Interpreting Spectra of High- and Intermediate-Mass Stars

"Chp. 2"

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Scope

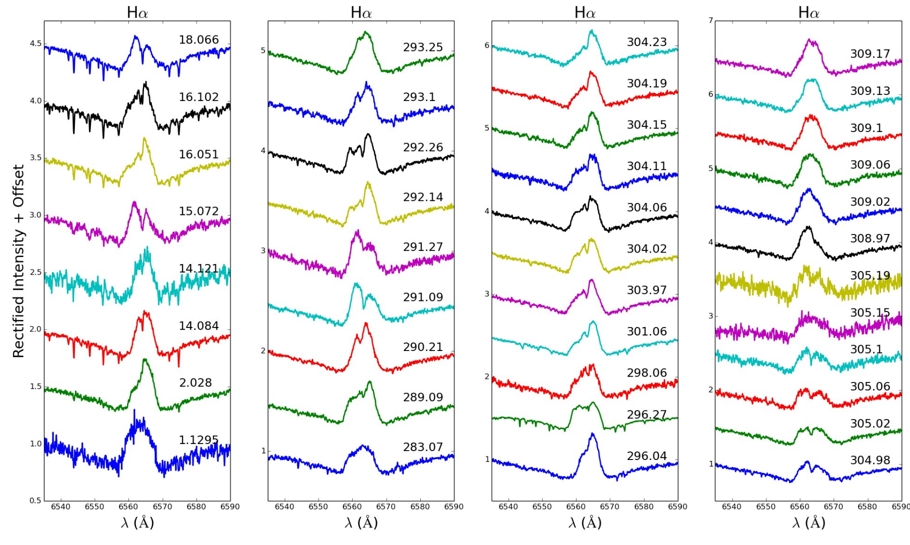
1. Physical Properties of Intermediate- and High-Mass Stars

2. Observable Properties of B-type and Emission-Line B-type (B*e*) Stellar Spectra

3. Emission *versus* Absorption: A Qualitative Look

4. Emission *versus* Absorption: A Physical Approach

5. Studying Rapid Spectroscopic Variability



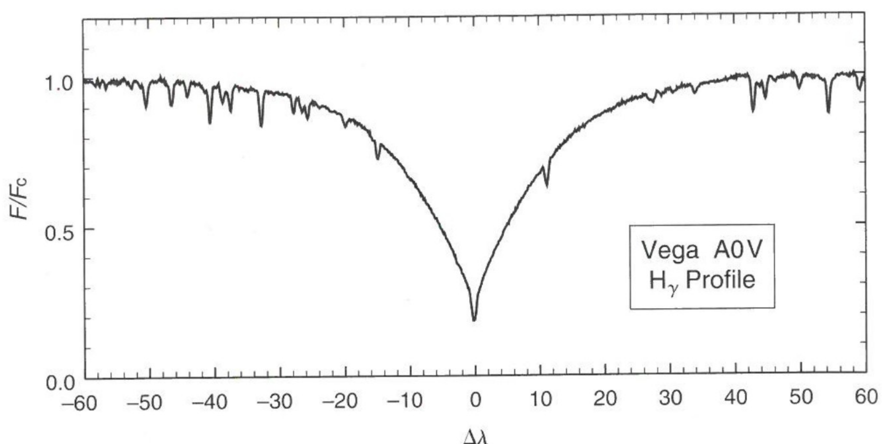
1. Physical Properties of Intermediate- and High-Mass Stars

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:



Gray, Fig. 11.5

- 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

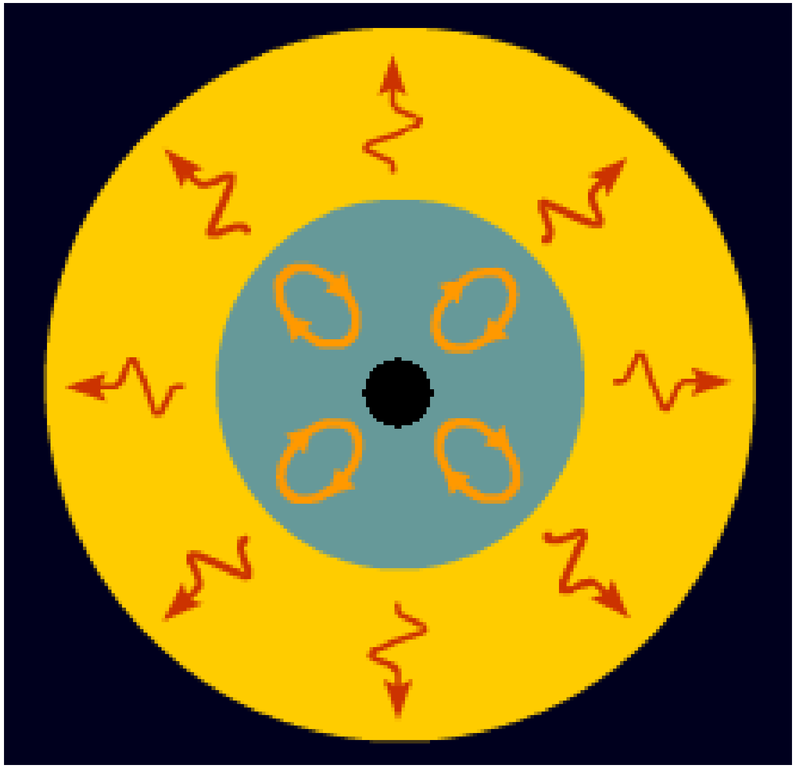
Data from: David Gray's *The Observation and Analysis of Stellar Photospheres*
Richard Gray & Christopher Corbally's *Stellar Spectral Classification*

Photospherically:

- Weaker H lines
- He ionization layer is near or at the surface

NOT Considering O8 and above:

- Convective interior, puffier stars



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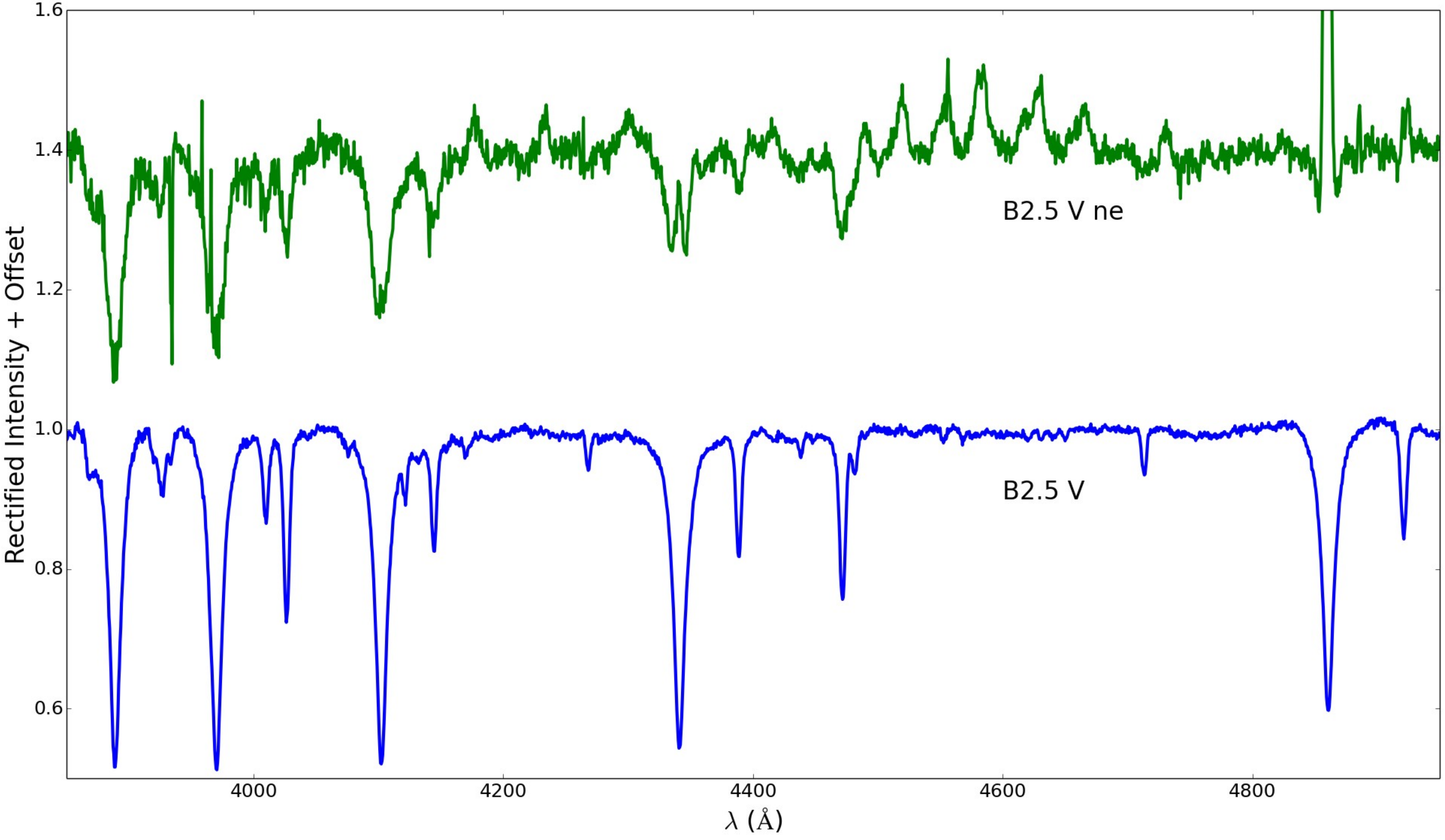
2. Observable Properties of B-type and Be Stars



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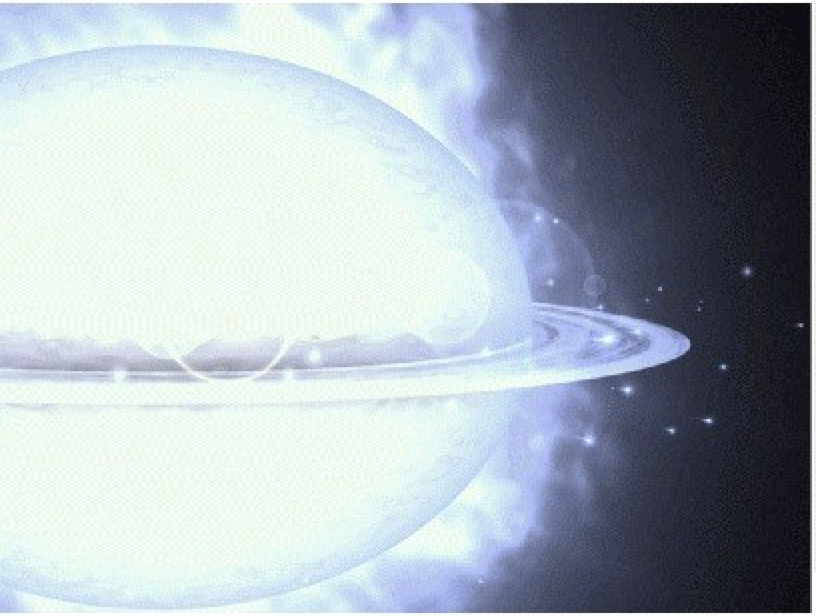
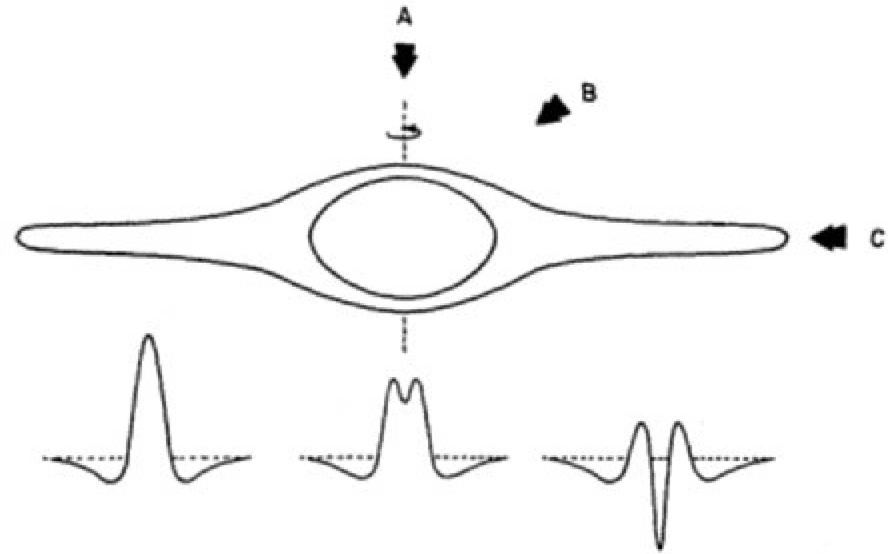
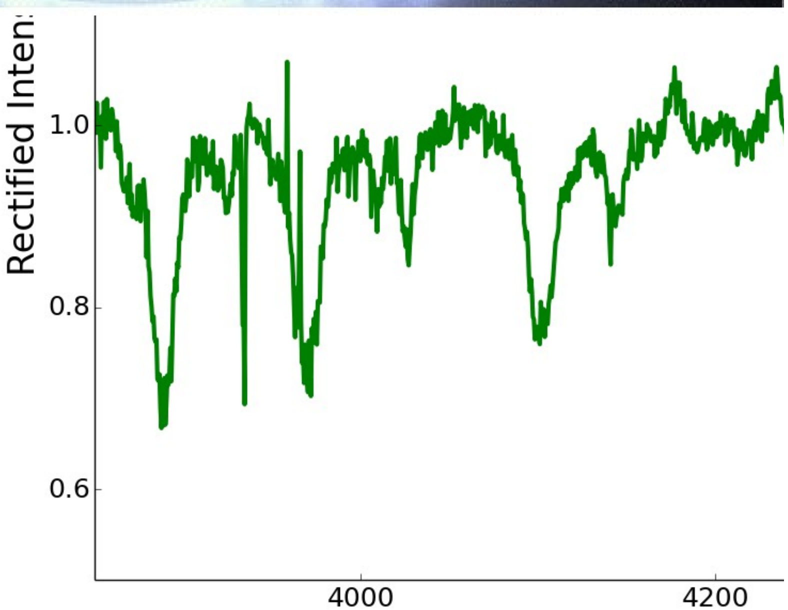
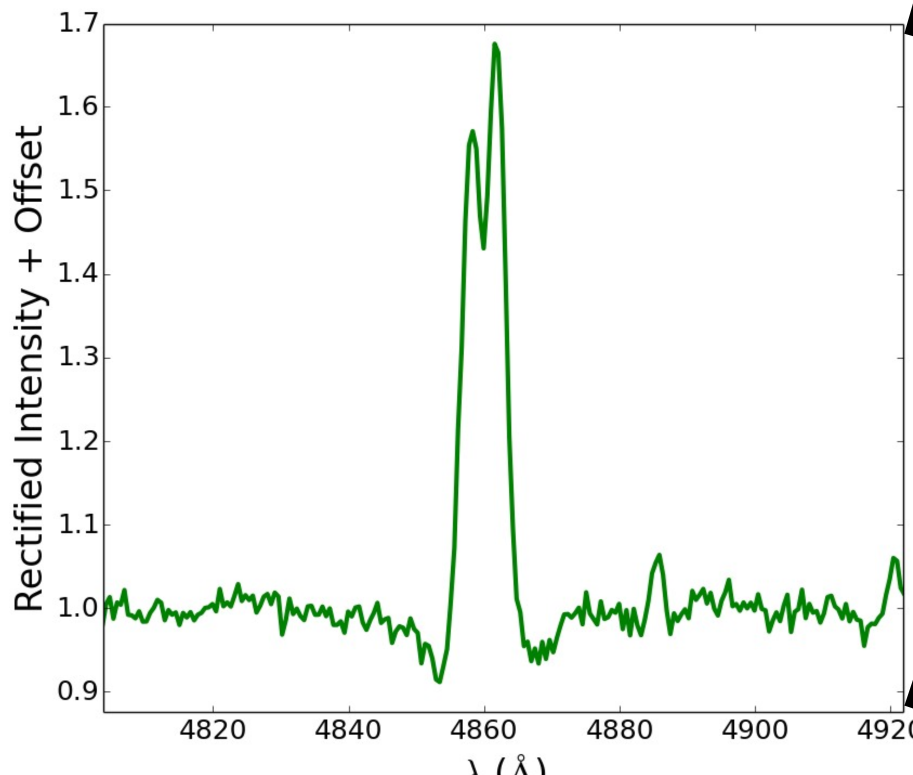
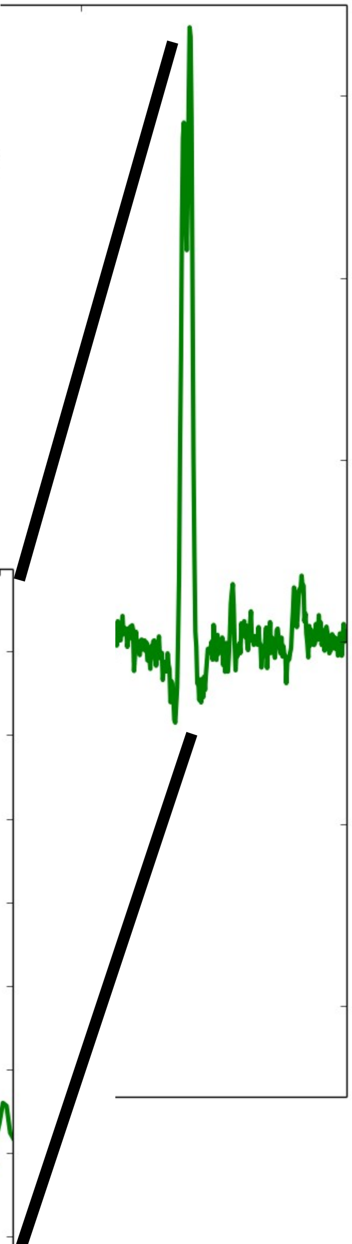




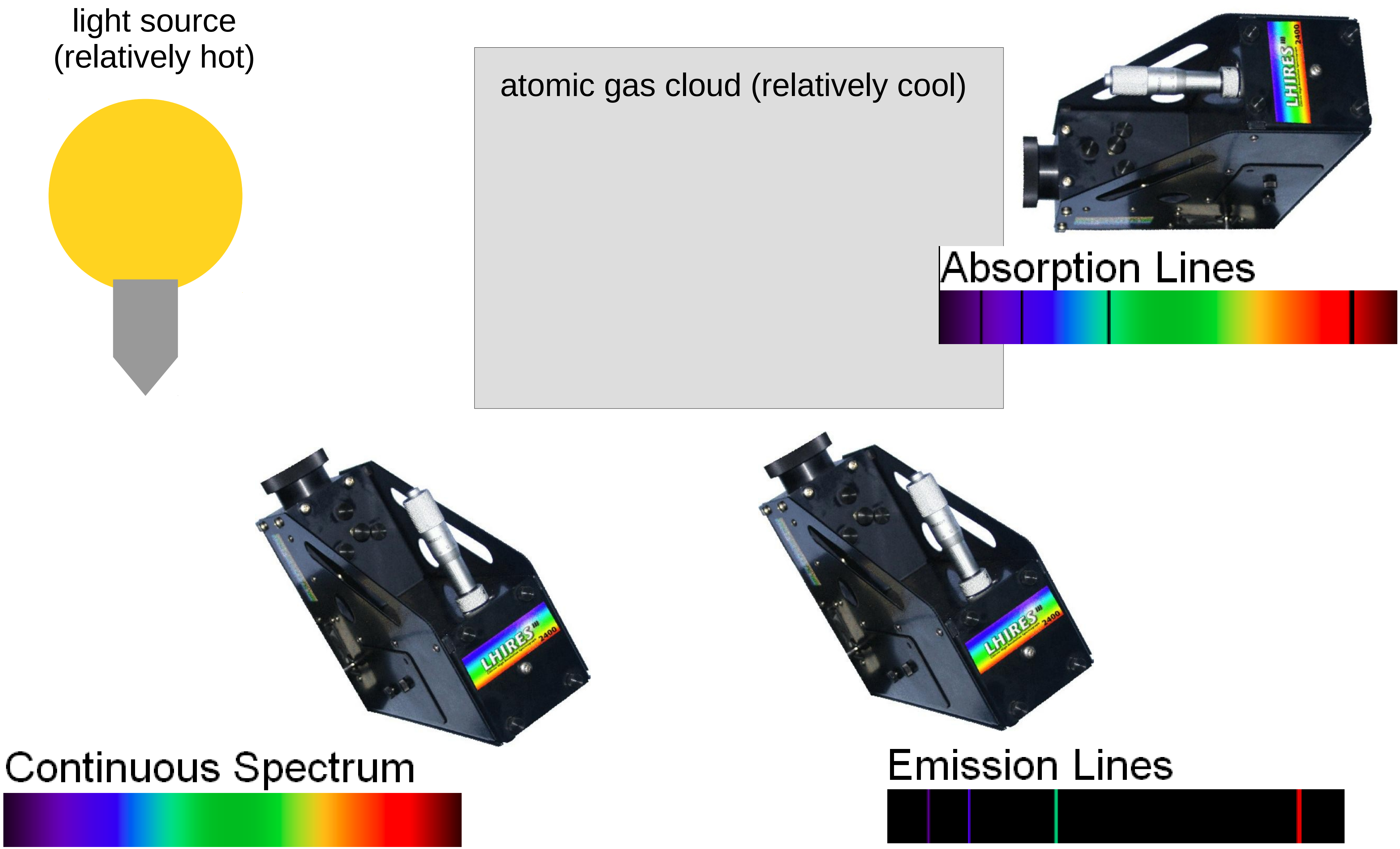






http://lasp.colorado.edu/~cranmer/cranmer_st_hot.h

3. Emission *versus* Absorption: A Qualitative Look



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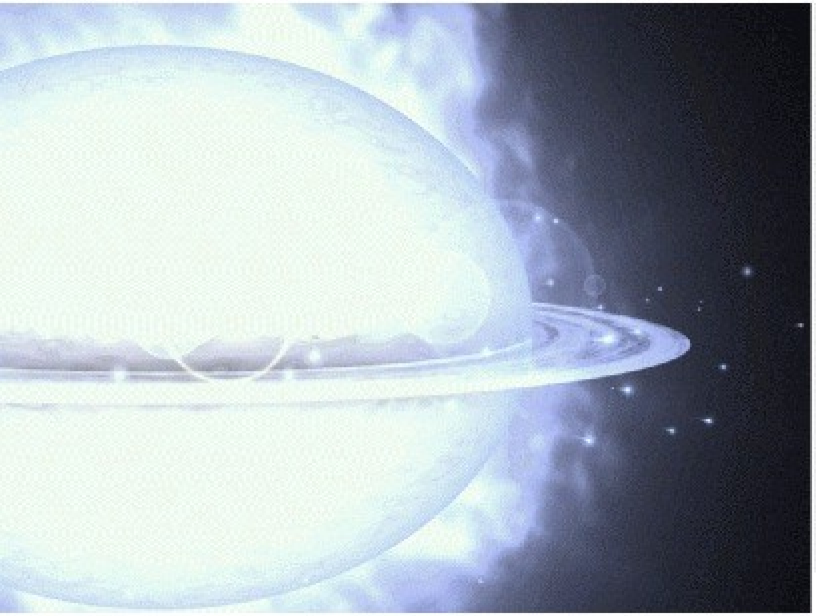
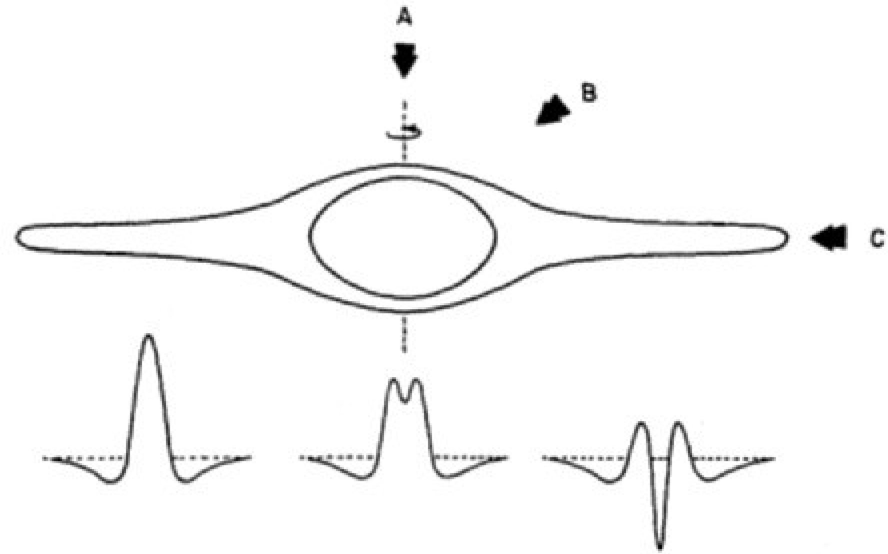
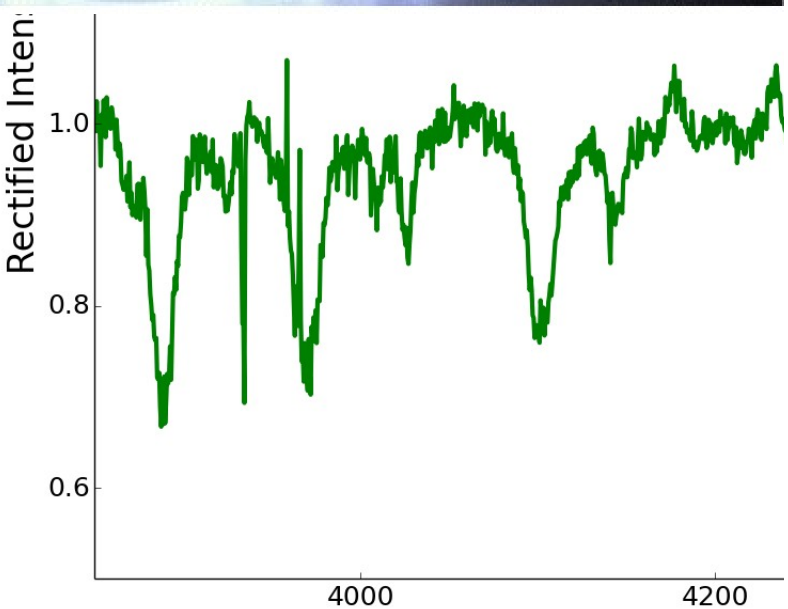
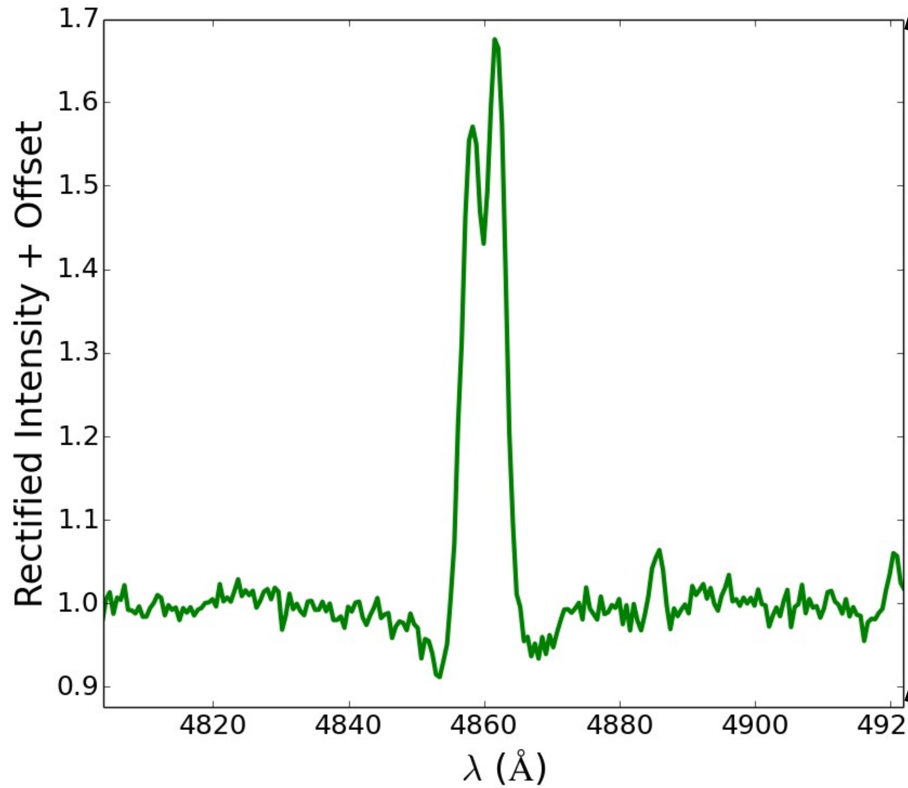
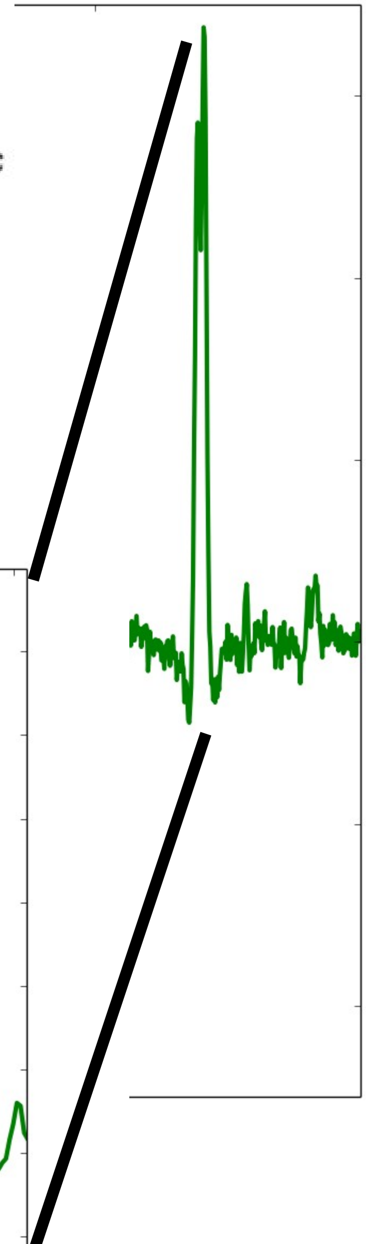




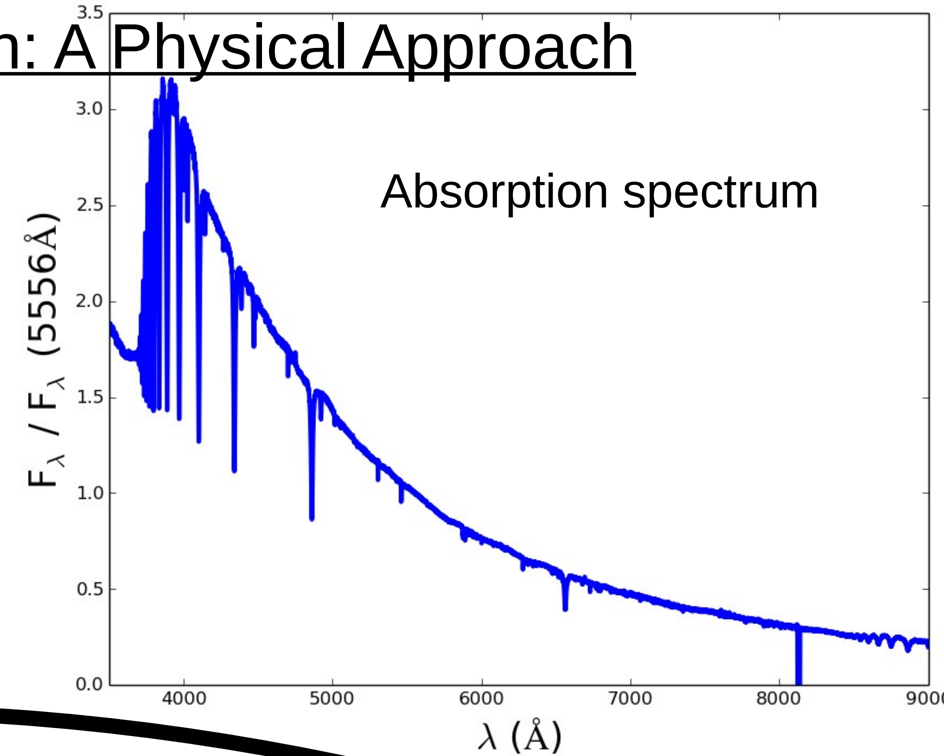




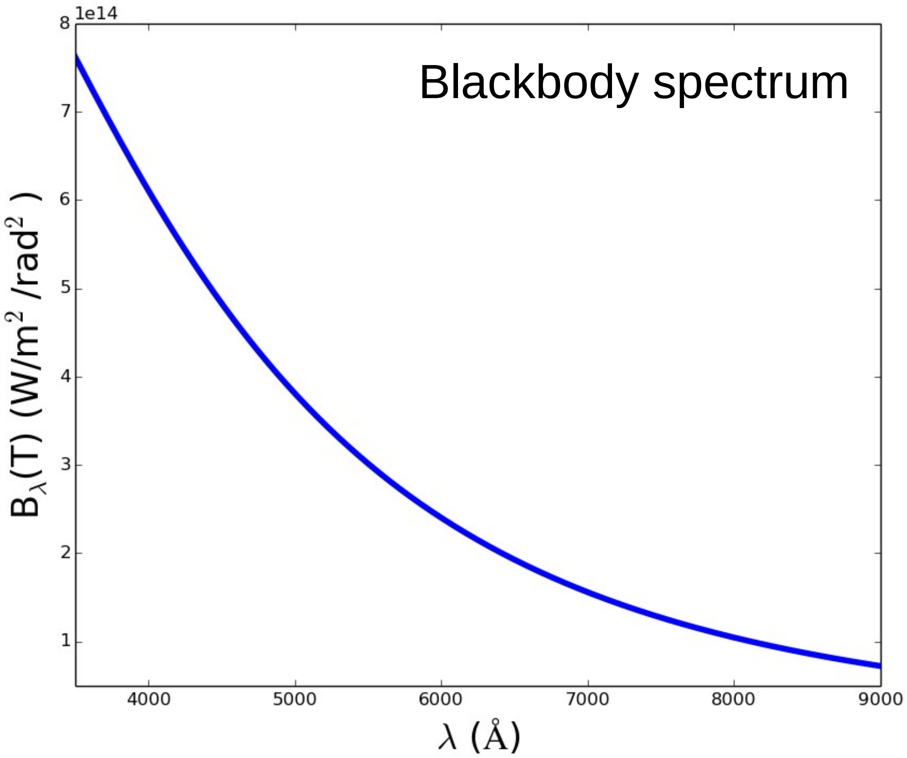


http://lasp.colorado.edu/~cranmer/cranmer_st_hot.h

4. Emission *versus* Absorption: A Physical Approach

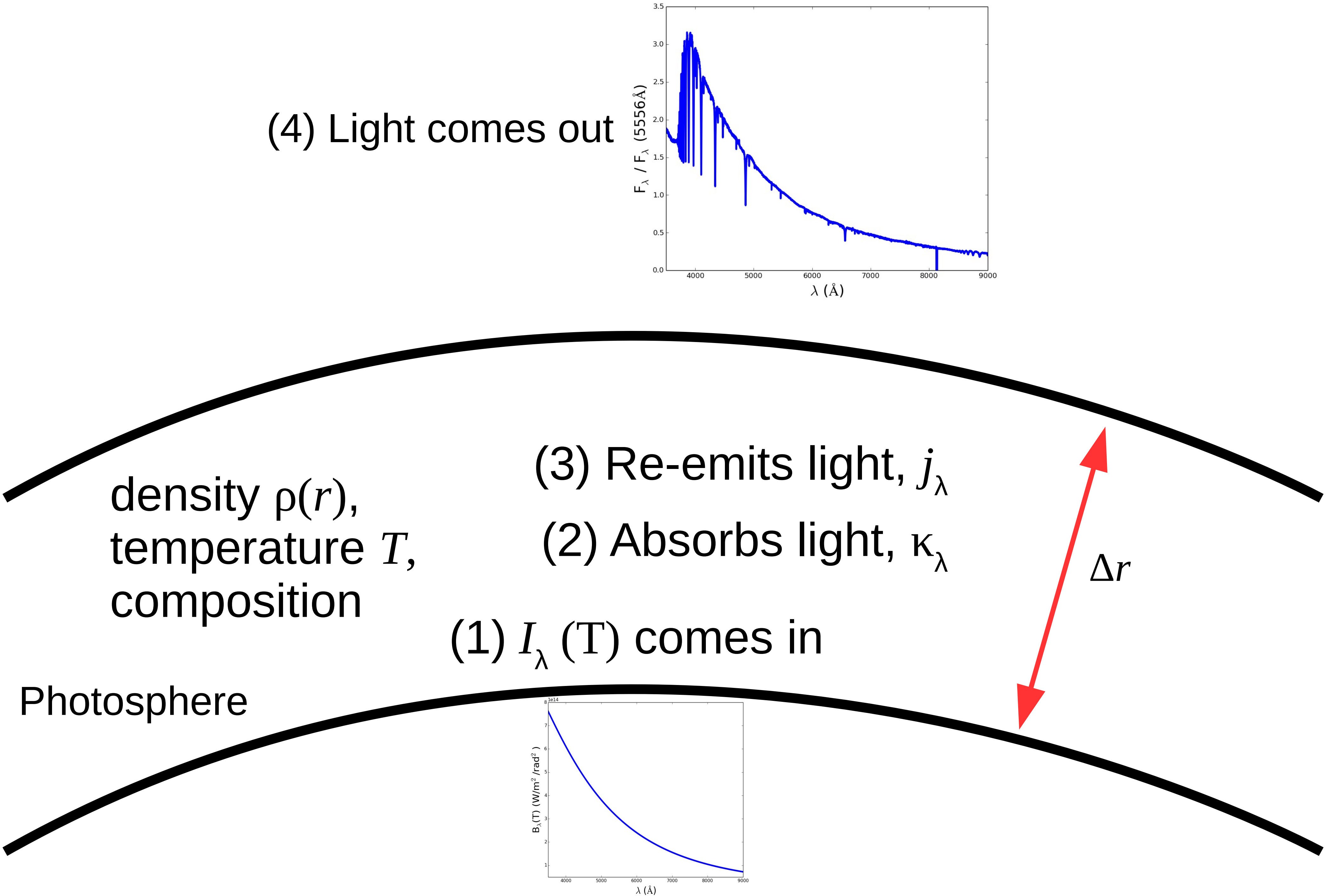


Photosphere
(cooler)



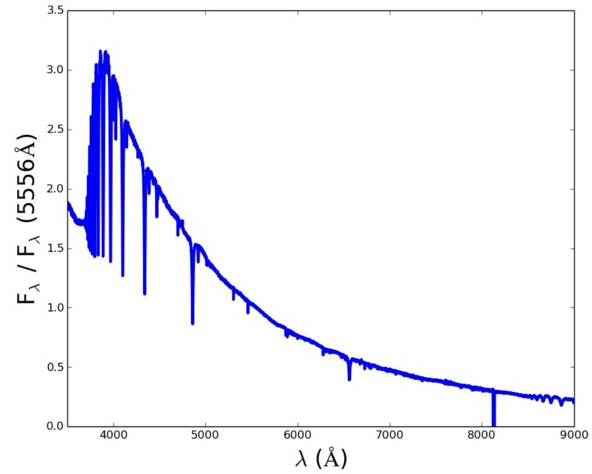
Stellar Interior
(hot)

4. Emission *versus* Absorption: A Physical Approach



4. Emission *versus* Absorption: A Physical Approach

(4) $I_\lambda = I_\lambda^0 + \Delta I_\lambda^{absorbed} + \Delta I_\lambda^{emitted}$



(3) $\Delta I_\lambda^{emitted} = j_\lambda \rho \Delta r$

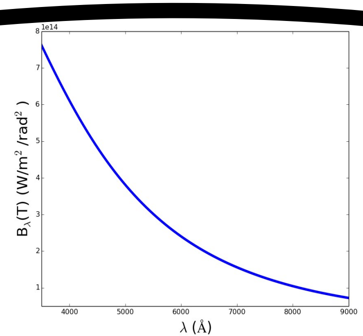
density $\rho(r)$,
temperature T,
composition

(2) $\Delta I_\lambda^{absorbed} = -\kappa_\lambda \rho I_\lambda^0 \Delta r$

Δr

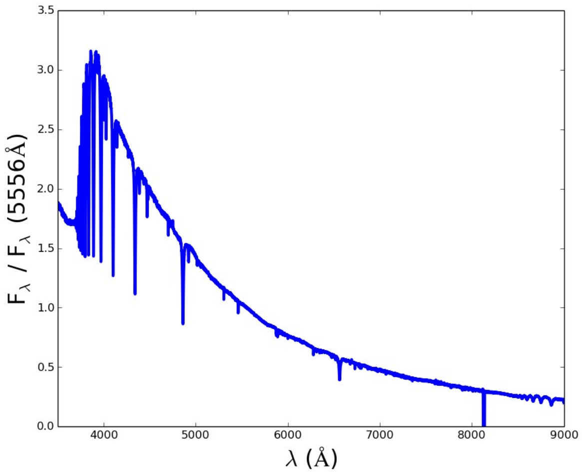
(1) I_λ^0

Photosphere



4. Emission *versus* Absorption: A Physical Approach

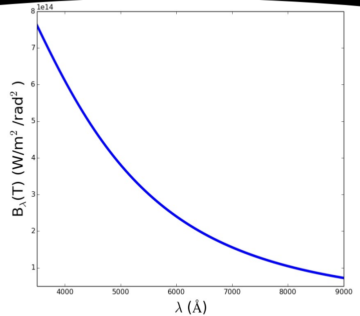
$$I_\lambda = I_\lambda^0 + \Delta I_\lambda^{absorbed} + \Delta I_\lambda^{emitted}$$



$$S_\lambda = \frac{j_\lambda}{\kappa_\lambda}$$

$$\Delta \tau_\lambda = \kappa_\lambda \rho \Delta r$$

Photosphere



4. Emission *versus* Absorption: A Physical Approach

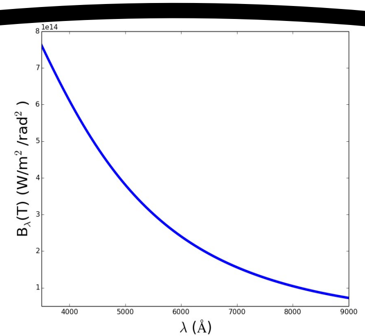
$$I_\lambda = I_\lambda^0 e^{-\tau_\lambda} + S_\lambda \left(1 - e^{-\tau_\lambda}\right)$$

(final intensity) (light taken out) (light added by the cloud)

$$S_\lambda = \frac{j_\lambda}{\kappa_\lambda}$$

$$\Delta \tau_\lambda = \kappa_\lambda \rho \Delta r$$

Photosphere



4. Emission *versus* Absorption: A Physical Approach

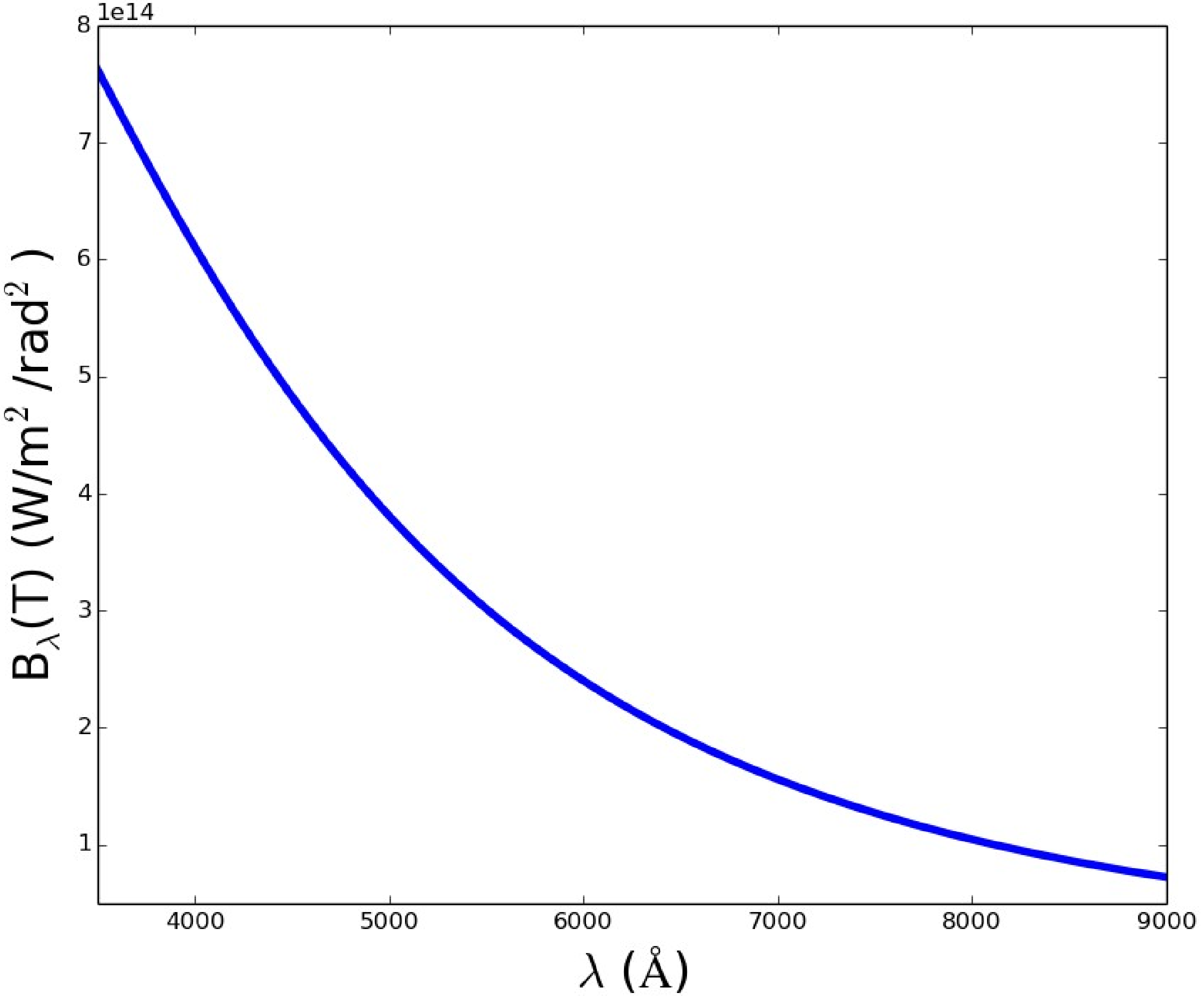
$$I_\lambda = I_\lambda^0 e^{-\tau_\lambda} + S_\lambda \left(1 - e^{-\tau_\lambda}\right)$$

Limit A. The cloud layer is optically thick

$$\tau_\lambda \rightarrow \infty$$

$$e^{-\tau_\lambda} \rightarrow 0$$

$$I_\lambda \rightarrow S_\lambda$$



4. Emission *versus* Absorption: A Physical Approach

$$I_\lambda = I_\lambda^0 e^{-\tau_\lambda} + S_\lambda \left(1 - e^{-\tau_\lambda}\right)$$

Limit B. The cloud layer is optically thin

$$e^{-\tau_\lambda} \rightarrow 1 - \tau_\lambda$$

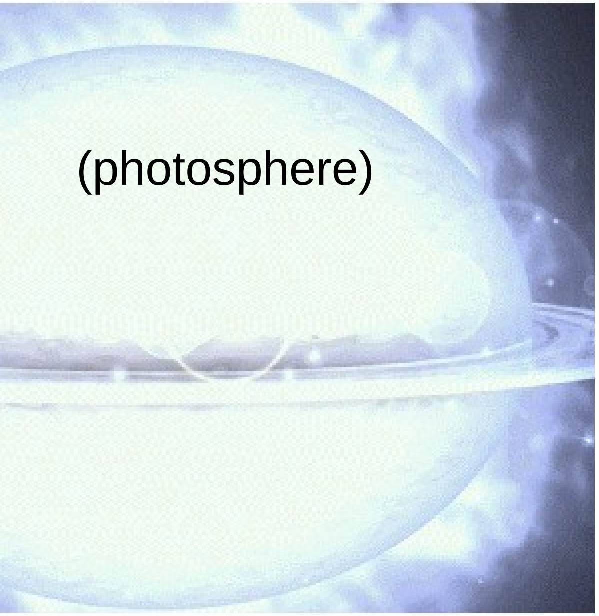
$$I_\lambda = I_\lambda^0 + [S_\lambda - I_\lambda^0]\tau_\lambda$$

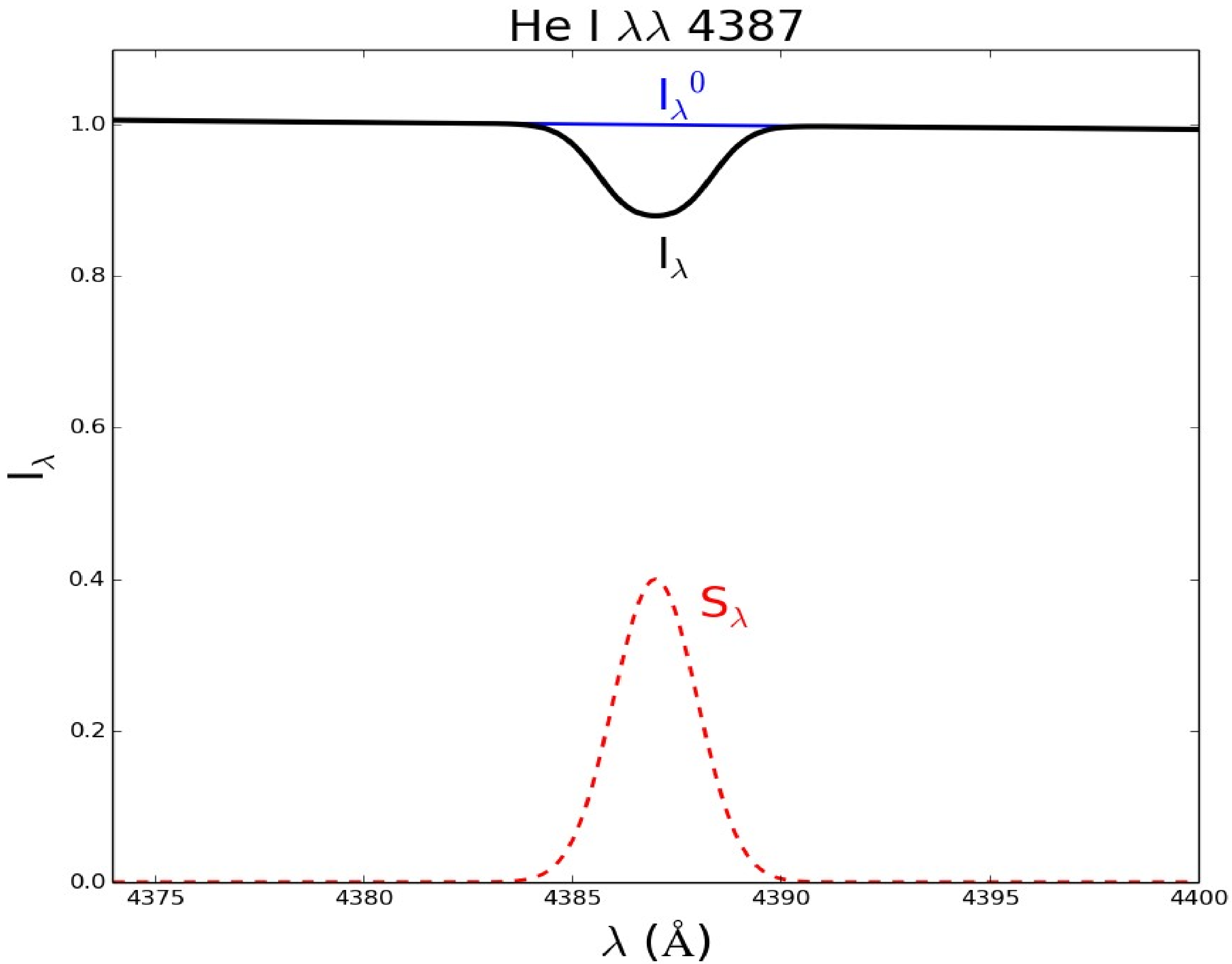
4. Emission *versus* Absorption: A Physical Approach

$$I_\lambda = I_\lambda^0 + [S_\lambda - I_\lambda^0]\tau_\lambda$$

Limit B. The cloud layer is optically thin

Case I. $I_\lambda^0 > S_\lambda$



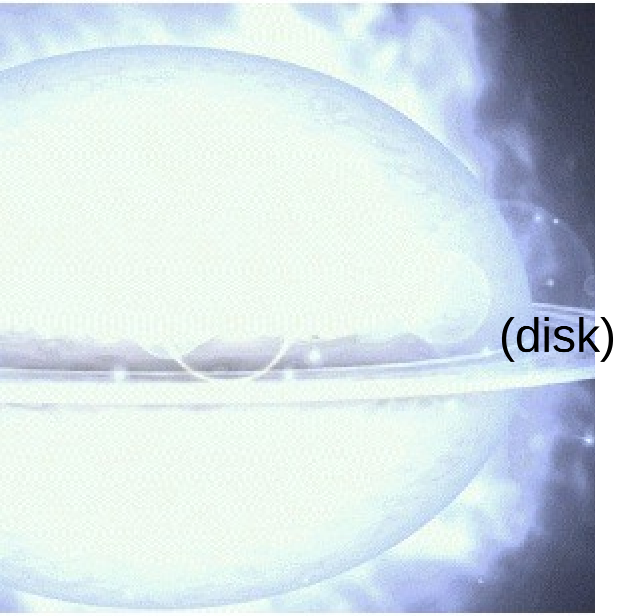


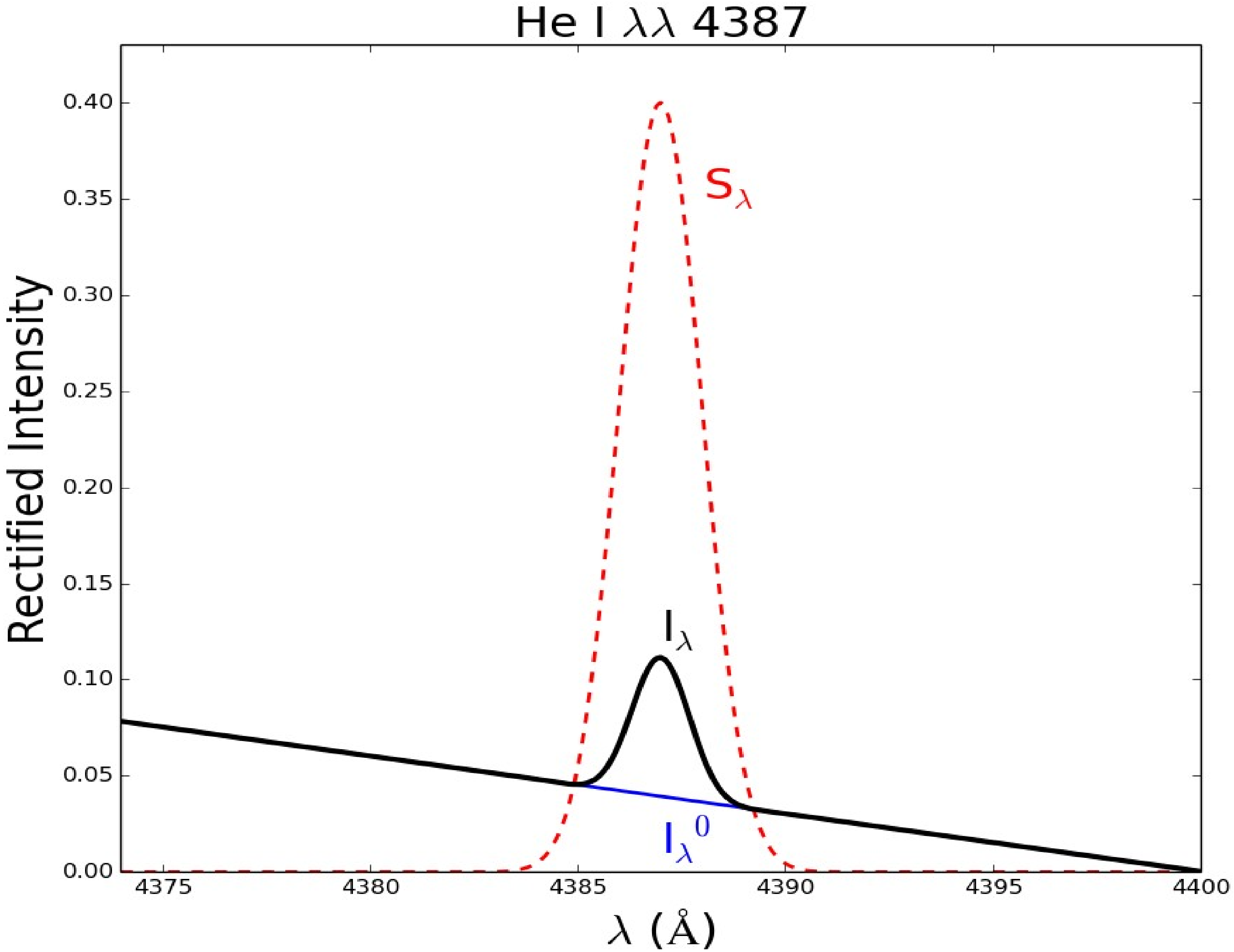
4. Emission *versus* Absorption: A Physical Approach

$$I_\lambda = I_\lambda^0 + [S_\lambda - I_\lambda^0]\,\tau_\lambda$$

Limit B. The cloud layer is optically thin

Case II. $I_\lambda^0 < S_\lambda$





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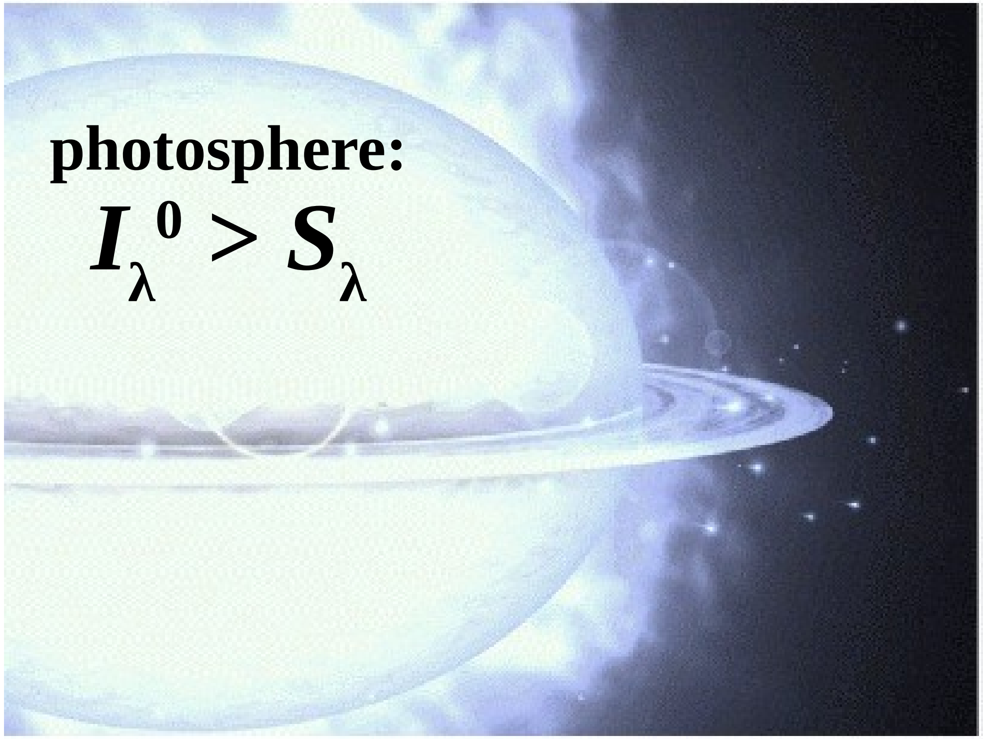

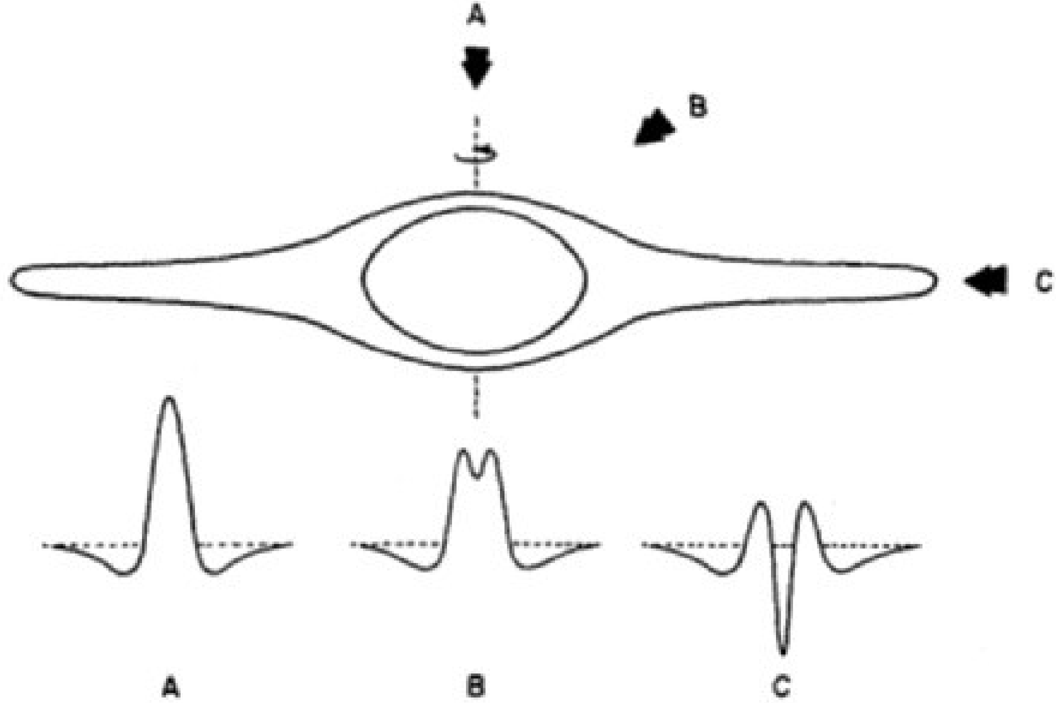

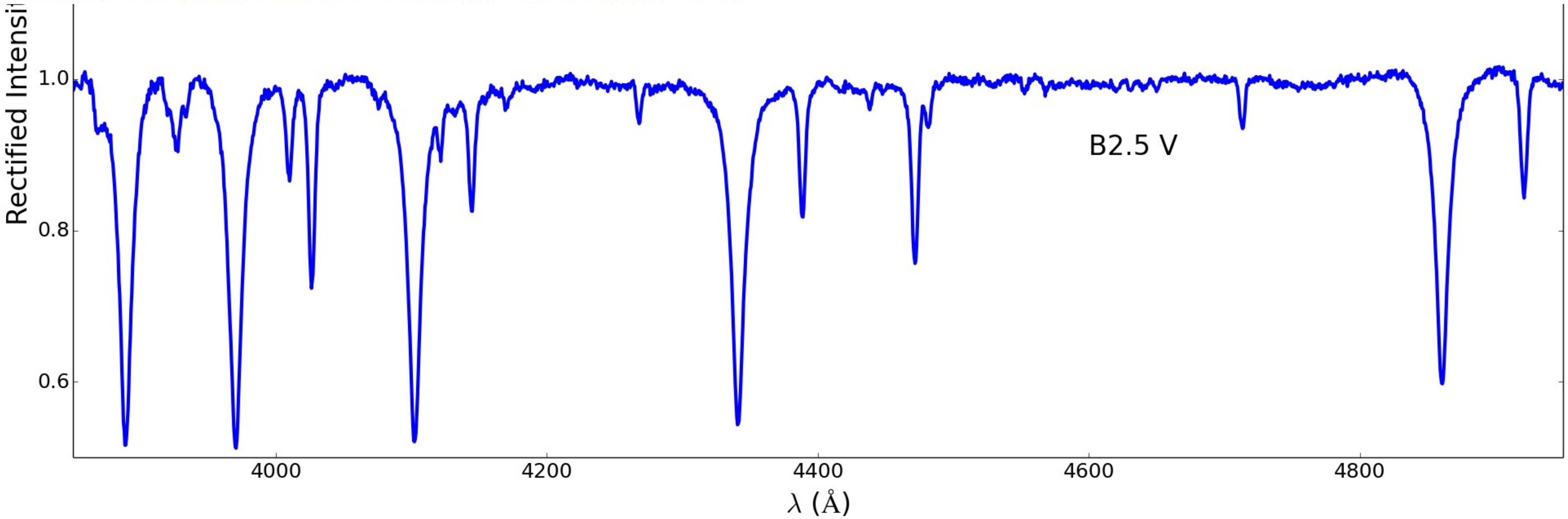

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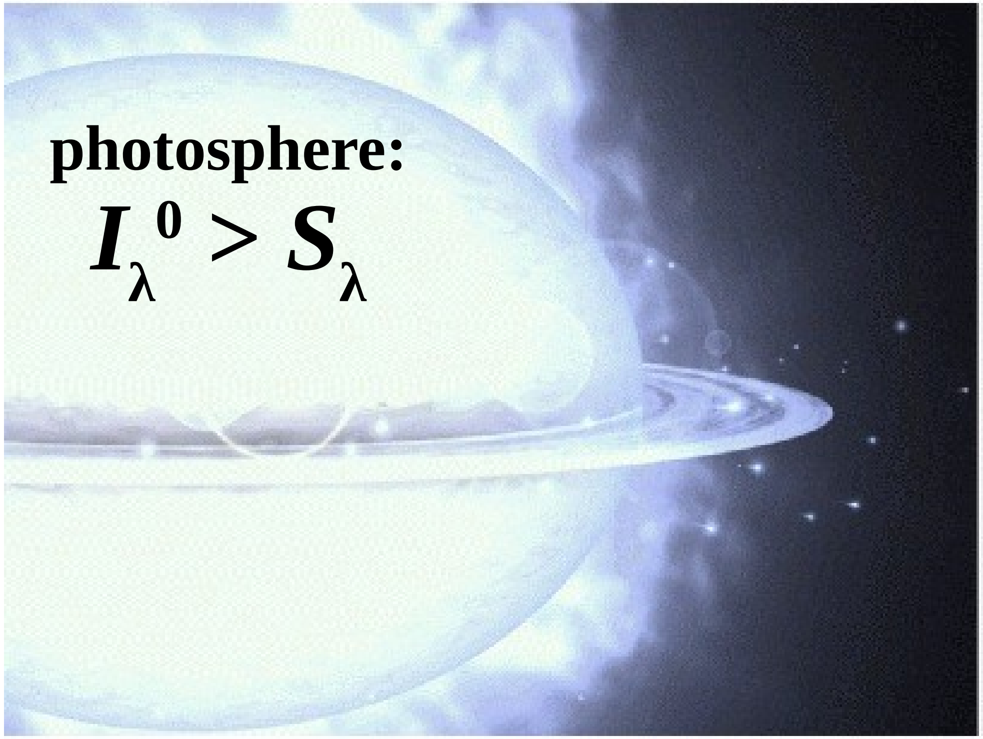
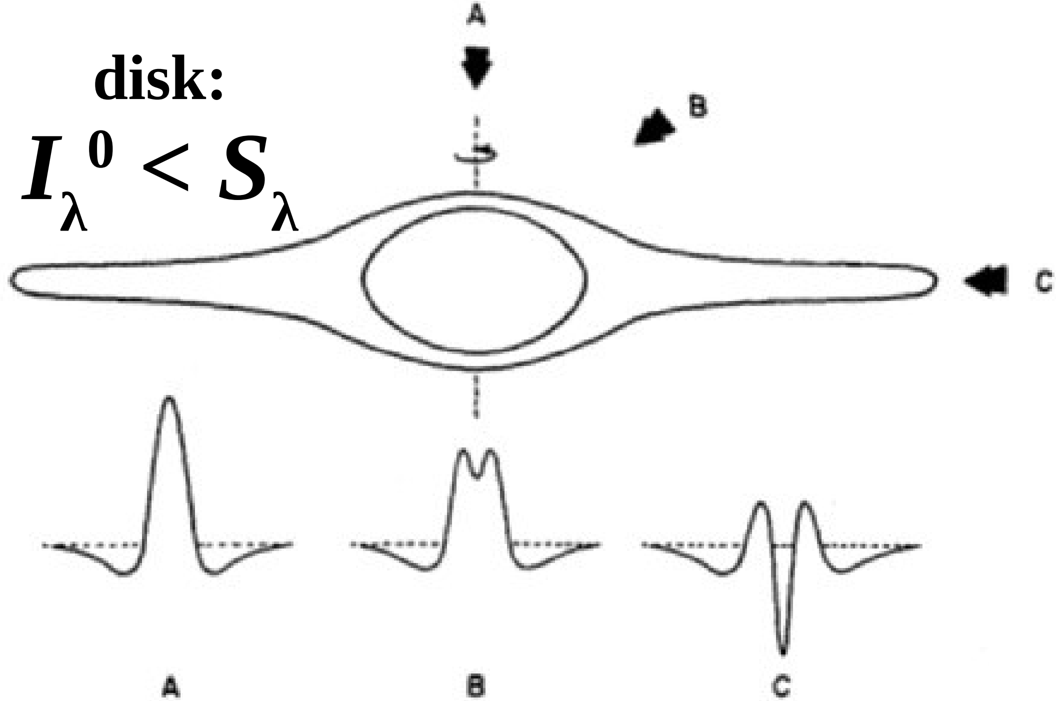
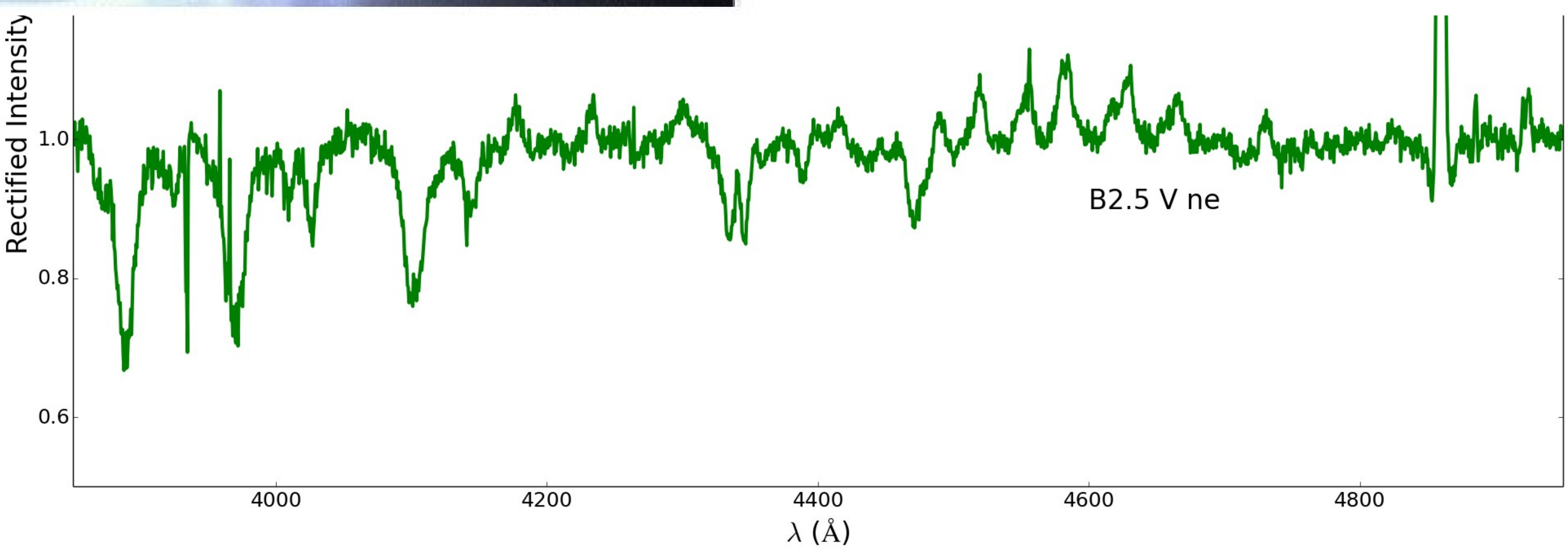
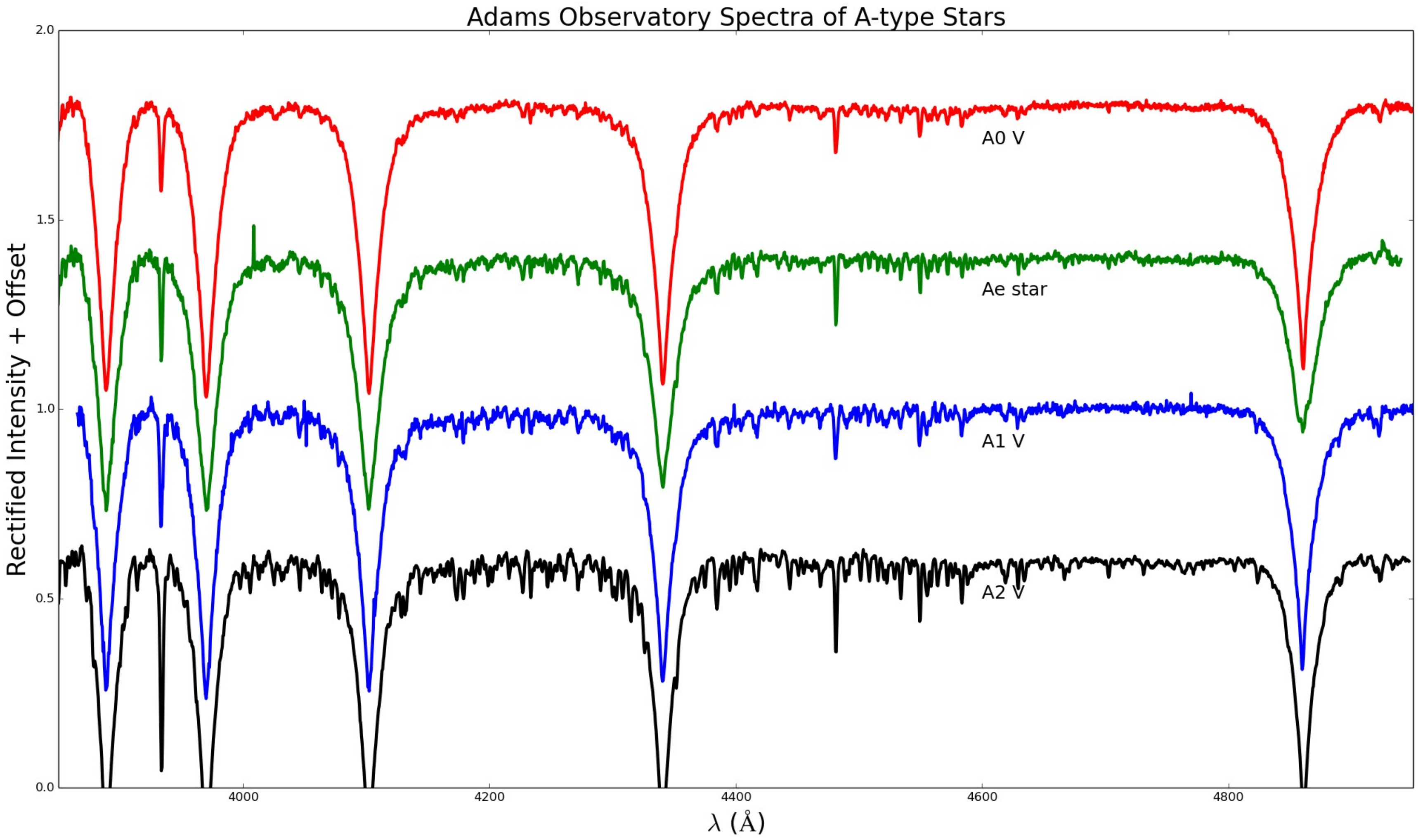






5. Studying Rapid Spectroscopic Variability



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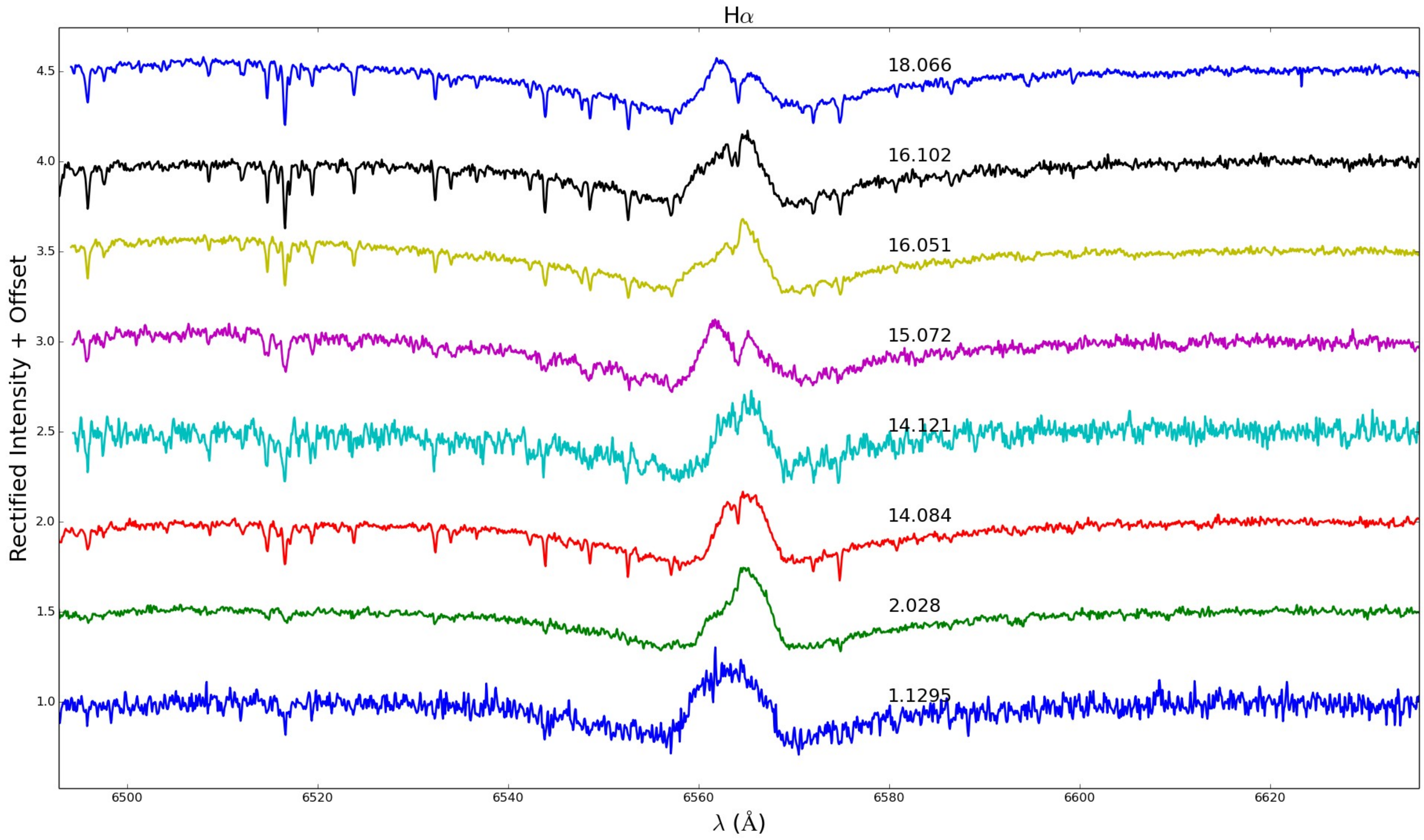

5. Studying Rapid Spectroscopic Variability

RNAAS RESEARCH NOTES OF THE AAS

HD 63021: An Ae Star with X-Ray Flux

David G. Whelan[1], Jon Labadie-Bartz[2], S. Drew Chojnowski[3], James Daglen[4], and Ken Hudson[5]

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Research Notes of the AAS, Volume 2, Number 2

Figures ▾ References ▾

1. Spectroscopic Variability
2. Archival Data
3. Discussion and Future Work
References

+ Article information

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1. Spectroscopic Variability

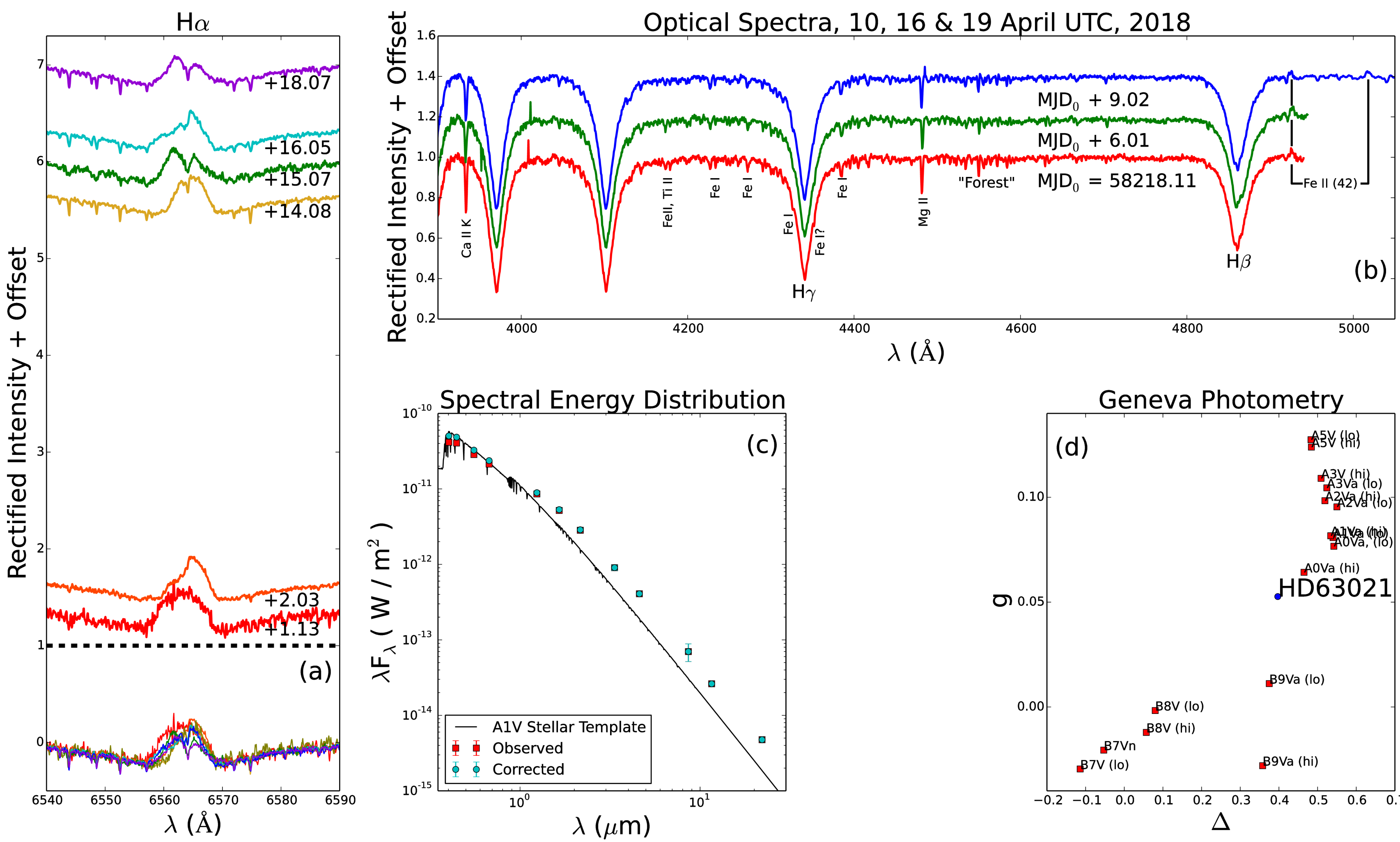
Balmer and Fe II (42) multiplet emission were discovered in a spectrum of HD 63021 on 10 April (UTC), 2018. Subsequent observations revealed variability in both photospheric absorption lines and Balmer line emission.

Figure 1(a) shows Hα observations over the course of 18 nights. The emission morphology changes on a nightly basis; additional spectra not exhibited show that emission changes perceptibly on the scale of hours.

5. Studying Rapid Spectroscopic Variability

RNAAS RESEARCH NOTES OF THE AAS

HD 63021: An Ae Star with X-Ray Flux



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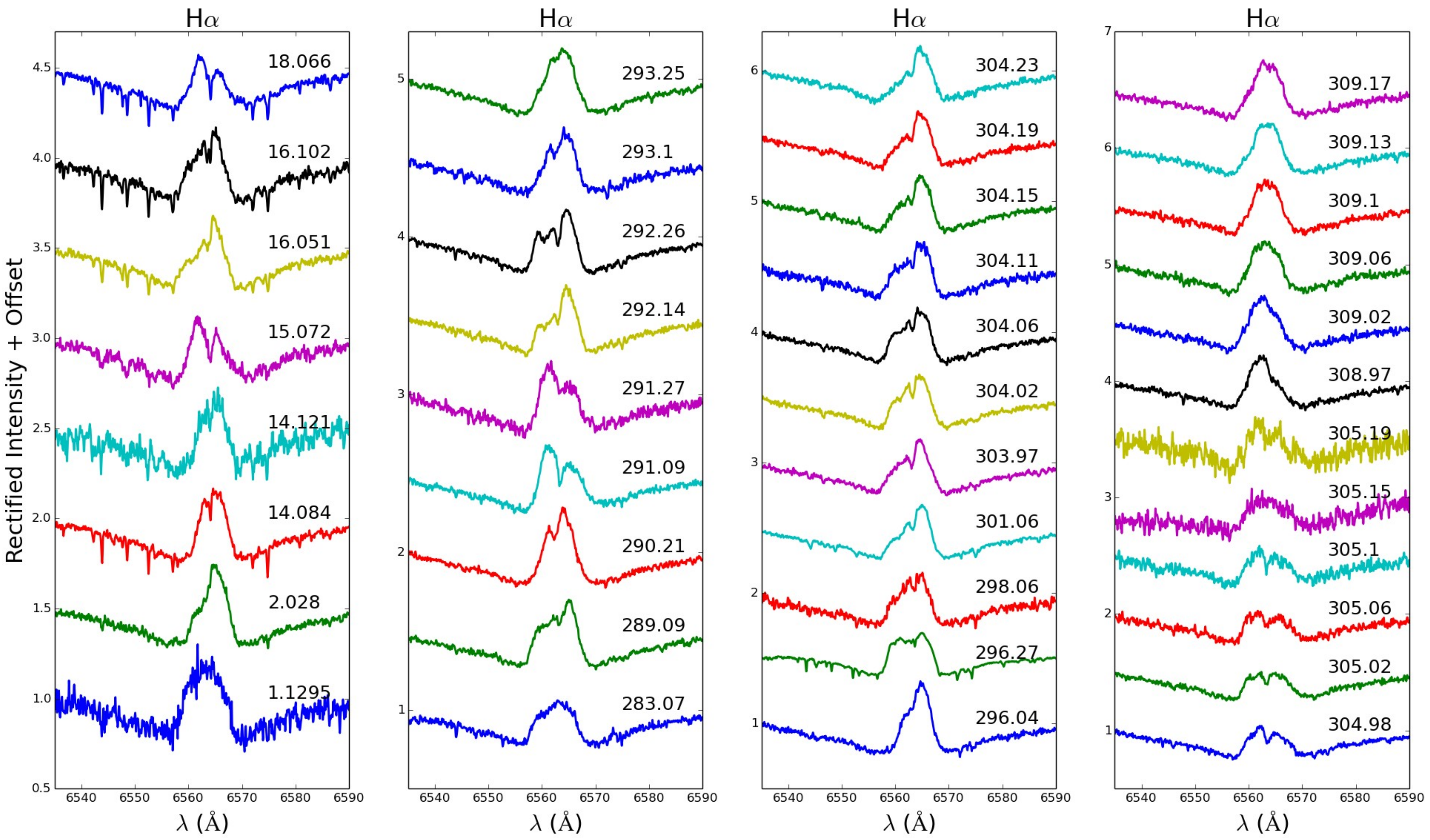

In Conclusion

1. Physical Properties of Intermediate- and High-Mass Stars
    a. Mass, Radius, Temperature
    b. Photospheric Absorption Lines

2. Observable Properties of B-type and Emission-Line B-type (B*e*) Stellar Spectra
    a. Hydrogen Lines
    b. Helium and Metal Lines
    c. Emission Signatures

3. Emission *versus* Absorption: A Qualitative Look
    a. Kirchhoff's Laws

4. Emission *versus* Absorption: A Pl
    a. Radiative Energy Transfer: *I*
    b. High Optical Depth Limit
    c. Formation of Spectral Lines

5. Rapid Spectroscopic Variability
    a. Answering New Questions...
        ...together!