Low mass star-formation: new insights from Herschel

- HEL.AS meeting, Ioannina, 2011

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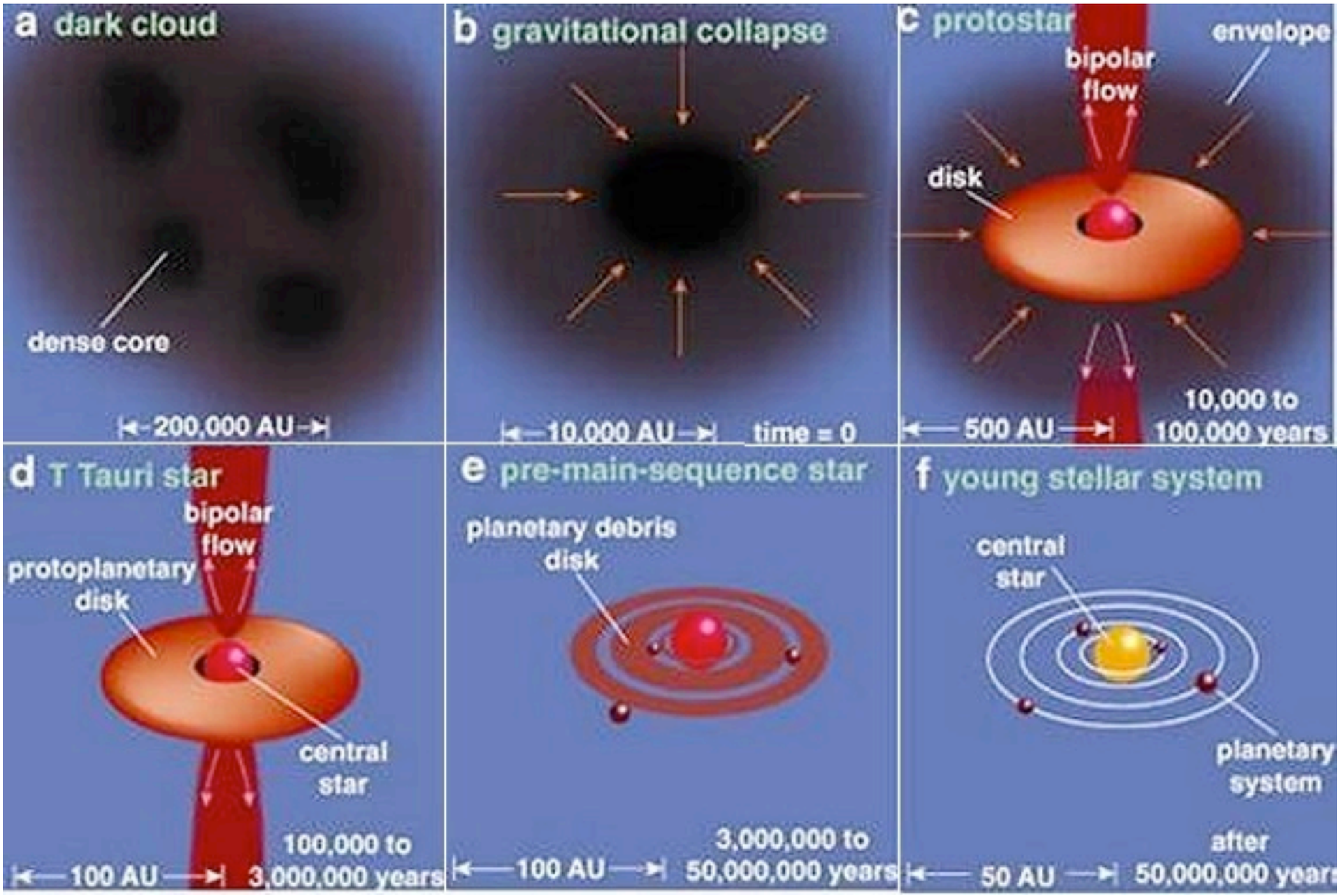
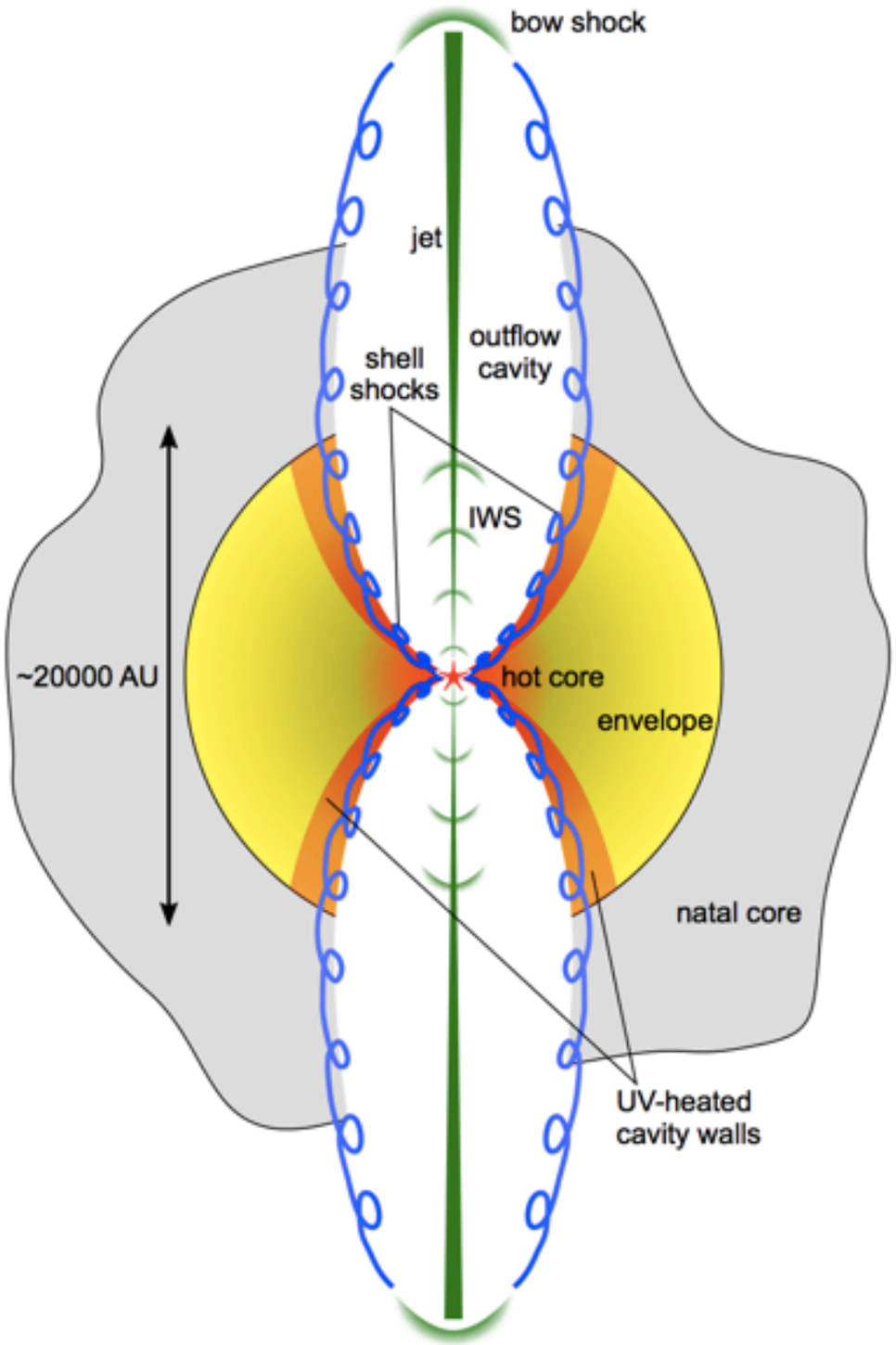
Low mass star-formation

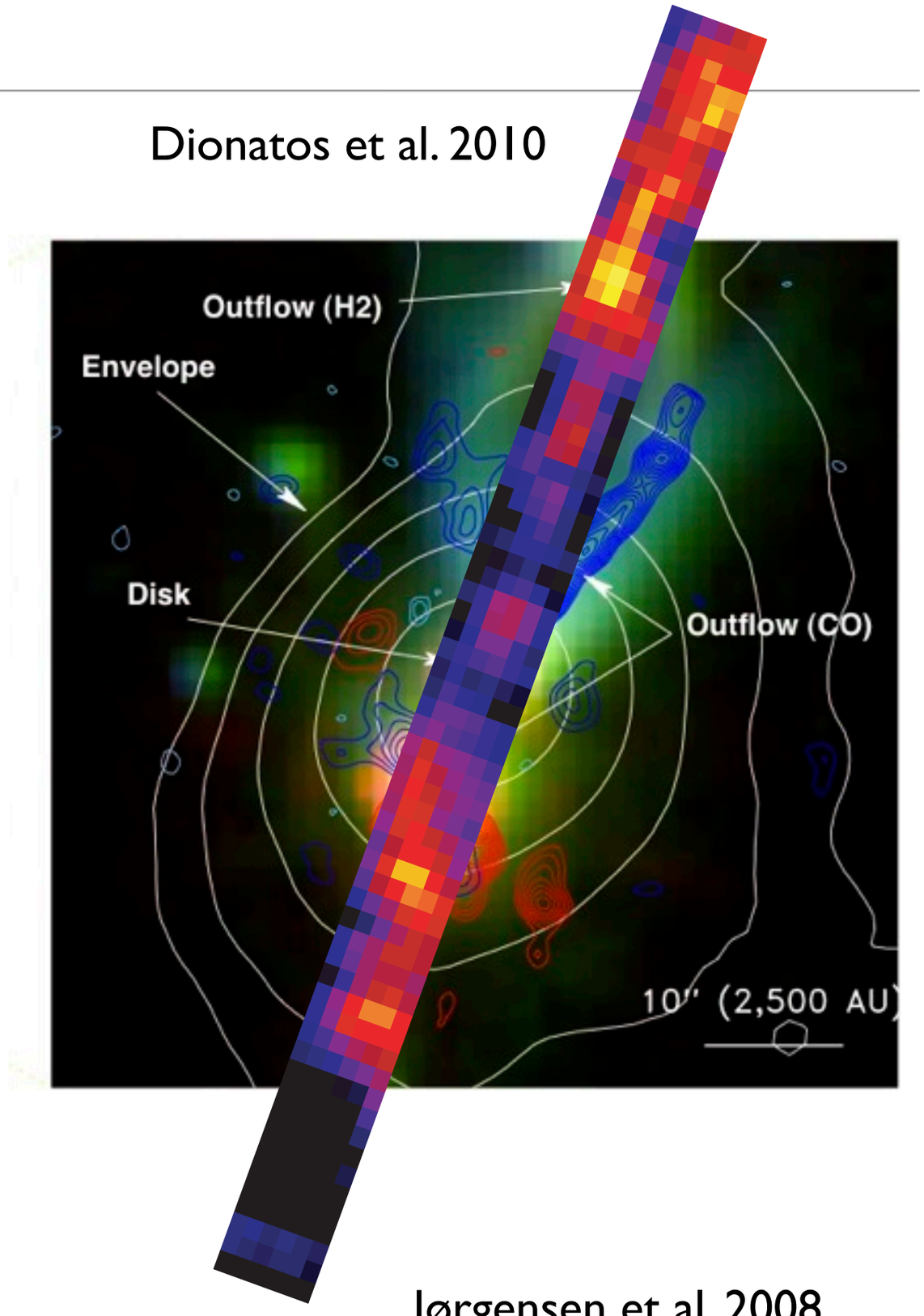


Source: Spitzer Science Center

The embedded phase

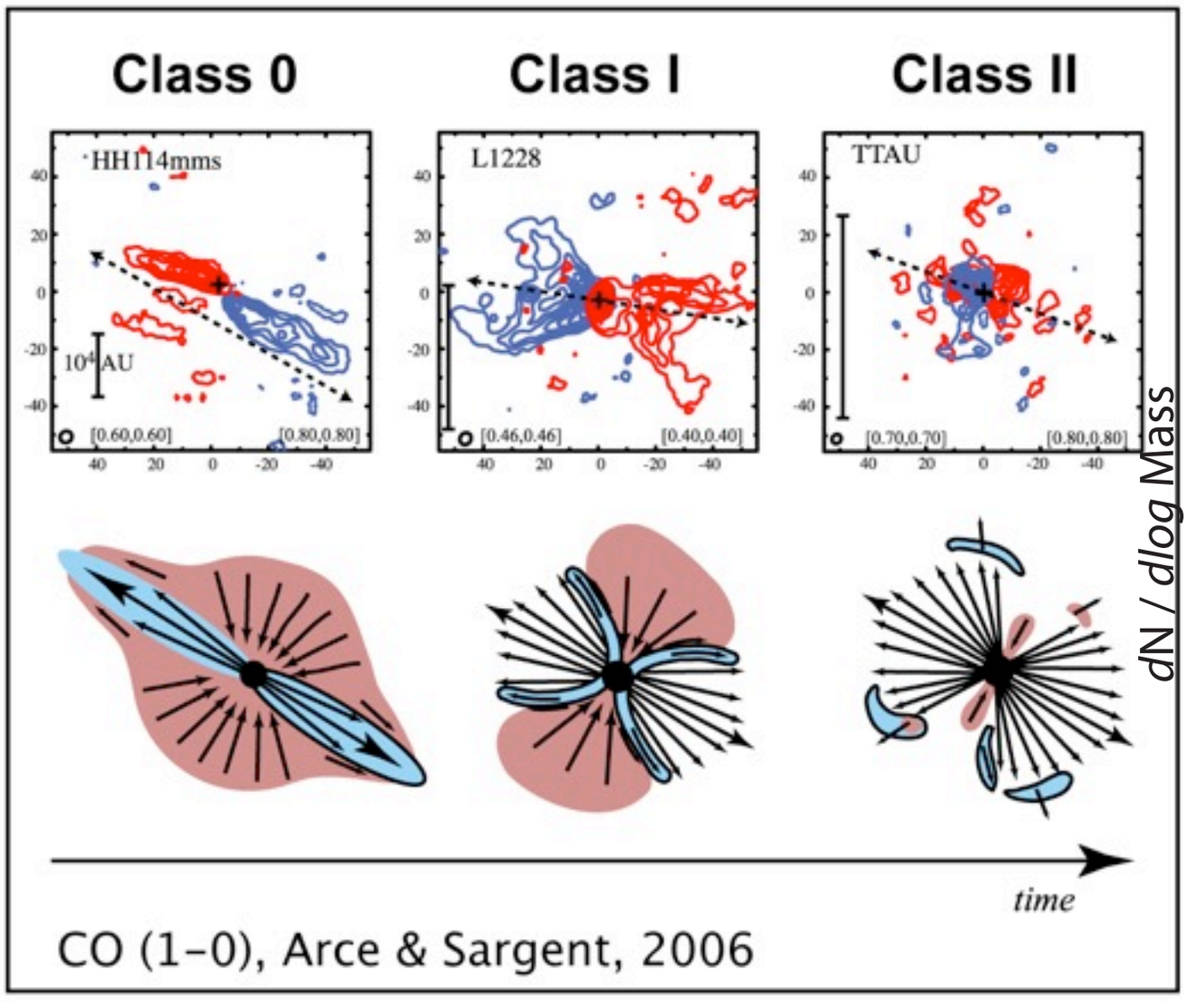


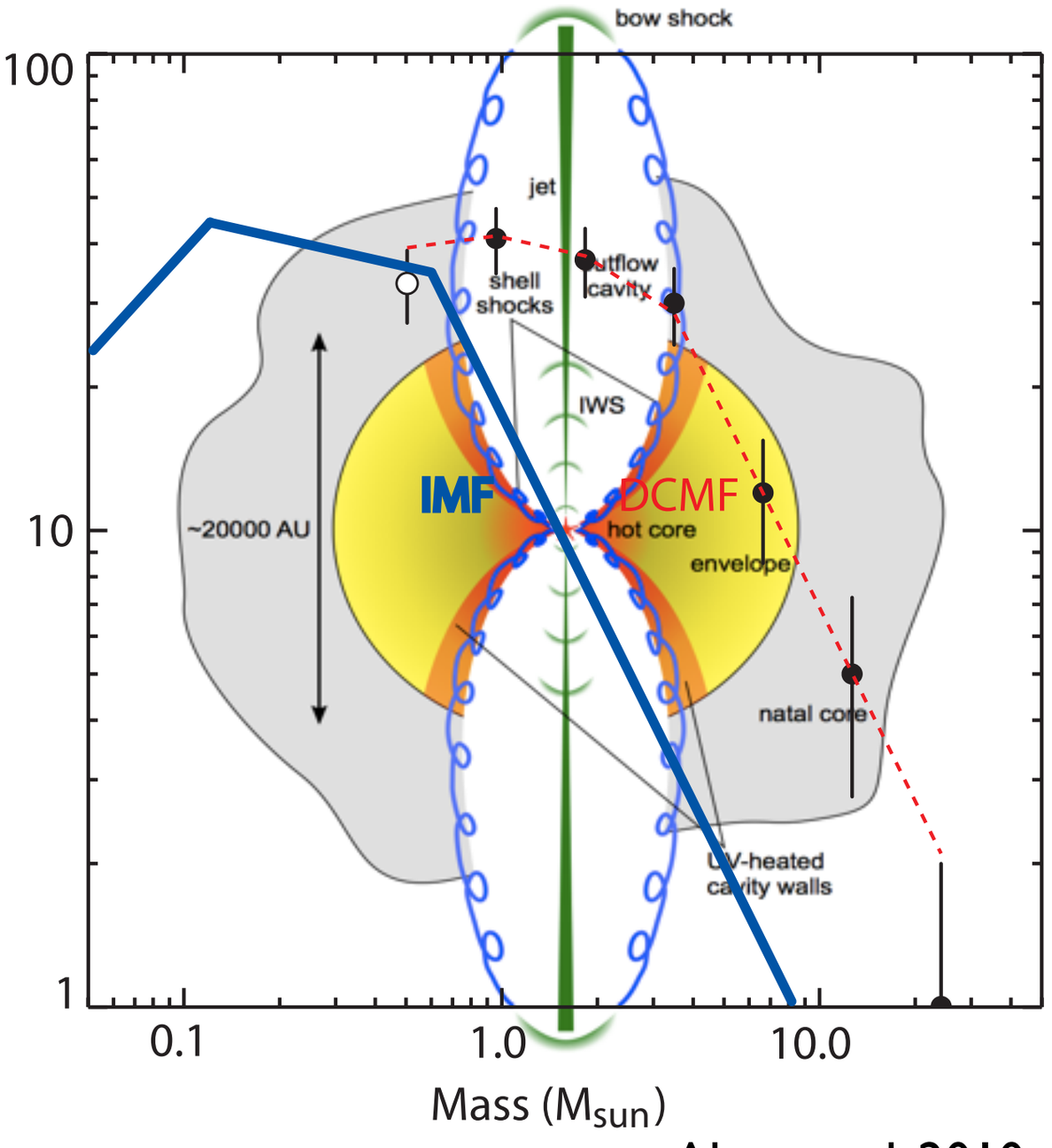
Dionatos et al. 2010



Jørgensen et al. 2008

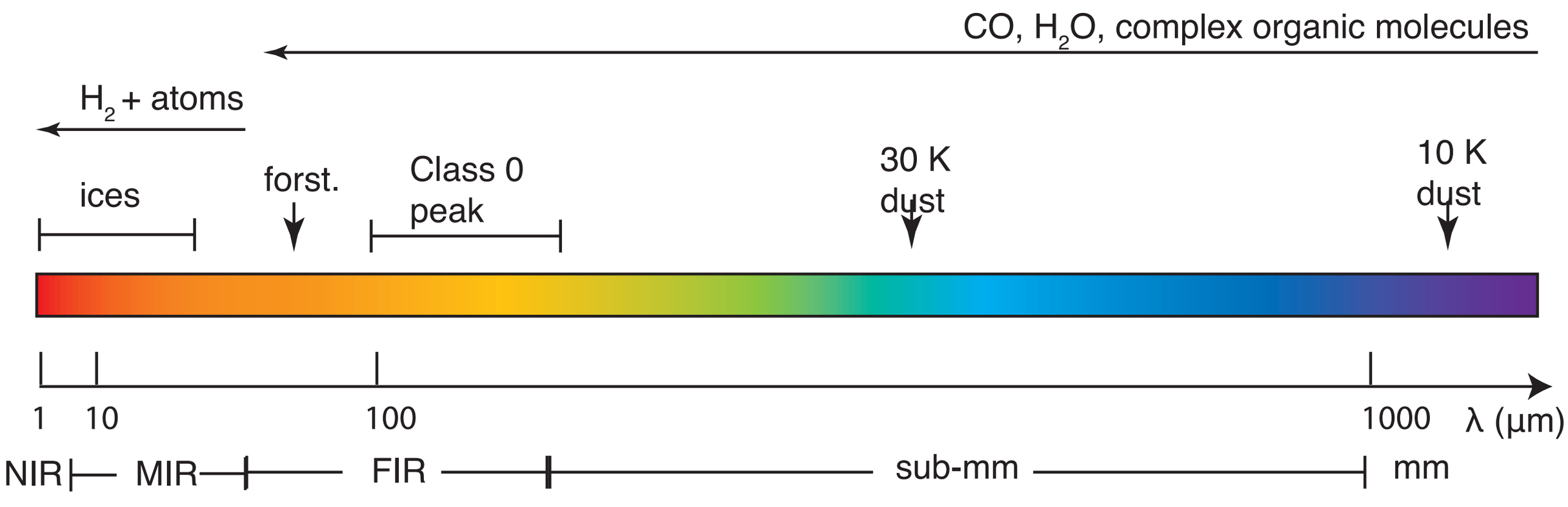
Protostellar envelope dispersal





Alves et al. 2010

Spectral coverage, angular and spectral resolution

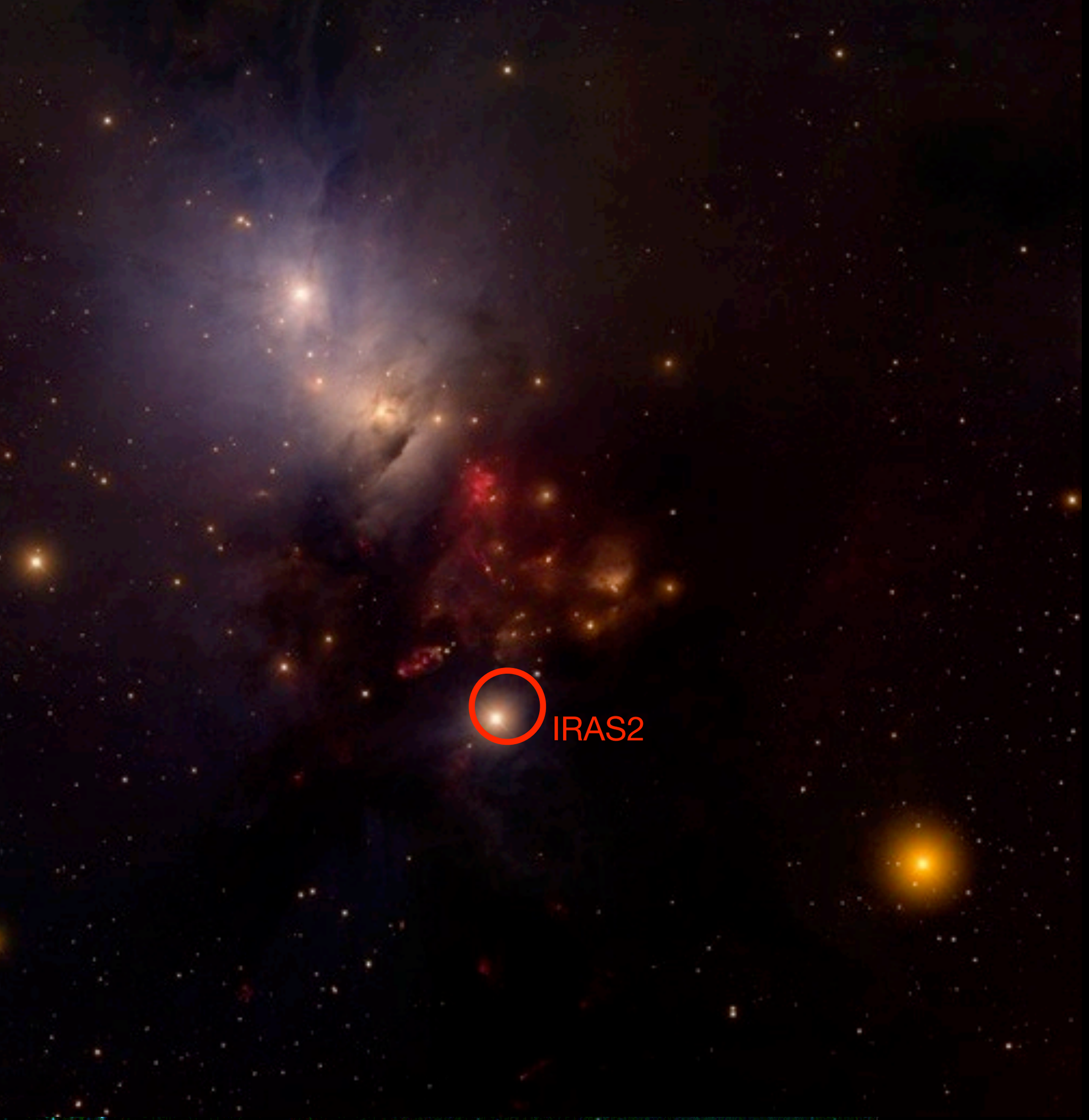


Higher energies: Accessible only from Space - single dish instruments

Lower energies: Accessible (partially) from ground - interferometers

NGC 1333

Source: J. K. Jørgensen



JCMT/SCUBA 850 μm

Sandell & Knee 2001
H. Kirk e.a. 2006

Spitzer 3.6, 4.5 and 8 μm

J.K. Jørgensen e.a. 2006
R.A. Gutermuth e.a. 2008

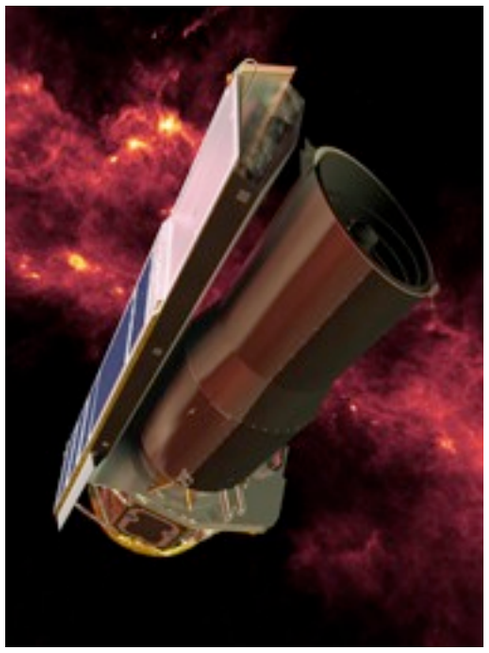
B, V, I and Hα (visible)

T.A. Rector/University of Alaska Anchorage, H. Schweiker/WIYN and NOAO/AURA/NSF

Accessing the mid- and far- infrared

Spitzer Space Telescope (85 cm ø)

- IRAC: 3.4, 4.5, 5.8, 8.0 μm imaging
- MIPS: 24, 70, 160 μm imaging
- IRS: 5.2-38 μm, R~60-600 + IFS

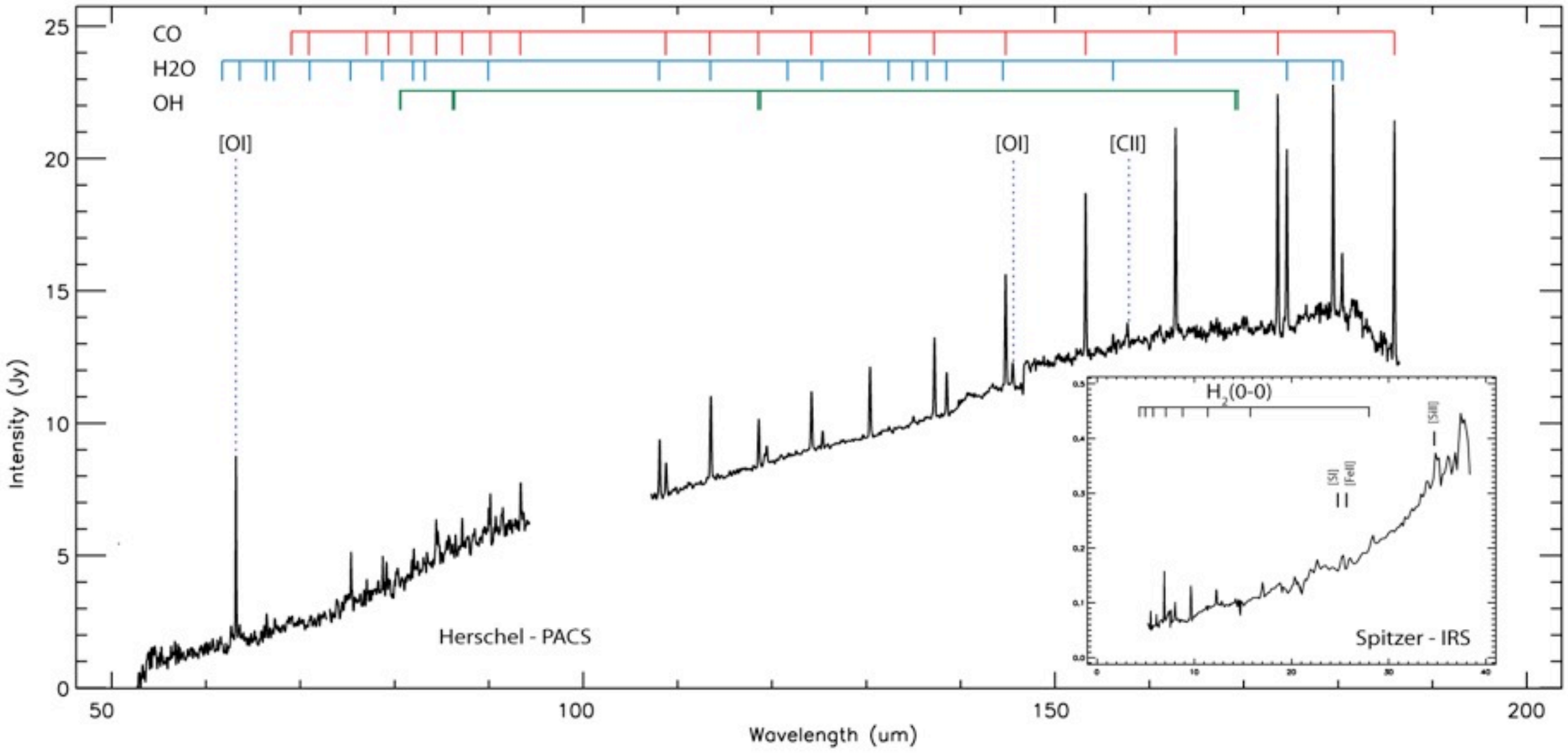


Herschel Space Observatory (3.5 m ø)

- PACS: 50-210 μm, 5x5 array, 9.4”, R~2000
- SPIRE: 174-762μm, 19”-37”, R~50-1000
- HiFi:150-500μm, single pixel, R~10^7

Combined power of IRS & PACS: 5-210 μm + IFS

Herschel and Spitzer Spectra

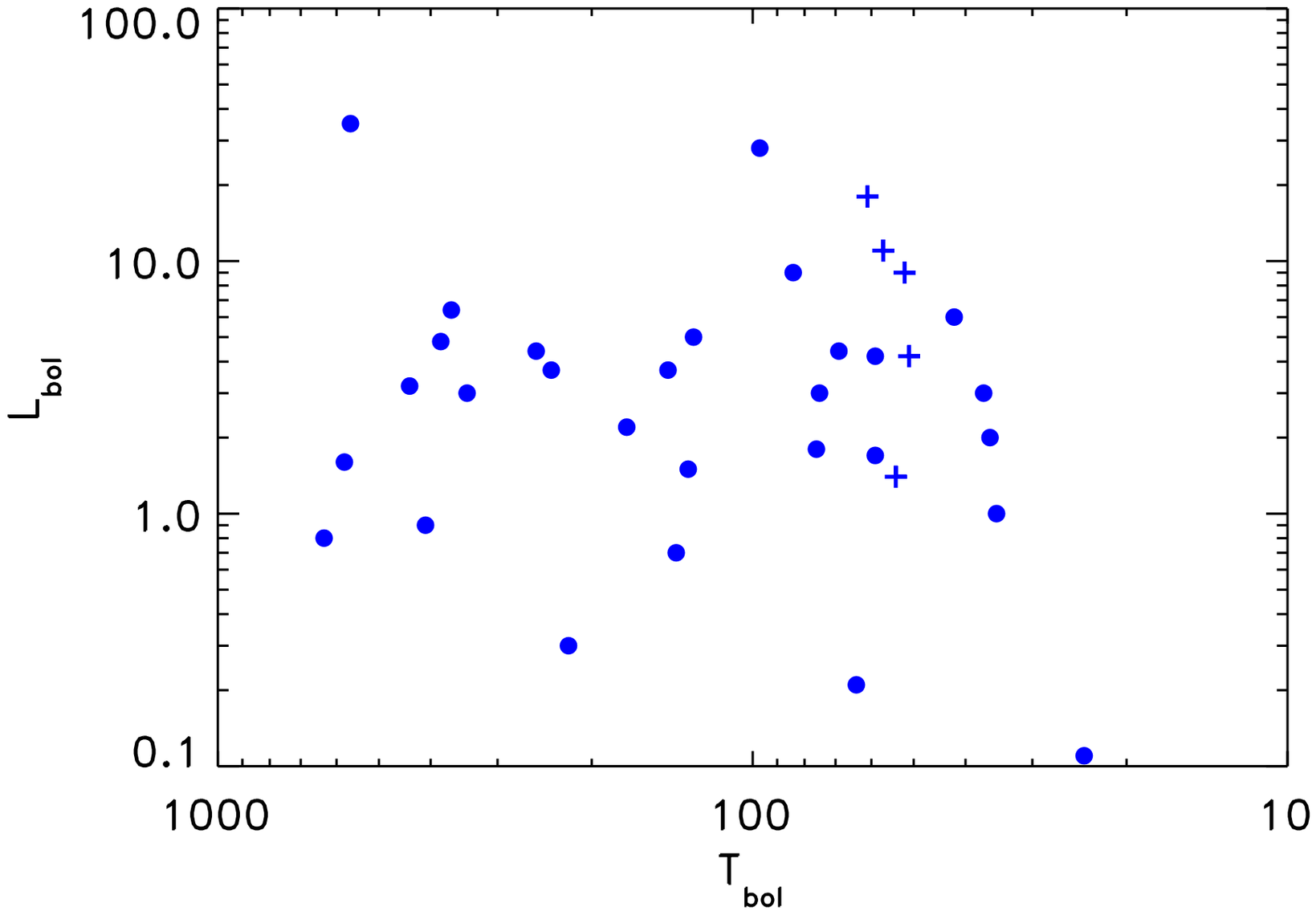


- Herschel/PACS: CO (up to 38-37), H_2O, OH, [OI],[CII]
- Spitzer/IRS: H_2, [FeII], [SiII], [SI]
- Extended energy coverage of all major molecular coolants!

The DIGIT embedded objects sample

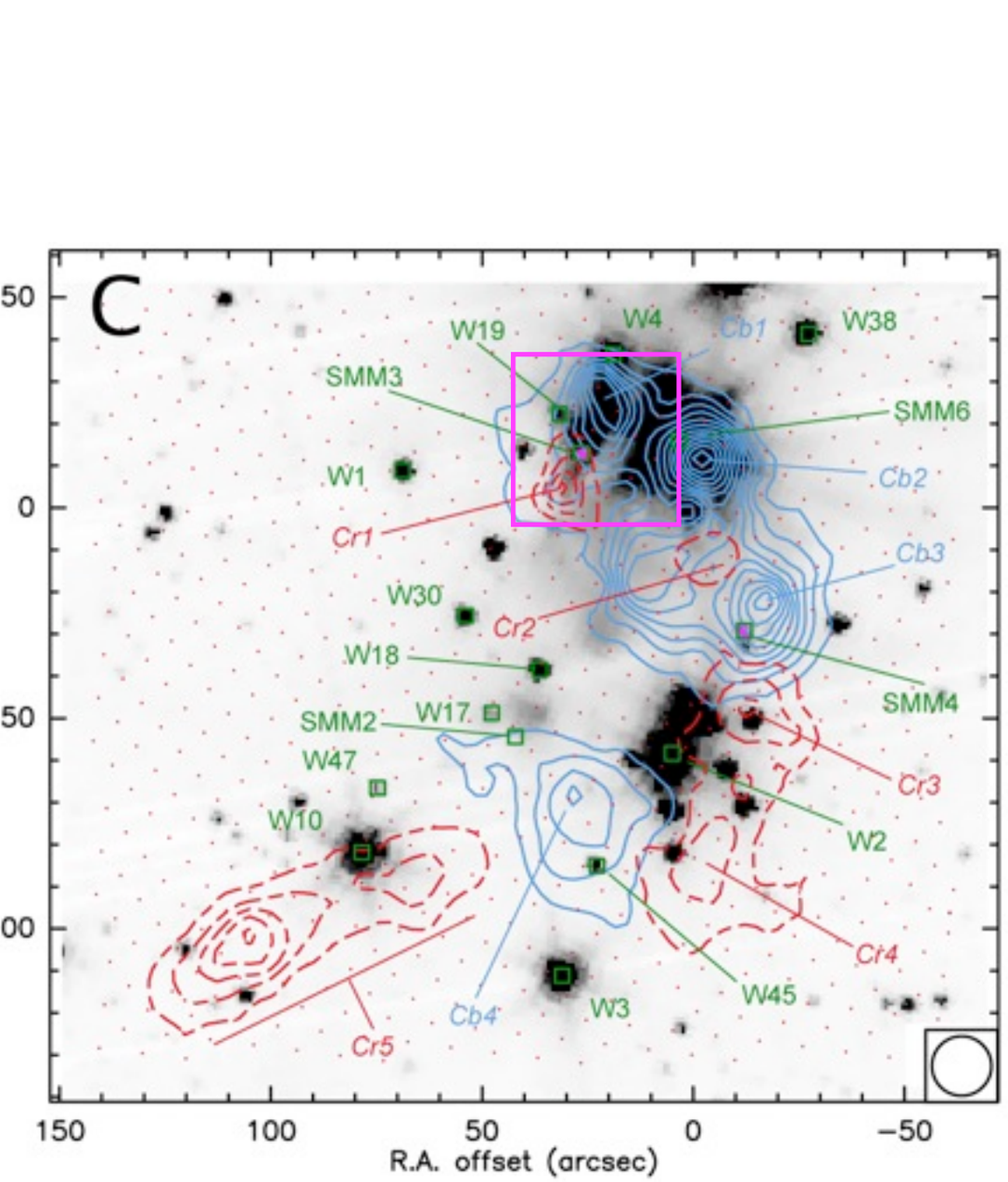
- Full PACS spectral scans
- Sample of 29 Class 0/I YSOs.
- Spitzer maps exist for 7 sources
- Currently 24 sources have been observed.
- Sources selected to cover a wide range of luminosities and temperatures

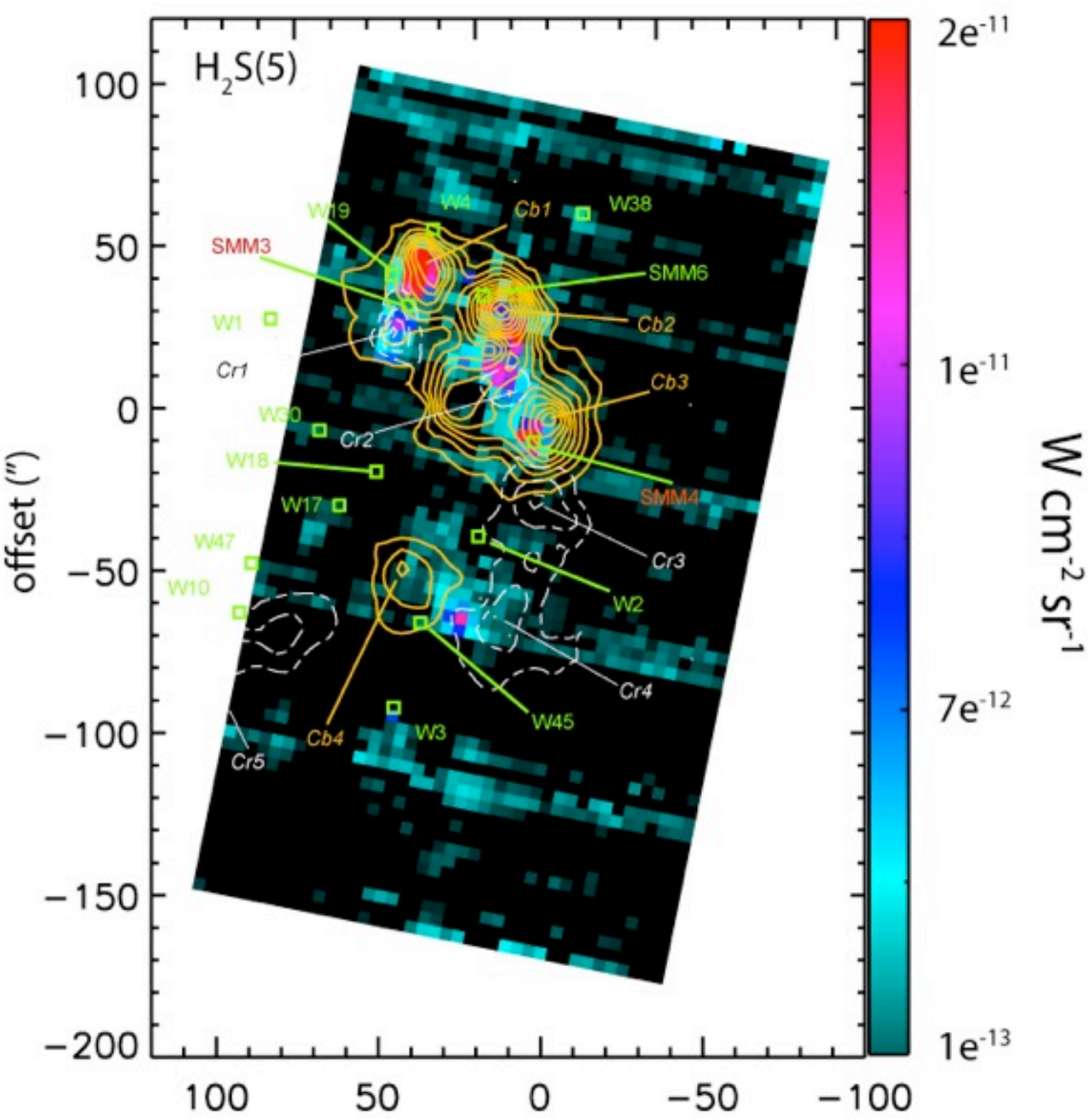
DIGIT embedded objects: L-T diagram



circles: DIGIT; plus-signs: WISH sources

Case: Serpens SE (JCMT and Spitzer)

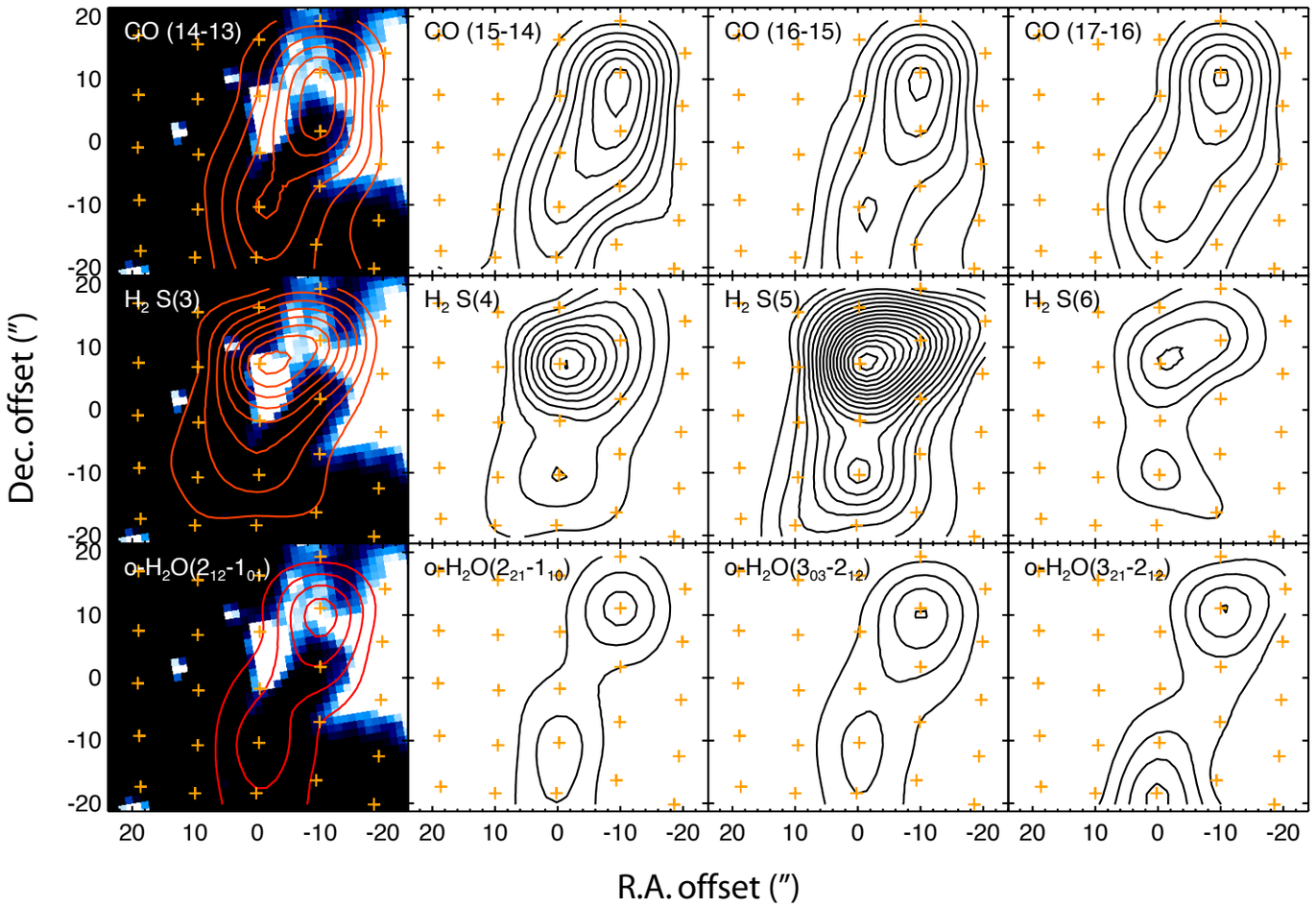




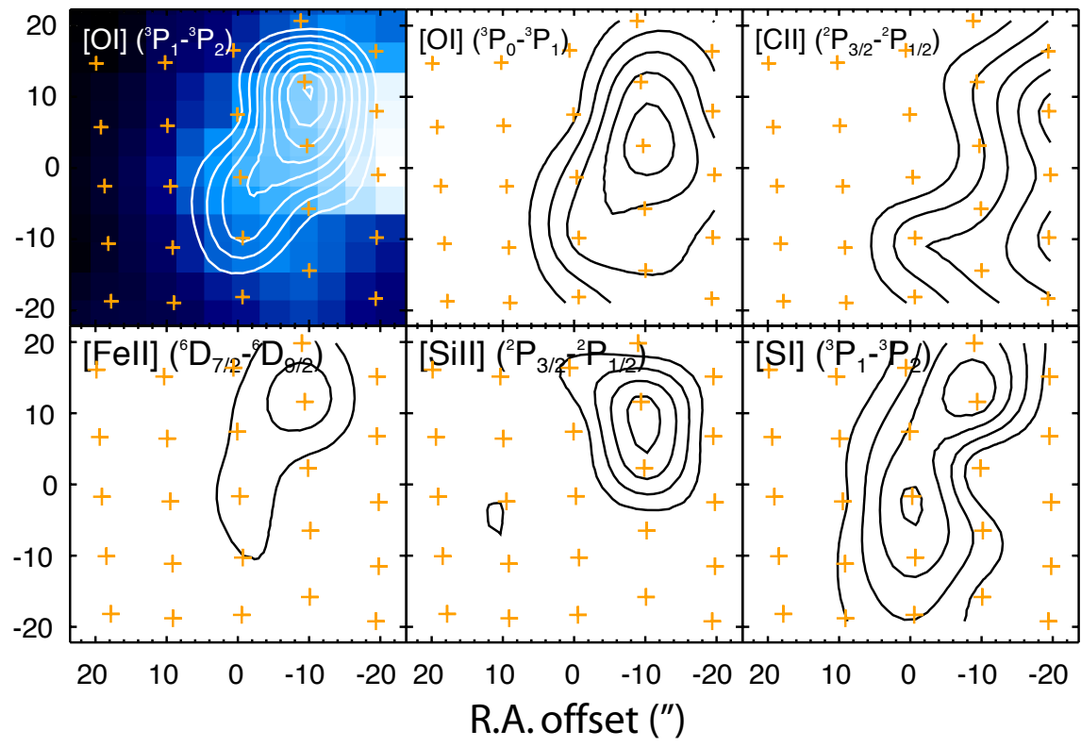
Dionatos et al. 2010

Case: Serpens SMM3 (Spitzer & Herschel)

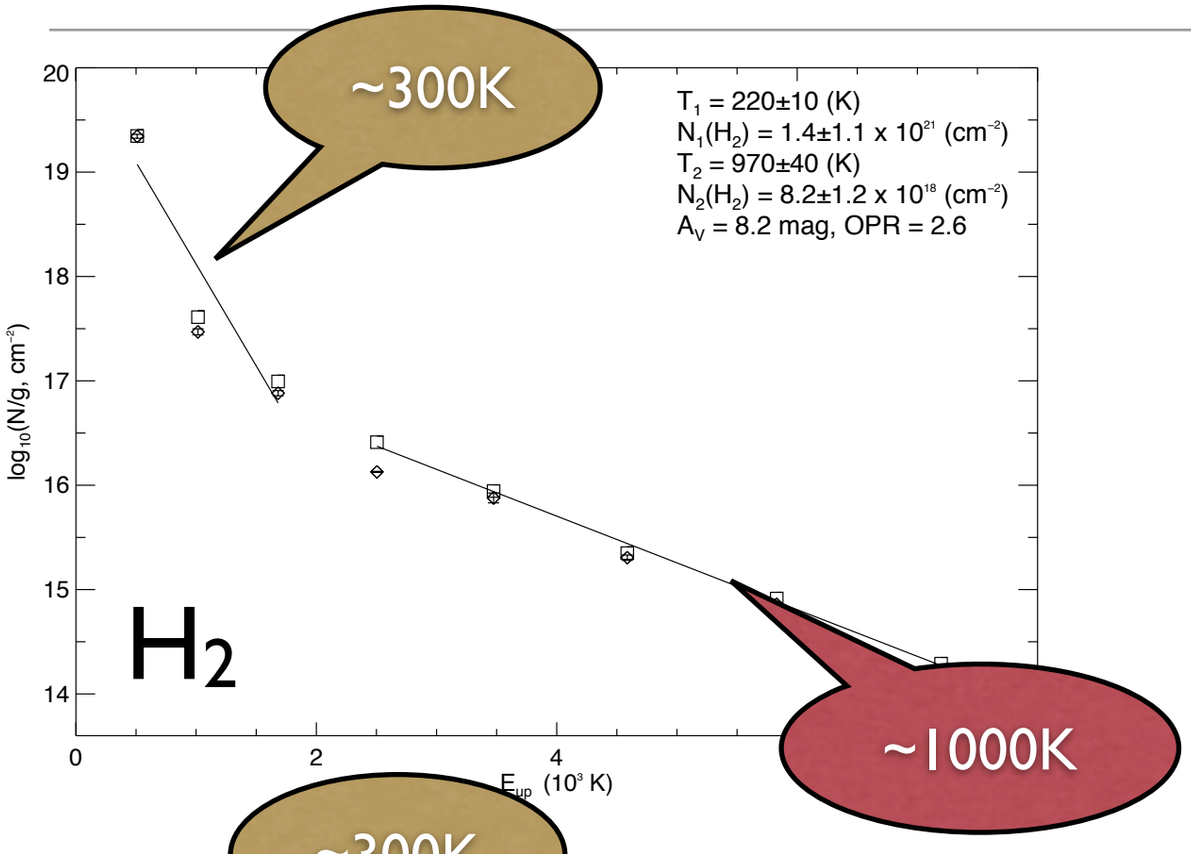
Molecules

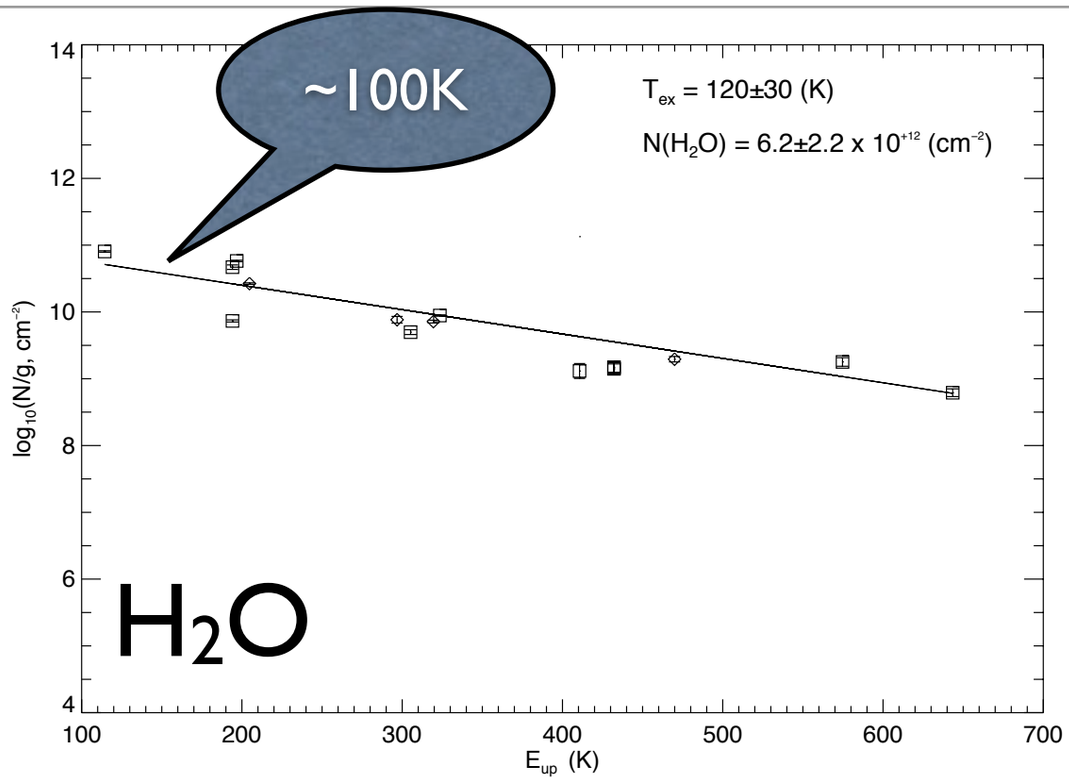


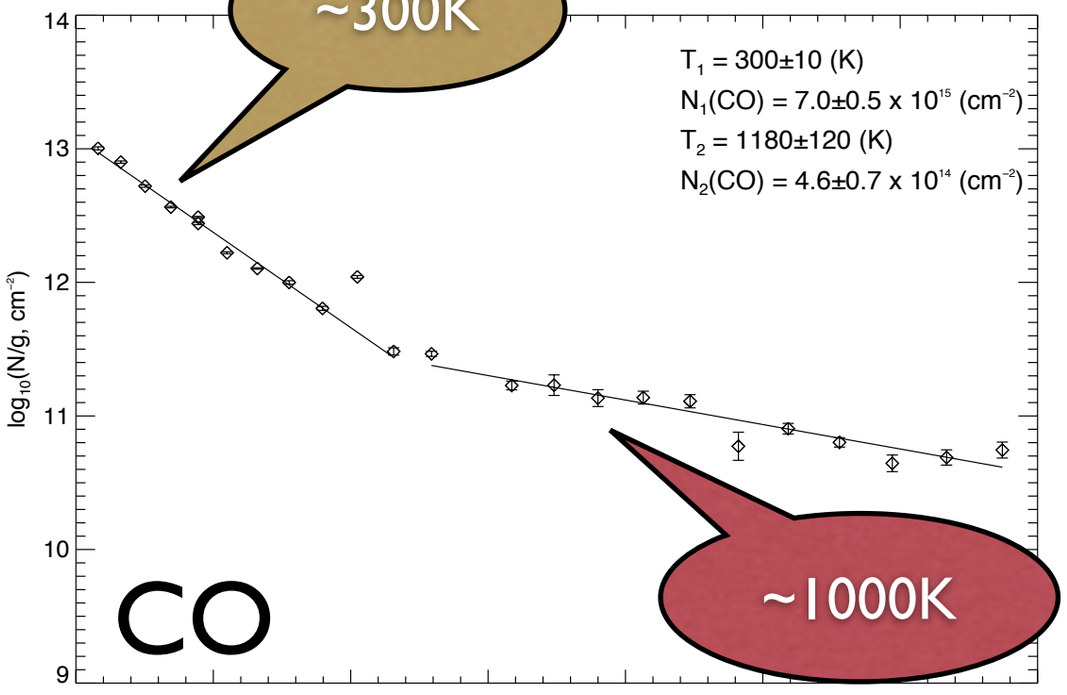
Atoms

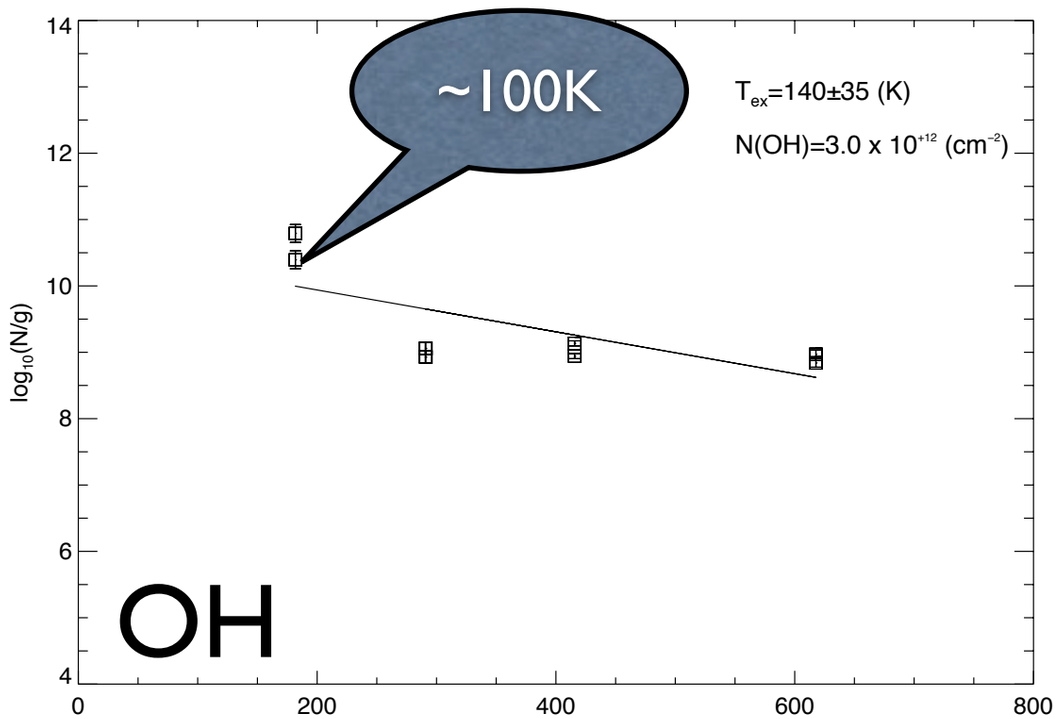


Excitation analysis









DIGIT ongoing data exploitation

- Almost all embedded sources show CO emission with two temperature components at 200-300K and 1000-1500K
  - The same temperature components are typically traced for H_2 with Spitzer - CO and H_2 trace the same volume of gas, most likely excited in shocks
  - Current estimations of the CO/H_2 ratio: one order of magnitude than the ‘canonical’ value
- About half of the sources have H_2O rich spectra
  - Water is a powerful diagnostic of energetic conditions - evaporates from dust grains at T~100K
  - High velocity water has been detected with HiFi (Kristensen, 2011)
- A different half of sources shows the full OH ladder at T~150K
  - OH may be a byproduct of H_2O dissociation from UV radiation
- Many sources show extended emission in molecular lines
  - Outflows
- Comparison with Shock and UV models can decipher the origin of different components

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