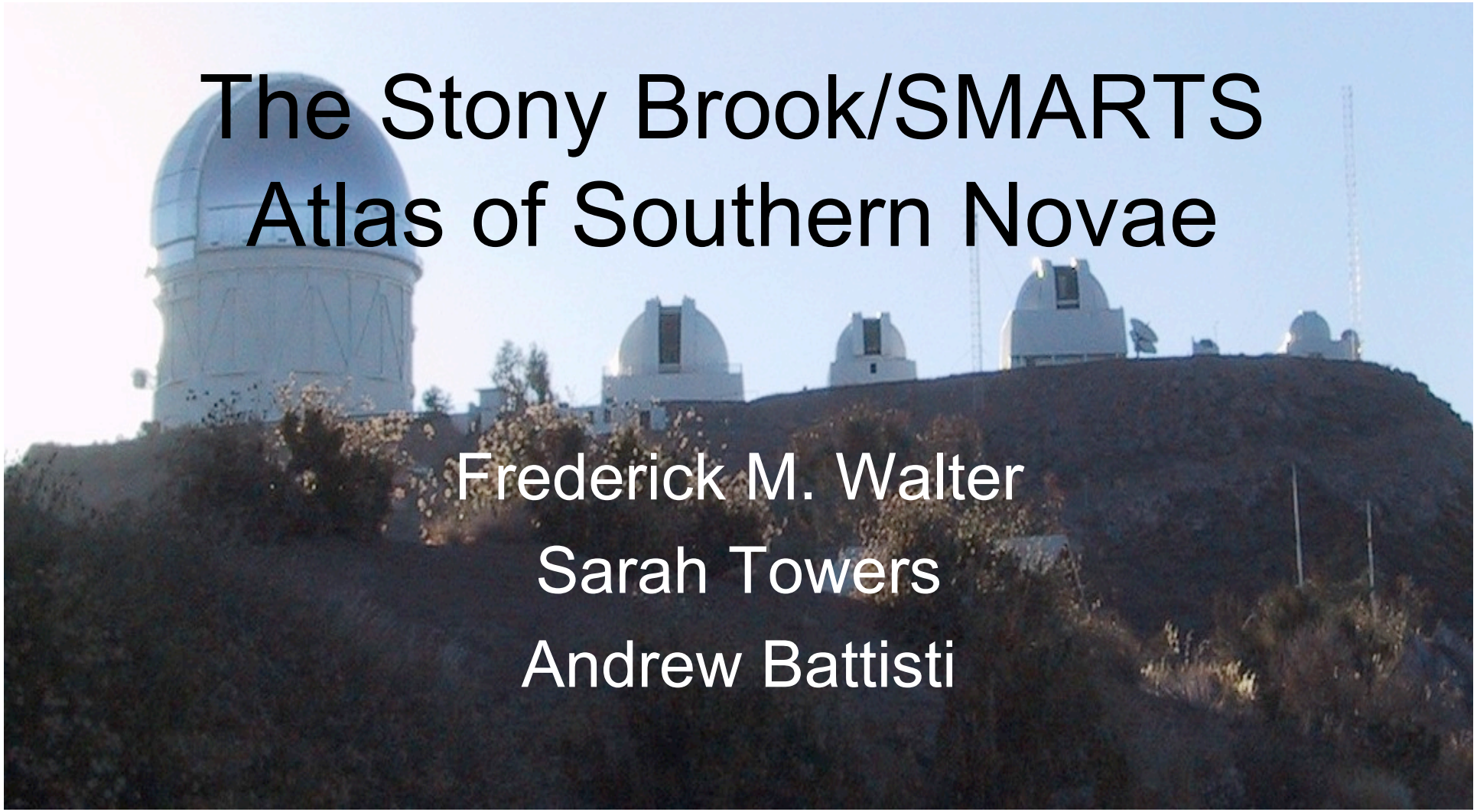


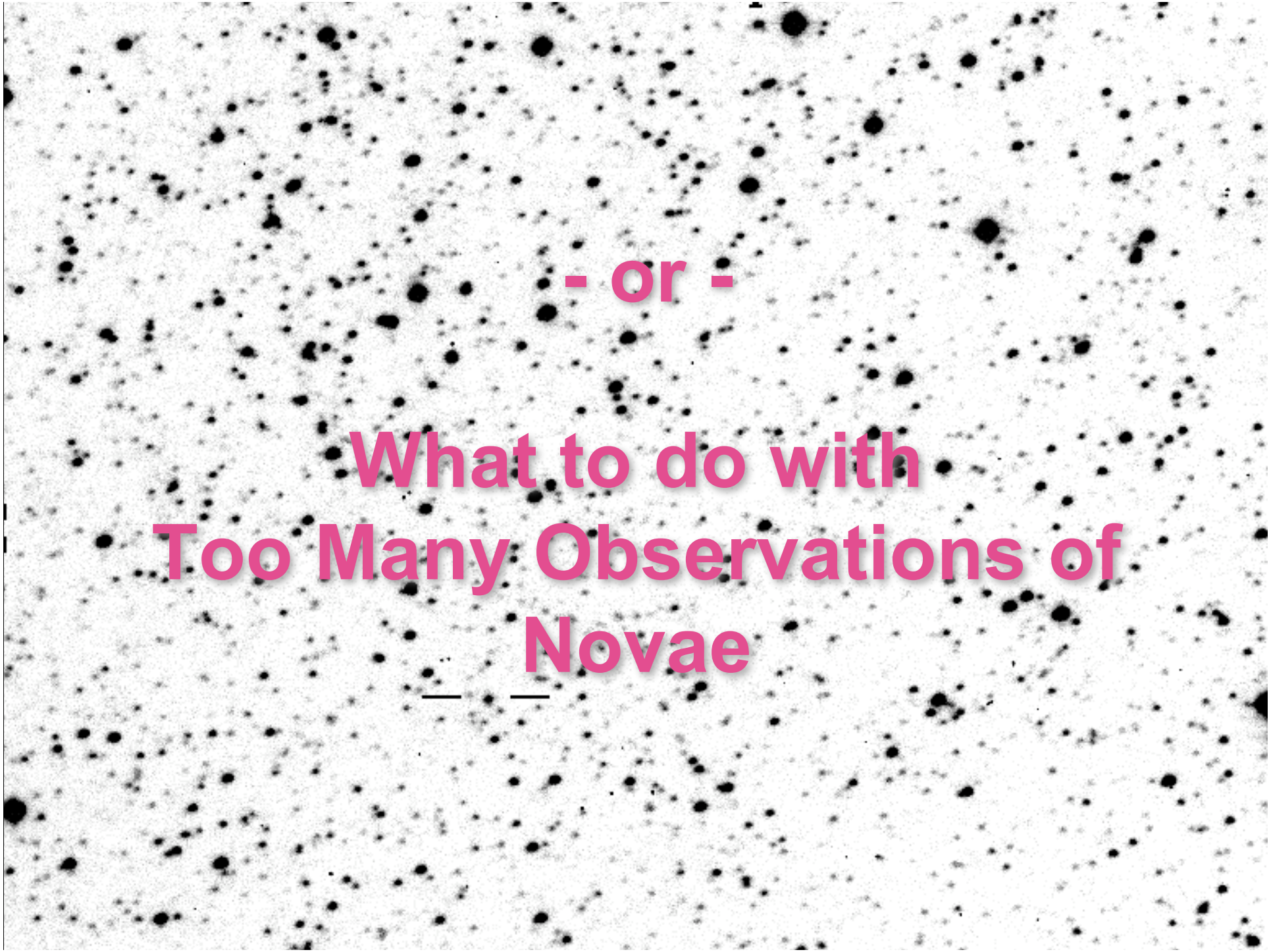
The Stony Brook/SMARTS Atlas of Southern Novae

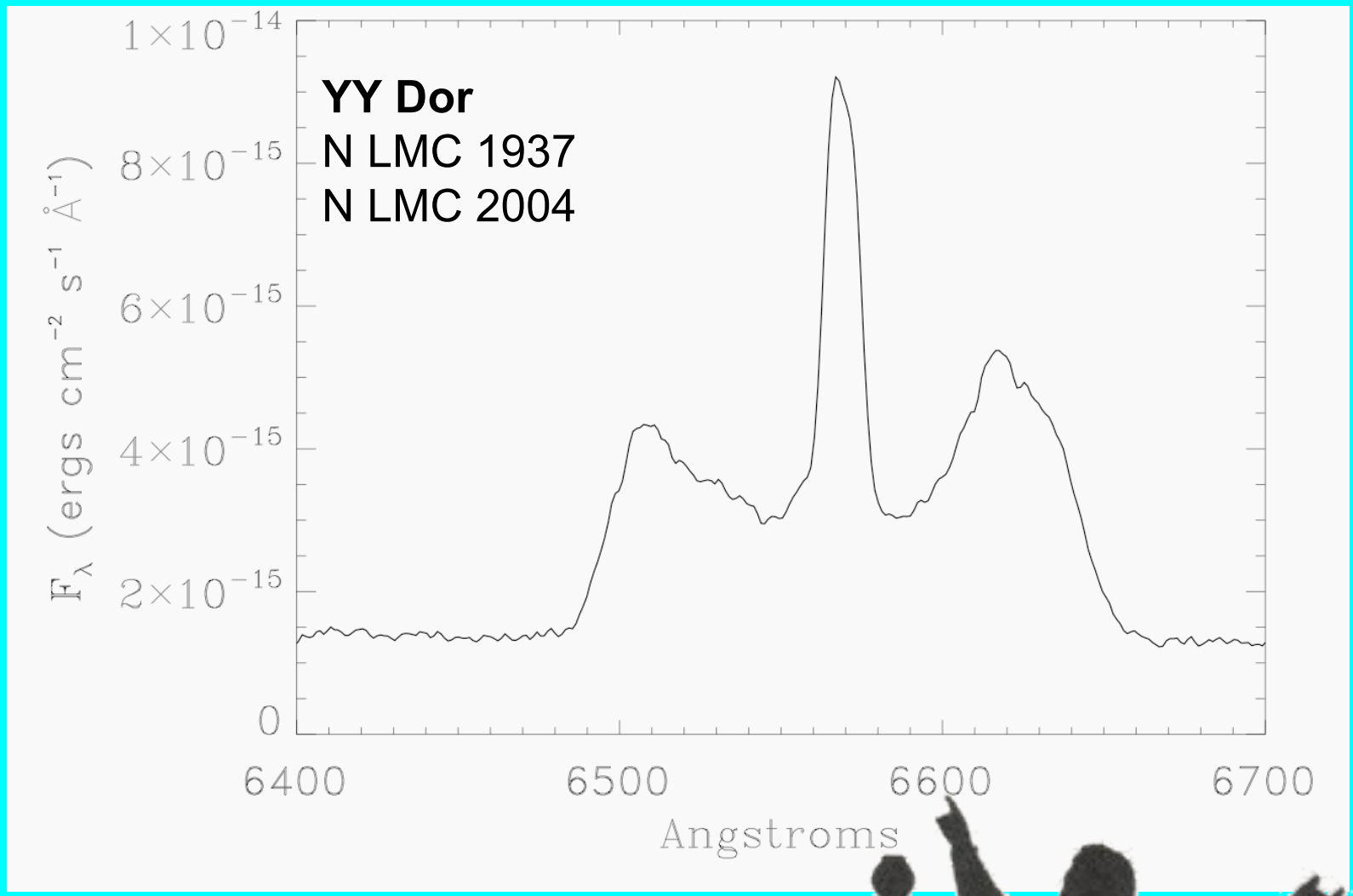
Frederick M. Walter
Sarah Towers
Andrew Battisti

http://www.astro.sunysb.edu/fwalter/SMARTS/NovaAtlas/

With prodding from Howard Bond and Guy Stringfellow

STONY BROOK UNIVERSITY


- or -
What to do with
Too Many Observations of
Novae


YY Dor
N LMC 1937
N LMC 2004
1×10^{-14}
8×10^{-15}
6×10^{-15}
4×10^{-15}
2×10^{-15}
0
F_λ (ergs cm^{-2} s^{-1} Å^{-1})
6400
6500
6600
6700
Angstroms

Atlas Statistics

- Observations of **70 Novae**
  - First observation: 4 April 2003 (V4743 Sgr)
  - Latest Observation: probably last night
- Lots of data (as of 1 January 2013)
  - Over 2700 photometric obs (*BVRIJHK*)
  - Over 3000 spectra
- Over **8 years** coverage in cases

Spectroscopy

- **RC spectrograph** on the CTIO 1.5m
- Primary observing modes
  - 13/I: 3200 – 9500A; R=400
  - 26/I: 3660 – 5450A; R=1000
  - 47/I: 5650 – 6070A; R=2000
  - 47/II:4070 – 4740A; R=3000
- Limiting magnitudes:
  - ~16 (continuum); ~18 (lines)

Photometry

- **Andicam imager** on CTIO 1.3m
- Simultaneous optical (BVRI) and nIR (JHK_s) imaging
- Limiting magnitudes:
  - ~15 (K)
  - ~22 (V)
- Differential photometry calibrated later

Populations of the Atlas

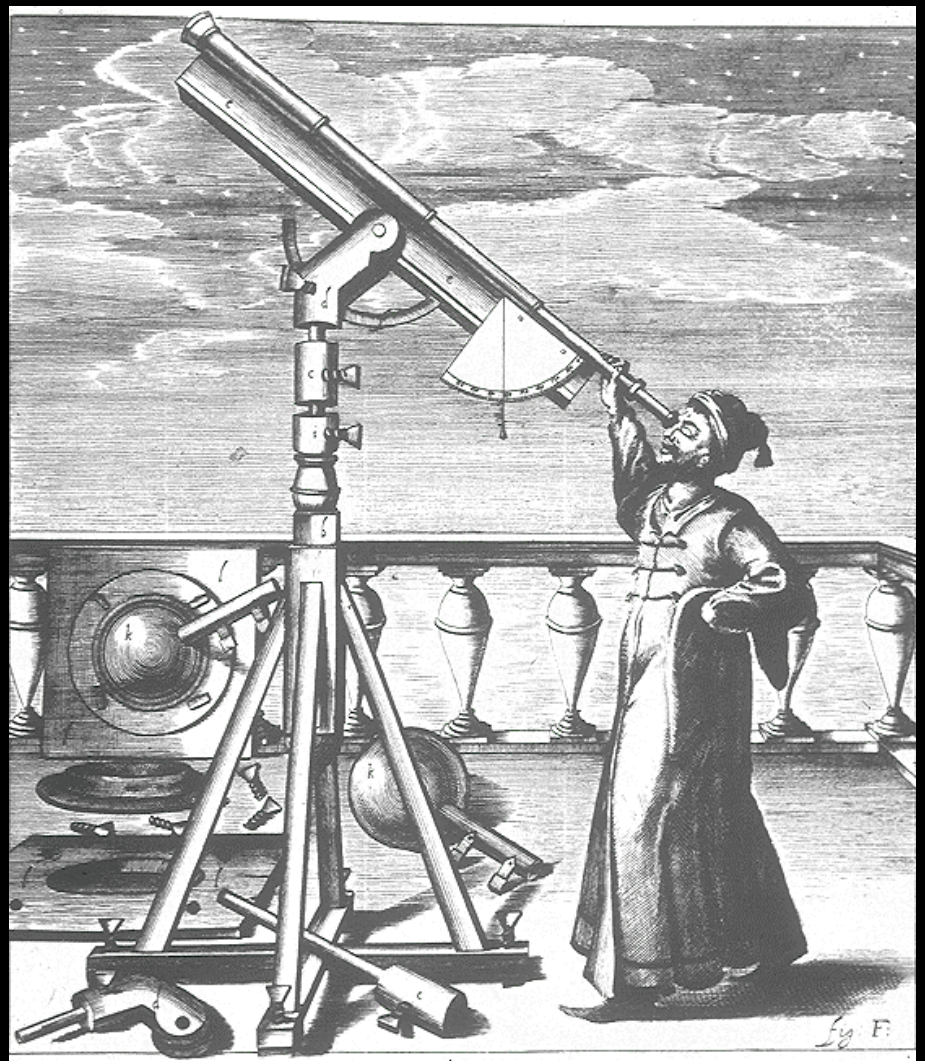
- 25% He-N; 75% Fe II
- >50% exhibit P Cyg absorption

- 6 LMC novae (3 He-N; 1 O-Ne-Mg)
- 1 SMC nova (O-Ne-Mg)

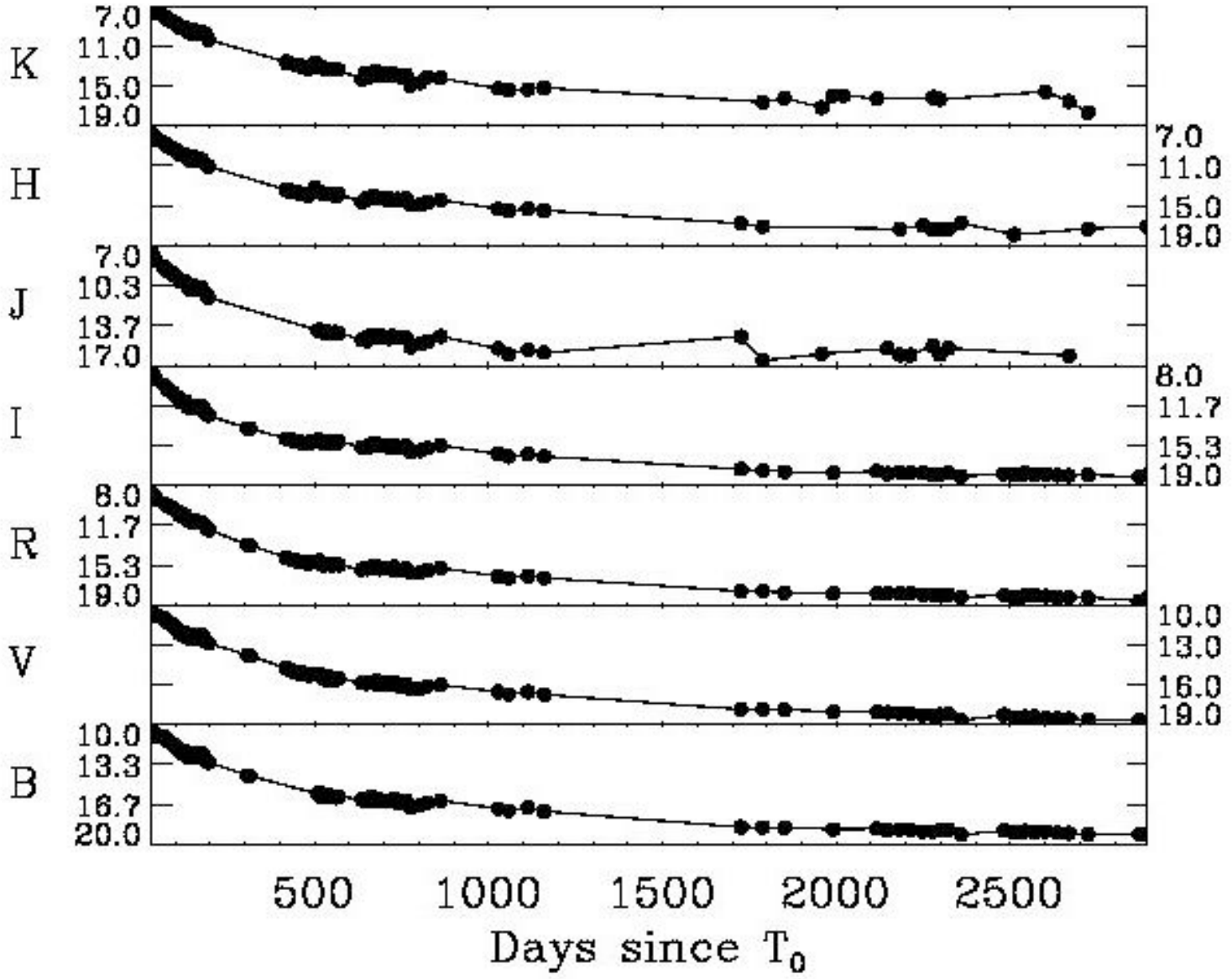
- Not complete


Nova Chevy 1969

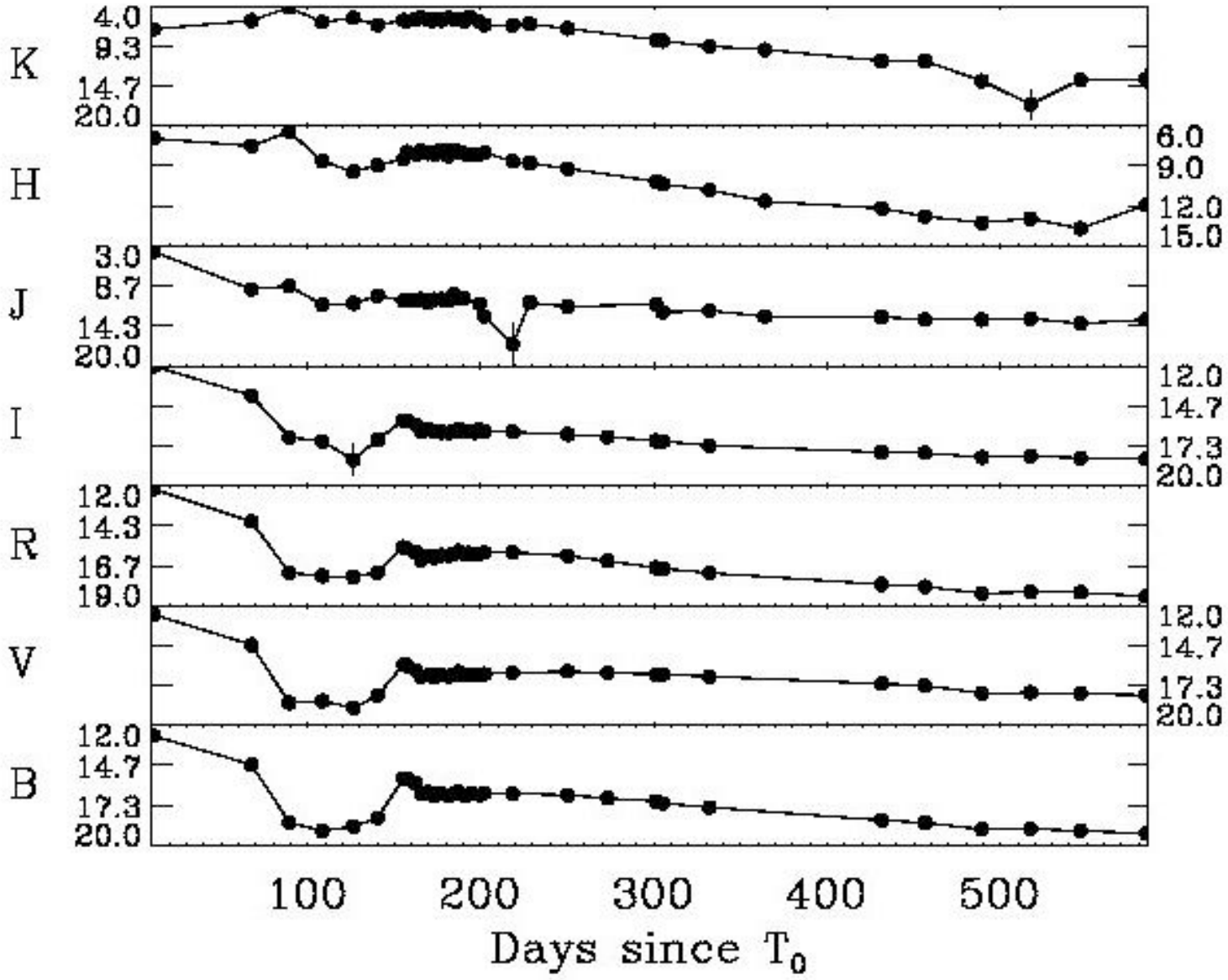
Examples of Data: Photometry



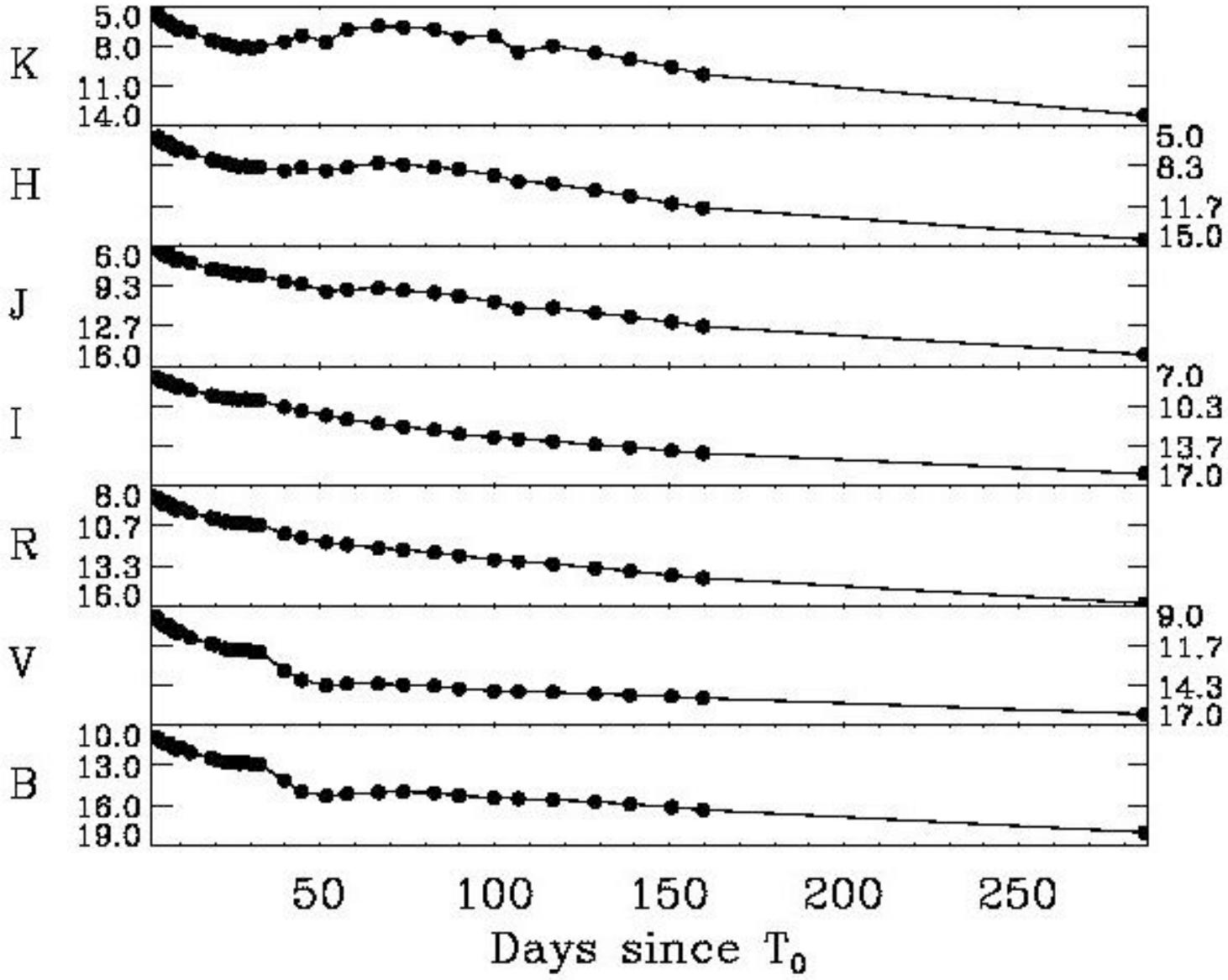
V574 Pup


K
H
J
I
R
V
B
7.0
11.0
15.0
19.0
7.0
10.3
13.7
17.0
8.0
11.7
15.3
19.0
10.0
13.3
16.7
20.0
500
1000
1500
2000
2500
Days since T_0

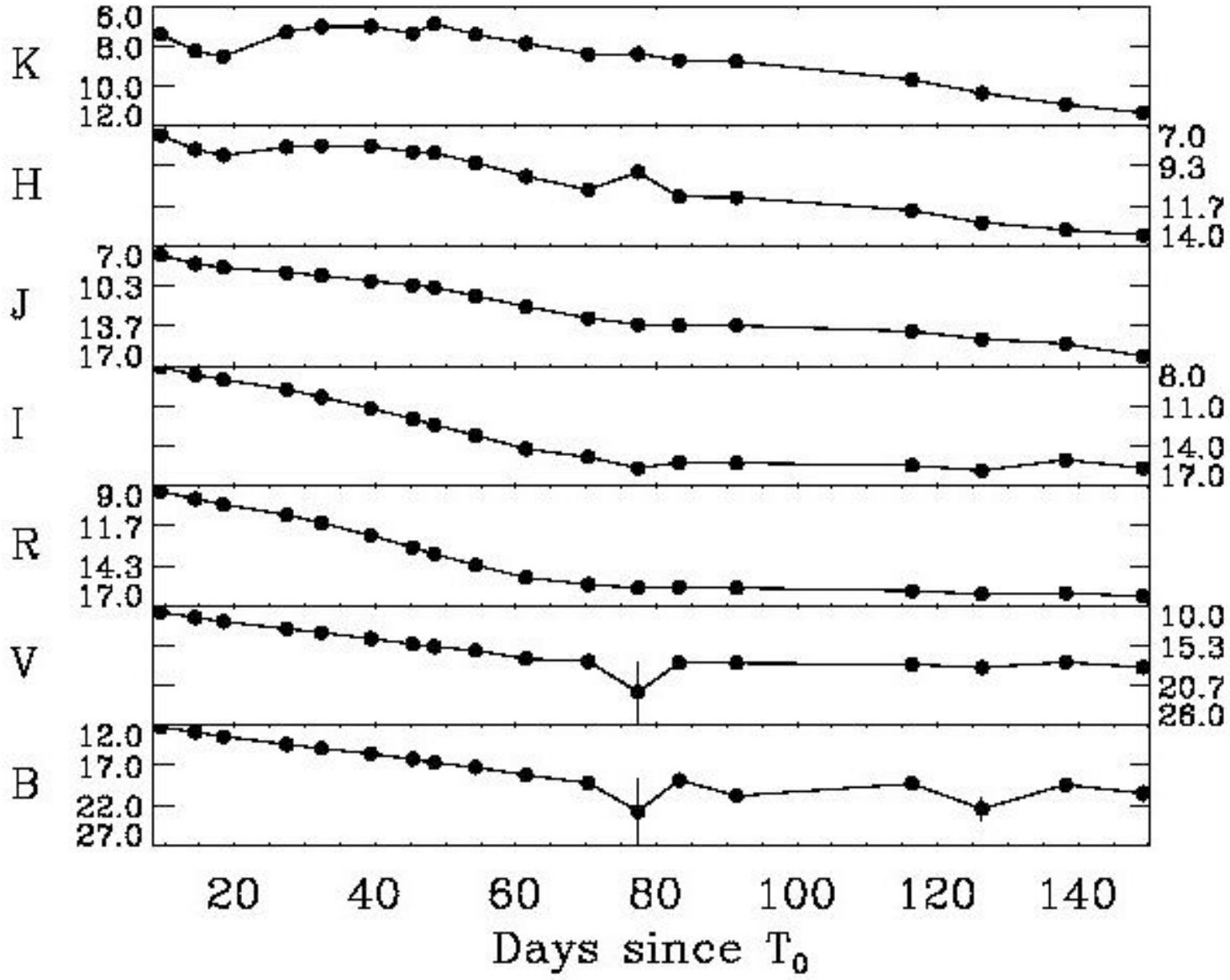
N LMC 2009b


K
4.0
9.3
14.7
20.0
H
6.0
9.0
12.0
15.0
J
3.0
8.7
14.3
20.0
I
12.0
14.7
17.3
20.0
R
12.0
14.3
16.7
19.0
V
12.0
14.7
17.3
20.0
B
12.0
14.7
17.3
20.0
100
200
300
400
500
Days since T_0

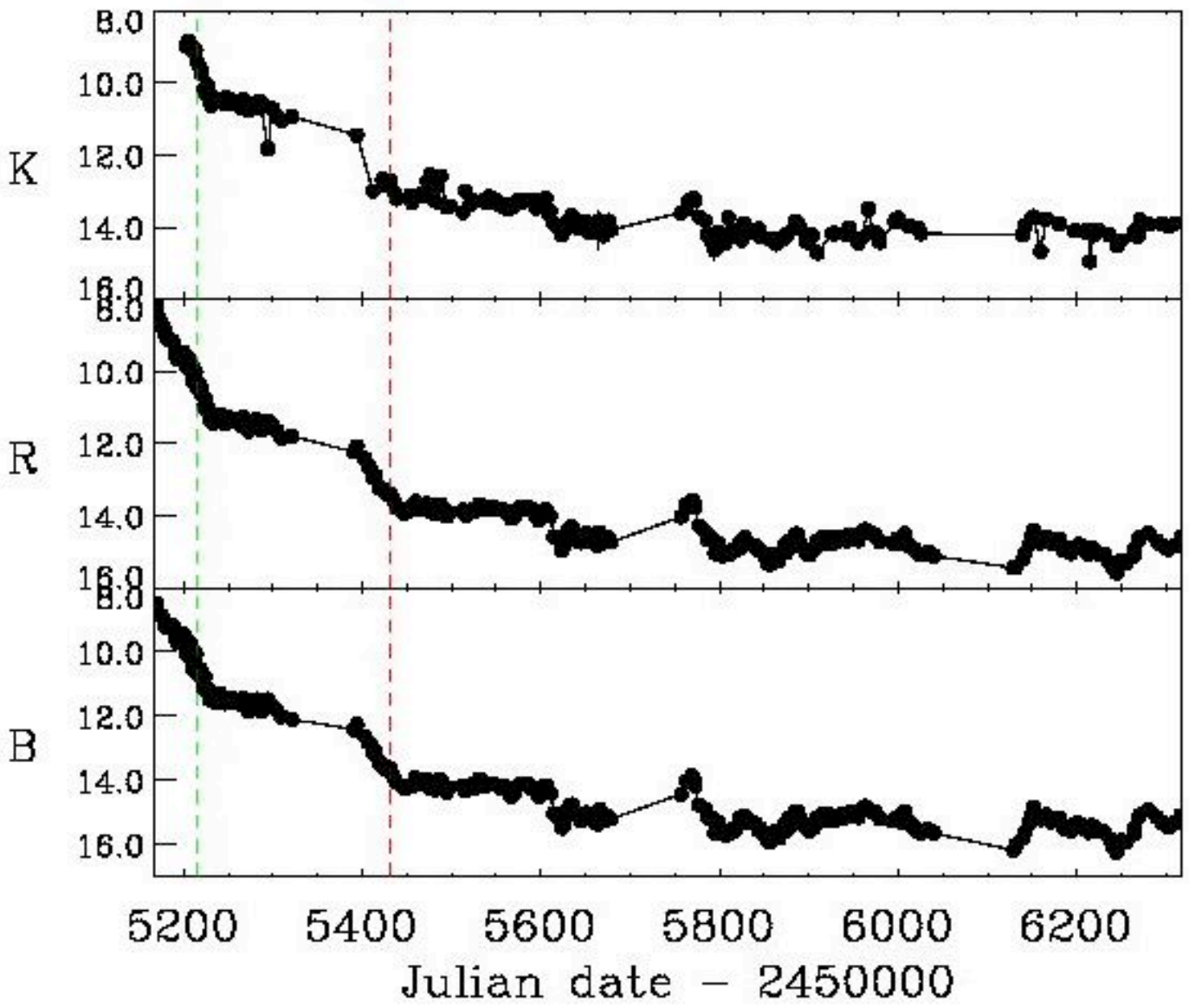
N Cen 2012


K
H
J
I
R
V
B
5.0
8.0
11.0
14.0
5.0
8.3
11.7
15.0
6.0
9.3
12.7
16.0
7.0
10.3
13.7
17.0
8.0
10.7
13.3
16.0
9.0
11.7
14.3
17.0
10.0
13.0
16.0
19.0
50
100
150
200
250
Days since T_0

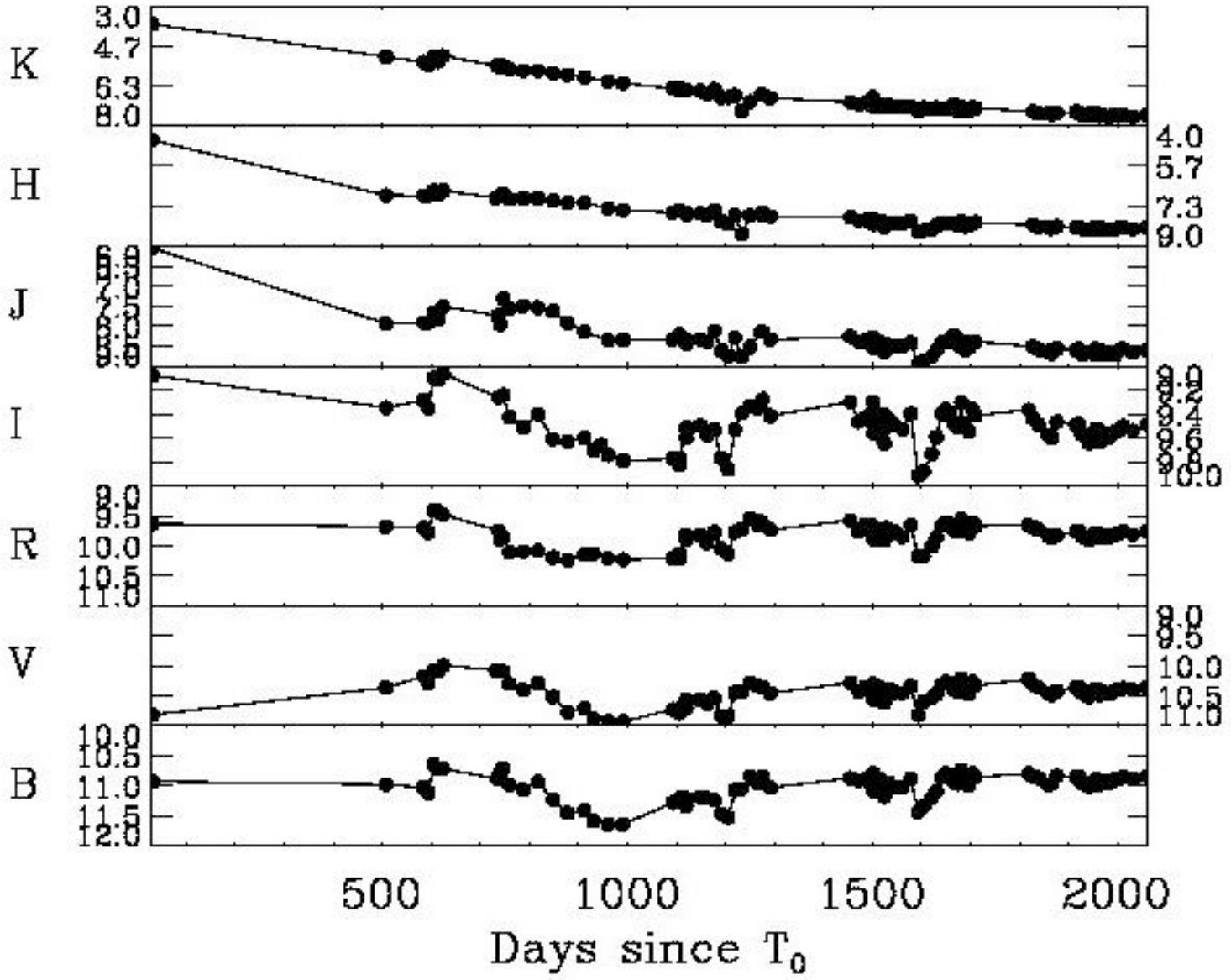
N Cen 2012b


K
6.0
8.0
10.0
12.0
H
7.0
9.3
11.7
14.0
J
7.0
10.3
13.7
17.0
I
8.0
11.0
14.0
17.0
R
9.0
11.7
14.3
17.0
V
10.0
15.3
20.7
26.0
B
12.0
17.0
22.0
27.0
20
40
60
80
100
120
140
Days since T_0

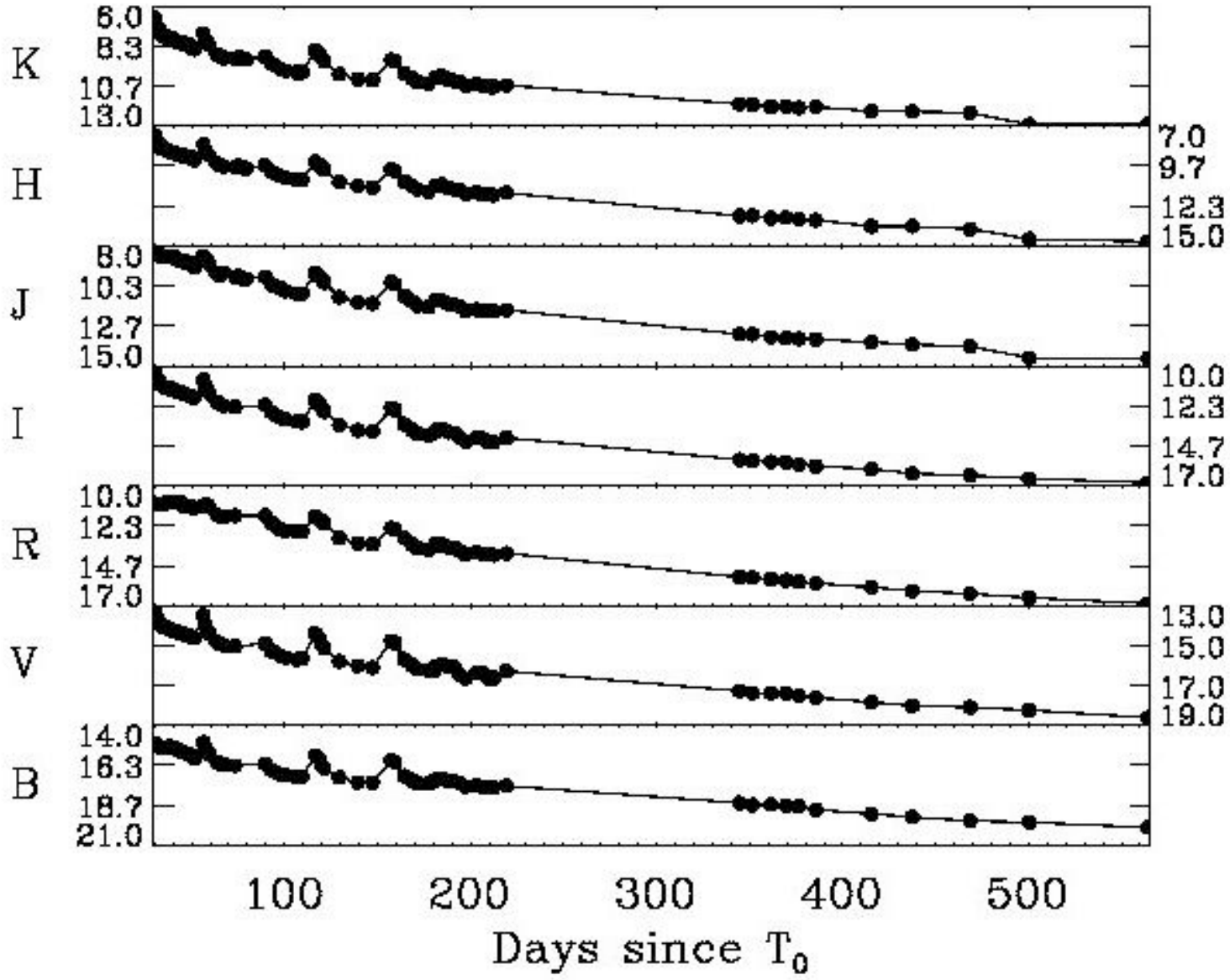
KT Eri


K
R
B
8.0
10.0
12.0
14.0
16.0
5200
5400
5600
5800
6000
6200
Julian date − 2450000

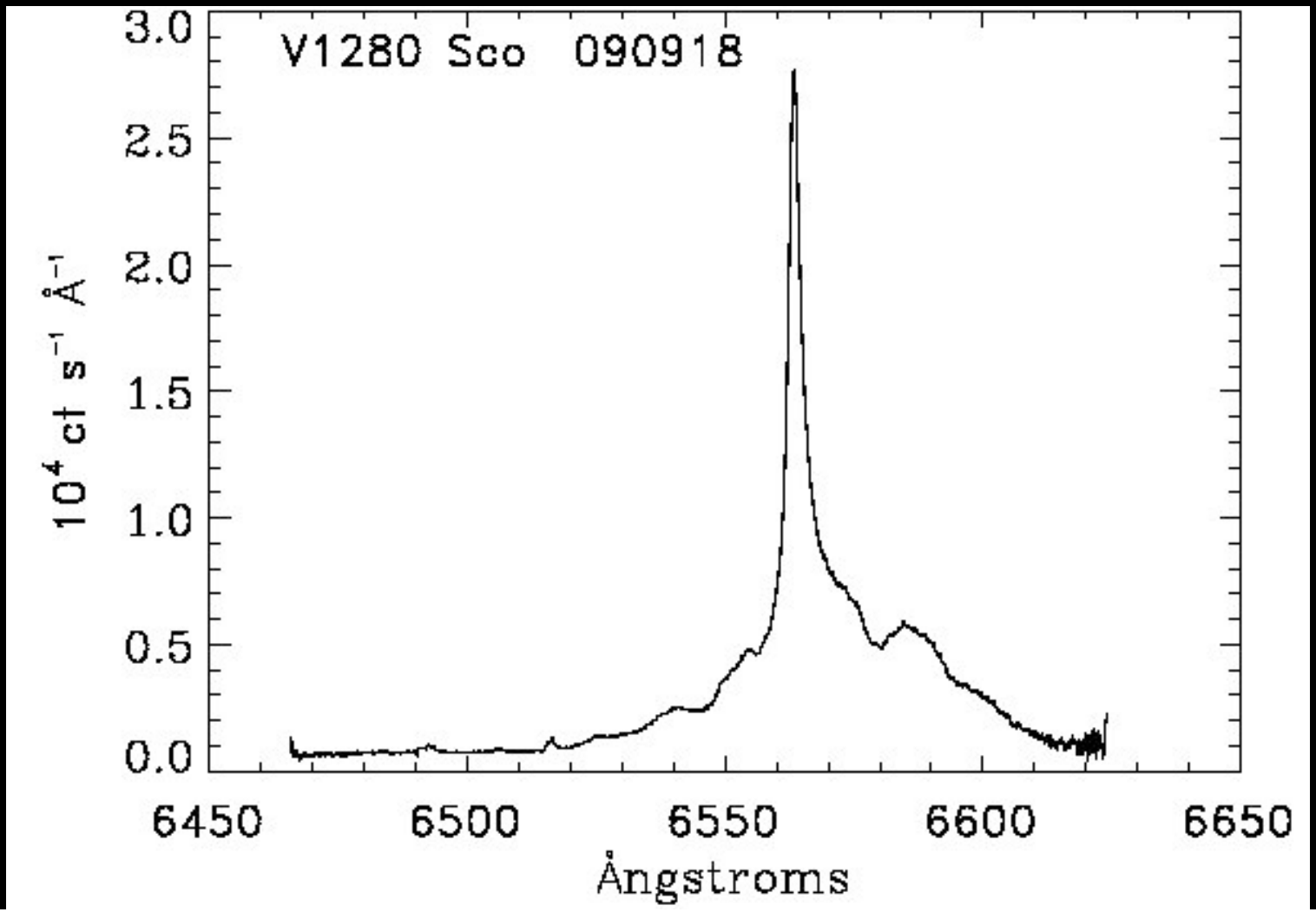
V1280 Sco


K
H
J
I
R
V
B
3.0
4.7
6.3
8.0
4.0
5.7
7.3
9.0
9.5
10.0
10.5
11.0
11.5
12.0
500
1000
1500
2000
Days since T0

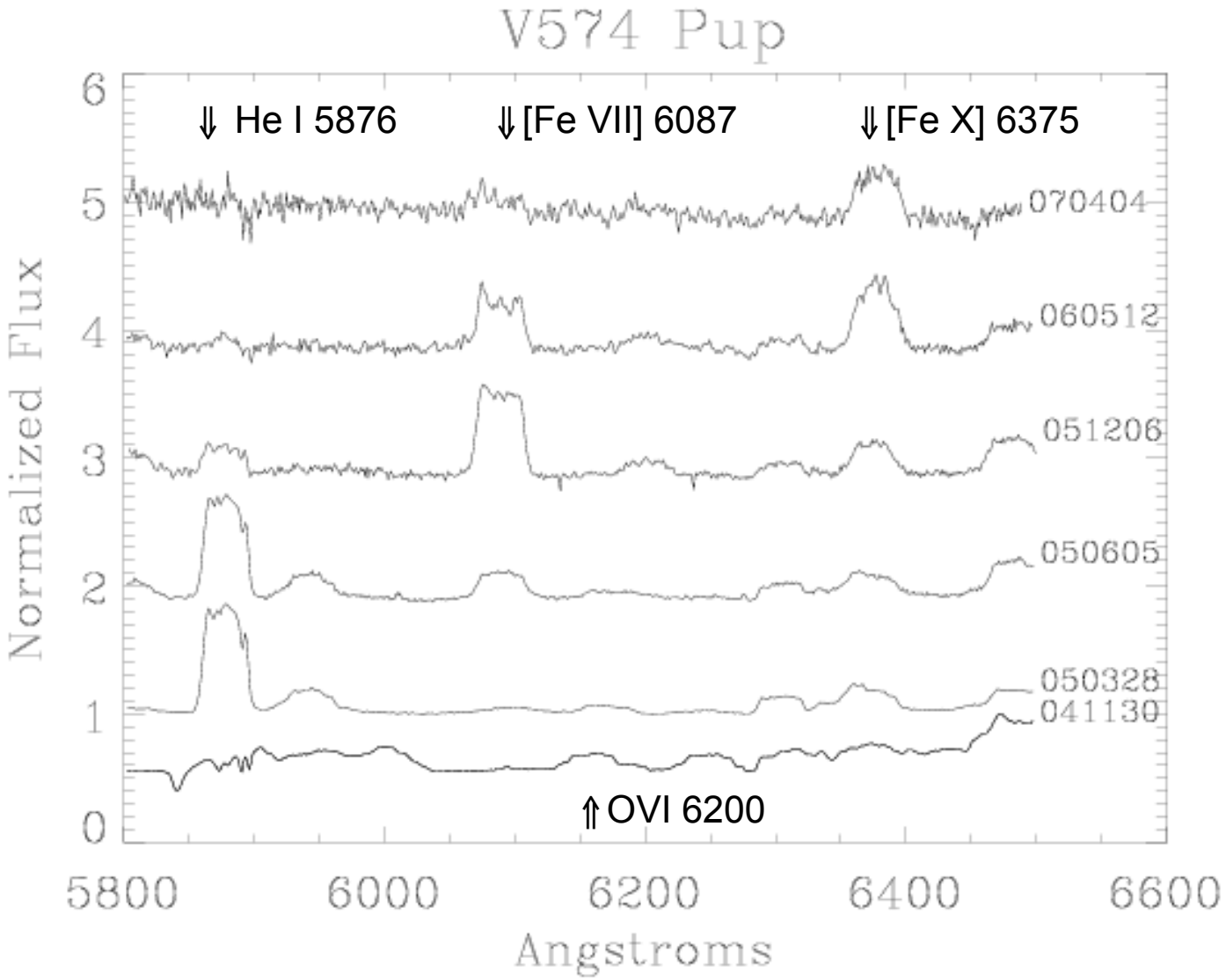
V5588 Sgr


K
H
J
I
R
V
B
6.0
8.3
10.7
13.0
7.0
9.7
12.3
15.0
8.0
10.3
12.7
15.0
10.0
12.3
14.7
17.0
10.0
12.3
14.7
17.0
13.0
15.0
17.0
19.0
14.0
16.3
18.7
21.0
100
200
300
400
500
Days since T_0

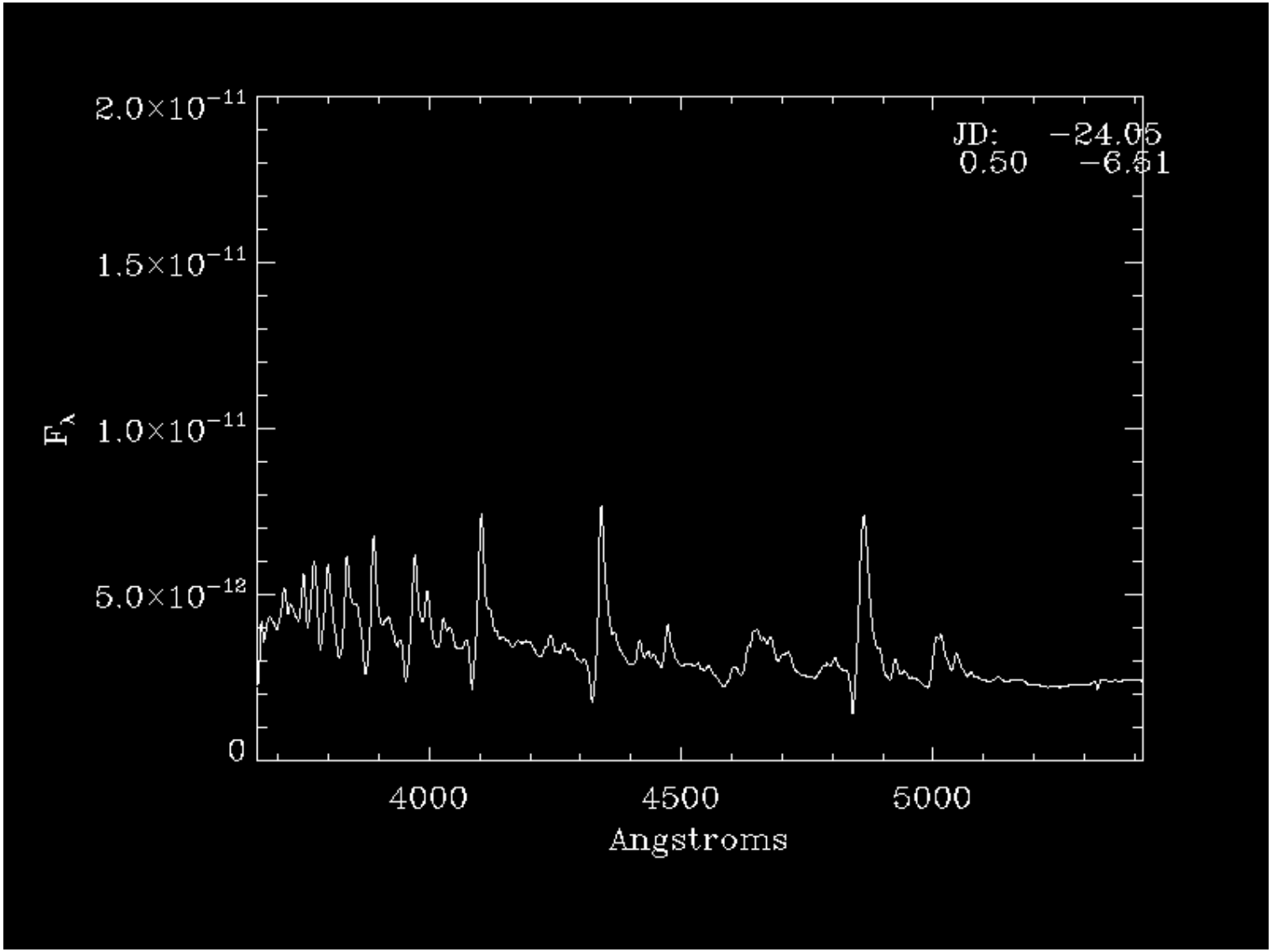
Examples of Data: Spectroscopy



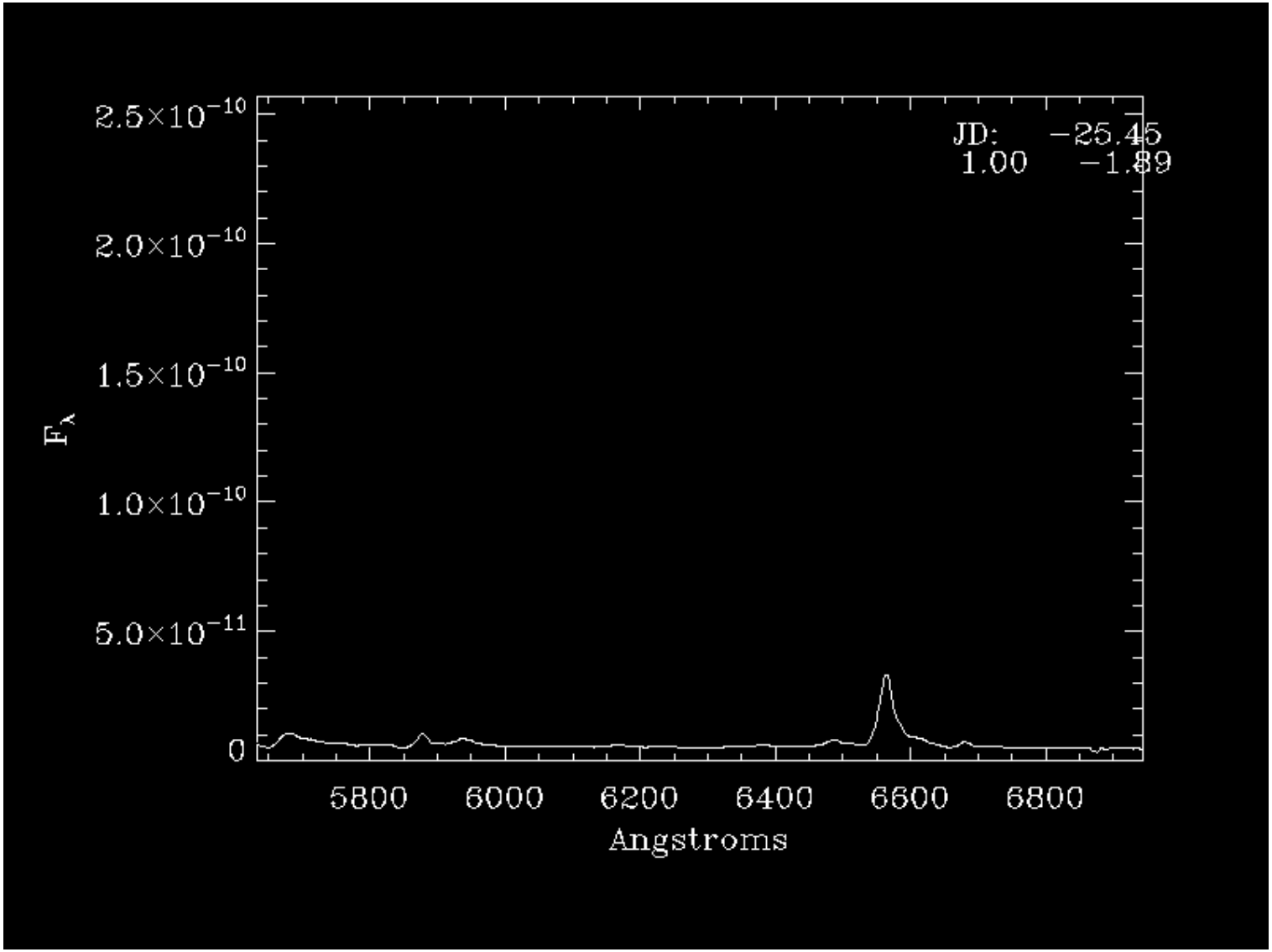
Coronal lines in V574 Pup



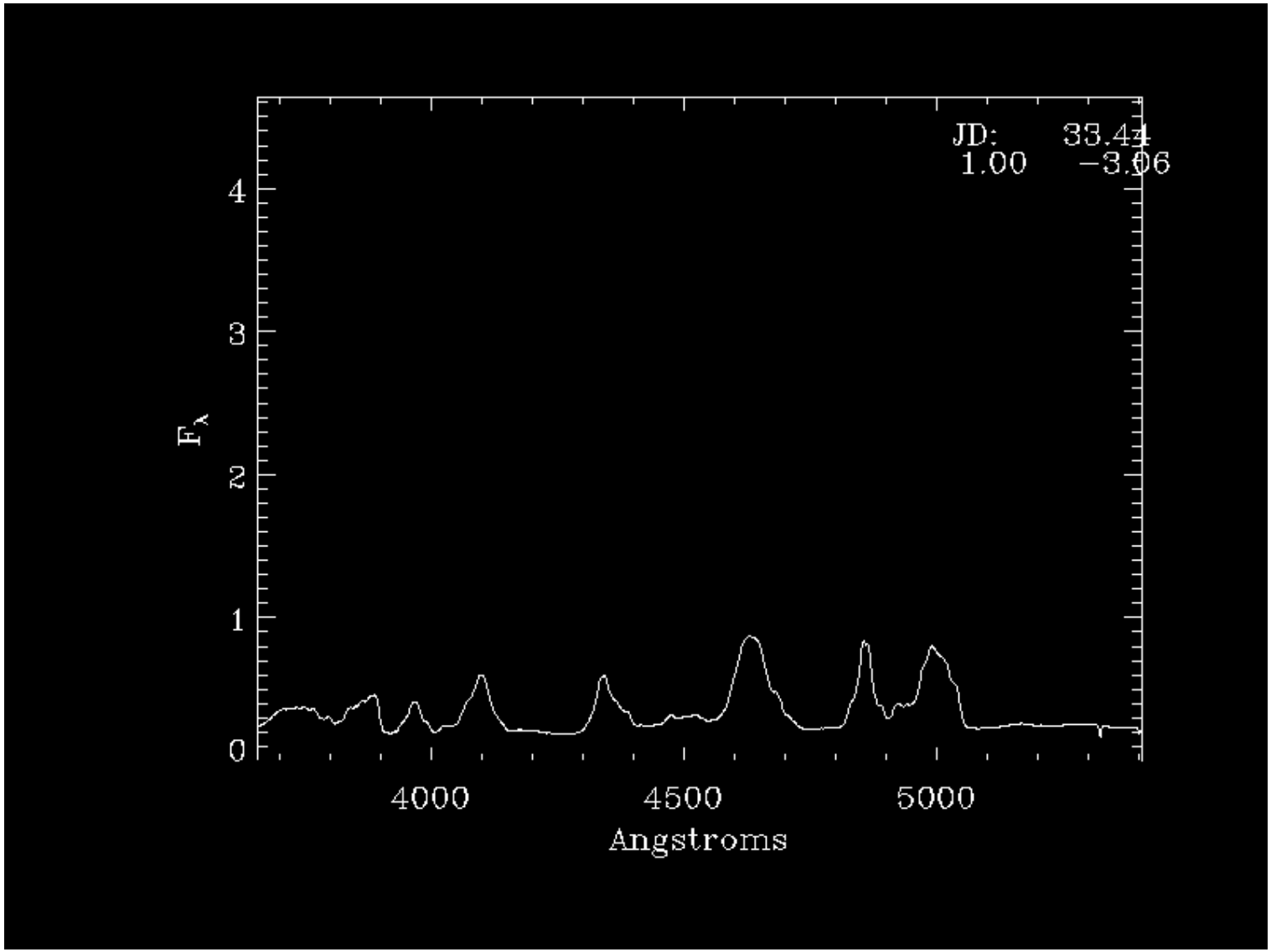
T Pyx


2.0×10⁻¹¹
1.5×10⁻¹¹
1.0×10⁻¹¹
5.0×10⁻¹²
0
Fλ
JD: −24.05
0.50 −6.51
4000
4500
5000
Angstroms

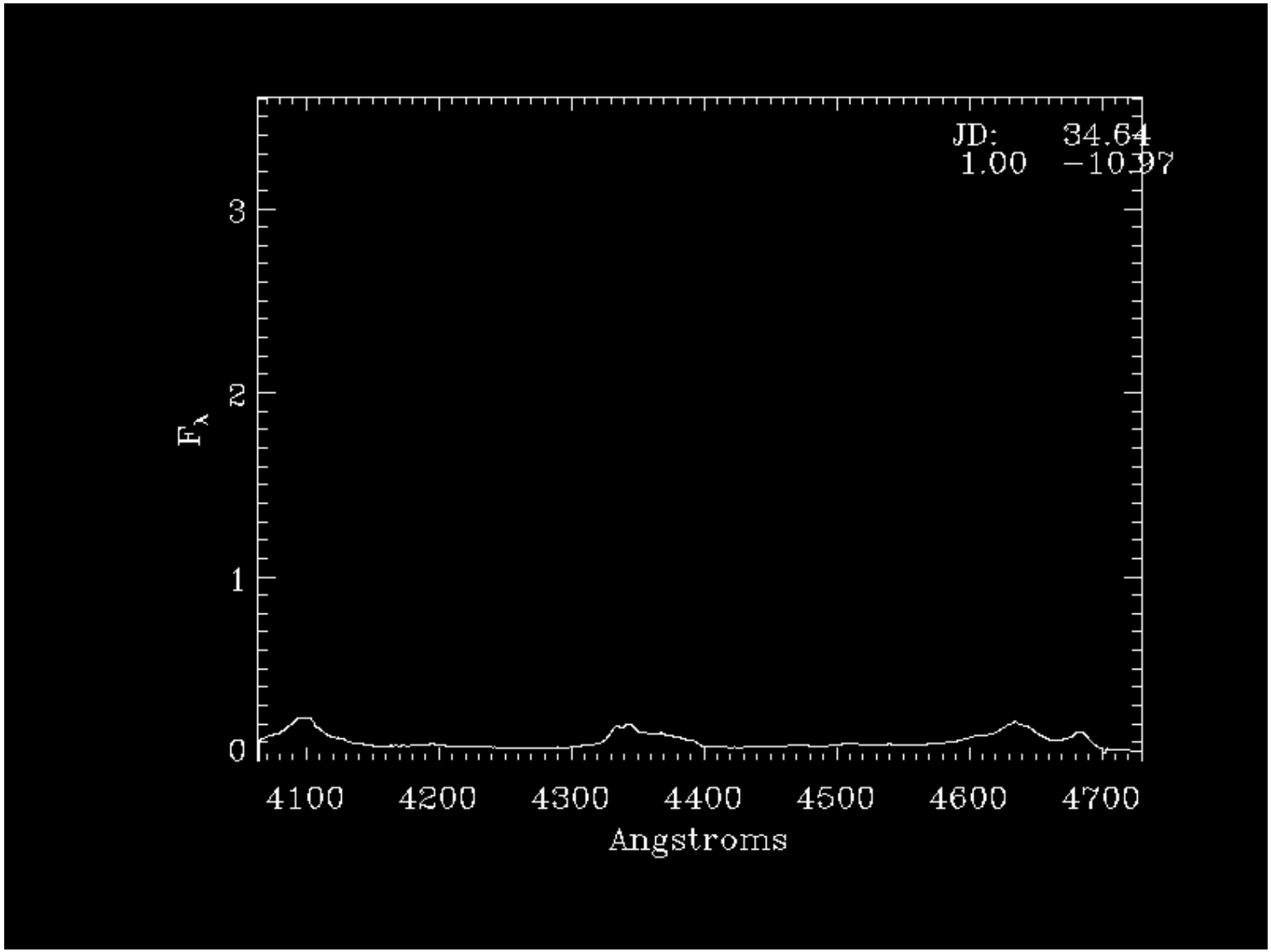
T Pyx


JD: −25.45
1.00 −1.89
2.5×10⁻¹⁰
2.0×10⁻¹⁰
1.5×10⁻¹⁰
1.0×10⁻¹⁰
5.0×10⁻¹¹
0
Fλ
5800
6000
6200
6400
6600
6800
Angstroms

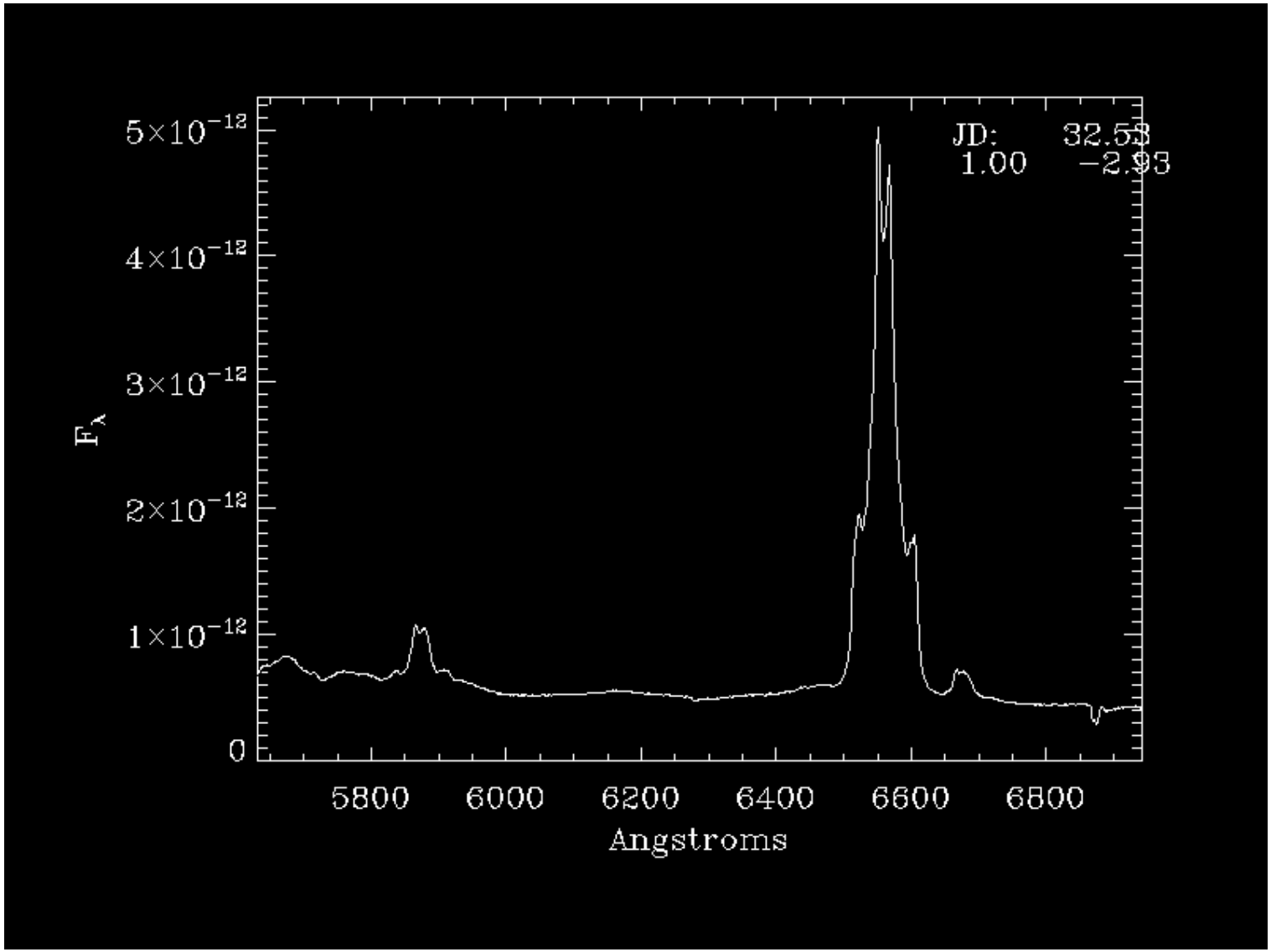
KT Eri



KT Eri


JD: 34.64
1.00 −10.97
3
2
1
0
F_λ
4100
4200
4300
4400
4500
4600
4700
Angstroms

KT Eri


JD:
1.00
5×10^{-12}
4×10^{-12}
3×10^{-12}
2×10^{-12}
1×10^{-12}
0
F_λ
5800
6000
6200
6400
6600
6800
Angstroms

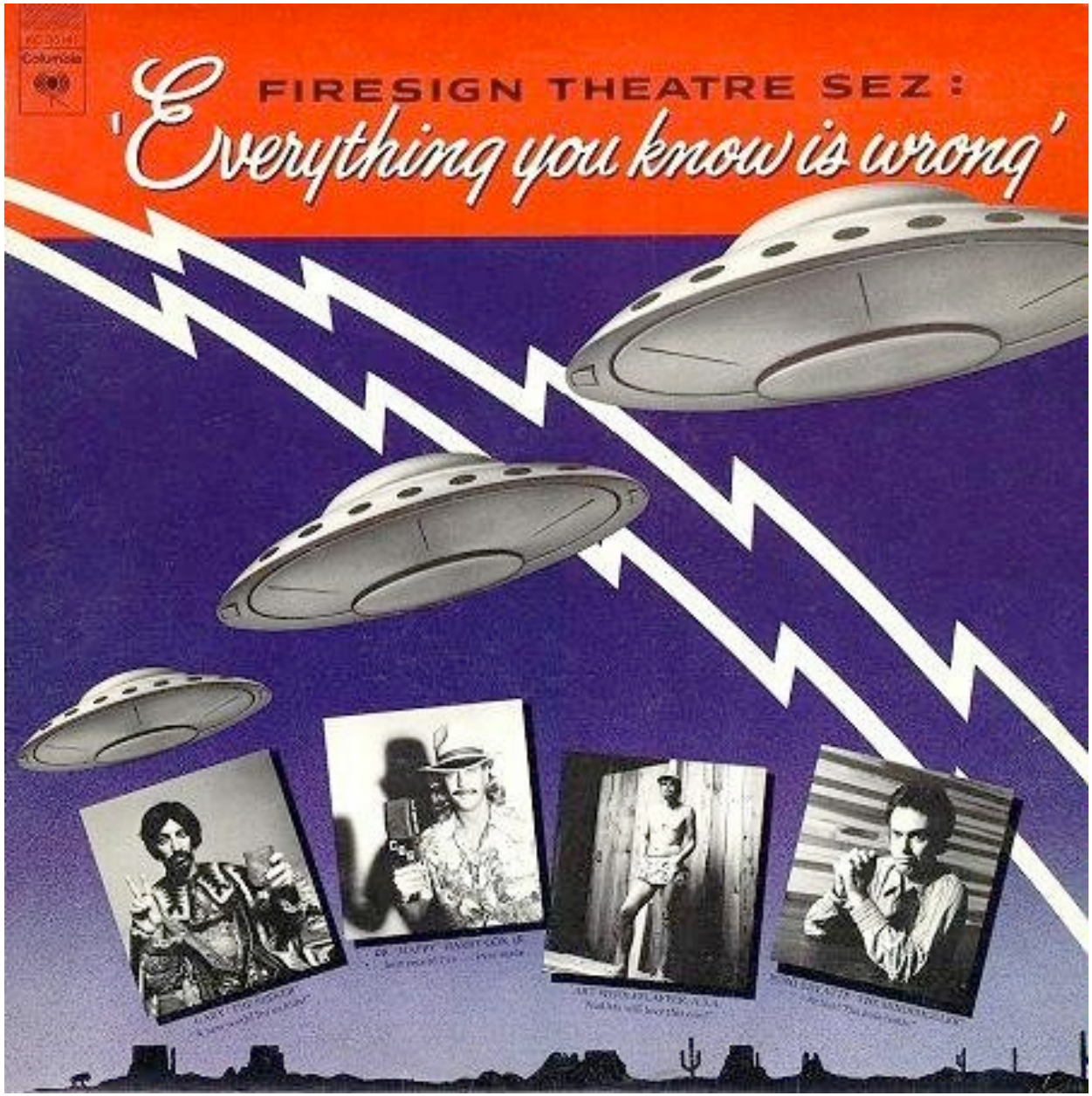
Motivation (Unsolved Problems)

- What are the progenitor systems?
- Why do He-N novae and Fe II novae differ?
- Where does the Neon come from?
- What kinds of systems form dust?
- What determines the length of the SSS phase?
- Are there optical proxies of the SSS?
- Line profiles:
  - Ejecta or disks?
  - Are there bi-polar jets?

How the Atlas Helps

- Systematic observations for over 8 years
  - Timescales for line evolution
  - Contemporaneous with X, UV, IR observations
- Multi-wavelength B - K_s OIR photometry
  - Separate line/continuum fluxes
  - Identify dust even if not in line of sight
- Optical spectroscopy
  - 3300-9500A
  - Ionization states through Fe XIV
  - Line profiles resolved
- Mostly unbiased
  - Declination < $+10^o$
  - V_{max} < 12 mag

Selected Science



Line profiles in He-N novae:

Accretion disks or expanding rings?

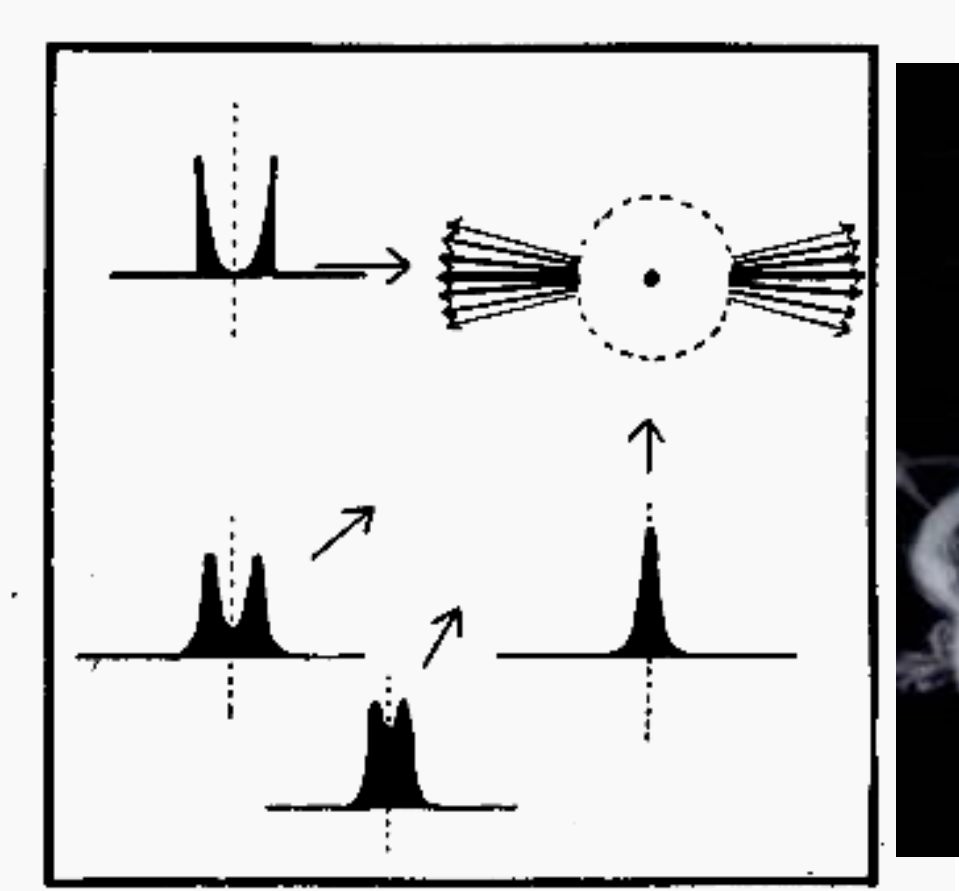
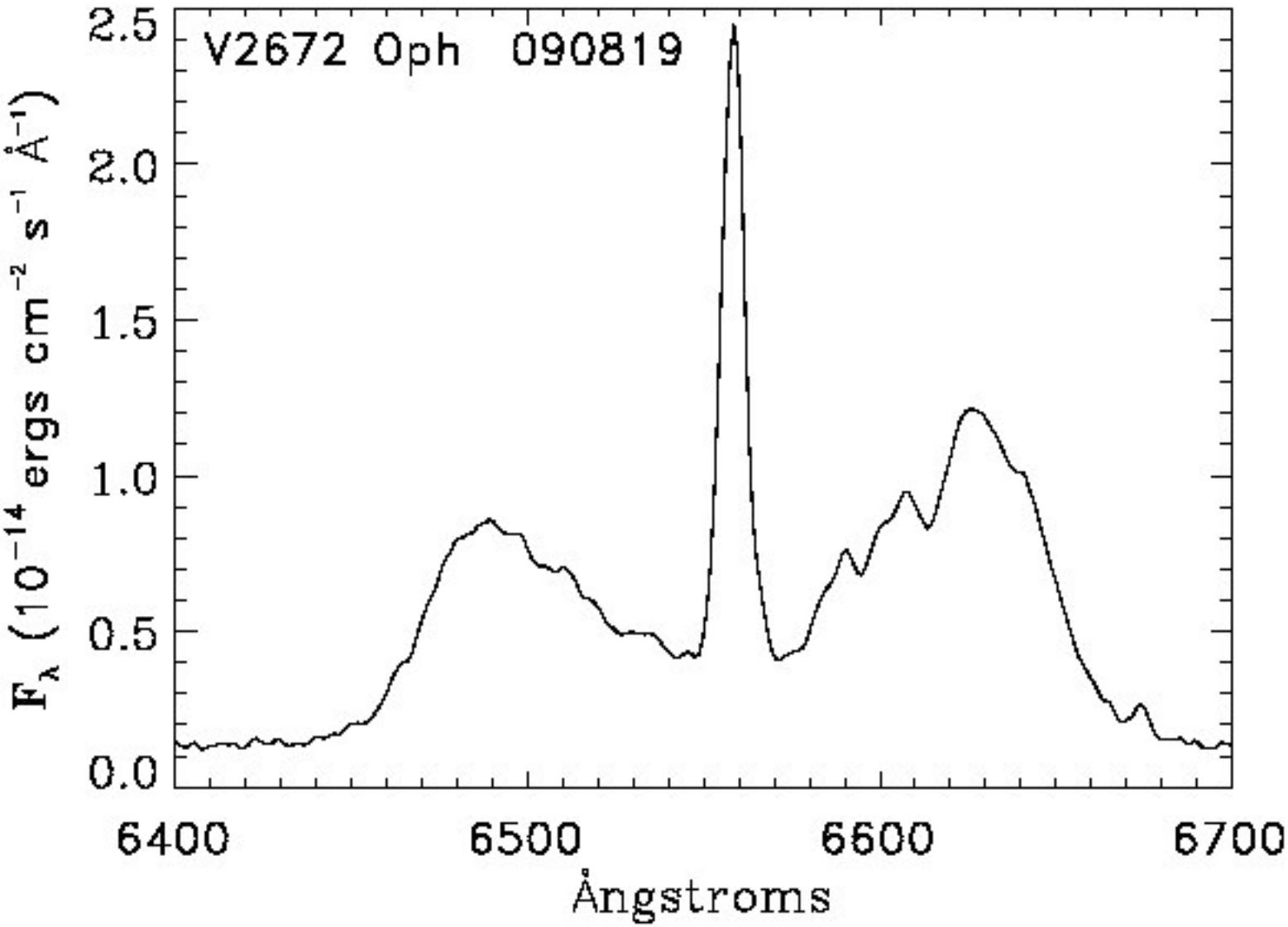
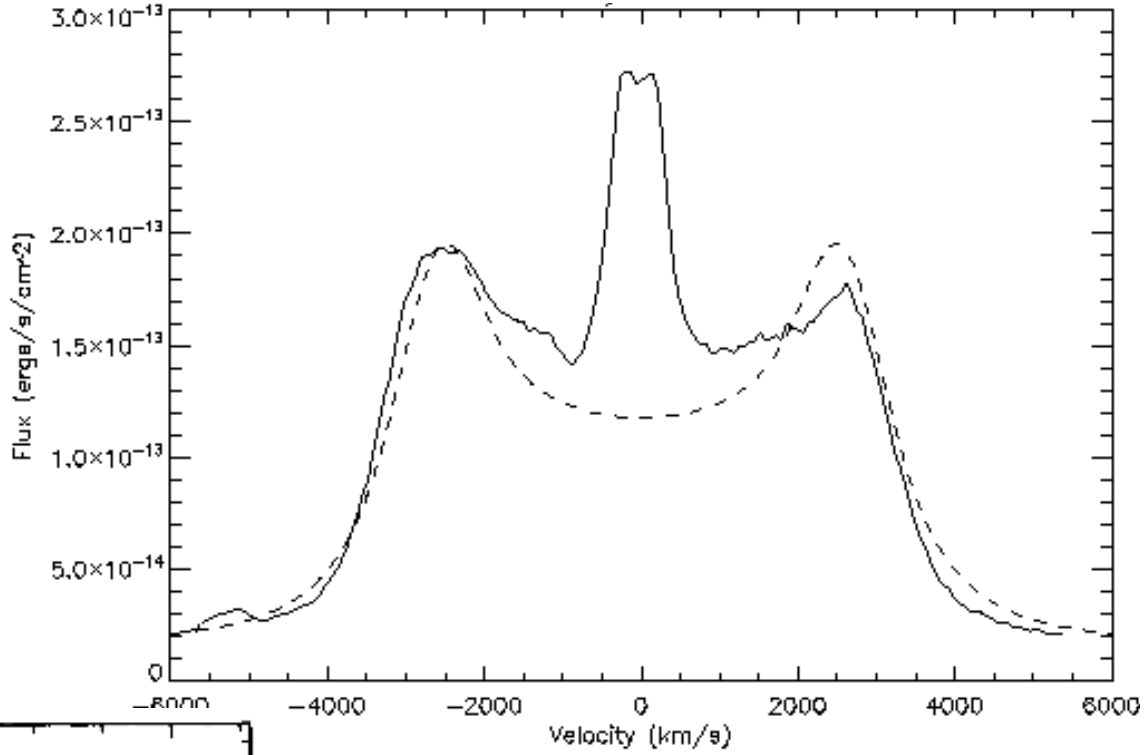
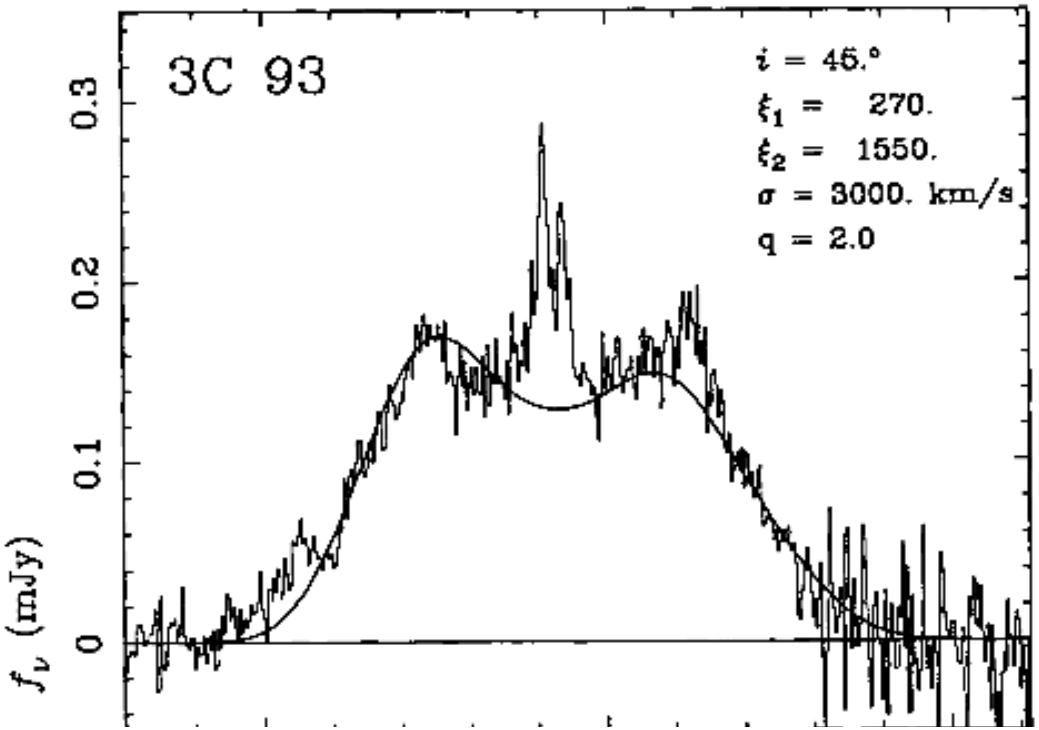


FIGURE 2


V2672 Oph 090819
2.5
2.0
1.5
1.0
0.5
0.0
F_λ (10^{-14} ergs cm^{-2} s^{-1} Å^{-1})
6400
6500
6600
6700
Ångstroms

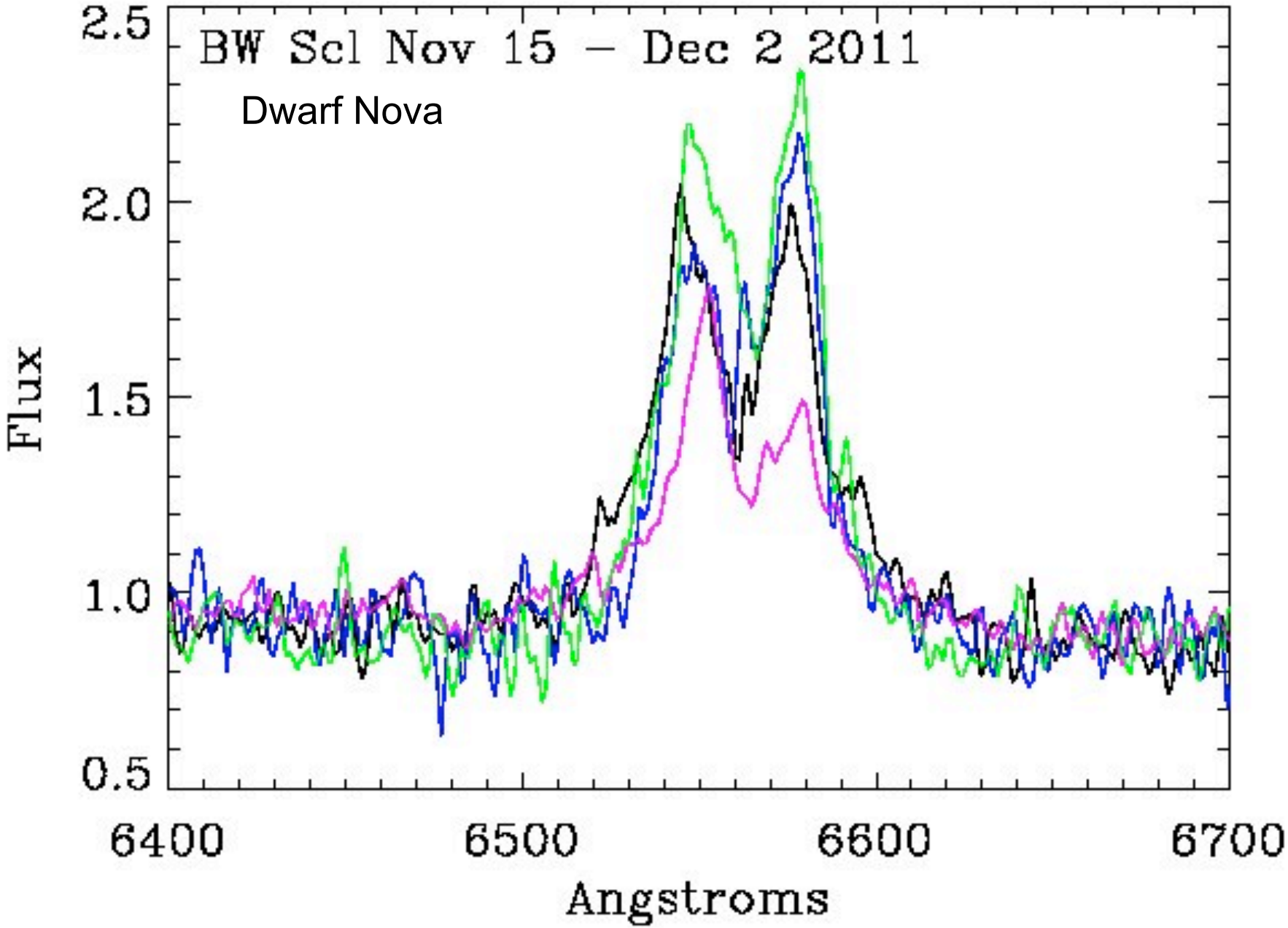
Simple disk model ⇒
for YY Dor.
$M_{WD} = 1.3\ M_{\odot}$



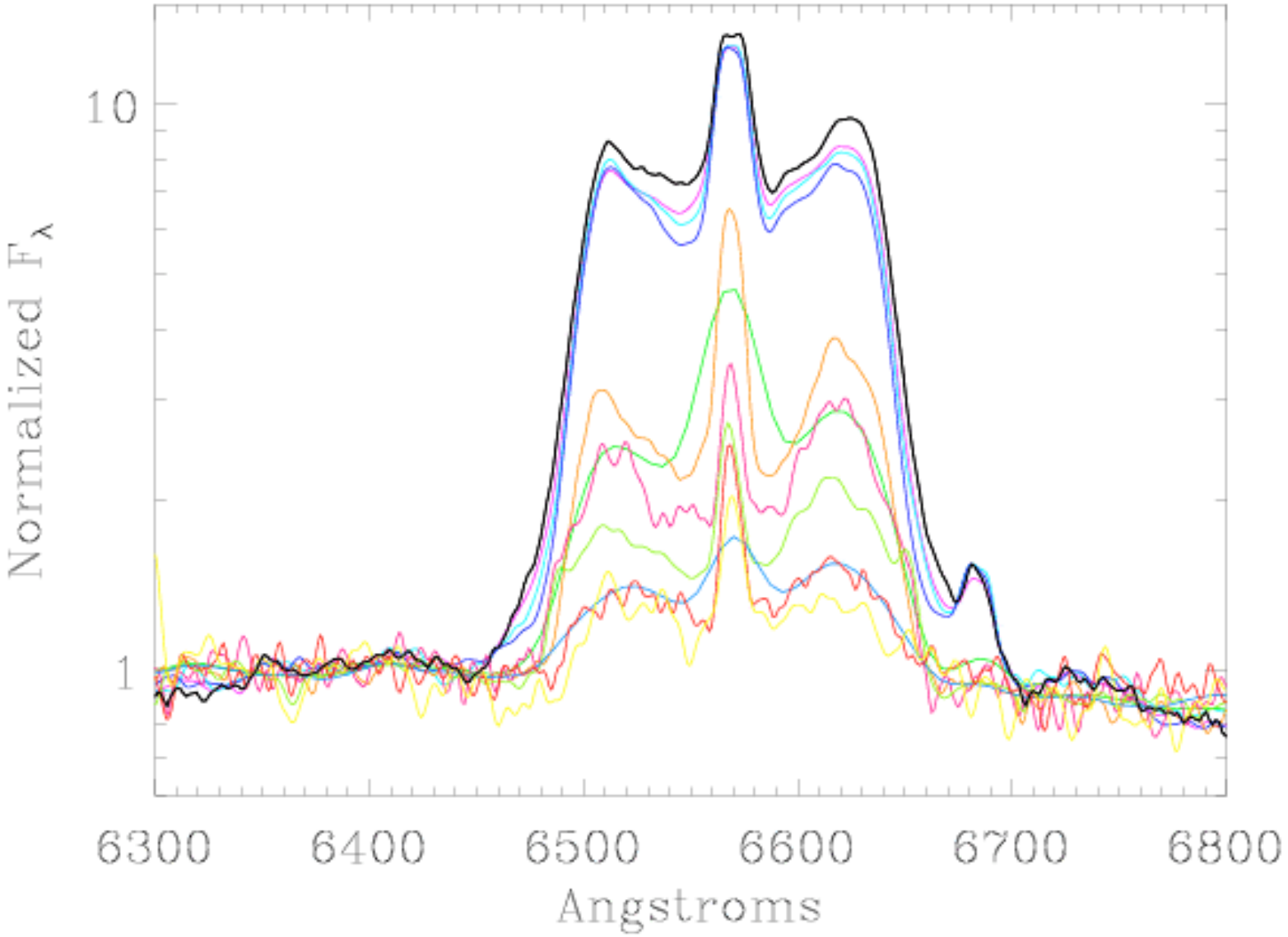


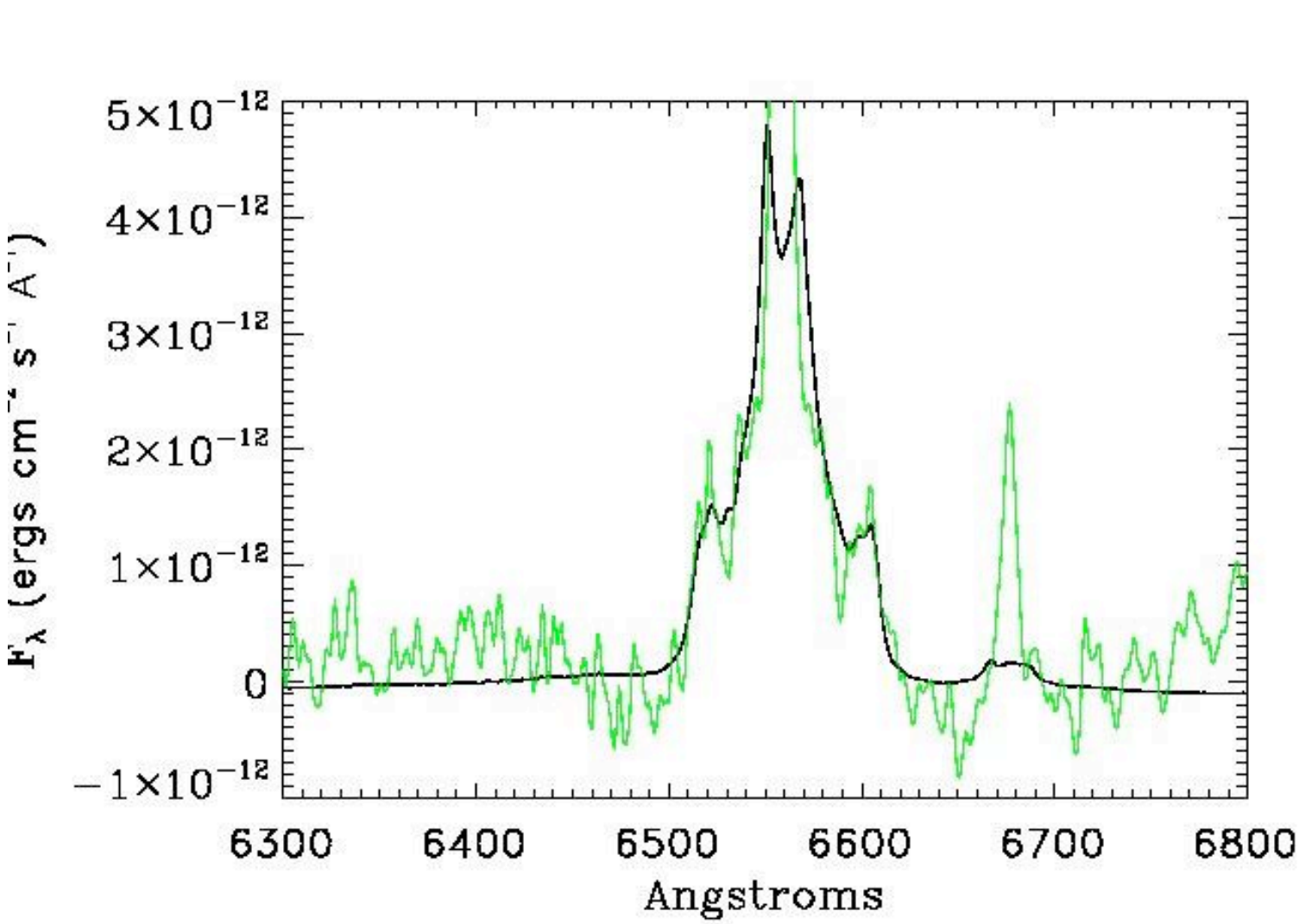
⇐Accretion disk in AGN
Eracleous & Halpern (1994)

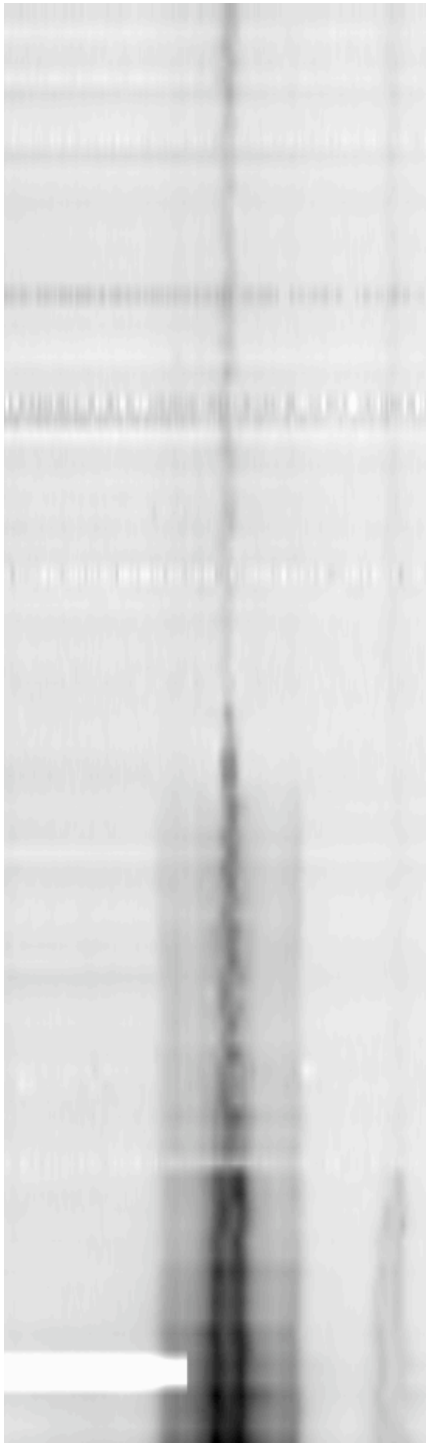
Optically Thin Disks in Dwarf Novae



Evolution of the Hα profiles in YY Dor

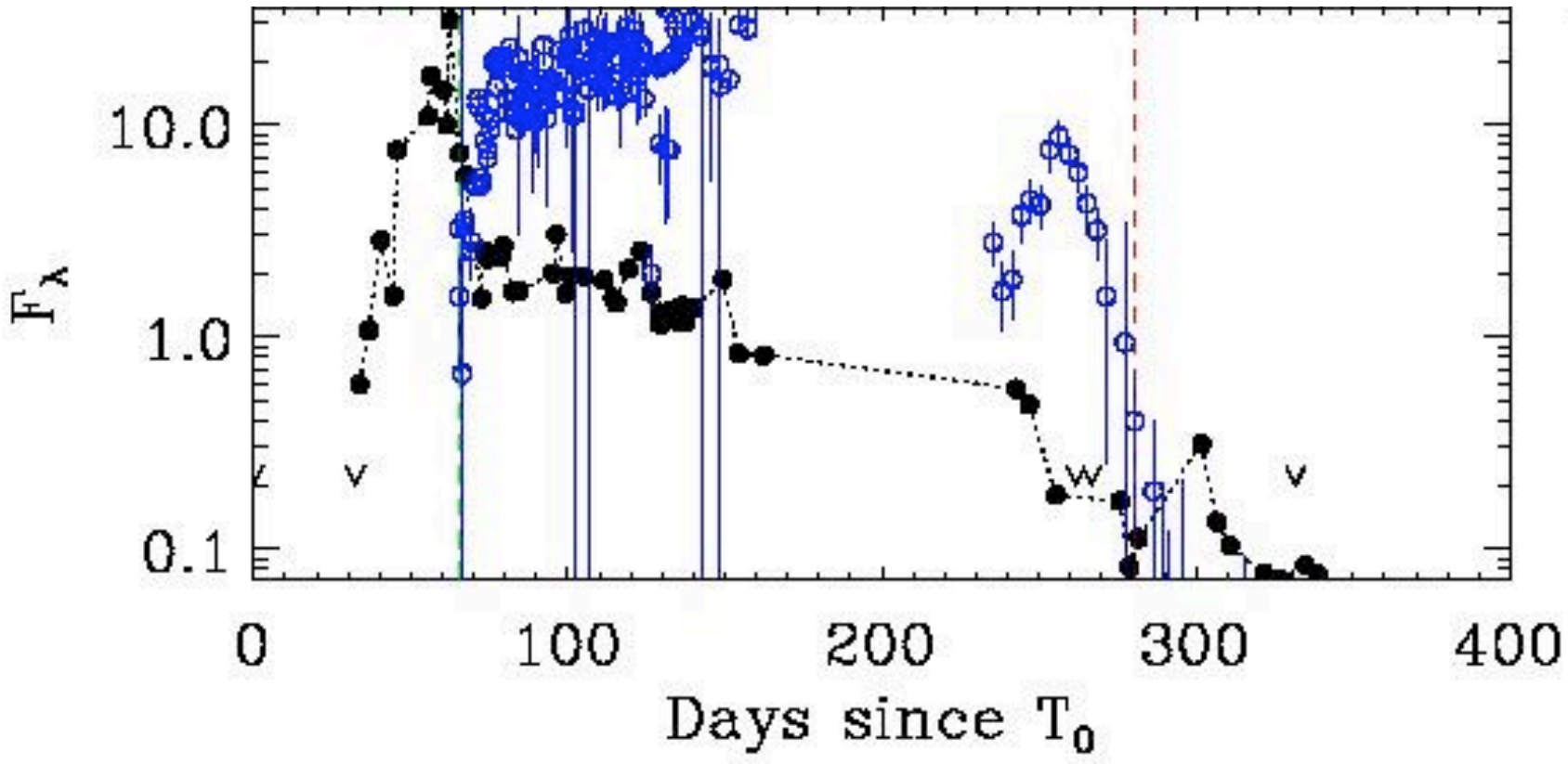






KT Eri Hα days 31, 380.

Day 380 spectrum scaled by 3000x



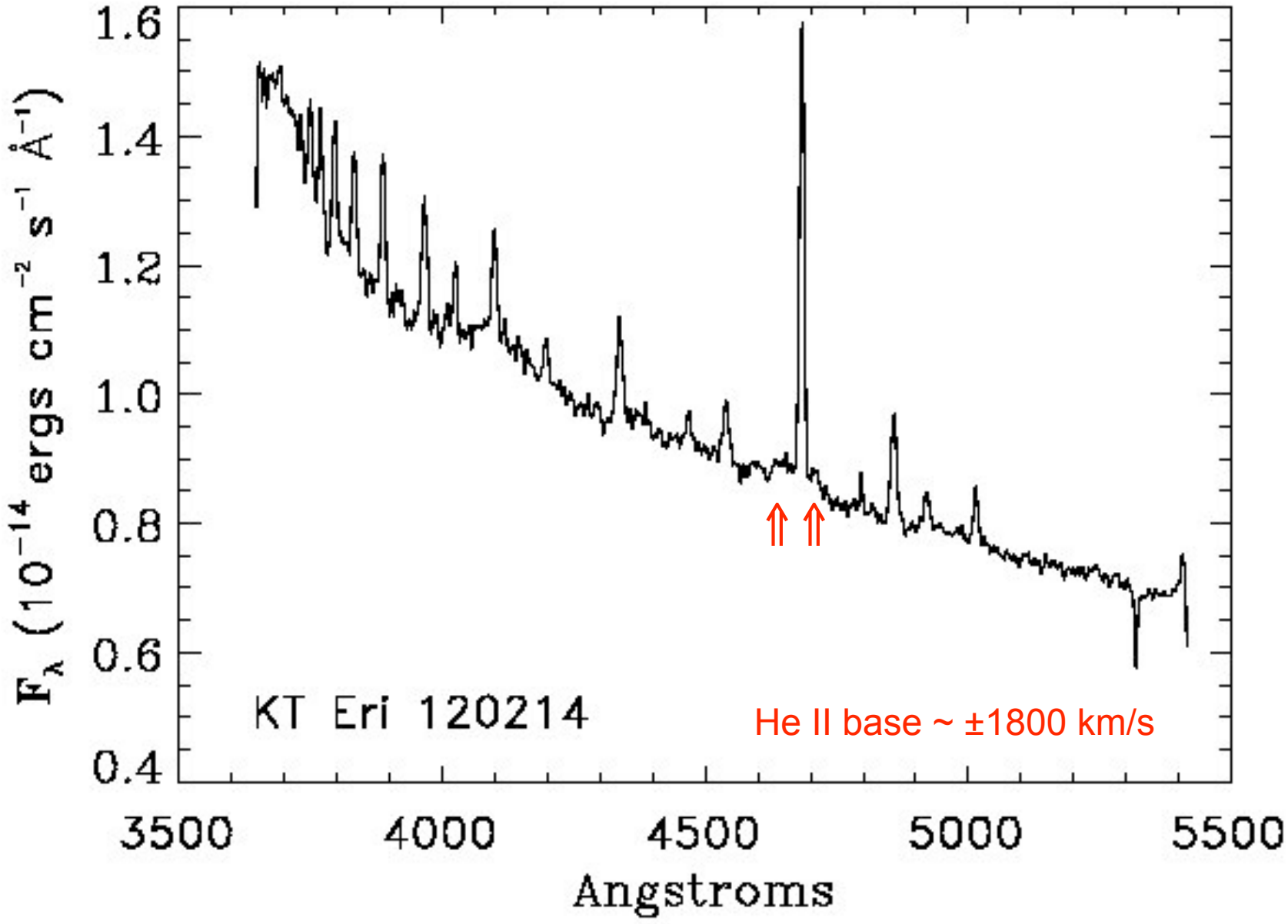
Black: He II 4686 flux

Blue: SSS X-ray flux

Decrease in He II flux from peak is comparable to the decrease in the X-ray flux

Line Flux in an Expanding Torus

- Volume ~ A x $2\pi(R_o+vt)$
  - –A = cross section of torus
  - –R_0 = WD radius
  - –v = expansion velocity (2000 km/s)
- Density ~ ρ_0/Avt (A optimistically assumed constant)
- EM (n_e^2V) ~ t^{-1}
- Illumination ~R^{-2} ~ t^{-2}
- Recombination line brightness ~ t^{-3}
- Ring >470 AU across in KT Eri (day 380).
- Expected flux decrease>1.E5;
- observed decrease ~ 3000



Day 822: ring radius ~ 1000AU

Goal

Determine why all the He-N novae

- have similar line profiles, and
- Why the resemble accretion disks

Explain the narrow central emission spike

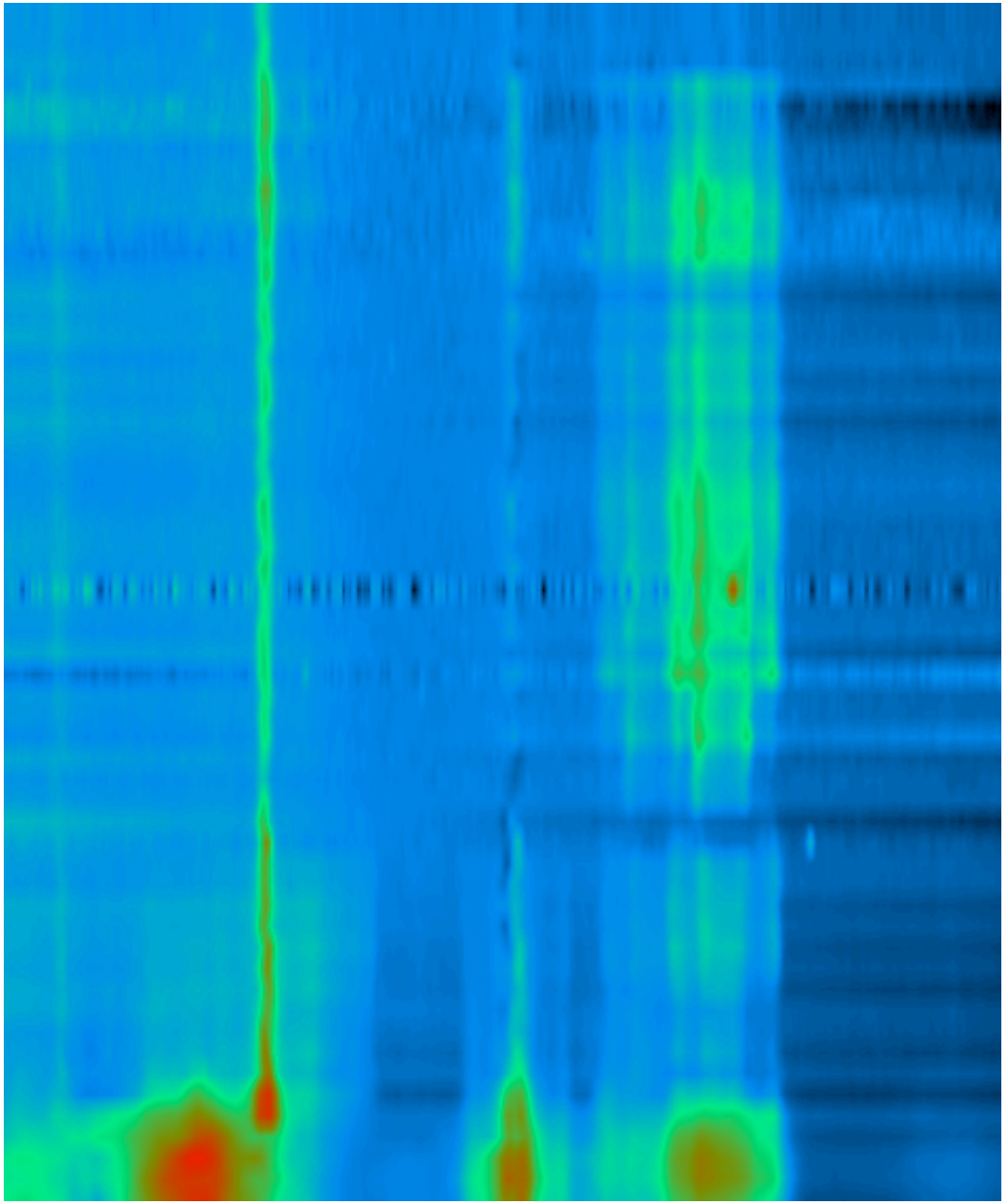
The λ4640 complex and He II 4686

- Unexpectedly strong N III 4640A emission is seen in:
  - Planetary Nebulae
  - Low mass X-ray binaries
  - Cataclysmic Variables
  - Seyfert galaxies
  - and novae!
- This is generally attributed to the Bowen Fluorescence mechanism

Bowen Fluorescence (greatly simplified)

- **He II** Lyman λ 303.783
- pumps **O III** 303.799
- Decays via Bowen lines λλ3100-3400A
- Returns to ground via 374.437
- Pumps **N III** 374.434, 374.441
- Produces λλ4634, 4641, 4642 lines

A probe of the unobservable EUV



Line Evolution in KT Eri

Bowen Fluorescence in the Dynamical Case

I. Initially, only the N III is visible.
II. He II 4686 turns on
III. 4640 turns off
IV. 4686 turns off as the SSS turns on

A temperature sequence?

What is the role of opacity?

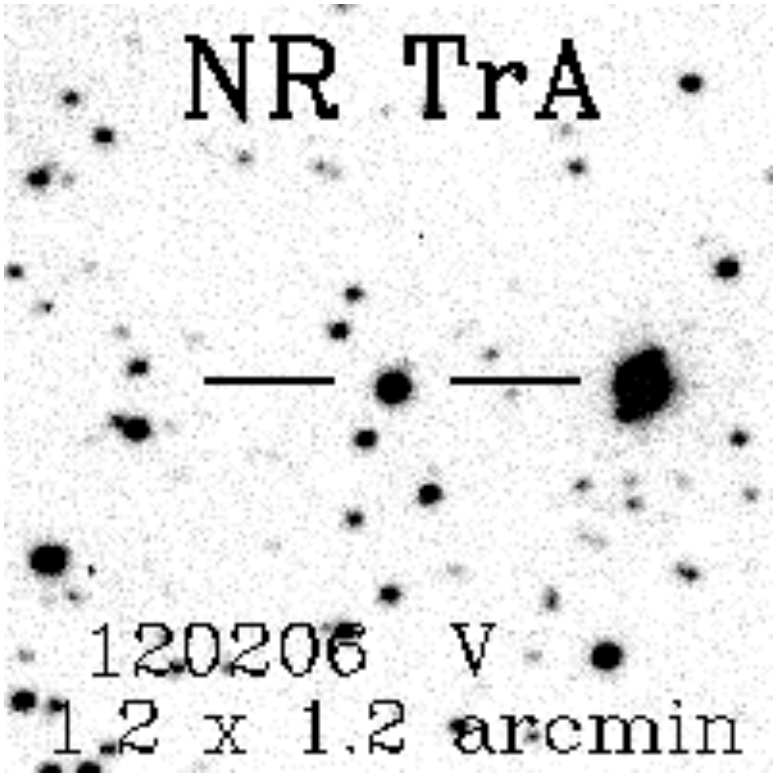
Goal

- Understand the excitation mechanisms
- Use the dynamical evolution of the lines as a probe of conditions within the optically-thick envelope

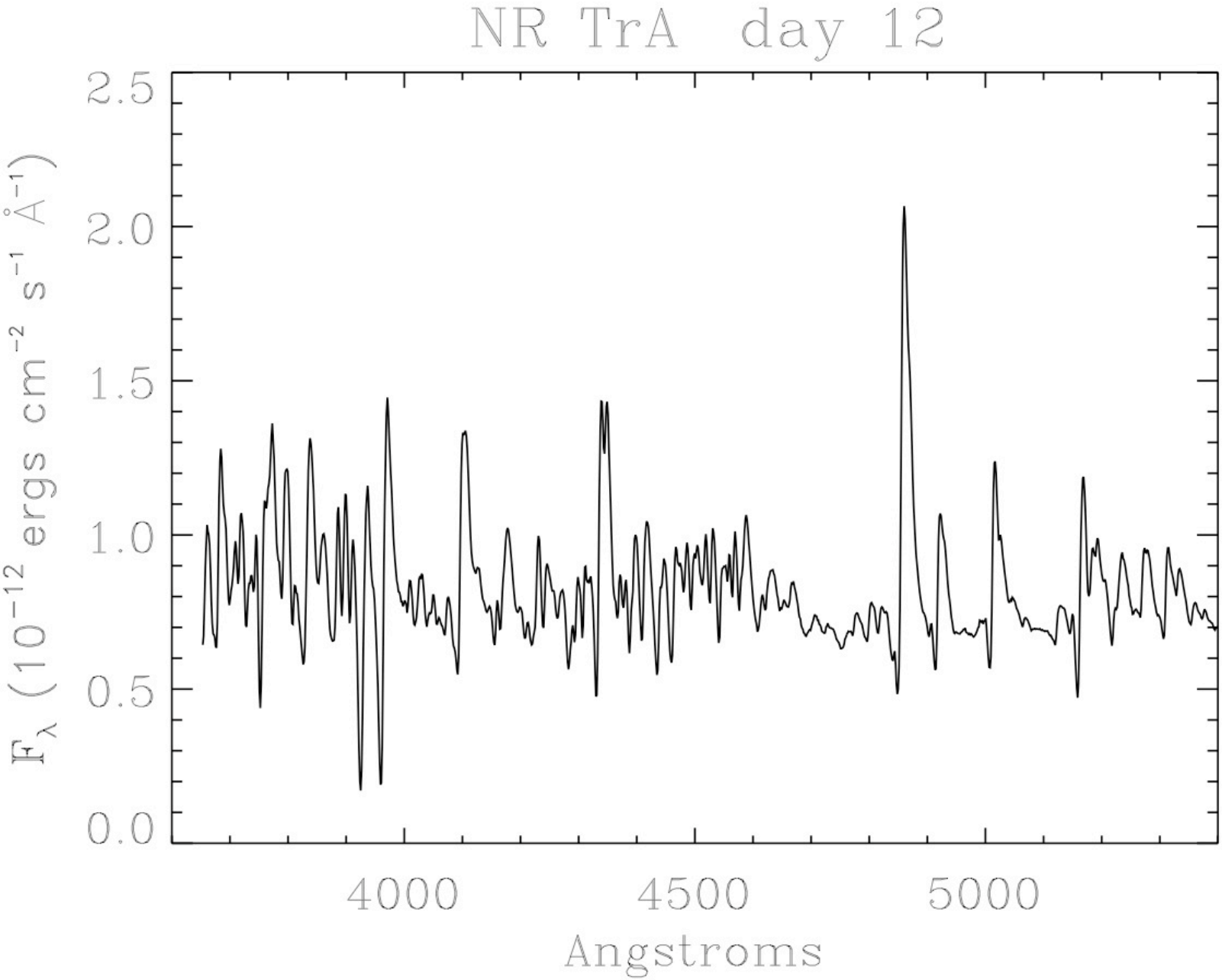
The V Sge Stars

- Binary systems, 5h < P < 12h
  - Broad, V-shaped eclipse
  - Weak secondary eclipse
- Permitted N V, O VI lines
- He II 4686 > Hβ
- He I weak or absent
- W_λ(Hα) > 50A
- Resemble the persistent SSS

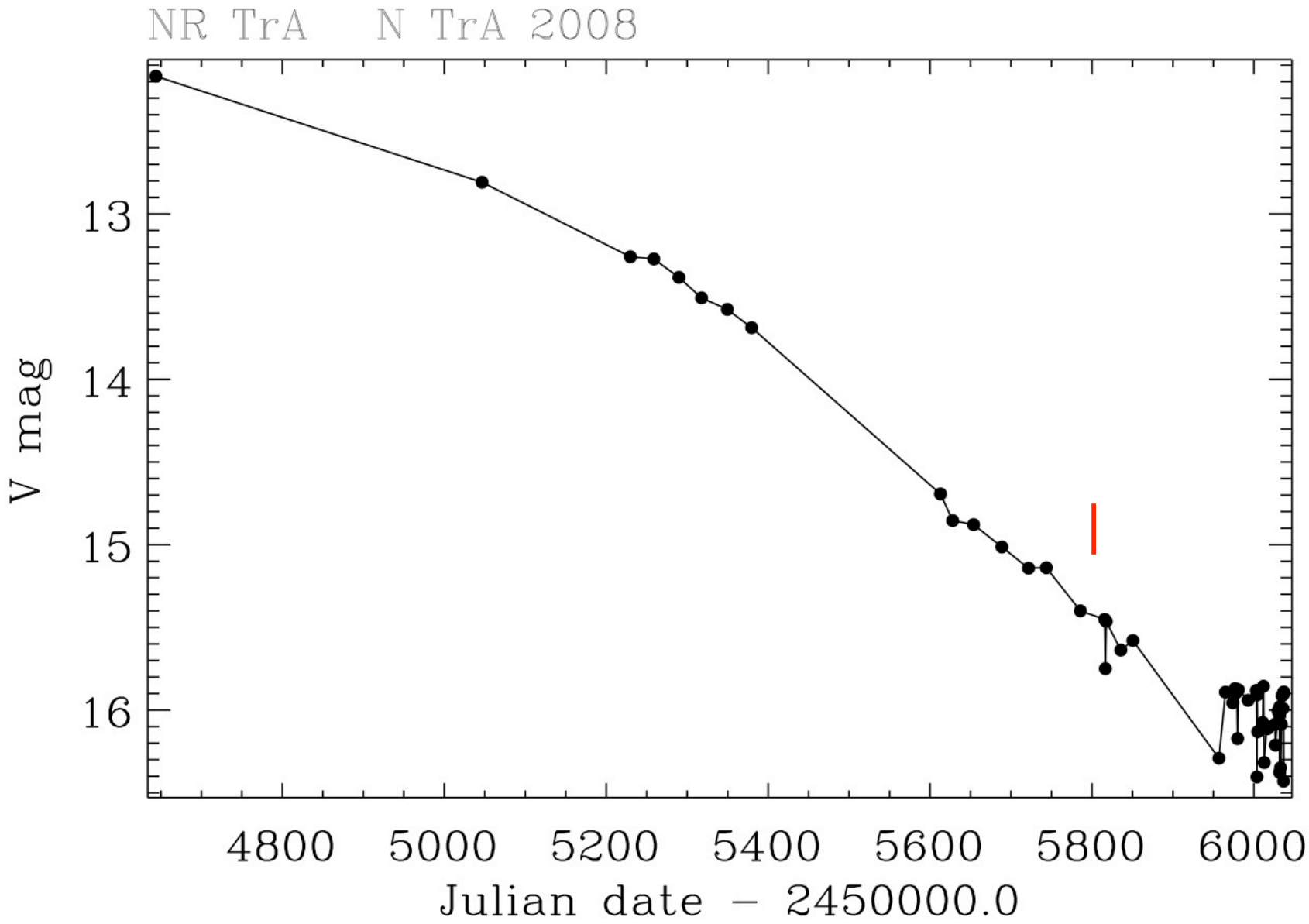
The Evolution of NR TrA
(Nova TrA 2008)



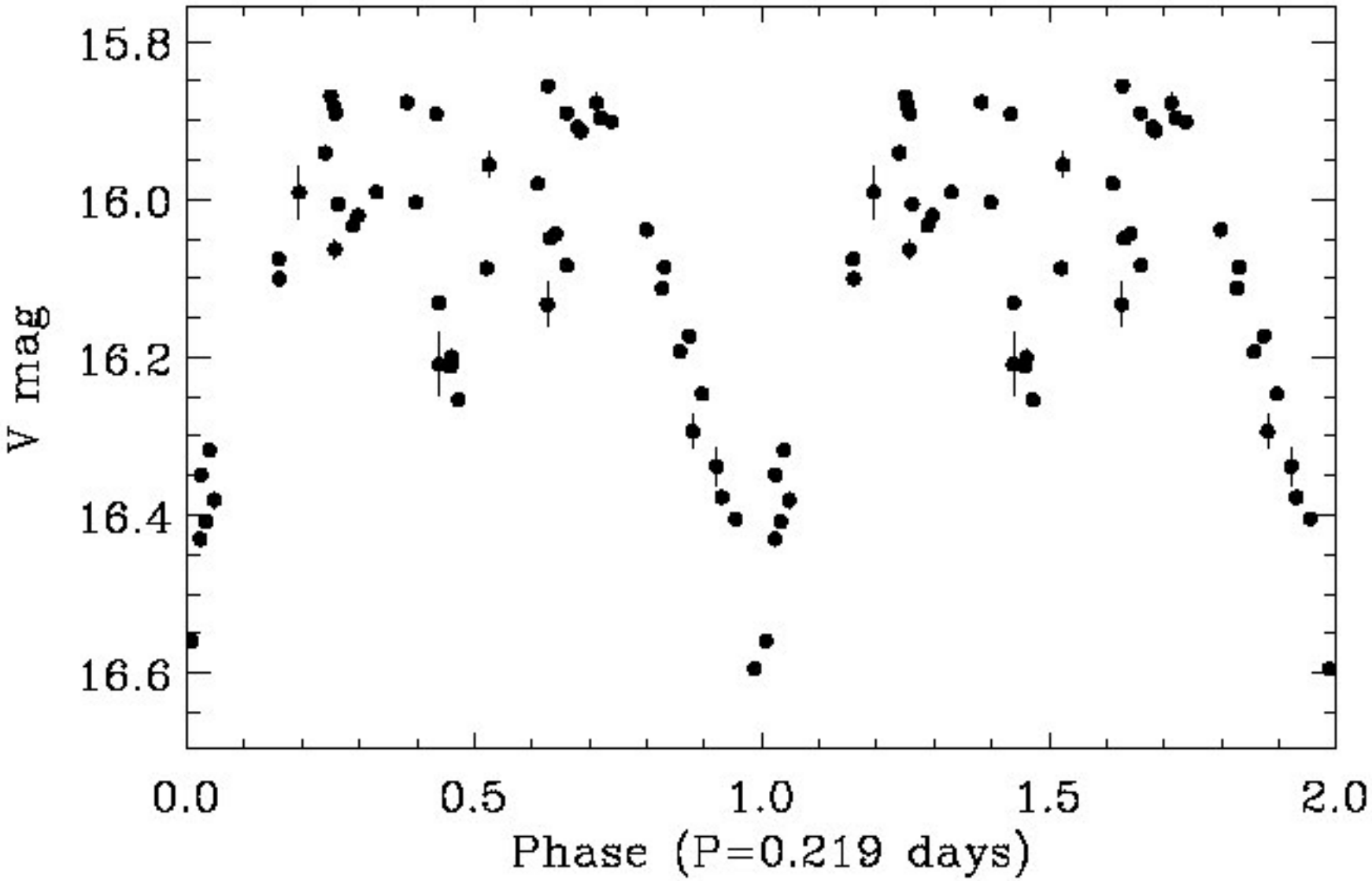
An Fe II Nova


NR TrA day 12
2.5
2.0
1.5
1.0
0.5
0.0
F_λ (10^{-12} ergs cm^{-2} s^{-1} Å^{-1})
4000
4500
5000
Angstroms

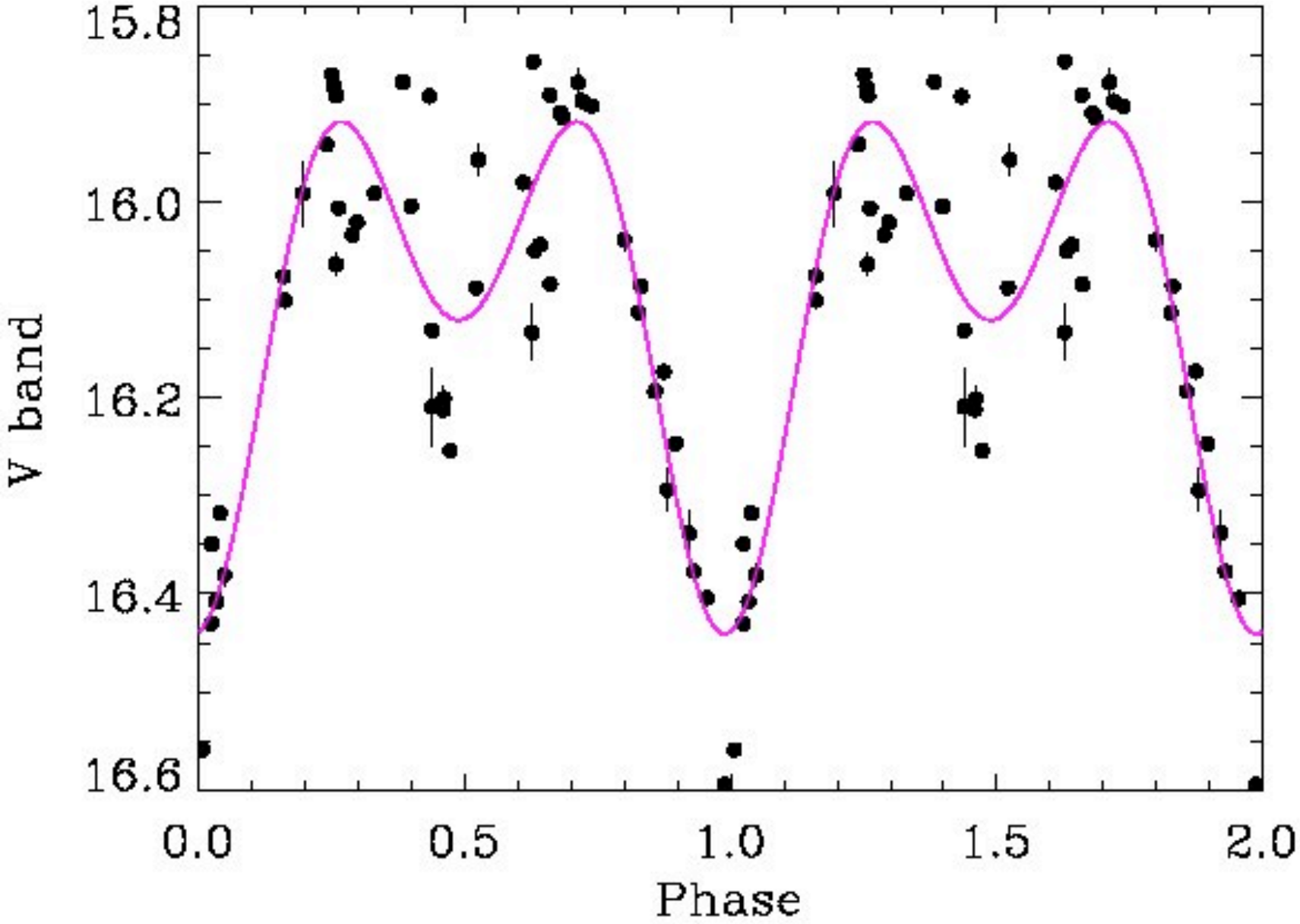
Developed Eclipses ~ day 1300



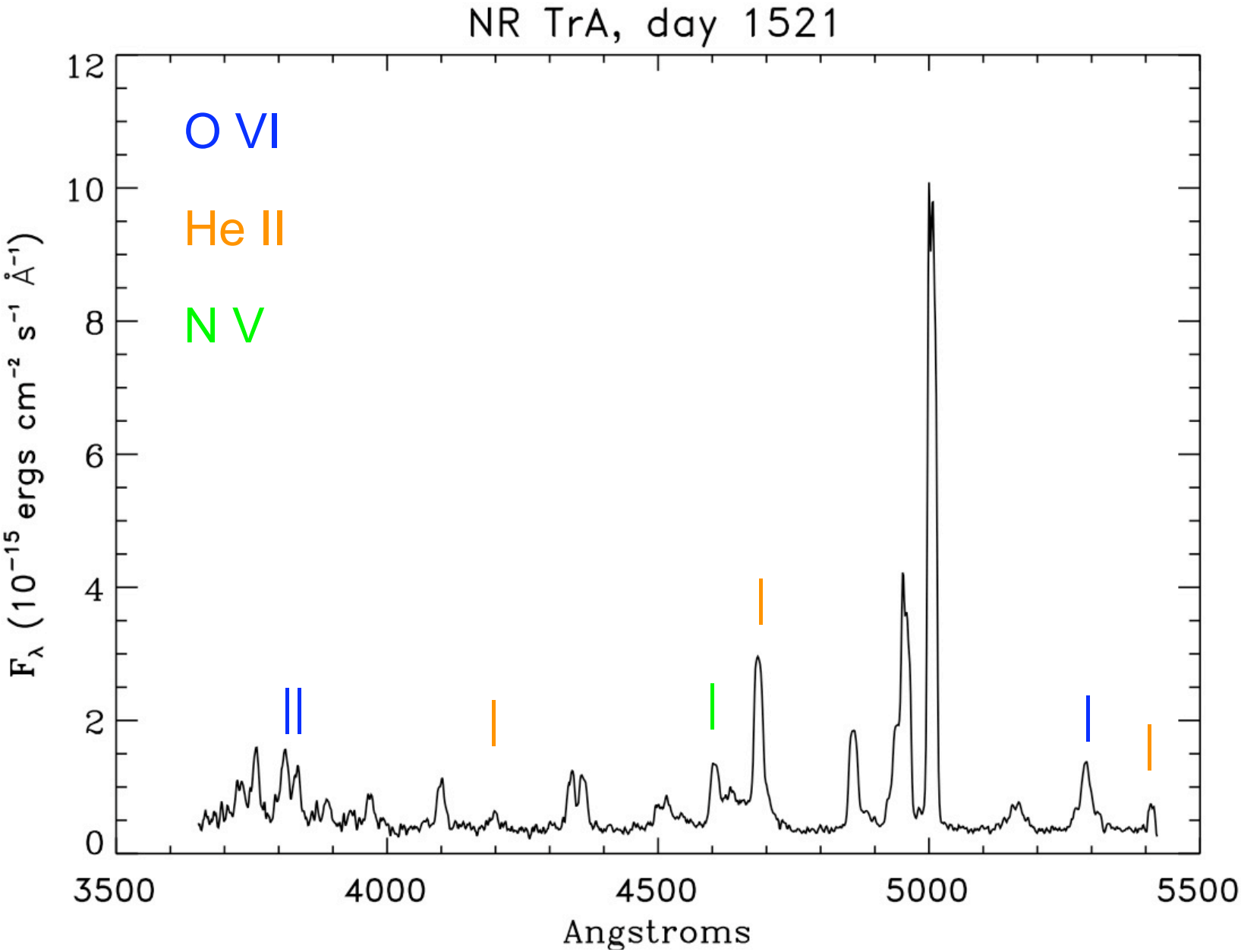
Folded, P=5.25 hours

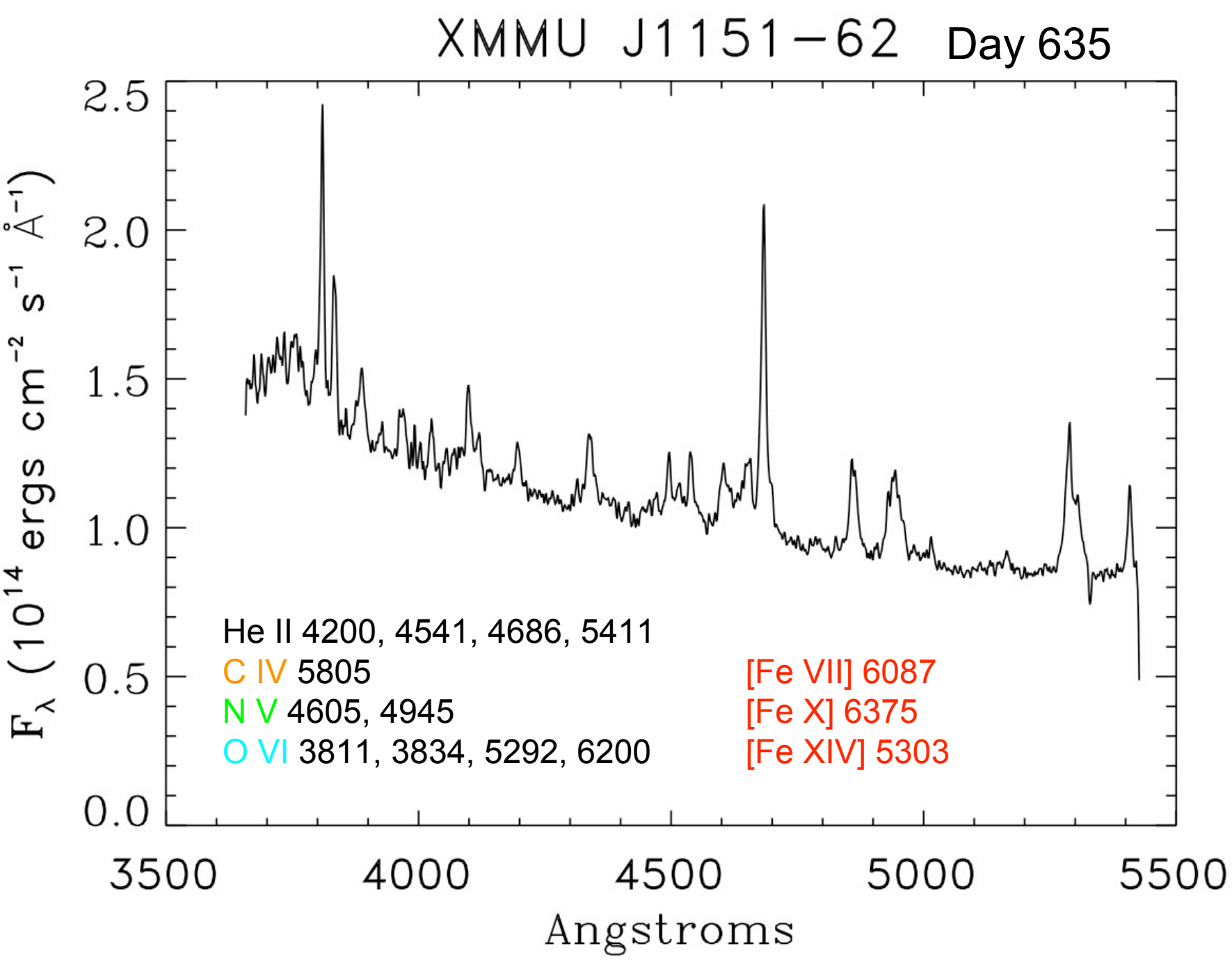


Folded, P=5.25 hours



Current Spectrum



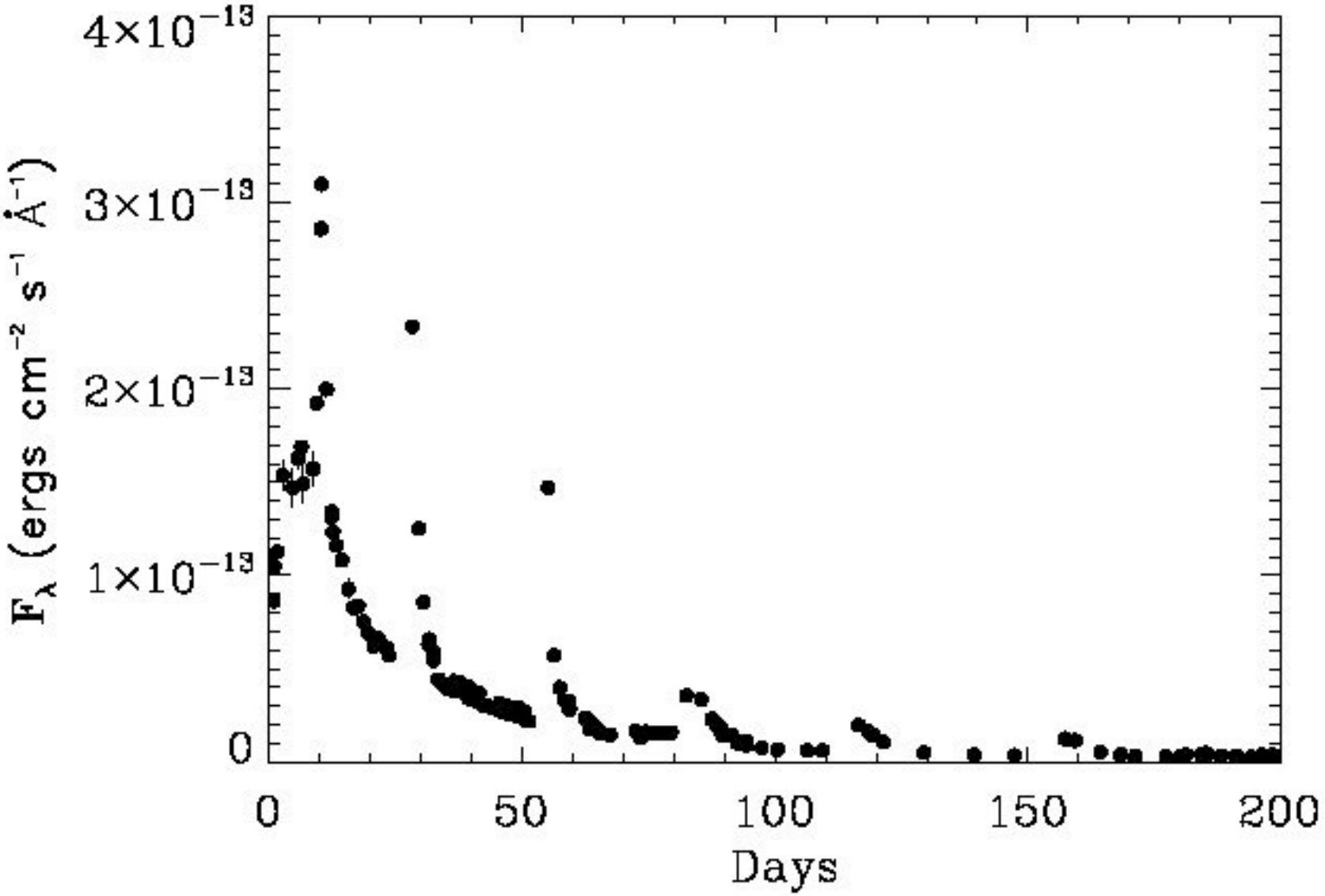

XMMU J1151−62
Day 635
F_λ (10^{14} ergs cm^{-2} s^{-1} Å^{-1})
2.5
2.0
1.5
1.0
0.5
0.0
3500
4000
4500
5000
5500
Angstroms
He II 4200, 4541, 4686, 5411
C IV 5805
N V 4605, 4945
O VI 3811, 3834, 5292, 6200
[Fe VII] 6087
[Fe X] 6375
[Fe XIV] 5303

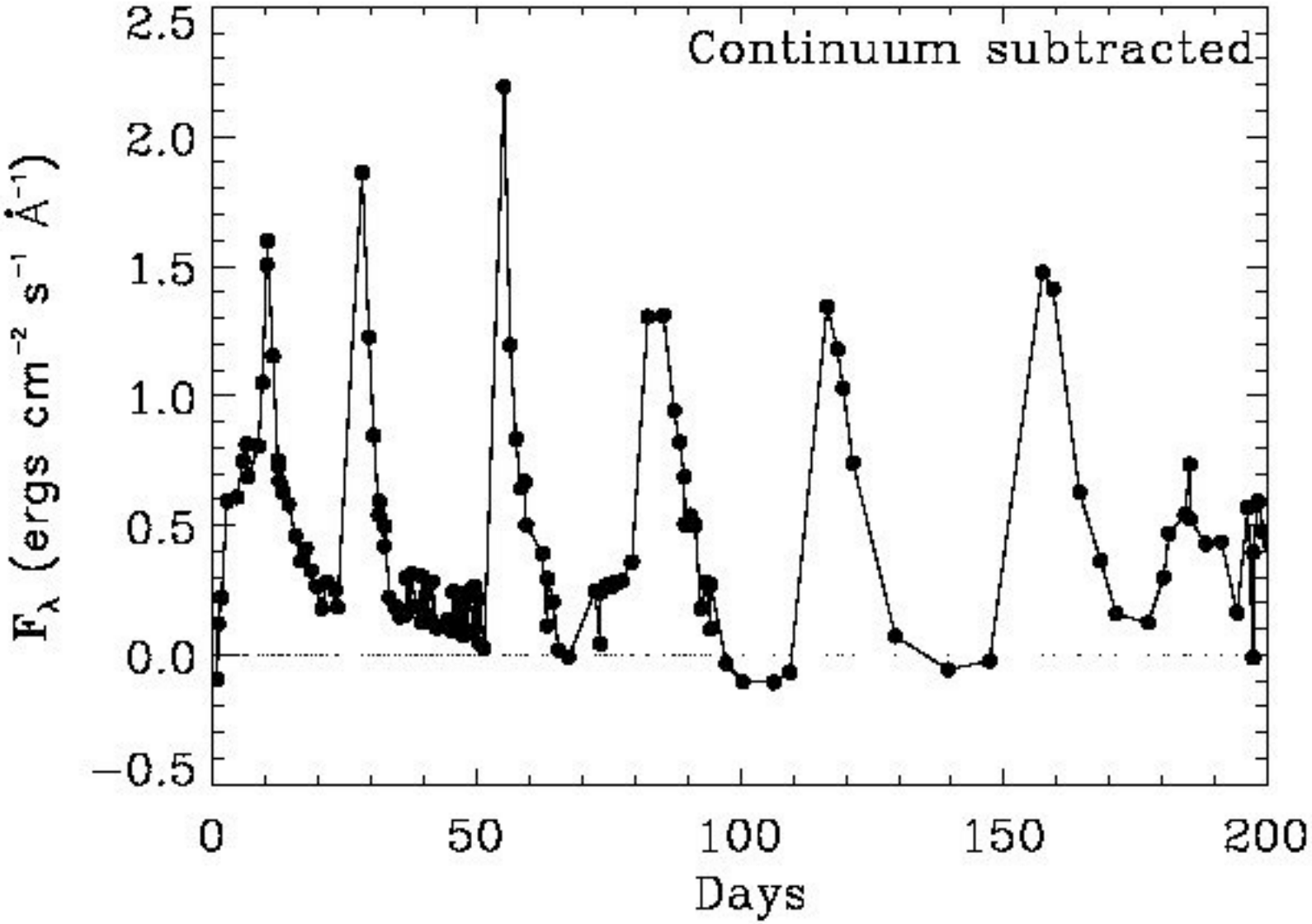
Implications for V Sge

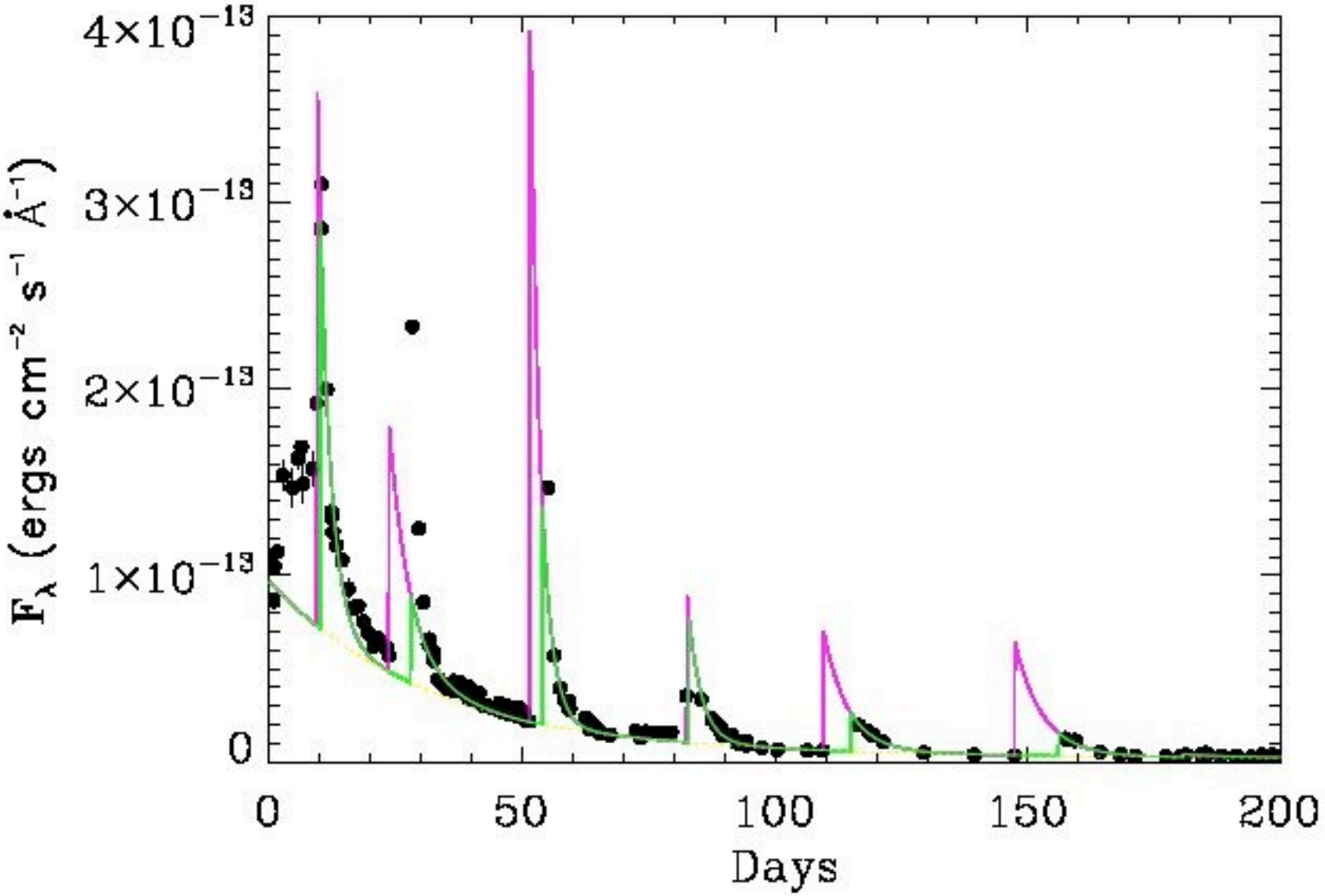
- Nova contain a WD
- NR TrA and XMMU J1151 were SSS; they may still be
- They are likely WDs undergoing steady surface nuclear burning
- Are the V Sge stars “recent” novae?

V5588 Sgr

- A Relaxation Oscillation?


4×10⁻¹³
3×10⁻¹³
2×10⁻¹³
1×10⁻¹³
0
F_λ (ergs cm⁻² s⁻¹ Å⁻¹)
0
50
100
150
200
Days


Continuum subtracted
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
F_λ (ergs cm^{-2} s^{-1} Å^{-1})
0
50
100
150
200
Days


4×10⁻¹³
3×10⁻¹³
2×10⁻¹³
1×10⁻¹³
0
F_λ (ergs cm⁻² s⁻¹ Å⁻¹)
0
50
100
150
200
Days

Summary

The Stony Brook/SMARTS Atlas of (mostly) southern novae is provided as a resource to the community.

High cadence, Long term, Multiwavelength investigations

- –provide synergies with other observations (*e.g., Swift*) and
- –reveal new insights into this highly dynamic nova phenomenon

Details: **PASP, 124, 1057 (2012)**

Light Dawns on Marblehead