Photometer Extended Source Photometry

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on behalf of the SPIRE ICC

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- Convert point source map to extended source fluxes.
- Correction factors to take into account
  - Color correction
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  - Aperture correction
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- Derive aperture correction factors for semi extended sources
- Uncertainties

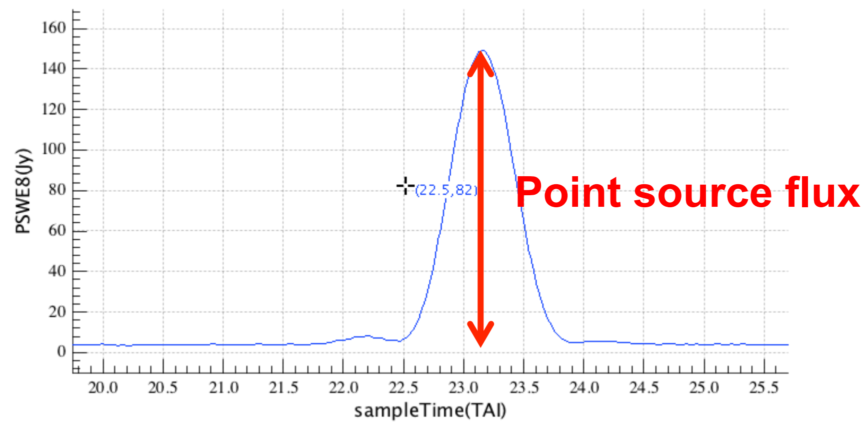
Some Caveats

- The SPIRE photometric calibration is based on point sources.
- In this case extended emission is harder to calibrate and the errors are larger.
- This is a complex topic and calibration work on determining the beam profiles and solid angles is still ongoing, so we won't always present final answers.
- However, we will show material and ways to make progress and how to work out solutions for specific problems.

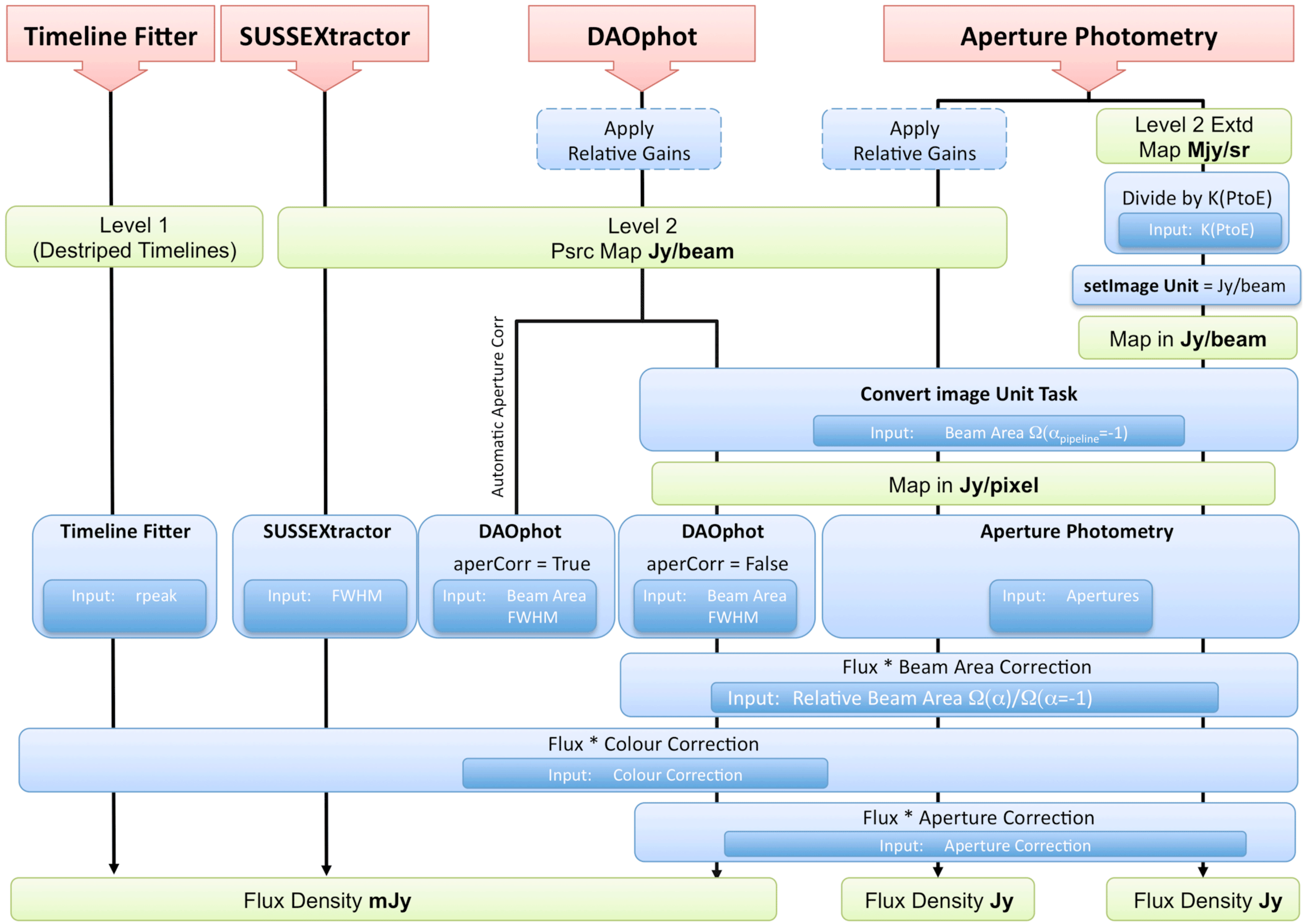
Recap Point Source Photometry

- The SPIRE calibration is based on point source photometry (Prime calibrator: Neptune)
- Standard SPIRE unit is Jy/beam
- When a detector is scanned centrally over a point source, the peak deflection of the signal timeline equals the brightness of the source.
- The spire broad-band photometry is quantified as monochromatic flux density at a reference wavelength (250, 350, 500μm) assuming a reference spectrum of νF_ν = const.
- For a different reference spectrum a color correction must be applied.

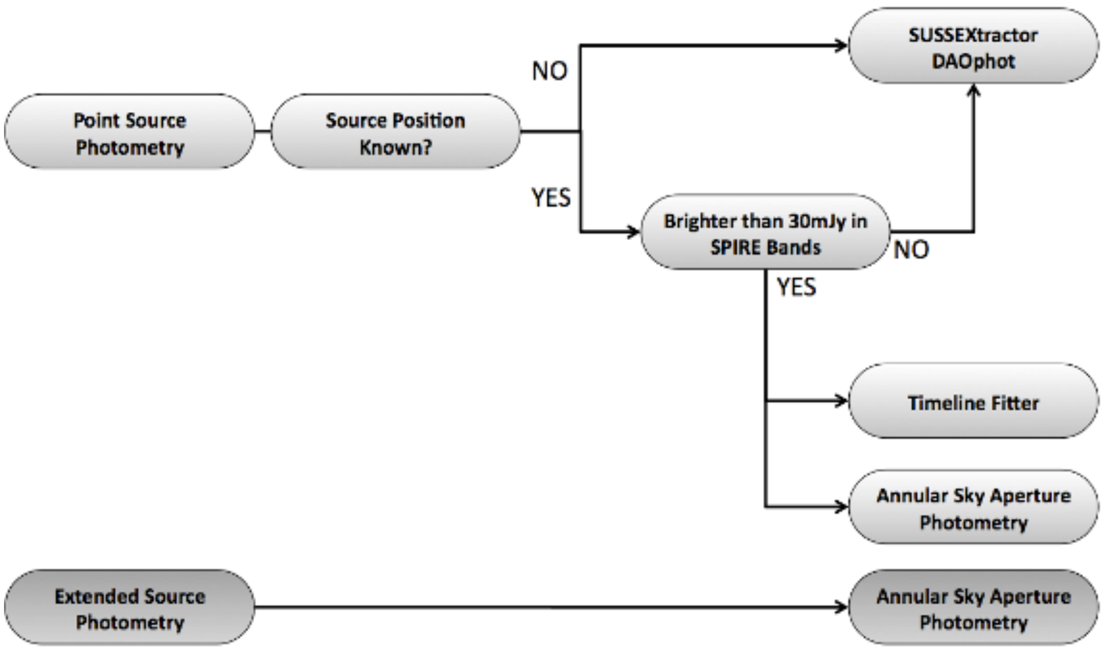
Scan of detector PSWE8 over Neptune, obsid 1342187440

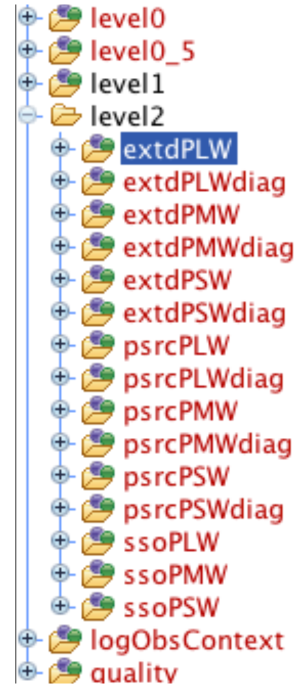


RECIPES FOR **SPIRE POINT SOURCE** PHOTOMETRY



The Right Photometry Choice

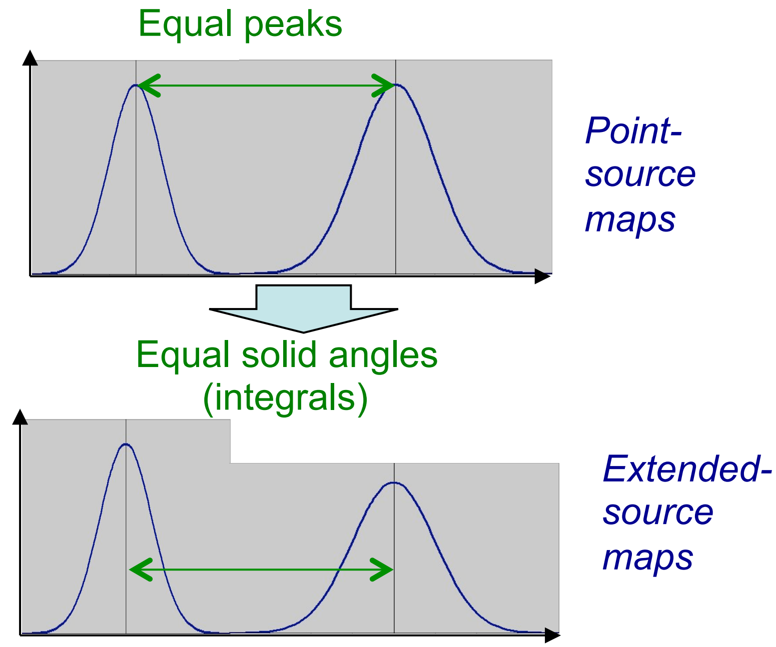


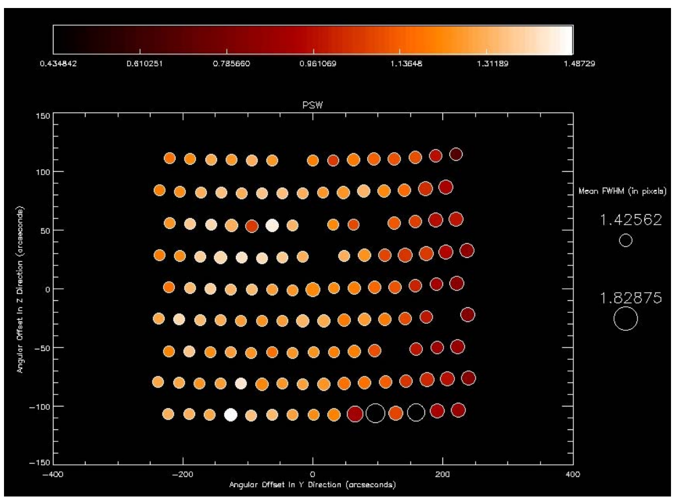


- For point sources there are several choices and it depends a bit on the task at hand.
- For large and small extended sources there is only aperture photometry.
- The SPIRE Level 2 products fortunately already contain a product that comes in extended source units MJy/sr, ready for aperture photometry.

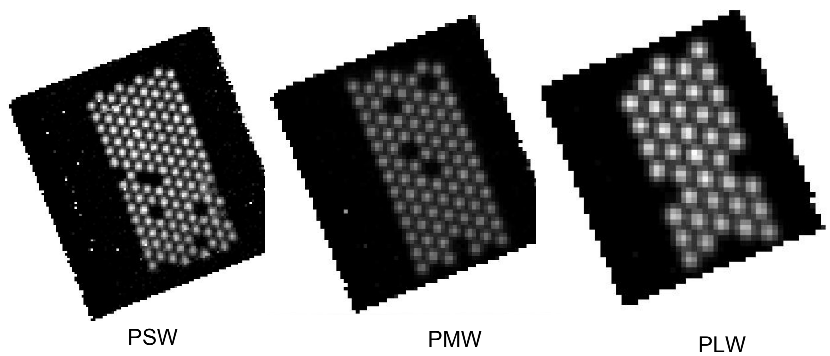
Extended Gain Correction

- Not all detector beam-profiles have the same width.
- Applying the Extended Gains equalizes the detector areas (instead of the peaks).
- The numbers are provided in the SPIRE calibration tree.
- These gain factors should be applied before median subtraction, or destriping, and map-making.



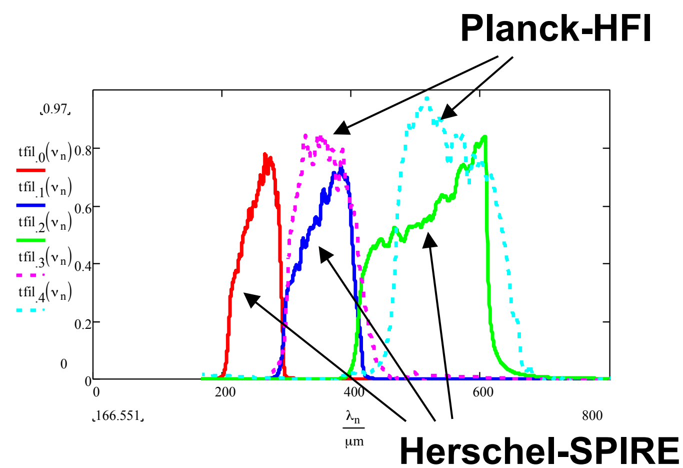


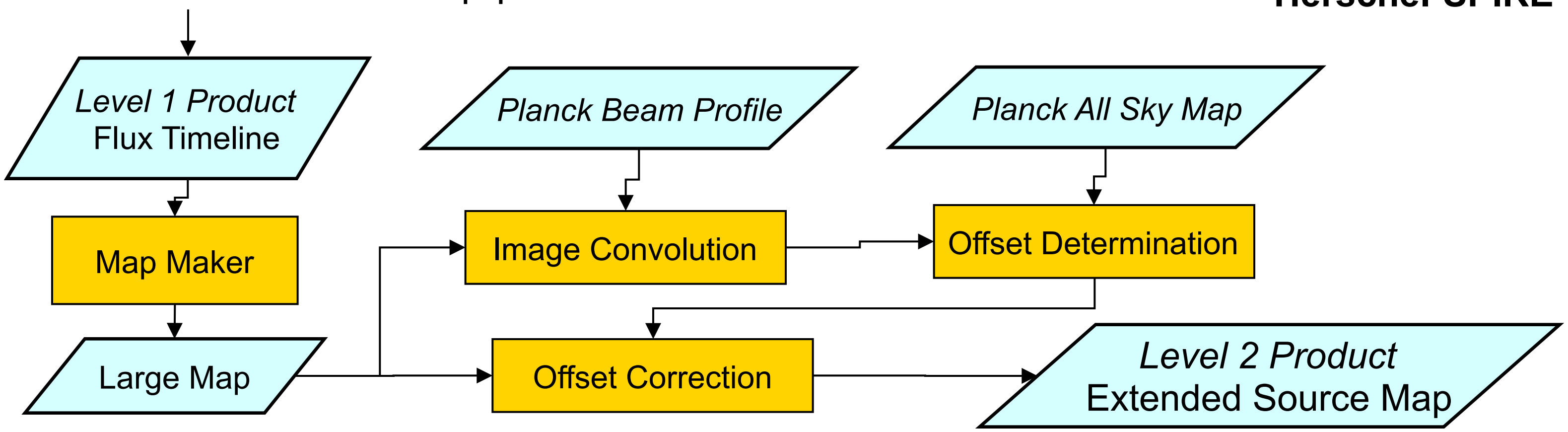
PSW: FWHMs are exaggerated



Herschel-SPIRE/Planck-HFI X-Calib.

- SPIRE and Planck-HFI overlap in SPIRE filters at 350 and 500μm (HFI 857 and 545 GHz filters).
- Planck HFI is using photometric gains from Uranus and Neptune radiative models and zero-levels from correlation of HI (21cm) gas column density with CIB mean level added (Planck Collaboration VIII. 2013, In prep.)
- Latest analysis shows very good correspondence of SPIRE and HFI photometric gains. We still multiply the HFI 545GHz map by 0965 for consistency.
- The SPIRE standard pipeline uses fits to gain and color corrected HFI maps to provide absolute flux offsets in the extended flux map products.



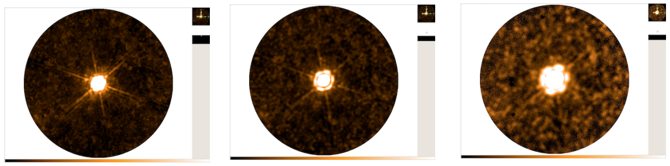


Aperture Photometry

- Aperture photometry sums up map pixels, i.e. expects the map signal in extended source units like MJy/sr, Jy/’’□, or Jy/pixel.
- The solid angle needed for the conversion is color dependent and was derived from large fine scan maps (1” pixels) of Neptune that go out to 700” radius.
- The extended flux source maps in the HSA are converted for a νF_ν=const. spectrum and corrections need to be applied to aperture photometry.

- Color correction:
  - Source SED different from assumed reference spectrum νF_ν=const.
- Aperture correction
  - Correction for Flux lost outside of integration aperture.
- Background correction
  - Correction for flux of the beam still inside of the annulus where backround is determined.
- Omega correction
  - Correction for change in effective solid angle when source SED is different from νF_ν=const.

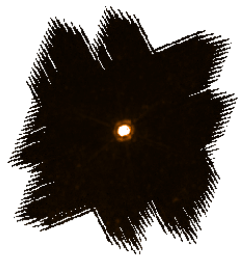
Solid angles in [arcsec^2]	PSW	PMW	PLW
Measured with Neptune spectrum	450	795	1665
SPIRE photometer reference spectrum (nu*F_nu = const.)	465	822	1768



See: http://herschel.esac.esa.int/twiki/bin/view/Public/SpirePhotometerBeamProfile

Aperture Photometry on Point Sources

extdPxW
[MJy/sr]



Best to start with extended source map

Convert Image Unit Task

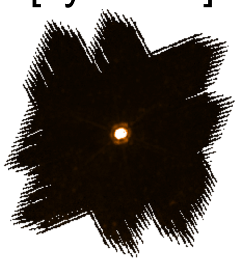
[Jy/pixel]

Aperture Photometry Task

[Jy/pixel]

Convert Image Unit Task

psrcPxW
[Jy/beam]



Aperture Correction

	Perfect BG			BG annulus 60"-90"		
alpha	PSW	PMW	PLW	PSW	PMW	PLW
-4.0	1.277	1.227	1.216	1.282	1.234	1.236
-3.5	1.275	1.226	1.214	1.280	1.234	1.234
-3.0	1.274	1.226	1.213	1.279	1.234	1.232
-2.5	1.273	1.226	1.212	1.277	1.233	1.231
-2.0	1.272	1.225	1.210	1.276	1.233	1.229
-1.5	1.271	1.225	1.209	1.276	1.232	1.227
-1.0	1.270	1.224	1.208	1.275	1.232	1.226
-0.5	1.269	1.224	1.207	1.274	1.231	1.224
0.0	1.269	1.223	1.205	1.273	1.231	1.222
0.5	1.268	1.223	1.204	1.272	1.231	1.221
1.0	1.267	1.222	1.203	1.272	1.230	1.219
1.5	1.267	1.222	1.202	1.271	1.230	1.218
2.0	1.266	1.222	1.201	1.270	1.229	1.216
2.5	1.265	1.221	1.200	1.269	1.229	1.215
3.0	1.264	1.221	1.199	1.269	1.229	1.213
3.5	1.264	1.220	1.198	1.268	1.228	1.212
4.0	1.263	1.220	1.197	1.267	1.228	1.211
4.5	1.262	1.219	1.196	1.266	1.227	1.209
5.0	1.262	1.219	1.195	1.266	1.227	1.208

Color Correction

Table 5.12. Color Corrections for Point Sources and Extended Emission

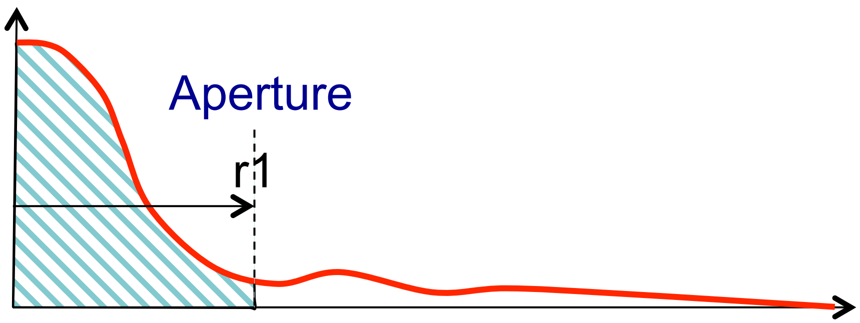
Spectral Index	Point Source Colour Correction			Extended Emission Colour Correction		
($F_{nu}=nu^{alpha}$)	PSW	PMW	PLW	PSW	PMW	PLW
-4	0.9800	0.9791	0.9333	0.9407	0.9405	0.8703
-3.5	0.9884	0.9875	0.9525	0.9549	0.9547	0.8982
-3	0.9948	0.9940	0.9687	0.9675	0.9673	0.9239
-2.5	0.9992	0.9986	0.9817	0.9784	0.9783	0.9472
-2	1.0016	1.0011	0.9913	0.9875	0.9874	0.9679
-1.5	1.0019	1.0016	0.9974	0.9948	0.9947	0.9855
-1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
-0.5	0.9960	0.9963	0.9990	1.0032	1.0033	1.0111
0	0.9899	0.9906	0.9945	1.0043	1.0046	1.0187
0.5	0.9818	0.9829	0.9864	1.0034	1.0038	1.0227
1	0.9716	0.9732	0.9751	1.0003	1.0009	1.0230
1.5	0.9594	0.9615	0.9606	0.9951	0.9960	1.0197
2	0.9454	0.9481	0.9432	0.9878	0.9890	1.0128
2.5	0.9296	0.9329	0.9231	0.9784	0.9800	1.0025
3	0.9121	0.9161	0.9005	0.9671	0.9691	0.9889
3.5	0.8930	0.8978	0.8758	0.9538	0.9563	0.9721
4	0.8725	0.8780	0.8492	0.9388	0.9418	0.9526
4.5	0.8507	0.8571	0.8210	0.9220	0.9255	0.9304
5	0.8278	0.8350	0.7916	0.9036	0.9077	0.9059

For aperture photometry, starting with a point source map is not recommended but possible.

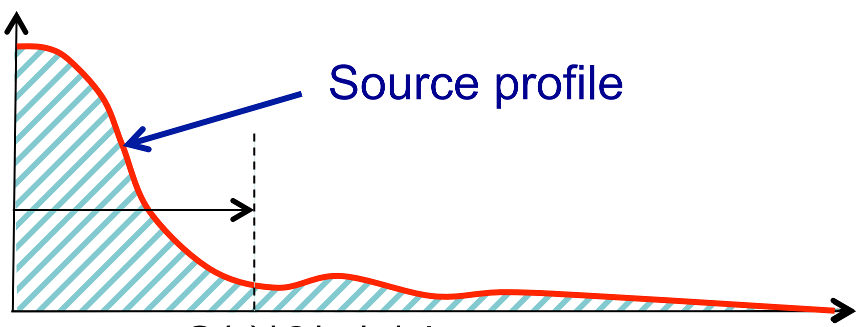
Solid angles in [arcsec^2]	PSW	PMW	PLW
SPIRE photometer reference spectrum (nu*F_nu = const.)	465	822	1768

Aperture Correction Factors

If background was perfectly known and subtracted.

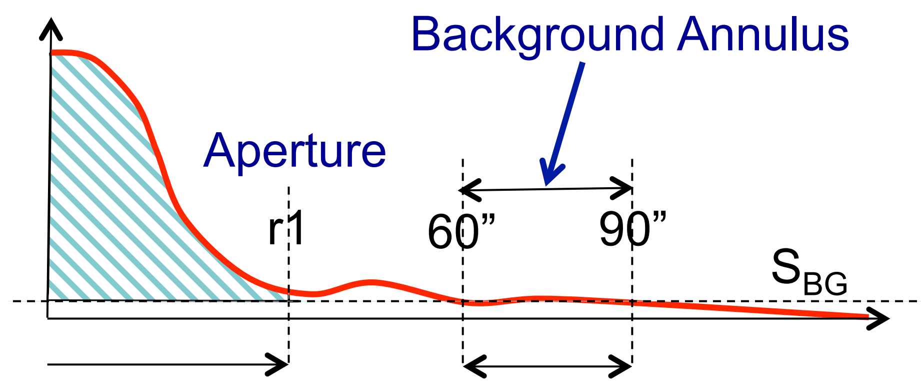


$\Omega_{aper}=\Sigma_{0..r1}\ S(r)*2*\pi*r*dr$



$\Omega_{total}=\Sigma\ S(r)*2*\pi*r*dr$

Take into account error due to beam residual in background estimation.



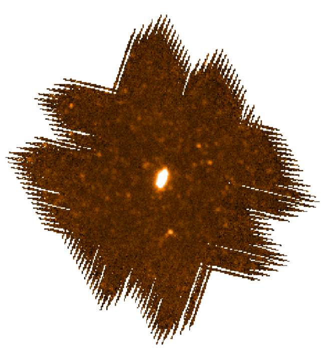
$\Omega_{aper}=\Sigma_{0..r1}\ (S(r)-S_{BG})\ *2*\pi*r*dr$

$\boxed{aperCorr = \Omega_{total} / \Omega_{aper}}$

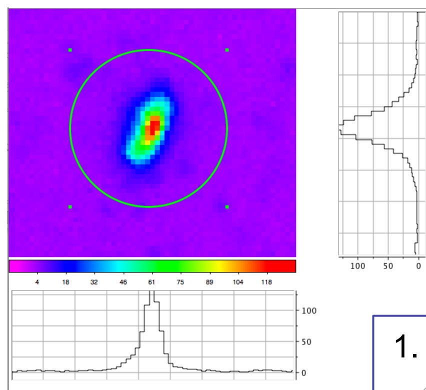
The same principles apply for both, point, and extended sources.

Aperture Photometry on Extended Sources

extdPxW
[MJy/sr]



Aperture Correction



Color+Omega Correction

Table 5.12. Color Corrections for Point Sources and Extended Emission

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0	0.9899	0.9906	0.9945	1.0043	1.0046	1.0187
0.5	0.9818	0.9829	0.9864	1.0034	1.0038	1.0227
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1. For a large bright source the aperture can be large and aperture correction is negligible.
2. For a small faint source the aperture can not be too large and the aperture correction must be derived by modeling the source flux distribution to obtain precise results.

[Jy/pixel]

Convert Image Unit Task

Aperture Photometry Task

Flux Uncertainty

- Uncertainty in the derived flux
  - Includes the instrument
  - Confusion noise
    - (minimum of about 5 mJy for point sources)
  - Background estimate
- ~10% of flux density for calibration uncertainty
  - 2% statistical reproducibility
  - 4% absolute level of Neptune model
    - (systematic)
  - 4% uncertainty in solid angle determination
    - (systematic)
    - This one may go away as it can in principle be bootstrapped out.