PACS Benchmarking:
Comparison with Ancillary Data Sets II– Spitzer MIPS

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Procedure

To compare PACS and MIPS data:

1. **We select data (galactic and extra-galactic) for which at least some good fraction of the data is in the linear regime (will return on this point later);**
2. **We convert PACS units from Jy/pixel to MJy/sr (MIPS units);**
3. **We convolve the PACS data to the MIPS angular resolution (19” @ 70 micron and 40” @160 micron):**

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

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

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

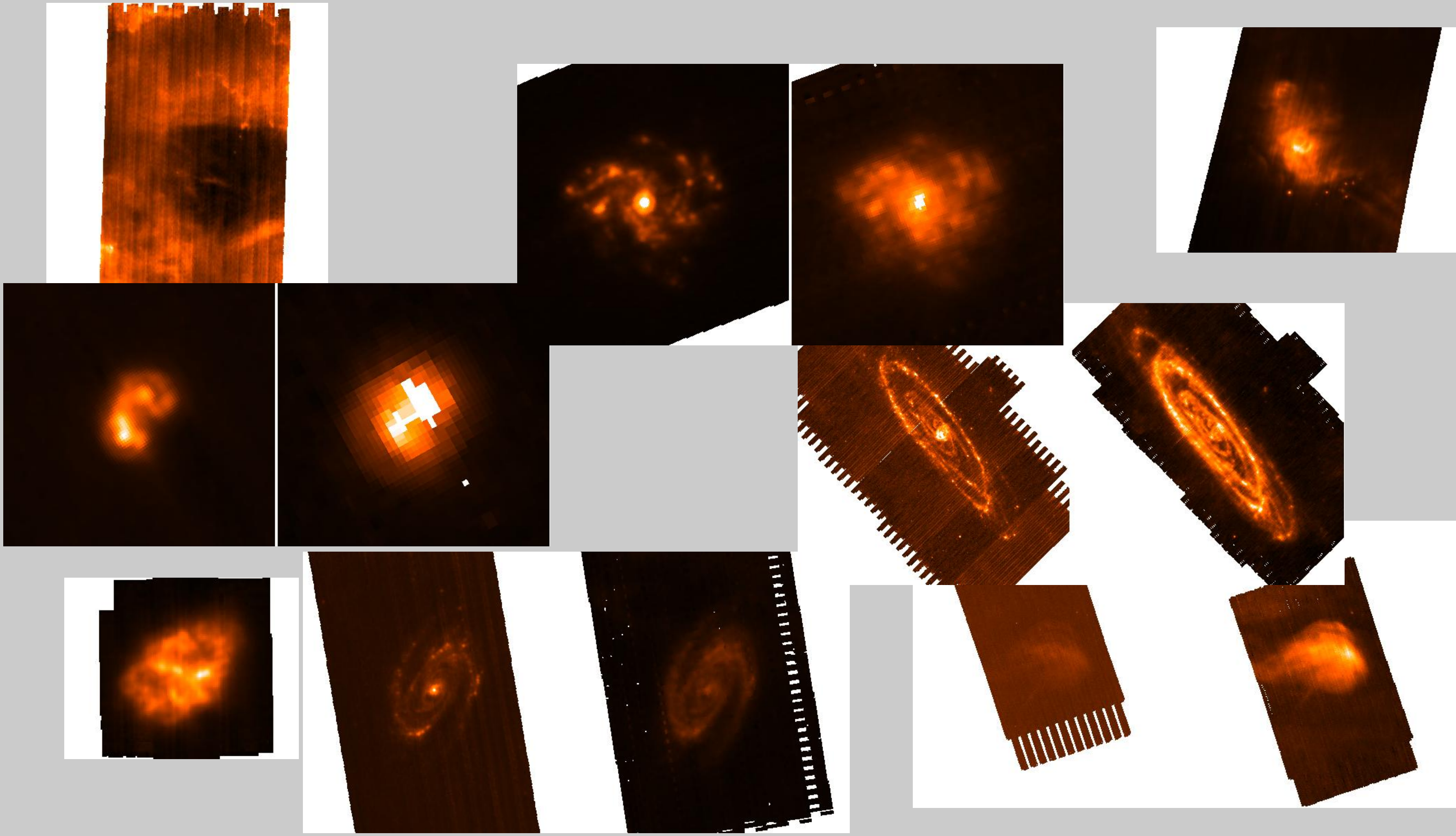
gain

offset

8 MIPS DATA SETS

- **Antennae** 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)

Let's look at the MIPS data …



DYNAMIC RANGE (max in MJy/sr)

	70 micron	160 micron
Antennae	~ 600	~ 300
Crab	~ 500	-
IC348	~ 1000	-
LDN1780	~ 200	~ 150
M31	~ 200	~ 100
M81	~ 150	~ 100
NGC 6946	~ 350	~ 300
Rosette	~ 500	-

COLOR CORRECTIONS – I

• **PACS color corrections from: PICC-ME-TN-038 (April 12 2011 - T. Muller)**

• **MIPS color corrections from MIPS Data Handbook (/http://irsa.ipac.caltech.edu/data/SPITZER/docs/mips/mipsinstrumenthandbook/51/)**

• **Assumptions:**

→ 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

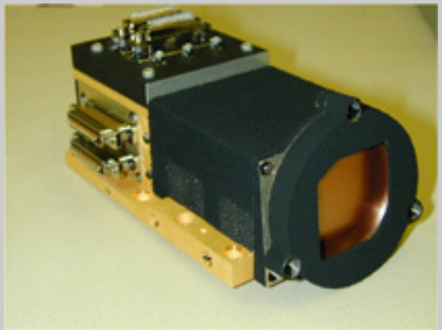
$PACS^{cc}_{70}$	$PACS^{cc}_{160}$	$MIPS^{cc}_{70}$	$MIPS^{cc}_{160}$	$scale_{70-71.4}$	$scale_{160-155.9}$	T_D
1.224	0.963	1.052	0.944	1.153	0.959	20 K
1.034	0.976	0.901	0.954	1.078	0.995	30 K
0.982	1.010	0.893	0.971	1.023	1.022	50 K

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

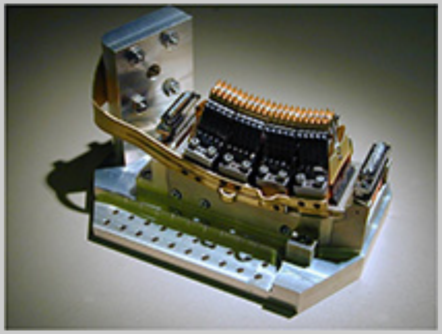
$$MIPS^{cc'}_{\lambda'} = MIPS_{\lambda} / MIPS^{cc}_{\lambda}$$

Multiband Imaging Photometer for Spitzer (MIPS): non-linearity – I

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



MIPS 70 micron: Ge:Ga 32 X 32 array



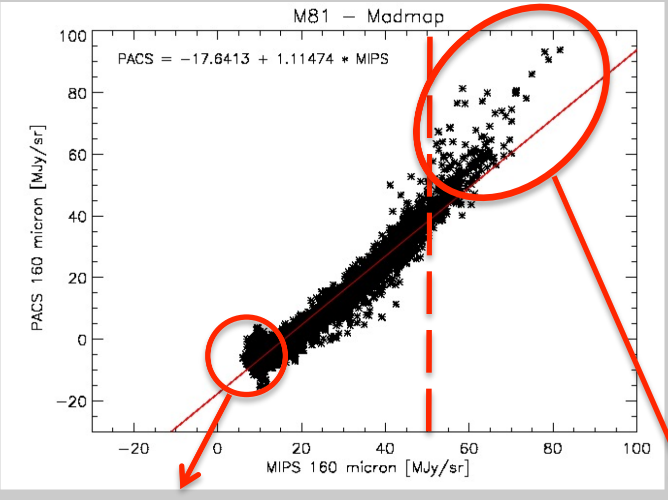
MIPS 160 micron: Ge:Ga 2 X 20 array

<u>Documentation:</u>

- ***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 – II

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

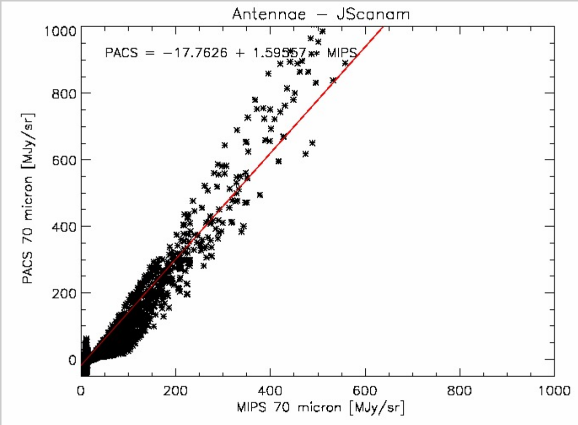
WARNINGS/NOTES:

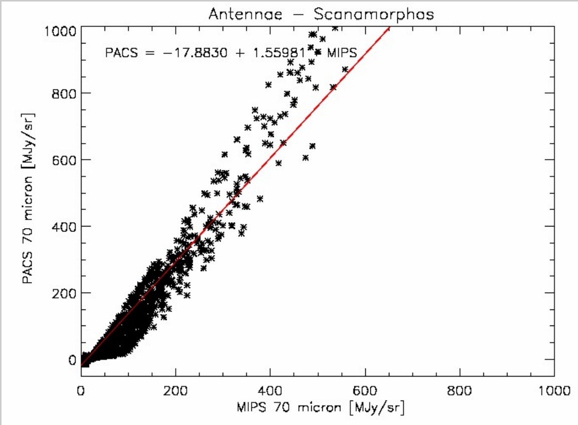
- **No IC348/NGC6946 maps processed by JScanam**

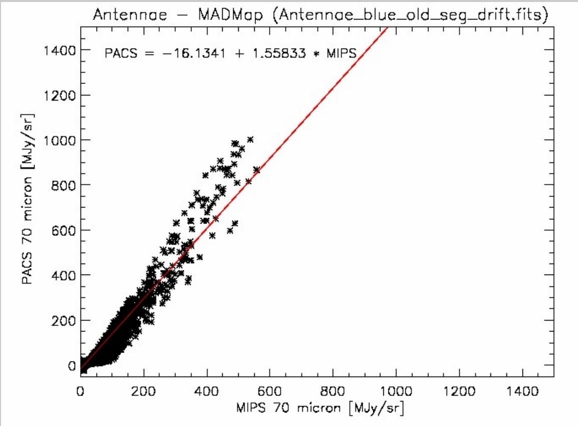
- **MIPS processing is minimal at both 70 and 160 micron: mosaics are combined with MOPEX starting from archive BCDs**

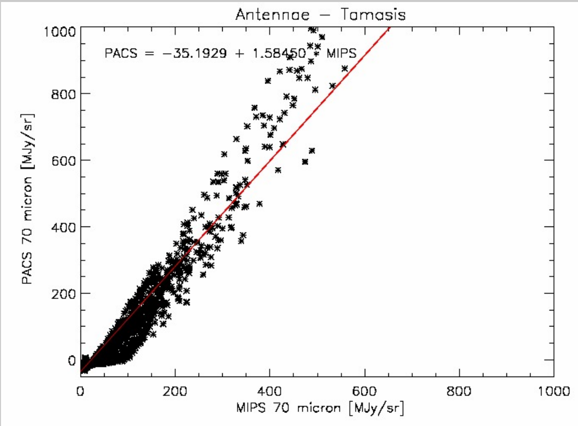
- **Since not all PACS mappers provide errors, for consistency fitting was performed setting all weights = 1 (PACS & MIPS)**

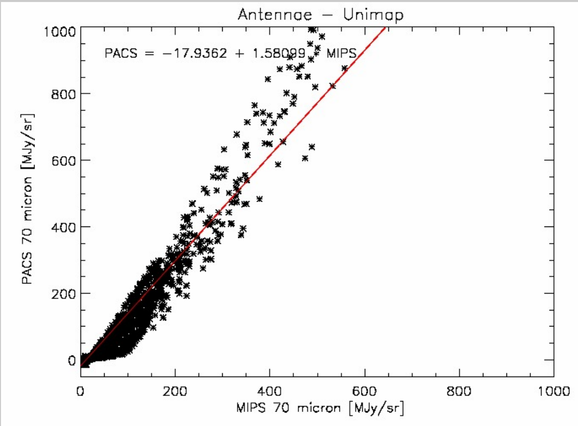
Antennae – 70 micron



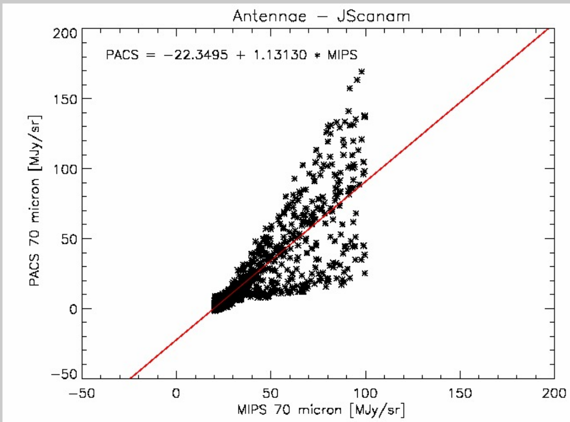


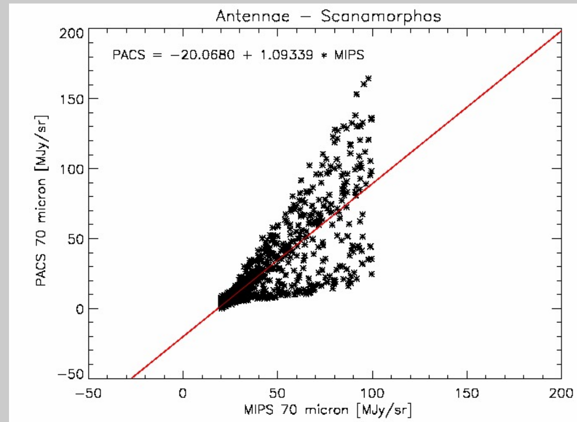


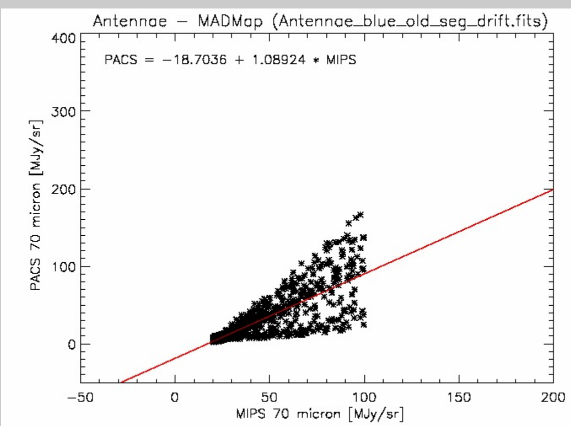


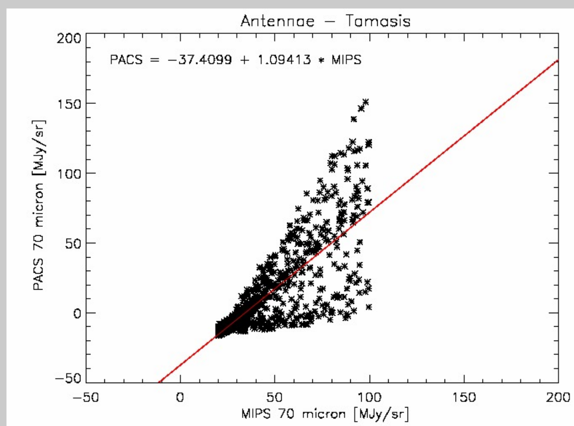


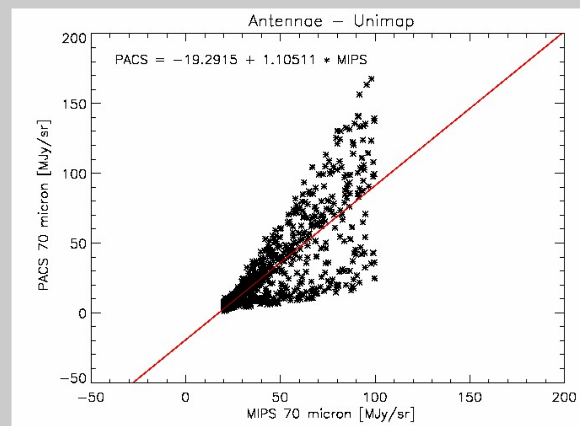
Antennae – 70 micron / linear



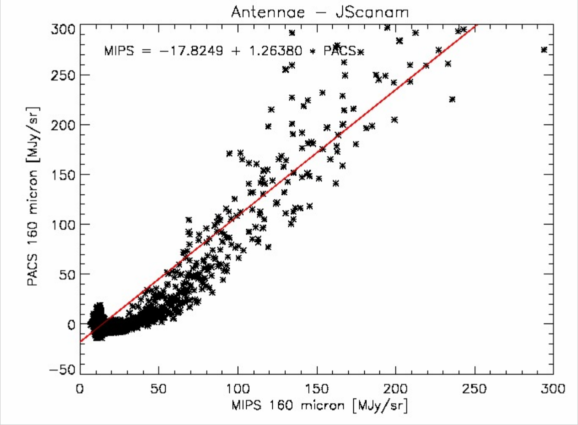


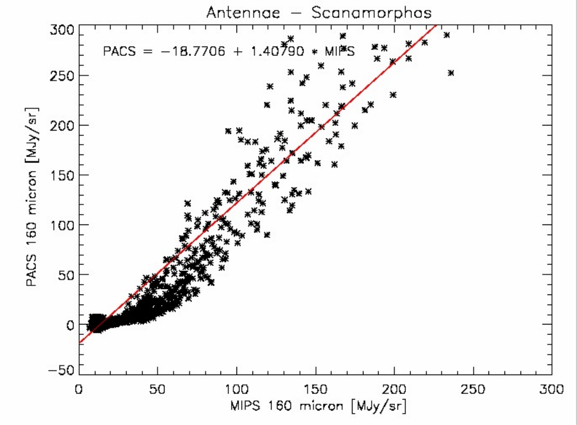


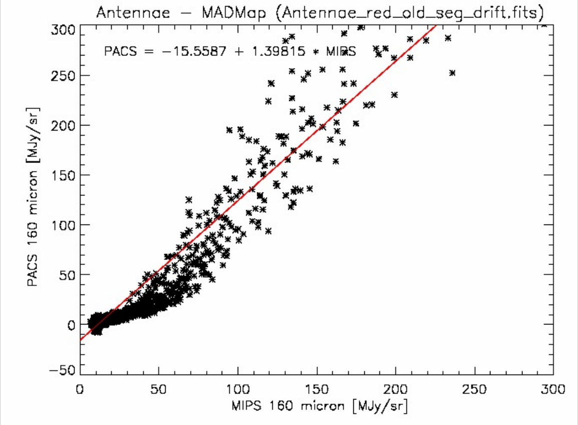


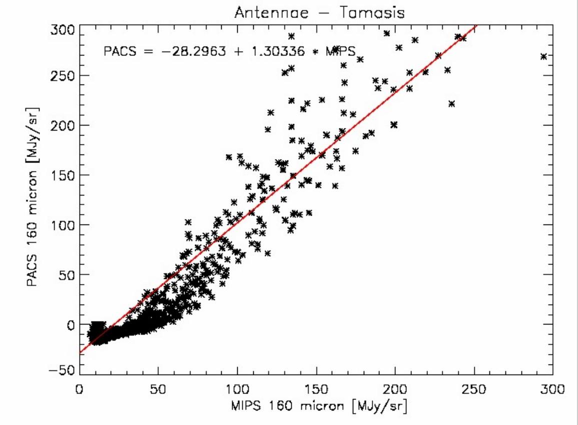


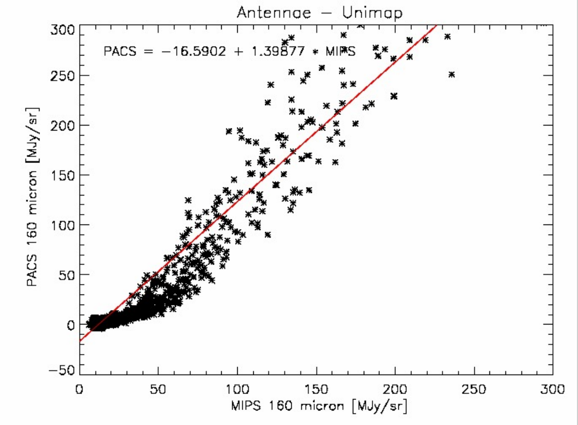
Antennae – 160 micron



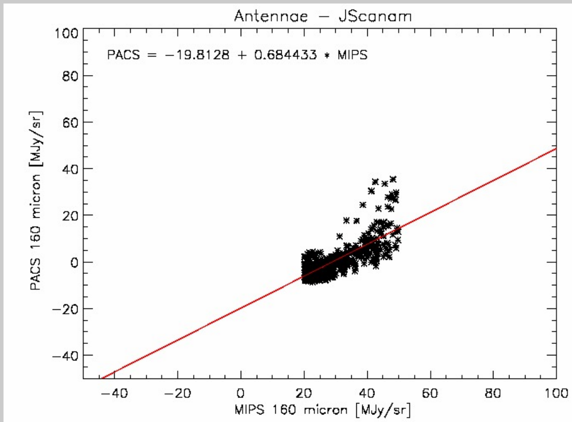


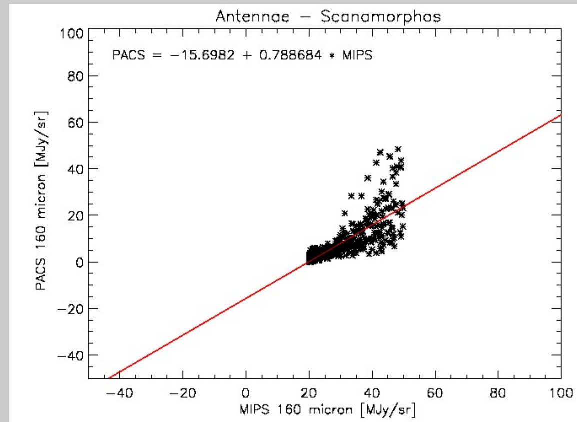


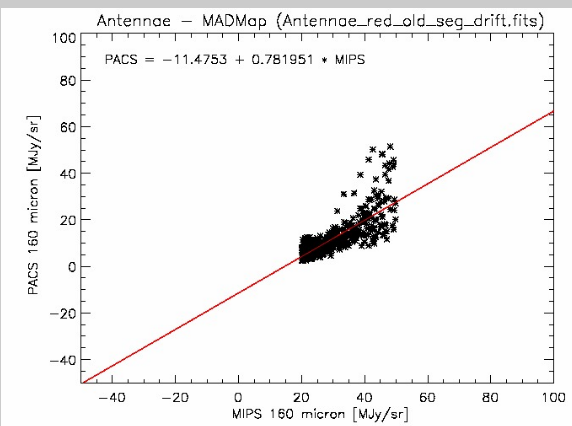


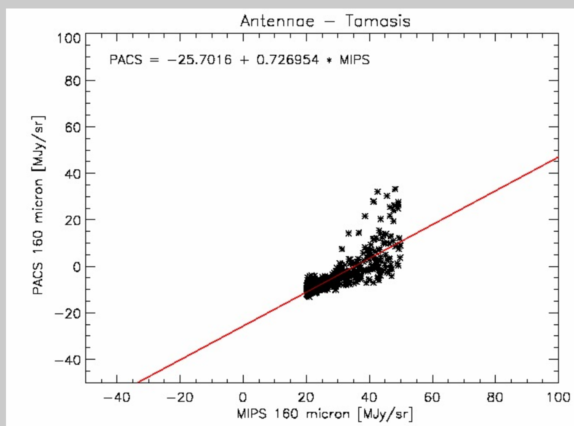


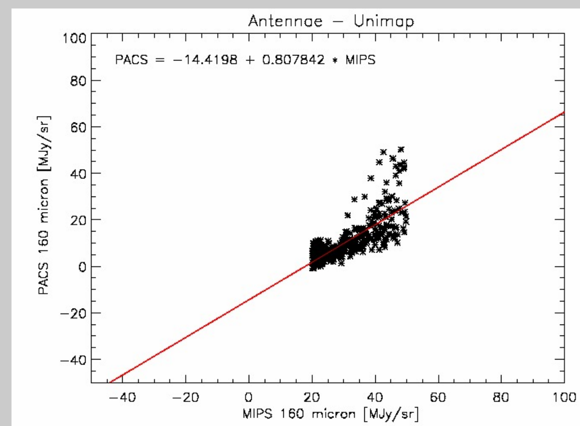
Antennae – 160 micron/linear



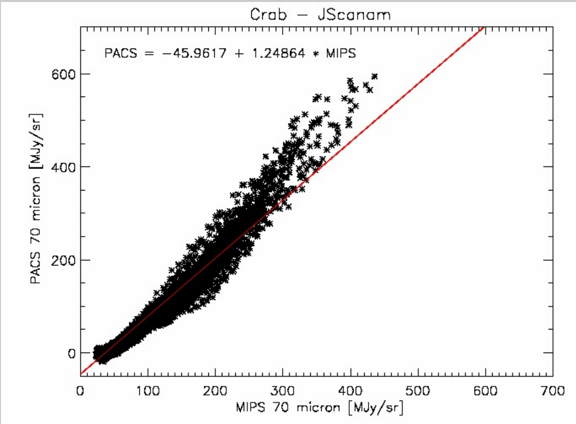


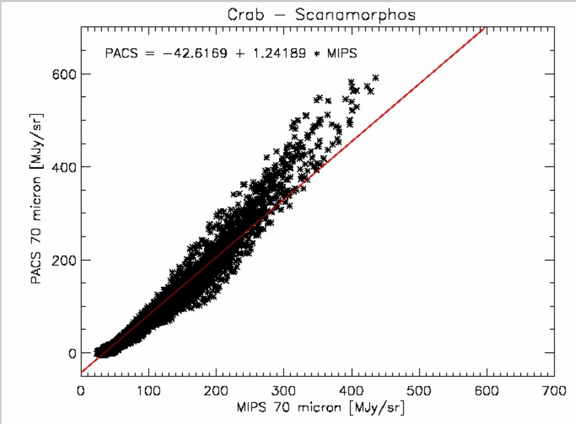


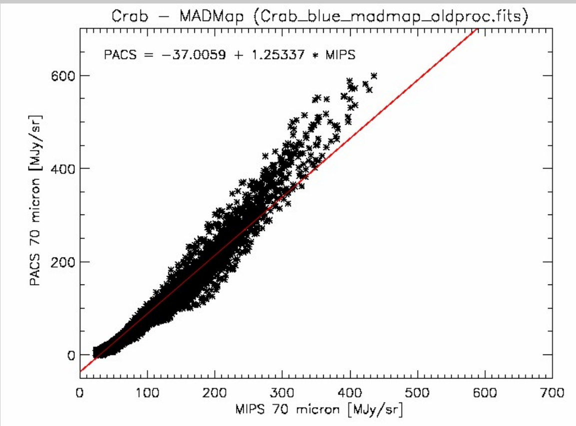


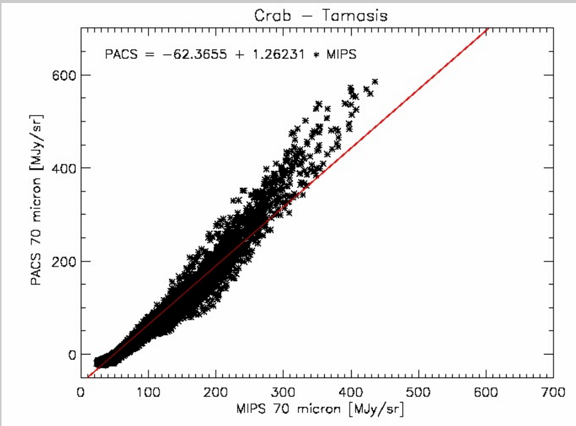


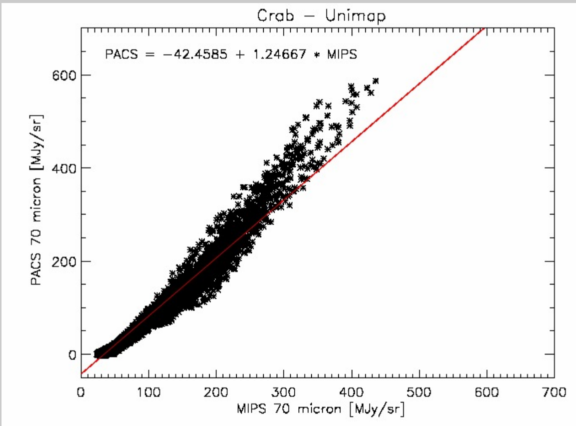
Crab – 70 micron



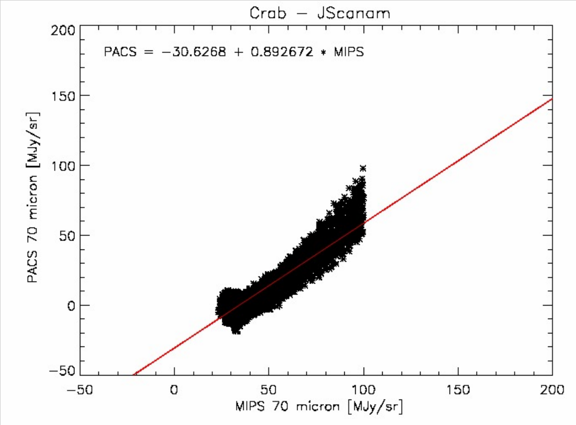


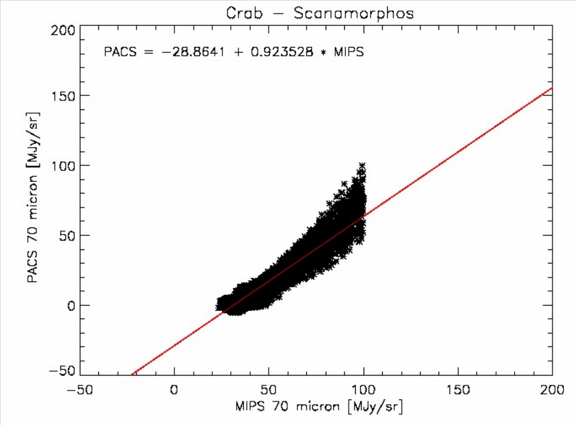


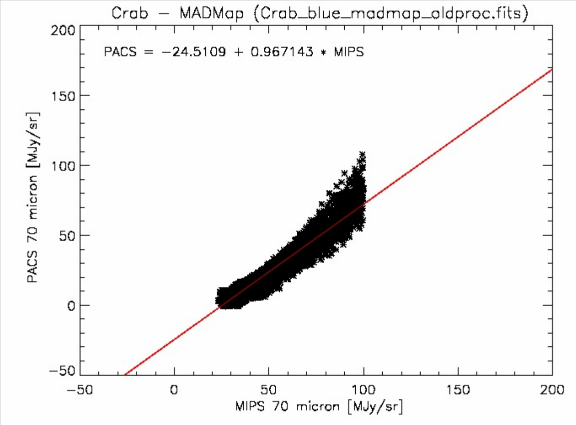


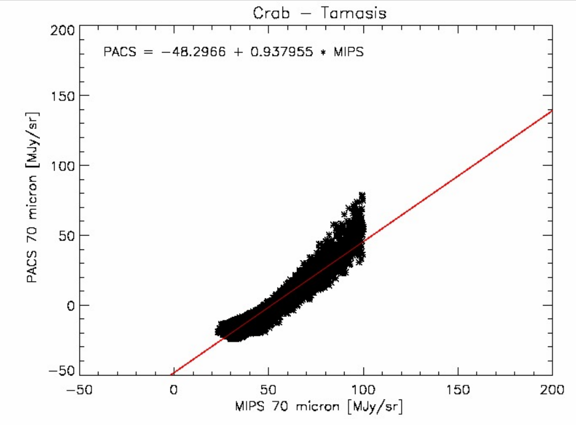


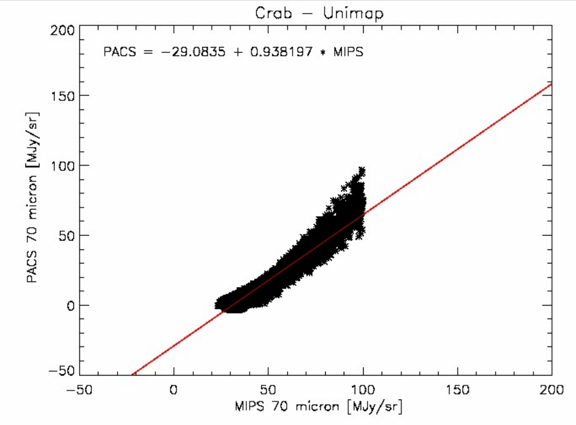
Crab – 70 micron/linear



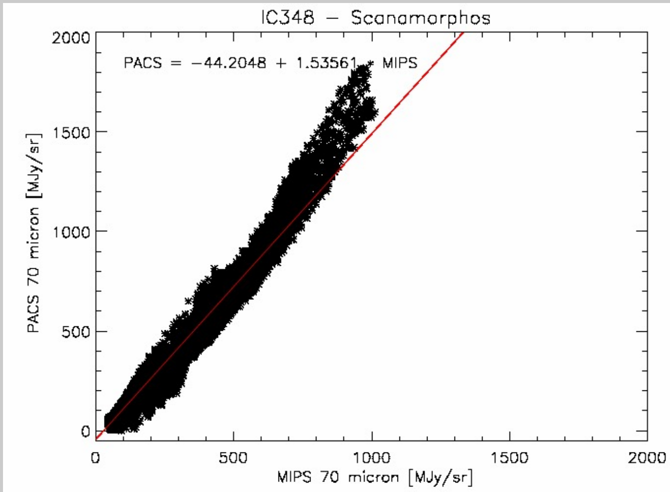


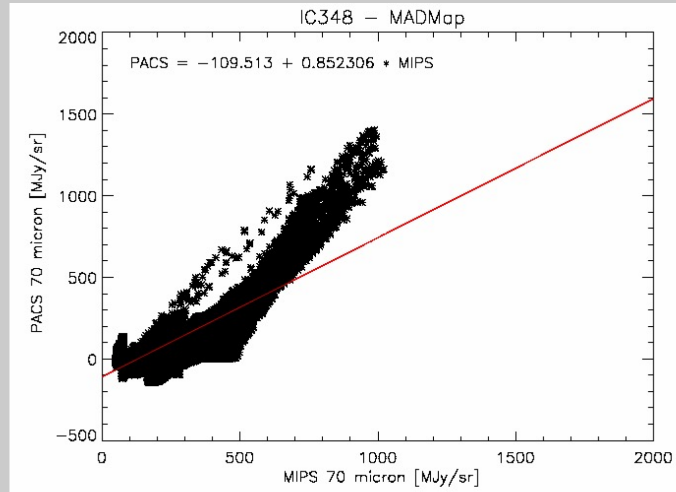


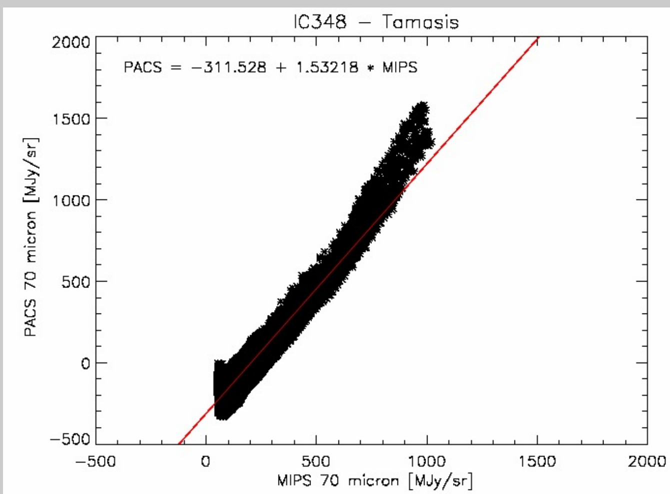


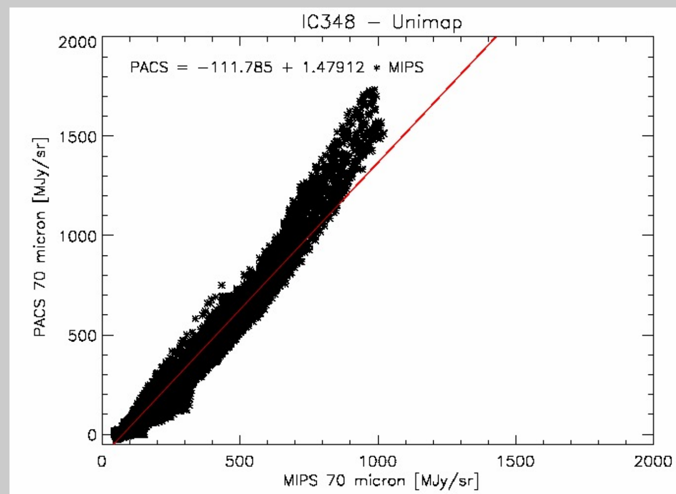


IC348 – 70 micron

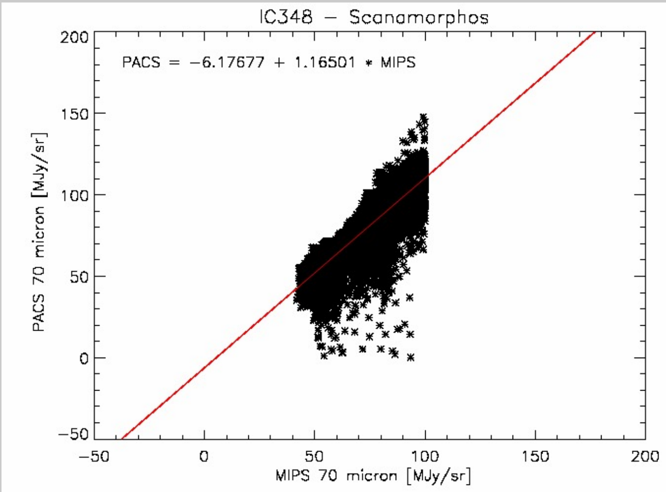


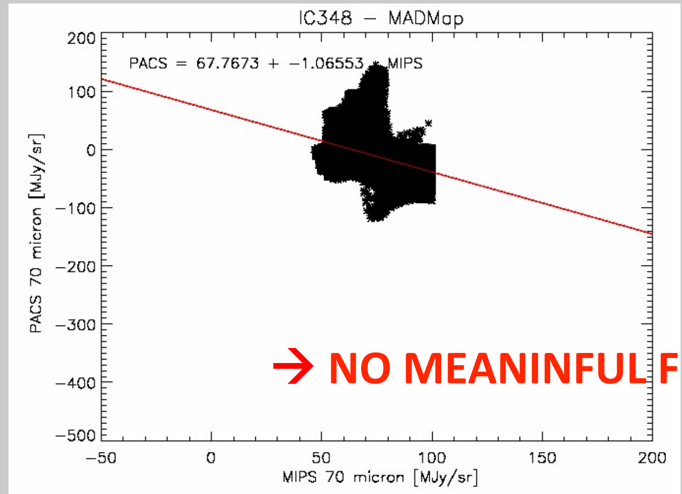




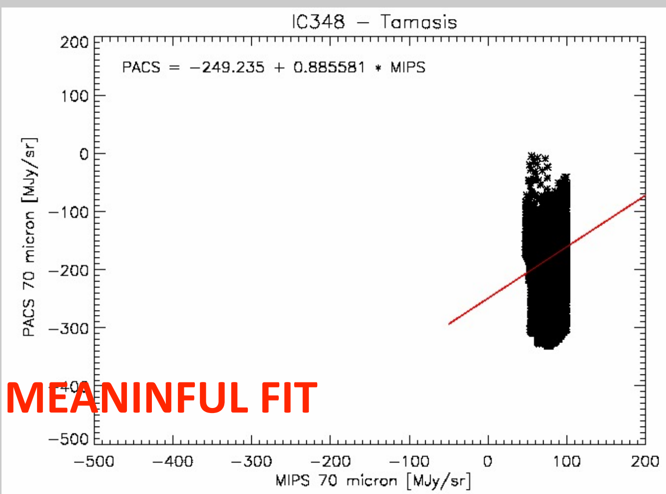


IC348 – 70 micron/linear





→ NO MEANINFUL FIT



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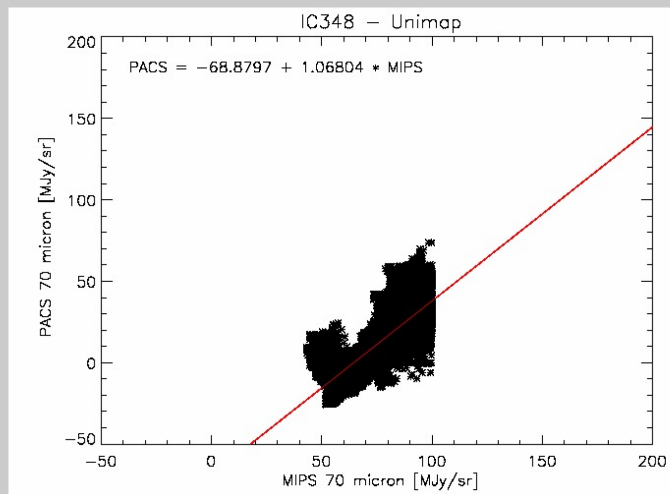
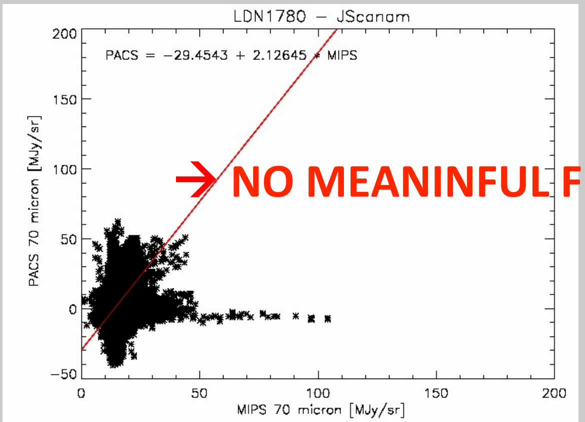


LDN 1780 – 70 micron



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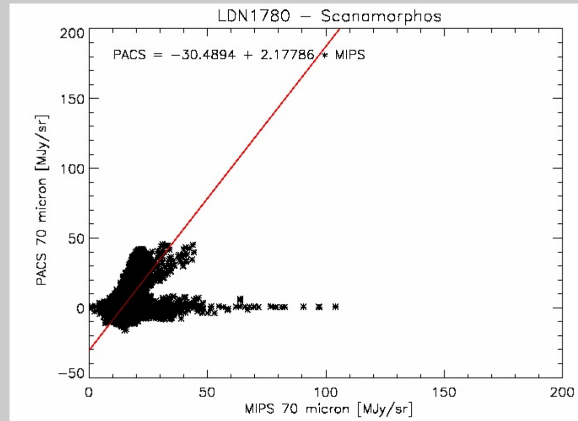

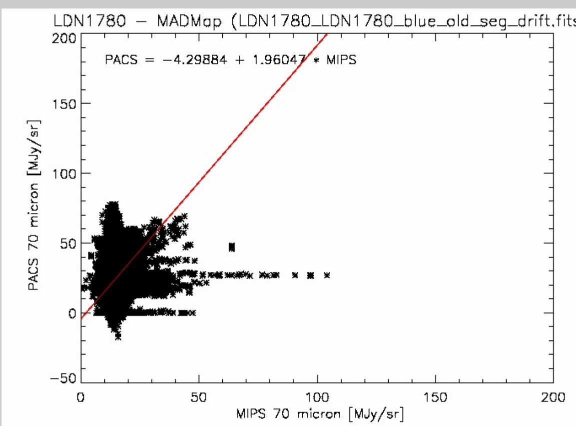

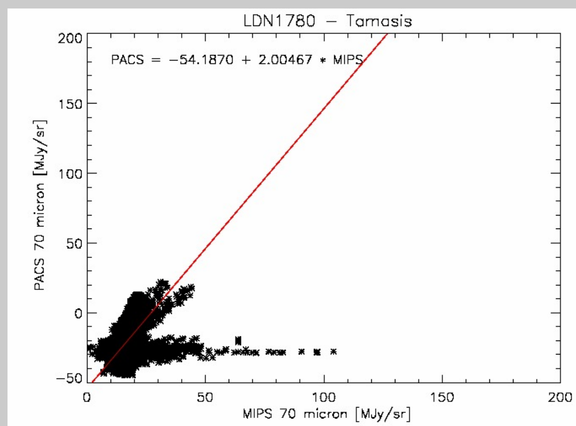

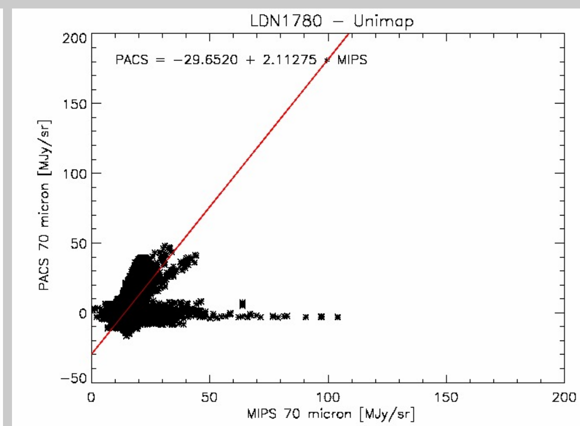

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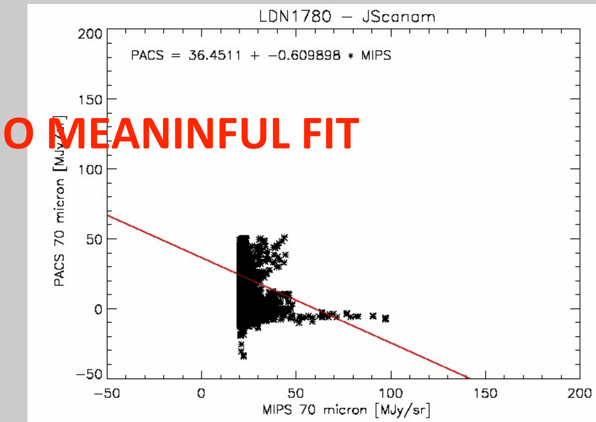
LDN 1780 – 70 micron/linear



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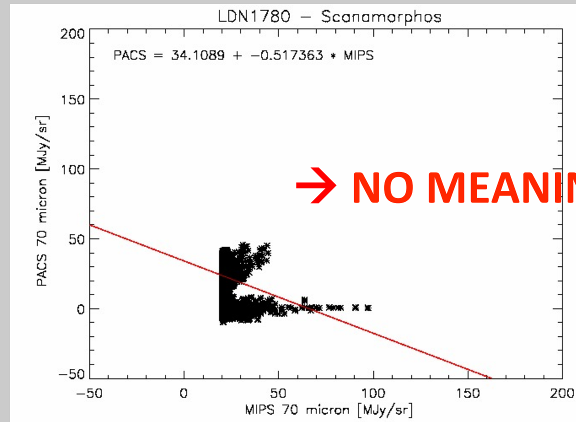

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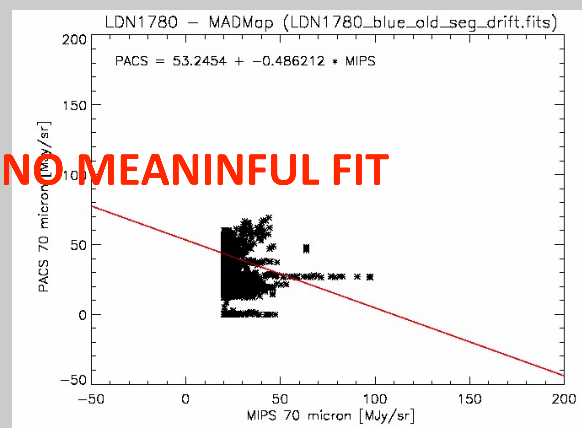

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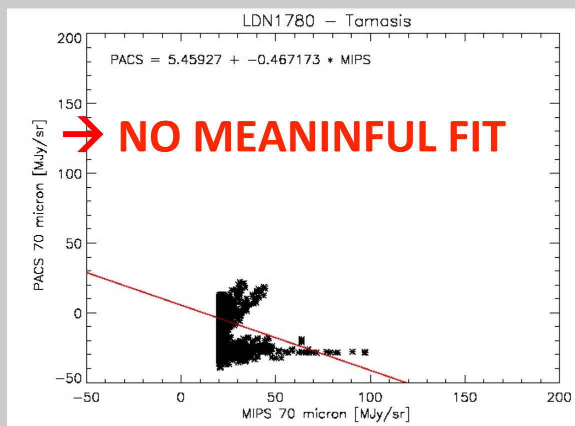

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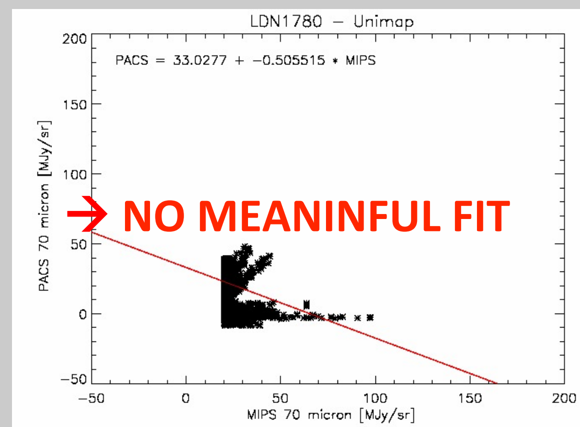
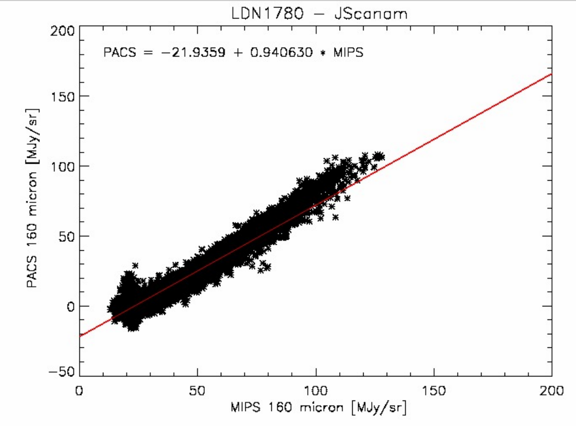
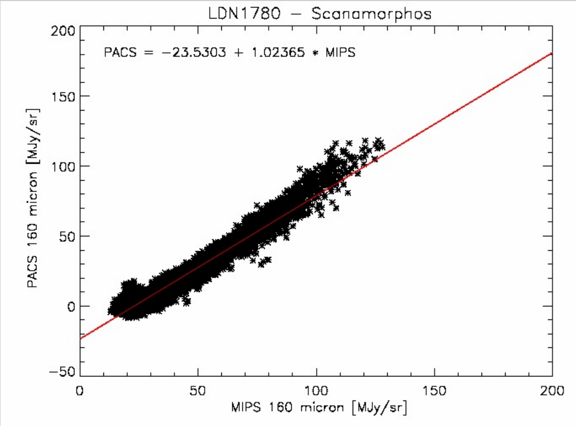
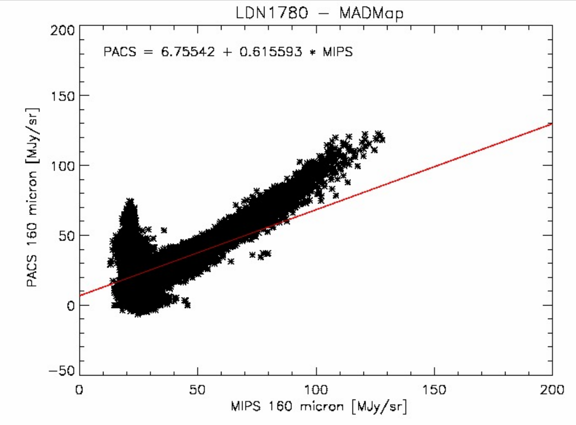


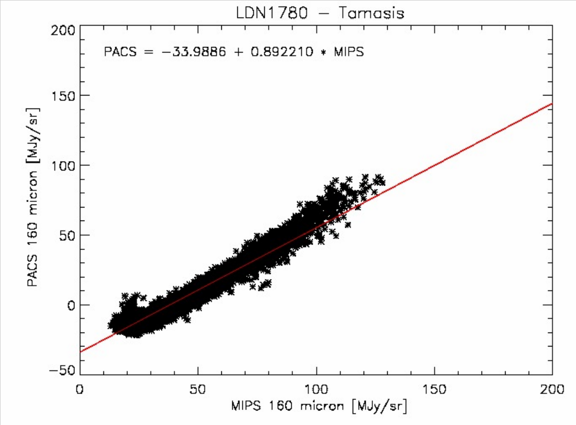
→ NO MEANINFUL FIT

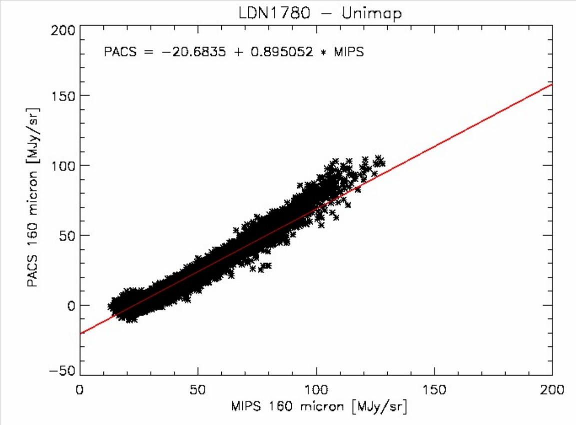
LDN 1780 – 160 micron



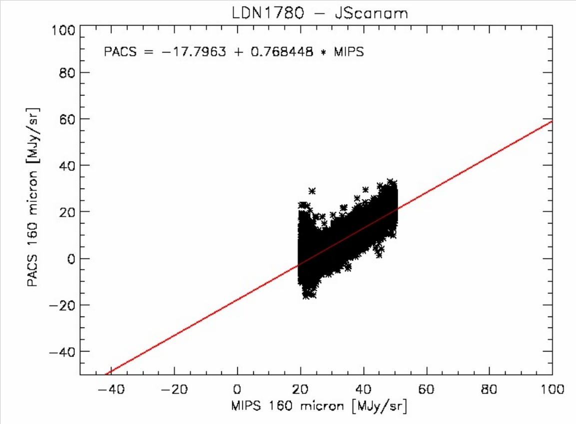


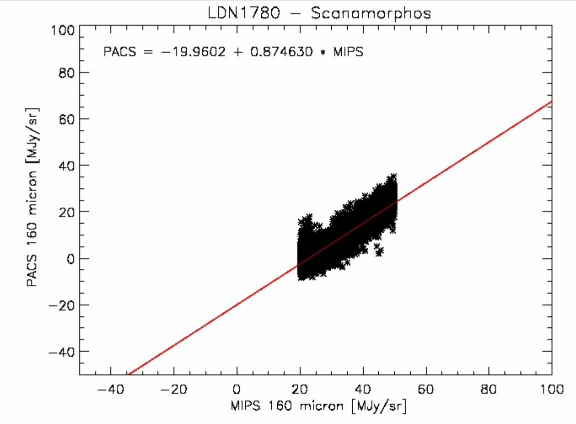


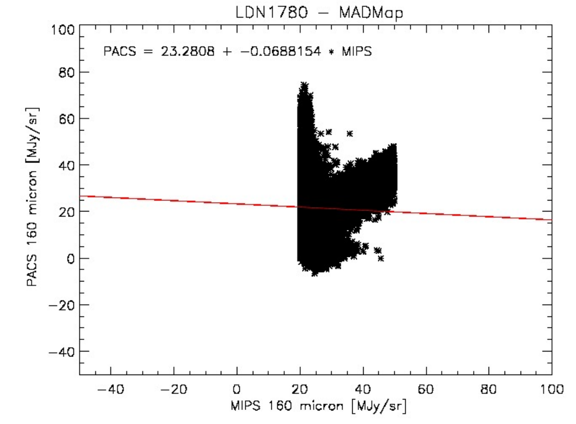


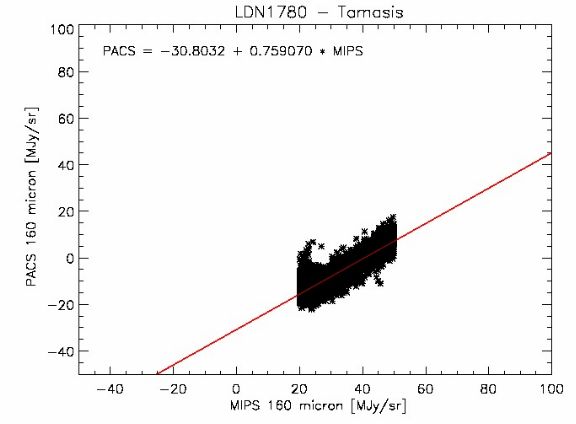


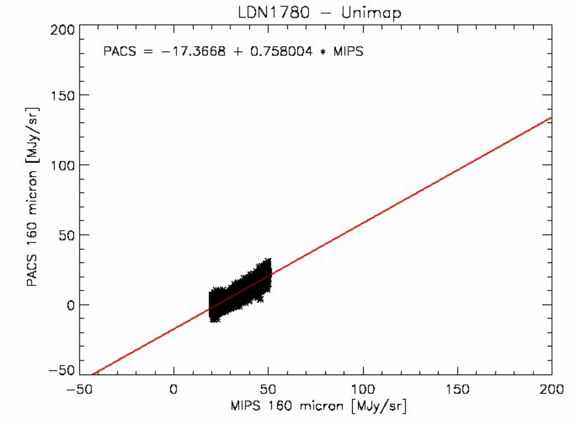
LDN 1780 – 160 micron/linear





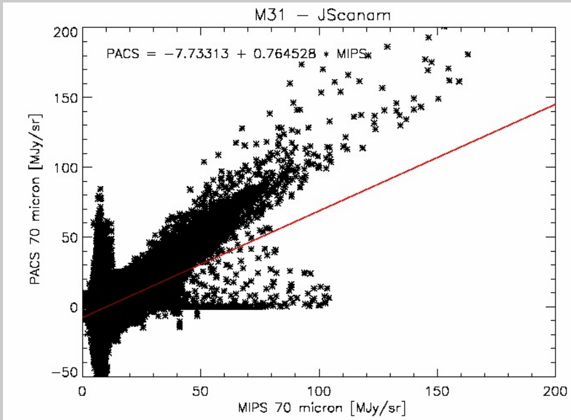


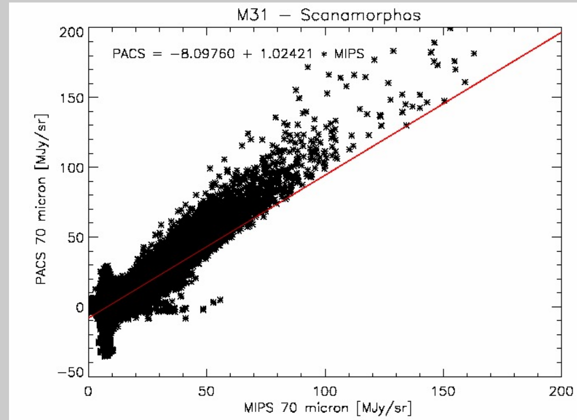


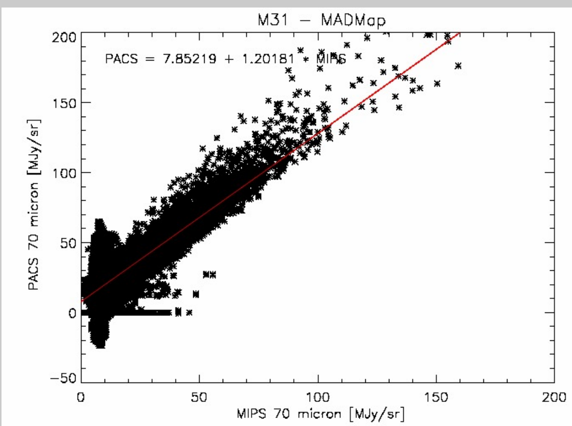


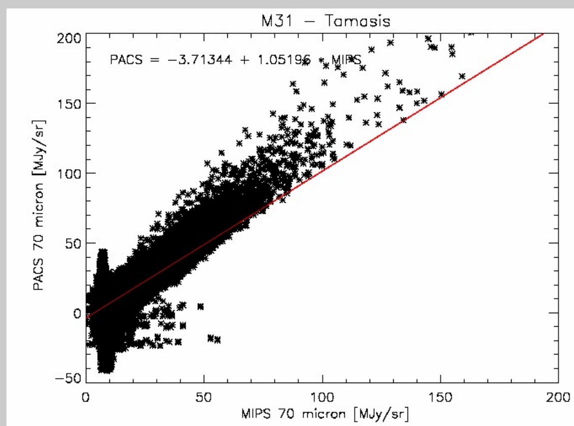
→ **NO MEANINFUL FIT**

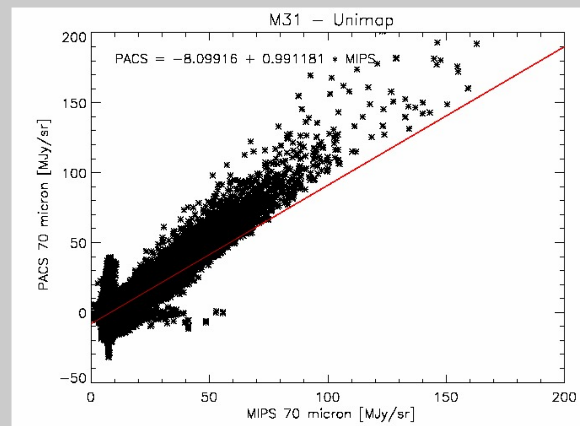
M31 – 70 micron



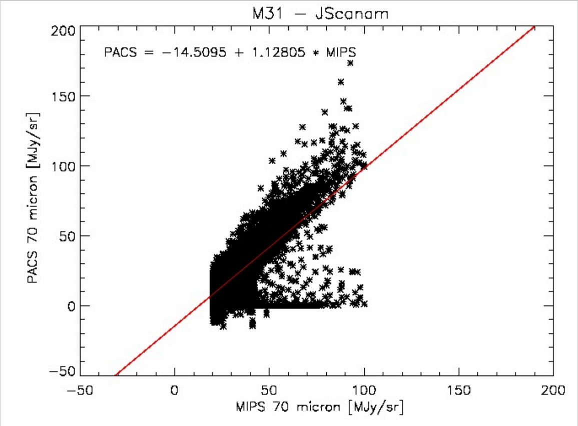


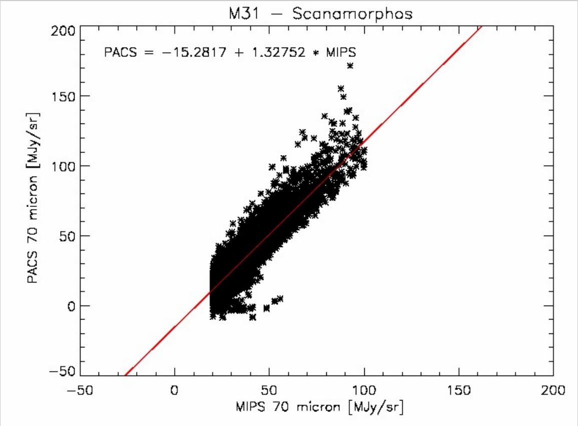


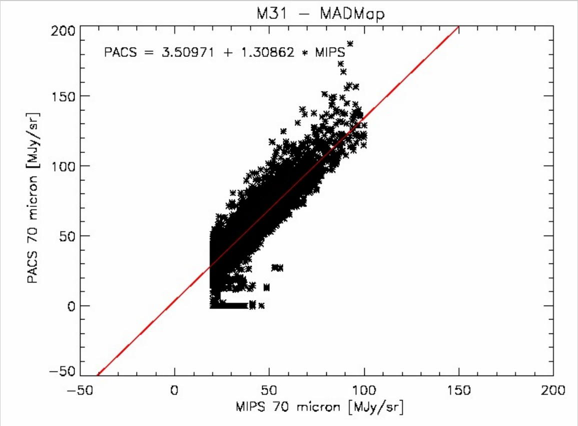


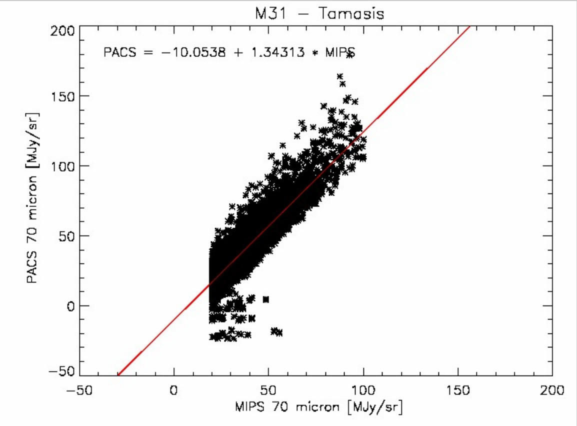


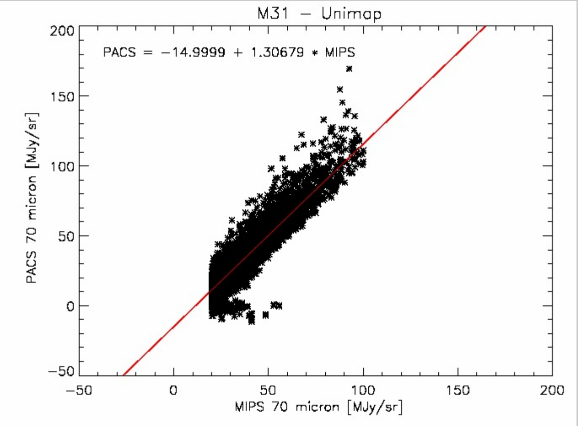
M31 – 70 micron/linear



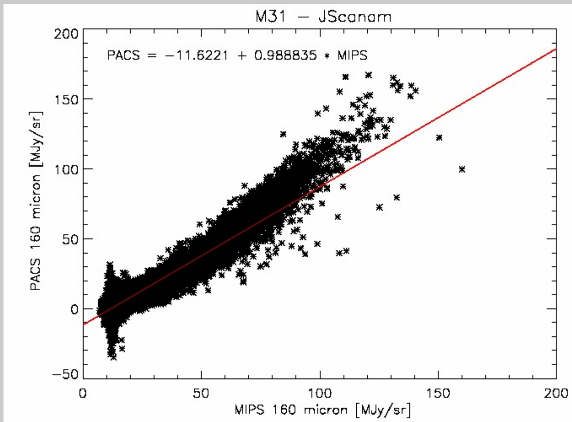


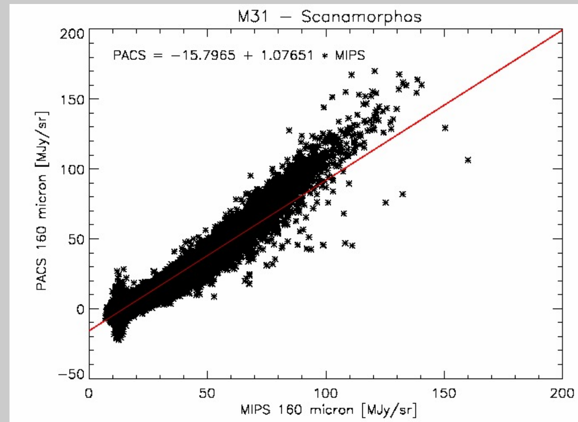


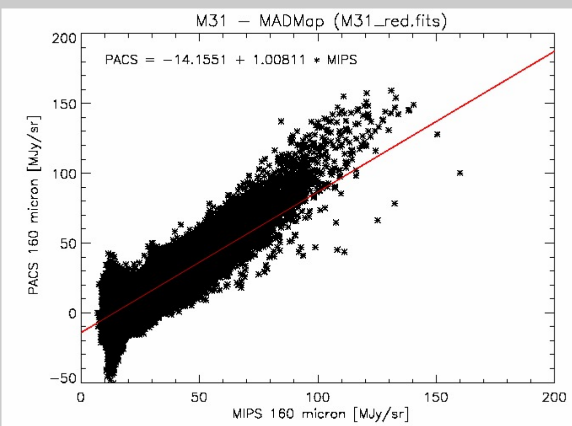


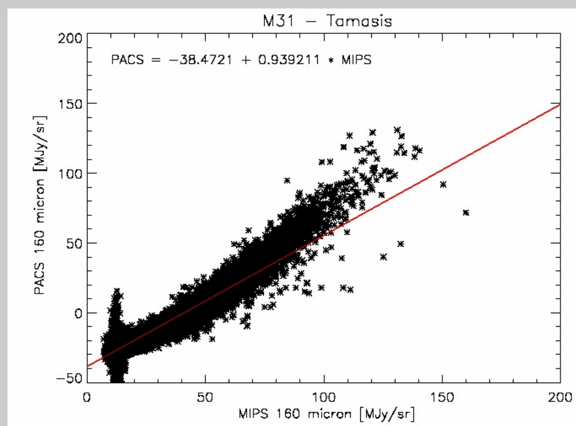


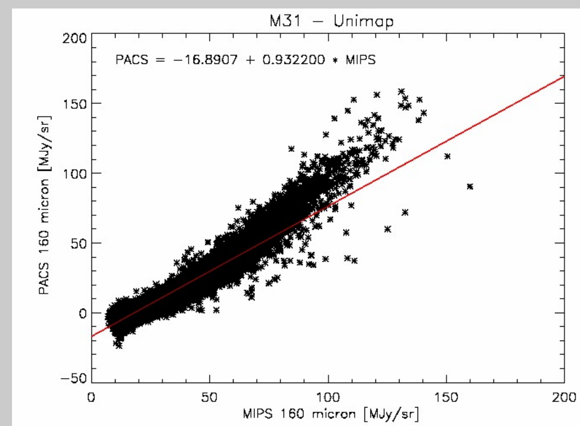
M31 – 160 micron



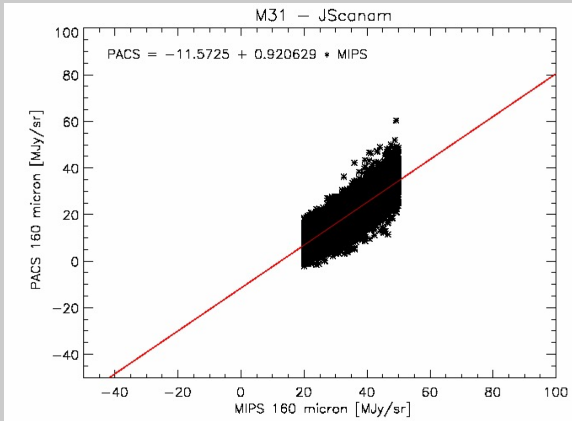


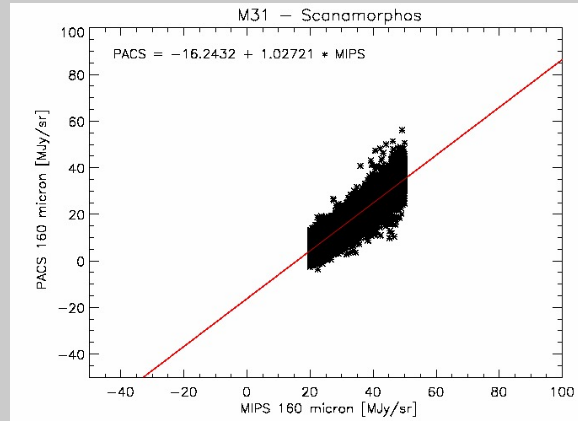


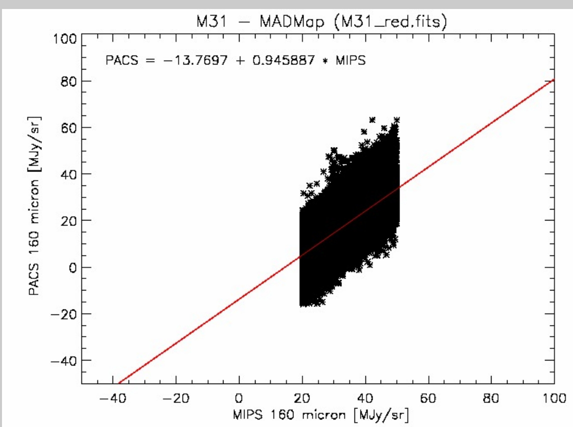


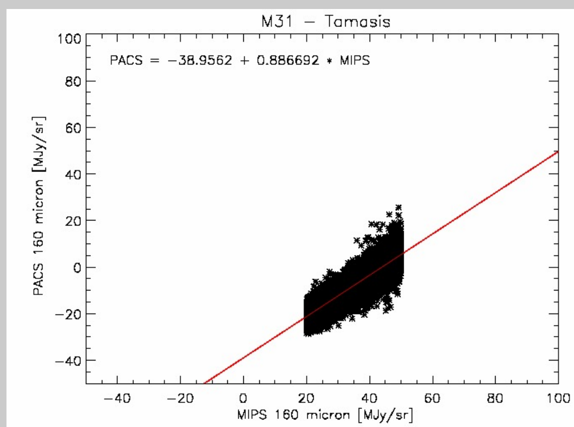


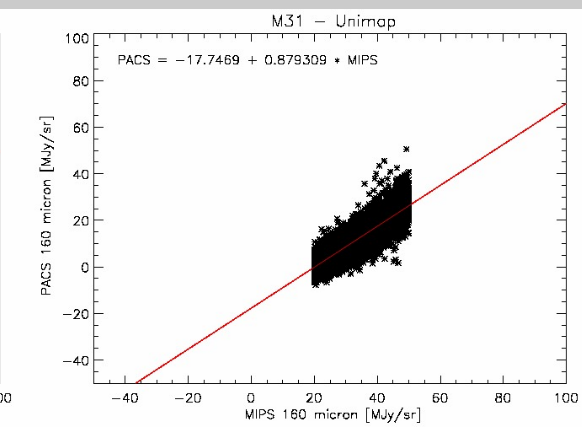
M31 – 160 micron/linear



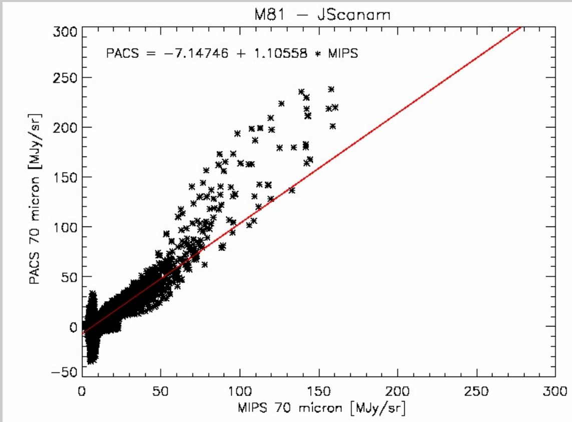


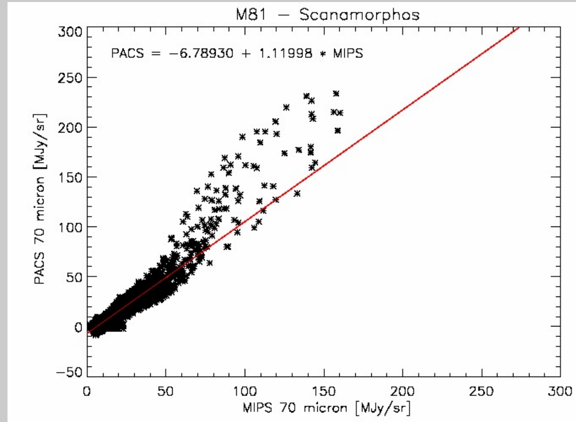


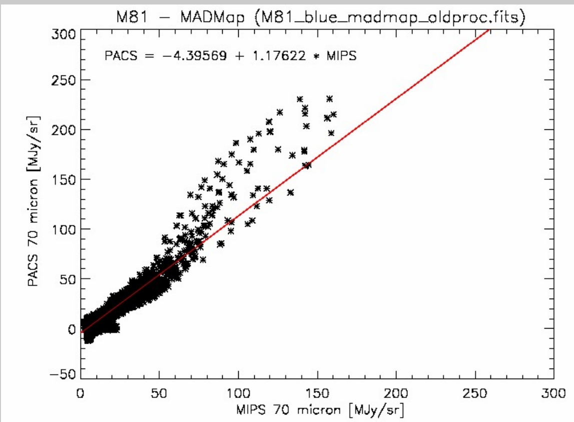


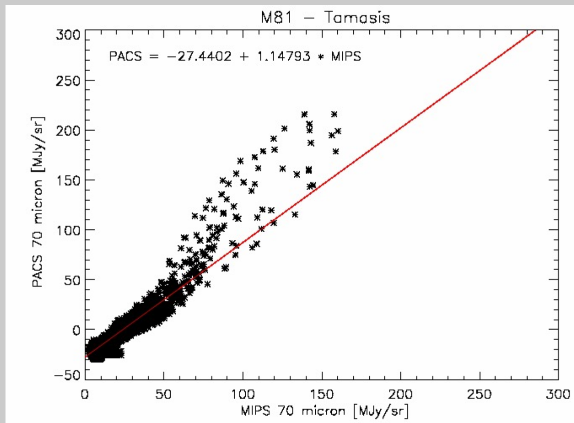


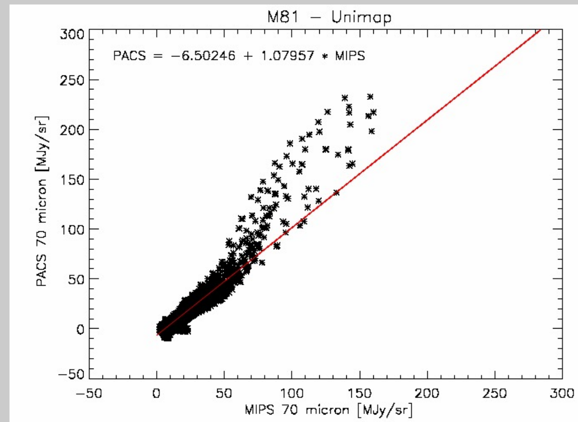
M81 – 70 micron



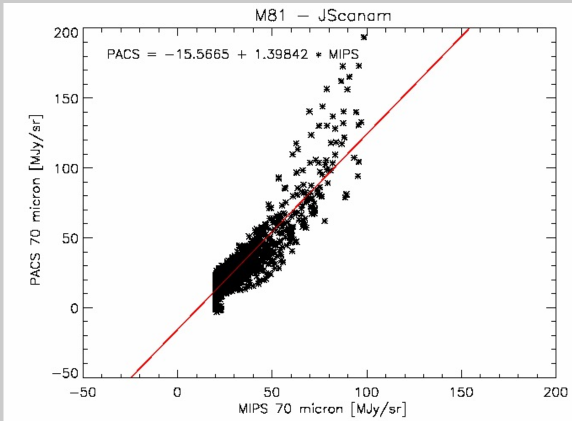


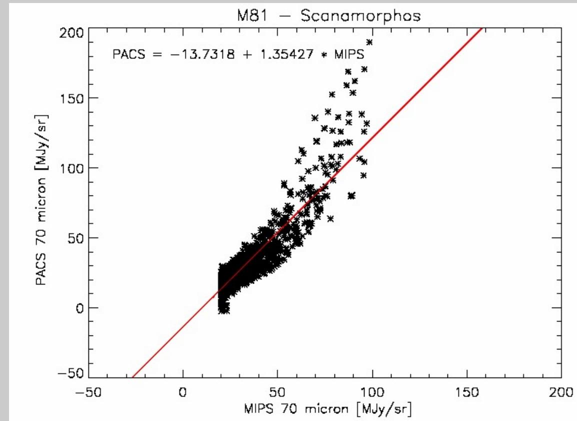


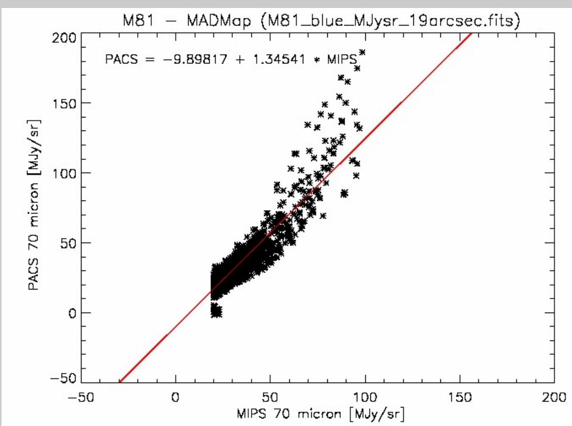


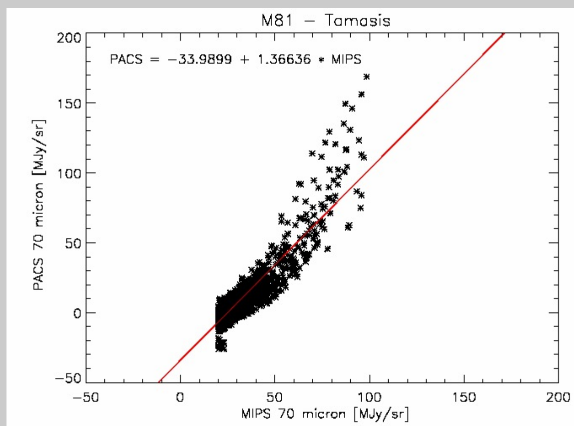


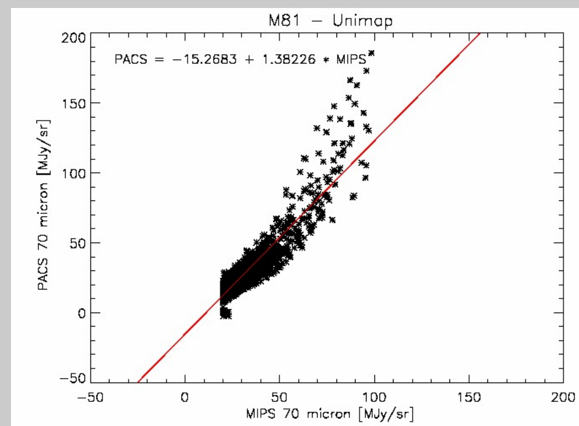
M81 – 70 micron/linear



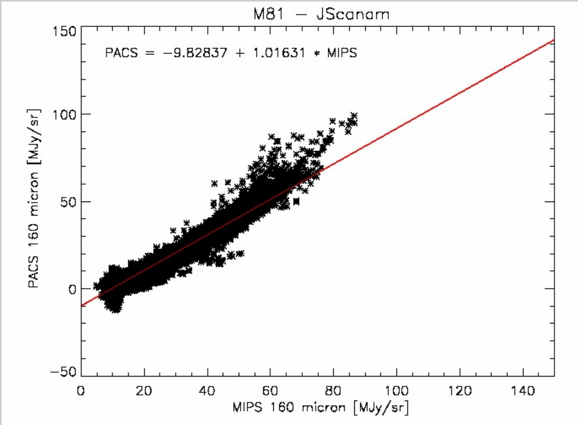


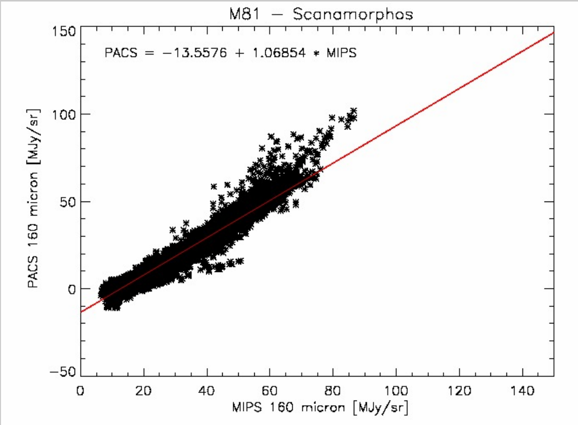


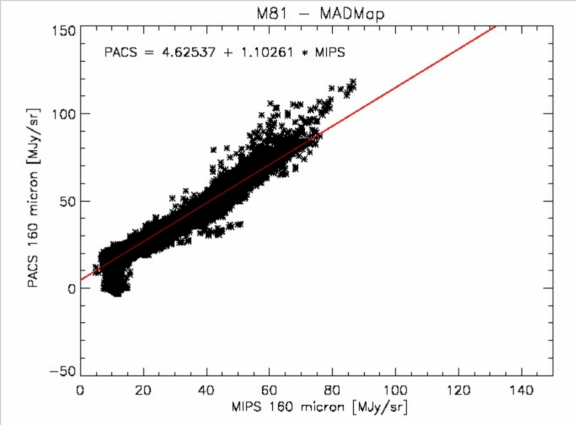


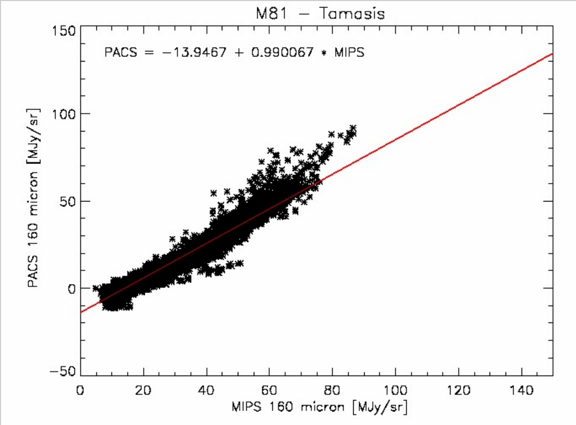


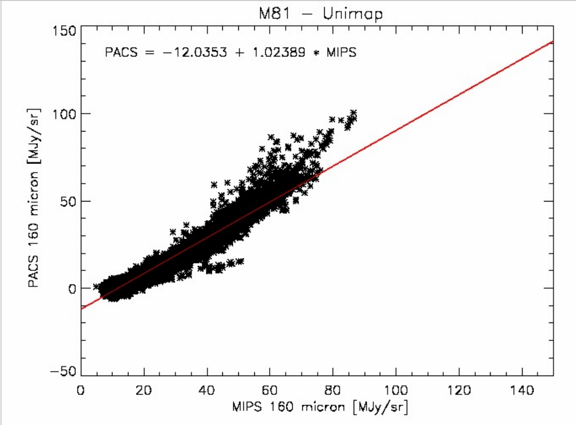
M81 – 160 micron



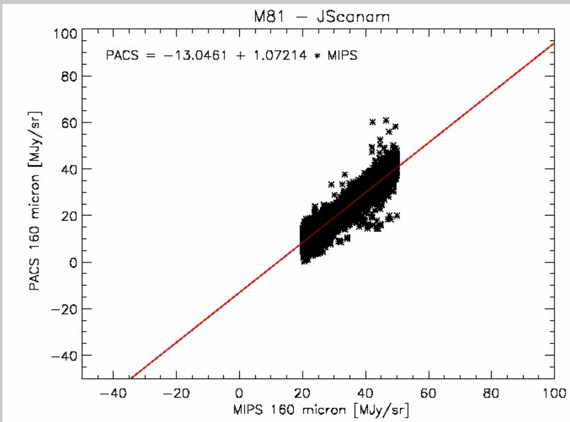


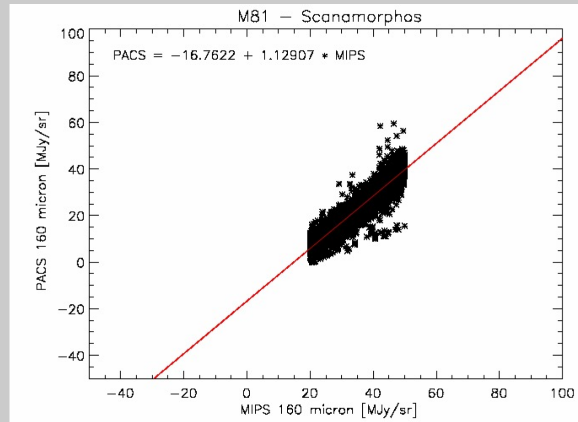


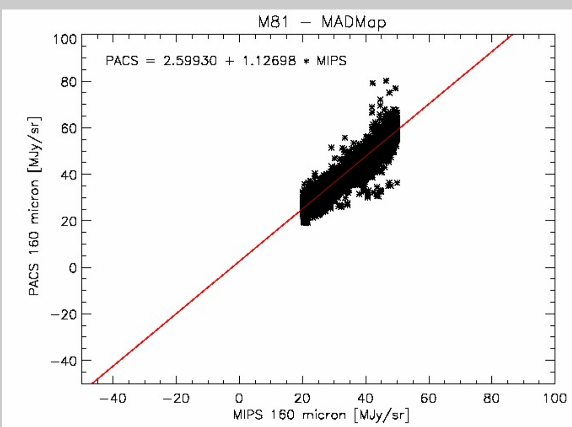


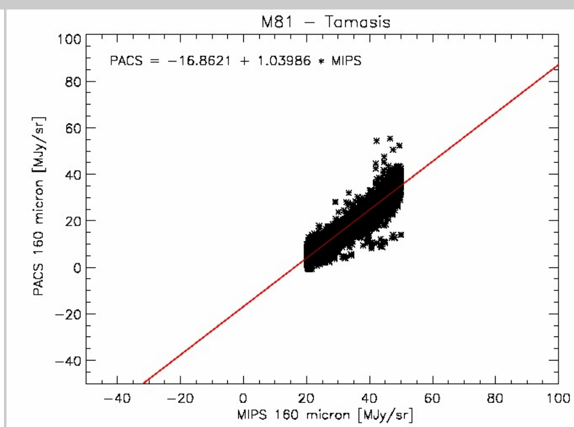


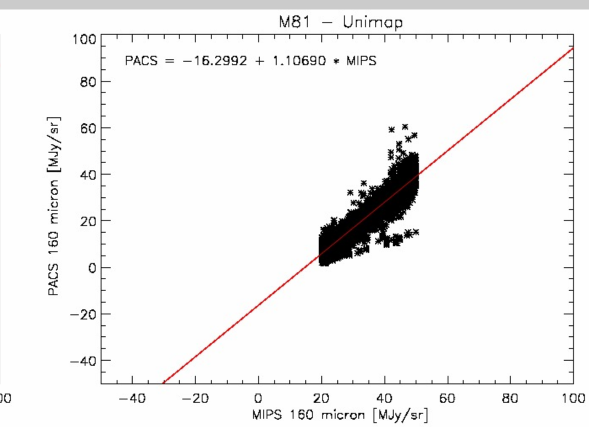
M81 – 160 micron/linear



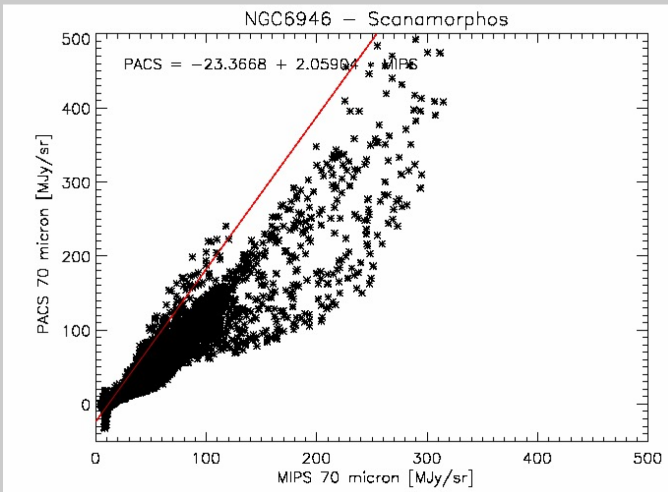


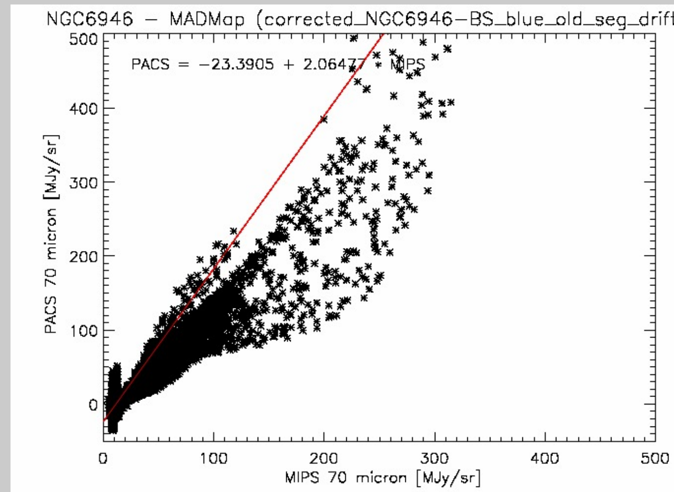


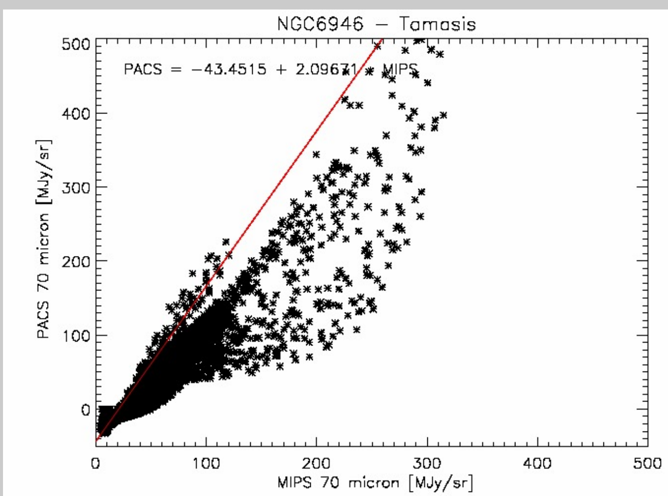


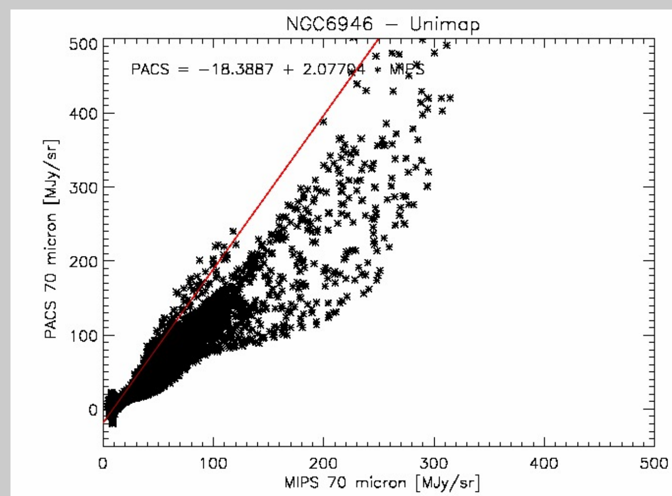


NGC6946 – 70 micron

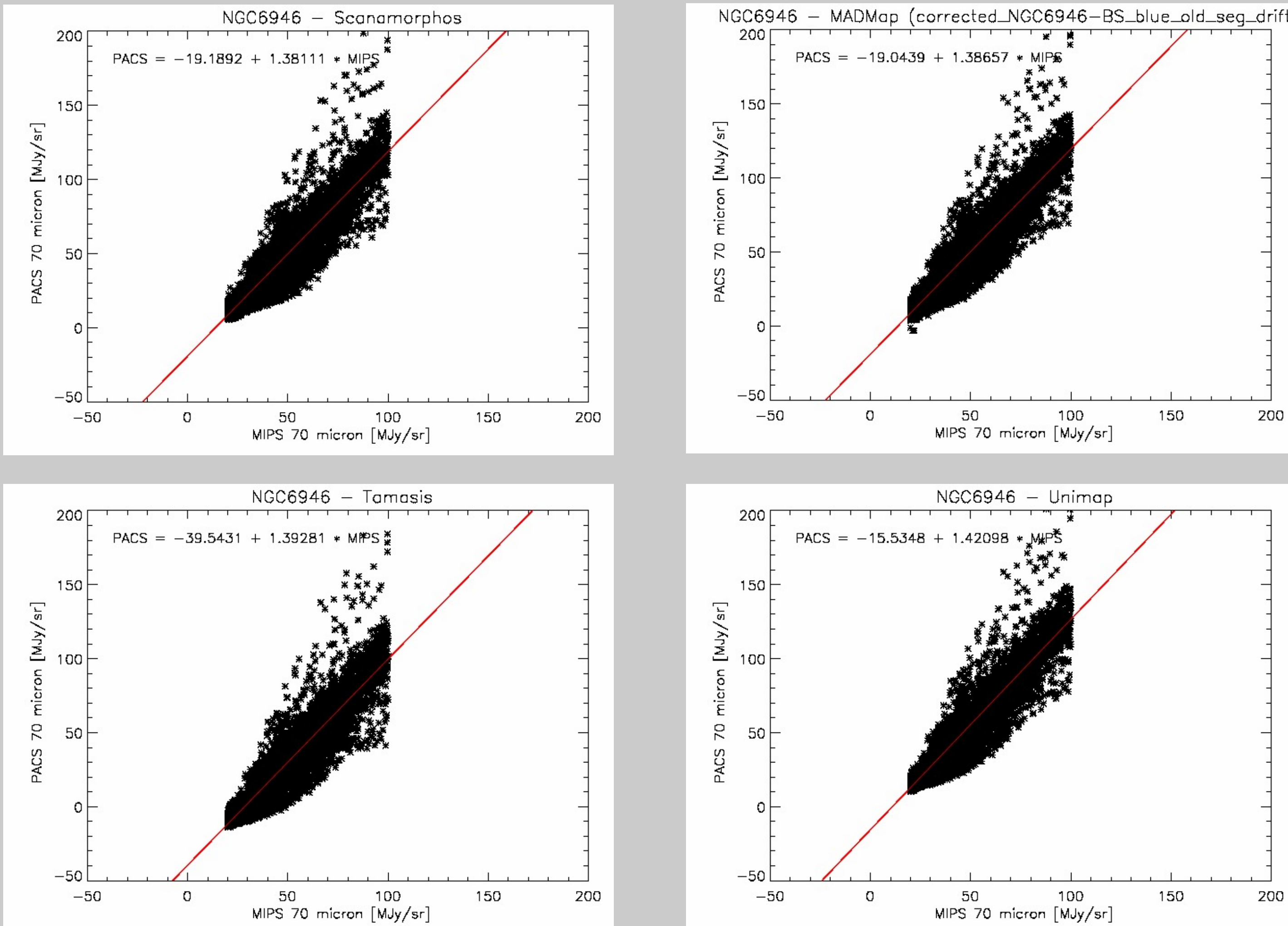




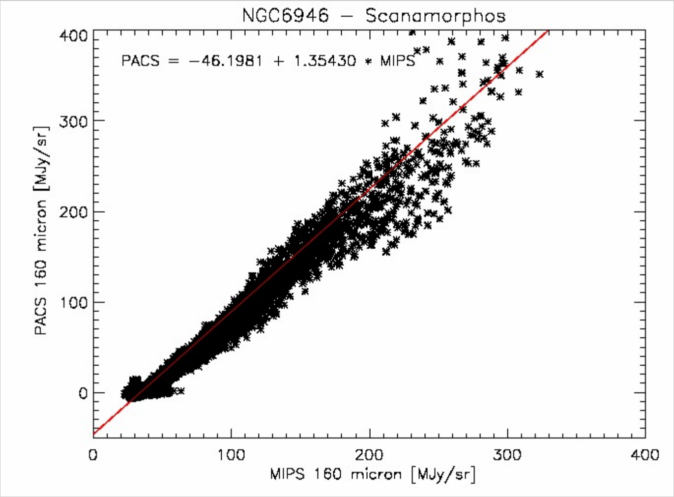


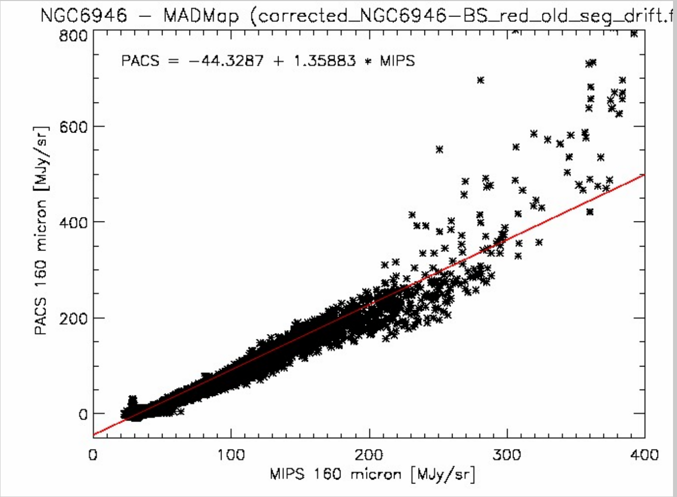


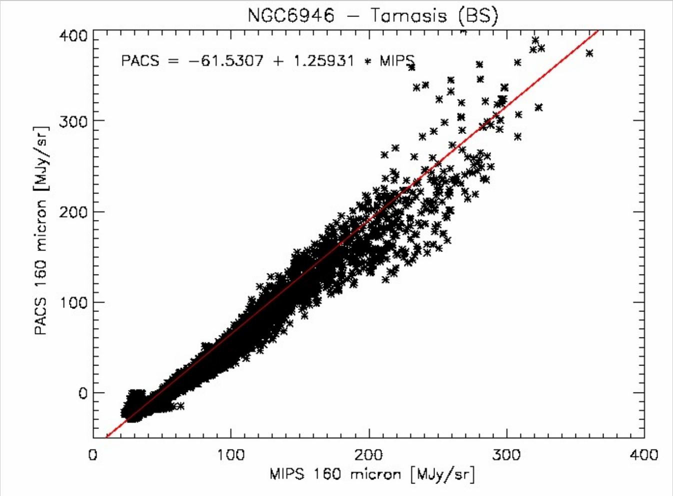
NGC6946 – 70 micron/linear

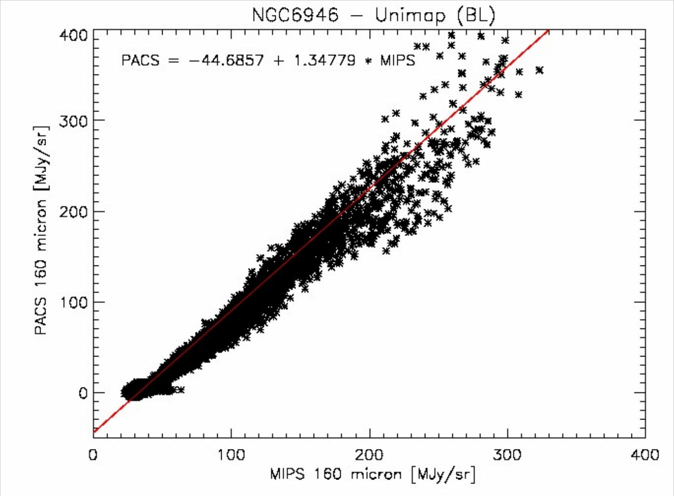


NGC6946 – 160 micron

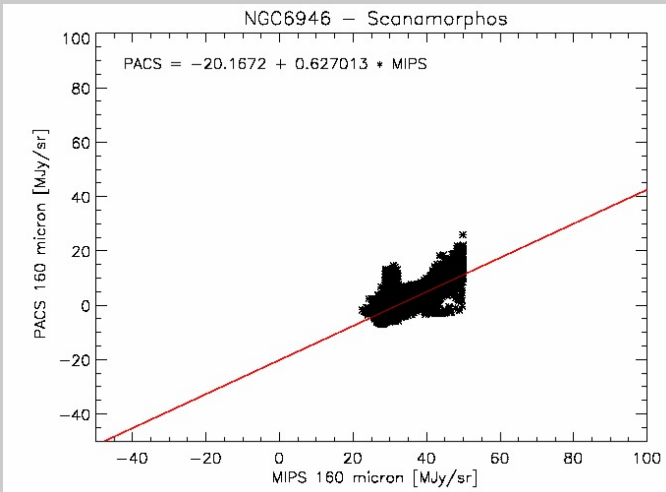


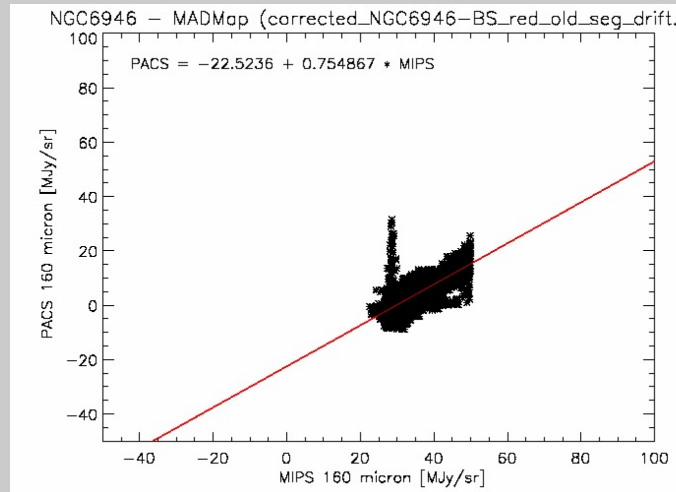


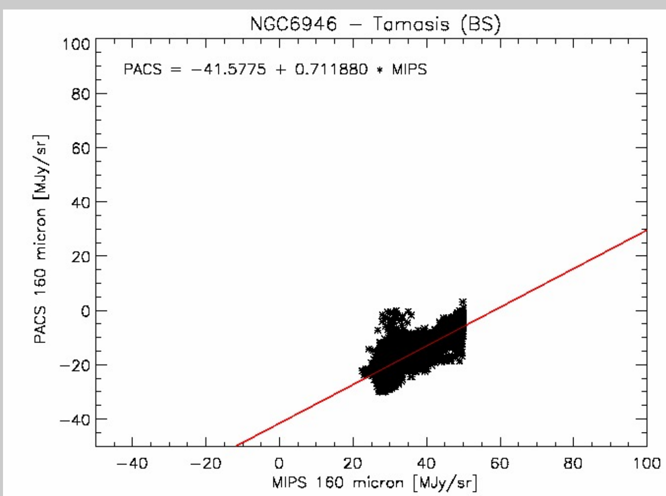


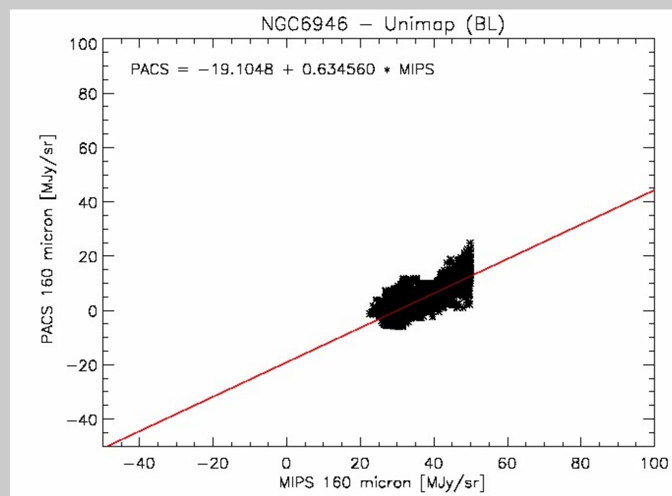


NGC6946 – 160 micron/linear

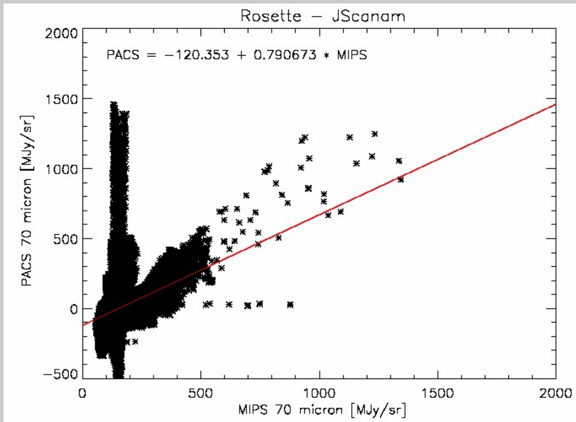


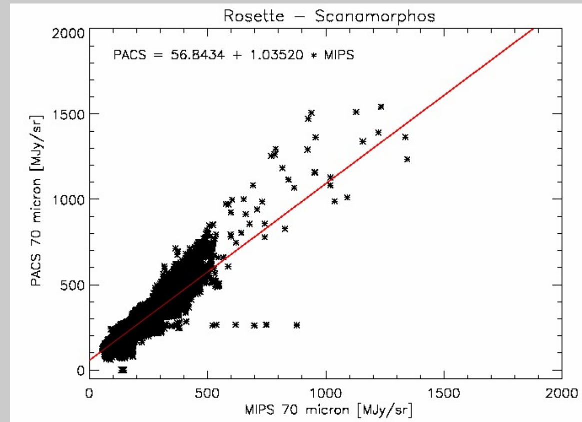


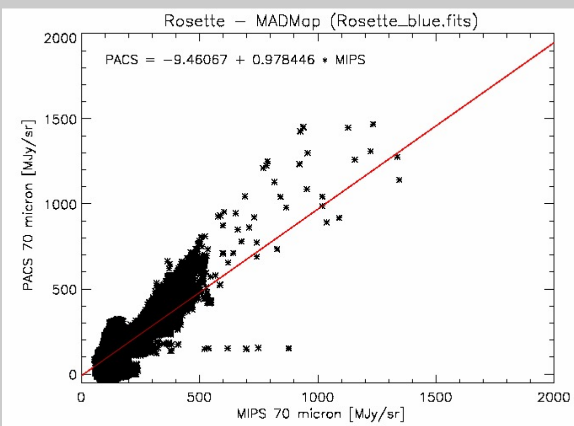


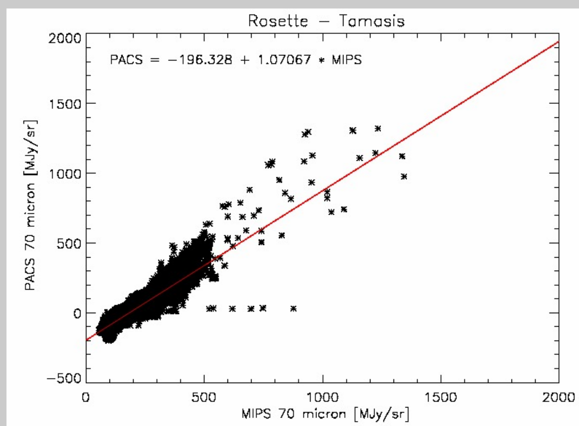


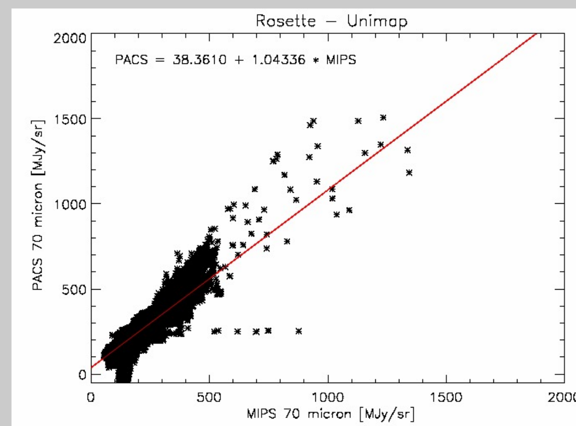
Rosette – 70 micron



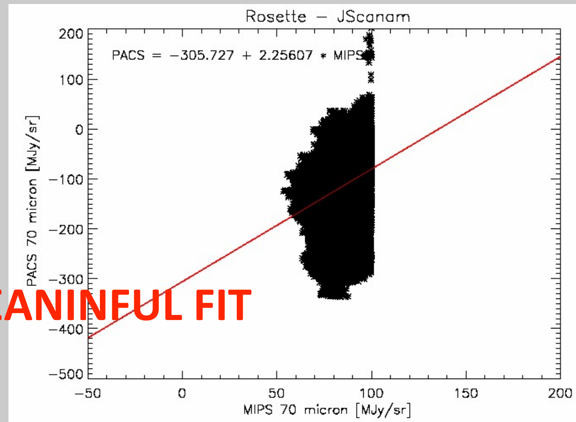




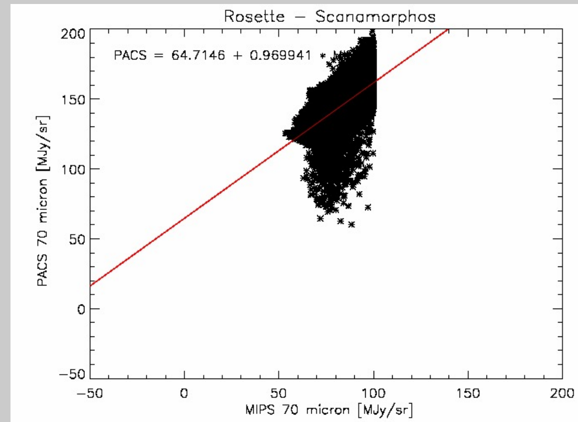


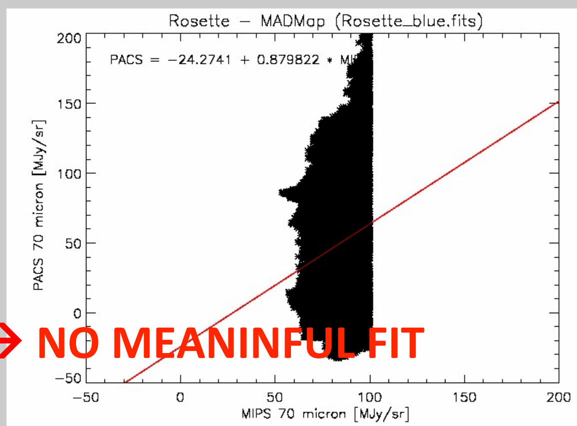


Rosette – 70 micron/linear

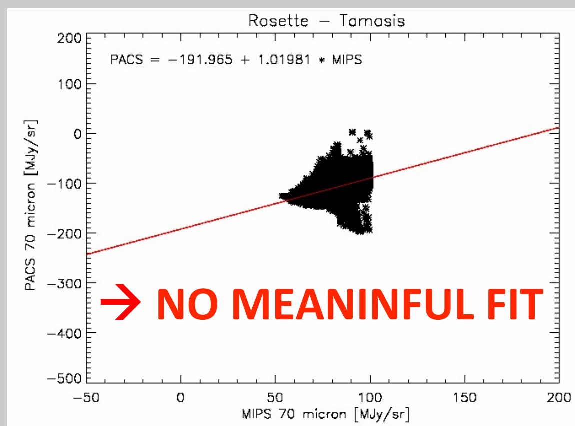


→ NO MEANINFUL FIT

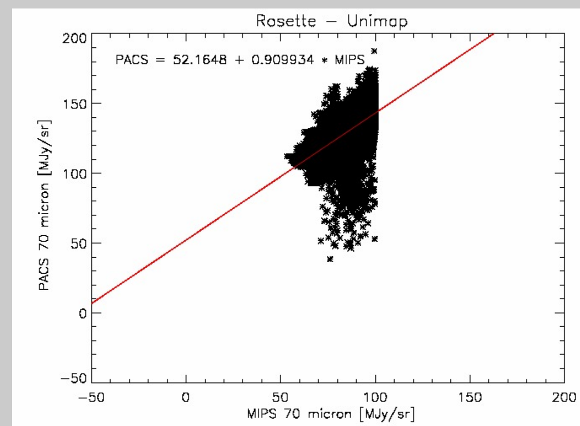




→ NO MEANINFUL FIT



→ NO MEANINFUL FIT



Summary: offsets$_{70}$ (linear)

	Jscanam	Scanamorphos	MADMap	Tamasis	Unimap
Antennae	-22.35	-20.07	-18.70	-37.41	-19.29
Crab	-30.63	-28.86	-24.51	-48.30	-29.08
IC348	-----	-6.18	+67.77	-249.23	-68.88
LDN1780	+36.45	+34.11	+53.24	+5.46	+33.03
M31	-14.51	-15.28	+ 3.51	-10.05	-15.00
M81	-15.57	-13.73	-9.90	-33.99	-15.27
NGC6946	-----	-19.19	-19.05	-39.54	-15.53
Rosette	-305.73	+64.71	-24.27	-191.96	+52.16

Summary: gains_{70} (linear)

	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

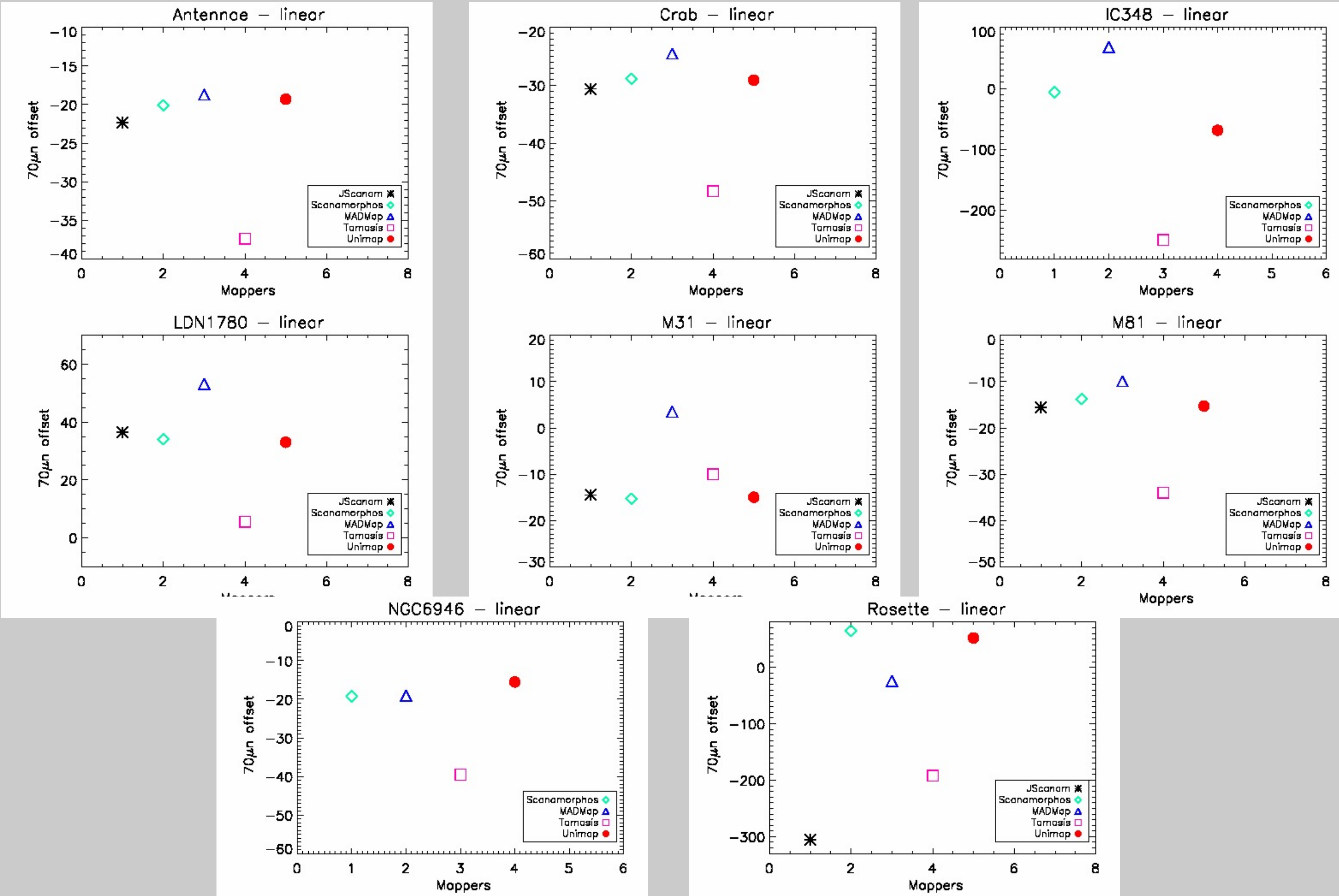
Summary: offsets$_{160}$ (linear)

	JScanam	Scanamorphos	MADMap	Tamasis	Unimap
Antennae	+19.82	-15.70	-11.47	-28.70	-14.42
LDN1780	-17.79	-19.96	+23.28	-30.80	-17.37
M31	-11.57	-16.24	-13.77	-38.96	-17.75
M81	-13.05	-16.76	+2.60	-16.86	-16.30
NGC6946	-------	-20.17	-22.52	-41.74	-19.10

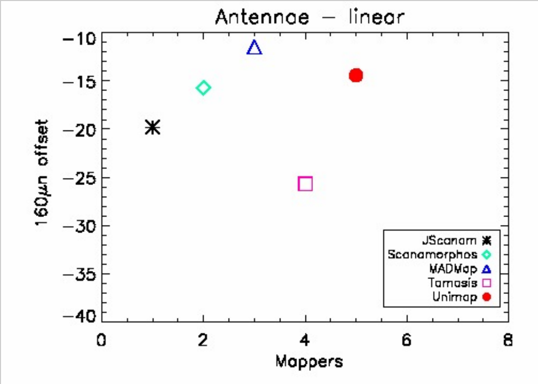
Summary: gains_{160} (linear)

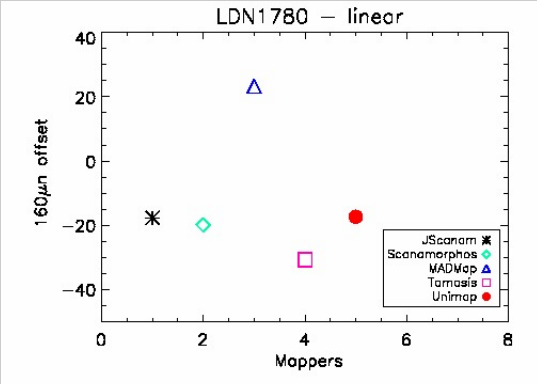
	JScanam	Scanamorphos	MADMap	Tamasis	Unimap
Antennae	0.68	0.79	0.78	0.73	0.81
LDN1780	0.77	0.87	-0.07	0.76	0.76
M31	0.92	1.03	0.94	0.89	0.88
M81	1.07	1.13	1.13	1,04	1.11
NGC6946	------	0.63	0.75	0.71	0.63

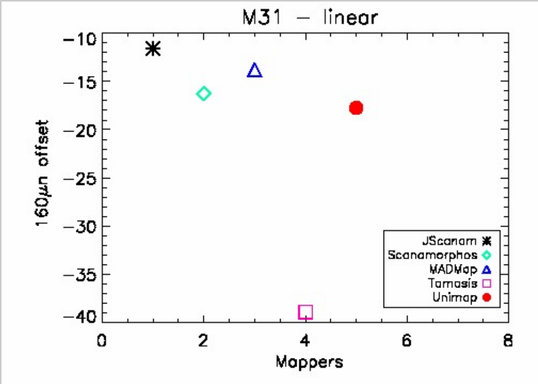
Offsets I - 70 micron/linear

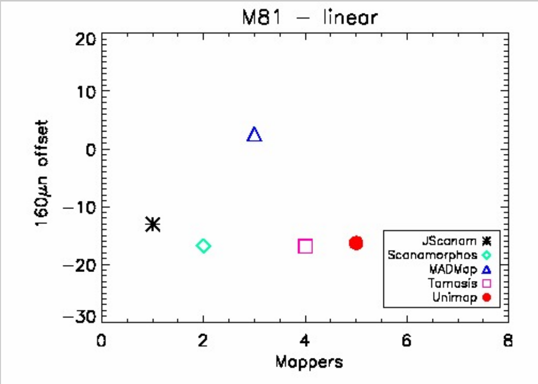


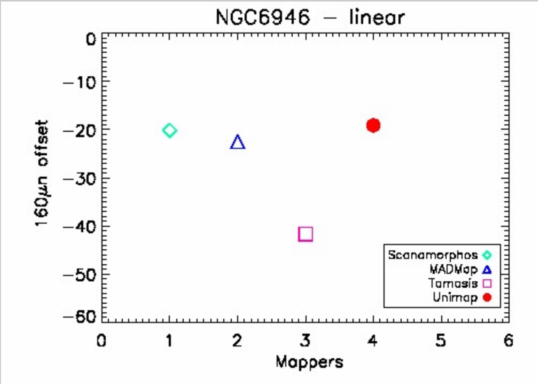
Offsets I - 160 micron/linear



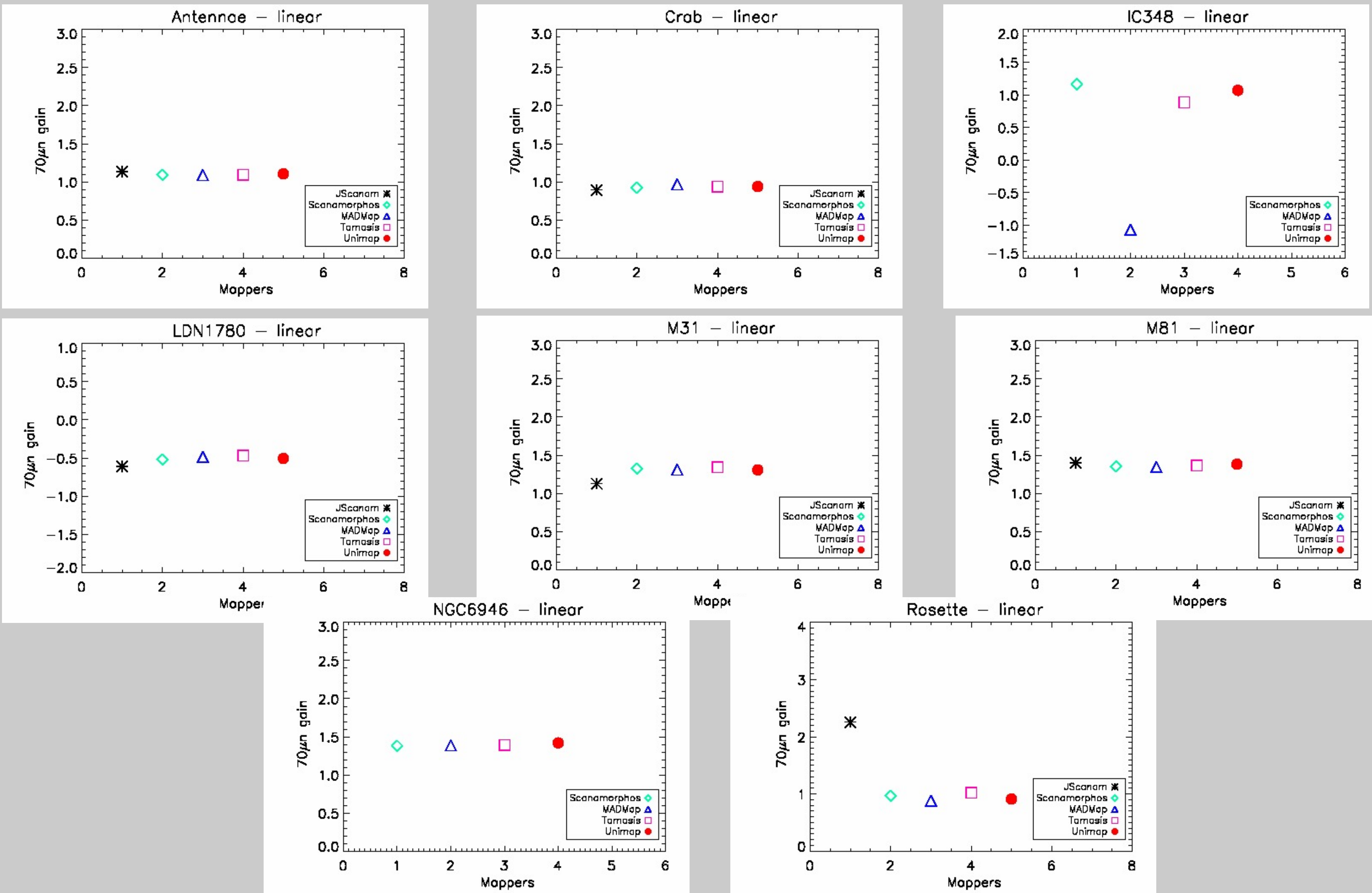




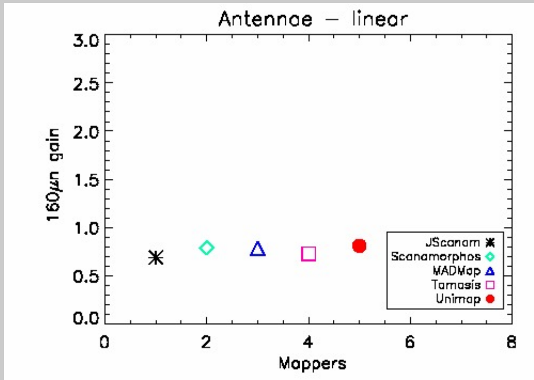


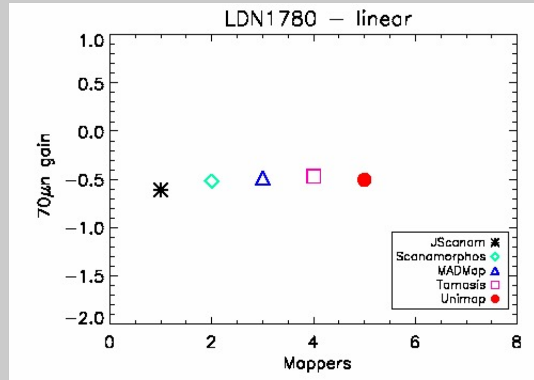


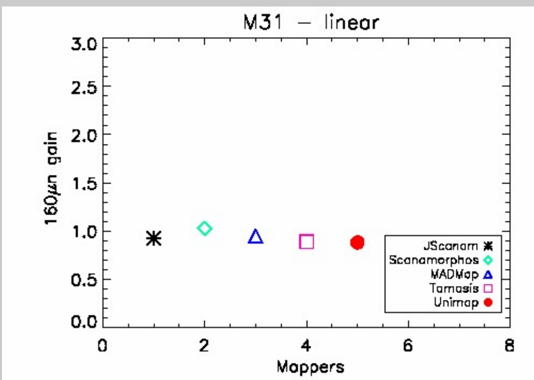
Gains I - 70 micron/linear

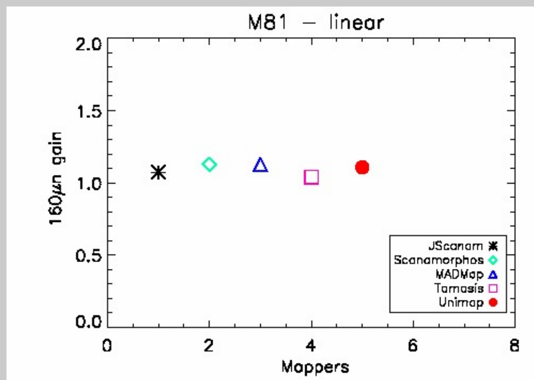


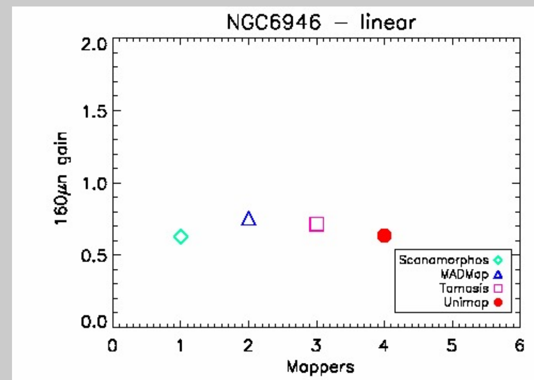
Gains I - 160 micron/linear



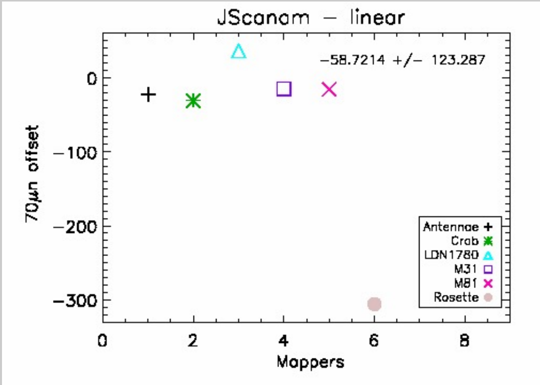


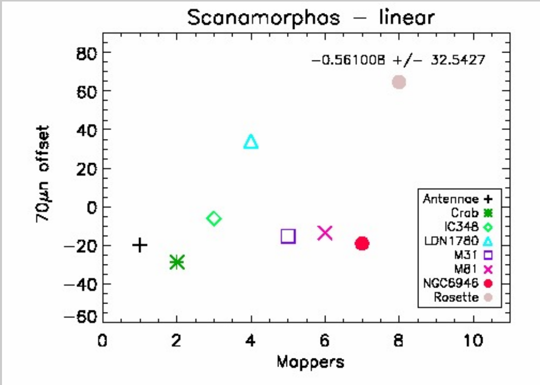


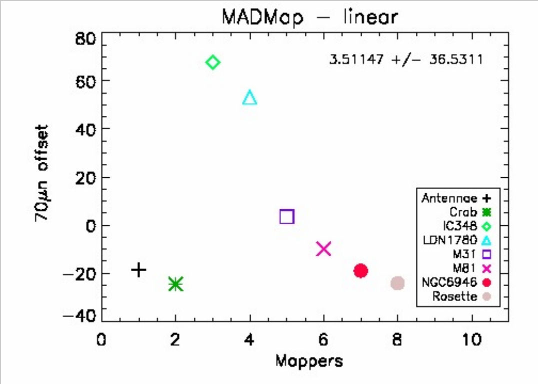


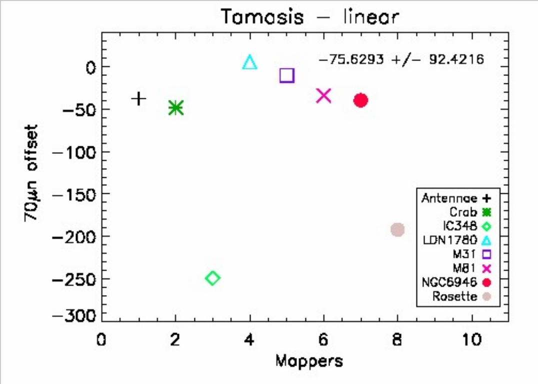


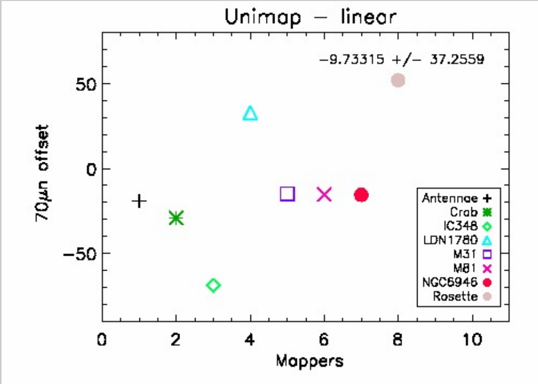
Offsets II - 70 micron/linear



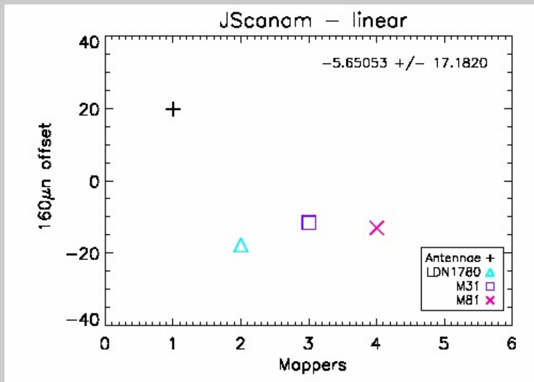


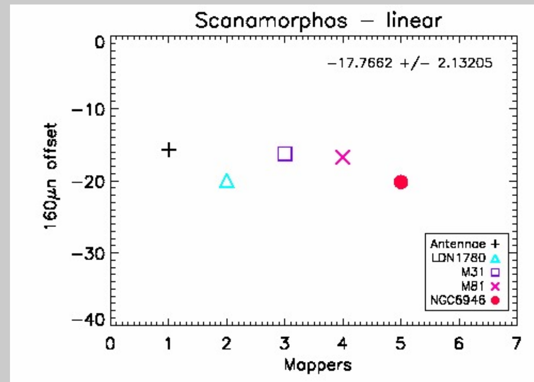


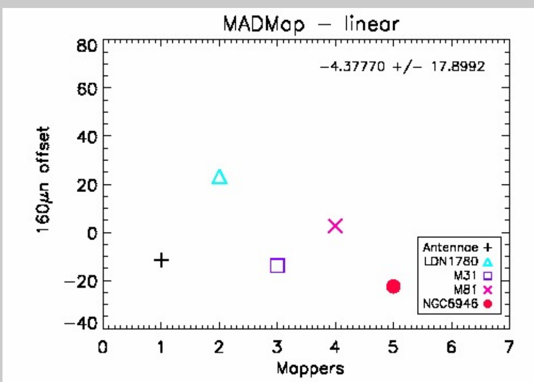


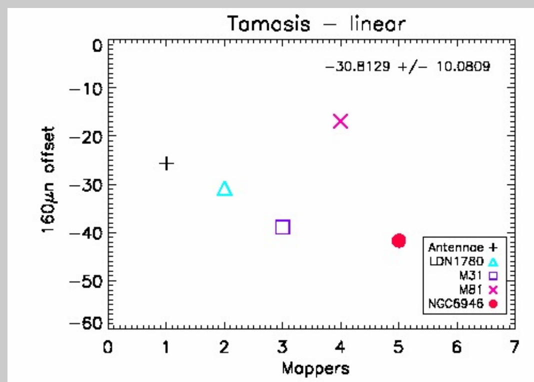


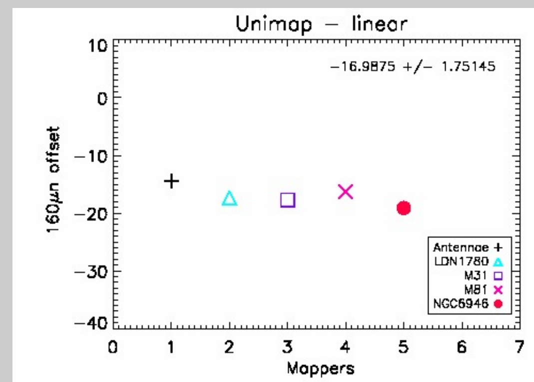
Offsets II - 160 micron/linear



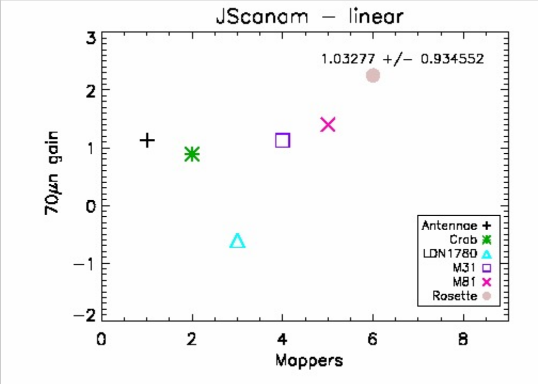


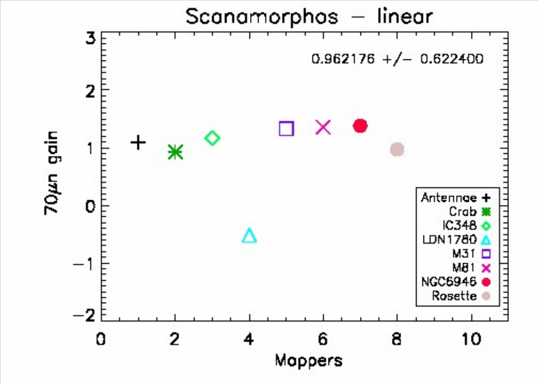


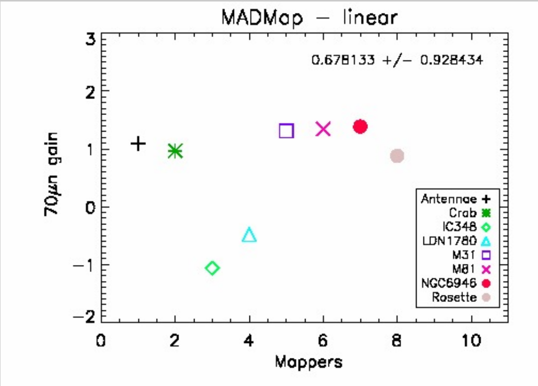


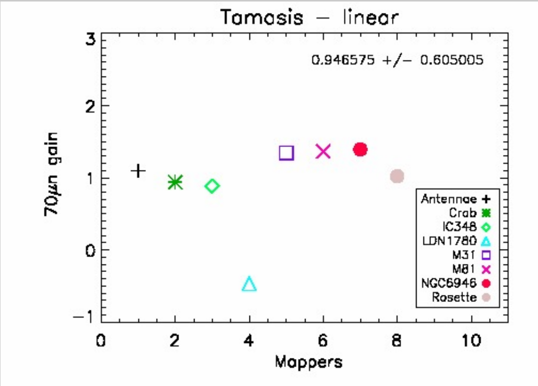


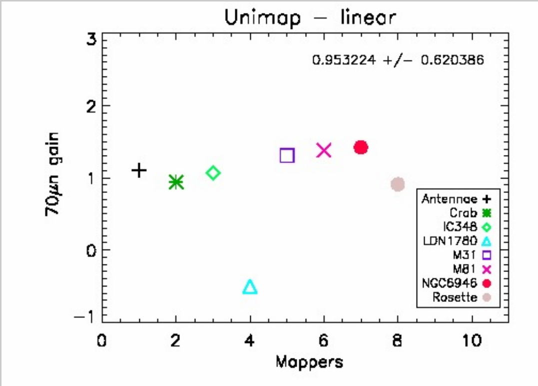
Gains II - 70 micron/linear



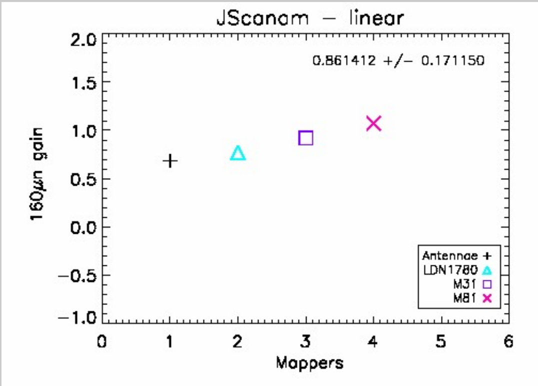


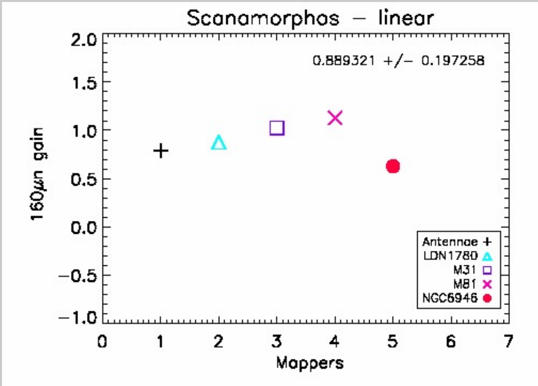


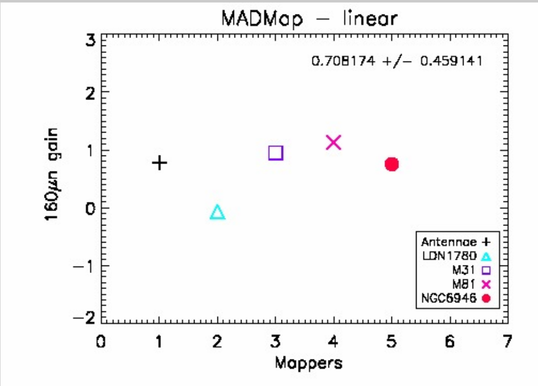


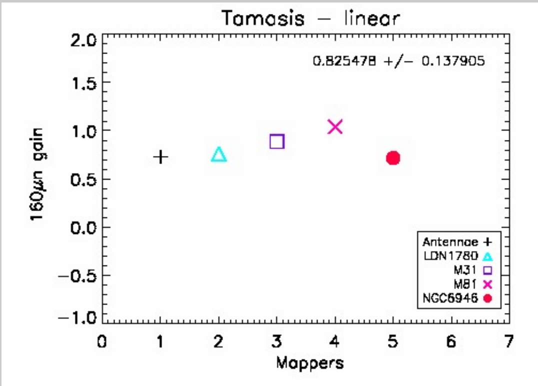


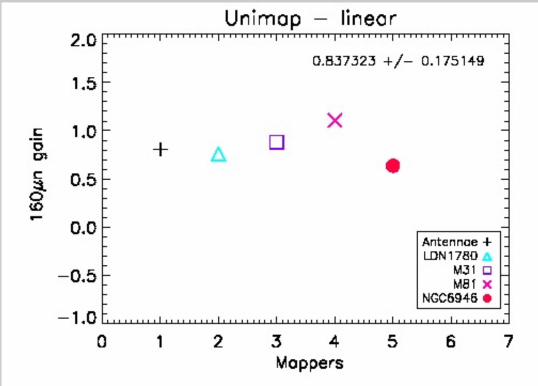
Gains II - 160 micron/linear











Summary

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

- **For each data set, different map-making approaches seem to recover approximately the same offsets**

- **Importantly, one has to consider that – given the amount of uncertainties involved in this comparison (e.g. non-linearity effects, color corrections, beams, etc.) - such a comparison is only <u>indicative</u> of the PACS extended emission calibration**