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Properties of Intermediate-Luminosity Protostars and Circumstellar Disks in OMC-2

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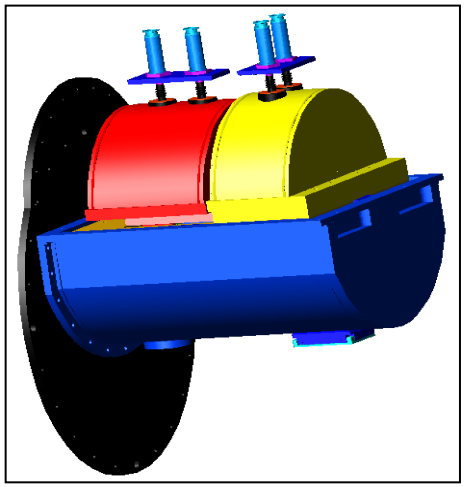
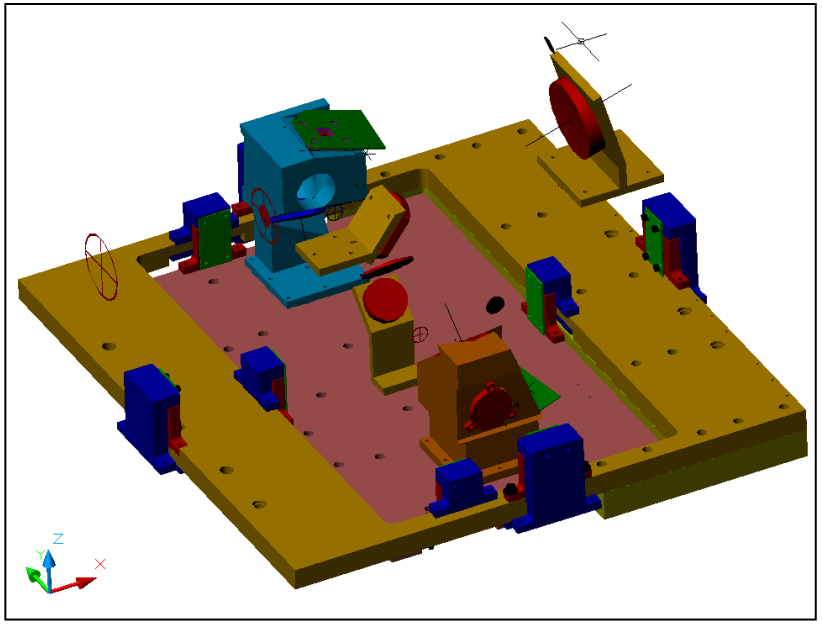
FORCAST Overview

- Facility Instrument for SOFIA
- Dual-Channel 256x256 Camera w/ Si BIB arrays
  - 5-25 μm with Si:As array
  - 25-40 μm with Si:Sb array
- 0.77 arcsec/pixel (rectified) over 3.4×3.2 arcmin FOV
- Diffraction-limited imaging for $\lambda > 15$ μm
- Selectable Filters in 5-40 μm range
- Easily accommodates grisms for spectroscopic capability





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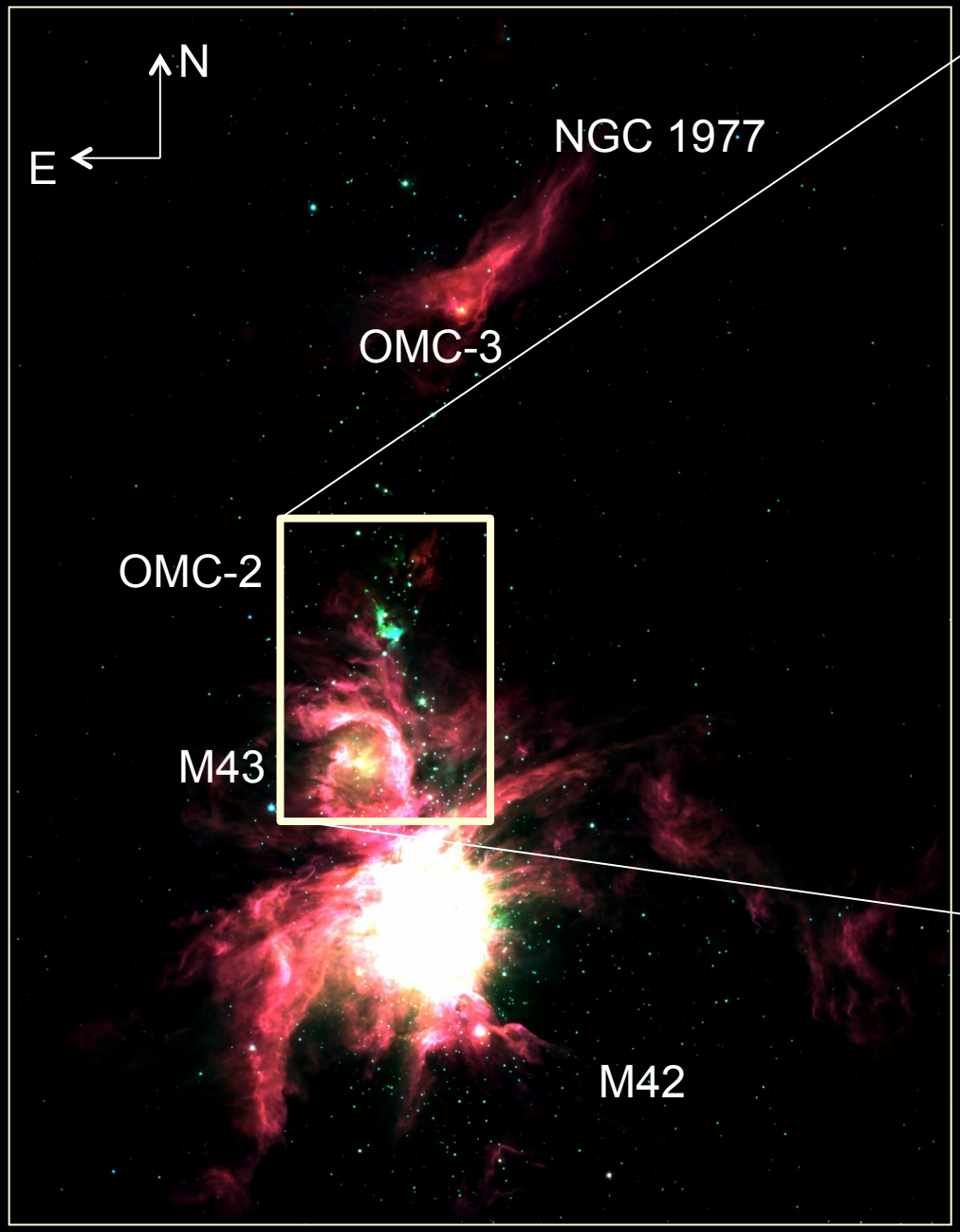
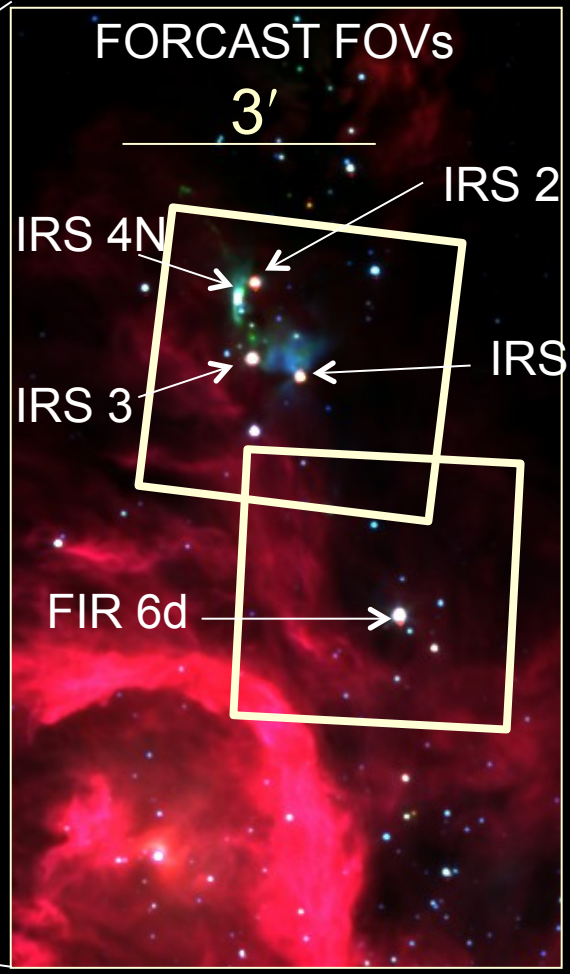
Why Study OMC-2?

- OMC-2 is a nearby, active site of star formation
  - It is one of the most luminous regions in Orion
  - Contains numerous protostars and young stars with circumstellar disks (Nielbock et al. 2003, Peterson & Megeath 2008)
  - Contains cold dusty cores often associated with stellar components and submm emission (Chini et al. 1997, Lis et al. 1998)
  - Shock activity seen in 3.6 cm VLA observations (Reipurth et al. 1999) and 2.12 μm H_2 line emission (Yu et al. 1997)
  - Possible triggered star formation from outflow activity (Shimarjiri et al. 2008)

Observations

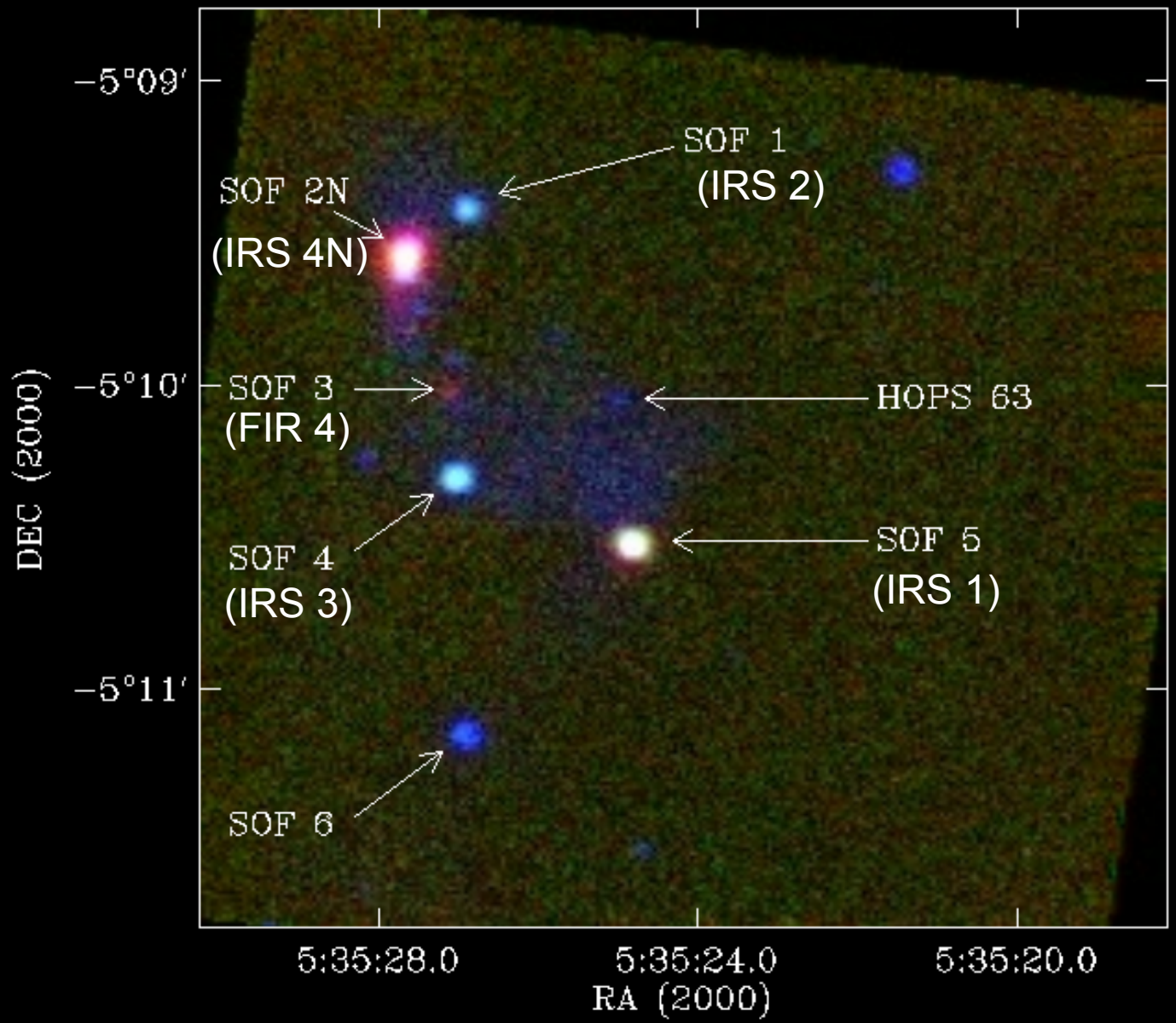
- OMC-2 was observed by SOFIA during Short Science in Nov.-Dec. 2010 during 2 different Orion flight legs
  - 19/37, 19/31, 37 μm
  - 43,000 ft. altitude
- 2 pointing fields covering 3.4’ x 3.2’ FOVs
- 5 x 30 sec integrations in C2N and C2NC2 modes
- Include Spitzer/IRAC/MIPS data at 3.6, 4.5, 5.8, 8.0, 24 μm (Megeath et al. 2005, Peterson & Megeath 2008)
- Include Herschel/PACS photometry at 70 and 160 μm (HOPS; Fischer et al. 2010)
- Include ESO APEX SABOCA and LABOCA photometry at 350 and 850 μm





Spitzer/IRAC 3.6, 4.5, 8.0 μm
Megeath et al. (2005),
Peterson & Megeath (2008)
Gately et al. (1974)
Chini et al. (1997)

OMC-2 at 4.5 μm, 19.7 μm, and 37.1 μm



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Models

Envelope Models

- Sheet collapse (Hartmann, Calvet & Boss (1994)
- Outflow cavity
- Grain Mixture: Silicates, graphite, troilite, water ice
- 0.005 – 0.3 μm grain sizes
- Dust opacity values based on class I object L1551 (Osorio et al. 2003)
- Temperature and SED profiles are calculated from radiative transfer codes (Kenyon, Calvet, and Hartmann 1993).
- External heating modeled as ~30 K single temperature blackbody

Accretion Disk Models (D'Alessio 1999, 2006)

- Flared geometry
- Temperature distribution is determined by viscous dissipation and stellar irradiation
- Grain growth and grain settling to midplane

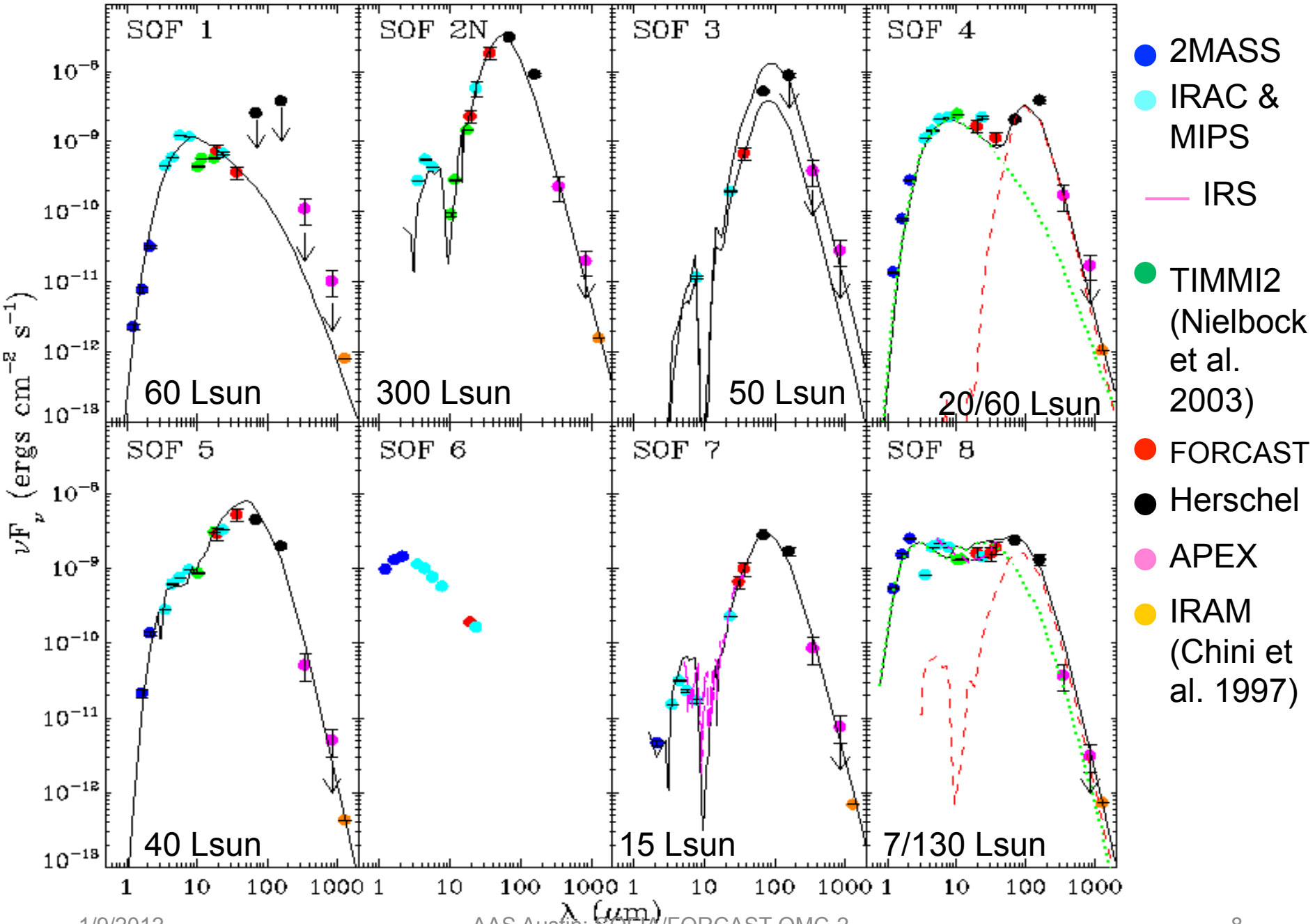
SOF 1
SOF 2N
SOF 3
SOF 4
SOF 5
SOF 6
SOF 7
SOF 8
60 Lsun
300 Lsun
50 Lsun
20/60 Lsun
40 Lsun
15 Lsun
7/130 Lsun
νF_ν (ergs cm^-2 s^-1)
λ (μm)
2MASS
IRAC & MIPS
IRS
TIMMI2 (Nielbock et al. 2003)
FORCAST
Herschel
APEX
IRAM (Chini et al. 1997)

Table 3. Constrained model parameters for FORCAST-detected OMC-2 sources.[a]

			Envelope							Disk	
Source	L ($L_\odot$)	i (degrees)	η	R_c (AU)	θ (degrees)	$R_{\rm max}$ (AU)	$\rho_{1\,\rm AU}$[b] (10^{-13} g cm^{-3})	$\dot{M}_{\rm inf}$[b,c] ($M_\odot$ yr^{-1})	$M_{\rm env}$ ($M_\odot$)	$R_{\rm disk}$ (AU)	$M_{\rm disk}$ ($M_\odot$)
SOF 1	60	40	...	...	...	...	...	...	...	40	1
SOF 2N	300	80	3	300	40	5000	1.5	$\sim3\times10^{-5}$	0.8	280	1.6
SOF 3	50	50	2	380	8	5000	20	$\sim4\times10^{-4}$	10	380	0.6
								$\sim1\times10^{-4}$			
SOF 4[d]	20	70	2.5	100	0	5000	9.0	$\sim2\times10^{-4}$	4	...	...
	60	40	...	...	...	...	...	...	...	40	1.5
SOF 5	40	50	2.5	100	5	10000	1.5	$\sim3\times10^{-5}$	2	100	0.2
SOF 7	15	70	2.5	100	30	5000	2.0	$\sim4\times10^{-5}$	1	100	0.8
SOF 8[d]	7	50	2	100	0	5000	6.0	$\sim1\times10^{-4}$	3	...	...
	130	30	...	...	...	...	...	...	...	100	0.1

Adams et al., submitted to ApJL

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Conclusions

- SOFIA/FORCAST has detected eight intermediate-luminosity (20 – 300 Lsun) sources in OMC-2
  - Modeling suggests that four are protostars
  - Two sources are likely disks
  - Two sources are binary systems containing a protostar and a star+disk system.
- SOFIA's unique wavelength and resolution capabilities are a critical component to multi-wavelength characterization of such objects in nearby, luminous star forming regions