



**RS Oph:  
A new look at the evolution  
of 2006 outburst in X-rays**

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# Overview

## RS Oph

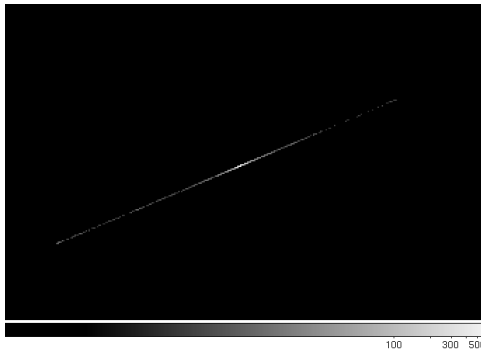
- symbiotic recurrent nova  
(outbursts every  $\sim 20$  years)
- last outburst in year 2006
- $P = 456$  days,  $i \approx 50^\circ$
- near-Chandrasekhar-mass white dwarf + red giant



# Swift space observatory

Burst Alert Telescope (BAT): 15 - 150 keV

X-ray Telescope (XRT): 0.3 - 10 keV

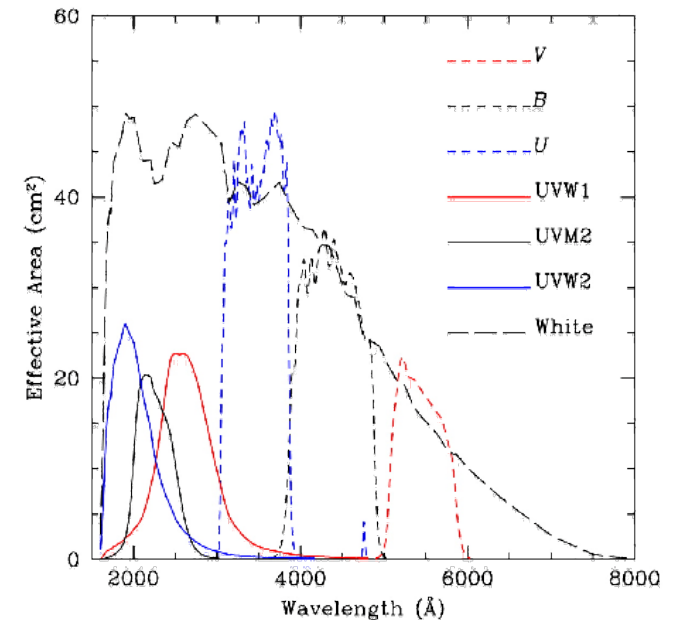
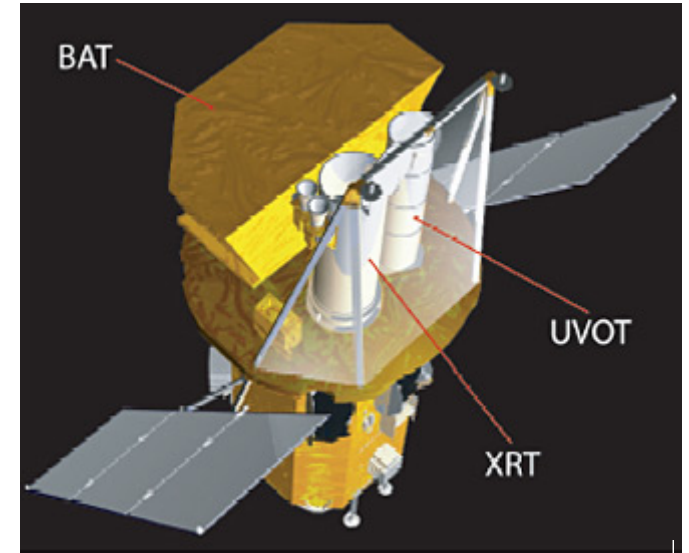


Windowed Timing mode [WT]



Photon Counting mode [PC]

UV/Optical Telescope (UVOT): 170 - 600 nm



# HEASARC

<https://heasarc.gsfc.nasa.gov/cgi-bin/W3Browse/w3browse.pl>

~120 simultaneous XRT & UVOT observations of **RS Oph** during and after the outburst in 2006

- tool to build Swift-XRT light curve or spectrum:

[http://www.swift.ac.uk/user\\_objects/](http://www.swift.ac.uk/user_objects/)

Archive HEASARC Browse Tip Archive Hera HELP

Other Browse interfaces: [Notification Service](#) | [Batch](#) | [Correlation](#) | [Index of all tables](#) | [Keyword Search](#) Query File And Session Uploads

1. Do you want to search around a position ... ?  
(If you want to search on parameters other than object name or coordinates, select "Detailed Mission/Catalog Search".)

Object Name or Coordinates:  and/or   No file chosen

e.g. Cyg X-1 or 12 00 00, 4 12 6 or Cyg X-2; 12.235, 15.345 (Note use of semi-colons (;) to separate multiple object names or coordinate pairs)

Coordinate System:

Search Radius:

Default uses the optimum radius for each catalog searched.

... and/or search by date?  YYYY-MM-DD hh:mm:ss or MJD: DDDDD.ddd

Not all tables have observation dates. For those that do, the time portion of the date is optional. Separate multiple dates/ranges with semicolons (;). Range operator is '..' (e.g. 1992-12-31; 48980.5; 1995-01-15 12:00:00; 1997-03-20 .. 2000-10-18)

2. What missions and catalogs do you want to search? (Bold text indicates mission is active)

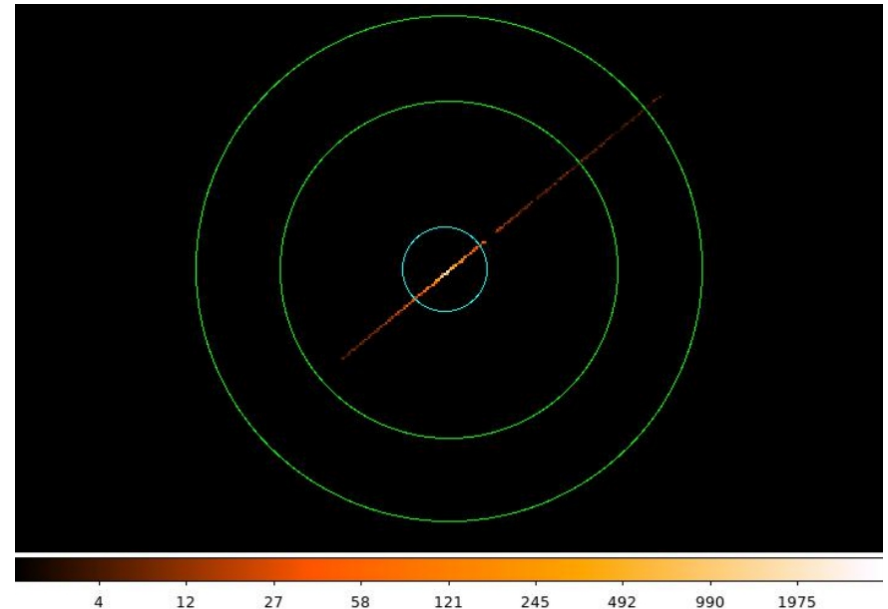
- Most Requested Missions**
  - Chandra **[CXC, CSC]**
  - NuSTAR **[CalTech]**
  - Swift
  - Fermi
  - ROSAT
  - WMAP
  - Hitomi
  - RXTE
  - XMM-Newton **[XSA]**
  - NICER
  - Suzaku
- Other X-Ray and EUV Missions**
  - Ariel V
  - Copernicus
  - Ginga
  - OSO8
  - ASCA
  - Einstein
  - HEAO 1
  - SAS 3
  - BBXRT/Astro-1
  - EUVE **[MAST]**
  - Kvant
  - Uhuru
  - BeppoSAX
  - EXOSAT
  - MAXI **[DARTS]**
  - Vela 5B
- Other Gamma-Ray Missions**
  - AGILE **[ASDC]**
  - INTEGRAL **[ISDA, ISDC]**
  - CGRO
  - SAS 2
  - COS B
  - Gamma-Ray Bursts
  - HETE-2
  - RHESSI
- Missions and Facilities**
  - AKARI (IR) **[Project]**
  - FAUST/Atlas-1 (UV)
  - Herschel (IR-submm) **[ESA]**
  - IUE (UV) **[MAST]**
  - SDSS (Opt) **[Project]**
  - WISE (IR) **[IRSA]**
  - ANS (UV)
  - FUSE (UV) **[MAST]**
  - HST (UV-NearIR) **[MAST]**
  - LPF **[ESA]**
  - Spitzer (IR) **[SSC]**
  - COBE (IR/sub-mm) **[LAMBDA]**
  - GALEX (UV) **[MAST]**
  - IRAS (IR)
  - MSX (UV-IR)
  - TD1 (UV)
  - CoRoT (Opt) **[CNES]**
  - Ground-Based (Opt-Radio)
  - ISO (IR) **[IDA]**
  - Planck (submm-radio) **[ESA, IRSA]**
  - UIT/Astro-1 (UV) **[MAST]**
- Popular Catalog Choices

# Data reduction and analysis

## HEASoft:

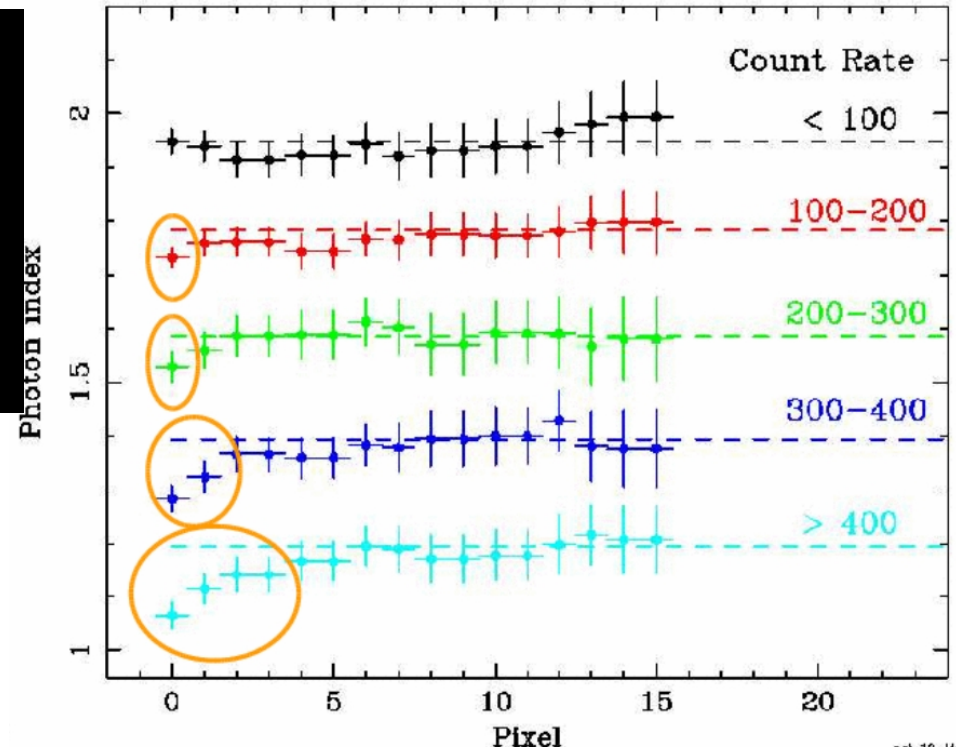
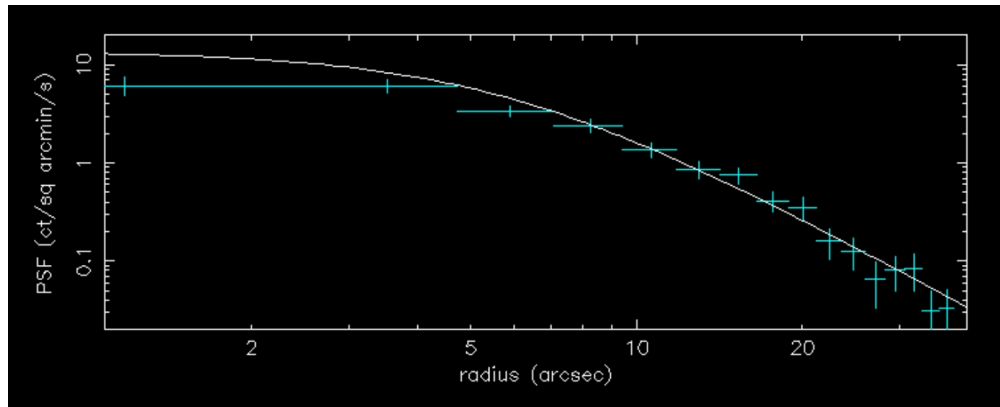
<https://heasarc.gsfc.nasa.gov/docs/software/heasoft>

- produce cleaned event-list
- correct for the pile-up
- define source and background region
- extract spectrum
- build ancillary response file
- link all necessary files
- spectral analysis (Xspec)



# Pile-up

- one or more photon hit the same pixel at the same time
- pile-up can occur for **count rate above**: 0.5 c/s for PC, 100 c/s for WT

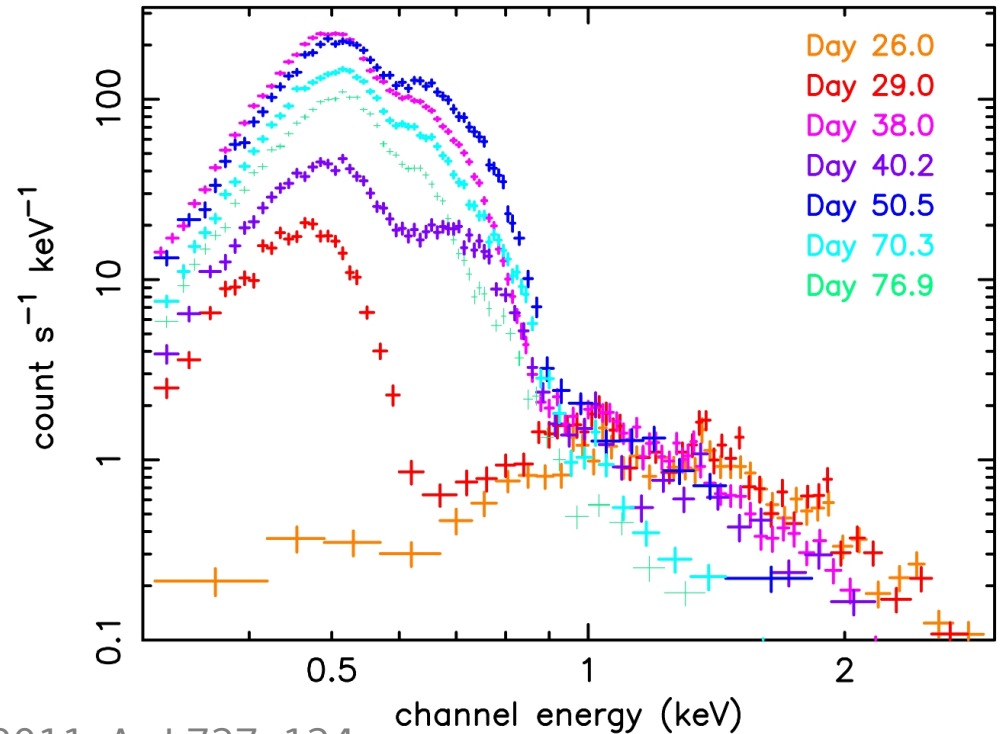
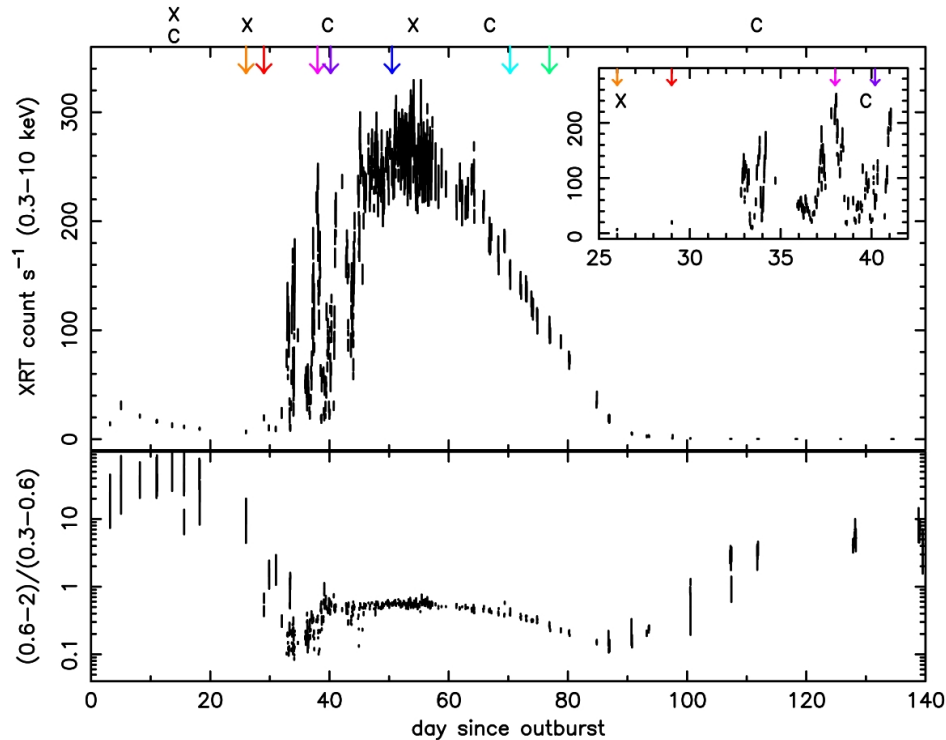


- point spread function fitted by the King function:

$$PSF(r) = [1 + (r/r_c)^2]^{-\beta}$$

# RS Oph 2006 outburst

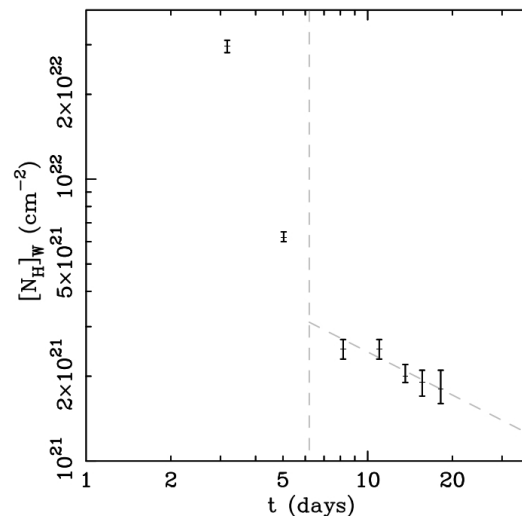
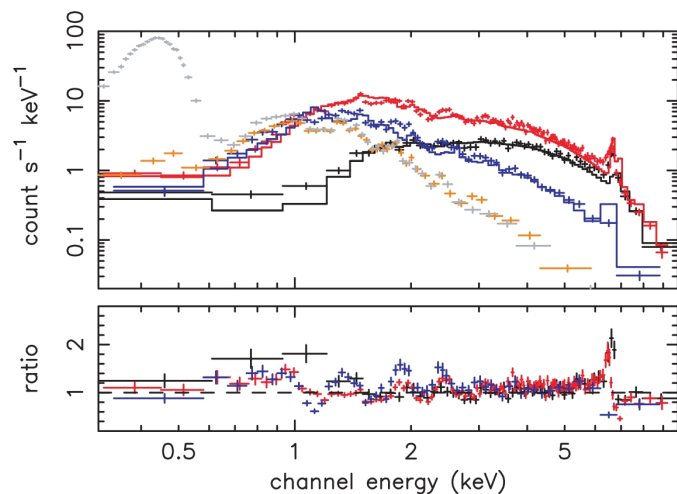
- February 12 at a magnitude of 4.5
- hard phase + variable SSS phase + stable SSS phase + hard phase toward quiescence



# Initial hard phase

Bode et al. 2006, ApJ 652, 629

- high-velocity ejecta from WD interact with preexisting red giant wind  
--> creation of **shocks**



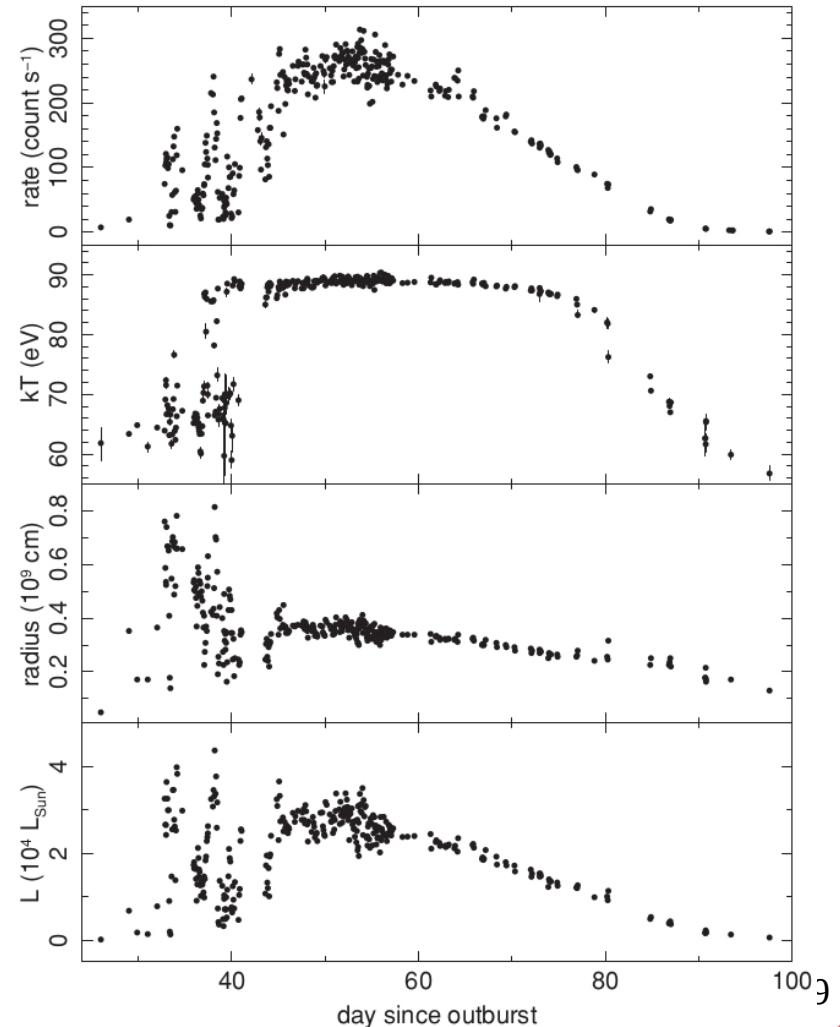
- **model**: thermal emission from optically thin plasma (**SHOCKS**) - MEKAL model  
x absorption (ISM + RG wind)
- $N_H$ : profile as expected for a red giant wind ahead of the shock



# Supersoft source (SSS) phase

Osborne et al. 2011, ApJ 727, 124

- **model:** ( plasma ( $T_1$ ) - APEC model  
+ plasma ( $T_2$ ) - APEC model  
+ hot WD atmosphere - Rauch 2003 )  
x absorption (ISM + unshocked RG wind)
- $N_H$ :  $N_{H, \text{wind}} = 7.5 \times 10^{21} t^{-0.5} \text{cm}^{-2}$   
(Bode et al. 2006)
- X-ray spectra during SSS phase dominated by radiation from the **unveiled WD surface** due to the ongoing **nuclear fusion**
- reestablished accretion **ruled out** as the origin of SSS component



# Quiescence

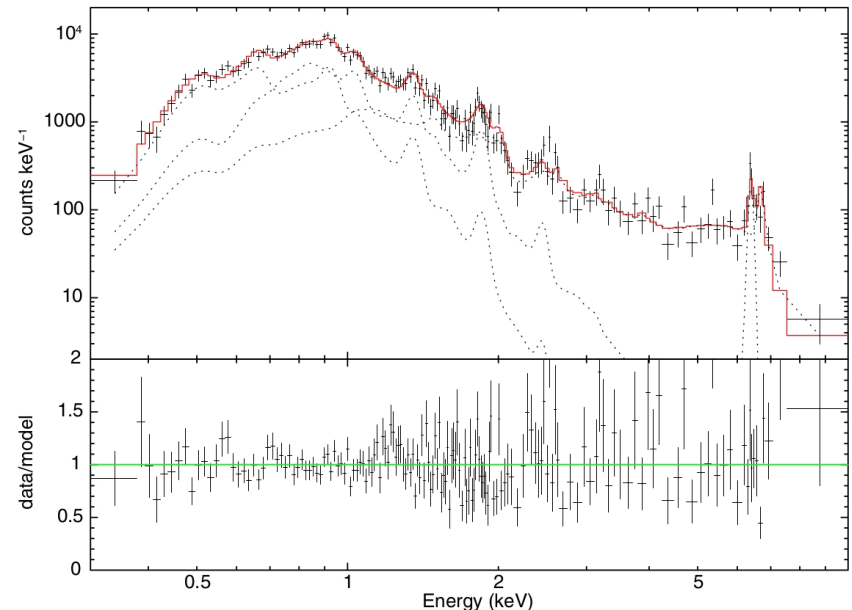
Nelson et al. 2011, ApJ 737, 7

- two-component plasma model:
  - > **shocked nova ejecta**
  - > **accretion disk boundary layer**
- to reproduce the continuum above 2 keV:
  - > **partially covering absorber**

$$f \times \exp[-n_H \sigma(E)] + (1-f)$$

- **model:** ( **plasma ( $T_1$ )** - VAPEC model  
+ **plasma ( $T_2$ )** - VAPEC model  
+ **partially covering abs. x (plasma ( $T_3$ ) + Fe line)** )  
**x absorption** (ISM + unshocked RG wind)

- $N_H$ :  $N_{H, \text{total}} = 2.4 \times 10^{21} \text{ cm}^{-2}$   
 $N_{H, \text{part. cov.}} = 1.3 \times 10^{24} \text{ cm}^{-2}$

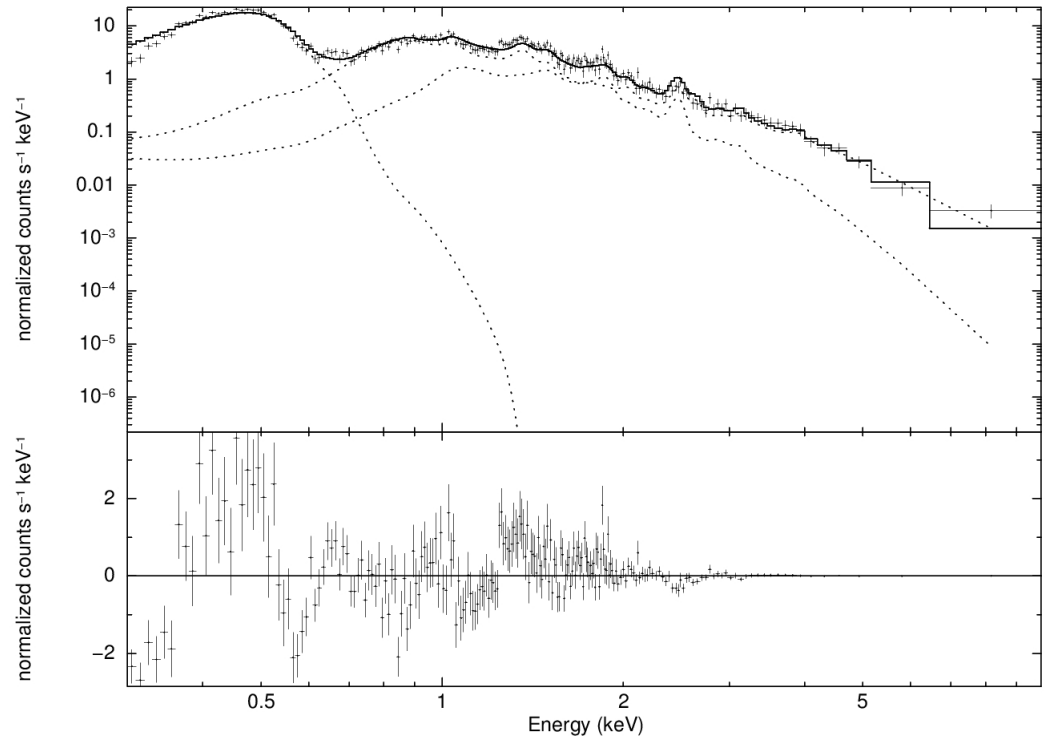


# Modelling Swift XRT spectra

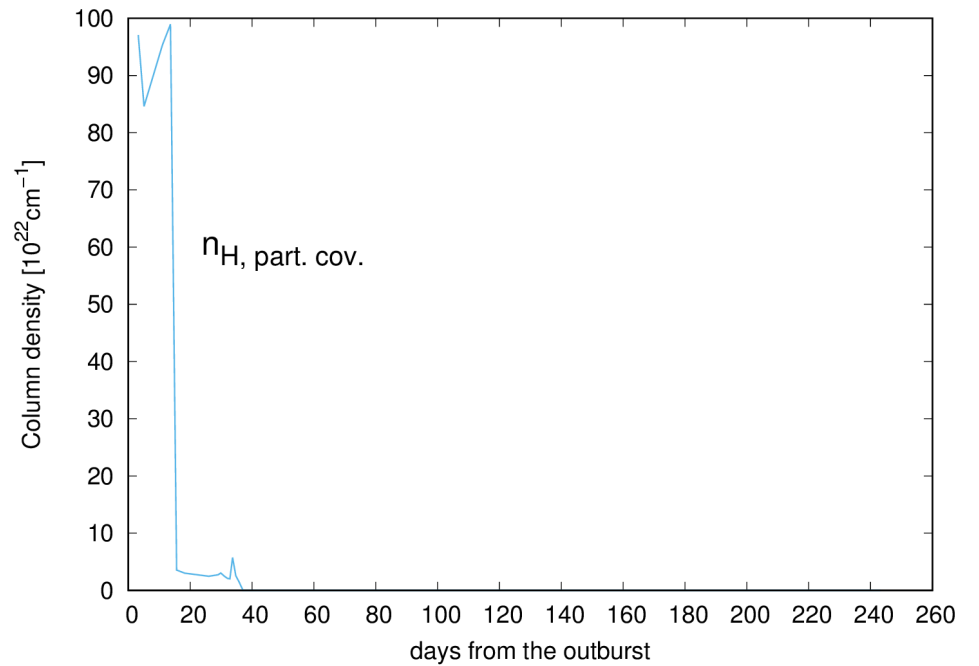
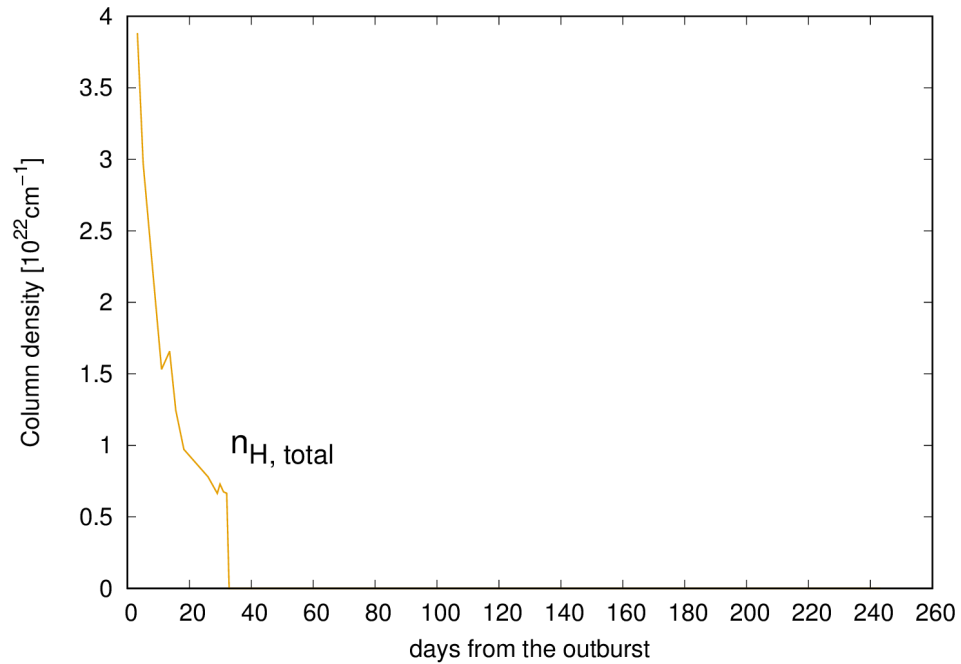
- **model:** ( **abs.** (unshocked RG wind) x **plasma** ( $T_1$ ) - VAPEC model  
+ **partially covering abs.** x (plasma ( $T_2$ ) + hot WD atmosphere) )  
x **absorption** (ISM)

- $N_H$ :
  - $N_{H, \text{total}}$  - free parameter
  - $N_{H, \text{part. cov.}}$  - free parameter

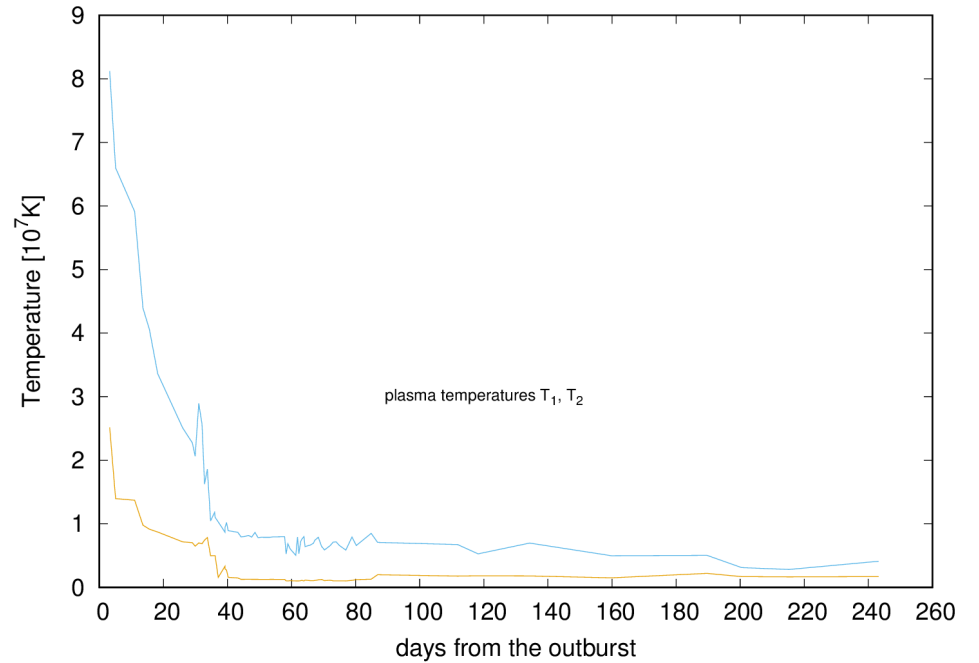
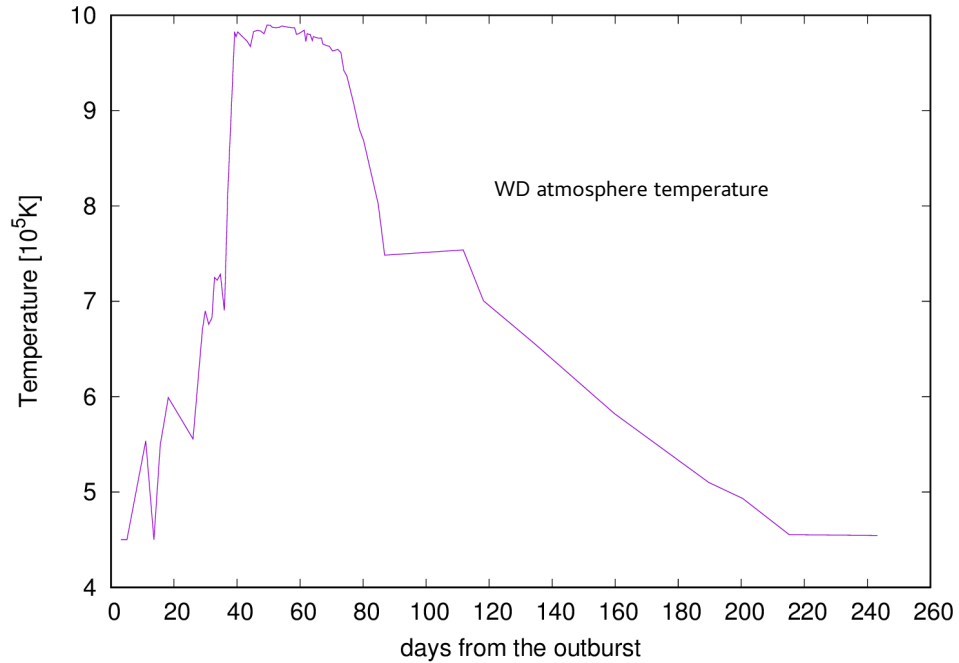
- **abundances:**
  - Wilms et al. 2000 (ISM)
  - Ness 2007 (**shock**)
  - Ness 2009 (**shock**)
  - Pavlenko 2008 (**RG wind**)



# Column densities

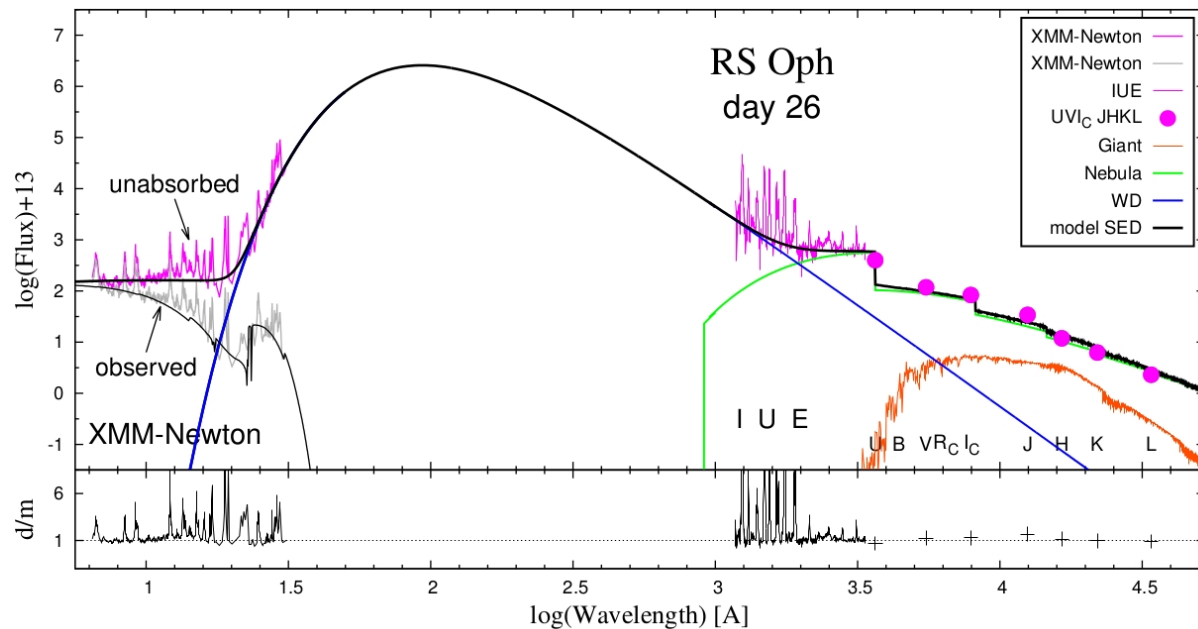


# Temperatures



# Future outlook

- extend the dataset by simultaneous **UVOT** observations
- compare with existing multiwavelength (**supersoft X-rays – IR**) models
- **luminosity problem**: Eddington vs highly super-Eddington ( $\sim 65L_{\text{Edd}}$ )



# Conclusions

- our model is consistent with the WD atmosphere as a source of the supersoft radiation during the supersoft phase of the 2006 outburst
- need of the multiwavelength studies to resolve the luminosity problem

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**Thank you for attention!**