Revealing Embedded Super Star Clusters in M82

María Jesús Jiménez Donaire
Observatorio Astronómico Nacional

Super star clusters (SSCs) are young stellar clusters of large mass and compactness that constitute the most extreme episodes of star formation. However, many aspects about this mode of star formation remain unknown.

Our recent ambitious SMA campaign observed the nearby starburst galaxy M82 with unprecedented resolution in the 350GHz dust continuum and molecular line emission.

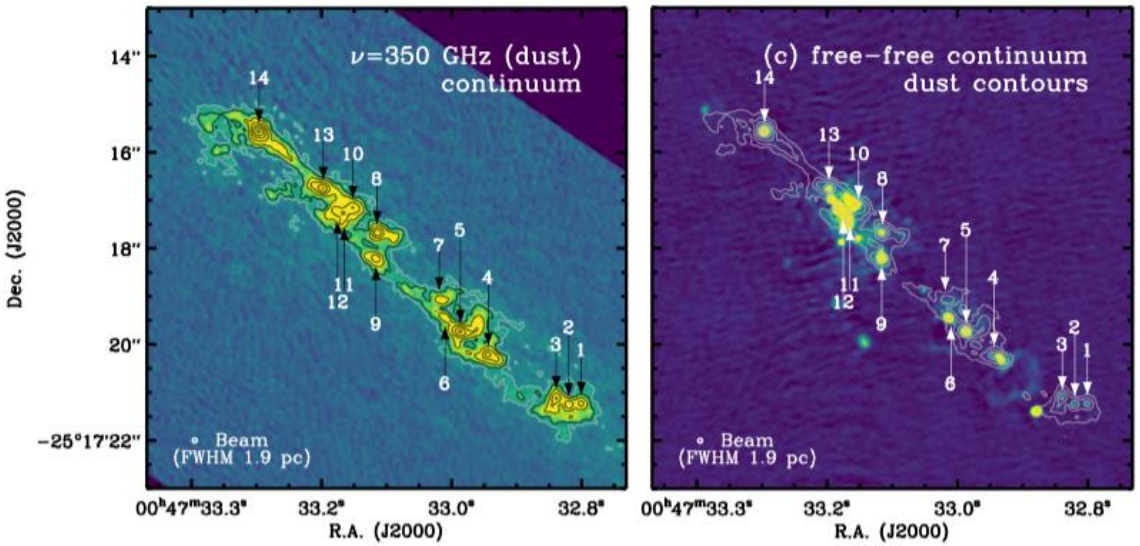
Our observations reveal >20 bright, compact sources of dust emission, associated with free-free emission and of dense, excited gas. Based on the estimated gas, stellar and dynamical masses, most of these SSCs are still forming, their gas content contributing a large fraction of their total mass.

Image Credit: Pablo Rodríguez-Gil, Pablo Bonet (IAC)

Team: María Jesús Jiménez (PI, CfA > OAN), Adam Leroy (OSU), David Wilner (CfA), Alberto Bolatto (Maryland), Glen Petitpas (CfA), Josh Marvil (NRAO), Rebeca Levy (Maryland)

Scientific Context: Proto Star Clusters

Young stellar clusters of very large mass (>10^5 M_{sun}) and compactness (2−5pc) found in local starburst galaxies.



Compact, gas-rich structures associated with heavily embedded, high-mass star formation seen in free-free maps (Leroy+18).

Although cluster formation is expected to be a main mode of star formation in starbursts, many aspects remain poorly constrained. Why?

- They are extremely small, deeply embedded and have short timescales. Thus, they must be resolved in the submm and radio, in the most nearby starbursts.
- The Milky Way has only very few young massive proto-clusters (e.g., Bressert+12,Ginsburg+12, Longmore+14) and at most one proto-SSC (Sgr B2, Ginsburg+18).

Observing SSCs in M82


Image credit: Nimesh Patel (CfA)

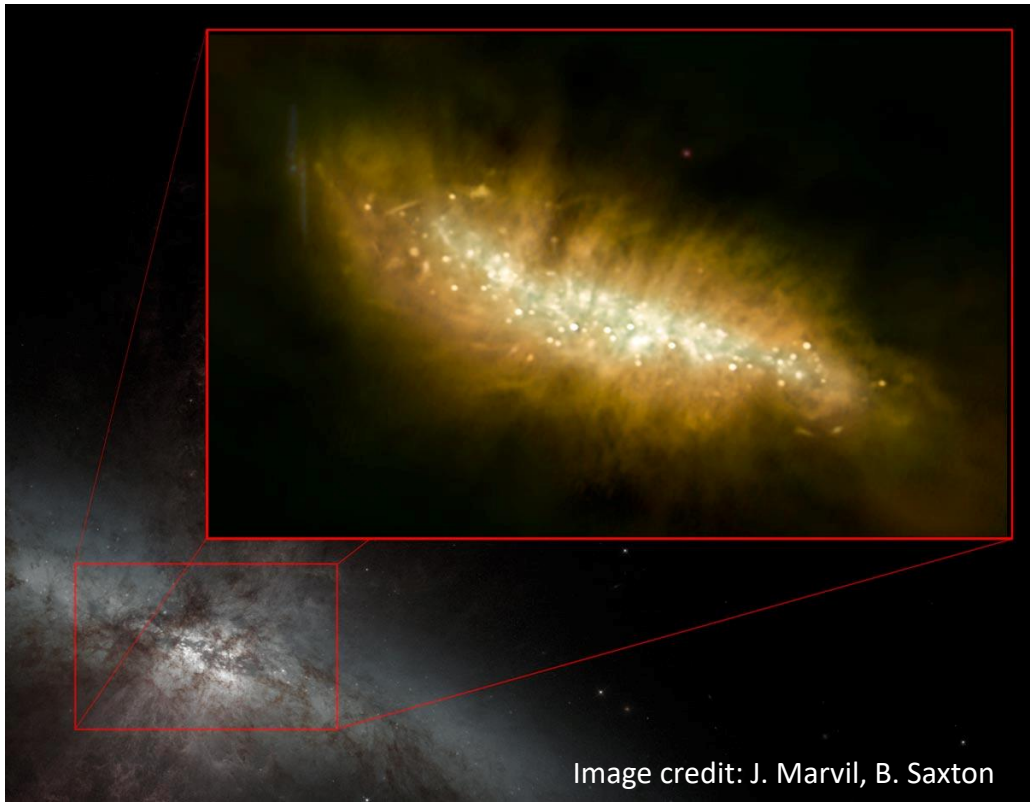


Image credit: J. Marvil, B. Saxton

Inset: VLA radio emission. The bright dots are a mix of star-forming regions and supernova remnants. Wispy features related to starburst-driven superwind.

M82 is the ideal candidate to investigate forming SSCs. It is the nearest (3.6 Mpc) northern starburst, forming ~10 M_{sun}/yr in a dense nuclear burst.

There has been no sub-mm data sufficient to study their properties. We require deep~3pc resolution targeting both tracers of dust and gas and signatures of massive star formation.

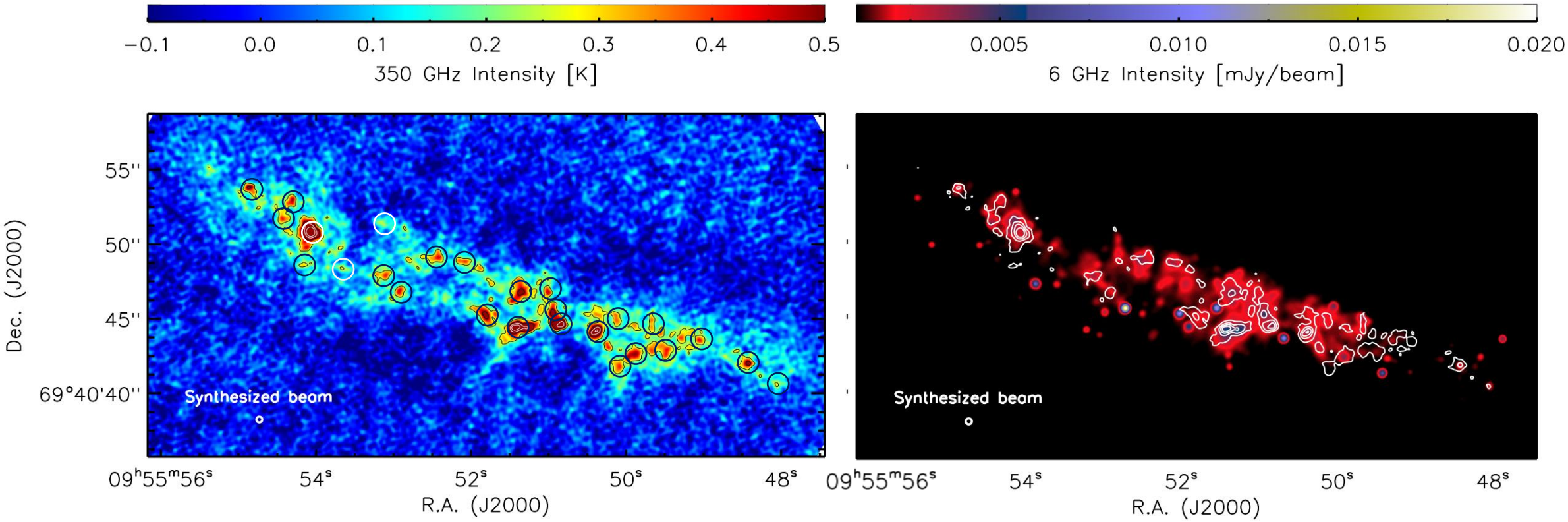
Submillimeter Array (SMA) observations

- Configurations:
  1 x Subcompact track
  1 x Compact tracks
  1 x Extended track
  2 x Very Extended tracks
- 350GHz continuum, ^{12}CO(3-2), HCO^+(4-3), HCN(4-3), H^{13}CN(4-3)
- Resulting 0.3” resolution

Proto cluster candidates in M82

The SMA multiconfiguration observations revealed more than 20 proto-cluster candidates in M82

Jiménez-Donaire et al. (in prep.)

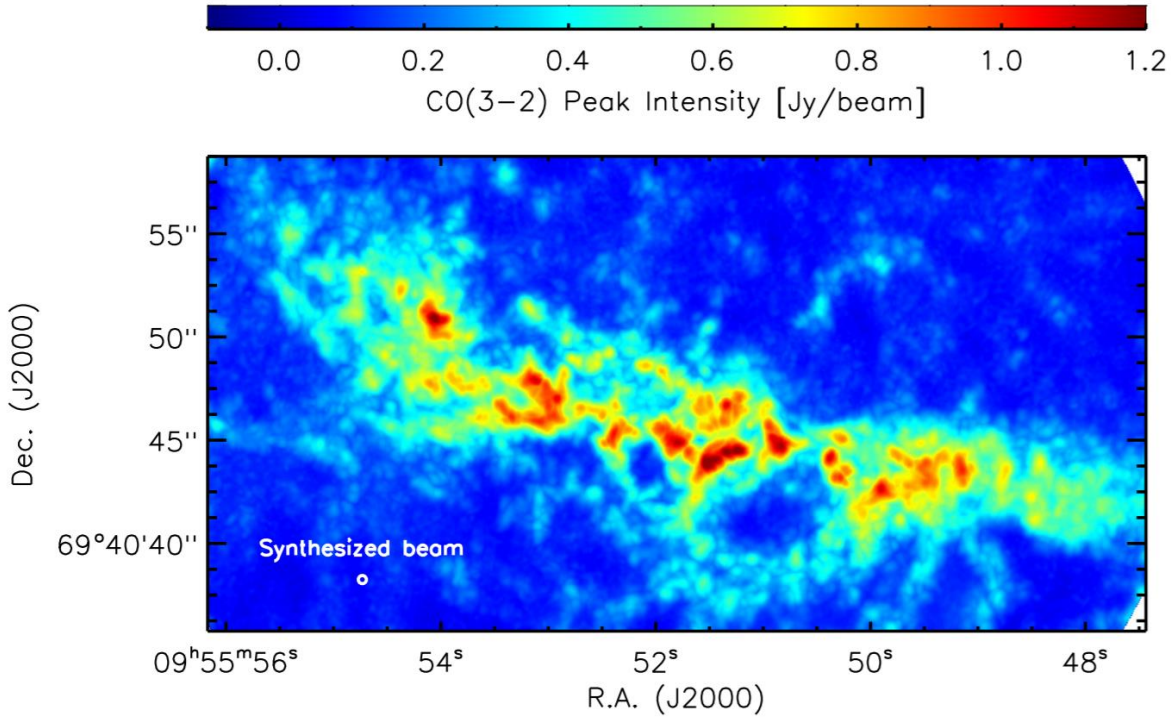


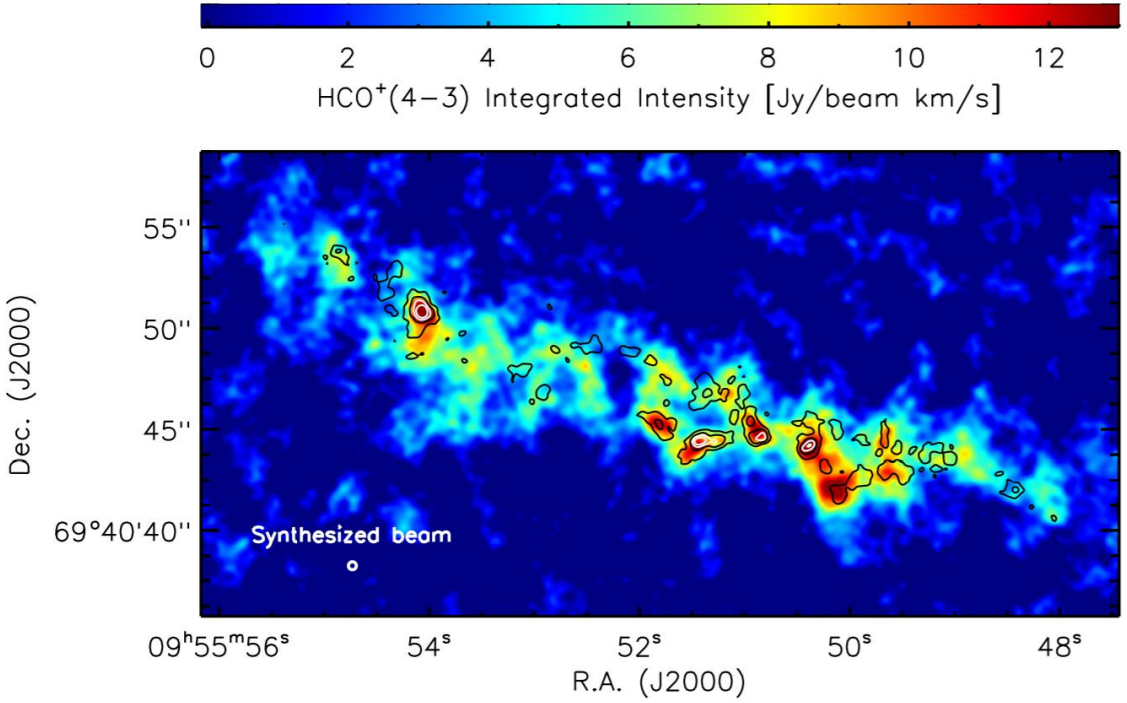
This is the first sub-arcsecond, sub-mm thermal dust image of M82

SMA contours on VLA 5cm emission

Proto cluster candidates in M82

Jiménez-Donaire et al. (in prep.)



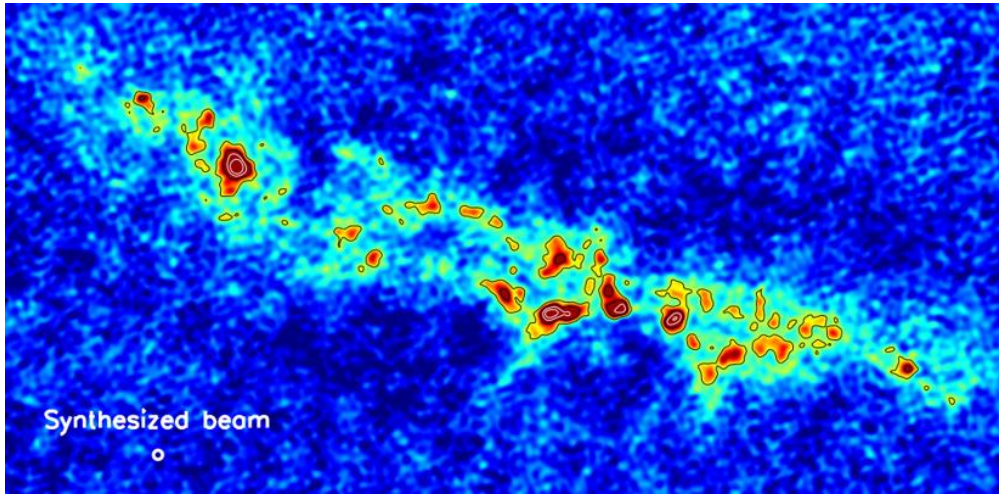


Compact dust structures are associated with the ^{12}CO(3-2) and HCO$^+$(4-3) emission lines, indicating warm (>50 K) and very dense ($\sim 10^7$cm^{-3}) molecular gas surround these SSCs.

Summary and prospects

Our SMA observations reveal >20 bright, compact (2-4 pc) sources of dust emission, associated with 36GHz radio continuum emission and coincident with emission from tracers of dense, excited gas.

Based on the estimated gas (log=3.5-5.2), stellar (log=4.5-6.0) and dynamical masses (log=5.2-6.7), most of these SSCs are still forming.



These observations have the prospect to test models of cluster formation. We will carry out the first comparative study of proto-SSCs: interaction-driven systems (M82), nuclear starbursts (NGC 253) and low metallicity galaxies (Turner+17, Oey+17).

Differences between the populations may reflect different timescales and varying chemical and dynamical environments, which will be key to understand the evolution of these systems