Constructing a Spectra Energy Distribution (example SO518)

1. We need to compile fluxes or magnitudes for each desired wavelength. For young stellar objects, the basic data to take into account are 2MASS (Cutri+ 2003), WISE (Cutri+ 2013), Spitzer IRAC/MIPS (e.g., for SO518; Hernandj et al. 2007), Herschel PACS (e.g., for SO518, Maucó, et al. 2016). You can add optical data (e.g., GAIA, PANSTARRS, Johnson) or millimetric fluxes (e.g., SCUBA, ALMA).

2. To convert magnitudes (m[λ]) to fluxes, you need to know the zero point fluxes magnitudes (Fzero[λ]) and also apply a reddening correction assuming an extinction law (Al[λ]).

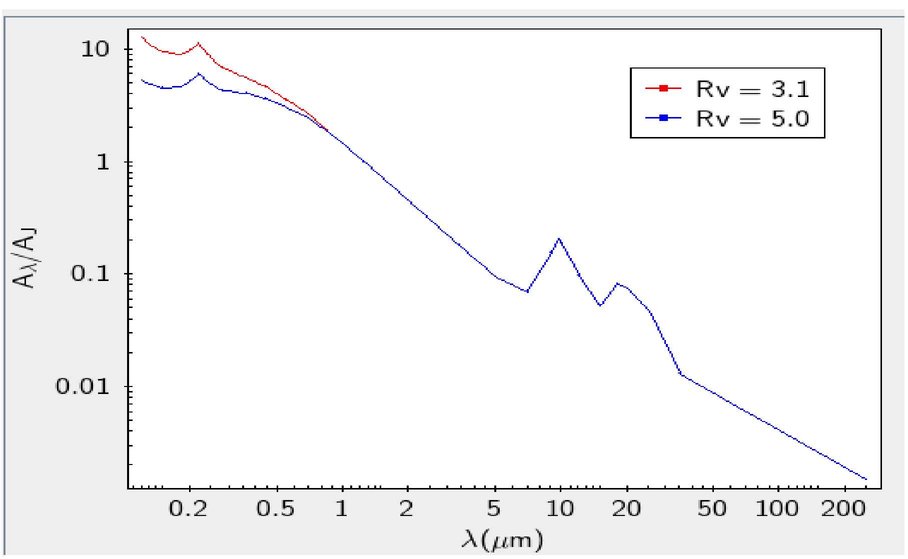
   Fo[λ]=Fzero[λ]*10^(-0.4m[λ])*10^(0.4Al[λ])

   In the case that you already have the data in the unit of fluxes (F[λ]), you only need to apply the reddening correction.

   Fo[λ]=F[λ]*10^(0.4Al[λ])

   Here, you need to double-check that all your fluxes are in the same units. E.g. F[λ] and Fzero[λ] in erg/cm².s.microns

3. You can choose the extinction law. In general, the parameter Rv is important for wavelengths smaller than 1 micron. For example, the plot shows the extinction law of Mathis 1990, for Rv=3.1 (normal interstellar law) and Rv=5.0. You can interpolate in Mathis's table to obtain the extinction in a specific wavelength.



Alternatively, you can use Cardelli, Clayton, and Mathis, 1989 (for λ<3.5 microns), Schlafly et al. 2016, Fitzpatrick et al. 2019, and McClure 2009.

4. You can obtain the zero points for photometric systems directly from the literature, project's webpage, or compiled tables. For example,

Filter	λ(μm)	Zero (Jy)	Zero(erg/cm².s.μm)	Comments
U	0.36	1823.04 **	4.22e-5	Allen's Astrophysical Quantities (2000)
B	0.44	4130.13 **	6.40e-5	Allen's Astrophysical Quantities (2000)
V	0.55	3781.25 **	3.75e-5	Allen's Astrophysical Quantities (2000)
Rc	0.641	2981.63 **	2.177e-5	Bessell et al. 1998; Johnson-Cousin
Rj	0.71	2940.58 **	1.75e-5	Allen's Astrophysical Quantities (2000)
Ic	0.798	2390.14 **	1.126e-5	Bessell et al 1998; Johnson-Cousin
Ij	0.97	2634.52 **	8.4e-6	Allen's Astrophysical Quantities (2000)
J	1.235	1594.0	3.129E-6	Cohen et al 2003 (1)
H	1.662	1024.0	1.133E-6	Cohen et al 2003 (1)
K	2.159	666.7	4.283E-7	Cohen et al 2003 (1)
W1	3.35	309.540	8.17870e-08	Jarrett et al. 2011 (2)
W2	4.6	171.787	2.41500e-08	Jarrett et al. 2011 (2)
W3	11.6	31.6740	6.51510e-10	Jarrett et al. 2011 (2)
W4	22.1	8.36300	5.09010e-11	Jarrett et al. 2011 (2)
I1	3.6	280.9	6.48148e-08**	IRAC Instrumental handbook (3)
I2	4.5	179.7	2.66222e-08**	IRAC Instrumental handbook (3)
I3	5.8	115.0	1.02556e-08**	IRAC Instrumental handbook (3)
I4	8.0	64.9	3.00609e-09**	IRAC Instrumental handbook (3)
M1	23.68	7.17	3.73438e-11**	MIPS Instrumental handbook (3)
M2	71.42	0.778	4.76327e-13**	MIPS Instrumental handbook (3)
M3	155.9	0.159	1.87500e-14**	MIPS Instrumental handbook (3)

** using the conversion Fv[Jy]=F[erg/cm².s.μm] x (λ[μm])²/3.0e-9 . This relation is useful for narrow bands and is a good proxy for wide bands. The recommended wideband filter procedure implies converting the VEGA flux to Jy or erg/cm².s.μm before applying the convolution using the filter's response.

(1) https://old.ipac.caltech.edu/2mass/releases/allsky/doc/sec6_4a.html

(2) https://wise2.ipac.caltech.edu/docs/release/allsky/expsup/figures/sec4_4ht9.gif

(3) http://www.adamgginsburg.com/filtersets.htm

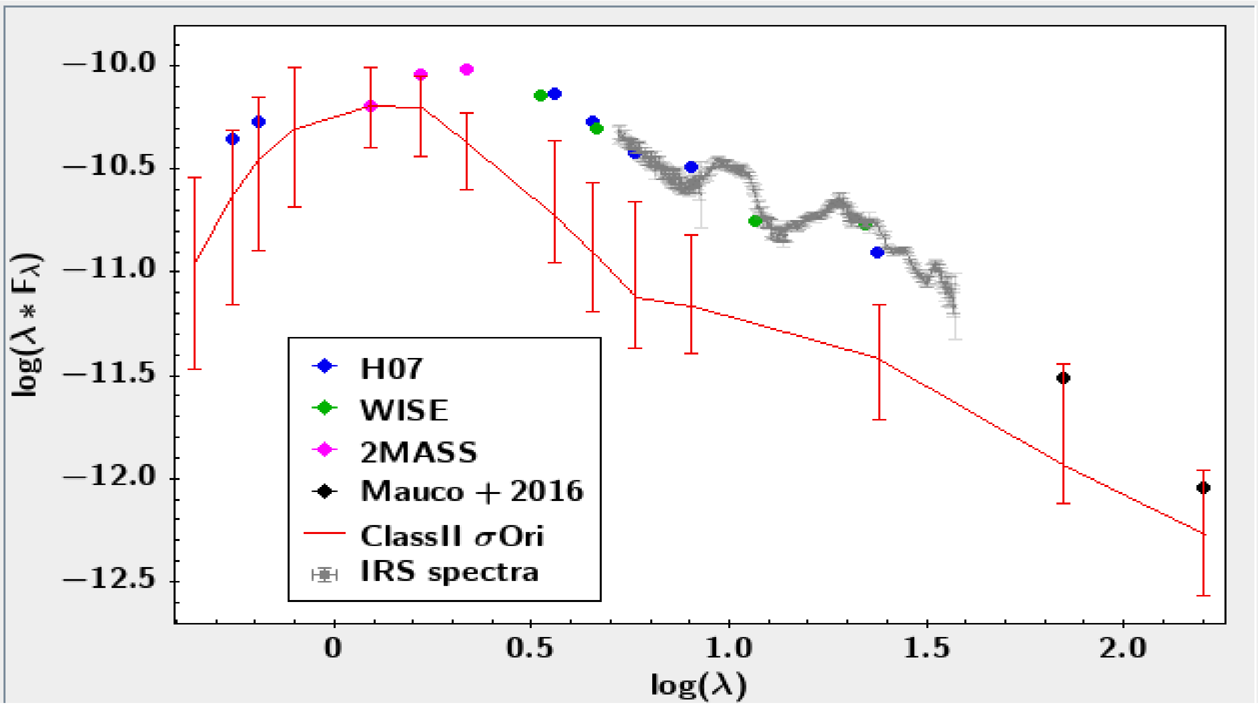
5. You can use any plots to construct the SED. In the X-axis → log(λ) and Y-axis → log(λ*Fo[λ]). For example, for topcat, you can do a table with the compiled data, the zero points and the extinction for the corresponding wavelength. For example for SO518, you can use the following format:

Filter	λ(μm)	Zero erg/cm².s.μm	Al/Aj Rv=3.1	Al/Aj Rv=5.0	Mag	Merr	Comment
U	0.36	4.22e-5	5.579	4.077	--	--	--
B	0.44	6.40e-5	4.700	3.670	--	--	--
V	0.55	3.75e-5	3.550	3.060	14.16	0.01	Hernandez et al 2007
Rc	0.641	2.177e-5	3.010	2.678	13.54	0.02	Hernandez et al 2007
Rj	0.71	1.75e-5	2.612	2.394	--	--	--
Ic	0.798	1.126e-5	2.190	2.072	--	--	--
Ij	0.97	8.4e-6	1.560	1.560	--	--	--
J	1.235	3.129E-6	1.030	1.030	11.955	0.028	2MASS
H	1.662	1.133E-6	0.619	0.619	10.792	0.026	2MASS
K	2.159	4.283E-7	0.400	0.400	9.944	0.028	2MASS
W1	3.35	8.17870e-08	0.190	0.190	8.940	0.022	WISE
W2	4.6	2.41500e-08	0.117	0.117	8.381	0.020	WISE
W3	11.6	6.51510e-10	0.117	0.117	6.564	0.017	WISE
W4	22.1	5.09010e-11	0.064	0.064	4.539	0.030	WISE
I1	3.6	6.48148e-08	0.171	0.171	8.75	0.03	Hernandez et al 2007
I2	4.5	2.66222e-08	0.122	0.122	8.36	0.03	Hernandez et al 2007
I3	5.8	1.02556e-08	0.085	0.085	7.98	0.03	Hernandez et al 2007
I4	8.0	3.00609e-09	0.114	0.114	7.18	0.03	Hernandez et al 2007
M1	23.68	3.73438e-11	0.055	0.055	4.62	0.03	Hernandez et al 2007
M2	71.42	4.76327e-13	0.006	0.006	--	--	--
M3	155.9	1.87500e-14	0.003	0.003	--	--	--

Since the Y=log(λ*Fo[λ]) and M= -2.5log(Fo)+zeropoint, Yerr=Merr/2.5

Maucó et. al 2016 reported Herschel/PACS photometry **at 70 microns (71.8+-2.3 mJy) and 160 microns (48.1+-4.9)**. In this case, Merr=1.08574*Ferr/F and Yerr=1.0857*(Ferr/F)/2.5

In Maucó et. al 2016 also reported an Av=0.0, thus extinction correction is not necessary. The following Figure shows the SED for SO518. The photometric error bars are within the symbol size.



The median flux for class II in the sigma Orionis cluster (Moucó et al 2016) is plotted as reference.

Table 4
Median SEDs and Quartiles of Disk-bearing Stars with PACS Detections in σ Ori

Wavelength (μm)	log λF_λ		
	Median	Lower	Upper
0.44	−10.84	−11.35	−10.42
0.55	−10.50	−11.04	−10.19
0.64	−10.33	−10.77	−10.03
0.79	−10.18	−10.56	−9.89
1.235	−10.07	−10.28	−9.89
1.662	−10.08	−10.32	−9.93
2.159	−10.25	−10.48	−10.10
3.6	−10.60	−10.84	−10.24
4.5	−10.78	−11.07	−10.44
5.8	−11.00	−11.25	−10.54
8.0	−11.04	−11.28	−10.70
24.0	−11.30	−11.59	−11.04
70.0	−11.81	−12.00	−11.32
160.0	−12.15	−12.45	−11.84