Young Massive Star Clusters in the Antennae galaxy

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I present various ALMA continuum data of young massive clusters (YMCs) in the Antennae galaxy. YMCs are generally found in starburst systems and will help us understand the star formation mechanism in this extreme environment, which is a lot more common in early universe. We plan to use continuum from various wavelength to quantify various properties in these objects, such as stellar mass, gas mass and ages. We are also going to compare the emission from different scales to see how much emission of giant molecular clouds comes from these compact YMCs. In our study, we found a source close to the south nucleus with significant time variability, which indicates the existence of AGN or supernovae at that position.

Introduction

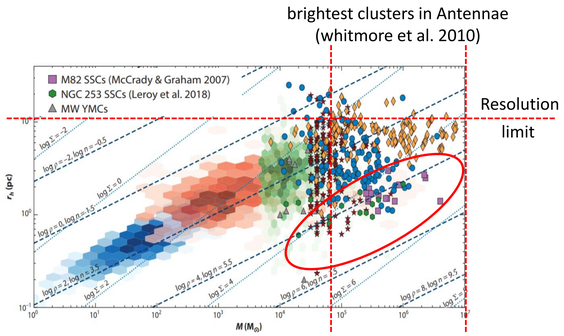
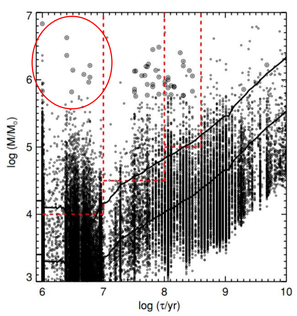


Fig 1. The size-mass relation of globular clusters (GCs) and YMCs (Krumholz et al. 2019). The red ellipse encircles most of currently found YMCs.

- YMCs resembles old globular clusters but are lot more compact
- YMCs are generally found in starburst systems.



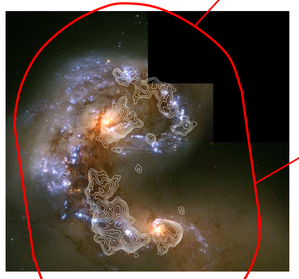


Fig 2. (Left) Age versus mass for clusters in the Antennae galaxy identified from HST data (Whitmore et al. 2010). The red ellipse encircles the most massive clusters with age < 10 Myr. (Right) The HST optical image of the Antennae galaxy overlaid by the CO J=1-0 contours (Wilson et al. 2000).

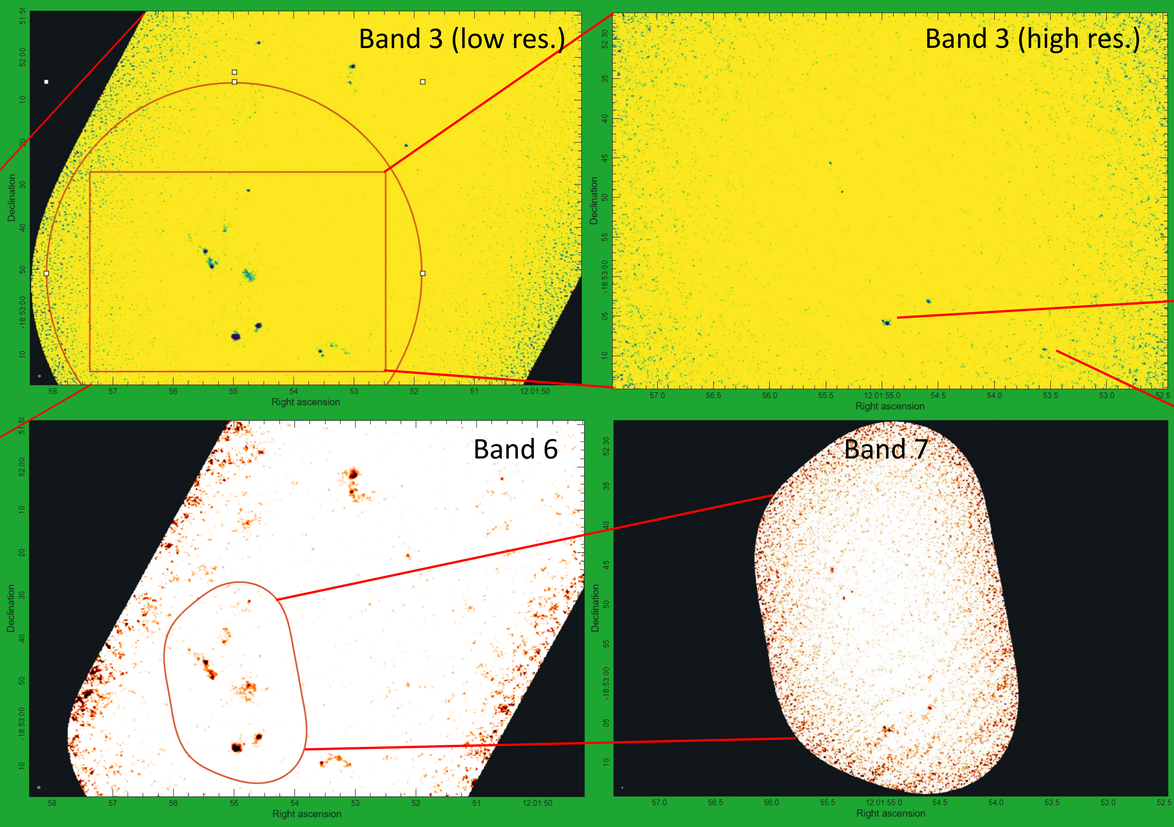
- NGC 4038/4039 has over 1500 young star clusters with age < 16 Myr (Zhang & Fall 2001).

Data Summary

- Band 3 (low res.) and Band 6 data are taken in 2018 with 12m and 7m array. Band 3 (high res.) and Band 7 data are take in 2016 with only 12m array.
- Band 3 (high res.) are made with single pointing while other images are made with mosaic.
- Band 3 (low res.) and Band 6 observation covers the spectral line while Band 3 (high res.) and Band 7 observation deliberately avoid the spectral lines.

	Sensitivity (mK)	Resolution (pc)	Frequency (GHz)	LAS.[a]
Band 3 (low res.)	6.0	50	~ 100	7 kpc
Band 3 (high res.)	96	10	~ 100	130 pc
Band 6	4.0	55	~ 220	3 kpc
Band 7	24	10	~ 340	147 pc

a. LAS. stands for the largest angular scale that ALMA can recover the flux.



Analysis

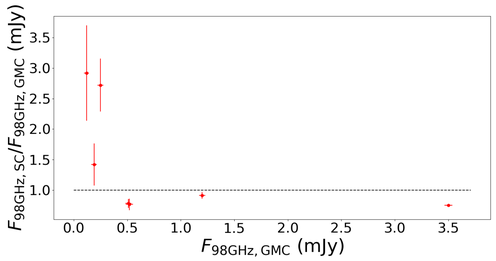


Fig 3. The fraction of GMC flux from star clusters versus the GMC flux.

- The ratio between star cluster flux and GMC flux should be smaller than 1.0. But it's not true for some sources

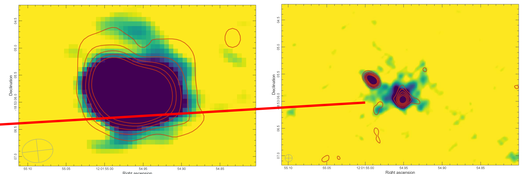


Fig 4. The brightest source in the overlap region of NGC 4038/4039. (Left) Band 3 (low res.) image overlaid with Band 6 contours. (Right) Band 3 (high res.) image overlaid with Band 7 contours

- Band 3/Band 7 emission ~ 0.9, pure free-free emission
- Band3/Band 6 emission ~ 0.75, 80% free-free emission

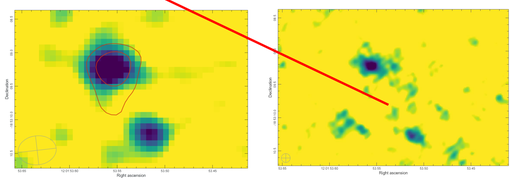


Fig 5. Similar to Fig. 4 for the nucleus region of NGC 4039

- GMC flux is smaller than star cluster flux
- It's near the south nucleus of the galaxy. It's probably a source of AGN or SN with time variability.

References

Krumholz et al. 2019, ARA&A, 57, 227 • Whitmore et al. 2010, AJ, 140, 75 • Wilson et al. 2000, ApJ, 542, 120 • Zhang & Fall, 2001, AJ, 561, 727