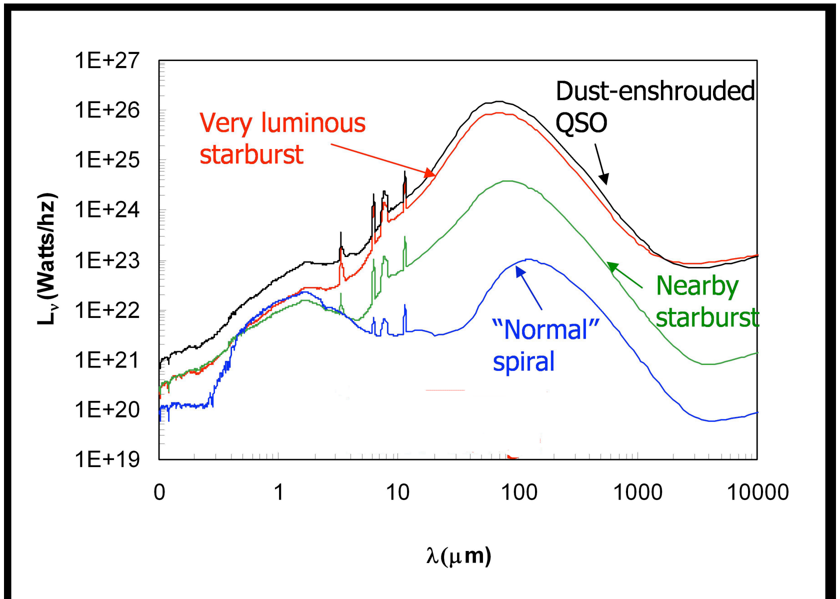
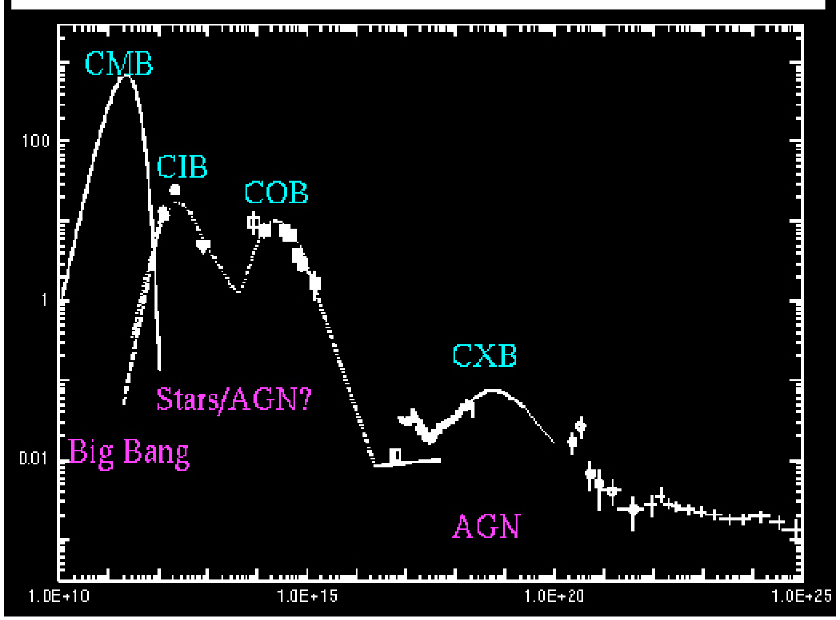
Some Useful Astronomical Definitions

(Ref: B&M S 2.3, Lena Ch. 2)

- Spectral Energy Distribution
- Flux, Flux Density, & Luminosity
- Magnitudes
- Measuring flux
- Color
- Absolute Magnitude
- Parsec
- An Example

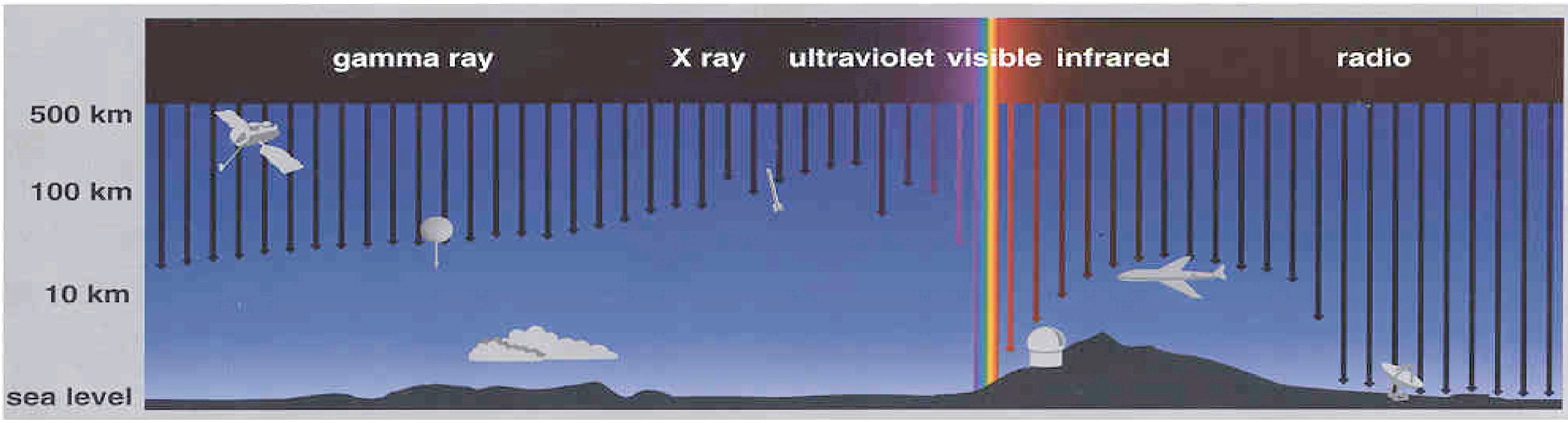
Spectral Energy Distribution





- The energy emitted from a source as a function of wavelength/frequency
- The whole SED of a source is difficult to measure

Transmission of the Atmosphere



- Optical, some infrared (IR), and Radio are easily accessible
- Other wavelengths require satellites/planes
  1) Absorption scattering
  2) Airglow
  3) Thermal emission

Flux Density, Flux

- Flux density: f_ν or f_λ, measured in units of W m^{-2} Hz^{-1} or W m^{-2} μm^{-1} (or the equivalent)

- Flux: measured in units of W m^{-2} (or the equivalent). To convert flux density to flux,

$$f = \nu f_\nu \quad \text{or} \quad f = \lambda f_\lambda$$

Luminosity

- For a source at a distance *R* & measured flux *f*, the luminosity is,

$$L_\nu = 4\pi R^2 f$$

- Luminosity is measured in units of Watts (I.e., J/s) or ergs/s, & it is determined for whatever wavelength/frequency the flux is determined at.
- **Bolometric Luminosity**: the luminosity of an object measured over all wavelengths

Magnitude

- The magnitude is the standard unit for measuring the apparent brightness of astronomical objects
- If m_1 and m_2 = magnitudes of stars with fluxes f_1 and f_2, then,

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

- Alternatively,

$$f_1/f_2 = 10^{-0.4(m_1 - m_2)}$$

Note that 1 mag corresponds to a flux ratio of 2.5

Note that 5 mag corresponds to a flux ratio of 100

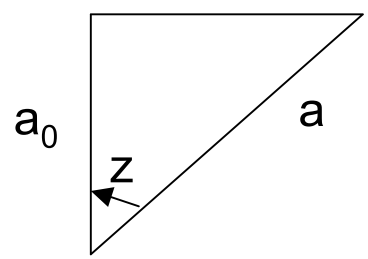
The lower the value of the magnitude, the brighter the object

Measuring flux

- We don't directly measure the flux that reaches us from a source. We measure:

$$f = \int_0^\infty f_\nu T_\nu F_\nu R_\nu d\nu$$

- Where f_ν = flux of the astronomical source
- T_ν = the transmission of the atmosphere ~ e^{-a}.



$$\text{air mass} = a/a_0 = \text{hypotnuse}/\text{adjacent} = \sec z$$

$$m(z) = k\sec z + \text{constant}$$

Effects of extinction: make standard stars measurements are different *z*

- F_ν = Transmission of the filter
- R_ν = Telescope efficiency

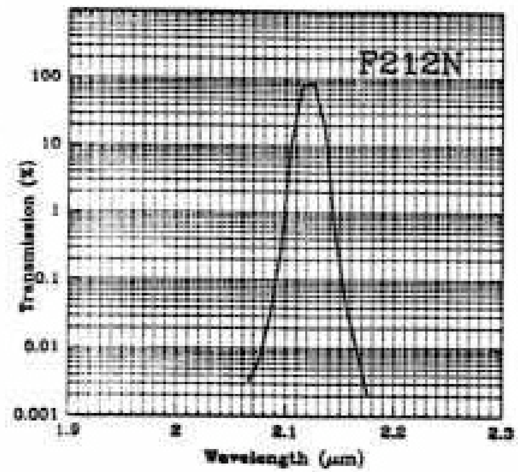
Filter Parameters

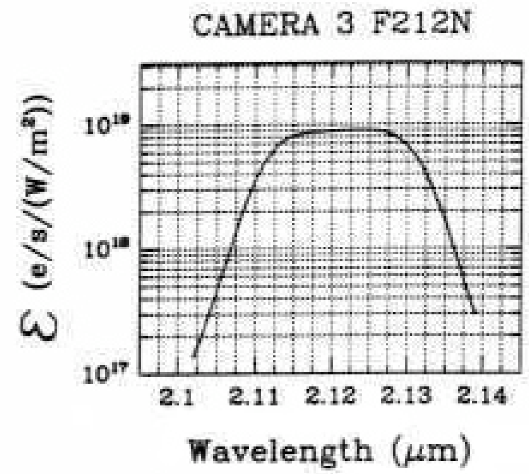
Camera 3, Filter F212N

H_2 line
Also available in Camera 2.
Thermal background important.

Central wavelength (μm)	Mean wavelength (μm)	Peak wavelength (μm)	FWHM (μm)	Range	MaxTr %	Pixel fraction
2.1211	2.1213	2.1228	0.0206	1%	90.90	0.63

Figure 11.89: Camera 3, Filter F212N





- Effective wavelength (λ_{eff}) = the central wavelength of the filter
- The FWHM transmission of the filter: the λ difference over which f_ν falls to half its peak value

Photometric System

Table 1. UBVRIJHKLM Filters

Band	λ_{eff} μm	FWHM μm	$f_X(m_X = 0)$* Jy**	
U	0.365	0.066	1780	ultraviolet
B	0.445	0.094	4000	blue
V	0.551	0.088	3600	visible
R	0.658	0.138	3060	red
I	0.806	0.149	2420	
J	1.220	0.213	1570	↓ near-infrared ↓
H	1.630	0.307	1020	
K	2.190	0.390	636	
L	3.450	0.473	281	
M	4.750	0.460	154	

*$m_X = 0$ for a star with spectral type and luminosity A0 V.

**Note: 1 Jy = 10^{-26} W m^{-2} Hz^{-1}.

- Johnson & Morgan UBV system expanded into the infrared
- These filters are commonly referred to as bands or wavebands
- Flux density, mag, or luminosity in a particular band X = f_X, m_X, and L_X

Filters (continue)

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- f_X (m_X = 0) = zero point flux density of *X*. I.e., the flux density of a zero magnitude star (the star Vega)
- If the flux density of wavelength *X* is measured, then the mag is,

$$m = -2.5 \log \frac{f_x(\text{source})}{f_x(m_x = 0)}$$

Color

- **Color**: the difference in mags measured in 2 different wavebands

$$m_X - m_Y = \mathrm{constant} - 2.5\ \log(f_X/f_Y)$$

- Typically, it is written as *X*-*Y*

Absolute Magnitude

- If the flux *F* of a source is measured at a distance *D*, then the flux *f* measured from the same source at a distance *d* is,

$$f = (D/d)^2 F$$

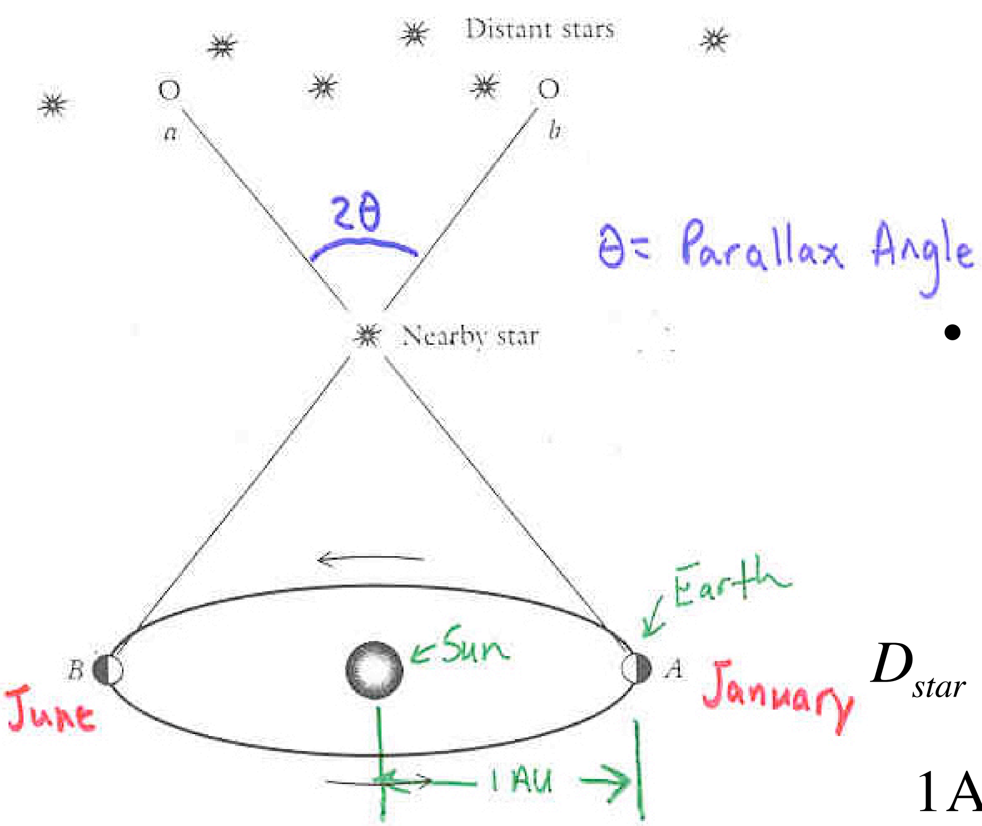
- Absolute Magnitude: M is the apparent magnitude a source would have were it at a standard distance *D* = 10 pc. Thus,

$$m - M = -2.5\ \log(f/F) = 5\ \log(d/D) = 5\log(d) - 5$$

where *d* is measured in parsecs (pc).

Parsec - a commonly used measure of distance in extragalactic astronomy

FIGURE 2.1 As the Earth moves around the Sun from position *A* to position *B*, an observer with a powerful telescope will see the nearby star appear to move from position *a* to position *b* among the background stars. This proves that the Earth moves around the Sun.



- Method: Parallax – the apparent displacement of an object caused by the motion of the observer

$$\theta = \frac{\text{Earth} - \text{Sun Distance}}{\text{Distance to Star}}$$

- A star with a parallax angle of 1” is at a distance of 1 pc = 3.1x10^{16} m (~ 3.25 light years). I.e.,

$$D_{star} = \frac{D_{1\mathrm{AU}}}{\theta}$$

$$= \frac{1\,\mathrm{AU}}{1''} \cdot \frac{3600''}{1^{\circ}} \cdot \frac{180^{\circ}}{\pi} = 3.1 \times 10^{16}\,\mathrm{m} = 1\,\mathrm{pc}$$

An Example

- The Sun's absolute B magnitude is M_B = 5.48. At 1 astronomical unit (AU = 4.87x10^{-6} pc), the sun's apparent *B* mag is,

$$m_B = 5\ \log(4.87 \times 10^{-6}\ \mathrm{pc}) - 5 + 5.48 = -26\ \mathrm{mags\ at\ B}$$

- For galaxies, M_B = -7 to -26. I.e., very luminous galaxies have M_B = m_B (sun). Comparing solar & luminous galaxy *B*-band luminosities,

$$\frac{L_B(\mathrm{gal})}{L_B(\odot)} = \frac{f_B(\mathrm{gal})4\pi D^2_{10\ \mathrm{pc}}}{f_B(\odot)4\pi d^2_{1\ \mathrm{AU}}} = 4.2 \times 10^{12}$$

- I.e., it would take 4.2x10^{12} suns to make up the luminosity of a massive galaxy,

Example (cont)

- The flux density of the sun can be calculated using the zero-point B-band flux density of f_B (m_B = 0) = 4000x10^{-26} W m^{-2} Hz^{-1}. So,

$$m_B(\odot) = -2.5 \log[f_B(\odot)/f_B(m_B = 0)]$$

can be rewritten

$$f_B(\odot) = f_B(m_B = 0) \times 10^{-[m_B(\odot)/2.5]}$$

$$f_B(\odot) = 4000 \times 10^{-26} \times 10^{-(-26/2.5)}$$

$$f_B(\odot) = 1.00 \times 10^{-12} \text{ W m}^{-2} \text{ Hz}^{-1}$$

Example (cont')

- What is the amount of *B*-band energy the earth receives per second from the sun?

At **B** band, the frequency is simply,

$\nu = c/\lambda = 2.9979 \times 10^8 \text{ m}/0.44 \times 10^{-6} \text{ m} = 6.81 \times 10^{14}$ Hz

Thus, the energy received per second is,

$$\nu f_B(\odot) 2\pi R_{\text{earth}}^2$$

$$= (6.81 \times 10^{14} \text{m})(1.00 \times 10^{-12} \text{ W m}^{-2} \text{ Hz}^{-1}) 2\pi (6.4 \times 10^6 \text{ m})^2$$

$$= 1.76 \times 10^{17} \text{W}$$

By comparison, the Sun's *B*-band & bolometric luminosities are,

$$L_B(\odot) = \nu f_B(\odot) 4\pi R_{1\ \text{AU}}^2 = 1.9 \times 10^{26} \text{W}$$

$$L_{\text{Bol}} = 3.9 \times 10^{26} \text{ W}$$