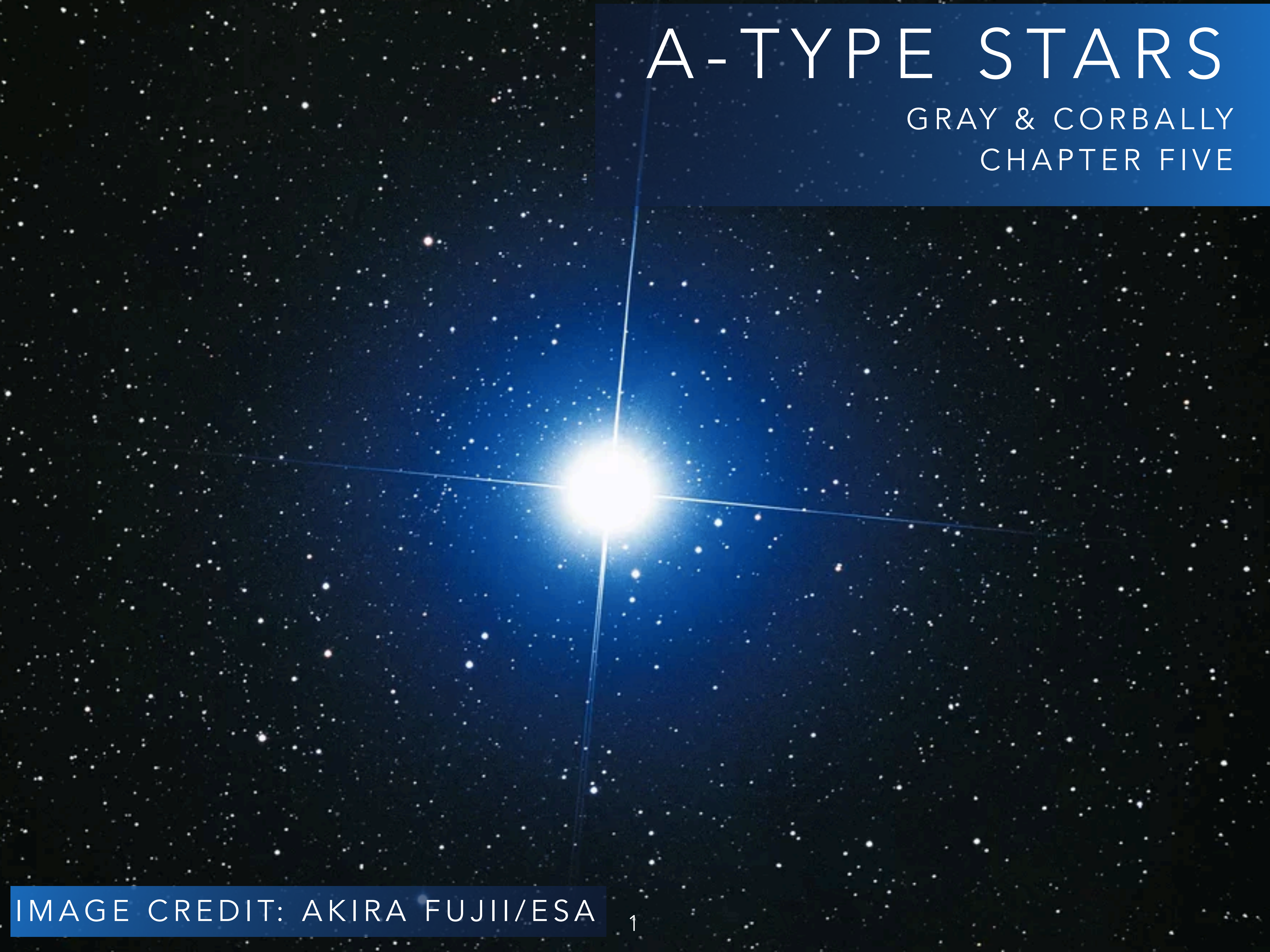
A-TYPE STARS

GRAY & CORBALLY

CHAPTER FIVE



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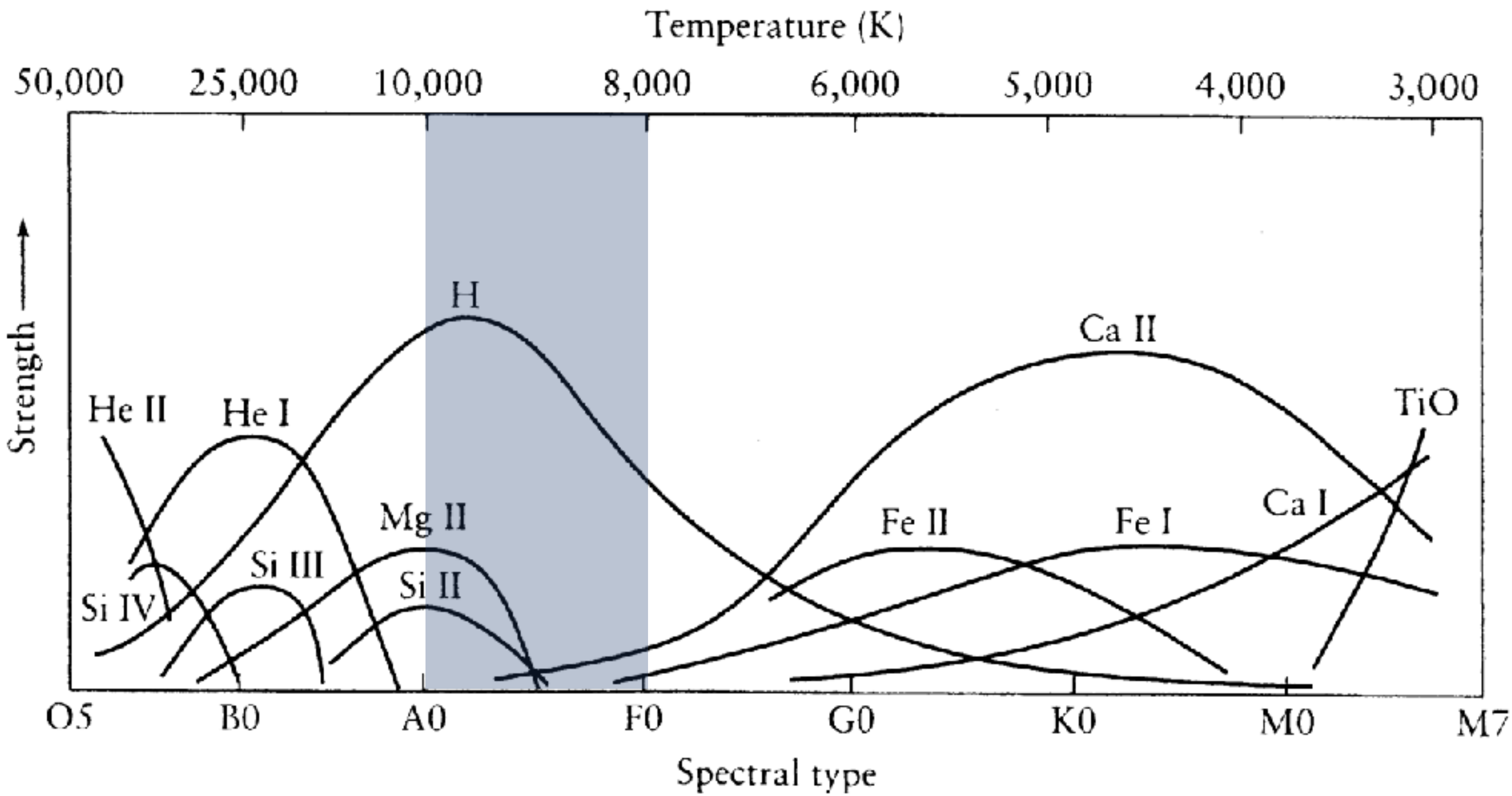
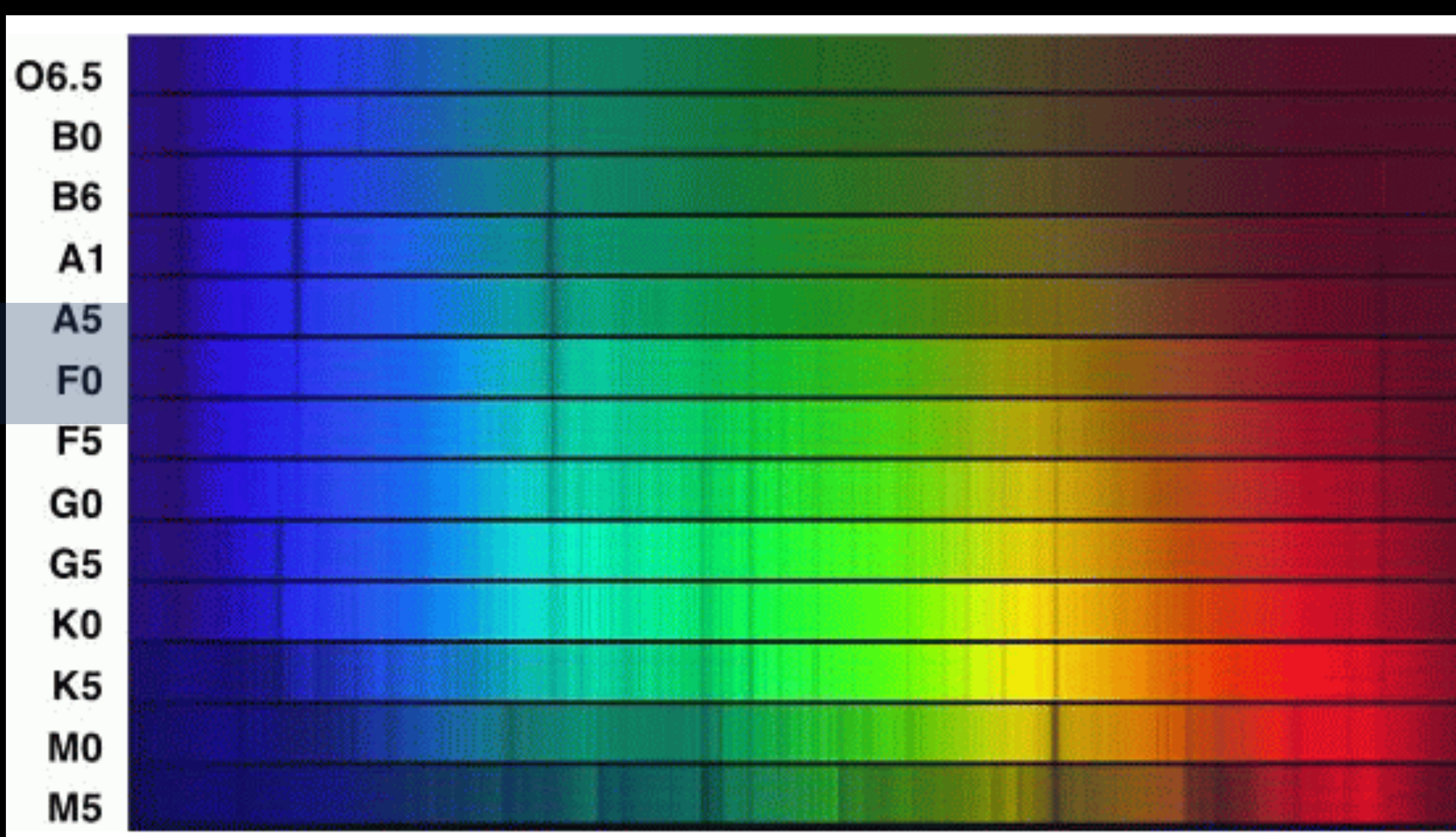
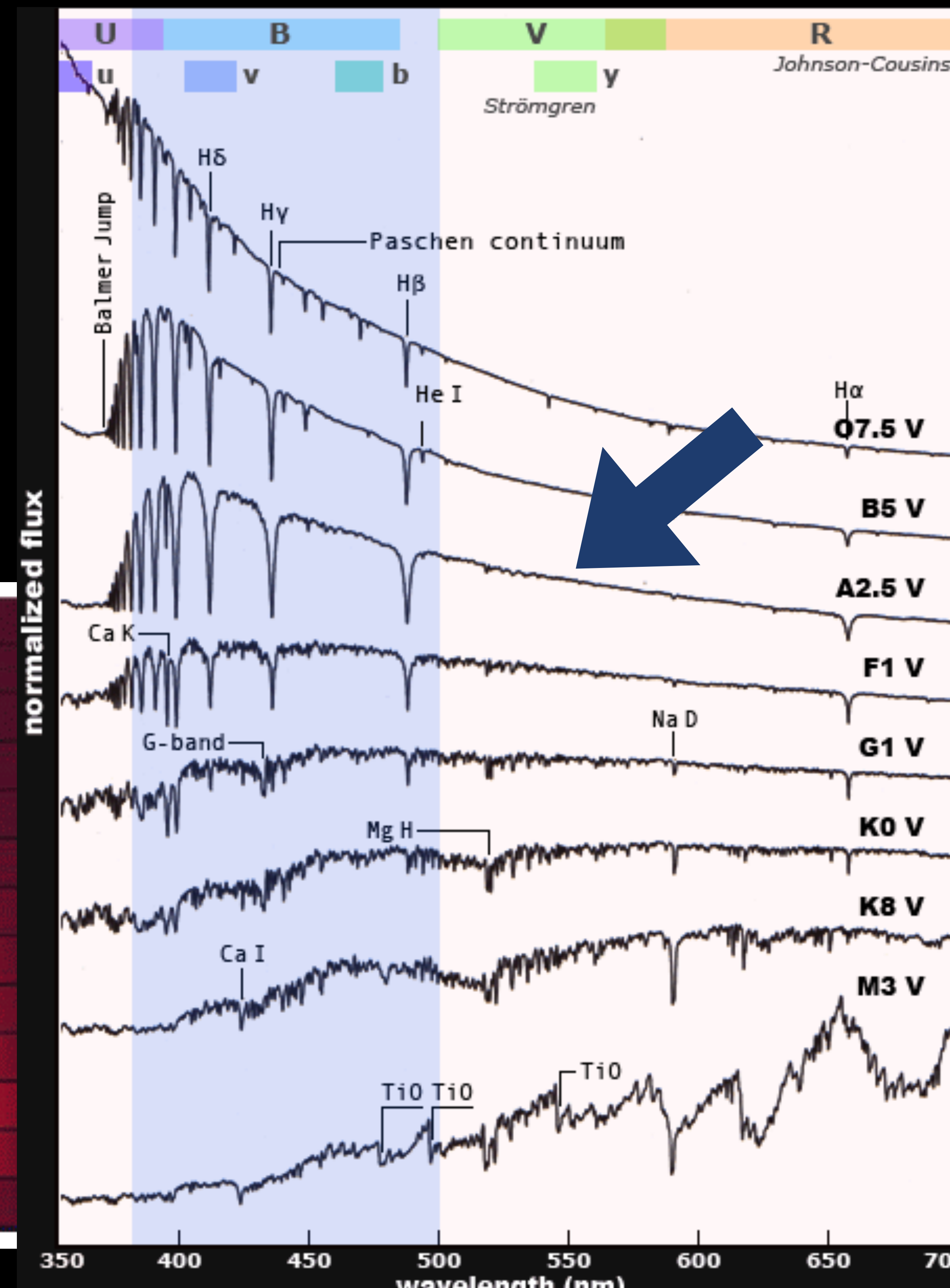
LINE STRENGTH VS. TEMPERATURE



A-TYPE STARS: INTRODUCTION

- Appear "featureless and uninteresting"
- Strong Hydrogen Balmer lines
- But over 30% show chemical peculiarity



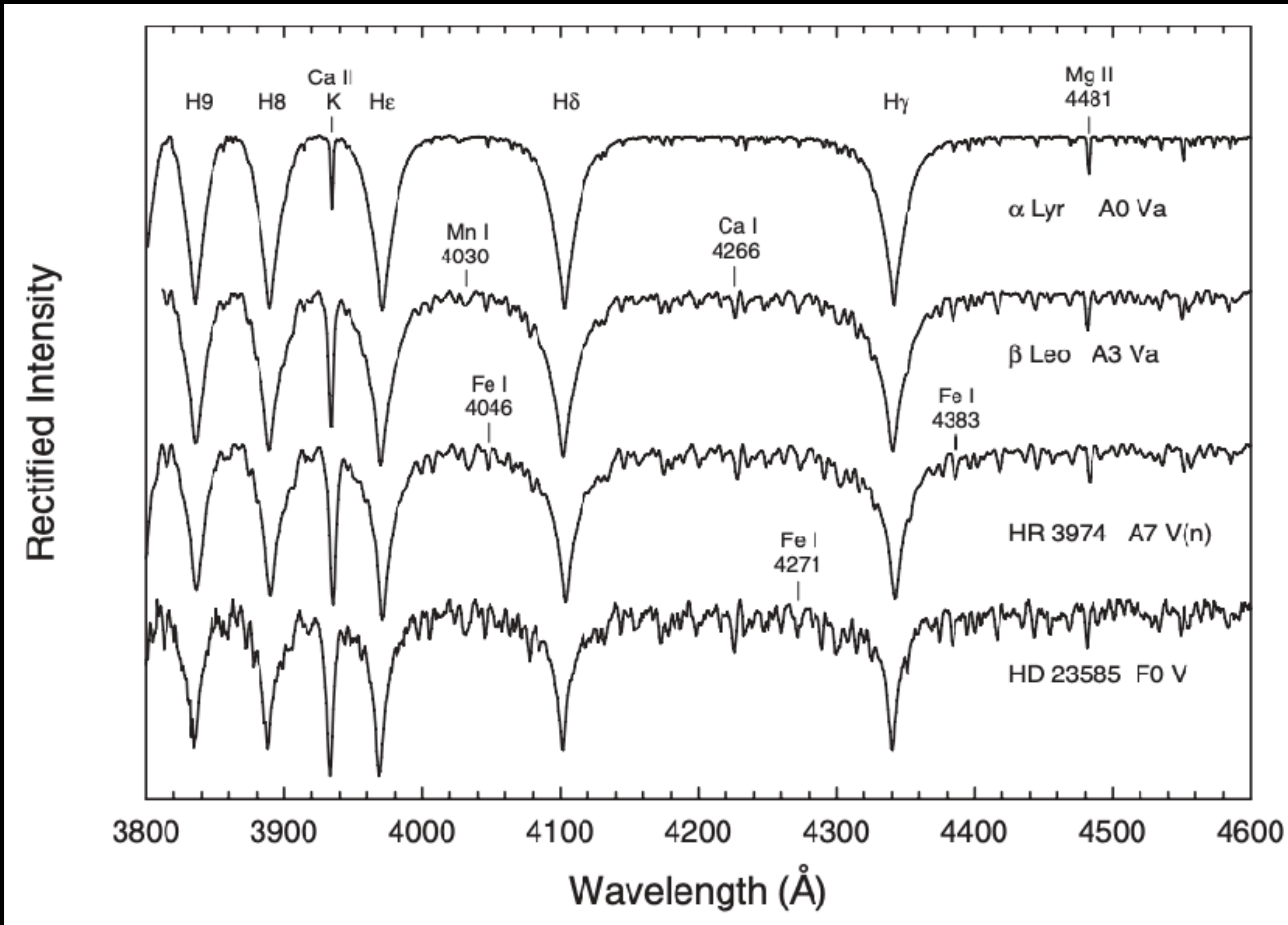


TEMPERATURE CRITERIA FEATURES

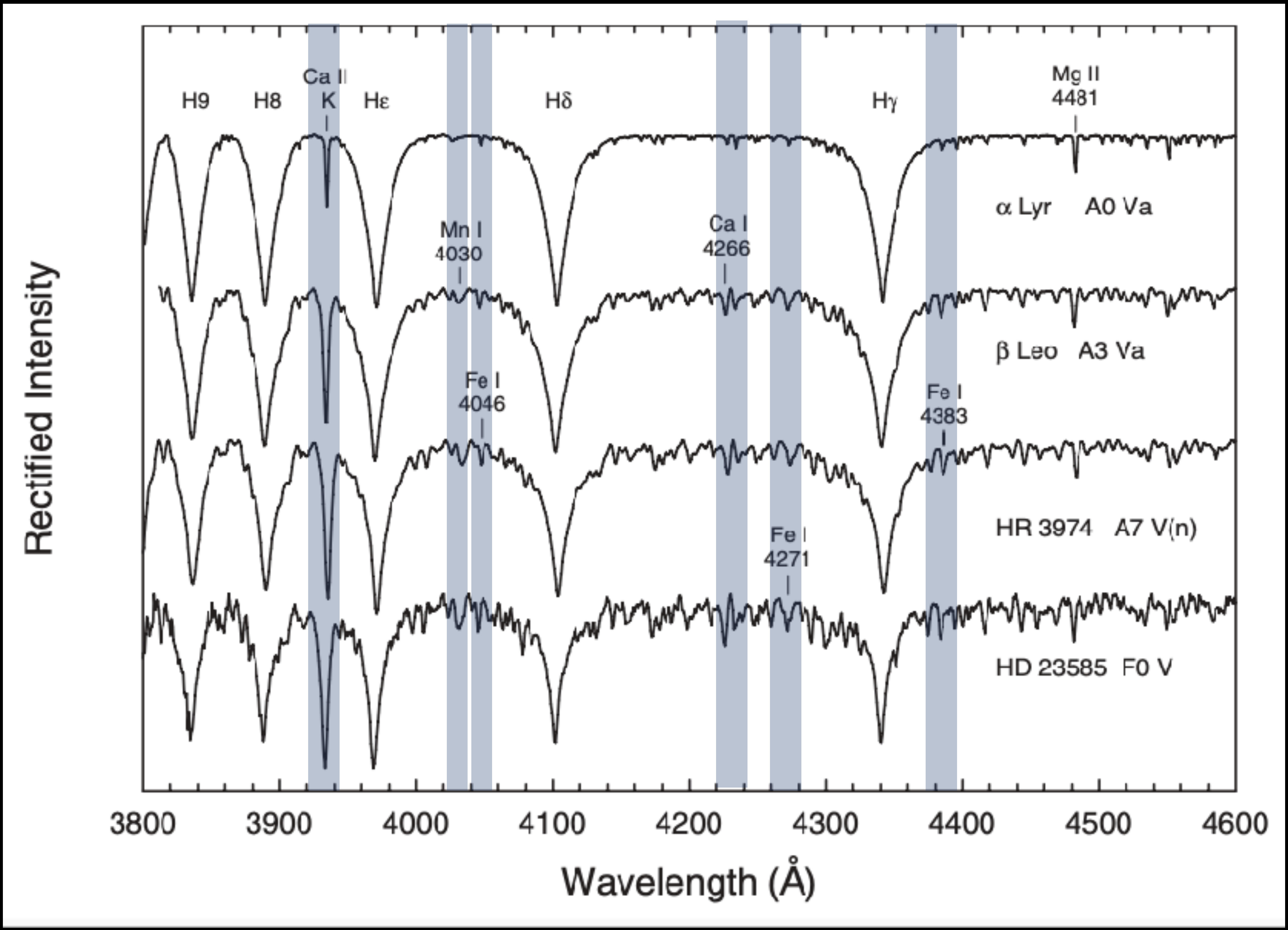
(For Normal A-type stars)

- Hydrogen Balmer lines (maximum at A2)
- Calcium II K-line (increasing toward later types)**
- Metallic lines: Fe I, Ca I, and Mn I (increasing toward later types)

TEMPERATURE CRITERIA



TEMPERATURE CRITERIA

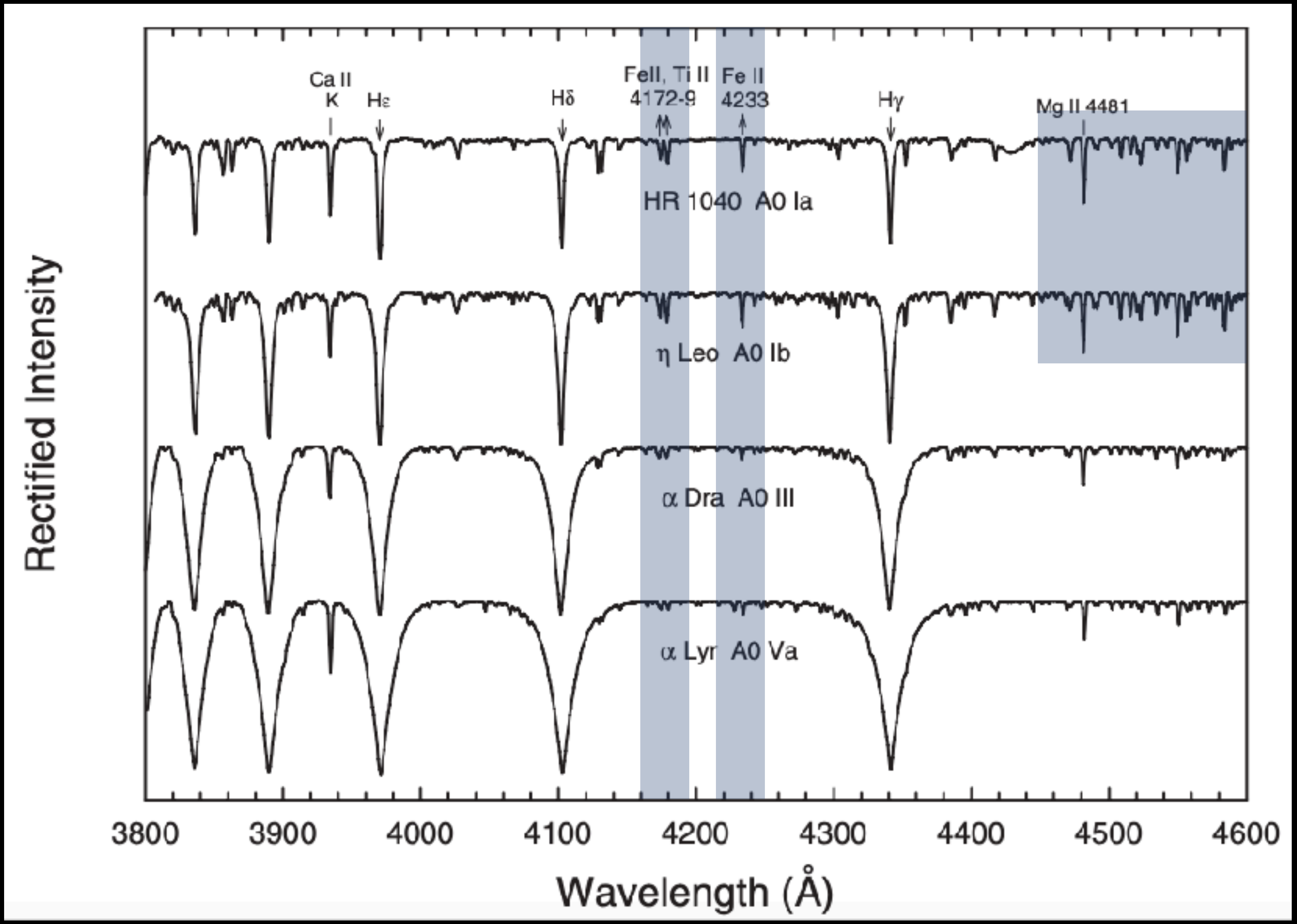


LUMINOSITY CRITERIA FEATURES

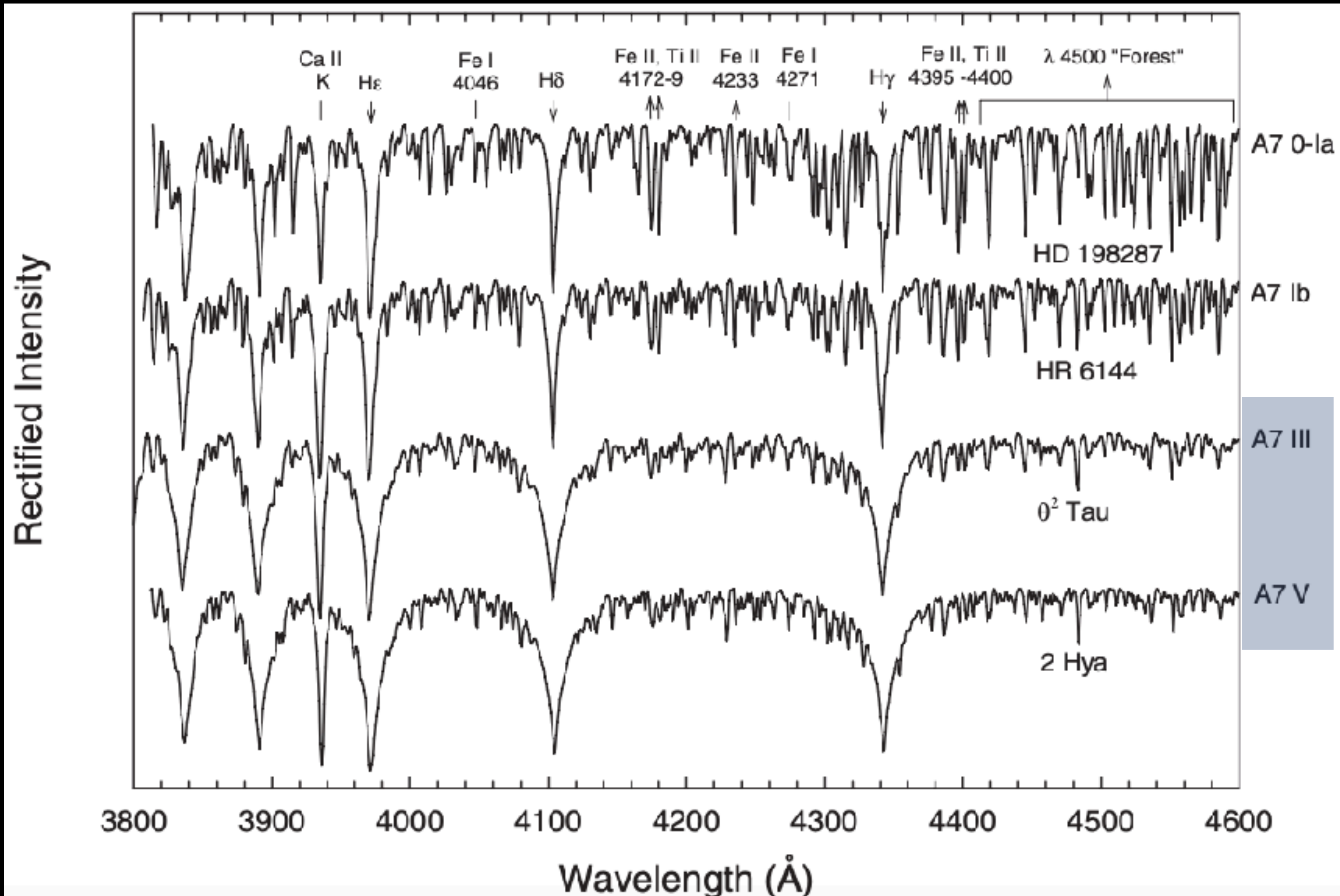
(For Normal A-type stars)

- Primary: wings of the Hydrogen lines
- Zero-age main sequence stars — noticeably broader wings than Vega (class Va, the MK A0 Va Standard). These given luminosity class of Vb.
- In later types, luminosity judged by enhanced lines of Fe II and Ti II (whole “forest” in more luminous stars.)

LUMINOSITY CRITERIA FEATURES

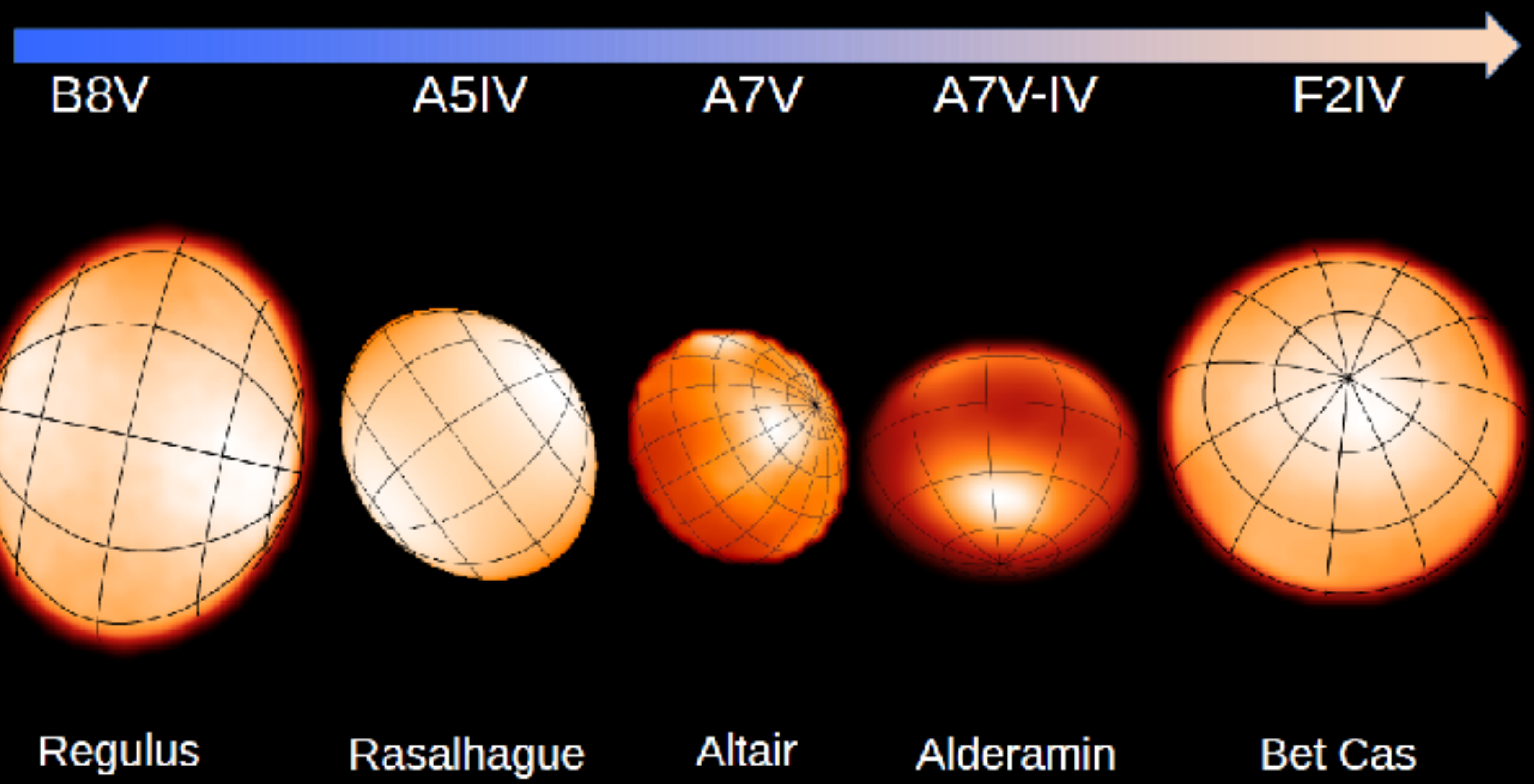


LUMINOSITY CRITERIA FEATURES



ROTATION EFFECTS

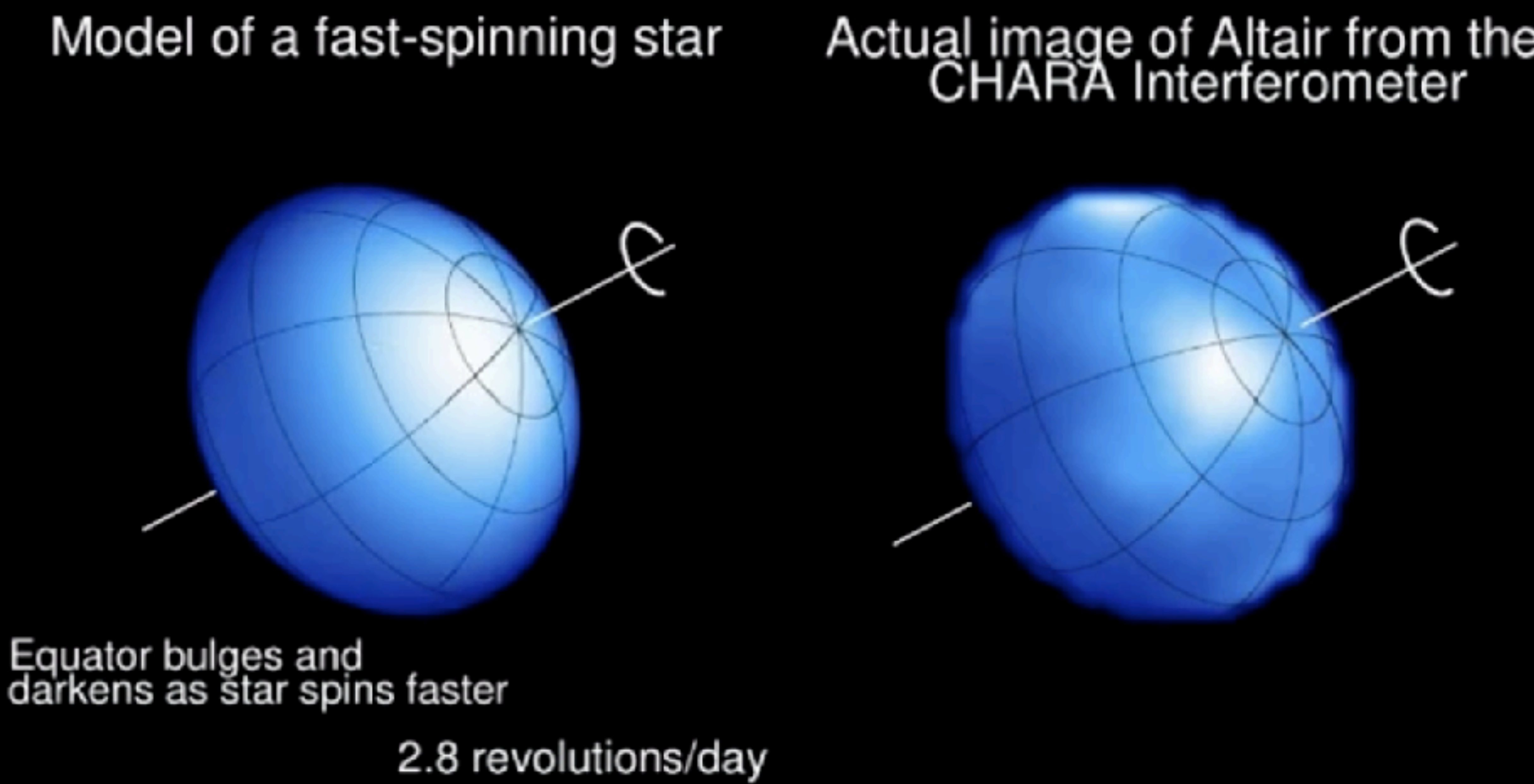
- Broadens spectral lines
- Introduces physical changes into stellar atmosphere
  - Local effective temperature & gravity vary over surface



ROTATION EFFECTS

CREDIT: MING ZHAO, UNIVERSITY OF MICHIGAN

ROTATION EFFECTS



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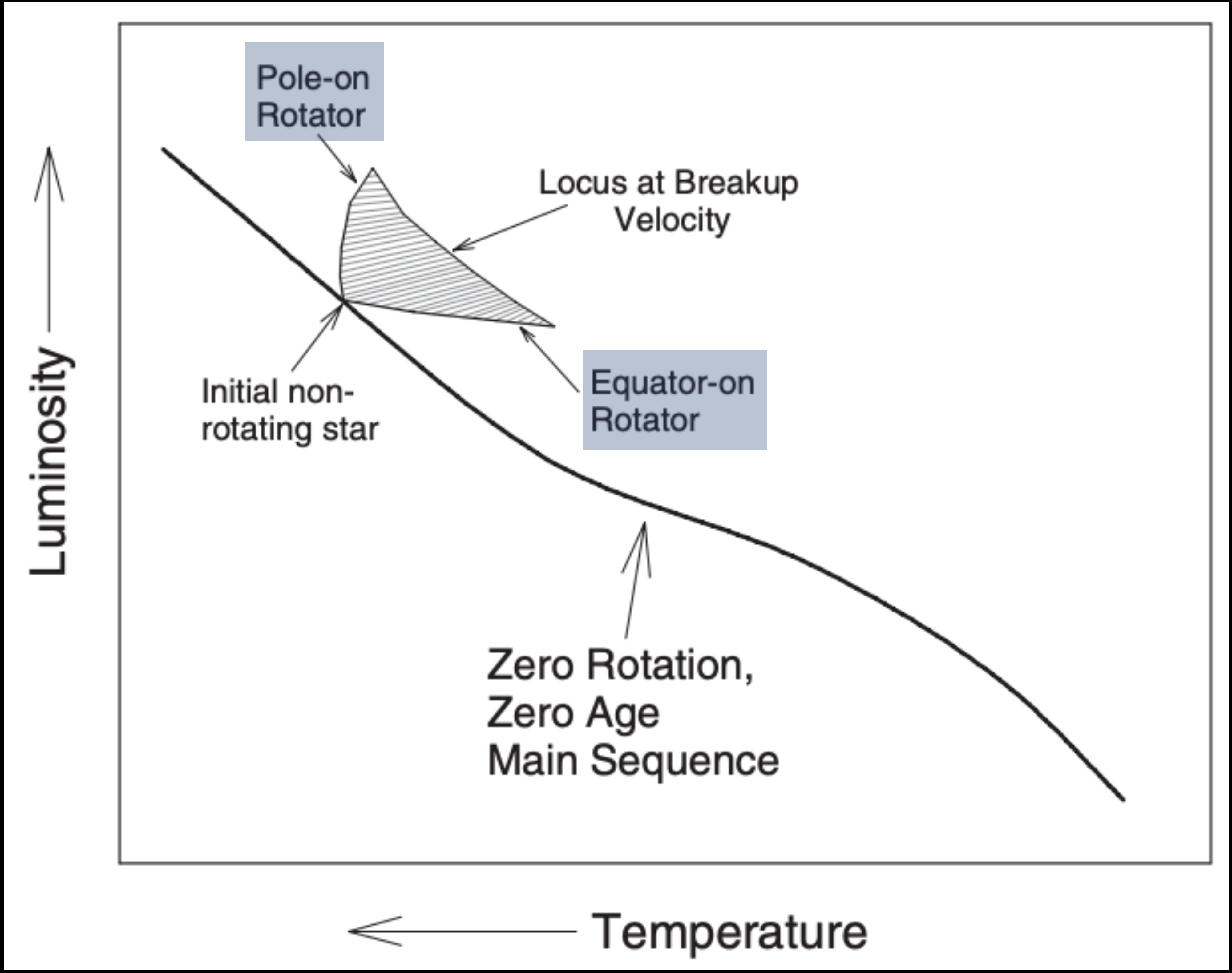
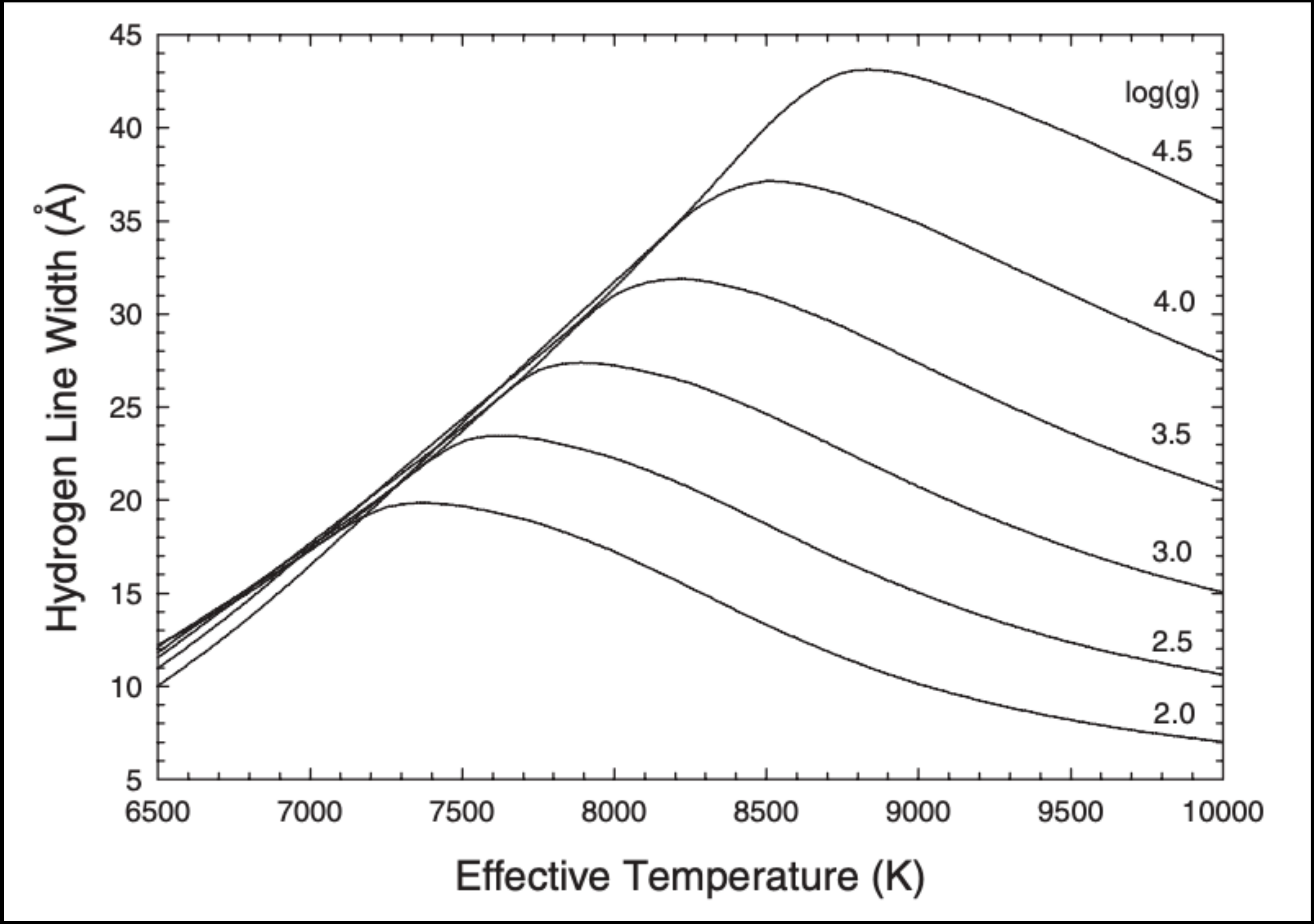
ROTATION EFFECTS

- Broadens spectral lines
- Introduces physical changes into stellar atmosphere
    - Local effective temperature & gravity vary over surface
- Displaces star in the H-R Diagram (example: Vega)

ROTATION EFFECTS



PHYSICAL BASIS OF CLASSIFICATION



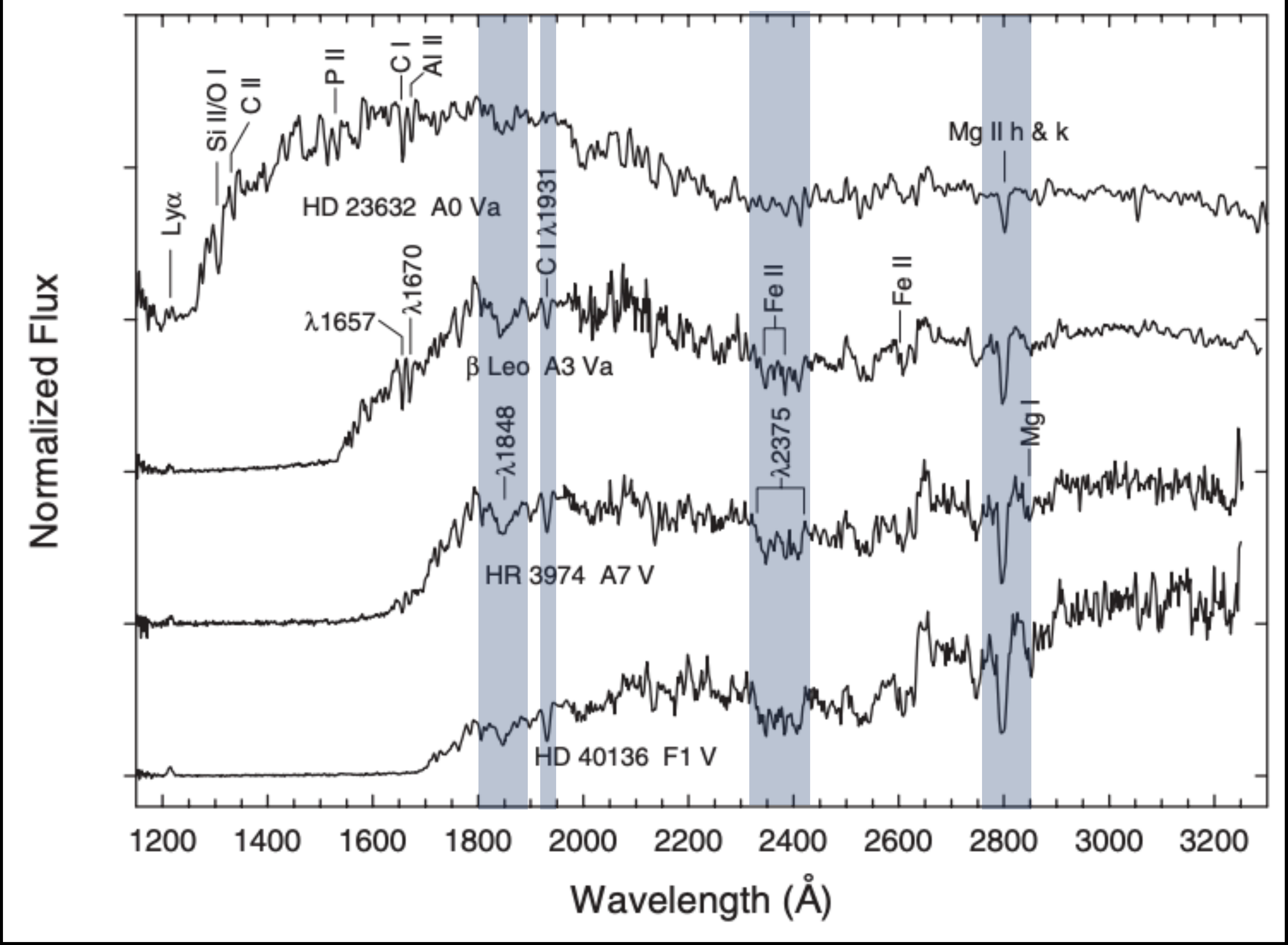
ULTRAVIOLET CLASSIFICATION

- Very little work done on A-type UV classification
- Initial UV classification discouraging
- Considered impractical for A-stars because enormous density of UV spectral lines — almost no “true” continuum points.

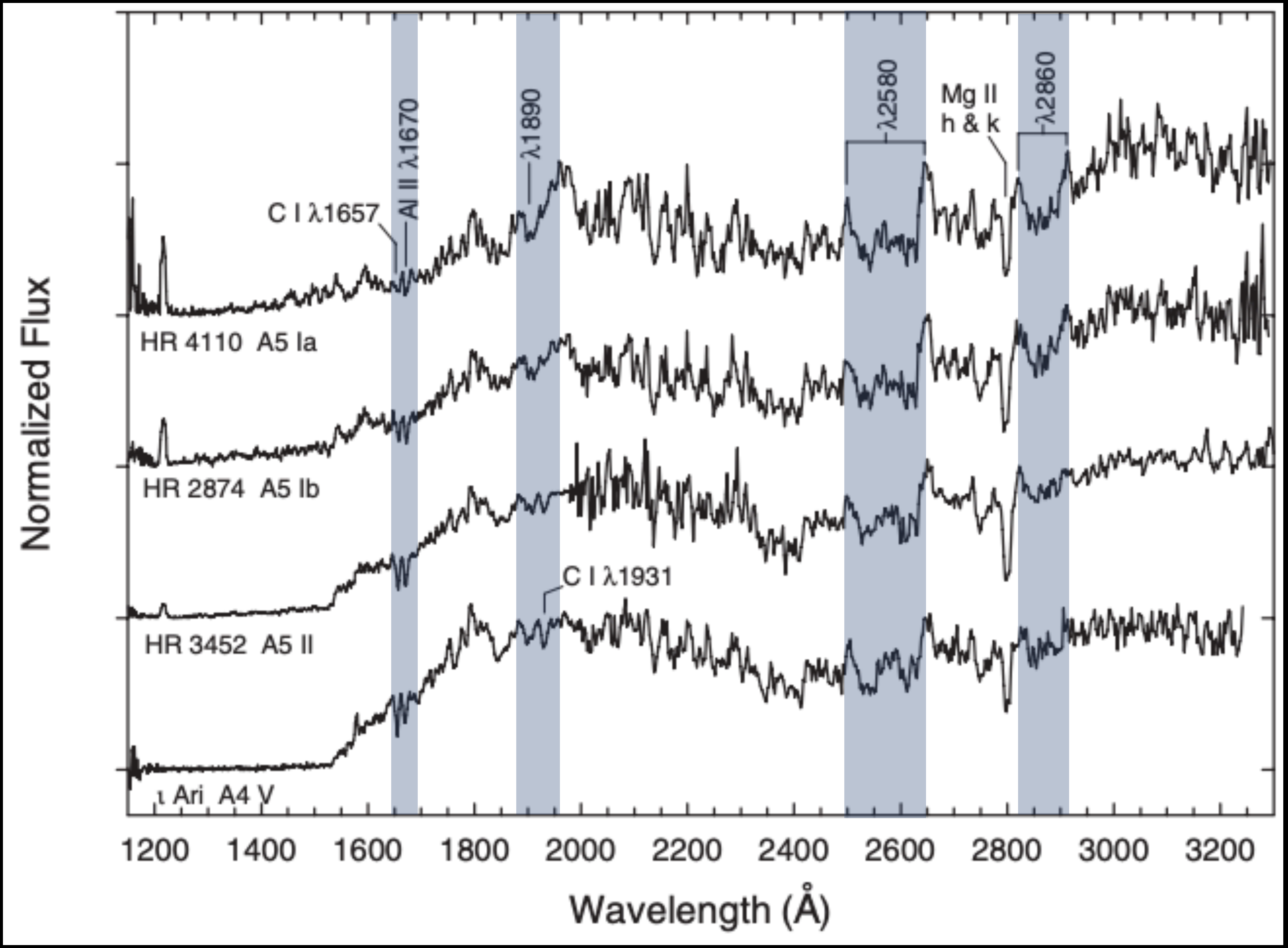
- Temperature classification criteria:
  - Overall shape of SED
  - Increasing strengths of Mg II h & k blend
  - λ 1848 feature relative to C I λ 1931
  - λ 2375 feature shape

- Luminosity classification criteria:
  - C I / Al II
  - λ 1890 to C I
  - Morphologies of λ 2580 and λ 2860 regions

ULTRAVIOLET CLASSIFICATION



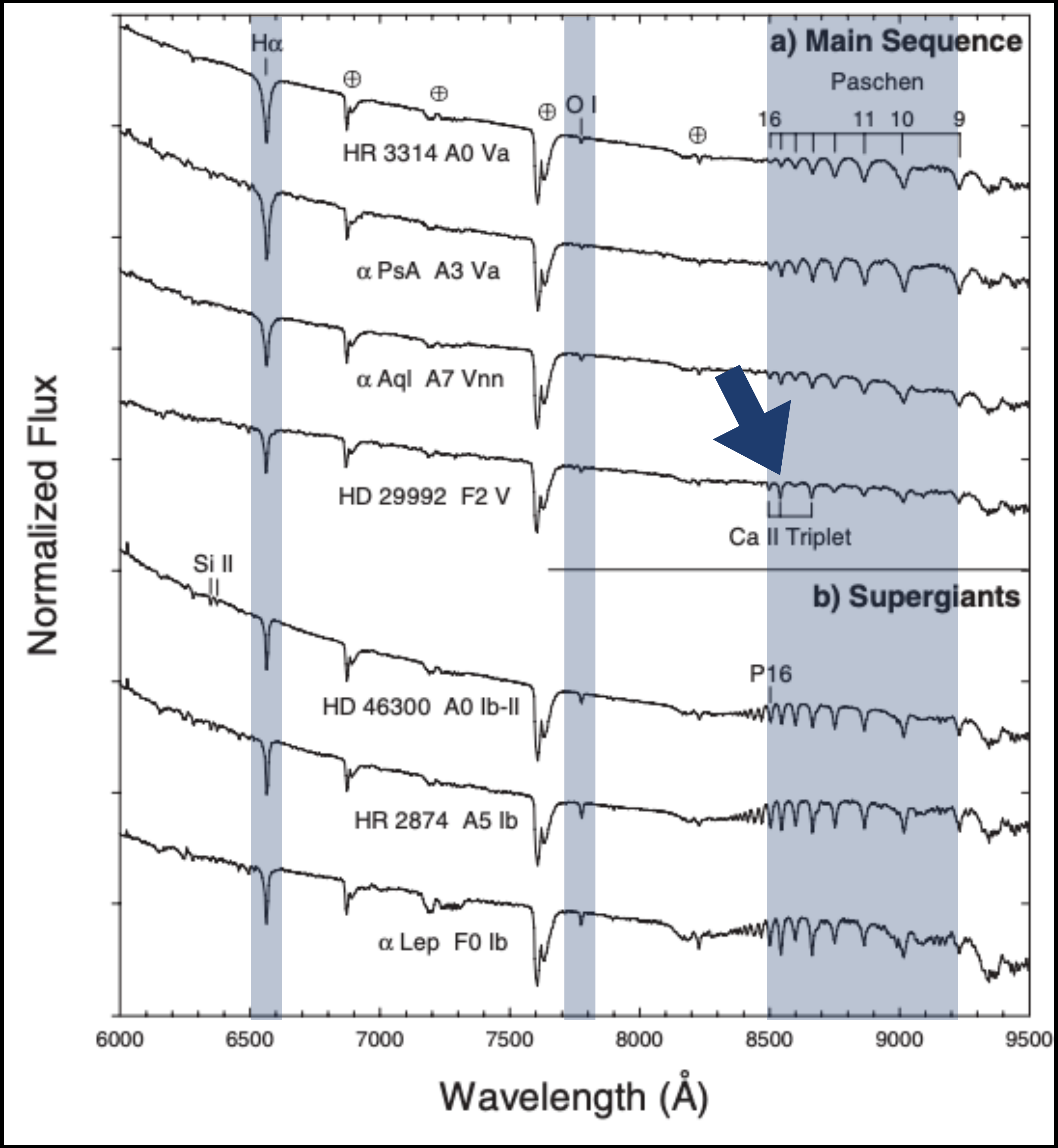
ULTRAVIOLET CLASSIFICATION



NEAR-IR

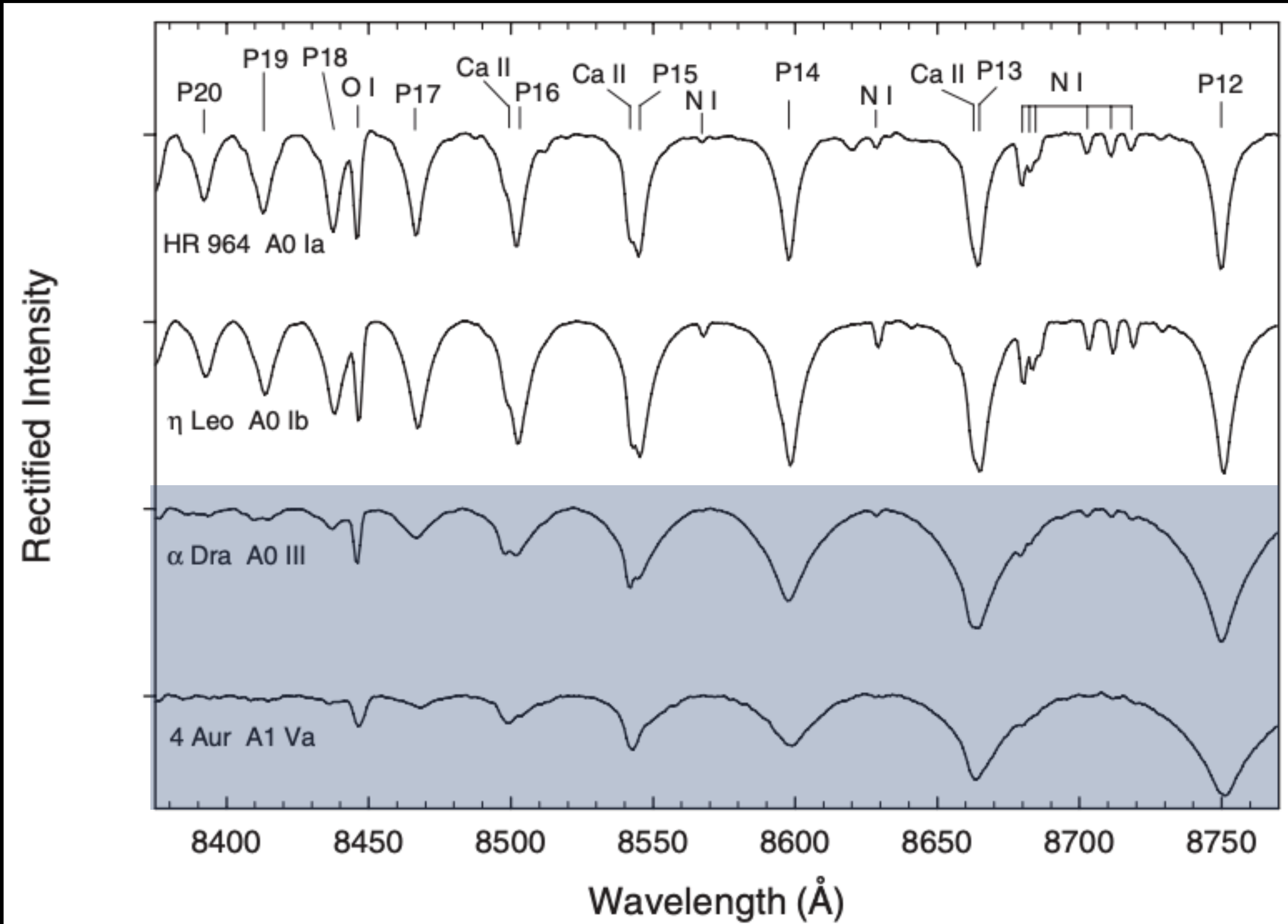
- Dominant spectral features include H-alpha, the O I triplet, the higher Paschen-series hydrogen lines, and the Ca II triplet lines.
- Intersected by strong telluric bands, including 7604 Angstrom O2 feature.
- Dwarf A-type —> changing appearance of Paschen lines
- Early A-type —> Paschen line stronger than Ca II triplet
- Later A-type —> Ca II triplet begins to dominate

NEAR-IR



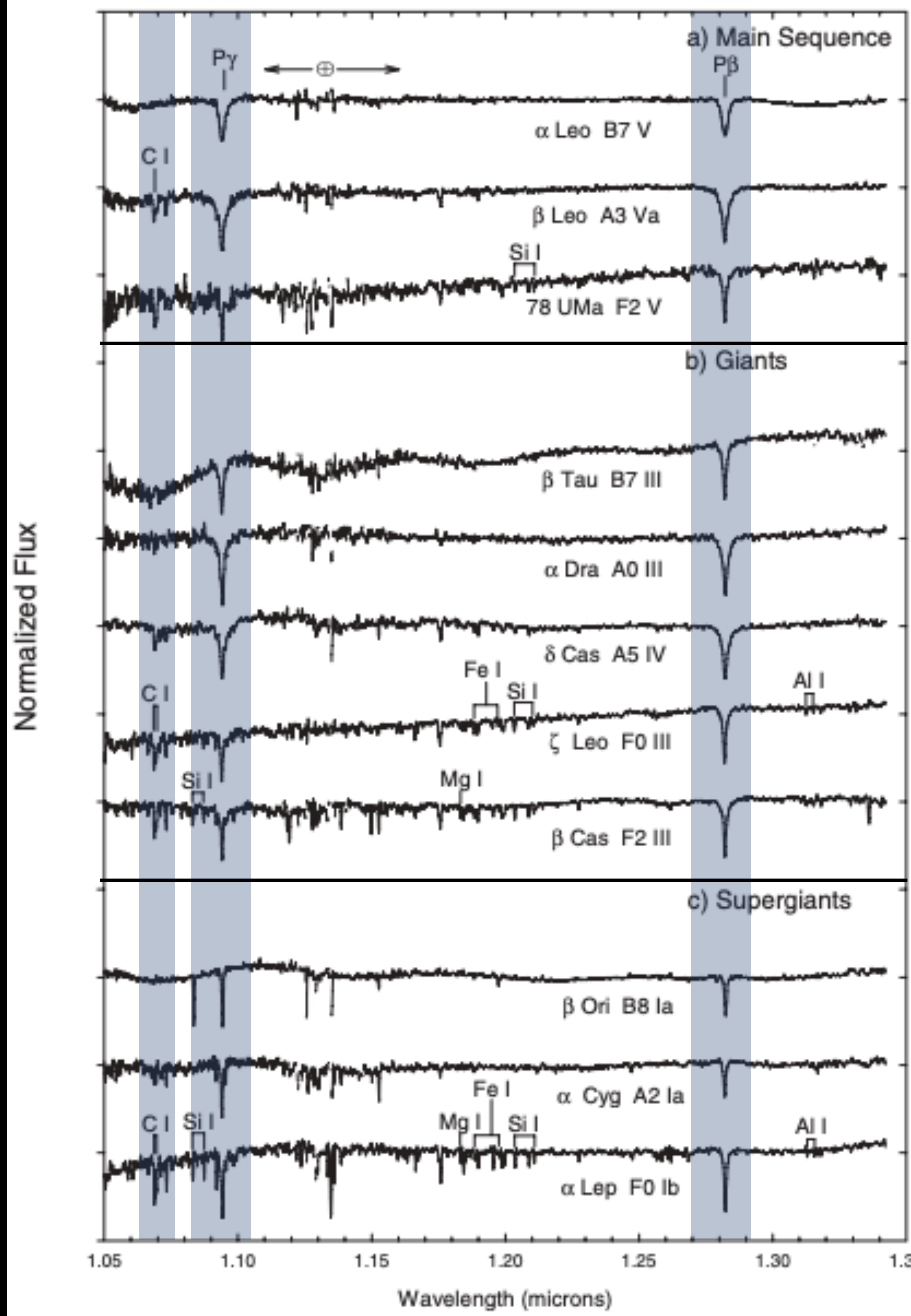
a) Main Sequence
Paschen
16
11 10
9
Hα
O I
HR 3314 A0 Va
α PsA A3 Va
α Aql A7 Vnn
HD 29992 F2 V
Ca II Triplet
b) Supergiants
Si II
P16
HD 46300 A0 Ib-II
HR 2874 A5 Ib
α Lep F0 Ib
Normalized Flux
6000
6500
7000
7500
8000
8500
9000
9500
Wavelength (Å)

NEAR-IR


P20
P19
P18
O I
P17
Ca II
P16
Ca II
P15
N I
P14
N I
Ca II
P13
N I
P12
HR 964 A0 Ia
η Leo A0 Ib
α Dra A0 III
4 Aur A1 Va
Rectified Intensity
8400
8450
8500
8550
8600
8650
8700
8750
Wavelength (Å)

IR J,H,K, AND L BANDS

- Earth's atmosphere partially transparent here — good for ground-based spectroscopy.
- Paschen β and γ lines dominate here & can be used for temperature and luminosity classification.



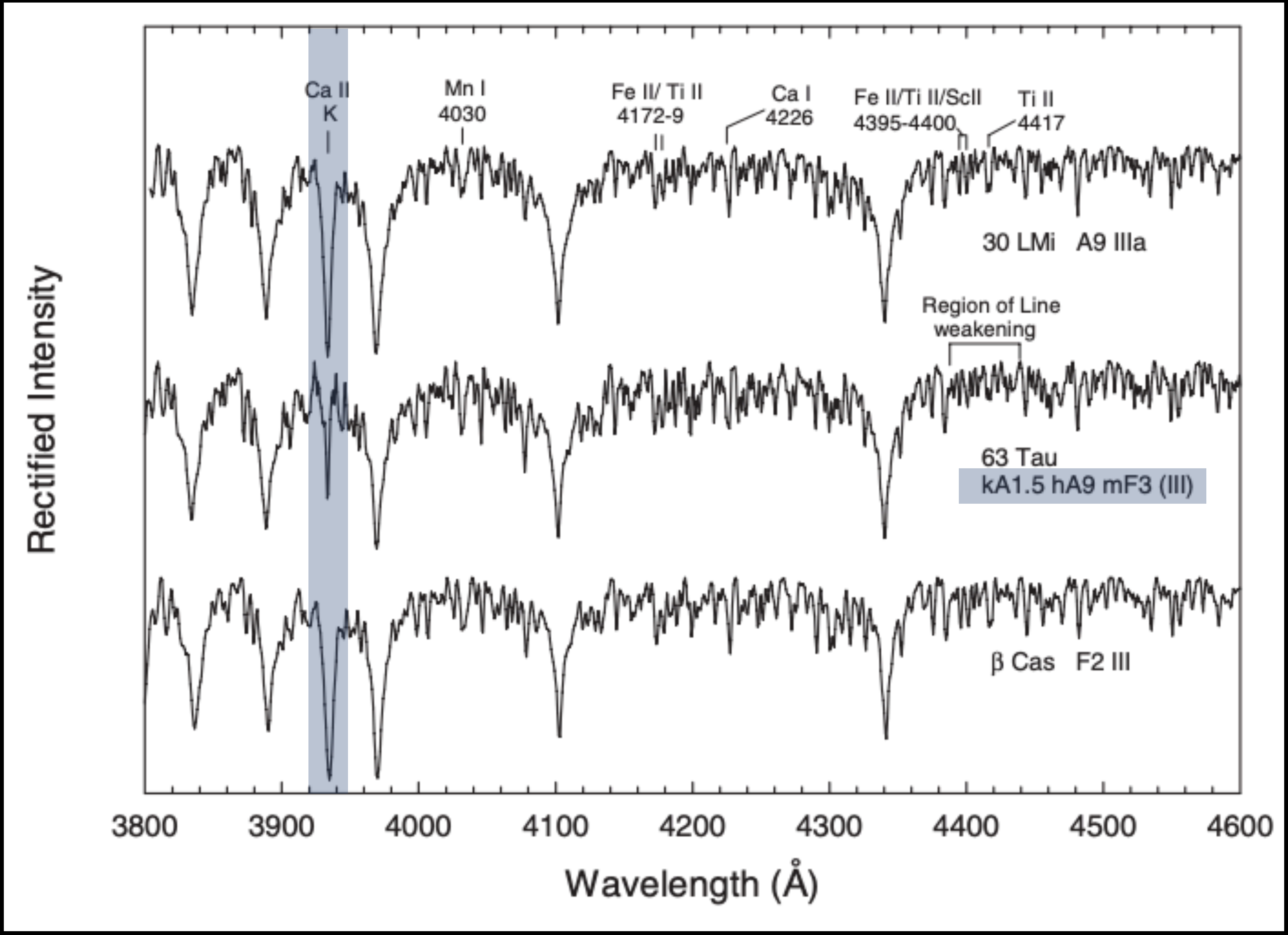
CHEMICALLY PECULIAR STARS:

The Am Stars

- “Metallic-line” stars: A- and early F-type stars where the Ca II K-line type earlier than the metallic-line type by at least five spectral subclasses
- “Proto-Am” stars: difference less than five subclasses
- Anomalous Luminosity Effect: discrepancy in the luminosity criteria, shown in parenthesis at end of spectral type
- Strange abundances (Ca & Sc underabundant, Fe & metals overabundant — H least affected)
- Line blanketing

CHEMICALLY PECULIAR STARS:

The Am Stars



CHEMICALLY PECULIAR STARS:

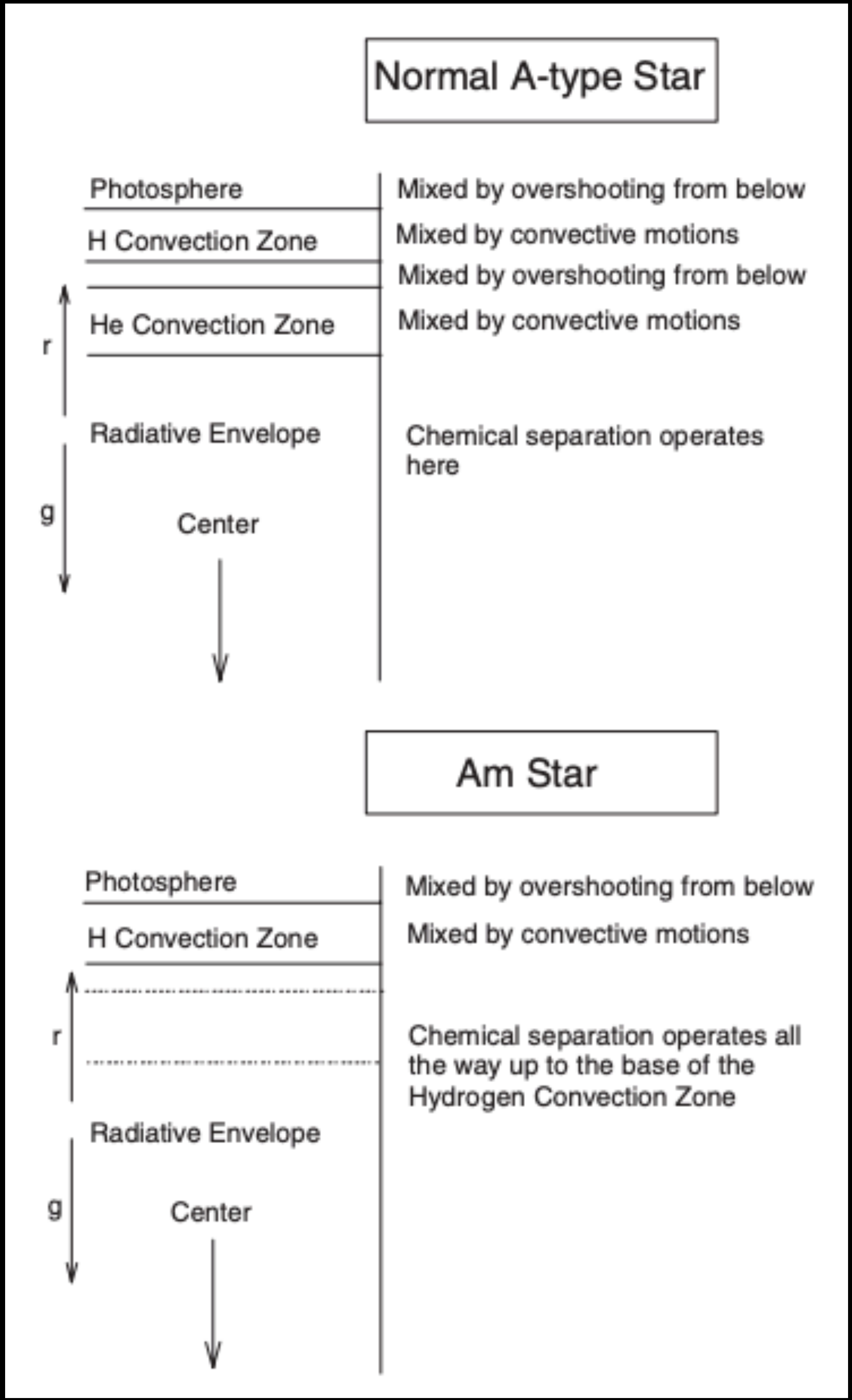
The Am Stars - how are they produced?

- Abundance peculiarities may be understood from chemical separation
- When in hydrostatic equilibrium, individual atoms/ions may feel unbalanced force
- Atoms/ions with many UV spectral lines feel outward push. “Poor” UV spectra sink —> separation
- Fast rotation overwhelms chemical separation
- —> all Am stars are *slow rotators*

CHEMICALLY PECULIAR STARS:

The Am Stars - Slow Rotators

- All members of close binaries*
- Tidally locked
- He (poor UV spectra) sinks, helium convection zone disappears
- Chemical separation all the way up to H convection zone
- Only goes to F2 — after that, convection overwhelms separation.



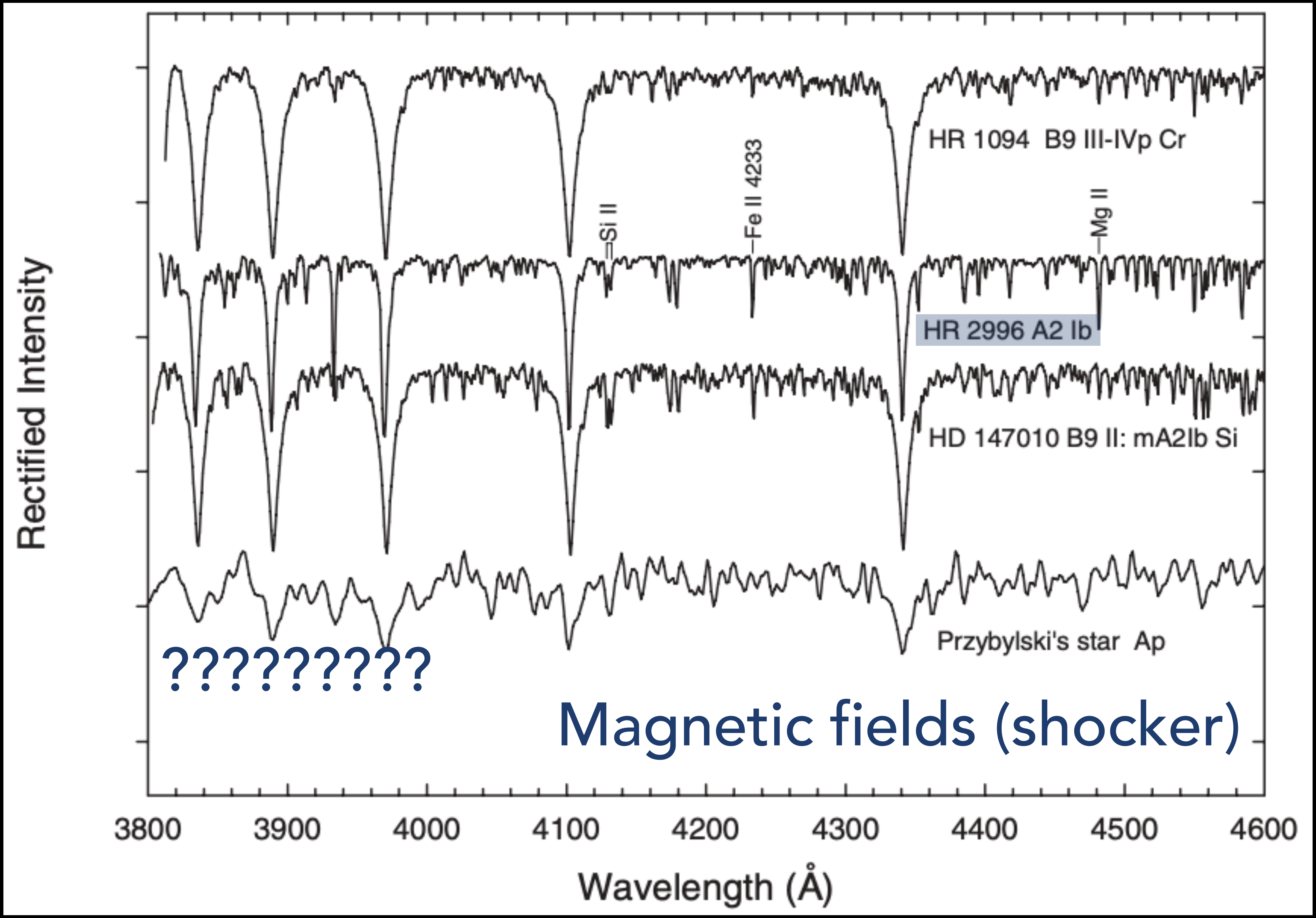
CHEMICALLY PECULIAR STARS:

The Ap Stars

- Peculiar A-type stars: only select elements have greatly enhanced abundances
- Classification begins with MK type (determined by H-lines)**, then determine predominant chemical peculiarities (often Si II, Cr II, Eu II, and Sr II)
- Weird ones: overabundances of chlorine, cobalt, gold, mercury, rare earths, dwarfs with supergiant features. Weirdest: Przybylski's Star, strongest abundance from holmium.

CHEMICALLY PECULIAR STARS:

The Ap Stars



CHEMICALLY PECULIAR STARS:

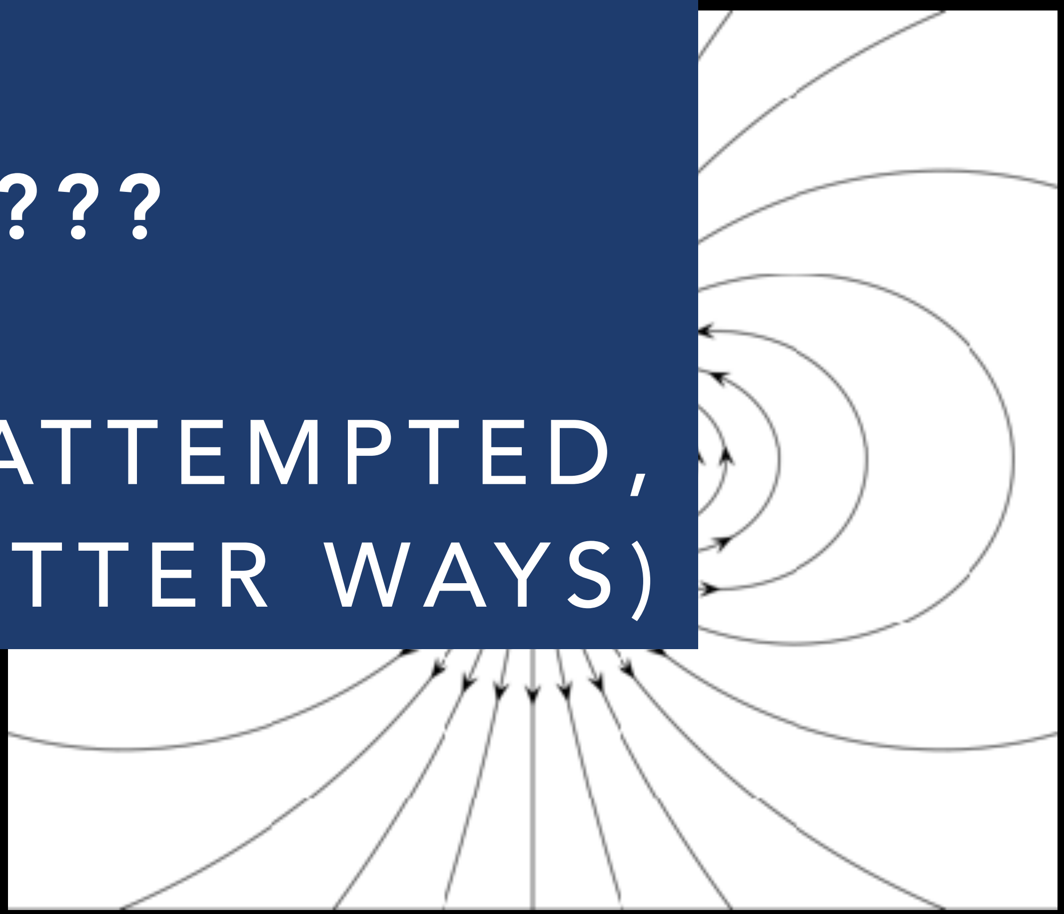
The Ap Stars

- At least 1/2 of Ap stars are spectroscopic variables
- Abundar separati Lorentz
- Magneti Weakest horizont
- Ap stars usually slow rotators.
- Magnetic field can stabilize atmosphere, encourage diffusion.

CLASSIFICATION…

??????????????

(CLUSTER ANALYSIS ATTEMPTED, BUT REALLY NEED BETTER WAYS)



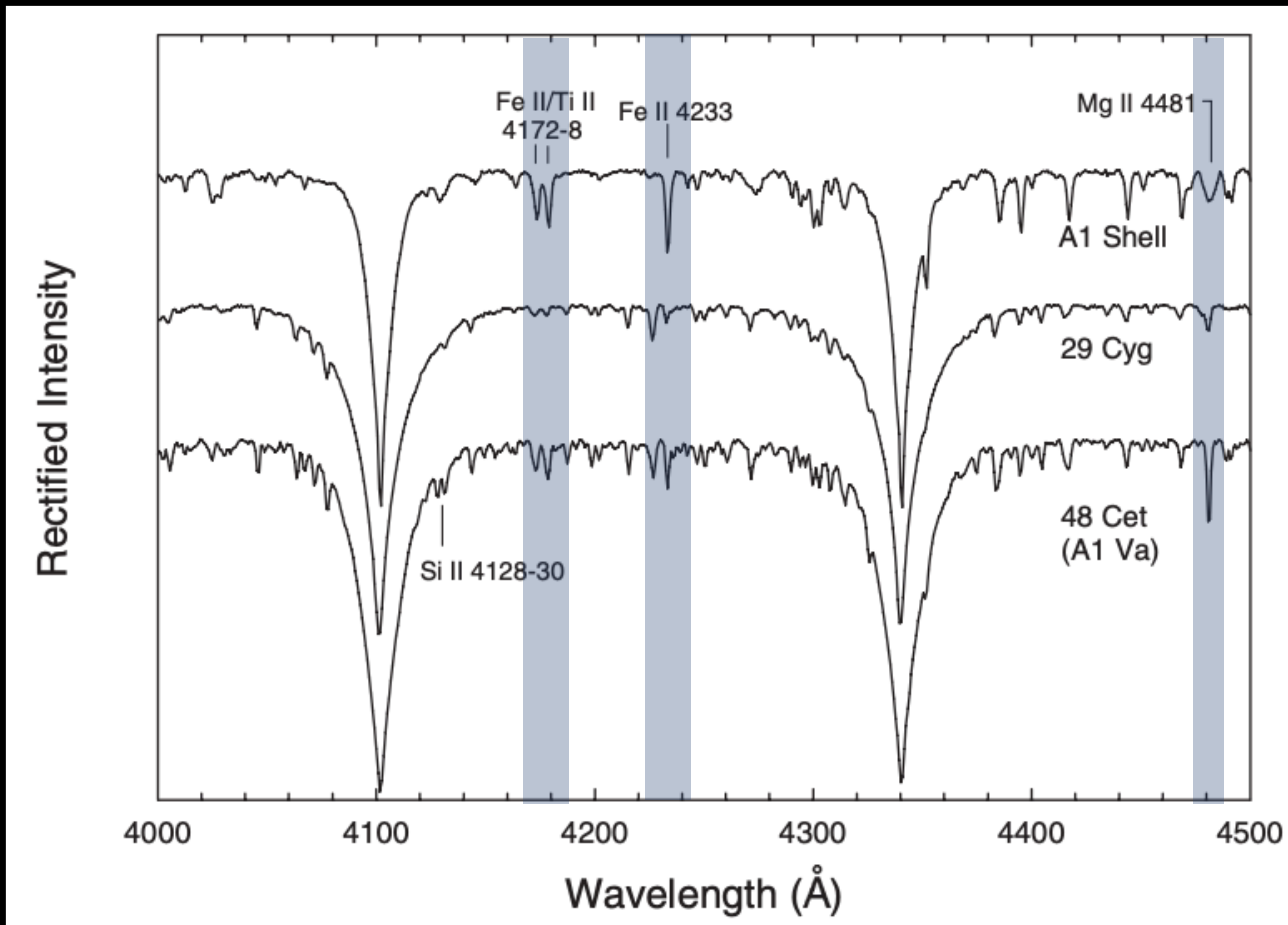
CHEMICALLY PECULIAR STARS:

The λ Bootis Stars

- Metal-weak, population I A-type stars
- Characterized by broad H-Balmer series, general metal-weak character (weak K-line & Mg II lines), no enhanced lines of Fe II and Ti II like shell stars
- Difficult to distinguish from metal weak horizontal branch stars & lower temp adds to confusion
- Given 3 spectral types: based on H, K-line, & metallic lines
  Example: F0V kA1mA1.5λBoo (wow)

CHEMICALLY PECULIAR STARS:

The λ Bootis Stars

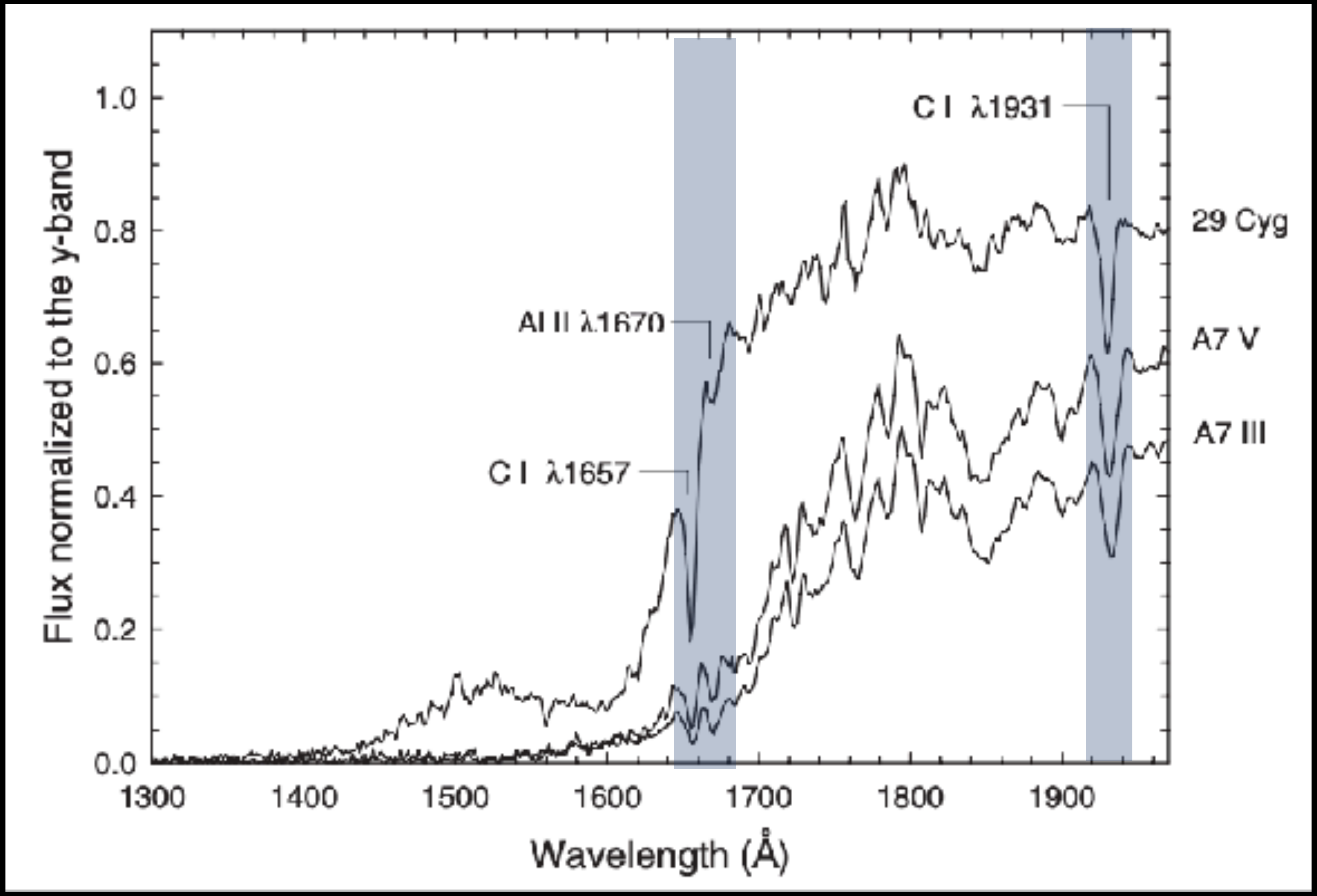


CHEMICALLY PECULIAR STARS:
The λ Bootis Stars (UV)

- Significantly higher UV fluxes than normal A-type stars

- 23% of λ Bootis stars show IR excesses (some also show evidence for circumstellar gas — β *Pictoris shell stars.*

- Why aren't they metal-rich?



Herbig Ae/Be stars

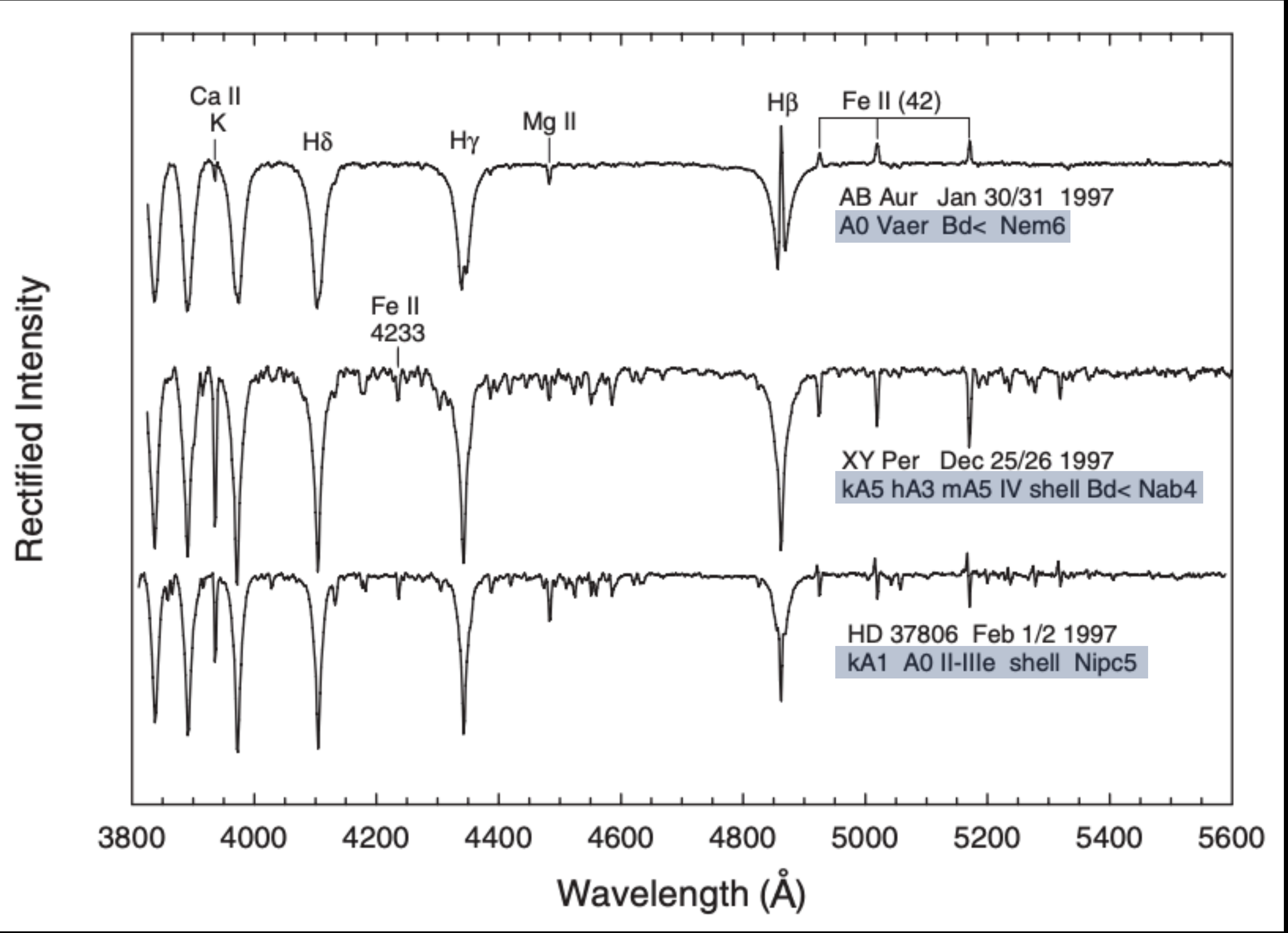
- Pre-main-sequence A & B type stars (emission lines!)
- Also located in obscured region & show “broad” IR excess
- Large extinction due to dust —> spectral classification only way to get characteristics of underlying star
- Classified with normal MK type then extended to include (warning, these get weird):

1. Presence of emission or shell cores in Balmer lines & whether these cores are shifted to blue or red with respect to line center

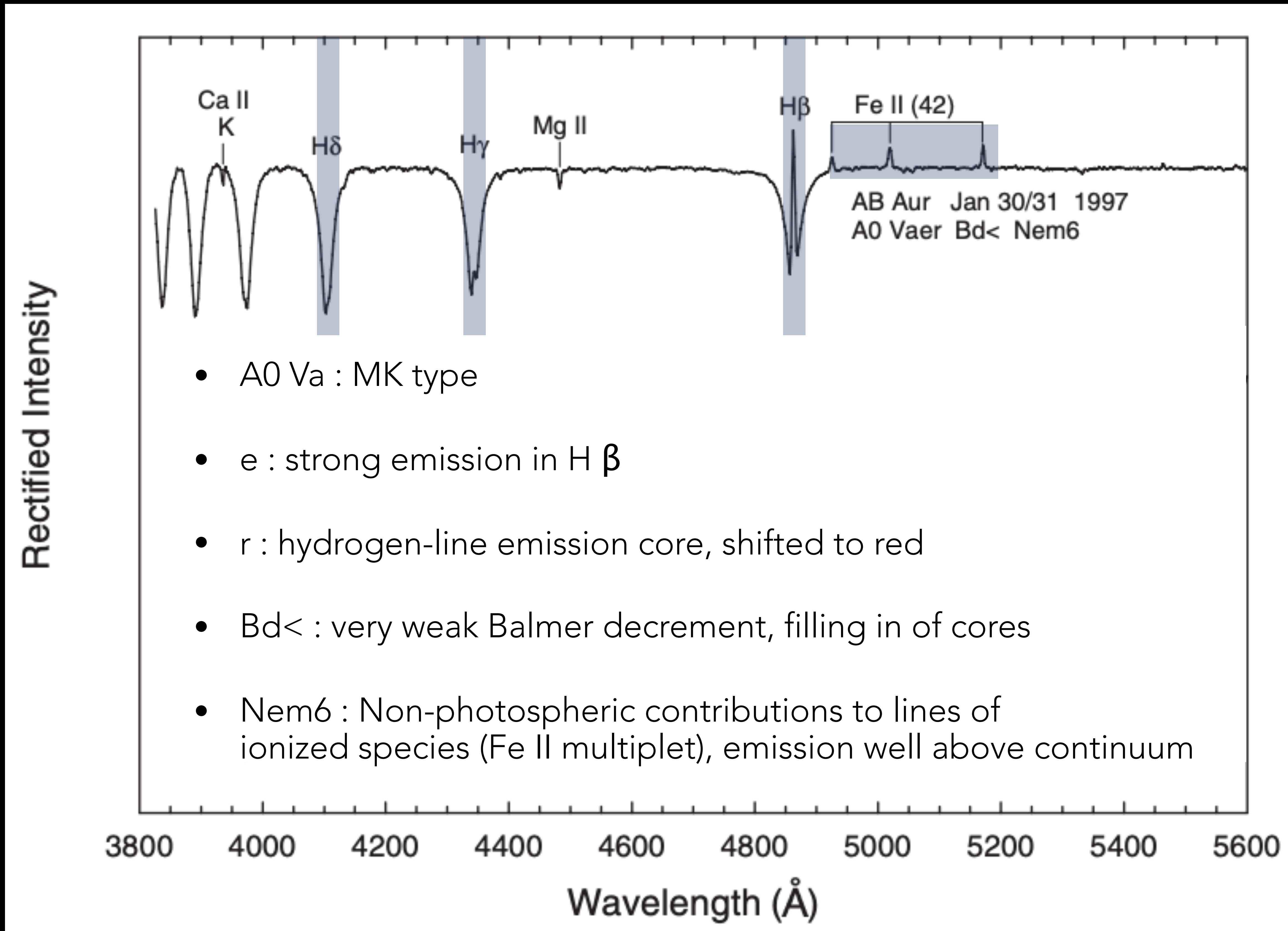
2. Strength of Balmer decrement

3. Presence of non-photospheric contributions (emission/enhanced absorption) due to ionized metals

Herbig Ae/Be stars: Classification



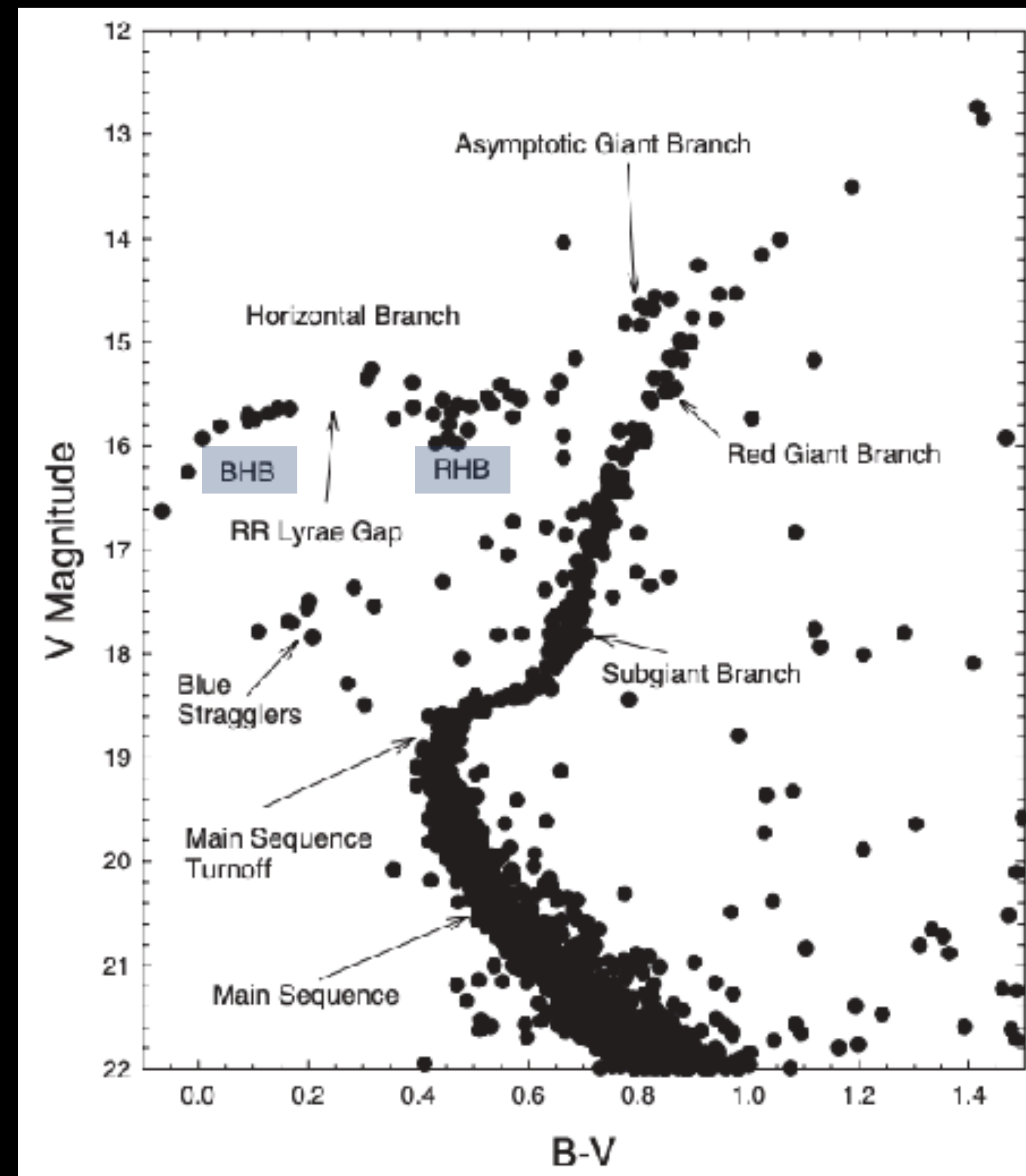
Herbig Ae/Be stars: Classification



- A0 Va : MK type
- e : strong emission in H β
- r : hydrogen-line emission core, shifted to red
- Bd< : very weak Balmer decrement, filling in of cores
- Nem6 : Non-photospheric contributions to lines of ionized species (Fe II multiplet), emission well above continuum

A-Type stars in Advanced Evolutionary Phases: Horizontal Branch (HB) Stars

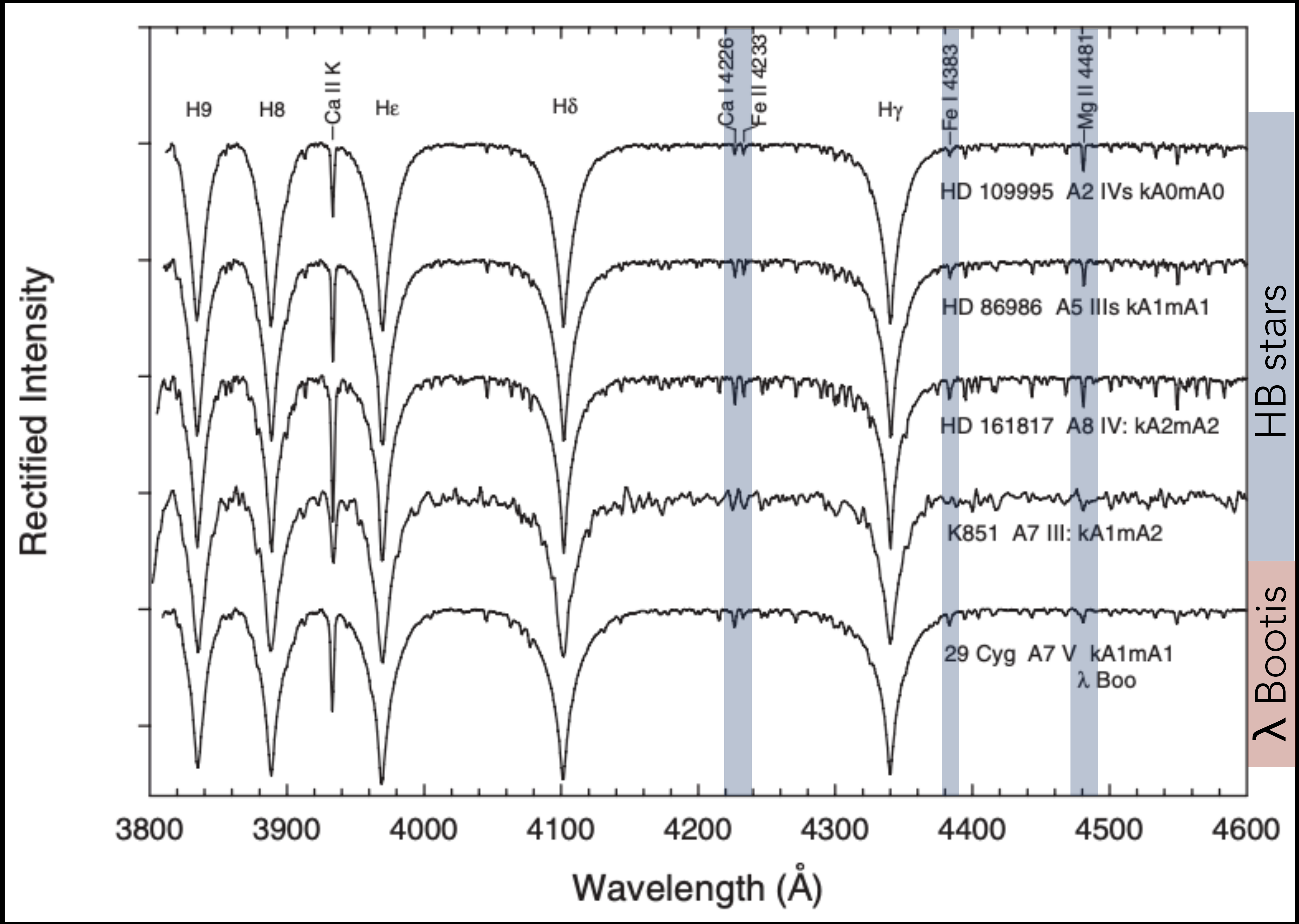
- Intermediate-mass stars, burning He in cores
- History of mass loss during red giant phase determines location on horizontal branch
- Metal-weak
- Classifications: H-line type, Ca II K-line type, & metallic-line type. (Ex: A2 IVs kA0mA0, a FHB star)



A-Type stars in Advanced Evolutionary Phases: Horizontal Branch (HB) Stars Classification

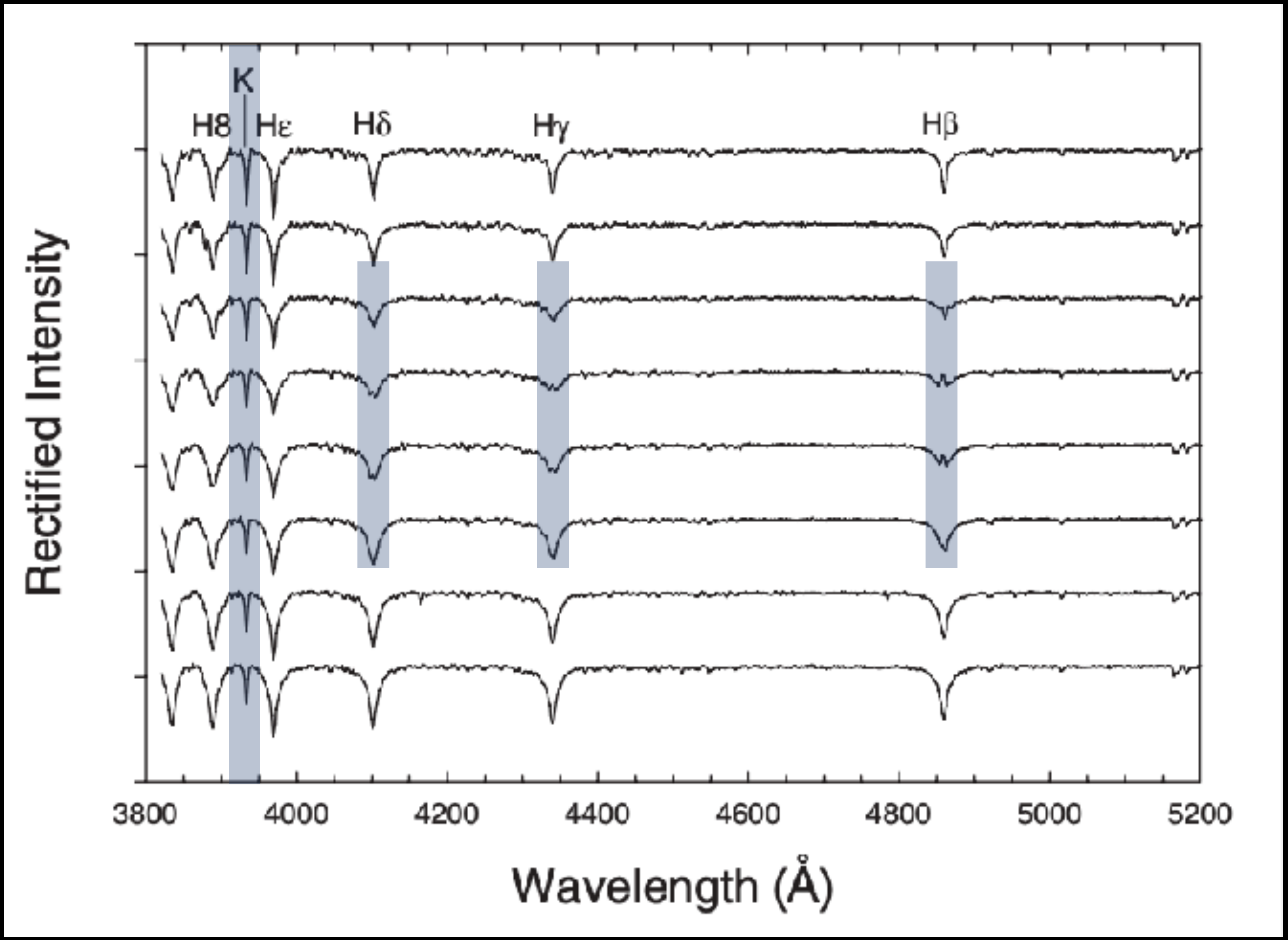
- Spectra of BHB stars and λ Bootis stars very difficult to distinguish in the blue-violet
  - λ Bootis stars: broader lines & H-wings
  - BHB stars: ratio of Mg II λ4481 to Fe I λ4383 always unity or greater
  - Fe II 4233 always weaker than Ca I 4266 in λ Bootis stars
- Externally: compare velocities, CNO abundances in UV, near-IR O I triplet.

A-Type stars in Advanced Evolutionary Phases: Horizontal Branch (HB) Stars



A-Type stars in Advanced Evolutionary Phases: RR Lyrae Stars

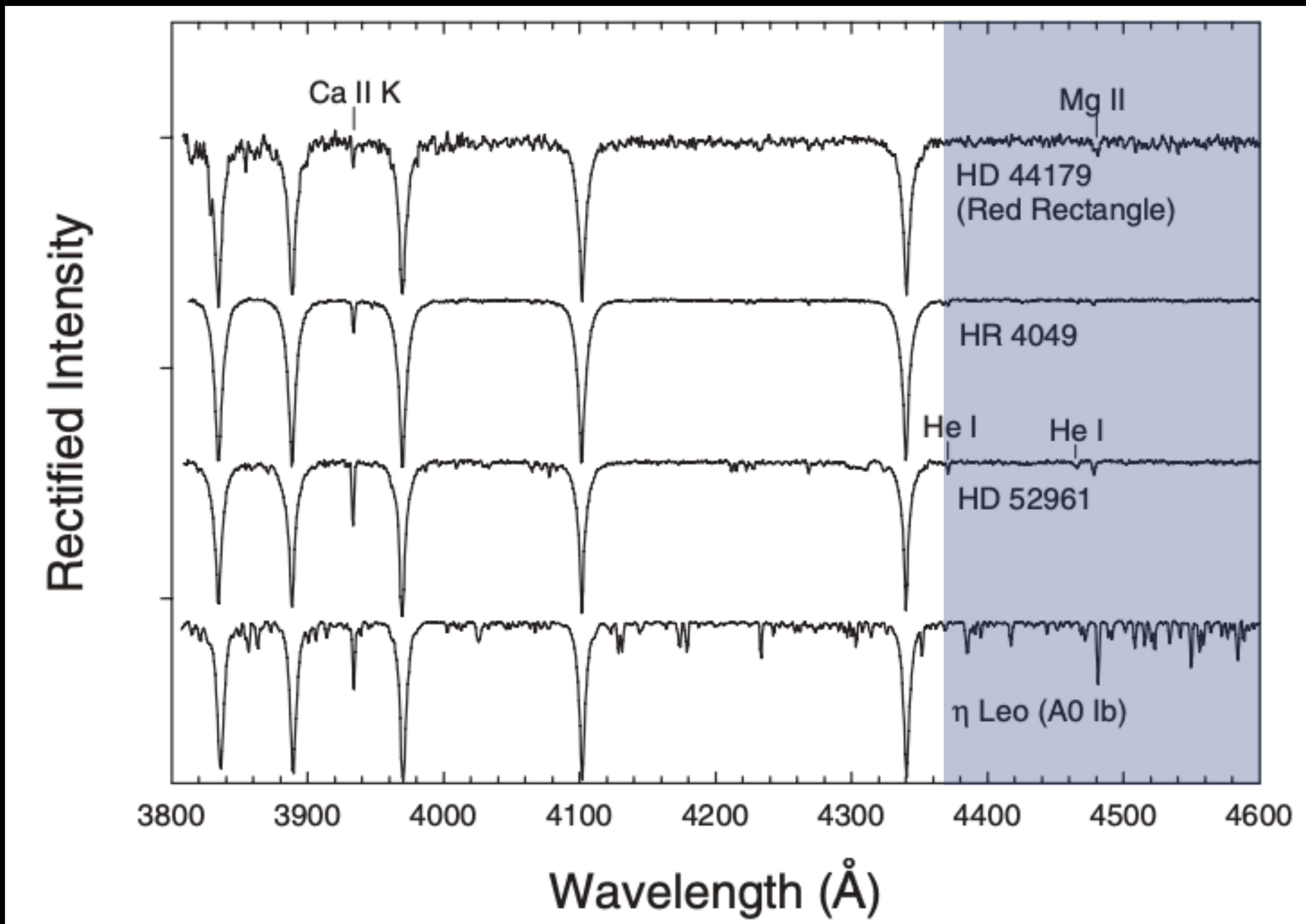
- RR Lyrae: Pulsating, variable HB stars with A and F spectral types
- RR Lyrae spectra similar to those of the cooler BHB (except during rising light)



A-Type stars in Advanced Evolutionary Phases: Post-HB & Post-AGB stars

- Post HB stars: exhausted He, zooming toward AGB. Rarely caught.
- Post AGB stars, also known as proto-planetary nebulae (PPNe): stars in process of ejecting gas/dust that will become PN
- Short-lived phase: star evolves rapidly through K → G → F → A → OB → Planetary Nebula nucleus track
- A part: appear as as A supergiants with peculiar abundances & show large IR excess
- Spectra look like massive supergiants, actually one Solar mass or less

A-Type stars in Advanced Evolutionary Phases: Post-AGB stars



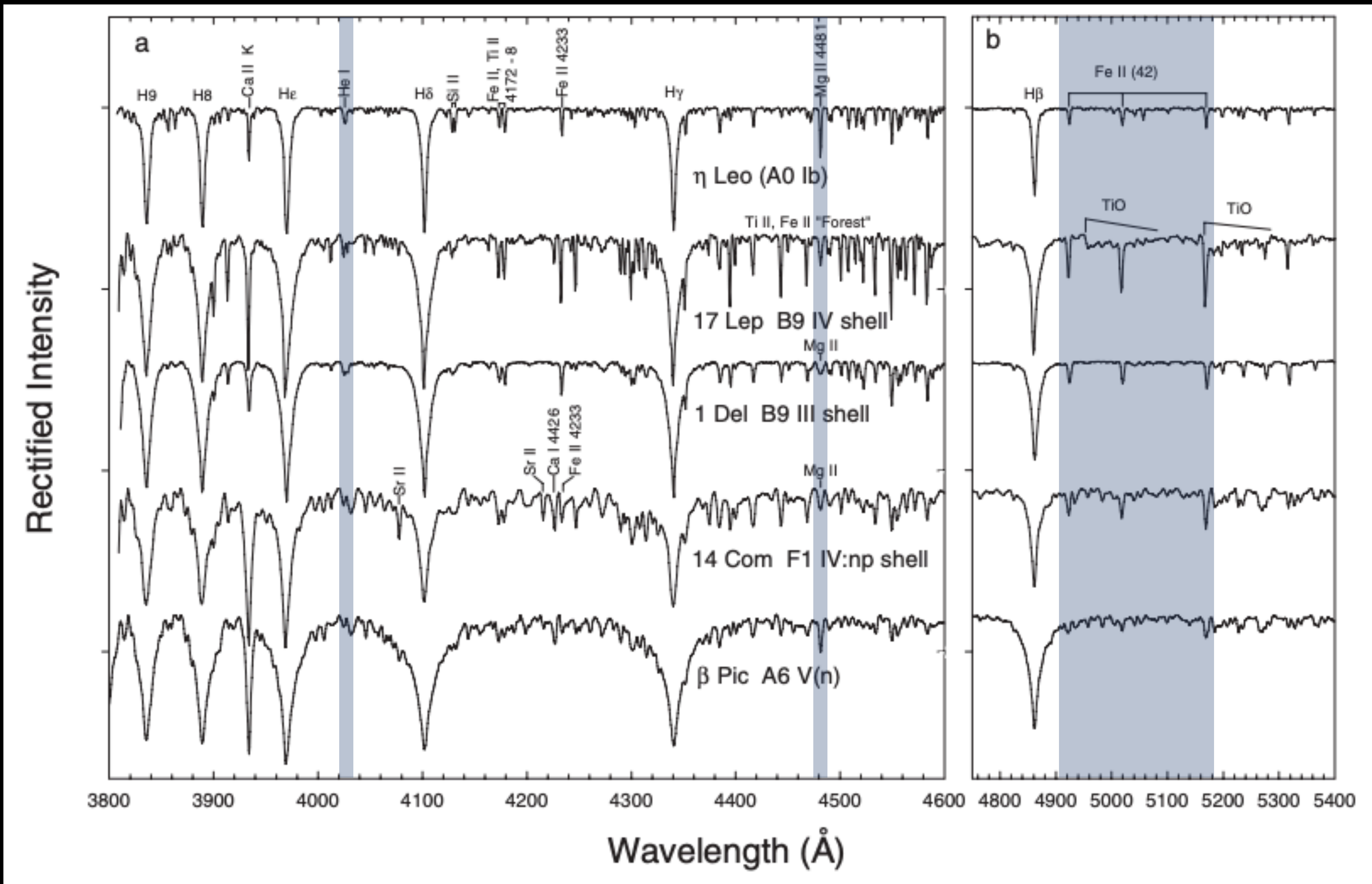
A-Type Shell Stars

- Circumstellar shell surrounding the star
- Shows broad absorption lines (from star) plus some very narrow absorption lines (from shell)
- Denoted by:
  shell —> strong shell spectrum
  (shell) —> moderate shell spectrum
  ((shell)) —> marginally visible shell
- Main goal: determine spectral type of underlying star. Can be done by only considering photospheric features, not shell features.

A-Type Shell Stars

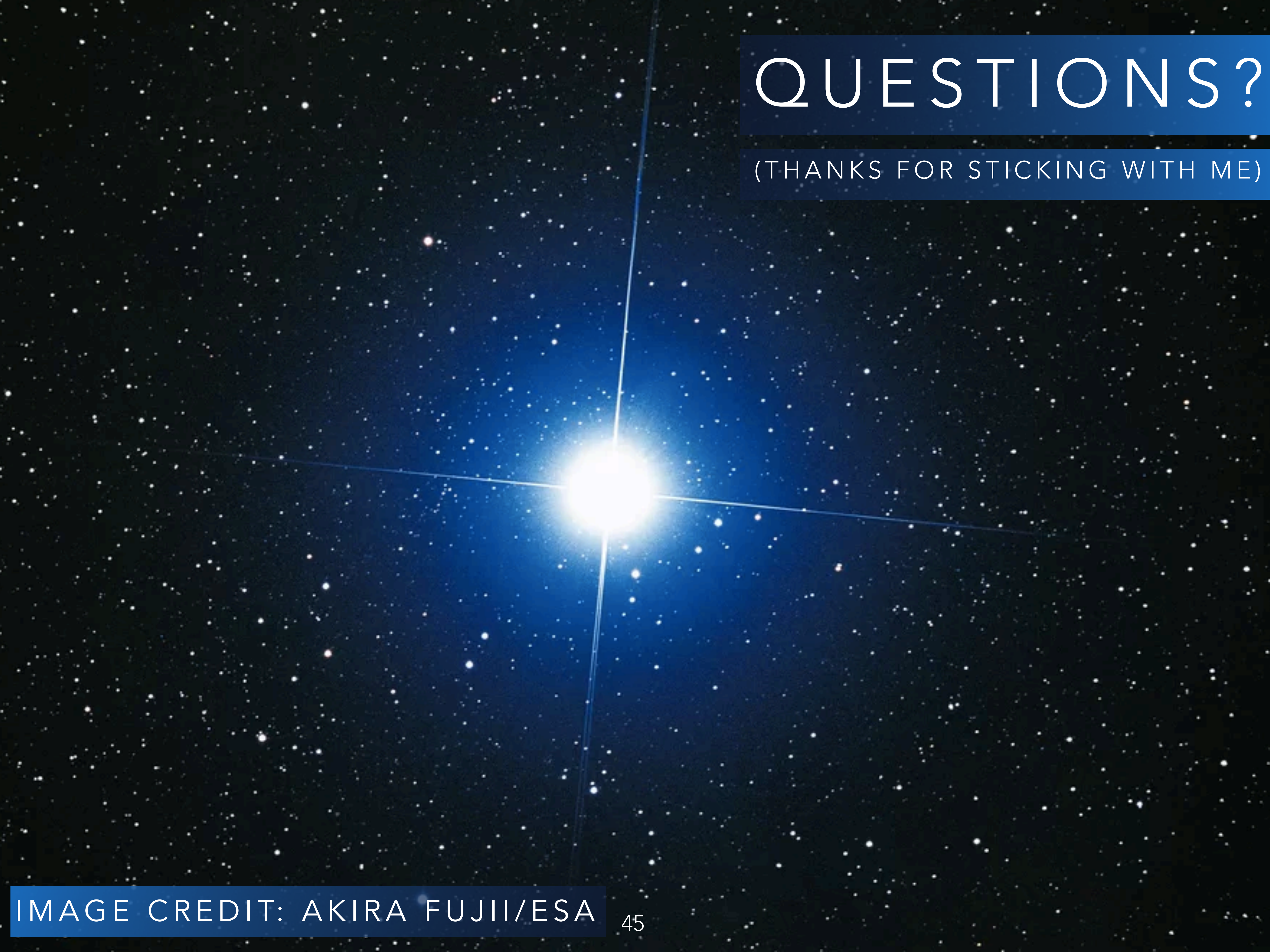
- Shell stars have strongly enhanced lines of Fe II multiplet 42, may show strong absorption cores in the Balmer lines, and have a strong Ca II K-line with unusual profile.
- Photospheric features unaffected by shell: wings of Balmer lines & He I lines, and Mg II 4481 line.
- True "classical A-type shell stars" relatively small — most are actually rapidly-rotating late B-type shell stars.
- Second type: β Pictoris shell stars (surrounded by a protoplanetary disk that contains gas in addition to dust)

A-Type Shell Stars



QUESTIONS?

(THANKS FOR STICKING WITH ME)



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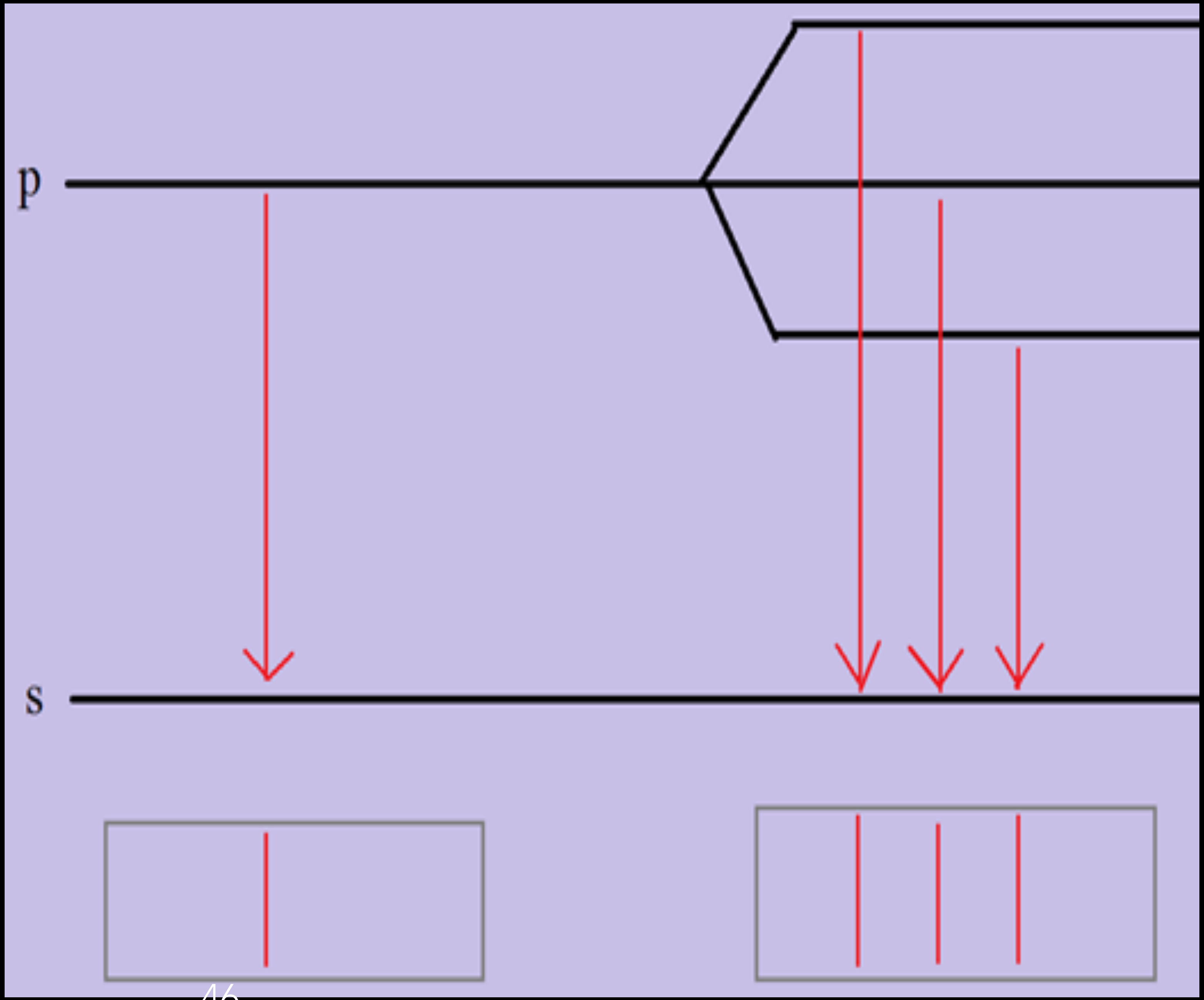
PHYSICAL BASIS OF CLASSIFICATION

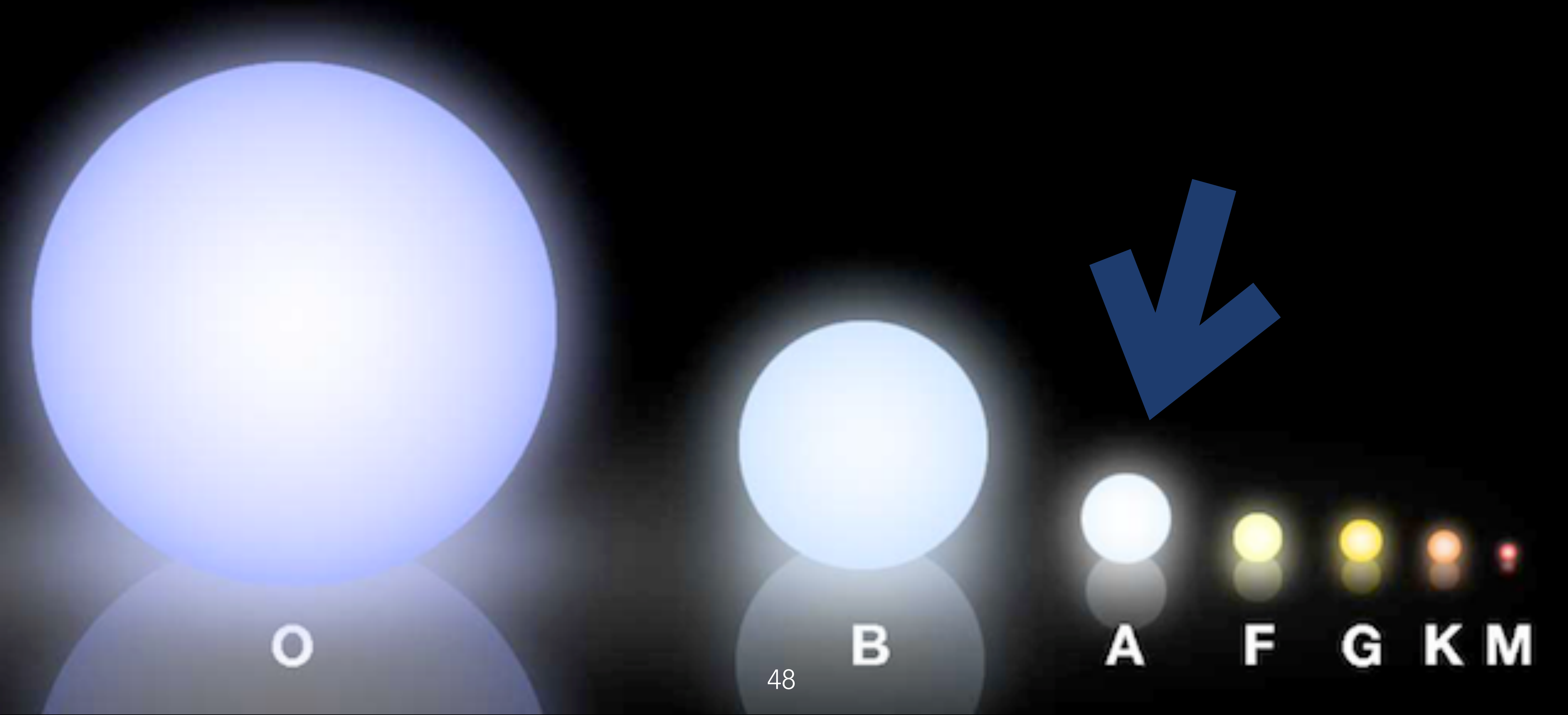
- Enormous width of hydrogen lines in A-type stars, due to interaction of electrons and ions with neutral hydrogen atom.
- Called the "Stark Effect"
- H atom subject to external electric field
- Causes shifting and splitting of spectral lines of atoms and molecules



SENSITIVITY OF FE II AND TI II LINES TO LUMINOSITY

- Relatively insensitive to luminosity (gravity) in early & mid A-type stars, only useful in very late A and early F
- Microturbulance????
  - Desaturates core of spectral line, strengthening it
  - A-type giants have same microturbulent velocity as dwarfs.
  - Related to lack of convection in atmospheres.

A-TYPE STARS



A-TYPE STARS: INTRODUCTION

Within the A-type stars, we have:

- Am stars & Ap stars — bizarre abundance patterns
- λ Bootis stars — underabundances of metals
- Slow rotators
- Rapid rotators
- And more!

CHEMICALLY PECULIAR STARS:

The λ Bootis Stars

- Many (but not all) λ Bootis stars show evidence for circumstellar gas. Ones that do are called β *Pictoris shell stars.*
- Possible that all do, but constrained to a disk & could be inclined out of sight?
- Population I stars *should* be metal-rich. What's going on?? (Accretion/diffusion?)