boloSource()

source extraction from the Herschel PACS timeline

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Abstract

The 'boloSource()' algorithm has been developed to subtract point- and compact sources from the diffuse background of large-scale Galactic maps observed by PACS and SPIRE photometers. This novel algorithm can produce suitable products for analysis of extended-emission and filamentary structures but it could also provide an alternative way of source photometry in highly confused regions. Here we present results of the photometric capabilities of the algorithm. The tasks have been executed on small fields observed by PACS and centered on standard stars, having reliable and stable brightness. From the multiple repetitions light curves have been extracted and the results of the regular aperture photometry was compared to that of the boloSource() photometry.

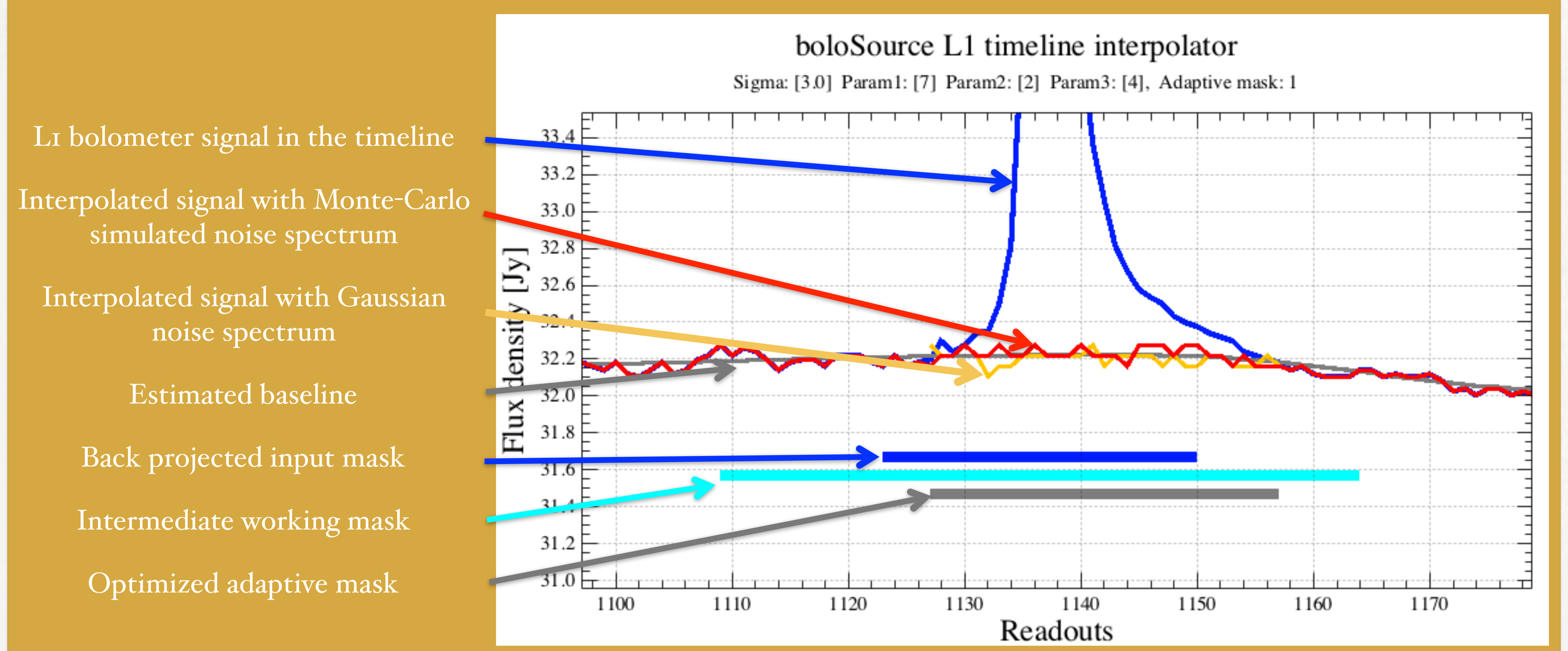
Motivation

- Extended emission analysis requires clean maps
- Compact objects contribute to the image power spectra with a significant power at a broad range of spatial frequencies:
  - modify the image at frequencies comparable to the beam-size
  - depending on the surface density and the clustering strength, lower spatial frequencies are contaminated with a smaller power density but typically at large bandwidth
- Image analysis techniques are difficult to compare if sources are not subtracted, because their sensitivity to discrete sub-structures may be quite different
- Techniques using sparsity information could be disturbed by even a few point sources
- Techniques analyzing full intensity maps are more sensitive to clustering
- For extended emission analysis we need a technique to subtract sources that fall within a well defined range of spatial frequencies
- A major requirement: preserve noise properties of the image!
  - Classical way: try modeling the source intensity **I(x,y)** in the position-position space and subtract from the image - This is not easy, but one could reduce the problem to 1D in the detector timeline
- Subtract sources from the detector timeline and re-project the image

Concept

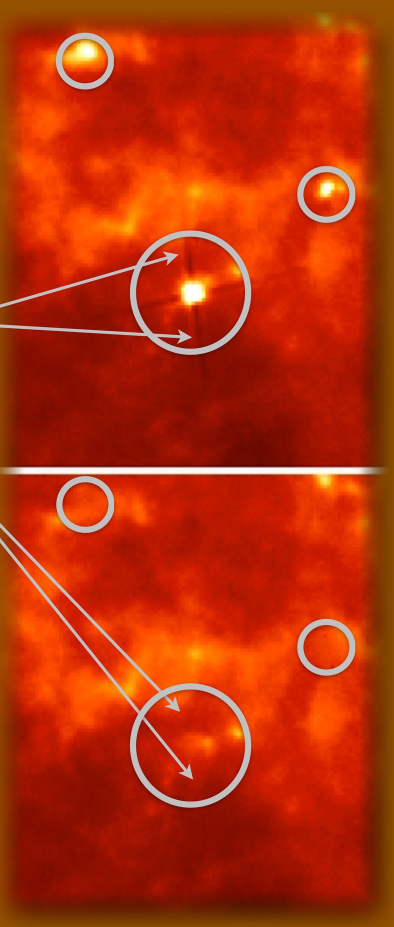
We are mainly interested in to subtract high-frequency components. In the masked part of the timeline one could interpolate with simulated noise + sky background

$$\underbrace{I_{(t)}}_{\text{Interpolated intensity in masked timeline}} = \underbrace{N^{1/f}_{(t)} + N^{D}_{(t)} + N^{det}_{(t)}}_{\text{Simulated noise}} + \underbrace{I^{S(low freq)}_{(t)}}_{\text{Baseline estimate from data}}$$

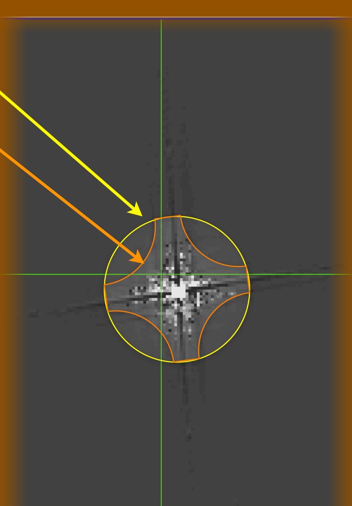


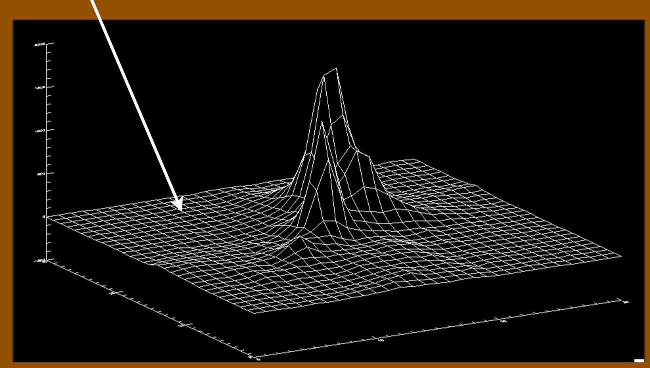
First results - HI-GAL L297

- Sources are removed
- Background is quite well preserved
- Byproduct: MadMap reconstruction noise (undershooting artifacts) could be eliminated
- For the analysis of extended emission there is no strict need for other cleaning techniques



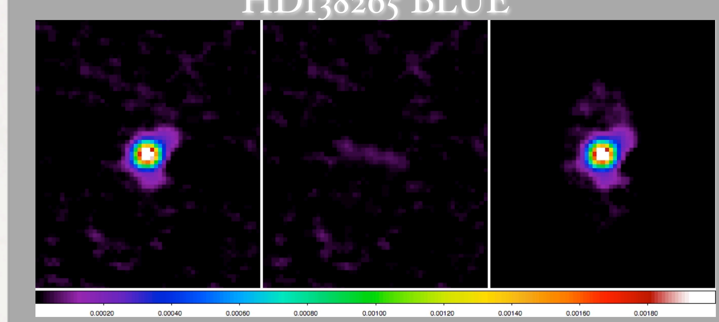
- Input mask
- Adaptive mask
- Another byproduct: Source-only map with flat, zero level background





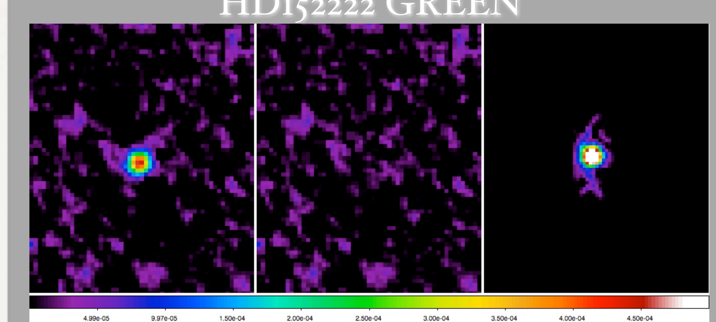
Standard star photometry with boloSource() - the dataset

HD138265 BLUE



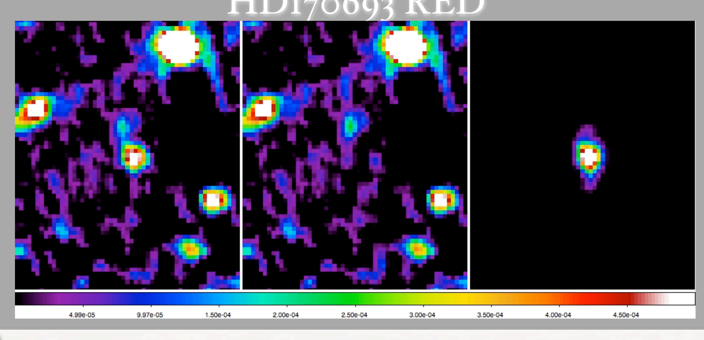
The predicted brightness of HD138265 in the PACS BLUE channel (70 μm) is 111.4 mJy. The observation contains 21 repetitions for both scan and cross-scan. Figures and light curves are shown for cross-scan. Panels from left to right show maps created from the untouched timeline, the interpolated timeline and the differential timeline, respectively. Images are scaled from 0 to 2 mJy.

HD152222 GREEN



The predicted brightness of HD152222 in the PACS GREEN channel (100 μm) is 18.57 mJy. The observation contains 32 repetitions for both scan and cross-scan. Figures and light curves are shown for cross-scan. Panels from left to right are identical to that shown for HD138265. Images are scaled from 0 to 1 mJy.

HD170693 RED

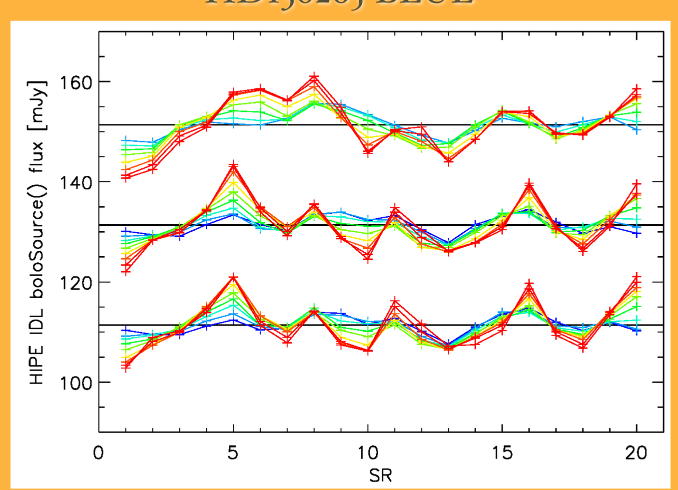


The predicted brightness of HD170693 in the PACS RED channel (160 μm) is 28.27 mJy. The observation contains 20 repetitions for both scan and cross-scan. Figures and light curves are shown for cross-scan. Panels from left to right are identical to that shown for HD138265. Images are scaled from 0 to 0.5 mJy.

Standard star photometry with boloSource() - results and conclusion

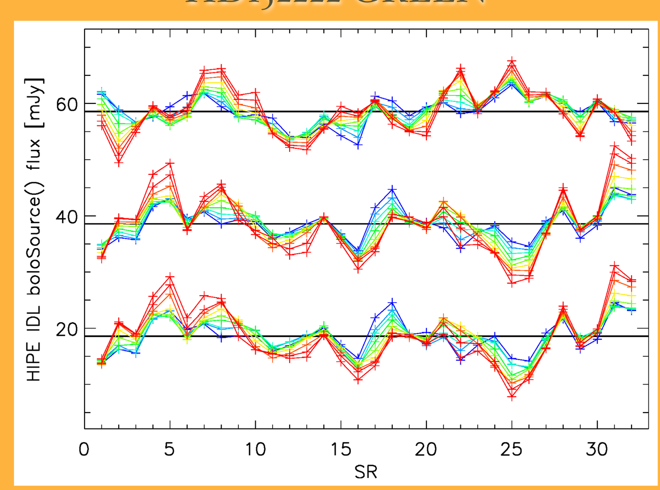
Each plot shows the light curve of the given star, constructed by merging two consecutive repetitions. The number of the starting repetition is presented along the X axis. The bottom curve presents the light curve obtained with HIPE. The light curve in the middle was calculated with IDL and was shifted with +20 mJy for visibility. These values were measured with simple aperture photometry, where the sky radii were set to 20 and 40 arcseconds. The upper curve shows the brightness coming from the boloSource() differential (source-only) maps, also shifted with +20 mJy for visibility. In this case the sky value was set to zero, as it is on the map. Black horizontal lines present the brightness predicted by stellar photosphere models. Colours from blue to red are presenting different aperture sizes, with which the photometry was done, from 2 to 10 arcseconds radius. The standard deviation of measured brightnesses (with 5" aperture radius) are listed in the figure captions. The average brightness of the light curve was corrected to match the predicted value. The correction factors are also listed. The noise on the maps was measured with the implanted source method.

HD136265 BLUE



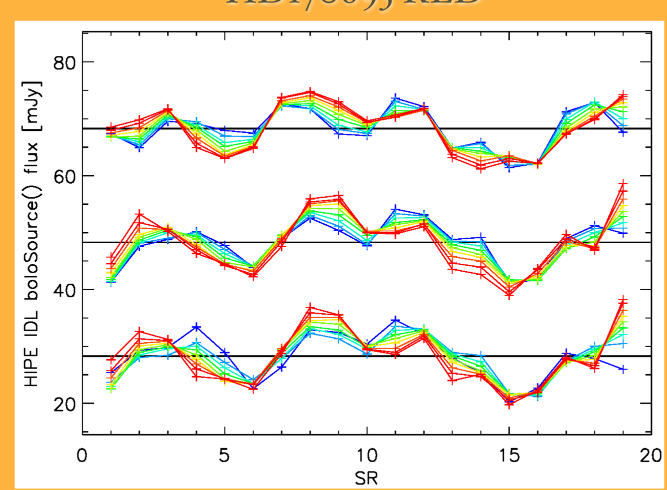
Predicted brightness in the BLUE channel:
111.4 mJy
Standard deviation and correction factor:
HIPE: **2.29** mJy, **0.87**
IDL: **2.30** mJy, **0.92**
boloSource(): **2.78** mJy, **0.99998**
Measured noise on the maps:
3.56 ± **0.35** mJy

HD152222 GREEN



Predicted brightness in the GREEN channel:
18.57 mJy
Standard deviation and correction factor:
HIPE: **2.76** mJy, **0.91**
IDL: **2.89** mJy, **0.95**
boloSource(): **2.77** mJy, **1.06**
Measured noise on the maps:
4.56 ± **0.33** mJy

HD170693 RED



Predicted brightness in the RED channel:
28.27 mJy
Standard deviation and correction factor:
HIPE: **4.11** mJy, **1.06**
IDL: **3.89** mJy, **1.002**
boloSource(): **3.28** mJy, **0.97**
Measured noise on the maps:
14.68 ± **1.46** mJy

As the light curves show, independently of the method used to derive the photometric values, and independently of the size of the aperture, the brightnesses of the standard stars show some variation along the repetitions. Our method, the boloSource() algorithm subtracts the sources directly from the timeline, and is able to produce a source-free map and a source-only map without background at the same time. The measured fluxes with a commonly used 5" aperture radius, and their uncertainties coming from this method are in good agreement with that of the others. In the BLUE channel, where the Herschel observations have the less background, our method is less reliable, but is still comparable to the simple aperture photometry, while in the RED channel (where the background is the most disturbing) it shows a better reliability than the regular method.

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