SOFIA Science Status

Erick Young
SOFIA Science Mission Operations

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Anchorage, Alaska
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Agenda

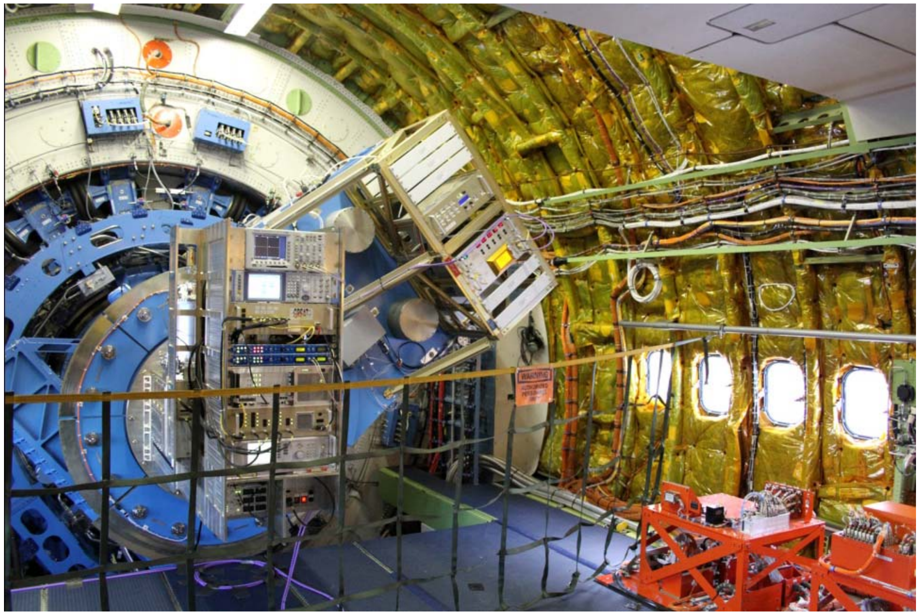
- SOFIA Early Science Highlights
- Cycle 1 Call for Proposals

Early Science Motivation

- SOFIA Early Science was conducted over roughly the previous year prior to completion of all the observatory systems
- Demonstrate of the interactions between instrument teams, observatory, and astronomical community
  - Essentially a dry run of Normal Operations
- Provide a sample of the kinds of science that would be possible with SOFIA
- Generate good will with community
  - While none of the early flights were completely trouble free, but we learned a huge amount that informed the development leading to full operations

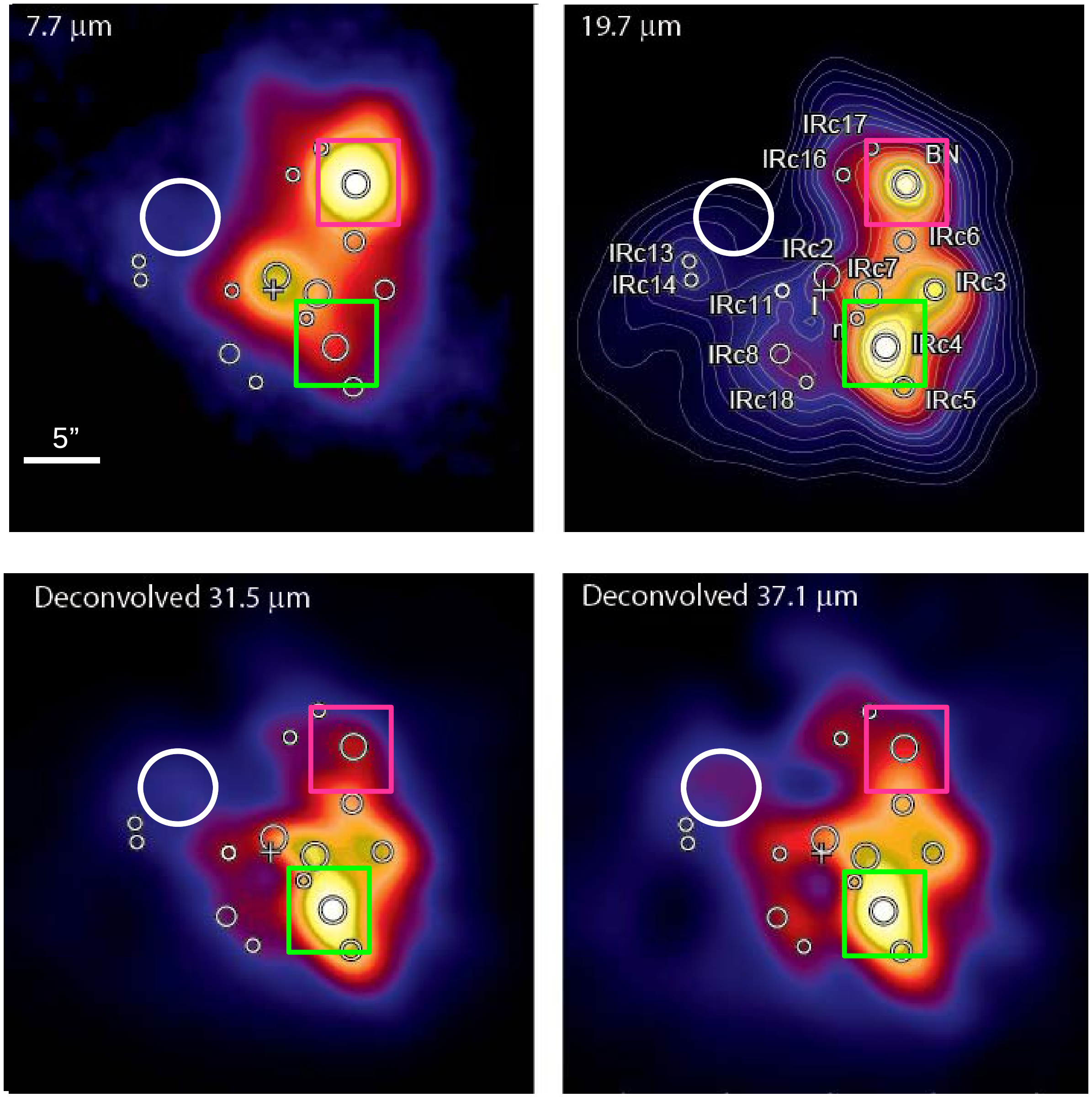
Successful SOFIA Early Science

- **Short Science 1**
  - Series of 3 flights with FORCAST
  - Completed December 2010
- **Short Science 2**
  - Series of 3 flights with GREAT heterodyne spectrometer
  - Completed in April 2011
- **Basic Science 1**
  - Series of 10 flights with FORCAST mid-infrared camera
  - Guest Investigator programs
  - Flight series completed in June 2011
- **Pluto Occultation**
  - Successful observation occultation of a background star by Pluto on June 23, 2011.
  - Demonstrated advantage of SOFIA mobility
- **Basic Science 2 and German Science Demonstration Time**
  - Series of 13 flights with the GREAT
  - Included substantial Guest Investigator program
  - Final flight November 2011



GREAT mounted in SOFIA

FORCAST Observations of Orion BN/KL



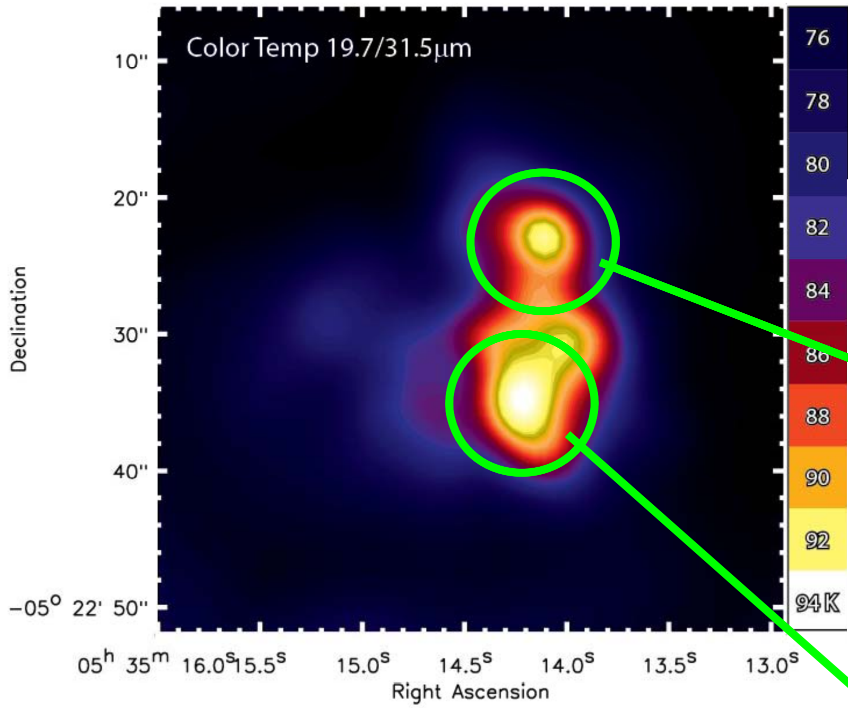
BN declines in prominence at longer λ’s

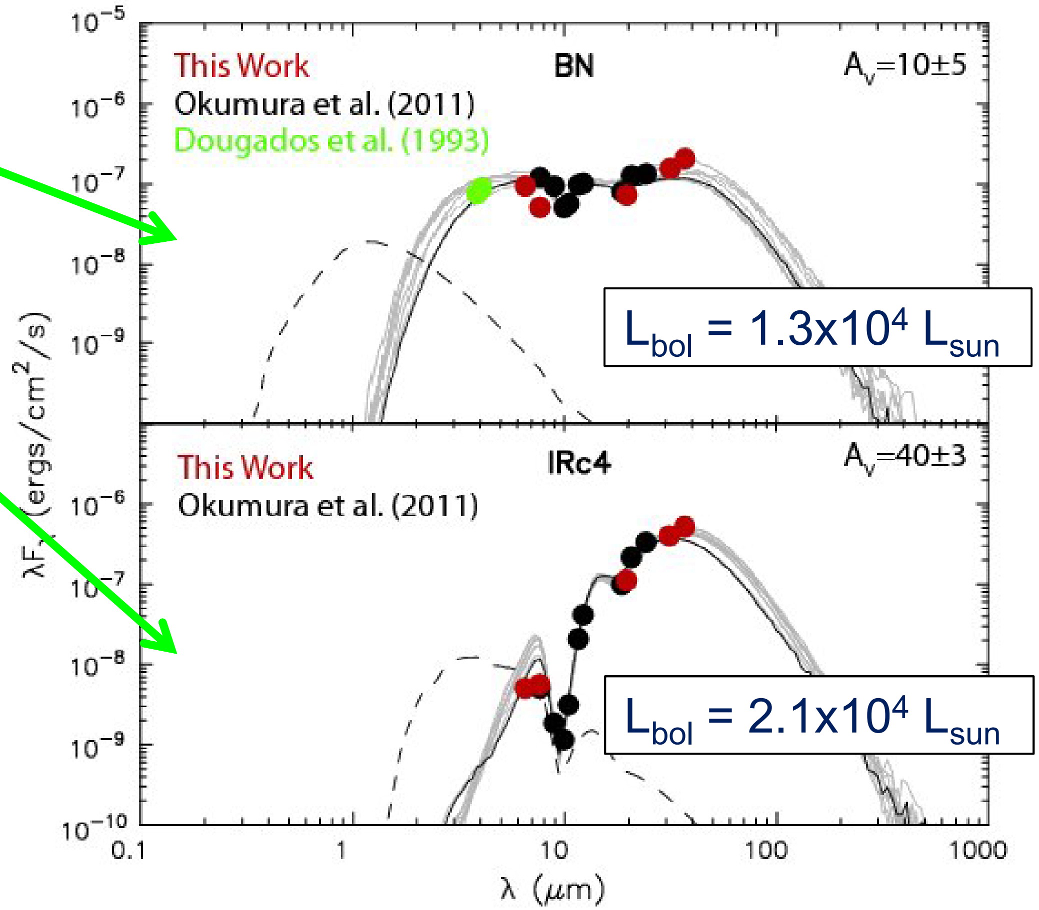
IRc4 dominates at λ >31um

A previously unidentified area of emission is apparent at λ >31um (SOF1)

De Buizer et al. 2012, ApJ, 749, L23
Shuping et al. 2012, ApJ, 749, L22

Like BN, IRc4 is a self-luminous source



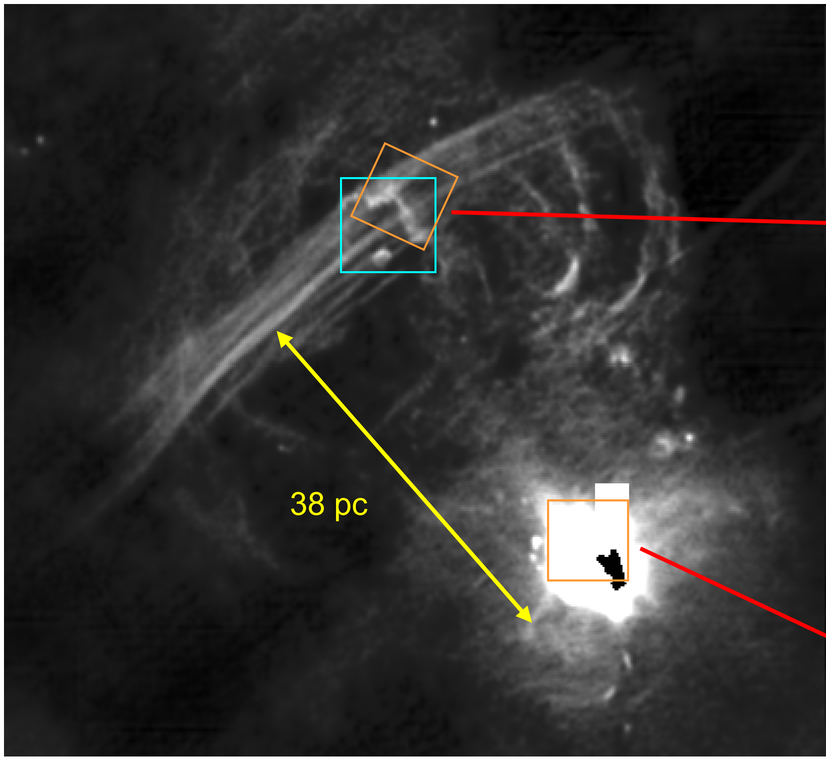


IRc4 luminosity is too high to be caused by externally heating

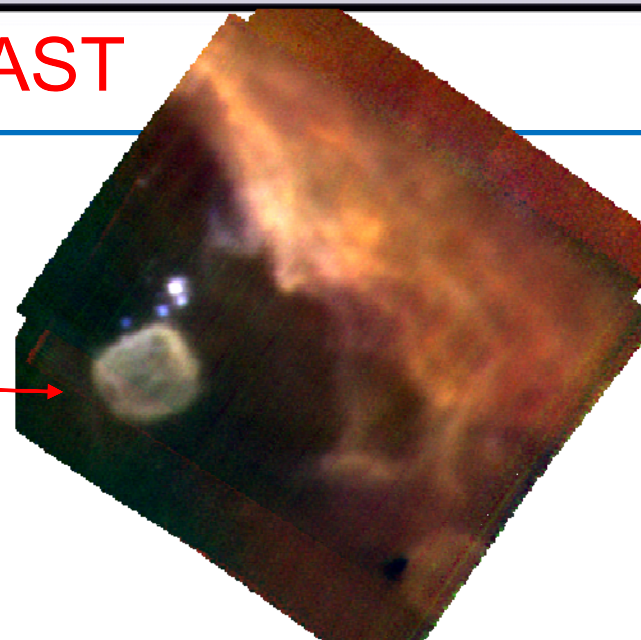
BN+IRc4 account for ~50% of the ~10^5 L_{sun} of the BN/KL

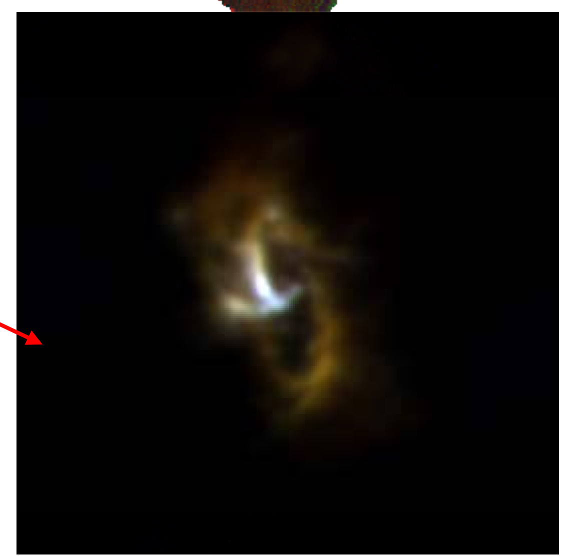
De Buizer et al. 2012, ApJ, 749, L23

The Galactic Center with FORCAST



Radio image of Sgr A, Pistol, Sickle, filaments and Arches





- At right are mulitcolor infrared images of two regions of the center of the Milky Way made from SOFIA.

SOFIA/FORCAST images at 19.7 (blue), 31.5 (green), 37.1 (red) μm

Herter et al. 2012, in prep.

Sgr A – CND with FORCAST

19.7 (blue), 31.5 (green), 37.1 (red)

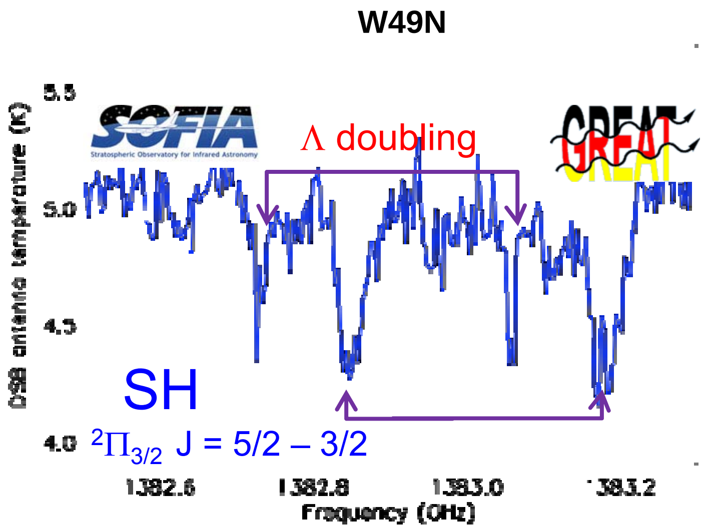
- Multicolor image of circumnuclear disk (CND) in the Galactic Center.
- Scaling varies from left (scaled to central brightness) to right (scaled to emphasize ring)

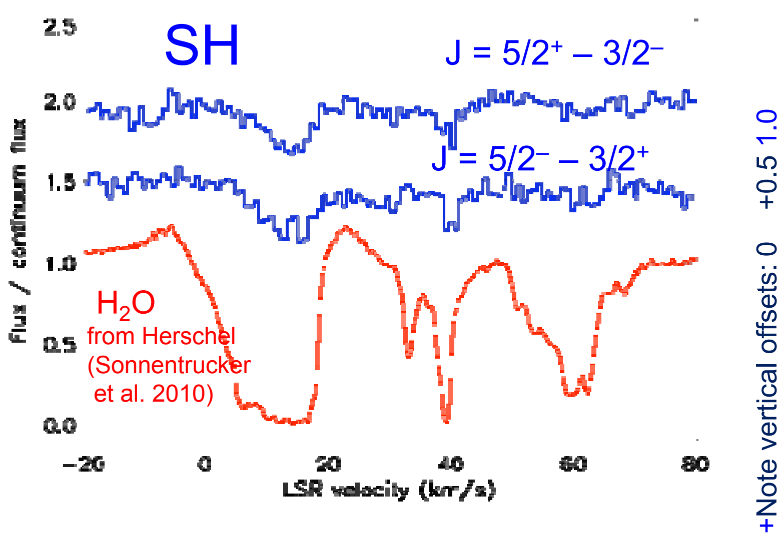
Herter et al. 2012, in prep.

GC Science with FORCAST

- Pistol Nebula & Quintuplet Cluster
  - Pistol star may be the most luminous star in our galaxy (T_{eff} ~ 14,000 K)
    - Nebula is a result of mass loss from the star
  - Ryan Lau is finishing up paper on morphology and dynamics of the nebula
    - What is source of heating of the dust?
    - What are the dynamics of the stellar winds in the region?
- Circumnuclear ring
  - Almost perfect r ~ 1.5pc ring around the 4×10^6 M_{sun} BH
  - Thickness/Diameter ~ only 1/10; inclination to galaxy ~18°
  - Clear color gradient seen across the ring: internally heated probably by young stars interior to the ring
  - Interesting structure on fine scales

SOFIA/GREAT discovery of interstellar mercapto radicals (SH)





SH has been detected in absorption toward W49N and W31C (G10.62 – 0.4)

The 1.383 THz ground state transition lies in the gap between Herschel/HIFI Bands 5 and 6.

SH is a key hydride, for which astronomical data was conspicuously missing until now.

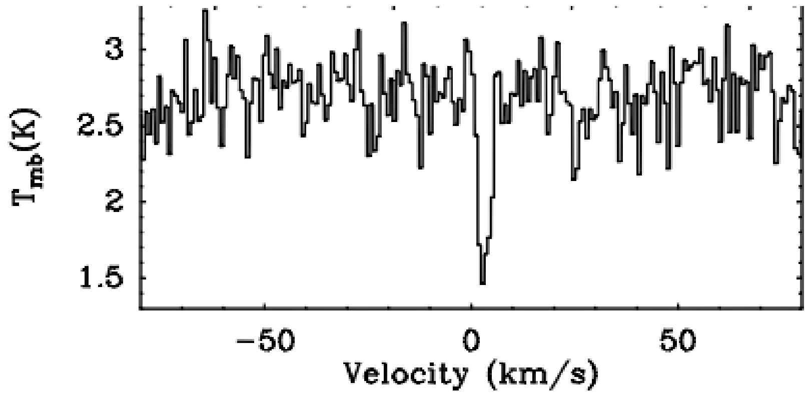
Its presence suggests a "warm chemistry", driven by shocks or turbulent dissipation, that can enable endothermic formation paths.

Eight neutral diatomic hydrides have now been detected in the ISM:

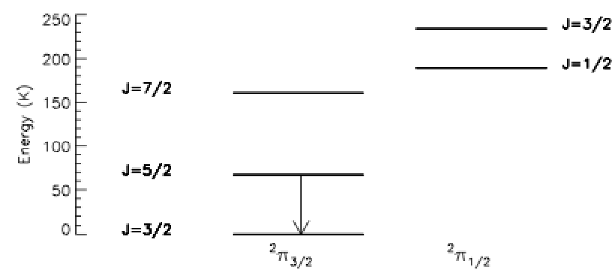
CH (Swings & Rosenfeld 1937)	OH (Weinreb 1963)
H_2 (Carruthers 1970)	HCl (Blake et al. 1985)
NH (Meyer & Roth 1991)	HF (Neufeld et al. 1995)
SiH (tent.; Schilke et al. 200	**SH (SOFIA/GREAT 2011)**

Neufeld et al. 2012, A&A, 542, L6

First Detection of OD outside the Solar System



OD J=5/2->3/1 transition observed toward protostar IRAS16293, smoothed to 0.79



Ground state transition: Sensitive to cold gas

- In cold and dense clouds, chemical reactions forming molecules with Hydrogen prefer the isotope Deuterium. This process, called fractionation, leads to relatively high abundances of deuterated molecules.
  - Fractionation is driven by the fact that the heavier molecule (OD) has a lower energy ground state than the lighter one (OH)
- SOFIA/GREAT observations detected OD, the deuterated form of the hydroxyl radical, OH, which is important in the chemical pathway for forming water, in the protostar IRAS 16293-2422.
- The inferred abundance of OD is 17-90 times more than HDO, higher than predicted by chemistry models

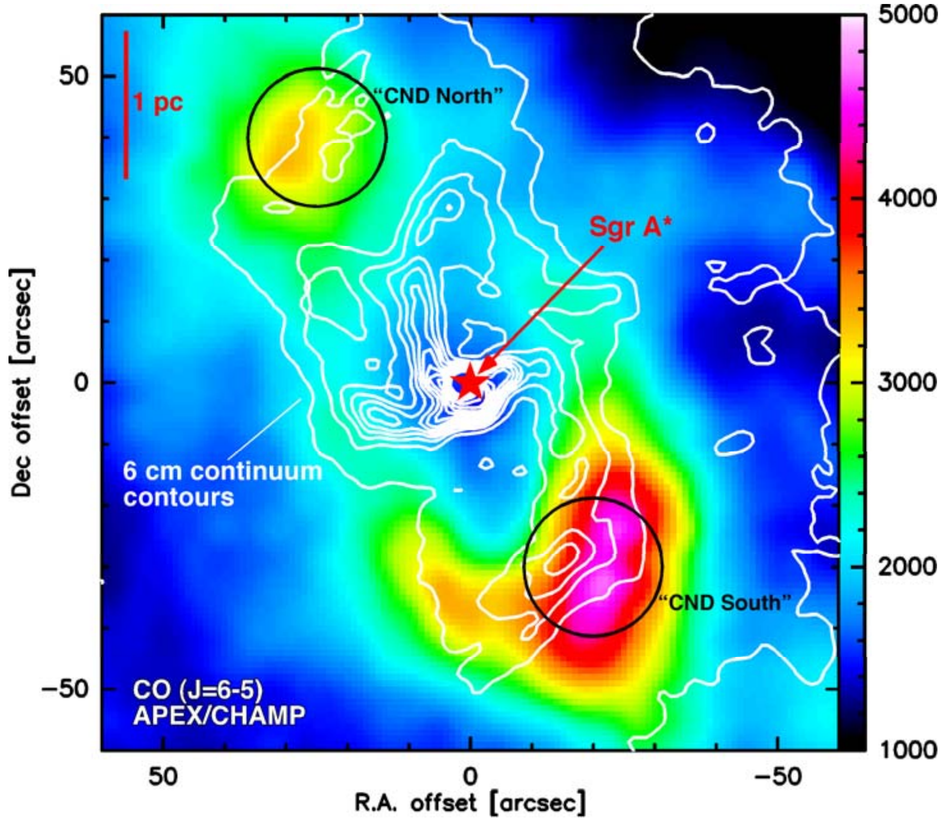
Parise et al. 2012, A&A, 542, L5

SOFIA studies the Galactic Circumnuclear Disk

Temperature and density measurements using multi-transition observations of CO

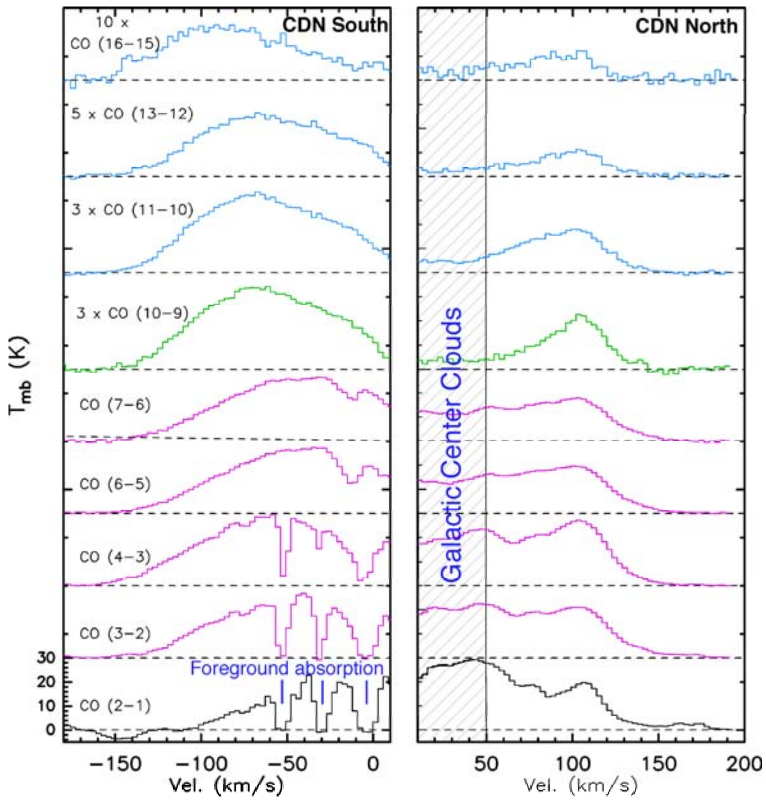
- The Galactic Center provides a nearby laboratory for the physics of active galactic nuclei
- Tells us about processes around super-massive black holes
- What is the state of the "Circumnuclear Disk" (CND)?

Combining ground, space, and airborne observations allows tight constraints on the density and temperature of the gas in the CND



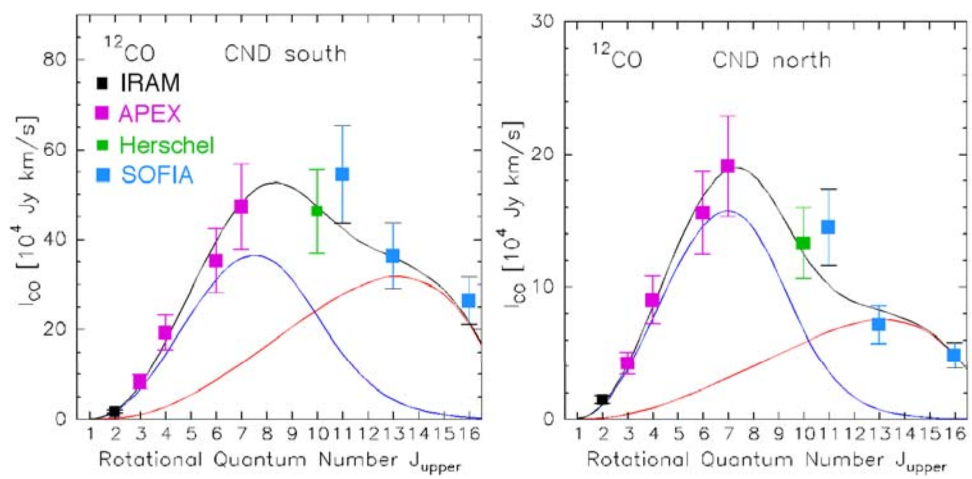
Requena-Torres et al., 2012, A&A, 542, L21

SOFIA studies the Galactic Circumnuclear Disk



	gas phase	r_0 (pc)	T_{kin}	log n(H_2)	log N(H_2)
CND-S	low exc.	0.31	200^{+300}_{-70}	$4.5^{+0.2}_{-0.5}$	22.64
	high exc.	0.08	500^{+100}_{-210}	$5.2^{+0.4}_{-0.2}$	23.34
CND-N	low exc.	0.32	175^{+425}_{-45}	$4.5^{+0.3}_{-0.7}$	22.35
	high exc.	0.06	325^{+275}_{-165}	$5.3^{+0.6}_{-0.3}$	23.15

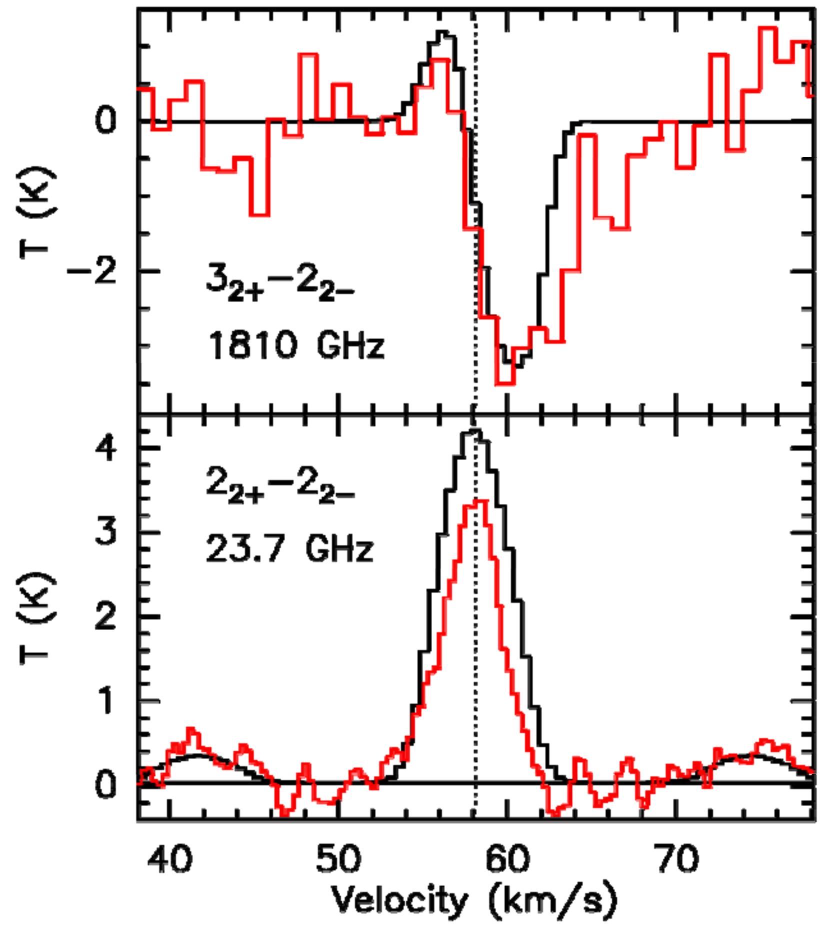
- SOFIA/GREAT observations provide a critical set of high-J CO lines, showing the need for a second, high temperature gas component
- The LVG modeling of the CO spectral energy distribution indicates clouds heated by shocks
- The relatively low space densities derived imply that the gas is not gravitationally stable against tidal shear, which suggests that the CND clumps are transient features
- The mass of the clumpy inner CND affects the accretion rate onto the central black hole.



- **Requena-Torres et al., 2012, A&A, 542, L21**

THz NH_3 as a Probe of Infall

- Observations of NH_3 $3_{2+} - 2_{2-}$ line at 1810.4 GHz in three sources: W43 MM1, G31.41+0.31, and G34.26+0.15
- Systemic velocities from $C^{17}O$
- Modeled ammonia line profiles with RATRAN code
- Derived infall rates of 3 – 10 x 10^{-3} M_{sun} yr^{-1}

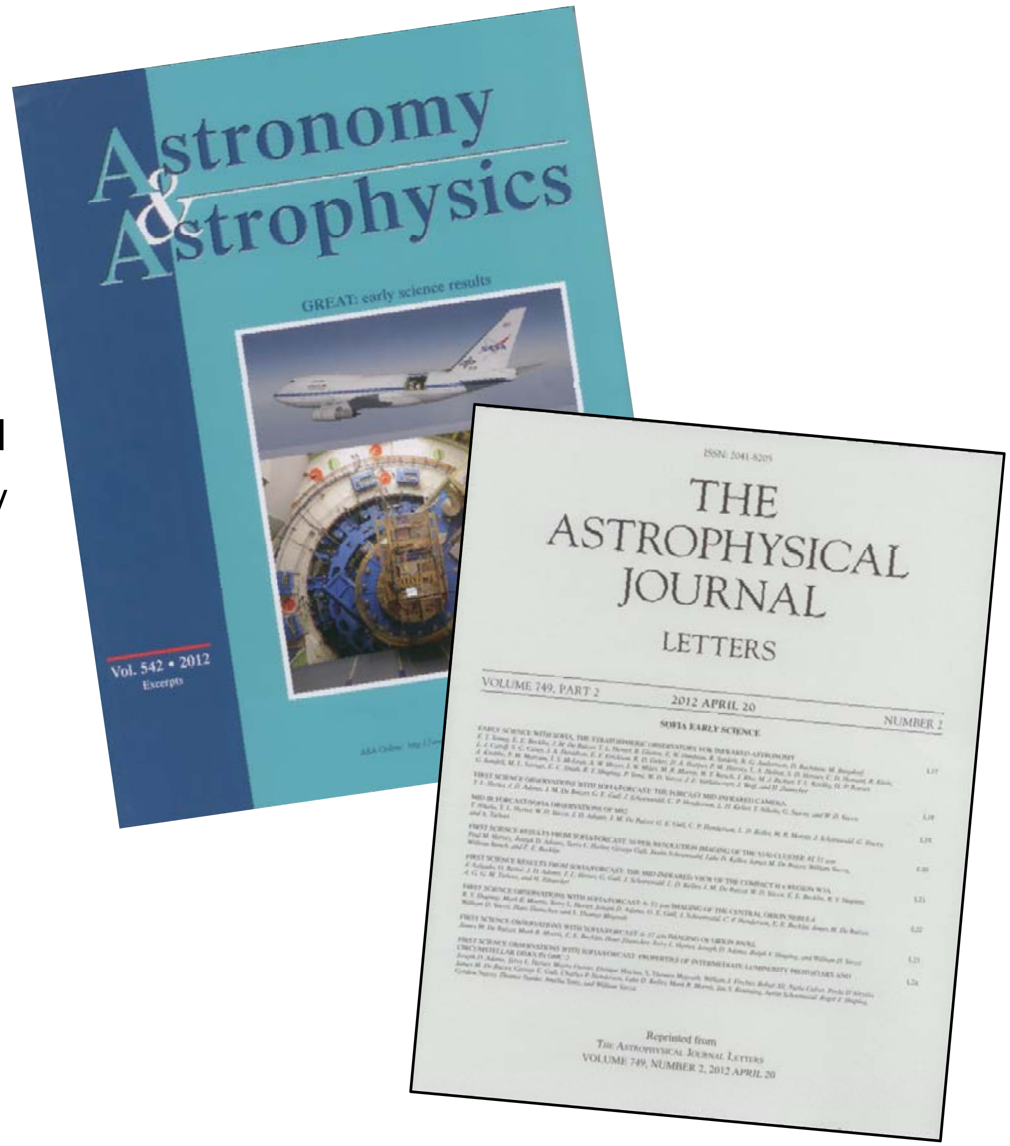


G34.26+0.15 NH_3 SOFIA and Effelsberg (Churchwell et al 1990) spectra in red compared with model

Wyrowski, et al 2012, A&A, 542, L15

First Year of SOFIA Science

- Austin Meeting of American Astronomical Society, January 2012
  - Special Science Session featuring SOFIA results
  - Press conference: An Infrared Extravaganza
- Special Issue of Astrophysical Journal
  - Features FORCAST results from Early Science
  - 8 papers were published in the 2012 April 20 issue.
- Special Issue of Astronomy & Astrophysics
  - Features GREAT results from Early Science
  - 22 papers were published in June 2012

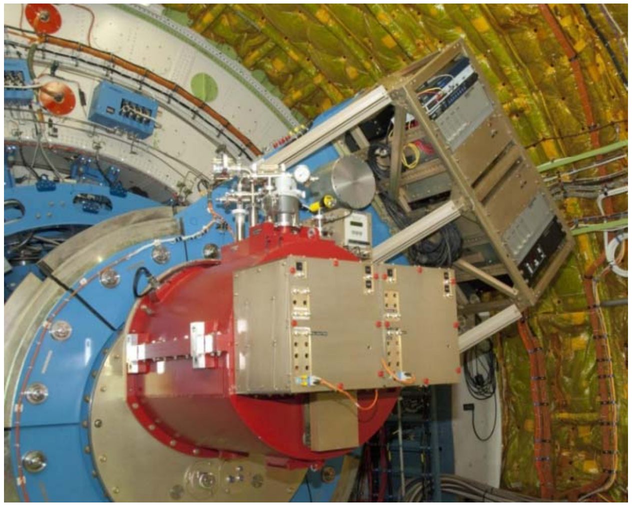


Cycle 01 Call for Proposals

- 1 year (~200 hours) of observing offered with 4 instruments
- 133 US proposals and 39 German proposals received with >5X oversubscription rate
- US Time Allocation Committee meet April 4-6
- German Time Allocation Committee met April 17-18

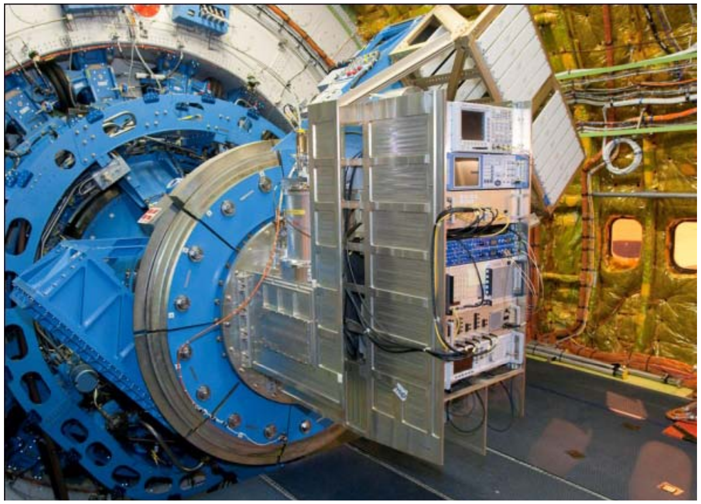
- More than enough very high quality proposals to fill up the available Cycle 01 observing time

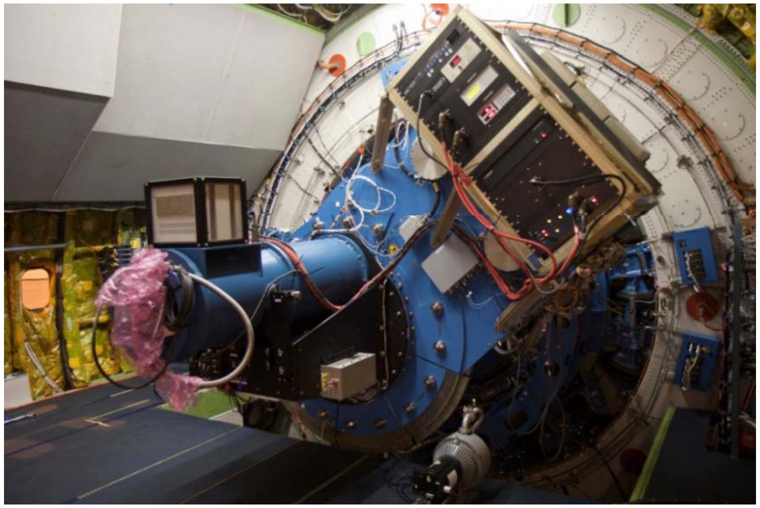
Four 1st Generation Instruments Available for Cycle 01



FORCAST
Mid-IR Camera

GREAT
Heterodyne
spectrometer





FLITECAM
Near IR Camera

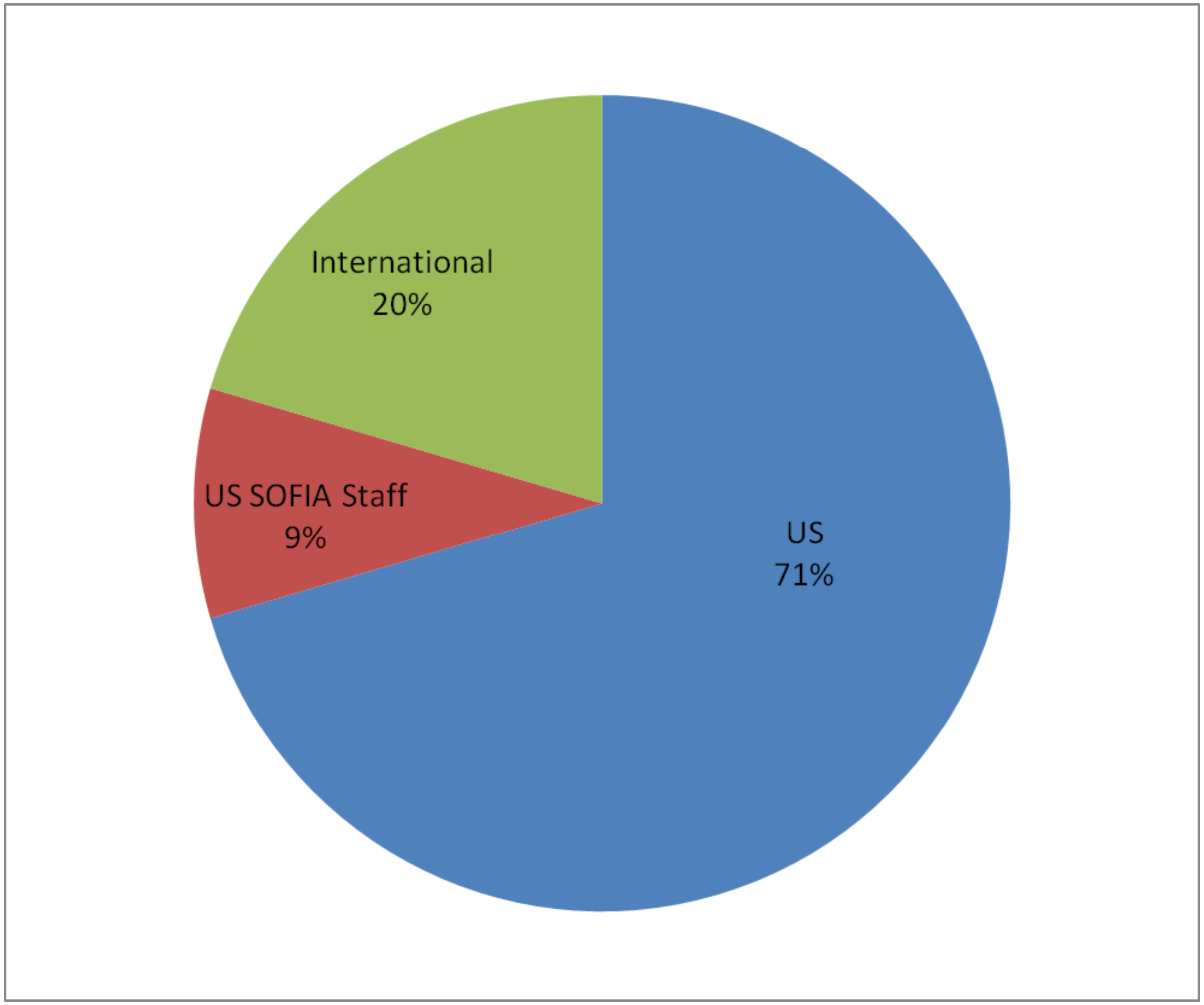
HIPO
Occultation Photometer

(co-mounted on SOFIA)

Cycle 1 Instrument Capabilities

- FORCAST
  - Facility Class Infrared Camera
  - Imaging modes fully supported in Facility Instrument Mode 5-40 μm
  - GRISM spectroscopy will be offered with resolutions of typically a few hundred (see SOFIA web site.) on a shared risk basis
- GREAT
  - Principal Investigator Class Spectrometer
  - L1a/b and L2 modes offered
  - GO and GREAT team collaborate after selection
- FLITECAM
  - Facility Class Instrument
  - Imaging modes will be fully supported after commissioning
  - GRISM spectroscopy (R~2000) offered as shared risk
- HIPO/ FLIPO
  - Special purpose instrument
  - Requires collaboration with instrument PI

US Queue Distribution of Proposals



Status of Cycle 1

- The original schedule had Cycle 1 starting in July-August 2012 and lasting for one year
- There has been some slippage of the SOFIA development schedule, and to maintain the full year of visibility, we are moving Cycle 1 to Nov 2012 through December 2013
- Announcement of the TAC results is delayed to July 2012
  - The announcement will come after first system-level test of enhanced SOFIA systems
  - We will have much better knowledge of the observatory efficiency and performance after “line operations”.
  - We want to ensure the feasibility of the selected investigations.
- We expect future observing cycles to adopt the January to December window with proposals due in late April each year.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N747NA
http://www.sofia.usra.edu