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# ASTR 4201/5201: STELLAR ASTROPHYSICS AND RADIATION

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# GRADING SCHEME

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## ASTR 4201

- 50% HW
- 20% Midterm
- 30% Final

## ASTR 5201

- 45% HW
  - 20% Midterm
  - 25% Final
  - 10% Project
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# ASTR 520 I PROJECT

- <http://mesa.sourceforge.net>
- Grad students will be using the MESA code and will have a project due at the end of the semester with a presentation the final week.
- Details later, but note that this requires access to a Mac or Linux computer.

The screenshot shows a web browser window with the URL "mesa.sourceforge.net" in the address bar. The page title is "MESA home". On the left, there's a sidebar with a "MESA" logo and links to "MESA home", "code capabilities", "prereqs & installation", "getting started", "using pgstar", "MESA output", "beyond inlists (extending MESA)", "troubleshooting", and "FAQ". The main content area features a large blue "MESA" logo. Below it, a text block says: "You may also want to visit [the MESA community portal](#), where users share the inlists from their published results, tools & utilities, and teaching materials." A section titled "Why a new 1D stellar evolution code?" discusses the MESA Manifesto and its key points. Another section at the bottom talks about stellar evolution calculations. On the right, there's a "Latest News" sidebar with a list of recent updates:

- 10 Aug 2016  
» [Documentation Archive](#)
- 19 Jun 2016  
» [Release 8845](#)
- 03 Feb 2016  
» [Release 8118](#)
- 29 Jan 2016  
» [New MESA SDK Version](#)
- 10 Jan 2016  
» [Summer School 2016](#)
- 27 Sep 2015  
» [Instrument Paper 3](#)
- 14 Sep 2015  
» [MESA-Web Updates](#)
- 08 Sep 2015  
» [New MESA SDK Version](#)
- 03 Sep 2015  
» [Updated MESA Maps](#)

# WHAT WILL WE COVER?

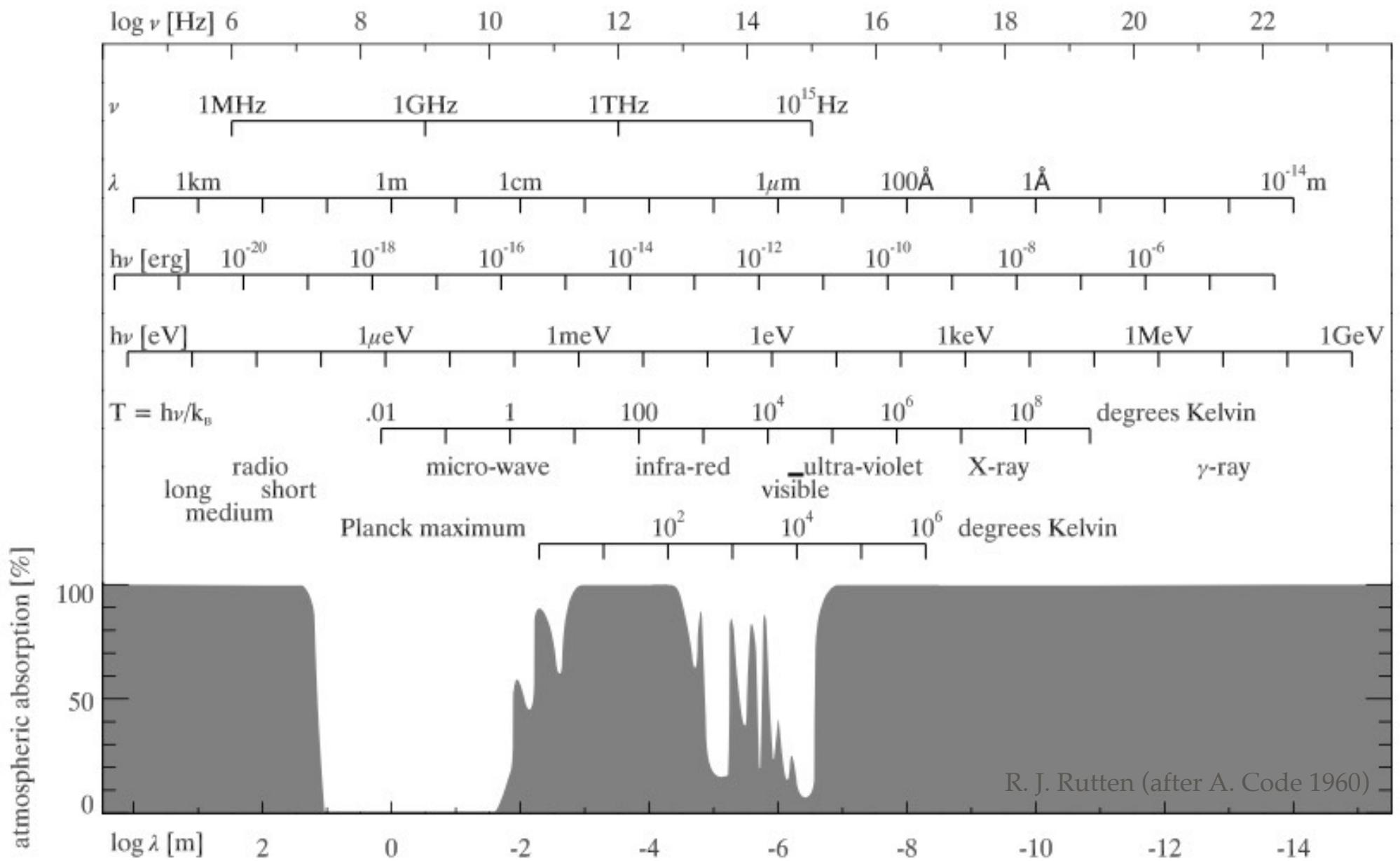
**Course Description:** Introduction to radiative transfer, including radiation mechanisms, and formation of spectral lines; discusses the physics of the cold interstellar medium and its relationship to star formation; and provides an overview of stellar evolution and stellar remnants, including white dwarfs, supernovae, and neutron stars.

- Radiative transfer and mechanisms
- Stellar structure
- Stellar evolution

# UNITS

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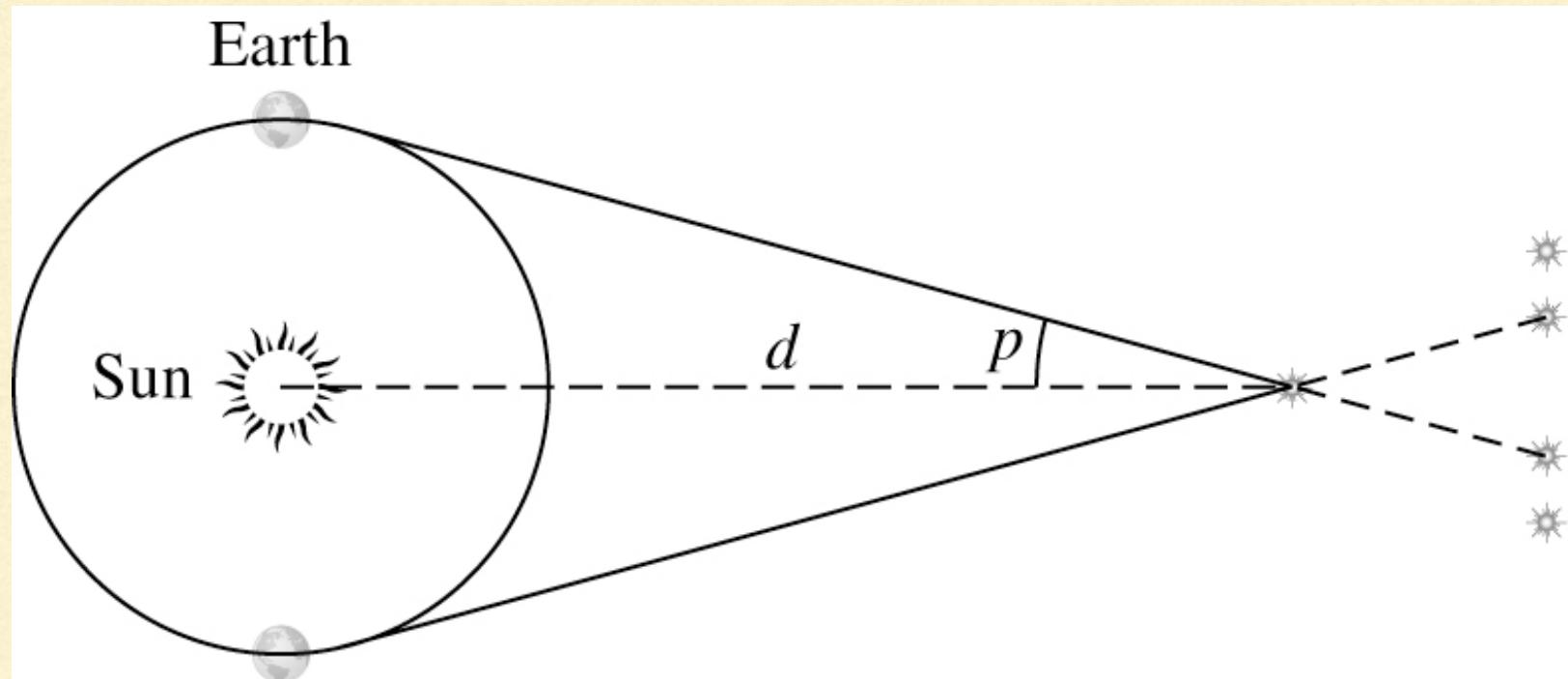
- Astronomers frequently use cgs (e.g.,  $10^7 \text{ erg} = 1 \text{ J}$ )
    - Note: Carroll & Ostlie use SI (so I will try to standardize on that), but RL and HKT use cgs
  - $1 M_{\odot} = 1.99 \times 10^{33} \text{ g} = 1.99 \times 10^{30} \text{ kg}$
  - $1 L_{\odot} = 3.8 \times 10^{33} \text{ erg/s} = 3.8 \times 10^{26} \text{ W}$
  - $1 R_{\odot} = 6.96 \times 10^{10} \text{ cm} = 6.96 \times 10^8 \text{ m}$
  - $T_{\odot} = 5777 \text{ K}$
-



For UV/optical wavelengths, we use  $1 \text{\AA} = 0.1 \text{ nm} = 10^{-10} \text{ m}$   
 (so middle of the visible range is  $\sim 5500 \text{\AA}$ )

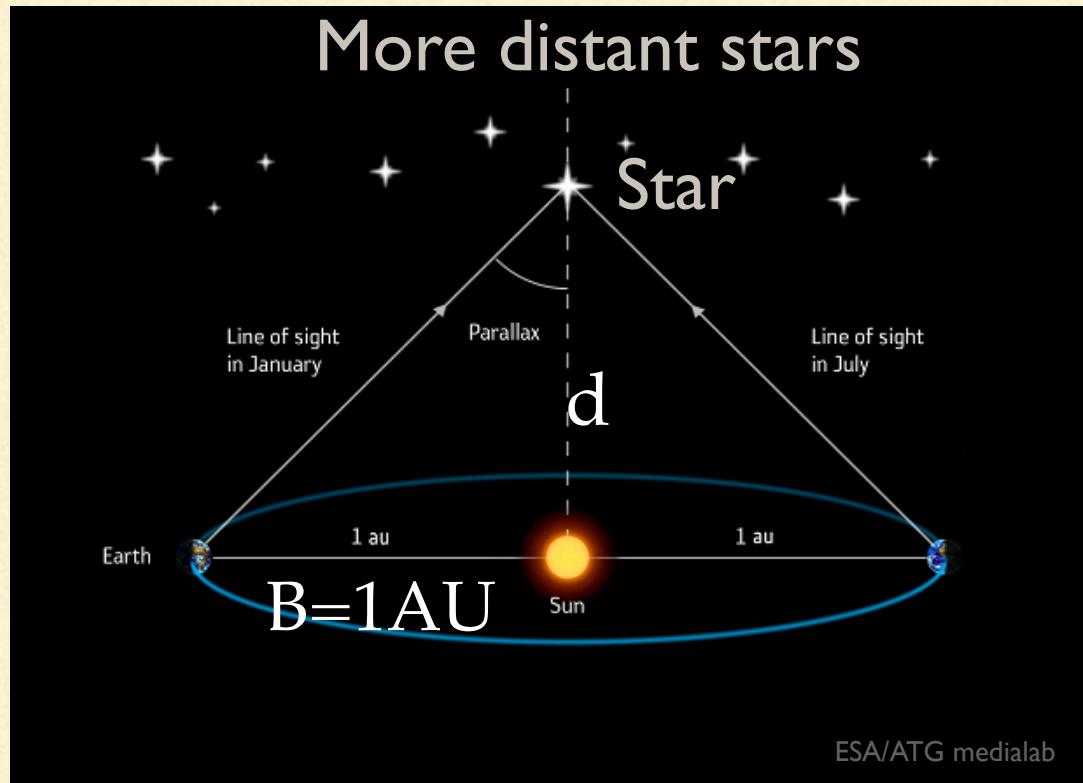
Note:  $k \sim 8.617 \times 10^{-5} \text{ eV K}^{-1}$  and thus where  $kT$  falls

# PARALLAX



- The positions of nearby stars move relative to more distant stars due to the Earth's orbit around the Sun
- The largest measured parallax (for the nearest star) is 0.77 arc seconds =  $0.0002^\circ$
- 1 circle = 360 degrees ( $^\circ$ )   1 degree = 60 arcminutes ( $'$ )   1 arcminute = 60 arcseconds ( $''$ )

# TRIGONOMETRIC PARALLAX



$$\tan(p) = B/d \approx p \quad \text{so} \quad d = B/p \quad (B=1\text{AU}=1.5 \times 10^{11} \text{ m})$$

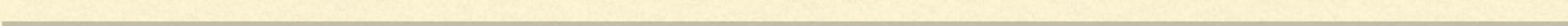
$$d(\text{pc}) = 1/p(\text{"})$$

parsec = parallax arcsecond

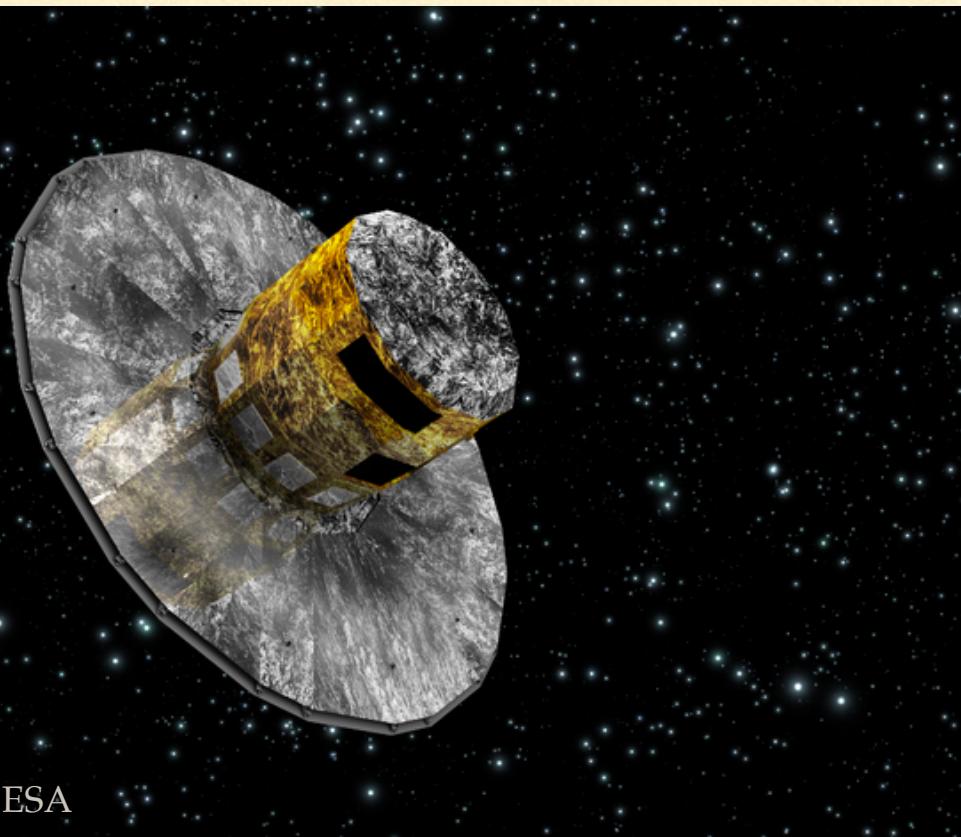
# DISTANCES

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- A standard unit of distance is the *parsec*.
- $1 \text{ pc} = 3.26 \text{ light-year} = 3.09 \times 10^{16} \text{ m}$
- Sun = 8 kpc from Galactic center;  
nearest galaxy (Sagittarius dwarf) is  $\sim$ 20 kpc;  
nearest big galaxy is M31=Andromeda galaxy at about 780 kpc from us



# GAIA



ESA

- Launched in 2013 for a 5 yr main mission
- First data release scheduled for September 14th!
- Will measure parallaxes to  $\sim 10^9$  stars ( $\sim 1\%$  of the Galaxy)
- Precision of  $\sim 20$   $\mu$ arcsec.
- Previous standard was Hipparcos ( $10^5$  stars with 1 milliarcsec precision)

# LUMINOSITY AND FLUX

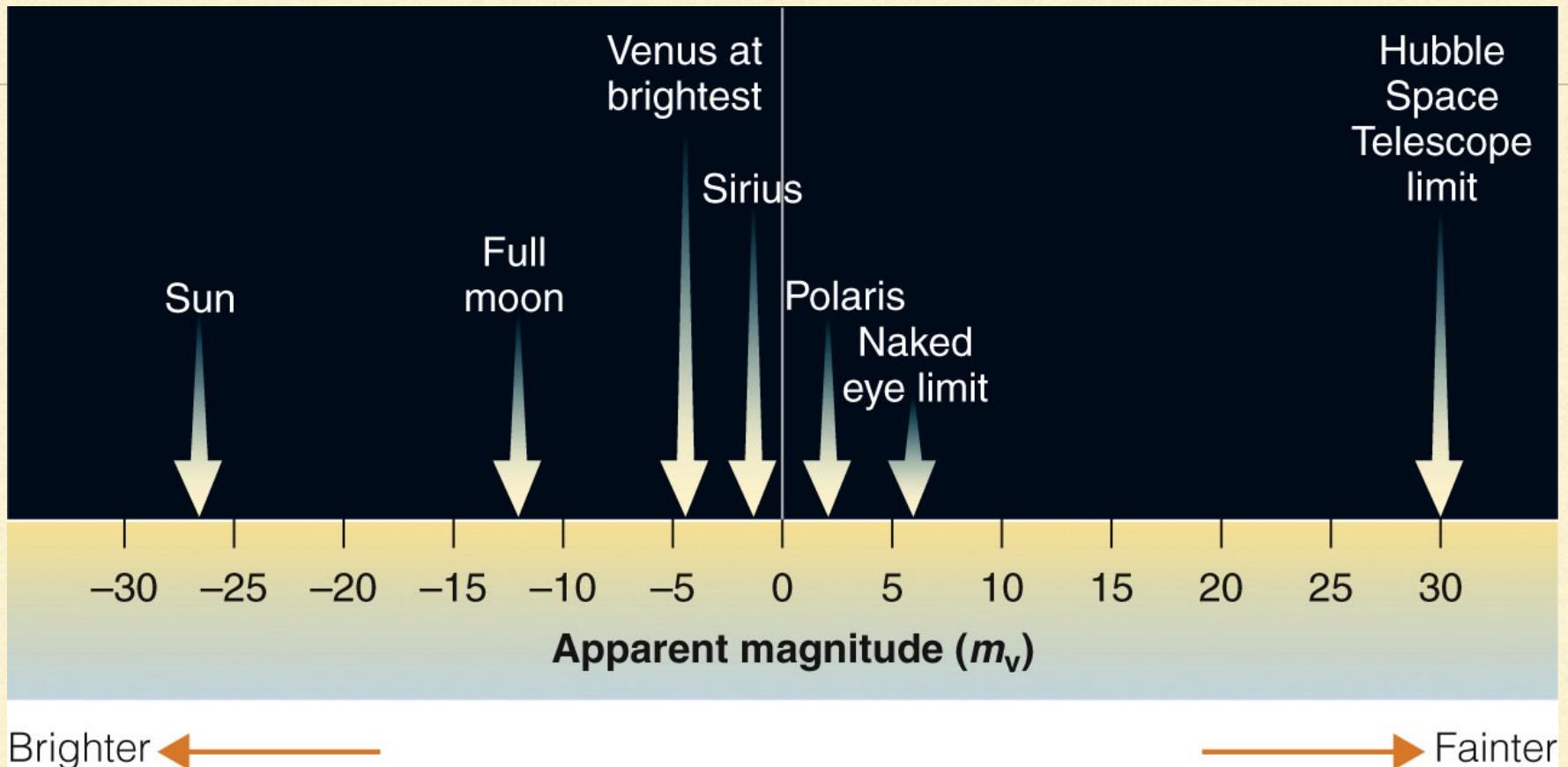
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- Luminosity = Energy emitted per unit time (intrinsic quantity of source)
- Flux = Energy per unit time per unit area passing through our detector (i.e., inverse square law:  $F=L/4\pi d^2$ )
- Magnitudes:  $-2.5 \log_{10}(\text{flux}) + \text{constant}$

A common choice of normalization is that  $m(\text{Vega})=0$

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# APPARENT MAGNITUDES



- Logarithmic: 2.5 mags = factor of 10 in flux, smaller numbers are brighter
- usually denoted by lowercase  $m$
- Blame the ancient Greeks!

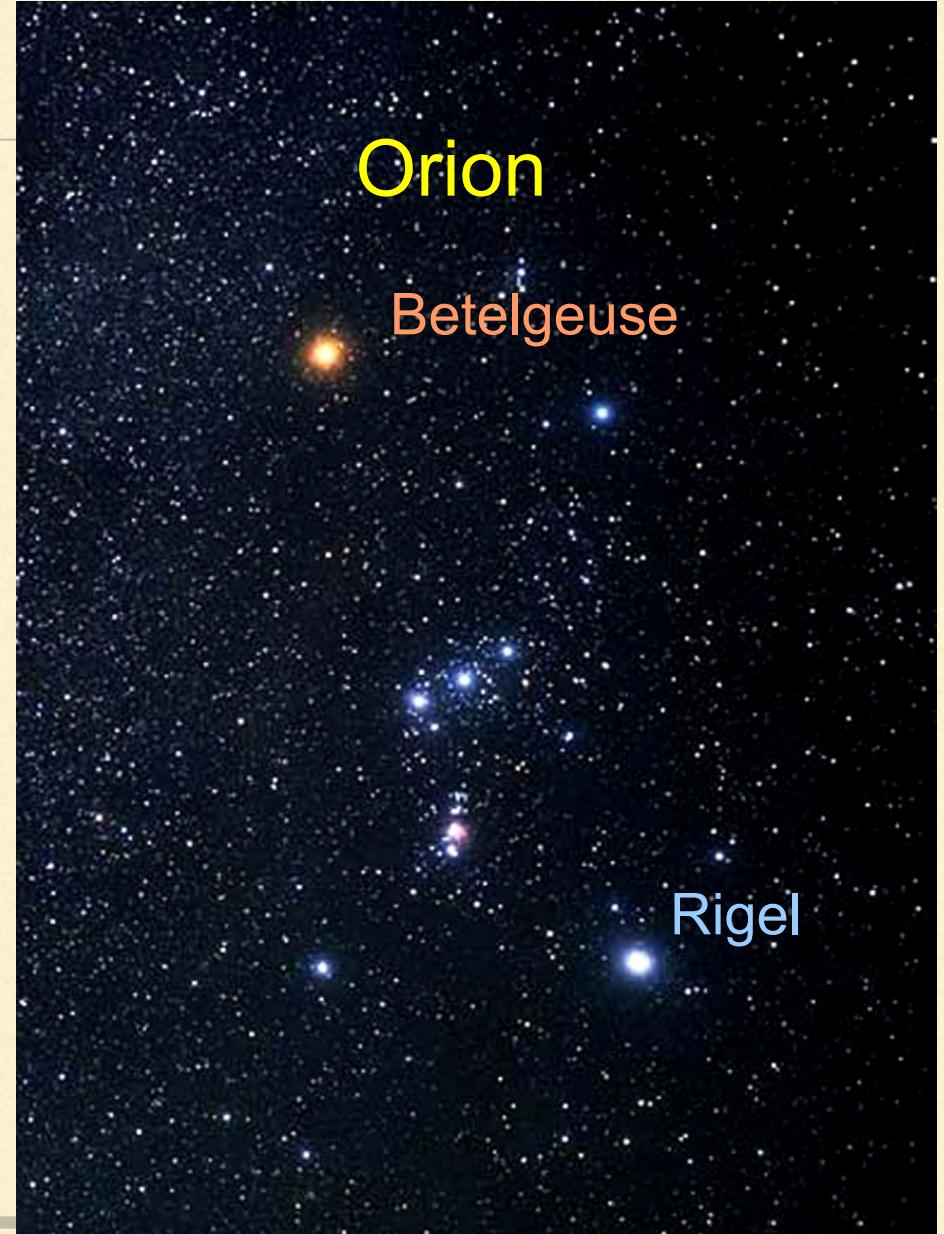
# ABSOLUTE MAGNITUDES

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- Absolute magnitude (uppercase M) is the apparent mag that a source would have at d=10 pc
  - Distance modulus:  $m - M = 5 \log_{10} (d / 10\text{pc})$
  - Solar values:  $M_{\odot,\text{bol}} = 4.74 \text{ mag}$      $M_{\odot,V} = 4.82 \text{ mag}$
  - Bolometric magnitudes are integrated over wavelength (total emitted flux)
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# COLOR

Stars appear in different colors,  
from blue (like Rigel)  
via yellow  
to red (like Betelgeuse).



# COLOR AND TEMPERATURE

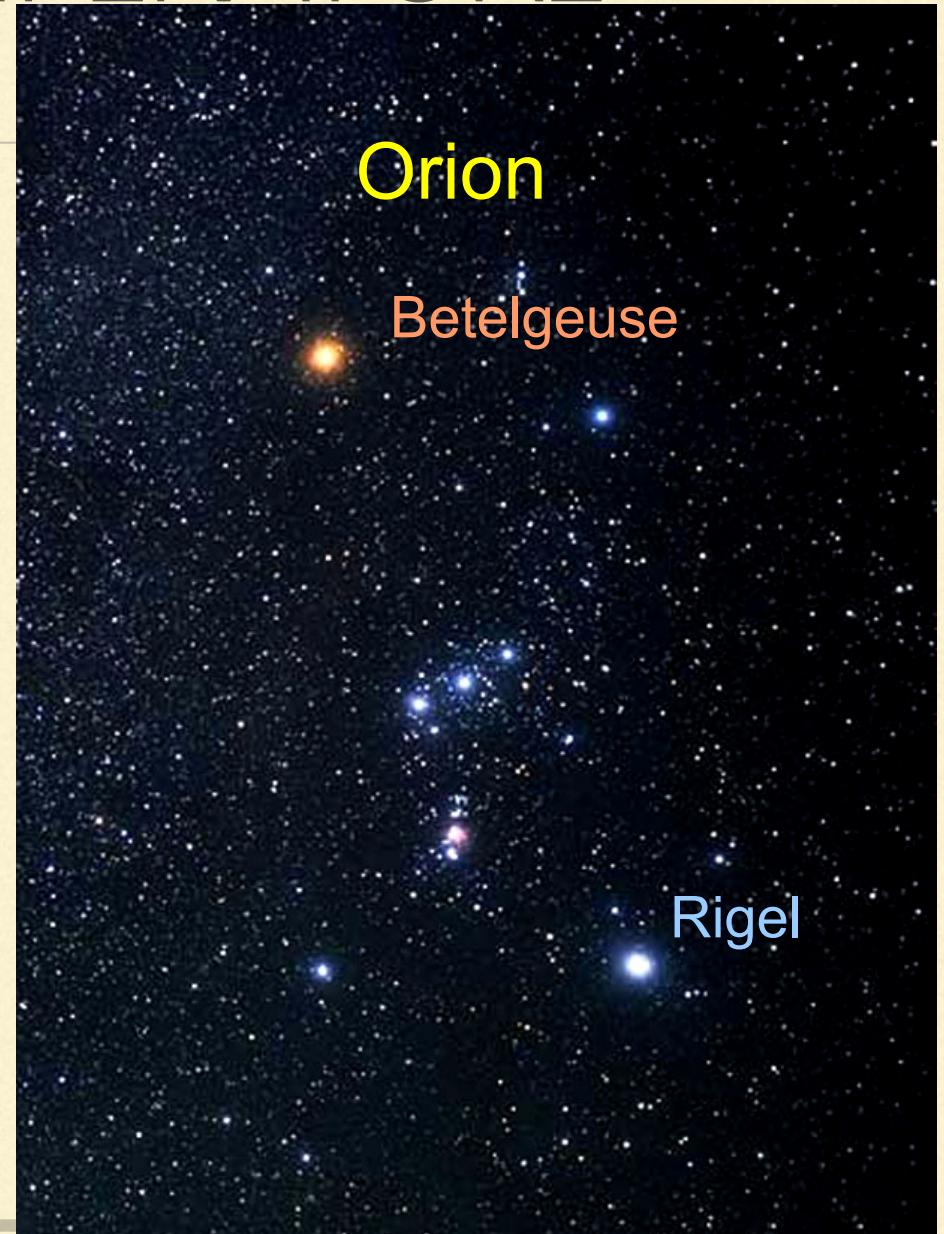
Stars appear in different colors,

from blue (like Rigel)

via yellow

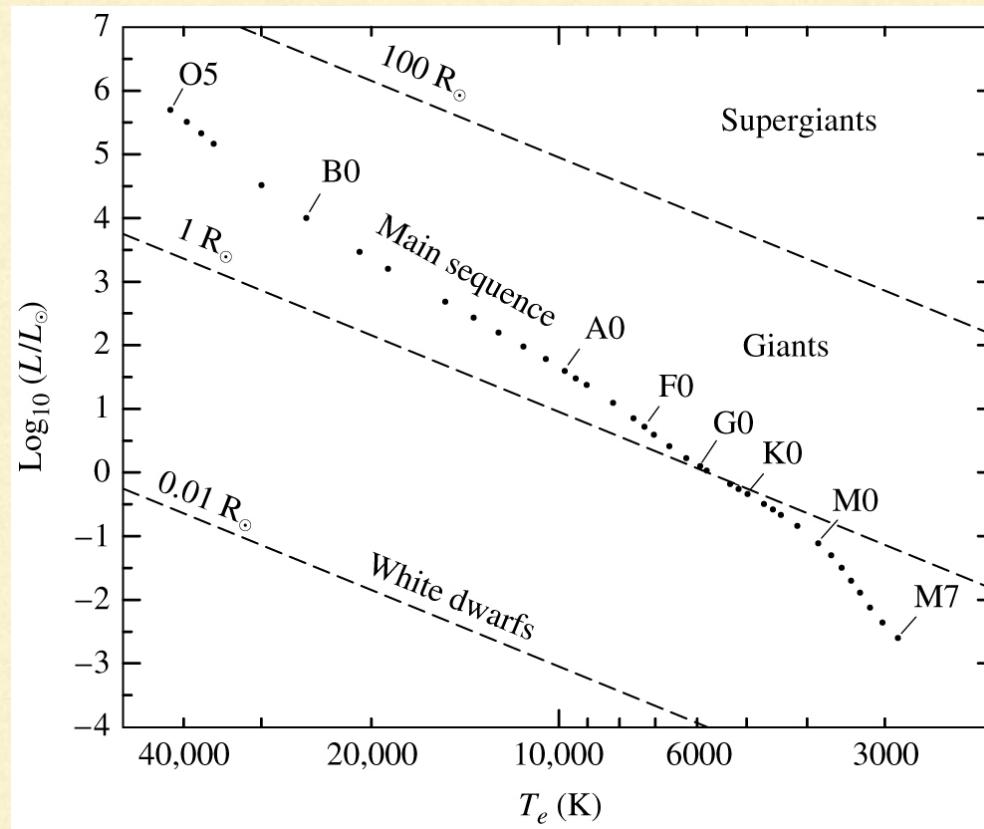
to red (like Betelgeuse).

These colors tell us about  
the star's temperature.



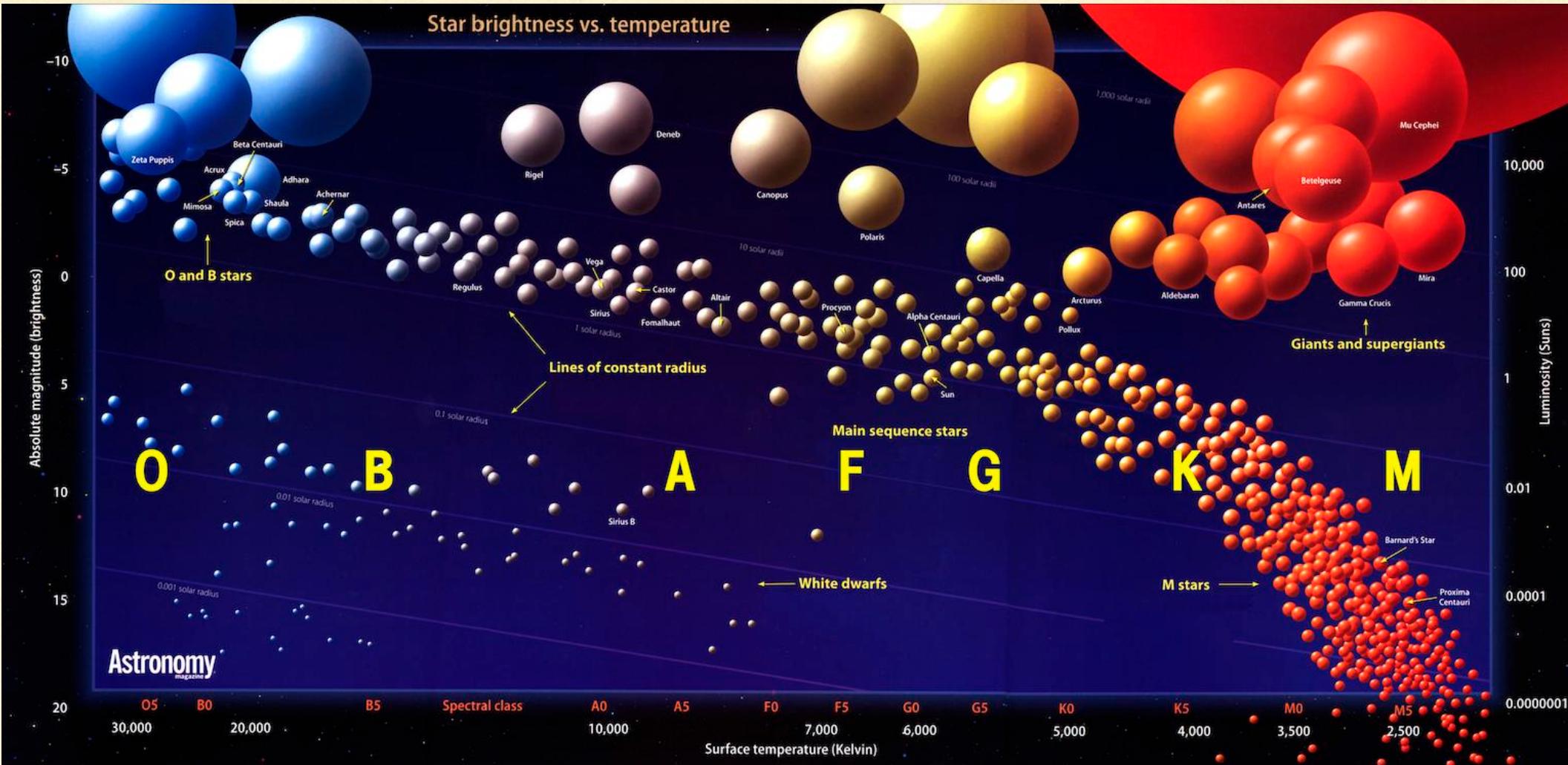
# HERTZSPRUNG-RUSSELL DIAGRAM

Or: Magnitude



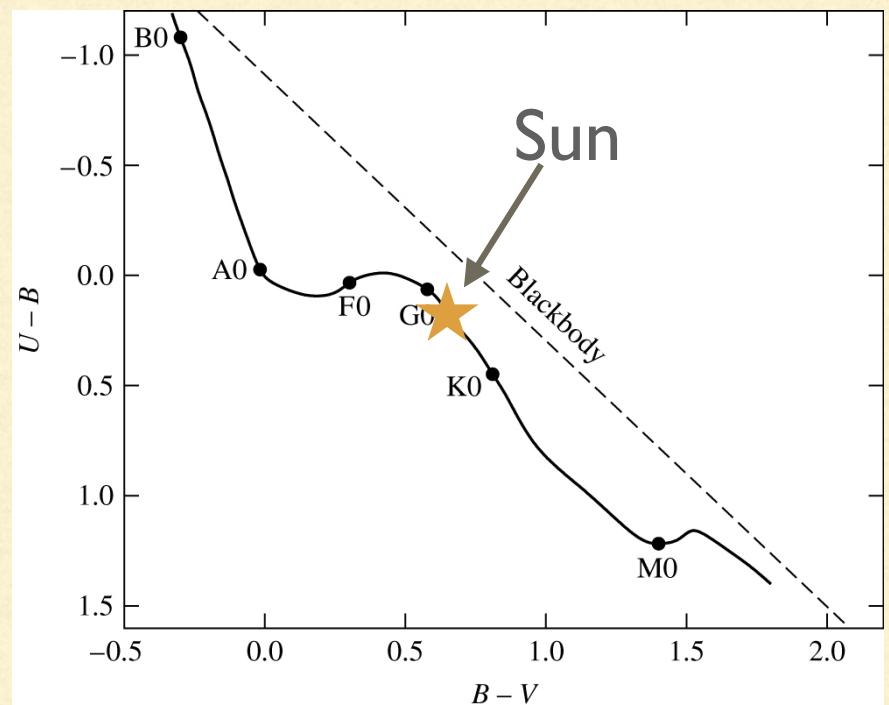
Or: Color

# HERTZSPRUNG-RUSSELL DIAGRAM

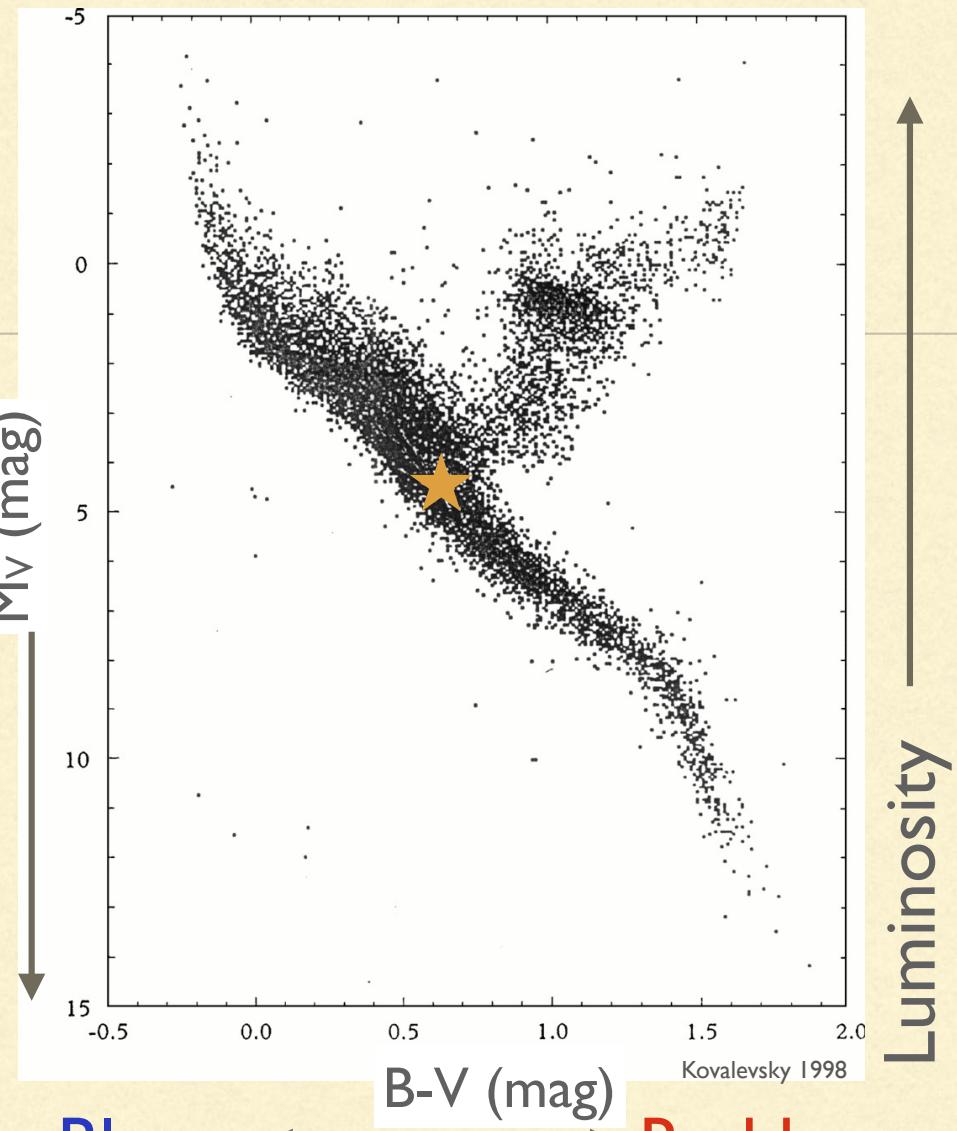


# COLORS

Redder ↘ Bluer



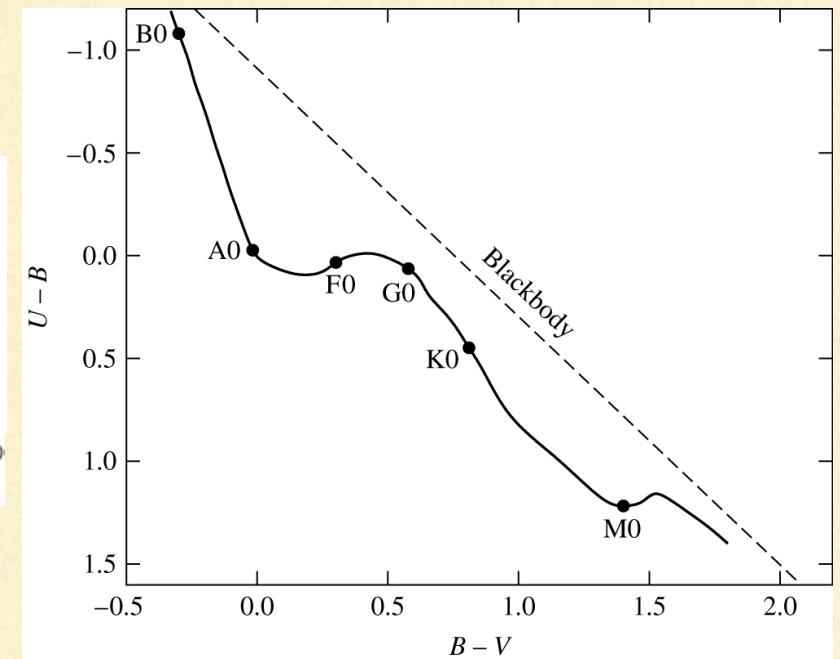
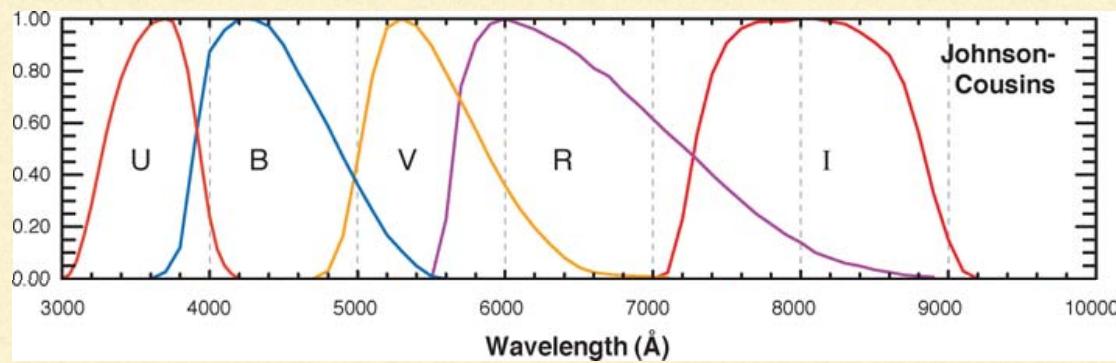
Bluer Hotter ←→ Redder Cooler



Bluer Hotter ←→ Redder Cooler

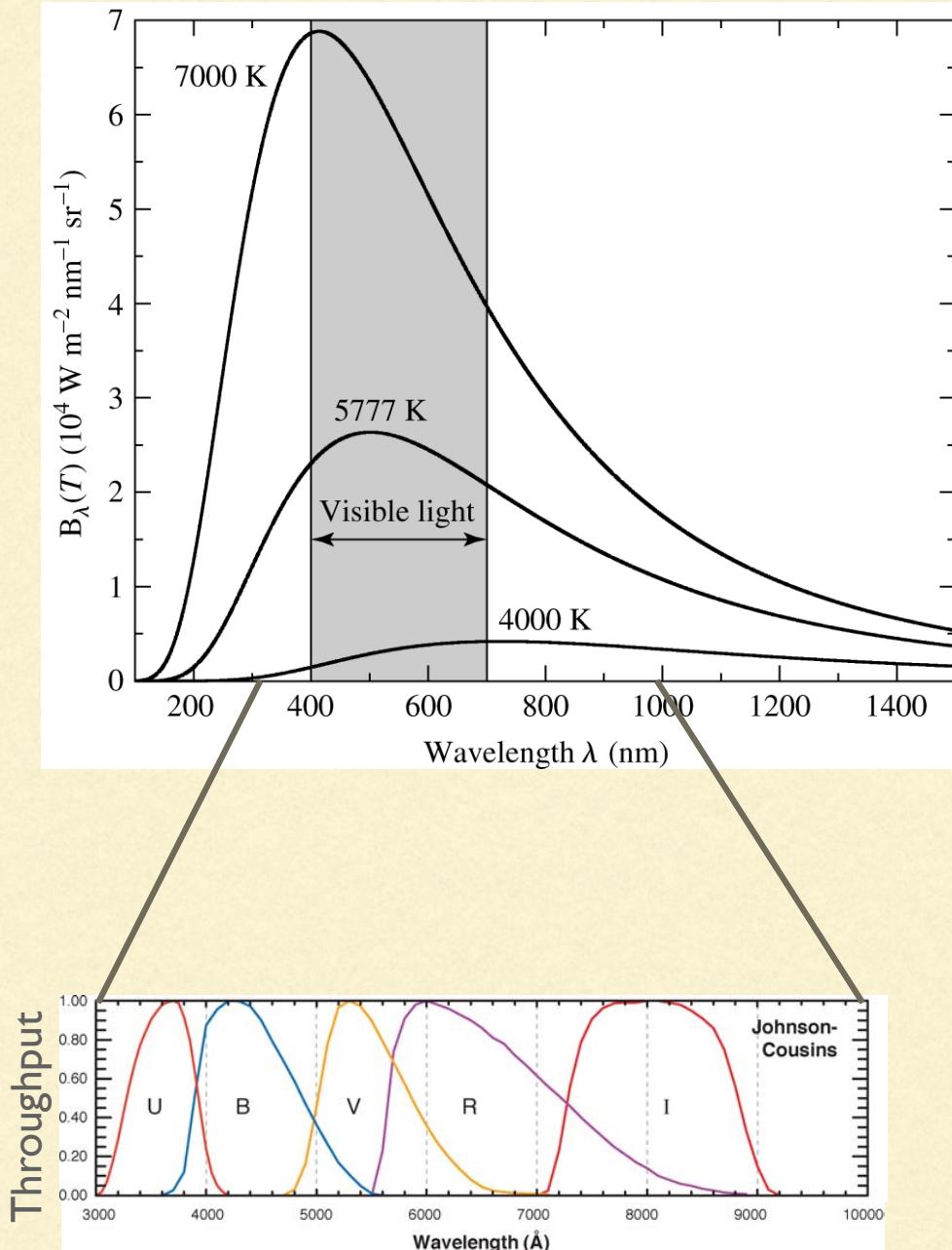
(Hipparcos data for stars within 100 pc)

# COLORS



A difference in magnitudes = a ratio of fluxes

# FILTERS AND COLORS



- We only measure part of the light when we observe through a filter. For example:

$$V = -2.5 \log_{10} \left( \int_0^{\infty} F_\lambda S(V) d\lambda \right) + \text{Constant}(V)$$

- The bolometric correction is a conversion factor:

$$\text{BC} = m_{\text{bol}} - V = M_{\text{bol}} - M_V$$

- For Sun:  $M_{\odot, \text{bol}} = 4.74 \text{ mag}$   $M_{\odot, V} = 4.82 \text{ mag}$

$$\text{So BC} = -0.08 \text{ mag}$$

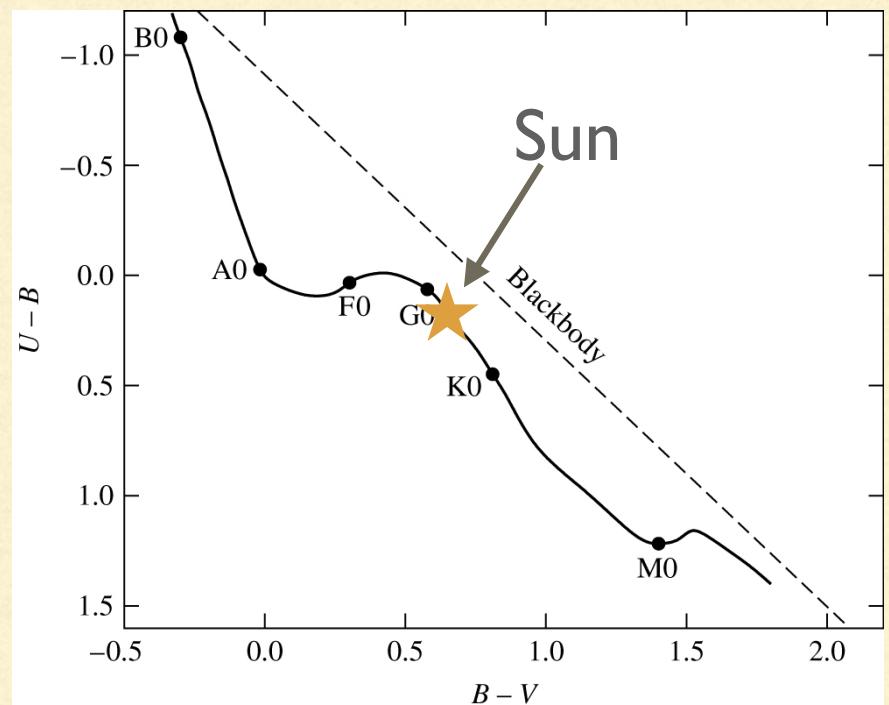
# COLOR INDEX

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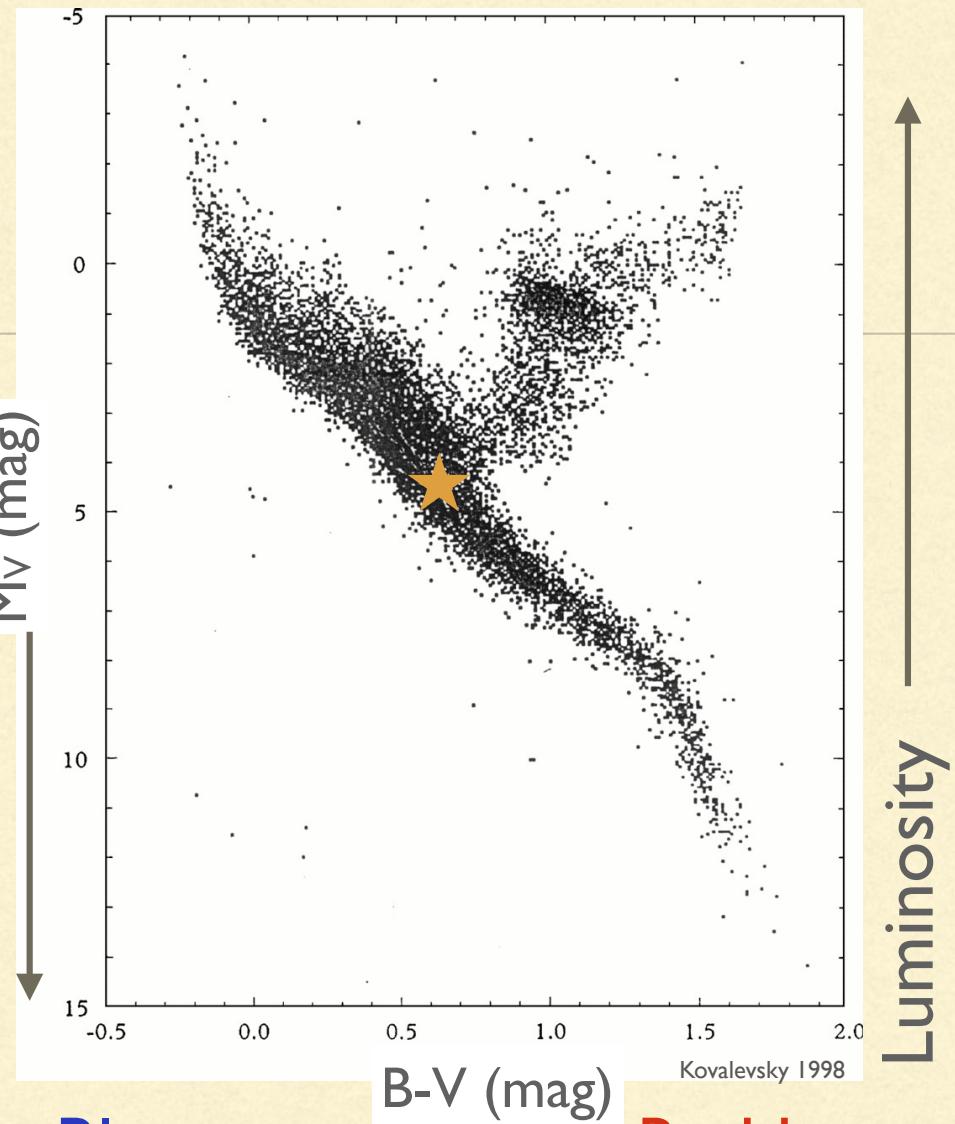
- We can define a *color index* as a difference in magnitudes: e.g., B-V
  - Smaller numbers = bluer    Bigger numbers = redder
  - For Sun:  $M_B = 5.47 \text{ mag}$     $M_V = 4.82 \text{ mag}$   
—————> so  $B-V = 0.65 \text{ mag}$
  - Stars with similar  $T_{\text{color}}$  will have similar color index B-V
  - Remember: differences in magnitudes = ratio of fluxes
    - so a color index is independent of how bright a source is
-

# COLORS

Redder ↘ Bluer



Bluer Hotter ← → Redder  
Cooler ← →



Bluer Hotter ← → Redder  
Cooler ← →

(Hipparcos data for stars within 100 pc)