c2d-IRS spectroscopy of low-mass embedded young stars
- gas-phase emission -

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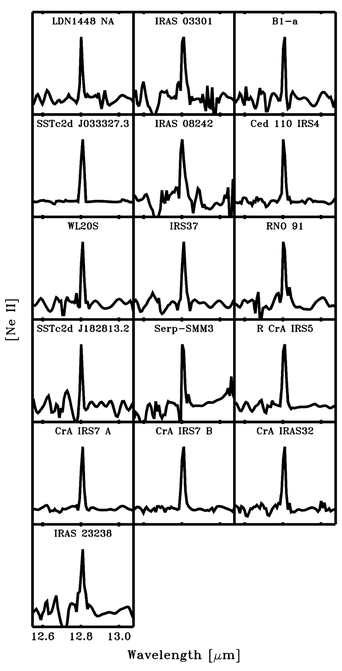
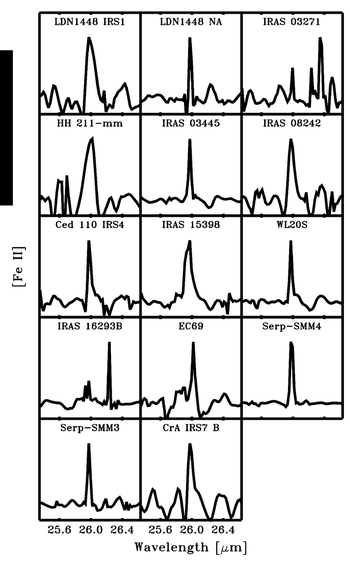
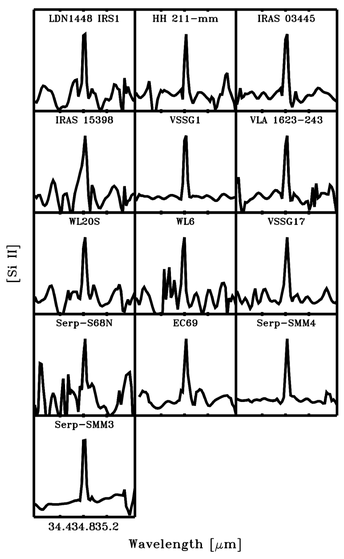
We present Spitzer-IRS observations of H_2, H_2O and various atoms including [Ne II], observed toward a sample of 60 embedded low-mass (proto)stars in nearby star-forming regions. The sources are selected from the Spitzer "Cores to Disks" (c2d) legacy program and consist of truly embedded protostars, disk sources embedded in their remnant envelope and (self-)extincted disk sources (edge-on disks and disks extincted by foreground absorption).

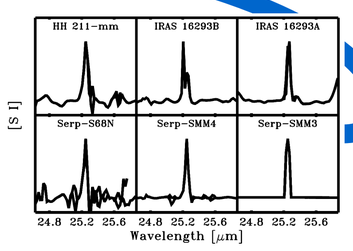
The environment of (embedded) protostars is complex both in its physical structure (envelopes, outflows, jets, protostellar disks) and the physical processes (accretion, irradiation by UV and/or X-rays, slow and fast outflow shocks) which take place. The mid-IR spectral range hosts a suite of diagnostic lines. By comparing the observed line emission with PDR and shock models our aim is to learn which of these physical processes dominates.

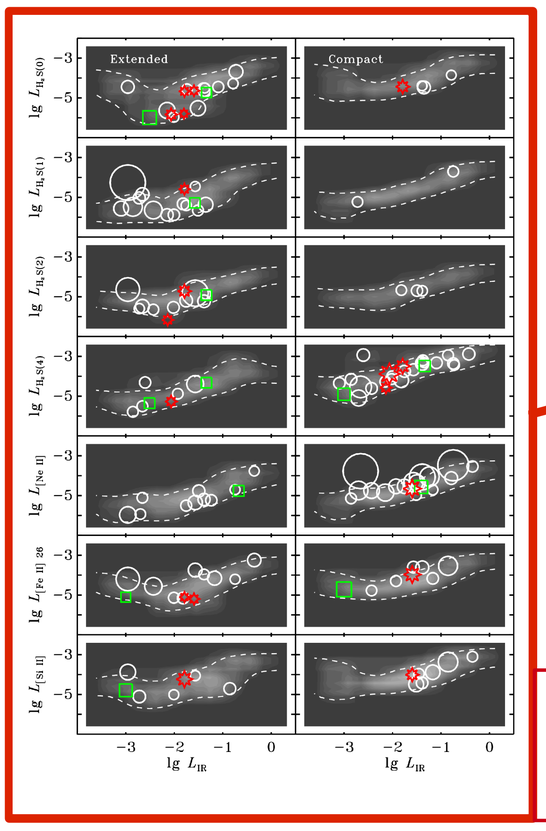
Atomic emission lines



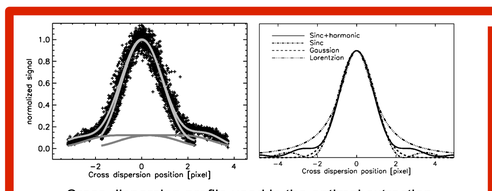




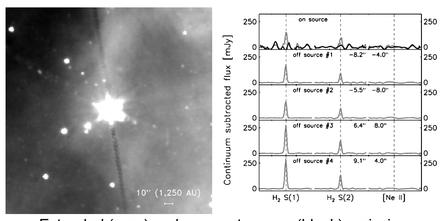




Grayscales represent the upper limit density distribution.
Source type:
- ● embedded
- ◪ unclassified
- ★ disk sources



Cross dispersion profile used in the optimal extraction.
The extraction is calibrated using standard starts

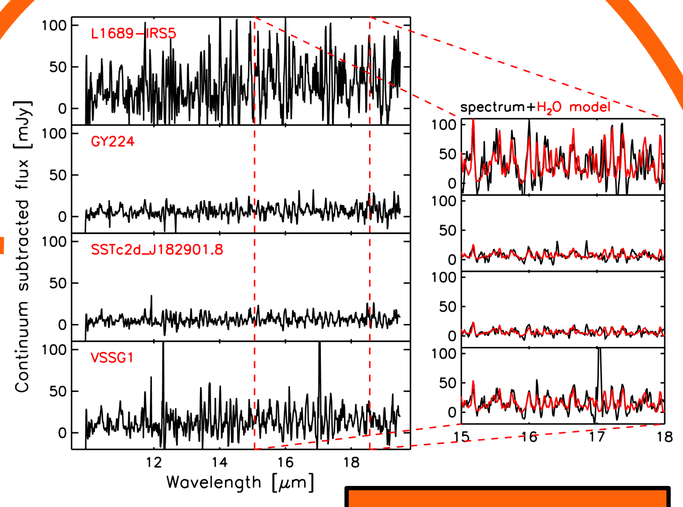


Extended (gray) and compact source (black) emission toward VSSG1 in Ophiuchus in on- and off-source spectra

Optimal extraction

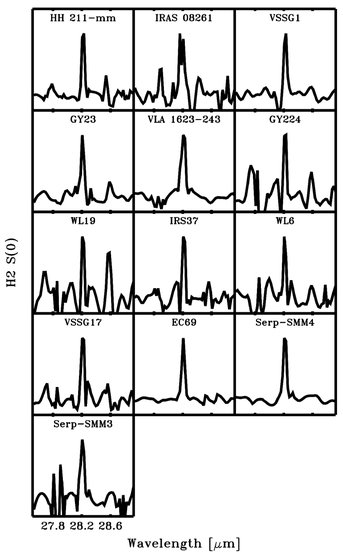
Key in the analysis is to spatially resolve emission in the IRS spectra. An optimal extraction method, developed by the c2d team, is used to separate both spatially unresolved (compact, up to a few hundred AU) and spatially resolved (extended, thousand AU or more) emission in IRS pointed observations. This will allow to distinguish between extended envelope emission and compact source emission associated with outflow shocks and/or the circumstellar disk.

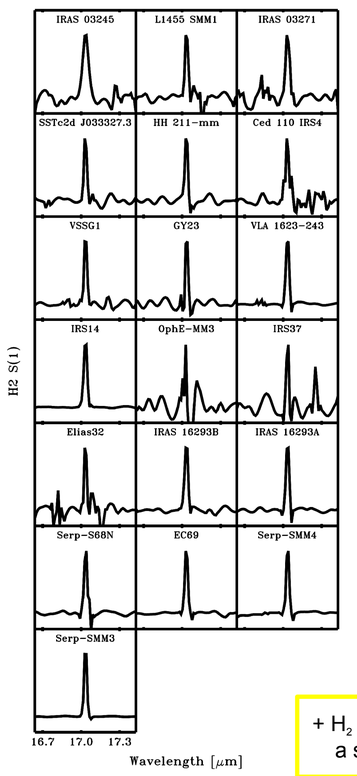
Hot water

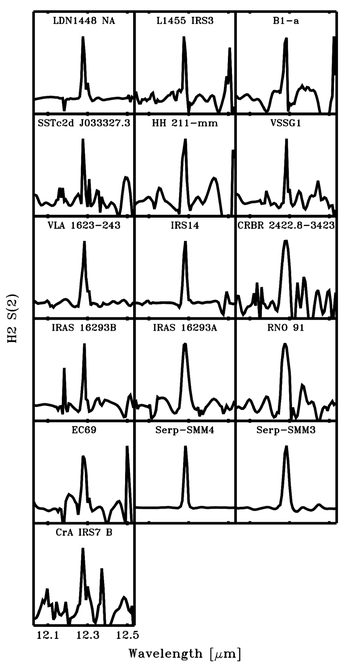


Hot water emission is positively detected toward four sources, two disk sources and two non-classified sources. Tentative hot water detections are made toward eleven more sources, both embedded sources and disk sources.

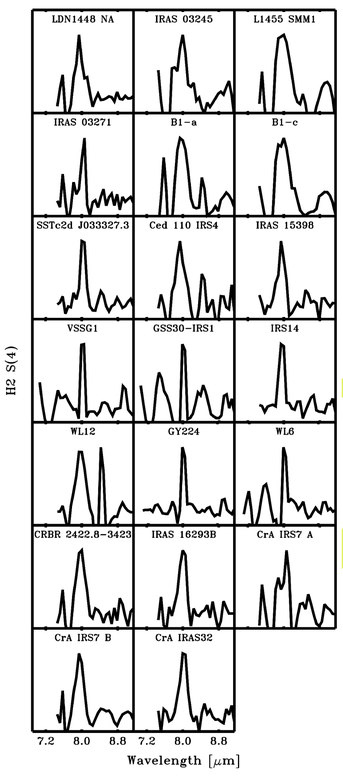
H_2 emission







+ H_2 S(5), S(6) and S(7) toward a small number of sources



Atomic, H_2 and H_2O emission has been detected toward a large fraction of the sample (~3/4 has detections in one or more lines)

Observed:
- H_2 S(0), S(1) and S(2) (warm T_{ex}<700K) is spatially unresolved
- H_2 S(4) (T_{ex}>700K), [NeII] and hot H_2O is (mostly) spatially resolved
- [Fe II] and [Si II] are observed both in the resolved and unresolved component

Emission traces:
- PDR and low velocity shocks along the extended outflow cavities
  - Warm H_2, [FeII] and [SiII]
- Emission from (high-velocity) shocks
  - [NeII], [FeII], [SiII], hot H_2, hot H_2O
- Protoplanetary disk emission
  - [NeII], hot H_2, hot H_2O