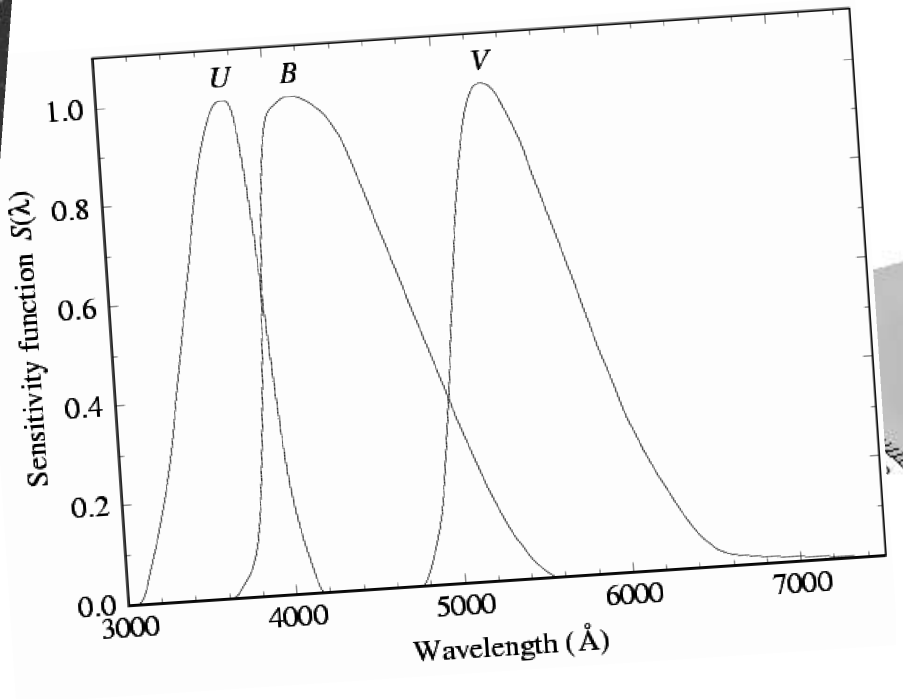
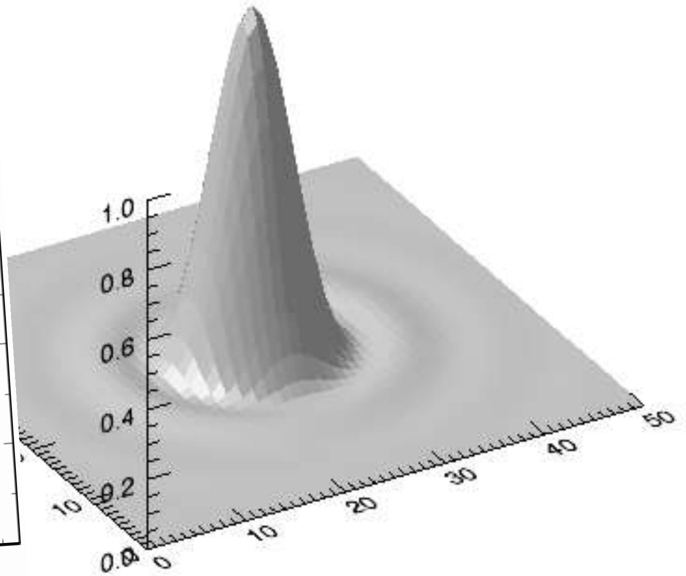
AGA 414: Métodos Observacionais

Jorge Meléndez

Fotometria II

Redução de dados





Atualização: 08/04/2014

Redução de dados

Photoelectric photometry

Publications of the Astronomical Society of the Pacific
106: 1172–1183, 1994 November

Calibration of the *UBVRI* High-Speed Photometer of Laboratório Nacional de Astrofísica, Brazil

F. JABLONSKI[1]

Instituto Nacional de Pesquisas Espaciais, P.O. Box 515, São José dos Campos, Brazil, 12201-970
Electronic mail: chico@das.inpe.br

R. BAPTISTA

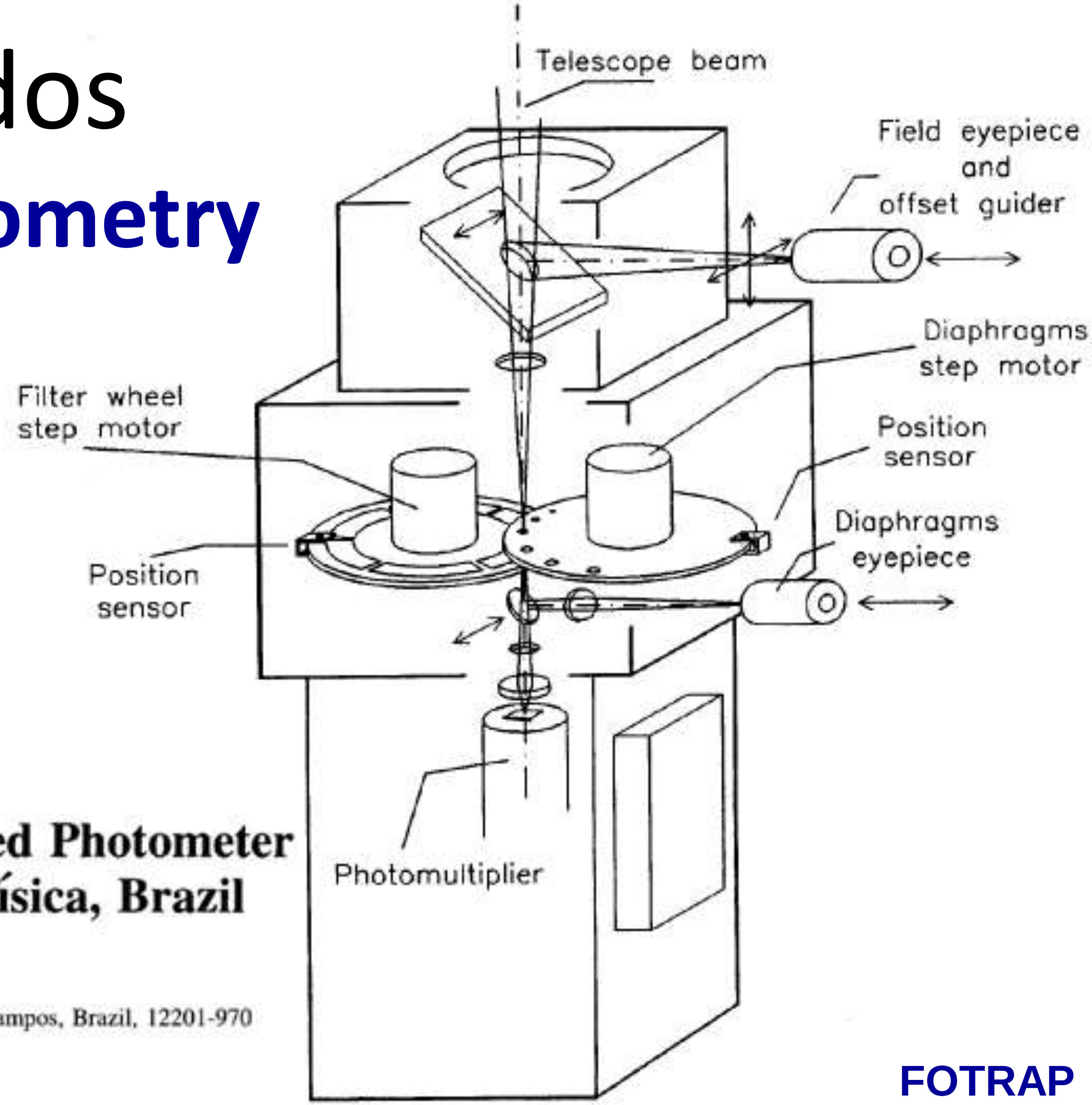
Space Telescope Science Institute, Baltimore, Maryland 21218
Electronic mail: bap@stsci.edu

J. BARROSO, JR.

Observatório Nacional, Rio de Janeiro, Brazil

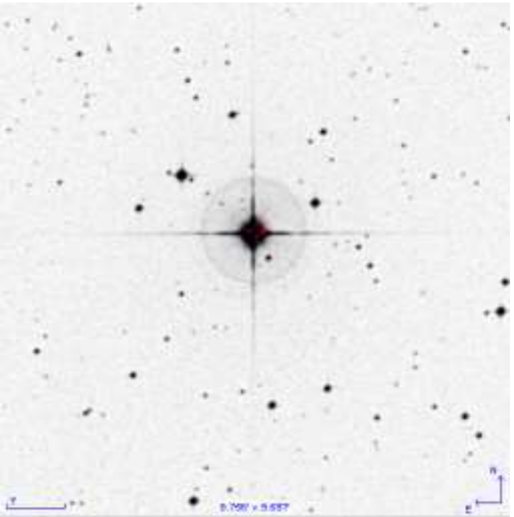
C. D. GNEIDING, F. RODRIGUES, AND R. P. CAMPOS

Laboratório Nacional de Astrofísica, Itajubá, Brazil



FOTRAP

Redução de dados



The FOTRAP Diaphragm Set

#	diameter (arcsec) 0.6 m	1.6 m
1	52.2	24.5
2	41.2	19.3
3	33.0	15.5
4	27.7	11.6
5	19.2	9.0
6	16.5	7.7
7	13.7	6.4
8	11.0	5.1
9	164.9	77.3

Photoelectric photometry

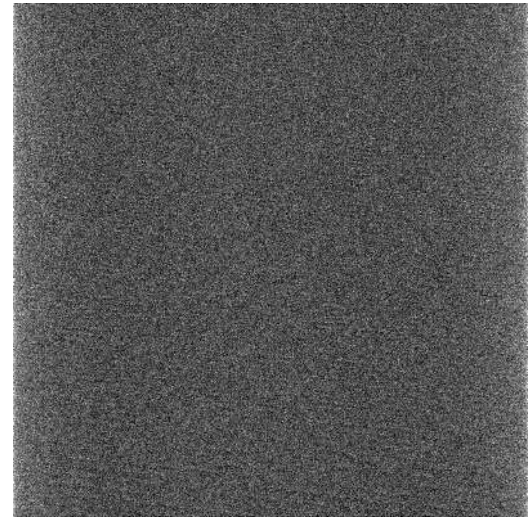
- Flux = $Count_{Star+Sky}/s - Count_{Sky}/s$
- $m_X - m_Y = -2.5 \log F_X/F_Y$ *or*
- $m_X - m_Y = -2.5 \log F_X + 2.5 \log F_Y$
- $\underbrace{m_X - m_Y - 2.5 \log F_Y}_{m} = -2.5 \log F_X$
- m
- $m = -2.5 \log F_X$
- $m_{instrument} = -2.5 \log Fluxo$

Redução de dados

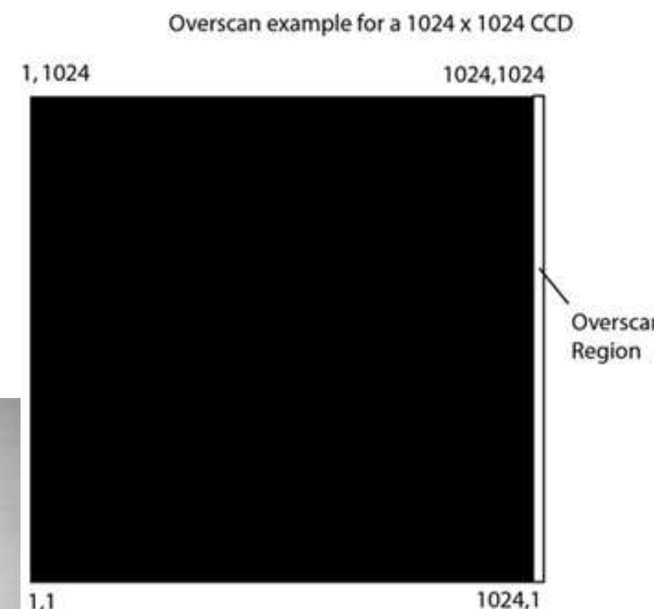
- Flux = $Count_{Star+Sky}/s - Count_{Sky}/s$
- **$m_{instrument}$ = -2.5 log Fluxo**
- **v** = $-2.5 \log Flux_v$
- **b - v** = $-2.5 \log (Flux_b / Flux_v)$
- **u - b** = $-2.5 \log (Flux_u / Flux_b)$
- **u,b,v** : magnitudes instrumentais a serem calibradas (por ex. no sistema U, B, V)

Redução de dados

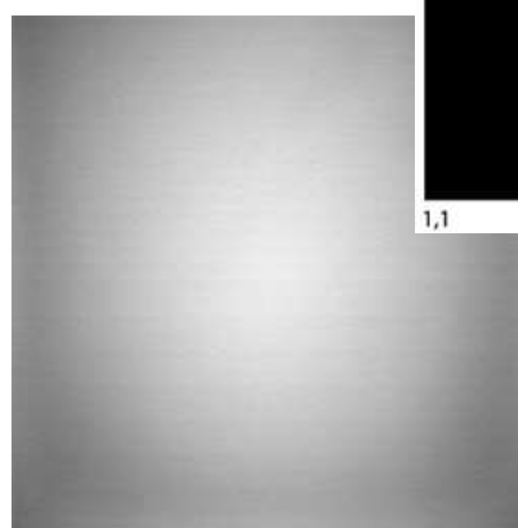
CCD



- **Bias** : offset (ponto zero, algumas centenas de contagens). Obter com tempo de exposição = 0. ***Overscan region*** also indicates the bias level.



- **Flat** : pixel-to-pixel variations



Redução de dados

CCD

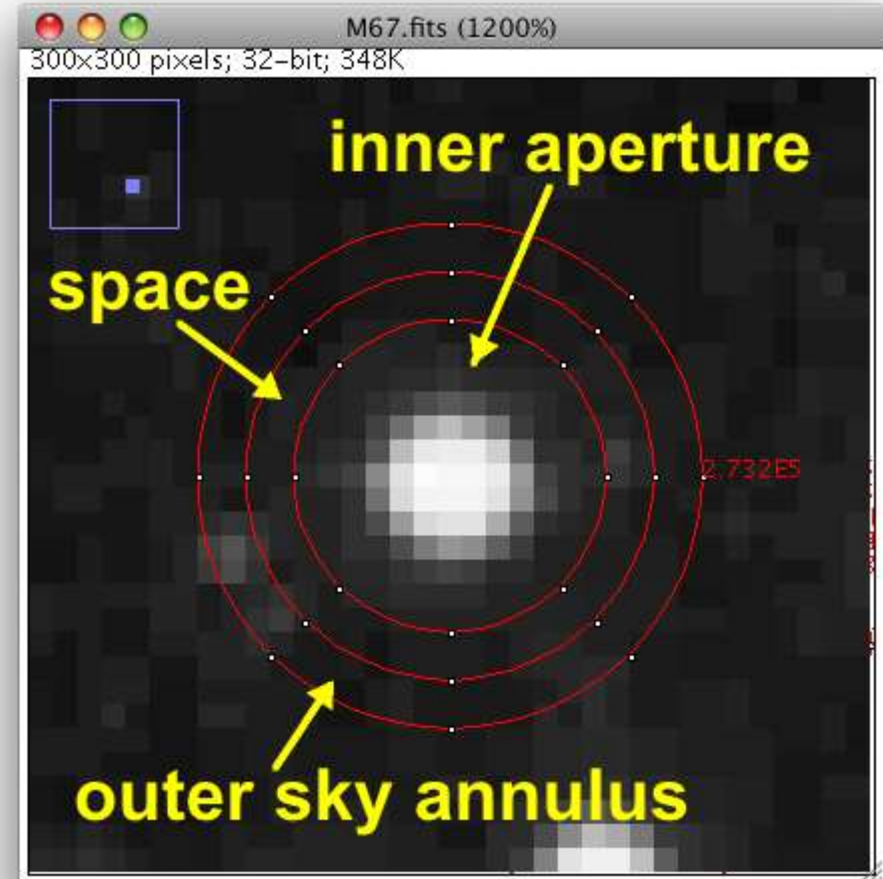
Preparação simples

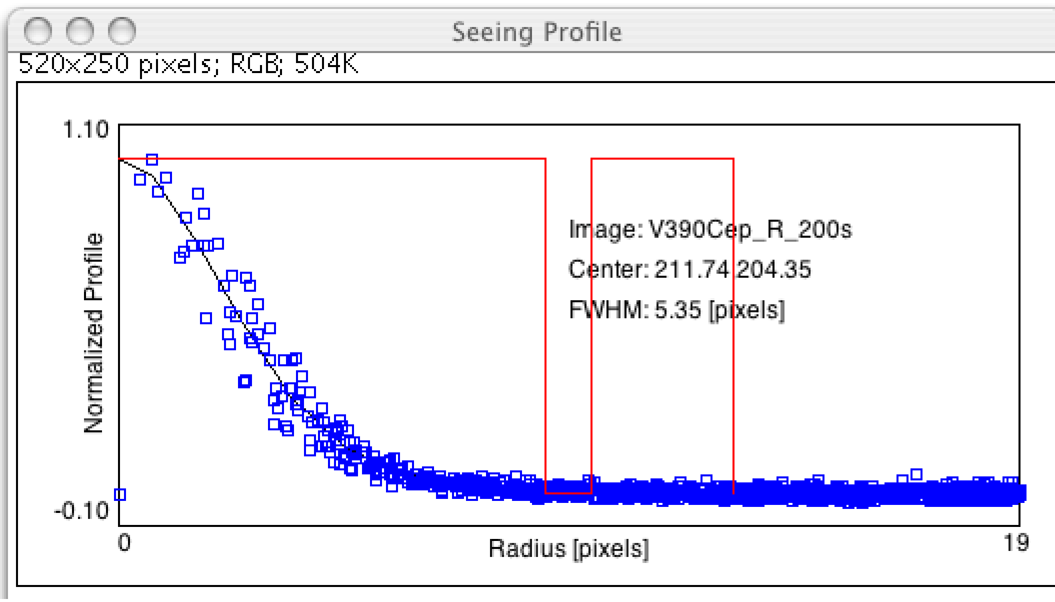
- Bias combinado (e.g. mediana)
- Flat combinado (e.g. mediana)
- FlatB = Flat - Bias
- FlatN = FlatB / mediana(FlatB)   [flat normalizado ~ 1]
- [(Imagem do alvo) – Bias] / FlatN

Nota: normalizando o flat a 1.0 preservamos as contagens

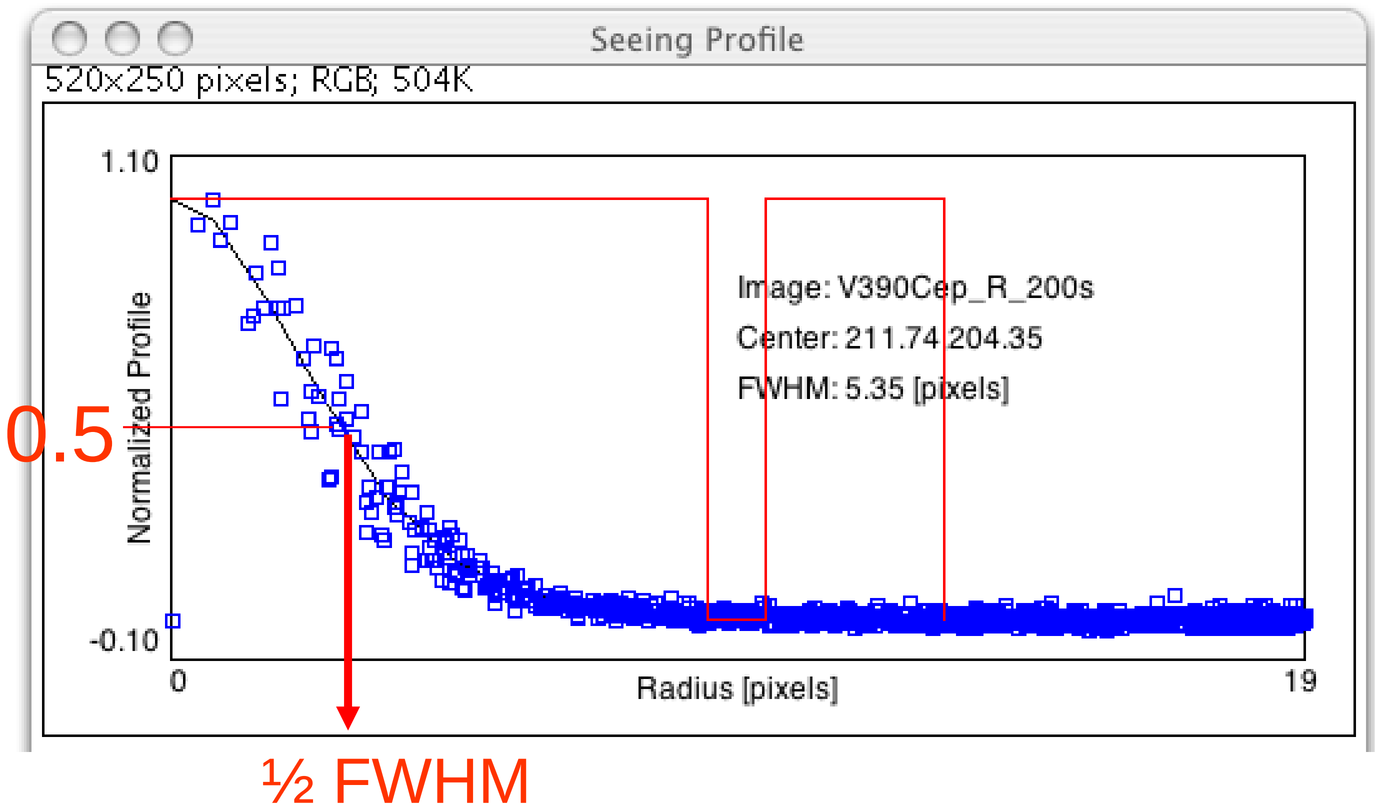
Mas como fazer as medidas?

Mais simples: aperture photometry



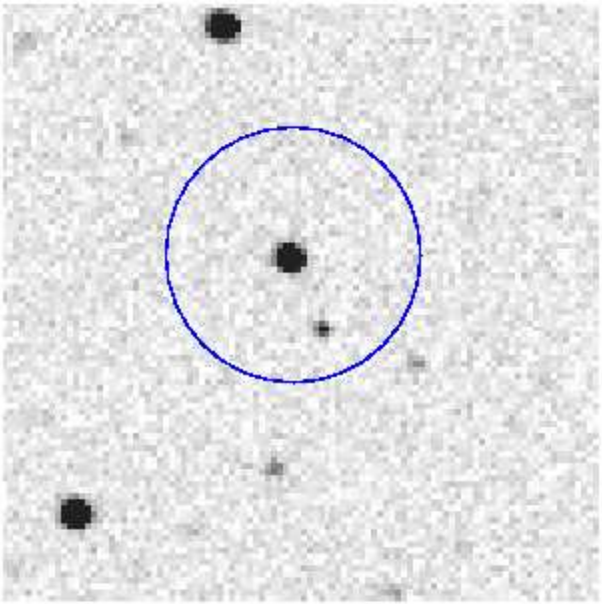


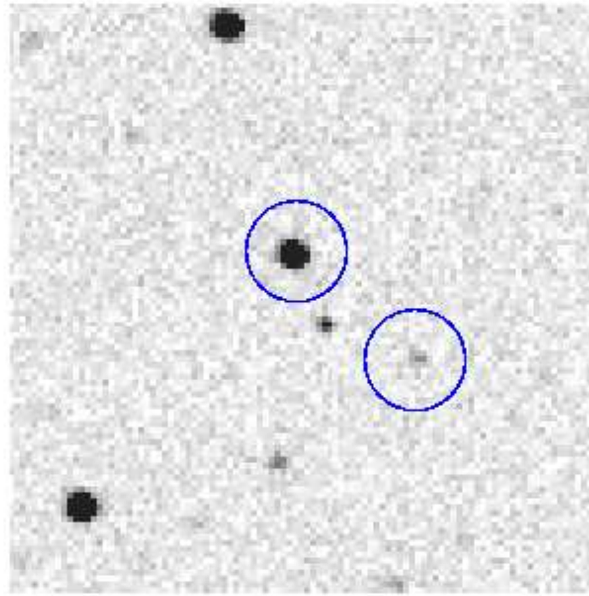
É importante medir o FWHM do perfil da estrela (em pixels)

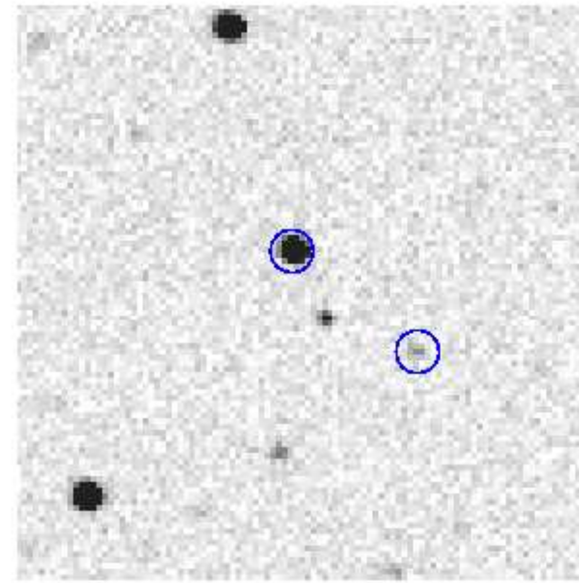


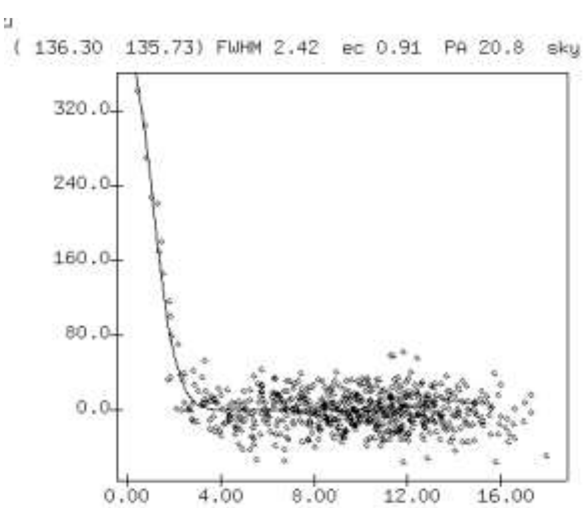
Aperture photometry

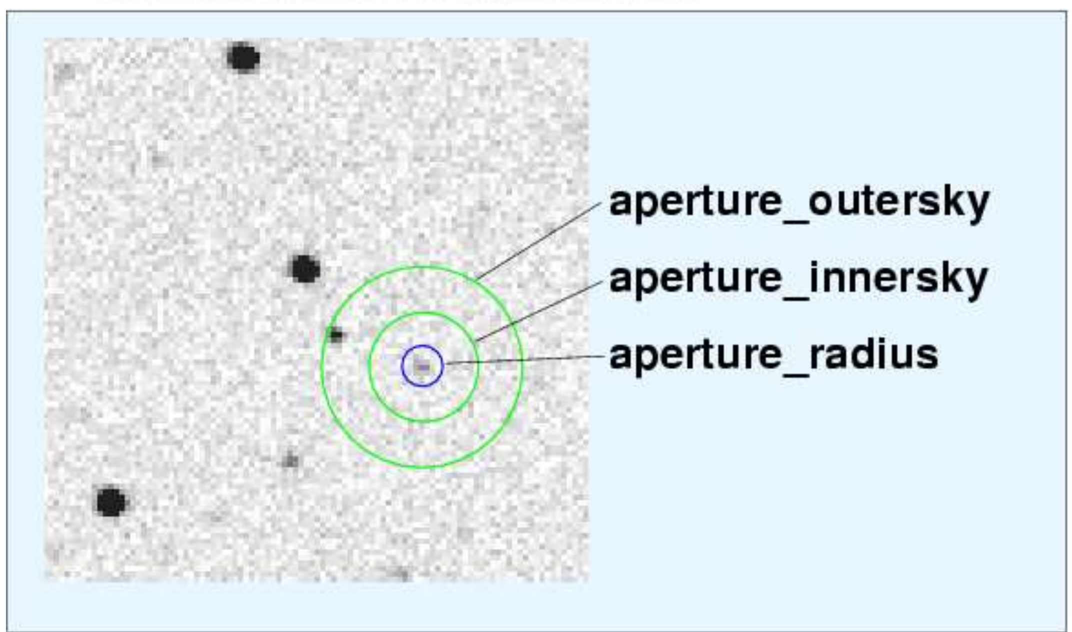
não exagerar no tamanho da apertura !











Somar *inner*
2-3 FWHM

Céu: 5-7 FWHM

De contagens a magnitudes (caso ideal)

- Assumindo uma resposta linear:
- Fluxo = contagens x constante
- Usando a relação de Pogson:
- $m = -2.5 \log (F/F_0)$

  $= -2.5 \log (F) + \text{constante}$
- onde F_0 é o fluxo de um objeto com $m = 0$
- A "constante" é chamada de ponto zero (PZ)
- **$m = -2.5 \log (F) + PZ$**

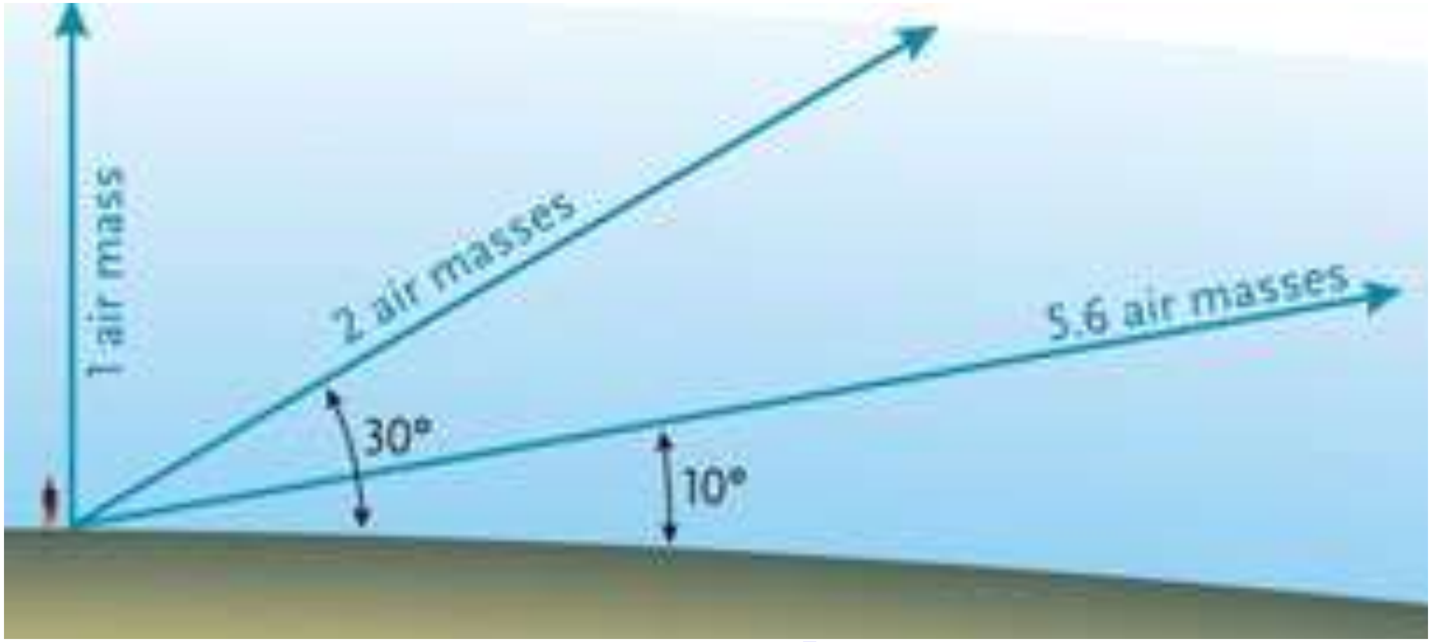
De contagens a magnitudes (caso real)

- m = -2.5 log (F) + PZ + termo_de_atmosfera + termo_de_cor + atmosfera*termo_de_cor + ...
- **m = -2.5 log(F) + X**
- **Para obter dados úteis precisamos de muitas estrelas padrões cobrindo um intervalo de cores e observadas a diferentes massas de ar**

Extinção atmosférica

1 massa de ar: massa de ar *overhead* (zenit)

airmass = sec z = $(\text{sen}\phi \, \text{sen}\delta + \cos\phi \cos\delta \cos H)^{-1}$



H = S.T. - α

Coeficiente de extinção ***k***: magnitudes por massa de ar

Exemplo, k = 0,16 mag/airmass e m_{obs}(zenit) = 10

Estrela fora da atmosfera seria 0,16mag mais brilhante

m_0 = 10 + 0,16 = 10,16 (fora da atmosfera)

Bouguer's law: $m_0 = m_z + k \sec z$

m_0 : fora da atmosfera

m_z : *magnitude a distância zenital z*

k : coeficiente de extinção

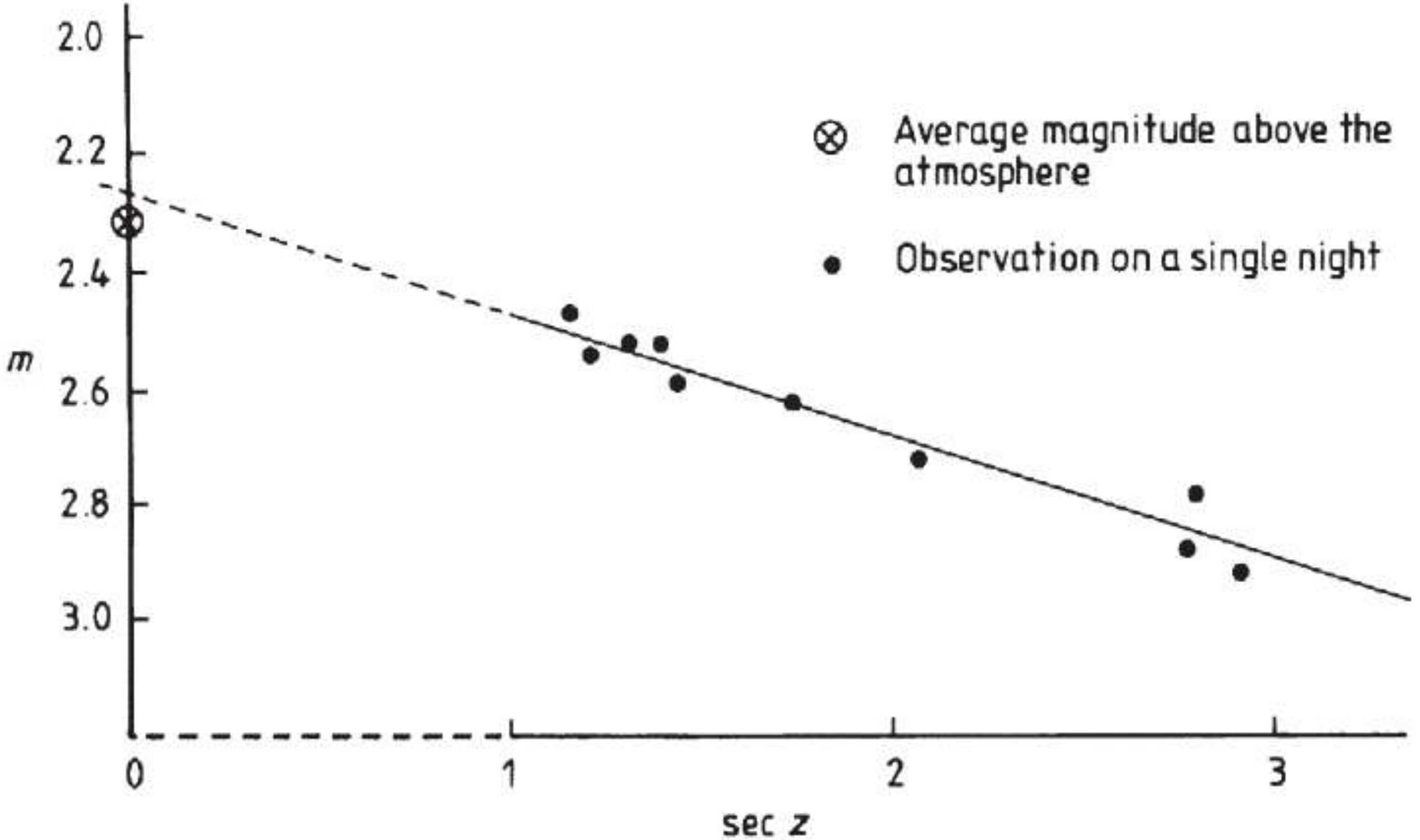


Figure 3.2.5. Schematic variation in magnitude of a standard star with zenith distance

Exemplo de extinção *k* no OPD

$$m_0 = m_z + k \sec z$$

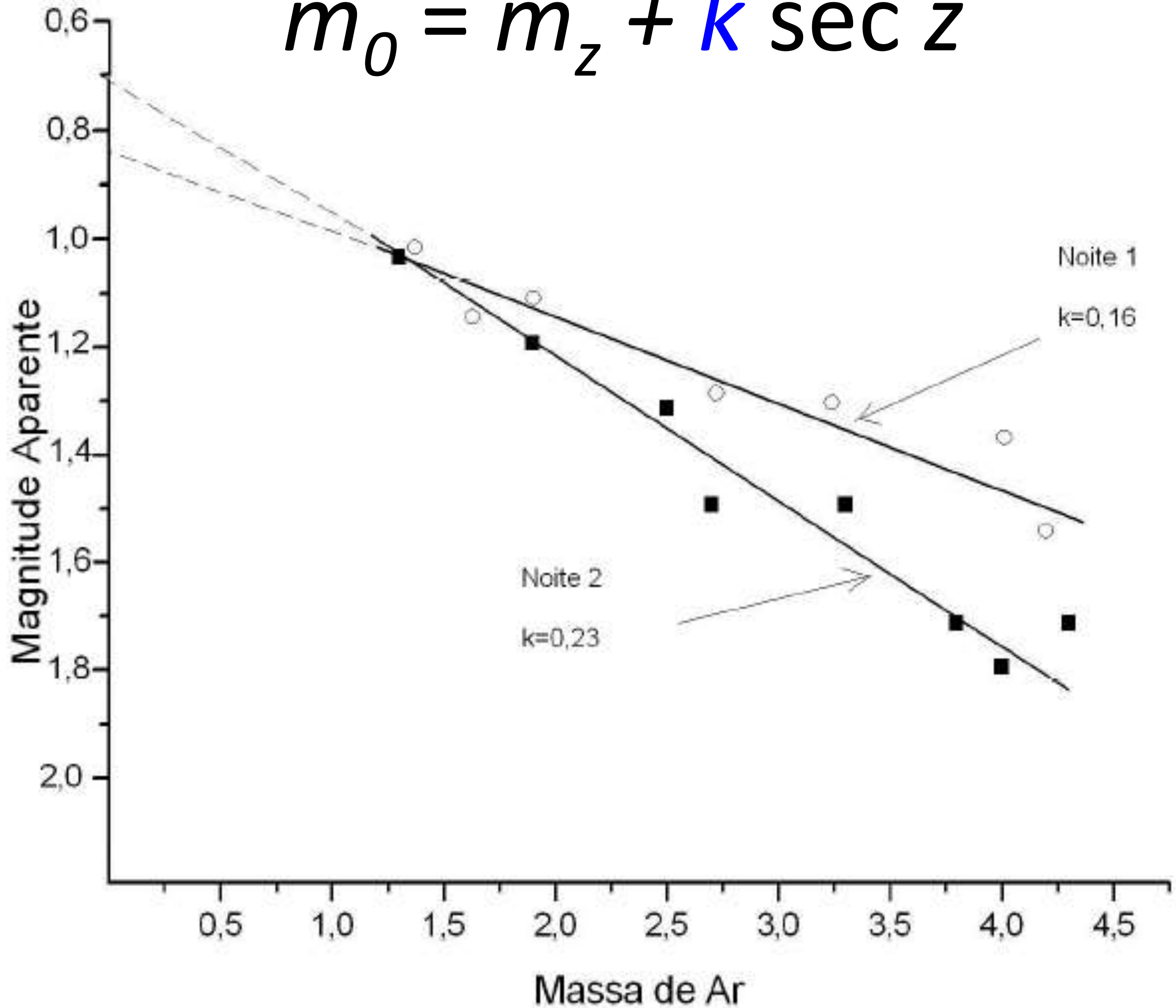
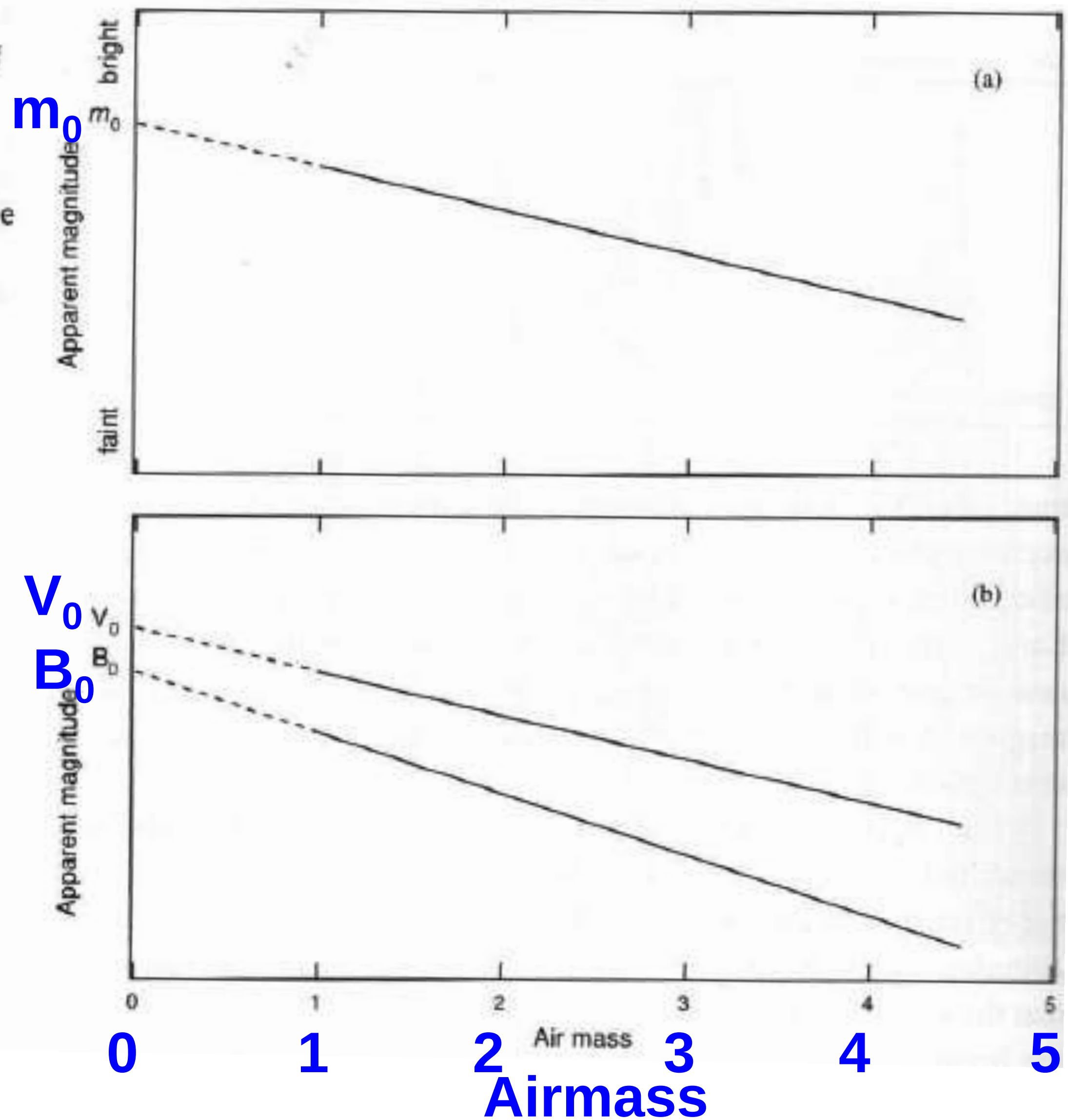


Gráfico 1 - Exemplo de curva de extinção
Fonte: Elaboração própria.

Atmospheric extinction

Wavelength dependence

Figure 7.3. (a) Method of determining the coefficient of extinction. The slope of the solid line is the extinction coefficient. The magnitude when the air mass is zero is the magnitude outside the atmosphere. (b) Dependence of extinction on wavelength.



Atmospheric extinction

Dependence with Wavelength

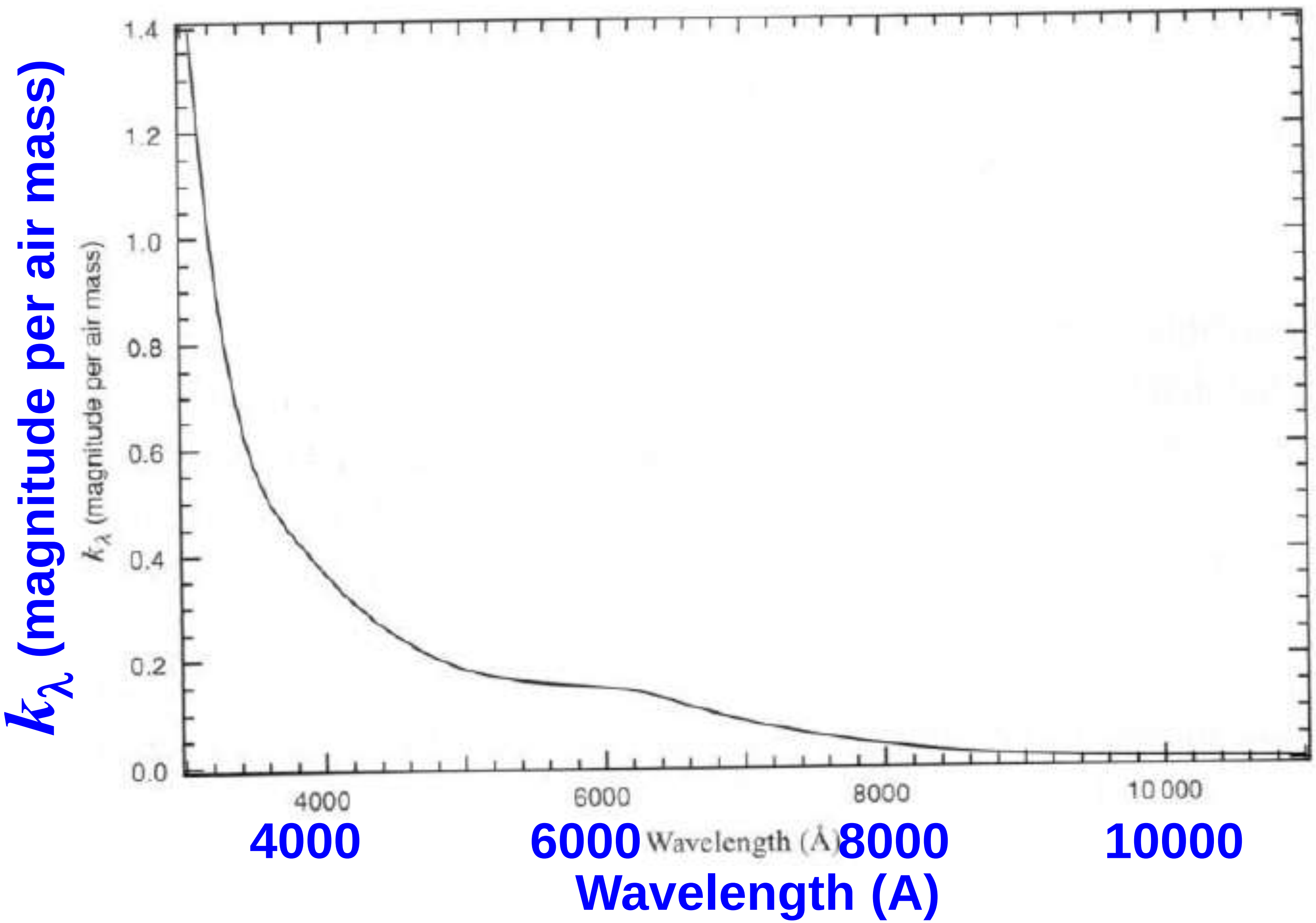


Figure 7.5. Variation of extinction with wavelength. The data are from the Cerro Tololo Interamerican Observatory in Chile (see Stritziger *et al.*, 2005).

Atmospheric extinction

Dependence with Wavelength

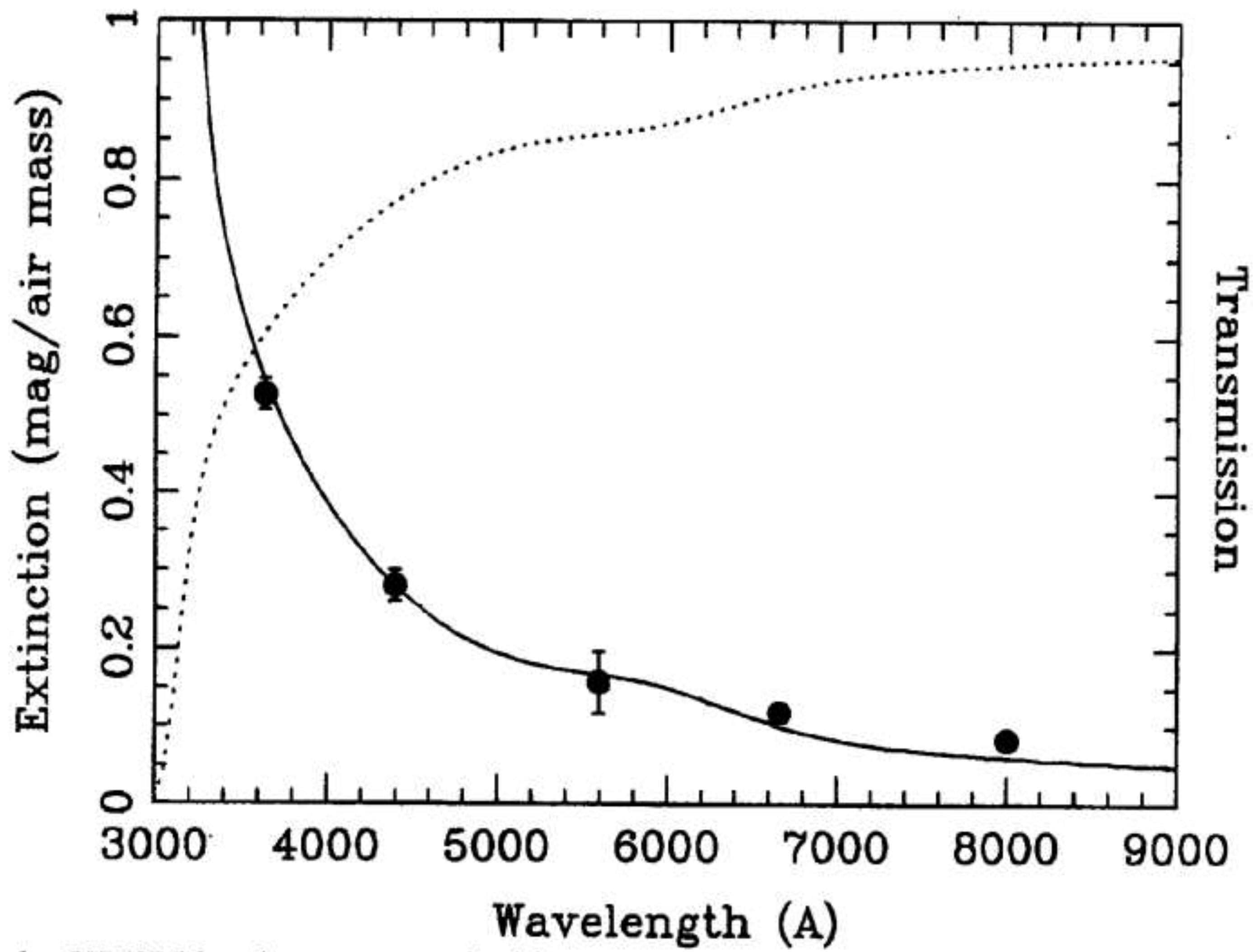


FIG. 5—The atmospheric extinction in the *UBVRI* bands as measured with FOTRAP at LNA (1864 m above sea level). The continuous curve is the semiempirical model of Bessell (1990) and Hayes and Latham (1975) for the extinction. The dotted line is the corresponding transmission. This curve is used to obtain the *UX* and *BX* passbands of Table 3 and Fig. 3.

Atmospheric extinction

Second-order extinction (color term)

$$k_V = k'_V + k''_{V,BV} \cdot (B - V)$$

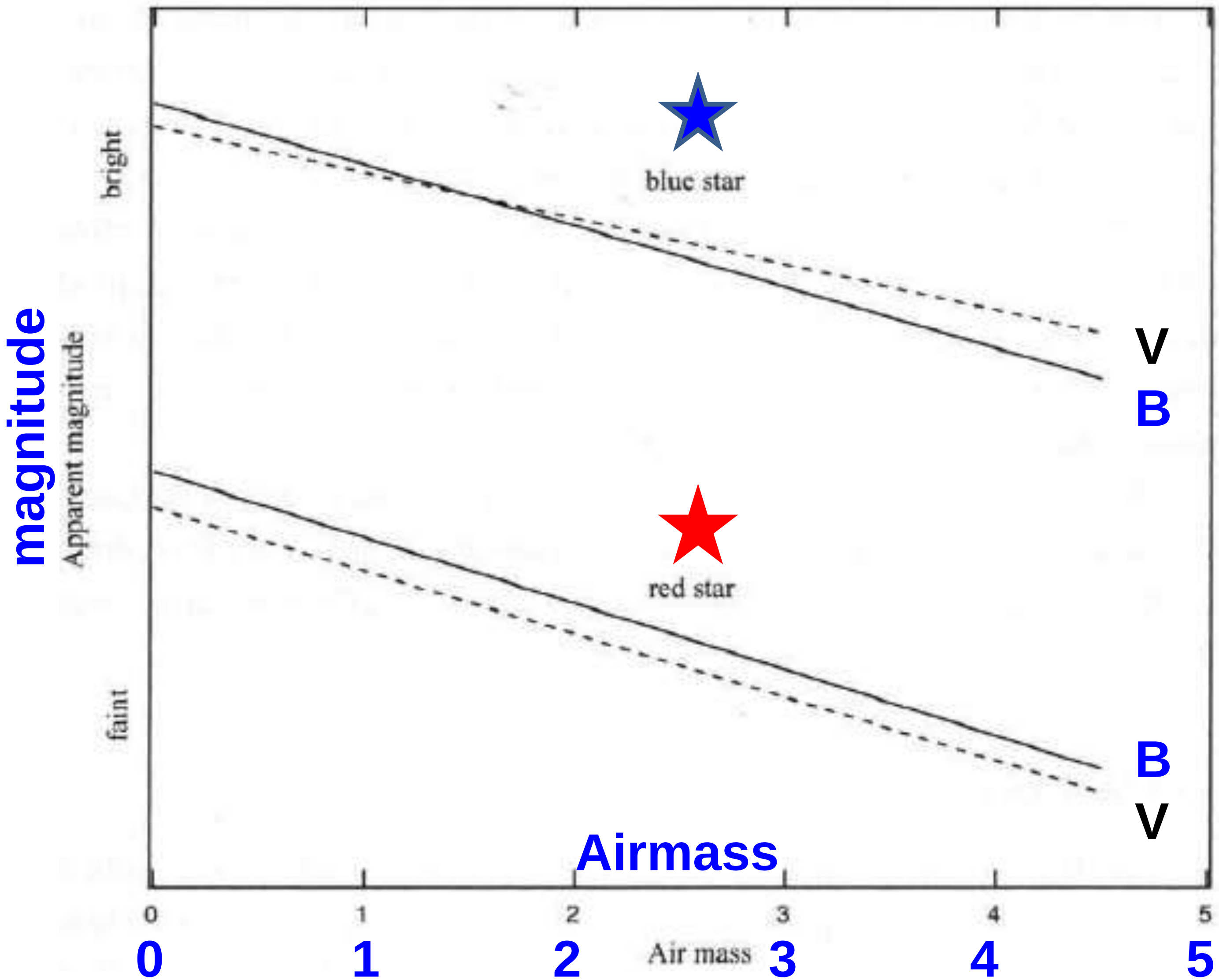


Figure 7.6. The extinction coefficient depends on the color of the star. The solid lines are for blue magnitudes and the dashed lines are for visual magnitudes.

Após a correção das magnitudes instrumentais pela extinção atmosférica …

Conversion to a standard system

Observed instrumental *magnitudes of standards:* ***b_0 , v_0 , r_0 , i_0***

Magnitudes of standard stars in the $BV(RI)_C$ system: ***B , V , R , I***

- Most simple transforming relations:

The transformation coefficients are obtained by relating the standard and extinction-corrected magnitudes as follows

$$B - V = \phi_{bv} + \mu_{bv}(b - v)_0$$

$$V = v_0 + \phi_v + \varepsilon(B - V)$$

$$V - R = \phi_{vr} + \mu_{vr}(v - r)_0$$

$$R - I = \phi_{ri} + \mu_{ri}(r - i)_0$$

Coeficientes de transformação

Standard stars (e.g. Landolt)

Table 10.1. *Landolt Standard Area 110 standard and instrumental magnitudes*

Star	V	B – V	V – R	R – I	v_0	$(b-v)_0$	$(v-r)_0$	$(r-i)_0$
496	13.004	1.040	0.607	0.681	−8.830	1.815	0.772	0.288
499	11.737	0.987	0.600	0.674	−10.097	1.695	0.792	0.121
502	12.330	2.326	1.373	1.250	−9.589	3.030	1.512	0.799
503	11.773	0.671	0.373	0.436	−10.044	1.375	0.537	−0.003
504	14.022	1.248	0.797	0.683	−7.848	2.070	0.928	0.225
506	11.312	0.568	0.335	0.312	−10.506	1.247	0.489	−0.135
507	12.440	1.141	0.633	0.579	−9.391	1.839	0.781	0.120

THE ASTRONOMICAL JOURNAL, 137:4186–4269, 2009 May
doi:10.1088/0004-6256/137

UBVRI PHOTOMETRIC STANDARD STARS AROUND THE CELESTIAL EQUATOR: UPDATES AND ADDITIONS

ARLO U. LANDOLT[1]
Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803-4001, USA; landolt@phys.lsu.edu
Received 2008 November 10; accepted 2008 December 24; published 2009 April 2

ABSTRACT

New broadband *UBVRI* photoelectric observations on the Johnson–Kron–Cousins photometric system have been made of 202 stars around the sky, and centered at the celestial equator. These stars constitute both an update of and additions to a previously published list of equatorial photometric standard stars. The list is capable of providing, for both celestial hemispheres, an internally consistent homogeneous broadband standard photometric system around the sky. When these new measurements are included with those previously published by Landolt (1992), the entire list of standard stars in this paper encompasses the magnitude range $8.90 < V < 16.30$, and the color index range $-0.35 < (B - V) < +2.30$.

Table 2
UBVRI Photometry of Standard Stars

											Mean Error of the Mean					
Star (1)	α (J2000.0) (2)	δ (J2000.0) (3)	*V* (4)	*B−V* (5)	*U−B* (6)	*V−R* (7)	*R−I* (8)	*V−I* (9)	*n* (10)	*m* (11)	*V* (12)	*B−V* (13)	*U−B* (14)	*V−R* (15)	*R−I* (16)	*V−I* (17)
TPhe I	00 30 04.593	−46 28 10.17	14.820	+0.764	+0.338	+0.422	+0.395	+0.817	25	13	0.0026	0.0032	0.0072	0.0036	0.0098	0.0110
TPhe A	00 30 09.594	−46 31 28.91	14.651	+0.793	+0.380	+0.435	+0.405	+0.841	29	12	0.0028	0.0046	0.0071	0.0019	0.0035	0.0032
TPhe H	00 30 09.683	−46 27 24.30	14.942	+0.740	+0.225	+0.425	+0.425	+0.851	23	12	0.0029	0.0029	0.0071	0.0035	0.0077	0.0098
TPhe B	00 30 16.313	−46 27 58.57	12.334	+0.405	+0.156	+0.262	+0.271	+0.535	29	17	0.0115	0.0026	0.0039	0.0020	0.0019	0.0035
TPhe C	00 30 16.98	−46 32 21.4	14.376	−0.298	−1.217	−0.148	−0.211	−0.360	39	23	0.0022	0.0024	0.0043	0.0038	0.0133	0.0149
TPhe D	00 30 18.342	−46 31 19.85	13.118	+1.551	+1.871	+0.849	+0.810	+1.663	37	23	0.0033	0.0030	0.0118	0.0015	0.0023	0.0030
TPhe E	00 30 19.768	−46 24 35.60	11.631	+0.443	−0.103	+0.276	+0.283	+0.564	38	10	0.0017	0.0013	0.0025	0.0007	0.0016	0.0020
TPhe J	00 30 23.02	−46 23 51.6	13.434	+1.465	+1.229	+0.980	+1.063	+2.043	28	15	0.0023	0.0043	0.0059	0.0011	0.0015	0.0011
TPhe F	00 30 49.820	−46 33 24.07	12.475	+0.853	+0.534	+0.492	+0.437	+0.929	19	10	0.0008	0.0024	0.0095	0.0005	0.0014	0.0029
TPhe K	00 30 56.315	−46 23 26.04	12.935	+0.806	+0.402	+0.473	+0.429	+0.909	2	2	0.0007	0.0007	0.0163	0.0007	0.0001	0.0007

Padrões fotométricas de Landolt no campo em torno da variable Mira T Phe

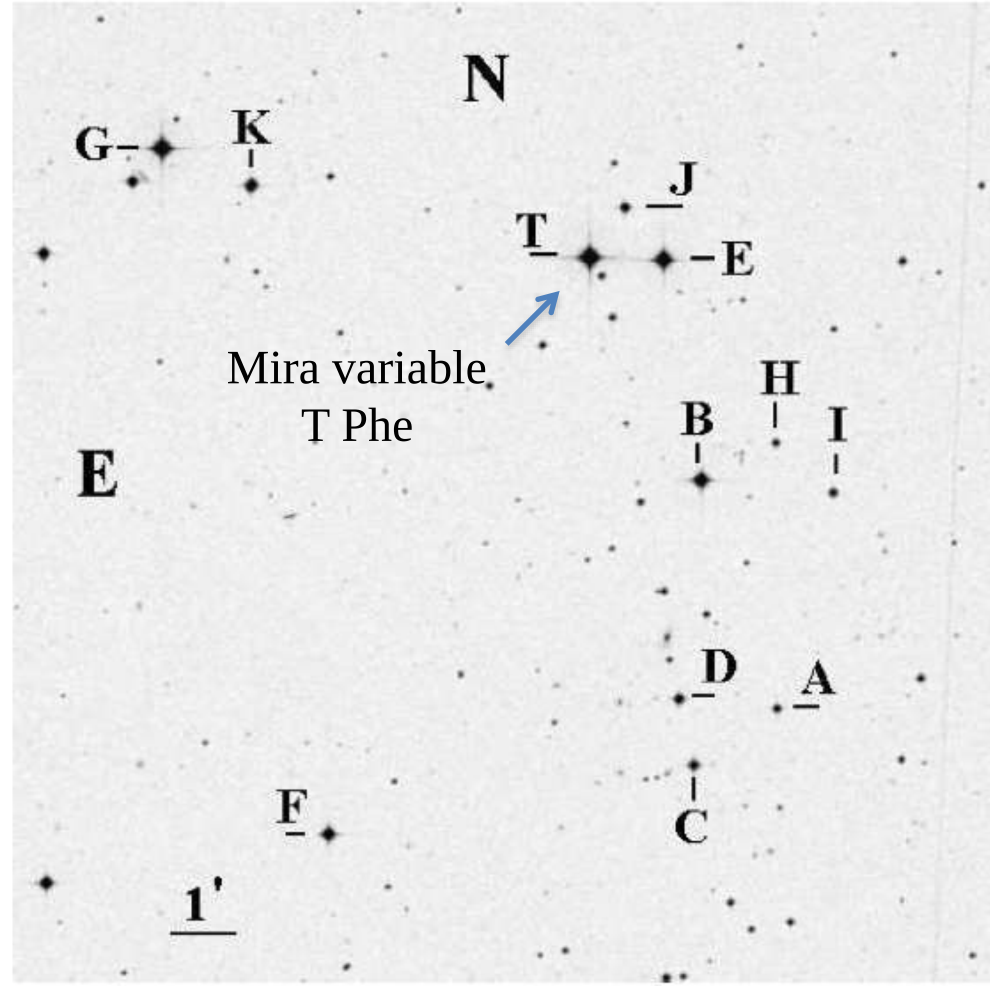


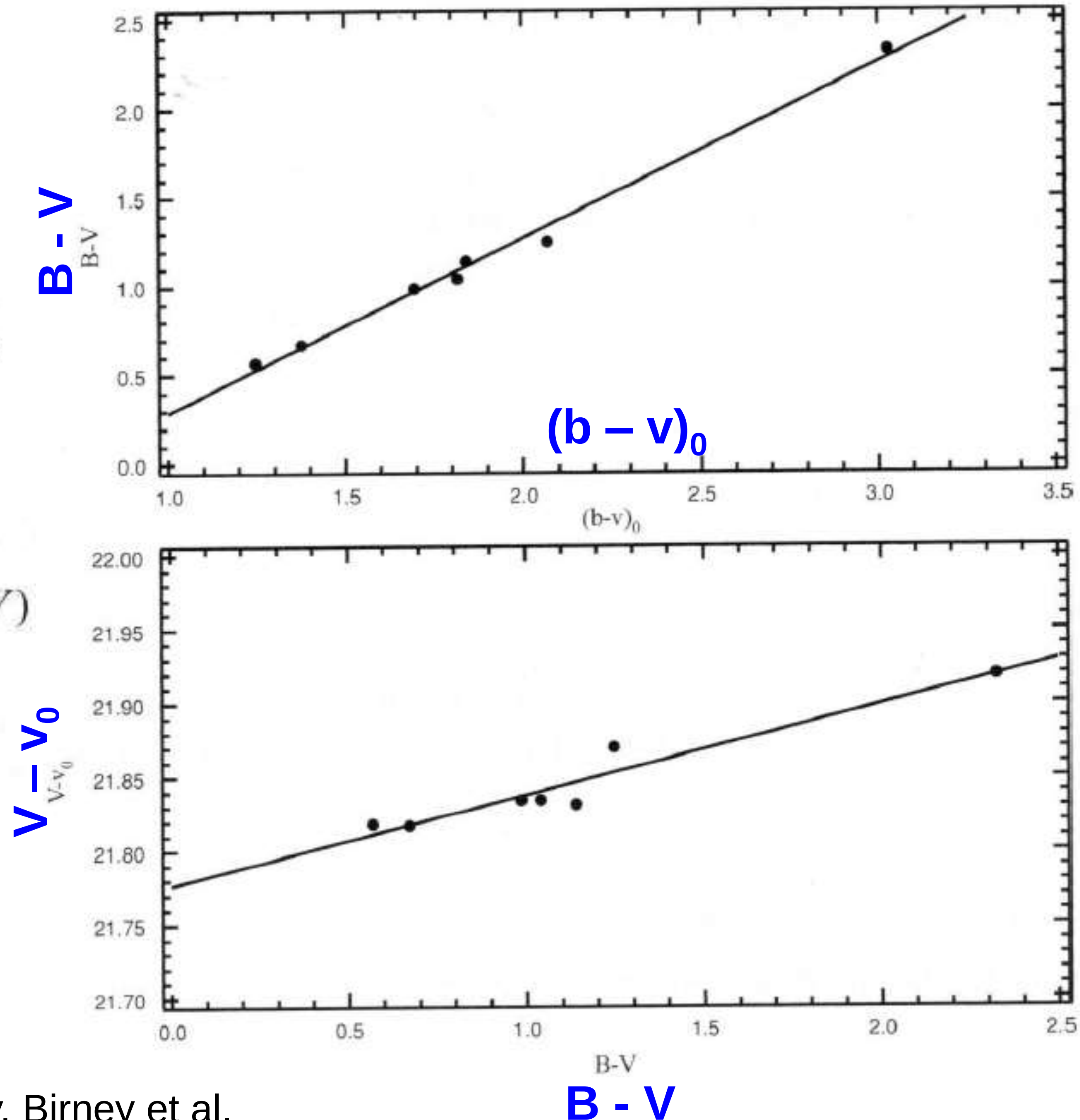
Figure 1. Field, 15′ on a side, of the sequence in the vicinity of the Mira variable star T Phe, marked as "T" in the figure.

Table 2
UBVRI Photometry of Standard Stars

											Mean Error of the Mean					
Star (1)	α (J2000.0) (2)	δ (J2000.0) (3)	V (4)	$B-V$ (5)	$U-B$ (6)	$V-R$ (7)	$R-I$ (8)	$V-I$ (9)	n (10)	m (11)	V (12)	$B-V$ (13)	$U-B$ (14)	$V-R$ (15)	$R-I$ (16)	$V-I$ (17)
TPhe I	00 30 04.593	−46 28 10.17	14.820	+0.764	+0.338	+0.422	+0.395	+0.817	25	13	0.0026	0.0032	0.0072	0.0036	0.0098	0.0110
TPhe A	00 30 09.594	−46 31 28.91	14.651	+0.793	+0.380	+0.435	+0.405	+0.841	29	12	0.0028	0.0046	0.0071	0.0019	0.0035	0.0032
TPhe H	00 30 09.683	−46 27 24.30	14.942	+0.740	+0.225	+0.425	+0.425	+0.851	23	12	0.0029	0.0029	0.0071	0.0035	0.0077	0.0098
TPhe B	00 30 16.313	−46 27 58.57	12.334	+0.405	+0.156	+0.262	+0.271	+0.535	29	17	0.0115	0.0026	0.0039	0.0020	0.0019	0.0035
TPhe C	00 30 16.98	−46 32 21.4	14.376	−0.298	−1.217	−0.148	−0.211	−0.360	39	23	0.0022	0.0024	0.0043	0.0038	0.0133	0.0149
TPhe D	00 30 18.342	−46 31 19.85	13.118	+1.551	+1.871	+0.849	+0.810	+1.663	37	23	0.0033	0.0030	0.0118	0.0015	0.0023	0.0030
TPhe E	00 30 19.768	−46 24 35.60	11.631	+0.443	−0.103	+0.276	+0.283	+0.564	38	10	0.0017	0.0013	0.0025	0.0007	0.0016	0.0020
TPhe J	00 30 23.02	−46 23 51.6	13.434	+1.465	+1.229	+0.980	+1.063	+2.043	28	15	0.0023	0.0043	0.0059	0.0011	0.0015	0.0011
TPhe F	00 30 49.820	−46 33 24.07	12.475	+0.853	+0.534	+0.492	+0.437	+0.929	19	10	0.0008	0.0024	0.0095	0.0005	0.0014	0.0029
TPhe K	00 30 56.315	−46 23 26.04	12.935	+0.806	+0.402	+0.473	+0.429	+0.909	2	2	0.0007	0.0007	0.0163	0.0007	0.0001	0.0007

Conversion to a standard system

Figure 10.3. Transformation coefficient examples. Top: standard B–V magnitudes are plotted against instrumental magnitudes. Bottom: difference between standard and instrumental visual magnitudes are plotted against B–V. The data are from Table 10.1. The straight lines are least-squares fits to the data.



$$B - V = \phi_{bv} + \mu_{bv}(b - v)_0$$

$$V = v_0 + \phi_v + \varepsilon(B - V)$$

$$V - R = \phi_{vr} + \mu_{vr}(v - r)_0$$

$$R - I = \phi_{ri} + \mu_{ri}(r - i)_0$$

Another option: simultaneously solve for extinction and transformation coefficients

X: massa de ar

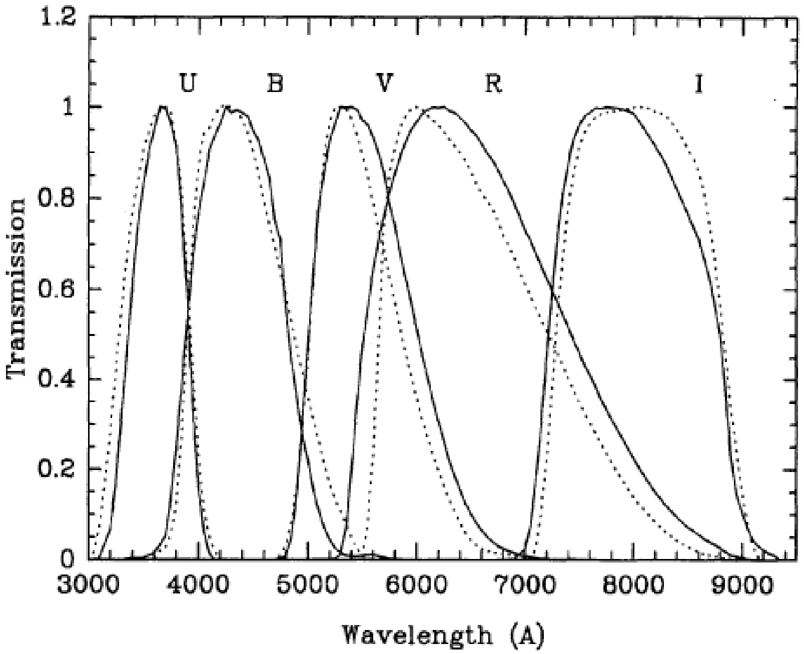


FIG. 3—The FOTRAP passbands (continuous curves) compared to the standard recipe (Bessell 1990; dotted curves). FOTRAP has a slightly narrower *U* but wider *V* and *R* responses with respect to the standard system. The *U* and *B* passbands shown here take into account the effect of the transparency of the atmosphere at one airmass (the *UX* and *BX* bands in Table 3).

The reduction program implements the prescriptions of Harris, Fitzgerald, and Reed (1981) to solve simultaneously for extinction and transformation coefficients. For each standard star the *V* magnitude and color indices can be written as

$$v-V=a_1+a_2X+a_3(B-V)+a_4X(B-V)+a_5(B-V)^2, \quad (1)$$

$$u-b=b_1+b_2X+b_3(U-B)+b_4X(U-B)+b_5(U-B)^2, \quad (2)$$

$$b-v=c_1+c_2X+c_3(B-V)+c_4X(B-V)+c_5(B-V)^2, \quad (3)$$

$$v-r=d_1+d_2X+d_3(V-R)+d_4X(V-R)+d_5(V-R)^2, \quad (4)$$

$$r-i=e_1+e_2X+e_3(R-I)+e_4X(R-I)+e_5(R-I)^2, \quad (5)$$

where the left-hand terms correspond to instrumental values and the capital symbols in the right hand are used to denote catalog values. *X* is the airmass. In the simultaneous least-squares solution each star's measurement is weighted by an error estimate calculated at acquisition time (which takes into account the contributions of photon noise, scintillation, misguiding, etc.). An adapted version of the subroutine LFIT in Press et al. (1986) was used for the simultaneous least-squares fit.

PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC
93:507–517, August 1981

PHOTOELECTRIC PHOTOMETRY: AN APPROACH TO DATA REDUCTION*

WILLIAM E. HARRIS
Department of Physics, McMaster University, 1280 Main Street West, Hamilton, Ontario, Canada L8S 4M1
M. PIM FITZGERALD AND B. CAMERON REED
Department of Physics, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1

THE ASTROPHYSICAL JOURNAL, 752:5 (13pp), 2012 June 10

Cores do Sol incluindo medidas do Brasil (OPD), Mexico e Africa

THE $UBV(RI)_C$ COLORS OF THE SUN

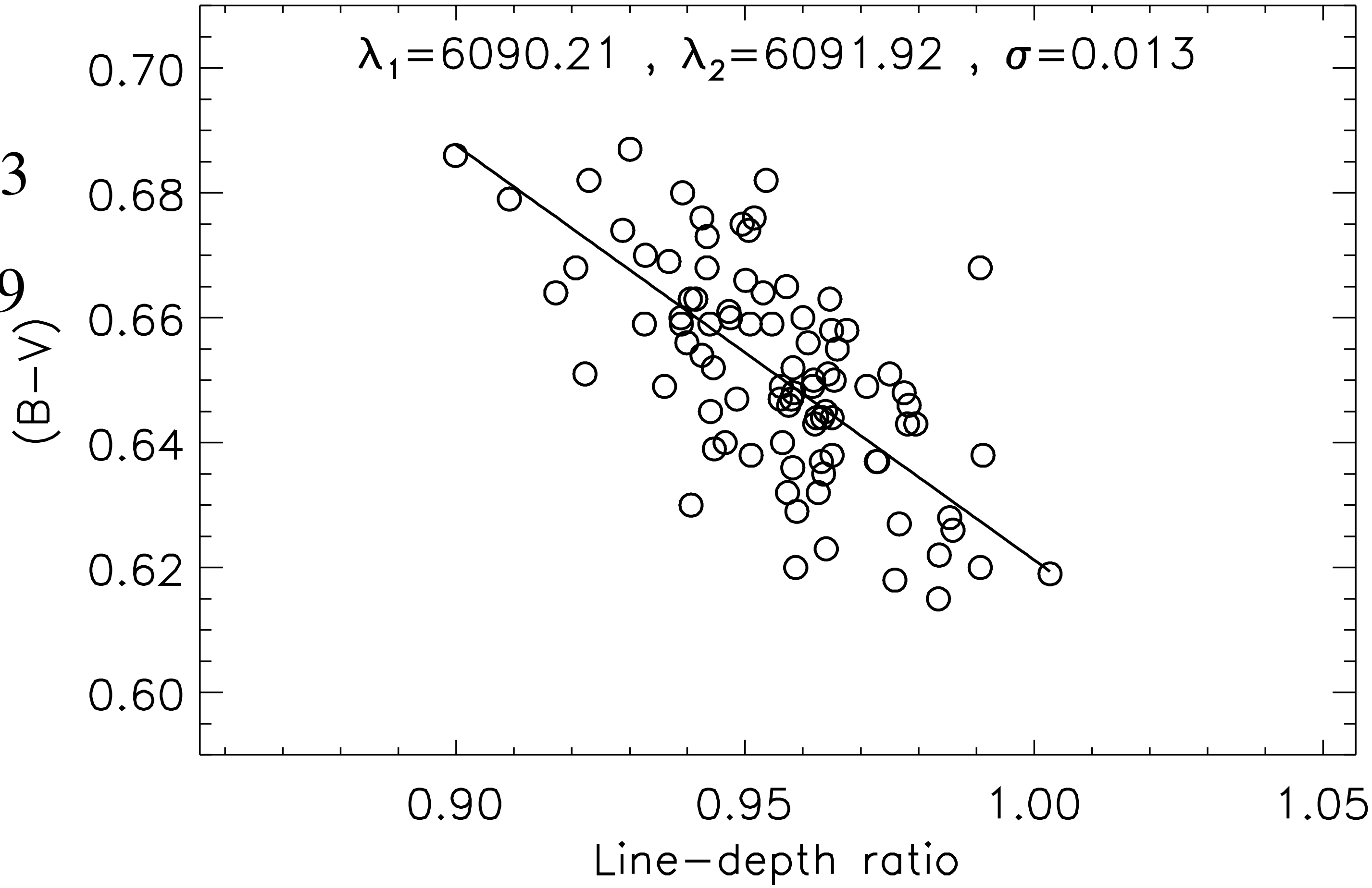
I. RAMÍREZ[1], R. MICHEL[2], R. SEFAKO[3], M. TUCCI MAIA[4,5], W. J. SCHUSTER[2], F. VAN WYK[3],
J. MELÉNDEZ[5], L. CASAGRANDE[6], AND B. V. CASTILHO[7]
[1] McDonald Observatory and Department of Astronomy, University of Texas at Austin, 1 University Station, C1400 Austin, TX 78712-0259, USA
[2] Observatorio Astronómico Nacional, Universidad Nacional Autónoma de México, Apartado Postal 877, Ensenada, B.C., CP 22800, Mexico
[3] South African Astronomical Observatory, P.O. Box 9, Observatory 7935, Cape Town, South Africa
[4] UNIFEI, DFQ–Instituto de Ciências Exatas, Universidade Federal de Itajubá, Itajubá MG, Brazil
[5] Departamento de Astronomia do IAG/USP, Universidade de São Paulo, Rua do Mãtao 1226, São Paulo, 05508-900 SP, Brazil
[6] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, Postfach 1317, D-85741 Garching, Germany
[7] Laboratório Nacional de Astrofísica/MCT, Rua Estados Unidos 154, 37504-364 Itajubá, MG, Brazil
Received 2012 February 22; accepted 2012 April 3; published 2012 May 18

$$(B-V)_\odot = 0.653 \pm 0.003$$

$$(U-B)_\odot = 0.158 \pm 0.009$$

$$(V-R)_\odot = 0.356 \pm 0.003$$

$$(V-I)_\odot = 0.701 \pm 0.003$$

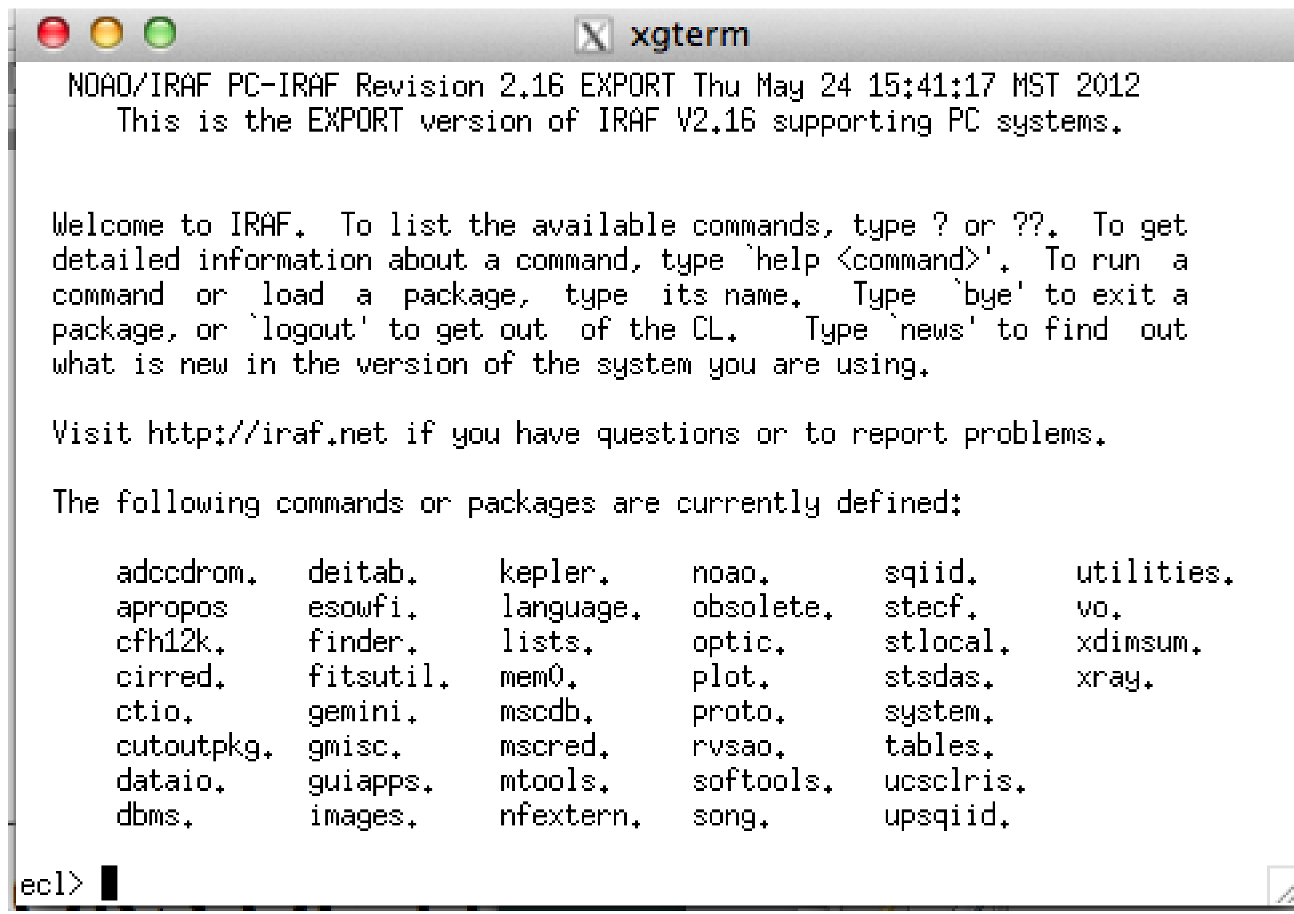


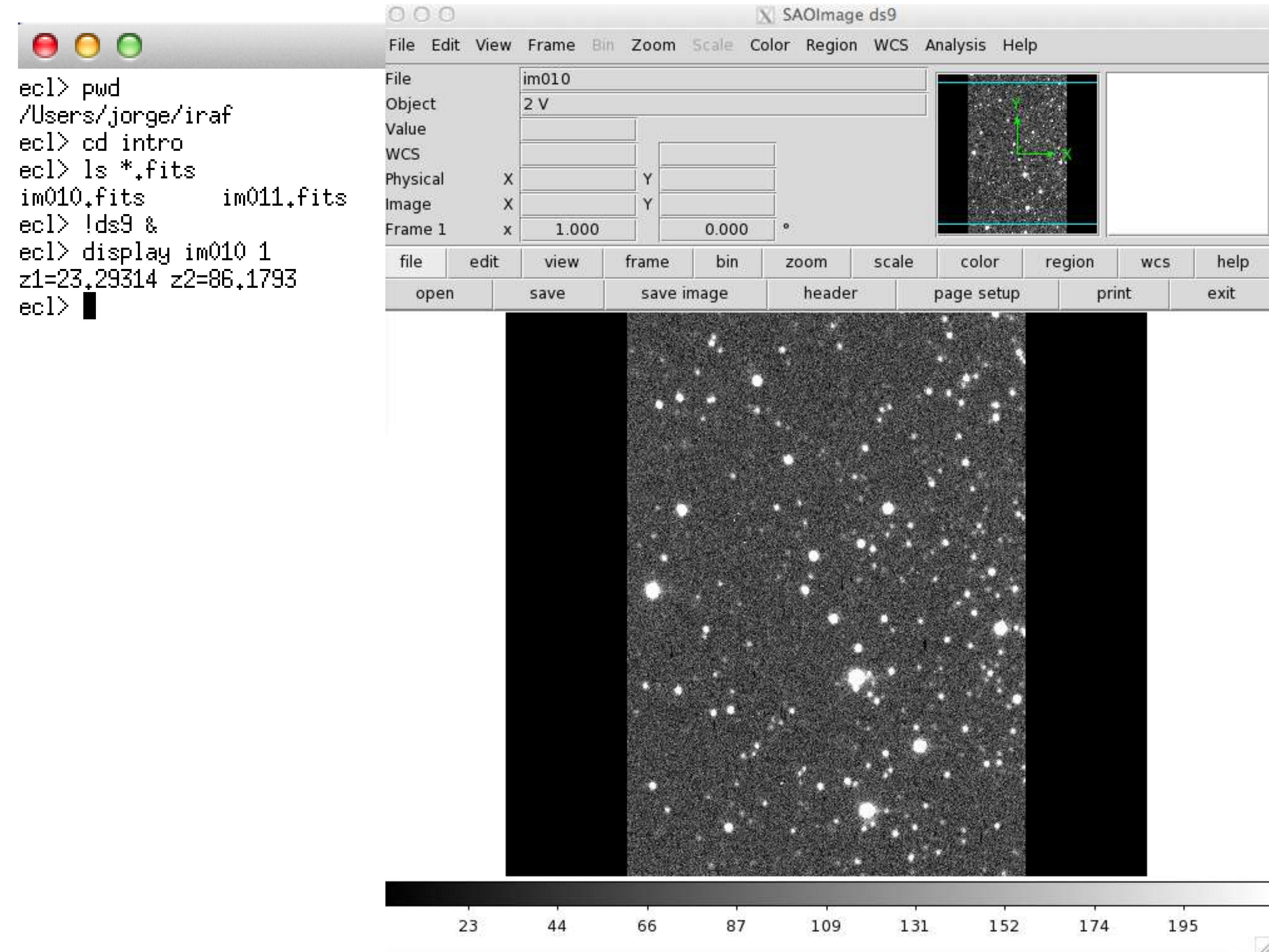
Fotometria básica com o IRAF

- Exemplo usando as imagens de M92 do tutorial básico do IRAF:
- im010.fits
- im011.fits
- Call iraf (type *cl*)

in a xgterm window

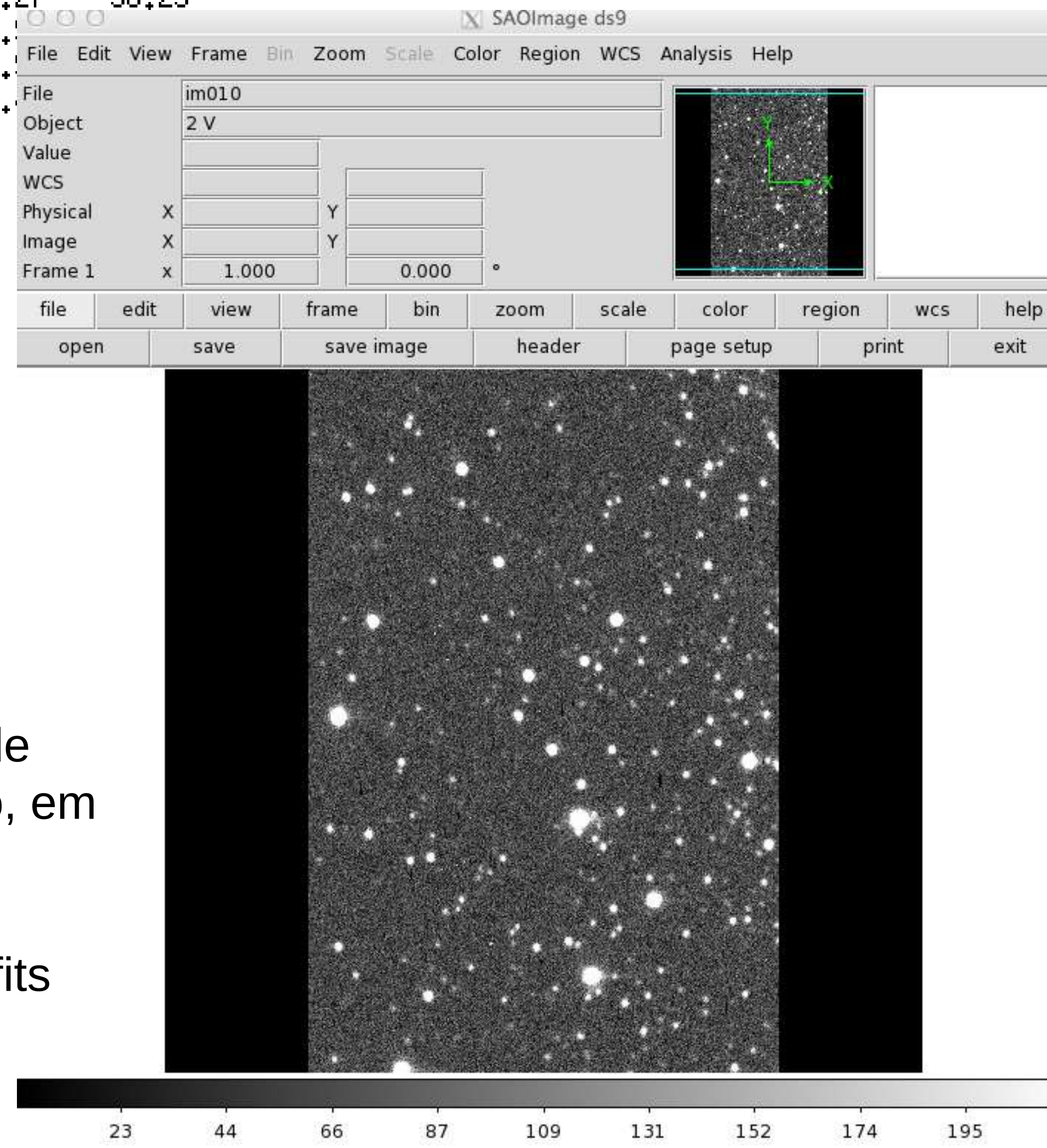
in the directory iraf




ecl> pwd
/Users/jorge/iraf
ecl> cd intro
ecl> ls *.fits
im010.fits im011.fits
ecl> !ds9 &
ecl> display im010 1
z1=23.29314 z2=86.1793
ecl>
SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File im010
Object 2 V
Value
WCS
Physical X Y
Image X Y
Frame 1 x 1.000 0.000 °
file edit view frame bin zoom scale color region wcs help
open save save image header page setup print exit
23 44 66 87 109 131 152 174 195

Imexam para estimar o céu (m)

```
ecl> imexam
#          SECTION     NPIX     MEAN   MEDIAN   STDDEV      MIN      MAX
  [153:157,415:419]      25     40.6    41.32     6.68    27.25    55.06
    [60:64,358:362]      25    40.36    39.05    6.935     28.6    52.28
    [62:66,301:305]      25     40.2    39.38    9.008    23.54    58.13
    [26:30,214:218]      25     39.5    38.84    5.543    27.12     47.9
  [128:132,195:199]      25     38.6    39.48    8.176    17.55    52.31
  [223:227,174:178]      25    42.13    38.29    8.028    32.27    56.25
  [104:108,107:111]      25    40.54      41.    8.078    23.
    [145:149,52:56]      25    42.65    41.12    6.715    28.
    [47:51,135:139]      25    41.07    40.49    8.399    27.
```



Não é necessario tirar o céu pois as tarefas de fotometria ajustam o nivel do céu. No entanto, em primeiro aproximação:

imarith imagem.fits – ceu imagem_sem_ceu.fits
No exemplo acima, ceu ~ 40.

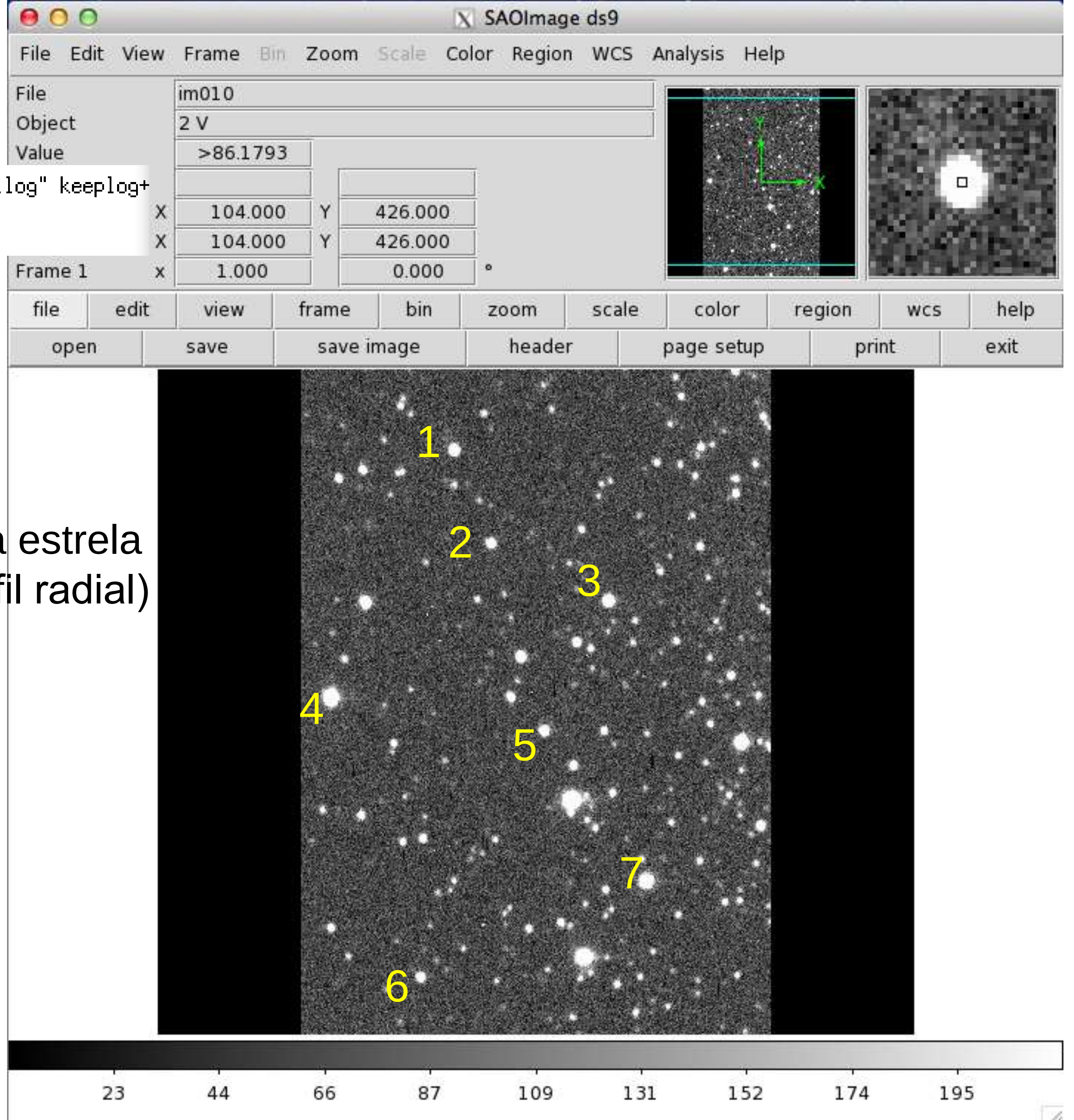
```
xgterm
ecl> epar imexamine
```

epar: editar parâmetros

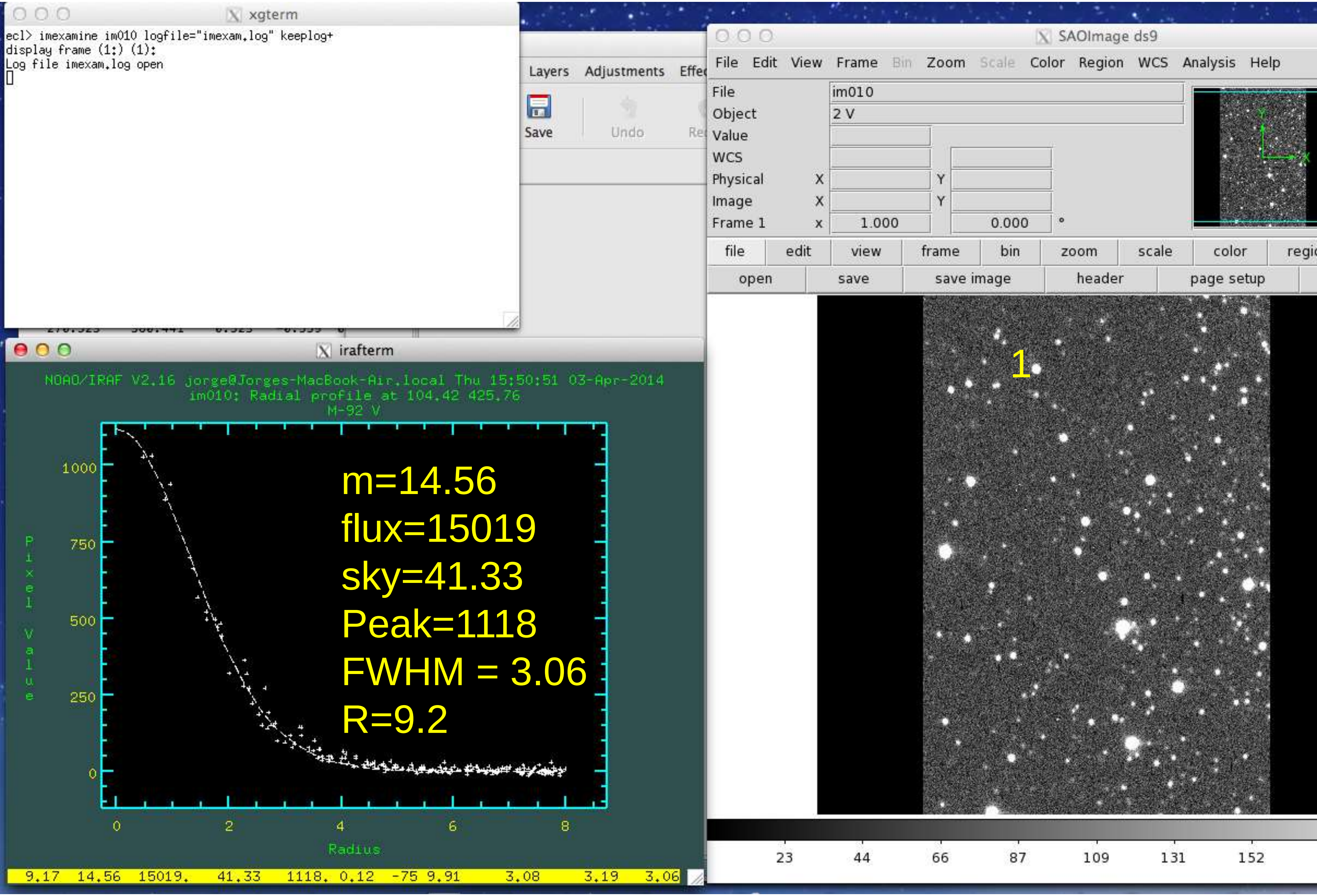
```
xgterm
                              I R A F
                Image Reduction and Analysis Facility
PACKAGE = tv
   TASK = imexamine

input   =                          images to be examined
(output =                        ) output root image name
(ncoutpu=                     101) Number of columns in image output
(nloutpu=                     101) Number of lines in image output
frame   =                       1  display frame
image   =                          image name
(logfile=                        ) logfile
(keeplog=                      no) log output results
(defkey =                       a) default key for cursor list input
(autored=                     yes) automatically redraw graph
(allfram=                     yes) use all frames for displaying new images
(nframes=                       0) number of display frames (0 to autosense)
(ncstat =                       5) number of columns for statistics
(nlstat =                       5) number of lines for statistics
(graphcu=                        ) graphics cursor input
(imagecu=                        ) image display cursor input
(wcs    =                 logical) Coordinate system
More
ecl> imexamine im010 logfile="imexam.log" keeplog+
```

Para sair: CTRL-D

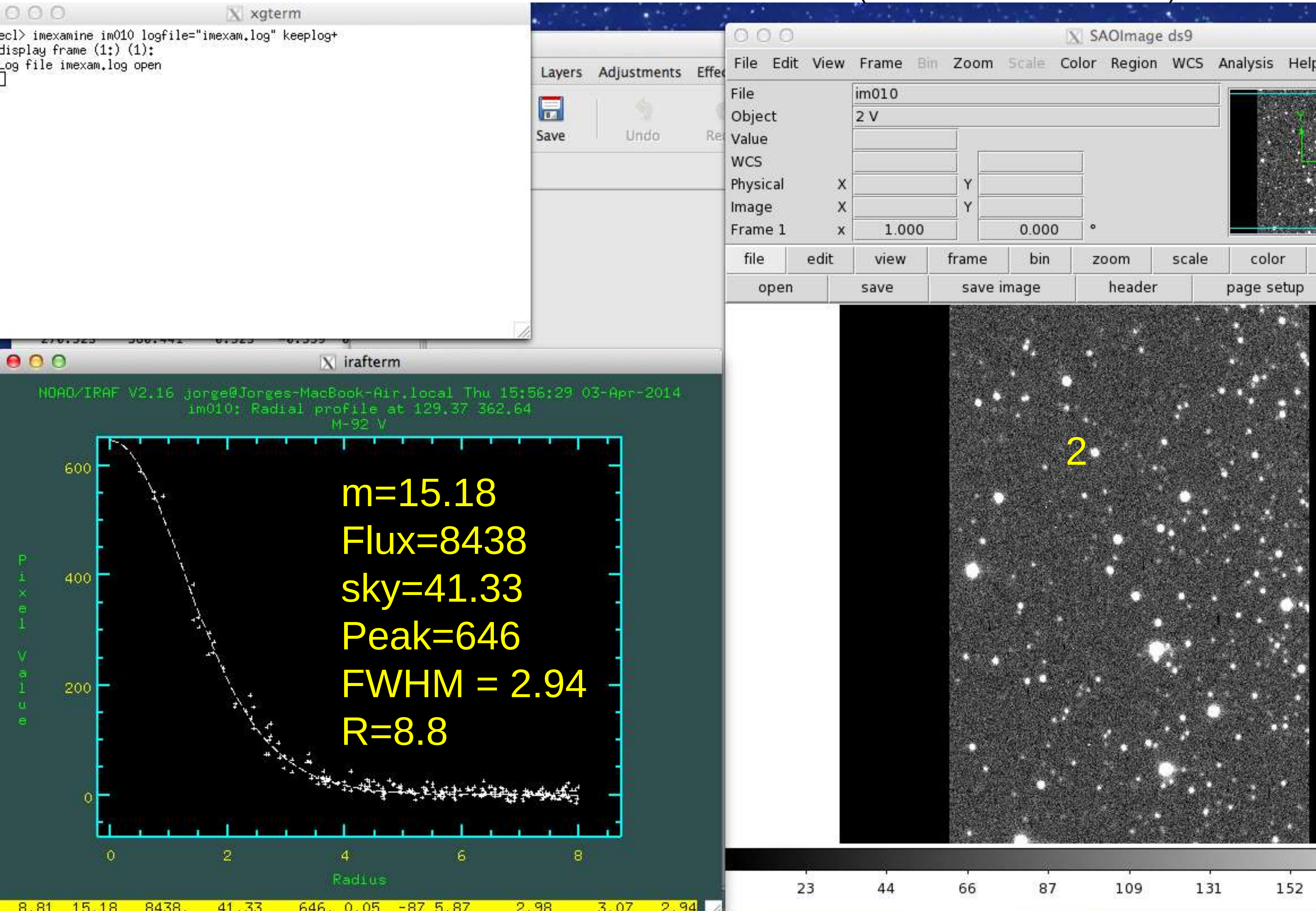
```
ecl> imexamine im010 logfile="imexam.log" keeplog+
display frame (1:) (1):
Log file imexam.log open
```



Posicionar o cursor na estrela indicada e dar “r” (perfil radial) “r” no ds9 (centralizado na estrela)



“r” no ds9 (centralizado na estrela)



cl>!gedit imexam.log (para linux)

ou

cl> !open –a textedit imexam.log (para mac)

imexam.log

```
# [1] im010 - M-92 V
#   COL     LINE    COORDINATES        R      MAG      FLUX       SKY      PEAK     E    PA BETA ENCLOSED    MOFFAT DIRECT
 104.42   425.76 104.42 425.76      9.17    14.56    15019.     41.33     1118.  0.12   -75 9.91      3.08      3.19   3.06
#   COL     LINE    COORDINATES        R      MAG      FLUX       SKY      PEAK     E    PA BETA ENCLOSED    MOFFAT DIRECT
 129.37   362.64 129.37 362.64      8.81    15.18     8438.     41.33      646.  0.05   -87 5.87      2.98      3.07   2.94
```

Algumas dicas básicas adicionais

http://www.astronomy.pomona.edu/astro101/iraf.phot.html

- Para uma fotometria mais completa de amostras de estrelas pode ser usado o pacote digiphot

cl> digiphot

apphot. daophot. photcal. ptools.

Usar o sub-pacote apphot

- **di> apphot**
- aptest findpars@ pconvert polymark psort center fitpsf pdump polypars@ qphot centerpars@ fitsky pexamine polyphot radprof daofind fitskypars@ phot prenumber wphot datapars@ pcalc photpars@ pselect

E fazer fotometria com a tarefa phot

Para criar listas de estrelas usar a tarefa daofind

Para extrair a fotometria dos arquivos de magnitudes, usar a tarefa txdump