Astronomical Magnitude Systems

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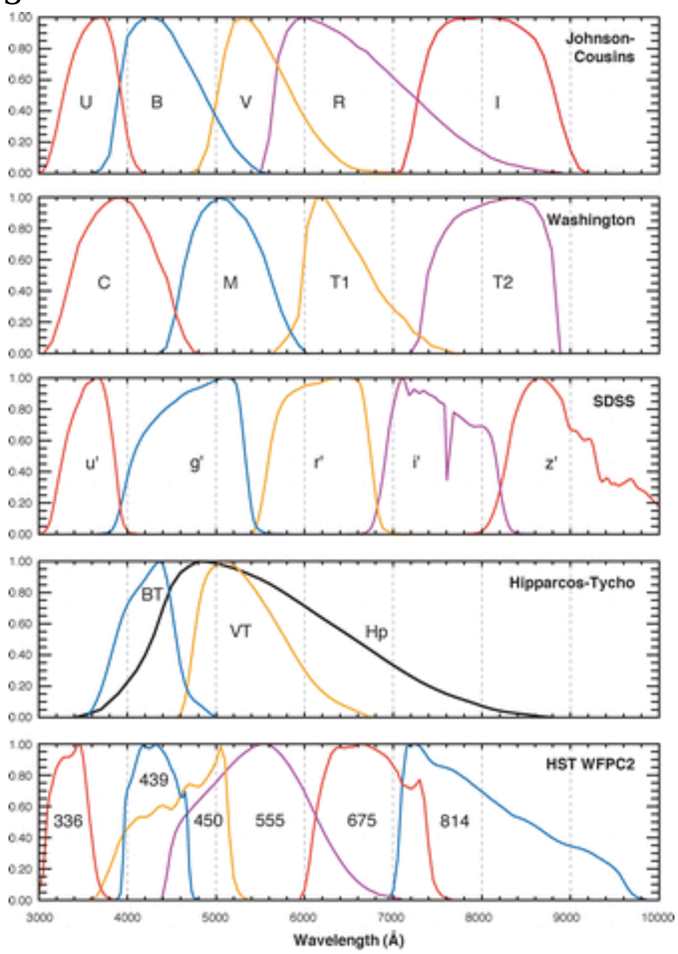
Definitions of astronomical magnitude systems:

A major review of astronomical magnitude systems and their calibration is given by

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

Johnson System

This system is defined such that the star Alpha Lyr (Vega) has V=0.03 and all colors equal to zero. Alternatively, the zero-color standard can be defined to be the mean of a number of unreddened A0 V stars of Pop I abundance, using the ensemble of Johnson-Morgan standards to fix the flux scale. It remains to calibrate on an absolute scale the flux of Alpha Lyr or some other appropriate star, Such as aclaibration has been accomplished by Hayes and Lathan (1975), which yielded 3500 Jansky at 5556A for Alpha Lyr. Articles discussing the UBVRI passbands include Bessel (1979), Bessel (1983), and Bessel (1990).



Bessell, MS. 2005
Annu. Rev. Astron. Astrophys. 43: 293–336

References:

- Bessel, M. S. 1990, PASP, 91, 589
- Bessel, M. S. 1983, PASP, 95, 480

- Bessel, M. S. 1990, PASP, 102, 1181
- Hayes, D. S., & Latham, D. W. 1975, ApJ, 197, 593
- Johnson, H. L. & Morgan, W. W. 1953, ApJ, 117, 313

In practice, while observing, one monitors groups of standard stars such as those tabulated by Landolt:

- Landolt, A. U. 1992, AJ, 104, 340
- Landolt, A. U. 1983, AJ, 88, 439
- Landolt, A. U. 2007, AJ, 133, 2502

Various observatories have posted electronic versions of the Landolt standards, e.g.,
Lick | WIYN | CFHT
these are of course derivative products and one should always check their veracity against the original work by Landolt.

Filters: UBVRIJHK
The original Johnson system consists of the UBV filters whose calibration was intimately tied to the photoelectric detectors in use at the time. The system has since been extended to the red with optical RI and near-infrared JHK filters. The definitions of these filters are not always independent of the detectors involved and can vary slightly fmor observatory to observatory.

JHK:
The filters JHK are an important extension of the Johnson system to near-infrared wavelengths. Technology requires different detectors for these wavelengths than UBVRI, so different calibration stars are required (Landolt's standards are useful for optical UBVRI observations).
The JHK filters have been used in the 2MASS all sky survey. Since 2MASS is (in principle) completely and uniformly calibrated, any non-variable object in the sky (its coverage is nearly complete) can (in principle!) be used as a calibration reference.
Note that 2MASS uses a "short" K filter which is slightly different from the original definition of K but is now in common uses because of its superior suppression of thermal terrestrial emission.

Gunn griz System

This was originally defined in terms of photoelectric detectors (Thuan & Gunn 1976; Wade et al. 1979), but is now used primarily with CCDs (Schneider, Gunn, & Hoessel 1983; Schild 1984). The griz system is defined by a few dozen standard stars, and the star BD+17deg4708, a subdwarf F6 star with B-V=0.43, is defined to have colors equal to zero. The absolute calibration of this system is simply the monochromatic flux of the star (Oke & Gunn 1983), scaled from g=9.50 to g=0.0, at the effective wavelengths of the griz bands. A number of detailed aspects of broad-band photometry in the specific context of measurements of galaxies at large redshifts are reviewed in Schneider, Gunn, & Hoessel (1983).

References:

- Oke, J. B., & Gunn, J. E. 1983, ApJ, 266, 713
- Schild, R. 1984, ApJ, 286, 450
- Schneider, D. P., Gunn, J. E., & Hoessel J. G. 1983, ApJ, 264, 337
- Thuan, T. X., & Gunn, J. E. 1976, PASP, 88, 543
- Wade, R. A., Hoessel, J. G., Elias, J. H., Huchra, J. P. 1979, PASP, 91, 35

The Gunn-Thuan griz system is employed by the Sloan Digital Sky Survey. Since the SDSS is (in principle) completely and uniformly calibrated, any non-variable object in the large swath of sky it covers could (in principle!) be used as a calibration reference.

AB magnitude System

This magnitude system is defined such that, when monochromatic flux f_nu is measured in erg sec^-1 cm^-2 Hz^-1,

```
m(AB) = -2.5 log(f_nu) - 48.60
```

where the value of the constant is selected to define m(AB)=V for a flat-spectrum source. In this system, an object with constant flux per unit *frequency* interval has zero color.

It is helpful to bear in mind the identity

```
lambda*f_lambda = nu*f_nu
```

so

```
f_nu = f_lambda*(lambda/nu) = f_lambda*lambda^2/c.
```

References:

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

STMAG system

This magnitude system is defined such that an object with constant flux per unit *wavelength* interval has zero color. It is used by the Hubble Space Telescope photometry packages.

References:

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

The Absolute Magnitude of the Sun:

Filter	$M_{\odot}$	Source
U	5.61	B&M

B	5.48	B&M
V	4.83	B&M
R	4.42	B&M
I	4.08	B&M
J	3.64	B&M
H	3.32	B&M
K	3.28	B&M
K'	3.27	*
Spitzer		
3.6µ	3.24	Oh
4.5µ	3.27	Oh
SDSS		
u	6.55	S&G
g	5.12	S&G
r	4.68	S&G
i	4.57	S&G
z	4.60	S&G

B&M = Binney & Merrifield
S&G = Sparke & Gallagher
Oh = Oh et al (2008) AJ, 136, 2761
*My (SSM) estimate for the K' filter used by 2MASS after long and painful hunting through the calibration literature.

Note that the absolute magnitude of the sun is uncertain by typically 0.03 mag. in most bands. The "right" answer depends on whether we're talking about the sun itself, the mean of solar type stars, or stellar atmosphere models.

See also Chris Willmer's page on the absolute magnitude of the sun.

Conversions among magnitude systems:

Conversion from AB magnitudes to Johnson magnitudes:

The following formulae convert between the AB magnitude systems and those based on Alpha Lyra:

```
 V  =   V(AB) + 0.044       (+/- 0.004)
 B  =   B(AB) + 0.163       (+/- 0.004)
Bj  =  Bj(AB) + 0.139       (+/- INDEF)
 R  =   R(AB) - 0.055       (+/- INDEF)
 I  =   I(AB) - 0.309       (+/- INDEF)
 g  =   g(AB) + 0.013       (+/- 0.002)
```

```
 r  =   r(AB) + 0.226       (+/- 0.003)
 i  =   i(AB) + 0.296       (+/- 0.005)
 u' =  u'(AB) + 0.0
 g' =  g'(AB) + 0.0
 r' =  r'(AB) + 0.0
 i' =  i'(AB) + 0.0
 z' =  z'(AB) + 0.0
Rc  =  Rc(AB) - 0.117       (+/- 0.006)
Ic  =  Ic(AB) - 0.342       (+/- 0.008)
```

Source: Frei & Gunn 1994, AJ, 108, 1476 (their Table 2).

Conversion from STMAG magnitudes to Johnson magnitudes:
See the WFPC2 Photometry Cookbook

Photon Flux:

Given the passband and the magnitude of an object, the number of tphotons incident at the top of the atmosphere may be estimated using the data in this table:

Band	lambda_c	dlambda/lambda	Flux at m=0	Reference
	um		Jy	
U	0.36	0.15	1810	Bessel (1979)
B	0.44	0.22	4260	Bessel (1979)
V	0.55	0.16	3640	Bessel (1979)
R	0.64	0.23	3080	Bessel (1979)
I	0.79	0.19	2550	Bessel (1979)
J	1.26	0.16	1600	Campins, Reike, & Lebovsky (1985)
H	1.60	0.23	1080	Campins, Reike, & Lebovsky (1985)
K	2.22	0.23	670	Campins, Reike, & Lebovsky (1985)
g	0.52	0.14	3730	Schneider, Gunn, & Hoessel (1983)
r	0.67	0.14	4490	Schneider, Gunn, & Hoessel (1983)
i	0.79	0.16	4760	Schneider, Gunn, & Hoessel (1983)
z	0.91	0.13	4810	Schneider, Gunn, & Hoessel (1983)

Also useful are these identities:

```
1 Jy = 10^-23 erg sec^-1 cm^-2 Hz^-1
1 Jy = 1.51e7 photons sec^-1 m^-2 (dlambda/lambda)^-1
```

See also Strolger's units page.

Example: How many V-band photons are incident per second on an area of 1 m^2 at the top of the atmosphere from a V=23.90 star? From the table, the flux at V=0 is 3640 Jy; hence, at V=23.90 the flux is diminished by a factor 10^(-0.4*V)=2.75e-10, yielding a flux of 1.e-6 Jy. Since dlambda/lambda=0.16 in V, the flux per second on a 1 m^2 aperture is

```
f=1.e-6 Jy * 1.51e7 * 0.16 = 2.42 photons sec^-1
```

Filter Transformations:

All filter transformations depend to some extent on the spectral type of the object in question. If this is known, then you are probably best off using the SYNPHOT package in IRAF/STSDAS to compute the transformation. Some transformations are listed below for convenience:

Bands	Equation	Reference
Gunn g to Johnson B:	B = g + 0.51 + 0.60*(g-r)	[1]
Gunn g to Johnson V:	V = g - 0.03 - 0.42*(g-r)	[1]
Gunn r to Mould R:	R = r - 0.51 - 0.15*(g-r)	[1]
Gunn g to Photographic J:	J = g + 0.39 + 0.37*(g-r)	[1]
Gunn r to Photographic F:	F = r - 0.25 + 0.17*(g-r)	[1]
Gunn i to Mould I:	I = i - 0.75 (approx)	[1]

References:

1. Windhorst, R. W., et al. 1991, ApJ, 380, 362

Night Sky Brightnesses:

These values are appropriate for taken from CTIO but should serve as reasonable approximations for most dark sites:

Lunar Age (days)	U	B	V	R	I
0	22.0	22.7	21.8	20.9	19.9

3	21.5	22.4	21.7	20.8	19.9
7	19.9	21.6	21.4	20.6	19.7
10	18.5	20.7	20.7	20.3	19.5
14	17.0	19.5	20.0	19.9	19.2

Source: NOAO Newsletter #10.

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Also in Romanian