

# Science Progress at SOFIA SMO

Margaret Meixner, Director of SMO  
Bernhard Schulz, Deputy Director of SMO

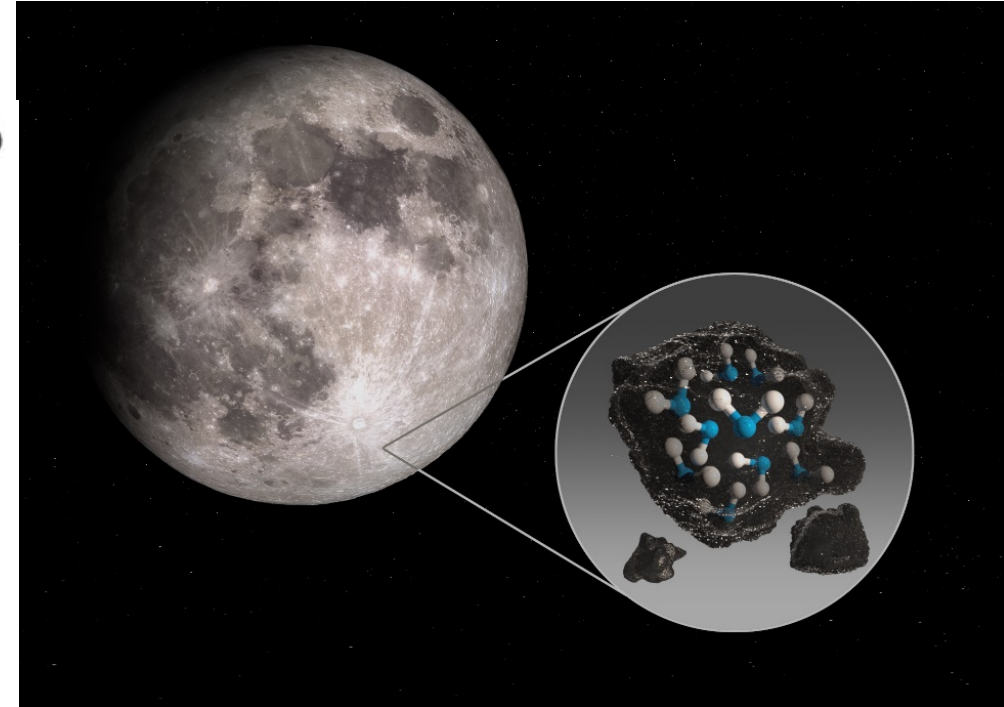
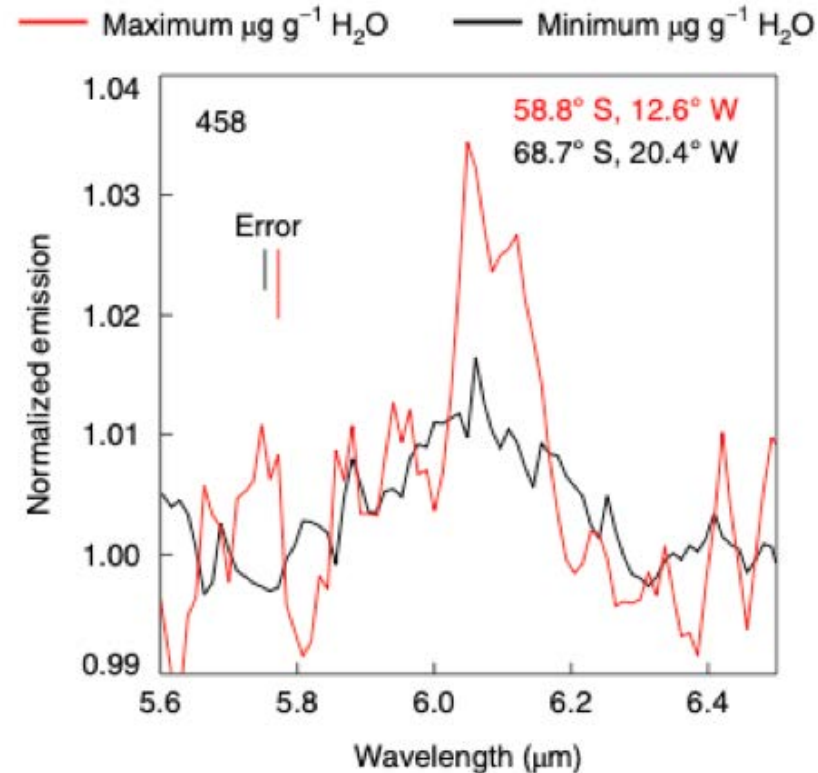
December 2020

# Outline

- Science Highlights
- SMO Strategic Response to FMR
- Science Community Engagement plan
  - US community
  - Germany community
- Summary

# Researchers using SOFIA have made the first-ever detection of the water molecule (H<sub>2</sub>O) on the sunlit surface of the Moon.

- This discovery refines our understanding of the behavior of water and how volatile elements and compounds interact with airless bodies.
- SOFIA targeted high lunar latitudes near the South Pole.
- It is the extreme sensitivity of SOFIA that allowed scientists to detect this miniscule amount of water, which is 100 times less than that in the Sahara Desert.



Paper: [Molecular water detected on the sunlit Moon by SOFIA](#)

C.I. Honniball, et al., Nature Astronomy 2020



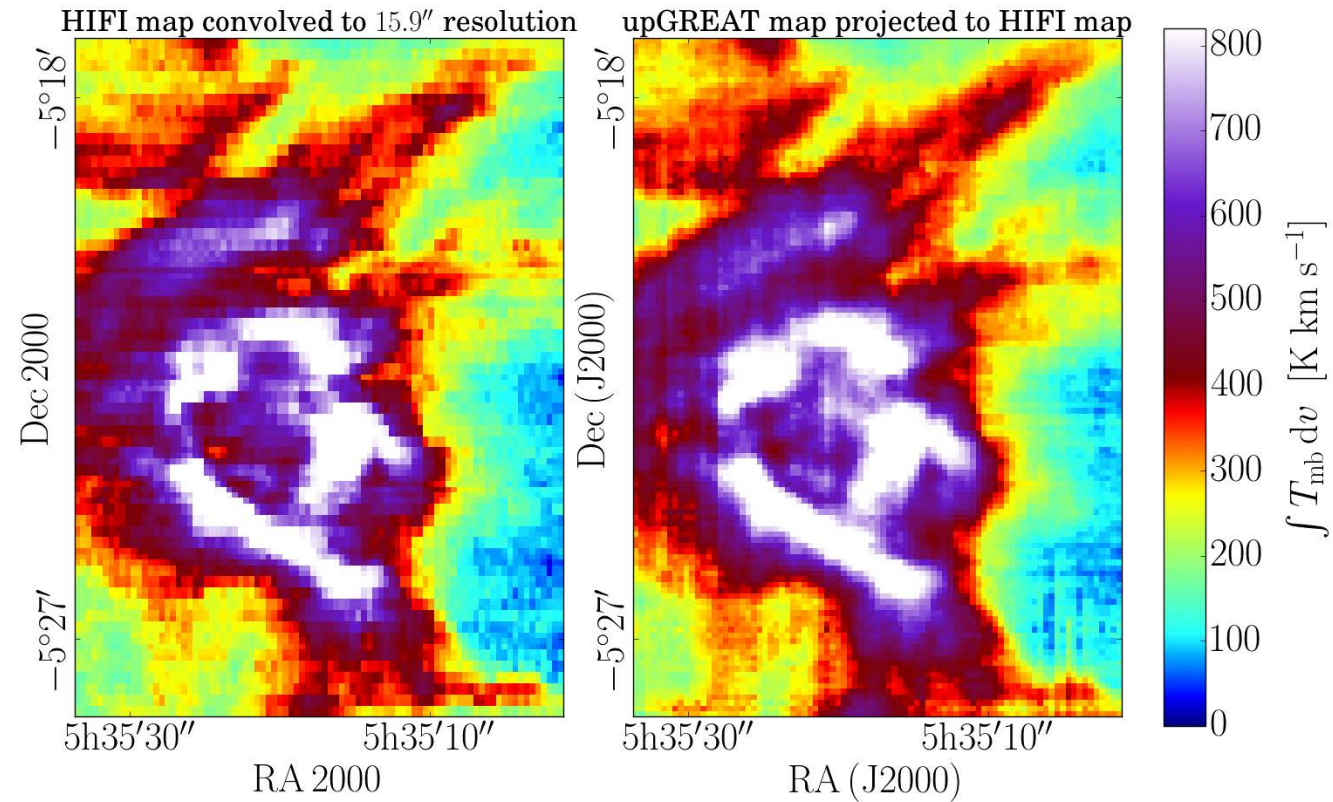
# SOFIA Legacy Programs: Galactic Center mapping



Courtesy of Matt Hankins

Hankins et al. 2020

# SOFIA's View of Orion

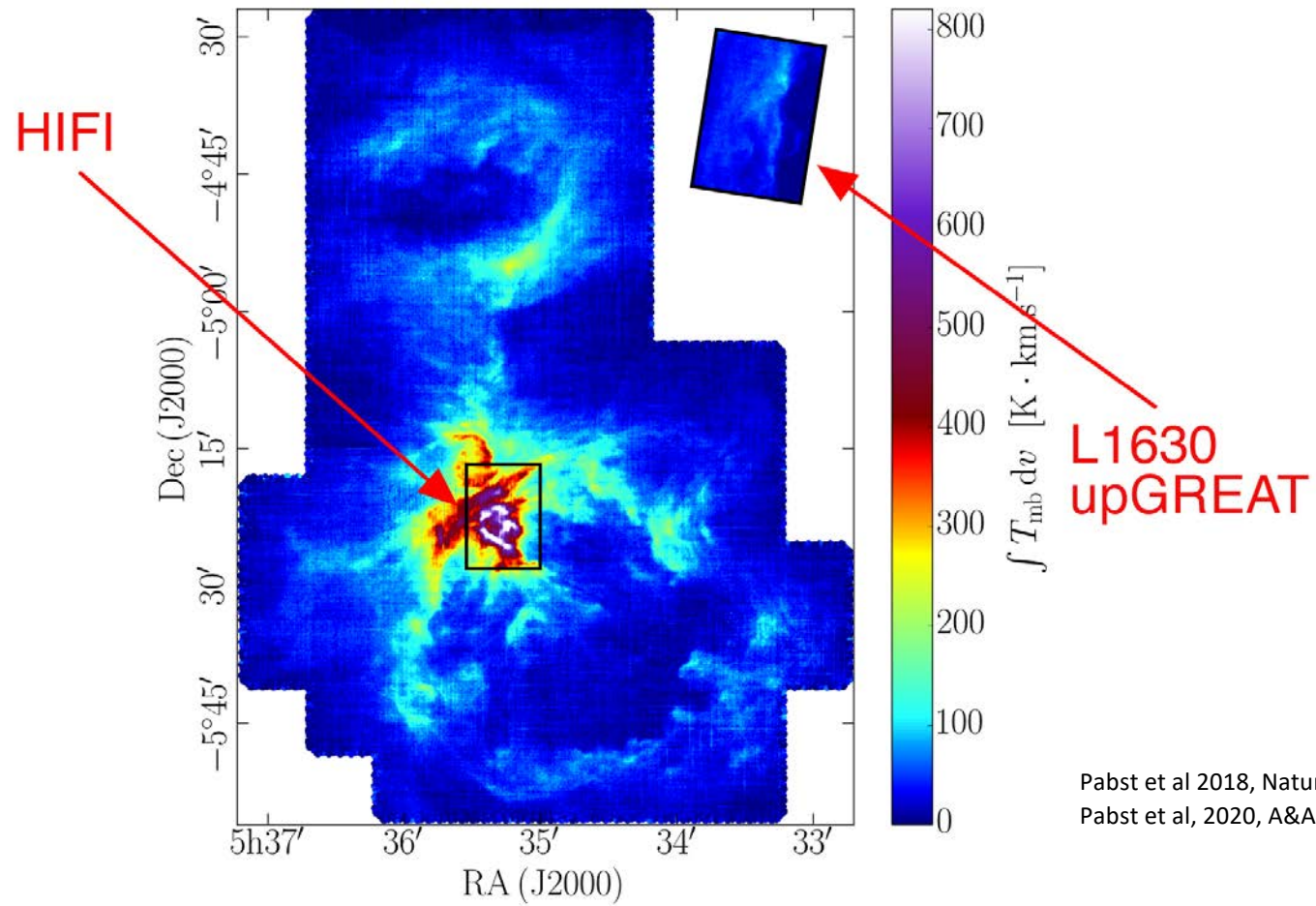


HIFI/Herschel  
9 Hours

upGREAT/SOFIA  
~35 minutes

Goicoechea et al, 2015, ApJ, 812, 75  
Higgins et al 2020, to be submitted

# SOFIA's View of Orion

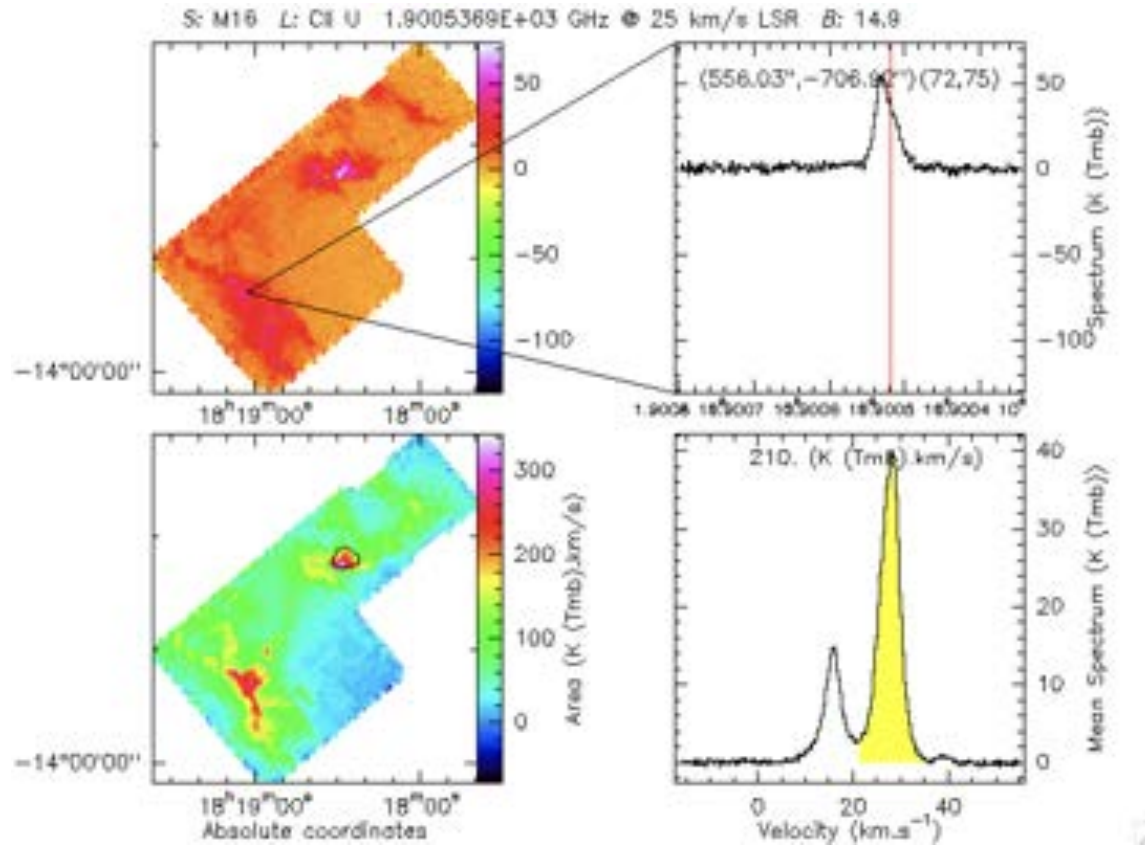


Pabst et al 2018, Nature, 565, 618  
Pabst et al, 2020, A&A, in press



# Legacy Program: FEEDBACK

M16 as observed so far

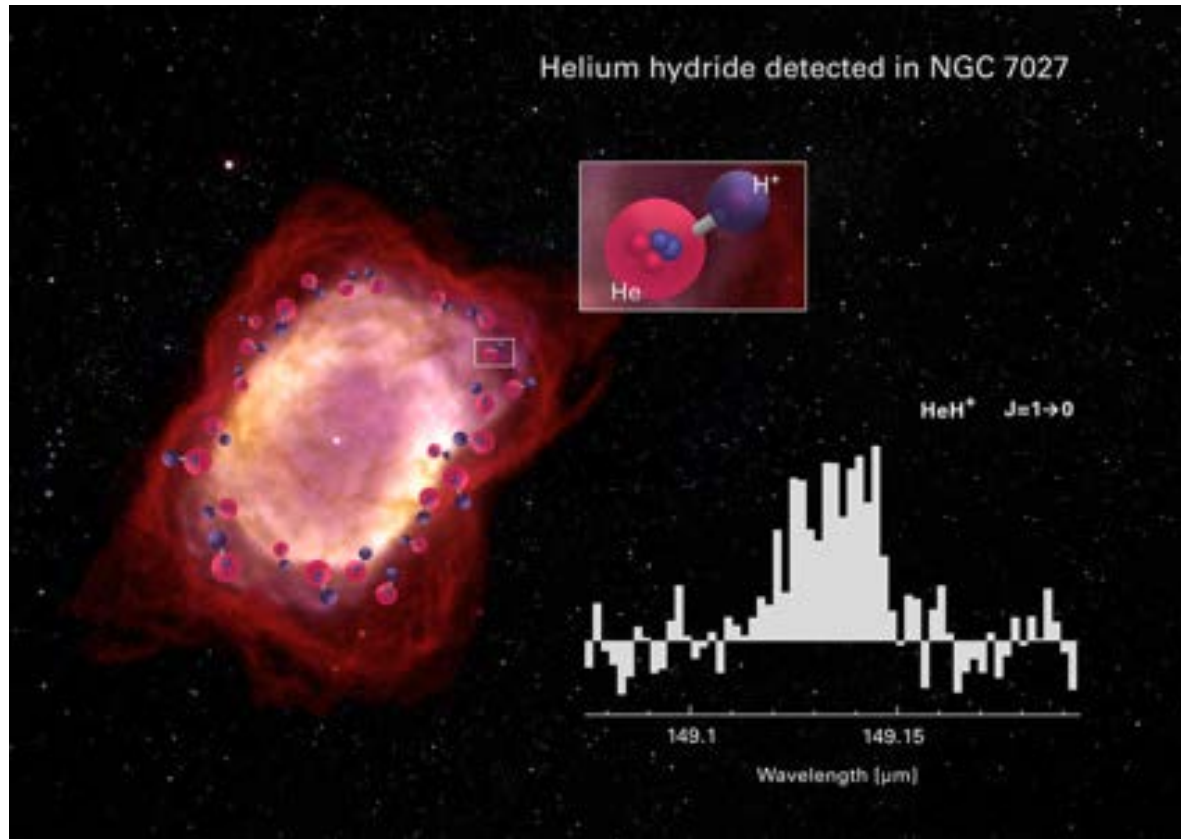


## Radiative and mechanical feedback in regions of massive star formation (FEEDBACK)

PIs: Tielens and Schneider (07\_0077)

- [CII] (and [OI]) data cubes of 11 prominent Galactic sources
- 6000 arcmin<sup>2</sup>
- 96 hours awarded, 33 observed
- Allows to study mechanical and radiative feedback of massive stars
- Orion [CII] was pilot in a sense

# First Detection of Helium Hydride in Space with GREAT



HeH<sup>+</sup> First molecule of different atoms that formed after the Big Bang

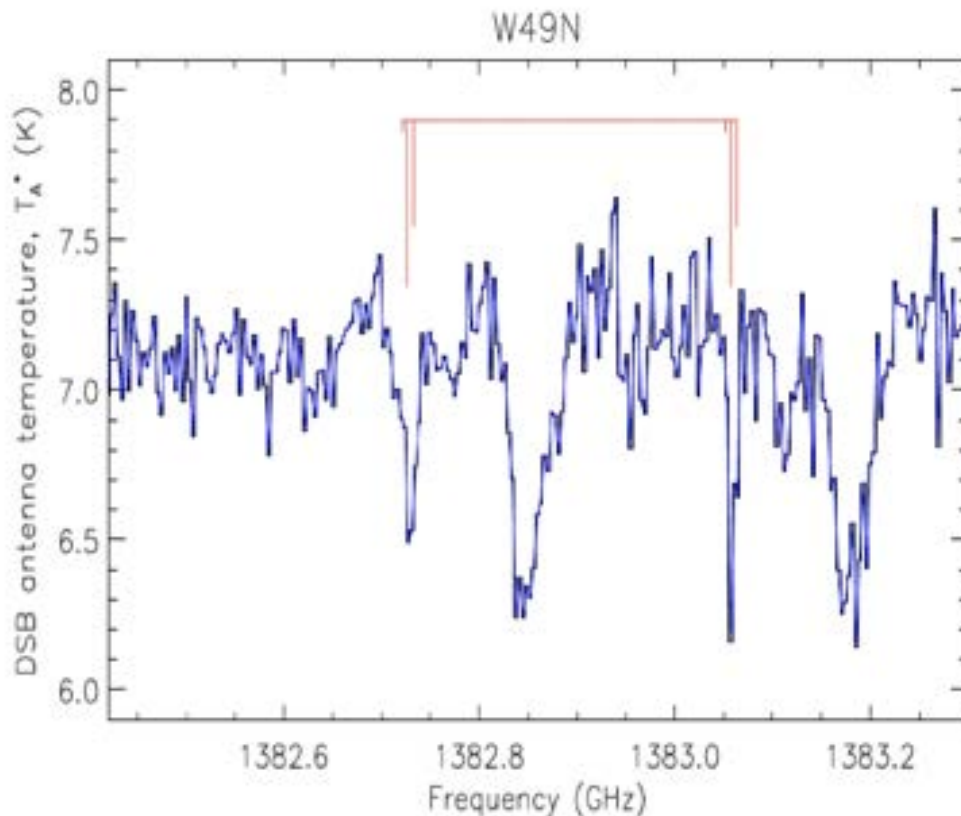
HeH<sup>+</sup> reacted then with neutral H providing pathway to H<sub>2</sub>

Conditions in planetary nebulae predicted to be right for its formation today

Line at 2.01 THz observed with GREAT



# Legacy Program: HyGal



SH in absorption with SOFIA (Neufeld et al. 2012 )

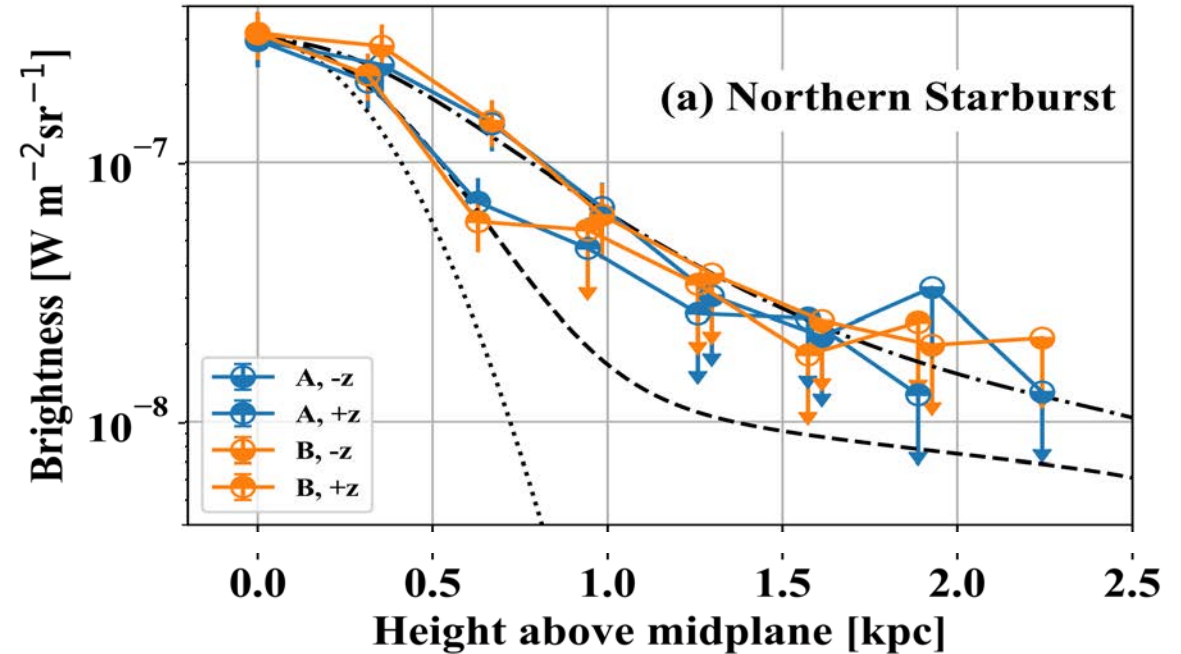
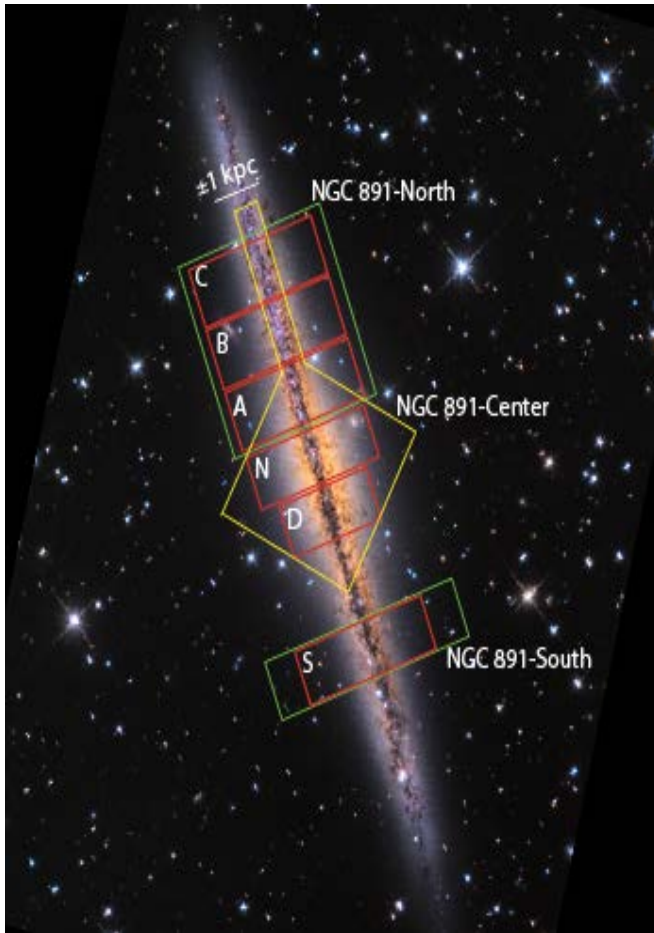
## Characterizing the Galactic Interstellar Medium with Hydrides (HyGAL)

PIs: Neufeld and Schilke (08\_0038)

- Absorption-line spectroscopy
- 22 sight lines in the Galactic plane
- Column densities of OH<sup>+</sup>, H<sub>2</sub>O<sup>+</sup>, ArH<sup>+</sup>, SH, OH and CH C<sup>+</sup> and O
- 82 hours awarded
- Distribution for the H<sub>2</sub> fraction
- Cosmic-ray ionization
- Characterization of ISM turbulence

# SOFIA's View of Galaxies

## Driving gas out of a galactic plane



**(Left)** A Visible-light image of NGC 891 with overlays showing the locations of the fields in which [C II] was observed with SOFIA/FIFI-LS (green boxes).

**(Above)** Vertical profiles of [C II] in NGC 891 at two locations in the Northern field observed by SOFIA/FIFI-LS. Dashed and dashed-dotted black lines shows the exponential scale-height model fits for the +z and -z directions.

# SOFIA's View of Galaxies



**Magnetic field alignment over an entire galaxy, NGC 1068**

Image credits: NASA/SOFIA; NASA/JPL-Caltech/Roma Tre Univ.



**Weighing a Galactic Wind Provides Clues to the Evolution of Galaxies**

Image credits: NASA/SOFIA; NASA/JPL-Caltech



# Magnetized gas flows feed a young star cluster

Cover of December Issue  
of Nature Astronomy



*Composite image of the Serpens South Cluster. Magnetic fields observed by SOFIA are shown as streamlines over an image from the Spitzer Space Telescope.*

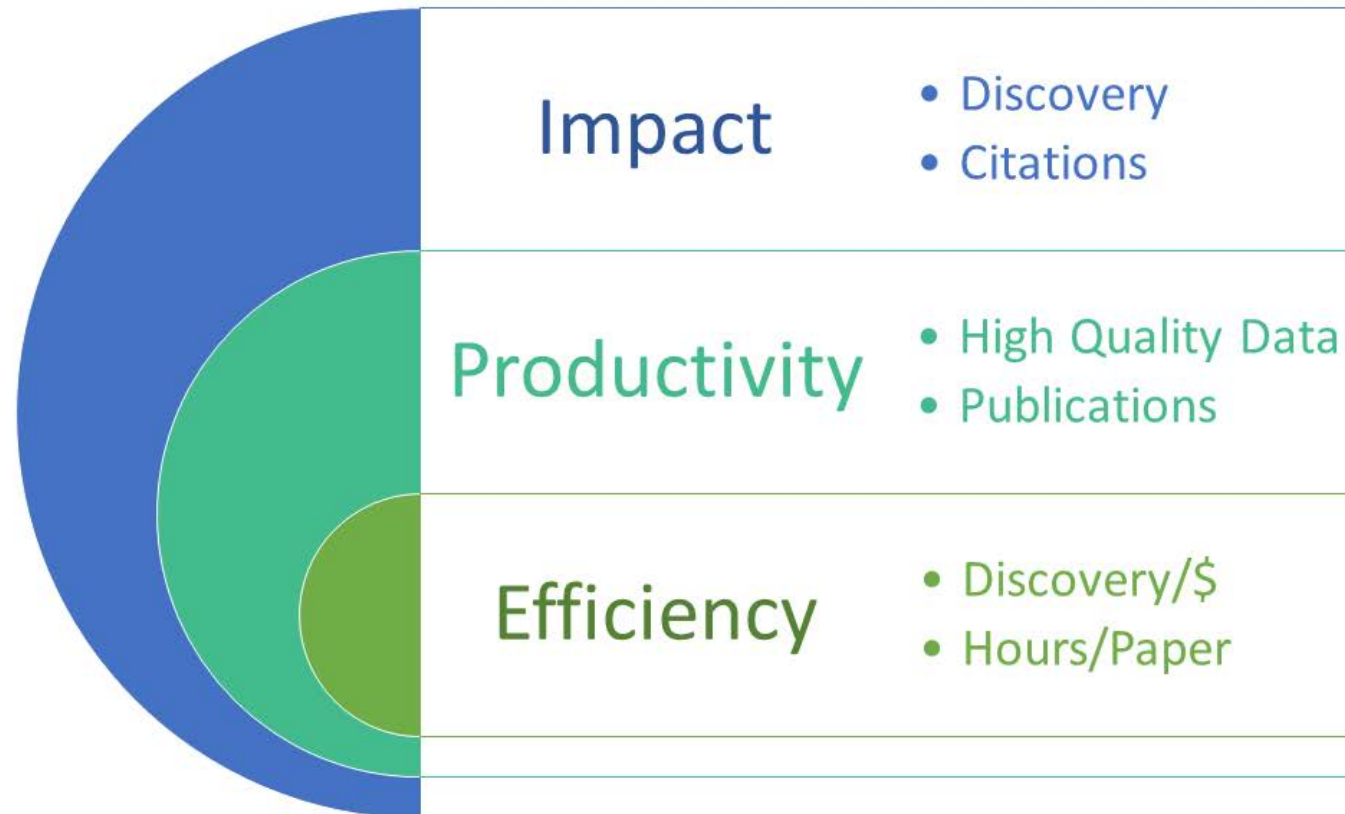
*Credit: NASA/SOFIA/T. Pillai/J. Kauffmann; NASA/JPL-Caltech/L. Allen*

- High spatial resolution polarimetric imaging of cloud filaments in Serpens South with HAWC+.
- Low-density gaseous filaments aligned parallel to magnetic field lines.
- High-density filaments aligned perpendicular to magnetic field lines.
- But, in some high-density filaments field lines align again parallel as gravity takes over, feeding matter to young stellar clusters.
- Spatial resolution an order of magnitude higher than Planck revealed this additional twist.
- SOFIA reveals the complex interplay between turbulence, gravity, and magnetic field.

Pillai et al., Nature Astronomy (17 August 2020)

# Strategic Themes





The SOFIA Science Leadership Team has developed a strategic plan with three major themes, each with several initiatives, to deliver on the SOFIA vision.



# Initiatives Dashboard: FY20 in Review







= COVID-19 Impact

Initiatives	Q1	Q3	Q4 Update	ETC
A – Legacy 	Green	Green	We did get some Legacy data in Cycle 8 and are on track for Cycle 9 this is close to GREEN	3/21
B – Optimize Data Quality	Green	Green	Implemented more rigorous post-TAC technical reviews	4/21
C – Optimize Proposal Selection	Green	Green	Implemented Dual Anonymous Review; used USPRITE TAC software system to minimize errors, German TAC used Google Docs to streamline voting and observer feedback editing.	COMPLETE
D – Fly more in Southern Hemisphere  	Green	Yellow	FY20 New Zealand deployment was cancelled; however, we have added extra deployment to FY21 (March)	2/21
E – Science Culture 	Green	Green	Exploring cloud solution to improve scientific computing	9/21
F – Increase Science Time	Green	Green	Hiring 3 new instrument scientists	3/21
G – Strategic Instrument Planning	Yellow	Yellow	Instrument Roadmap Complete	COMPLETE
H – Friend of the Project	Green	Green	Continue to work with guest observers	COMPLETE
I – Carry Over Policies	Green	Green	Decision has been made and implemented to keep all accepted proposals live for 2 years for scheduling	COMPLETE
J – Pipeline	Green	Green	Approved to apply for open-source license; several new tools developed for FORCAST, support for HAWC+ Band B filter	9/21



# Initiatives Dashboard – FY20 In Review (cont.)

 = COVID-19 Impact

Initiatives	Q1	Q2	Q3	Q4	ETC
K – Increase Postdocs and Students				2 new postdocs have been onboarded and 3 more will be hired	9/21
L – Optimize SI Operations				Cycle 9 designed to minimize SI swaps; SI Decommissioning in the SI Roadmap	2/21
M – Strategic Partnerships				HST Programs will be implemented soon, Unilaterally offered Cycle 9 time to support JWST	3/21
N – Automation				Successfully being implemented across multiple functional areas – see initiative slide for details	9/21
O – Cross training 				Training continuing but limited due to COVID-19 operational restrictions	9/21
P – Learning from other Observatories 				Dual anonymous review training with HST and NASA HQ – <b>this is becoming a continuous improvement initiative</b>	9/21
Q – Staff Feedback				Multiple initiatives sourced from staff, developed into proposals, and submitted to NASA as work packages which will result in improvements to the observatory	COMPLETE
R – Evaluate Alternative Flight Cadences				This was completed in Q2	COMPLETE
S – Breaking down Stove Pipe 				Increased integration between SMO and DSI in meetings – <b>this is becoming a continuous improvement initiative</b>	9/21

# Science Metrics Goals by 2022 Table from FMR Response

Table 1.4 – SOFIA Key Metrics and Goals

SCIENCE METRIC	GOAL
Publications per year:	> 75 (100)*
Scientific Impact Citation H-Index <sup>2</sup> :	> 30 (44)*
Oversubscription Rate <sup>3</sup> :	≥ 5
Data Processing and Archiving Time:	15 workdays
Completion Rate for High-Priority Programs <sup>4</sup> :	≥ 80%
Fraction of Completed High-Priority Programs Resulting in Publications <sup>5</sup> :	≥ 80%
High-Quality Observing Time:	≥ 90%
% research hours <sup>6</sup> at precipitable water vapor < 15 μm	≥ 90%
% on-sky efficiency <sup>7</sup> at precipitable water vapor < 15 μm	≥ 90%

\* stretch goals are in parentheses

# Science Metrics Goals by 2022 Table from FMR response

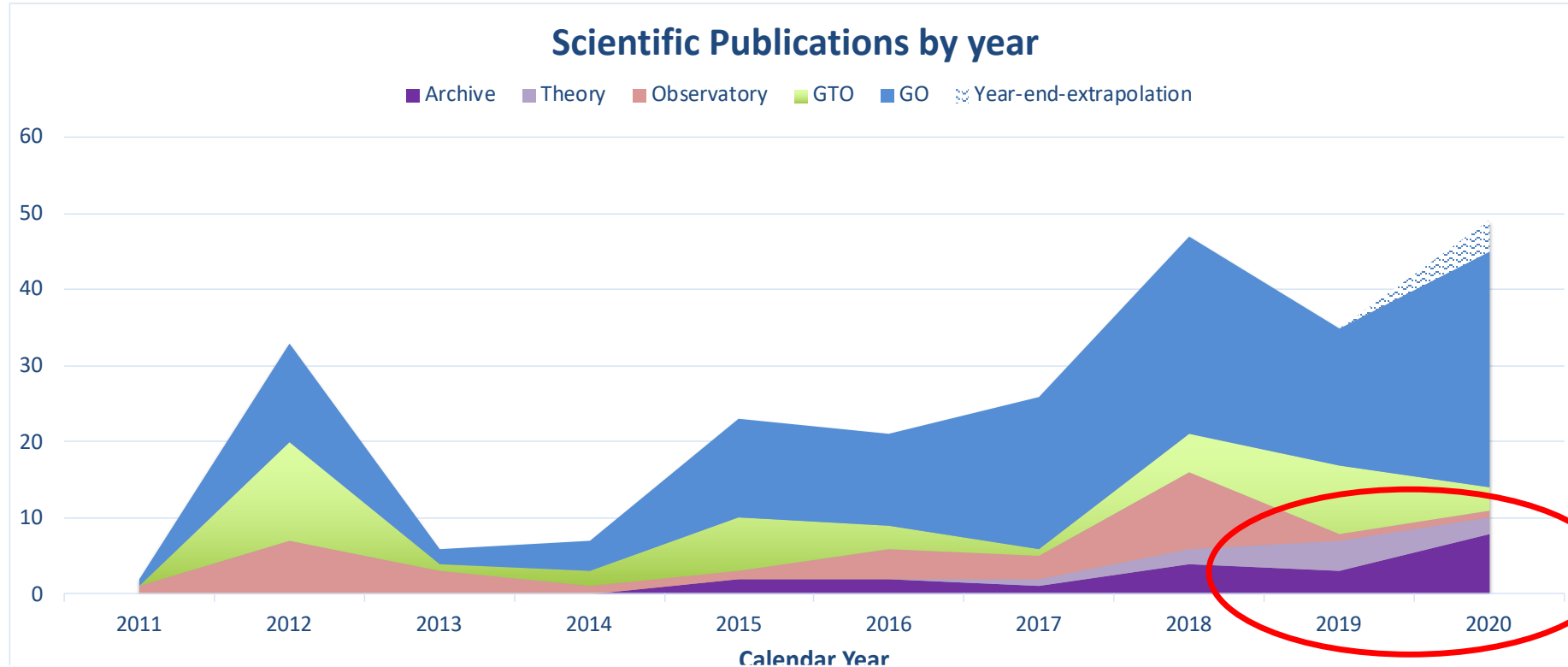
Table 1.4 – SOFIA Key Metrics and Goals

SCIENCE METRIC	GOAL	Current
Publications per year:	> 75 (100)*	43 (FY20), >49 (2020)
Scientific Impact Citation H-Index <sup>2</sup> :	> 30 (44)*	23
Oversubscription Rate <sup>3</sup> :	≥ 5	6.6 time Cy8
Data Processing and Archiving Time:	15 workdays	15 days for 20% data Goal is for 70% of data
Completion Rate for High-Priority Programs <sup>4</sup> :	≥ 80%	68% Cycle 7
Fraction of Completed High-Priority Programs Resulting in Publications <sup>5</sup> :	≥ 80%	32% Cy5; 52% Cy4; 71% Cy2
High-Quality Observing Time:		On target
% research hours <sup>6</sup> at precipitable water vapor < 15 μm	≥ 90%	
% on-sky efficiency <sup>7</sup> at precipitable water vapor < 15 μm	≥ 90%	

\* stretch goals are in parentheses

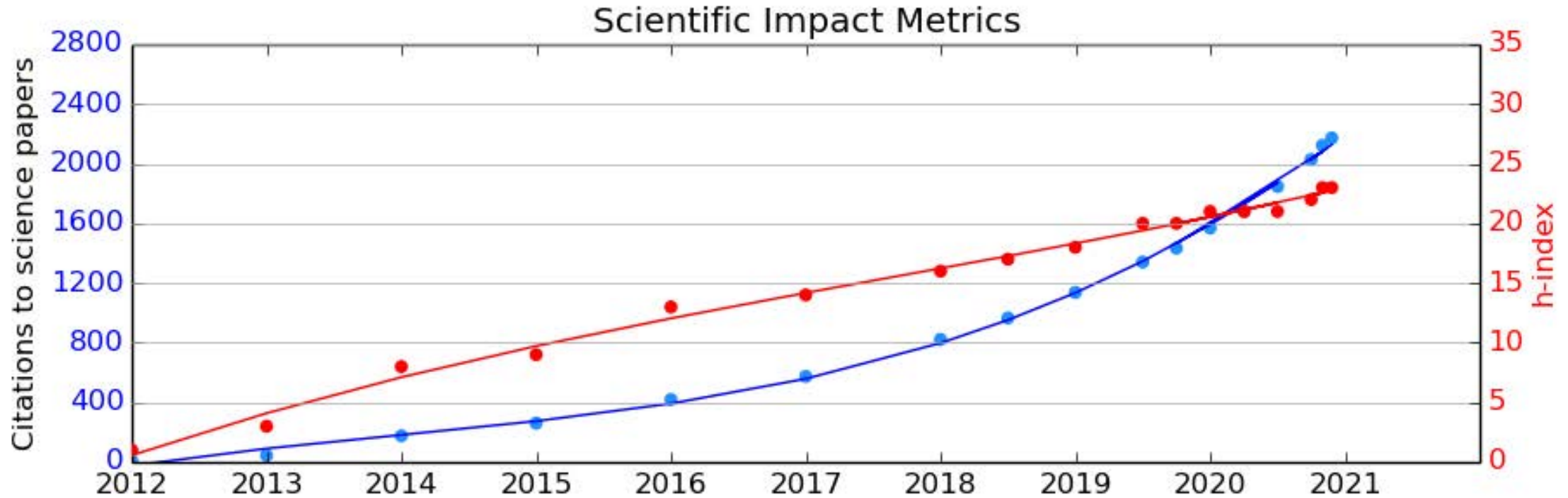


# Science Metrics: Publications by Calendar Year



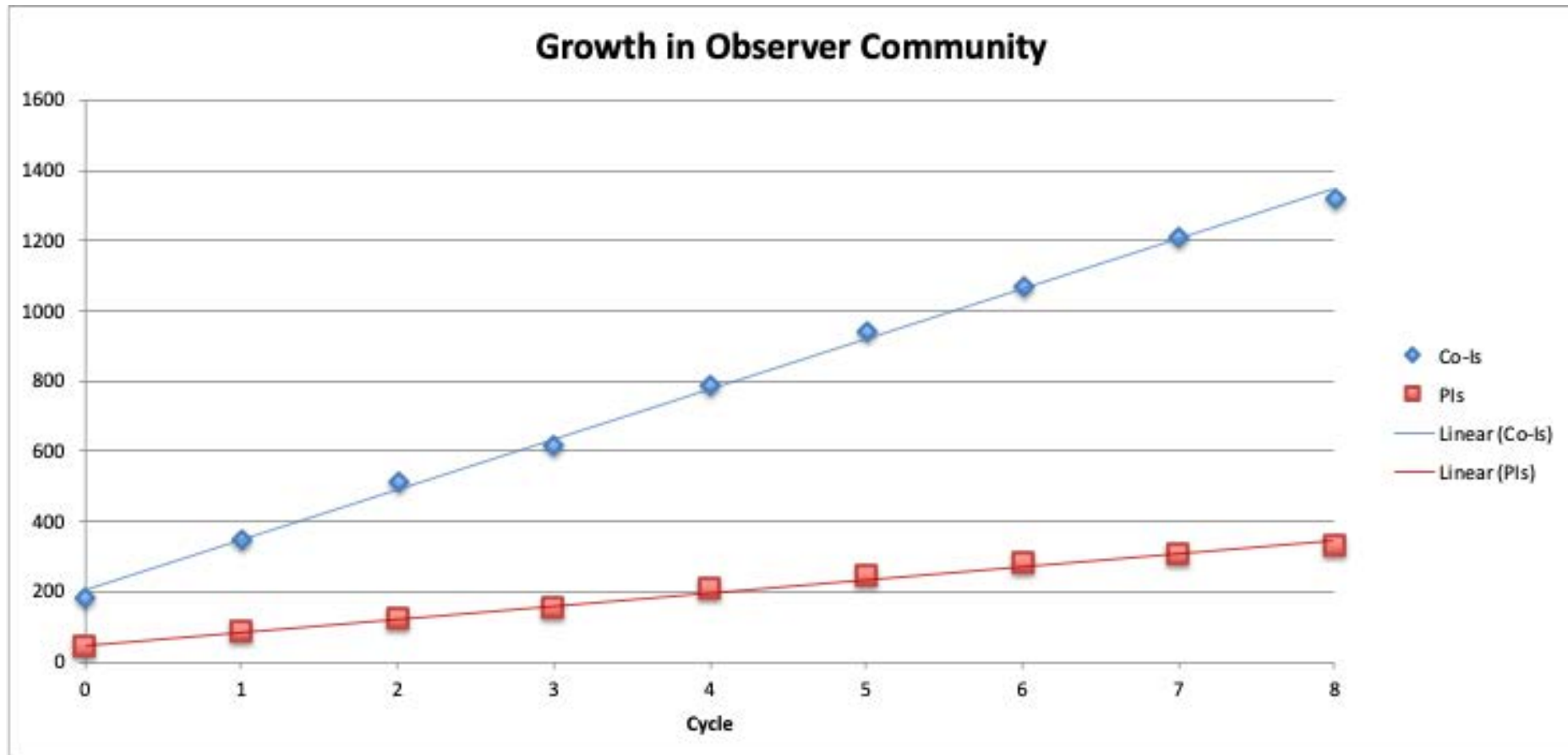
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	sum
Archive	0	0	0	0	2	2	1	4	3	8		20
Theory	0	0	0	0	0	0	1	2	4	2		9
GO	1	13	2	4	13	12	20	26	18	31		140
GTO	0	13	1	2	7	3	1	5	9	3		44
Observatory	1	7	3	1	1	4	3	10	1	1		30
Year-end-extrapolation										4	0.0	
sum	2	33	6	7	23	21	26	47	35	49		234

# Science Metrics: Impact



	1/1/12	1/1/13	1/1/14	1/1/15	1/1/16	1/1/17	1/1/18	1/1/19	1/1/20	3/30/20	6/30/20	11/25/20
Citations	8	45	176	261	419	574	822	1137	1569	1669	1812	2173
h-index	1	3	8	9	13	14	16	18	21	21	21	23

# Unique PI's and Co-I's have increased



# SMO Community Engagement: Core Duties

- Communications
    - E newsletter, print newsletter
    - Promote SOFIA news
    - website
  - Program Selection
    - Issue call for proposals
    - Time allocation committee process
    - Selection process
  - Science Events:
    - SOFIA presence at AAS meetings
    - Colloquium series, SOFIA teletalks
  - User Support:
    - handbooks, cookbooks, tutorials, helpdesk
- User Support:



# German SMO Participation

- DSI Telescope Maintenance
- FIFI-LS Instrument Scientists
- **Deputy SMO Director**
  - More a German Co-Director
  - Real deputy role infeasible in current NASA/USRA setup
- **Yearly Call for Proposals**
  - Assist preparing US and German calls
  - Selection official for German science program
  - TCX Process at DSI
  - Creation of combined SOFIA obs. program
  - Monitoring of program execution
- **Strategic and management advice to SMO**
  - Strategic FMR Response Plan
  - Observatory Initiatives “Pitches”
  - Instrument Roadmap Preparation
  - Future of GREAT plan
- **Liaison**
  - DSI and SMO
  - DLR and SMO
  - German scientific community
  - GSSWG
  - talks at institutes
  - Instrument PI teams
- **Science Outreach**
  - Scientific consultation for German outreach team

# German Future Initiatives

- Increase German User Base
  - make SOFIA better known through talks
  - Highlight SOFIA publications through scientific outreach
  - Increase publication rate
  - Potential German archive call
- Proposed Plan for GREAT Future on SOFIA
  - Compensate ramp down of GREAT personnel in Sep. 2022
  - Hire 2 Instr. hardware specialists in Apr. 2021 for training with GREAT team
  - Provide 3 SMO instrument scientists
  - Preliminary planning horizon is end 2023
  - Goal to ensure continued GREAT operation until 2026+
- German Instrumentation Funding for SOFIA
  - DFG and MPG main sources of instrument funding
  - MoU between DLR and NASA limited typically to 4 years
  - NASA 3 year Senior Review cycle incompatible with 5-6 year time frame needed to build and use a new instrument
  - German funding agencies ask for assurances about investment return
  - NASA Instrument roadmap and investments in SOFIA future could help change the perception on German side
  - Instrument roadmap suggests only one instrument taken on by NASA with either coherent or incoherent detectors
  - A German funded second instrument in 2026 timeframe very desirable

# Goal for FY21: To grow and diversify the SOFIA community

- Increase Archival Research Productivity
  - US SOFIA archival research call released Dec. 4
  - Deadline Feb. 12
    - <https://www.sofia.usra.edu/science/announcements/funding-available-archival-research>
- Host 3 Virtual Science workshops
  - March 2021: "Solids in the Solar System"
  - Magnetic fields, spiral galaxy structure, post-main sequence evolution
  - Legacy program oriented workshops
- Large SOFIA Science Conference
- Collaboration with other observatories: GBT, HST, ALMA, JWST
- Summer school in Far-infrared Astronomy

# Archival Inventory

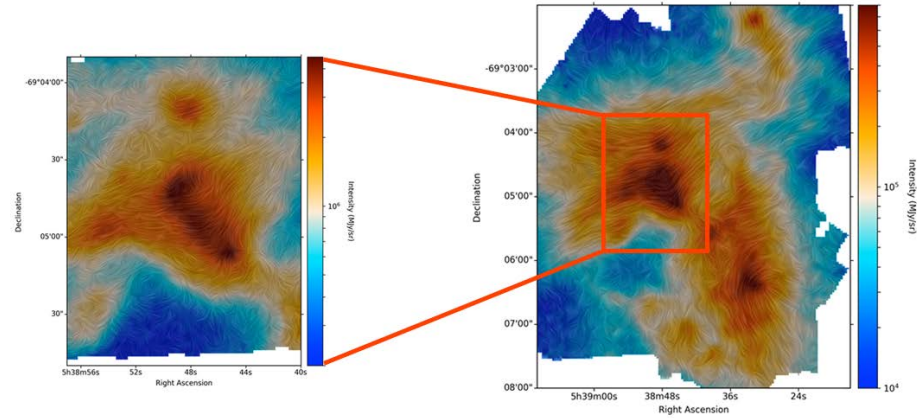
- Science Operations have assessed the current SOFIA data archive
  - A large number of high-quality yet unpublished data sets are available now to the community.
  - Several large, underutilized data sets also exist, which have had one or two publications, but have the potential to feature in many other papers using different analyses to solve different problems.
- These high-quality archival data sets can be found at:  
<https://www.sofia.usra.edu/science/data/selected-highlights-data-archive>
- We feature one of these datasets in each of our newsletters.



# Example Archival Datasets

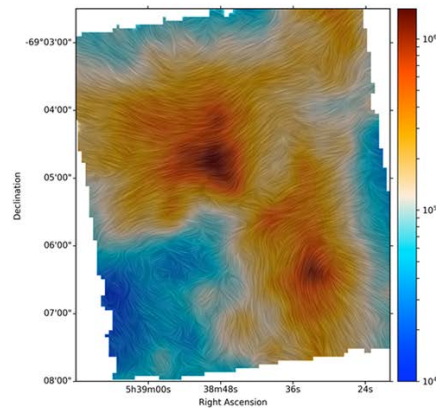
## HAWC+ Polarimetry of 30 Doradus

- Polarization maps of the high-mass star cluster 30 Doradus in the Large Magellanic Cloud at four far-infrared wavelengths.

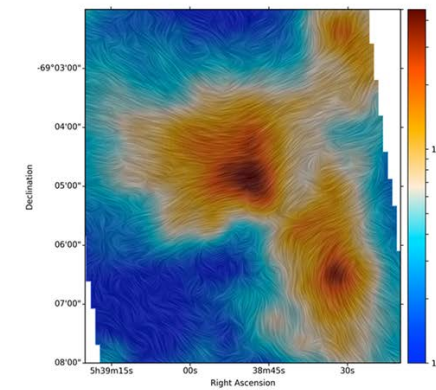


53 microns

89 microns



154 microns



214 microns

# SMO Ingredients for a Successful Senior Review

- Focus on Science, Science and Science
- Increase postdocs at SMO to improve publications, connection to science community, improve science driven culture
- Increase community engagement: virtual workshops, conferences
- Increase archival publications: Cycle 9 archival call
- A strong US and German partnership based on mutual trust