Novae as X-ray sources and "SSS" in the Galaxy, MC and M31

First statistics and comparisons

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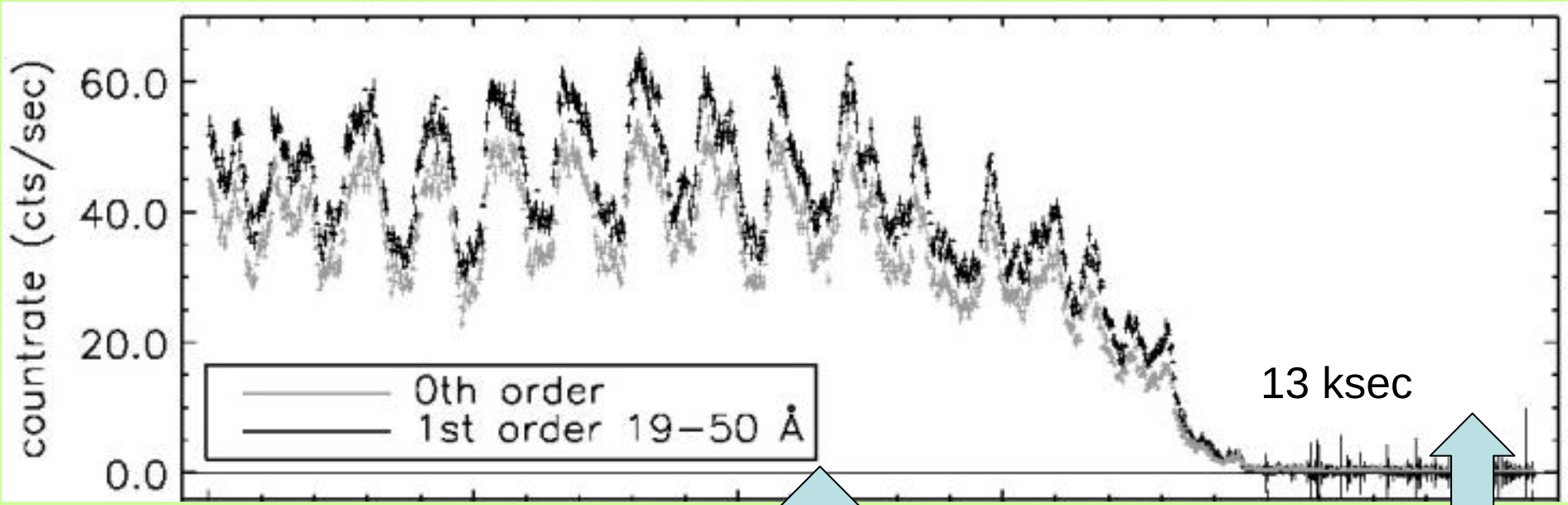
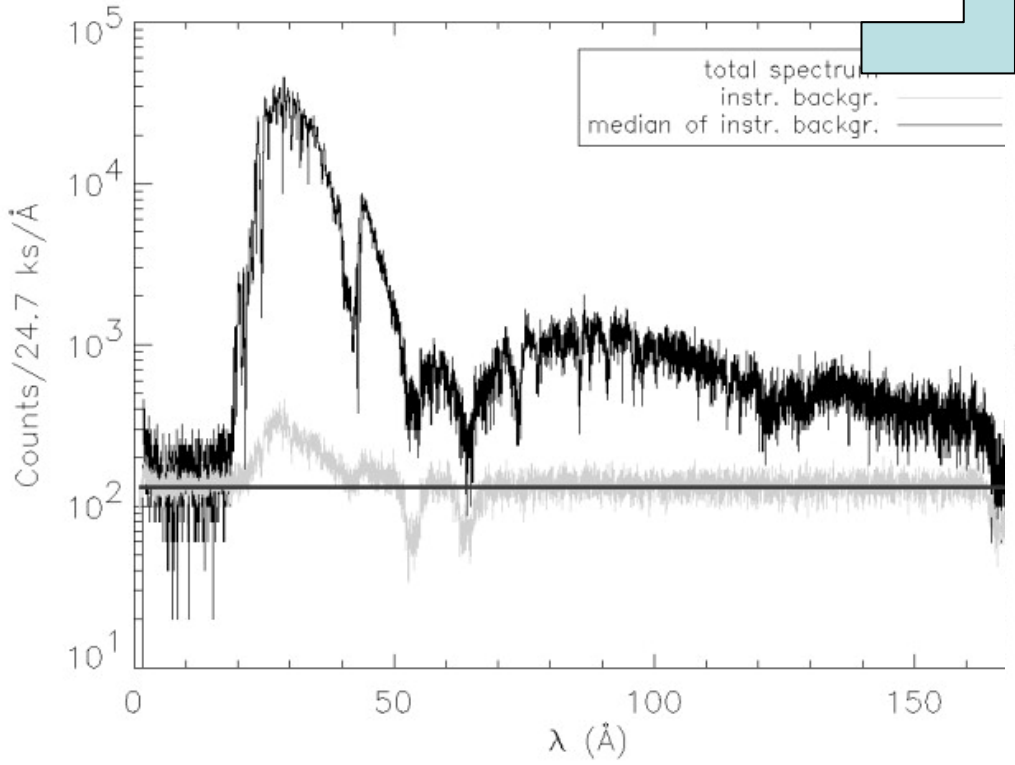
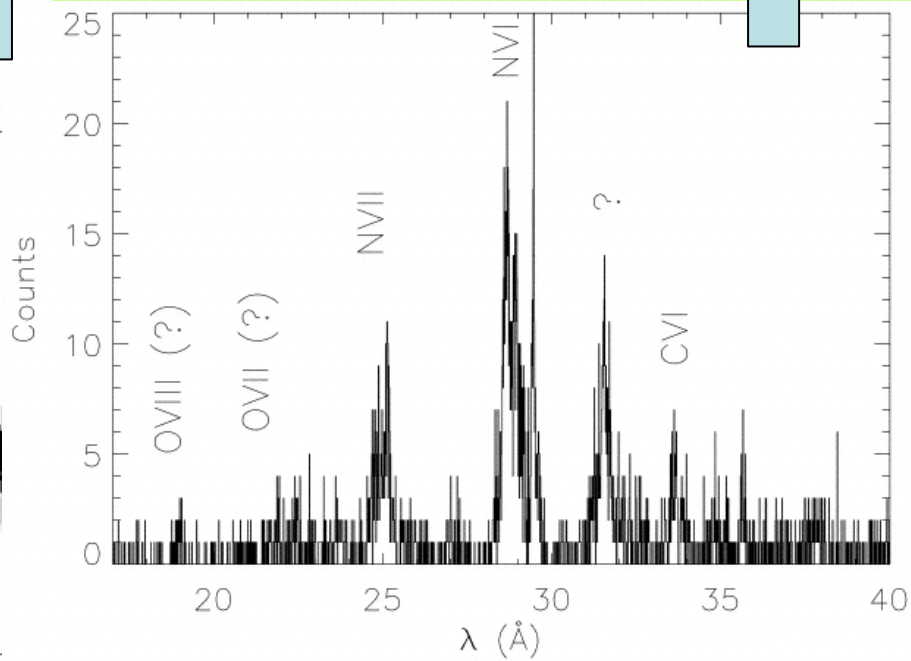
Novae as X-ray sources

- **Importance of detecting the WD as EUV-SSS to test the theory.**
- **Only easy-to-find template of H-burning in a shell. Revealed by the outburst!**
- **X-ray emission almost always detected from the ejecta, rarely reaching L(X)~10(36) erg/s, only ~10(34) erg/s at maximum if no red giant present. The X-rays start mostly after 1-2 weeks, often last for more than a year.**
- **A very soft emission lines spectrum, at late stages, also associated with wind or ejecta.**
- **Even if shell emission provides estimate of intrinsic N(H), its spectrum is super-imposed on the WD, and complicated to disentangle.**
- **The SSS is VARIABLE at first!!! Periodic time scales of 10 seconds and 10 minutes, but also irregular obscurations of hour time scales… clumps???**

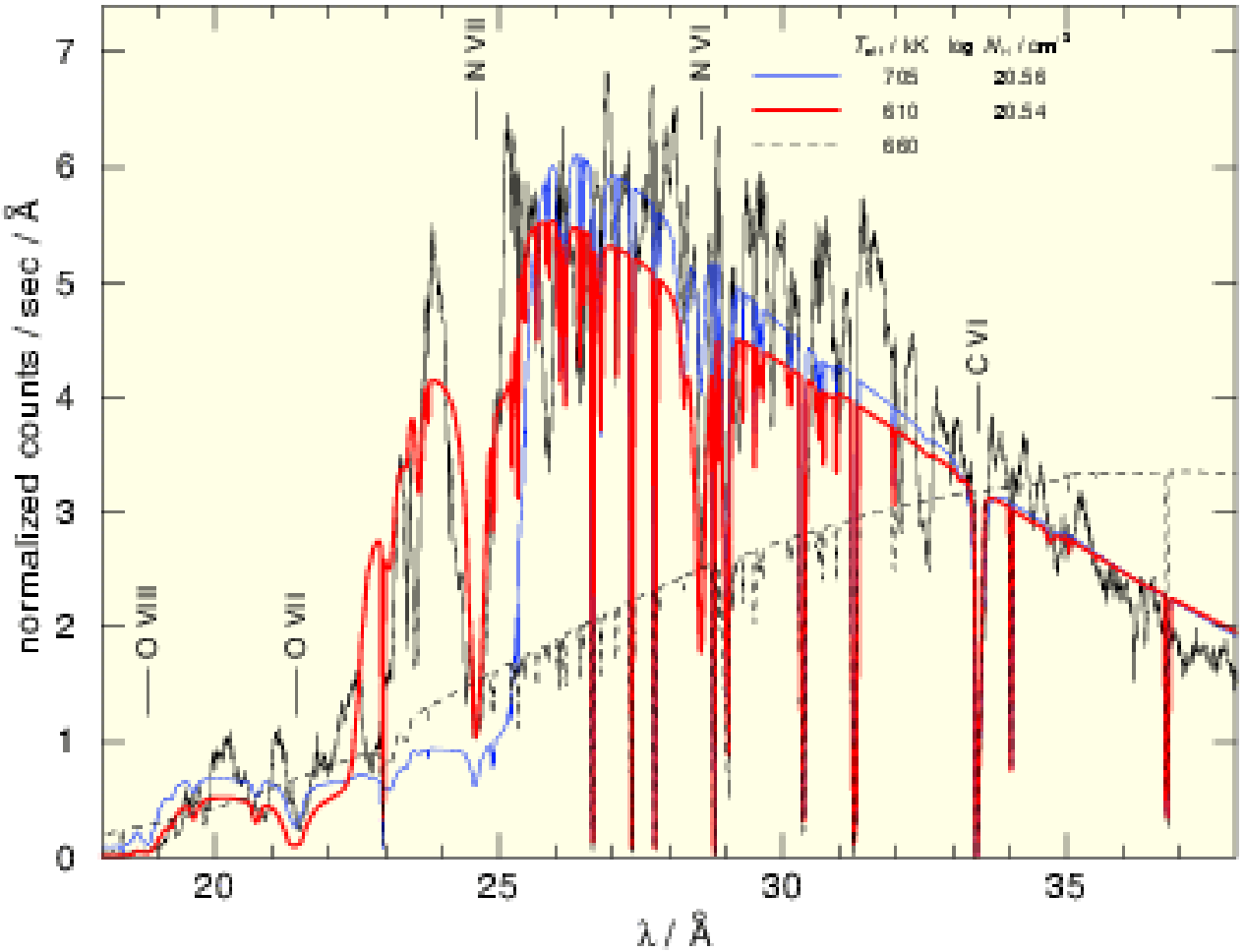

countrate (cts/sec)
60.0
40.0
20.0
0.0
0th order
1st order 19–50 Å
13 ksec


total spectrum
instr. backgr.
median of instr. backgr.
Counts/24.7 ks/Å
λ (Å)


Counts
OVIII (?)
OVII (?)
NVII
NVI
?
CVI
λ (Å)

What do we want to learn?

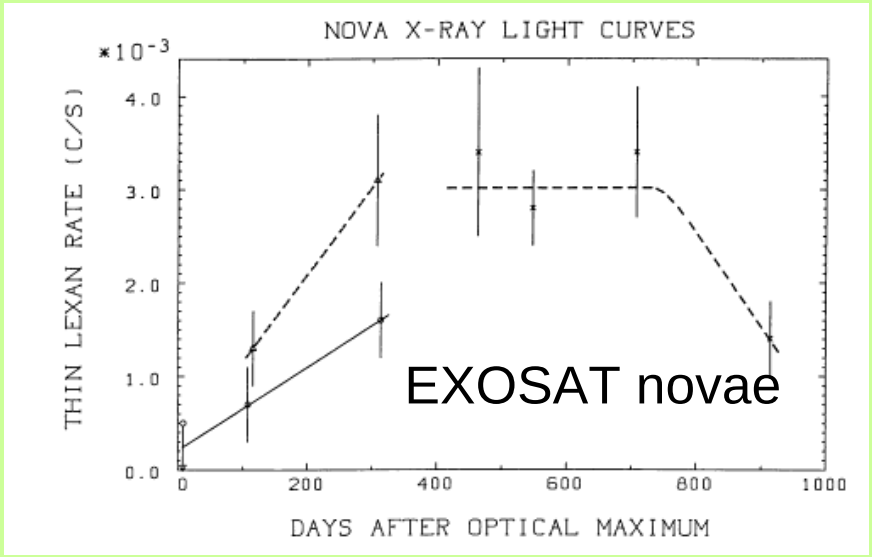
- Are we still interested in novae as potential type Ia SN progenitors, or do we rule out everything except a few RN (see RS Oph)?
- Or do we want to use only novae as “templates”? Then statitsics are not fundamentally important.
- Two groups claim all envelope is ejected and WD eroded.
- 10(-6) M(sol) of envelope have to be left at time H-burning ceases.
- Short P novae seeem to be more frequent SSS=> is it because of high mdot in general or because of renewed mdot due to irradiation?
- However, the H-burning material is delpeted in C and has high C/N ratio in V4743 Sgr…

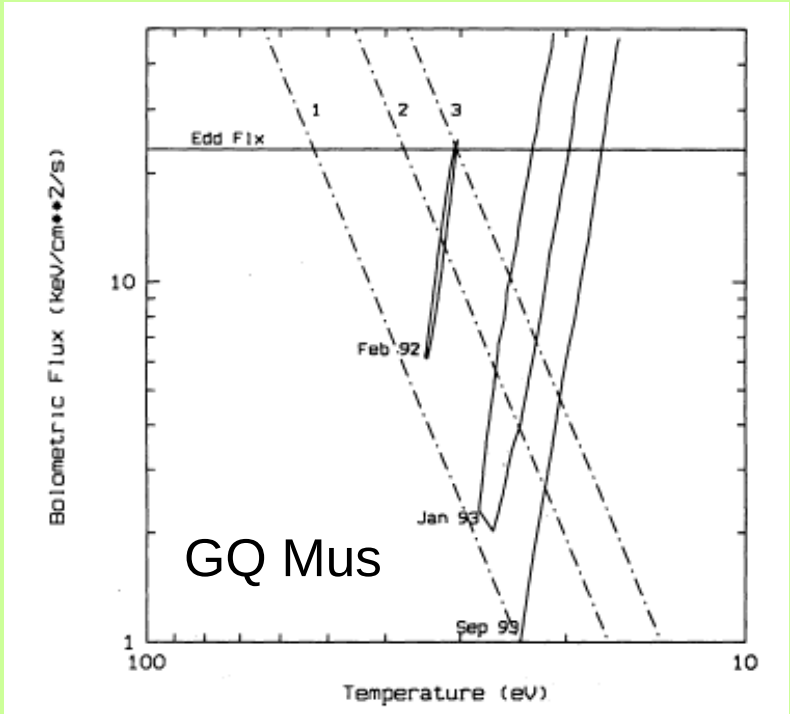

normalized counts / sec / Å
λ / Å
O VIII
O VII
N VII
N VI
C VI
T_{eff} / kK
log N_H / cm^{-2}
705
20.56
610
20.54
660

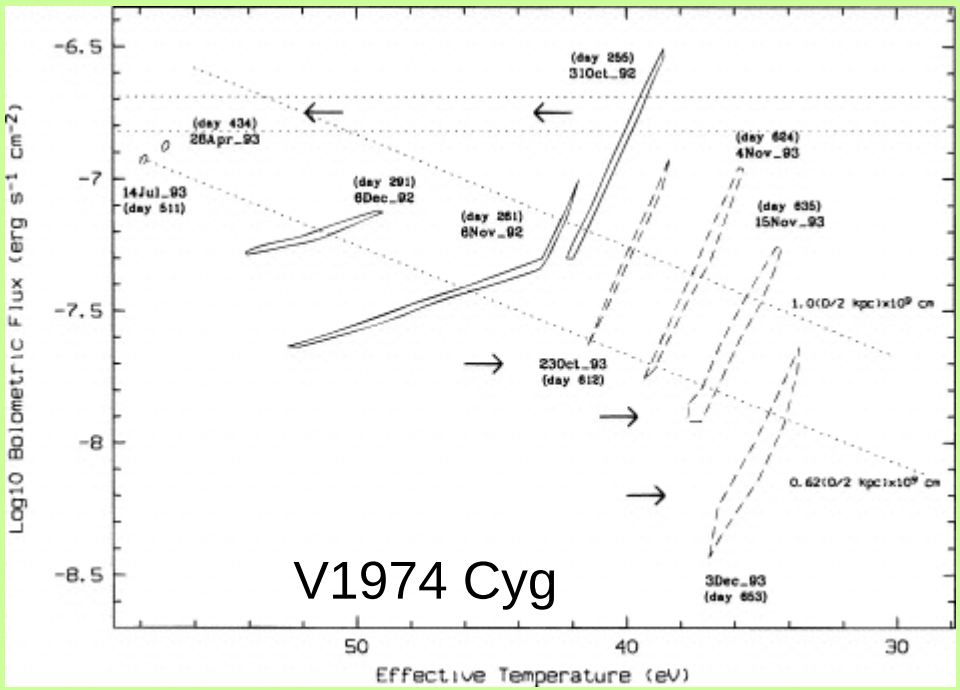
Galactic surveys:

- **EXOSAT: 4 pointings, 4 detections! (All within two years). Only one certain SSS, that lasted for 10 years. RS Oph observed at the end of 2nd month, apparently hard.**

- **ROSAT: 5 novae within 1 year, one hard source only bright initially, one bright SSS after 6 months, for ~1 year (but also shell emission before and after). 11 other novae @2-6 years=> only 2 detections (accreting sources). 3 @6-10 years => only already known GQ Mus is still SSS.**


NOVA X-RAY LIGHT CURVES
*10-3
THIN LEXAN RATE (C/S)
4.0
3.0
2.0
1.0
0.0
0
200
400
600
800
1000
DAYS AFTER OPTICAL MAXIMUM
EXOSAT novae


Bolometric Flux (keV/cm**2/s)
Edd Flx
1
2
3
10
1
Feb 92
Jan 93
Sep 93
GQ Mus
100
10
Temperature (eV)

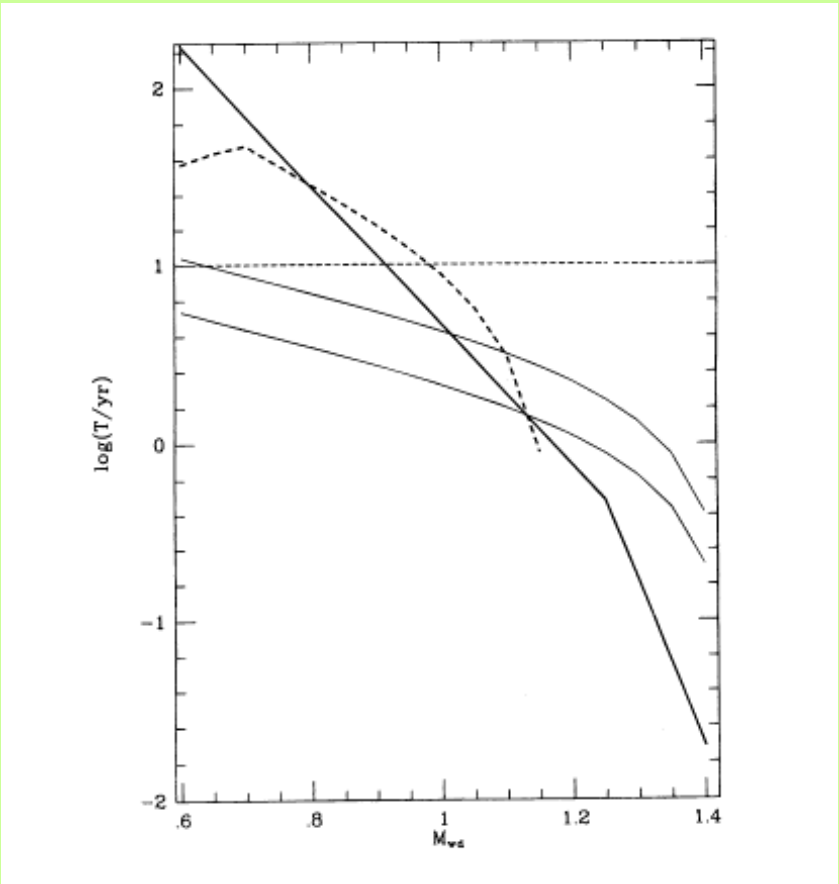

Log10 Bolometric Flux (erg s-1 cm-2)
-6.5
-7
-7.5
-8
-8.5
(day 256)
31Oct_92
(day 434)
28Apr_93
(day 624)
4Nov_93
(day 291)
8Dec_92
14Jul_93
(day 511)
(day 261)
8Nov_92
(day 635)
15Nov_93
1.0(D/2 kpc)x10^9 cm
23Oct_93
(day 612)
0.62(D/2 kpc)x10^9 cm
3Dec_93
(day 653)
V1974 Cyg
50
40
30
Effective Temperature (eV)

Galactic surveys (continued)

- **Beppo-SAX: 3 pointings in 1st year, one SSS, one ejecta-source, 1 RN (U Sco) with possibly prompt and short SSS component.**
- **Swift: 8 novae within 1 year, 4 (or 5?) detections, only one clearly SSS. 3 novae @3-10 years, one likely SSS.**
- **Chandra: 6 within 2 years including 3 RN, only one non detection, 3 SSS. Follow-up of BeppoSAX SSS revealing supersoft emission spectrum (wind, ejecta) and 2 other WD-SSS, clearly lasting<2 years.**
- **XMM-Newton: Only follow-up of Galactic novae, but beautiful grating spectra for 2 sources. Survey of 5 novae @3-5 years (more to come) => no SSS, 1 accreting source, 1 possibly shell-emitting. Turn off in 1-2 years observed for two other SSS.**

The Galactic statistics:

- 36 Galactic novae followed (in 23 years…) within 2, mostly 1 year. 7 “certain SSS”, 2 more likely, 2 dubious.
- Only 5 really bright well-studied SSS.
- Many more hardish sources due to ejecta.
- Decline within 2 years in 7/9 cases, only 2 ~>10 years sources.
- 20 classical novae observed 3-10 years post-outburst. 18 were “absolutely off”.



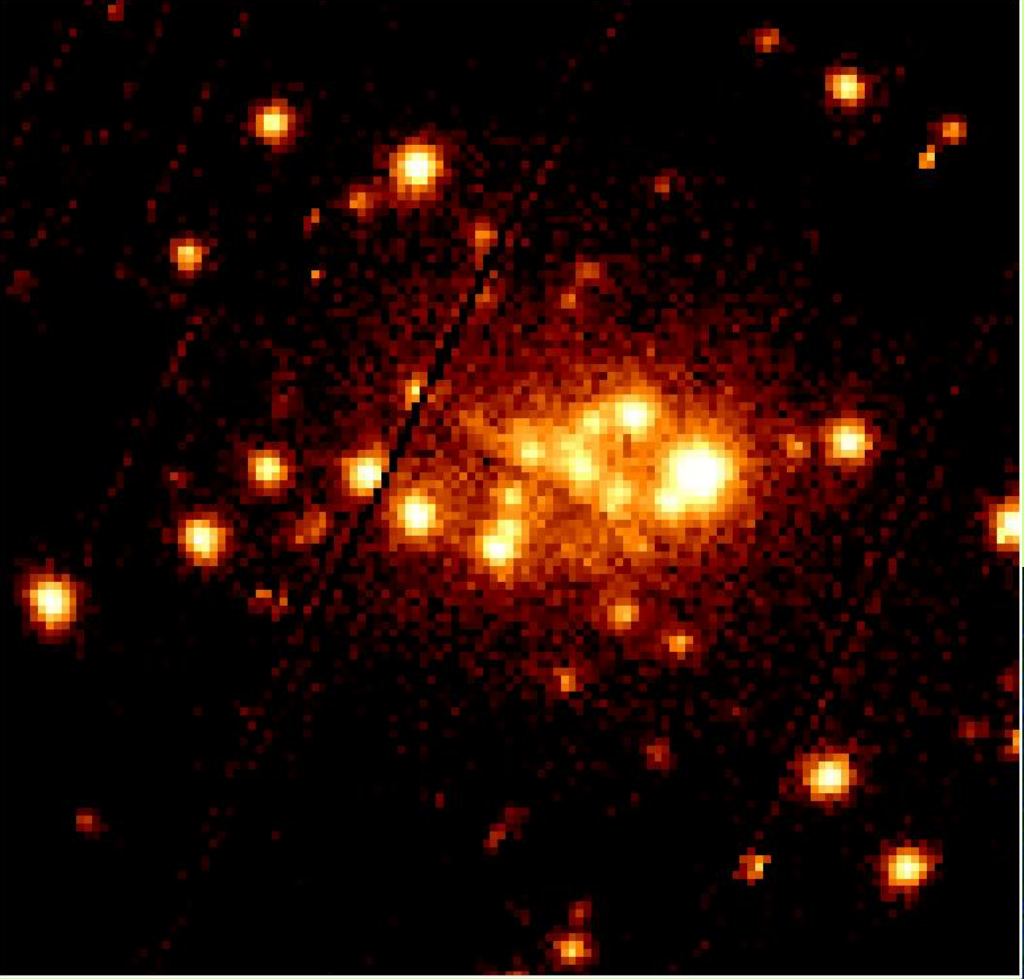
The forecast in this plot, of many WD emerging as SSS after more than a year and lasting for >10 years, seems ruled out.

Peak temperatures of WD:

GQ Mus 350,000K
V1974 Cyg ~600,000 K
N LMC 1995 400-450,000
V4743 Sgr ~610,000 K
RS Oph~800,000 K

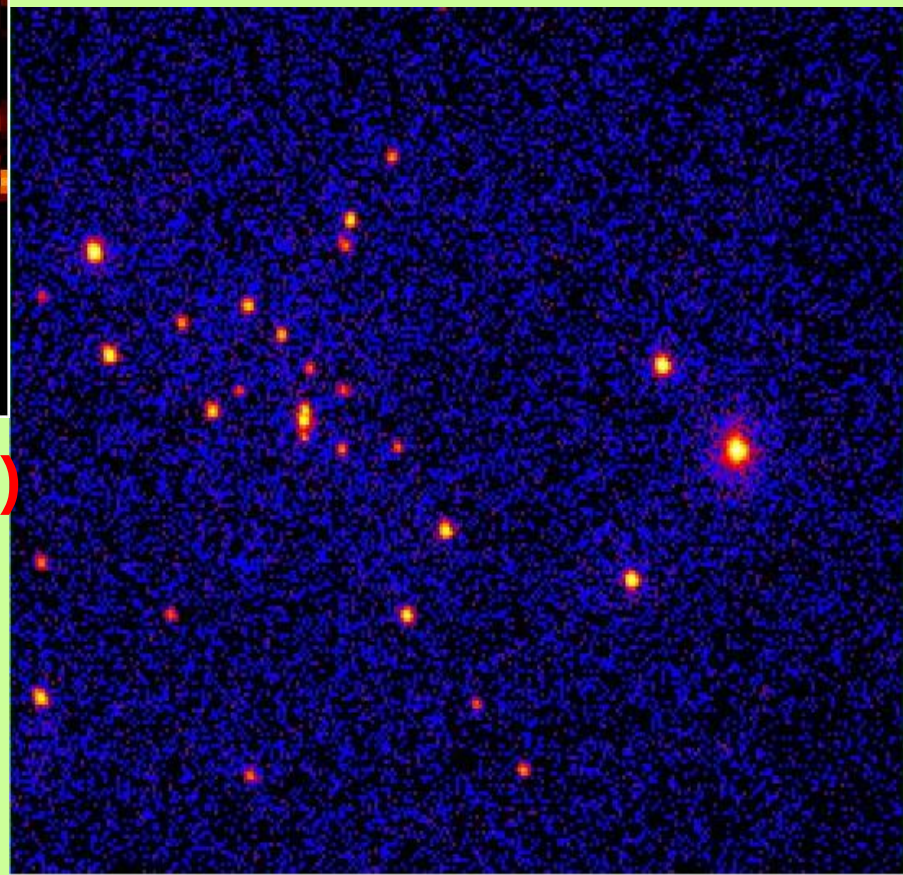
Novae as X-ray sources in the MC

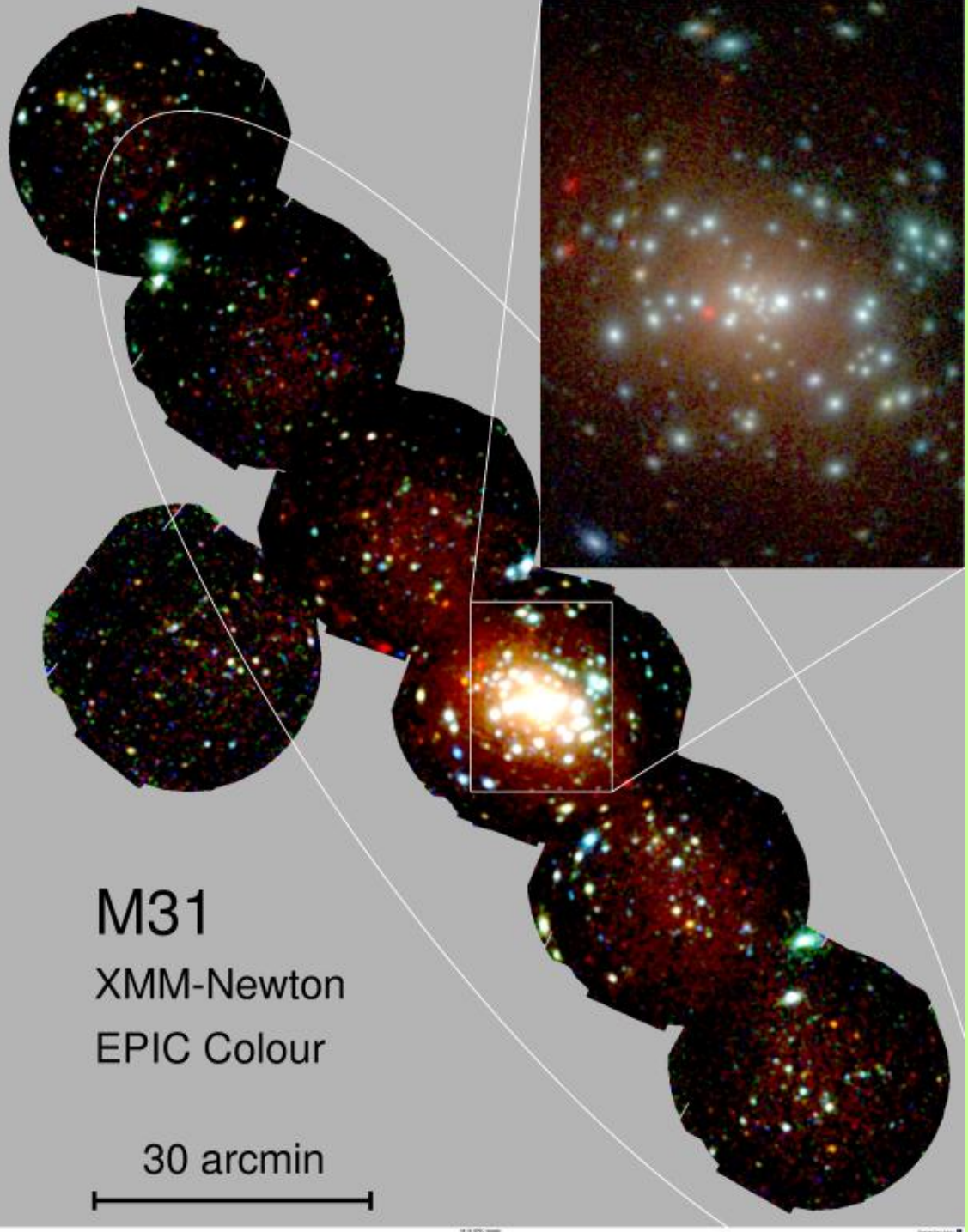
- 4 classical novae observed in DEEP exposures within first year: only 1 SSS. 1 nova shell also detected since 1st month.
- 2 more shallower exposures within one year, one detection.
- The only clear SSS lasted for ~7.5 years.
- 10 more novae observed at different dates 2-10 years post-outburst in deep ROSAT-XMM-Chandra exposures=> no detection!
- 10 other non-nova sources in MC, of which only for 2 a possible nova id is not completely ruled out yet.



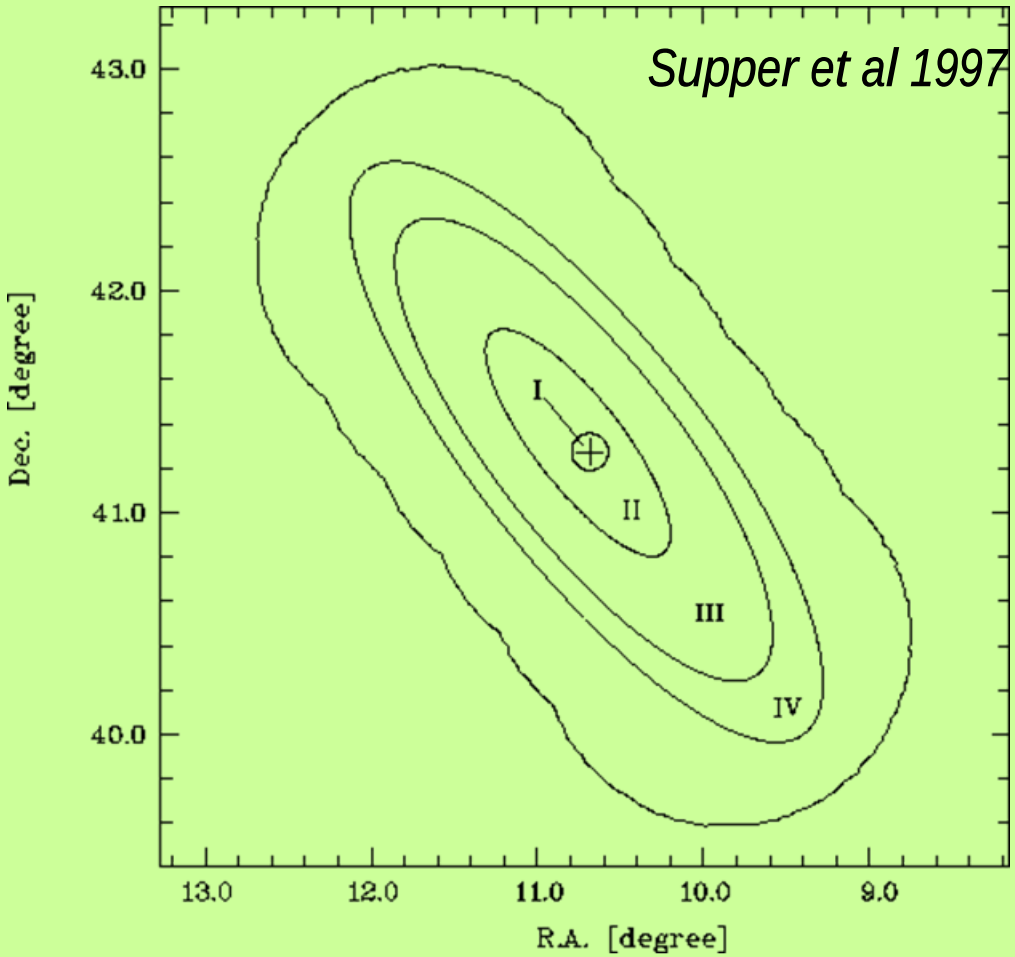
Exposure of the inner 8 arcmin(2) of the M31 thick disk observed with EPIC-pn (XMM-Newton)

Exposure of inner 2 arcmin(2) observed with ACIS-S . 17% of XRS (and stars) are here





There is no ideal X-ray instrument with sufficient spatial and Spectral resolution to study novae in M31, but a combination of EPIC and Chandra HRC has recently been chosen.
The lower limit on the X-ray luminosity is 10(34) -10**(35) erg/s in the existing Chandra and XMM-Newton images: selection effect against nova shell detection after maximum.**

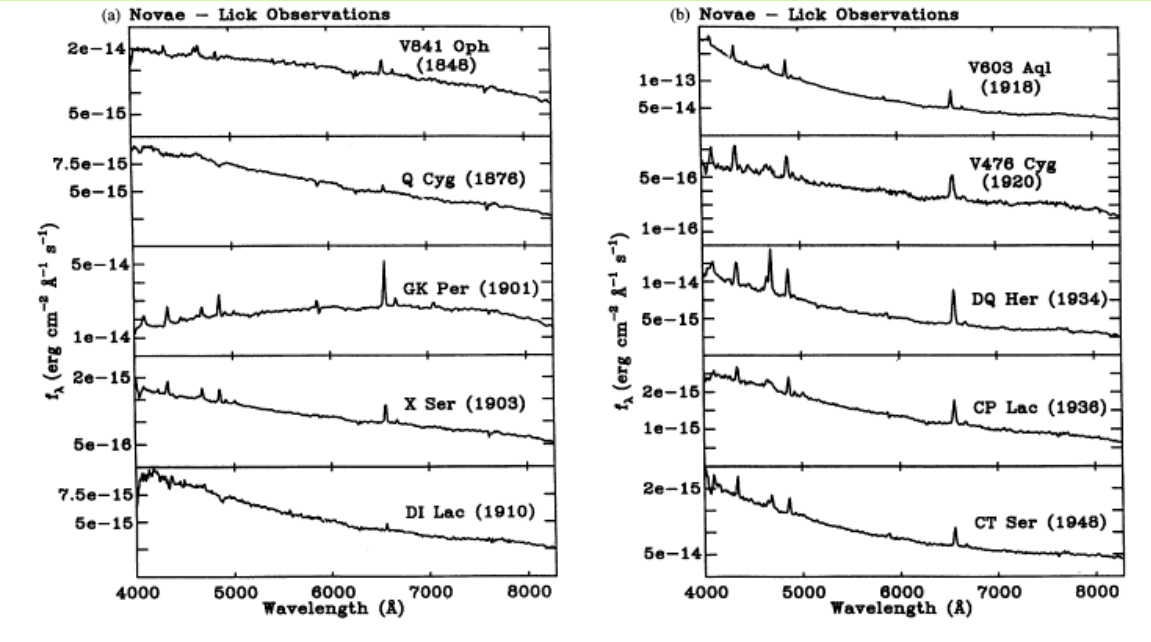


N(H) in cm(-2):
7x10(20)/cm(2)in the core,
1.1 x10(21) in reg. II,
1.7x10(21) in reg. II and IV,
7.7x10(21) in reg III
⇒No SSS found in reg III, even if very hot and massive WD would still be detected.
T(eff)<80 eV in general.

Selection effect against low T(eff) in a large part of the Galaxy.

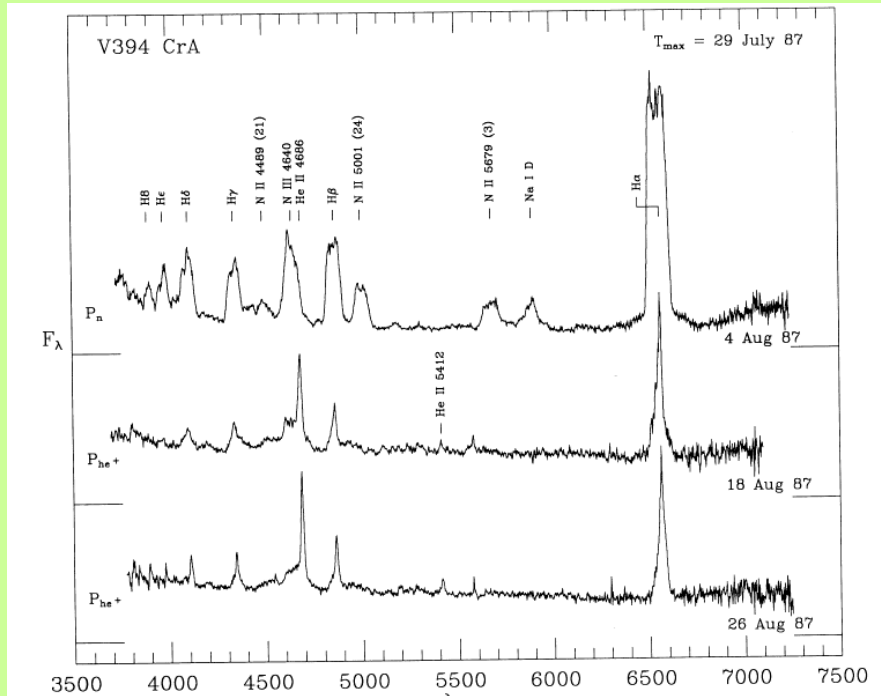
Summary of M31 nova monitoring:

- 40 novae observed within 1 year, 19 detected (but only 11/32 randomly chosen in same year).
- However, very little or no spectral information (ACIS-I used to select SSS) on 11 recent novae of 2005 Pietsch et al. paper.
- 19 (18) XMM-Chandra detections of novae several years post-outburst, including 3 uncertain detections, 3 harder sources.
- At least two of these last "novae" in exact Chandra positions of sources, one of them variable in flux and spectrum.
- Of the 18 "late" X-ray sources of Pietsch et al. , 3 are claimed to have emerged only 3-7 years after optical outburst: however one uncertain detection, two do not appear to be SSS.
- Despite lack of "universal" SSS definition, only 1/3 of M31 SSS seem to be novae.



H(alpha) in quiescence and in outburst in novae versus bht.
(20 vs. ~200 in Galaxy)

Novae at quiescence in M31 are at R>24, in outburst R=17-18 H(alpha) very prominent. No quiescent comparison possible.



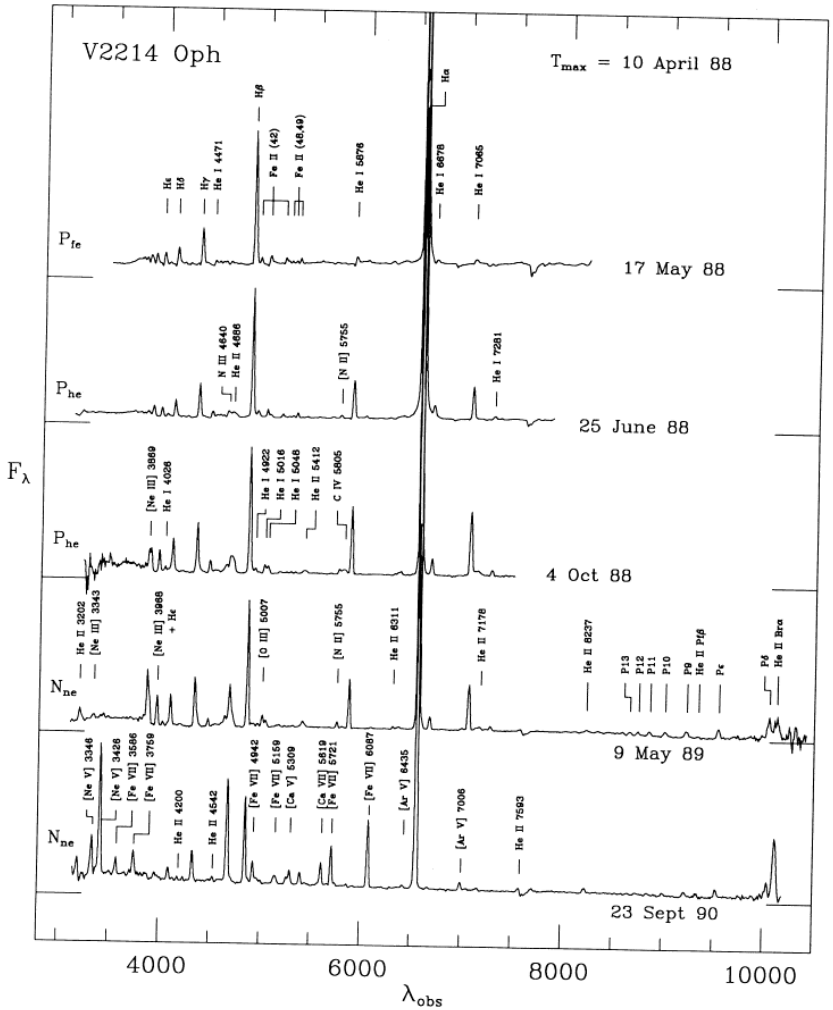
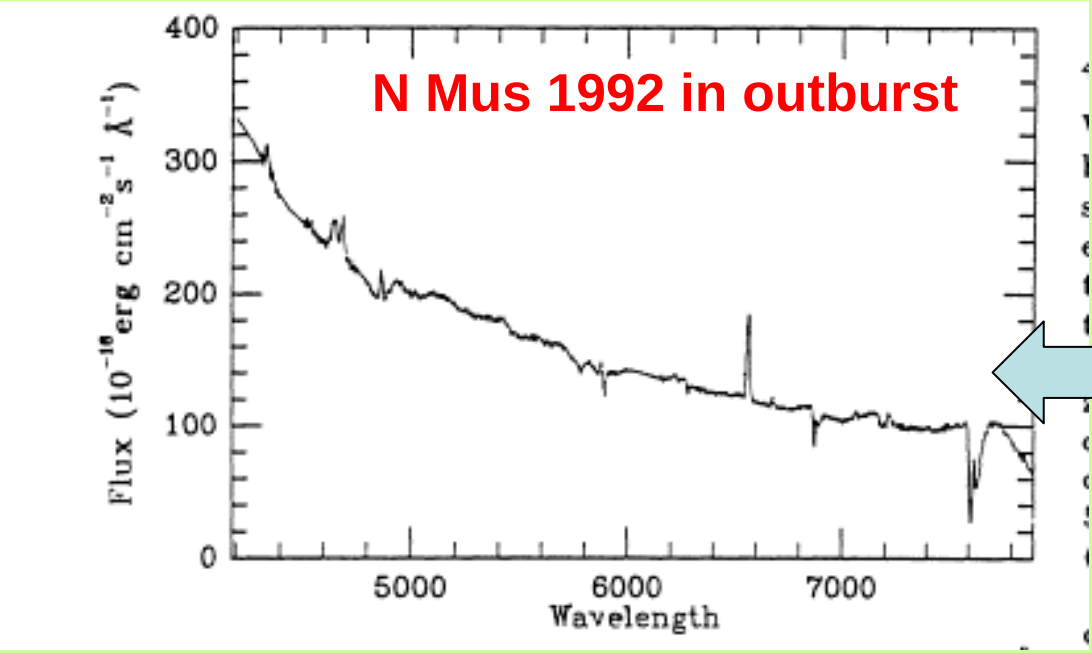
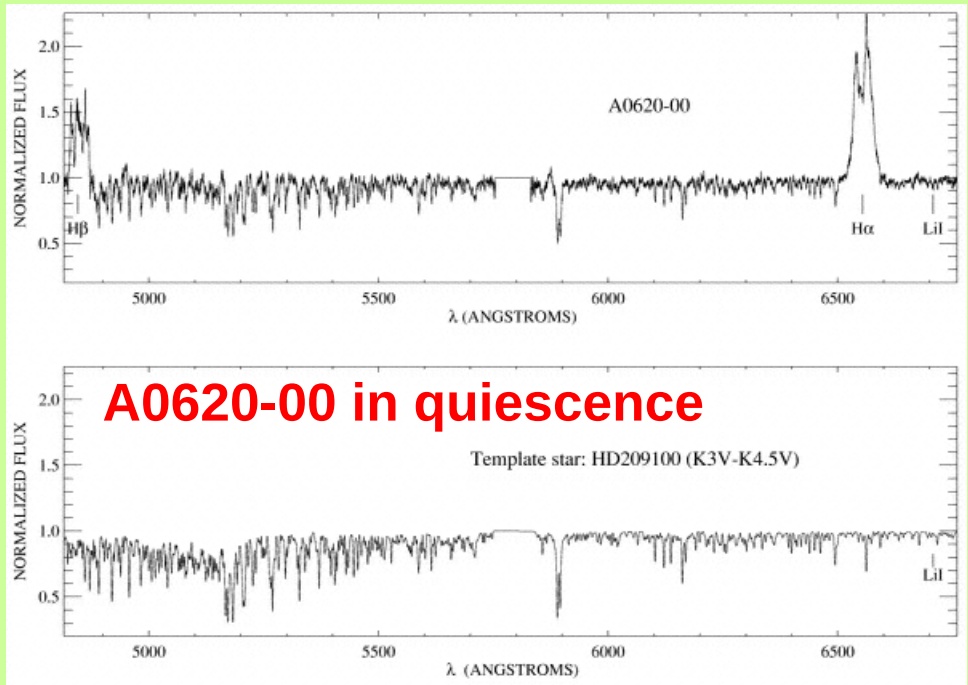


FIG. 2.—Spectral scans of the nova V2214 Oph (Nova Ophiuchi 1988) following its 1988 April outburst



The possibility of Picking up a bht in an H(alpha) survey, despite less prominent H(alpha) on continuum, is very real because of technical problems (10%?)



What can we learn from M31?

- We can place upper limits on T(WD) based on statistical arguments.
- X-ray luminosity given by Pietsch et al. is based on crude assumptions and may be wrong by more than an order of magnitude.
- Statistics may be distorted by inclusion of up to 10% bht, by uncertain detections, lack of spectral information, inclusion of ROSAT sources (wide spatial error boxes).
- Ejected mass cannot be estimated from present data sets.
- Despite doubts on correct definition of SSS (there is NO "correct" definition!) at present 65-70% of SSS CANNOT be associated with novae.
- Random pointings of novae 1 year after outburst reveal a SSS in a third of them. Of 11 novae in same year in M31:

  3 detected after 1m

  2 after 2 months

  2 after 3,

  5 after > 6 m.