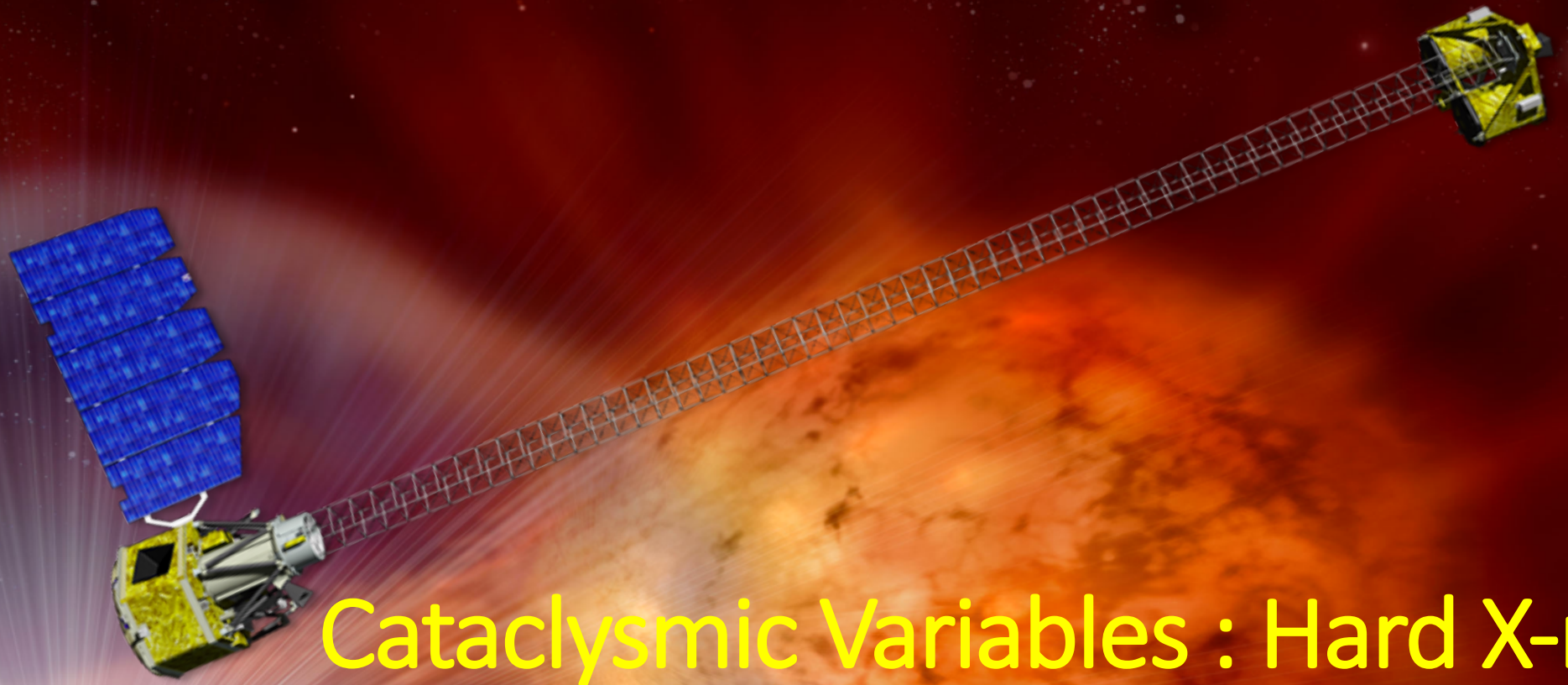


Cataclysmic Variables : Hard X-ray View from NuSTAR

Vikram Rana
Caltech

Wide band X-ray spectral and timing study of Cosmic X-ray sources

TIFR Jan 2017

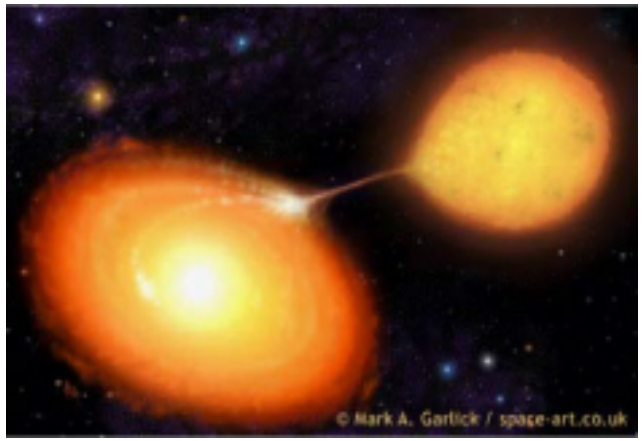
Classification of CVs

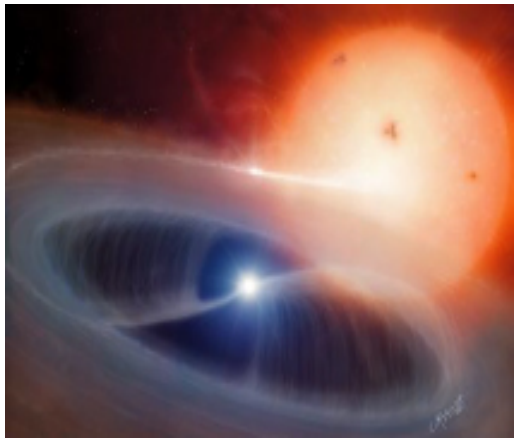
Non-magnetic CVs

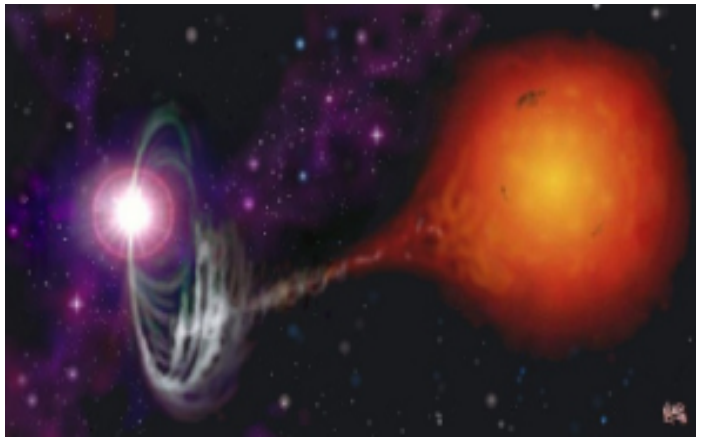
Magnetic CVs

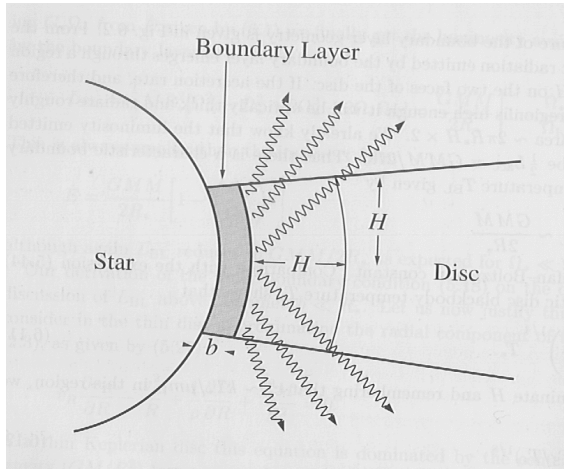
Intermediate Polars (IPs)

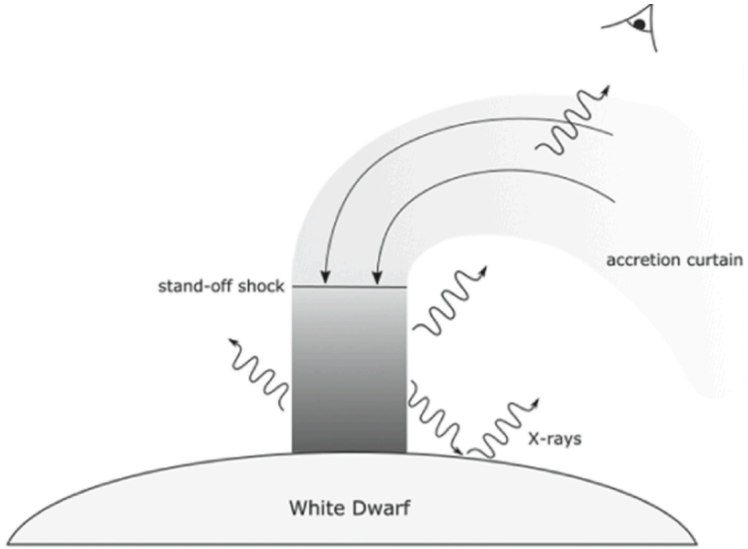
Polars





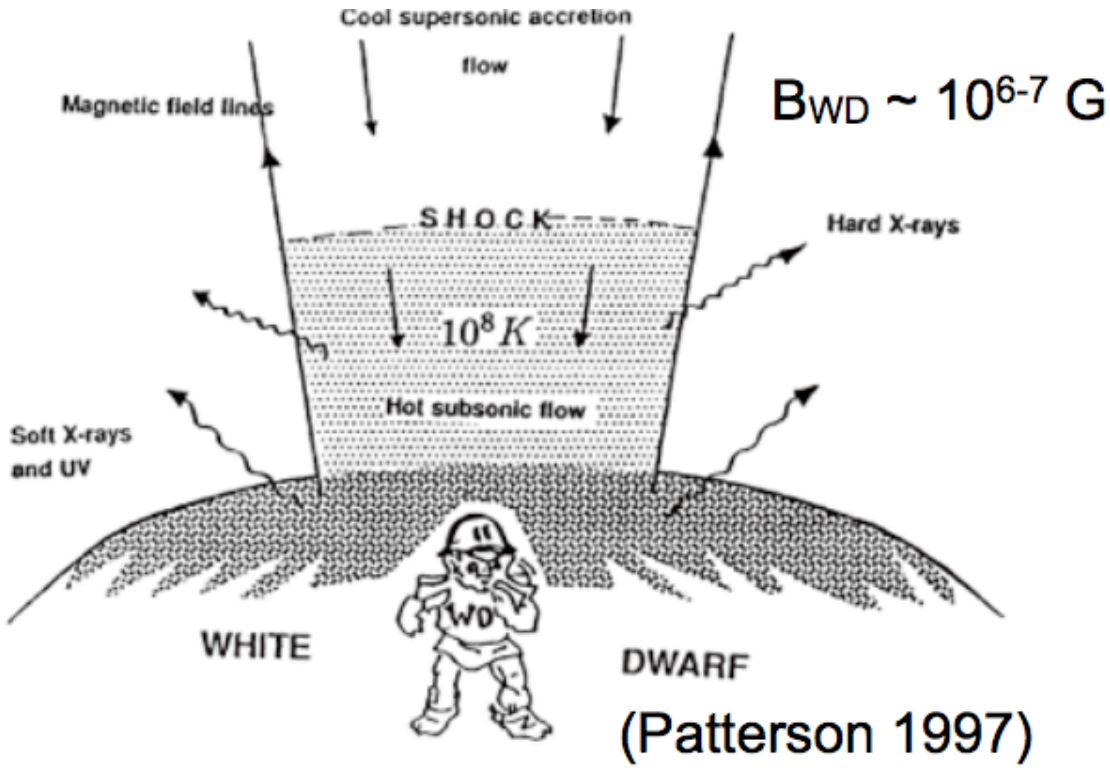




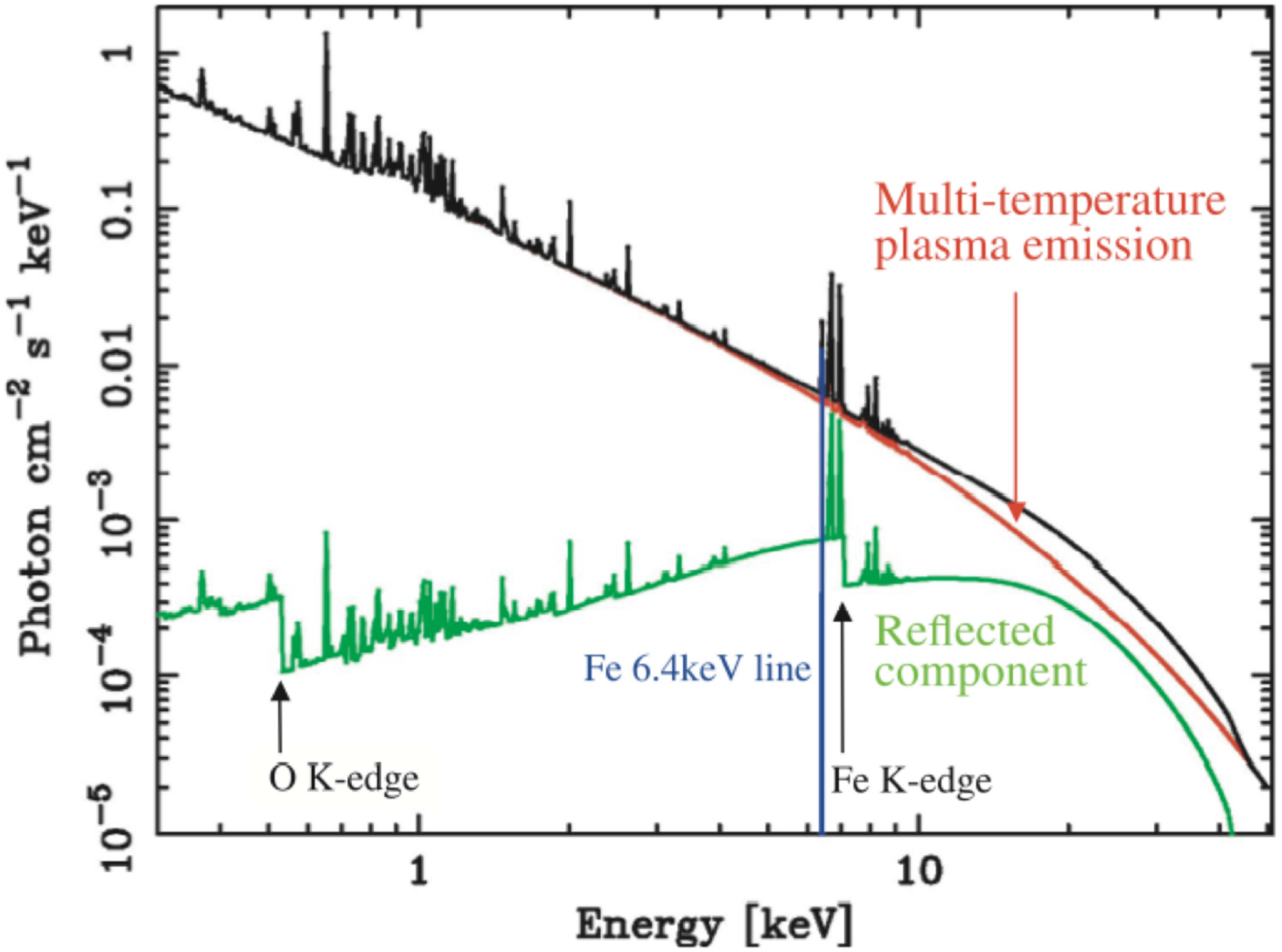


Standard Model for MCVs

- Standard Model of accretion column by Aizu 1973.
- Gravitational Shock heating
- Multi-temperature nature of plasma



Broadband SED of CVs

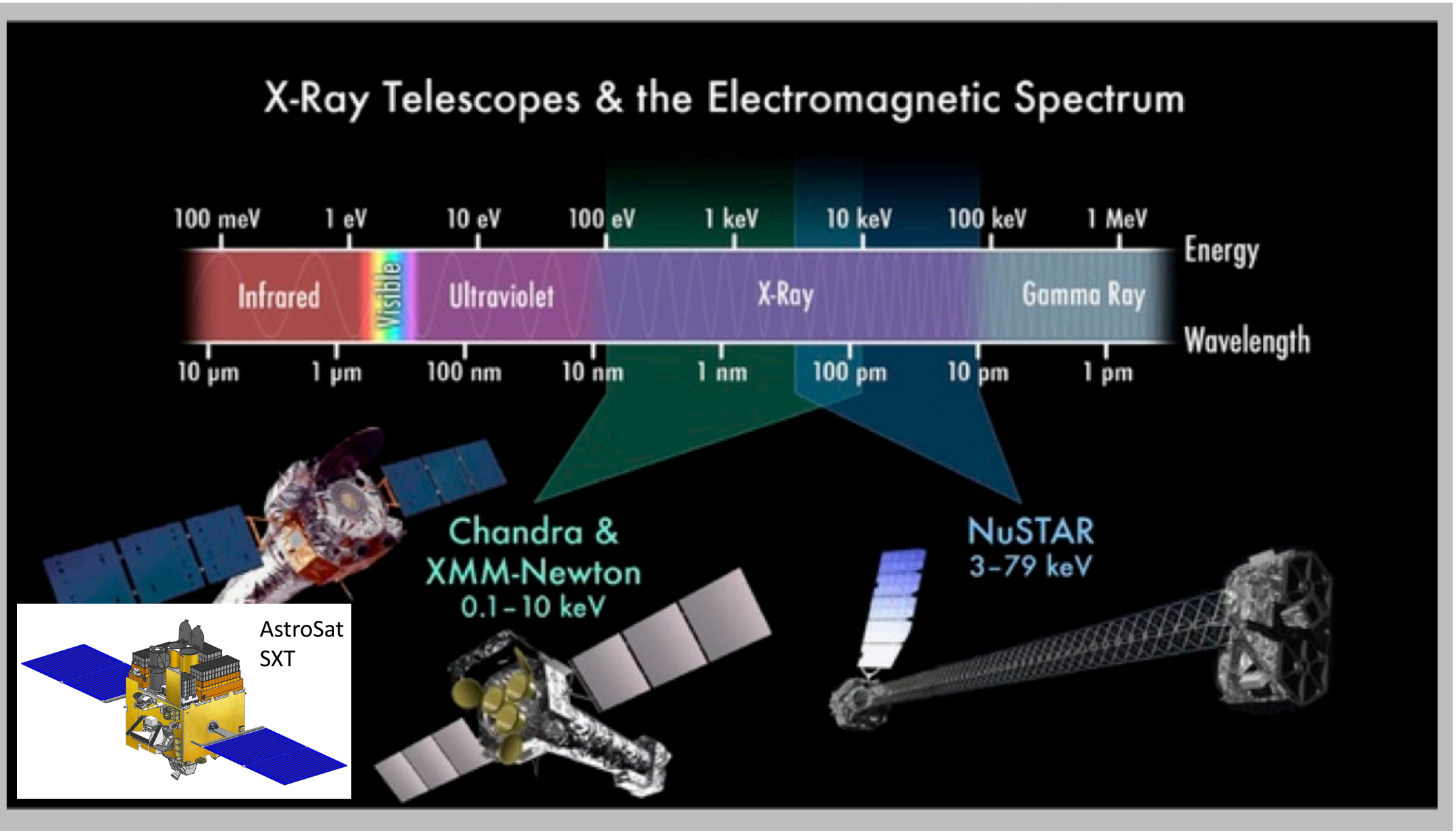


Ingredients of a broad-band X-ray spectrum

Reflection – very poorly studied phenomenon in CVs.

Fe 6.4 keV => Presence of reflection component

Ishida et al. (2009)


X-Ray Telescopes & the Electromagnetic Spectrum
100 meV
1 eV
10 eV
100 eV
1 keV
10 keV
100 keV
1 MeV
Energy
Infrared
Visible
Ultraviolet
X-Ray
Gamma Ray
Wavelength
10 μm
1 μm
100 nm
10 nm
1 nm
100 pm
10 pm
1 pm
Chandra &
XMM-Newton
0.1 – 10 keV
NuSTAR
3 – 79 keV
AstroSat
SXT

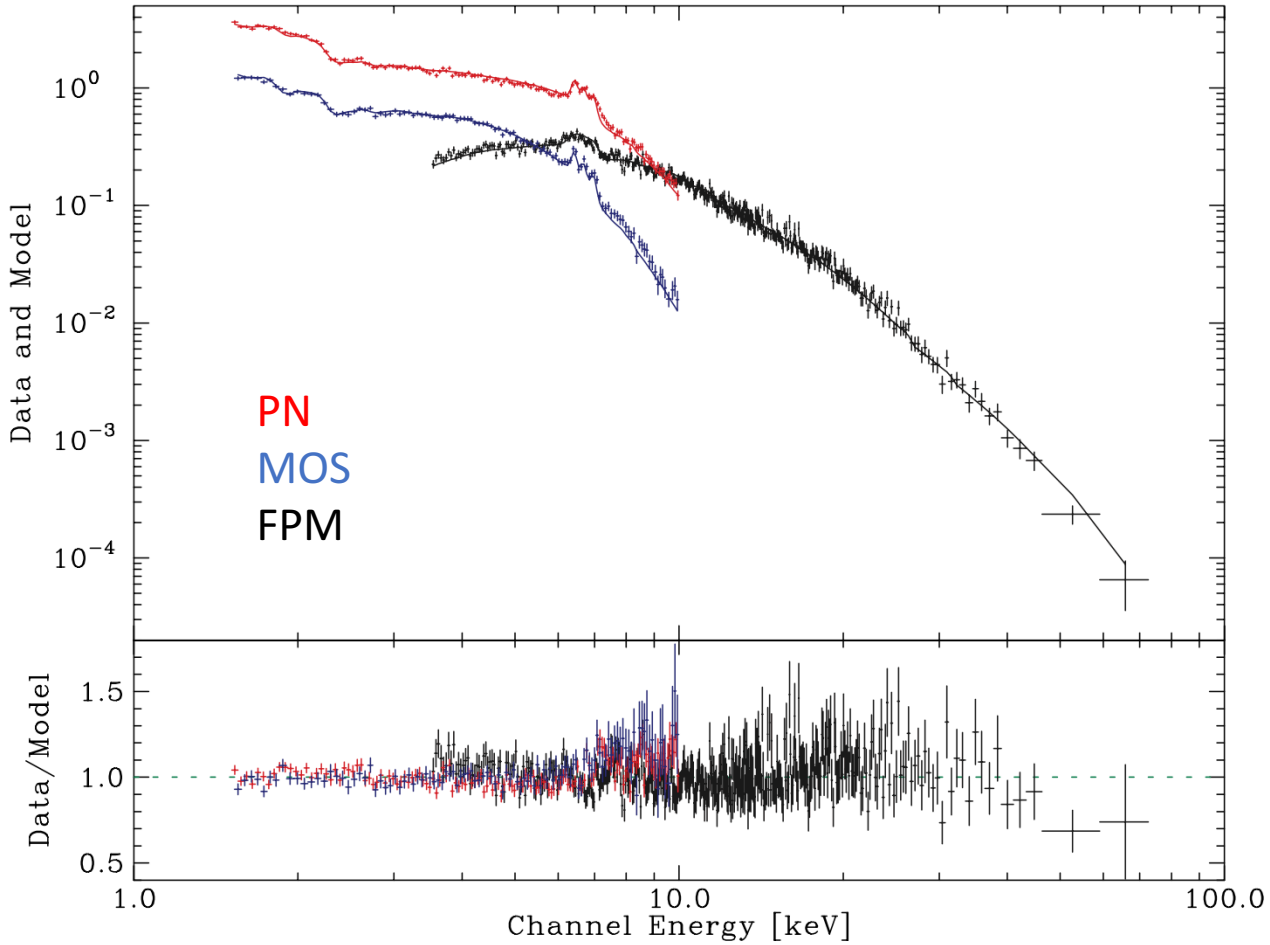
Three IPs with XMM & NuSTAR

- Highest Swift/BAT fluxes in 14-195 keV band
- V1223 Sgr
  - Spin of WD = 745.63 s (Osborne et al. 1985)
  - Orbit ~ 3.4 hrs
- V709 Cas
  - Spin of WD = 312.75 s (de Martino et al. 2001)
  - Orbit ~ 5.4 hrs
- NY Lup
  - Spin of WD = 693.01 s (de Martino et al. 2006)
  - Orbit ~ 9.9 hrs

Object	Obs. Date	*NuSTAR*		pn		MOS	
		Start Time	Exp. (ks)	Start Time	Exp. (ks)	Start Time	Exp. (ks)
V709 Cas	2014-07-07	02:01	26	04:43	23	04:37	31
NY Lup	2014-08-09	14:51	23	08:19	26	08:13	36
V1223 Sgr	2014-09-16	02:26	20	02:17	12	02:11	16

Simultaneous XMM-Newton & NuSTAR Data

Broadband Spectra

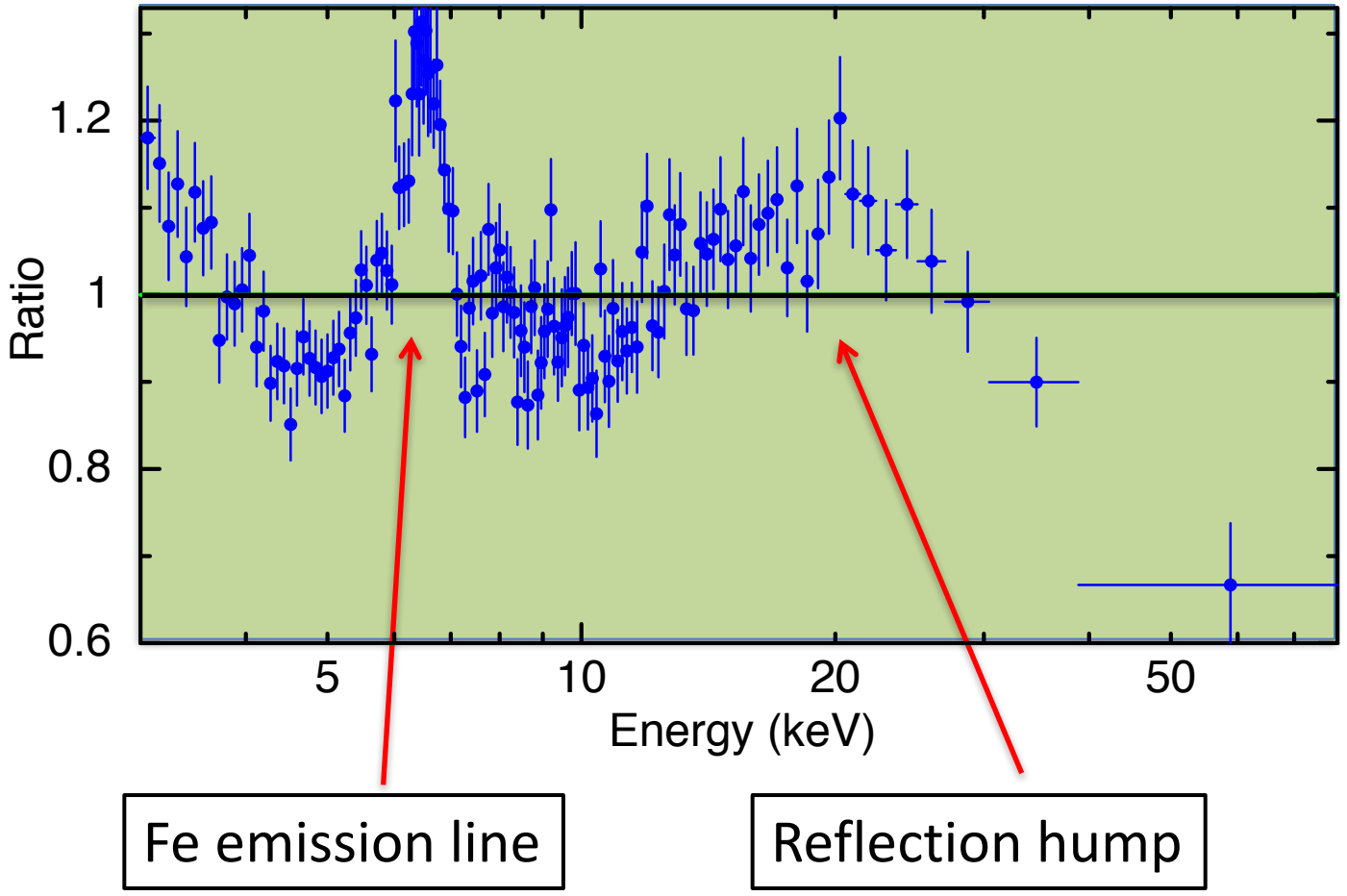


V1223 Sgr

Absorber+ mkcflow + reflect + Fe 6.4 keV line

Hard X-ray sensitivity => High quality broadband X-ray spectra

Reflection with NuSTAR



V1223 Sgr

High SN data up to ~78 keV

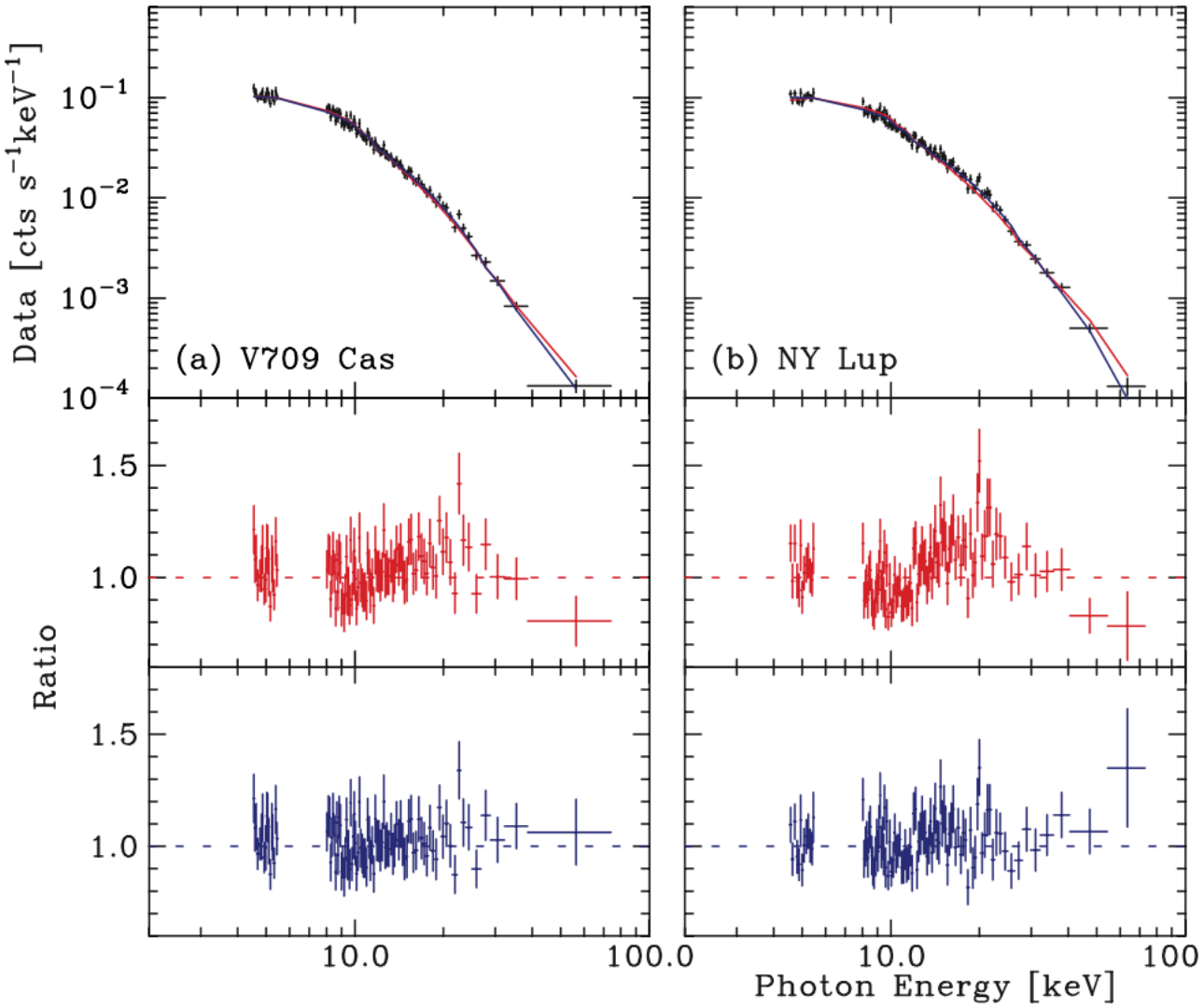
Compton reflection hump around 20 keV

Refl amp=0.62±0.16
Fe 6.4 keV line
eqw = 90±18 eV

Mukai, K., Rana, V. R., et al. (2015)

V709 Cas

NY Lup



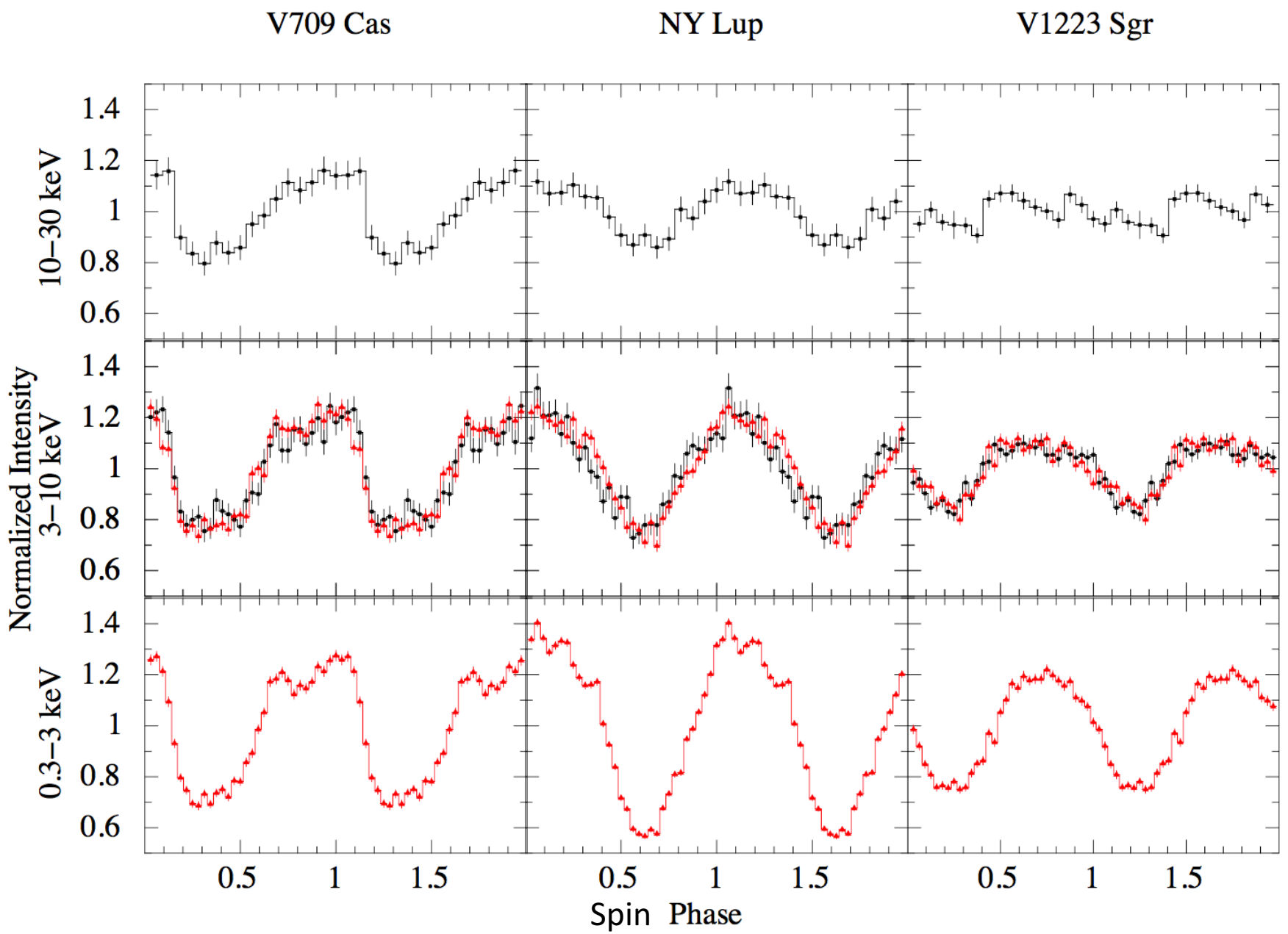
Bremsstrahlung fit to continuum without and with reflection

V709 Cas

Refl Amp = ~0.35
Fe 6.4 keV line
Eqw = 105 ± 11 eV

NY Lup

Refl Amp > 0.8
Fe 6.4 keV line
Eqw = 132 ± 12 eV

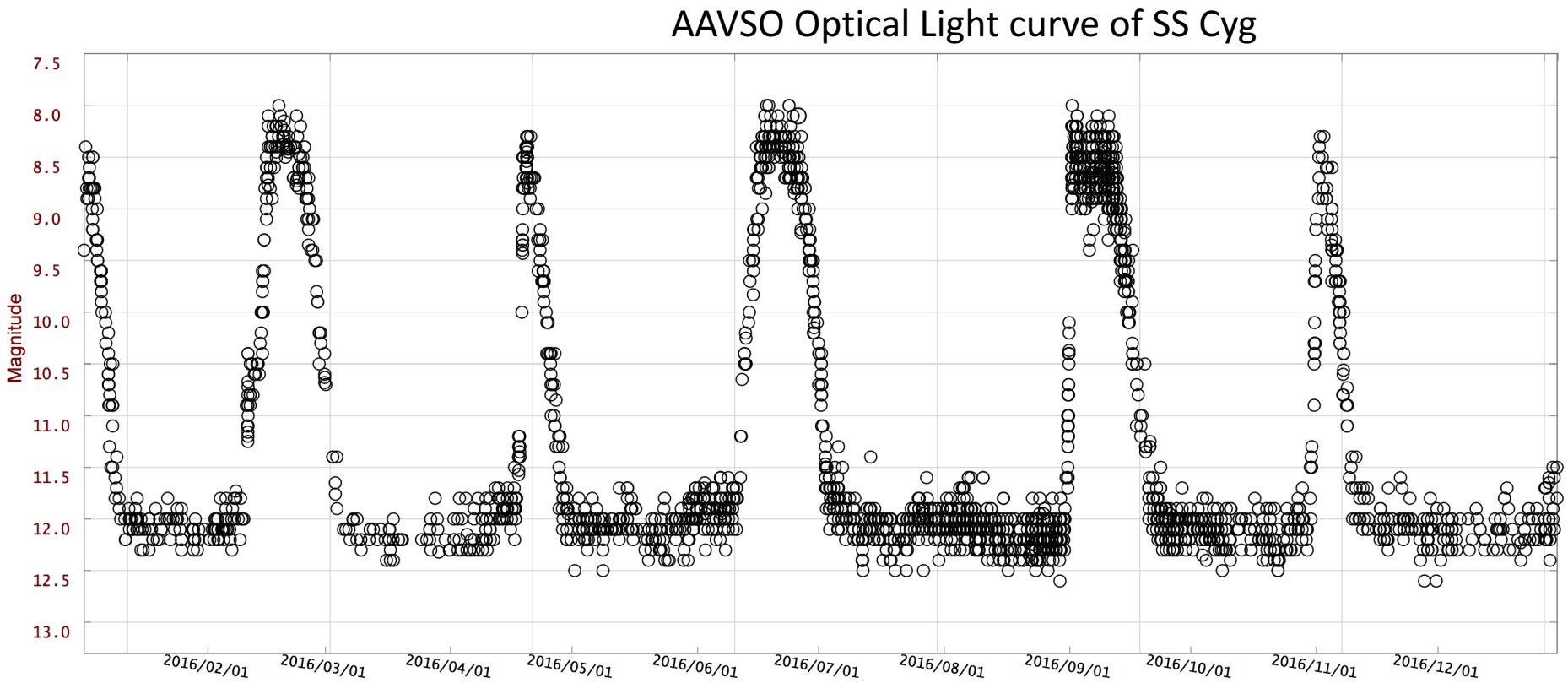


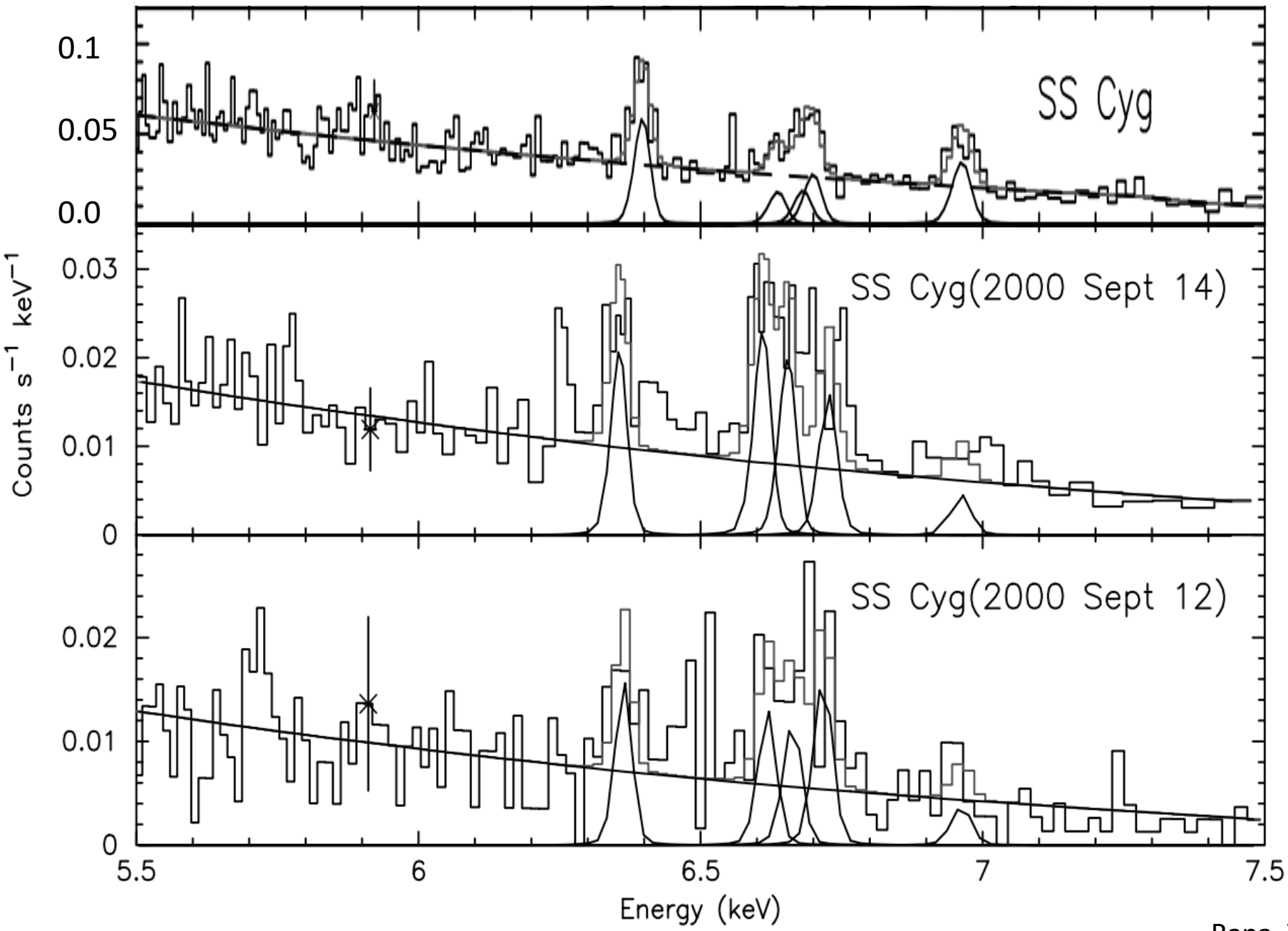
XMM-Newton
NuSTAR

Mukai, K., Rana, V. R., et al. (2015)

SS Cyg – A Bright Dwarf Nova

- WD of ~1 M_{sun} and secondary of 0.7 M_{sun}
- Orbital period = 6.6 hours and distance = 114 pc
- Optical outburst in about every 50-60 days and lasts for about 10-15 days.





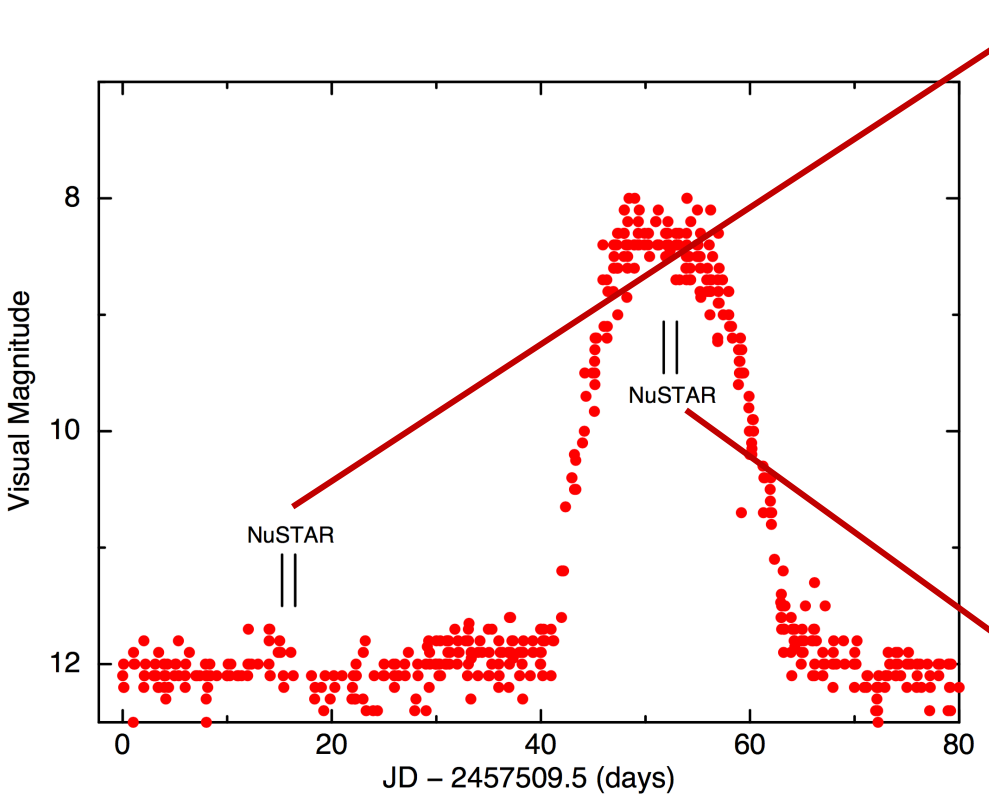
Chandra HEG spectra of SS Cyg during optical quiescence and outburst

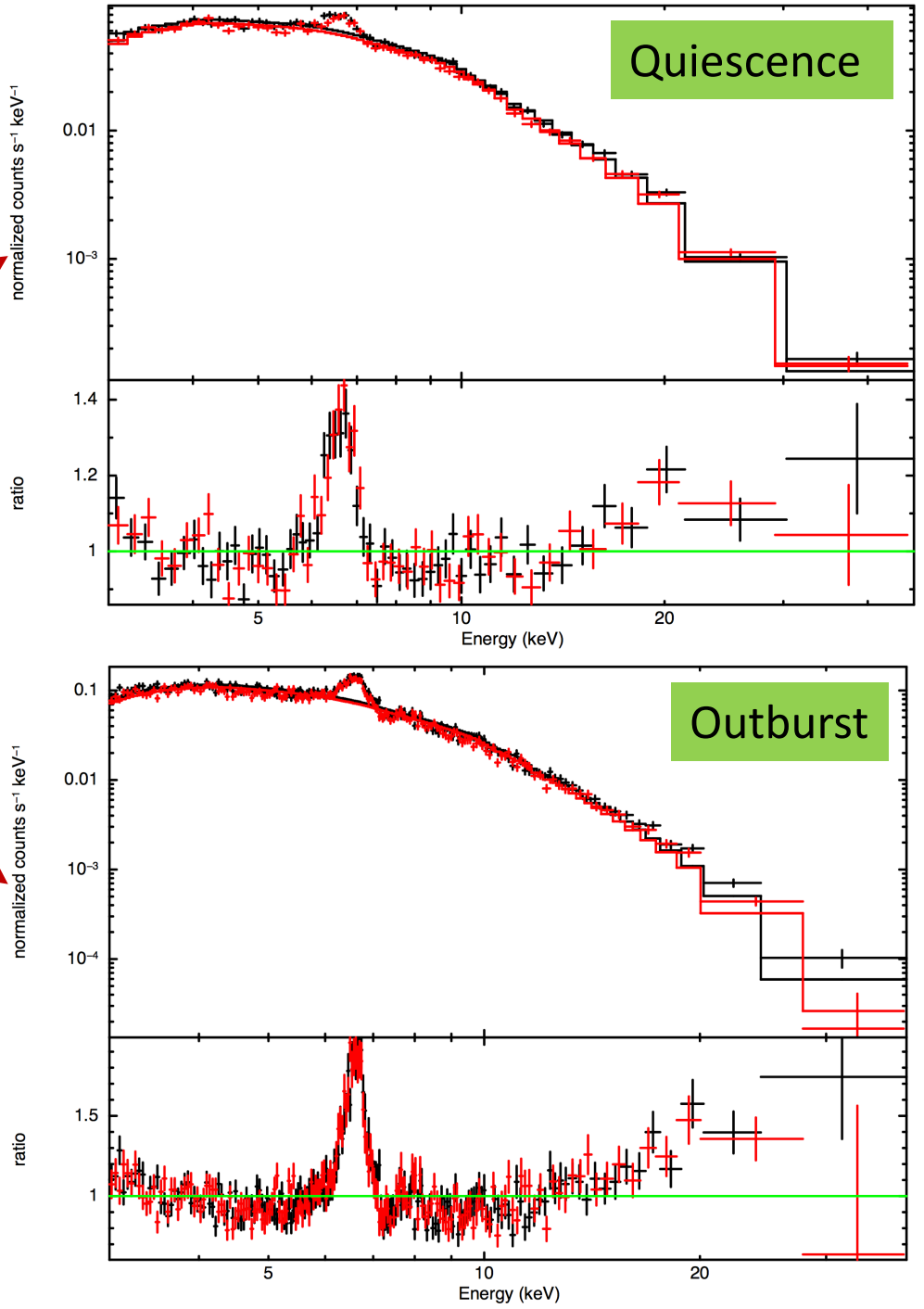
Fe K_{alpha} emission lines

Fluorescence line at 6.4 keV => reflection

Rana, V. R., Singh, K. P., et al., (2006)

NuSTAR observations of SS Cyg

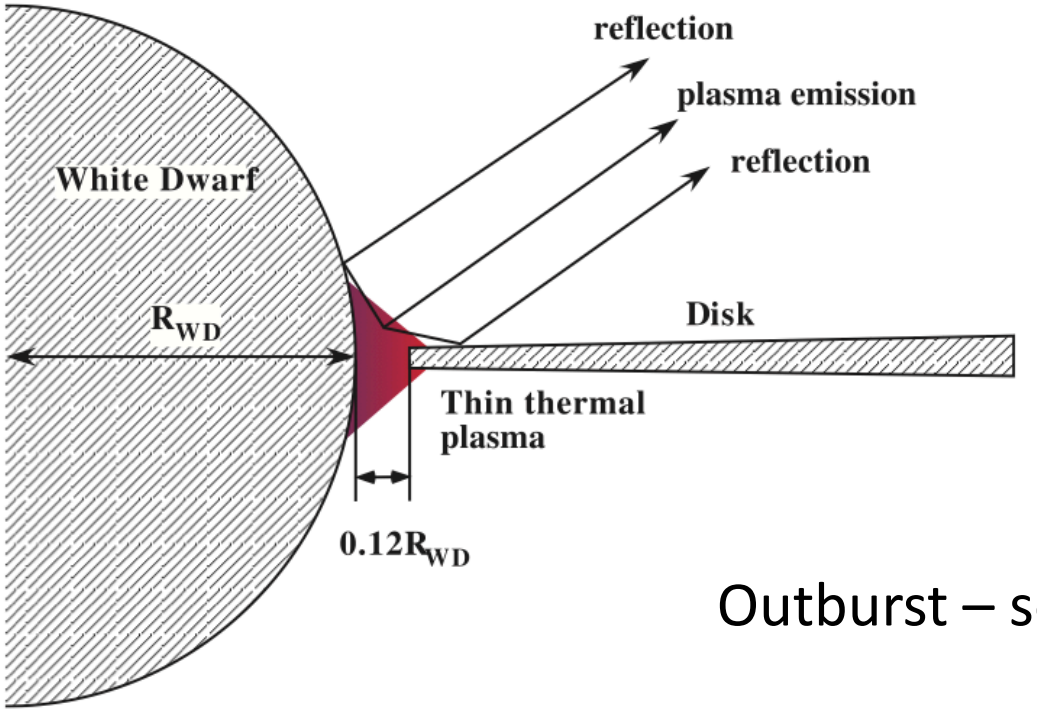




kT = 15±0.4 keV
Nh = 1.19±0.6 cm^{-2}
Line E = 6.62±0.04 keV
Width = 0.26±0.04 keV
Eqw = ~370 eV

kT = 6.5±0.1 keV
Nh = 2.94±0.4 cm^{-2}
Line E = 6.60±0.01 keV
Width = 0.16±0.02 keV
Eqw = ~660 eV

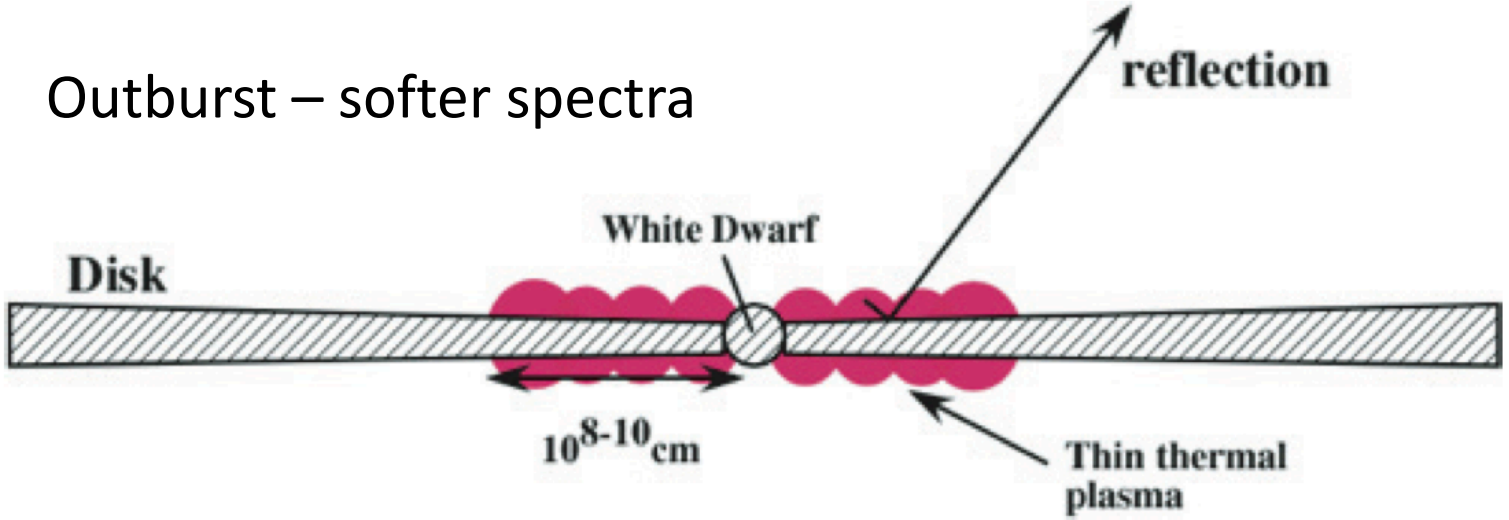
Non magnetic CVs



Quiescence

enhanced hard X-ray emission

Outburst – softer spectra



Ishida et al. 2009

Conclusions

- Detection of reflection is very encouraging for IP sample
  - Increase the sample size for better statistics
  - Spin dependent reflection to define geometry of the system

- Hard X-ray spin modulations
- Different height of X-ray emitting regions in these CVs
- Bright non-magnetic CVs (novae) in their optical outburst as well as quiescent state, for eg. SS Cyg and U Gem
- Astrosat – Ideal for broadband spectroscopy covering UV to hard X-ray energy range