Suzaku Observations of Stellar X-ray Sources and Cataclysmic Variables

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Stars and CVs observed with Suzaku

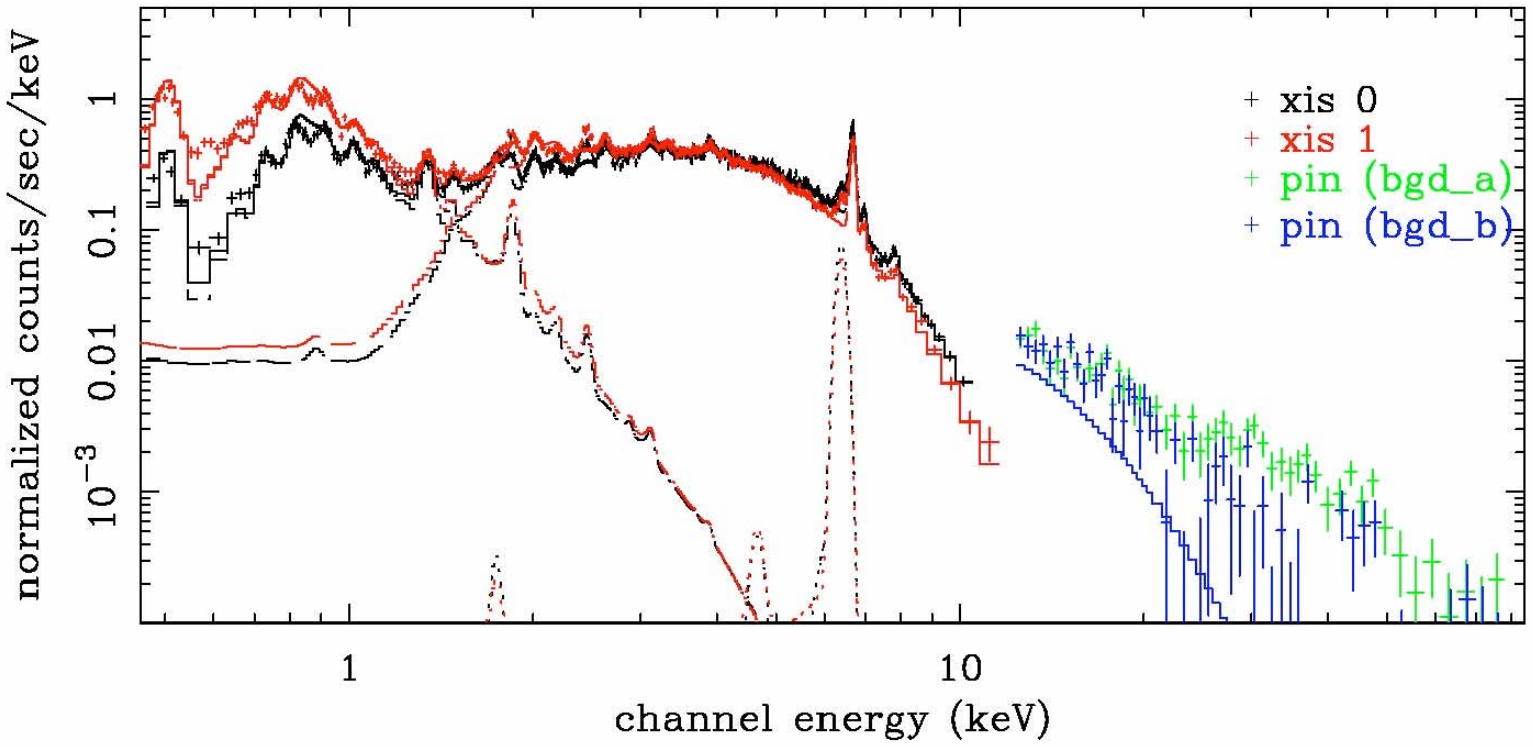
- AB Dor and AM Her (short, “step-point” observations)
- eta Car
- SS Cyg (non-magnetic CV; once in quiescence and once in outburst)
- AE Aqr and XY Ari (magnetic CVs)
- CH Cyg (peculiar symbiotic star)

...and more to come during AO-1

What can Suzaku do for these objects?

- They often show multi-temperature plasma emission - Suzaku can constrain the high T (Fe Kalpha) and low T (~1 keV lines) components
- Many CVs and some stars have emission above E=10 keV that are poorly constrained
  - In some cases, hard X-rays may be non-thermal
- The fluorescent Fe Kalpha line at 6.4 keV contains clues about the geometry of the emission region

Suzaku spectra of Eta Carinae

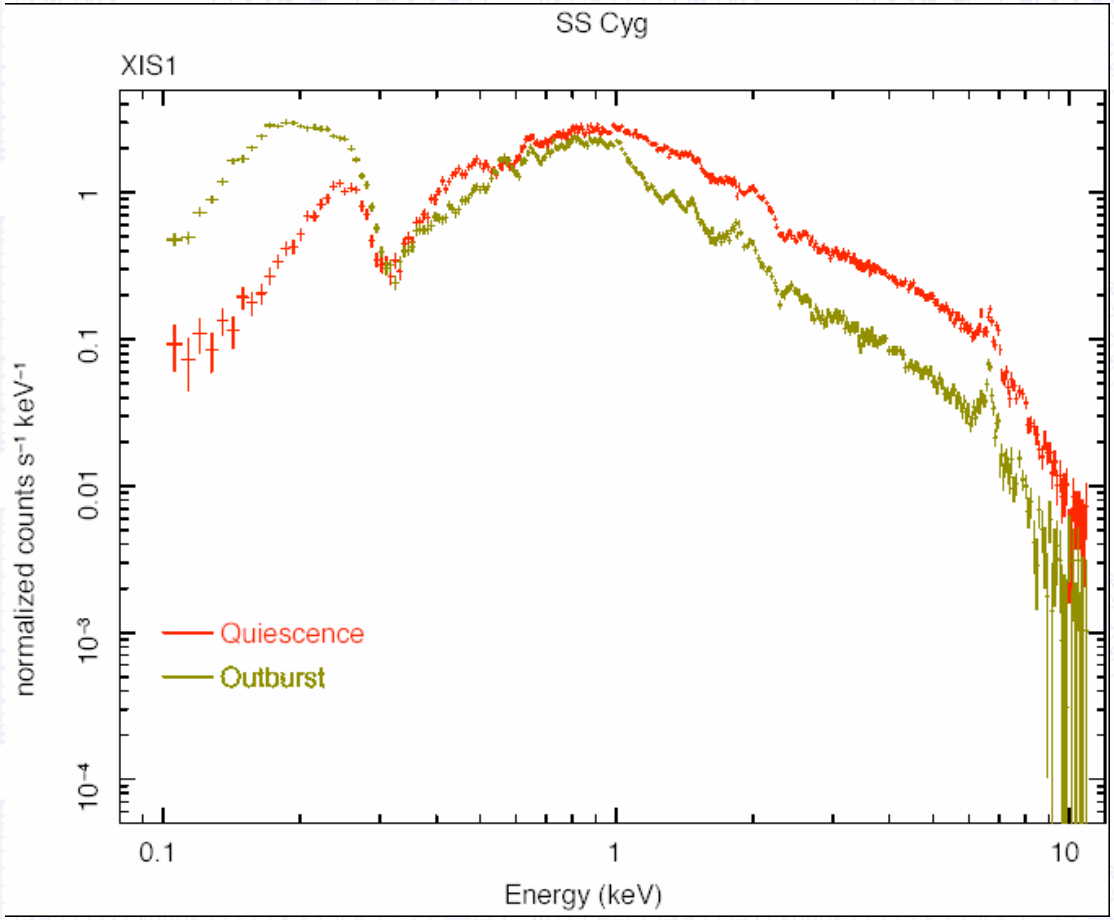


Is there non-thermal hard component in eta Car?

SS Cyg: the Brightest Dwarf Nova

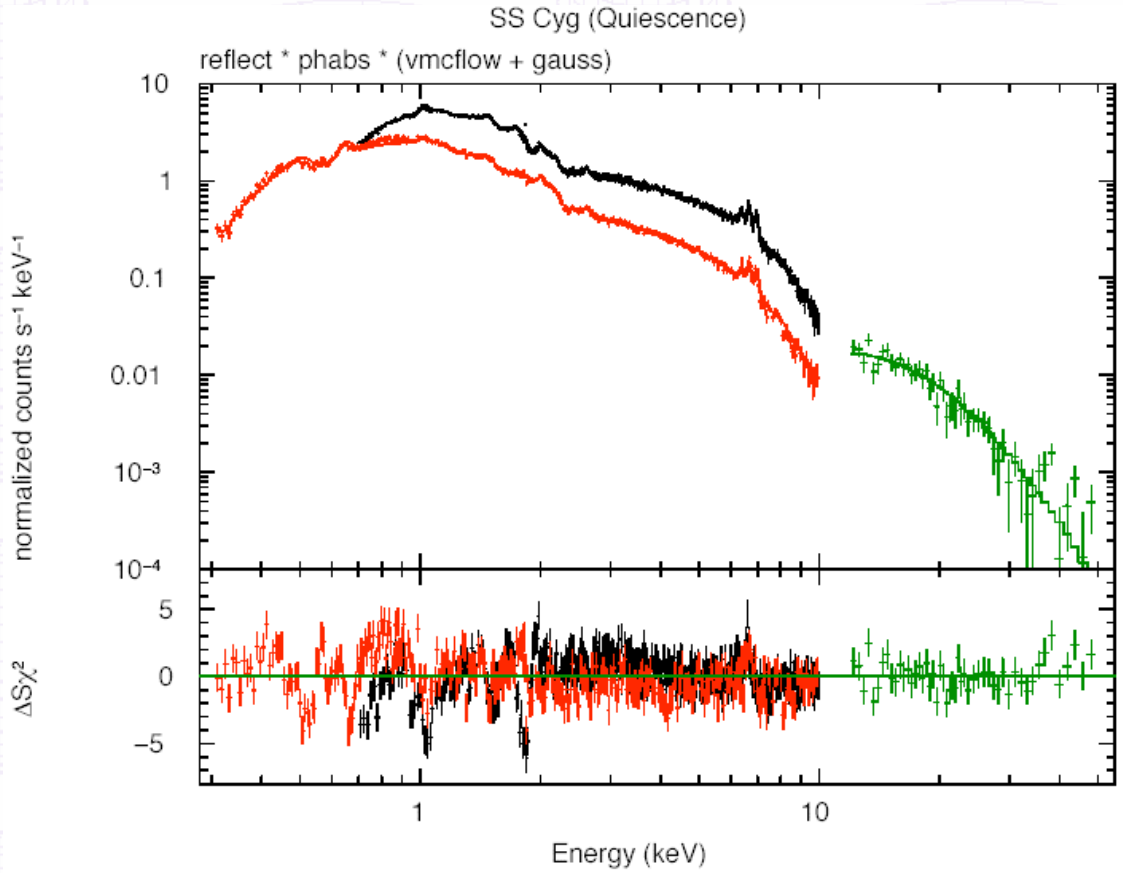
- Dwarf nova outburst is believed to be caused by an instability of the accretion disk that extends down to the white dwarf surface
  - White dwarf analog of soft X-ray transients, which have provided the best evidence for black holes
- Boundary layer between the disk and the primary emits X-rays
- Accretion during quiescence is poorly understood - X-ray luminosity higher than the simplest models of the quiescent disk predicts

Suzaku Observations



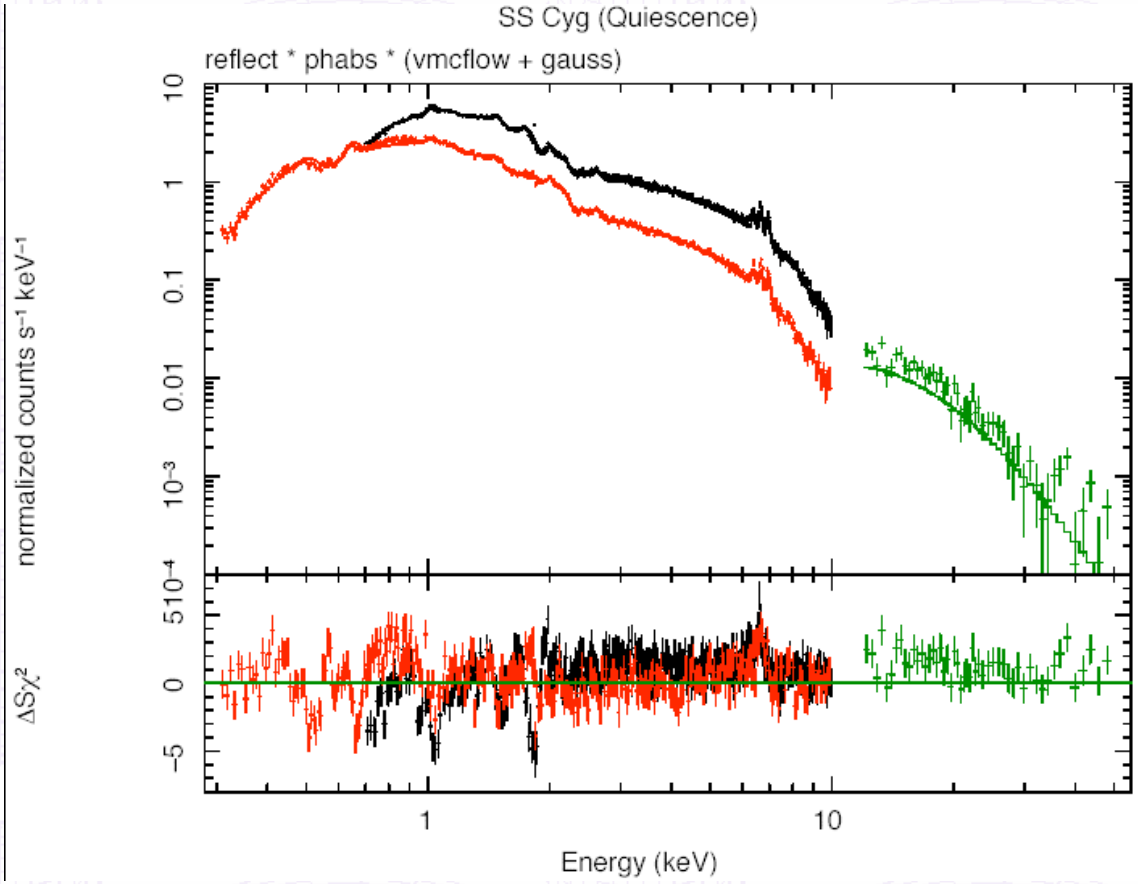
Two Suzaku observations captured the well-known differences in the X-rays: SS Cyg is soft X-ray bright and hard X-ray dim during outburst

Broad-band Spectrum during Quiescence



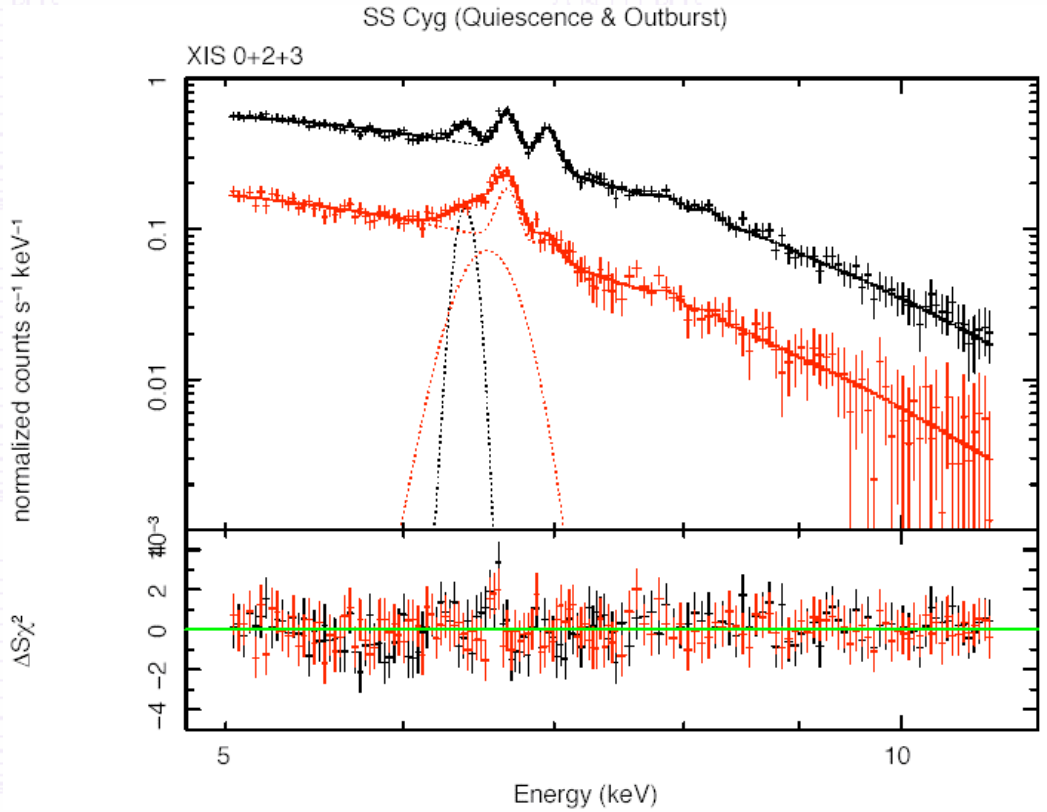
Multi-temperature (kt: 33-0.1 keV) model provides an adequate description, with 6.4 keV line from reflection, in quiescence.

Reflection during Quiescence



Fit is noticeably worse when reflection component is turned off: emission region is very close to the white dwarf surface

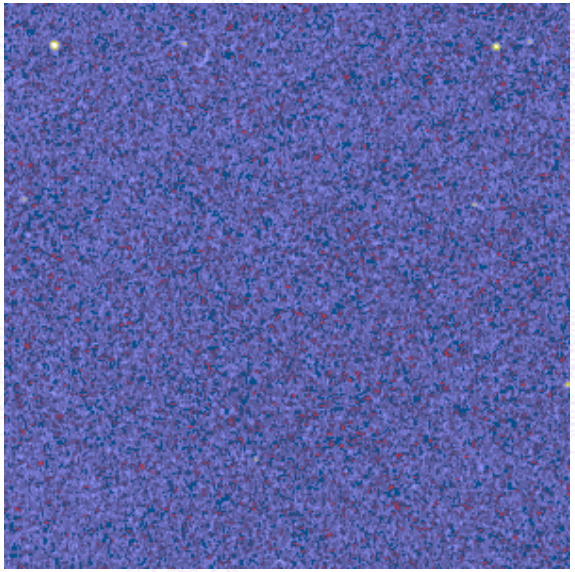
Fe Kalpha Profiles



In quiescence, 3 narrow lines are seen - in outburst, there is an additional broad 6.4 keV line. Reflection off the white dwarf surface (narrow) and the inner disk (broad)?

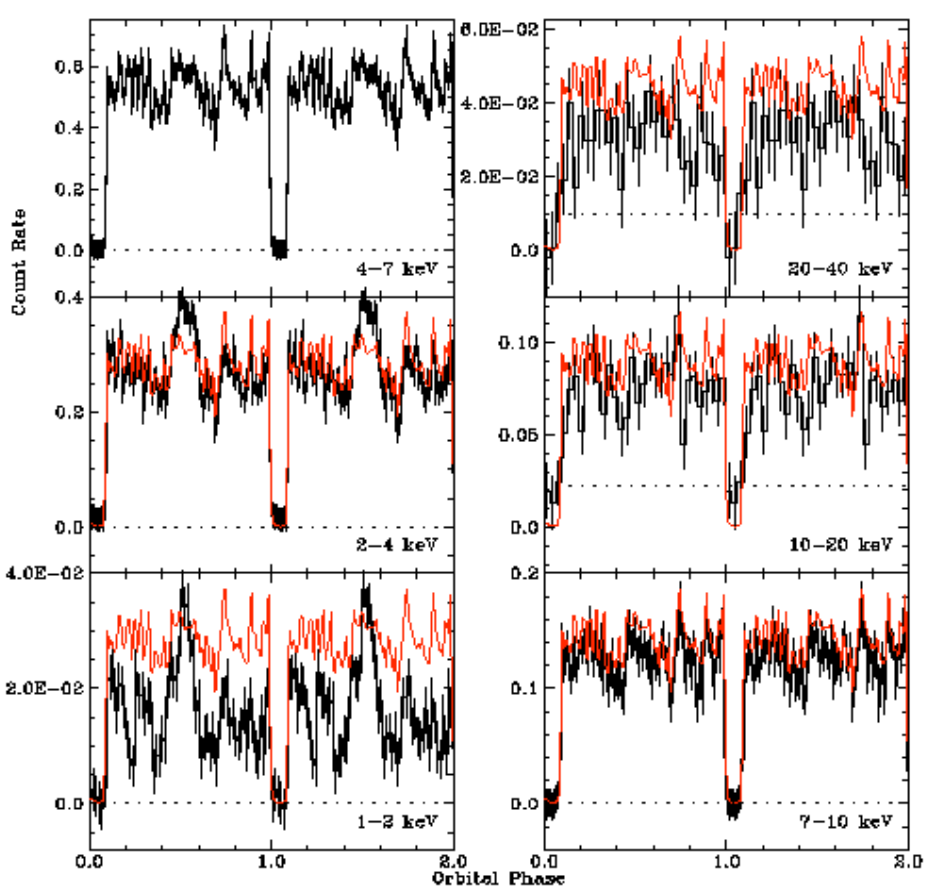
Intermediate Polar XY Ari

- Intermediate polar (IP) XY Ari is located behind the molecular cloud MBM 12
- MBM 12 was observed for the study of Galactic diffuse soft X-ray emission
- Suzaku data above 1.5 keV is dominated by XY Ari
- It is also the only deeply eclipsing IP known, which is therefore an important IP to study



Optical finding chart for XY Ari

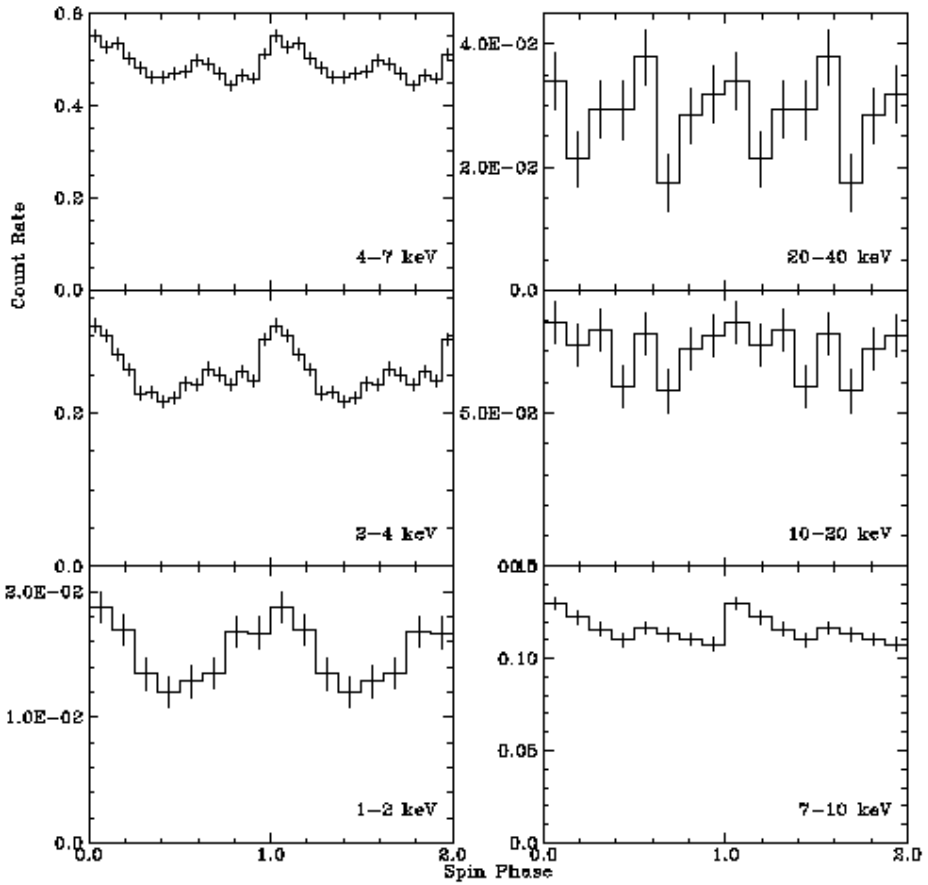
Orbital Modulation of XY Ari



Folding the XIS and PIN light curves of XY Ari on the orbital period, the eclipse is clearly visible up to 40 keV.

This validates the background subtraction

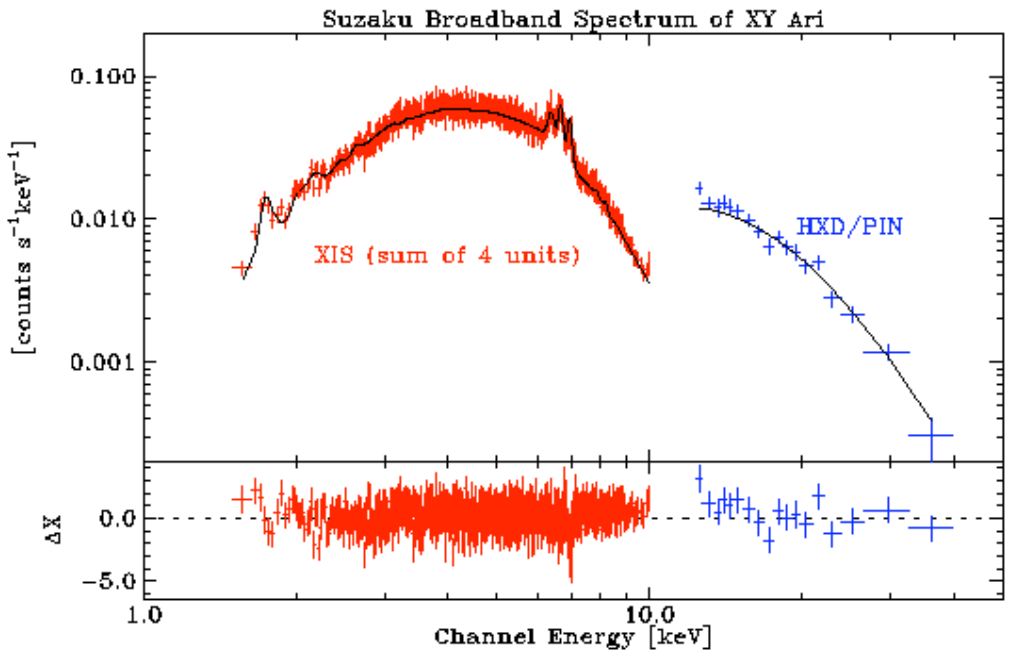
Spin Modulation of XY Ari



Spin modulation is detected in the XIS data, but not (confidently) in the PIN data.

Note the strong and sinusoidal modulation below 2 keV

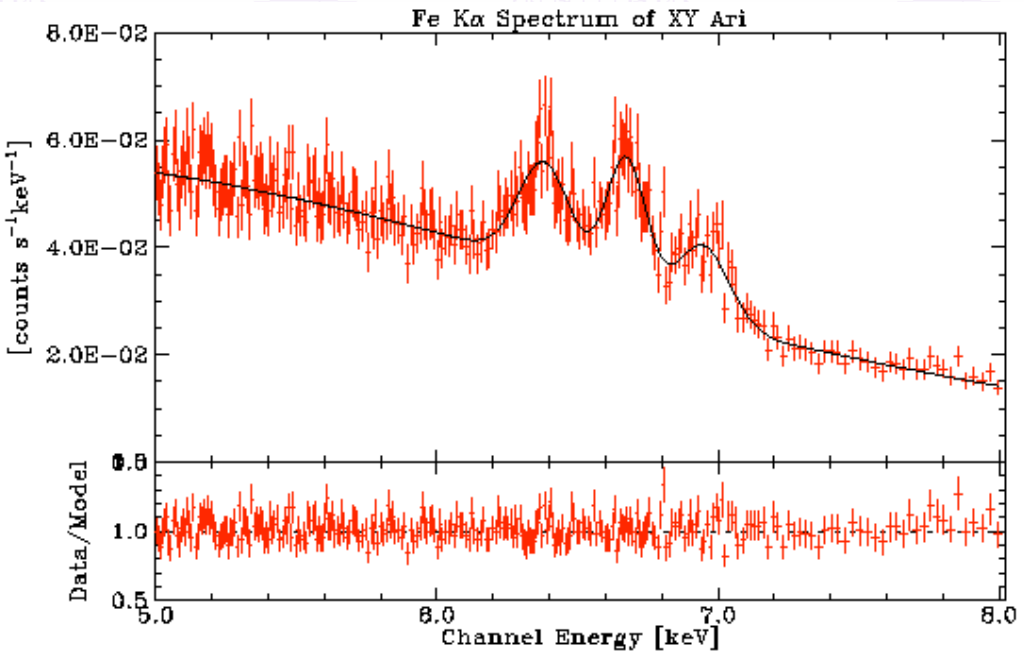
Broad-Band Spectrum of XY Ari



Model incorporates:
complex absorber, multi-temperature plasma, reflection, and 6.4 keV line

XY Ari is a relatively faint IP - previous spectral studies (with Ginga and RXTE) were limited to E<20 keV. Suzaku has the potential to make an important test of broad-band spectral models of IPs such as XY Ari

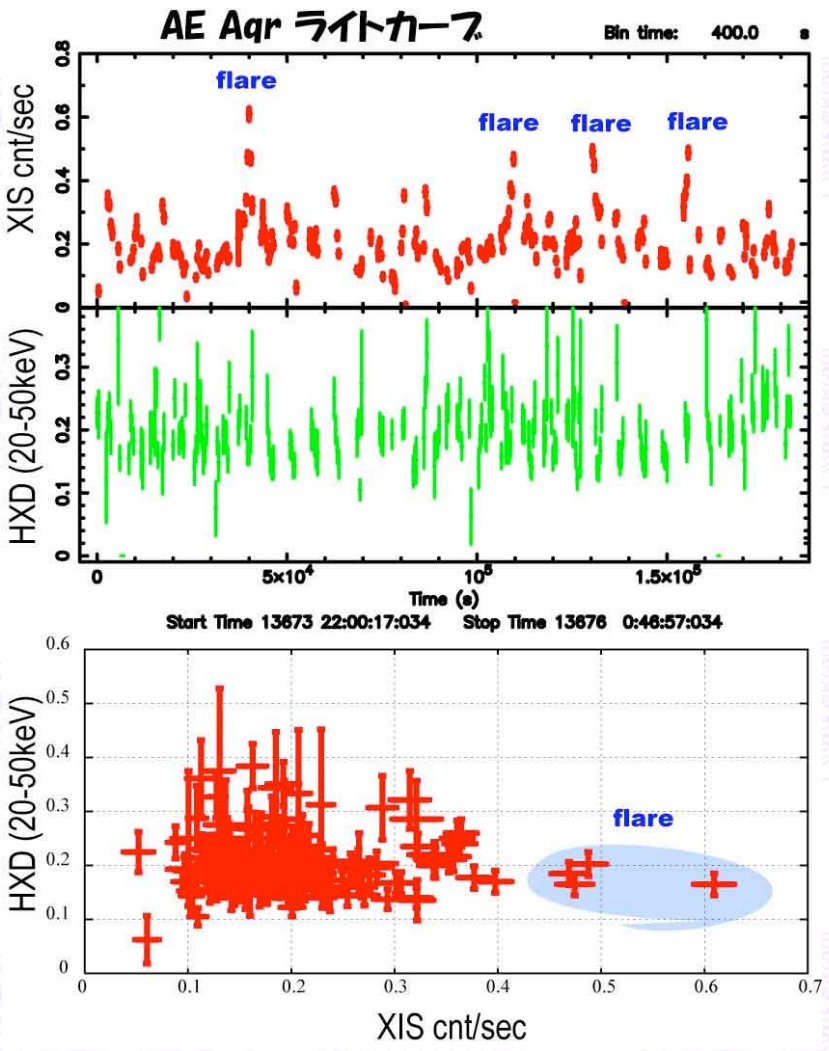
Fe Kalpha Lines of XY Ari



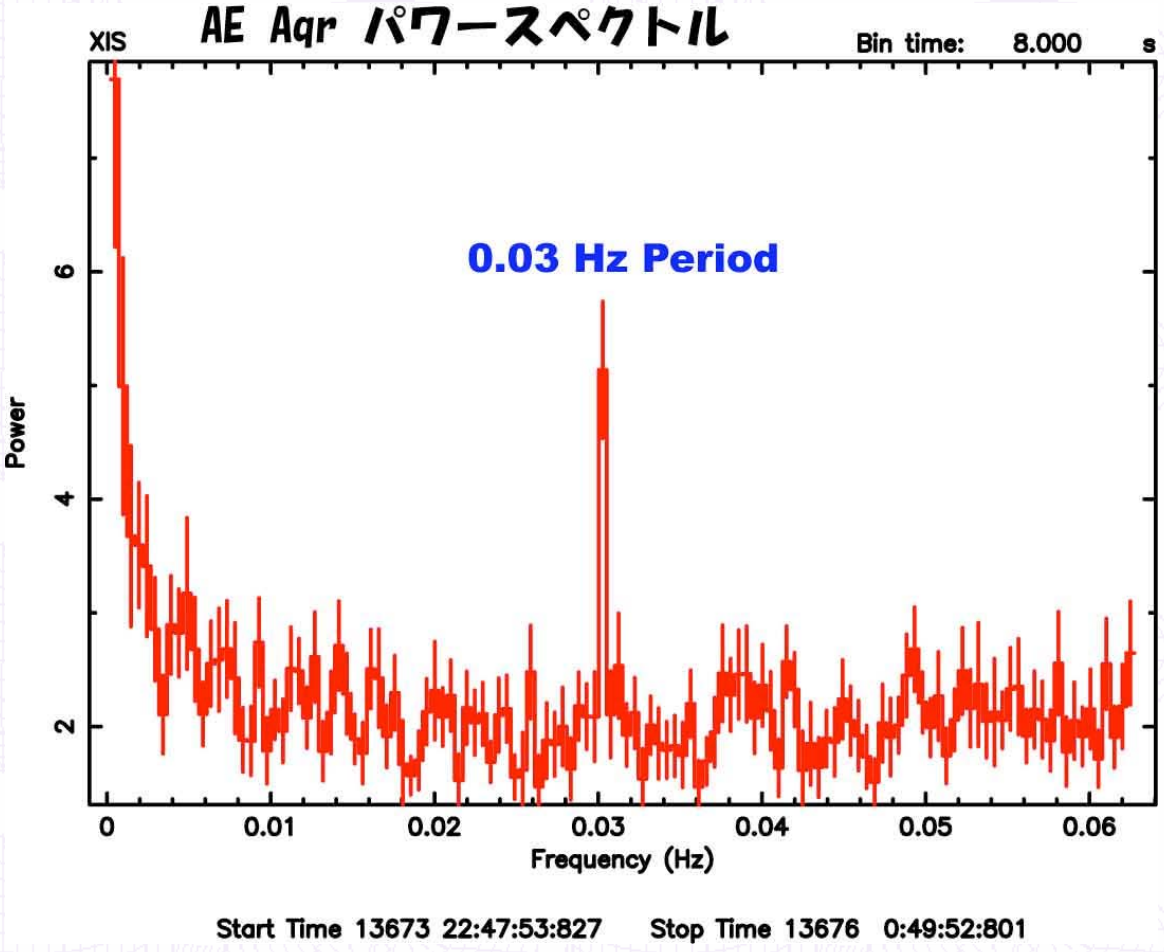
The ratio of H-like and He-like lines is sensitive to the high kT component of the plasma; 6.4 keV line adds information on reflection

AE Aqr: A Propeller System

Although a member of the IP family, AE Aqr is thought to be powered by the spin-down energy of the rapidly rotating (P=33s) white dwarf. Optical emisison lines and other spectral components are likely due to material flung out by the spinning white dwarf (=propeller). AE Aqr has been detected from radio to TeV gamma-ray wavelength ranges.

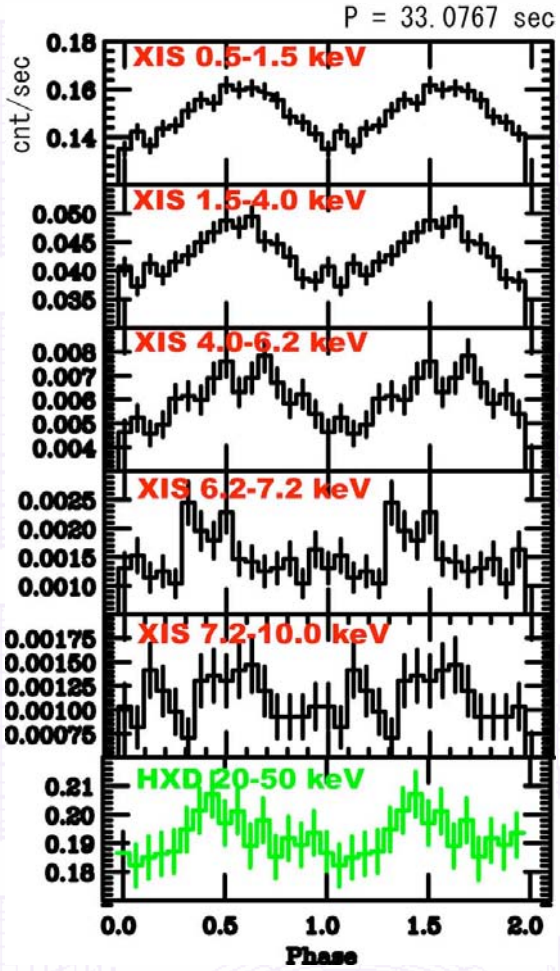


Period Analysis



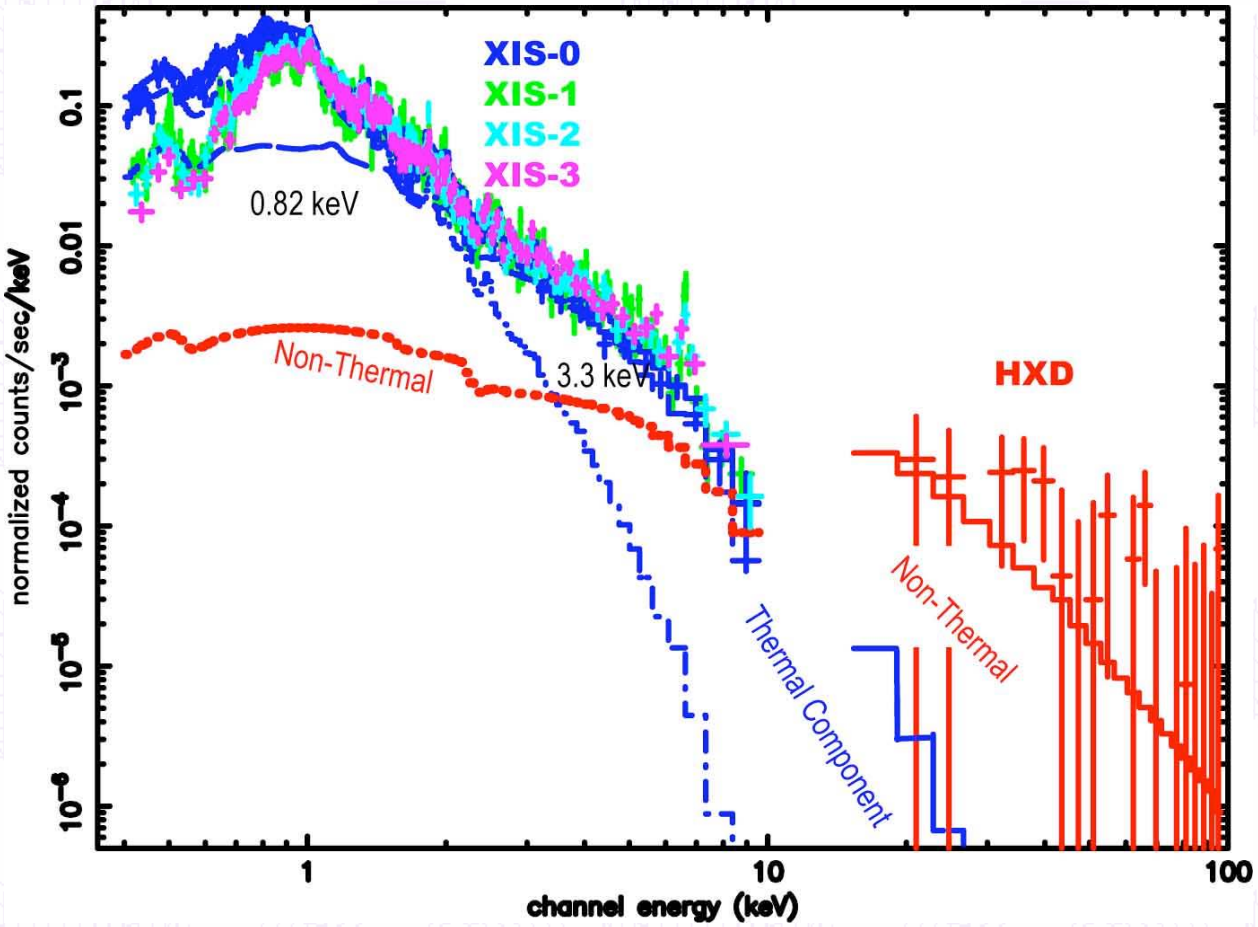
The white dwarf spin period is strongly detected in the XIS data - this allows more sensitive search for the hard X-ray emission

Faint Hard X-ray Emisison in AE Aqr



AE Aqr has a relatively soft X-ray spectrum, and any hard X-ray emission is within the current systematic uncertainties of background subtraction of HXD/PIN. Nevertheless, spin-folded light curve of the HXD 20-50 keV data shows a definite modulation, suggesting that AE Aqr is indeed detected with HXD/PIN.

Non-thermal Emission?



A plausible interpretation is that of particle acceleration (also related to radio and gamma-ray emisison) producing non-thermal hard X-rays

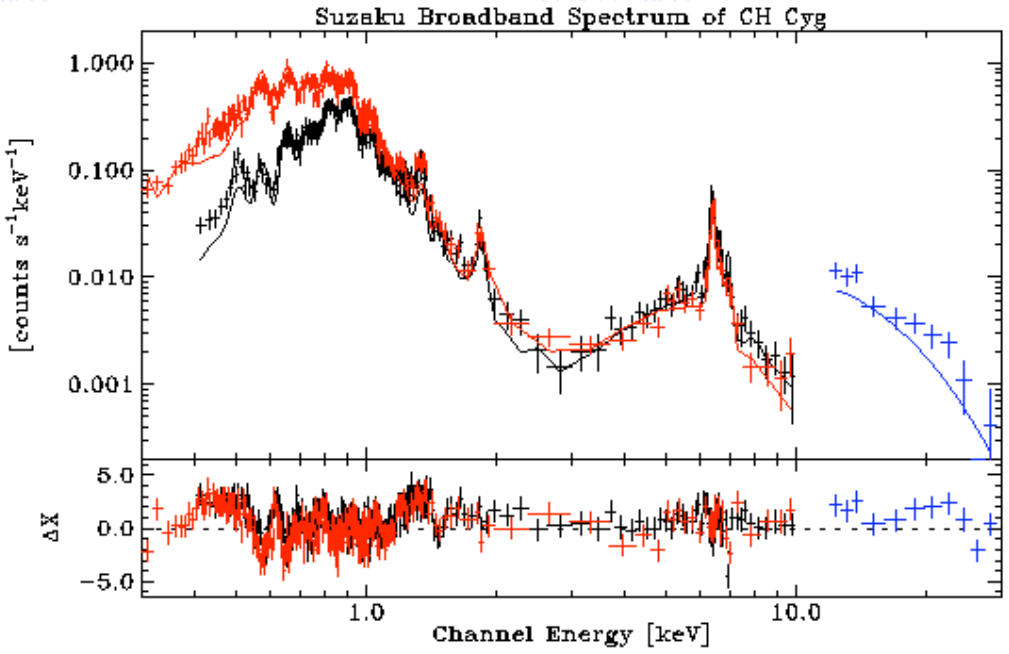
Symbiotic Stars

- Symbiotic stars are red giants with an additional blue component
- Heterogeneous class, but many are red giant-white dwarf binaries
- Wind accretion and occasional thermonuclear runaway (recurrent nova outbursts) provide the energy for the blue component
- Symbiotic stars are close relatives of cataclysmic variables (CVs) and may include Type Ia progenitors.

Hard X-rays from Symbiotics

- The Swift BAT and Integral Galactic Plane surveys have revealed a subset of Symbiotic Stars as a new class of hard X-ray emitting objects
  - New, unexplored science
  - Hard X-ray emission mechanism uncertain
  - In one case (RT Cru), hard X-ray emission drew attention to a previously obscure symbiotic star
- Pointed observations using Suzaku's wide energy range are essential to make progress

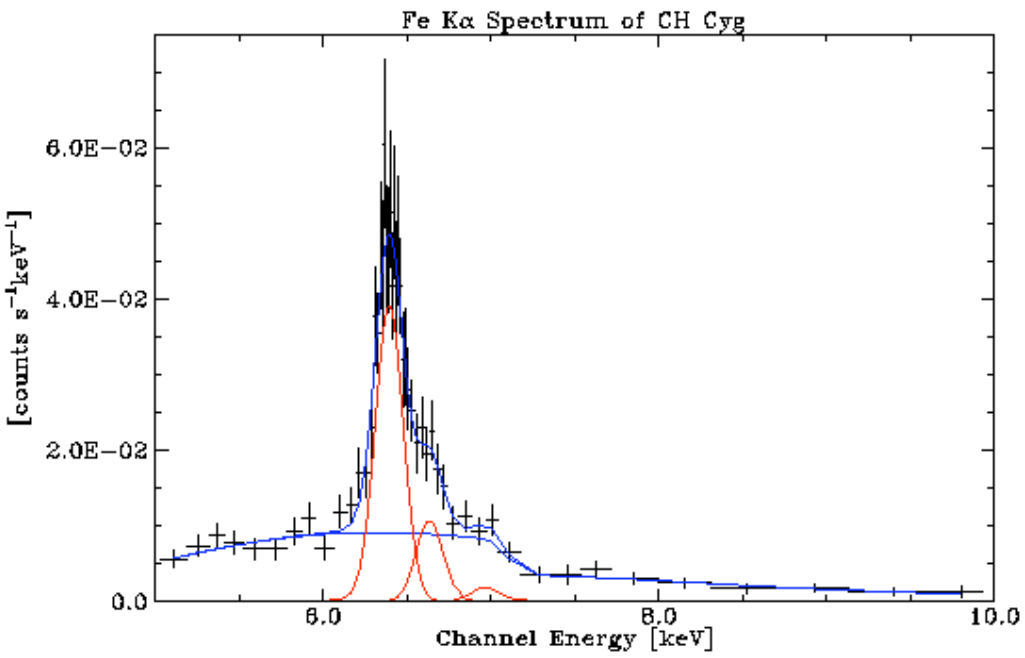
Broad-band Spectrum of CH Cyg



- Clearly shows the two-component spectrum already known from ASCA data
- Hard component is much weaker than, but soft component is comparable to ASCA data

- HXD/PIN detection is reasonably secure, but the spectral shape is not (CH Cyg is weak compared to cal. uncertainties)

Scattering Dominated Spectrum



- Suzaku data in the Fe K region is dominated by a very strong (EqW~700 eV) fluorescent line at 6.4 keV
- This is different from Chandra or ASCA data

- Likely indicates that the hard component in CH Cyg was dominated by a scattered component at this epoch

Summary

- Suzaku's capabilities match the needs of CV research well (and those of a few exceptional stars)
- In particular, the simultaneous measurements of soft and hard thermal components, and of Fe K lines and hard continuum, have the potential to revolutionize the field