Review - Exam 1

Questions?

email me!

exam prep: extra office hours

Mon Oct 30: 10-11am, 1-4pm

Tuesday, Oct 31: Exam #1

Exam #1 - Policies

PAA A10

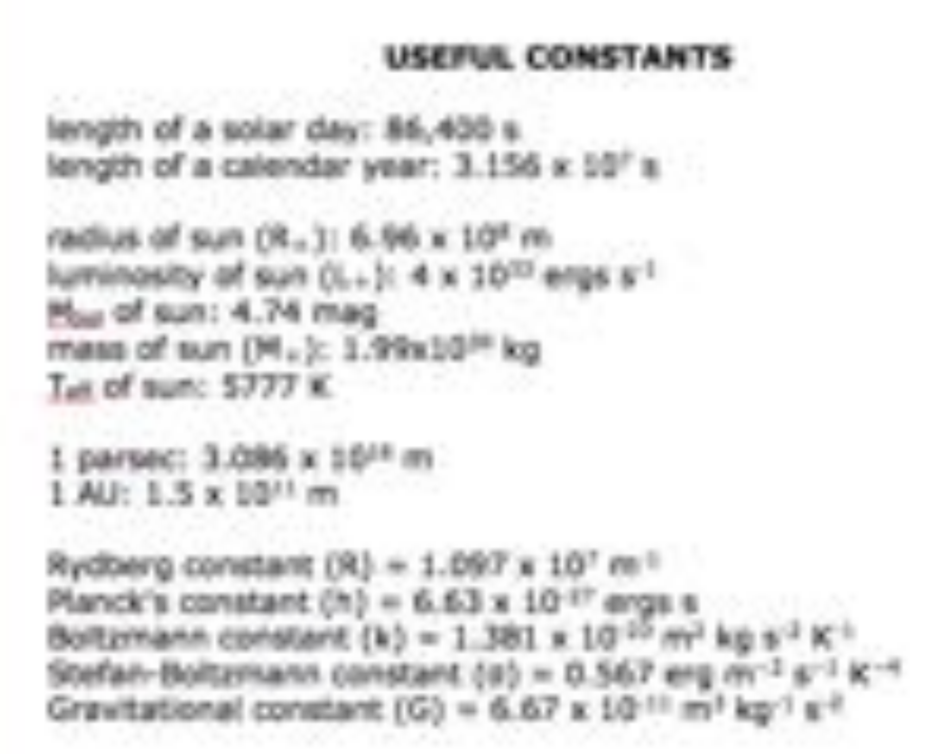
— format: short answers (problems, paragraphs)

— exam goes from 1:30pm - 2:50pm

— scientific calculators are the **only** devices allowed

— one 8.5x11 page of notes (both sides) is allowed

You will be given this:



USEFUL CONSTANTS

length of a solar day: 86,400 s
length of a calendar year: 3.156×10^7 s

radius of sun ($R_\odot$): 6.96×10^8 m
luminosity of sun ($L_\odot$): 4×10^{33} ergs s^{-1}
M_{bol} of sun: 4.74 mag
mass of sun ($M_\odot$): 1.99×10^{30} kg
T_{eff} of sun: 5777 K

1 parsec: 3.086×10^{16} m
1 AU: 1.5×10^{11} m

Rydberg constant (R) = 1.097×10^7 m^{-1}
Planck's constant (h) = 6.63×10^{-27} ergs s
Boltzmann constant (k) = 1.381×10^{-23} m^2 kg s^{-2} K^{-1}
Stefan-Boltzmann constant (σ) = 0.567 erg m^{-2} s^{-1} K^{-4}
Gravitational constant (G) = 6.67×10^{-11} m^3 kg^{-1} s^{-2}

You will **not** be given:

— equations

— relations

— basic units (microns, angstroms, Hz)

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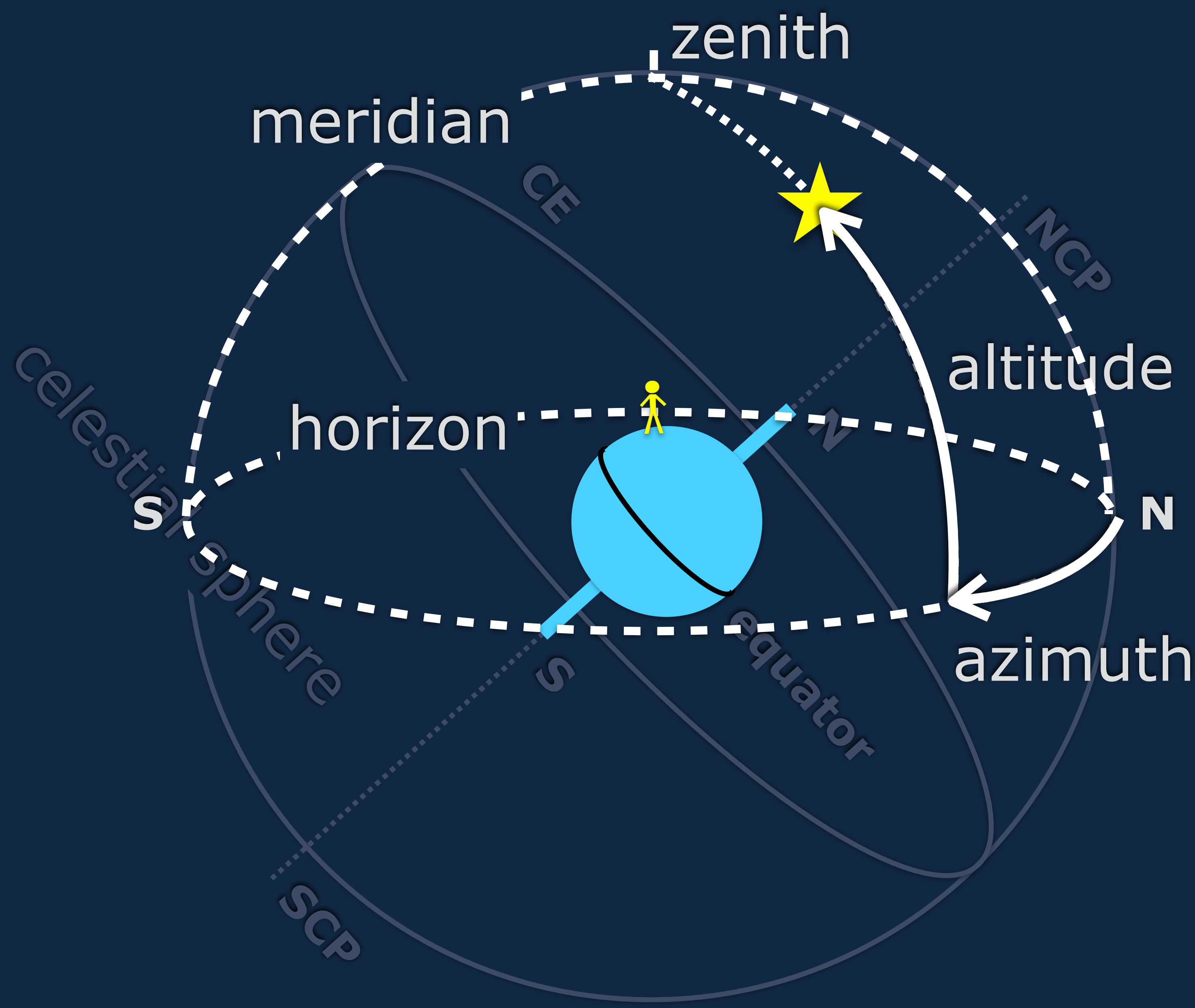

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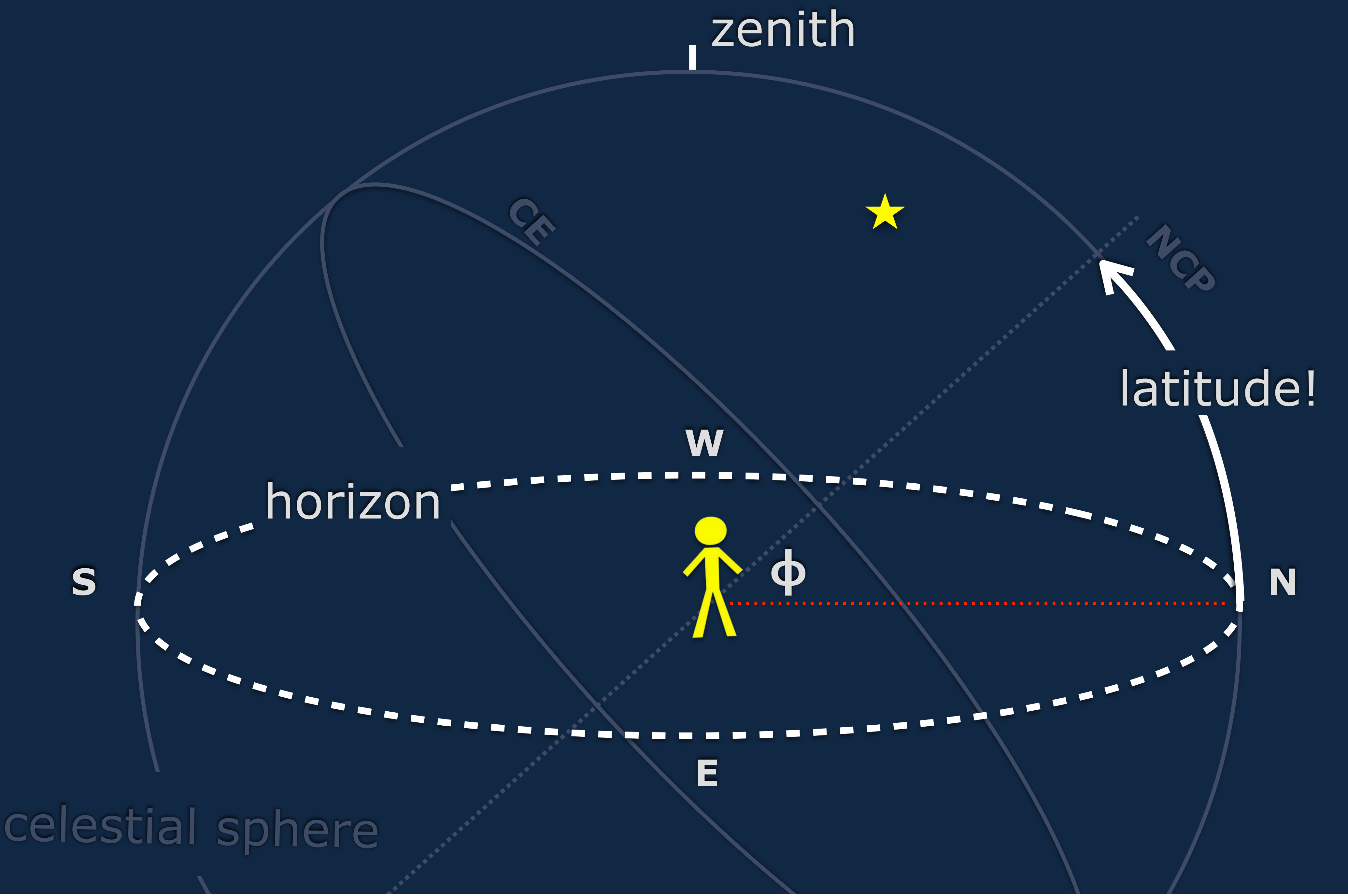

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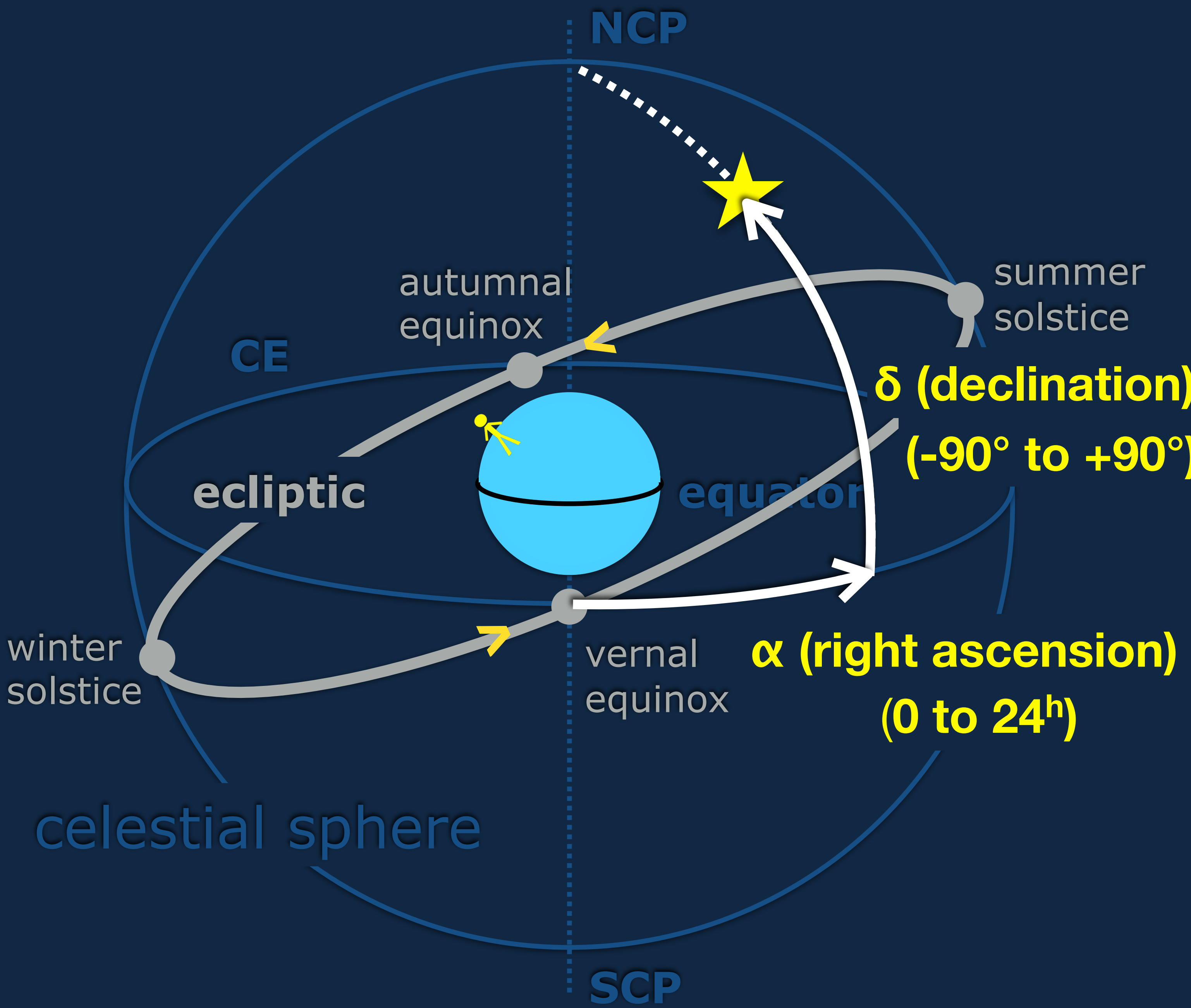

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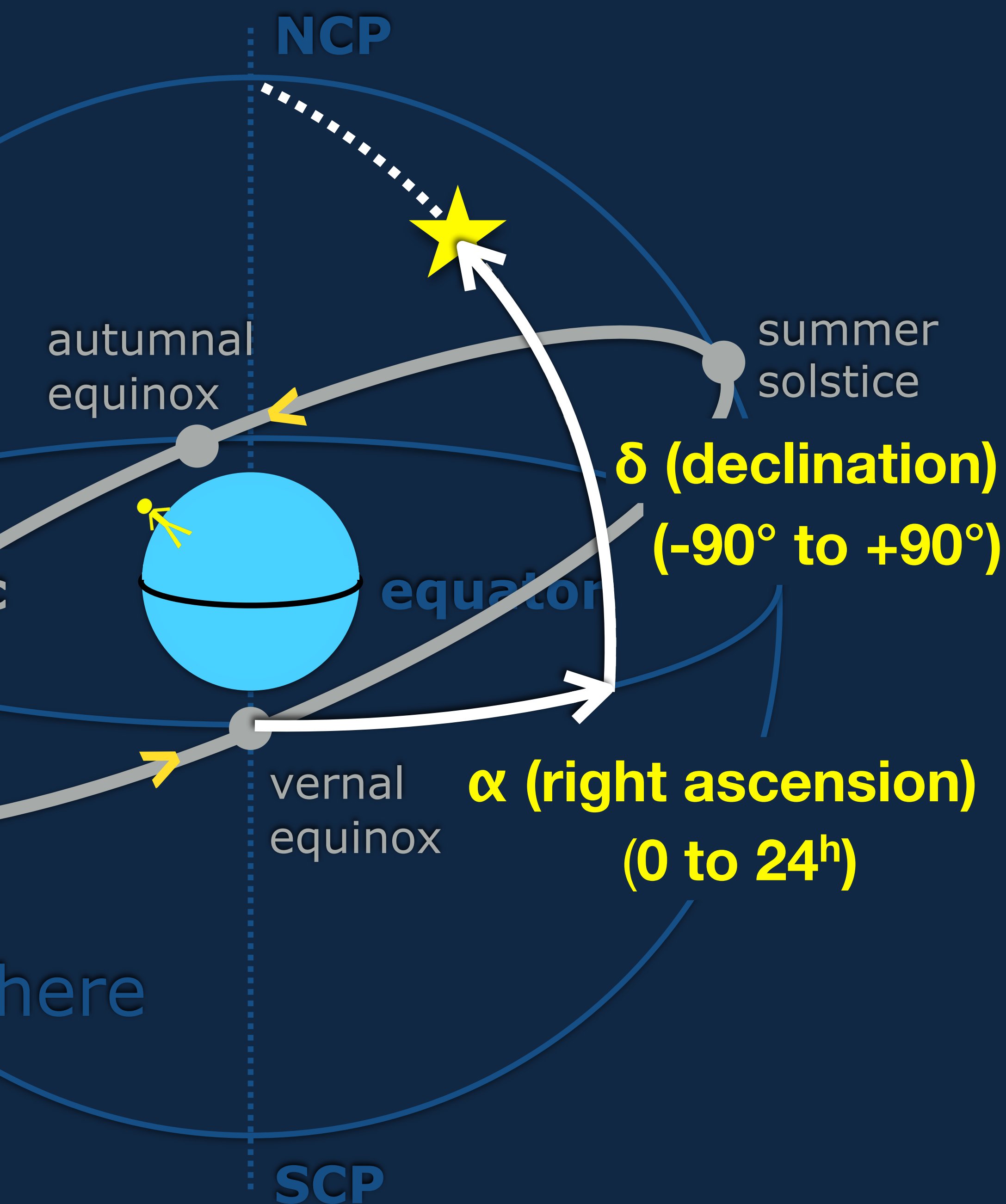

declination: CE + δ

altitude: 90 - lat + δ

Peak RA & Months?

Mar: 12

June: 18

Sep: 0

Dec: 6

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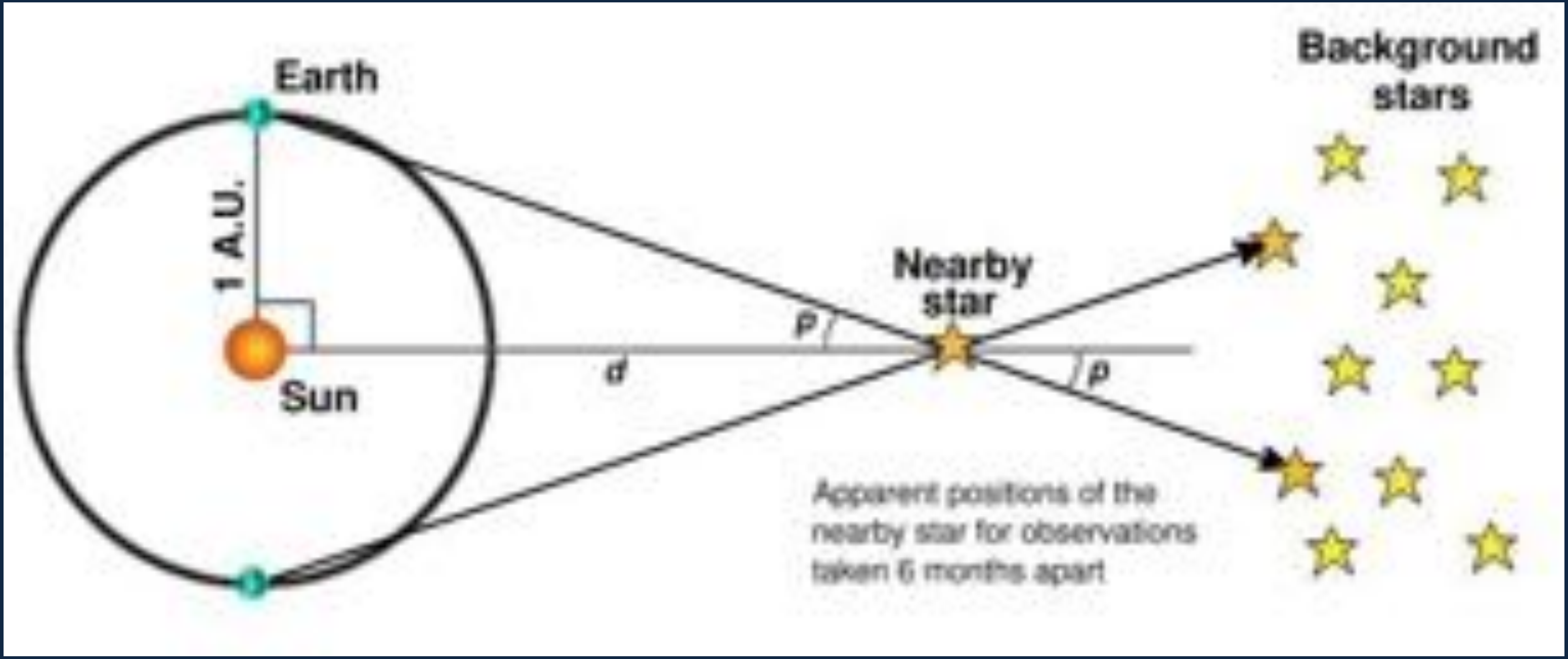
Distance and parallax

$$d = \frac{1\ \text{AU}}{\tan(p)} \simeq \frac{1}{p}\ \text{AU} \rightarrow \frac{206265}{p''}\ \text{AU}$$ **parsec!** $$\boxed{d = \frac{1}{p''}\ \text{pc}}$$

But p is in **radians**…

Remember **1 radian ~ 206265″…**



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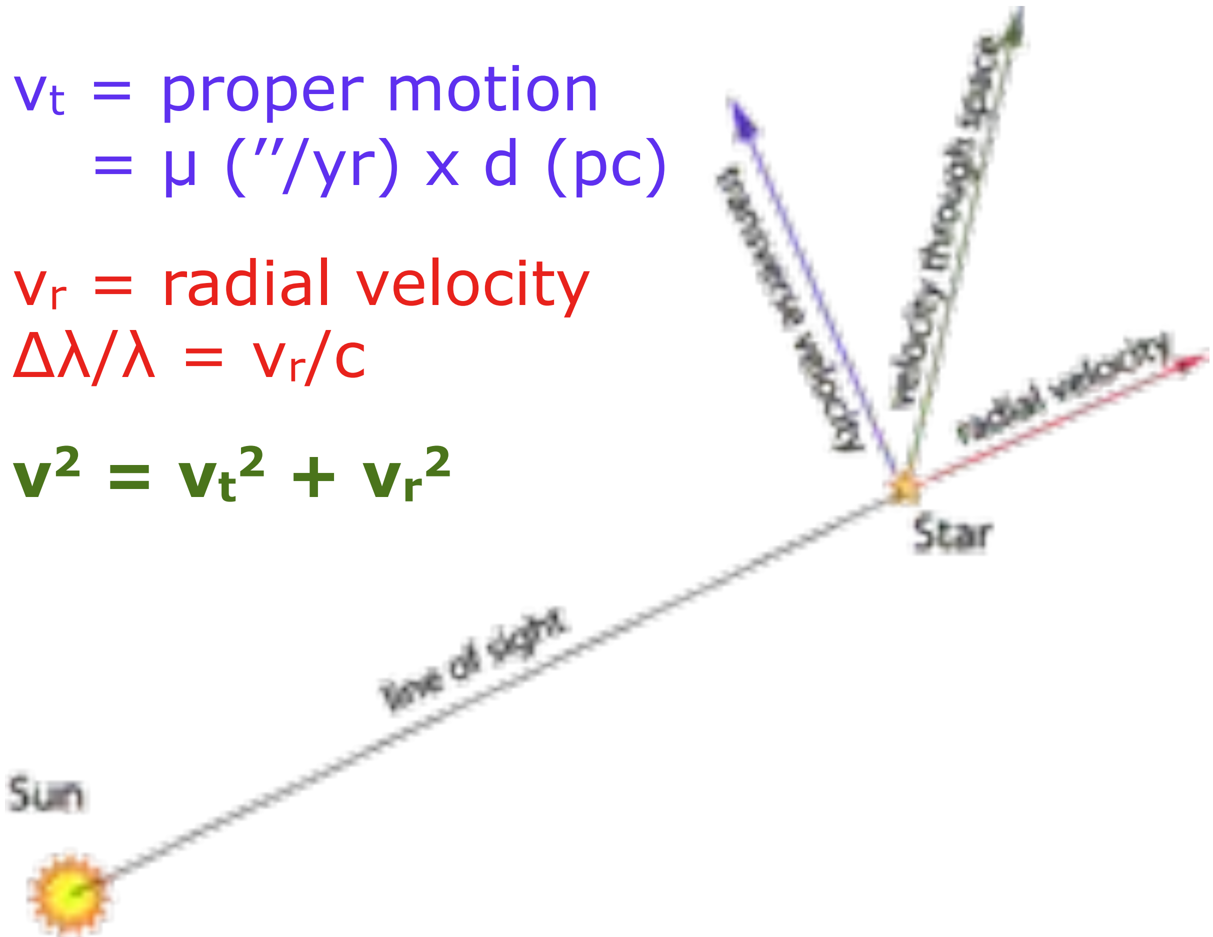
Determining a star's velocity through space can be done by combining observable components…

v_t = proper motion
$= \mu\ ('' / yr) \times d\ (pc)$

v_r = radial velocity
$\Delta\lambda/\lambda = v_r/c$

$$\mathbf{v^2 = v_t^2 + v_r^2}$$



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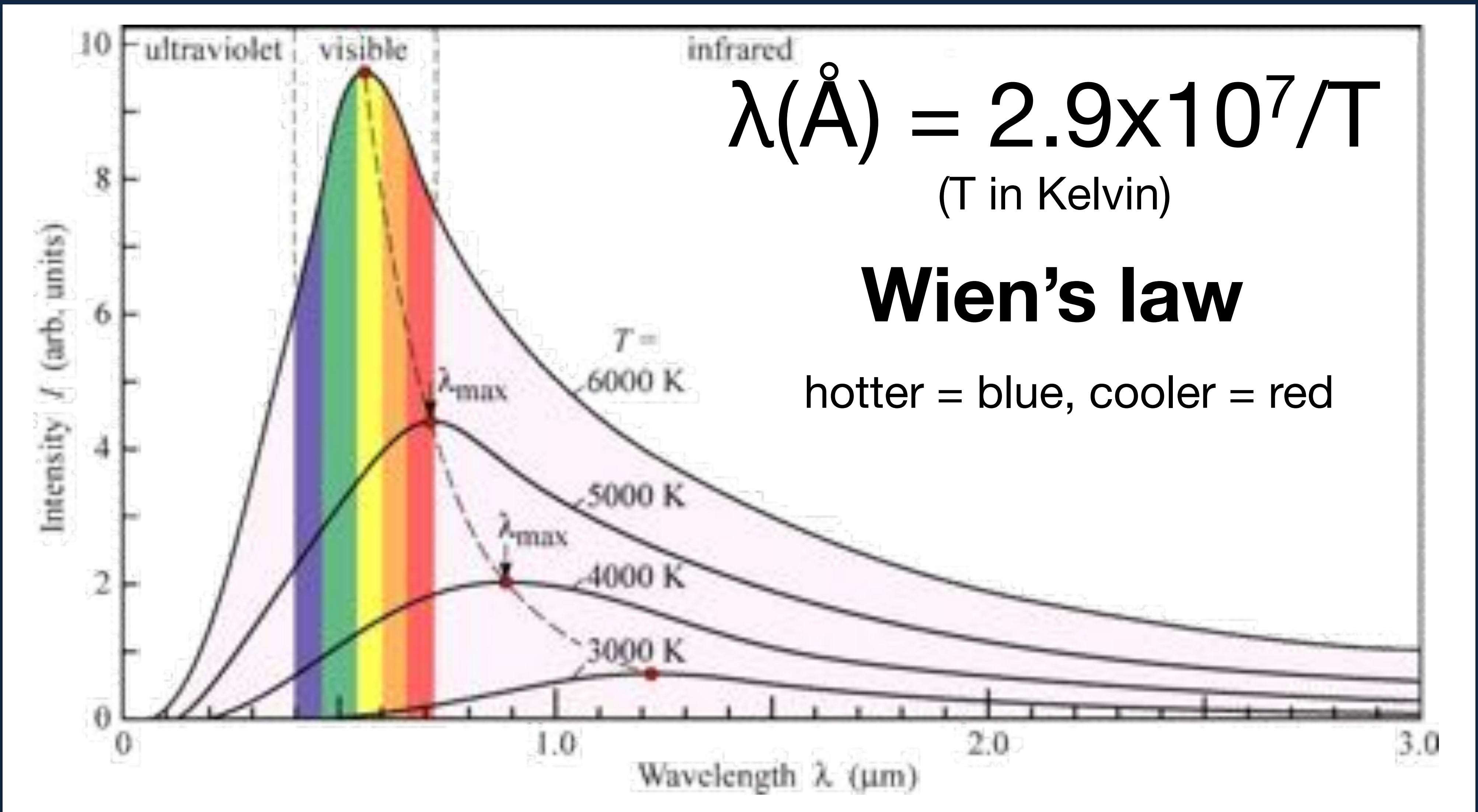
Continuum radiation is approximated by a **blackbody**; energy given by Planck function



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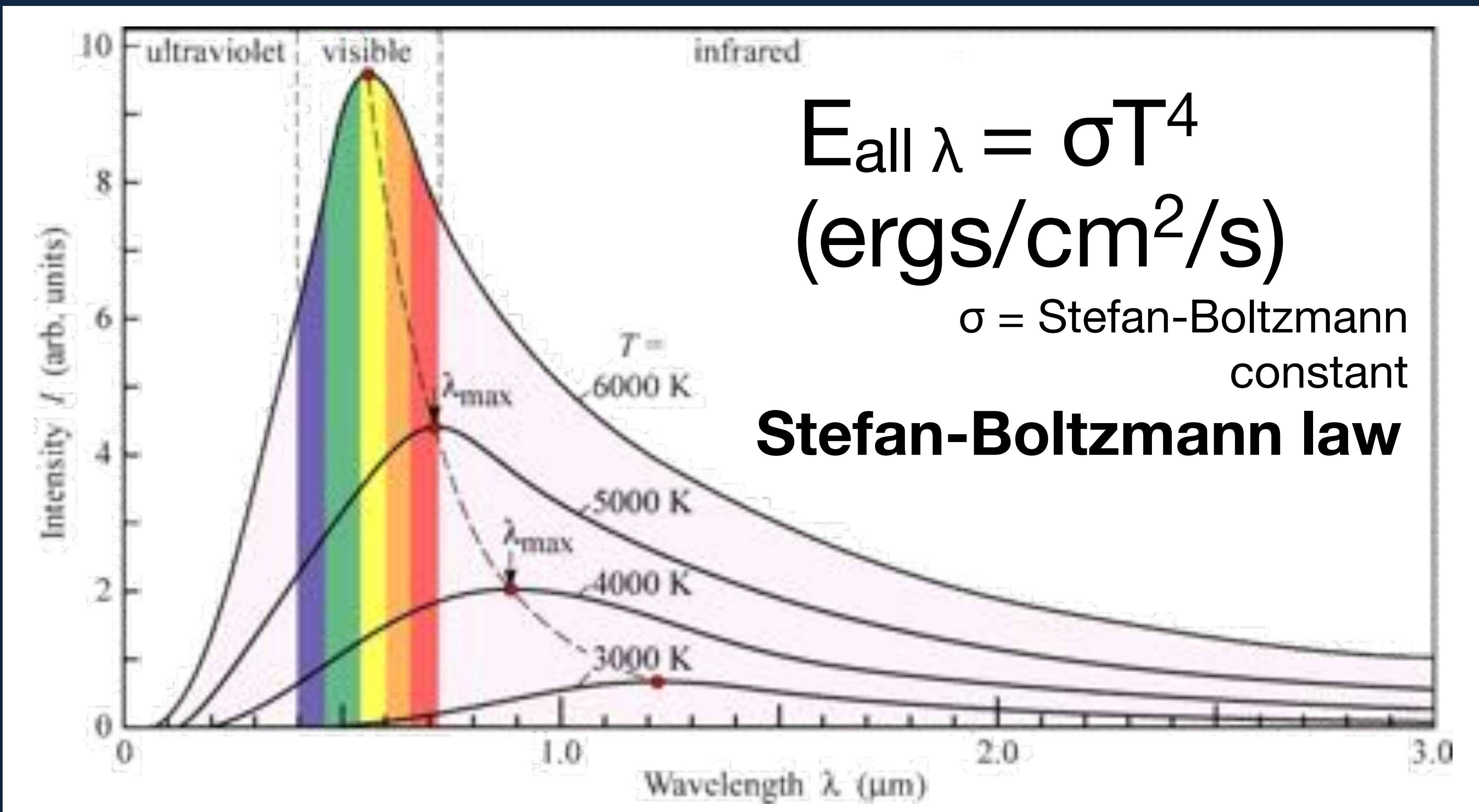
Continuum radiation is approximated by a **blackbody**; energy given by Planck function



$$E_{all\ \lambda} = \sigma T^4$$

$(ergs/cm^2/s)$

σ = Stefan-Boltzmann constant

Stefan-Boltzmann law

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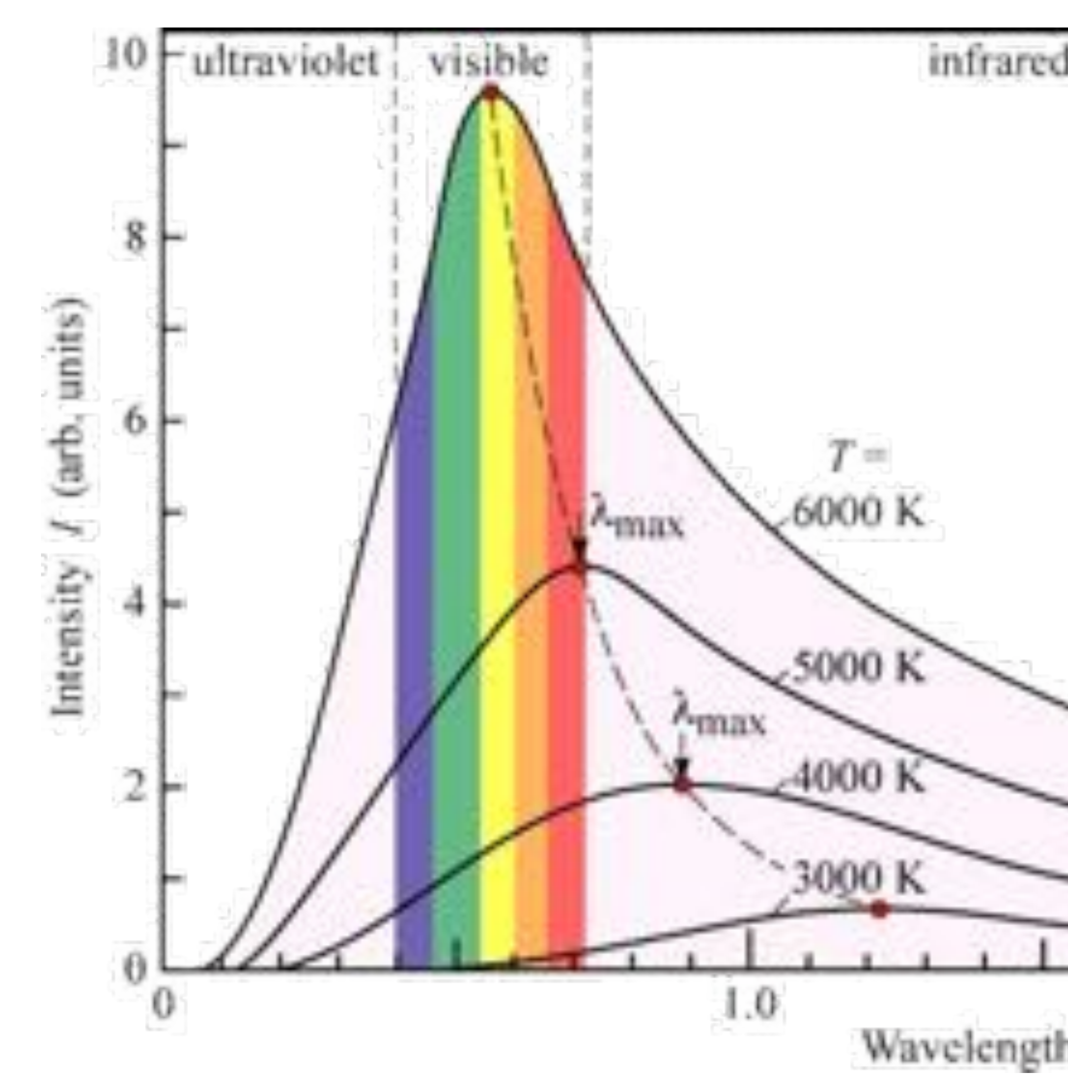
Continuum radiation is approximated by a **blackbody**; energy given by Planck function



$E_{\text{all }\lambda}$ = (ergs/cm²/s)

$L = 4\pi R^2 \sigma T^4$

(ergs/s)

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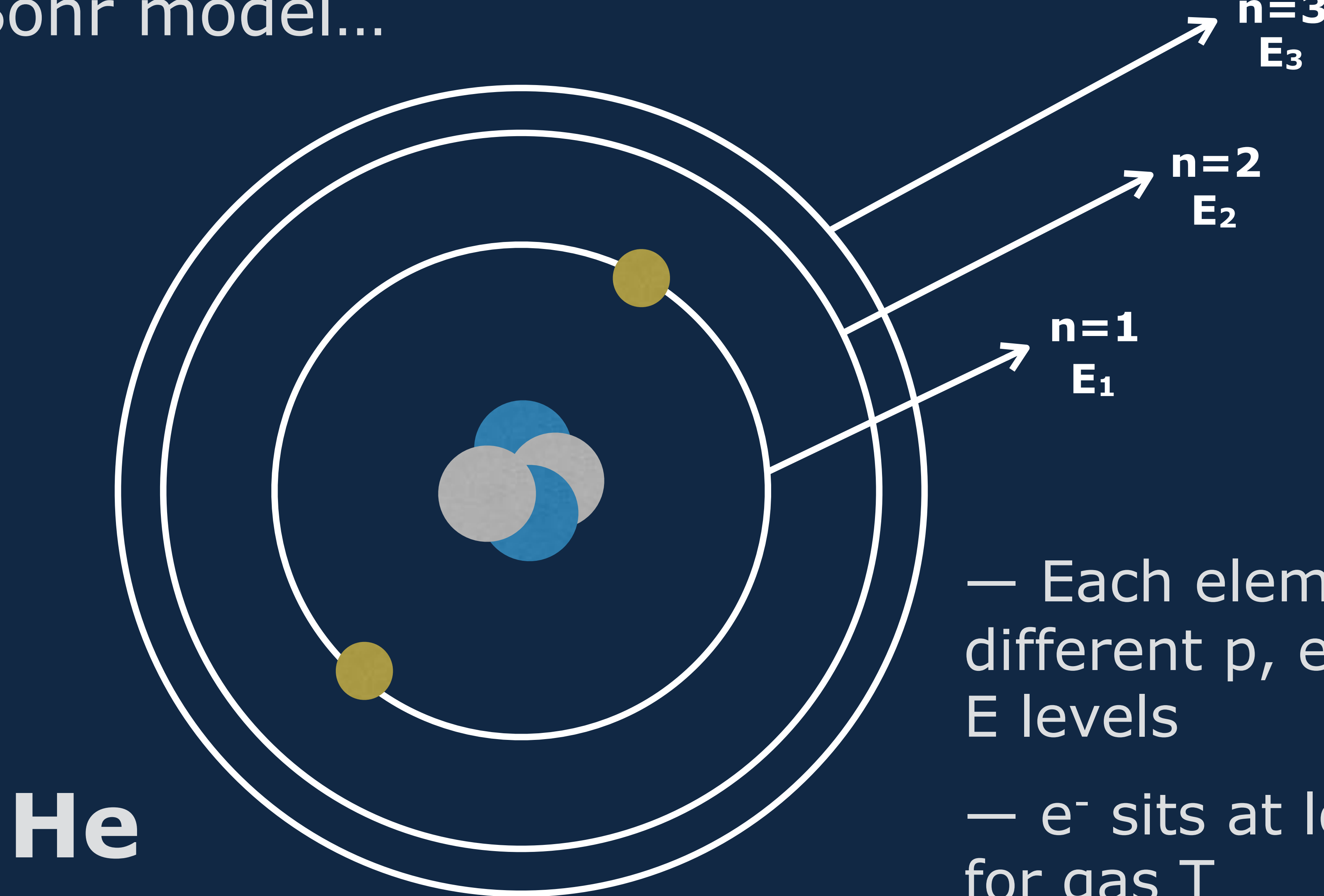
Lines in spectra can be approximated by the Bohr model…



— Each element has different p, e^-, n, E levels

— e^- sits at lowest E for gas T

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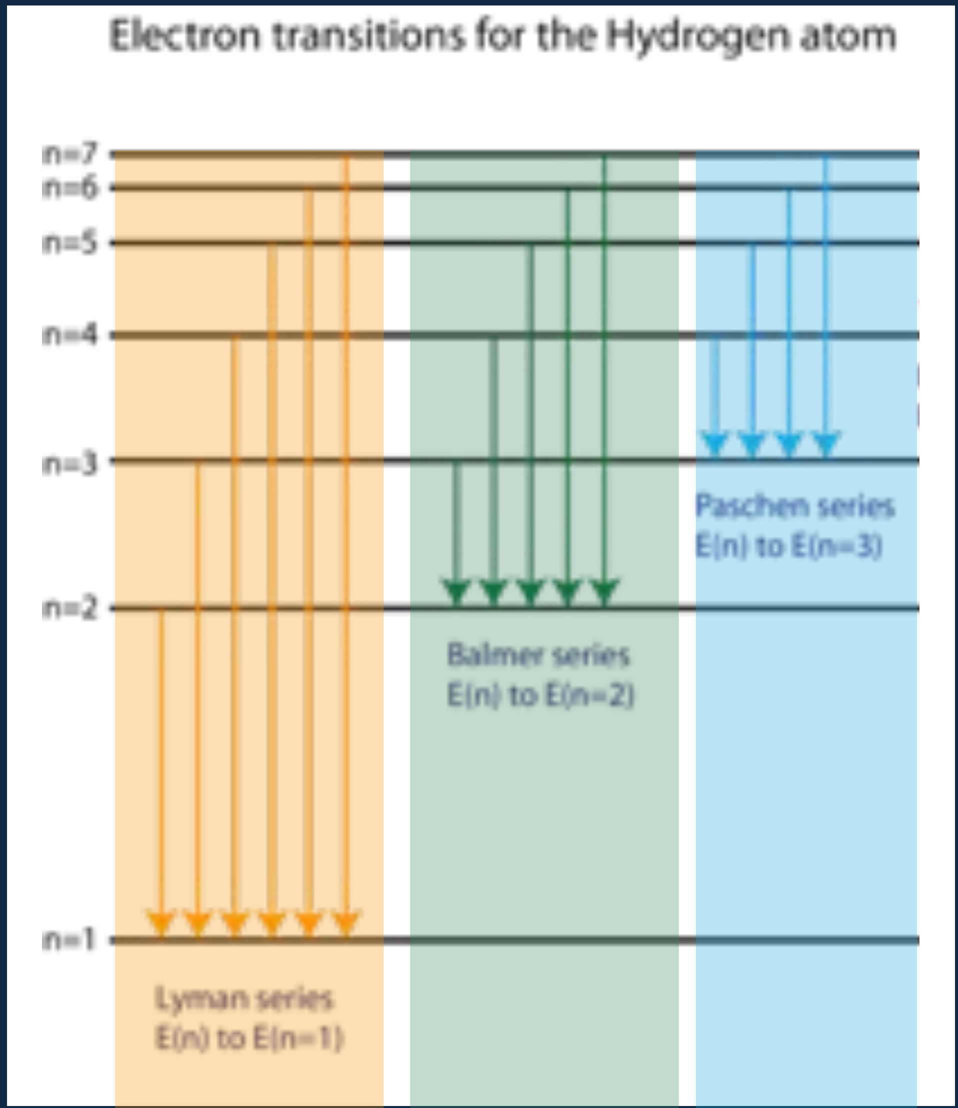
Rydberg equation

$$\frac{1}{\lambda_{\mathrm{vac}}} = RZ^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

R =

$1.097 \times 10^{7}\ m^{-1}$



ɣ-ray X-ray UV visible IR radio

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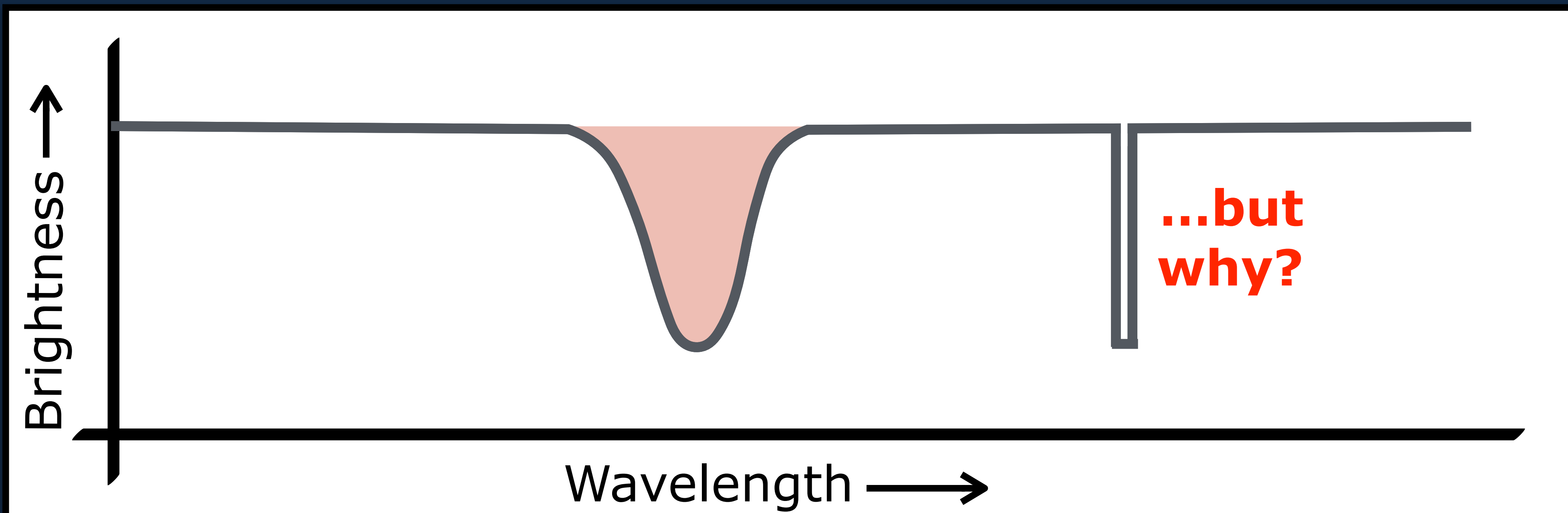
Anatomy of a spectral line

Rest-frame wavelength: composition; T
(gas T determines E, which determines level occupied)

Strength/flux: # of e^- in that level; composition/abundance

Width: ?



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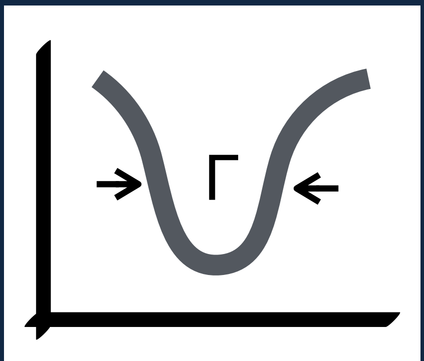
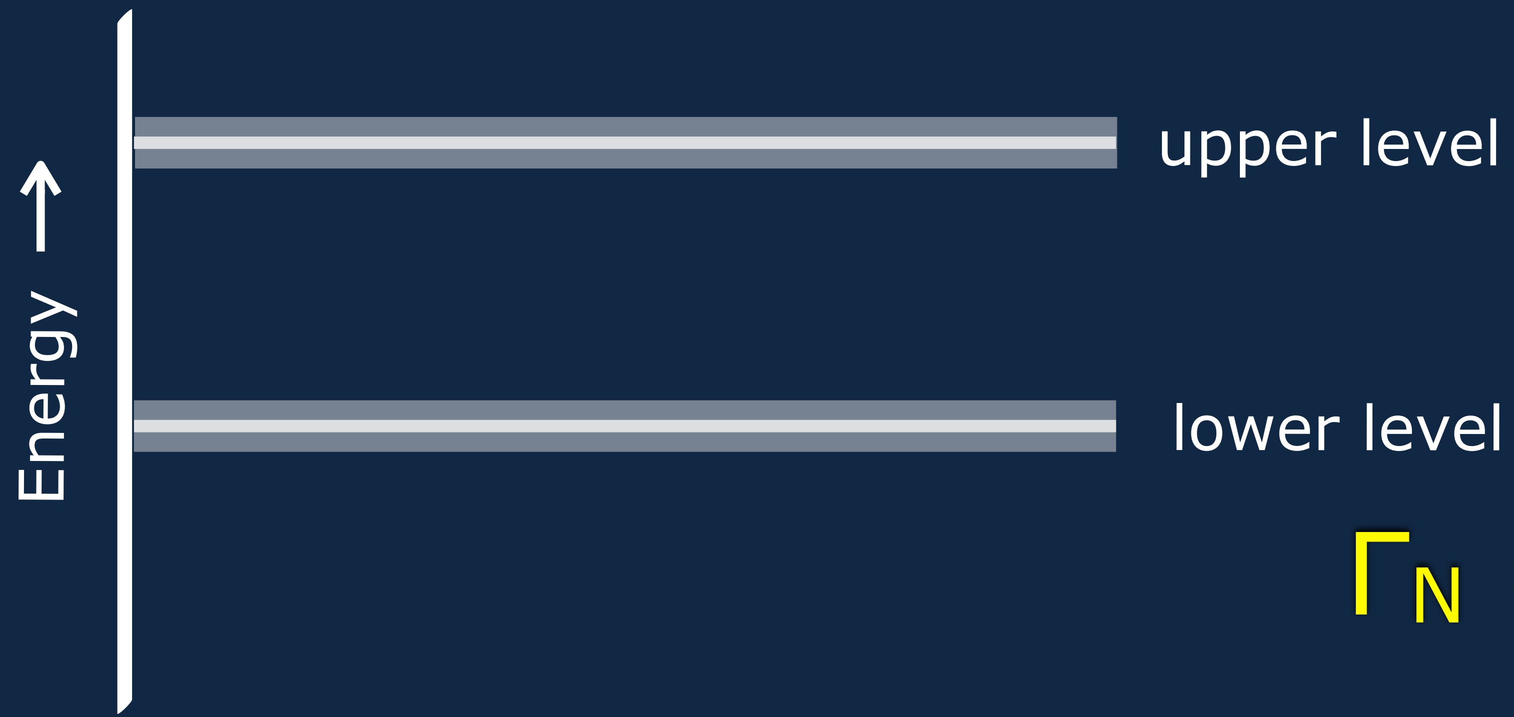
Sources of Line Broadening

1) Heisenberg: $\Delta E \Delta t > \hbar/2$

Lorentzian





$$\Gamma_N = \Gamma_u + \Gamma_l$$

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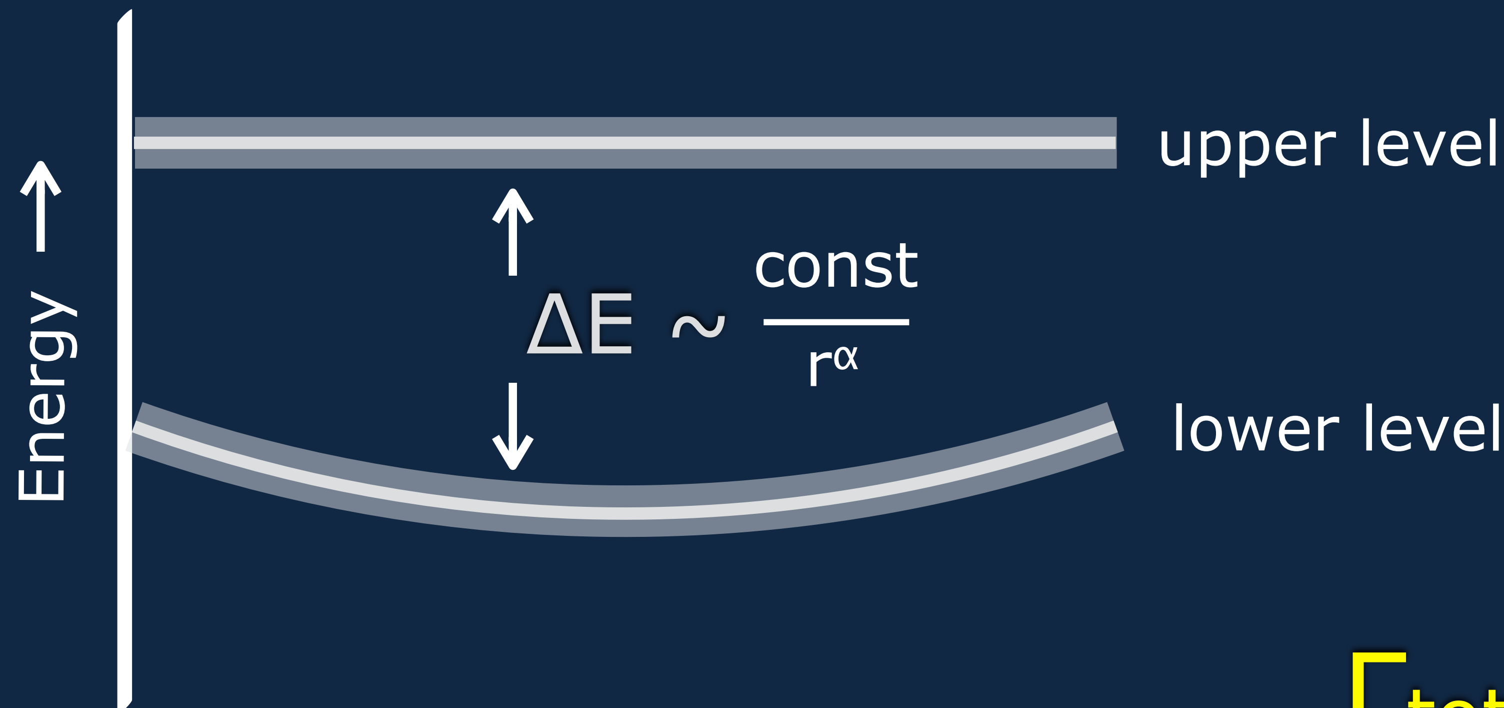
Sources of Line Broadening

1) Heisenberg (Lorentzian)

2) Pressure (also Lorentzian)



$$\Gamma_P$$

$$\downarrow$$

$$\Gamma_{tot} = \Gamma_N + \Gamma_P$$

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Sources of Line Broadening

1) Heisenberg (Lorentzian)

2) Pressure (also Lorentzian)

3) Thermal

$\Delta\nu/\nu \sim u/c$ ← Doppler!

$u_0 = \sqrt{2kT/m}$ ← average thermal velocity

$\Delta\nu_D = \nu \times u_0/c$ ← total change in frequency

total distribution
is a Gaussian

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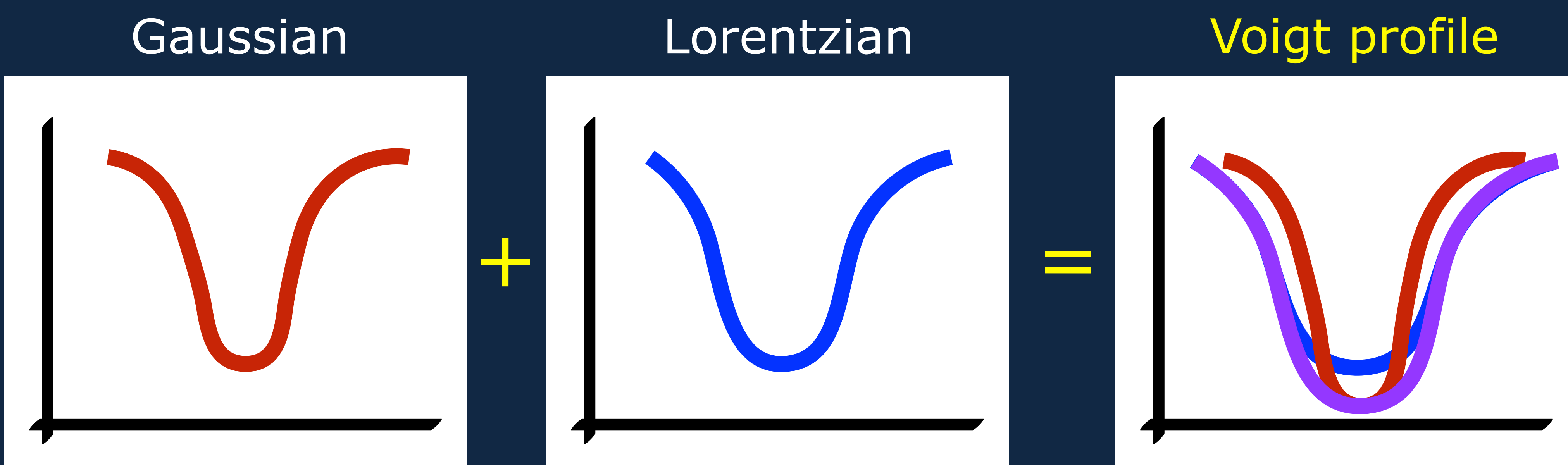
Sources of Line Broadening

1) Heisenberg (Lorentzian)
2) Pressure (also Lorentzian)
3) Thermal (Gaussian)



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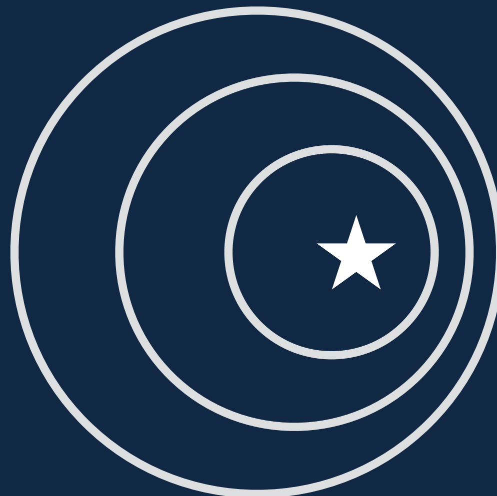
Doppler shift

If $v \ll c$, $\Delta\lambda/\lambda = v/c$

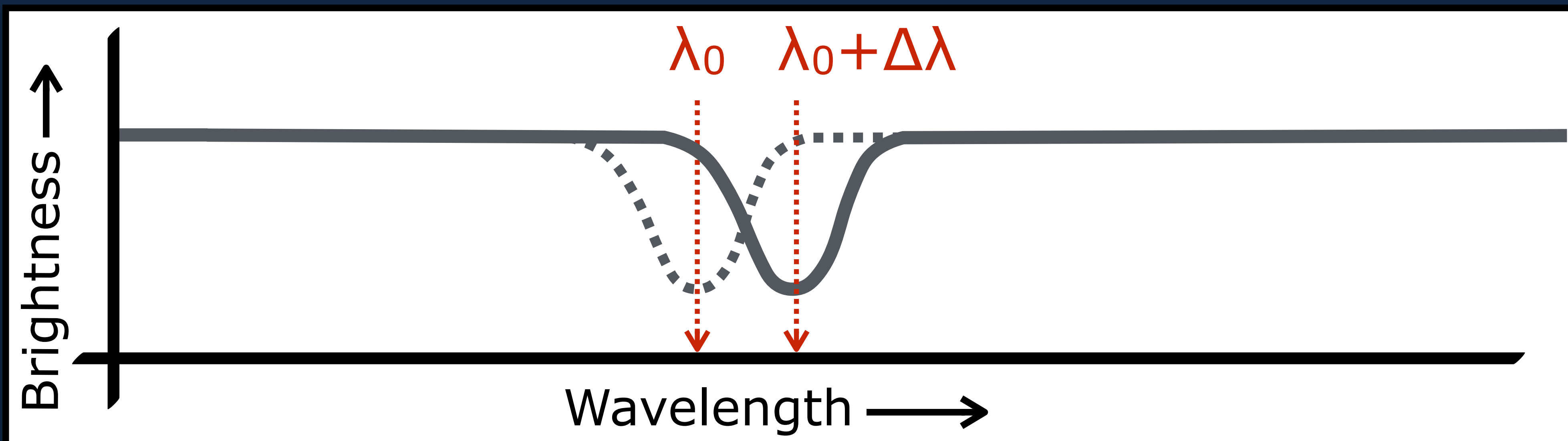
$\Delta\lambda$ = observed shift
v = velocity
λ = rest-frame wavelength
$c = 3\times10^5$ km/s

source moving right ⟶

red shift seen here



blue shift seen here



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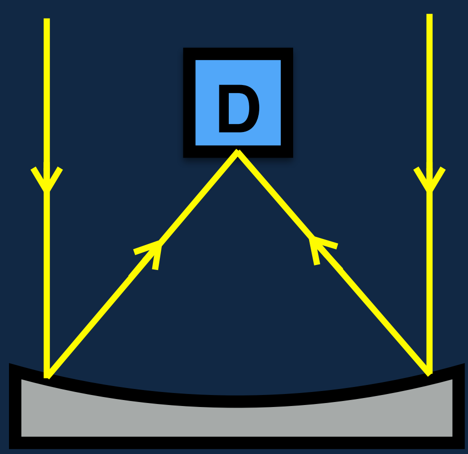
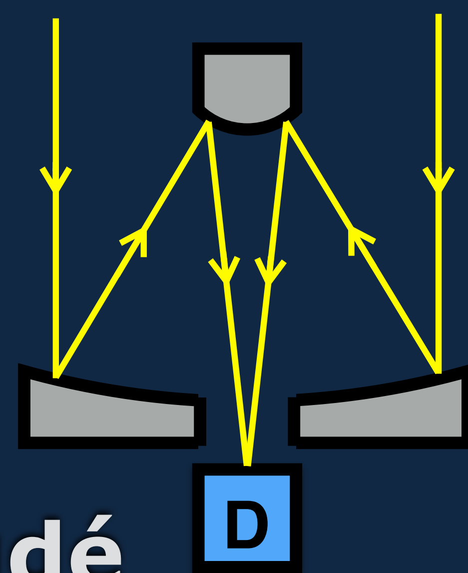
Reflecting Telescope Designs

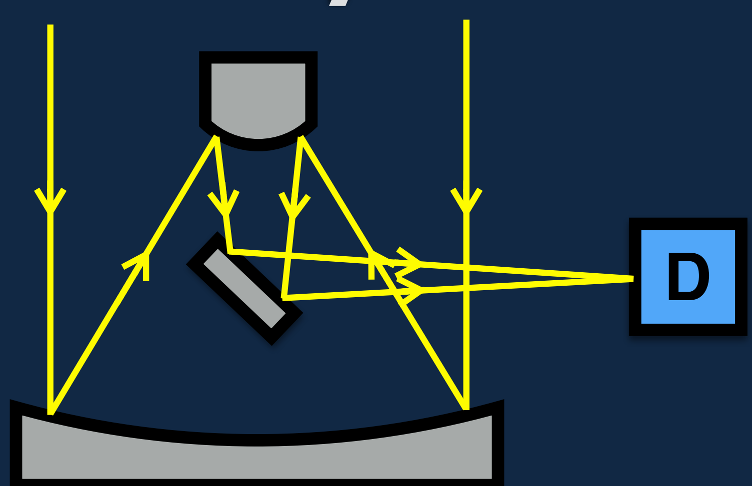
Prime focus



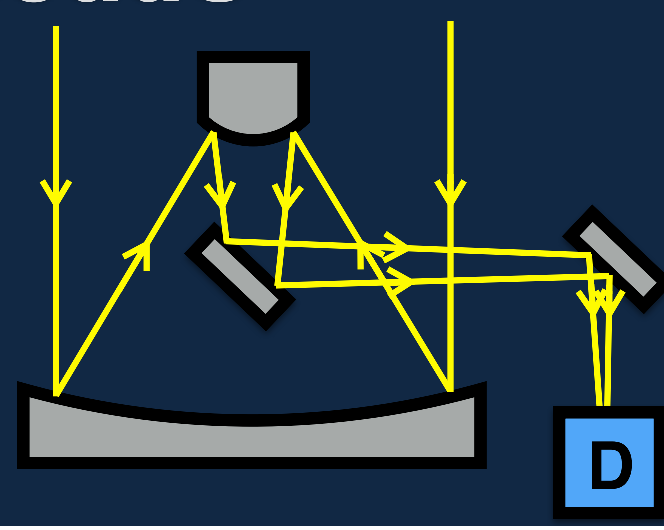
Cassegrain



Nasmyth



Coudé



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Reflecting Telescope Designs

Problems to tackle…

1) Spherical aberration
2) Coma - variation in magnification
3) Astigmatism - variation in focus w/ plane
4) Distortion - variation in magnification w/ plane

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Key properties of telescopes & instruments

f-ratio: f/D; often written as "f/11"

resolution: $\alpha = 206265'' \times \lambda/D \times 1.22$

plate scale: how linear measure on detector corresponds to angular measure on sky

$$d\theta/dy = 1/f \quad \text{(in rad } \mathbf{cm}^{-1}\text{)}$$

$$\text{or } s = f \times 4.85 \times 10^{-6} \quad \text{(in } \mathbf{cm}/''\text{)}$$

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We express stars' brightness in magnitudes.

apparent mag, V : brightness from Earth

$$m = -2.5\log(\text{flux}) + \text{const}$$

$$m_2 - m_1 = -2.5\log(f_2/f_1)$$

absolute mag, M_V : brightness from 10 pc

$$m - M = 5(\log(d) - 1) \quad \text{(d in parsecs)}$$

(distance modulus)

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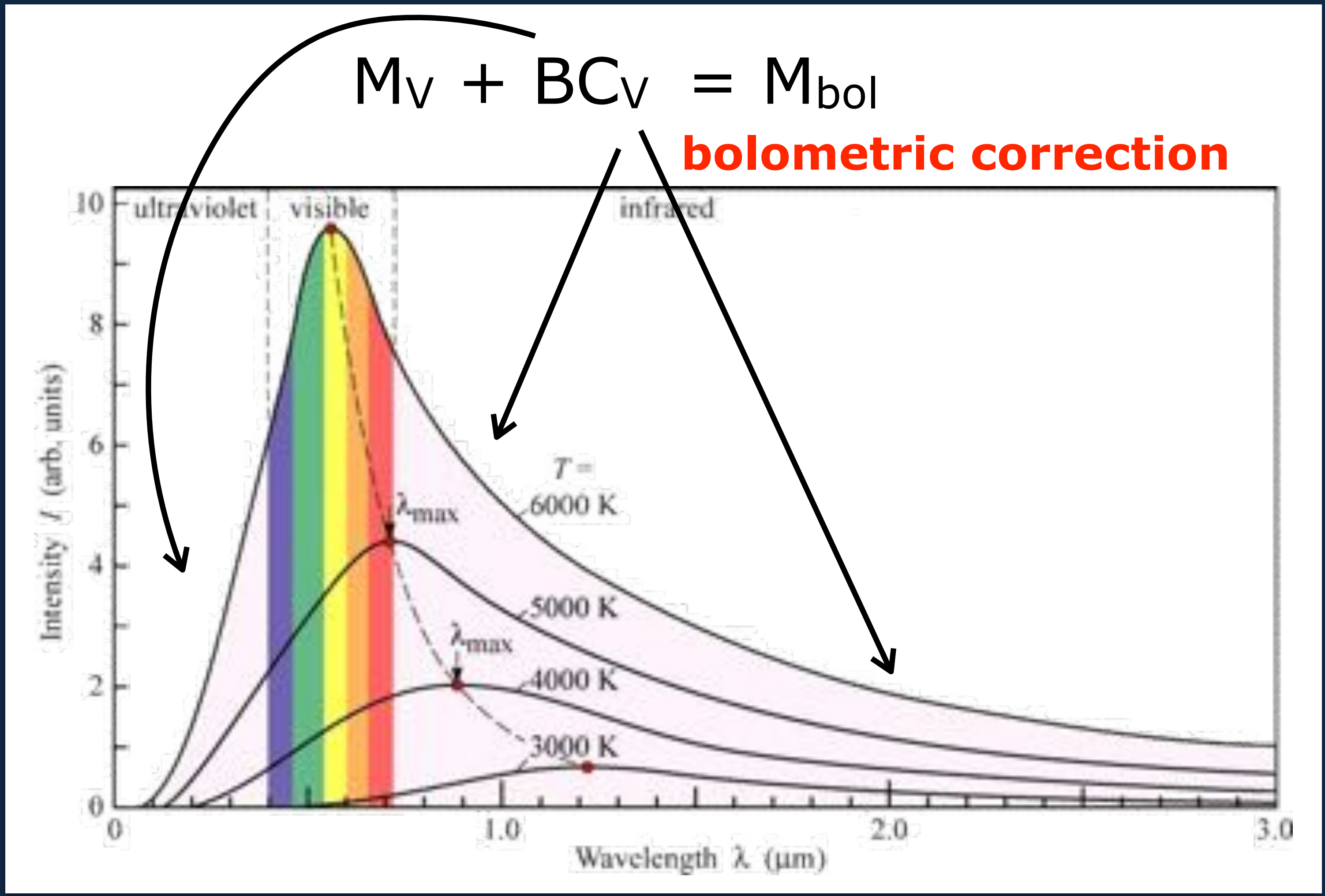
We express stars' brightness in magnitudes.

$M_{\text{all wavelengths}}$ = "bolometric" magnitude, M_{bol}



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We express stars' brightness in magnitudes.

$\mathbf{M_{all\ wavelengths}}$ = "bolometric" magnitude, $\mathbf{M_{bol}}$

$$\mathbf{M_V + BC_V = M_{bol}}$$

$$M_{bol} - M_{bol,\ sun} = -2.5\log(L/L_{sun})$$

$$L = 4\pi R^2 \sigma T^4$$

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$$L = 4\pi R^2 \sigma T^4$$

Stars are assigned **luminosity classes** that serve as a rough proxy for size

more luminous

I - supergiants (more luminous)
II - bright giants
III - giants
IV - subgiants
V - dwarfs

Combine w/ **spectral classes**:

O B A F G K M

...and more...

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1) Distance - parallax, Cepheids
2) Velocity - proper motion, radial velocity
3) Brightness - magnitudes, luminosity
4) Temperature - effective temp (usually)
5) Mass - luminosity, binaries
6) Radius - lunar, interferometry, binaries, L & T

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Types of Stellar Temperature

Excitation - ratio of atoms in different states of excitation, defined by Boltzmann equation

Ionization - ratio of atoms in different stages of ionization, defined by Saha equation

Kinetic - Maxwell-Boltzmann distribution

Color - blackbody assumption

Effective - at the “surface” of a star

$$L = 4\pi R^2 \sigma T^4$$

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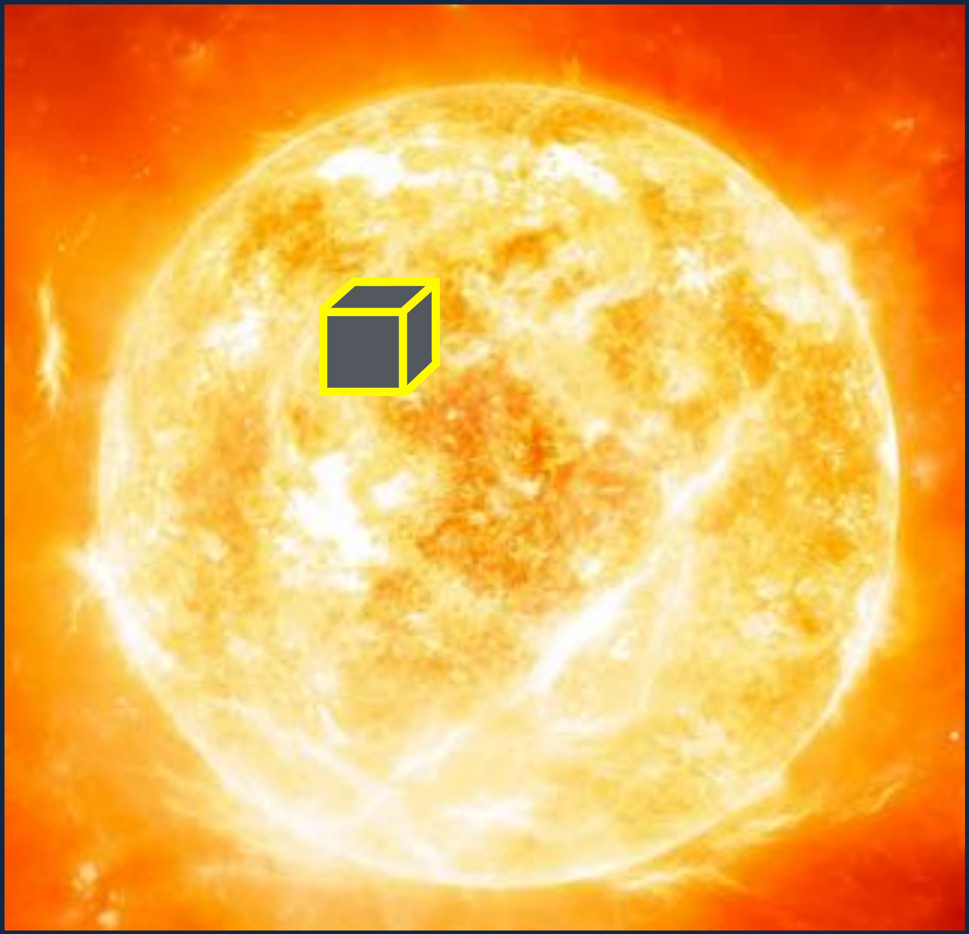
Types of Stellar Temperature

Why aren't these all the same?

Simplest scenario:

- **L**ocal
- **T**hermodynamic
- **E**quilibrium



Excitation
Ionization
Kinetic
Color
Effective

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Determining Stellar Mass

A spectroscopic binary is a classic example of center-of-mass physics:

orbital period P

$$m_1 d_1 = m_2 d_2$$

$$v = 2\pi d/P \text{ so } d = vP/2\pi$$

$$\frac{m_1}{m_2} = \frac{v_2}{v_1}$$

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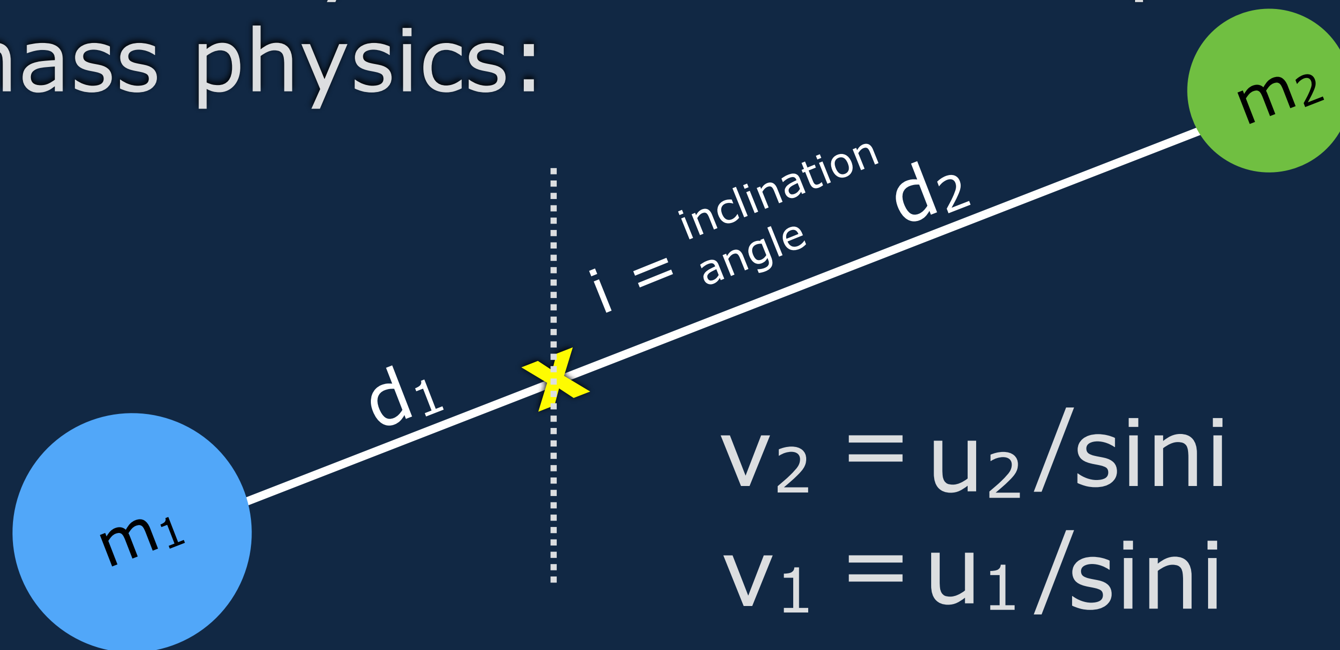
Determining Stellar Mass

A spectroscopic binary is a classic example of center-of-mass physics:



$$v_2 = u_2/\sin i$$

$$v_1 = u_1/\sin i$$

i = 0: face on

i = 90: along orbital plane

$$\frac{m_1}{m_2} = \frac{v_2}{v_1} = \frac{u_2}{u_1}$$

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Determining Stellar Mass

$$\frac{m_1}{m_2} = \frac{v_2}{v_1} = \frac{u_2}{u_1}, \quad v_1 = u_1/\sin i$$

$$m_1 + m_2 = \frac{4\pi^2 (a_1 + a_2)^3}{GP^2}, \quad v_1 = \frac{2\pi a_1}{P}$$

$$\downarrow$$

$$m_1 + m_2 = \frac{P(u_1 + u_2)^3}{2G\pi \sin^3 i}$$

mass from a spectroscopic binary

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