

SEDs, f_ν and f_λ 's

Nic “What Have I got wrong here” Ross

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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		$\text{W m}^{-2} \text{ Hz}^{-1}$	-27 – -35
spectral flux density	f_ν	Jansky	$\text{W m}^{-2} \text{ Hz}^{-1} 10^{-26}$	μ to 10's of milli
spectral flux density	f_ν		$\text{erg s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1}$	-24 – -32
spectral flux density	f_ν	Jansky	$\text{erg s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1} 10^{-23}$	μ to 10's of milli
spectral flux density	f_λ		$\text{W m}^{-2} \text{ m}^{-1}$	
spectral flux density	f_λ		$\text{W m}^{-2} \mu\text{m}^{-1}$	
^a energy density	νf_ν	$\text{erg s}^{-1} \text{ cm}^{-2}$		-12 – -16
^b –	νF_ν			
^c –	L_ν	$\text{erg s}^{-1} \text{ Hz}^{-1}$		26 – 34
^a Luminosity	νL_ν	erg s^{-1}		43 – 47
^a Luminosity	L	erg s^{-1}		43 – 47

Table 1: ^asee e.g. Fig. 10 of ?.

^be.g. URL [1]

^ce.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 bol	sym- Dimension	Notes
Radiant energy	Q_e	Joule	J	$M L^2 T^{-2}$	Energy of electromagnetic radiation.
Radiant energy density	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	$\phi_{e,\nu}$ or $\phi_{e,\lambda}$	Watt per hertz	W/Hz	$M L^2 T^2$	Radiant flux per unit frequency or wavelength.
		or	or	or	
		Watt per metre	W/m	$M L T^{-3}$	

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

^aAlso sometimes called “radiant power”.

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

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 $1.0\mu\text{m}$, you just have to multiply by 3×10^{14} (Hz), and this gives e.g. $\approx 3 \times 10^{44} \text{ erg s}^{-1}$:-)

$$m_{\text{AB}} = -2.5 \log_{10} \left(\frac{f_\nu}{3631 \text{ Jy}} \right) \quad (1)$$

$$= -2.5 \log_{10} \left(\frac{f_\nu}{\text{Jy}} \right) + 8.90 \quad (2)$$

$$= -2.5 \log_{10} f_\nu - 48.60 \quad (3)$$

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

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 \AA then, c must be in \AA s^{-1} , i.e., $c = 3 \times 10^{18} \text{\AA s}^{-1}$. Then you just replace:

$$f_\nu = \frac{\lambda^2}{c} f_\lambda \quad (6)$$

$$f_\nu(\text{in Jy}) = 1 \times 10^{23} / (3e18) \frac{\lambda^2}{\text{\AA}} f_\lambda \quad (7)$$

$$f_\nu(\text{in Jy}) = 0.3 \times 10^5 \times \lambda^2 \times f_\lambda \quad (8)$$

$$f_\nu(\text{in Jy}) = 3.34e4 \times \lambda^2 \times f_\lambda \quad (9)$$

$$\frac{f_\nu}{[\text{Jansky}]} = 33,356 \left(\frac{\lambda}{[\text{\AA}]} \right)^2 \frac{f_\lambda}{\text{ergs}^{-1} \text{cm}^{-2} \text{\AA}^{-1}} \quad (10)$$

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

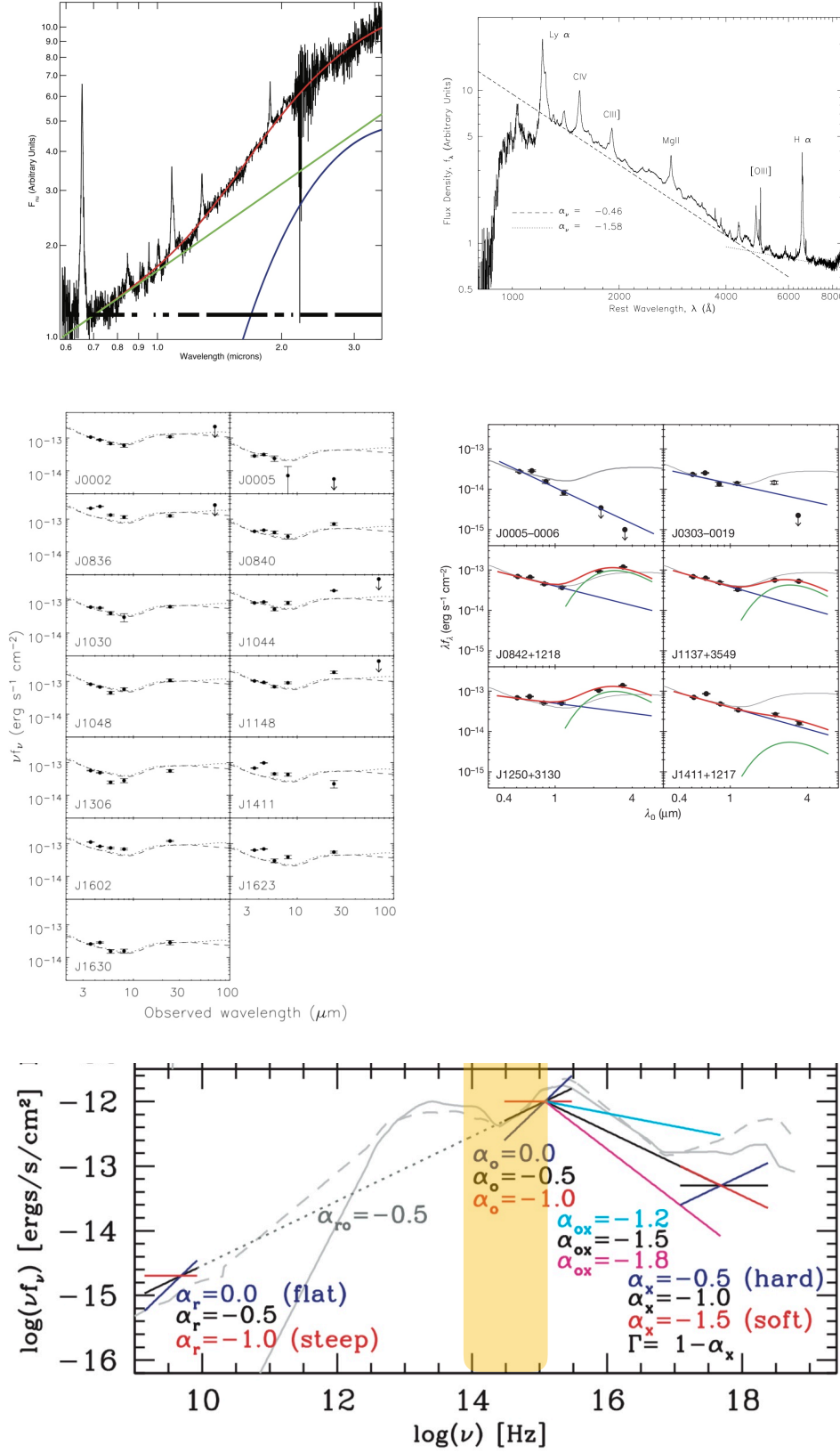


Figure 1: *Top Left:* Fig. 7 from Glikman et al. (2006). y -axis is F_ν ; Power-law plus blackbody fit to their composite quasar spectrum plotted in F_ν - λ on logarithmic axes. The combined fit is shown in red, the power-law component with a best-fit spectral index of $\alpha_\nu = -0.92$ is shown in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

Top Right: Fig. 3 from Vanden Berk et al. (2001). y -axis is f_λ Composite

Following e.g. URL [5],

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

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

$$(13)$$

where f_ν is the ‘energy flux’, aka the spectral flux density, measured in Janskys ($10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}$), f_γ is the ‘photon flux’ measured in $\text{s}^{-1} \text{ m}^{-2} \mu\text{m}^{-1}$, λ is the wavelength measured in μm and Planck’s constant is $6.626 \times 10^{-34} \text{ m}^2 \text{ kg s}^{-1}$ (i.e. $6.626\text{e-}34 \times 1\text{e}26 = 6.626\text{e-}8$).

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: $c = 2.997924 \times 10^{10} \text{ cm sec}^{-1}$.

Also note/recall,

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

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

2.1 Assef et al. 2010

To go from Table 1 (F_ν in $\text{erg s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1}$) to Figure 3 (with y-axis νF_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' arbitrary 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!! ;-):

$$S_\nu[\mu\text{Jy}] = 10^6 \cdot 10^{23} \cdot 10^{-AB+48.6/2.5} \quad (15)$$

$$= 10^{(23.9-AB)/2.5} \quad (16)$$

$$(17)$$

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 ,

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

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 $f_\nu = \text{constant}$, 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:

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

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, $B_\nu(T)$ 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