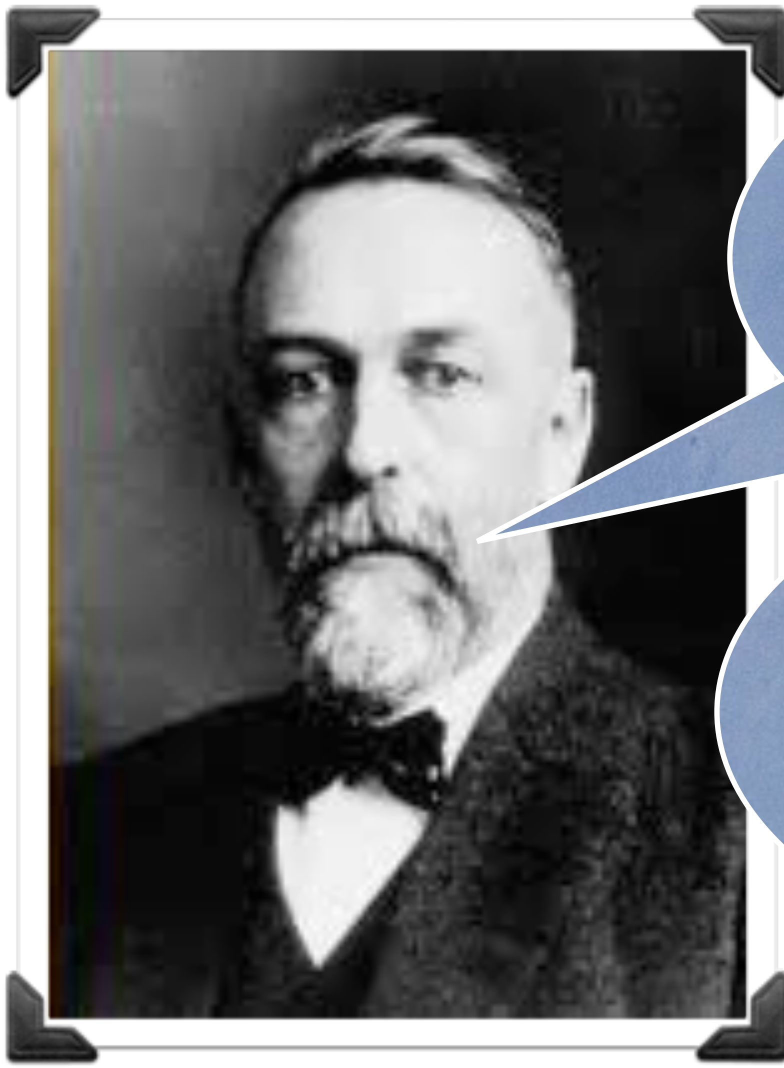
Principles of Astrophysics and Cosmology



Welcome Back to PHYS 3368

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Ejnar Hertzsprung
October 1873 - October 1967

Henry Russell
October 1877 - February 1957

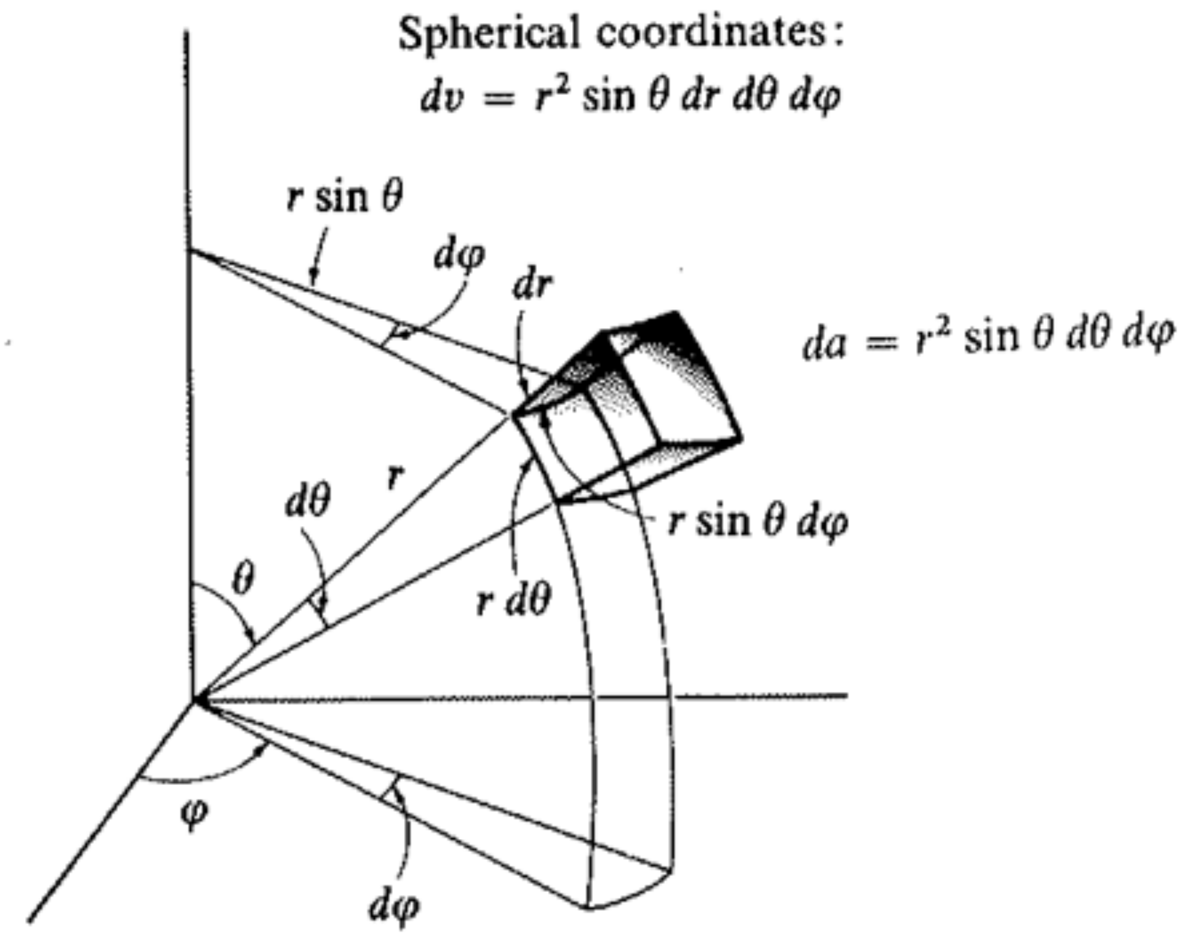
Announcements

- Reading Assignments: Chapter 2 all.
- Problem Set 2 is due Wednesday, February 4th, 2015.
- Next lab is Monday, February 9th. Be sure to report to FOSC 032 that day.
- Note: Your textbook contains errors, including the alleged solutions to some problems. I will point out corrections if/when I notice mistakes. However, I will leave it to you to find mistakes in any "answers" to problems. Use with caution.

Why can I see a faint star out of the corner of my eye, but not when I look straight on?

Your eye has two kinds of receptors: rods and cones. The rods are much more sensitive to light than the cones. The cones are concentrated directly behind the lens, while the rods tend to occupy the periphery.

Review Spherical Coordinates



The volume element is

$$dV = r^2 \sin\theta dr d\theta d\phi$$

The surface element is

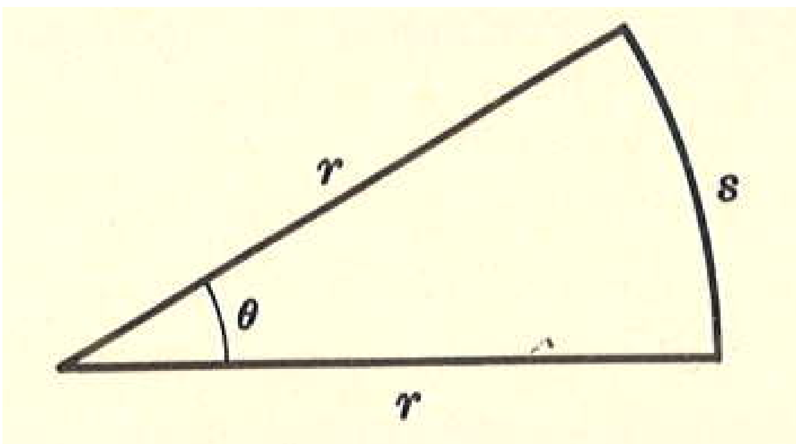
$$da = r^2 \sin\theta d\theta d\phi$$

The solid angle element is

$$d\Omega = \sin\theta d\theta d\phi$$

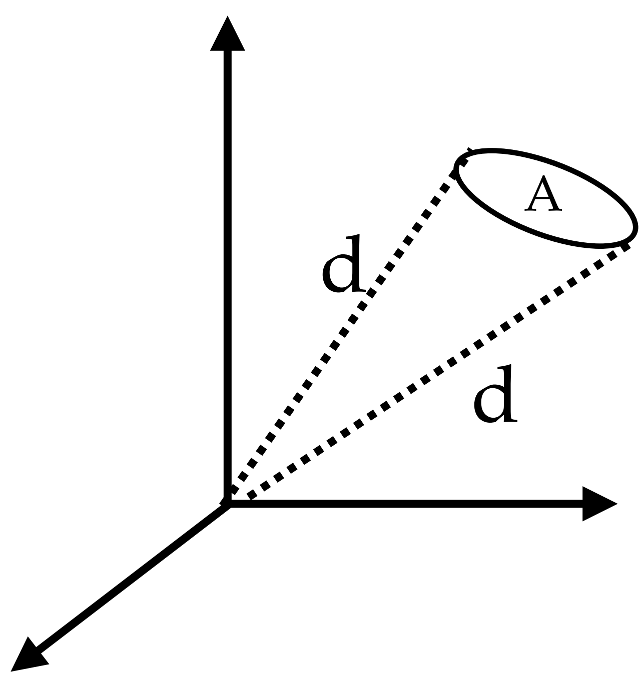
Small Angle Approximation

Arc Length:



$$s = r\theta$$

Solid Angle:



$$A = d^2\Omega$$

Which has the larger surface area, the sun or the moon?

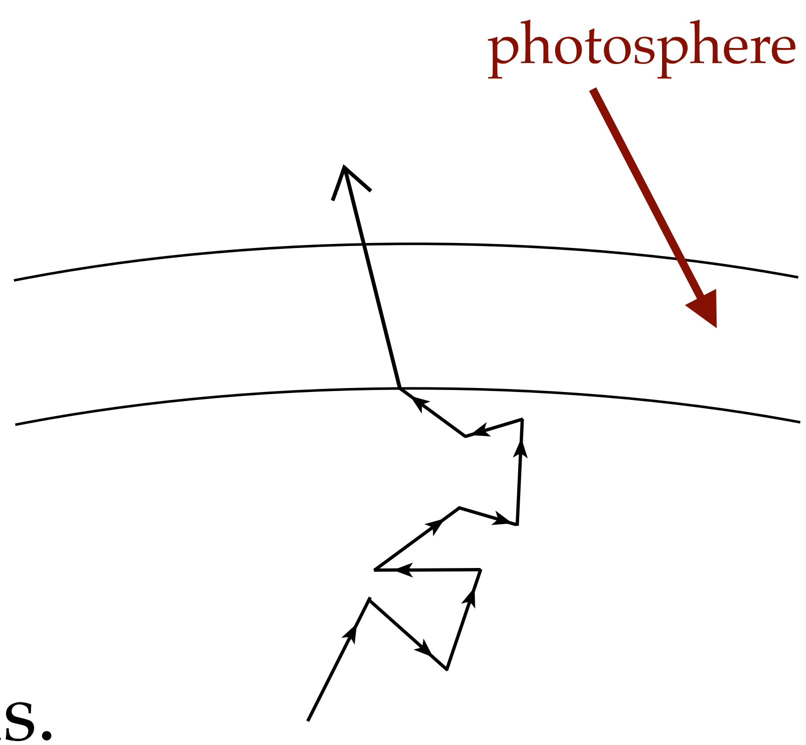
The sun.

Which has the larger solid angle as viewed from Earth, the sun or the moon?

They are the same!

In class activity on solid angle.

Stellar Temperatures and Stellar Types



<u>Photosphere:</u>

The outer most "surface" of a star. Roughly this is the region from which photons can escape without further scattering.

<u>Notes:</u>

- The temperature of a star varies with radius.
- The depth of the photosphere depends on the photon wavelength. Does this make sense?
- The emitted spectrum of a star is largely determined by the temperature of the photosphere.
- The **<u>color temperature</u>** of a star is the temperature of the blackbody spectrum that best fits the observed stellar spectrum.

How might we find the color temperature of a star?

1. Wein's Law: If we could identify the peak of the blackbody spectrum, we could use Wein's law to calculate the temperature. (This is often not possible as the peak is frequently outside the region for which we have data.)

2. Take the ratio of fluxes at two different wavelengths and find the temperature of the blackbody that gives that ratio.

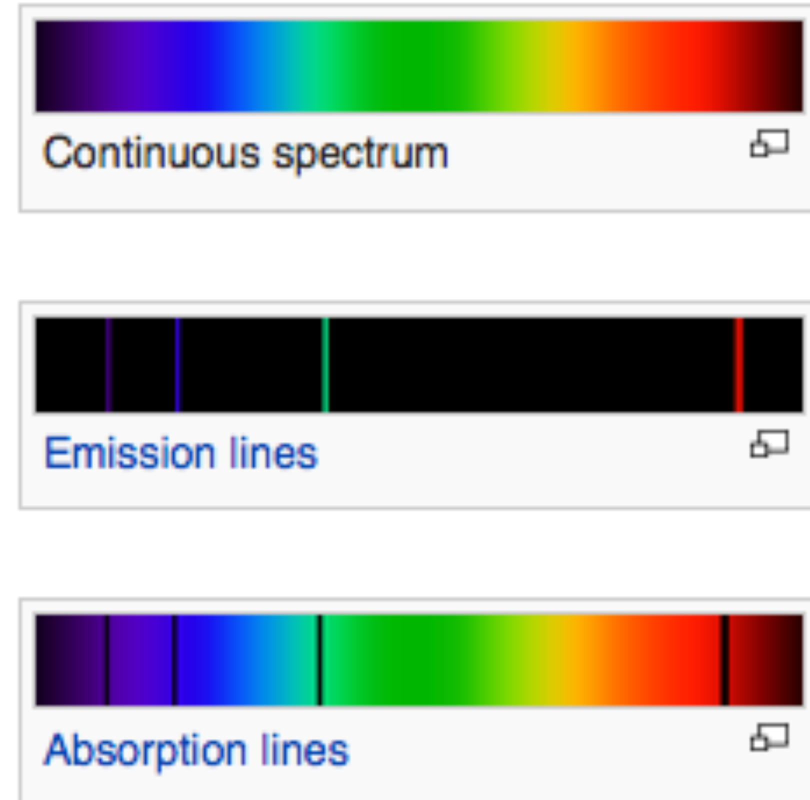
$$f_\lambda(\lambda_1)/f_\lambda(\lambda_2)$$

This ratio is what astrophysicists mean by color.

Example: What does it mean to be red?

We measure a larger ratio of red to blue photons for "red" than we do for "white".

Gustave Kirchhoff and Robert Bunsen developed the idea that every element produces its own pattern of spectral lines an can thus be identified by a unique spectral line "fingerprint".



Kirchhoff's Laws:

1. A hot, dense gas or hot solid object produces a continuous spectrum with no dark spectral lines.

2. A hot, diffuse gas produces bright spectral lines (**emission lines**).

3. A cold, diffuse gas in front of a source of continuous spectrum produces dark spectral lines (**absorption lines**) in the continuous spectrum.

Review: Atomic Structure

- Electrons "orbit" around the nucleus only at fixed energy levels. Thus, the emission and absorption spectrum of any atom consists of a discrete set of lines.

- The energy levels in the hydrogen atom are given by:

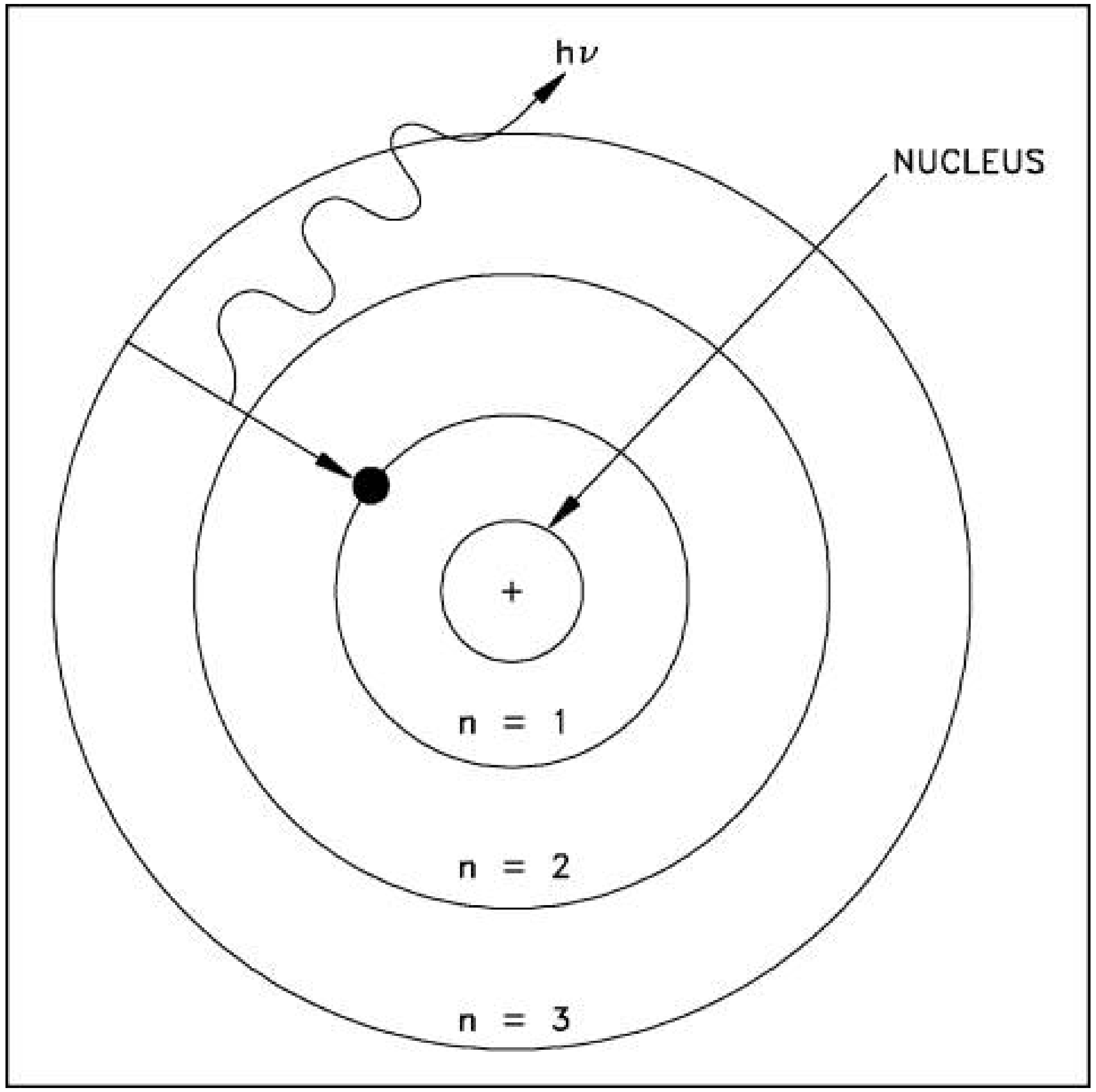
$$E_n = -\frac{e^4 m_e}{2\hbar^2}\frac{1}{n^2} = -13.6\,\mathrm{eV}\,\frac{1}{n^2}$$

- The energy difference between levels is given by:

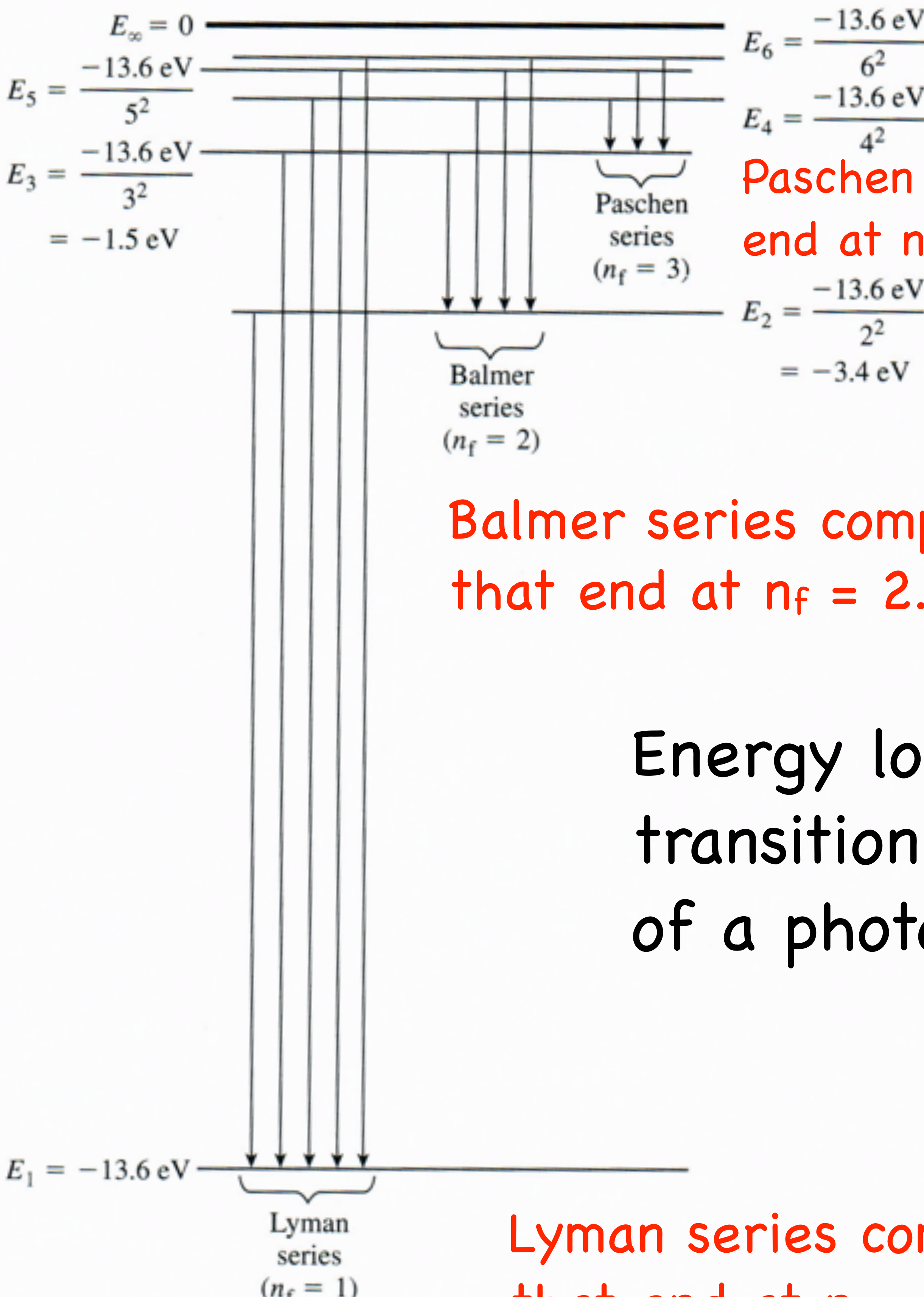
$$E_{n_1,n_2} = 13.6\,\mathrm{eV}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

- The wavelength of a photon emitted or absorbed in a radiative transition is given by:

$$\lambda_{n_1,n_2} = \frac{hc}{E_{n_1,n_2}} = \frac{911.5\ \text{Å}}{1/n_1^2 - 1/n_2^2}$$



Notation: I prefer n_f and n_i, rather than n_1 and n_2. In your book's notation, n_2 is the final state.



Paschen series comprises all transitions that end at $n_f = 3$.

Balmer series comprises all transitions that end at $n_f = 2$.

Energy lost by the downward transition is emitted in the form of a photon.

Lyman series comprises all transitions that end at $n_f = 1$.

Special Names:

The Lyman and Balmer series have special names for some transitions.

$$\text{Ly}\alpha\text{: } 2 \leftrightarrow 1, 1216 \text{ Å};$$
$$\text{Ly}\beta\text{: } 3 \leftrightarrow 1, 1025 \text{ Å};$$
$$\text{Ly}\gamma\text{: } 4 \leftrightarrow 1, 972 \text{ Å};$$
$$\vdots$$
$$\text{Lyman continuum} = \infty \leftrightarrow 1, <911.5 \text{ Å}$$

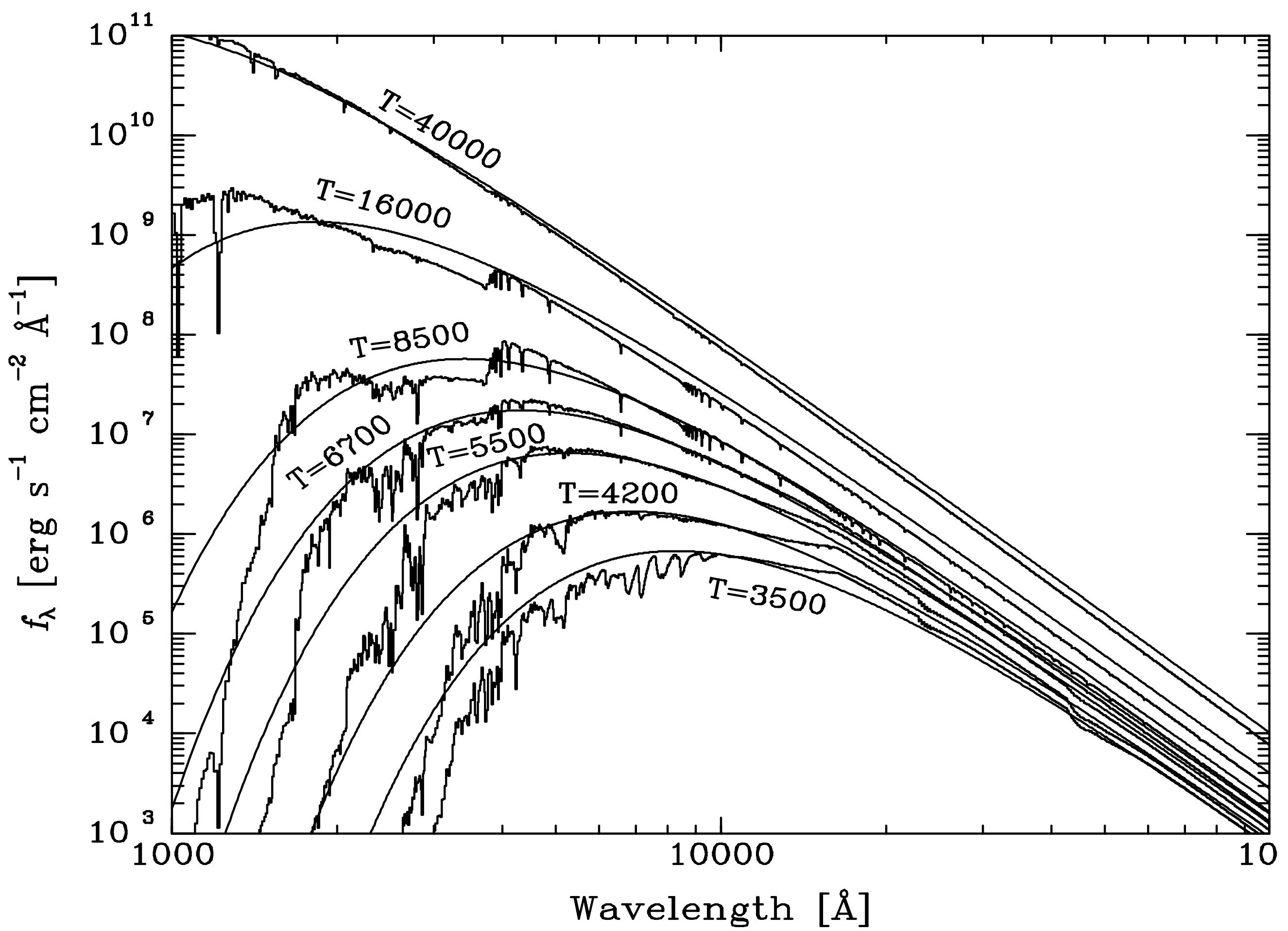
Photon wavelengths are in UV region.

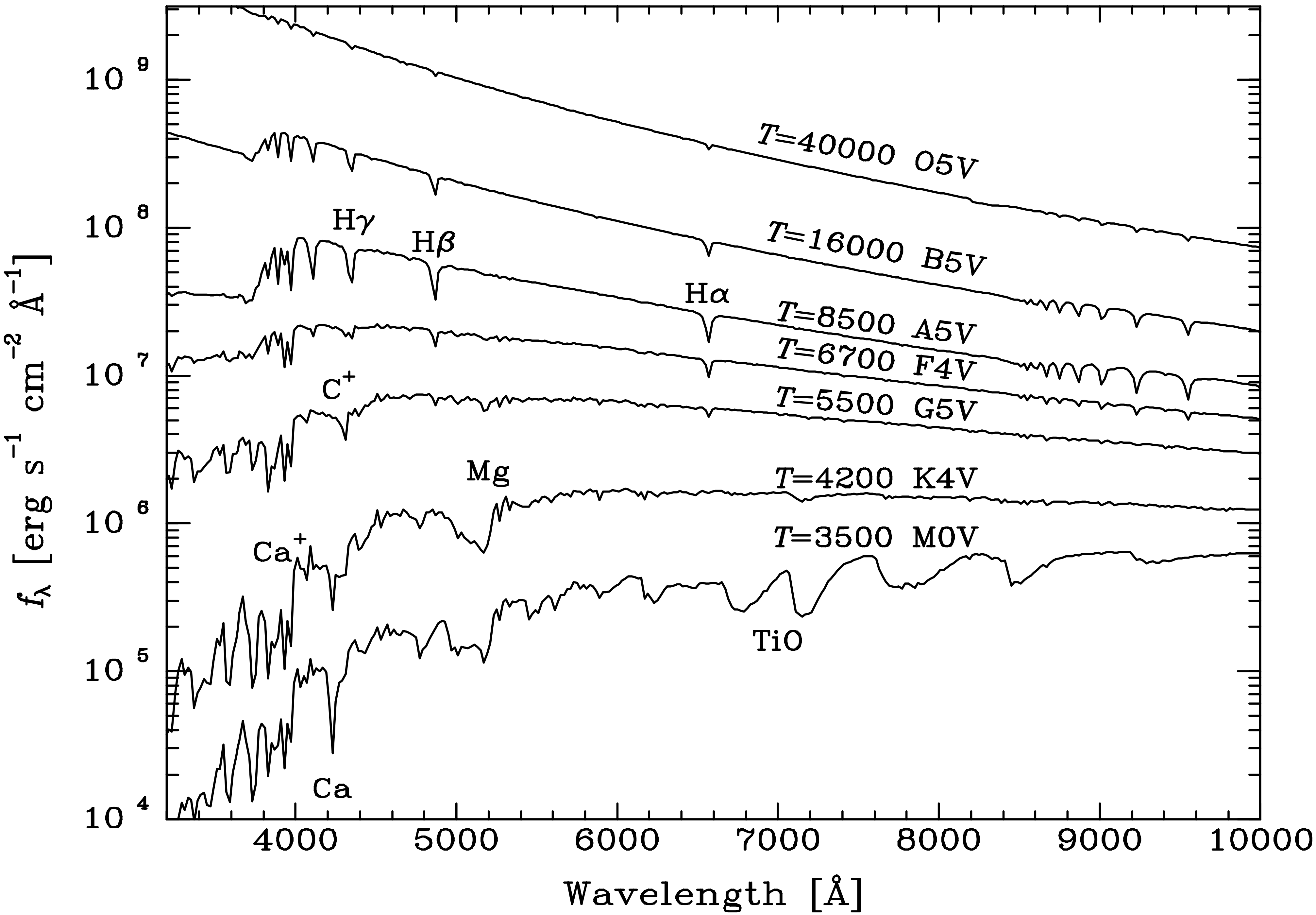
$$\text{H}\alpha\text{: } 3 \leftrightarrow 2, 6563 \text{ Å}$$
$$\text{H}\beta\text{: } 4 \leftrightarrow 2, 4861 \text{ Å}$$
$$\text{H}\gamma\text{: } 5 \leftrightarrow 2, 4340 \text{ Å}$$
$$\vdots$$
$$\text{Balmer continuum} = \infty \leftrightarrow 2, <3646 \text{ Å}$$

Photon wavelengths are in optical region.

Classification of Stars

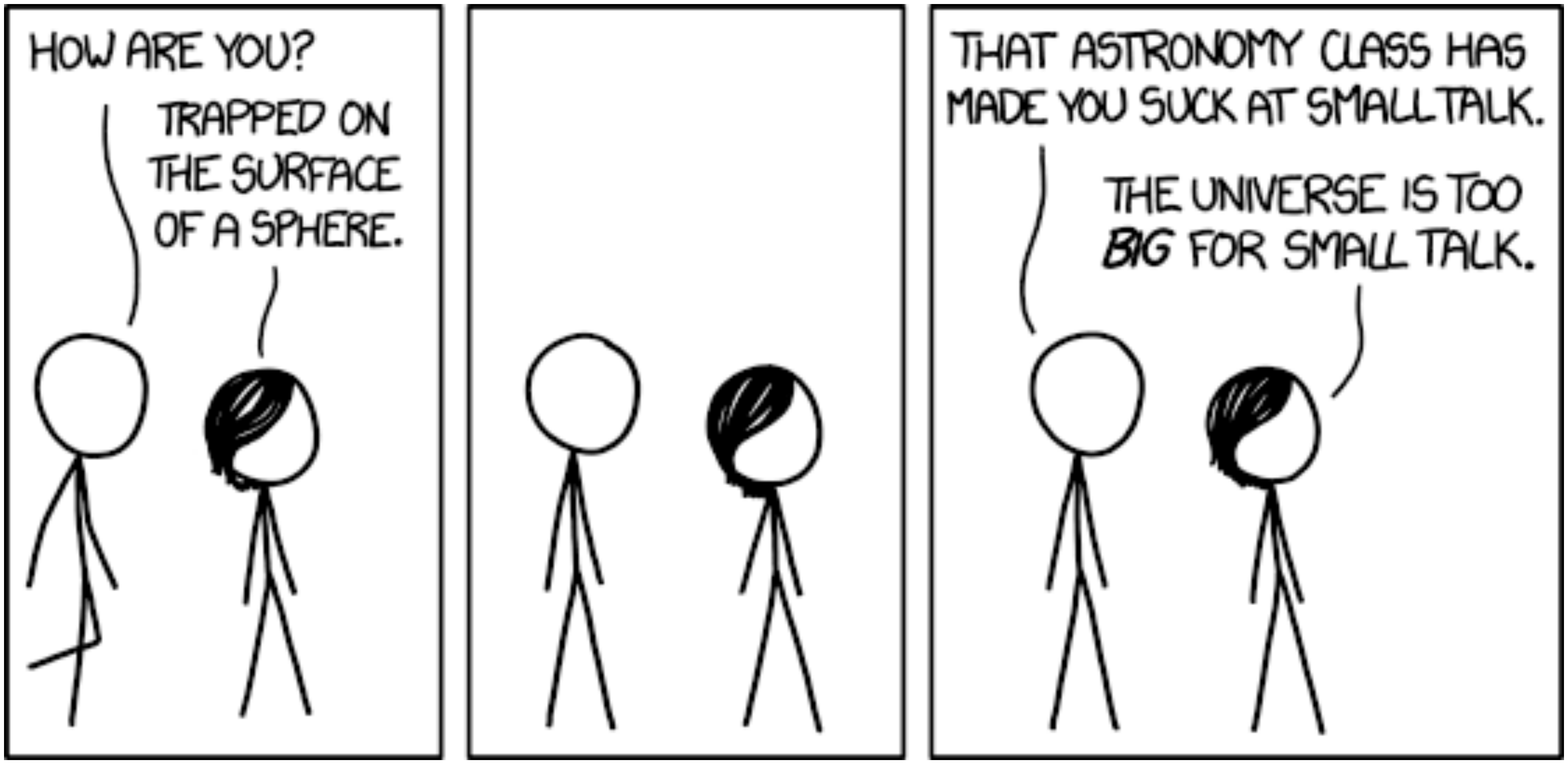
- Stars are classified according to their surface (color) temperature.
- Spectral types are OBAFGKM with a digit 0 - 9 in order from hottest (O1) to coldest (M9).
- A Roman numeral is added to the classification to indicate size: I = giant and V = dwarf.





Atomic spectral lines produced in the photosphere also depend on temperature and provide another means of classification.

The End (for today)!



http://xkcd.com/1248/