Cataclysmic variables in the eROSITA sky

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Outline

- Introduction
  - CV taxonomy
  - X-ray production in CVs
- Status and open questions after ROSAT+...
  - CV demography & the Milky Way
  - CV evolution
  - (M)CV physics
- Optical follow-up
- Resume

CV taxonomy

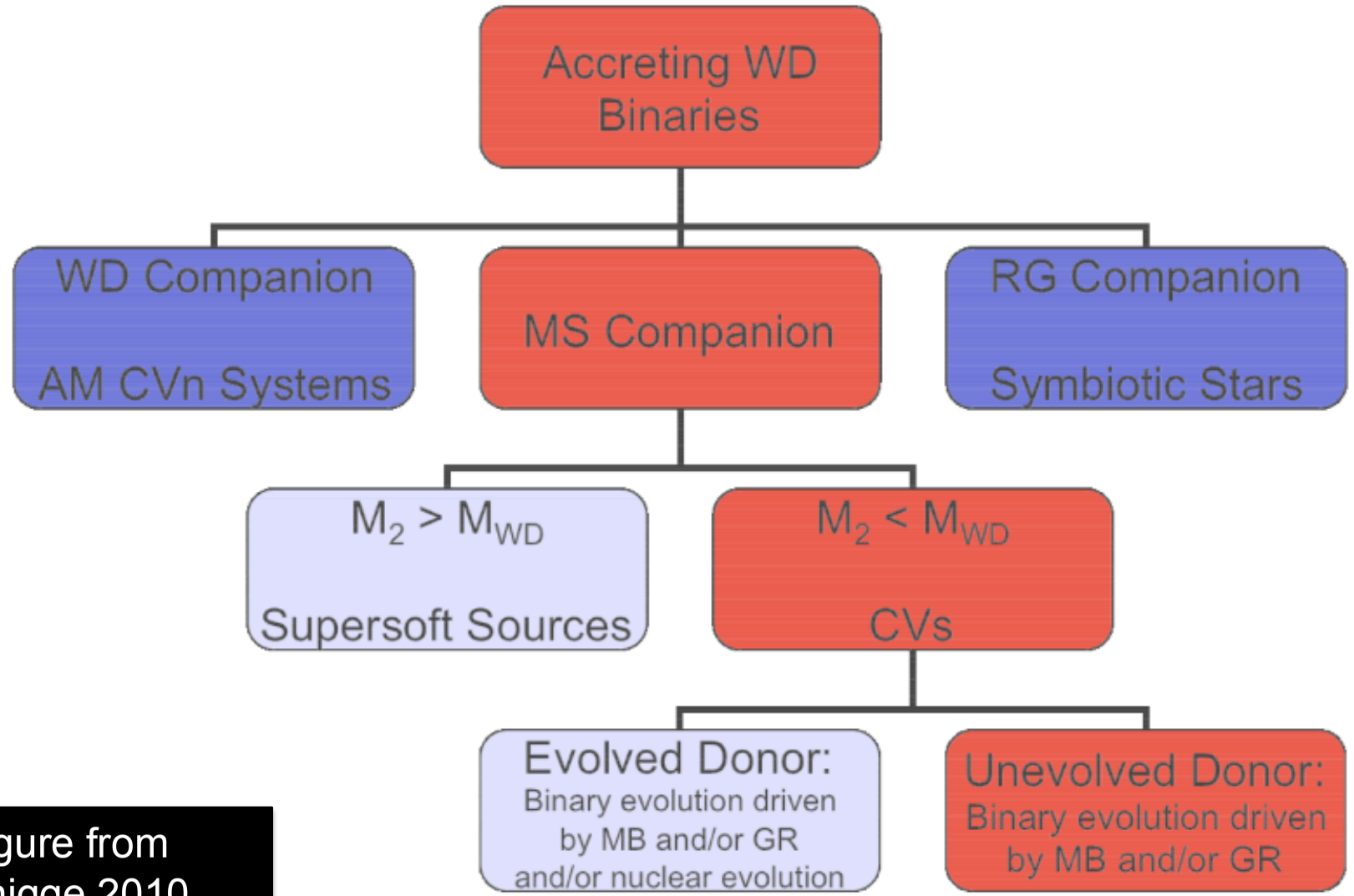
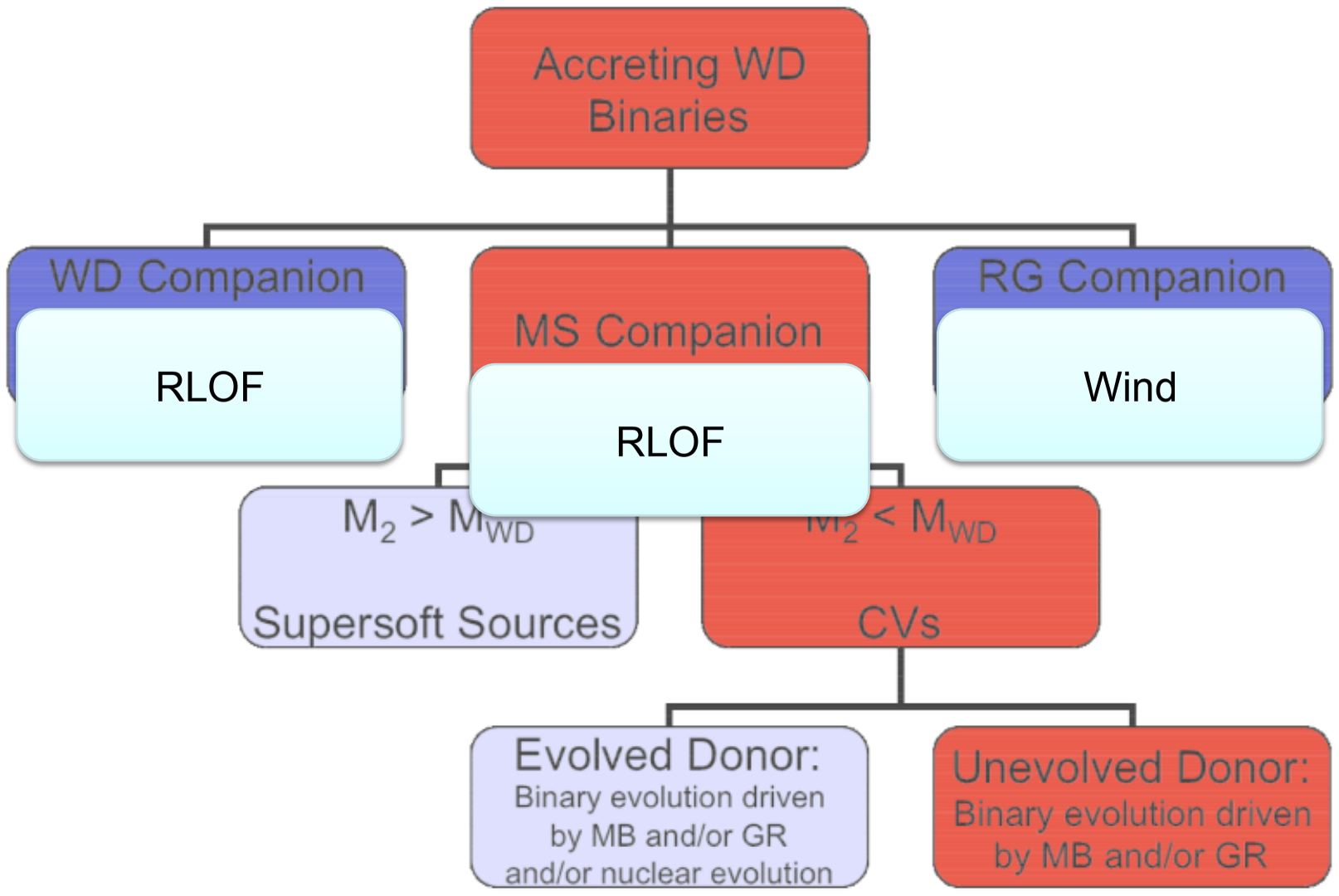
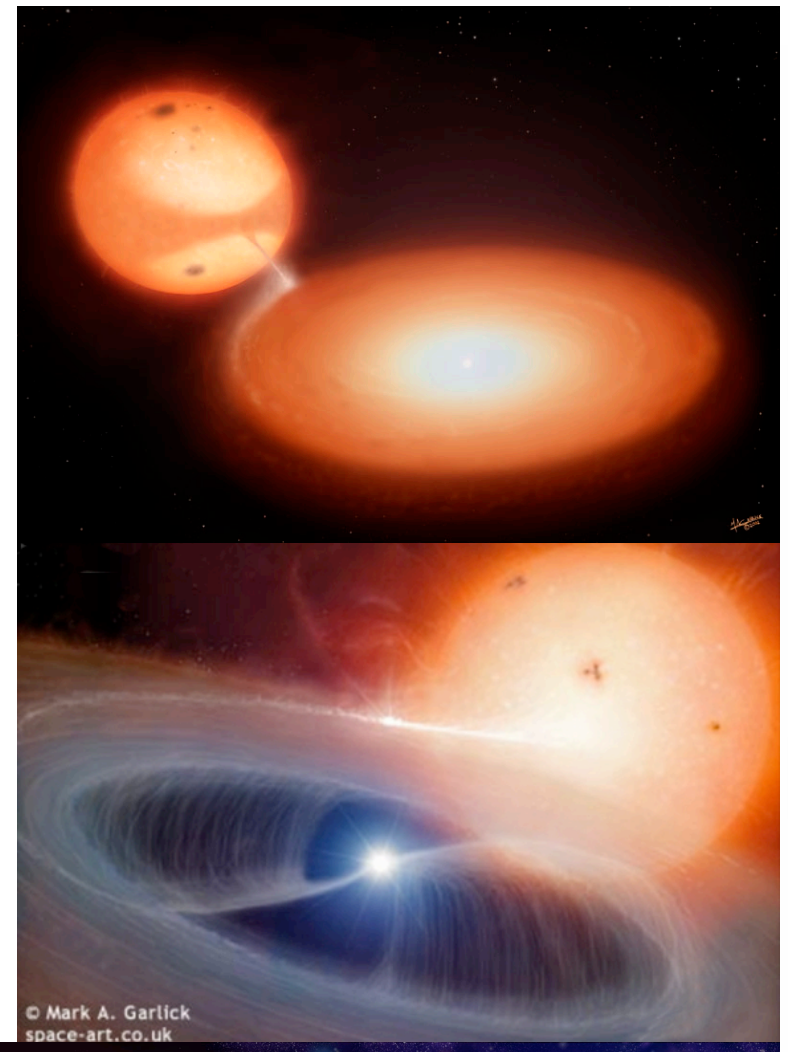


Figure from Knigge 2010

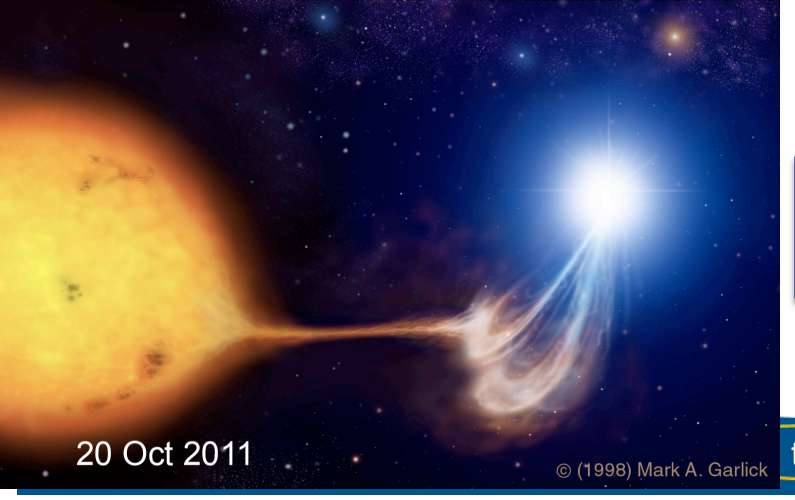
Accretion mode





nova-like
dwarf nova

$$\mu \leq 10^{33}\ Gcm^3$$
$$R_* \approx R_M << a$$



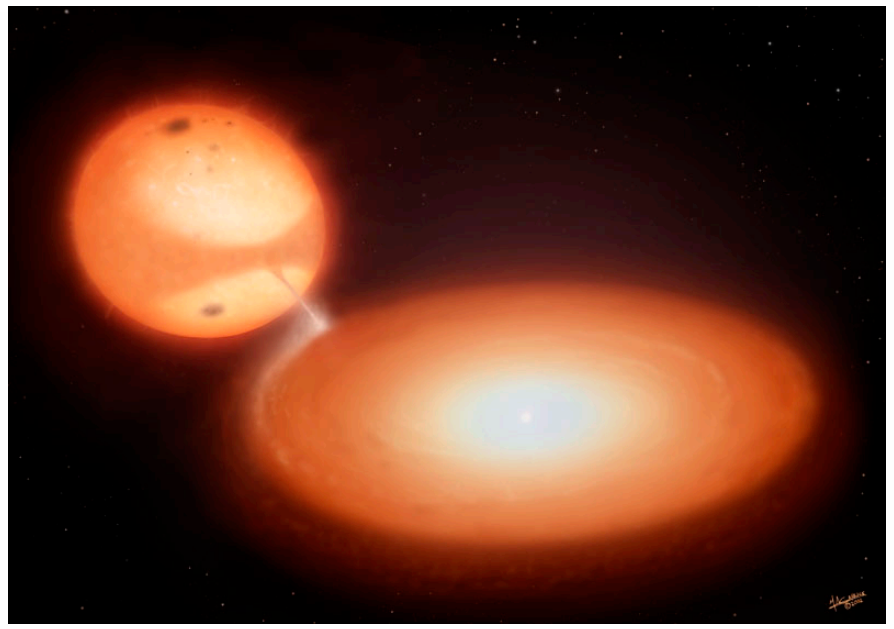
Intermediate Polar

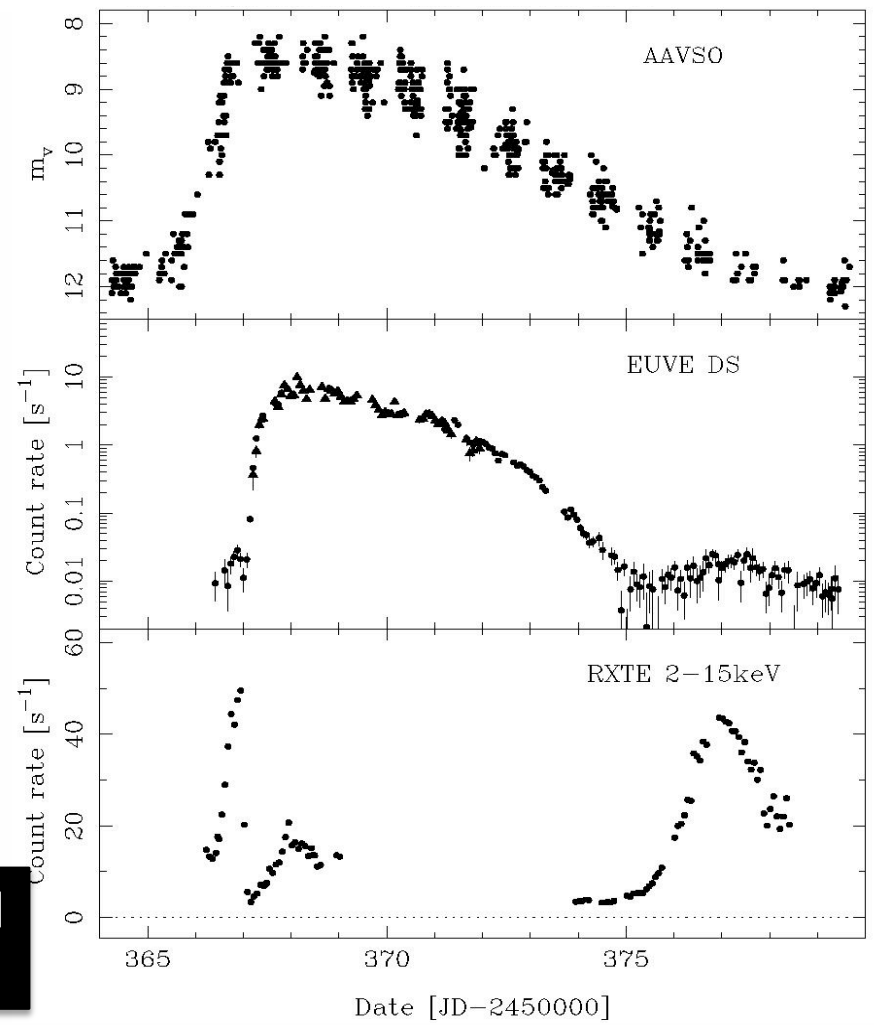
$$\mu \leq 10^{34}\ Gcm^3$$
$$R_* << R_M < a$$

Polar
(AM Herculis star)

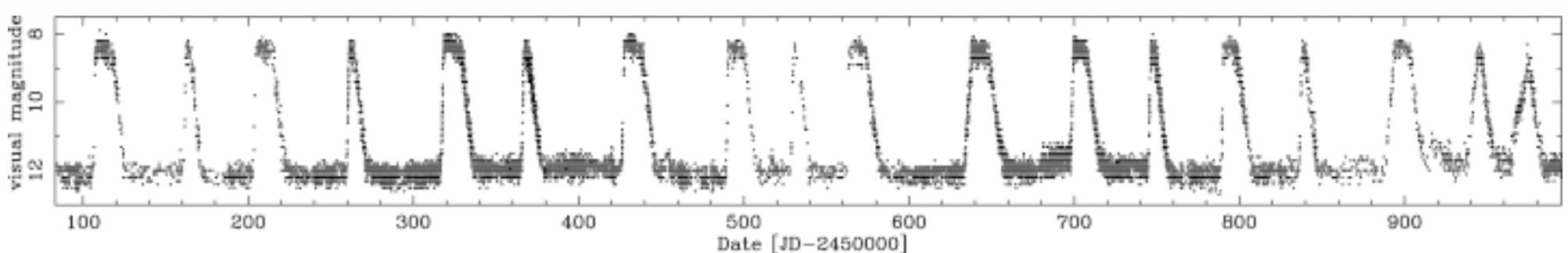
$$\mu \geq 10^{34}\ Gcm^3$$
$$R_* << R_M \approx a$$

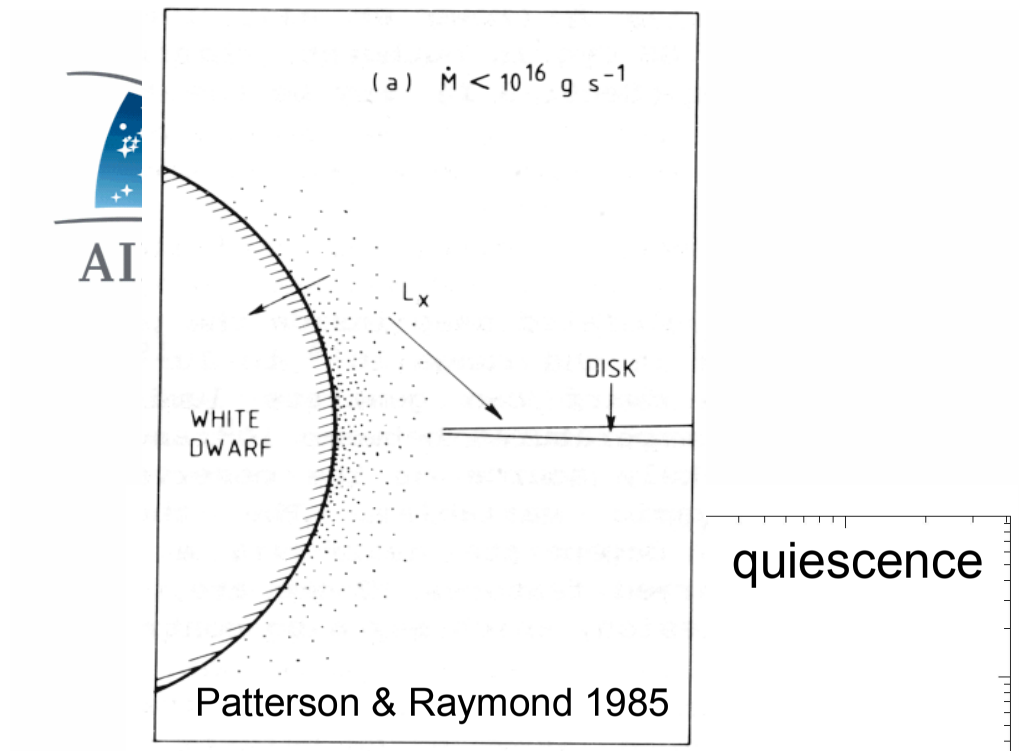
AIP





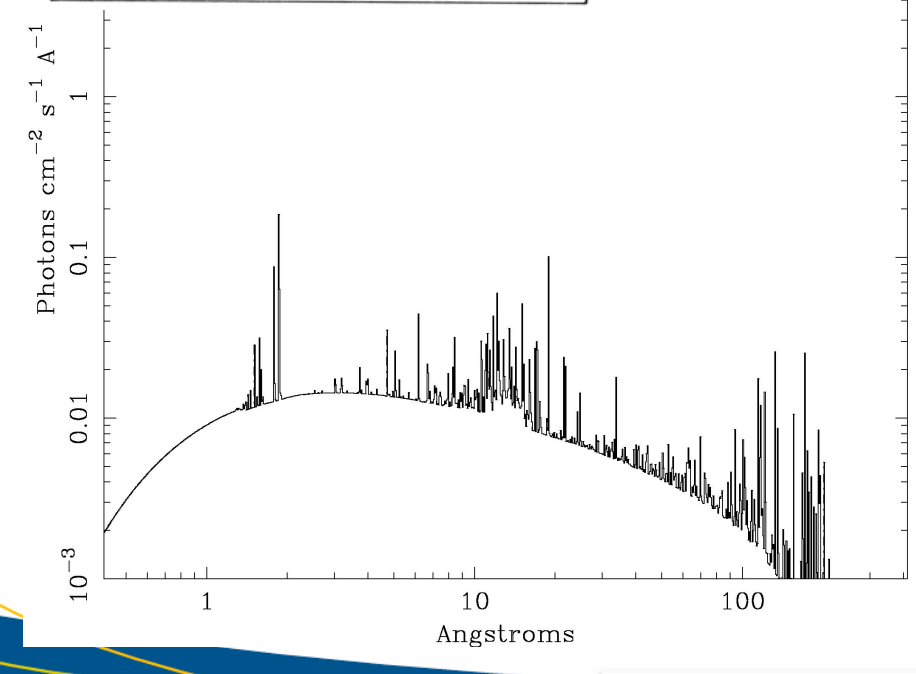
Figures from Wheatley et al 2003, MN and AAVSO (bottom)

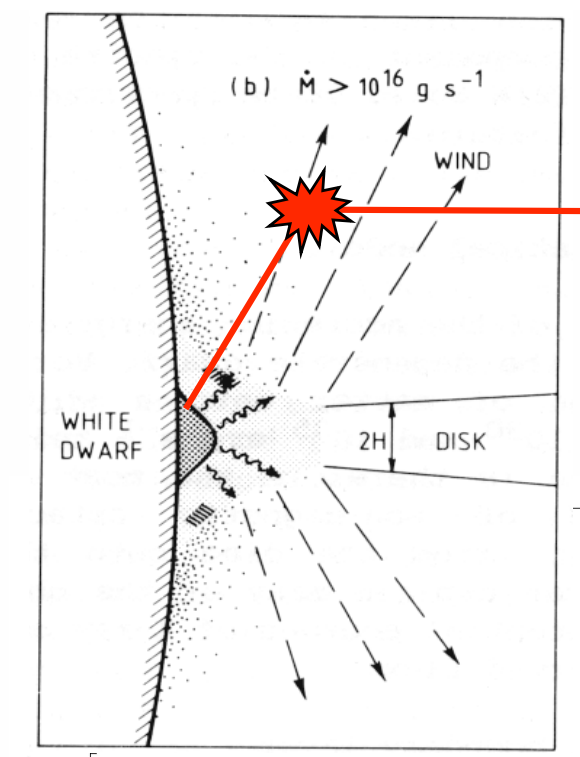




Patterson & Raymond 1985

quiescence





N_H~3x10^{19} cm^{-2}

outburst

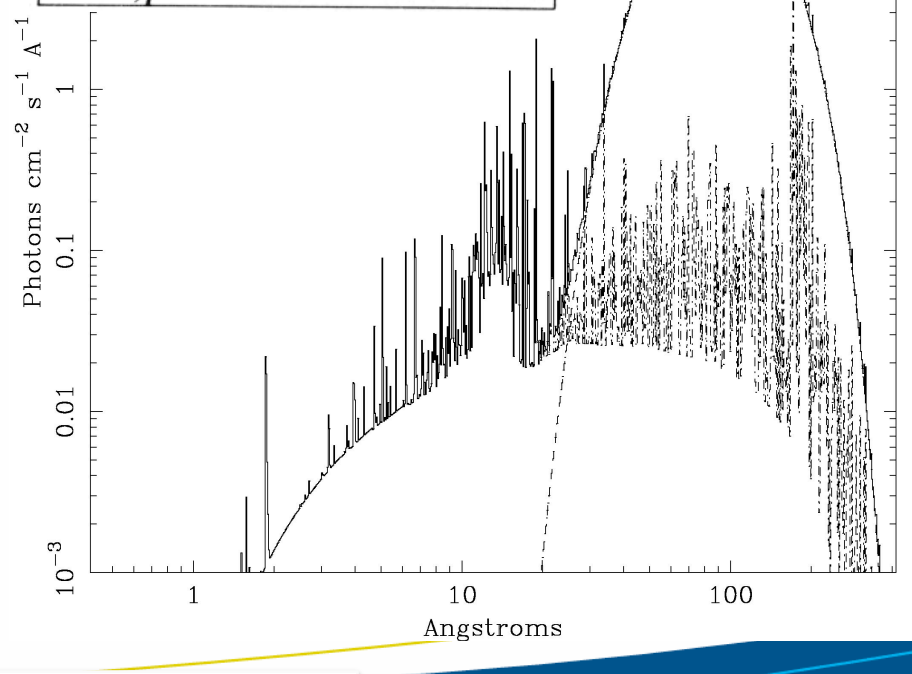
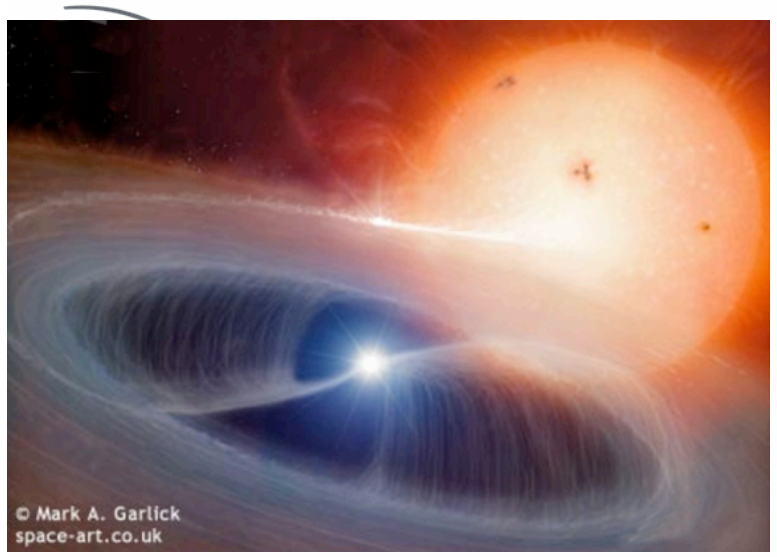
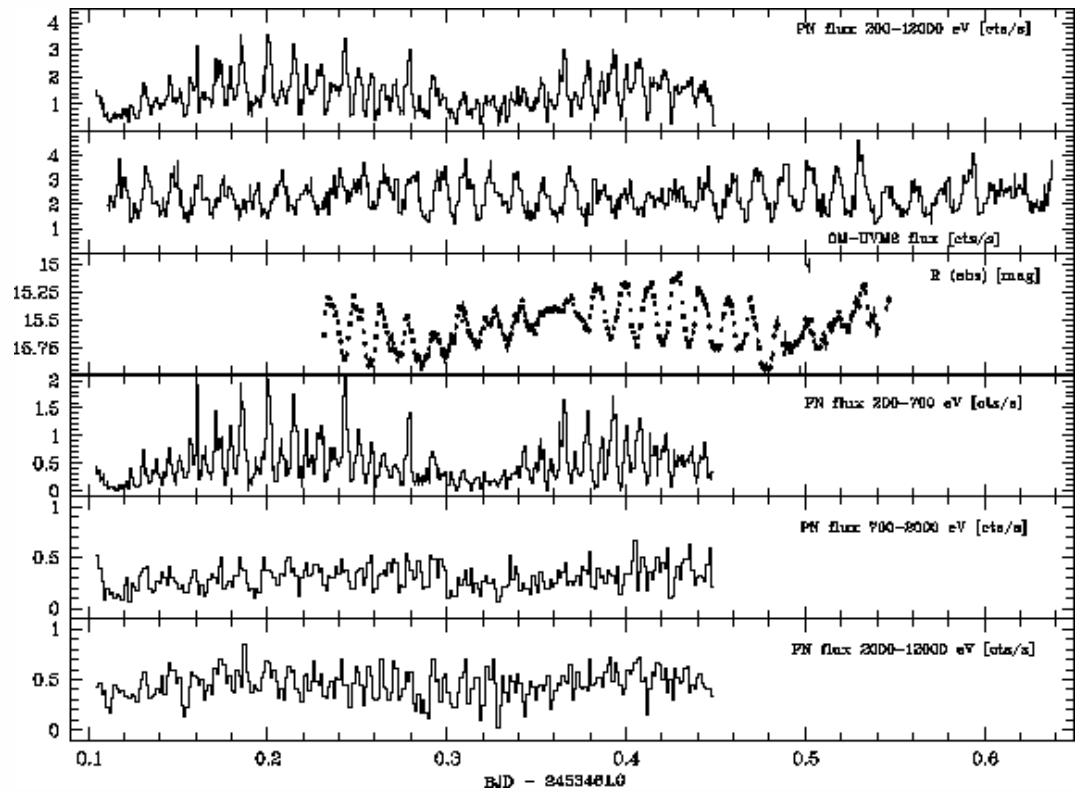
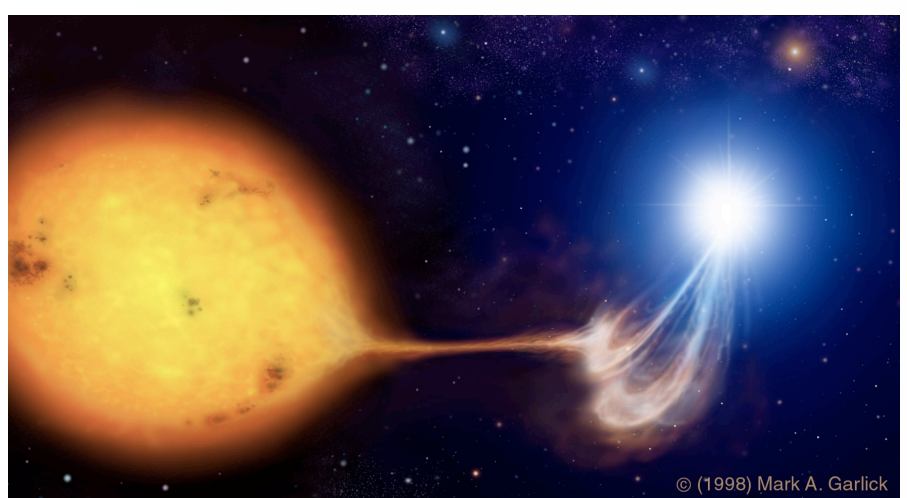


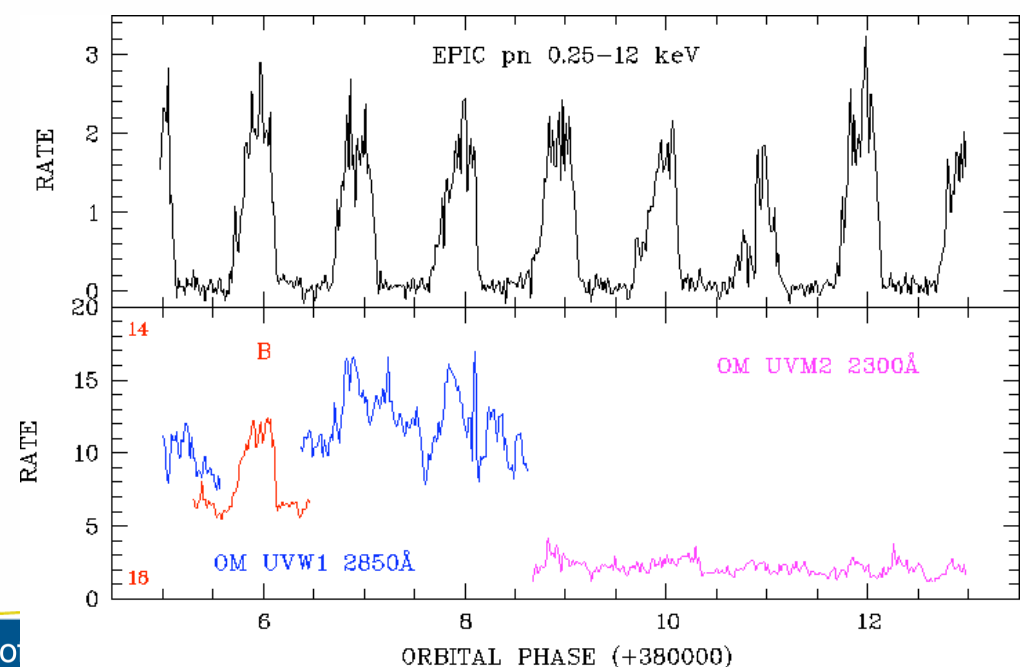
Fig. Courtesy Pete Wheatley



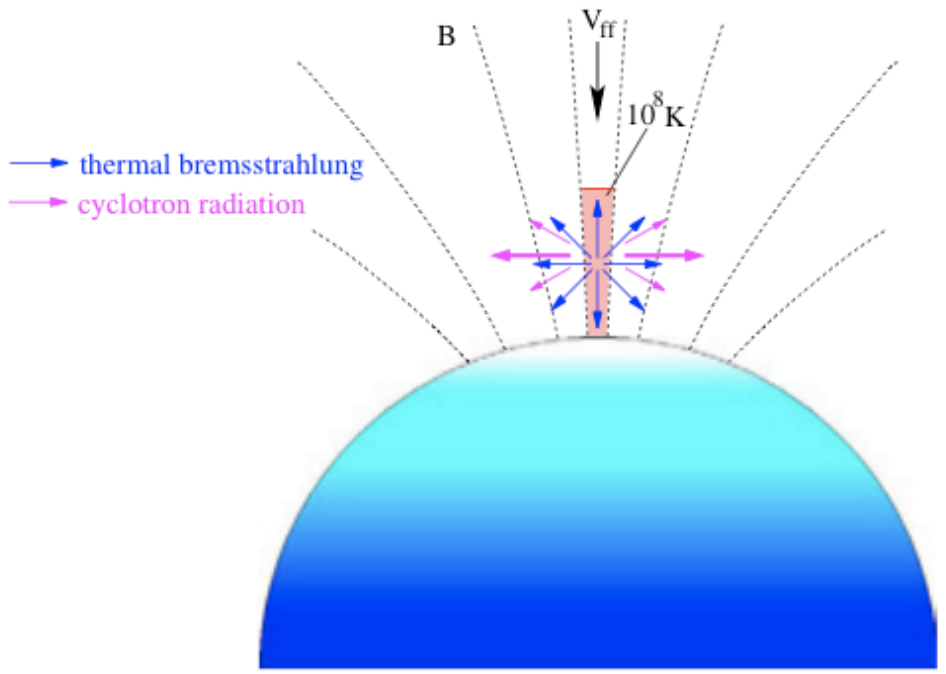


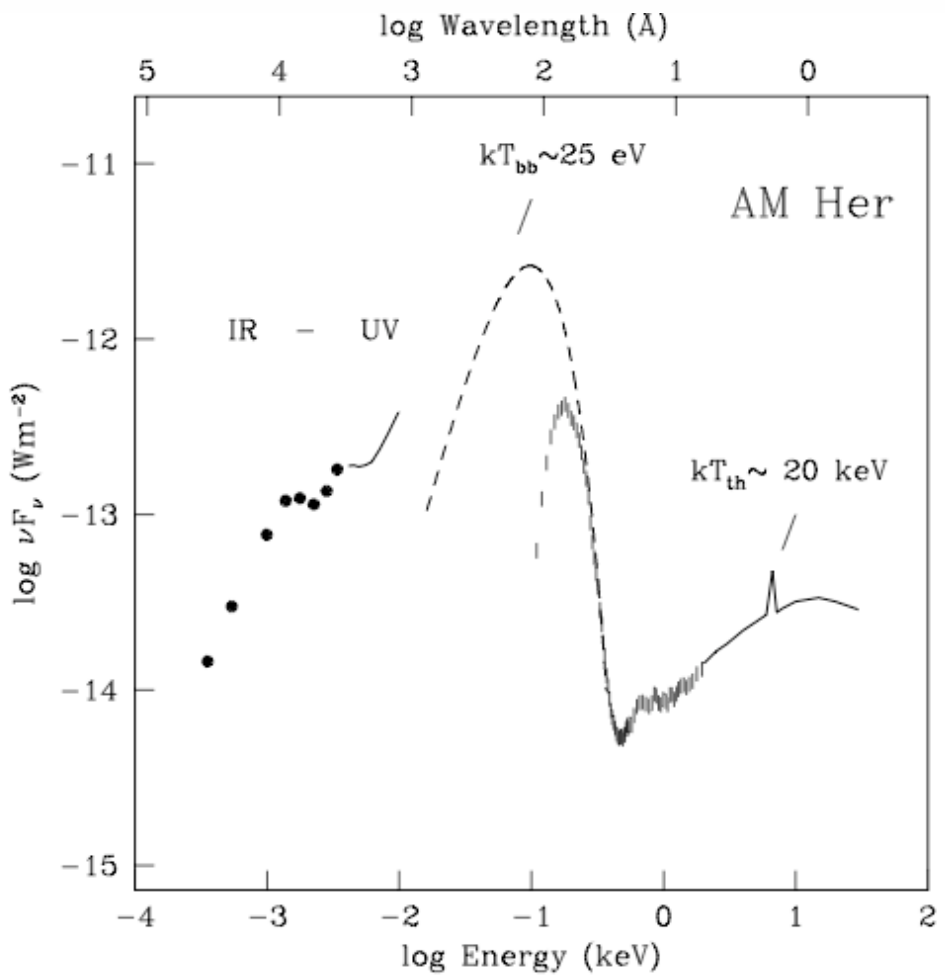
Figures from Staude et al 2008 (AA 486) and Schwope et al. 2008 (X-ray Universe 2008)





Accretion column and SED





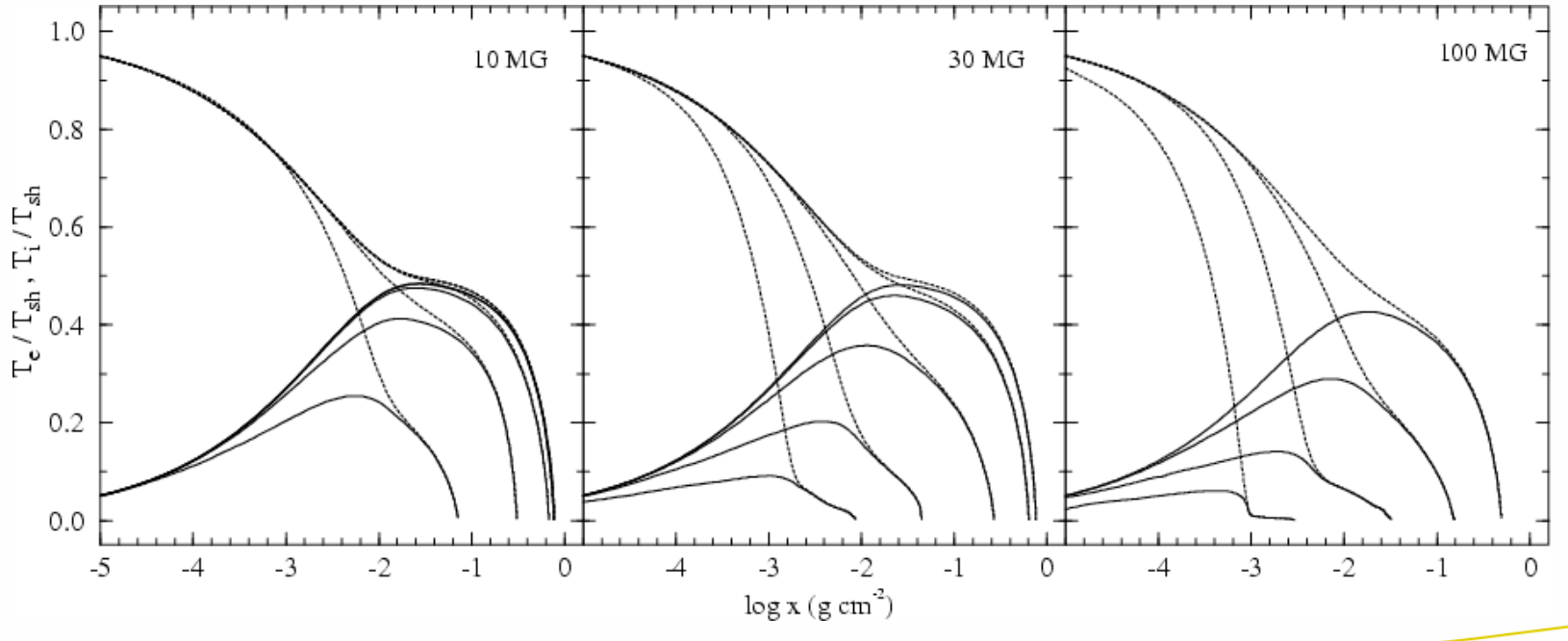
Figures from Beuermann 2003, ASP

Conditions in the accretion column

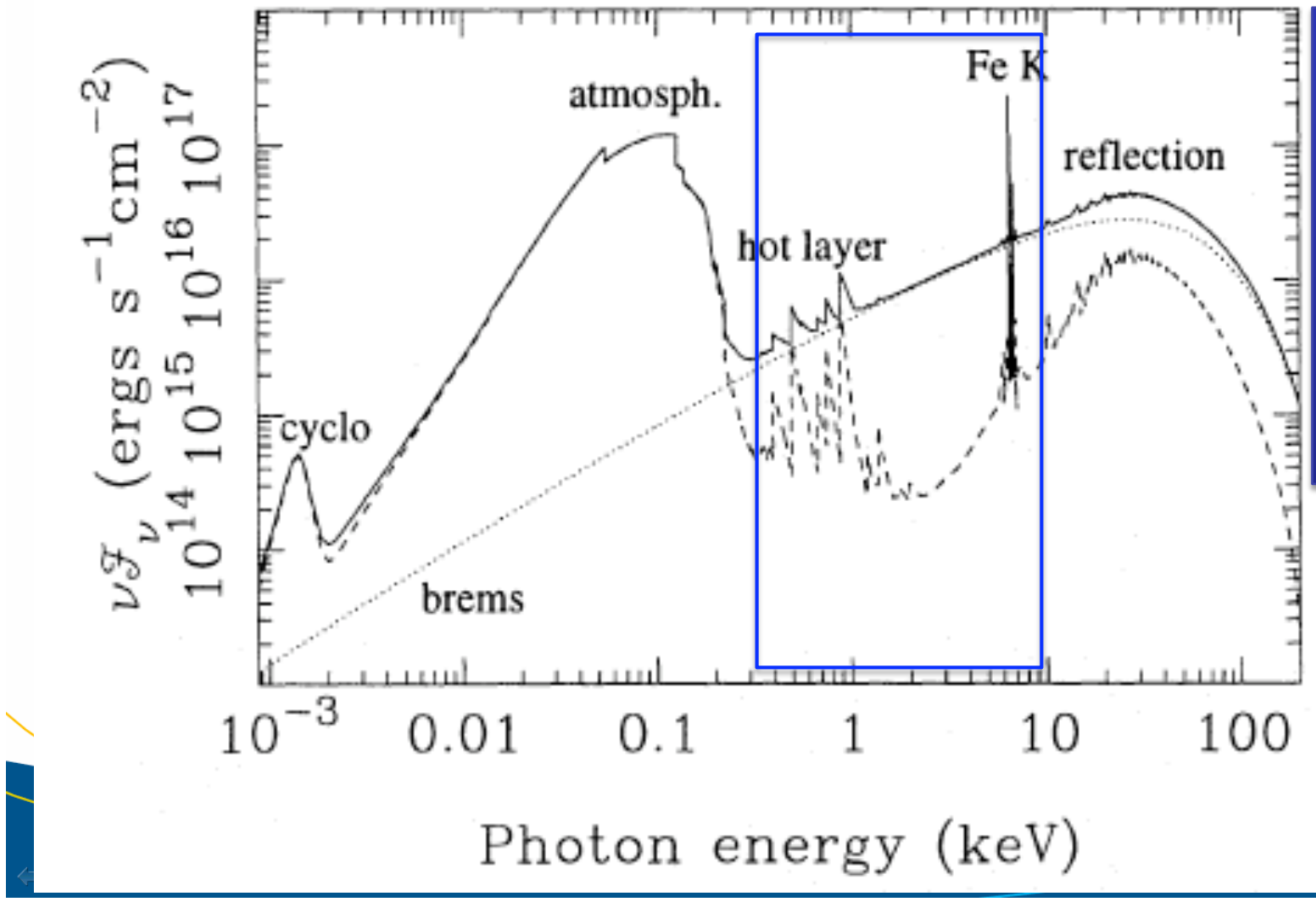
(Fischer & Beuermann 01, AA)

Governing parameters: M_{WD}, dm/dt, B

Shock heating (hydro) vs particle heating
Cooling via thermal plasma and cyclotron (RT-1D)



Column environment:
Reprocessing, Fe fluorescence and Compton reflection
(v. Teeseling+96, AA)



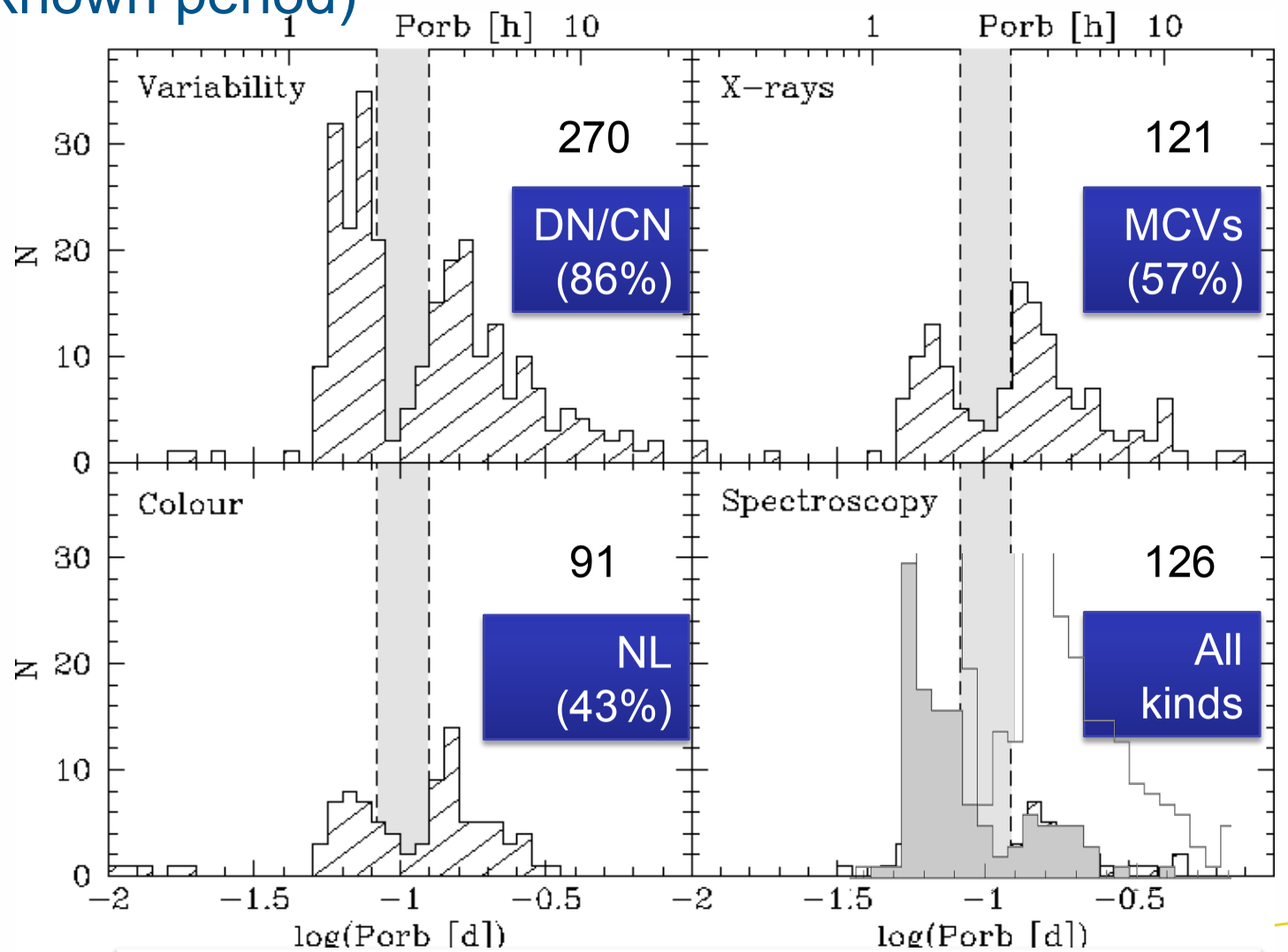
Multi-T thermal spectra aka cooling flow

Cold & warm absorbers

Compton reflection hump

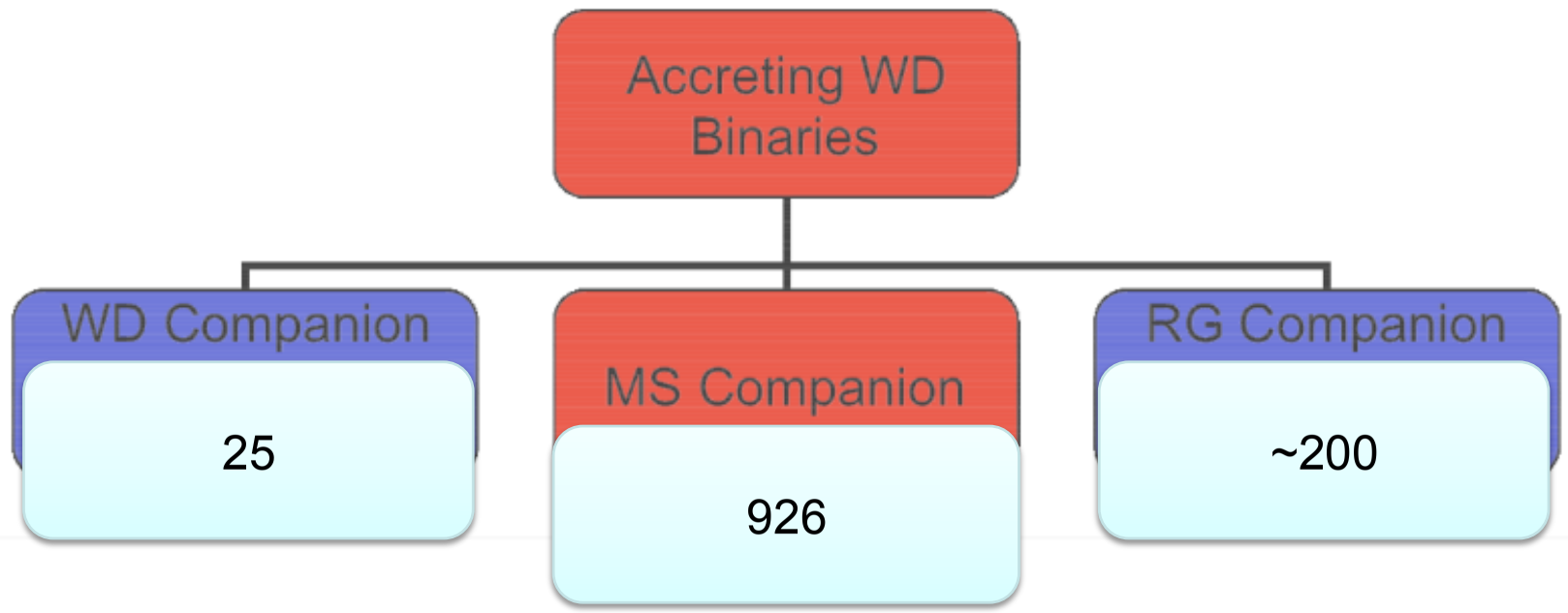
How to find a CV

(detection history for 531 CVs in RK03 with known period)



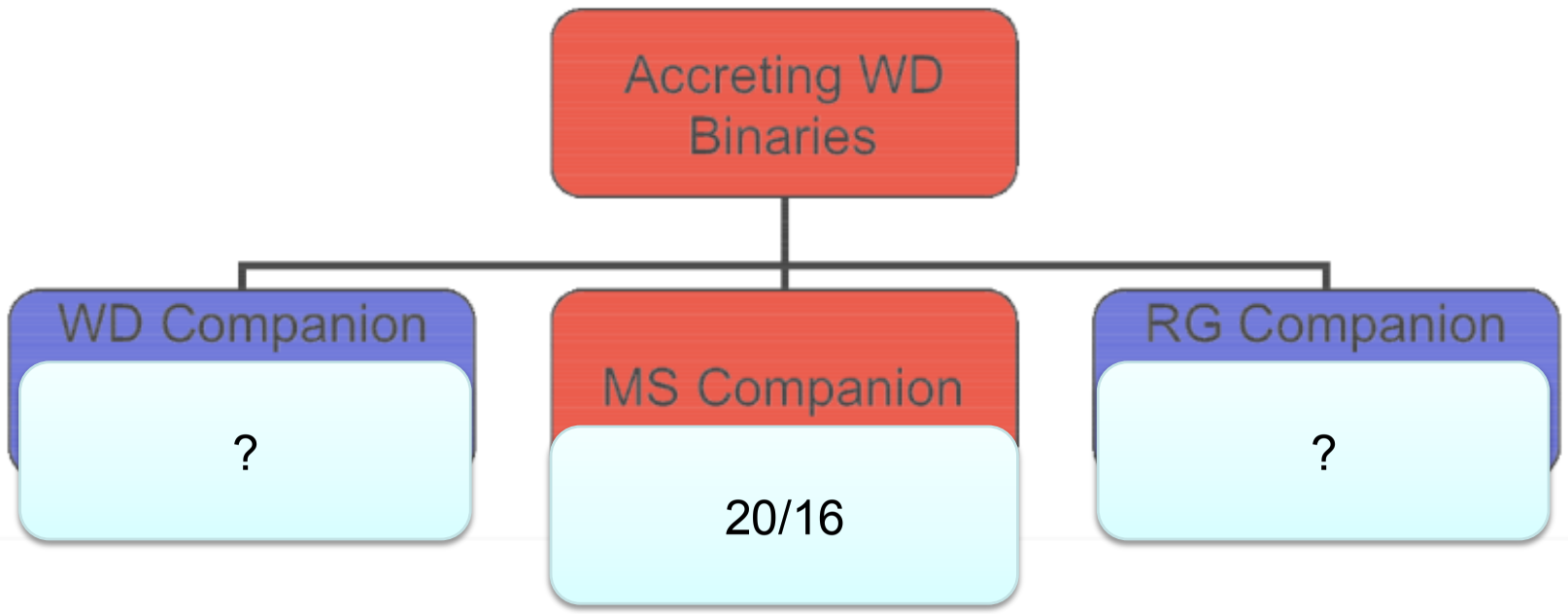
Gänsicke 2005, 2009 (ASPC & MNRAS)

Numbers



CVs: RKcat7.16; Jun 30, 2011
Symb: Belczynski et al. 2000, A&AS 146, 407
DDs: Nelemans 2011 (wiki)

X-ray flux-limited, distance known



Non-magnetic CVs: Schwope+2002, Pretorius & Knigge2011
Magnetic CVs (IPs): Revnivtsev+2008 (distance estimated)

Q: CV Demography

- What is the luminosity function?
- What is their galactic scale height?
- What‘s the CV contribution to the GRXE?

Luminosity functions

ROSAT

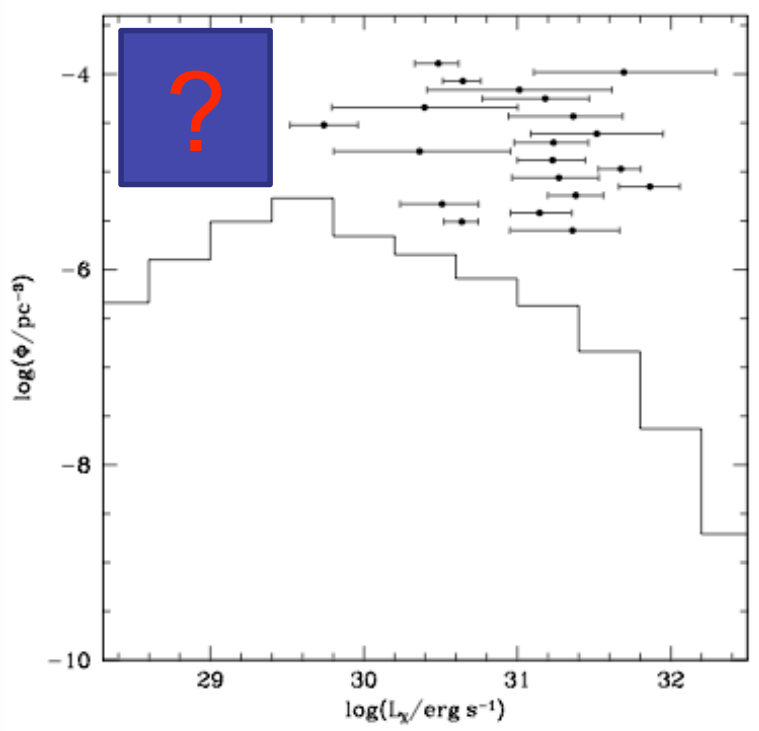


Figure 3. The histogram shows the observed X-ray luminosity function. As explained in Section 4.2, the calculation that yields this histogram does not produce an estimate of the errors on it. The points with error bars show the estimates of L_X for the 20 non-magnetic CVs that the calculation is based on (these points are arbitrarily offset in the vertical direction, for display purposes).

INTEGRAL

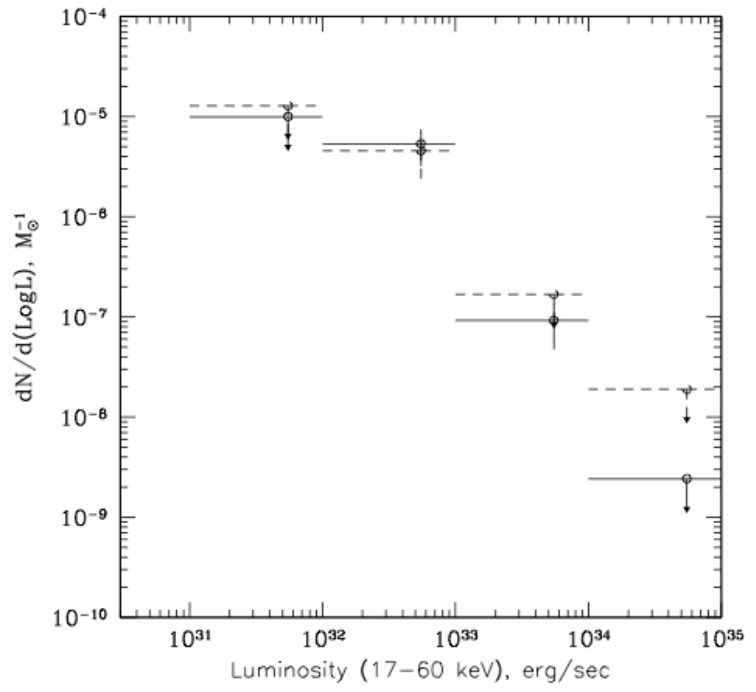


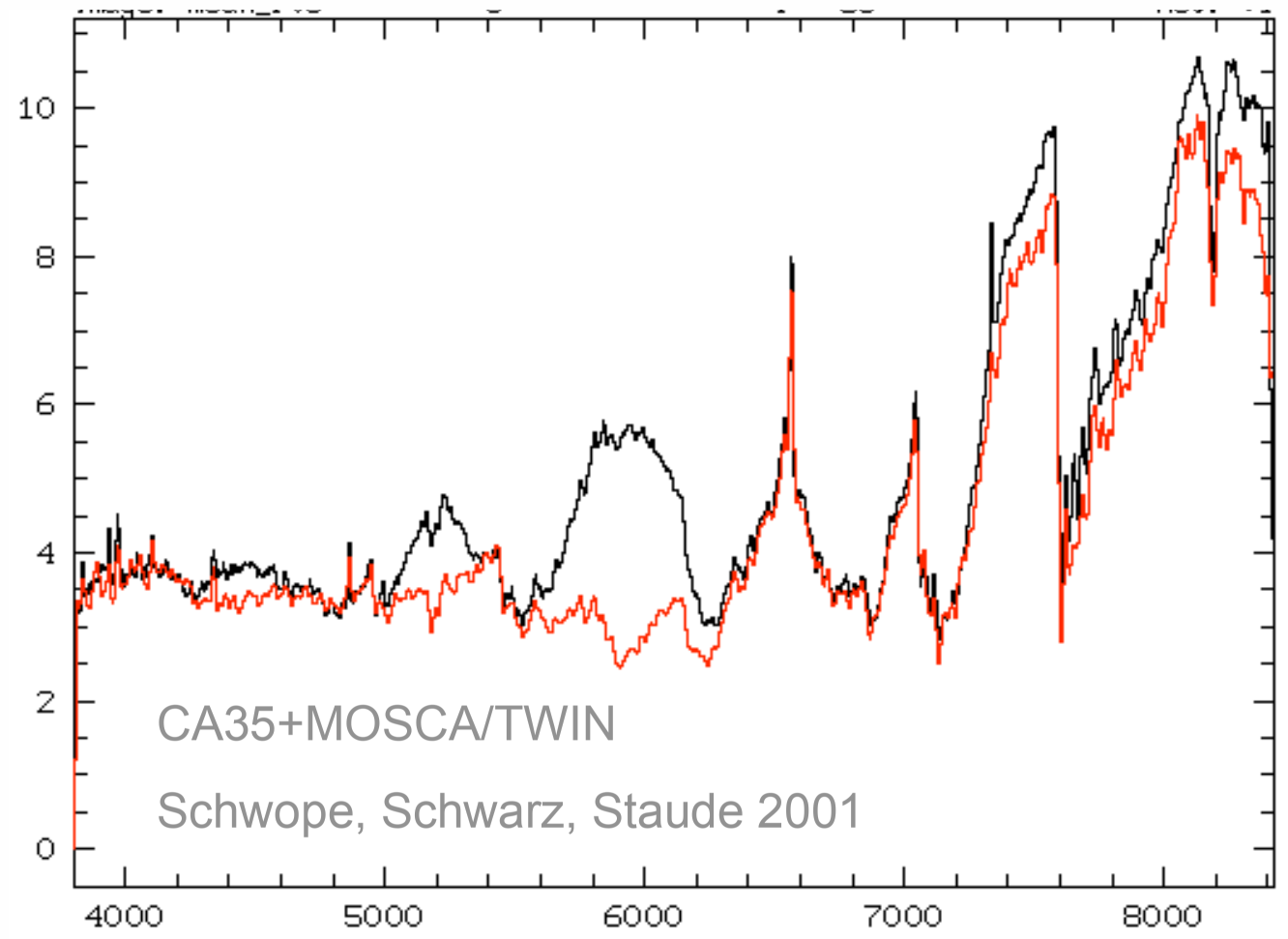
Fig. 3. Luminosity function of CVs detected by the INTEGRAL all-sky survey (solid crosses). Dashed crosses show the luminosity function constructed from those INTEGRAL CVs located at $|b| > 5°$, where the survey identification is almost complete. Arrows denote 95% upper limits to the space density.

Pretorius & Knigge 2011
20 non-magnetic CVs

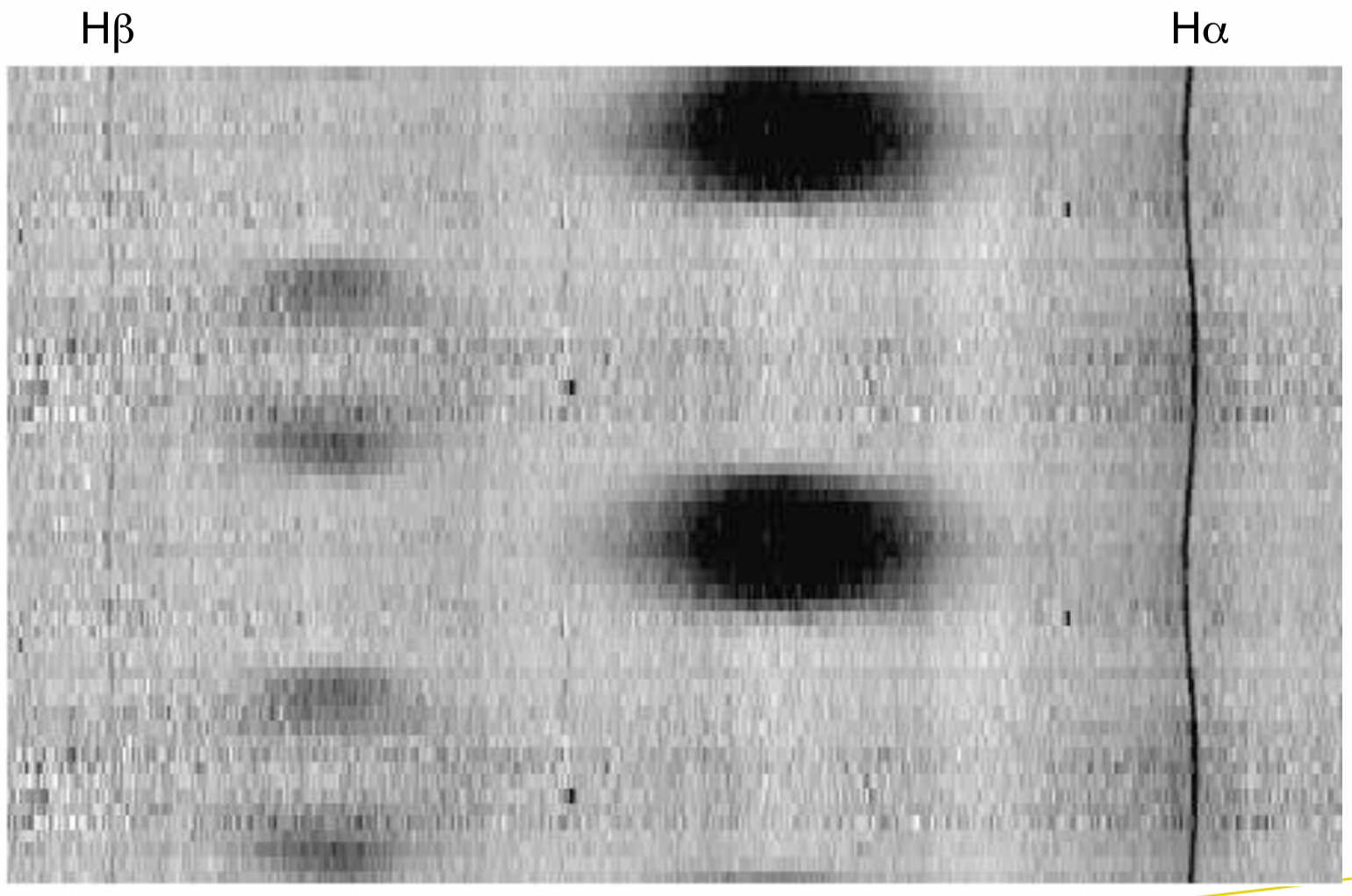
Revnivtsev+2008
~15 IPs

QSO candidate: HS1023+39

(Reimers et al. 1999)



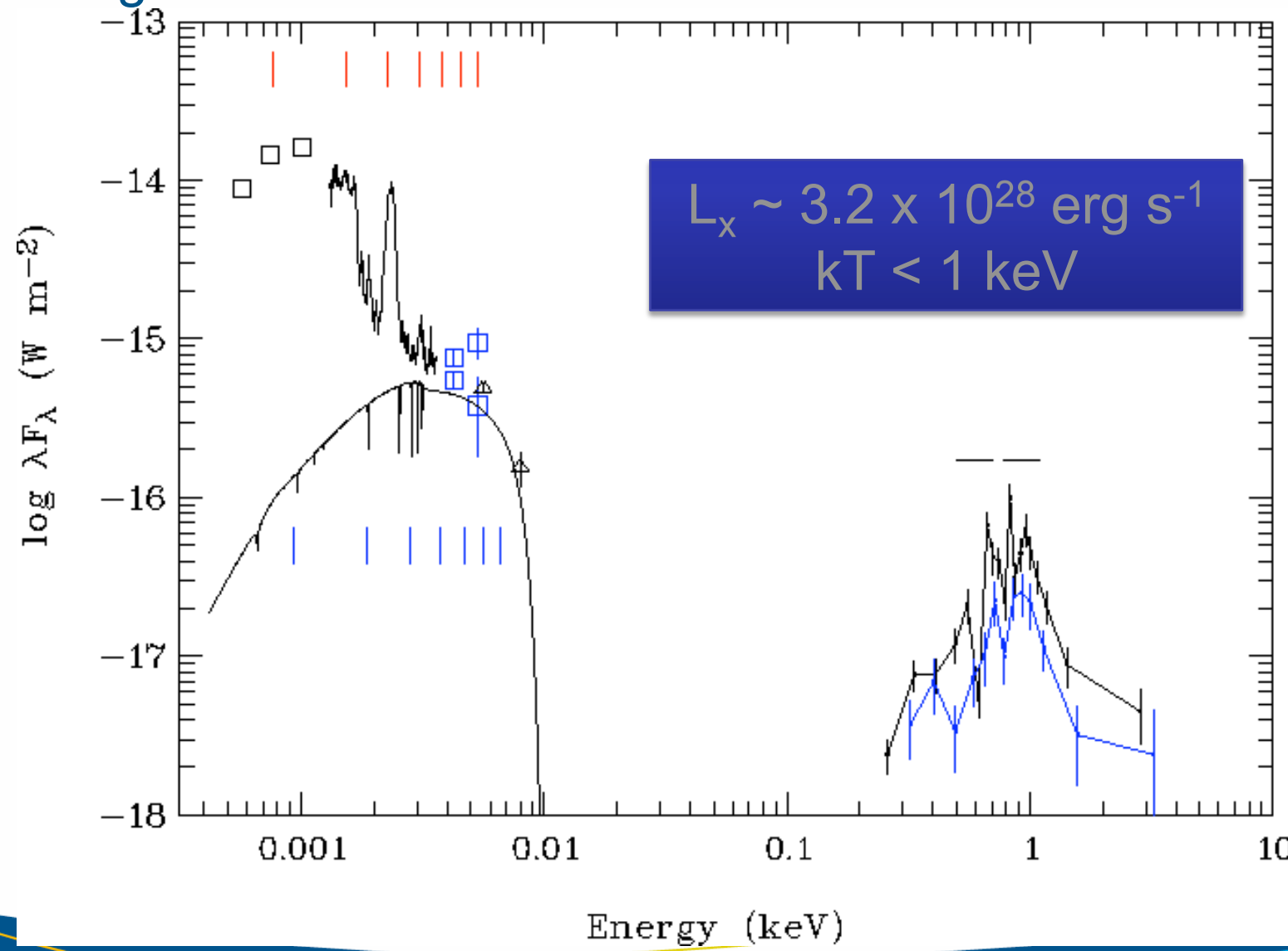
HS1023+3900:
a cyclotron light house



Schwope+04

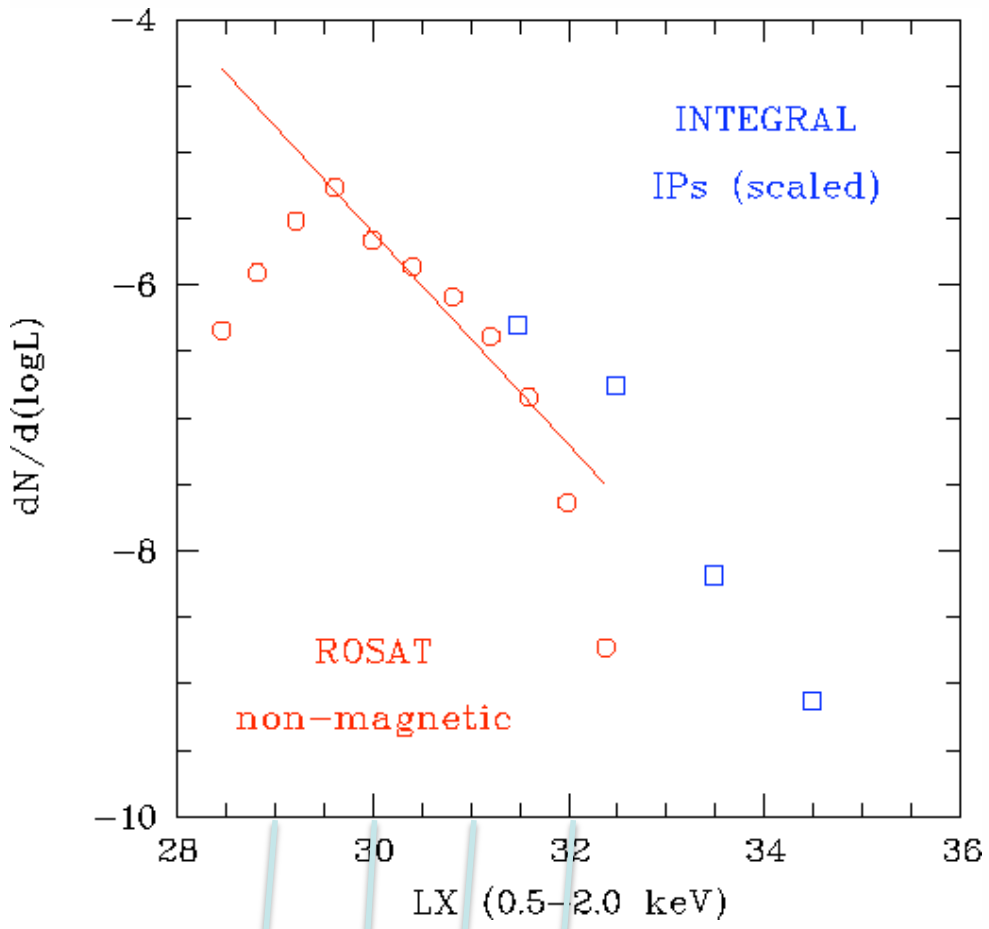
SED HS0922

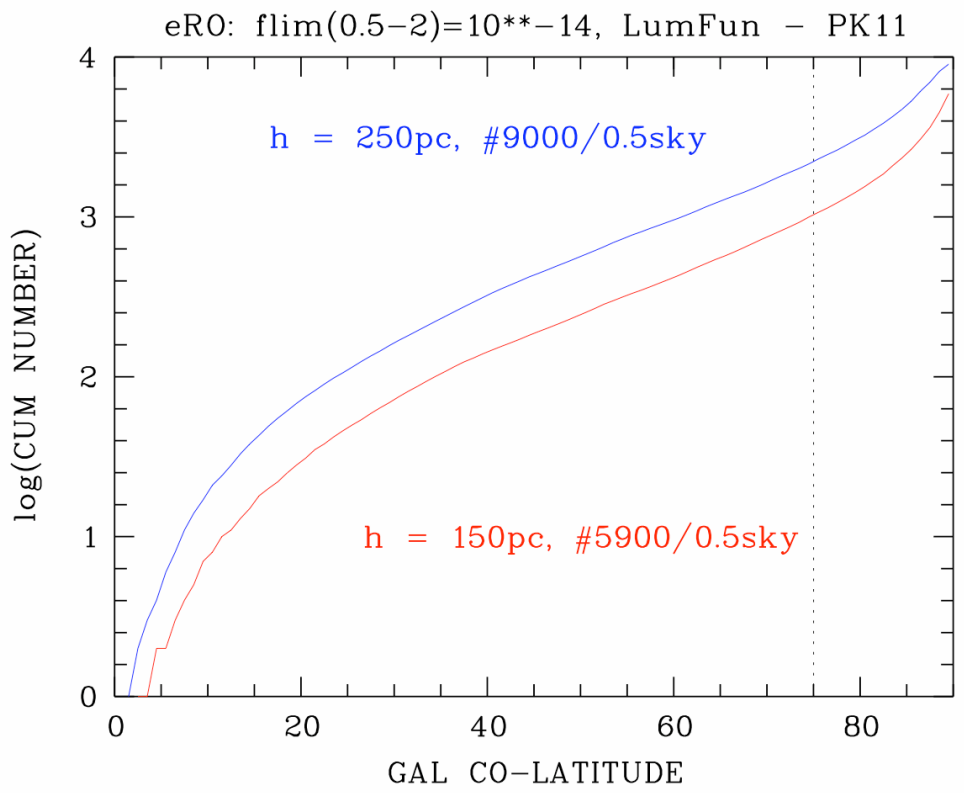
Vogel+11 AA



L_x ~ 3.2 x 10^{28} erg s^{-1}
kT < 1 keV

eROSITA forecast



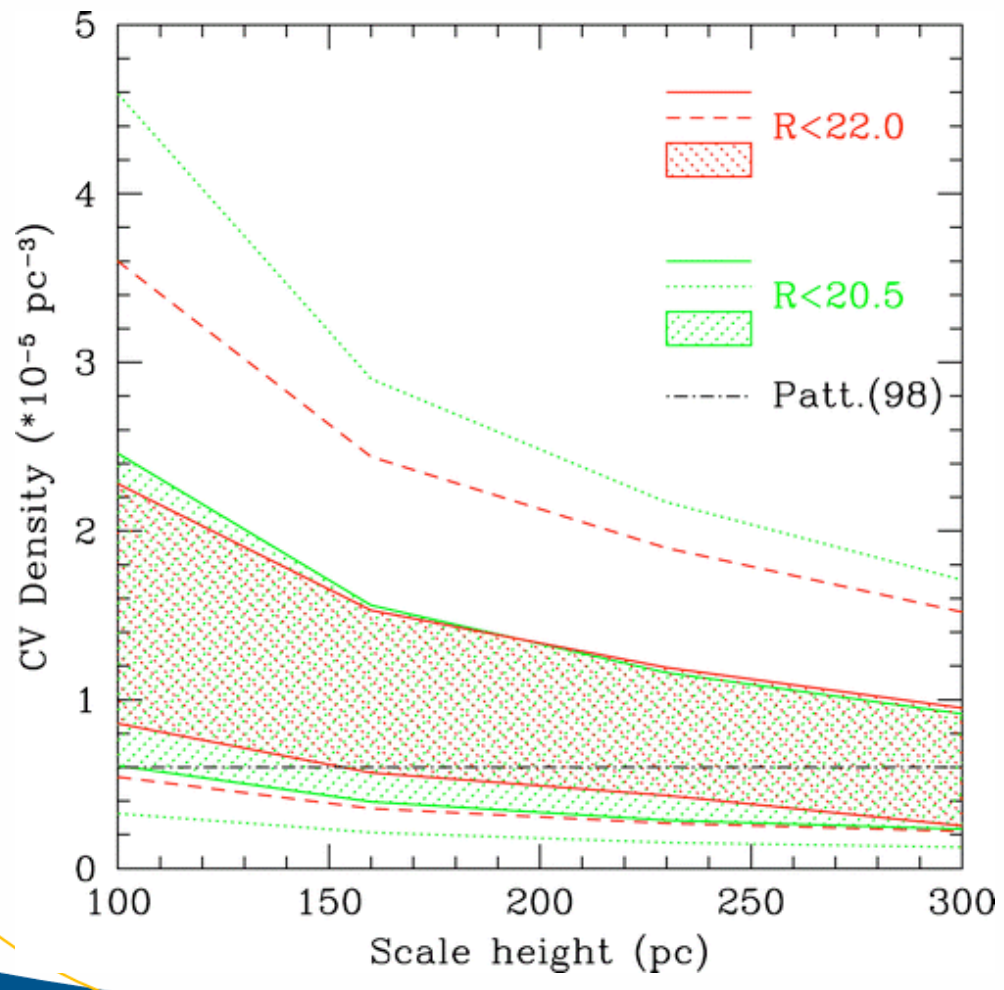


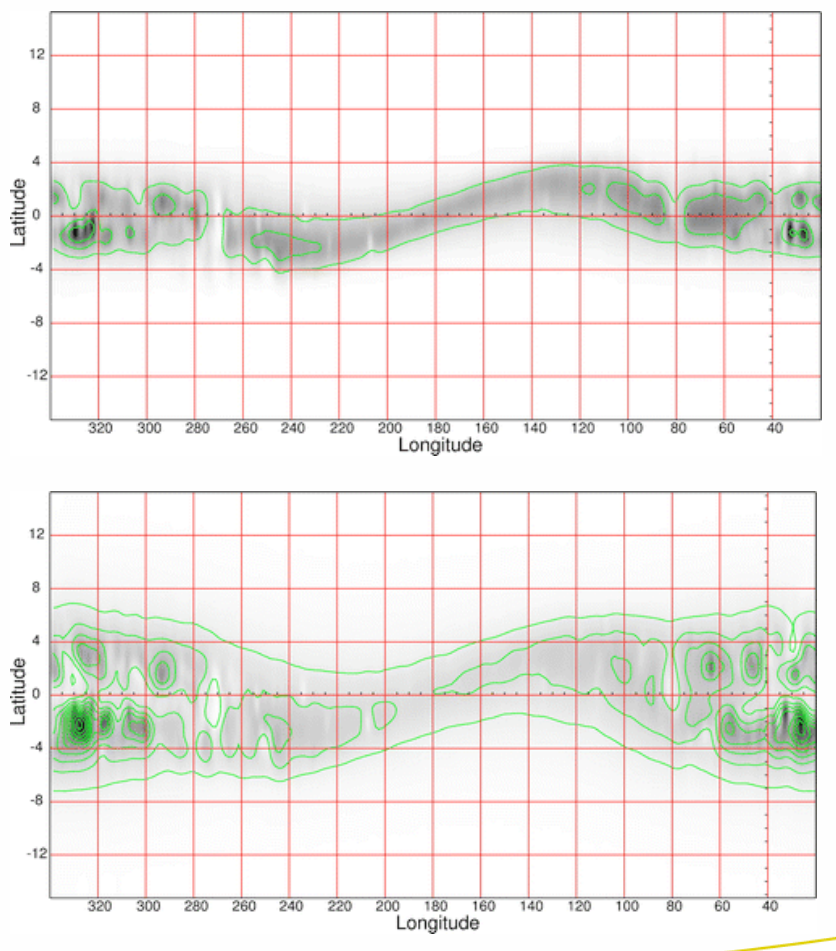
Sazonov+06:
XSS 12 IPs @ 2.5×10^{-11} cgs (3-20)
eROSITA: 2×10^{-13} cgs (2-10)
→ Up to 10^4 IPs all sky

300pc | 900pc | 2900pc | 9100pc

CHAMPLane forecast

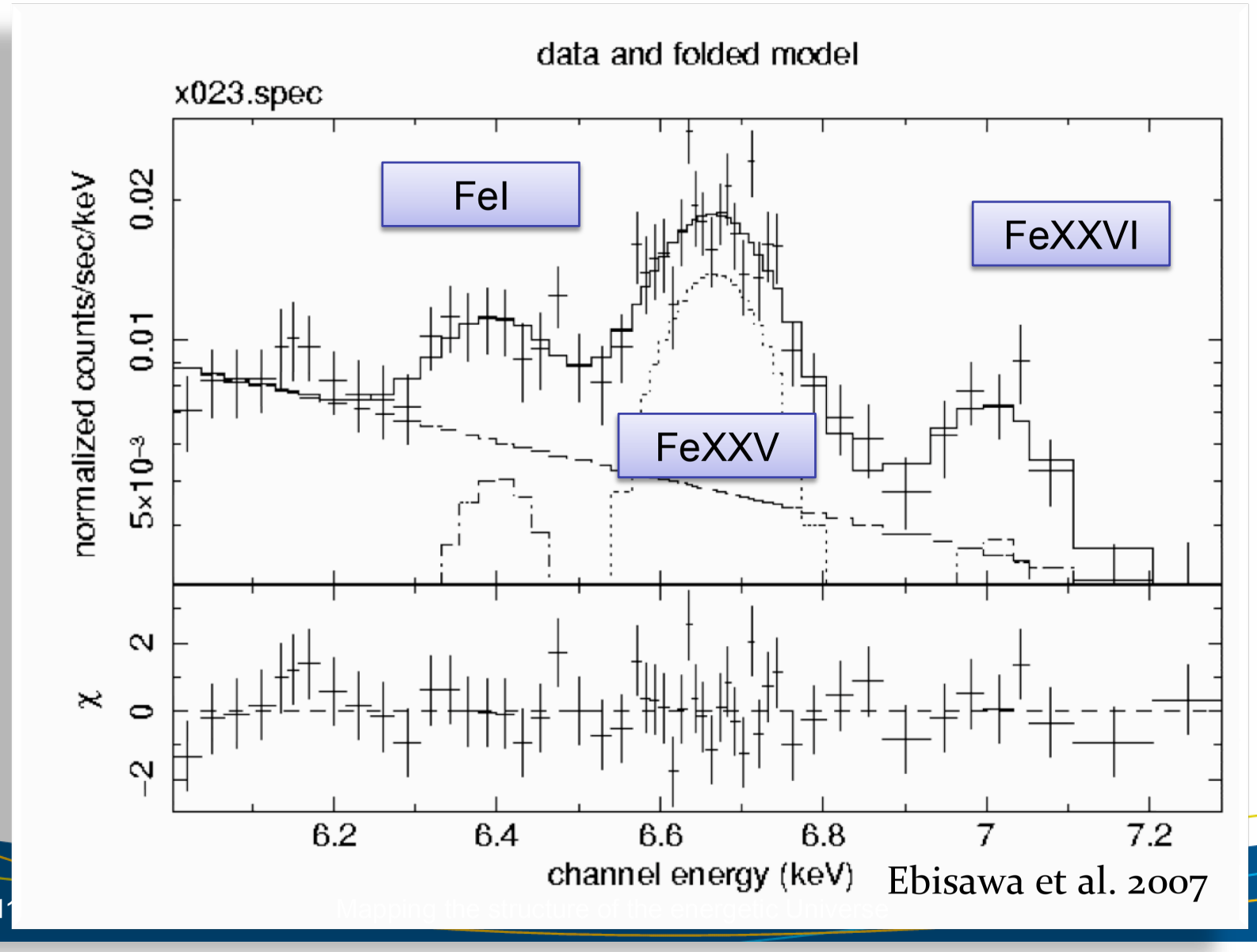
(Rogel et al. 2008)





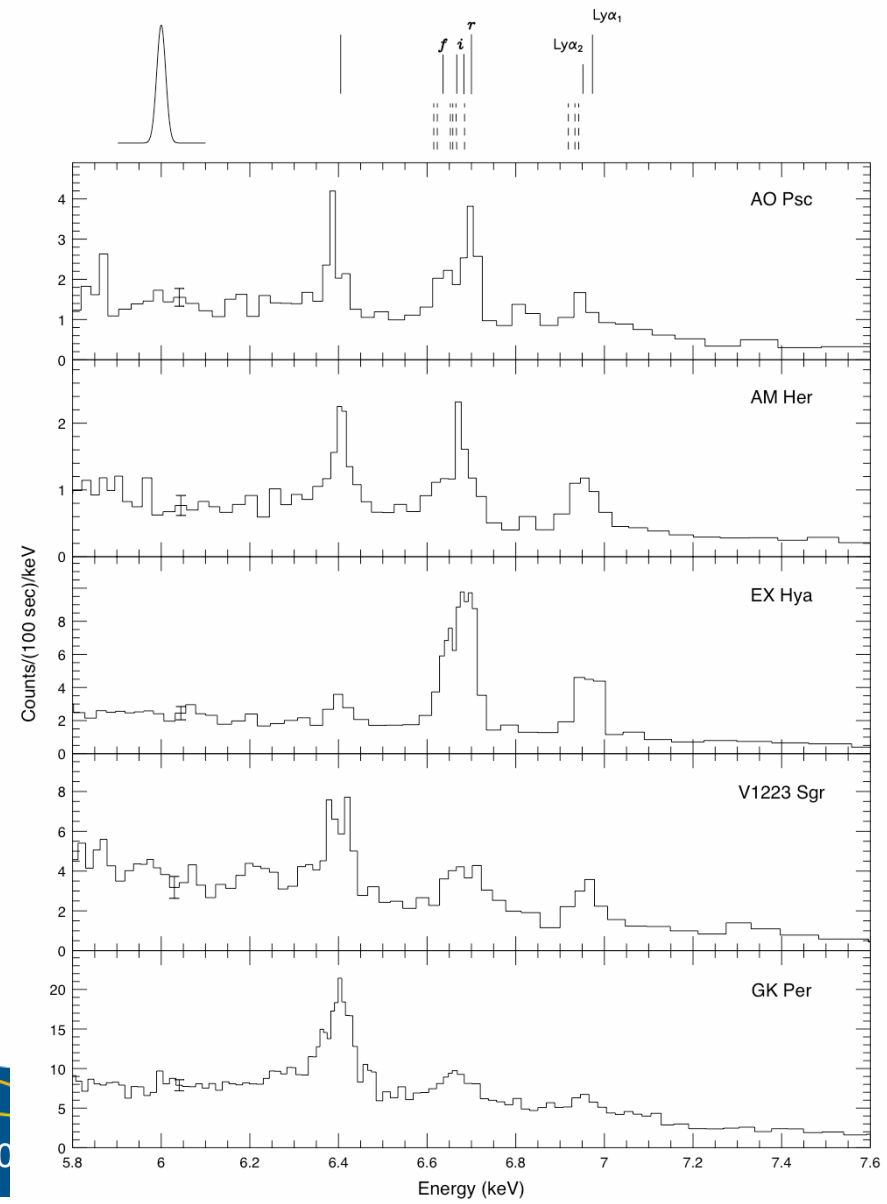
← CV age

SUZAKU GRXE spectrum
The Fe line complex



Ebisawa et al. 2007

MCVs: Fe-line complex at HETG resolution (Hellier & Mukai 04)



eROSITA discovery
4MOST identification
Gaia distance

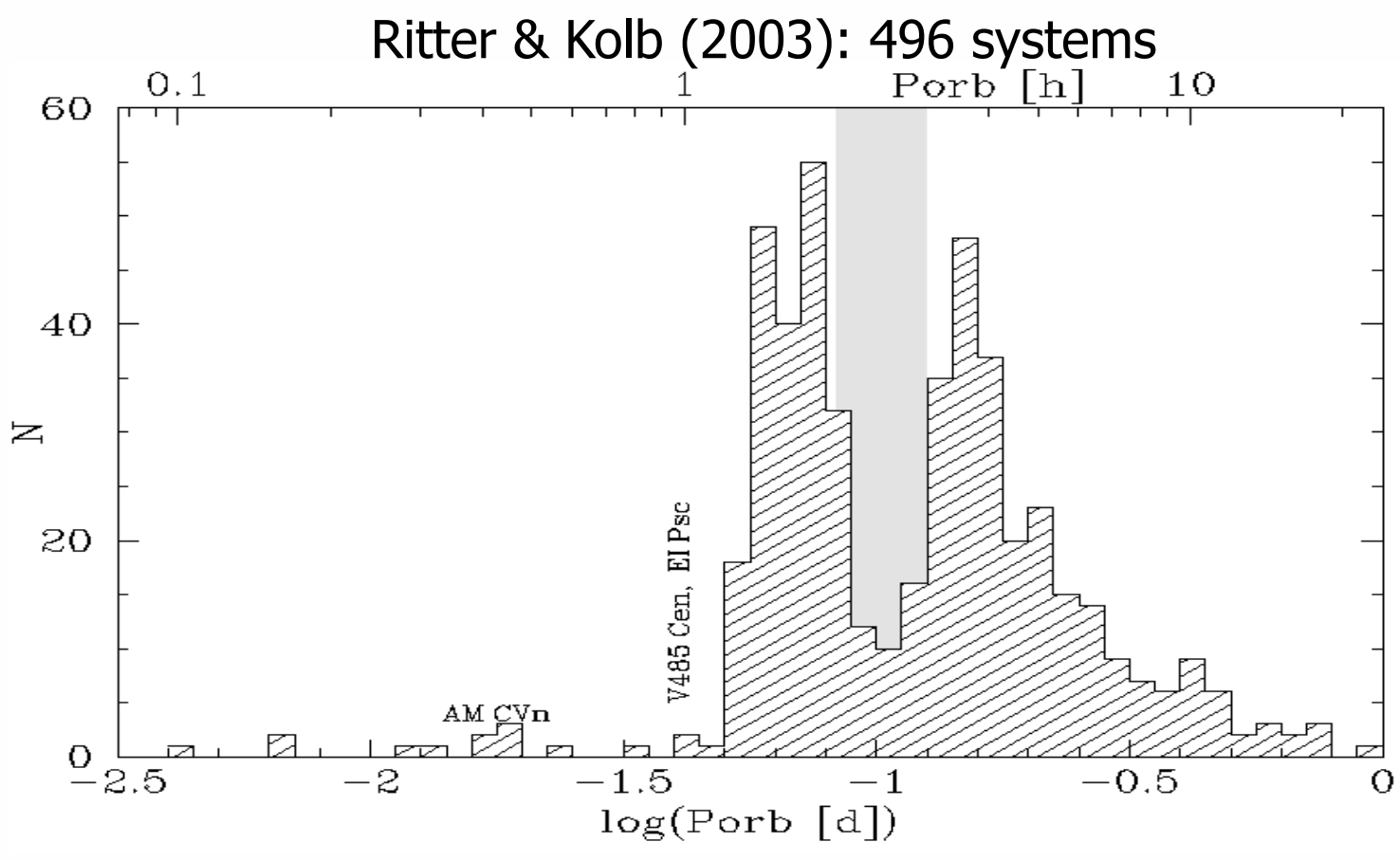
→Local luminosity functions (magn & non-magnetic) and scale height

→Galactic model, GRXE synthesis

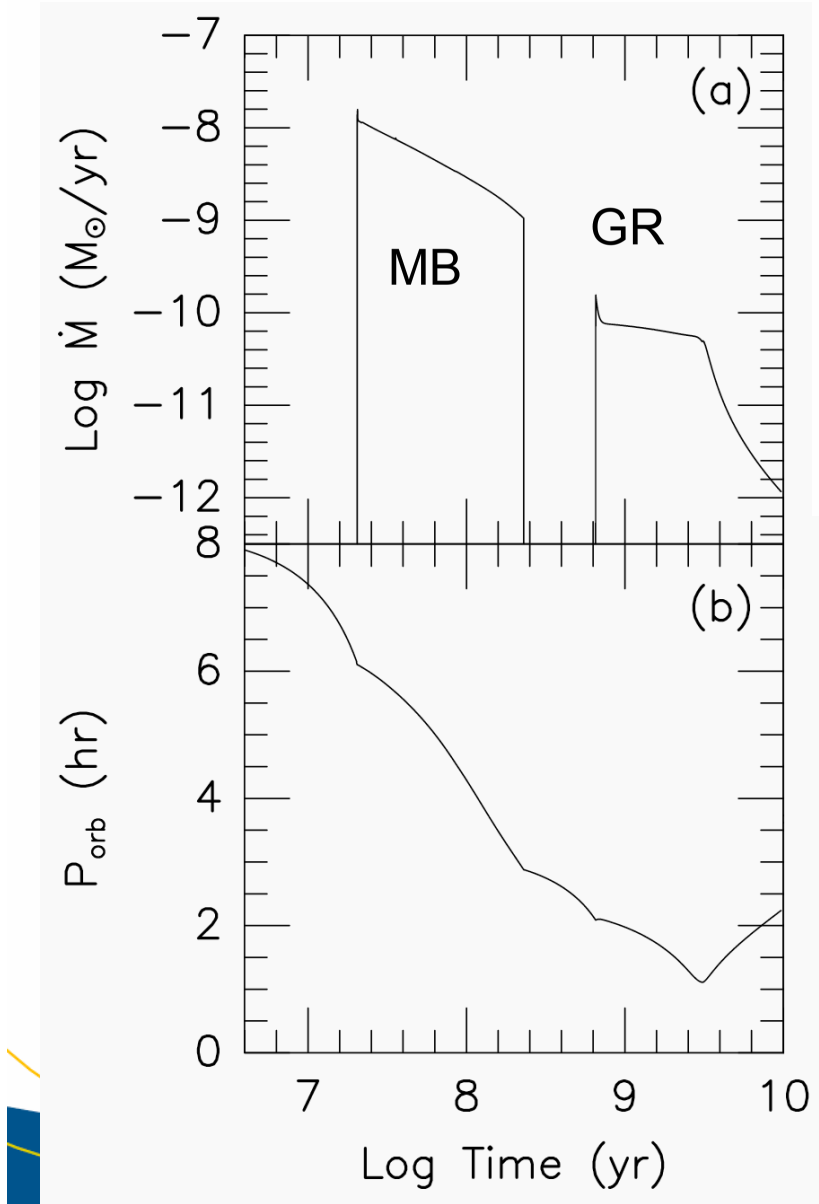
Q: CV evolution

- Does the disrupted magnetic braking scenario applies quantitatively?
- What‘s the impact of WD magnetism on evolution ?

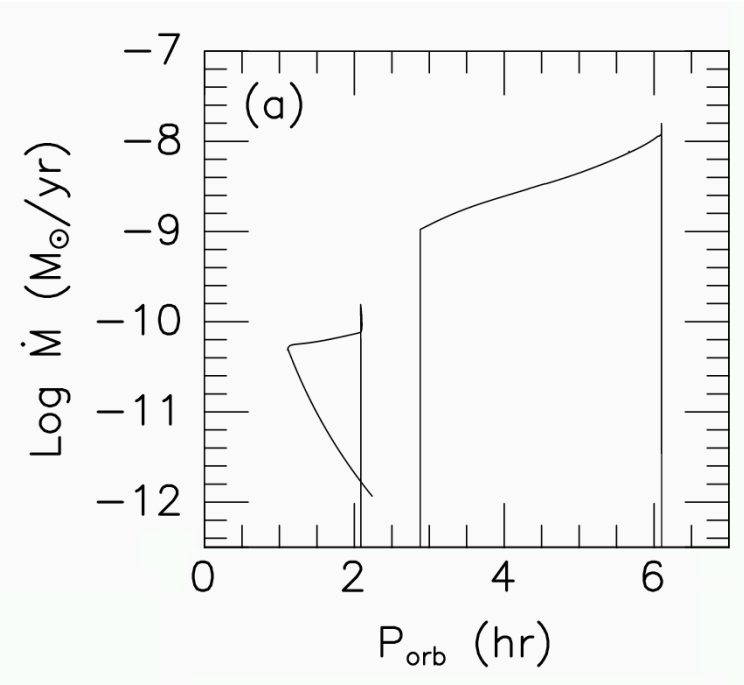
Orbital period distribution



CV Evolution in a nutshell

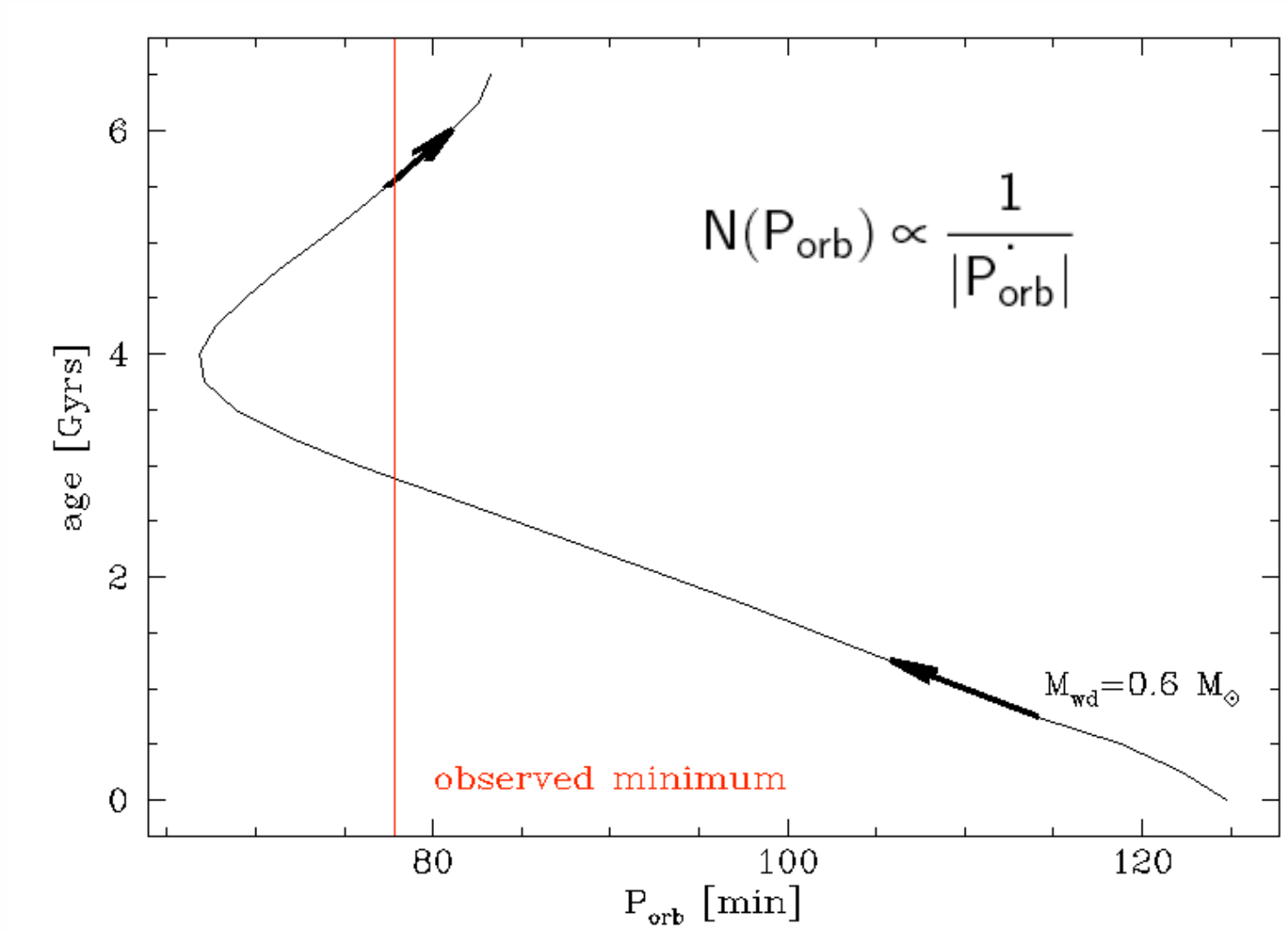


- Angular momentum loss MB/GR
- Porb decreases down to Pmin
- Donor becomes degenerate BD
- Porb increases again



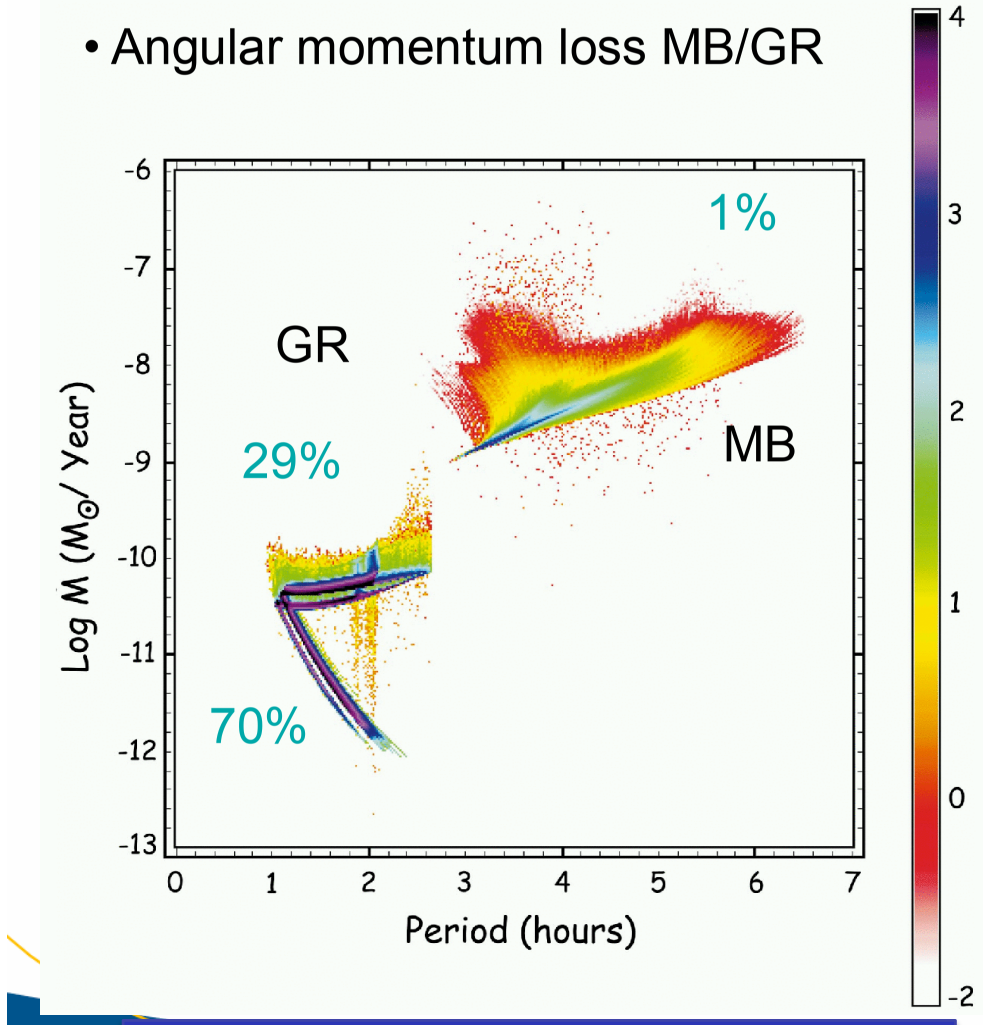
Howell et al. (2001)

Period bouncing



CV evolution in a nutshell

• Angular momentum loss MB/GR



Howell et al. 2001, ApJ 550, 897

Testing the prediction:

How strong is MB?

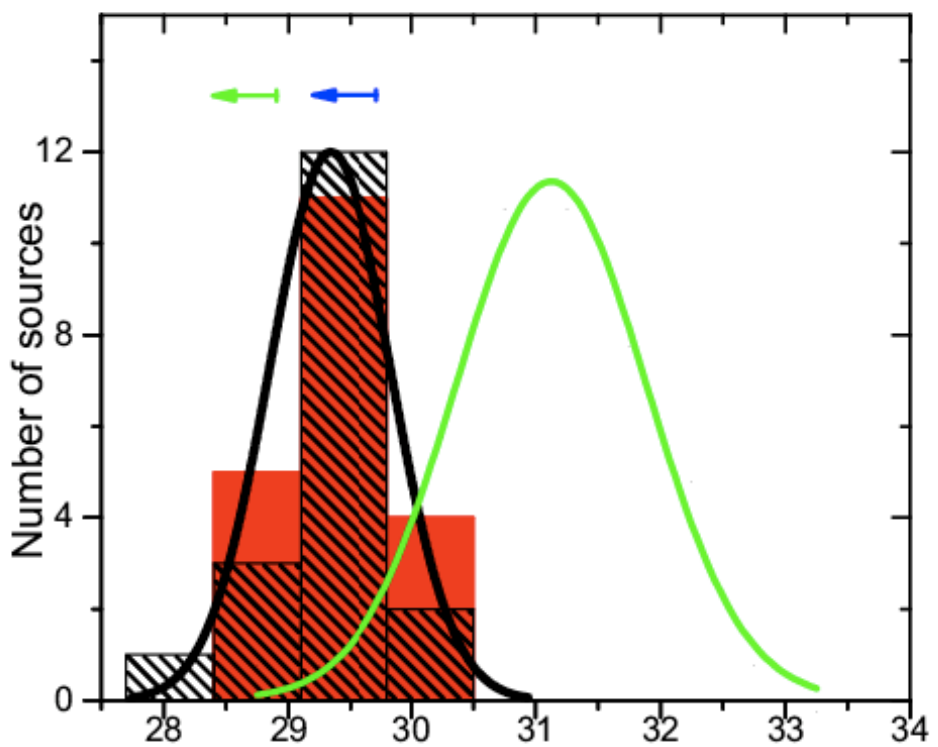
Where are the period bouncers?

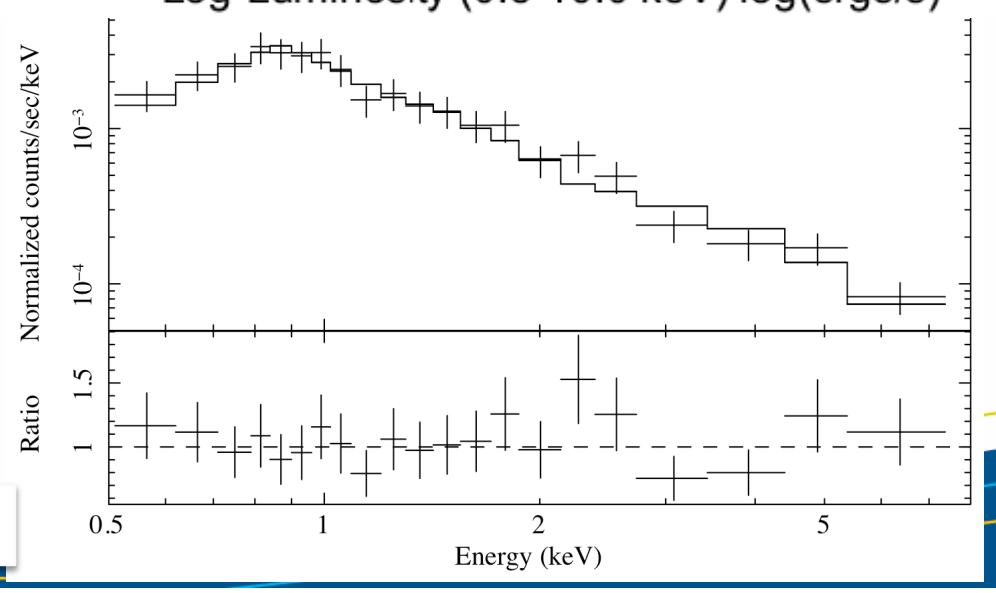
Establish complete samples with periods measured

X-ray luminosities of white-dwarf dominated CVs

Reis et al., in prep

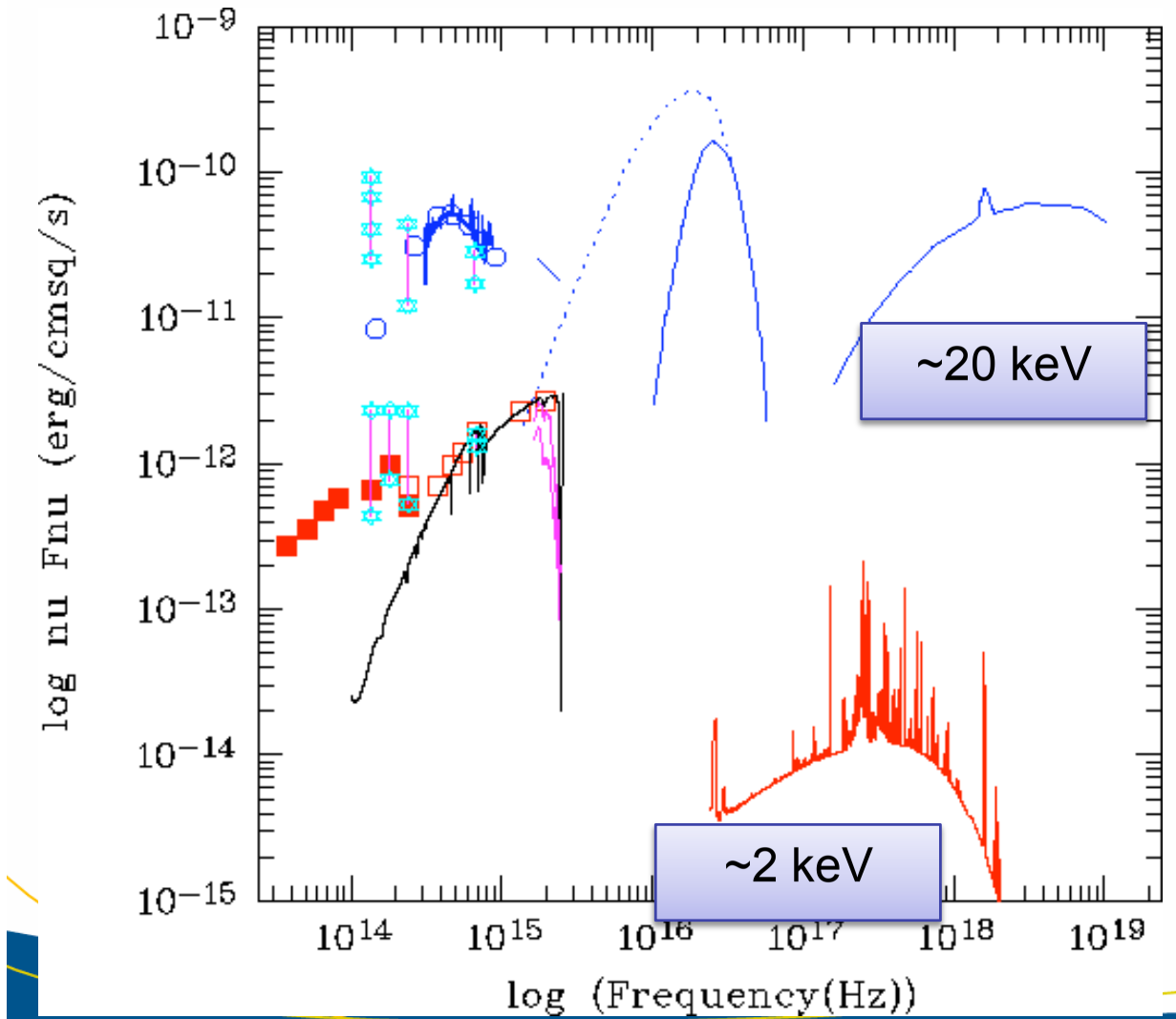
Target name	Luminosity (0.5–10.0 keV) ($\times 10^{29}$ erg s^{-1})
HS2331+3905	0.4 ± 0.1
ASAS0025+1217	6.2 ± 0.1
SDSS1339+4847	4.2 ± 0.8
SDSS1238-0339	6.4 ± 1.1
SDSS1702+3229	1.6 ± 0.35
SDSS1556-0009	2.8 ± 0.4
SDSS0131-0901	5.5 ± 1.2
SDSS0137-0912	3.9 ± 1.0
SDSS1137+0148	2.2 ± 0.8
PQ AND	0.45 ± 0.13
RE1255+266	0.67 ± 0.34
SDSS1610-0102	2.4 ± 0.6
SDSS0904+0355	3.2 ± 0.9
SDSS2048-0610	6.6 ± 0.9
SDSS0904+4402	0.12 ± 1.1
SDSS1501+5501	3.3 ± 1.2
SDSS1457+5148	4.4 ± 1.2
SDSS0919+0857	-1.3 ± 6.5
SDSS1507+5230	3.9 ± 0.8
SDSS0843+2751	-1.9 ± 2.7





10^{29} erg s^{-1} ~ 10^{12} g s^{-1} ~ 10^{-14} M_{Sun} yr^{-1}

Q: How many EF Eri-like objects are in the sky (period bouncer)?



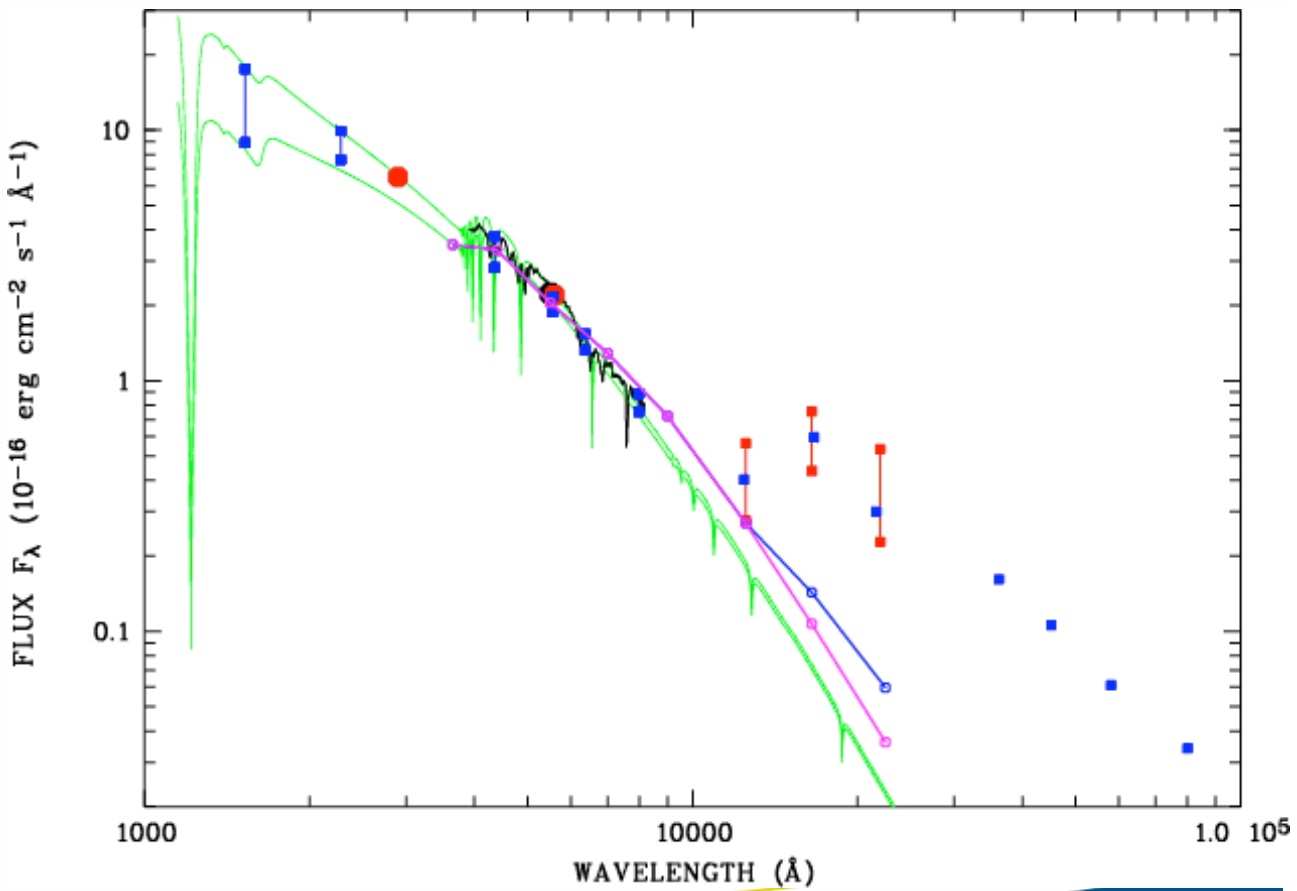
EINSTEIN (BSP87):
Textbook example of a shock-dominated polar
FHX ~ 1.5 x 10^{-10} erg cm^{-2} s^{-1}
FSX ~ 5.5 x 10^{-10} erg cm^{-2} s^{-1}

XMM (AS+07):
Textbook example of a cyclotron-dominated polar
FX ~ 6 x 10^{-14} erg cm^{-2} s^{-1}
LX ~ 2 x 10^{29} erg s^{-1}

EF Eri: period bouncer

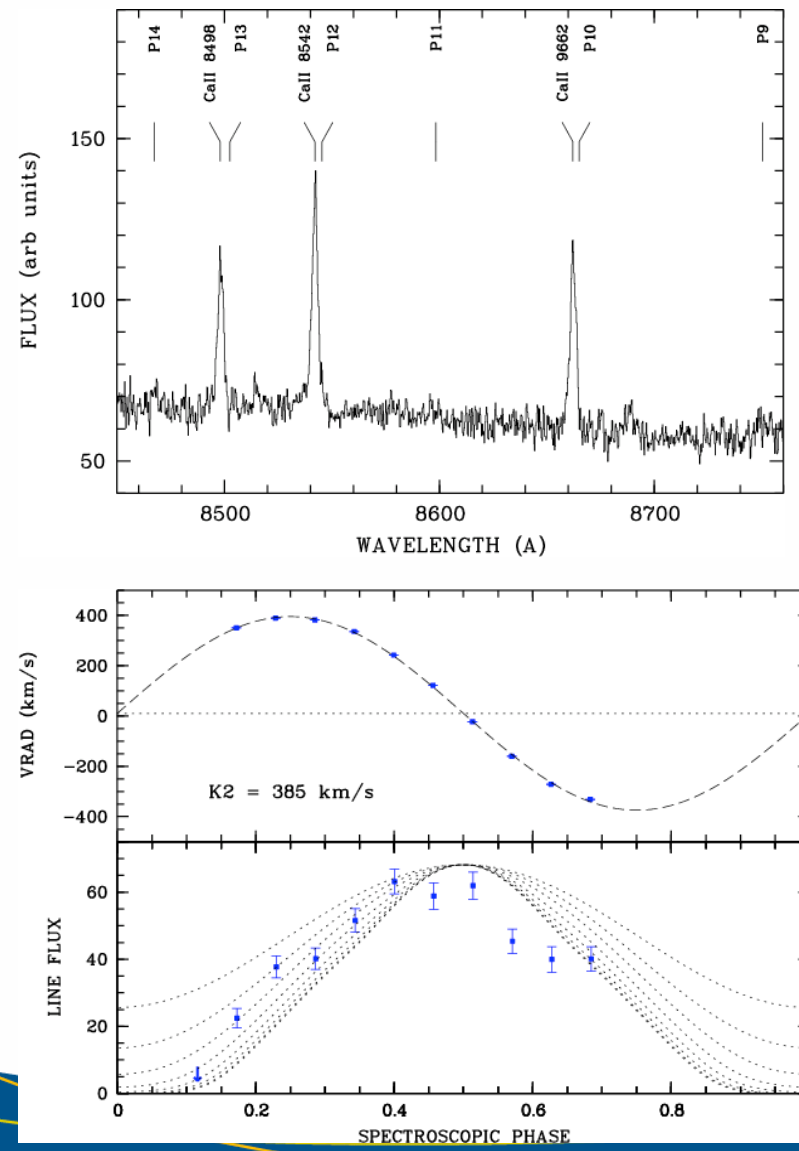
(Schwope+07, +10)

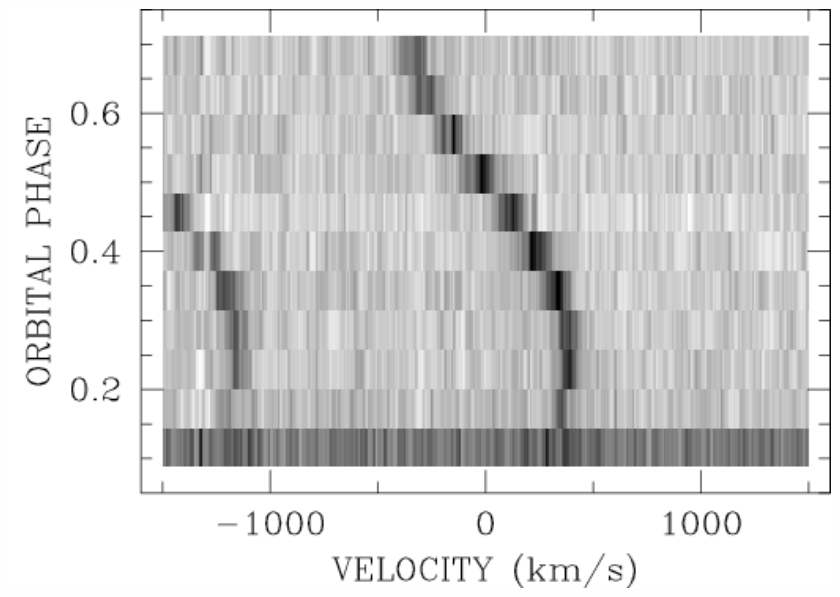
- Optical spectrum: WD
- Accretion:
  - Emission lines
  - Cyclotron
  - X-ray



X-Shooting EF Eri: irradiated donor

Schwope & Christensen 2010, AA





M2 ~0.045 M_o

The first sub-stellar donor in a magnetic CV!

Prototype of large sample?

Q: what is the parent population of CVs, fraction of magnetic systems?

MWDs among

- Observed CV sample: ~15%
- Field WDs (~7000): ~2%
- WD&MS (~2000): << 1%

- X-ray selection will be overcome by eRASS
- Single & binary WD samples seem to be mutually exclusive (Liebert+06)
- Selection effects (mass, temperature)?
- Where are the progenitors of the MCVs?

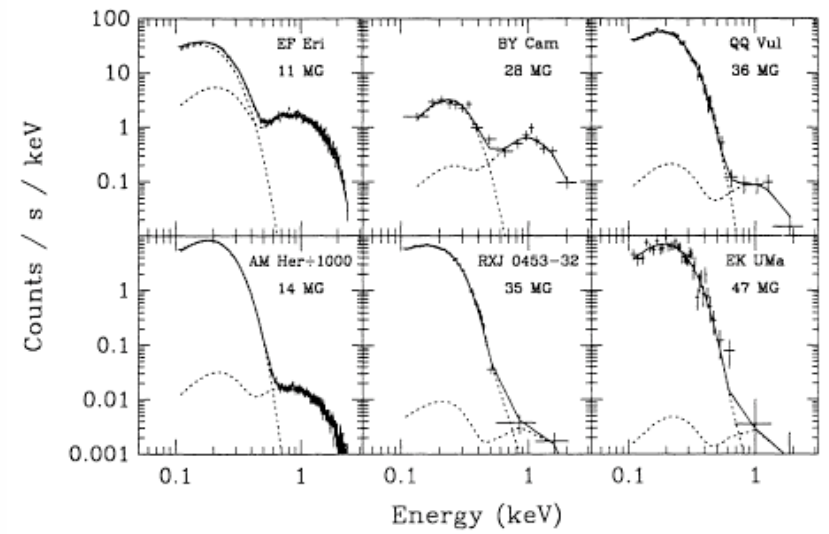
Accretion physics

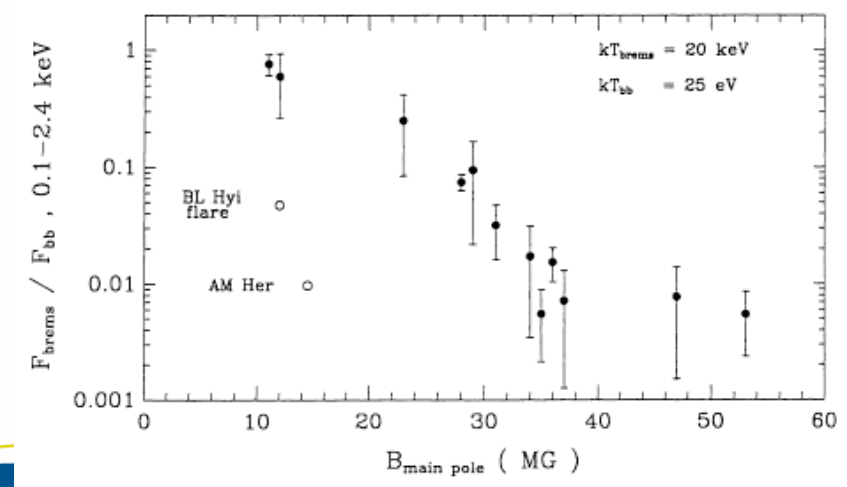
- SEDs
- Eclipsing systems
- Accretion column diagnostics

The legacy of ROSAT/EUVE

(Beuermann&Schwope94, Beuermann&Burwitz95, Ramsay+94)

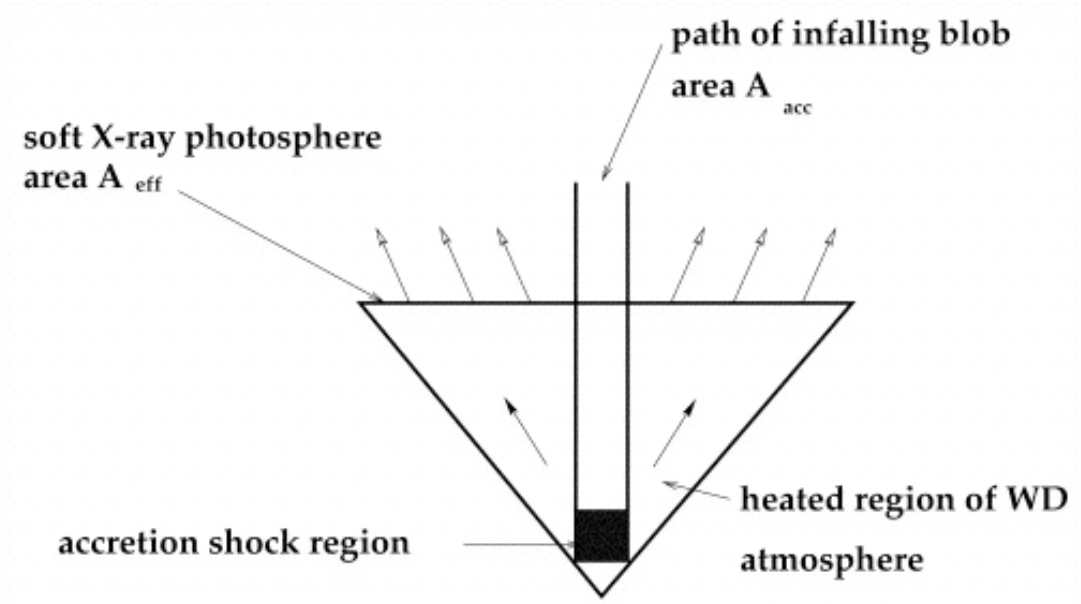
- Numerous new systems
- Polars as soft X-ray sources (soft X-ray puzzle)
- Blobby accretion scenario
  (Frank, King, Lasota ’88)

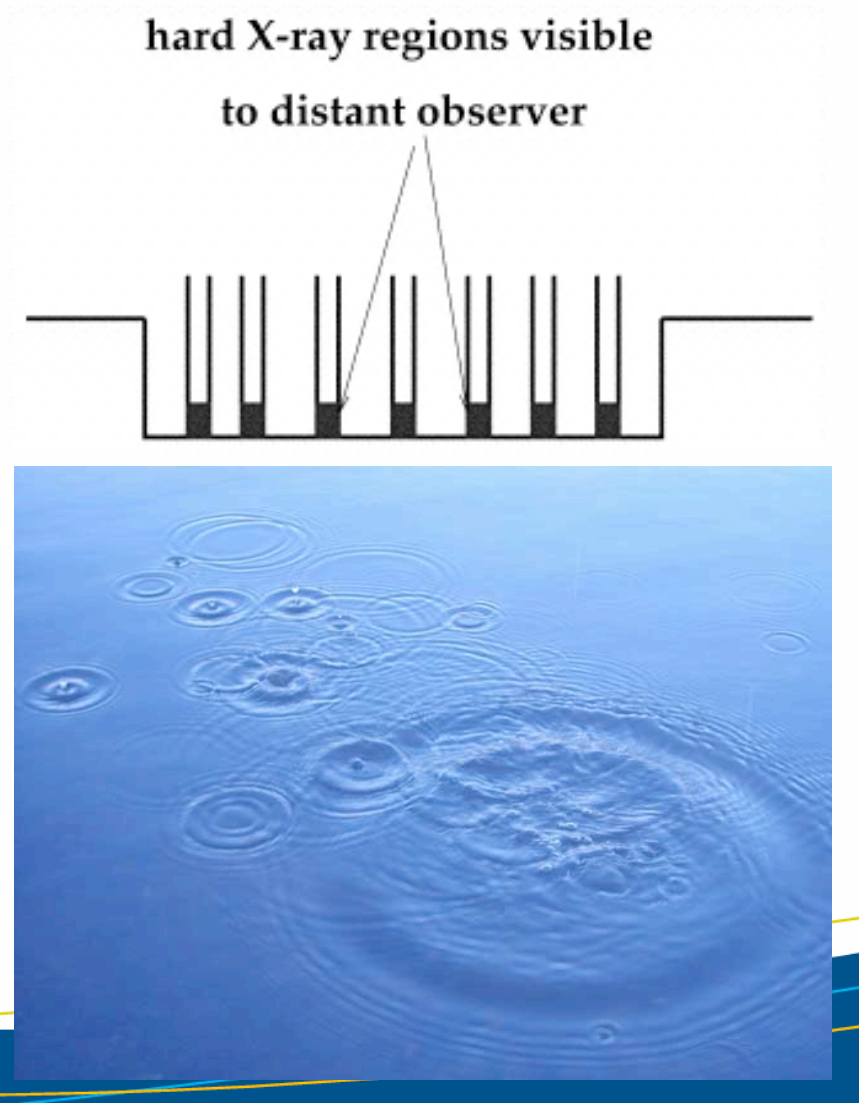




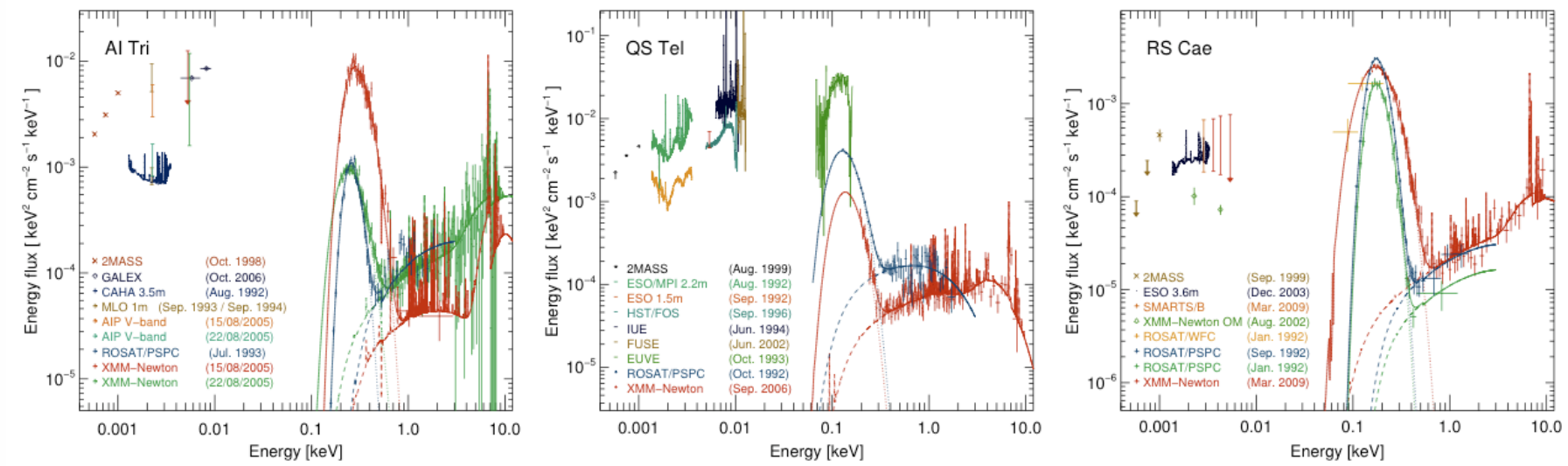
Blobby accretion

(Frank+88, King00)





Q: SED of magnetic accretion?



Spectral energy distributions of three soft X-ray selected polars, comprising our recent XMM-Newton observations and archival data. The X-ray spectra are fitted with multi-component XSPEC models. An absorbed black body represents the emission from the heated photosphere of the white dwarf, and a partially absorbed bremsstrahlung or plasma model the emission from the accretion column. For the 2005/08/22 observation of AI Tri, we have employed multi-temperature models.

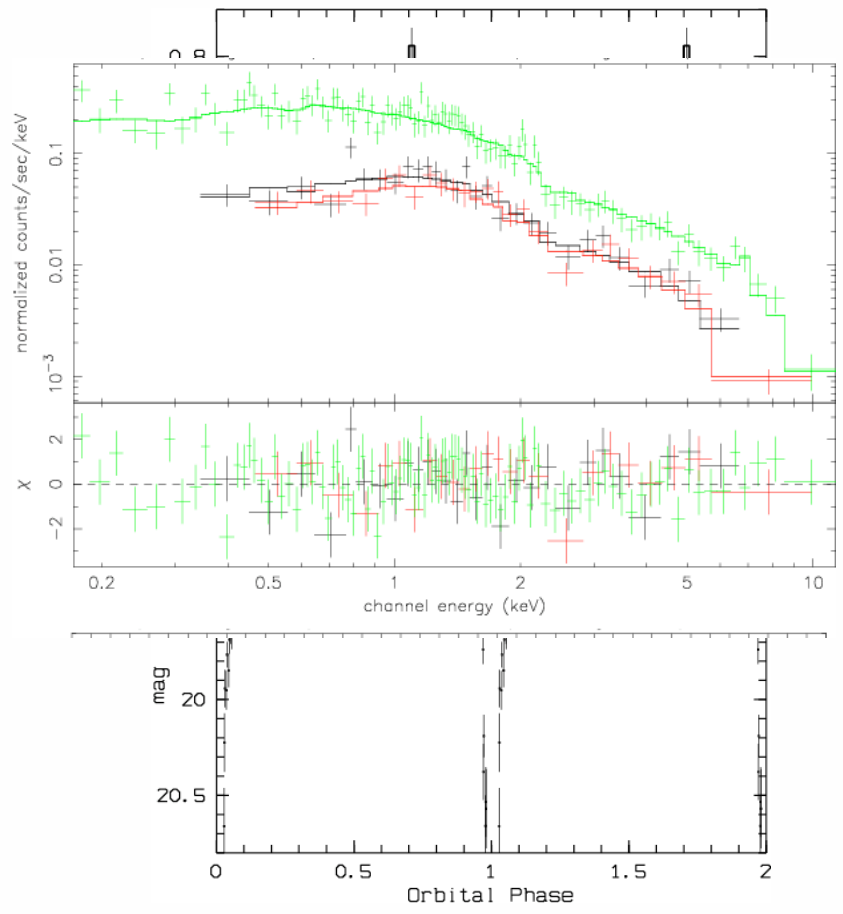
Soft X-ray excess for soft X-ray selected polars confirmed (Traulsen+2010, 2011, in prep), BUT ...

New perception of magnetic accretion?

1. XMM polar snapshot survey
   1/3 of all polars have no SX
   (Ramsay+04)

2. New XMM and SDSS polars
   with pure thermal spectra
   (Homer+06,07)

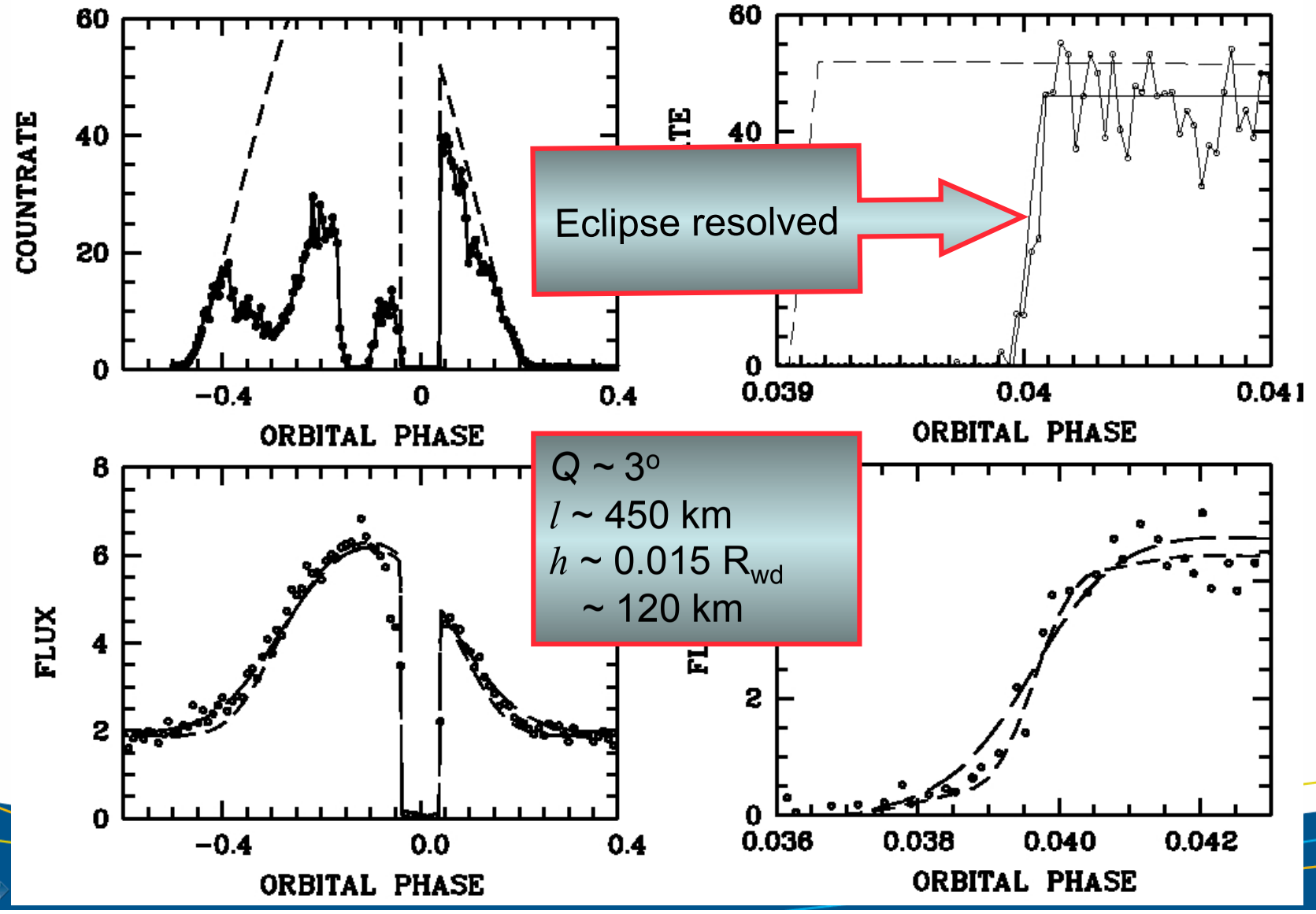
→ SEDs of unbiased sample?
Accretion luminosity?



2XMM 1312+1737
Vogel+08, AA

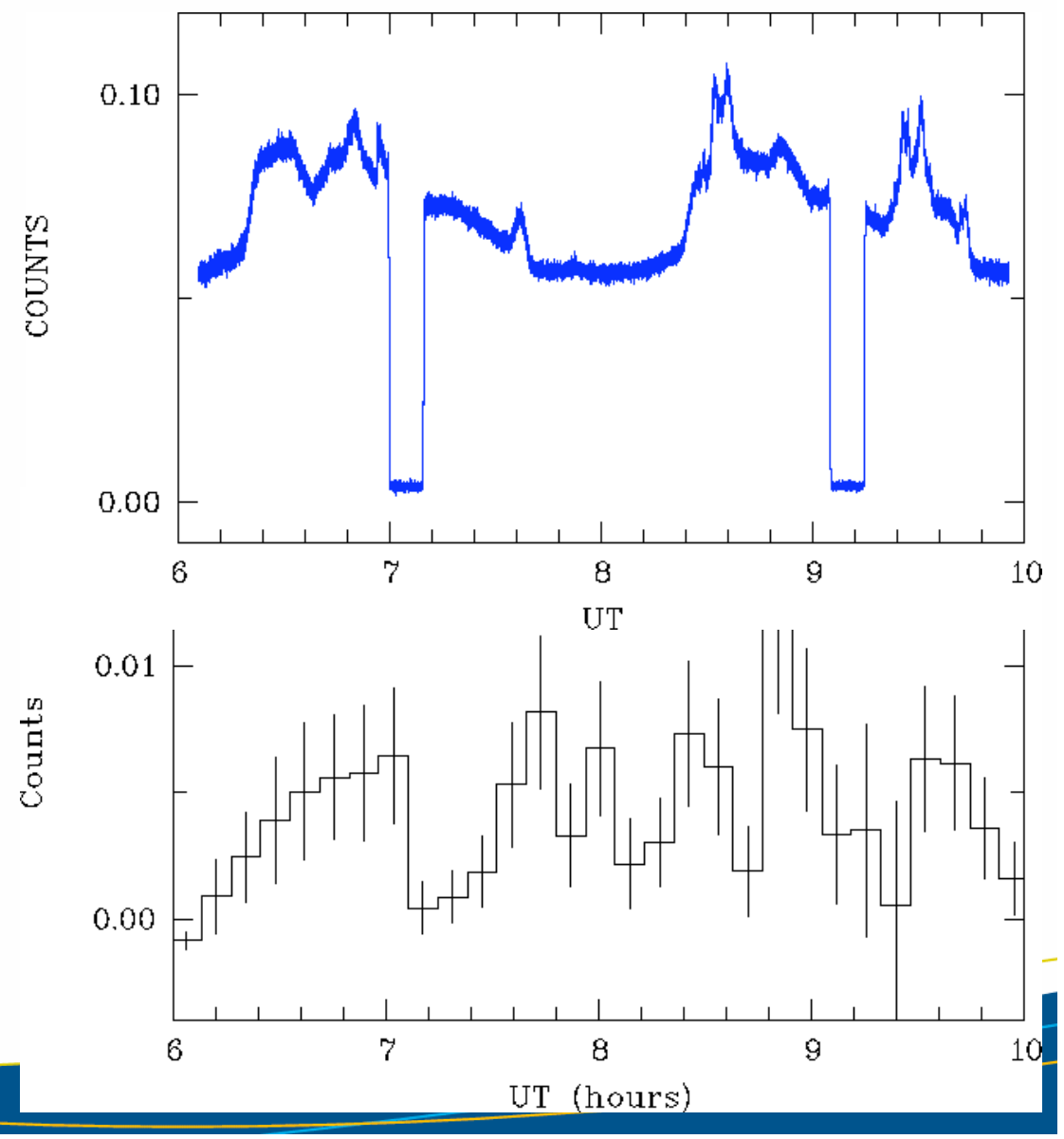
HU Aqr (RXJ2107-05): Accretion structure

(Schwope+01)



Simultaneous X-ray/optical observations of the ‚bright' eclipsing polar HU Aqr

VLT/ULTRACAM g &
XMM EPIC pn

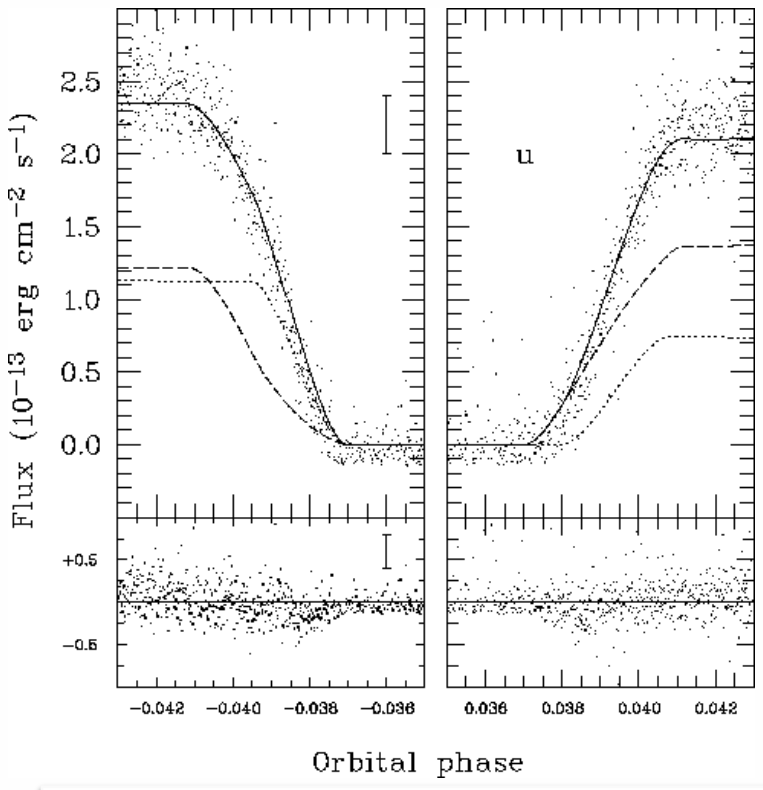


MCV duty cycle ~50%

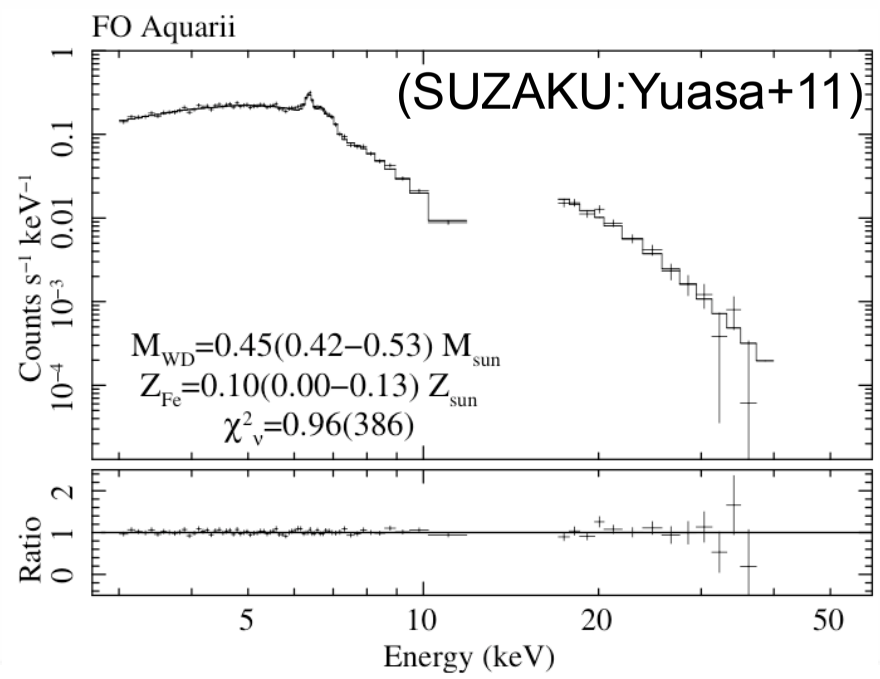
eROSITA will discover the complementary sky to ROSAT

Schwarz et al 2009, A&A, in press

Mass determination of the accreting WD (see below for lines)



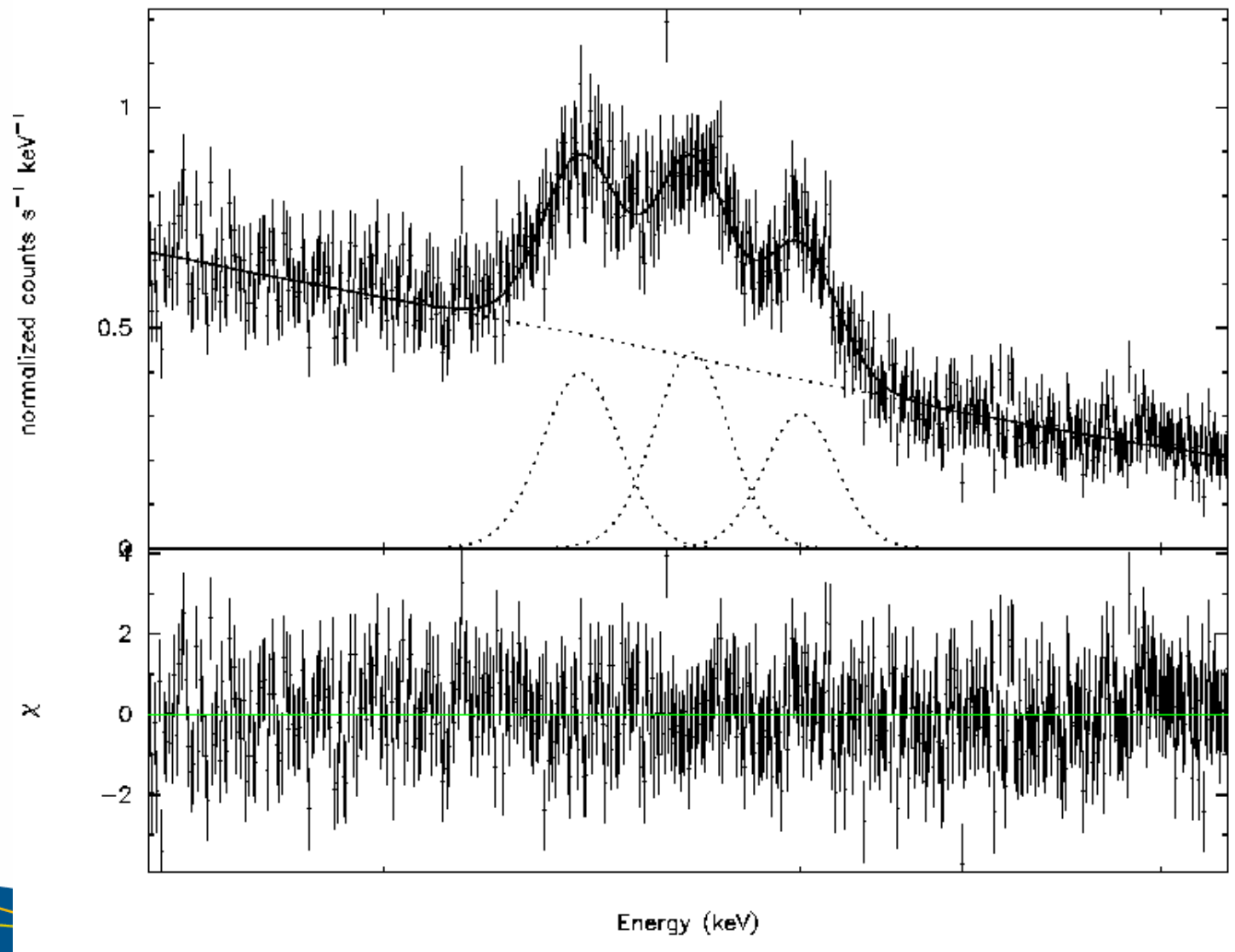
M_{WD} ~0.9 M_o (Vogel+08)



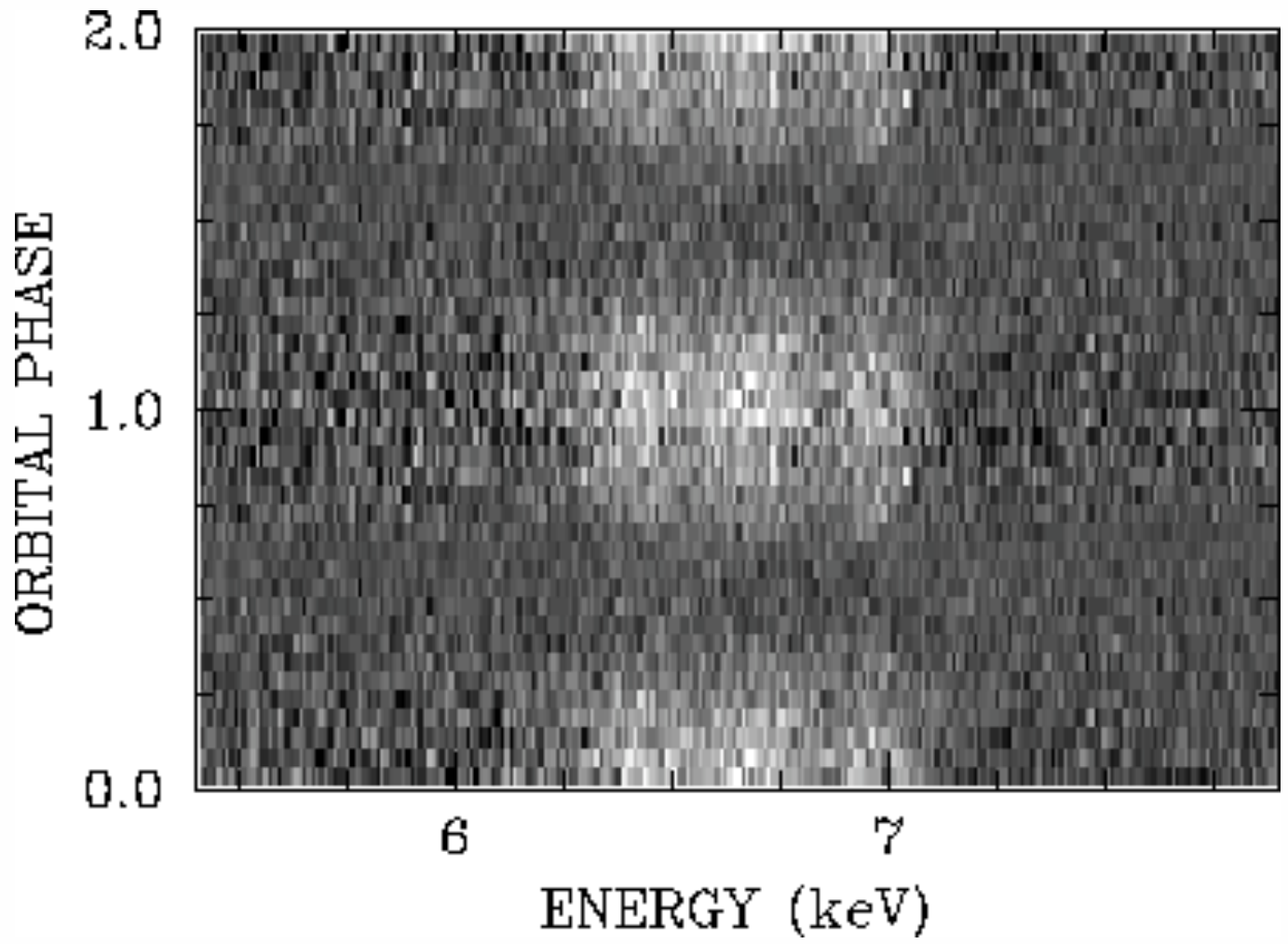
- WD mass calibration with a sample of eclipsing CVs
- WD mass growth from PCEB (0.5M_o) to MCV (~0.9 M_o) stage
- Nova ejection efficiency

Accretion physics – line diagnostics

AM Her – plasma lines and Kα reflection

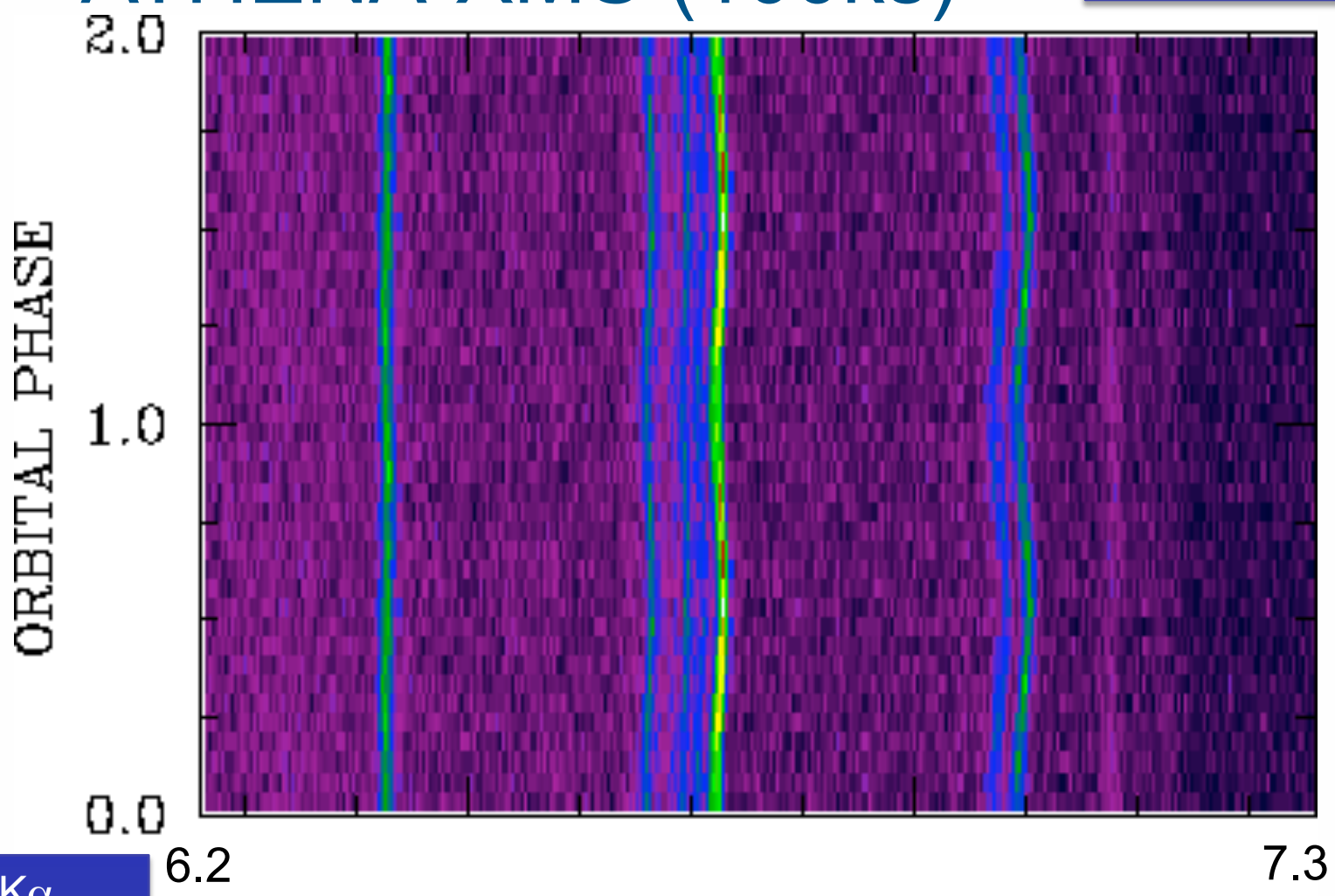


XMM (eROSITA): Phase-resolved X-ray spectra



ATHENA-XMS (100ks)

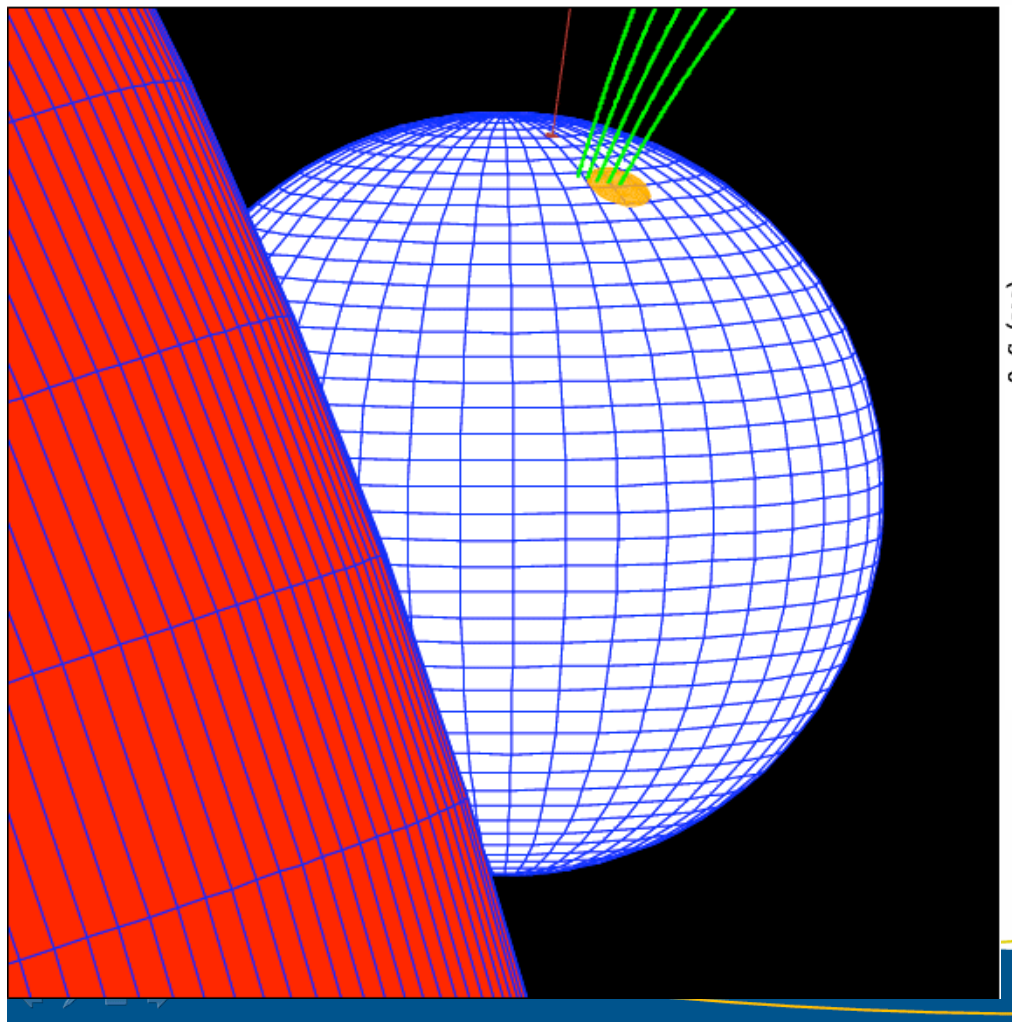
He-like and H-like Fe
&
streaming bulk motion

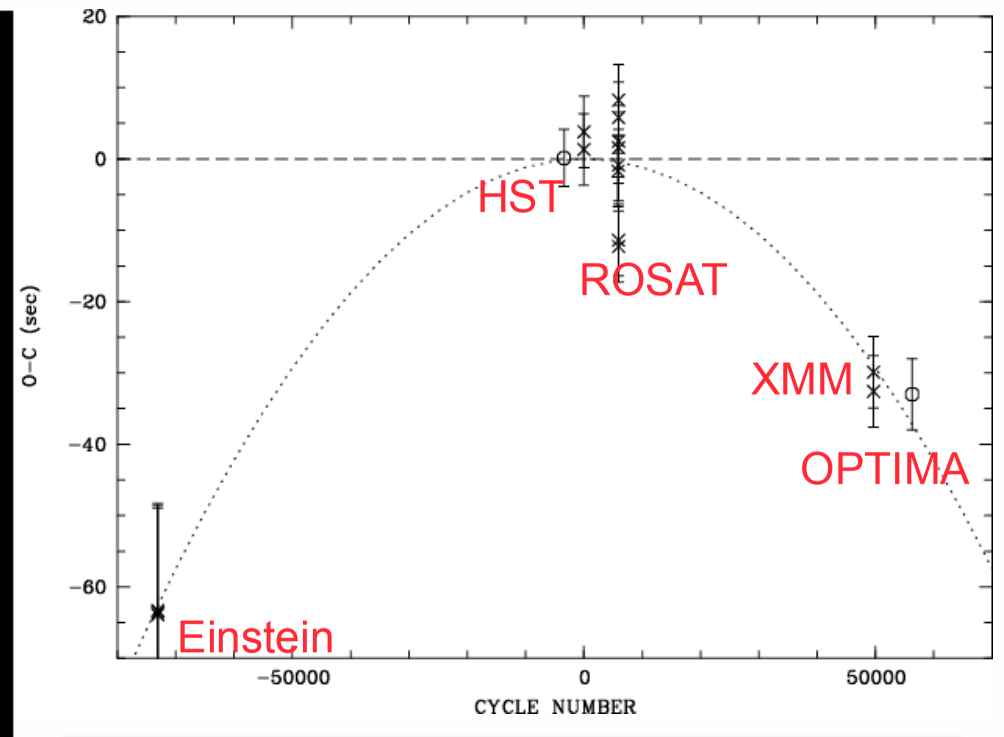


Fe Kα
Grav redshift
&
Orbital motion

Modeling by Iris Traulsen & Alexander Kolodzig

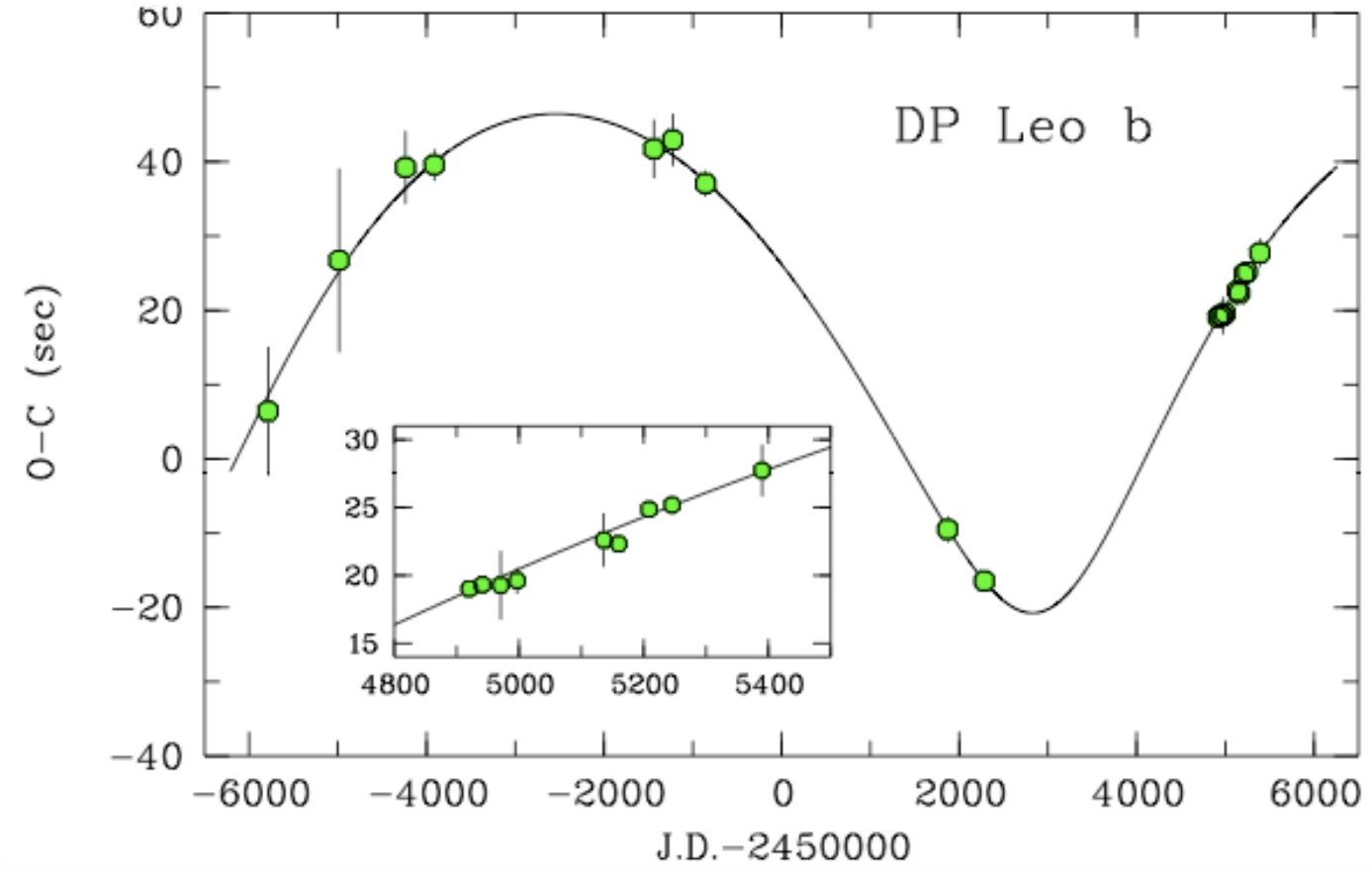
Expect the unexpected: Eclipse ephemeris DP Leo





Quadratic term significant
Braking mechanism?
(AS+2001)

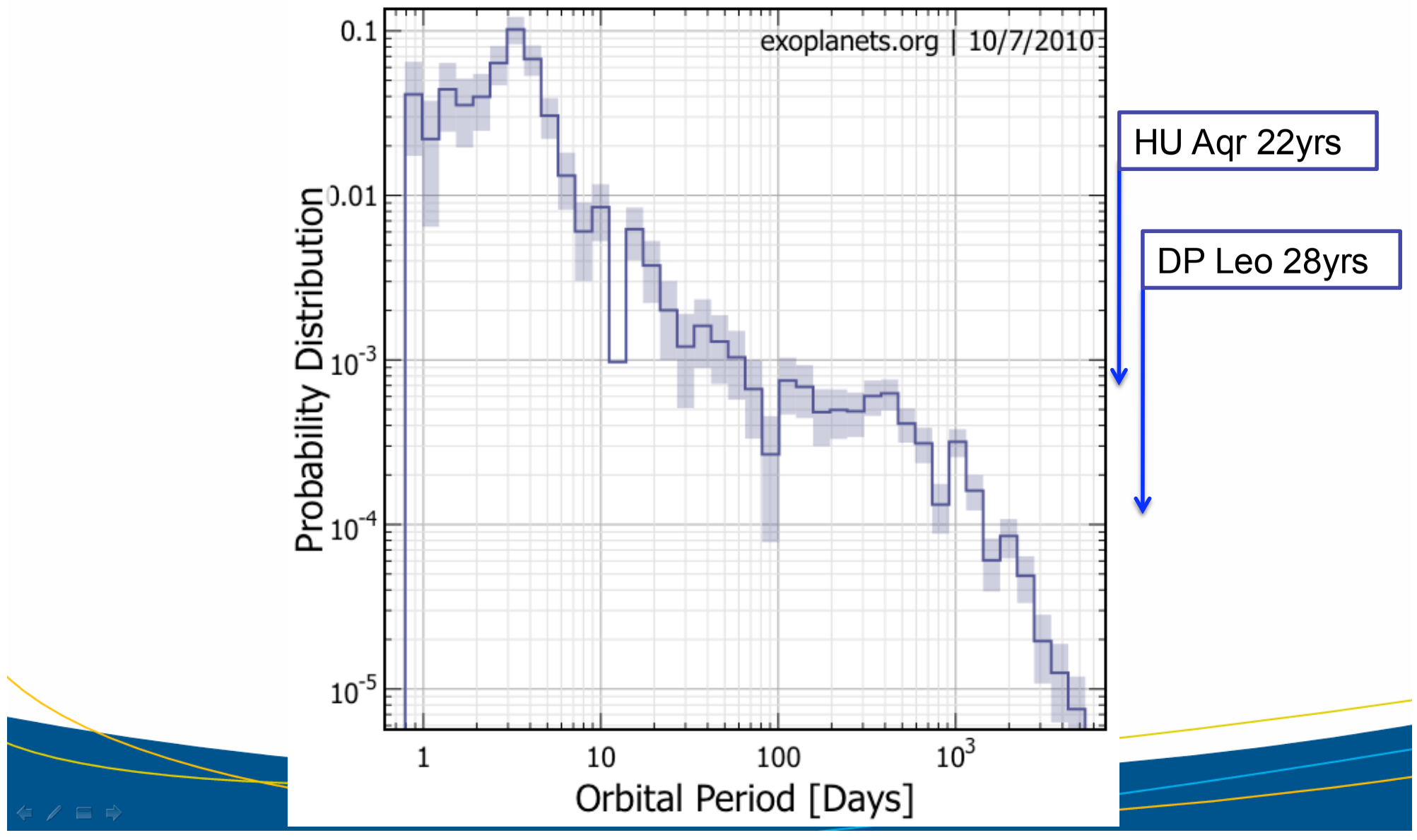
Expect the unexpected: Eclipse ephemeris DP Leo



P_c = 28.0 ± 2.0 yrs, a_c = 8.2 ± 0.4 AU, e_c = 0.39 ± 0.13, sini$_c$ M_c = 6.1 ± 0.5 M_{jup}

Beuermann+11, AA526

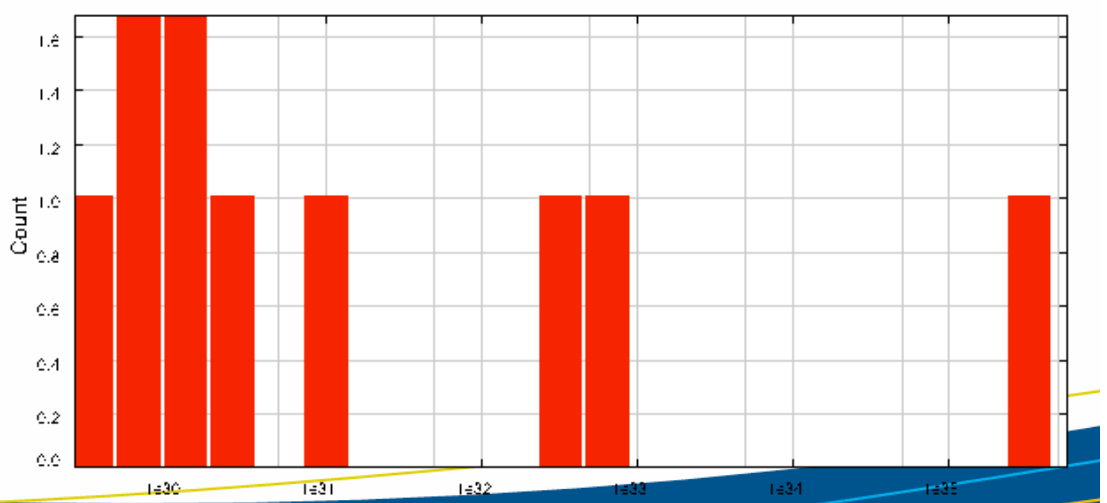
White spot in the exo-planets landscape



AM CVns/DDs/UCBs

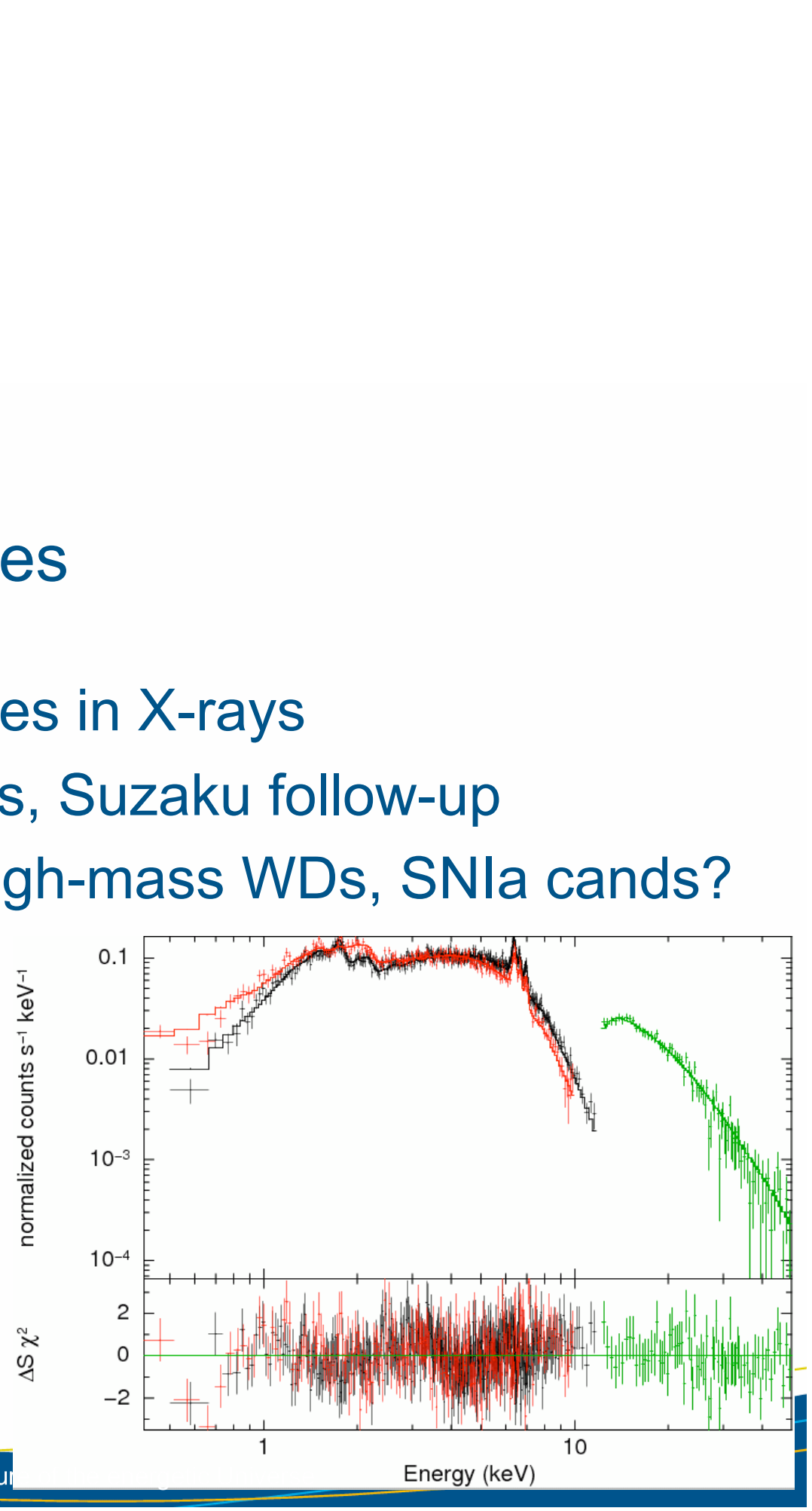
SNIa progenitors, LISA calibration sources

- Nelemans: 31 objects (ROSAT+SDSS)
- Correlated with 2XMM-DR3
  → 11 X-ray detections, log(LX) > 30...33
- eRASS: ~500 new dets

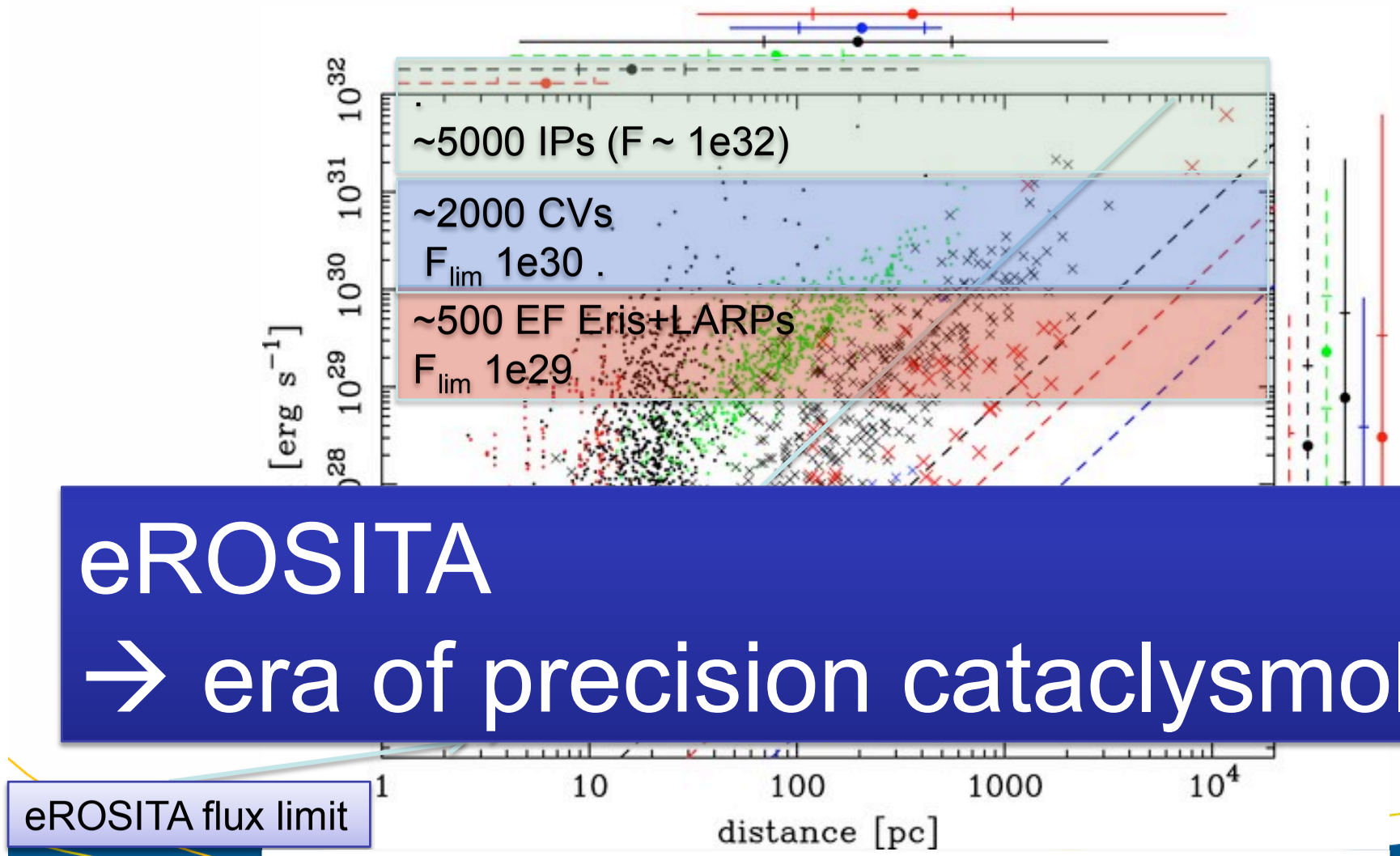


Rare objects:
Symbiotic binaries

- Little systematic studies in X-rays
- 4 Swift BAT detections, Suzaku follow-up
- hard X-ray spectra, high-mass WDs, SNIa cands?
- 1% of the CV pop?



Luminosity vs distance of selected X-ray surveys



eROSITA
→ era of precision cataclysmology

eROSITA flux limit

Wright et al 2010: Chandra Cosmos survey