Star Formation: Early Herschel Results From ESLAB 2010

Paul M. Harvey

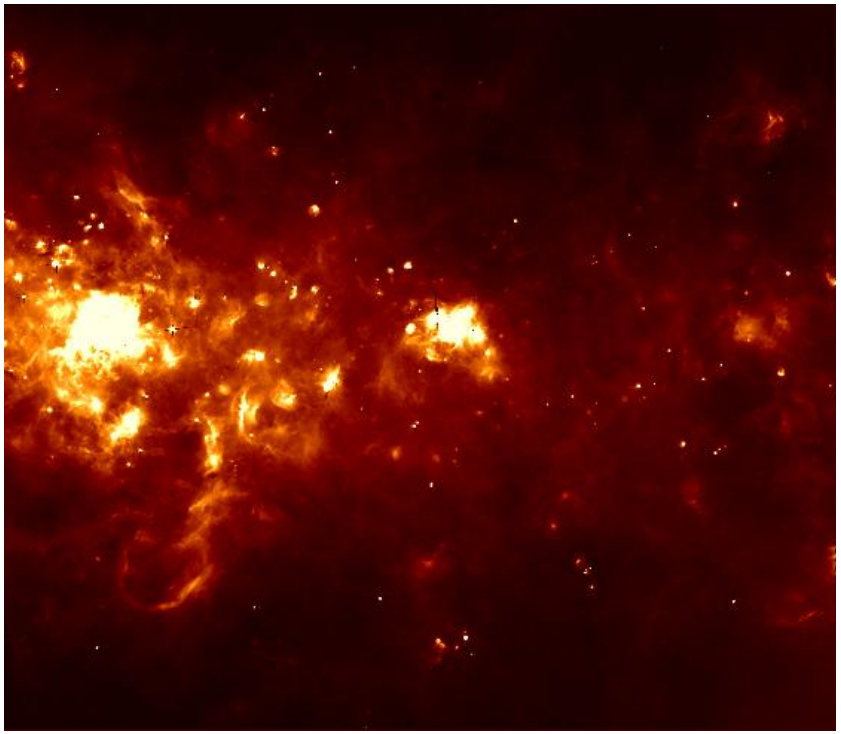
With help from many ESLAB presenters!

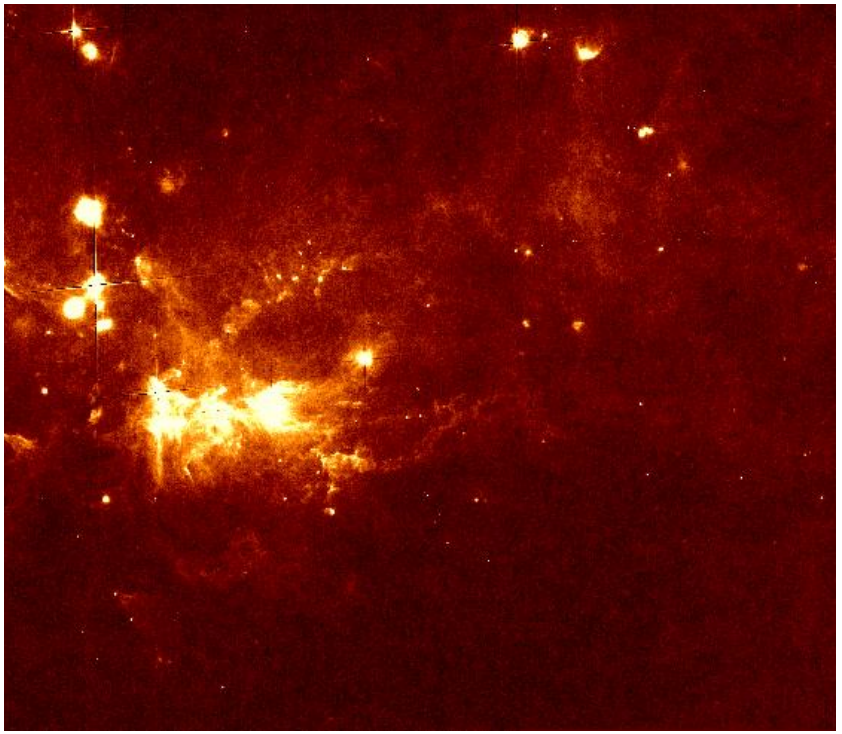
The "Problem"

- 7 Key Programs + GT and PV data
- 21 talks and 26 posters on star formation w/PACS and SPIRE
- Large Surveys
  - Molinari/HIGAL
  - André/Gould Belt
- Focused Surveys
  - HOBYS/OB Star Formation
  - HOPS/Orion Survey
  - EPOS/Youngest Clouds
  - SPIRE GT-PV/FTS Spectra
  - DIGIT/PMS PACS Spectroscopy
- And all mostly just Science Demo Data ~ 1 month!

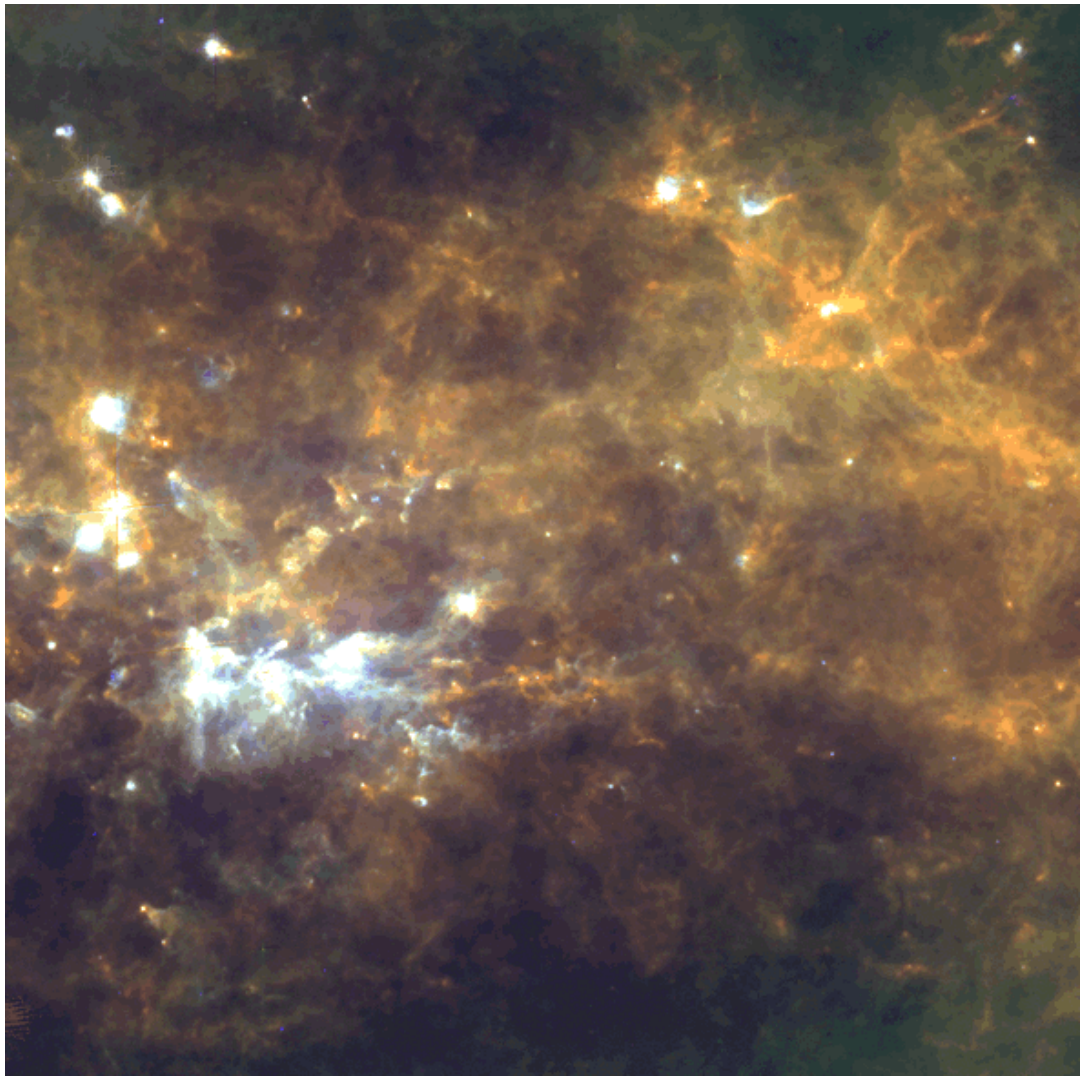
HIGAL

ℓ = 30º and ℓ = 59º
(eventually ℓ = -60º to +60º)

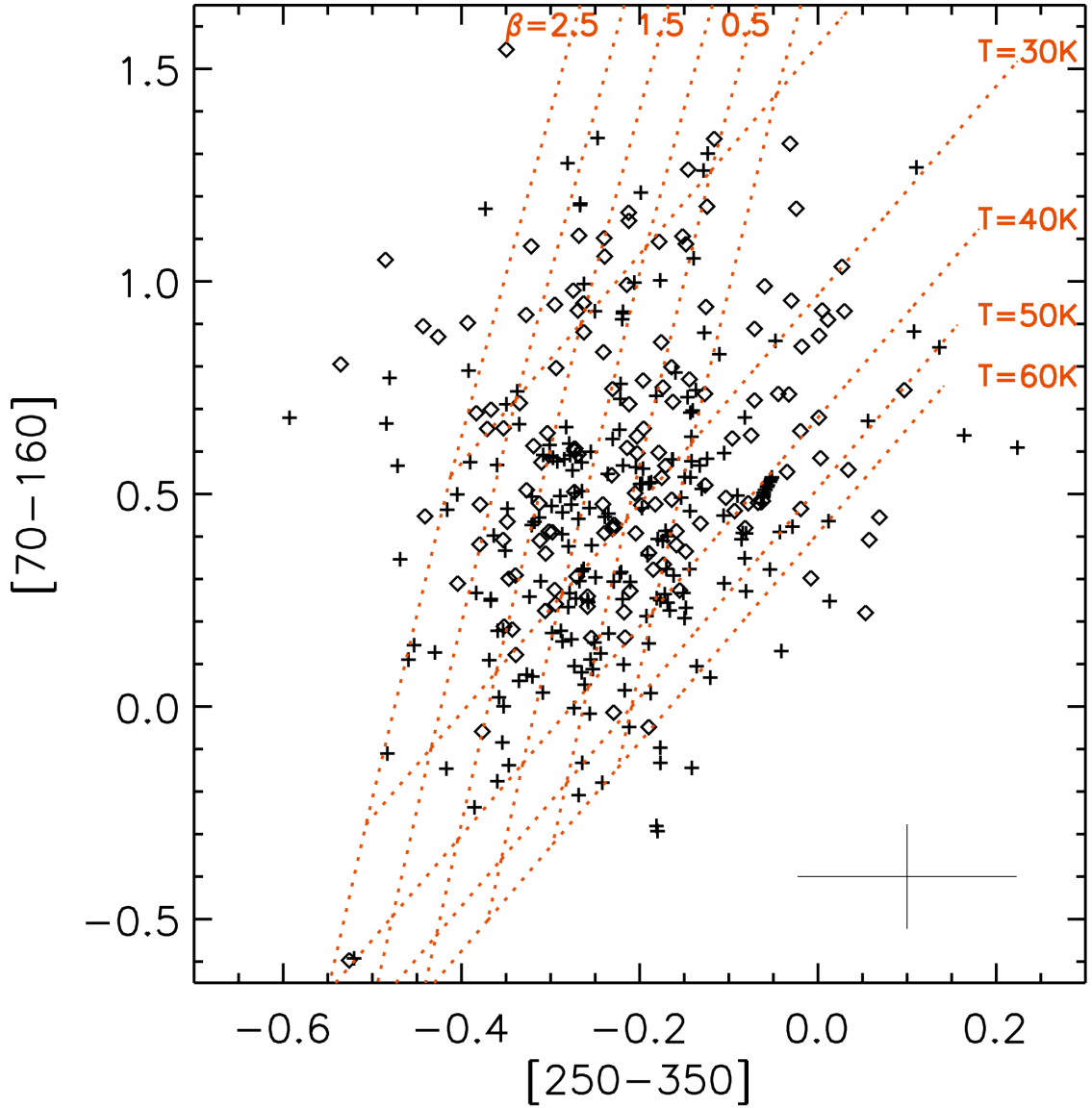




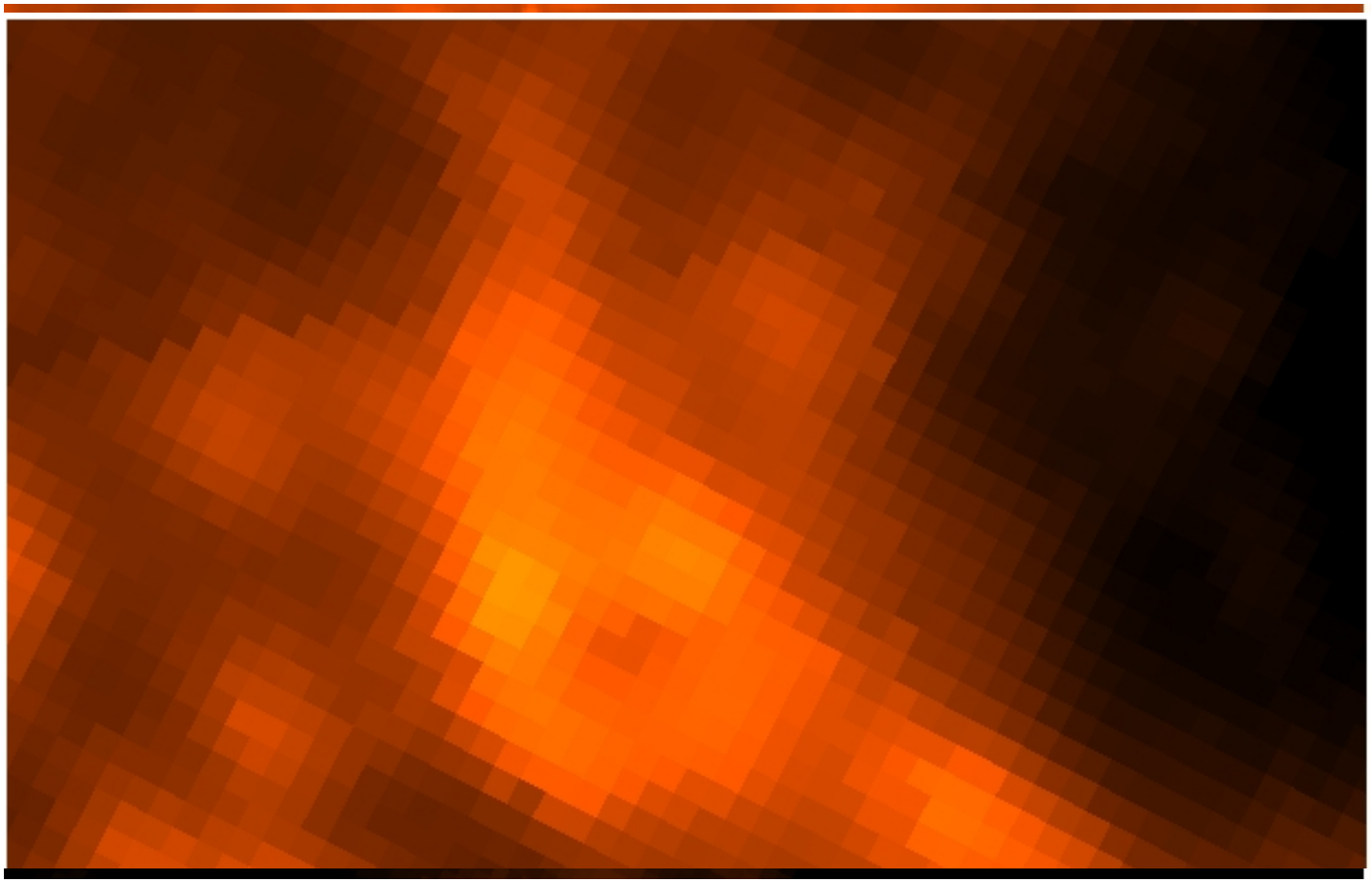
$\ell = 59^{o}$



HIGAL (Far-IR Color/Color)



IRDCs with Hi-GAL: Shadows… and Lights



MIPS 24

PACS 70

PACS 160

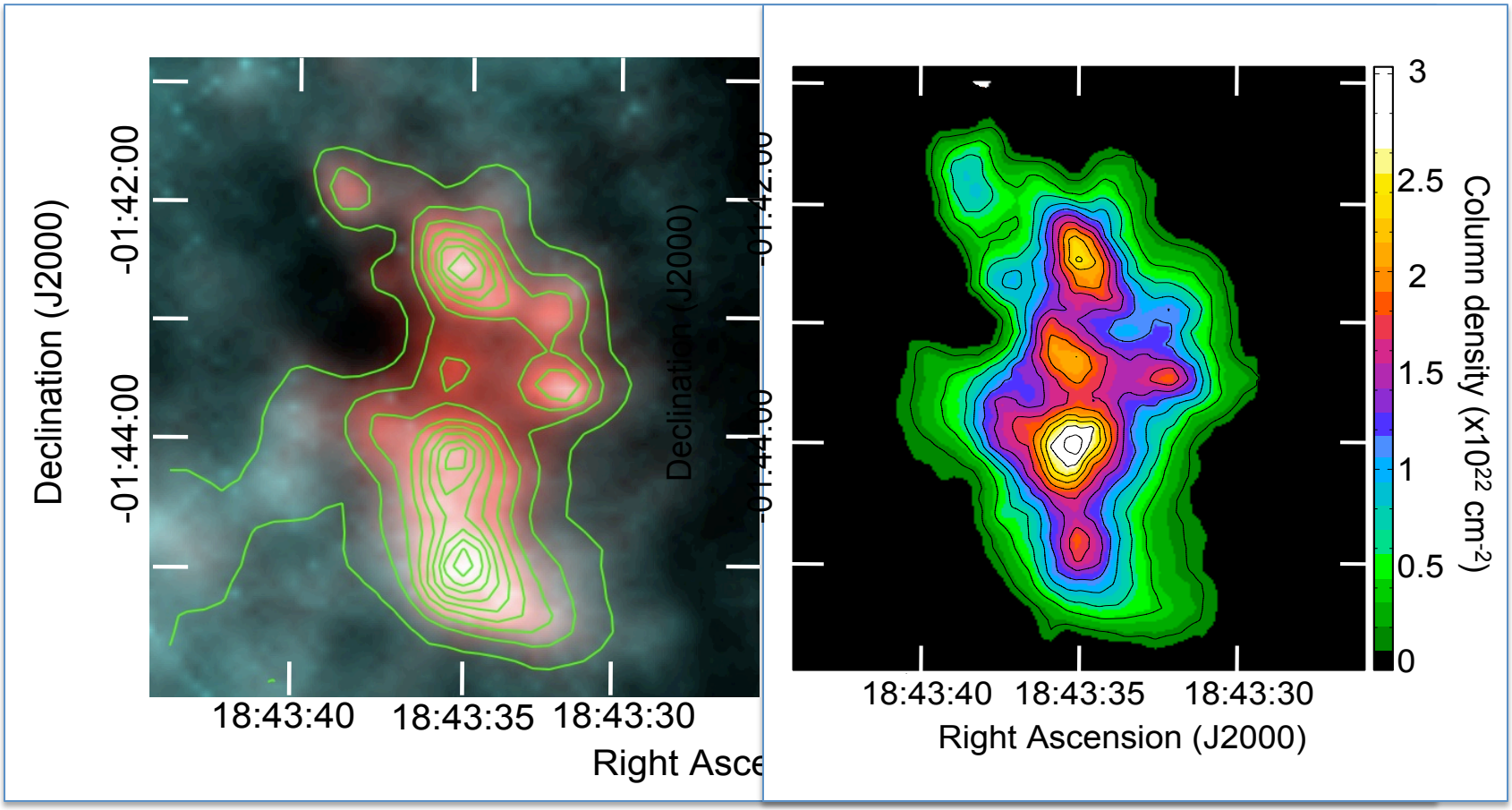
SPIRE 250

SPIRE 350

SPIRE 500

- The earliest stages of massive SF (Peretto+ 2010, Wilcock+ 2010)
- The lifetime of pre-stellar phase (Olmi+ 2010)

Dust temperature and column density structure of IRDCs

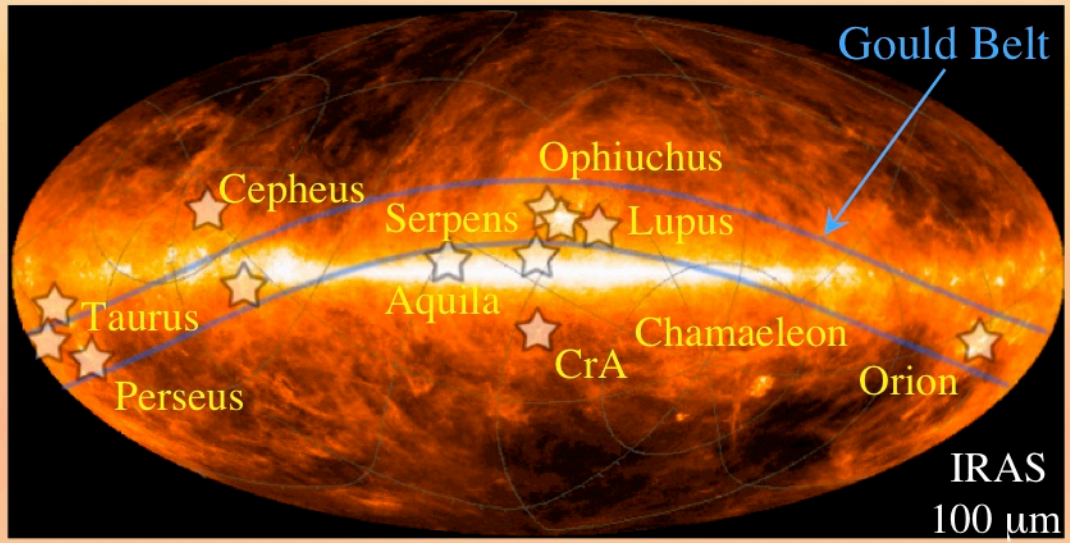


Peretto et al. (2010)

The *Herschel* Gould Belt Survey

http://gouldbelt-herschel.cea.fr/

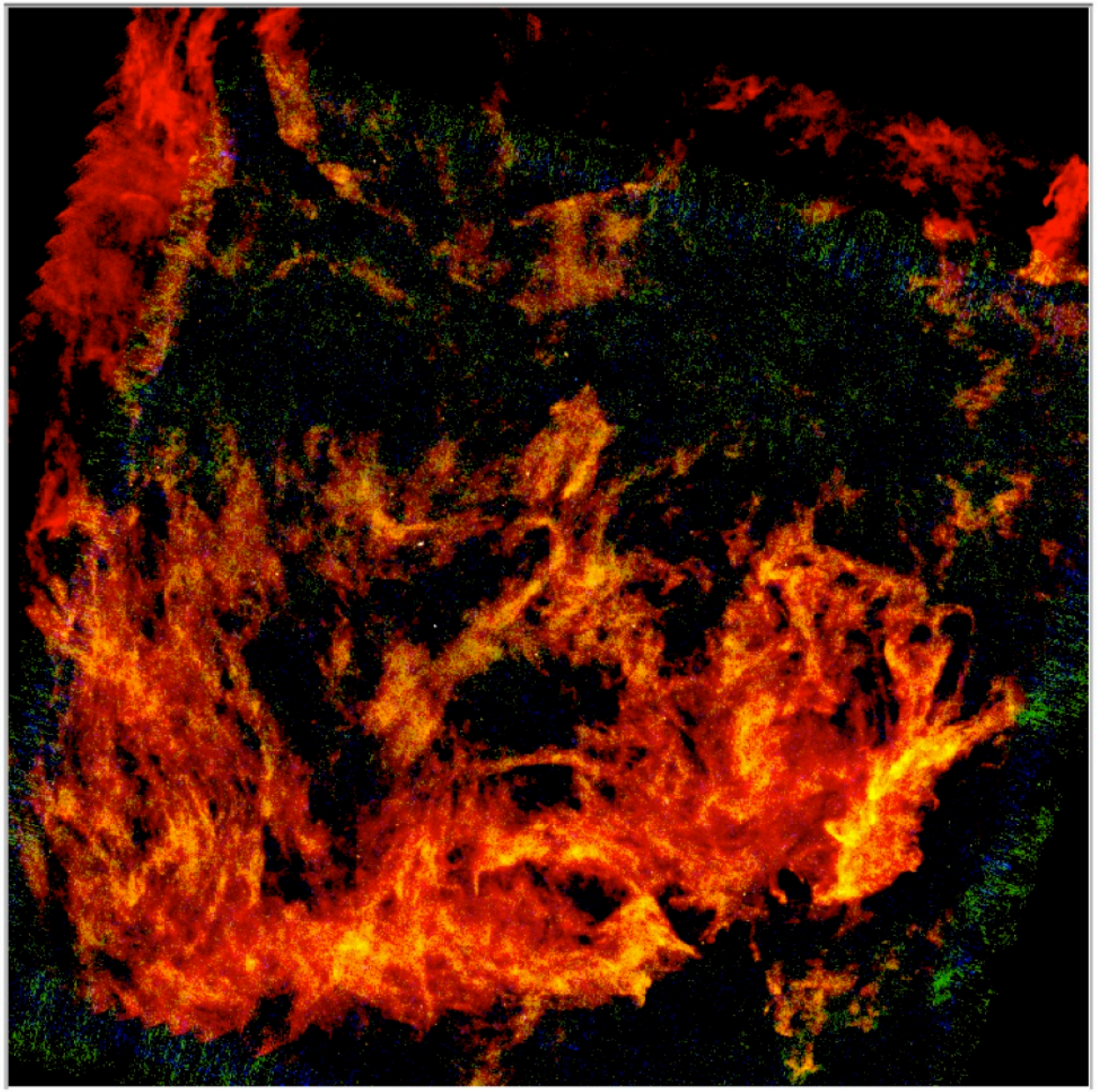
SPIRE/PACS 70-500 μm imaging of the bulk of nearby (d < 0.5 kpc) molecular clouds (~ 160 deg^2), mostly located in Gould's Belt.



Motivation: Key issues on the early stages of star formation

- What determines the distribution of stellar masses = the IMF ?
- What generates prestellar cores and what governs their evolution to protostars and proto-brown dwarfs ?

"First images" from the Gould Belt Survey



1) Polaris translucent cloud

(d ~ 150 pc)

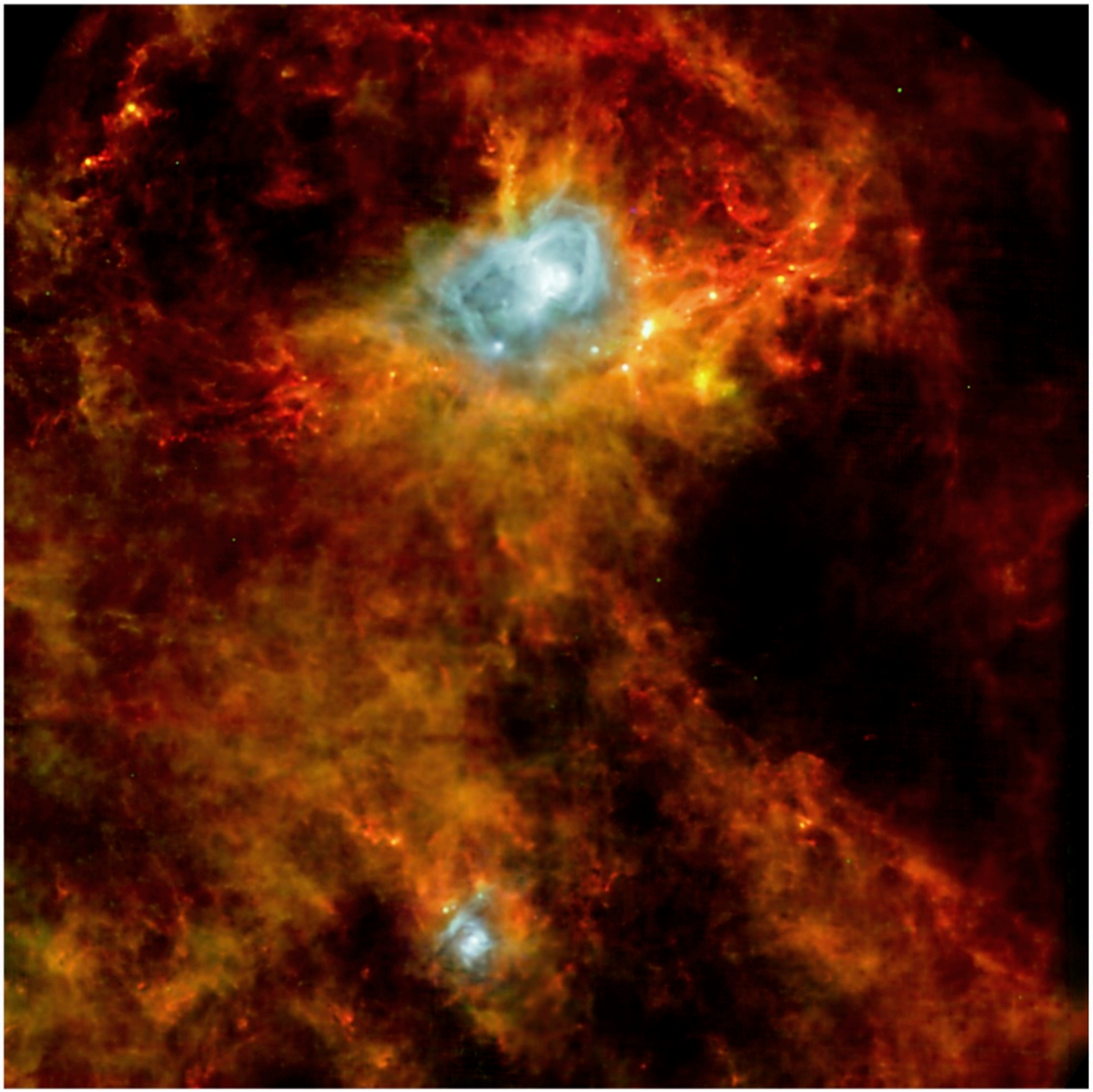
23 Oct 2009

Red : SPIRE 500 μm
Green : SPIRE 250 μm
Blue : PACS 160 μm

~ 7 deg^2 field

Ward-Thompson et al. 2010
Miville-Deschênes et al. 2010
A&A special issue

“First images” from the Gould Belt Survey



2) Aquila Rift star-forming cloud (d ~ 260 pc)

24 Oct 2009

cf. http://oshi.esa.int

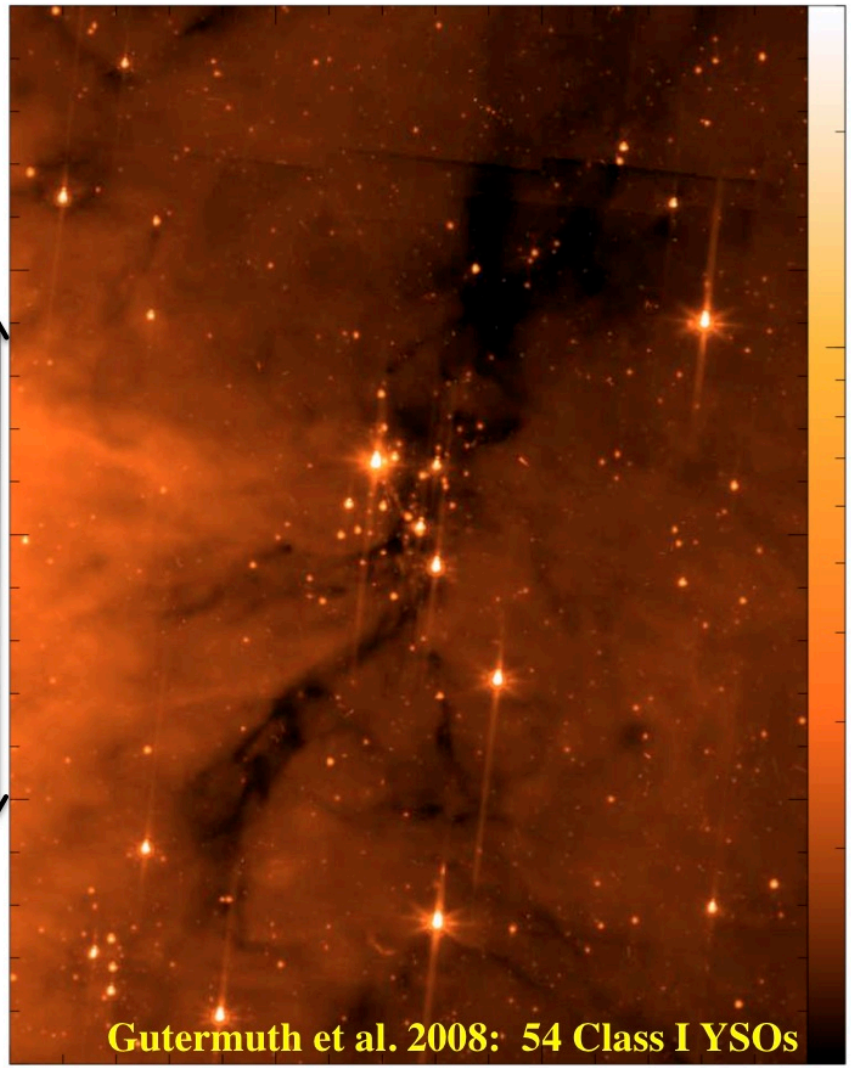
Red : SPIRE 500 μm
Green : SPIRE 160 μm
Blue : PACS 70 μm

~ 3.3 deg x 3.3 deg field

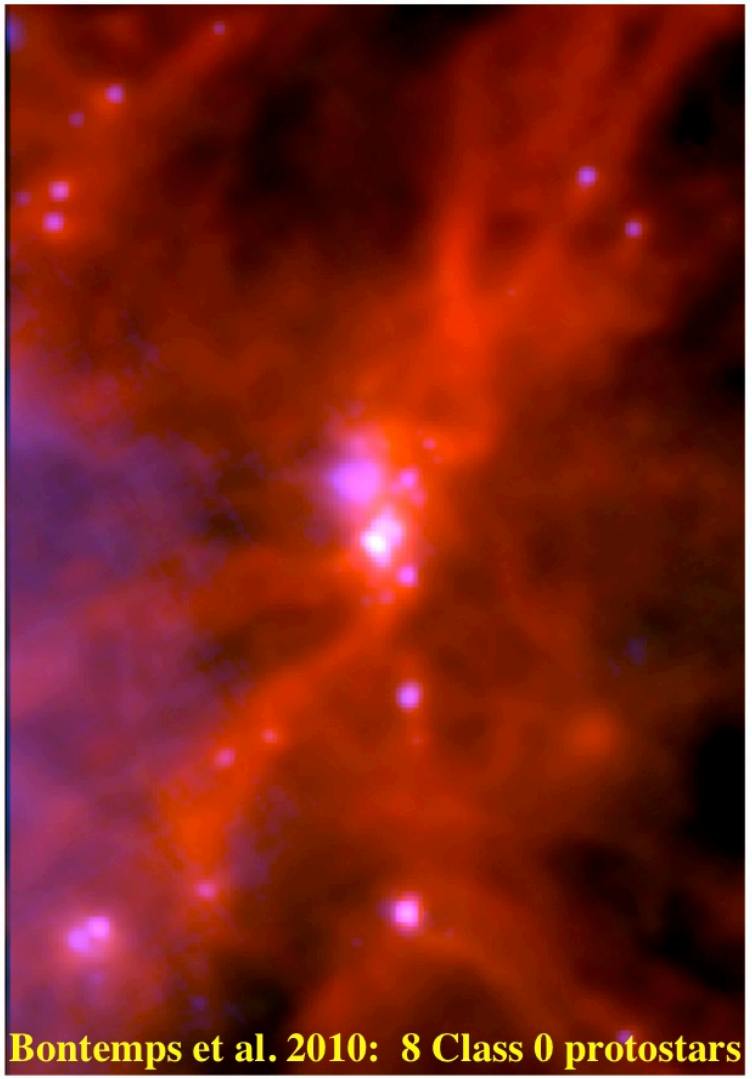
Könyves et al. 2010
Bontemps et al. 2010
André et al. 2010
A&A special issue

Aquila/Serpens-South dark filament: A rich protocluster in the making

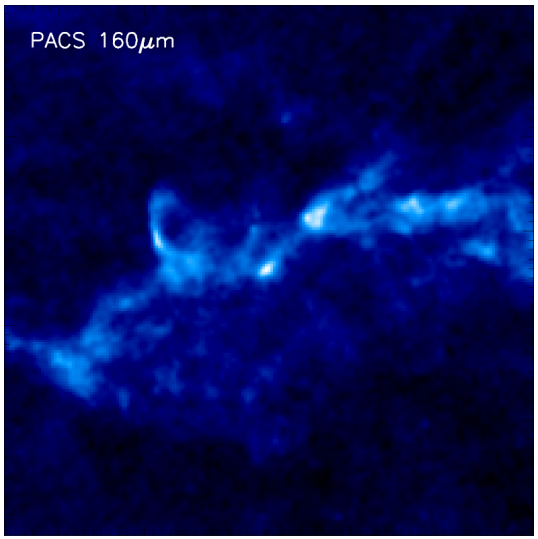
Spitzer/IRAC 8 μm

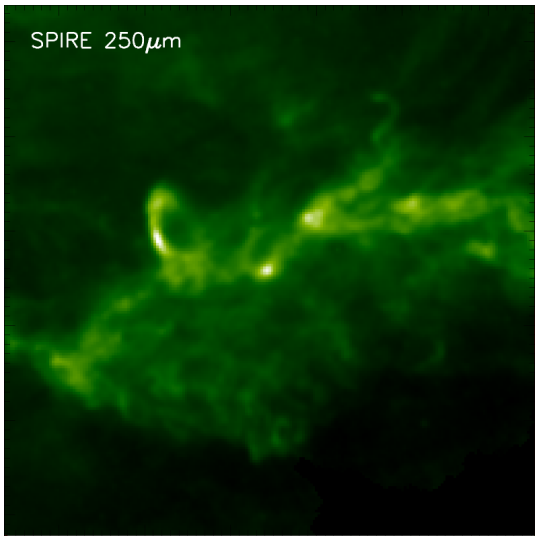


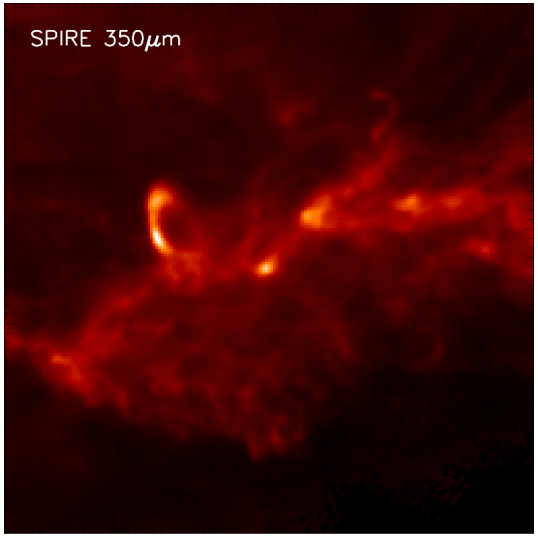
SPIRE 250 μm + PACS 160/70 μm

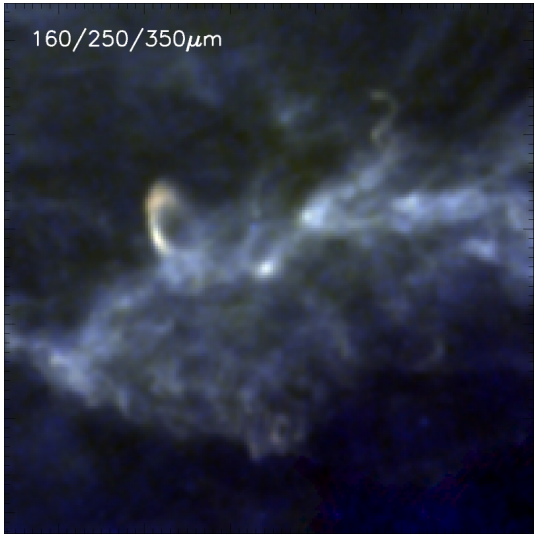


Polaris Flare (D.Ward-Thompson) MCLD 123 and Loop 1

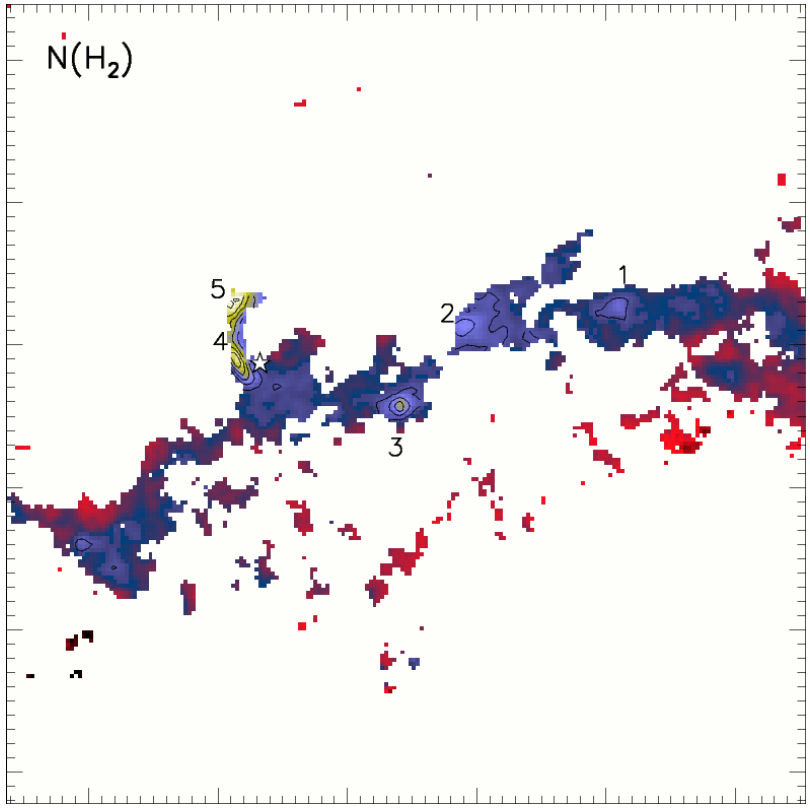


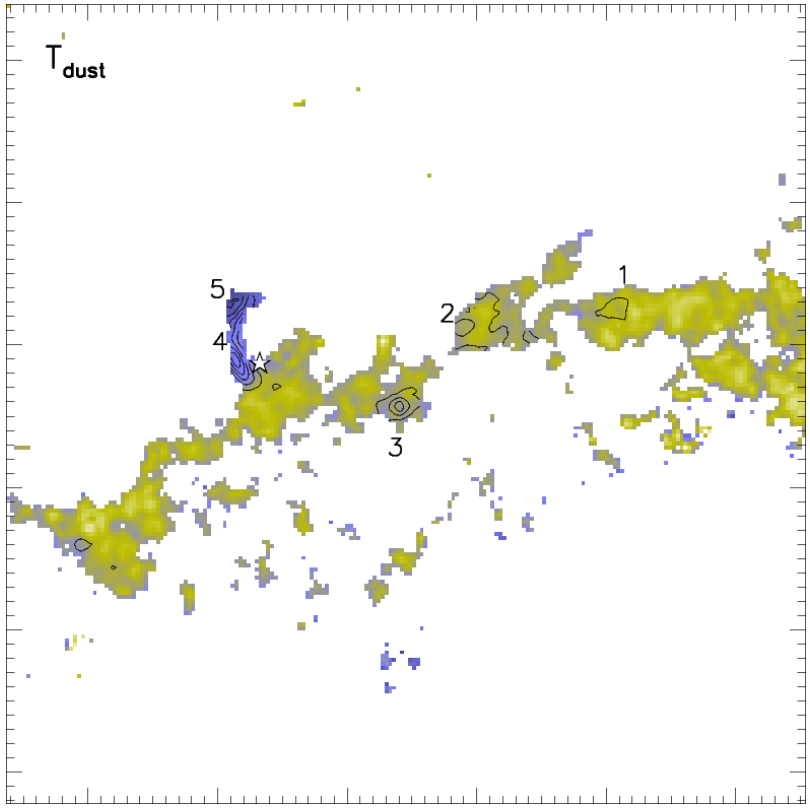






Column density and temperature

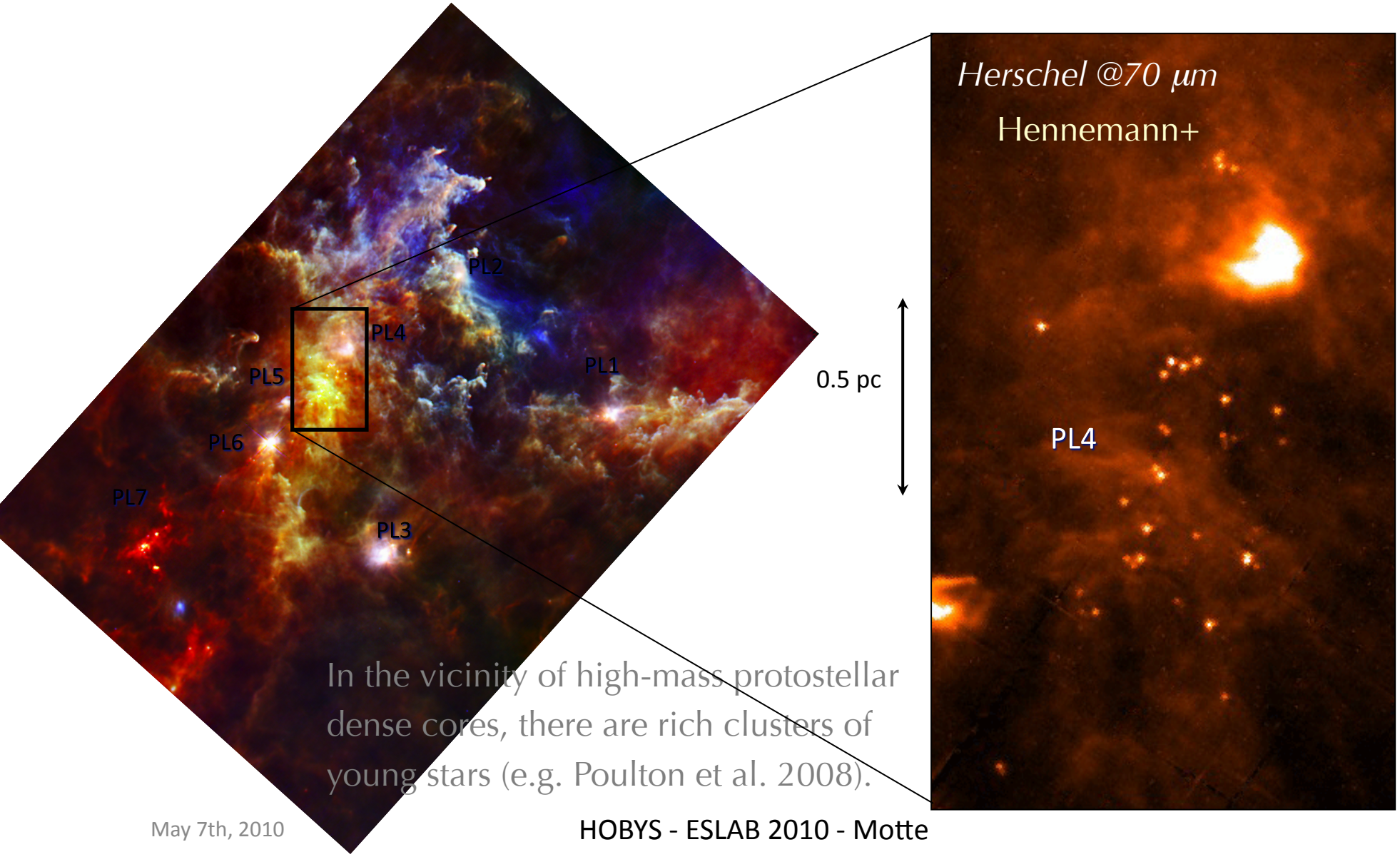




Range: ~6-12 x 10^{21}cm^{-2}

Range: ~10-12K

Rich clusters of protostars in the Rosette



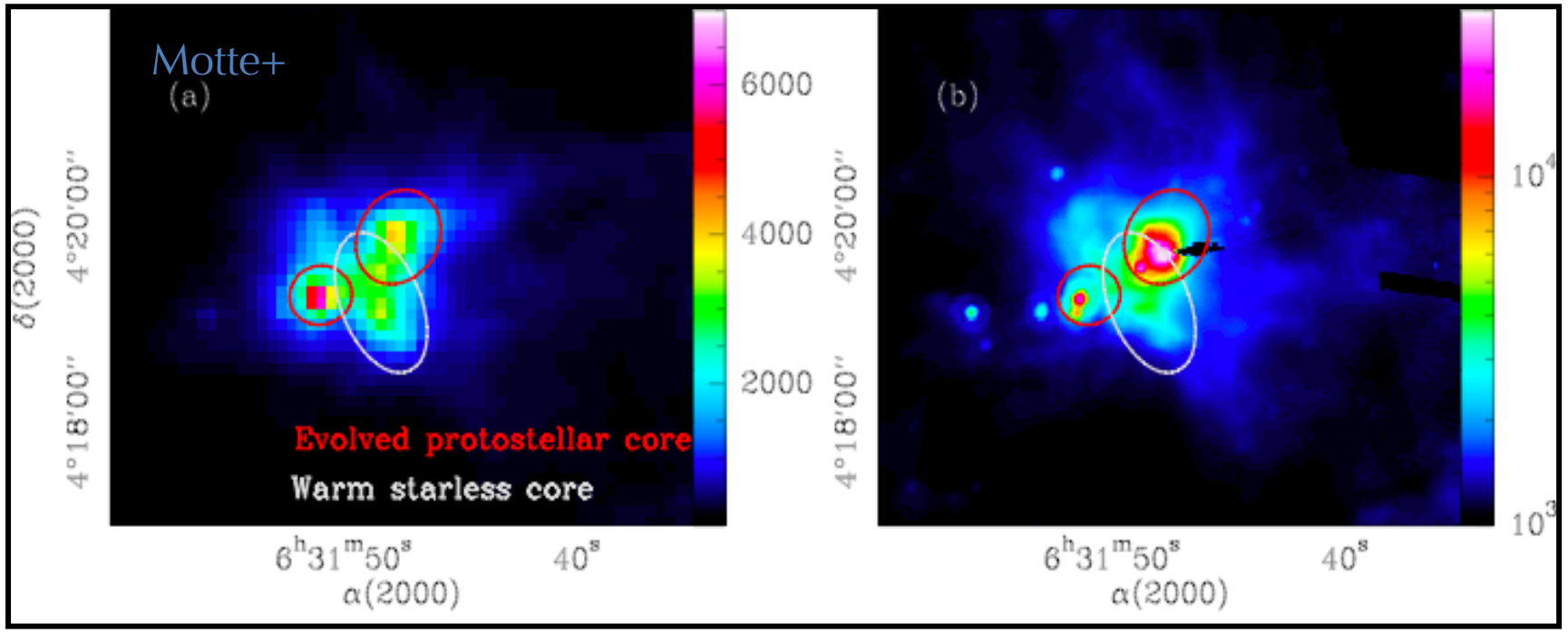
In the vicinity of high-mass protostellar dense cores, there are rich clusters of young stars (e.g. Poulton et al. 2008).

Where are the massive prestellar dense cores?

Not a single massive prestellar core has been identifed in the Cygnus X and NGC 6334 molecular complexes (Motte et al. 2007; Russeil et al. 2010).

In Rosette, we find 3 massive prestellar dense cores: ~0.22 pc, ~30 $M_\odot$. They are cold (~13 K) and dense (~10^5 cm^{-3}) and may thus form high- to intermediate-mass stars. Statistical lifetime ~ 8 x 10^4 yr, > in Cygnus X, < in nearby clouds.

We also discovered a handful of warm starless cores: ~0.14 pc, 1-9 $M_\odot$, 27 K



HOPS Observations

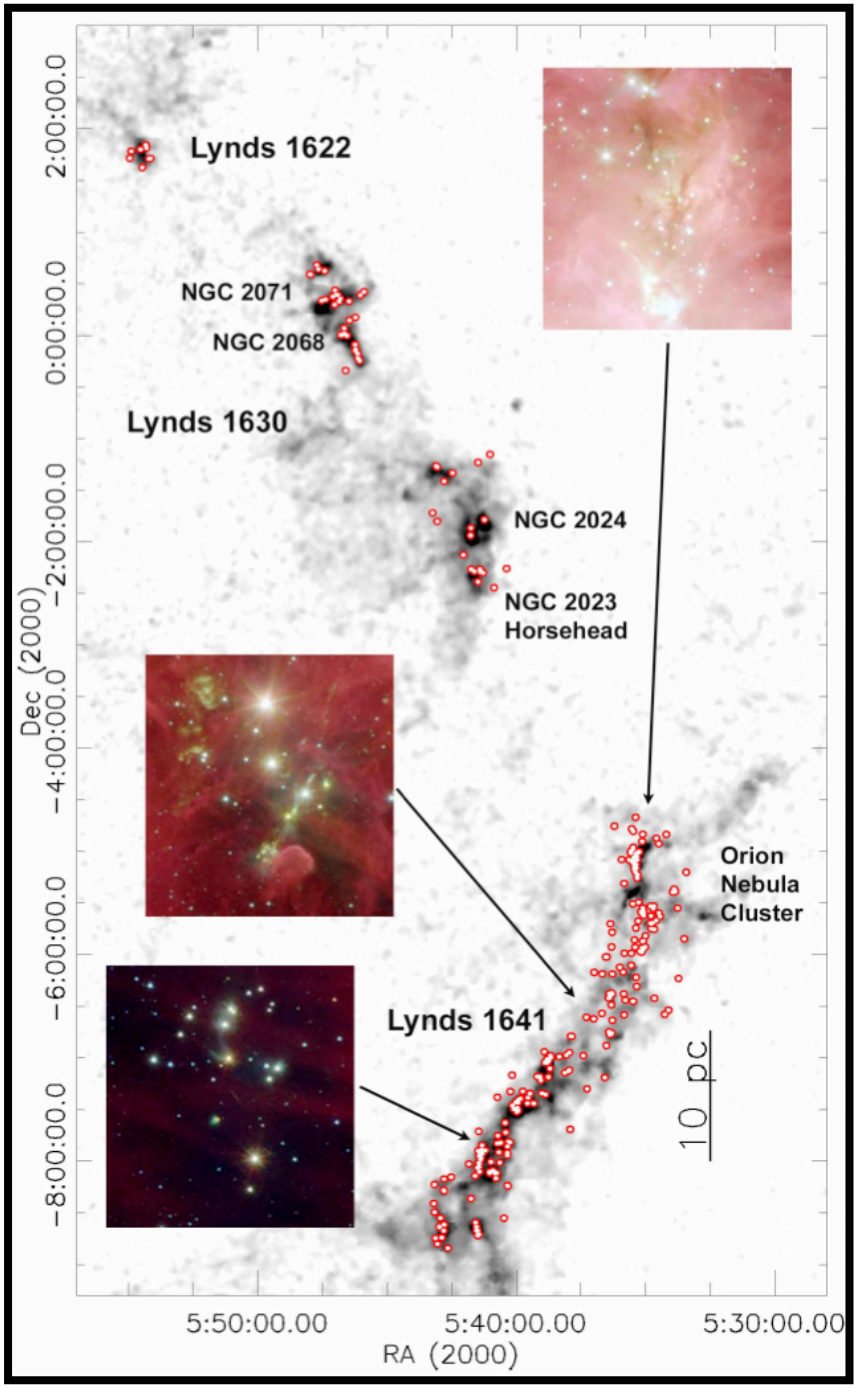
PACS imaging of 278 protostars:

- 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

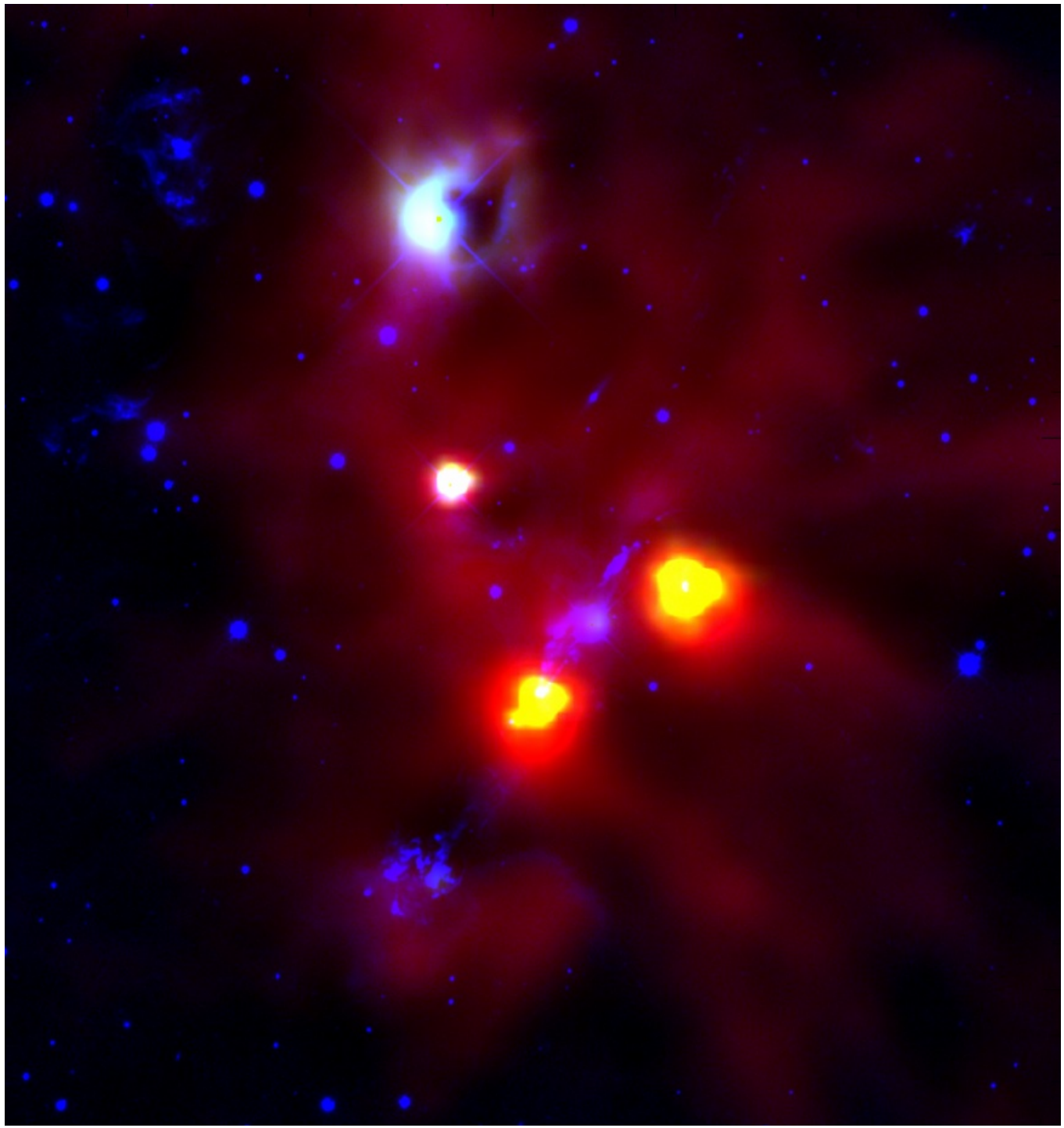


HOPS Science Demo Field

V380 Ori / HH 1-2 region in L1641

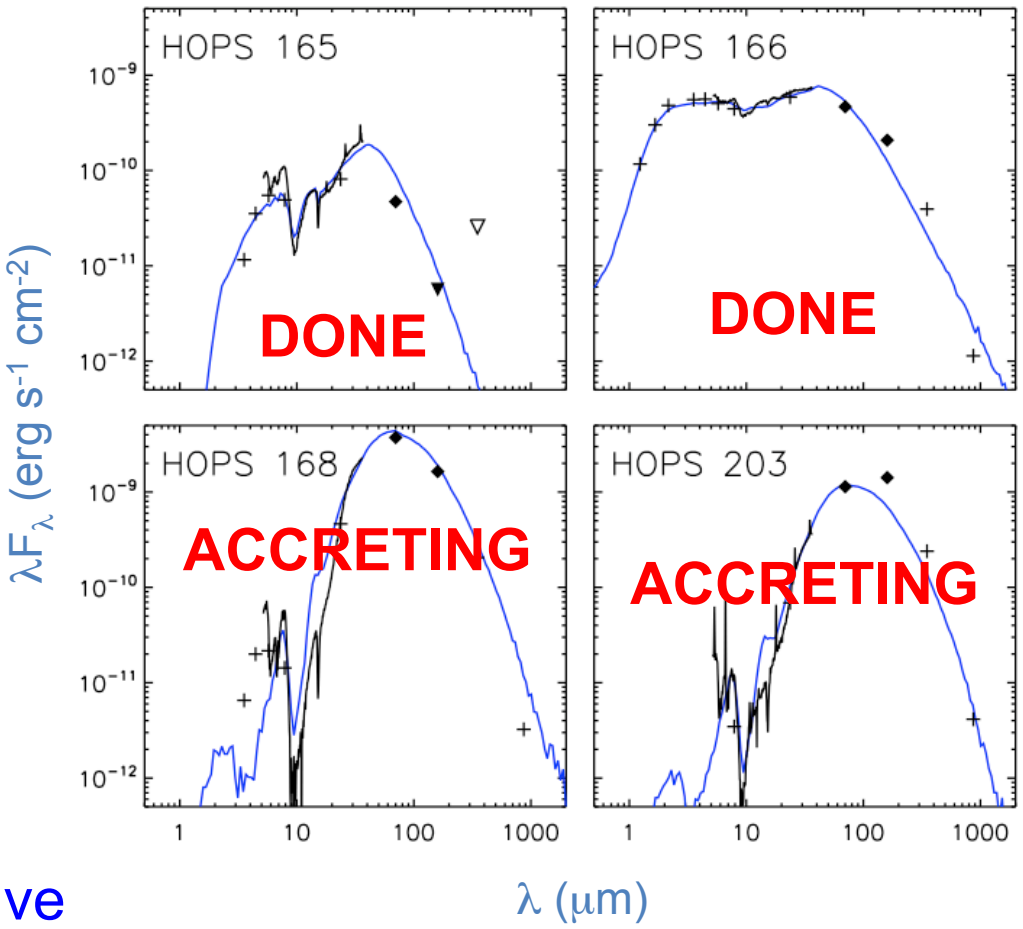
8’ square field centered at $5^h36^m22.1^s$, $-6^o45’41”$

NEWFIRM 2.2 μm
PACS 70 μm
PACS 160 μm

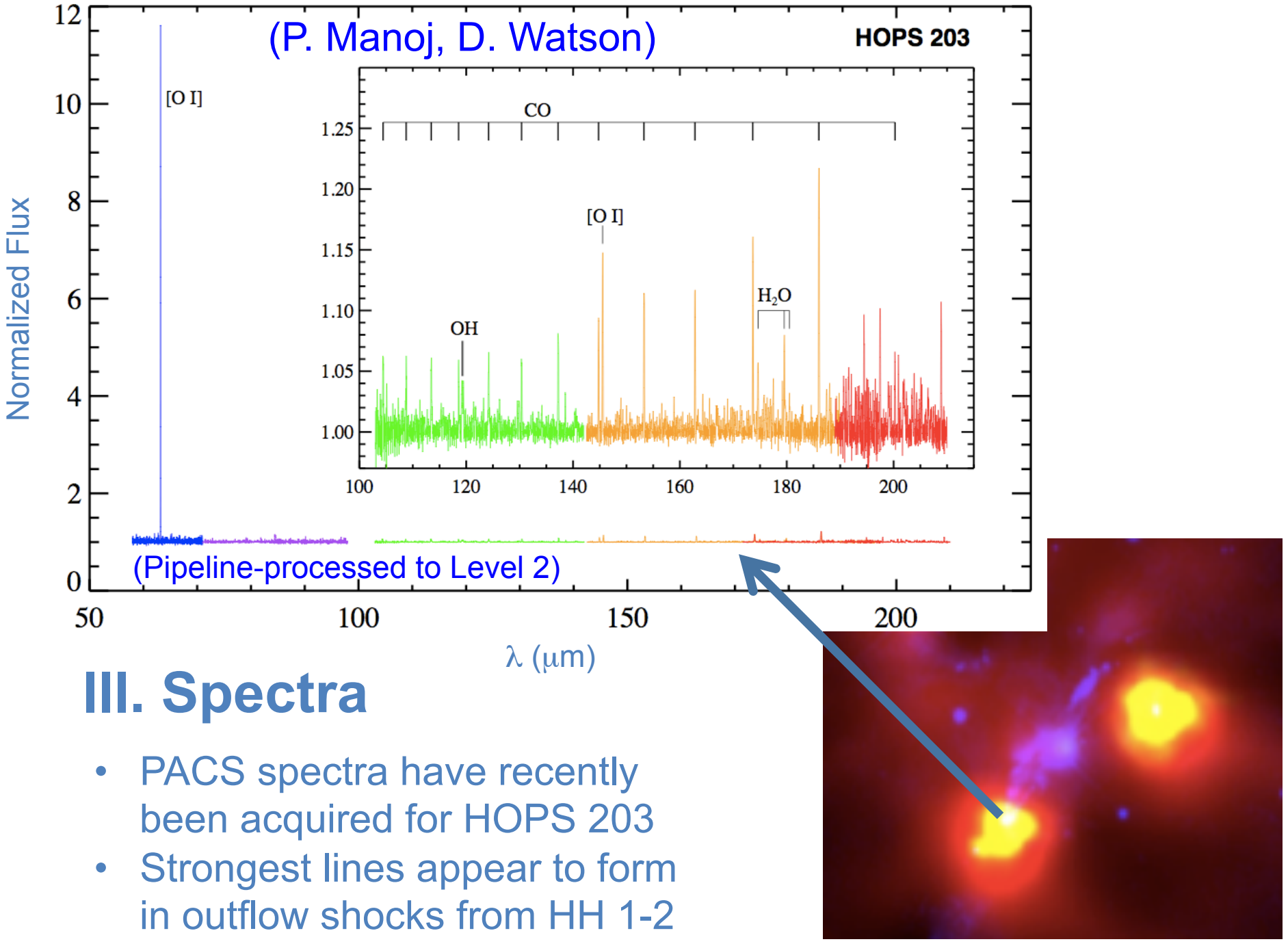


SED Modeling

	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

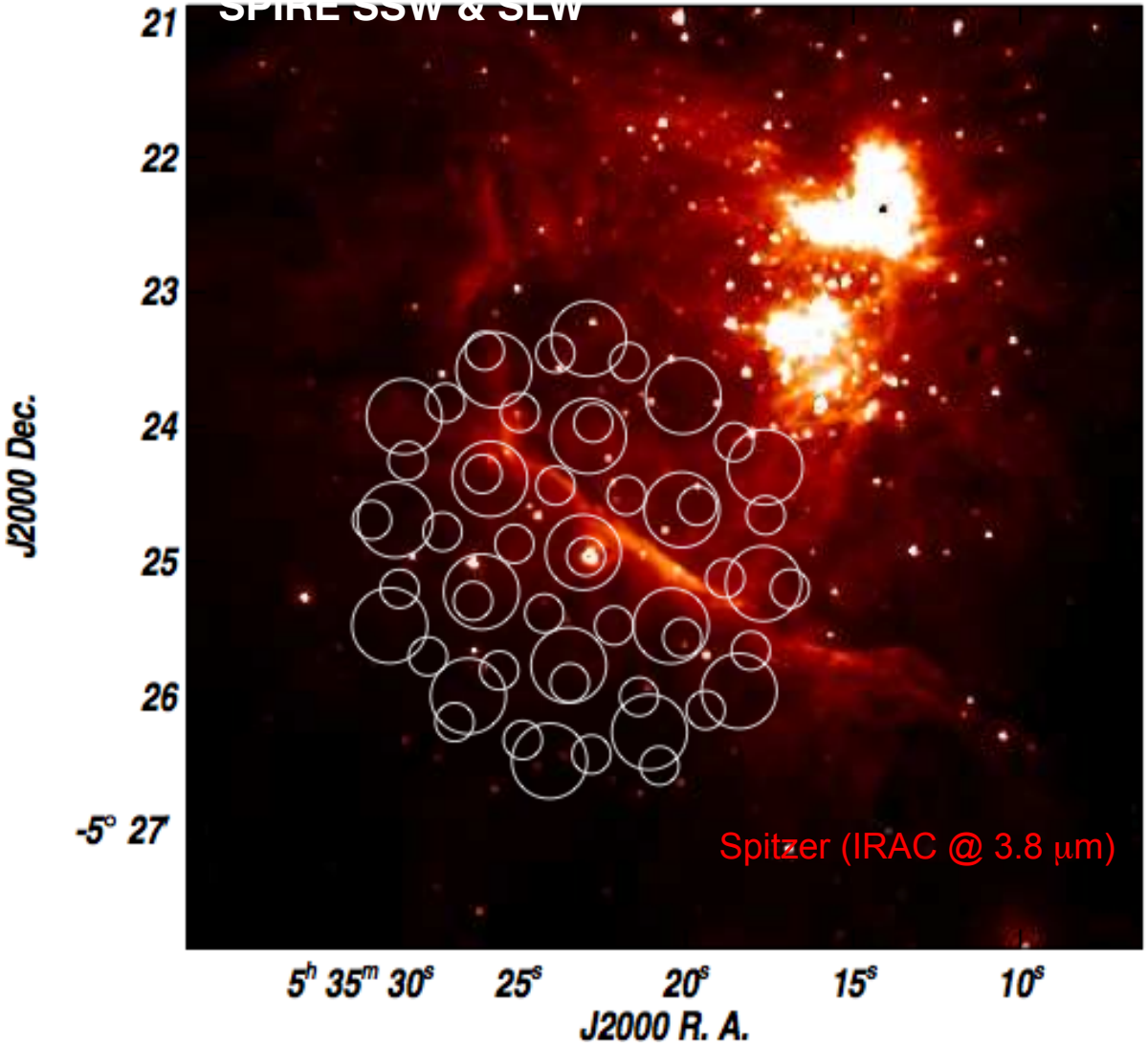


III. Spectra

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

Abergel/Habart - Evolution of ISM Dust

SPIRE/FTS observation



- **Single pointing**

  (coverig all the Bar)

- **FWHM beam-widths**

  (SSW : 17-21'')

  (SLW : 29-42'')

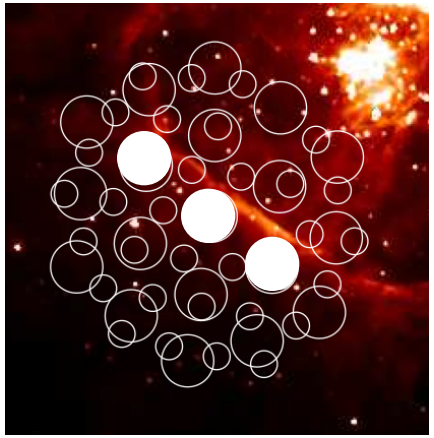
- **High resolution**

  ($\Delta\sigma$=0.04 cm^{-1})

- **2 scans/repetition**

- **Duration: 266.45 s**

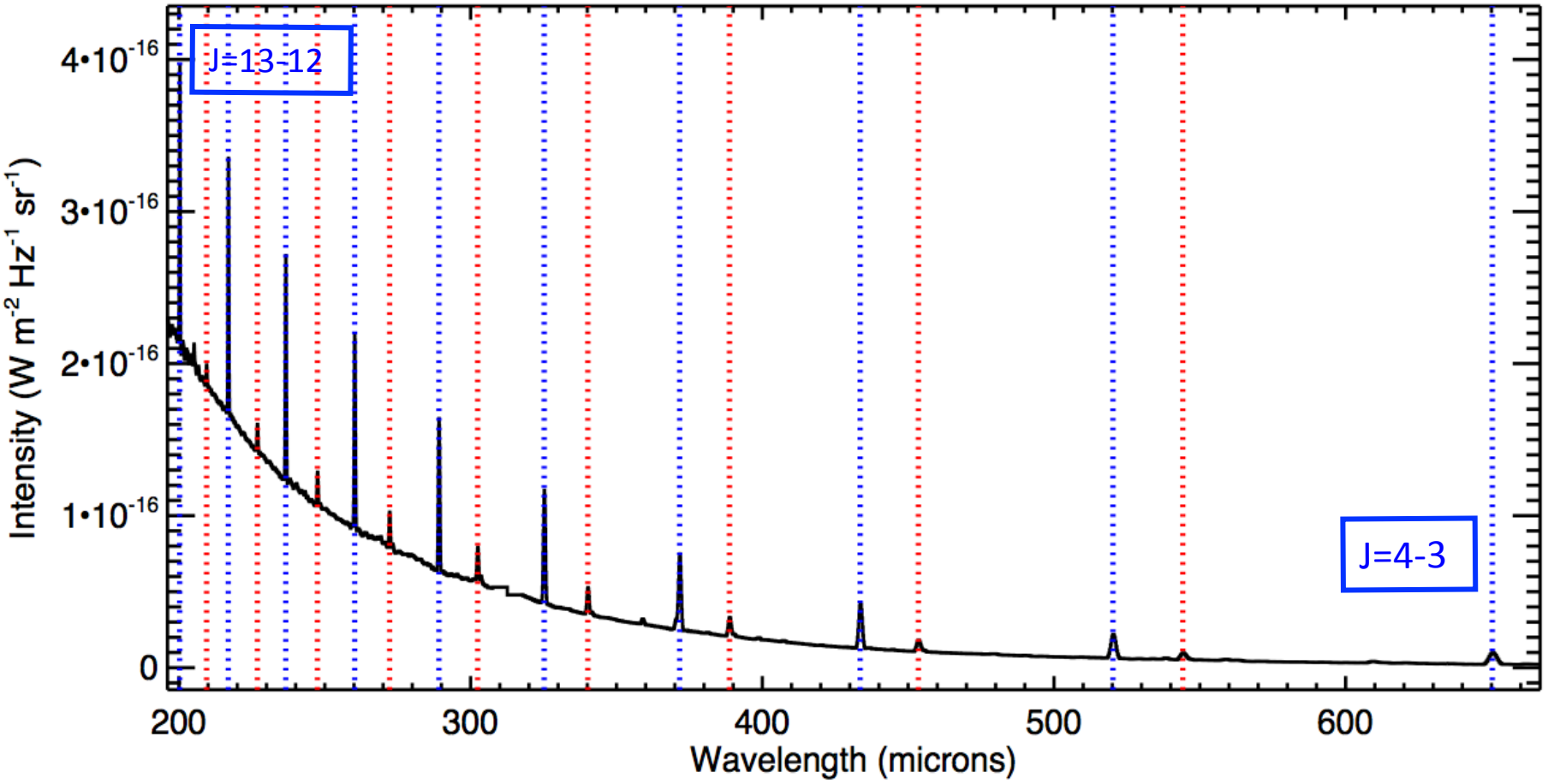
data reduction & line fitting
E. Polehampton, D. Naylor



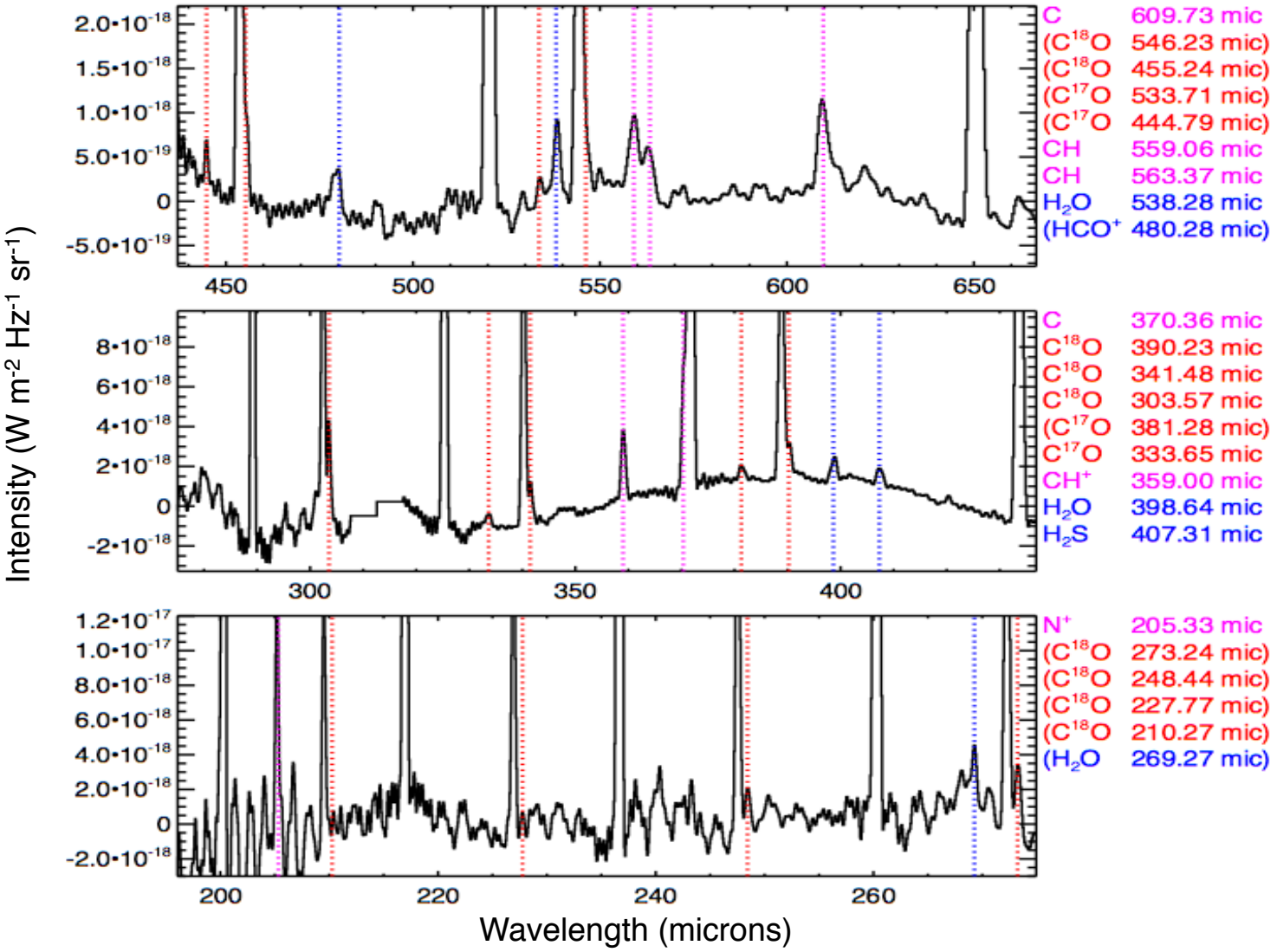
Average apodized spectra on the three arrays on the Bar

(corrected for obliquity effects)

A wealth of bright narrow ^{12}CO & ^{13}CO rotational lines



Zoom of the average apodized spectra

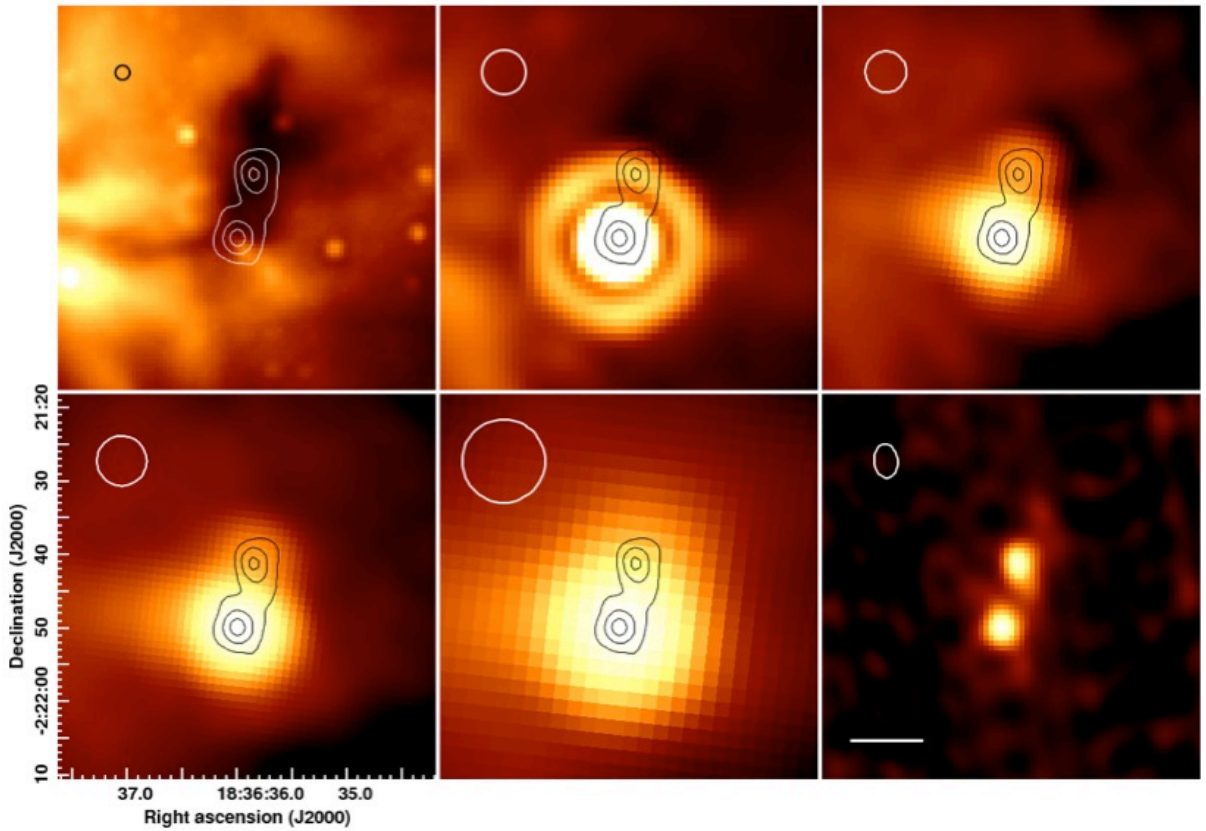


- **most of the $C^{18}O$ (blended with ^{13}CO), some $C^{17}O$, fine structure lines of C and N+**
- **radicals and molecules : CH^+, CH, H_2O, H_2S, HCO^+, (HCl, HCN, CN..) & hydrocarbons (C_2H)**

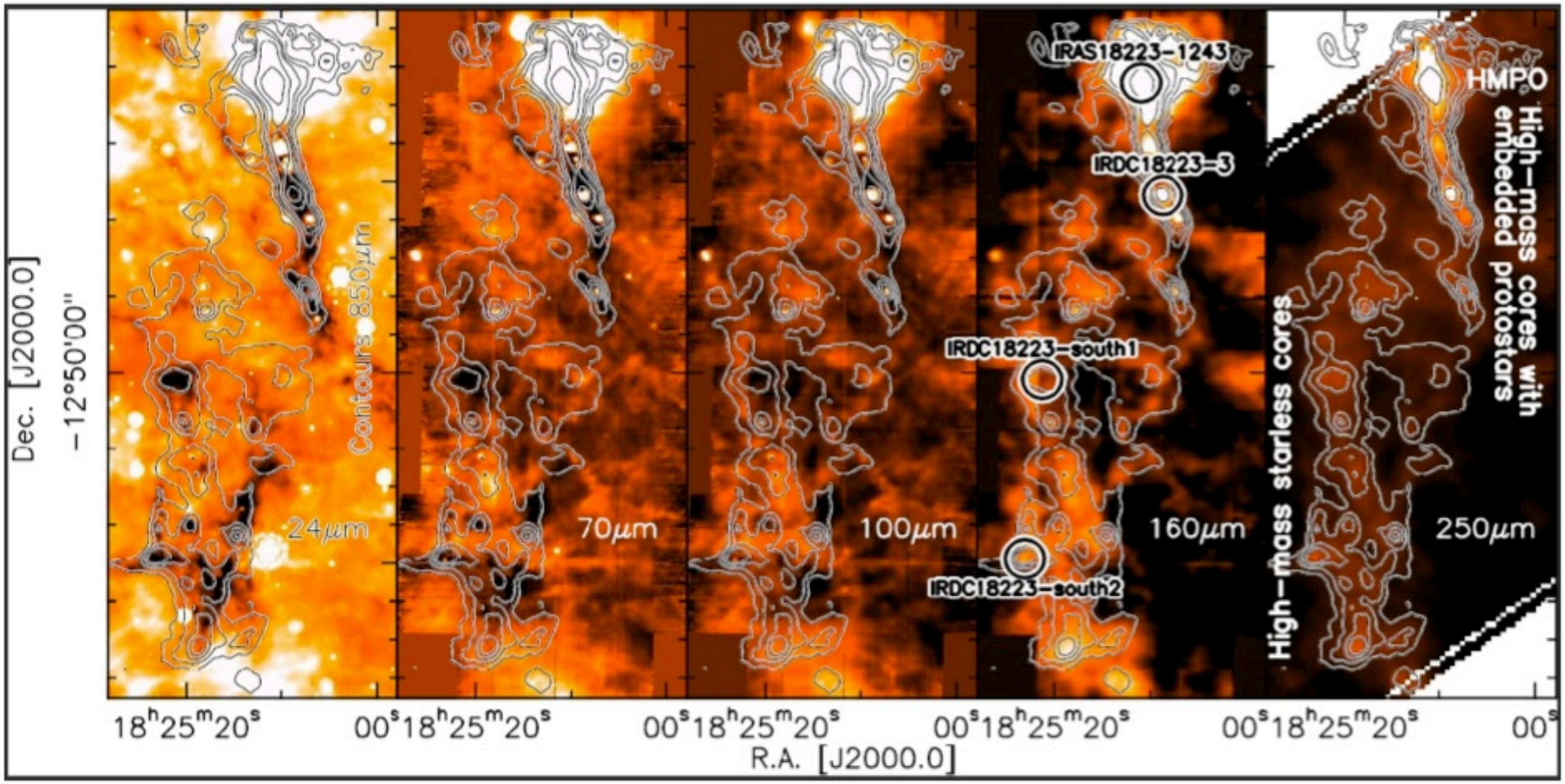
EPoS
The Search for the Earliest Phases of Massive Star Formation

Henning et al.

ISOSS J18364-0221: The boon of high spatial resolution in the FIR

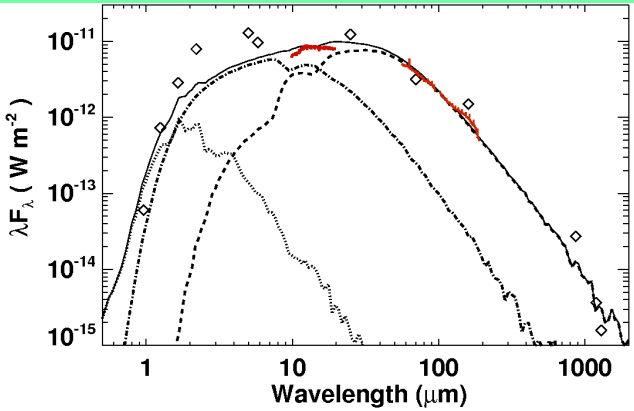


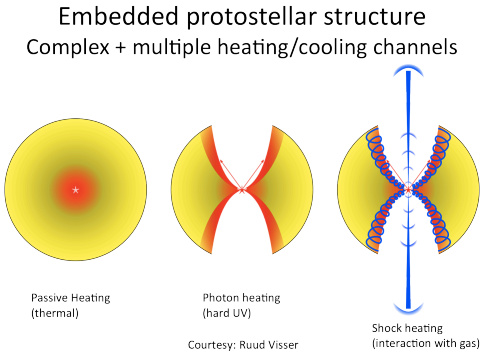
I18223-1243: The possible sequence of high-mass star formation on display

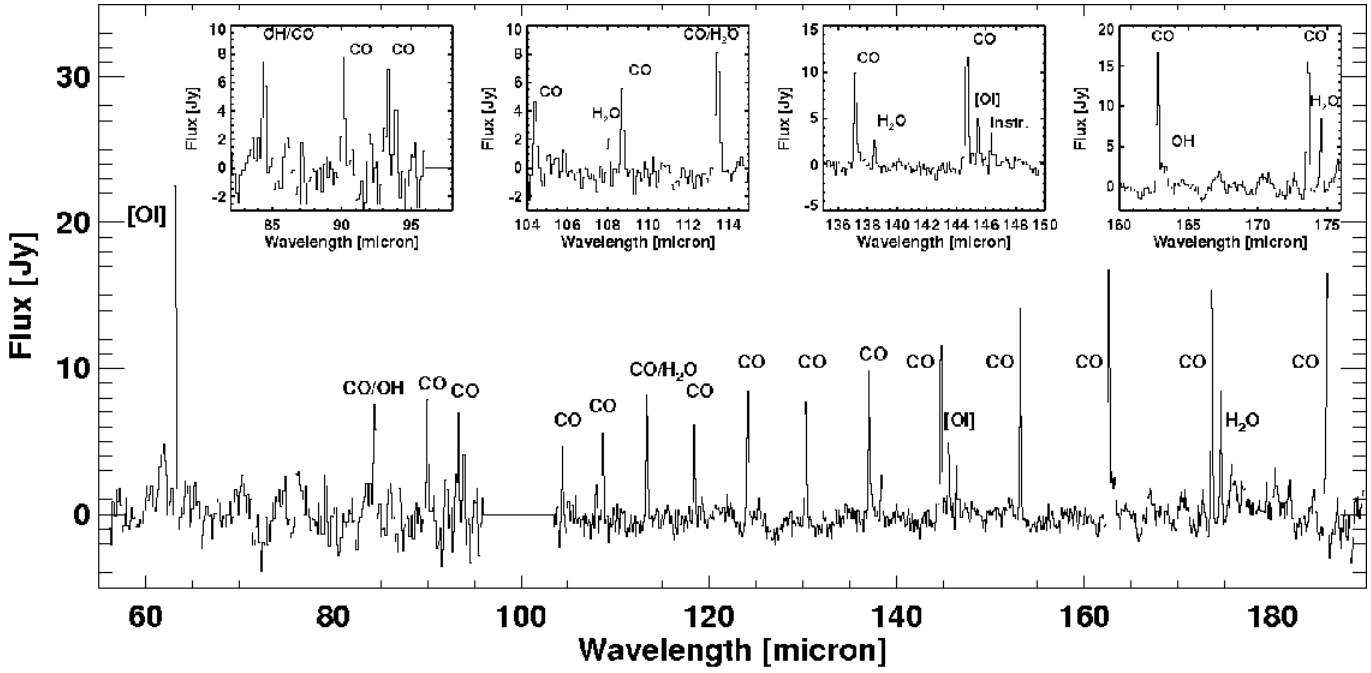


Highlights from DIGIT (Dust, Ice, and Gas in Time)
Herschel-PACS Full Spectral Scans of Young Stars

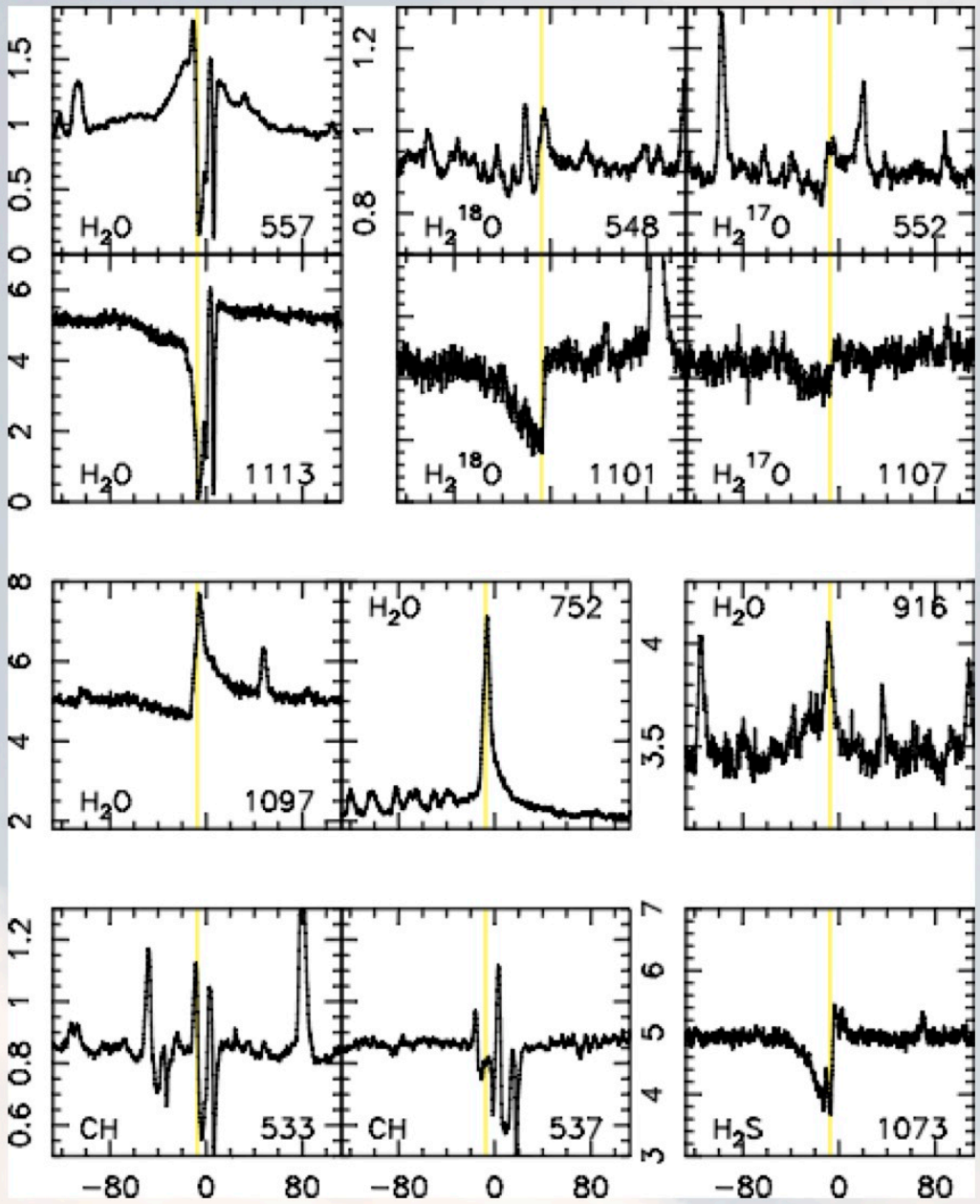
DK Cha: Emerging from its Cocoon?







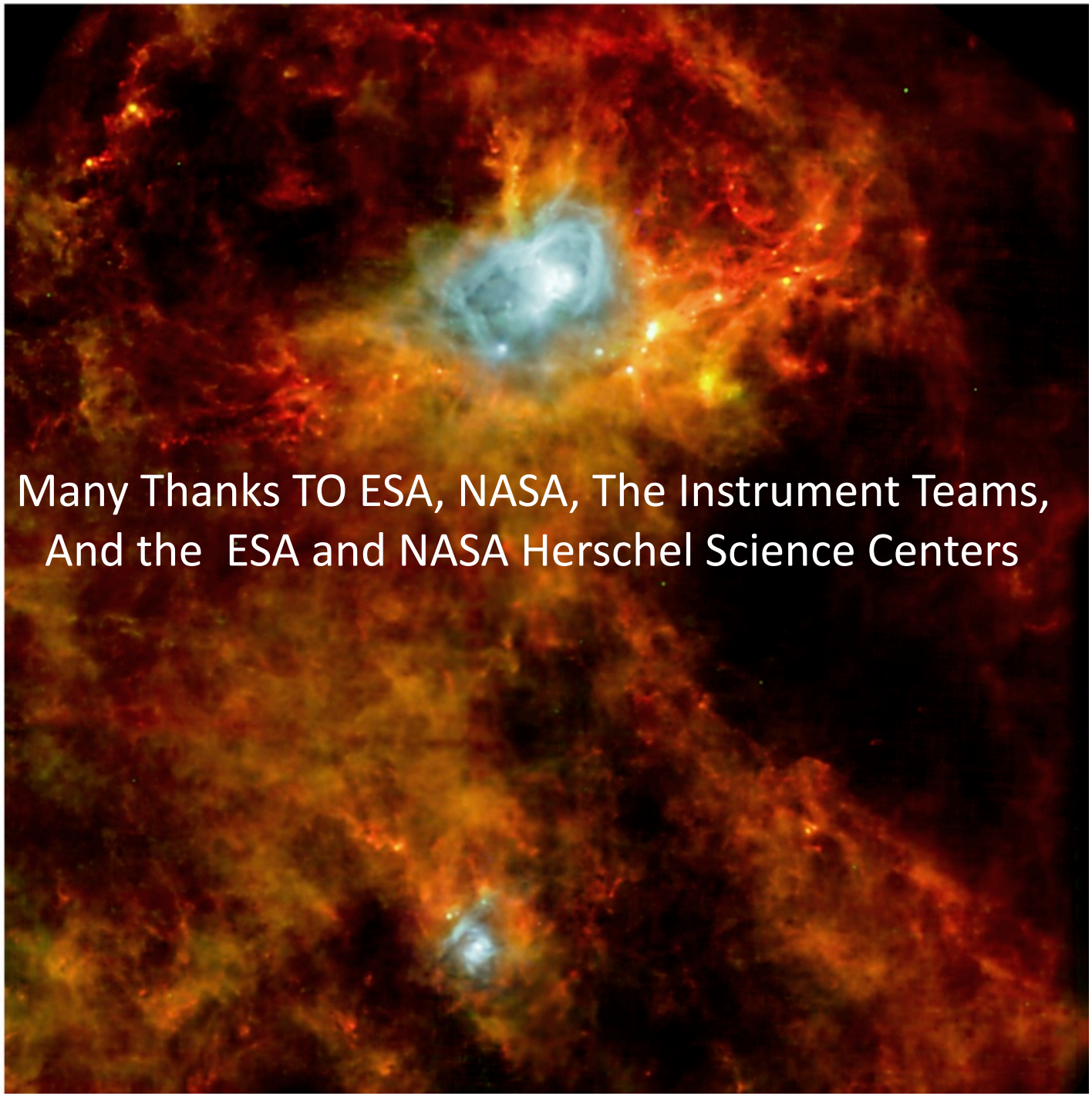
And Herschel Has HIFI For Velocity Information!



NGC 6334I: Foreground Absorption and Outflow

- Preliminary analysis indicates low water o/p ratio in the foreground gas
- Prominent absorption in the blue lobe of the outflow (e.g., H_2O, H_2S)
- Warm outflow: 3_{12}—3_{03} absorption (E_l=197 K)
- Water emission from the hot core gas

Emprechtinger et al.


Many Thanks TO ESA, NASA, The Instrument Teams,
And the ESA and NASA Herschel Science Centers