Applying the MCM super-resolution method to SPIRE scan maps

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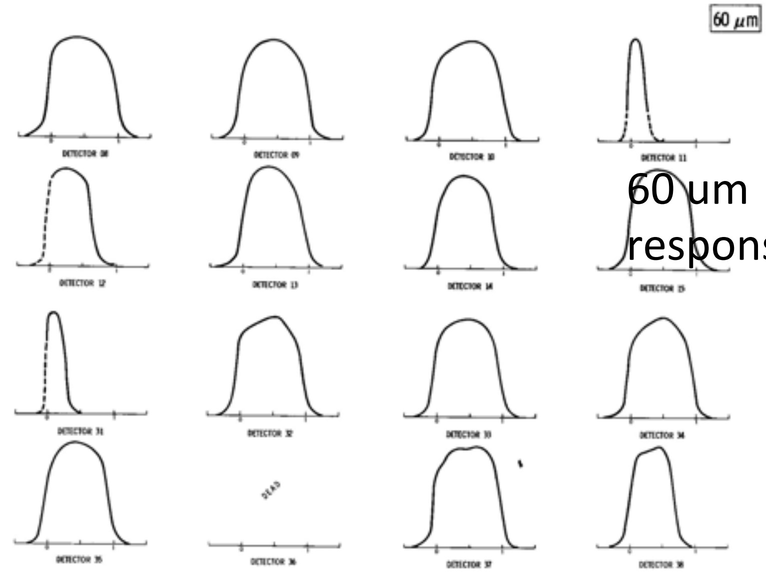
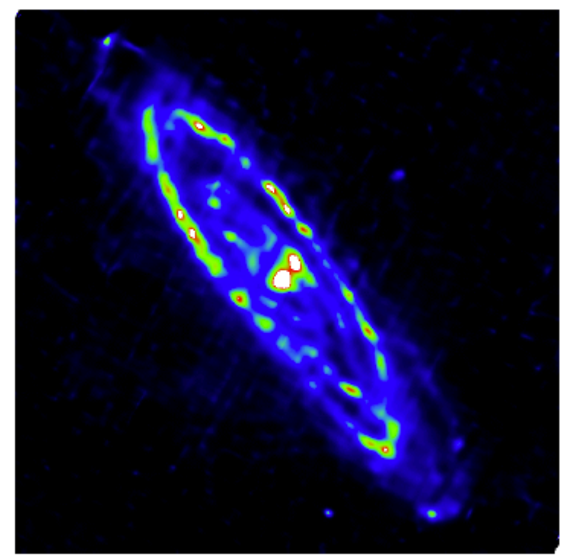
Maximum Correlation Method (MCM) was developed for IRAS

Aumann, Fowler & Melnyk 1990



60 um responses

Handles wildly-varying beam profiles, overlapping data, noise estimates.



M31 at 100 microns (J. Fowler)

Hi-Res/MCM for SPIRE

- The MCM/HiRes algorithm
- Software Implementations
- Inputs and Outputs
- Tips and Caveats

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The MCM algorithm follows these five steps

1. The model: begin with a flat image (default) or an image prior
2. Use detector PRFs to observe the model inputs (e.g. predict the inputs)
3. For each detector sample *i* contributing to pixel *j*, compute the ratio of measurement to model flux as the correction factor
4. Average all the correction factors for pixel *j*
5. Multiply model image pixels by average correction factor to make new model

Iterating the MCM method

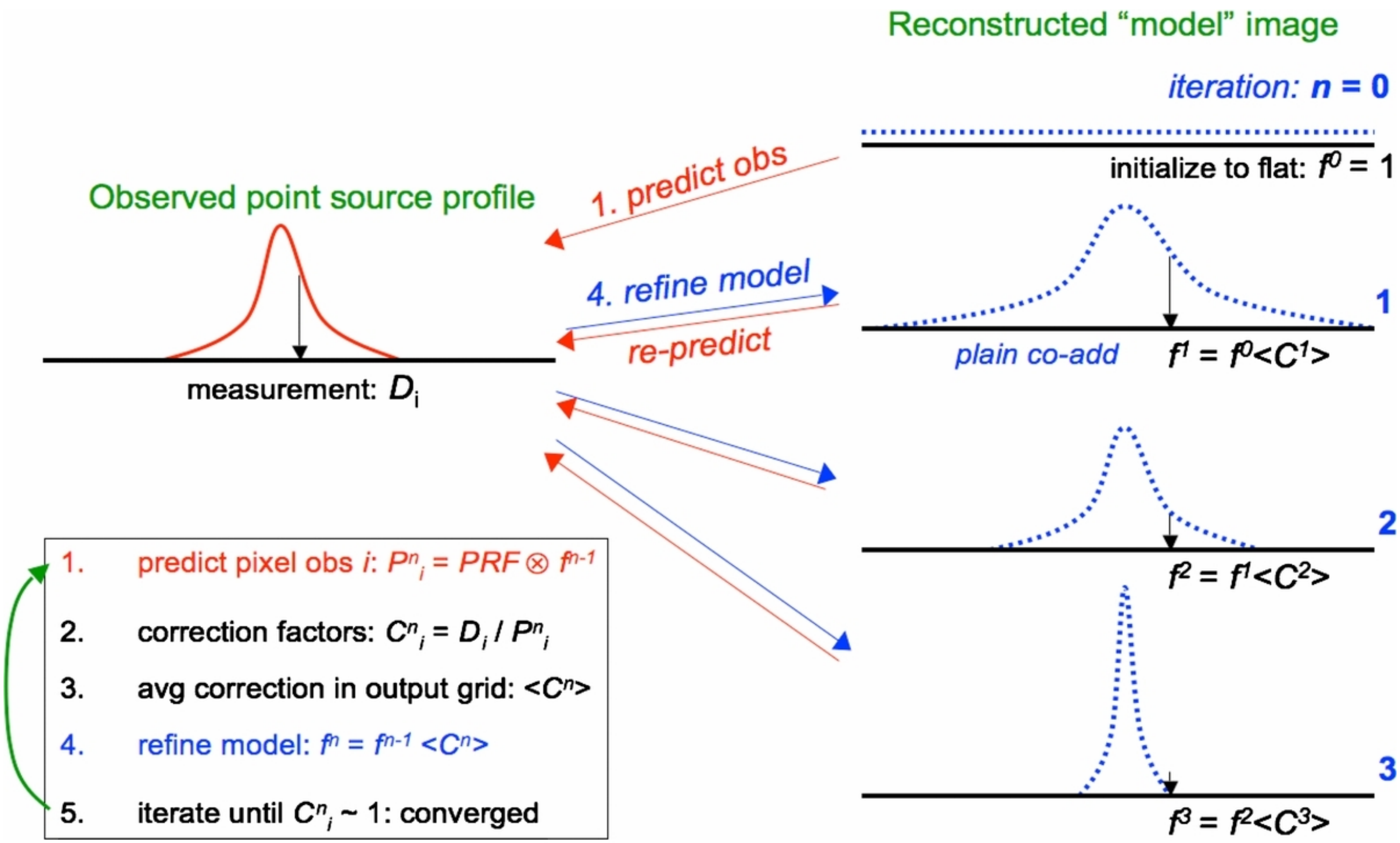


Figure 2 from Constructing a WISE High Resolution Galaxy Atlas
T. H. Jarrett et al. 2012 The Astronomical Journal 144 68 doi:10.1088/0004-6256/144/2/68

Hi-Res/MCM for SPIRE

- The MCM/HiRes algorithm
- Software Implementations
  - Python-Hires for maps from SPIRE timelines
  - ICORE for deconvolving SPIRE maps
- Inputs and Outputs
- Tips and Caveats

Hi-Res: IRAS-based implementation

- Works on the timestreams (Level 1)
  - Based on Fortran implementation for IRAS
    - IRAS HiRes is still a supported service
    - Re-implemented in C-based Python (Bob Narron) for other projects (Planck, SPIRE)
  - Fast input of millions of samples for SPIRE
  - 20 iterations take ~4 hr for 1 deg^2 field
  - Planned to release the code following Caltech procedures
- SPIRE ICC is investigating a HIPE implementation for EDP 10

ICORE: Image Coaddition with Optional Resolution Enhancement

- MCM capability is included in the WISE coadder
  - Chief developer: Frank Masci, IPAC
  - Application to WISE imaging of nearby galaxies in Jarrett et al., 2012, AJ, 144, 68 and Jarrett et al. 2013 AJ, 145, 6
- Operates on images
  - Single image, or overlapping ones to be coadded
  - Can specify a varying PRF but WISE uses a single one
- Released on 12 January
  - Distributed as C source code
  - Multithreading capability (20 minutes for 1 deg^2 map)
  - http://web.ipac.caltech.edu/staff/fmasci/home/icore.html
  - Manual posted there, and as arXiv:1301.2718

Example of application to WISE data

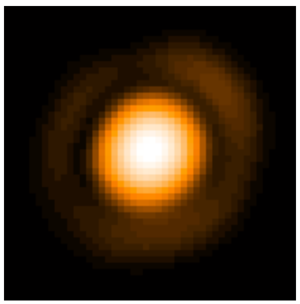
Figure 1 from Constructing a WISE High Resolution Galaxy Atlas
T. H. Jarrett et al. 2012 The Astronomical Journal 144 68 doi:10.1088/0004-6256/144/2/68

WISE composite compared to Spitzer composite for NGC 1566

Hi-Res/MCM for SPIRE

- The MCM/HiRes algorithm
- Software Implementations
- Inputs and Outputs
  - Input data and beam profiles
  - Correction-factor-variance diagnostic
  - Flux maps (M33 example)
- Tips and Caveats

Python-HiRes inputs include beam profile image(s), and timelines

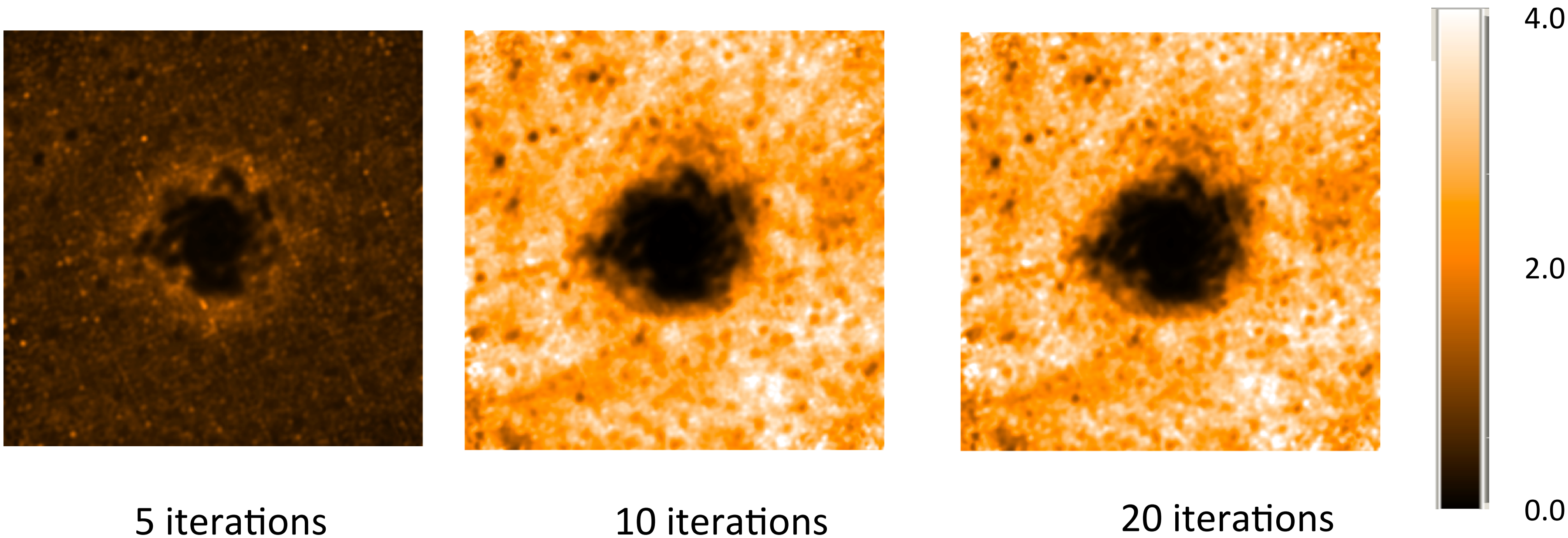


- Beam profiles can be specified for each detector, or an average used for all
  - So far run with average beam profile (1 arcsec/pixel)
- Level 1 timelines
  - Signal, RA, Dec, mask for each sample
  - Position angle of each scan
  - Noise estimates (in implementation)

ICORE inputs include the beam profile, and image and uncertainty

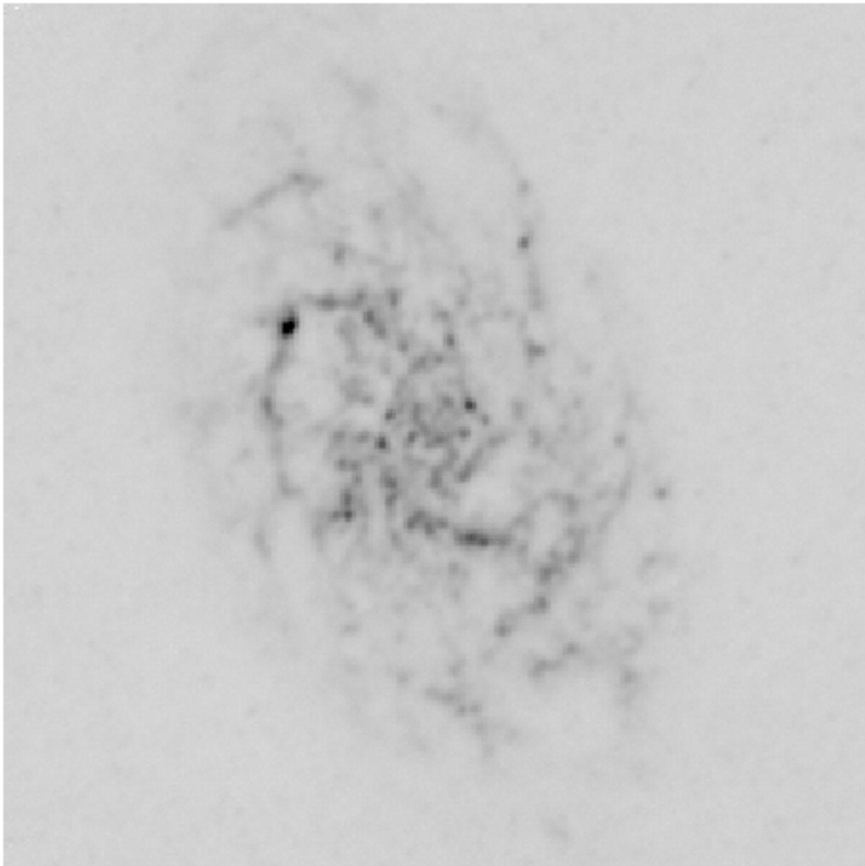
- Provision for variable PSFs
  - So far, run with average beam profile (1 arcsec/pixel)
- For SPIRE, a single image is used as the measurement
- Optionally input an uncertainty map
- A simple SPIRE example is included in the distribution

The correction-factor-variance image shows areas of convergence

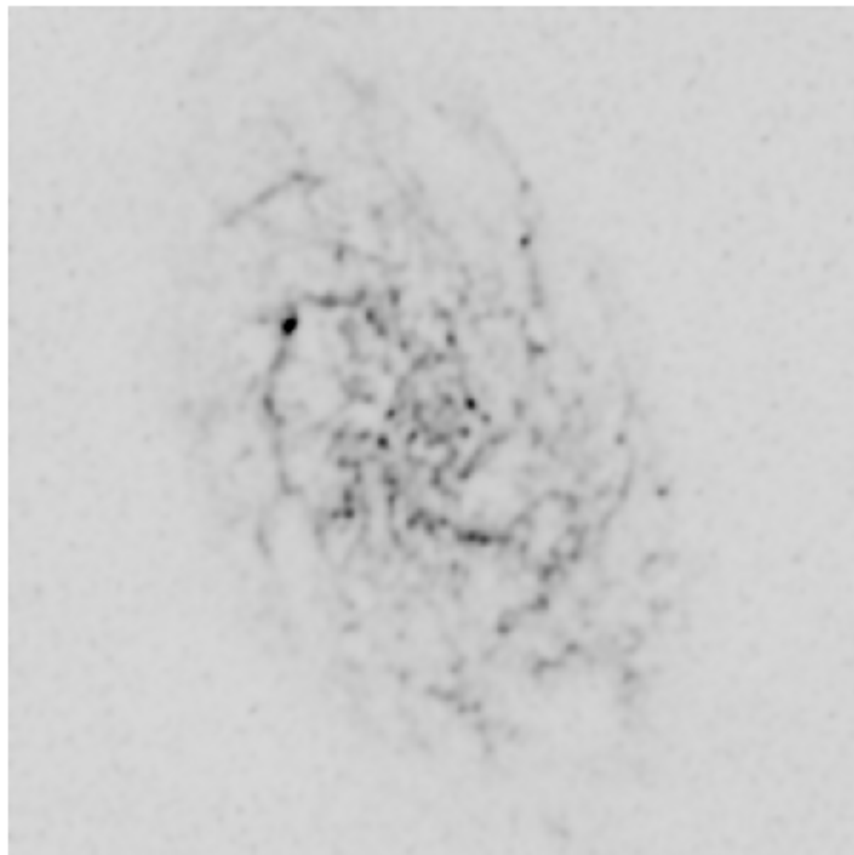


Perfect convergence would be a variance of zero (black).
Large values indicate data that do not agree, e.g. outliers, noise, saturation etc.
Outlier correction factors at a high iteration can be used to mask data.
The CFV image can be thresholded to serve as a mask for photometry.

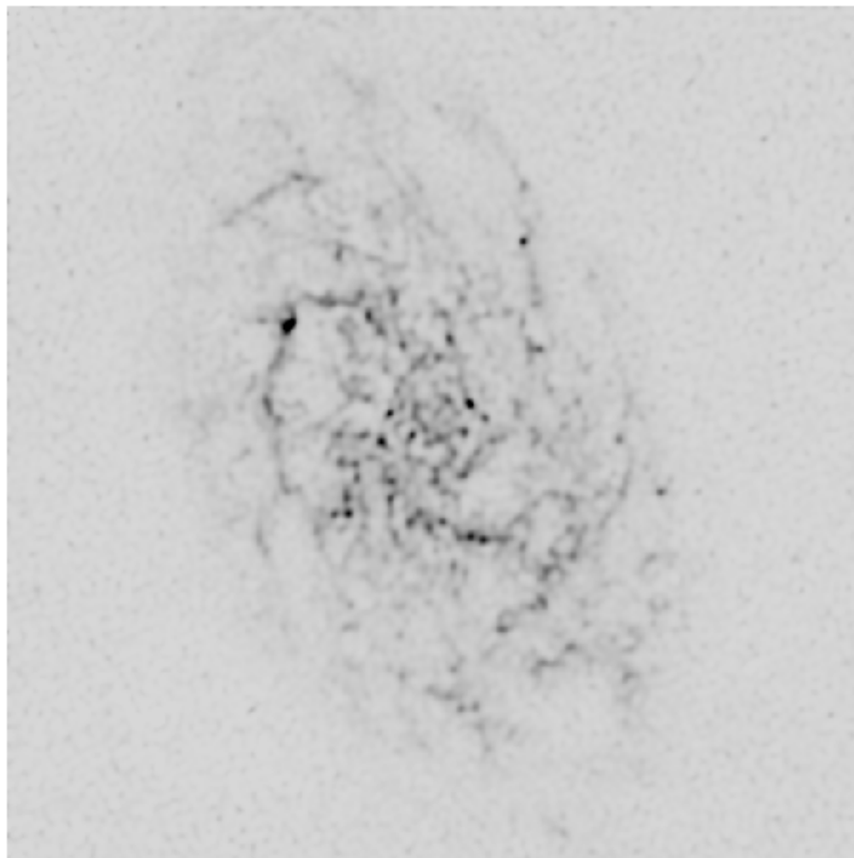
M33 PLW naivemap



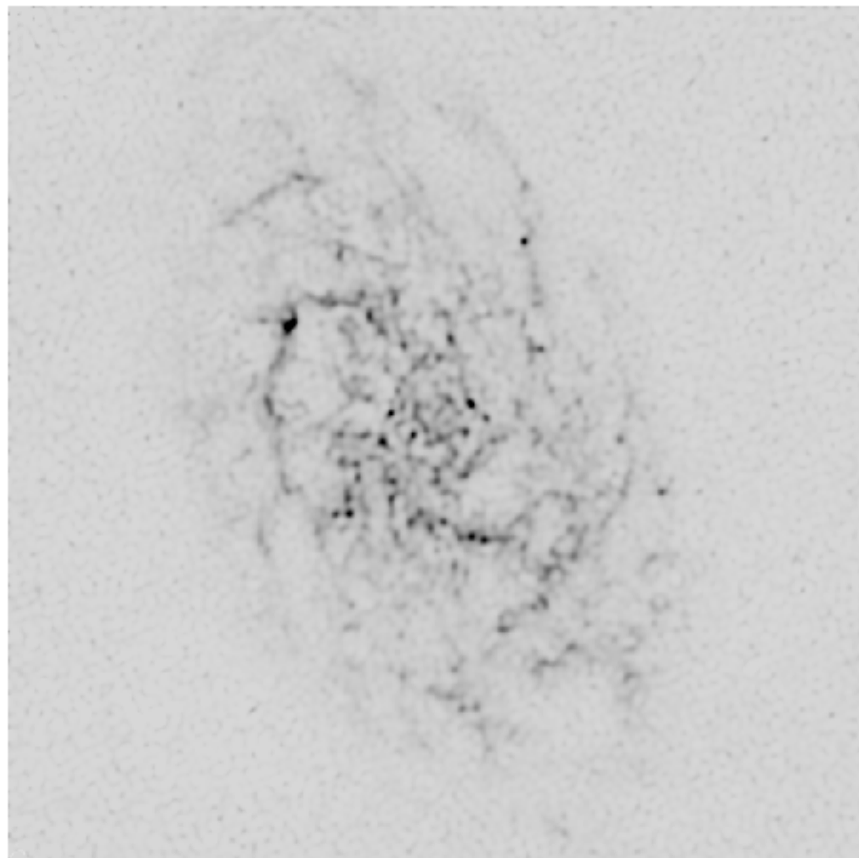
M33 PLW Hi-Res: 5 iterations



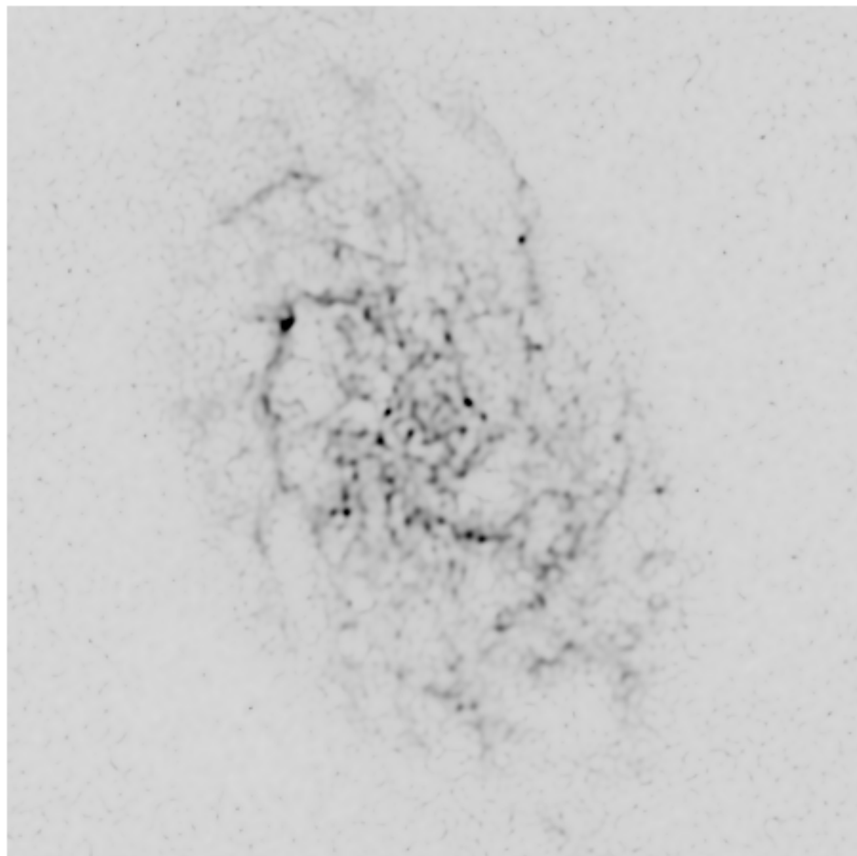
M33 PLW Hi-Res: 20 iterations



M33 PLW Hi-Res: 40 iterations



M33 PLW ICORE processing
(F. Masci)



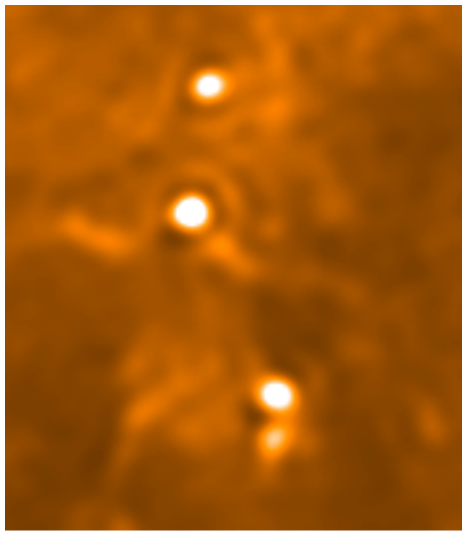
Hi-Res/MCM for SPIRE

- The MCM/HiRes algorithm
- Software Implementations
- Inputs and Outputs
- Tips and Caveats
  - Artifact and baseline removal
  - Handling negative fluxes
  - Ringing suppression

The input data must be free of artifacts and have baselines normalized

- MCM assumes all the measurements are valid
  - (however note that outliers in the correction factors can be excluded)
- For the Level 1 HiRes we use pipeline-deglitched timelines and the destriper

The background should be removed but data values cannot be negative



- A constant background allows point sources to ring
- Negative values are masked to a small value 1.e-15

Ringing suppression and recovery of noise properties is included in ICORE

1. Subtract background
2. Set negative fluxes to zero and add a small value (1.e-20) to all data
3. Run MCM until convergence
4. Add the background
5. Run MCM for a few iterations to debias the noise

Summary

- MCM method can be applied to SPIRE data
  - Similar results for timelines and images as the input (metrics presentation later)
  - ICORE deconvolution is publicly available now, timelines versions on the path to release
- Some open issues and missing features for the Python-Hires (Level 1) version
  - Measurement errors in the weighting and uncertainty output
  - Variations in beam profiles
  - Convergence criteria

Acknowledgments

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- SPIRE ICC