ASSIGNMENT #5: due Friday, April 1st

ABSOLUTE MAGNITUDE AND H-R DIAGRAM

Apparent magnitude (bolometric, i.e., integrated over all wavelengths or frequencies):

$$m = -2.5 \log_{10} f + ZP$$

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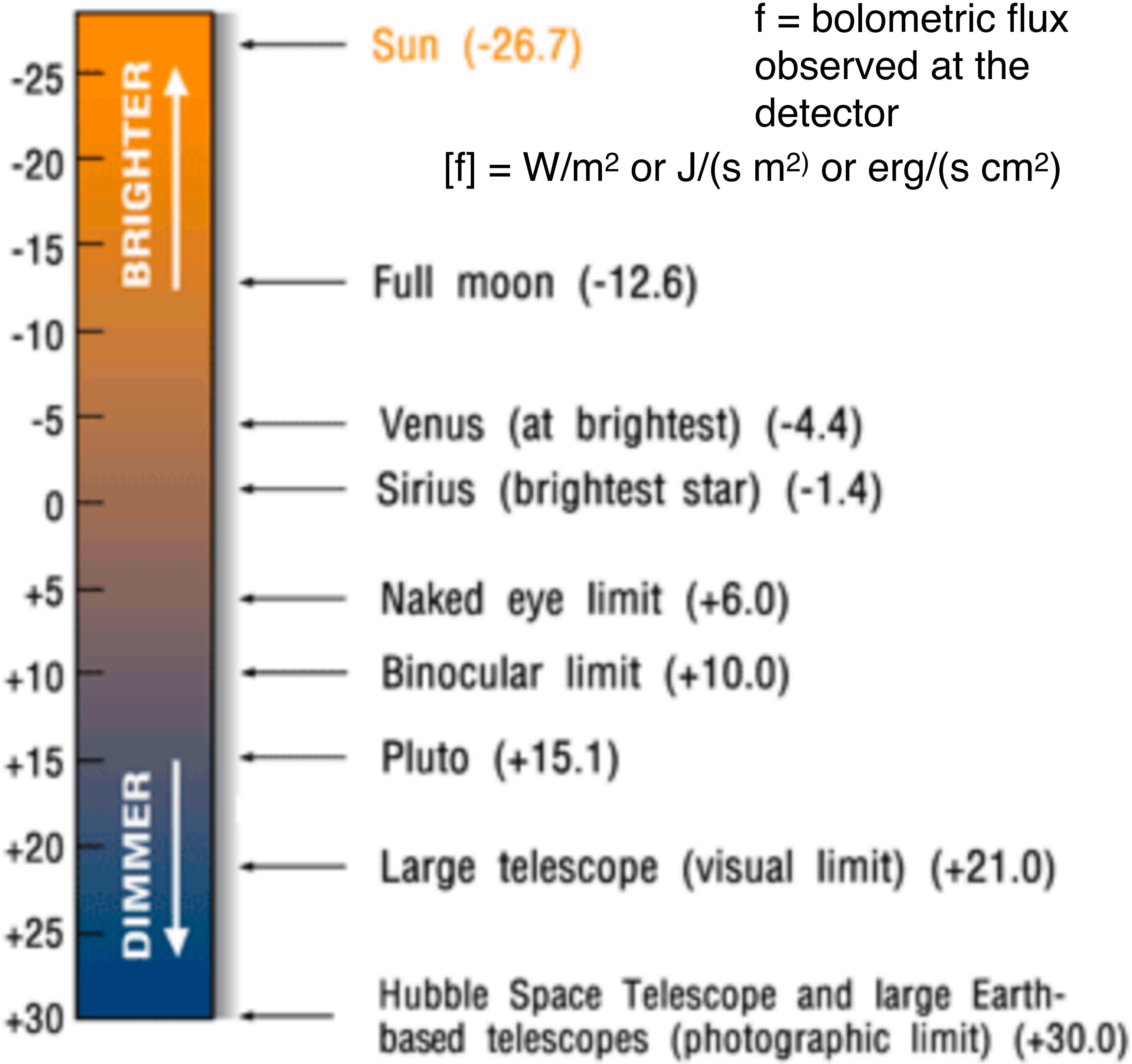

Bolometric luminosity: $L = 4\pi d^2 f$

d = distance from observer to source

[L] = W or J/s or erg/s

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$$M = -2.5 \log \frac{L}{4\pi(10pc)^2} + ZP = -2.5 \log \left(\frac{d}{10pc}\right)^2 f + ZP$$

This is bolometric (because f is the integral over all frequencies or wavelengths)

AB magnitude system

$$m_x = -2.5 \log \frac{\int \frac{d\nu}{\nu} f_\nu(\nu) \cancel{R}(\nu)}{\int \frac{d\nu}{\nu} g_\nu^x(\nu) \cancel{R}(\nu)}$$

AB magnitude system

Flux density of the source
[energy / (area * time * frequency)]
[erg/(s cm^2 Hz)]

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Filter transmission curve

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Filter transmission curve

Spectral density of flux for the standard/calibration source. For the Vega magnitude system, this is the flux density of the star Vega. For the AB magnitude system:

$$g_\nu^{AB}(\nu) = 3631\ Jy = 3631 \times 10^{-26}\ \frac{W}{m^2\ Hz} = 3631 \times 10^{-23}\ \frac{erg}{s\ cm^2\ Hz}$$

$$\Rightarrow \quad m_X^{AB} = -2.5 \log \frac{\int \frac{d\nu}{\nu} f_\nu(\nu) X(\nu)}{\int \frac{d\nu}{\nu} X(\nu)} - 48.6$$

Apparent magnitude in the filter X in AB mag

$$\underline{\underline{\text{IF}}} \quad [f_\nu(\nu)] = \frac{\text{erg}}{\text{s cm}^2\ \text{Hz}}$$

$$M_X^{AB} = -2.5 \log \frac{\int \frac{d\nu}{\nu} \frac{L_\nu(\nu)}{4\pi (10\,\text{pc})^2} X(\nu)}{\int \frac{d\nu}{\nu} X(\nu)} - 48.6$$

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Absolute magnitude in the filter X in AB mag

NOTE: the templates in Assignment #5 already provide

$$\frac{L_\lambda(\lambda)}{4\pi(10pc)^2} = f_\lambda \ @ \ d = 10pc$$

$$\frac{L_\nu(\nu)}{4\pi(10pc)^2} = \frac{L_\lambda(\lambda)}{4\pi(10pc)^2} \frac{\lambda^2}{c}$$

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Apparent magnitude in the filter X in AB mag

IF $[f_\nu(\nu)] = \frac{erg}{s\ cm^2\ Hz}$

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SUN: M_V=4.8, T_{eff}=5800 K, Type=G2V

Blackbody flux density:

$$F_\nu = \frac{2\pi h \nu^3}{c^2} \frac{1}{e^{h\nu/kT} - 1} \equiv f(\nu, T) \quad \frac{\text{erg}}{\text{s cm}^2\,\text{Hz}}$$

w/ $h = 6.626068 85 \times 10^{-27}$ erg/s

$c = 2.99792458 \times 10^{10}$ cm/s

$k = 1.38064852 \times 10^{-16}$ erg/K

Table.dat

```
# FILENAME      SpectralType    LumClass  T_eff[K]
pickles_uk_1    O5              V         39810.7
pickles_uk_2    O9              V         35481.4
pickles_uk_3    B0              V         28183.8
pickles_uk_4    B1              V         22387.2
pickles_uk_5    B3              V         19054.6
pickles_uk_6    B6              V         14125.4
pickles_uk_7    B8              V         11749.0
pickles_uk_9    A0              V         9549.93
pickles_uk_10   A2              V         8912.51
pickles_uk_11   A3              V         8790.23
pickles_uk_12   A5              V         8491.80
pickles_uk_14   F0              V         7211.08
pickles_uk_15   F2              V         6776.42
pickles_uk_16   F5              V         6531.31
pickles_uk_20   F8              V         6039.48
pickles_uk_23   G0              V         5807.64
pickles_uk_26   G2              V         5636.38
pickles_uk_27   G5              V         5584.70
pickles_uk_30   G8              V         5333.35
pickles_uk_31   K0              V         5188.00
pickles_uk_33   K2              V         4886.52
```

pickles_uk_8.ascii

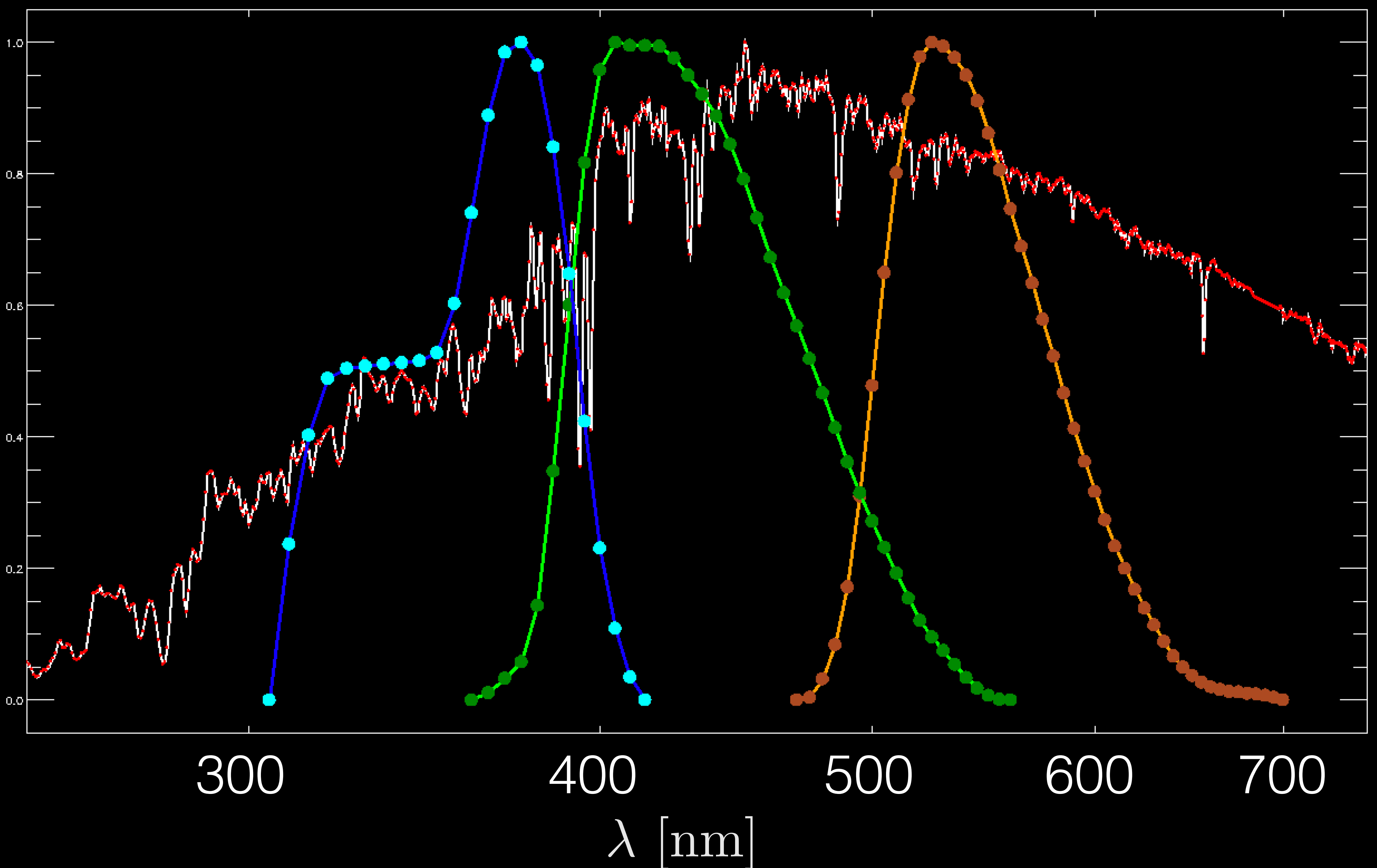
```
# Wavelength is in Angstrom
# Fluxes are tabulated in units of erg/s/cm^2/A @ d=10pc
# wavelength    flux
  1.150000E+03  0.000000E+00
  1.155000E+03  0.000000E+00
  1.160000E+03  0.000000E+00
  1.165000E+03  0.000000E+00
  1.170000E+03  0.000000E+00
  1.175000E+03  0.000000E+00
  1.180000E+03  0.000000E+00
  1.185000E+03  0.000000E+00
  1.190000E+03  0.000000E+00
  1.195000E+03  0.000000E+00
  1.200000E+03  0.000000E+00
  1.205000E+03  0.000000E+00
  1.210000E+03  0.000000E+00
  1.215000E+03  0.000000E+00
  1.220000E+03  0.000000E+00
  1.225000E+03  0.000000E+00
  1.230000E+03  0.000000E+00
  1.235000E+03  0.000000E+00
  1.240000E+03  0.000000E+00
```

V155 filter

```
#    47 REST_FRAME/maiz-apellaniz_Johnson_V.res 2006AJ....131.1184M lambda_c= 5.4794e+03 AB-Vega= 0.002 w95=1369.1
1      4.70000e+03 0.00000e+00
2      4.75000e+03 4.00000e-03
3      4.80000e+03 3.20000e-02
4      4.85000e+03 8.40000e-02
5      4.90000e+03 1.72000e-01
6      4.95000e+03 3.10000e-01
7      5.00000e+03 4.78000e-01
8      5.05000e+03 6.50000e-01
9      5.10000e+03 8.02000e-01
10     5.15000e+03 9.13000e-01
11     5.20000e+03 9.78000e-01
12     5.25000e+03 1.00000e+00
13     5.30000e+03 9.94000e-01
14     5.35000e+03 9.77000e-01
15     5.40000e+03 9.50000e-01
16     5.45000e+03 9.11000e-01
17     5.50000e+03 8.62000e-01
18     5.55000e+03 8.06000e-01
19     5.60000e+03 7.47000e-01
20     5.65000e+03 6.90000e-01
```

columns to add after calculating magnitudes/colors

# template	type	class	temp[K]	M_V[AB]	M_B[AB]	M_U[AB]	U-B[AB]	B-V[AB]
pickles_uk_1	O5	V	39810.70	-5.400	-5.893	-6.212	-0.319	-0.493
pickles_uk_2	O9	V	35481.40	-4.000	-4.444	-4.717	-0.273	-0.444
pickles_uk_3	B0	V	28183.80	-3.700	-4.155	-4.352	-0.198	-0.455
pickles_uk_4	B1	V	22387.20	-3.200	-3.556	-3.663	-0.107	-0.356
pickles_uk_5	B3	V	19054.60	-2.100	-2.413	-2.274	0.139	-0.313
pickles_uk_6	B57	V	14125.40	-0.700	-0.951	-0.550	0.401	-0.251
pickles_uk_7	B8	V	11749.00	0.000	-0.220	0.371	0.591	-0.220
pickles_uk_9	A0	V	9549.93	0.600	0.504	1.357	0.854	-0.096
pickles_uk_10	A2	V	8912.51	1.100	1.018	1.920	0.902	-0.082
pickles_uk_11	A3	V	8790.23	1.400	1.378	2.271	0.893	-0.022
pickles_uk_12	A5	V	8491.80	1.900	1.943	2.860	0.917	0.043
pickles_uk_14	F0	V	7211.08	2.600	2.794	3.683	0.889	0.194
pickles_uk_15	F2	V	6776.42	2.900	3.187	4.026	0.840	0.287
pickles_uk_16	F5	V	6531.31	3.400	3.750	4.565	0.815	0.350
pickles_uk_20	F8	V	6039.48	3.900	4.335	5.251	0.916	0.435
pickles_uk_23	G0	V	5807.64	4.300	4.764	5.747	0.983	0.464
pickles_uk_26	G2	V	5636.38	4.700	5.227	6.268	1.040	0.527
pickles_uk_27	G5	V	5584.70	5.200	5.781	6.916	1.136	0.581
pickles_uk_30	G8	V	5333.35	5.600	6.247	7.483	1.236	0.647
pickles_uk_31	K0	V	5188.00	5.900	6.566	7.865	1.299	0.666
pickles_uk_33	K2	V	4886.52	6.400	7.221	8.741	1.521	0.821
pickles_uk_36	K5	V	4187.94	7.200	8.307	10.334	2.027	1.107
pickles_uk_37	K7	V	3999.45	7.900	9.171	11.161	1.989	1.271
pickles_uk_38	M0	V	3801.89	9.000	10.223	12.312	2.089	1.223
pickles_uk_40	M2	V	3548.13	11.200	12.539	14.503	1.964	1.339
pickles_uk_43	M4	V	3111.72	13.400	14.895	17.218	2.323	1.495
pickles_uk_44	M5	V	2951.21	14.600	16.165	18.404	2.239	1.565
pickles_uk_46	B2	IV	19952.60	-3.400	-3.815	-3.884	-0.069	-0.415



1.0
0.8
0.6
0.4
0.2
0.0
300
400
500
600
700
λ [nm]

$\vec{\lambda}_{filter}^{v} = [\lambda_1^v, \lambda_2^v, \dots, \lambda_N^v]$ } filter table

$\vec{T}_v$

$\vec{\lambda}^* = [\lambda_1^*, \lambda_2^*, \dots, \lambda_M^*]$ } star spectrum/template

$\vec{f}_\lambda^* = \frac{L_\lambda(\lambda)}{4\pi(10pc)^2} = [f_1^*, f_2^*, \dots, f_M^*]$

$$M_X^{AB} = -2.5 \log \frac{\int_0^\infty \frac{d\nu}{\nu} \frac{L_\nu(\nu)}{4\pi(10pc)^2} T(\nu)}{\int_0^\infty \frac{d\nu}{\nu} T(\nu)} - 48.6$$

IF $\left[\frac{L_\nu(\nu)}{4\pi(10pc)^2}\right] = \frac{erg}{s\, cm^2\, Hz}$

1) $\frac{L_\nu(\nu)}{4\pi(10pc)^2} = \vec{f}_\lambda^* \cdot \frac{\vec{\lambda}^{*2}}{c} = \vec{f}_\nu^*$

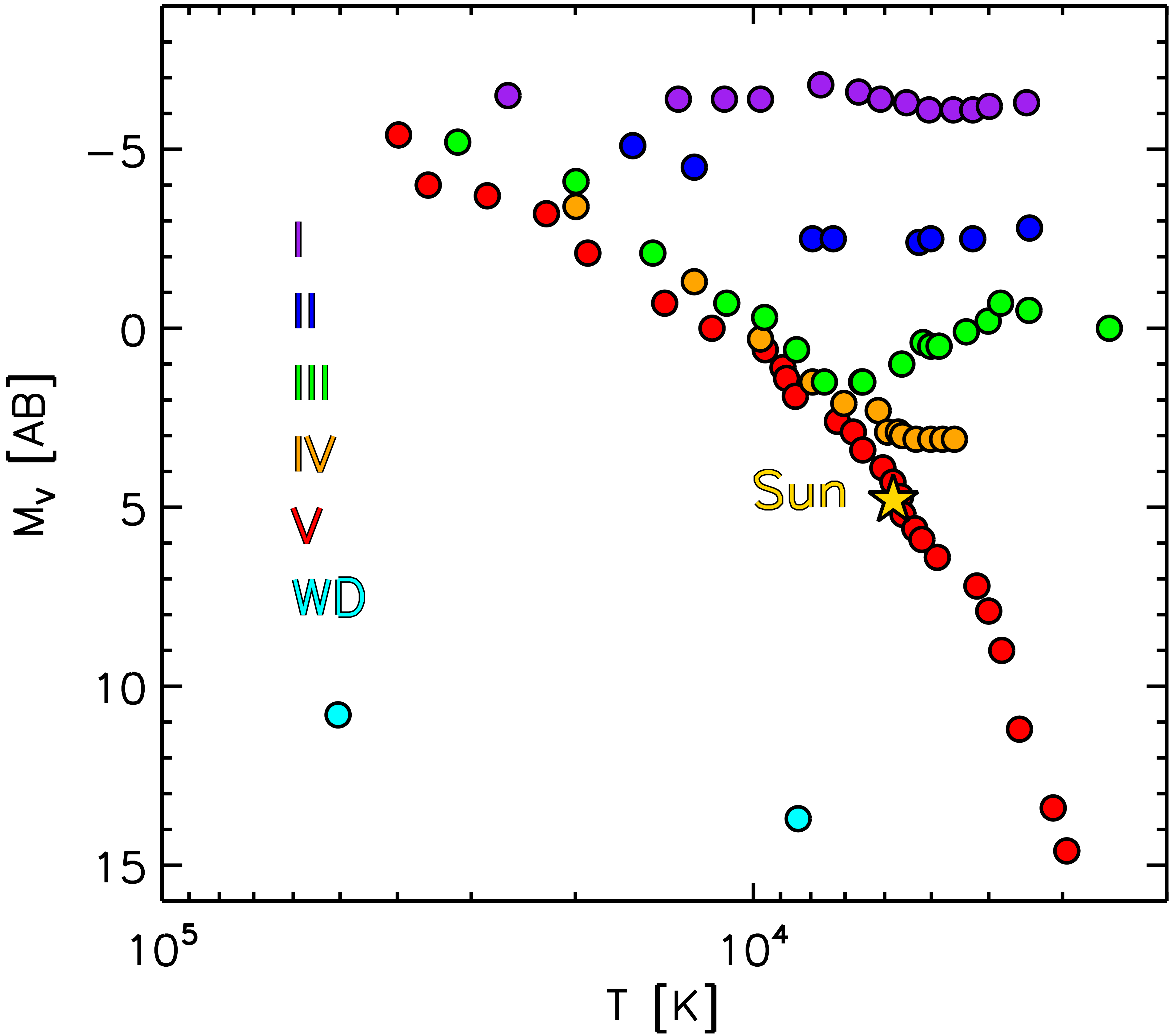
from star template

$\vec{\nu}_{filter} = \frac{c}{\vec{\lambda}_{filter}}$

$\vec{\nu}^* = \frac{c}{\vec{\lambda}^*}$

2) Interpolate $\vec{\nu}^*, \vec{f}_\nu^*$ @ $\vec{\nu}_{filter}$

H-R diagram - v1



H-R diagram - v2