

# The HOPS survey: from Spitzer, via Herschel, to SOFIA



## Thomas Stanke ESO

**Tom Megeath** (PI; U. of Toledo) ; **Amy Stutz** (MPIA); **Will Fischer** (U. of Toledo), **John Tobin** (Leiden); **Babar Ali** (NHSC/IPAC), **Lori Allen** (NOAO), **Ted Bergin** (U. of Michigan), **Nuria Calvet** (U. of Michigan), **James Di Francesco** (Herzberg Institute), **Elise Furlan** (JPL), **Beatriz Gonzalez-Garcia** (HSC), **Lee Hartmann** (U. of Michigan), **Thomas Henning** (MPIA), **Oliver Krause** (MPIA), **Sébastien Maret** (Grenoble Observatory), **James Muzerolle** (STScI), **Phil Myers** (SAO), **Zsofia Nagy** (U.Toledo), **David Neufeld** (Johns Hopkins U.), **Mayra Osorio** (Instituto de Astrofisica de Andalucia), **Klaus Pontoppidan** (Caltech), **Charles Poteet** (U. of Toledo), **Manoj Puravankara** (Tata Inst.), **Roland Vavrek** (HSC), **Dan Watson** (U. of Rochester), **Tom Wilson** (NRL) , **Friedrich Wyrowski** (MPIfR)

# HOPS Summary

200h open time key project

## PACS imaging of 286 protostars:

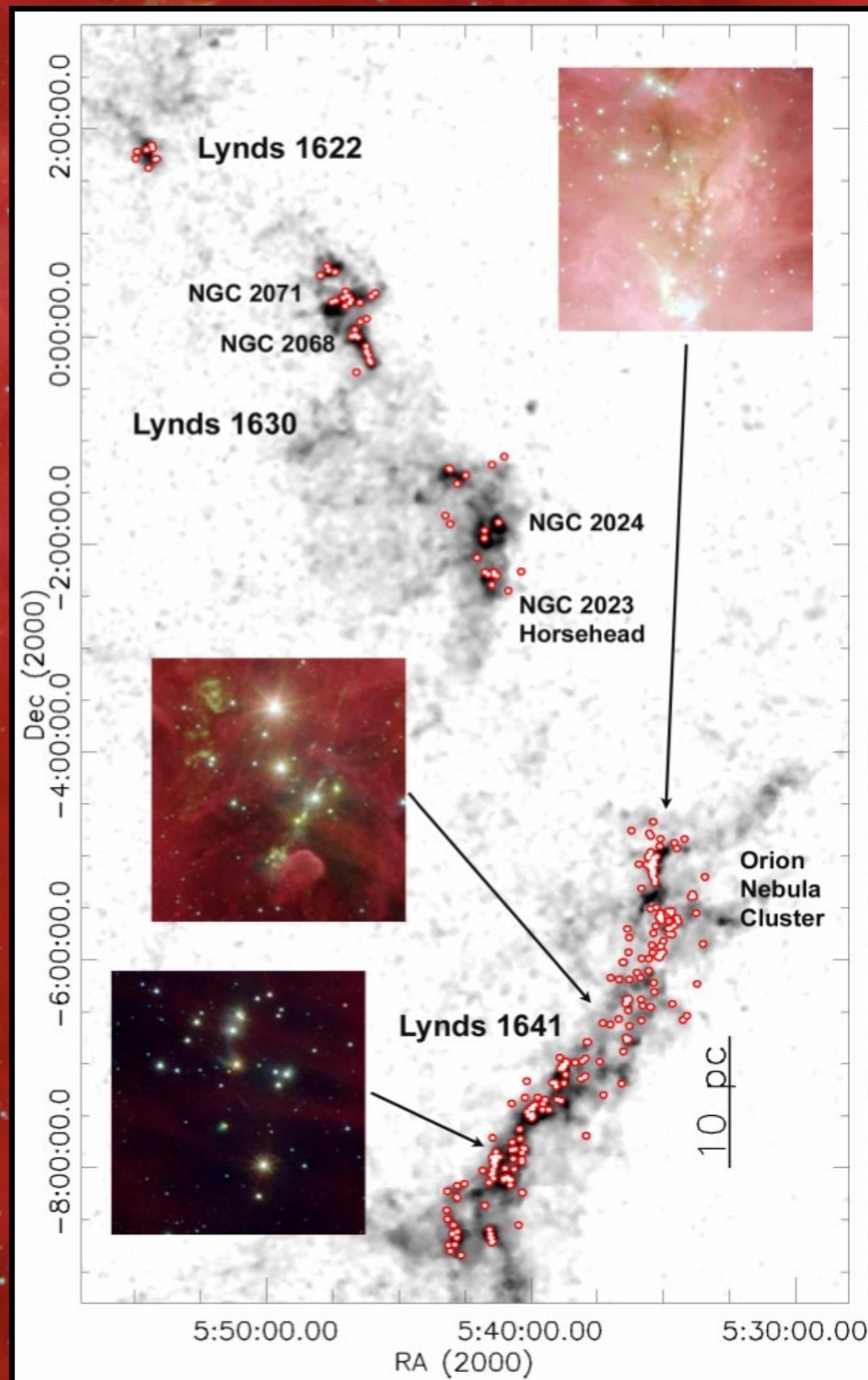
- Spitzer-identified protostars with extrapolated fluxes  $> 42$  mJy at  $70 \mu\text{m}$
- 5' to 8' square fields
- Medium ( $20''/\text{s}$ ) scan rate
- 70 and  $160 \mu\text{m}$  scans & cross-scans

## PACS spectroscopy of 36 protostars:

- 24 face-on sources, 12 at other inclinations
- Source fluxes from 100 mJy to  $\sim 10$  Jy
- Spectral coverage from 57 to  $190 \mu\text{m}$
- Water, OH, CO, [O I] & [C II] lines

## Sources sample environments:

from isolated to clustered  
range of densities & UV environment

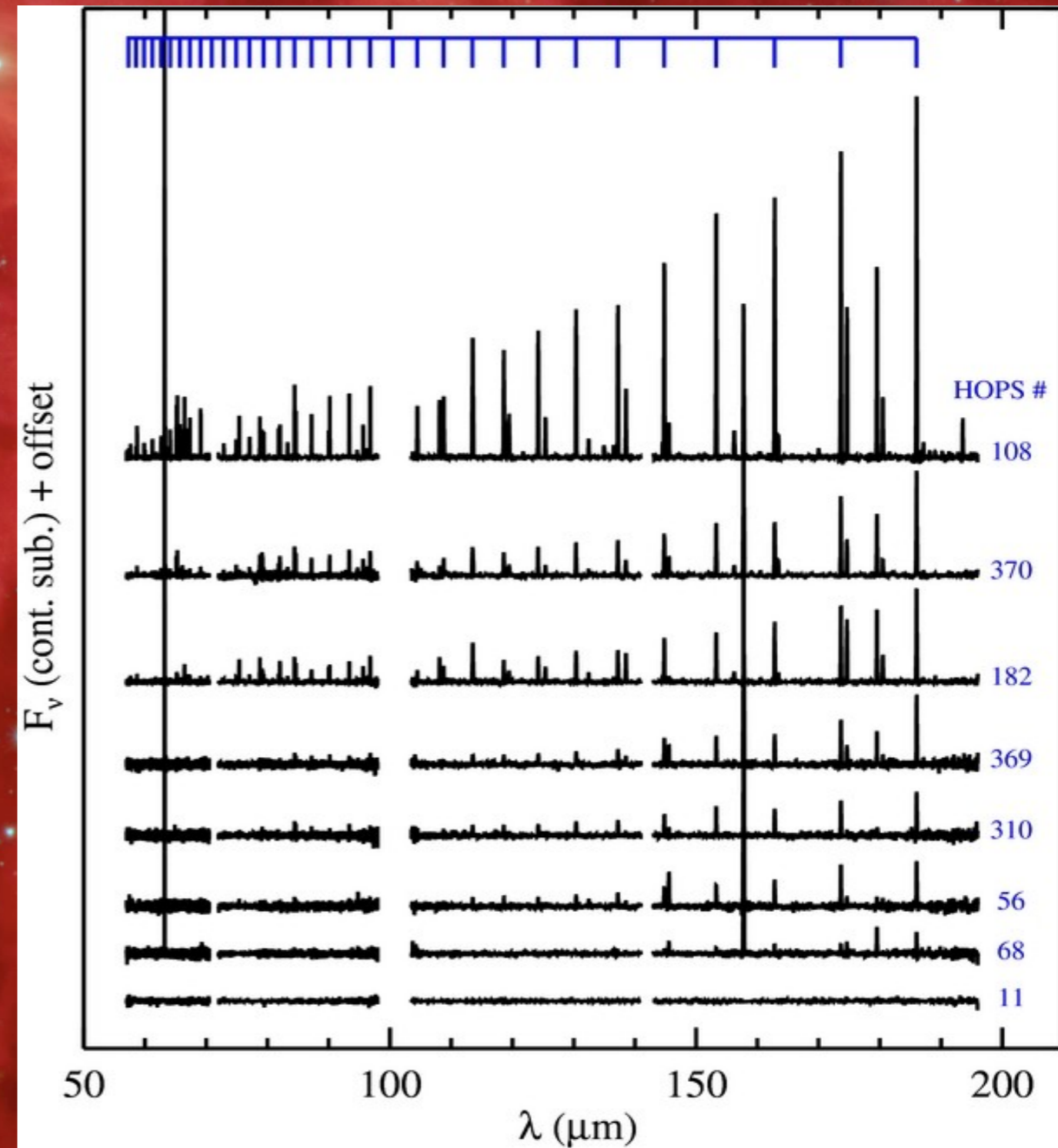


# HOPS: a multi-observatory survey of *Spitzer* identified protostars in Orion

- *Spitzer* IRAC & MIPS -> 372 protostar candidates (Megeath et al.)
- *Spitzer* IRS: *SL-LL* for all; *LH* for half the sample
- **Herschel PACS**
  - Imaging: 70 & 160 $\mu$ m
  - Spectroscopy
- **NIR imaging & spectroscopy**
  - HST (*NICMOS/WFC3*): 200 orbits; multiplicity survey of HOPS targets
  - VLT (*NACO*), NEWFIRM, PANIC
  - IRTF (*SPEX/NSFCAM2*)
- **Submm & mm imaging & spectroscopy**
  - APEX (*LABOCA* & *SABOCA* & *ArTeMis*; *SHeFI*; *Flash*, *Champ+*), IRAM 30m, PdB
  - JCMT (*HARP*): CO (3-2) & HCO<sup>+</sup> (4-3) line mapping of HOPS targets
  - CARMA: measuring various flow rates in protostars

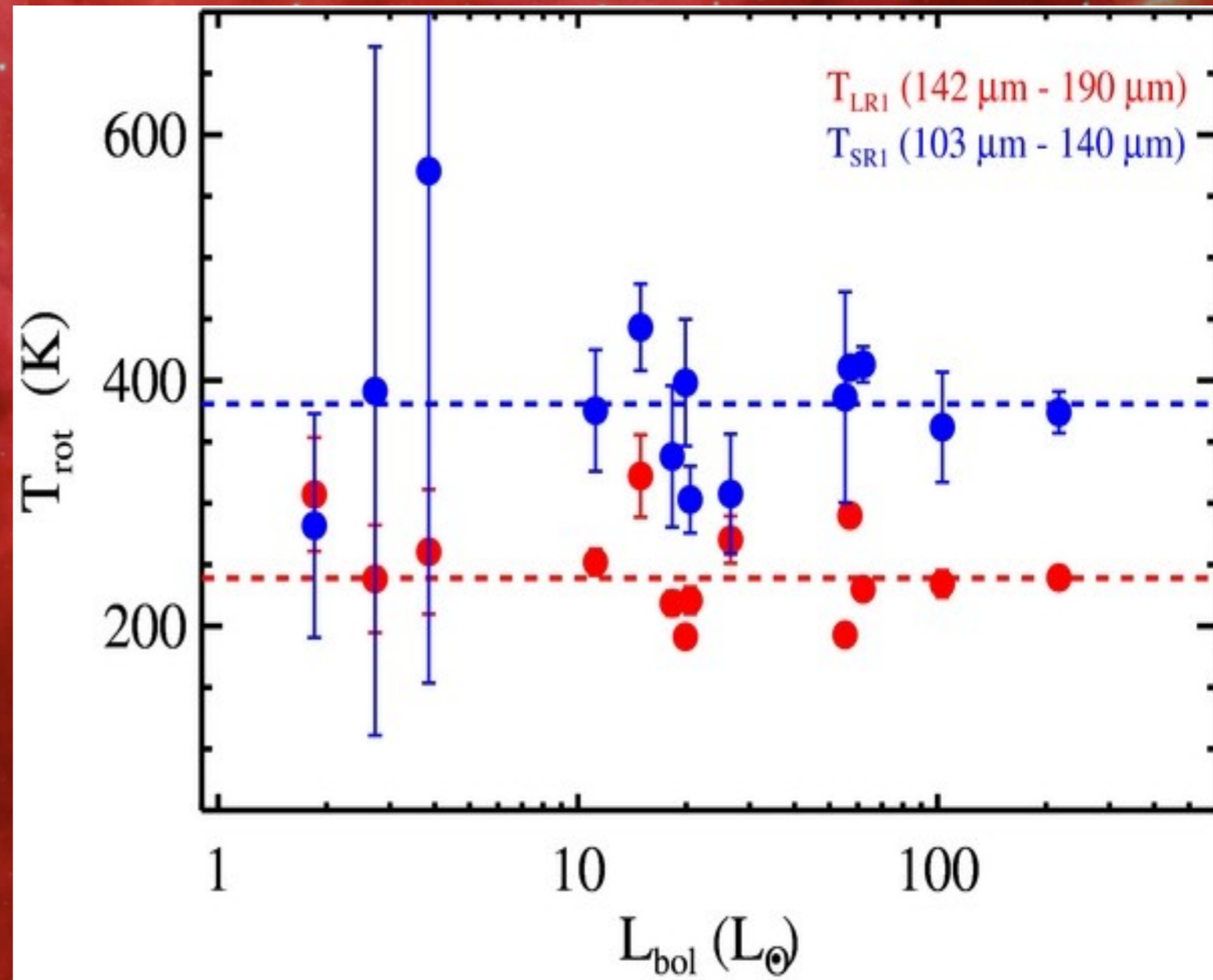
# PACS spectroscopy: 30 HOPS protostars

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- $L_{\text{CO}}$  scales with  $L_{\text{bol}}$
- (mix of)  $T_{\text{CO}}$  does NOT scale with  $L_{\text{bol}}$
- CO lines trace shocks (outflows) at 2000AU from protostar



# PACS spectroscopy: 8 PACS Bright Red Sources(PBRs)

- (Herschel passed away before all 14 had been observed)
- $L_{CO}$  scales with CO outflows
- (mix of)  $T_{CO}$  cooler than HOPS protostars(?)
- [OI] ... hard to tell ...

# SOFIA FIFI-LS spectroscopy: 3 PACS Bright Red sources(PBRs)

- (to be observed now-ish)
- 3 PBRs (outflow properties/types only sampled once by PACS)
- CO (14-13), (17-16) ->  $T_{\text{rot}}$ ; (21-20) -> hotter component?
- [OI] ... any trends to confirm?
- Is CO related (exclusively?) to outflow?
- In which cases do we get [OI]?

# SOFIA GREAT [OI] spectroscopy: 5 HOPS protostars

- (to be observed some time...)
- Sample: the most luminous protostar in HOPS, the HOPS protostar with the brightest FIR lines, 3 moderate luminosity HOPS protostars with well studied outflows

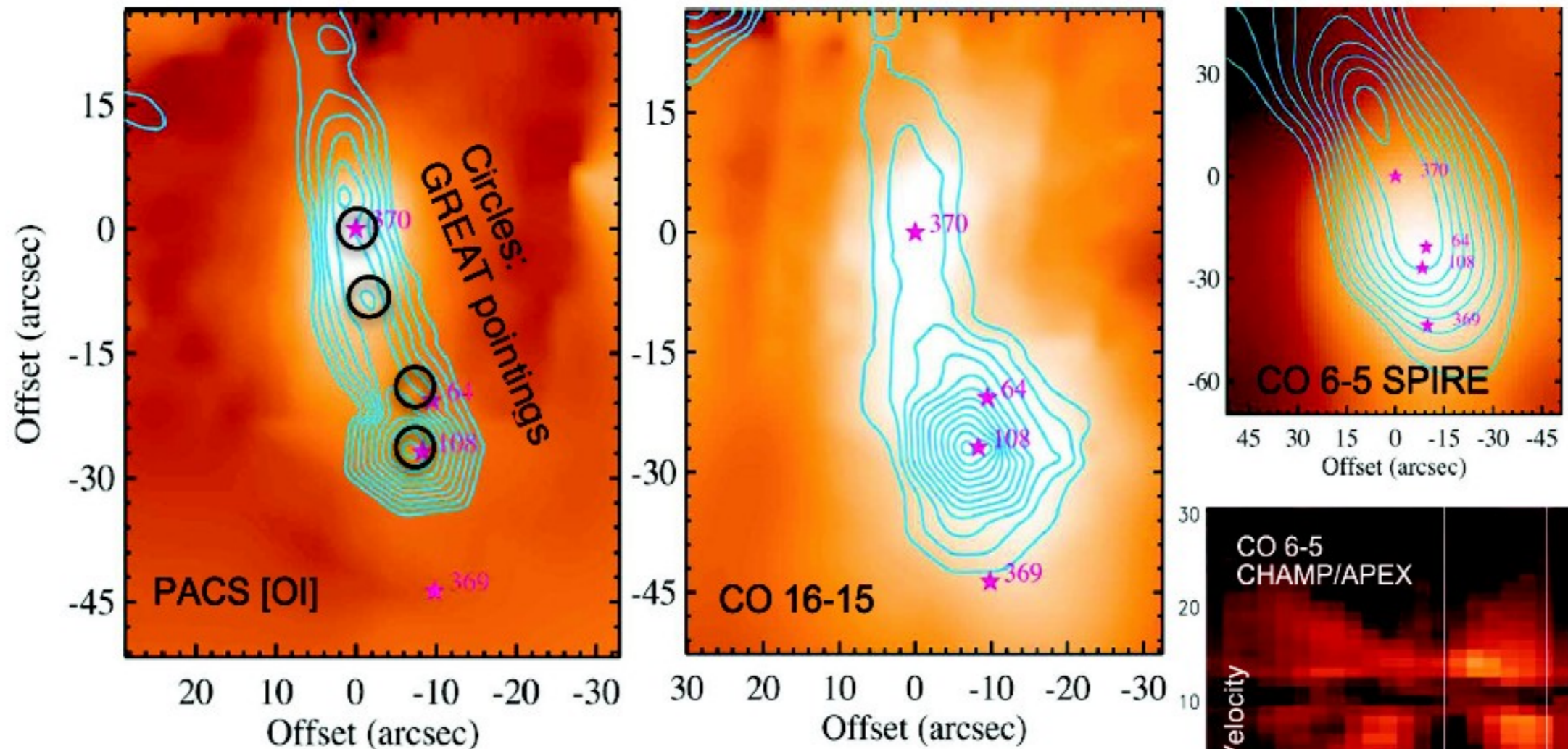


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Gonzalez-Garcia et al, in prep.)



**Figure 3:** PACS, SPIRE and CHAMP maps of the HOPS 370/HOPS 108 outflow(s). The [OI], CO 16-15 and CO 6-5  $\mu\text{m}$  maps show the integrated intensity of the line emission in contours overlaid on the continuum emission in a color scale. The CO (6-5) APEX data with 9" resolution is shown in a position velocity diagram. Note different field sizes.

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- J-shock models: [OI] emission counts ions going into shock -> direct tracer of mass flow rate! (Hollenbach 1985; Leurini yesterday)

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**(we'll ask for time until everybody has flown...)**

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