Fluxes and Magnitudes

What is observed is a **flux** = energy per unit area and unit time. If it is integrated over the entire spectrum, it is called the *bolometric* flux. But more often, it is measured at a given frequency or wavelength, so it is also per unit frequency or wavelength, and it is called a *specific* flux.

A standard unit of specific flux is Jansky: 1 Jy = 10^{-23} erg s^{-1} cm^{-2} Hz^{-1}

In optical/IR astronomy, fluxes are traditionally expressed as *magnitudes*, which are *logarithmic relative* measurements of flux F:

$$mag = -2.5 \log_{10} F + \text{const.}$$

where the constant is given by the zero point of that particular system (see below). If F is the bolometric flux, that is a bolometric magnitude; if F is a specific flux, then it is a magnitude in the corresponding bandpass. Notice the minus sign: larger magnitude means fainter sources.

In a given bandpass, the difference in magnitudes gives the ratio of the fluxes:

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

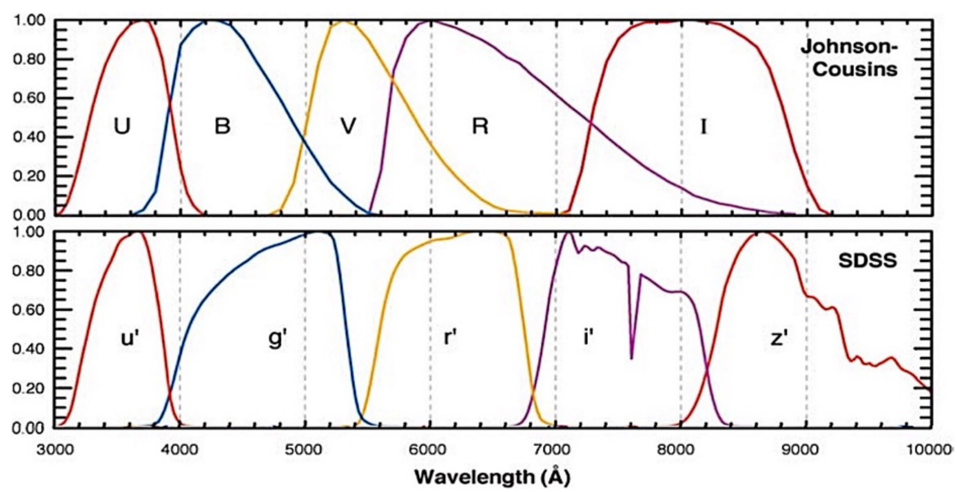
A difference of 5 mags implies a factor of 100 in the flux ratio.

Standard photometric systems:

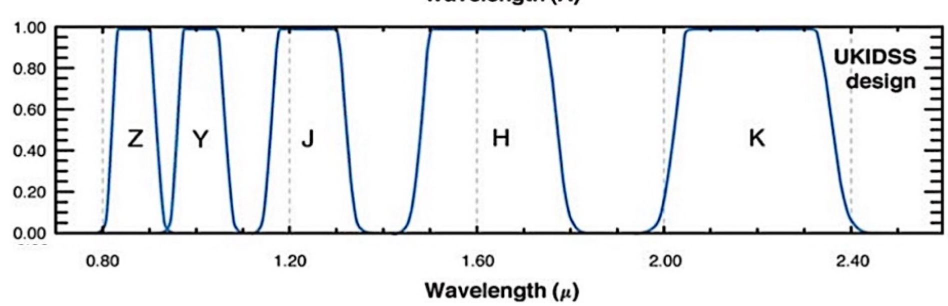
In practice, it is always measured over some *finite bandpass*, defined by a particular filter (say, V band) and the instrument response. Spectrum of an object, integrated over a bandpass, gives you the flux measured in that bandpass.

A set of bandpasses can form a photometric system, and there are some "standard" systems, e.g., Johnson-Cousins-Bessel-etc. *UBVRI* (continuing in IR as *JKLM*) or Gunn/SDSS *ugriz(y)*, but unfortunately there are many, many variations.

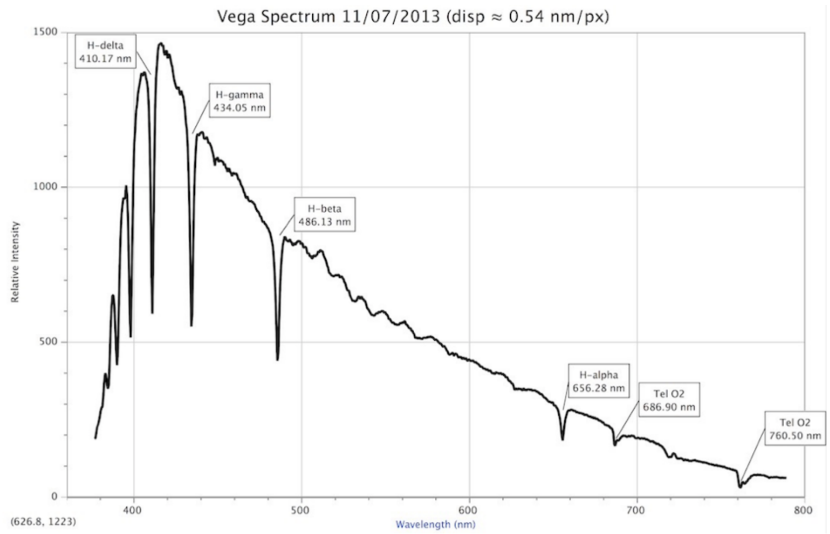
Indicative bandpass curves are shown here (from Bessel 2005, ARAA 43, 293):



And in near IR:



Magnitude zero-points:



To convert magnitude in any given bandpass into a flux, we need to know the flux that corresponds to *mag* = 0 in that bandpass. Traditionally it was decided that Vega will have *mag* = 0 in any bandpass.

Unfortunately, this is what the spectrum of Vega looks like:

So *mag* = 0 corresponds to a very different flux at different wavelengths.

To make it worse, Gunn/SDSS system uses a different star as a fundamental standard.

For quick estimates, for Vega in the V band ($\lambda \sim 5556$Å) : $f_\nu = 3.50 \times 10^{-20}$ erg s^{-1} cm^{-2} Hz^{-1} = 3.5 kJy, $f_\lambda = 3.39 \times 10^{-9}$ erg s^{-1} cm^{-2} Å^{-1} , $N_\lambda = 948$ photons s^{-1} cm^{-2} Å^{-1}.

Here are the estimated fluxes for magnitude zero points of some of the "more standard" systems, along with the effective mean wavelengths and widths, from Fukugita et al. 1995, PASP 107, 945:

Characteristics of Photometric Bands

bandpass system	band	ref[a]	$\lambda_{\rm eff}$ (Å)	FWHM (Å)	$\lambda_{\rm eff}^{\rm Vega}$ (Å)	$f_{\lambda,\rm eff}^{\rm Vega}$ ($\times 10^{-9}$cgs/Å)	$c(\nu_{\rm eff}^{\rm Vega})^{-1}$ (Å)	$f_{\nu,\rm eff}^{\rm Vega}$ ($\times 10^{-20}$cgs/Hz)
Johnson-Morgan	U_3	Buser 78	3652	526	3709	4.28	3617	1.89
	B_2	AS69	4448	1008	4393	6.19	4363	4.02
	V	AS69	5505	827	5439	3.60	5437	3.59
Cousins	R_C	Bessell 90	6588	1568	6410	2.15	6415	3.02
	I_C	Bessell 90	8060	1542	7977	1.11	7980	2.38
Johnson	R_J		6930	2096	6688	1.87	6693	2.89
	I_J		8785	1706	8571	0.912	8545	2.28
SDSS	u'		3585	556	3594	3.67	3530	1.54
	g'		4858	1297	4765	5.11	4748	3.93
	r'		6290	1358	6205	2.40	6210	3.12
	i'		7706	1547	7617	1.28	7623	2.51
	z'		9222	1530	9123	0.783	9098	2.19

Apparent vs. Absolute Magnitudes:

The absolute magnitude M is defined as the apparent magnitude a source would have if it were at a distance of 10 pc: $M = m + 5 - 5 \log d/\text{pc}$.

It is a measure of the luminosity in some bandpass. For Sun: $M_{\odot B} = 5.47$, $M_{\odot V} = 4.82$, $M_{\odot \rm bol} = 4.74$, while its absolute bolometric luminosity is $L_\odot = 3.0128 \times 10^{26}$ W $= 3.0128 \times 10^{33}$ erg s^{-1}.

Distance modulus is a measure of the distance to the source: (M–m) = 5 log (d /10 pc).