Consistency Between PACS Mappers: Point Sources and Extended Emission

Roberta Paladini - NHSC/Caltech

Herschel Calibration Workshop – March 25th – 27th 2013

The Map-Making Workshop: Motivation

- increasing "rumors" about problems with PACS extended emission calibration (→ e.g. Aniano et al. 2012)

- need to investigate the issue, although no reason to think instrumental gain should be different for point sources and extended emission…

- How extended emission data are processed (→ *map-making*) is likely to play a role

The Map-Making Workshop: How We Got There…

- First discussion about having a Herschel Map-Making Workshop was in March 2012 at the Herschel Calibration Workshop…

- After a lot of work (!), a joint PACS & SPIRE Map-Making Workshop was held at ESAC on January 28^{th} to 31^{st} 2013, attended by ~60 participants

http://herschel.esac.esa.int/2013Mapmaking.shtml

Philosophy of PACS Benchmarking

Goal of the benchmarking is to test the *performance* of the participating map-making algorithms using both *real* and *simulated* Herschel data sets

MADmap	HIPE/Java implementation
Scanamorphos	http://www2.iap.fr/users/roussel/herschel/
Jscanam	HIPE/Java implementation of Scanamorphos (→ HIPE 11)
SANEPIC	http://www.ias.u-psud.fr/sanepic/
Unimap	http://infocom.uniroma1.it/~lorenz/Unimap/
Tamasis	http://pchanial.github.com/tamasis-pacs/

ALL THE MAPMAKING PACKAGES ARE PUBLICLY AVAILABLE (OR SOON WILL BE)

About the Map-Making Codes

MADmap	→	baseline fitting + GLS
Scanamorphos	→	destriper
Jscanam	→	destriper
SANEPIC*	→	GLS
Unimap	→	destriper + GLS
Tamasis	→	destriper + GLS

* Only 5 maps processed out of 36

GLS = Generalized Least Square

Real Data Sets: Selection

The selection of the data set is performed to allow the coverage of a parameter space as large as possible in terms of:

- source surface brightness
- background surface brightness
- depth (i.e. # of repetitions)
- size of covered sky area
- observing mode

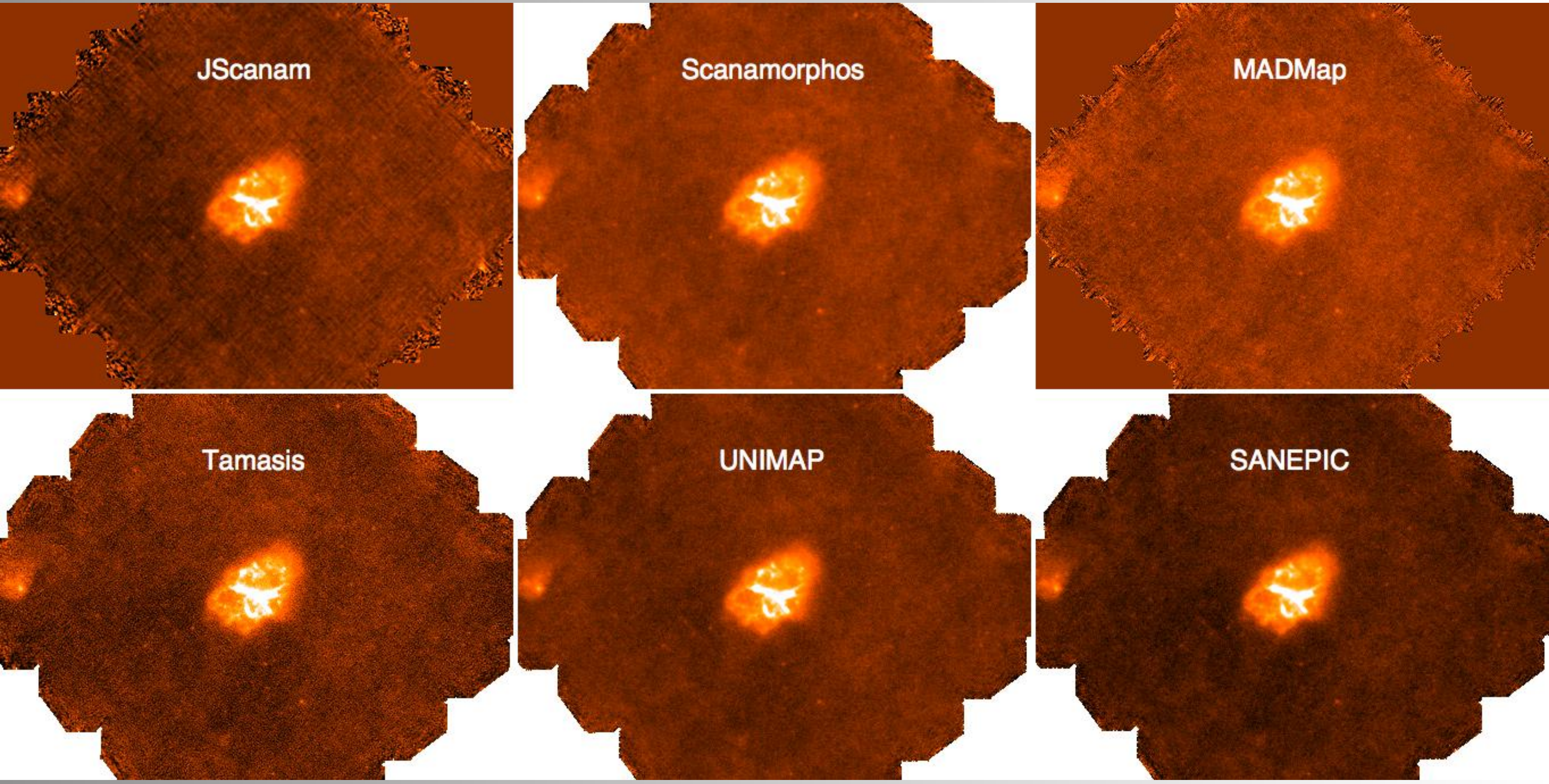
Real Data Sets: Selection (cont.)

Field	Source	Background	Size	Coverage	AOT
Crab	Bright/ extended	Flat	Medium	Medium	Scan map
HiGAL l=30	Bright/fills the field	Bright	Large	Shallow	Parallel mode
GRB-110422A	Faint/point-like	Flat	Small	Deep	Scan map
IC 348	Bright/ extended (lots of point sources)	Bright/Flat	Small/ Medium	Deep	Scan map
Atlas	Faint point sources	Flat	Large	Shallow	Parallel
NGC 6946	Moderately extended	Flat	Medium	Medium	Scan map
NGC 6334	Bright/fills the field	Bright	Large	Shallow	Parallel mode
M31	extended	Flat-ish	Large	Deep	Parallel mode

Real Data Sets: Selection (cont.)

Field	Source	Background	Size	Coverage	AOT
M81	Moderately extended	Flat	Medium	Medium	Scan map
Polar Bear	Cirrus	Flat	Large	Medium/deep	Scan map
LDN1780	Faint/diffuse emission	Flat	Large	Medium	Parallel mode
HOPS Group 38	Bright/fills the field	Bright	Medium	Medium	Scan Map
Rosette	extended/fills the field	Bright	Large	Shallow	Parallel mode
HOPS Group 306	Bright/fills the field	Bright	Small	Medium	Scan map
Sa 187/188 MMS 3-5	Diffuse emission with lots of sources	Moderate	Medium	Shallow	Scan Map
HOPS Group 79	Very Bright point source	Flat-ish	Small	Medium	Scan map
Antennae	Moderately extended	Flat-ish	Medium	Medium	Scan Map

Real Data Sets: Selection (cont.) Example – Crab / red channel



Simulated Data Sets

Simulated *hybrid* data:

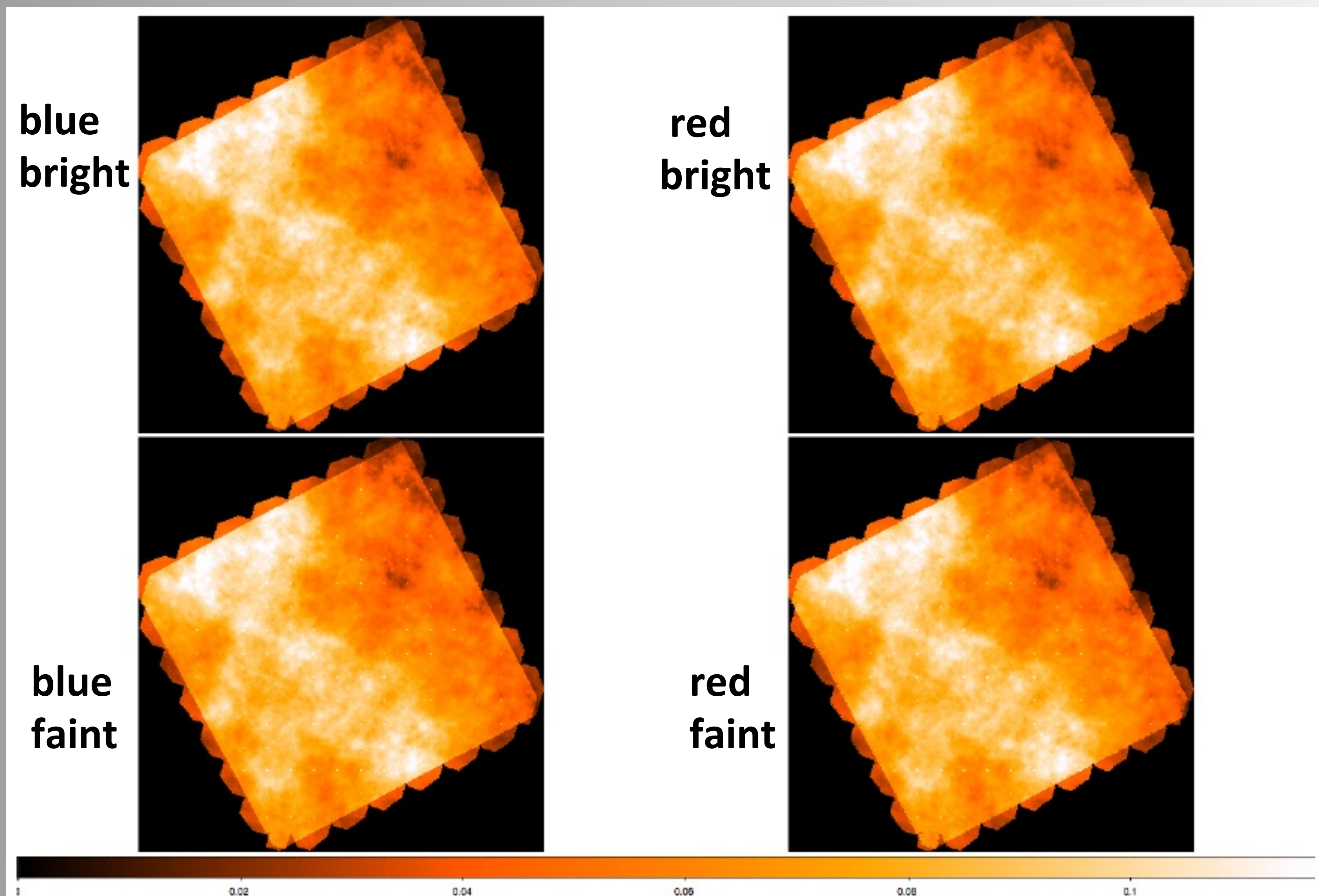
A) Simulated sky signal
(2D pink-noise)

+

B) pure instrument noise
(staring calibration observation)

} Flux calibrated Level 1 detector timeline

Simulated Data Sets (cont.)



PACS Benchmarking: Metrics

1. Power spectrum estimation

2. Point Source photometry

3. Noise statistics

4. Difference matrix

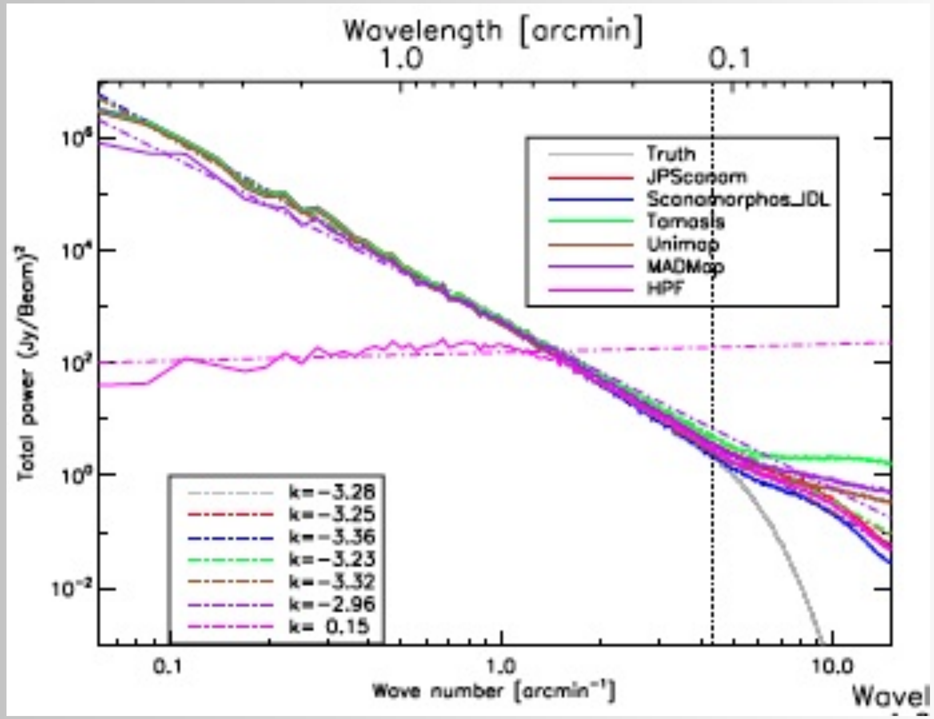
5. Comparison with ancillary data I/II

PACS Benchmarking – Metrics (cont.): Power Spectrum Estimation (G. Marton)

2d-angle averaged power spectrum analysis

↓

common tool for PACS and SPIRE



PACS Benchmarking – Metrics (cont.): Point Source Photometry (Z. Balog, V. Konyves, B. Altieri)

Procedure:

1. Find the mass coordinates of the sources visible in a given map;

2. Perform gaussian fitting of the source at designated coordinates;

3. Do aperture photometry at the position derived by the gaussian fitting using same source and sky apertures for each source;

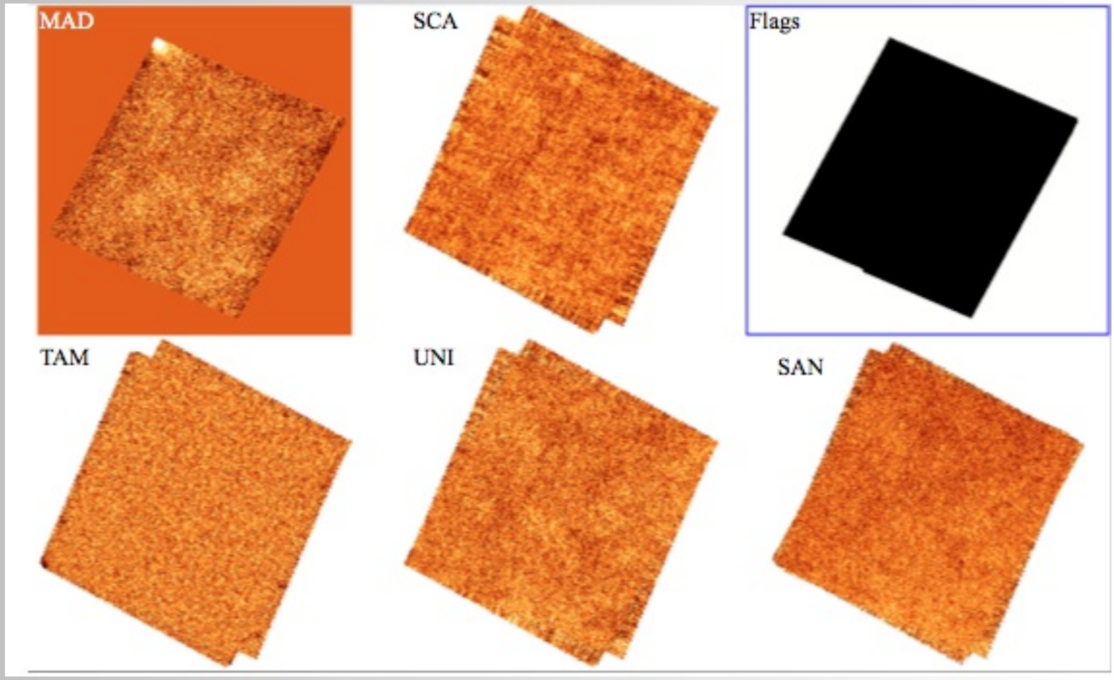
4. Extract the astrometric and photometric information from the result product (flux, $fwhm_x$, $fwhm_y$, RA, DEC);

5. Compare the RA and DEC values with known 2MASS coordinates

PACS Benchmarking – Metrics (cont.): Noise Statistics (L. Piazzo)

Procedure:

1. Select a data set containing close to no signal (e.g. Atlas field);
2. flag out sources;
3. Obtain a sample of the noise introduced by the mapmaking codes;
4. Estimate: NOISE VARIANCE, NOISE 1D-PS, NOISE 2D-PS



PACS Benchmarking – Metrics (cont.): Difference Matrix (V. Konyves)

Procedure:

1. Compare real observations processed with different mapmaking algorithms with respect to a reference (e.g Scanamorphos);

2. Compare simulated observations processed with different mapmaking algorithms with respect to true input sky → scatter plot/difference of standard deviation

PACS Benchmarking – Metrics (cont.): Comparison with AncillaryData – IRAS/IRIS (B. Ali)

<u>Procedure:</u>

1. We select data (galactic and extra-galactic) for which at least some good fraction of the data is in the linear regime
2. We convert PACS units to MJy/sr (IRAS/IRIS units)
3. We convolve the PACS data to the IRIS angular resolution:

$$fwhm_{eff} = \sqrt{(fwhm_{IRIS}^2 - fwhm_{PACS}^2)}$$

4. We apply color corrections and scaling factors as appropriate
5. We generate scatter plots:

$$I_{PACS} = A \times I_{IRIS} + B$$

gain → A; offset → B

PACS Benchmarking – Metrics (cont.): Comparison with AncillaryData – MIPS (R. Paladini)

Procedure:

1. We select data (galactic and extra-galactic) for which at least some good fraction of the data is in the linear regime
2. We convert PACS units to MJy/sr (MIPS units)
3. We convolve the PACS data to the MIPS angular resolution:

$$fwhm_{eff} = \sqrt{(fwhm^2_{MIPS} - fwhm^2_{PACS})}$$

4. We apply color corrections and scaling factors as appropriate
5. We generate scatter plots:

$$I_{PACS} = A \times I_{MIPS} + B$$

gain (→ A) offset (→ B)

What The Benchmarking Did Not Include

- test memory consumptions and run time → fair only if individual packages run on the same type of machine
- test specific features which only apply to some map-making packages (e.g. high resolution)

PACS Benchmarking: Preliminary Results

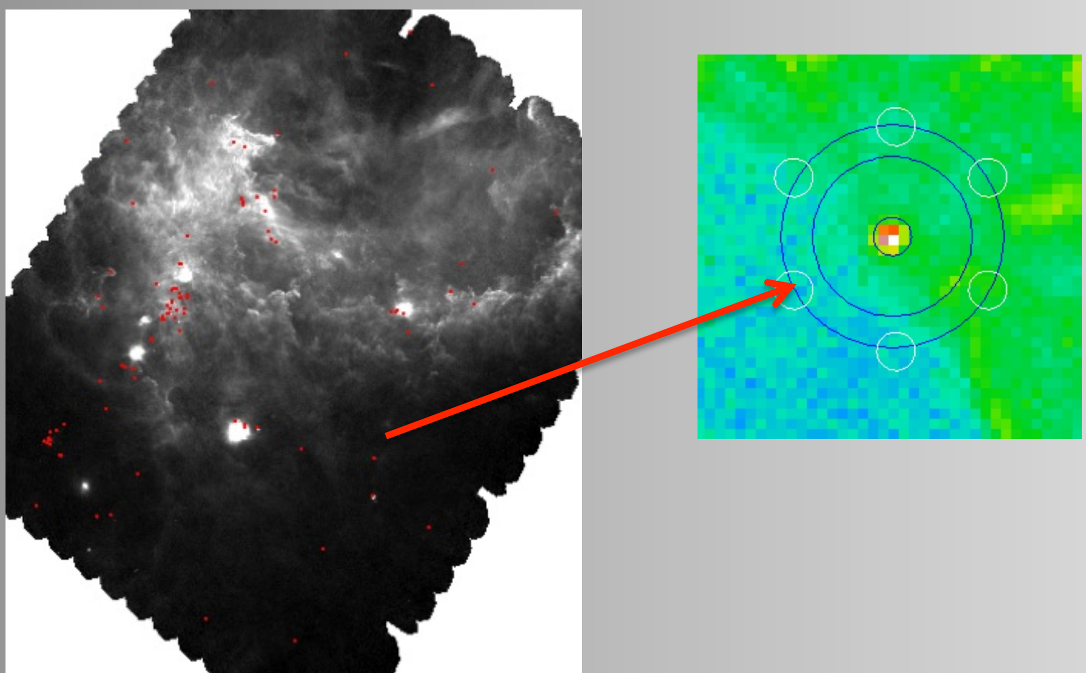
1. Power spectrum estimation
2. Point Source photometry
3. Noise statistics
4. Difference matrix
5. Comparison with ancillary data II (MIPS)

PACS Benchmarking – Preliminary Results (cont.): Point Source Photometry

→ Simulated Data: injected sources (150) were too faint with respect to simulated background

→ Real Data: here we will only talk about this case

PACS Benchmarking – Preliminary Results (cont.): Point Source Photometry



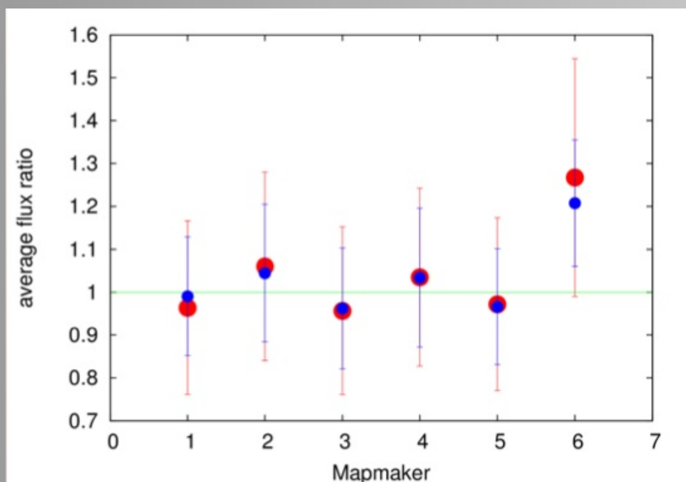
~100 sources – 0.3 – 50 Jy
(Hennemann et al. 2010)

- Aperture Photometry
- HIPE 10 b2743
- Re-centering during phot
- Two source apertures: 12"/20"
- Sky aperture: 25" – 35"
- Error estimate: empty apertures around source

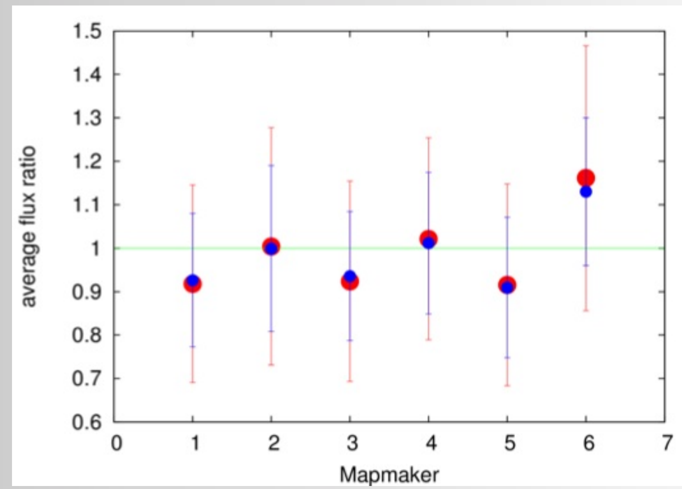
(credit: Zoltan Balog)

PACS Benchmarking – Preliminary Results (cont.): Point Source Photometry

R = 12"



R = 20"



1) Scanamorphos
2) Jscanam
3) UNIMAP
4) Tamasis
5) MADMap
6) SANEPIC

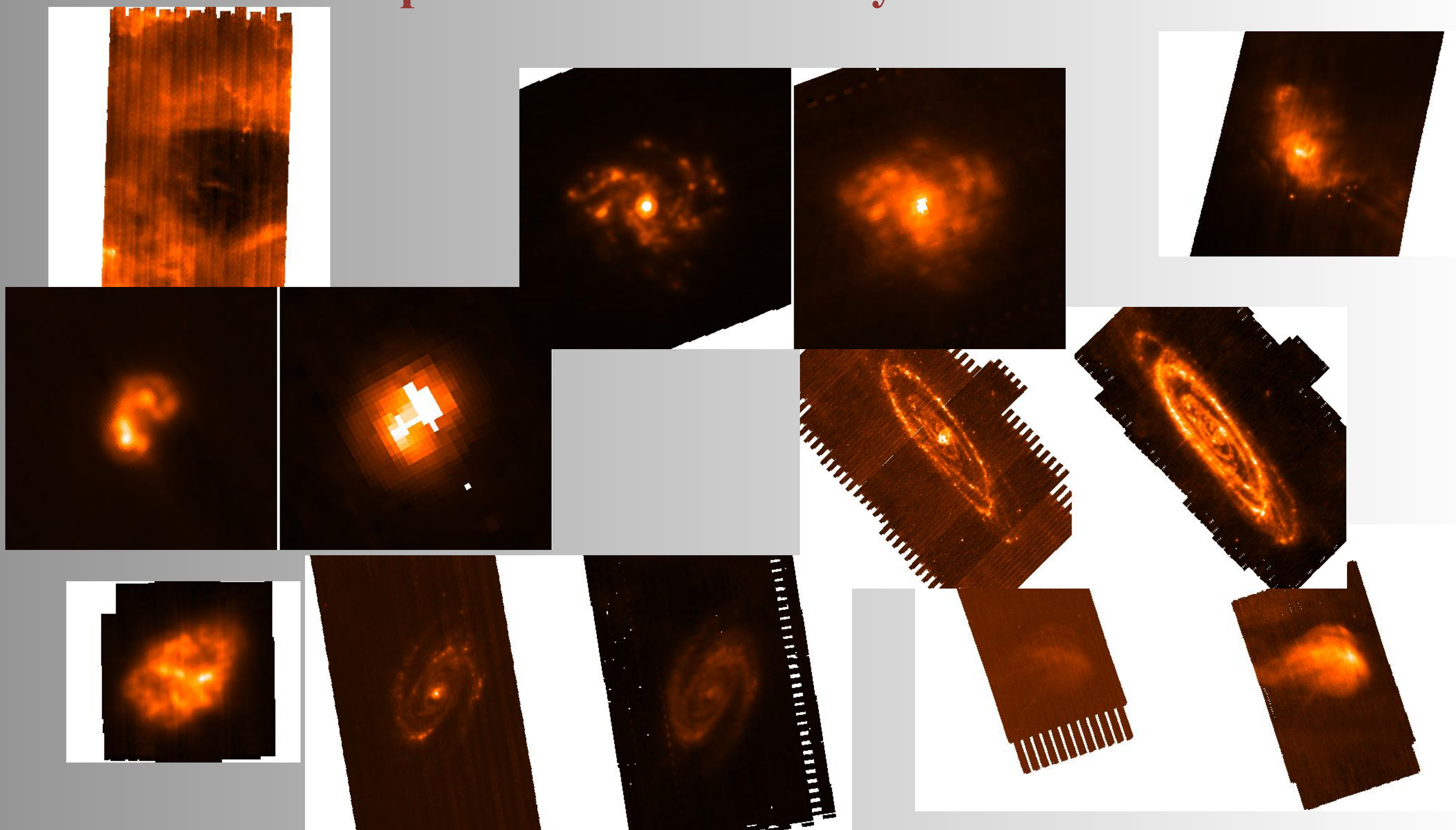
NOTE: difference between smaller and larger aperture may suggest changes in the shape of the PSF

(credit: Zoltan Balog)

PACS Benchmarking – Preliminary Results (cont.): Comparison with Ancillary Data – MIPS

- Antenne 70, 160 micron (Fazio – pid 32)
- Crab 70 micron (Gehrz – pid 130)
- IC348 70 micron (Muzerolle – pid 40372/Rieke – pid 58 → programs were combined)
- LDN1780 70, 160 micron (Gordon – pid 40154)
- M31 70, 160 micron (Rieke – pid 99)
- M81 70, 160 micron (Rieke – pid 717)
- NGC 6946 70, 160 micron (Kennicutt – pid 159)
- Rosette 70 micron (Rieke – pid 58)

PACS Benchmarking – Preliminary Results (cont.): Comparison with Ancillary Data – MIPS



Color Corrections

- PACS color corrections from: PICC-ME-TN-038 (April 12th 2011 –T. Muller)
- MIPS color corrections from MIPS Data Handbook (/http://irsa.ipac.caltech.edu/data/SPITZER/docs/mips/mipsinstrumenthandbook/51/)
- <u>Assumptions:</u>

→ Galaxies (Antennae, M31, M81, NGC 6946): @ 20 K
→ Crab: @ 50 K
→ LDN 1780: @ 20 K (NOTE: likely too warm, but not an issue..)
→ star formation regions (IC348, Rosette): @ 30 K

COLOR CORRECTIONS – II

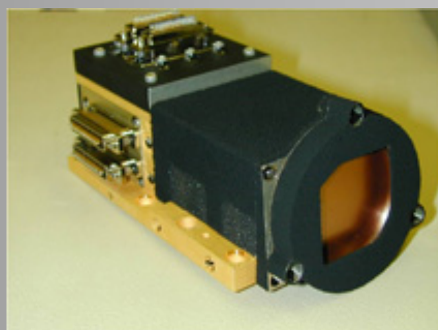
$PACS^{cc}_{70}$	$PACS^{cc}_{160}$	$MIPS^{cc}_{70}$	$MIPS^{cc}_{160}$	$scale_{70-71.4}$	$scale_{160-155.9}$	T_D
1.224	0.963	1.052	0.944	1.153	0.959	20 K
1.034	0.976	0.901	0.954	1.078	0.995	30 K
0.982	1.010	0.893	0.971	1.023	1.022	50 K

$$PACS^{cc'}_{\lambda'} = PACS_{\lambda} / PACS^{cc}_{\lambda} * Scale_{\lambda'}$$

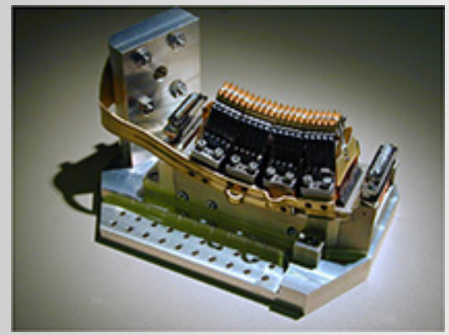
$$MIPS^{cc'}_{\lambda'} = MIPS_{\lambda} / MIPS^{cc}_{\lambda}$$

MIPS Non-Linearity (see Alberto's talk)

Flux non-linearity effects are known to affect Ge:Ga detectors



MIPS 70 micron: Ge:Ga 32 X 32 array



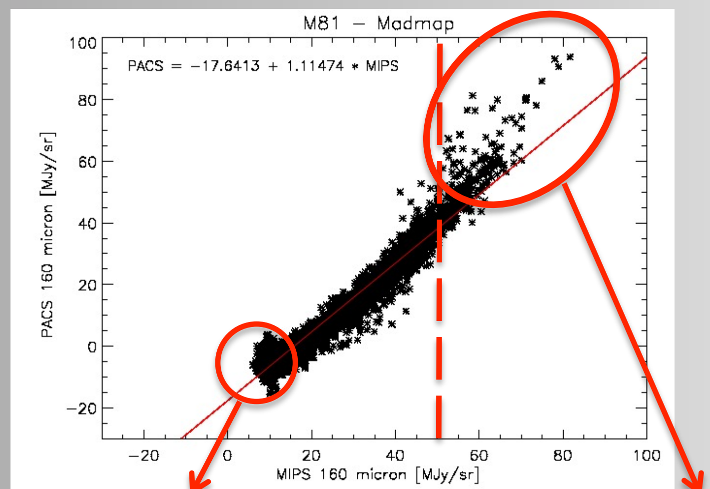
MIPS 160 micron: Ge:Ga 2 X 20 array

Documentation:

- *Absolute Calibration and Characterization of the Multiband Imaging Photometer for Spitzer. II. 70 micron imaging*, Gordon, K. D., et al., 2007, PASP, 119, 1019
- *Characterization of the MIPS 70 micron non-linearity,* MIPS IST TN, Paladini R. & Noriega-Crespo, A., 2009 (http://irsa.ipac.caltech.edu/data/SPITZER/docs/files/spitzer/Non_linearity_70um_v2.pdf)

MIPS Non-Linearity (cont.)

PICC-NHSC-TR-034, April 2012 - Paladini, Linz, Altieri, Ali:
https://nhscsci.ipac.caltech.edu/pacs/docs/Photometer/PICC-NHSC-TR-034.pdf



Background -> some of this is “garbage”

MIPS 160μm non-linearity: ~ 50 MJy/sr !

For the present analysis, we adopt 100 MJy/sr (~ 1 Jy) and 50 MJy/sr (~2 Jy) as thresholds for MIPS non linearity at 70 and 160 micron, respectively

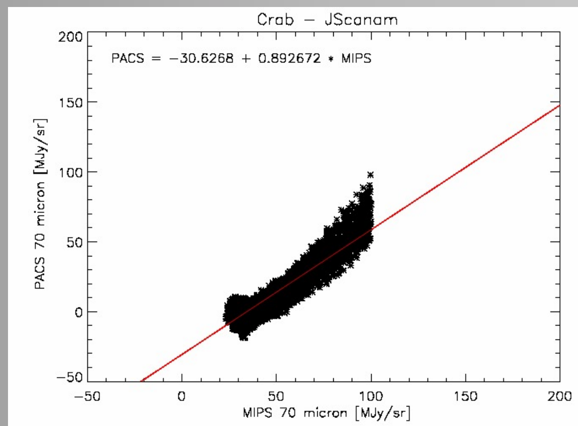
Notes About Processing:

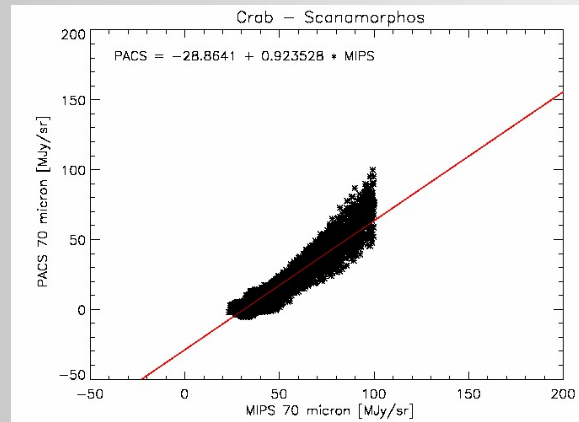
- No IC348/NGC6946 maps processed by JScanam

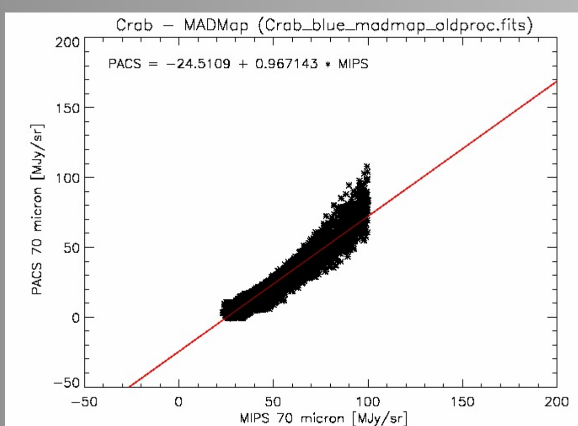
- MIPS processing is minimal at both 70 and 160 micron: mosaics are combined with MOPEX starting from archive BCDs

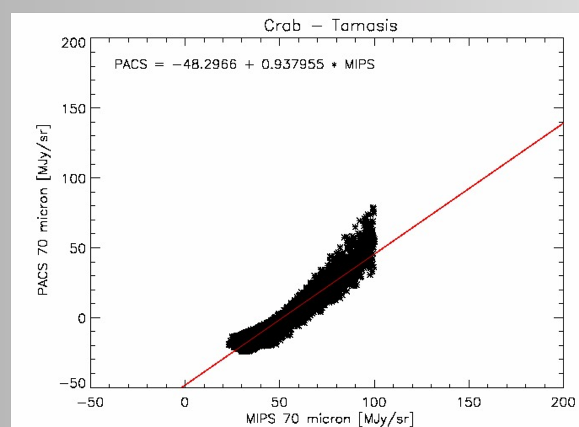
- Since not all PACS mappers provide errors, for consistency fitting was performed setting all weights = 1 (PACS & MIPS)

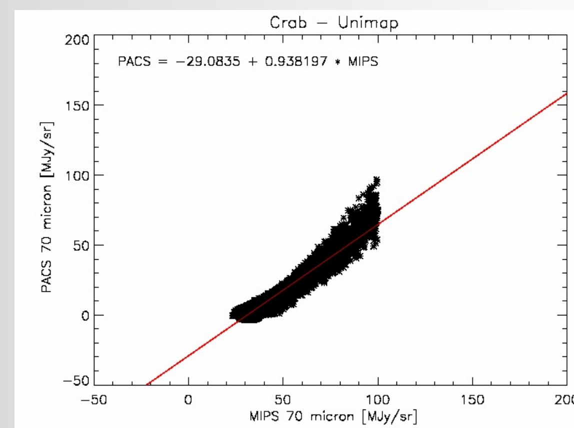
Example: Crab – 70 micron/linear



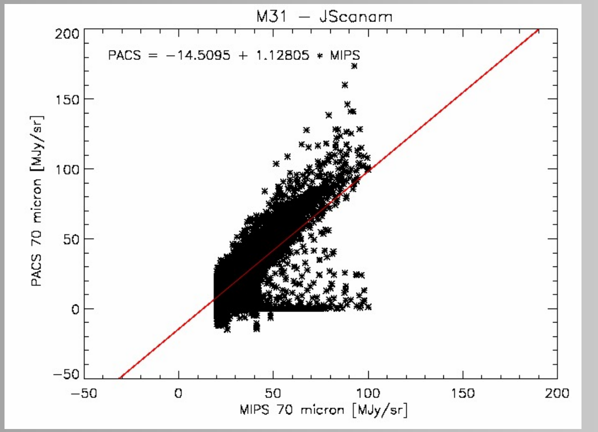


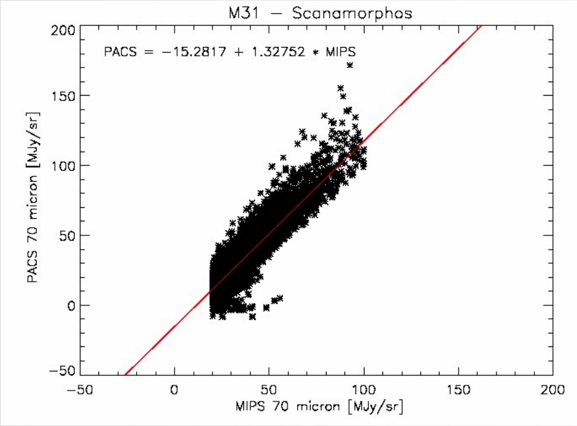


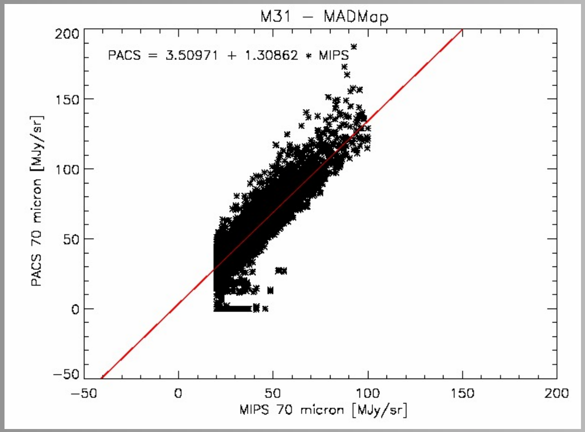


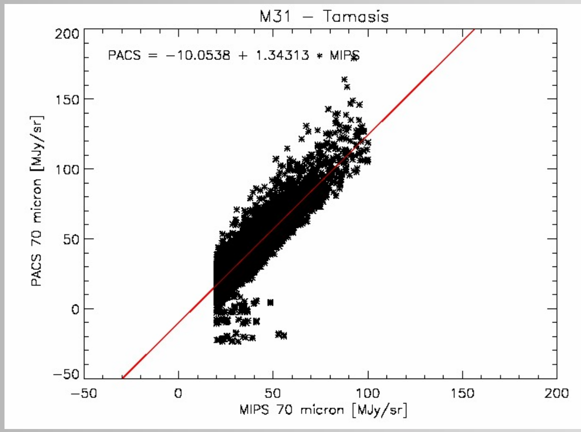


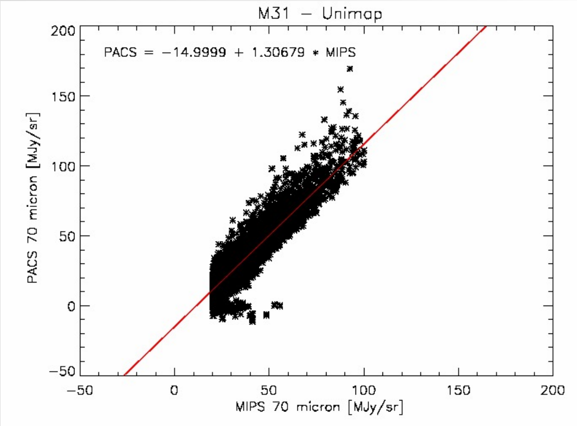
Example: M31 – 70 micron/linear



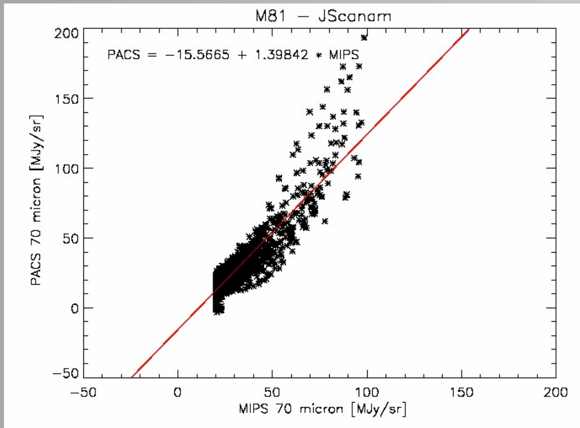


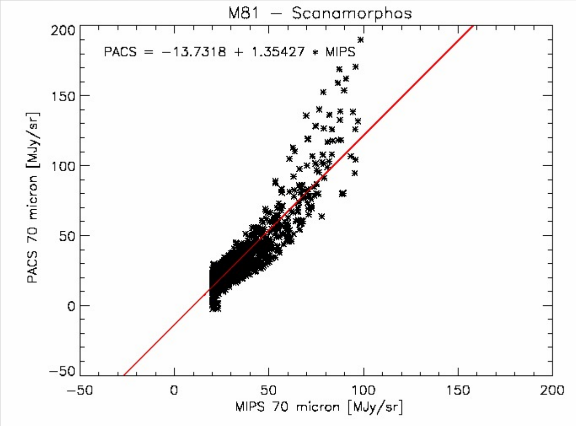


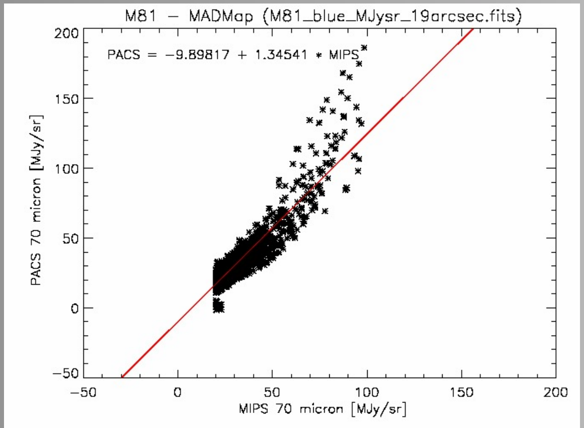


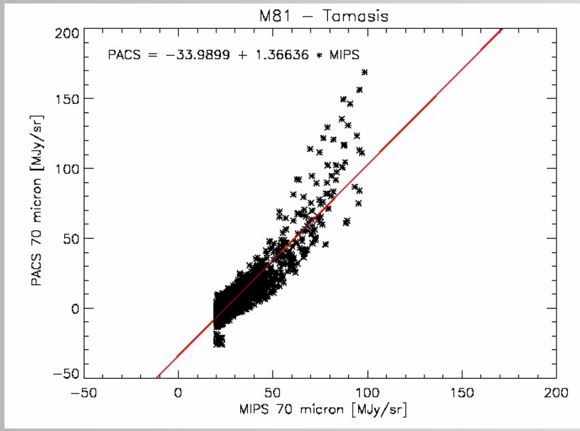


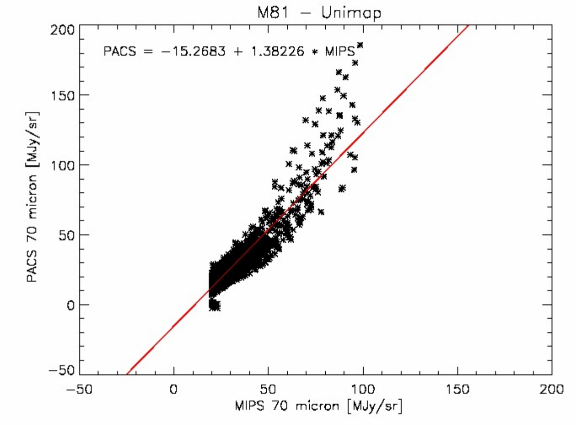
Example: M81 – 70 micron/linear



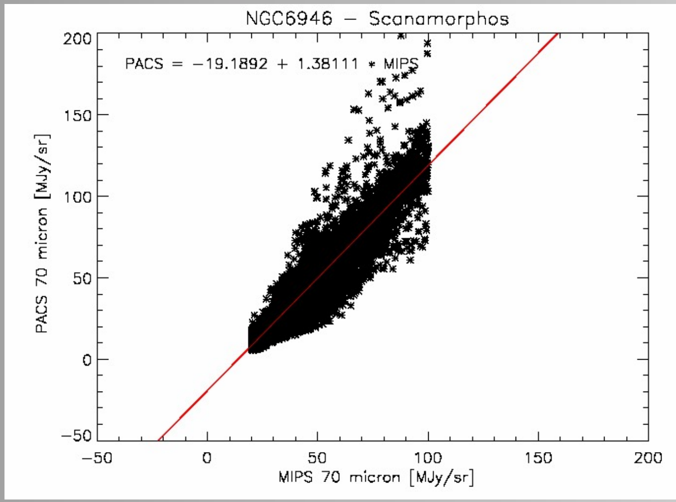


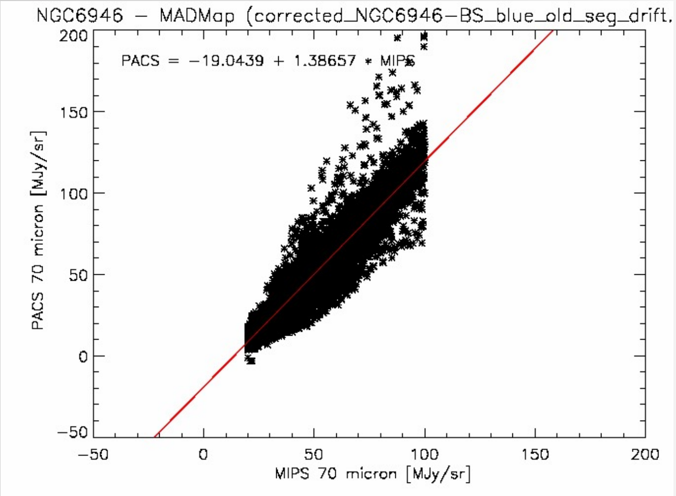


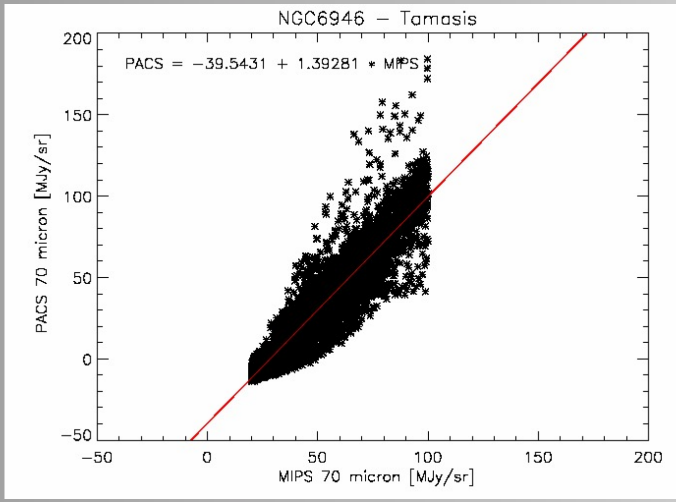


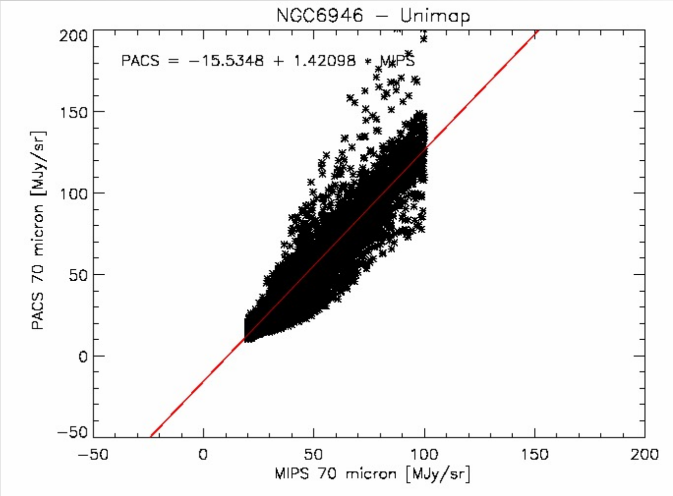


Example: NGC6946 – 70 micron/linear

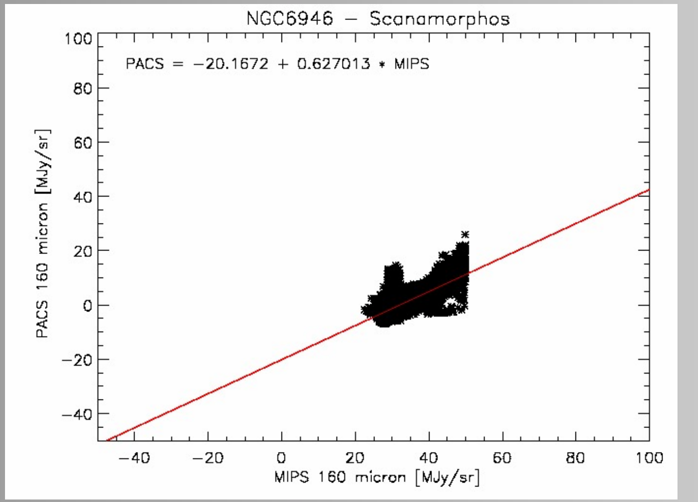


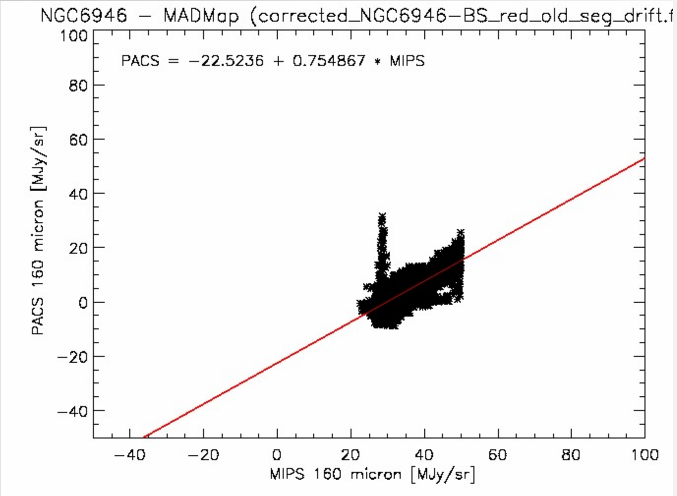


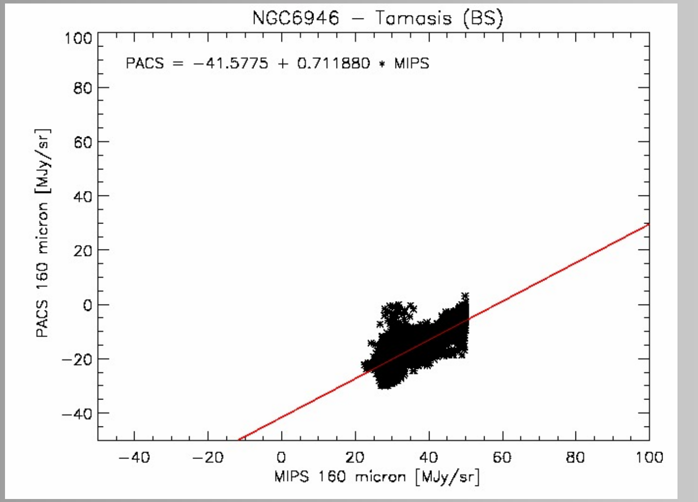


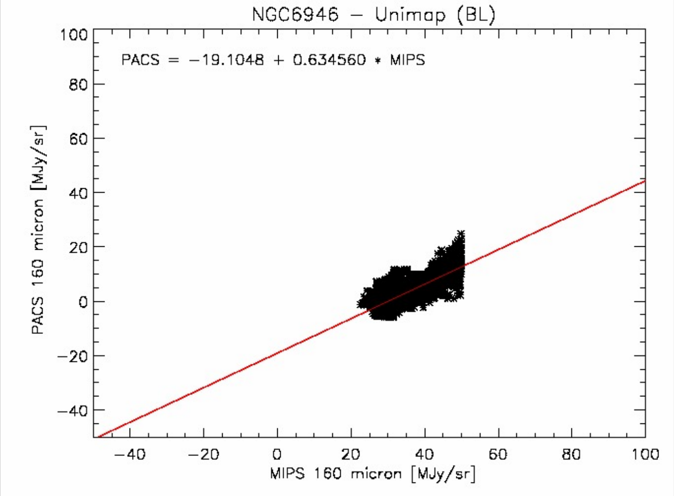


Example: NGC6946 – 160 micron/linear









PACS Benchmarking – Metrics (cont.): Comparison with Ancillary Data – MIPS

70 micron (gains)	JScanam	Scanamorphos	MADMap	Tamasis	Unimap
Antennae	1.13	1.09	1.09	1.09	1.10
Crab	0.89	0.92	0.97	0.94	0.94
IC348	-----	1.16	-1.06	0.88	1.07
LDN1780	-0.61	-0.52	-0.48	-0.47	-0.51
M31	1.13	1.33	1.31	1.34	1.31
M81	1.40	1.35	1.34	1.37	1.38
NGC6946	-----	1.38	1.39	1.39	1.42
Rosette	2.26	0.97	0.88	1.02	0.91

160 micron (gains)	JScanam	Scanamorphos	MADMap	Tamasis	Unimap
Antennae	0.68	0.79	0.78	0.73	0.81
LDN1780	0.77	0.87	-0.07	0.76	0.76
M31	0.92	1.03	0.94	0.89	0.88
M81	1.07	1.13	1.13	1.04	1.11
NGC6946	-----	0.63	0.75	0.71	0.63

These results take MIPS non-linearity into account !

Summary & Future

- When MIPS non-linearity effects for both 70 and 160 micron are taken into account, the average agreement between the PACS and MIPS observations at these wavelengths is of the order of ~15% ($<gain_{70}> = 1.17$ +/-0.26), $<gain_{160}> = 0.86$ +/-0.16)

- Significant departures from these values (cfr. M81, NGC6946 @70μm) are likely due to convolution effects and residual responsivity variations in the MIPS data (→ further investigation is on-going)

- A preliminary report summarizing these results will be released to the community in ~May 2013. A final report will be released in ~1-year time

Acknowledgements

PACS Map-Making Team

- Babar Ali (Roberta Paladini) → MADMap
- Helene Roussel → Scanamorphos
- Michael Wetzstein → Jscanam
- Pierre Chanial/Pasquale Panuzzo → Tamasis
- Alexandre Beelen → SANEPIC
- Lorenzo Piazzo → Unimap

PACS Benchmarking Team

- Babar Ali
- Bruno Altieri
- Vera Konyves
- Gabor Marton
- Roberta Paladini
- Lorenzo Piazzo
- Roland Vavrek
- Zoltan Balog