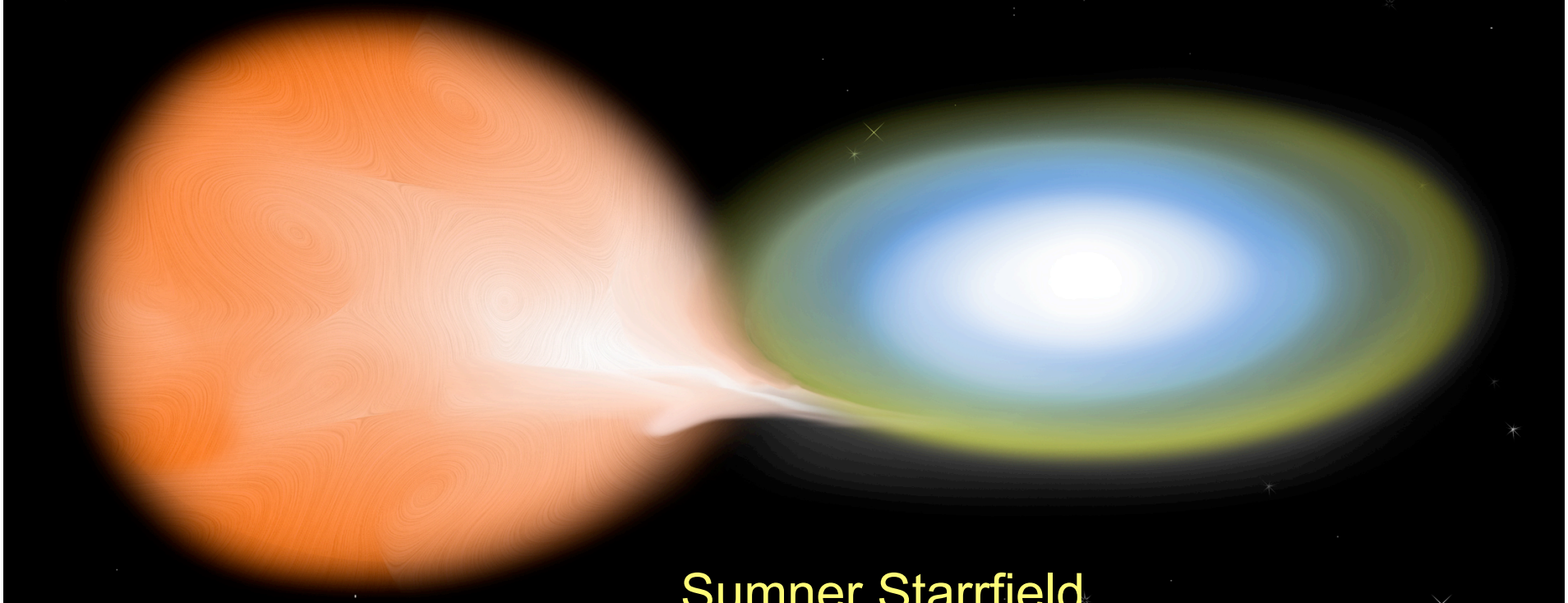
Swift Observations of Recurrent and Classical Novae in Outburst (and quiescence)



Sumner Starrfield
School of Earth and Space Exploration
Arizona State University

HEAD meeting Los Angeles March 31, 2008

Collaborators:

Jan-Uwe Ness, Julian Osborne, Mike Bode, Jeremy Drake, Kim Page, Tim O'Brien, Joachim Krautter , Greg Schwarz, Andy Beardmore, Neil Gehrels, Bob Gehrz, Chick Woodward, Nye Evans, Stew Eyres, Karen Vanlandingham, (+Swift CV working group)

…

WHY Swift?

Rapid Response

XRT has about the same resolution as the ACIS on Chandra

BUT

has a smaller effective area

Rapid Response

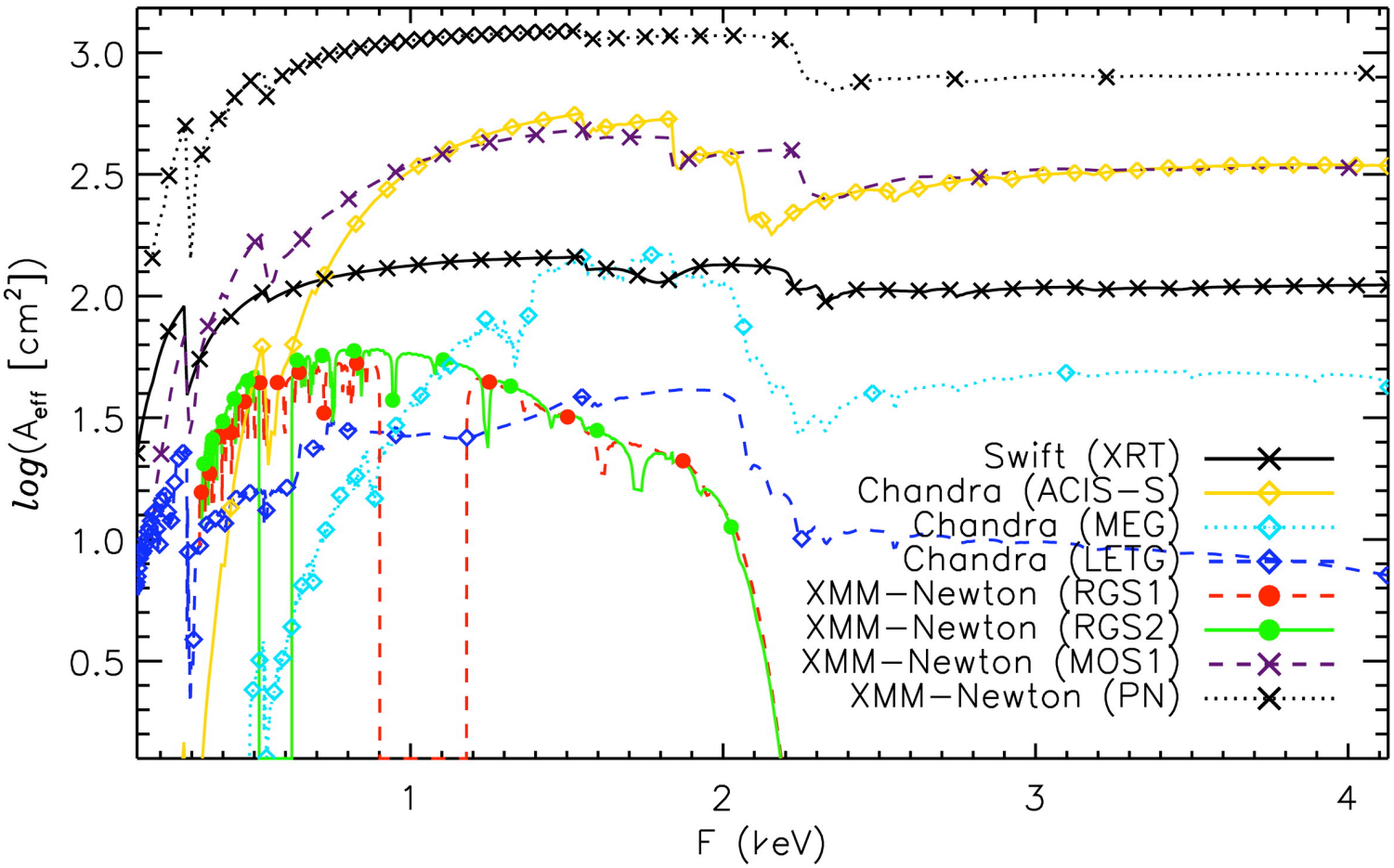


Fig. 1.— Comparison of XRT effective areas of Swift with other X-ray instruments that are sensitive in the same spectral region. None of the Chandra or XMM-Newton gratings have a higher effective area than the XRT. The CCD detectors, ACIS-S (Chandra) and EPIC (PN/MOS1; XMM-Newton), have higher effective areas. The spectral resolution of the XRT is similar to either the ACIS or EPIC detectors, but the spectral resolution of the gratings is far superior.

Ness et al. 2007

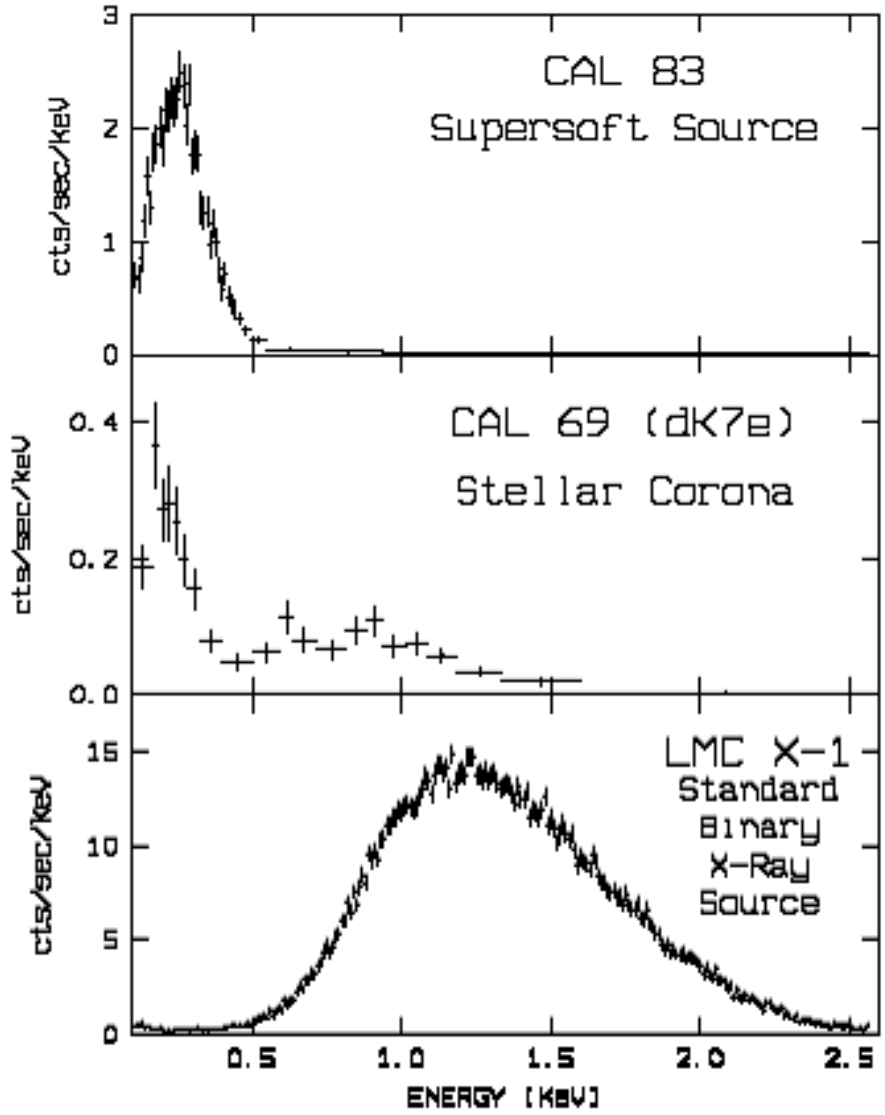


Figure 1 ROSAT PSPC count spectra of three objects in the Large Magellanic Cloud (LMC)

PSPC = Position Sensitive Proportional Counter

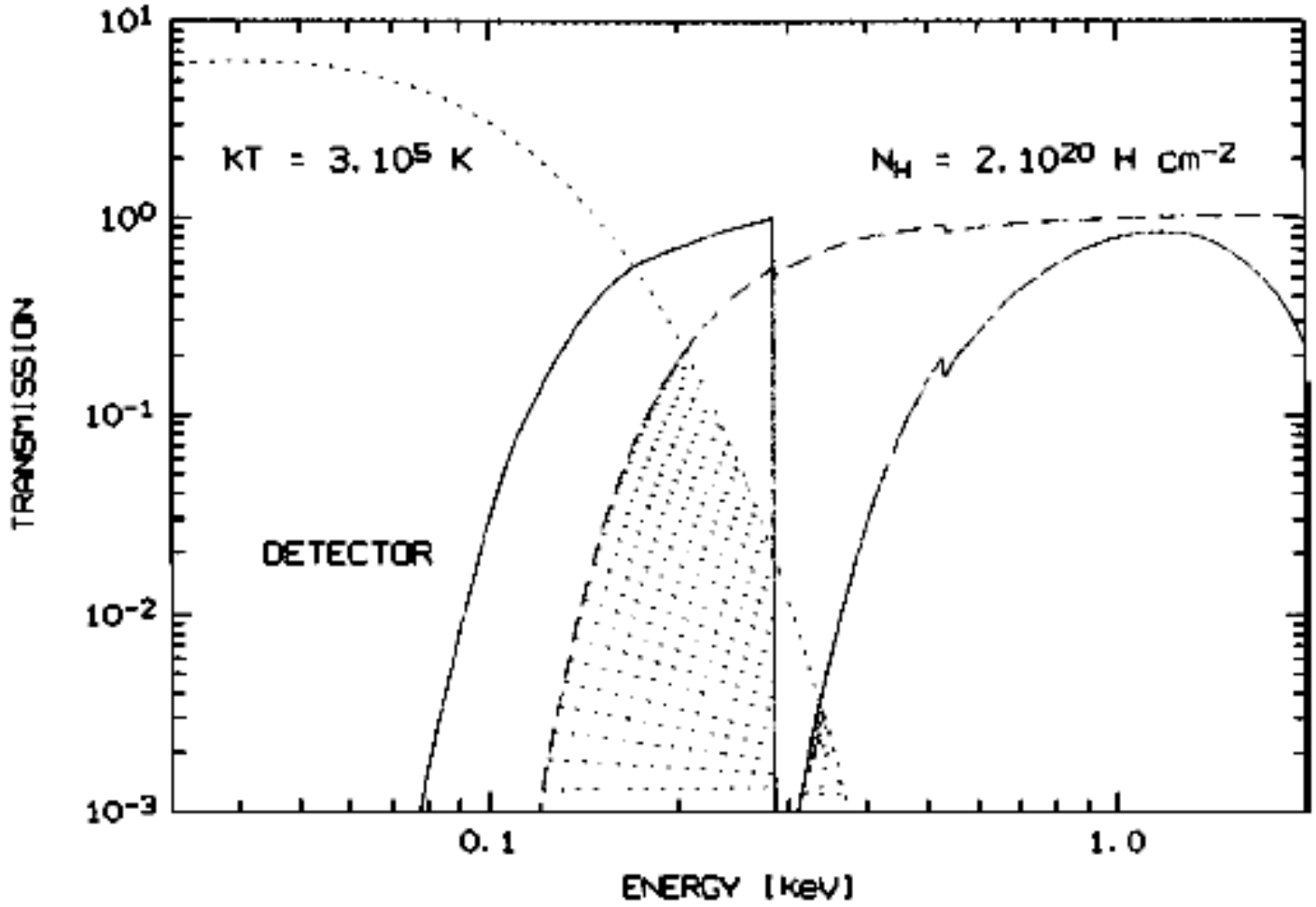


Figure 2 ROSAT PSPC efficiency (*solid curve*), transmission of ISM for hydrogen column of 2.10^{20} H atoms cm^{-2} (*dashed line*), distribution of a 3.10^5-K blackbody spectrum (*dotted line*) and folded (observed) distribution (*hatch marks*) (SA Rappaport, private communication).

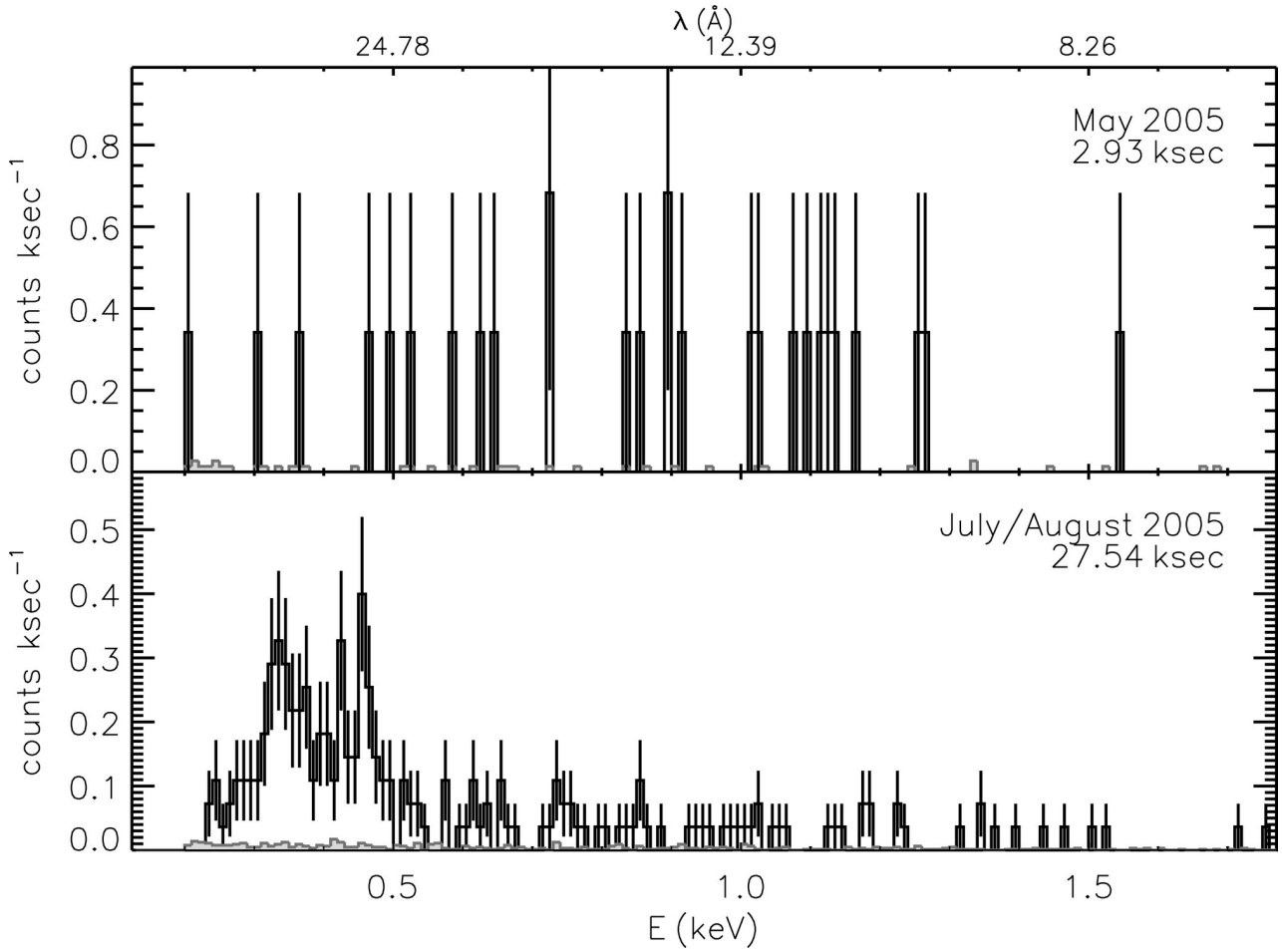
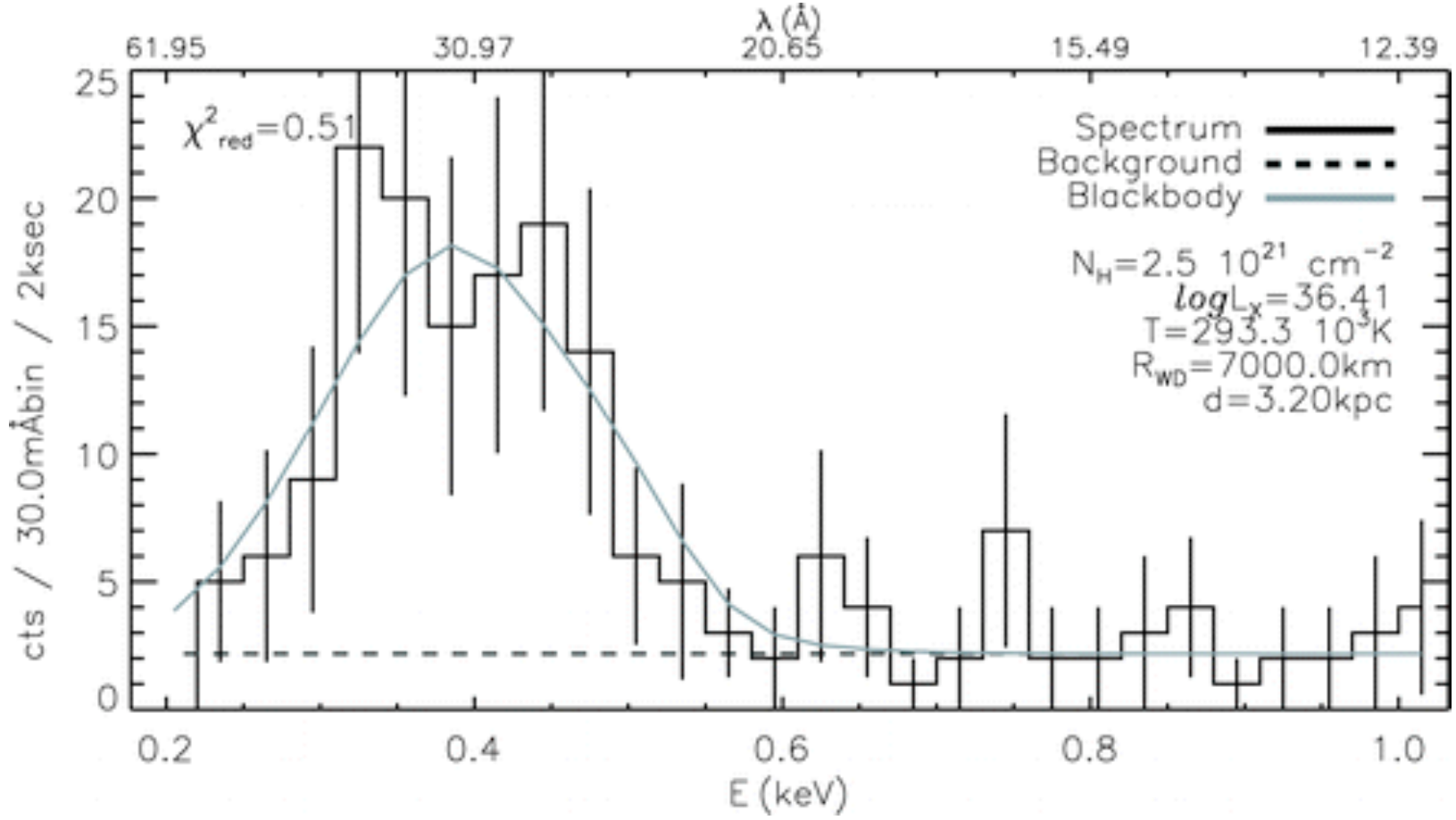


Fig. 3.— Grouped XRT observations of V574 Pup comparing the May 2005 (top panel) and the July through August data sets (bottom panel). The comparison shows that V574 Pup has evolved from a hard early spectrum (top panel) into a SSS spectrum (bottom panel). The count rate is higher in the top panel, which may be due either to the higher sensitivity of the detector at higher energies or the higher amounts of absorption at soft energies. Ness et al. 2007



Grouped and rebinned XRT spectrum of V574 Pup covering July 2005 to August 2005 . The histogram (plus error bars) gives the observed spectrum, and a smooth line showing a blackbody model is overplotted purely to guide the eye.

Ness et al. 2007

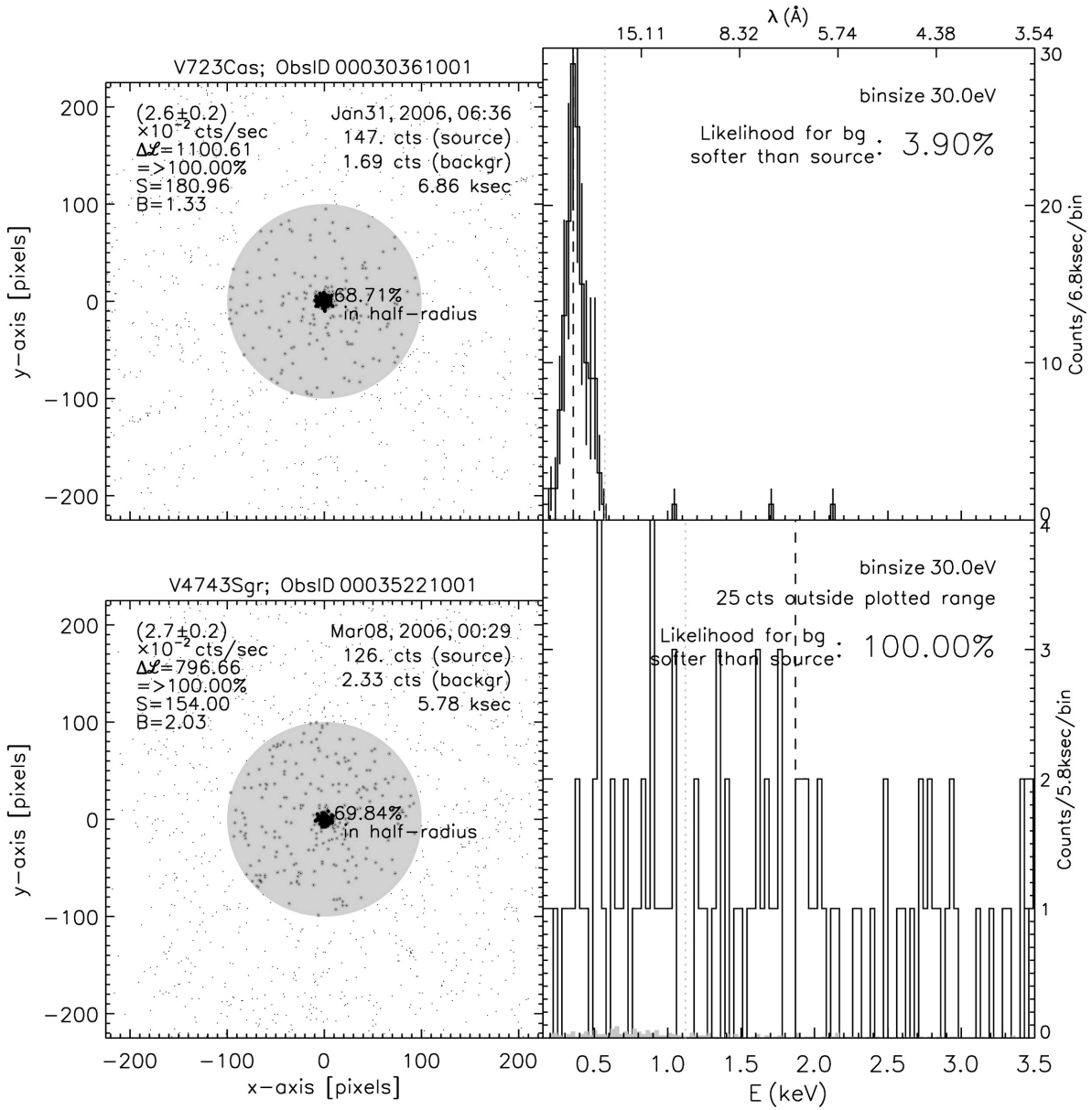
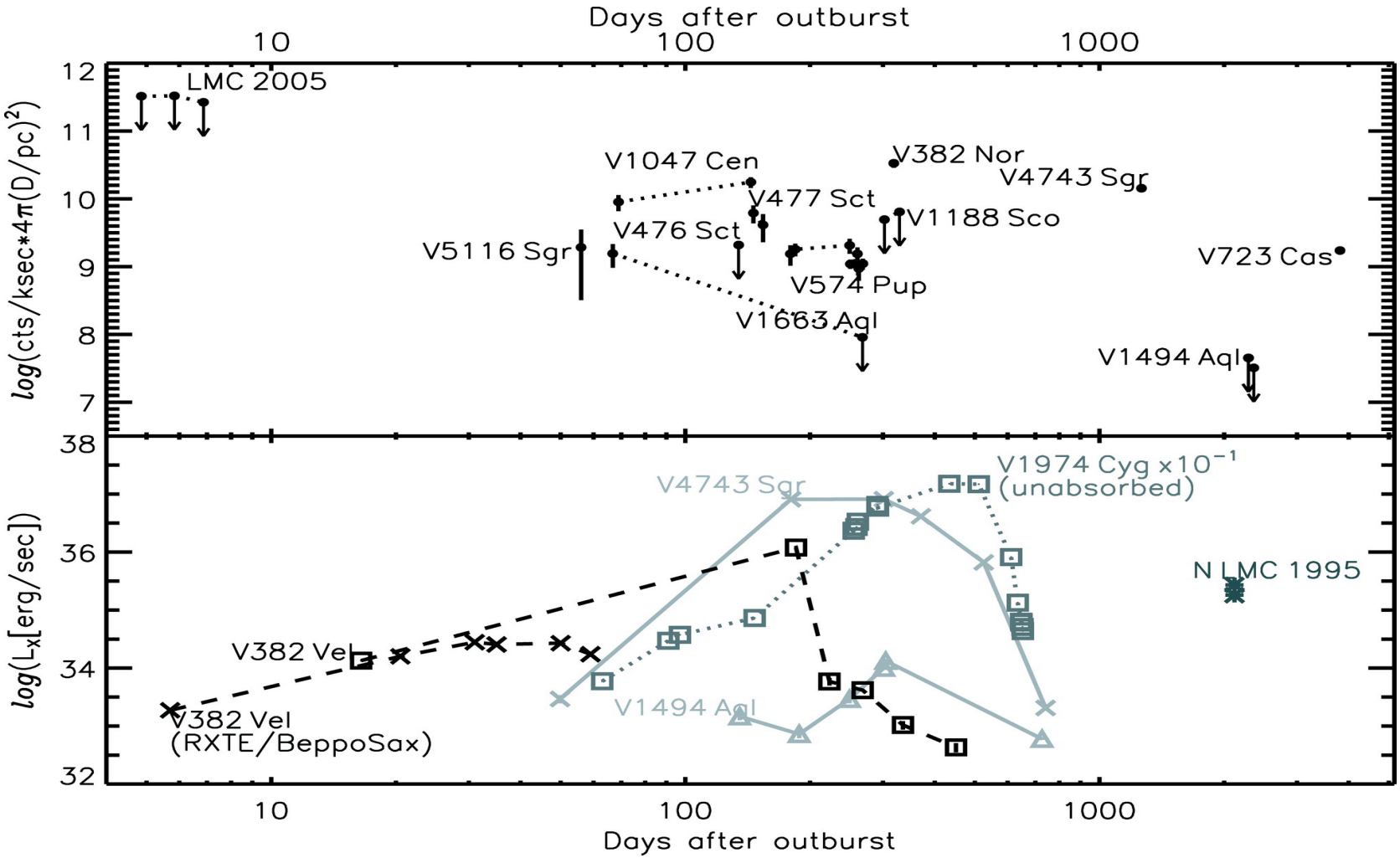


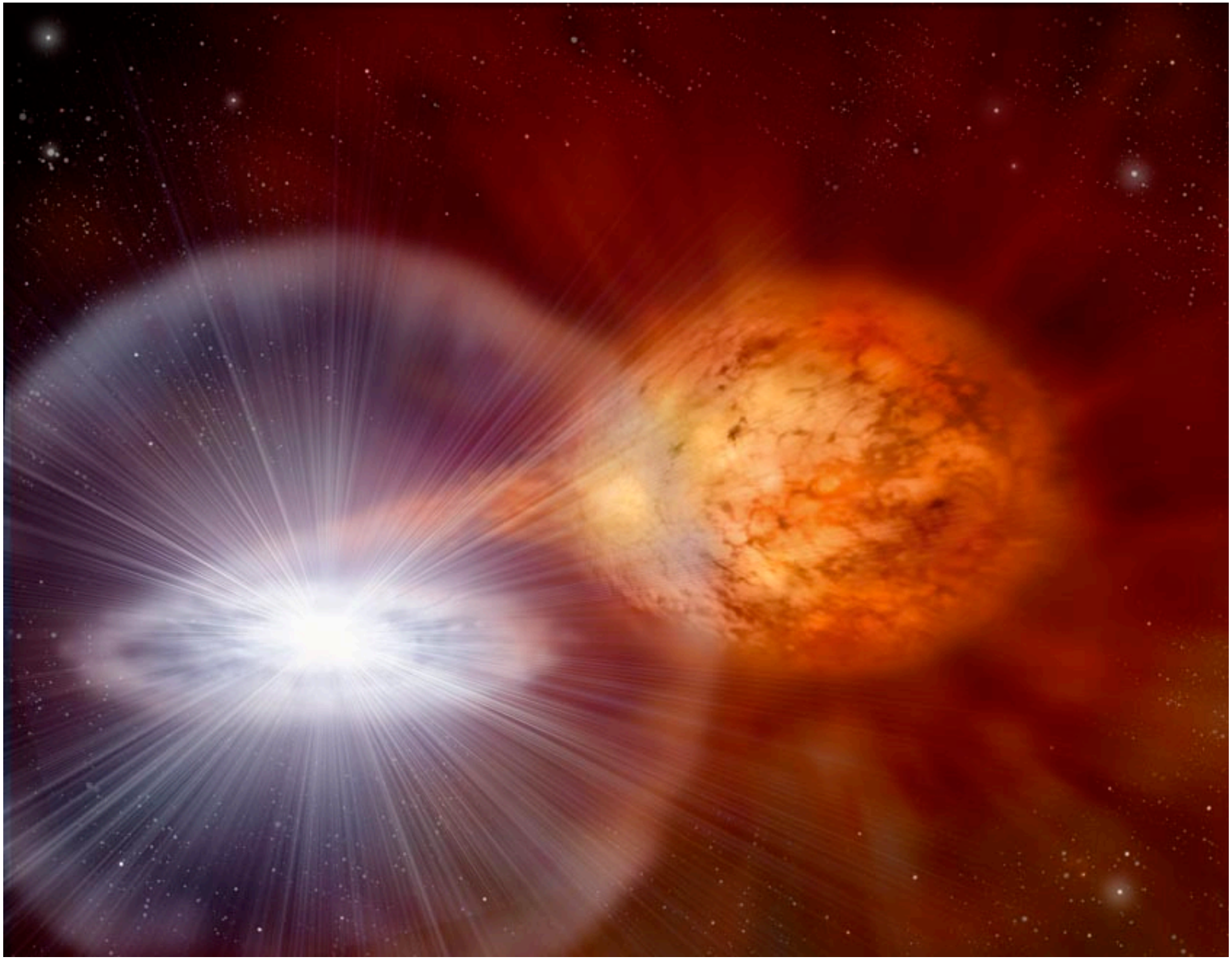
Illustration of extraction of counts for V723 Cas (top) and V4743 Sgr (bottom).

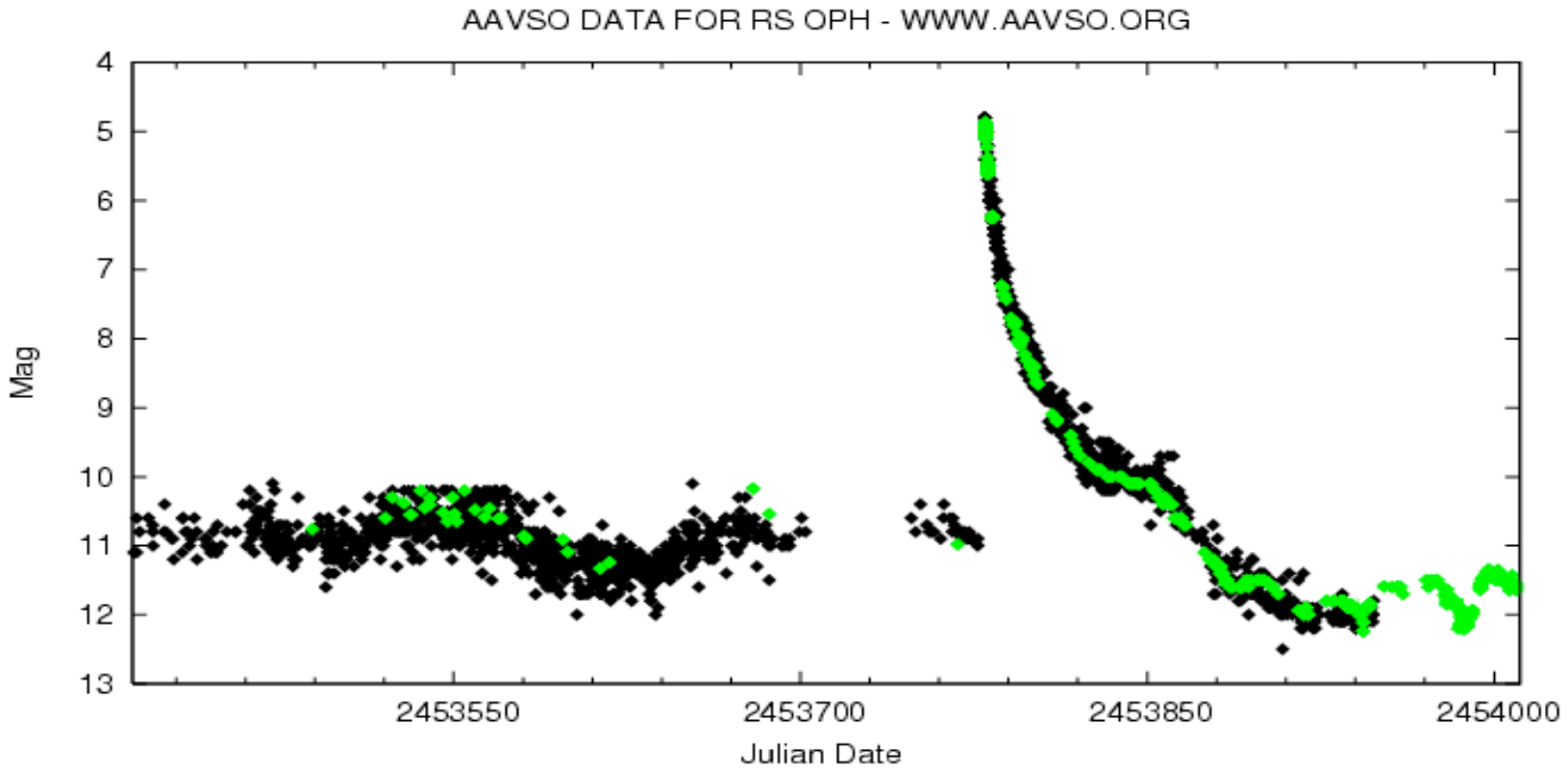
V723 Cas now the longest nova observed in X-rays “in outburst”

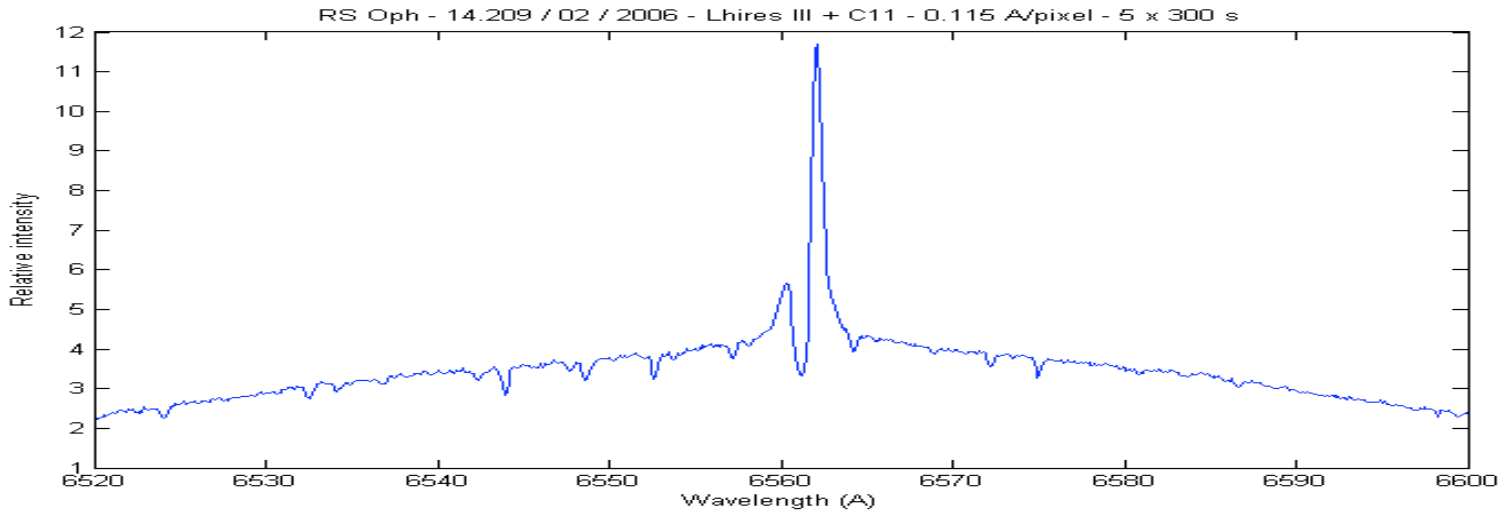
Ness et al. 2007, 2008



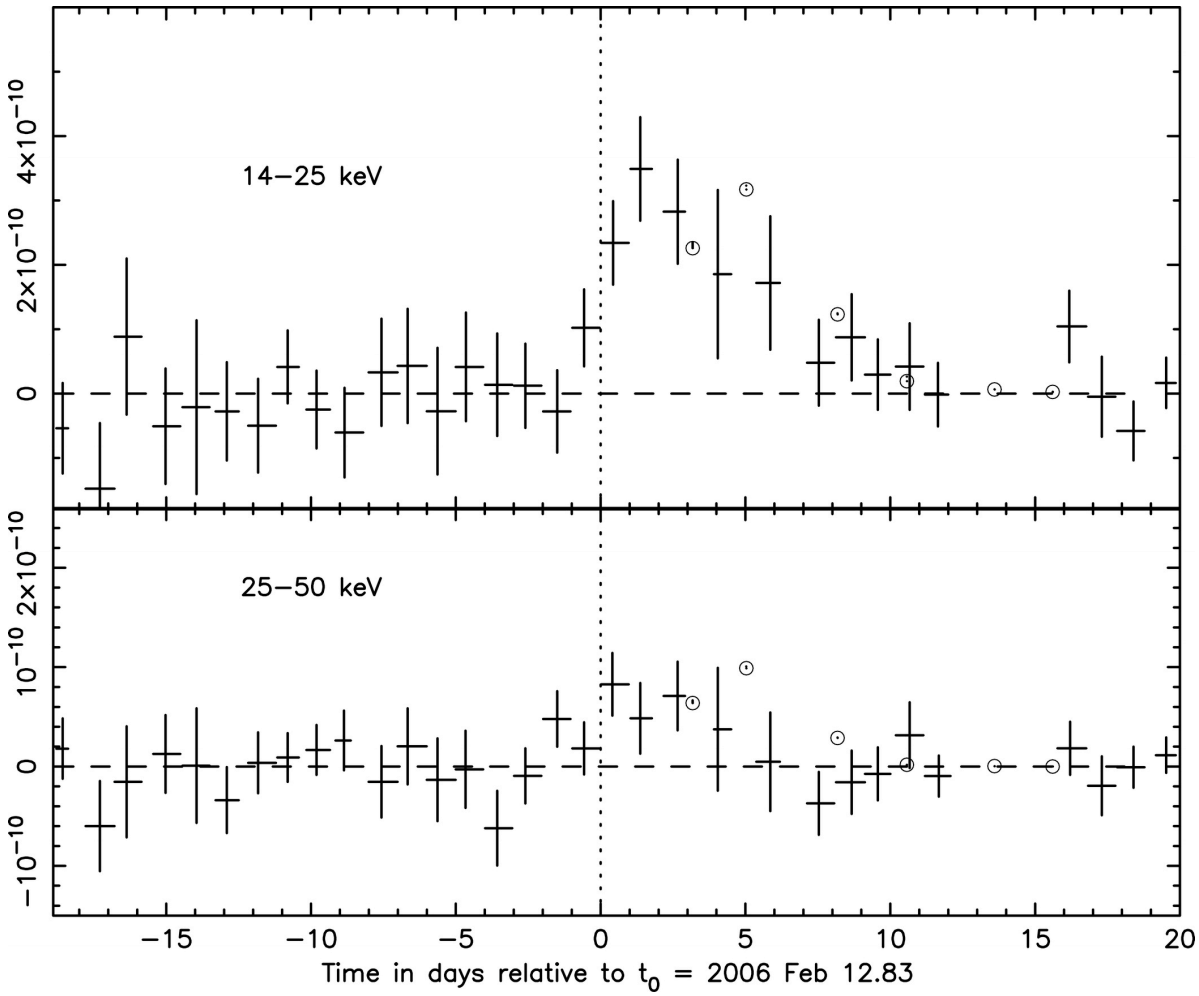
- XRT count rates of all sources in our sample, plotted against the day of observation after their outbursts. The count rates are corrected for distance squared, which is uncertain. Multiple observations of the same targets are connected with dotted lines.
- Bottom: Observations from various other missions. The observed X-ray luminosities (not corrected for absorption, except for V1974 Cyg, which is instead rescaled) of recent well-observed novae with SSS phases. Similar plots have been created by Pietsch et al. (2005, 2006). Ness et al. 2007



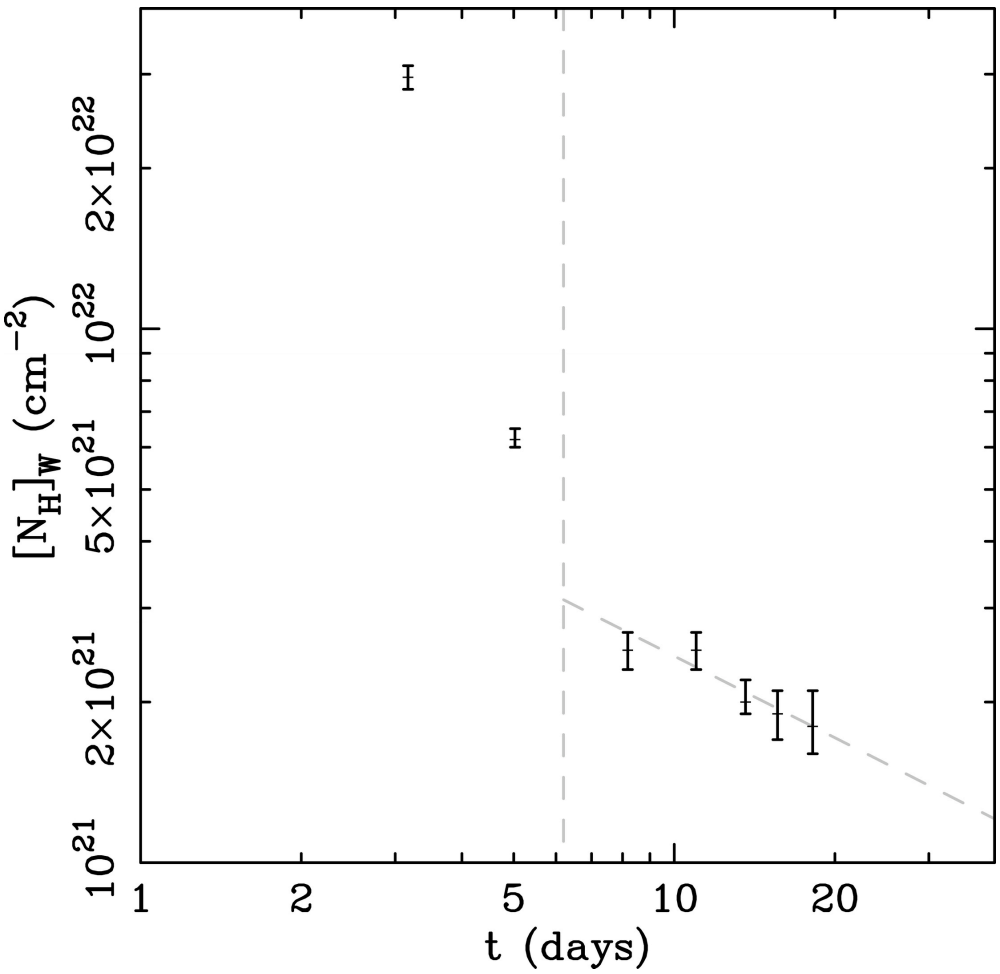

AAVSO DATA FOR RS OPH - WWW.AAVSO.ORG
Mag
4
5
6
7
8
9
10
11
12
13
2453550
2453700
2453850
2454000
Julian Date


RS Oph - 14.209 / 02 / 2006 - Lhires III + C11 - 0.115 A/pixel - 5 x 300 s
Relative intensity
12
11
10
9
8
7
6
5
4
3
2
1
6520
6530
6540
6550
6560
6570
6580
6590
6600
Wavelength (A)

SWIFT Burst and Transient (BAT) Observations of RS Oph



Flux from RS Oph in the 14–25 and 25–50 keV bands observed with *Swift* BAT. Units are ergs cm^{-2} s^{-1} and are based on count rates in these bands, assuming the spectral form found from observation 1 XRT data. The circles show the flux in the same energy bands from extrapolation of the models. Means have been calculated over 24 hr periods and are represented by a point at the weighted mean time, with horizontal error bars stretching from the first to the last sample included in the mean. The very irregular sampling leads to uneven horizontal error bars. The dotted line is the time of the first optical detection of the outburst. Bode et al. 2006



Temporal behavior of the overlying absorbing column in the red giant wind, net of the assumed interstellar column of cm^{-2}, derived from the XRT spectral fits. A vertical dashed line on this figure indicates the expected end of phase I development. The diagonal dashed line is a power law extrapolation. Bode et al. 2006

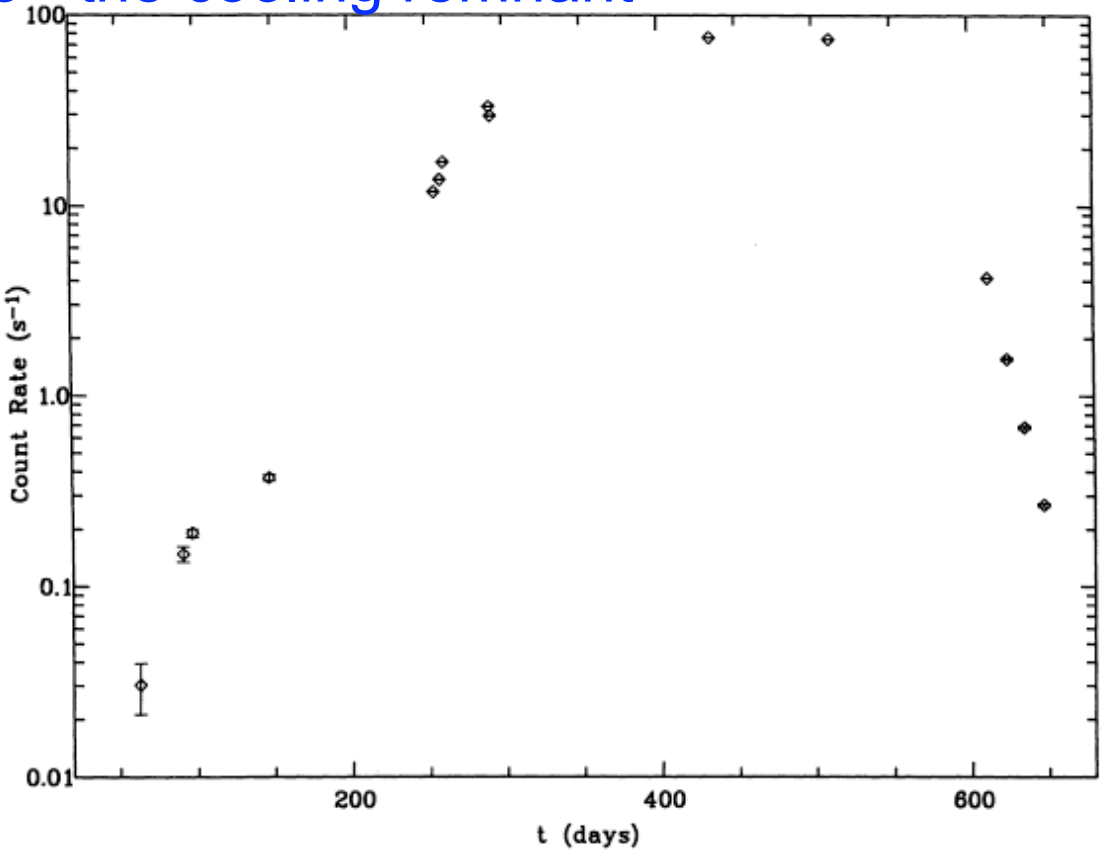
Previous Best observed Nova in X-rays:

Nova Cyg 1992: V1974 Cyg

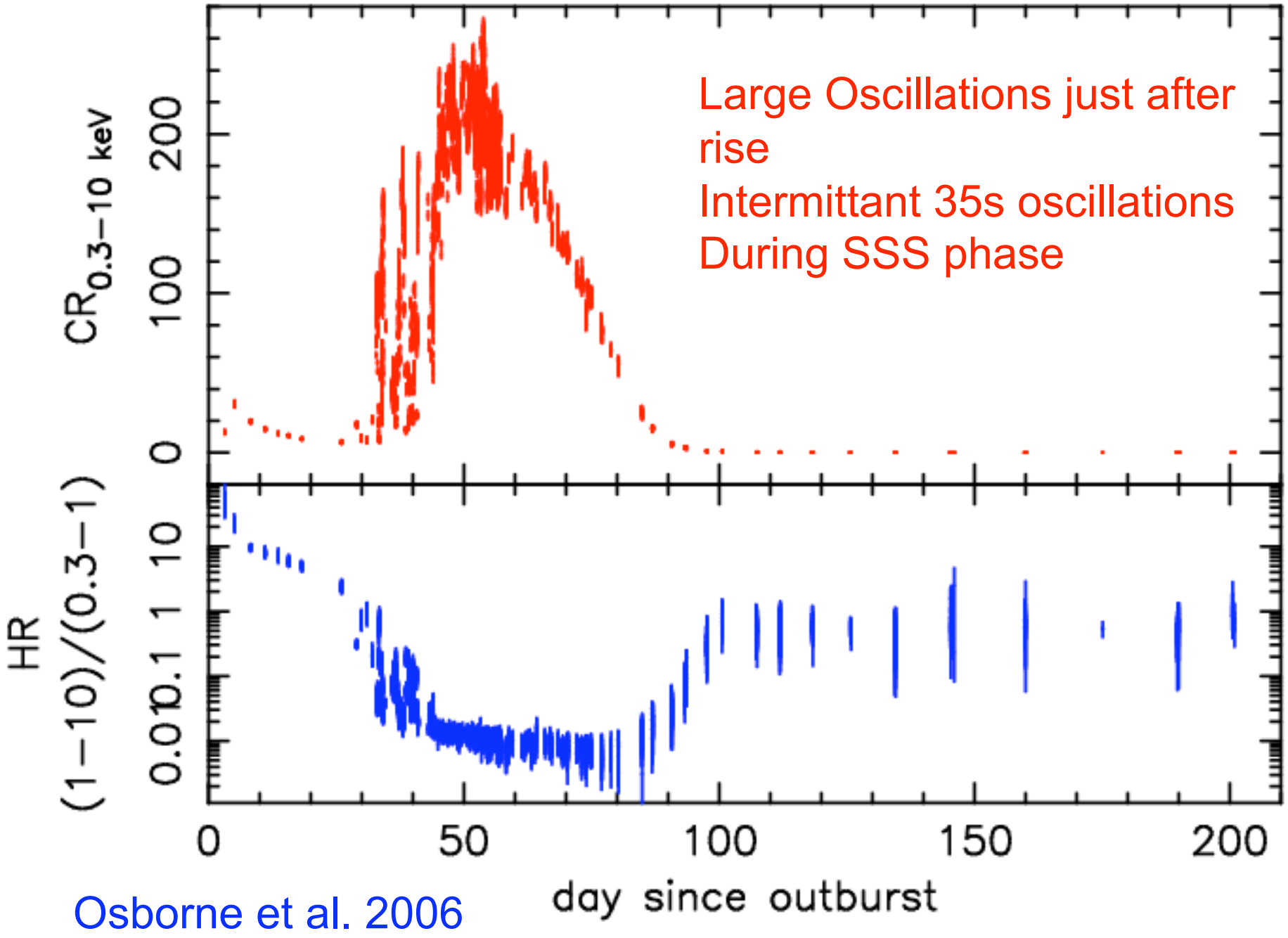
18 observations with ROSAT - brightest SSS in 1993

Slow Rise THE CLEARING OF THE EJECTA!

Rapid Decline - the cooling remnant



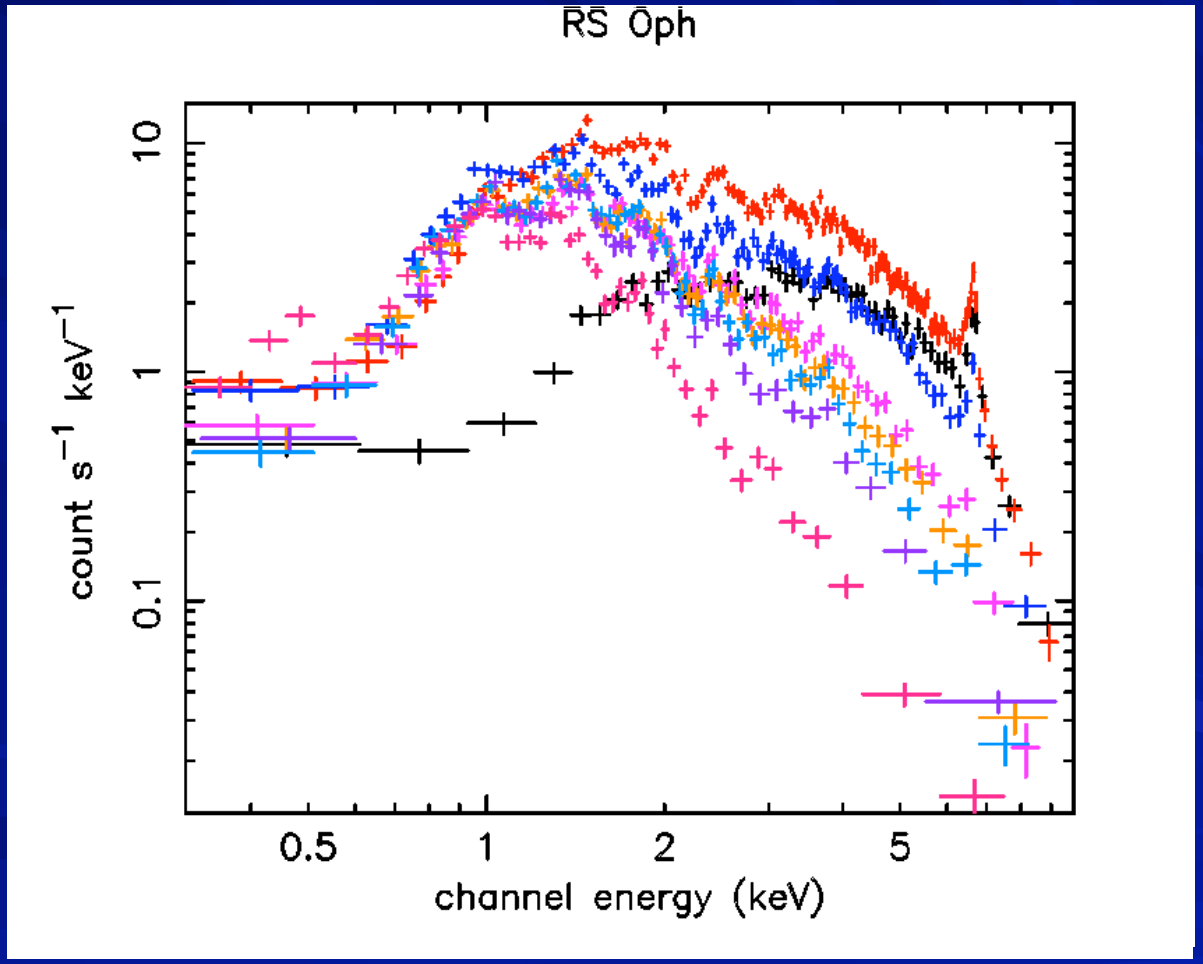
Krautter et al. 1996



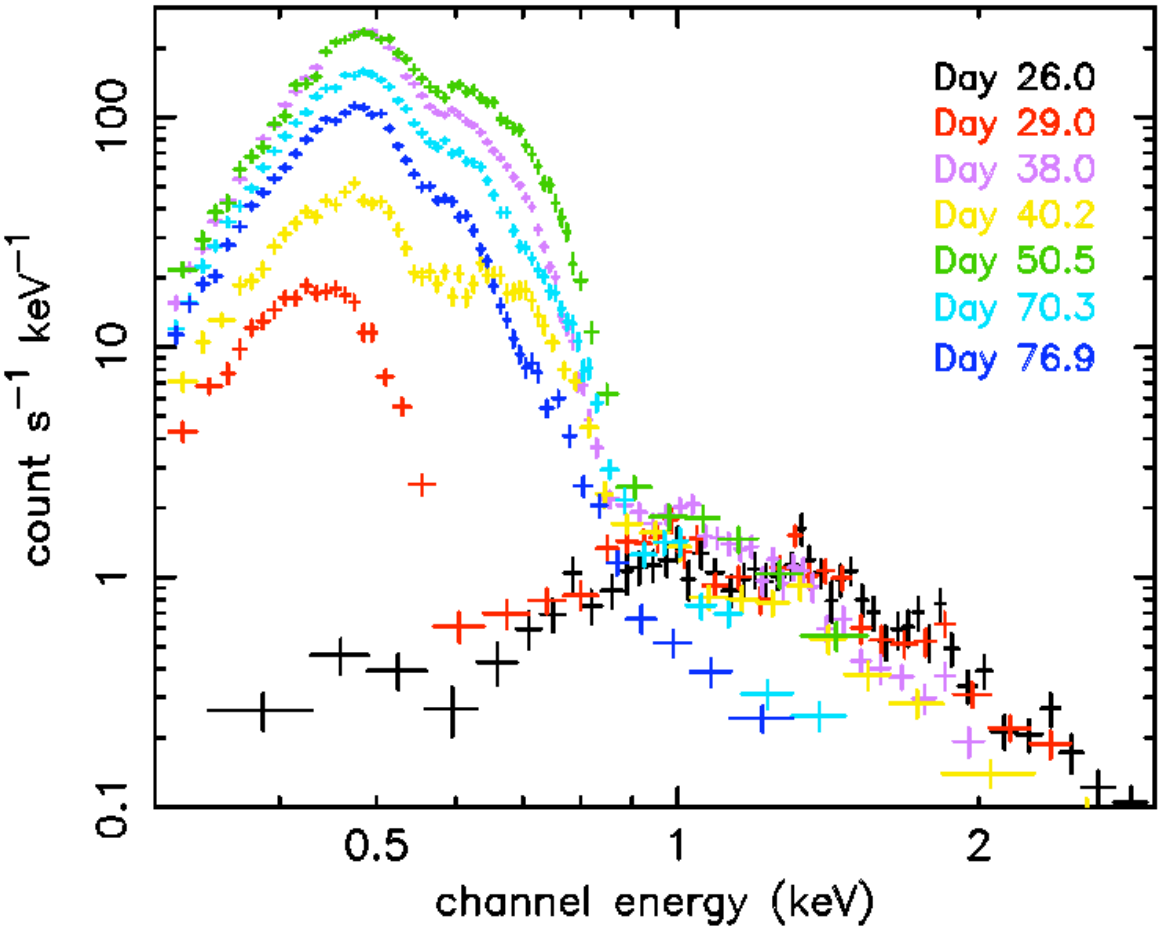
Osborne et al. 2006

Swift Observations: First 26 days

day
3.17
5.03
8.18
10.99
13.60
15.61
18.17
25.99



Later Swift X-ray spectra



1st appearance of hot WD on day 26

kT_{BB}=30 eV on day 29,
= 54 eV on day 50.5

Variable neutral oxygen absorption (0.54 keV)

Late flux decline consistent with temperature drop at day 76.9

Swift:*

1. **First Observations within 3 days**
2. **Detected with BAT and UVOT**
3. **On some days obtained one observation every 90 minutes**
4. **Followed entire outburst**
5. **About 350 ksec of data with XRT**
6. **Did NOT see the Super Soft Source (SSS) until ~ day 30**
7. **SSS => emission from hot white dwarf stellar atmosphere (Krautter et al. 1996 for V1974 Cyg)**

* Osborne et al., Bode et al.

Conclusions:

- Swift provided an unparalleled view of the explosion of RS Oph
- Initial shock reaches a temperature exceeding 10^8K
- Super Soft Source (hot white dwarf atmosphere) does not appear until about day 30 of the outburst--WHY?
- The turn-on of the SSS drives large amplitude oscillations that persist for a few weeks (oscillations seen in other novae in outburst.
- 35 sec oscillations seen in Swift data from time to time during SSS phase
- White dwarf probably massive and growing in mass to the Chandrasekhar Limit. BUT too much hydrogen in system and explosion unlikely to be called a SN Ia ?
- Need T CrB to explode - but not until we are back home