SEDs, f_ν and f_λ's

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Abstract

"README" and "Cheat Sheet" to SEDs, f_ν and f_λ and all that carry-on...

Physical Quantity	symbol	Unit name	Units	e.g. log(OoM)
spectral flux density[a]	f_ν		W m^{-2} Hz^{-1}	-27 – -35
spectral flux density	f_ν	Janksy	W m^{-2} Hz^{-1} 10^{-26}	μ to 10's of milli
spectral flux density	f_ν		erg s^{-1} cm^{-2} Hz^{-1}	-24 – -32
spectral flux density	f_ν	Jansky	erg s^{-1} cm^{-2} Hz^{-1} 10^{-23}	μ to 10's of milli
spectral flux density	f_λ		W m^{-2} m^{-1}	
spectral flux density	f_λ		W m^{-2} μm^{-1}	
[a]energy density	νf_ν	erg s^{-1} cm^{-2}		-12 – -16
[b] –	νF_ν			
[c] –	L_ν	erg s^{-1} Hz^{-1}		26 – 34
[a]Luminosity	νL_ν	erg s^{-1}		43 – 47
[a]Luminosity	L	erg s^{-1}		43 – 47

Table 1: [a]see e.g. Fig. 10 of **?**.
[b]e.g. URL [1]
[c]e.g. Bourne et al. (2011)

1 Definitions, terms and Units

Starting off with just some basic definitions, terms and units. A big push here will be to be consistent and also as comprehensive as possible.

Name	Symbol	Unit name	Unit symbol	Dimension	Notes
Radiant energy	Q_e	Joule	J	M L^2 T^{-2}	Energy of electromagnetic radiation.
Radiant energy density	$\mathrm{w_e}$	Joule per cubic metre	J/m^3	M L^{-1} T^{-2}	Radiant energy per unit volume.
Radiant flux	ϕ_e	Watt	W = J/s	M L^2 T^{-3}	Radiant energy emitted per unit time[a].
Spectral flux	$\phi_{\mathrm{e},\nu}$ or $\phi_{\mathrm{e},\lambda}$	Watt per hertz or Watt per metre	W/Hz or W/m	M L^2 T^2 or M L T^{-3}	Radiant flux per unit frequency or wavelength.

Table 2: **STRAIGHT FROM::** https://en.wikipedia.org/wiki/Optical_depth

[a] Also sometimes called "radiant power".

Unit Name	Physical Quantity	symbos	Units
Janksy	spectral flux density	f_ν	10^{-26} W m^{-2} Hz^{-1}
Jansky	spectral flux density	f_ν	10^{-23} erg s^{-1} cm^{-2} Hz^{-1}

Table 3: e.g. Fig. 10 of Richards et al. (2006b).

2 Some examples

From Table 2, to get from L_ν to νL_ν, at say 1.0μm, you just have to multiply by 3×10^{14} (Hz), and this gives e.g. $\approx 3 \times 10^{44}$ erg s^{-1} :-)

$$
\begin{aligned}
m_{\rm AB} &= -2.5 \log_{10}\left(\frac{f_\nu}{3631\ \rm Jy}\right) && (1)\\
&= -2.5 \log_{10}\left(\frac{f_\nu}{\rm Jy}\right) + 8.90 && (2)\\
&= -2.5 \log_{10} f_\nu - 48.60 && (3)
\end{aligned}
$$

with the -48.6 thing coming in if in cgs units of erg s^{-1} cm^{-2} Hz^{-1}.

So, with $\nu f_\nu = \lambda f_\lambda$, we can have:

$$
f_\nu = \frac{\lambda^2}{c} f_\lambda \qquad (4)
$$

$$
(5)
$$

Now, if f_ν is in Jansky's and λ is in Å then, c must be in Å s^{-1}, i.e., $c = 3 \times 10^{18}$ Å s^{-1}. Then you just replace:

$$
\begin{aligned}
f_\nu &= \frac{\lambda^2}{c} f_\lambda && (6)\\
f_\nu(\text{in Jy}) &= 1 \times 10^{23}/(3e18)\ \frac{\lambda^2}{\AA}\ f_\lambda && (7)\\
f_\nu(\text{in Jy}) &= 0.3 \times 10^5 \times \lambda^2 \times f_\lambda && (8)\\
f_\nu(\text{in Jy}) &= 3.34e4 \times \lambda^2 \times f_\lambda && (9)\\
\frac{f_\nu}{[\text{Jansky}]} &= 33,356 \left(\frac{\lambda}{[\AA]}\right)^2 \frac{f_\lambda}{\text{ergs}^{-1}\text{cm}^{-2}\AA^{-1}} && (10)
\end{aligned}
$$

with 1 cm being 1×10^8Å and $c = 2.99792 \times 10^{10}$ cm s^{-1}.

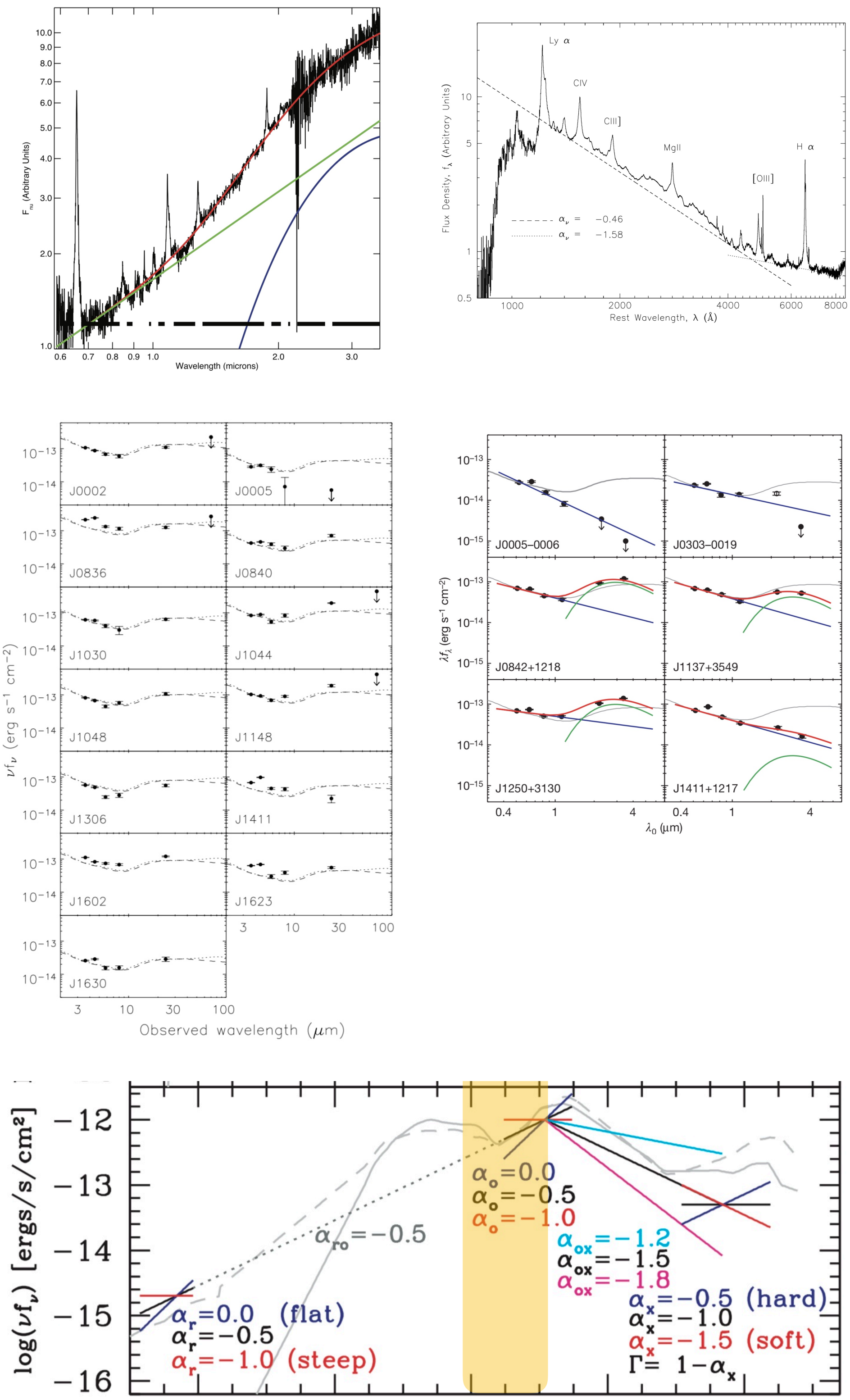

Figure 1: *Top Left:* Fig. 7 from Glikman et al. (2006). y-axis is F$_\nu$; Power-law plus blackbody fit to their composite quasar spectrum plotted in F$_\nu$-λ on logarithmic axes. The combined fit is shown in red, the power-law component with a best-fit spectral index of $\alpha_\nu = -0.92$ is shown in green, and the blackbody with the best-fit dust temperature of $T_{\rm dust} = 1260$K is shown in blue.
Top Right: Fig. 3 from Vanden Berk et al. (2001). y-axis is f$_\lambda$ Composite

Following e.g. URL [5],

$$f_\nu = A \times \lambda f_\gamma \quad (11)$$

$$f_\nu(\text{in Jy}) = 6.626 \times 10^{-8} \frac{\lambda}{[\mu m]} f_\gamma \quad (12)$$

$$(13)$$

where f_ν is the 'energy flux', aka the spectral flux density, measured in Janskys (10^{-26} W m^{-2} Hz^{-1}), f_γ is the 'photon flux' measured in s^{-1} m^{-2} μm^{-1}, λ is the wavelength measured in μm and Planck's constant is 6.626×10^{-34} m^2 kg s^{-1} (i.e. 6.626e-34*1e26 = 6.626e-8).

Take your f_ν measurements that are in Jy. (Ensure they are in Jy! If they're in magnitudes, convert them to Jy first; see 'magnitude' discussion above.) Multiply by 1×10^{-23} to get them into *cgs* units. Multiply these f_ν values by $\frac{c}{\lambda^2}$ to get them into f_λ. Multiply them by λ to get them into λf_λ. WATCH YOUR UNITS. NB: $c = 2.997924 \times 10^{10}$ cm sec^{-1}.

Also note/recall,

$$\nu f_\nu = \lambda f_\lambda \quad (14)$$

with units of ergs s^{-1} cm^{-2}.

2.1 Assef et al. 2010

To go from Table 1 (F_ν in erg s^{-1} cm^{-2} Hz^{-1}) to Figure 3 (with y-axis ν F_ν) I did::

```
lam = wave * 1e-6
nu = 3e8/lam
ax1.plot(Assef_wave, Assef_AGN*nu*1e-17, color='black')
ax2.plot(Assef_wave, Assef_E *nu *1e-19, color='red')
ax3.plot(Assef_wave, Assef_Sbc *nu *4e-20, color='green')
ax4.plot(Assef_wave, Assef_Im *nu *1e-19, color='cyan')

## Noting the 1e-17, 1e-19, 4e-20 and 1e-19 factors here
## are 'completely' arbitary and just to get things on the
## same plot...
```

3 Unit Conversions

3.1 Flux density to AB

The flux density in Jy can be converted to a magnitude basis:
(straight from Wiki!! ;-):

$$\begin{aligned} S_\nu[\mu\text{Jy}] &= 10^6 \cdot 10^{23} \cdot 10^{-\text{AB}+48.6/2.5} & (15) \\ &= 10^{(23.9-\text{AB})/2.5} & (16) \\ & & (17) \end{aligned}$$

4 WISE

The source flux density, in Jansky [Jy] units, is computed from the calibrated WISE (Vega) magnitudes, m_{Vega} using: N.B the WISE webpage (given in the URL notes below) uses F_ν for source flux density. I'm going to stick with my convention and use little f, f_ν,

$$f_\nu[\text{Jy}] = f_{\nu,0} \times 10^{(-m_{\text{Vega}}/2.5)} \tag{18}$$

where $f_{\nu,0}$ is the zero magnitude flux density corresponding to the constant that gives the same response as that of Alpha Lyrae (Vega). For most sources, the zero magnitude flux density, derived using a constant power-law spectra, is appropriate and may be used to convert WISE magnitudes to flux density [Jy] units. Table 1 lists the zero magnitude flux density (column 2) for each WISE band.

For sources with steeply rising MIR spectra or with spectra that deviate significantly from f_ν =constant, including cool asteroids and dusty star-forming galaxies, a color correction is required, especially for W3 due to its wide bandpass. With a given flux correction, f_c, the flux density conversion is given by:

$$f_\nu[\text{Jy}] = (f^*_{\nu,0}/f_c) \times 10^{(-m_{\text{Vega}}/2.5)} \tag{19}$$

where $f^*_{\nu,0}$ is the zero magnitude flux density derived for sources with power-law spectra: $f_\nu \propto \nu^2$, listed in Table 1 (column 3) and the flux correction, f_c, listed in Table 2 for $f_\nu \propto \nu^{-\alpha}$, where the index α ranges from: -3, -2, -1, 0, 1, 2, 3, and 4, and for blackbody spectra, B_ν(T) for a variety of temperatures, and for stars of two main-sequence spectral types (K2V and G2V).

5 Links

Some of these are old/broken... :-(

[1] http://www.iasf-milano.inaf.it/~polletta/templates/images/new_Arp220_template.jpg
[2] http://www.astro.soton.ac.uk/~td/flux_convert.html
[3] http://coolwiki.ipac.caltech.edu/index.php/Units
[4] http://wise2.ipac.caltech.edu/docs/release/allsky/expsup/sec4_4h.html
[5] http://www.astro.ljmu.ac.uk/ ikb/convert-units/node1.html

[6] http://xingxinghuang.blogspot.co.uk/2013/06/hello-everybody-if-you-still-get.html
http://ssb.stsci.edu/doc_tmp/stsci_python_dev/pysynphot.doc/html/units.html
http://www.stsci.edu/∼strolger/docs/UNITS.txt
https://github.com/spacetelescope/pysynphot/blob/master/doc/source/units.rst
https://www.astro.umd.edu/∼ssm/ASTR620/mags.html

References

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Jiang L., et al., 2006, AJ, 131, 2788

Jiang L., et al., 2010, Nat, 464, 380

Richards G. T., et al., 2006, ApJS, 166, 470

Vanden Berk D. E., et al., 2001, AJ, 122, 549