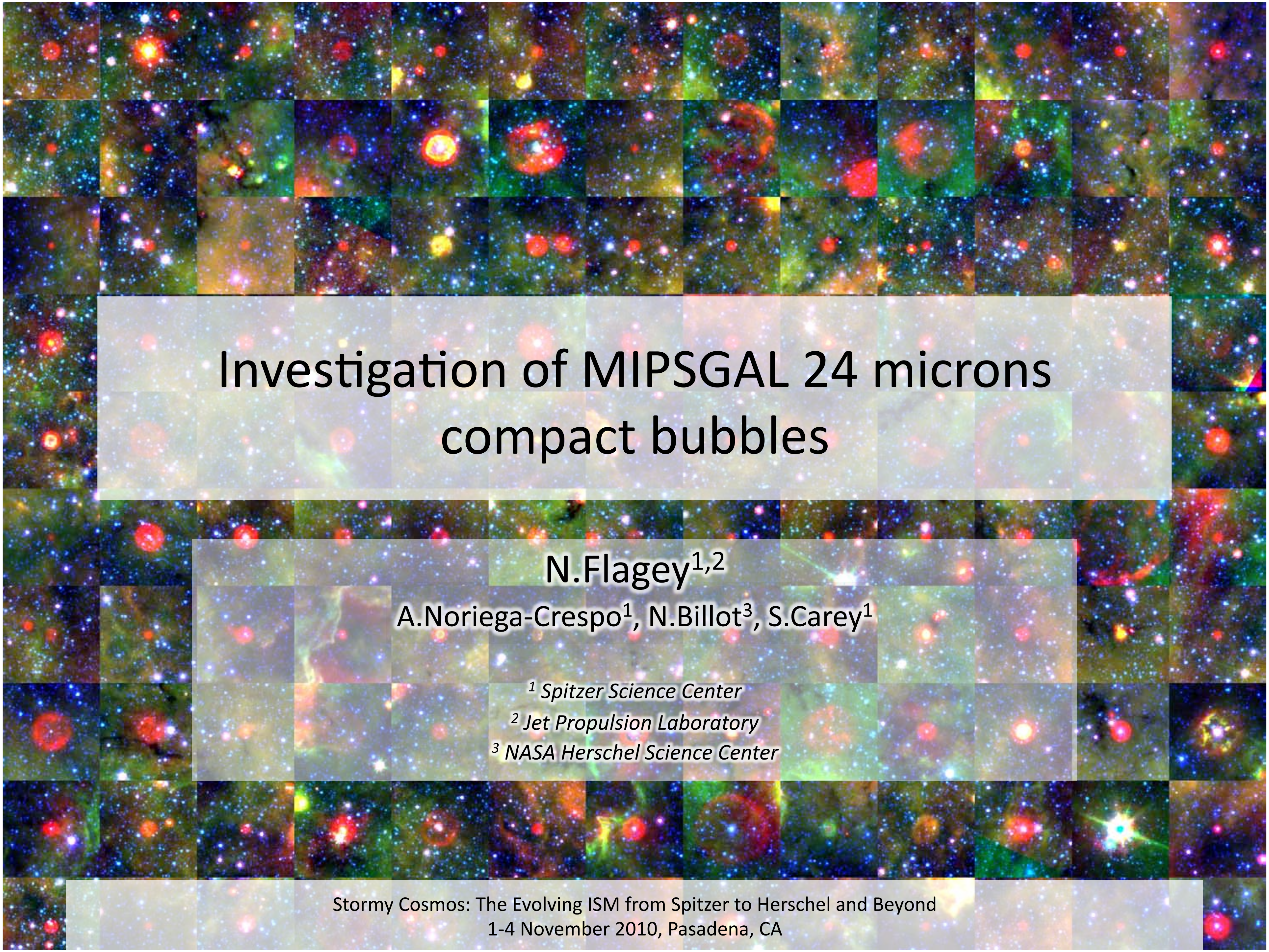


Investigation of MIPSGAL 24 microns compact bubbles

N.Flagey[1,2]

A.Noriega-Crespo[1], N.Billot[3], S.Carey[1]

[1] Spitzer Science Center

[2] Jet Propulsion Laboratory

[3] NASA Herschel Science Center

Stormy Cosmos: The Evolving ISM from Spitzer to Herschel and Beyond

1-4 November 2010, Pasadena, CA

Investigation of MIPSGAL 24 microns compact bubbles

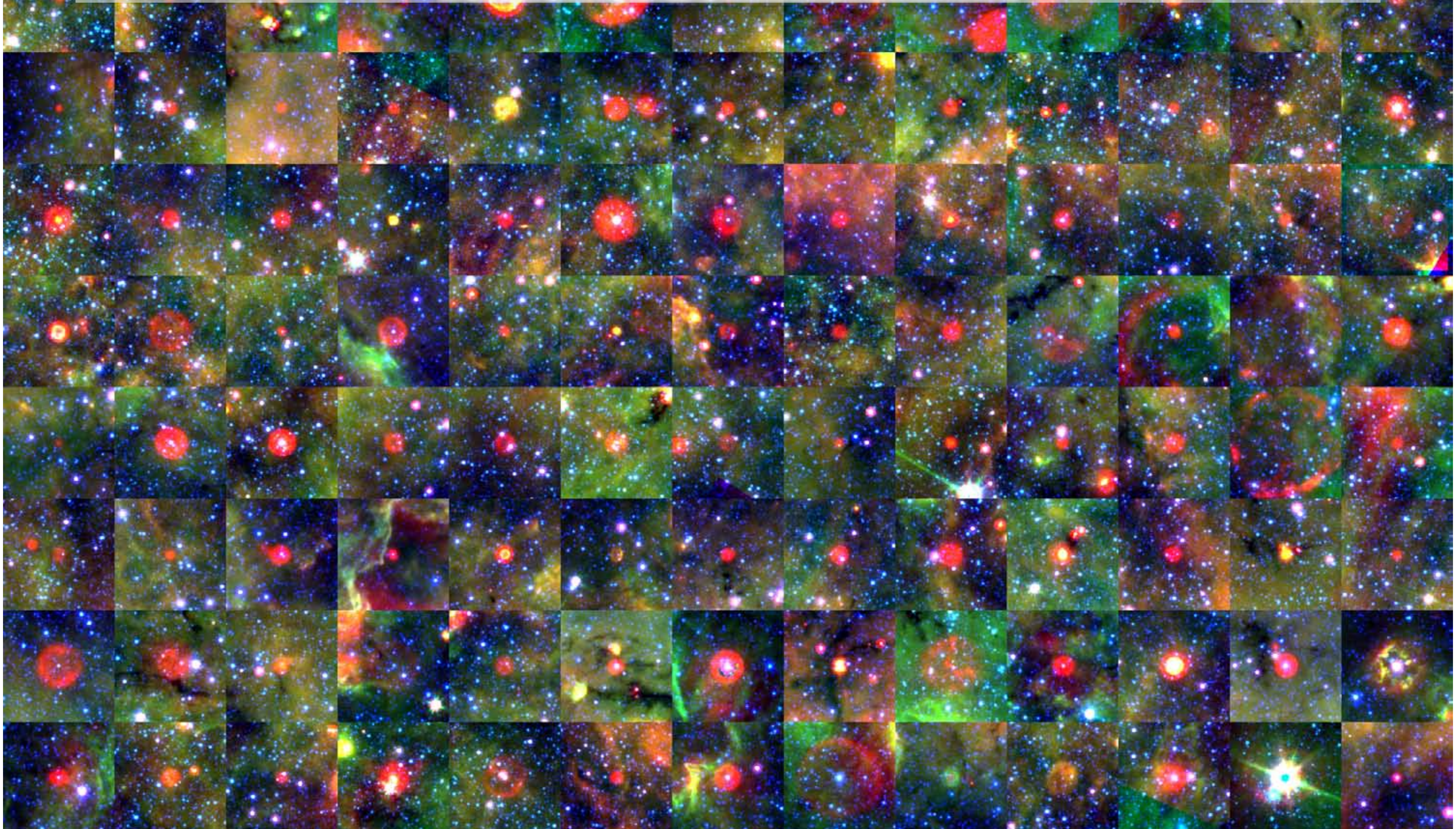
OUTLINE

1. Catalog of MIPSGAL 24 microns compact bubbles and **broadband** analysis

2. IR **spectroscopic** identification of unknown objects

MIPSGAL 24 microns compact bubbles catalog

MIZUNO, D. R. ET AL. 2010, AJ, 139, 1542



MIPSGAL 24 microns compact bubbles catalog

CATALOG

- 428 MIPSGAL bubbles (MBs) identified from visual inspection of the MIPSGAL survey *(Carey et al. 2009)* 24 microns mosaic images
- General properties
  - 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. (4th quad.), 1 / sq.deg. (1st quad.), 2 / sq.deg. (near G.C.)
- Counterparts
  - 25% show a counterpart in MIPSGAL 70 microns images
  - 10% show a counterpart at 8 microns (GLIMPSE, *Benjamin et al. 2003*)
- Central source
  - 15% show a central source at 24 microns
  - twice as much show a central source in 2MASS and/or GLIMPSE

MIPSGAL 24 microns compact bubbles catalog

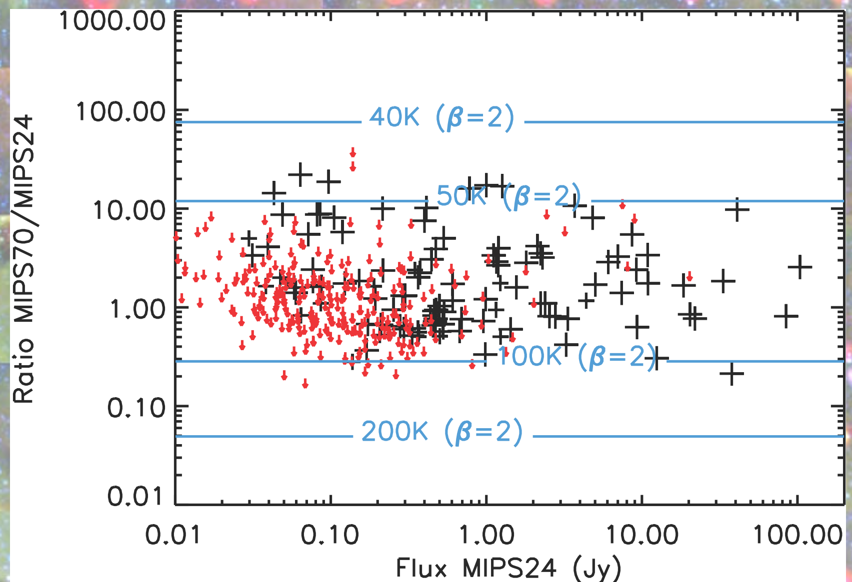
<u>IDENTIFICATION</u>

- 15% of previously identified objects
  - Mostly PNe
  - Several SNRs, LBVs, WRs and Em*

- 85% of unknown objects
  - Ongoing effort to identify most of these objects:
    - mid-IR spectroscopy (Spitzer/IRS)
    - near-IR observations of the central source (Palomar/TripleSpec)
    - radio (eVLA)
    - far-IR spectroscopy (Herschel/PACS)

MIPSGAL 70 microns counterparts

- Measurement
  - Specific data reduction
  - 25% of the MBs show a counterpart
  - Radius, flux and/or upper-limit
  - f70/f24 ranges from 0.2 to 30: matches temperature from 48 to 110K (beta=2)



- f70/f24 vs f24
  - f70/f24 slightly decreases as f24 increases
  - Warmer MB are brighter (f24)

- But: is the mid-IR emission dominated by the dust ?
- Broadband observations of central source (see poster 67, Anthony P Marston)

Identification

- Why do we care?

- Evolved stars are:
  - significant contributors to the ionizing photons budget and kinetic energy released in the ISM through their intense winds and radiation *(Crowther et Dessart 1998)*.
  - the main sources of dust in the Galaxy and beyond.
- Massive evolved stars believed to be present in the Galaxy are still "missing" *(Shara et al. 1999)*:
  - about 2500 PNe are known in our Galaxy but only 224 central stars with spectral types are reported in the Strasbourg-ESO Catalogue of Galactic PNe *(Acker et al. 1992; Acker et al. 1996)*.
  - at least 1000 WRs stars are expected to be located within our Galaxy (van der Hucht 2001), but only 300 have been observed so far *(van der Hucht 2006)*.
  - only a few tens of LBVs are known or identified as candidates *(Clark et al. 2005)*.

- Therefore, it is essential to hunt for these evolved stars in order to determine their true nature , obtain an accurate census of the dust production in the Milky Way as well as in other galactic systems and better understand their interaction with the ISM

Identification

- How?
- Near-IR or optical spectroscopy of the central source
  - Biased towards MBs with an IR central source
- Mid-IR spectroscopy of the shell
  - Identification of the MIPS24 emission's origin
- Other (not discussed here):
  - eVLA, Herschel/PACS

Identification

- How?

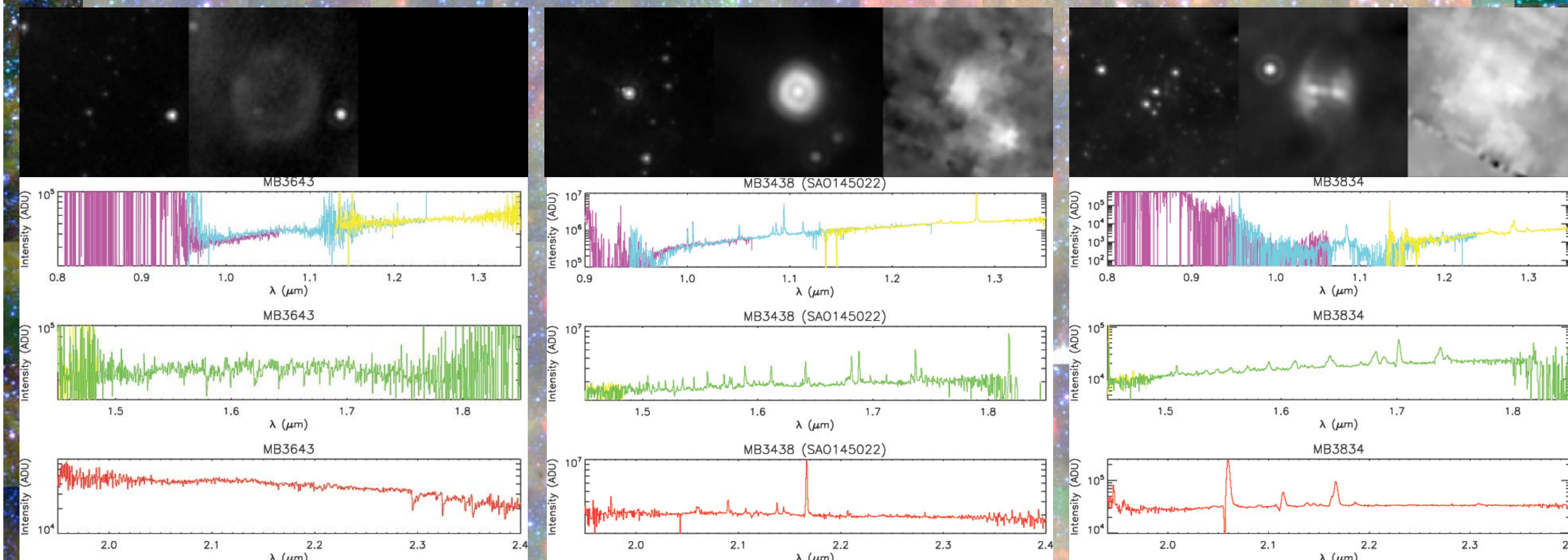
- **Near-IR or optical spectroscopy of the central source**
  - **Biased towards MBs with an IR central source**

- Mid-IR spectroscopy of the shell
  - Identification of the MIPS24 emission's origin

- Other (not discussed here):
  - eVLA, Herschel/PACS

Near-IR identification

- Palomar/Tspec observations of 16 MBs (current semester)
  - Several late-type stars
  - At least 2 new cLBV
  - Several shells detected in near-IR emission lines (H I)



Near-IR identification

- Wachter et al. (2010) and Gvaramadze et al. (2010) conducted similar observations (near-IR and optical spectroscopy of the central source):
  - Wachter et al. (2010)
    - Selected MIPS24 shells with central source in 2 channels among 24/8.0/3.6/Ks/J
    - 62 bubbles selected, 38 observed, **35 new identifications**, 10 previously known
    - About 50% late-type stars
    - Early-type stars: 4 WR, 4 Oe/WN, 5 Be, 6 LBV (candidates)
  - Gvaramadze et al. (2010)
    - Selected MIPS24 shells with detectable central source
    - 115 bubbles selected (MIPSGAL + Cygnus-X), about 24 observed, mostly LBV, blue supergiants and WNL
  - Poster 67

- Near-IR is a powerful tool to identify the MB but limited to those with a central source (about 25%)

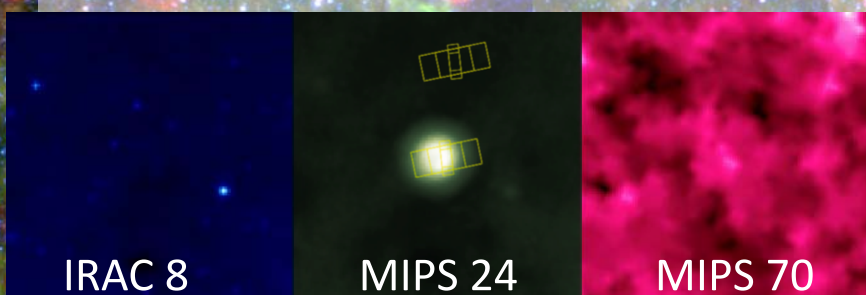
Identification

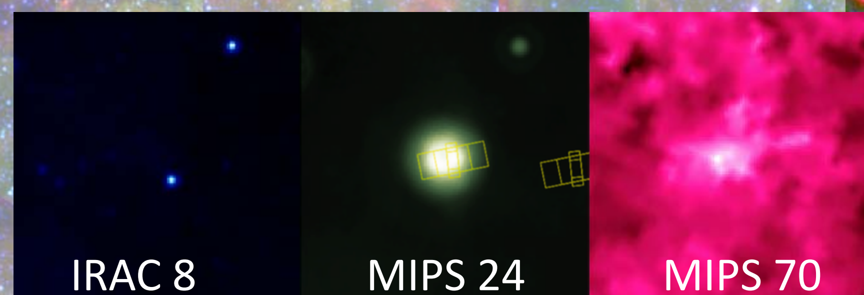
- How?
- Near-IR or optical spectroscopy of the central source
  - Biased towards MBs with an IR central source
  - Palomar/TSpec observations of the central source of 16 MBs
  - Detection of several shells
  - Similar observations: Gvaramadze et al (2010), Wachter et al (2010)
- **Mid-IR spectroscopy of the shell**
  - **Identification of the MIPS24 emission's origin**
  - **2 proposals accepted: 11 MBs in low-resolution (GO5) and 4 MBs in high-resolution (DDT, right before end of cryo mission)**
  - **Unique set of observations**
- Other (not discussed here):
  - eVLA, Herschel/PACS

Mid-IR identification

Dust-poor MBs

- Broadband
  - "Flat" morphology at 24 microns
  - No IR central source
  - No IRAC counterpart
  - Weak MIPS70 counterpart

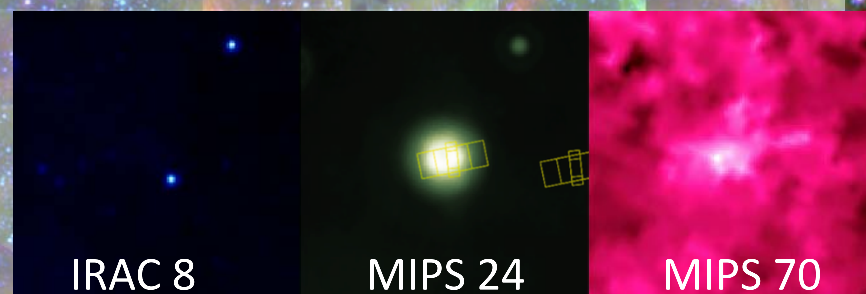


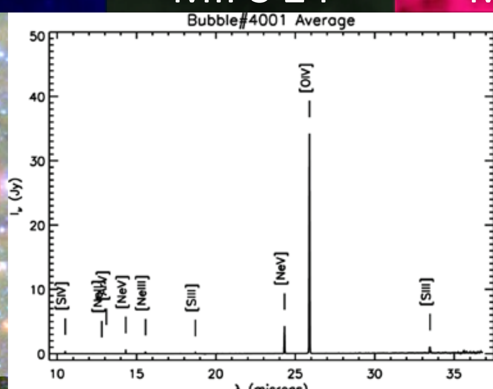


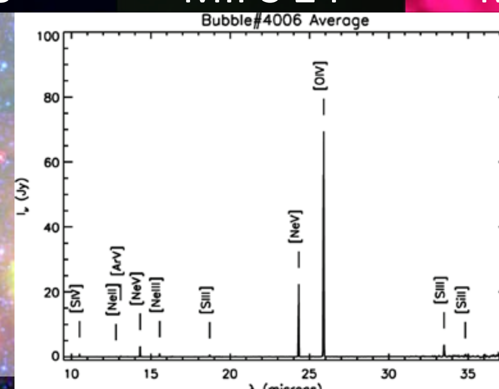
Mid-IR identification

<u>Dust-poor MBs</u>

- Spectrum
  - Very high excitation lines ([OIV]25.9, [NeV]14.3 and 24.3)
  - [NeV]14.3 and 24.3 >> [NeIII]15.5 >> [NeII]12.8
  - Very weak continuum (contribution of 15% and 30% to MIPS24), no PAH features
  - Similar to SMP83, a Magellanic Cloud PN *(Bernard-Salas et al. 2008)* and a 'dust-free-SNR' in Cepheus *(Morris et al. 2006)* later identified as a PN *(Fesen & Milisavljevic 2010)*



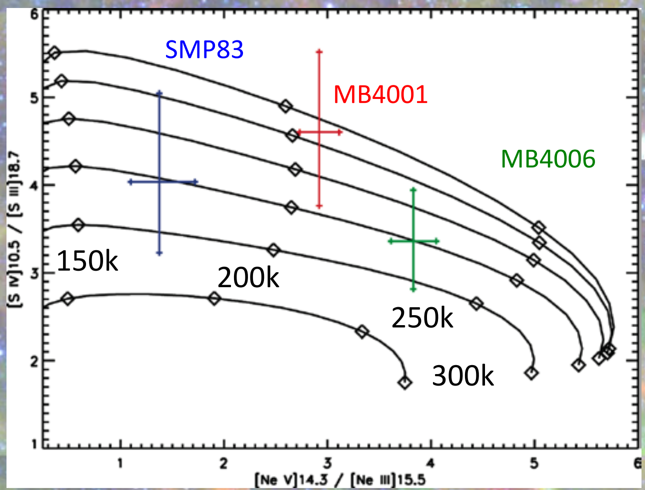




Mid-IR identification

<u>DUST-POOR MBS</u>

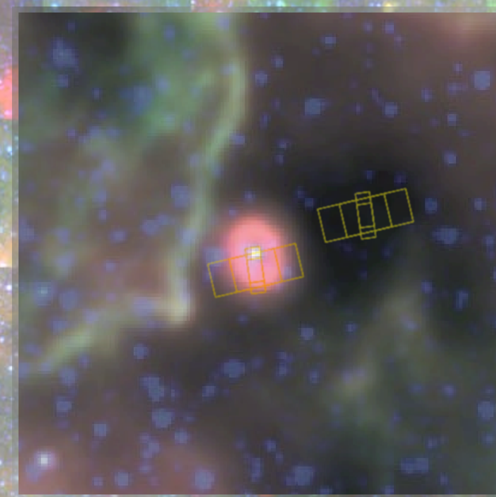
- [NeIII]15.5/[NeII]12.8 vs [SIV]10.5/[SIII]18.7 in agreement with PNe *(Groves et al. 2008)*
- MAPPINGS III modeling of the gas lines
  [SIV]10.5/[SIII]18.7 vs [NeV]14.3/[NeIII]15.5 leads to a central sources temperature of about $2x10^5$K (i.e. white dwarf) and gas densities of about 5000-15000cm^{-3}



Iso-density contours from 1000 to 11000 cm-3

Mid-IR identification

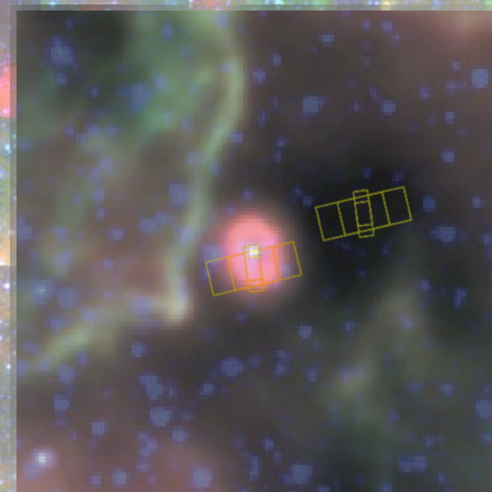
Dust-rich MB (1)



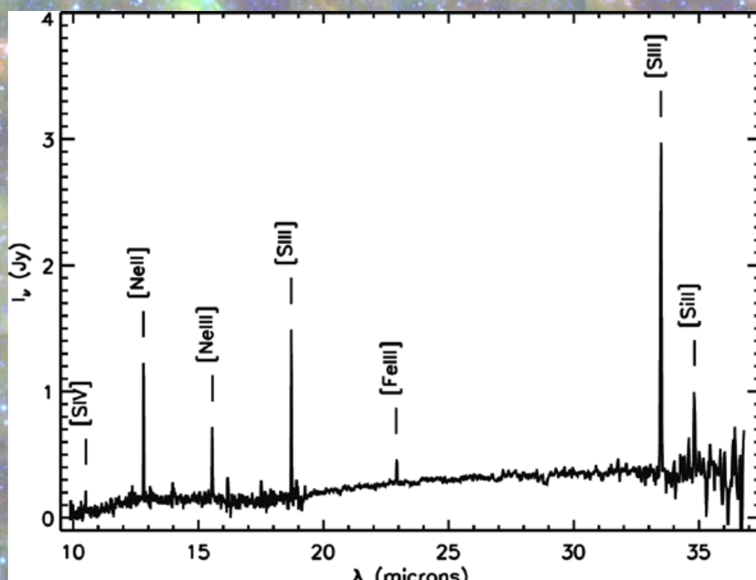
- Broadband
  - "Torus" morphology at 24 microns
  - Central source detected in 2MASS and IRAC channels (not in MIPS24)
  - No counterpart in IRAC or MIPS70

Mid-IR identification

DUST-RICH MB (1)

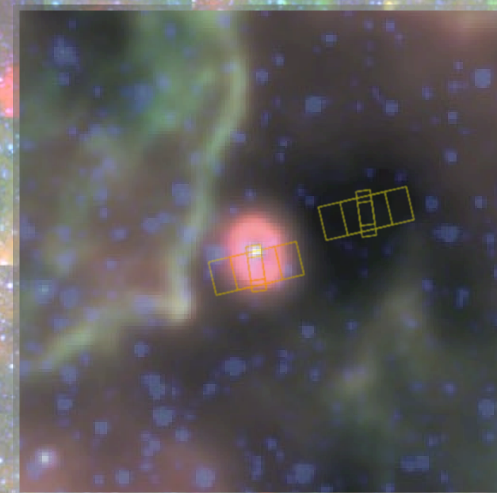


- IRS spectrum
  - No PAH features but continuum
  - High excitation gas lines:
    - [SIV]10.5, [SIII]18.7 and [SIII]33.5
    - [NeII]12.8 and [NeIII]15.5
    - [SiII]34.8
    - [FeIII]22.9 !



Mid-IR identification

<u>DUST-RICH MB (1)</u>



- [SIII]18.7/33.5
  ⇒ few 10^2 cm^{-3} *(Alexander et al. 1999)*

- If shock, [NeIII]15.5/[NeII]12.8
  ⇒ shock of 200-300 km/s *(Hewitt et al. 2009)*

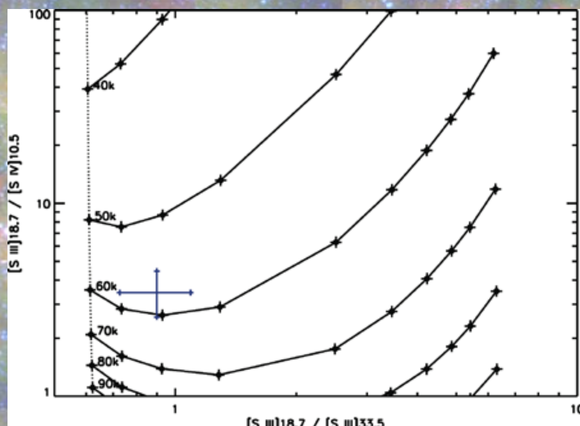
- But, in those conditions, [FeIII]22.92 would not be the only iron line
  [FeII]17.9, 24.5 and 26.0 would be at least 10x brighter than [FeIII]22.92

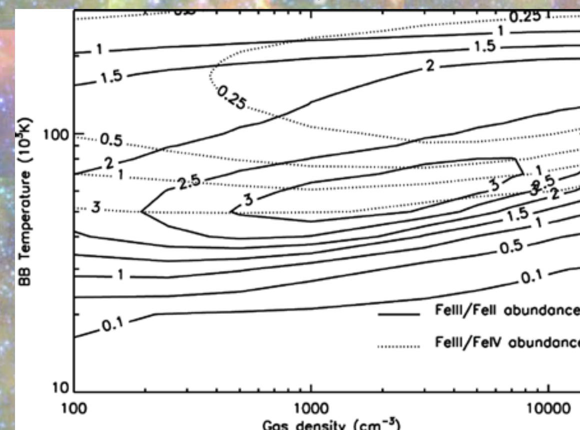
⇒ not a shock

Mid-IR identification

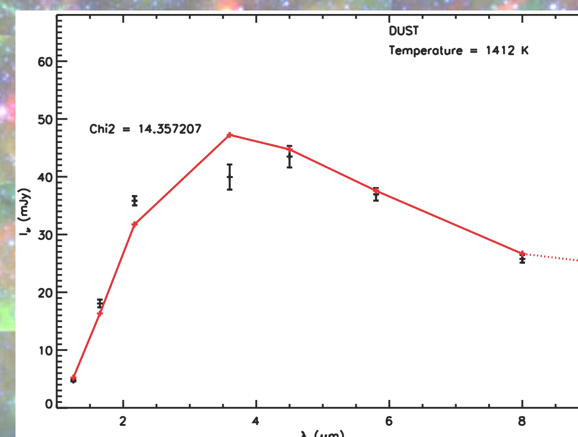
<u>DUST-RICH MB (1)</u>

- MAPPINGS III model of photo-ionization
  - best match for a central source of $6x10^4$ K (i.e white dwarf or WR) and a gas density of a few 100 cm^{-3}





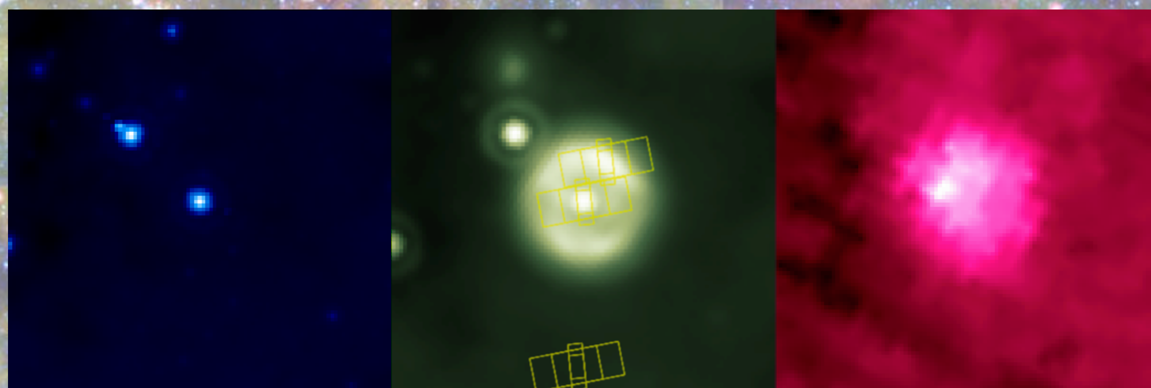
- IR excess for the central source SED: unresolved circumstellar disk of hot dust near the white dwarf (like in the Helix Nebula, *Su et al 2007*)

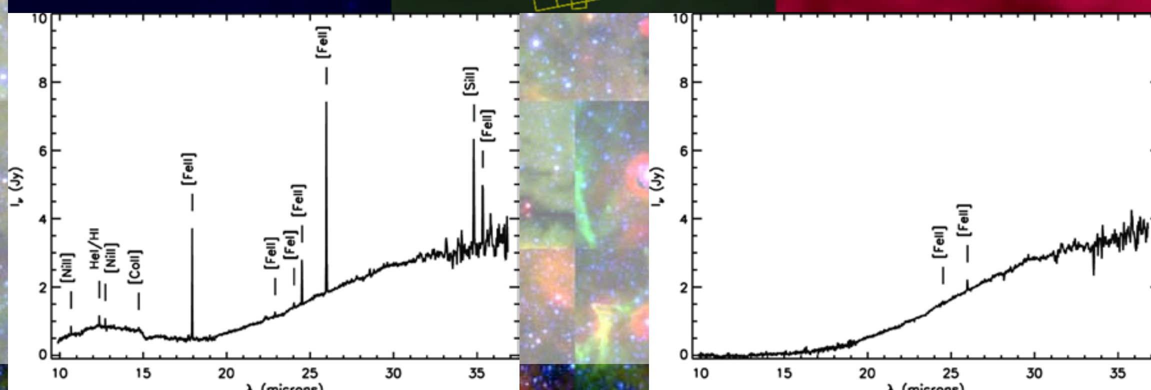


Mid-IR identification

<u>DUST-RICH MB (2)</u>

- Shell-like MB
  - Counterpart of the MB at 70 microns
  - Central source in 2MASS, IRAC and MIPS24
- LBV candidate from near-IR observations of the central source *(Wachter et al 2010)*
- Spitzer/IRS towards 2 positions: the central source and the shell

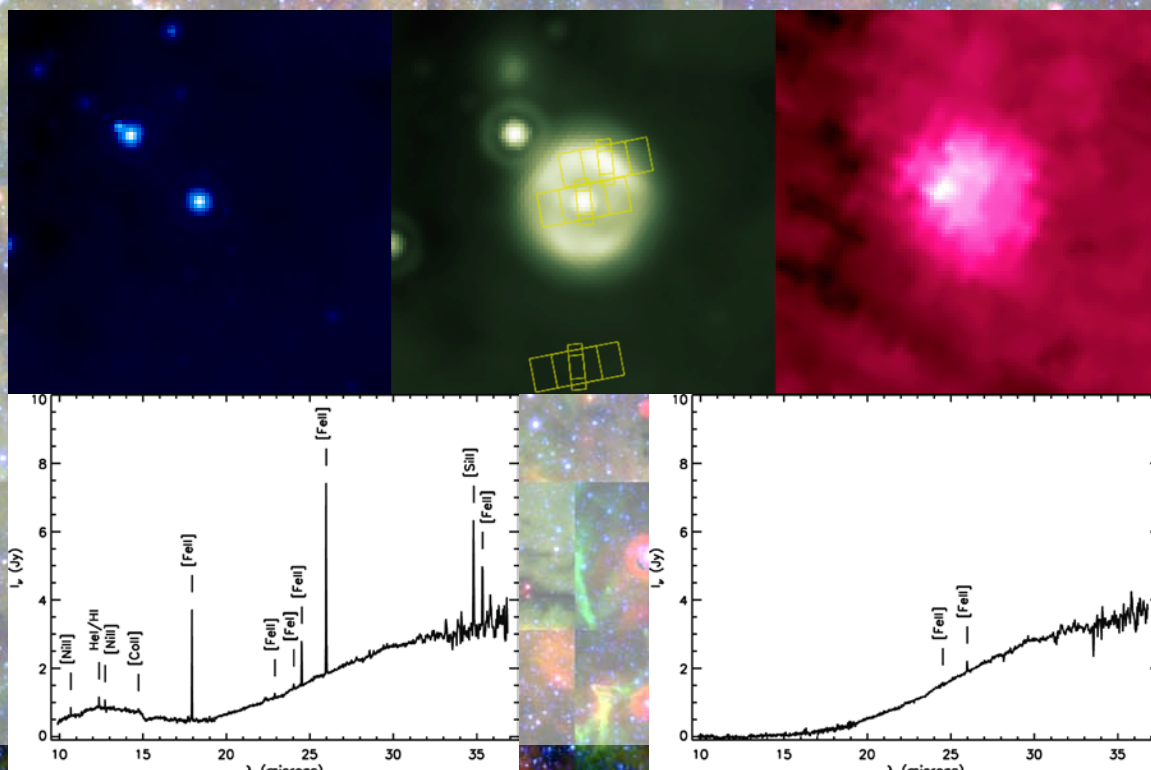




Mid-IR identification

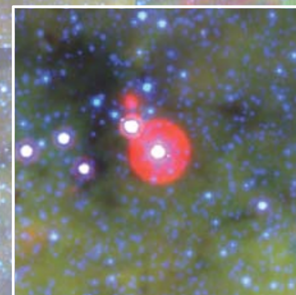
DUST-RICH MB (2)

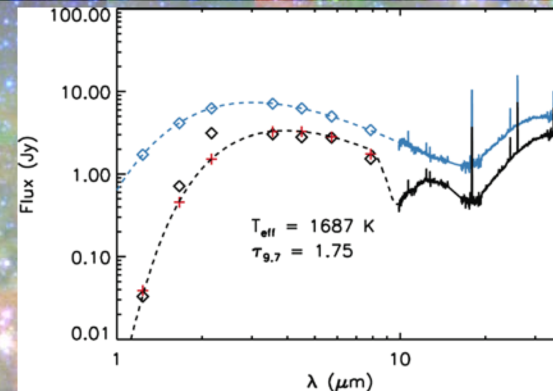
- Spectra
  - Continuum dominated: long wavelengths continuum from outer shell
  - Many [FeII] lines: arise from central source
  - Absorption features: from IRDC along the line of sight



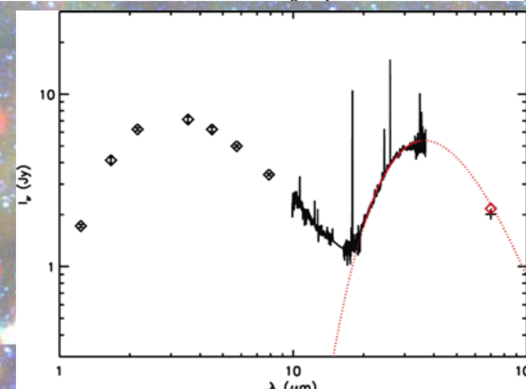
Mid-IR identification

DUST-RICH MB (2)

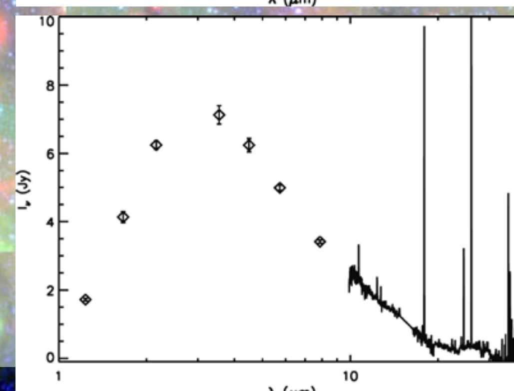




- Extinction correction
  - $N(CO_2) = 5.7 \times 10^{17} cm^{-2}$
  - Silicate correction performed on the central source full SED leads to
    - Av of about 20-30 mag
    - Temperature of about 2000K
      too cold for an LBV, even in active phase ⇒ inner shell



- Outer shell:
  - Dust continuum (T=80K with β=2.2)
  - Match with MIPS70 flux



- Inner source:
  - Iron lines ratio matches a 3×10^4 K inner source
    ⇒ quiescent LBV candidate

Herschel investigation

- HiGAL
  - Broadband observation of the Galactic plane (70, 170, 250, 350 and 500 microns)
  - Preliminary comparison reveal no MB detected in SPIRE wavelengths, only 1 in PACS170 and same detection in PACS70 than in MIPS70
- AO OT1 (?):
  PACS full range spectroscopy of 35 MBs detected at 70 microns
  - Comparison with templates from MESS key program
  - Dust continuum if present
  - Atomic and/or molecular gas lines

Investigation of MIPSGAL 24 microns compact bubbles

<u>Conclusions</u>

- 428 MBs detected in MIPSGAL 24 microns survey
  - 15% previously identified objects (only evolved stars)
  - 85% unknown objects

- Identification
  - Near-IR spectroscopy of the central source (25% of MBs):
    - half late-type
    - half early-type
    - significant increase of known/candidate WR and LBV
  - Mid-IR spectroscopy of the shell (and central source if present):
    - unique sample to constrain the nature of the MIPS24 emission
    - PNe, WR and cLBV
  - Far-IR spectroscopy (?) and photometry with Herschel

DustEM

physical dust model developed at IAS (Orsay, France) in collaboration with CESR (Toulouse, France) and CITA (Toronto, Canada) now available online!

http://www.ias.u-psud.fr/DUSTEM/

Compiegne et al. 2010, accepted for publication in A&A (http://arxiv.org/abs/1010.2769)