Star formation in the infrared bubble G10.32-0.13

Shari Breen | ARC DECRA Fellow
Soul of high-mass star formation
The region: G10.32-0.13 (CN 148; Churchwell et al. 2007)
The Methanol Multibeam Survey (MMB)

Unbiased, systematic search for 6.7 GHz methanol masers within the Galactic plane and the Magellanic clouds

- 6.7 GHz methanol masers exclusively trace sites of high-mass star formation (Minier et al. 2003, Xu et al. 2008, Breen et al. 2013)

- $3\sigma$ survey sensitivity of 0.7 Jy
- $\sim$1000 detections, $\sim$40% new sources
- 20 to 60 longitude about to be submitted!
Water maser follow-up 6 – 20 longitude

Two special regions stood out immediately:

Titmarsh et al. (2013)  Titmarsh et al. (2014)
The G10.32-0.13 infrared bubble

- Located in the W31 complex
- Distance of 4.95 kpc determined by parallax (Sanna et al. 2014)
- Diffuse 21 cm radio continuum fully covers the bubble, extending ~10pc either side of its center due to pressure driven expansion at 10 – 30 km/s
- Dynamical age ~ 3 – 10 x 10^5 years (Kim & Koo 2002)
  - << sound crossing time (1.3 x 10^7 years for a 4 pc structure at a temperature of 20 K) so information on the initial conditions will still be present.

RED: BGPS
GREEN: 21cm radio continuum
Star formation in bubble rims

- High-mass stars form in clusters and infrared bubbles form from high-mass stars --> more YSOs near bubbles than in the field
- Thompson et al. (2012) shows statistically that there is an overdensity
- Estimated that 20 – 30% of high-mass star formation is triggered by the expansion of infrared bubbles (Thompson et al. 2012)
- But how exactly does that triggering occur?
MASERS!

- 6 separate sites of maser emission (A-E) embedded in ridge of molecular gas
- Maser F is a chance alignment
- Methanol maser lifetime estimated to be 2.5 – 4.5 x 10⁴ years (van der Walt 2005), an order of magnitude smaller timeframe than the bubble age → star formation has been triggered by the bubble expansion
Molecular gas and dust in the region

• Enhanced CO and CS towards maser-associated YSOs (esp. B; Kim & Koo 2012, Beuther et al. 2011)

• \( \text{N}_2\text{H}^+ \), HCN, HNC and HCO\(^+\) (1-0) from MALT90 shows a similar distribution.
  • but \( \text{N}_2\text{H}^+ \) systematically at greater radii, suggesting that the gas is cooler in the other parts of the rim

• 4 of the maser sources are associated with ATLASGAL compact source (Contreras et al. 2013)
  • Conservatively estimate 3 of the 4 to be > 1000 Msol

→ Age and environment of the YSOs in the bubble rim are well constrained by the observational data
Comparing with collect and collapse expectations

- Radius, time and fragmentation mass using Whitworth et al. (1994)
- Green box shows the parameter space consistent with the sources in the bubble rim
- Colour of the points represents the average density of the ambient gas
- Lines represent a different flux of ionising photons (B3 (left) through O3 (right))
ATCA observations
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- ATCA located ~600km NW of Sydney
  - CABB allows sensitive continuum and line observations to be made simultaneously
  - Receivers from 1 – 105 GHz

- Made observations at 12, 7 and 3mm of 36 lines and 3 x 4 GHz continuum to:
  1) determine the locations of the star forming cores
  2) measure the mass distribution and the dynamics of the molecular gas
Soul of high-mass star formation 2015
G10.32-0.13
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What’s next

• Finish reducing the ATCA data...
• VLBA proposal to measure the proper motions of the masers

Summary

• MMB catalogue series nearly complete and is highlighting many interesting regions of high-mass star formation
• G10.32-0.13 has many advantages over other star formation regions and the masers are key to this (parallax, proper motions)
• Current data appears to be inconsistent with expectations of collect and collapse
• New ATCA data covers many lines and continuum at 12, 7 and 3mm and should provide more interesting results
Thank you

Astronomy and Space Science
Shari Breen
ARC DECRA Fellow

t  +61 2 9123 4325
e  shari.breen@csiro.au
w  www.atnf.csiro.au
Used the rotational temperature estimated from CH3CN (Purcell et al. 2006) the parallax distance, a gas to dust ratio of 100, dust absorption coefficient of 1.85 cm$^2$ g$^{-1}$ and a mean molecular mass 2.8 times H.