Galactic bubbles: an ALMA characterization of their role in the enrichment of the ISM

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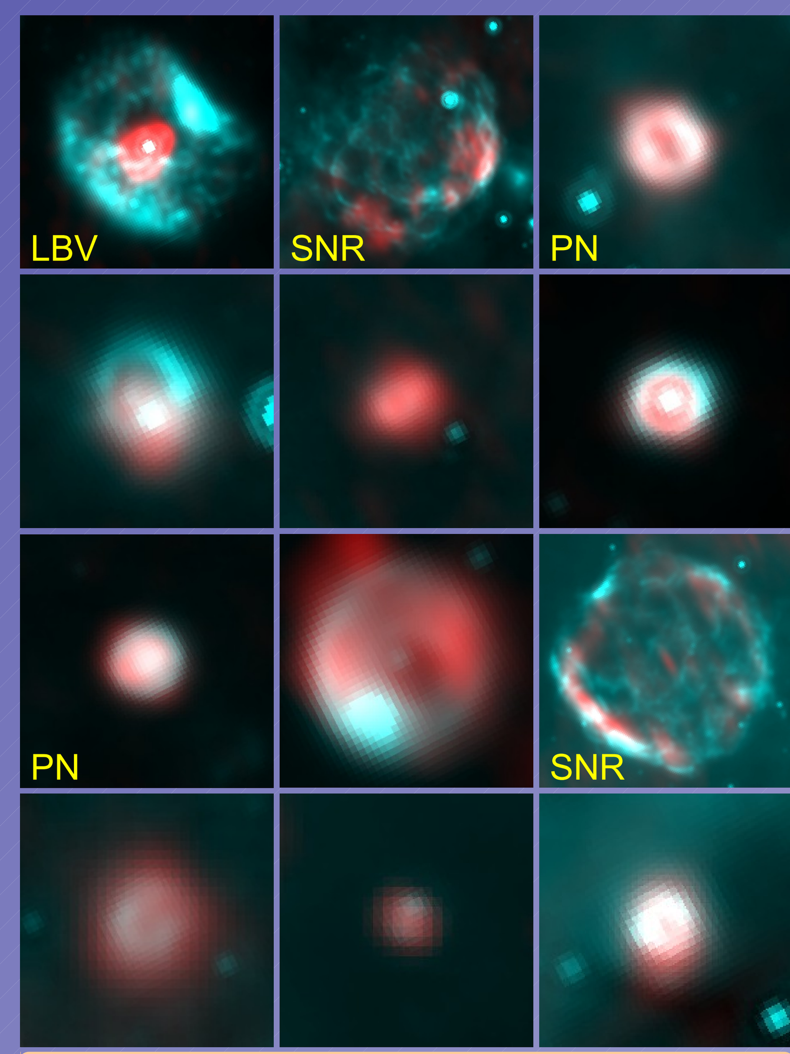
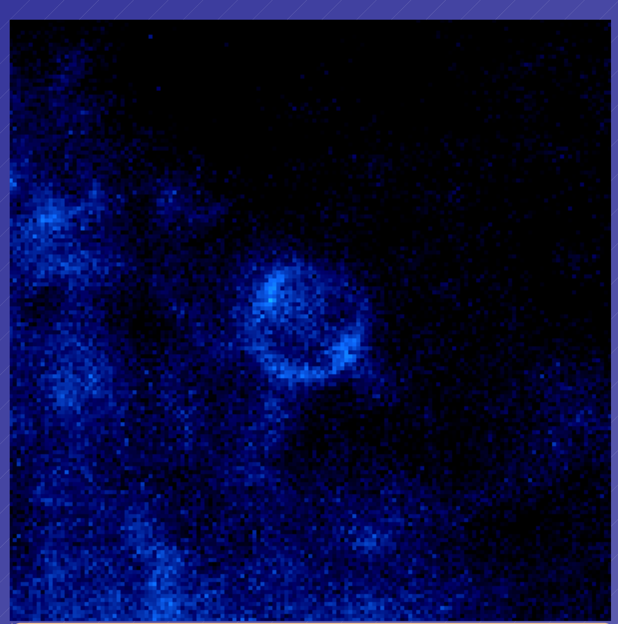
Discovery of galactic “bubbles” with MIPSGAL
The Spitzer MIPSGAL survey [1] at 24 µm (covering the area with *l*<|60°| and *b*<|1°|, or *b*<|3°| toward the galactic center) discovered nearly 400 compact roundish objects surrounded by a more diffuse emission with typical dimensions less than 1', named “bubbles” [2]. These objects are distributed approximately uniformly throughout the galactic plane with a density of about 1.5 bubbles per square degree. Other IR surveys, like GLIMPSE (from 3.6 µm to 8 µm), failed in detecting them. They are thought to be different kinds of evolved star, such as PN, LBV, SNR, AGB, etc., but only about the 10% of them are classified [3] [4] [5]; the nature of most of bubbles is still unclear.

The role of massive stars
Evolved stars undergo, in different way, mass-loss phases, during which a fraction of this processed matter is ejected into the circumstellar space. In particular the most massive stars are responsible for the enrichment of ISM with elements heavier than iron. Therefore, in this scenario, the bubbles may play a central role in the ISM chemical evolution. Furthermore massive stars influence their host galaxies contributing to most of the ultraviolet radiation, winds and shocks.



Some bubbles at 24 µm (cyan) and 6 cm (red).

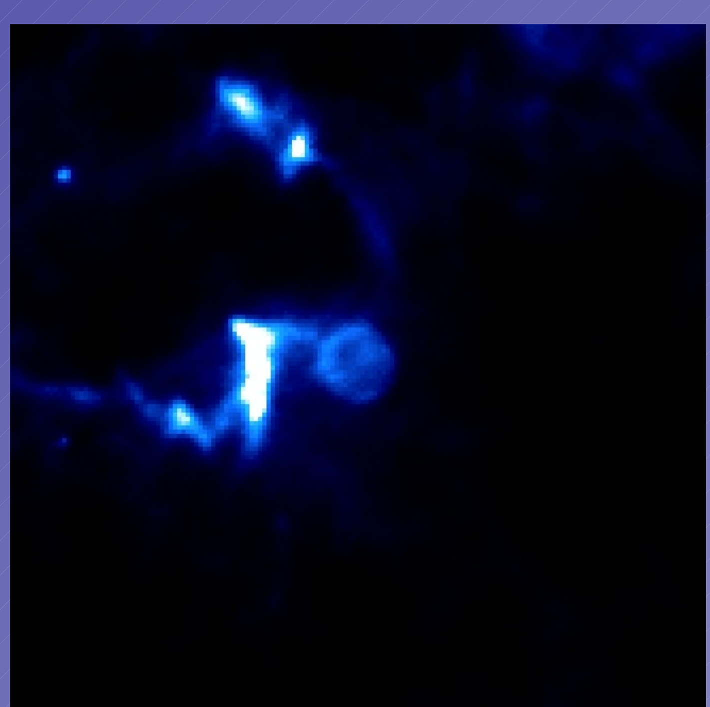
Improving statistics and overcome observational limits...
The bubbles are all located on the galactic plane, therefore these objects have no obvious counterparts at visual or near-IR wavelengths. For this reason we need to observe the bubbles at longer wavelength in order to fully characterize and classify them. Their classification is important in order to build a better statistics of each class of objects, hence improve or validate stellar evolution models.


Bubble #3347 at 70 µm (Hi-GAL)

Radio observations
After this discovery, mainly in order to classify the unknown bubbles, a subset of bubbles previously observed at radio wavelengths (MAGPIS or NVSS) has been observed, using EVLA, at 6 cm, and other observations at 20 cm are in progress. Preliminary data show that many bubbles are well detected at 6 cm and sometimes the morphology is different with respect to 24 µm. The radio emission originates from the circumstellar gas ionized by the stellar ultraviolet radiation, and this is typical of objects like PNe, LBVs and SNRs. Some bubbles seem to show no continuum radio emission, and this can be a clue indicating that those objects are very likely red-giant, AGB or post-AGB stars which are not able to ionize the circumstellar gas.

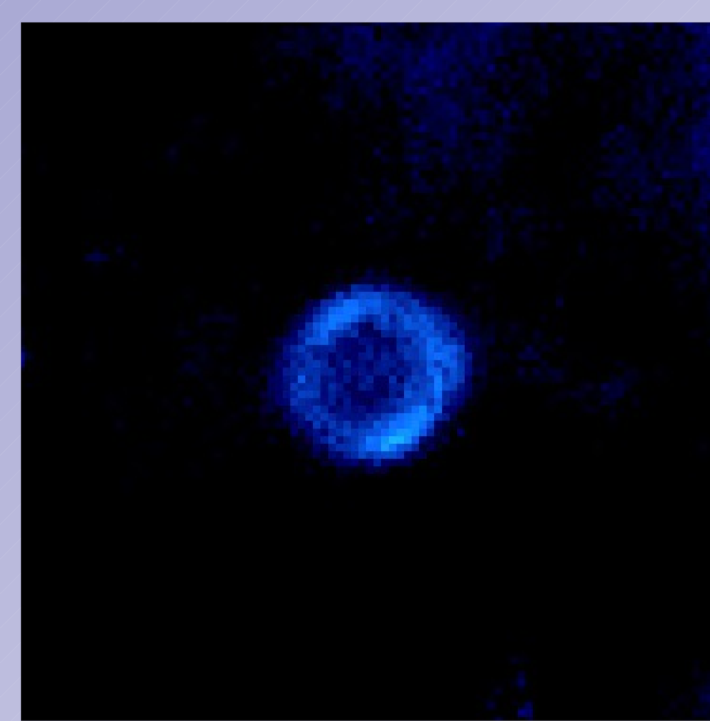
Spectral energy distribution
With radio multi-frequency observations it is possible to obtain a spectral index of the objects. This is fundamental to identify the kind of emission (thermal or non-thermal) therefore allowing us to shed light on the nature of each bubble. However to have a complete characterization it is necessary to build a spectral energy distribution at IR wavelengths, even because they are usually surrounded by dust, which is not a radio emitter. For example, using multi-wavelength IR data, we can have a complete description of how the different population of grains contribute to the observed emission and how these different populations are spatially distributed within the bubbles. Combining radio and IR measurements, we can build the full spectral energy distribution of these objects and, therefore, have a comprehensive understanding of their physical properties.

The Hi-GAL survey
The Herschel key program Hi-GAL is mapping our inner galaxy (*l*<|60°| and *b*<|1°|) in five bands between 60 and 600 µm with a spatial resolution between 6” and 40”. This survey can allow us to characterize the circumstellar envelope of our objects distinguishing the different kinds of dusts. In fact, we can obtain a spectral emissivity index β, and we can model the dust using, e.g., Cloudy or Dusty. Different distribution and mixture of dust can lead to define peculiar properties for each kind of objects.

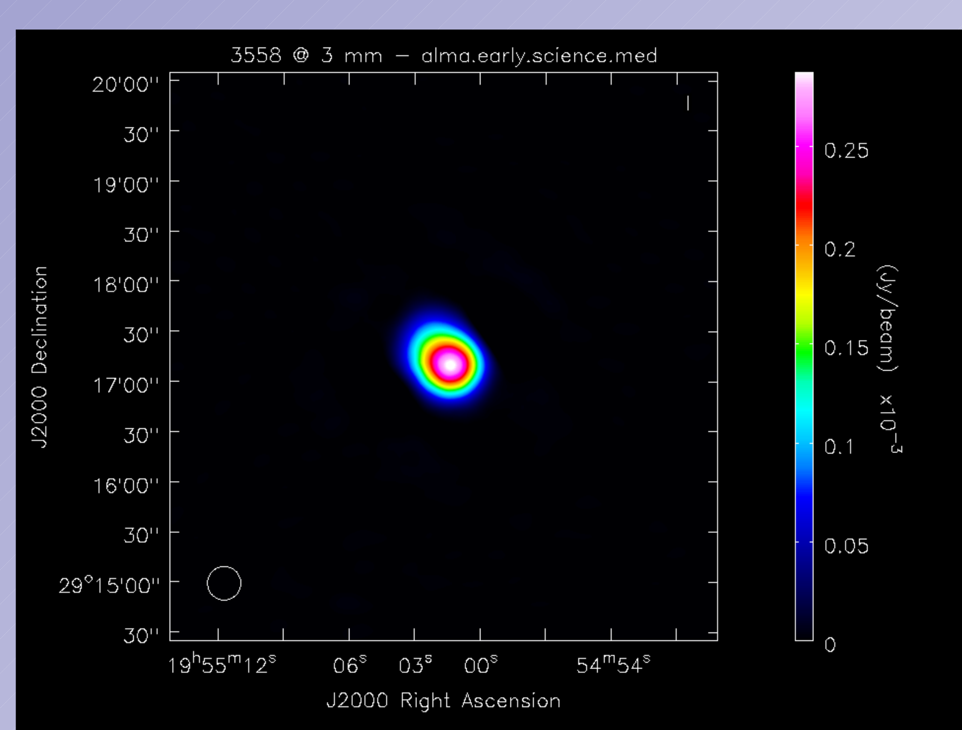

Bubble #3354 at 70 µm (Hi-GAL)

First Hi-GAL results
Preliminary analyses of Hi-GAL tiles show that several bubbles are detected at 70 µm and even at 160 µm (some of them as point sources) [6], resulting therefore in a significant improvement with respect to Spitzer. Unfortunately, at the Hi-GAL frequency range, the background, toward the galactic plane, is so bright and confused that many bubbles can hardly been detected.

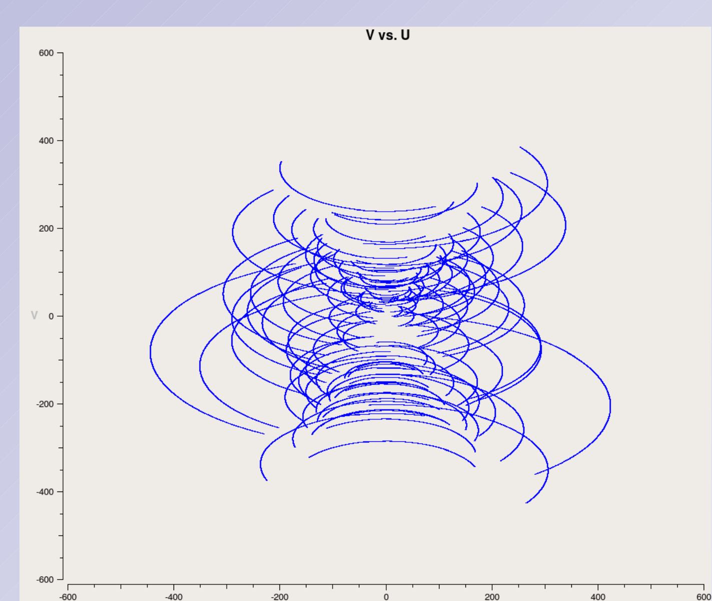
Preparing for ALMA observations
It is possible to select a sample composed of all those bubbles detected with Hi-GAL in order to make a well planned observation campaign with ALMA. Even with the early science limitation, with a better spatial resolution we may be able to reconstruct possible multiple mass-loss episodes, seen as multiple shells; imaging the central object we can also study the stellar wind and calculate the current mass-loss rate.


Bubble #3779 at 70 µm (Hi-GAL)

Simulating ALMA observations with CASA
The lack of informations at millimetric and submillimetric wavelengths must then be overcome with ALMA. Using our EVLA and Herschel data we are able to roughly give an estimated flux density for these objects in the ALMA frequency range. Furthermore, thanks to CASA **simdata2** task, it is possible to simulate how ALMA would see each bubble. In particular we used the ALMA Early Science capabilities (16 antennae) with a maximum baseline of about 500 m, to simulate an observation at 3 mm. The simulated flux density has been set by an extrapolation of the flux density at 6 cm. the resulting clean components have been convolved with a 20” beam to take in to account the spatial resolution of the model (the EVLA image at 6 cm). With an 8-h observation we obtain a well-detected object with a signal-to-noise ratio of about 100. It is also possible to appreciate the good *uv*-coverage even with only 16 antennae.



Simulated image of #3558 at 3 mm with ALMA (Early Science)


Simulated *uv*-coverage for an 8-h observation

REFERENCES:
[1] Carey et al. 2009, PASP 121, 76
[2] Mizuno et. al. 2010, AJ 139, 1542
[3] Flagey et al. 2009, AAS 21431604
[4] Flagey et al. 2010, AAS 21530105
[5] Billot et al. 2009, AAS 21431605
[6] Flagey et al., *in prep.*