Measuring Photometry from SPIRE Observations

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on behalf of the SPIRE ICC

SPIRE Photometry

- SPIRE Calibration
- Photometry of Point and Compact Sources
- Extended Source Photometry
- Color Corrections

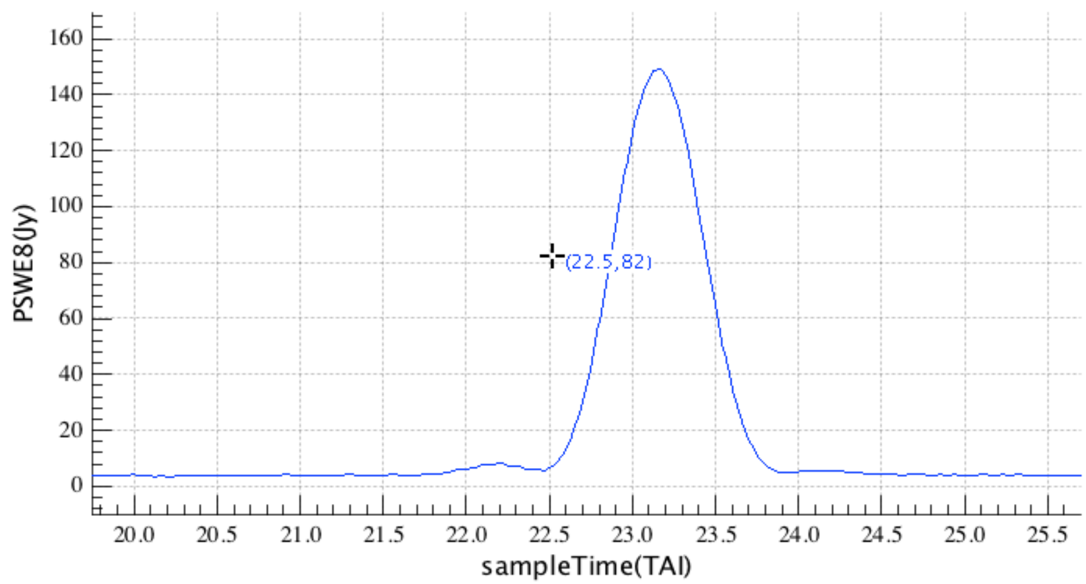
SPIRE Photometry

- SPIRE Calibration
  - How Calibration is Defined
  - Units and Beam Areas
  - Extended Gains
  - DC-Level calibration
- Photometry of Point and Compact Sources
- Extended Source Photometry
- Color Corrections

SPIRE calibration is defined by the peak deflection when scanning

- When a detector is scanned directly over a point source, the peak deflection of the signal timeline equals the brightness of the source.

Scan of detector PSWE8 over Neptune, obsid 1342187440



The timeline-based definition leads to some accounting corrections

- Units are in Janskys per beam
  - Most software wants Jy/pixel or MJy/sr

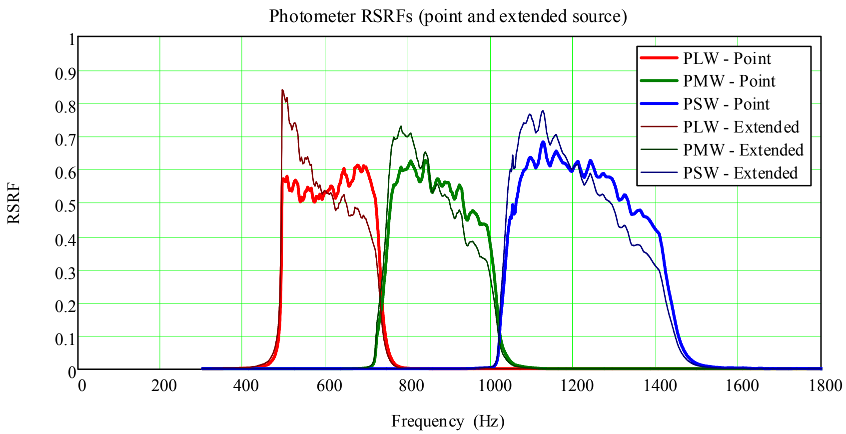
- Calibration is for point source peaks
  - Some detectors have bigger areas

- Calibration is for nu*Fnu = constant
  - Color correction for other spectral shapes

Use the “fine-scale” beam areas to convert Jy/beam to other units

- The fine-scale beam areas were measured from Neptune maps with 1-arcsec pixels
  - 250um: 423 sq arcsec
  - 350um: 751 sq arcsec
  - 500um: 1587 sq arcsec
- These values will change slightly in the near future
  - [450, 795, 1665] sq arcsec +/- 4%
- The “convertImageUnit” task will change maps to Jy/pixel or MJy/sr

Color Dependence of Solid Angle

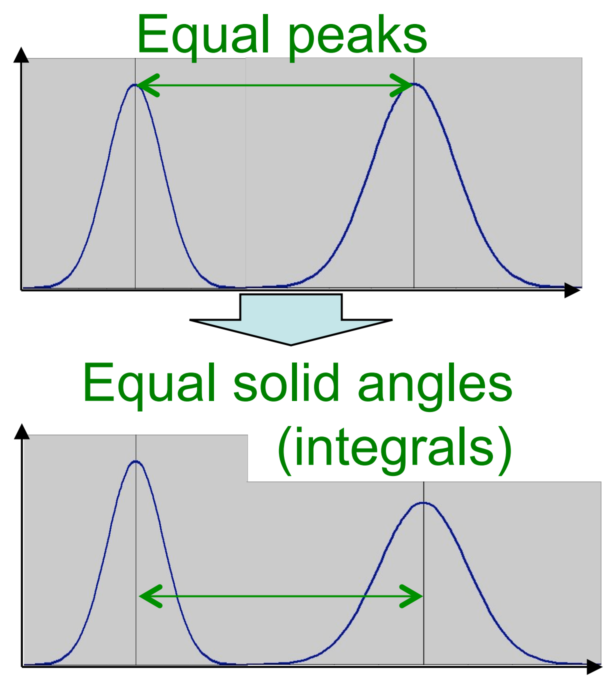


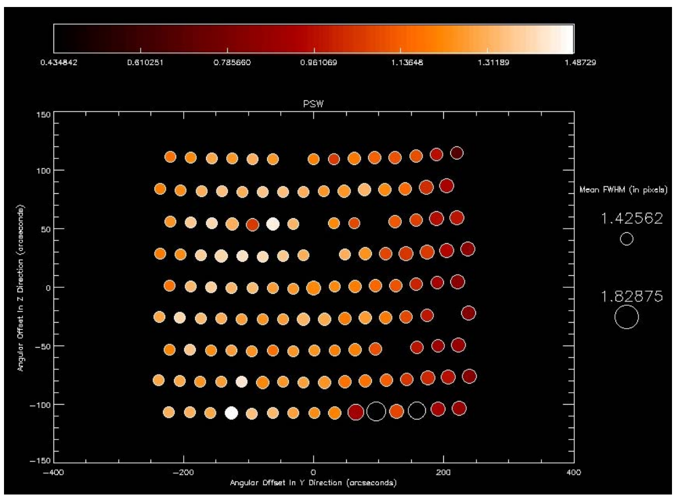
The dependence of the solid angle on wavelength can be factored into the RSRF for convenience. It should be noted however that these are two different physical effects.

- The solid angle for infinitely extended sources depends on wavelength.
- For broad-band filters like those of SPIRE, this dependence significantly impacts color correction.
- Currently the Observer's Manual recommends using a modified relative spectral response function (RSRF). It is derived by weighting the RSRF for point sources by λ^2.
- This dependence is under investigation and expected to change to a smaller exponent because of the way the bolometer feedhorns couple to the Herschel telescope.
- The intermediate case of a slightly extended point source can be handled analytically, but this is more complex and requires assumptions about the source shape.

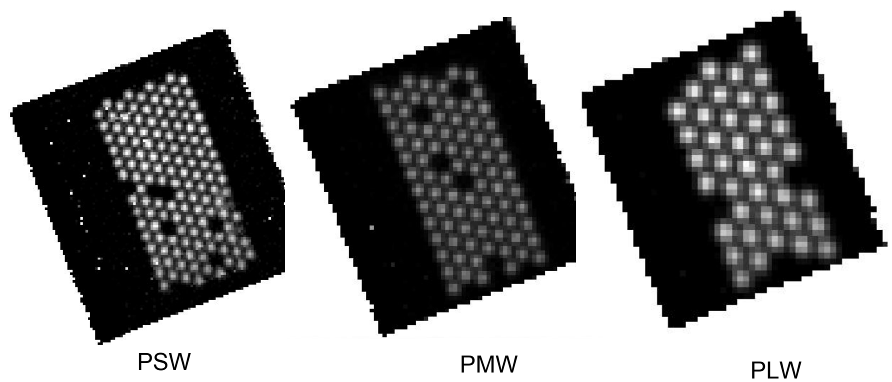
Extended Gain Correction

- 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.

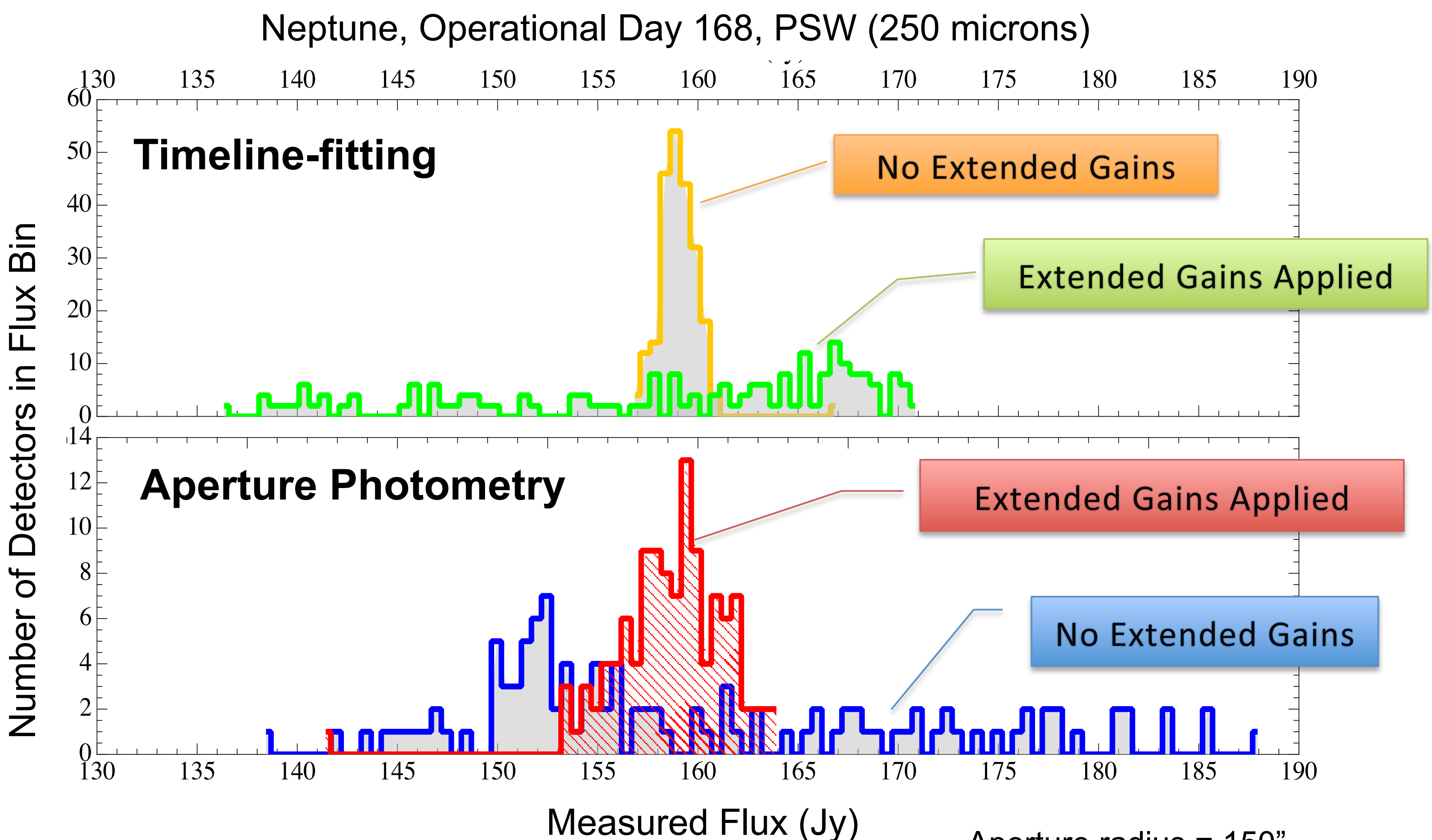




PSW: FWHMs are exaggerated



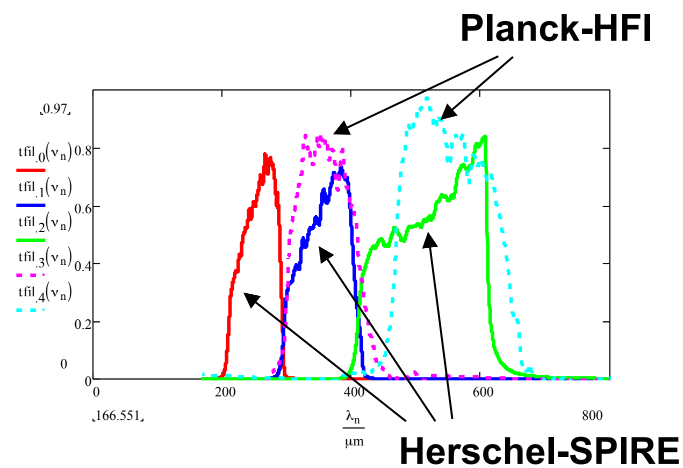
Single-detector Neptune maps show the gains reduce the spread in large apertures

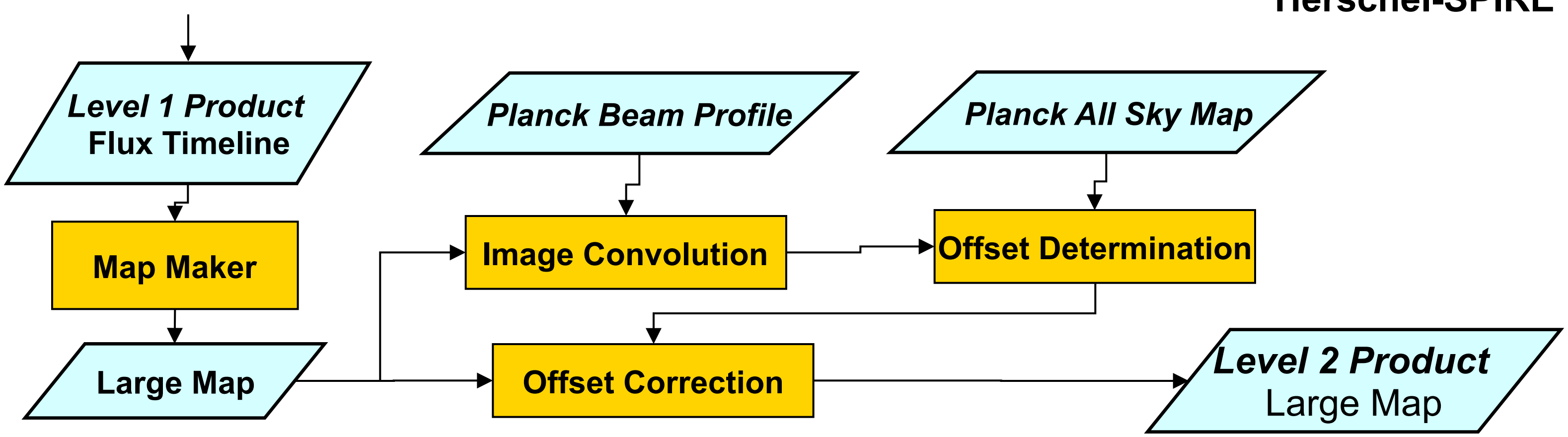


Aperture radius = 150”
Aperture correction = 1.027

Herschel-SPIRE/Planck-HFI X-Calib.

- SPIRE and Planck-HFI overlap in SPIRE filters at 350 and 500μm.
- Planck HFI is using absolutely calibrated COBE-FIRAS maps for their calibration.
- Eventually the pipeline will produce zero-point corrected SPIRE maps

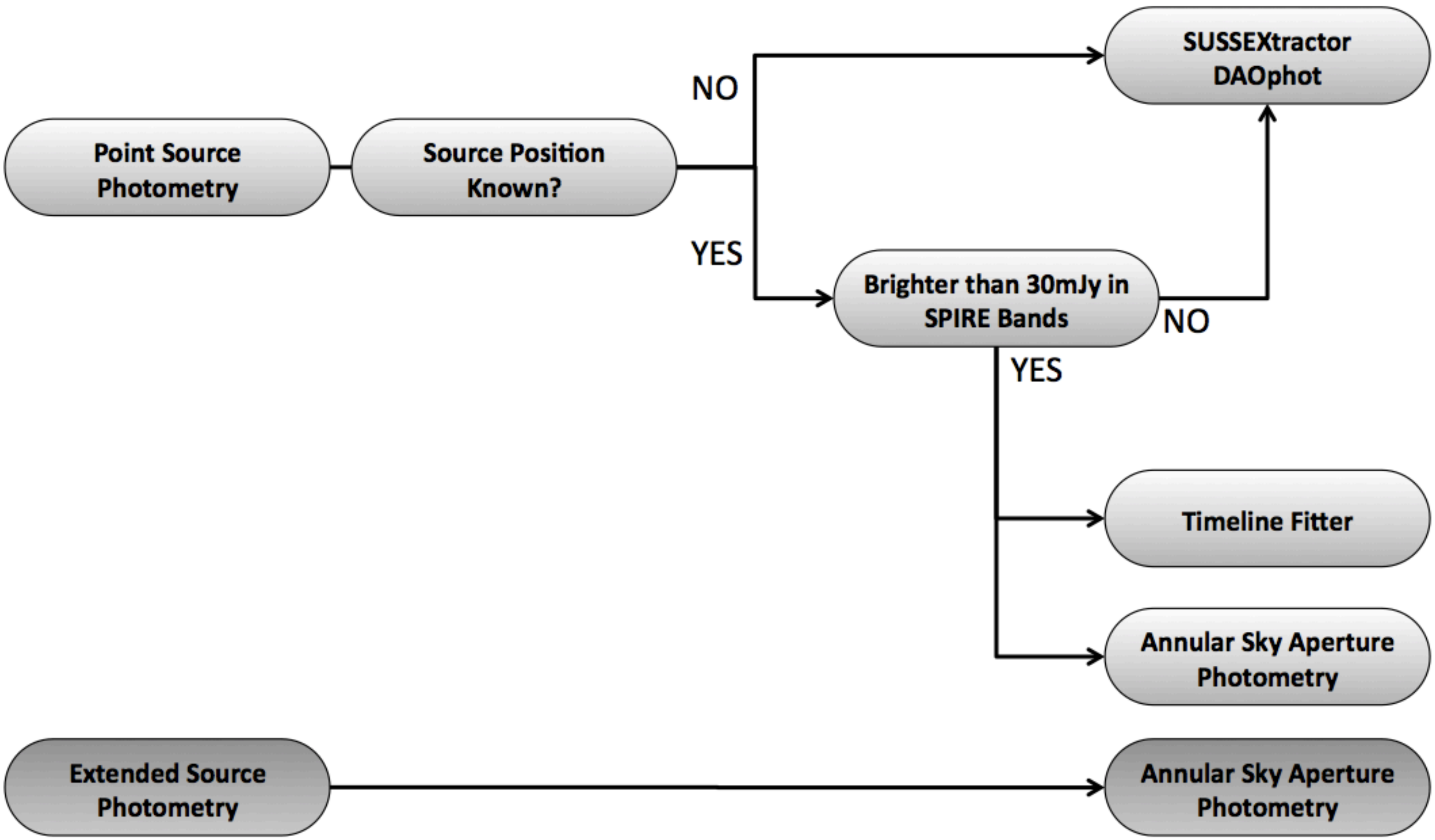




SPIRE Photometry

- SPIRE Calibration
- Photometry of Point and Compact Sources
  - Choosing the Photometry Method
  - Source Detection and Extraction
  - Timeline-fitting and aperture photometry
  - Estimating uncertainties
- Extended Source Photometry
- Color Corrections

The choice of photometry tool depends on details of your data



To *detect* sources, use either of the source extractors in HIPE

- **sourceExtractorSussextractor**
  - Sussextractor algorithm *(Savage & Oliver 2007)*
  - Good for detecting sources
  - Flux density is peak of smoothed image
- **sourceExtractorDaophot**
  - Algorithms from IDL AstroLib
  - FIND for detection
  - APER for photometry (not PSF-fitting!)

The simplest operation of extractors uses the FWHM of each band

- Averages for nominal pixels:
  - 250um: 18.2 arcsec
  - 350um: 24.9 arcsec
  - 500um: 36.3 arcsec
- You can supply your own PRF image

For *point sources* with *known positions,* timeline-fitting photometry is best

- Timeline-fitting photometry: **sourceTimelineFitter** task
  - Requires Level 1 data (timelines)
  - Remove baselines first
  - Takes a source list as input coordinates
  - Must be point sources
  - If < 30 mJy, use **sourceExtractorSussextractor**

- Aperture photometry is a good second option *(required if not point sources)*
  - **annularSkyAperturePhotometry**: one source at a time
  - **sourceExtractorDaophot**: can take a source list

Official aperture corrections are in the SPIRE Data Reduction Guide

- Values in Photometry Recipe:
  - 1.2750 (250μm) 22” radius, sky 60”-90”
  - 1.1933 (350μm) 30” radius, sky 60”-90”
  - 1.2599 (500μm) 42” radius, sky 60”-90”
  - Uncertainties at 5% level

- Apply these for **annularSkyAperturePhotometry** or **sourceExtractorDaophot**

To estimate the total uncertainty in flux, combine these terms in quadrature

- Uncertainty in the fitted amplitude
  - Includes the instrument and confusion noise (minimum of about 6 mJy)
  - (Errors computed by **annularSkyAperturePhotometry** are over-estimated)
- 7% of flux density for calibration uncertainty
  - 2% statistical reproducibility
  - 5% absolute level of Neptune model (this term does not apply to SPIRE colors)

Example: Timeline-fitting on Gamma Dra at 250 microns

```
obs = getObservation(1342195871)
scans = baselineRemovalMedian(obs.level1)
ra = obs.meta['raNominal'].value
dec = obs.meta['decNominal'].value
list = sourceExtractorTimeline(input=scans,\
     array='PSW',rPeak=22.0,\
     inputSourceList=[ra,dec])
flux = list['sources']['flux'].data[0]*0.9417
error = list['sources']['fluxPlusErr'].data[0]*0.9417
print 'Flux density %5.1f +/- %4.1f mJy'%\
       (wavel[array],flux,error)
```

Baseline removal

Color correction

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Caveats for extended emission

- No absolute level
  - In time, will come from Planck
- Baseline-removal technique will affect extended emission
- Correction factors for extended emission are being recalculated

Units correction and extended correction must be applied

- Correct units e.g. to MJy/sr
  - convertImageUnit task
  - Beam solid angles
- Multiply by these factors for extended relative spectral response function
  - 250um 0.9939/1.0113
  - 350um 0.9898/1.0060
  - 500um 0.9773/1.0065

Checklist for photometry of extended sources

- ❑Use the map made with relative gains applied
- ❑Run one of the aperture photometry tasks
- ❑Apply extended source correction
- ❑Apply extended source color correction

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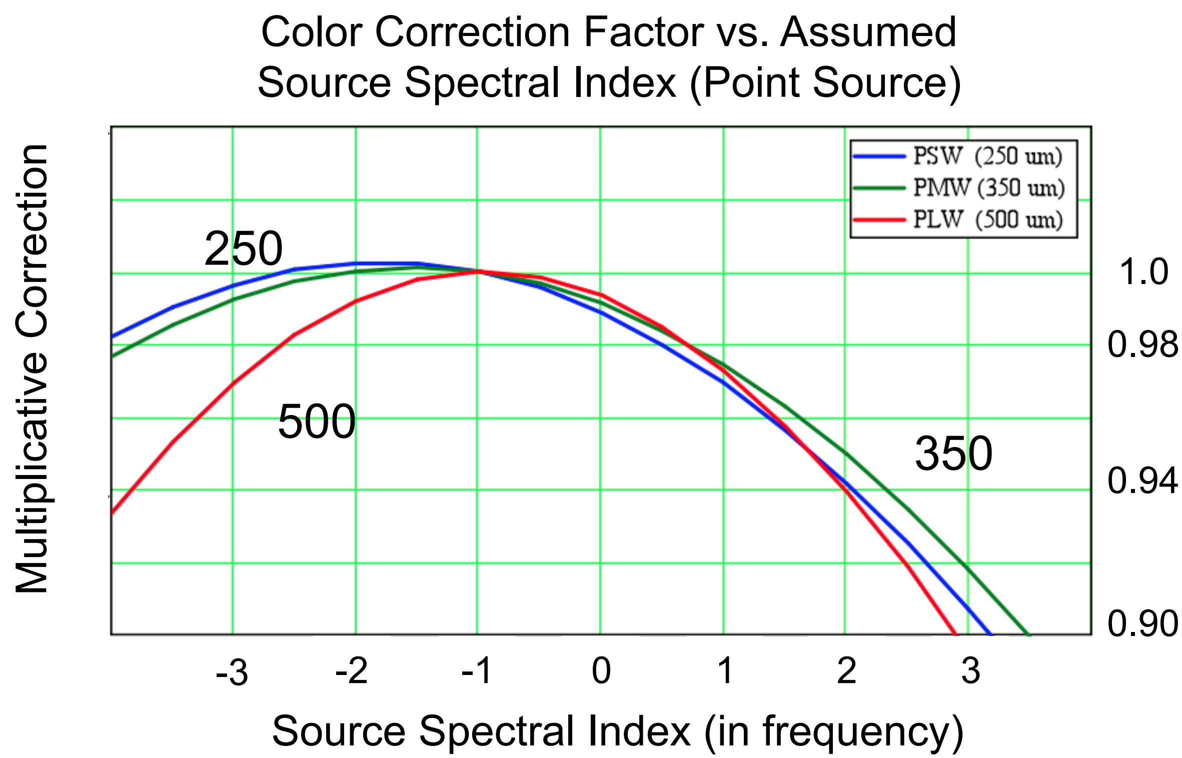
Color corrections are described in the SPIRE Data Reduction Guide

- See Sec 5.7
- Multiply by the value appropriate for your source
- For specific cases, compute your own correction from the filter RSRFs



Multiplicative color corrections for point sources from SDRG

Table 5.7. Point Source Color Corrections

Spectral Index (α in fν ∝ να)	PSW Correction	PMW Correction	PLW Correction
-4.000	0.9820	0.9700	0.9336
-3.500	0.9902	0.9798	0.9530
-3.000	0.9964	0.9877	0.9693
-2.500	1.0005	0.9938	0.9823
-2.000	1.0025	0.9978	0.9918
-1.500	1.0023	0.9999	0.9978
-1.000	1.0000	1.0000	1.0000
-0.500	0.9955	0.9980	0.9986
0.000	0.9888	0.9940	0.9935
0.500	0.9801	0.9880	0.9849
1.000	0.9692	0.9799	0.9729
1.500	0.9564	0.9700	0.9577
2.000	0.9417	0.9582	0.9395
2.500	0.9252	0.9446	0.9186
3.000	0.9070	0.9293	0.8952
3.500	0.8873	0.9125	0.8698
4.000	0.8662	0.8942	0.8424

Further reading and viewing

- SPIRE Data Reduction Guide
  - Section 5.7, "Recipe for SPIRE Photometry"
- SPIRE Photometry Webinar
  https://nhscsci.ipac.caltech.edu/sc/index.php/Spire/PointSourcePhotometryWebinar
- SPIRE Observer's Manual
  - Section 5.2
- SPIRE Instrument & Calibration page
  - http://herschel.esac.esa.int/twiki/bin/view/Public/SpireCalibrationWeb