Observatori Astronòmic
VNIVERSITAT DE VALÈNCIA

FORTH
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Correlated spectral and aperiodic variability in 1A 1118-615 and A 0535+262

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&
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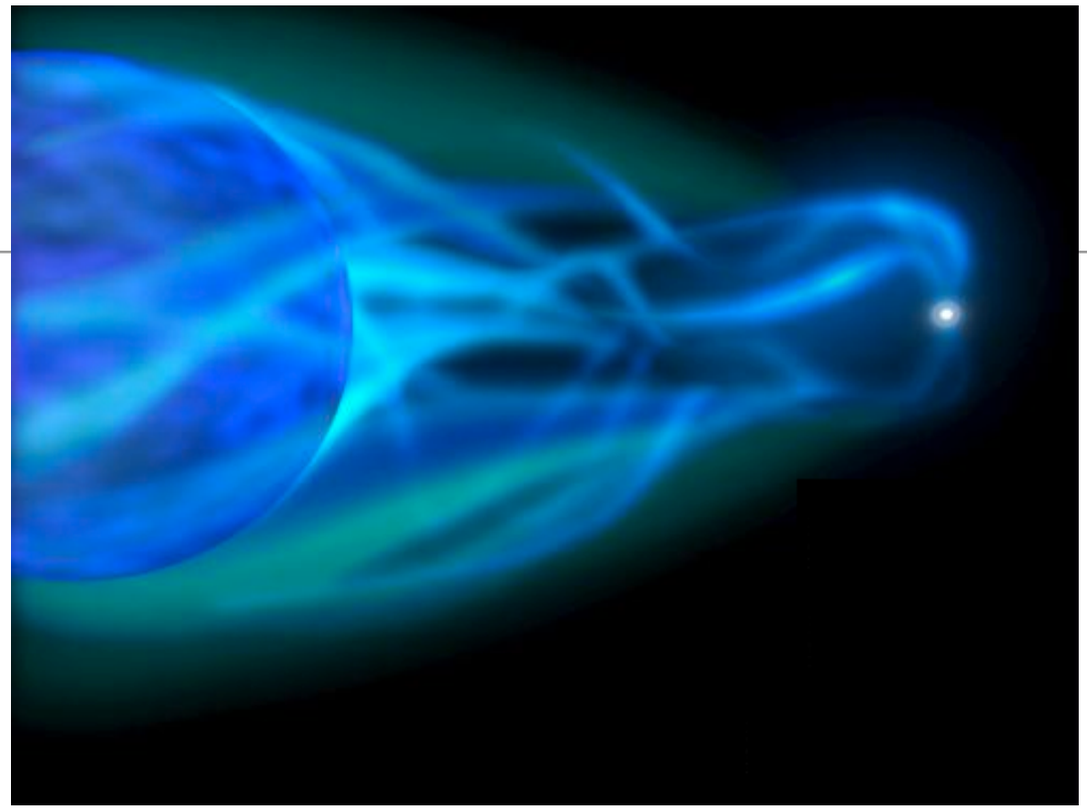
Outline

- HMXBs: definition, sub-classes
- Be/X-ray binaries
- The systems: 1A 1118-61 and A 0535+262
- Type II (giant) outbursts analyzed
- A novel approach to BeXRBs: it's time for timing!
- Analysis, results
- Conclusions and... open questions

HMXBs



- A compact object orbiting a massive OB star

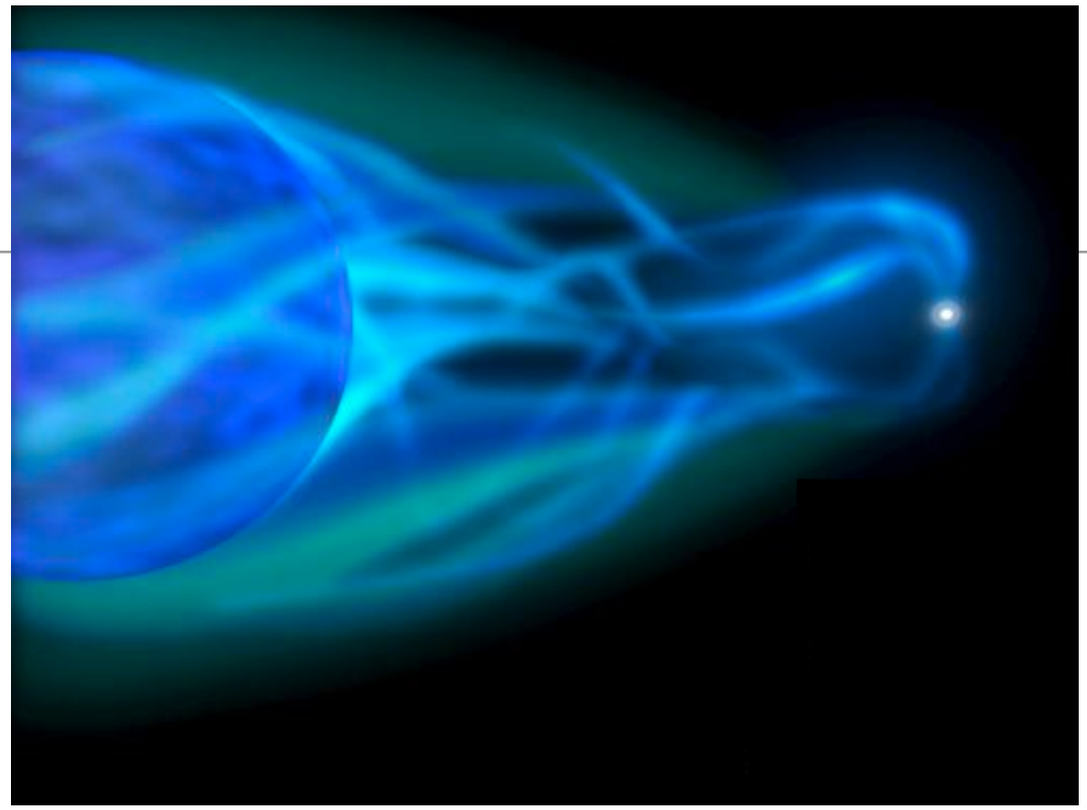
- Strong X-ray emission due to accreted matter from the OB companion

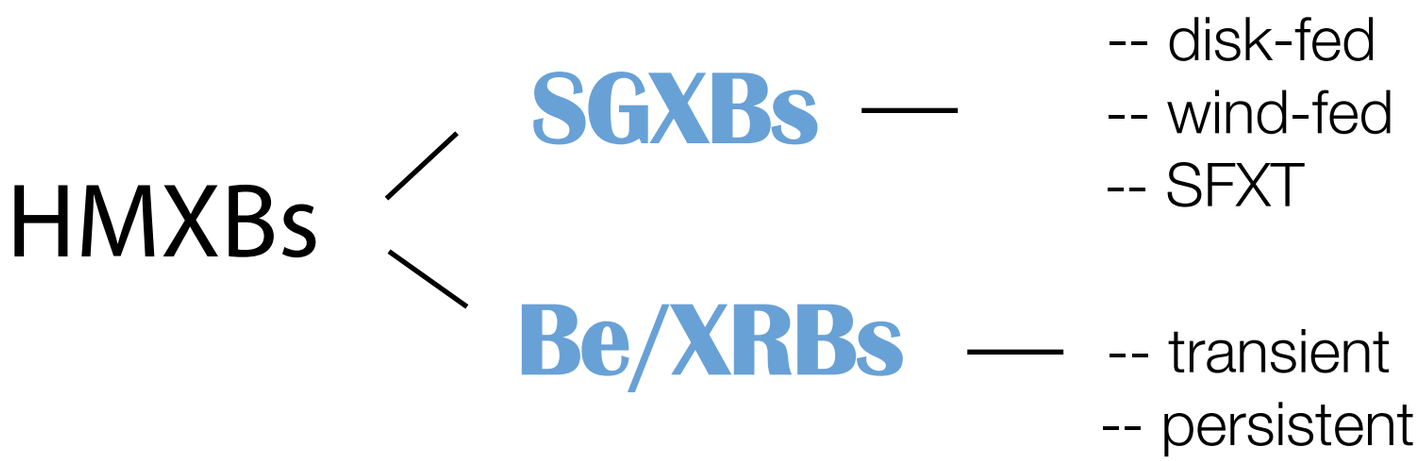
- Constitute the youngest galactic population of X-ray emitters

- Short lives
  Remain close to their birthplaces ⇨ trace the recent stellar formation history in the Milky Way and other Local Group galaxies.

HMXBs

- Sub-classes, according to the evolutionary status of the optical companion





HMXBs: sub-classes

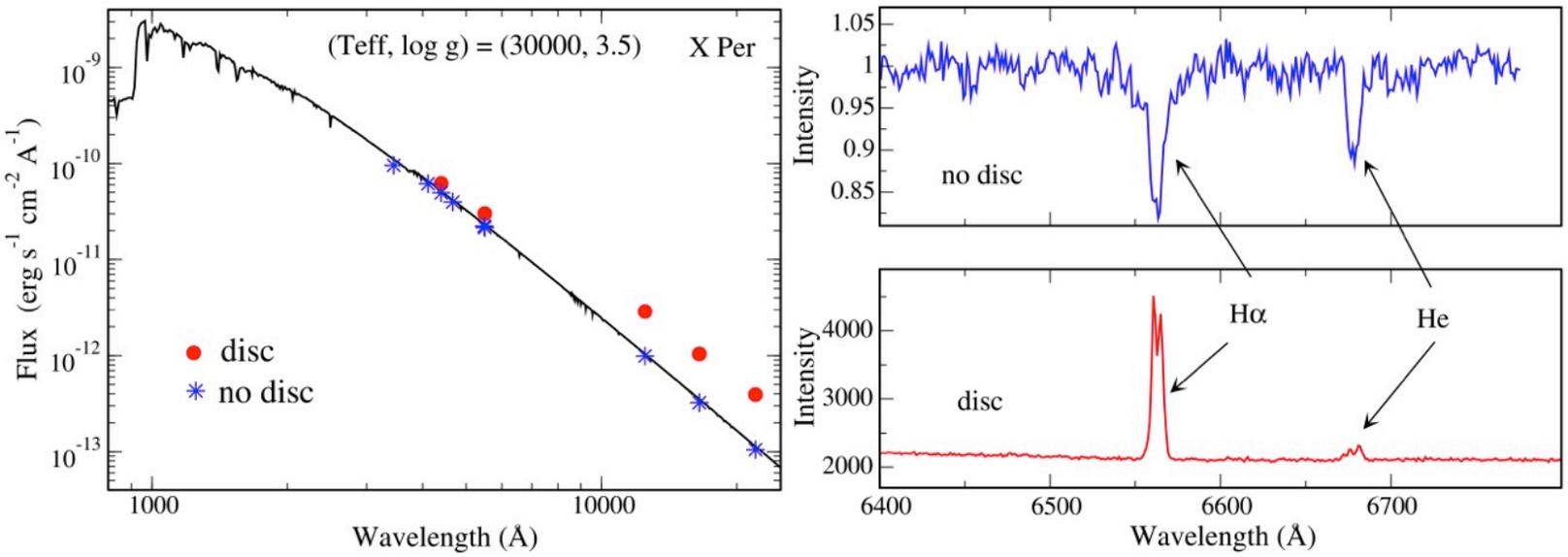
SGXBs

- Supergiant companion
- Strong stellar wind (10^{-6}–10^{-8} $M_\odot$ yr^{-1} , v_∞~2000 Km s^{-1})
- Roche-lobe overflow
- Generally persistent

HMXBs: sub-classes

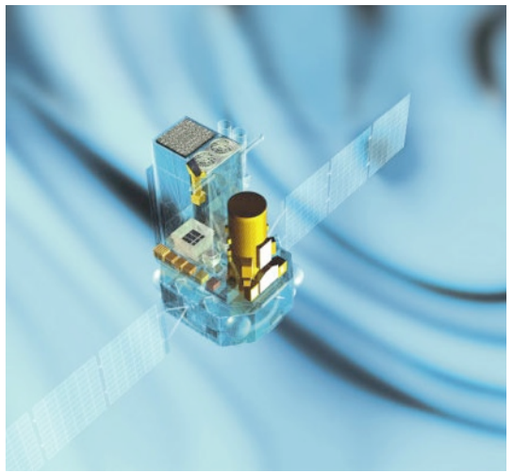
Be/XRBs

- Be companion (emission lines, IR excess --> equatorial disk)
- Accretion from a circumstellar disk
- Periodic/occasional X-ray outbursts
- Generally transient

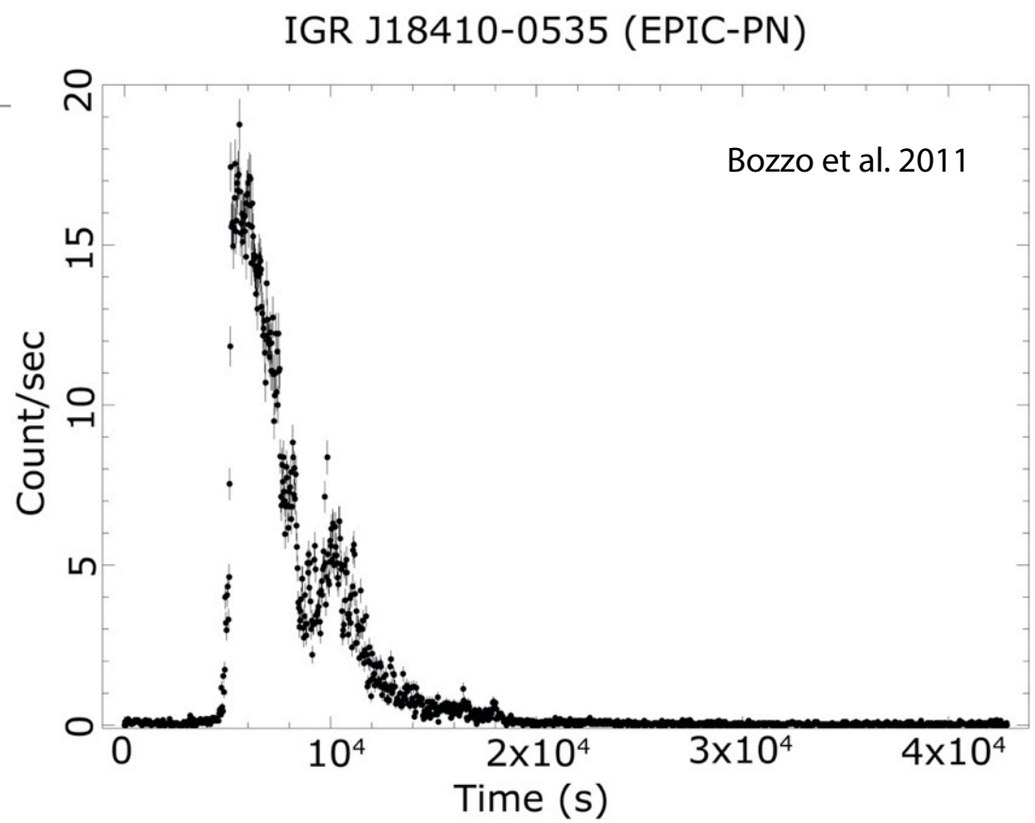


Reig, 2010

HMXBs: sub-classes

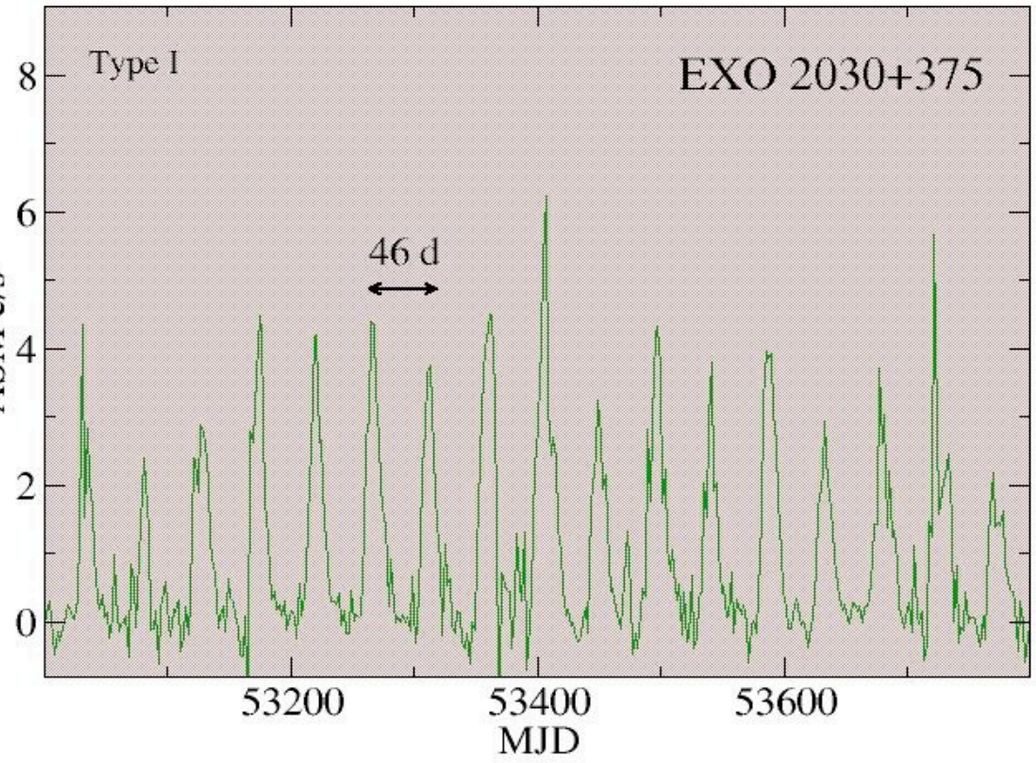


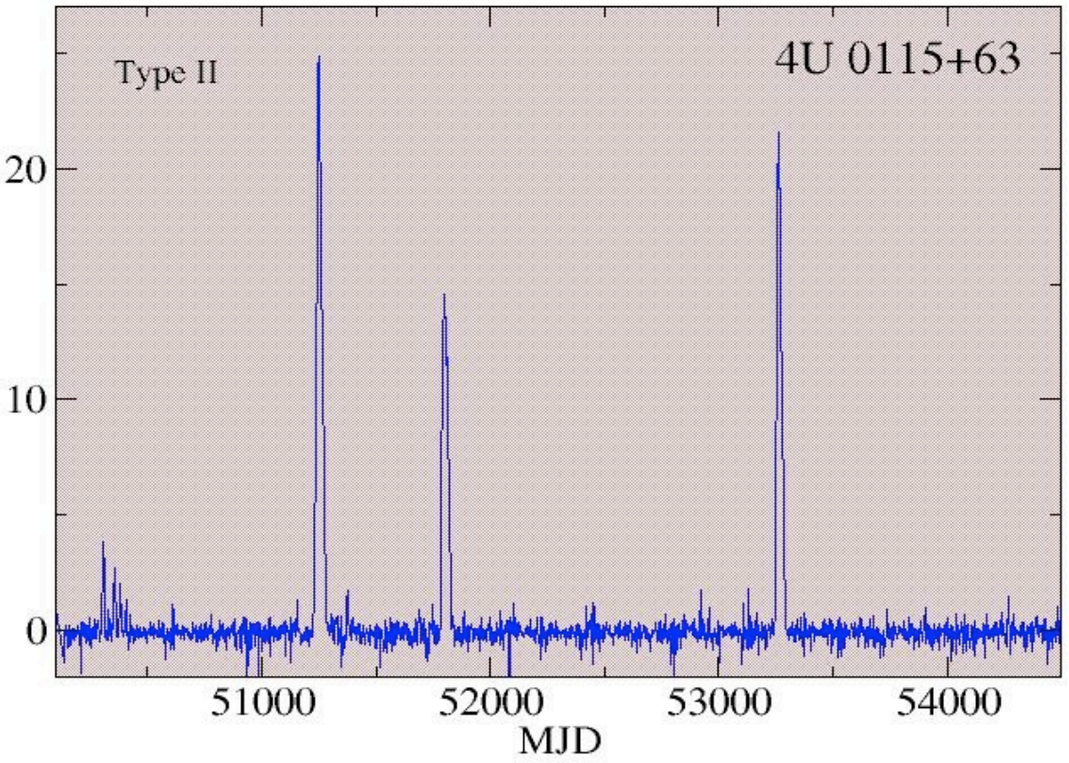
SFXTs



- Transient systems with supergiant companion
- Hard to detect (almost always in quiescence)
- Very short X-ray outbursts

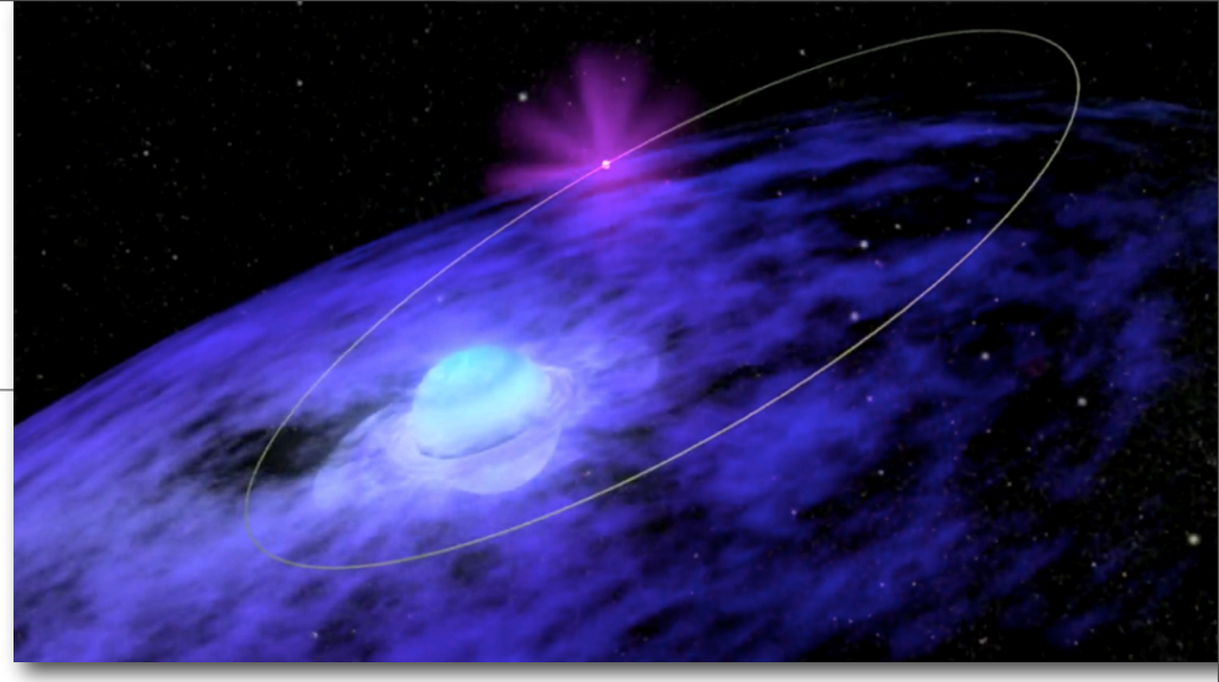
Be/X-ray binaries





- Two types of X-ray outbursts
  - Type I ("normal"): $L_x < 10^{37}$ erg s^{-1}, (quasi)periodic P_{orb}, short
  - Type II ("giant"): $L_x \sim 10^{37}$–10^{38} erg s^{-1}, unpredictable, long

Be/X-ray binaries

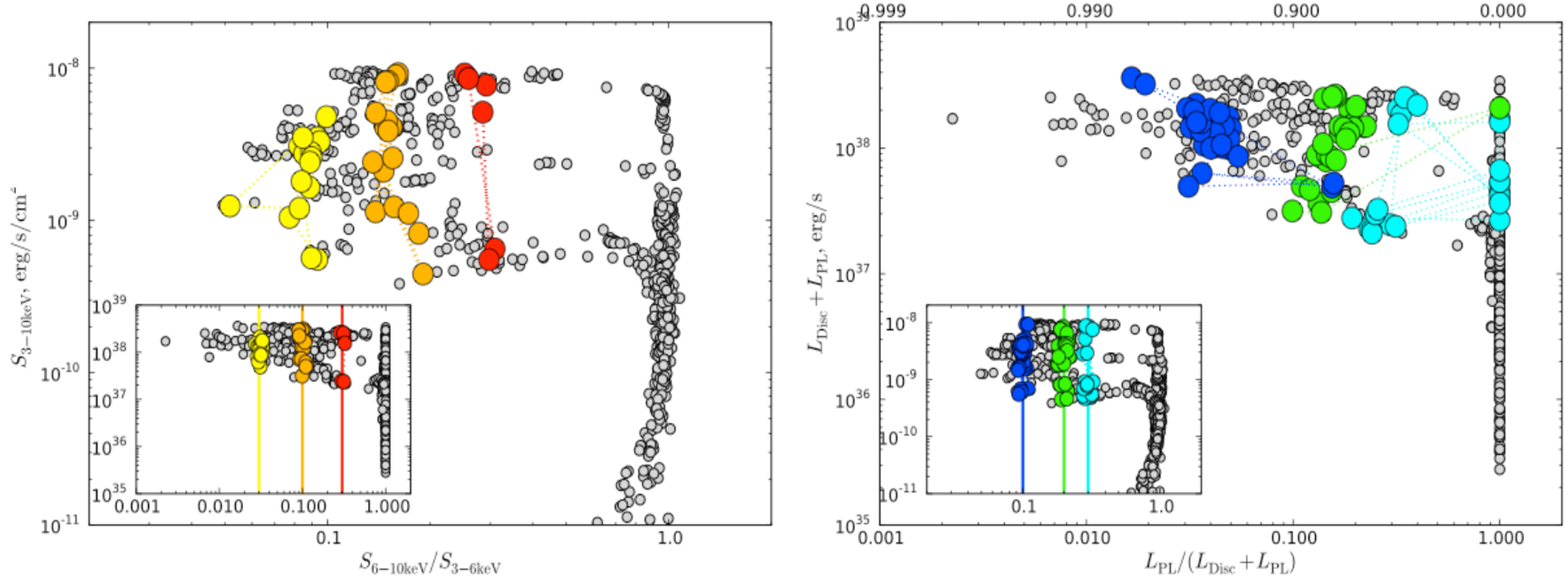


Much more complex picture than this!

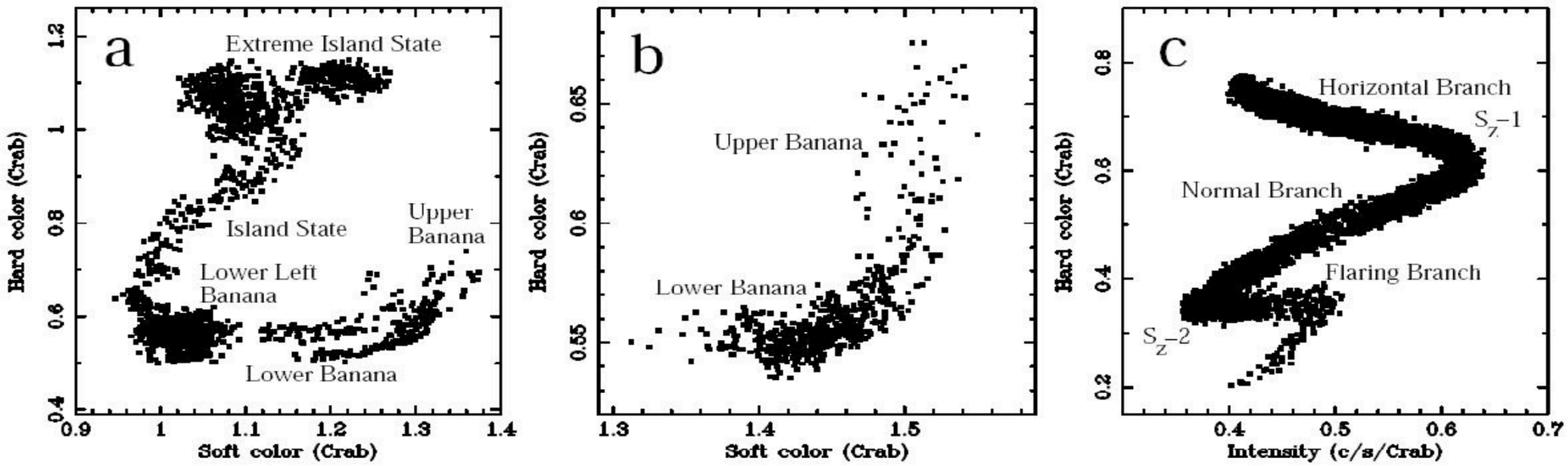
- both transient and persistent sources
- highly eccentric and nearly circular orbits
- fast (P_{spin} ~ few seconds) and slow (P_{spin} ~ few hundred of seconds) rotating neutron stars
- Type I-II outburst is a too strict classification!

Source states

Dunn et al. 2009



CD/HID in LMXB introduced the crucial notion of *spectral states*



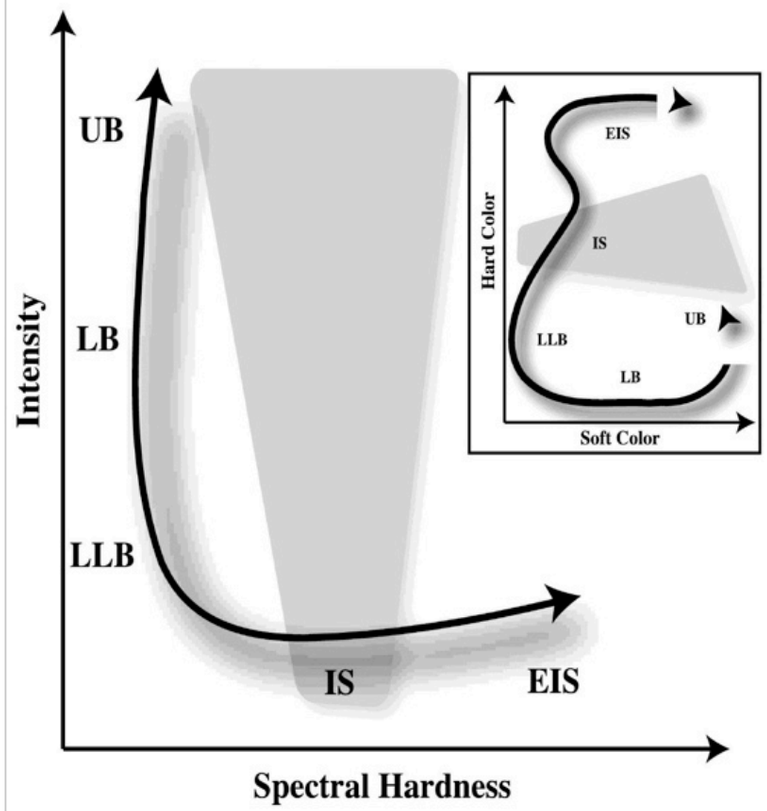
(a) van Straaten et al. (2003), (b) van der Klis (2006), (c) Jonker et al. (2000)

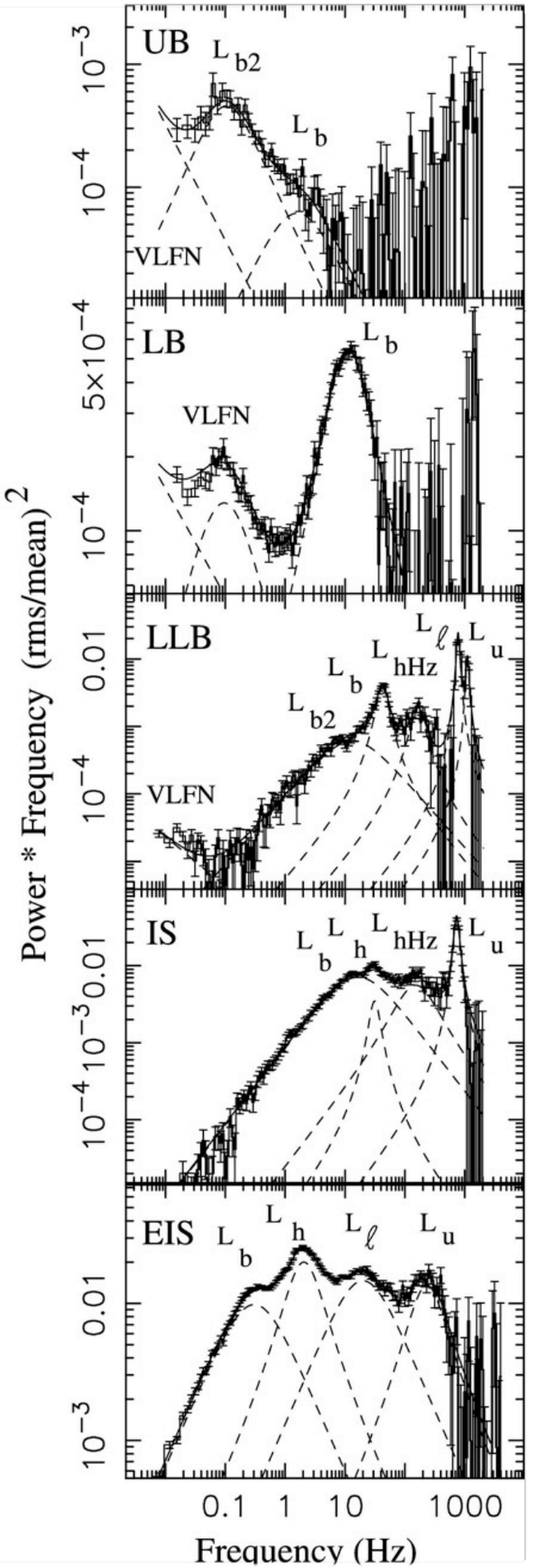
Analysis: a novel approach to BeX

With the exception of QPOs, aperiodic behavior of HMXBs has not been investigated as deeply as in LMXBs (see Reig 2008)

Together with color and spectral analysis, timing analysis turned out to be a useful tool to address the phenomenology of accretion in LMXBs (--> spectral states!)

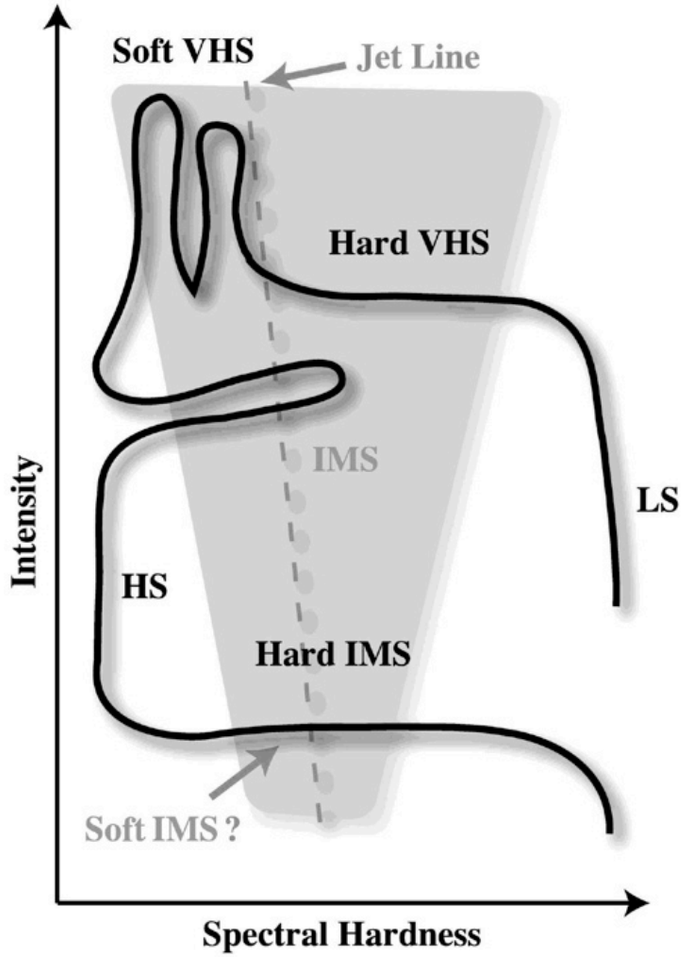
LMXBs: Atolls

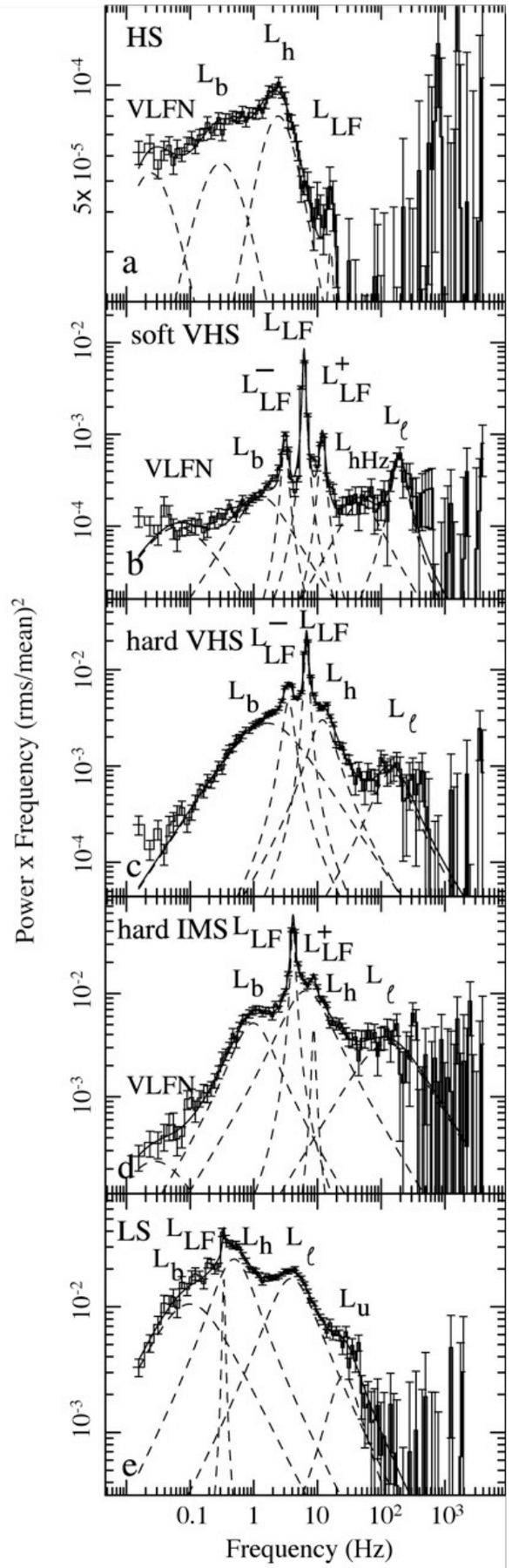




Adapted from Klein Volt & van der Klis (2007)

LMXBs: BHBs





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Analysis: a novel approach to BeX

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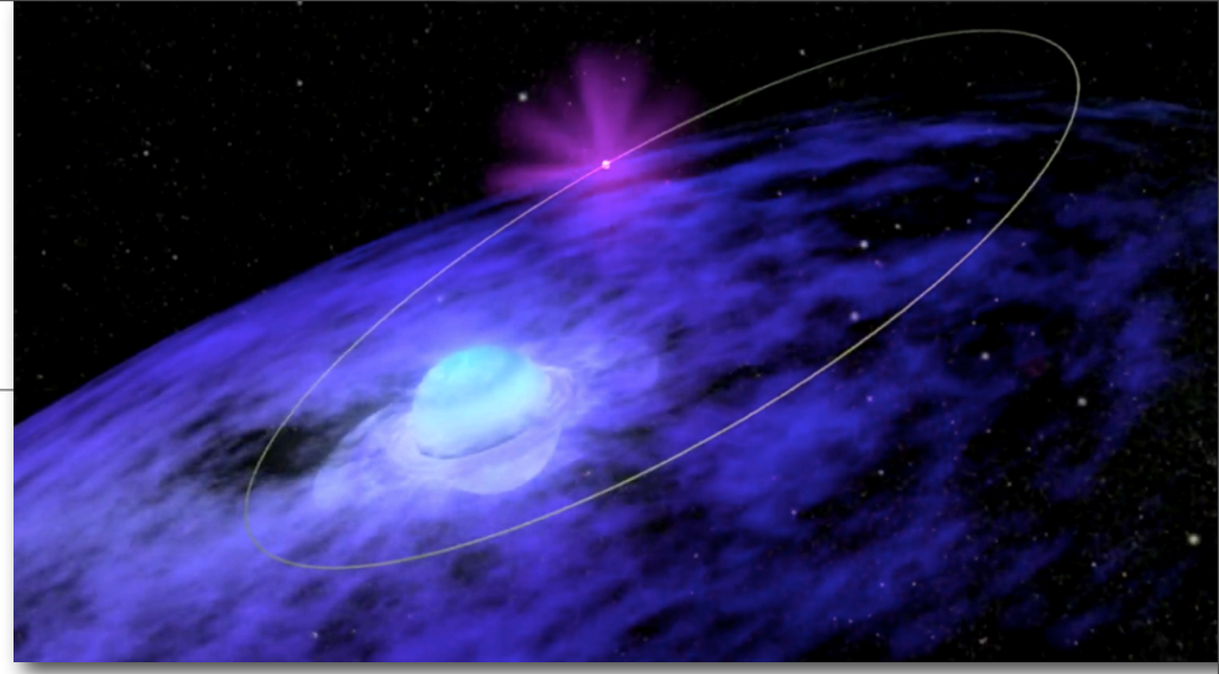
Why not focus on aperiodic variability in BeX?

The systems



- 1A 1118-615

  Discovered in 1974 by *Ariel V*

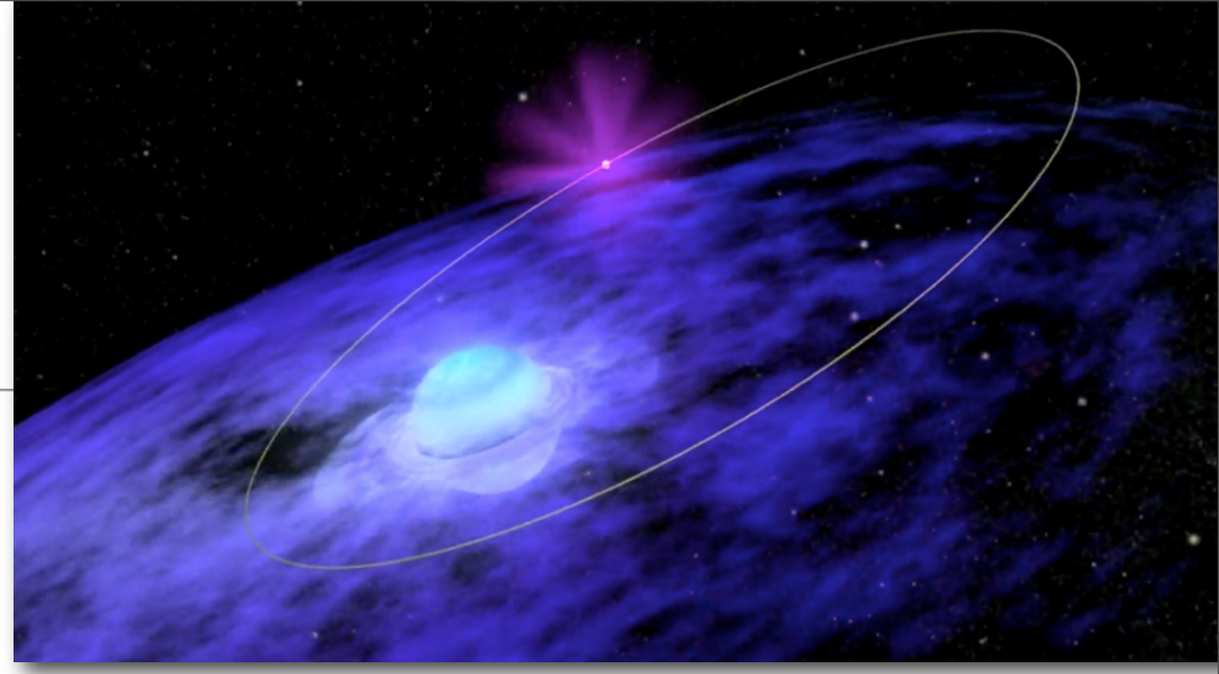
  Second giant outburst: January 1992 (strong Hα emission and IR excess)

  - Remarkable absorption (N_H~6x10^{22} cm^{-2})

  - Exhibits pulsed emission at low luminosities

  - CRSF @ ~55 keV

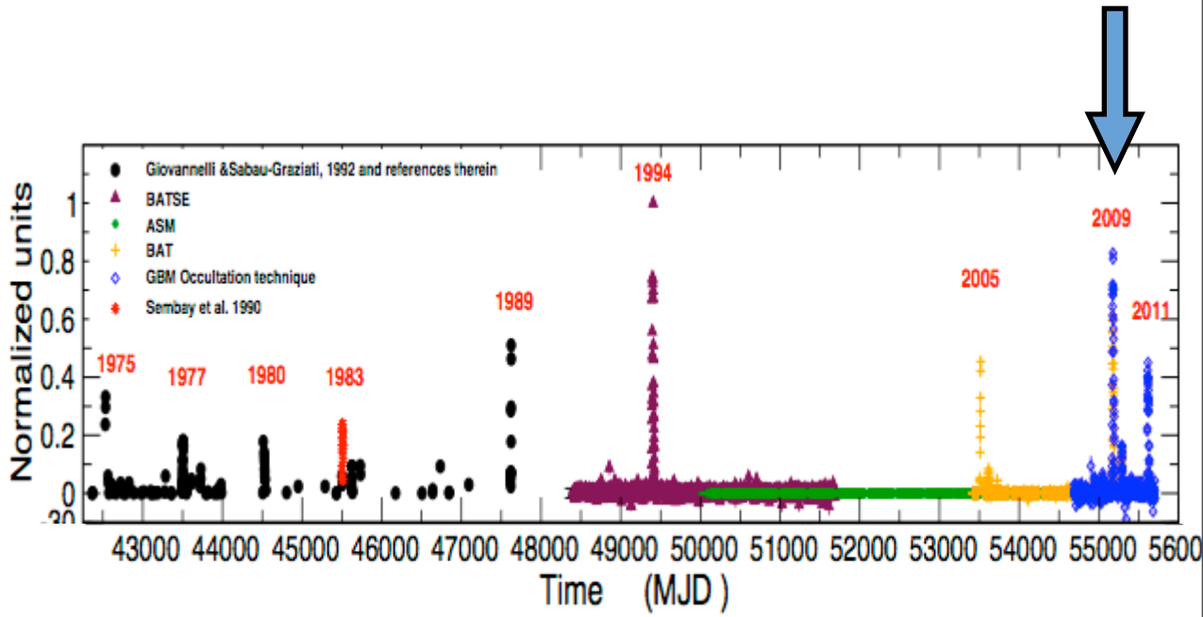
The systems



- A 0535+262

Discovered in 1975 by *Ariel V*

Nine giant outbursts



Camero-Arranz et al., submitted to ApJ

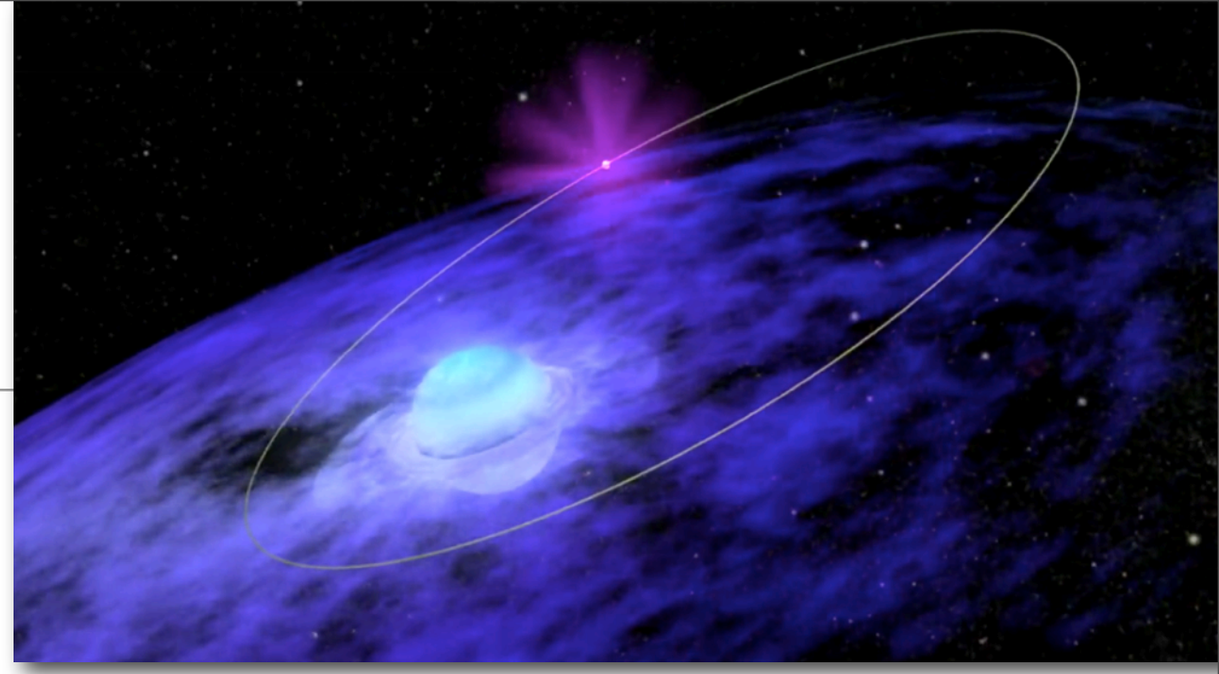
- high eccentricity ~0.47

- 111d orbital period

- Exhibits pulsed emission at low luminosities

- CRSFs @ ~45 keV, 100 keV

The systems



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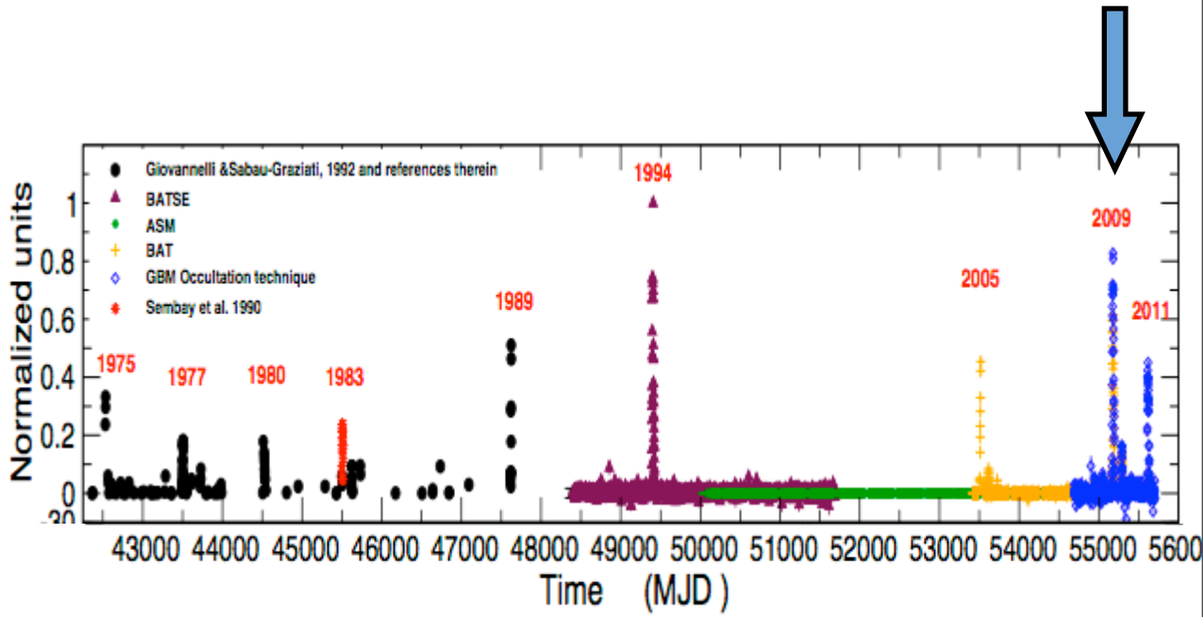

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- high eccentricity ~0.47

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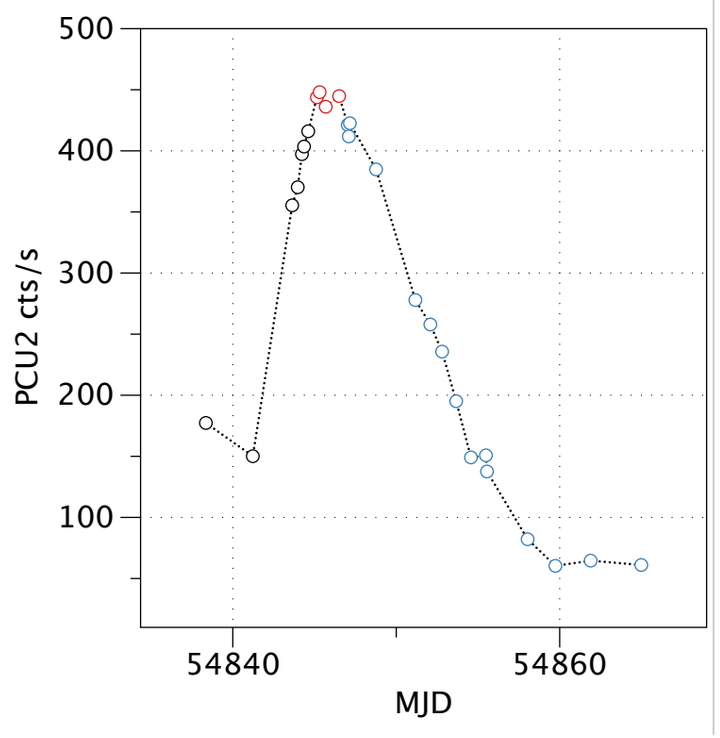
- CRSFs @ ~45 keV, 100 keV

Type II outbursts

- 1A 1118-615

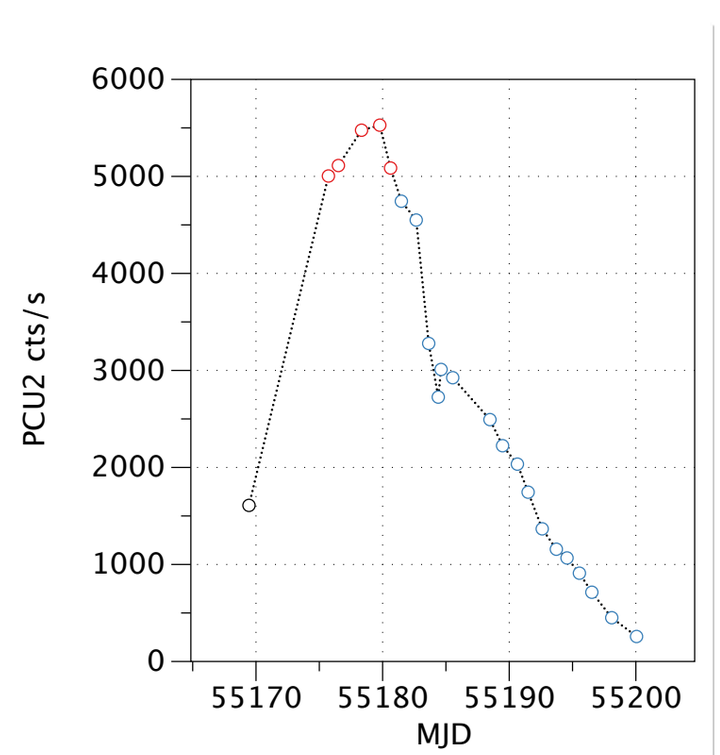
2009
26 RXTE pointings, ~1.5 months
$L_{X\,max} = 2.8 \times 10^{37}$ erg s^{-1}

(Nespoli & Reig, 2011)



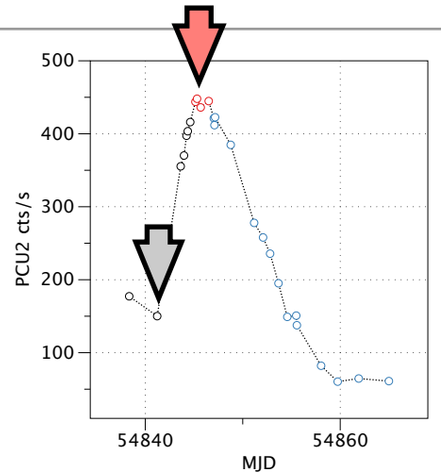
- A 0535+262

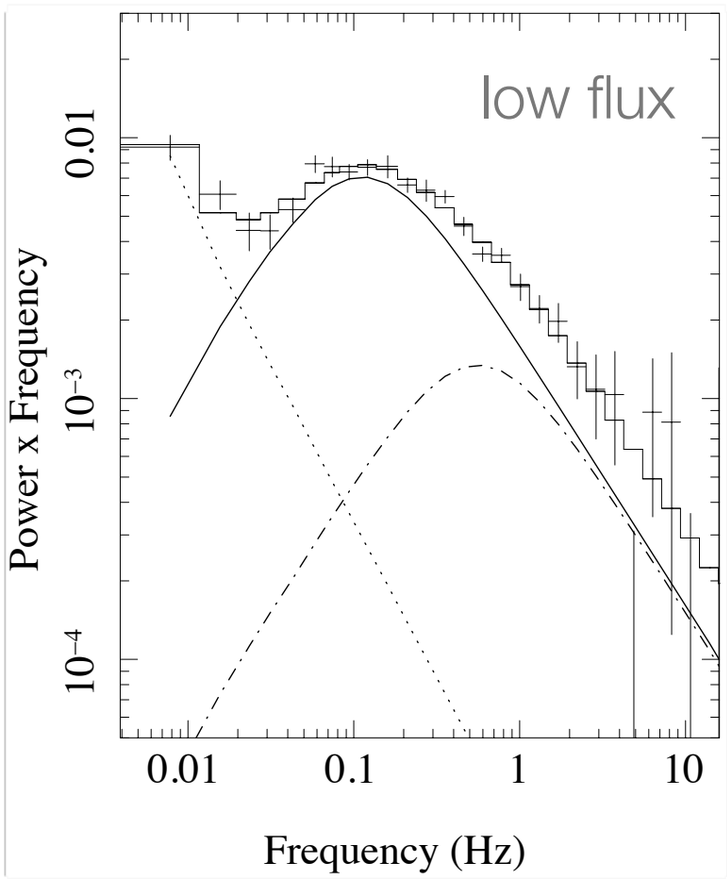
2009
23 RXTE pointings, ~1.5 months
$L_{X\,max} = 0.7\text{-}2.3 \times 10^{37}$ erg s^{-1}

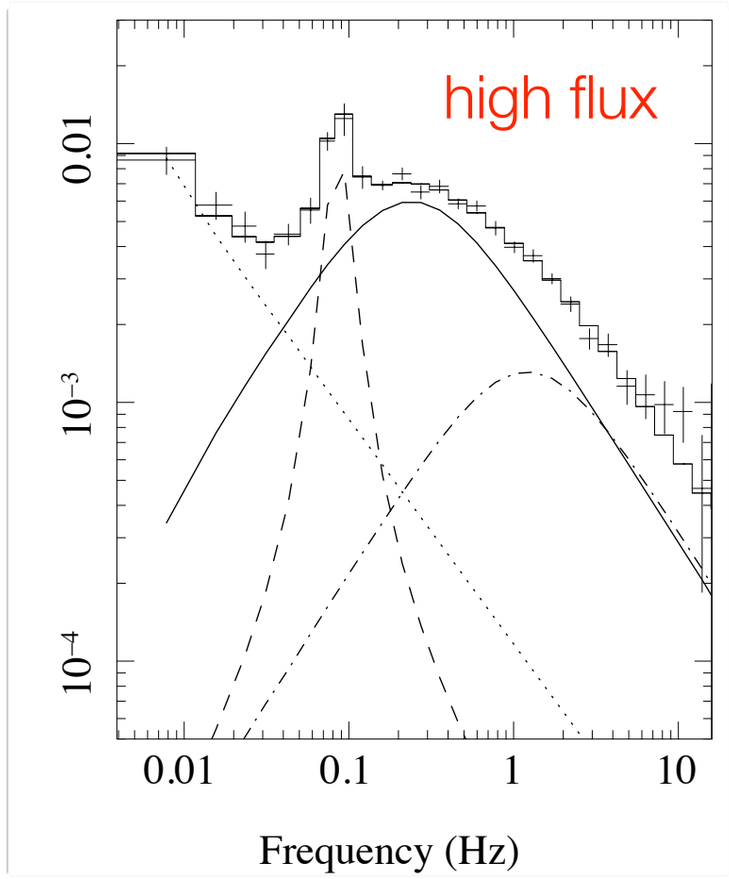


Analysis: aperiodic variability

- 1A 1118-615
  - broad noise: Lorentzians + a power law
  - QPO @0.08Hz (in bright observations only)

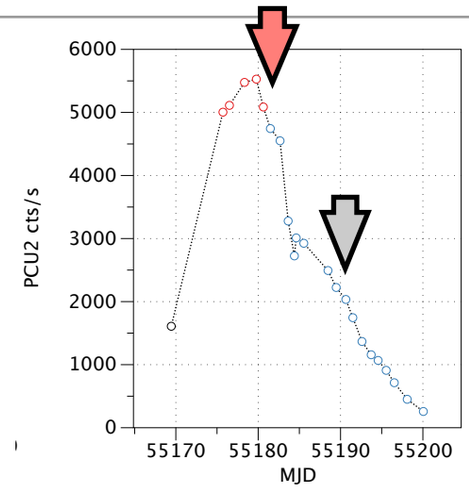


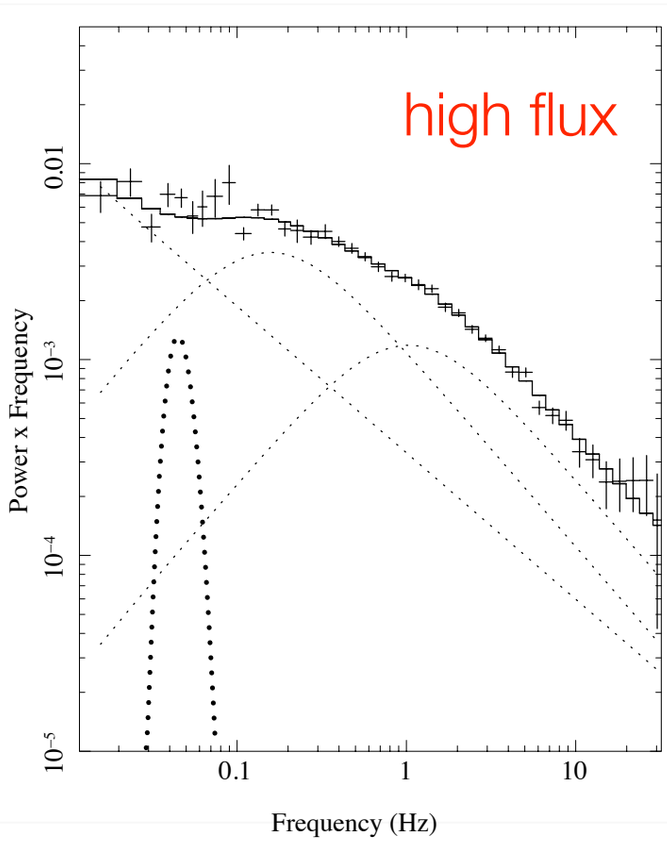


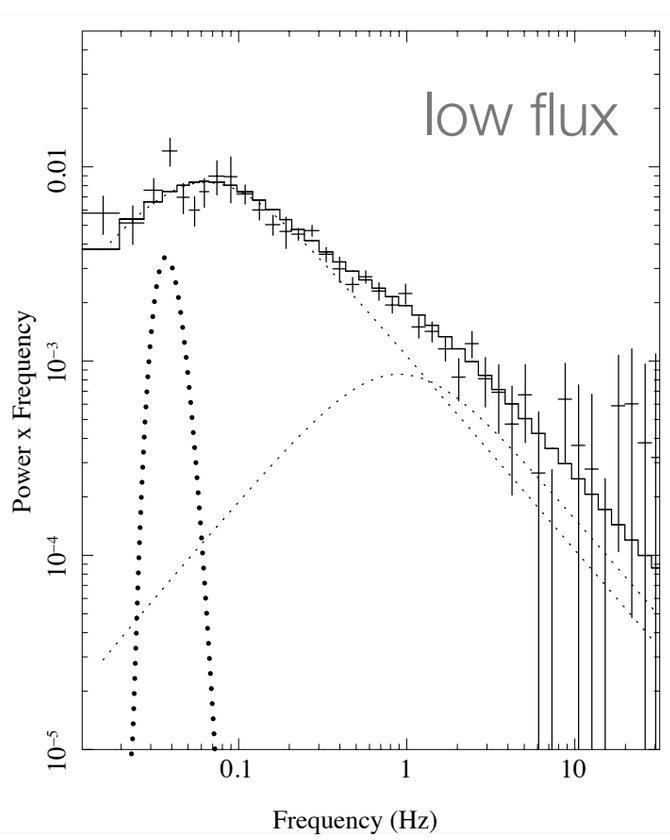


Analysis: aperiodic variability

- A 0535+262
  - broad noise: Lorentzians + a power law
  - QPO @0.05Hz

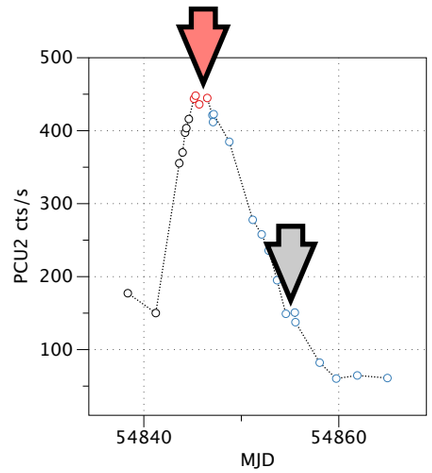


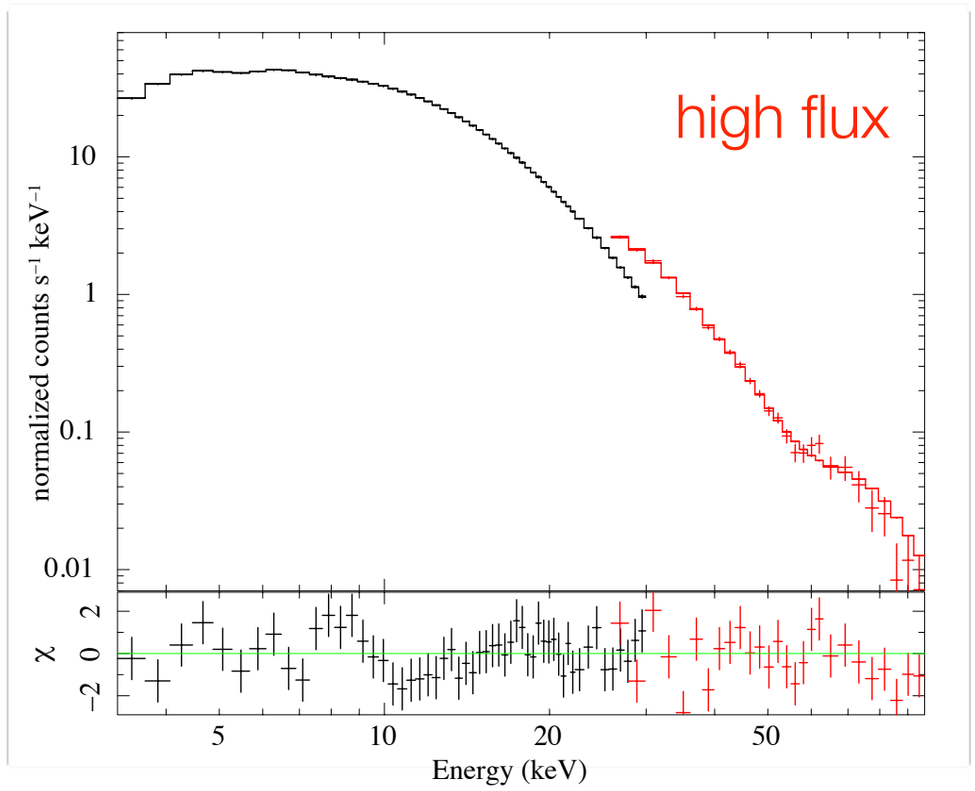


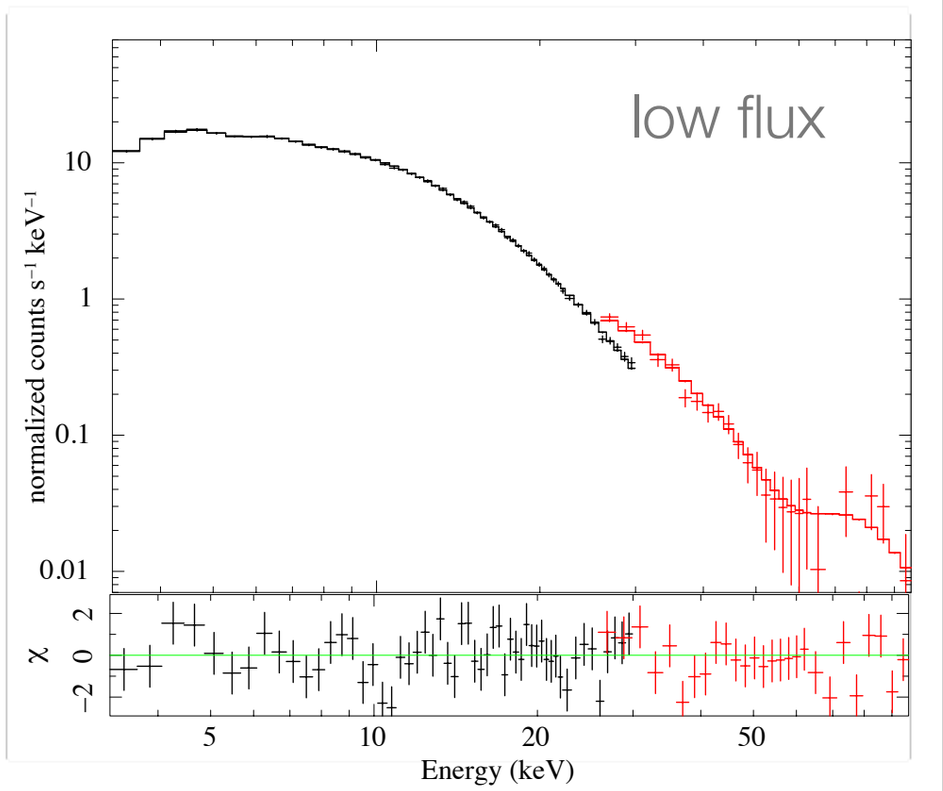


Analysis: energy spectra

- 1A 1118-615
  - absorbed power law + cutoff
  - Gaussian @6.5 keV
  - CRSF @~60 keV



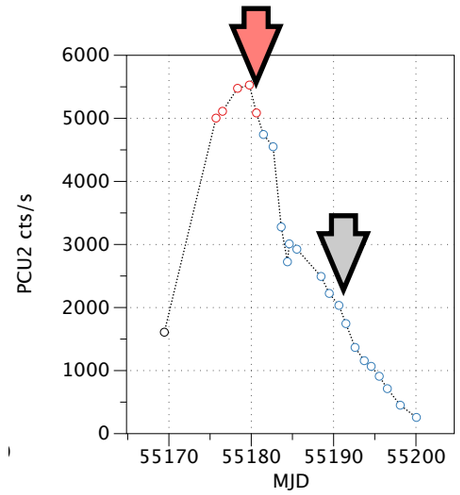


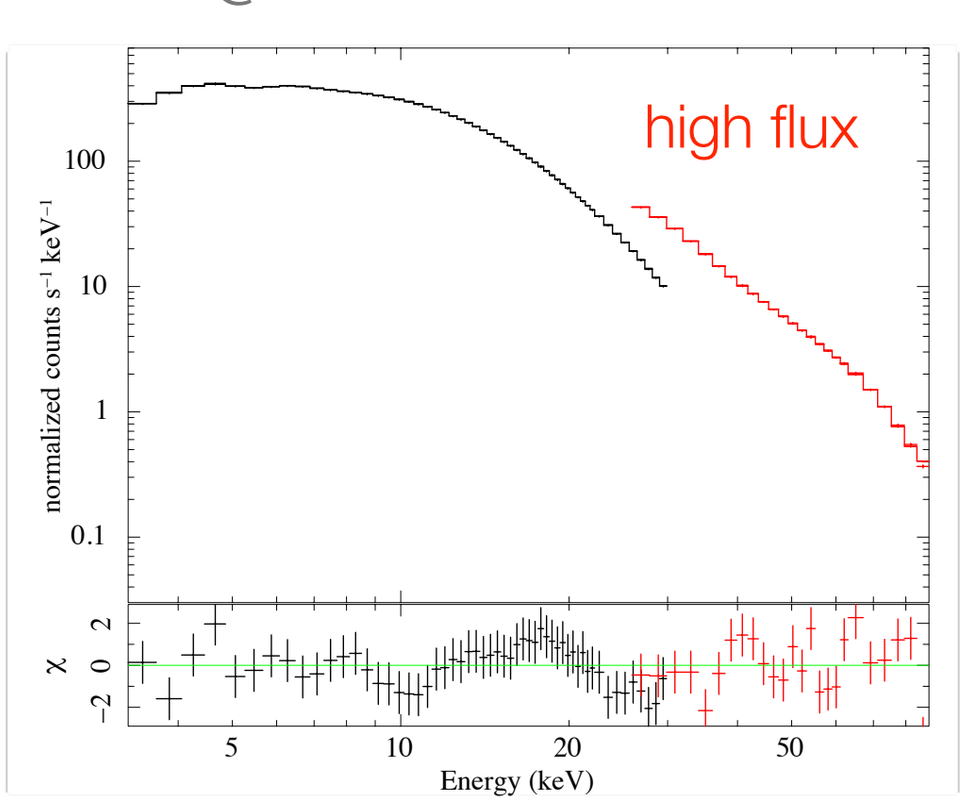


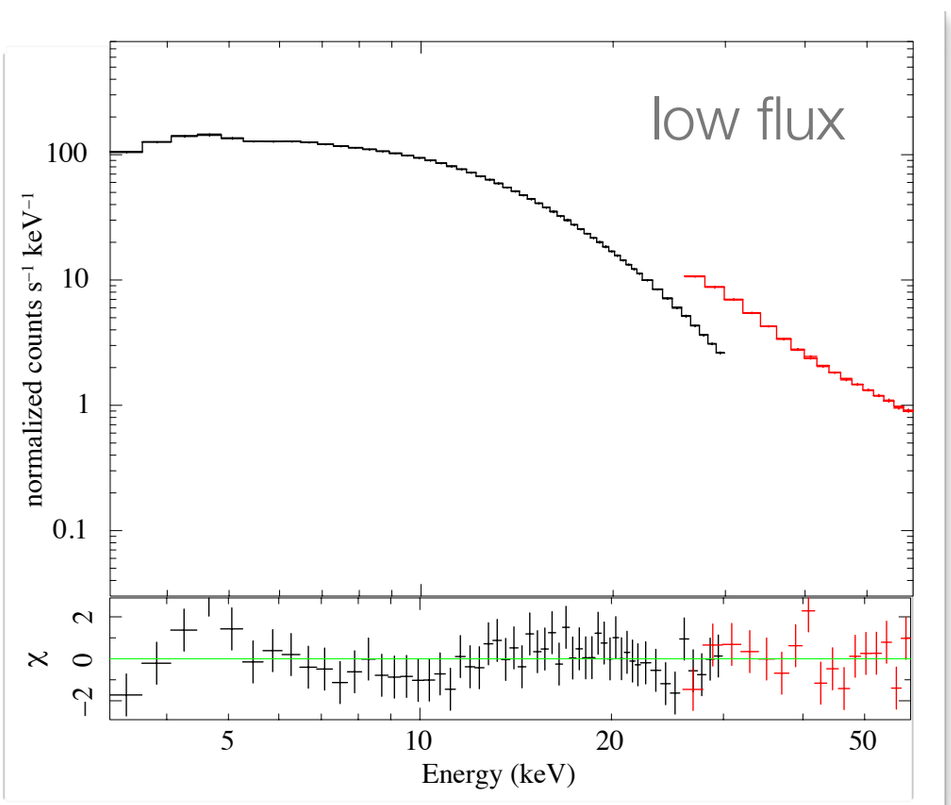
Analysis: energy spectra

- A 0535+262

  - blackbody kT~1 keV
  - absorbed power law + cutoff
  - Gaussian @6.5 keV
  - CRSF @40-45 keV

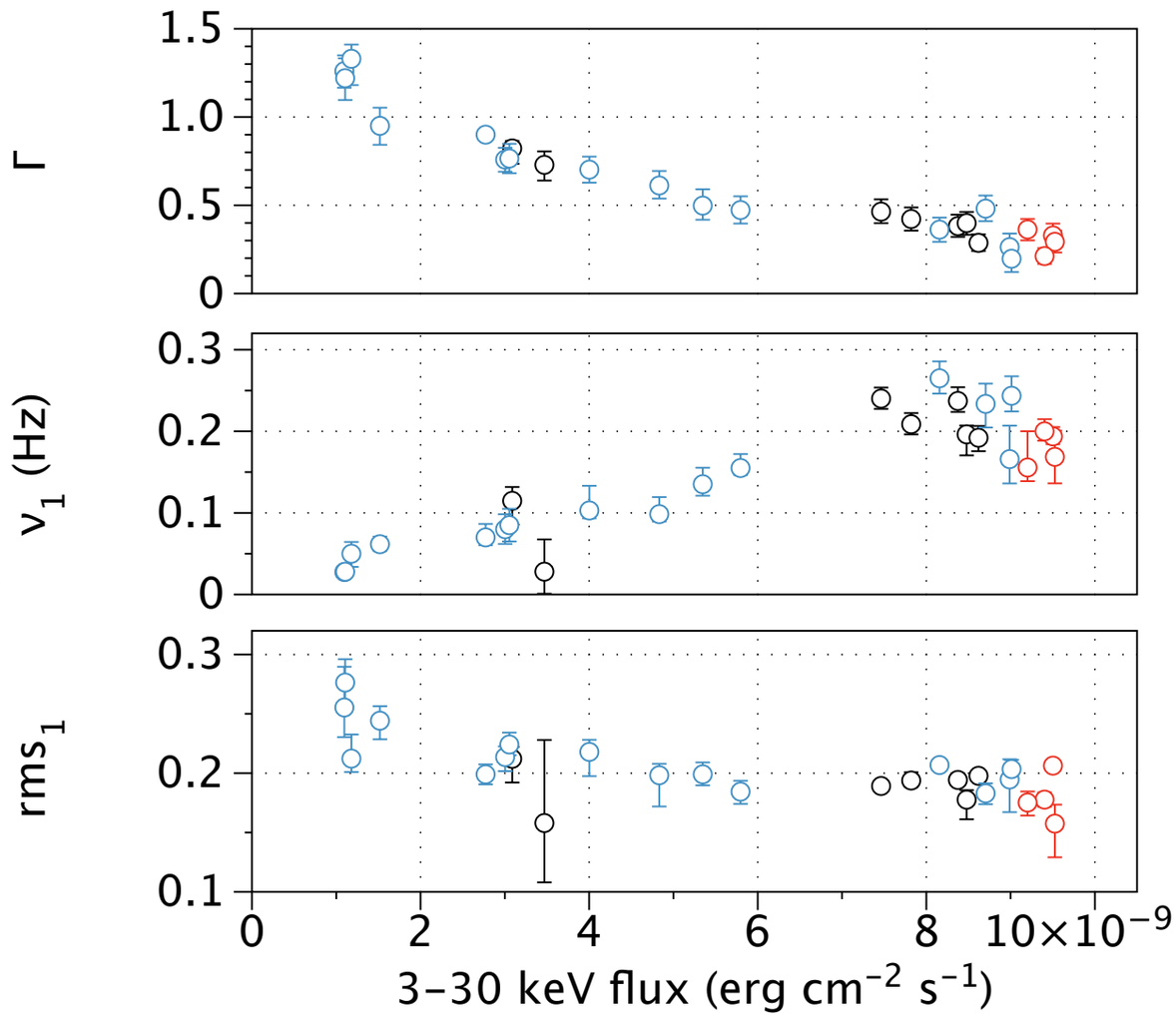


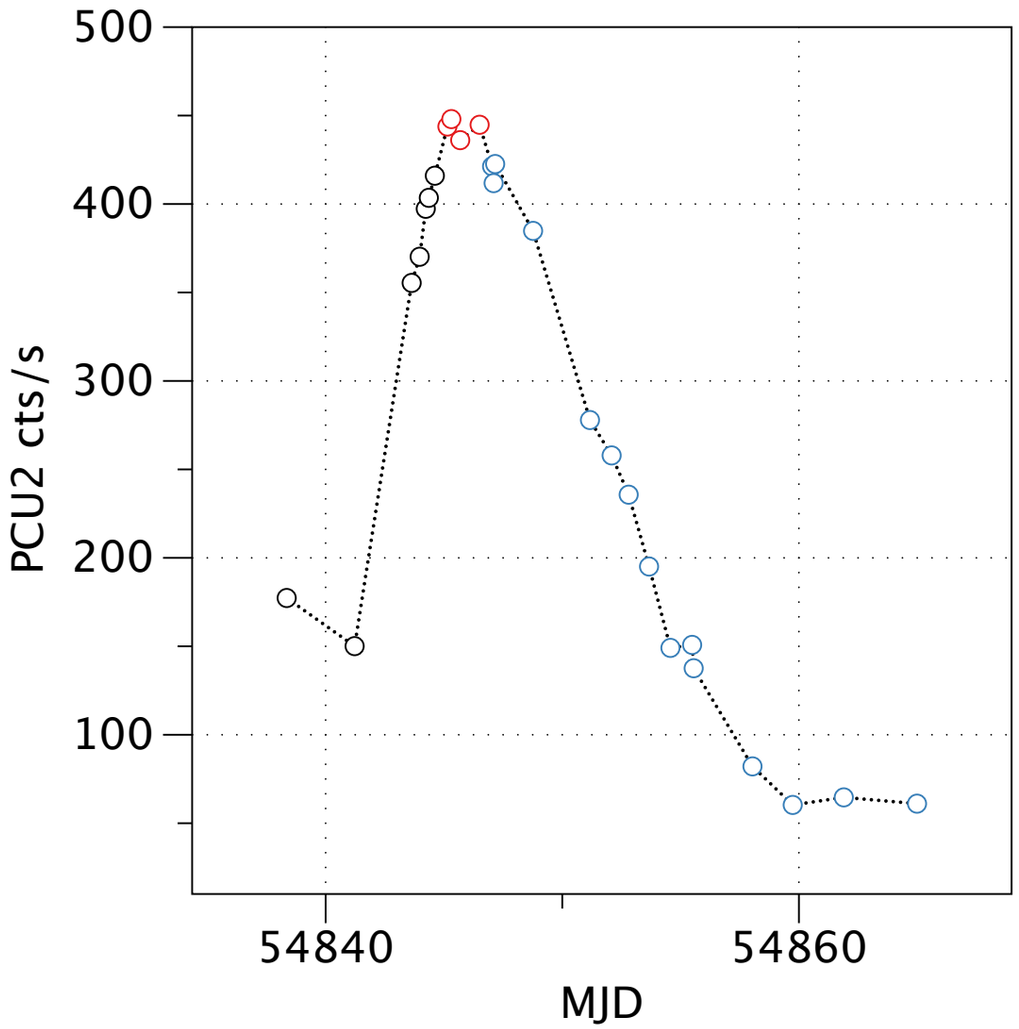




Results: correlated spectral/timing behavior

- 1A 1118-615





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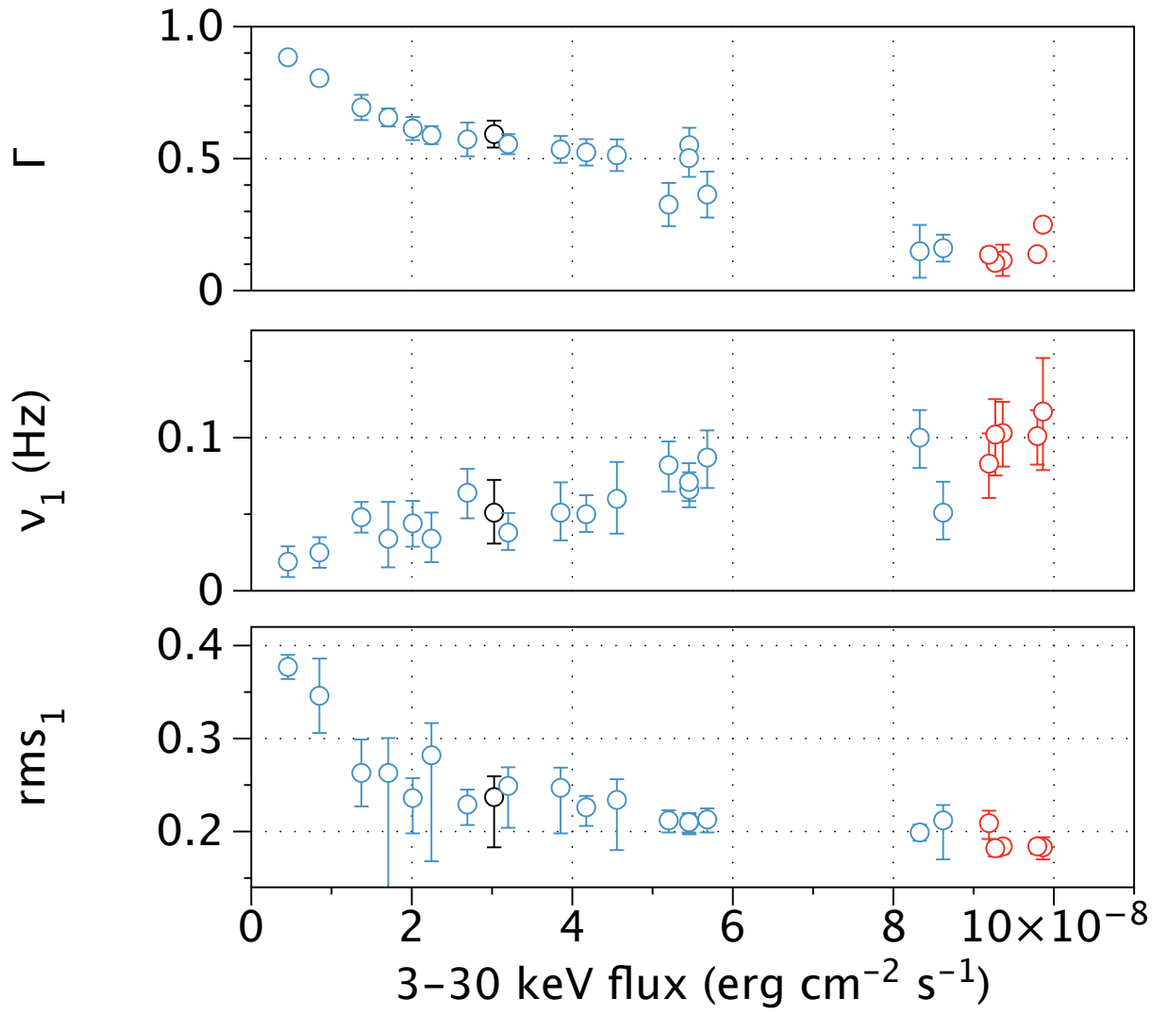
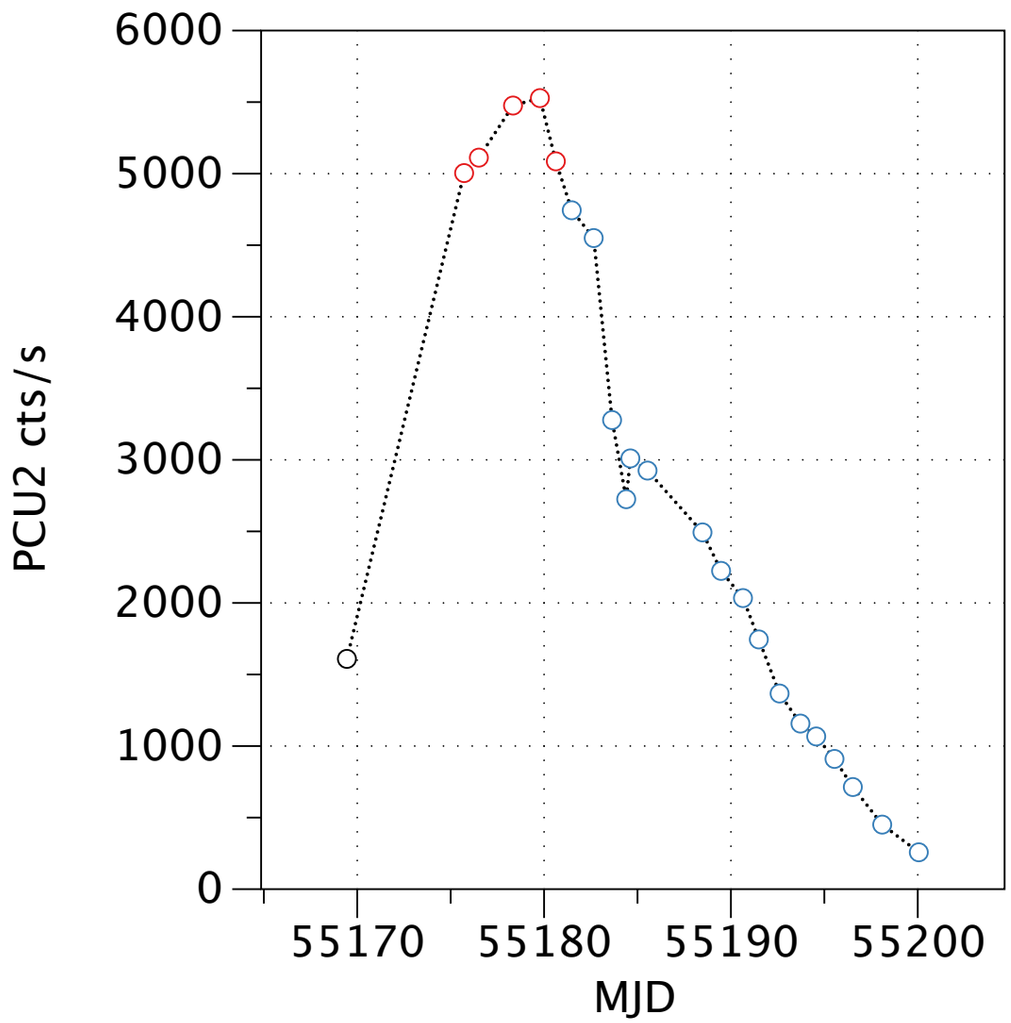
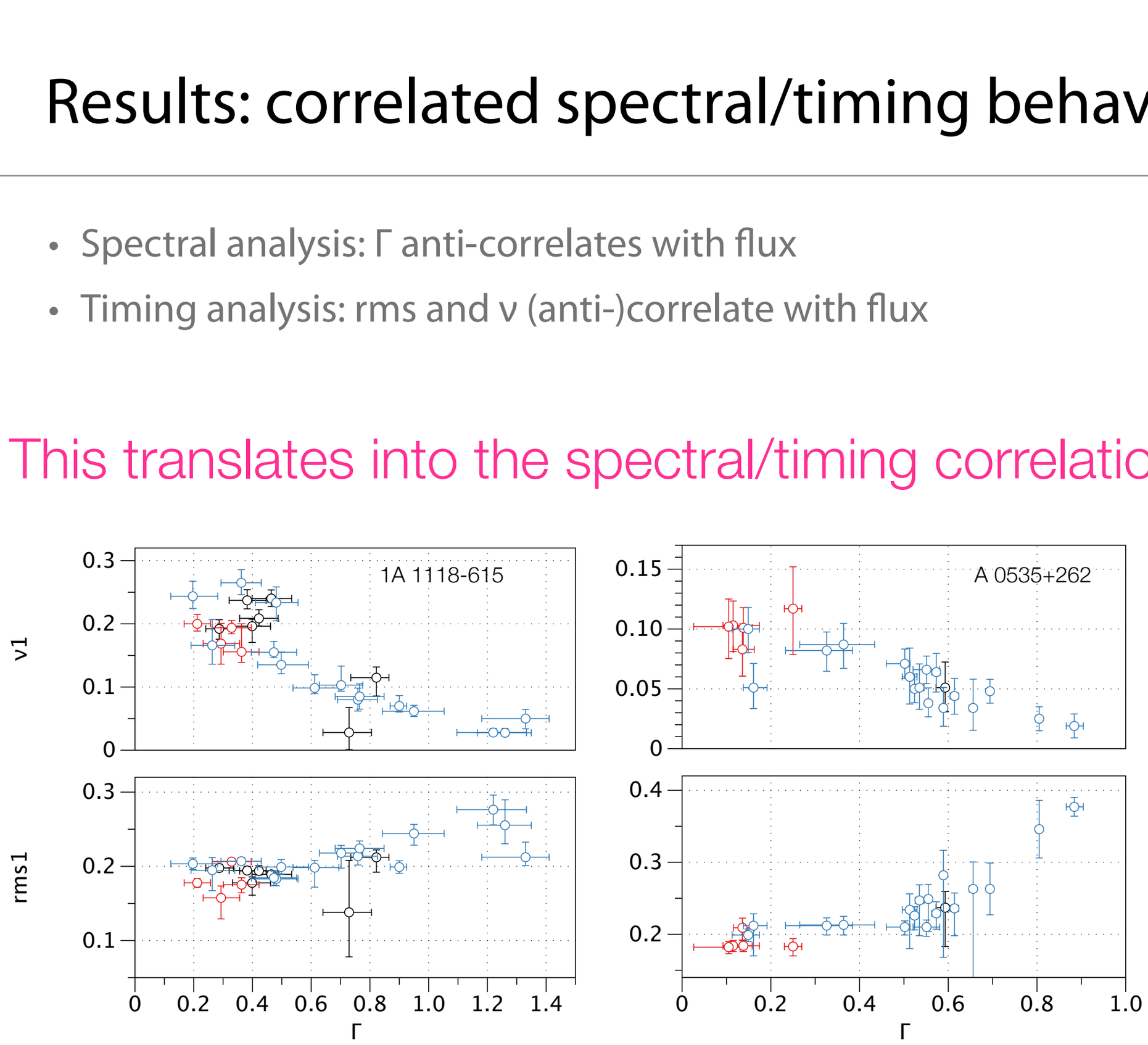




Results: correlated spectral/timing behavior

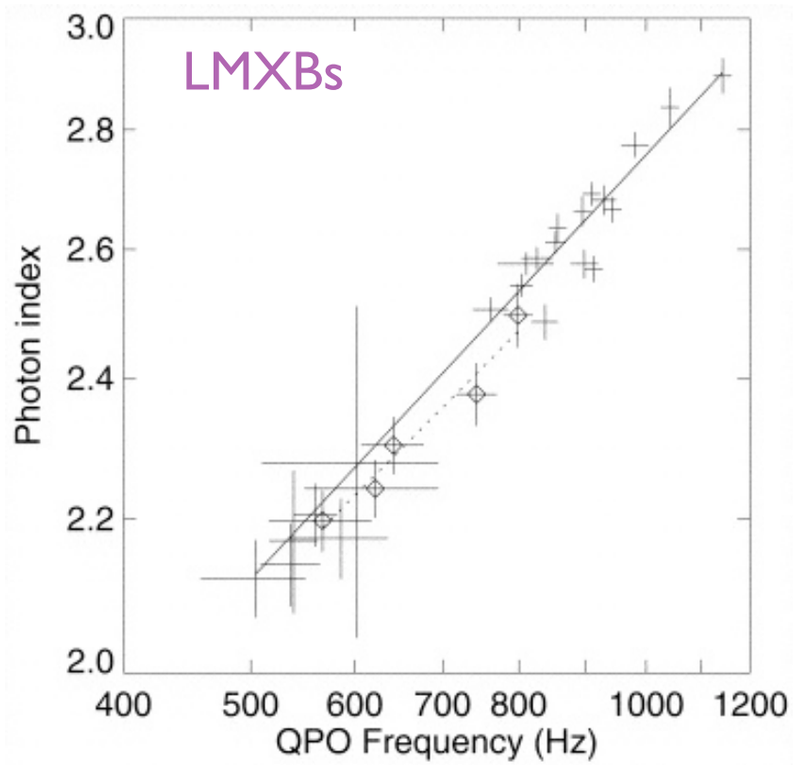
- Spectral analysis: Γ anti-correlates with flux
- Timing analysis: rms and ν (anti-)correlate with flux

This translates into the spectral/timing correlation

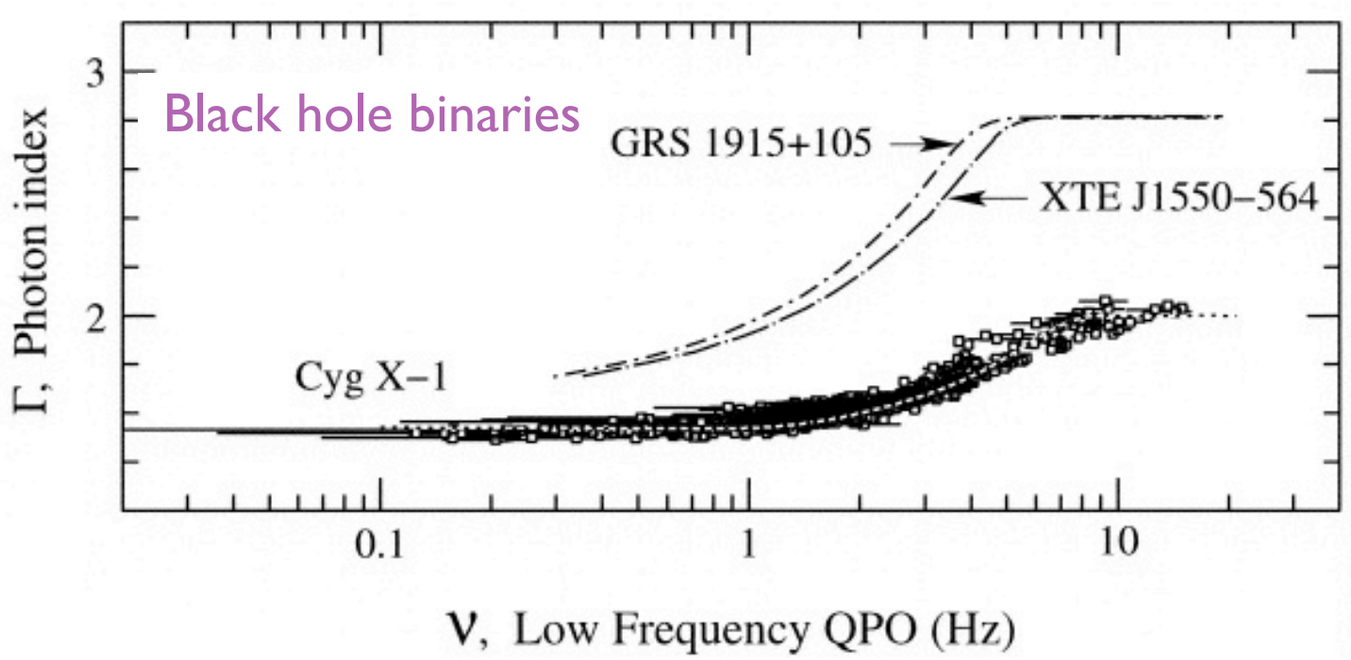


LMXBs and BHBs

Kaaret et al. 1998

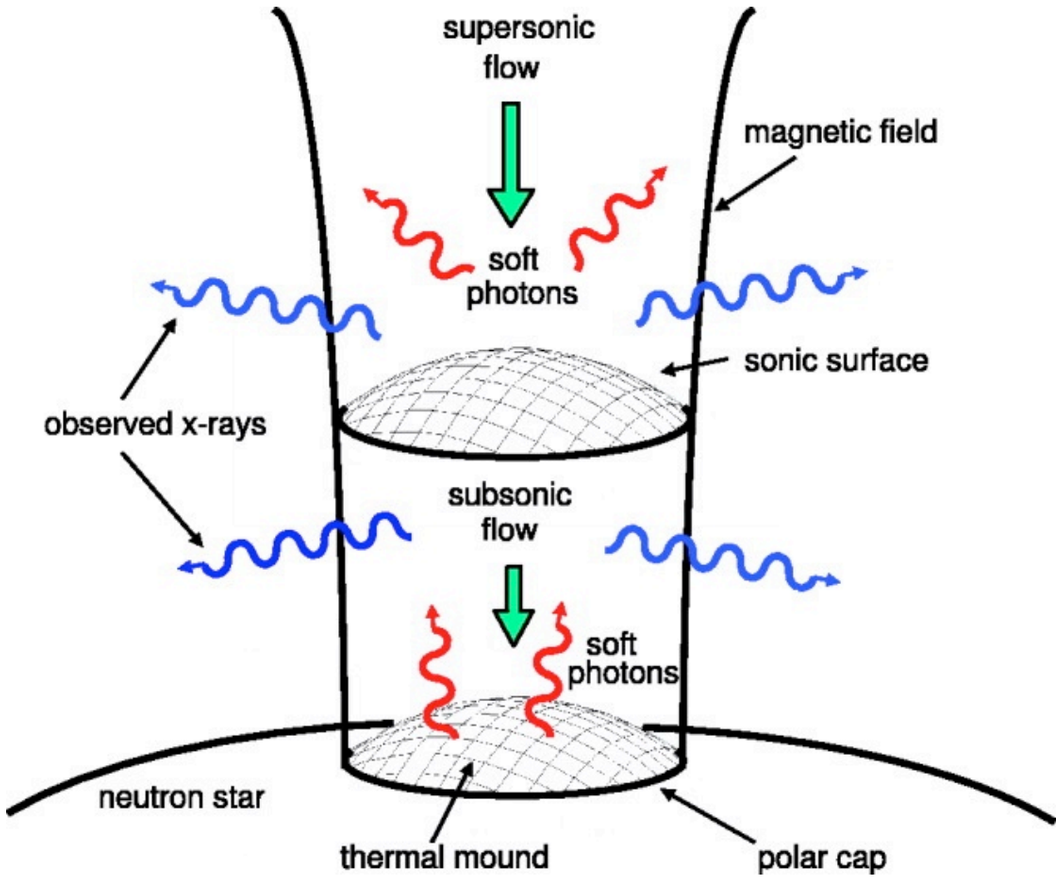


Titarchuk et al. 2007



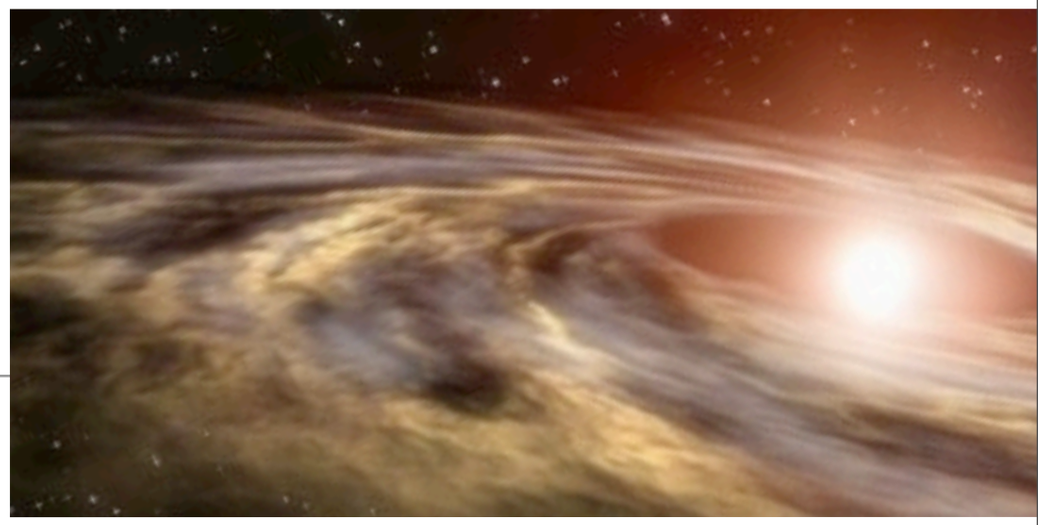
What do models say?

- Spectra are produced by photons in the accretion column (thermal mound)



from Becker & Wolff 2007

What do models say?



- No models for timing! But... at least we do have models for QPO production.

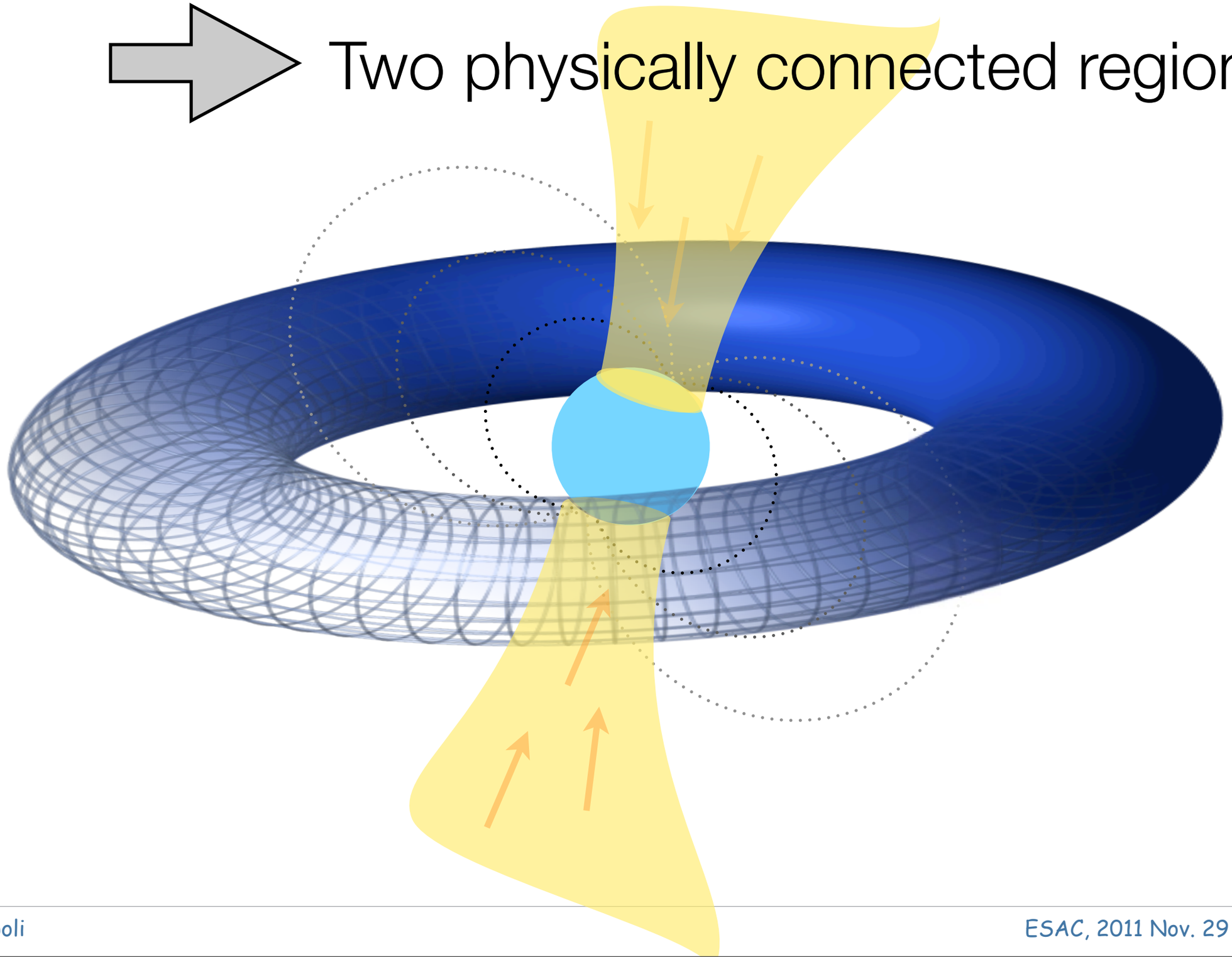
Beat frequency model (BFM, Alpar & Shaham 1985): $\nu_{QPO} = \nu_K - \nu_s$

Keplerian-frequency model (KFM, van der Klis et al. 1987): $\nu_{QPO} = \nu_K$

Both models relate the QPO to the presence of an accretion disk

Results: correlated spectral/timing behavior

Two physically connected regions



Conclusions... and open questions

- We are still far from drawing an exhaustive picture of BeXRBs
- So far, no "source states" have been identified in all BeXRBs (but see Reig 2008)
- Aperiodic variability can provide a complementary tool for the characterization of these systems
- ...together with X-ray color and spectral analysis, and multiwavelength study

Thanks!

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