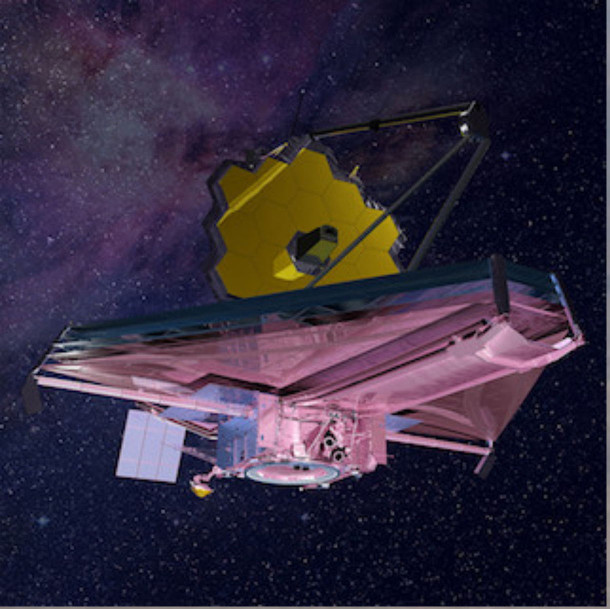


SOFIA – JWST Synergies

Tom Greene (NASA Ames)

SOFIA International Summit

14 November 2017

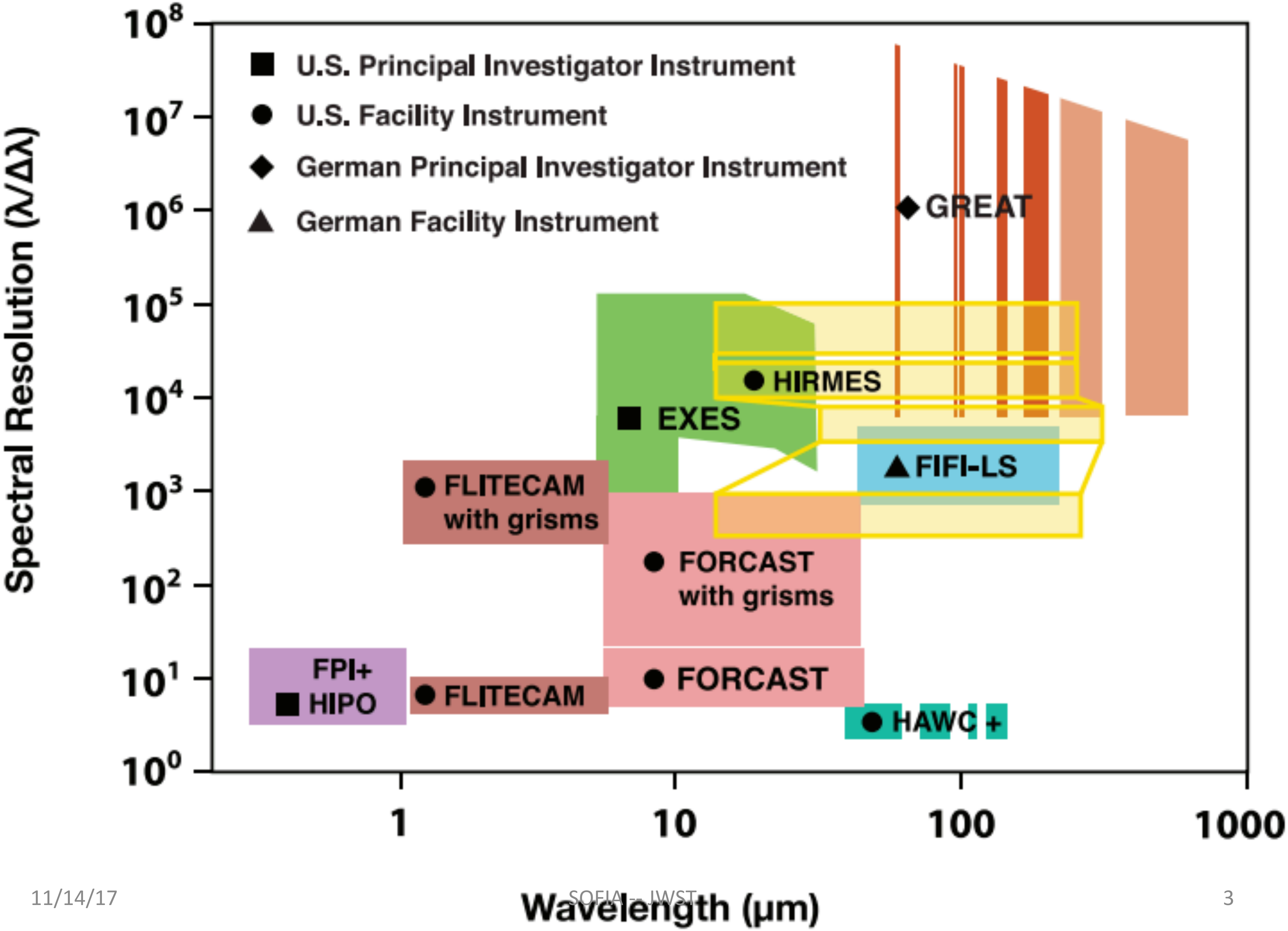
Getting the Big Picture of Cosmic Origins

Technical and Mission Information

- 6.5-m, 25 m^2 primary, T ~ 40 K
- 0.6 – 28 μm imaging & spectroscopy
- Faint target optimized
- > 8000 hours / year
- Launch in 2019, 5 – 10+ years operations

- 2.5-m, 4.5 m^2 primary, T ~ 220 K
- ~0.35 – ~250 μm imaging & spectroscopy
- Bright target optimized
- < 1000 hours / year
- Operational now, extended mission 2019+?

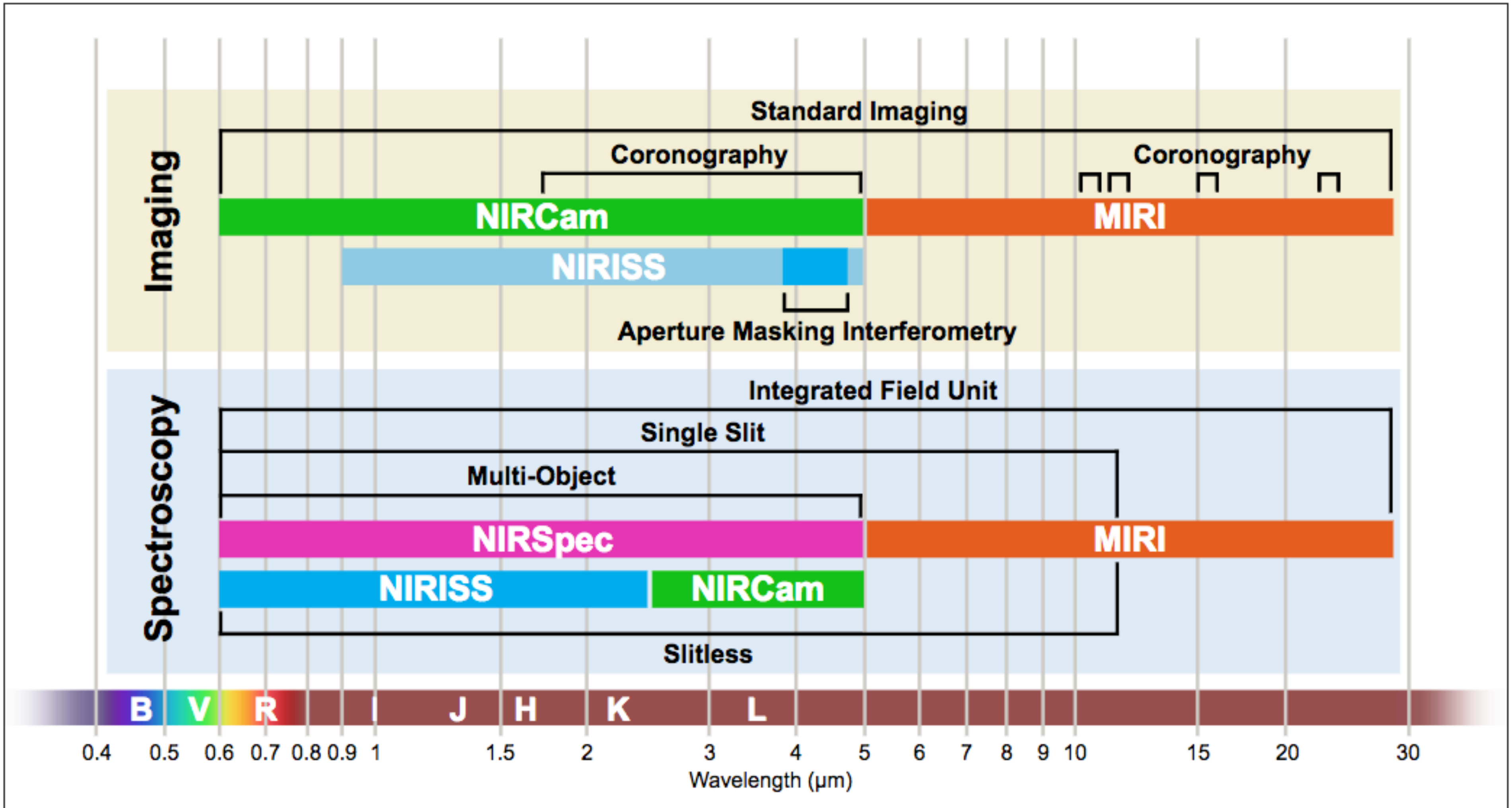
The SOFIA Instruments



James Webb Space Telescope (JWST)

- 6.5-m primary mirror; 25 m^2
- 18 segments, T~40K, zodi-limited to 10 µm
- Instruments:
  - NIRCam: λ = 0.7 – 5 µm imager and slitless spec.
  - NIRSpec: λ = 0.6 – 5 µm wide-field, slit, and IFU spec.
  - MIRI: λ = 5 – 28 µm imager, slit, slitless, IFU spec
  - NIRISS/FGS: λ = 0.6–5 µm imager, slitless spec
- 2019 launch
  - GO Cycle 1 due 6 Apr 2018
  - 5 yr req life, >10 yr goal

JWST Science Instruments



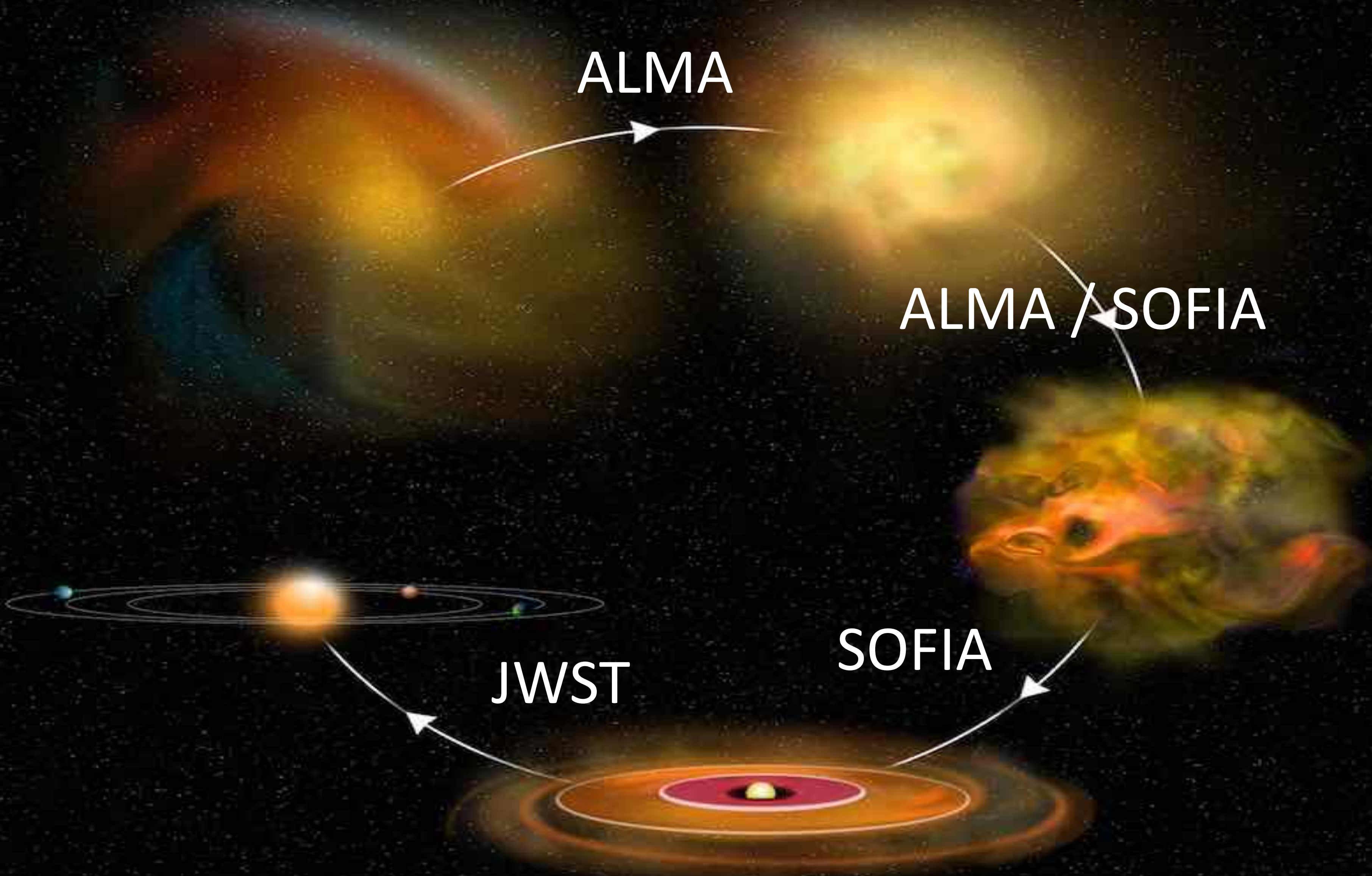
How are they synergistic or complementary?

	SOFIA	JWST
Wavelength range	Wide: 0.3 – 250+ μm	Subset of SOFIA
Dynamic range	Bright objects > 10 Jy OK	Bright objects saturated
SI Fields of View	HAWC+ > ~10 $arcm^2$	< 10 $arcm^2$ per SI
Mapping efficiency	High	Low or moderate

- SOFIA and JWST will likely not observe the same objects in the same way
- Joint programs could exploit complementary capabilities to tackle large-scale problems
  - e.g., energy transfer and balance across large spatial and thermal scales at high visual extinction

(stars → jets → clouds, or AGN → jets → galaxies

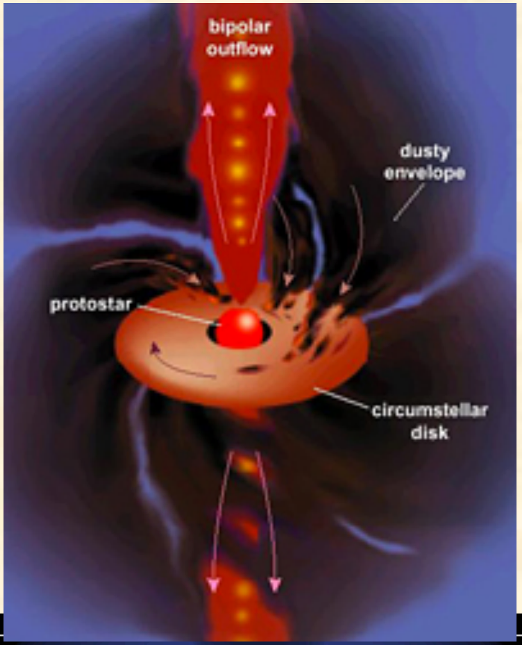
Multiple Observatories are needed to understand global processes

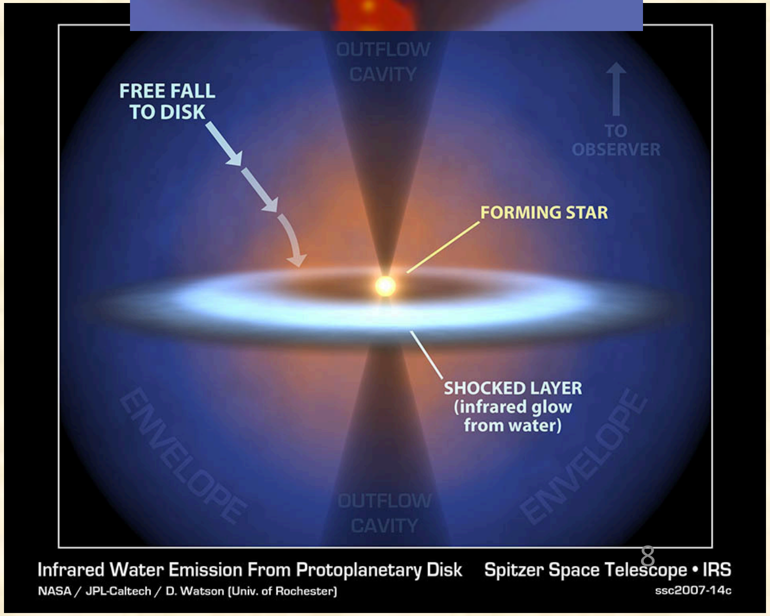


Example 1: Gas and shocks in protostellar jets

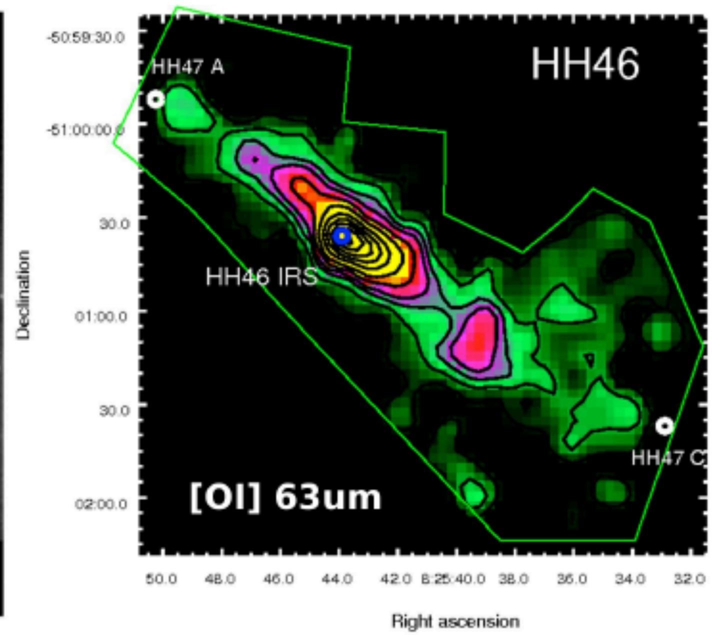
(Jochen Eisloeffel)

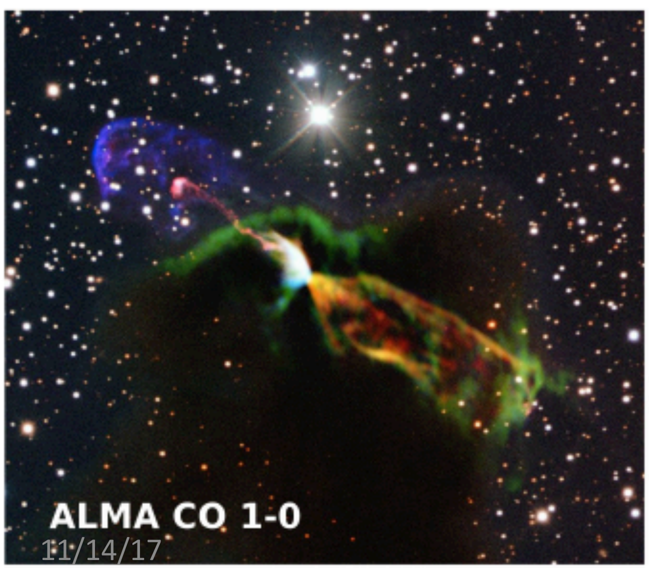
- How is energy transferred from accretion disks to the jets of young stars?
- How does this feed back into the molecular clouds where stars form (large energy & size scales)
- Requires observations of molecular lines and continuum emission on many size and energy scales

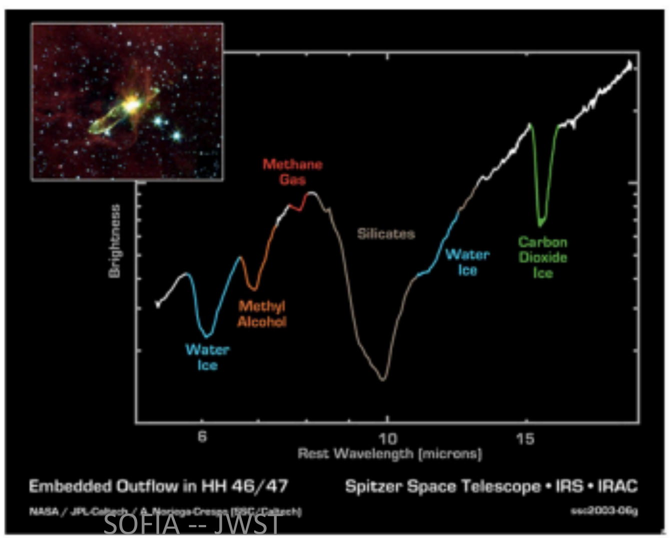




Example 1: HH46 and jet / outflow (B. Nisini)







JWST and SOFIA data probe and inventory the gas over a range of excitations: from hot to warm

Example 1: Gas and shocks in protostellar jets

(Jochen Eisloeffel)

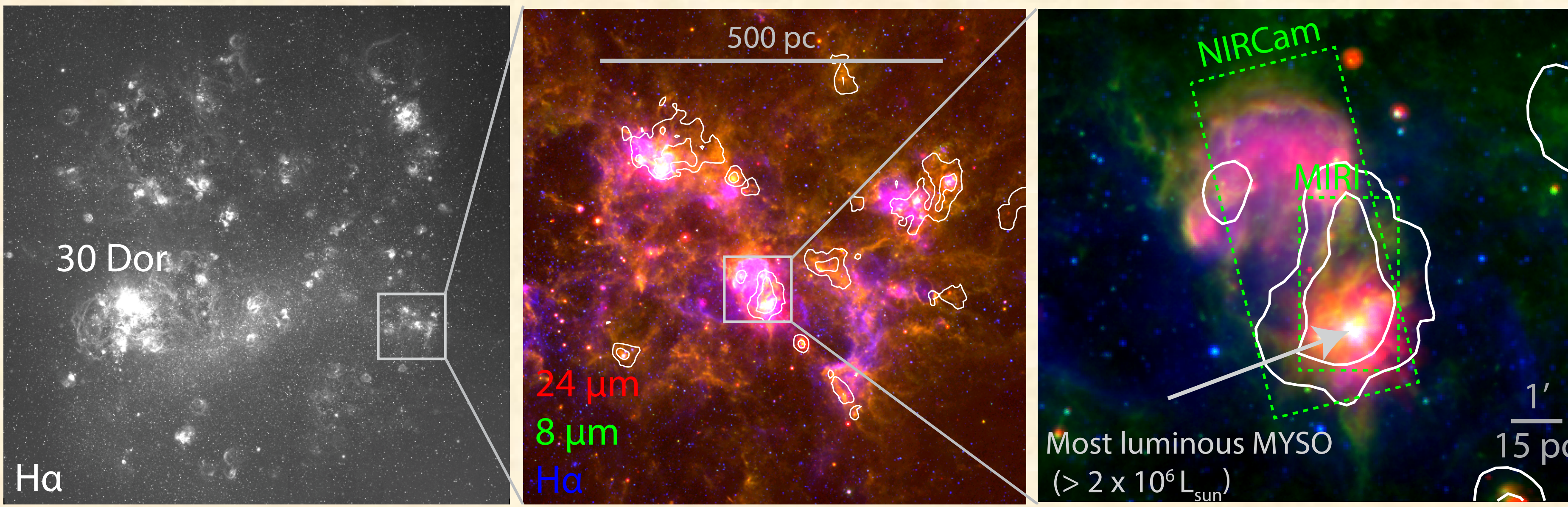
- What gas is flowing in jets?
  - JWST samples faint (high Av) high excitation
    - Fe forbidden lines give T_e, n, A_V
    - Warm H_2 rotation & ro-vibration in jets and H_2O in shocks
    - 2 x 2 / 3 x 3 NIRSpec and MIRI MRS IFU maps (~10" x 10") are sensitive to S/N > 30 on 5E-5 erg/s/pixel lines in ~900 s each position
  - SOFIA samples low excitation
    - 63 and 145 μm [OI] measure mass flux of warm flows
    - 1 hr GREAT to 10^{-18} W m^{-2} $arcsec^{-2}$, i.e. 4x10-17 W m^{-2} $pixel^{-1}$
- Modest and comparable integration times on each observatory allow census of numerous objects

Example 2: Star formation in the LMC
(Margaret Meixner)

- How does star formation occur in low metallicity environments, and how does it differ from the Milky Way?
  - LMC N79 Super Star Cluster and its high mass YSO H72.97-69.39 are good targets
- JWST will observe the young stellar population
  - Luminosities, timescales, circumstellar material (PAHs)
- ALMA will study the molecular gas
- SOFIA will study shock-excited gas
  - 63 μm [OI]
  - PDR in 158 μm [CII] and high-J CO

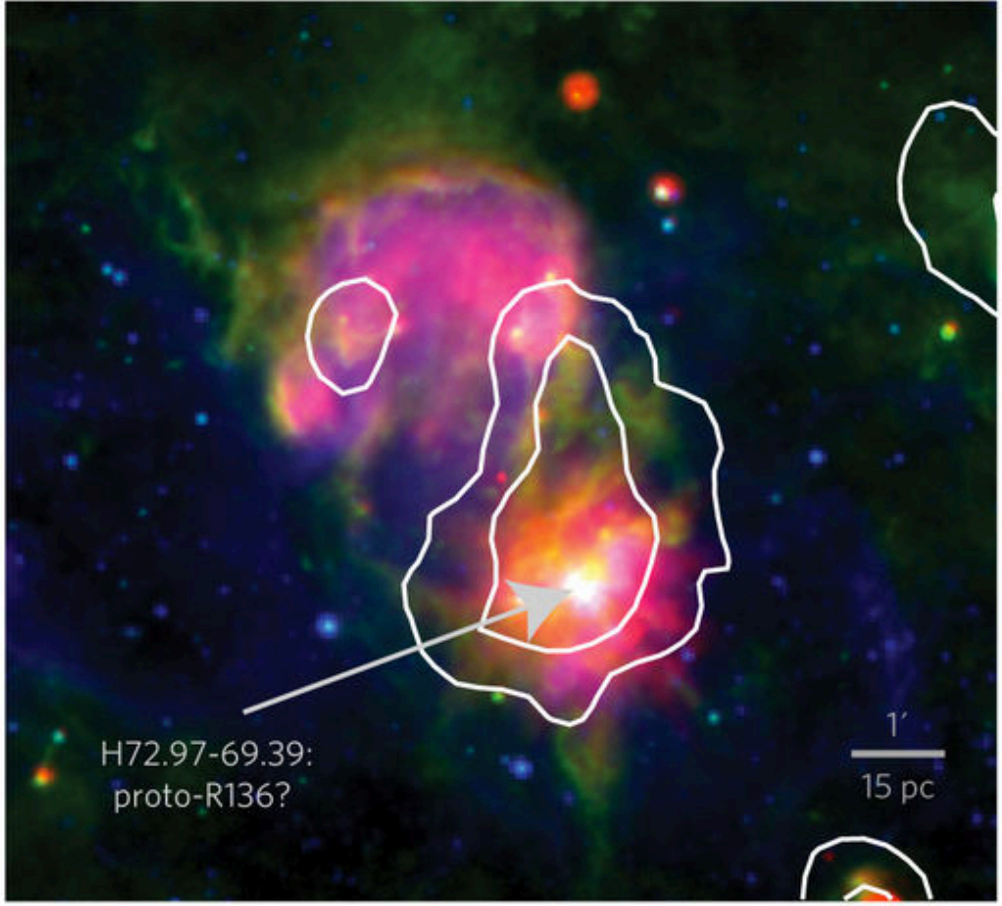
Large Magellanic Cloud: N79

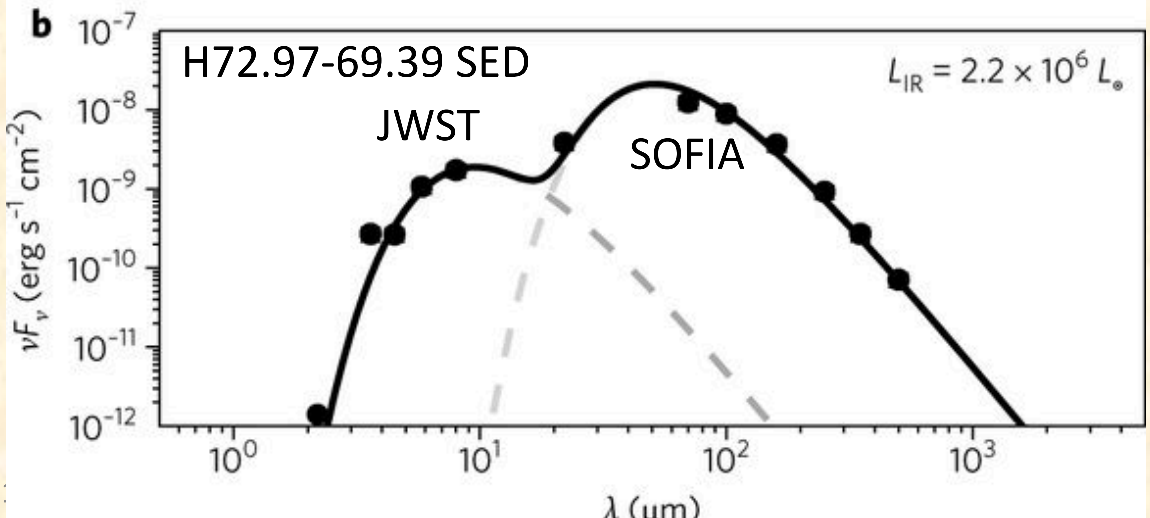
Investigating super-star cluster formation at low metallicity



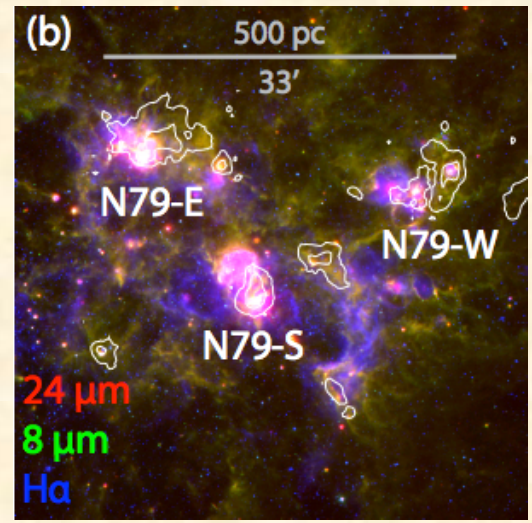
Ochsendorf et al. (2017 Nat Astr)

Star formation in LMC-N79



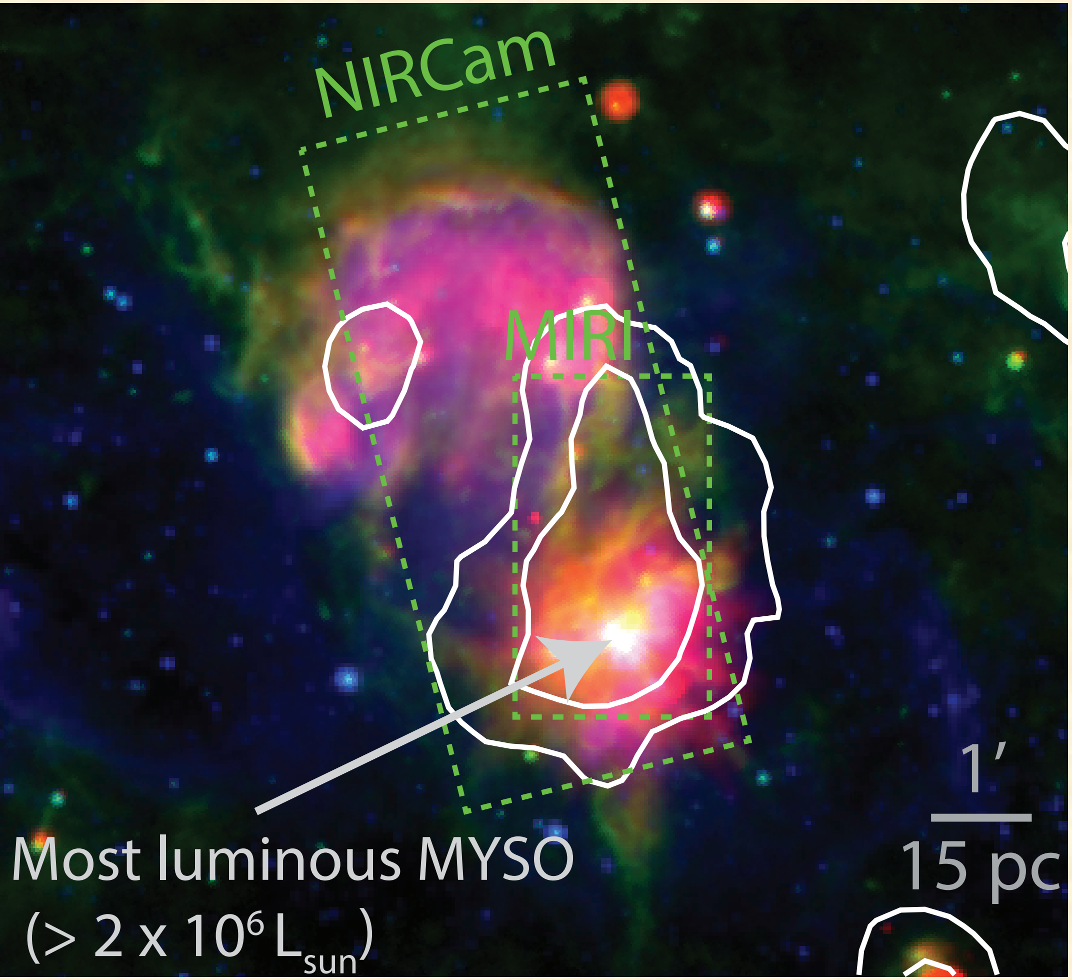


Rival to 30 Dor in Lum, but more Av



B. Ochsendorf, H. Zinnecker, …
Meixner+ 2017 Nature Astronomy

LMC-N79 (continued)



Comprehensive study of

Most luminous YSO:

-ALMA CO, HCN, HCO+

-Magellan-FIRE spectra

-Herschel HERITAGE photometry

-Spitzer-SAGE photometry

-SAGE-Spec spectra

-near-IR photometry

-SOFIA spectroscopy:

- High J CO
- [CII] 158 μm
- [OI] 63 μm

Nayak et al. in prep.

M. Meixner JWST GTO program (~ 8 hrs):

MIRI imaging 3 fields:
F770W, F1000W, F1130W,
F1500, F1800W, F255W

NIRCam imaging 4 fields:
F150W/F356W, F200W/F444W,
F115W/F300M

Summary & further thoughts

- Yes, there are ways that SOFIA and JWST observations can work together to address science questions
- Most fruitful applications may be in attacking 'big picture' problems that require an inventory of lines or objects across a wide range of wavelengths and dynamic ranges
  - 2 Cosmic Origins examples presented here
- The community will likely come up with more innovative and interesting programs
  - A multi-observatory call of some sort may yield good proposals
    - May want to consider a workshop first to generate interest & define call
- Consider legacy-like datasets for extended SOFIA mission?