

SOFIA Science Highlights Cycle 4 Progress

Hal Yorke

SOFIA Science Center





Executive Summary – Since Last SUG



- Harold Yorke appointed SOFIA SMO Director effective 15 Oct 2016
- Cycle 4 is still continuing. Progress as of 31 October 2016:
 - 315 Hours GI Time
 - 68 Hours GTO Time
 - 11 Hours DDT
- Deployment in New Zealand 4 Jun – 26 Jul 2016
- Cycle 5 Selection: letters of acceptance/rejection sent 24 Oct 2016
 - US TAC meeting held 17-18 Aug 2016; German TAC 1-2 Sep 2016
 - Cycle 5 selection delay due to uncertain status of HAWC+
- NASA HQ selected HIRMES (PI: Harvey Mosley, GSFC) as a 3rd Generation instrument for SOFIA.
 - Schedule calls for commissioning of HIRMES in 2019.
- SOFIA Science Symposium *The Local Truth: Star Formation in the SOFIA Era* held in Asilomar 17-21 Oct 2016
 - Over 90 participants with a strong international component





Cycle 4 Progress



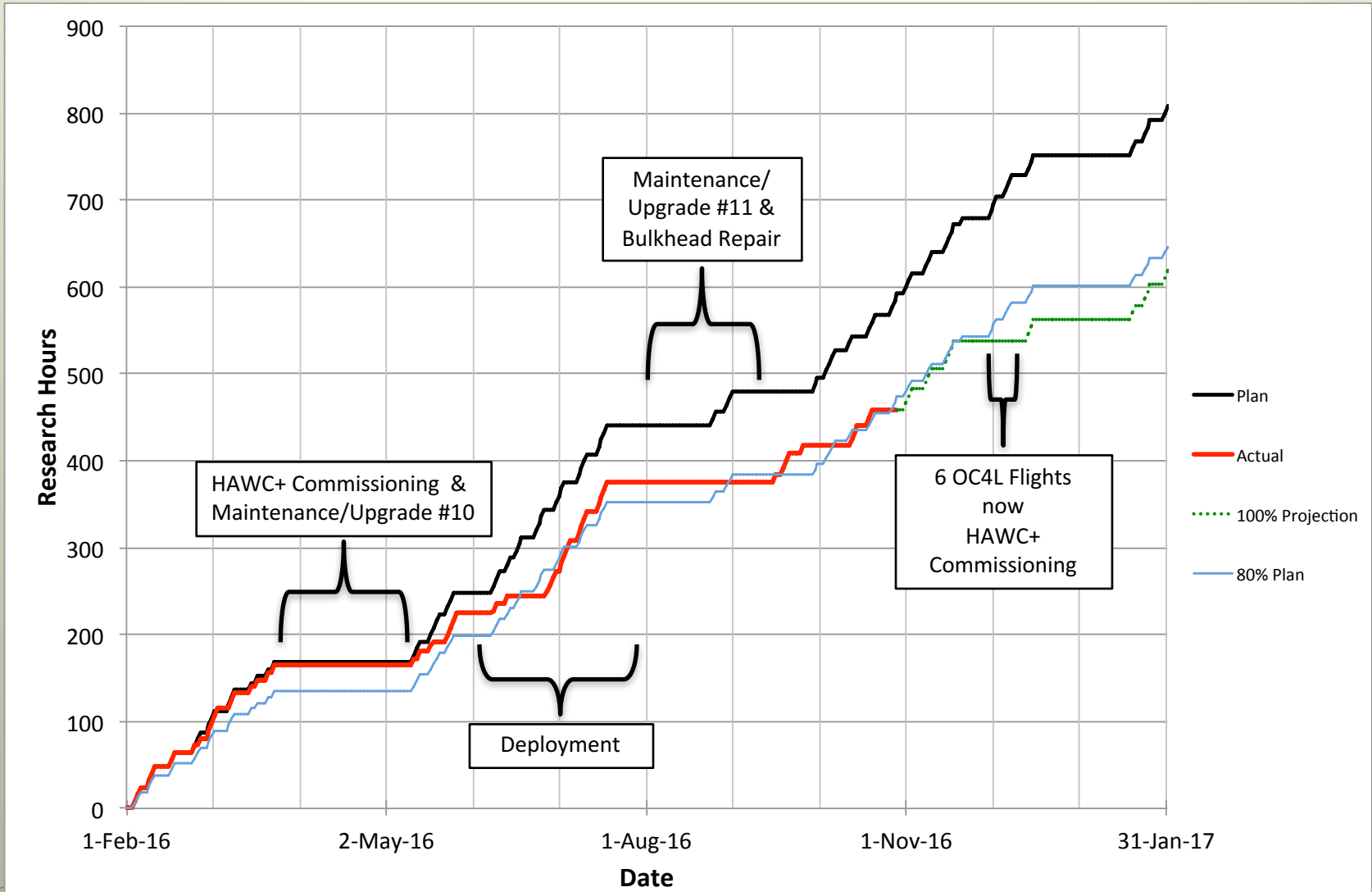
Campaign	Net Flights	Instrument	Flight Hours	GTO Hours	GI Hours	Calibration Hours	DDT Hours	Engineering Hours	Dep/Arr Hours	Other
OC4A	8	FORCAST	74.71	2.82	50.61	11.86	0.00	1.00	8.43	0.00
OC4B	8	FIFI-LS	74.68	11.02	44.26	11.47	0.00	0.00	7.94	0.00
OC4C	4	EXES	37.25	0.00	29.97	2.42	0.00	0.00	4.87	0.00
HAWC+	3	HAWC+	21.77							
OC4D	7	upGREAT	73.37	7.95	51.03	5.67	0.00	1.28	8.15	0.49
OC4E	2	upGREAT	20.83	7.03	9.34	2.42	0.00	0.00	2.03	0.00
OC4F	8	FIFI-LS	69.33	7.22	35.78	8.43	10.67	0.00	7.23	0.00
OC4G	8	FORCAST	75.21	5.98	54.55	8.33	0.00	0.00	6.35	0.00
OC4H		HAWC+								
OC4I	5	FORCAST	47.05	8.33	26.70	5.80	0.00	1.17	5.05	0.00
OC4J	5	FLITECAM	46.83	17.85	12.25	9.32	0.00	2.58	4.83	0.00
OC4K	2	upGREAT	18.89	0.00	0.00	1.00	0.00	15.57	2.32	0.00
OC4L		HAWC+								
OC4M		EXES								
Totals	60		559.91	68.20	314.48	66.71	10.67	21.60	57.19	0.49

Notes: CAL Hours includes 0.5 hour per flight for TA setup.
OTHER includes dead legs.



Through 31 October 2016



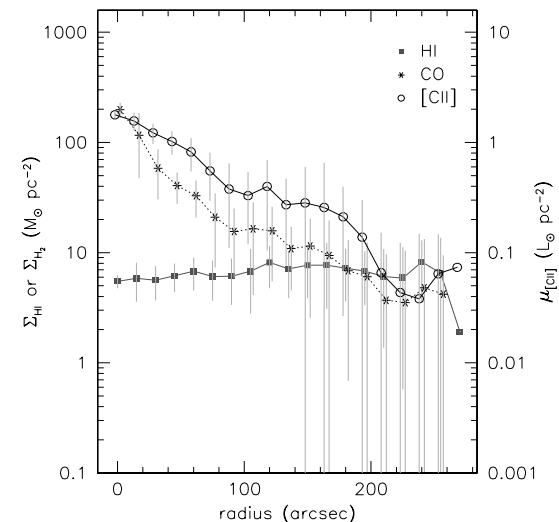
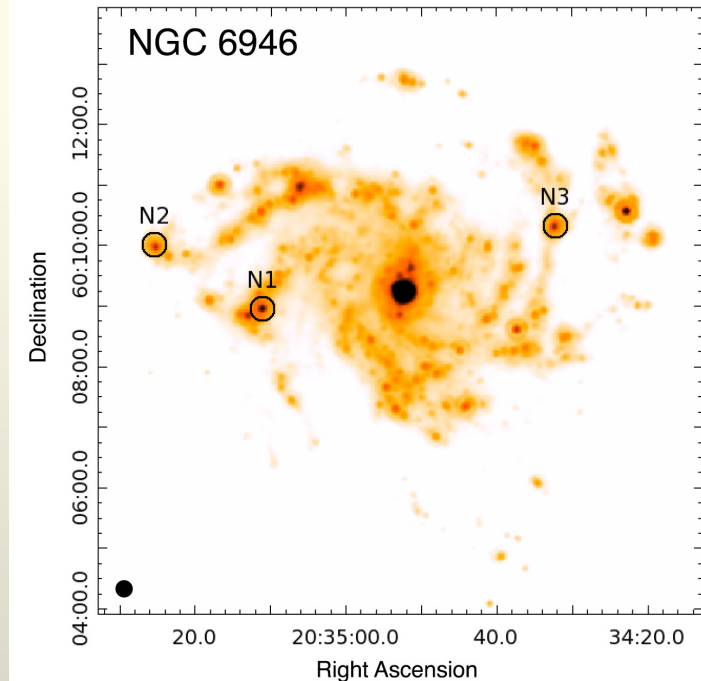


(W.J.G. De Blok et al., 2016, ArXiv 1604.08777v1)

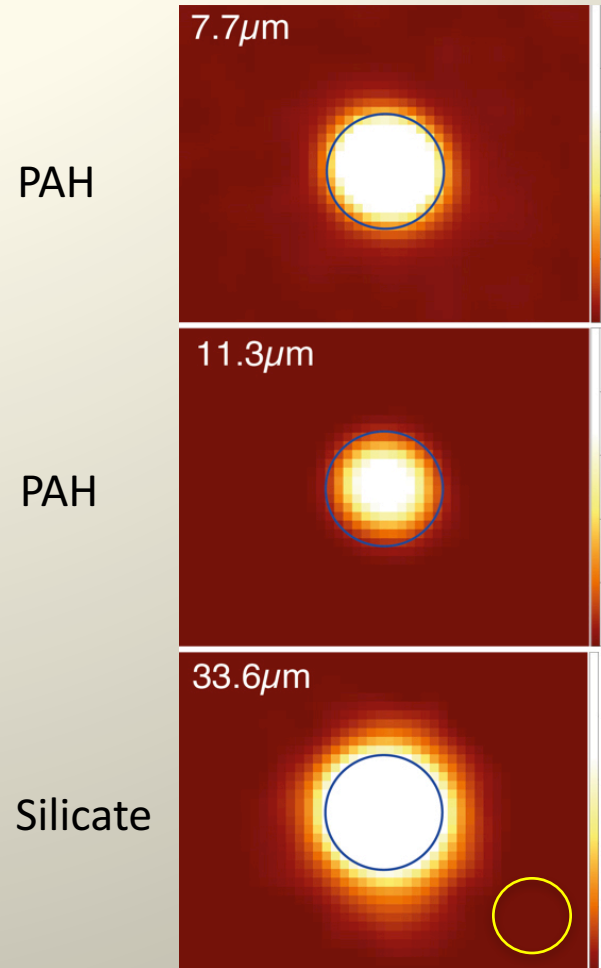
- Comparison of various tracers used to determine the dynamical mass of galaxies for a sample of nearby objects
- H I atomic hydrogen has been the traditional tracer of gas in galaxies
- CO has been used to trace the molecular gas
- [C II] at 158 μm is a newer tracer available with SOFIA that probes intermediate gas as well as “CO-dark” molecular gas.
- Line widths and scale lengths for [C II] are more similar to CO. The radial extent is similar to the optical disk.

Top: Regions observed with SOFIA overlaid on 24 μm Spitzer image of NGC 6946.

Bottom: Radial profile of H I, CO, and [C II] in NGC 5055.



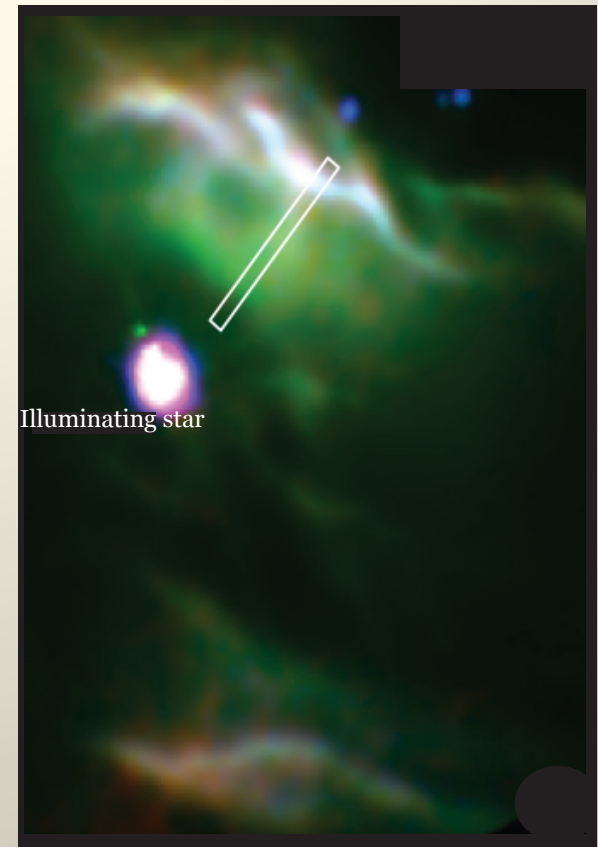
- Planetary Nebula BD+30 3639 was observed by FORCAST at wavelengths that sample carbon-rich and oxygen-rich minerals
- Is the material well mixed or segregated?
- FORCAST observations show carbon rich material is prominent in inner parts of the envelope while the outer parts are rich in oxygen
- Carbon was dredged up from the core of the star over only ~ 1000 years, which is very short compared to the lifetime of the star



(Guzman-Ramirez et al.)

(Excerpted from the 2016 June *SOFIA Newsletter*)

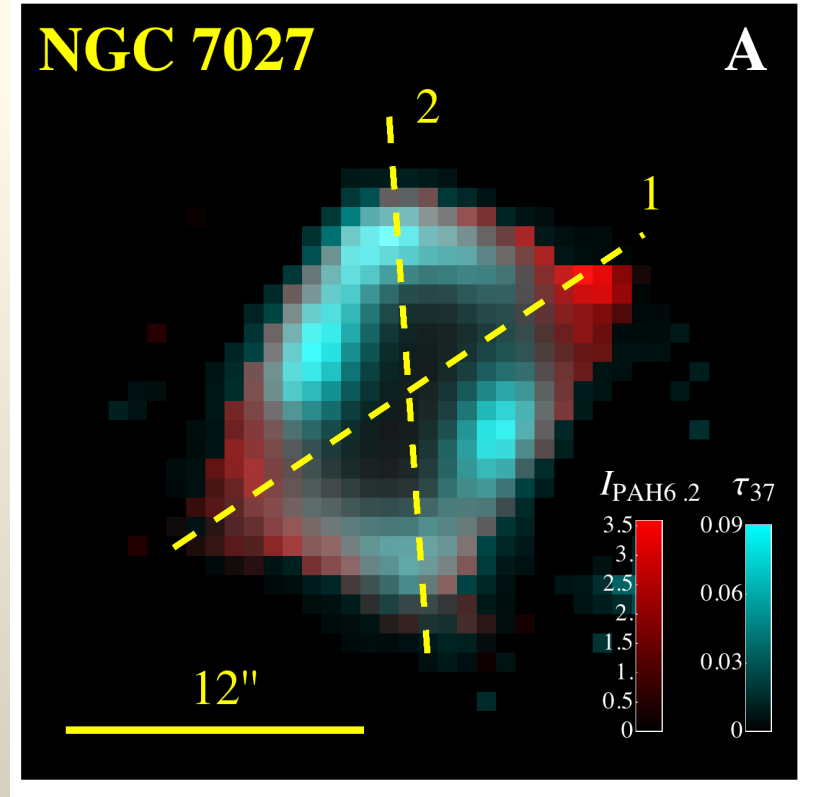
- Interstellar carbonaceous material evolves depending upon the strength of radiation field it is exposed to
- A Cycle 2 guest investigator project led by Olivier Berné (IRAP Toulouse, France) utilized the luminous, B-type star in reflection nebula NGC 7023 to study variations in the carbonaceous material with radiation field
- The colors vary in the sense that the 7.7 & 8.6 μm features get brighter relative to the 11.3 and 3.28 μm features closer to the star
- Explanation is relatively more ionized PAH, and less of the larger “very small grain” PAH clusters, in the more-intense radiation field closer to the star
- The daughter products converting to the relatively hardy buckminsterfullerene (C_{60}) closest to the star.
- SOFIA was essential due to the wide field of view and the narrow 3.3 and 11.2 filters which allowed the size estimation of the PAH. “To observe on the fly with SOFIA was a unique experience,” says Guest Investigator Bavo Croiset.



Mid-Infrared image of reflection nebula NGC 7023.
 Blue: FLITECAM 3.28 μm PAH filter.
 Green: Spitzer filter with 7.7 & 8.6 μm PAH.
 Red: FORCAST 11.3 μm PAH filter.
 (B. Croiset, O. Berné / Toulouse)

Evidence of PAH Formation Along a Recent Outflow in NGC 7027

- NGC 7027 is a young, carbon-rich **planetary nebula**, an evolved star that has thrown off its outer envelope, leaving the expanding shell and a white dwarf
- FORCAST observations in the infrared allow astronomers to study the formation of dust and other materials in the remnants of this event.
- Polycyclic Aromatic Hydrocarbon (PAH) emission comes from the region external to the ionized gas, showing where the PAH molecules form.
- FORCAST observations show that the dust thermal emission comes from the central ionized region of the nebula



False-Color SOFIA FORCAST images of NGC 7027
 37 μm dust optical depth is depicted in cyan.
 6.2 μm PAH intensity is depicted in red.
 The dashed line labeled 1 shows the axis of the outflow from the central star.

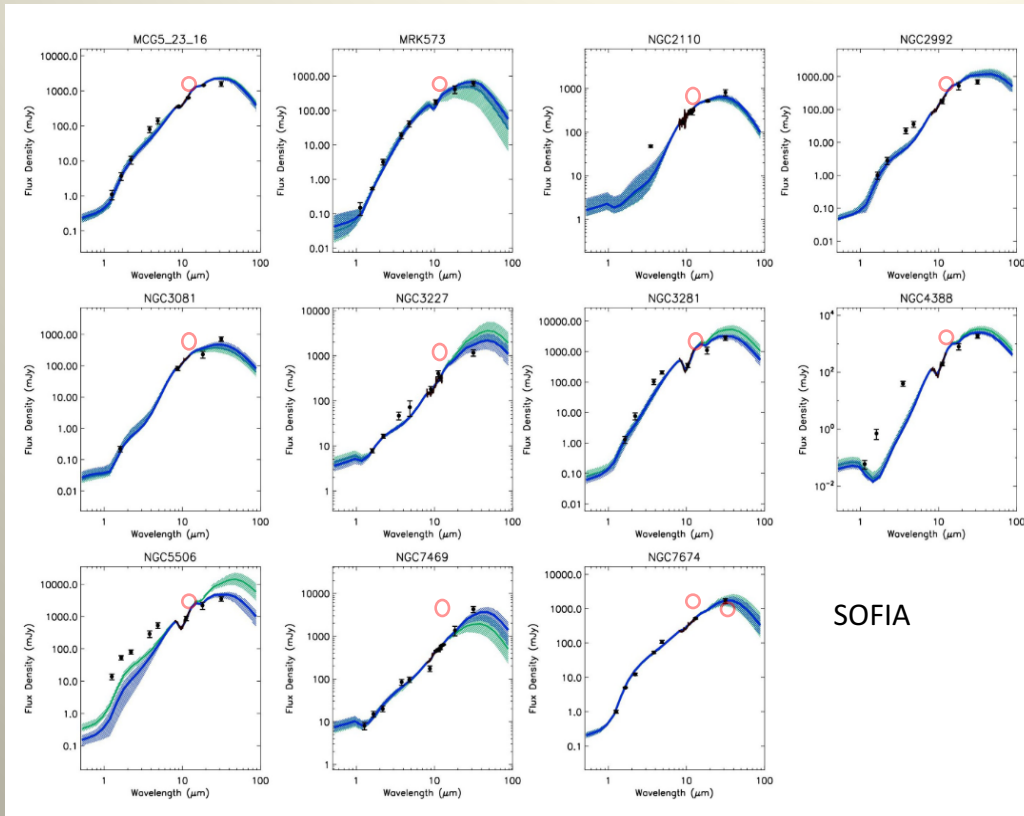
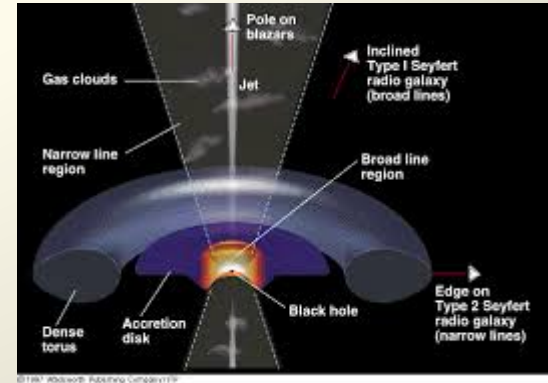
Lau et al. 2016, arXiv:1609.02569v1



Investigating the dusty torus of Seyfert galaxies using SOFIA/FORCAST photometry



The different kinds of Active Galactic Nuclei (AGN) may simply be a matter of *different viewing angles* → toroidal dust distribution measure needed to test this “unified model”



SOFIA

- 11 Seyfert galaxies observed with FORCAST at 31.5 μm
- FORCAST’s *high angular resolution at 31.5 μm* allows decomposition of point-like AGN and extended emission from underlying galaxy
- Inclusion of 31.5 μm improved past measurements of torus extent for 10 of the 11 galaxies: 6 decreased in size, while 4 increased.

(L. Fuller et al., 2016, MNRAS)

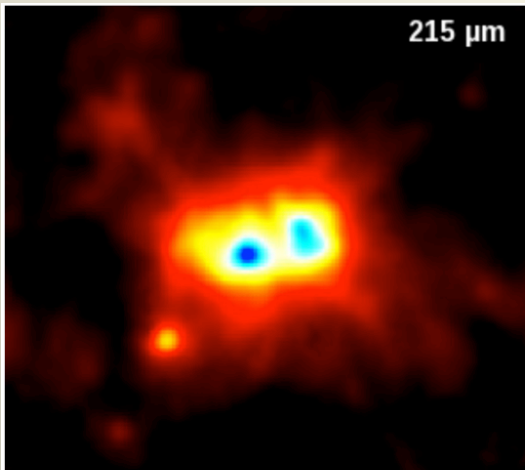




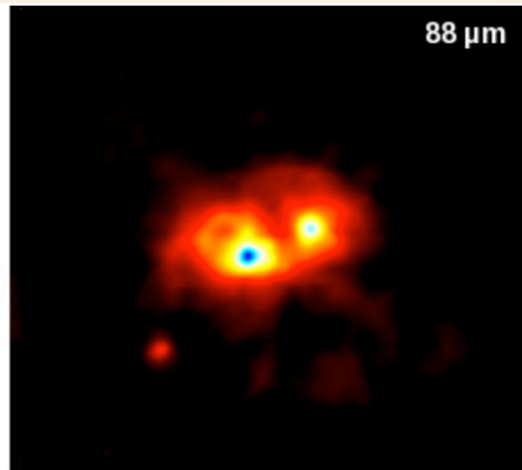
Science Highlights



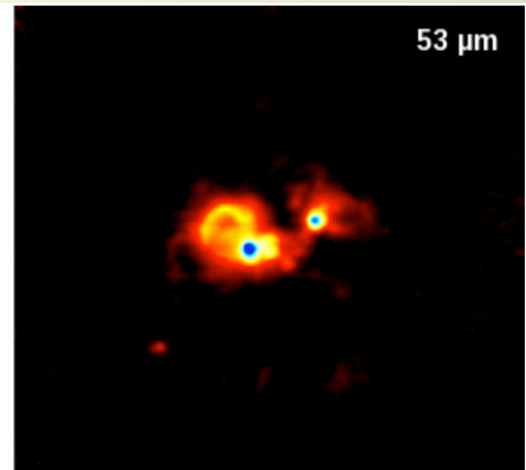
HAWC+ Images of W3 (October 3 & 5)



2.2 min. (elapsed time)



4.1 min. (elapsed time)

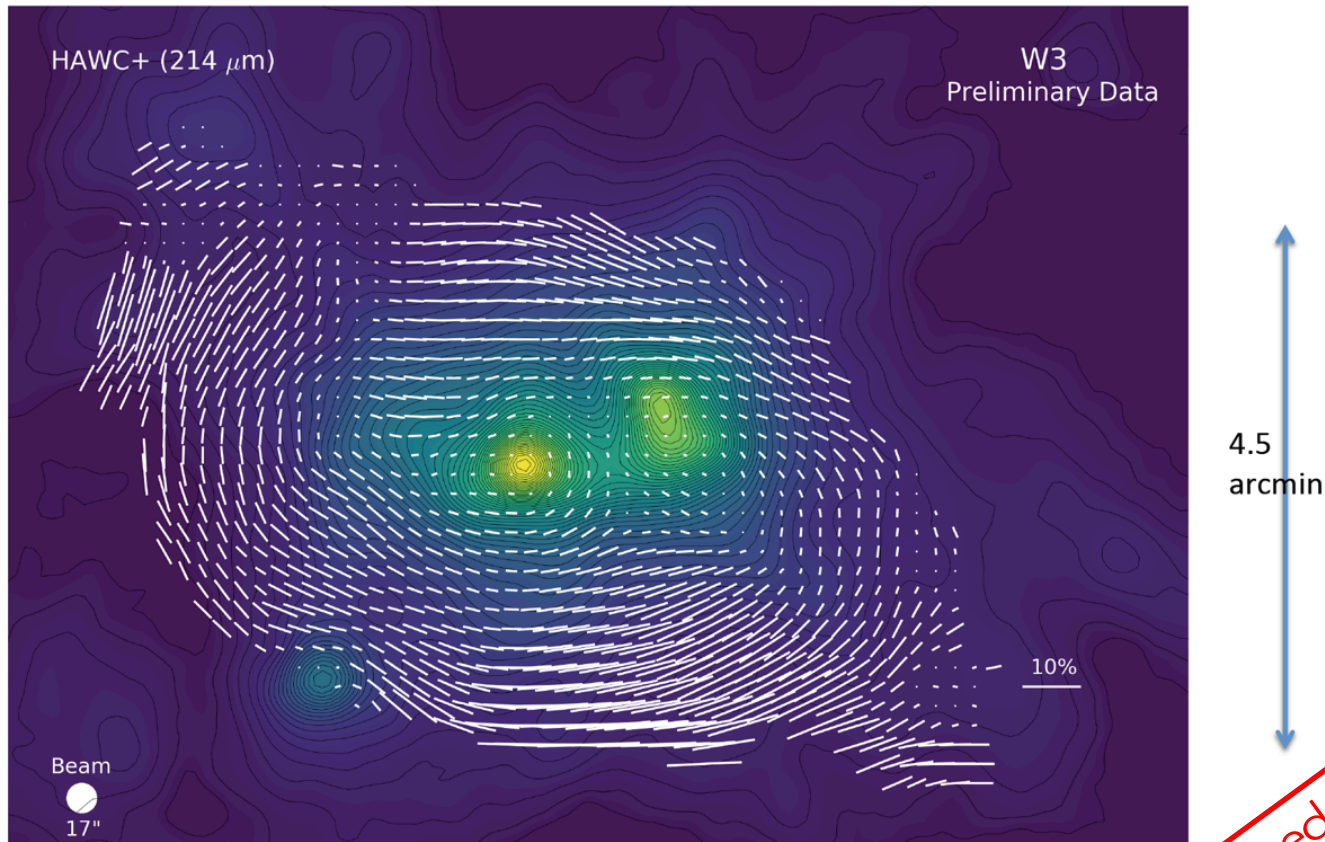


3.0 min. (elapsed time)

Embargoed Data



Polarimetry (Chop-Nod mode)



Vectors displayed have $P/\sigma(P) > 4$ (statistical).
Background intensity image is from HAWC Lissajous scan.

Embargoed Data



SOFIA Asilomar Conference Photo



