The XMM-Newton window on nova LMC 2009 and other novae in the Magellanic Clouds

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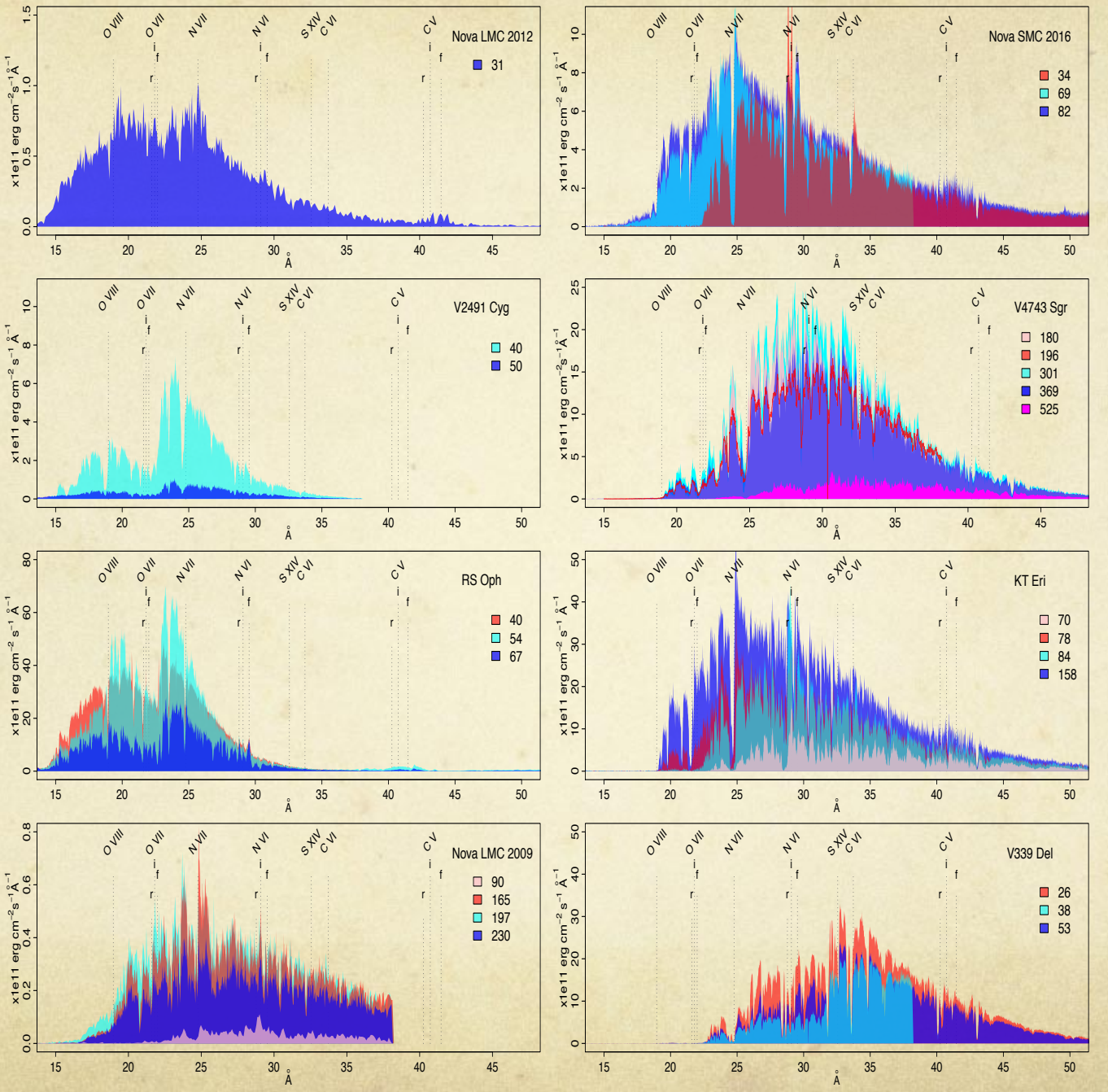
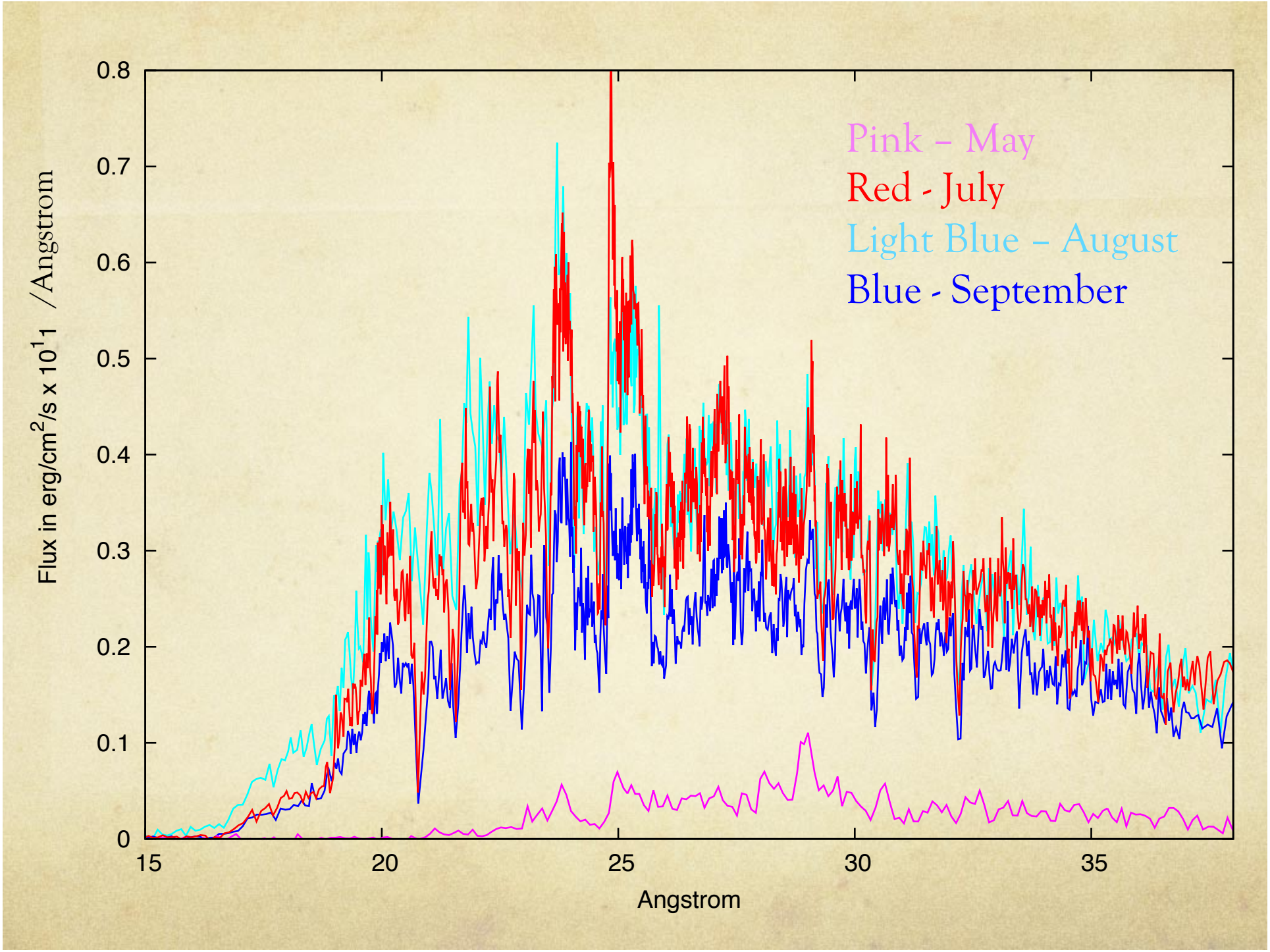
Reasons to obtain high resolution X-ray spectra of novae in outburst

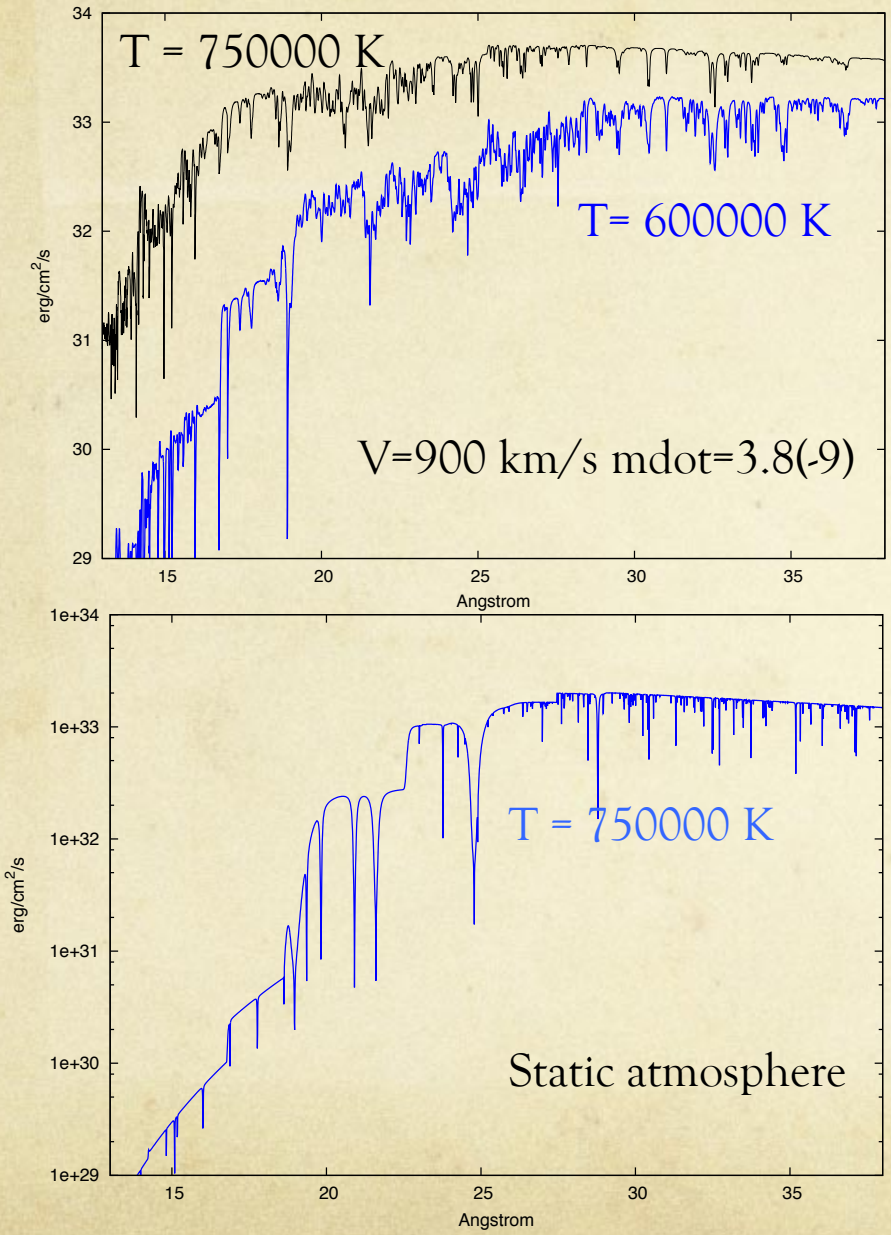
- They are very X-ray luminous, “perfect” targets
- The supersoft X-rays are the only window to observe nuclear burning (usually H-burning) with only a very thin atmosphere on top.
- All novae are amazing laboratories of basic astrophysical phenomena: also the ejected shell emits X-rays (usually shocked material)
- The X-ray range allows us to probe the WD mass, its chemical composition, and the nova chemical yields in the ISM


Nova LMC 2012
31
Nova SMC 2016
34
69
82
V2491 Cyg
40
50
V4743 Sgr
180
196
301
369
525
RS Oph
40
54
67
KT Eri
70
78
84
158
Nova LMC 2009
90
165
197
230
V339 Del
26
38
53
O VIII
O VII
N VII
N VI
S XIV
C VI
C V
x1e11 erg cm⁻² s⁻¹ Å⁻¹
Å

RGS gratings observations of N LMC 2009a

- A recurrent nova (outburst repeated on human lifetime) with a previous recorded eruption in 1971, observed again on 2/5/2009
- Periodic modulations with 1.2 days' period – probably orbital period, probably evolved (but not red giant) secondary
- Multi-λ observations summarized by Bode et al. (2009)
- Optical lines: ejection velocity up to 4000 km/s (varying with time and for each line)
- XMM-RGS observations on 2009 May, July, August, September

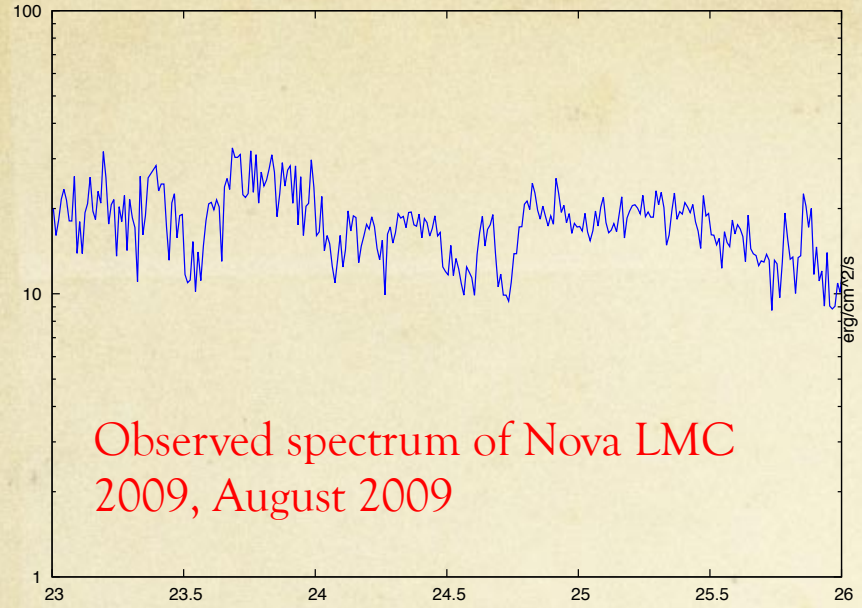

Pink – May
Red - July
Light Blue – August
Blue - September
Flux in erg/cm^2/s x 10^{11} /Angstrom
Angstrom
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15
20
25
30
35

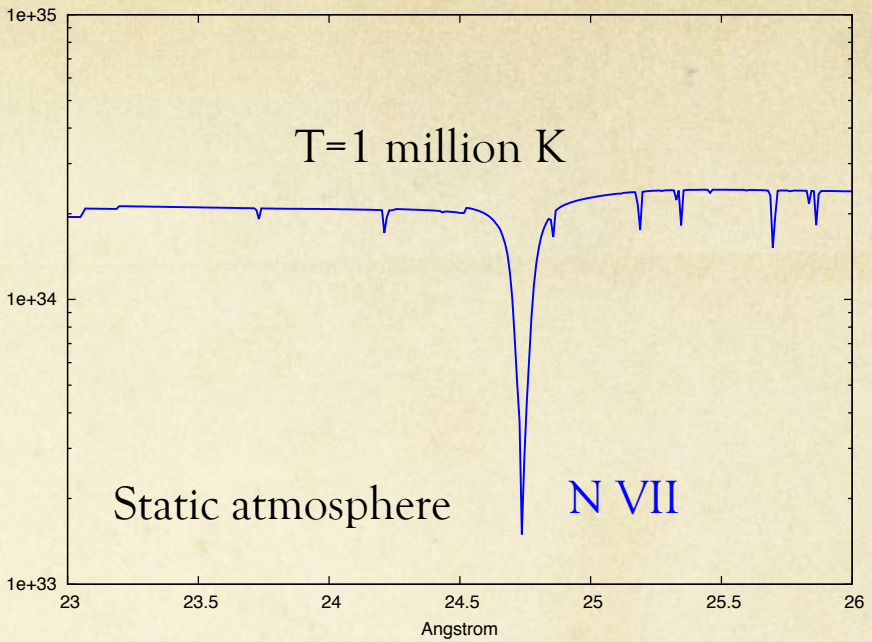


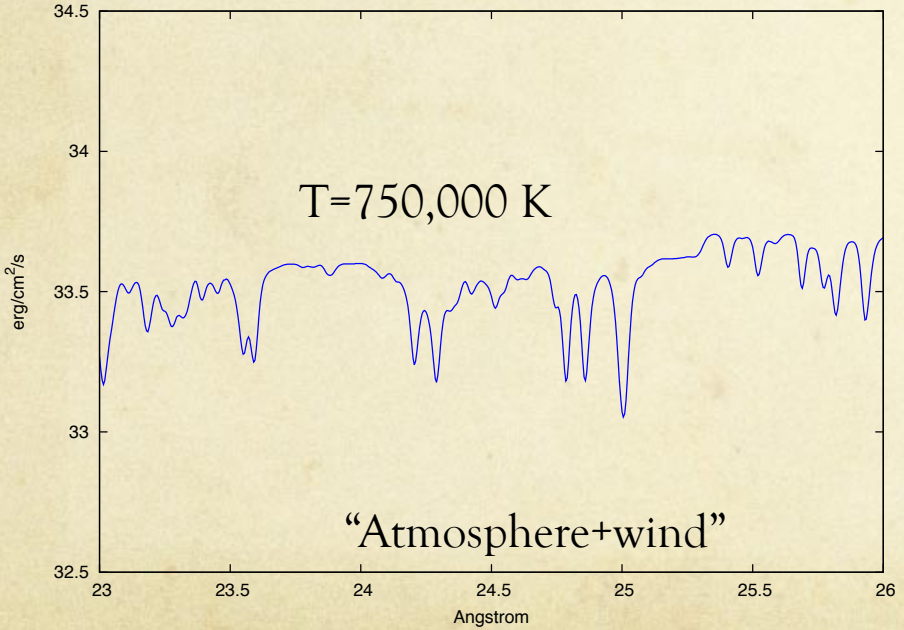
The SSS was almost always observed after the "nominal" end of mass loss: models and some observational facts suggested that the WD radius shrinks while no more outflows occur.

But… we observe blue-shifted absorption features in most novae!

Top plot: atmosphere-wind model by van Rossum (2012) compared with (bottom) static atmosphere by Rauch (2010)





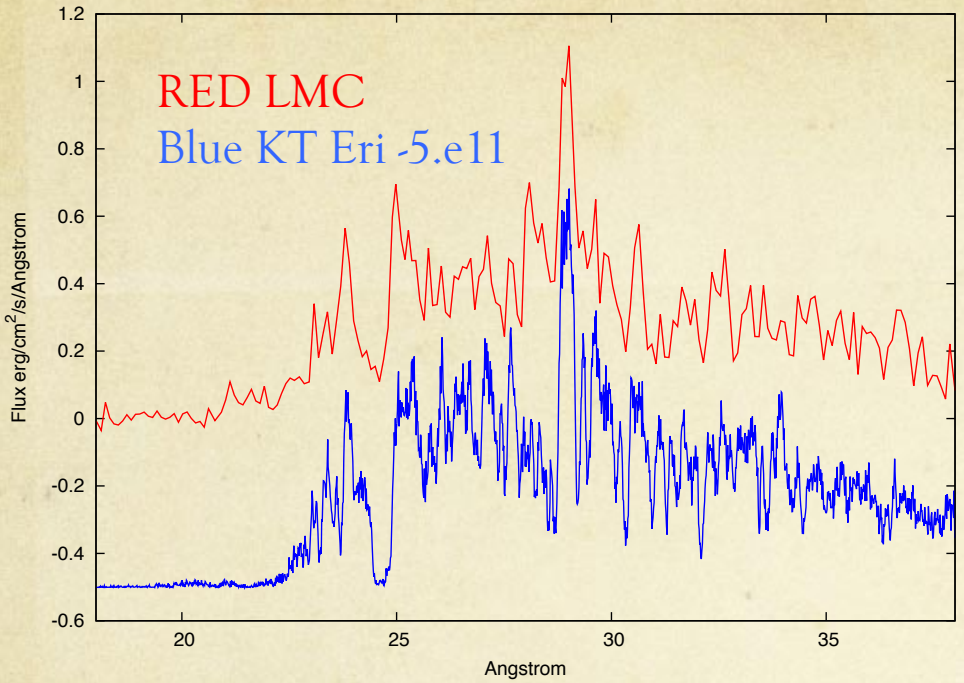


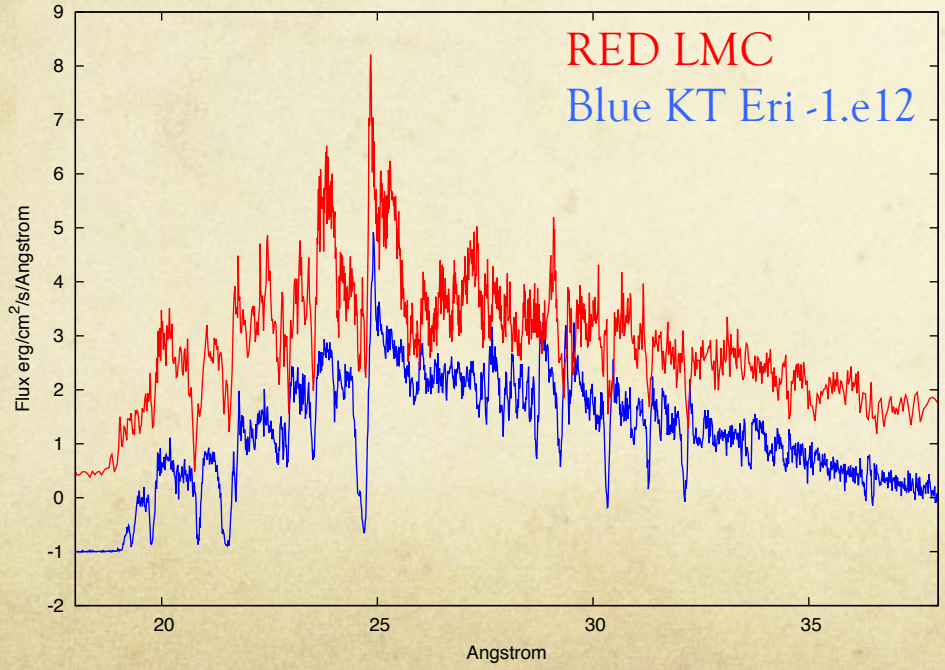
Comparing specific spectral ranges can be extremely useful. We see here that the addition of the wind fits this zone of N lines better, but… we still do not have a perfect fit
(grid for wind model still inadequate)

Interesting possibility that the unidentified lines are o intermediate atomic weight elements, especially S, Ca => ONe WD?

The spectral evolution

- 600,000 K < T_{eff} < 750,000 K in May 2009
- Peak temperature 750,000 K < T_{eff} < 980,000 K
- Residual mass loss rate most likely not exceeding few 10^{-9} $M_{\odot}$/year (compare with ~ 10^{-5} $M_{\odot}$/year in first months)
- The light curve is always variable, with irregular oscillations of amplitude ranging from almost 5 in first observations decreasing to ~ 1.5 in the last exposure
- For the whole duration of first observation the WD was not entirely observed, but was partially obscured = as it occurred also in other novae – perhaps due to clumpy ejecta and/or irregular mass outflow in time?
- 33 s period (Ness et al. 2015) like in RS Oph => g-mode nonradial oscillation due to ε mechanism during nuclear burning?





Comparison of the fluxed spectrum of N LMC 2009 on day 90 vs. kT Eri at day 84 assuming KT Eri at d=5 kpc (top) and at days 165/158 assuming KT Eri at d=2.5 kpc

The overall spectrum of N LMC 2009 at early epochs is almost a factor of 10 less luminous than a WD atmosphere in the 600,000-750,000 K range => we always saw only a portion of the WD

KT Eri, a Galactic nova with very similar evolution and strikingly similar X-ray spectrim, was twice much more luminous at early epoch

Serendipitous observations of novae

- We want to verify whether nuclear burning may last longer at low metallicity
- The SMC is rich of SSS in the low T(eff) range, observed for 20-30 years – is this an effect of low N(H) (easy detection) or are they really due to the abundances? And… are these X-ray sources post-outburst (but missed in outburst) novae?
- Initial statistics: 13 novae in the MC (6 LMC+7 SMC) observed in pointings of other sources.
- 4 novae were detected as luminous SSS with time(burning)>1.8, >4 and <11, >6, >9 years
- 7 novae had turned off after more than 3-11 years post-outburst, similarly to most Galactic novae