Suzaku Observations of Accreting White Dwarf Binaries

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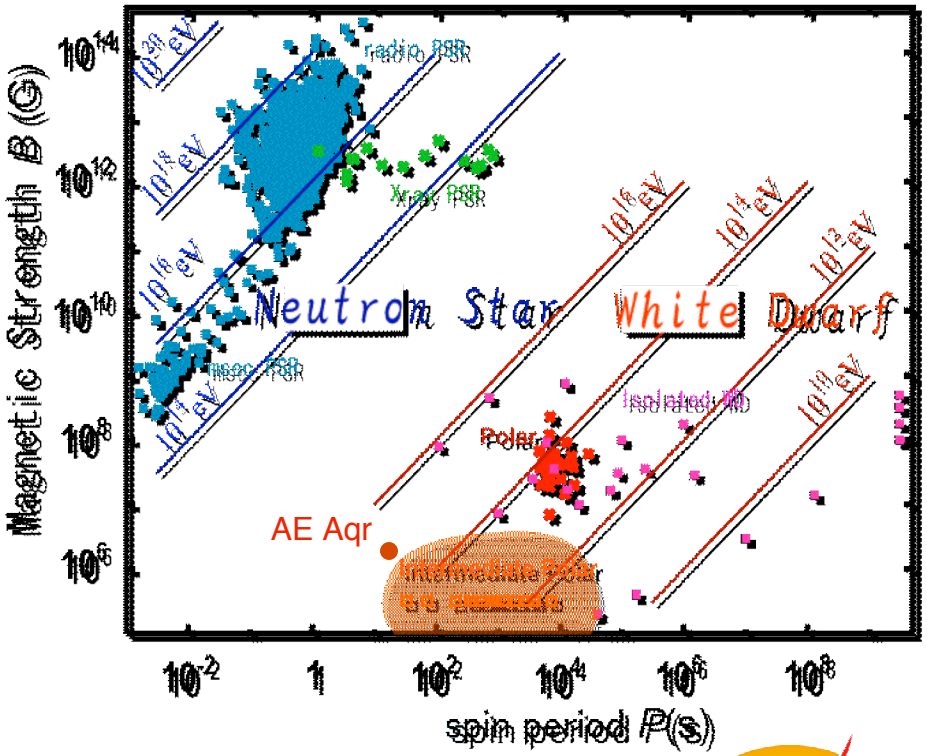
Outline

- Magnetic CVs
  - First discovery of article acceleration from the white dwarf in AE Aquarii. (Terada)
  - Intermediate Polars with soft X-ray emission. (Mukai)
- Dwarf Novae
  - Hard X-ray emission site of SS Cyg in outburst. (Ishida)
  - Distance-limited unbiased survey for the luminosity function. (Mukai)
- New type of symbiotic star SS73 17. (Smith)
- Serendipitous super-soft source Suzaku J0105-72 in SMC. (D. Takei)

The Intermediate Polar AE Aquarii

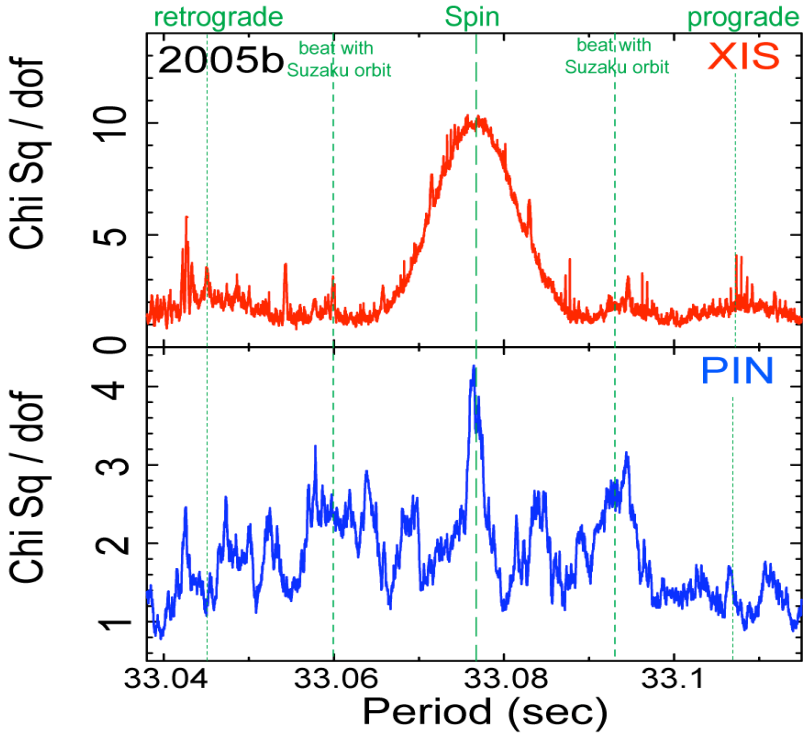
- IP: Asynchronous rotator, $P_{spin} \sim 0.1 P_{orb}$.
- AE Aqr
  - $B \approx 10^{5-6}$ G.
  - Fastest rotator, P_{spin}=33.08 sec, ~35% of the break-up speed (Patterson 1979; Casares et al 1996). ⇨ $V \approx 6\times10^{14}$ eV.
  - Steady spin down (de Jager 1994, M⇧auche 2006): loss rate $\approx 5\times10^{33}$ergs s^{-1}.
  - Radio synchrotron flares (Bastian et al 1988, Simon et al 1990).
  - TeV gamma-ray pulsations (Brink et al 1990, Meintjes et al 1992, 1994).

$$V \approx \left| e\frac{\vec{v}}{c} \times \vec{B} \right| \cdot L = \frac{2\pi e R_{WD}^2 B}{cP}$$



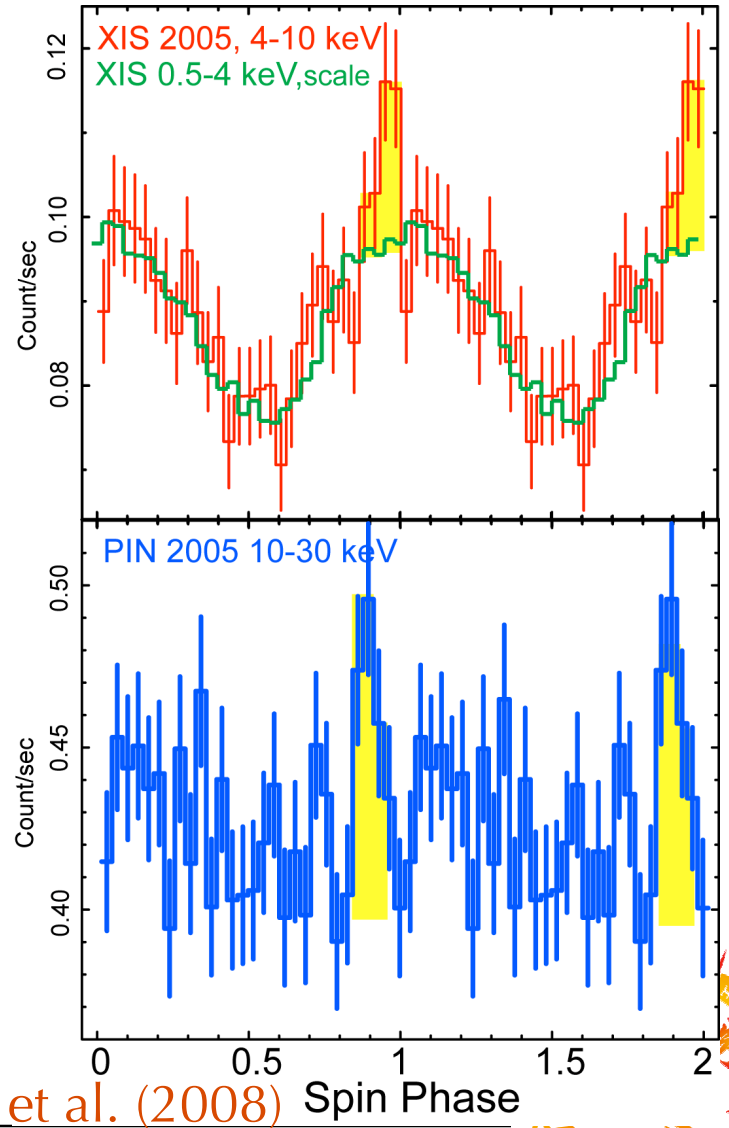
Suzaku Observations of AE Aqr

- 2005 Nov. 70/49ks (XIS/HXD)
  2006 Oct. 53/42ks (XIS/HXD)
- Epoch-folding analysis ⇨ χ^2 peak at
  P_{XIS} = 33.0769±0.0001 sec
  $P_{PI⌂N}$ = 33.076 ±0.005 sec
  consistent with the rotational period (Mauche 2006).
- The peak is sharper for PIN.



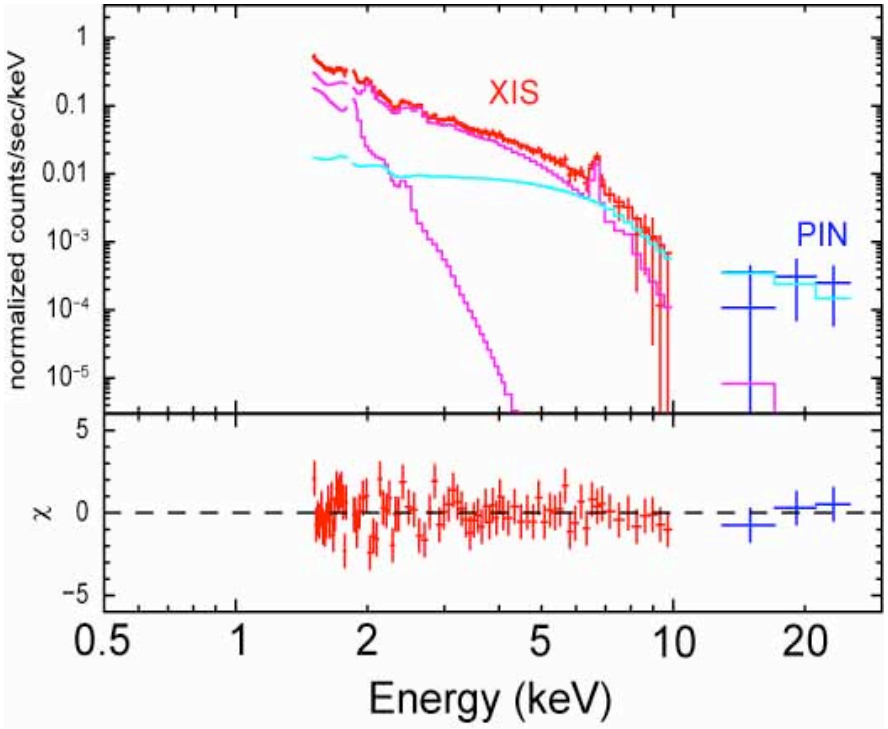
New pulsating component in the PIN band

- Pulse profile is sinusoidal below ~4 keV.
- Above 10 keV (PIN), a separate spiky pulse appears, which is also visible in the XIS 4-10 keV band.
- Relative phase-shift of ~1 sec could be due to premature XIS timing calibration.



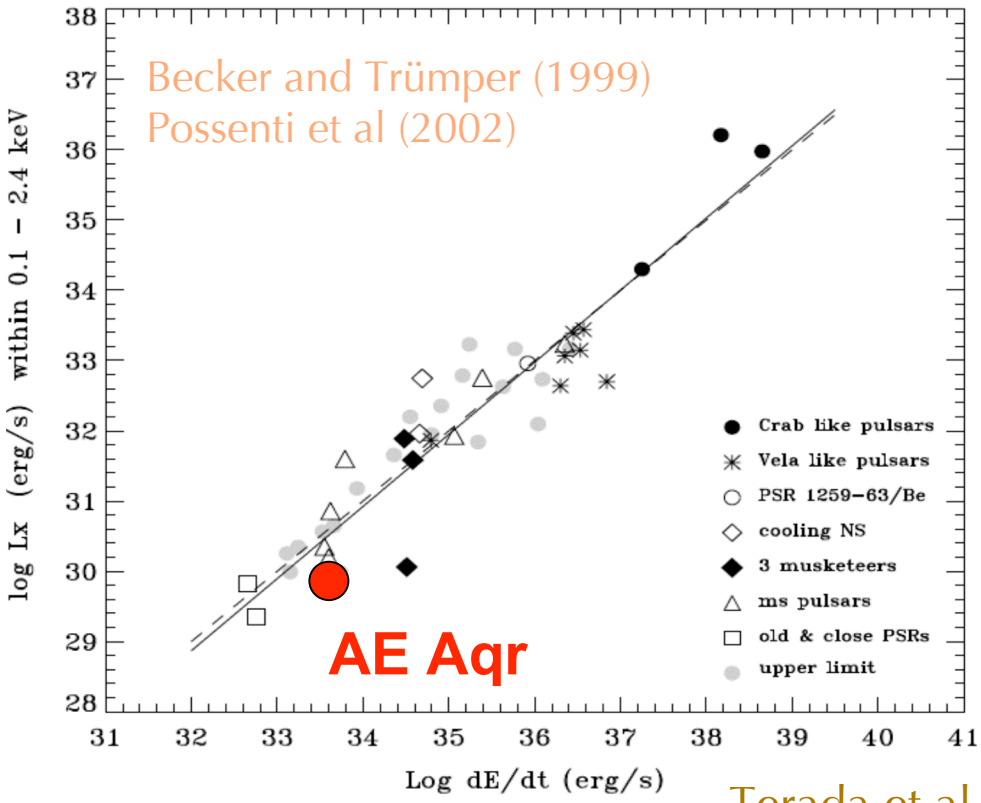
Terada et al. (2008)

Suzaku Spectra



- XIS spectra in the 1.5-10 keV band can be fit with two-temperature mekal model with kT = 0.5 and 3 keV, as before (Choi et al. 1999).
- The PIN flux cannot be explained by the thermal model.
- If power law, $\Gamma = 1.1 \pm 0.6$, in the range of NS pulsars (Gotthelf 2002).

Luminosity



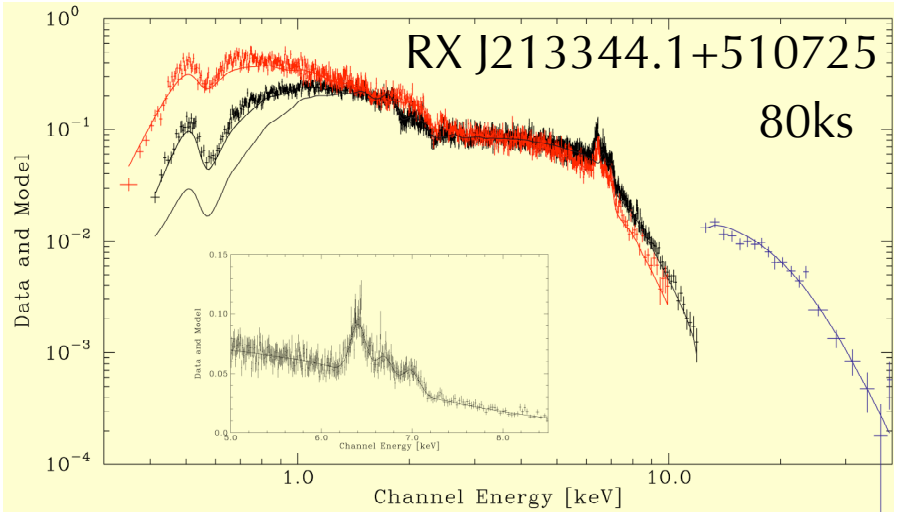
Terada et al. (2008), Poster A30

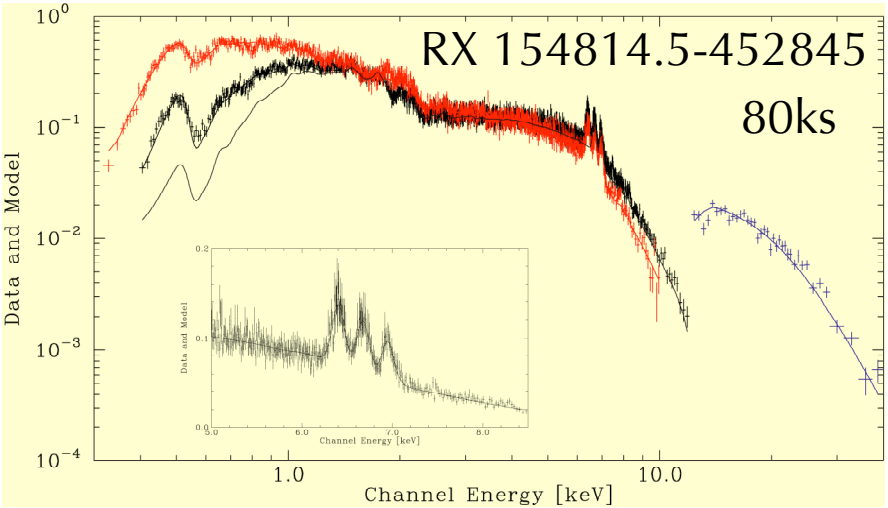
- $L_{HX} = 5.3\times10^{29}$ ergs s^{-1} (0.09% of the spin-down energy).
- Likely to be synchrotron emission (curveture radiation, non-thermal bremsstrahlung, inverse Compton radiation are considered).

Observations of Soft Intermediate Polars

- IPs are the hardest ($kT \approx$30keV) and the most luminous ($L_{hard} \approx 10^{32\text{-}34}$ergs s^{-1}) X-ray sources among all CVs.
- Although $L_{soft} \approx L_{hard}$ is expected as the shock is low, no IP showed any detectable soft component until 10 years ago.
- Recently a few IPs are found to have soft blackbody emission, but with higher $kT_{bb} \approx$90-100eV (de Martino et al. 2004). ⇨Suzaku BI-CCD.
- These soft IPs are good targets of Suzaku in that
  - ➢ High sensitivity and a wide band (0.2-50keV).
  - ➢ Good energy resolution to resolve emission lines.

Observations of two Soft IPs



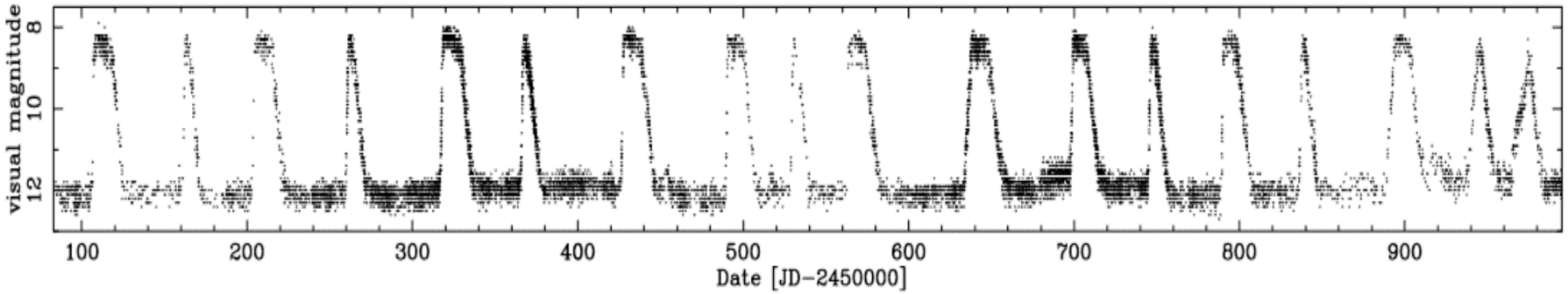


Mukai et al. Poster A28

- Observations of two IPs which are reported to have a soft blackbody component.
- Preliminary analysis indicates multi-phase plasma, reflection from the white dwarf surface, ionized absorber, as well as the blackbody component.

The dwarf nova SS Cygni

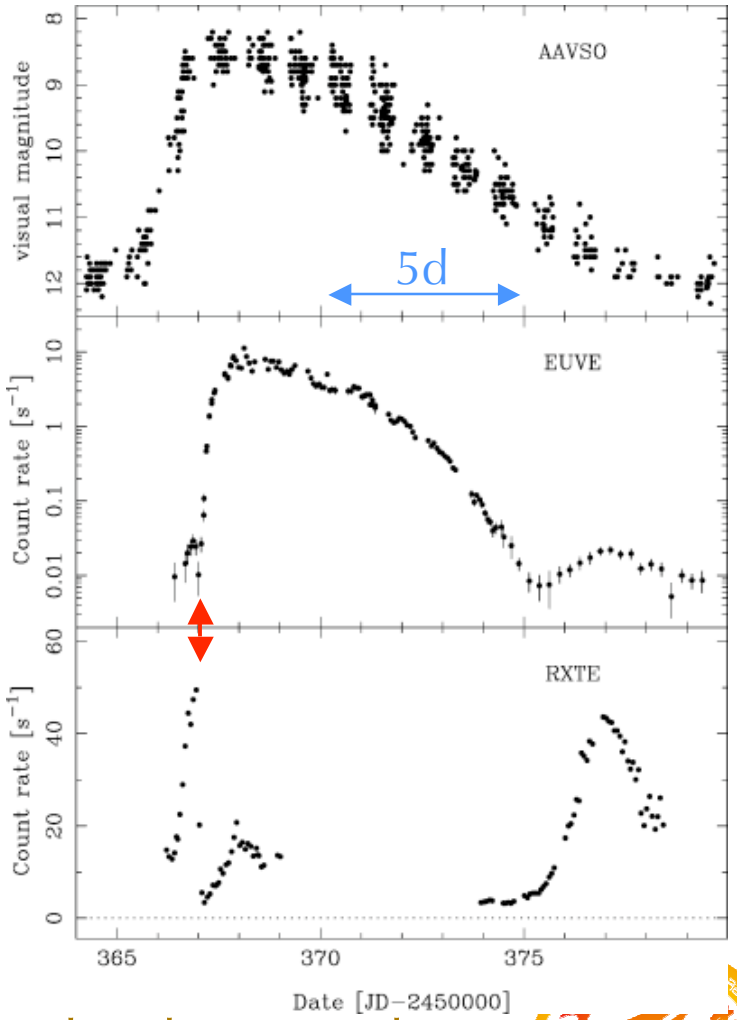
- Optical outburst in every ~50d, Δm_V ~4.
- Outburst is due to the thermal instability in an outer disk (Osaki 1996), where disc viscosity increases associated with hydrogen ionization.



Wheatley, Mauche & Mattei (2003)

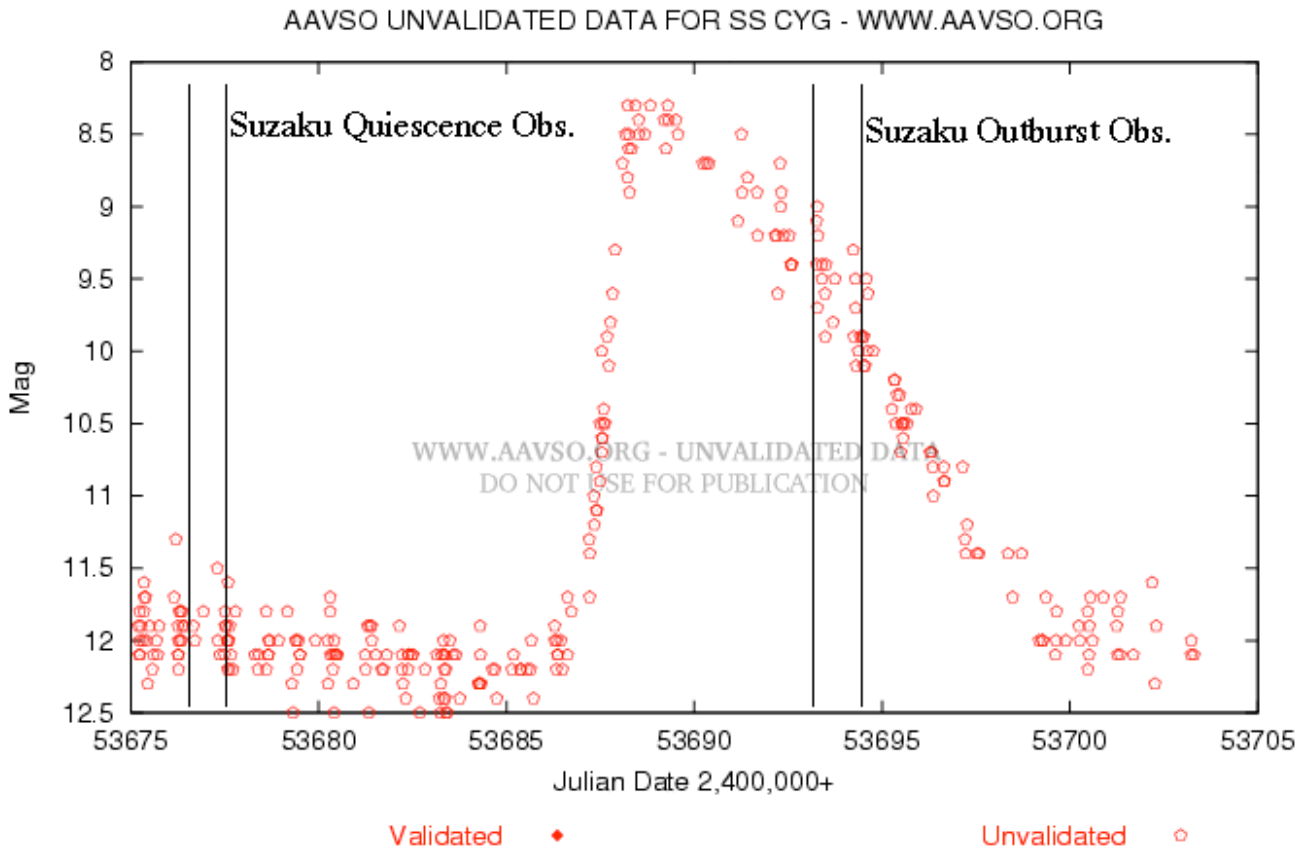
BL/Inner Disc Behaviour

- Multi-waveband observation in 1996 Oct.
  - ➢AAVSO: Outer accretion disc
  - ➢EUVE: Inner accretion disc (optically thick BL)
  - ➢RXTE: Optically thin BL (2-15keV).
- Optically thin to thick transition of BL is detected.
- Optically thin hard X-ray flux never disappears.
- Hard X-ray emission site in outburst has not been identified.



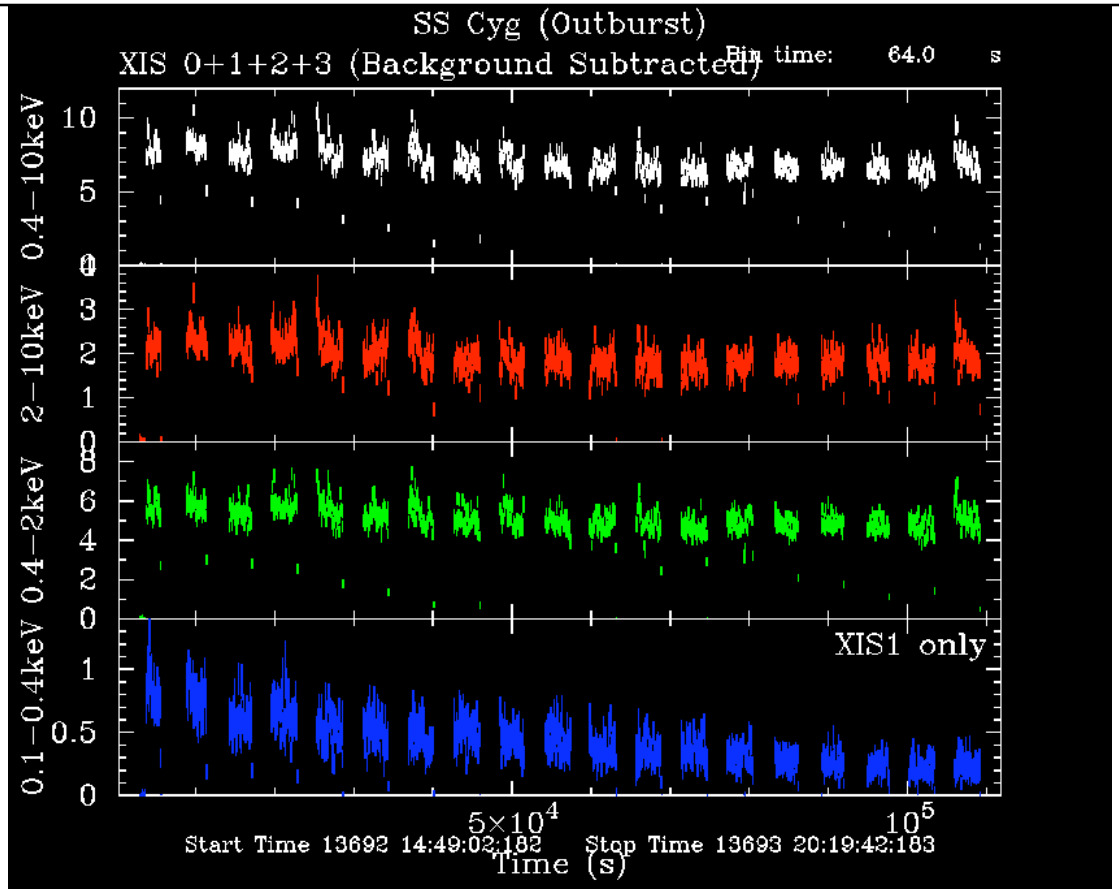
Wheatley, Mauche & Mattei (2003)

Suzaku Observation of SS Cyg



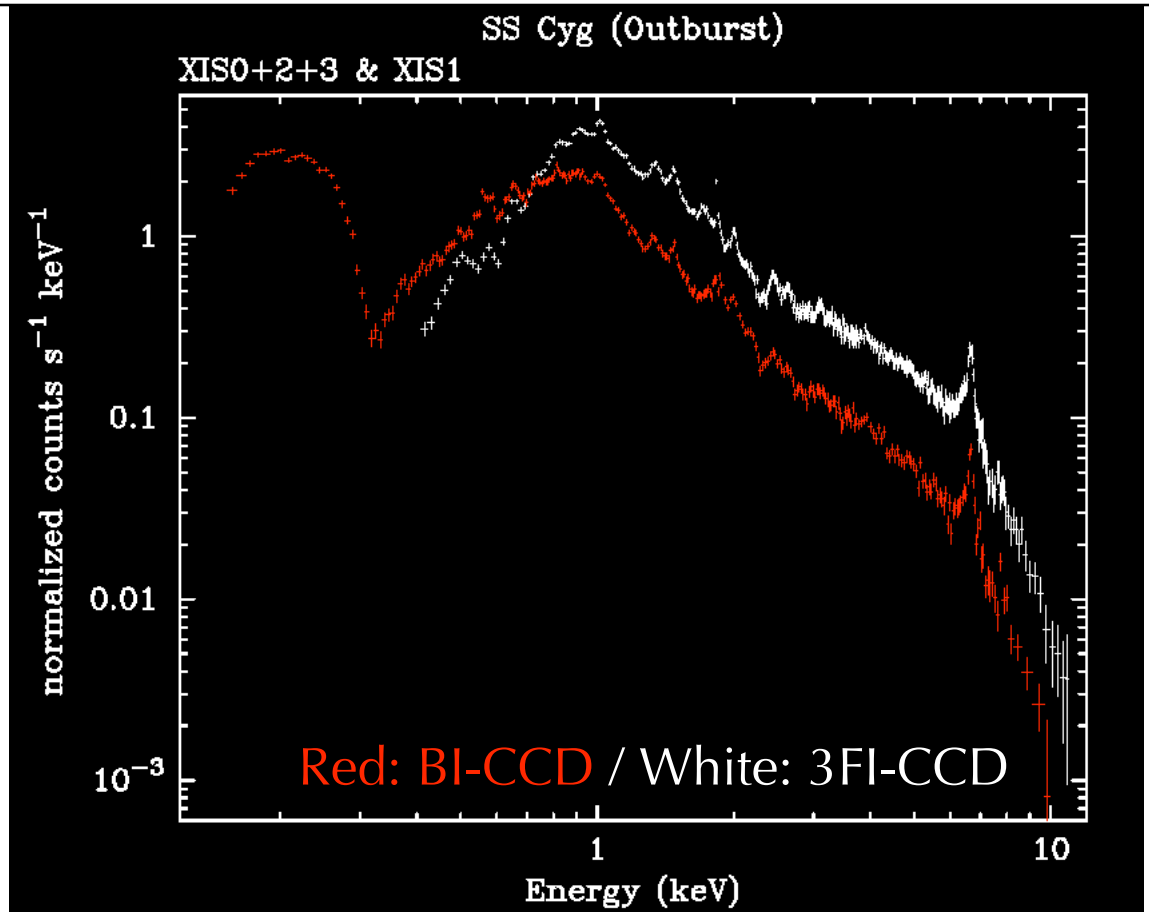
- Observation in Quiescence: 2005 Nov. 2 /40ksec
- Observation in Outburst (ToO): 2005 Nov.18 /60ksec

Light curves in the outburst of SS Cygni



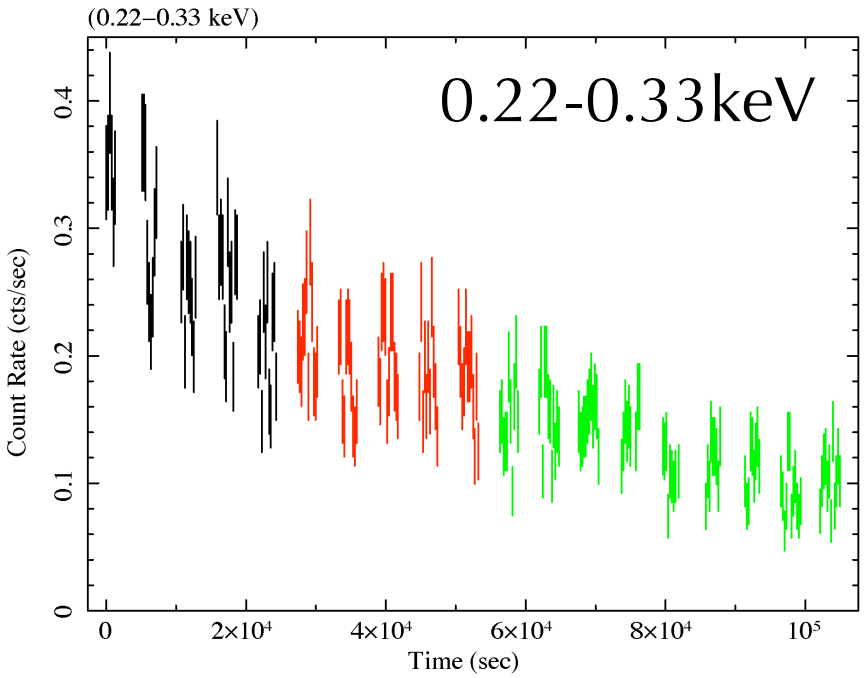
- Unlike $E > 0.4$keV, $E < 0.4$keV declines monotonically.
  - ⇨ Dominated by emission from the optically thick BL.

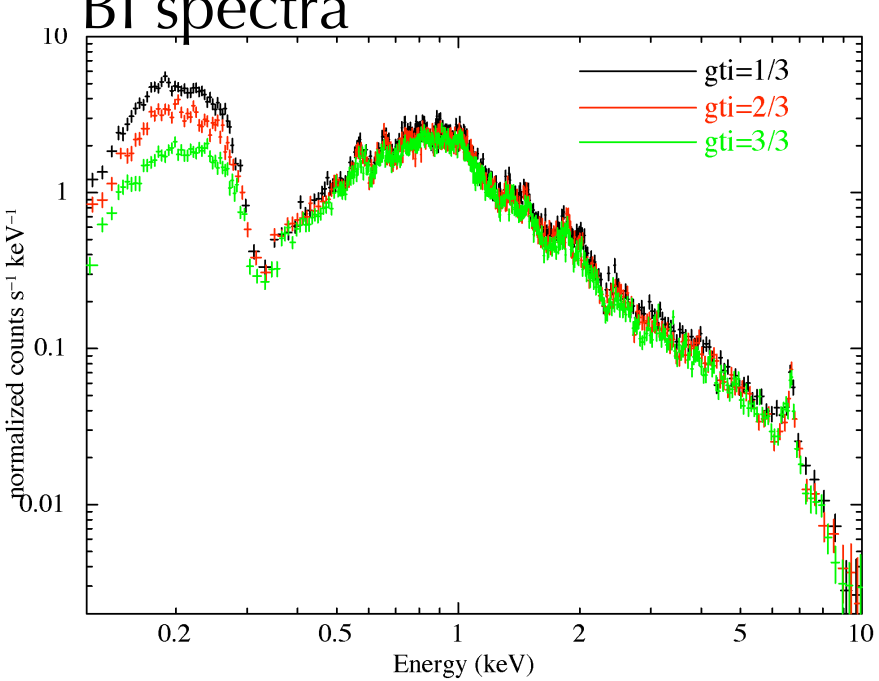
XIS Spectra



- H/He-like K_α lines from O to Fe in outburst.
- Soft disc blackbody component below 0.3 keV.

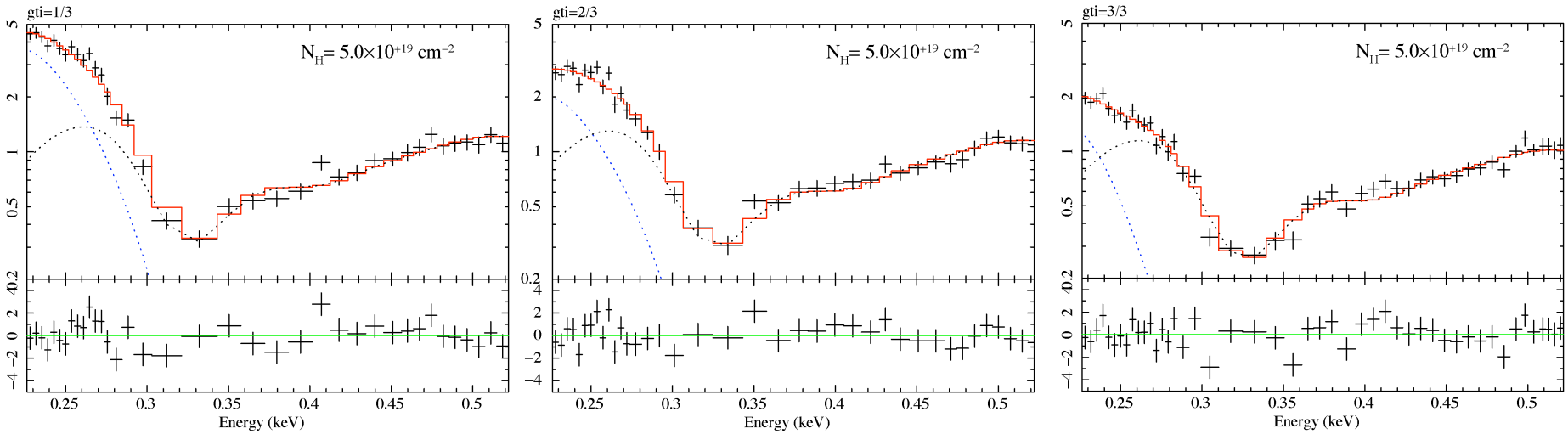
Time-resolve spectra of the soft component

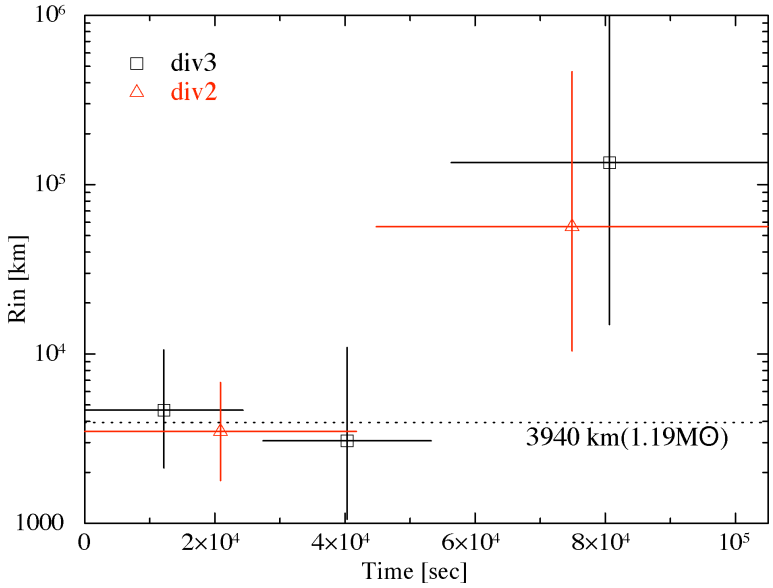




- Segmented into three spectra with equal counts for the soft component.
- Intensity declines below 0.3 keV.

Disk BB fit



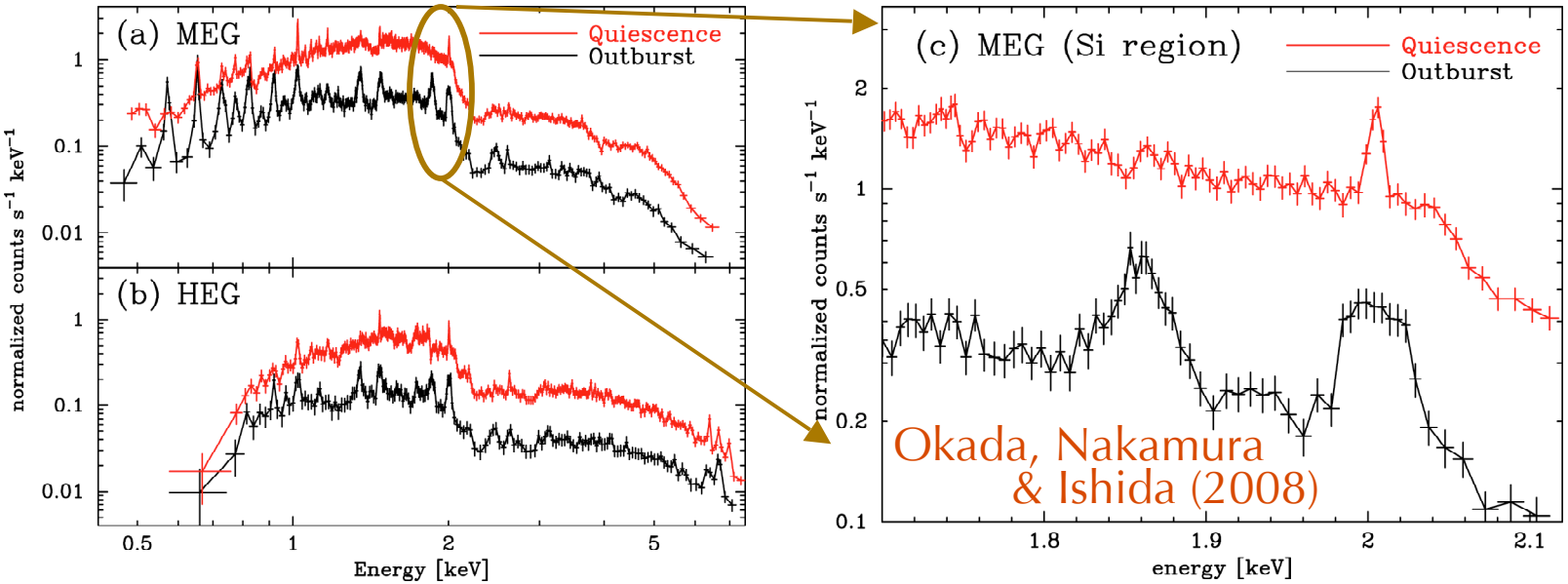


- N_H=5.0$^{+2.9}_{-1.5}$×10^{19}cm^{-2}, (interstellar ⇳3.5×10^{19}cm^{-2}; Mauche et al (1988))
- Innermost radius is consistent with the 1.2$M_\odot$ white dwarf radius.
  - ➢ ΔR_{in} ≈1000km due to N_H uncertainty.

⇨ The disc can be interpreted as reaching the WD surface in outburst.

⇨ No space for hard X-ray emitter in the disc plane.

Chandra HETG observation in outburst



- Chandra observation of SS Cyg in outburst (Mukai et al. 2003; Mauche et al. 2005; Rana et al. 2006).
- Emission lines are all broad in outburst.
- H-like Kα lines are incompatible with a simple Gaussian profile (Okada, Nakamura, Ishida 2008).

Hard X-ray emission in outburst

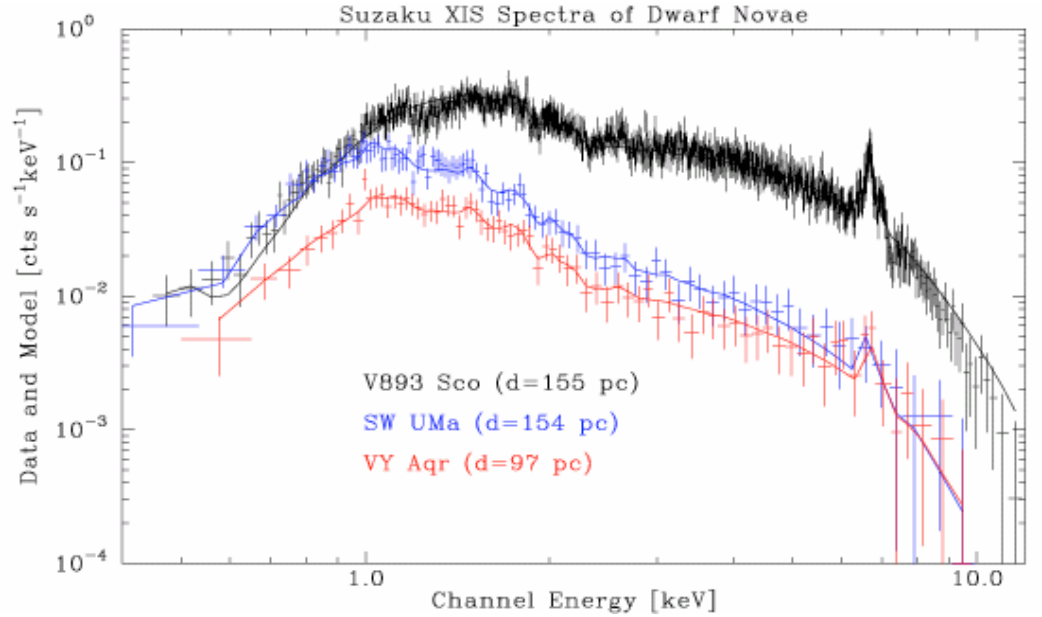
- Line profiles can be fit by a diskline model (R_{in} ~ 1000R_S).
  - ⇨Hard X-ray emission region extends over the disc, like an accretion disc corona.

Distance-limited survey of dwarf novae

- Non-magnetic CVs occupy⇧ more than 80% of all CVs.
- $N \approx 3\times10^{-5}$ pc^{-3} (Schwope et al. 2002).
- Fainter in X-rays ($L_X < 10^{32}$ ergs s^{-1}) than mCVs.
- Dwarf novae are the majority.
- Potential constituents of the GRXE (Revnivtsev et al. 2006).
  ⇔ Truly diffuse emission (Ebisawa et al. 2005).
- It is important to know the luminosity function of DNe and their spectra in the range $L_X < 10^{30}$ ergs s^{-1}.
- The existing ensemble⇧s (Mukai & Shiokawa 1993; Baskill et al. 2005) are not enough because they are weighted to higher luminosity sources.

⇨ Unbiased observations of DNe with $d < 200$ pc based on parallax measurements since AO-1 (lead by KM).

Suzaku survey of dwarf novae



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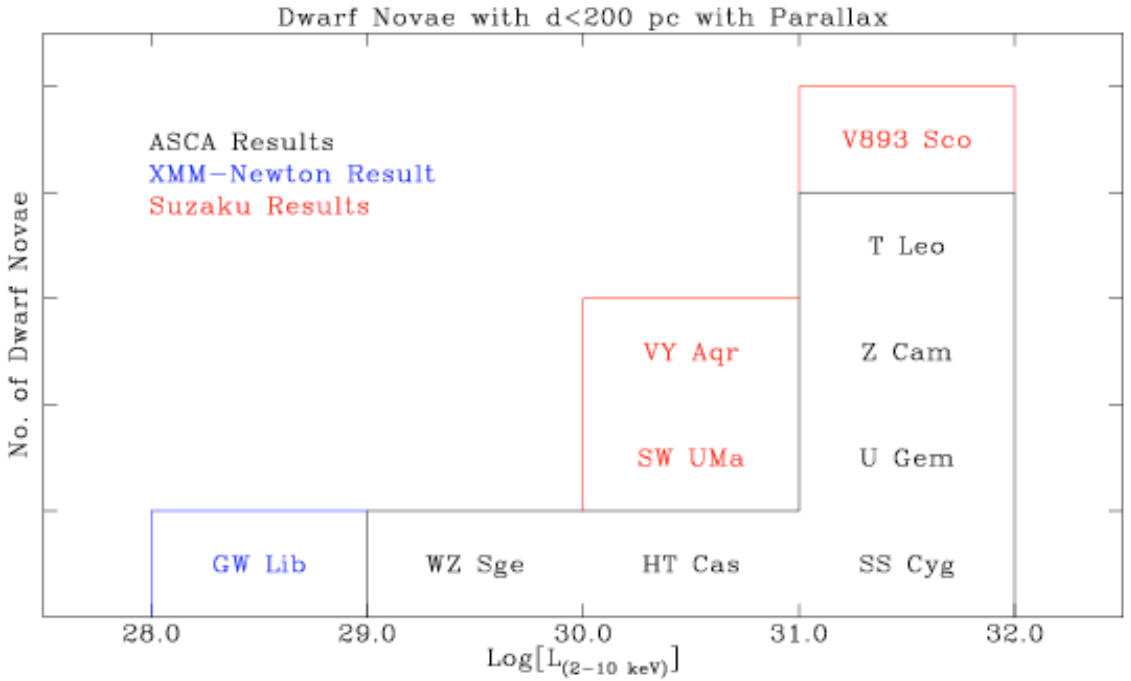
- In total 15 DNe are firmly known to be within 200pc based on the parallax measurements (Thorstensen and others).
- V893 Sco (AO-1) / ⇧SW UMa, VY Aqr (AO-2).
- $kT \approx 3$–7 keV if a single temperature mekal model is applied.
- $L_X \approx 1\times10^{30}$–$6\times10^{31}$ ergs s^{-1}.

Current luminosity function of DNe



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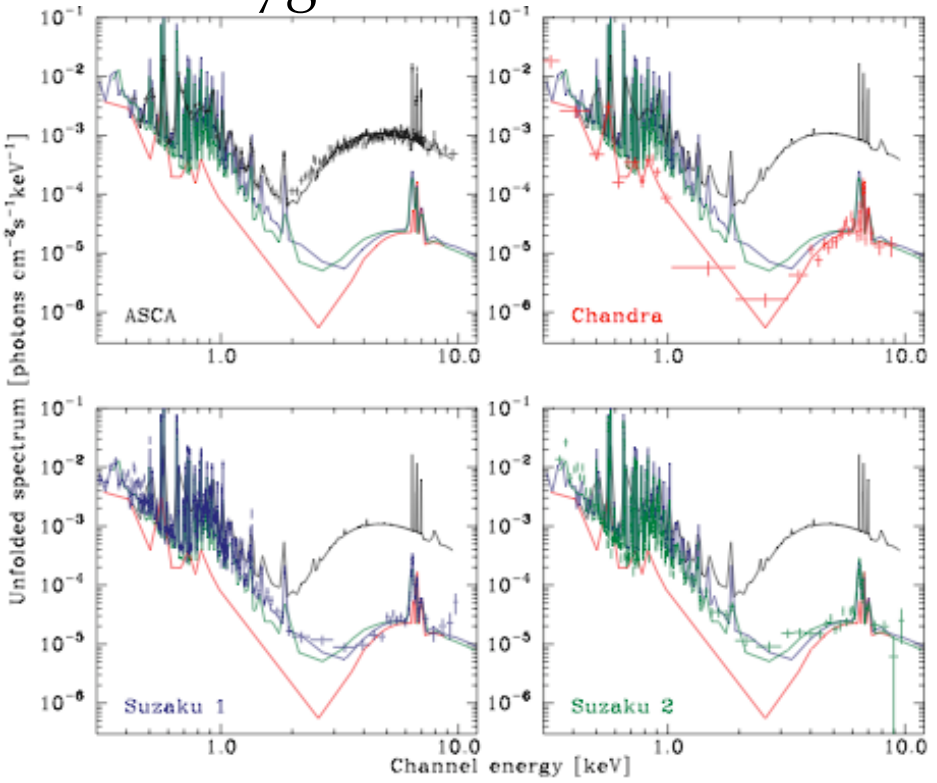
- Three Suzaku-observed DNe together with GW Lib (XMM-Newton) significantly broaden the ASCA luminosity function which strongly peaks at L_X⏢=10^{31}–10^{32} ergs s^{-1}.
- In total ≈1000 DNe are expected within 200pc.
- e-ROSITA survey (luminosity-weighted selection effect ?).

Symbiotic Star

- Binary of a red giant star and a hot blue companion.
- A white dwarf accretes from the wind of the red giant.
- According to ROSAT results (Mürset et al. 1997),
  - SSS
  - Soft thin plasma $kT \approx 0.2$keV
  - With hard spectral component
- The hard source are relatively rare: CH Cyg (Ezuka et al. 1998), RT Cru (Masetti 2005), CI Cam (Ishida et al. 2004), T CrB (Trueller et al. 2005).

Luna et al. Poster A27

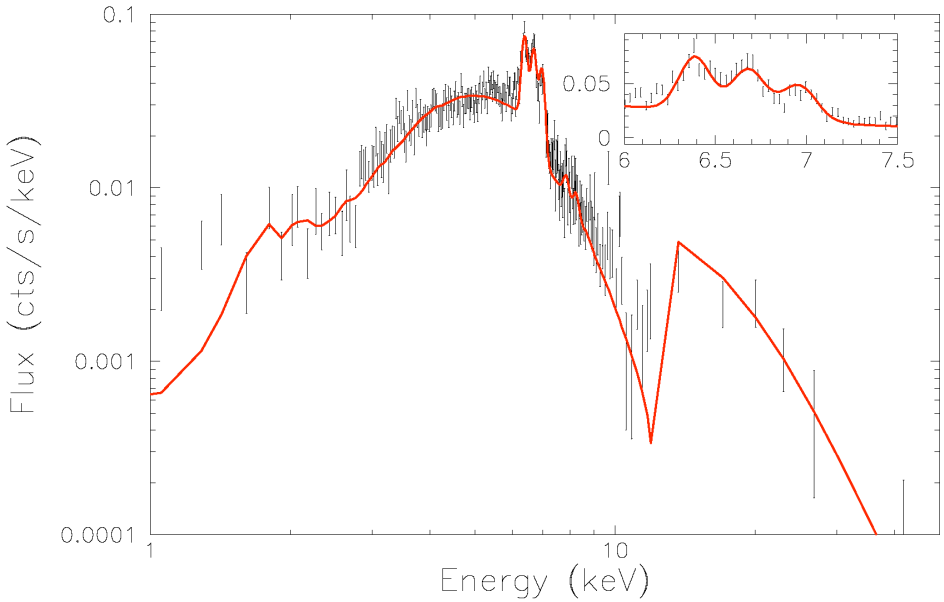
CH Cygni



Mukai et al. (2007)

SS73 17

- Discovered by INTEGRAL and Swift.
  - IGRJ10109-5746 (Revnivtsev et al 2006)
  - Swift J101103.3-574818 (Trueller et al 2005)
- A member of "highly-absorbed X-ray binaries" (Kuulkers 2005).
- Suzaku observation: 2006 June 5.
- The first symbiotic star that has hard X-ray component without significant soft X-ray emission.

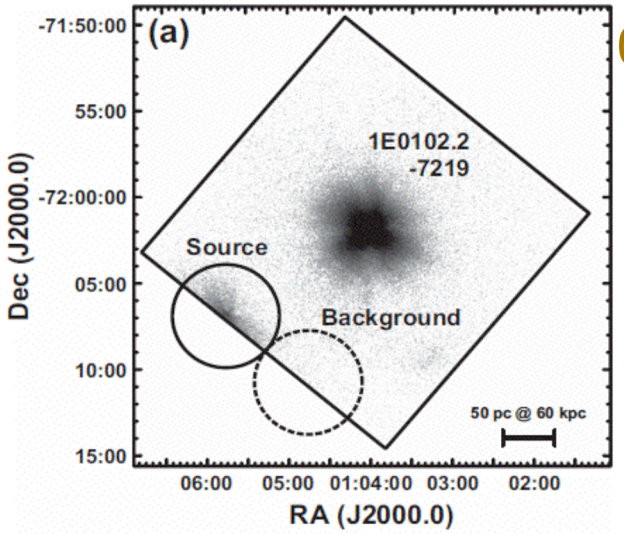


Smith et al. (2008)

- Thin thermal spectra $kT \approx 9$keV
- Partial covering $CF \approx 92\%$
- $N_H \approx 2 \times 10^{23}$ H cm^{-2}

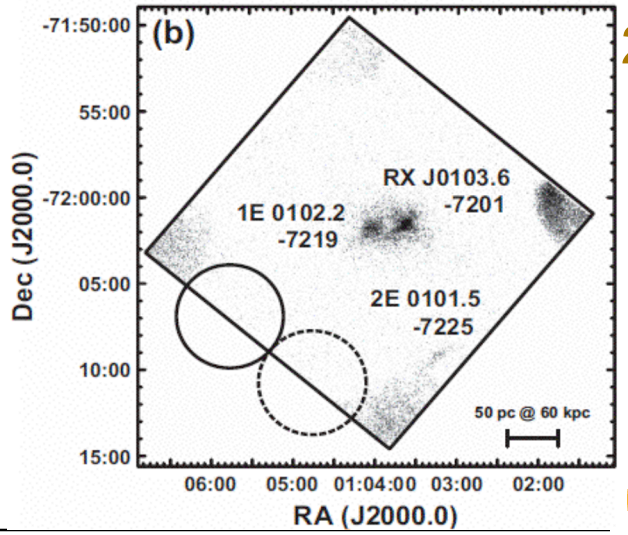
Discovery of a new super soft source in SMC

- E0102-72 (an SNR in SMC) is an XIS calibration source.
- Observed 16 times until 2007 March.
- An outbursting source is detected from one of these observations carried out on 2005 August 31.
- Detected only <2keV.
- No source was found in the error circle at a comparable brightness from Einstein, ROSAT, ASCA, Beppo-SAX, Chandra and XMM-Newton.



0.2-2.0keV

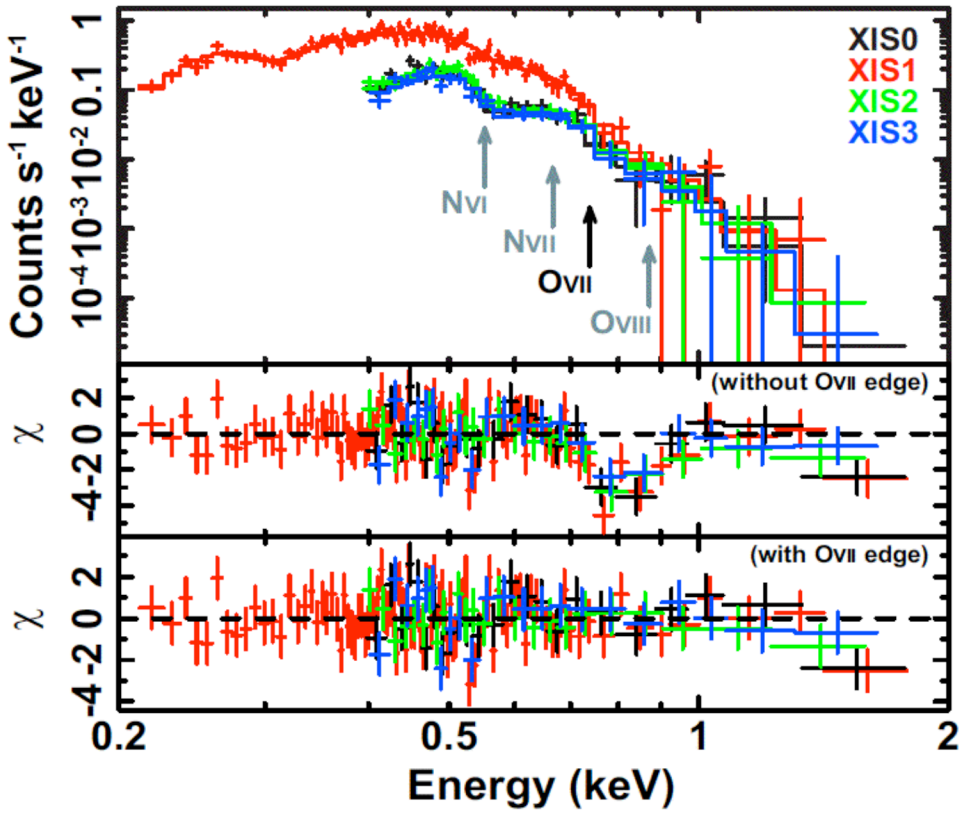
Takei, D. et al. (2008)



2.0-12keV

Spectra of Suzaku J0105-72

- Blackbody with $kT_{bb} \approx 72$eV
- $N_H \approx 4.9\times10^{20}$ H cm^{-2}, consistent with the value to SMC.
- $L_{bol} \approx 1\times10^{37}$ ergs s^{-1} with d =60kpc.
- $R \approx 10^8$ cm ⇨ White dwarf
- OVII K-edge at 0.74keV (τ = 1.2).
- All these characteristics are consistent with those of SSS.



The End

BI calibration with PKS2155-304

- The observation carried out on 2005 Nov. 30.
- Broken power law with

  $N_H = 1.7\times10^{20}$ H cm^{-2} needs
  - Extra carbon edge at E = 0.2842 keV (τ = 0.88±0.05)
  - Extra NH = (8.2±0.7)×10^{19} H cm^{-2}.
- The band E > 0.23 keV can be used.