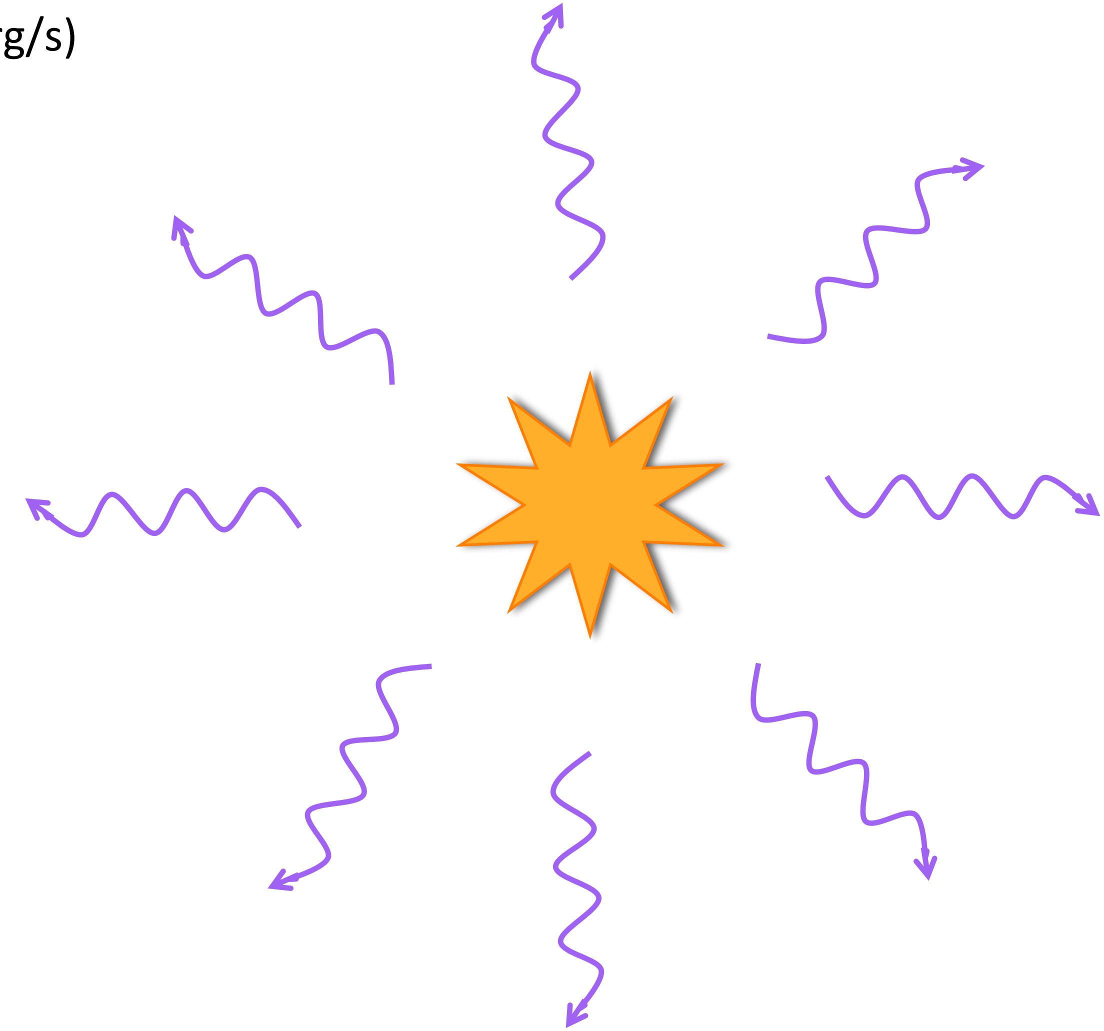
Fluxes

1 March 2016

intrinsic **luminosity**
L = energy emitted
per second (erg/s)



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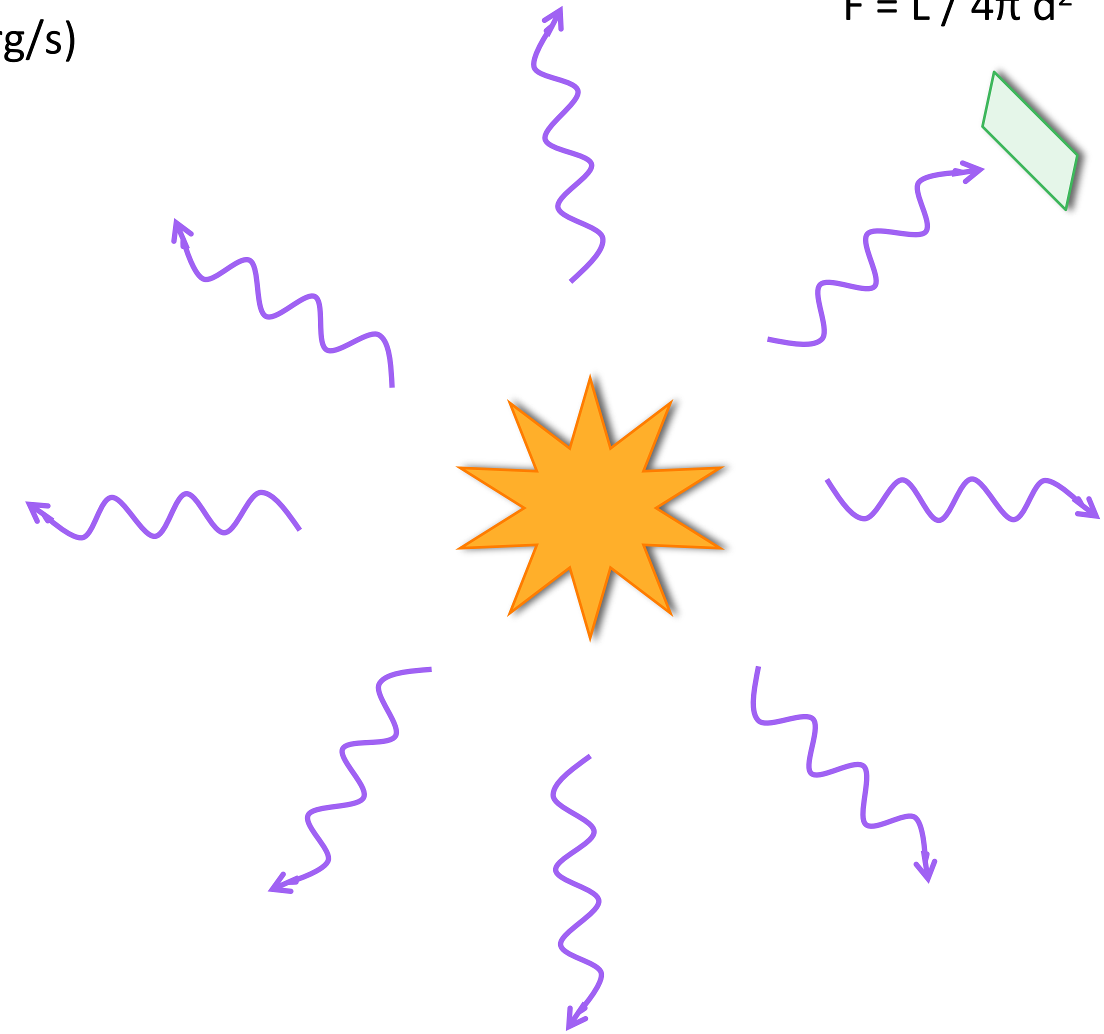
flux F = energy received
per unit area
$F = L / 4\pi d^2$ (erg/s/cm^2)



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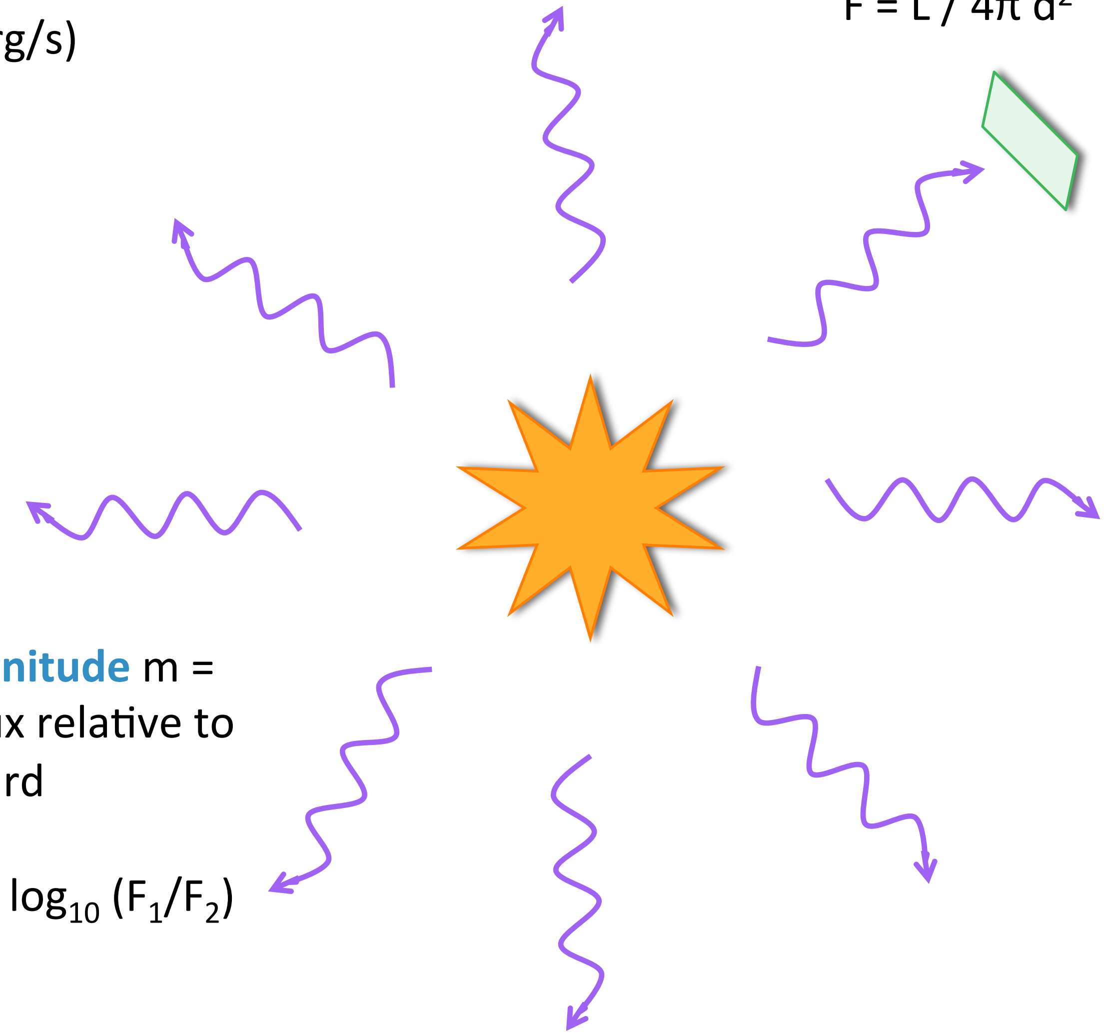

apparent magnitude m =
measure of flux relative to
chosen standard

$m_1 - m_2 = -2.5 \log_{10} (F_1/F_2)$

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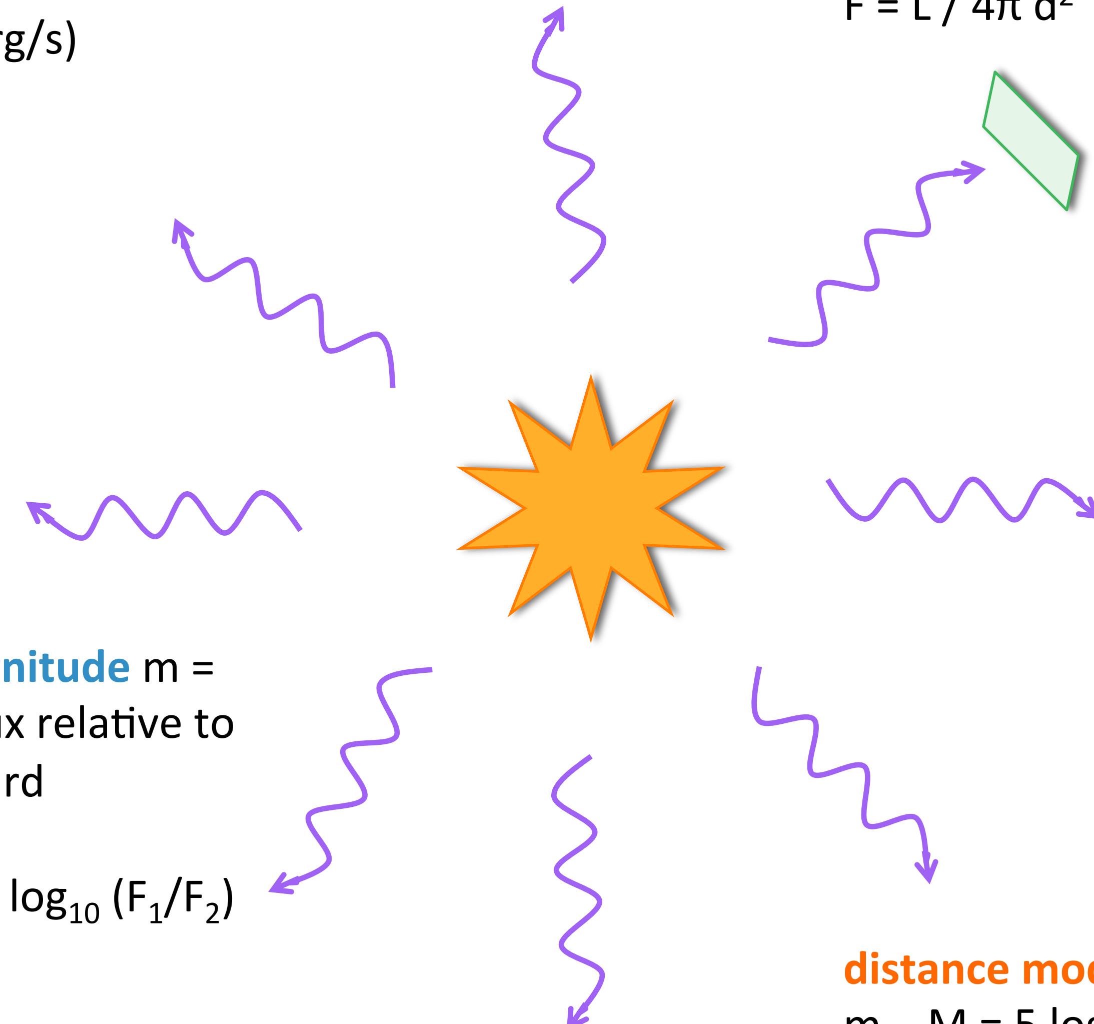

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distance modulus
$$m - M = 5 \log_{10} (d/10\text{pc})$$

absolute magnitude M = measure of flux
you would see if you were 10 pc away

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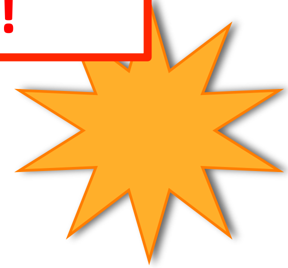

flux density = flux per unit wavelength or per unit frequency

$F_\lambda = erg/s/cm^2/Å$
$F_\nu = erg/s/cm^2/Hz$ or
Jansky (Jy) =
$10^{-26}\ W/m^2/Hz$

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$m - M = 5 \log_{10} (d/10pc)$

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Luminosity can be either in a given band or
"**bolometric**" = covering all wavelengths

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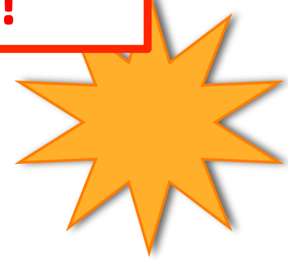

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In pairs…

- If one star is 5 magnitudes fainter than another, how much longer do you have to integrate to get the same number of counts on the fainter star as you got on the brighter star?

- Remember: $m_1 - m_2 = -2.5 \log_{10} (F_1/F_2)$

- (3 minutes)

Main magnitude systems: 1

- Vega magnitudes (Johnson System)
  - Defined so that the magnitude of Vega in any wavelength band is 0. (But better flux calibrations show it is now actually 0.03.)

  - $m_{*,\text{Vega system}} = -2.5 \log_{10} (F_*/F_{\text{vega}})$

Flux Densities of Vega in Various Bands (in Jy=10^{-26} W m^{-2} Hz^{-1})				
U	B	V	R	I
1810	4260	3640	3080	2550
J	H	K	L	M
1520	980	620	280	153

See Bessel, M.S. 2005, ARA&A, 43, 293

Main magnitude systems: 2

- AB Magnitudes
  - Defined so that an object with constant flux *per unit frequency* (F_ν in units of erg/s/cm^2/Hz) has the same magnitude in all bands and therefore zero color
    - $m_{band1} - m_{band2}$ = "band1 – band2 color"
  - $m_{AB} = -2.5 \log_{10}(F_\nu \text{ in erg/s/cm}^2\text{/Hz}) - 48.60$

Oke, J.B. 1974, ApJS, 27, 21

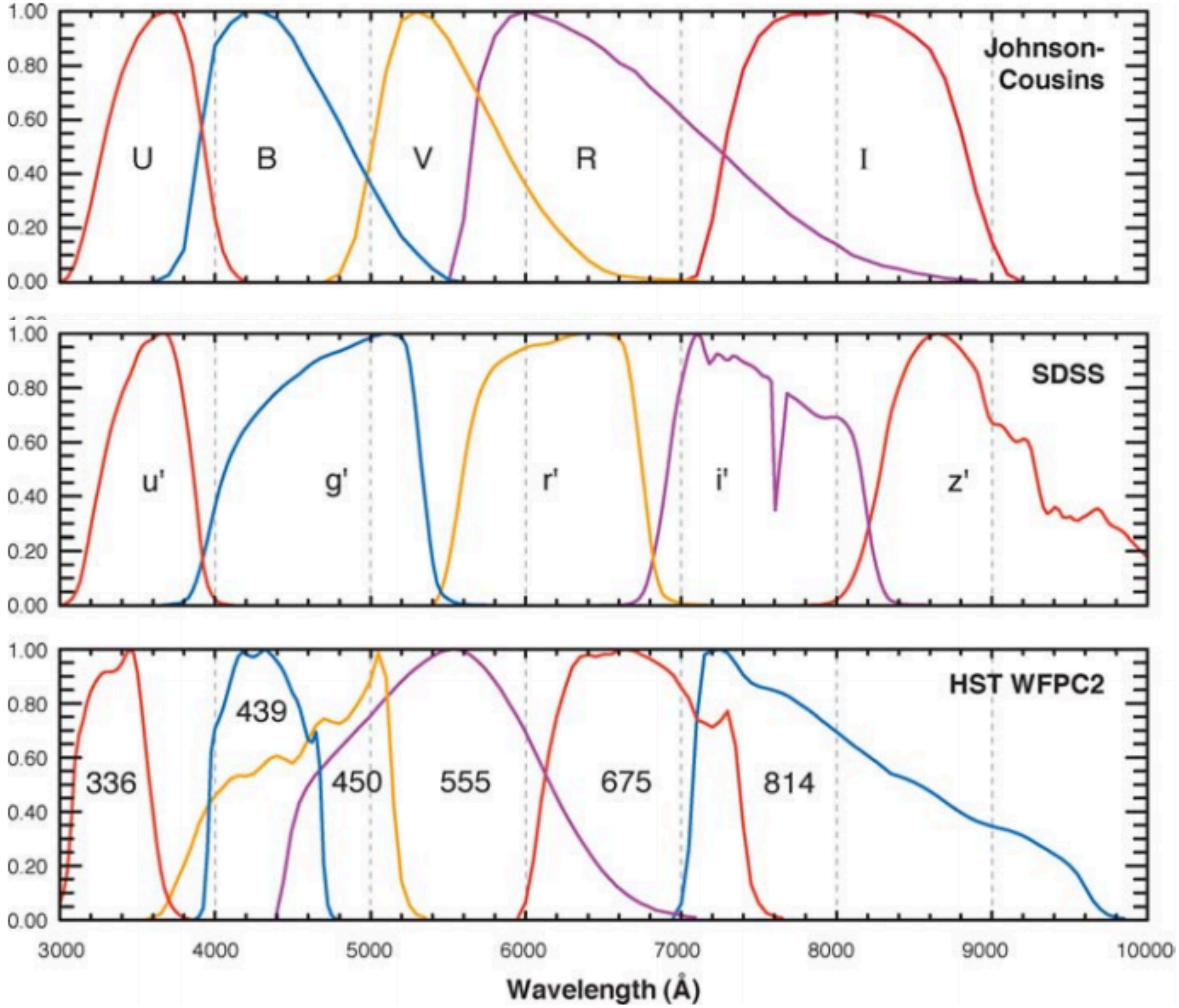
Main magnitude systems: 3

- ST Magnitudes
  - Defined so that an object with constant flux *per unit wavelength* (F_λ in units of erg/s/cm^2/Å) has the same magnitude in all bands and therefore zero color
  - Remember, $F_\lambda\, d\lambda = F_\nu\, d\nu$
  - $m_{ST} = -2.5 \log_{10}(F_\lambda \text{ in erg/s/cm}^2/\text{Å}) - 21.10$

Stone, R. P. S. 1996, ApJS, 107, 423

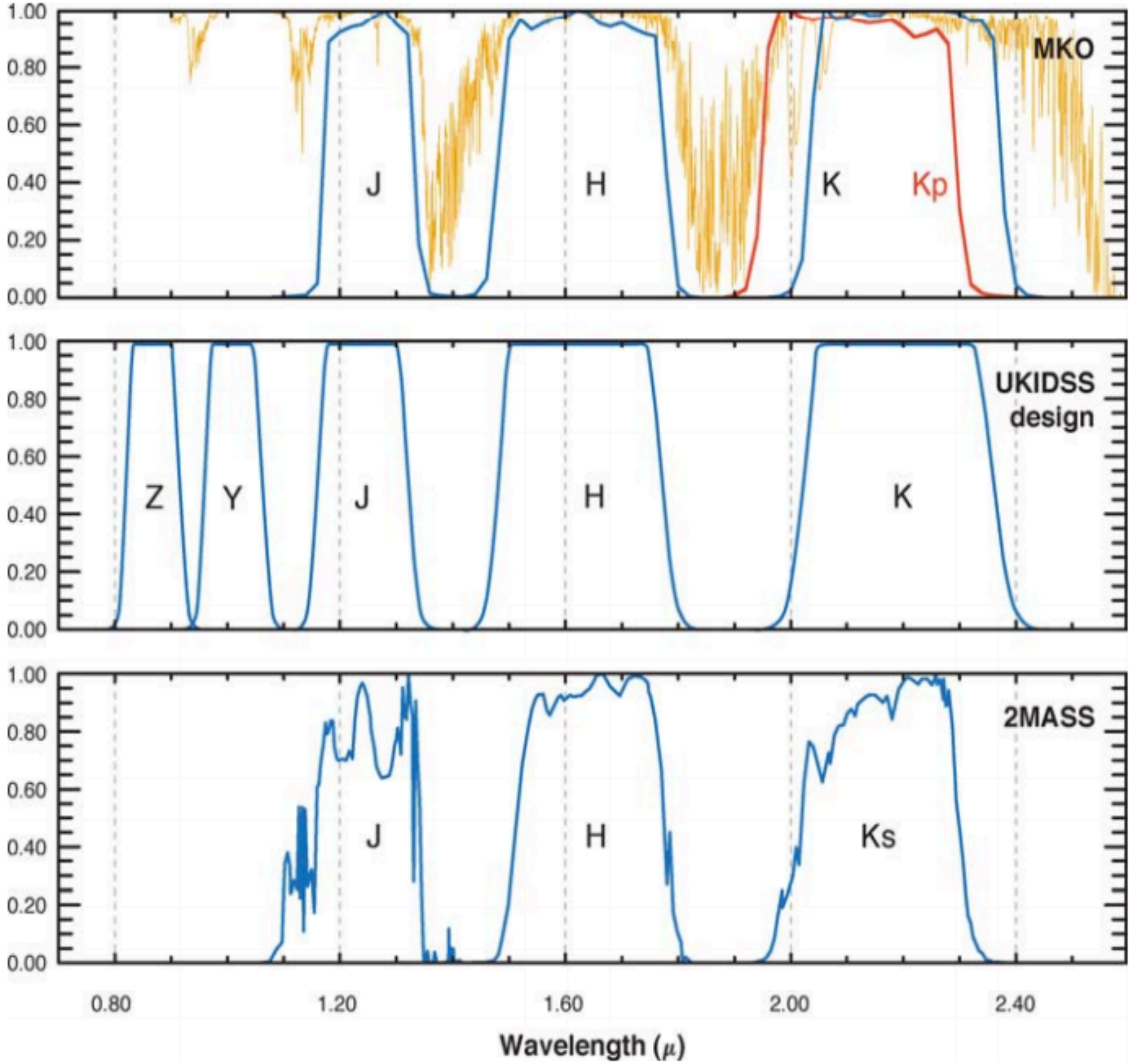
Filter Sets

- Can be broad band (few hundred nm wide) or narrow band (<20 nm)
- There are as many filter sets as there are telescopes (practically!)



Some common optical bands

Bessel, M.S. 2005, ARA&A, 43, 293



NIR bands trace atmospheric windows

Bessel, M.S. 2005, ARA&A, 43, 293

Flux Densities

- Beyond the optical / near-infrared, other photometric systems use flux density instead of magnitudes (usually in Jy)
  - IRAS + Spitzer in (mid- and) far-infrared
  - Radio
  - UV
  - X-ray

In pairs…

- In the AB magnitude system, your favorite object has a K-band magnitude of 19 and a color of zero. What is its K-band magnitude in the ST system?

- Assume K-band is from 2.0-2.4 microns
  - Remember, $F_\lambda \, d\lambda = F_\nu \, d\nu$
  - $m_{ST} = -2.5 \log_{10}(F_\lambda \text{ in erg/s/cm}^2/\text{Å}) - 21.10$
  - $m_{AB} = -2.5 \log_{10}(F_\nu \text{ in erg/s/cm}^2/\text{Hz}) - 48.60$

- (5 minutes)

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Converting Flux Densities

$$F_\lambda \, d\lambda = F_\nu \, d\nu$$

$\lambda\nu = c$ $\nu = c / \lambda$ $\lambda = c / \nu$

$$\boxed{\mathbf{d\lambda/d\nu = \lambda^2/c}}$$

$$\mathbf{F_\nu = F_\lambda \lambda^2/c}$$

Flux Calibrating Your Data

- For the most accurate calibration you must:
  - Select (in advance) standard stars bracketing the color of your object
  - Observe them over a range of airmasses at the start and end of the night
    - Gives atmospheric extinction
  - Observe several standards each hour throughout the night
    - Measures variations in zero point (transparency of atmosphere)

Quicker version

- Select a standard star similar in color to your object
- Observe it before and after your observations
- You want your observations of the standard to be at similar airmass when you observe them to the airmass of your object when you observed it!

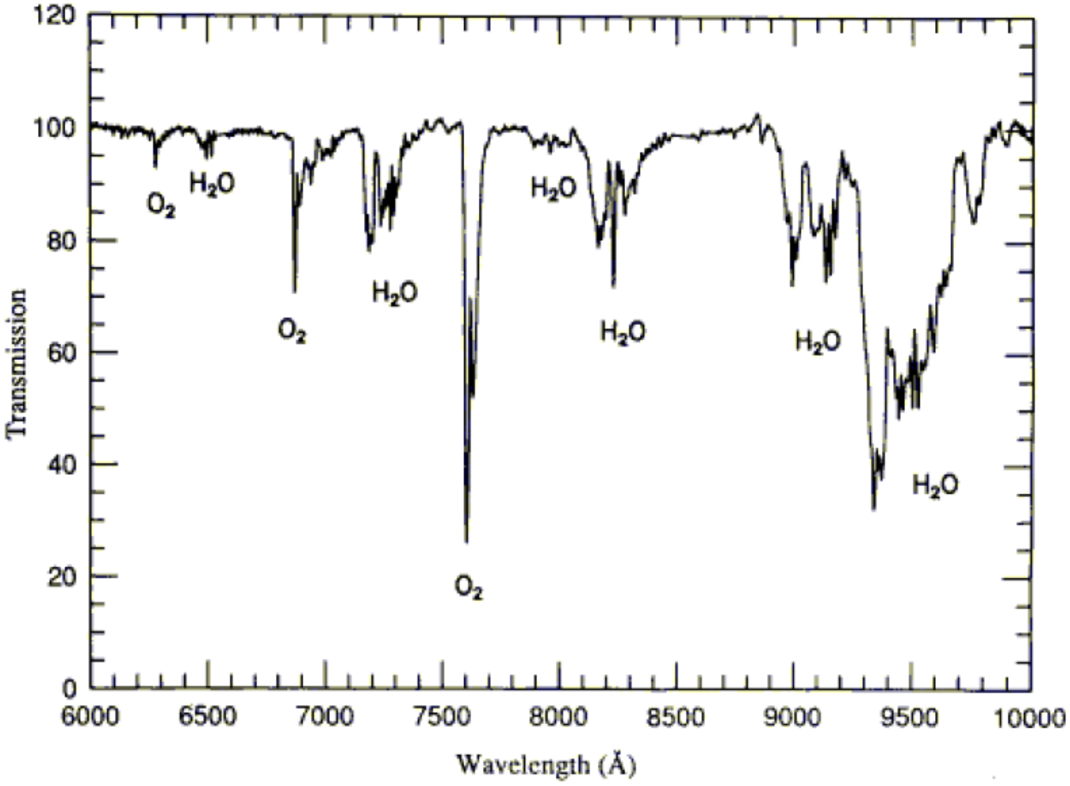
- If you are observing your object over a wide range of airmasses, you still have to go get standards every hour or so

When you get home…

- After reducing your data, you can calculate instrumental magnitudes
  - $m_{ins} = -2.5 \log_{10}(\text{counts/s})$
- Final answer $m = m_{std}$ + zeropoint + x(airmass) + y(B-V)
  - Use your instrumental magnitudes of your standard stars to calculate the zeropoint and x and y.
  - Usually you can use multiple nights of data to calculate the coefficient for the B-V term but the airmass coefficient should be done nightly.
- Most filters have a zeropoint in the manual, but it's probably only roughly accurate; you should always calibrate yourself!

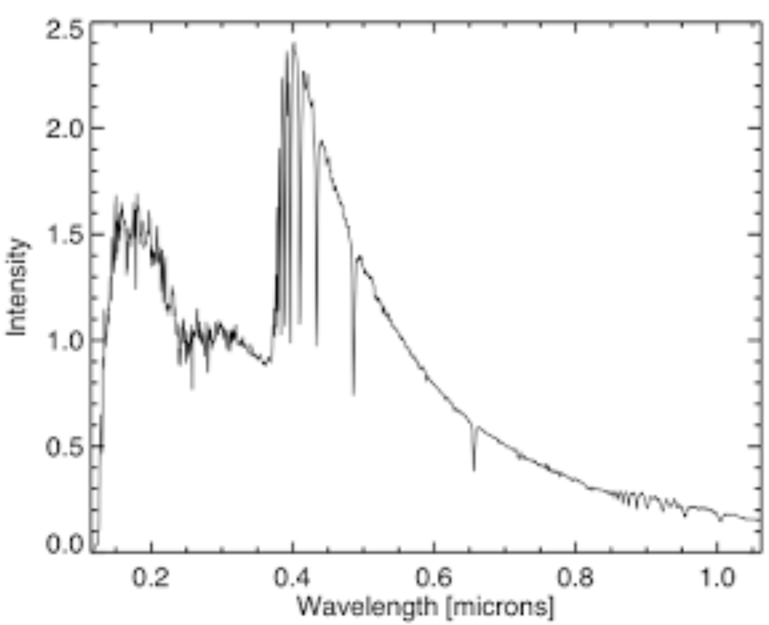
Flux calibrating spectra

- Similar in theory, except now you take spectra of standard stars and correct directly to them.



Flux calibrating IR spectra

- In the IR, there are no well-calibrated spectrophotometric standards, so you have to correct directly for the telluric absorption by observing a hot star
- Hot stars (commonly A0V) are relatively featureless blackbodies except for Balmer absorption
  - Can divide out the blackbody (and remove hydrogen lines) and recover the transmission curve
  - irtfweb.ifa.hawaii.edu/cgi-bin/spex/find_a0v.cgi



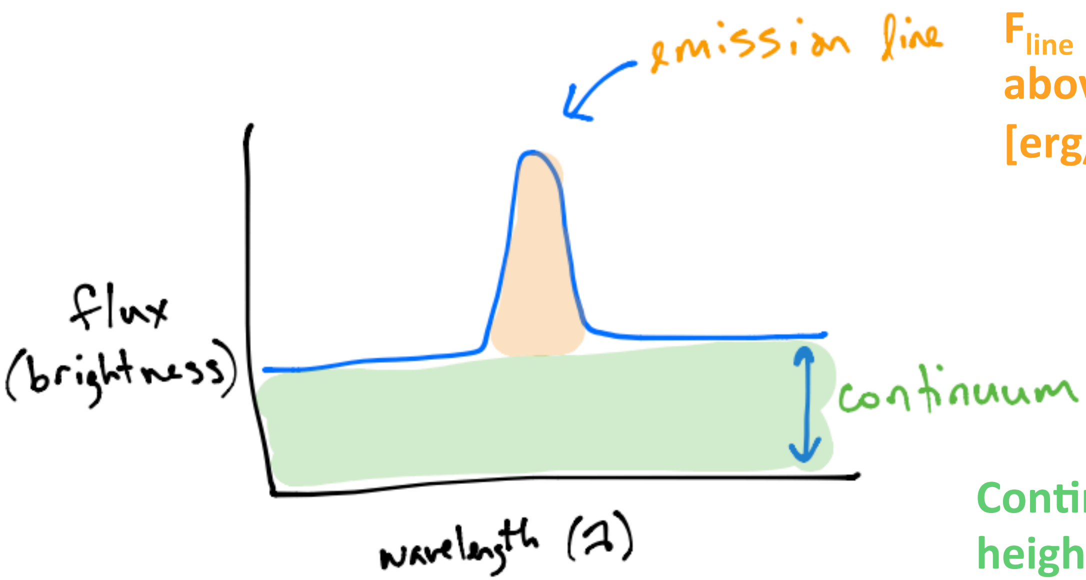
Flux calibrating IR spectra 2

- Once you've corrected for the telluric spectrum, there are some flux calibrator stars that are tabulated in ~50 Å bands, so you can bin your spectrum to match

- Lots of IRAF and IDL (and maybe python) routines to accomplish all of these things!

Spectra

- Spectra generally contain three possible components:
  - A smooth continuum (e.g. blackbody radiation)
  - Emission lines (adding to the continuum)
  - Absorption lines (removing the continuum)

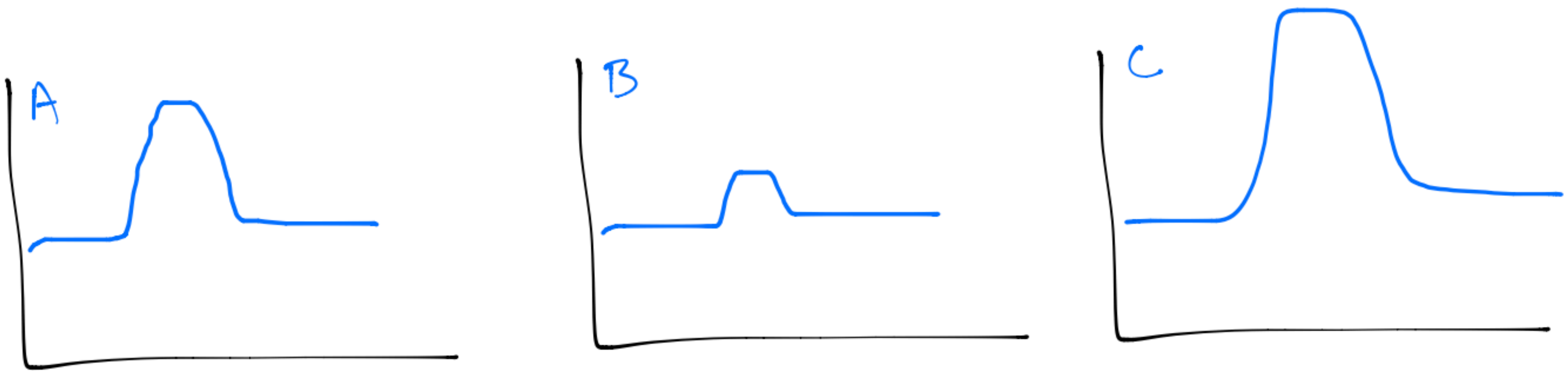


F_{line} = area under the curve, above continuum [erg/s/cm²]

Continuum level = $F_{\lambda,cont}$ = height of continuum [erg/s/cm²/Å]

Equivalent Widths

- Instead of measuring precise fluxes of emission or absorption lines in a spectrum, we sometimes want to measure the strength of the line relative to the continuum



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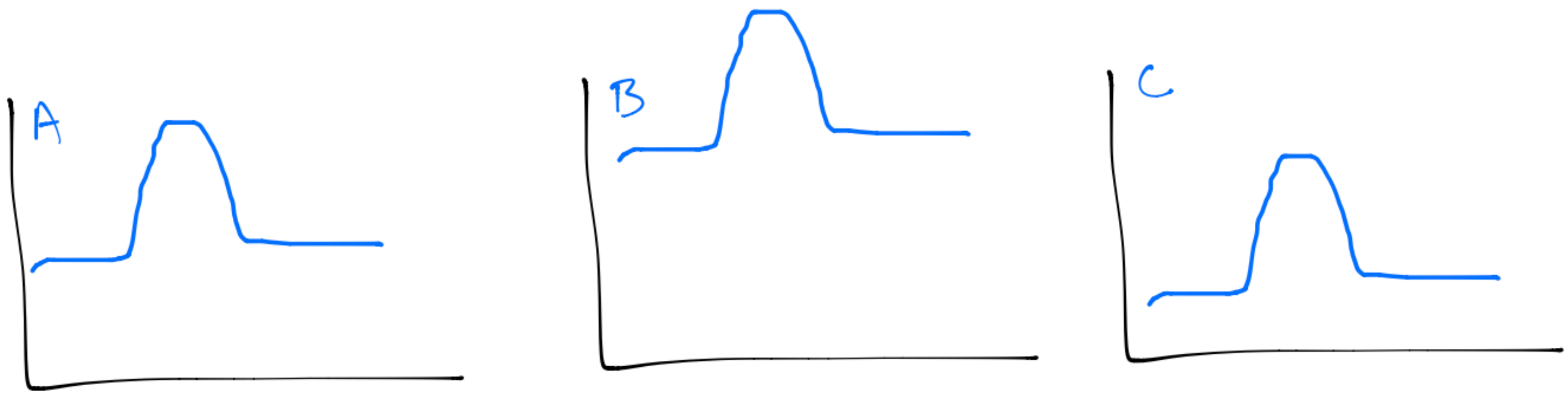

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Equivalent Widths

- "Equivalent width" refers to the width of the continuum containing the same amount of flux as the line
- EW = F_{line} / continuum level
- Usually absorption = positive, emission = negative EW