

# Data Processing Status

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# SOFIA Pipeline Products

Defined in the Data Processing Plan for SOFIA SIs :

**Level 1:** raw SI data in standardized format (FITS)

**Level 2:** corrected for instrumental artifacts (e.g. dark current, bad pixels, etc...)

**Level 3:** flux calibrated (using FITS keywords; Jy)

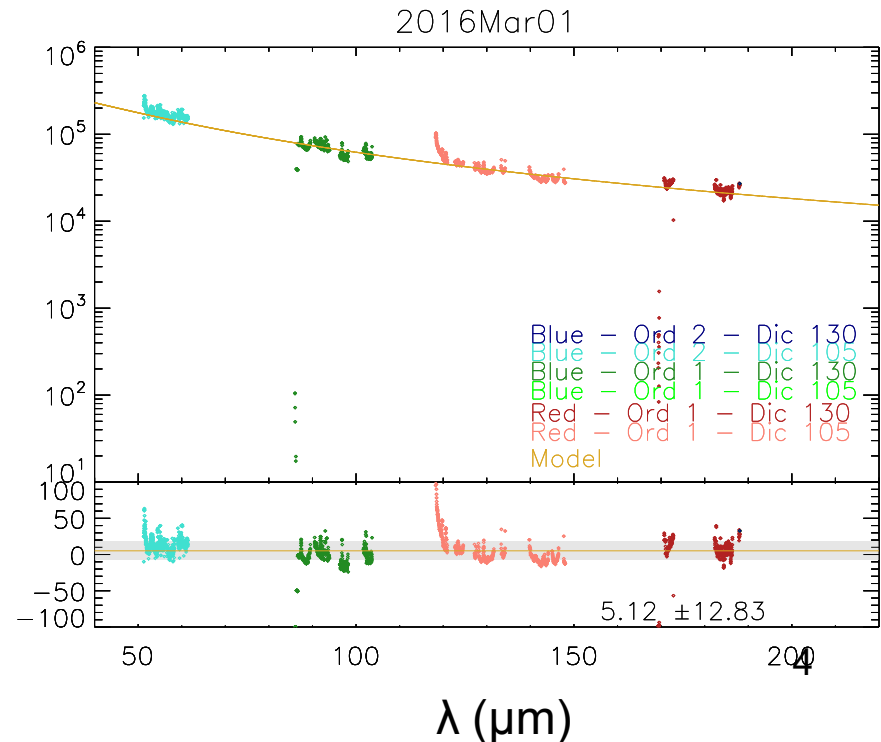
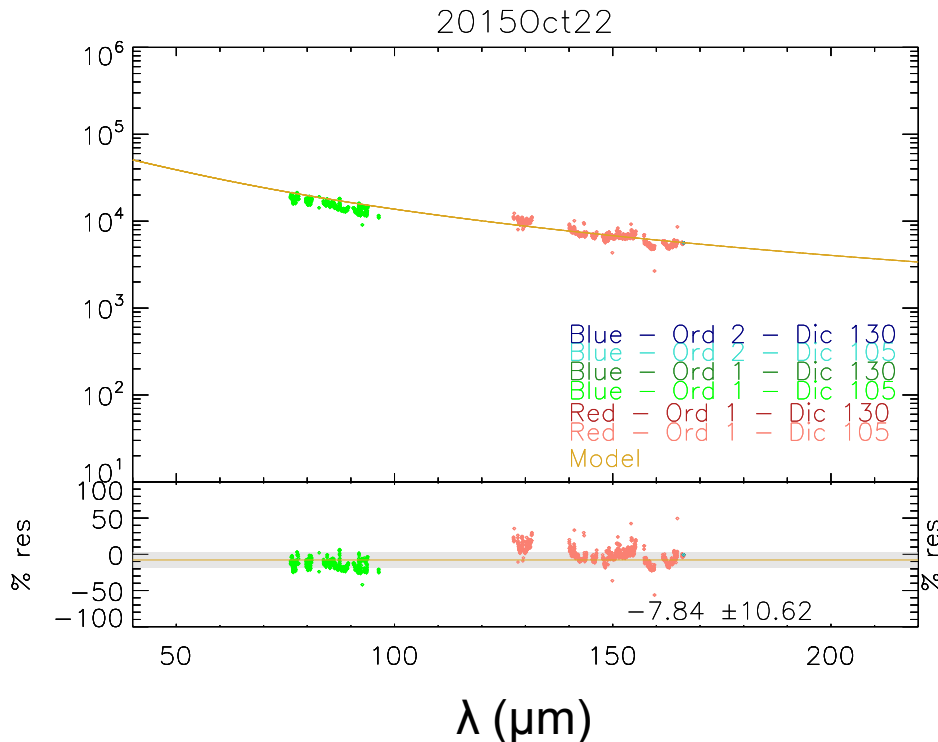
**Level 4:** high-order products possibly combining multiple observations  
(e.g. mosaics, spectral cubes)

# Pipeline Development

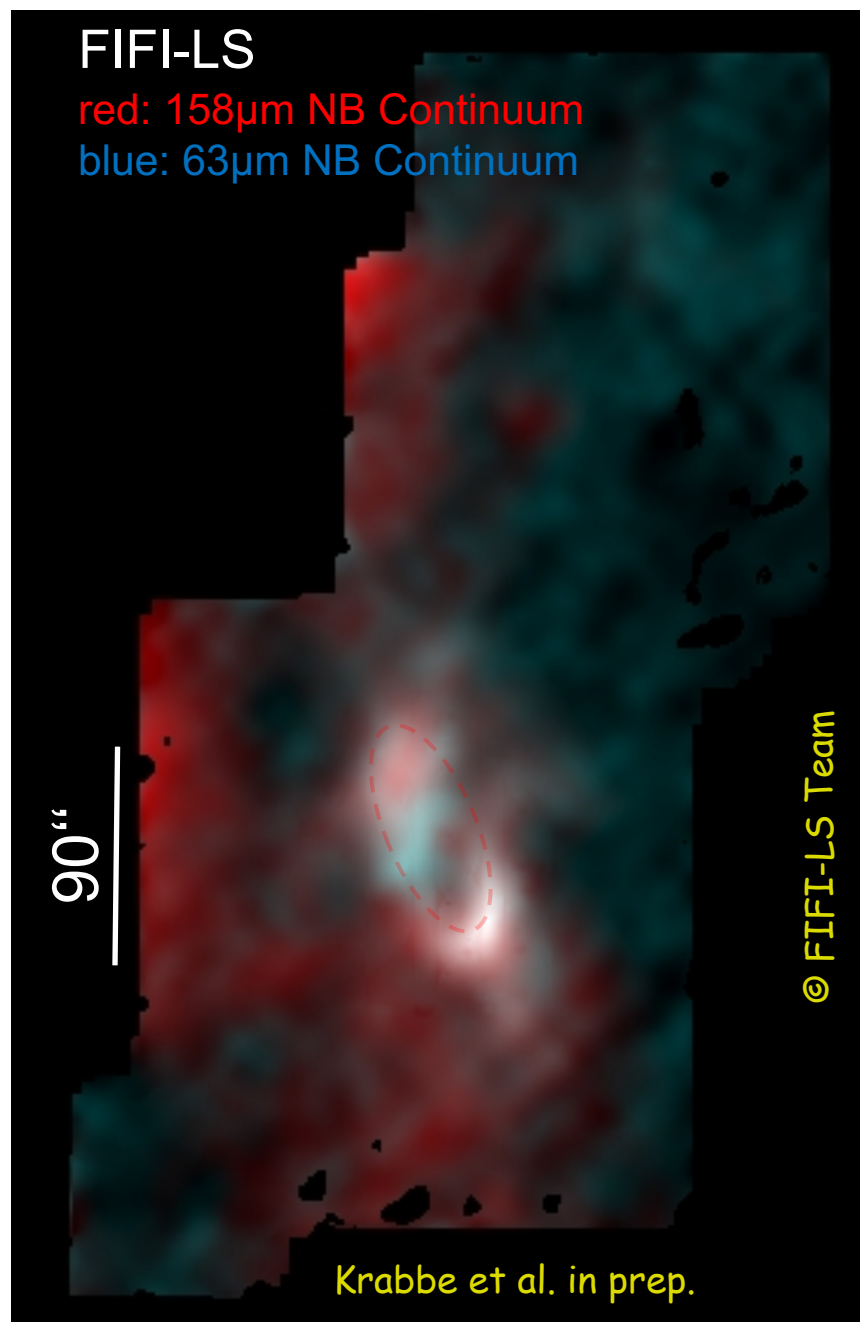
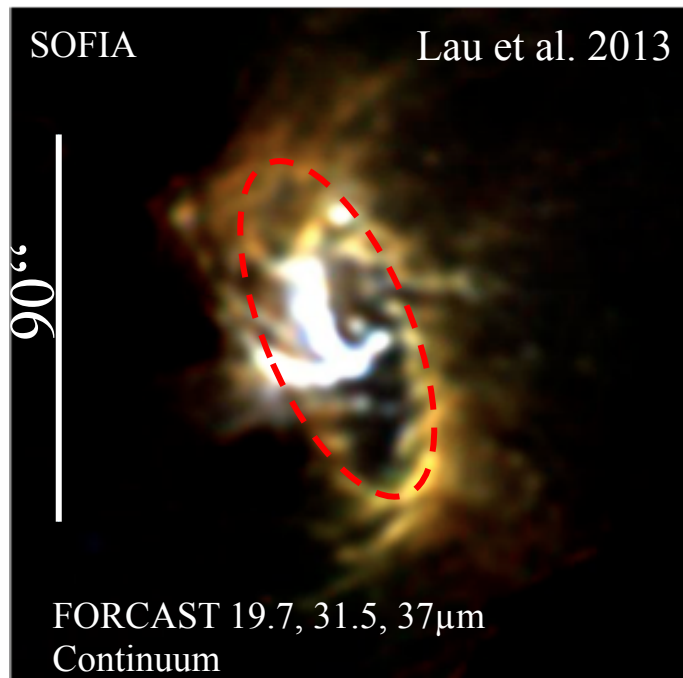
- FLITECAM
  - Incorporated grism telluric correction and flux calibration into pipeline process
- FORCAST
  - Improved G227 and G329 grism response functions, derived from asteroids
  - Developed more accurate method of implementing telluric corrections, and estimate the PWV during observations
  - Minor improvements, including better centroiding, suppression of edge artifacts, better treatment of bad pixels, improved rotation and alignments
- FIFI-LS
  - Implemented support that allows pipeline to be run across multiple missions
  - Implemented parallel processing in several steps to increase speed
  - Incorporated bad pixel masks
  - Incorporated telluric correction step
  - Implemented flux calibration step
  - Provide flux-calibrated, but not telluric-corrected cubes as separate extension
  - Improved the weighting algorithm in the spatial re-sampling step
- HAWC
  - Received beta-version of pipeline and initial drafts of manuals from SI team; tested with on-sky data from commissioning flights
  - Modified pipeline interface (Redux) and infrastructure (pipetools) to accept and process HAWC data

## FIFI-LS Flux Calibration

- Derived from observations of Mars during NZ deployment, which yields responses
- Generally good to better than 20%, but accuracy at any given  $\lambda$  point depends on proximity to atmospheric absorption features
- Fluxes agree with PACS results to better than 10% for M82 and M51
- We are investigating claims of discrepant results
- Pipeline cuts off corrections when nominal transmission < 60%
- Calibrated spectra could be improved with accurate PWV values from WVM



# GC Circumnuclear Disk



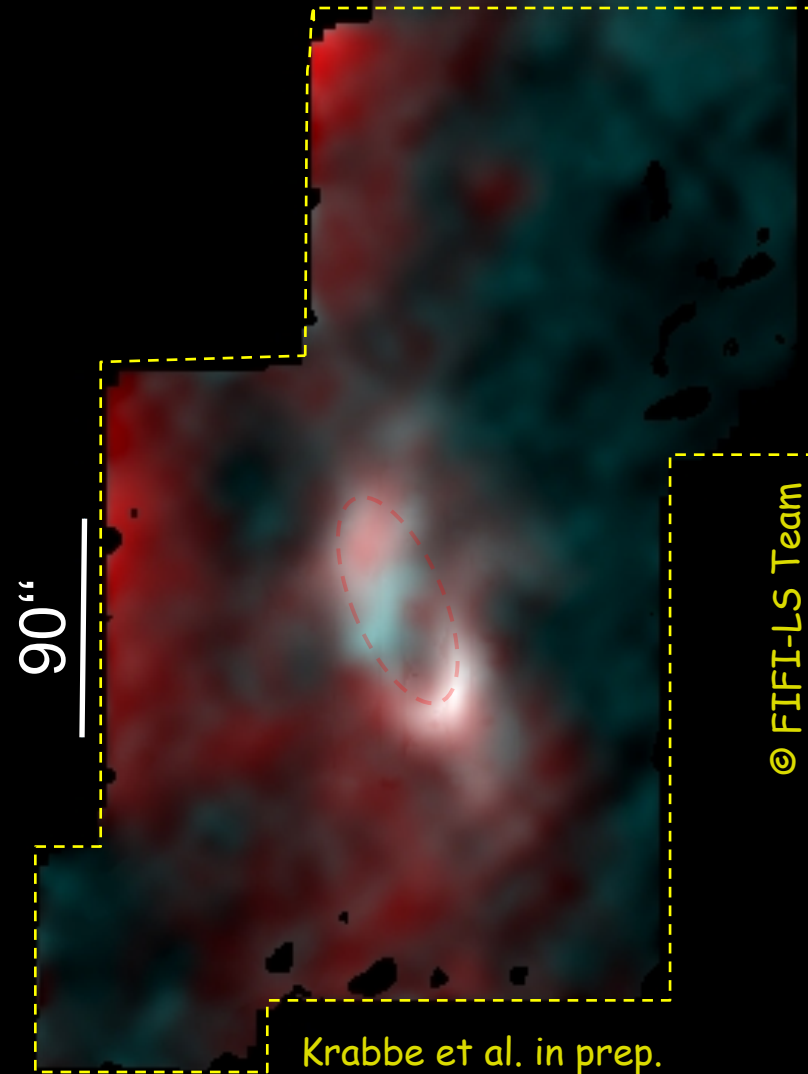
# GC Circumnuclear Disk

PACS **red: 160 $\mu$ m BB Continuum**  
**blue 70 $\mu$ m BB Continuum**

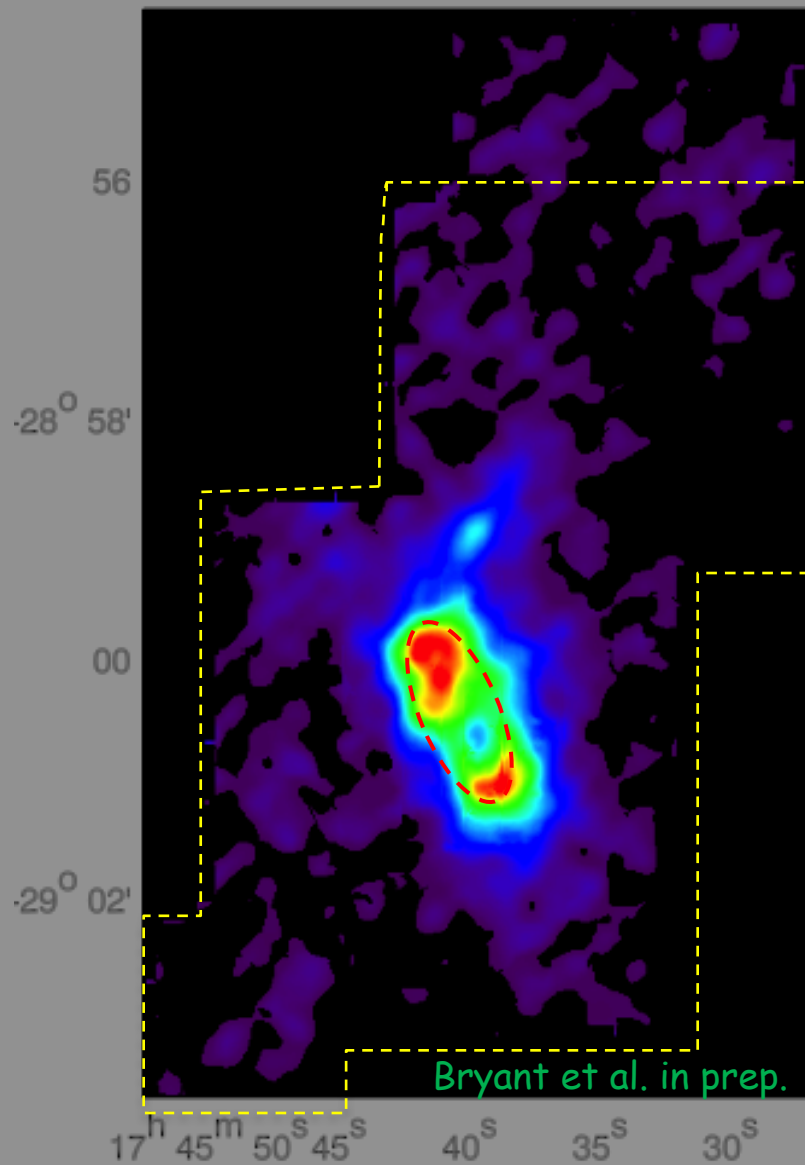


FIFI-LS

**red: 158 $\mu$ m NB Continuum**  
**blue: 63 $\mu$ m NB Continuum**



[OI] 63 $\mu$ m Line Emission

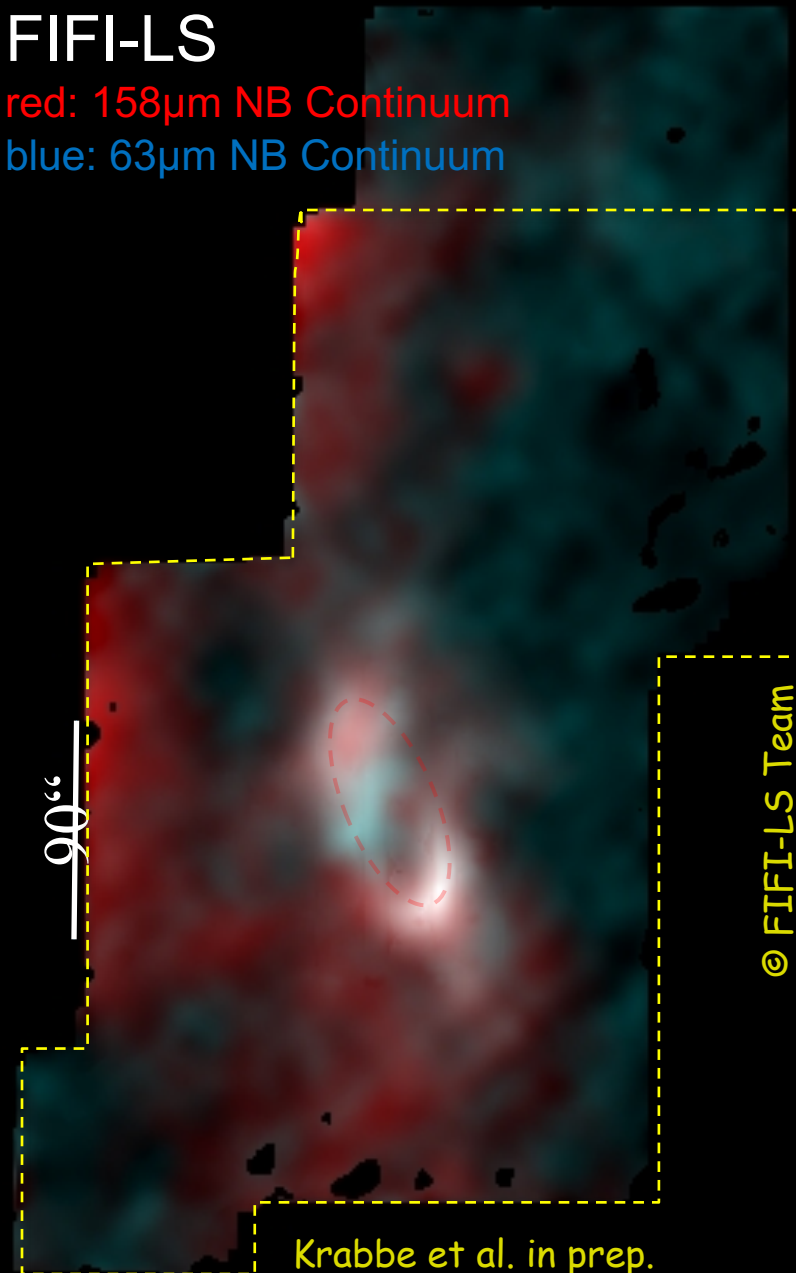


Bryant et al. in prep.

# FIFI-LS

red: 158 $\mu$ m NB Continuum

blue: 63 $\mu$ m NB Continuum

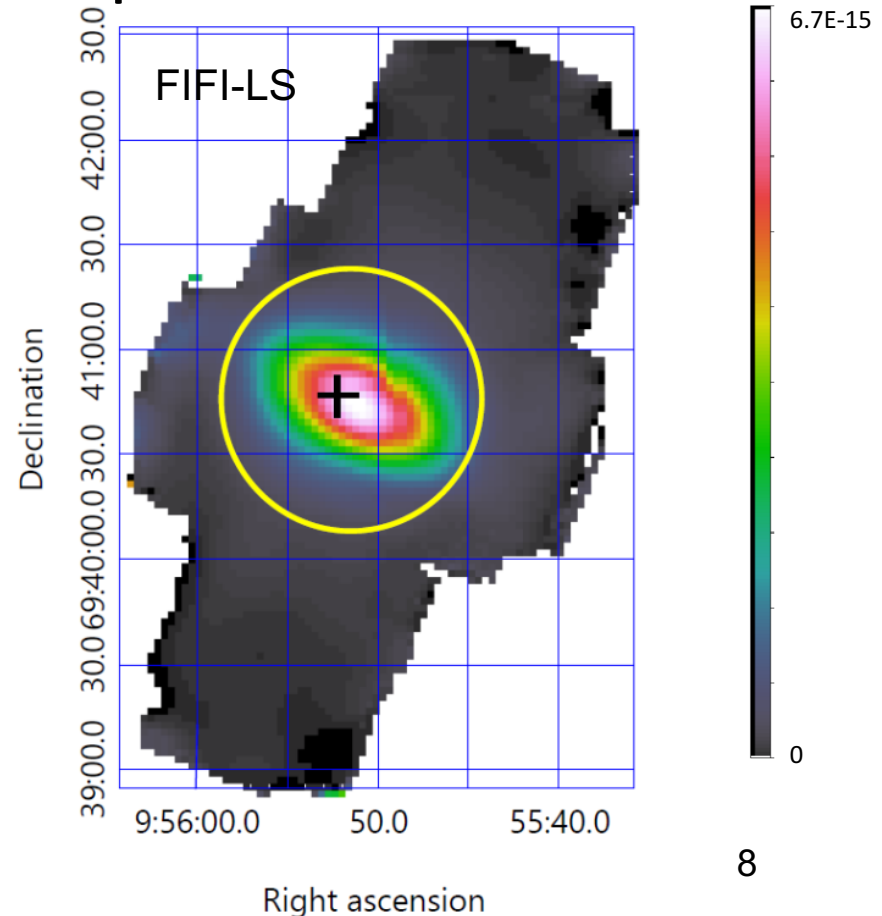
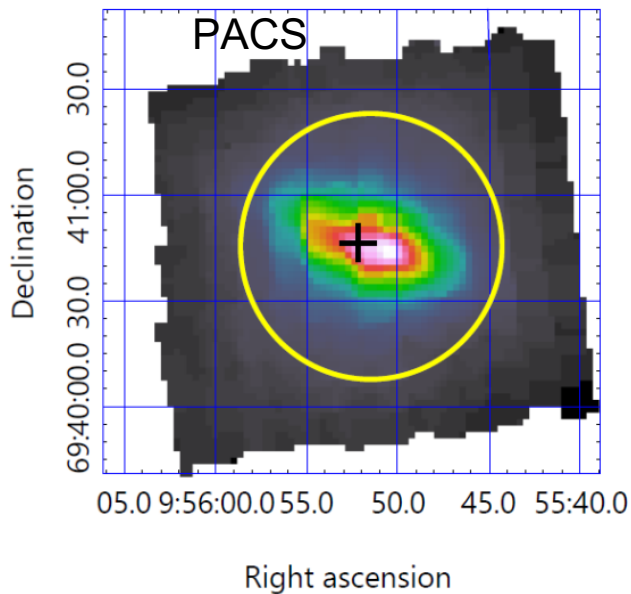


Krabbe et al. in prep.

© FIFI-LS Team

## Comparison of Flux between FIFI-LS and PACS at [CII]

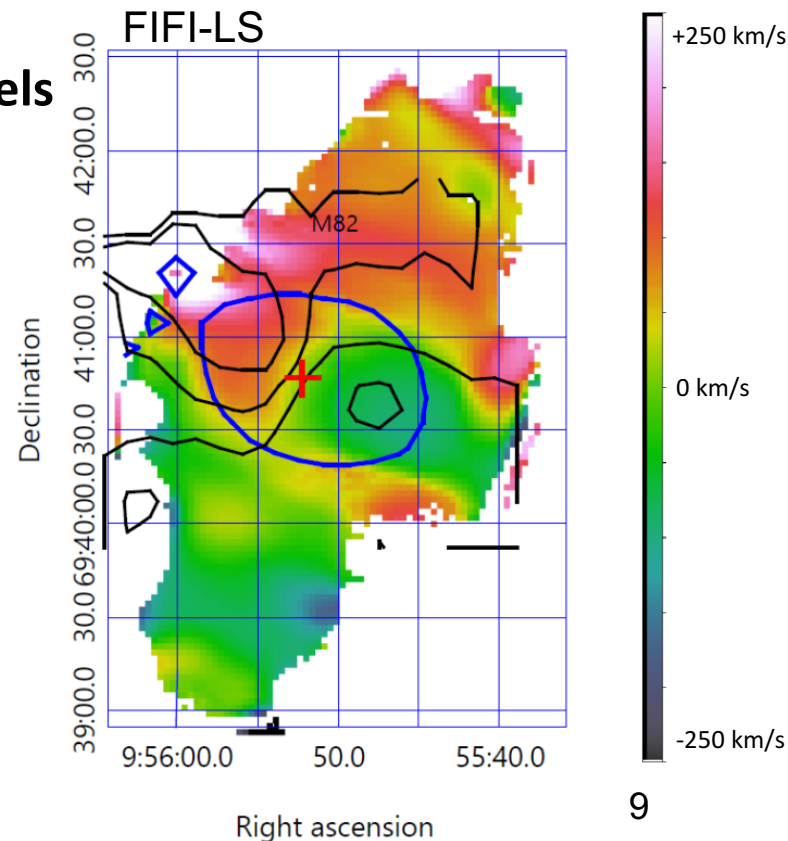
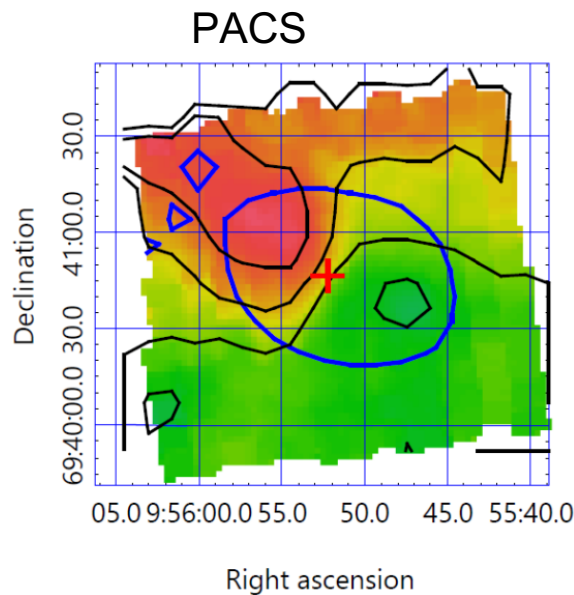
- Fitted line flux of [CII] at 157.741  $\mu\text{m}$
- Black cross marks center of the galaxy
- Maximum flux levels match almost perfectly
- Total fluxes in yellow circle are within 15 %
- Flux is shown in  $\text{W}/\text{m}^2$  per PACS 9.4''x9.4'' spaxel
- General topology matches well





## Comparison of Velocity maps between FIFI-LS and PACS

- Velocity of fitted line relative to [CII] position with  $z = 0.000677$
- Spectral Resolution of FIFI-LS is 270 km/s here
- Black contours are from PACS velocities, cross is center of M82
- Blue contours are 10% maximum line flux FIFI-LS
- General topology matches well (rotation and outflow)
- Very good match above 10% flux level
- Some issues with FIFI-LS, mostly on edges
  - Some homework on errors and bad pixels



# Summary of FIFI-LS Pipeline and Data

- **PIPELINE**

- All reduction steps have been implemented, including telluric correction, flux calibration, spectral and spatial re-sampling onto uniform grids
- Response curves have been derived for both channels and both dichroics from observations of Mars
- Level 4 products (data cube maps with multiple extensions) look very good, in general and agree with PACS data, both in spatial appearance and absolute flux
- Major development work is completed

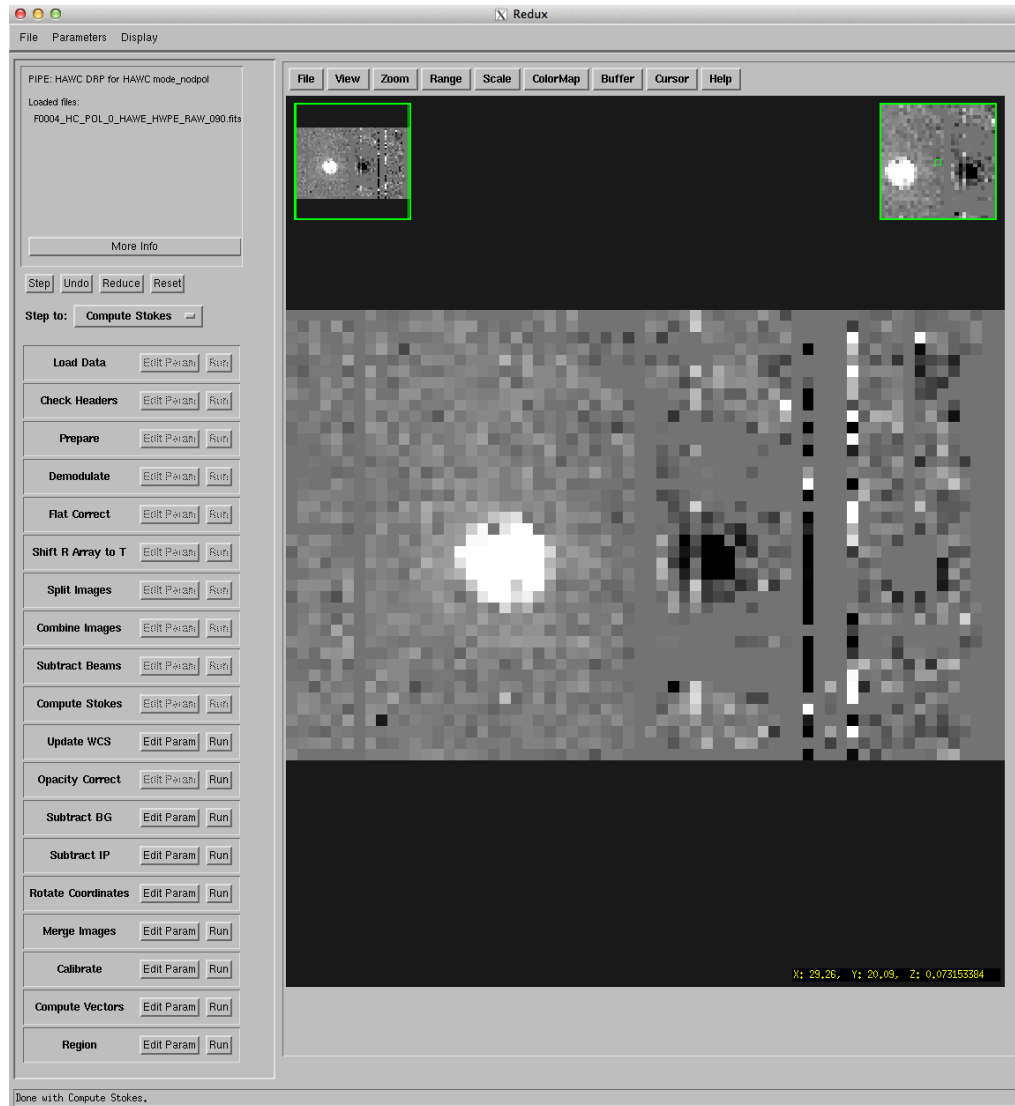
- **DATA**

- Reduced (Level 4) data from individual flights in OC2-F, OC3-B, OC3-K, OC4-B, and OC4-F series
- Generated Level 4 maps for targets observed on multiple missions/series
- Both sets of data have been ingested into the Archive and GIs will be notified
- Limiting factor in accuracy is telluric correction without WVM; currently the pipeline uses a standard atmospheric model, and applies ATRAN correction curves appropriate for the altitude and zenith angle of the observation

## HAWC pipeline status

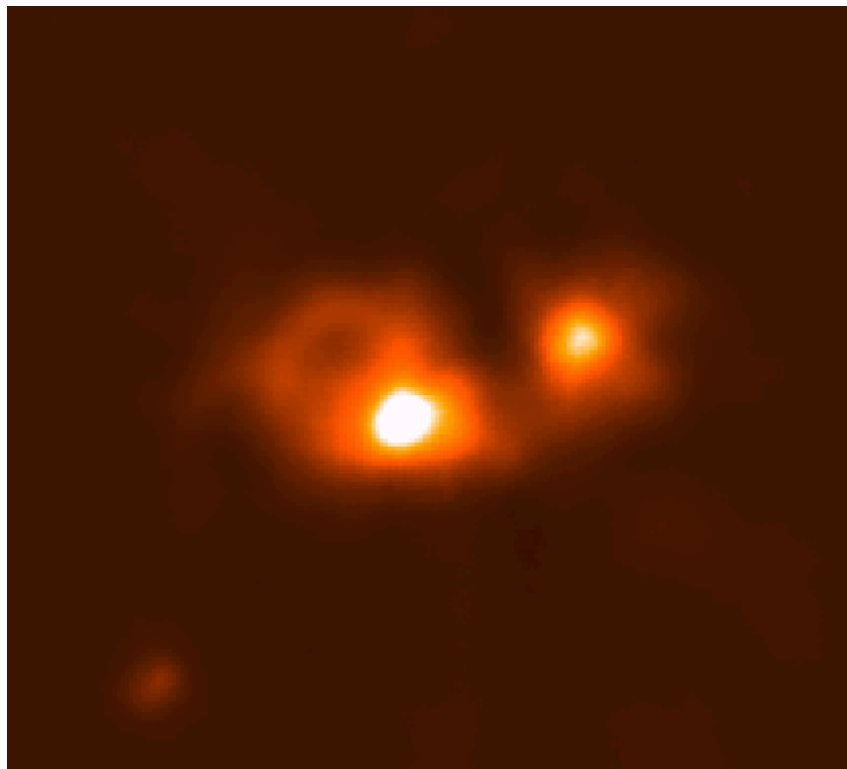
- DPS has received a working version of the HAWC+ pipeline
  - Pipeline developed by HAWC+ team (G. Novak et al.)
  - DPS Team flew on last two HAWC+ commissioning flights
  - Pipeline has been partially integrated into DPS infrastructure and with Redux interface
  - CRUSH software (A. Kovacs) works well for reduction of scanning imaging mode data (polarization mode not supported)
  - Chop-nod mode (primary mode for polarization observations) pipeline gives comparable results
- Next steps:
  - Design review
  - Verification & Validation
  - Finish documentation
  - Full integration into DPS infrastructure
  - Calibration
  - Instrumental polarization characterization

# HAWC pipeline within Redux (M. Clarke)

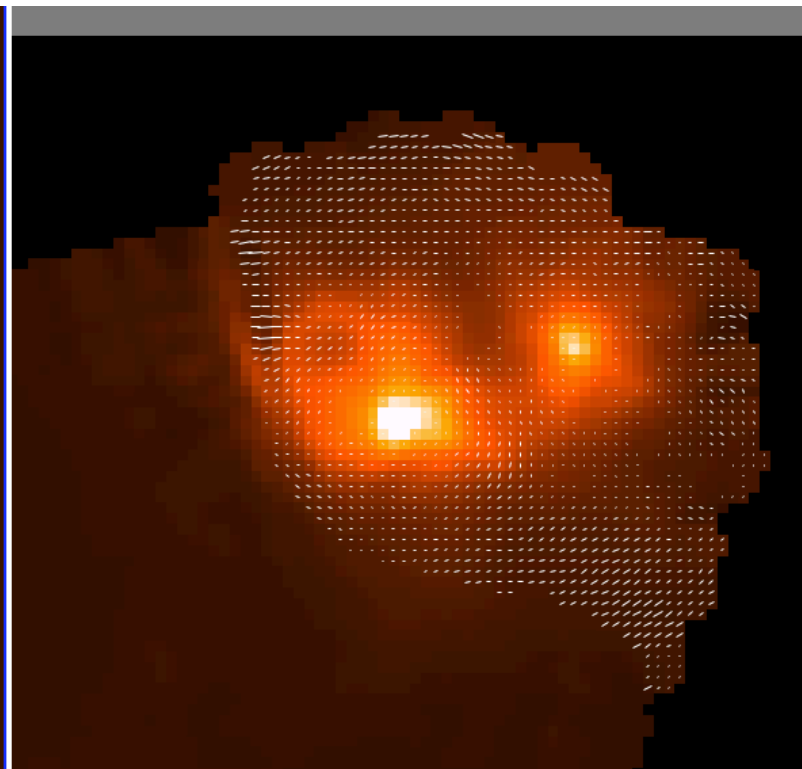


Neptune in Nod/Pol Mode

## HAWC pipeline – W3 (band C: 88 $\mu\text{m}$ )



Scan Mode (CRUSH)



Chop/Nod (NodPol) Mode

## Pipeline Operations

- FORCAST, EXES, FPI+:
  - OC4 processing/archiving complete to date
  - Re-processing of FORCAST data:
    - Clean up of problematic data
    - Will re-process all FORCAST grism spectra with better response curves and improved telluric correction in Winter 2016/2017
- FLITECAM:
  - OC4-J processing underway
- FIFI-LS:
  - Processed individual FIFI-LS flights from OC2-F, OC3-B/K, OC4-B/F FIFI-LS data to L3/L4
  - Multi-mission maps (L4) from OC2-F, OC3-B/K, and OC4-B also produced
  - All L4 data archived by 02 Nov 2016
- HAWC+:
  - Will run the pipeline on Dec data, with QA help from SI team
  - Will take over pipeline processing in Spring 2017

# Cycle 4 Data Processing Status

Observing Campaign	Science Instrument	Last Flight	Baseline L3	Completed/ Expected L3
4-A	FORCAST	18-Feb-16	9-Mar-16	10-Mar-16
4-B	FIFI-LS	10-Mar-16	11-May-16	24-Jun-16
4-C	EXES	25-Mar-16	21-Apr-16	26-Apr-16
4-D	GREAT	27-May-16	22-Aug-16	29-Jul-16
4-E	GREAT (NZ)	20-Jun-16	13-Sep-16	29-Jul-16
4-F	FIFI-LS (NZ)	5-Jul-16	6-Sep-16	30-Sep-16
4-G	FORCAST (NZ)	21-Jul-16	11-Aug-16	25-Aug-16*
4-I	FORCAST	13-Oct-16	2-Nov-16	18-Oct-16
4-J	FLITECAM	21-Oct-16	10-Nov-17	
4-K	GREAT	22-Nov-16	17-Feb-17	
4-L	HAWC+	16-Dec-16	26-Apr-17**	
4-M	EXES	1-Feb-17	2-Mar-17	

Green Expected completion on Track  
Yellow Expected completion less than 2 weeks after baseline  
Red Expected completion more than 2 weeks after baseline

\* Approved waiver for delay

\*\* Note: HAWC+ data processed as “best effort” for Cycle 4 because it is a newly commissioned instrument. Dates posted are an estimate.

## Summary

- DPS team has been able to meet most scheduled deadlines for reductions of FSI data (aside from FIFI-LS) despite also supporting flights (serving as Inst. Sci. and reducing data in-flight)
- All FIFI-LS data have been (re-)processed to L3/L4 with revised pipeline and will be ingested soon (today!)
- DPS team has taken delivery of a version of the HAWC pipeline and is integrating it into our environment/structure
- DPS team continues to make improvements to FSI pipelines
- Improvements in reduction products would result from a working WVM (especially for FIFI-LS)
- Correcting FITS Headers or improving WCS values still consumes a large fraction of time for processing data from some instruments (FIFI-LS, FLITECAM, FORCAST)



## DPS Staff

- **Scientists:**
  - **W. Vacca** – DPS Lead, pipeline development, QA, calibration scientist for FORCAST, FLITECAM, FIFI-LS, HAWC
  - **R. Shuping** (SSI) – 80%; processing and operations support
  - **J. Radomski** – QA scientist for FORCAST, (HAWC)
  - **S. Shenoy** – QA scientist for FORCAST, FLITECAM
  - **D. Fadda** – QA scientist for FIFI-LS
- **Software Engineers:**
  - **M. Clarke** – Development Lead; Redux (pipeline interface), develops/maintains four pipelines, header checker, QA tools; testing, documentation
  - **K. Shabun** – DPS database project
  - **E. Omelian** (NASA) – IT&V lead; testing, documentation, guiding us through NASA hoops
- **IT:**
  - **D. Sandel** – DPS hardware and ops support
  - **E. Proudfit** – DPS machine set-up and maintenance



# FSI Data Processing Flow (Shuping and Vacca)

