

**ASSIGNMENT #5: due Friday, April 1<sup>st</sup>**

# **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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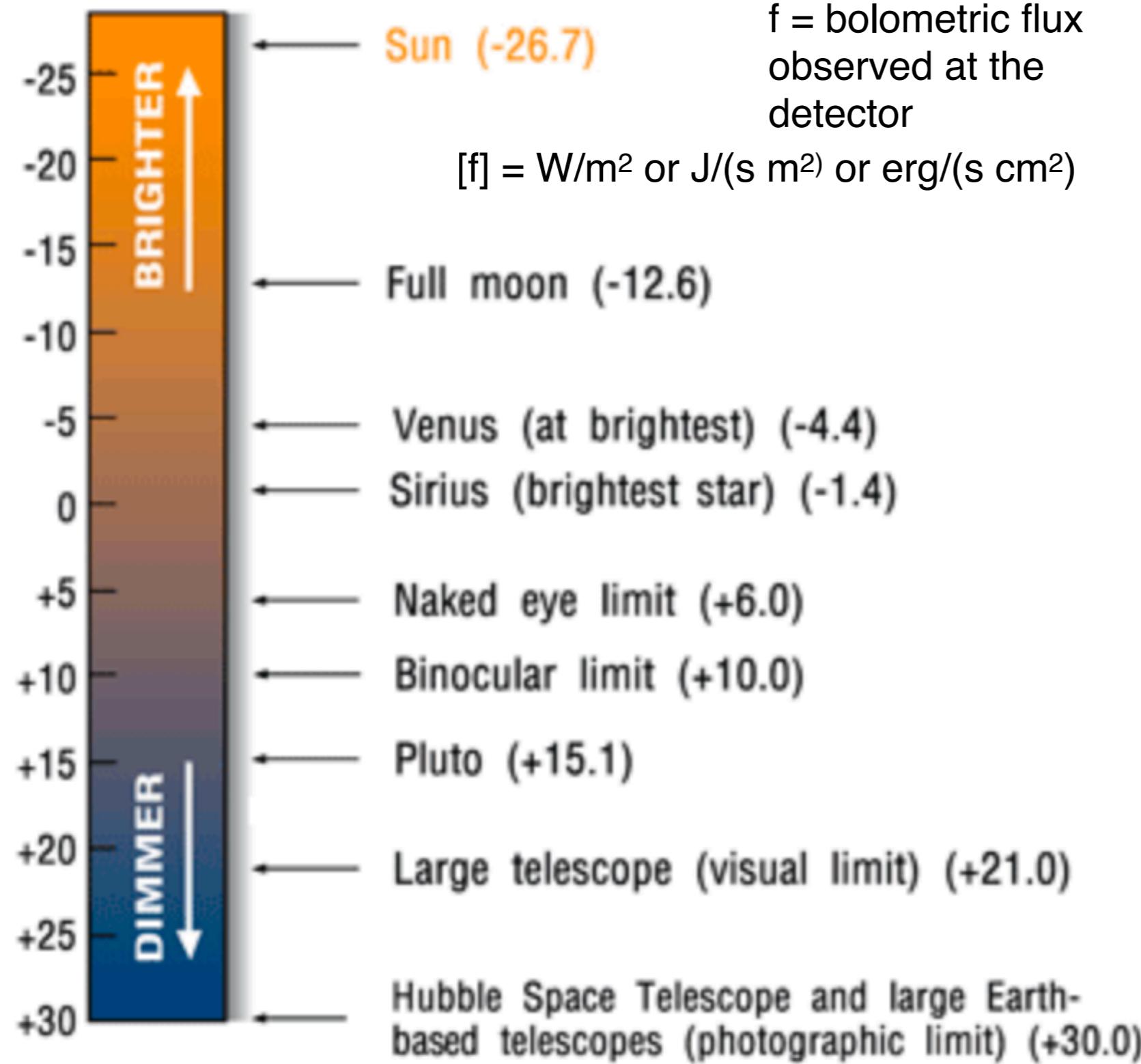
ZP = zeropoint of the magnitude  
system; it depends on the units of  $f$   
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$[L] = \text{W or J/s or erg/s}$   
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observer to source

**Absolute magnitude** is the apparent magnitude that a source would have if it were located at a distance of 10 pc from us

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

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

## AB magnitude system

$$m_x = -2.5 \log \frac{\int \frac{d\nu}{\nu} f_\nu(\nu) X(\nu)}{\int \frac{d\nu}{\nu} g_\nu^*(\nu) X(\nu)}$$

## AB magnitude system

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

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Filter transmission curve

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$$m_x = -2.5 \log \frac{\int \frac{d\nu}{\nu} f_\nu(\nu) X(\nu)}{\int \frac{d\nu}{\nu} g_\nu^{AB}(\nu) X(\nu)}$$

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:

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

$$\rightarrow M_X^{AB} = -2.5 \log \frac{\int \frac{d\nu}{\nu} f_\nu(\nu) X(\nu)}{\int \frac{d\nu}{\nu} X(\nu)} - 48.6$$

Apparent magnitude in the filter X in AB mag

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

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

Absolute magnitude in the filter X in AB mag

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Apparent magnitude in the filter X in AB mag

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

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

Absolute magnitude in the filter X in AB mag

**NOTE:** the templates in Assignment #5 already provide

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

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

$$\rightarrow M_X^{AB} = -2.5 \log \frac{\int \frac{d\nu}{\nu} f_\nu(\nu) X(\nu)}{\int \frac{d\nu}{\nu} X(\nu)} - 48.6$$

Apparent magnitude in the filter X in AB mag

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

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

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

Blackbody flux density:

$$F_\nu = \frac{2\pi h\nu^3}{c^2} \frac{1}{e^{h\nu/KT} - 1} = f(\nu, T)$$

w/  $h = 6.62606885 \times 10^{-34}$  erg/s

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

$$K = 1.38064852 \times 10^{-23}$$
 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

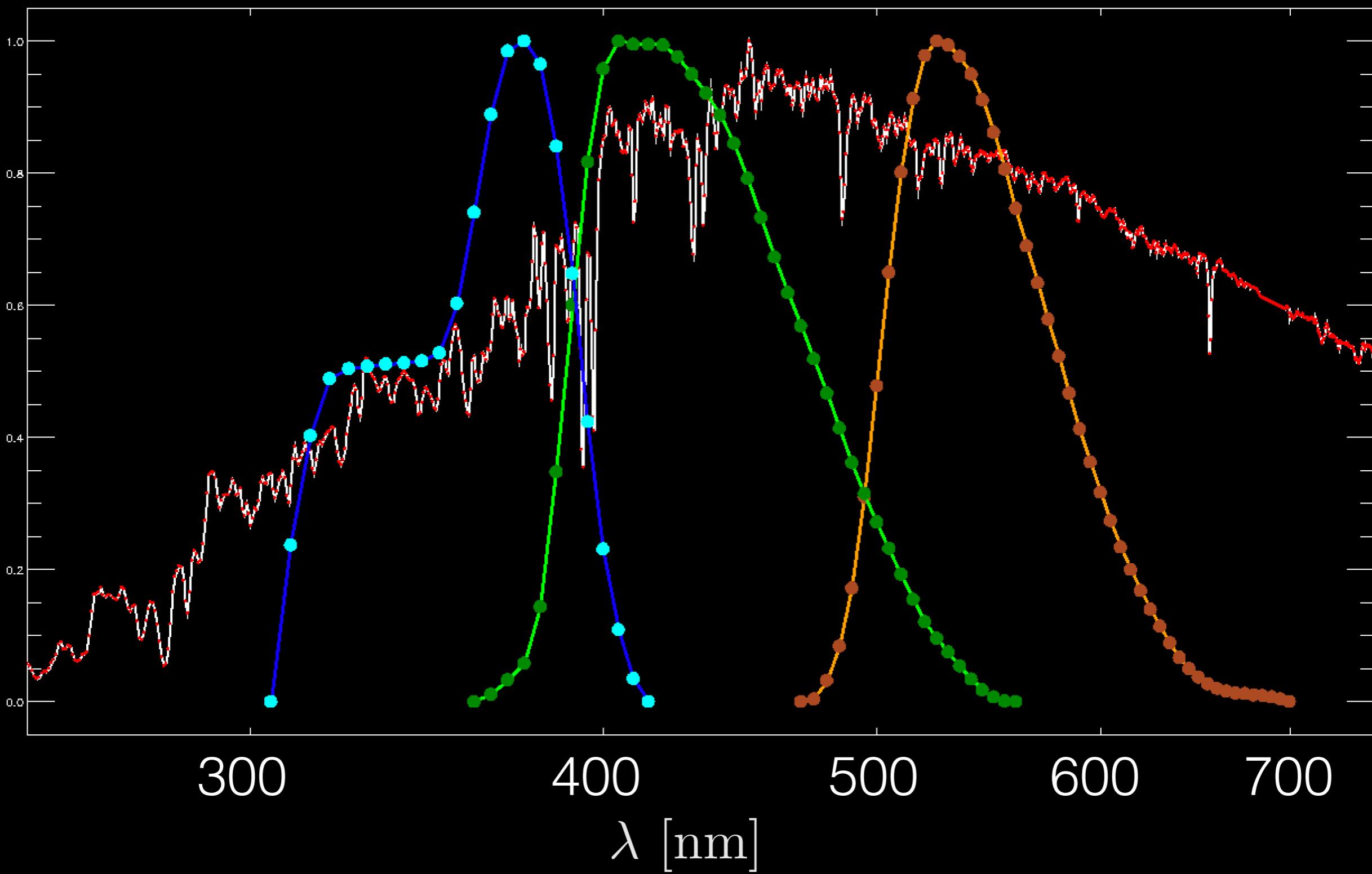
```
# Wavelength is in Angstrom
# Fluxes are tabulated in units of erg/s/cm^2/A @ d=10pc
# wavelength    flux
1.150000E+03  0.000000E+00
1.155000E+03  0.000000E+00
1.160000E+03  0.000000E+00
1.165000E+03  0.000000E+00
1.170000E+03  0.000000E+00
1.175000E+03  0.000000E+00
1.180000E+03  0.000000E+00
1.185000E+03  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
21     5.70000e+03 6.31000e-01
22     5.75000e+03 5.69000e-01
23     5.80000e+03 5.05000e-01
24     5.85000e+03 4.38000e-01
25     5.90000e+03 3.70000e-01
26     5.95000e+03 3.00000e-01
27     6.00000e+03 2.28000e-01
28     6.05000e+03 1.55000e-01
29     6.10000e+03 8.10000e-02
30     6.15000e+03 1.50000e-02
31     6.20000e+03 1.00000e-02
32     6.25000e+03 5.00000e-03
33     6.30000e+03 1.00000e-03
34     6.35000e+03 5.00000e-04
35     6.40000e+03 1.00000e-04
36     6.45000e+03 5.00000e-05
37     6.50000e+03 1.00000e-05
38     6.55000e+03 5.00000e-06
39     6.60000e+03 1.00000e-06
40     6.65000e+03 5.00000e-07
41     6.70000e+03 1.00000e-07
42     6.75000e+03 5.00000e-08
43     6.80000e+03 1.00000e-08
44     6.85000e+03 5.00000e-09
45     6.90000e+03 1.00000e-09
46     6.95000e+03 5.00000e-10
47     7.00000e+03 1.00000e-10
48     7.05000e+03 5.00000e-11
49     7.10000e+03 1.00000e-11
50     7.15000e+03 5.00000e-12
51     7.20000e+03 1.00000e-12
52     7.25000e+03 5.00000e-13
53     7.30000e+03 1.00000e-13
54     7.35000e+03 5.00000e-14
55     7.40000e+03 1.00000e-14
56     7.45000e+03 5.00000e-15
57     7.50000e+03 1.00000e-15
58     7.55000e+03 5.00000e-16
59     7.60000e+03 1.00000e-16
59     7.65000e+03 5.00000e-17
59     7.70000e+03 1.00000e-17
59     7.75000e+03 5.00000e-18
59     7.80000e+03 1.00000e-18
59     7.85000e+03 5.00000e-19
59     7.90000e+03 1.00000e-19
59     7.95000e+03 5.00000e-20
59     8.00000e+03 1.00000e-20
59     8.05000e+03 5.00000e-21
59     8.10000e+03 1.00000e-21
59     8.15000e+03 5.00000e-22
59     8.20000e+03 1.00000e-22
59     8.25000e+03 5.00000e-23
59     8.30000e+03 1.00000e-23
59     8.35000e+03 5.00000e-24
59     8.40000e+03 1.00000e-24
59     8.45000e+03 5.00000e-25
59     8.50000e+03 1.00000e-25
59     8.55000e+03 5.00000e-26
59     8.60000e+03 1.00000e-26
59     8.65000e+03 5.00000e-27
59     8.70000e+03 1.00000e-27
59     8.75000e+03 5.00000e-28
59     8.80000e+03 1.00000e-28
59     8.85000e+03 5.00000e-29
59     8.90000e+03 1.00000e-29
59     8.95000e+03 5.00000e-30
59     9.00000e+03 1.00000e-30
59     9.05000e+03 5.00000e-31
59     9.10000e+03 1.00000e-31
59     9.15000e+03 5.00000e-32
59     9.20000e+03 1.00000e-32
59     9.25000e+03 5.00000e-33
59     9.30000e+03 1.00000e-33
59     9.35000e+03 5.00000e-34
59     9.40000e+03 1.00000e-34
59     9.45000e+03 5.00000e-35
59     9.50000e+03 1.00000e-35
59     9.55000e+03 5.00000e-36
59     9.60000e+03 1.00000e-36
59     9.65000e+03 5.00000e-37
59     9.70000e+03 1.00000e-37
59     9.75000e+03 5.00000e-38
59     9.80000e+03 1.00000e-38
59     9.85000e+03 5.00000e-39
59     9.90000e+03 1.00000e-39
59     9.95000e+03 5.00000e-40
59     1.00000e+04 1.00000e-40
59     1.00500e+04 5.00000e-41
59     1.01000e+04 1.00000e-41
59     1.01500e+04 5.00000e-42
59     1.02000e+04 1.00000e-42
59     1.02500e+04 5.00000e-43
59     1.03000e+04 1.00000e-43
59     1.03500e+04 5.00000e-44
59     1.04000e+04 1.00000e-44
59     1.04500e+04 5.00000e-45
59     1.05000e+04 1.00000e-45
59     1.05500e+04 5.00000e-46
59     1.06000e+04 1.00000e-46
59     1.06500e+04 5.00000e-47
59     1.07000e+04 1.00000e-47
59     1.07500e+04 5.00000e-48
59     1.08000e+04 1.00000e-48
59     1.08500e+04 5.00000e-49
59     1.09000e+04 1.00000e-49
59     1.09500e+04 5.00000e-50
59     1.10000e+04 1.00000e-50
59     1.10500e+04 5.00000e-51
59     1.11000e+04 1.00000e-51
59     1.11500e+04 5.00000e-52
59     1.12000e+04 1.00000e-52
59     1.12500e+04 5.00000e-53
59     1.13000e+04 1.00000e-53
59     1.13500e+04 5.00000e-54
59     1.14000e+04 1.00000e-54
59     1.14500e+04 5.00000e-55
59     1.15000e+04 1.00000e-55
59     1.15500e+04 5.00000e-56
59     1.16000e+04 1.00000e-56
59     1.16500e+04 5.00000e-57
59     1.17000e+04 1.00000e-57
59     1.17500e+04 5.00000e-58
59     1.18000e+04 1.00000e-58
59     1.18500e+04 5.00000e-59
59     1.19000e+04 1.00000e-59
59     1.19500e+04 5.00000e-60
59     1.20000e+04 1.00000e-60
59     1.20500e+04 5.00000e-61
59     1.21000e+04 1.00000e-61
59     1.21500e+04 5.00000e-62
59     1.22000e+04 1.00000e-62
59     1.22500e+04 5.00000e-63
59     1.23000e+04 1.00000e-63
59     1.23500e+04 5.00000e-64
59     1.24000e+04 1.00000e-64
```

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	05	V	39810.70	-5.400	-5.893	-6.212	-0.319	-0.493
pickles_uk_2	09	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



$$\vec{\lambda}_{\text{filter}} = [\lambda_1, \lambda_2, \dots, \lambda_n] \quad \left. \right\} \text{filter table}$$

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

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

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

- 48.6

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

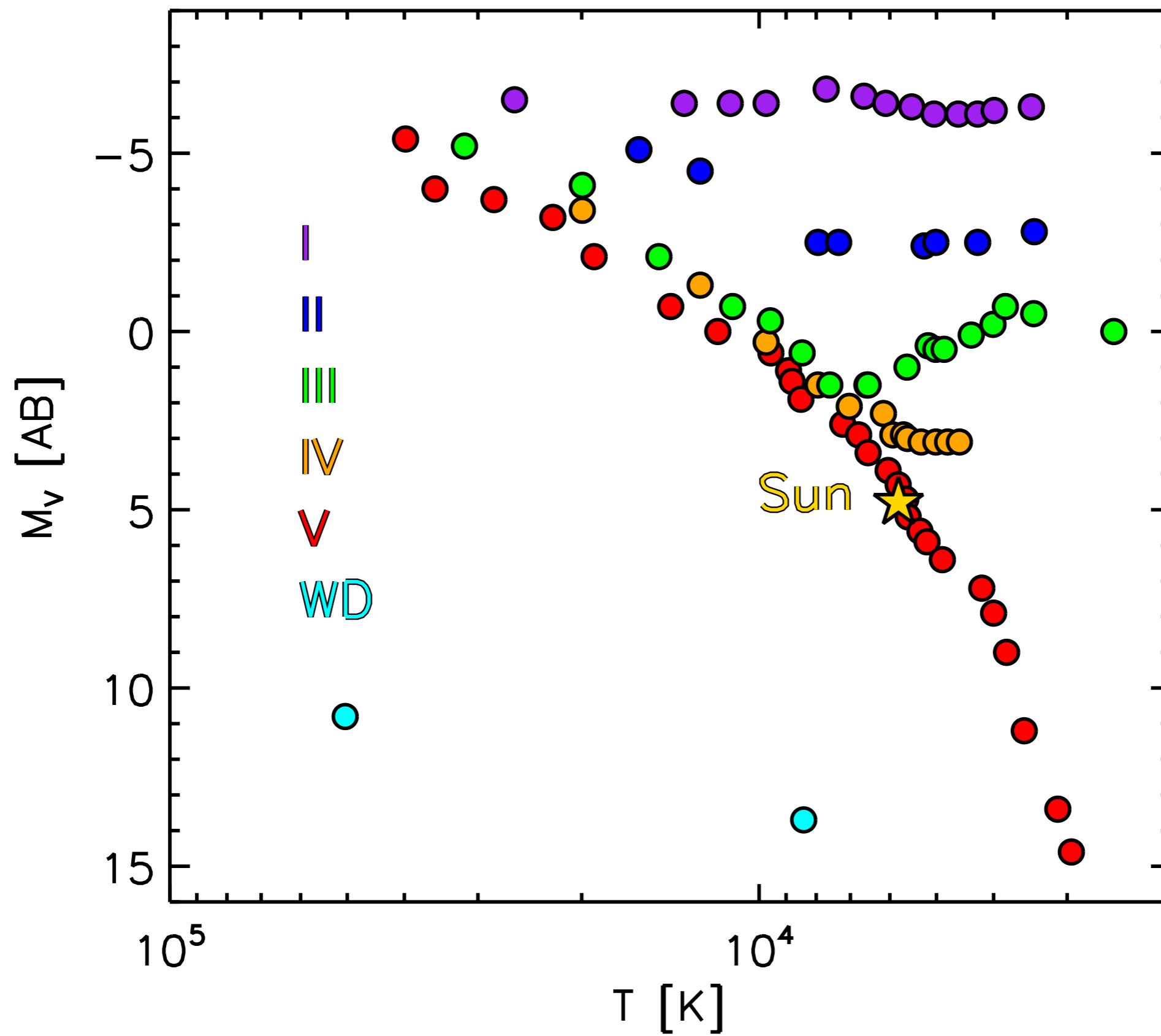
$$1) \frac{L_\nu(\nu)}{4\pi(10\text{pc})^2} = \vec{f}_\lambda^* \cdot \frac{\vec{\lambda}^2}{c} \stackrel{?}{=} \vec{f}_\nu^*$$

from  
star  
template

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

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

## H-R diagram - v1



## H-R diagram - v2

