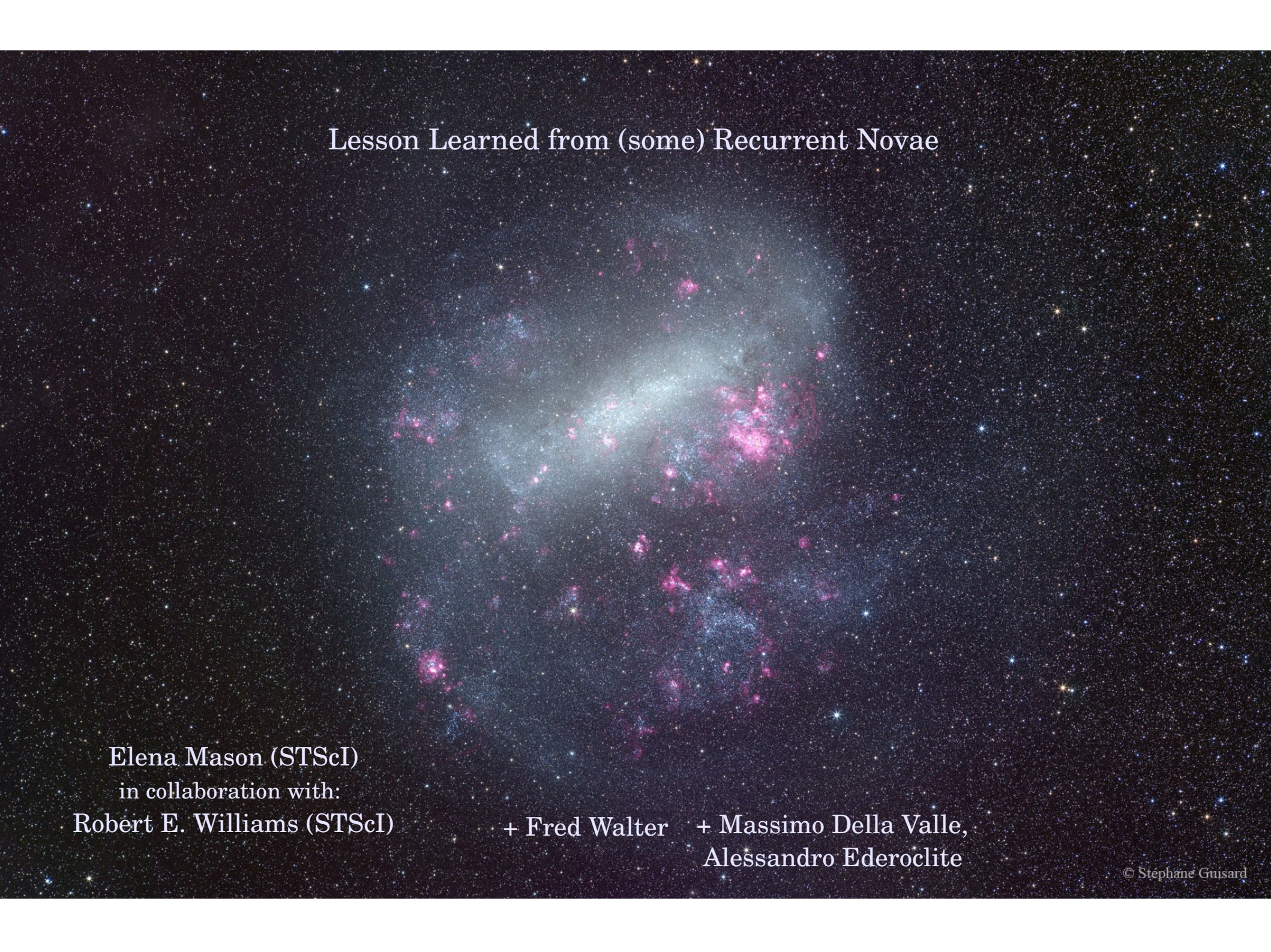
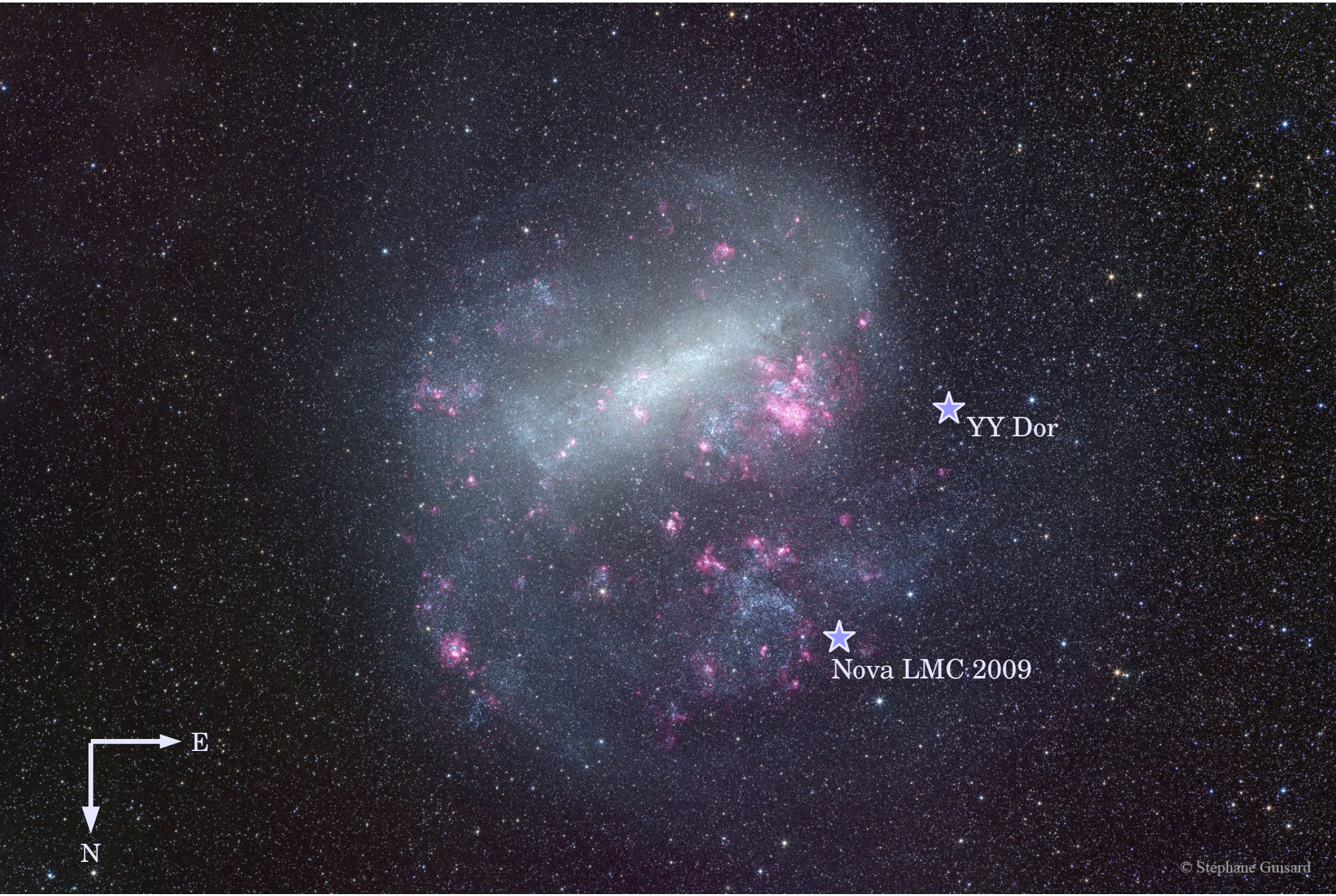
Lesson Learned from (some) Recurrent Novae



Elena Mason (STScI)
in collaboration with:
Robert E. Williams (STScI)
+ Fred Walter
+ Massimo Della Valle,
Alessandro Ederoclite


YY Dor
Nova LMC 2009
E
N
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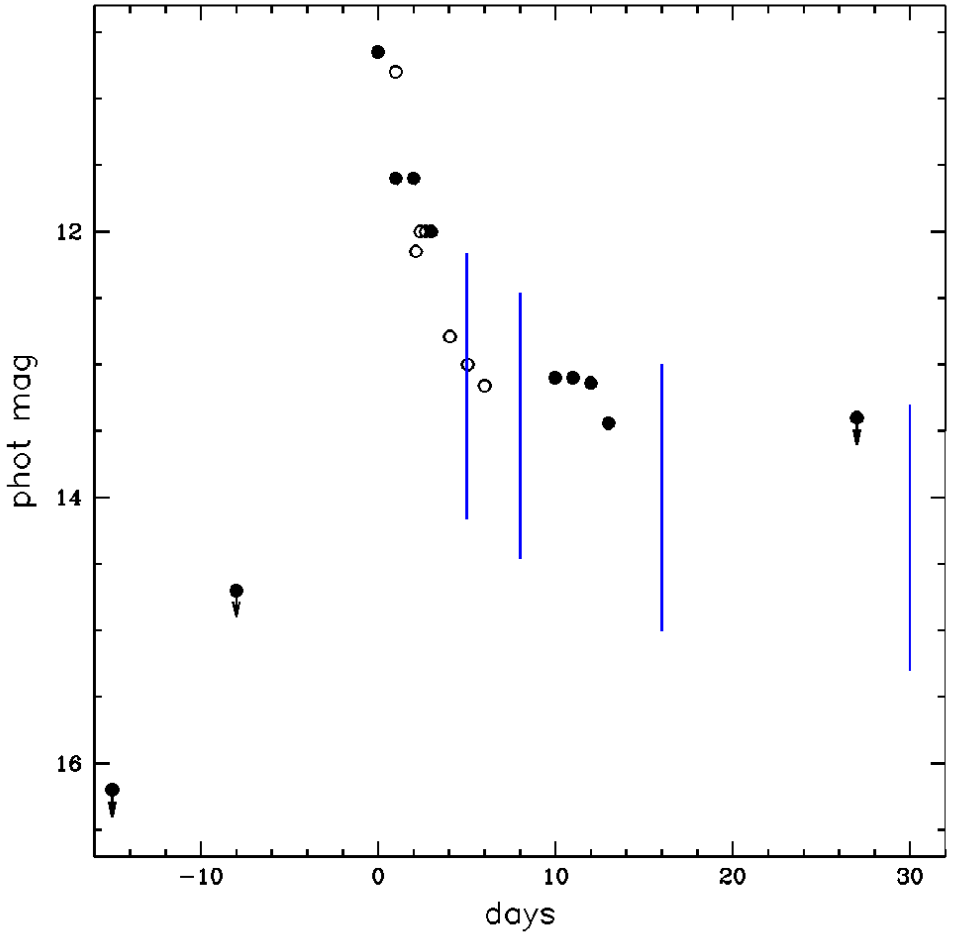
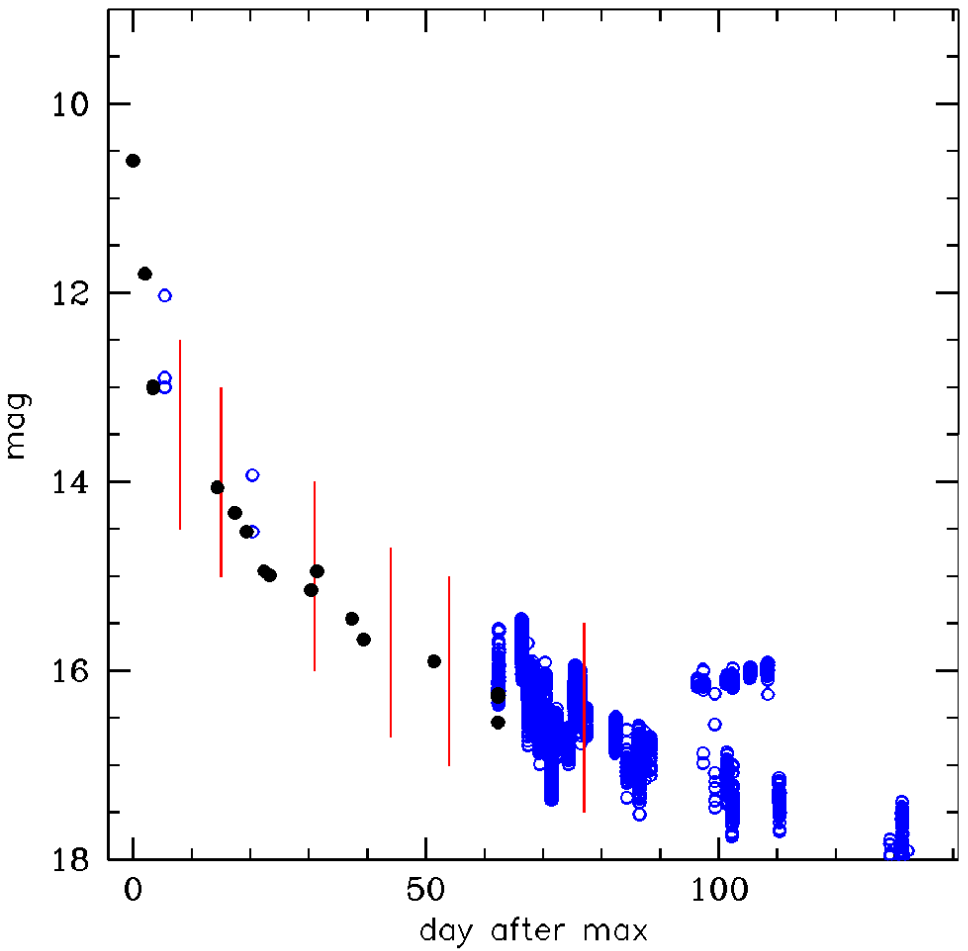
YY Dor 1934 (•) and 2004 (o) outburst LC

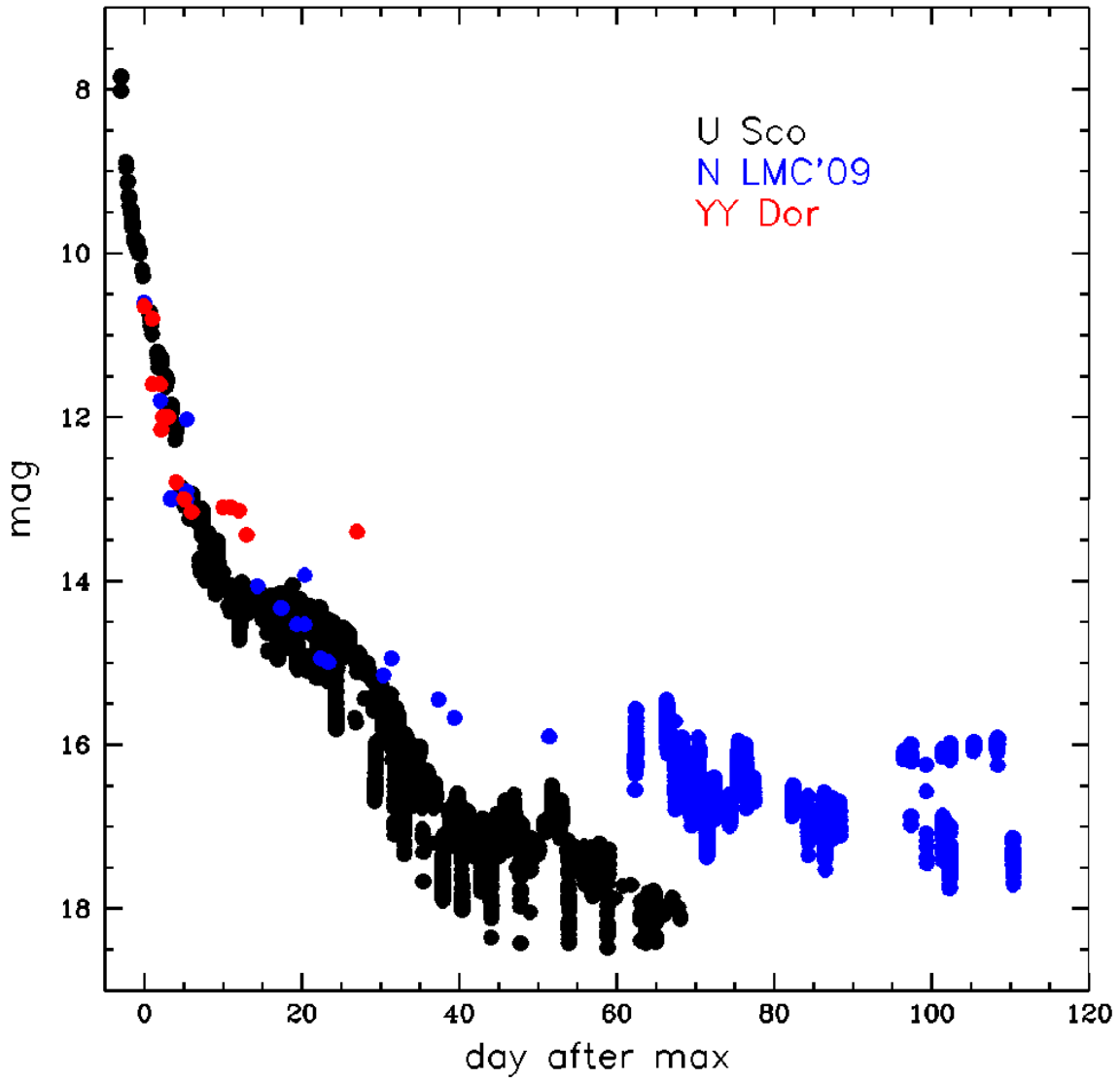


4-5 2.2m/FEROS spectra

nova LMC 2009 outburst LC (V: •; vis o)



5 VLT/UVES spectra



U Sco: t2=1.8 t3=4.1 days

N LMC 2009: t2~5 t3~11 days

YY Dor: t2~4 t3≥10 days

courtesy of B. Schafer

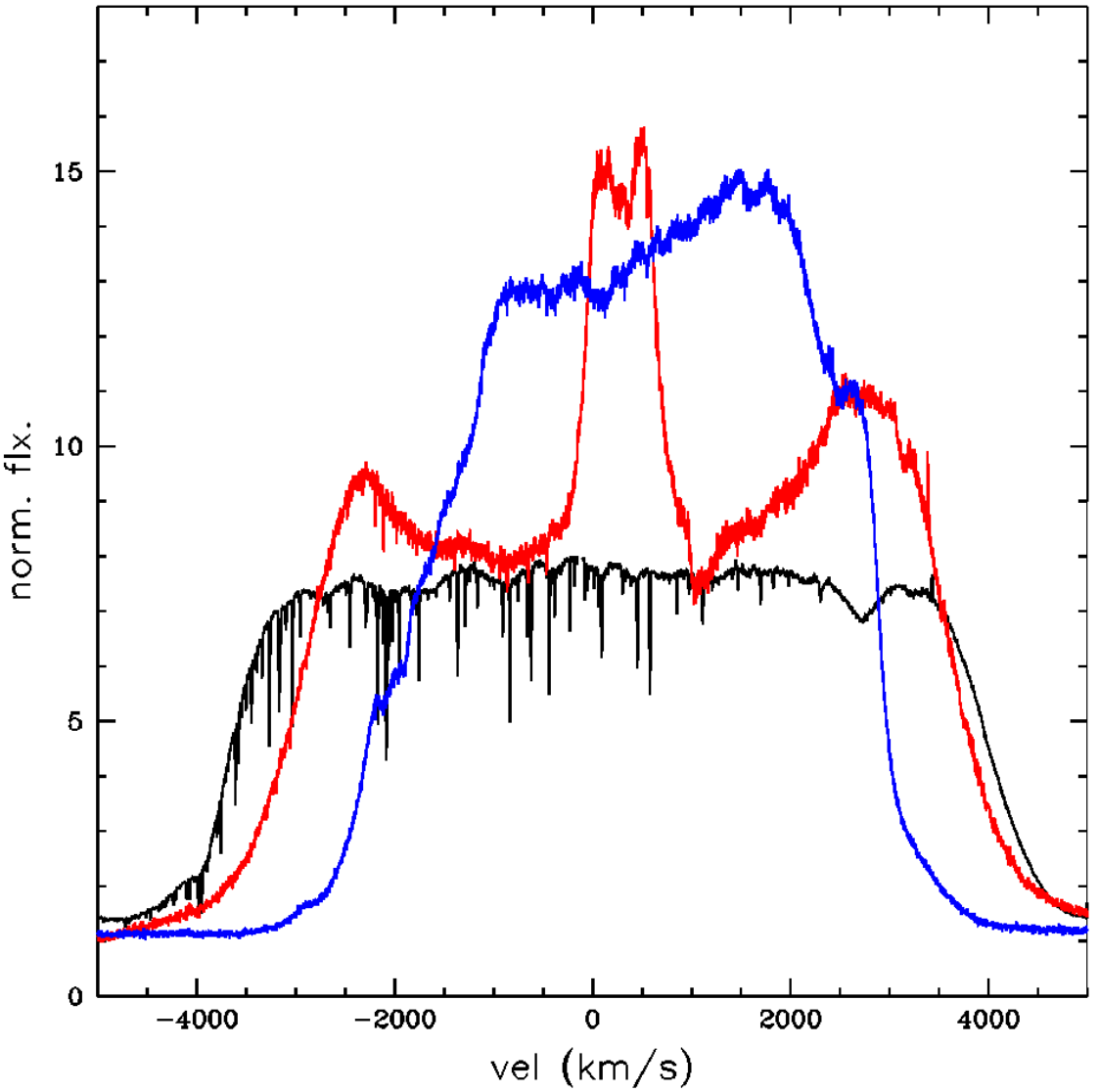
DATA POINTS: courtesy of AAVSO & W. Liller

from Liller (2004) & Mc Kibben (1941)

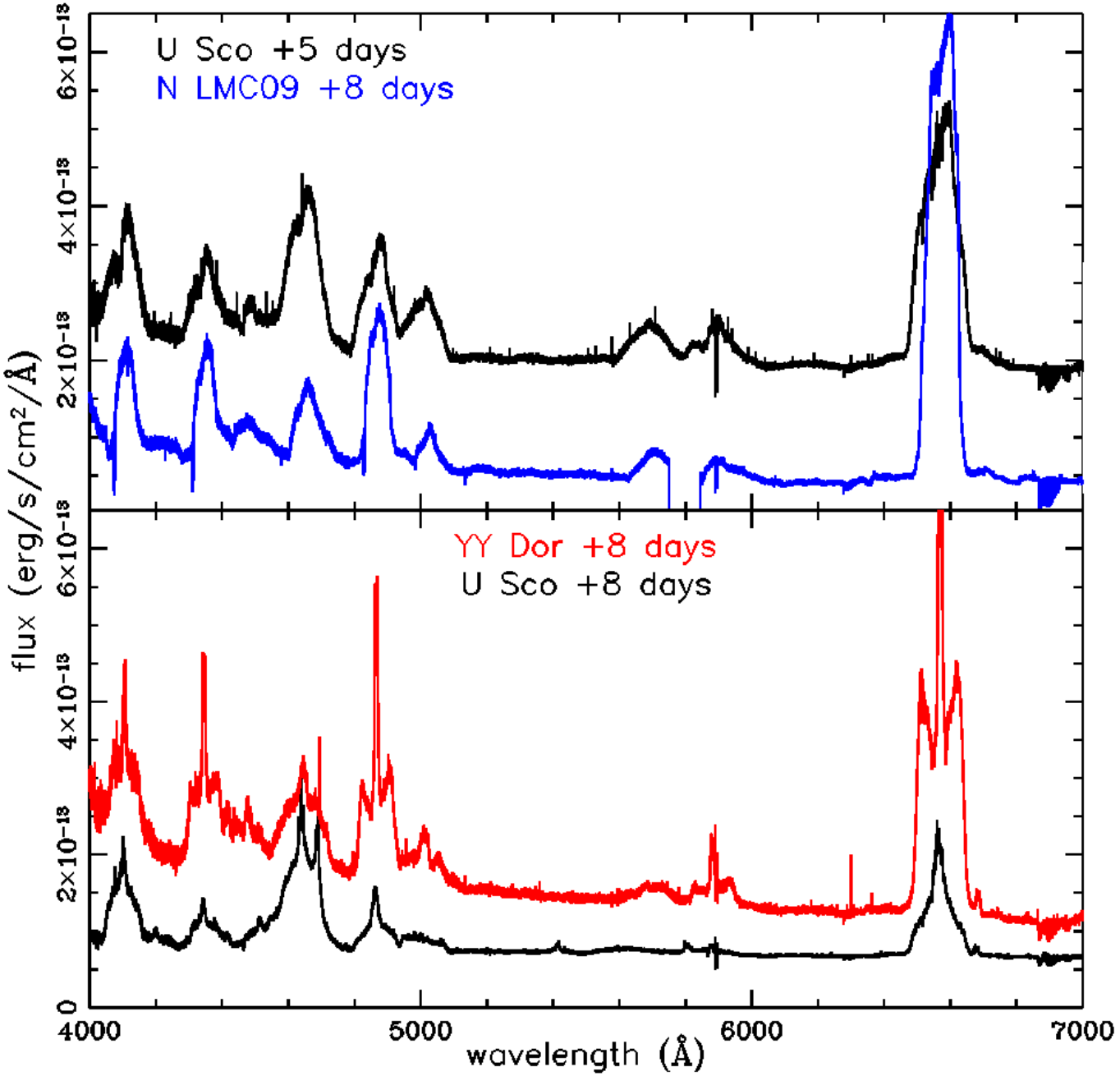
U Sco: FWHM~7500 FWZI~10000 km/s

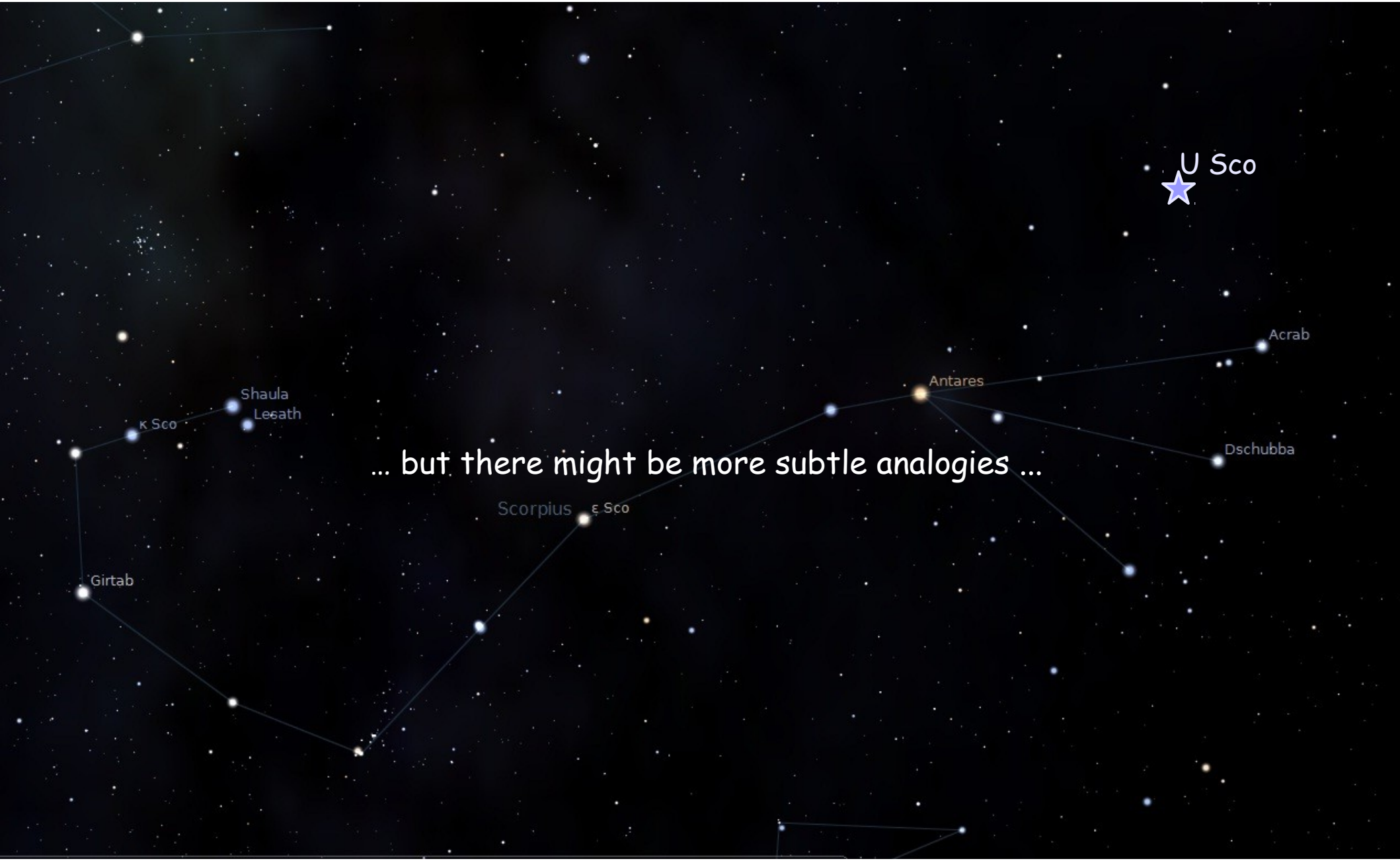
N LMC 2009: FWHM~5000 FWZI~6800 km/s

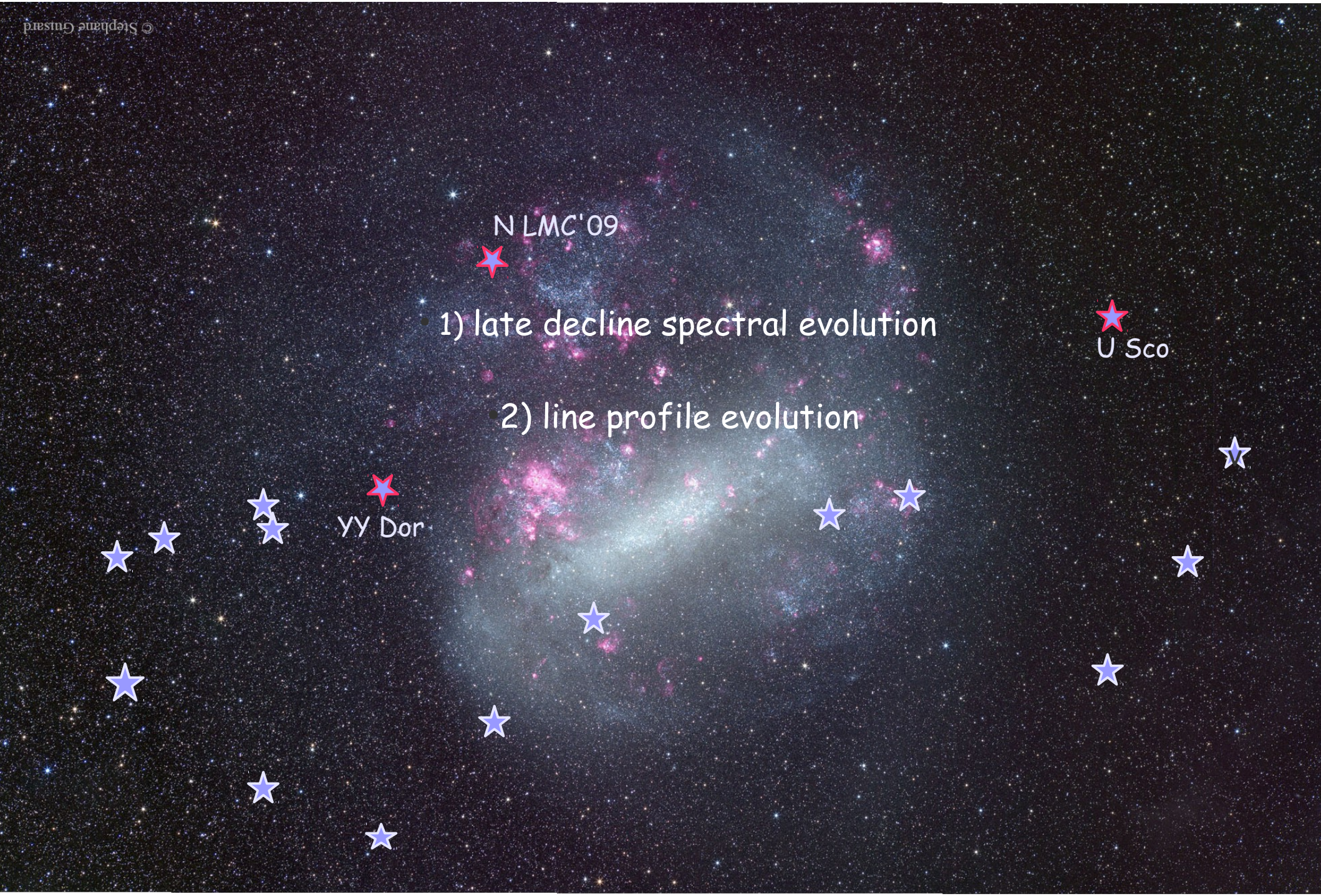
YY Dor: FWHM~7000 FWZI~10000 km/s



AT MAXIMUM/EARLY DECLINE ...




U Sco
Acrab
Antares
Shaula
Lesath
κ Sco
Dschubba
… but there might be more subtle analogies …
Scorpius
ε Sco
Girtab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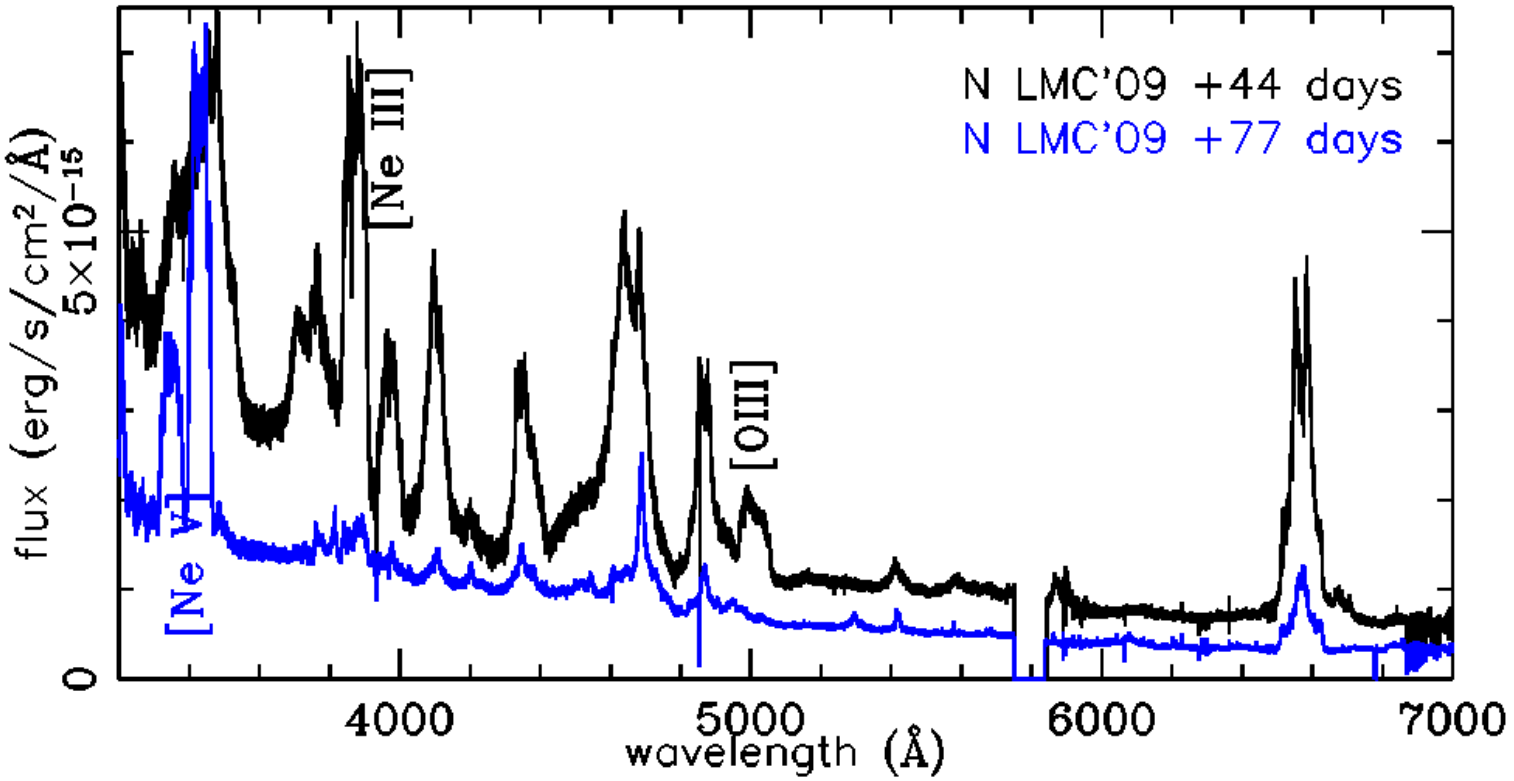
N LMC'09
1) late decline spectral evolution
2) line profile evolution
U Sco
YY Dor

- at MAX: H, He and N as a typical He/N CNe
- during the NEBULAR phase: little N, O and quite strong Ne (III and V)



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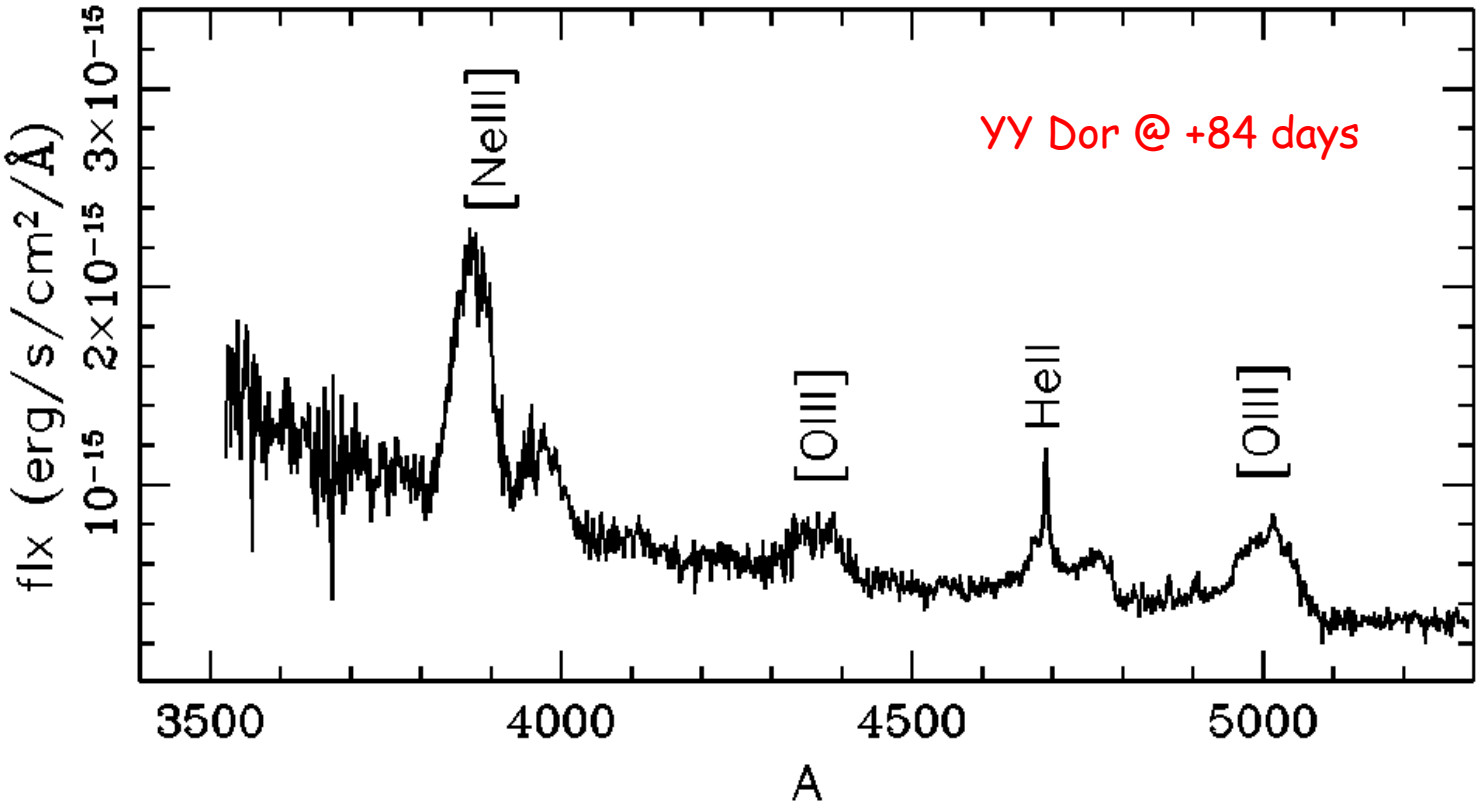


...when it comes to [Ne] emission lines:

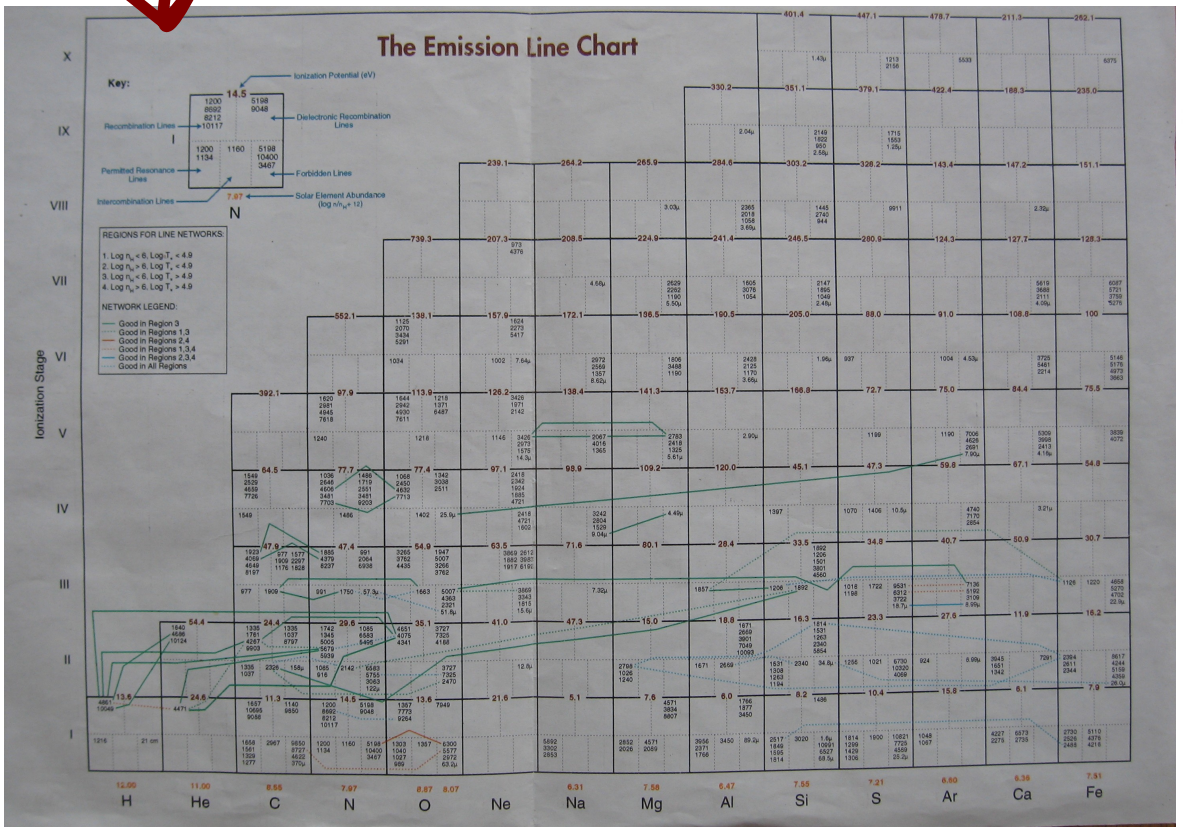
- Ne abundances

- WD composition ↔ SN-Ia connection

- is U Sco peculiar or is that ALL RN (of the U Sco type) hosts ONe WD as suggested by Webbink in 1990?

- is erosion taking place ?

Kingdon & Williams (1997) showed that it is possible to derive relative (not absolute) elemental abundance pairing "appropriate" lines.



nova	WD	[Ne/O]	ref.
V693 CrA	ONeMg	+1.21	Vanlandingham et al. (1999)
V1370 Aql	ONeMg	+1.76	Livio & Truran (1994)
V1974 Cyg	ONeMg	+0.47	Vanlandingham et al. (2005)
V382 Vel	ONeMg	+0.66	Shore et al. (2003)
V4160 Sgr	ONeMg	+0.69	Schwarz et al. (2007a)
V838 Her	ONeMg	+1.61	Schwarz et al. (2007a)
QU Vul	ONeMg	+0.92	Schwarz (2002)
V1065 Cen	ONeMg	+0.74	Helton et al. (2010)
LMC 1990 N.1	ONeMg	+0.45	Vanlandingham et al. (1999)
U Sco	ONeMg	+1.69	this paper
RR Pic	?	+0.94	Livio & Truran (1994)
V977 Sco	?	+0.60	Livio & Truran (1994)
V1186 Sco	CO	−0.82	Schwarz et al. (2007b)
LMC 1991	CO	−1.65	Schwarz et al. (2001)
QV Vul	CO	−0.96	Livio & Truran (1994)
HR Del	CO	−0.53	Livio & Truran (1994)
V1500 Cyg	CO	−0.069	Livio & Truran (1994)
V1688 Cyg	CO	−0.62	Livio & Truran (1994)
GQ Mus	CO	−1.09	Livio & Truran (1994)
PW Vul	CO	−0.67	Livio & Truran (1994)
V842 Cen	CO	−0.86	Livio & Truran (1994)
V827 Her	CO	−0.73	Livio & Truran (1994)
V2214 Oph	CO	+0.11	Livio & Truran (1994)
V443 Sct	CO	−1.04	Livio & Truran (1994)

† The [Ne/O] abundances have been compared assuming the solar values in Asplund et al. (2009).

Mason (2011) showed that the WD composition (CO/ONe) can be pinpointed on the basis of the ejecta relative [Ne/O] abundance (>0 in ONe WD and <0 in CO WD).

[Ne/O]: Usco=1.16, NLMC'09=2.07, YY Dor=1.98

CAVEAT:

- assume same line forming region
- is not too precise at large density

but no doubts about the 2 LMC RNe:
[Ne III] > [OIII]

nova	obs. out.	epoch of 1st neb/last spc	[Ne/O] >0	REF.
U Sco	2010	46/104	y	Mason et al '12 + Diaz et al '10
V394 Cra	1987	-/67	-	Sekiguchi et al'87
CI Aql	2000	66/66	n	Iijima '12
LMC 1990/2	1990	-/10-15	-	Williams et al '91 + Sekiguchi et al'90
YY Dor	2004	41/92	y	Walter et al '12
LMC 2009	2009	44/77	y	this work
V2672 Oph	2009	-/8	-	Munari et al '11
V2487 Oph	(1998)	-/-	-	
EK Tri	(2009)	274/274	?	Imamura et al'12

nova	obs. out.	epoch of 1st neb/last spc	[Ne/O] >0	REF.
U Sco	2010	46/104	y	Mason et al '12 + Diaz et al '10
V394 Cra	1987	-/67	-	Sekiguchi et al'87
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LMC 1990/2	1990	-/10-15	-	Williams et al '91 + Sekiguchi et al'90
YY Dor	2004	41/92	y	Walter et al '12
LMC 2009	2009	44/77	y	this work
V2672 Oph	2009	-/8	-	Munari et al '11
V2487 Oph	(1998)	-/-	-	
EK Tri	(2009)	274/274	?	Imamura et al'12
T Pyx	2011	~180/360	n	Ederoclite et al Shore et al. '12
RS Oph				
T CrB				
V3890 Sgr				
V745 Sco				
V723 Sco				

late decline spectral evolution “conclusions”:

- most of the objects have not been followed long enough into their nebular phase

- U Sco type RNe observed at late stages seem -all- heavily enriched in Ne suggesting an ONe WD

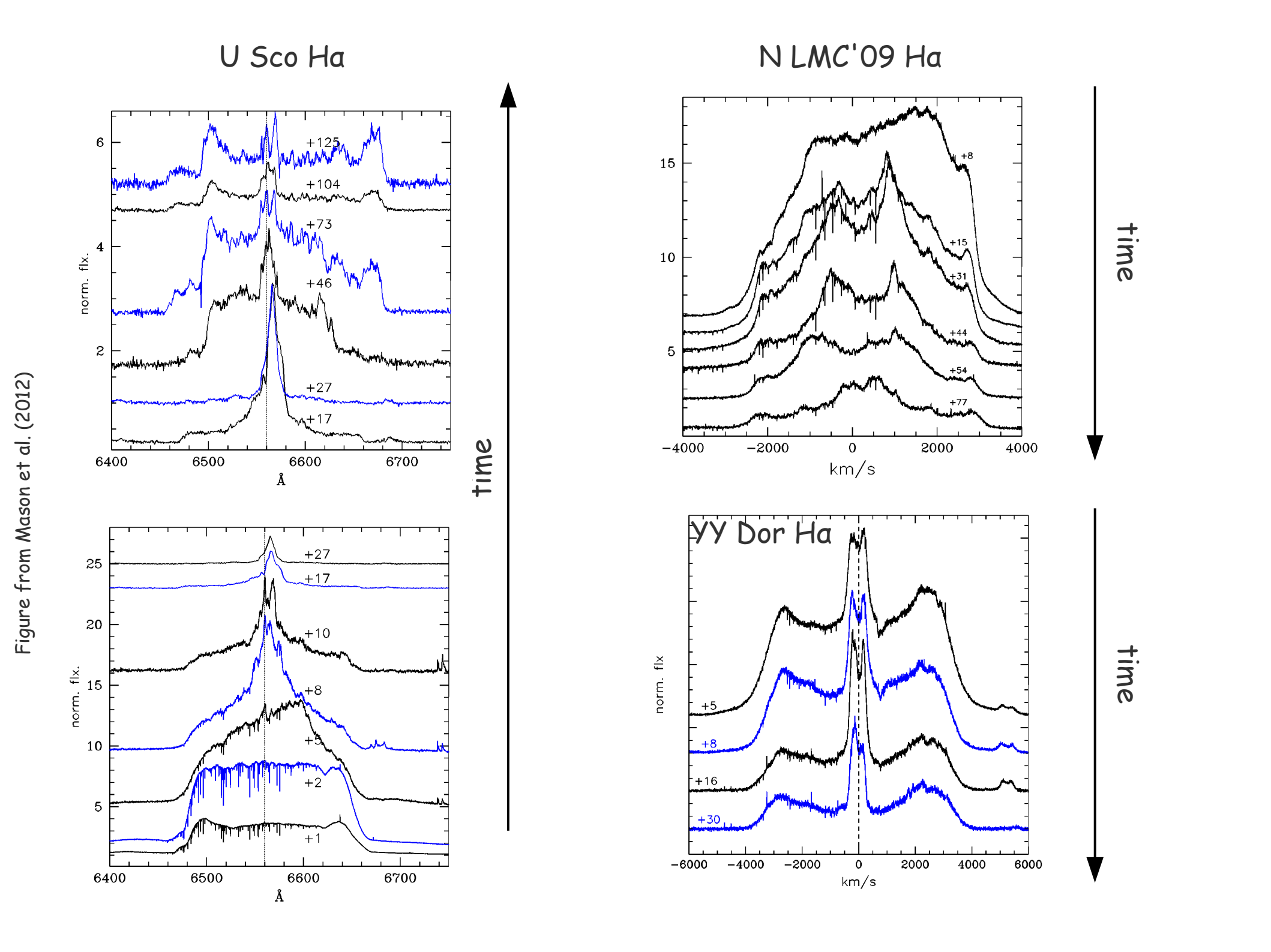
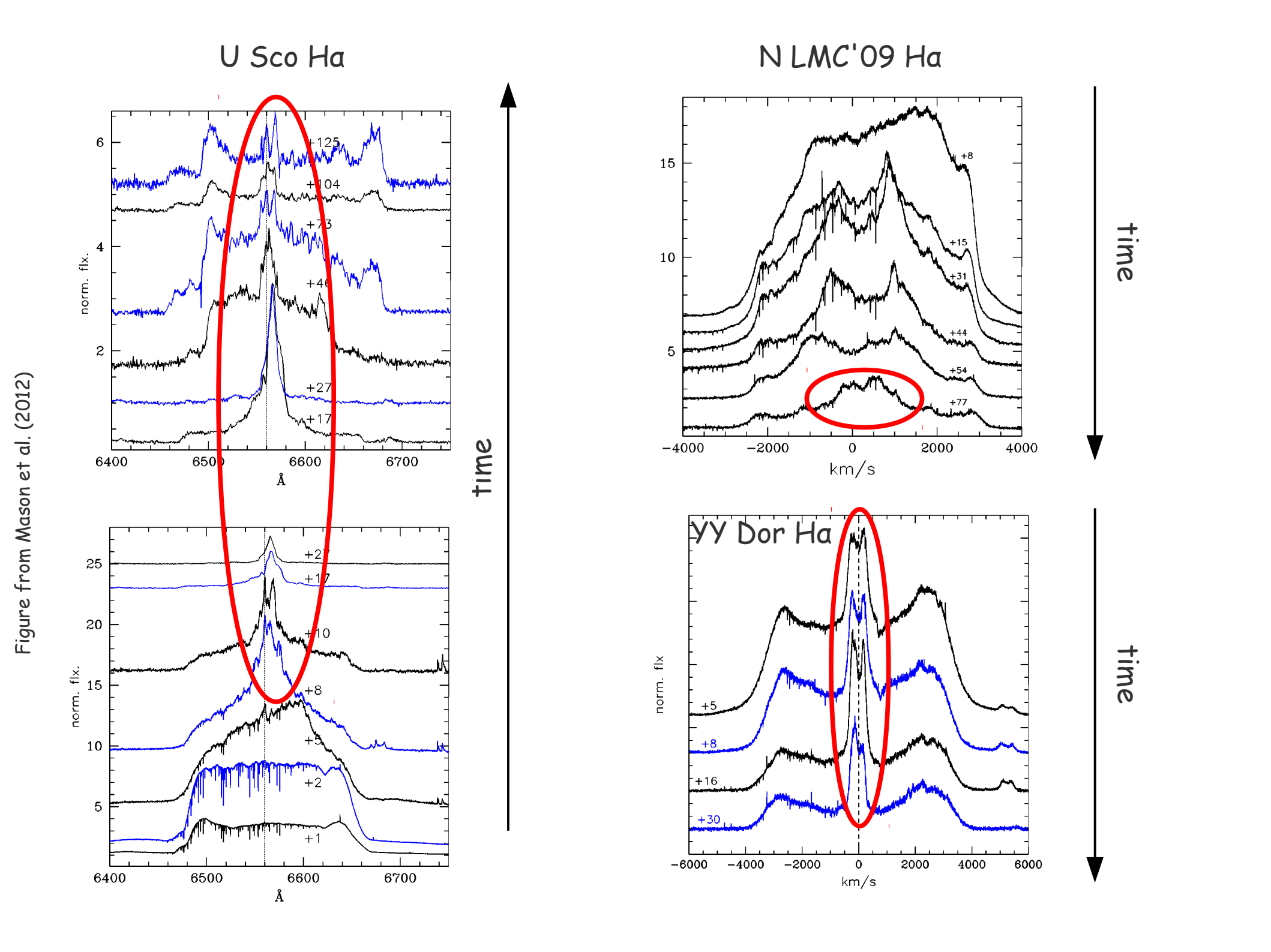


Figure from Mason et al. (2012)



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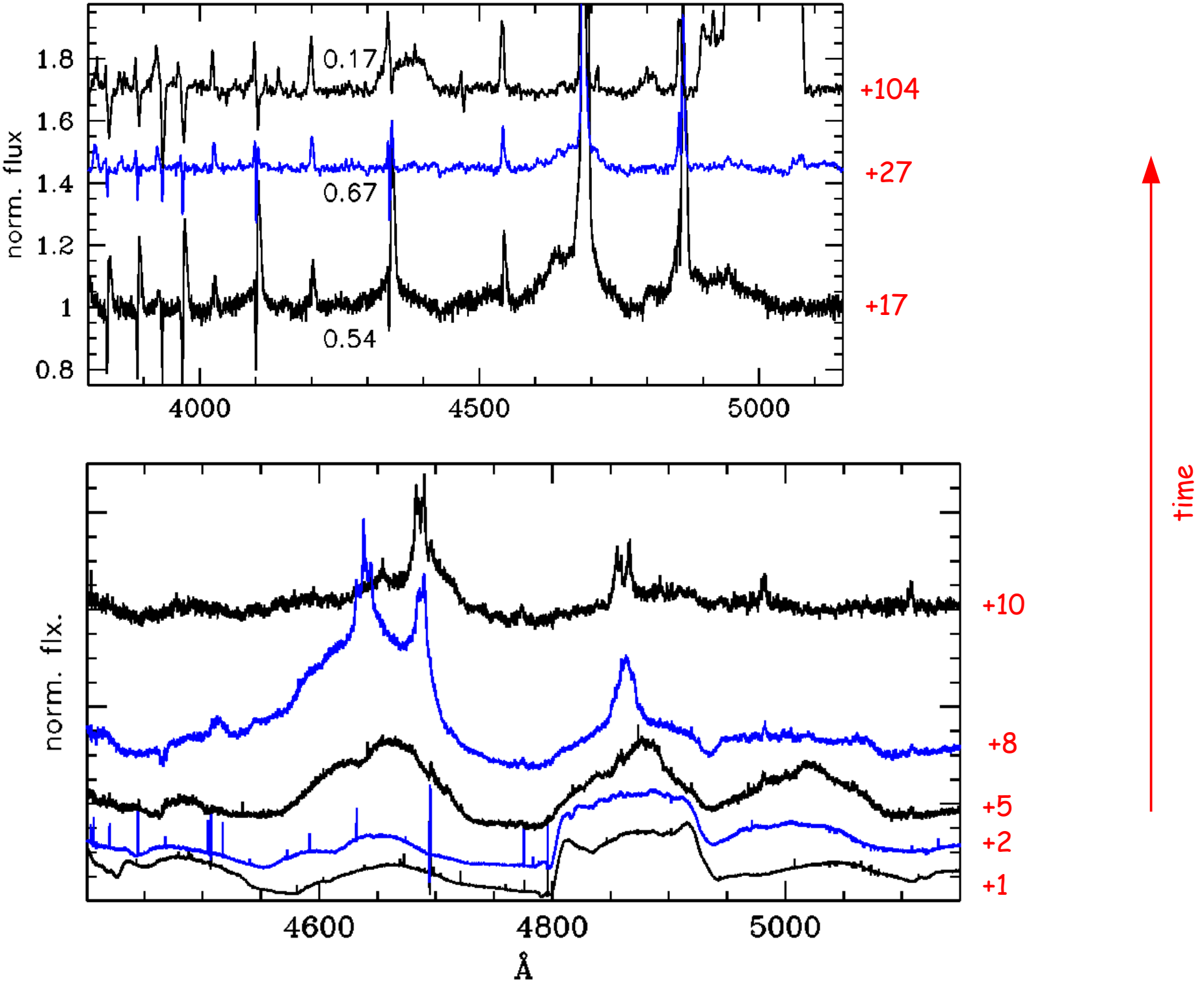
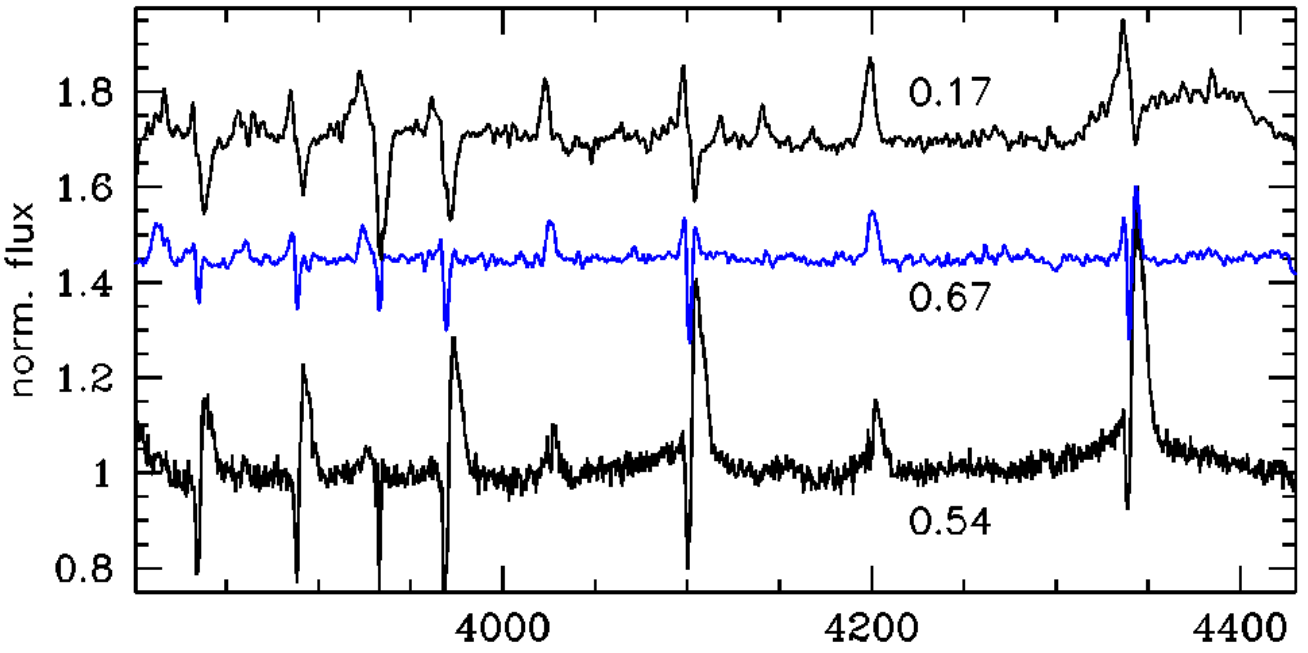
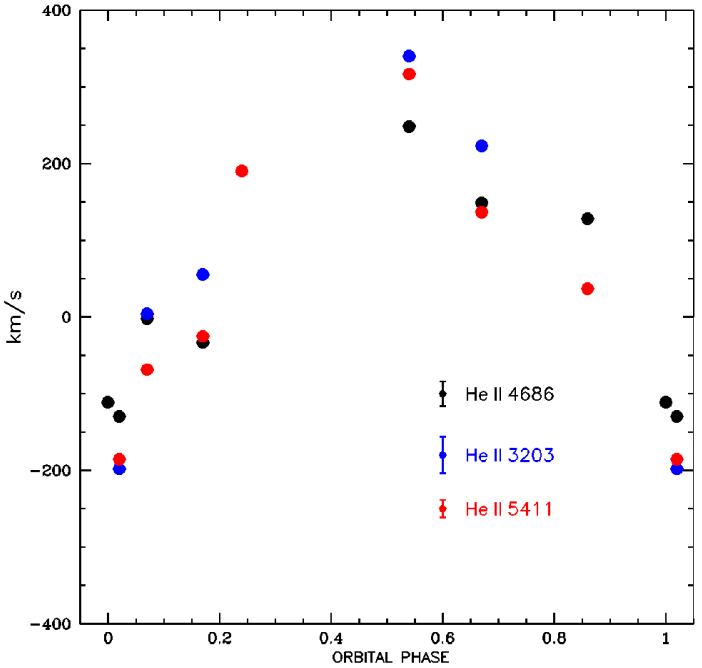
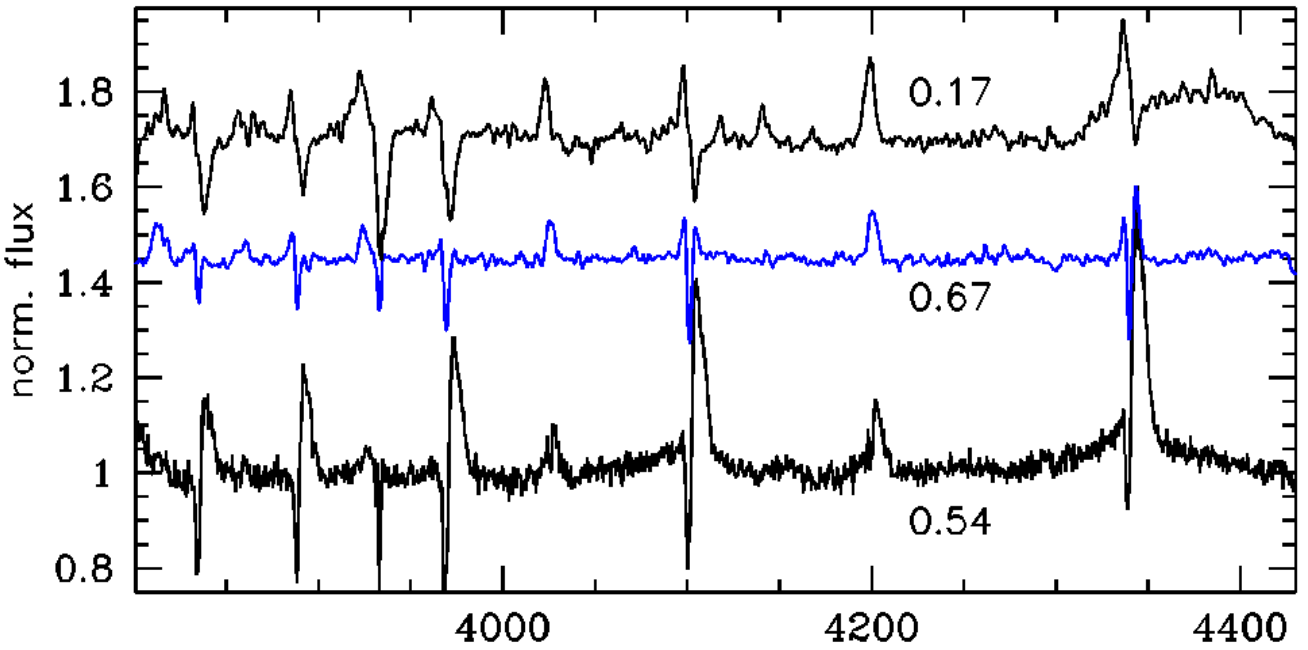
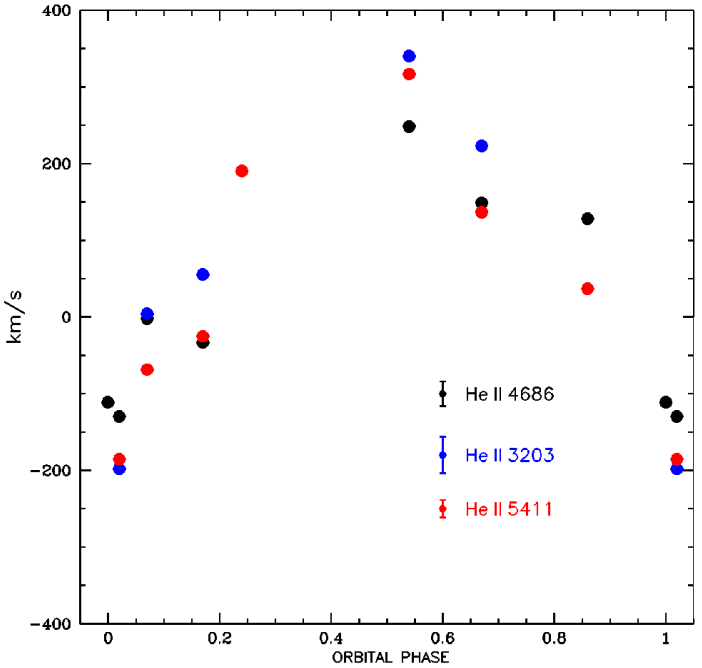

norm. flux
1.8
1.6
1.4
1.2
1
0.8
0.17
0.67
0.54
+104
+27
+17
4000
4500
5000
norm. flx.
+10
+8
+5
+2
+1
4600
4800
5000
Å
time

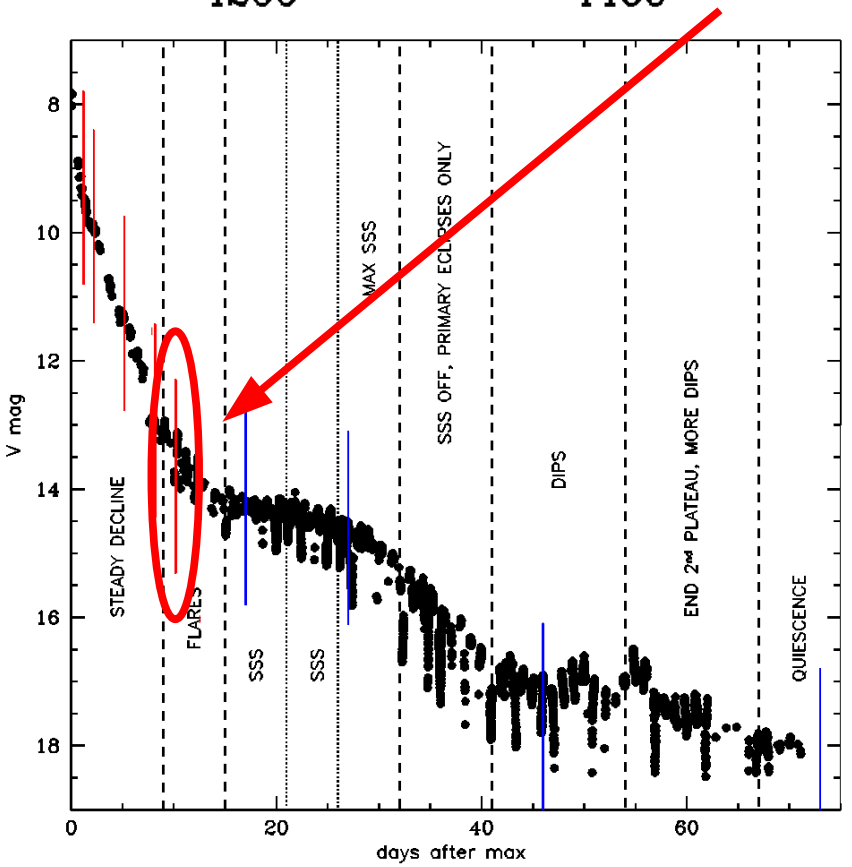




Figures from Mason et al. (2012)







Figures from Mason et al. (2012)

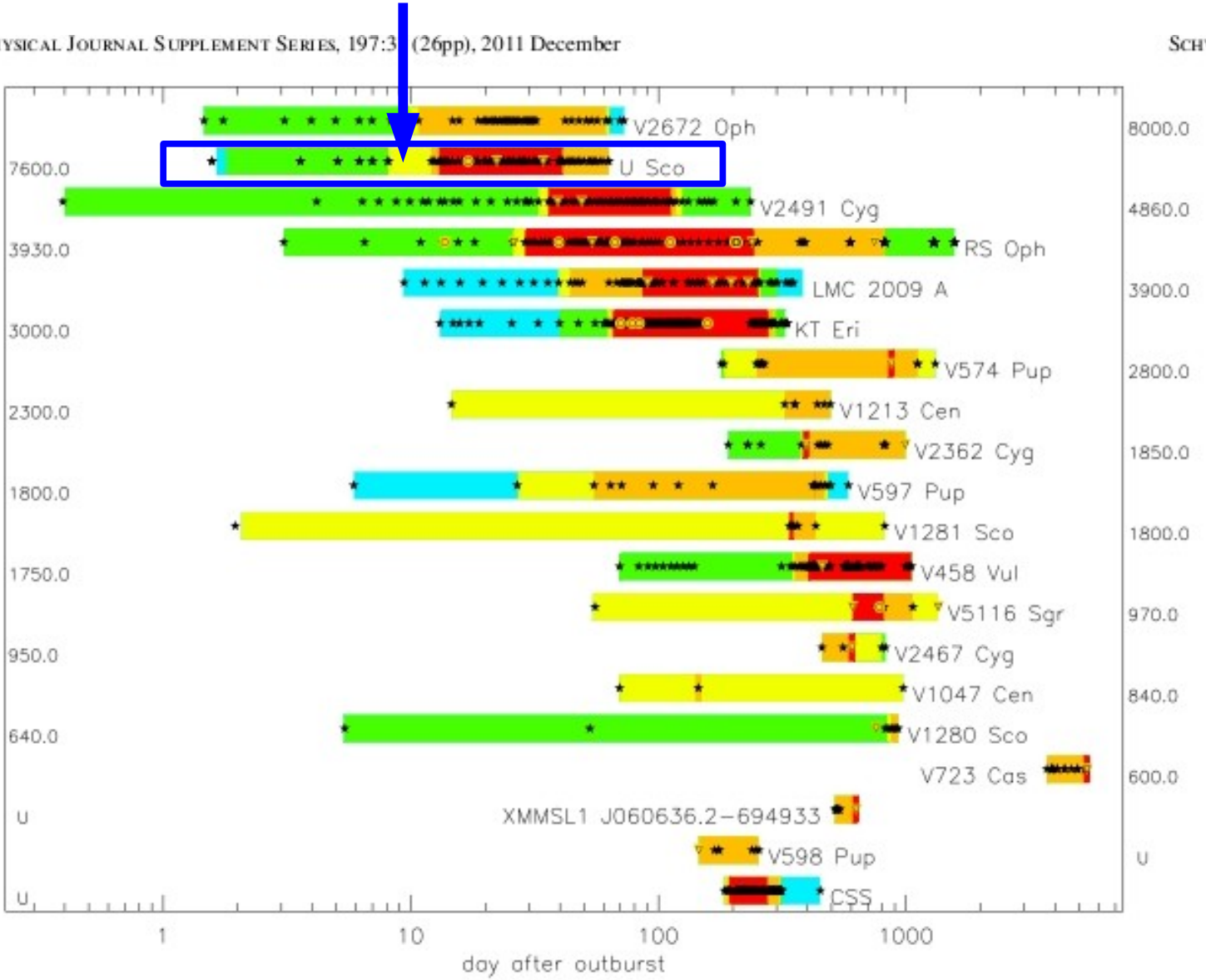
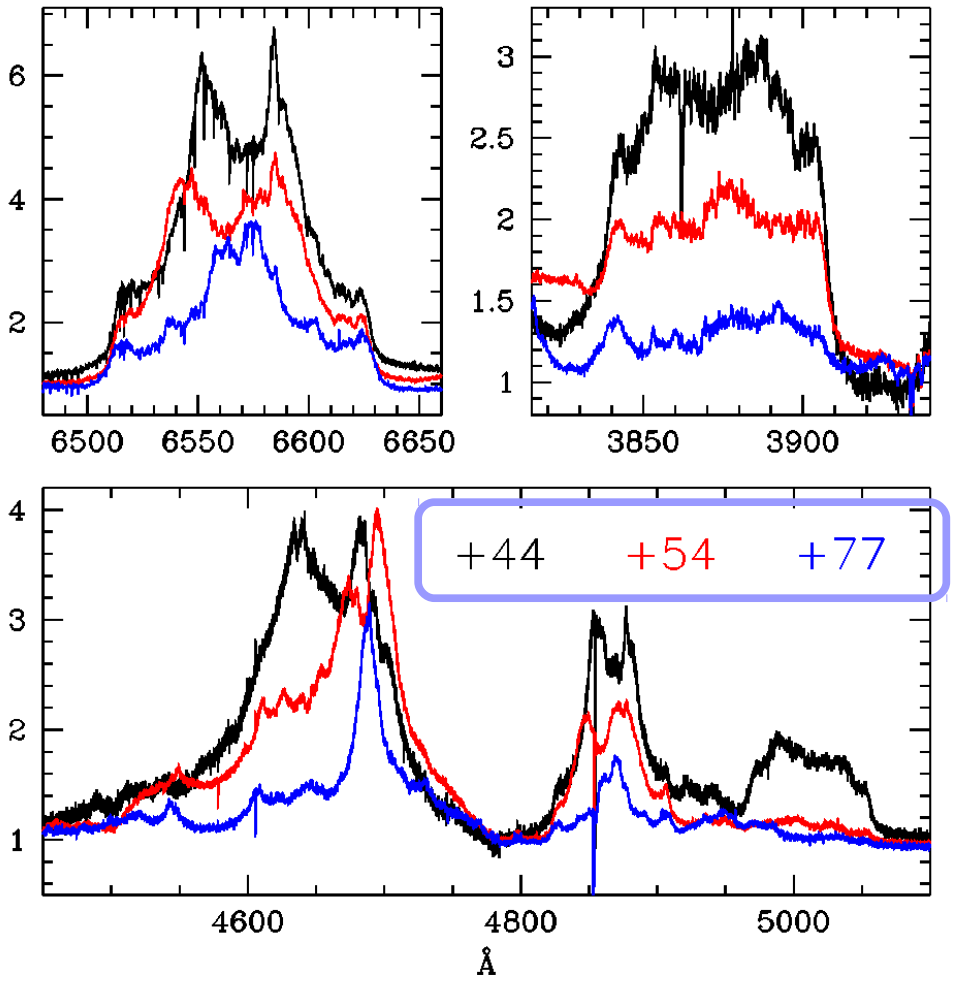
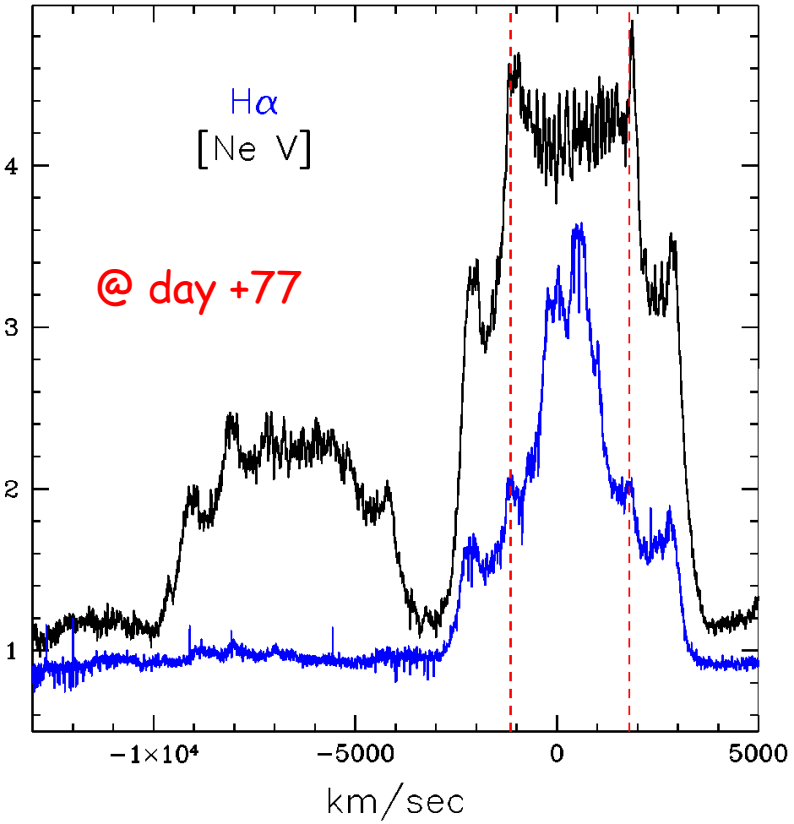


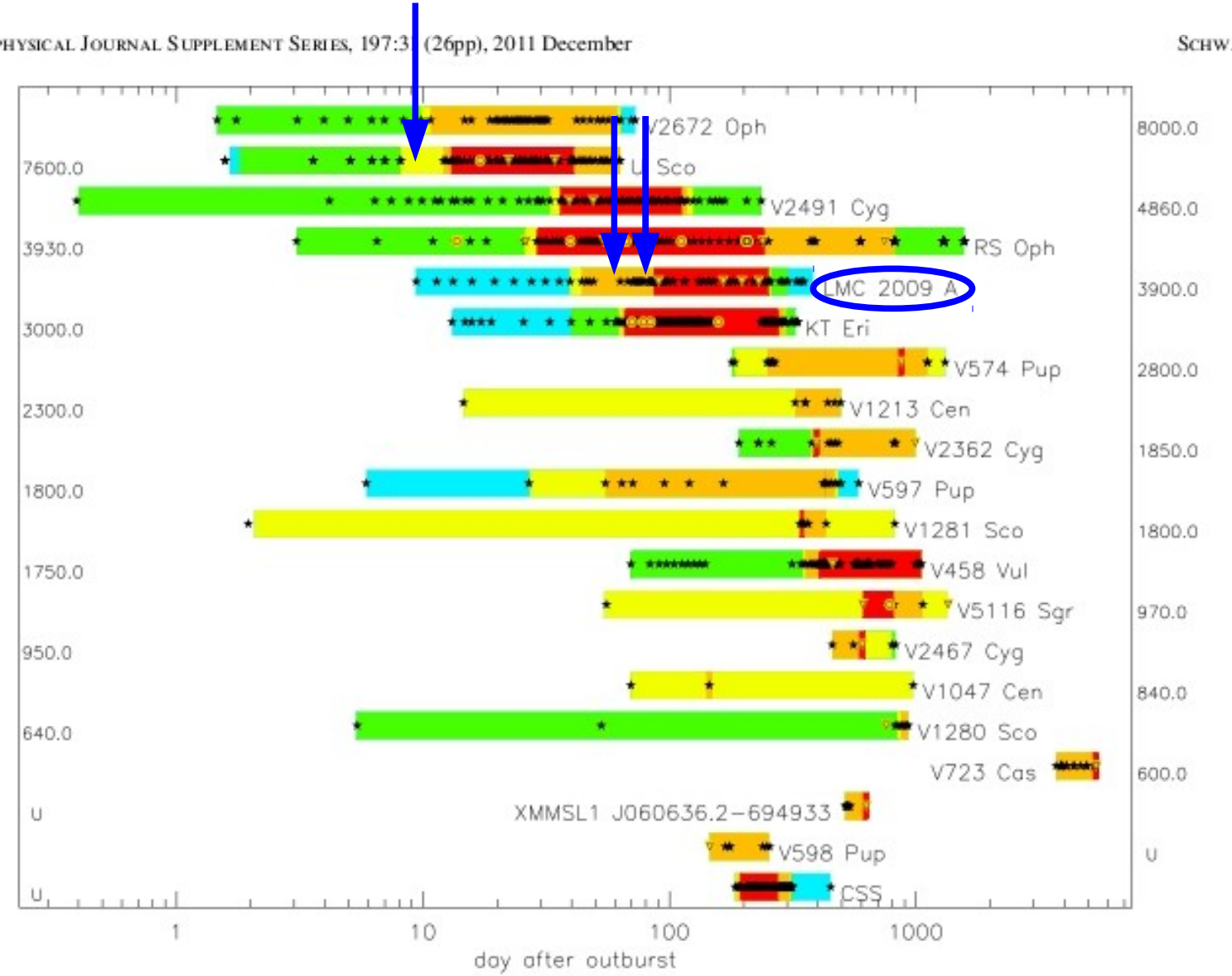
Figure 4. X-ray epochs for *Swift* sources with the best SSS phase coverage. The novae are arranged by increasing optical emission line FWHM with the FWHM values shown either left or right of the source. "U" is used for novae with unknown FWHM velocities. Refer to Table 3 for a summary of the color coding.

from Schwarz et al. (2011)

LMC'09 line profiles:







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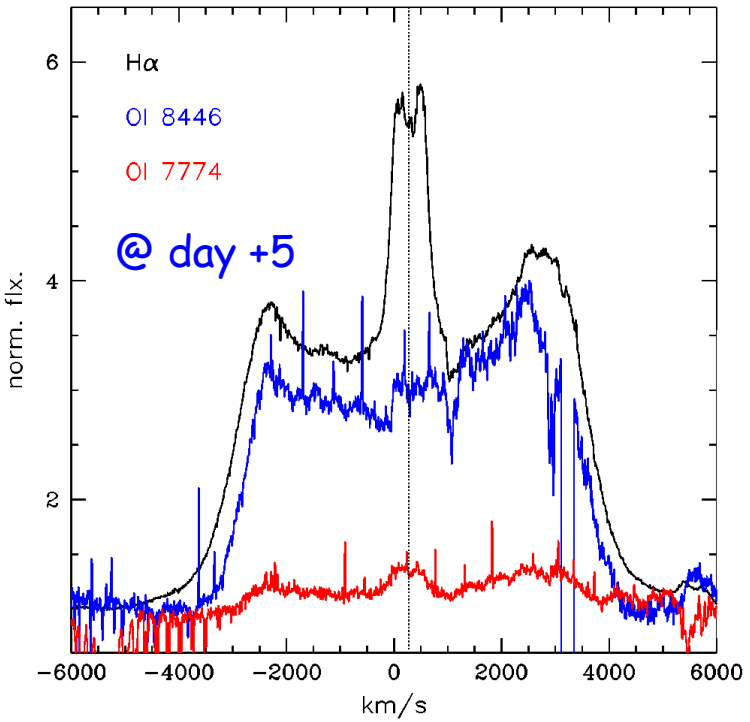
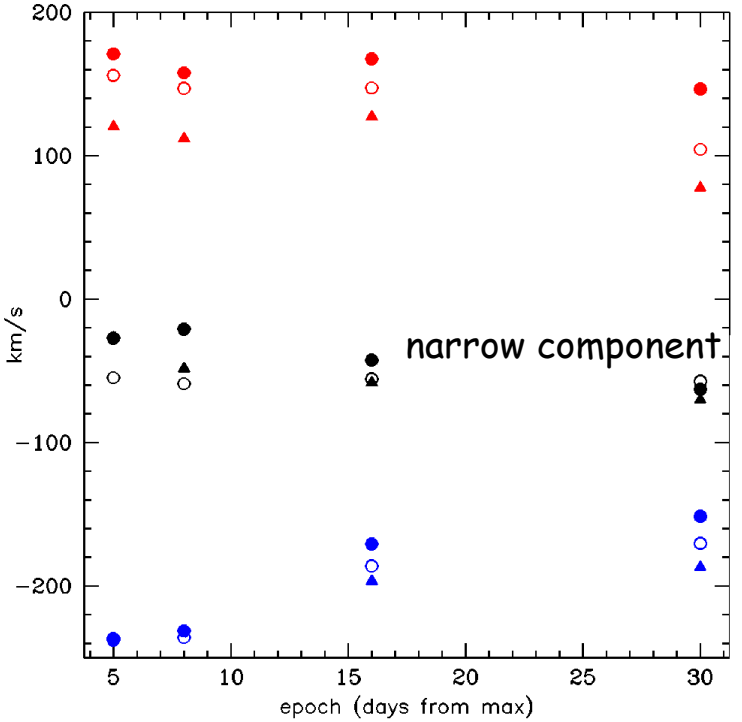


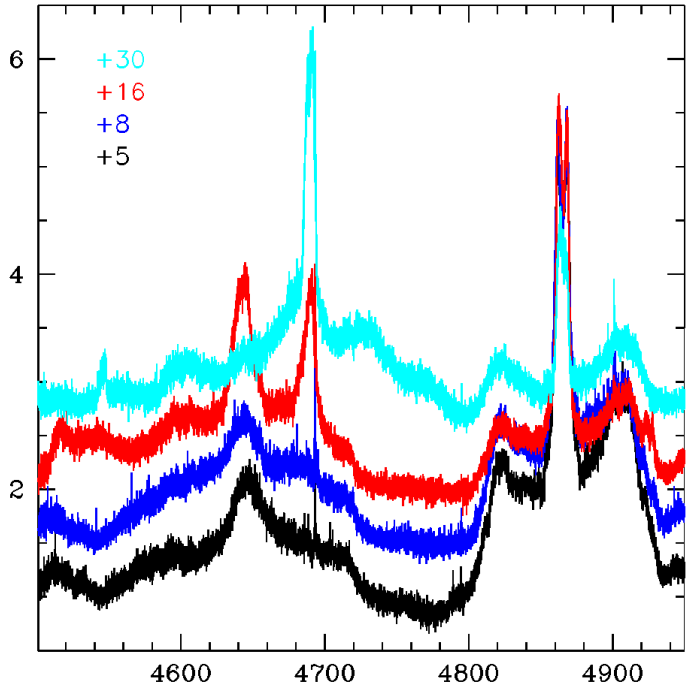


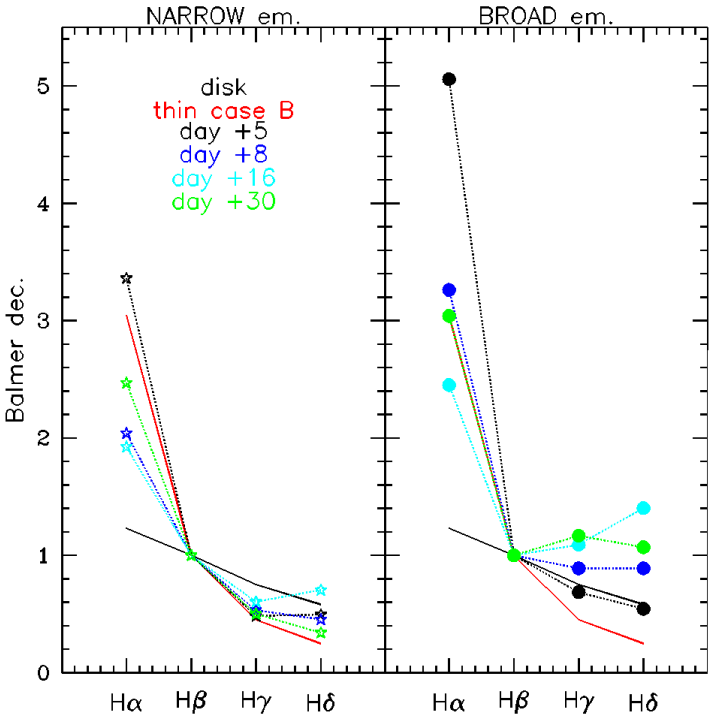
red peak

narrow component flux barycenter

blue peak

YY Dor line profile:





nova	obs. out.	narrow comp. appearance	HeII appearance	HeII>Hb	SSS start	REF.
U Sco	2010	8	8	y	8-12	Mason et al '12 + Diaz et al '10
V394 Cra	1987	~20	-	y	-	Sekiguchi et al'87
CI Aql	2000	n	n:	n	?	Iijima '12
LMC 1990/2	1990	~9	-	y	-	Williams et al '91 + Sekiguchi et al'90
V2487 Oph	(1998)	-/-	-	-	-	
YY Dor	2004	<5	y	y	-	this work
LMC 2009	2009	54/77	54/77	y	50	this work
V2672 Oph	2009	1	-	-	10	Munari et al '11
V1721 Aql	2008	2.5	?	?	?	Hounsell et al '11
KT Eri	2009	55-65	55-65	y	65	Imamura et al '12
V2491 Cyg	2008	21?/n	21?/n	n	30	Munari et al '10

line profile evolution “conclusions”:

- the narrow is common to the majority of U Sco type RNe

- there might be a correlation between the He II emission and the start of the SSS phase

Conclusions:

- U Sco type RNe are possibly an homogeneous class with:
  a) ONe WD
     → no SN-Ia progenitor → only U Sco type or all RNe?
     → eroded WD
  b) narrow emission and HeII in particular
     if early accretion recovery:
     → no wind phase within the outburst ?
     → SSS fueled in part by accretion ?
     if ejecta: → what special about these RNe?

- need:
  a) more observation during the late decline/nebular phase
  b) address the possible correlation HeII - SSS phase
  c) more data sampling the appearance/evolution of the
     narrow component including time resolved spectroscopy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