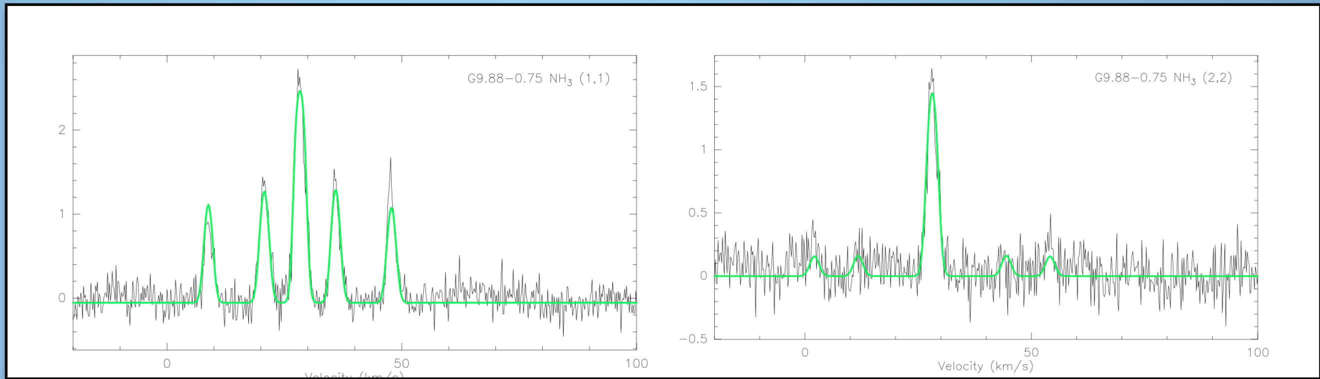
Characterising young high mass stars: using NH_3 emission



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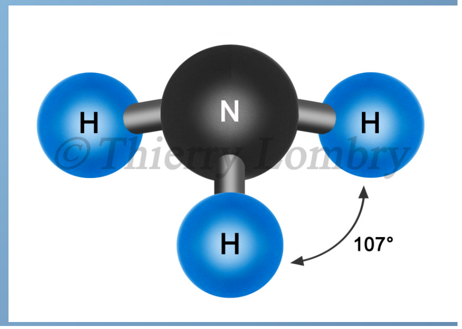

Physical characterisation of southern massive star-forming regions using Parkes NH_3 observations

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ABSTRACT

We have undertaken a Parkes ammonia spectral line study, in the lowest two inversion transitions, of southern massive star formation regions, including young massive candidate protostars, with the aim of characterising the earliest stages of massive star formation. 138 sources from the submillimetre continuum emission studies of Hill *et al.* were found to have robust (1,1) detections, including two sources with two velocity components, and 102 in the (2,2) transition.

We determine the ammonia line properties of the sources: linewidth, flux density, kinetic temperature, NH_3 column density and opacity, and revisit our SED modelling procedure to derive the mass for 52 of the sources. By combining the continuum emission information with ammonia observations we substantially constrain the physical properties of the high-mass clumps. There is clear complementarity between ammonia and continuum observations for derivations of physical parameters.

The MM-only class, identified in the continuum studies of Hill *et al.*, display smaller sizes, mass and velocity dispersion and/or turbulence than star-forming clumps, suggesting a quiescent prestellar stage and/or the formation of less massive stars.

Key words: line: profiles – stars: formation – stars: fundamental parameters – stars: early-type – ISM: molecules – masers.

Background

- Formation/evolution of HMS not well understood.
  - especially the earliest stages
- Difficulty in unambiguous identification & characterisation of these phases.
- Natal molecular cloud expected to be:
  - dense, massive and cold
  - detectable only at (sub)mm wavelengths
- Initial protostar is:
  - massive, cool, low luminosity
  - evolution sees increase in mass, temp, luminosity

Cold Core Search

- Hill et al (2005) SIMBA survey (1.2mm)
  - Target methanol maser & UC HII regions
  - Identified 'mm-only' cores
  - Proposed evolutionary phase.
- mm-only cores
  - Assoc. with water masers (Breen et al)
  - Hyper compact HII regions?
- Different phases of SF traced by different objects:
  - Masers (CH_3OH, H_2O), UC HII, HC HII?
  - i.e. indicative of evolutionary phase?

Characterising Protostars

- Luminosity, mass, temperature are fundamental physical attributes
  - Use to characterise nature/evolutionary status
  - Similarly as for low mass stars (Andre et al.)
- Temperature places constraints on
  - Chemical composition of core
    - Which species present
  - Size and type of grains that form
- Properties derived from SED modelling.

SED Modelling

- Using Bayesian Inference
  - Considers potential correlations between parameters
  - Produce quantitative range of validity of parameters
  - Probability of occurrence of each parameter
    - Not just *the* best parameter
  - Systematic sampling in reasonable period
  - Radiative transfer on limited data results in degeneracies
- Modelled a two-component blackbody
  - central warm core surrounded by cold dust envelope.
  - Hot component radiates as blackbody
  - Cold component from optically thin emission.

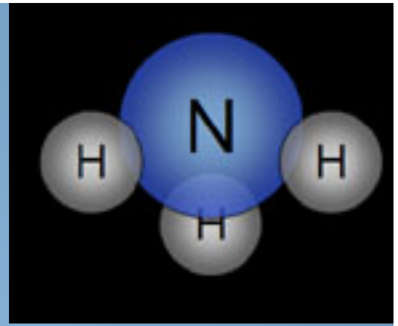
BC: Before Ammonia

- Hill et al. (2009)
  - Fit SED models to sample of 180 sources
    - Representing diff. stages of evolution
  - SIMBA (Hill05), SCUBA (Hill06), MSX, IRAS
  - 2-component or single
  - Only works well if observational data well constrained.
    - i.e. well sample in wavelength space.
  - Extract temperature, mass, luminosity
  - Mm-only appear to be younger, colder examples of HMSF
    - Early stage protostars?

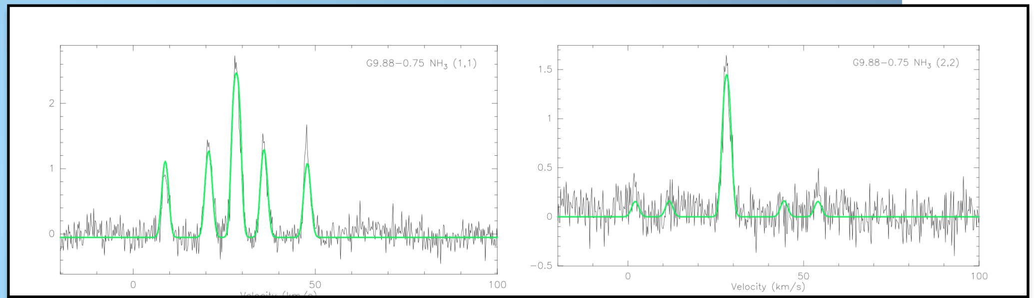
Parkes Ammonia Obs.
(Hill et al. 2010)

- NH_3 (1-1) and (2-2)
  - simultaneous
- New K-band receiver
  - 16-26GHz
- 55m dish at 23GHz
- 5min on source
- 244 sources
- Position switch mode
- Reduced with ASAP, fit with CLASS

Ammonia (NH_3)



- Excellent molec. cloud thermometer
  - Kinetic/rotational temperature.
- Readily detectable in quiescent clouds & low-luminosity regions
  - i.e. birthplace of HMS
- Probe high-density gas



- Resilient to depletion (as opposed to CS)
- Five-fingers give optical depth info.
- Gives density & molecular abundance
- Physical parameters: linewidth, V_{LSR}, column density and virial mass.

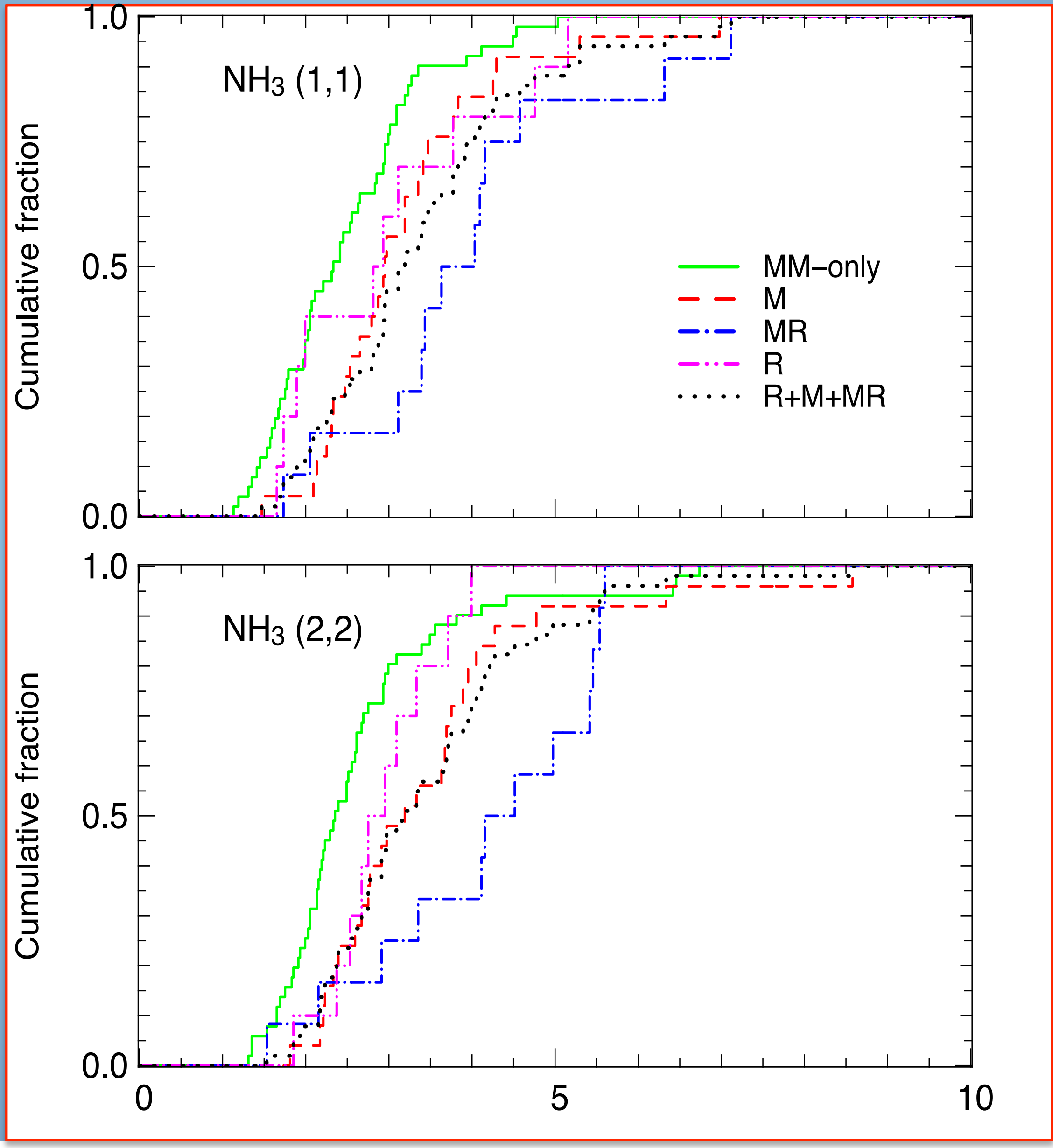
Constraining Protostars

Linewidth

- Indicator of evolution - Sridharan et al. (2005)
- Larger for UC HII (Churchwell et al. 1990)
- mm-only narrower linewidth than maser & UC HII
- Masers trace that of the whole sample
  - Masers ubiquitous tracers of SF
- NH_3 (1,1) and (2,2) from same gas
  - Similar linewidths
  - Broader NH_3 (2,2) linewidths could be interpreted as internal heating
- Thermal linewidths indicates turbulence is clearly dominating for all sources

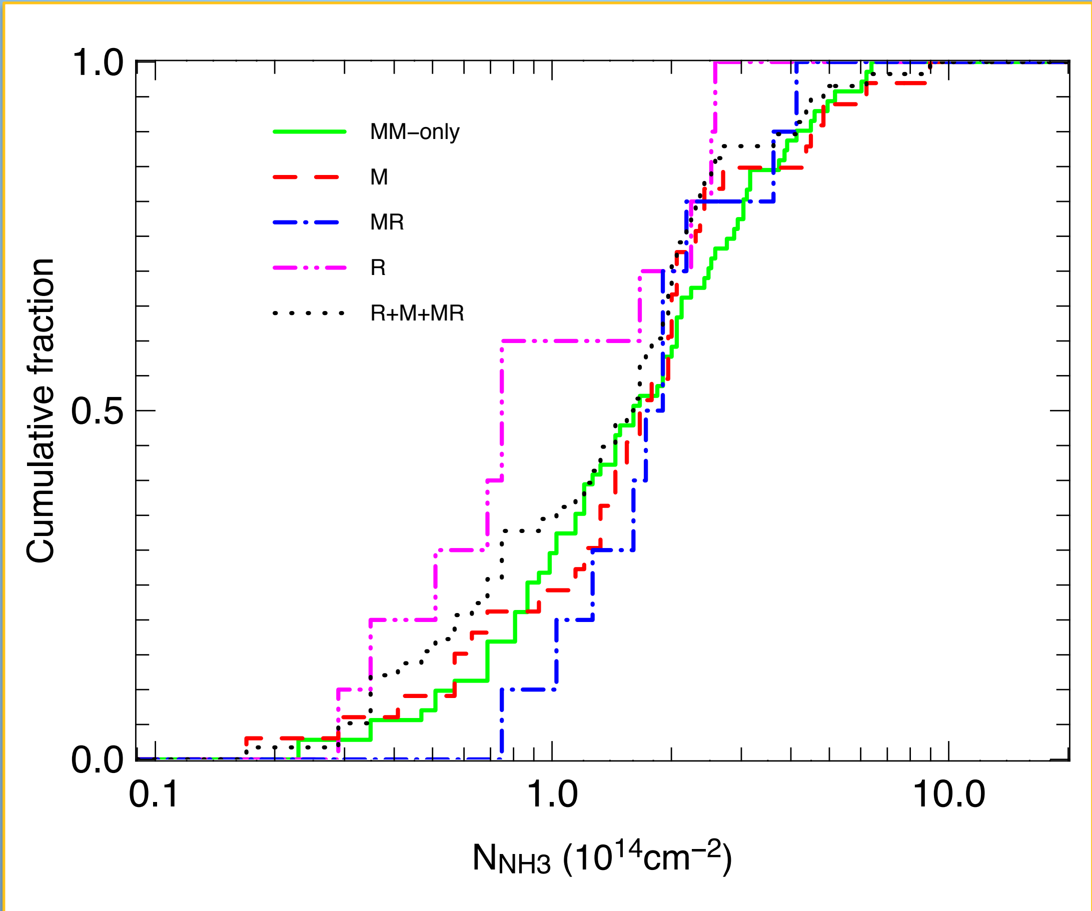
Constraining Protostars

Linewidth



Constraining Protostars:

- Optical Depth: not different between classes.
- Column Density: not very different



Constraining Protostars
Temperature

- Median is 20K
  - NH3 (1,1) & (2,2) reliable up to 30K.
- mm-only cooler on average
- Pillai et al. (2006) found for IRDCs 11–17 K
- Churchwell et al. (1990) find half of their UC HII sample to range between 15 and 25 K and the other half to have temperatures > 25K.

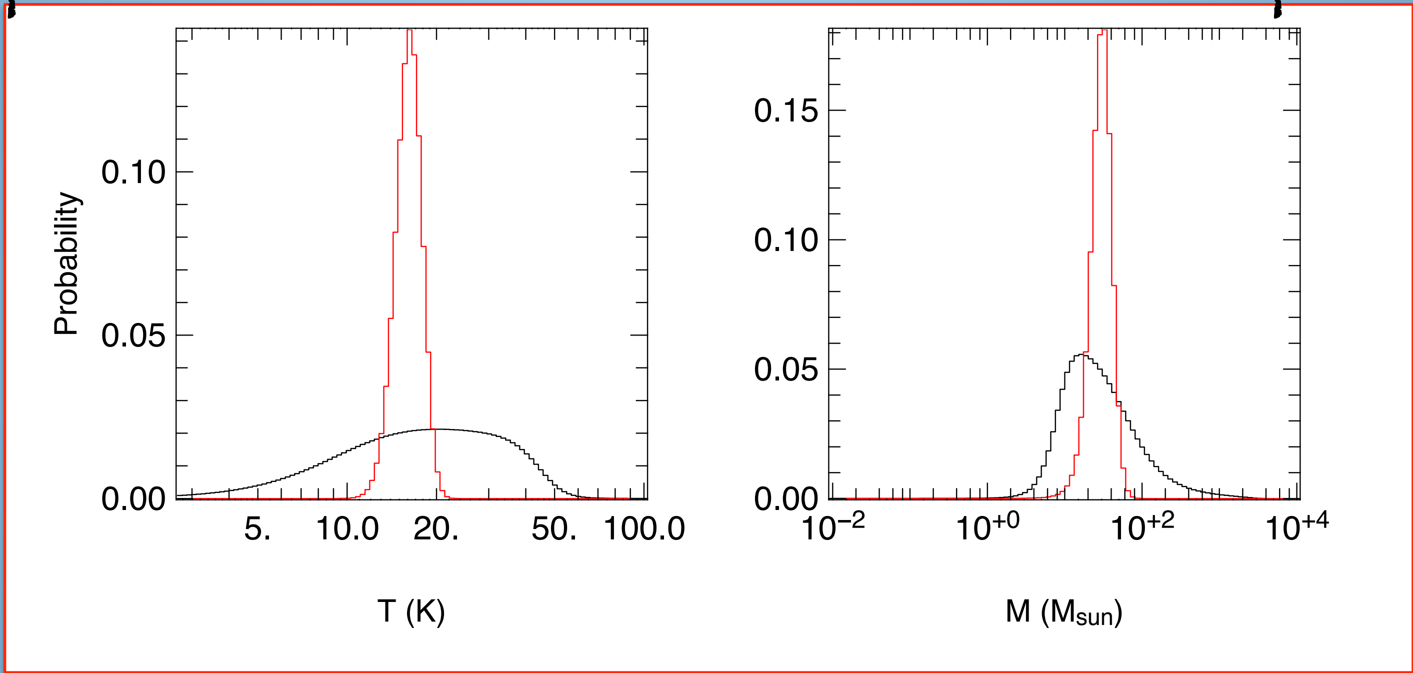
Previous SED Modelling

Hill et al. (2009)

- 180 sources
- Fit for 4 free parameters: T_{hot}, R_{hot}, T_{cold}, M_{cold}
- Absence of FIR data, where the peak of the dust emission lies, hinders accurate determinations of the source temperature.
- The mass and luminosity of a source are highly correlated with the temperature, thus assessing the evolutionary status of a source from SED fitting alone is difficult

SED modelling using NH_3

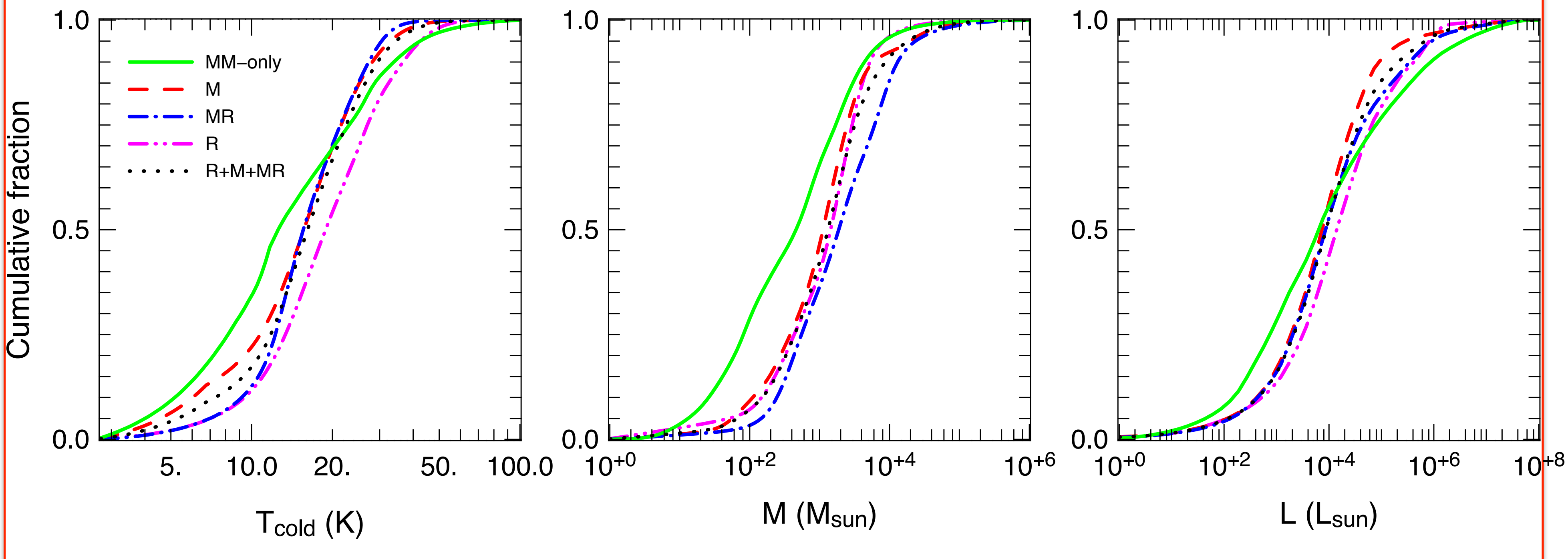
- NH_3 provides a more accurate and independent determination of the temperature



- Comparison of old and new SED modelling
  - Black=old prob, temp fit for. Red= SED, temp. as derived from NH_3. Source has limited sampling of SED

Results

- Accurate temperatures necessary for accurate mass derivations.



Usefulness of NH_3

- Constrains
  - SED modelling
  - Resultant parameters
    - Luminosity, mass, temperature
  - Understanding of sources
  - Evolutionary State.
- Puts us in a position to better position to understand HMSF
- NH_3 and continuum observations provide complementary constraints