Swift Cataclysmic Variables and Novae

Julian Osborne

University of Leicester

Swift nova-CV group

Cataclysmic Variables

CVs consist of a white dwarf accreting from a binary companion

They have a rich temporal phenomenology

- Multiple periods if WD is magnetic or oscillating
- Outbursts due to:
  - accretion events = dwarf novae
  - thermonuclear runaway reaction on WD = novae

1 – Observation of non-magnetic CV through outburst

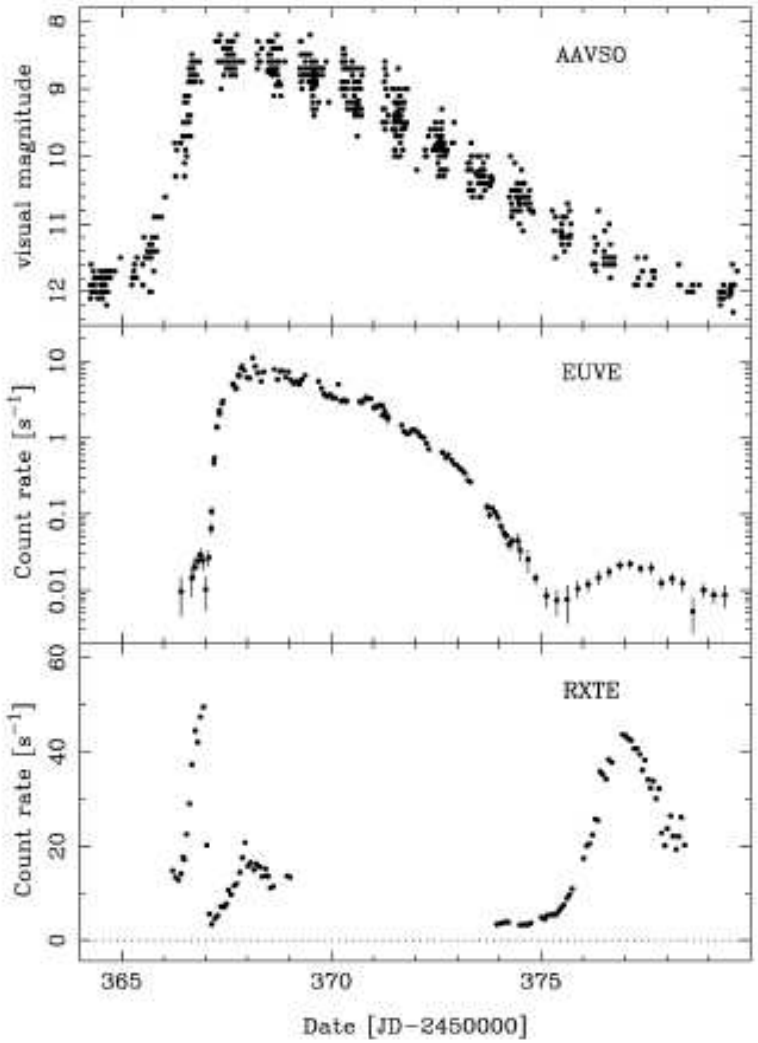
Expectation from model:

- Rising hard X-ray flux as accretion rate rises
- Hard X-ray flux suppressed as WD-disk boundary layer become optically thick
- Resumption of hard X-ray flux as boundary layer becomes optically thin
- Decline of hard flux as accretion rate continues to decline to quiescence

- Only archetypal object SS Cyg has been observed sufficiently to see this

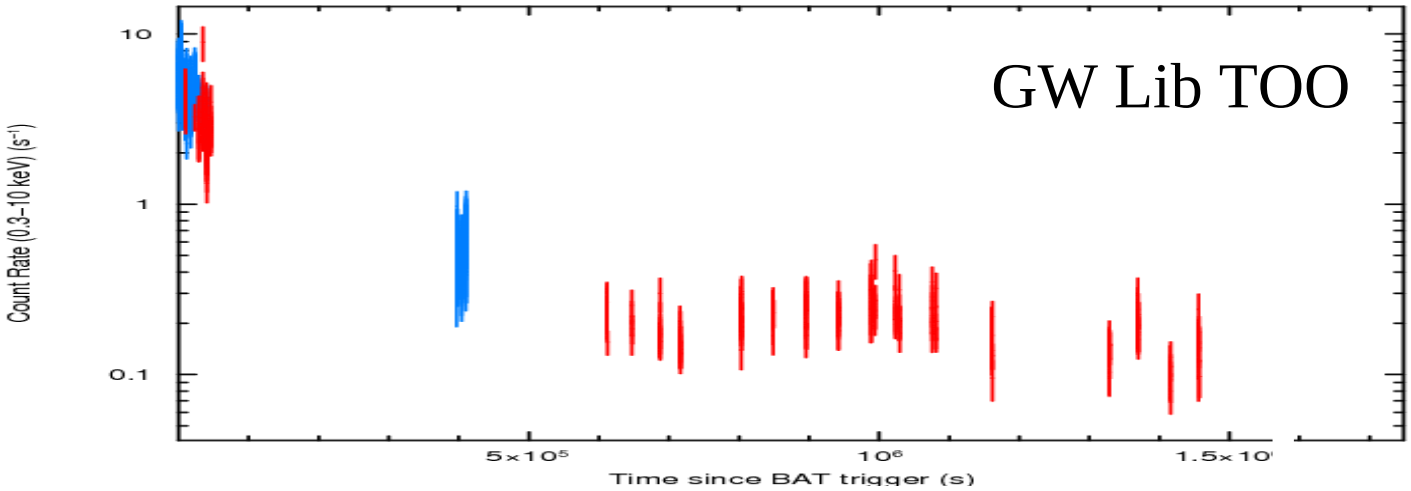
Non-magnetic CV through outburst

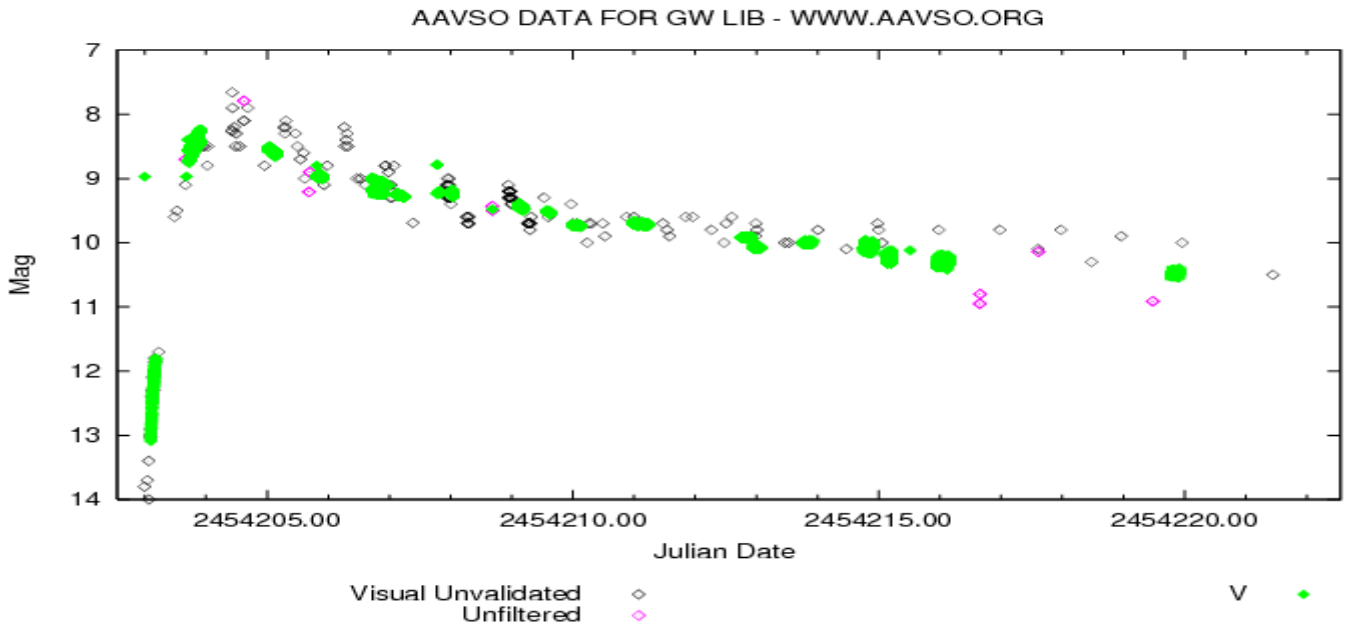
SS Cyg



Wheatley et al 03

Non-magnetic CV through outburst

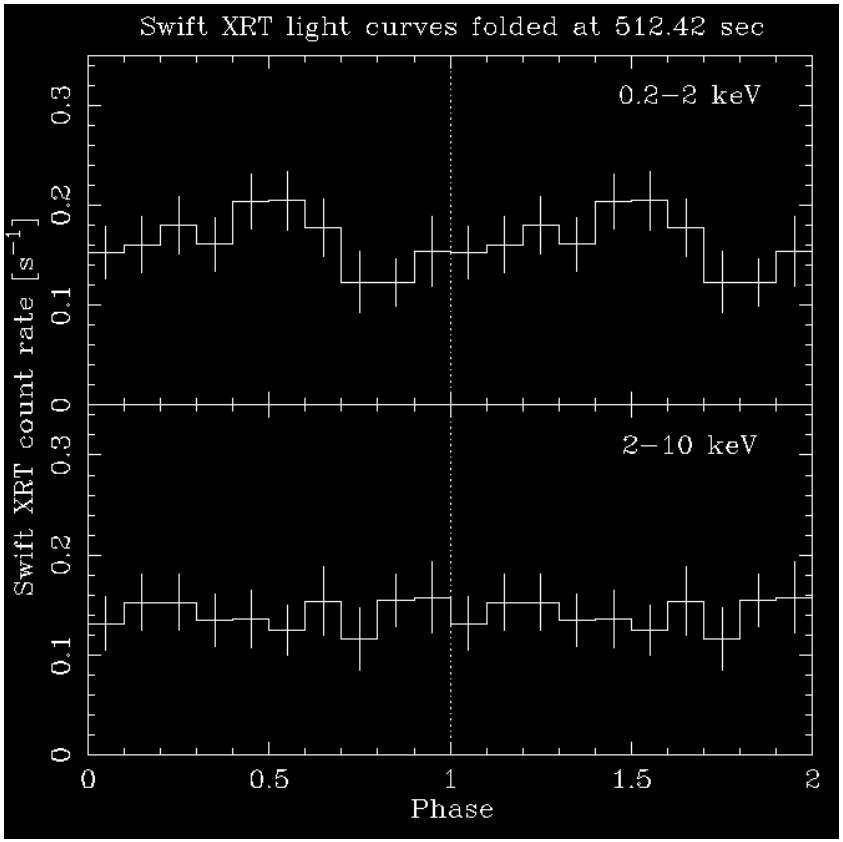


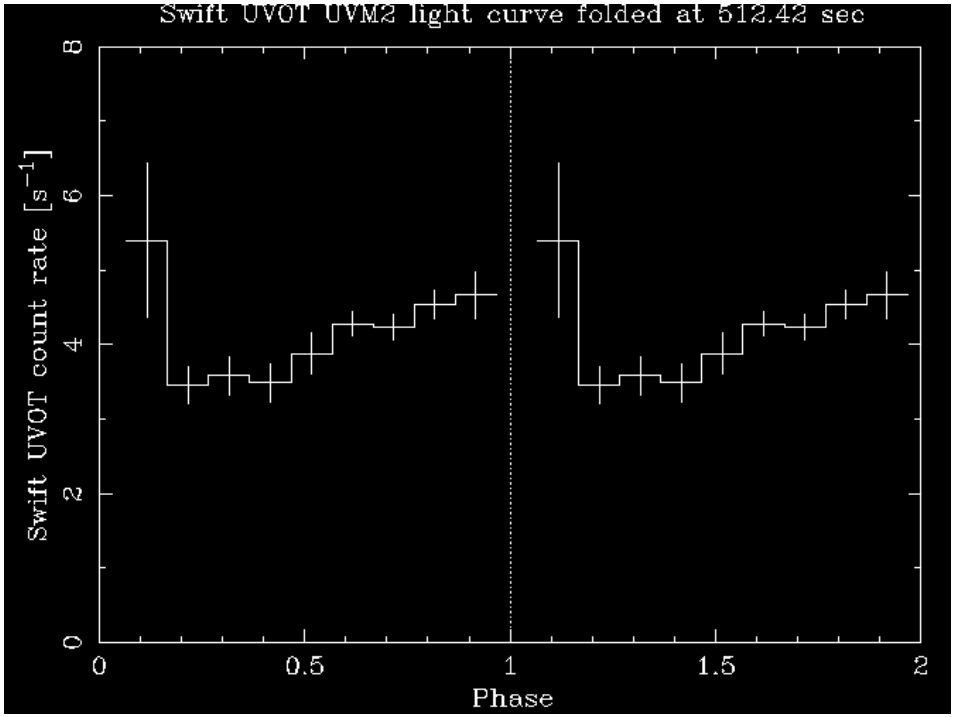


2 – classification of magnetic CV

- New BAT source
- Located by XRT
- Associated 2MASS object suggested CV classification
- 512 sec optical period discovered
- X-ray confirmation of optical period in XRT & UVOT data
- 5.5 hr optical period discovered
- Hence Intermediate Polar classification complete

Swift J0732.5-1331





Wheatley et al ATel 765

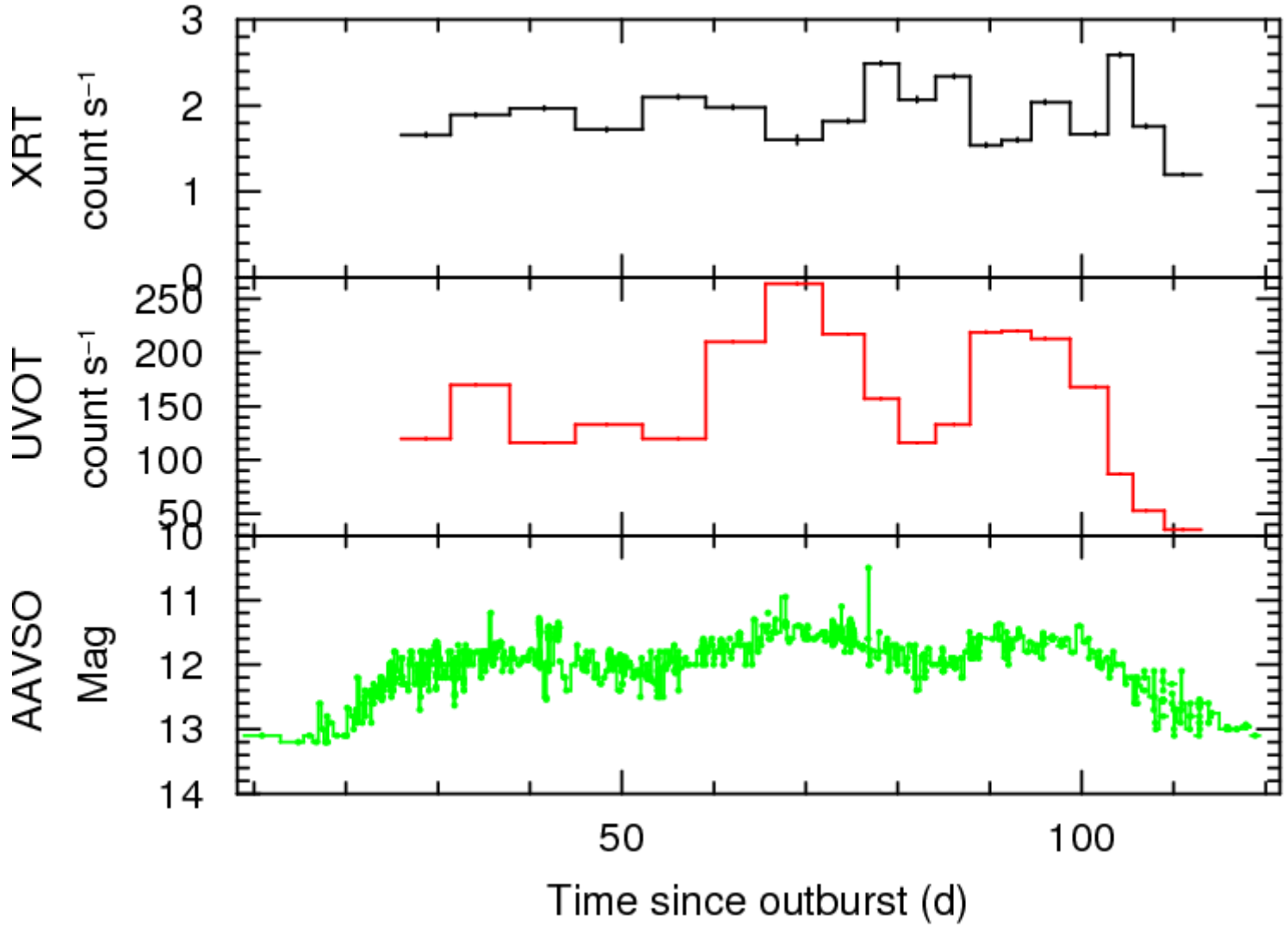
- Swift hard X-ray source (Ajello et al ATel 697)
- Optical 512 sec and 5.5 hr periods
- XRT 512 sec period in soft X-rays due to varying NH confirms intermediate polar classification

3 – A magnetic CV in outburst

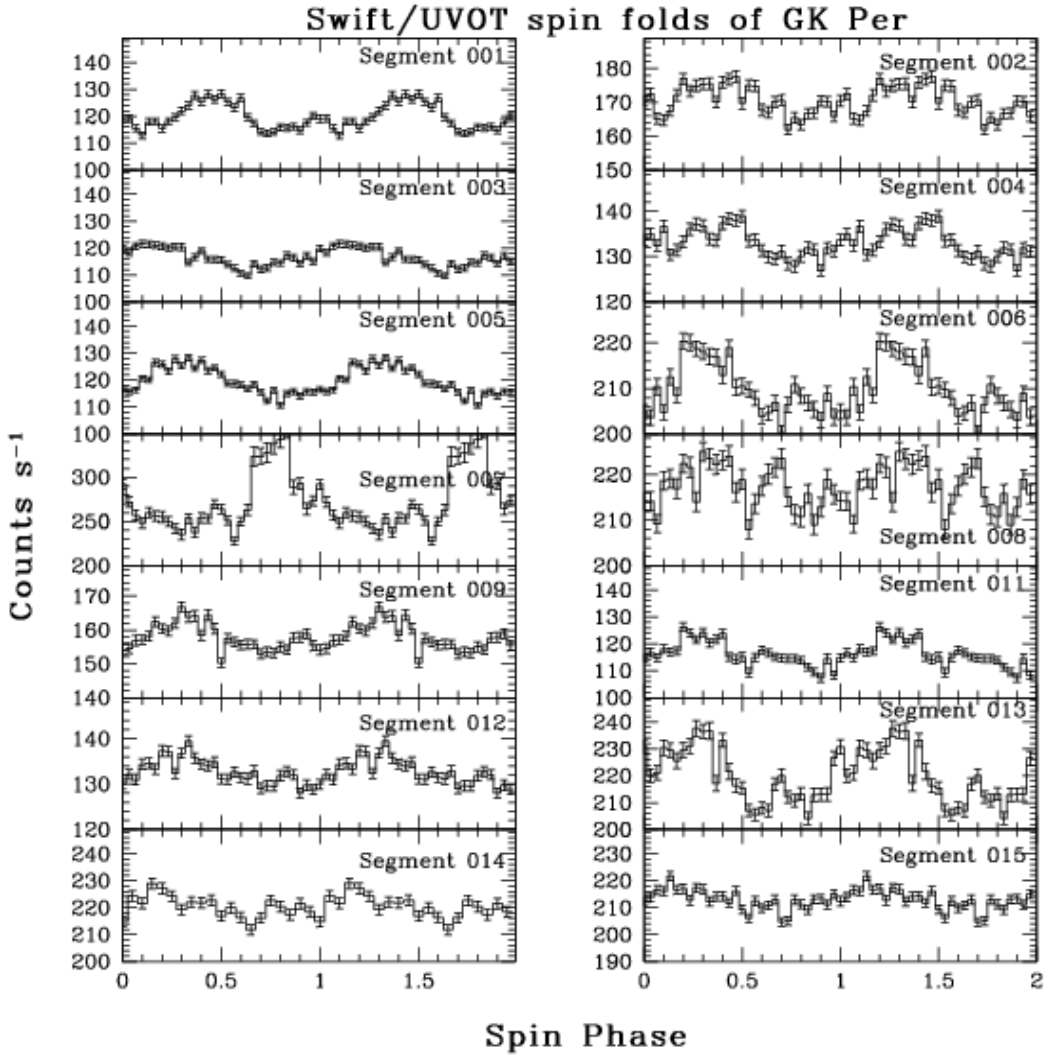
- GK Per is an ex-nova with a 2-day orbit
- Hence has a large accretion disk
- 351 sec X-ray period due to spinning white dwarf
- Shows dwarf nova-like outbursts, unlike most intermediate polars
- Can monitor accretion geometry under changing accretion rate
- Outburst ended late last month

(Evans and Beardmore)

GK Per TOO


XRT
count s^{-1}
3
2
1
0
UVOT
count s^{-1}
250
200
150
100
50
AAVSO
Mag
10
11
12
13
14
50
100
Time since outburst (d)

GK Per TOO


Swift/UVOT spin folds of GK Per
Segment 001
Segment 002
Segment 003
Segment 004
Segment 005
Segment 006
Segment 007
Segment 008
Segment 009
Segment 011
Segment 012
Segment 013
Segment 014
Segment 015
Counts s⁻¹
Spin Phase

4 – Novae

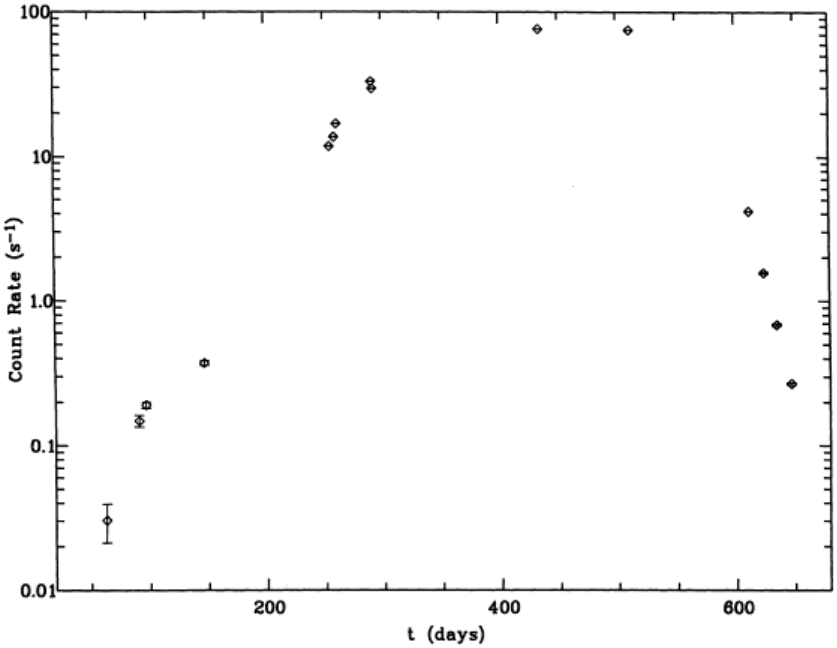
X-ray observations so far have been highly sporadic – need to establish patterns of behaviour

Expectations for X-ray emission:

- Short-lived hot envelope at ignition (not seen)
- Nova wind shocks (internal or external)
- Super-soft emission from nuclear burning WD
- Post-explosion re-establishment of accretion
- Compton degredation of Na^{22} gamma-rays (not seen)

Swift nova group collaborates in obtaining observations

Previous best observed nova in X-rays



Krautter et al 1996

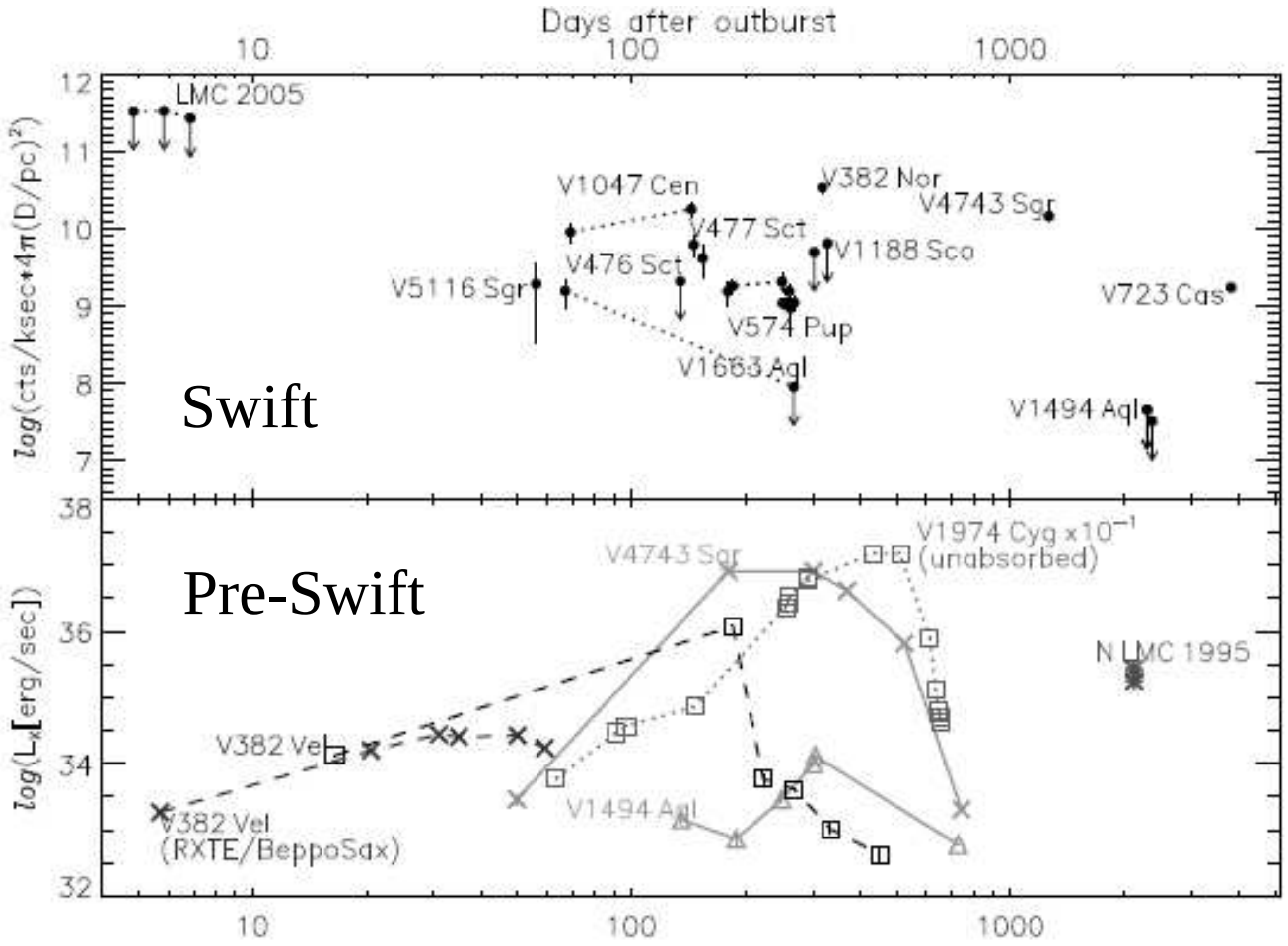
Nova Cyg 1992
(V1974 Cyg)

- Rosat PSPC
- 18 observations
- SSS lasts ~400 days

- Duration of SSS phase generally unknown – important constraint on WD mass

Classical novae

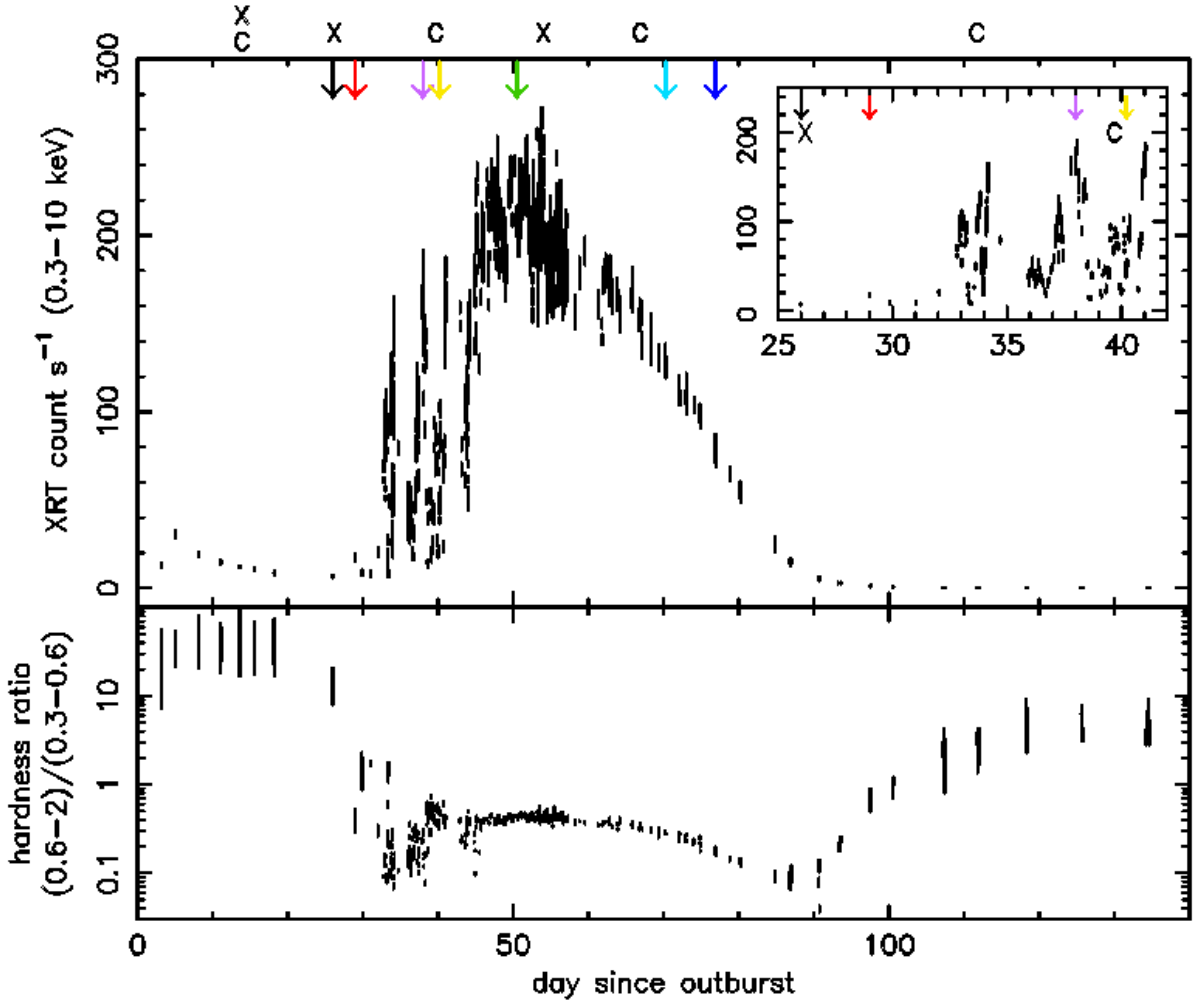
1st Swift nova paper has 12 novae



Swift is building a more complete sample than was previously available

Ness et al 07

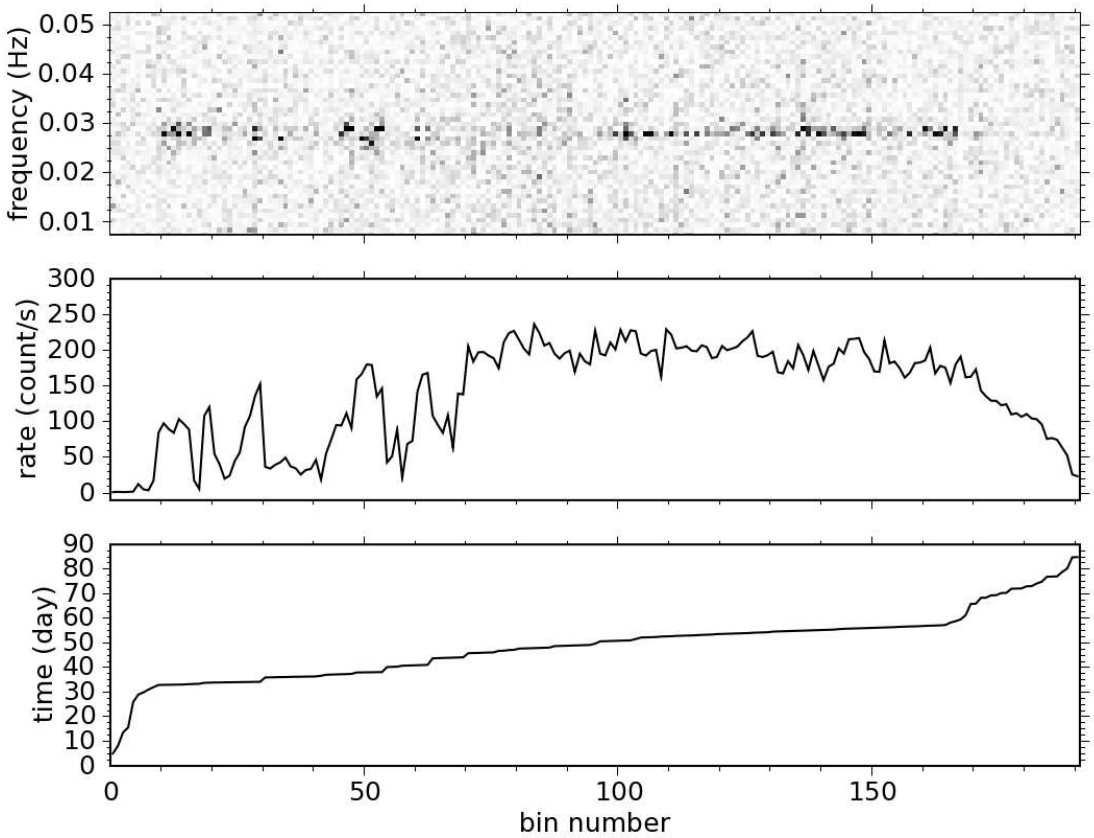
Recurrent nova RS OPh



Swift XRT 0.3-10 keV light curve shows:

- Cooling hot gas emerging from red giant wind
- Noisy onset of super-soft phase, which lasts ~64 day in total
- Very short SSS phase → WD near Chand limit

RS Oph QPO



~35 sec modulation mostly present when SSS is bright

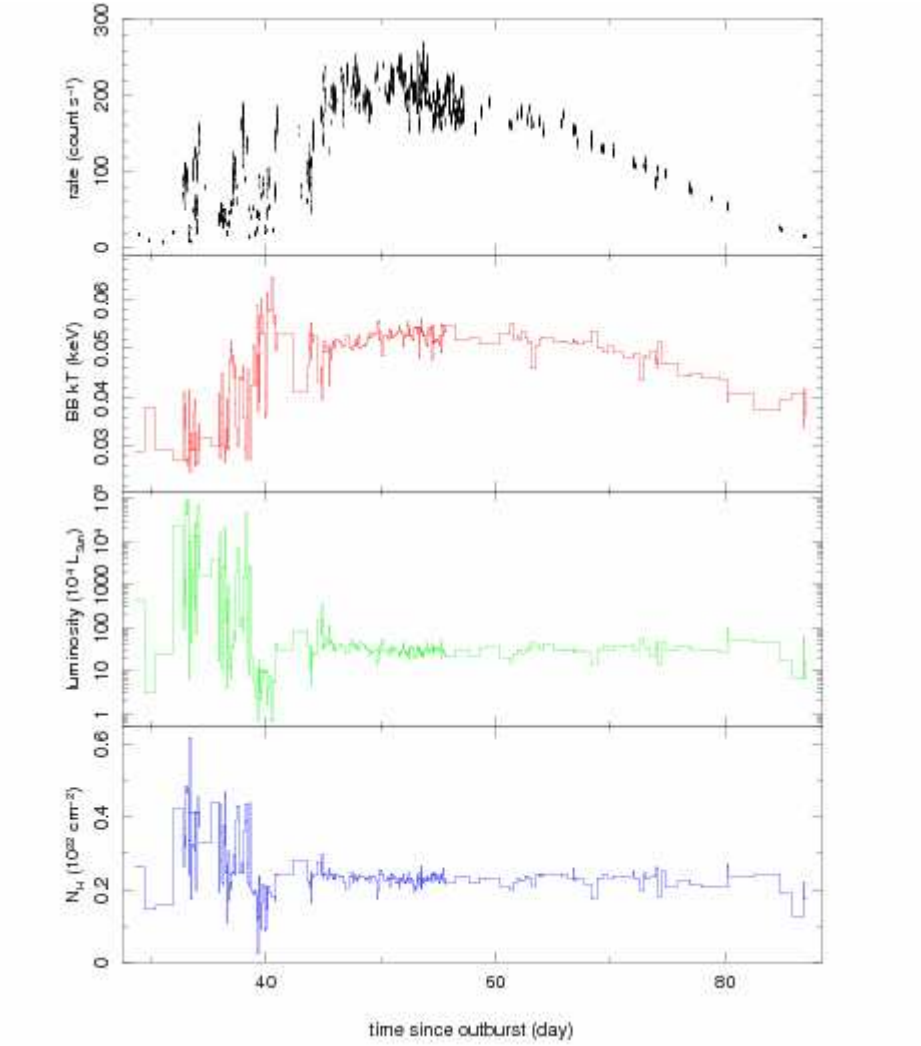
Fastest period seen in a nova so far – possible nuclear burning instability?

RS Oph X-ray spectra

Preliminary high temporal density spectral fits

Blackbody cooling clear during late SSS phase

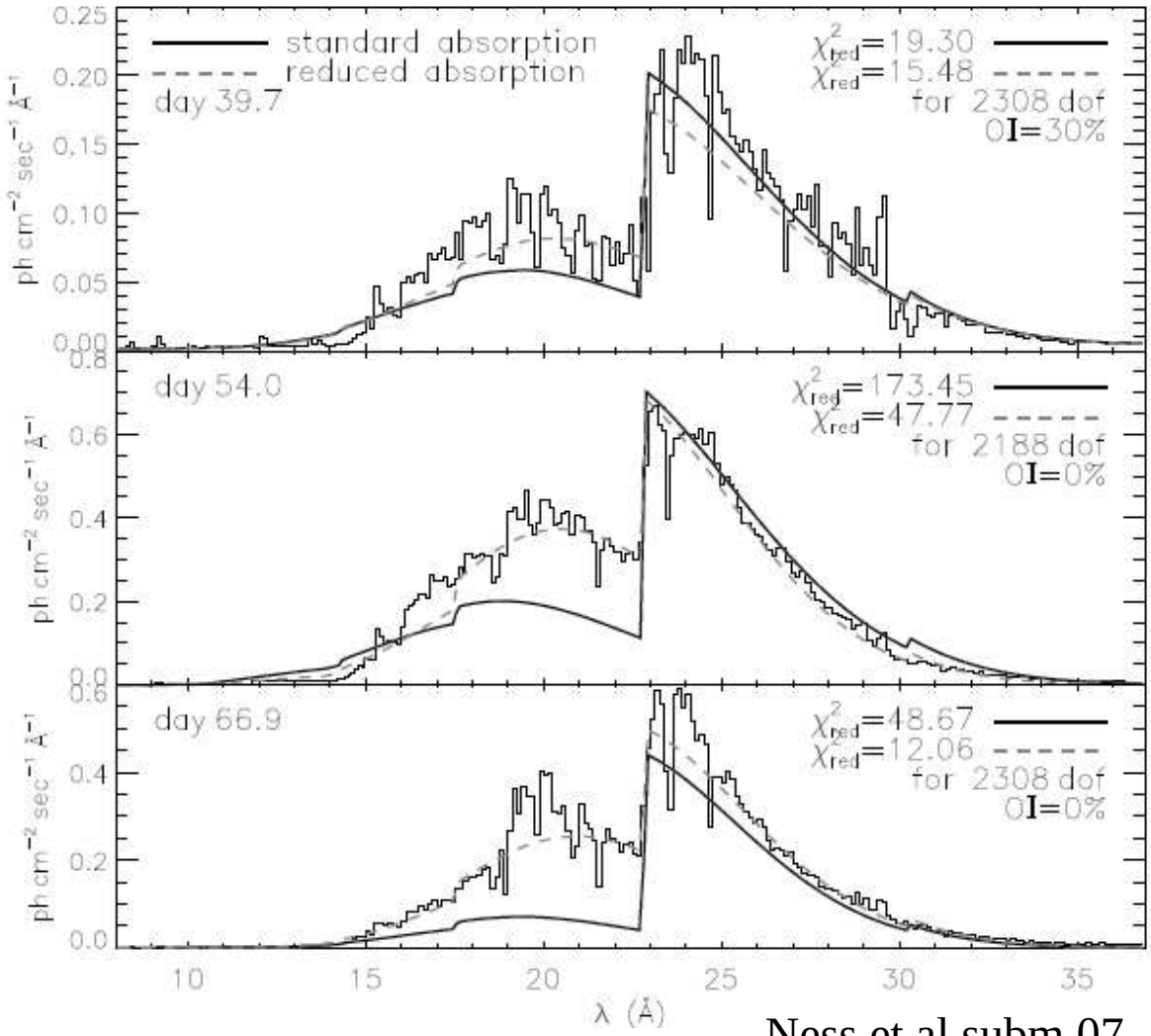
All parameters uncertain at SSS onset due to highly variable absorption in nova ejecta



RS Oph grating X-ray spectra

3 epoch Chandra grating spectra suggest reduced Oxygen in absorber

Model atmosphere modelling now starting

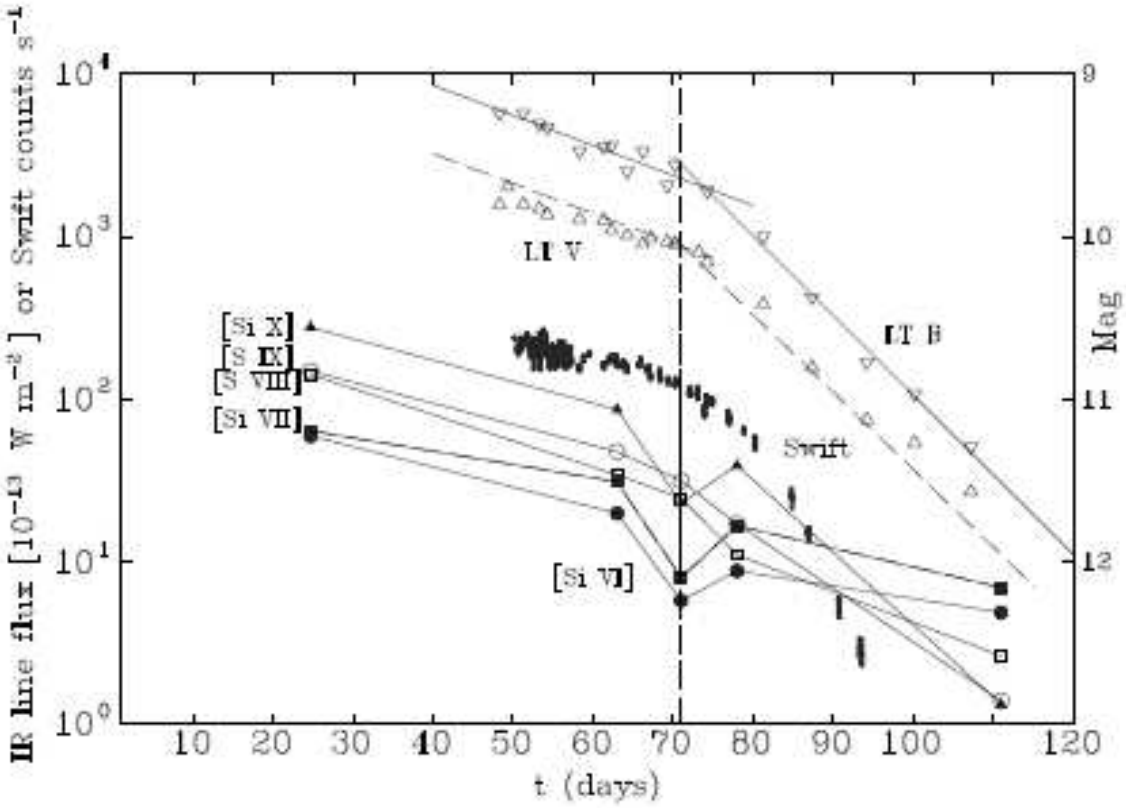


Ness et al subm 07

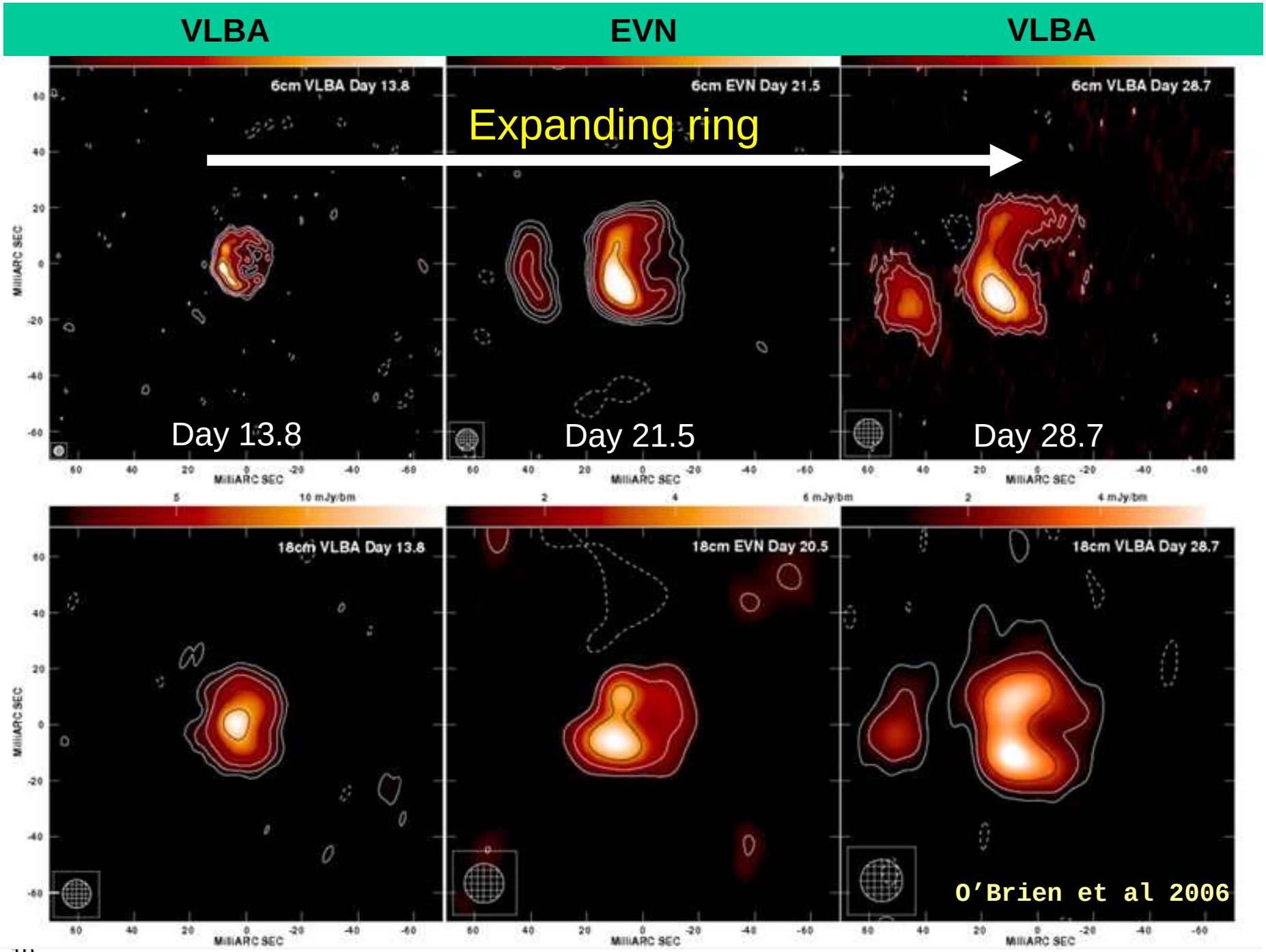
RS Oph IR spectra

Spitzer emission lines
→ T ~ 1.5 & 9 x10^5 K
(consistent with XRT)

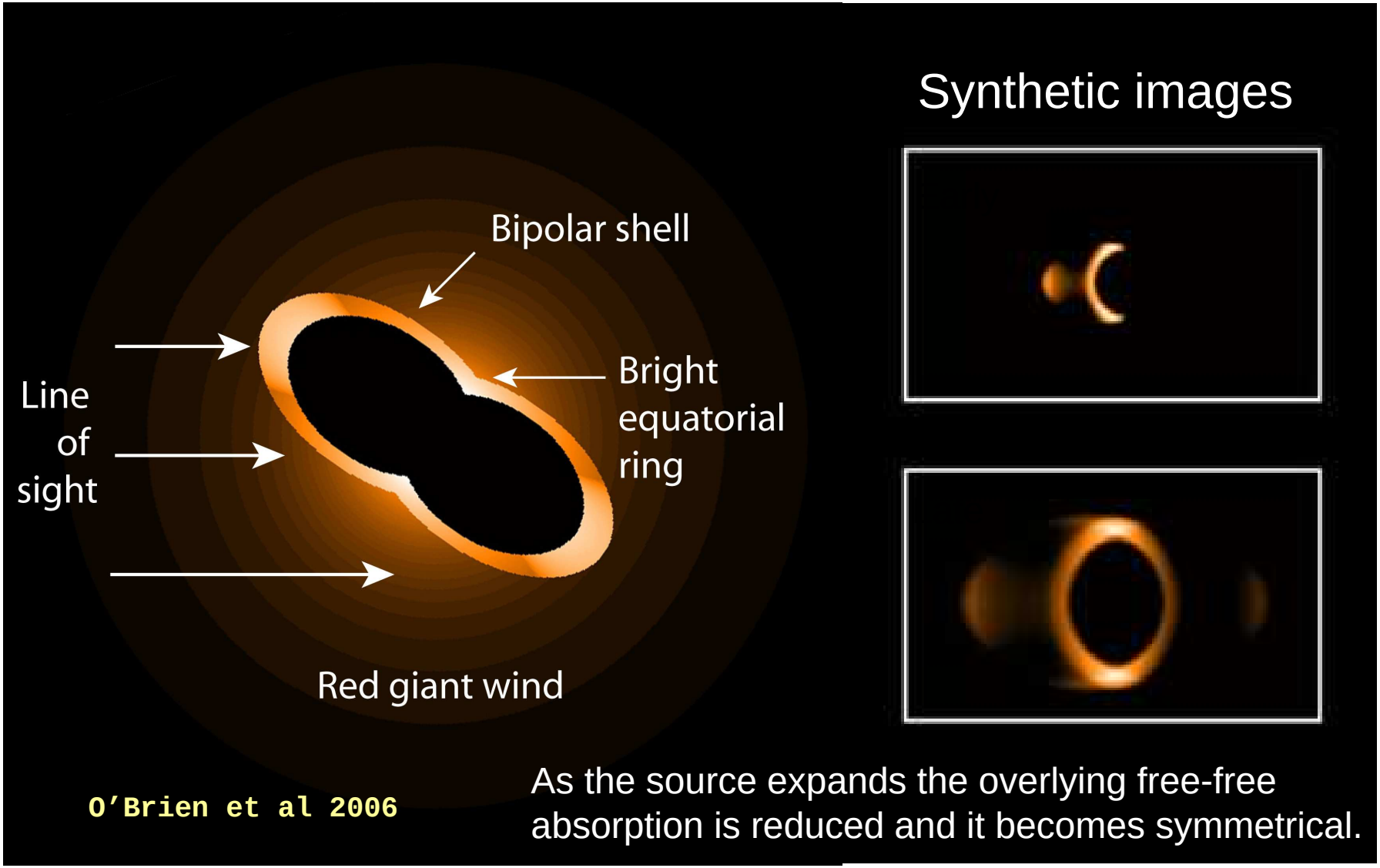
Line flux drop at 70 days coincides with optical ‘knee’, around time of shock breakout from red giant wind - no simple explanation



Evans et al subm 07

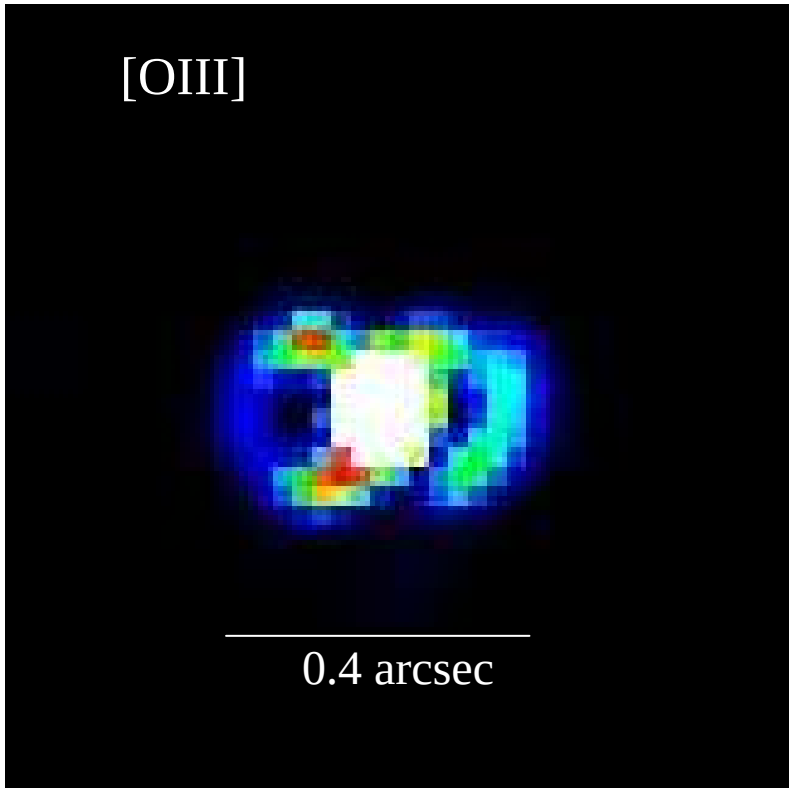

VLBA
EVN
VLBA
6cm VLBA Day 13.8
6cm EVN Day 21.5
6cm VLBA Day 28.7
Expanding ring
Day 13.8
Day 21.5
Day 28.7
MilliARC SEC
10 mJy/bm
6 mJy/bm
4 mJy/bm
18cm VLBA Day 13.8
18cm EVN Day 20.5
18cm VLBA Day 28.7
O'Brien et al 2006

RS Oph radio model



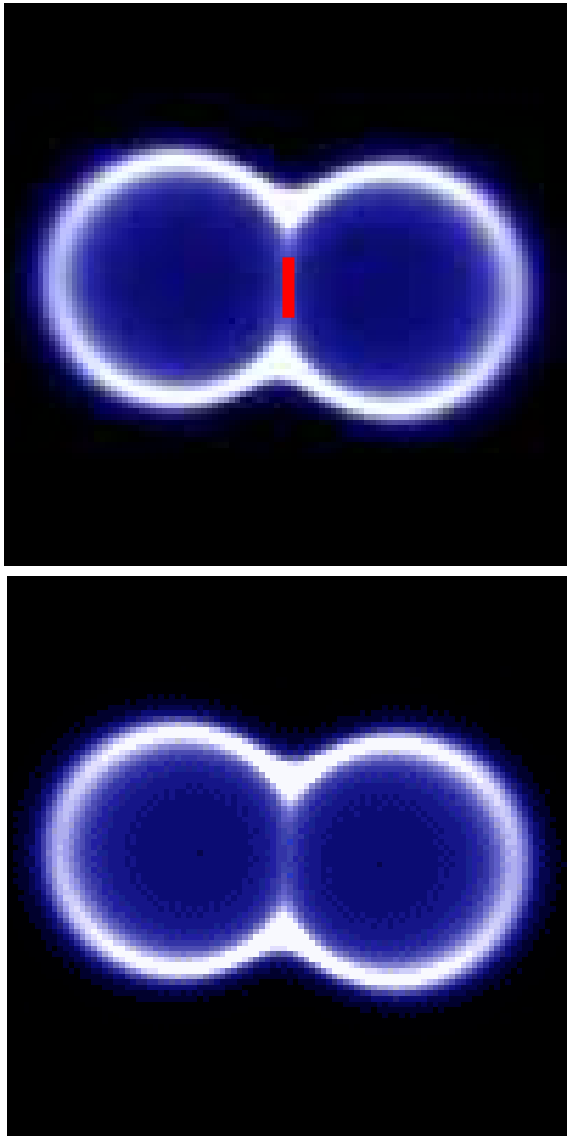
RS Oph HST image

- HST ACS/HRC DDT, *t* = 155d
- 2 orbits, [OIII]5007, Ha, [NeV]3426
- Extended structure detected in [OIII] and [NeV] (+possibly Ha)
- Elongated structure ~380 mas, E-W, comparable with constant velocity of expansion of outer radio lobes
- *v* ~ 3400 km/s (in plane of sky)



Bode et al subm 07

Model of Remnant Structure



- O'Brien et al. suggested VLBI evolution modelled by bipolar structure
- Here, "peanut" with axial ratio 3:1 consistent with v = constant (major axis), deceleration (minor) *cf.* radio
- $i = 35^{o}$ → binary orbital plane in "waist"; v_{ej} = 5900 ± 1200 km/s
- Consistent (first order) model of geometry

(Bode et al. 2007, ApJ, submitted)


"RS Ophiuchi (2006) and the Recurrent Nova Phenomenon II"
Conference
12 – 14 June 2007
University of Keele, UK
http://www.astro.keele.ac.uk/rsoph/

Nova observational strategy

Galactic nova strategy –

- Vmax < ~8 to ensure possible X-ray detection and other follow-up
- Short observation as soon as possible
- Monitor if detected, otherwise observe again at 3 mags below max
- For low extinction novae monitor for SS phase onset (weekly for fast novae, monthly for slow novae)
- For SS novae measure duration of SS phase for WD mass

Magellanic Cloud novae have lower metalicity and extinction, meriting less stringent Vmax selection

Swift CVs & Novae Future

Swift is a near-ideal rapid-reaction, multi-wavelength facility

Swift is making a very significant impact in this area

- Nova properties
- Accreting systems under varying accretion rate

Large Swift programs can bring in the contribution of other facilities

Such programs need exploratory TOOs to motivate them

Desiderata:

- Grism calibration
- Annular photometry for bright UVOT sources
- Continuation of current TOO regime