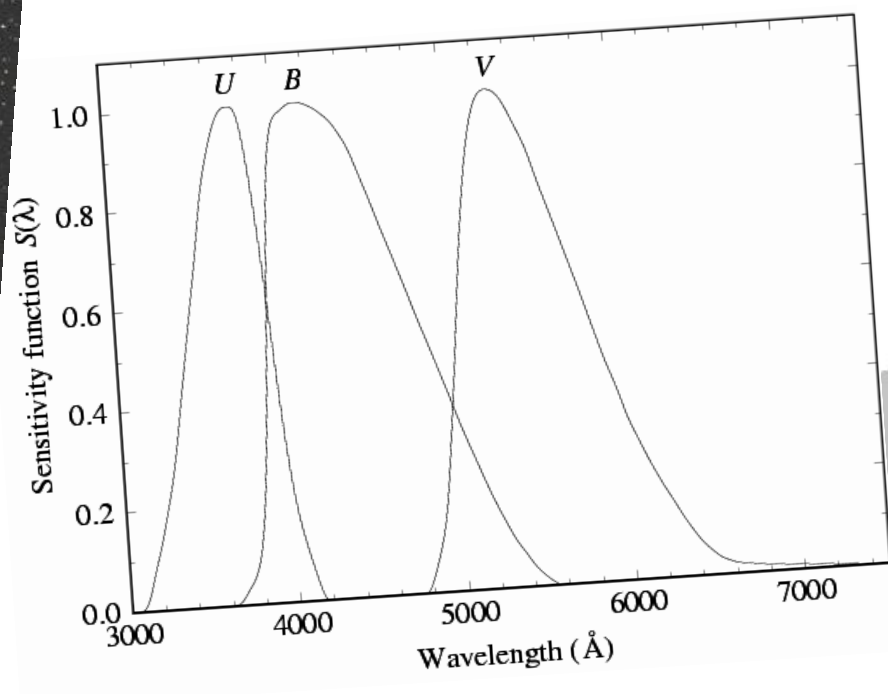
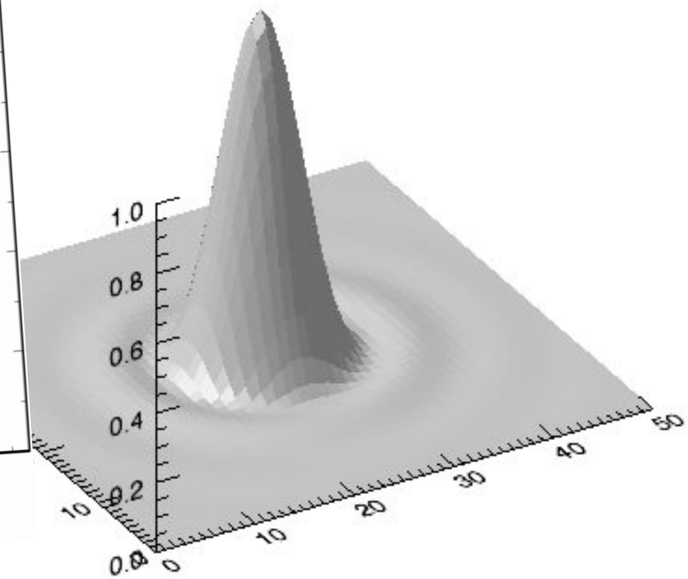
AGA 5802: Astrofísica Observacional

Jorge Meléndez

Photometry I

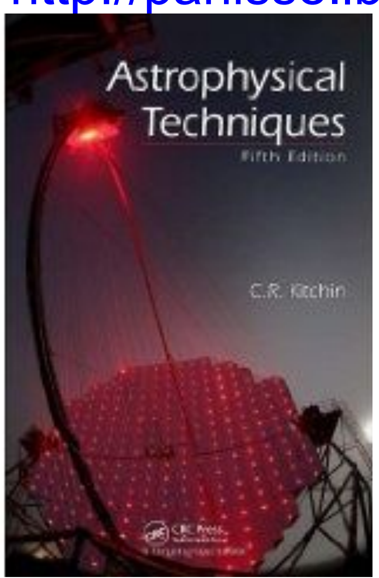


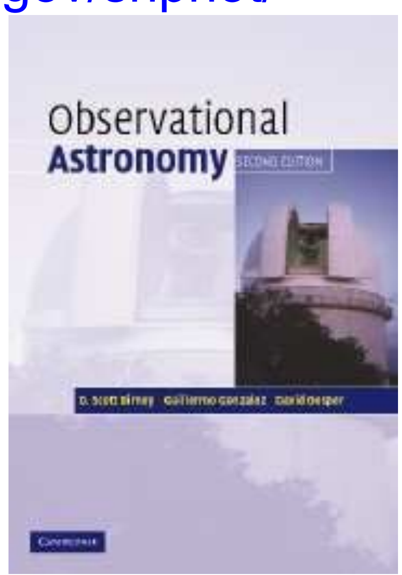


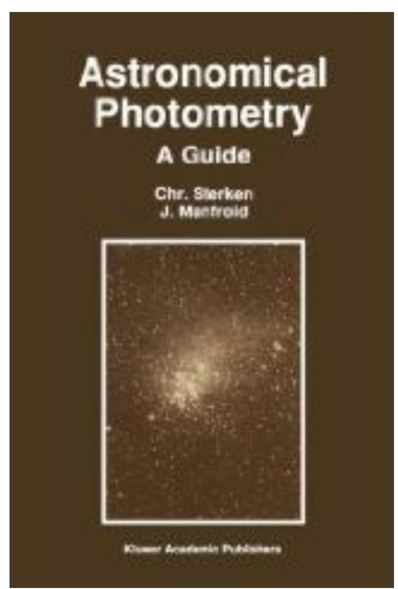
Atualização: 3/29/18

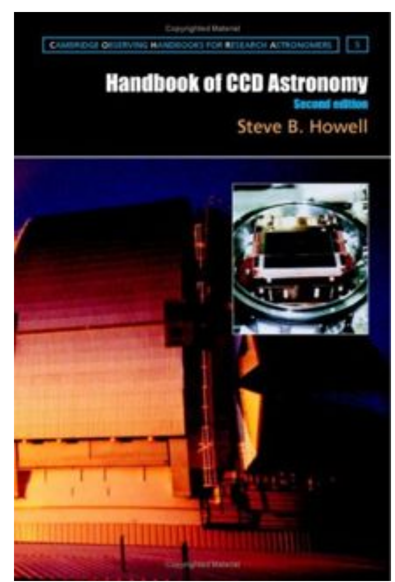
Bibliography

- Kitchin – Astrophysical Techniques (5th Ed, 2009), Cap. 3
- Birney – Observational Astronomy (2nd Ed, 2008), Cap.5 e 10
- Howell – Handbook of CCD Astronomy (2nd Ed, 2006), Cap. 5
- Sterken & Manfrod – Astronomical Photometry (1992)
- Romanishin – Introduction to Astronomical Photometry (2006) FREE
- *Notas de Aula, Prof. Antonio Mário Magalhães*
- www.das.inpe.br/~claudia.rodrigues/ http://www.astro.caltech.edu/~george/ay122/ http://panisse.lbl.gov/snphot/









Introduction to Astronomical Photometry using CCDs

http://observatory.ou.edu

Romanishin

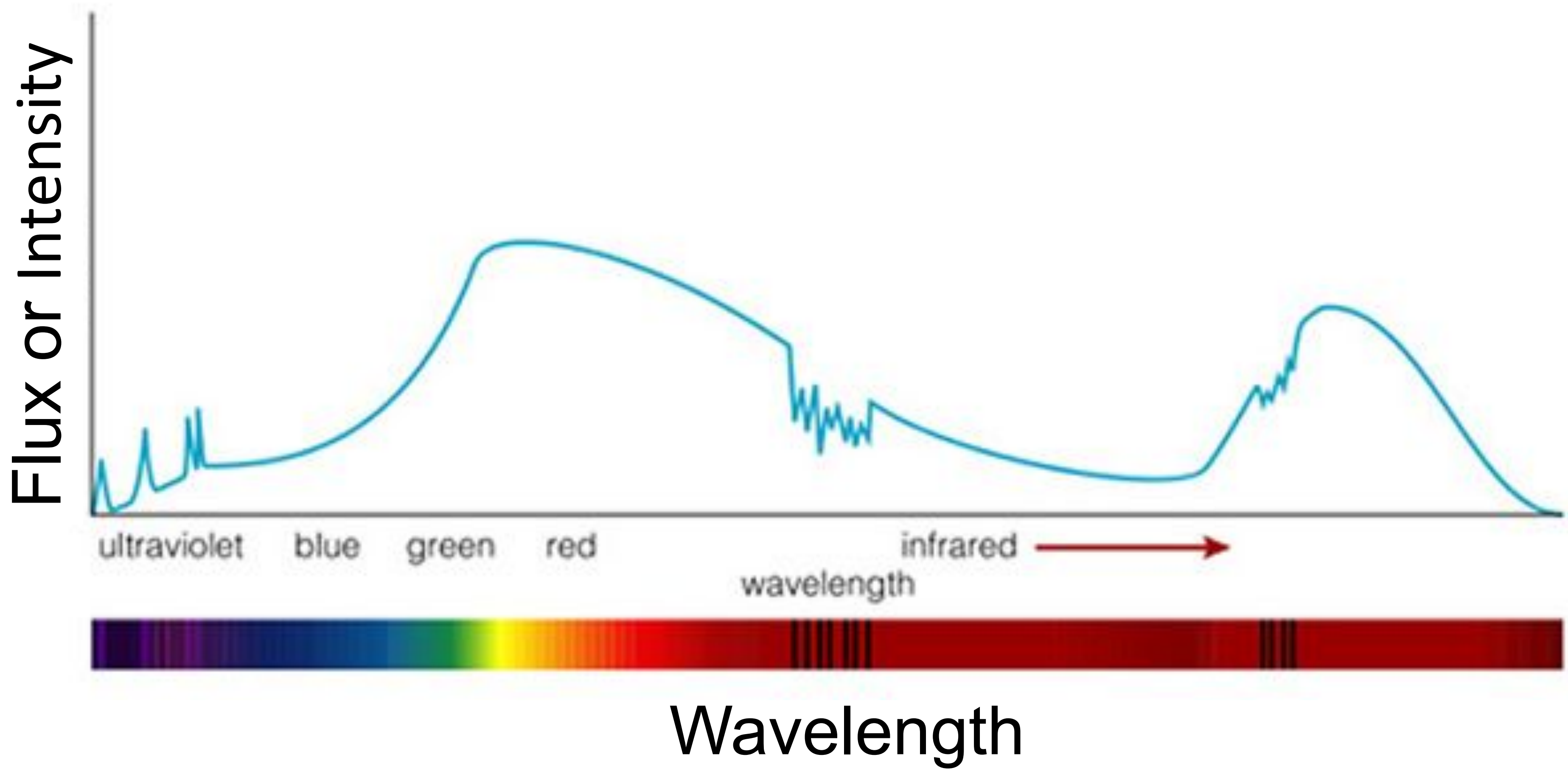
Astronomical Photometry

First, chat with the students about:

- Difference between photometry & spectroscopy
- What is spectrophotometry?
- Differential & absolute photometry: advantages
- Magnitude & Flux
- Absolute Magnitude
- Vega
- What is a photometric system?
- Broad band vs narrow band
- Applications?

Photometry: flux (or intensity) in a broad (or intermediate) band

Spectroscopy: measurements of the relative flux at low, medium or high spectral resolution



Spectrophotometry: Flux distribution (or intensity) at very low spectral resolution

A&A 509, A28 (2010)

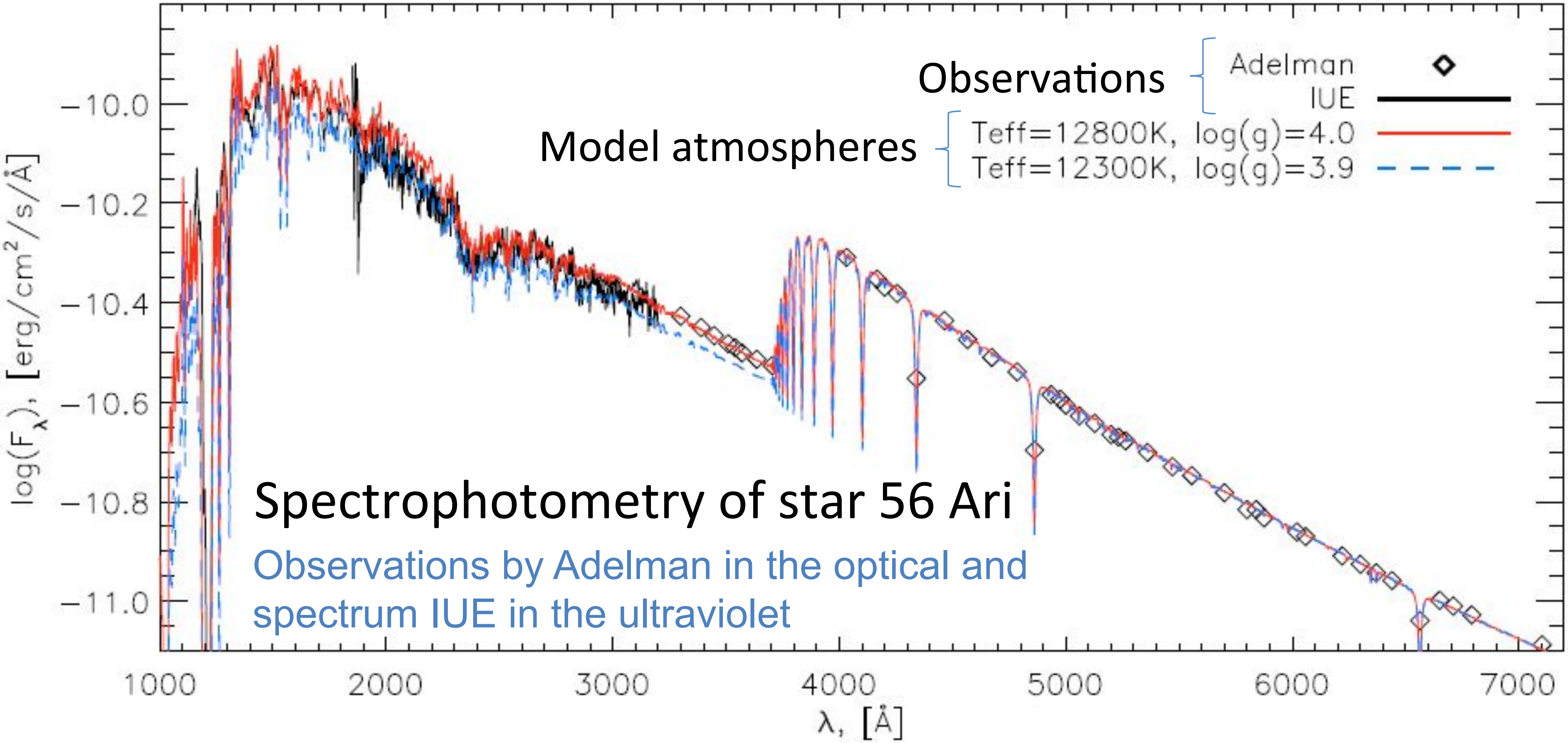
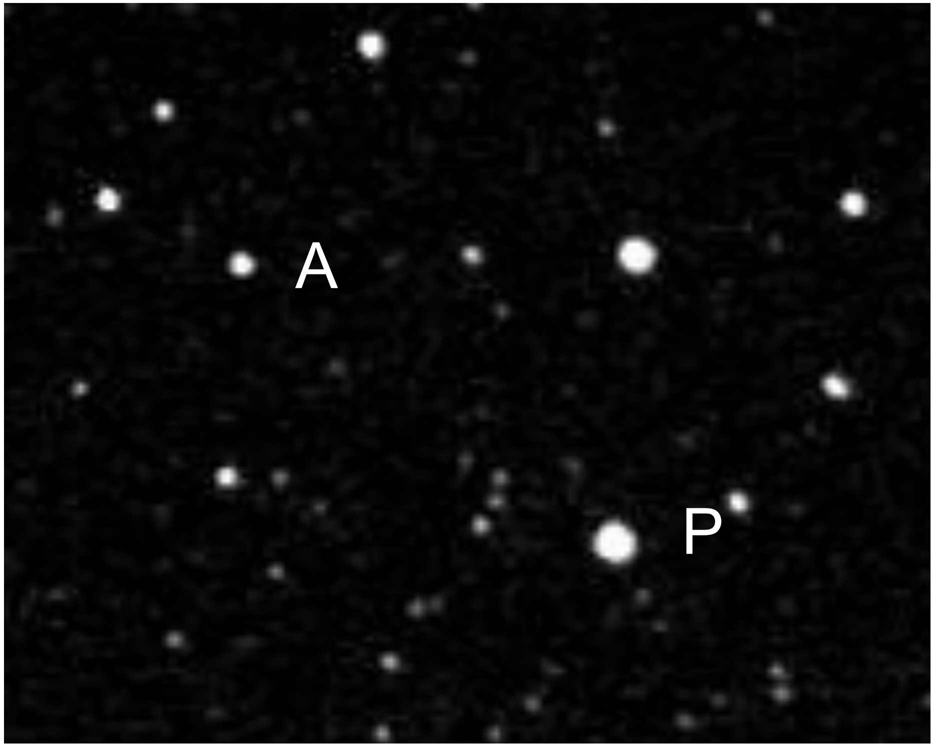


Fig. 1. Comparison of the observed and computed spectral energy distributions of 56 Ari. Theoretical models correspond to $T_{\rm eff}$ = 12 300 K, log(g) = 3.9 and $T_{\rm eff}$ = 12 800 K, log(g) = 4.0. The model fluxes have been convolved with an $FWHM$ = 10 Å Gaussian kernel for a better view.

D. Shulyak[1], O. Kochukhov[2], G. Valyavin[3], B.-C. Lee[4], G. Galazutdinov[5], K.-M. Kim[4], I. Han[4], and T. Burlakova[6]

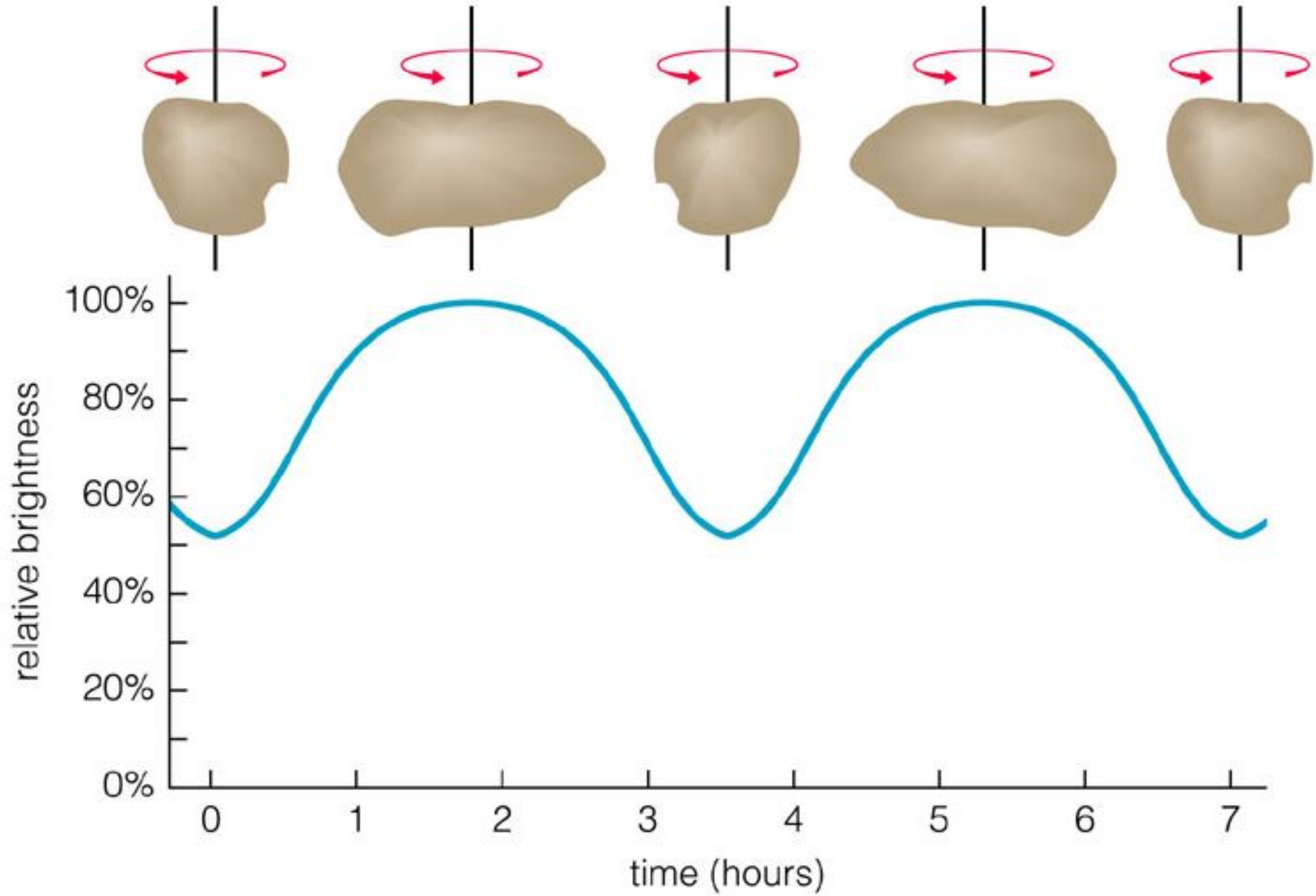
Differential Photometry

- Example: measure the brightness of star A relative to star P (without knowing necessarily the real magnitude of star P)



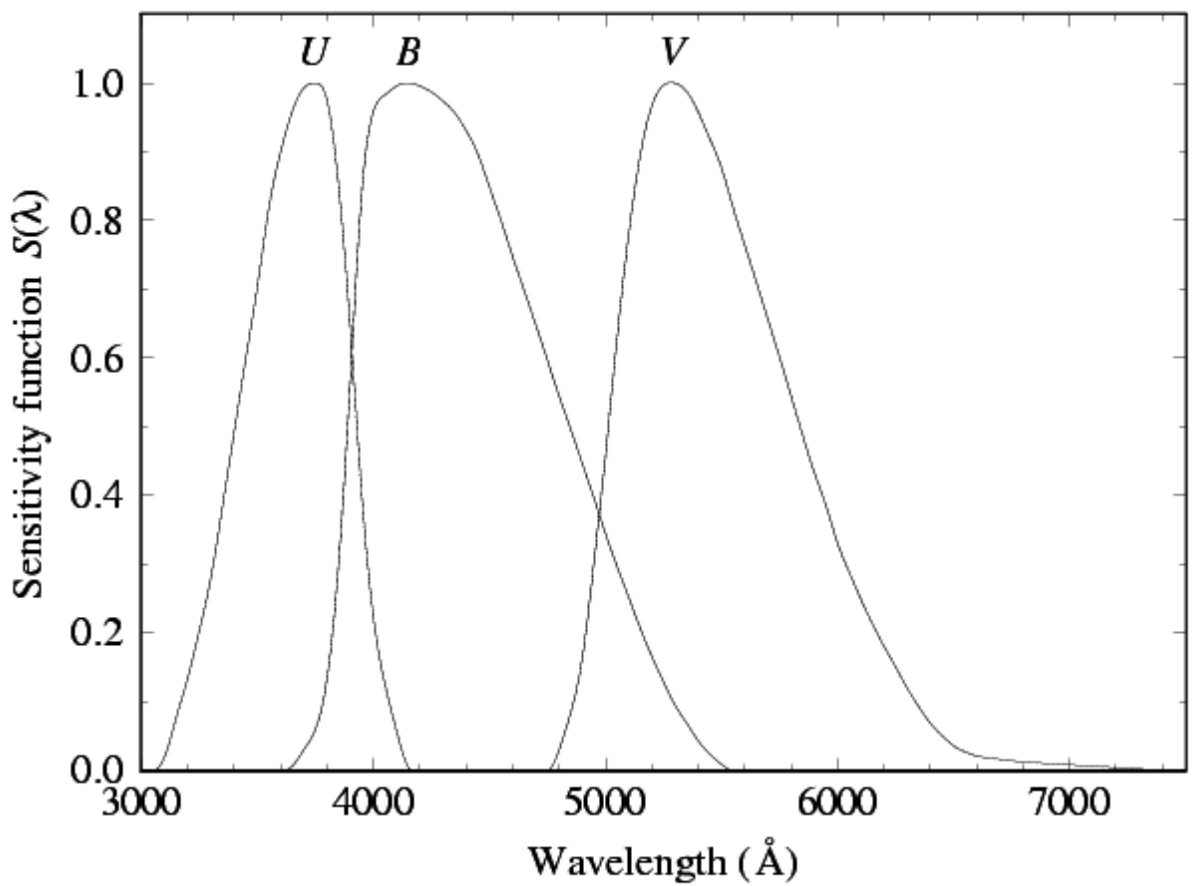
Differential photometry

- Rotation period of an asteroid



Absolute photometry

- Measurement of brightness in an standard system
- Is possible to compare with other observers
- We can transform magnitudes to absolute fluxes



Historically …

Hipparchus (190-125 BC)

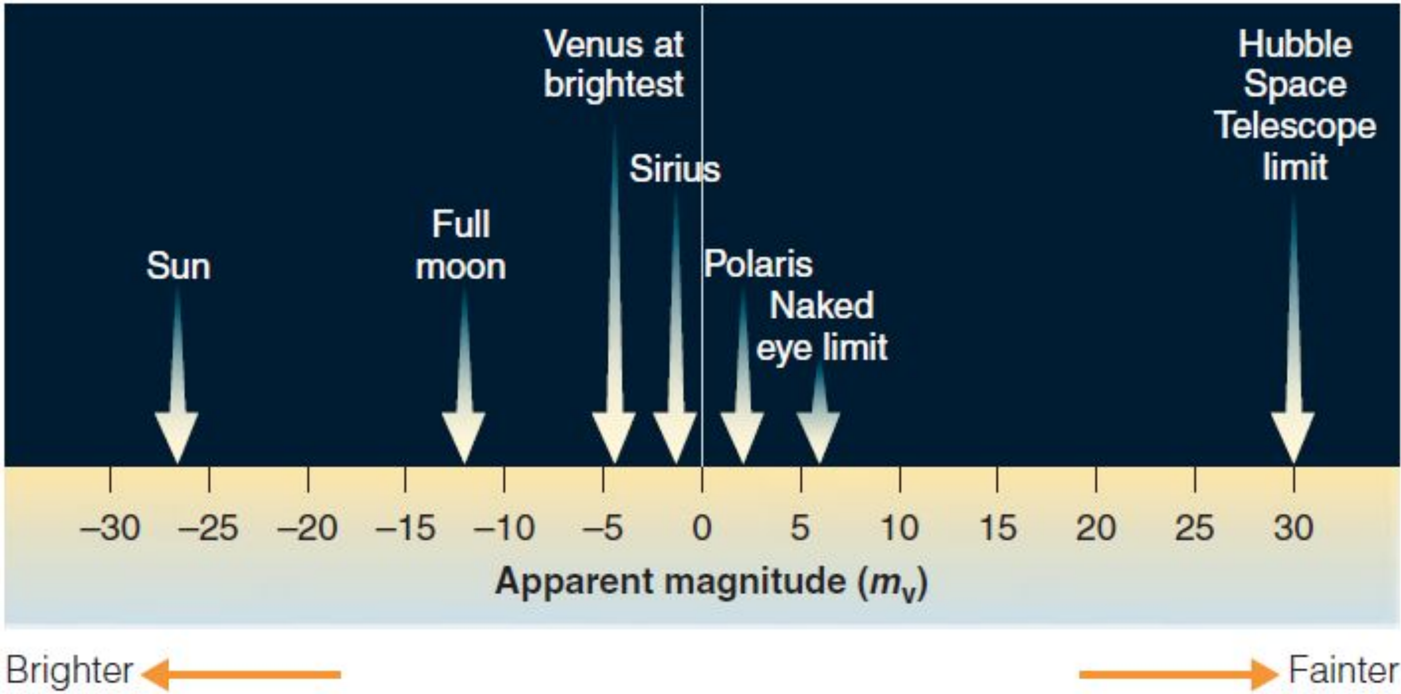
- Based on apparent brightness at naked eye
- Brightest: class 1
- Faintest: class 6

Magnitudes

brightest stars at naked eye: m ~ -1 to 0

faintest stars: m ~ 5 to 6

Logarithmic scale



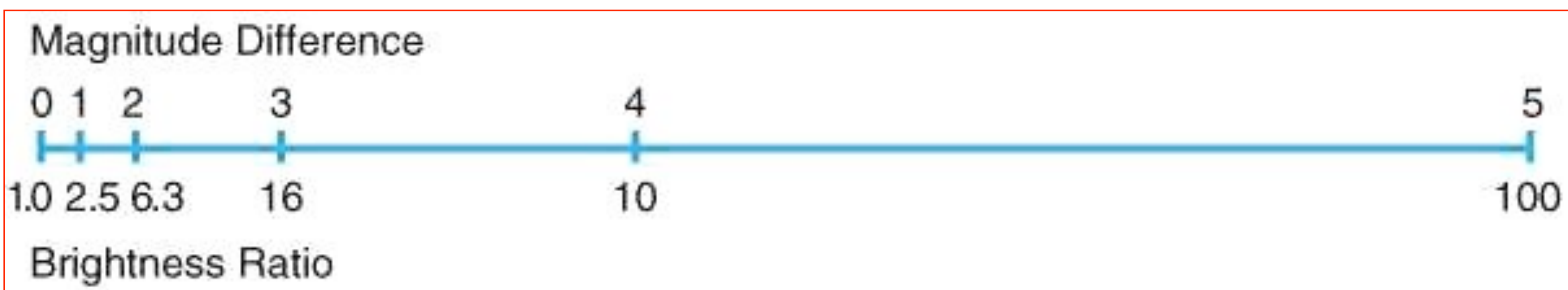
Pogson (1856): logaritmic scale

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

m: apparent magnitude

f: brightness (flux)

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



Example: exposure time

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

As discussed in class, the exposure time is inversely proportional to the flux (fainter objects requires longer exposure time) →

$$t_2/t_1 = 10^{-0.4(m_1 - m_2)} = 10^{+0.4(m_2 - m_1)}$$

$$t_2/t_1 = 2.512^{(m_2 - m_1)}$$

Example: exposure time

If a star of magnitude m = x needs an exposure of 100 s, what time would be needed for a star with m = x + 1?

$$t_2/t_1 = 2.512^{(m_2 - m_1)}$$

t_1= 10s $m_1 = x$ $m_2 = x + 1$ → $m_2 - m_1 = 1$

$$t_2/t_1 = 2.512^{1.0} = 2.512$$

$$t_2 = 2.512 \times 100\text{s} = 251 \text{ s}$$

Absolute Magnitude: M

The apparent magnitude *m* does not tell us about the intrinsic brightness of the star

Absolute Magnitude M: apparent magnitude that an object would have at a distance of 10pc

$$m - M = 5 \log d - 5$$

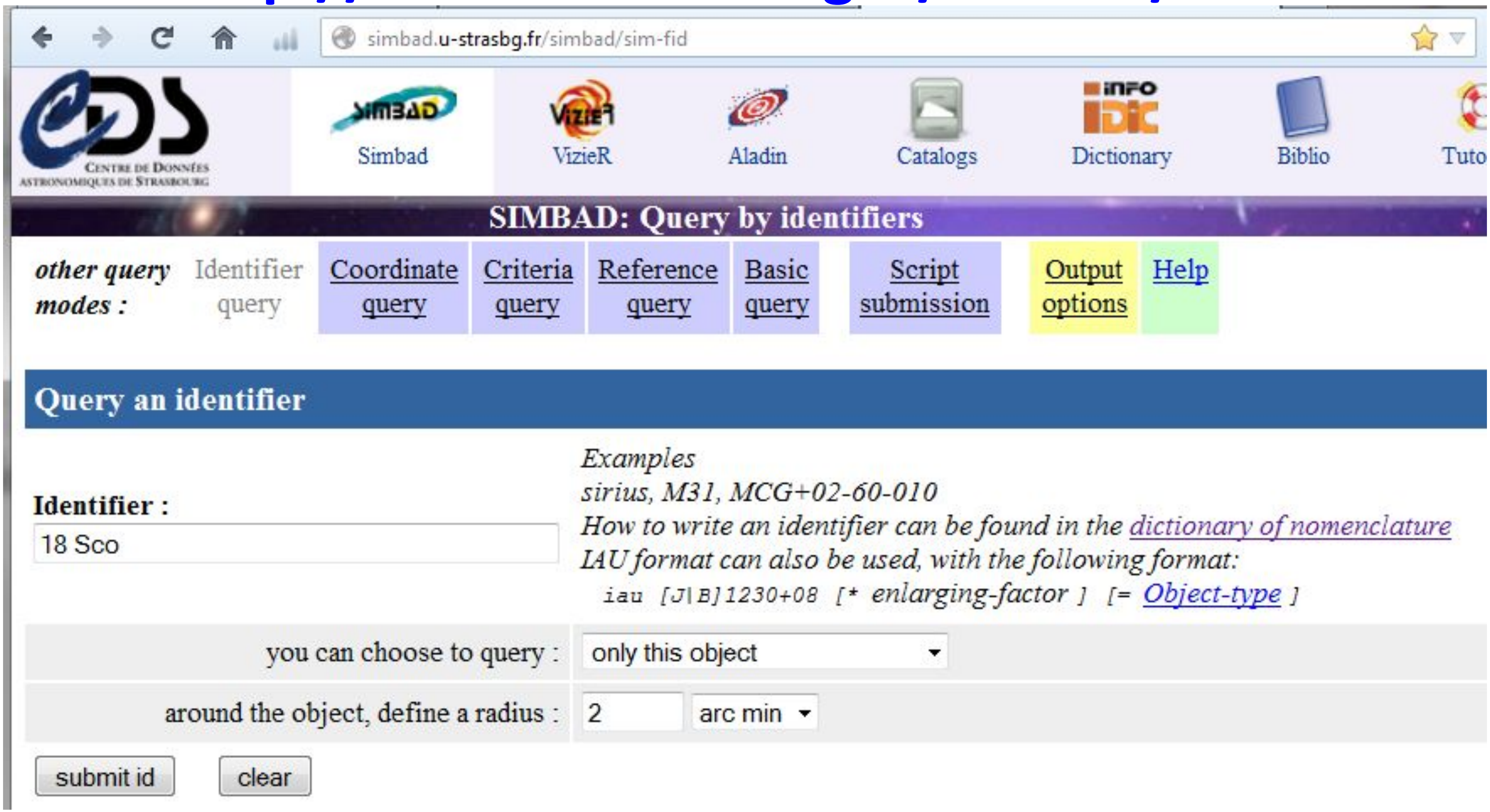
d : parsecs

p : ” (arcsec)

$$M = m + 5 \log p + 5$$

Example: Absolute Magnitude of solar twin *18 Sco*

http://simbad.u-strasbg.fr/simbad/sim-fid



simbad.u-strasbg.fr/simbad/sim-id?Ident=18+Sco&NbIdent=1&Radius=2&Radius.unit=arcmin&submit=submit+ic

Basic data :

* 18 Sco -- Variable Star

query around with radius

Other object types:	* (*,BD,CSI,GC,GCRV,GEN#,GJ,HD,HIC,HIP,HR,L [B10]) , **PM*** (Ci,LFT,LHS,LTT,NLTT,PM) , ** (TD1)
ICRS coord. (ep=J2000) :	16 15 37.26946 -08 22 09.9870 (Optical)
FK5 coord. (ep=J2000 eq=2000) :	16 15 37.269 -08 22 09.99 (Optical) [4
FK4 coord. (ep=B1950 eq=1950) :	16 12 53.98 -08 14 19.0 (Optical) [25.
Gal coord. (ep=J2000) :	004.6952 +29.1570 (Optical) [4.48 2.90
Proper motions *mas/yr* [error ellipse]:	230.77 -495.53 [0.51 0.33 0] A 2007A&A...
Radial velocity / Redshift / cz :	V(km/s) 10.6 [2] / z(~) 0.000035 [0.00000
Parallaxes *mas*:	71.94 [0.37] A 2007A&A...474..653V
Spectral type:	G2Va C 2011ARep...55...31S
Fluxes (5) :	B 6.15 [~] C ~
	V 5.50 [~] C ~

m.a.s. = 10^{-3} ”

Magnitude m_V

p = 71,94 x 10^{-3} ”

m_V = 5,5

Absolute Magnitude of *18 Sco*

Absolute Magnitude M: the apparent magnitude that an object would have at a distance of 10 pc

$$M = m + 5 - 5 \log d \quad [d: \text{parsecs}]$$

$$\mathbf{M = m + 5 + 5 \log \boldsymbol{p}} \ [p: \text{parallax in}\ '']$$

$$m_V = 5{,}5;\ p = 71{,}94 \times 10^{-3}\ ''$$

$$M_V = 5{,}5 + 5 + 5 \log (71{,}94 \times 10^{-3})$$

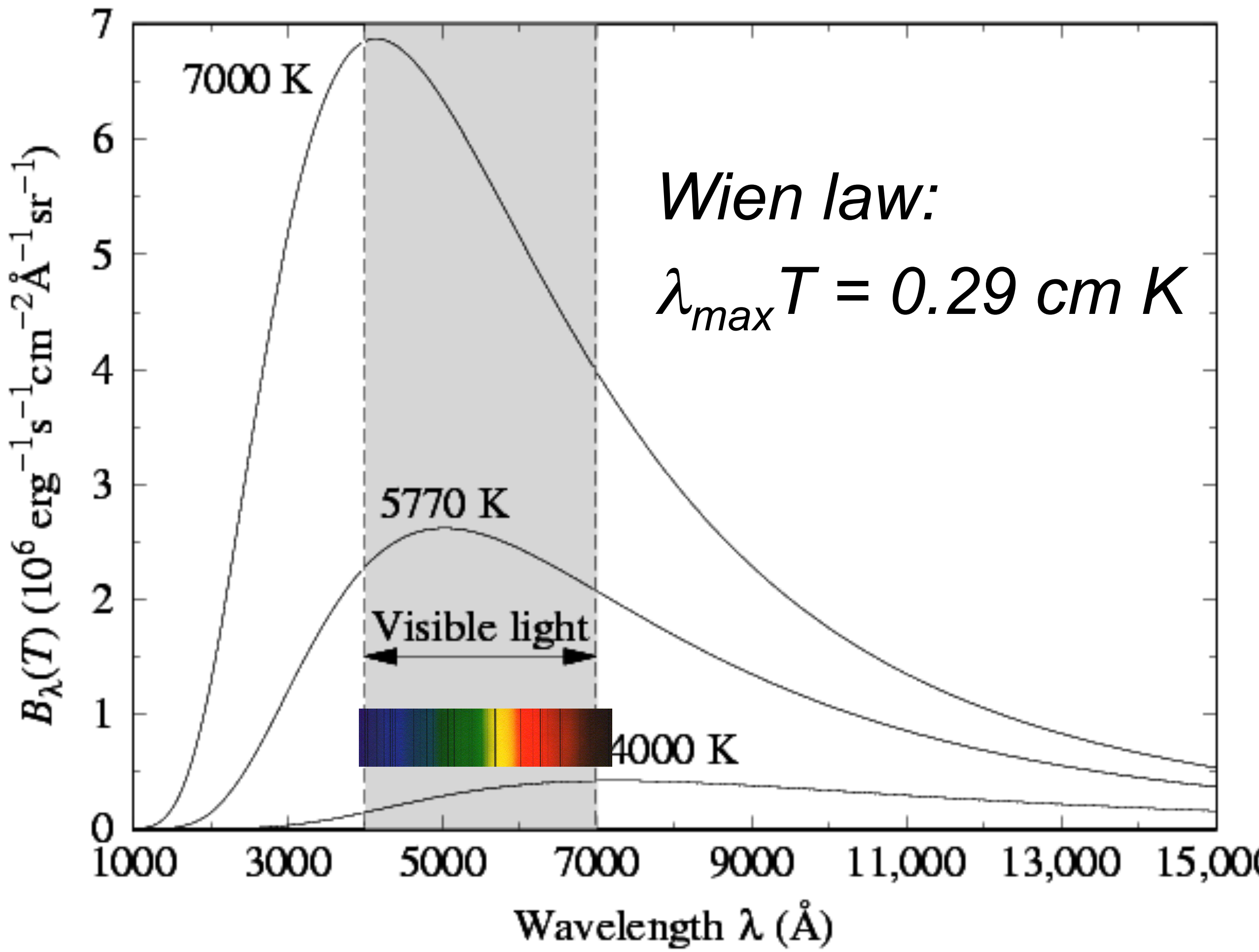
$$= 10{,}5 + 5 \times (\mathbf{-1.14})$$

$$= 4{,}8$$

For comparison, the Sun has $M_V = 4.83$

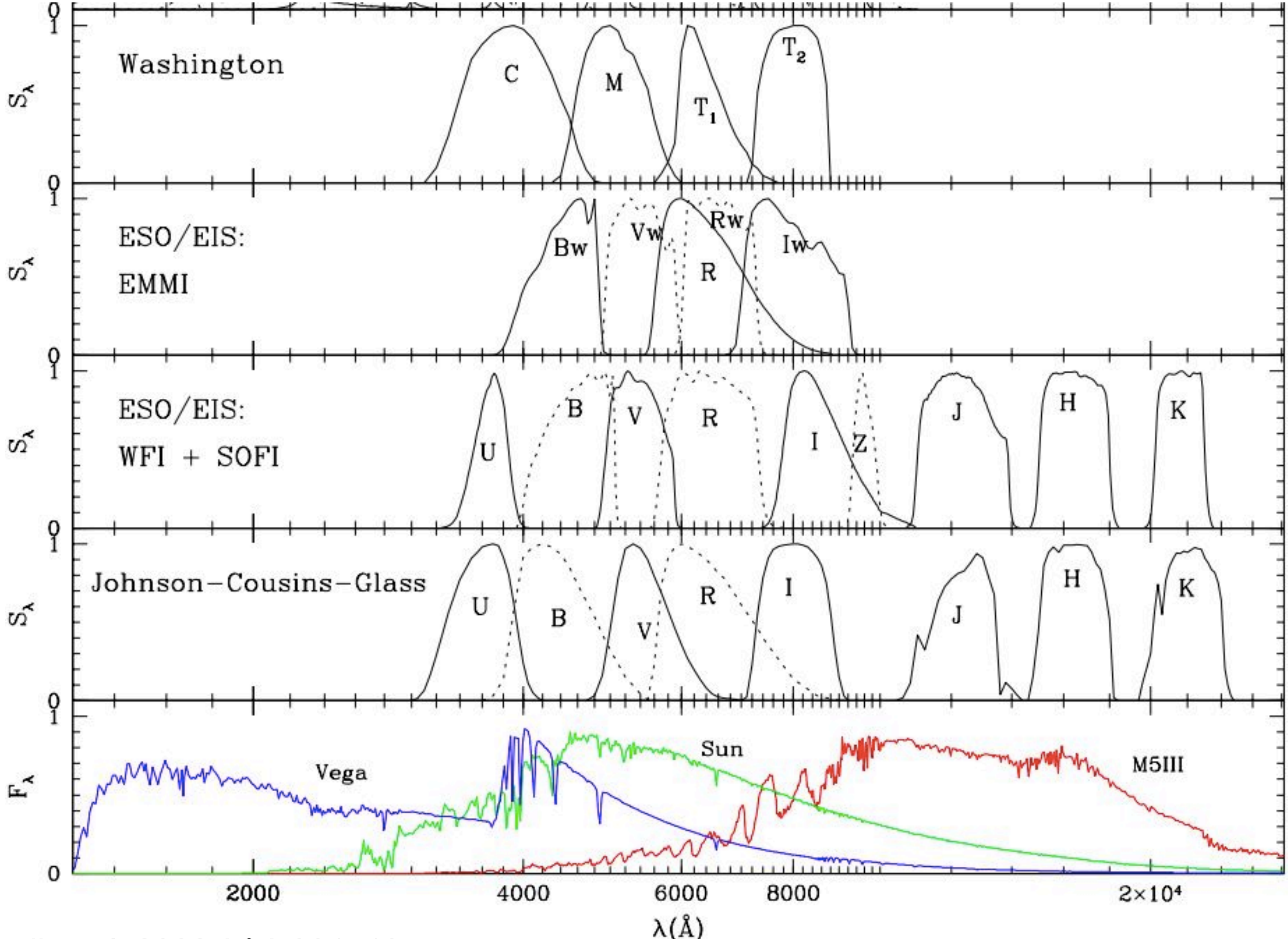
Stars shine in different colors

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{(hc/\lambda kT)} - 1}$$



Our eye sees only part of the SED

Photometric Systems and their applications



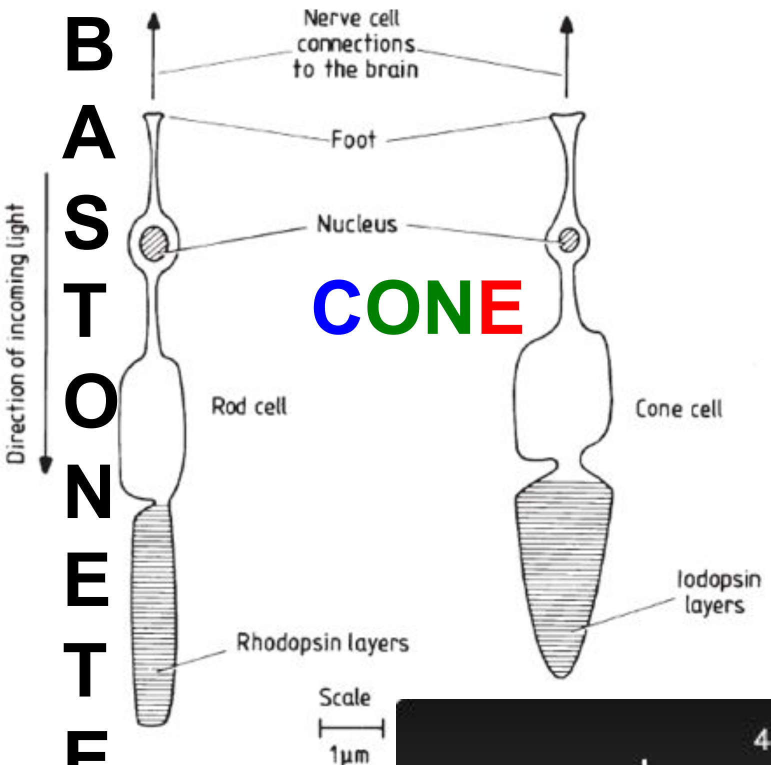
Girardi et al. 2002 A&A 391, 195

Our eye defined the first photometric system

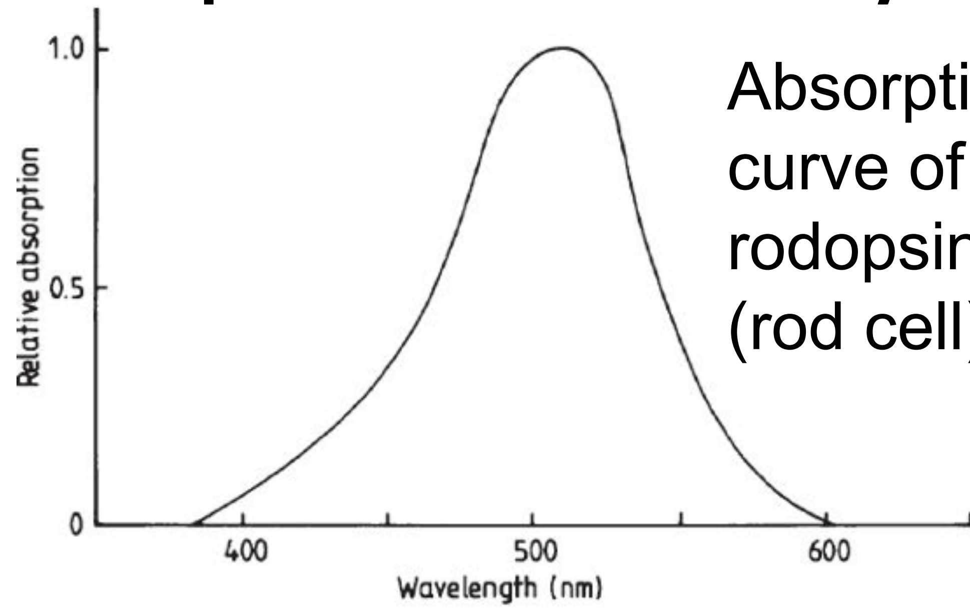
Na retina há 2 tipos de células responsáveis pelo sentido da visão

BASTONETE

CONE



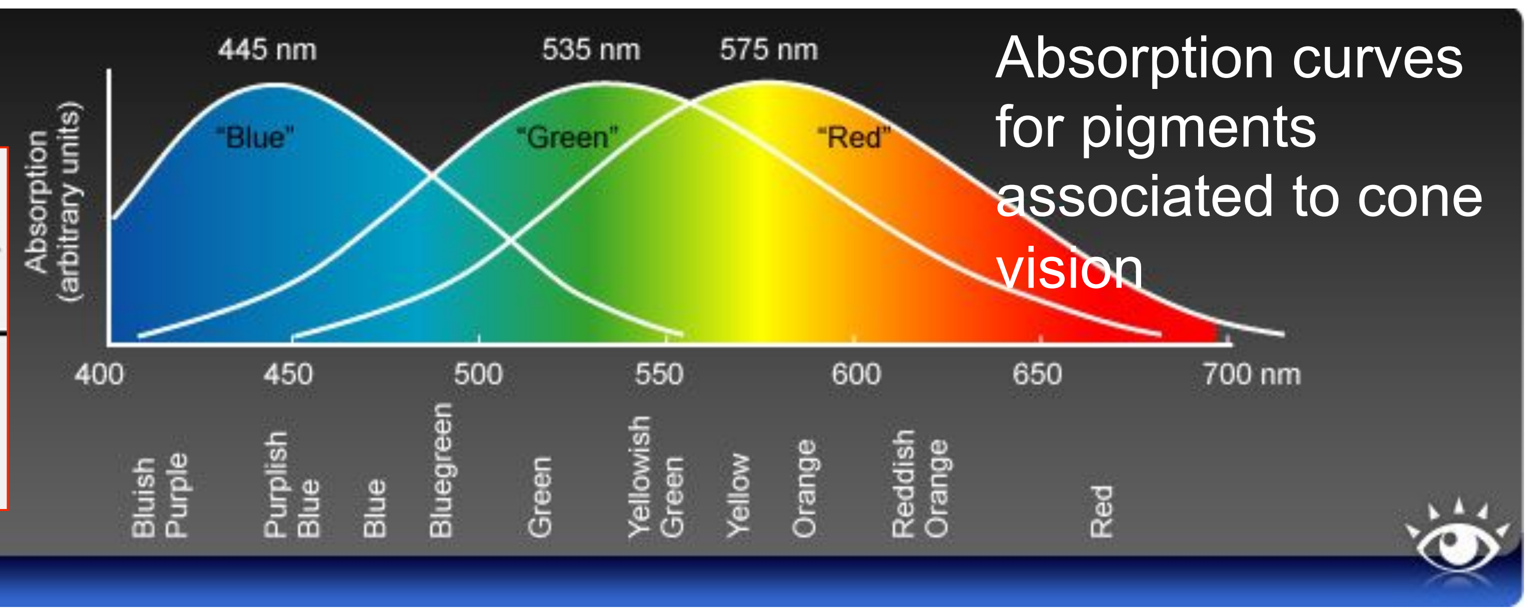
Retinal receptor cells.



Rhodopsin absorption curve.

Absorption curve of rodopsina (rod cell)

$$F = \frac{\int_0^\infty f(\lambda)\, s(\lambda)\, d\lambda}{\int_0^\infty s(\lambda)\, d\lambda}$$



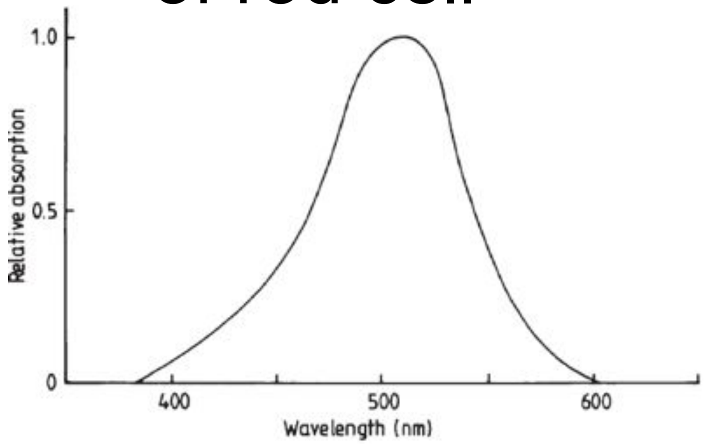
Absorption curves for pigments associated to cone vision

Instrumental system

Observed flux *F*:

$$F = \frac{\int_0^\infty f(\lambda)s(\lambda)d\lambda}{\int_0^\infty s(\lambda)d\lambda}$$

Sensibility *s(λ)* of rod cell



Rhodopsin absorption curve.

- $f(\lambda)$: flux of the object outside Earth's atmosphere
- $s(\lambda)$: transmission curve (sensibility curve [filter transmission]; detector; Earth's atmosphere; …)

Hundreds of photometric systems …

Annu. Rev. Astron. Astrophys. 2005. 43:293–336
doi: 10.1146/annurev.astro.41.082801.100251

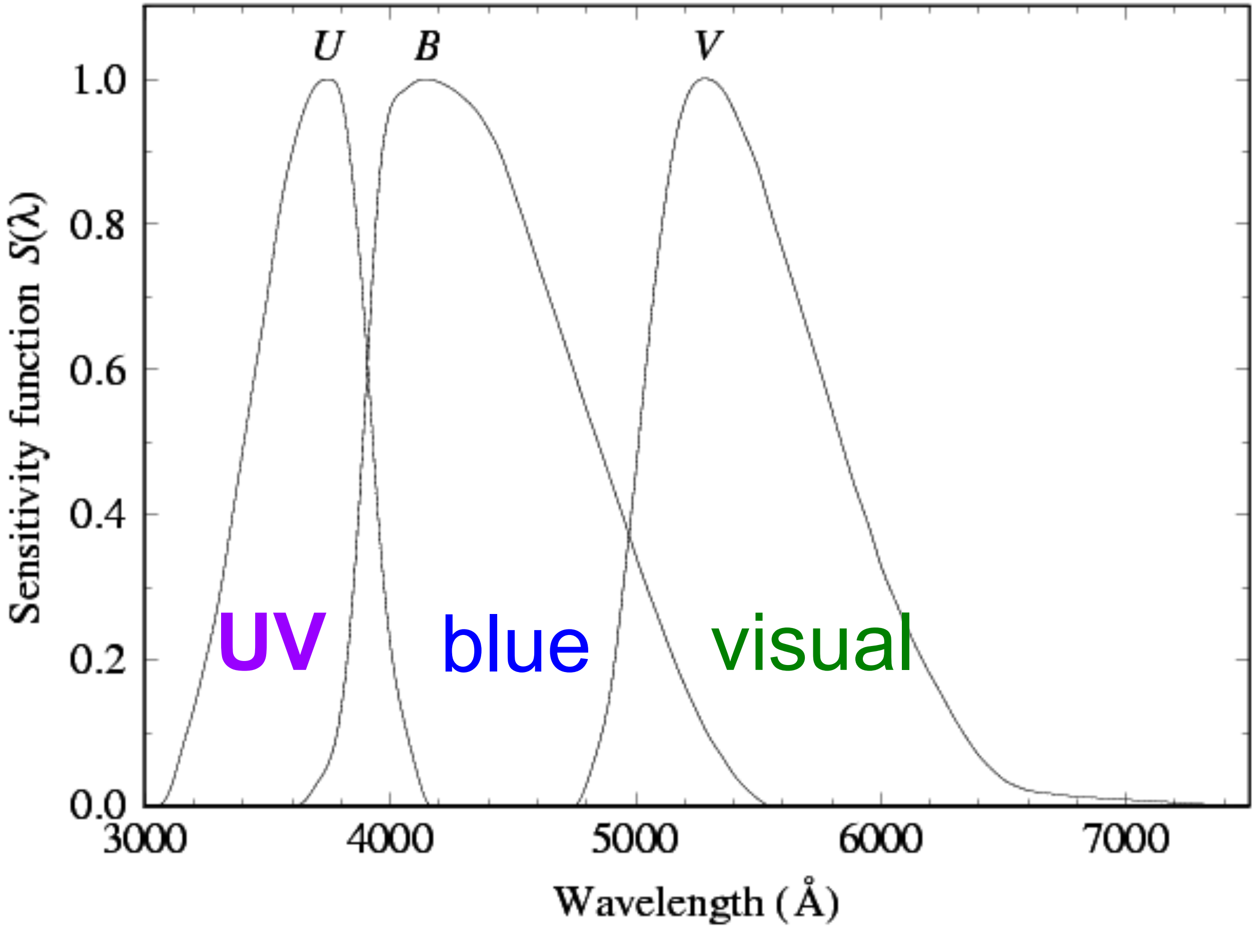
Standard Photometric Systems

Michael S. Bessell
Research School of Astronomy and Astrophysics, The Australian National University, Weston, ACT 2611, Australia; email: bessell@mso.anu.edu.au

Mike Bessell. *Autoridade mundial em sistemas fotométricos*

- Born in 1942 in Tasmania
- Found CD-380245
- Recognised for his work on photometry
- His filter systems have become standard at most observatories throughout the world
- http://nla.gov.au/nla.oh-vn3566297

Broad band photometric systems: **UBV**



Apparent magnitude

U B V

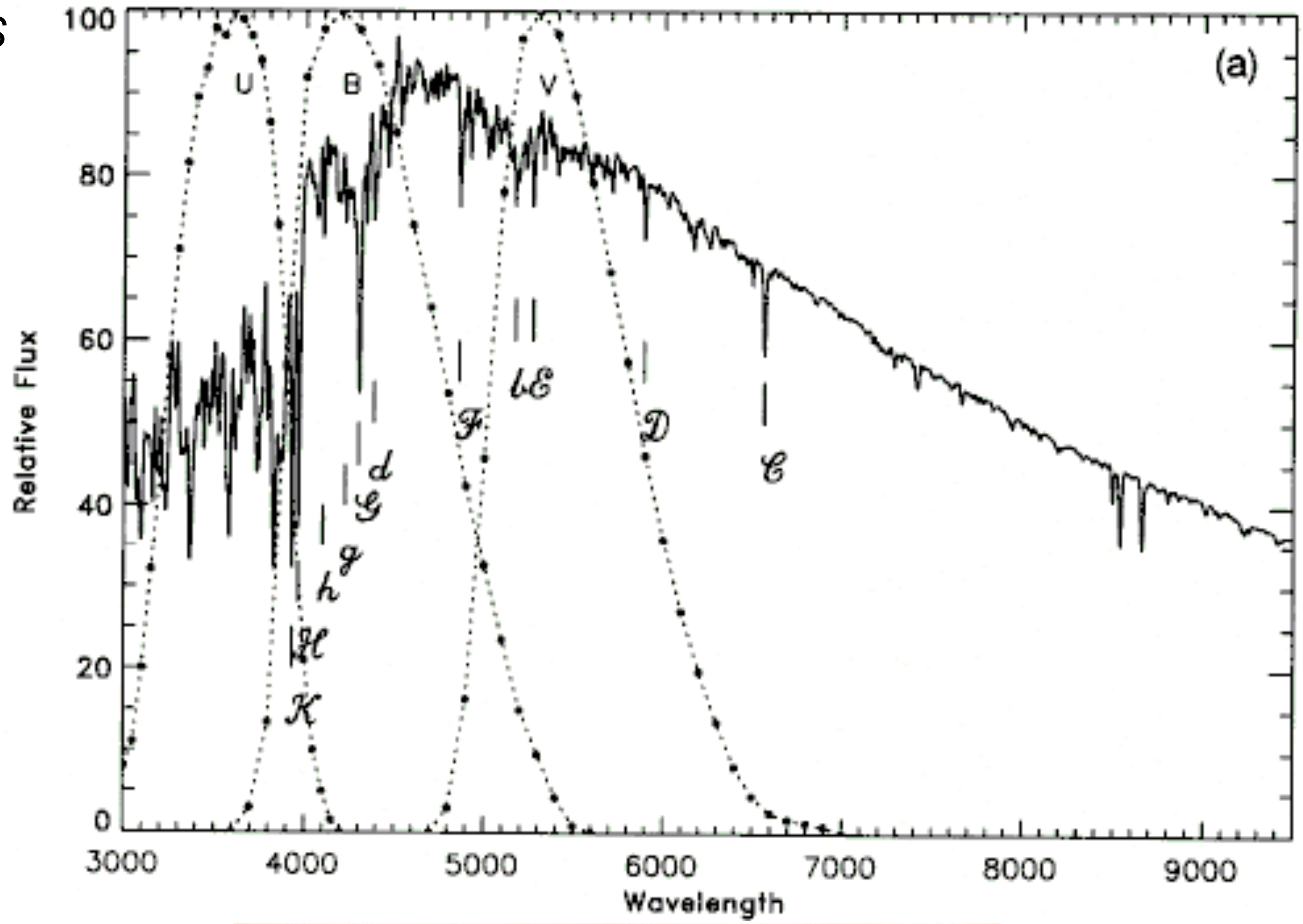
UBV - Johnson & Morgan 1953

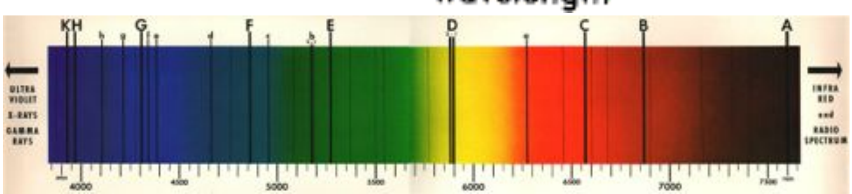
band	U	B	V
λ_0 (Å)	3580	4390	5450
½$\Delta\lambda$ (Å)	550	990	850

Solar spectrum & UBV system

774 *R. A. Bell, G. Paltoglou and M. J. Tripicco*

(1994, MNRAS 268, 771)





Color index (or "color")

Diference between magnitudes in two bands. In the UBV system, the magnitudes m_v , m_B , m_V are written U, B, V

The color indexes are:

B-V index: B – V

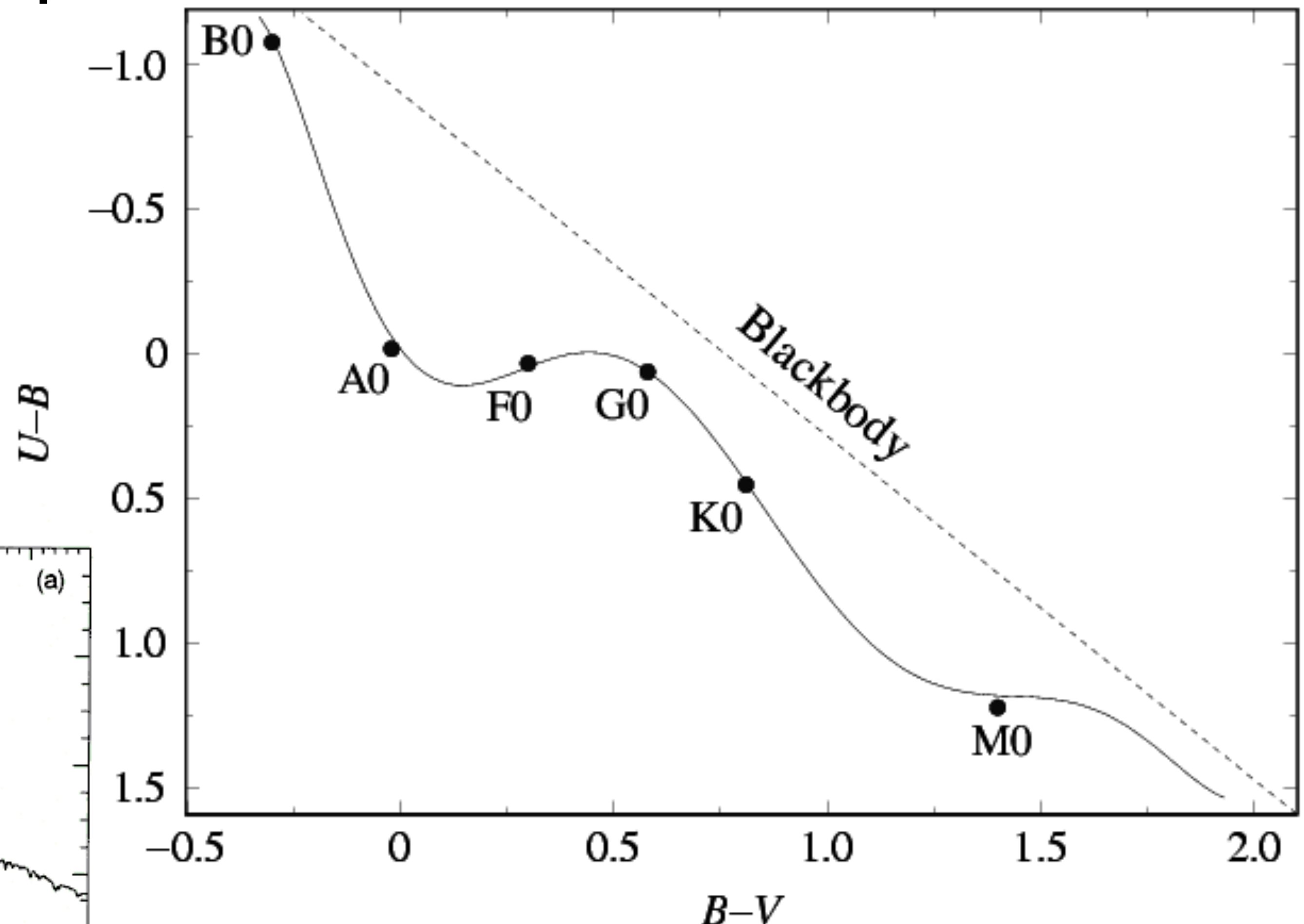
U-B index: U - B

Color index

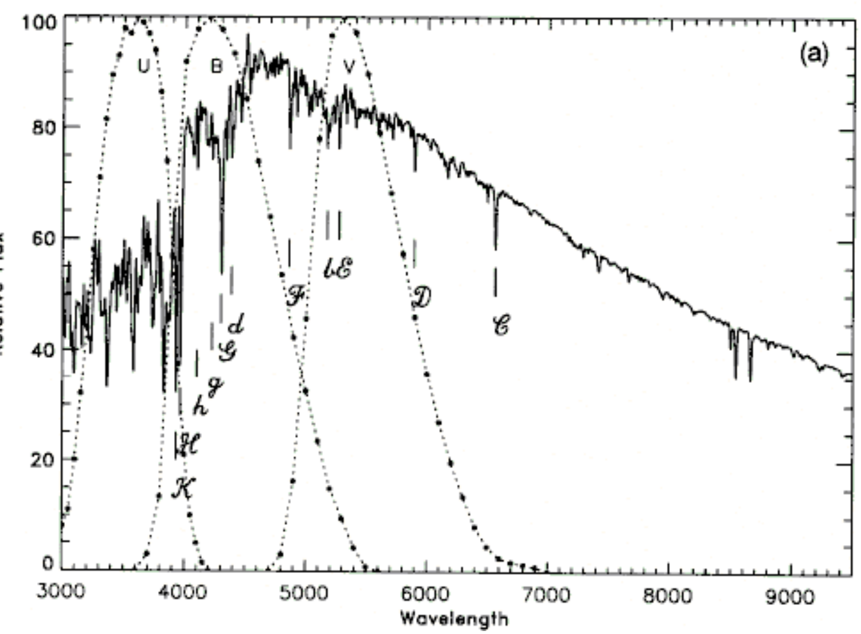
B-V: Temperature

U-B: chemical composition

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{(hc/\lambda kT)}-1}$$



G. Paltoglou and M. J. Tripicco



Nancy Roman, 1954, AJ, 59, 307

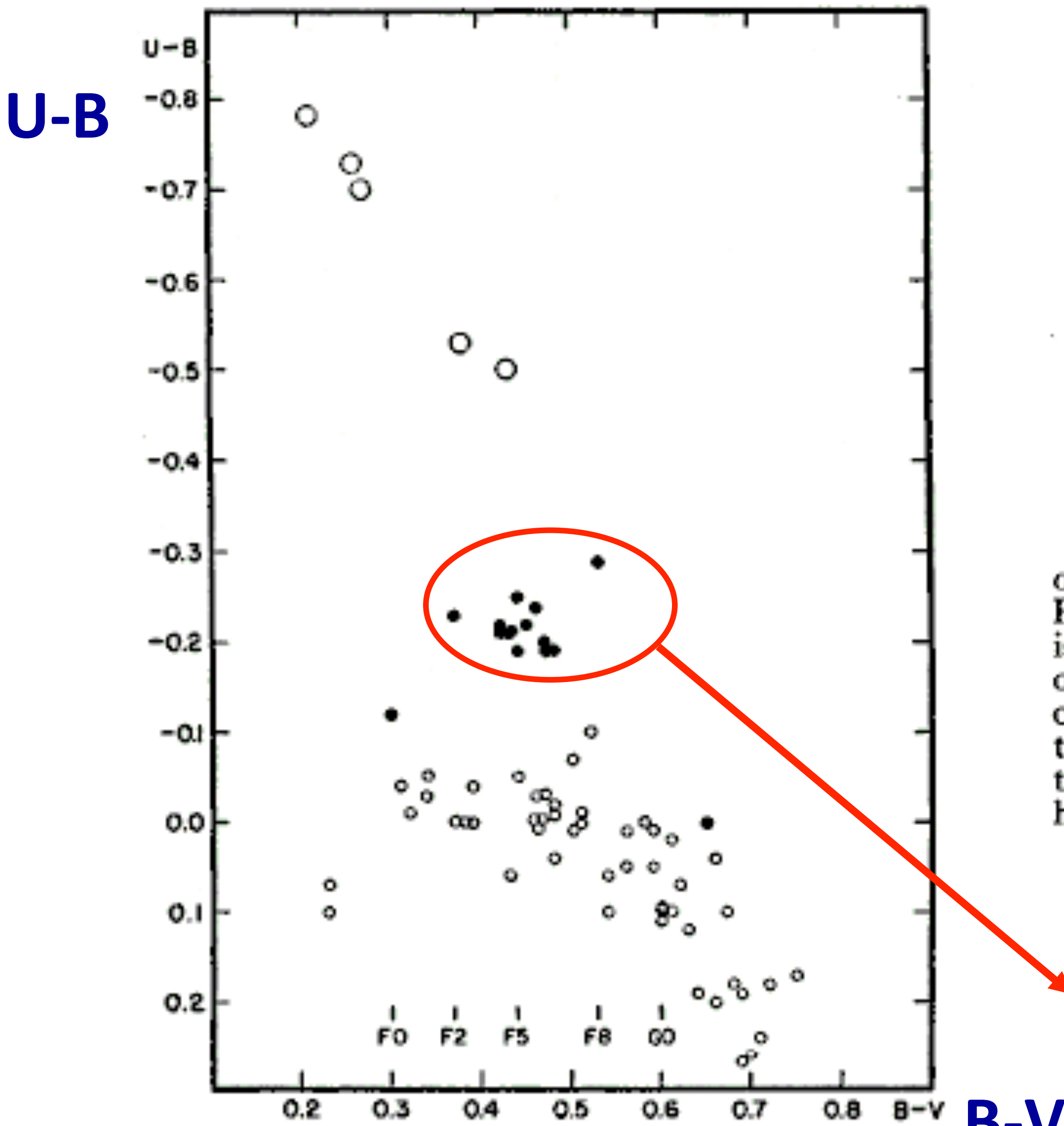


Figure 1. Two-color plot. Filled circles indicate the stars listed in Table I; small open circles are main sequence stars with *B-V* colors between +0.20 and +0.75; large open circles represent reddened O and B stars in the same range of color.

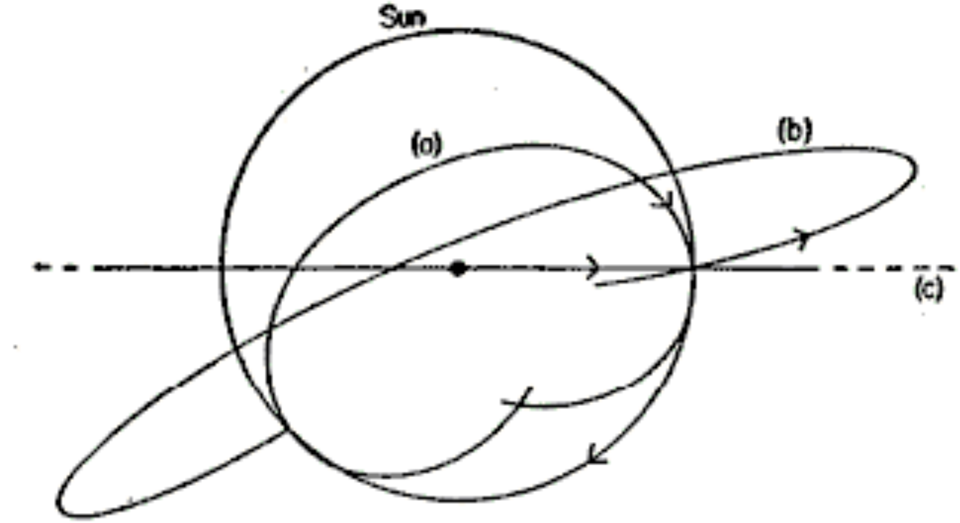


Figure 3. The orbit of the sun and portions of the orbits of (a) HD 16031, (b) BD +17°4708, and (c) BD +2°3375. For the latter three, a mean absolute magnitude of +5.0 is assumed. The scale of the diagram is given by the radii of the sun's orbit, 8.3 kpc, and of the dot at the galactic center, 200 pc. Arrows indicate the direction in which the stars move in the orbits. Notice that the stars which travel through more than one type of force field do not have closed orbits.

UV excess vs. metal deficiency

abundances of the following elements: Na, Mg, Si, Ca, Sc, Ti, Cr, Fe, and Ni. Manganese and barium have been omitted from the mean because manganese often shows an appreciable deficiency as compared with the other elements and barium is represented by only two lines and may show significant deviations from the mean. Some stars that have been analyzed by others are included in Table 1.

In Figure 1 we plot [M/H] against the ultraviolet excess. It can be seen that the correlation is good enough that the metal abundance of a main-sequence star whose color lies between $B - V = 0.45$ and 0.65 can be inferred from three-color photometry about as

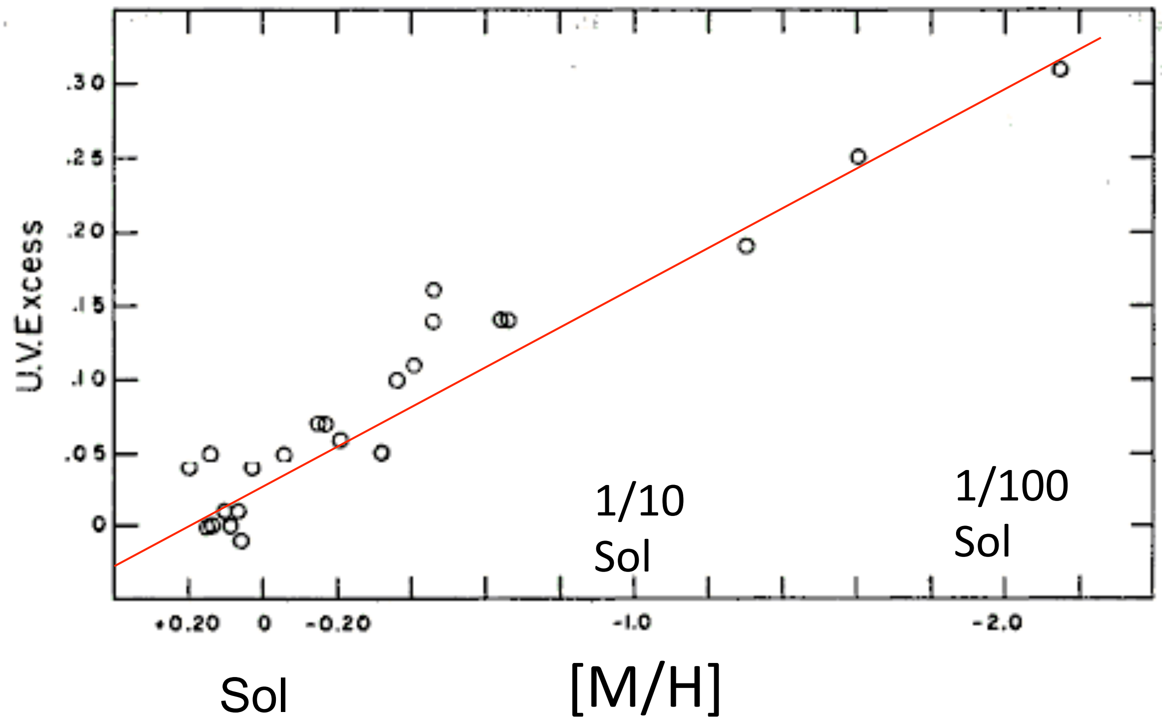


FIG. 1.—The metal deficiency plotted against ultraviolet excess for late F and early G dwarfs

well as by spectrophotometric analysis. For example, Arp (1959) has reported the ultraviolet excess of main-sequence stars ($B - V = +0.6$) in three globular clusters. For the clusters M5, M13, and M2 he quotes ultraviolet excesses of 0.21, 0.22, and 0.33 mag., respectively. Reference to Figure 1 shows that M5 and M13 are deficient in metals by a factor of about 20, while M2 must be deficient by about 200.

This material will be fully presented and more completely discussed at a later time.

GEORGE WALLERSTEIN
MAURICE CARLSON

BERKELEY ASTRONOMICAL DEPARTMENT
UNIVERSITY OF CALIFORNIA, BERKELEY

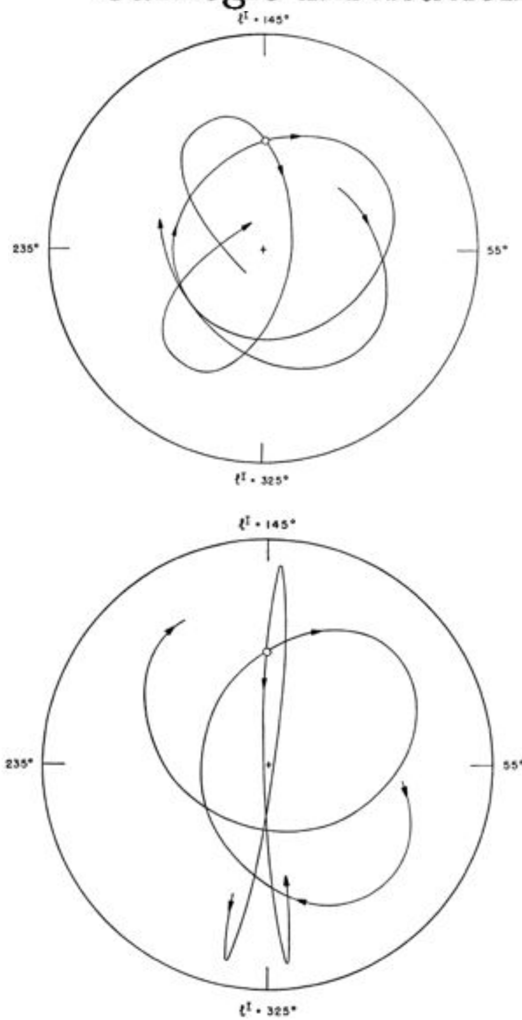
Wallerstein & Carlson 1960
ApJ 132, 276

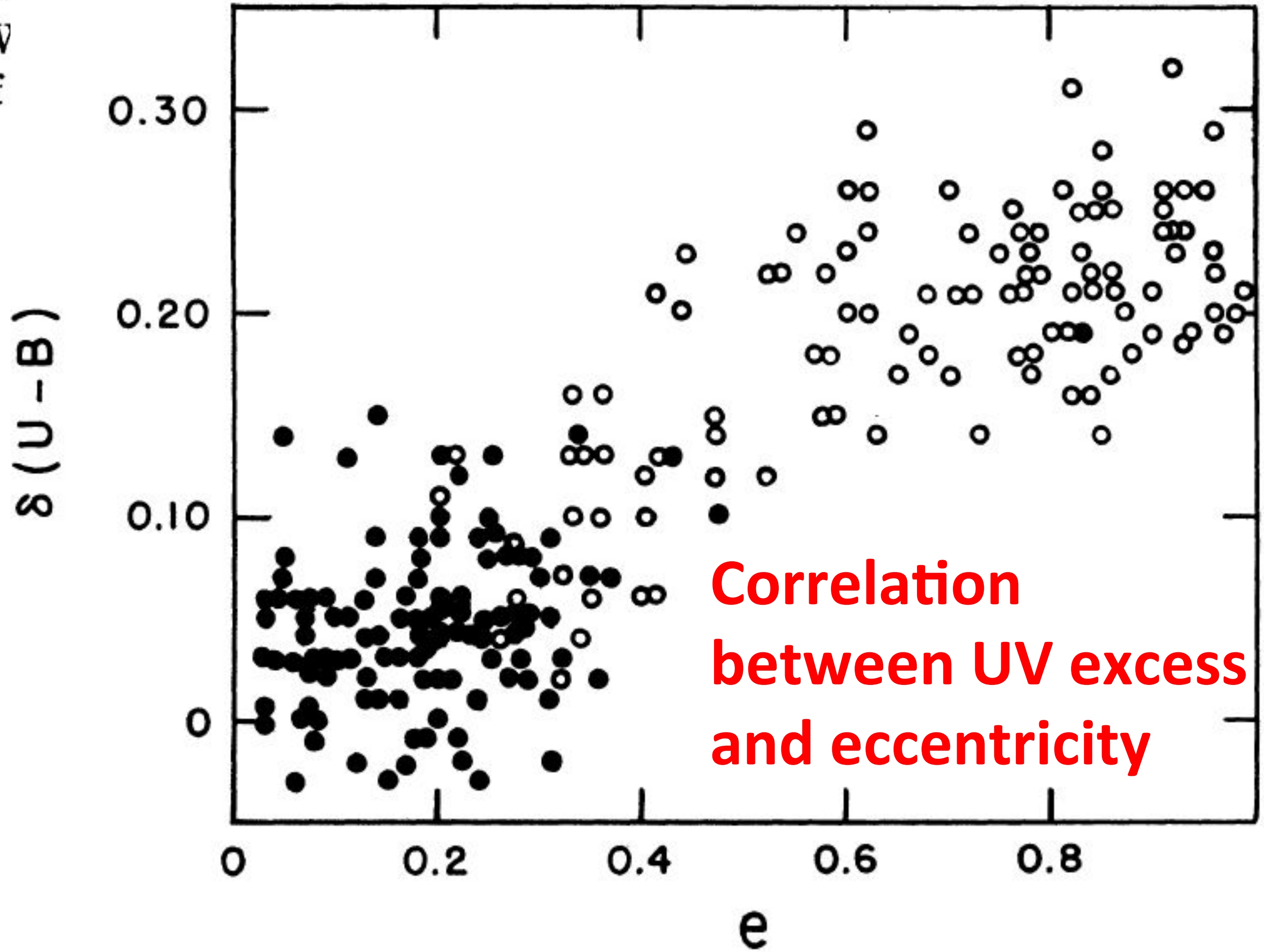
Formation of our galaxy

EVIDENCE FROM THE MOTIONS OF OLD STARS
THAT THE GALAXY COLLAPSED

ELS, 1962, ApJ, 136, 748

O. J. EGGEN, D. LYNDEN-BELL,* AND A. R. SANDAGE
Mount W
Carnegie Institution of





Correlation between UV excess and eccentricity

Color-magnitude diagram

UBV

Johnson & Morgan 1953, ApJ 117, 313

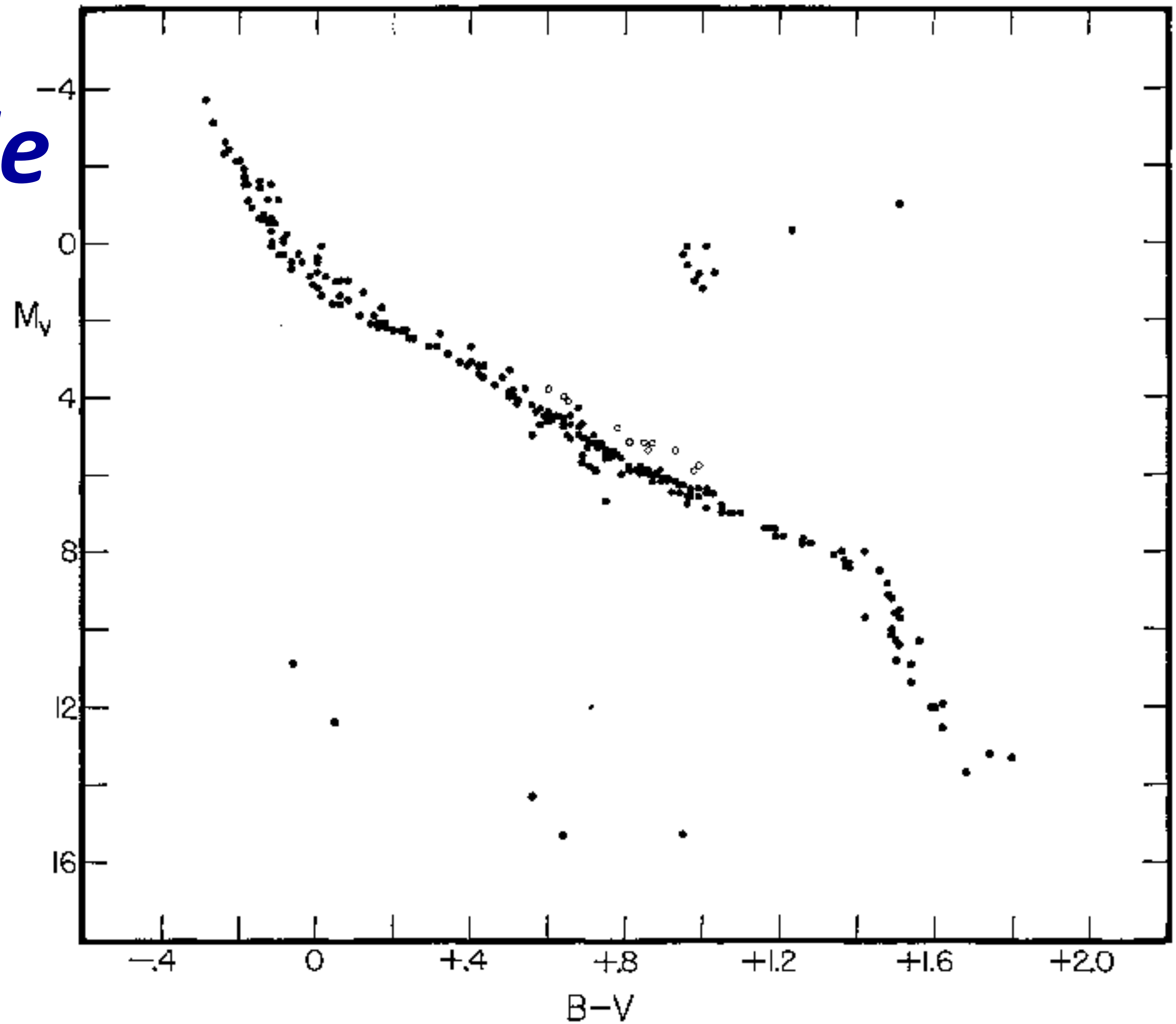
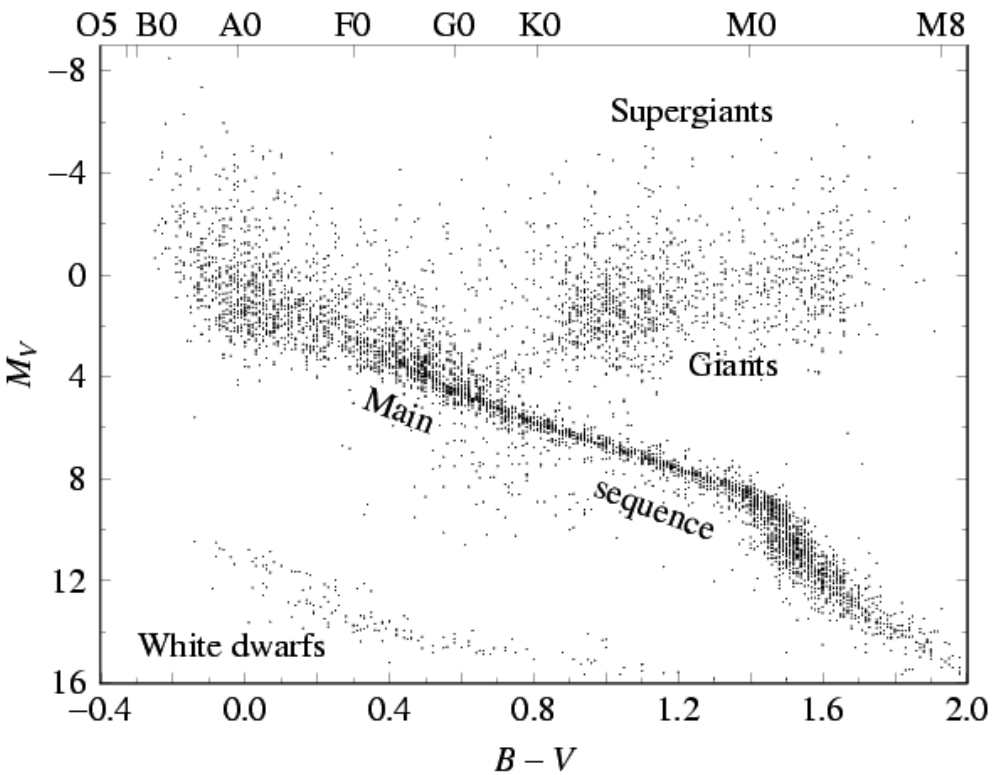


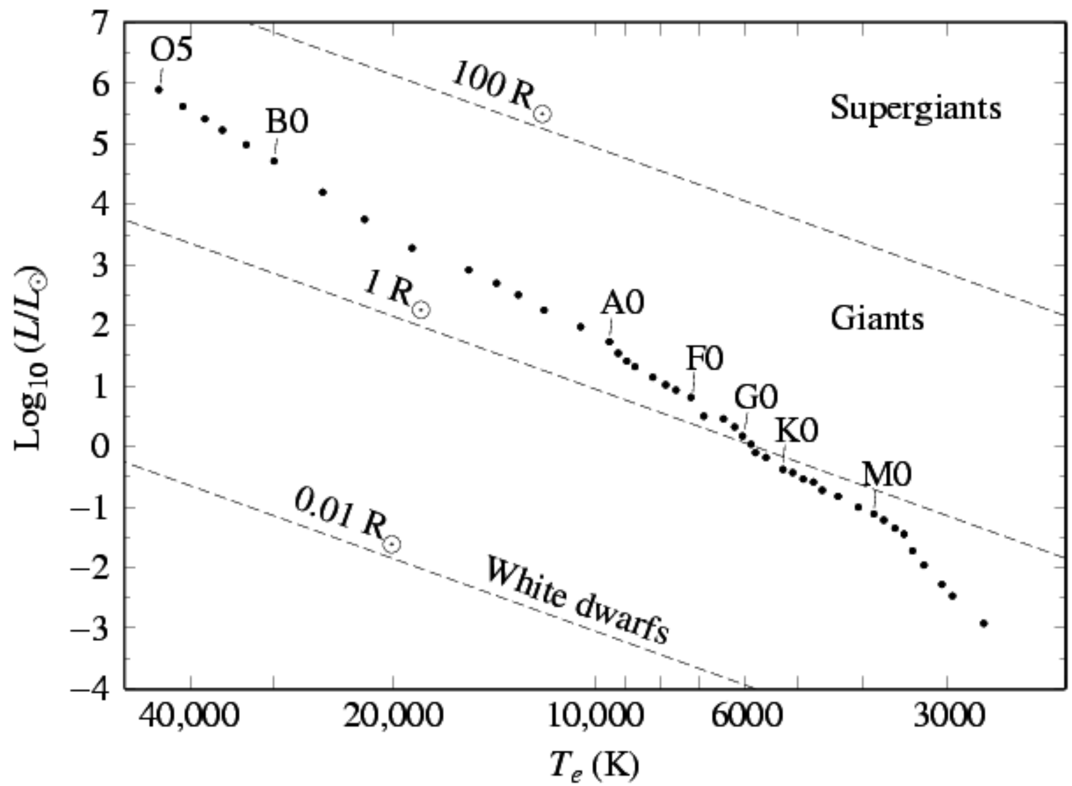
FIG. 5.—A standard main sequence for the color system $B - V$ and the absolute-magnitude system M_V. The stars plotted include main-sequence objects: (*a*), which have trigonometric parallaxes $\geqslant 0\overset{''}{.}100$; (*b*) the Pleiades, corrected for a mean interstellar reddening (one highly reddened A star omitted); (*c*) Praesepe; (*d*) NGC 2362 corrected for a mean interstellar reddening. In addition, five white

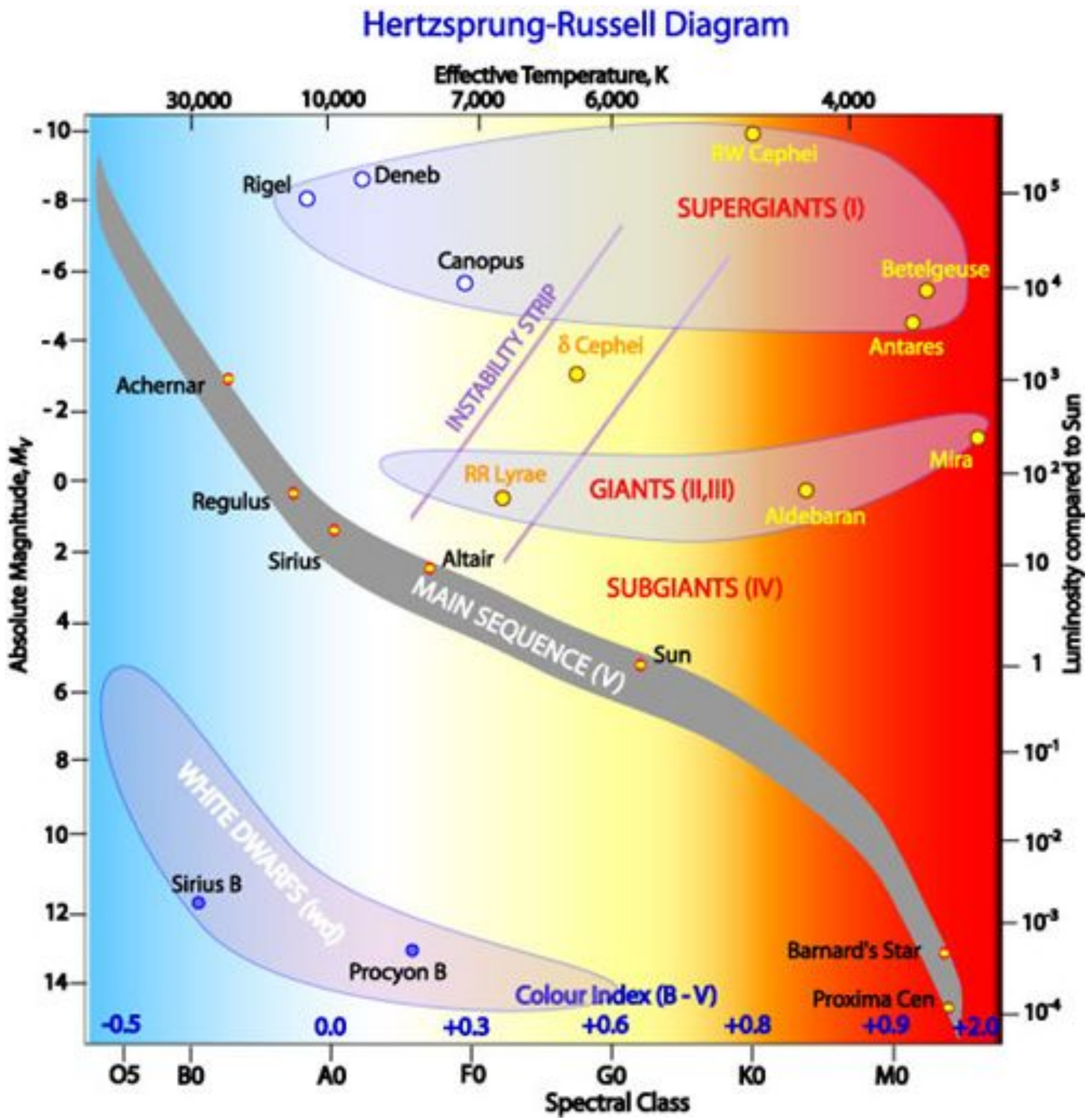
CMD observational & theoretical

Observational



Theoretical





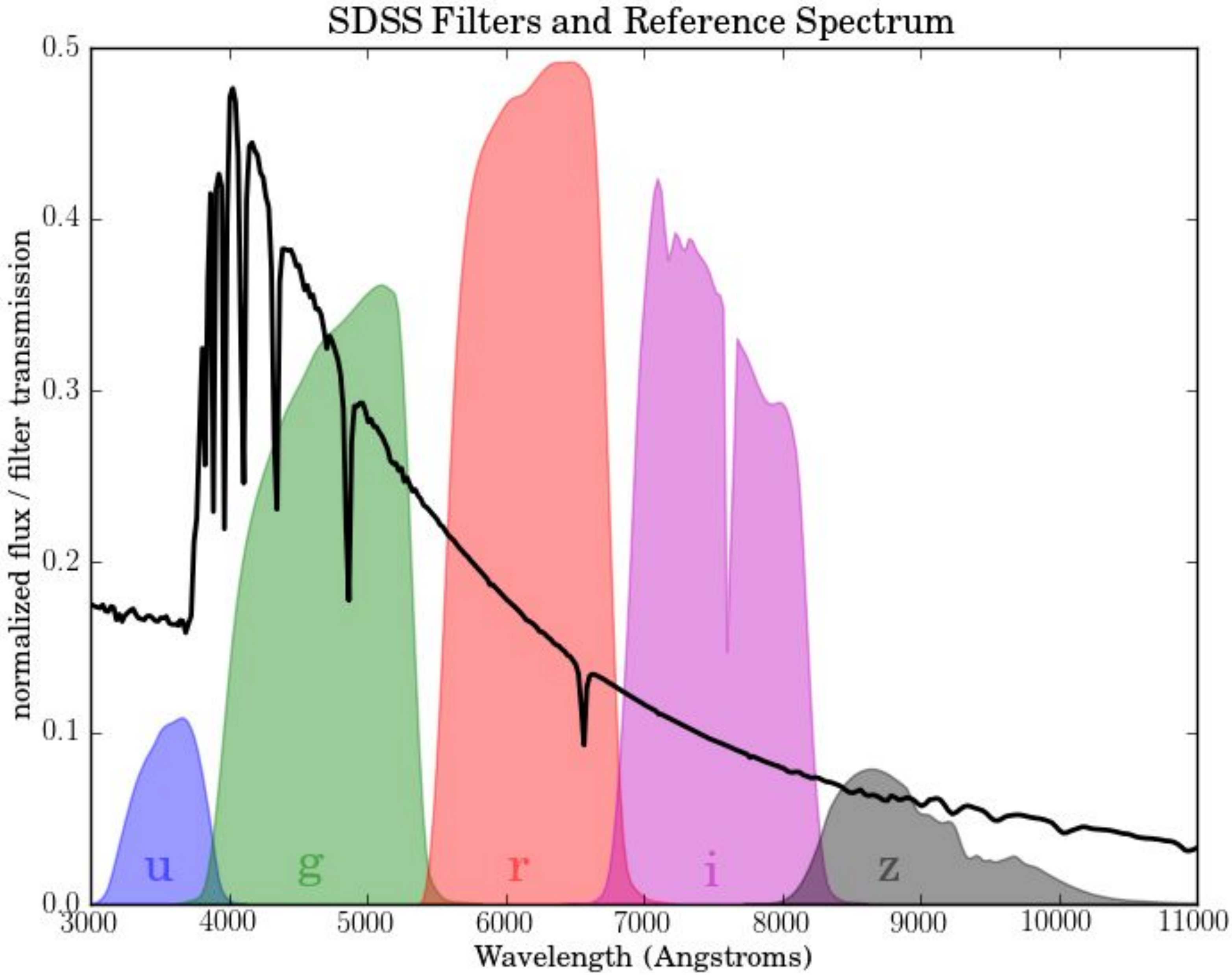
http://outreach.atnf.csiro.au/education/senior/astrophysics/stellarevolution_hrintro.html

Zero point of UBVRI system : Vega

Vega's magnitude in U-band: U = 0.0
Vega's magnitude in B-band: B = 0.0
Vega's magnitude in V-band: R = 0.0
Vega's magnitude in R-band: V = 0.0
Vega's magnitude in I-band: I = 0.0

Actually other A0 stars are used but Vega is always very close to 0.00

Photometric systems are defined in such a way that m = 0 for Vega (or close to 0)



Absolute fluxes (meaning fluxes in physical units; so there are not related to absolute magnitudes!). Below the fluxes for m = 0 in several, systems

Table A2. Effective wavelengths (for an A0 star), absolute fluxes (corresponding to zero magnitude) and zeropoint magnitudes for the UBVRI JHKL Cousins-Glass-Johnson system

	U	B	V	R	I	J	H	K	Kp	L	L*
λ_{eff}	0.366	0.438	0.545	0.641	0.798	1.22	1.63	2.19	2.12	3.45	3.80
f_ν	1.790	4.063	3.636	3.064	2.416	1.589	1.021	0.640	0.676	0.285	0.238
f_λ	417.5	632	363.1	217.7	112.6	31.47	11.38	3.961	4.479	0.708	0.489
$zp(f_\lambda)$	0.770	-0.120	0.000	0.186	0.444	0.899	1.379	1.886	1.826	2.765	2.961
$zp(f_\nu)$	-0.152	-0.602	0.000	0.555	1.271	2.655	3.760	4.906	4.780	6.775	7.177

f_ν (10^{-20} ergs cm^{-2} sec^{-1} hz^{-1})

f_λ (10^{-11} ergs cm^{-2} sec^{-1} Å^{-1})

$$mag_\lambda = -2.5 \log (f_\lambda) - 21.100 - zp(f_\lambda)$$

$$mag_\nu = -2.5 \log (f_\nu) - 48.598 - zp(f_\nu)$$

Astron. Astrophys. 333, 231–250 (1998)

Model atmospheres broad-band colors, bolometric corrections and temperature calibrations for O - M stars*

M.S. Bessell[1], F. Castelli[2], and B. Plez[3,4]

Absolute fluxes

$m_1 - m_2 = -2,5 \log(f_1/f_2)$

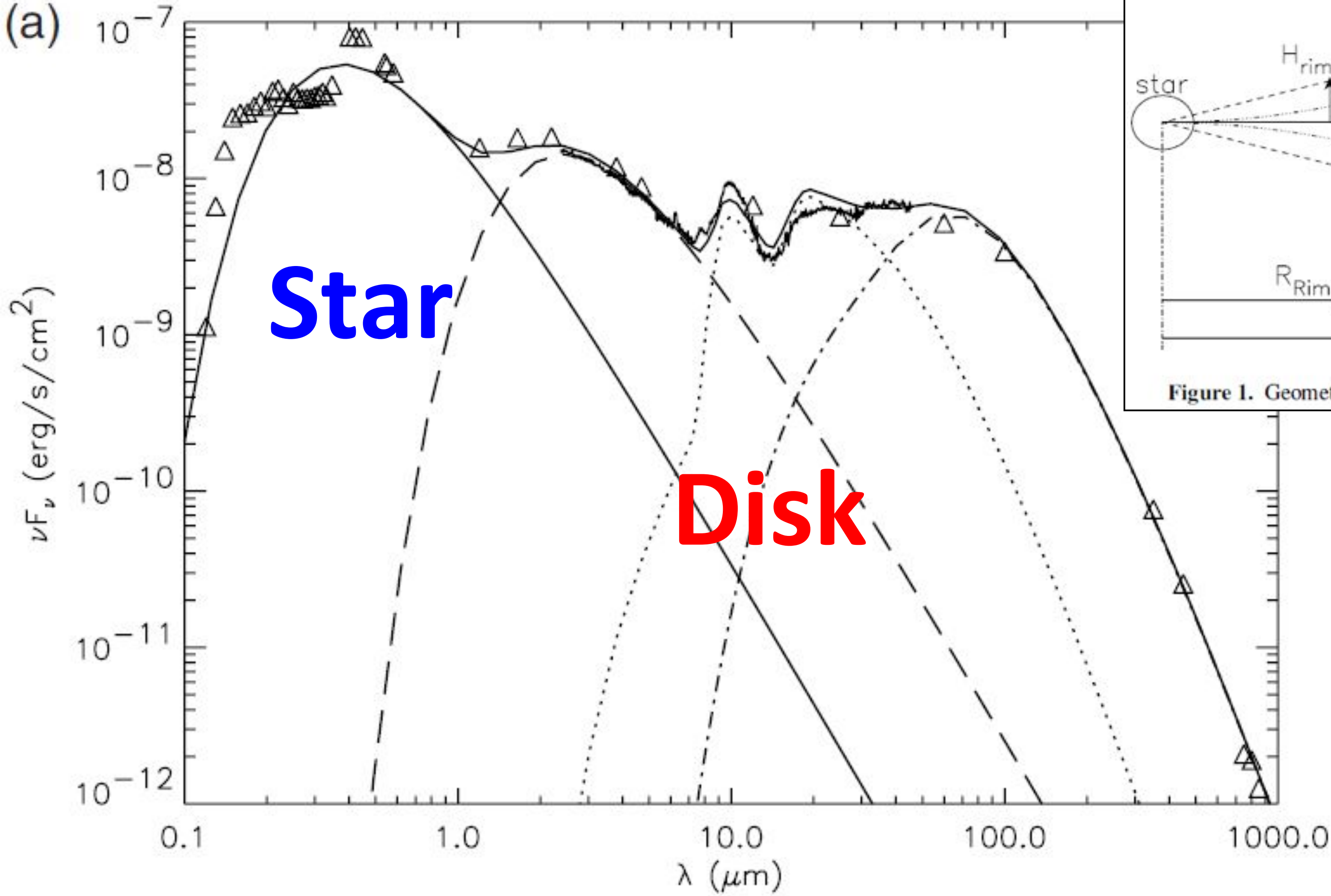
For $m_2 = 0$ use fluxes f_λ from last table:

$$f_1 = f_\lambda\, 10^{m_1/(-2,5)}$$

$$f = f_\lambda\, 10^{-0,4m}$$

Example, for Vega V = 0 → the flux received on Earth:

$f_V = 363,1 \times 10^{-11}$ erg cm^{-2} s^{-1} Å^{-1}



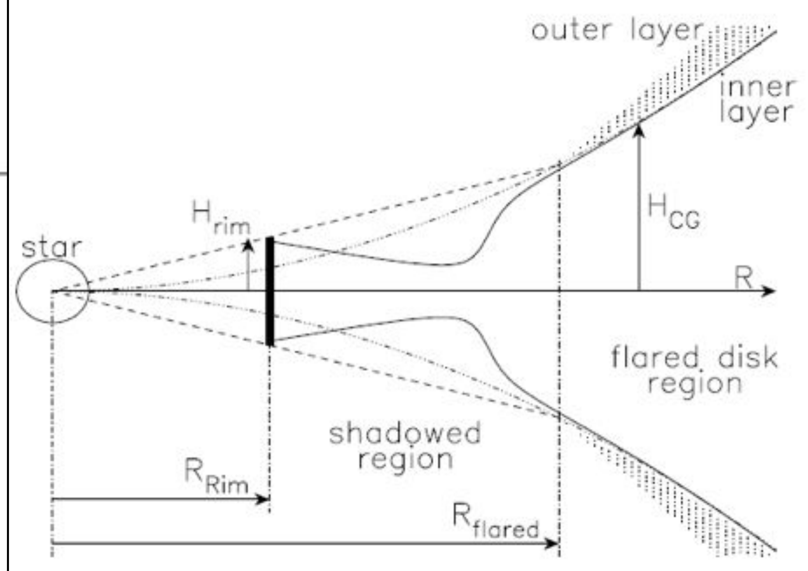


Figure 1. Geometric scheme for the model adapted from DNN01.

The use of genetic algorithms to model protoplanetary discs

Mon. Not. R. Astron. Soc. **382**, 1707–1718 (2007)

Annibal Hetem, Jr[1]★ and Jane Gregorio-Hetem★

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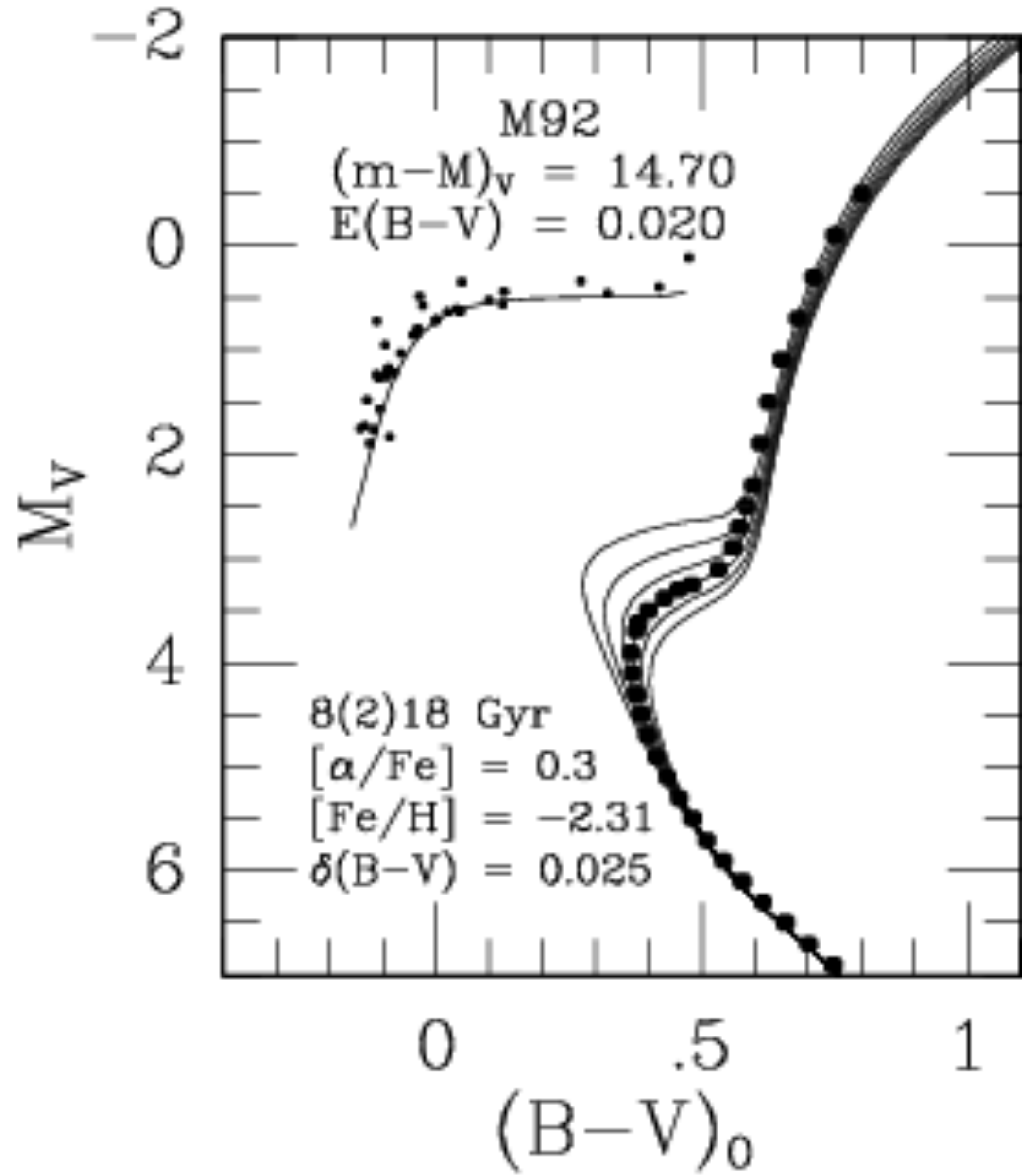
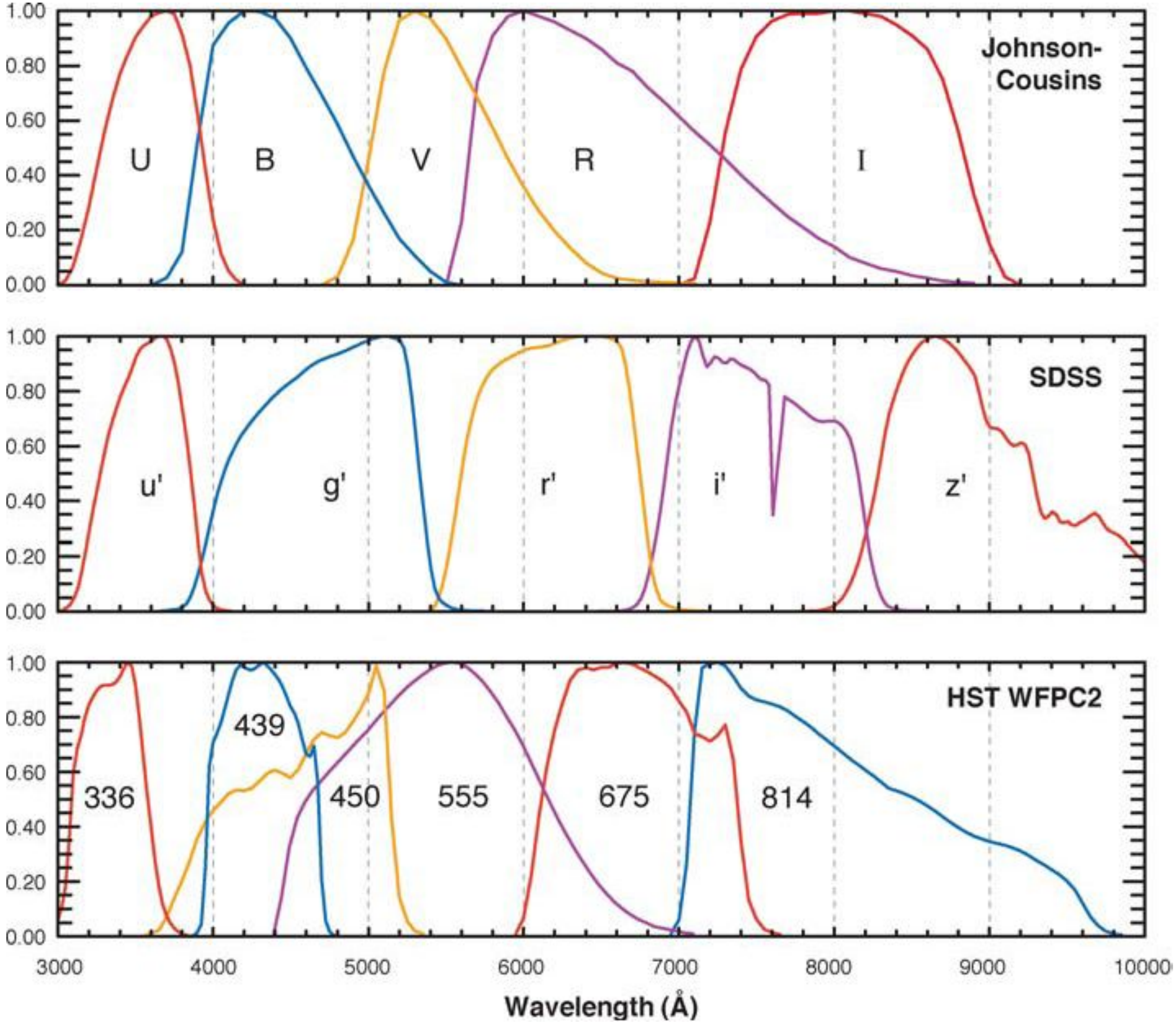
Globular cluster ages

M92



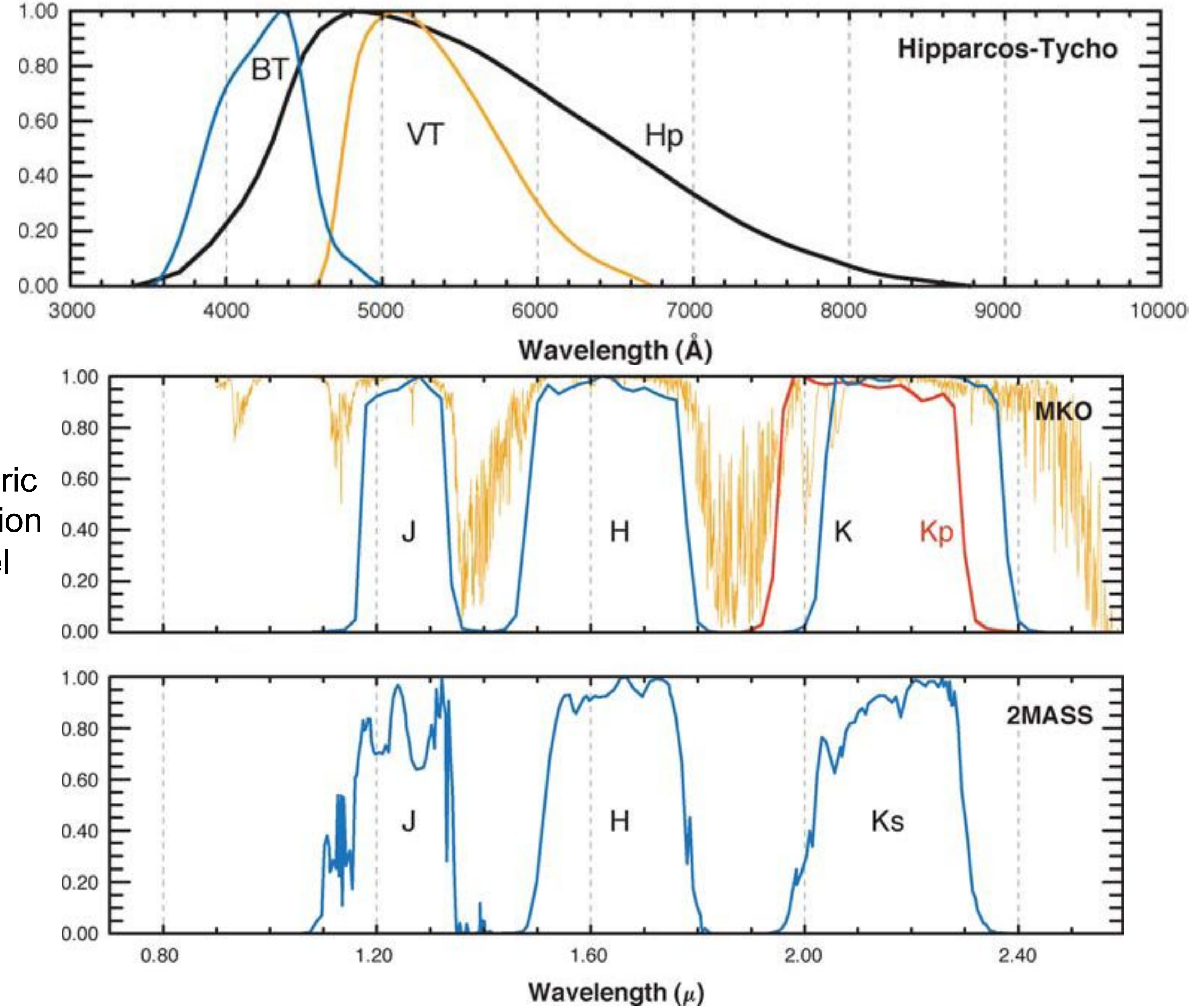
VandenBerg (2000)

Other photometric systems



Bessell 2005, ARA&A

Other photometric systems



The terrestrial atmospheric transmission of a model is shown

Bessell 2005, ARA&A

Model atmospheres broad-band colors, bolometric corrections and temperature calibrations for O - M stars*

M.S. Bessell[1], F. Castelli[2], and B. Plez[3,4]

Astron. Astrophys. 333, 231–250 (1998)

Temperature calibrations

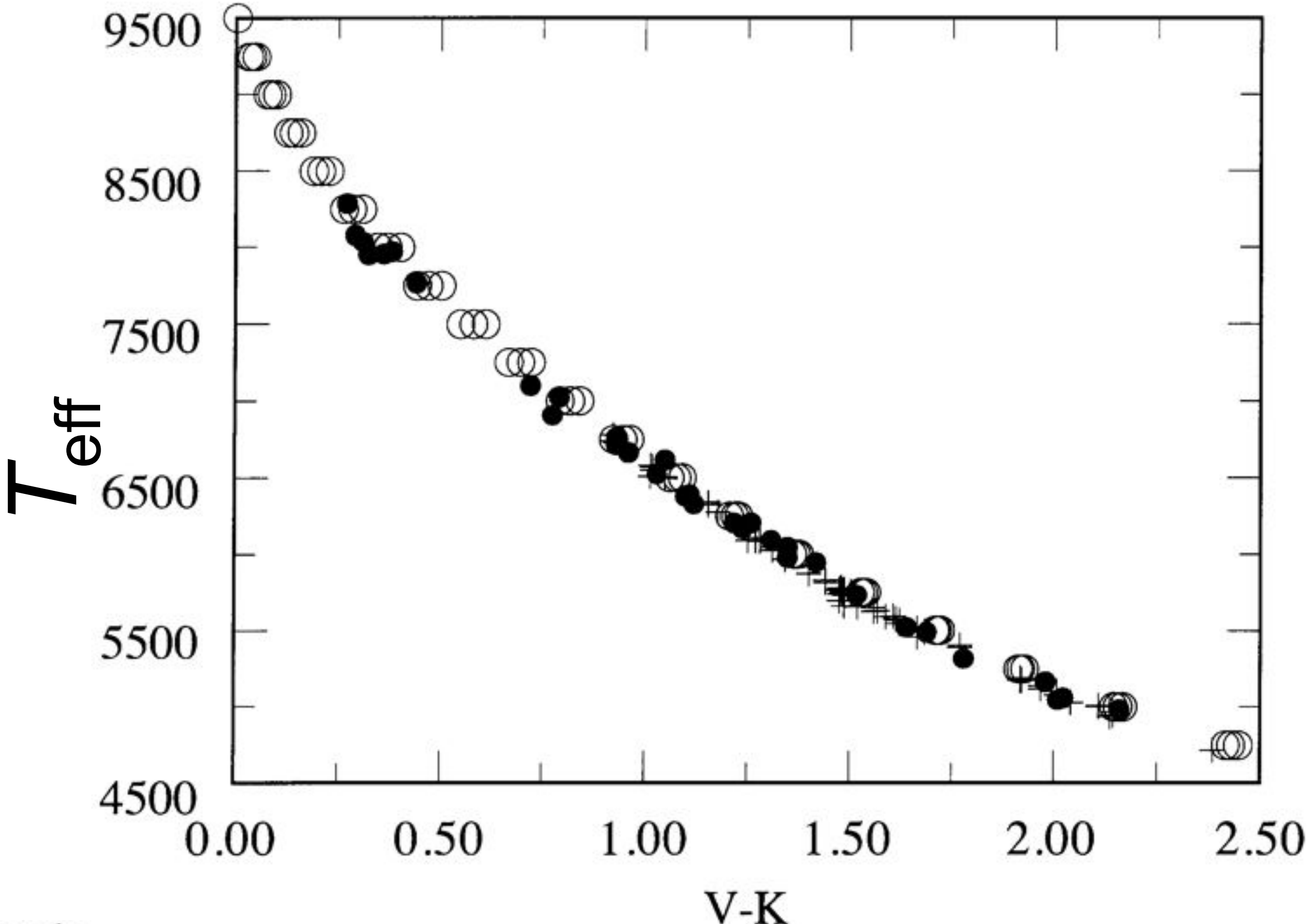


Table A3. Observed and model magnitudes and colors for the Sun and a mean solar analog

	V	U-B	B-V	V-R	V-I	V-K	J-K	H-K	Ref
Sun	-26.76								Stebbins & Kron 1957
Sun_ref	-26.75	0.128	0.649	0.370	0.726	1.511	0.372	0.039	Colina et al. 1996
Analog		0.185	0.652	0.355	0.692	1.50	0.38	0.045	Cayrel de Strobel 1996; Table 6
Model	-26.77	0.135	0.679	0.367	0.725	1.524	0.373	0.041	SUN-OVER
Model	-26.77	0.145	0.667	0.361	0.715	1.524	0.376	0.032	SUN-NOVER

A&A 512, A54 (2010)
DOI: 10.1051/0004-6361/200913204

F, G, K dwarf stars

Astronomy & Astrophysics

An absolutely calibrated T_{eff} scale from the infrared flux method

Dwarfs and subgiants★

L. Casagrande[1], I. Ramírez[1], J. Meléndez[2], M. Bessell[3], and M. Asplund[1]

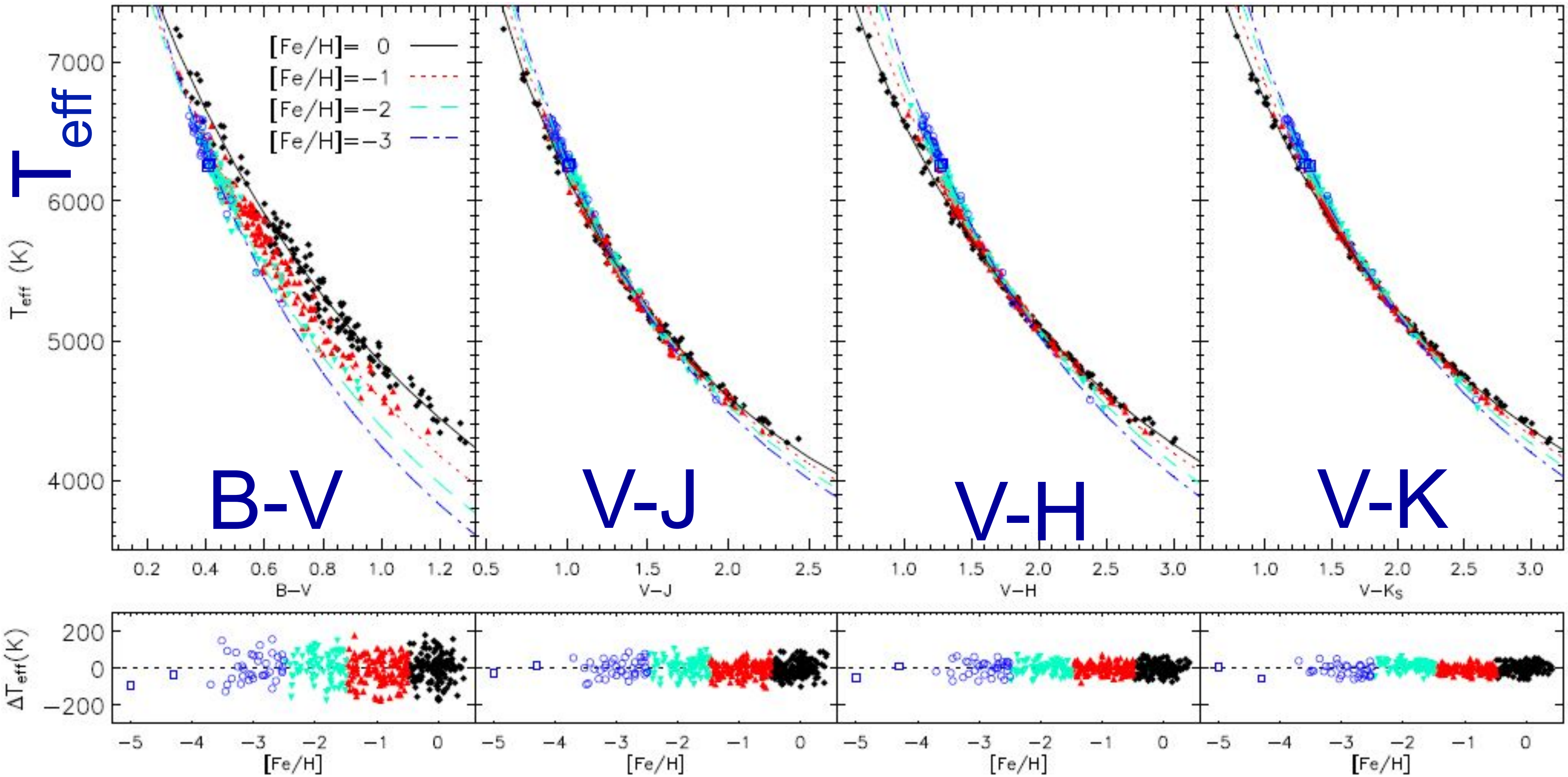


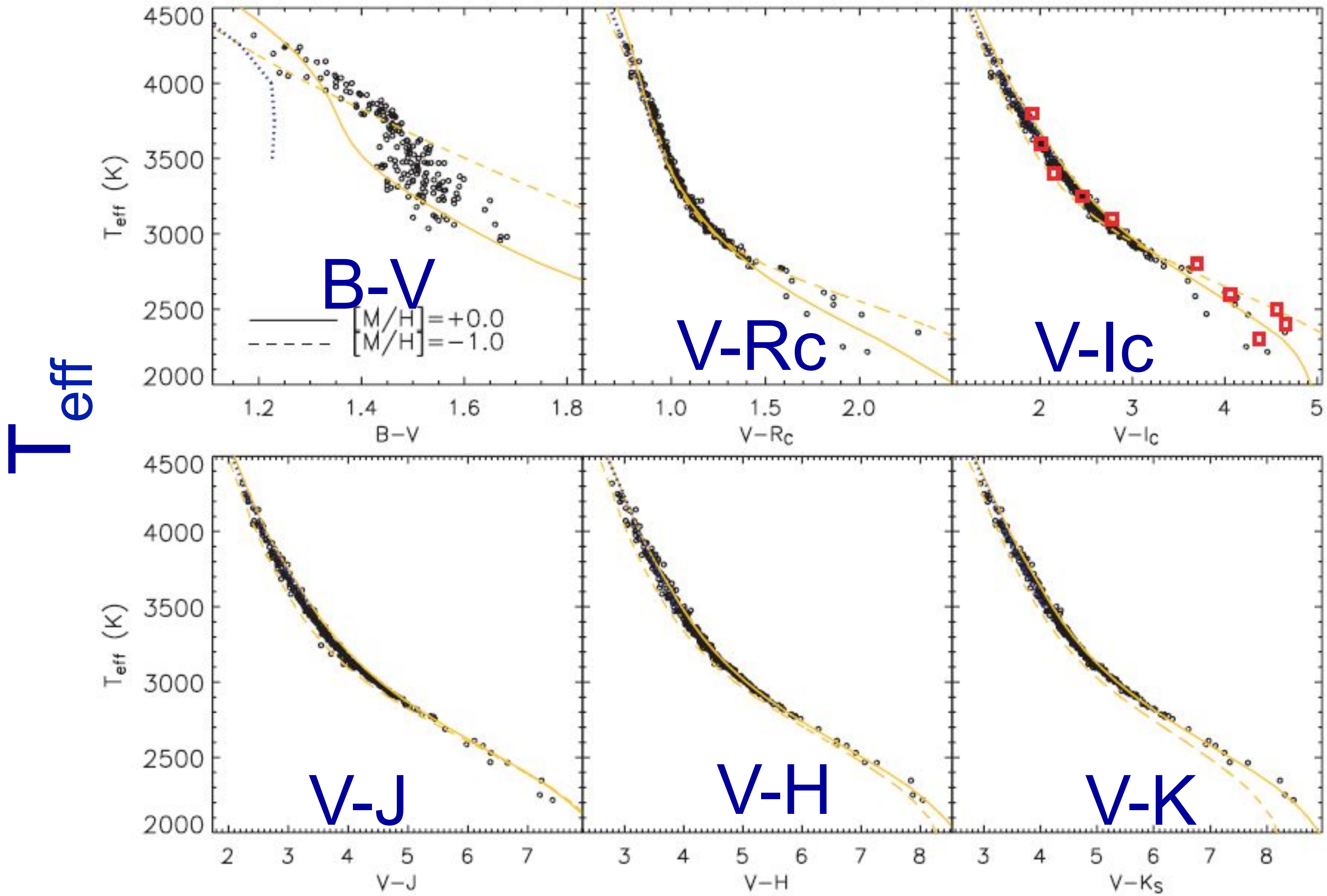
Fig. 14. Upper panels: empirical colour–temperature–metallicity calibrations in the metallicity bins $-0.5 < [Fe/H] \leq 0.5$ (filled diamonds), $-1.5 < [Fe/H] \leq -0.5$ (upward triangles), $-2.5 < [Fe/H] \leq -1.5$ (downward triangles) and $[Fe/H] \leq -2.5$ (open circles). Open squares are for the hyper metal-poor stars HE0233-0343 and HE1327-2326. Lower panels: residual of the fit as function of metallicity. For the two hyper-metal-poor stars, the residual is with respect to the fit at $[Fe/H] = -3.5$.

Effective temperature of M dwarfs

Mon. Not. R. Astron. Soc. 389, 585–607 (2008)

M dwarfs: effective temperatures, radii and metallicities

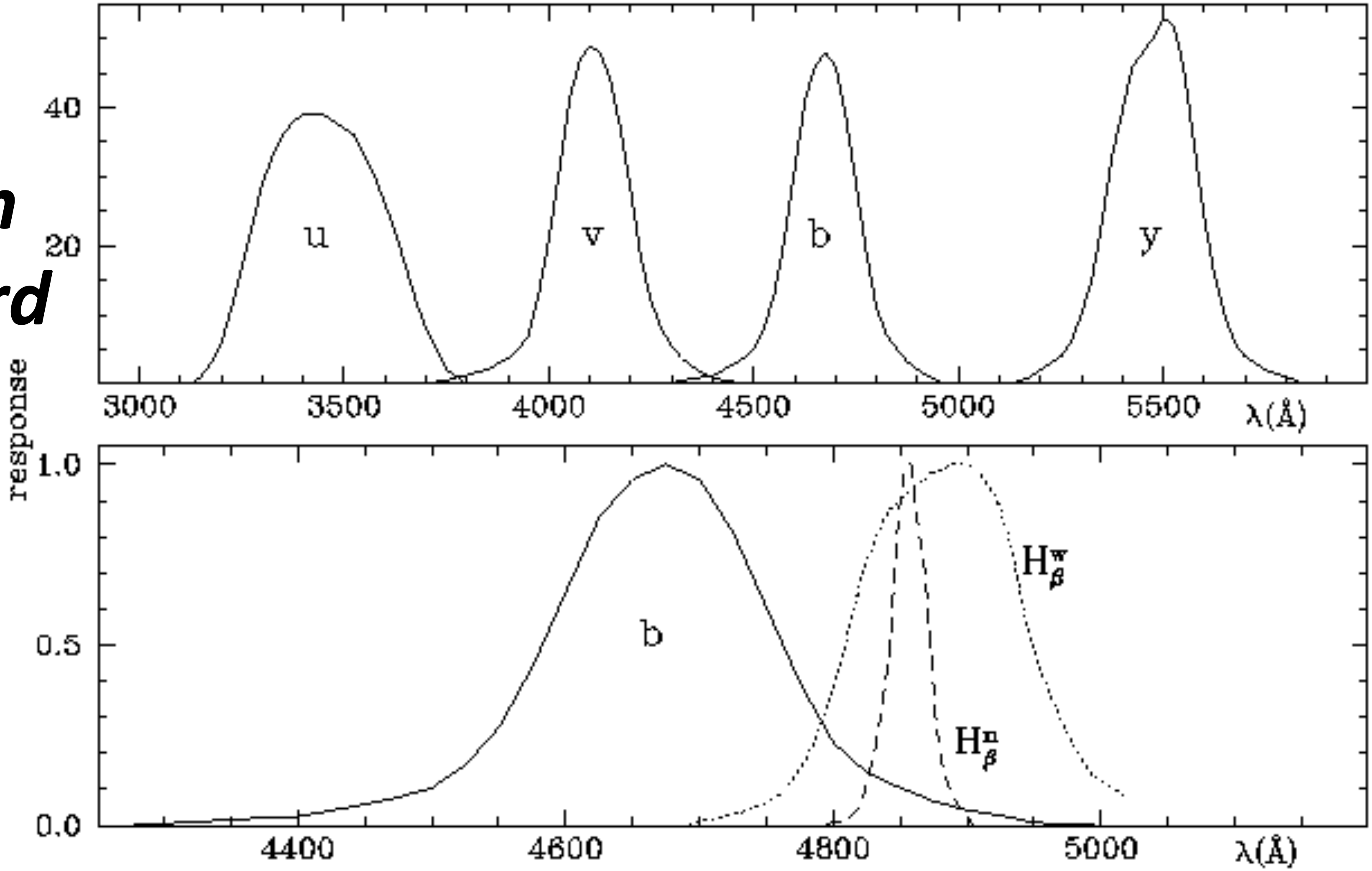
Luca Casagrande,[1★] Chris Flynn[1] and Michael Bessell[2]



9. Colour–$T_{\rm eff}$ plots in different bands for our M dwarfs. Overplotted are the prediction from the Phoenix models (solid and dashed lines) for two nt metallicities which roughly bracket our sample of stars. Also shown for comparison the prediction from the Castelli & Kurucz (2003) models for ıetallicity (dotted line). Squares in the $T_{\rm eff}$ versus $V-I_{\rm C}$ plot are from the temperature scale of Reid & Hawley (2005).

Photometric systems of intermediate bands

***uvby-H$_\beta$* Strömgren & Crawford 1956**



band	*u*	*v*	*b*	*y*	$H_{\beta n}$	$H_{\beta w}$
λ_{peak} (Å)	3500	4110	4670	5470	4859	4890
½Δλ (Å)	300	190	180	230	30	145

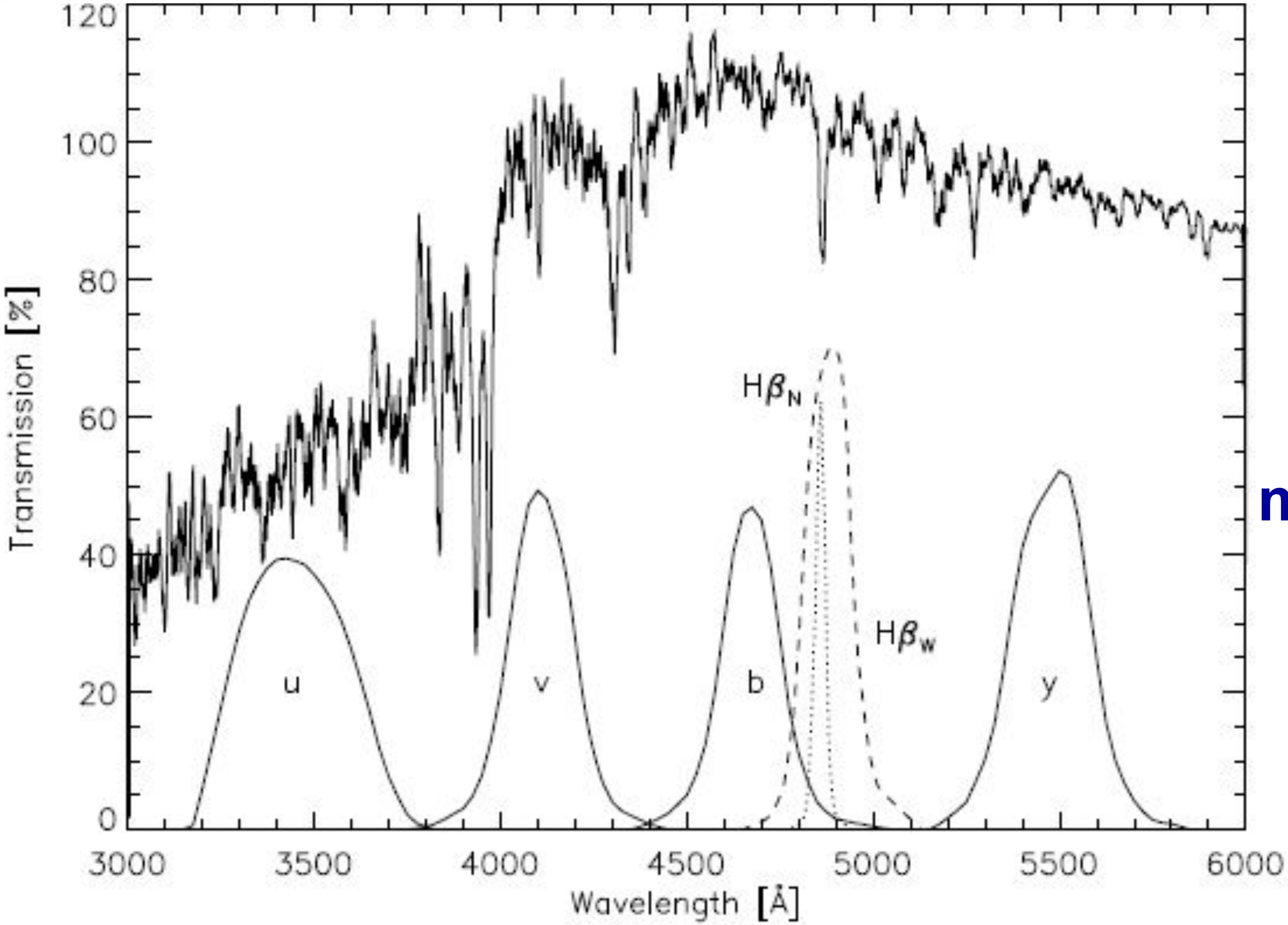
(b-y): temperature

c_1 = (u-v) - (v-b): Balmer disc.

m_1 = (v-b) - (b-y): metallicity

☐ 2009A&A...498..527O 1.000 05/2009 A E F D R C S O U

Önehag, A.; Gustafsson, B.; Eriksson, K.; Edvardsson, B. Calibration of Strömgren uvby-Hβ photometry for late-type stars - a model atmosphere approach



(b-y): Temperature

m_1 = (v-b) - (b-y): metallicity

Fig. 1. The *uvby*–Hβ transmission functions of the standard systems plotted as a function of wavelength. As a comparison, the flux (per Ångström unit) of a model with $T_{\rm eff} = 6000$ K, $\log g = 4.0$ and [Me/H] = 0.0 is plotted on an arbitrary flux scale.

ASTROPHYSICA NORVEGICA
VOL. IX NO. 31

1966, Ap. Norveiga 9, 333

ON THE CHEMICAL COMPOSITION AND KINEMATICS OF DISC HIGH-VELOCITY STARS OF THE MAIN SEQUENCE*

BY BENGT STRÖMGREN

Determination of [Fe/H] using Δm_1

Hyades

$$\Delta m_1 = m_1(b - y) - m_1$$

indicates the difference in metal-hydrogen ratio of the star in question in comparison with the Hyades cluster members. A positive Δm_1 means that the metal content is low relative to that of the Hyades stars.

For the main-sequence F8–G2 stars investigated by Wallerstein [6] there is a close correlation between Δm_1 and the Fe/H ratio. Following Wallerstein we define

$$\left[\frac{\mathrm{Fe}}{\mathrm{H}}\right] = \log\left(\frac{\text{abundance of Fe}}{\text{abundance of H}}\right)_{\text{star}} - \log\left(\frac{\text{abundance of Fe}}{\text{abundance of H}}\right)_{\text{sun}}$$

It has been found (cf. [20]) that the Wallerstein [Fe/H] values for main-sequence stars around spectral class G0 are well represented by a linear relation

$$\left[\frac{\mathrm{Fe}}{\mathrm{H}}\right] = 0.3 - 12 \cdot \Delta m_1$$

and that [Fe/H] can be predicted from Δm_1 with an accuracy of about 0.1 (p. e.) for the category of stars in question.

H. Bond (1970, ApJS 22, 117): $[Fe/H] = 0.16 - 13.6\ \Delta m_1$

$[Fe/H]_{uvby}$: Schuster & Nissen 1984

Schuster & Nissen 1984 (A&A 221, 65):

116 stars, $-2.6 < [Fe/H] < +0.4$

$0.37 < (b-y) < 0.59$, $0.03 < m_1 < 0.57$, $0.10 < c_1 < 0.47$

$[Fe/H] = -2.0965 + 22.45\, m_1 - 53.8\, m_1^2 - 62.04\, m_1(b-y) +$

$145.5\, m_1^2(b-y) + [\, 85.1\, m_1 - 13.8\, c_1 - 137.2 m_1^2\,]\, c_1$ $(s = 0.16$ dex$)$

$[Fe/H]_{uvby}$: Ramírez & Meléndez 2005a

1. For $0.19 \le (b-y) < 0.35$, with $\sigma = 0.17$ dex,

$$[Fe/H] = -4.29 - 66.0 m_1 + 444.2 m_1 (b-y) - 782.4 m_1 (b-y)^2 + (0.966 - 37.8 m_1 - 1.707 c_1) \log \eta, \quad (6)$$

where $\eta = m_1 - [0.40 - 3.0(b-y) + 5.6(b-y)^2]$.

2. For $0.35 \le (b-y) < 0.50$, with $\sigma = 0.13$ dex,

$$[Fe/H] = -3.864 + 48.6 m_1 - 108.5 m_1^2 - 85.2 m_1 (b-y) + 190.6 m_1^2 (b-y) + [15.7 m_1 - 11.1 c_1 + 17.7(b-y)] c_1. \quad (7)$$

3. For $0.50 \le (b-y)_0 \le 0.80$, with $\sigma = 0.15$ dex,

$$[Fe/H] = -2.63 + 26.0 m_1 - 41.3 m_1^2 - 45.4 m_1 (b-y) + 74.0 m_1^2 (b-y) + 17.0 m_1 c_1. \quad (8)$$

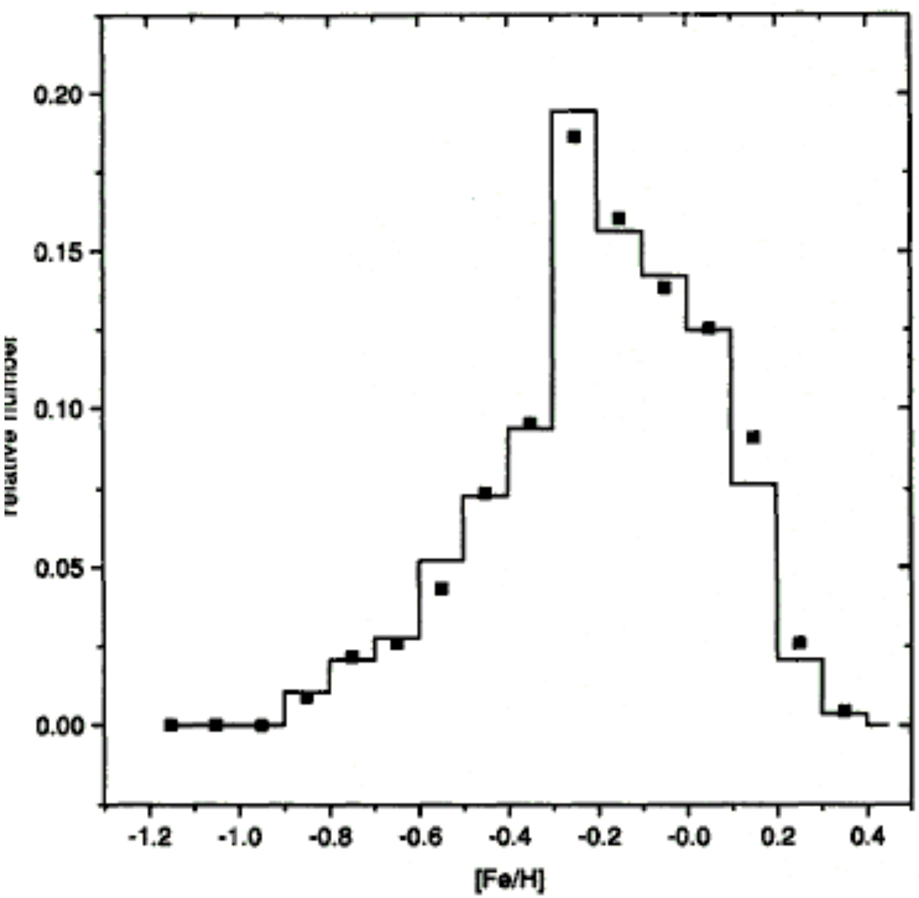
Mon. Not. R. Astron. Soc. **279**, 447–458 (1996)

Important observational constraint for chemical evolution models of the Galaxy

The metallicity distribution of G dwarfs in the solar neighbourhood

165 citations (29/3/2018)

H. J. Rocha-Pinto and W. J. Maciel
Instituto Astronômico e Geofísico, Av. Miguel Stefano 4200, 04301-904 São Paulo, Brazil



igure 2. Metallicity distribution of 287 dwarf stars with spectral types n the range G0 – G9 (continuous line), and 231 dwarfs of spectral ypes G2 – G9 (squares).

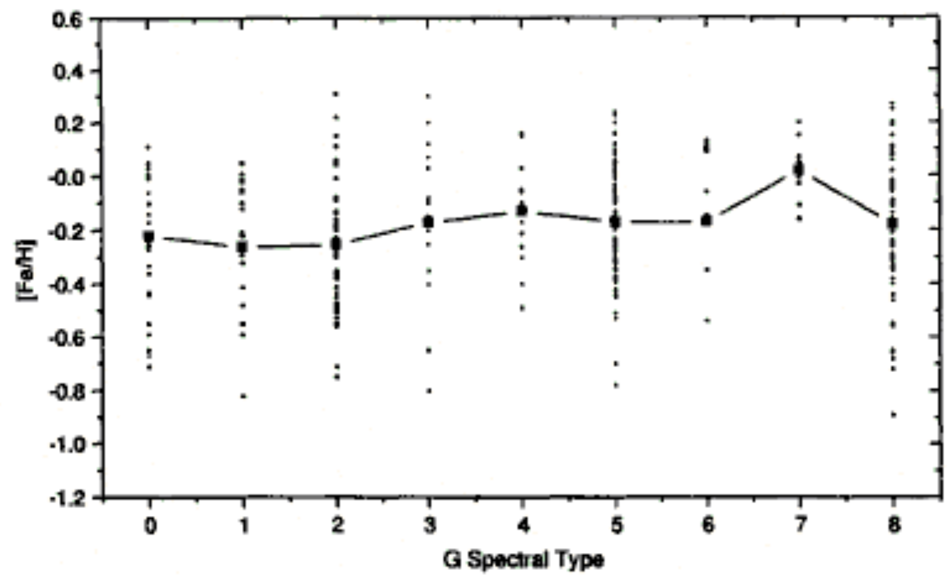
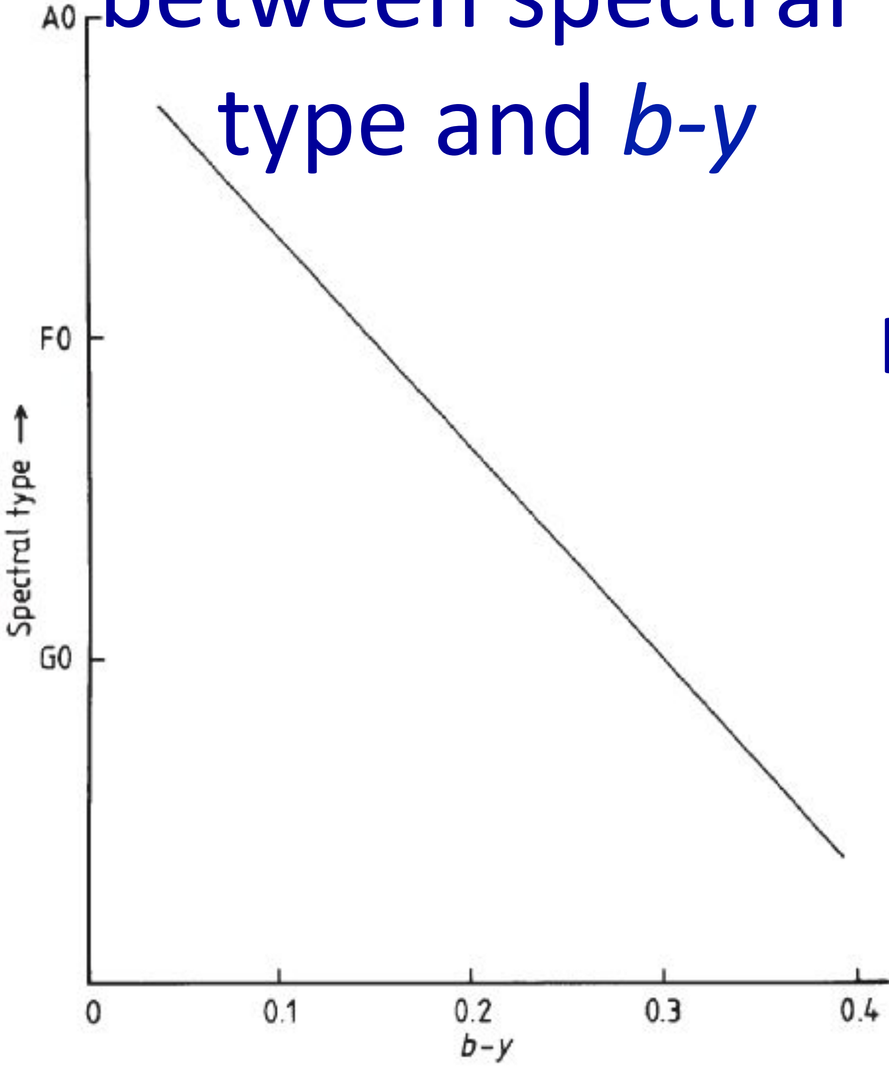


Figure 3. Abundances as a function of the spectral type (dots), and mean values for each type (squares). Stars of types G8 and G9 are merged in the same bin.

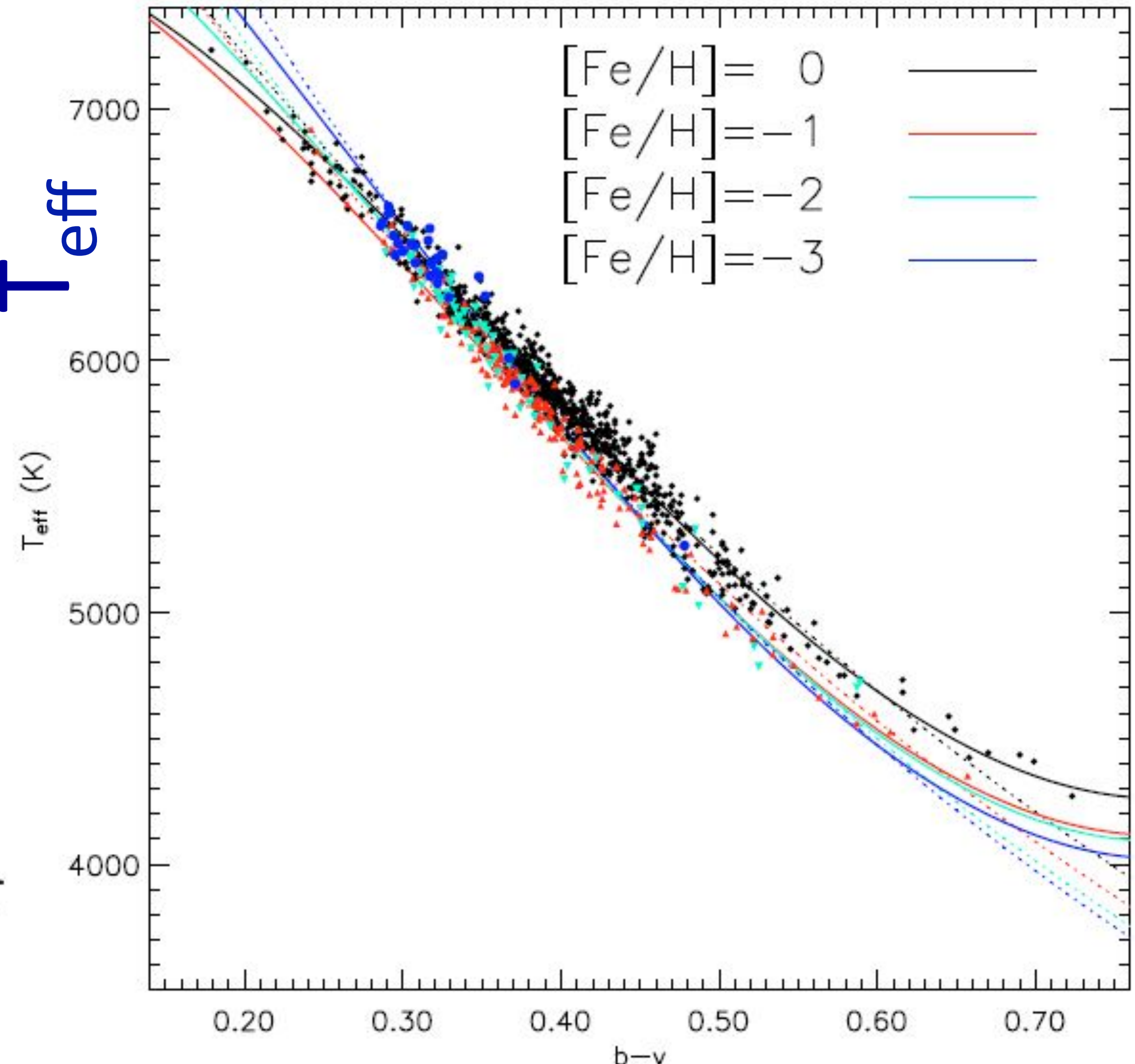
bias in the metallicity distribution, as was shown by Sommer-Larsen (1991). Since older stars generally have lower metallicities and larger scale heights relative to the galactic plane, we expect their relative number to be artificially reduced by the limitation of our sample within 25 pc of the Sun. To solve this problem, we have adopted the correction procedure introduced by Sommer-Larsen (1991), who defined a weight

Relationship between spectral type and *b-y*



© Fig. 3.1.9, Kitchin

Relationship between T_{eff} and *b-y*



T_{eff}

b - y

A&A 512, A54 (2010)

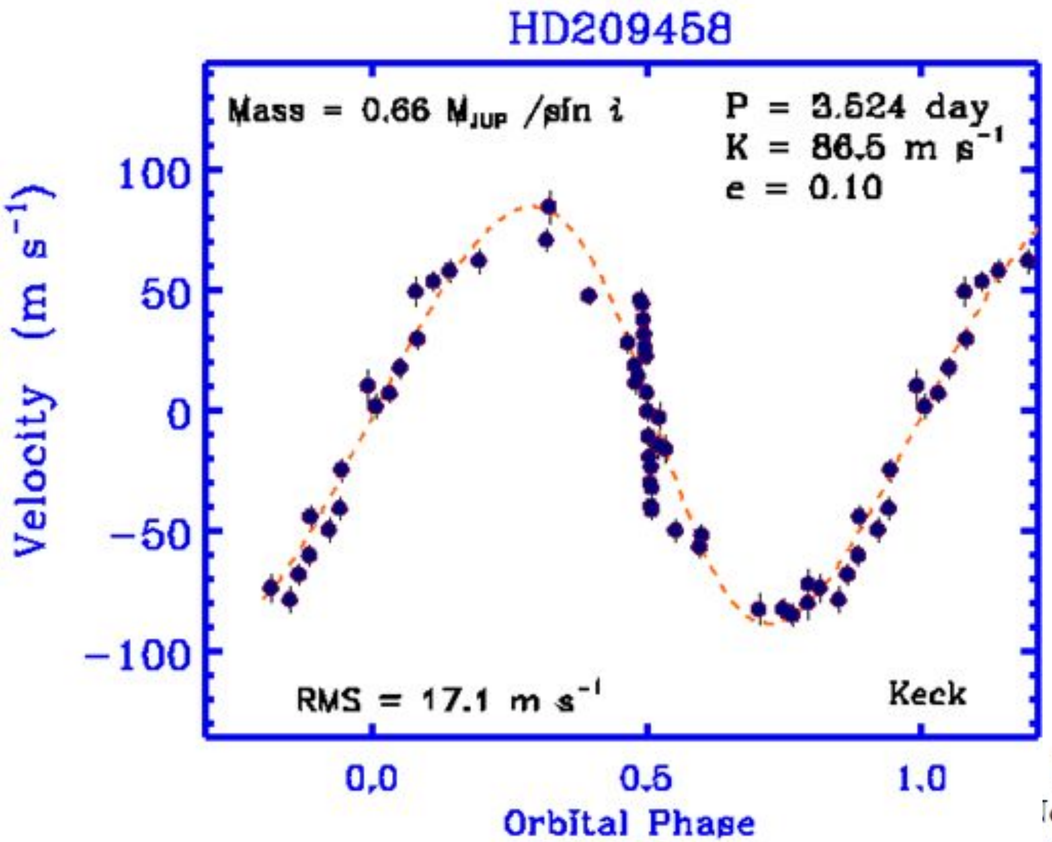
L. Casagrande[1], I. Ramírez[1], J. Meléndez[2], M. Bessell[3], and M. Asplund[1]

Discovering planets with photometry

THE ASTROPHYSICAL JOURNAL, 529:L41–L44, 2000 January 20

A TRANSITING "51 PEG–LIKE" PLANET[1]

GREGORY W. HENRY,[2] GEOFFREY W. MARCY,[3] R. PAUL BUTLER,[4] AND STEVEN S. VOGT[5]
Received 1999 November 18; accepted 1999 December 3; published 1999 December 16



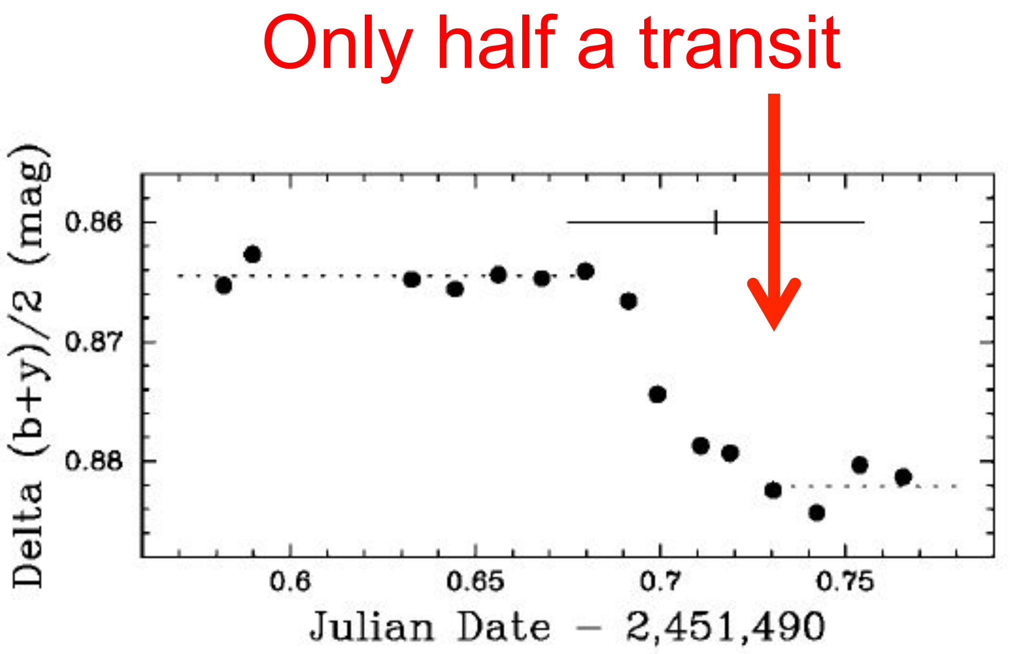
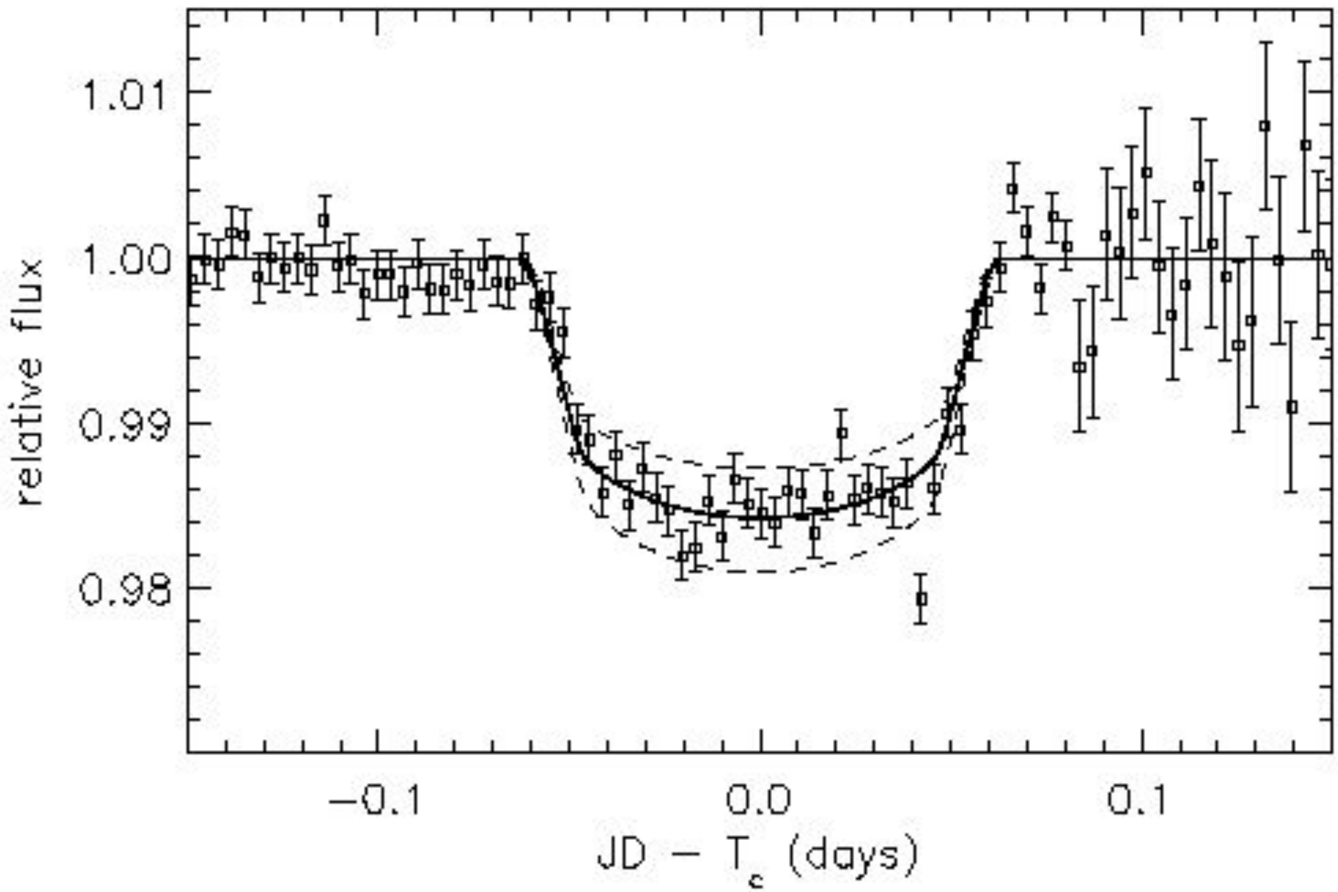


FIG. 3.—Photometric observations of HD 209458 from the night of 1999 November 7 UT showing ingress of the planetary transit. The measured transit depth is 0.017 ± 0.002 mag or 1.58% ± 0.18%. The error bar shows the time of inferior conjunction and its uncertainty predicted from the radial velocities in this Letter.

Finding exoplanets: Transits

HD 209458



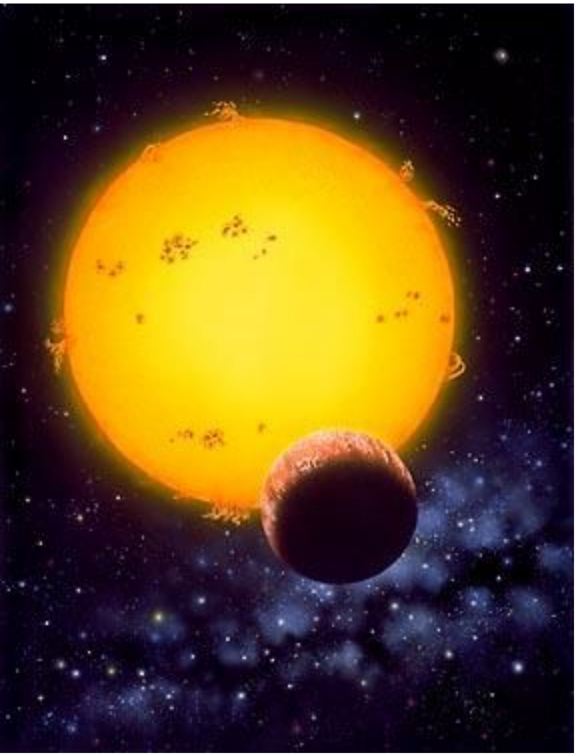
The Astrophysical Journal, 529:L45-L48, 2000 January 20

Detection of Planetary Transits Across a Sun-like Star

David Charbonneau ,[1,2] Timothy M. Brown ,[2] David W. Latham ,[1] and Michel Mayor [3]

Finding exoplanets: Transits

HD 209458



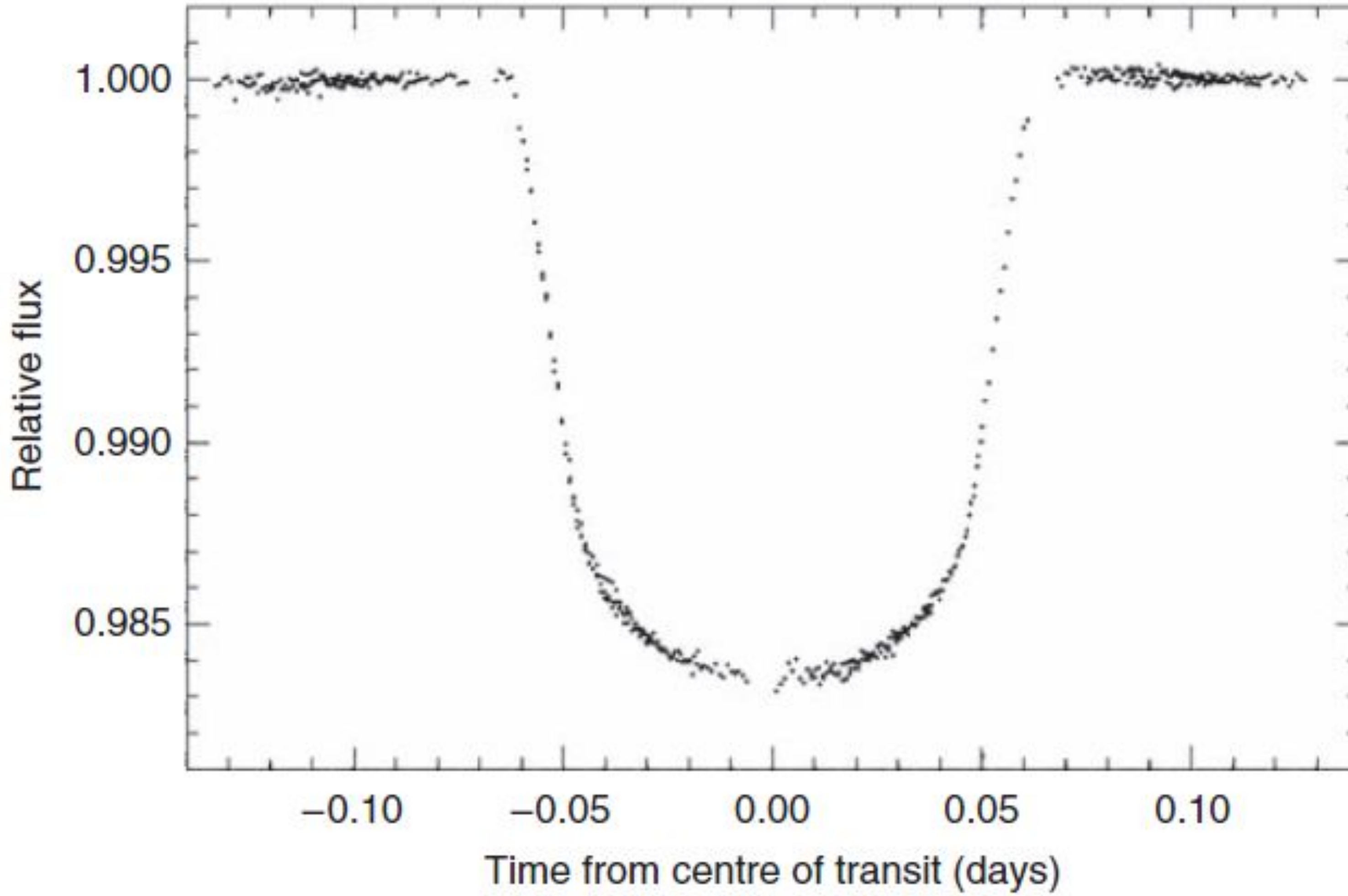
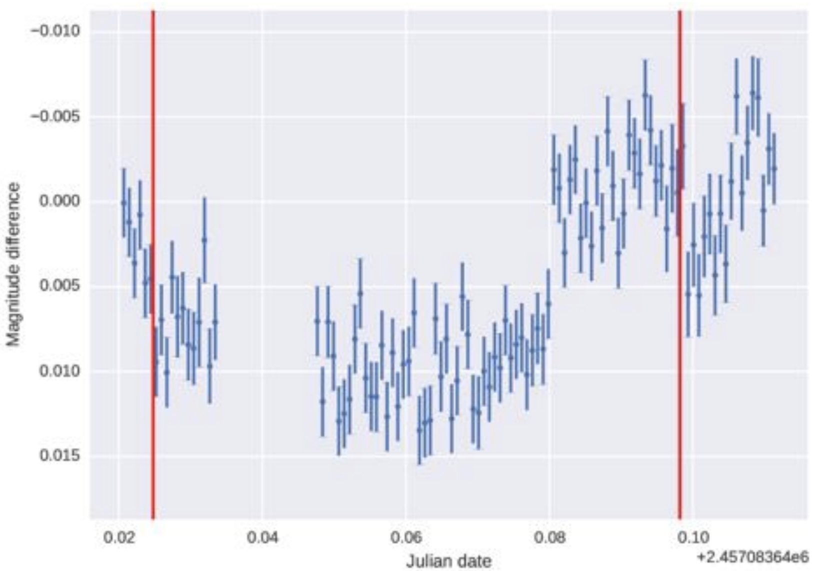


Figure 1.1 Eclipse of HD 209458 by its low-mass, presumed planetary, companion. The light curve has been combined from four separate recordings in April and May 2000 using the Imaging Spectrograph of the Hubble Space Telescope integrating over a yellow–orange region of the spectrum. Individual points are accurate to an estimated 1 part in 10 000. (From T. M. Brown *et al.*, 2001.)

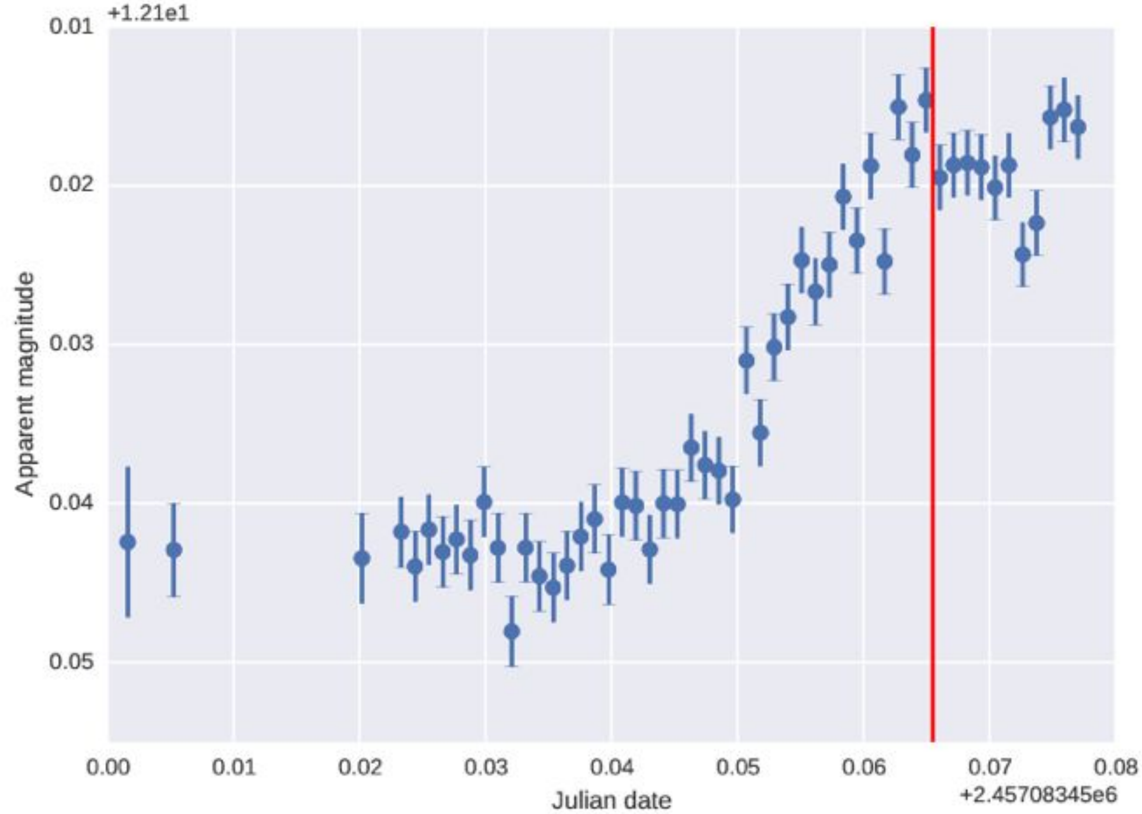
Transits at OPD/LNA

Detecting known exoplanets

WASP104



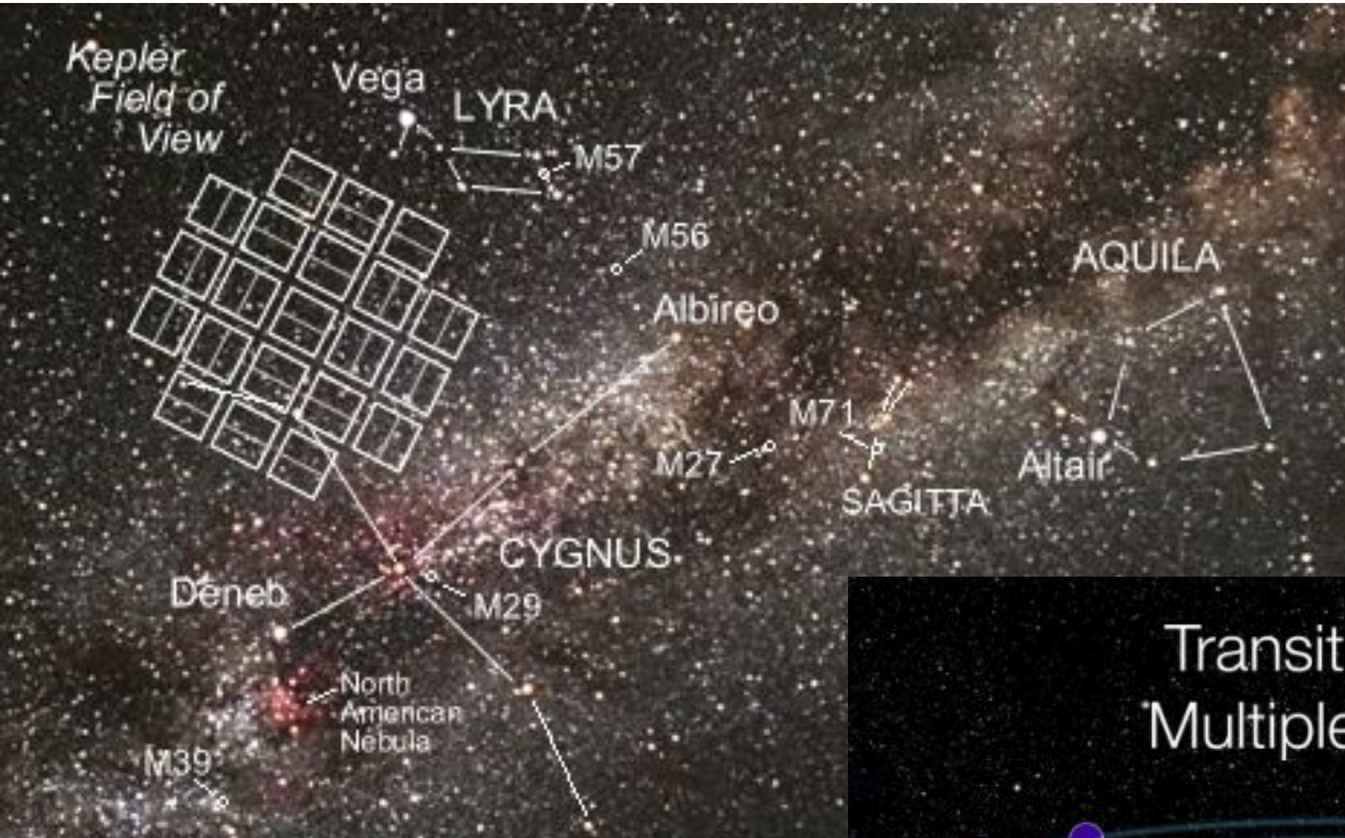
WASP19

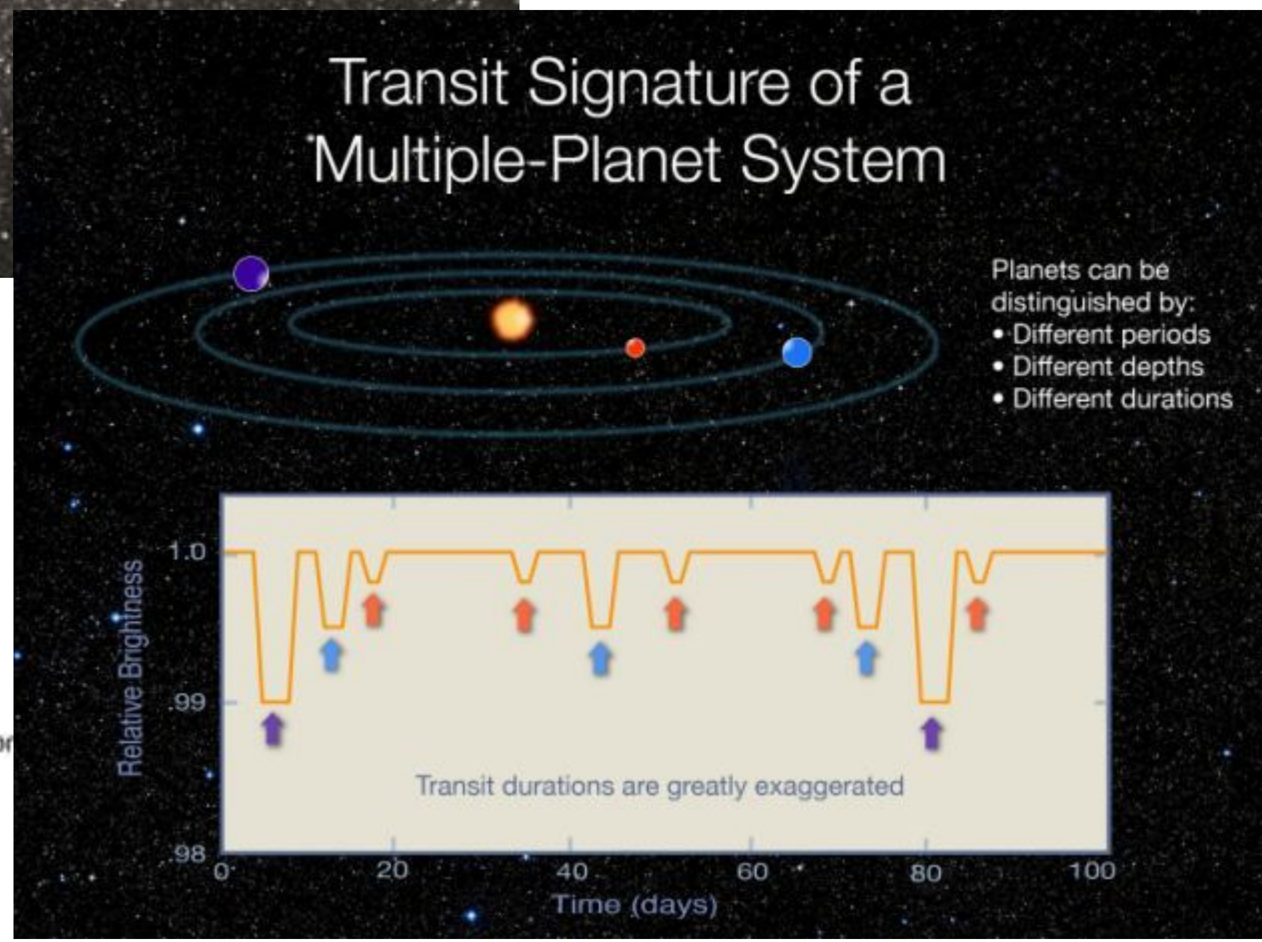


Light curves by Léo dos Santos (IAG/USP), 60cm (IAG) telescope

Kepler

continuously and simultaneously monitored the brightness of more than 100,000 stars for about 3 years [still operating in other fields]

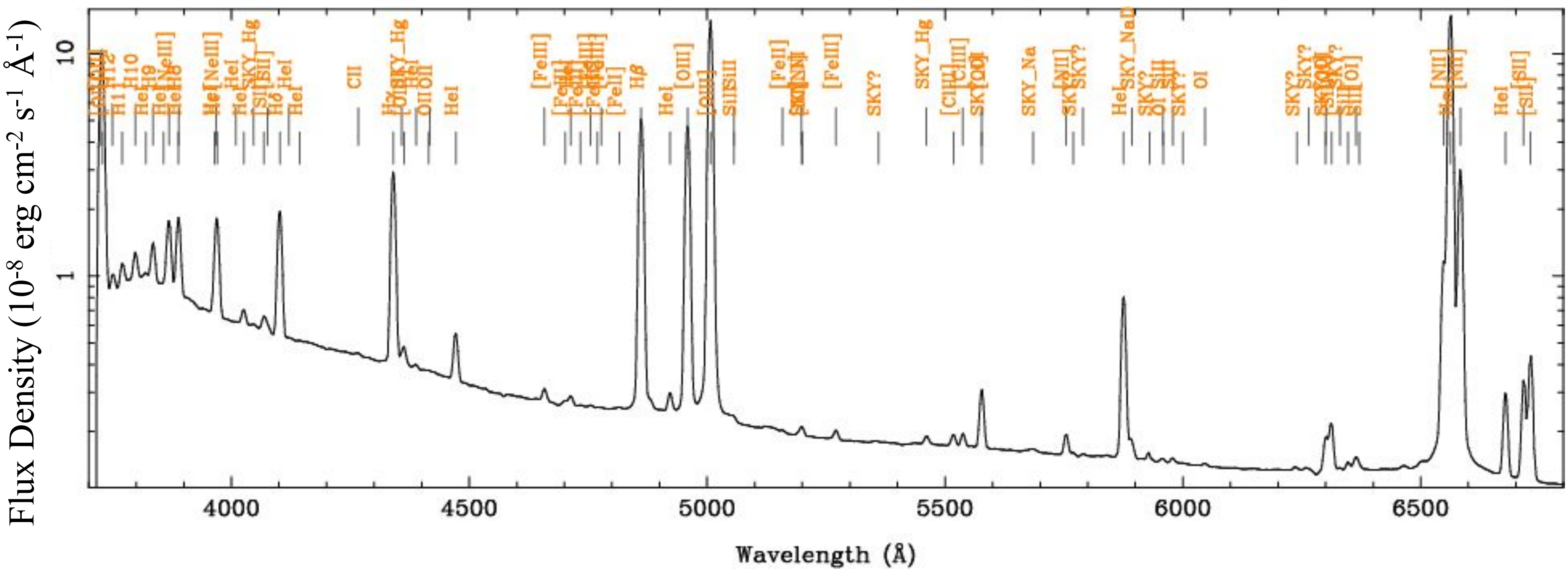




Narrow band filters

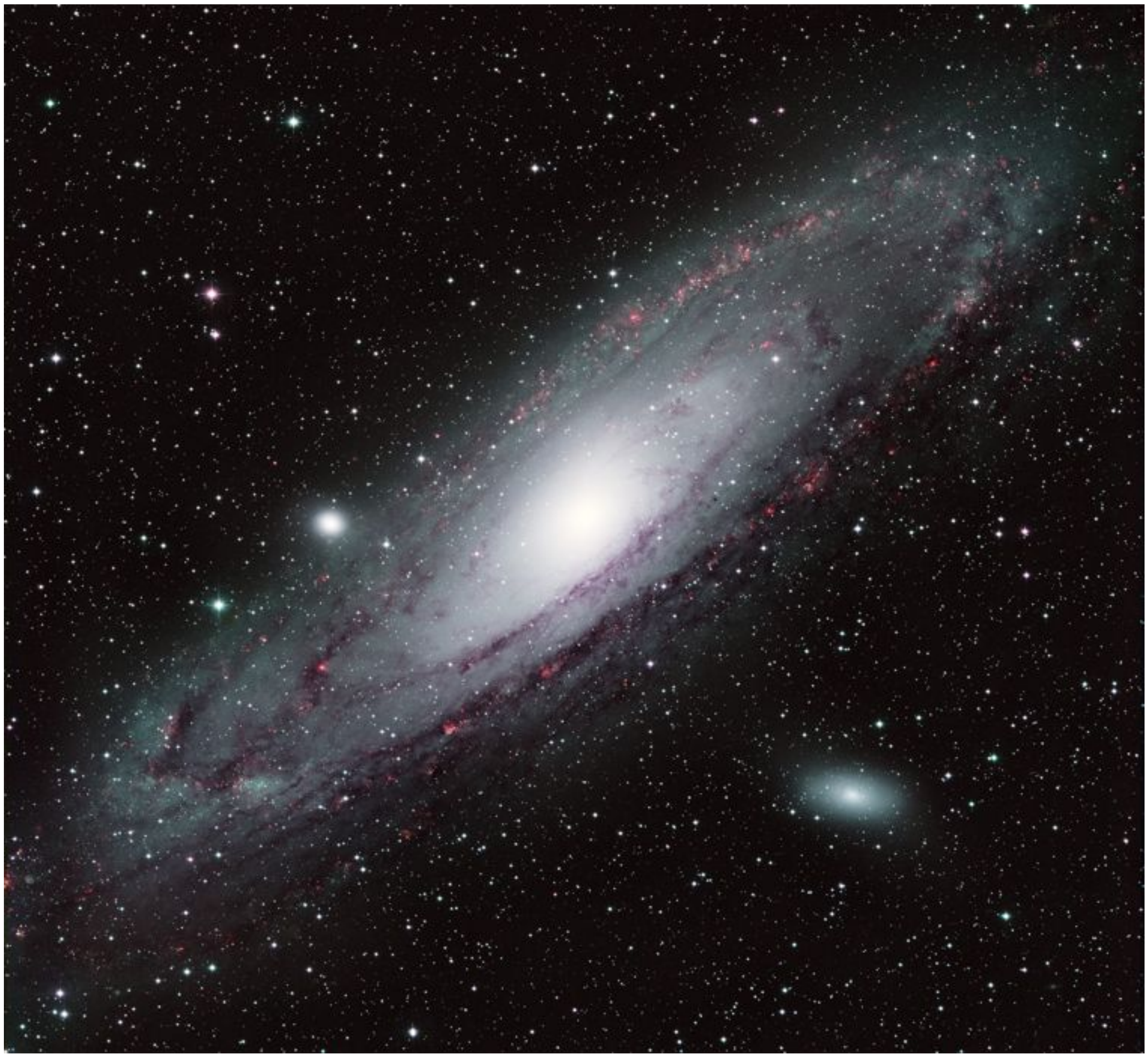
Restricted to a very narrow spectral range (sometimes just 1 line), but also the nearby continuum is measured

Spectrum of Orion Nebula



Example

Andromeda in narrow filters in $H\alpha$ and continuum



Example

Andromeda in Hα filter (continuum subtracted)