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...

1 Definitions, terms and Units

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		erg s^{-1} cm^{-2} Hz^{-1}	-24 – -32
spectral flux density	f_ν	Janksy	10^{-26} W m^{-2} Hz^{-1}	μ to 10's of milli
spectral flux density	f_ν	Jansky	10^{-23} erg s^{-1} cm^{-2} Hz^{-1}	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)

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].
	$\phi_{\mathrm{e},\nu}$	Watt per hertz	W/Hz	M L^2 T^2	Radiant flux per unit frequency or wavelength.
Spectral flux	or	or	or	or	
	$\phi_{\mathrm{e},\lambda}$	Watt per metre	W/m	M L T^{-3}	

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).

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} :-)

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

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:

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

$$(5)$$

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:

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

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

Following e.g. URL [5],

$$\begin{aligned} f_\nu &= A \times \lambda f_\gamma && (11) \\ f_\nu(\text{in Jy}) &= 6.626 \times 10^{-8} \frac{\lambda}{[\mu m]} f_\gamma && (12) \end{aligned}$$

$$(13)$$

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,

$$\nu f_\nu = \lambda f_\lambda \tag{14}$$

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

1.1 Assef et al. 2010

To go from Table 1 (F$_\nu$ in erg s^{-1} cm^{-2} Hz^{-1}) to Figure 3 (with y-axis ν F$_\nu$) 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...
```

2 Unit Conversions

2.1 Flux density to AB

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

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

3 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,

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

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:

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

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).

4 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