The multiwavelength spectral and timing properties of a major radio flare episode in Cygnus X-3

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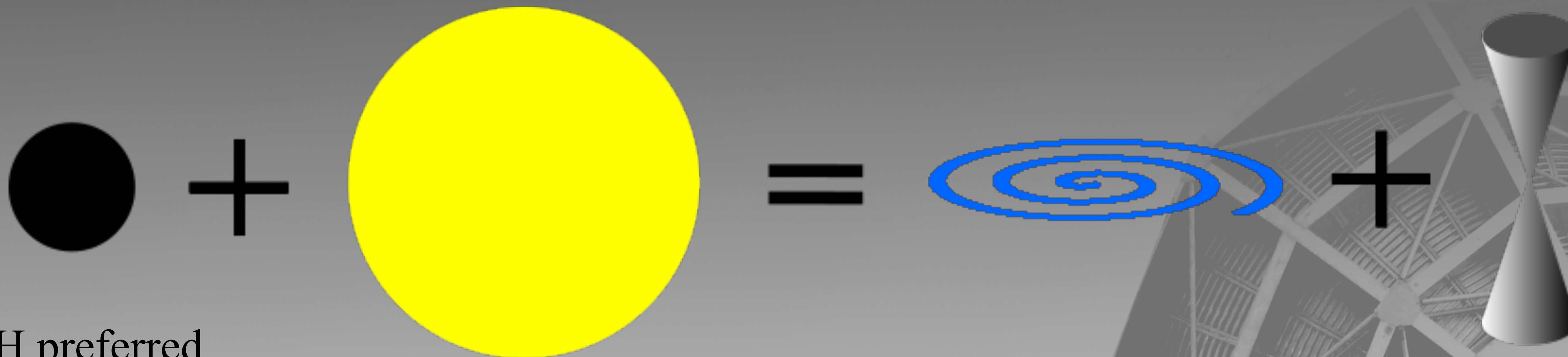
Outline

- Introduction
- The characteristics of a major radio flare episode
- Principal component analysis: a tool to unite spectral and timing information
- The need for additional thermal component
- Suggested solution: anisotropic stellar wind

Cyg X-3 simplified

Discovered in 1966 (Giacconi+ 67)
Located ~ 9 kpc in the plane of the galaxy (Predehl+ 00)
4.8 hour modulation in X-rays (Parsignault+ 72) and IR (Mason+ 86)

BH/NS | **Companion star** | **Accretion disk** | **Jet**



BH preferred from spectral resemblance to other BHBs

Mass ratio ~ 4 (Vilhu+ 09)

Wolf-Rayet star (UV/Optical/IR emission)

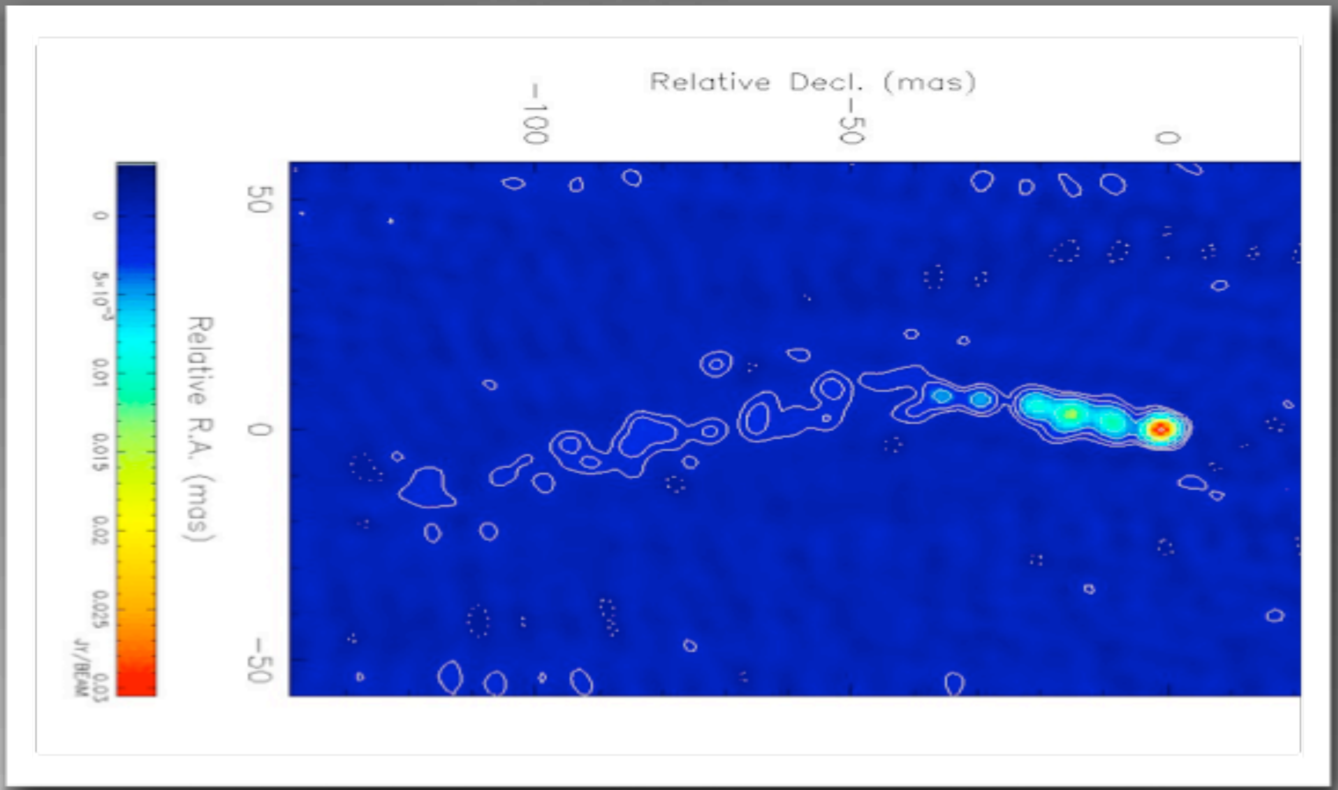
Stellar wind

Matter orbiting close to compact object (X-rays/UV/optical)

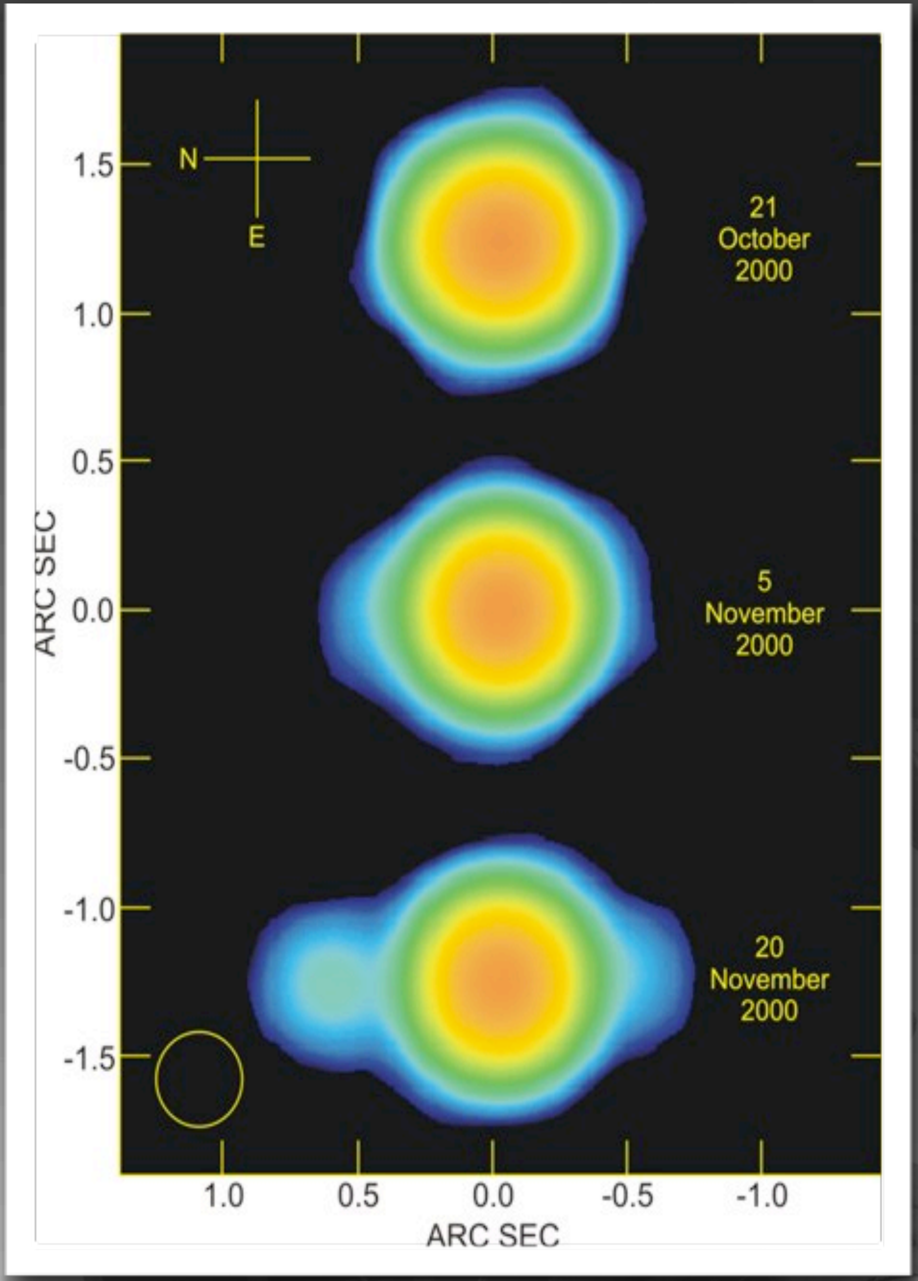
Relativistic particles (radio/mm/IR) colliding/scattering photons (X-rays/γ-rays)

Major radio flare episodes

- v ~ 0.5-0.8 c with inclination 14 deg → Microblazar?! (Mioduzewski+ 01)
- Sporadic, powerful events → $F_{2.25\ \mathrm{GHz}} \sim 20$ Jy (Waltman+ 95)
- Arcsec and mas images of jets



Mioduzewski+ 01



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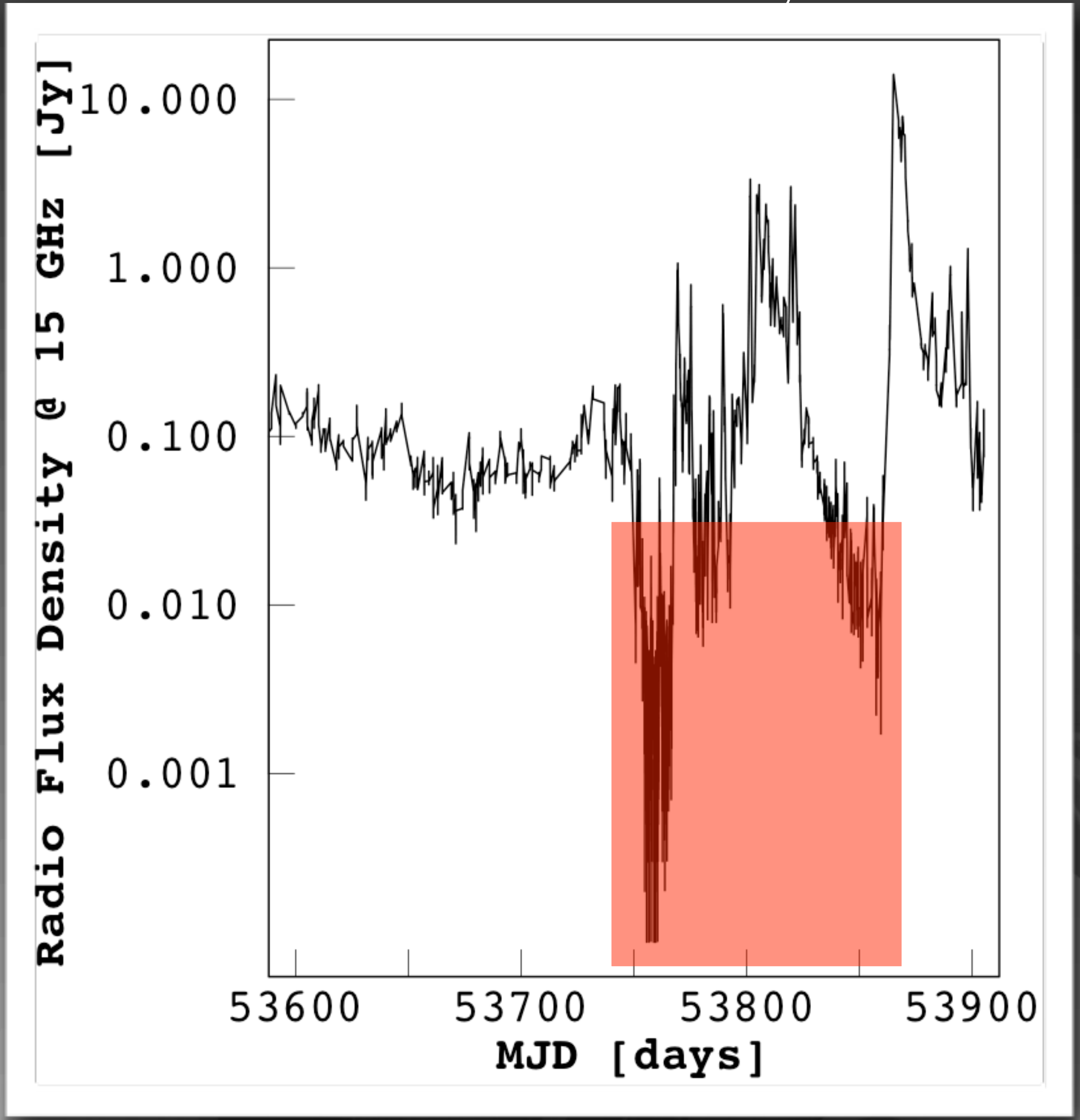
Major radio flares are always triggered by a special state

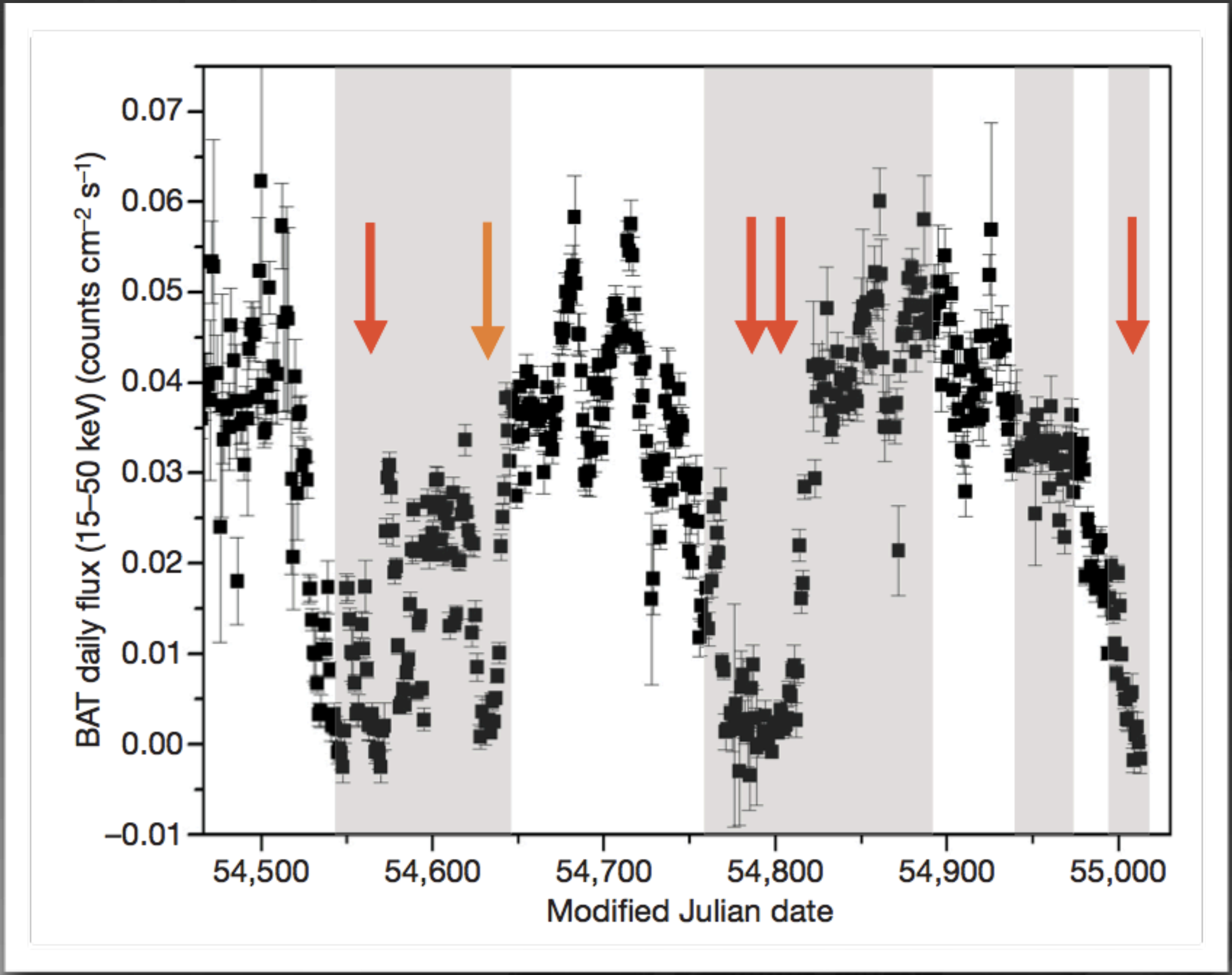
- Hypersoft radio/X-ray state (Koljonen+ 10)
  - Suppressed radio and HXR emission (< 10 mJy / ~ 0.0 cts s^{-1})
- Lasts from couple of days up to a month
- Major flare always follows
- What is the suppression mechanism?

Ryle 15 Ghz



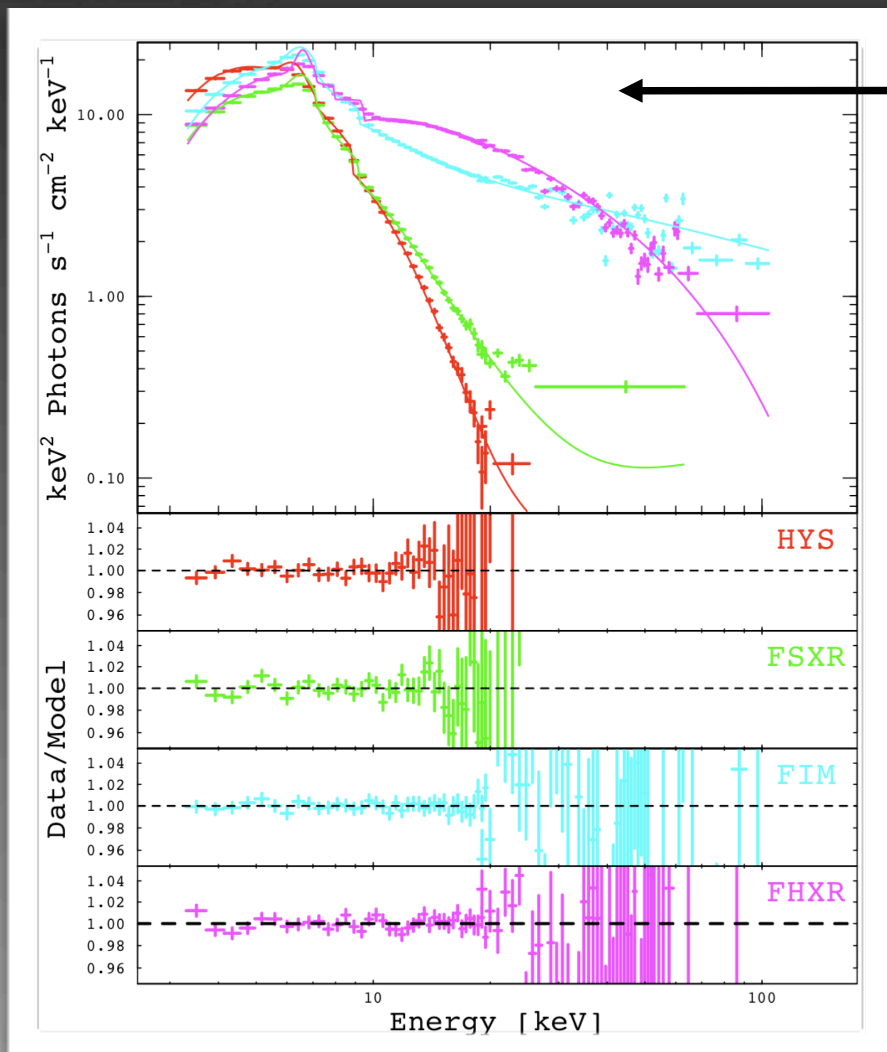
γ-ray emission is observed during transitions to/from the hypersoft state

- Emission mechanism:
  - High-energy electrons upscattering stellar/disk photons? (Dubus+ 10, Zdziarski+ 12, Piano+ in prep.)
  - Hadronic interaction, jet/ wind? (Romero+ 03, Piano+ in prep.)
- What is the connection to the hypersoft state / suppression of radio/HXR emission?



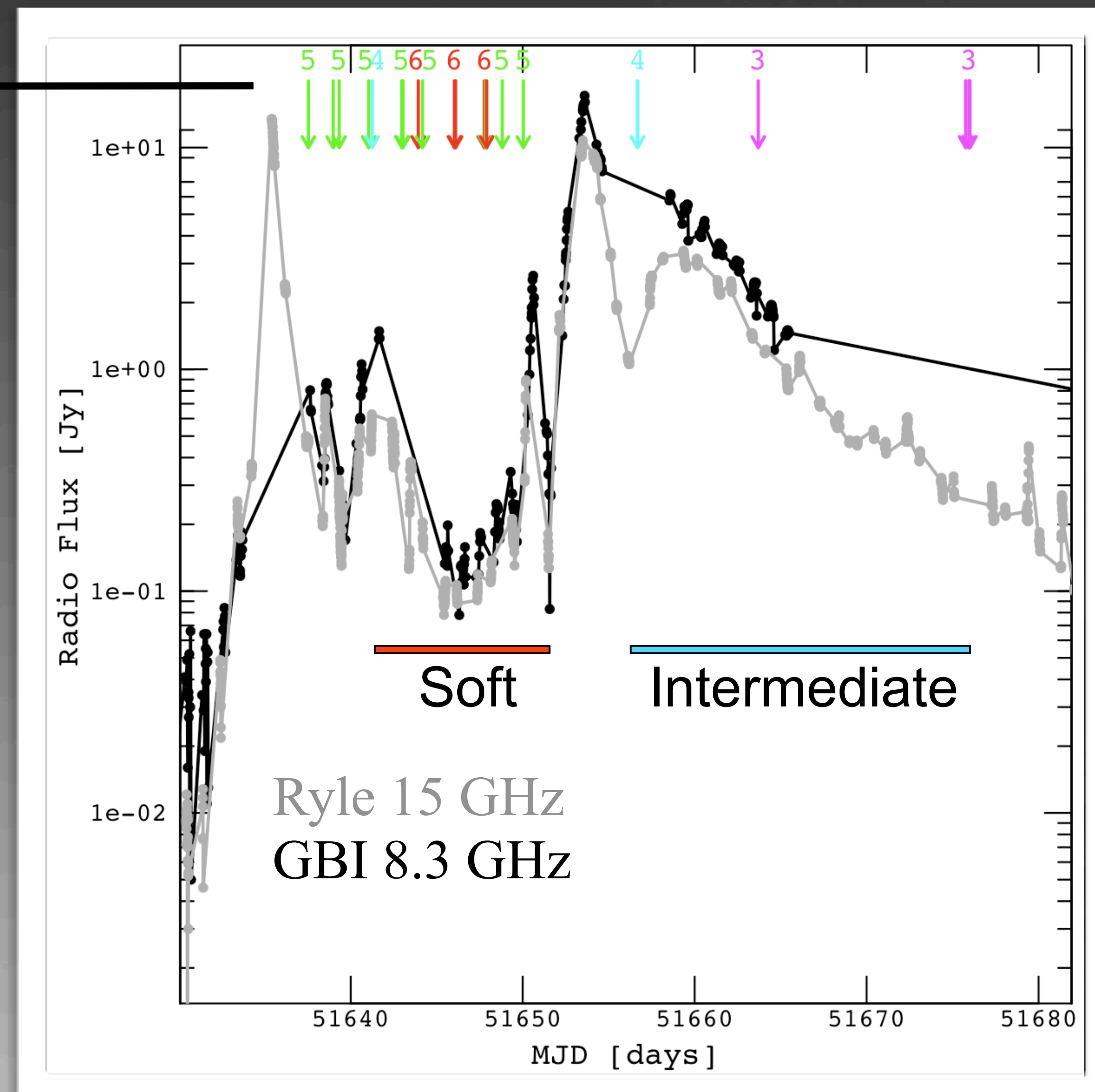
Tavani+ 09

X-ray spectral evolution throuhout the flare goes from soft to hard



Koljonen+ 10

Rising hard X-ray tail before cut-off ~ 30 keV

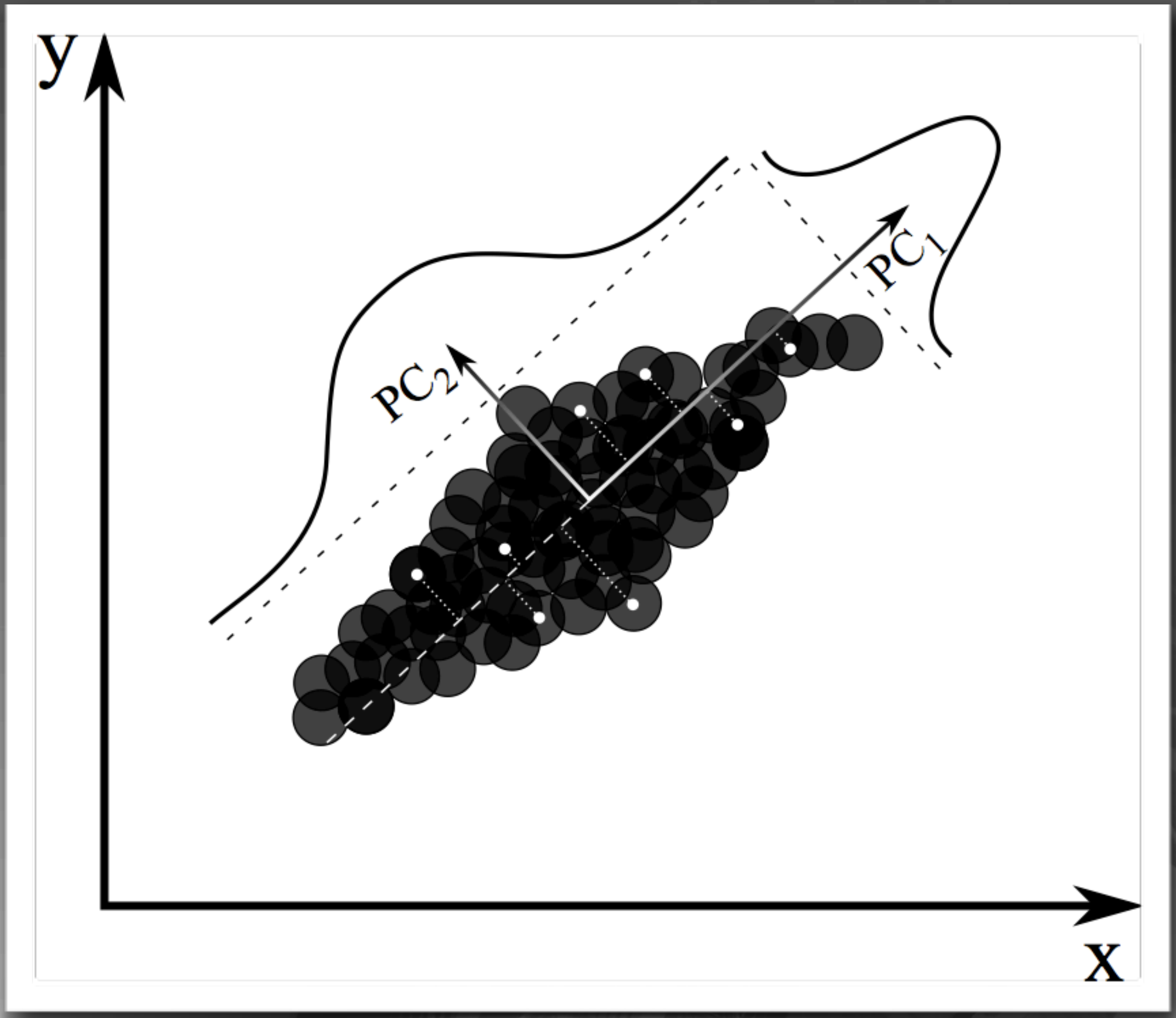


Koljonen+ 10

Soft state before major radio flare peak. Intermediate state after

Principal Component Analysis

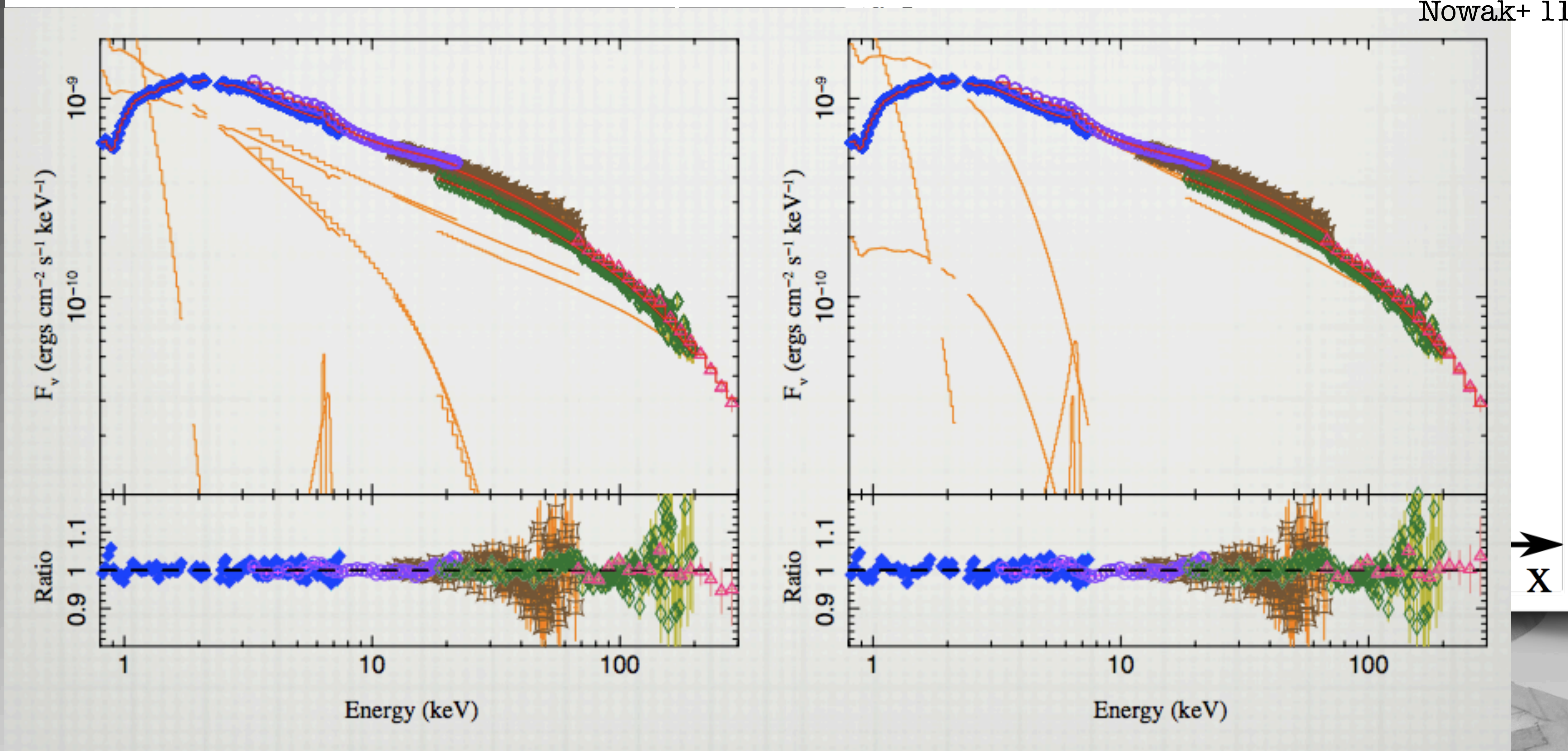
- Finds the least amount of components that are enough to explain the data
- Finds patterns in the data in a way that highlights the differences and similarities in the data set
- Basically a rotation of axis
- Can be easily applied to many dimensional cases
- e.g. Malzac+ 06 for application to X-ray spectra



Helps resolve degeneracies in fitting complicated models to X-ray spectra

Principal Component Analysis

Identical data, different fits, similar statistics



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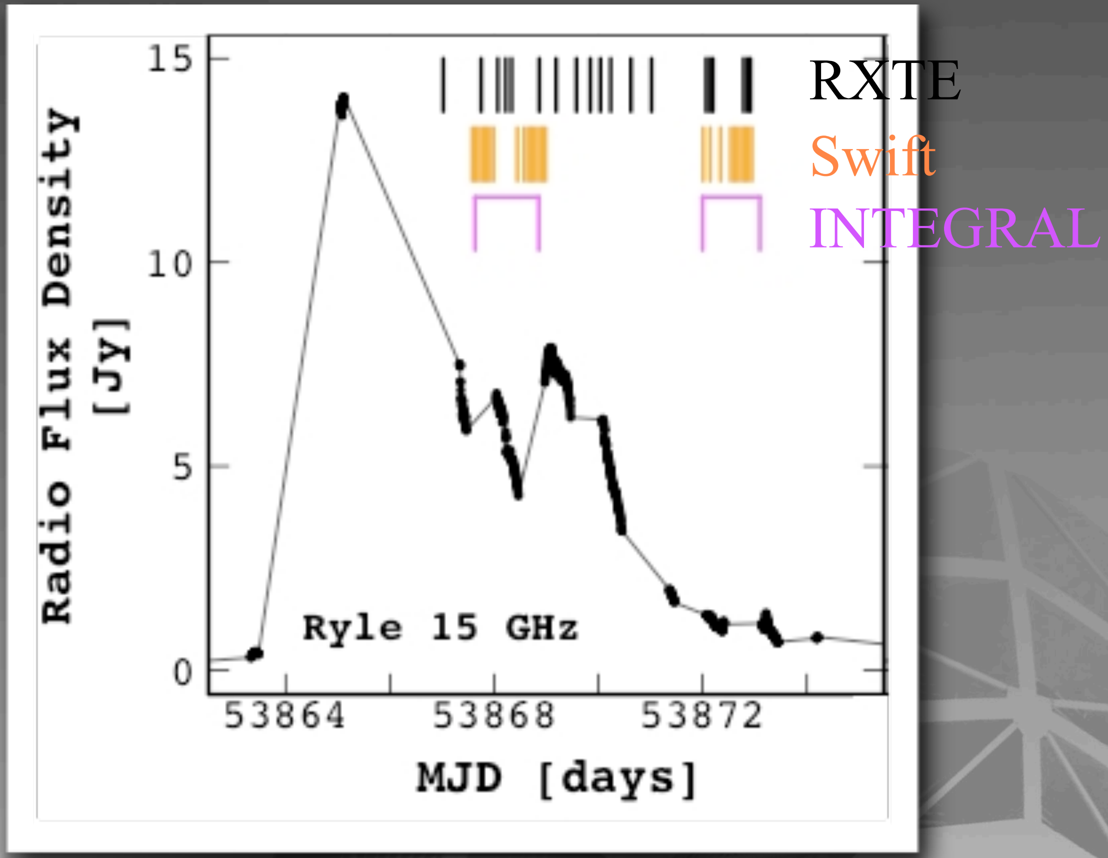
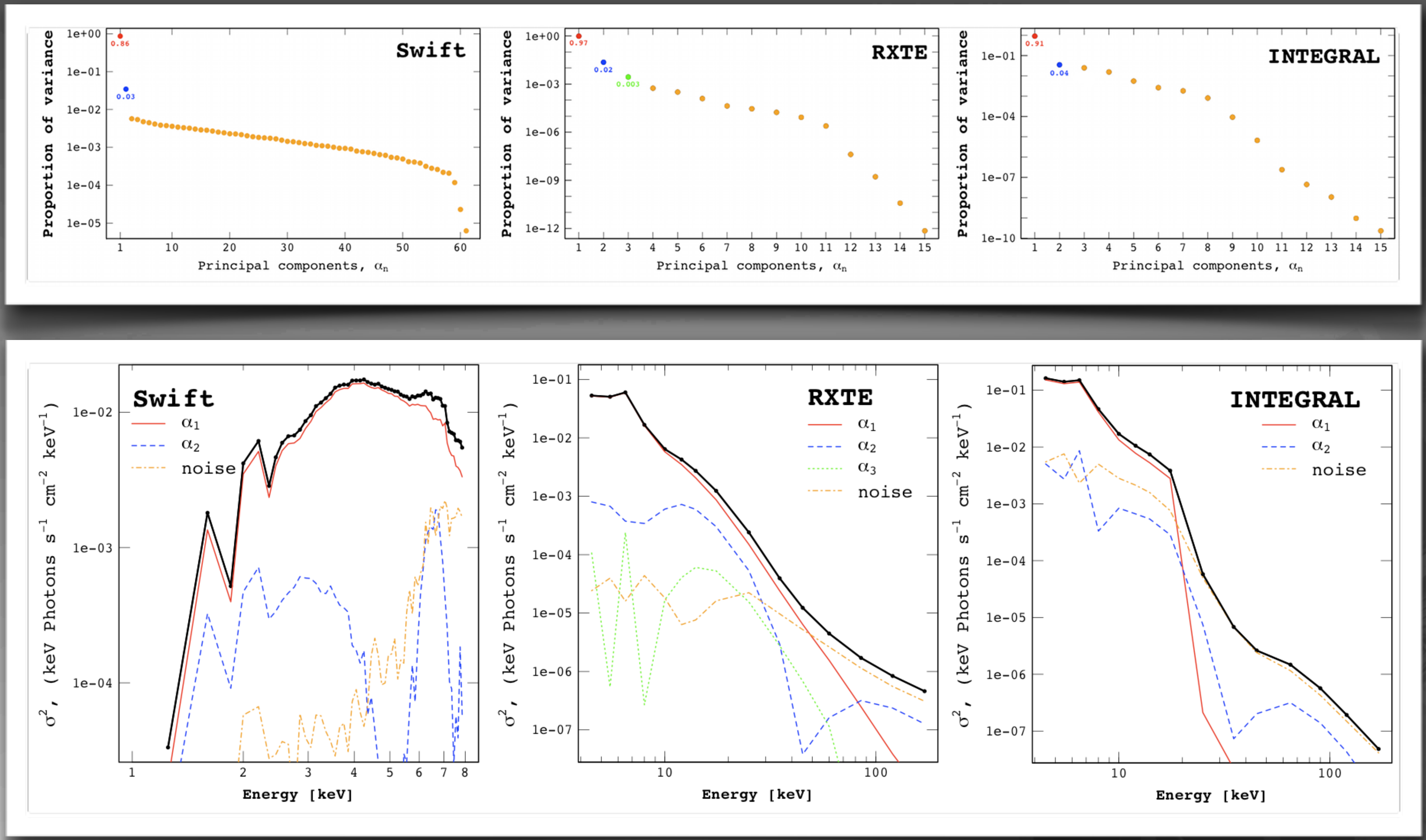
May 2006 major radio flare episode

- Simultaneous multisatellite coverage (Swift, RXTE, INTEGRAL)
- Supporting radio and IR monitoring (Ryle, PAIRITEL)



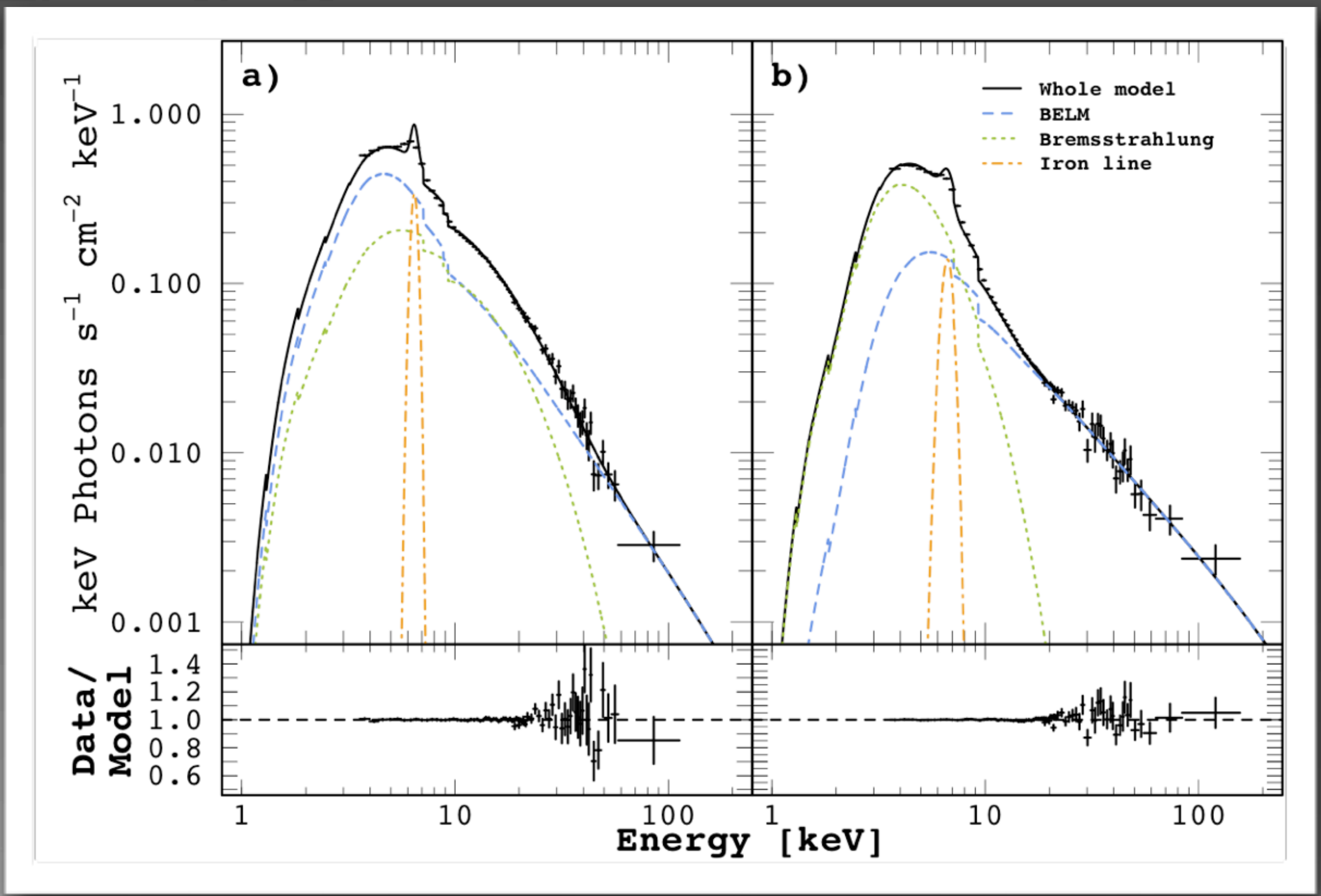
Koljonen+, in prep.

Variability spectra shows two significant components



Koljonen+, in prep.

Correlation of spectral parameters and principal components



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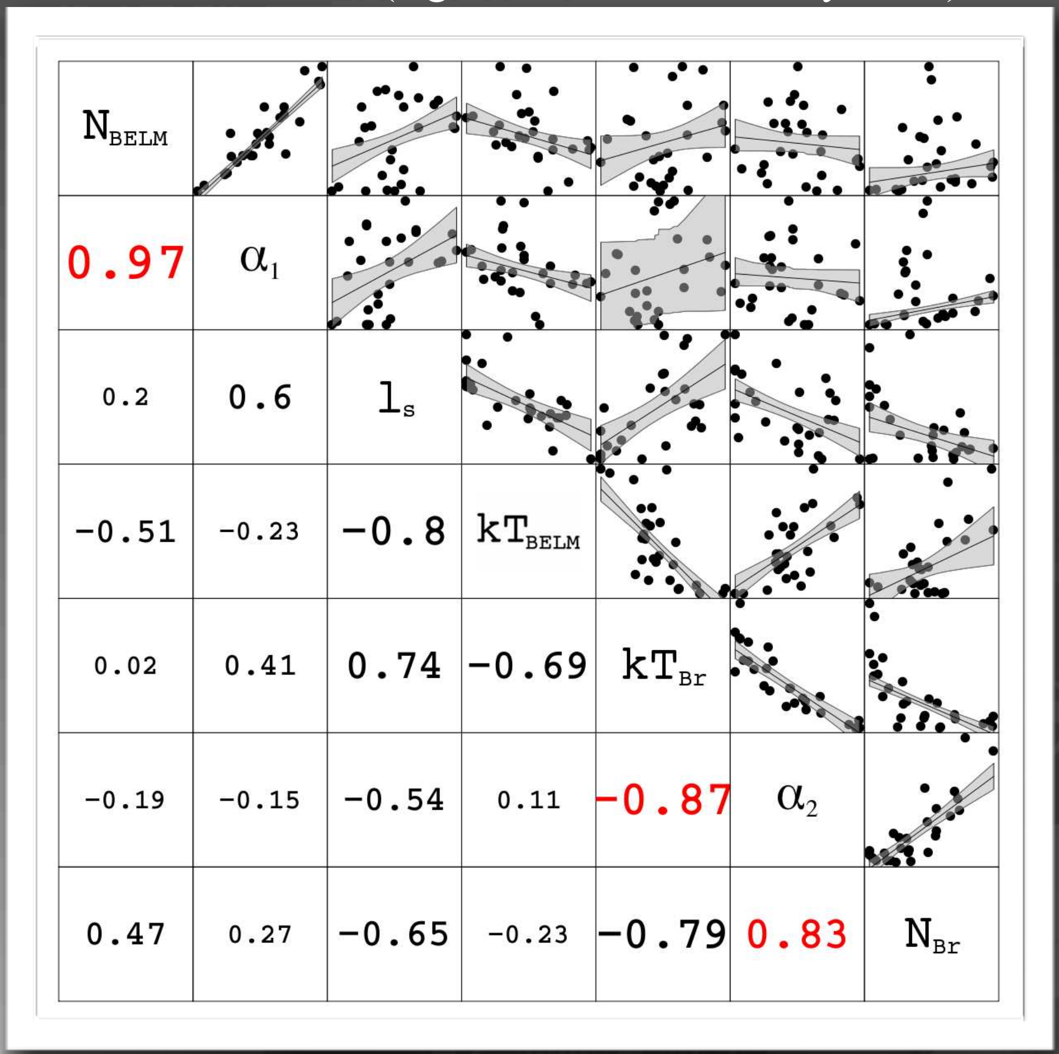
Robust correlation (e.g. Rousseeuw & Leroy 1987)



Koljonen+, in prep.

Best-fit model satisfying the principal component evolution consists of hybrid Comptonization (BELM, Belmont+ 08) and bremsstrahlung components.

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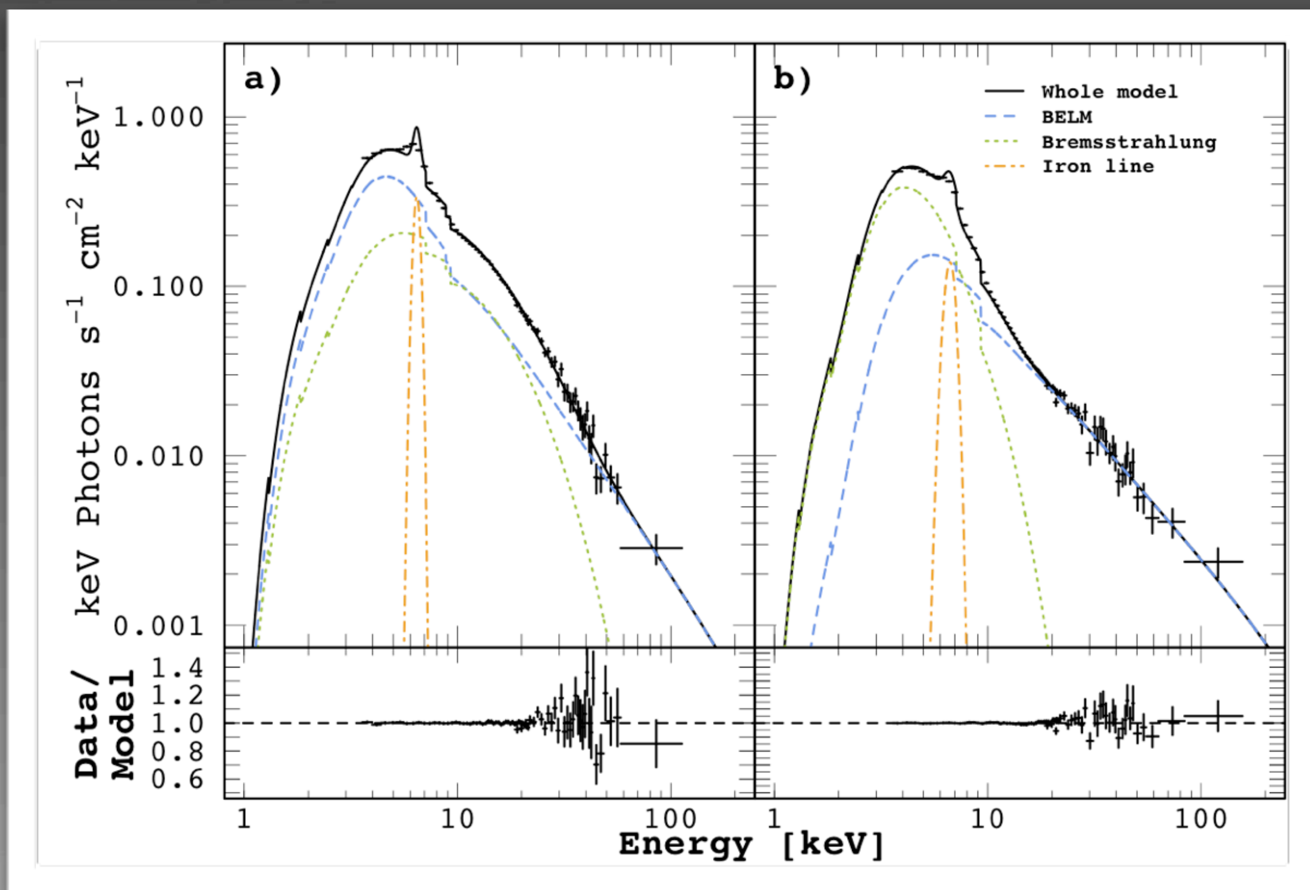

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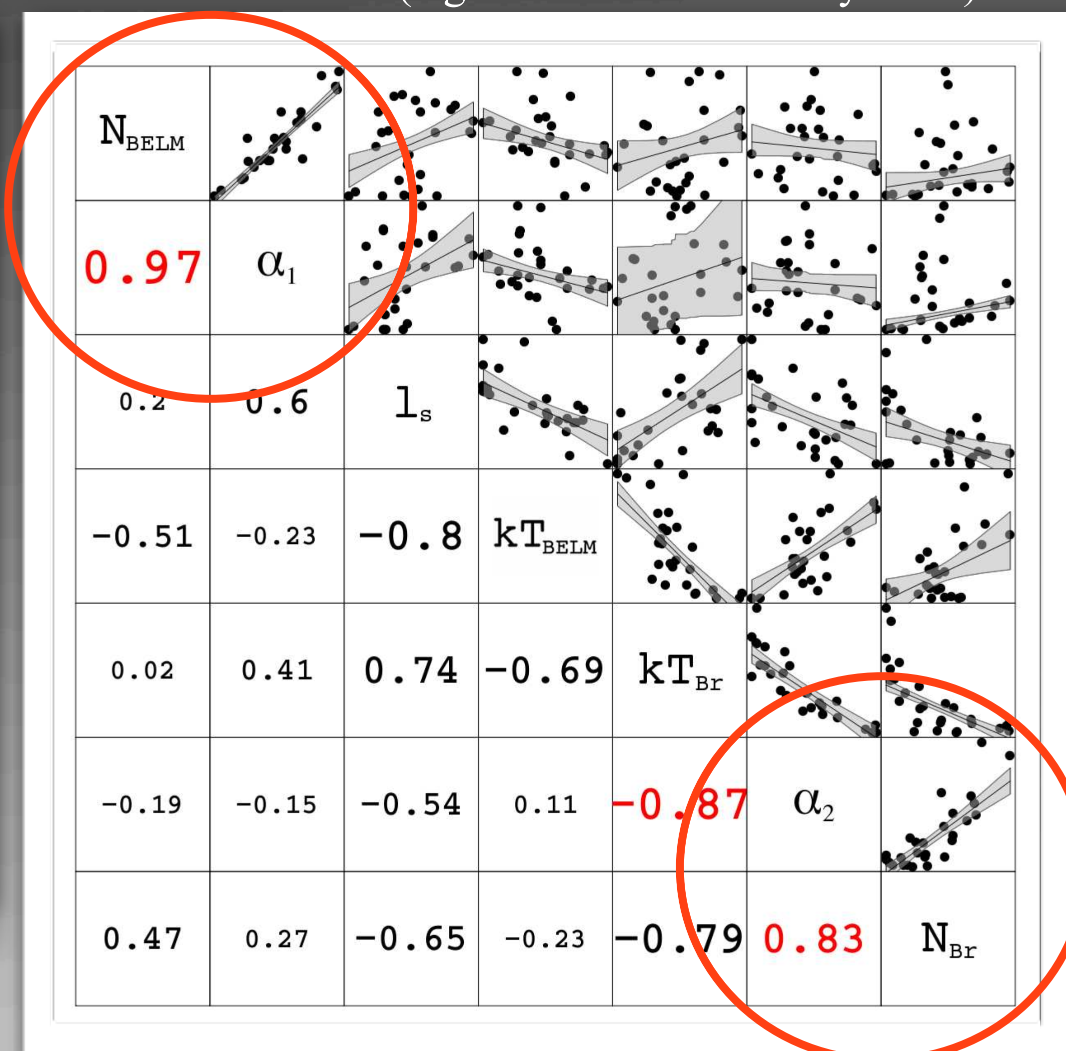

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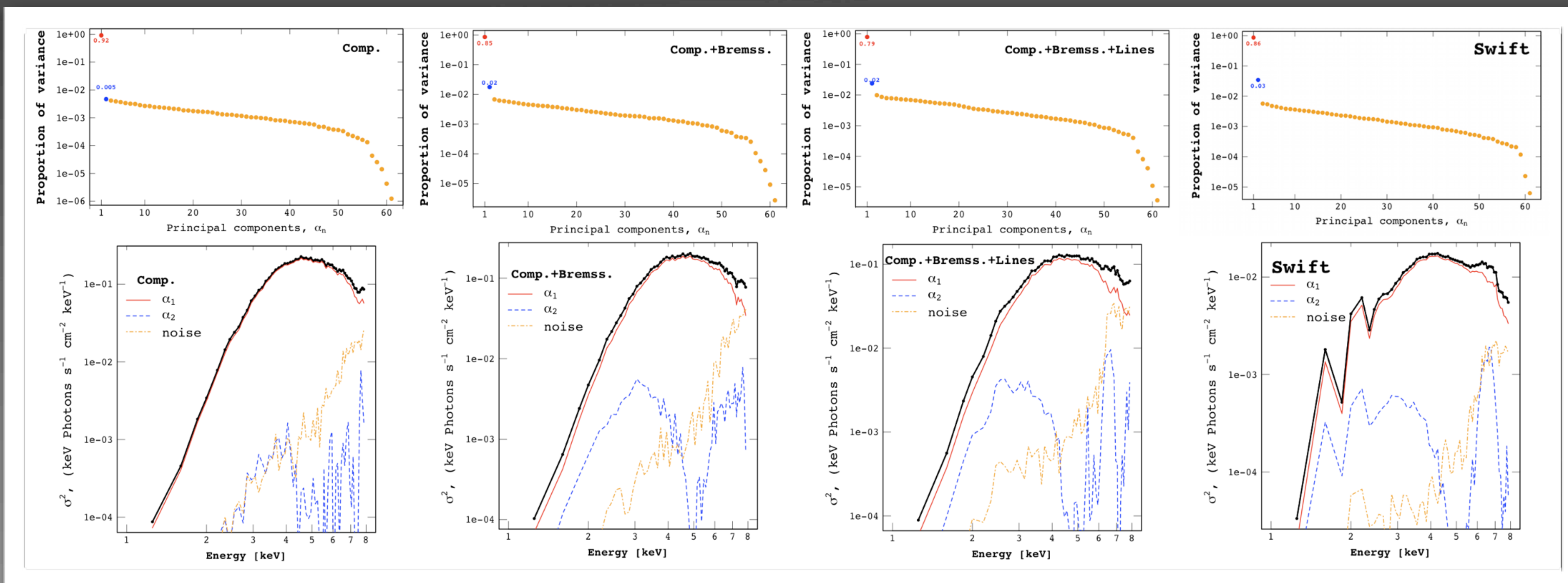
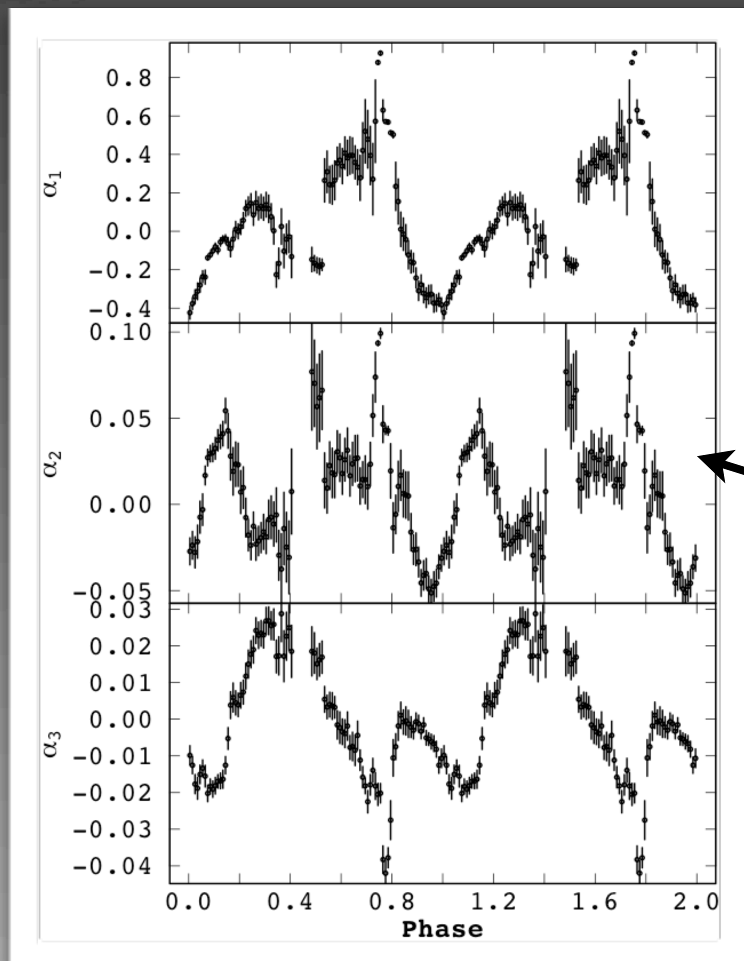
Simulating the variability spectra



Koljonen+, in prep.

Faking the best-fit model and feeding it through instrument response function

Phase dependencies



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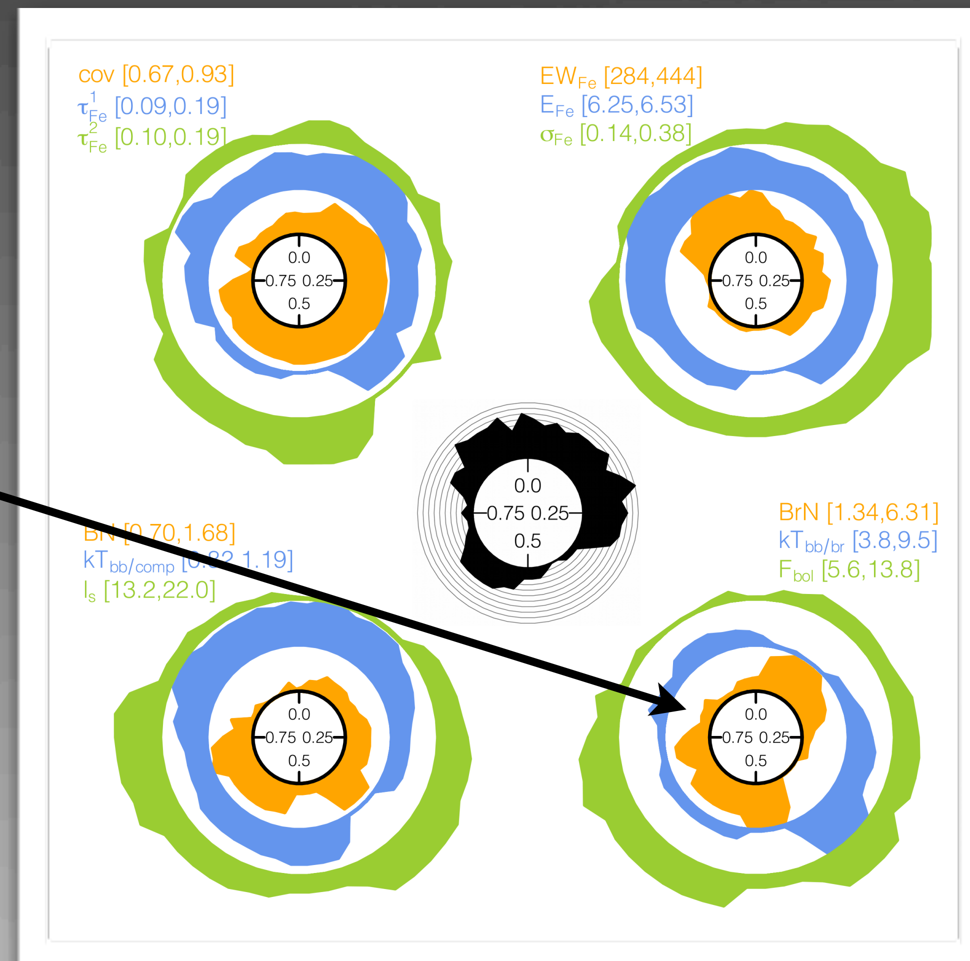

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Bremsstrahlung normalization ~ $n_e n_i V \rightarrow$ change in density

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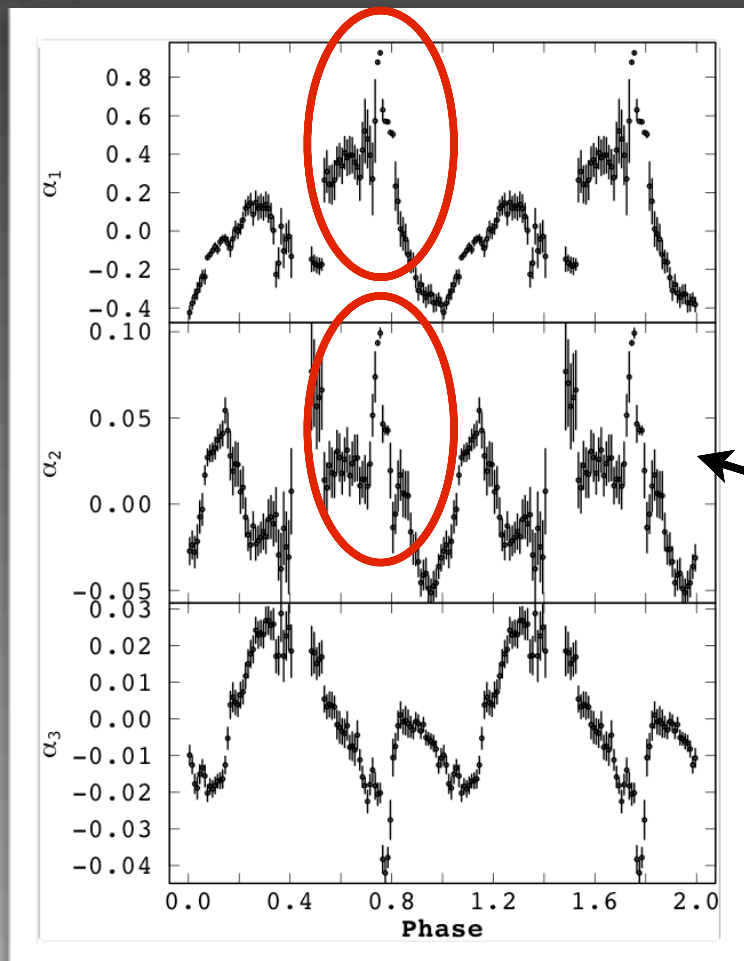

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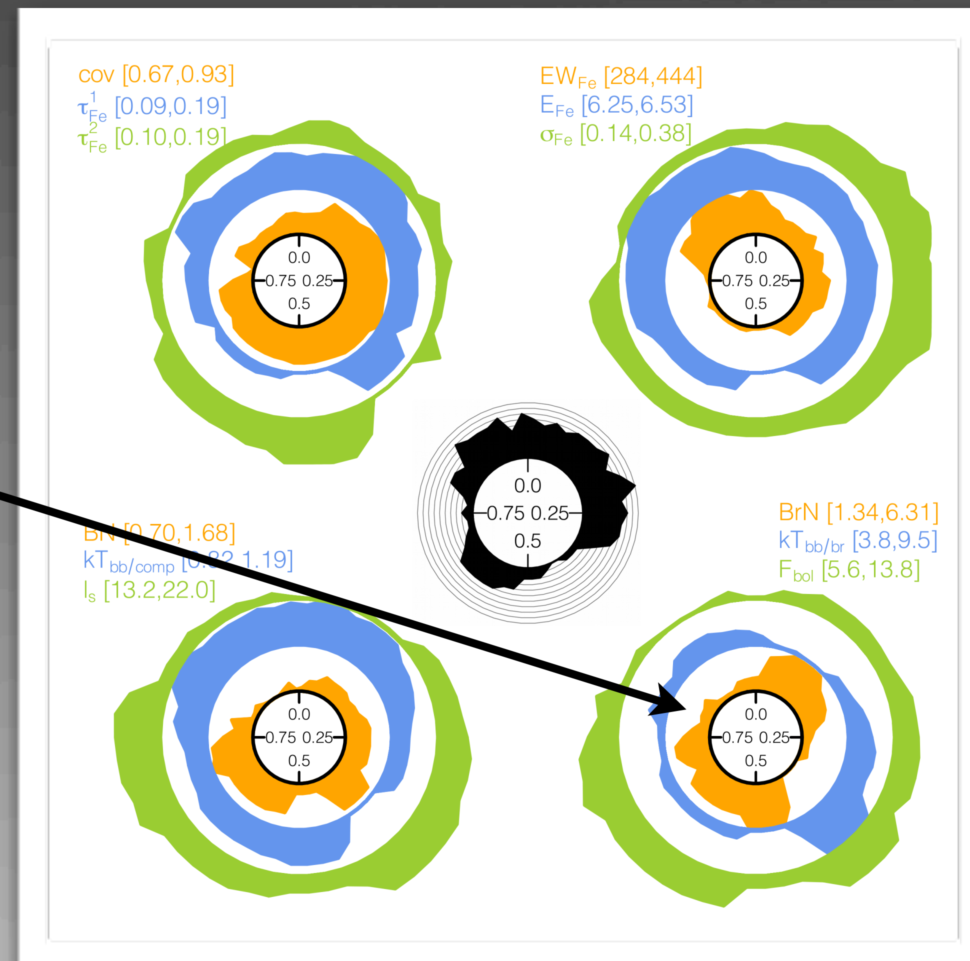

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Bremsstrahlung normalization ~ $n_e n_i V \rightarrow$ change in density

Similar additional thermal component in other microquasar/ XRB systems

- GRS 1915+105 (Mineo+ 2012, Titarchuk & Seifina 2009) in intermediate/high soft state/”heartbeat” state, model fitted with 3-6 keV color temperature thermal component.

- SS 433 (Seifina & Titarchuk 2010), intermediate state during radio outburst decay, model fitted with 4-5 keV color temperature thermal component.

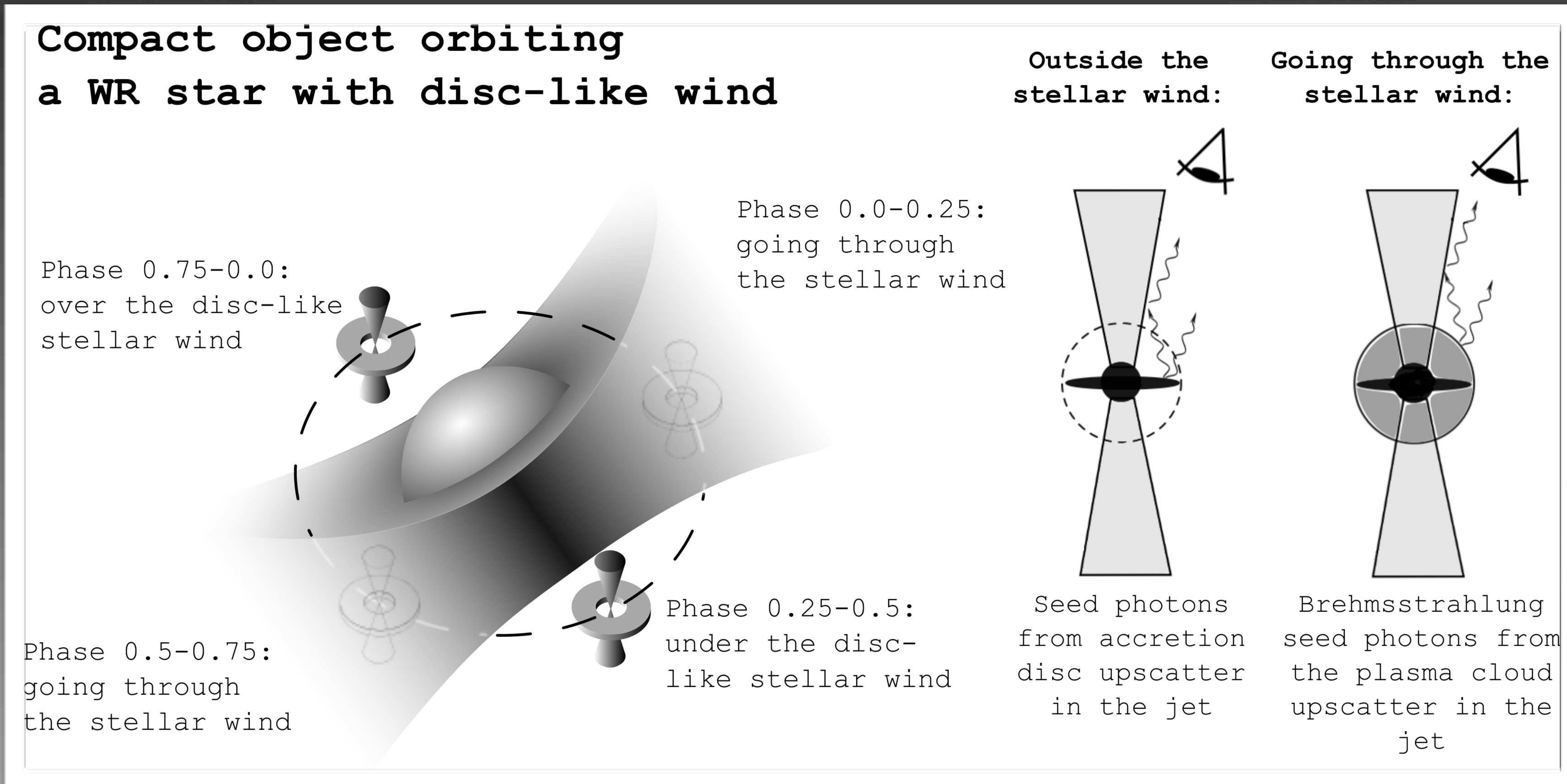
- GS 2000+25, GS 1124-68, XTE J1550-564 (Zycki+ 2001), model fitted with 2-4 keV color temperature thermal component.

These systems do not contain companion star with massive outflow → accretion disk wind?

Alternatives to explain the second thermal component (in brainstorming fashion)

- Gravitationally shifted annihilation line (Titarchuk, Seifina 09)? However, accretion disk not directly observed. Need to survive multiple scatterings.
- Hot disk heated by patchy corona? However, $F_{th} > F_{10\text{–}200\ keV}$ and only marginal reflection component.
- Three-phased accretion (Zycki+ 01)? How does it explain orbital changes? Warped disk?
- Thermal jet (Memola+ 02)? However, thermal component becomes more prominent as the radio flare decays.
- Hybrid electron distribution? Pure BELM does not fit the spectra.
- Scattering cloud (Zdziarski+ 09)? Thomson thick, low temperature plasma cloud surrounding the compact object (to explain low cut-off + lack of high frequencies in PDS). Collision between the stellar wind and compact object.

Suggested solution: anisotropic stellar wind during major radio flare episodes



15% of WR stars have anisotropic winds, which are most likely caused by equatorial density enhancements produced by high rotation rates (Harries et al. 1998)

Zdziarski+ 2012: The X-ray lightcurve modulation profiles are not consistent with a spherically symmetric wind

Thank you for your attention!

Questions?

...or send them to
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