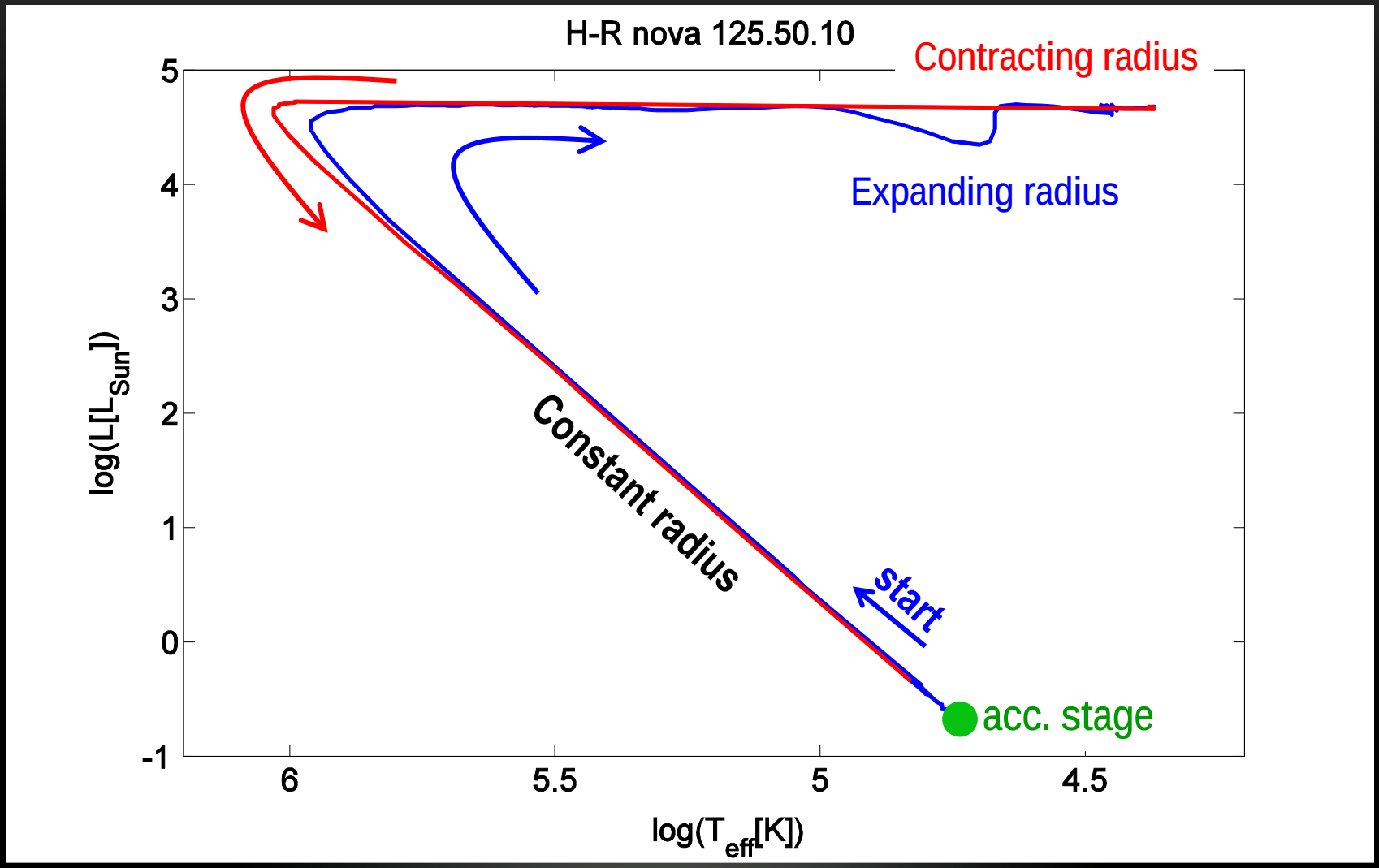
Understanding Features of Nova Outburst Light Curves as Derived From Modeling

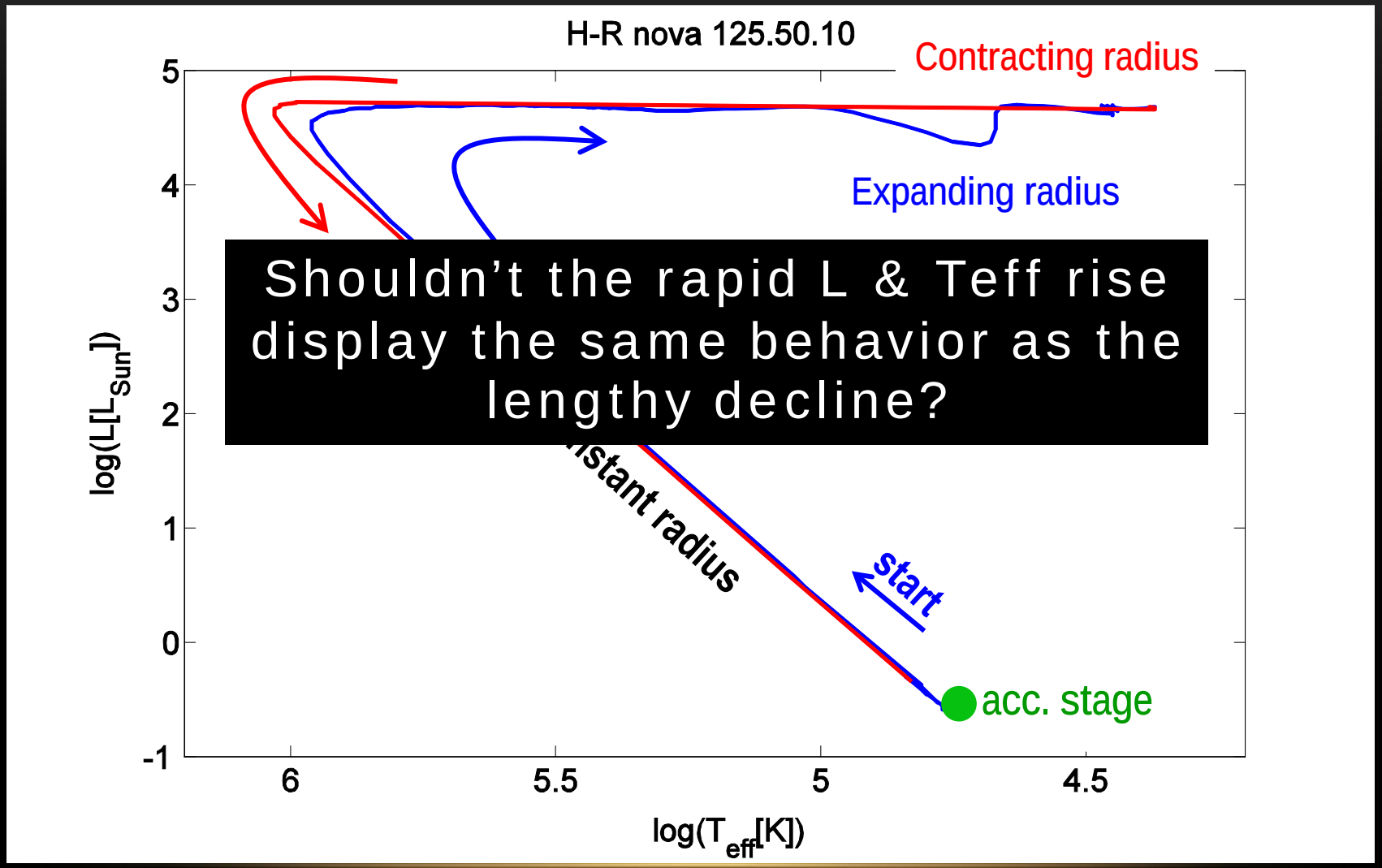
Y. Hillman, D. Prialnik, A. Kovetz, M. Shara & D. Neill

"Stella Novae – Past and Future Decades"

Feb. 2013 Cape Town

- Typical nova cycle
- Early pre-nova UV flash
- Peaks, halts & dips
- Nova cycle time table
- Decline characterization


H-R nova 125.50.10
Contracting radius
Expanding radius
Constant radius
start
acc. stage
5
4
3
2
1
0
-1
6
5.5
5
4.5
log(L[L_Sun])
log(T_eff[K])

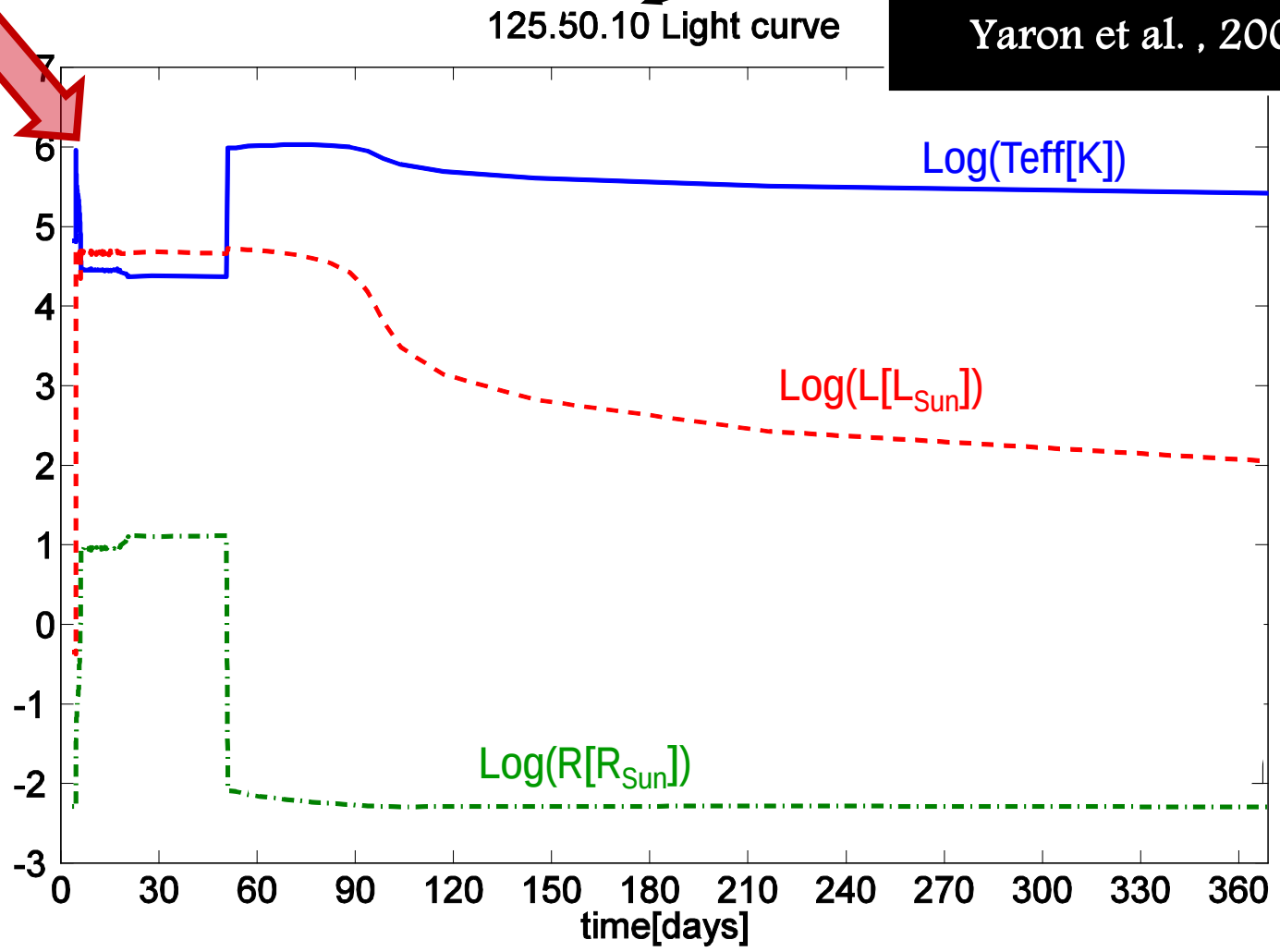

H-R nova 125.50.10
Contracting radius
Expanding radius
Shouldn't the rapid L & Teff rise display the same behavior as the lengthy decline?
start
acc. stage
log(L[L_Sun])
log(T_eff[K])
5
4
3
2
1
0
-1
6
5.5
5
4.5

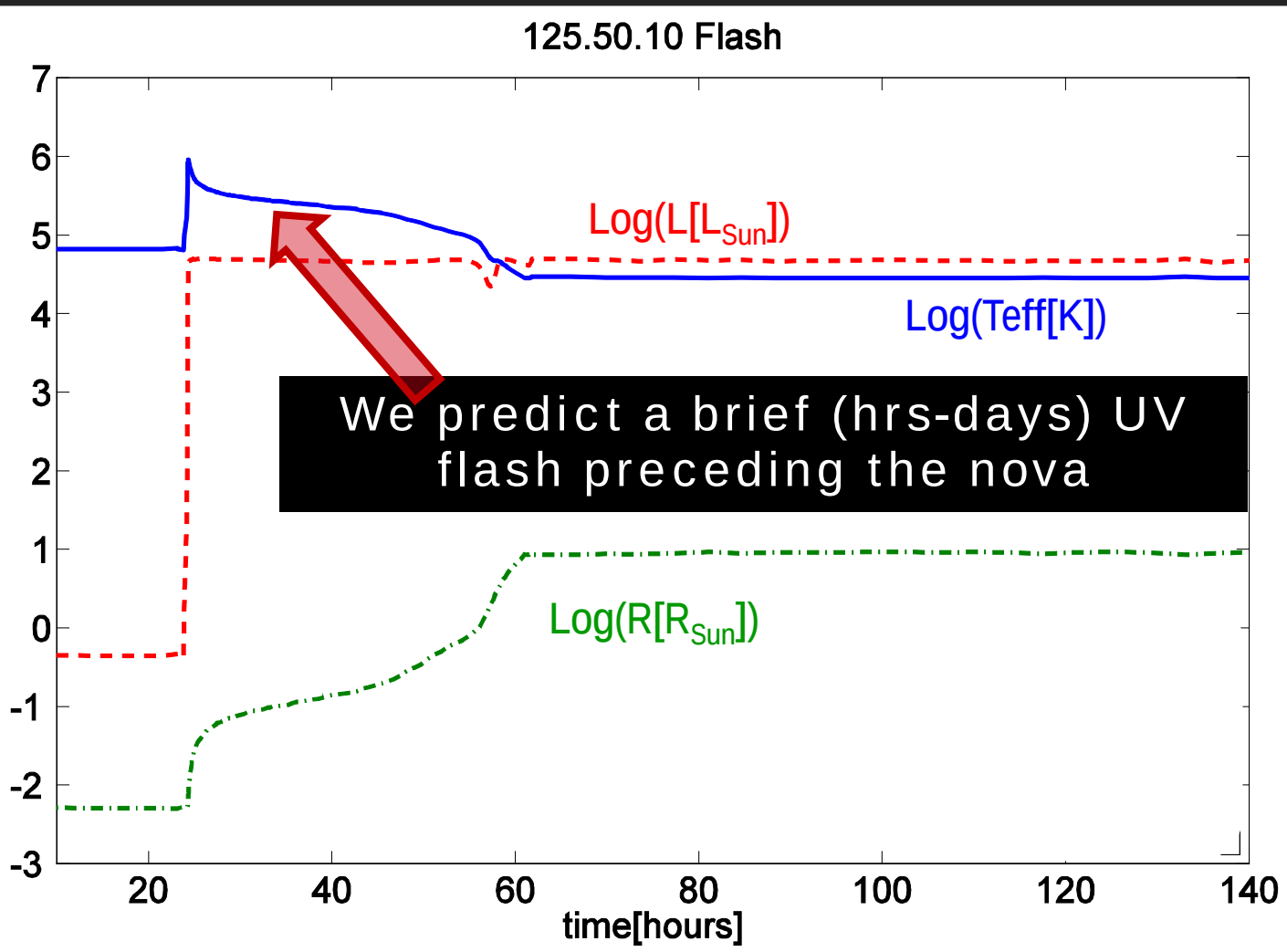
$M_{WD} = 1.25M_{Sun}$

$T_c = 50*10^6K$

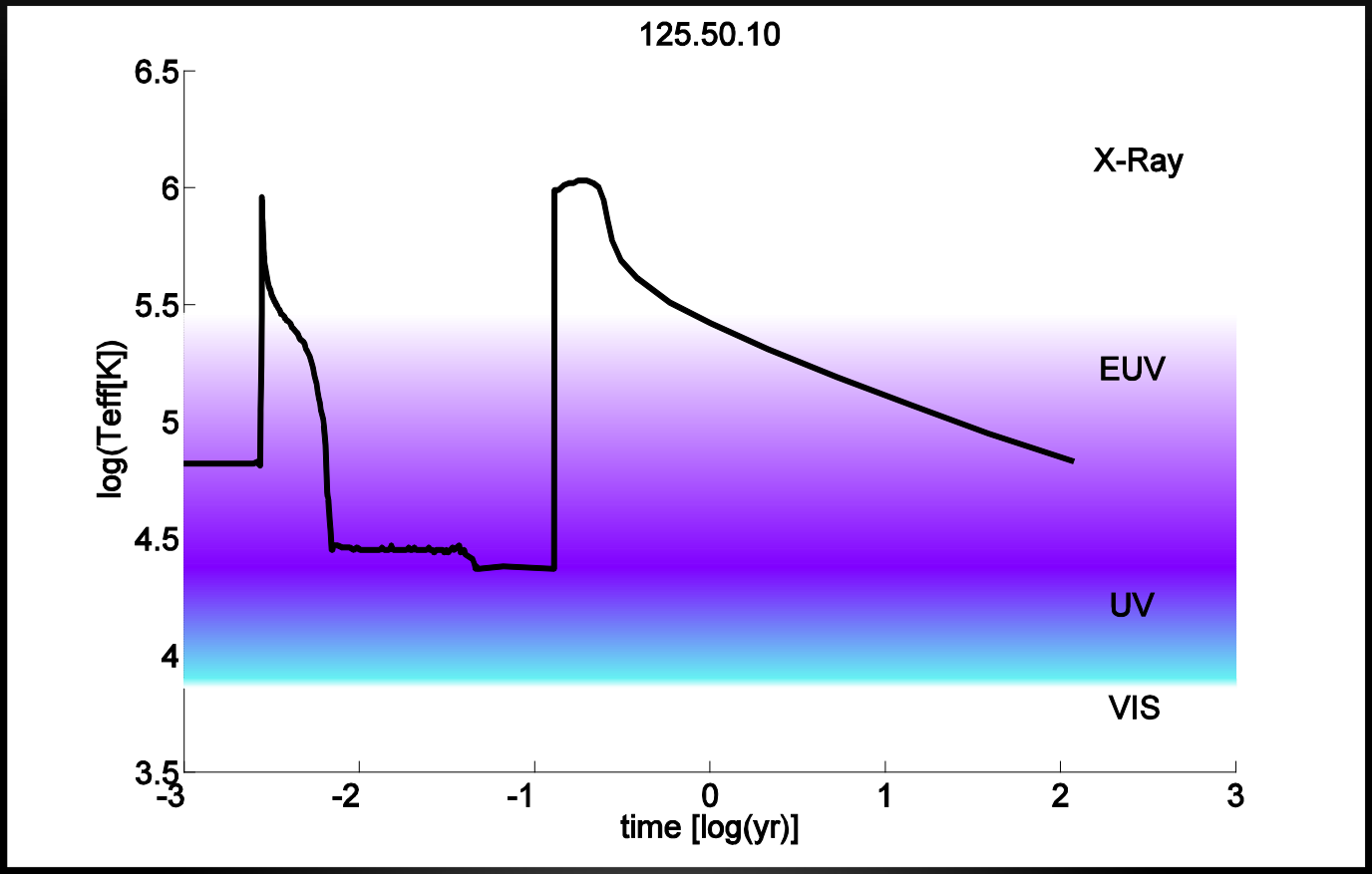
$M_{acc} = 10^{-10}M_{Sun}/yr$

Prialnik & Kovetz , 1995
Yaron et al. , 2005

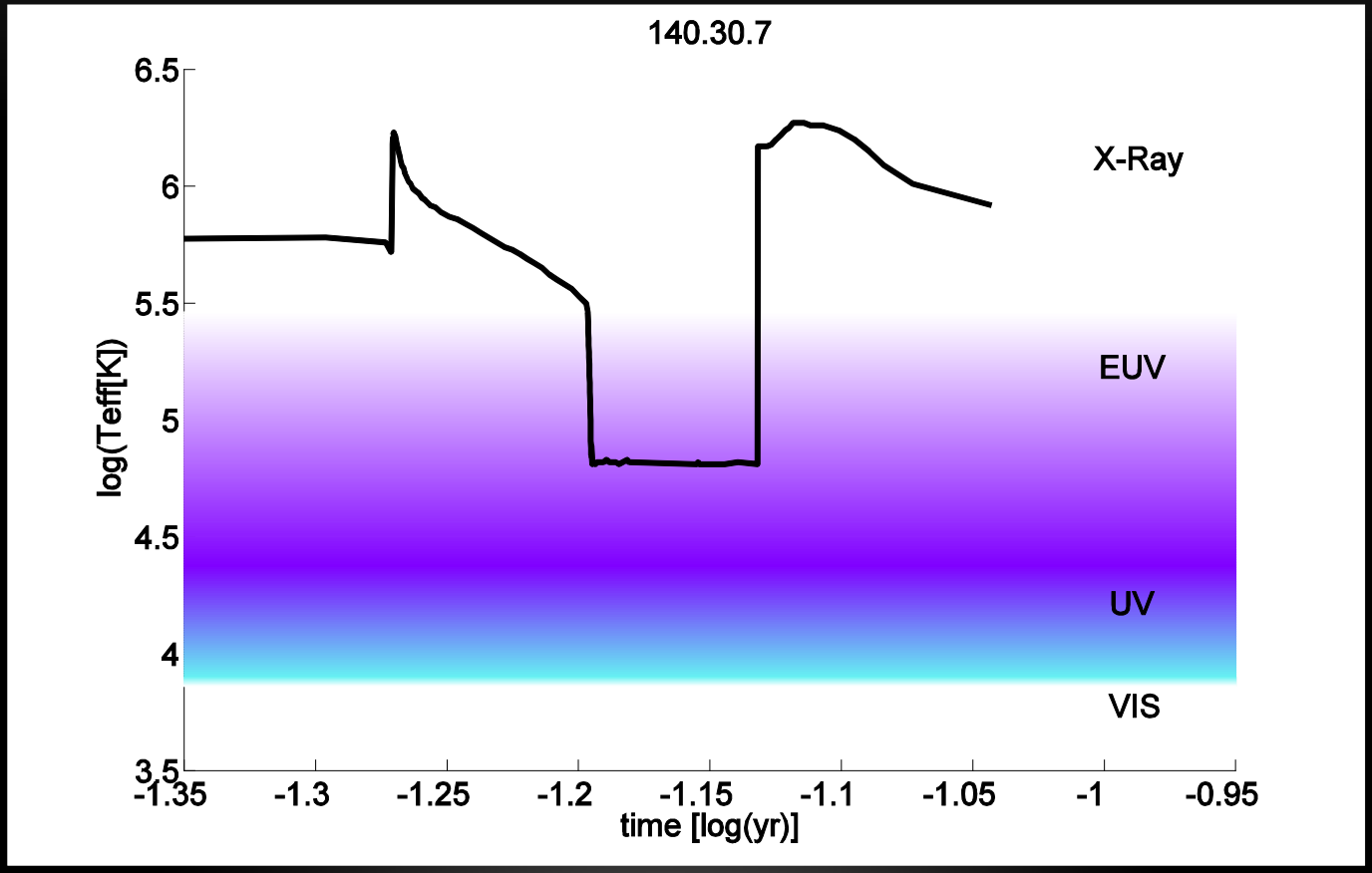



125.50.10 Flash
7
6
5
4
3
2
1
0
-1
-2
-3
20
40
60
80
100
120
140
time[hours]
Log(L[L_Sun])
Log(Teff[K])
Log(R[R_Sun])
We predict a brief (hrs-days) UV flash preceding the nova

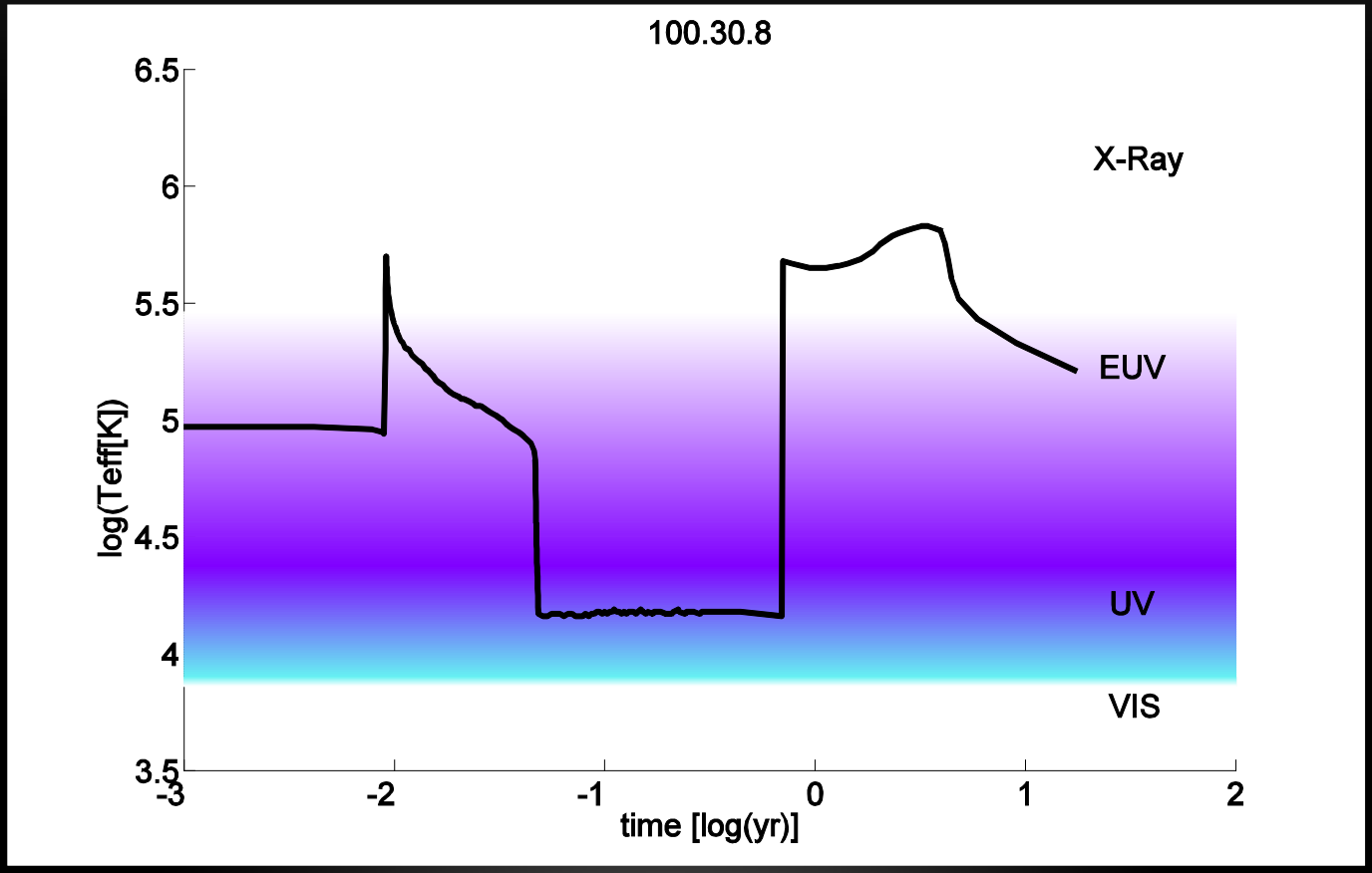
TEMPERATURE & WAVE LENGTH FOR 125.50.10



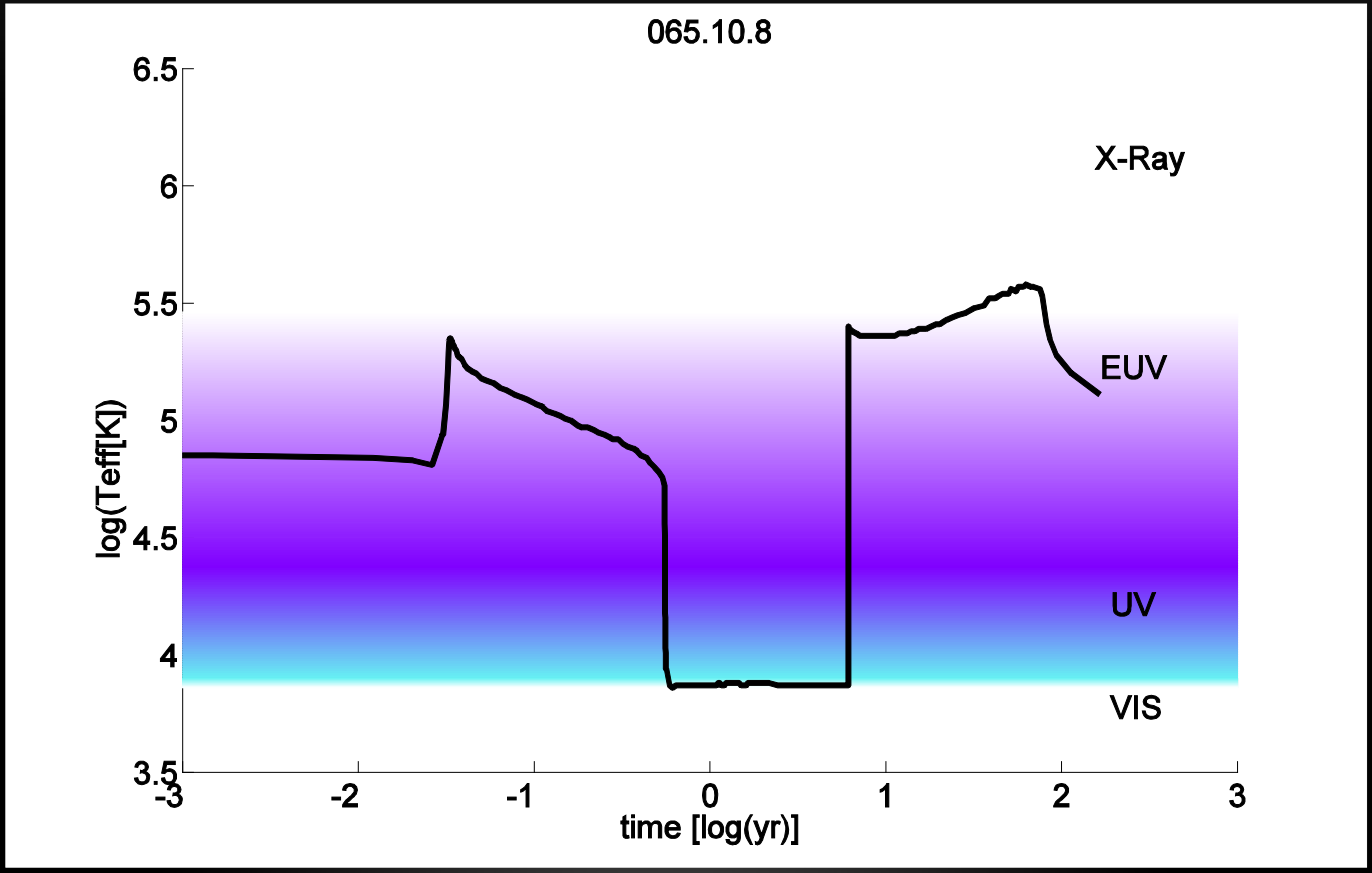
TEMPERATURE & WAVE LENGTH FOR 140.30.7



TEMPERATURE & WAVE LENGTH FOR 100.30.8

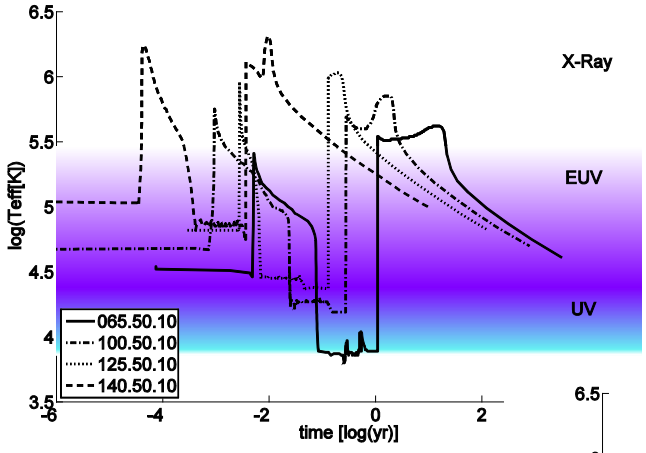


TEMPERATURE & WAVE LENGTH FOR 065.10.8

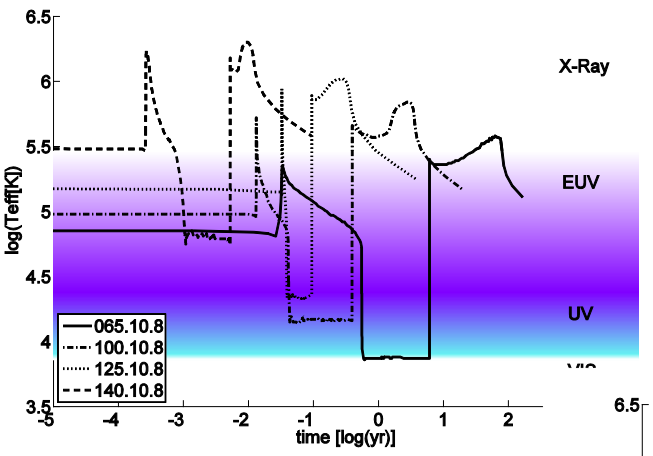


Prediction:
Brief, pre-nova UV - X-Ray flash
&
Slow, post-nova UV - X-Ray decline

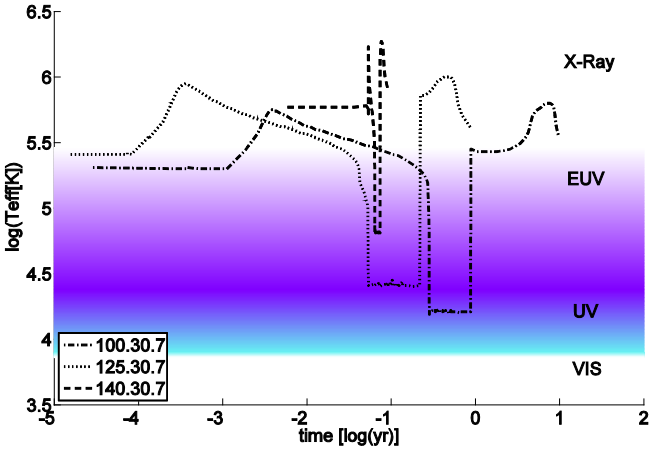
$\dot{M} = 10^{-10} M_{Sun}$



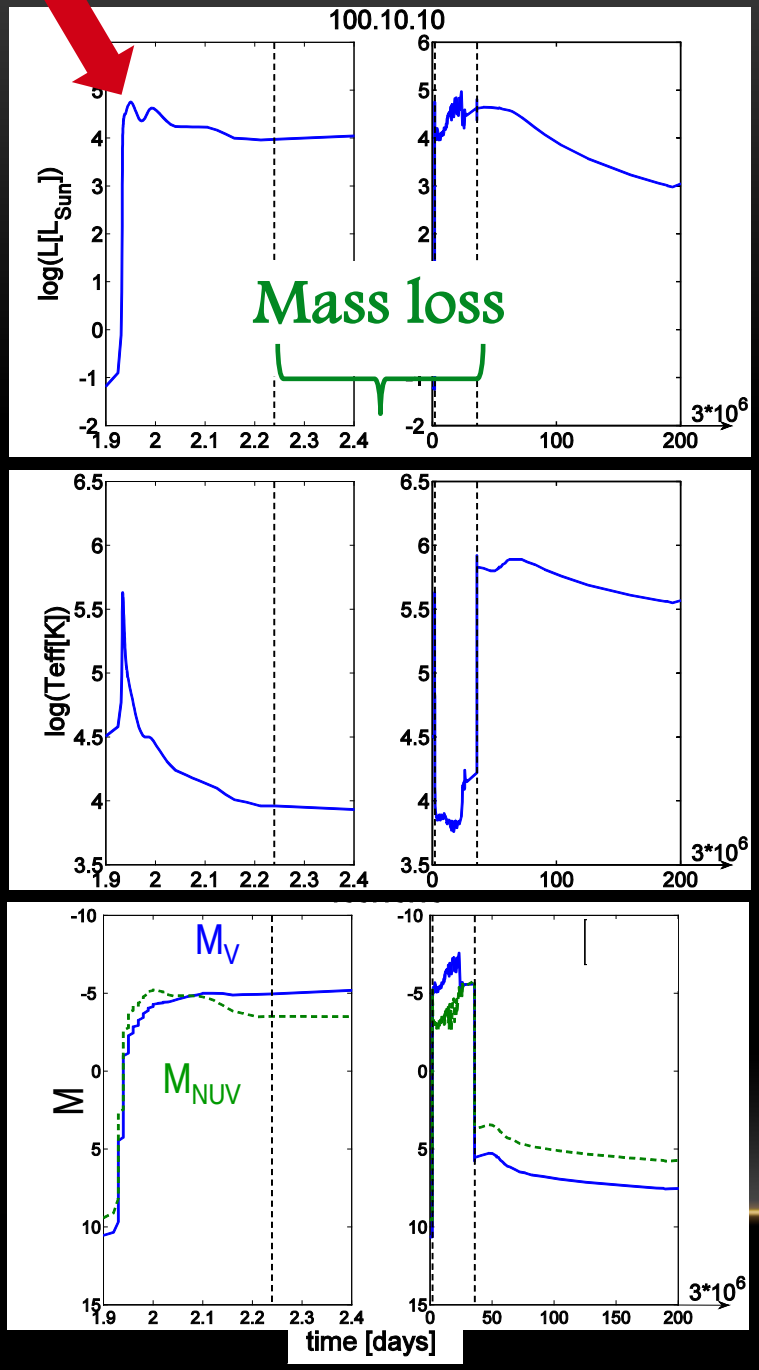
$\dot{M} = 10^{-8} M_{Sun}$



$\dot{M} = 10^{-7} M_{Sun}$



PEAKS

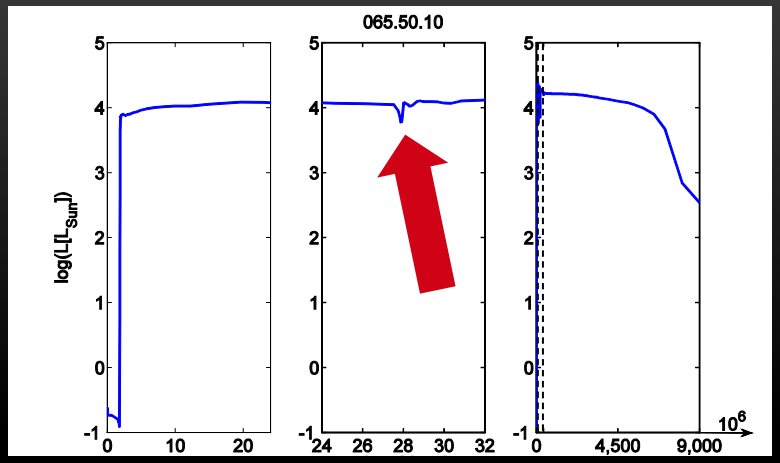


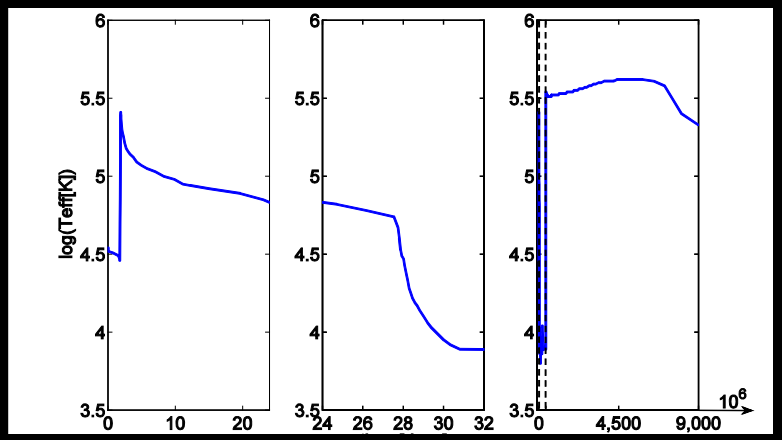
Convection

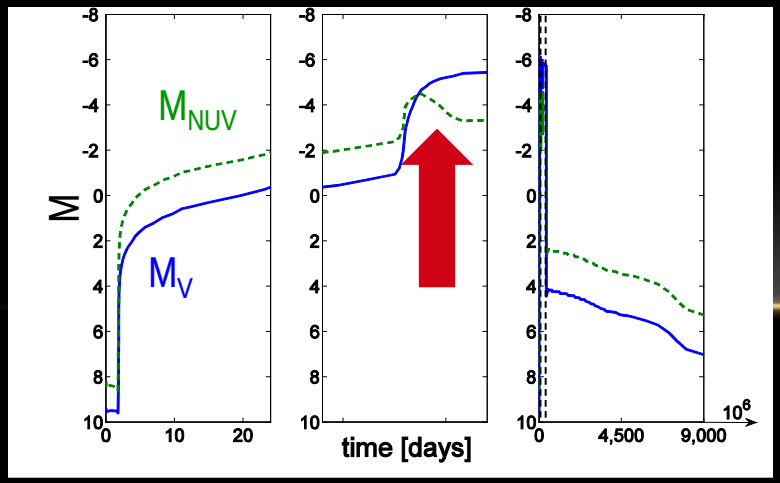
Recedes from the photosphere

~0.5 mag change in luminosity

HALTS & DIPS







Example: very slow nova

Mass loss begins @ day 97

and lasts ~ 300 days

L dip @ day 26
for ~ 24 hours,
before mass loss begins

Lower mass WD:

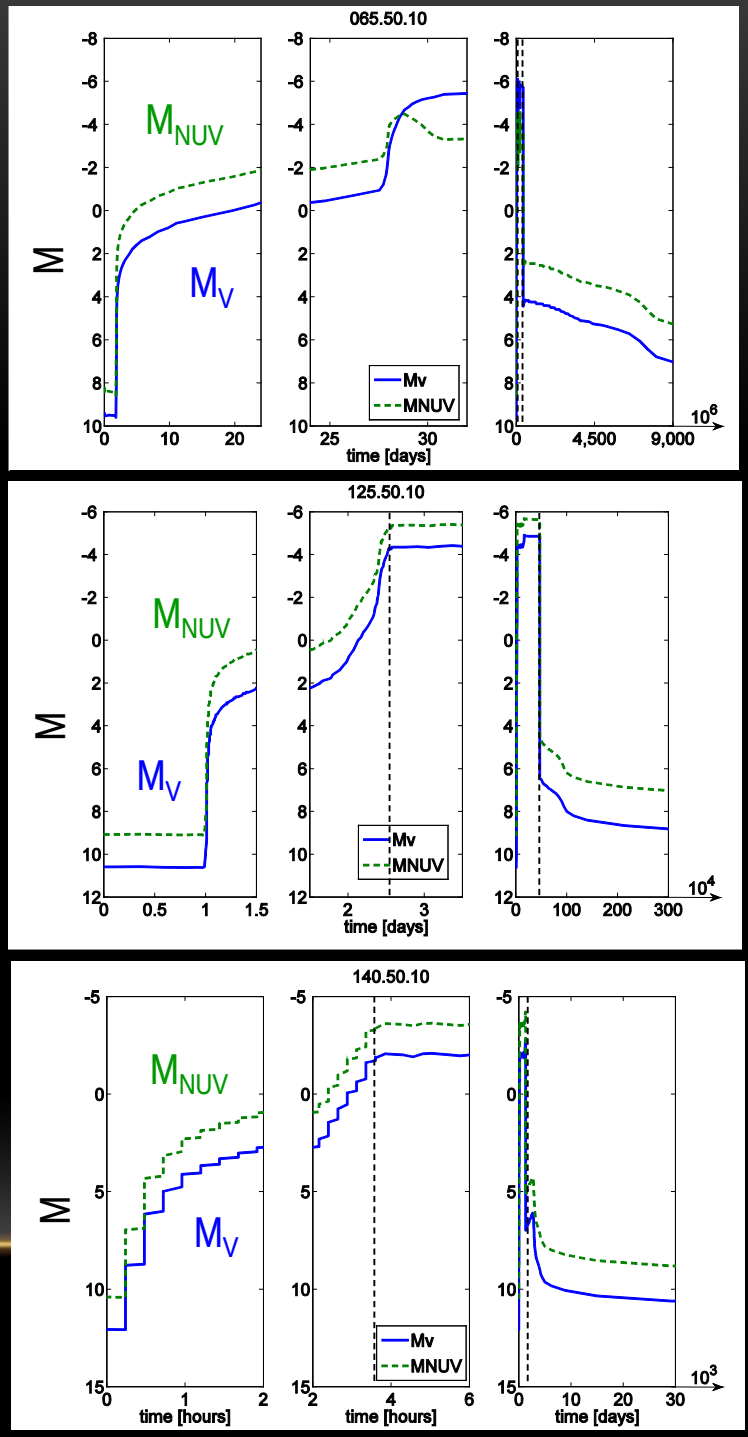
Visually brightest

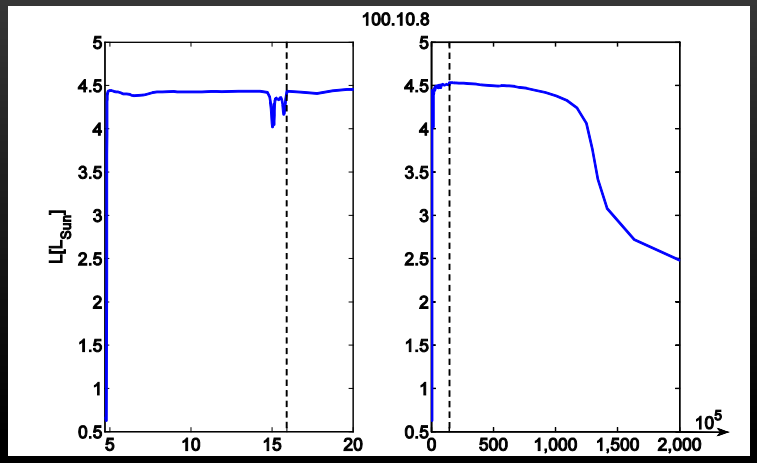
Intermediate mass WD:

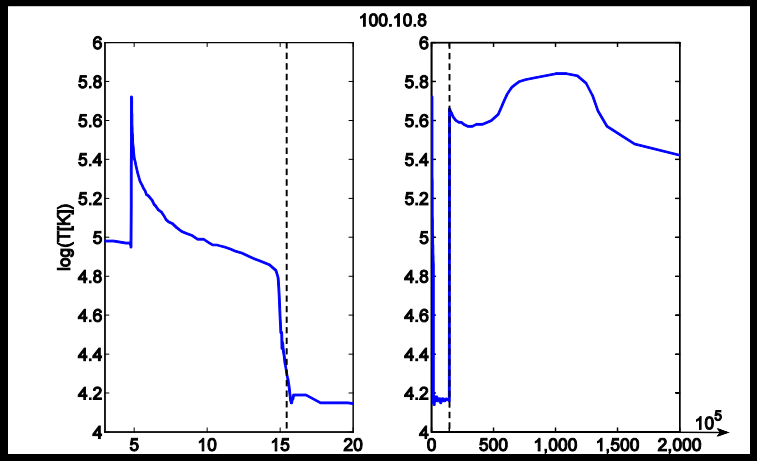
Intermediate visual brightness

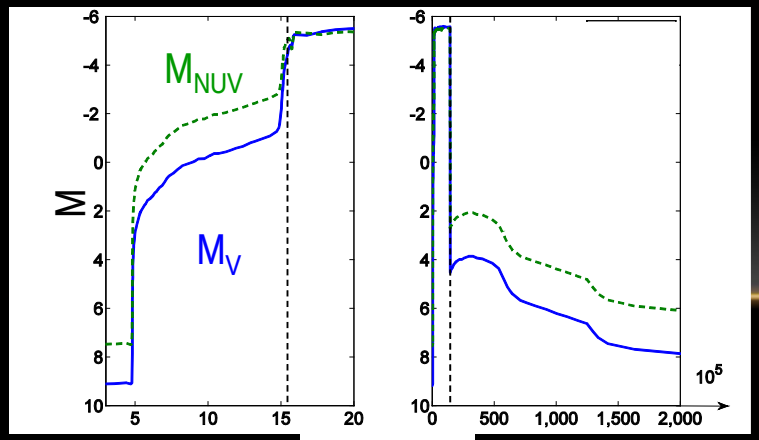
Higher mass WD:

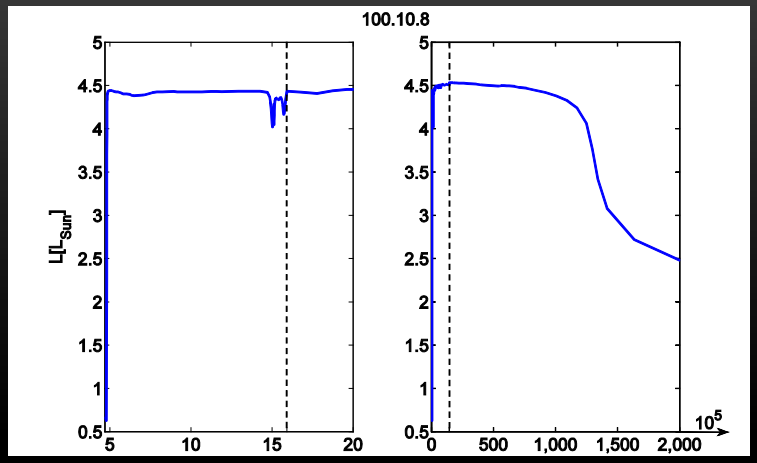
Visually faintest

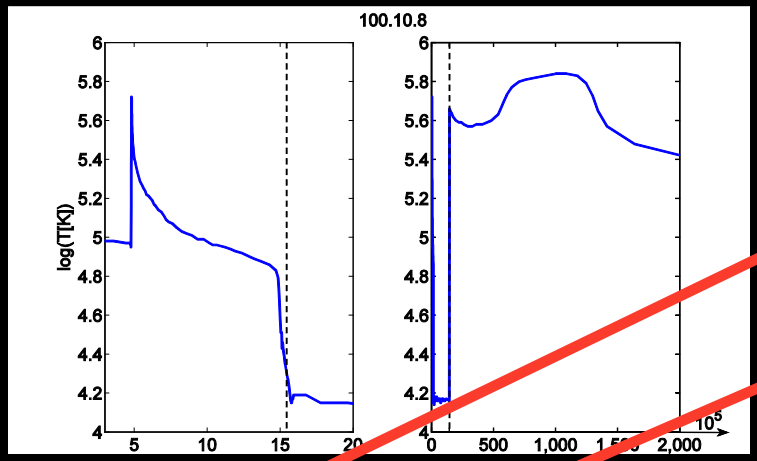


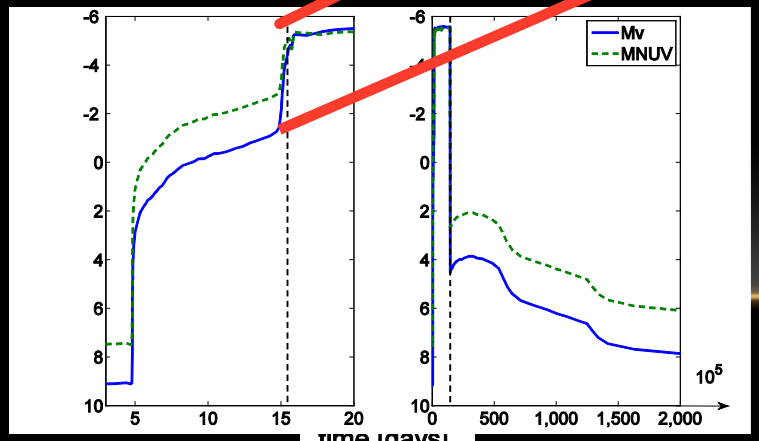

100.10.8
L[L_Sun]
10^5

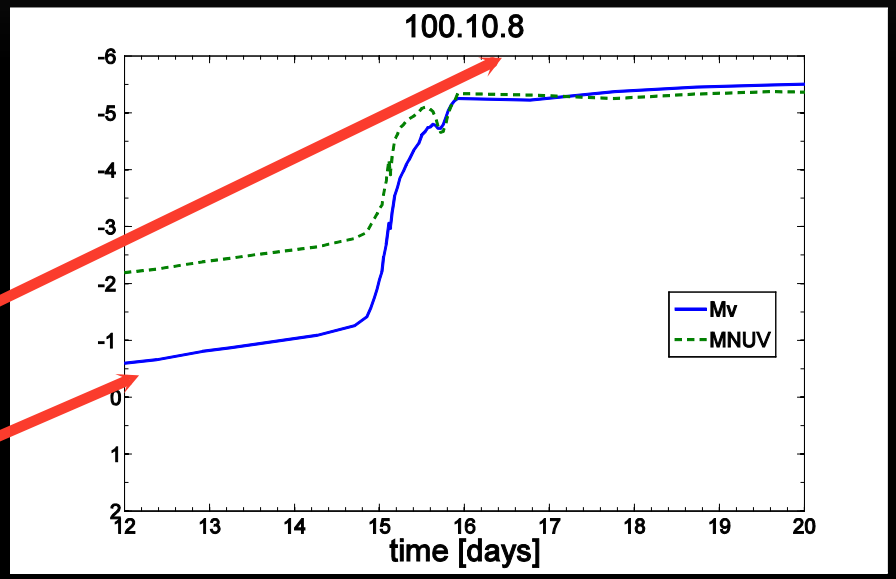

100.10.8
log(T[K])
10^5

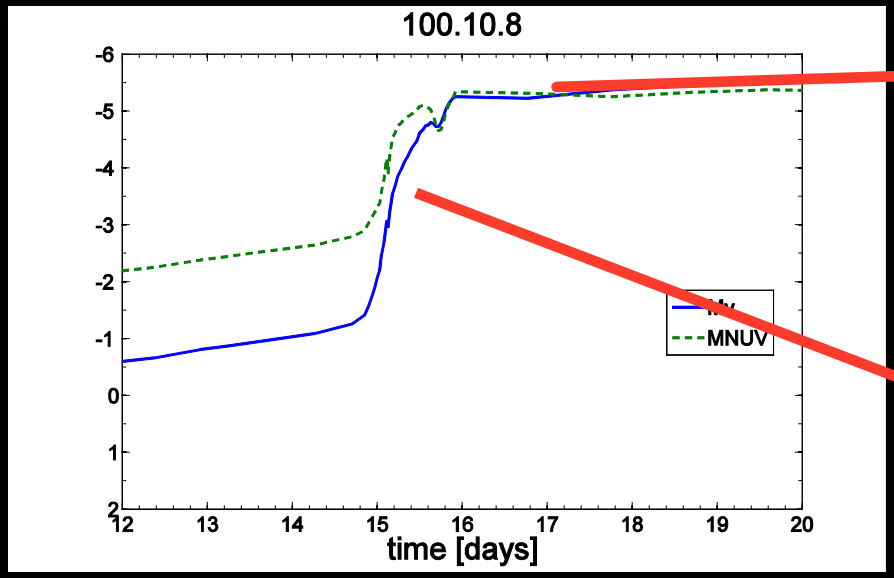

M_NUV
M_V
M
10^5
time [days]

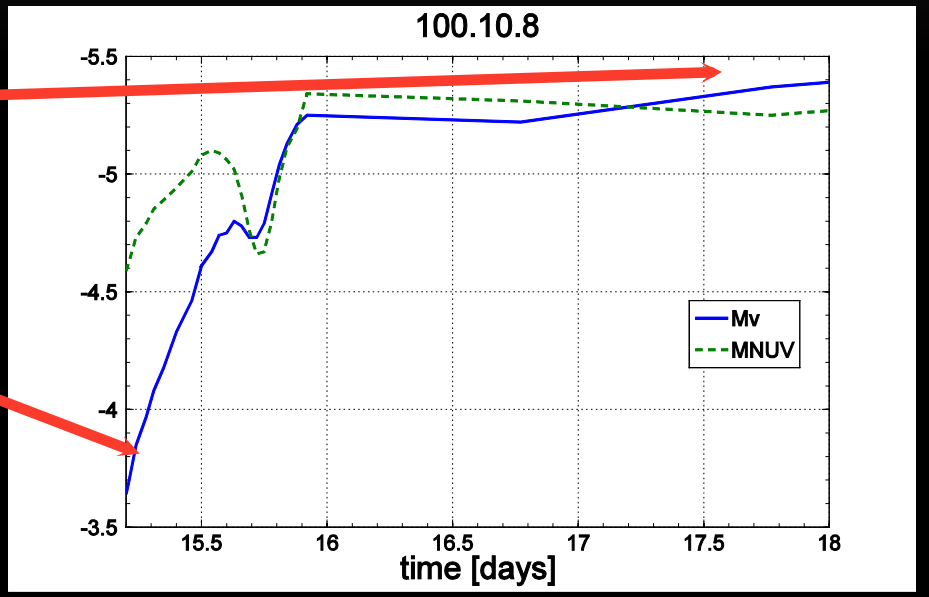

100.10.8
L[L_Sun]
10^5


100.10.8
log(T[K])
10^5

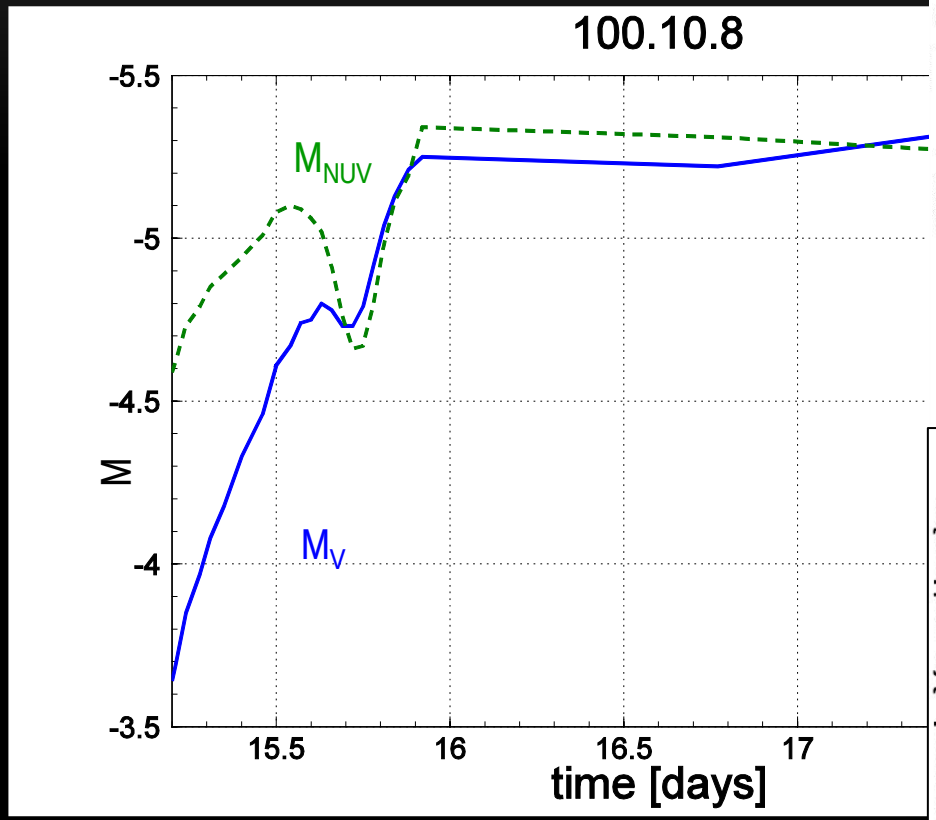

Mv
MNUV
10^5
time [days]

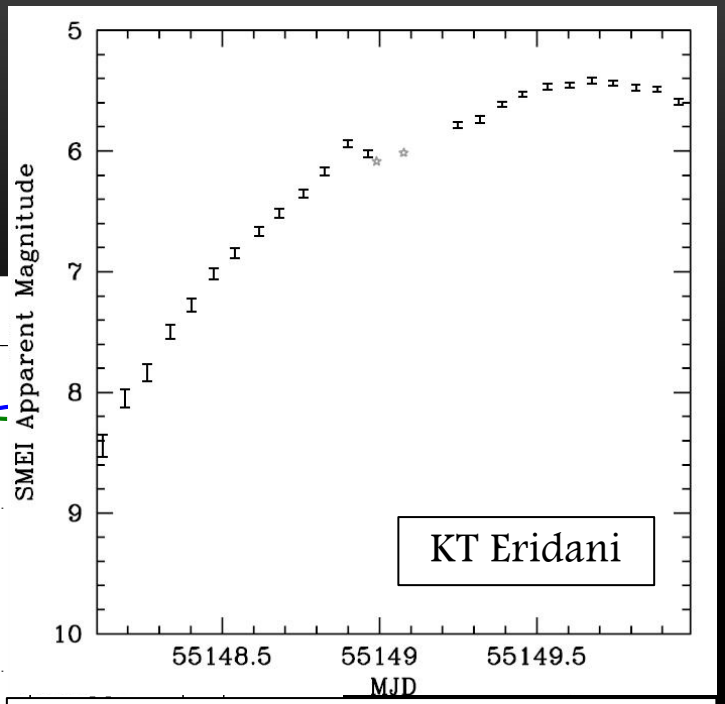

100.10.8
Mv
MNUV
time [days]

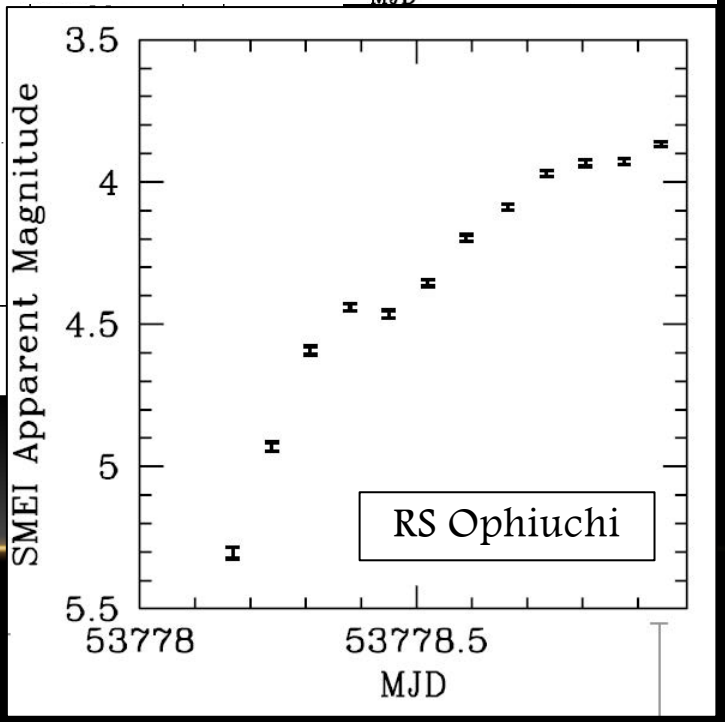

100.10.8
-6
-5
-4
-3
-2
-1
0
1
2
12
13
14
15
16
17
18
19
20
time [days]
MNUV


100.10.8
-5.5
-5
-4.5
-4
-3.5
15.5
16
16.5
17
17.5
18
time [days]
Mv
MNUV

- Halt ~ hours
- M_V change ~0.1 mag
- M_{NUV} change ~0.5 mag







Hounsell et al. 2010

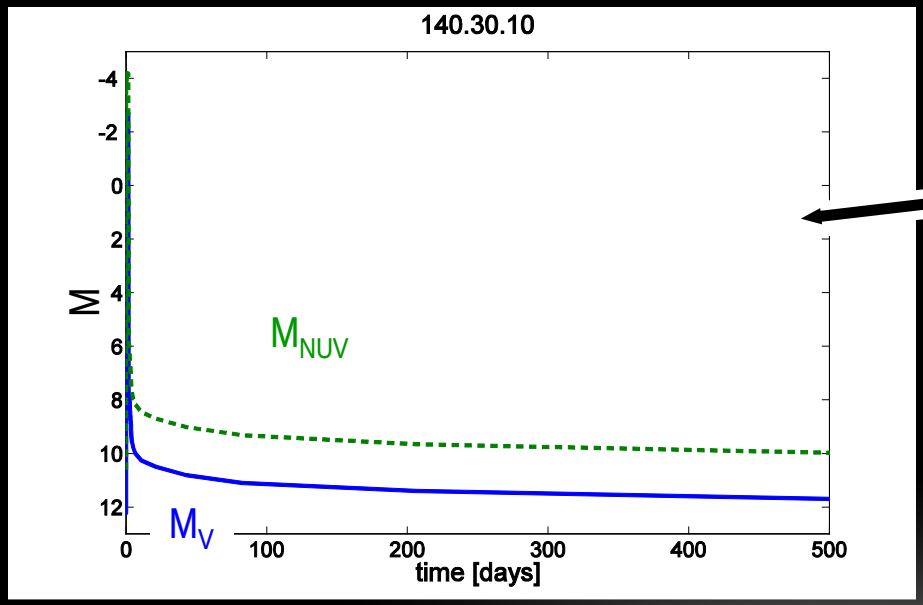
NOVAE SPECTRUM TIME TABLE

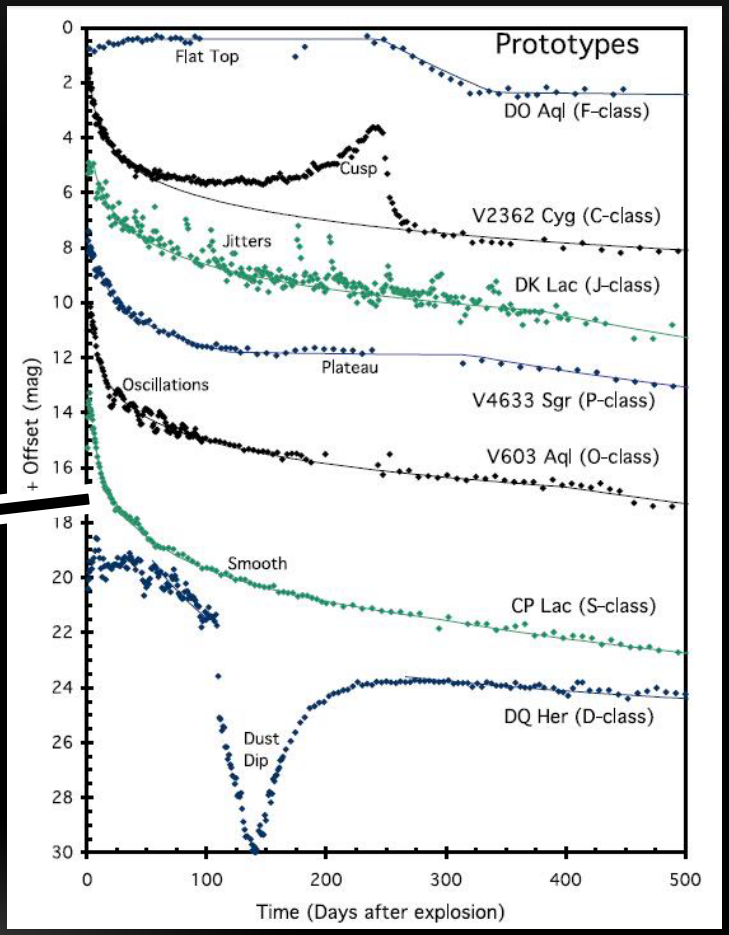
type	Model	early flash						sum [d]	during nova		after nova					sum [yr]
NS	65 10 10	X-ray	-------	EUV	8 d	UV	41 d	**49.00**	VIS (high)	0.5 yr	EUV	-------	X-ray	90 yr	EUV	1.3E+04 yr	**1.31E+04**
SymN	65 30 8	X-ray	-------	EUV	207 d	UV	-------	**207.00**	UV	10 yr	EUV	22 yr	X-ray	55 yr	EUV	120 yr	**1.97E+02**
NVS	65 30 9	X-ray	-------	EUV	50 d	UV	4 d	**54.00**	UV-VIS	2 yr	EUV	-------	X-ray	30 yr	EUV	600 yr	**6.30E+02**
NVS	65 30 10	X-ray	-------	EUV	16 d	UV	4 d	**20.00**	UV-VIS	1.5 yr	EUV	-------	X-ray	20 yr	EUV	2.5E+03 yr	**2.52E+03**
RN	100 10 7	X-ray	12 d	EUV	60 d	UV	-------	**72.00**	UV	210 d	EUV	-------	X-ray	8 yr	-------	-------	**8.00E+00**
NS	100 10 8	X-ray	3 hr	EUV	10 d	UV	35 hr	**11.50**	UV	125 d	EUV	-------	X-ray	4yr	EUV	15 yr	**1.90E+01**
NM	100 10 9	X-ray	15 min	EUV	40 hr	UV	25 hr	**2.70**	UV	150 d	EUV	-------	X-ray	3yr	EUV	500 yr	**5.03E+02**
RN	100 30 7	X-ray	24 d	EUV	80 d	UV	12 hr	**104.50**	UV	220 d	EUV	2 yr	X-ray	9 yr	-------	-------	**1.10E+01**
NS	100 30 10	X-ray	30 min	EUV	2.25 d	UV	11 hr	**2.70**	UV	120 d	EUV	-------	X-ray	2 yr	EUV	1E+03 yr	**1.00E+03**
NS	100 50 9	X-ray	2.5 hr	EUV	7 d	UV	1.5 d	**8.60**	UV	120 d	EUV	-------	X-ray	3 yr	EUV	100 yr	**1.03E+02**
NM	100 50 10	X-ray	5 hr	EUV	4.5 d	UV	1.5 d	**6.20**	UV	90 d	EUV	-------	X-ray	2.5 yr	EUV	800 yr	**8.03E+02**
NVF	125 10 9	X-ray	12 min	EUV	4.7 hr	UV	-------	**0.20**	UV (high)	10 d	EUV	-------	X-ray	275 d	EUV	70 yr	**7.08E+01**
NVF	125 10 10	X-ray	7 min	EUV	1.7 hr	UV	-------	**0.08**	EUV-UV	25 d	EUV	-------	X-ray	336 d	EUV	1E+03 yr	**1.00E+03**
RN	125 30 7	X-ray	9 d	EUV	11 d	UV	-------	**20.00**	EUV	60 d	EUV	-------	X-ray	236 d	-------	-------	**6.46E-01**
NF	125 30 10	X-ray	35 min	EUV	23 hr	UV	-------	**0.98**	EUV-UV	20 d	EUV	-------	X-ray	250 d	EUV	110 yr	**1.11E+02**
NM	125 50 8	X-ray	5.5 hr	EUV	2 d	UV	-------	**2.23**	EUV-UV	60 d	EUV	-------	X-ray	1.2 yr	EUV	1.5 yr	**2.70E+00**
NF	125 50 9	X-ray	5.2 hr	EUV	1.25 d	UV	-------	**1.47**	EUV-UV	25 d	EUV	-------	X-ray	300 d	EUV	20 yr	**2.08E+01**
NF	125 50 10	X-ray	7.2 hr	EUV	1.1 d	UV	-------	**1.40**	EUV-UV	45 d	EUV	-------	X-ray	243 d	EUV	120 yr	**1.21E+02**
RN	140 10 8	X-ray	6.5 hr	EUV	2.5 hr	UV	-------	**0.38**	EUV	1.5 d	EUV	-------	X-ray	35 d	-------	-------	**9.58E-02**
NVF	140 10 10	X-ray	15 min	EUV	13 min	UV	-------	**0.02**	EUV	0.7 d	EUV	-------	X-ray	90 d	EUV	120 yr	**1.20E+02**
----	140 50 7	X-ray	22 d	EUV	2.5 hr	UV	-------	**22.10**	EUV	3.5 d	EUV	-------	X-ray	5 d	-------	-------	**1.37E-02**
RN	140 50 8	X-ray	12 hr	EUV	5 hr	UV	-------	**0.71**	EUV	5 d	EUV	-------	X-ray	30 d	-------	-------	**8.21E-02**
NVF	140 50 9	X-ray	2 hr	EUV	2 hr	UV	-------	**0.17**	EUV	2 d	EUV	-------	X-ray	80 d	EUV	290 d	**1.01E+00**
NVF	140 50 10	X-ray	2 hr	EUV	1.1 hr	UV	-------	**0.13**	EUV	1.5 d	EUV	-------	X-ray	70 d	EUV	10 yr	**1.02E+01**

type	model	early flash						sum [d]
NS	65 10 10	x-ray	-------	EUV	8 d	UV	41 d	**49.00**
SymN	65 30 8	x-ray	-------	EUV	207 d	UV	-------	**207.00**
NVS	65 30 9	x-ray	-------	EUV	50 d	UV	4 d	**54.00**
NVS	65 30 10	x-ray	-------	EUV	16 d	UV	4 d	**20.00**
RN	100 10 7	x-ray	12 d	EUV	60 d	UV	-------	**72.00**
NS	100 10 8	x-ray	3 hr	EUV	10 d	UV	35 hr	**11.50**
NM	100 10 9	x-ray	15 min	EUV	40 hr	UV	25 hr	**2.70**
RN	100 30 7	x-ray	24 d	EUV	80 d	UV	12 hr	**104.50**
NS	100 30 10	x-ray	30 min	EUV	2.25 d	UV	11 hr	**2.70**
NS	100 50 9	x-ray	2.5 hr	EUV	7 d	UV	1.5 d	**8.60**
NM	100 50 10	x-ray	5 hr	EUV	4.5 d	UV	1.5 d	**6.20**
NVF	125 10 9	x-ray	12 min	EUV	4.7 hr	UV	-------	**0.20**
NVF	125 10 10	x-ray	7 min	EUV	1.7 hr	UV	-------	**0.08**

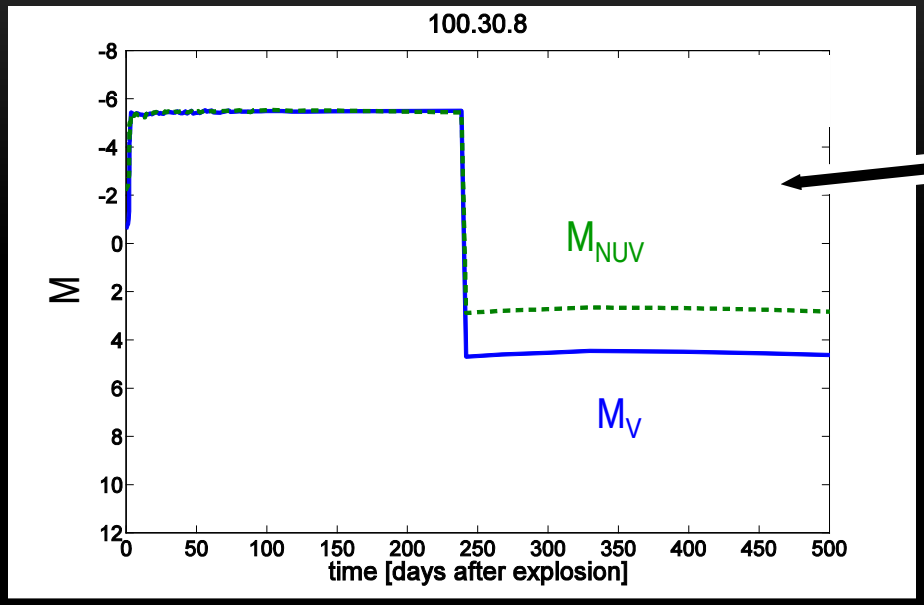
type	Model	early flash						sum [d]	during nova		after nova					sum [yr]
NS	65 10 10	X-ray	-------	EUV	8 d	UV	41 d	**49.00**	VIS (high)	0.5 yr	EUV	-------	X-ray	90 yr	EUV	1.3E+04 yr	**1.31E+04**
SymN	65 30 8	X-ray	-------	EUV	207 d	UV	-------	**207.00**	UV	10 yr	EUV	22 yr	X-ray	55 yr	EUV	120 yr	**1.97E+02**
NVS	65 30 9	X-ray	-------	EUV	50 d	UV	4 d	**54.00**	UV-VIS	2 yr	EUV	-------	X-ray	30 yr	EUV	600 yr	**6.30E+02**
NVS	65 30 10	X-ray	-------	EUV	16 d	UV	4 d	**20.00**	UV-VIS	1.5 yr	EUV	-------	X-ray	20 yr	EUV	2.5E+03 yr	**2.52E+03**
RN	100 10 7	X-ray	12 d	EUV	60 d	UV	-------	**72.00**	UV	210 d	EUV	-------	X-ray	8 yr	-------	-------	**8.00E+00**
NS	100 10 8	X-ray	3 hr	EUV	10 d	UV	35 hr	**11.50**	UV	125 d	EUV	-------	X-ray	4yr	EUV	15 yr	**1.90E+01**
NM	100 10 9	X-ray	15 min	EUV	40 hr	UV	25 hr	**2.70**	UV	150 d	EUV	-------	X-ray	3yr	EUV	500 yr	**5.03E+02**
RN	100 30 7	X-ray	24 d	EUV	80 d	UV	12 hr	**104.50**	UV	220 d	EUV	2 yr	X-ray	9 yr	-------	-------	**1.10E+01**
NS	100 30 10	X-ray	30 min	EUV	2.25 d	UV	11 hr	**2.70**	UV	120 d	EUV	-------	X-ray	2 yr	EUV	1E+03 yr	**1.00E+03**
NS	100 50 9	X-ray	2.5 hr	EUV	7 d	UV	1.5 d	**8.60**	UV	120 d	EUV	-------	X-ray	3 yr	EUV	100 yr	**1.03E+02**
NM	100 50 10	X-ray	5 hr	EUV	4.5 d	UV	1.5 d	**6.20**	UV	90 d	EUV	-------	X-ray	2.5 yr	EUV	800 yr	**8.03E+02**
NVF	125 10 9	X-ray	12 min	EUV	4.7 hr	UV	-------	**0.20**	UV (high)	10 d	EUV	-------	X-ray	275 d	EUV	70 yr	**7.08E+01**
NVF	125 10 10	X-ray	7 min	EUV	1.7 hr	UV	-------	**0.08**	EUV-UV	25 d	EUV	-------	X-ray	336 d	EUV	1E+03 yr	**1.00E+03**
RN	125 30 7	X-ray	9 d	EUV	11 d	UV	-------	**20.00**	EUV	60 d	EUV	-------	X-ray	236 d	-------	-------	**6.46E-01**
NF	125 30 10	X-ray	35 min	EUV	23 hr	UV	-------	**0.98**	EUV-UV	20 d	EUV	-------	X-ray	250 d	EUV	110 yr	**1.11E+02**
NM	125 50 8	X-ray	5.5 hr	EUV	2 d	UV	-------	**2.23**	EUV-UV	60 d	EUV	-------	X-ray	1.2 yr	EUV	1.5 yr	**2.70E+00**
NF	125 50 9	X-ray	5.2 hr	EUV	1.25 d	UV	-------	**1.47**	EUV-UV	25 d	EUV	-------	X-ray	300 d	EUV	20 yr	**2.08E+01**
NF	125 50 10	X-ray	7.2 hr	EUV	1.1 d	UV	-------	**1.40**	EUV-UV	45 d	EUV	-------	X-ray	243 d	EUV	120 yr	**1.21E+02**
RN	140 10 8	X-ray	6.5 hr	EUV	2.5 hr	UV	-------	**0.38**	EUV	1.5 d	EUV	-------	X-ray	35 d	-------	-------	**9.58E-02**
NVF	140 10 10	X-ray	15 min	EUV	13 min	UV	-------	**0.02**	EUV	0.7 d	EUV	-------	X-ray	90 d	EUV	120 yr	**1.20E+02**
----	140 50 7	X-ray	22 d	EUV	2.5 hr	UV	-------	**22.10**	EUV	3.5 d	EUV	-------	X-ray	5 d	-------	-------	**1.37E-02**
RN	140 50 8	X-ray	12 hr	EUV	5 hr	UV	-------	**0.71**	EUV	5 d	EUV	-------	X-ray	30 d	-------	-------	**8.21E-02**
NVF	140 50 9	X-ray	2 hr	EUV	2 hr	UV	-------	**0.17**	EUV	2 d	EUV	-------	X-ray	80 d	EUV	290 d	**1.01E+00**
NVF	140 50 10	X-ray	2 hr	EUV	1.1 hr	UV	-------	**0.13**	EUV	1.5 d	EUV	-------	X-ray	70 d	EUV	10 yr	**1.02E+01**

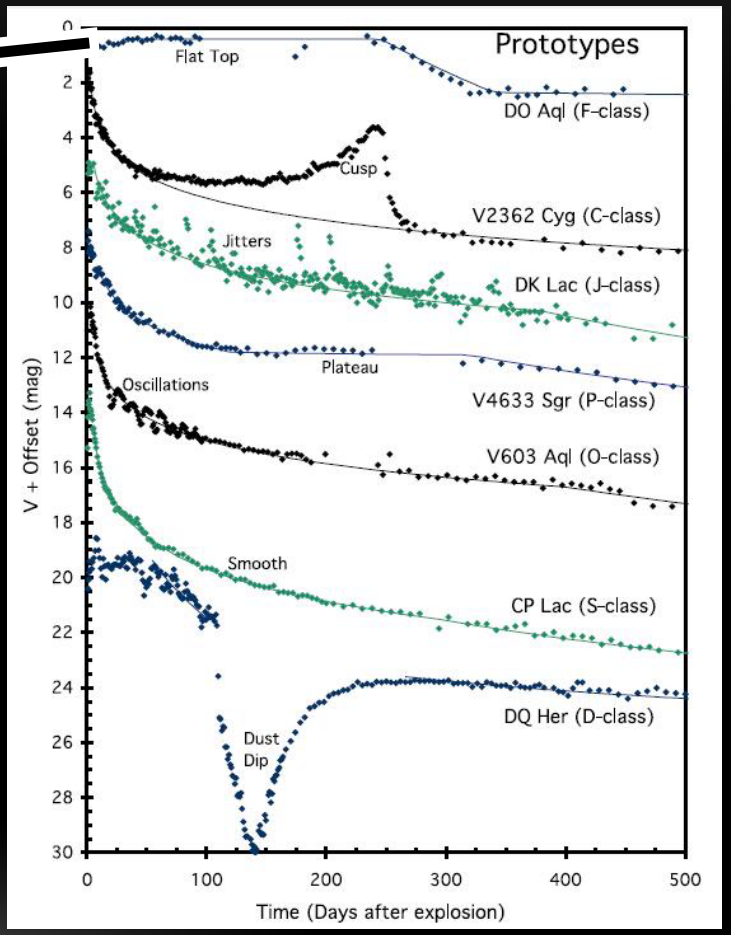
CLASSIFICATION BY DECLINE



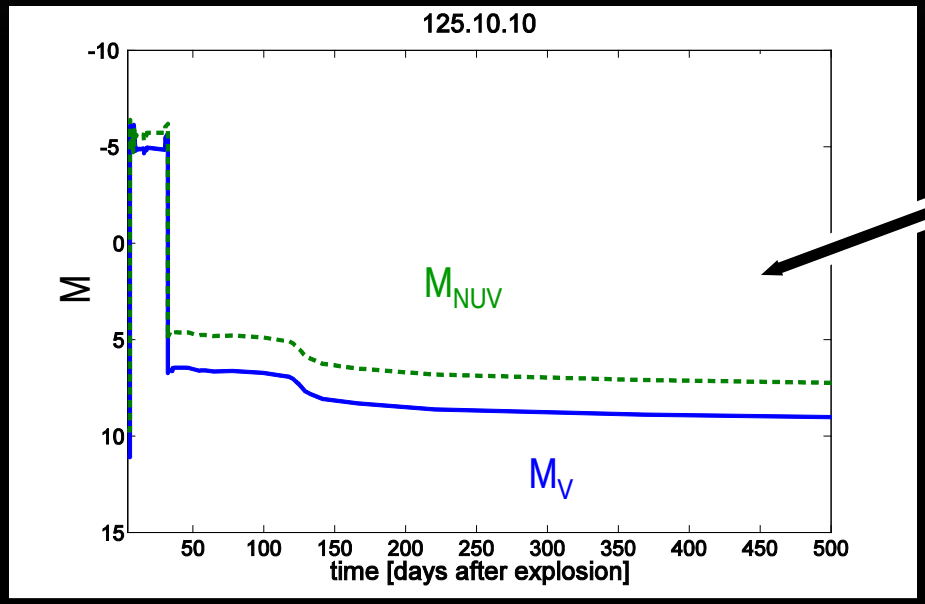


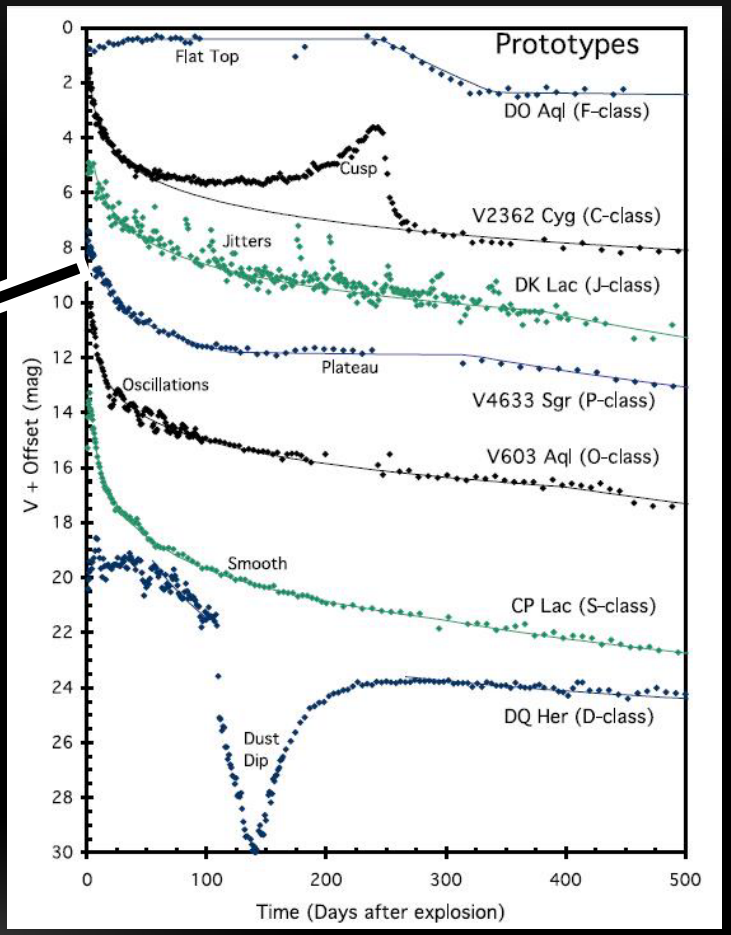
Strope et al., 2010





Strope et al., 2010





Strope et al., 2010

SUMMARY

- Prediction: a pre-nova UV – X-Ray flash, on time scales ranging from hours till tens of days
- Explanation: pre-maximum halts caused by convection receding from the photosphere
- Estimation of WD mass and mdot from multi wavelength observations
- Light curve categorization

THANK YOU!