Accreting White Dwarfs in Cataclysmic Binaries

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OUTLINE OF TALK

- 1. Overview
- 2. Types of Cataclysmics
- 3. Space Observations
- 4. Model Photospheres & Accretion Disks
- 5. Spectra of Accreting White Dwarfs
- 6. Evolutionary Tools
- 7. Summary of WDs in Cataclysmics
- 8. Open Questions & New Frontiers

Physical Processes in Isolated White Dwarfs

Thermal Cooling

Gravitational and Thermal Diffusion

Convection and Convective mixing

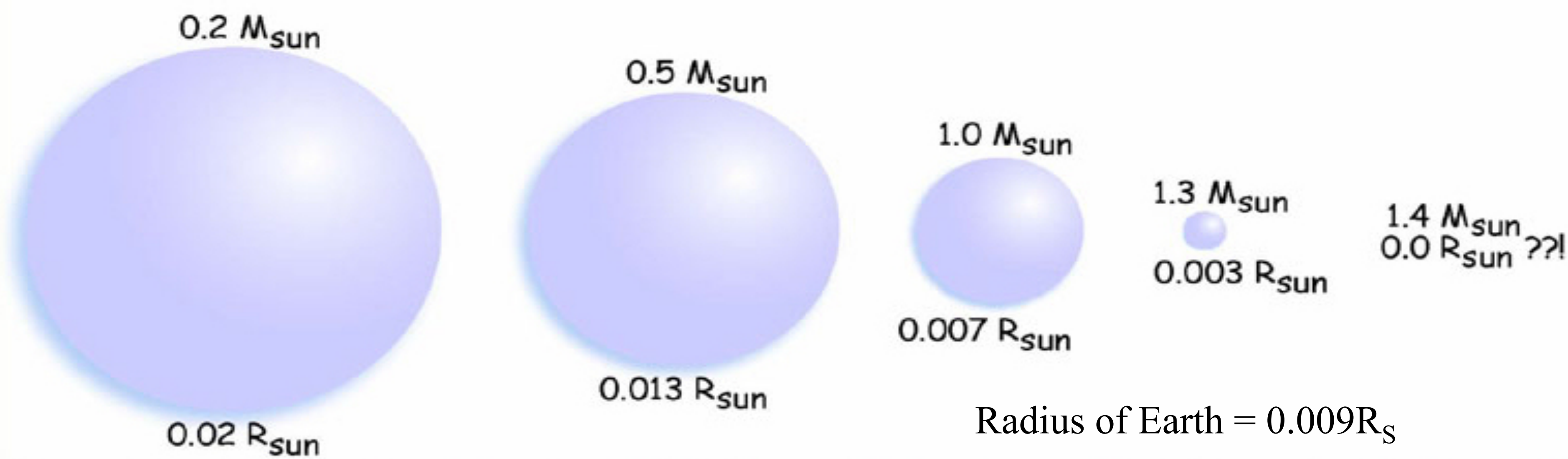
Radiative Levitation and Weak Winds

Accretion from Debris Disks and the Interstellar Medium

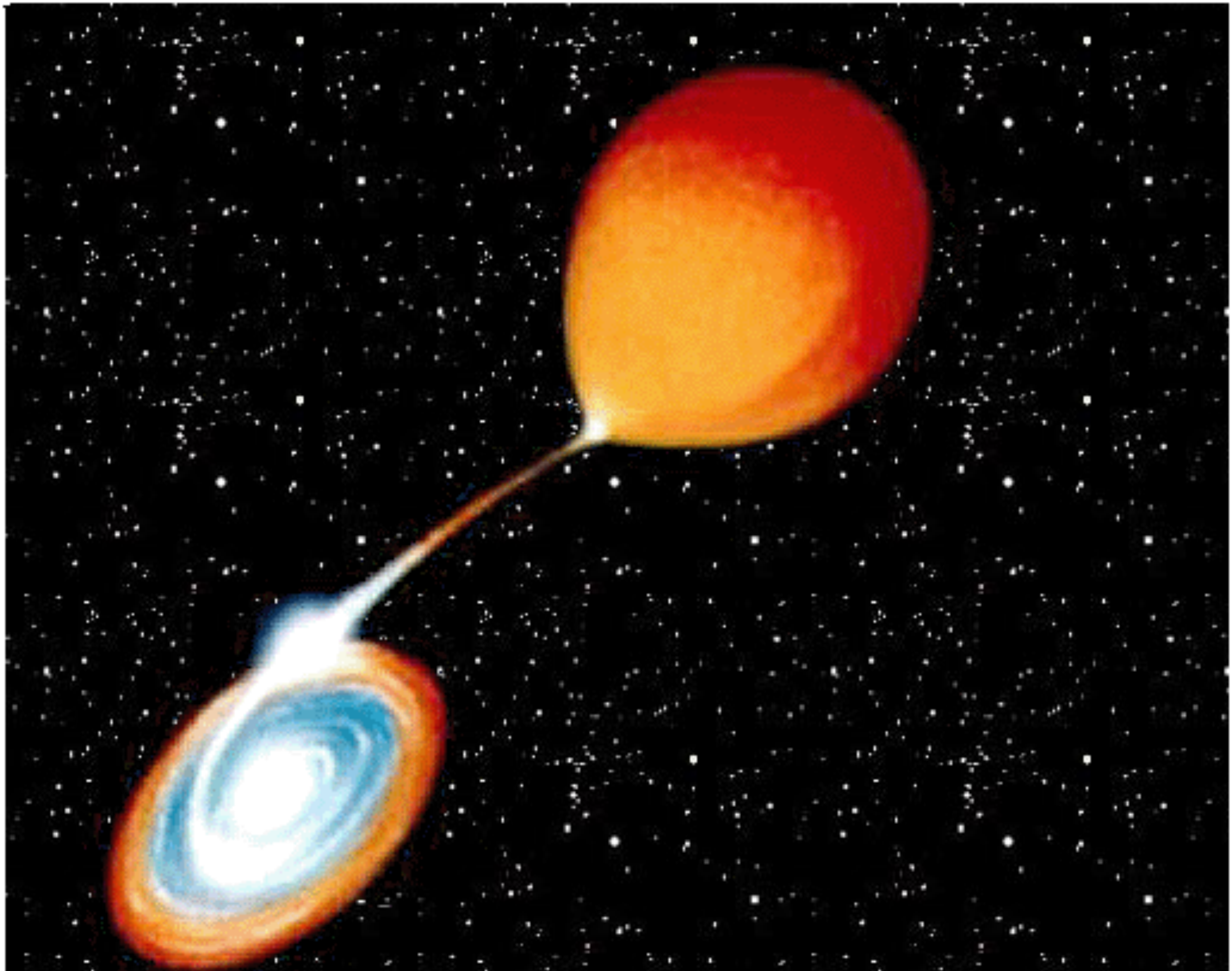
Core Crystallization

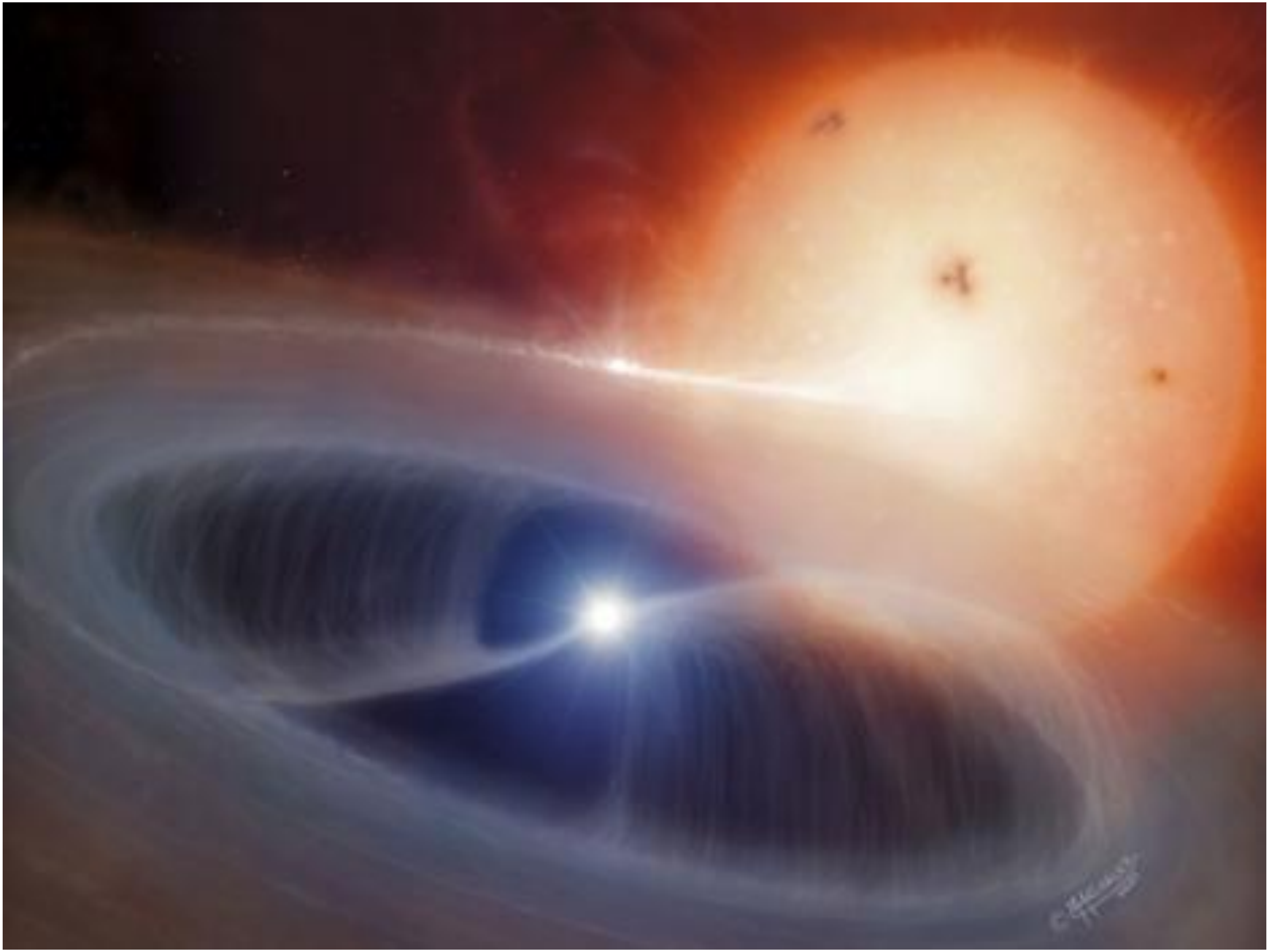
Residual Thermonuclear Burning

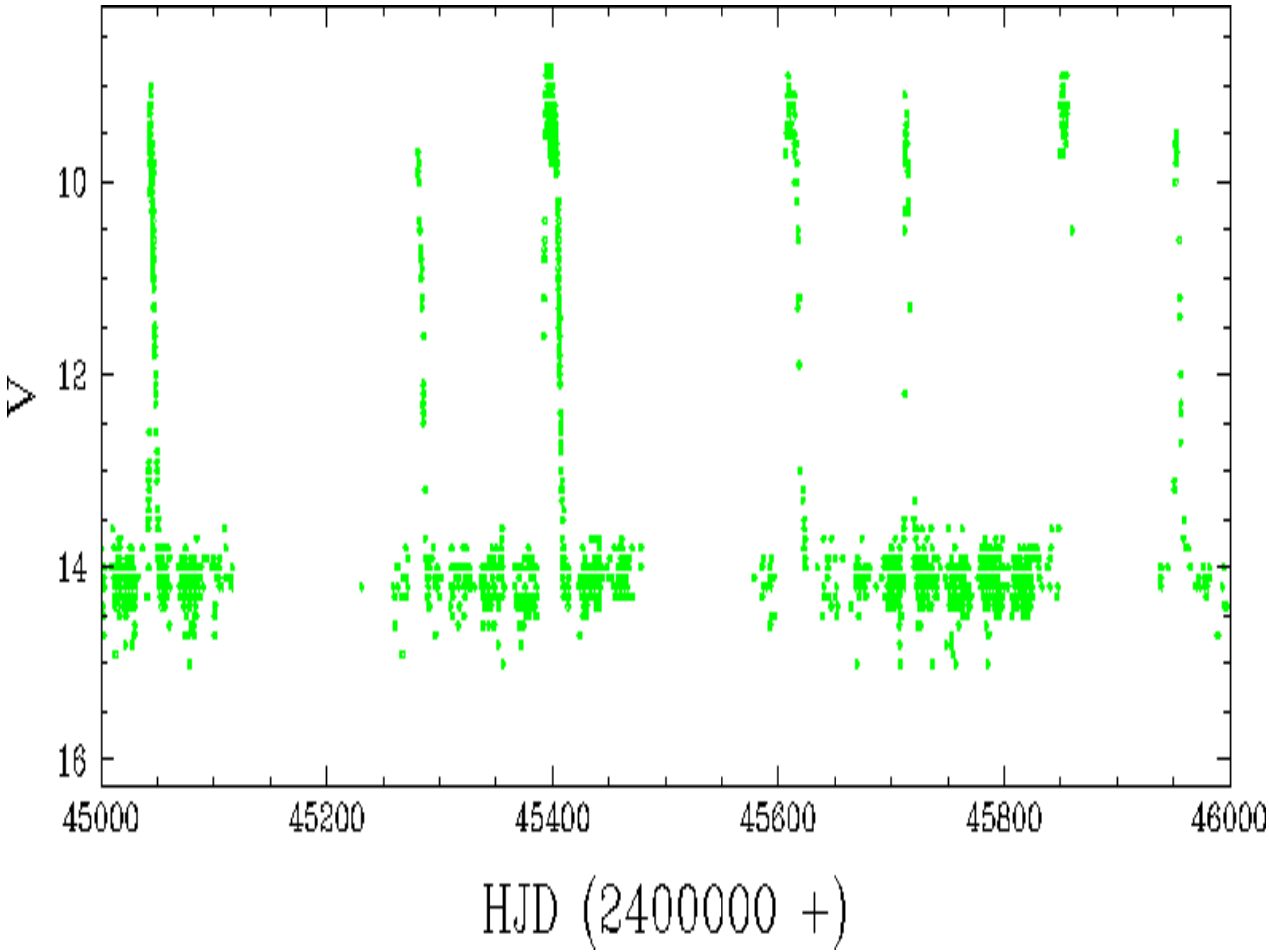
White Dwarf Stars



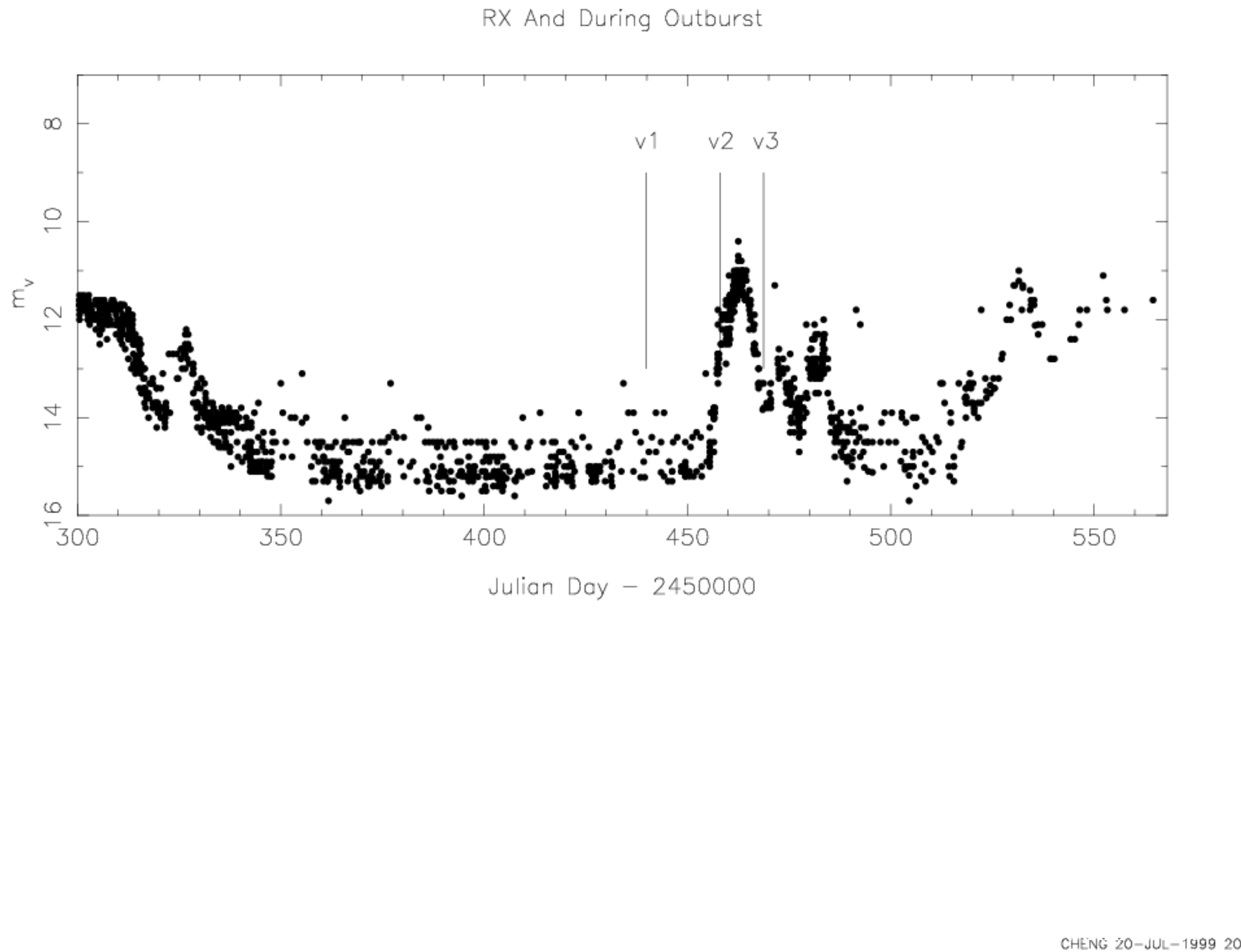
Radius of Earth = $0.009R_S$

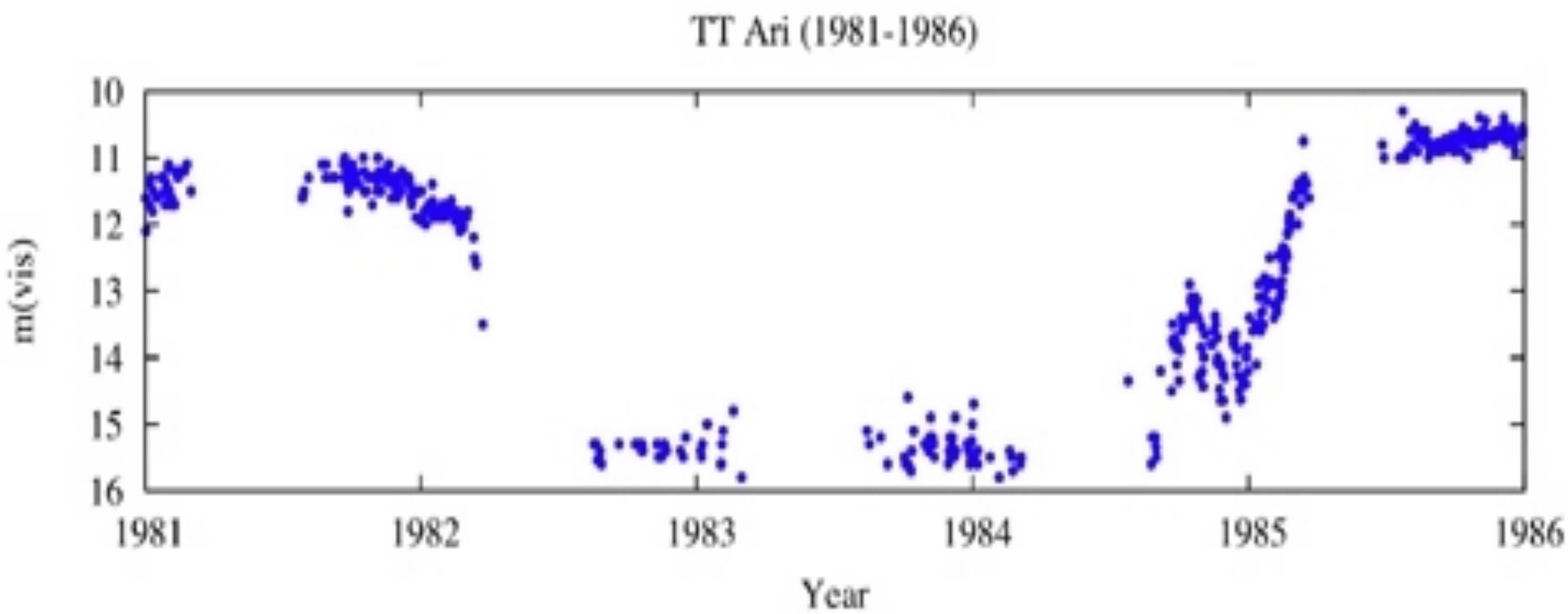




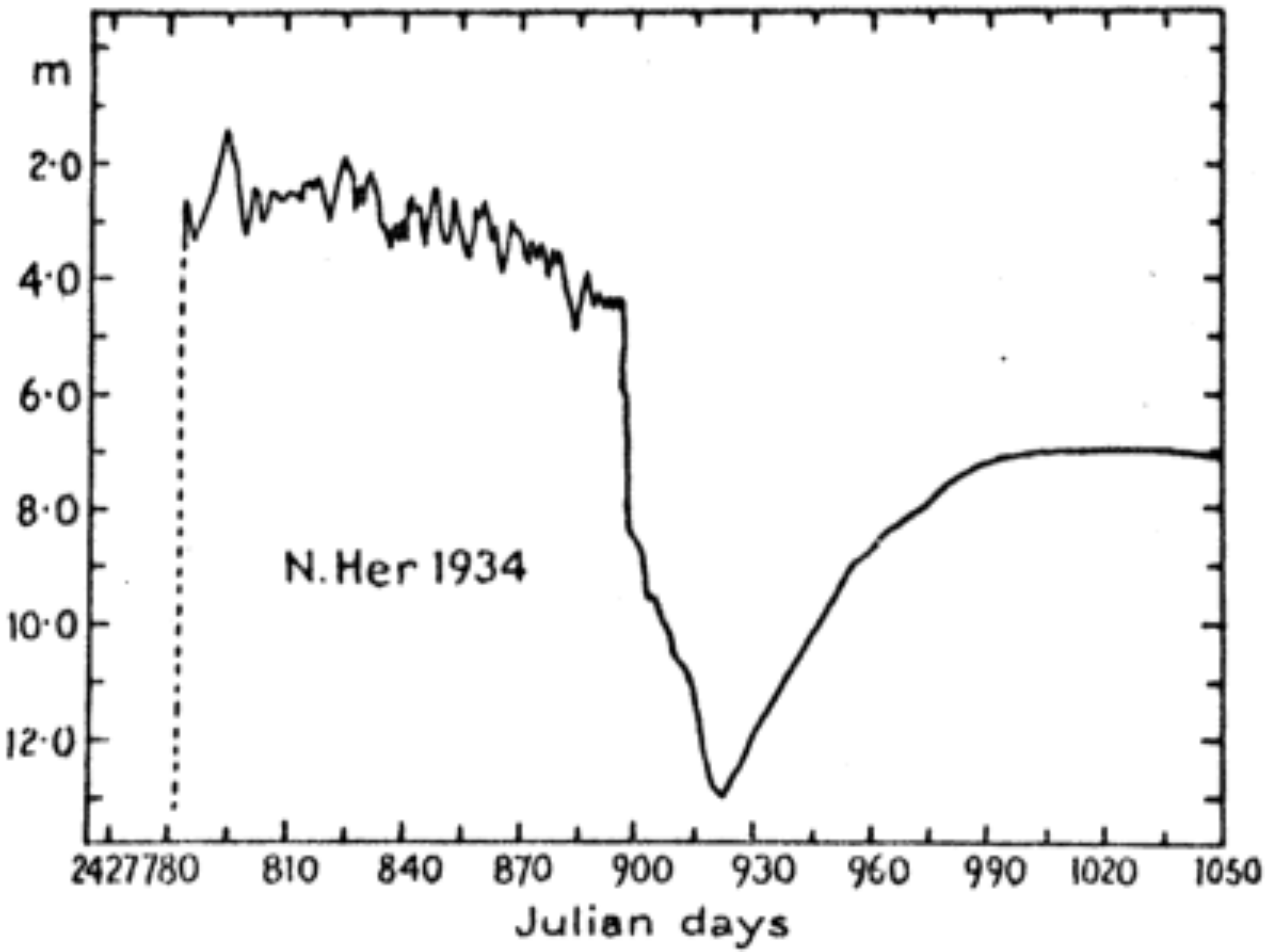


V
10
12
14
16
45000
45200
45400
45600
45800
46000
HJD (2400000 +)


RX And During Outburst
v1
v2
v3
m_v
Julian Day − 2450000
8
10
12
14
16
300
350
400
450
500
550
CHENG 20-JUL-1999 20



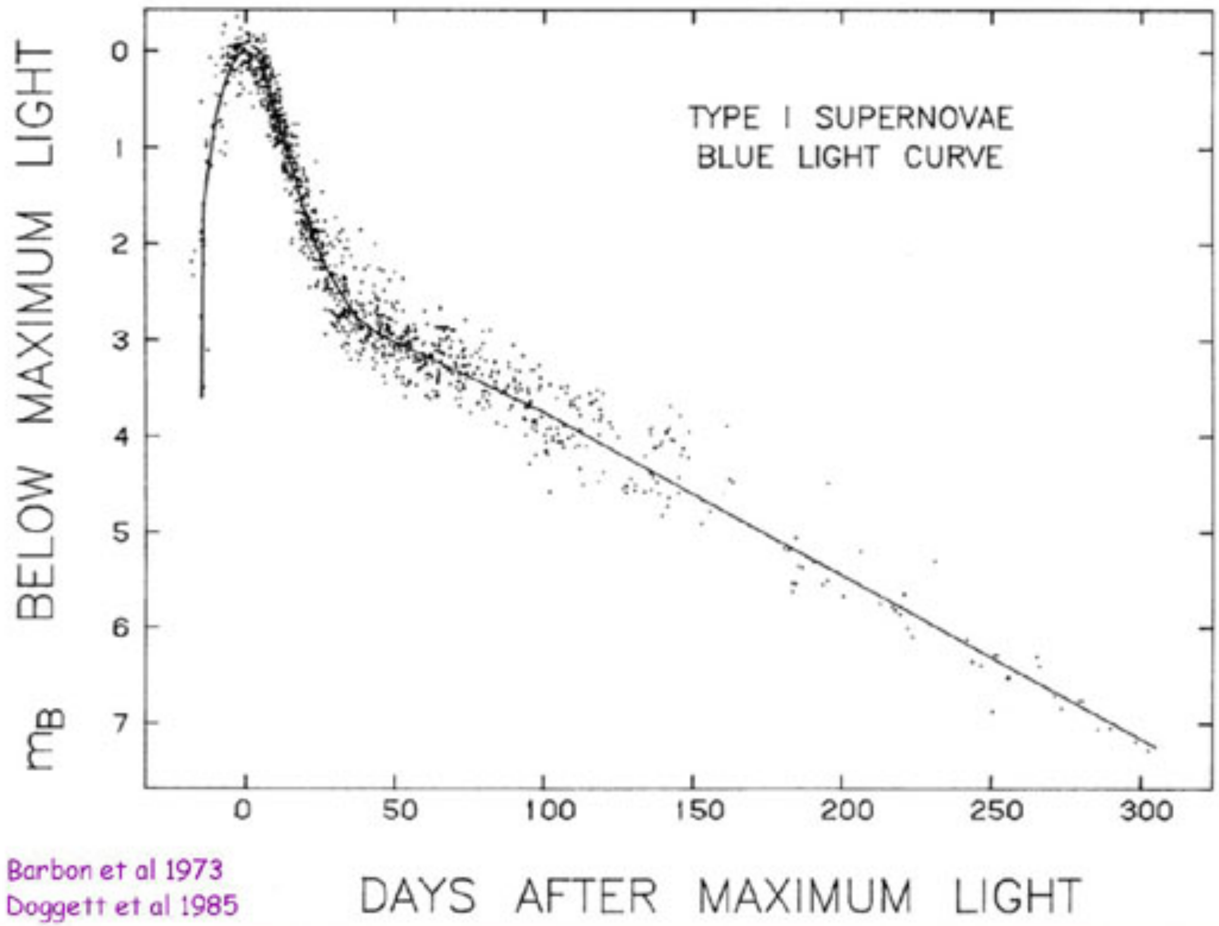
TT Ari (1981-1986)
m(vis)
10
11
12
13
14
15
16
1981
1982
1983
1984
1985
1986
Year


m
2·0
4·0
6·0
8·0
10·0
12·0
N. Her 1934
2427780
810
840
870
900
930
960
990
1020
1050
Julian days

Similar light curves

- The light curves of Type Ia events are similiar.

- The B-band (blue) light curves of 38 Type Ia supernovae.



Barbon et al 1973
Doggett et al 1985

Far Ultraviolet Spectra

- IUE Archival
- HST FOS, GHRS, STIS, COS
- FUSE
- EUVE

Synthetic Spectra

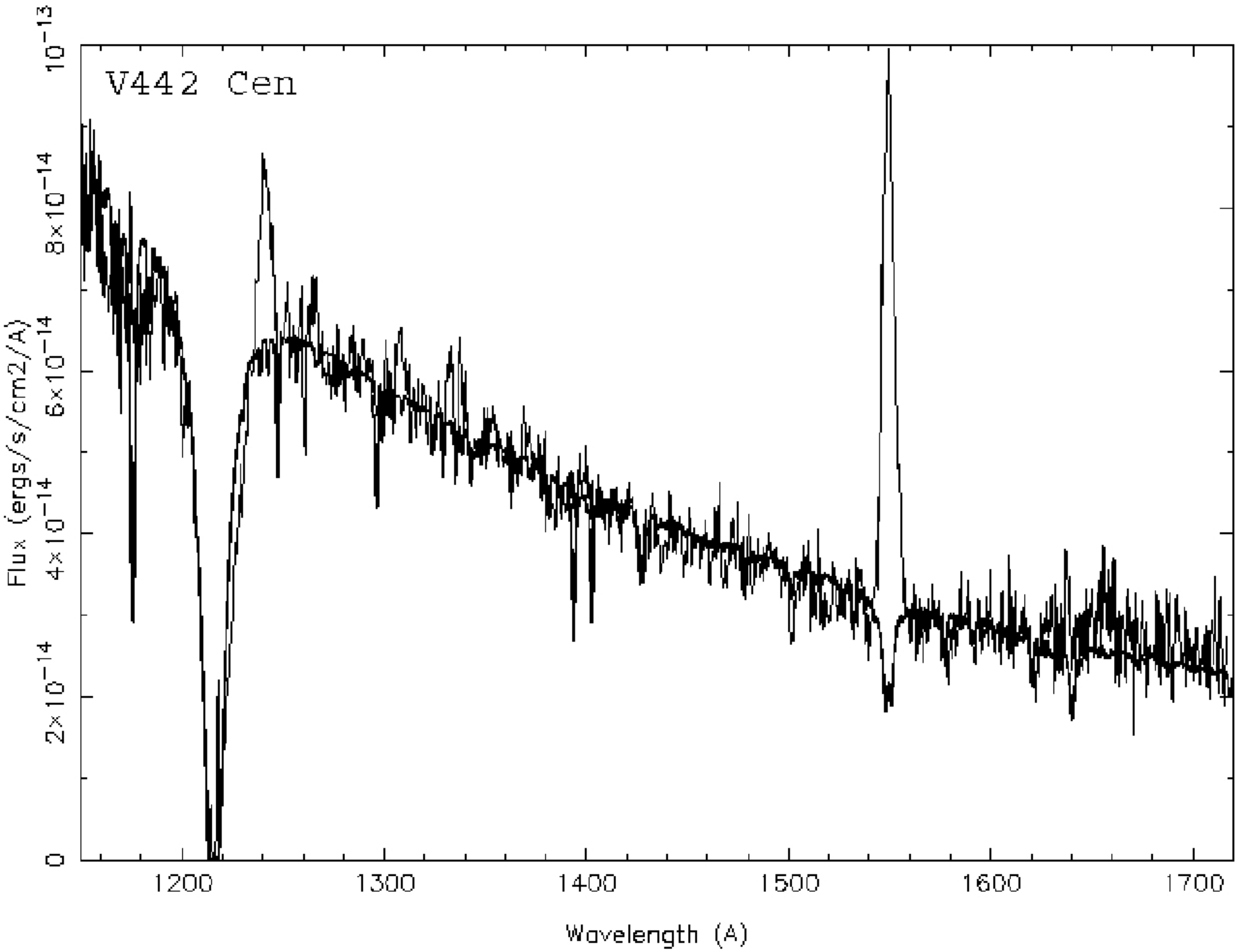
- High Gravity LTE and NLTE Model Atmospheres (TLUSTY200, SYNSPEC98)
- Optically Thick, Steady State, Accretion Disk Models (TLUSDISK200)
- Accretion Belt Models
- Accretion Rings
- Accretion Curtain Models

IP Peg	DN	1.16 ± 0.02	E
GY Cnc	DN	0.99 ± 0.12	E
U Gem	DN	1.14 ± 0.07	S
AM Her	Polar	0.88	S
SDSS1035+05	DN	0.94	E
SDSS1006+23	DN	0.78 ± 0.12	E
SDSS1702+32	DN	0.94	E
SDSS0926+36	AMCVn	0.84	E
MR Ser	Polar	0.71	S
QQ Vul	Polar	0.70	S
OY Car	DN	0.69	E
HT Cas	NL	0.61	E

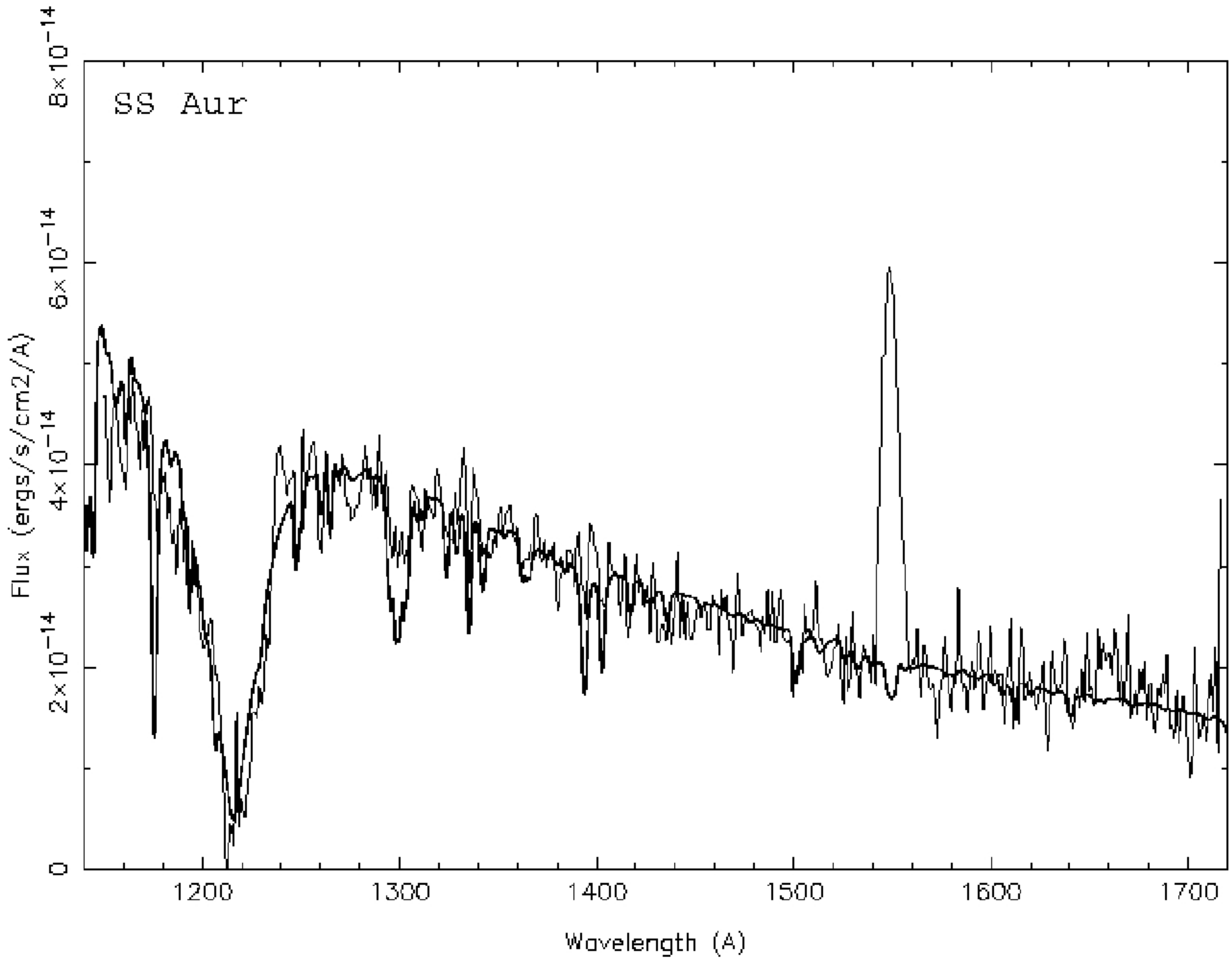
Z Cha	DN	0.54	E
OU Vir	DN	0.89	E
DQ Her	Nova	0.60 ± 0.07	E
WZ Sge	DN	0.85	S
EX Dra	DN	0.75 ± 0.02	E
V347 Pup	DN	0.63 ± 0.04	E
EM Cyg	DN	1.13 ± 0.08	E
AC Cnc	NL	0.76 ± 0.03	E
V363 Aur	NL	0.90 ± 0.06	E
QS Vir	DN	0.78	S
ST LMi	Polar	0.76	S

Southworth, J. et al.2009, A\&A, ; Sion,E.,
\& Szkody, P.2011, White Dwarfs, in press

Sion, E. M. et al. (2008), ApJ, 681, 543



Sion, E. M. et al.(2008), ApJ, 681, 543

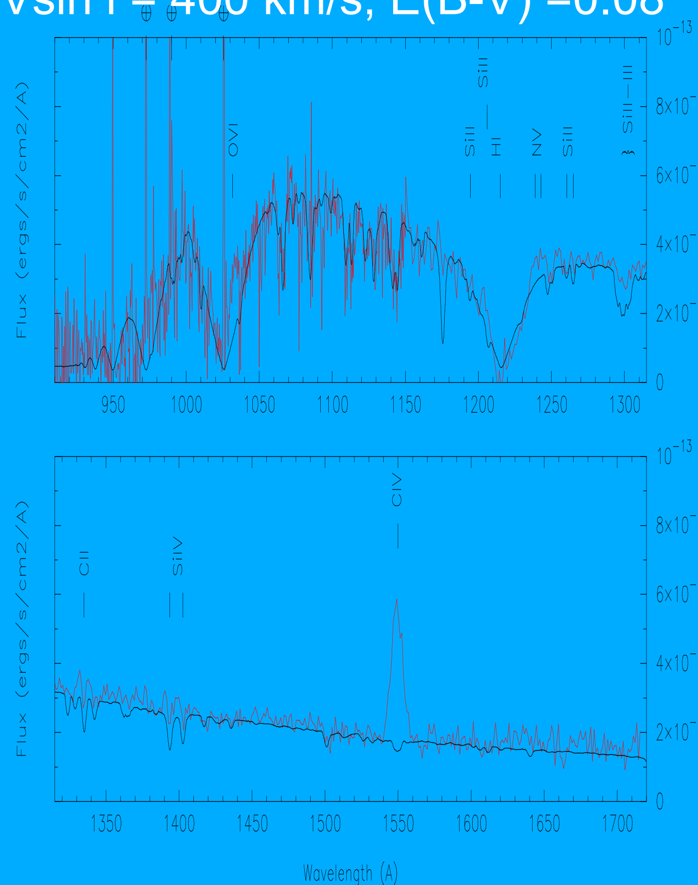


Godon, P. et al. (2008), ApJ, 679, 1447

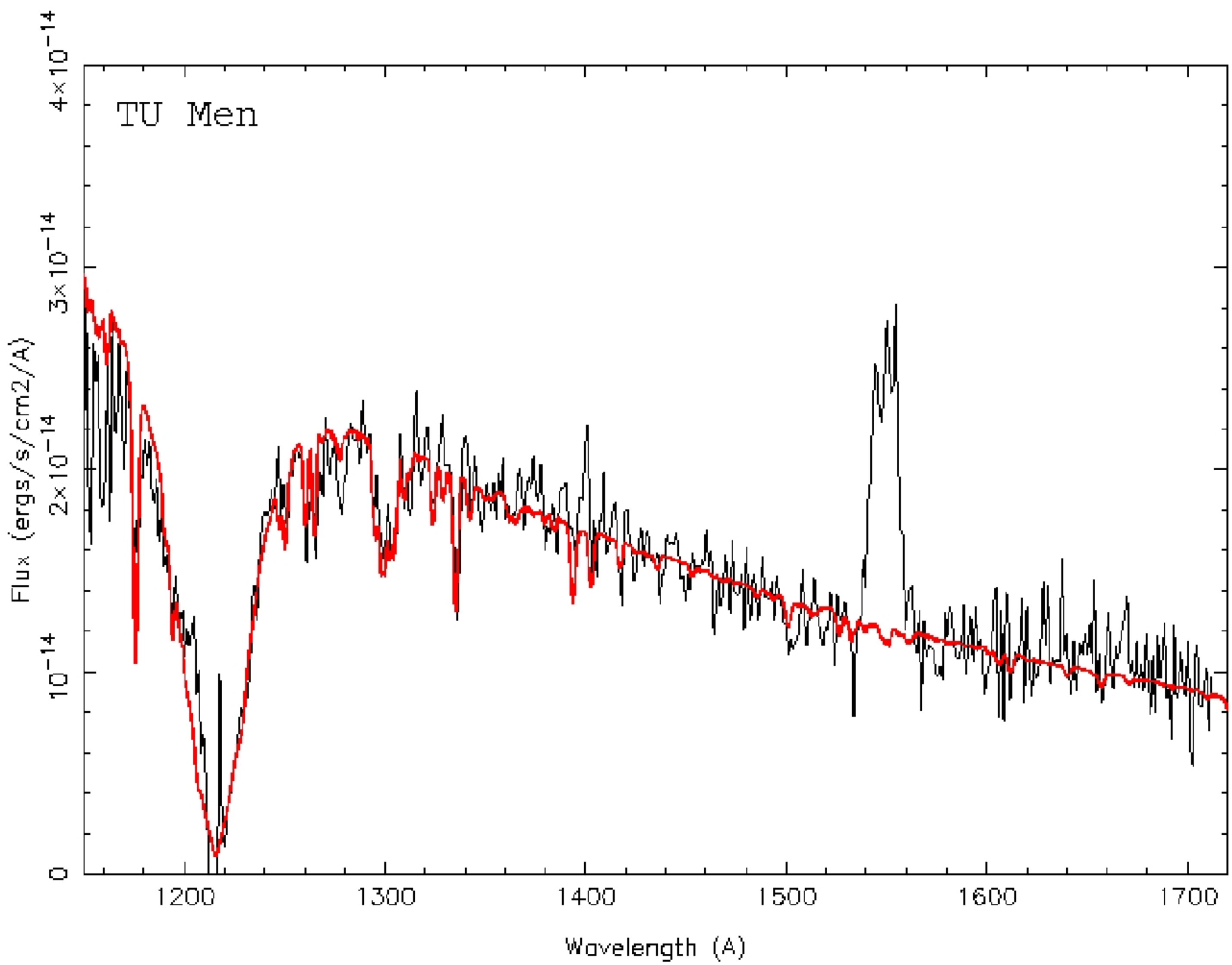
SS Aur

SS Aur

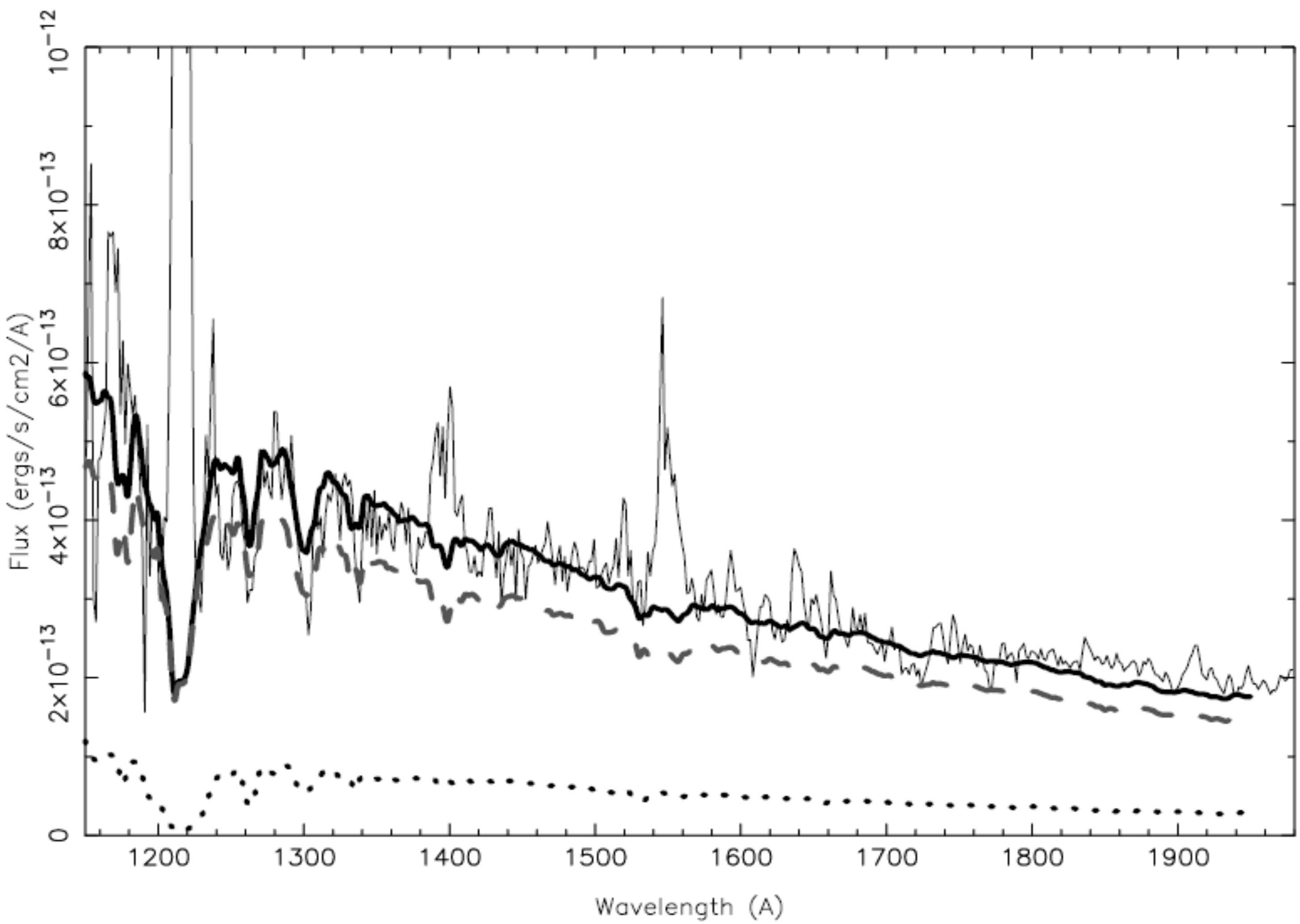
SS Aur, Teff = 34,000K, Log g = 9, Vsin i = 400 km/s, E(B-V) =0.08



Sion, E.M. et al. (2008), ApJ, 681, 543

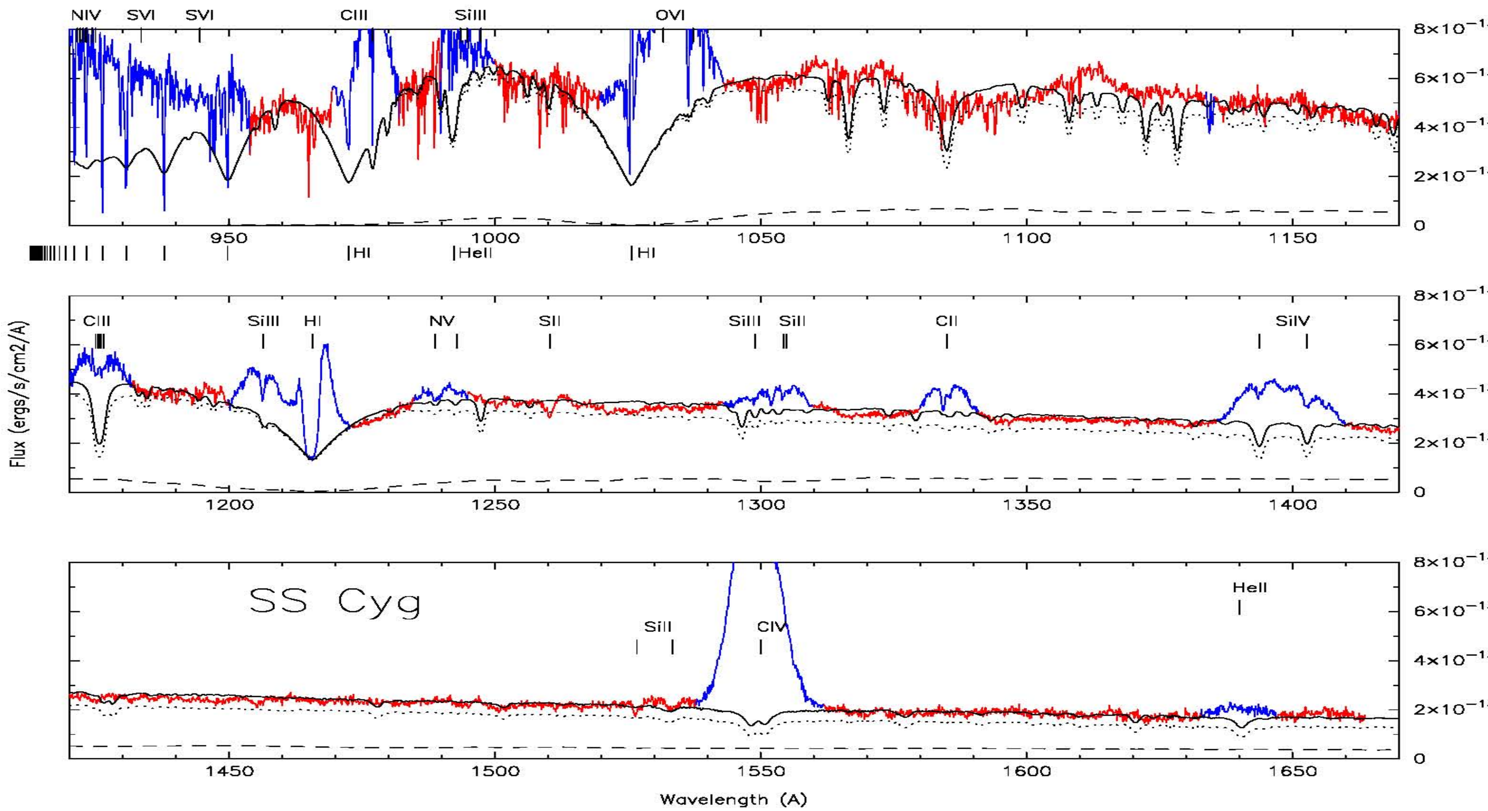


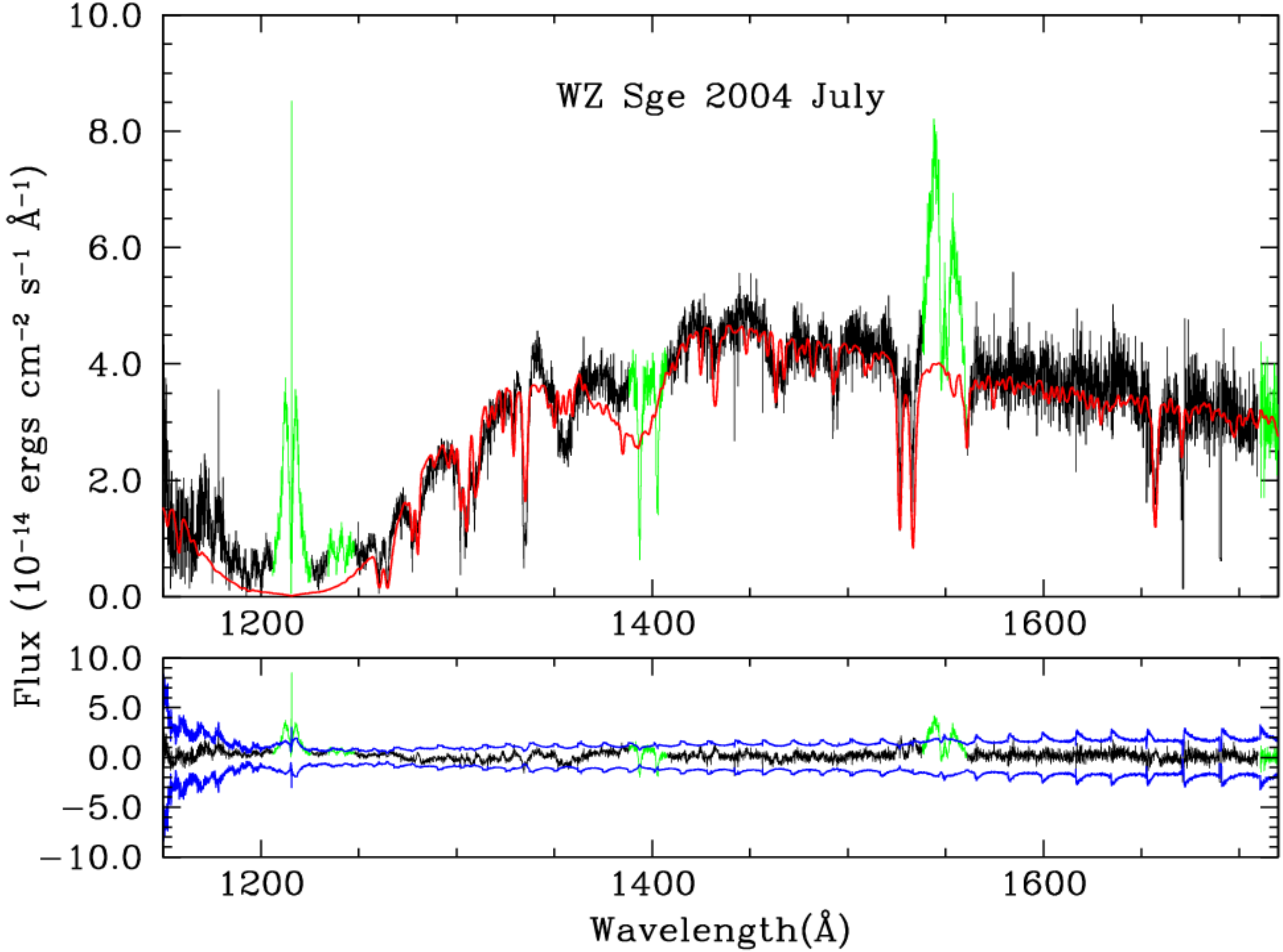
V442 Oph (Ballouz, R., \& Sion, E.2009, ApJ 697, 1717)



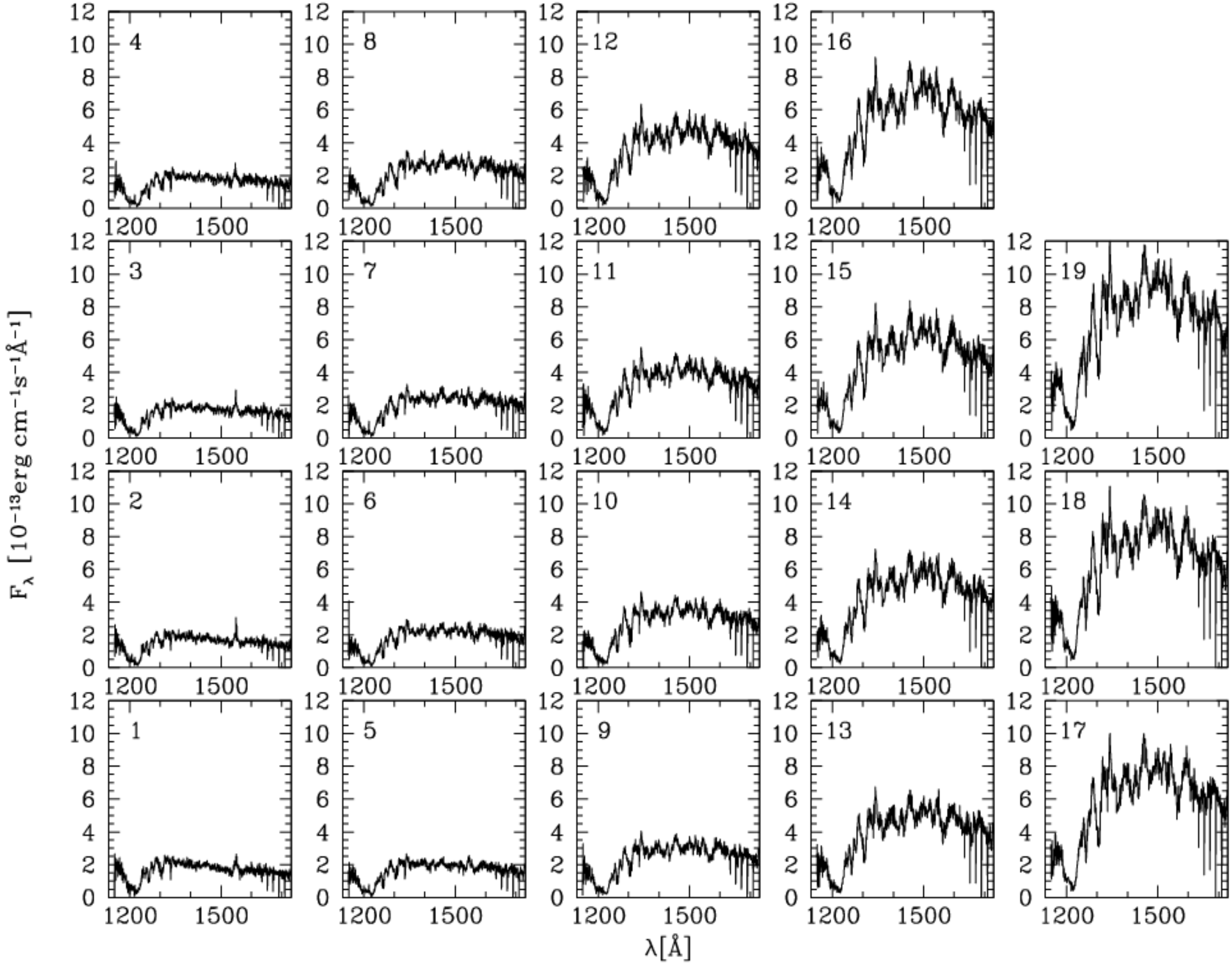
SS Cygni, d = 166 pc, P_orb = 6.6h, M_wd = 0.81 +/ 0.18
E(B-V) = 0.04, 0.07, i = 50 deg; T_wd =46,000K

Sion, E.M., et al. 2010, ApJ, 716, L157

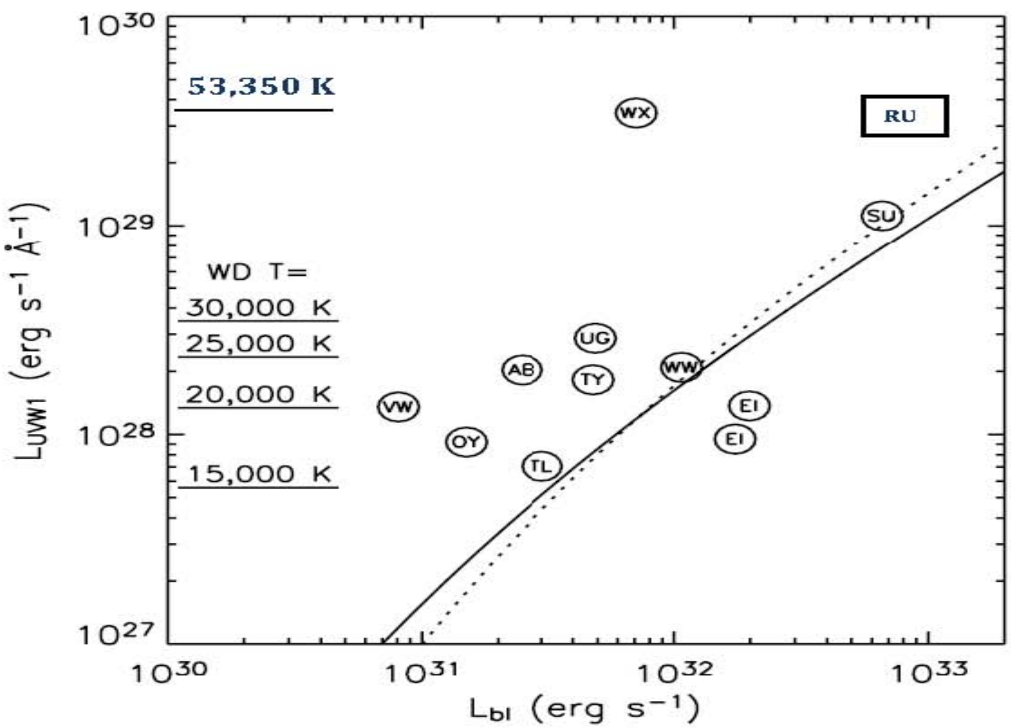




WZ Sge 2004 July
Flux (10^{-14} ergs cm^{-2} s^{-1} Å^{-1})
Wavelength(Å)
10.0
8.0
6.0
4.0
2.0
0.0
1200
1400
1600
5.0
−5.0
−10.0



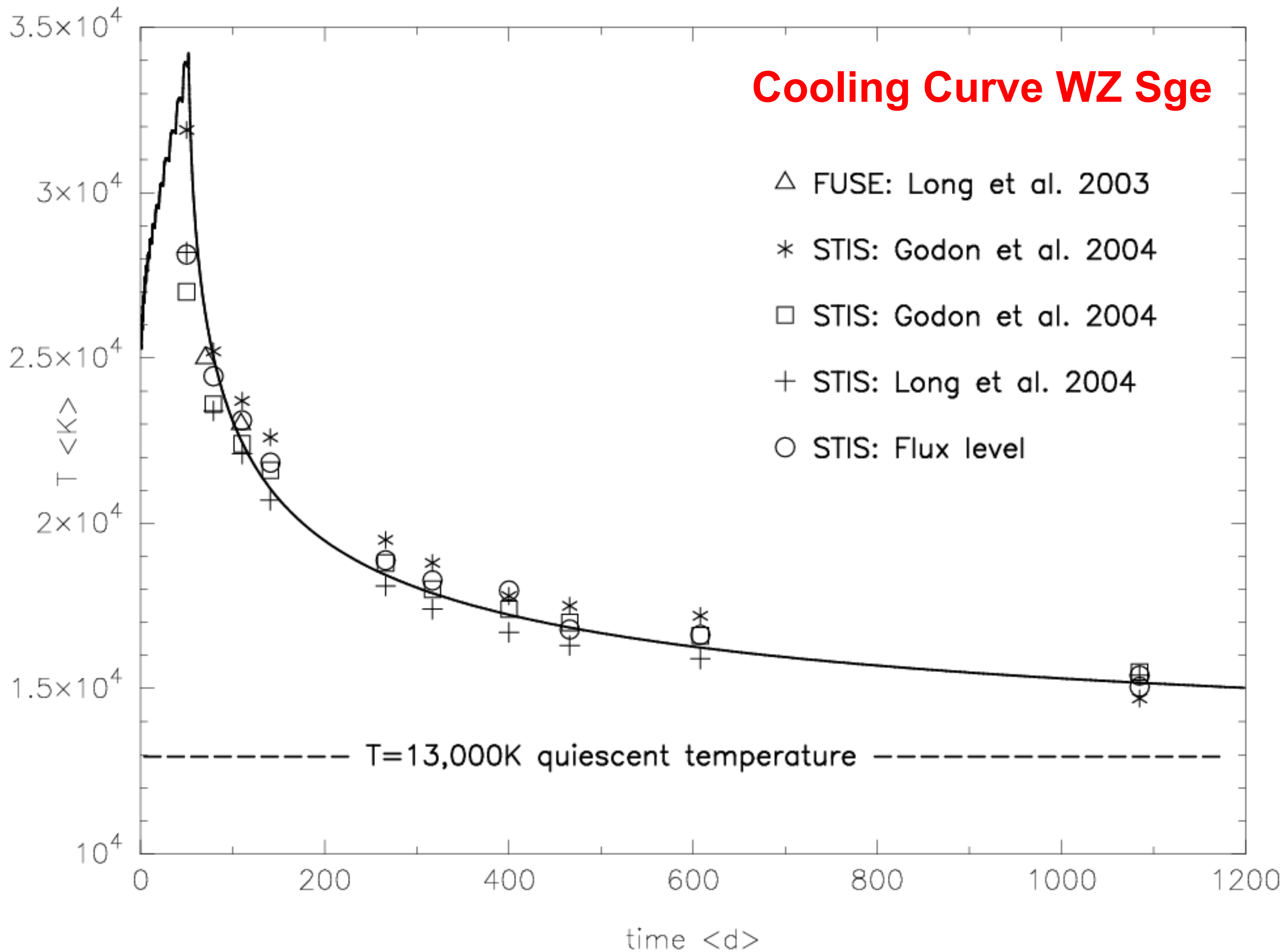
F_λ [10^{-13}erg cm^{-1}s^{-1}Å^{-1}]
λ[Å]
1200
1500
0
2
4
6
8
10
12
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19



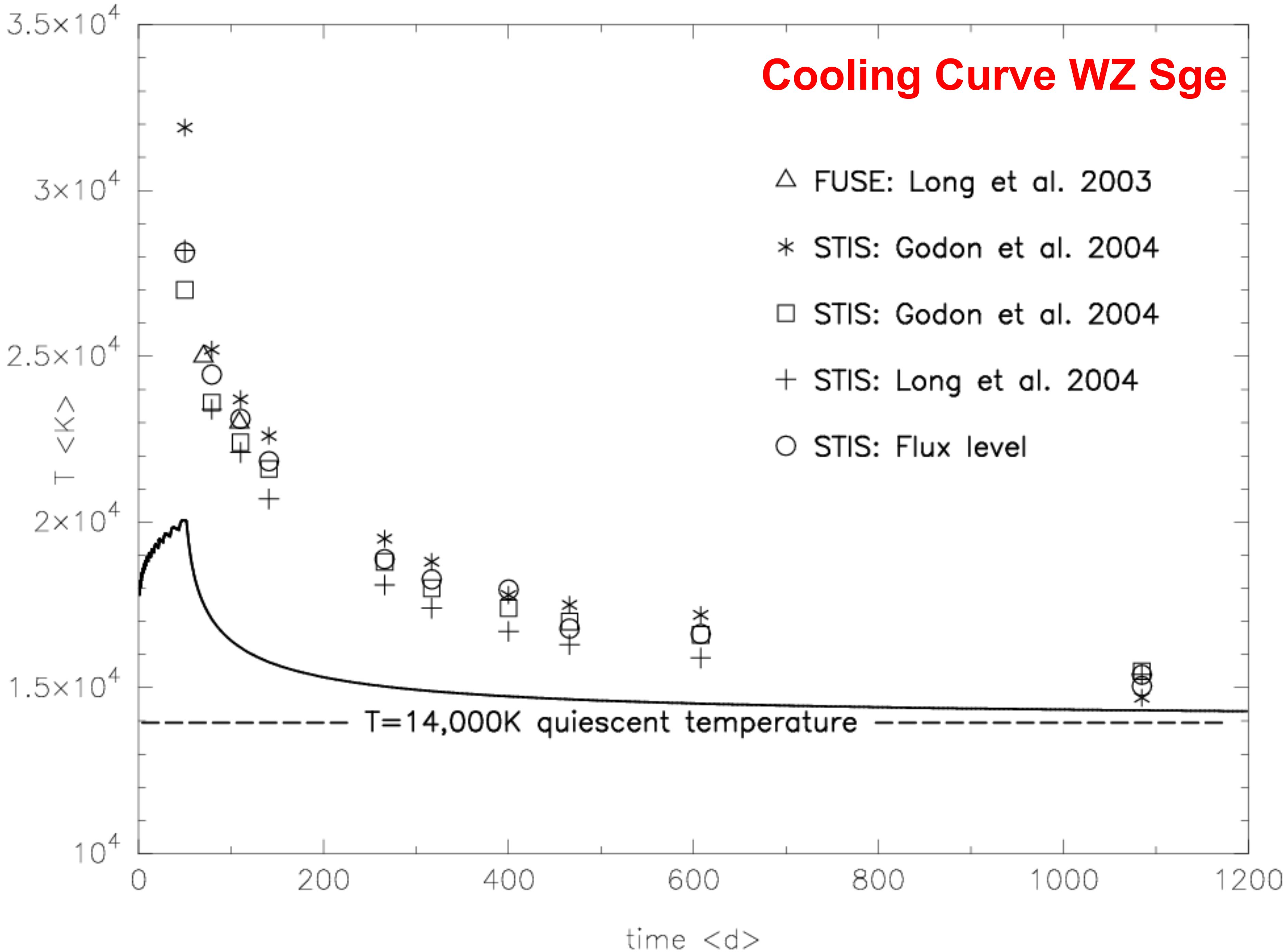
Balman, S. Godon, P, Sion, E.2011, ApJ, in press

Evolutionary Model Simulations of Accretion

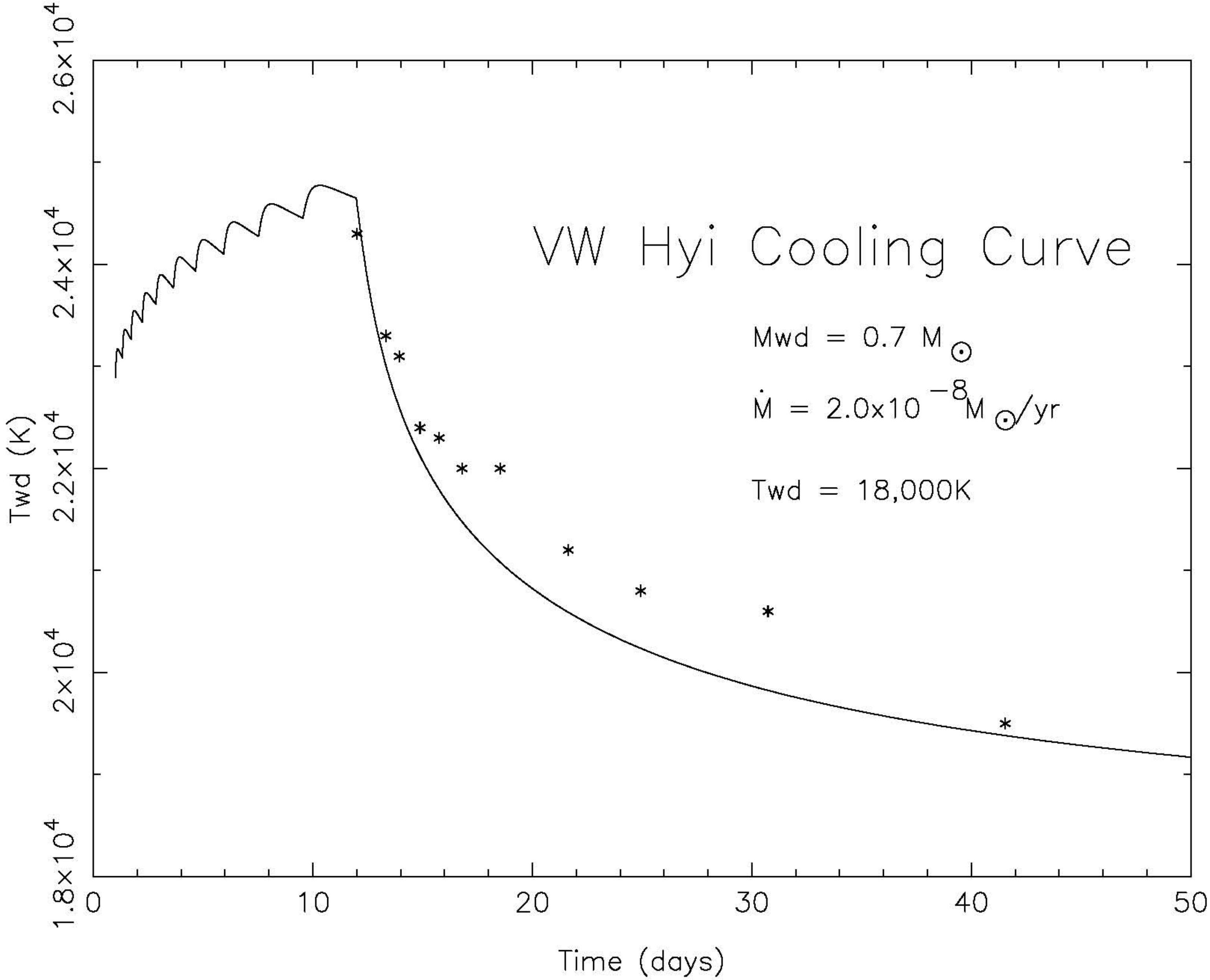
- 1D Quasi-Static Evolutionary Code,
- 2D Hydrodynamic Code
- OPAL Opacities
- Time-variable accretion with compressional heating and boundary layer irradiation with stellar rotation (Sion, E.1995, ApJ,438,876)
- Equations of State (ideal gas to relativistic degeneracy)



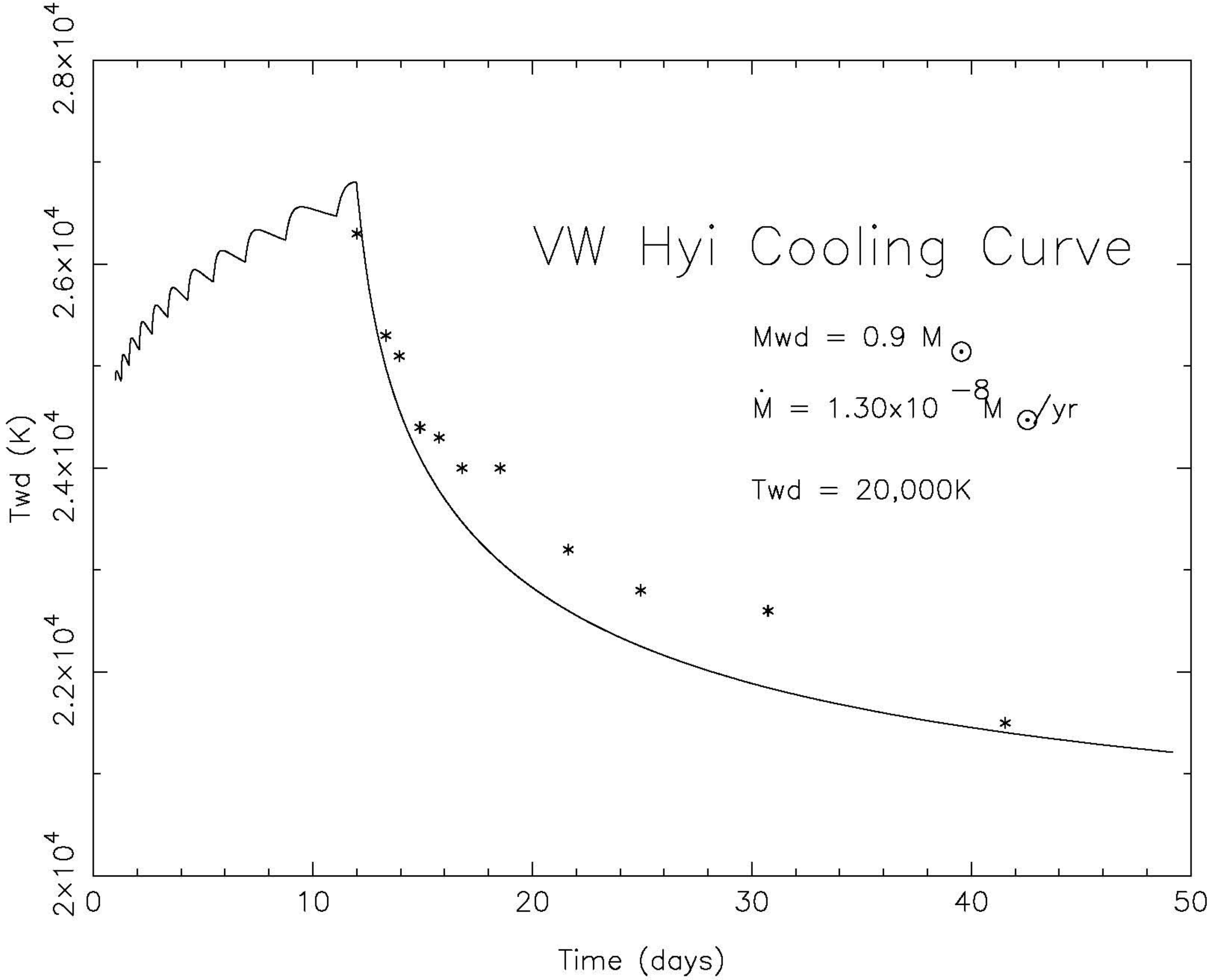
Cooling Curve WZ Sge
FUSE: Long et al. 2003
STIS: Godon et al. 2004
STIS: Godon et al. 2004
STIS: Long et al. 2004
STIS: Flux level
T=13,000K quiescent temperature
3.5×10^4
3×10^4
2.5×10^4
2×10^4
1.5×10^4
10^4
T <K>
0
200
400
600
800
1000
1200
time <d>



Cooling Curve WZ Sge
FUSE: Long et al. 2003
STIS: Godon et al. 2004
STIS: Godon et al. 2004
STIS: Long et al. 2004
STIS: Flux level
T=14,000K quiescent temperature
T <K>
time <d>
3.5×10^4
3×10^4
2.5×10^4
2×10^4
1.5×10^4
10^4
0
200
400
600
800
1000
1200

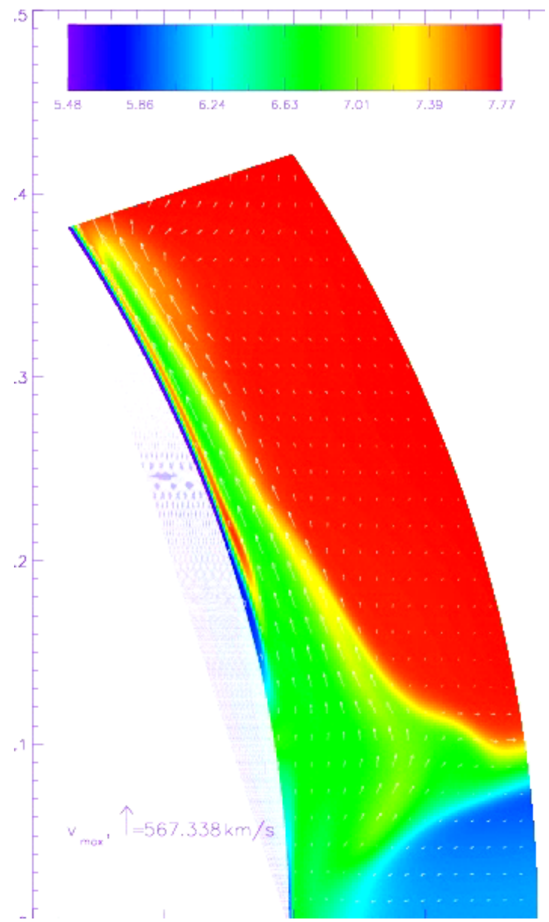


VW Hyi Cooling Curve
Mwd = 0.7 M⊙
Ṁ = 2.0x10^-8 M⊙/yr
Twd = 18,000K
Twd (K)
Time (days)
1.8×10^4
2×10^4
2.2×10^4
2.4×10^4
2.6×10^4
0
10
20
30
40
50



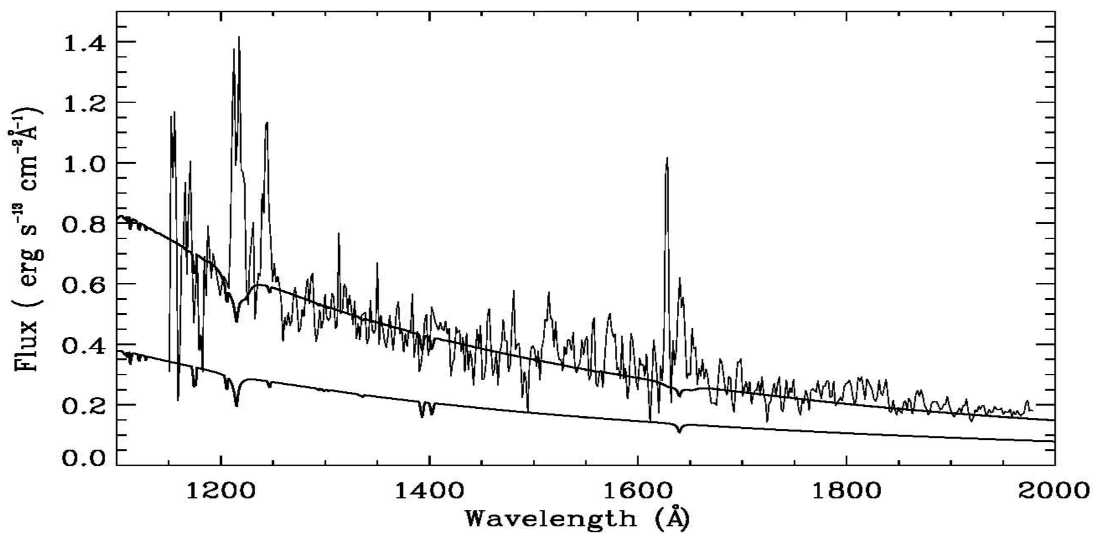
VW Hyi Cooling Curve
Mwd = 0.9 M⊙
Ṁ = 1.30x10^-8 M⊙/yr
Twd = 20,000K
Twd (K)
Time (days)
2×10^4
2.2×10^4
2.4×10^4
2.6×10^4
2.8×10^4
0
10
20
30
40
50

Balsara, D., Fisker, J., Godon,P., Sion,E. 2009,ApJ, 702, 1536



ES Ceti

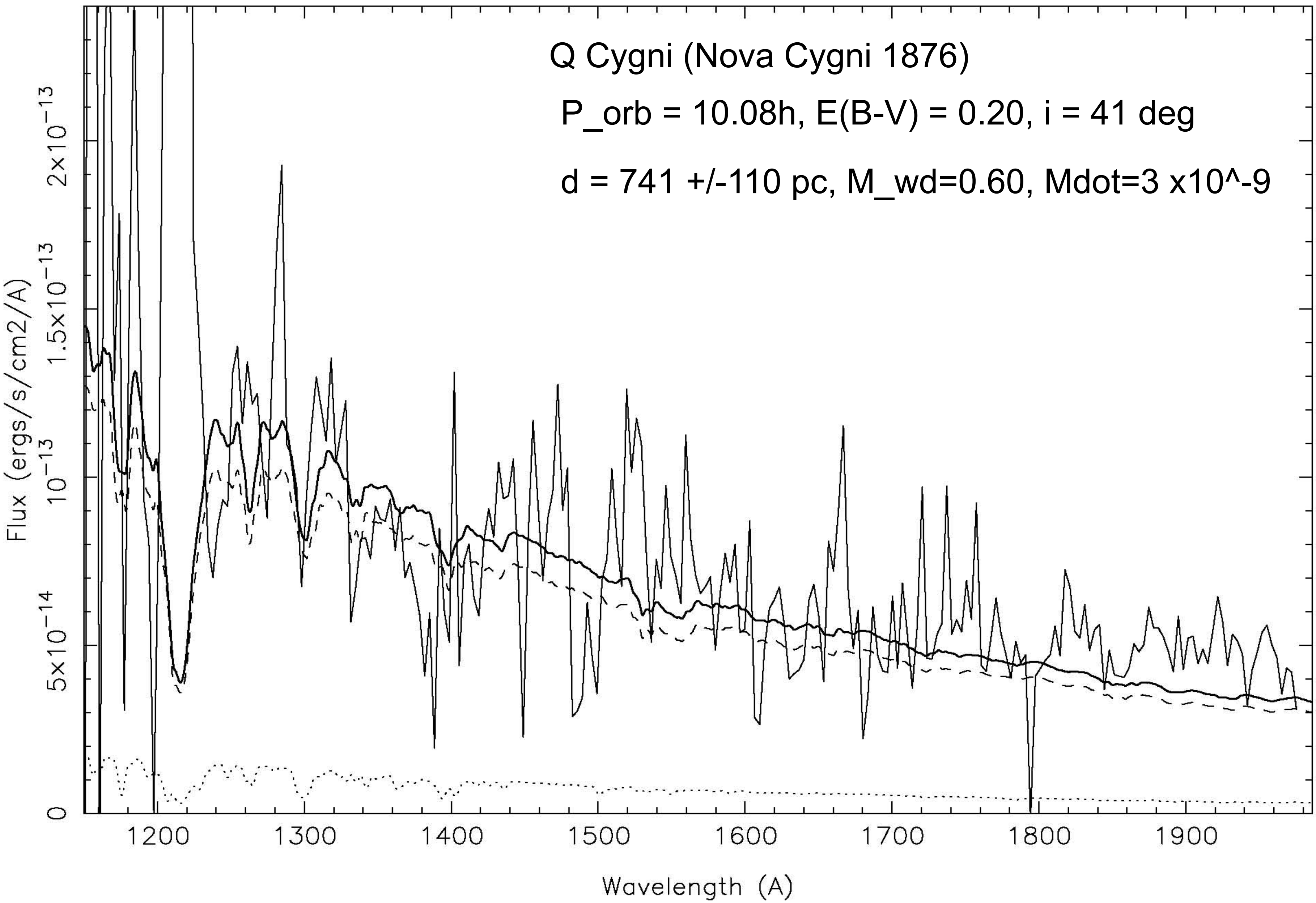
P_orb = 621 s



Sion, E., Linnell, A., Godon, P., Ballouz, R.2011, ApJ, in press

Kolobow, C.,\& Sion, E.2011, PASP, in press

Kolobow, C.\& Sion, E.2011, PASP, in press

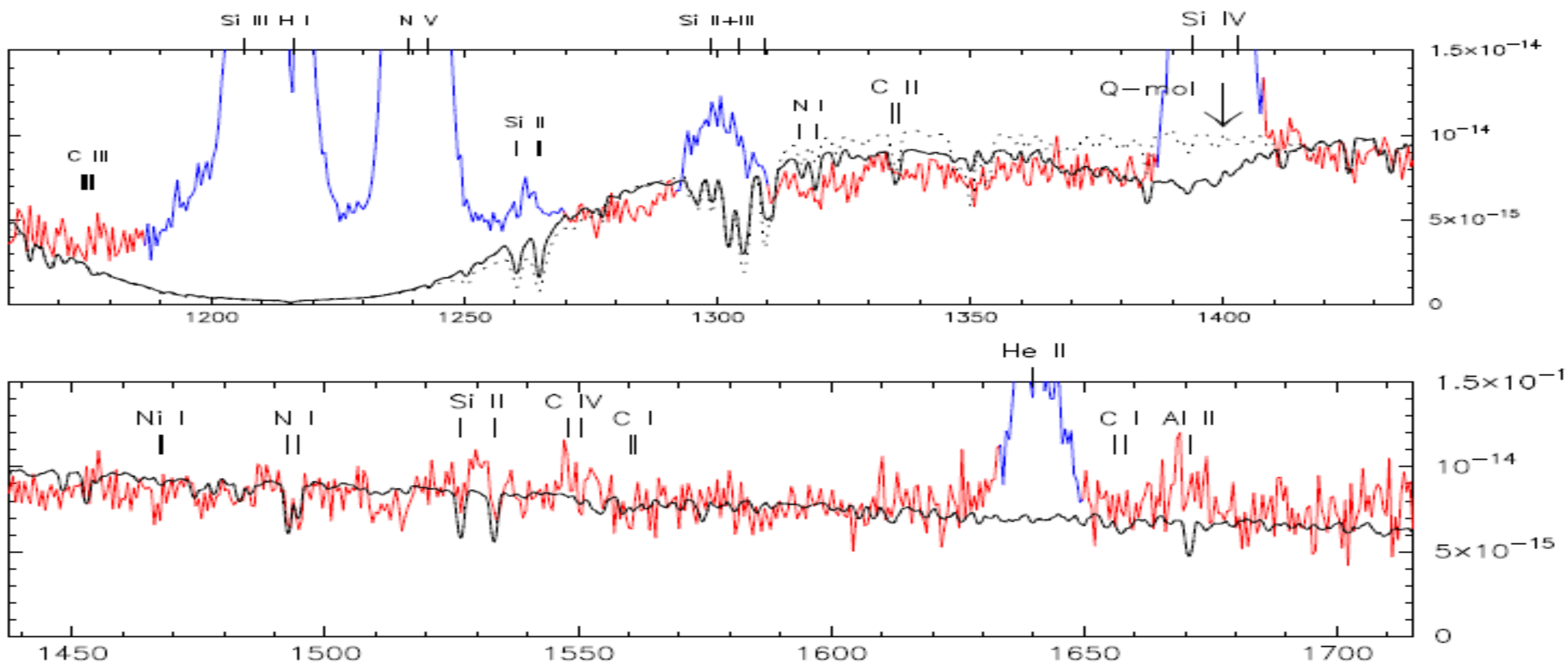


Object	Type	P_{orb}	Abundance
GW Lib	DN	76.8	Z ~ 0.1
BW Scl	DN	78.2	Al 3.0±0.8, rest 0.5±0.2
LL And	DN	79.2	Z ≤ ~1
WZ Sge	DN	81.6	C 0.5, Fe 0.1, S 0.1, Si 0.005
AL Com	DN	81.6	Z ~ 0.3
SW UMa	DN	81.8	Al 1.7±0.5, rest 0.2±0.1
HV Vir	DN	83.5	Z ~ 0.3
WX Cet	DN	83.9	Z ~ 0.1
EG Cnc	DN	86.4	Z ~ 0.3
BC UMa	DN	90.2	Al 2.0±0.5, rest 0.3±0.1
VY Aqr	DN	90.8	Si 0.05, C 1.0
EK Tra	DN	91.6	Z < 1

Object	Type	P_{orb}	Abundance
VW Hyi	DN	106.9	Si 0.3, C 0.3, N3, O 3, Al 2, P 20, Mn 50
EF Peg	DN	123	Z ~ 0.1-0.3
MV Lyr	NL	191.0	C0.5, N 0.5, Si 0.2
DW UMa	NL	198.0	Z ~ 0.47
WW Ceti	DN	253	C 0.1. N 2, Si 0.3
U Gem	DN	254.7	C 0.3 - 0.35, N 35 - 41, Si 1.4 - 4, 6.6 – 10
SS Aur	DN	263.2	C 0.1, Si 0.1, N 2.0
RX And	DN	302.2	C 0.05, Si 0.1
RU Peg	DN	539.4	C 0.1, Si 0.1, N ~ 8
BV Cen	DN	878.6	

Godon, P., Sion, E., Gaensicke, B., deMartino, D.2011, PASP, in press

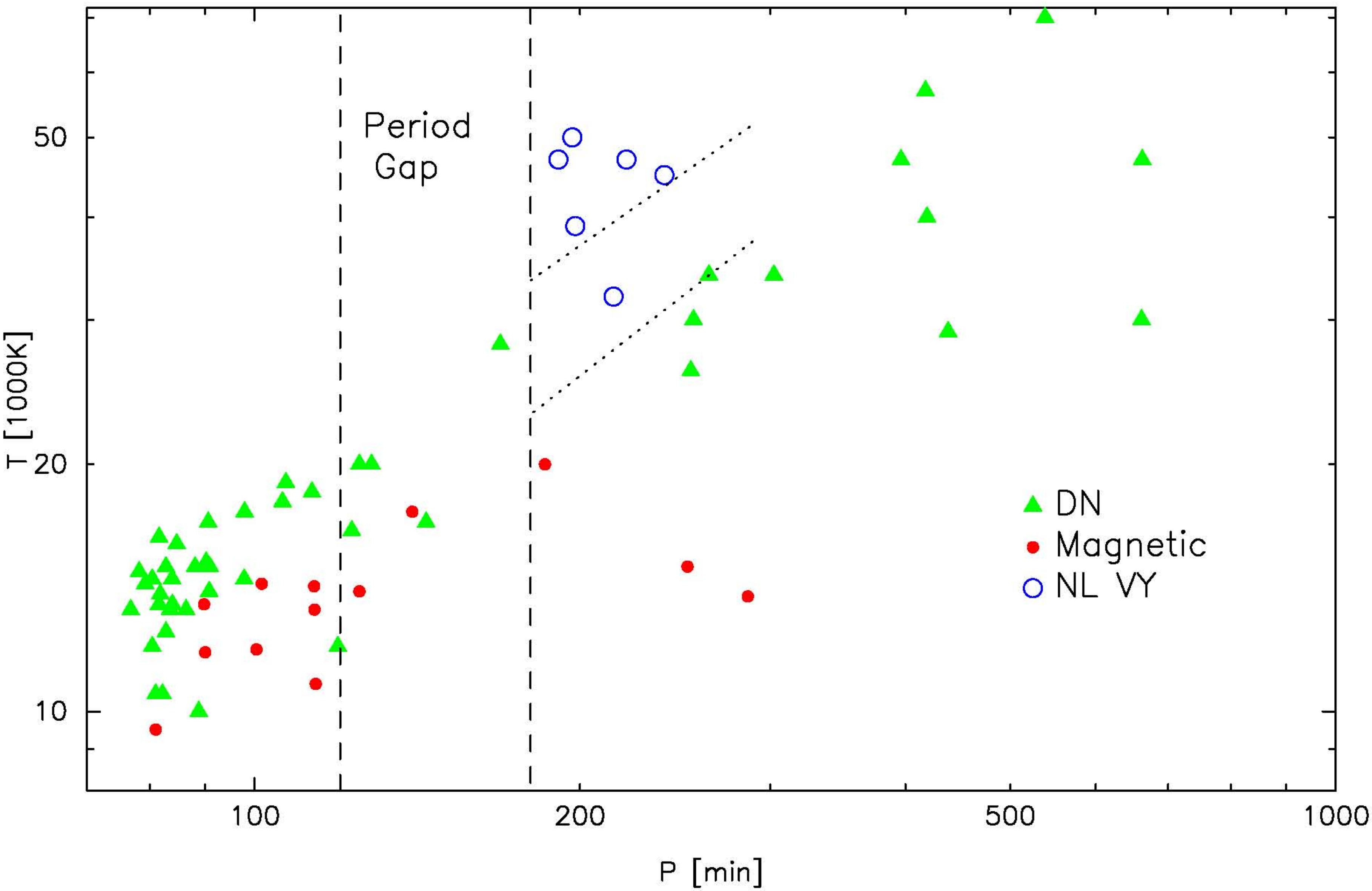
BZ UMa, Teff = 17,500K, Log = 8.5, Vsini = 200 km/s, d= 125 pc



Object	**Type**	**P_{orb}**	Vsini
GW Lib	DN	76.8	< 300
BW Scl	DN	78.2	< 300
LL And	DN	79.2	< 500
WZ Sge	DN	81.6	400/1200
AL Com	DN	81.6	< 800
SW UMa	DN	81.8	200
HV Vir	DN	83.5	400
WX Cet	DN	83.9	400
BC UMa	DN	90.2	300
VY Aqr	DN	90.8	400
EK Tra	DN	91.6	200
VW Hyi	DN	106.9	400

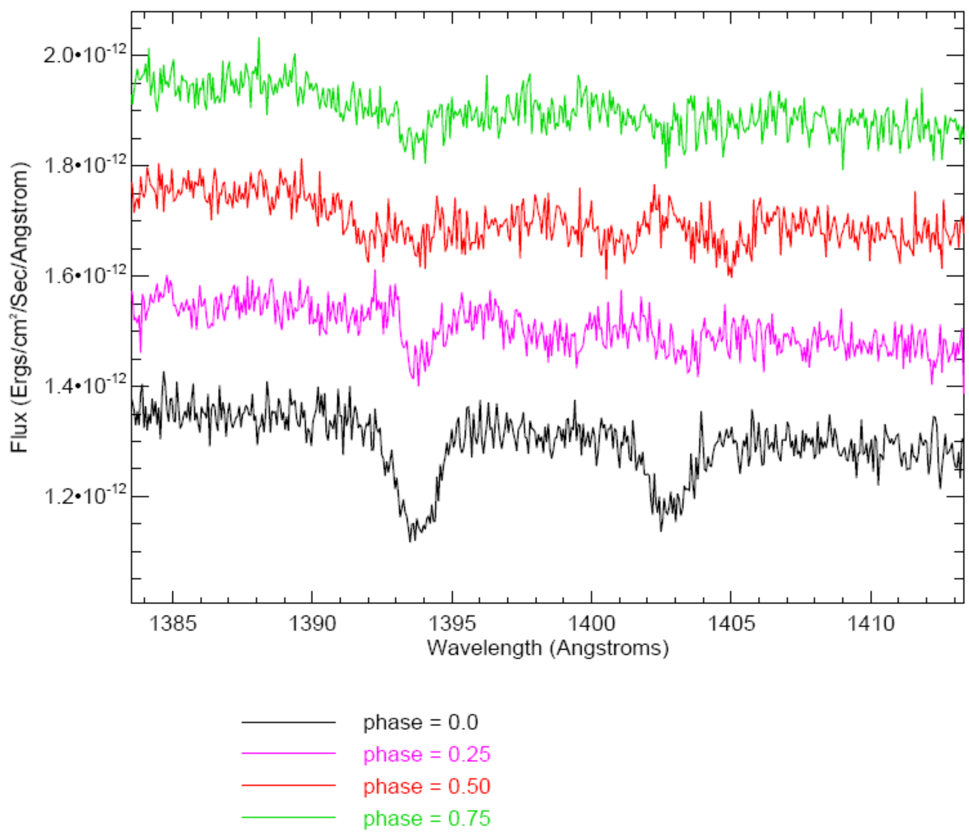
Object	**Type**	$\mathbf{P}_{orb}$	Vsini
EF Peg	DN	123	< 300
MV Lyr	NL	191.0	200
DW UMa	NL	198.0	370
VW Ceti	DN	253	600
U Gem	DN	254.7	150
SS Aur	DN	263.2	400
RX And	DN	302.2	500
Z Cam	DN	417.4	330
RU Peg	DN	539.4	100

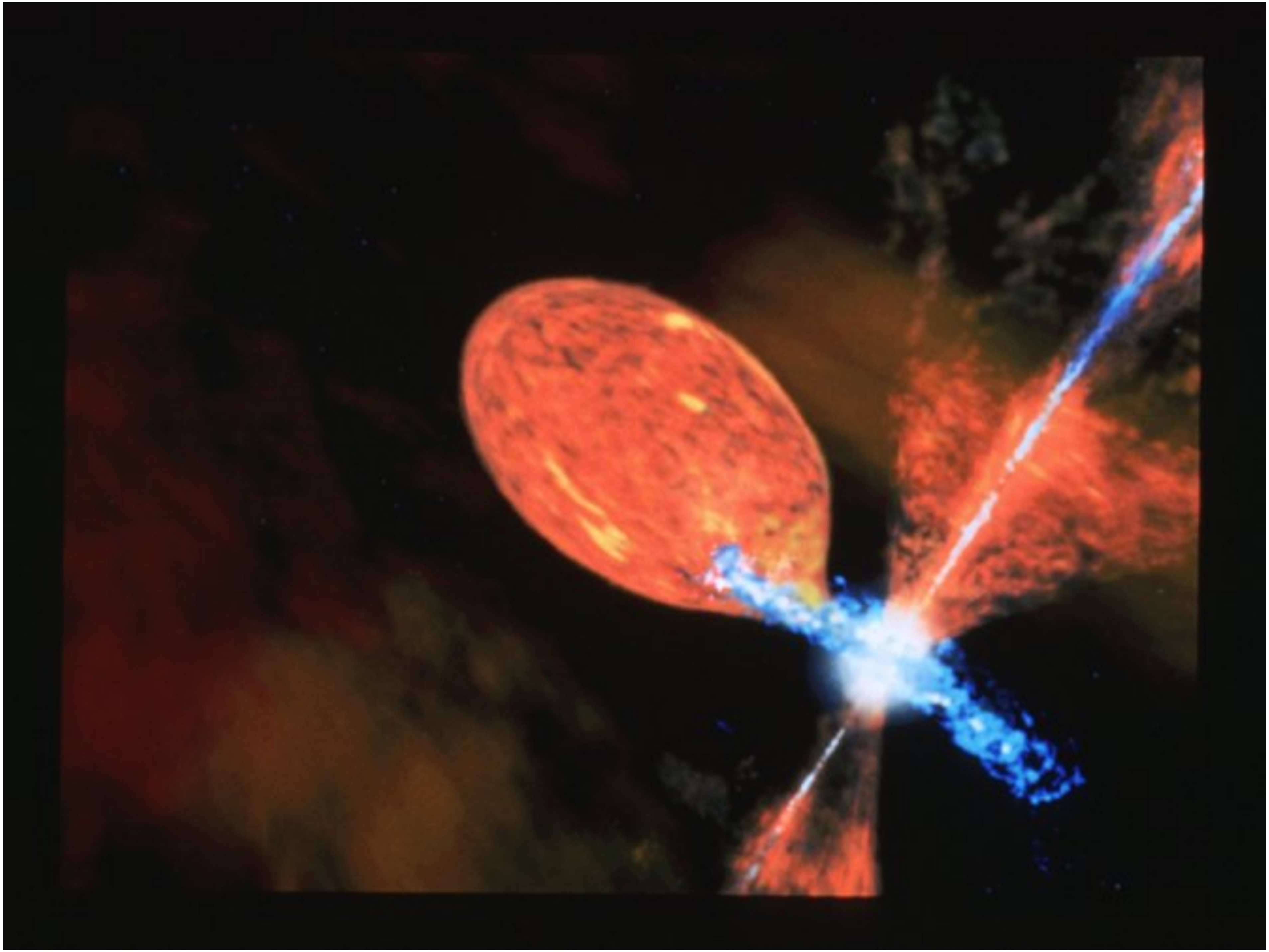
Object	**P_{orb}(min)**	**Pulsation P (sec)**	**Outbursts**	**Temperature**
GW Lib	77	230, 370, 650	1983, 2007	14700 (HST)
PQ And	79-81	634, 1263	1938, 1967, 1988	12000 (opt)
SDSS1610-01	81	221, 304, 345 607	-	14500 (HST)
HS2331+39	81	310, 336, 419	-	11400 (HST)
SDSS1339+48	83	642	-	12500 (opt)
SDSS0919+08	91	260	-	13000 (opt)
SDSS0745+45	86	611, 1230	-	11000 (opt)
SDSS0131-09	98	260, 335, 595	-	14500 (HST)
REJ1255+26	119	668, 1236, 1344	1994	13000 (opt)
SDSS2205+11	-	330, 475, 575	-	15000 (HST)
SDSS1514+45	-	559	-	-


Period
Gap
DN
Magnetic
NL VY
50
20
10
100
200
500
1000
T [1000K]
P [min]

Hyades post-common envelope, pre-cataclysmic, eclipsing binary

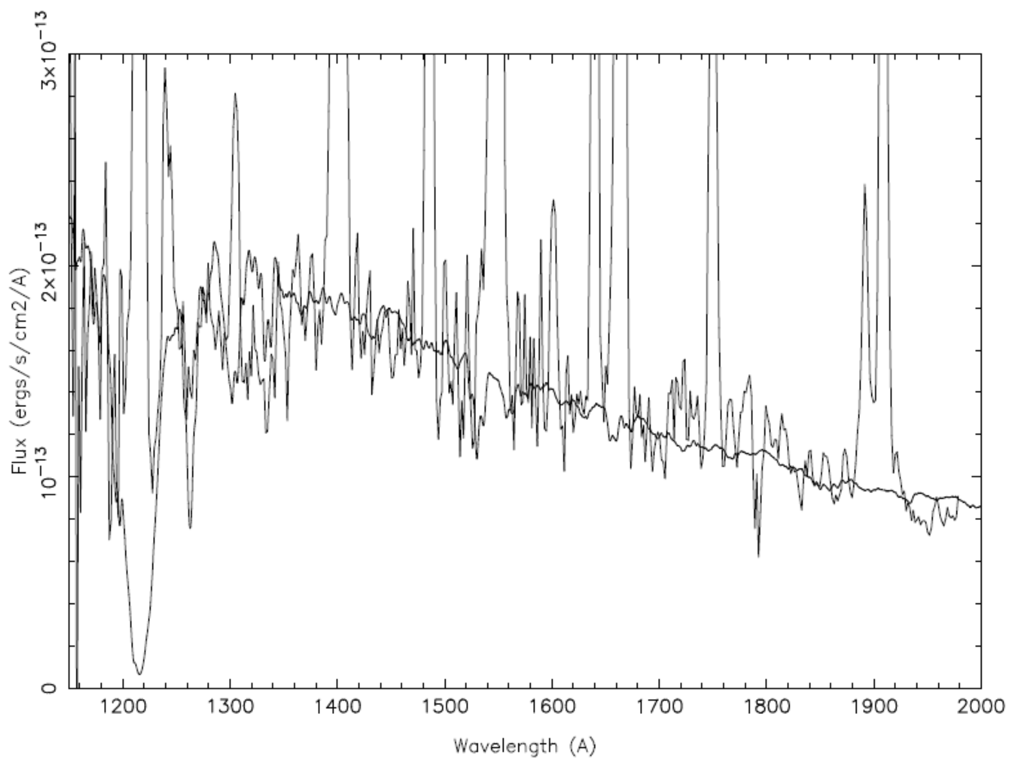
V471 Tauri





Villamil, C., Datin, K., Zimmerman, N., Sion, E., Mikolajewska, J.
2011, AJ, submitted

V443 Her, Symbiotic Variable, Mdot = 1 x 10^-9 Msun/yr, i = 75



SUMMARY OF CV WD PROPERTIES

- CV white dwarfs have temperatures 8000K < Teff < 70,000K
- CV white dwarfs have rotation velocities 150 < Vsini < 1200 km/s
- CV white dwarf metal abundances tend to be subsolar. Several have N/C ~ 5 to 10, suprasolar P, Al
- <Teff> = 15,000K below gap,

  <Teff> = 35,000K above gap

OPEN QUESTIONS & NEW FRONTIERS

- Do CVs evolve across the period gap?
- Do CV white dwarf masses increase, stay the same, or decrease with time?
- Are H-rich CVs with near-Chandrasekhar mass WDs Type Ia progenitors?
- Are AM CVn helium transfer binaries Type Ia SN progenitors?
- What is the evolutionary status of the Nova-like Variables?
- What is the correct angular momentum braking law for CVs above the period gap?
- Are the CNO-processed abundances due to core material from the donor or contamination of the donor star due to TNR burning on the white dwarf?