boloSource()

Source extraction from the Herschel PACS timeline

R. Vavrek[1], G. Marton[2], Cs. Kiss[1], Th. G. Müller[3], Tom Wilson[1]

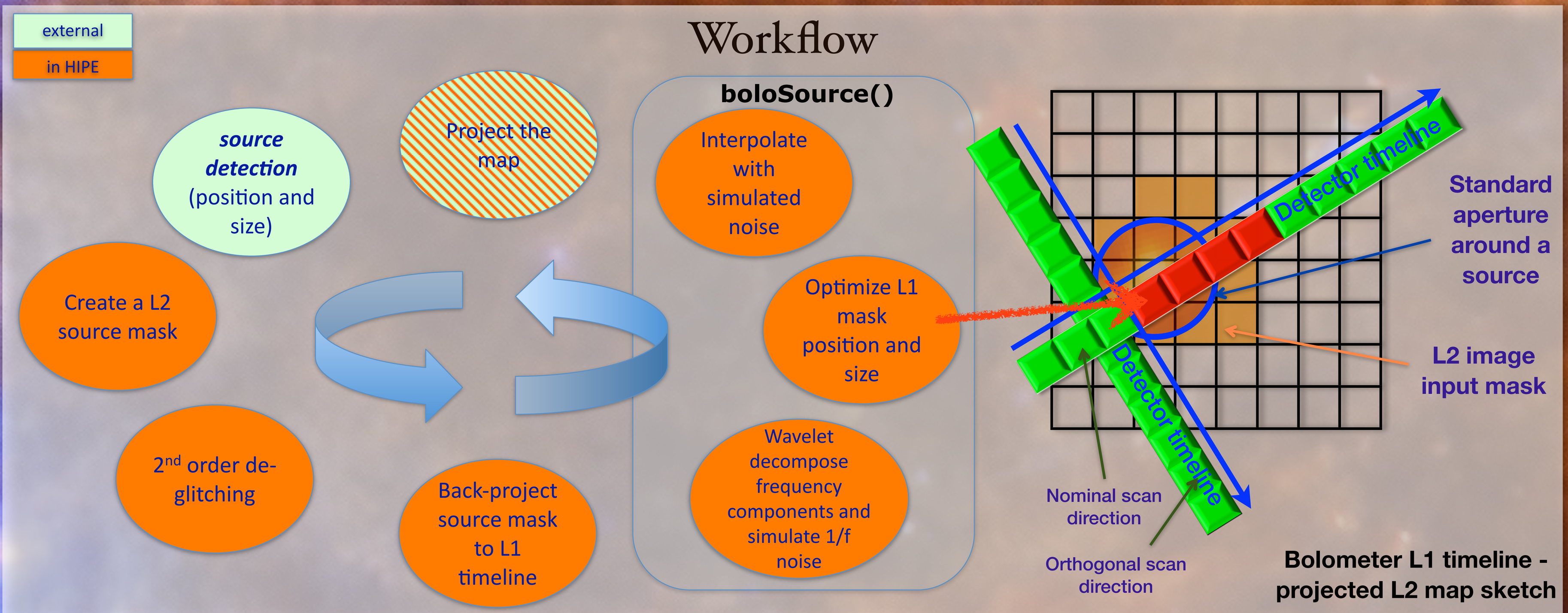
Abstract

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 the first results obtained on PACS Hi-Gal field l=297 deg. The tasks have been also 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 because compact objects contribute to the image power spectra with a significant power at a broad range of spatial frequencies:
  - impact image power at frequencies comparable to the beam-size
  - depending on the surface density and the clustering strength of embedded objects, 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
- A major requirement: preserve noise properties of the image!

Workflow

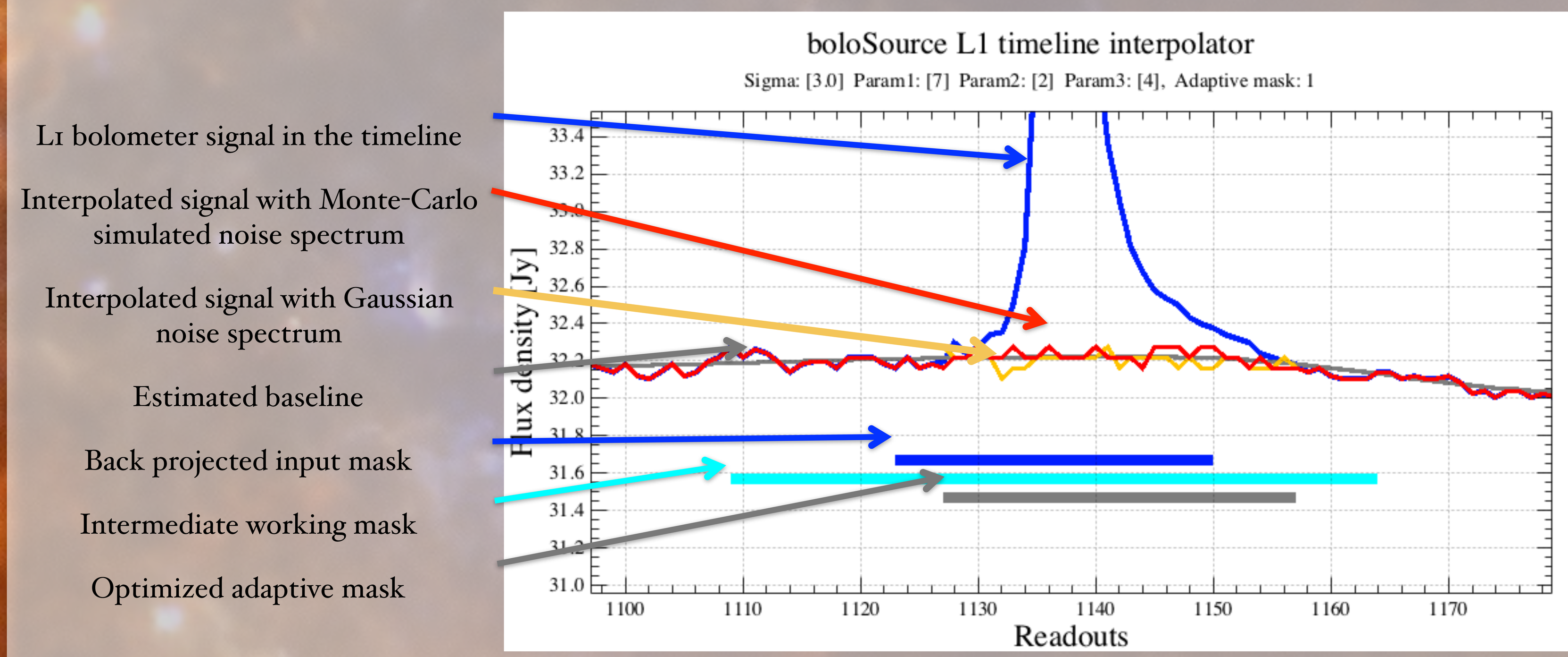


Bolometer timeline interpolation concept

Map-maker tools based on (W)GLS algorithms may introduce image artifacts and may change the overall noise properties of the projected image if the detector timeline is interrupted with values having non-representative noise properties. In the masked part of the timeline boloSource() interpolates with simulated 1/f noise + sky background:

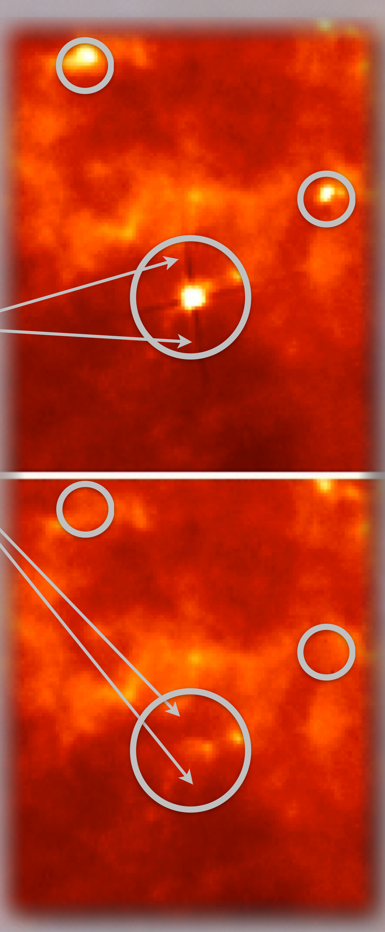
$$I_{(t)} = \left(N^{1/f}_{(t)} + N^{D}_{(t)} + N^{\det}_{(t)}\right) + I^{S(lowfreq)}_{(t)}$$

Interpolated intensity in masked timeline — Simulated noise — Baseline estimate from data

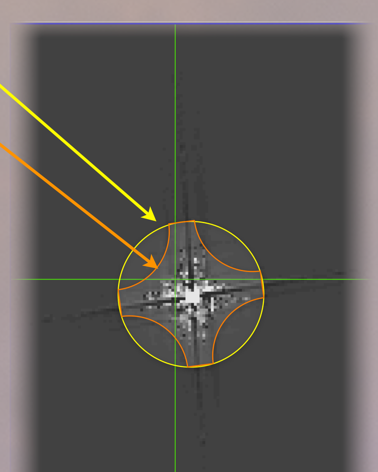


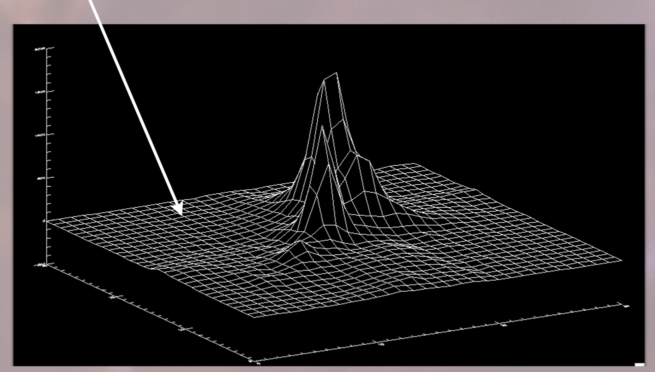
boloSource() products overview and first results on HI-GAL L297 field

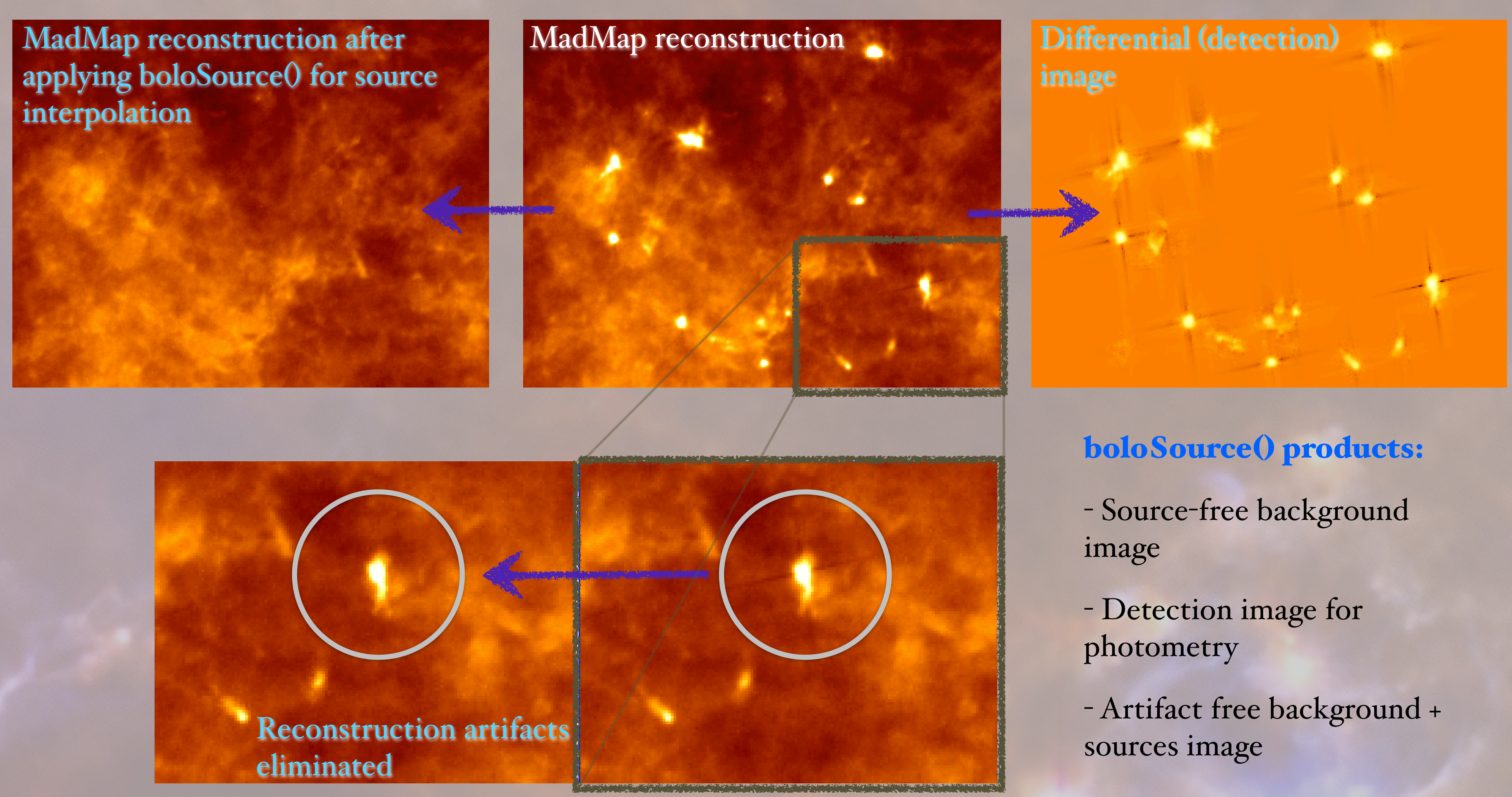
- Sources are removed
- Background is quite well preserved
- Byproduct: MadMap reconstruction noise (undershooting artifacts) could be eliminated
- For the analysis of extended emission there is no strict need for other cleaning techniques



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



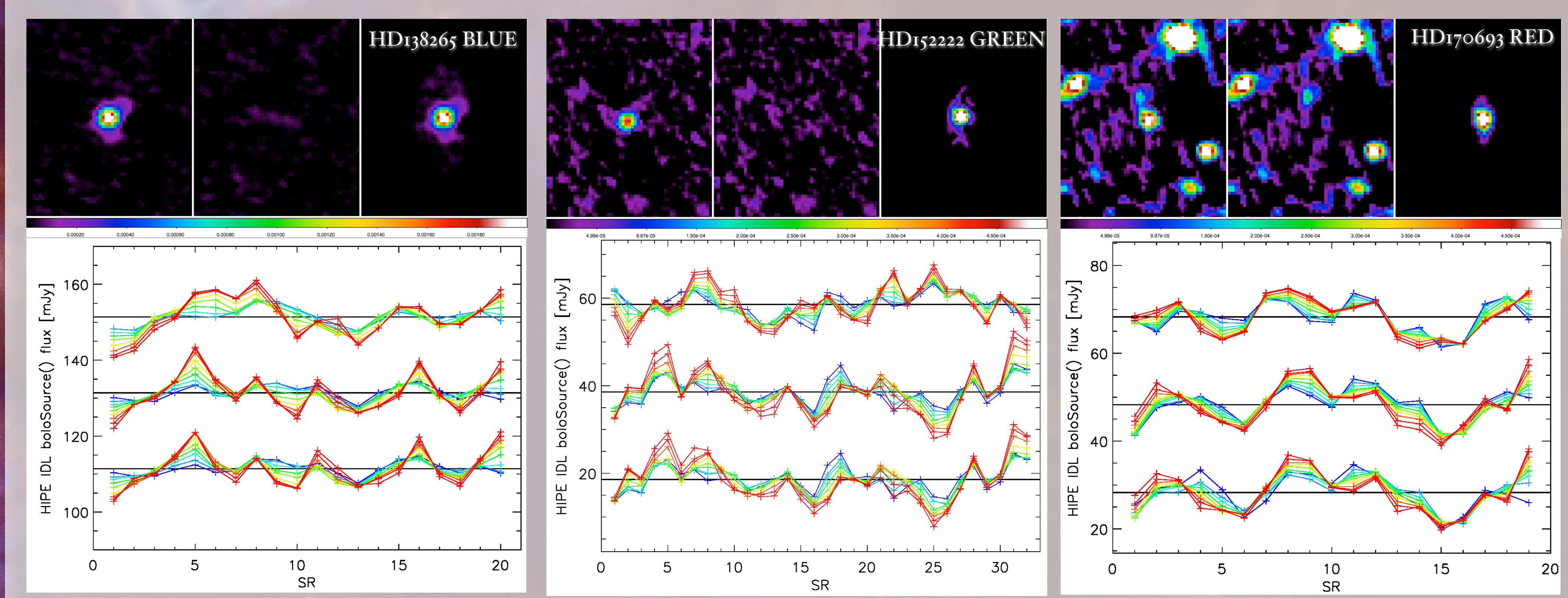




boloSource() products:

- Source-free background image
- Detection image for photometry
- Artifact free background + sources image

boloSource() application to standard star photometry



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

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

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

Observations contains 21, 32 and 20 repetitions for the three test sources for both scan- and cross-scan. Figures and light curves are shown for cross-scan. Panels from left to right show maps projected from the original timeline (left), from the boloSource() interpolated timeline (middle) , and the differential timeline (right). Images are scaled to 2 mJy.

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, from 2 to 10 arcseconds radius. The standard deviation of measured brightnesses (with 5" aperture radius) are listed in the figure captions.

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.

Acknowledgement: This work has been supported by the following grants: I) PECS contract no. 98073 of the Hungarian Space Office and the European Space Agency, II) Hungarian Research Fund (OTKA) grant numbers 101939 and 104607, and we acknowledge support from the Faculty of the European Space Astronomy Centre (ESAC)

[1]Herschel Science Centre, European Space Astronomy Centre (ESA), PO Box 78, 28691 Villanueva de la Cañada, Madrid, Spain, rvavrek@sciops.esa.int
[2]Konkoly Observatory of the Hungarian Academy of Sciences, H-1525 Budapest, P.O.Box 67., marton.gabor@csfk.mta.hu
[3]Max-Planck-Institut für extraterrestrische Physik (MPE), Giessenbachstrasse, 85748, Garching, Germany