X-ray observations of supersoft binaries: Status and perspectives

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Supersoft X-ray binaries: observational characteristics

Very soft X-ray spectra

$T_{eff} \sim 20 - 40$ eV

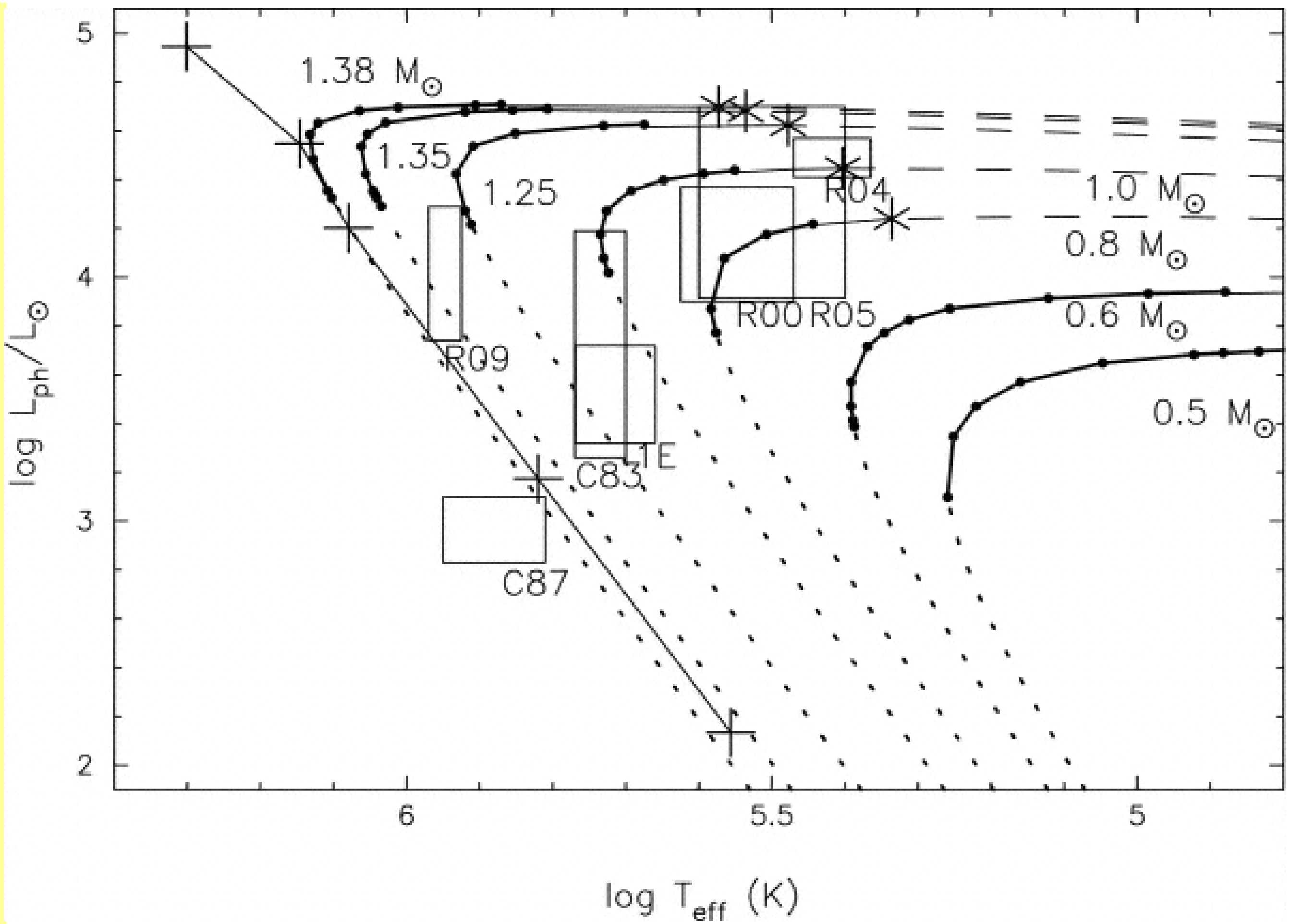
$L_{bol} \sim 10^{36} - 10^{38}$ erg/s

> 90 % of photons below 0.5 keV

Observationally defined class comprises:

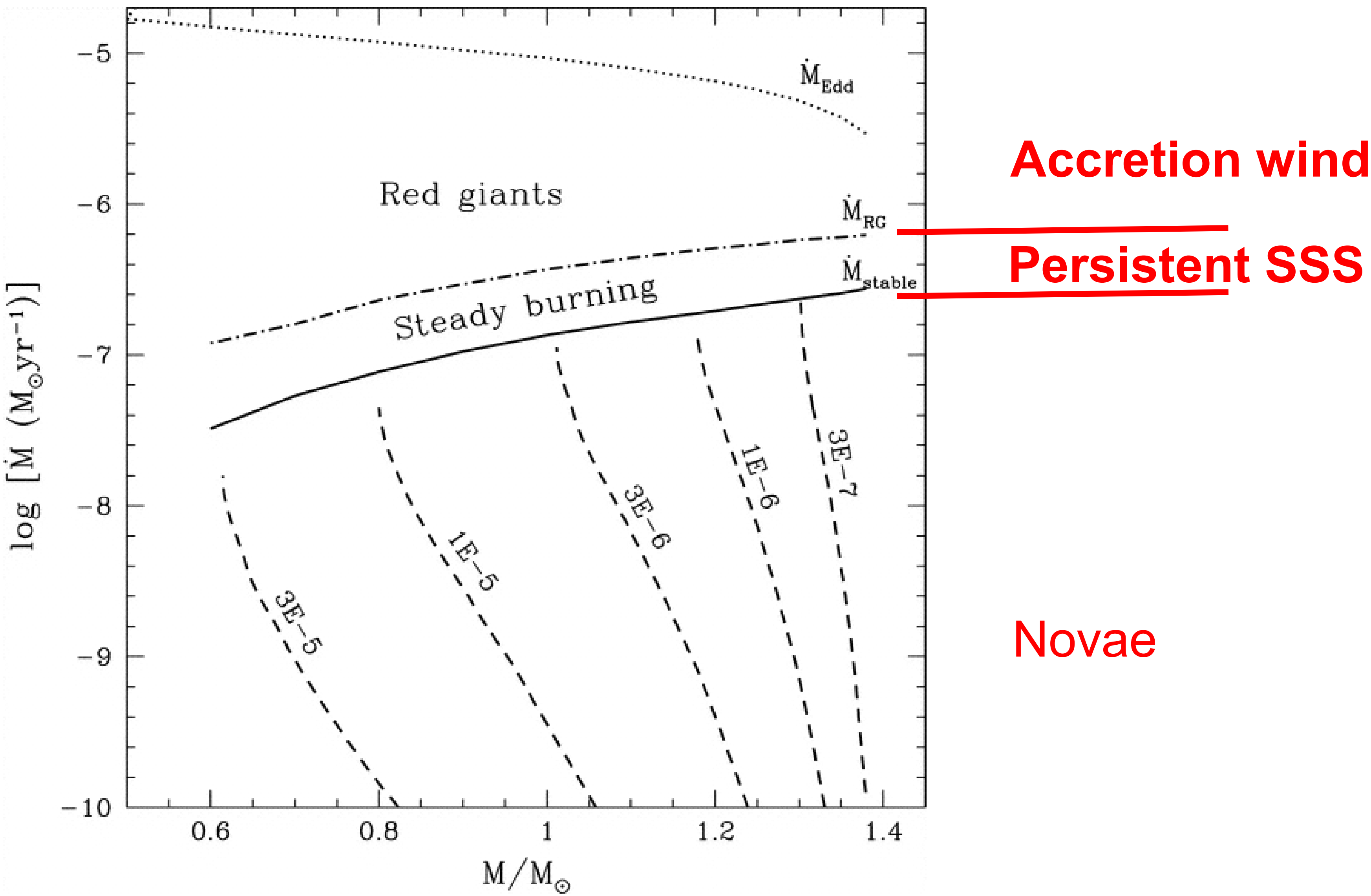
- novae (see other talks)
- symbiotic stars
- **near-Eddington accreting WD binaries**

SN Ia progenitors?



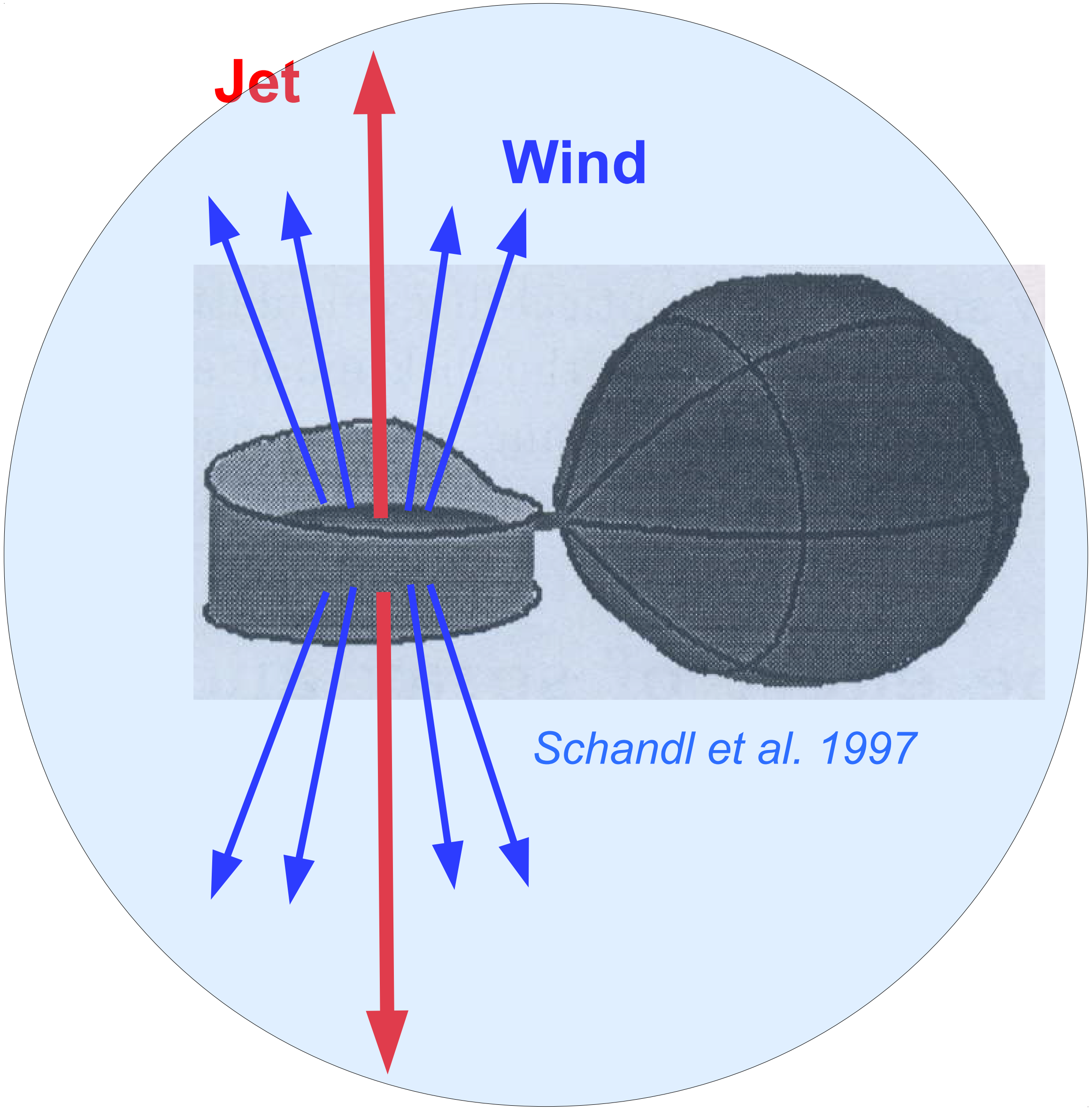
Nomoto et al. 2007, ApJ 663, 1269

Supersoft X-ray binaries: standard model



Nomoto et al. 2007, ApJ 663, 1269

Supersoft X-ray binaries: model components



White dwarf

+ main sequence donor

+ accretion disk + rim

+ wind

+ jet

+ circumbinary material

Nuclear burning WD directly visible or partially/ temporarily absorbed + scattered radiation

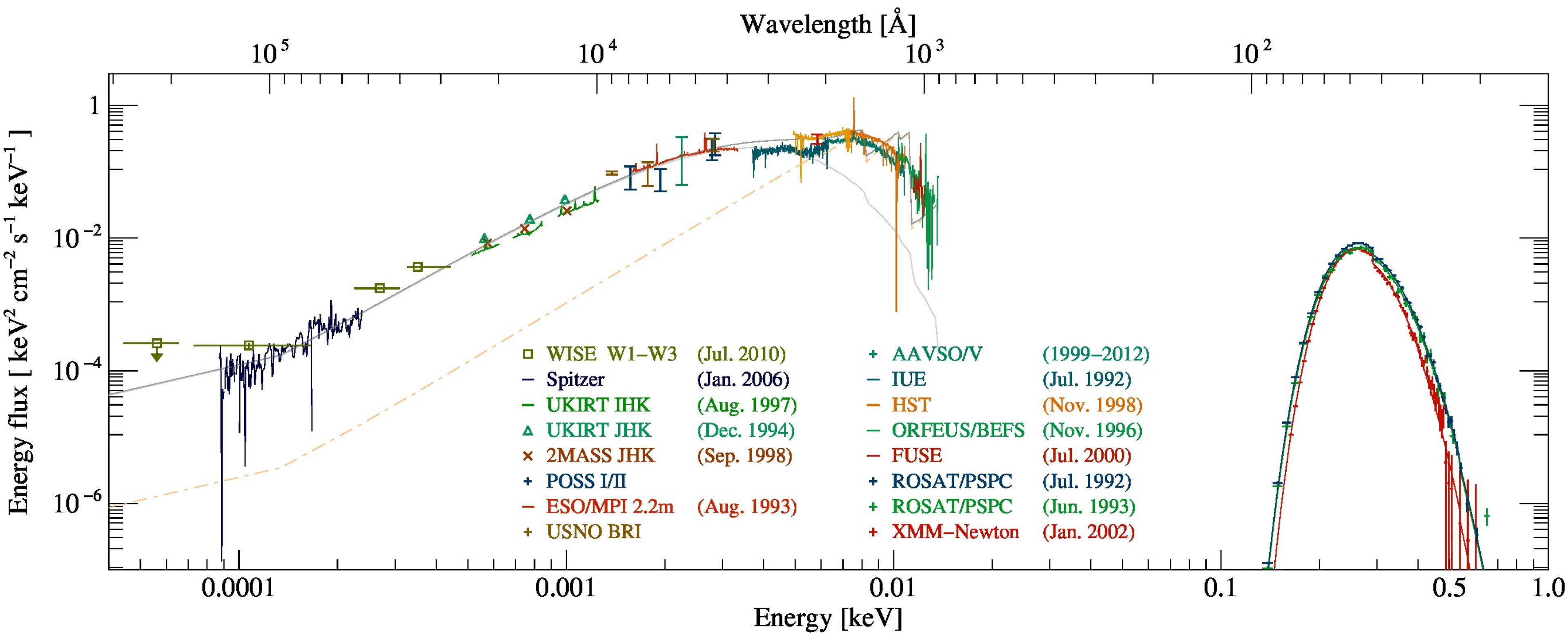
Spectral energy distribution

QR And: Two spectral components visible

Soft X-ray/ EUV: hot WD

n_H = (0.84±0.05) 10^{21} cm^2, kT_{bb} = (18.5±0.5) eV

IR – UV: accretion disk, no signature of donor star



Reinsch et al., in preparation

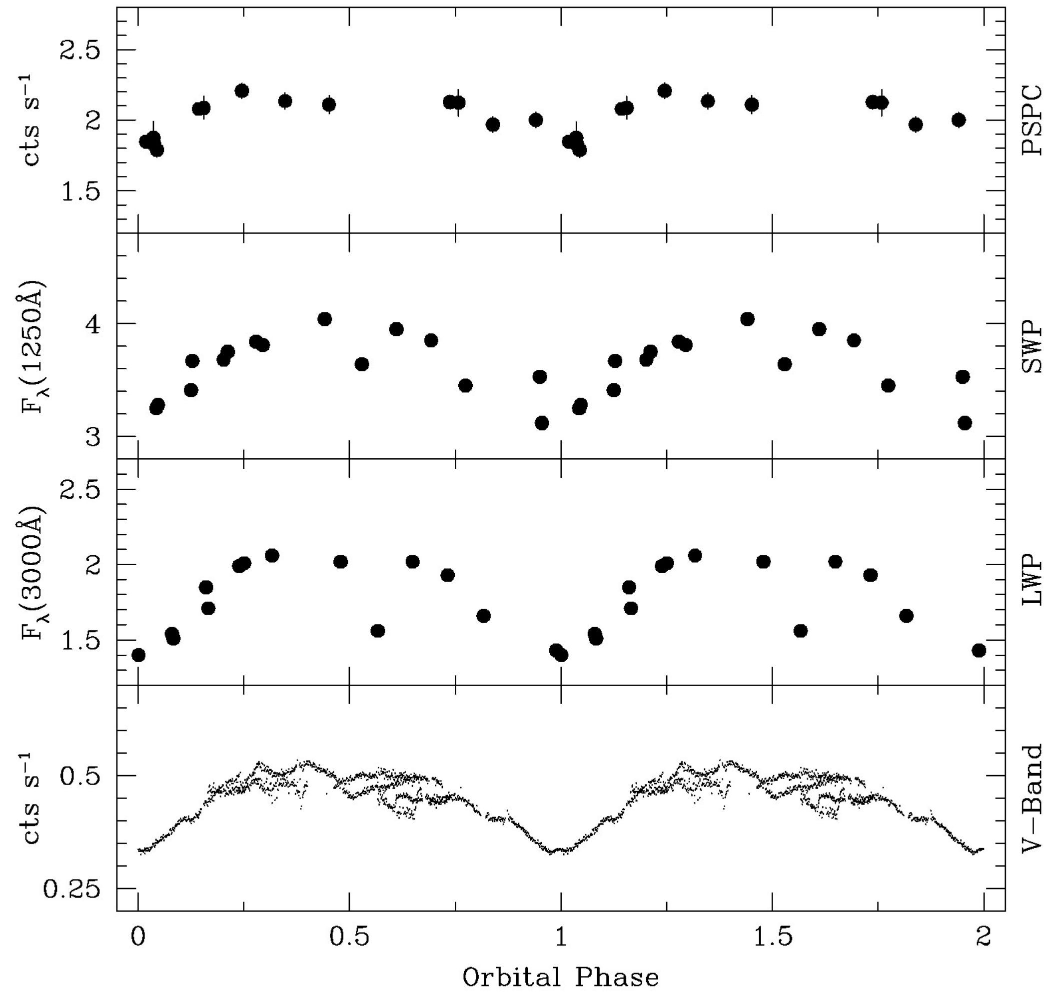
X-ray variability on the binary period

QR And

P_{orb} = 15.85 h

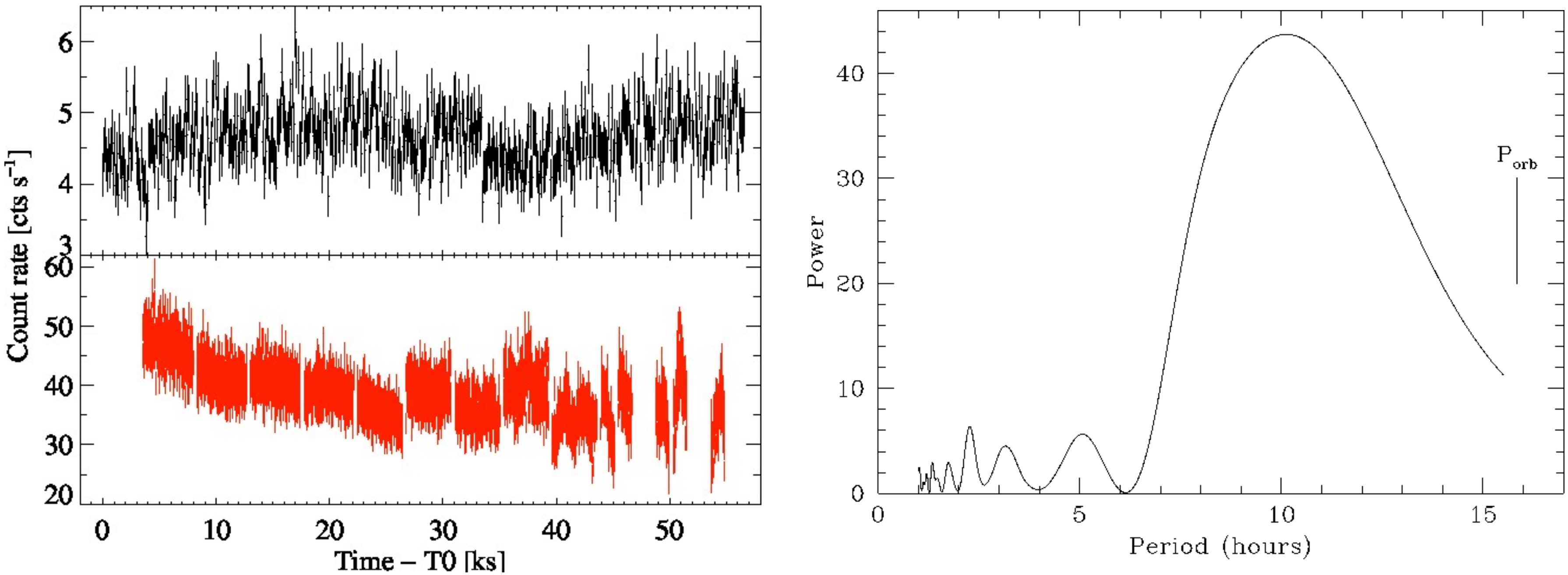
seen in optical and UV,

possibly in X-rays (ROSAT), not confirmed by XMM-Newton observation



Beuermann et al. 1995

Sub-orbital time-scale X-ray variability



QR And: XMM-Newton X-ray and UV (OM)

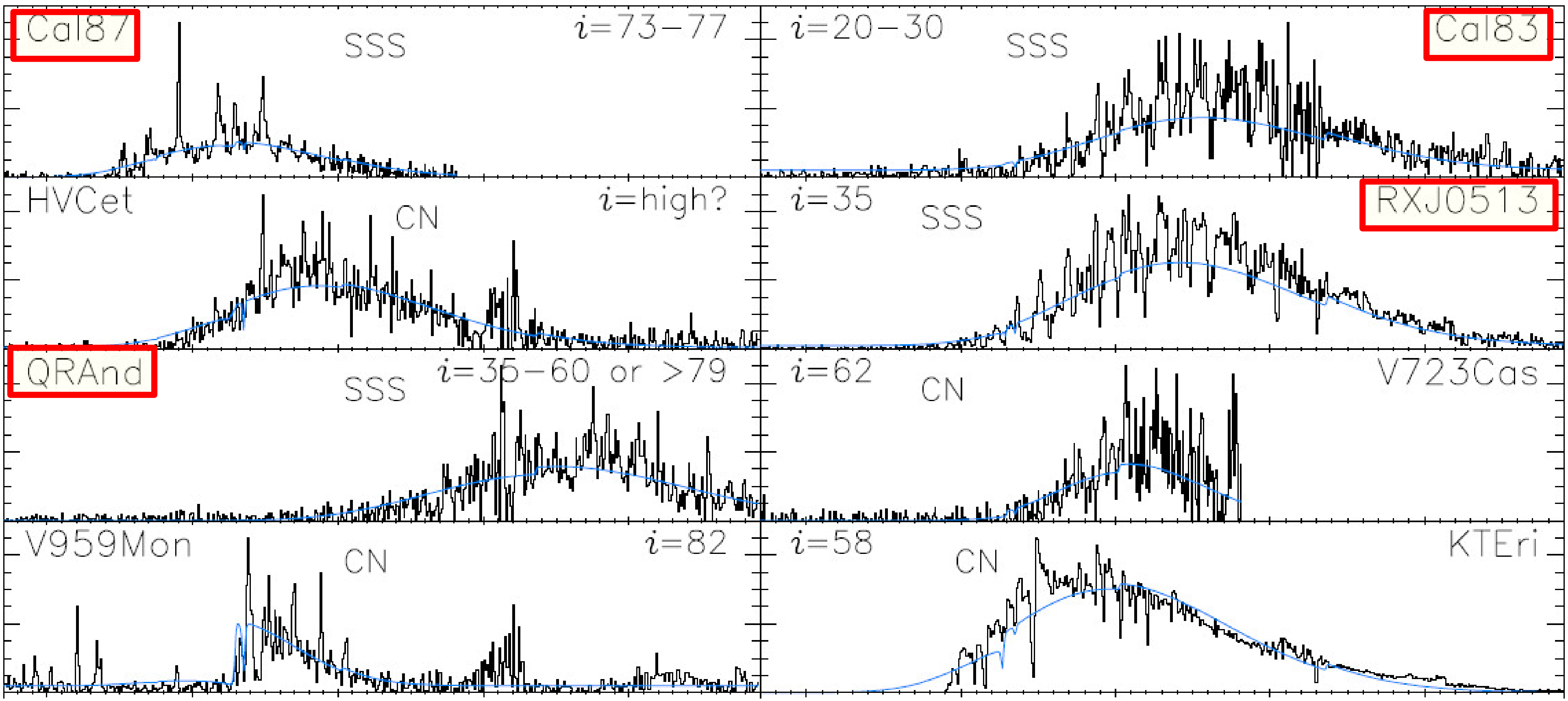
Origin of variation unknown

Reinsch et al., in preparation

High-resolution spectroscopy

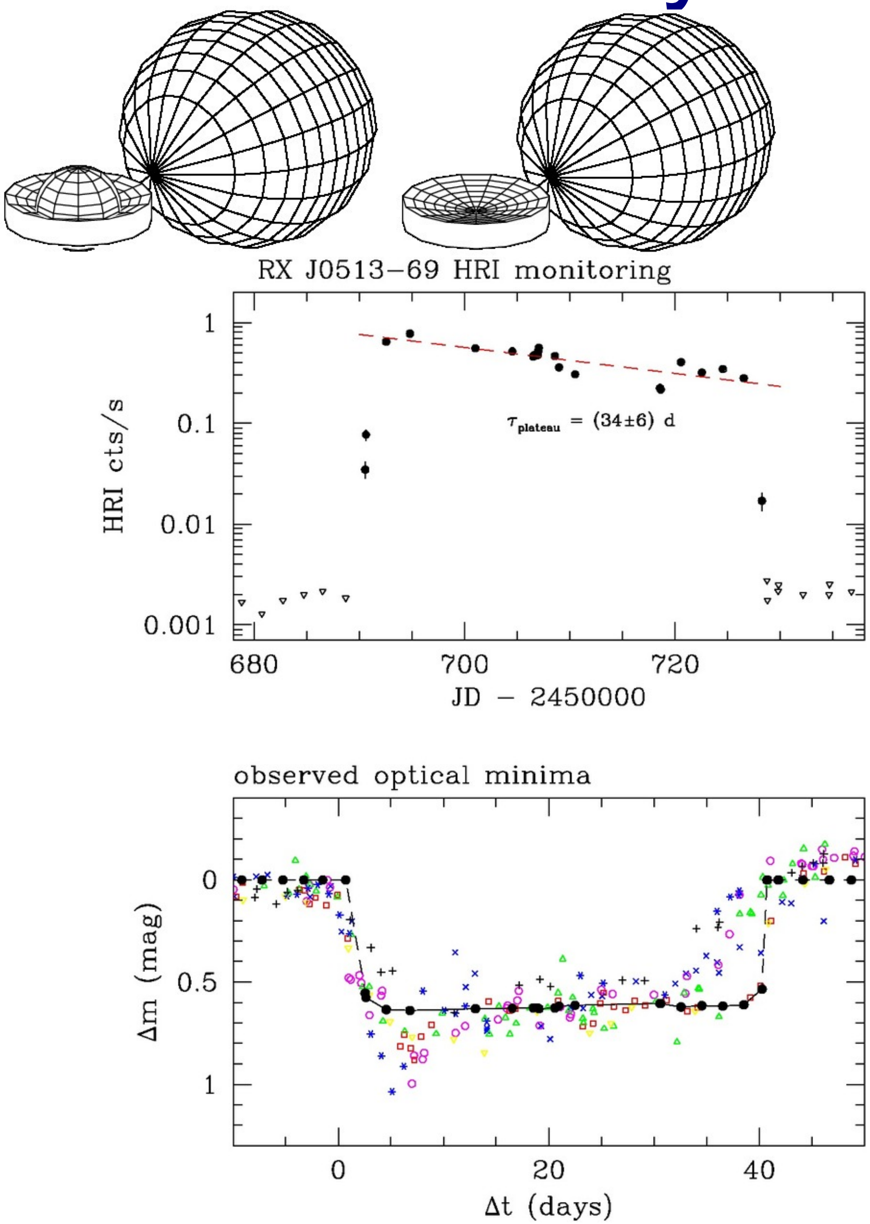
Complex spectra: absorption + emission-line features, Doppler-shifted components (expanding envelope, wind)

Inclination effect?



Ness et al. 2013, A&A 559, 50

X-ray on- and off-states



Reinsch et al. 2000, A&A 354, L37

RX J0513.9-6951

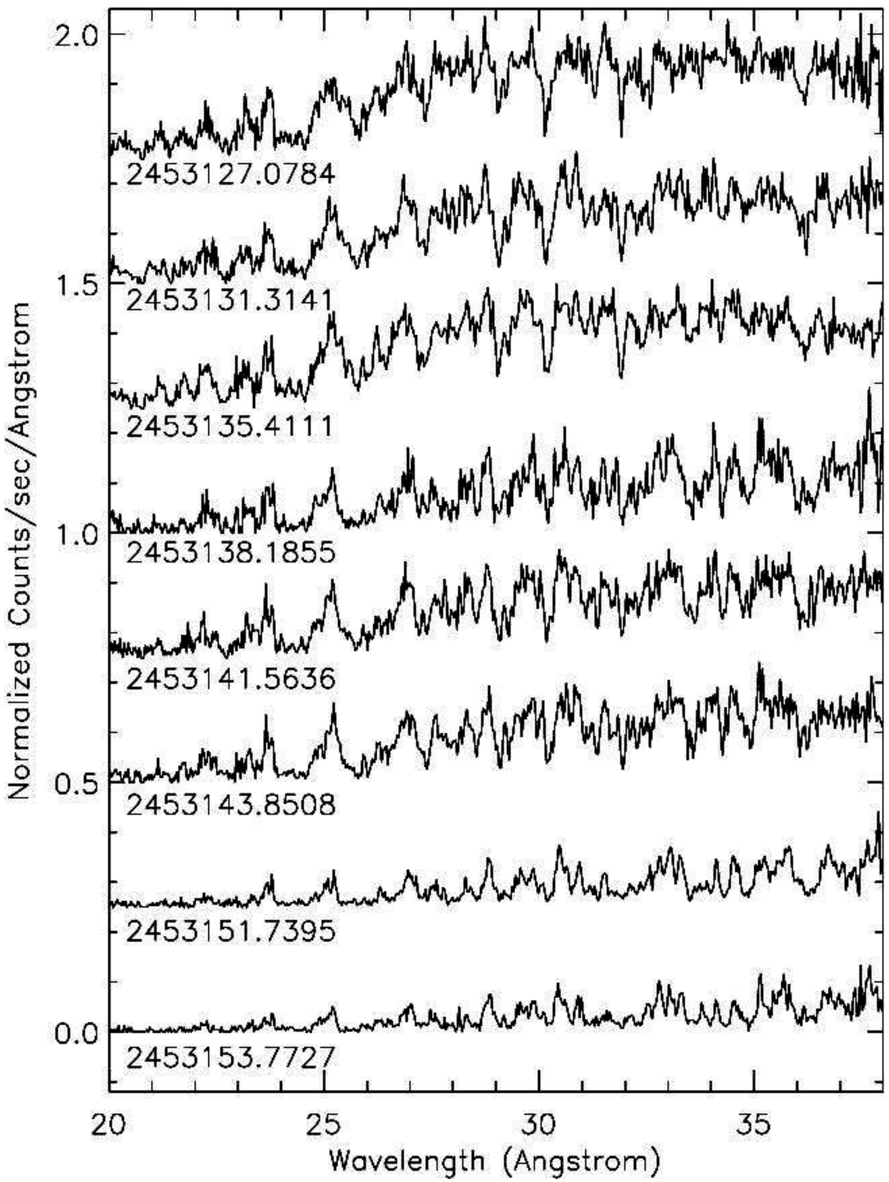
anti-correlated X-ray and optical variability

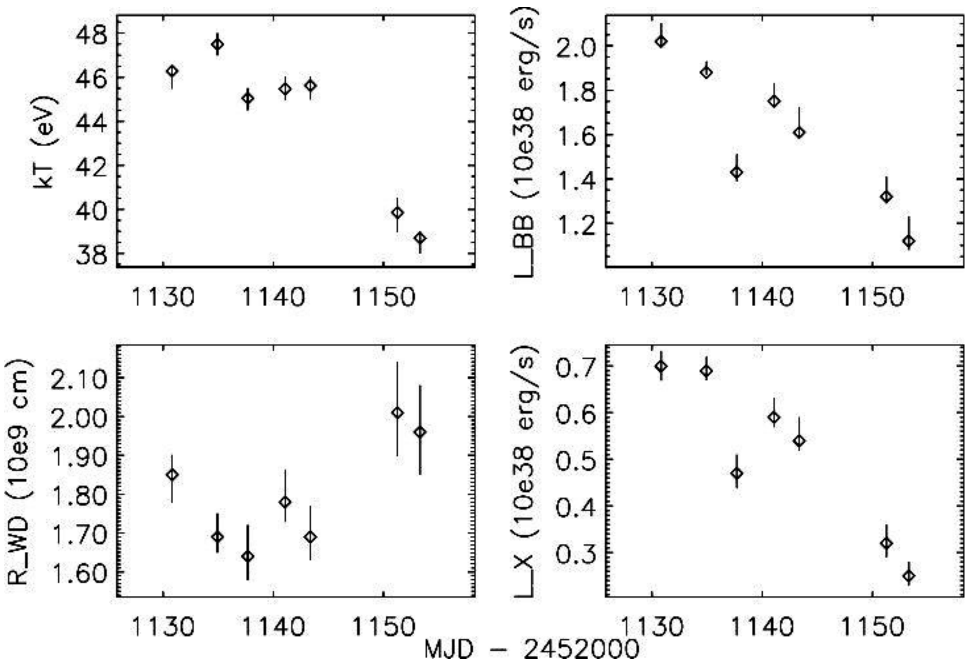
Suggested models:

Mass-transfer rate changes triggered by illuminated accretion disk + viscosity changes (Reinsch et al. 2000)

Accretion wind evolution (Hachisu & Kato 2003)

X-ray on- and off-states





RX J0513.9-6951

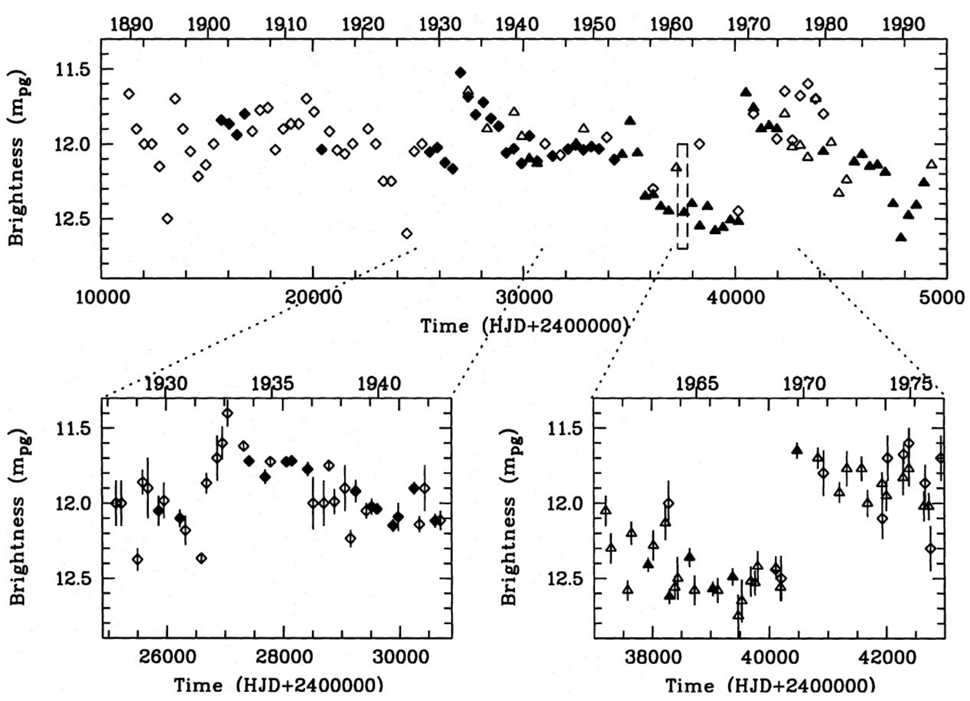
Spectral variability and physical parameters

McGowan et al. 2005, MNRAS 364, 462

Long-term X-ray variability and burning stability

QR And: optical

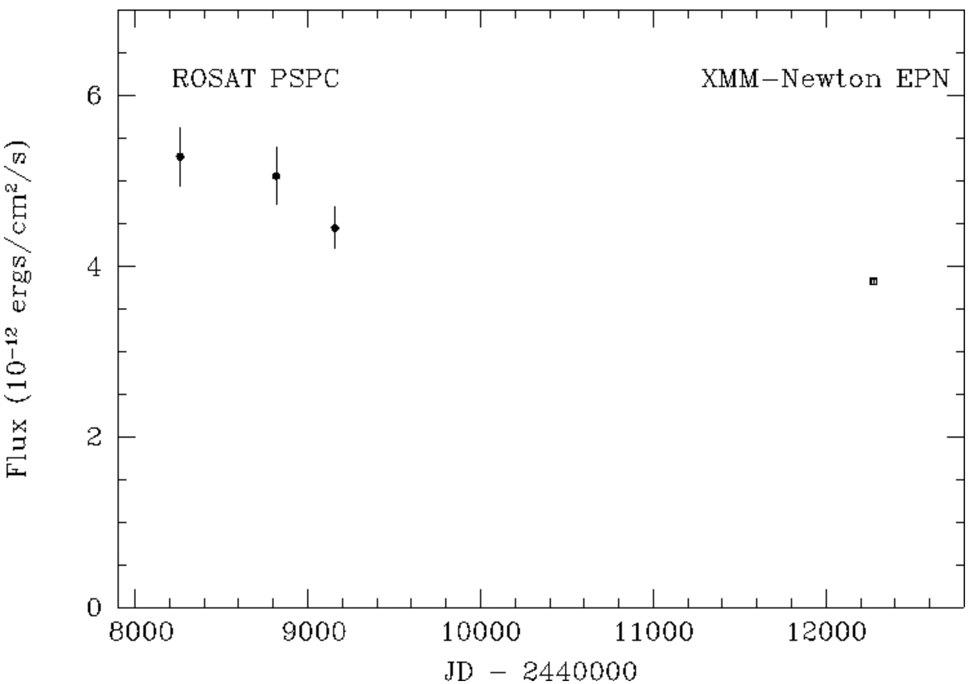
Episodes of rapid brightness changes



Greiner & Wenzel 1996, A&A 294, L5

X-ray

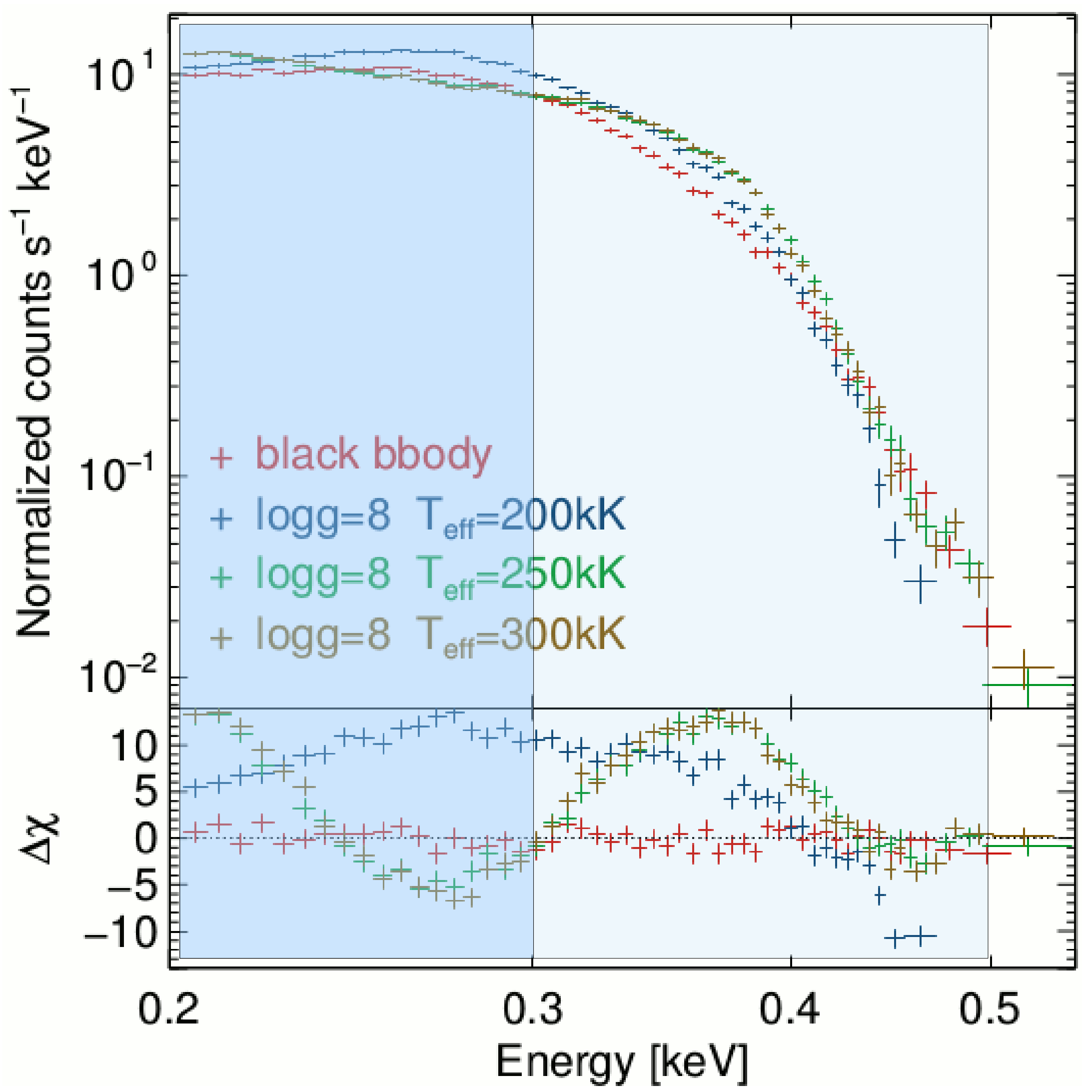
Indications for long-term flux variation



Open questions and problems

- Nature of the donor star?
  - Thermal time-scale vs. wind-driven mass transfer
  - Distance and luminosity of the system
- Origin of the X-ray emission?
  - Hot WD vs. scattering corona
  - Structure of surrounding environment
- Long-term stability of nuclear burning?
- Net mass balance in SSS phase?
- Where are the missing systems?
  - Predicted vs. observed population density

Observations of supersoft X-ray binaries with future X-ray missions



Simulation: I. Traulsen

eROSITA/ SRG

Simulation of 50 ksec pointed observation scaled to the EPIC/pn flux of QR And

- black body
- WD atmospheres (TMAP, Rauch et al.)

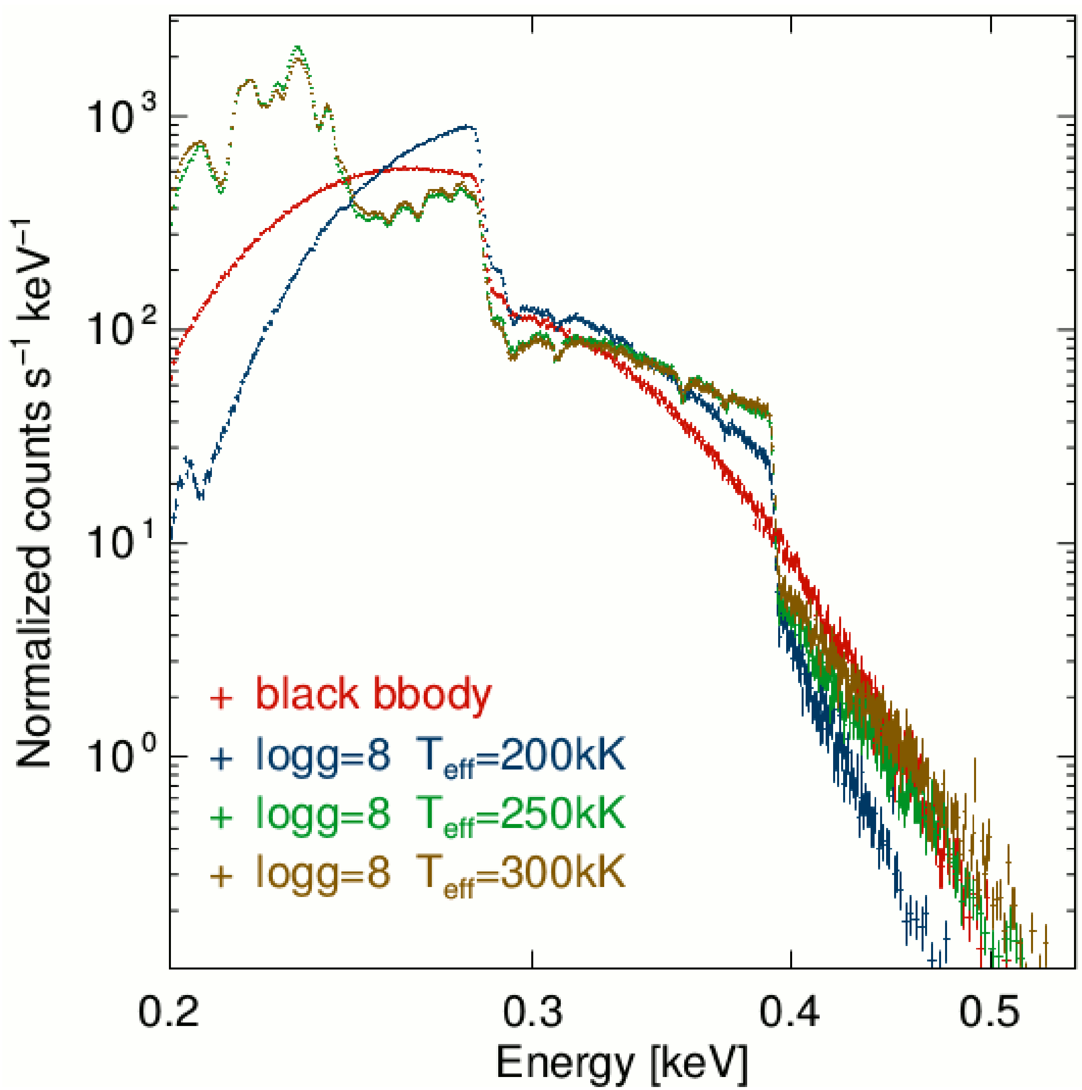
Energy range (designed):

0.5 – 10 keV

Low-energy limit proposed by WG compact objects:

0.3 – 10 keV

Observations of supersoft X-ray binaries with future X-ray missions



Simulation: I. Traulsen

Athena/ X-IFU

Simulation of 50 ksec pointed observation scaled to the EPIC/pn flux of QR And

- black body

- WD atmospheres (TMAP, Rauch et al.)

=> High-resolution spectroscopy

- detailed study of absorption/ emission components

- temporal variability

Summary and conclusions

- Current X-ray missions (XMM-Newton, Chandra, Swift) still provide high potential for the study of (persistent) supersoft X-ray binaries
  - Unique soft X-ray capabilities, long mission duration/ timebase with same instrumentation
- eROSITA/ SRG could provide the first all-sky census of supersoft sources since ROSAT if the energy cut-off would be lowered to 0.3 keV
- Detailed spectral diagnostics of the supersoft X-ray binaries, their environment, and their dynamics will become available with Athena+