Discovery Of Several Hundreds Of Compact-Extended Sources Within The MIPSGAL Survey

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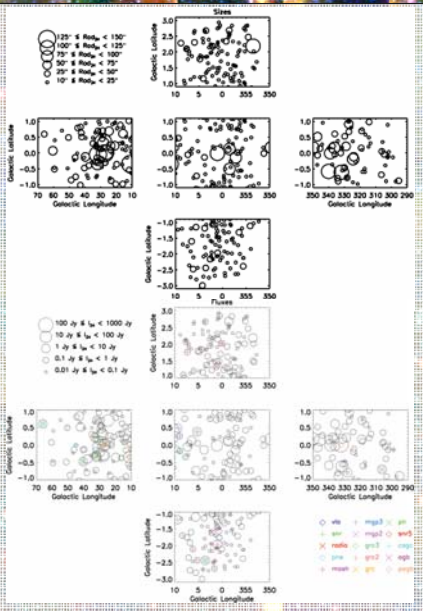
We present a catalog of compact sources detected in the Spitzer/MIPSGAL 24 microns survey data (P.I. Sean Carey). These small (< 1 arcminute) rings, bubbles, disks or shells are pervasive through the entire Galactic plane in the mid-infrared. Over 400 such sources are detected from visual inspection of the MIPSGAL mosaic images. Their average density is found to be around 1.5 bubbles per square degree.

We identify 10% of these objects by extensive cross matching with available catalogs. We find that the majority are planetary nebulae (PNe), three are supernova remnants (SNR) and one is a post-AGB star. The remaining 90% of the bubbles are yet unknown objects. Most of them are detected at 24 microns but neither at 8 nor 70 microns.

We also present Spitzer/IRS spectroscopic observations of a limited sub-sample of 15 objects. Their spectra show significant variations in the low to high excitation gas lines ratio, as well as in the dust continuum intensity, suggesting some are dust free objects. We compare these spectroscopic data to templates of evolved stars, including PNe, SNRs and extremely rare and massive luminous blue variables to constrain their true nature.



Top: Position and size of the MIPS24 bubbles
Bottom: Position and flux of the MIPS24 bubbles. Known objects are indicated:
PNe = Catalogue of Galactic Planetary Nebulae (Kohoutek, 2001)
AGB = High mass-loss AGB stars in the Galactic Bulge (Ojha+, 2007)
CSGC = 330MHz flux of 4 SNR near Galactic Centre (Roy+, 2002)
SNRS = Supernova Remnants at Meter Wavelengths (Kovalenko+ 1994)
PAGB = Torun catalog of post-AGB and related objects (Szczerba+, 2007)
SNR = A Catalogue of Galactic Supernova Remnants (Green 2001)
VLA = A 5-GHz VLA Survey of the Galactic Plane (Becker+ 1994)
GRC = Galactic radio compact HII regions at 1.4GHz (Giveon+, 2005)
GRC2 and GRC3 = Compact radio sources in the galactic plane (White+, 2005) 20 cm and 6 cm
MGPS:MGP2 = MAGPIS:20 cm survey (Helfand+, 2006)
PN = Strasbourg-ESO Catalogue of Galactic Planetary Nebulae (Acker+, 1992)
RADIO = Small-diameter radiosources catalogue (Zoonematkerman+, 1990)

MIPS24 CATALOG

Some numbers

More than 400 compact-extended objects (Disk, Shell, Donut, Twolobes, Ring) identified through careful observations of the MIPSGAL 24 microns Galactic plane survey.

Sizes about a few 10" (**95% smaller than 1'**)

Fluxes about a few 0.1 Jy (**85% smaller than 1 Jy**)

Average density around **1.5 bubble per square degree :**

0.5 / sq.deg. in the 4th quadrant, 1.0 / sq.deg. in the 1st quadrant
2 / sq.deg. in the Galactic Center region

59 objects (~14%) show a central source at 24 microns

IRAC 8 and MIPS 70 microns counterparts

112 bubbles (~25%) show a counterpart at 70 microns (MIPSGAL survey, Carey et al. 2009)

~ 10% show a counterpart at 8 microns (GLIMPSE survey, Benjamin et al. 2003)

⇒ most bubbles are "MIPS24-only" objects
Dust continuum ? Gas lines ? Extinction ?
Intrinsic property of the objects (no PAHs, no hotter dust or purely ionized gas emission) ?

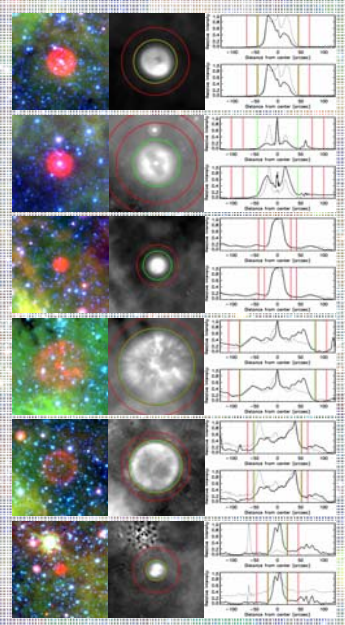
Identification

10% of these objects have been identified by carrying out an intensive cross reference of catalogs available from the VizieR database.

Majority found in the MASH Catalogue of Planetary Nebulae *(Parker et al. 2006)* and in the Catalogue of Galactic Planetary Nebulae *(Kohoutek 2001)*.
3 SNRs and 1 post-AGB star also identified from published catalogues
90% of the bubbles are yet unidentified objects

Suspects are evolved stars (SNRs, PNe, AGB, post-AGB, LBVs, WR …)

Emission from hot small dust grains in winds and ejecta
Main source of dust and heavy elements in the Galaxy and beyond



Top: (left) 3 colors (IRAC3.6, IRAC8.0, MIPS24) image, (middle) MIPS24 image and (right) MIPS24 profiles that show the different morphologies of the bubbles within the catalog

IRS SPECTRA

11 objects in Low Resolution *(P.I. Sean Carey)*, 4 in High Resolution *(P.I. Nicolas Flagey)*, only 1 bubble in this sub-sample is a known object (PN)

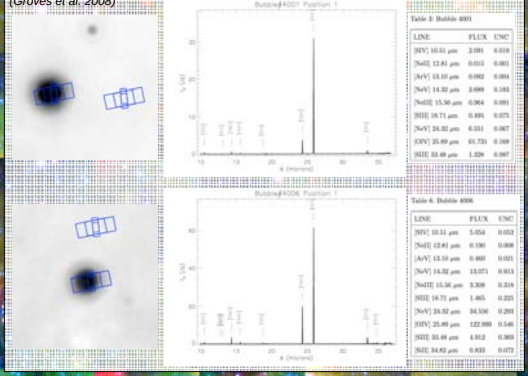
Dust-free PN Candidates

PNe are the most frequent identified objects in our catalog

If MIPS24 central source, could it be a white dwarf ?
One would not expect to see it in mid-IR, unless there is a surrounding disk of dust *(e.g. the Helix Nebula, Su et al. 2007)*

Very high excitation lines ([NeV] 14.3 and 24.3 >> [NeIII] 15.5 >> [NeII] 12.8)
Very weak or no dust continuum
No PAH features
Similar to some Magellanic Cloud PNe *(Bernard-Salas et al. 2008)*

[NeIII]15.5/[NeII]12.8 vs [SIV]10.5/[SIII]18.7 in agreement with PNe *(Groves et al. 2008)*



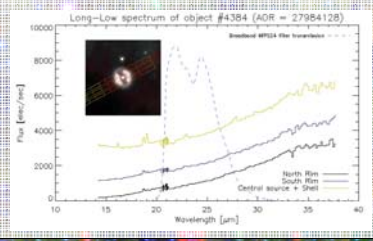
While most of these objects share common characteristics (MIPS24-only, size, flux) there are also significant differences within the catalog (IRAC8 or MIPS70 counterpart, morphology).

While they surely all are evolved massive stars, they could span the entire family of dying / exploding objects, from PNe to SNRs to LBVs.

LBV Candidate 1

MIPS24 morphology and spectra similar (continuum, Fe and He lines) to that of LBV G79.28+0.46

LBVs are extremely rare objects: 12 confirmed members and 23 candidates in the Galaxy*(Clark et al. 2005)*

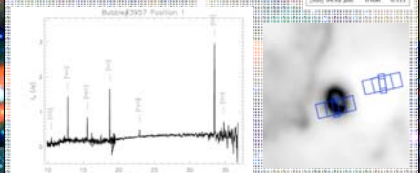


No Candidate

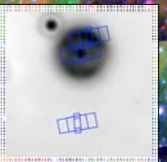
Dust continuum

[FeII] 22.92 line

[NeIII]15.5/[NeII]12.8 matches a 300km/s shock in n=100cm^{-3} *(Hewitt et al. 2009)*



LBV Candidate 2



Dust continuum:
Longer wavelength continuum = shell
Shorter wavelength continuum = central source
⇒ Hotter dust inner shell

MIPS24 central source, Fe-rich inner shell ?
(rules out the SNR interpretation)

MSX 15 microns flux (13 years ago) about a factor 2 lower than that measured on the IRS spectrum : variability of the central source ?

[FeII]17.9/26 ratio of the inner shell traces high temperature, high density medium *(Hewitt et al. 2009)*

Possible blue-shift of the lines (200km/s) that may trace the expansion of the outer shell

Similar morphologically and spectroscopically to HR Car *(Umana et al. 2009)* even though the line ratios are different and the 2 continuum are slightly hotter.

2 possible additional LBVs within our 15 objects subsample !