

# SOFIA instruments: Synergies with new and existing observatories

Margaret Meixner

Director

Science Mission Operations

June 22, 2020

# Outline

- SOFIA's 10<sup>th</sup> Anniversary of First Light
- Science highlights
- SOFIA's Science Mission
- SOFIA Instruments

Congratulations to SOFIA Team for 10<sup>th</sup> Anniversary of First Light!

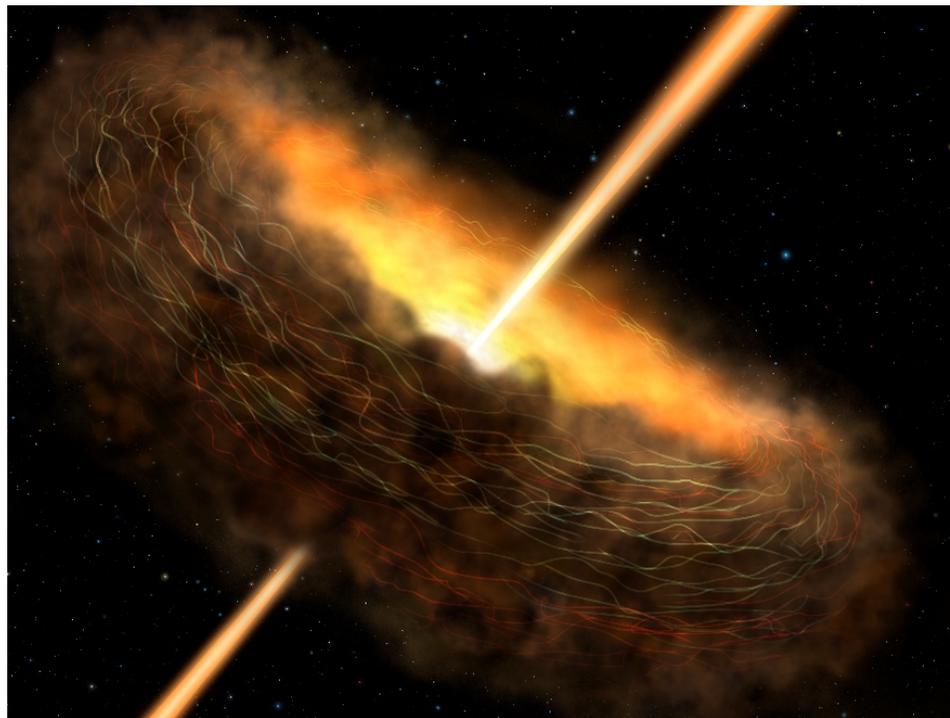


# Science Highlights from past 10 years



**Magnetic Fields May Be Keeping  
Milky Way's Black Hole Quiet**

Image credits: Dust and magnetic fields: SOFIA  
Star field: Hubble Space Telescope



**Magnetic Fields May Be Feeding  
Active Black Holes – Cygnus A**

Illustration credit: NASA/SOFIA/Lynette Cook

# Science Highlights from past 10 years



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

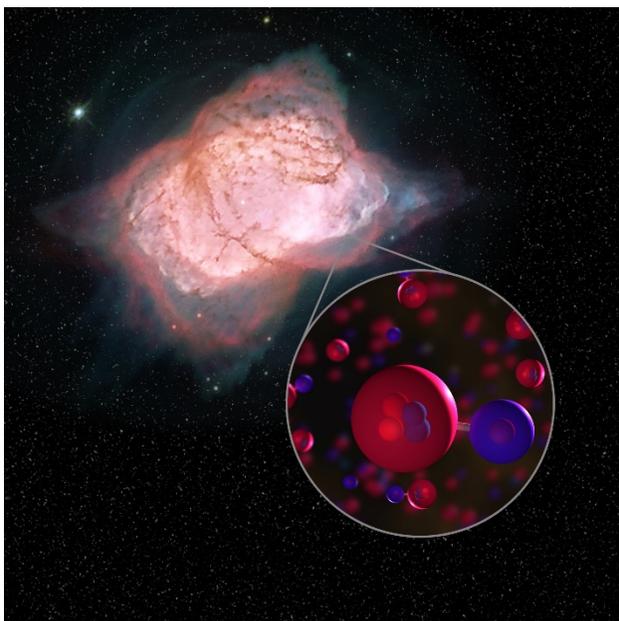
Image credits: NASA/SOFIA; NASA/JPL-Caltech/Roma Tre Univ.



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

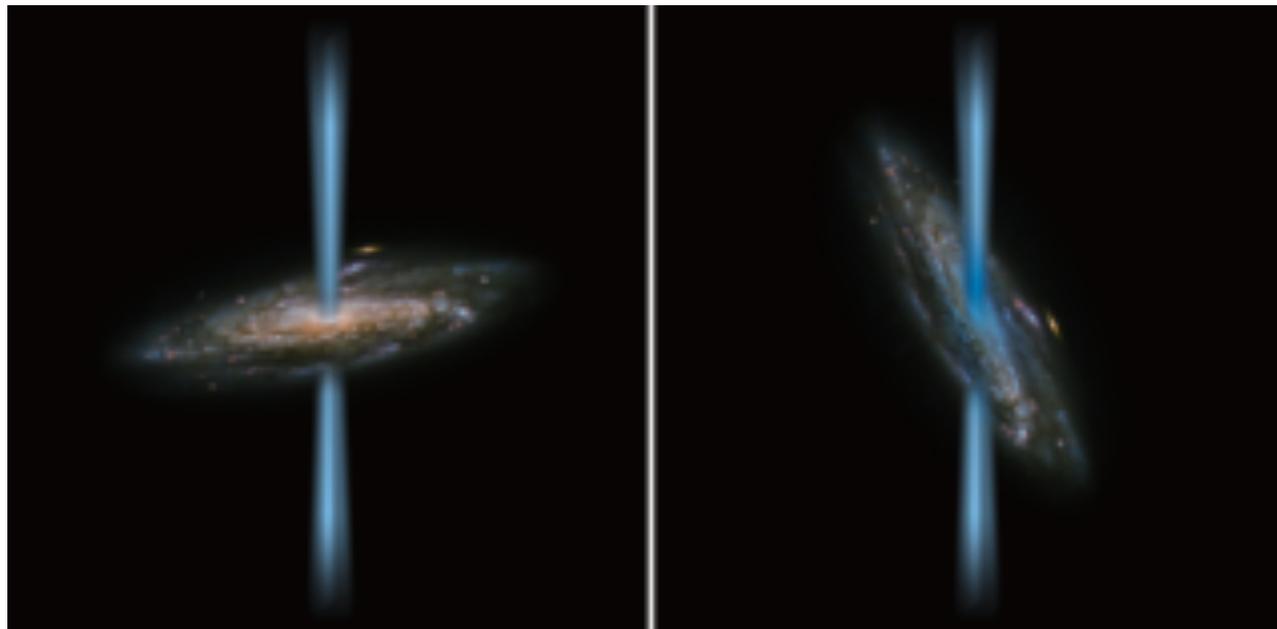
Image credits: NASA/SOFIA; NASA/JPL-Caltech

# Science Highlights from past 10 years



The Universe's First Type of Molecule, HeH<sup>+</sup>, Helium hydride, Found at Last

Image credits: NASA/ESA/Hubble  
Processing: Judy Schmidt



The excess [CII] 158  $\mu\text{m}$  line emission near this galaxy's center is caused by a jet shocking the gas in the disk.

Illustration credits: ESA/Hubble&NASA and NASA/SOFIA/L. Proudfit

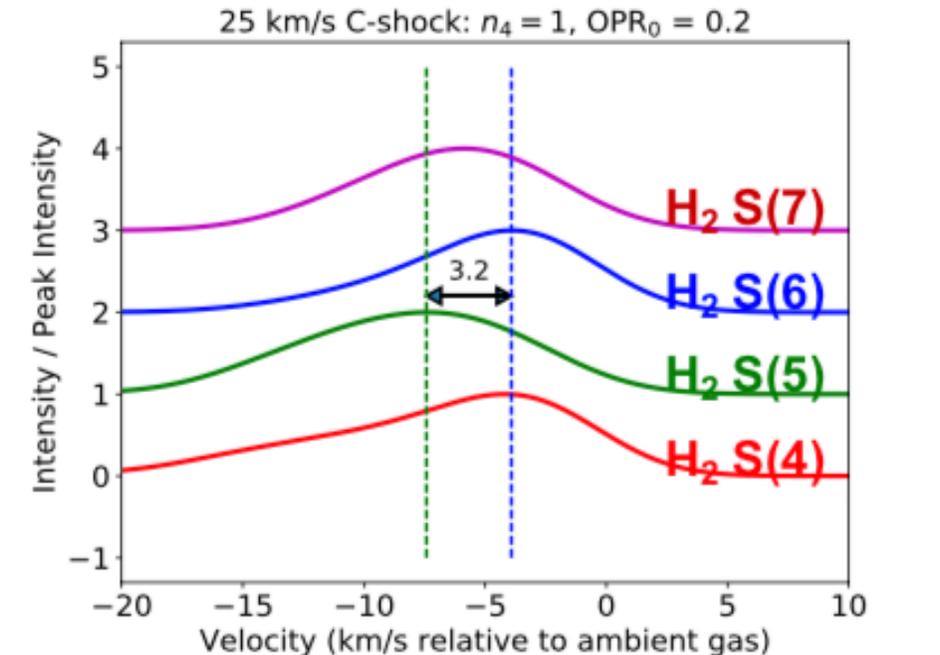
# David Neufeld

## New Evidence for a Special Type of Interstellar Shock

Molecular hydrogen exists in two forms: para-H<sub>2</sub> (proton spins antiparallel,  $J$  even) and ortho-H<sub>2</sub> (spins parallel,  $J$  odd)

In continuous (“C”)-type shocks, the gas is slowly decelerated while the conversion between ortho and para molecular hydrogen is happening

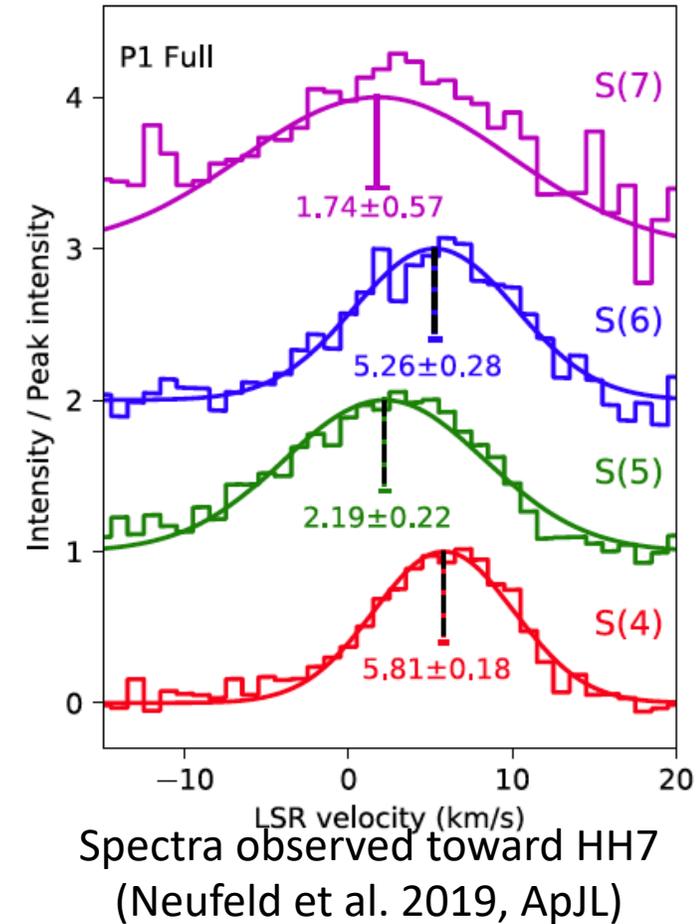
→ We expect a spectral shift between the even- and odd- $J$  lines



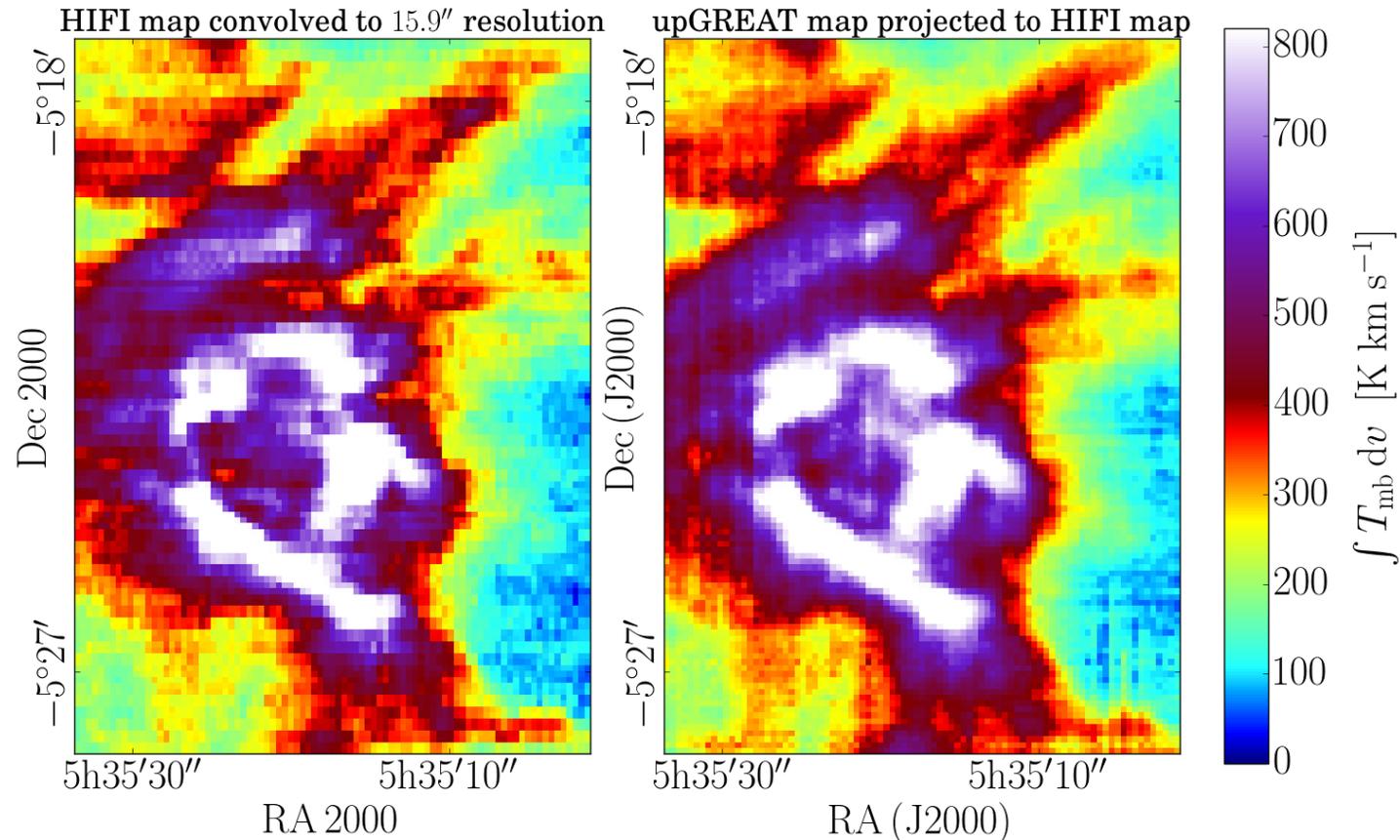
Pierre Lesaffre predictions  
(Paris-Durham shock code)

# Prediction Confirmed with SOFIA/EXES

- To test this prediction, we need very high spectral resolution in the 5 – 8  $\mu\text{m}$  region
- EXES, with  $\lambda/\Delta\lambda = 80,000$  and an operating altitude of 41kft, provided a unique opportunity to search for the predicted ortho-para shift



# Alexander Tielens: SOFIA's upGREAT View of Orion

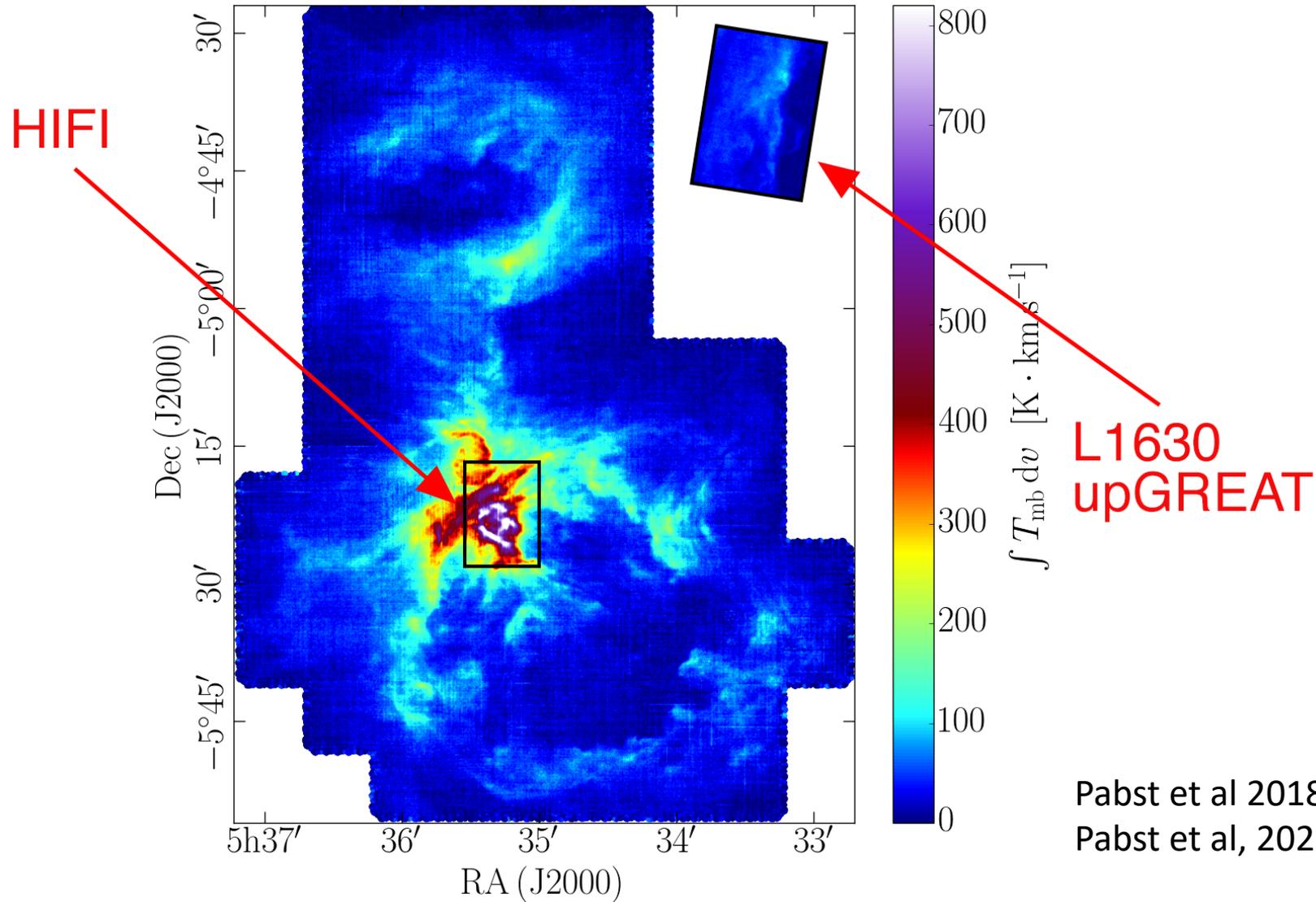


HIFI/Herschel  
9 Hours

upGREAT/SOFIA  
~35 minutes

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

# In Perspective



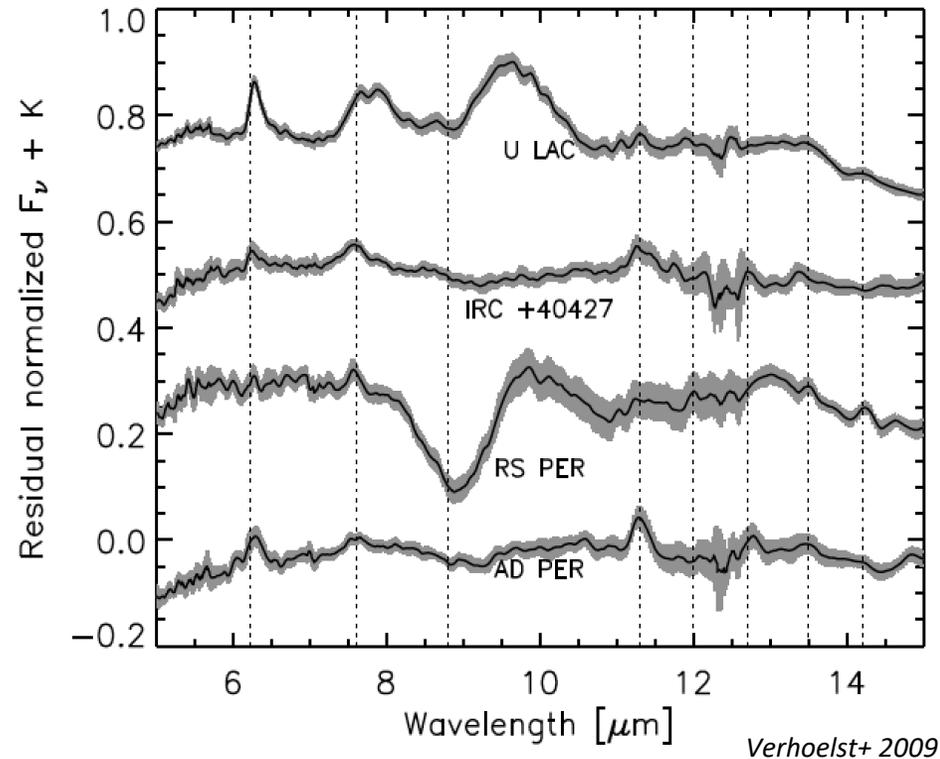
Pabst et al 2018, Nature, 565, 618  
Pabst et al, 2020, A&A, in press

# Emily Levesque: the adventures of observing



- Visits to Palmdale and New Zealand
- Flight, observations and aurora over Antarctica

# Mid-IR spectroscopy of the dust around red supergiants



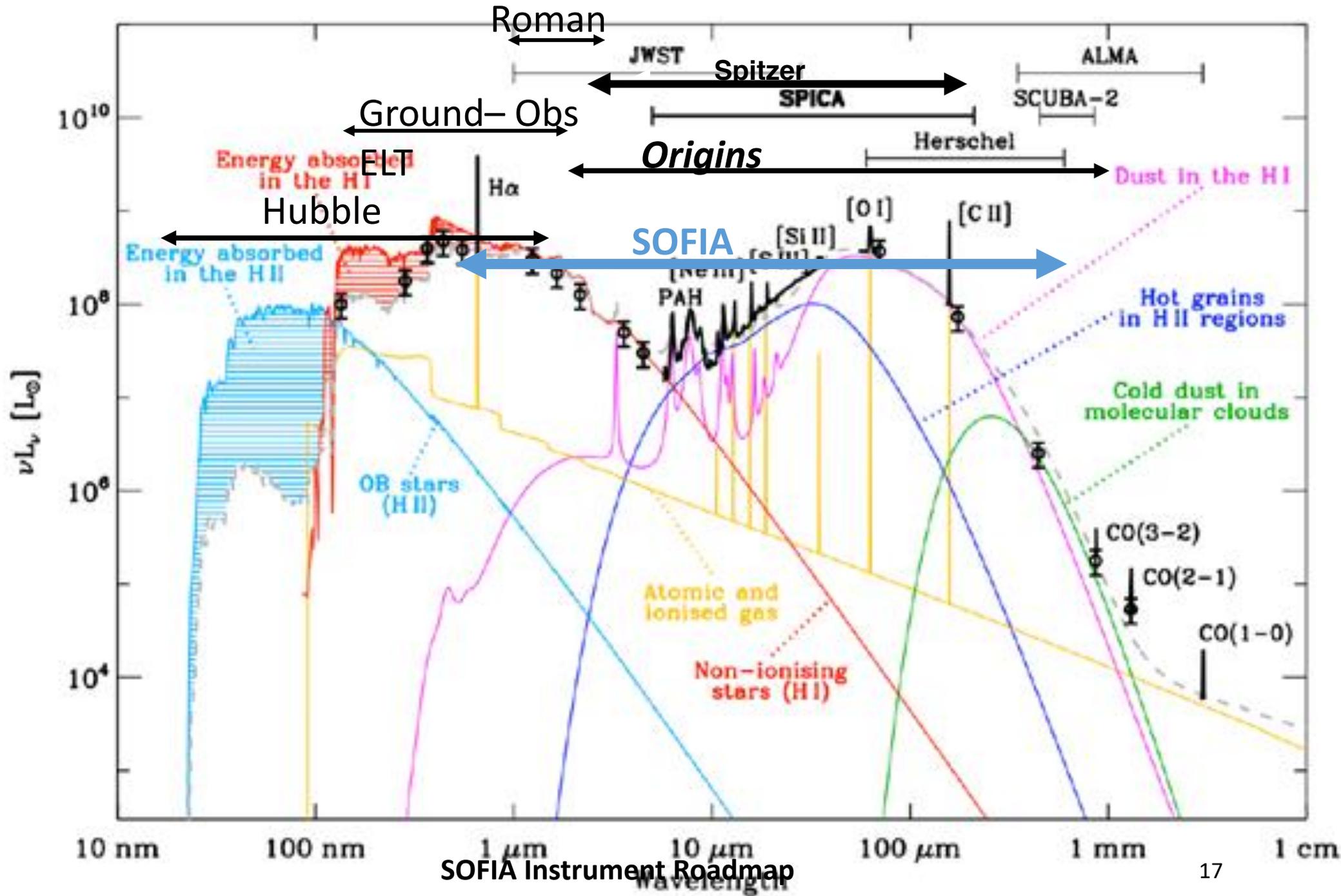
- Content and distribution of circumstellar dust
- RSG-driven contributions to ISM and enrichment
- Mass loss and environments of supernova progenitors

# SOFIA Legacy Programs: Galactic Center mapping Matt Hankins



# SOFIA's Science Mission

- **Emphasize Science, Science, Science**
- Science must drive the decisions for SOFIA's future instrumentation
- SOFIA holds a critical and unique science capability for astronomers

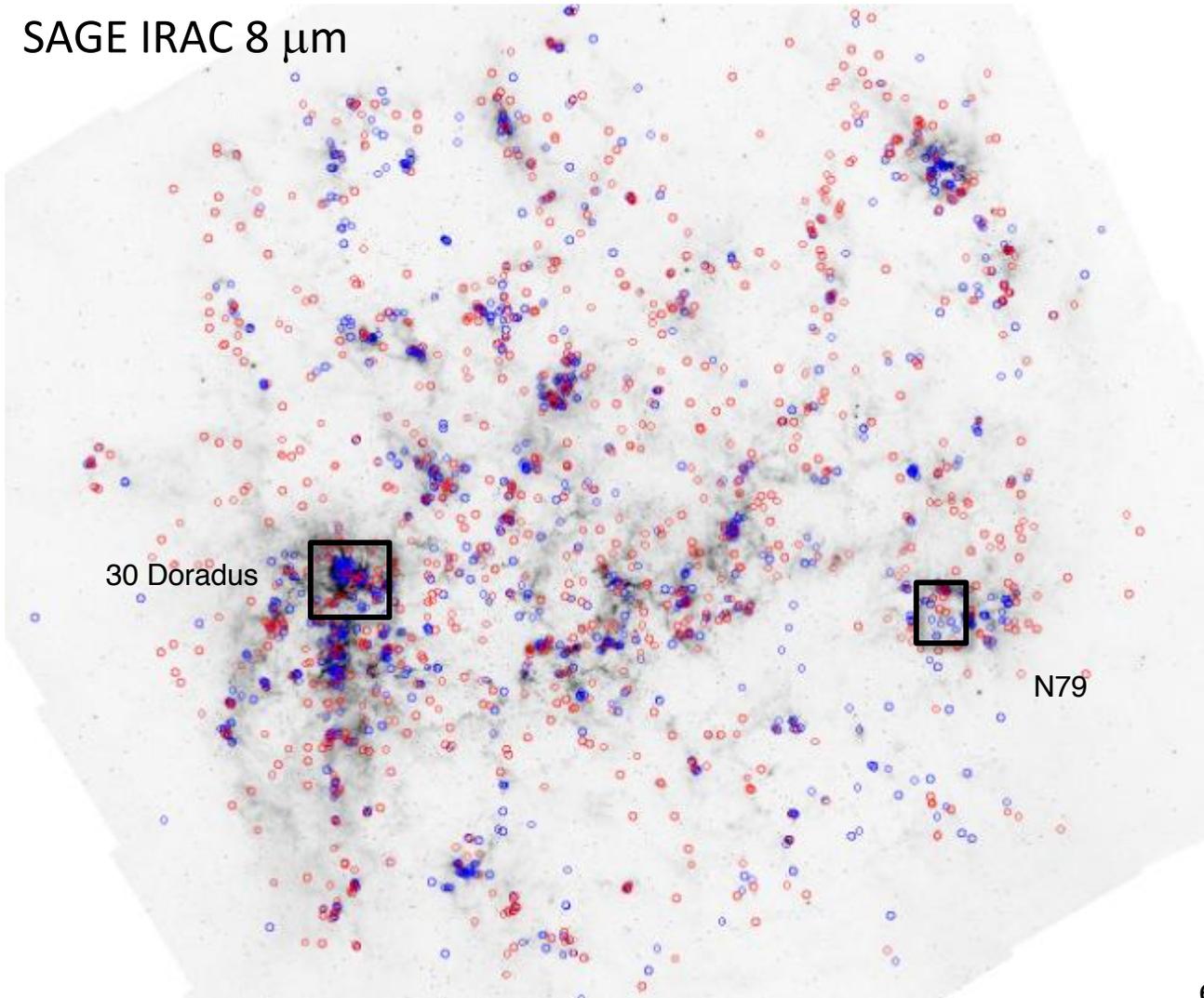


SOFIA Instrument Roadmap



# Spitzer Discovers Thousands Young Stellar Objects in the LMC

SAGE IRAC 8  $\mu\text{m}$



*Pre-Spitzer:*

~20 protostars known

*Spitzer:*

~1000 YSO candidates

Whitney, Sewilo et al. (2008)

~1200 YSO candidates

Gruendl & Chu (2009)

~1800 unique sources

More YSOs found  
with regional studies

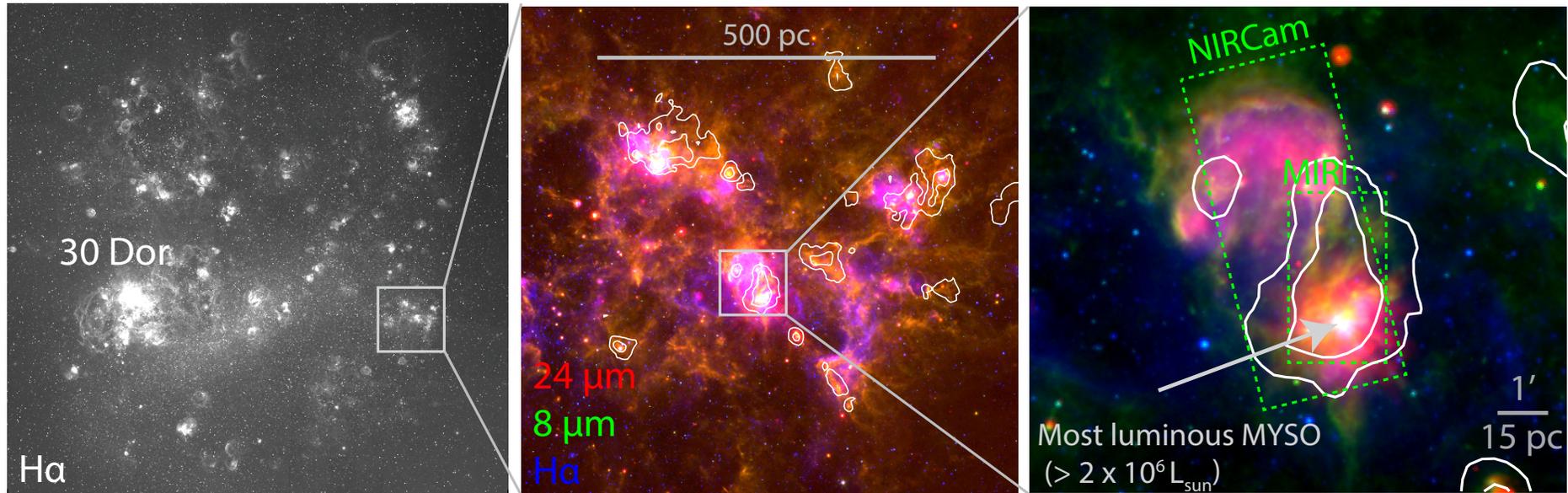
e.g. Carlson et al. 2011; Nayak et al. 2018

# Large Magellanic Cloud: N79

Investigating super-star cluster formation: H72.97-69.39

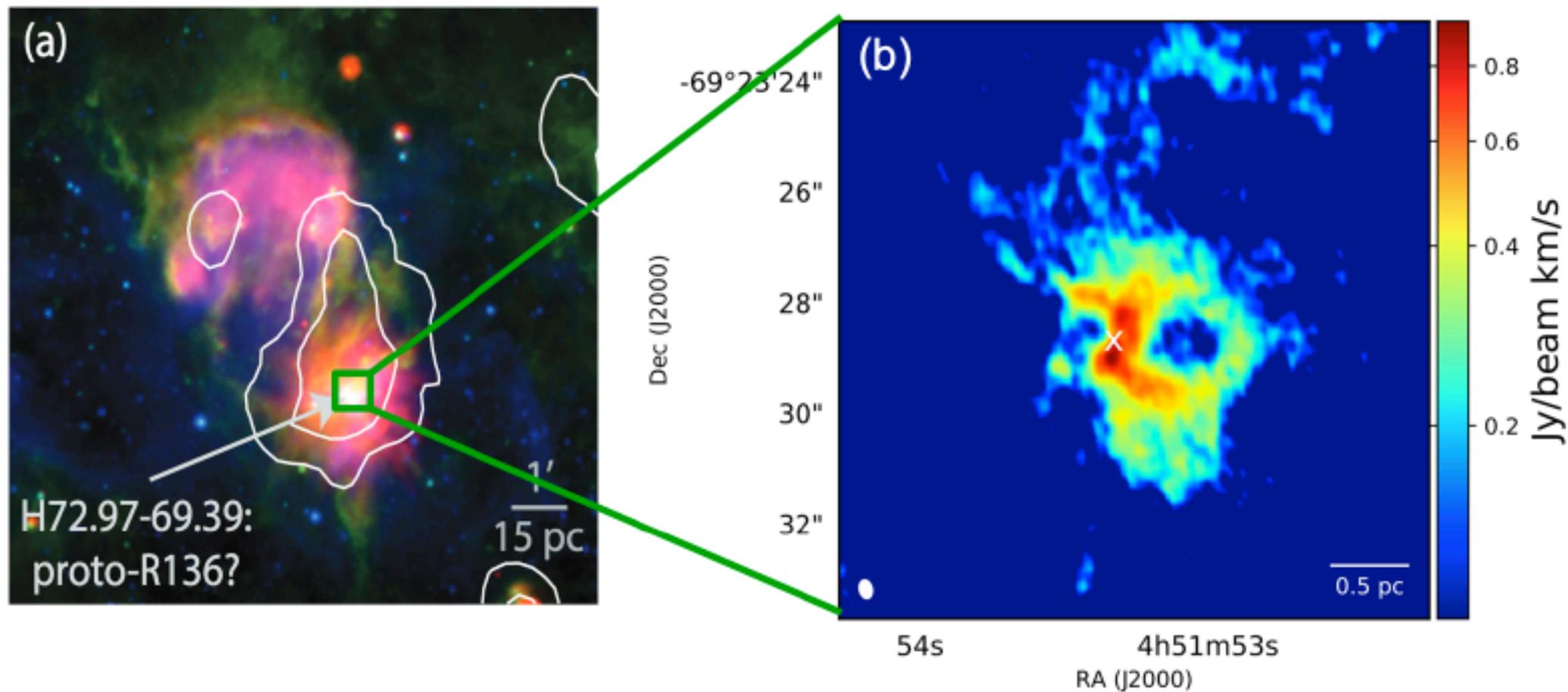
NIRCam and MIRI Imaging

MIRI MRS spectroscopy

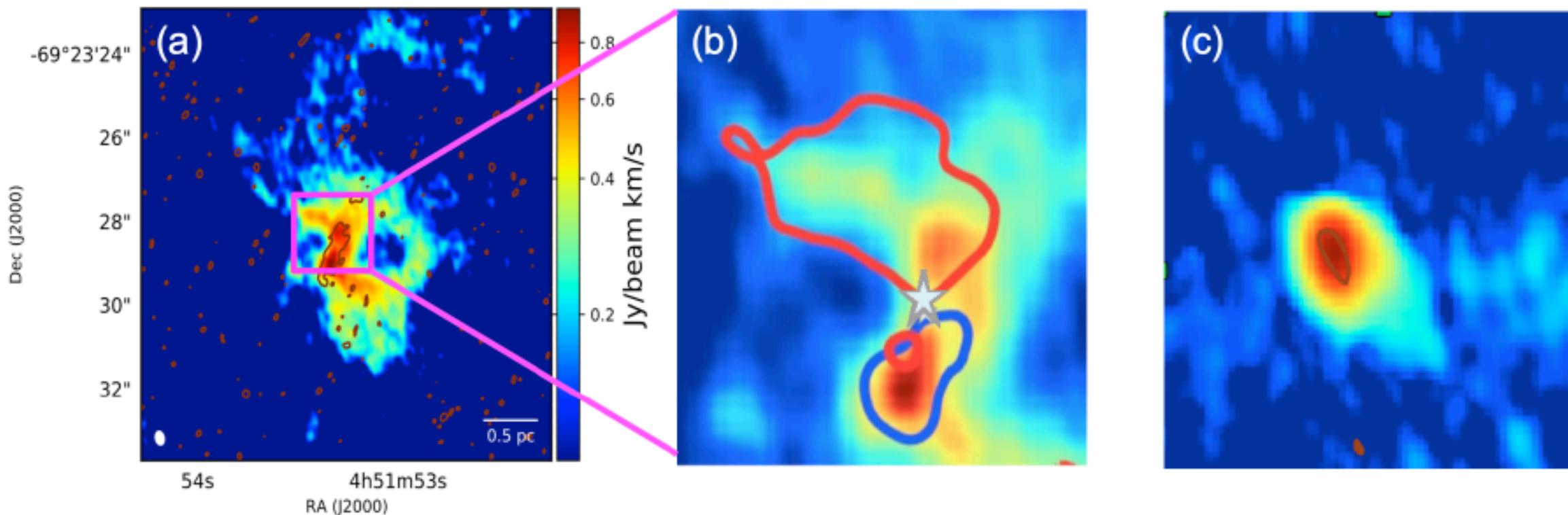


Ochsendorf et al. 2017, Nayak et al. 2019

# H72.97-69.39 – ALMA observations

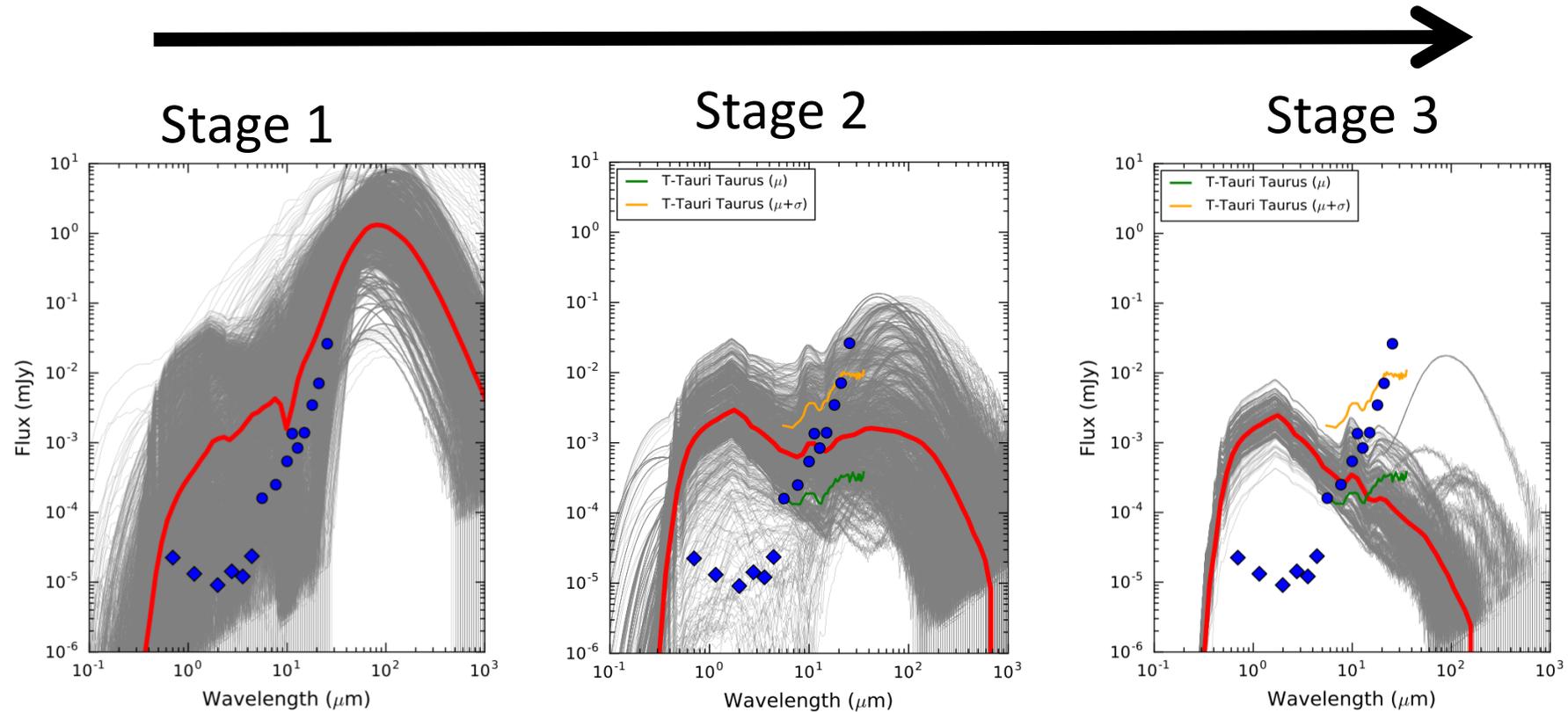


# H72.97-69.39 – ALMA observations



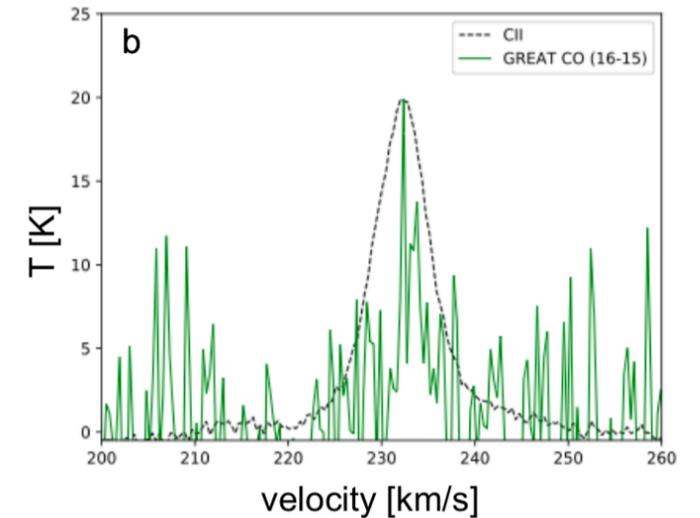
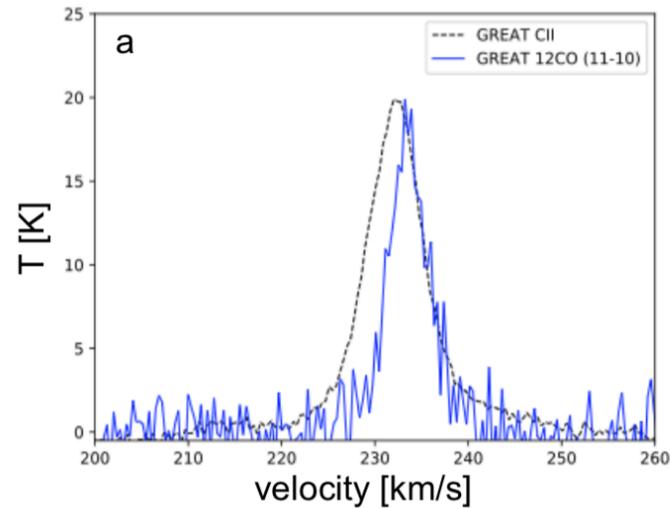
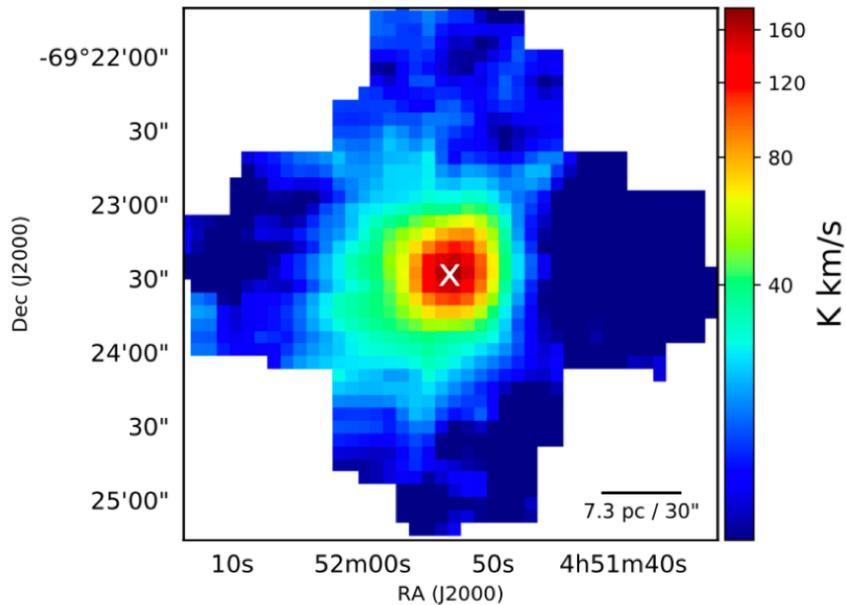
# H72.97-69.39: JWST observations

## Evolution of Young Stellar Object (YSO)



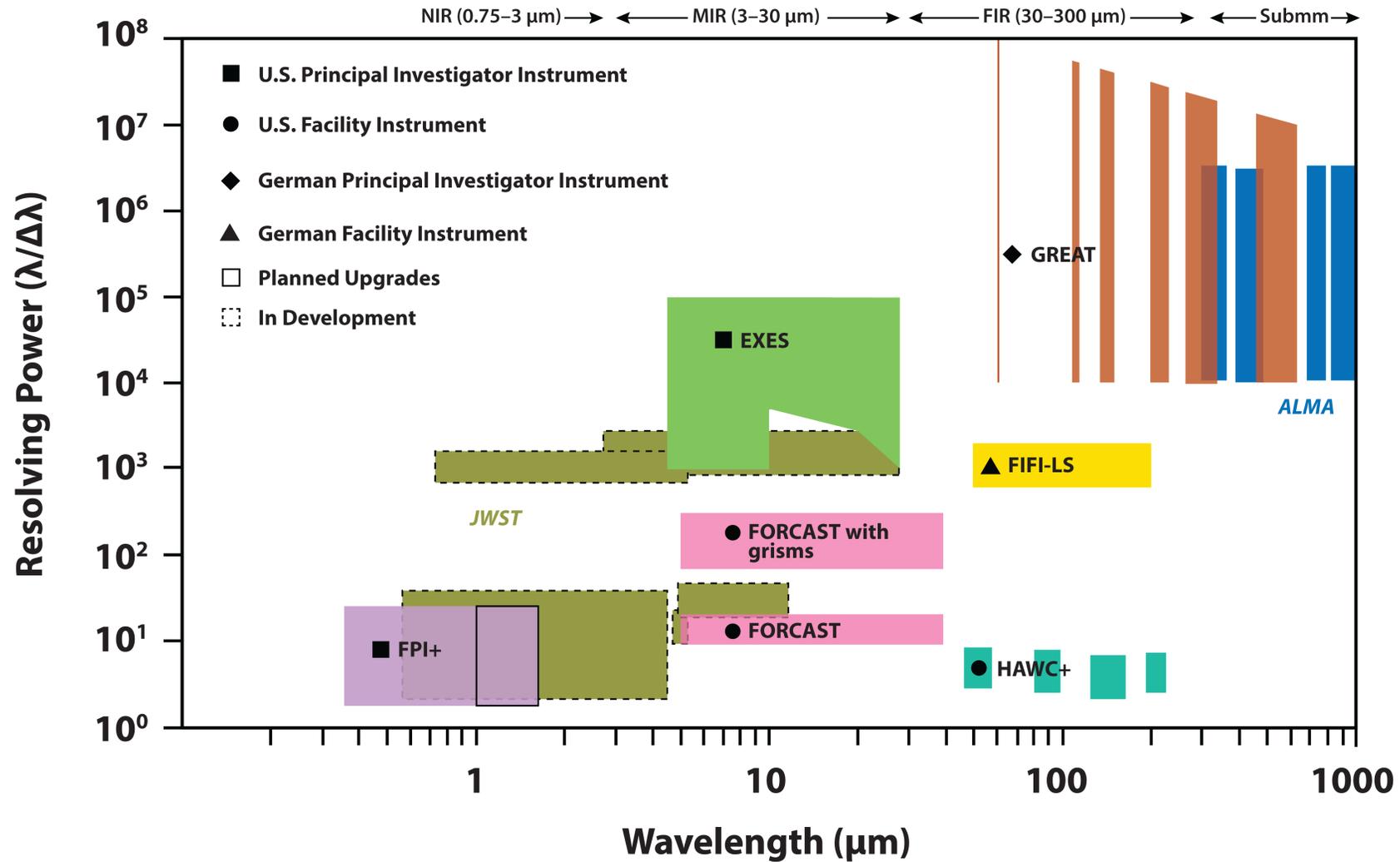
1  $M_{\odot}$  models, red line is median model spectra blue diamonds are JWST  $10 \sigma$  sensitivity limits in 3 minutes

# Stellar feedback: H72.97-69.39 with SOFIA/GREAT [CII], CO 11-10 and 16-15 PDR and shocks modelled



Nayak et al. submitted

# The SOFIA Instruments



# Questions?

## The SOFIA Instruments

