



M82



NGC 1068



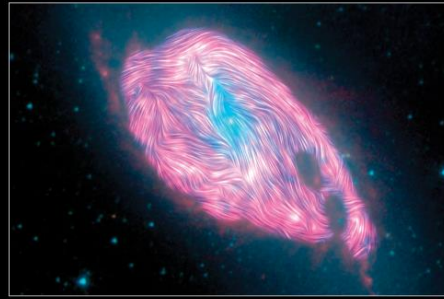
M51



Centaurus A



Antennae Galaxies



NGC 3627



NGC 2146



M83



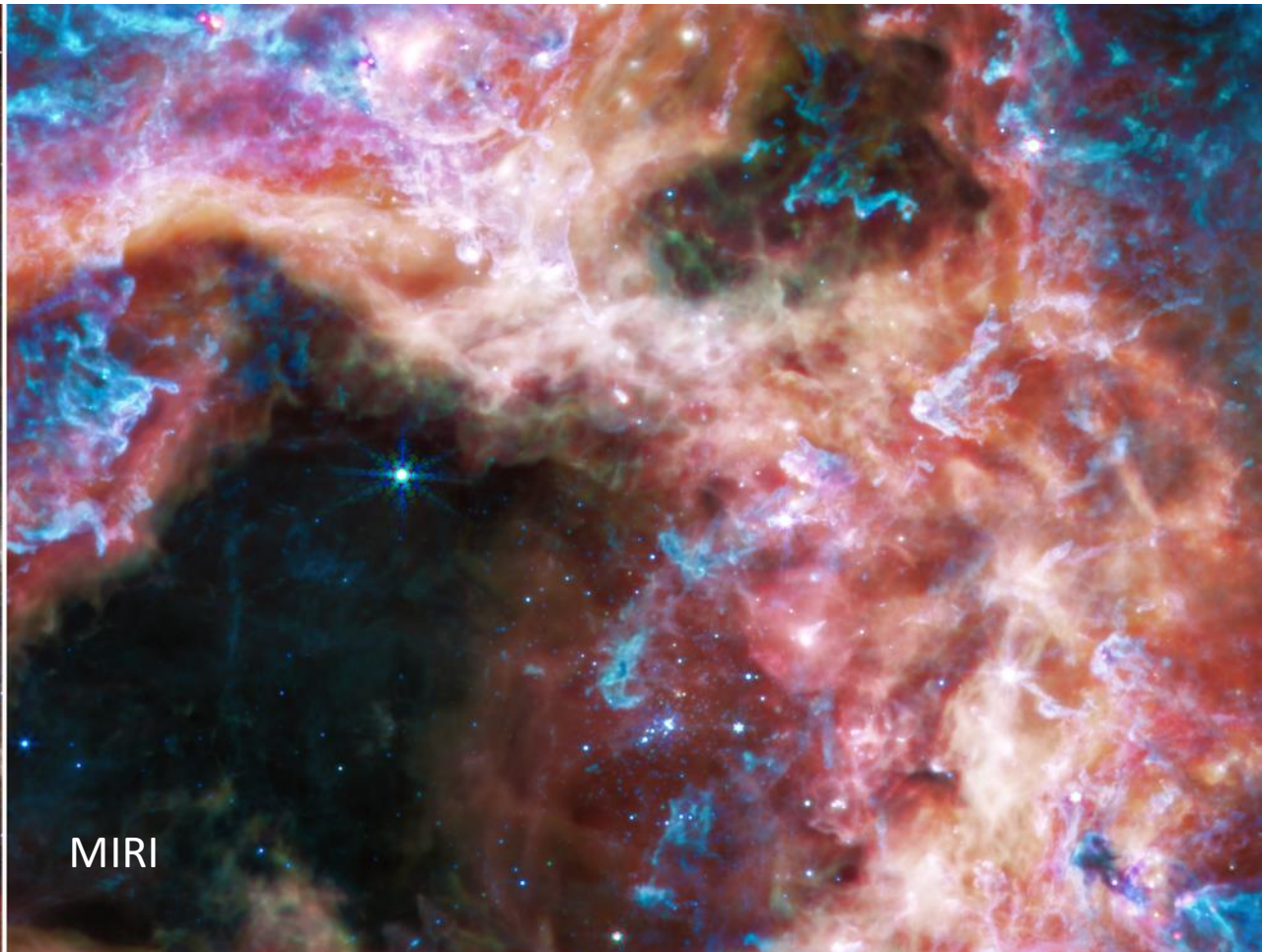
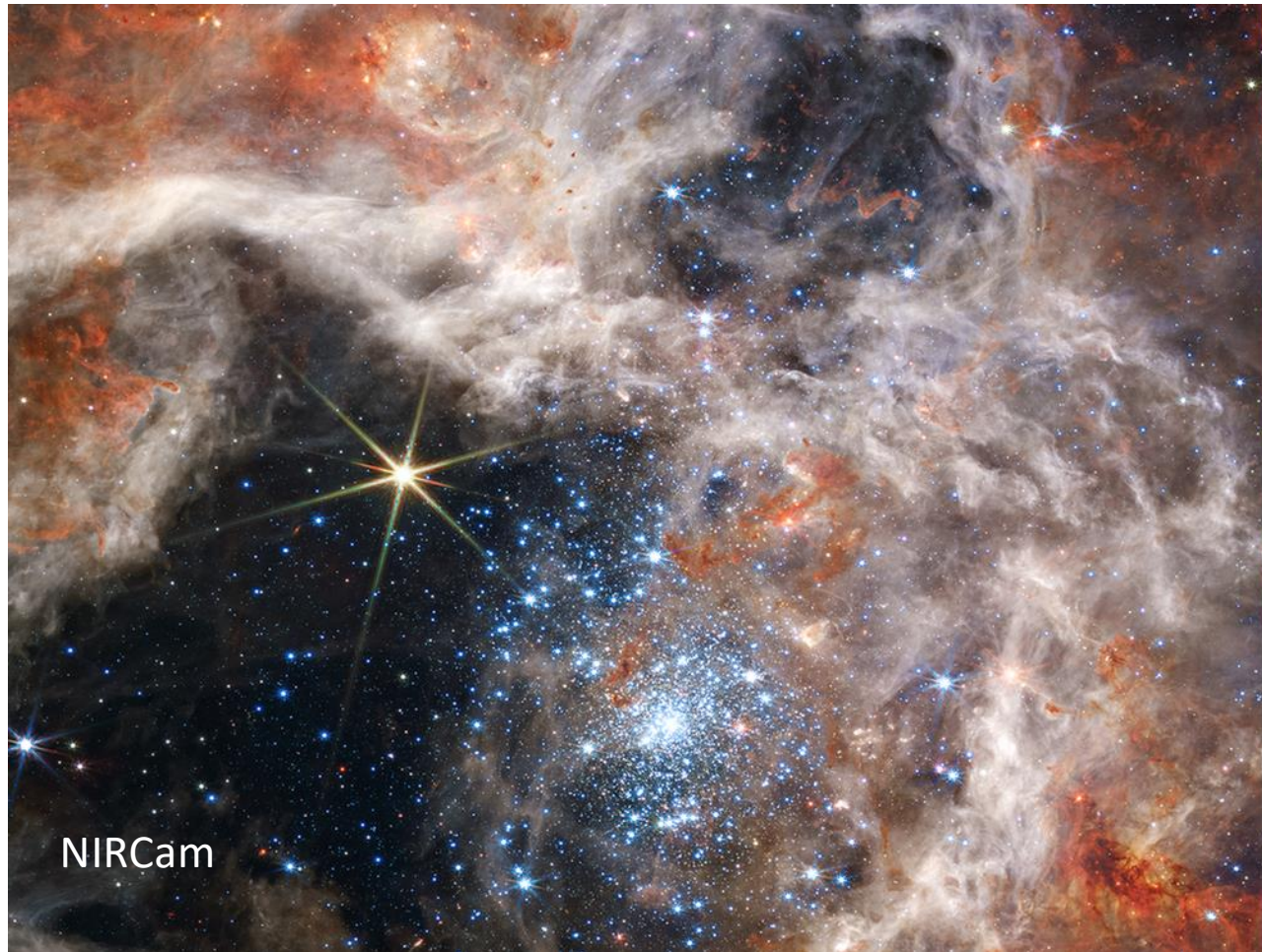
NGC 7331

Reflections on SOFIA

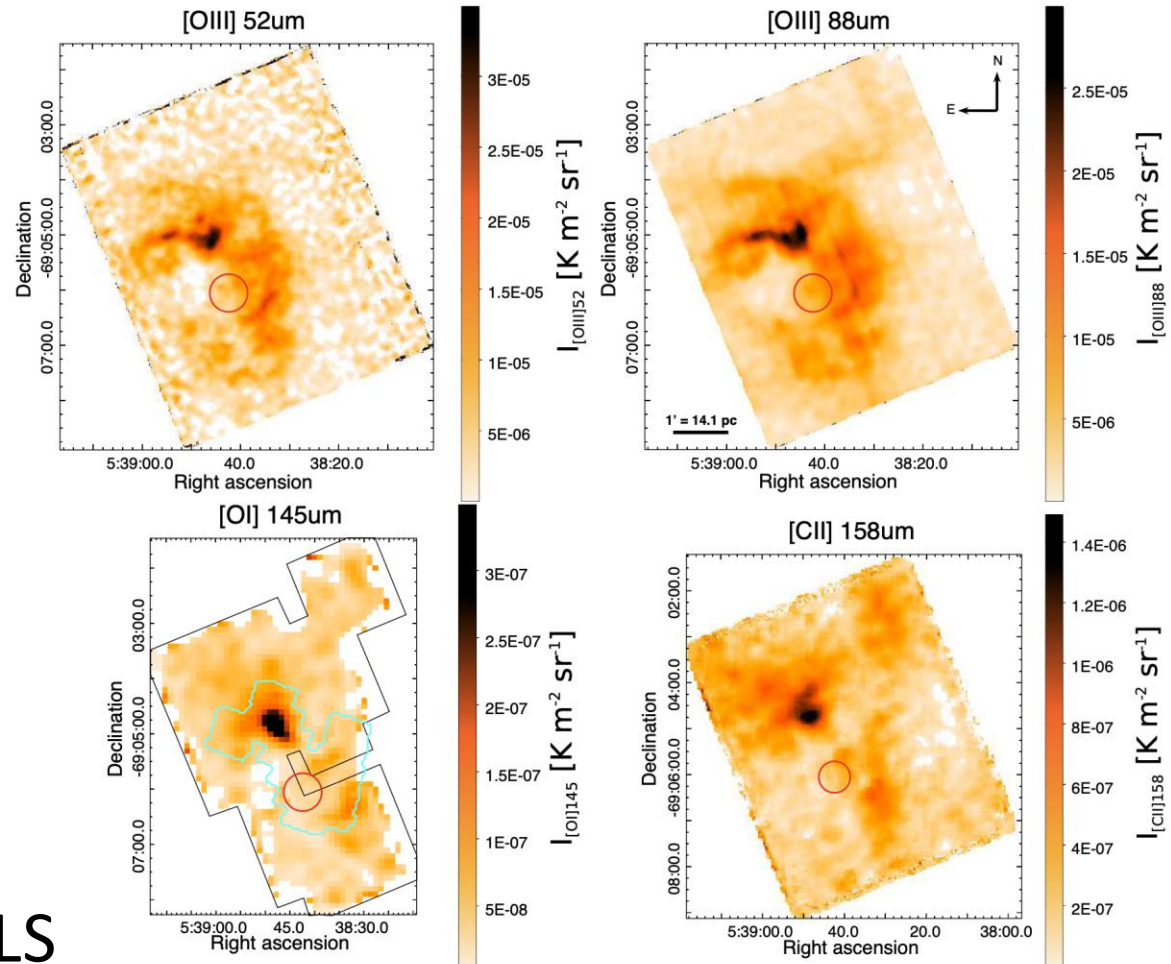
Alfred Krabbe
Margaret Meixner

SOFIA Users Group Meeting
November 4, 2022

The ISM is beautiful and mysterious: JWST images of 30 Doradus

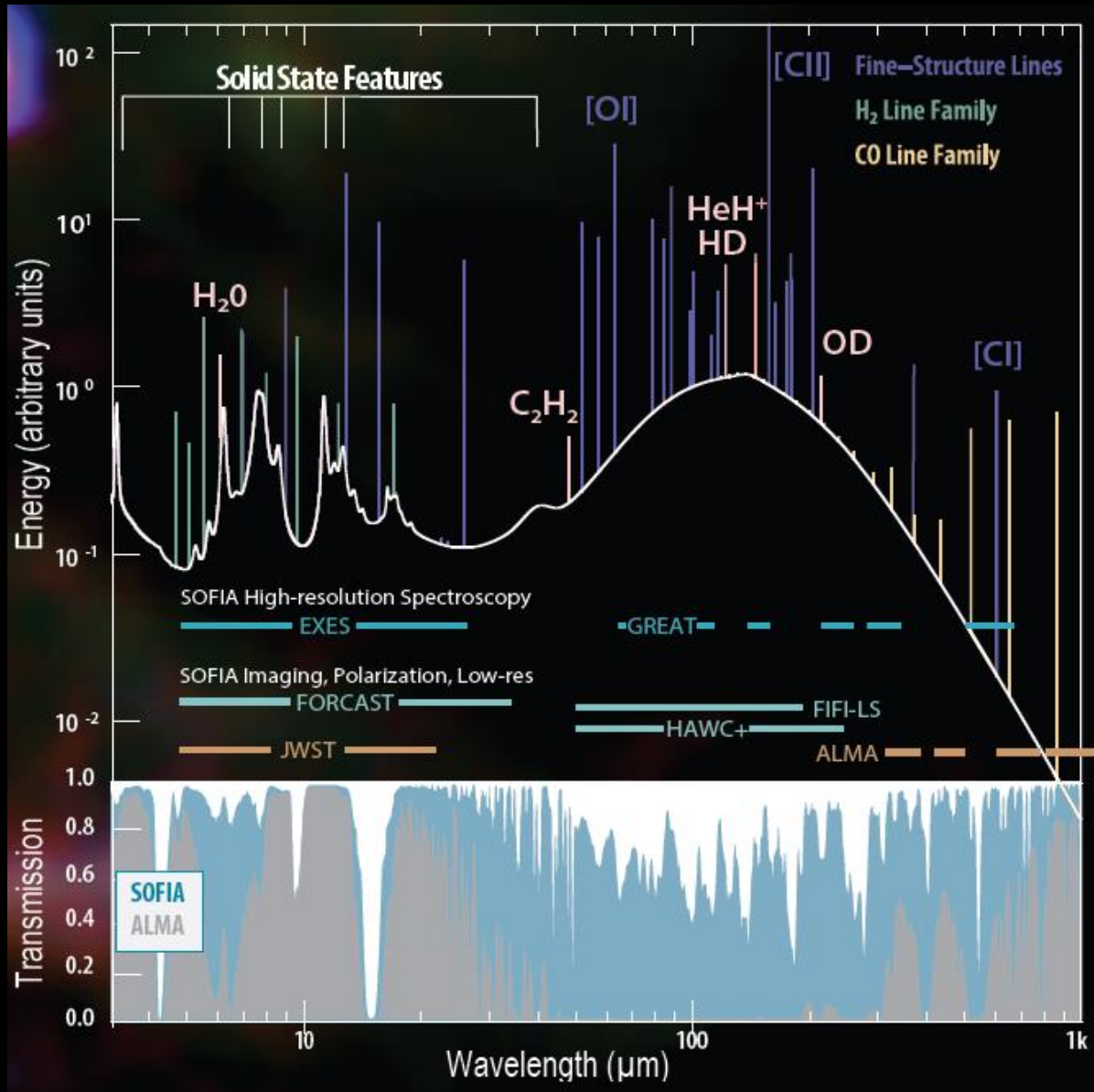


The ISM is beautiful and mysterious: SOFIA images of 30 Doradus



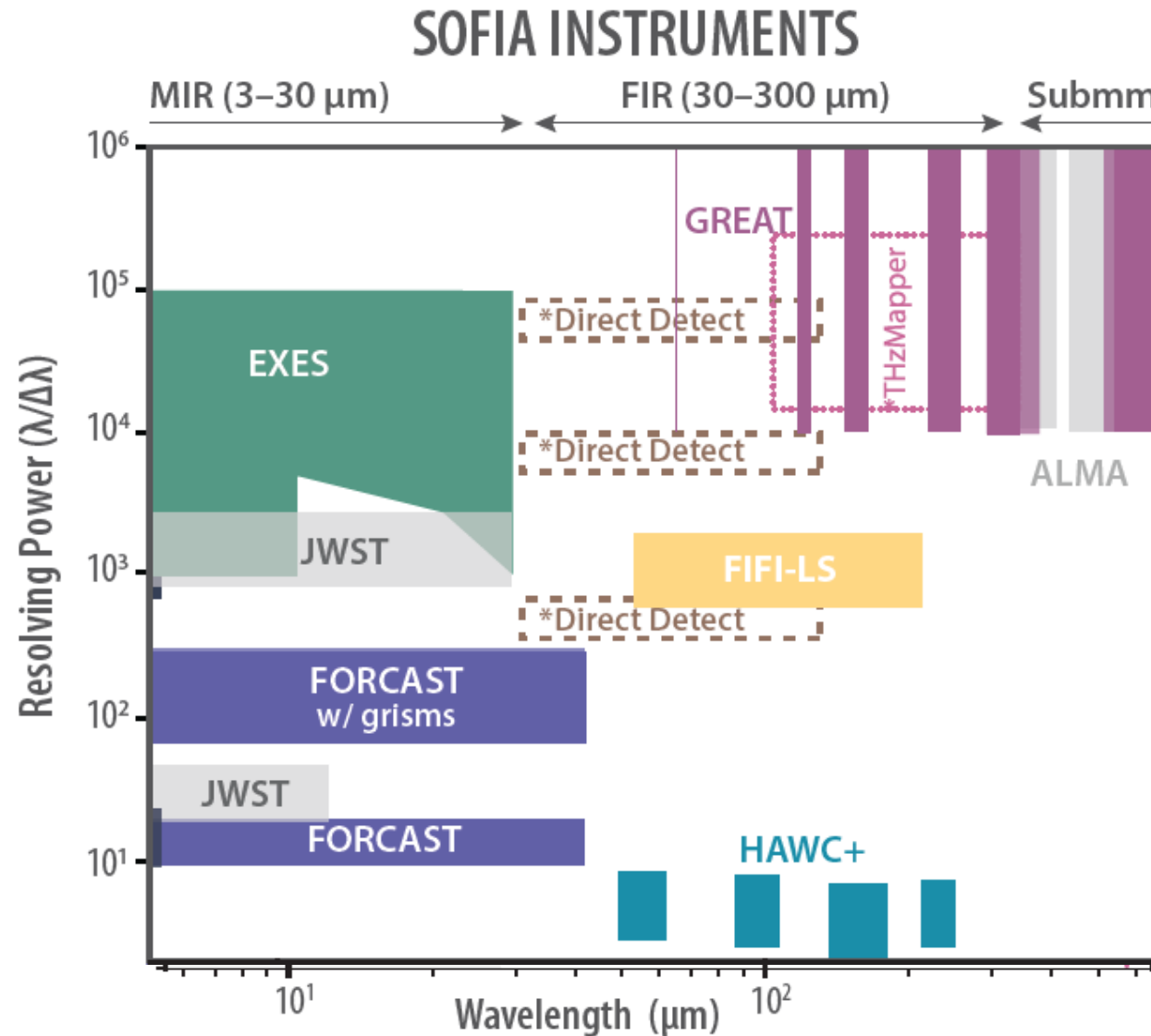
FIFI-LS

HAWC+



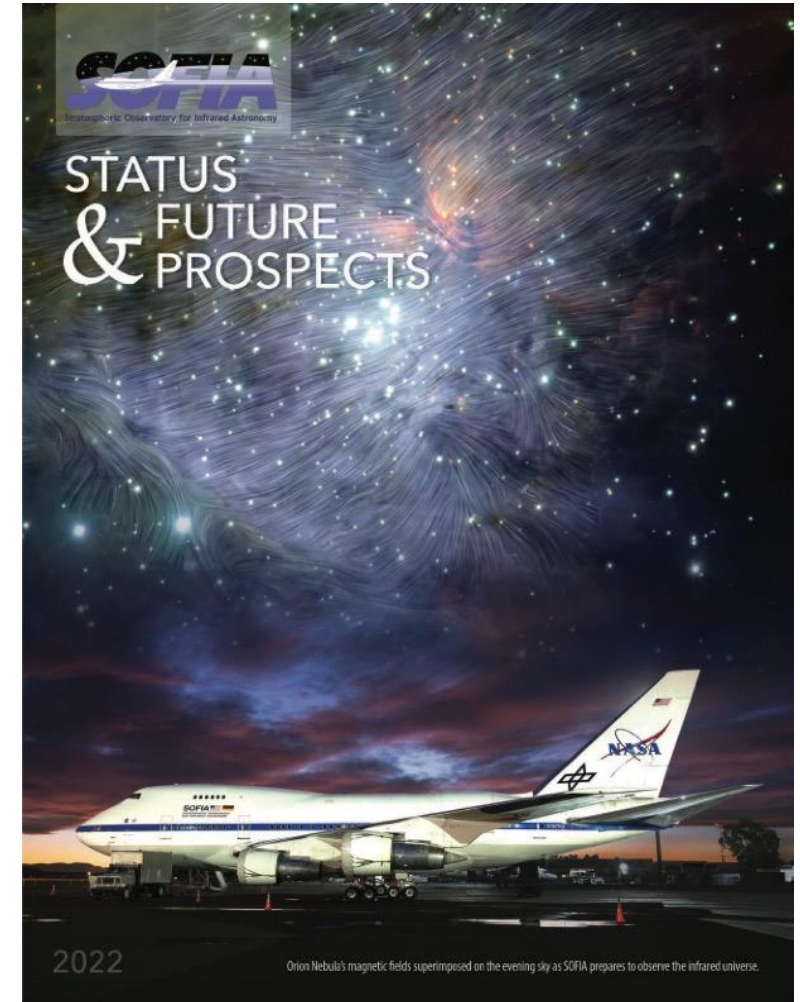
- ISM is an infrared, especially a FIR topic
- JWST and SOFIA are both needed to understand

SOFIA Instruments are Complementary to JWST and ALMA



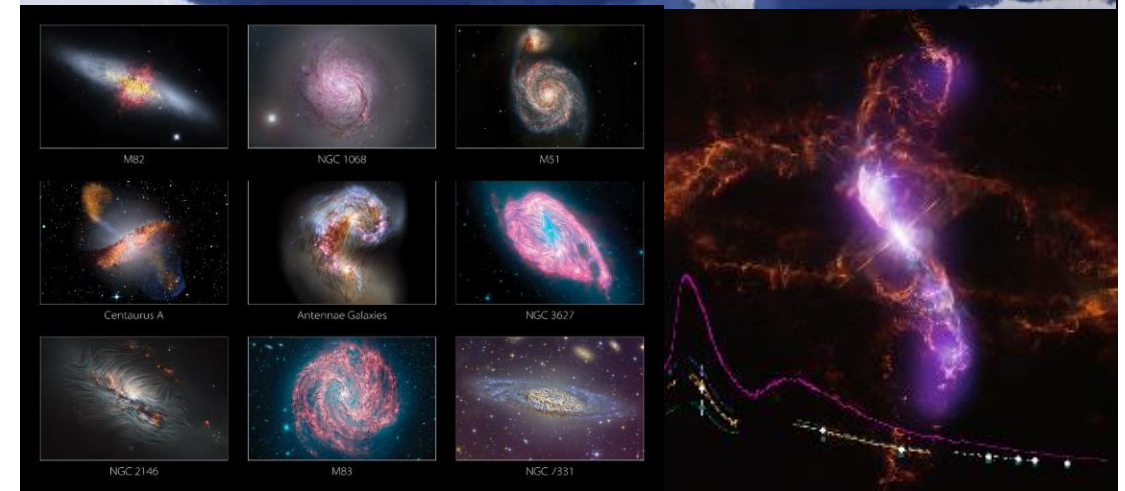
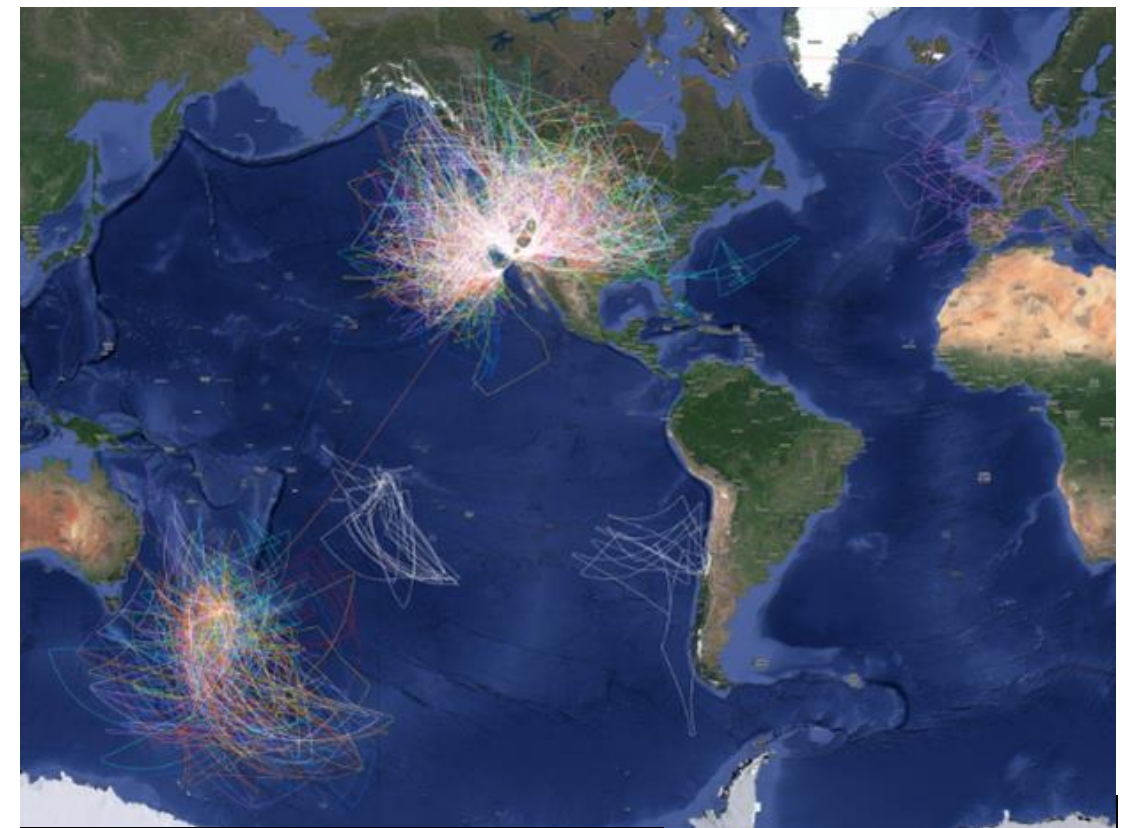
SOFIA: far-IR observatory for this decade

- SOFIA has transformed over the past 2 years, with tremendous growth in science productivity,
 - <https://www.sofia.usra.edu/SOFIA-Status-and-Future-Prospects>
- Annual publication rates for SOFIA have doubled over the past three years on topics ranging from the Earth to high-z galaxies.
 - <https://www.sofia.usra.edu/sites/default/files/2021-11/SOFIA-Science-2021.pdf>
- SOFIA advances Astro2020 science addressing **one half** of the decadal science priorities in all three science themes
 - Cosmic EcoSystems,
 - Worlds and Suns in Context,
 - New Messengers and New Physics.



SOFIA Finishes Strong!

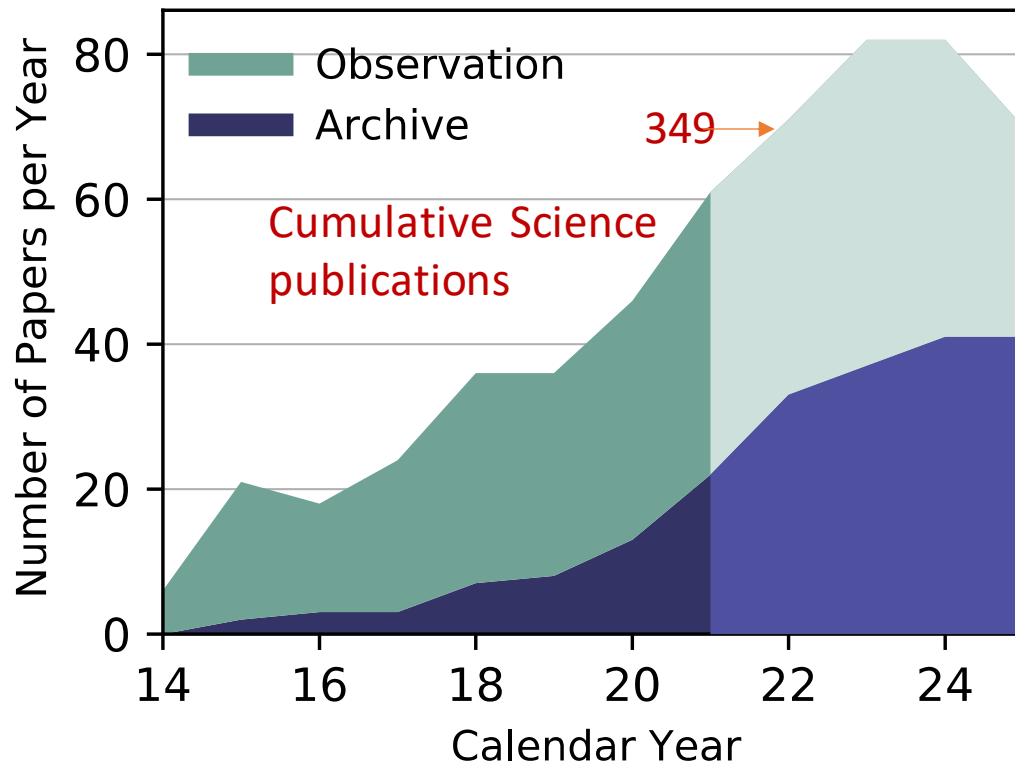
SOFIA Fiscal Year 2022 Metrics		
METRIC	TOTAL	Delta from FY21 / NOTES
Science Flights Offered	176	27% ↑ ; two southern deployments
Flown Science Flights	127	50% ↑
Flown Research Hours	1000	43 %↑
Science Programs Completed	>60%	Including Legacy programs
Publications	69	20%↑
Citations to SOFIA Papers	1276	28%↑
Archival Data Downloads (science community)	13,176 GB	
Press Releases / Media Stories	>50	
Community Outreach - Events	82	55% ↑; in the US and overseas both science and public
# Scientists Reached	>500	



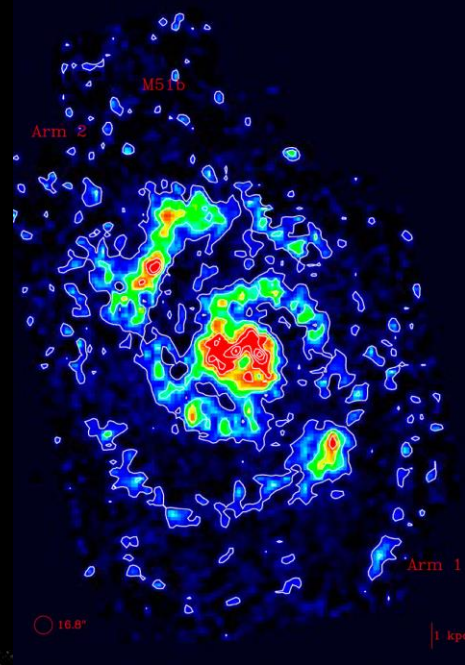
SOFIA vs. Space Missions



SOFIA Scientific Publications **513**



- SOFIA's science publications (330) are significantly higher than the science return from far-IR balloon programs (8).
- SOFIA has been compared to Hubble, a mature robotic space mission (~30 years) with a substantial archive.
- A better comparison is with Herschel, a recent far-IR mission that provided 23,500 hours and produced 2,145 publications within 8 years of launch.
- SOFIA has observed for 3,458 hours and produced 330 science publications within 8 years of science operations start.
- **SOFIA (10.5 hr/paper)** is the same as **Herschel (11 hr/paper)** in paper-writing efficiency.



SOFIA will live on in the Infrared Science Archive (IRSA)



<https://irsa.ipac.caltech.edu/Missions/sofia.html>

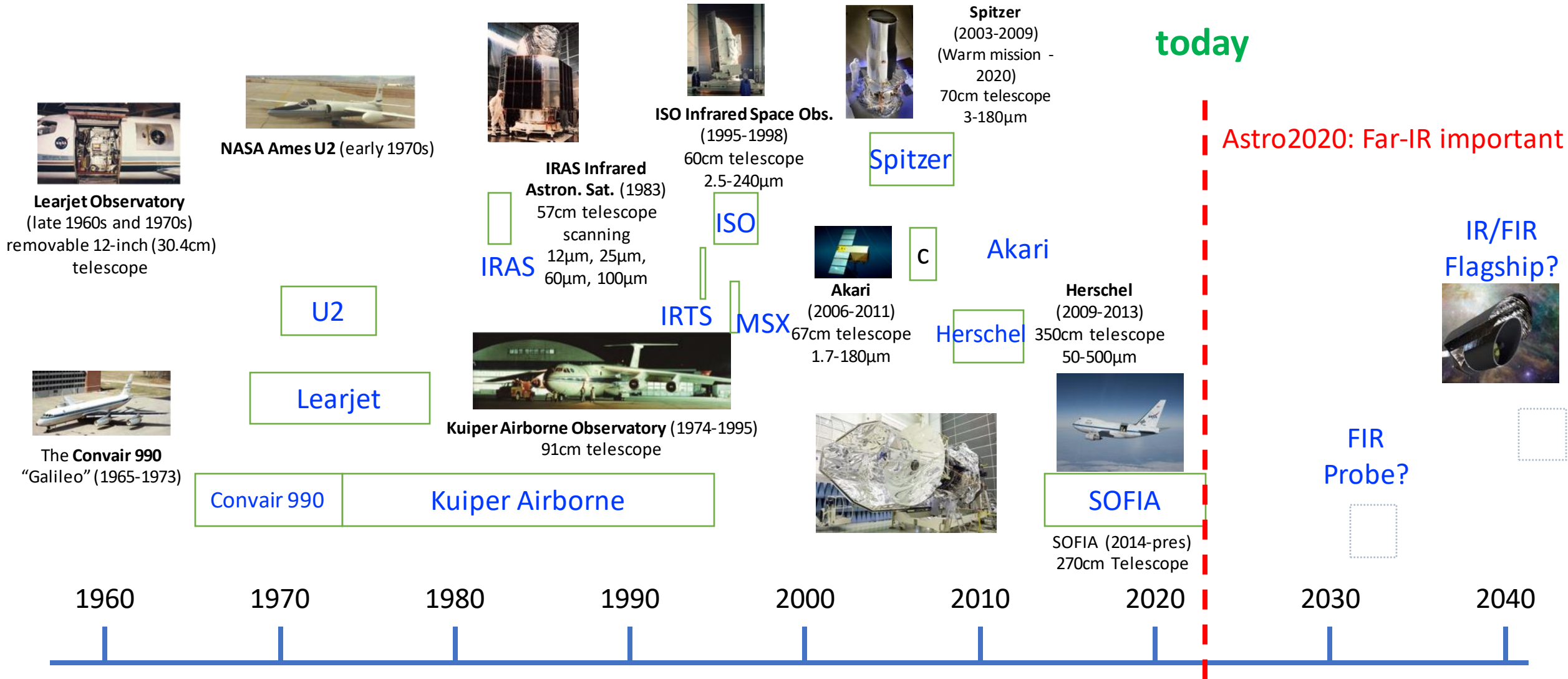
Far-Infrared

~~SOFIA~~ SCIENCE TRACEABILITY MATRIX

Decadal Science Questions [†]	Key Measurements	SOFIA Instruments	SOFIA Observations
HOW DID WE GET HERE? COSMIC ECOSYSTEMS			
F-Q1: How do star-forming structures arise from, and interact with, the diffuse interstellar medium?	[C II] 158 μ m, [O I] 63 & 145 μ m, light hydrides, kinematics & Far-IR polarimetry	GREAT, FIFI-LS, HAWC+, *THzMap	FEEDBACK, HyGal, LMC+, GalMag, C+SQUAD
F-Q2: What regulates the structure and motions within molecular clouds?	[C II] 158 μ m, light hydrides, Far-IR polarimetry at 0.1 pc	HAWC+, GREAT, *THz-Map	SIMPLIFI, GalCen, HyGal
F-Q3: How does gas flow from parsec scales down to proto-stars and their disks?	Far-IR polarimetry at 0.1 pc, Mid/Far-IR variability & high-res spectroscopy	HAWC+, EXES, GREAT, FORCAST, FIFI-LS, *DirectDet	FIELDMAPS, SIMPLIFI, HyGal
D-Q2: How do gas, metals, and dust flow into, through, and out of galaxies?	[C II] 158 μ m, light hydrides, [O III] 88 μ m, Far-IR polarimetry <200 pc	GREAT, FIFI-LS, HAWC+, *THzMap, *DirectDet	HyGal, GalMag, LMC+
D-Q4: How do the histories of galaxies and their dark matter halos shape their observable properties?	[C II] & [O III] in galaxies (< 200pc), [¹³ C II]	GREAT, FIFI-LS, *THzMap	M51, LMC+, Galaxies

https://www.sofia.usra.edu/sites/default/files/2022-01/SOFIA_Traceability_Matrix.pdf

Far-Infrared Astronomy Historically



Time Domain Astronomy

- A homework assignment for our field
- Our FIR missions have been short-lived (1 to 5 years) and time variable phenomena have not been thoroughly investigated
- SOFIA's longer life has opened this field some.
- Time domain measurements have been growing at other wavelengths
- What types of science can we support with time domain measurements in the FIR, e.g. a probe mission.

Time Domain Astronomy – with SOFIA

Examples of MIR/FIR time domain astronomy enabled by SOFIA

- Evolution of dust [formation] in novae (e.g. V5668 Sgr)
- Long term evolution in evolved stars (e.g. Sakurai's Object)
- Interacting binary events (e.g. R Aqr)
- Dust formation events in debris disks (e.g. HD 113766A)
- Disk response to high- and low-mass YSO accretion events (e.g. G358.93-0.030, S255, S255IR-NIR3, HOPS12, HPS 124, etc.)
- THz line spectroscopy of Solar System objects (especially comets)

Some Items Left on the Table

Some promising projects that were never fully realized

- The LMC+ Legacy program, proposed for 50h, achieved 15h limiting the area covered
- The Inner Galaxy Magnetic Field survey (GalMag/FIREPLACE), proposed for 73h achieved ~17h, acquiring one band, rather than two
- The two systematic cloud polarization surveys FIELDMAPS and SIMPLIFI requested 120h and achieved 66h limiting the total sample
- EXES never flew in a Southern Deployment, but had a very successful start of a Legacy program - including acquiring a full-spectral coverage high-resolution observation of IRC+10216.
- Potential synergies with JWST

Summary

- SOFIA is ending on a high note with peak performance in all areas.
 - <https://www.sofia.usra.edu/SOFIA-Status-and-Future-Prospects>
- SOFIA SMO team is amazing. They work hard and produce a lot for the resources at their disposal. Their dedication to the mission above and beyond.
- NASA has released a Draft AO for a Probe mission, either FIR or X-ray, SOFIA has set the stage for the next step in the FIR.
- Astro2020 outlines the need for a technology maturation plan for the next set of Great Observatories
- One of these Great Observatories is an IR/FIR observatory like the Origins Space Telescope mission concept
- The future is infrared bright for us!



SOFIA Deployment in Santiago, Chile March 2022