PACS photometry on extended sources

Total flux experiments
Bruno Altieri on behalf of Marc Sauvage

1. Point-source photometry status
2. Prospect on extended emission photometry from theory
3. Results from simulations
4. Total photometry on large galaxies (M. Sauvage)
5. Pixel-to-pixel comparison on KINGFISH galaxies
6. Conclusions
1. Point-source sensitivity

- Excellent absolute calibration coming up in FM Responsivity v6 with new PSFs:
  - ✓ 3% at 70 and 100µm
  - ✓ 5% at 160µm

Table 8: Observed and calibrated (“FM, 6”) monochromatic flux densities at 70, 100, 160µm divided by the corresponding model predictions for all 5 fiducial stars.

<table>
<thead>
<tr>
<th>Target name</th>
<th>blue obs/model</th>
<th>green obs/model</th>
<th>red obs/model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no.</td>
<td>median</td>
<td>mean</td>
</tr>
<tr>
<td>β And</td>
<td>2</td>
<td>—</td>
<td>1.011</td>
</tr>
<tr>
<td>α Cet</td>
<td>3</td>
<td>—</td>
<td>1.011</td>
</tr>
<tr>
<td>α Tau</td>
<td>4</td>
<td>—</td>
<td>0.987</td>
</tr>
<tr>
<td>α Boo</td>
<td>3</td>
<td>—</td>
<td>1.000</td>
</tr>
<tr>
<td>γ Dra</td>
<td>23</td>
<td>0.985</td>
<td>0.983</td>
</tr>
<tr>
<td>mean/stddev</td>
<td>0.999±0.013</td>
<td>1.000±0.013</td>
<td>0.997±0.013</td>
</tr>
</tbody>
</table>
2. Map-making

- The relation between sky map ($x$) and signal ($y$) is represented by a projection matrix $P$ whose elements are built from the geometrical intersection between the detector pixels and the sky pixels.

$$y = Px + n$$
2. Map-making

- Most map-making algorithms do not invert $P$ but try and estimate a map knowing the signal and $P$.

- photProject uses: $x_{phP} = \frac{PTy}{PT_1}$

- One can show that the algorithm is «flux conserving» even when an error is made on the detector pixel size.

- Flux conserving: the total flux of the objects is preserved by the map-making algorithm.

- An error in the pixel size translates in a multiplicative factor on the map (which is «calibrated out»).
2. Map-making

- Looking at the code, map-making should not be responsible for a distortion affecting only the extended sources.

- The map-making algorithm realizes a supplementary convolution of the data with a kernel that has a size comparable to the detector pixel size.

Example of the map-maker convolution kernel with map pixels of 4" while the detector is assumed to have pixels of 6.4"
2. Conclusions (theory)

- There is no reason to believe that the photometry of extended sources should follow a different scale from that of point sources.

- Total flux comparisons are simpler to interpret than pixel-to-pixel comparisons, because of the complex PACS PSF and the often neglected convolution performed by the map-making algorithms.
3. Simulations

- Take a "galaxy" of known surface brightness distribution.
- Simulate its observation (with YAPS, not taking into account bolometer time constants, PSF).
- Add actual noise and glitches (taken from LF Noise measurements in PV).
- Process it through my scan map pipeline using various options (HPF+PhP, MADmap, object masks of different size).
From simulation to reconstruction

variable parameters: 2nd level deglitching, size of the object mask
3. Photometric results

Integration of the flux in the image over an elliptical aperture including the object completely.
Errors combine photometric and data reduction errors.
Object flux should be 163.4 Jy at 70 and 160 µm.

Effect of the $n\sigma$ parameter in 2nd level deglitching on pure noise image

<table>
<thead>
<tr>
<th>$n\sigma$</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>25MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 µm</td>
<td>-1.38±0.65</td>
<td>-1.44±0.65</td>
<td>-1.35±0.65</td>
<td>-25.87±0.44</td>
</tr>
<tr>
<td>160 µm</td>
<td>-0.30±0.49</td>
<td>0.26±0.49</td>
<td>-0.28±0.49</td>
<td>-9.20±0.54</td>
</tr>
</tbody>
</table>

Effect of the object mask definition on signal and noise image

<table>
<thead>
<tr>
<th>Mask size</th>
<th>Full</th>
<th>1e-4 of Peak</th>
<th>1e-3 of Peak</th>
<th>1e-2 of Peak</th>
<th>Auto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Style</td>
<td>HPF+PhP</td>
<td>MADmap</td>
<td>HPF+PhP</td>
<td>MADmap</td>
<td>HPF+PhP</td>
</tr>
<tr>
<td>70 µm</td>
<td>160.57±0.64</td>
<td>110.13±0.45</td>
<td>161.94±0.65</td>
<td>159.44±0.65</td>
<td>110.58±0.45</td>
</tr>
<tr>
<td>160 µm</td>
<td>163.97±0.49</td>
<td>138.91±0.55</td>
<td>161.08±0.49</td>
<td>139.87±0.55</td>
<td>145.41±0.49</td>
</tr>
</tbody>
</table>

The effect of $n\sigma$ is not really severe on the map quality, so larger value are recommended. MADmap photometry is driven by the curvature of the background. Proper object masking is critical in the HPF+PhP branch, but mostly irrelevant in MADmap.
4. Total flux on large galaxies, no convolution, (M. Sauvage)

- PACS photometry from Hipe 6 private reduction (using the MIPS apertures).
- MIPS and IRAS photometry from Kingfish Twiki.
- Filled symbols: measured total flux ratio (no color correction).
- Crosses: color-corrected ratio (based on [60]/[100] and Dale & Helou's SED library).
- Horizontal line: uncertainty-weighted average flux ratio and associated uncertainty (shaded areas for color-corrected average ratio when significantly different).
- PACS is compatible with MIPS (remember the beam underestimation).
- Possible systematic gain difference with IRAS (20–30%), which can possibly be attributed to IRAS rather than PACS.
Reproducibility?

- NGC 6946 was observed in 09/09 in slow and fast parallel mode, and on 03/10 in prime mode for KINGFISH.

- Total flux @ 160/100 μm:
  - Prime: 591 / 289.97 Jy
  - Parallel Slow: 609 / 293.48 Jy
  - Parallel Fast: 629 / 294.48 Jy

- Variation is compatible with calibration.

- Some systematics?
5. New convolution kernels

- Gonzalo Aniano (Princeton, Kingfish) has produced new convolution kernels.
- He uses circularized PSF, and for PACS he is using the PSFs we have published.
- Experiments made with these kernels are much more satisfying.
- This is still with the old $r=60''$-normalized PSFs on 12 KINGFISH KP large galaxies.
5. New convolution kernels
Top: old Kernels, Bottom: new ones
Systematics still seen but more compatible with MIPS transients.
Pixel-to-pixel PACS-MIPS comparison
Convolved to MIPS beam, color-corrected

- 70μm: 1.09
- 160μm: 1.18
6. Conclusions

✓ No reason to believe there is a problem of PACS extended emission flux calibration / photometry

✓ PACS vs MIPS:
  • Total flux: good agreement already, new sensitivity expected to improve it even further slightly.
  • Surface brightness (pixel-to-pixel), currently within 20% (red) and 10% (blue), should go down to <10% with new PSF kernels.

• PACS vs IRAS: within 20-30%