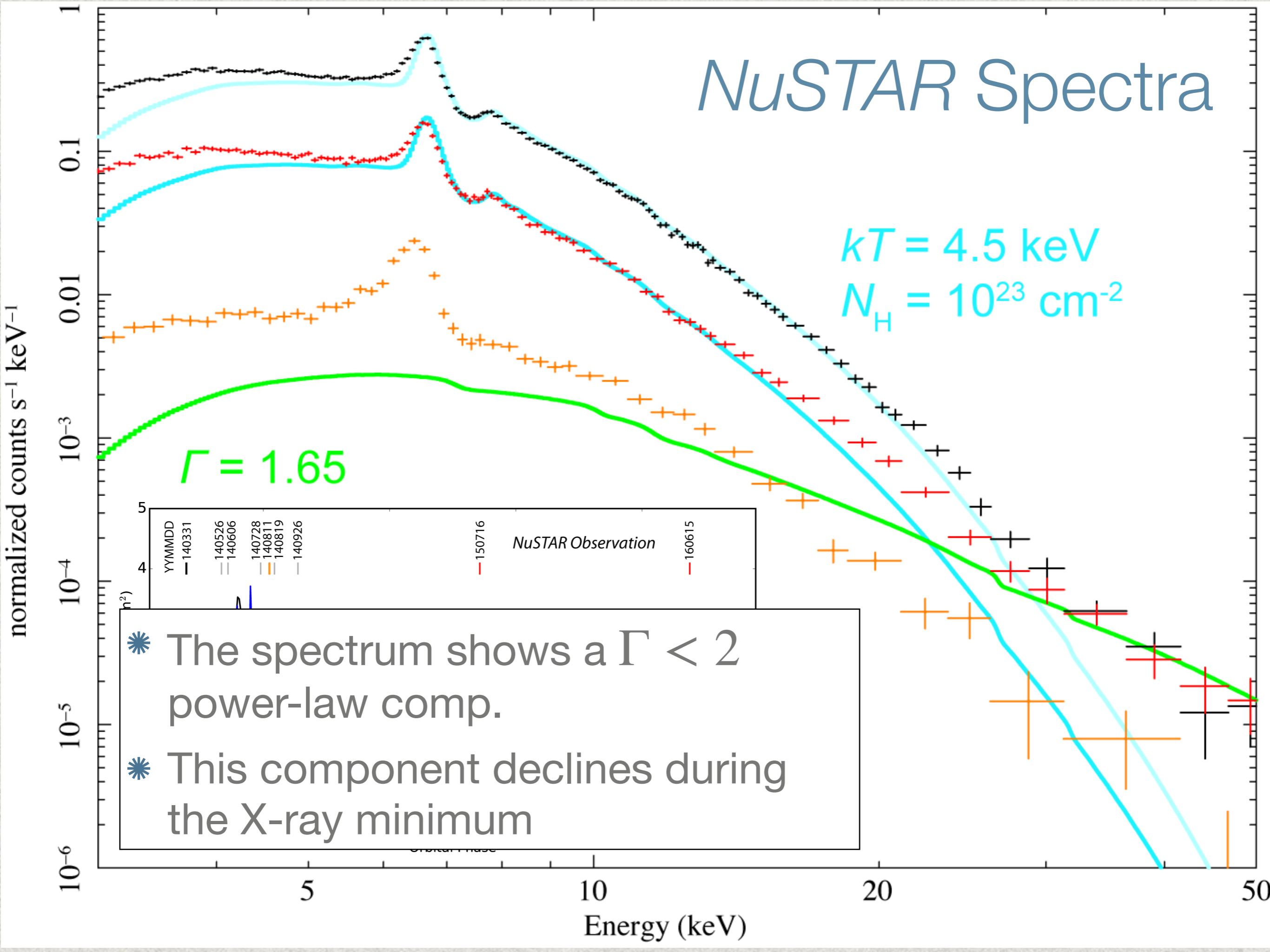
NuSTAR image



Background components



NuSTAR Spectra



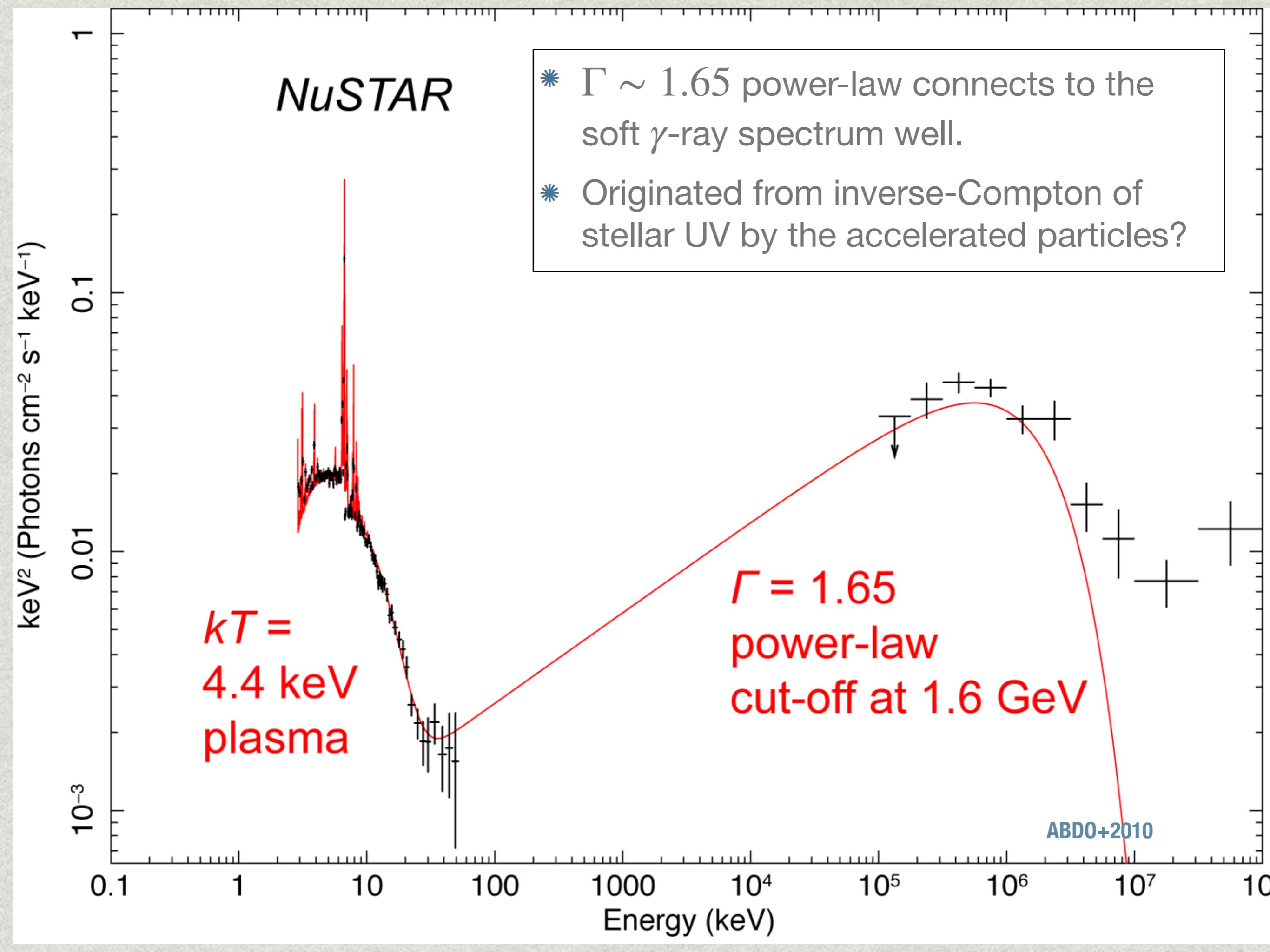
NuSTAR

- * $\Gamma \sim 1.65$ power-law connects to the soft γ -ray spectrum well.
- * Originated from inverse-Compton of stellar UV by the accelerated particles?

$kT =$
4.4 keV
plasma

$\Gamma = 1.65$
power-law
cut-off at 1.6 GeV

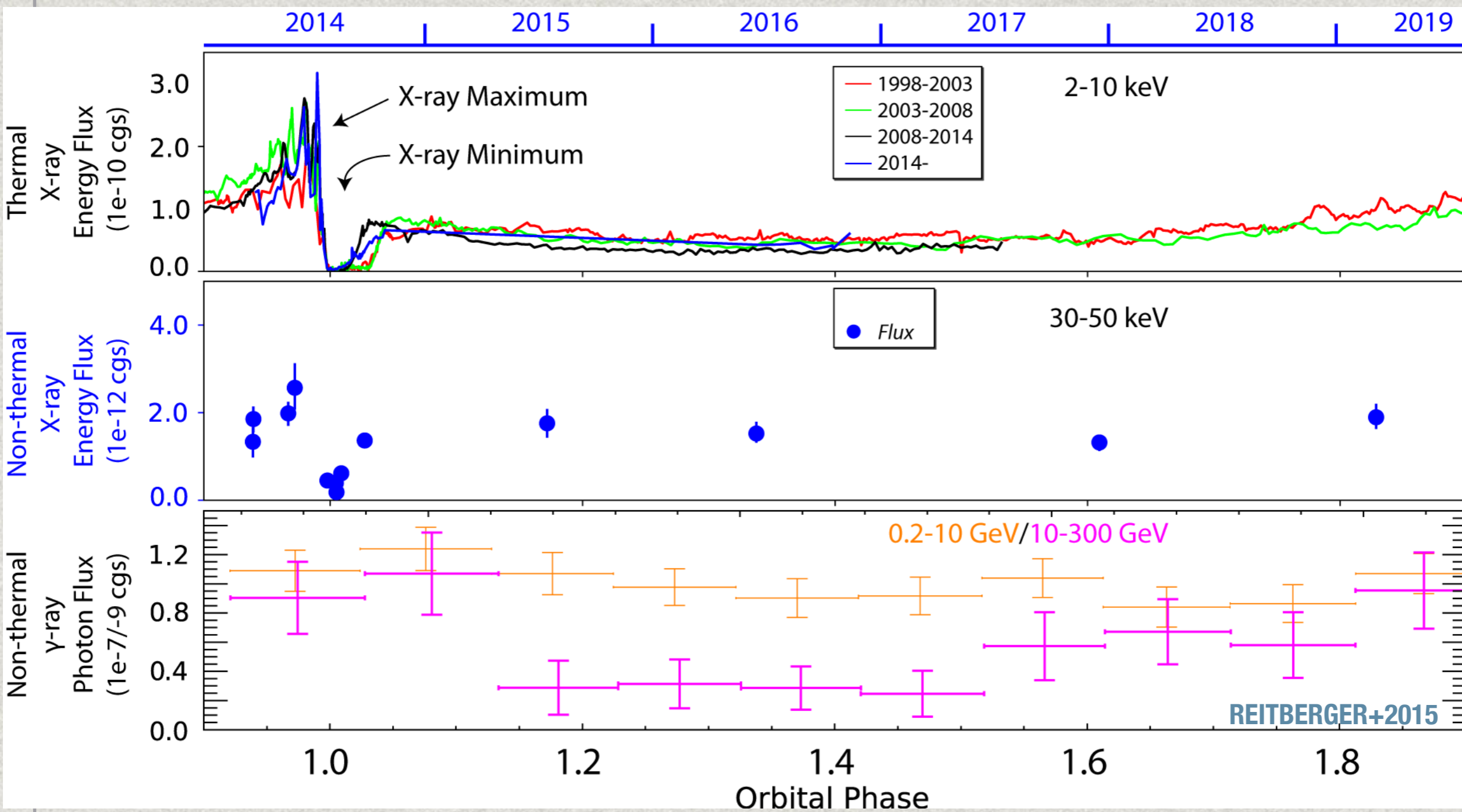
ABDO+2010



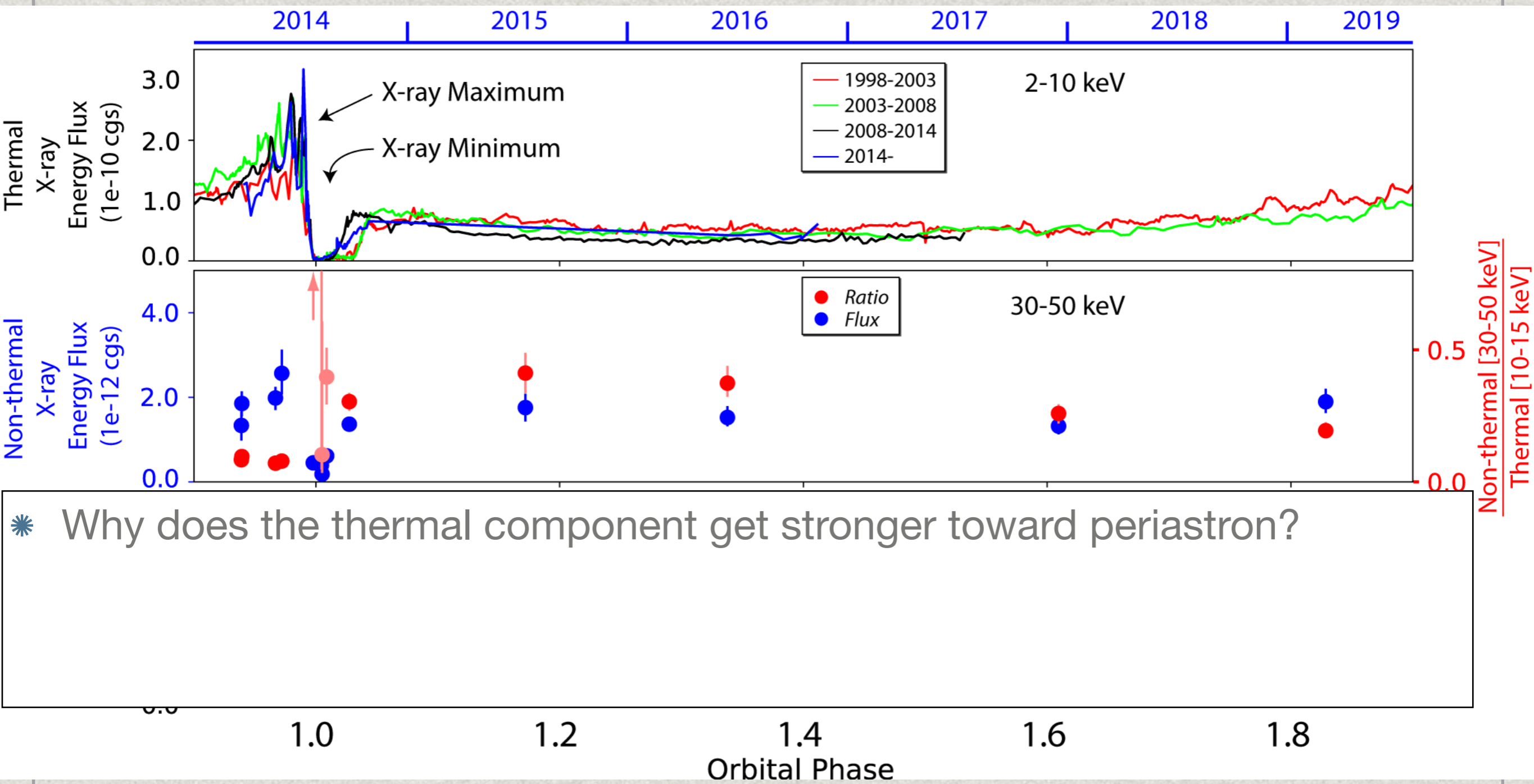
Flux Variation

Declines in both bands

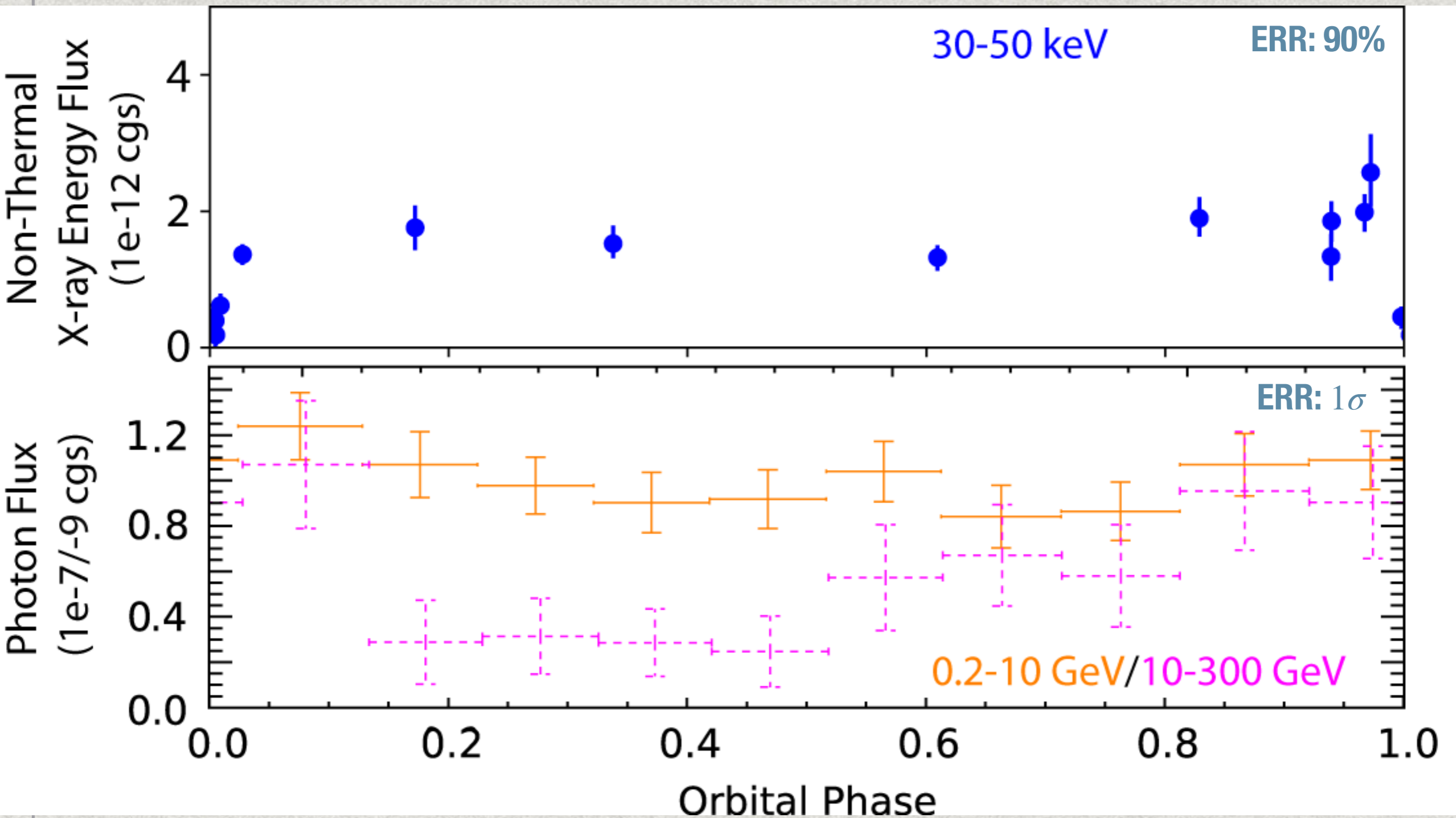
▶ originates from the wind colliding region



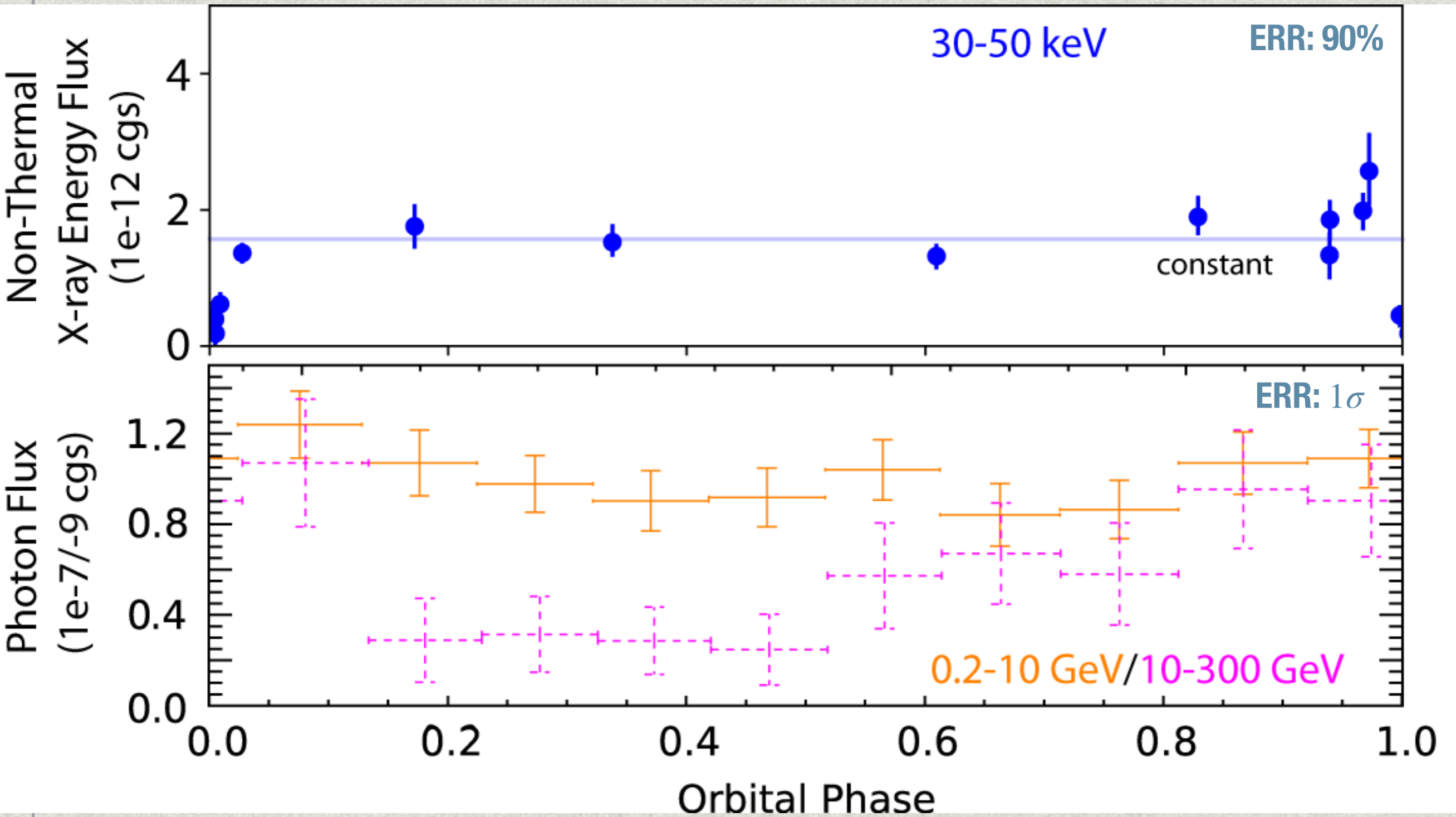
Flux Variation



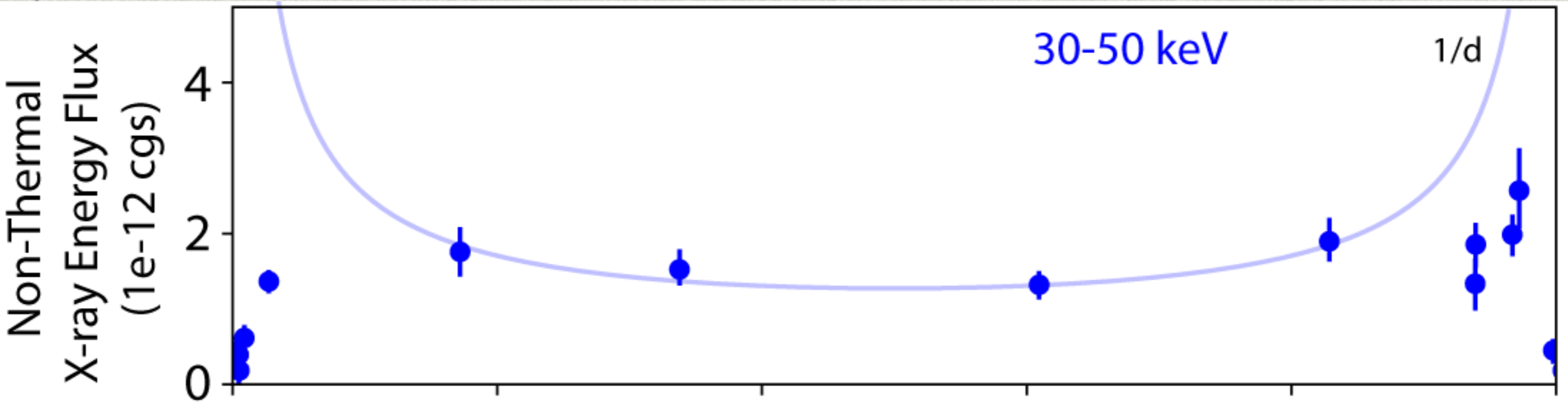
Non-thermal Flux Variation



Model



Model



- * If the non-thermal electrons fill the colliding wind region,

- * $N_{\text{acc}} \propto nV$

- * $n \propto d^{-2}$

- * $V \propto d^3$

- * $U_{\text{UV}} \propto d^{-2}$

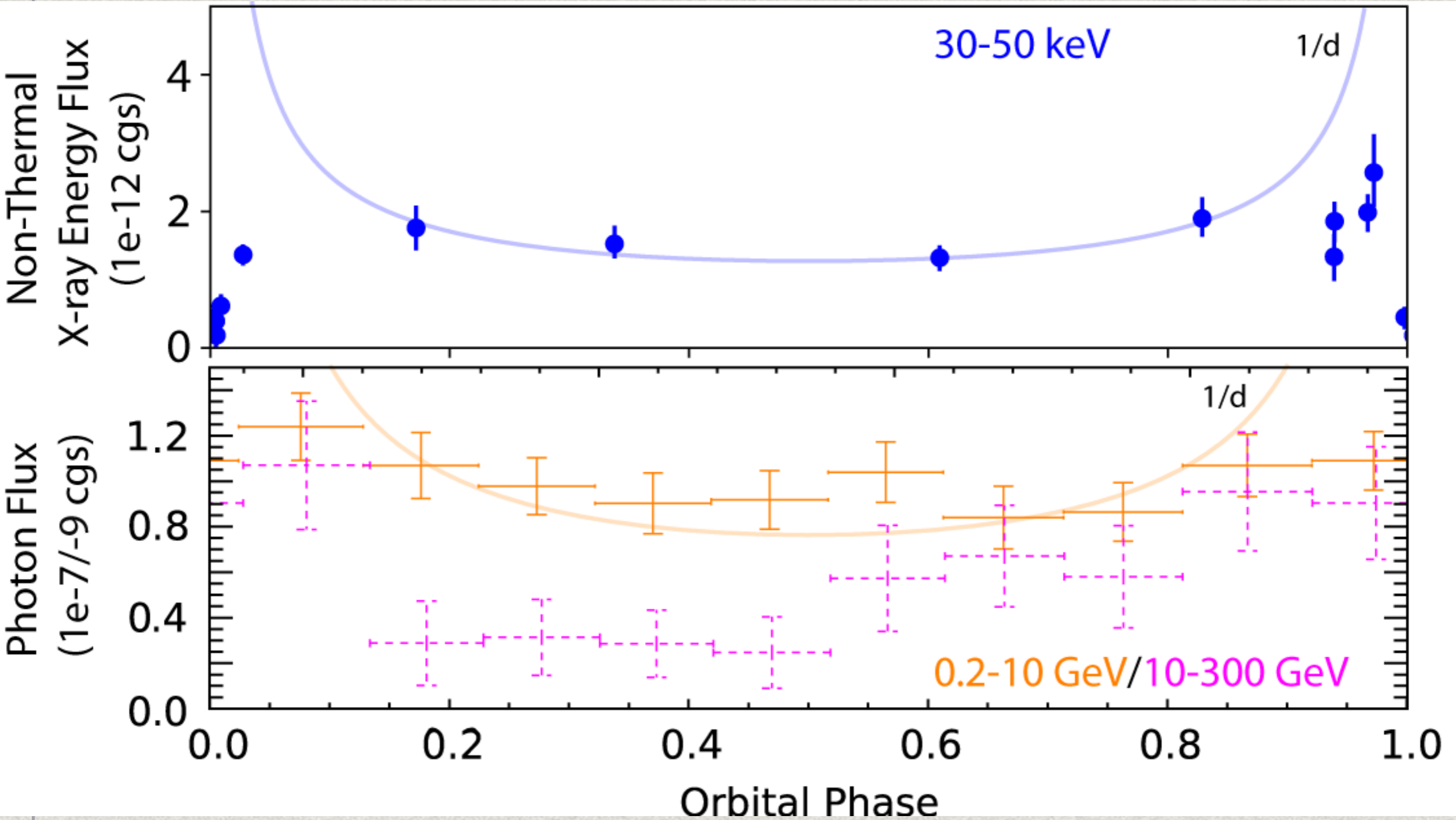
- * $L_{\text{IC}} \propto N_{\text{acc}} U_{\text{UV}} \propto d^{-1}$

- * n : plasma density

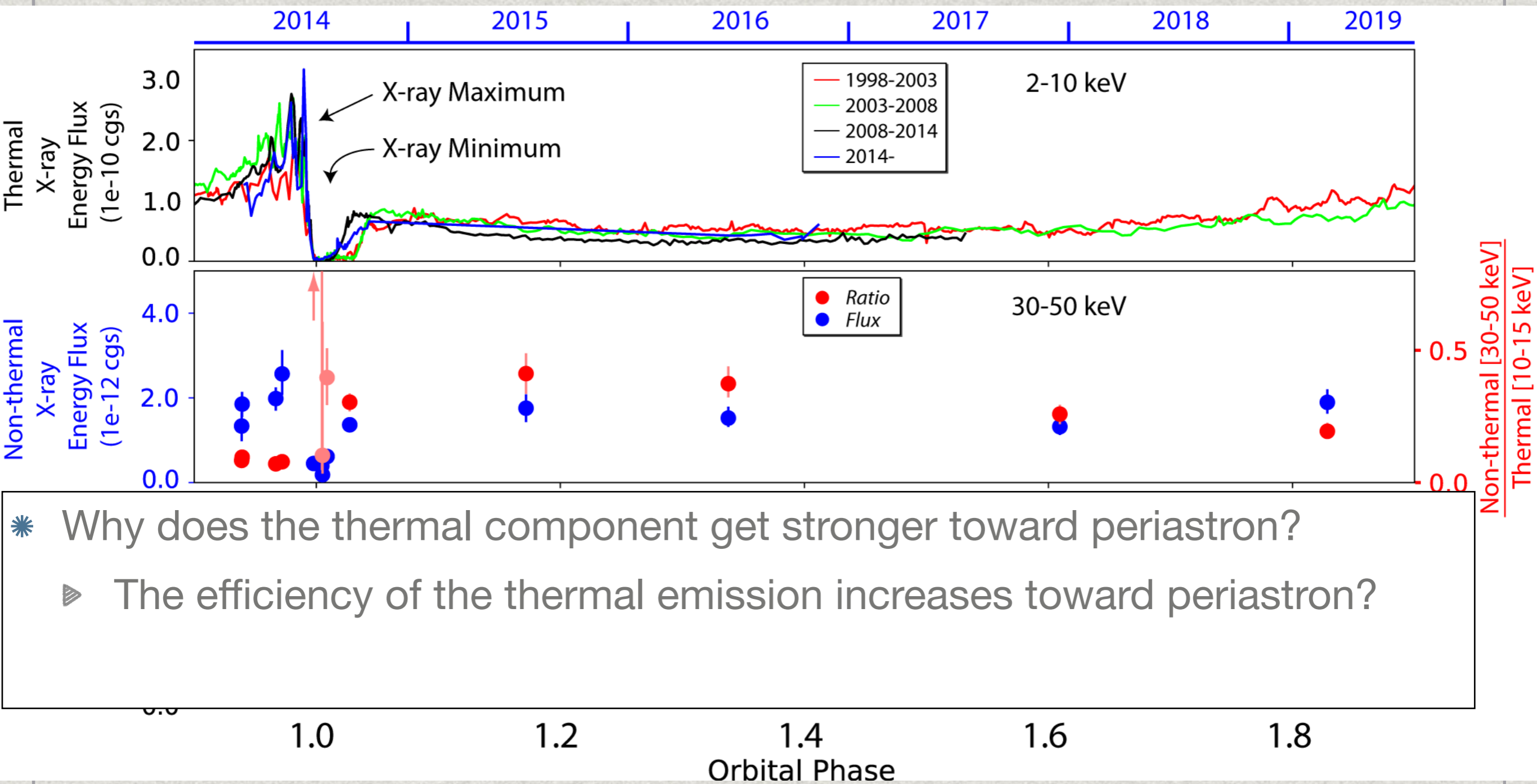
- * U_{UV} : stellar UV field

- * d : distance between two stars

Model

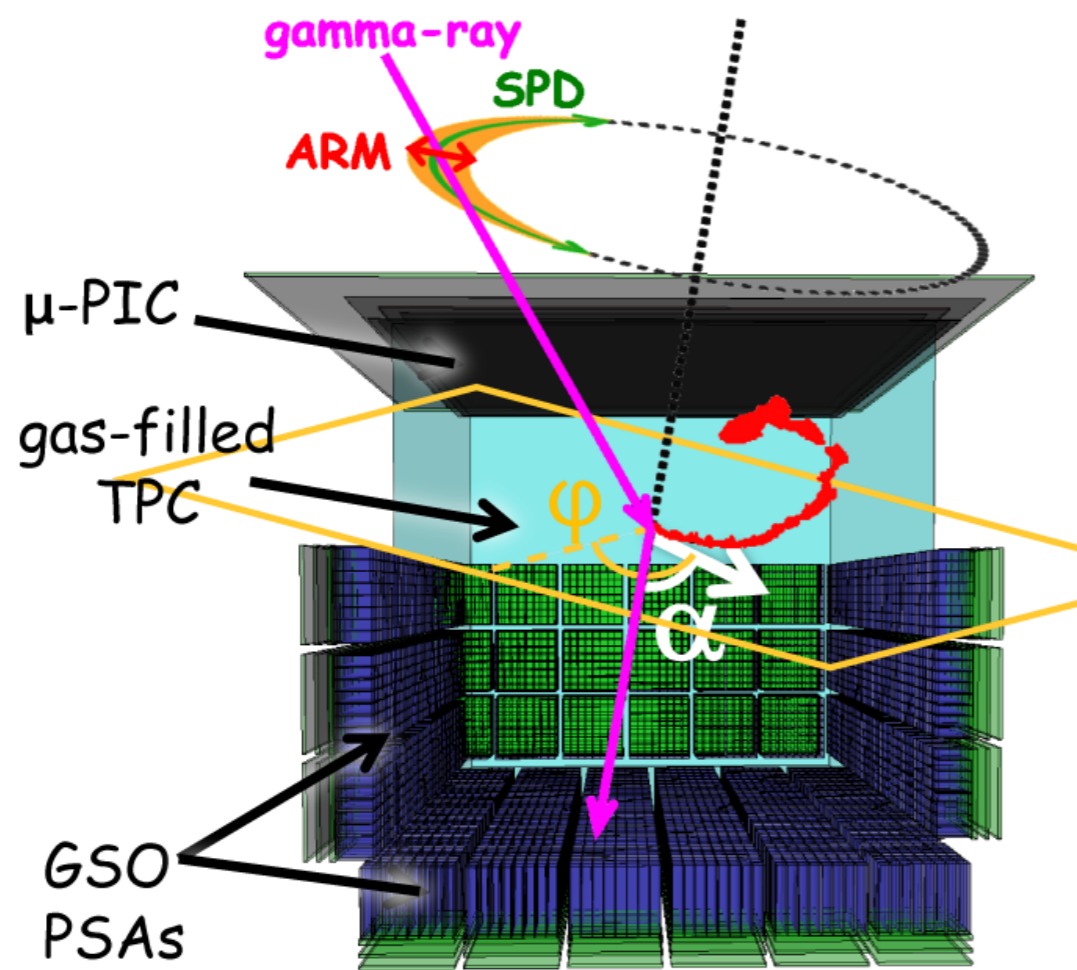


Flux Variation

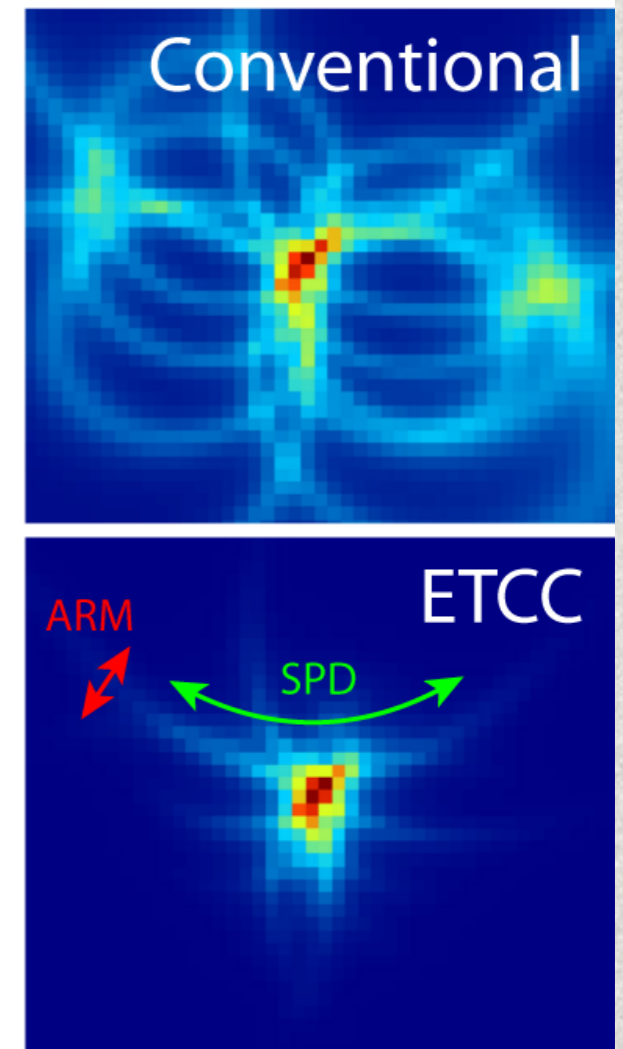
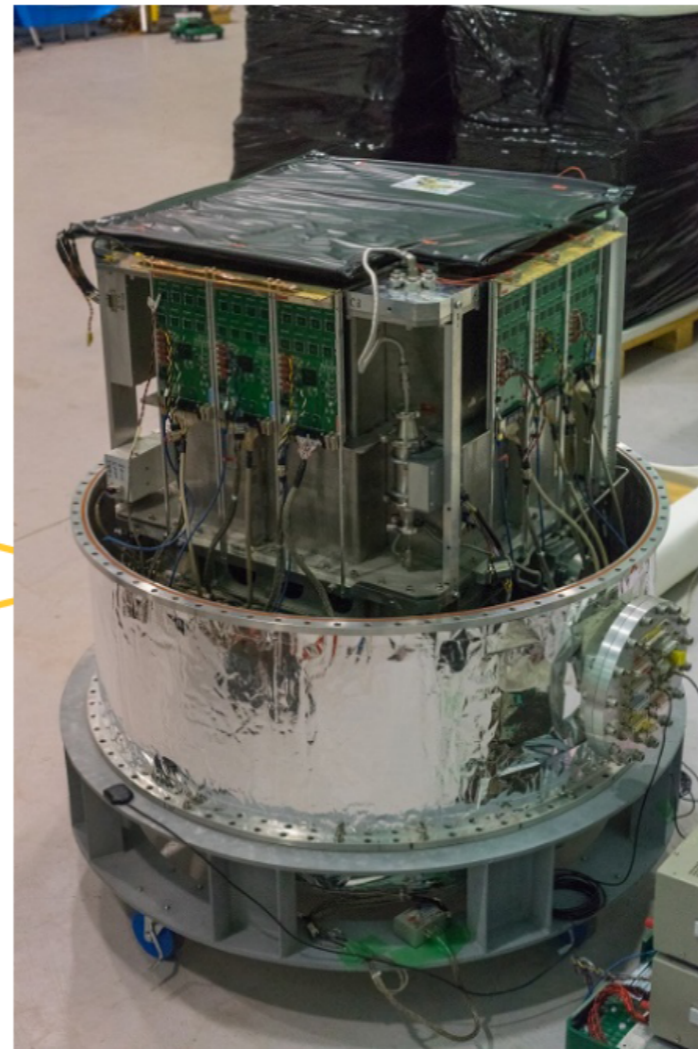


- * Why does the thermal component get stronger toward periastron?
 - ▶ The efficiency of the thermal emission increases toward periastron?

A Space-Based All-Sky MeV Survey with the Electron Tracking Compton Camera (ETCC)



SMILE PROJECT: TANIMORI ET AL.



* Hamaguchi, Tanimori, Takada et al. Astro2020 APC white paper

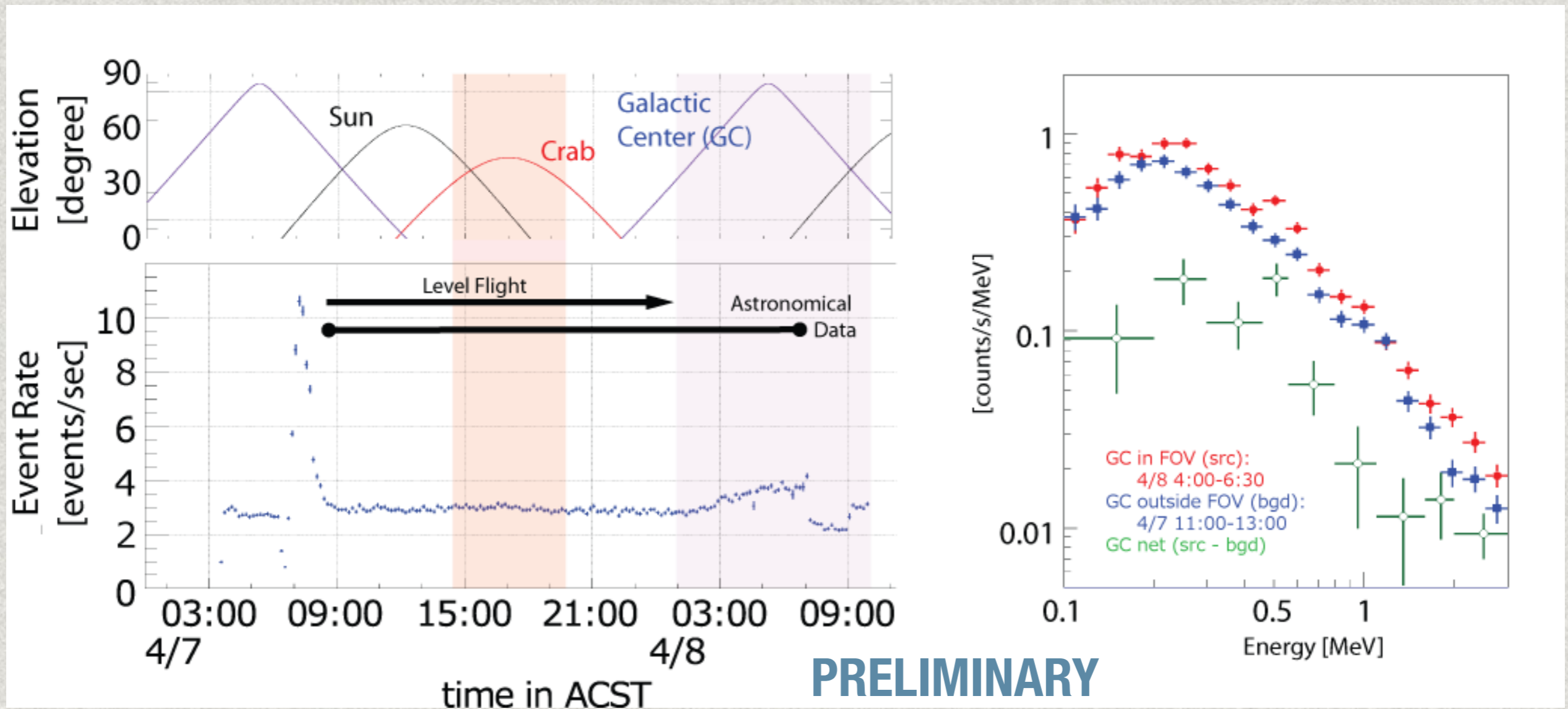
PROMOTOR

PI
SMILE
PROJECT

KEY
DEVELOPER

REF: COMPTTEL TALK BY PROF. COLLMAR

One day Balloon Flight in Australia in 2018



- * Background particle events are significantly reduced.
- * Detection of 511 keV emission from the galactic center region at $>5\sigma$ in 2.5 hours.

Future Satellite Mission with ETCCs

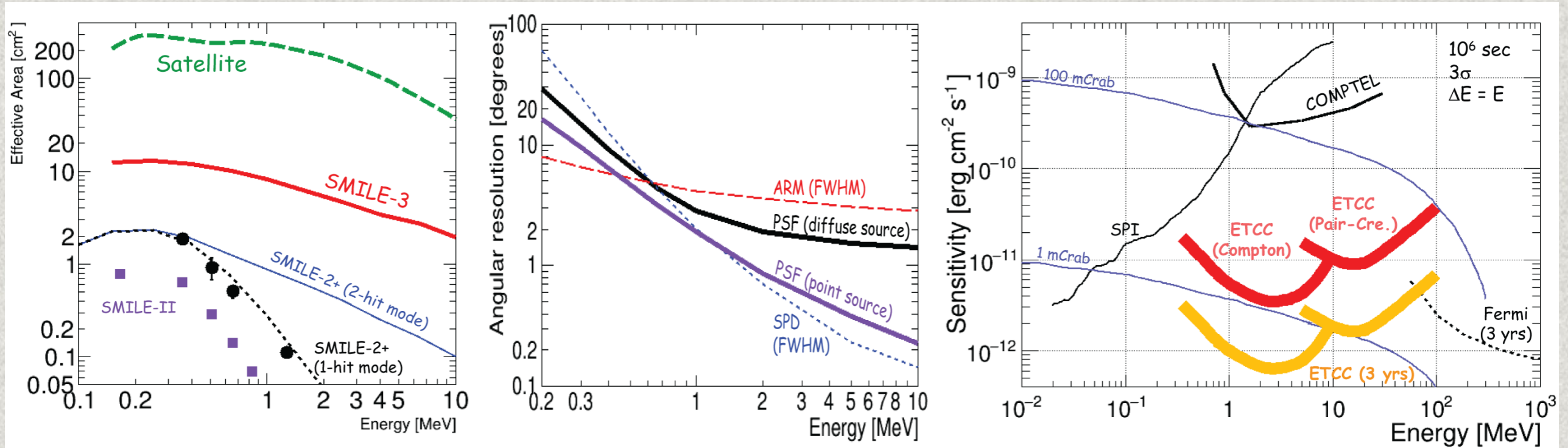


Table 1: Roadmap of the ETCC Development

Model	Eff (cm ⁻²)	$\Delta E/E^*$ (%)	PSF (degree)	Band (MeV)	FoV (str)	Sensitivity (mCrab)	Year
SMILE-2+	1	12	10	0.2–2 [†]	3 [‡]	100 [1 day]	2018
SMILE-3	10–20	8–9	5	0.2–10	3 [‡]	20 [14-50 day]	~2022
ETCC satellite	200	2	2	0.1–100	>4	1 [1 year]	~2030

Conclusion

- * Non-thermal component is detected in the extremely hard X-ray band outside of periastron.
- * NT originates from the wind-wind colliding region.
 - * 30-50 keV peak is within 5'' from η Car
 - * The flux declined during the X-ray minimum, when the thermal wind activity decays.
- * The NT variation may be consistent with the variation expected with the wind colliding theory, while the thermal emission is not. Why?

