Profiling Young Massive Stars

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Thesis work - UNSW
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Massive Star Formation

- Study is hindered - recall talk by de Buizer
- Optically obscured prior to main sequence evolution.
- Difficult to pinpoint individual stages of evolution.
- Low mass SF models?
- IR excellent tracer:
  - Stars emit bulk of radiation at wavelengths shorter than Lyman continuum limit
  - Circumstellar dust envelope absorbs radiation and re-emits in the infrared.
- Massive stars associated with infrared radiation (IRAS & MSX), UC H II regions, maser sources, millimetre & submillimetre emission.
- Do maser species trace different evolutionary stages?
  - Walsh et al (1998): Masers are the first readily detectable tracer of MSF
A Range of MSF Cores

1.2mm Continuum, SEST/SIMBA

Minier, Hill et al, 2005
So what happens before the onset of maser emission?
**SEST/SIMBA**

- Search for cold cores that mark the earliest stages of MSF
- **SEST**: Targeted positions of known methanol maser & UC H\textsc{ii} sources (131)
- **SIMBA**: large F.O.V \((240'' \times 480'')\)
- 405 sources detected \((3-\sigma)\)
- Generally, tracer position correlates with mm peak
- Evidence of star formation devoid of methanol masers and UC H\textsc{ii} regions \(\text{("mm-only cores")}\)
SIMBA maps

G10.47+0.0 SEST 1.2mm emission

G15.03−0.67 SEST 1.2mm emission

G10.15−0.34 SEST 1.2mm emission
Introducing the ‘mm-only’ core

~ 60% sources (255/405) detected have no maser &/or UC H II (mm-emission only). mm-only core

~ 45% do not have mid-IR MSX emission. [lower limit] or are devoid of a mid-IR source

What is their story?

- Younger? Deeply embedded?
- Intermediate mass? combination?
Profiling Young massive Stars

- Using: S IMBA, S CUBA, MS X, sometimes IRAS
- Assuming $\beta = 2$ (Hill et al. 2006)
- Levenberg-Marquardt least squares fit
- 162 sources (of 405)
- Fit results in 6 parameters:
  - Temperature, luminosity, mass, $H_2$ number density, surface density, $Lum/Mass$
- 8 parameters known (+ radius, distance)
- Analysis =>
Example SED mm-only core

\begin{align*}
L_{\text{total}} &= 5.3 \times 10^4 L_{\odot} \\
M_{\text{gas}} &= 9.6 \times 10^2 M_{\odot} \\
T_{\text{cold}} &= 48 \text{ K} \\
d_{\text{cold}} &= 27 \times 10^3 \text{ AU} \\
T_{\text{hot}} &= 200 \text{ K} \\
d_{\text{hot}} &= 3 \times 10^2 \text{ AU} \\
\beta &= 2
\end{align*}
Mass
Luminosity

Log (Luminosity/Lsun)

Fraction

mm-only
moser
moser+radio
radio

Number of Sources

Log (Luminosity/Lsun)
Correlation plots

- Log Radius (pc)
- Log Mass (Msun)
- Log Luminosity (L_sun)
- Temperature (K)

Symbols:
- mm-only
- maser
- maser+radio
- radio
So what’s up with the mm-only core?
Results: mm-only core

- Comparable mass to sources with methanol maser \&/or UC H\textsc{ii}
- But:
  - Smaller, Less luminous, Smaller L/M
  - and cooler
  - More dense (H\textsubscript{2} and surface)
  - than sources with methanol maser/radio continuum.
- KS test: distinctly different for luminosity, temperature, and L/M
- An earlier stage of massive star evolution?
- Bimodal temperature population!
Examining the Bimodal Nature of the mm-only Core
Bimodal mm-only Population

![Graphs showing bimodal mm-only population](image)
A nalysis cont....

[Graphs showing data with various labels]
Analysis revealed....

- Little distinction between warm-mm & sources with methanol maser and/or radio continuum source for all parameters tested.

- Cool-mm sources are distinctly different from the warm-mm sources, methanol maser and/or radio continuum source for all parameters tested bar for mass and radius.

- Cool-mm: less luminous, lower L/M, higher H$_2$ number and surface densities ($\Sigma$). They have smaller radii than those sources with an UC H$\text{II}$ region.

- The warm-mm display similar characteristics to those known to be forming massive stars (those with methanol maser &/or UC H$\text{II}$).
mm-only core: example of evolution?

- Indications: mm-only cores are younger examples of massive star formation
  - Prior to the onset of methanol maser emission
- mm-only comprised of two populations
  - Distinguished by temperature
  - Populations distinct from each other
- Warm-mm sources examples of young massive stars - hot cores?
- Cool-mm sources examples of failed/starless cores? (e.g. Vasquez-Semadeni et al. 2005)