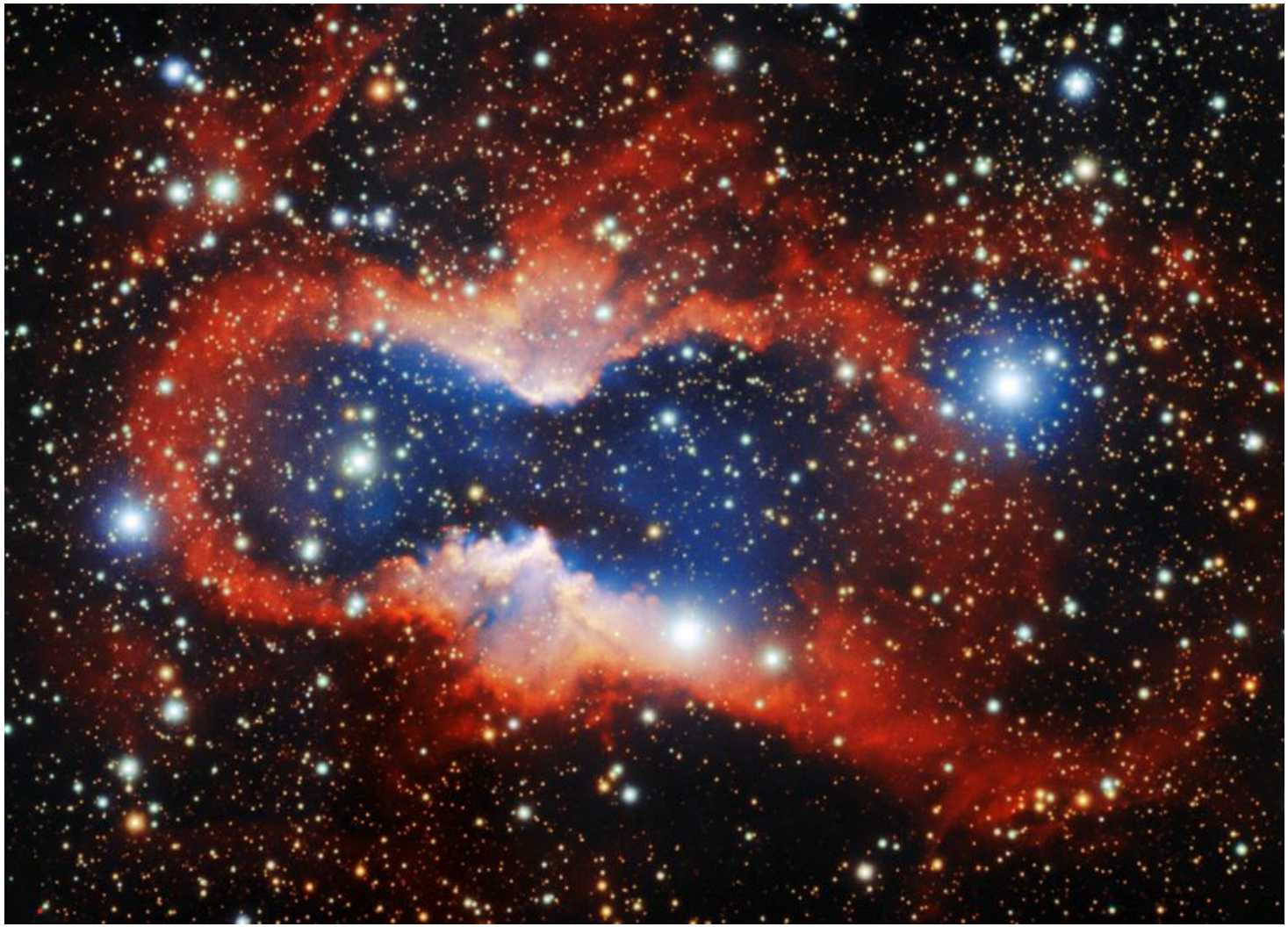
CVMP 1

6500 light-years distance

DEC = -55 deg



- **Please pick up your papers**
- **Course grades are posted**

- **Next TIMESTEP meeting (March 4; PAS 218)**
  - ***Resume Building and Interview Preparation***

- **Exam #1 (March 4)**
  - **Doodle Sheet comments**
    - **openbook**

"Journey to the Center of the Galaxy: Following the Gas to Understand the Past and Future Activity of Galaxy Nuclei"

Dr. Elisabeth Mills (Univ Kansas)

Centers of galaxies are some of the most extreme objects in our universe: hosting starbursts and active supermassive black holes that can launch jets and winds far outside the compact galaxy nucleus. The effects of the unique interactions between stars, gas, and black holes that occur here don't just stay confined to these small regions: they have an outsized influence on the overall evolution of galaxies as a whole.

I will present the results of research following the gas and its properties from kiloparsec to sub-parsec scales to understand why the Galactic center is so quiet right now and what the future holds.

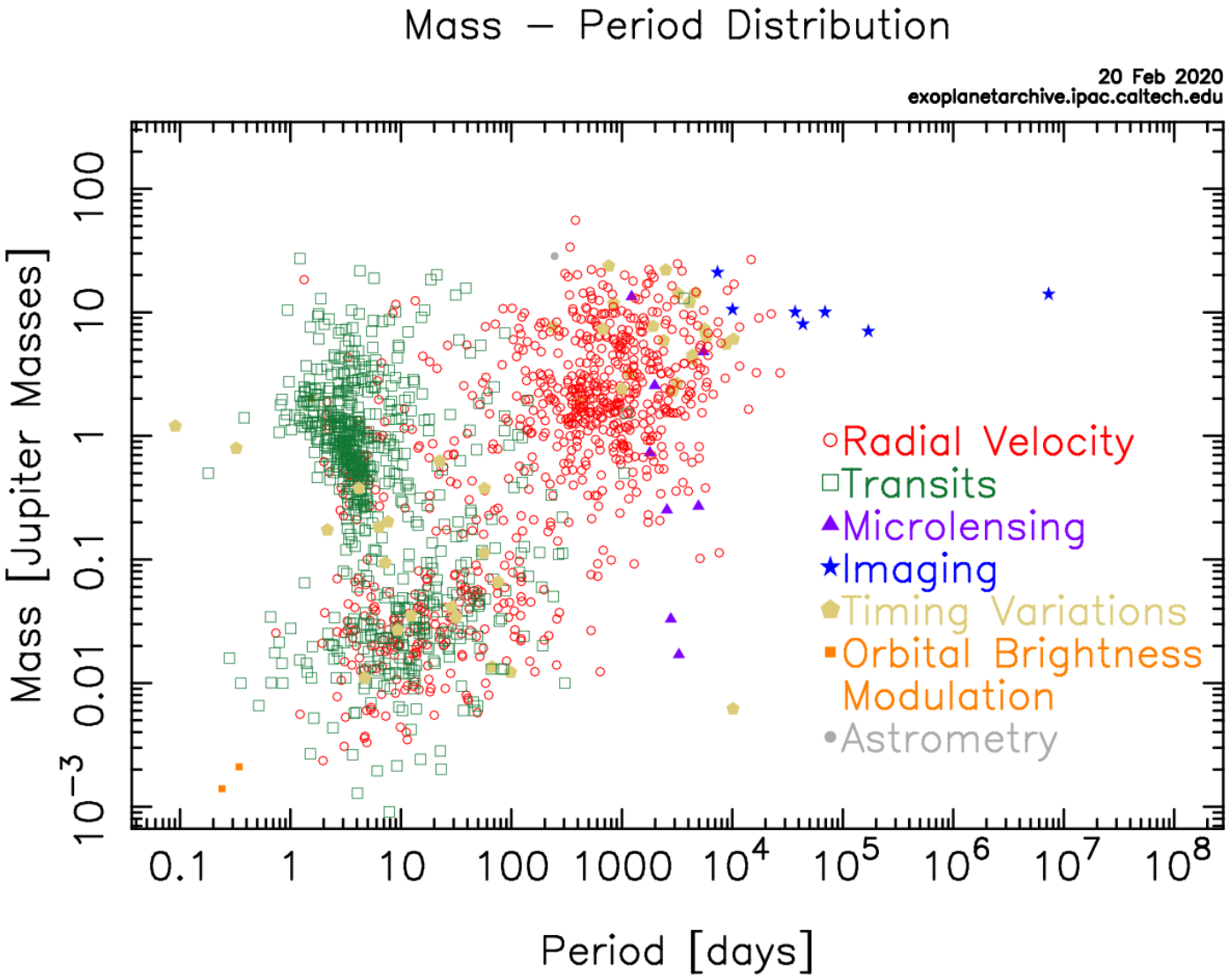
Steward Obs.

weekly colloquium - Thursdays

(3:30 pm in room N210)

4:30 pm refreshments in the lobby

NASA Exoplanet Archive



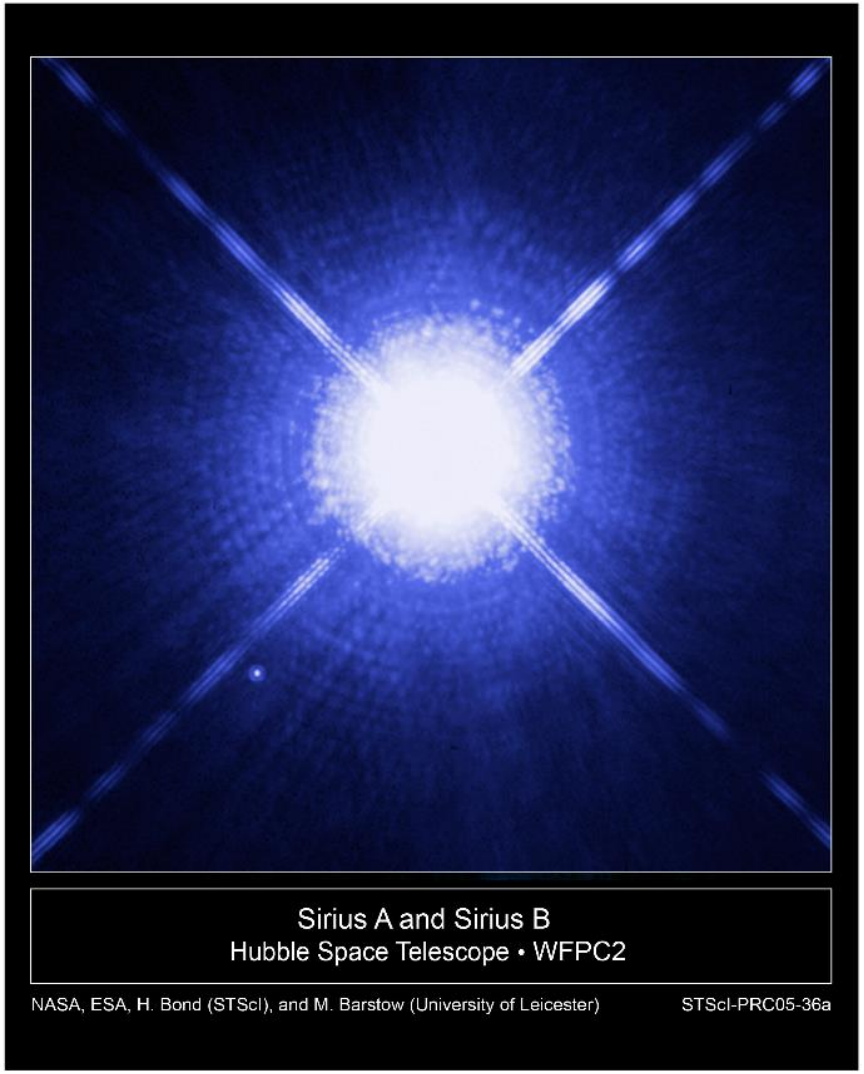
Astrophysics (since April 1992)

For a **specific paper**, enter the identifier into the top right search box.

- **Browse:**
  - new (most recent mailing, with abstracts)
  - recent (last 5 mailings)
  - current month's astro-ph listings
  - specific year/month:
    2020 ▾ all months ▾ Go
- **Catch-up:**
  Changes since: 17 ▾ 01 (Jan) ▾ 2020 ▾ , view results without ▾ abstracts Go
- **Search** within the astro-ph archive
- Article statistics by year:
  2020 2019 2018 2017 2016 2015 2014 2013 2012 2011 2010 2009 2008 2007 2006 2005 2004 2003 2002 2001 2000 1999 1998 1997 1996 1995 1994 1993 1992

Categories within Astrophysics

Direct Imaging of Exoplanets



Why would an alien be challenged to "see" Jupiter from a distance of 10 pc?

You should be able to calculate the relative brightness of Jupiter and Sun.

Solar energy reflected by Jupiter:

$$= A\,(L_{Sun} / 4\pi D^2)\,\pi R_J^2 = A\,L_{Sun}\,(R_J / 2D)^2$$

$$= A\,L_{Sun}\,(4.5 \times 10^{-5})^2$$

$$= L_{Sun}\,(10^{-9})$$

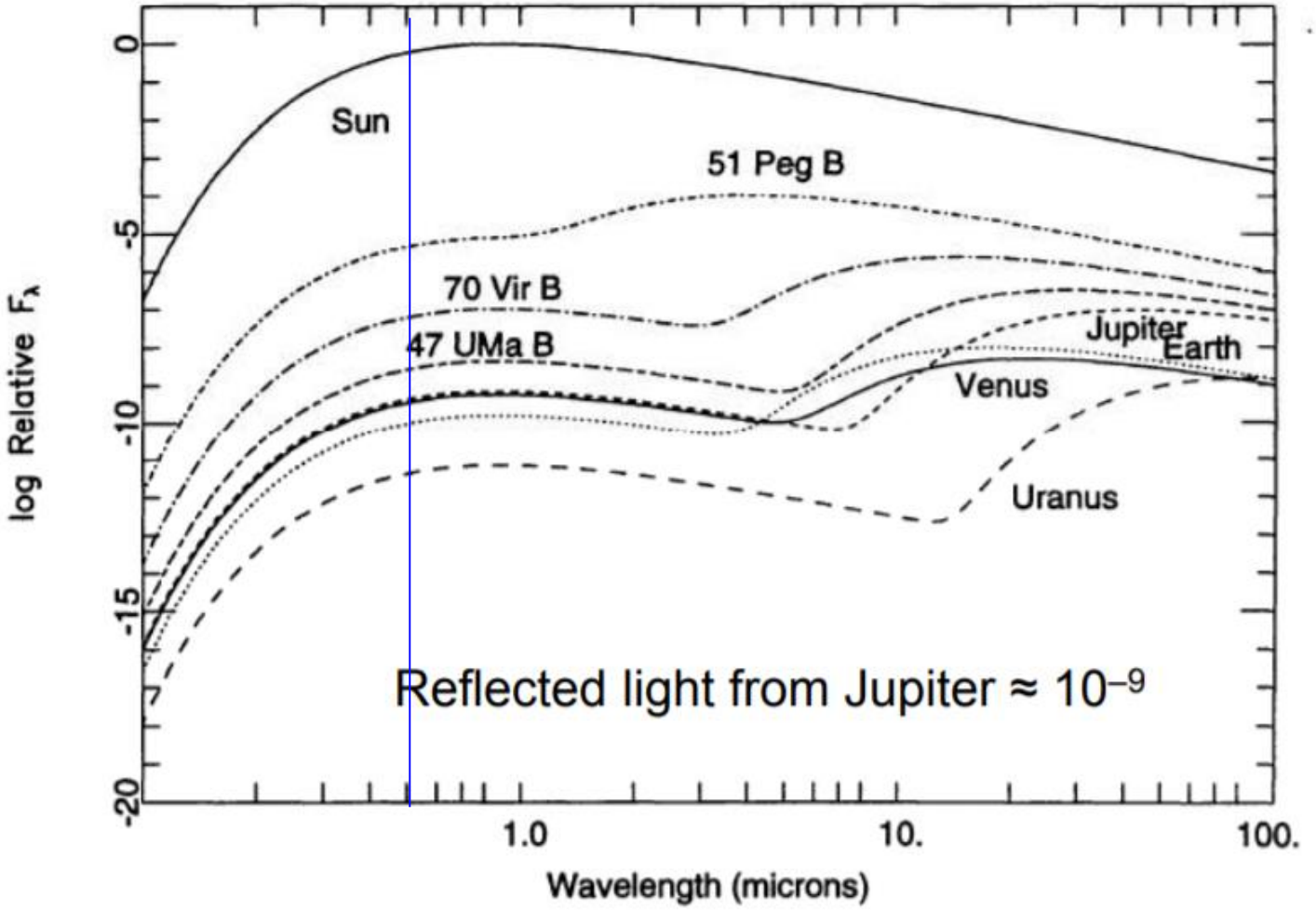


Figure 1. Relative fluxes of the Sun, Venus, Earth, Jupiter, Uranus, and the companion objects to 51 Pegasi, 70 Virginis, and 47 Ursae Majoris from 0.10 μm to 100 μm.

You should be able to calculate the angular separation of Jupiter from Sun as seen from 10 pc.

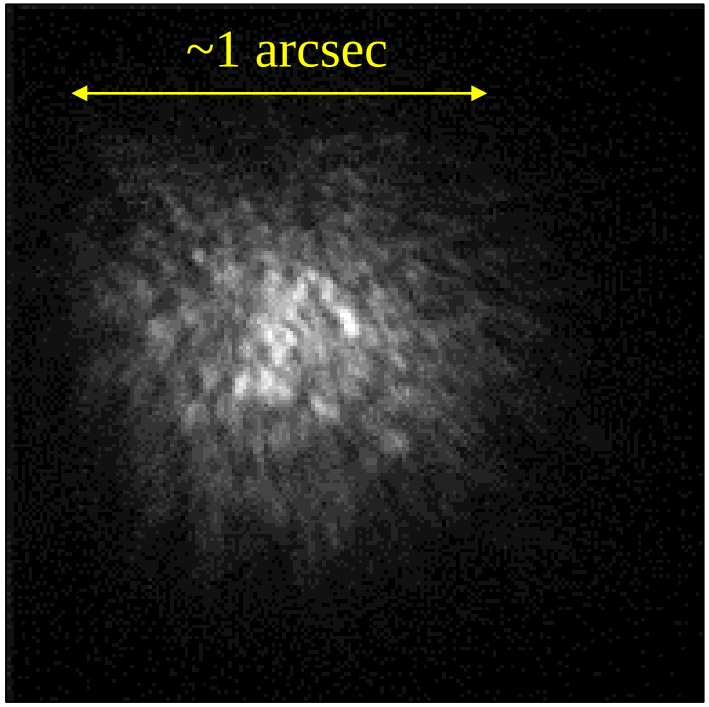
θ_{max} = 5.2 AU / 10 pc

Remember that 1 AU at 1 pc subtends 1 arcsec

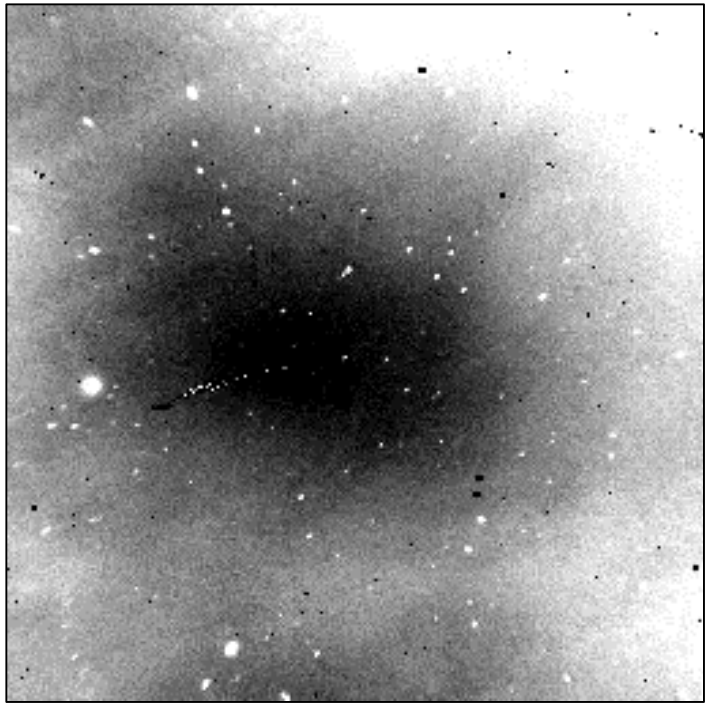
θ = 0.5 arcsec

Earth's Atmosphere Hurts !

absorbs, blurs, and even emits its own light.



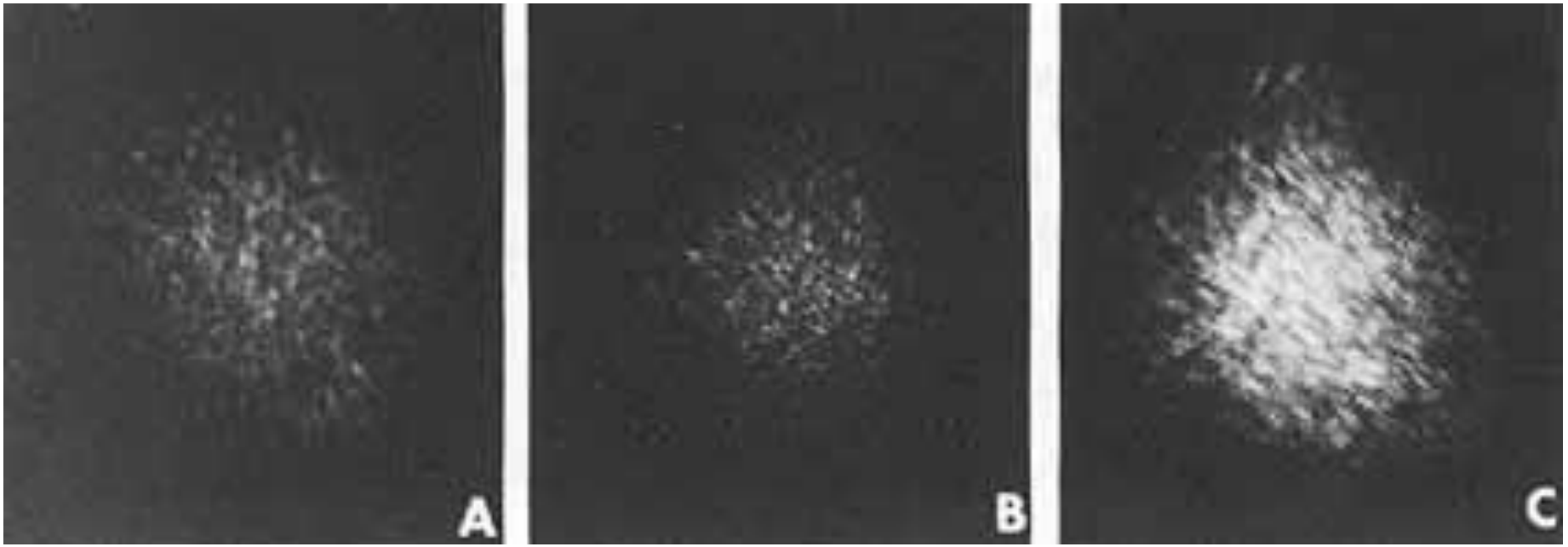
Turbulence blurs & twinkles starlight.
"seeing"
variable amplitude (0.25-10 arcsec)
frequency ~100 Hz



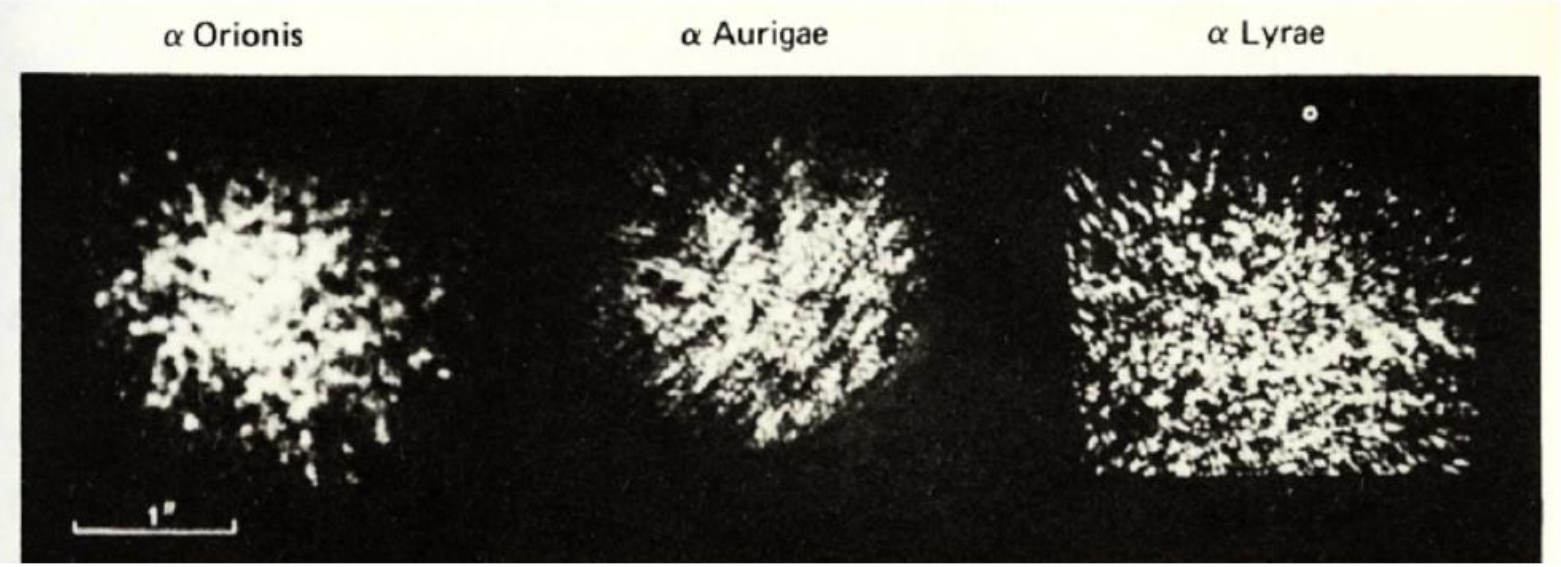
An infrared look through the atmosphere on a clear night

Speckle Patterns

Can you find Betelgeuse, the single star, and the binary star?



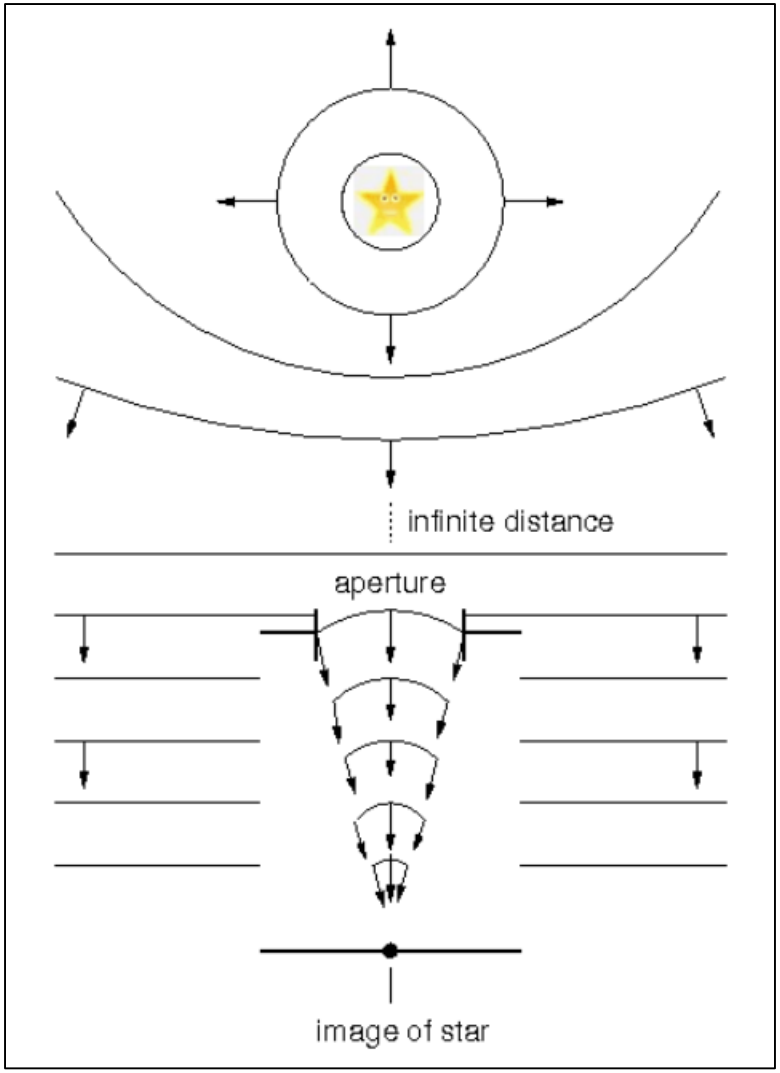
The Original Speckle Images



Labeyrie et al.'s (1974, ApJ, 194, L147) famous set of speckle images taken with the Palomar 200-inch telescope. Betelgeuse, Capella and Vega speckle photographs taken with a 20 nm bandpass at 500 nm. The f/ratio was 200 and the exposure times were 0.01 seconds. Note each image shows a different speckle structure. Adapted from Walker, *Astronomical Observations.*

Direct Imaging

What is a "perfect" image?



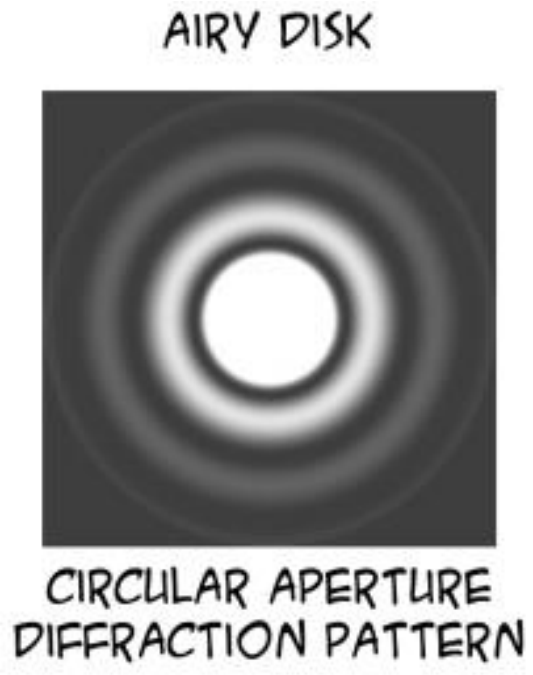
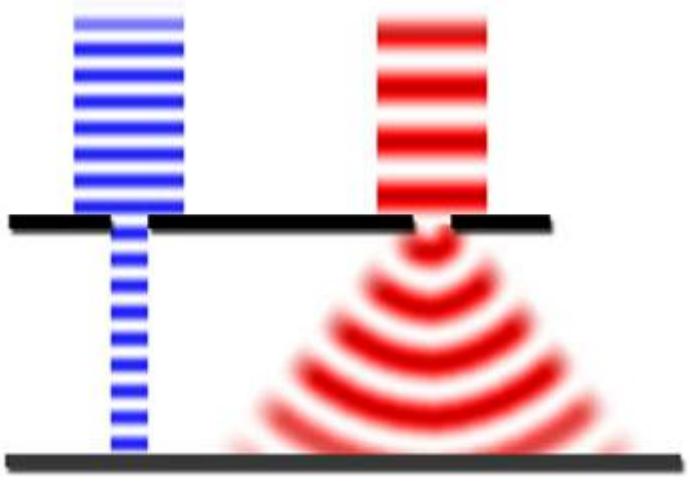


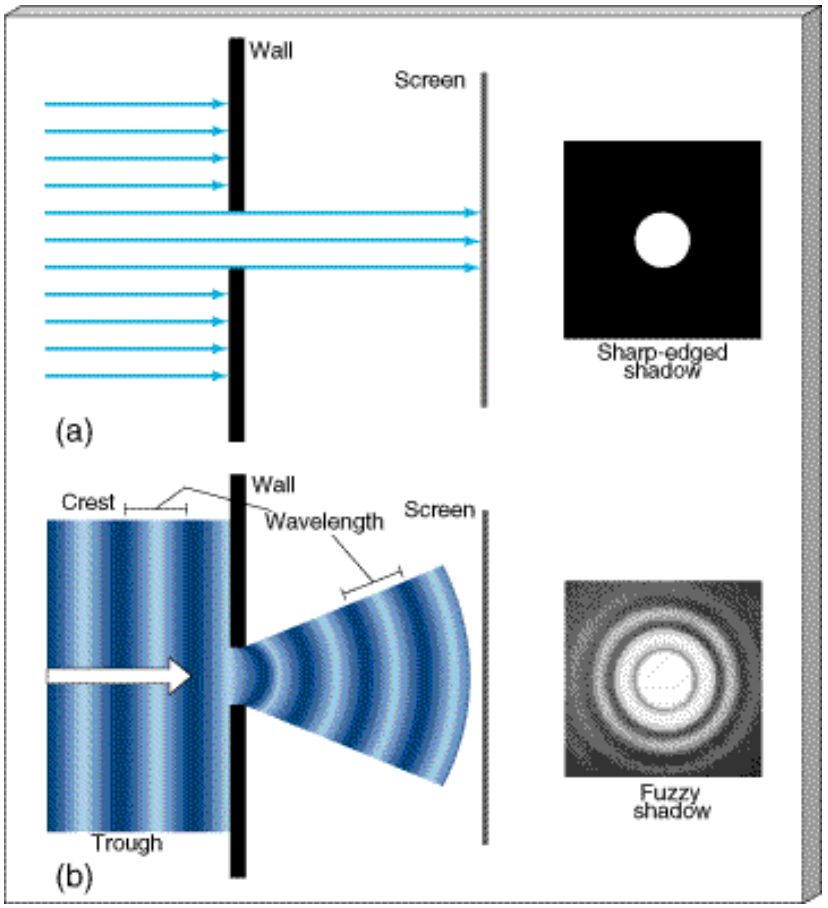
Image diameter = 2.44 λ / D

FWHM ≈ λ / D

(what units?)

Diffraction

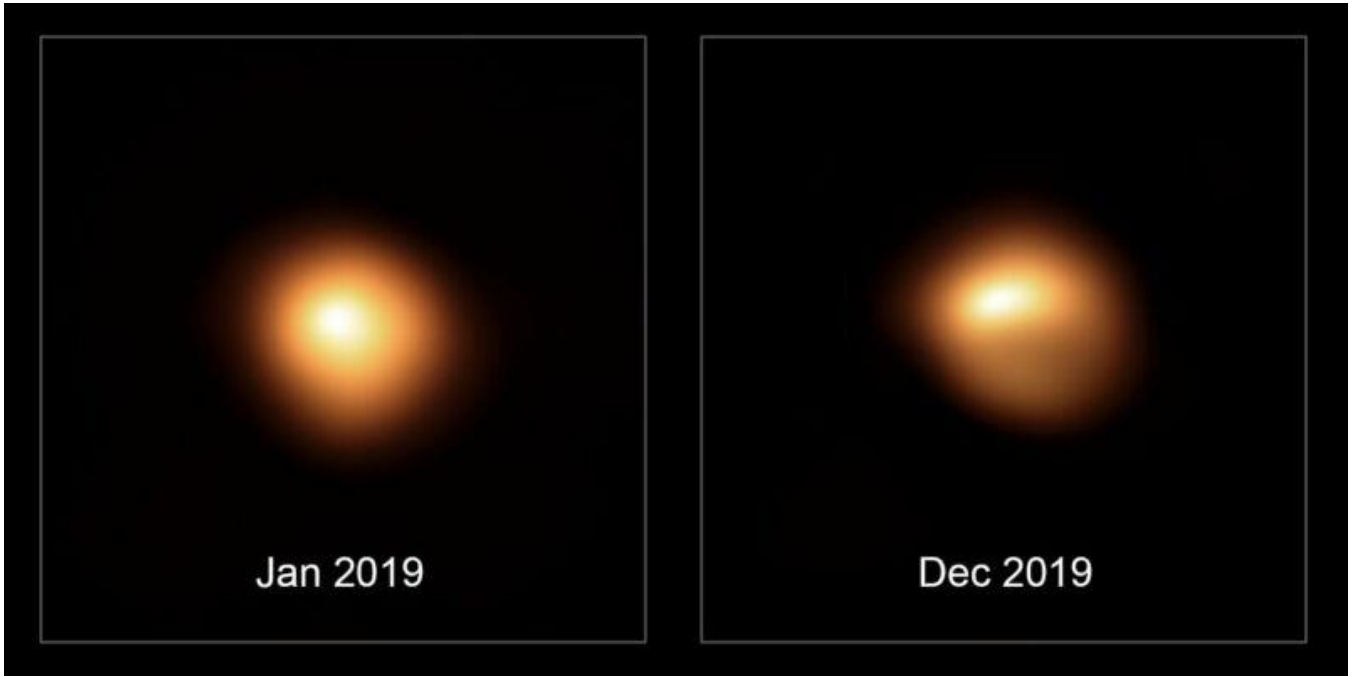




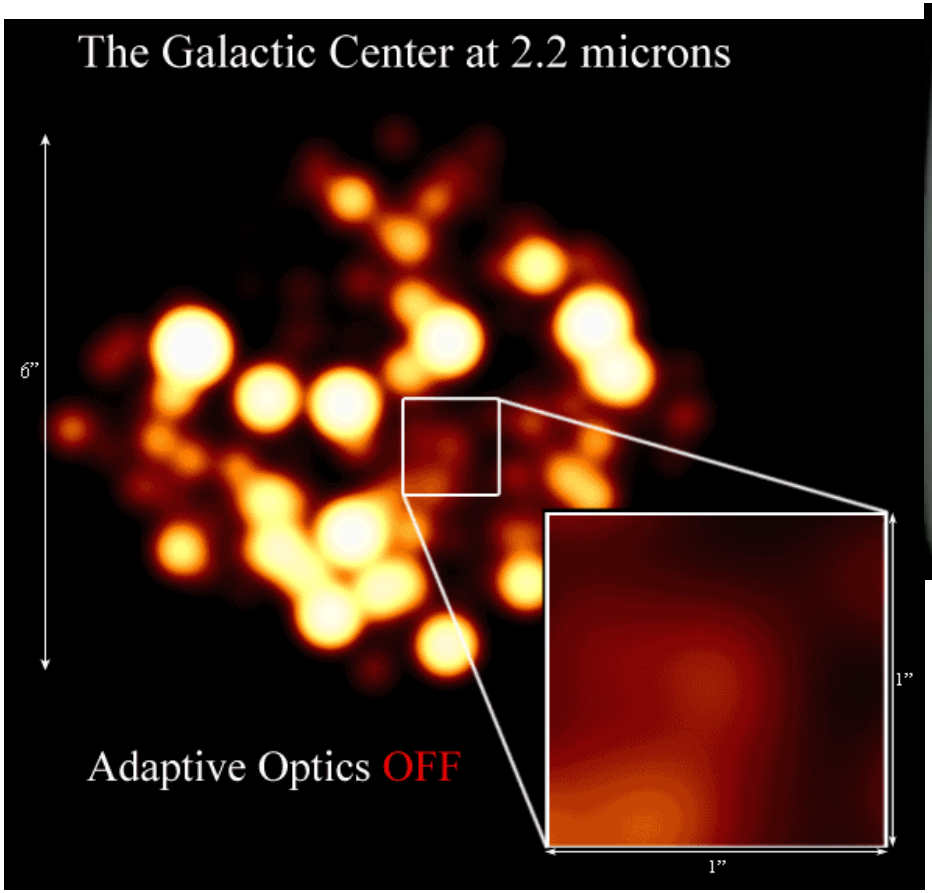
In the News
Betelgeuse

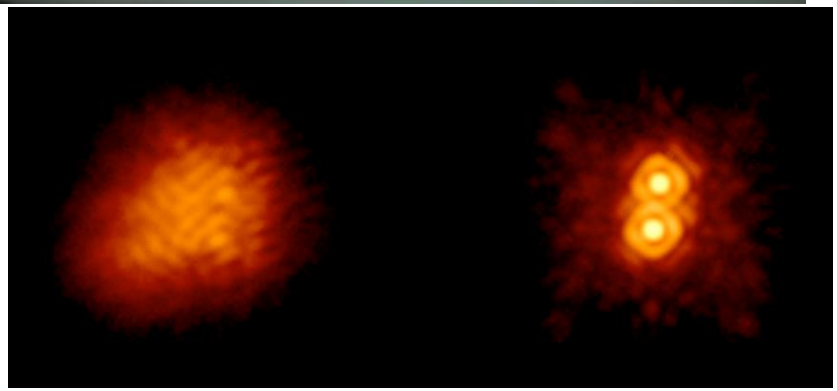
Calculate theoretical angular resolution (FWHM arcsec) for 8.2 m telescope at λ = 645 nm

Calculate expected angular diameter (arcsec) of the star given distance = 220 pc and R ≈ 1000 R_{Sun}

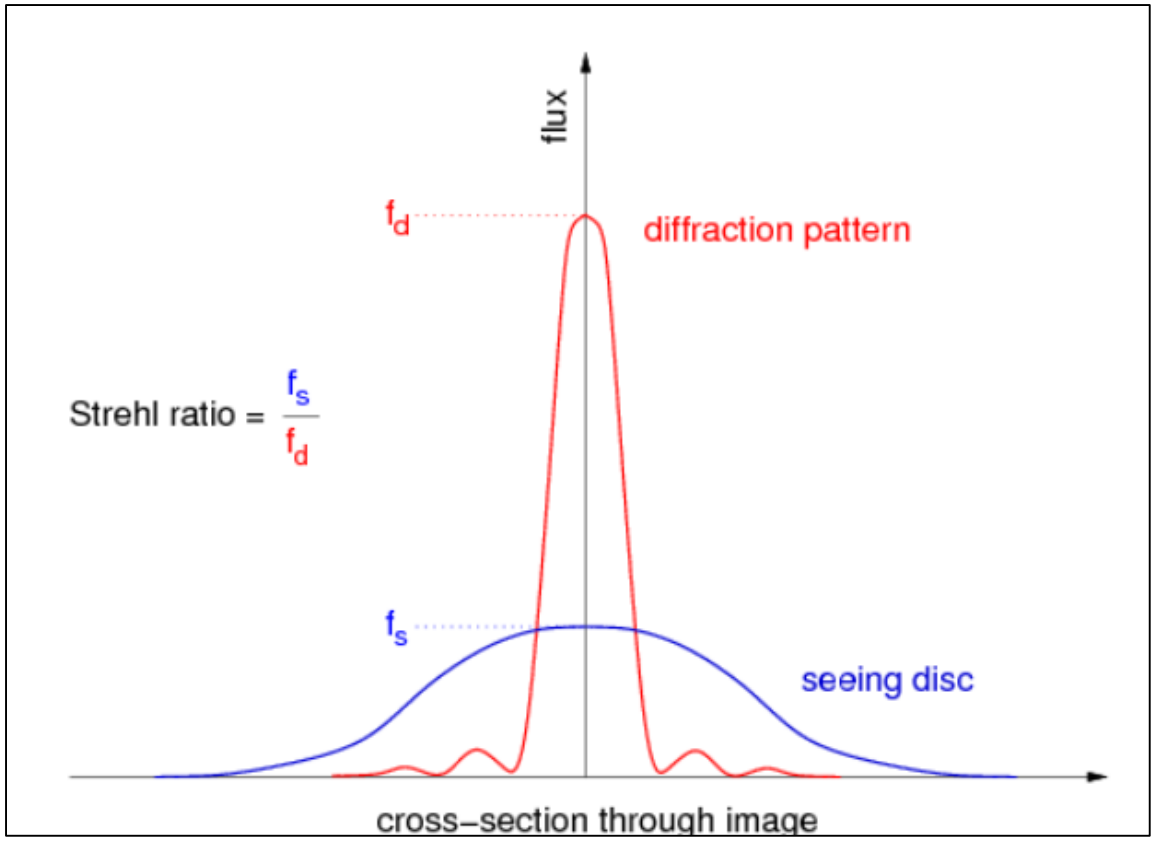


Adaptive Optics
"removing" atmospheric blurring





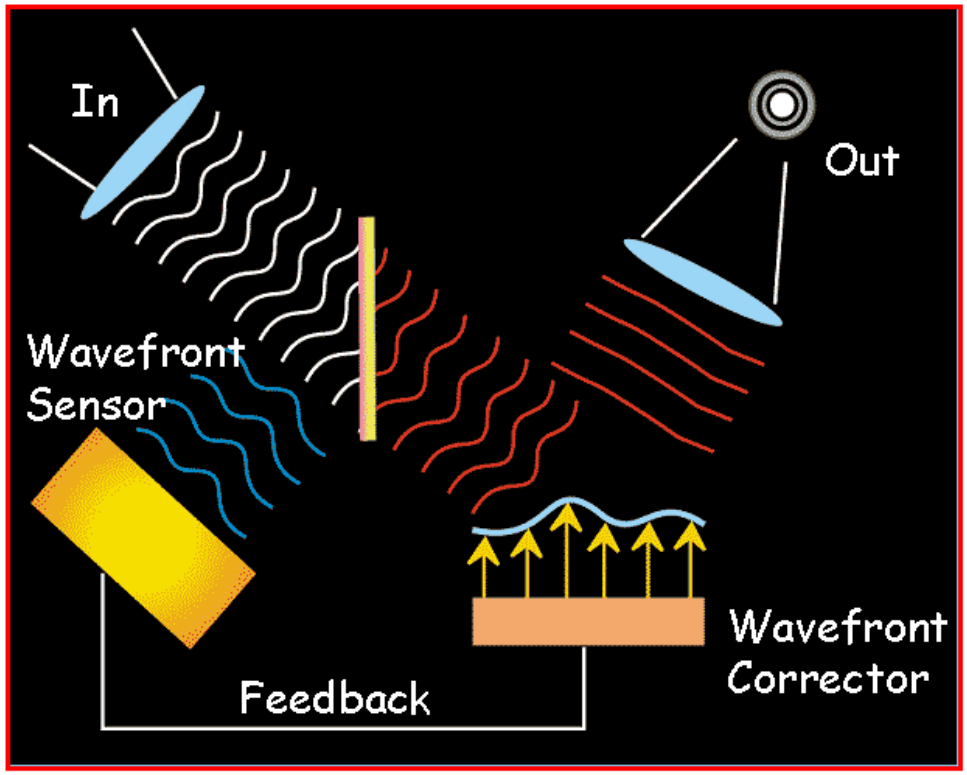
“Strehl Ratio”
a measure of image quality

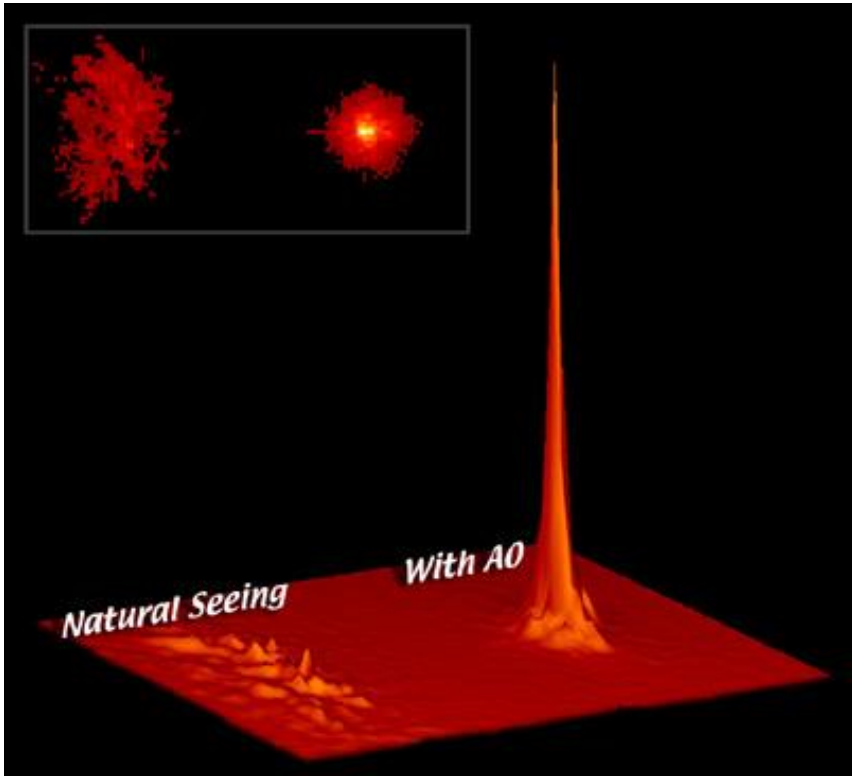


How much more concentrated would light from a star’s AO-image be than the seeing-limited image?

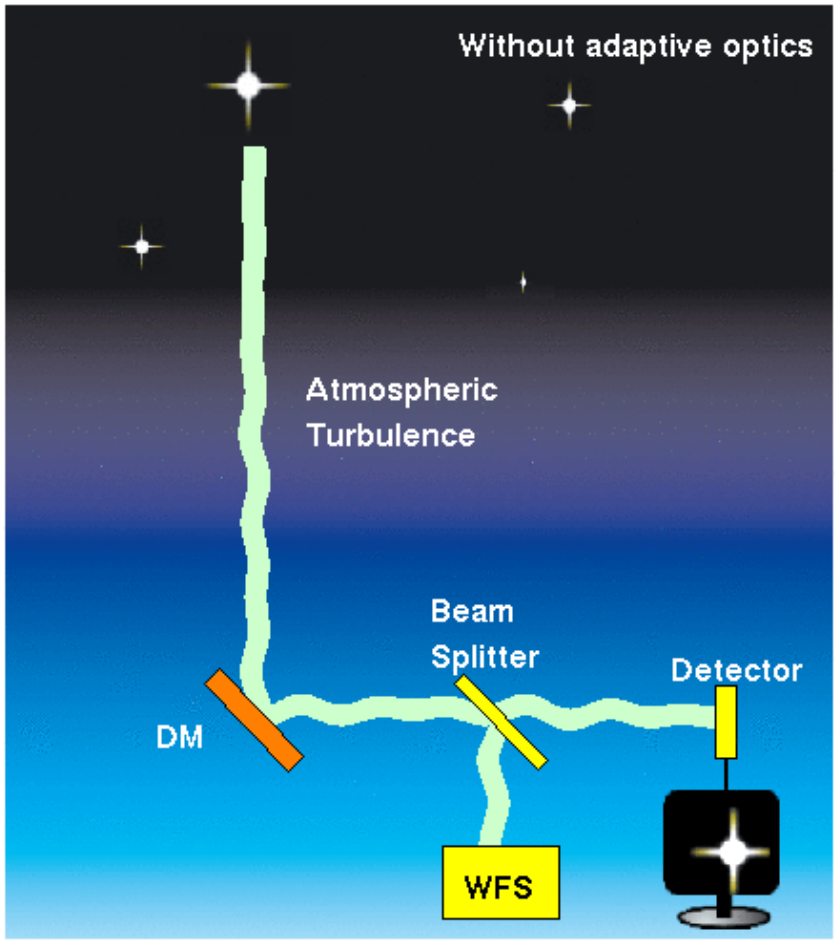
<u>Assume</u>:
D = 8.2 meters
FWHM seeing = 1”
FWHM Airy = λ / D

Adaptive Optics

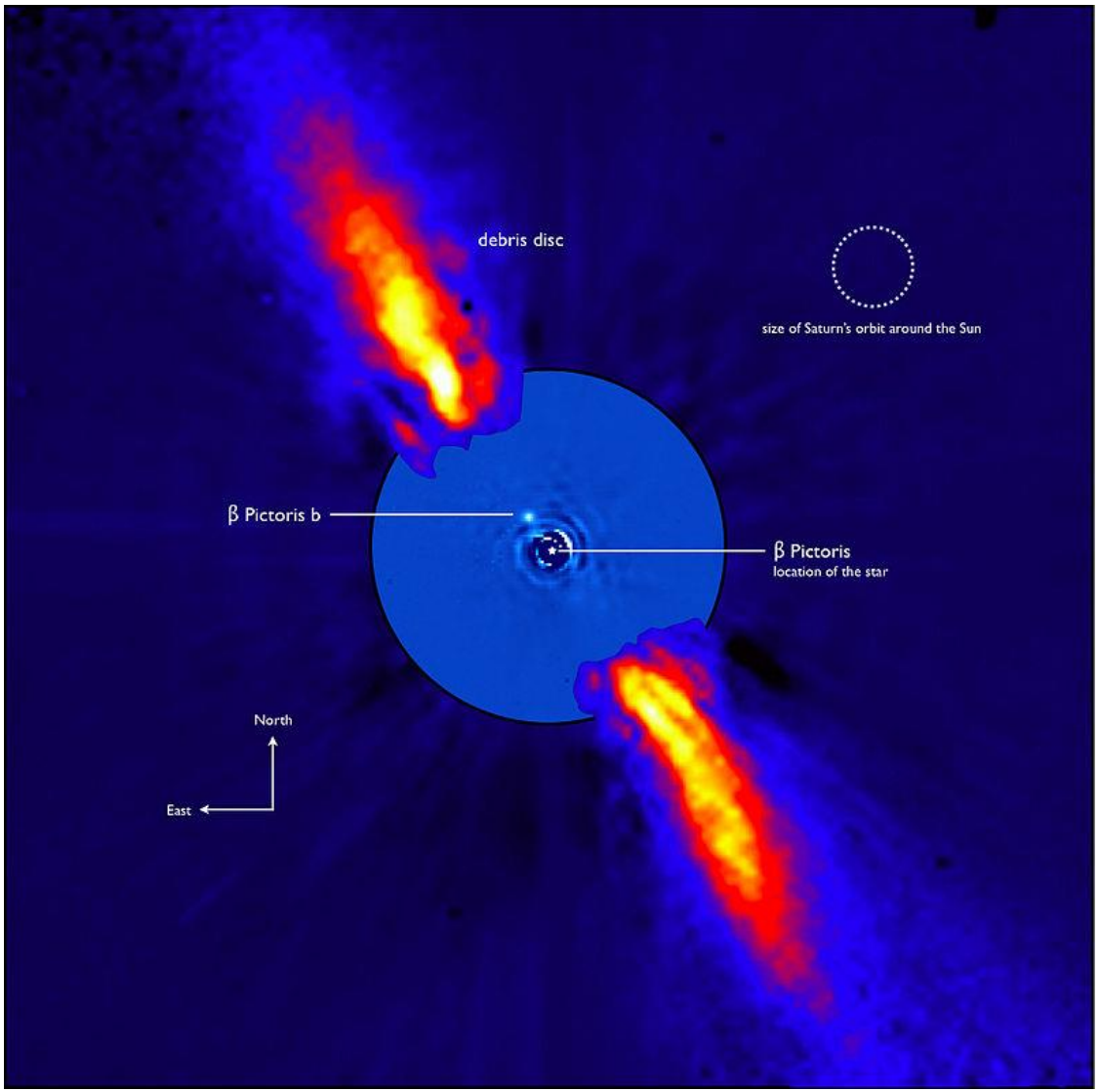




AO in Action

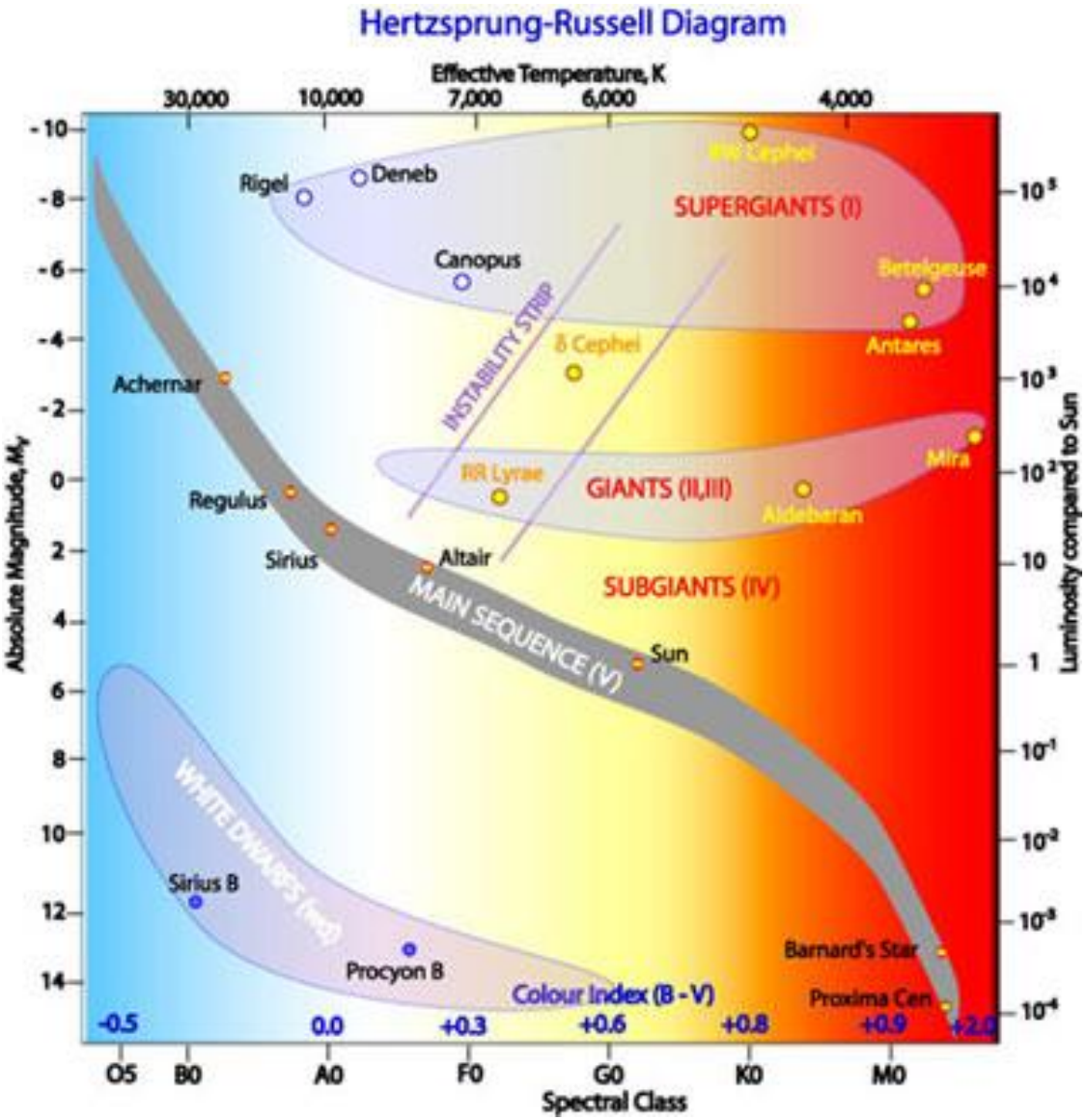

Without adaptive optics
Atmospheric
Turbulence
Beam
Splitter
Detector
DM
WFS

β Pic b
"coronagraphs"

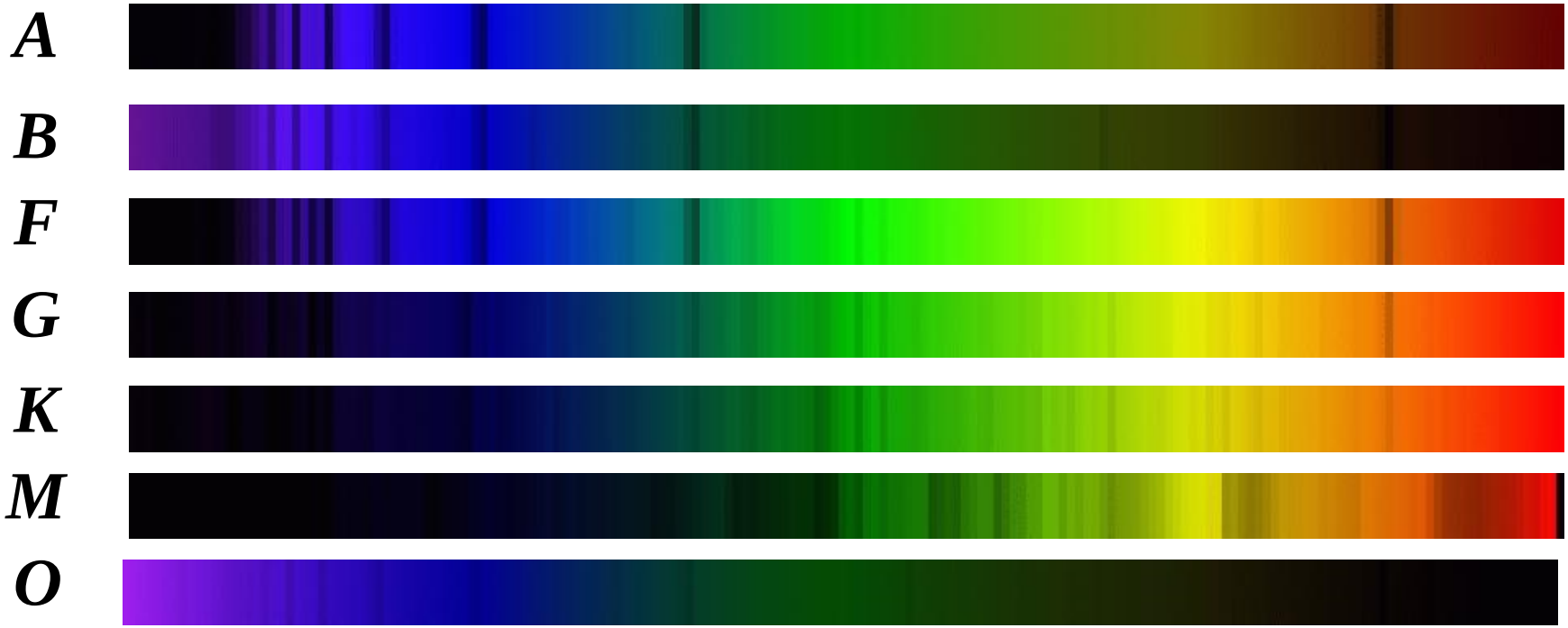


Take a Break from Telescopes

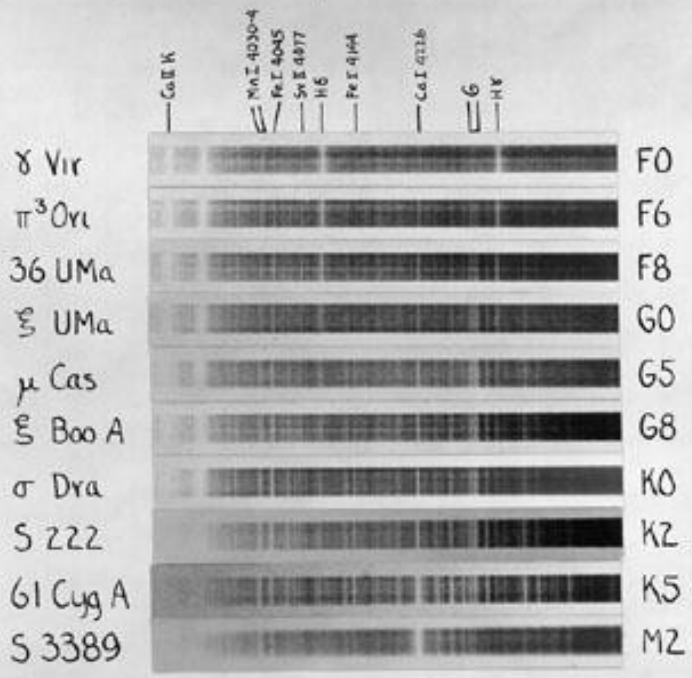
The Hertzsrpung-Russell Diagram



Stellar “Spectral Types”



Main Sequence F0 - M2



All stars illustrated are of luminosity class V
Cramer Hi-Speed Special.

Cecilia Payne-Gaposchkin
1900-1979

She showed that the spectral sequence was in order of stellar temperature.

Stars are made almost entirely of hydrogen and helium even though their spectra don't always show strong lines of these elements.

<u>STARS</u>: 90% hydrogen, 9% helium, trace of heavier elements ("metals")

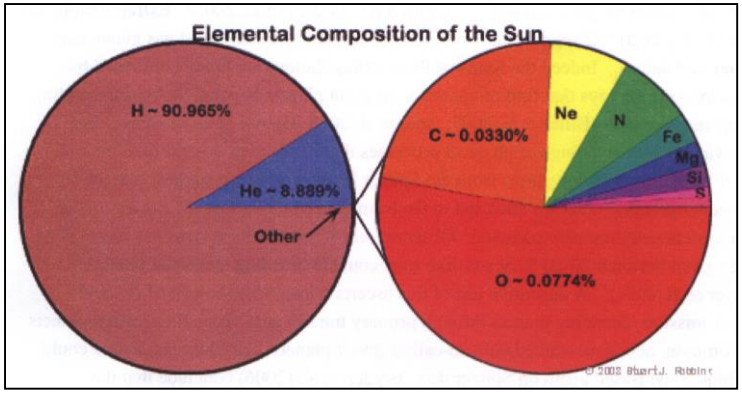
New discoveries in physics:

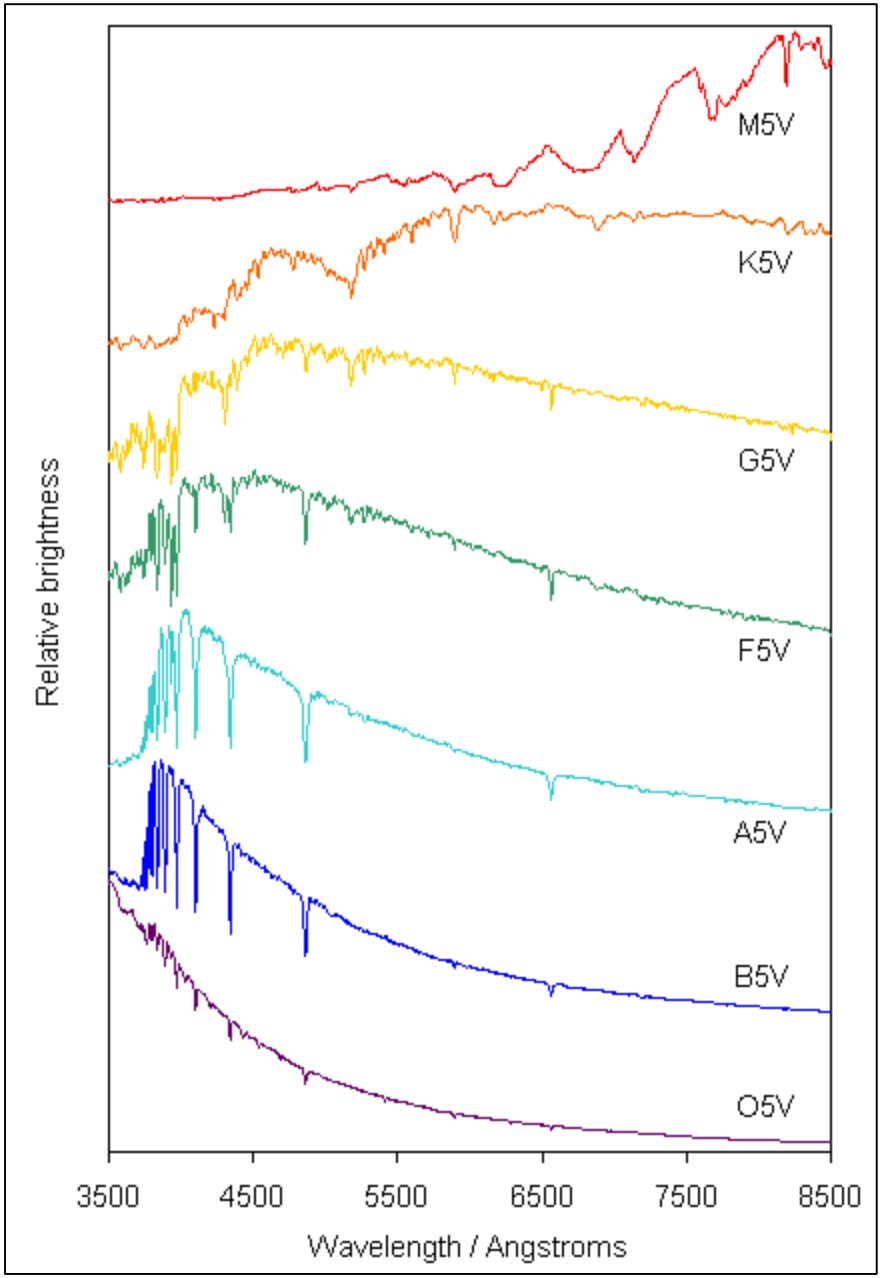
1. nuclei of atoms

2. fixed orbits of electrons;

3. different number of electrons for each element;

4. temperature can affect number of spectral lines.

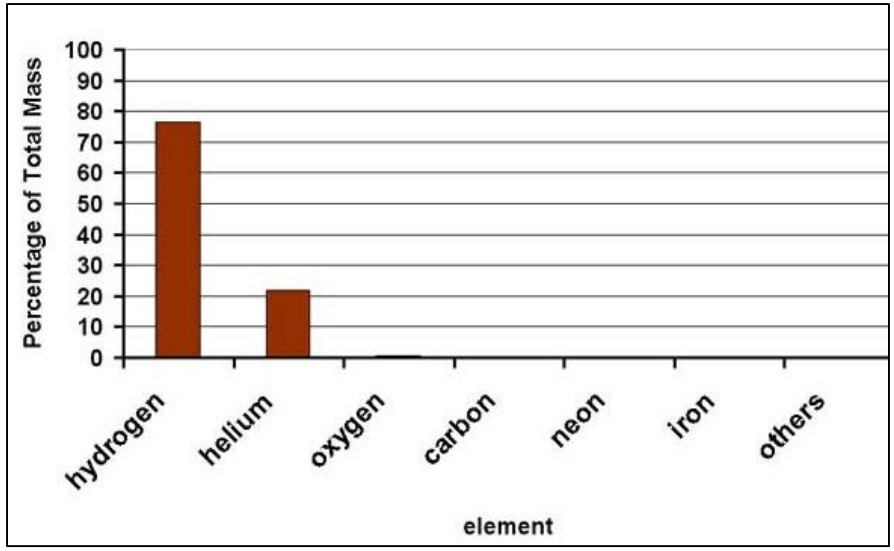




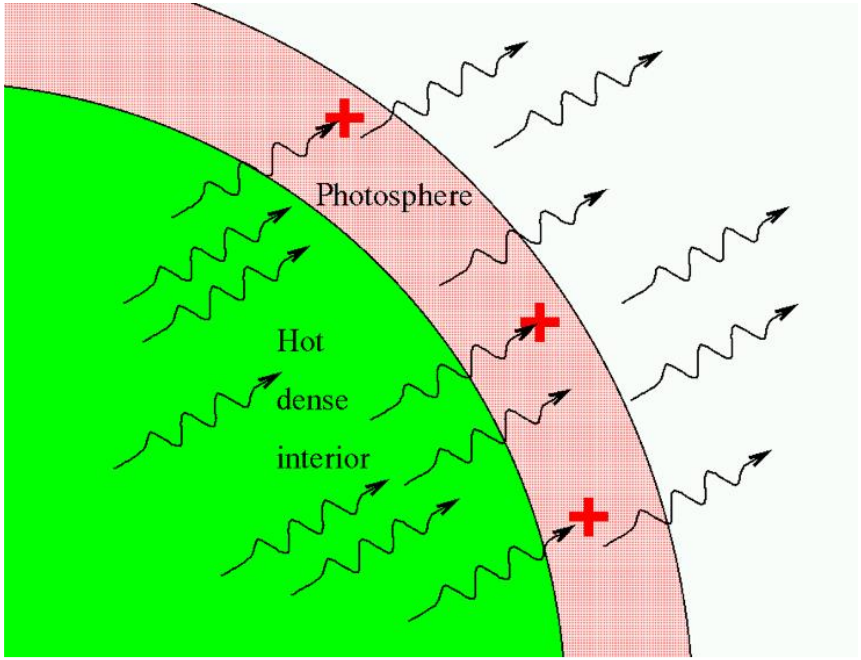
Real Spectra

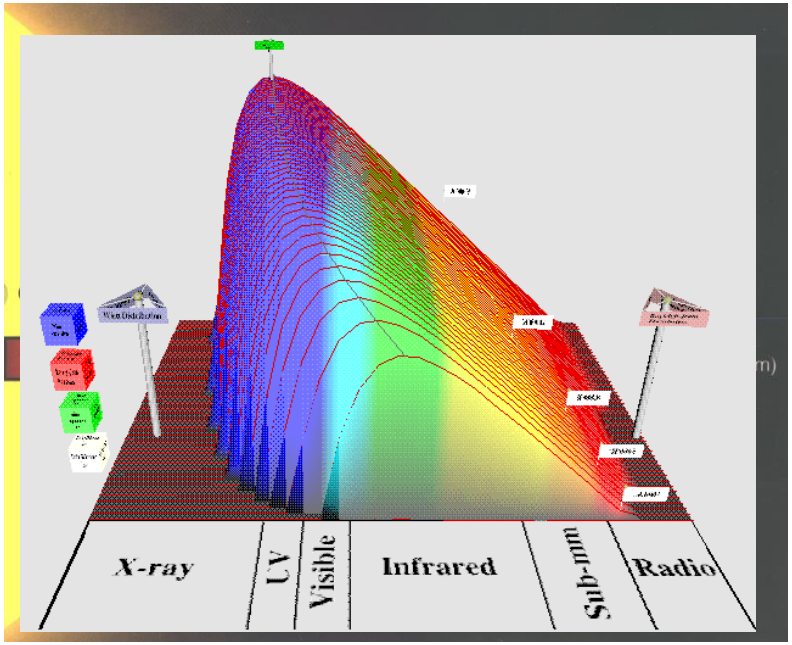
You will encounter such spectra in Homework #18.

Fit blackbody profile to real stellar spectra.



Put These Concepts Together
What causes absorption lines?

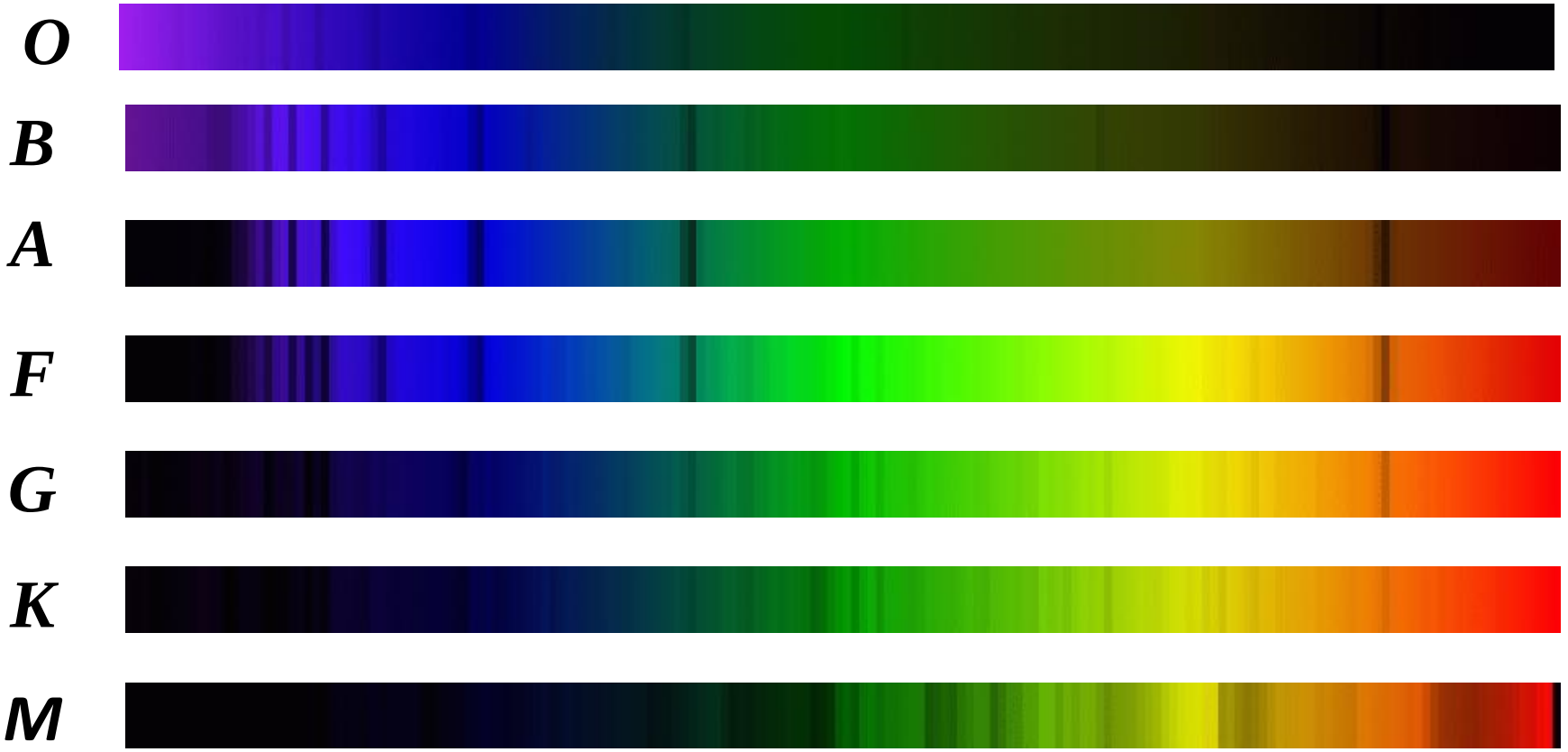




The hotter the object, the bluer its peak wavelength and the more light it emits.

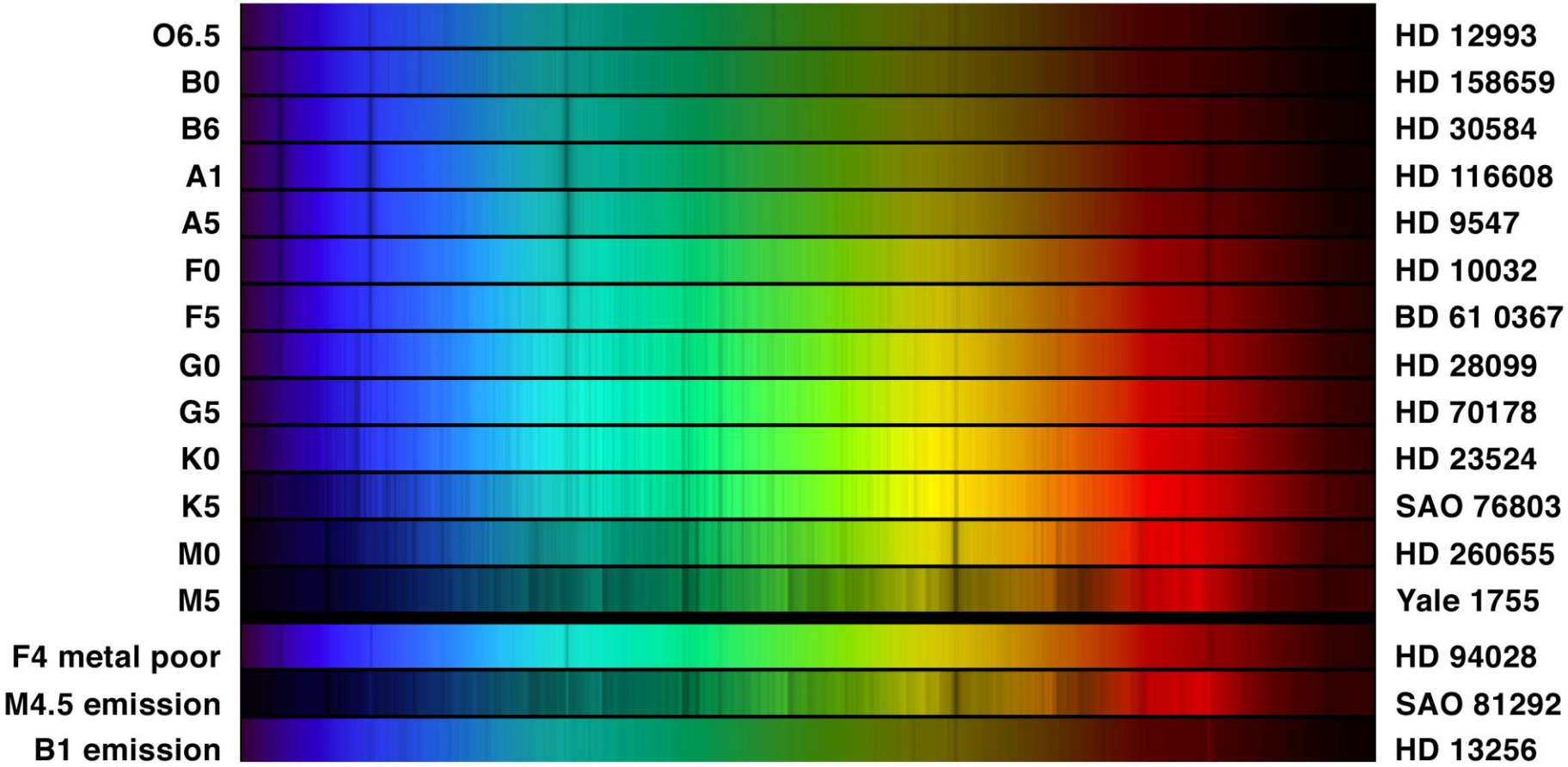
$$\lambda_{peak} = \frac{\text{constant}}{T} \quad \text{in nanometers}$$

The Spectral Sequence (Temperature) is continuous (i.e., very smooth)

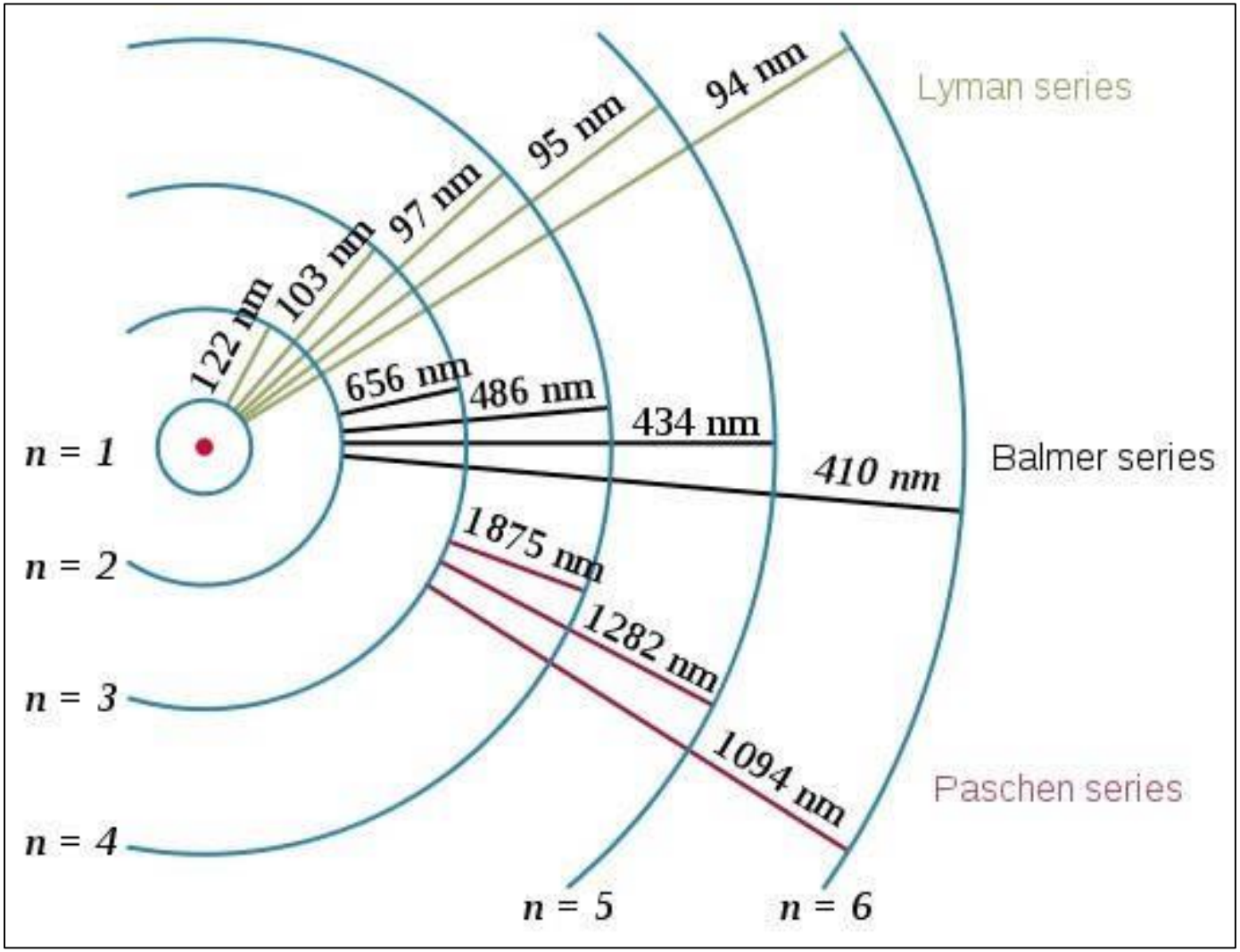


“Oh, Be A Fine Girl (or Guy) Kiss Me!”
“Only Boys Accepting Feminism Get Kissed Meaningfully.”
“One Bug Ate Five Green Killer Moths.”

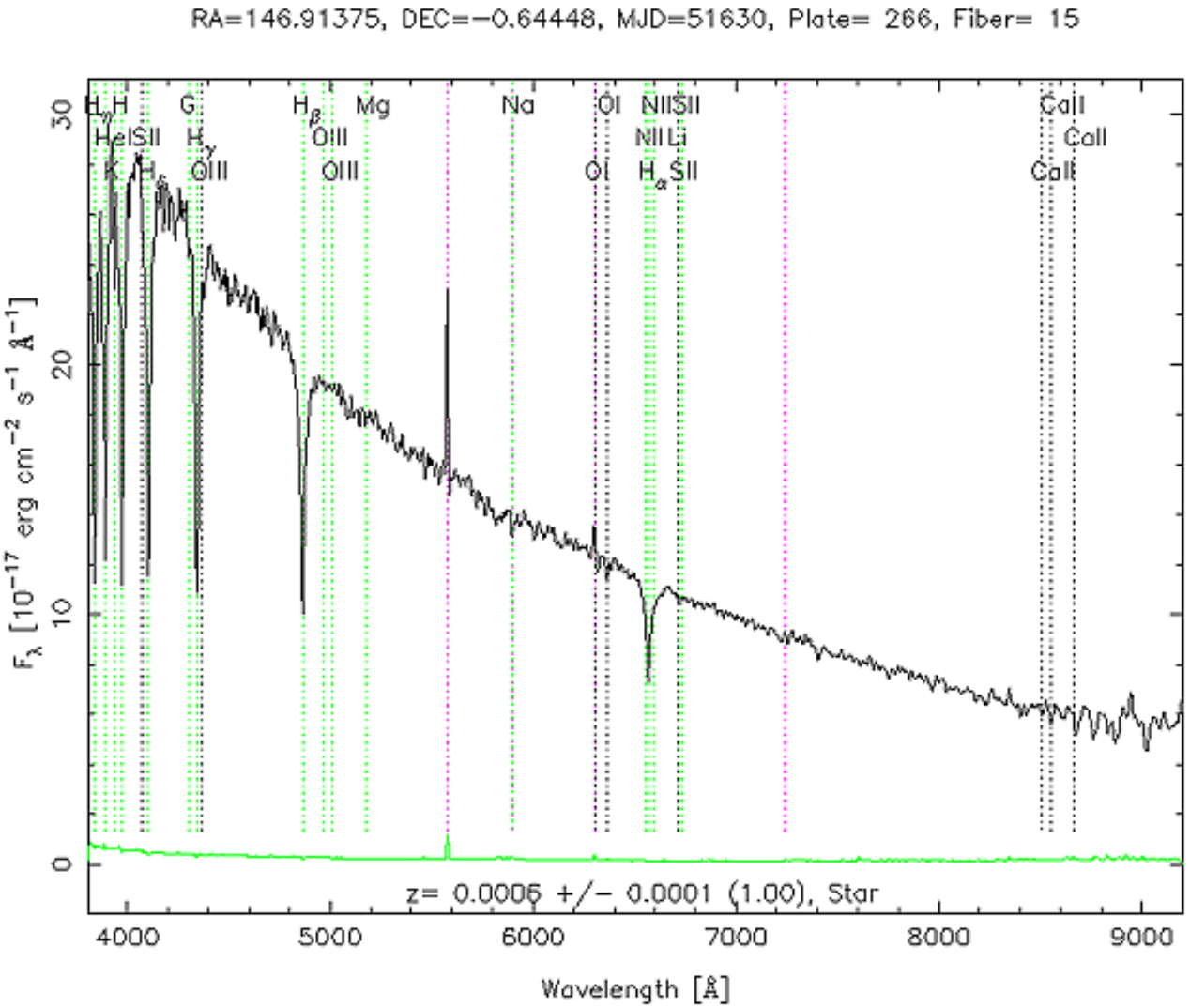
The Spectral Sequence (Temperature) is continuous (i.e., very smooth)



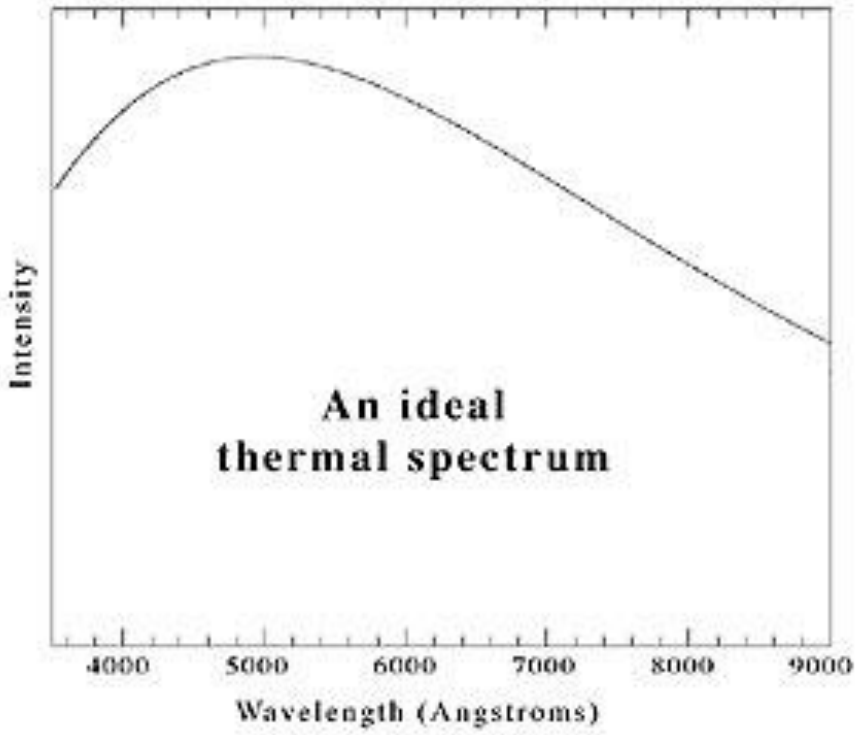
The Hydrogen Atom

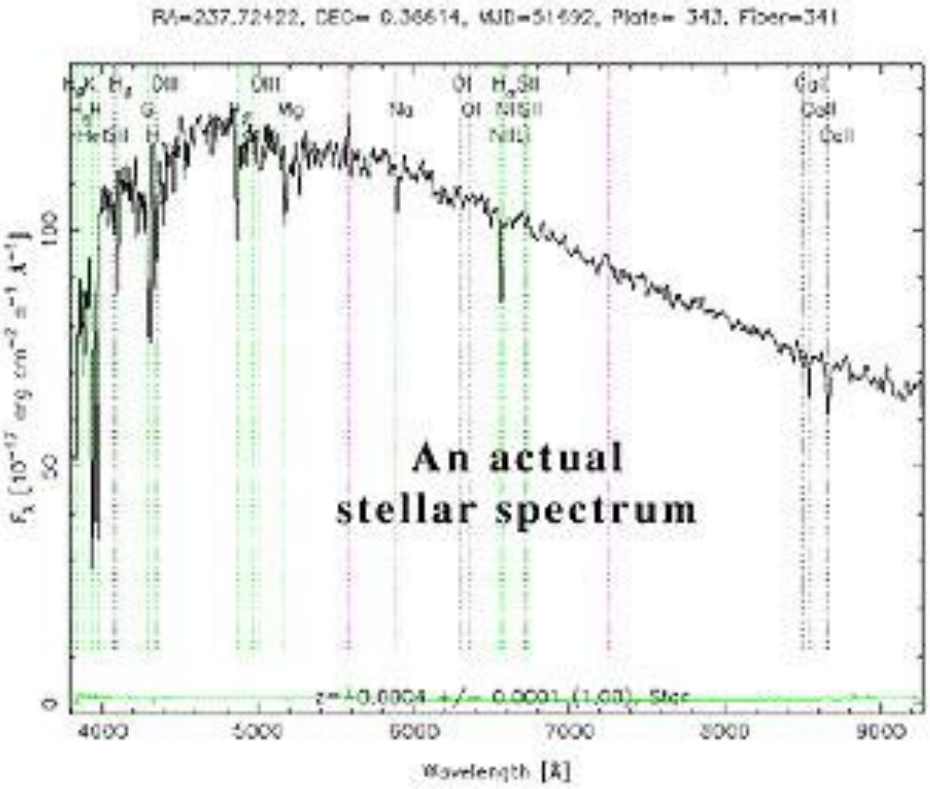


Homework #18
classify a spectrum from the SDSS

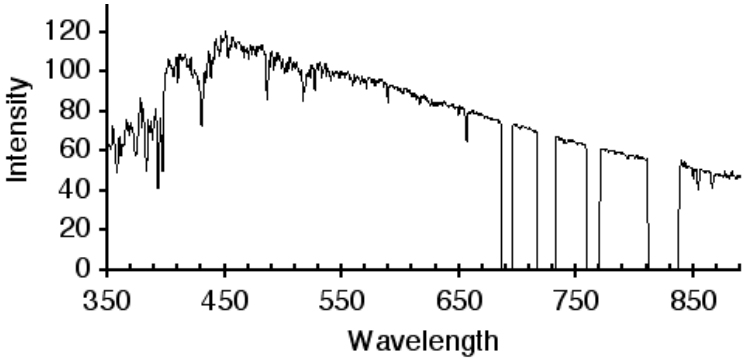


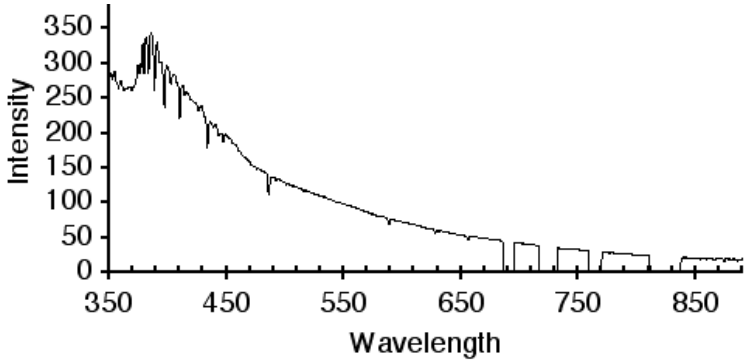
What primarily does the "absorbing" in the absorption line spectrum of a star?

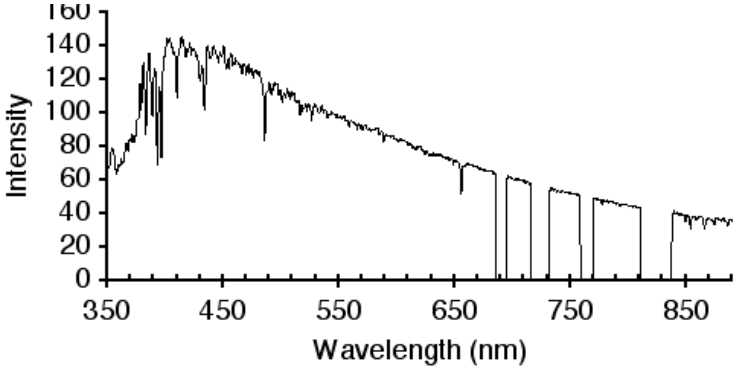




Which of these stars is hottest?

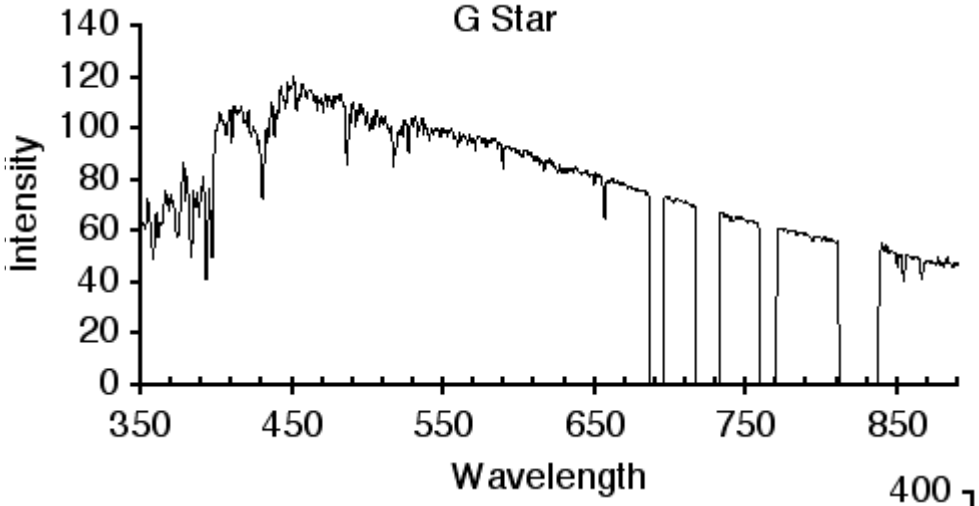


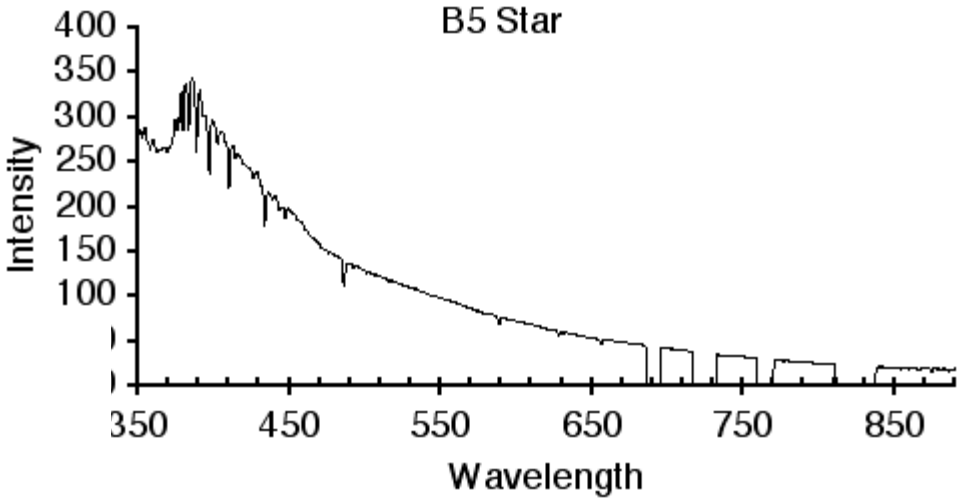


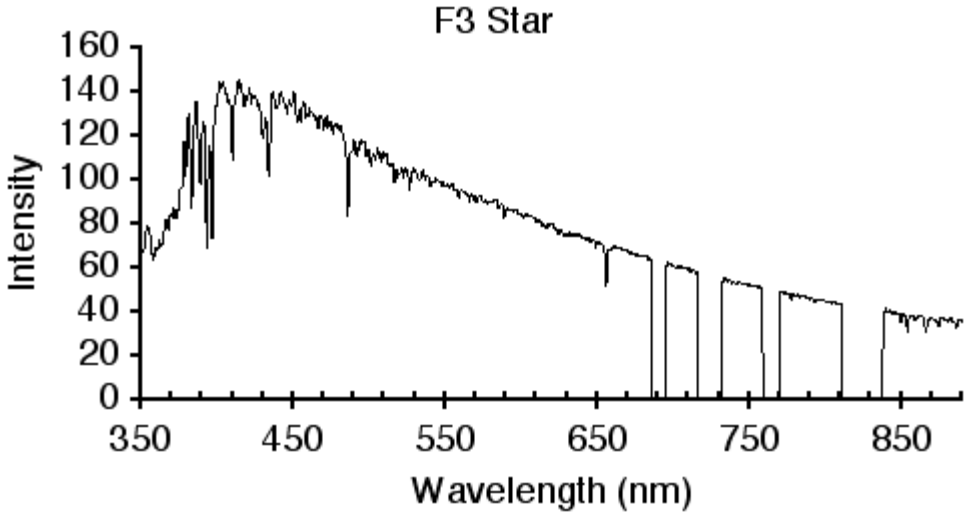


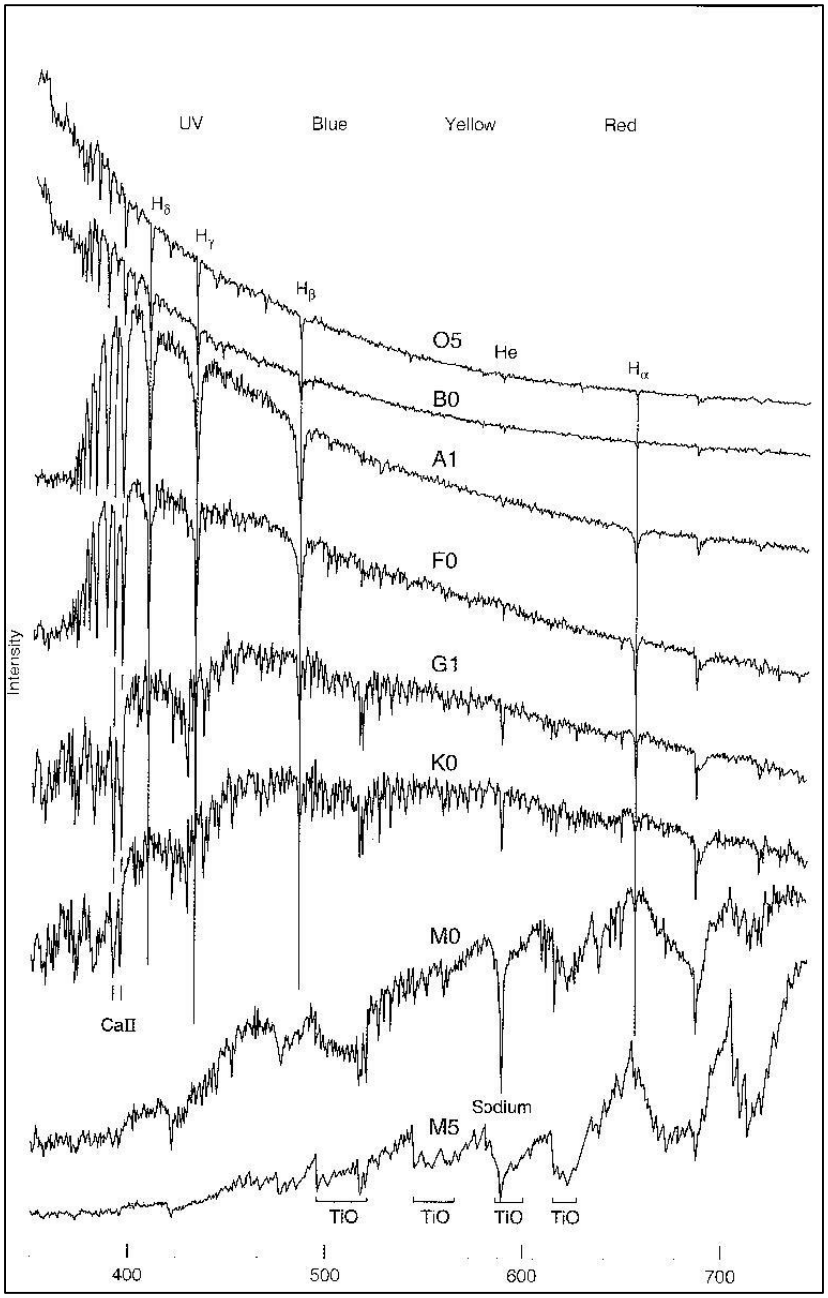
A. Top
B. Middle
C. Bottom

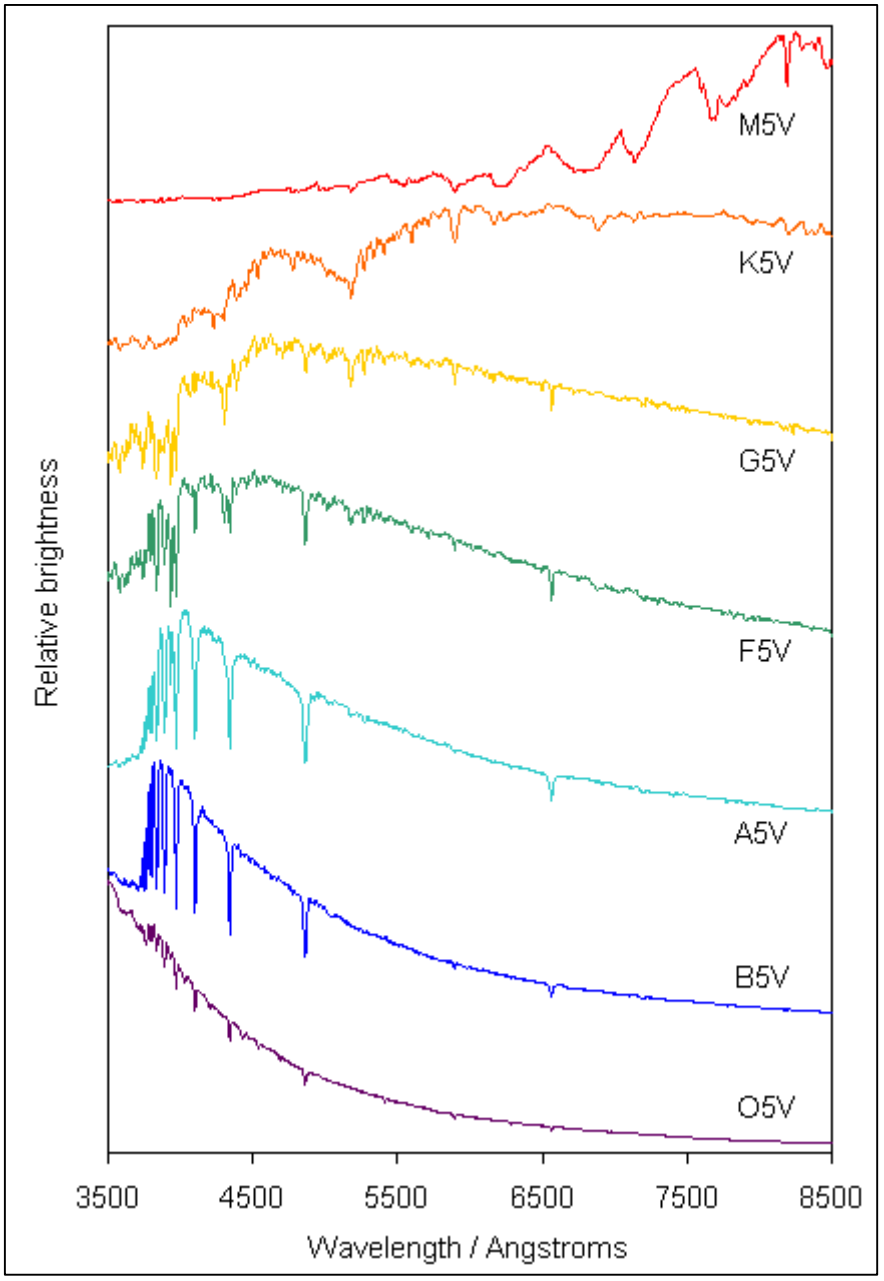
Work together!


G Star
Intensity
140
120
100
80
60
40
20
0
350
450
550
650
750
850
Wavelength


B5 Star
Intensity
400
350
300
250
200
150
100
350
450
550
650
750
850
Wavelength


F3 Star
Intensity
160
140
120
100
80
60
40
20
0
350
450
550
650
750
850
Wavelength (nm)


UV
Blue
Yellow
Red
H_δ
H_γ
H_β
H_α
He
O5
B0
A1
F0
G1
K0
M0
M5
CaII
Sodium
TiO
TiO
TiO
TiO
Intensity
400
500
600
700


M5V
K5V
G5V
F5V
A5V
B5V
O5V
Relative brightness
3500
4500
5500
6500
7500
8500
Wavelength / Angstroms

Homework #18
two classification methods