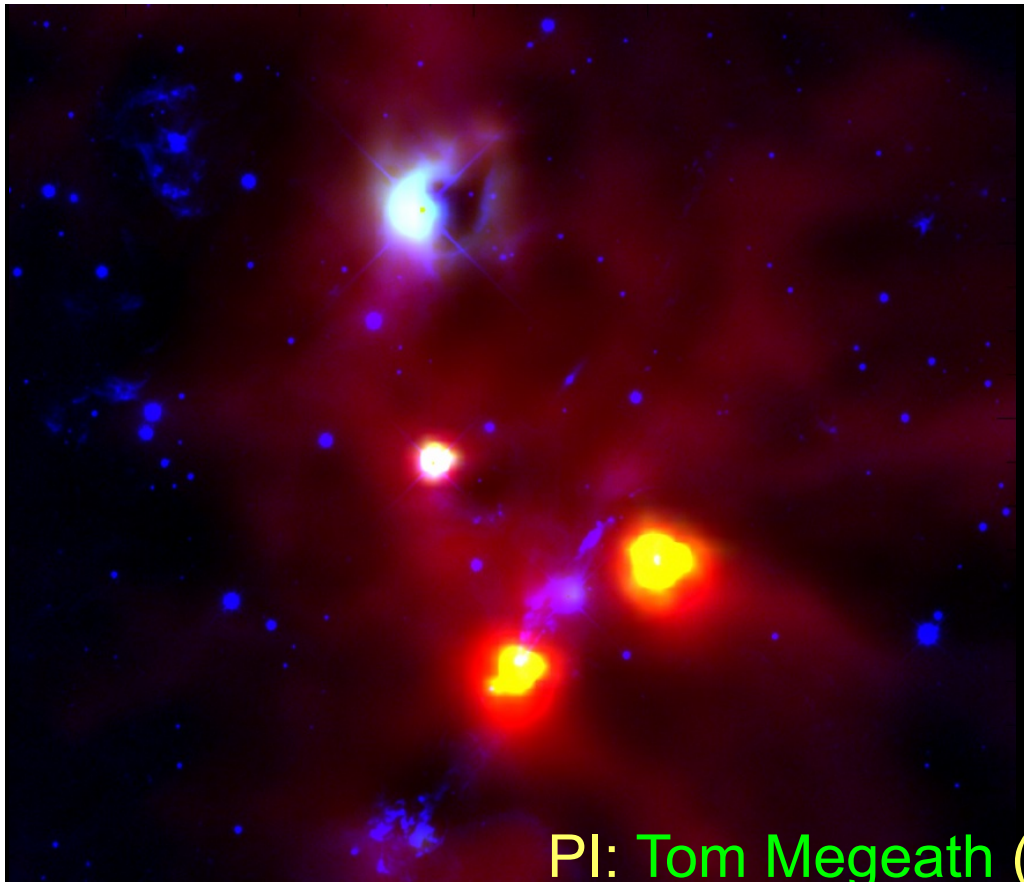
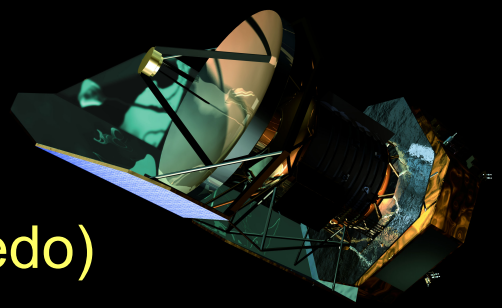


First Results from HOPS: The Herschel Orion Protostar Survey

Will Fischer
(U. of Toledo, USA)



PI: Tom Megeath (U. of Toledo)

Co-Is: Babar Ali (NHSC), Lori Allen (NOAO), Ted Bergin (U. of Michigan), Nuria Calvet (U. of Michigan), James Di Francesco (Herzberg Institute), Will Fischer (U. of Toledo), Elise Furlan (JPL), Lee Hartmann (U. of Michigan), Thomas Henning (MPIA), Oliver Krause (MPIA), Sébastien Maret (Grenoble Observatory), James Muzerolle (STScI), Phil Myers (SAO), David Neufeld (Johns Hopkins U.), Mayra Osorio (Instituto de Astrofisica de Andalucia), Klaus Pontoppidan (Caltech), Charles Poteet (U. of Toledo), Manoj Puravankara (U. of Rochester), Thomas Stanke (ESO), Amy Stutz (MPIA), John Tobin (U. of Michigan), Dan Watson (U. of Rochester), and Tom Wilson (ESO)

HOPS Observations

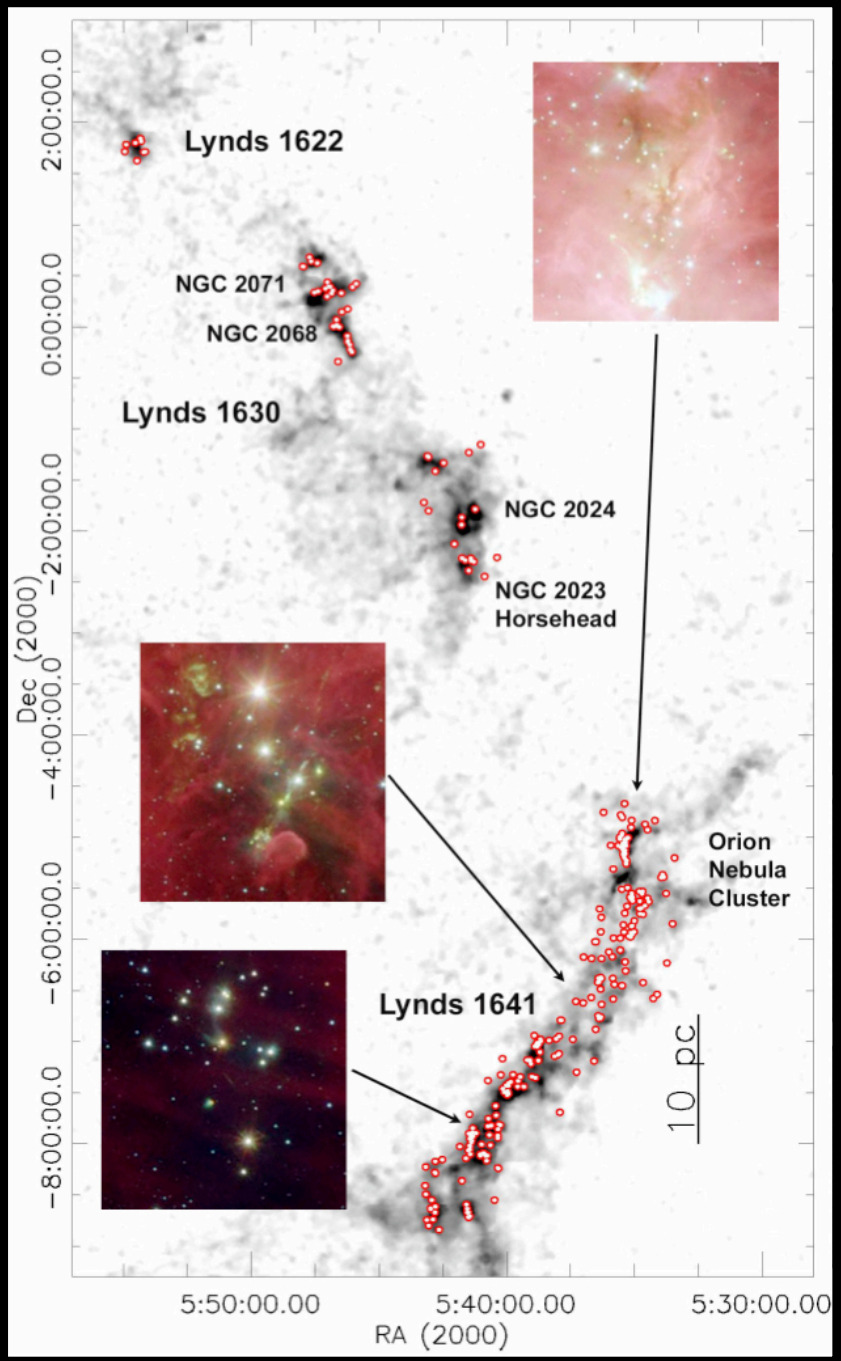
PACS imaging of 278 protostars:

- Spitzer-identified protostars with extrapolated fluxes > 42 mJy at 70 μm
- 5’ to 8’ square fields
- Medium (20”/s) scan rate
- 70 and 160 μm scans & cross-scans

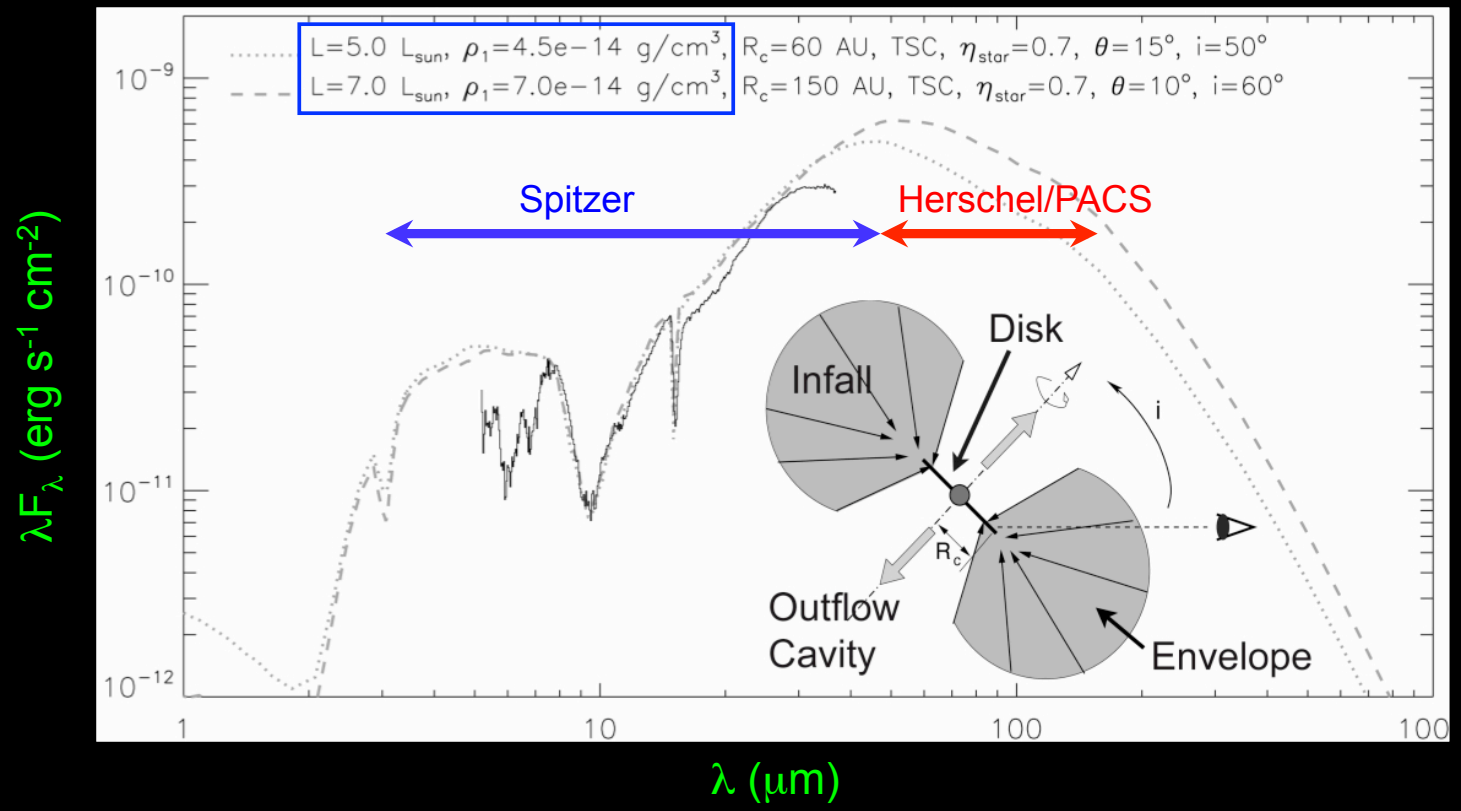
PACS spectroscopy of 37 protostars:

- 25 face-on sources, 12 at other inclinations
- Source fluxes from 100 mJy to ~10 Jy
- Spectral coverage from 57 to 185 μm
- Water, OH, CO, and [OI] (63 μm) lines

Sources sample environments from isolated to clustered



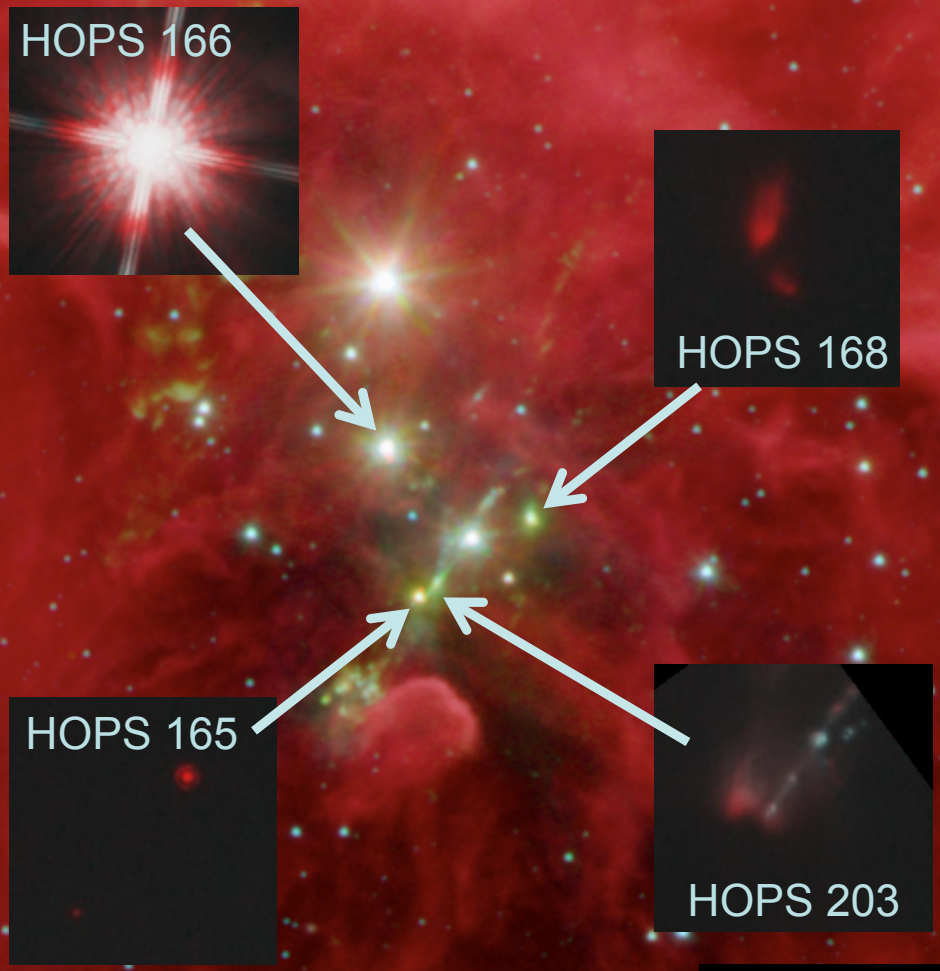
Science Goals



Study a large sample of protostars in a single cloud with combined Herschel, Spitzer, Hubble and ground-based data

- Robustly determine protostellar envelope properties
- Determine the influence of initial conditions
- Examine the role of environment
- Study protostellar evolution with a large sample
- Measure disk accretion vs envelope infall rate

IRAC image of the V380 Ori region
3.6 μm 4.5 μm 8.0 μm



NICMOS: 1.60 μm 2.05 μm

Supporting Data

- Spitzer
  - IRAC
  - IRS
  - MIPS 24 μm
- HST near-IR
  - NICMOS
  - WFC3
- Ground-based near-IR
  - Imaging
  - Spectra
- Ground-based sub-mm
  - Imaging

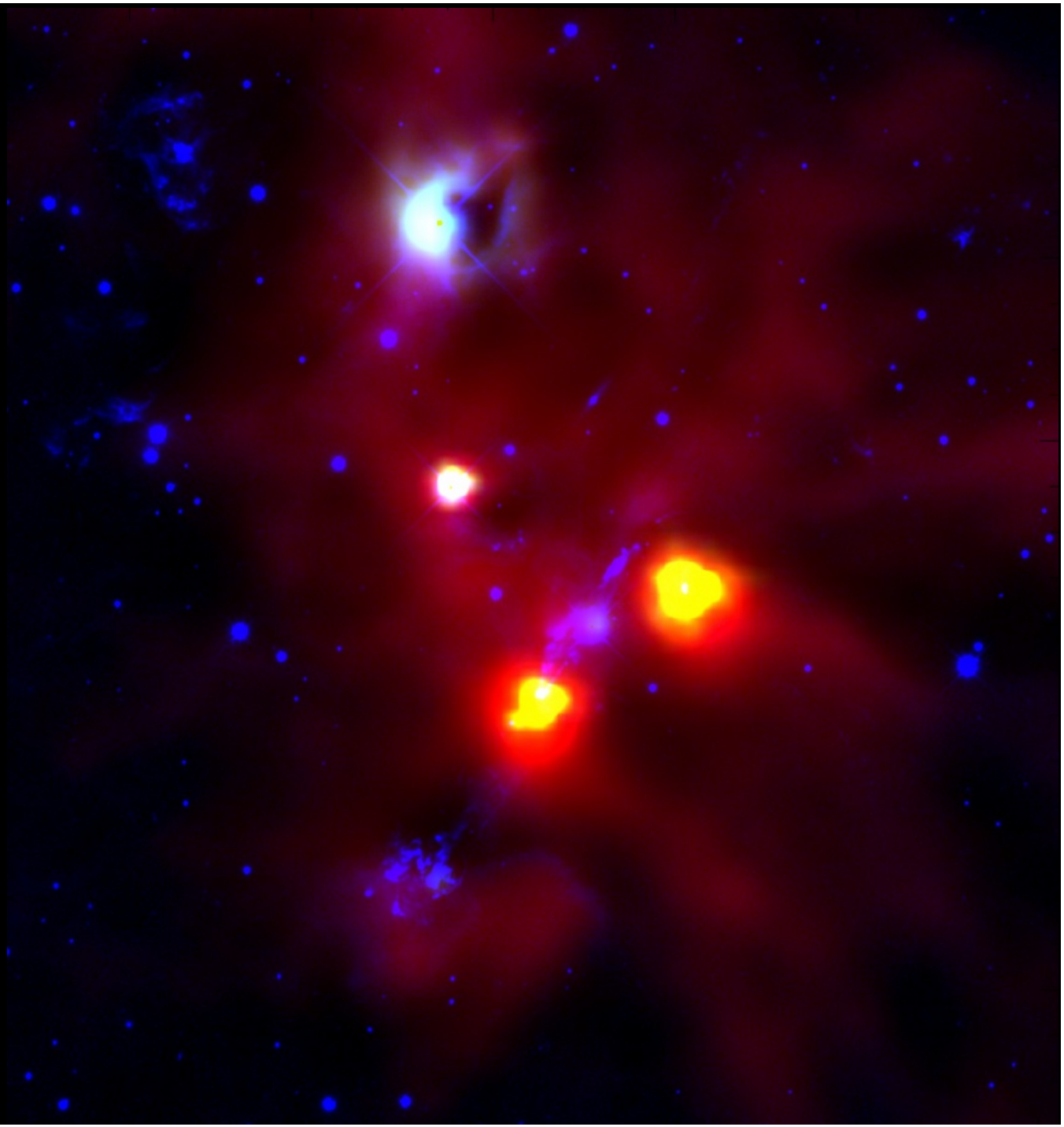
(NICMOS reduction by M. Kounkel)

HOPS Science Demo Field

V380 Ori / HH 1-2 region in L1641

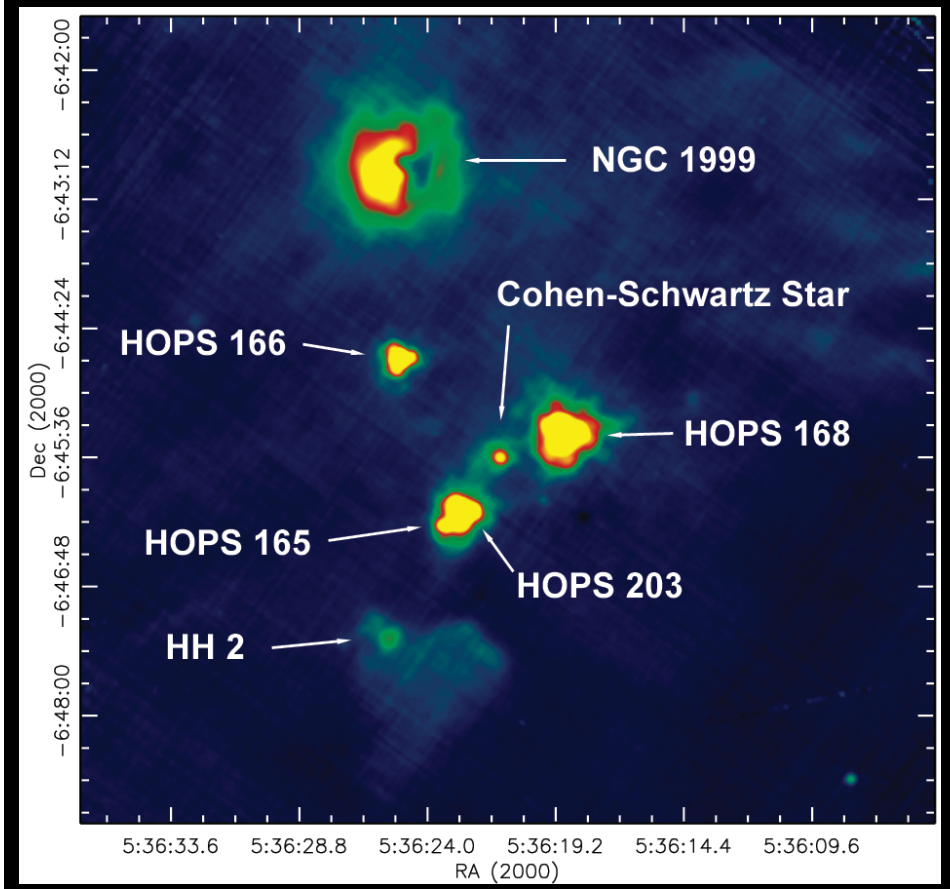
8’ square field centered at $5^h36^m22.1^s$, $-6^o45’41”$

NEWFIRM 2.2 μm
PACS 70 μm
PACS 160 μm

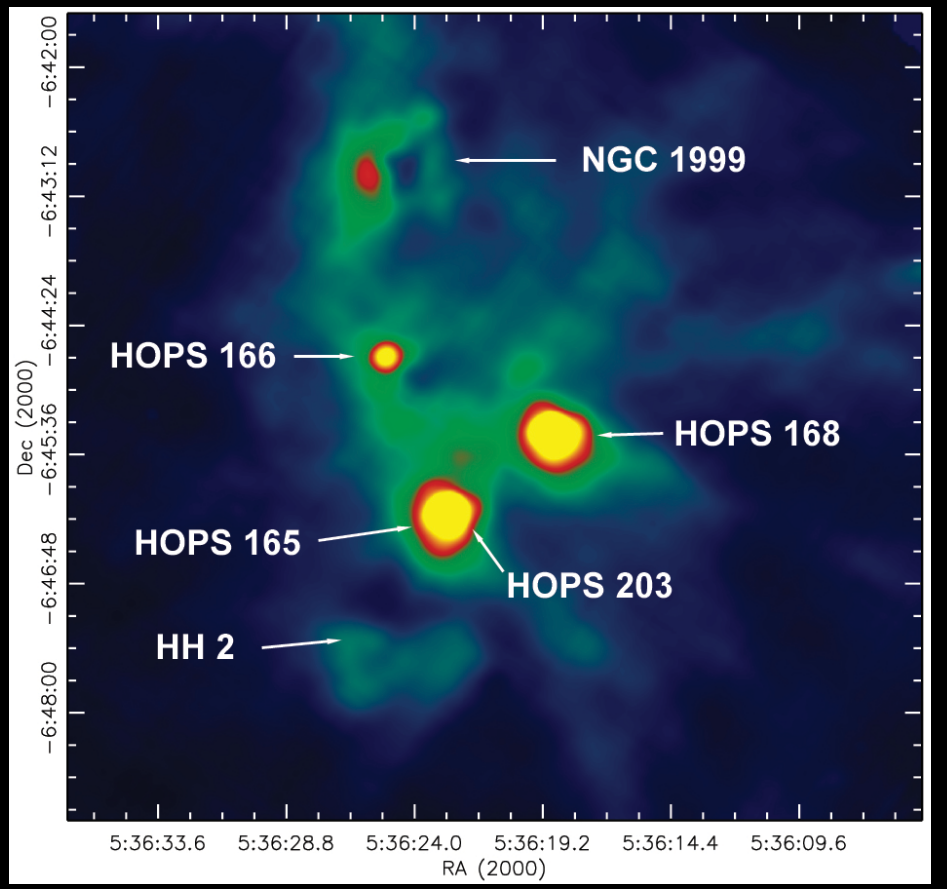


PACS Images

70 μm



160 μm

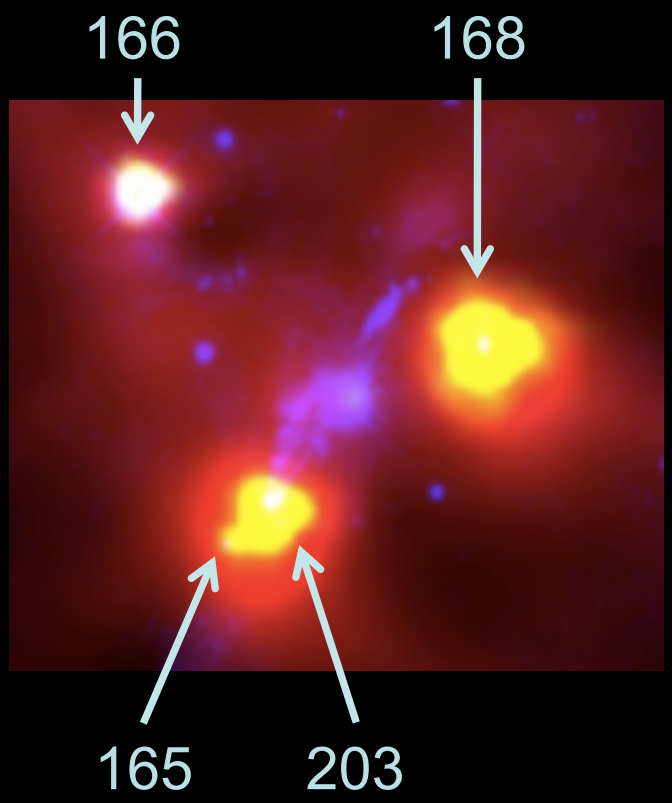


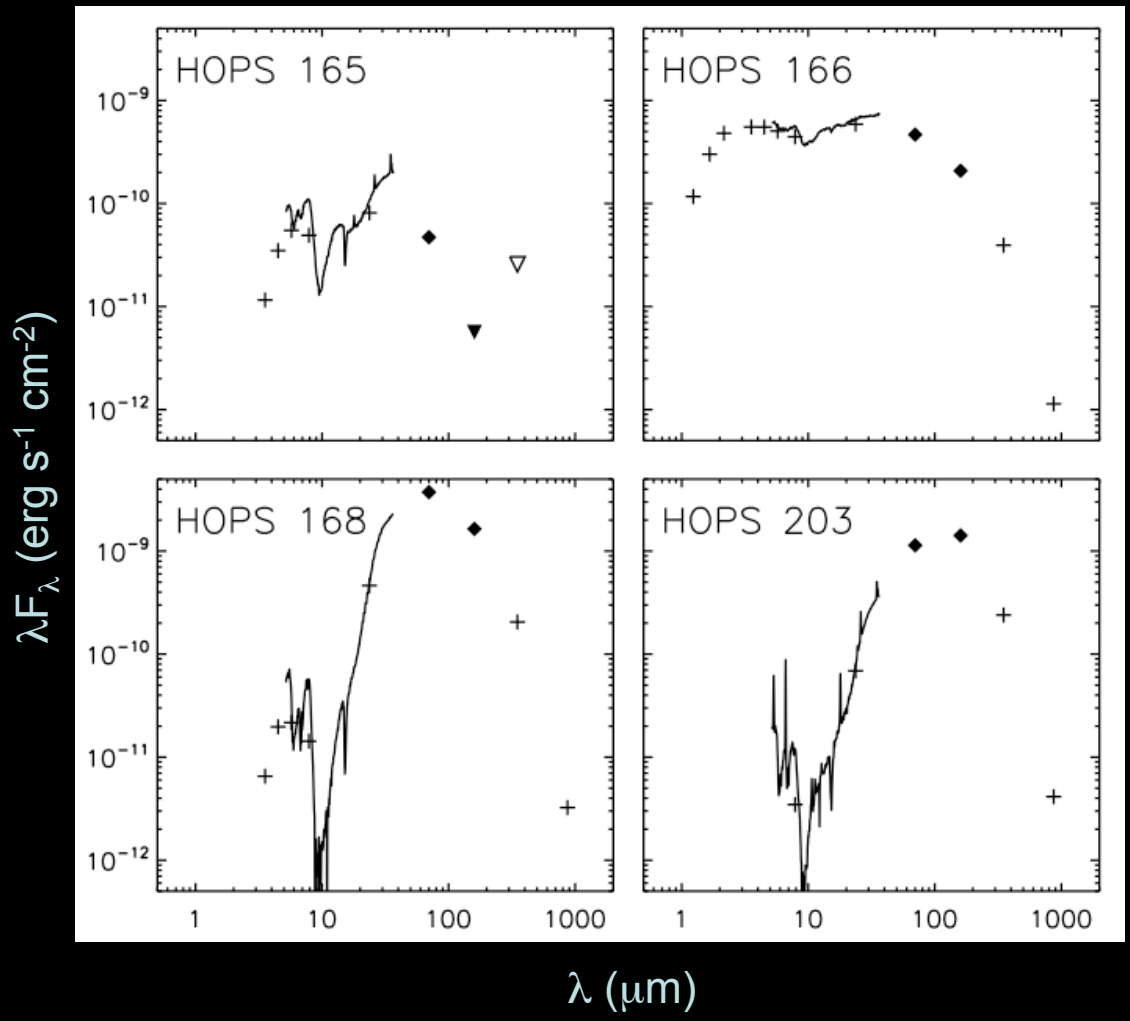
(Reduction by B. Ali)

I. Protostars

(Fischer et al. 2010, sub. to A&A)

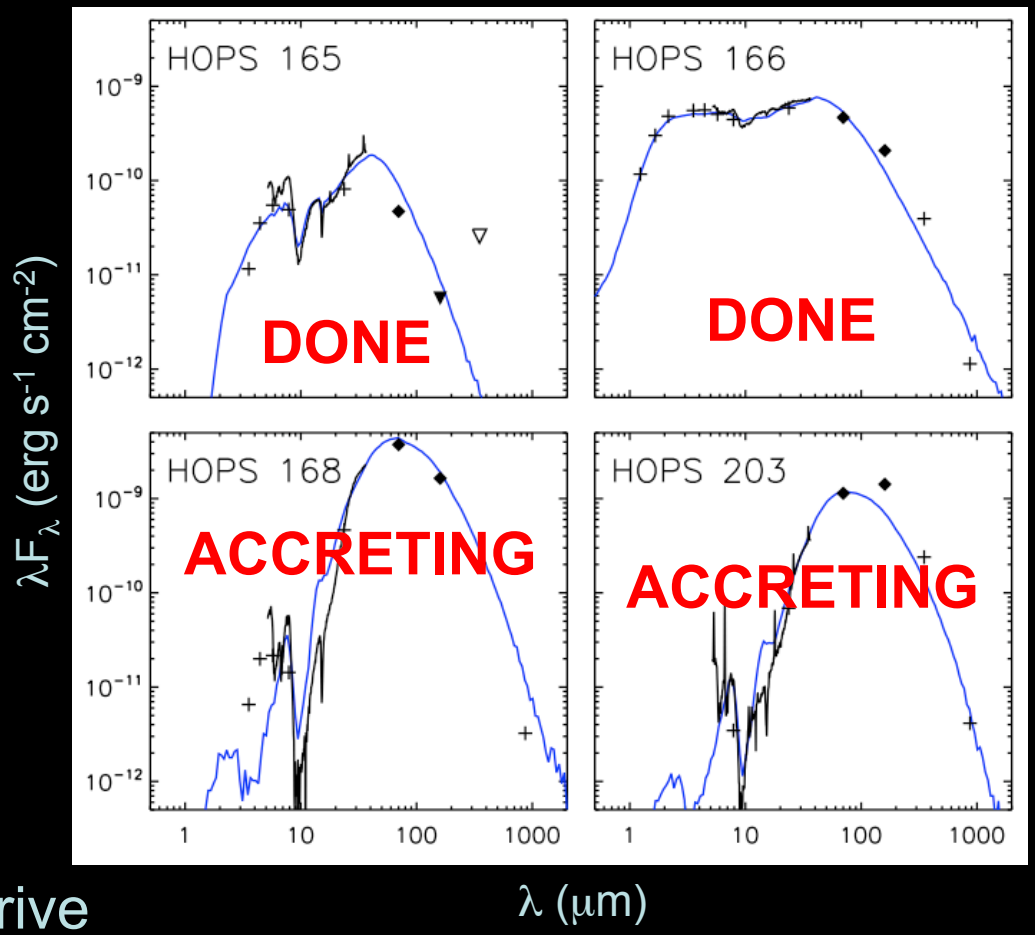
Construct SEDs from
2MASS, Spitzer, Herschel, APEX





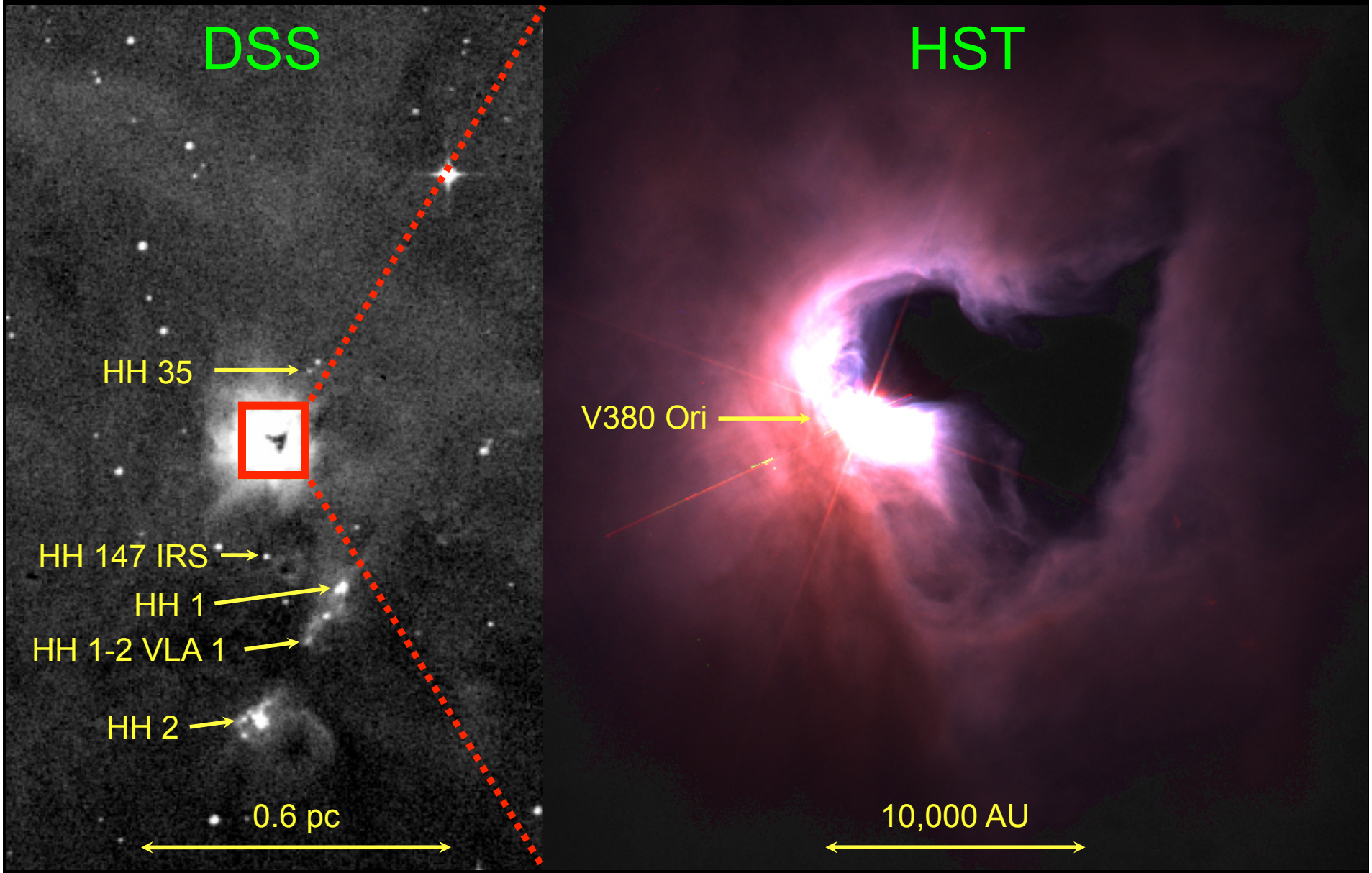
SED Modeling

	L (L_{sun})	dM_{env}/dt (M_{sun}/yr)	L_{acc} / L
165	12	2×10^{-7}	0.1
166	23	4×10^{-7}	0.2
168	84	3×10^{-5}	~ 1
203	23	2×10^{-5}	~ 1

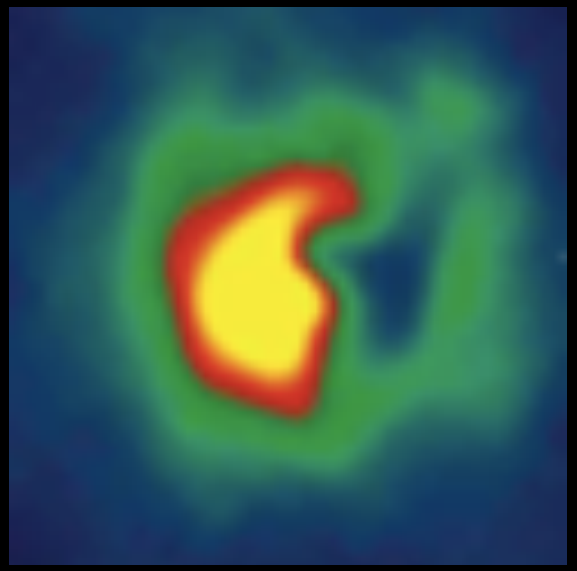


- Modeled SEDs with B. Whitney's RT code
- Key parameters
  - Luminosity
  - Envelope density
- With stellar parameters, derive
  - Envelope infall rate
  - Accretion luminosity
- HOPS 168, 203: $dM_{disk}/dt = dM_{env}/dt$ implies $M_{star} \sim 0.1\ M_{sun}$
  - Episodic accretion would allow larger masses

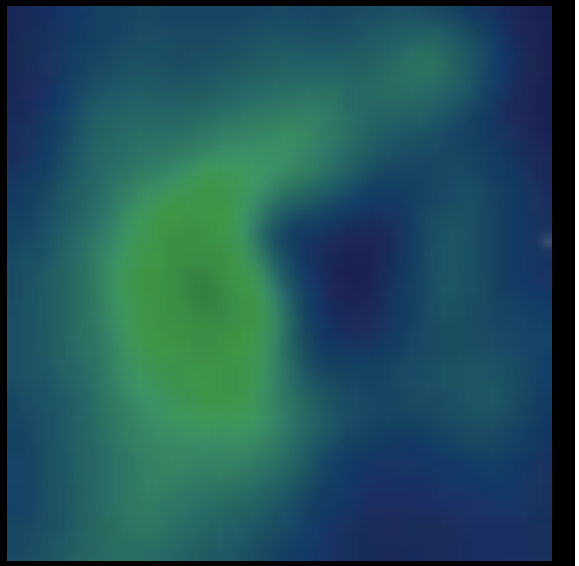
II. NGC 1999 (Stanke et al. 2010, submitted to A&A)



PACS 70 μm



PACS 160 μm

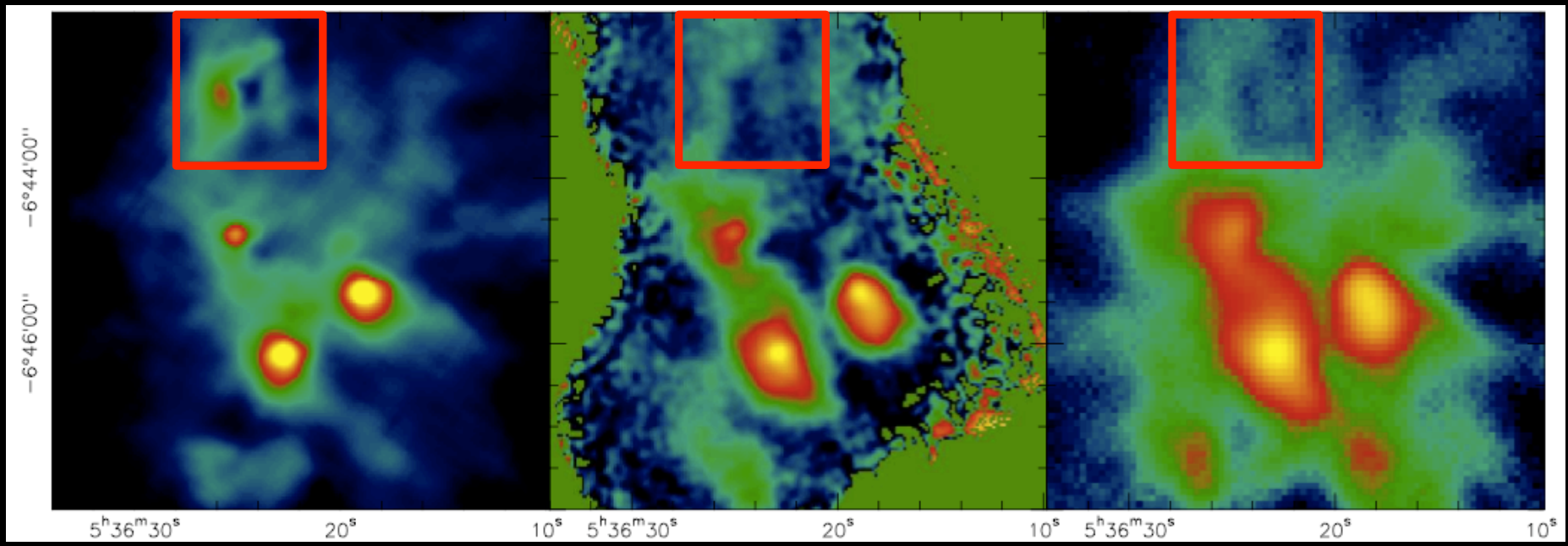


- The region remains dark at 70 and 160 μm: a far-IR dark cloud?
- Mass responsible for the flux decrement is wavelength-dependent!? (A. Stutz)
  - ~ 0.1 M_{sun} at 70 μm
  - ~ 2.5 M_{sun} at 160 μm
- Obtained ground-based follow-up

$$\tau = - \ln [(f + f_{BG}) / (f_0 + f_{BG})]$$

APEX

PACS 160 μm SABOCA 350 μm LABOCA 870 μm

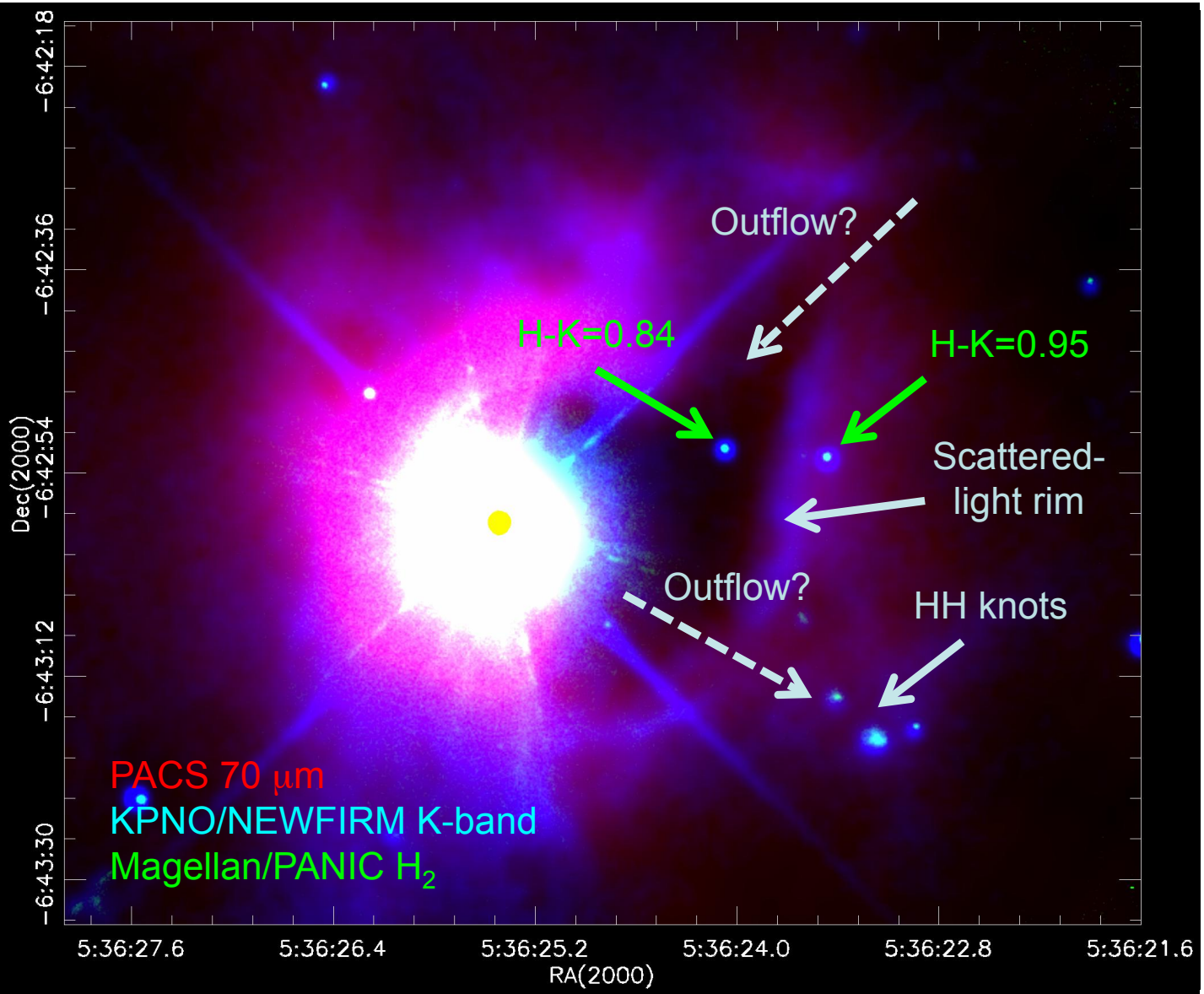


- IR dark cloud should be bright in sub-mm
  - Not detected
  - SABOCA (350 μm) upper mass limit: 2.4 x 10^{-2} M_{sun}

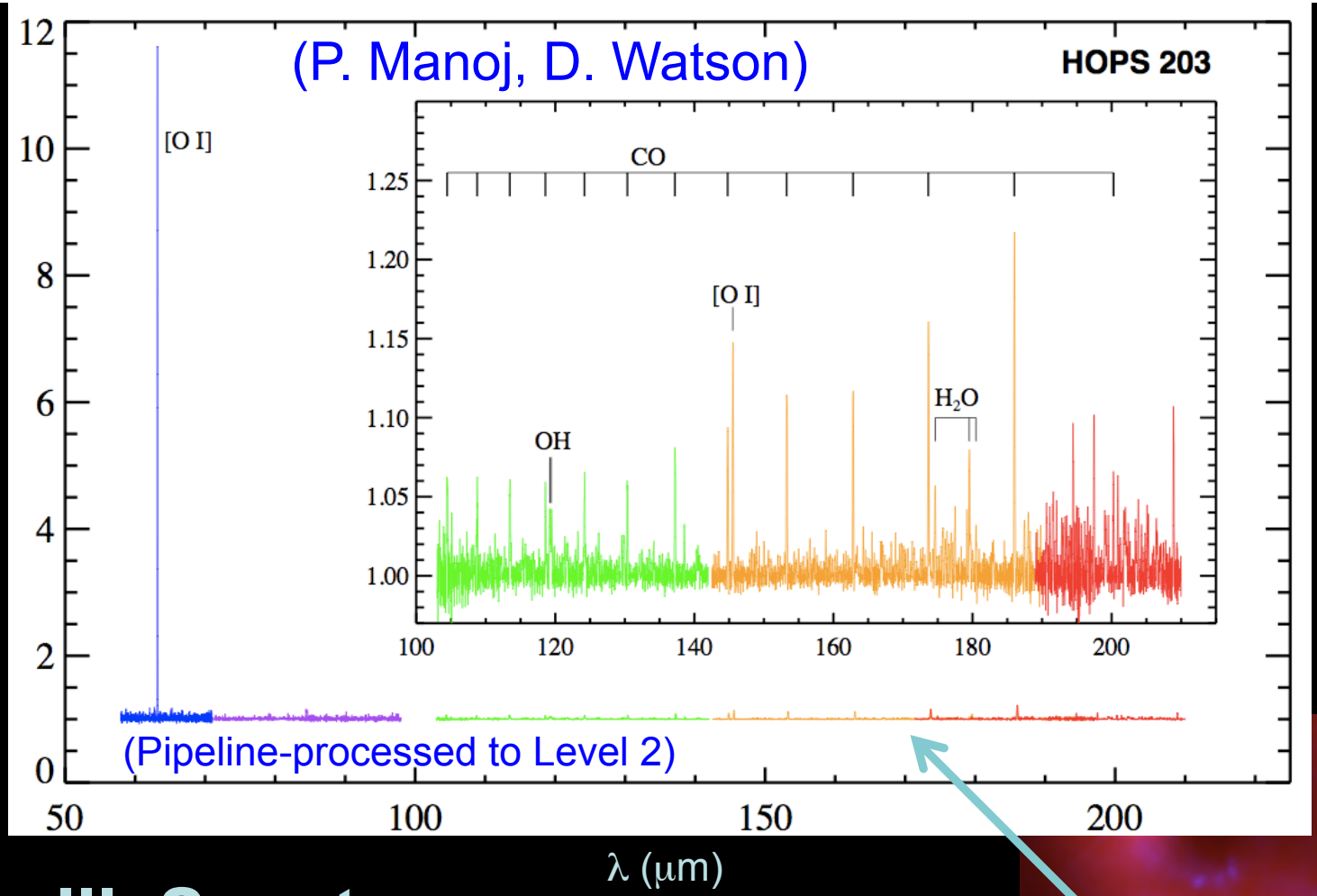
(T. Stanke, ESA DDT)

Near IR

(J. Tobin,
L. Allen,
E. Kryukova)

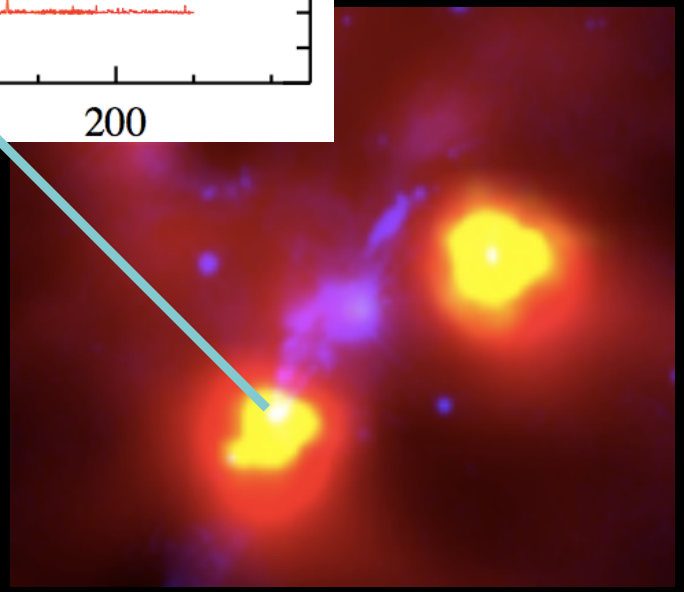


- H-K colors of stars imply A_V~10, not 100
- H-K colors of stars inside the dark patch are bluer than those of stars outside the patch
- This is not a dark cloud but a genuine *hole in the nebula* -- Carved by outflows?



III. Spectra

- PACS spectra have recently been acquired for HOPS 203
- Strongest lines appear to form in outflow shocks from HH 1-2



HOPS: The Herschel Orion Protostar Survey

Conclusions

- The NGC 1999 “dark globule” is really a cavity in the cloud carved by outflows
- Two of the four protostars in the V380 Ori region are actively accreting from their envelopes, while two have only residual envelopes
- We have demonstrated Herschel’s unique and critical ability to audit the mass flow from the outer envelope onto the central protostar