SPIRE Beams and Extended Sources

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on behalf of SPIRE ICC

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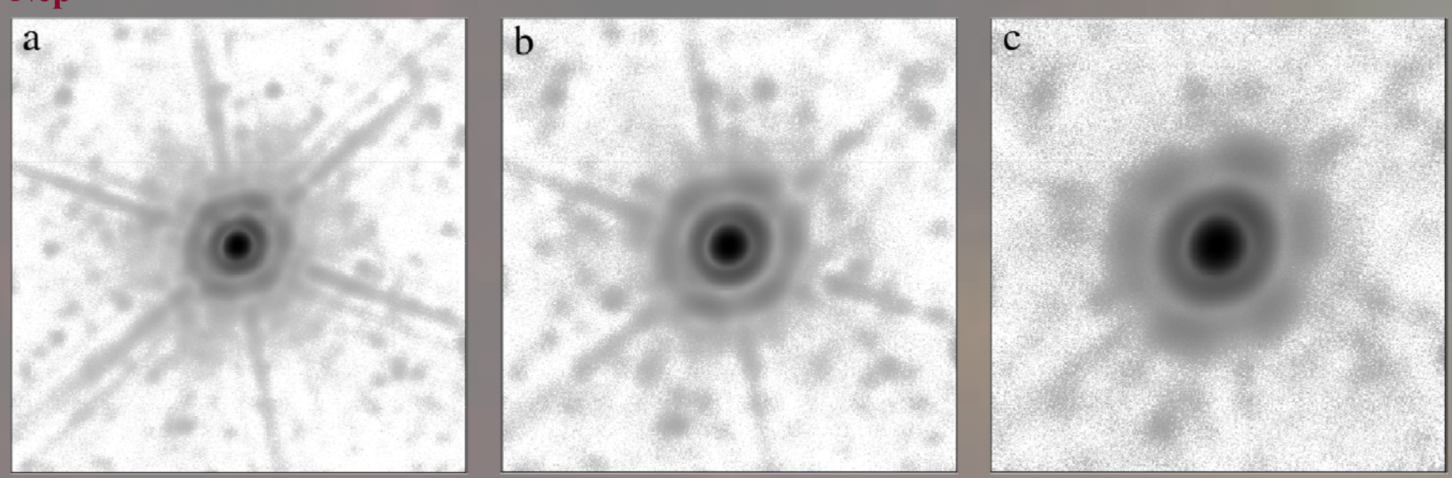
SPIRE measured beams

The SPIRE photometer beam response is determined through measurements of Neptune. The maps (Figure 1, right) have had a diffuse background and point sources removed to improve the estimate of the zero-point offset. The measured beam areas are **$\Omega_{\rm Nep}$ = (450, 795, 1665) sq.arcsec** at PSW, PMW, PLW respectively.



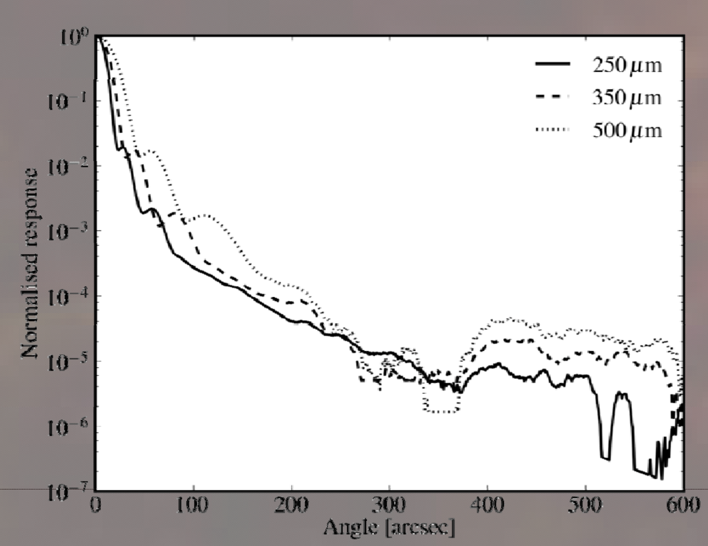


Figure 1: SPIRE beam maps for PSW, PMW, PSW (a-c), all shown with a width of 10'. Diffraction spikes from the secondary mirror supports are clearly seen. Left: radial beam response profiles of all three bands.

Extended sources

To calculate the monochromatic source surface brightness of an **infinitely extended source**, $I_\nu(\nu_0)$ for $\nu_0 = (250,350,500)\,\mu$m, we consider the calculation of measured in-band flux density, $S_{\rm meas}$

$$S_{\rm meas} = \frac{\int_\nu R_\nu\, \eta_\nu\, I_\nu(\nu_0)\,(\nu/\nu_0)^\alpha\, \Omega_\nu(\nu)\,{\rm d}\nu}{\int_\nu R_\nu\, \eta_\nu\, {\rm d}\nu}. \quad (4)$$

where η_ν is the aperture efficiency. To convert to monochromatic surface brightness, using Equations (1) and (4), is therefore:

$$K_{\rm monE}(\alpha) = \frac{I_\nu(\nu_0)}{S_{\rm meas}} = \frac{\int_\nu R_\nu\, \eta_\nu\, {\rm d}\nu}{\Omega_{\rm Nep} \int_\nu R_\nu\, \eta_\nu\, (\nu/\nu_0)^\alpha\, (\nu/\nu_{\rm eff})^{-1.7}\,{\rm d}\nu}. \quad (5)$$

Note that this conversion incorporates the conversion to surface brightness, and is included in the SPIRE standard pipeline for extended sources with α=-1 (HIPE v10+ only). The conversion from standard point source calibration (Jy/beam) to standard extended source calibration (MJy/sr) is given by **$K_{\rm PtoE}$ = (90.69, 51.43, 23.91)** for (PSW, PMW, PLW) respectively.

The colour correction required to give the surface brightness of a source with a different spectral index is

$$K_{\rm colE}(\alpha) = \frac{K_{\rm monE}(\alpha)}{K_{\rm monE}(-1)} = \frac{\int_\nu R_\nu\, \eta_\nu\, (\nu/\nu_0)^{-1}\, (\nu/\nu_{\rm eff})^{-1.7}\,{\rm d}\nu}{\int_\nu R_\nu\, \eta_\nu\, (\nu/\nu_0)^{\alpha}\, (\nu/\nu_{\rm eff})^{-1.7}\,{\rm d}\nu}. \quad (6)$$

The equivalent parameter for point sources, $K_{\rm ColP}$, is similar to (6) but without the $(\nu/\nu_{\rm eff})^{-1.7}$ term due to the frequency-dependent beam.

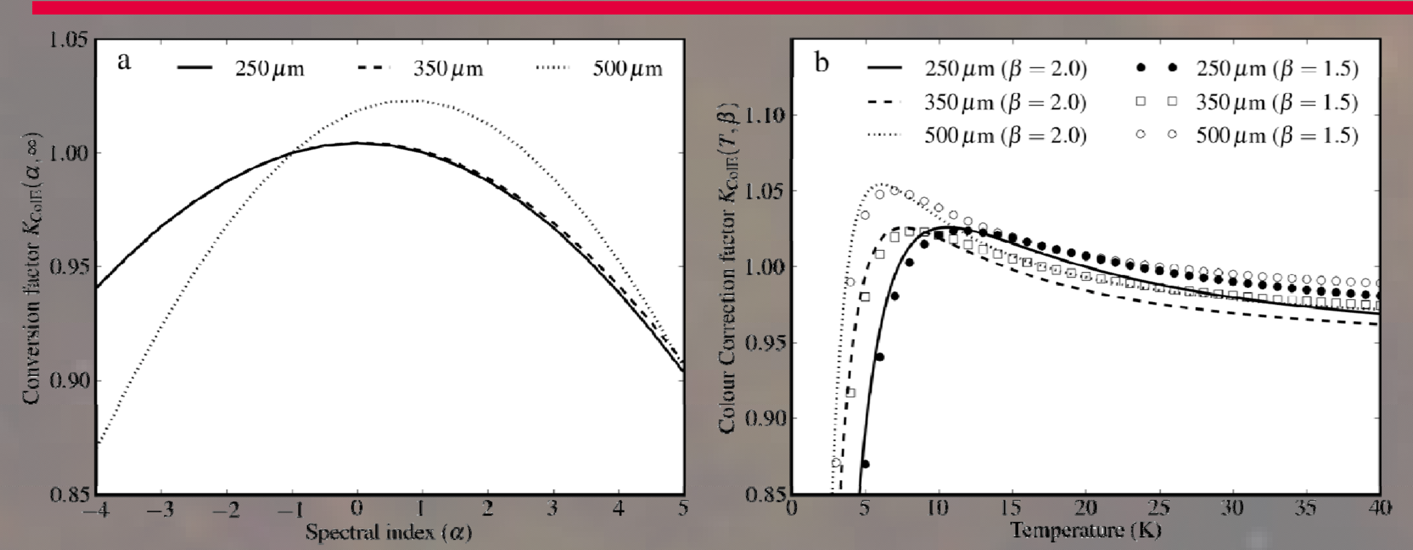


Figure 3: Colour corrections $K_{\rm colE}$ to convert from an extended source with power law spectrum with α=-1 to a source with (a) a different spectral index, and (b) with a grey-body spectrum.

Figure 4 (right): Flowchart of how the colour correction parameters should be used, for both point sources and extended sources. Note that all colour corrections conserve map units.

SPIRE effective beams

The beams are measured on a source with a particular spectral index ($I_\nu \propto \nu^\alpha$, where for Neptune $\alpha=\alpha_{\rm Nep}$=(1.29, 1.42, 1.47) in PSW, PMW, PLW respectively). Adjustments must therefore be made for sources with a different spectrum, which involves taking into account the frequency-dependence of the beam. The beam is assumed to vary with frequency as $\nu^{-0.85}$.

The monochromatic beam solid angle, $\Omega_\nu(\nu)$ therefore varies as in Equation (1). The effective beam area, $\Omega_{\rm eff}(\alpha)$, integrated over the instrument relative spectral response function (RSRF), R_ν, and source spectrum, ν^α, as in Eq (2).

$$\Omega_\nu(\nu) = \Omega_{\rm Nep} \cdot \left(\frac{\nu}{\nu_{\rm eff}}\right)^{-1.7} \quad (1) \quad ; \quad \Omega_{\rm eff}(\alpha) = \frac{\int_\nu R_\nu\, \nu^\alpha\, \Omega_\nu(\nu)\,{\rm d}\nu}{\int_\nu R_\nu\, \nu^\alpha\,{\rm d}\nu}. \,(2)$$

Equation (1) is normalised through the effective frequency, $\nu_{\rm eff}$, which is the frequency at which the monochromatic beam solid angle equals that as measured on Neptune, i.e. $\Omega_\nu(\nu_{\rm eff}) = \Omega_{\rm eff}(\alpha_{\rm Nep}) \equiv \Omega_{\rm Nep}$. For SPIRE, Equiation (2) then becomes:

$$\Omega_{\rm eff}(\alpha) = \Omega_{\rm Nep} \frac{\int_\nu R_\nu\, \nu^\alpha\, (\nu/\nu_{\rm eff})^{-1.7}\,{\rm d}\nu}{\int_\nu R_\nu\, \nu^\alpha\,{\rm d}\nu}. \quad (3)$$

This effective frequency is necessary for converting a map between flux density (Jy/beam) and surface brightness (e.g. MJy/sr or Jy/pix) units. The standard SPIRE pipeline uses the standard source convention of α=-1, which results in effective beam solid angles of **$\Omega_{\rm eff}(-1)$ = (465, 822, 1768)** sq.arcsec for PSW, PMW, PLW respectively.

Similar expressions to Eq (3) can be formulated for source spectra other than power laws. The variation of the beam solid angle with power-law spectral index and grey body temperature is shown in Figure 2 (below).

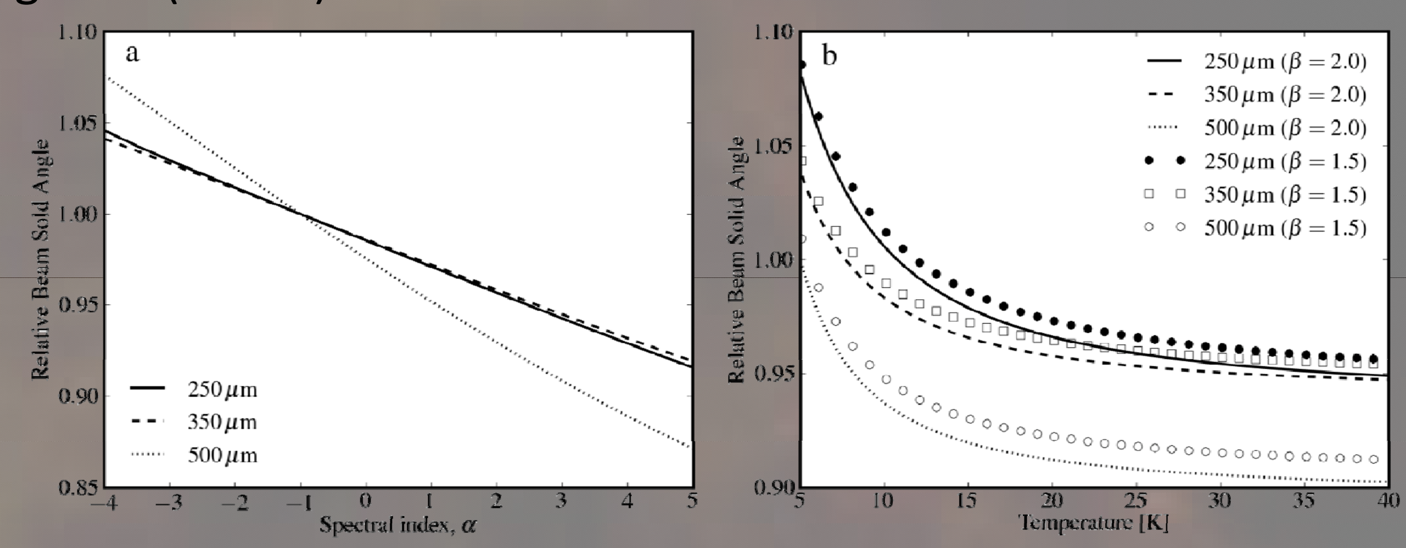


Figure 2: The variation of the effective beam solid angle with source spectrum, assuming (a) a power law spectrum, and (b) a grey-body spectrum with two values of the emissivity index, β (where emissivity $\varepsilon \propto \lambda^\beta$). The values are given relative to those calculated for the standard pipeline source spectrum, i.e. a power law spectrum with spectral index $\alpha = -1$.