Photomtery Systems

- Introduction
  - flux
  - magnitudes
    - Pogson, AB, ST, asinh
- Systems
  - ADPS database
  - conversions
- SDSS
  - ugriz system
  - which magnitude to use ?

M. G. Allen, October 26, 2006 – material from:

George Djorgovski's lecture notes: **http://www.astro.caltech.edu/~george/ay122/Ay122-photometry.pdf**
Asiago Database of Photometric Systems: **http://ulisse.pd.astro.it/Astro/ADPS/**
Sloan Digitial Sky survey Data Release: **http://www.sdss.org/dr5**

Measuring Flux = Energy/(unit time)/(unit area)

Real detectors are sensitive over a finite range of λ (or ν). Fluxes are always measured over some finite bandpass.

Total energy flux:

$$F = \int F_\nu(\nu)\,d\nu$$

Integral of f_ν over all frequencies

Units: erg s^{-1} cm^{-2} Hz^{-1}

A standard unit for specific flux (initially in radio, but now more common):

$$1 \text{ Jansky (Jy)} = 10^{-23} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1}$$

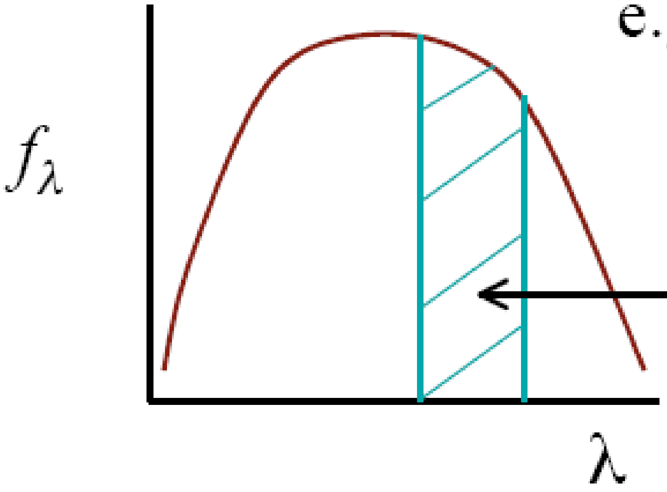
f_ν is often called the ***flux density*** - to get the ***power,*** one integrates it over the bandwith, and multiplies by the area

(From P. Armitage)

Fluxes and Magnitudes

For historical reasons, fluxes in the optical and IR are measured in magnitudes: $m = -2.5 \log_{10} F + \text{constant}$

If F is the total flux, then m is the bolometric magnitude. Usually instead consider a finite bandpass, e.g., V band.



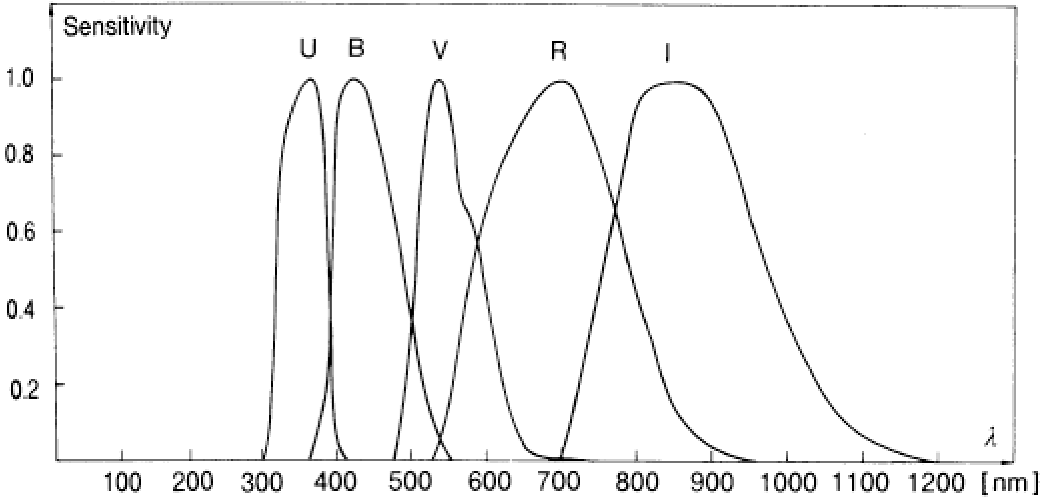
e.g. in the V band ($\lambda \sim$ 550 nm):

$$m_V = -2.5 \log_{10} F + \text{constant}$$

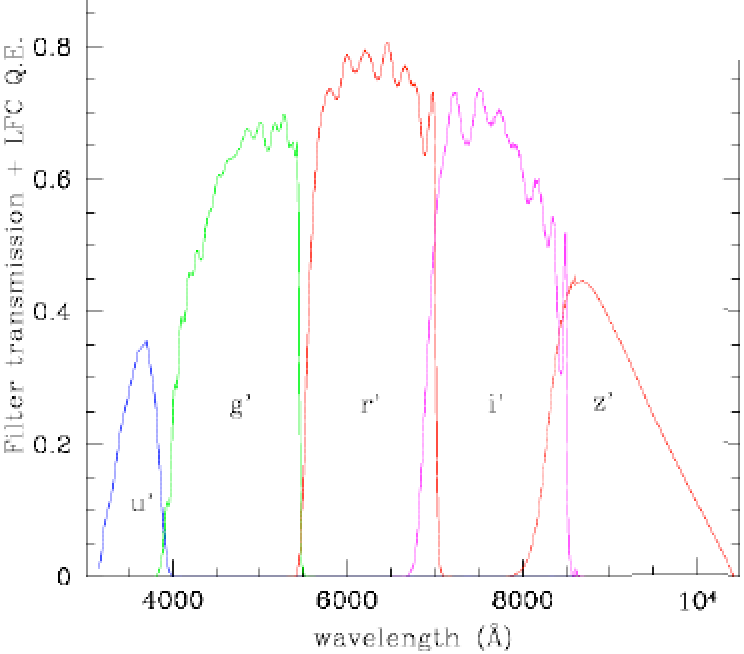
flux integrated over the range of wavelengths for this band

(From P. Armitage)

Johnson →

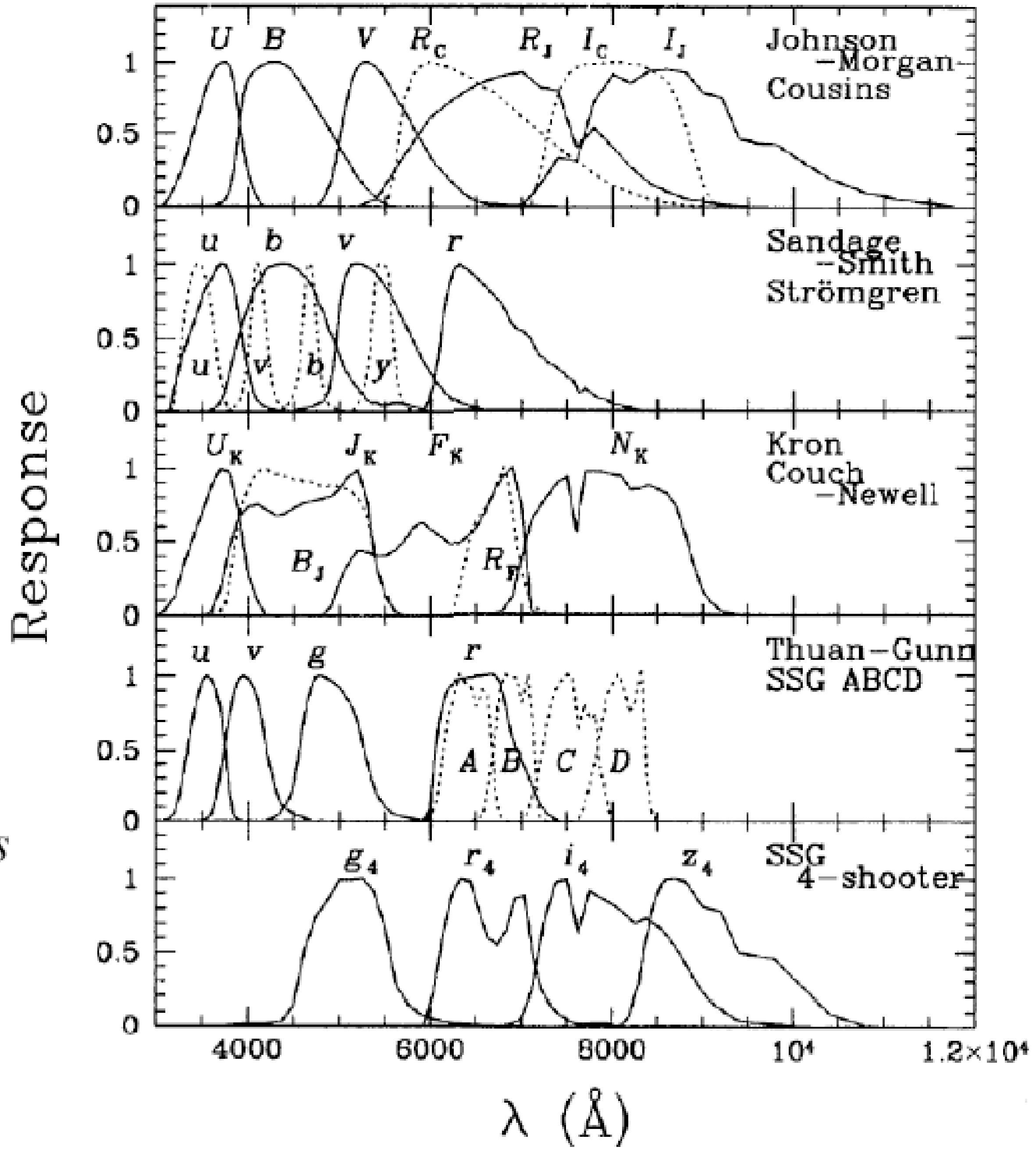


Gunn/SDSS
↓



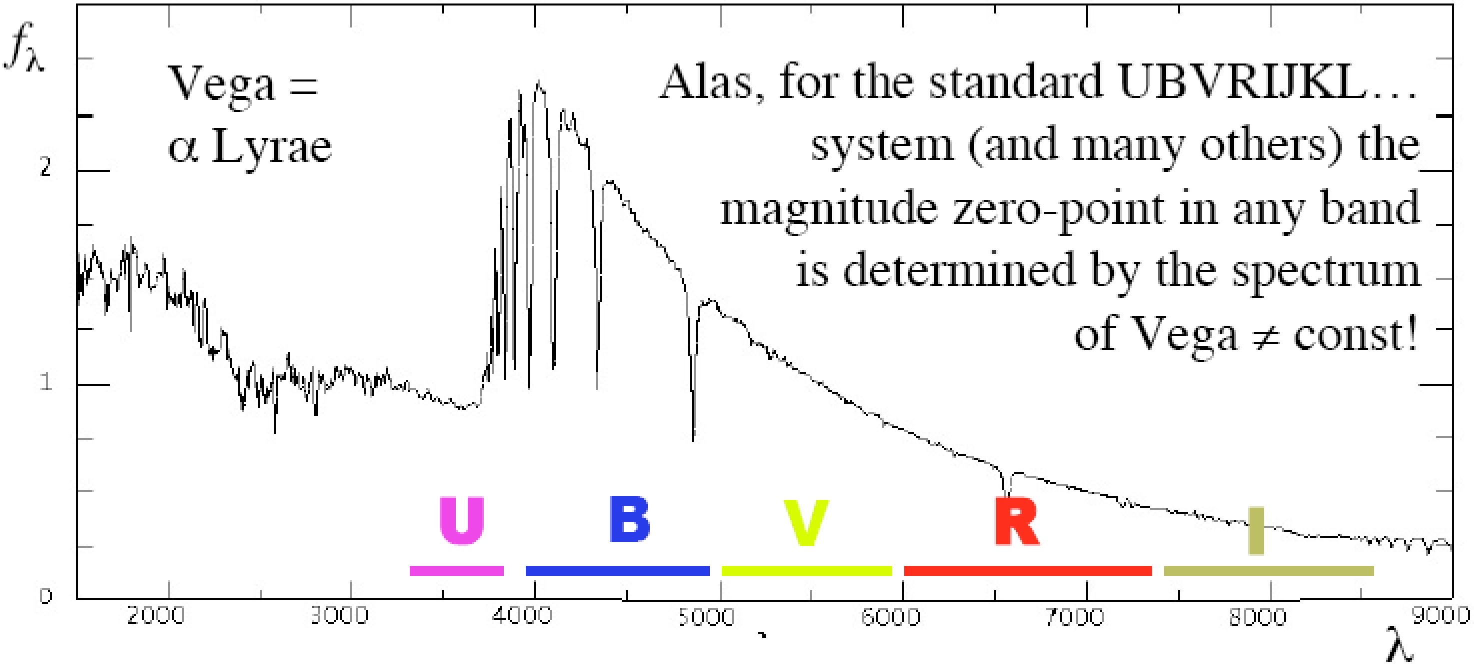
Some Common Photometric Systems (in the visible)

There are way, way too many photometric systems out there …



(Bandpass curves from Fukugita et al. 1995, PASP, 107, 945)

Magnitude Zero Points



Vega =
α Lyrae

Alas, for the standard UBVRIJKL…
system (and many others) the
magnitude zero-point in any band
is determined by the spectrum
of Vega ≠ const!

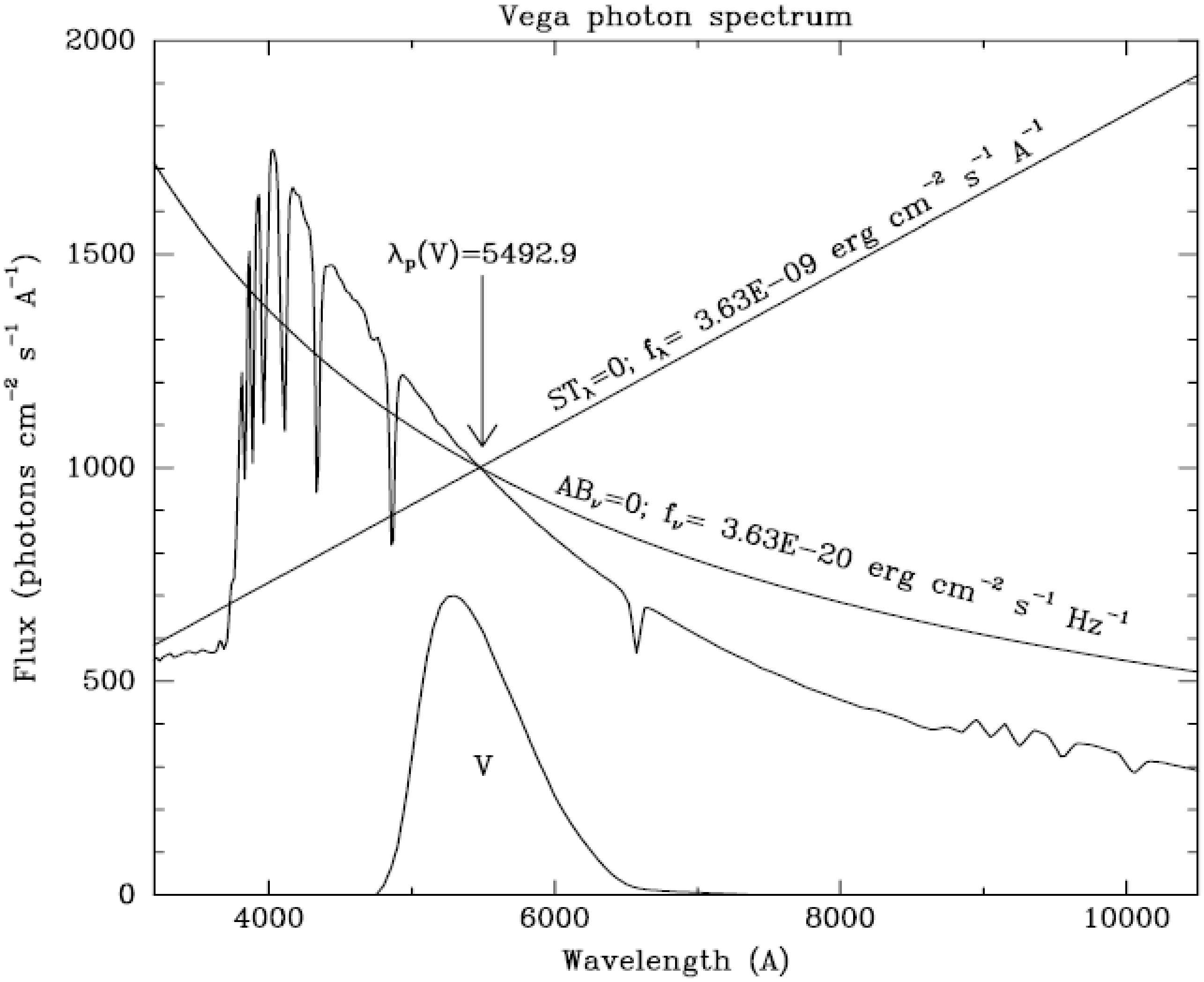
Vega calibration ($m = 0$): at $\lambda = 5556$: $f_\lambda = 3.39 \times 10^{-9}$ erg/cm^2/s/Å

$f_\nu = 3.50 \times 10^{-20}$ erg/cm^2/s/Hz

$N_\lambda = 948$ photons/cm^2/s/Å

A more logical system is AB_ν magnitudes:

$$AB_\nu = -2.5 \log f_\nu \text{ [cgs]} - 48.60$$


Vega photon spectrum
Flux (photons cm^{-2} s^{-1} A^{-1})
2000
1500
1000
500
0
4000
6000
8000
10000
Wavelength (A)
λ_p(V)=5492.9
ST$_\lambda$=0; f$_\lambda$= 3.63E−09 erg cm^{-2} s^{-1} A^{-1}
AB$_\nu$=0; f$_\nu$= 3.63E−20 erg cm^{-2} s^{-1} Hz^{-1}
V

Magnitude definitions

- Pogson: $m = -2.5 \log_{10}(F) + \text{constant}$
- Vega: $m = -2.5 \log_{10}(F/F_{\text{Vega}})$

$$m_i = -2.5 \log_{10} \frac{\int R_i(\lambda) F_\lambda(\lambda) d\lambda}{\int R_i(\lambda) F_\lambda^{\text{VEGA}}(\lambda) d\lambda} + 0.03$$

- Inverse hyperbolic sine magnitudes

$m = [-2.5 / \ln(10)] * [\operatorname{asinh}((F/F_0)/2b) + \ln(2b)]$

Monochromatic Magnitudes

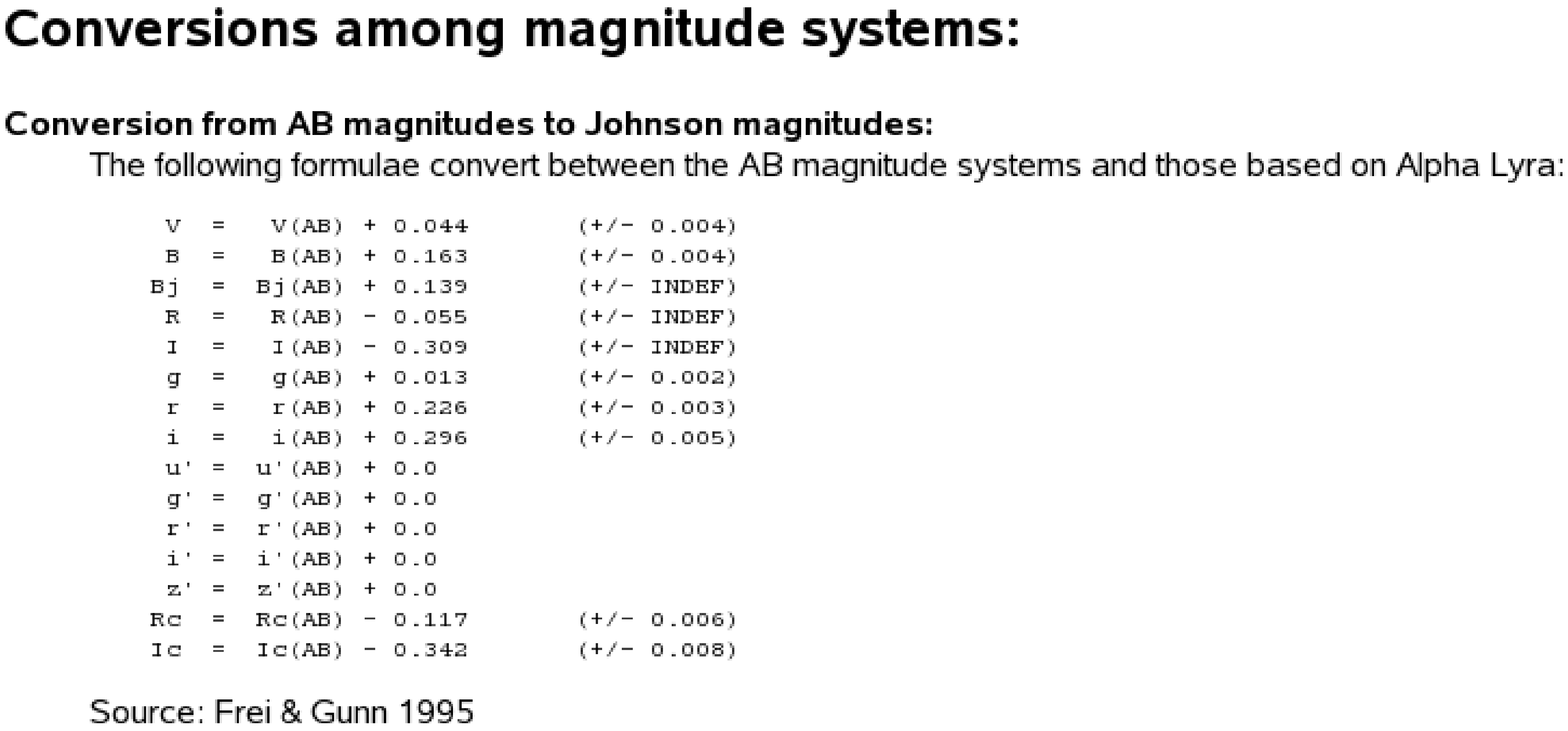
$$m_\lambda(\lambda) \equiv -2.5 \log_{10} F_\lambda(\lambda) - 21.1$$

where $F_\lambda(\lambda)$ is the spectral flux density of a source at the top of the Earth's atmosphere in units of $\mathrm{erg\ s^{-1}\ cm^{-2}\ \mathring{A}^{-1}}$. This is also known as the "STMAG" system because it is standard for the Hubble Space Telescope.

The corresponding system based on flux per unit frequency is

$$m_\nu(\lambda) \equiv -2.5 \log_{10} F_\nu(\lambda) - 48.6$$

where $F_\nu(\lambda)$ is in units of $\mathrm{erg\ s^{-1}\ cm^{-2}\,Hz^{-1}}$. This is also known as the "AB" or "AB$_\nu$" system.



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 1995

http://www.astro.utoronto.ca/~patton/astro/mags.html

ADPS

the Asiago Database on Photometric Systems

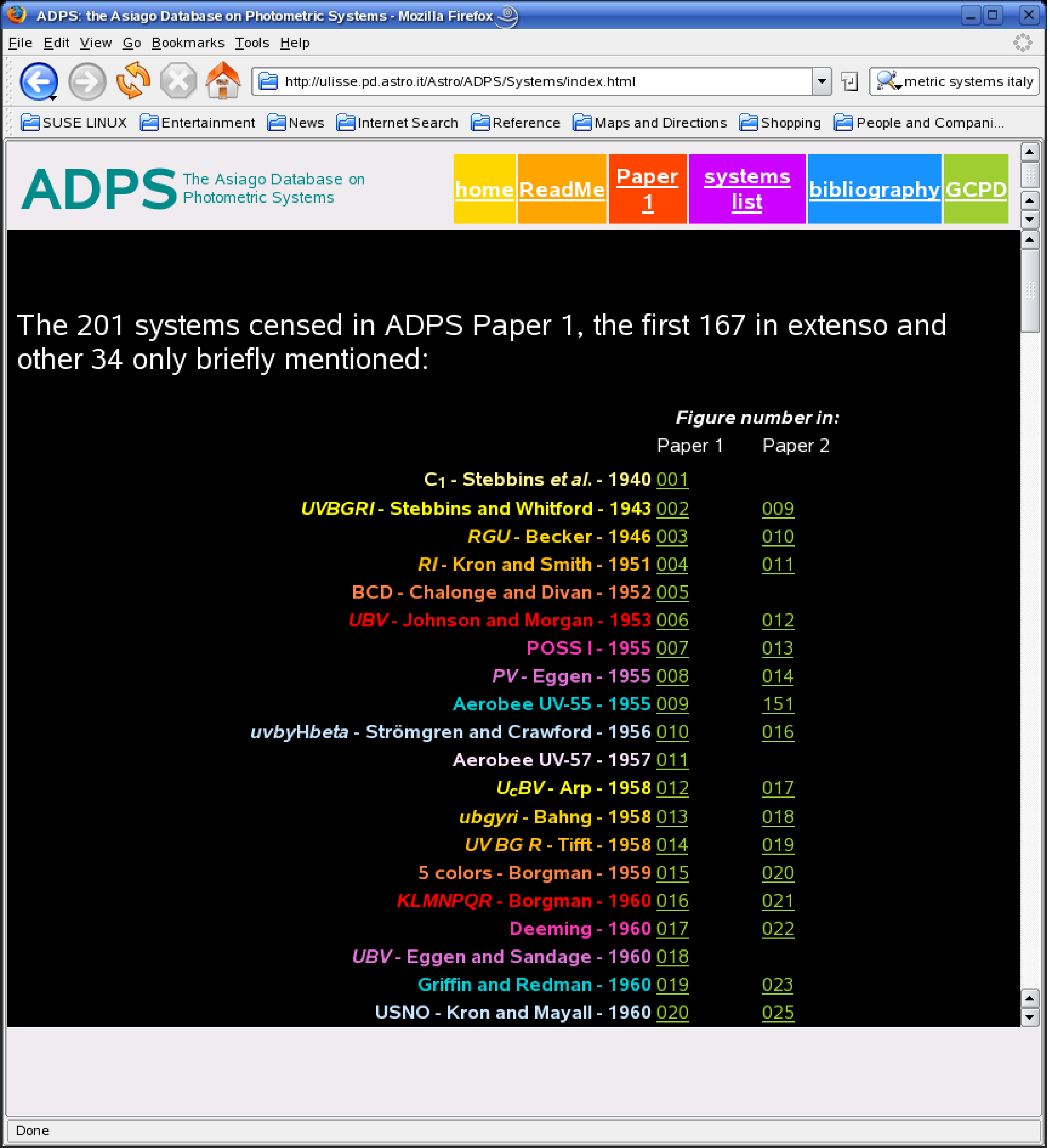
by Ulisse Munari, Massimo Fiorucci and Dina Moro

The Asiago Database on Photometric Systems (ADPS) project aims to cense and investigate existing photometric systems.

Paper 1 (Moro and Munari 2000, A&AS 147, 361) presents a compilation of basic information and reference data from literature for 201 photometric systems (167 censed in extenso, and 34 only briefly noted). General ascii lists about systems and bands can be found here.

Paper 2 (Fiorucci and Munari 2002, A&A, submitted) adds further 17 systems, bringing the total to 218 censed systems, and provides homogeneous band and reddening parameters for all the systems with known band transmission profiles (179). Spectra and reddening curves used in the synthetic photometry computation can be found here.

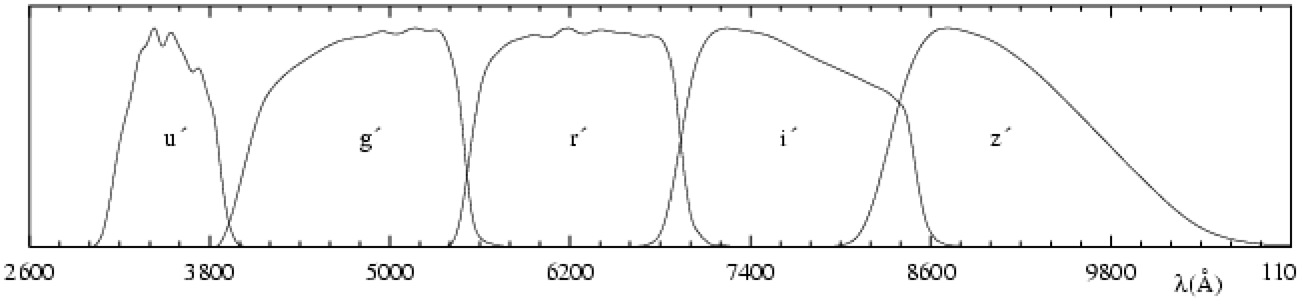
Planned Paper 3 will deal with calibration of the systems in terms of basic physical stellar parameters (temperature, gravity, metallicity, reddening), and Paper 4 with transformations between the systems.

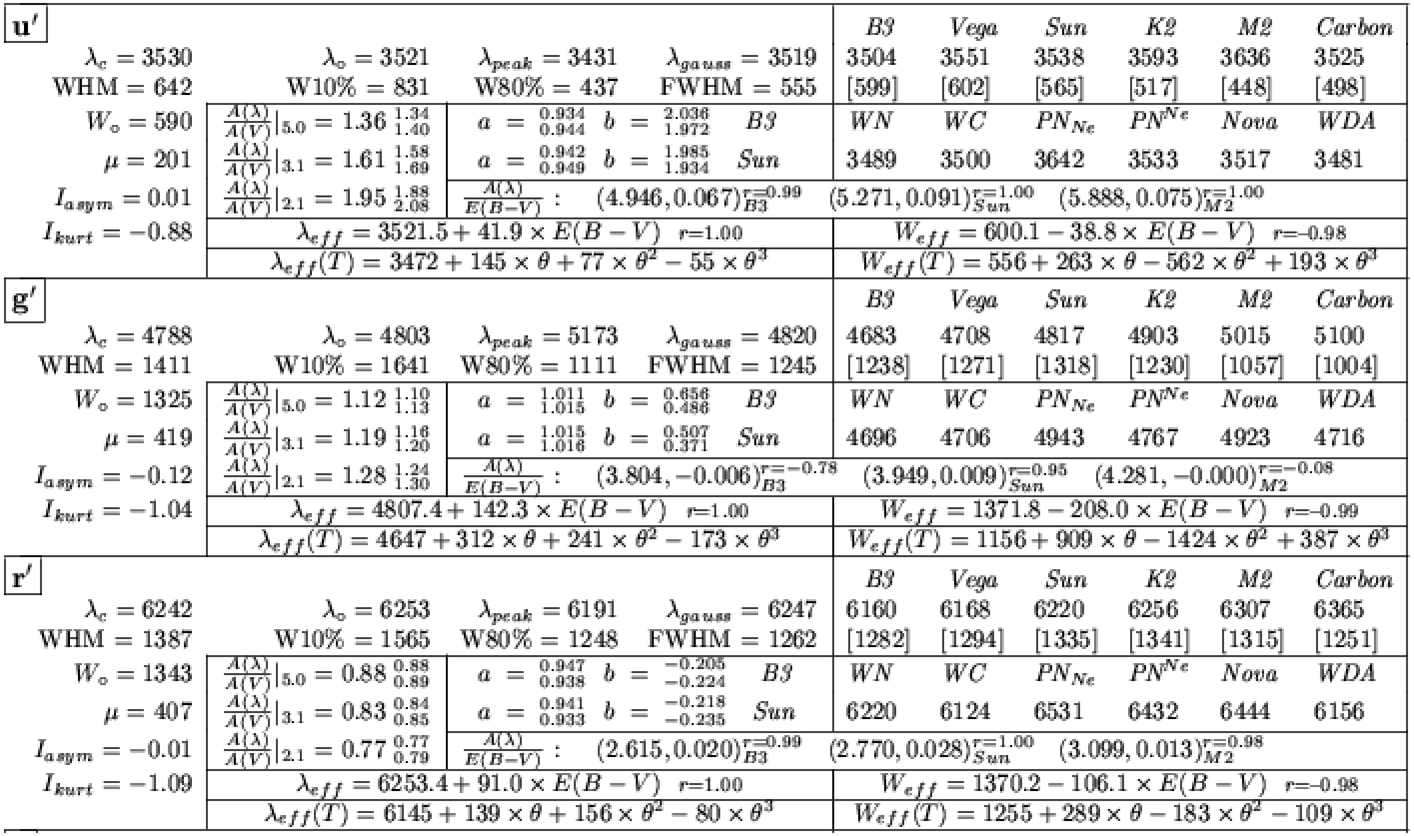


The 201 systems censed in ADPS Paper 1, the first 167 in extenso and other 34 only briefly mentioned:

	Figure number in:	
	Paper 1	Paper 2
C$_1$ - Stebbins *et al.* - 1940	001	
UVBGRI - Stebbins and Whitford - 1943	002	009
RGU - Becker - 1946	003	010
RI - Kron and Smith - 1951	004	011
BCD - Chalonge and Divan - 1952	005	
UBV - Johnson and Morgan - 1953	006	012
POSS I - 1955	007	013
PV - Eggen - 1955	008	014
Aerobee UV-55 - 1955	009	151
uvbyHbeta - Strömgren and Crawford - 1956	010	016
Aerobee UV-57 - 1957	011	
U_cBV - Arp - 1958	012	017
ubgyri - Bahng - 1958	013	018
UV BG R - Tifft - 1958	014	019
5 colors - Borgman - 1959	015	020
KLMNPQR - Borgman - 1960	016	021
Deeming - 1960	017	022
UBV - Eggen and Sandage - 1960	018	
Griffin and Redman - 1960	019	023
USNO - Kron and Mayall - 1960	020	025

Sloan DSS - Fukugita et al. - 1996





u′				*B9*	*Vega*	*Sun*	*K2*	*M2*	*Carbon*
$\lambda_c = 3530$	$\lambda_\circ = 3521$	$\lambda_{peak} = 3431$	$\lambda_{gauss} = 3519$	3504	3551	3538	3593	3636	3525
WHM = 642	W10% = 831	W80% = 437	FWHM = 555	[599]	[602]	[565]	[517]	[448]	[498]
$W_\circ = 590$	$\frac{A(\lambda)}{A(V)}\vert_{5.0} = 1.36\,^{1.34}_{1.40}$	$a = {}^{0.934}_{0.944}$ $b = {}^{2.036}_{1.972}$	*B9*	*WN*	*WC*	PN_{Ne}	PN^{Ne}	*Nova*	*WDA*
$\mu = 201$	$\frac{A(\lambda)}{A(V)}\vert_{3.1} = 1.61\,^{1.58}_{1.69}$	$a = {}^{0.942}_{0.949}$ $b = {}^{1.985}_{1.934}$	*Sun*	3489	3500	3642	3533	3517	3481
$I_{asym} = 0.01$	$\frac{A(\lambda)}{A(V)}\vert_{2.1} = 1.95\,^{1.88}_{2.08}$	$\frac{A(\lambda)}{E(B-V)}$: $(4.946, 0.067)^{r=0.99}_{B9}$		$(5.271, 0.091)^{r=1.00}_{Sun}$		$(5.888, 0.075)^{r=1.00}_{M2}$			
$I_{kurt} = -0.88$	$\lambda_{eff} = 3521.5 + 41.9 \times E(B-V)$ r=1.00			$W_{eff} = 600.1 - 38.8 \times E(B-V)$ r=−0.98					
	$\lambda_{eff}(T) = 3472 + 145 \times \theta + 77 \times \theta^2 - 55 \times \theta^3$			$W_{eff}(T) = 556 + 263 \times \theta - 562 \times \theta^2 + 193 \times \theta^3$					
g′				*B9*	*Vega*	*Sun*	*K2*	*M2*	*Carbon*
$\lambda_c = 4788$	$\lambda_\circ = 4803$	$\lambda_{peak} = 5173$	$\lambda_{gauss} = 4820$	4683	4708	4817	4903	5015	5100
WHM = 1411	W10% = 1641	W80% = 1111	FWHM = 1245	[1238]	[1271]	[1318]	[1230]	[1057]	[1004]
$W_\circ = 1325$	$\frac{A(\lambda)}{A(V)}\vert_{5.0} = 1.12\,^{1.10}_{1.13}$	$a = {}^{1.011}_{1.015}$ $b = {}^{0.656}_{0.486}$	*B9*	*WN*	*WC*	PN_{Ne}	PN^{Ne}	*Nova*	*WDA*
$\mu = 419$	$\frac{A(\lambda)}{A(V)}\vert_{3.1} = 1.19\,^{1.16}_{1.20}$	$a = {}^{1.015}_{1.016}$ $b = {}^{0.507}_{0.371}$	*Sun*	4696	4706	4943	4767	4923	4716
$I_{asym} = -0.12$	$\frac{A(\lambda)}{A(V)}\vert_{2.1} = 1.28\,^{1.24}_{1.30}$	$\frac{A(\lambda)}{E(B-V)}$: $(3.804, -0.006)^{r=-0.78}_{B9}$		$(3.949, 0.009)^{r=0.95}_{Sun}$		$(4.281, -0.000)^{r=-0.08}_{M2}$			
$I_{kurt} = -1.04$	$\lambda_{eff} = 4807.4 + 142.3 \times E(B-V)$ r=1.00			$W_{eff} = 1371.8 - 208.0 \times E(B-V)$ r=−0.99					
	$\lambda_{eff}(T) = 4647 + 312 \times \theta + 241 \times \theta^2 - 173 \times \theta^3$			$W_{eff}(T) = 1156 + 909 \times \theta - 1424 \times \theta^2 + 387 \times \theta^3$					
r′				*B9*	*Vega*	*Sun*	*K2*	*M2*	*Carbon*
$\lambda_c = 6242$	$\lambda_\circ = 6253$	$\lambda_{peak} = 6191$	$\lambda_{gauss} = 6247$	6160	6168	6220	6256	6307	6365
WHM = 1387	W10% = 1565	W80% = 1248	FWHM = 1262	[1282]	[1294]	[1335]	[1341]	[1315]	[1251]
$W_\circ = 1343$	$\frac{A(\lambda)}{A(V)}\vert_{5.0} = 0.88\,^{0.88}_{0.89}$	$a = {}^{0.947}_{0.938}$ $b = {}^{-0.205}_{-0.224}$	*B9*	*WN*	*WC*	PN_{Ne}	PN^{Ne}	*Nova*	*WDA*
$\mu = 407$	$\frac{A(\lambda)}{A(V)}\vert_{3.1} = 0.83\,^{0.84}_{0.85}$	$a = {}^{0.941}_{0.933}$ $b = {}^{-0.218}_{-0.235}$	*Sun*	6220	6124	6531	6432	6444	6156
$I_{asym} = -0.01$	$\frac{A(\lambda)}{A(V)}\vert_{2.1} = 0.77\,^{0.77}_{0.79}$	$\frac{A(\lambda)}{E(B-V)}$: $(2.615, 0.020)^{r=0.99}_{B9}$		$(2.770, 0.028)^{r=1.00}_{Sun}$		$(3.099, 0.013)^{r=0.98}_{M2}$			
$I_{kurt} = -1.09$	$\lambda_{eff} = 6253.4 + 91.0 \times E(B-V)$ r=1.00			$W_{eff} = 1370.2 - 106.1 \times E(B-V)$ r=−0.98					
	$\lambda_{eff}(T) = 6145 + 139 \times \theta + 156 \times \theta^2 - 80 \times \theta^3$			$W_{eff}(T) = 1255 + 289 \times \theta - 183 \times \theta^2 - 109 \times \theta^3$					

TABLE 9
Characteristics of Photometric Bands

bandpass system	band	ref$^{a)}$	$\lambda_{\rm eff}$ (Å)	FWHM (Å)	$\lambda_{\rm eff}^{\rm Vega}$ (Å)	$f_{\lambda,{\rm eff}}^{\rm Vega}$ ($\times10^{-9}$cgs/Å)	$c(\nu_{\rm eff}^{\rm Vega})^{-1}$ (Å)	$f_{\nu,{\rm eff}}^{\rm Vega}$ ($\times10^{-20}$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	$R_{\rm C}$	Bessell 90	6588	1568	6410	2.15	6415	3.02
	$I_{\rm C}$	Bessell 90	8060	1542	7977	1.11	7980	2.38
Johnson	$R_{\rm J}$		6930	2096	6688	1.87	6693	2.89
	$I_{\rm J}$		8785	1706	8571	0.912	8545	2.28
Sandage-Smith	u		3647	595	3710	4.30	3610	1.89
	b		4466	1028	4407	6.10	4369	3.97
	v		5423	823	5368	3.75	5365	3.64
	r		6712	969	6628	1.96	6629	2.90
Strömgren	u	Olson74	3465	363	3496	3.24	3452	1.31
	v	Matsu69	4109	197	4119	7.21	4103	4.12
	b	Olson74	4668	176	4666	5.68	4663	4.15
	y	Olson74	5459	244	5455	3.62	5453	3.60
Kron	$U_{\rm K}$	Koo 85	3656	556	3737	4.32	3617	1.93
	$J_{\rm K}$		4625	1550	4537	5.54	4467	3.82
	$F_{\rm K}$		6168	1330	5978	2.64	5982	3.25
	$N_{\rm K}$		7953	1786	7838	1.17	7842	2.44
Couch-Newell	$B_{\rm J}$		4604	1490	4515	5.73	4474	3.95
	$R_{\rm F}$		6694	517	6679	1.92	6677	2.86

Astronomy & Astrophysics manuscript no. 6082
September 5, 2006

Empirical Color Transformations Between SDSS Photometry and Other Photometric Systems

K. Jordi[⋆], E.K. Grebel, and K. Ammon

Astronomical Institute of the University of Basel, Department of Physics and Astronomy, Venusstrasse 7, CH-4102 Binningen, Switzerland
e-mail: `jordi@astro.unibas.ch, grebel@astro.unibas.ch, ammon@astro.unibas.ch`

Received August 14, 2006; accepted August 28, 2006

ABSTRACT

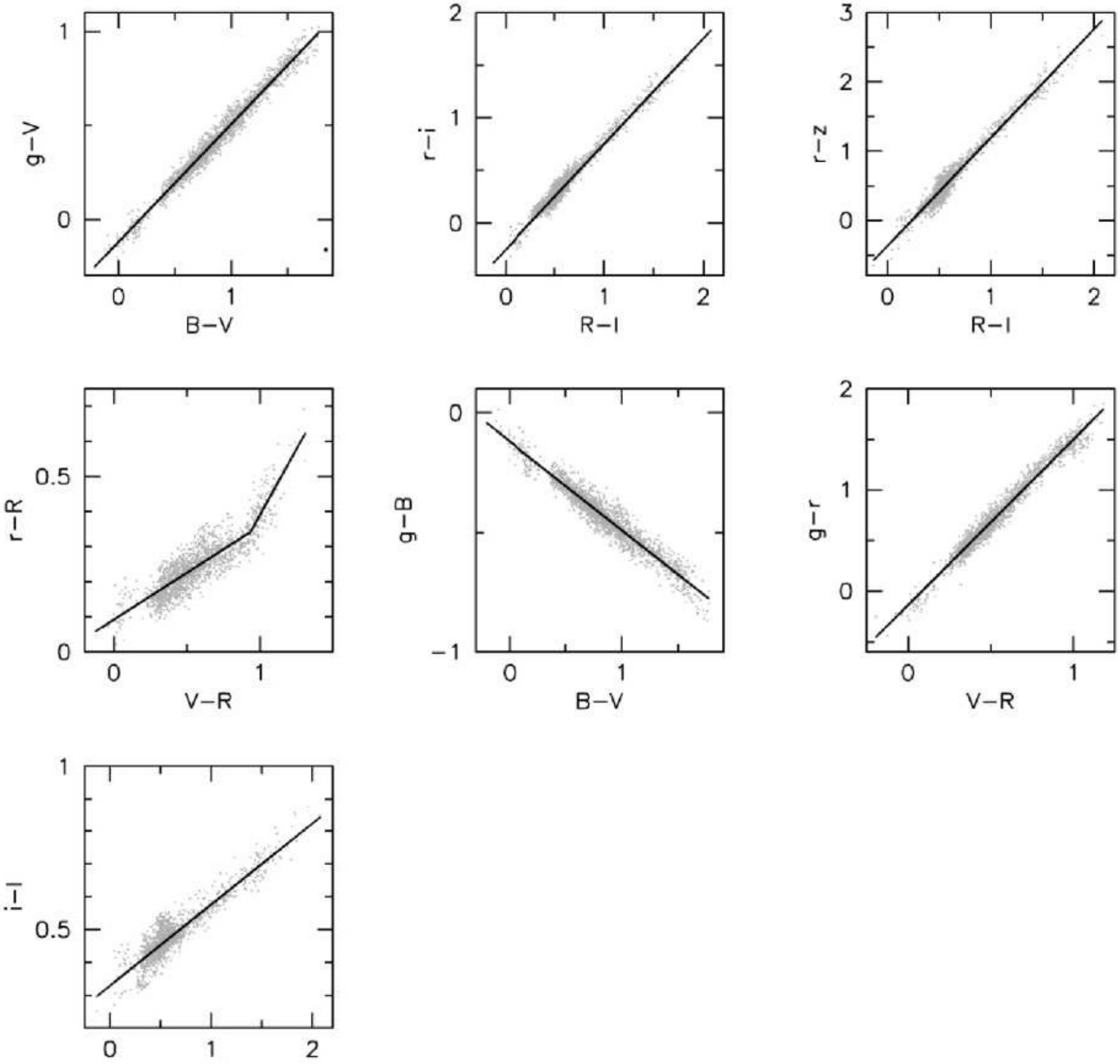
Aims. We present *empirical* color transformations between the Sloan Digital Sky Survey (SDSS) *ugriz* photometry and Johnson-Cousins *UBVRI* system and Becker's *RGU* system, respectively. Owing to the magnitude of data that is becoming available in the SDSS photometric system it is particularly important to be able to convert between this new system and traditional photometric systems. Unlike earlier published transformations we based our calculations on stars actually measured by the SDSS with the SDSS 2.5-m telescope. The photometric database of the SDSS provides in a sense a single-epoch set of 'tertiary standards' covering more than one quarter of the sky. Our transformations should facilitate their use to easily and reliably derive the corresponding approximate Johnson-Cousins or *RGU* magnitudes.
Methods. The SDSS survey covers a number of areas that were previously established as standard fields in the Johnson-Cousins system, in particular, fields established by Landolt and by Stetson. We used these overlapping fields to create well-photometered star samples on which our calculated transformations are based. For the *RGU* photometry we used fields observed in the framework of the new Basel high-latitude field star survey.
Results. We calculated *empirical* color transformations between SDSS photometry and Johnson-Cousins *UBVRI* and Becker's *RGU* system. For all transformations we found linear relations to be sufficient. Furthermore we showed that the transformations between the Johnson-Cousins and the SDSS system have a slight dependence on metallicity.

3. Results

3.1. Transformations between SDSS and Johnson–Cousins Photometry

The transformation between the Johnson–Cousins *UBVRI* photometry system and the SDSS *ugriz* system was carried out using the following eight general equations:

$$\begin{aligned}
g - V &= a_1\,(B - V) + b_1\\
r - i &= a_2\,(R - I) + b_2\\
r - z &= a_3\,(R - I) + b_3\\
r - R &= a_4\,(V - R) + b_4\\
u - g &= a_5\,(U - B) + b_5\,(B - V) + c_5\\
g - B &= a_6\,(B - V) + b_6\\
g - r &= a_7\,(V - R) + b_7\\
i - I &= a_8\,(R - I) + b_8
\end{aligned}$$



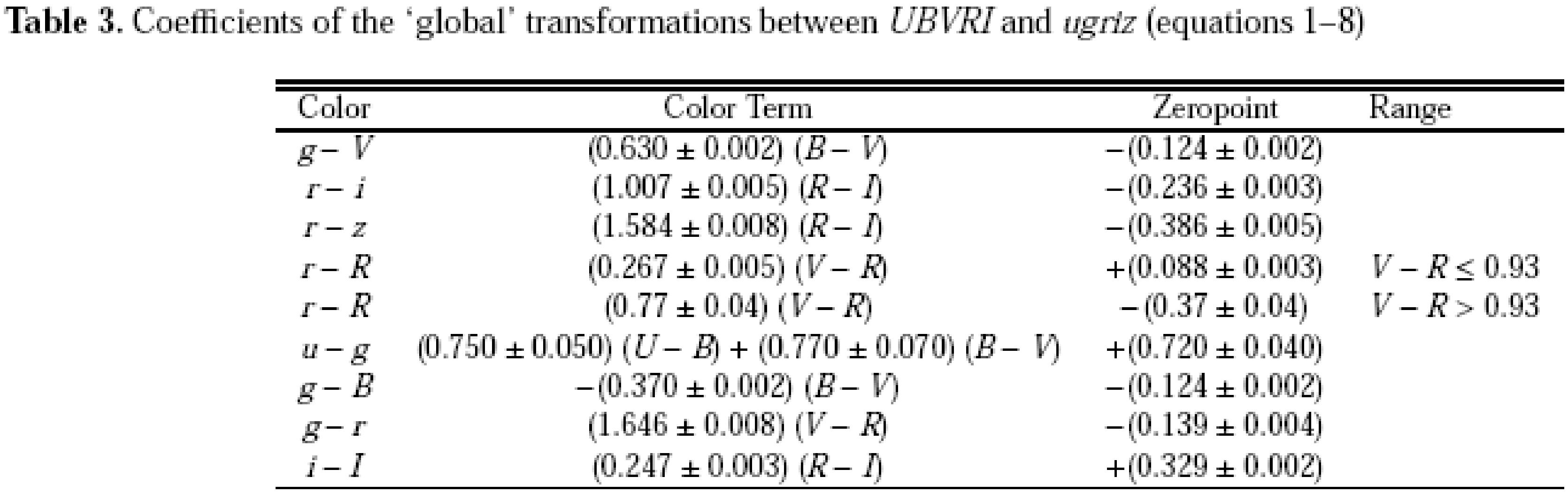


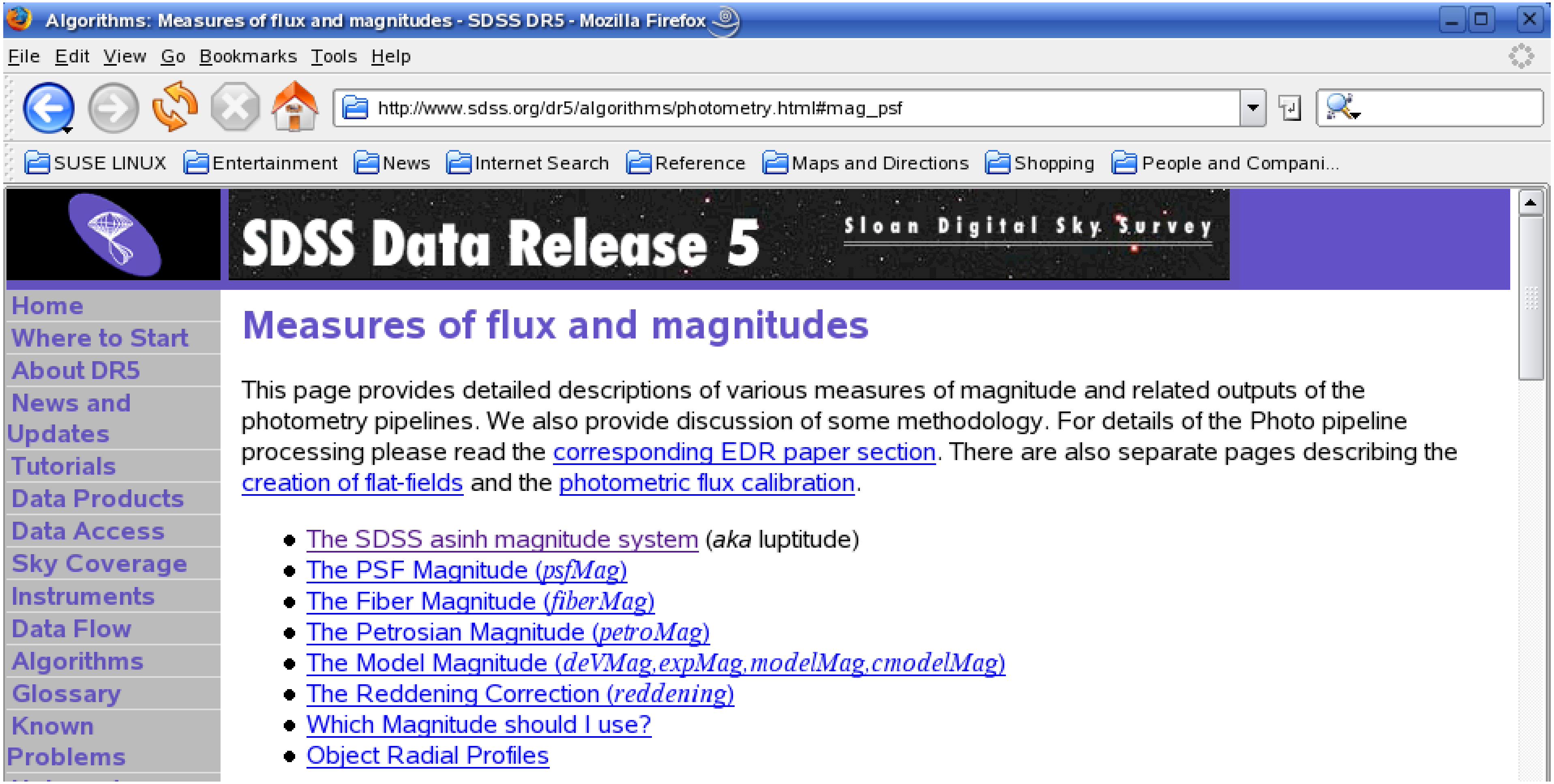
Table 3. Coefficients of the 'global' transformations between *UBVRI* and *ugriz* (equations 1–8)

Color	Color Term	Zeropoint	Range
$g - V$	$(0.630 \pm 0.002)\ (B - V)$	$-(0.124 \pm 0.002)$	
$r - i$	$(1.007 \pm 0.005)\ (R - I)$	$-(0.236 \pm 0.003)$	
$r - z$	$(1.584 \pm 0.008)\ (R - I)$	$-(0.386 \pm 0.005)$	
$r - R$	$(0.267 \pm 0.005)\ (V - R)$	$+(0.088 \pm 0.003)$	$V - R \leq 0.93$
$r - R$	$(0.77 \pm 0.04)\ (V - R)$	$-(0.37 \pm 0.04)$	$V - R > 0.93$
$u - g$	$(0.750 \pm 0.050)\ (U - B) + (0.770 \pm 0.070)\ (B - V)$	$+(0.720 \pm 0.040)$	
$g - B$	$-(0.370 \pm 0.002)\ (B - V)$	$-(0.124 \pm 0.002)$	
$g - r$	$(1.646 \pm 0.008)\ (V - R)$	$-(0.139 \pm 0.004)$	
$i - I$	$(0.247 \pm 0.003)\ (R - I)$	$+(0.329 \pm 0.002)$	

$$g = V + (0.630 \pm 0.002)(B - V) - (0.124 \pm 0.002)$$

Table 4. Metallicity-dependent transformations between *BVRI* and *griz* for metal-poor Population II and more metal-rich Population I stars.

Color	Color Term	Zeropoint	Validity
$g - V$	$(0.634 \pm 0.002)\ (B - V)$	$-(0.127 \pm 0.002)$	Population I
$g - V$	$(0.596 \pm 0.009)\ (B - V)$	$-(0.148 \pm 0.007)$	metal-poor Population II
$r - i$	$(0.988 \pm 0.006)\ (R - I)$	$-(0.221 \pm 0.004)$	Population I
$r - i$	$(1.06 \pm 0.02)\ (R - I)$	$-(0.30 \pm 0.01)$	metal-poor Population II
$r - z$	$(1.568 \pm 0.009)\ (R - I)$	$-(0.370 \pm 0.006)$	Population I
$r - z$	$(1.60 \pm 0.06)\ (R - I)$	$-(0.46 \pm 0.03)$	metal-poor Population II
$r - R$	$(0.275 \pm 0.006)\ (V - R)$	$+(0.086 \pm 0.004)$	$V - R \leq 0.93$; Population I
$r - R$	$(0.71 \pm 0.05)\ (V - R)$	$-(0.31 \pm 0.05)$	$V - R > 0.93$; Population I
$r - R$	$(0.34 \pm 0.02)\ (V - R)$	$+(0.015 \pm 0.008)$	$V - R \leq 0.93$; metal-poor Population II
$g - B$	$-(0.366 \pm 0.002)\ (B - V)$	$-(0.126 \pm 0.002)$	Population I
$g - B$	$-(0.401 \pm 0.009)\ (B - V)$	$-(0.145 \pm 0.006)$	metal-poor Population II
$g - r$	$(1.599 \pm 0.009)\ (V - R)$	$-(0.106 \pm 0.006)$	Population I
$g - r$	$(1.72 \pm 0.02)\ (V - R)$	$-(0.198 \pm 0.007)$	metal-poor Population II
$i - I$	$(0.251 \pm 0.003)\ (R - I)$	$+(0.325 \pm 0.002)$	Population I
$i - I$	$(0.21 \pm 0.02)\ (R - I)$	$+(0.34 \pm 0.01)$	metal-poor Population II



Measures of flux and magnitudes

This page provides detailed descriptions of various measures of magnitude and related outputs of the photometry pipelines. We also provide discussion of some methodology. For details of the Photo pipeline processing please read the corresponding EDR paper section. There are also separate pages describing the creation of flat-fields and the photometric flux calibration.

- The SDSS asinh magnitude system (*aka* luptitude)
- The PSF Magnitude (*psfMag*)
- The Fiber Magnitude (*fiberMag*)
- The Petrosian Magnitude (*petroMag*)
- The Model Magnitude (*deVMag,expMag,modelMag,cmodelMag*)
- The Reddening Correction (*reddening*)
- Which Magnitude should I use?
- Object Radial Profiles

SDSS magnitudes:

AB system, asinh magnitudes

- Fiber Magnitudes – flux in fiber aperture
- Model Magnitudes
  - model fits to objects using deVaucoulers profile, expoinential profile – relevant to galaxies
- Cmodel Magnitudes
  - flux in linear combination of best fitting models
- Petrosian Magnitudes
  - flux in circular aperture with r defined by azimuthally averaged light profile $RP_{P,lim}$ ~0.2
- PSF magnitudes
  - Point Spread Function fit – for isolated stars

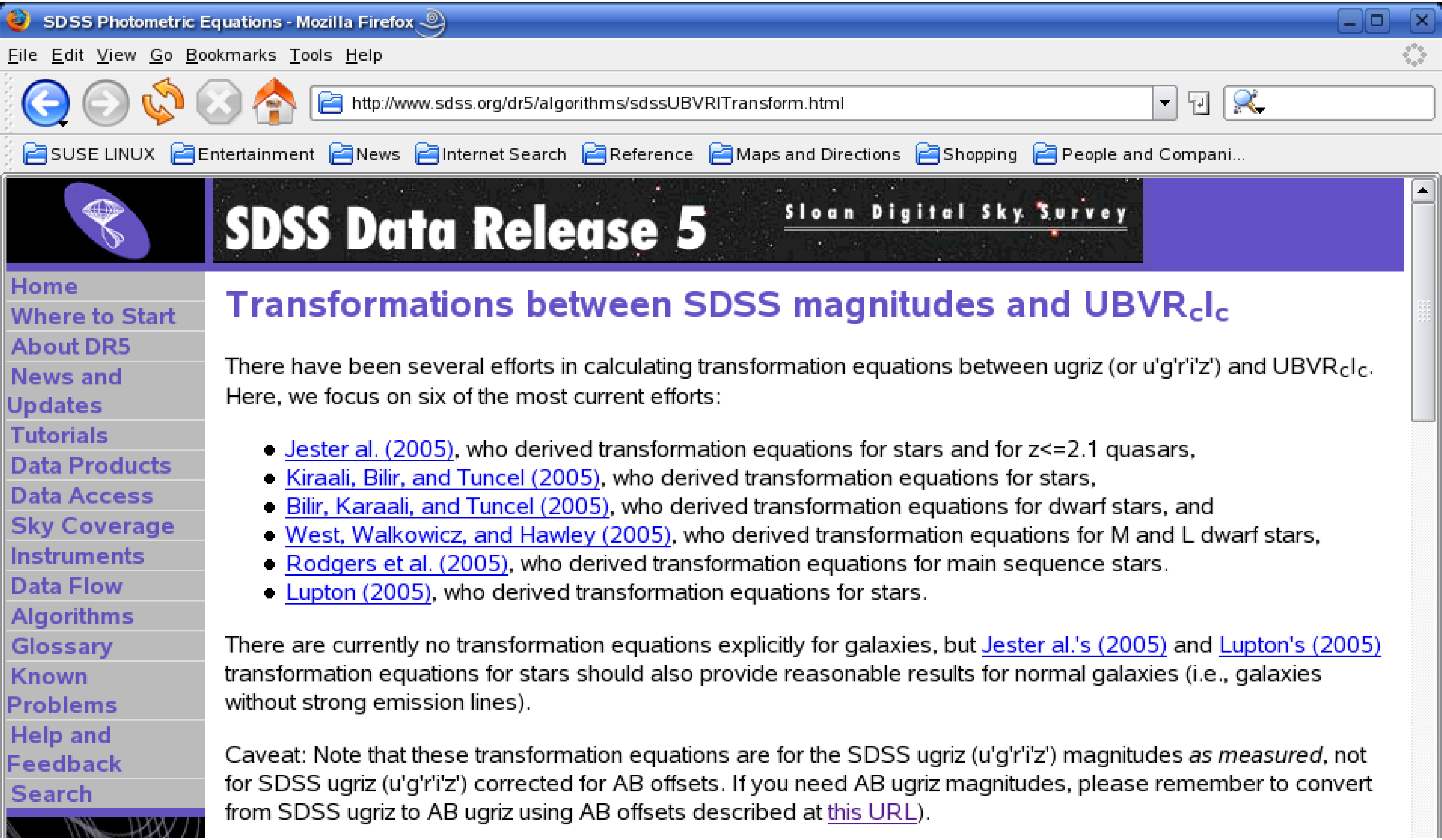
Which Magnitude should I use?

Faced with this array of different magnitude measurements to choose from, which one is appropriate in which circumstances? We cannot give any guarantees of what is appropriate for the science *you* want to do, but here we present some examples, where we use the general guideline that one usually wants to maximize some combination of signal-to-noise ratio, fraction of the total flux included, and freedom from systematic variations with observing conditions and distance.

Given the excellent agreement between *cmodel* magnitudes (see cmodel magnitudes above) and PSF magnitudes for point sources, and between *cmodel* magnitudes and Petrosian magnitudes (albeit with intrinsic offsets due to aperture corrections) for galaxies, the *cmodel* magnitude is now an adequate proxy to use as a universal magnitude for all types of objects. As it is approximately a matched aperture to a galaxy, it has the great advantage over Petrosian magnitudes, in particular, of having close to optimal noise properties.

Example magnitude usage

- **Photometry of Bright Stars**: If the objects are bright enough, add up all the flux from the profile *profMean* and generate a large aperture magnitude. We recommend using the first 7 annuli.
- **Photometry of Distant Quasars**: These will be unresolved, and therefore have images consistent with the PSF. For this reason, *psfMag* is unbiased and optimal.
- **Colors of Stars**: Again, these objects are unresolved, and *psfMag* is the optimal measure of their brightness.
- **Photometry of Nearby Galaxies**: Galaxies bright enough to be included in our spectroscopic sample have relatively high signal-to-noise ratio measurements of their Petrosian magnitudes. Since these magnitudes are model-independent and yield a large fraction of the total flux, roughly constant with redshift, *petroMag* is the measurement of choice for such objects. In fact, the noise properties of Petrosian magnitudes remain good to *r=20* or so.
- **Photometry of Galaxies**: Under most conditions, the *cmodel* magnitude is now a reliable estimate of the galaxy flux. In addition, this magnitude account for the effects of local seeing and thus are less dependent on local seeing variations.
- **Colors of Galaxies**: For measuring *colors* of extended objects, we continue to recommend using the model (not the *cmodel*) magnitudes; the colors of galaxies were almost completely unaffected by the DR1 software error. The model magnitude is calculated using the best-fit parameters in the *r* band, and applies it to all other bands; the light is therefore measured consistently through the same aperture in all bands.



Transformations between SDSS magnitudes and $UBVR_CI_C$

There have been several efforts in calculating transformation equations between ugriz (or u'g'r'i'z') and $UBVR_CI_C$. Here, we focus on six of the most current efforts:

- Jester al. (2005), who derived transformation equations for stars and for z<=2.1 quasars,
- Kiraali, Bilir, and Tuncel (2005), who derived transformation equations for stars,
- Bilir, Karaali, and Tuncel (2005), who derived transformation equations for dwarf stars, and
- West, Walkowicz, and Hawley (2005), who derived transformation equations for M and L dwarf stars,
- Rodgers et al. (2005), who derived transformation equations for main sequence stars.
- Lupton (2005), who derived transformation equations for stars.

There are currently no transformation equations explicitly for galaxies, but Jester al.'s (2005) and Lupton's (2005) transformation equations for stars should also provide reasonable results for normal galaxies (i.e., galaxies without strong emission lines).

Caveat: Note that these transformation equations are for the SDSS ugriz (u'g'r'i'z') magnitudes *as measured*, not for SDSS ugriz (u'g'r'i'z') corrected for AB offsets. If you need AB ugriz magnitudes, please remember to convert from SDSS ugriz to AB ugriz using AB offsets described at this URL).

```
UBVRcIc -> ugriz
================

Quasars at z <= 2.1 (synthetic)
        Transformation                RMS residual
    u-g     =    1.25*(U-B)    + 1.02      0.03
    g-r     =    0.93*(B-V)    - 0.06      0.09
    r-i     =    0.90*(Rc-Ic) - 0.20      0.07
    r-z     =    1.20*(Rc-Ic) - 0.20      0.18
    g       =    V + 0.74*(B-V) - 0.07    0.02
    r       =    V - 0.19*(B-V) - 0.02    0.08


Stars with Rc-Ic < 1.15 and U-B < 0
        Transformation                RMS residual
    u-g     =    1.28*(U-B)    + 1.14      0.05
    g-r     =    1.09*(B-V)    - 0.23      0.04
    r-i     =    0.98*(Rc-Ic) - 0.22      0.01
    r-z     =    1.69*(Rc-Ic) - 0.42      0.03
    g       =    V + 0.64*(B-V) - 0.13    0.01
    r       =    V - 0.46*(B-V) + 0.11    0.03


All stars with Rc-Ic < 1.15
        Transformation                RMS residual
    u-g     =    1.28*(U-B)    + 1.13      0.06
    g-r     =    1.02*(B-V)    - 0.22      0.04
    r-i     =    0.91*(Rc-Ic) - 0.20      0.03
    r-z     =    1.72*(Rc-Ic) - 0.41      0.03
    g       =    V + 0.60*(B-V) - 0.12    0.02
    r       =    V - 0.42*(B-V) + 0.11    0.03
```

What's coming?

- In context of VO
  - Data model for photometry
  - Something like WCS for coordinates, but for photometry to describe photometric systems
  - Problem recognized, but nothing has happended yet...

Suggestions for SIMBAD

- Convert current B and V mags into SDSS g
  - but current B and V mags have no references (?)
  - choose a published transformation, apply only to stars
- Include SDSS g (or ubgiz) where X-match in SDSS exits
    - and link to SDSS (in Vizier, or SDSS itself)
- Ingest measurements in well specified systems
    - e.g the list from Fukugita et al. 1995
    - contribute to development of Photometry Data Model and serialization

Magnitudes, A Formal Definition

$$m = -2.5 \left[\log \int d\lambda R(\lambda) f_\lambda - \log \int d\lambda R(\lambda) f_\lambda(\alpha\,\mathrm{Lyr}) \right]$$

Because Vega (= α Lyrae) is declared to be the zero-point! (at least for the UBV… system)

e.g.,

$$U = -2.5 \log \int d\lambda R_U(\lambda) f_\lambda - 14.08 + c_U\,,$$

$$B = -2.5 \log \int d\lambda R_B(\lambda) f_\lambda - 13.00 + c_B\,,$$

$$V = -2.5 \log \int d\lambda R_V(\lambda) f_\lambda - 13.76 + c_V\,,$$

where the peak of the response function is normalized to unity, and c represents the magnitude of α Lyr; $c_U = 0.02$, $c_B = c_V = 0.03$ (Johnson and Morgan 1953).

Defining effective wavelengths (and the corresponding bandpass averaged fluxes)

$$\lambda_{\rm eff} = \frac{\int d\lambda\, \lambda R(\lambda)}{\int d\lambda R(\lambda)},$$

$$f_\lambda^{\rm eff}(\alpha \text{ Lyr}) = \frac{\int d\lambda f_\lambda(\alpha \text{ Lyr}) R(\lambda)}{\int d\lambda R(\lambda)},$$

$$\lambda_{\rm eff}(\alpha \text{ Lyr}) = \frac{\int d\lambda\, \lambda f_\lambda(\alpha \text{ Lyr}) R(\lambda)}{\int d\lambda f_\lambda(\alpha \text{ Lyr}) R(\lambda)},$$

$$f_\nu^{\rm eff}(\alpha \text{ Lyr}) = \frac{\int d\nu f_\nu(\alpha \text{ Lyr}) R(\nu)}{\int d\nu R(\nu)},$$

$$\nu_{\rm eff}(\alpha \text{ Lyr}) = \frac{\int d\nu\, \nu f_\nu(\alpha \text{ Lyr}) R(\nu)}{\int d\nu f_\nu(\alpha \text{Lyr}) R(\nu)}$$

where $f_\nu = \lambda^2 f_\lambda / c$ and $R_\nu = R_\lambda$.