Interpreting Spectra of High- and Intermediate-Mass Stars

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Austin College

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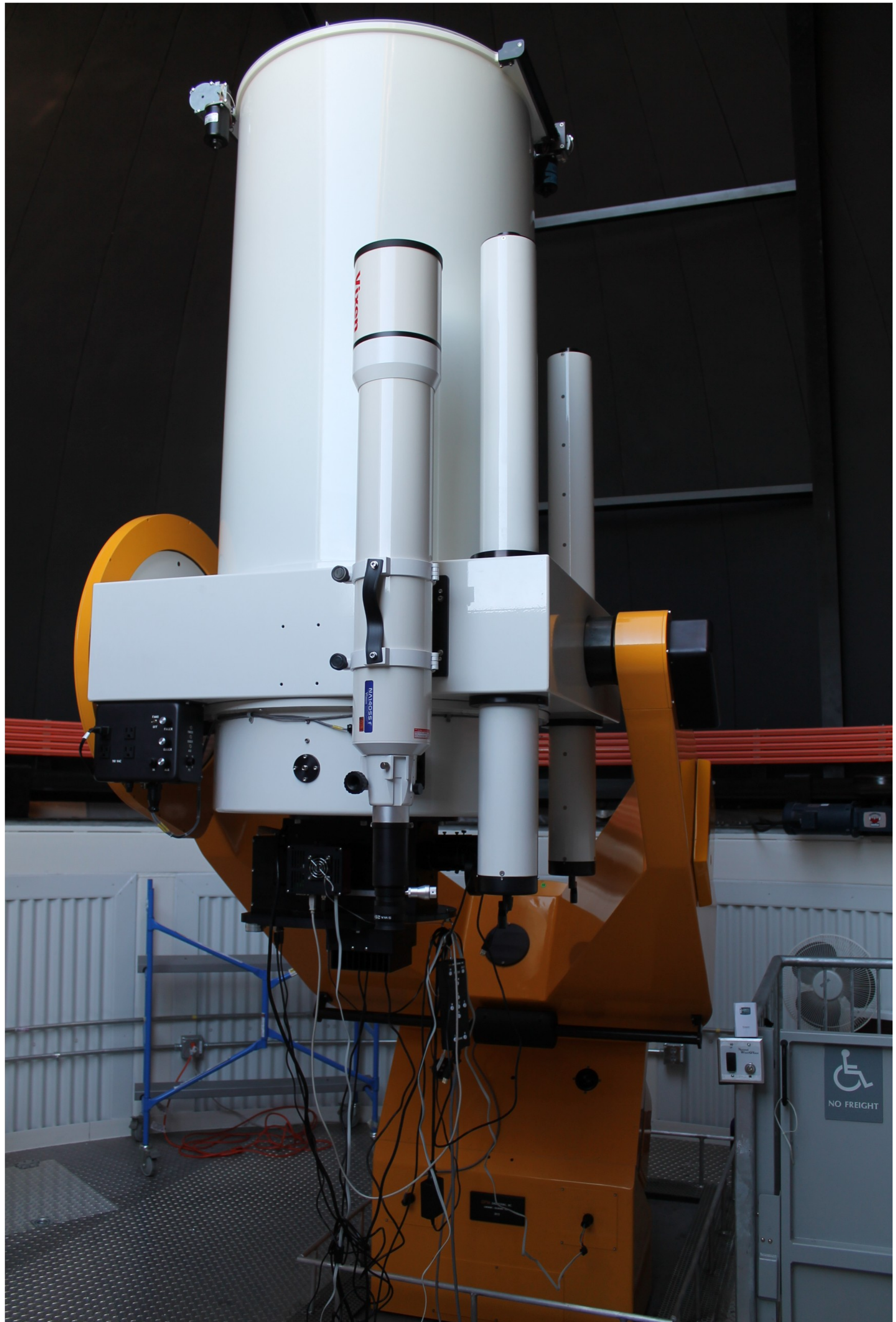
17 February, 2018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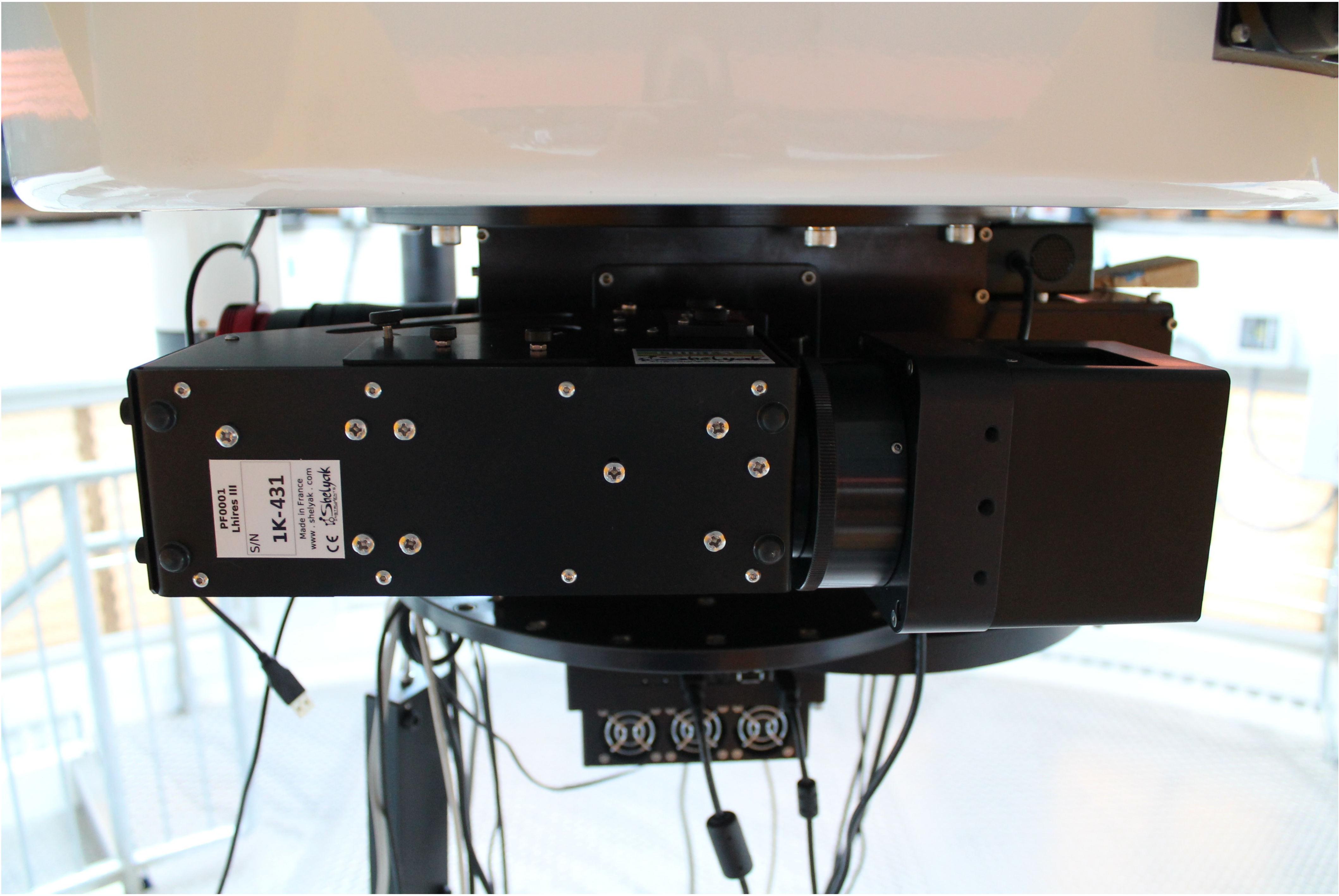
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1. Physical Properties of Intermediate- and High-Mass Stars

A2 V - B3 V: Intermediate - Mass Stars

Spec Type	Mass (M_{sol})	Radius (R_{sol})	T_{eff} (K)
A2	2.2	1.75	8,900
B3	6.3	3.5	16,500

Data from: David Gray's *The Observation and Analysis of Stellar Photospheres*
Richard Gray & Christopher Corbally's *Stellar Spectral Classification*

Photospherically:

- Strong Hydrogen absorption lines

--> weakening with increasing temperature (max. near A1/2)

- strengthening Helium absorption lines

--> maximum near B3

1. Physical Properties of Intermediate- and High-Mass Stars

B2 V and Above: High-Mass Stars

Spec Type	Mass (M_{sol})	Radius (R_{sol})	T_{eff} (K)
B2	8.3	4.7	19,500
O9	20?	9	32,882

Data from: David Gray's *The Observation and Analysis of Stellar Photospheres*
Richard Gray & Christopher Corbally's *Stellar Spectral Classification*

Photospherically:

- Weaker H lines

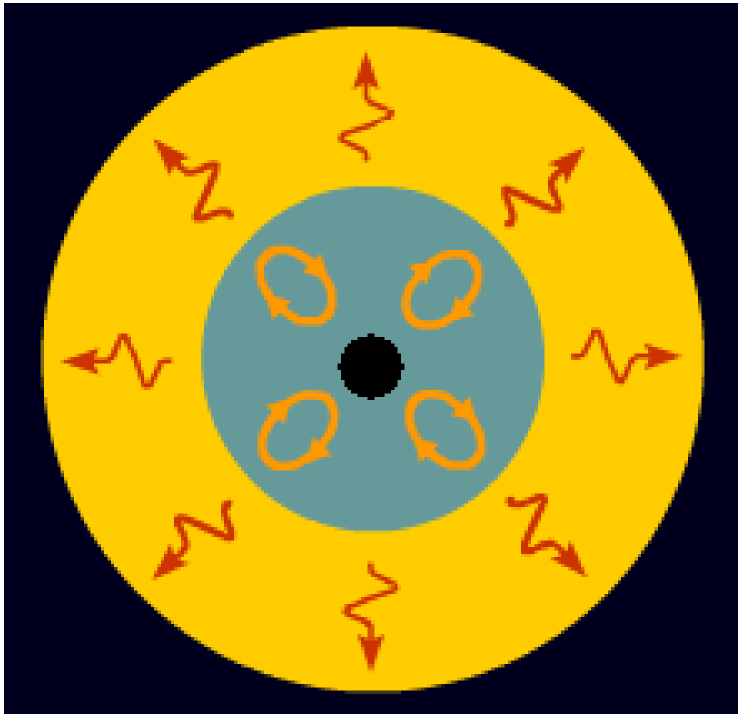
- He ionization layer is near or at the surface

NOT Considering O8 and above:

- Convective interior, puffier stars

1. Physical Properties of Intermediate- and High-Mass Stars

Internal Structure



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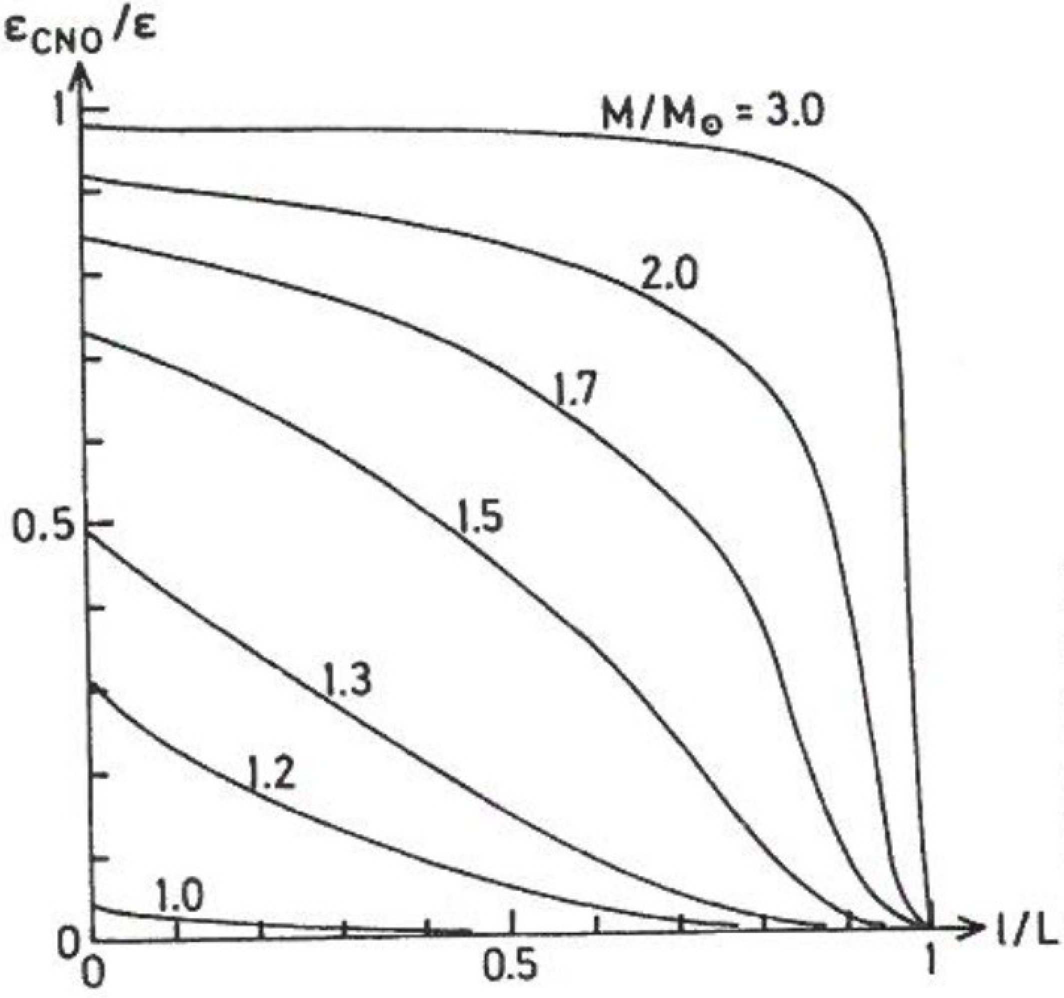
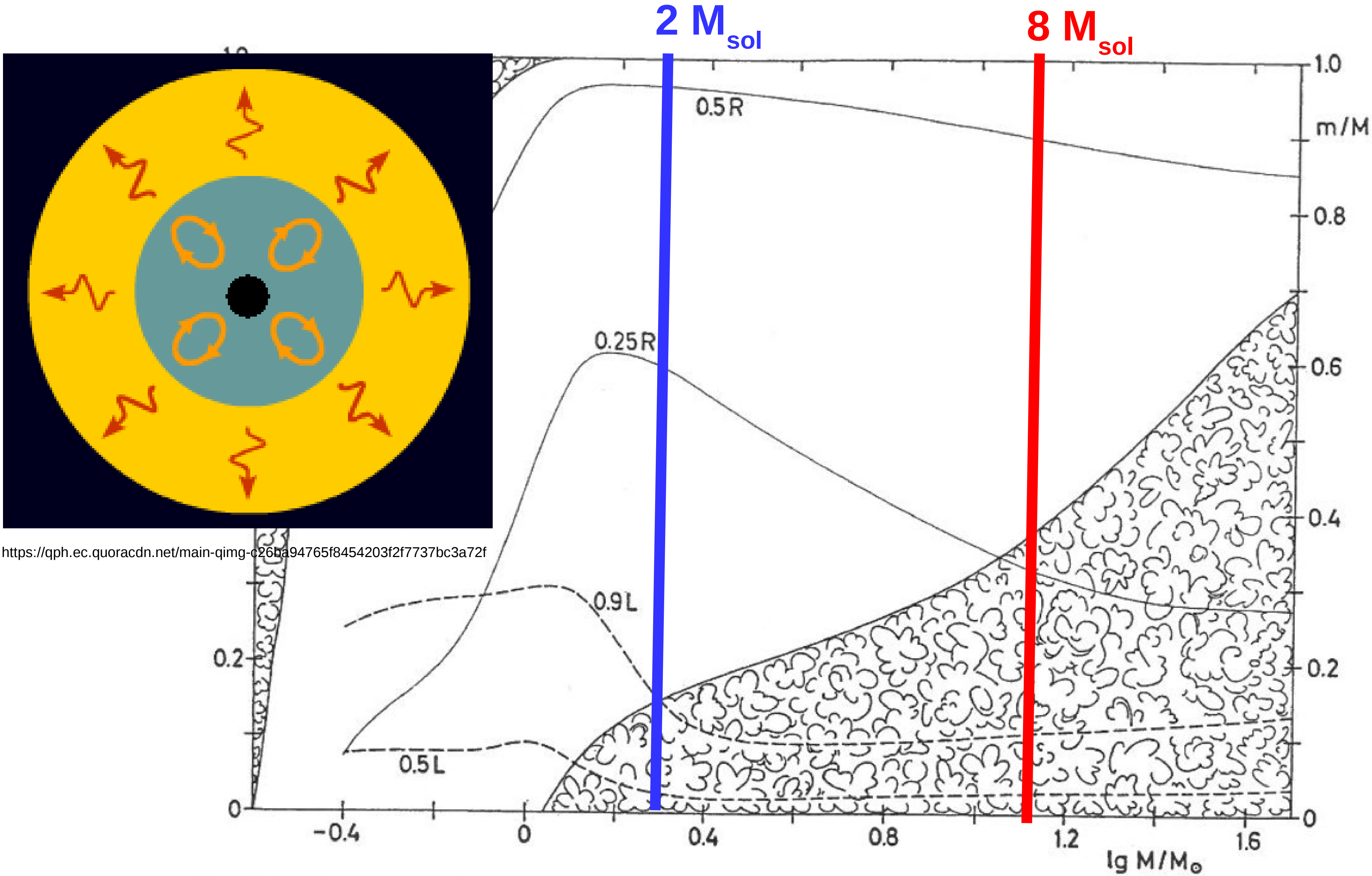


Kippenhahn & Weigert, *Stellar Structure and Evolution*, Fig. 22.6

1. Physical Properties of Intermediate- and High-Mass Stars

Internal Structure



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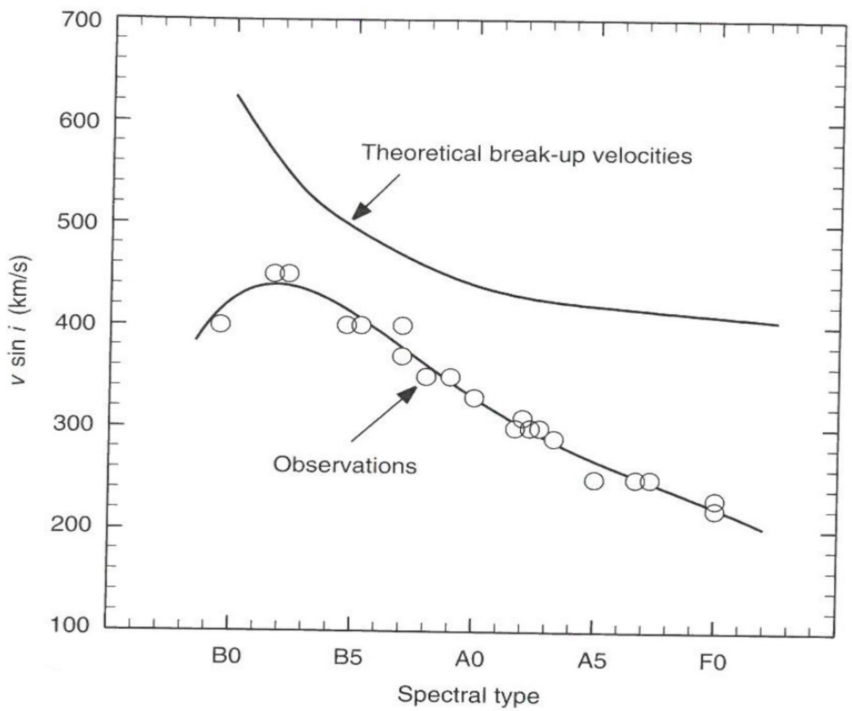
Kippenhahn & Weigert, *Stellar Structure and Evolution*, Fig. 22.7

1. Physical Properties of Intermediate- and High-Mass Stars

Rotation

Spec Type	Mass (M_{sol})	Radius (R_{sol})	T_{eff} (K)	$\overline{v \sin(i)}$ (km/s)	v_{crit} (km/s)
A2	2.2	1.75	8,900	244	400
B3	6.3	3.5	16,500	281	478
B2	8.3	4.7	19,500	284	473
O9	20?	9	32,882	292	530

Data from: David Gray's *The Observation and Analysis of Stellar Photospheres*
Richard Gray & Christopher Corbally's *Stellar Spectral Classification*



David Gray, *The Observation and Analysis of Stellar Photospheres*, Fig 18.25

$$v_{crit} = \sqrt{\frac{2GM}{3R_p}}$$

(Townsend et al. 2004)

1. Physical Properties of Intermediate- and High-Mass Stars

Binarity

Generally: ~50%
~60% for G- and F-type stars (Abt & Levy 1976)
< 40% for M-type stars (Fischer & Marcy 1992; Gizis et al. 2003)

B2-B5 stars: ~70% (Abt '90)

Cygnus OB2: > 80% of intermediate- and high-mass stars (Kobulnicky & Fryer 2007)

Sco OB2: 100% high-mass stars (Kouwenhoven 2007 b)

1. Physical Properties of Intermediate- and High-Mass Stars

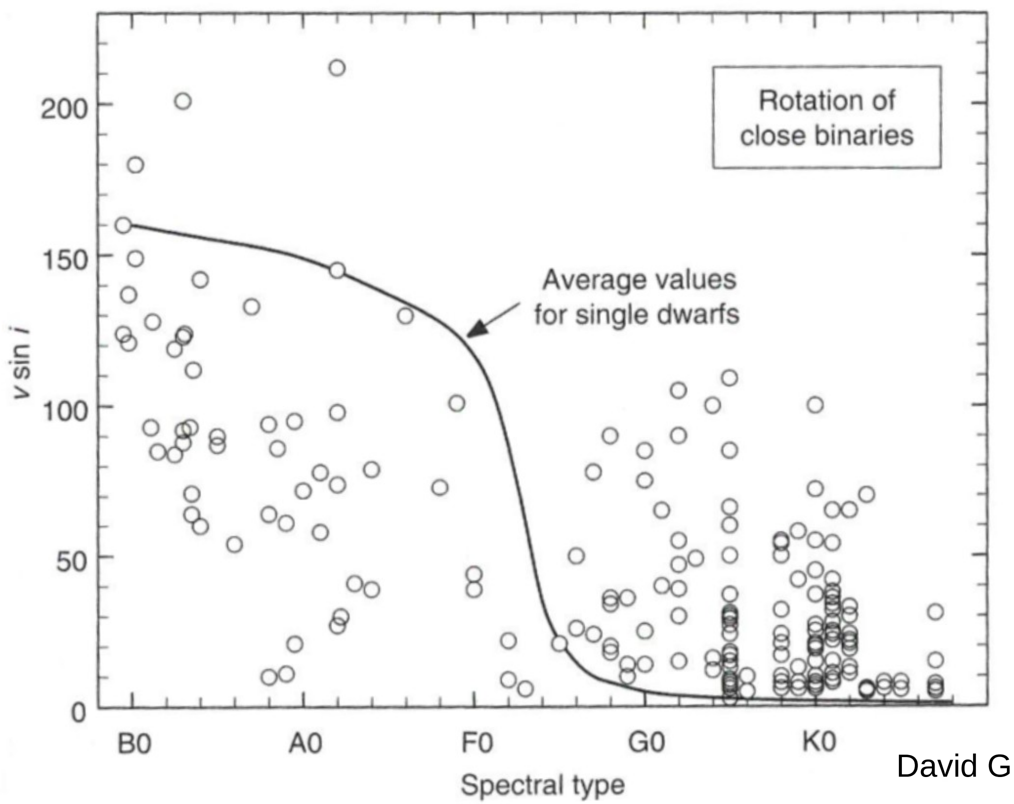
Binarity

Intermediate-mass stars: ≥ 70% are binaries

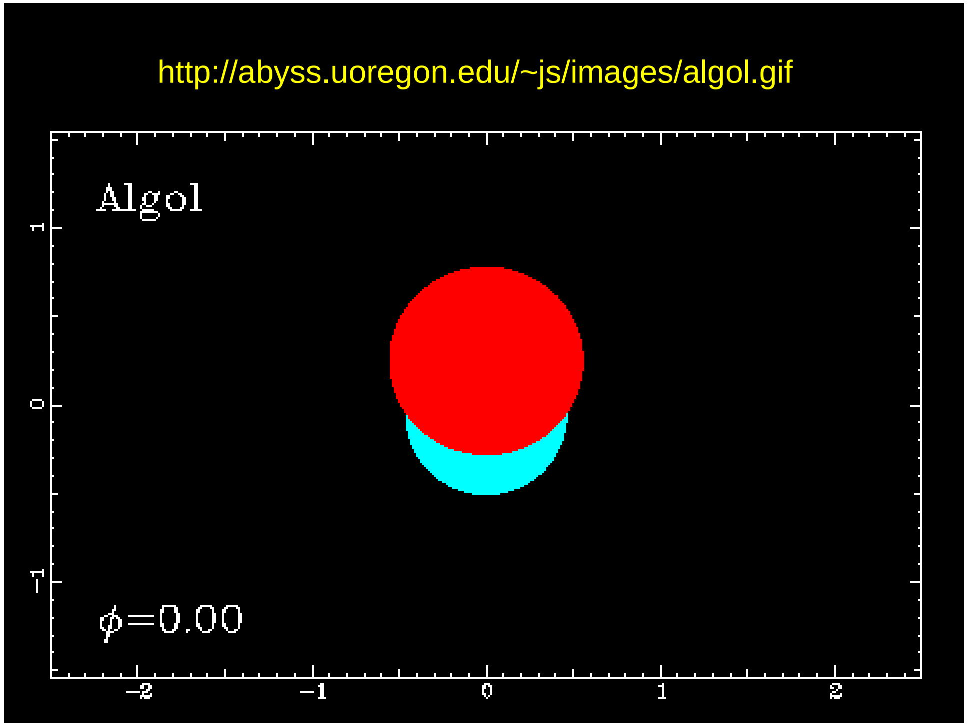
High-mass stars: ~ 100% are binaries

Close binaries (within a few stellar radii):

Stars exchange orbital and rotational angular momentum --> slow down



David Gray, *The Observation and Analysis of Stellar Photospheres*, Fig 18.27



1. Physical Properties of Intermediate- and High-Mass Stars

Binarity

Intermediate-mass stars: ≥ 70% are binaries

High-mass stars: ~ 100% are binaries

Close binaries (within a few stellar radii):

Stars exchange orbital and rotational angular momentum --> slow down

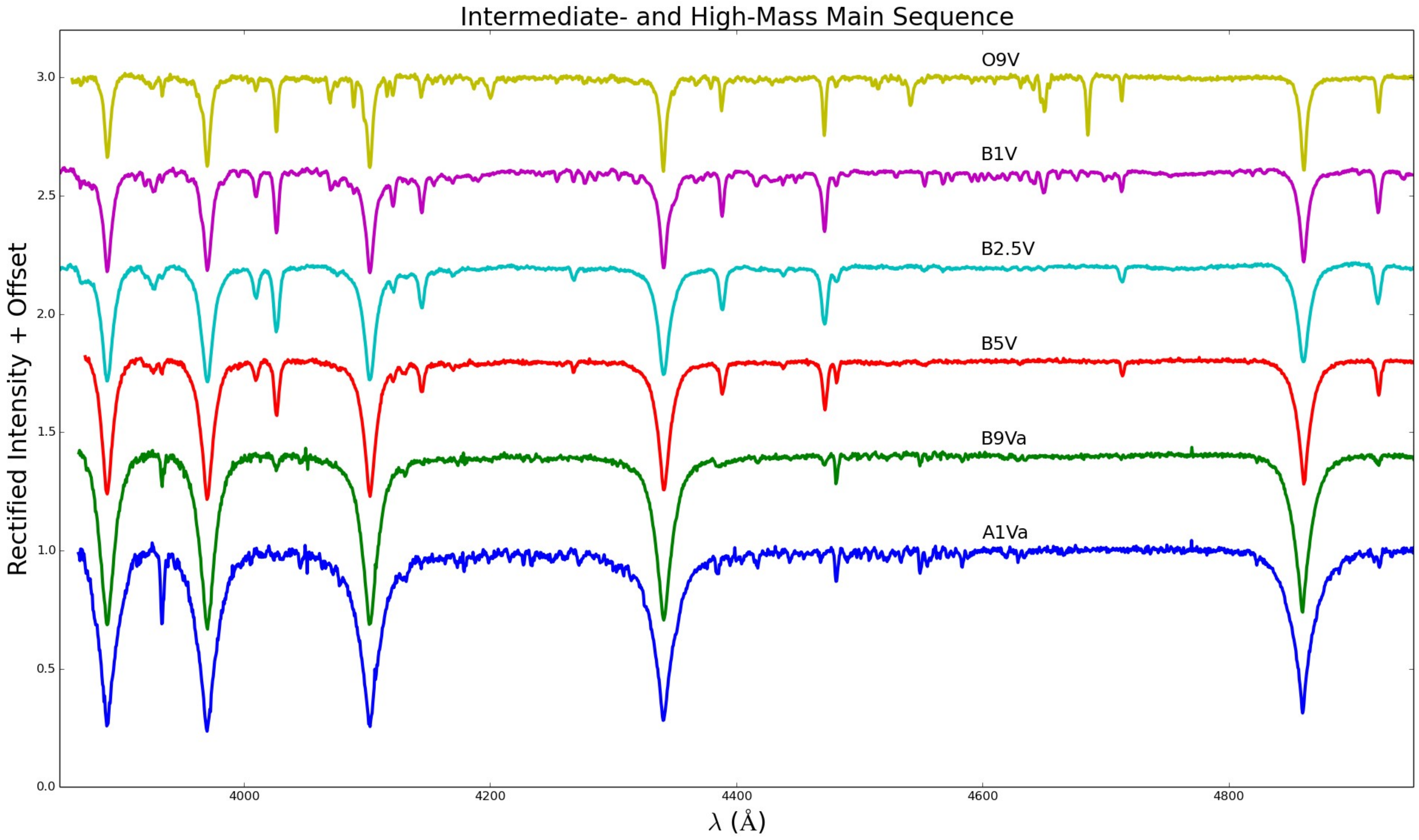
Wider binaries:

Tidal coupling does not take place

No observed evolutionary affects
(*e.g.,* the binary fraction of B*e* stars; Oudmaijer & Parr 2010)

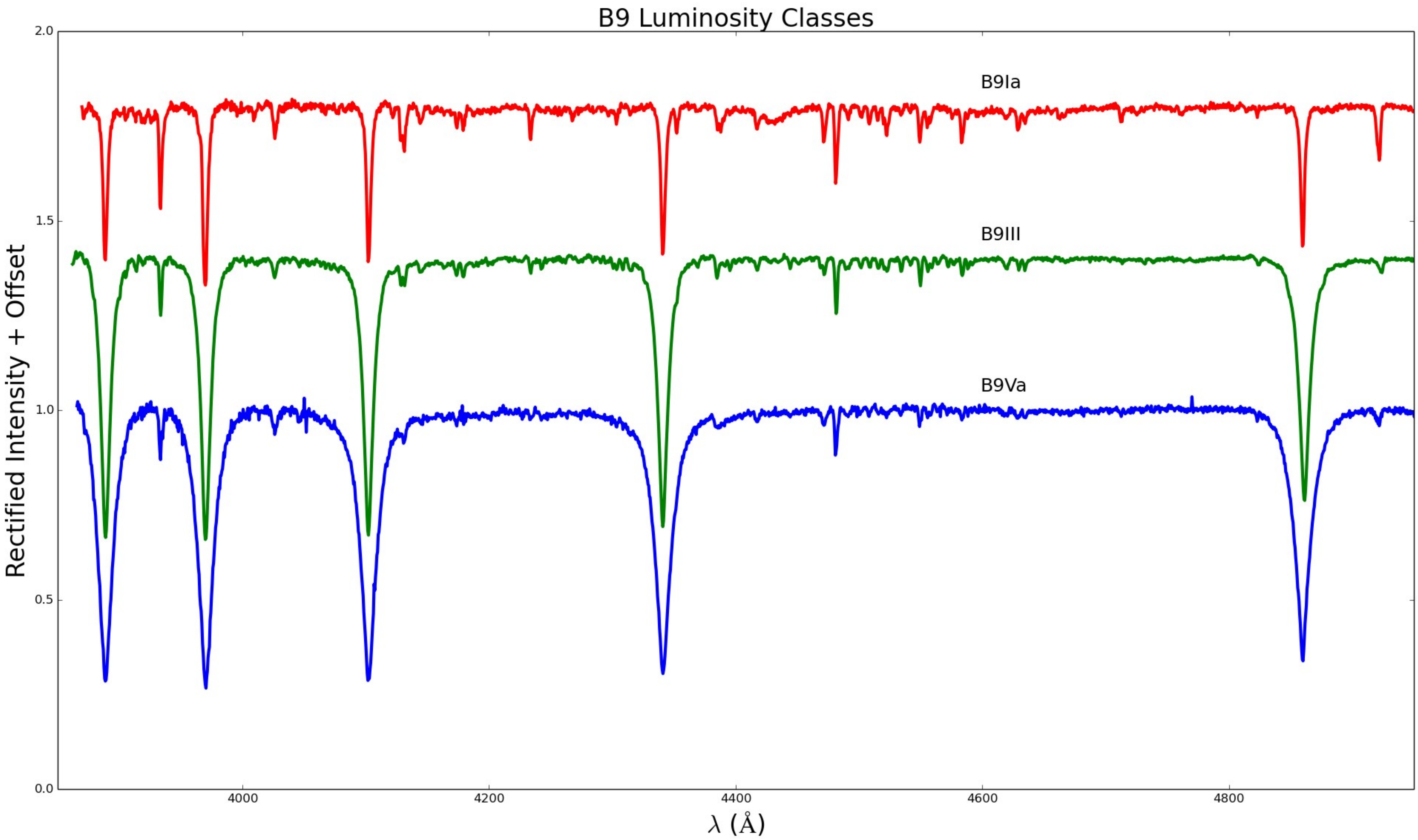
2. Observable Properties

The Spectral Sequence



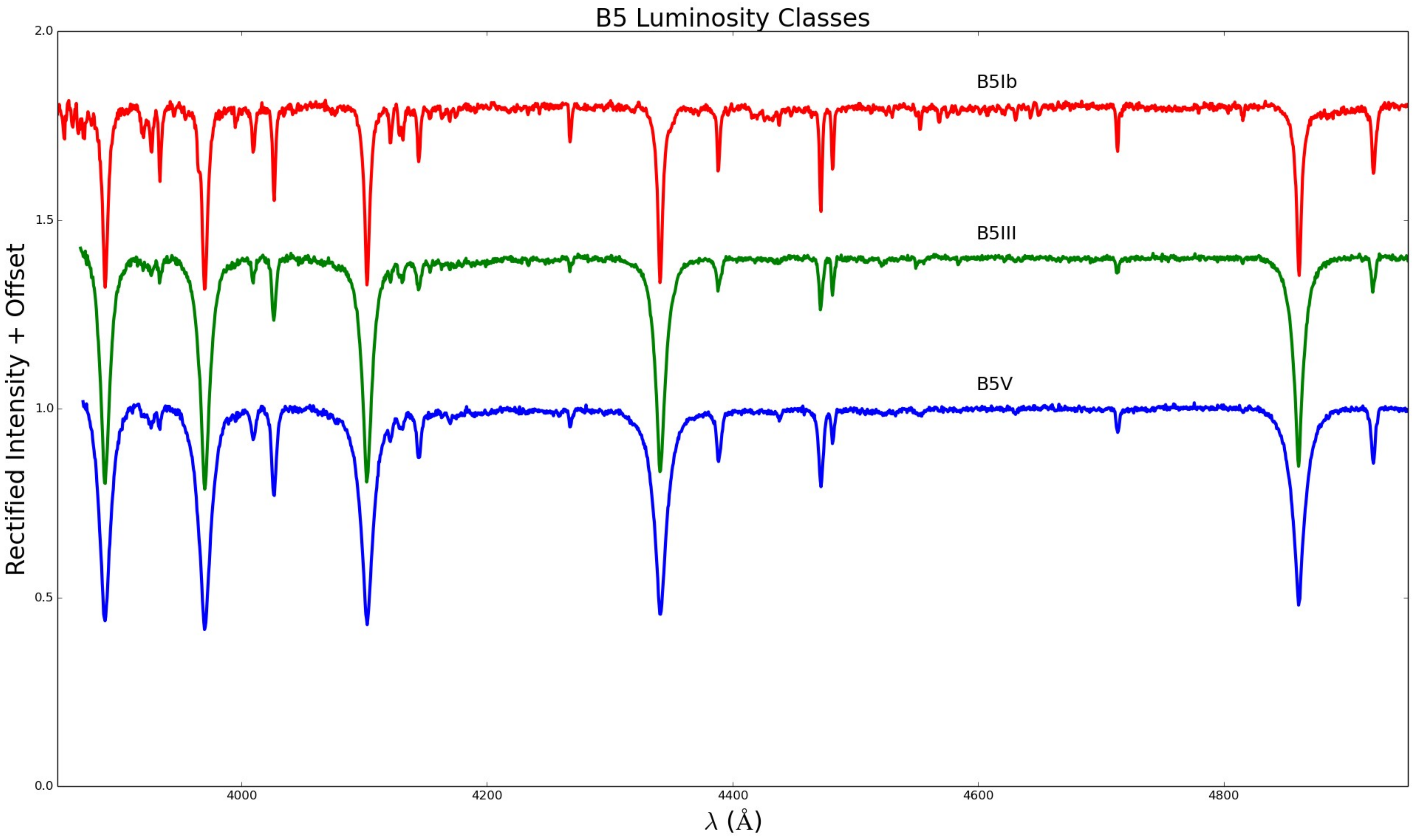
2. Observable Properties

Luminosity Classification



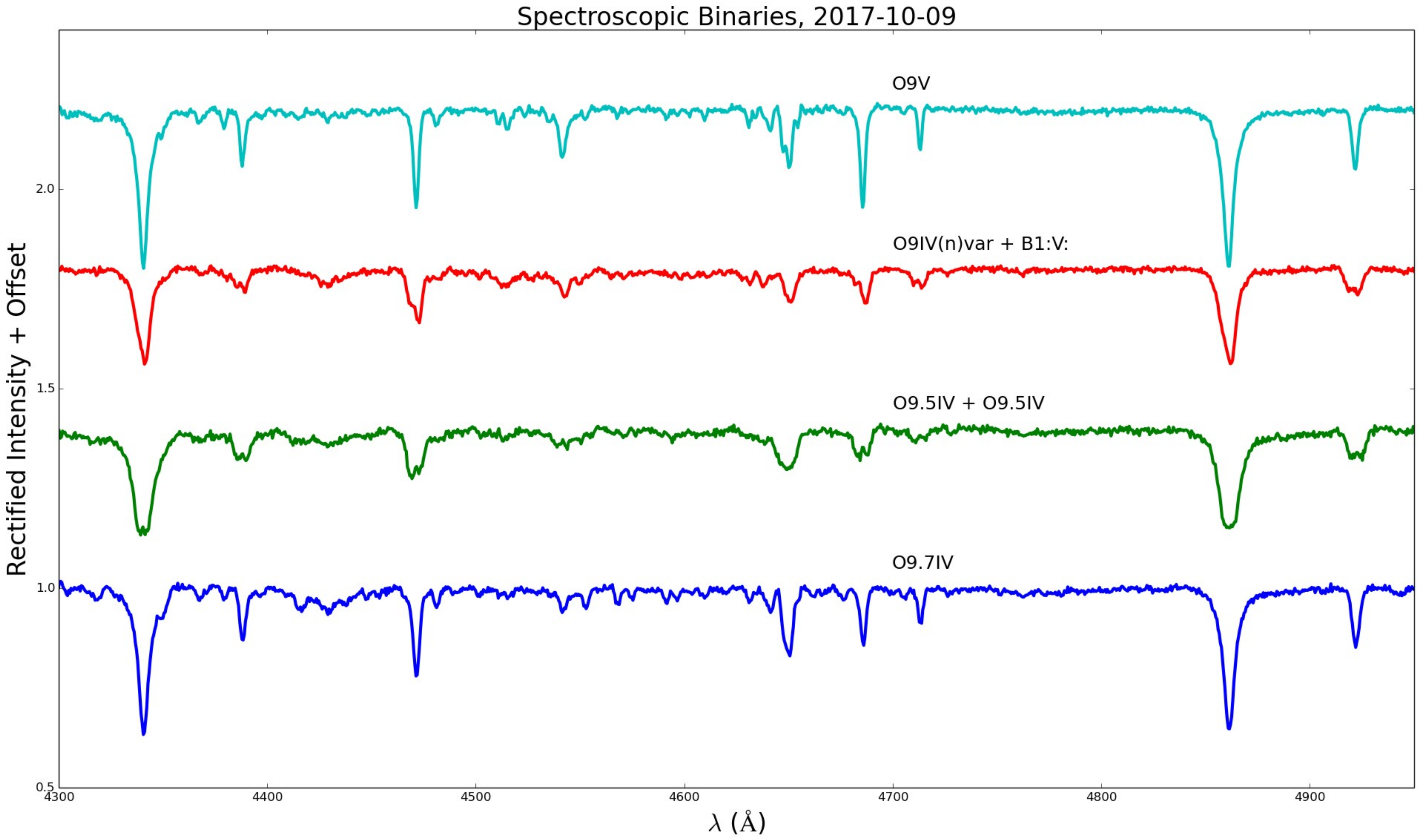
2. Observable Properties

Luminosity Classification



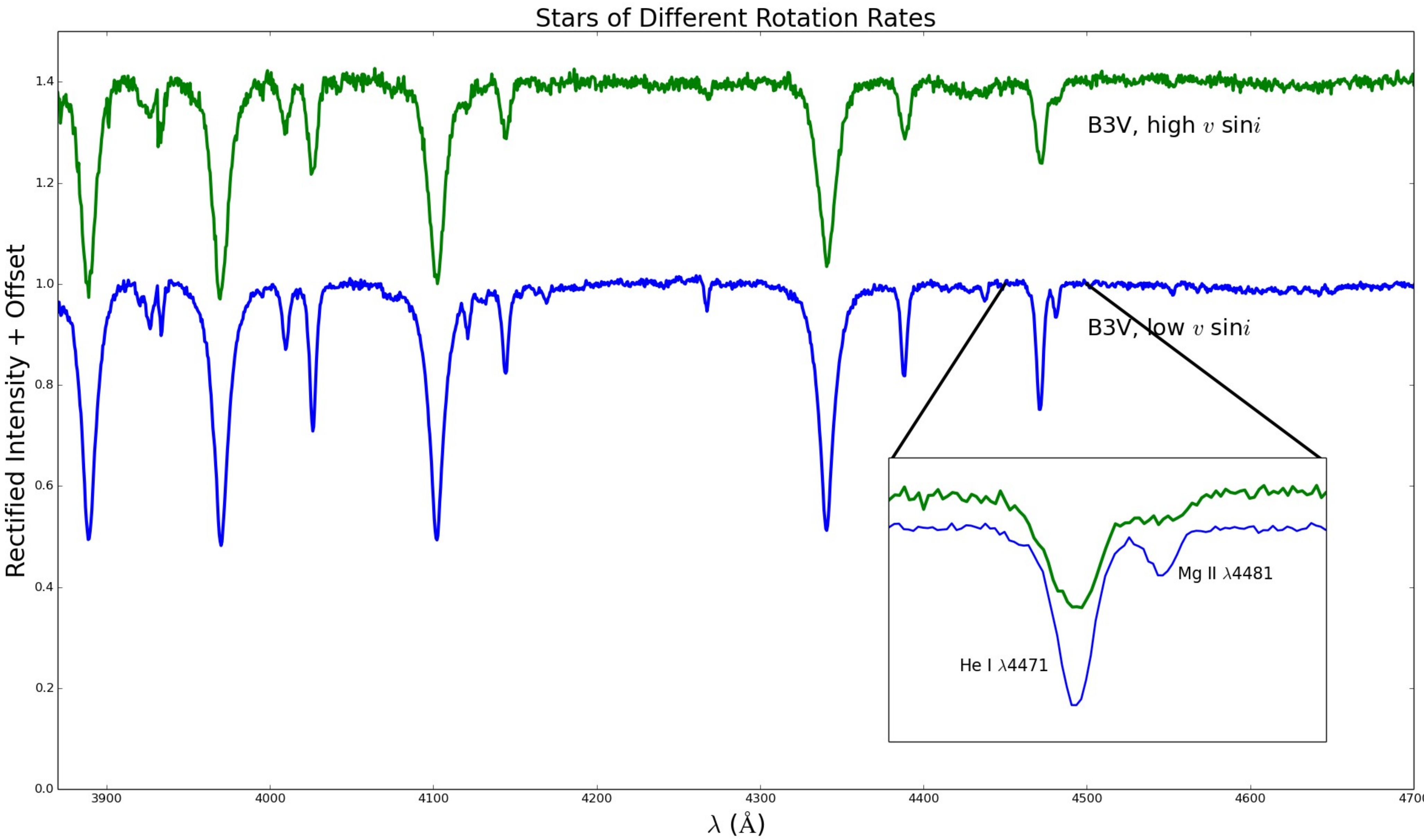
2. Observable Properties

Spectroscopic Binaries



2. Observable Properties

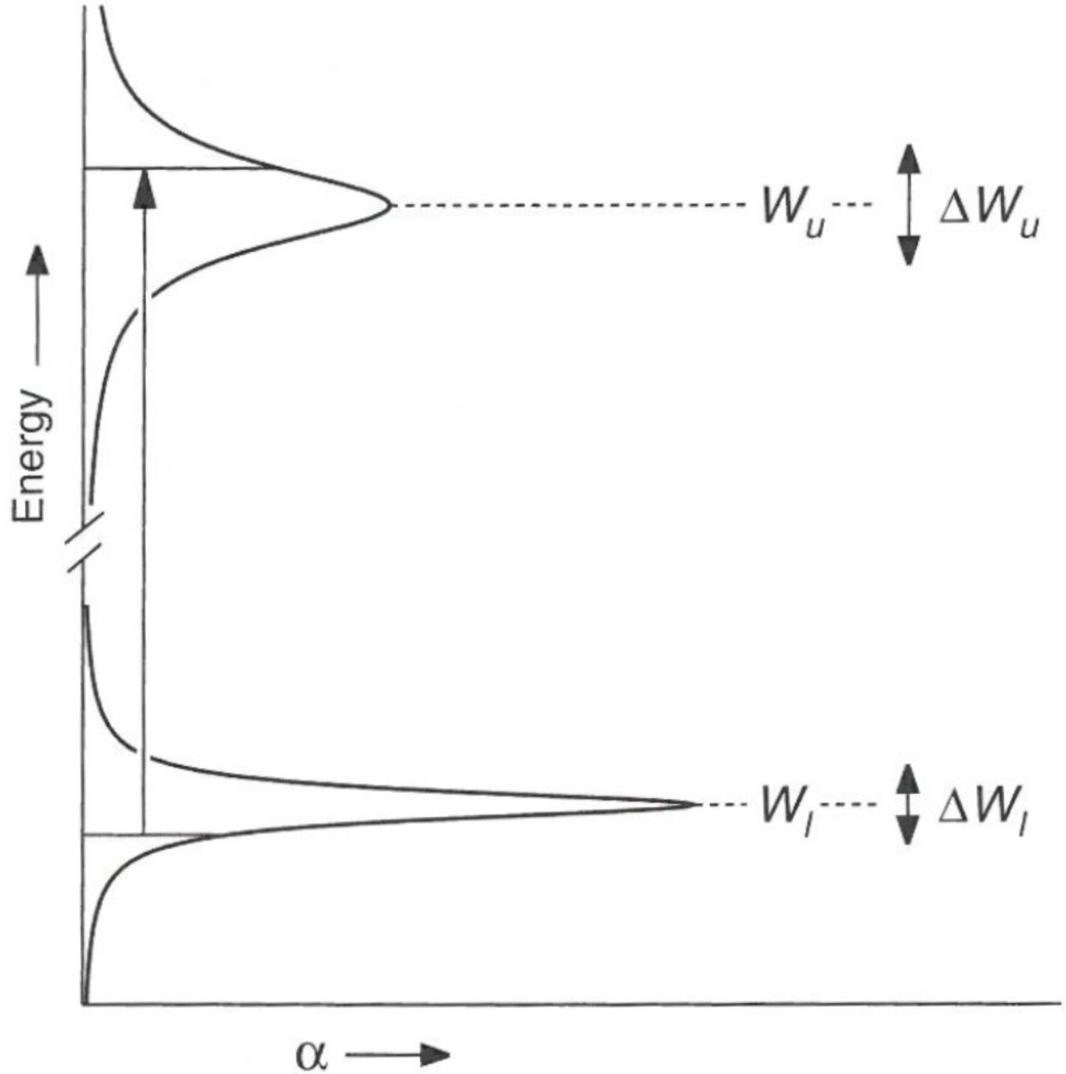
Same Spectral Type, Different $v \sin i$



3. Line Morphology

Natural Broadening

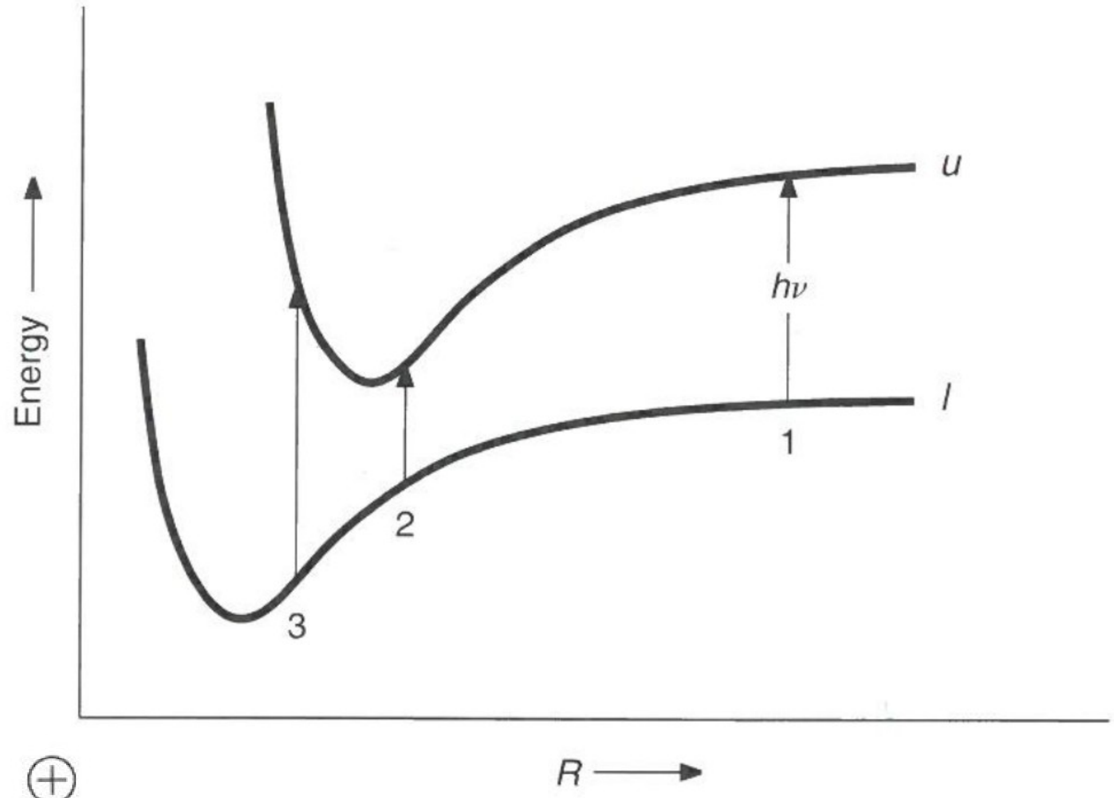
$$\Delta E \Delta T \gtrsim \hbar$$

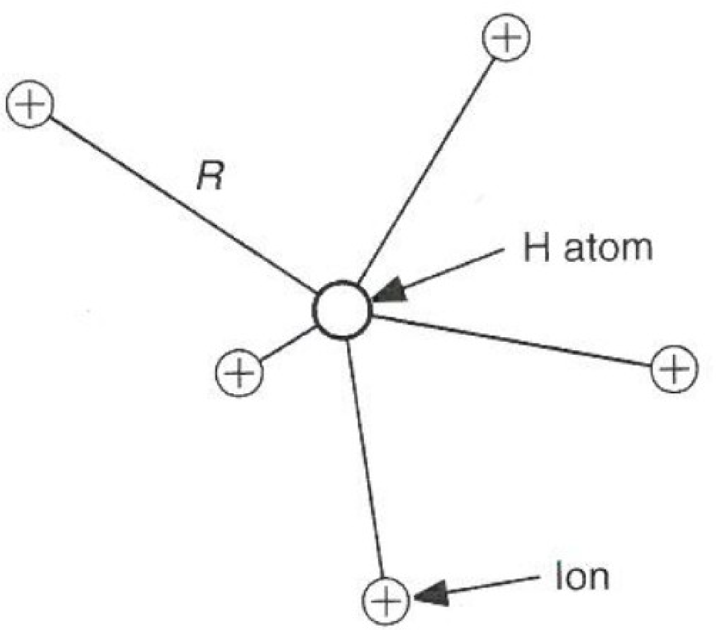


David Gray, *The Observation and Analysis of Stellar Photospheres,* Fig. 11.1

3. Line Morphology

Pressure broadening

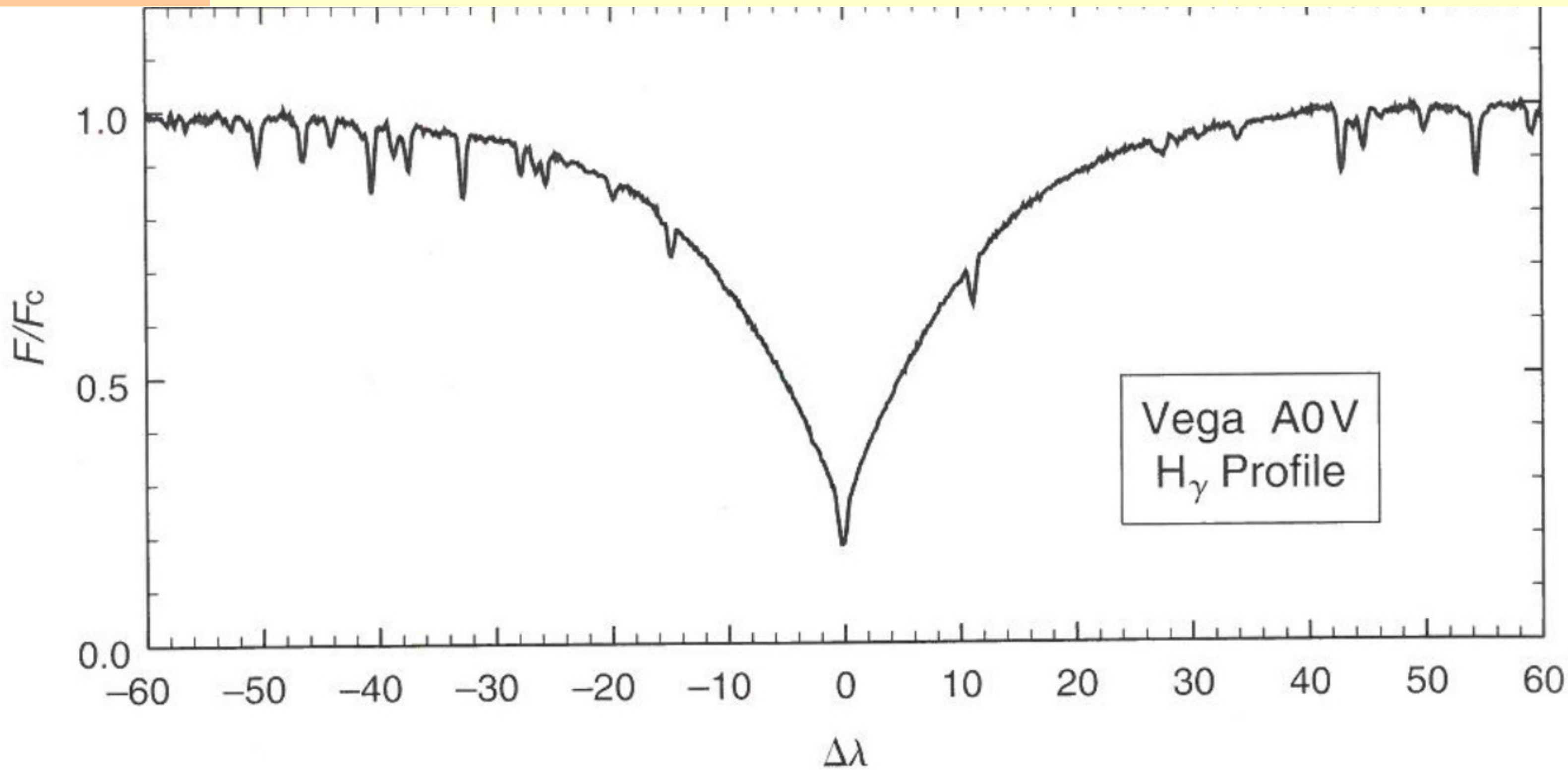




David Gray, *The Observation and Analysis of Stellar Photospheres,* Figs. 11.2, 11.6

3. Line Morphology

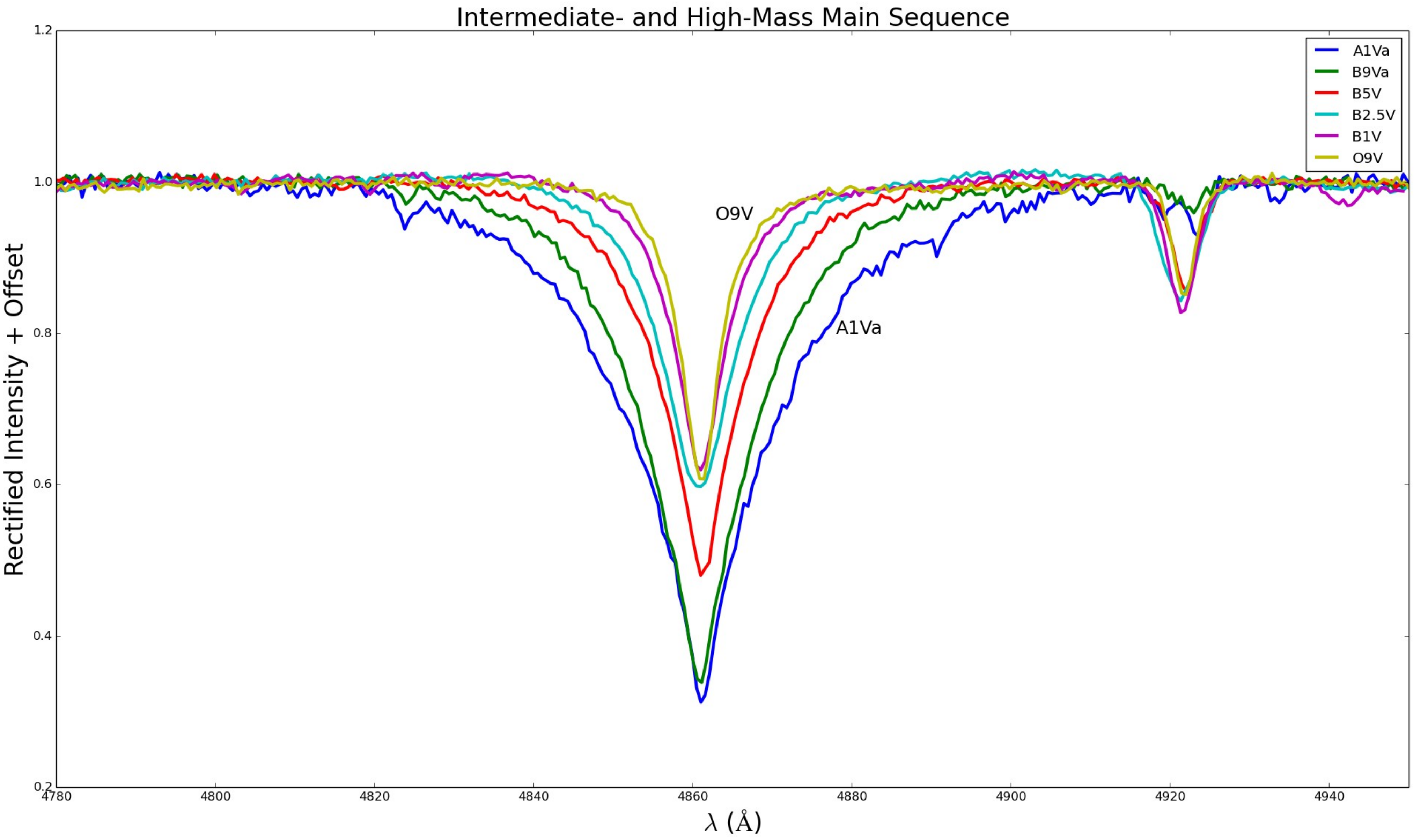
Profile Type	Cause	Hydrogen Lines	He, Metal Lines
Dispersion	natural broadening	√	√
	pressure broadening	(linear Stark)	(quadratic Stark)
Gaussian	microturbulence	√	√
	thermal broadening	√	√
	rotational broadening	√	√
	instrument profile	√	√
modified	gravity darkening	√	√



David Gray, *The Observation and Analysis of Stellar Photospheres,* Fig. 11.5

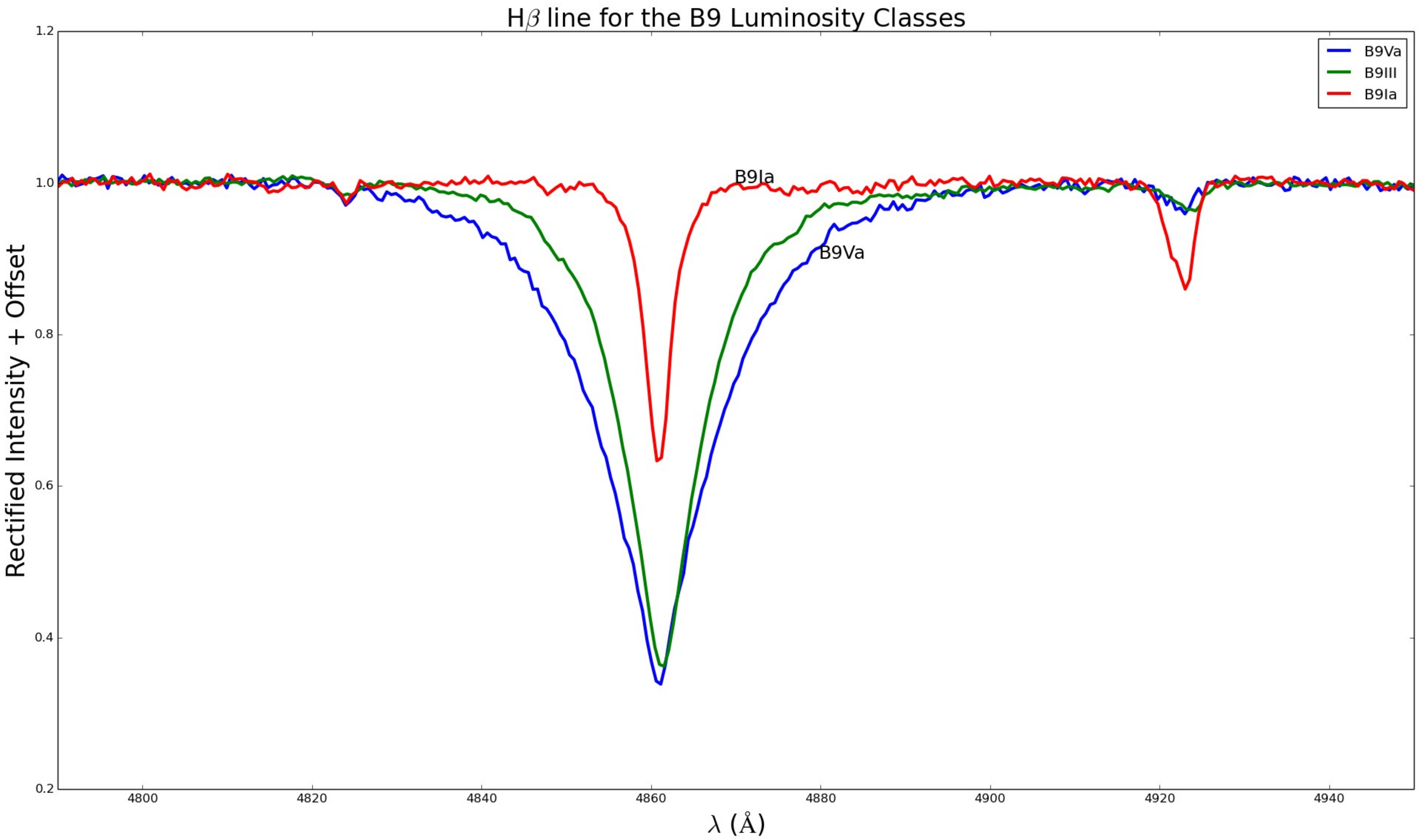
4. Spectral Typing O9 - A2 Stars

The Hydrogen line profile as a function of temperature



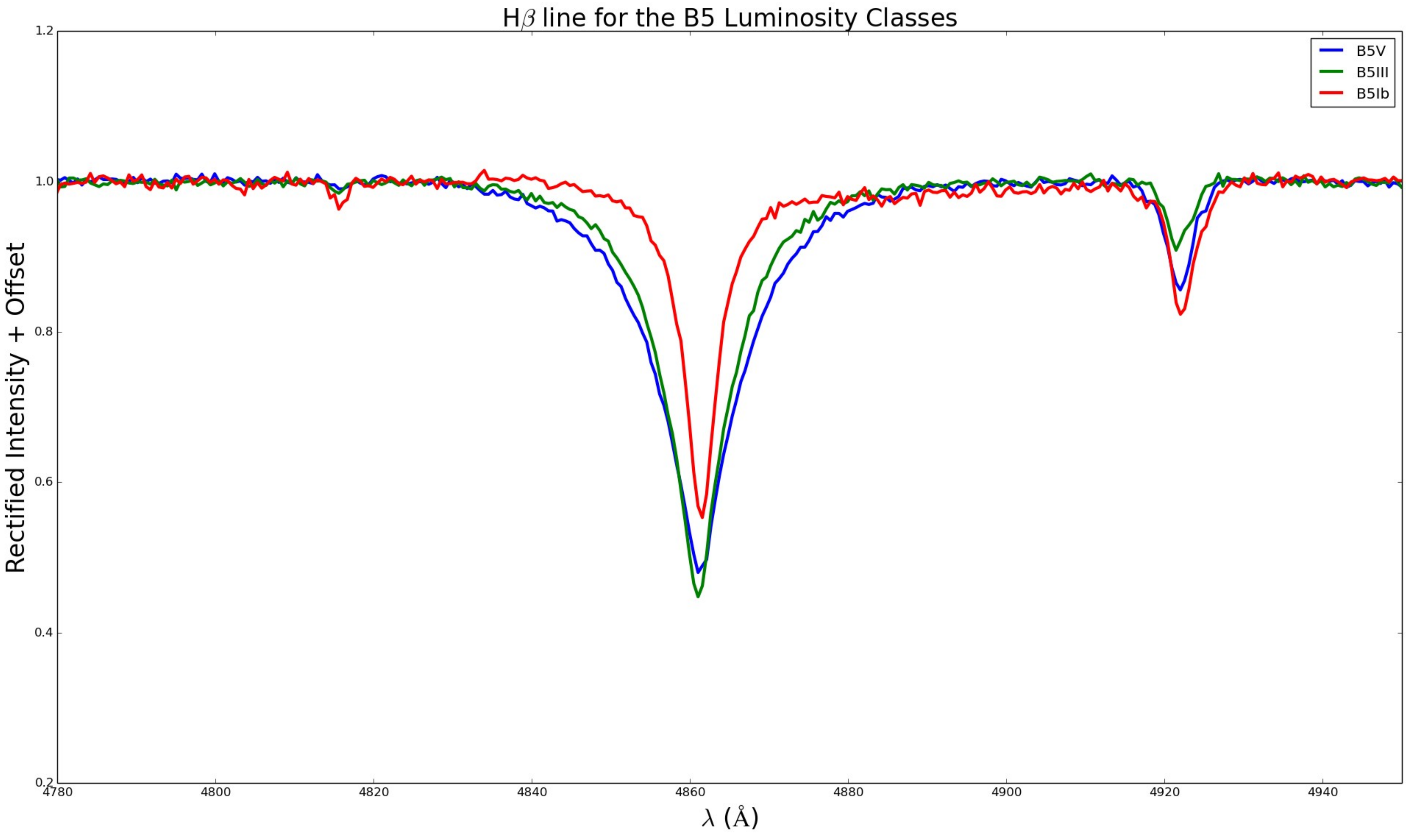
4. Spectral Typing O9 - A2 Stars

The Hydrogen line profile as a function of luminosity class



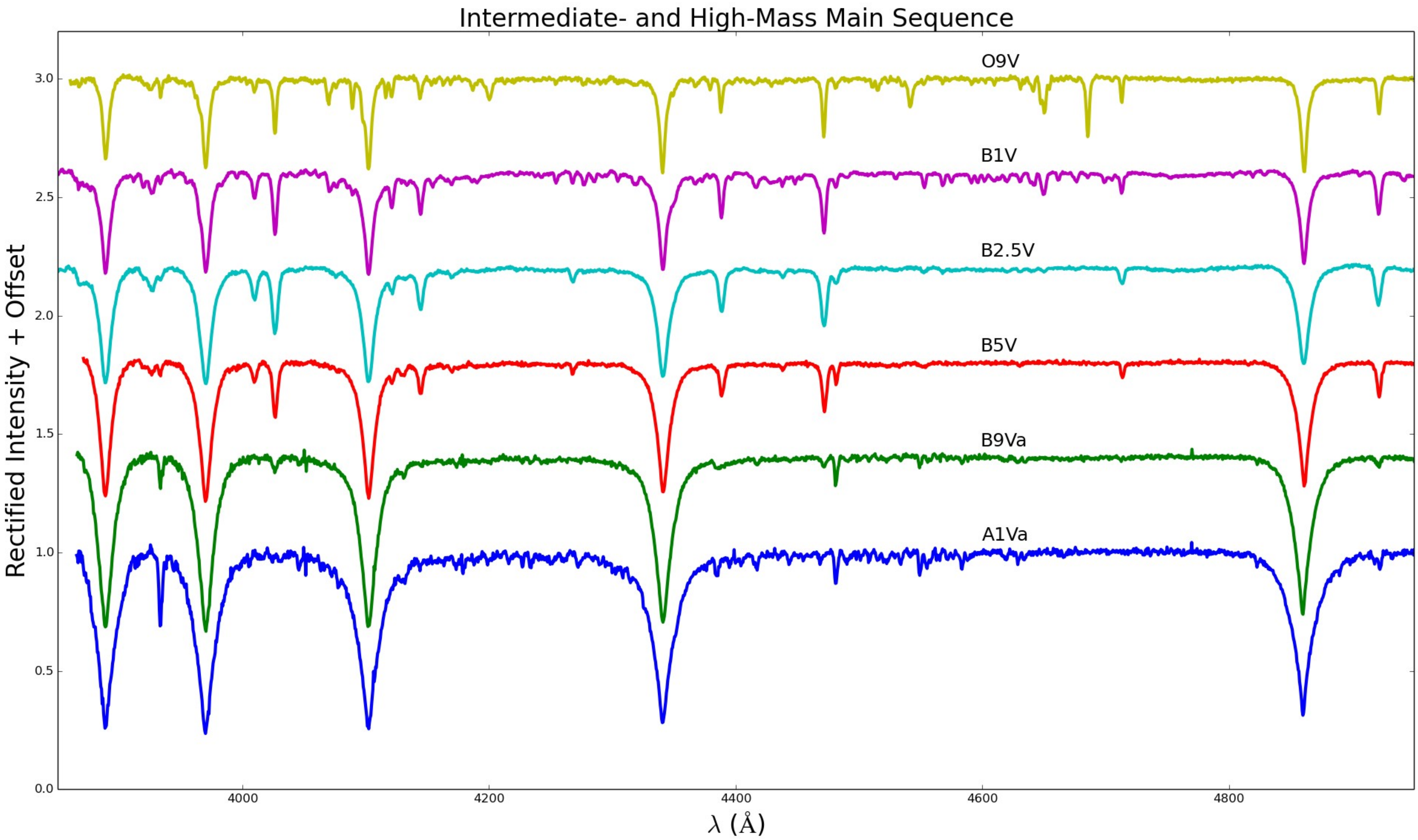
4. Spectral Typing O9 - A2 Stars

The Hydrogen line profile as a function of luminosity class



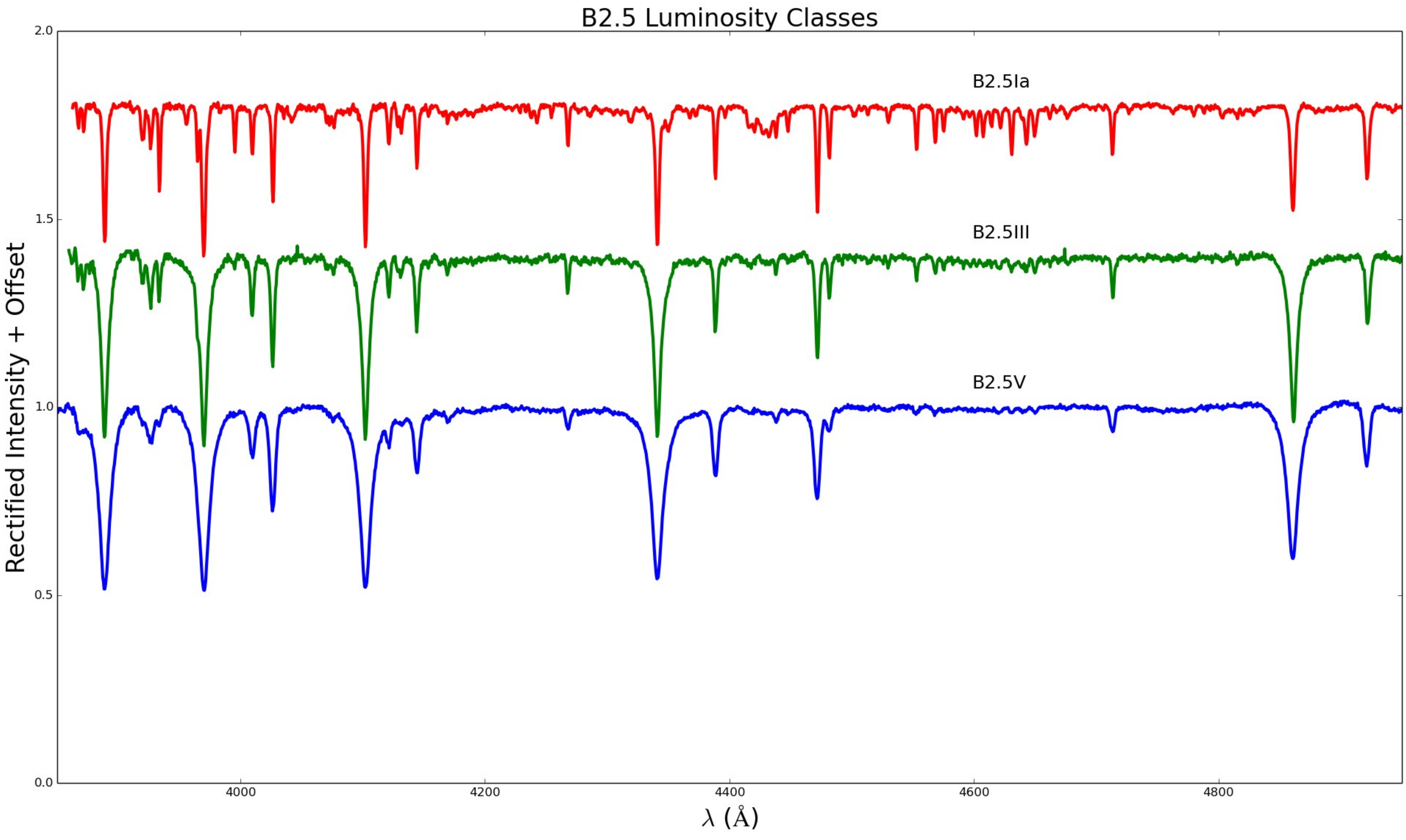
4. Spectral Typing O9 - A2 Stars

Helium and metal line strengths



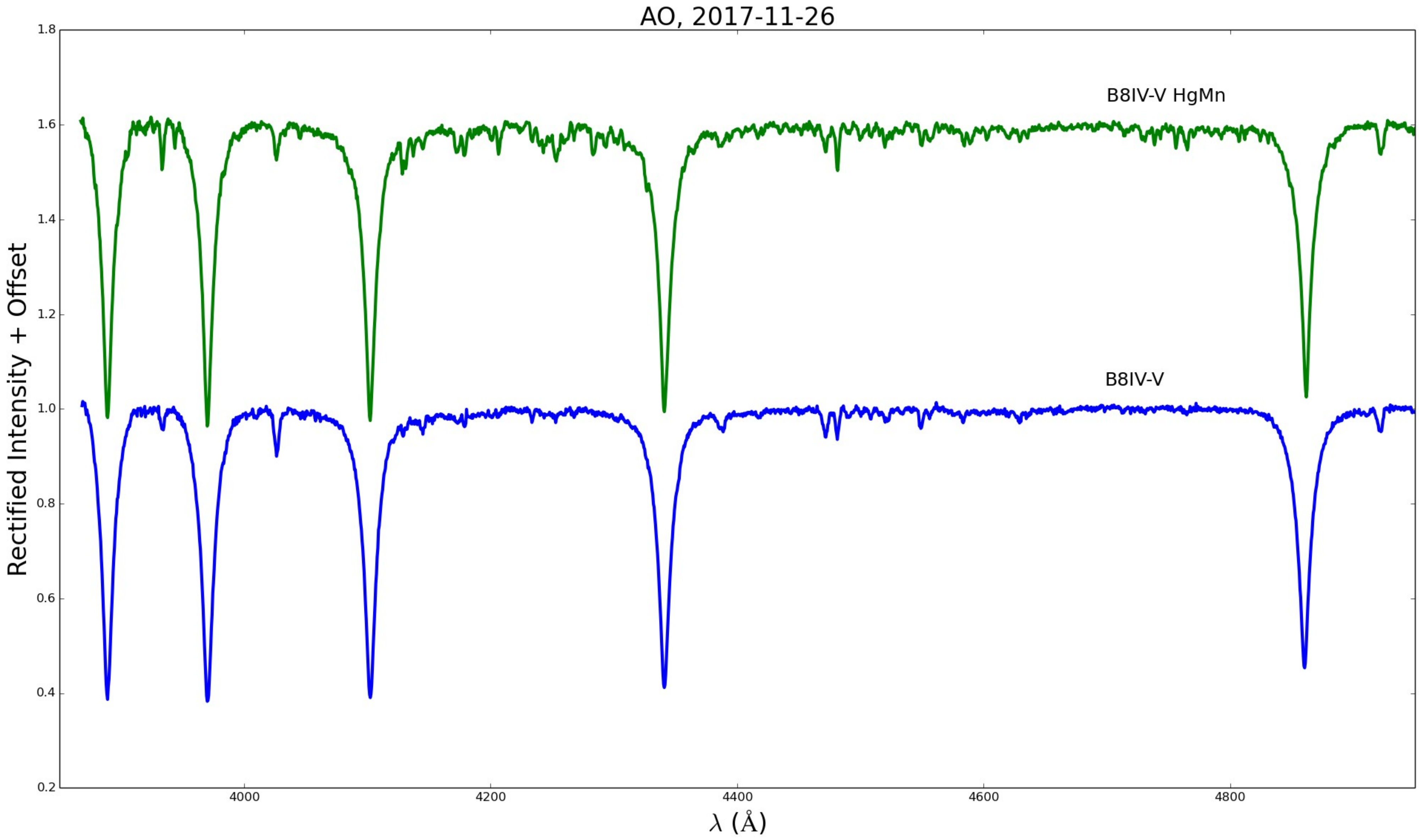
4. Spectral Typing O9 - A2 Stars

Helium and metal line strengths...can get confusing, too



4. Spectral Typing O9 - A2 Stars

Then, there are chemical peculiarities



4. Spectral Typing O9 - A2 Stars

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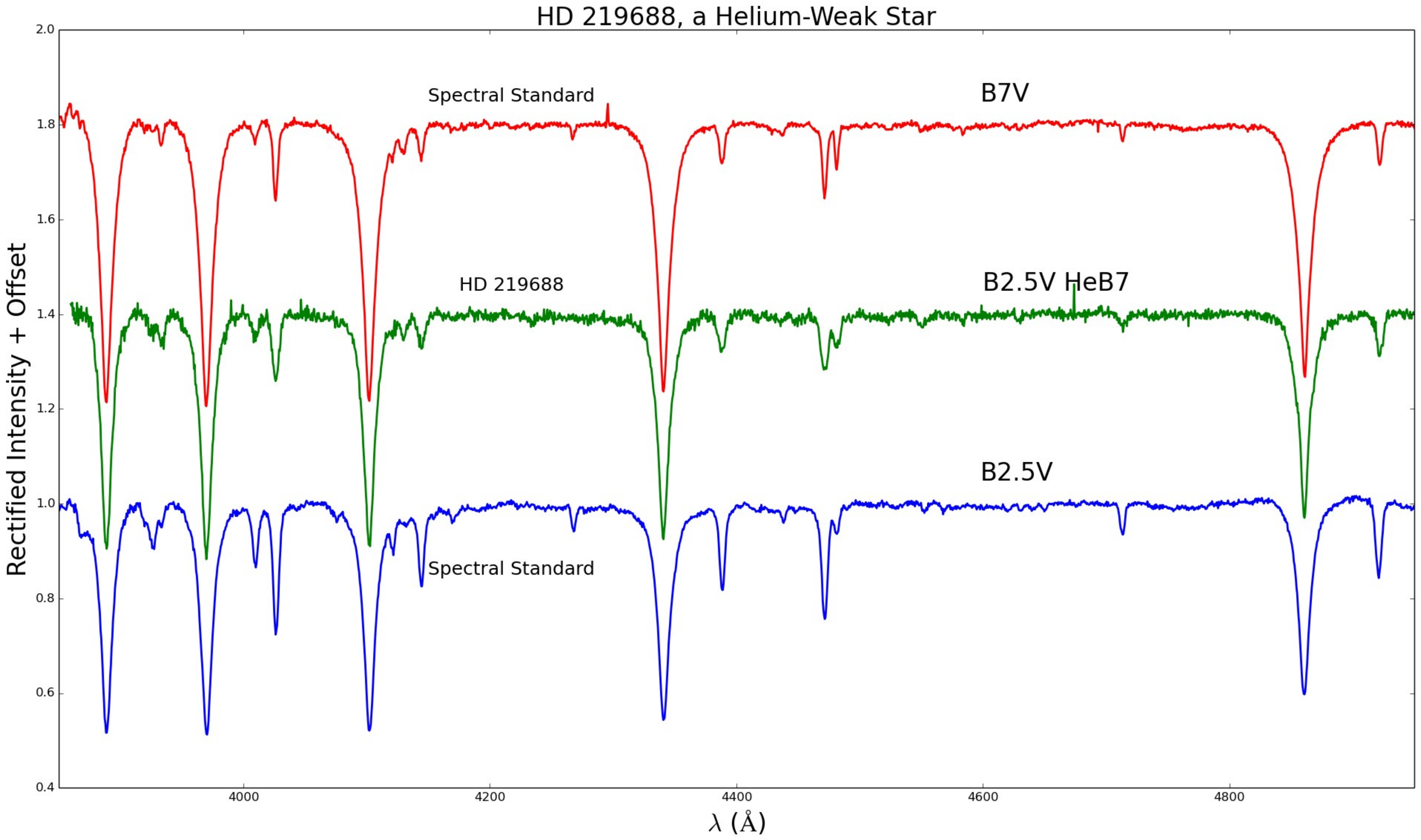
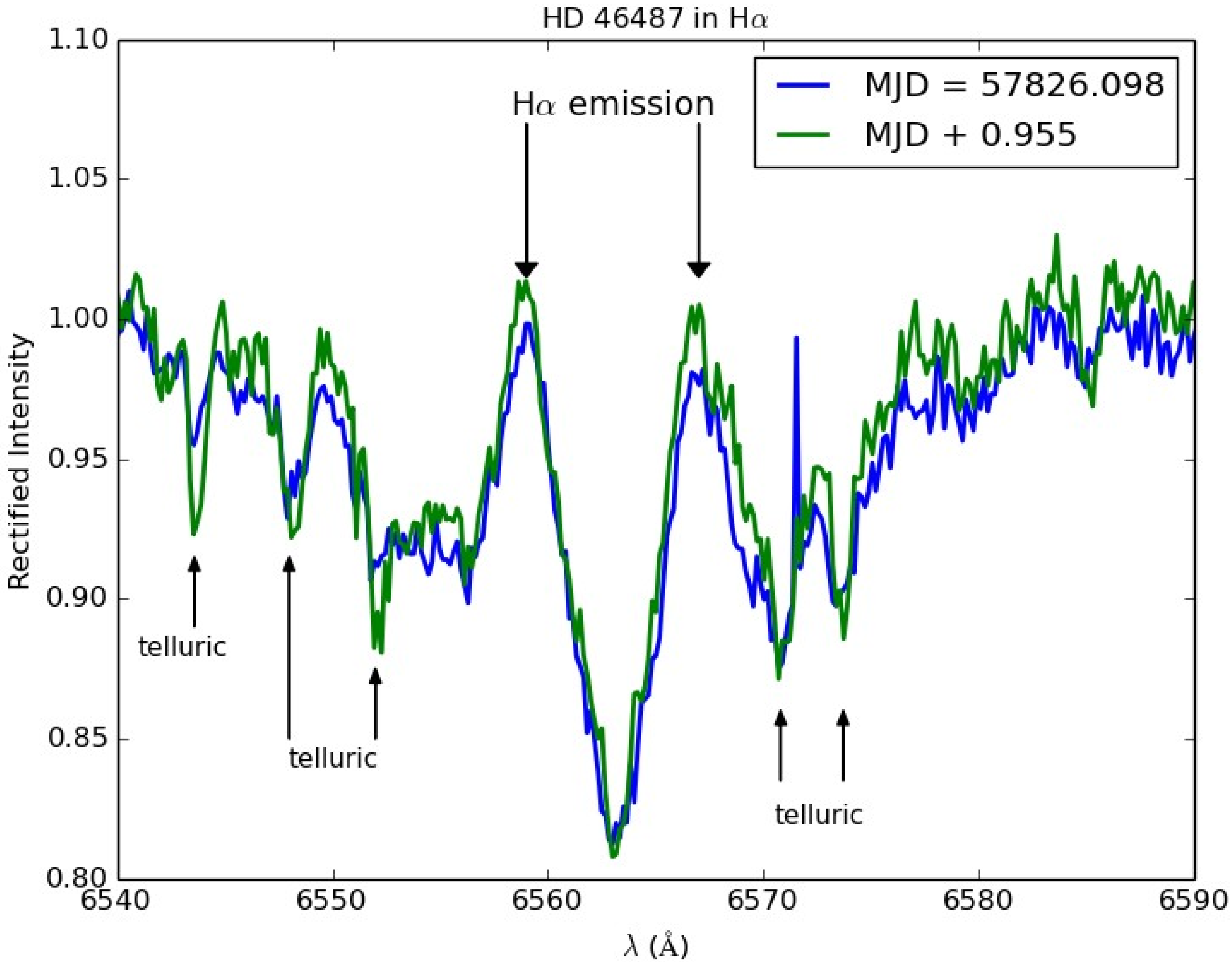


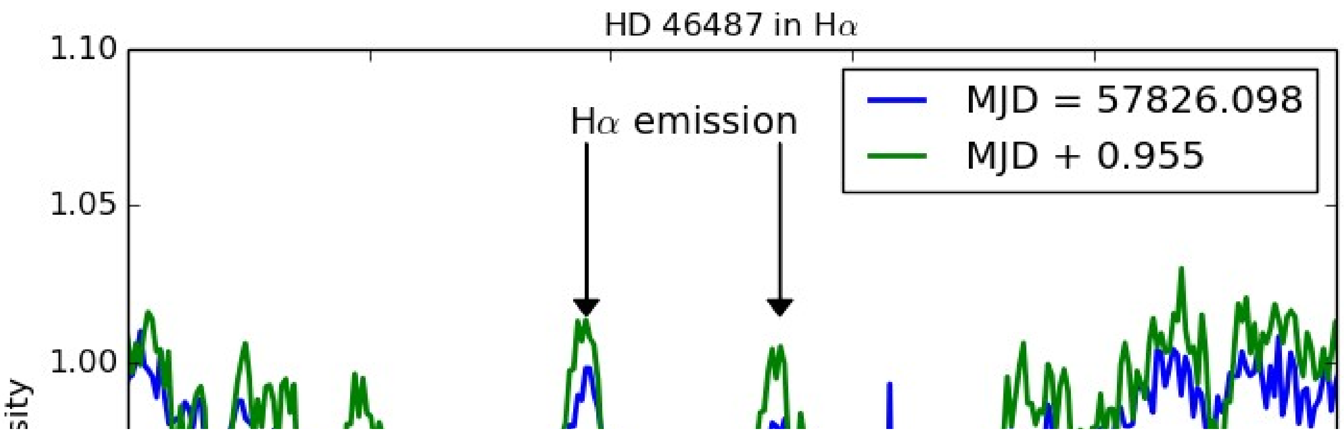
5. Spectroscopic Variability

Example #1: A New B*e* Star



5. Spectroscopic Variability

Example #1: A New Be Star



HD 46487 is Now a Classical Be Star

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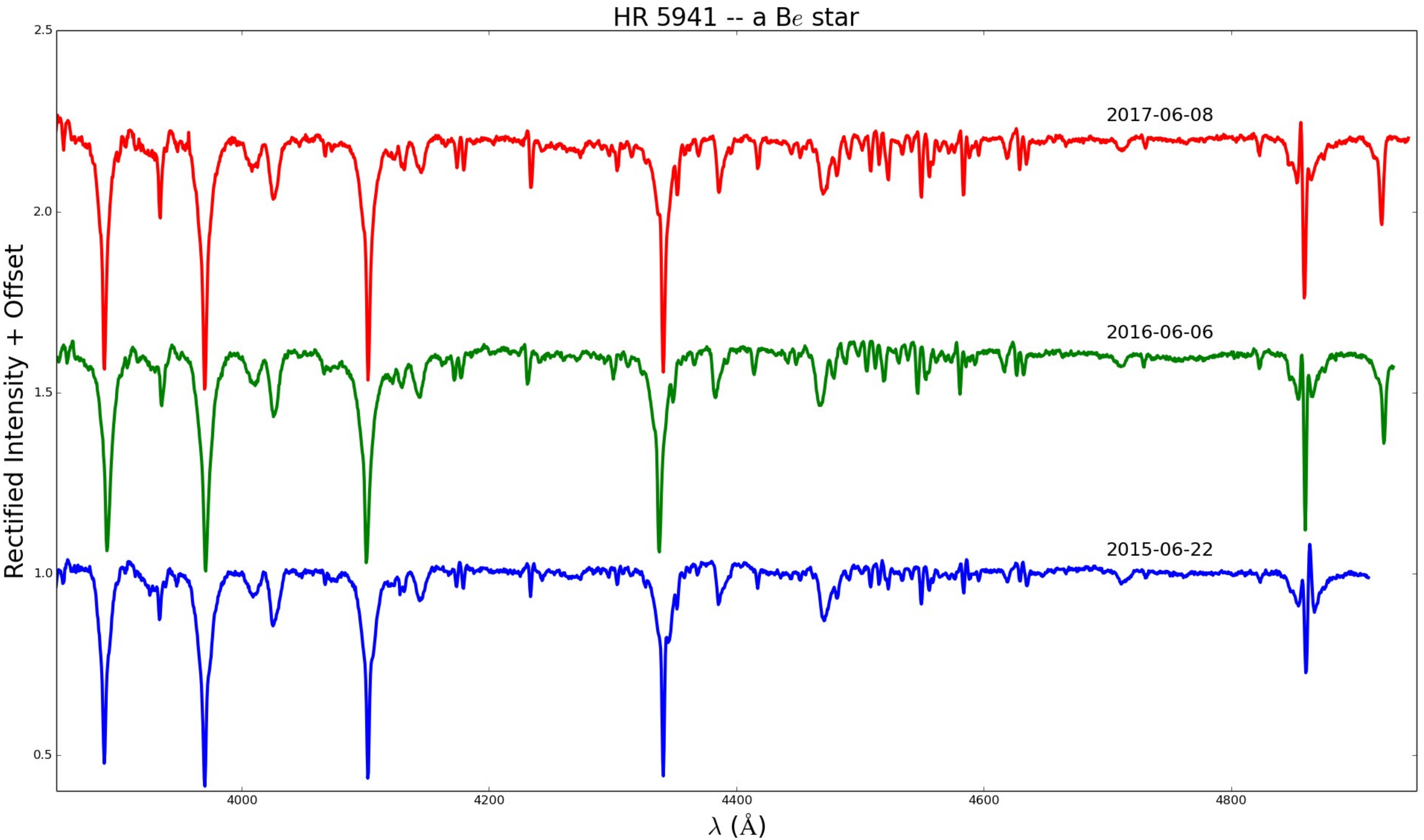
Abstract We present the first observations of hydrogen line emission detected around the B-type star HD 46487, a well-studied star in the CoRoT field of view. The emission is only evident in the Hα line, for which the observed violet-red peak separation ($\Delta \upsilon_p$) is typical of a Be star with a circumstellar disk. The absence of dust emission from the infrared spectral energy distribution excludes the possibility of a very young star. The star's magnitude (V = 5.079) and regular use in the literature for a variety of studies suggests that the line emission had a high probability of being found previously, had it been evident; since such was not the case, we believe that the Be phenomenon for HD 46487 has only very recently "turned on." We therefore recommend that this star be spectroscopically and photometrically monitored to track continued changes to its circumstellar morphology.

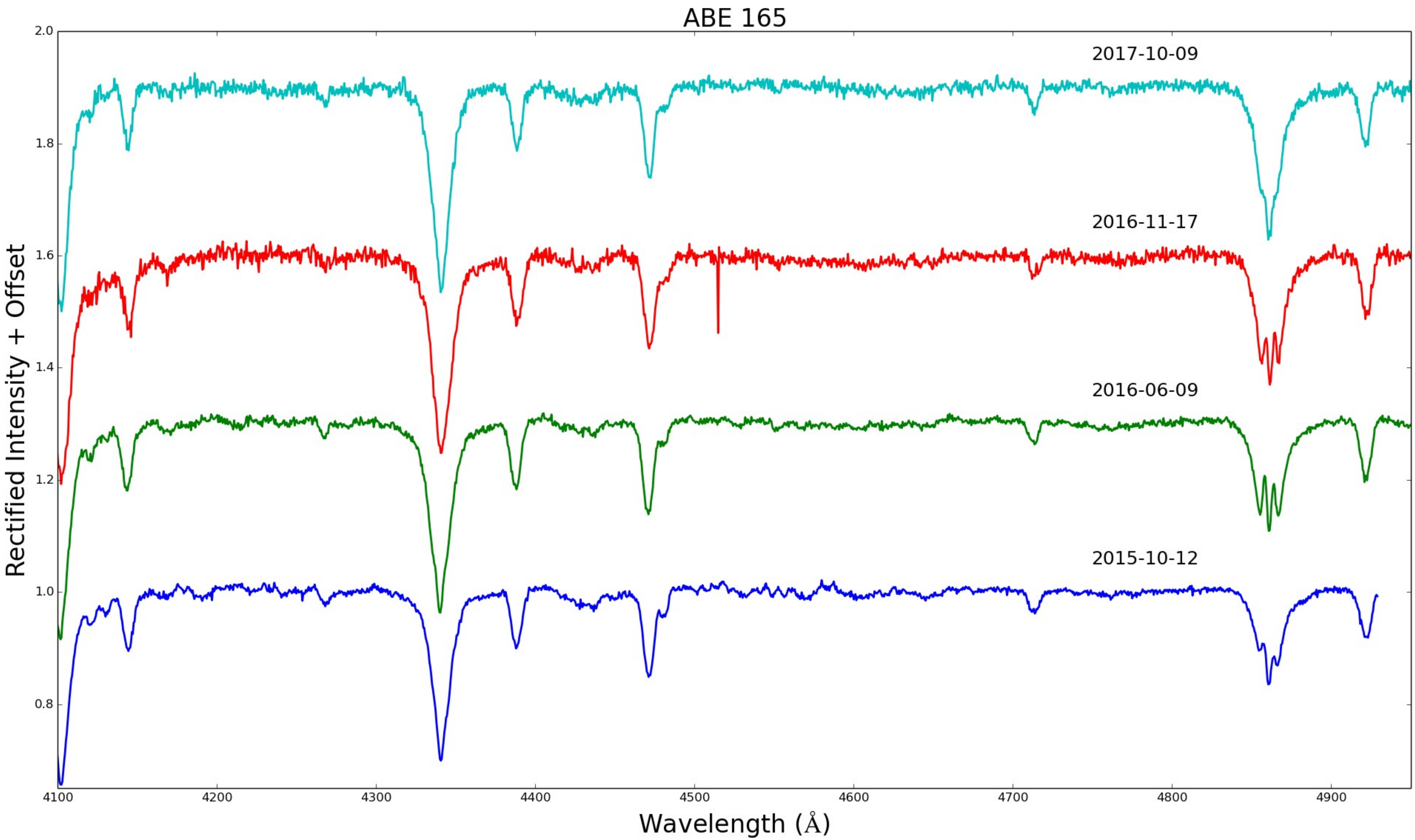
5. Spectroscopic Variability

Example #2: B*e* Disk Emission Variability



5. Spectroscopic Variability

Example #3: Changes to Emission *and* Absorption



In Conclusion

(1) Physical Properties
- a. Internal Structure
- b. Rotation
- c. Binarity

(2) Spectroscopic Properties
- a. Hydrogen absorption lines
- b. Helium and metal absorption lines
- c. Signatures of binarity
- d. Rotation Rate

(3) Line Morphology
- a. Dispersion profile
- b. Gaussian profile

(4) Spectral Typing
- a. An iterative pursuit
  - i. Hydrogen lines
  - ii. Helium and metal lines
  - iii. Chemical peculiarities?

(5) Spectroscopic Variability
- a. New Be stars
- b. Disk emission variability
- c. Spectral type variability