



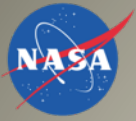
# SOFIA Science Highlights

## Cycle 4 Progress

## Cycle 5 Call for Proposals

Erick Young  
SOFIA Science Center



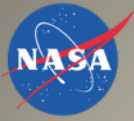


# Executive Summary - Since Last SUG



- Completed Cycle 3
  - 319 Hours GI Time
  - 122 Hours GTO Time
  - 5 Hours DDT
- Horsehead Nebula DDT Data Released
- Started Cycle 4 on 1 Feb 2016
  - OC4A - 8 FORCAST Flights Scheduled
  - OC4B - 9 FIFI-LS Flights Scheduled
    - -2 cancelled, +1 contingency
  - OC4C - 4 EXES Flights Scheduled
  - OC4D - 10 upGREAT Flights Scheduled
    - In progress
    - 3.5 flights lost, 1 contingency scheduled
- HAWC+ Commissioning started
- Cycle 5 Call for Proposals Released
- We are ready to go on deployment **next week**





# Cycle 3 Summary Statistics



Campaign	Net Flights	Instrument	Flight Hours	GTO Hours	GI Hours	Cal Hours	DDT Hours	OTHER	Notes
OC3A	5	EXES	47.67	21.38	14.62	5.47	0.00	6.21	1 Cancelled
OC3B	8	FIF-LS	75.63	12.85	44.25	9.50	0.91	8.12	
OC3C	6	FORCAST	53.45	3.22	29.87	12.70	0.00	7.62	
OC3D	7	FORCAST	66.22	6.08	40.91	12.83	0.00	6.39	3 Cancelled
OC3E	2	FLIPO	13.91	4.83	4.20	0.00	0.00	4.88	
OC3G	5	GREAT	47.69	22.92	13.49	3.50	0.00	5.02	1 Cancelled
OC3H	3	EXES	29.31	5.83	14.57	4.70	0.00	4.21	
OC3I	5	FORCAST	46.44	1.54	29.48	9.30	0.00	5.42	1 Cancelled
OC3J	3	FLITECAM	28.18	3.03	13.28	7.92	0.00	3.96	1 Cancelled
OC3K	8	FIF-LS	74.15	20.70	30.58	13.13	0.00	9.73	
OC3L	8	FORCAST	73.25	5.70	44.98	14.10	0.00	8.48	1 Cancelled
OC3M	9	GREAT	84.28	13.65	39.18	8.15	4.17	11.14	1 Cancelled
Totals	69		640.18	121.75	319.40	101.30	5.08	81.15	

441.15  
436.27

Note: CAL Hours includes 0.5 hour per flight for TA setup.  
OTHER includes Climb and Descent Time of typically 1 hour per flight, dead legs, and engineering legs.





# SOFIA Demonstration Observations

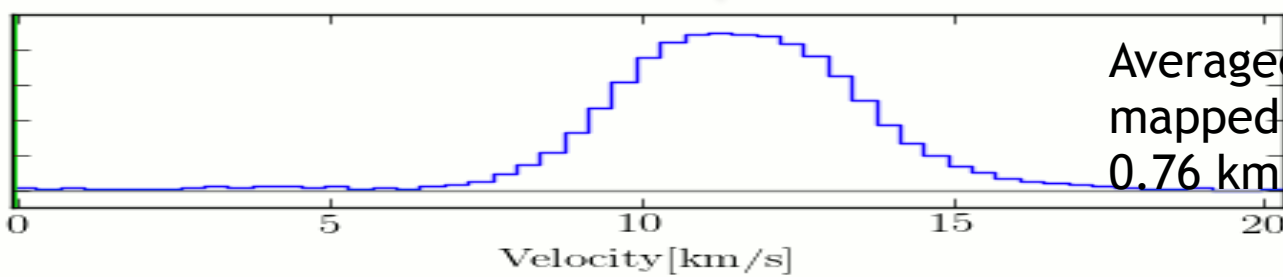
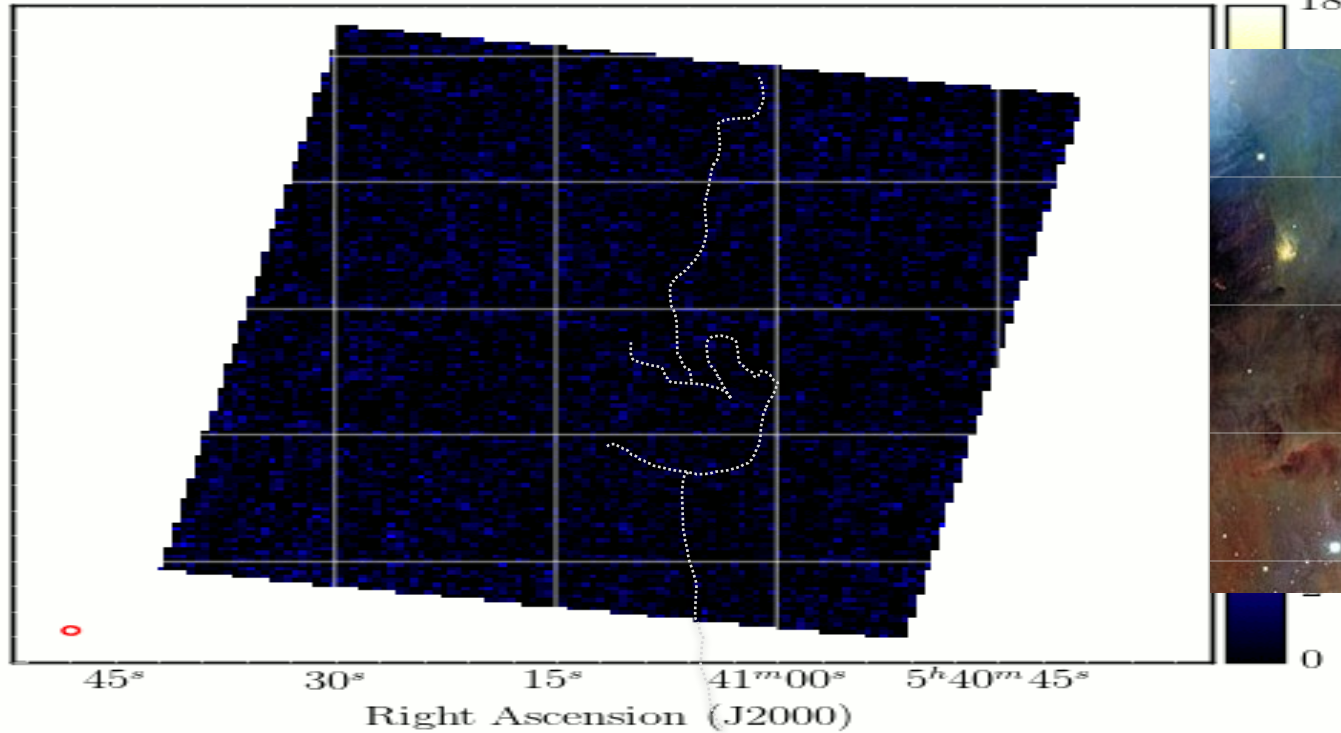


- Motivation for this observation was multifold:
  - Highlight a new capability that would be of wide interest to the SOFIA community
  - Provide a scientifically relevant data set for analysis
  - Demonstrate SOFIA's capability to deploy state-of-the-art instrumentation
  - Provide useful materials for science and public outreach
- Observations
  - Director's Discretionary Time
  - [C II] 158  $\mu\text{m}$  map of the Horsehead Nebula with the upGREAT 14-pixel heterodyne array
  - Observations made on 10 December 2015
  - Comparable observations would have taken ~200 hours on Herschel

Calibrated data cubes are available to the astronomical community with no proprietary restrictions



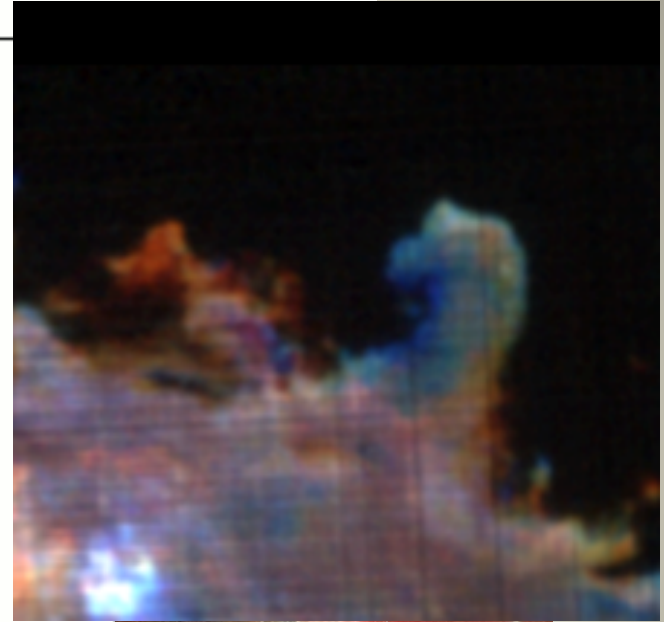
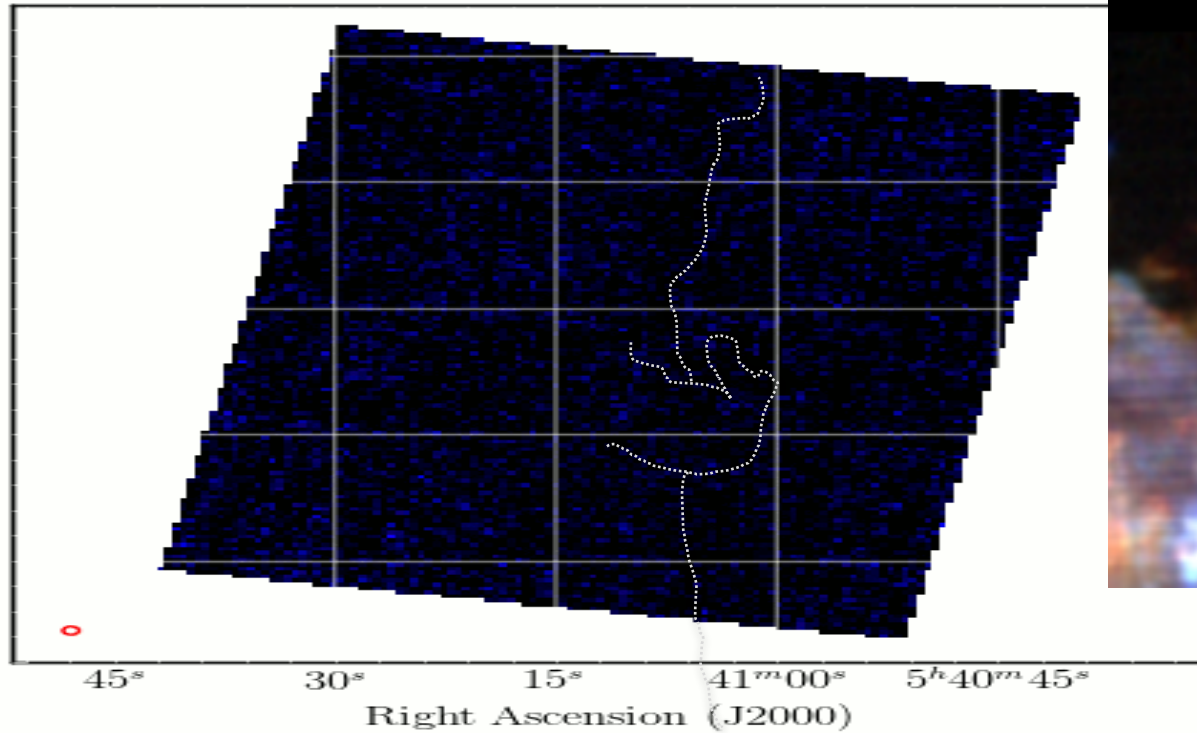
### Horsehead C<sup>+</sup> emission



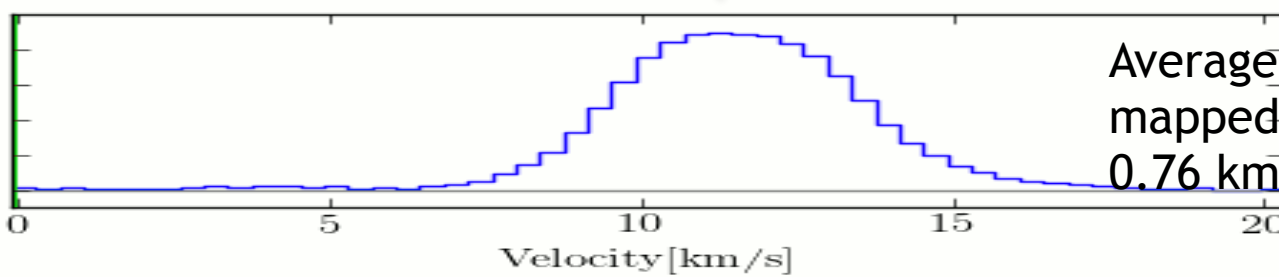
Averaged line profile over mapped region. Smoothed to 0.76 km/s velocity resolution



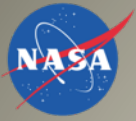
### Horsehead C<sup>+</sup> emission



G0 3-2 SuperCam on the APEX Telescope (Stanke 2015)



Averaged line profile over mapped region. Smoothed to 0.76 km/s velocity resolution



# Cycle 4 Progress



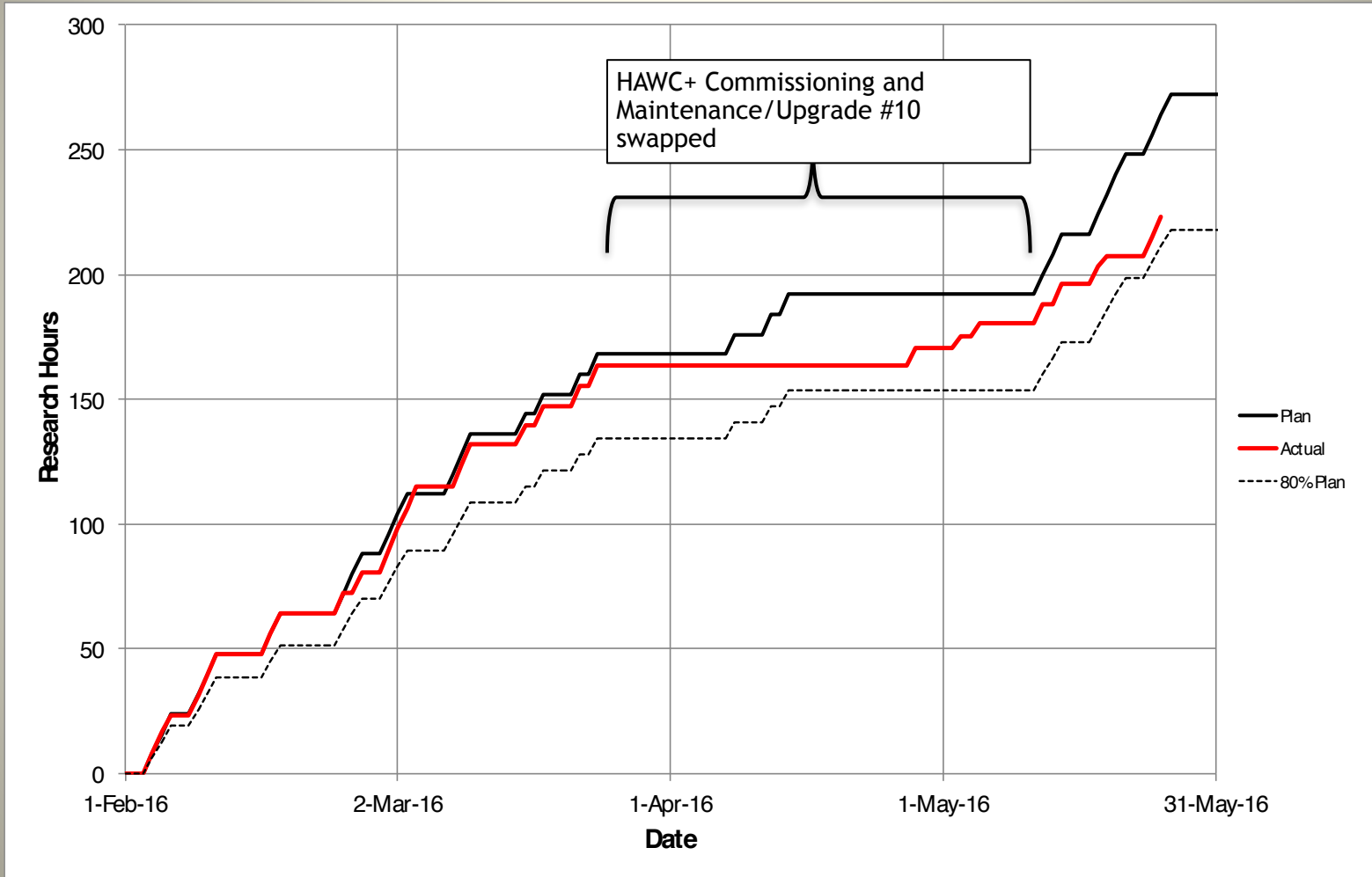
Campaign	Net Flights	Instrument	Flight Hours	GTO Hours	GI Hours	Calibration Hours	DDT Hours	Engineering Hours	Dep/Arr Hours	Other
OC4A	8	FORCAST	74.71	2.82	50.61	11.86	0.00	1.00	8.43	0.00
OC4B	8	FFI-LS	74.68	11.02	44.26	11.47	0.00	0.00	7.94	0.00
OC4C	4	EXES	37.25	0.00	29.97	2.42	0.00	0.00	4.87	0.00
HAWC+	3	HAWC+	21.77							
OC4D		upGREAT	55.94	7.95	36.96	4.67	0.00	0.00	5.87	0.49

Through 25 May 2016





# Cycle 4 Research Hours Progress





M42 - continuum at 158  $\mu\text{m}$

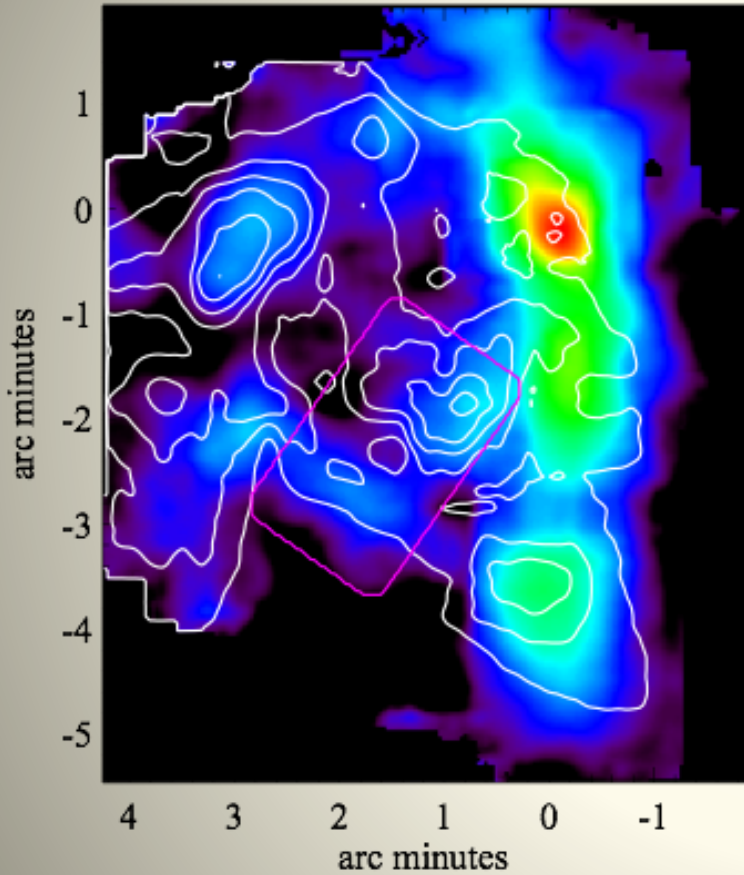


Image: log stretch; linear contours for [CII] flux

M42 - [CII] flux

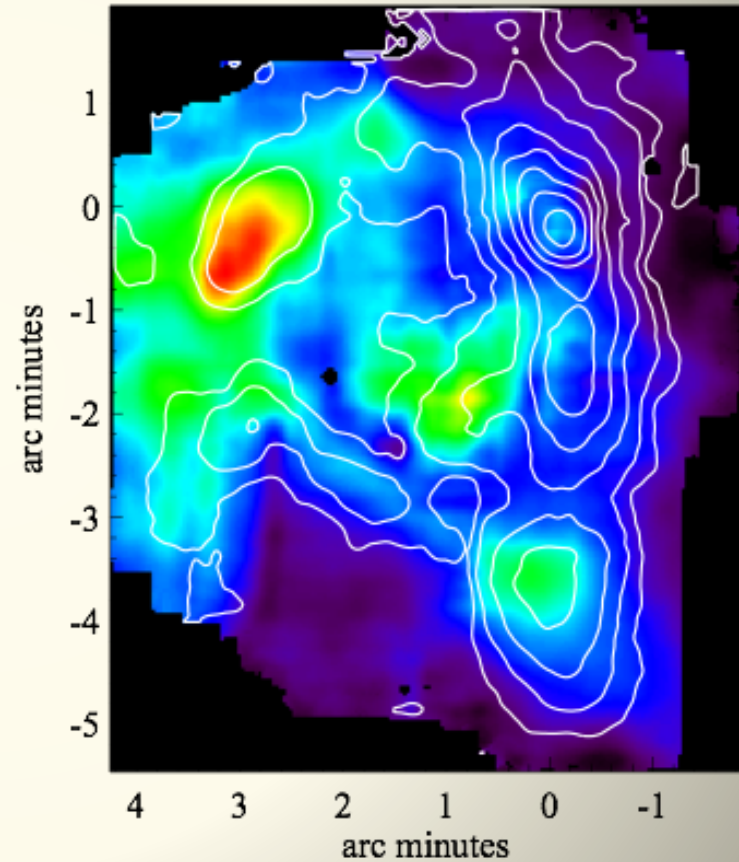
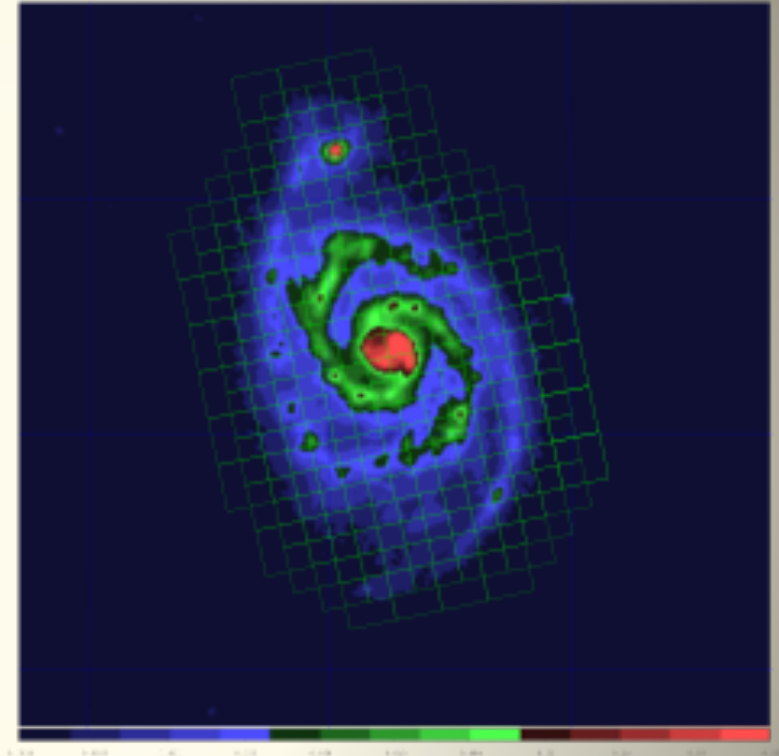


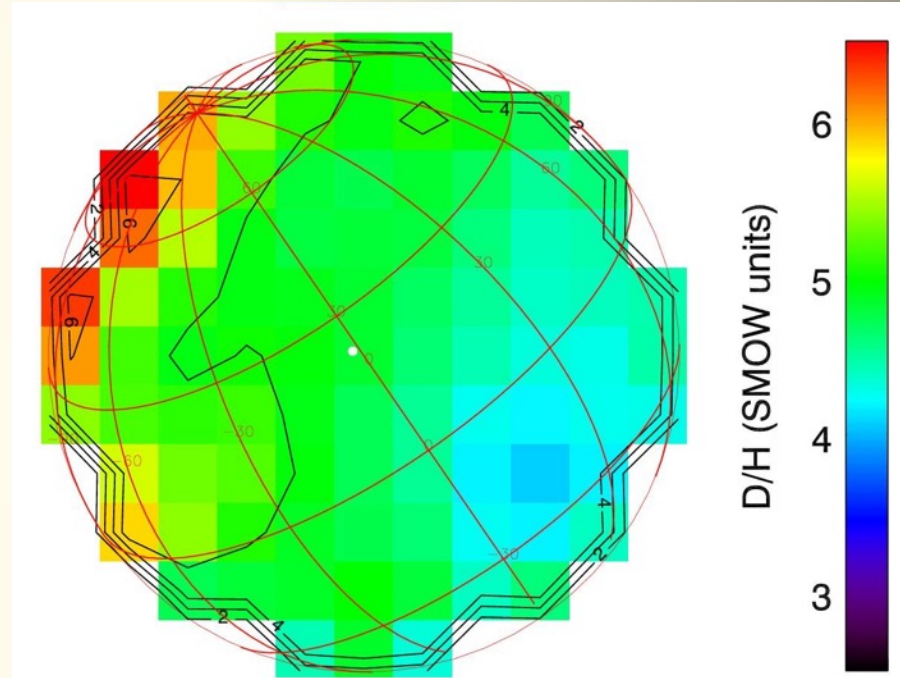
Image: linear stretch; log contours for 158  $\mu\text{m}$  continuum

- What is the role of density waves on star formation in grand design spirals?
- Joint Impact Proposals:  
04\_0116 Pineda (JPL)  
04\_0122 Stutzki (Köln)
- Velocity-resolved observations of  $158 \mu\text{m}$  [C II] line with upGREAT heterodyne spectrometer and mapping with FIFI-LS of inter-arm regions in classic spiral galaxy M51
- For the first time, the molecular gas will be mapped in the principal cooling line of the ISM over an entire galaxy
- Project is also a demonstration of the technological advancements of SOFIA, providing mapping speeds more than an order of magnitude faster than Herschel.



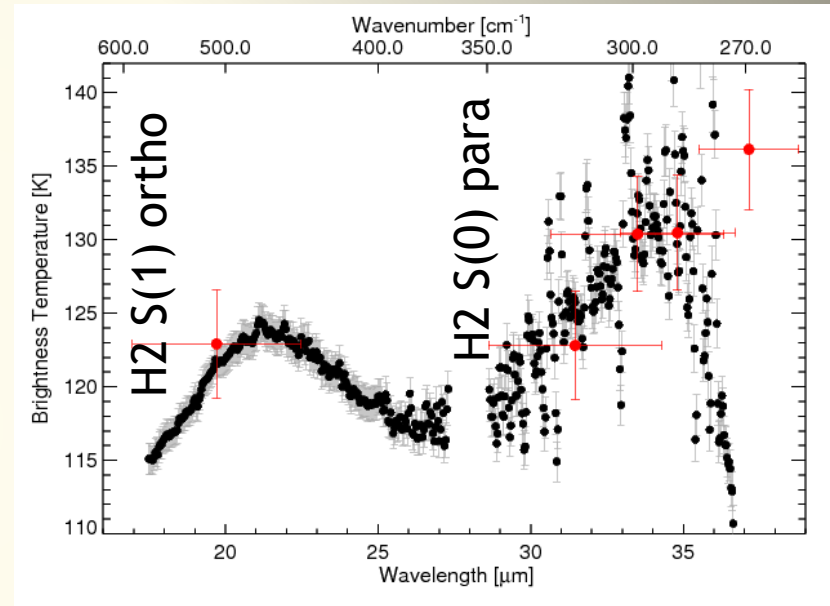
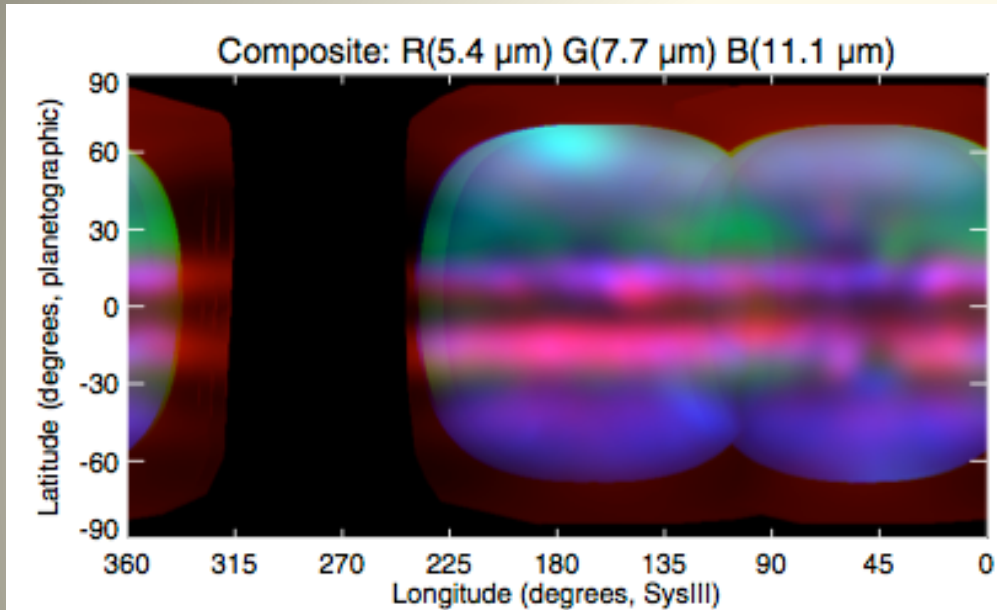
Impact Proposals 04\_0116 & 04\_0122  
[C II] Mapping of M51  
Footprint of FIFI-LS mapping region  
overlaid on Herschel image of M51

- Results recently published by Encrenaz et al., 2016, A&A, 586, A62
- D/H ratio is a diagnostic of the past history of water
  - Global enrichment of the heavier deuterated water gives a measure of the original amount of water on the planet
  - Local variations in D/H ratio can reveal sources and sinks of water vapor on Mars
- Measurements made with EXES at 7.2 mm where lines of both H<sub>2</sub>O and HDO are present.
  - Maps of abundance ratio obtained over surface of Mars at R ~ 100,000
- Disk integrated D/H is 4.4 times Vienna Standard Mean Ocean Water (VSMOW) abundance.
  - Consistent with previous determinations that vast majority of the primordial water on Mars has escaped

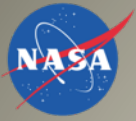


Deuterium/ Hydrogen ratio expressed as factor of Vienna Standard Mean Ocean Water abundance. Observed enrichment of Mars is a factor of 4 to 5 times Earth abundance.

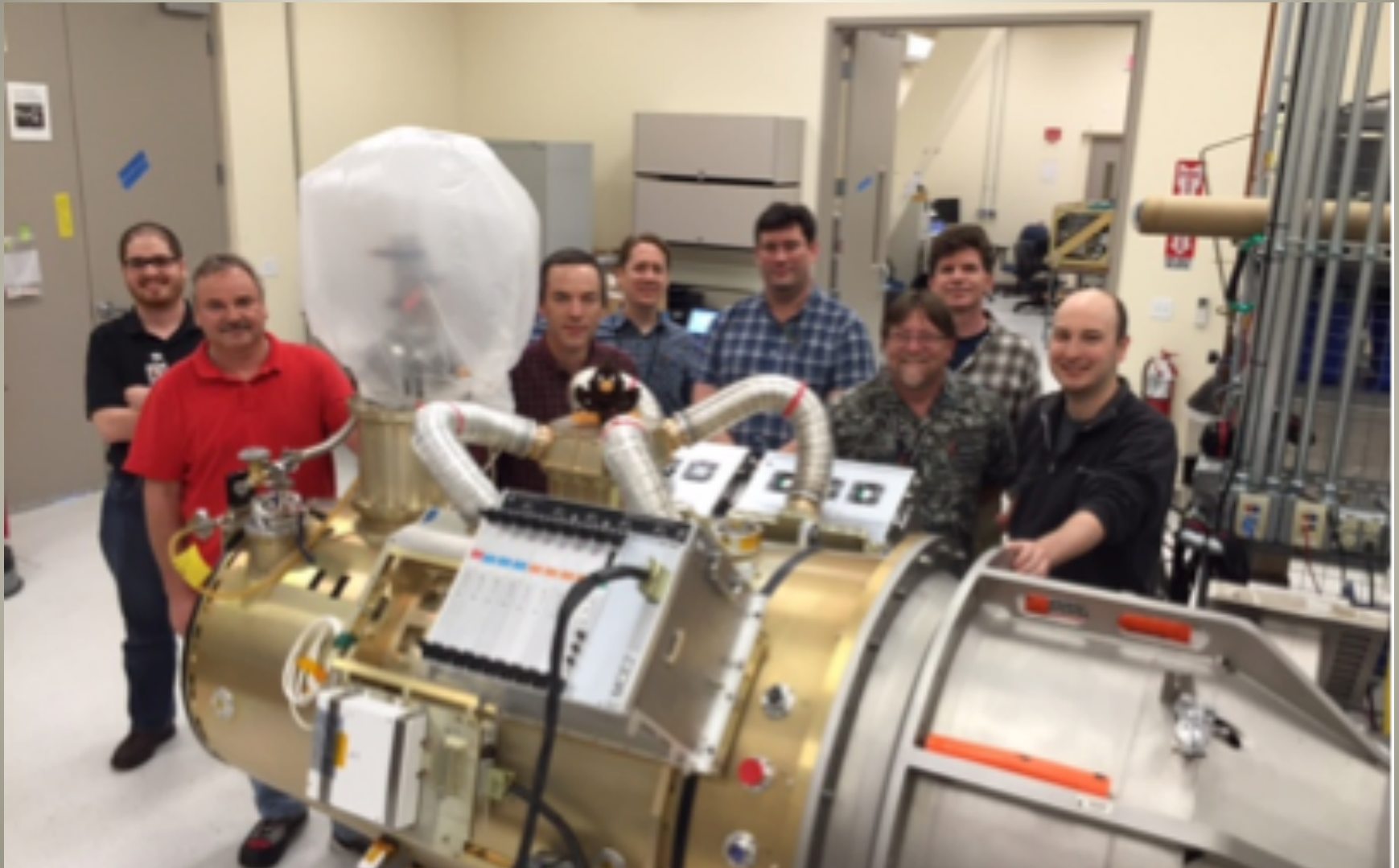


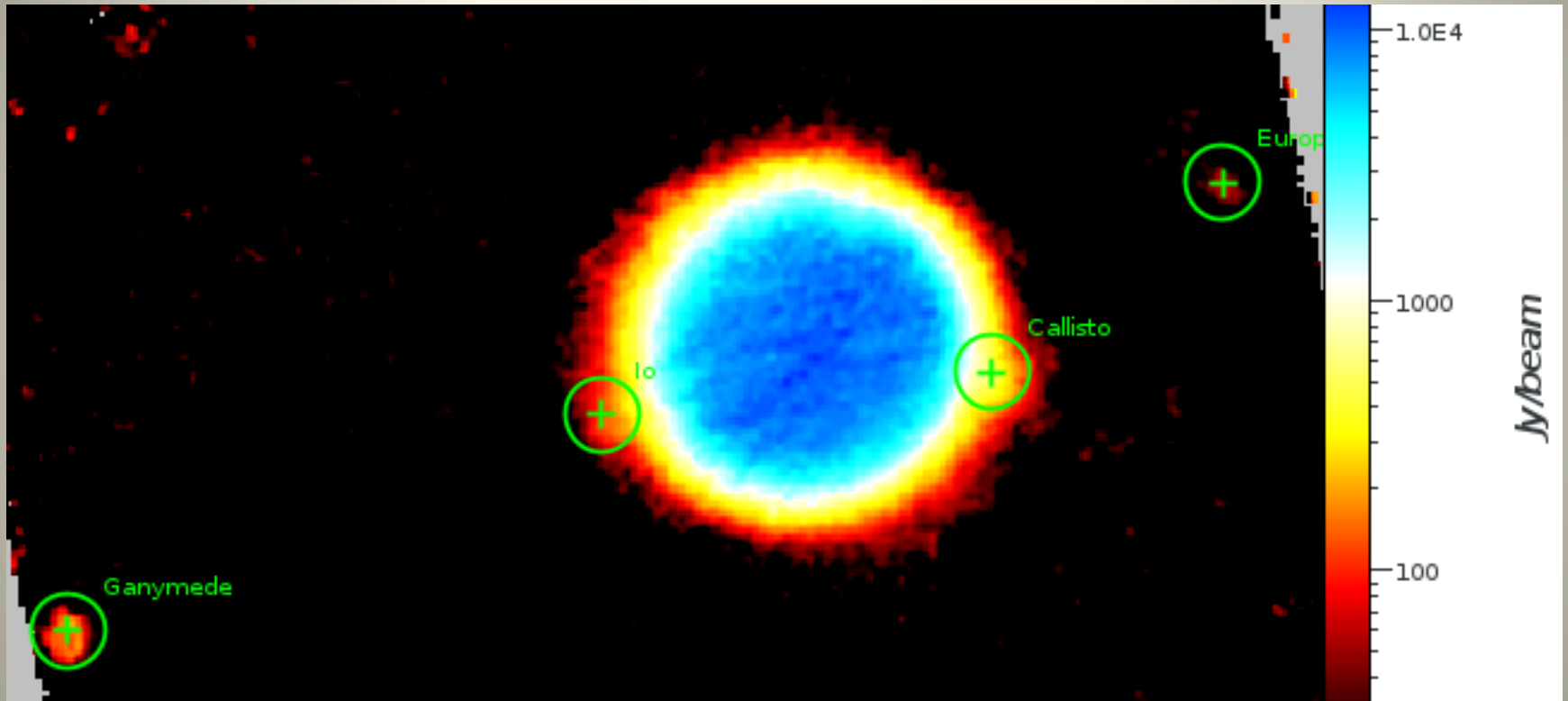


- Mid-infrared spectral maps of Jupiter for ortho/para H<sub>2</sub>
- Equatorial/high-lat para fraction is below/above equilibrium value
- Low-para H<sub>2</sub> from depth is upward transported to equator
- Low-para H<sub>2</sub> rapidly equilibrates on aerosols at high-latitude, and sinks back  
(Fletcher w/Reach, Submitted to Icarus)



# HAWC+





Jupiter and family at 53  $\mu\text{m}$



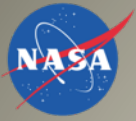


# SOFIA Cycle 5 Assumptions



- Program Office Guidance
  - 104 Science Flights
  - NASA: 476 CfP Hours
    - Note: Assumes 50 US GTO hours
  - DLR: 84 CfP Hours
    - Note: Assumes 55 DE GTO hours (33% German of allocation)
- Cycle 5 period: 1 February 2017 - 31 January 2018
- Southern Hemisphere Deployment in June-July
  - Two instrument baseline
- Available US funding: \$5 M





# Major Changes from Cycle 4



- Added capabilities:
  - HAWC+ commissioned, FIFI-LS as Facility Instrument
  - upGREAT High Frequency Array availability pending successful commissioning
- Capabilities Not Offered:
  - Cross dispersed FORCAST spectroscopy
  - M channel (2.7 THz) for GREAT





# New capabilities - details



- FIFI-LS will be operated as a Facility Instrument with full support of SMO
- GREAT H-channel will be offered in standard L2/H configuration. HFA will be commissioned after proposal selection . Availability of array is listed as “contingent on successful commissioning” , and L2/H proposals may be changed to L2/HFA if successful.
- HAWC+ will be operated as a Facility Instrument with full support of SMO, but performance is shared risk



- The cross-dispersed modes of FORCAST spectroscopy will not be offered in Cycle 5
- Grism G4 is not usable - severe ghosting
  - Throughput in cross-dispersed mode is only ~10%
  - Low proposal pressure in Cycle 3
  - Same wavelength coverage is available in non-X-dispersed FORCAST
    - To get “decent” S/N in the X-modes you have to smooth to ~the resolution of the non-X modes
  - For individual lines or narrow wavelength ranges, EXES is a better choice
- The M-channel for GREAT will not be offered in Cy 5.
  - Low proposal pressure
  - Too many modes to support and not enough flight opportunities to support configuration changes (Güsten)



## “Impact Programs”



- Large, multi-year (2-3 cycles) programs, aimed at specific scientific questions of high potential impact (not, primarily, “just” surveys).
  - Anticipate selecting 2-3 with 100hr-class observing each
  - Any instrument combination (except no mix of FSI/PSI and SSI)
- To encourage US-German scientific collaboration, the queues will allow submission of joint “Impact program” proposals to the US and German queues. If the two proposals are both successful the programs will be merged with the US and DE PIs becoming co-PIs on the resulting program and the time charged 80:20.
- Continuation of successful category introduced in Cycle 4
- Added language to emphasize importance of broader impact of investigations





## Timeline



- Call issued: April 29, 2016
- Call update: June 10, 2016
- Proposal deadline: July 1, 2016
- US TAC: late Aug 2016
- German TAC: early September 2016
- Selection announced: October 1, 2016
  
- Nominal Cycle 4 observing period:  
1 Feb 2017 - 31 January 2018.



