Stars and Supernovae

Some possibilities

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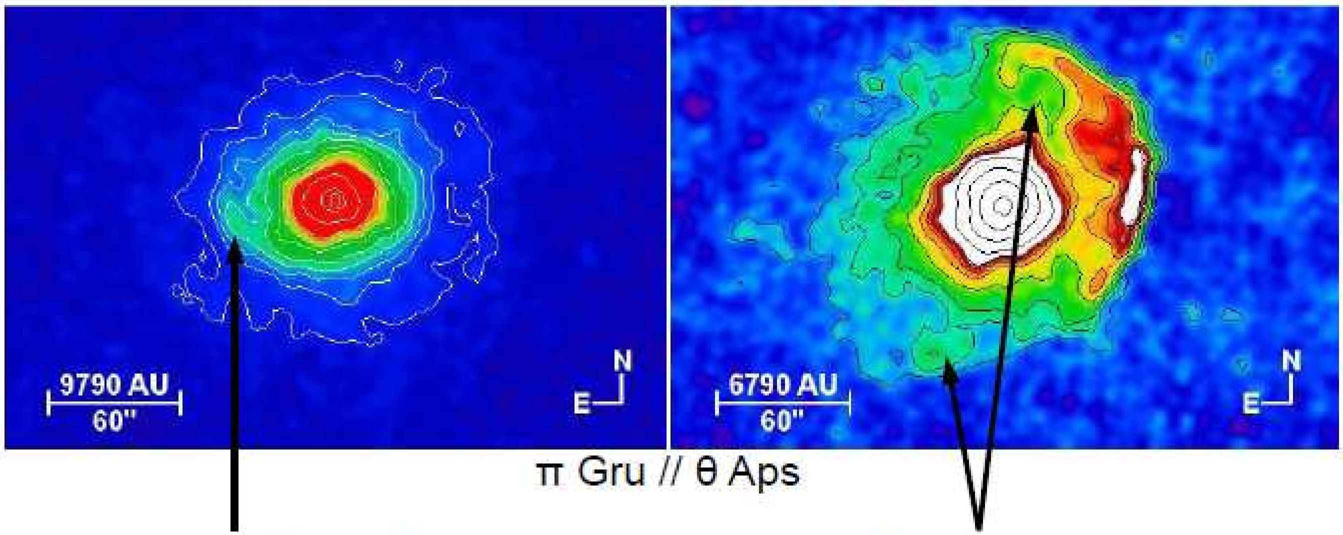
(Leisawitz et al. 2007 SPIRIT design study specs. used)

FIRI 2013 Meeting

Dozens of detached AGB dust shells have been detected by Herschel

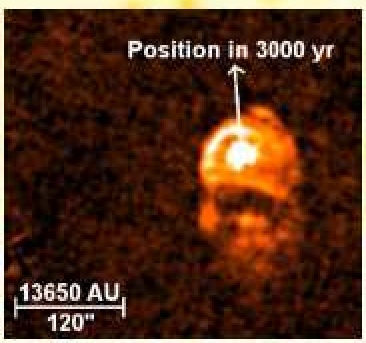
Herschel-PACS @ 70µm, deconvolved

Mayer, Kerschbaum et al.

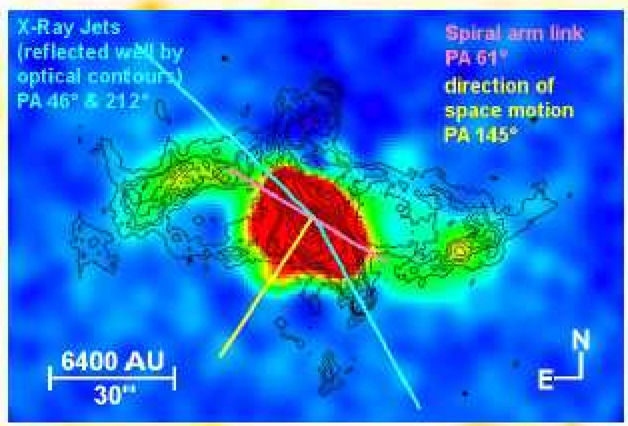


Part of disk around π Gru, jet, spiral arm?

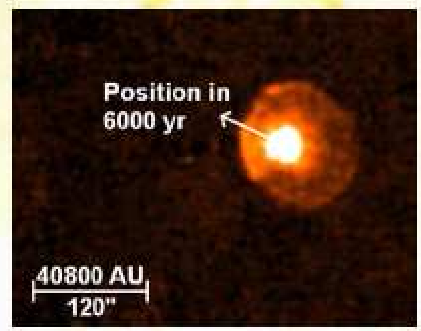
Bipolar outflow?



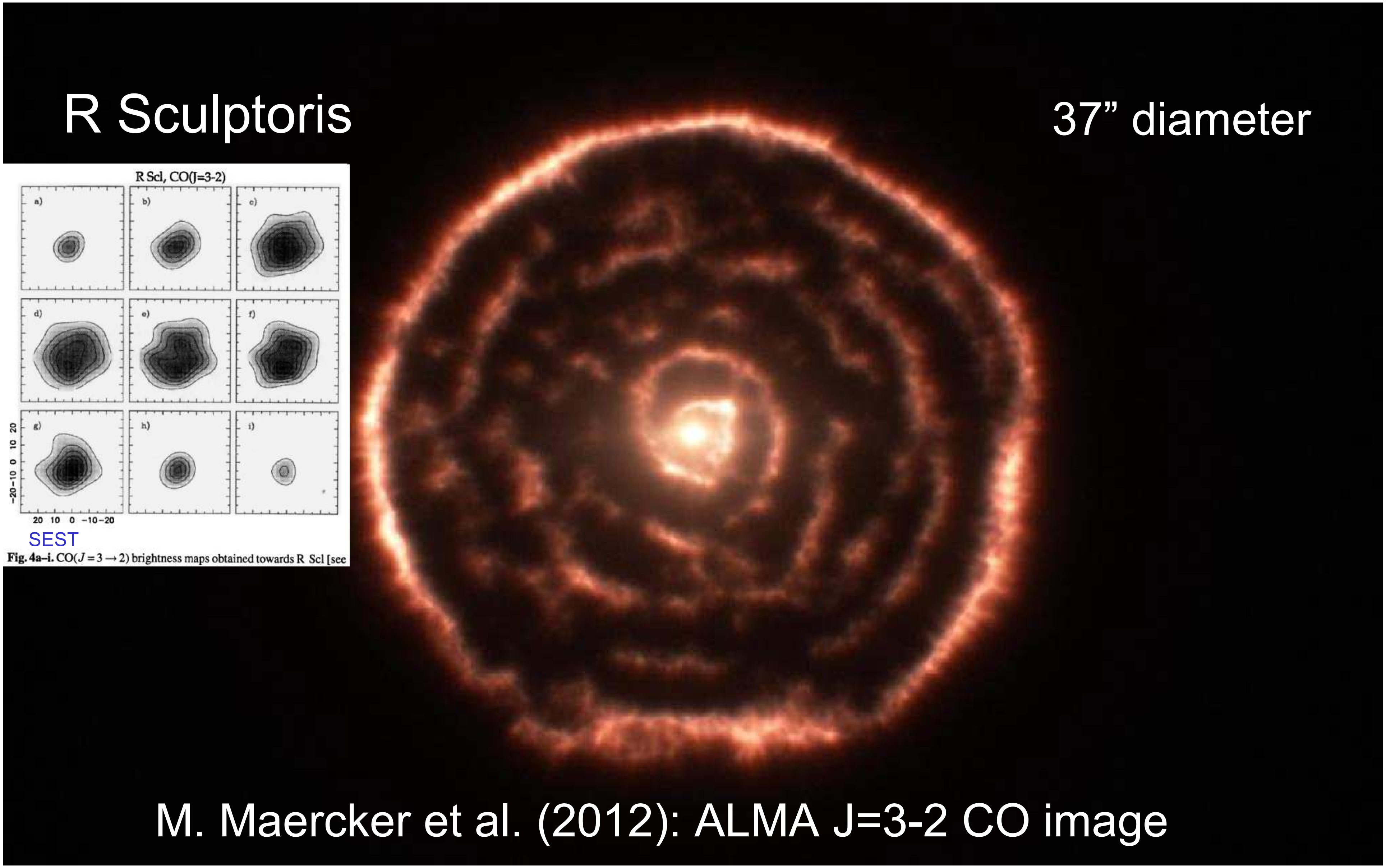
EP Aqr: Similar structures as in Mira; bow, spiral, tail; CO disk or bi-polar



R Aqr: spiral arms, NII correlation one ring? X-Ray jets



W Aql: Compressed? inclined Wilkinoid? broken bow real!

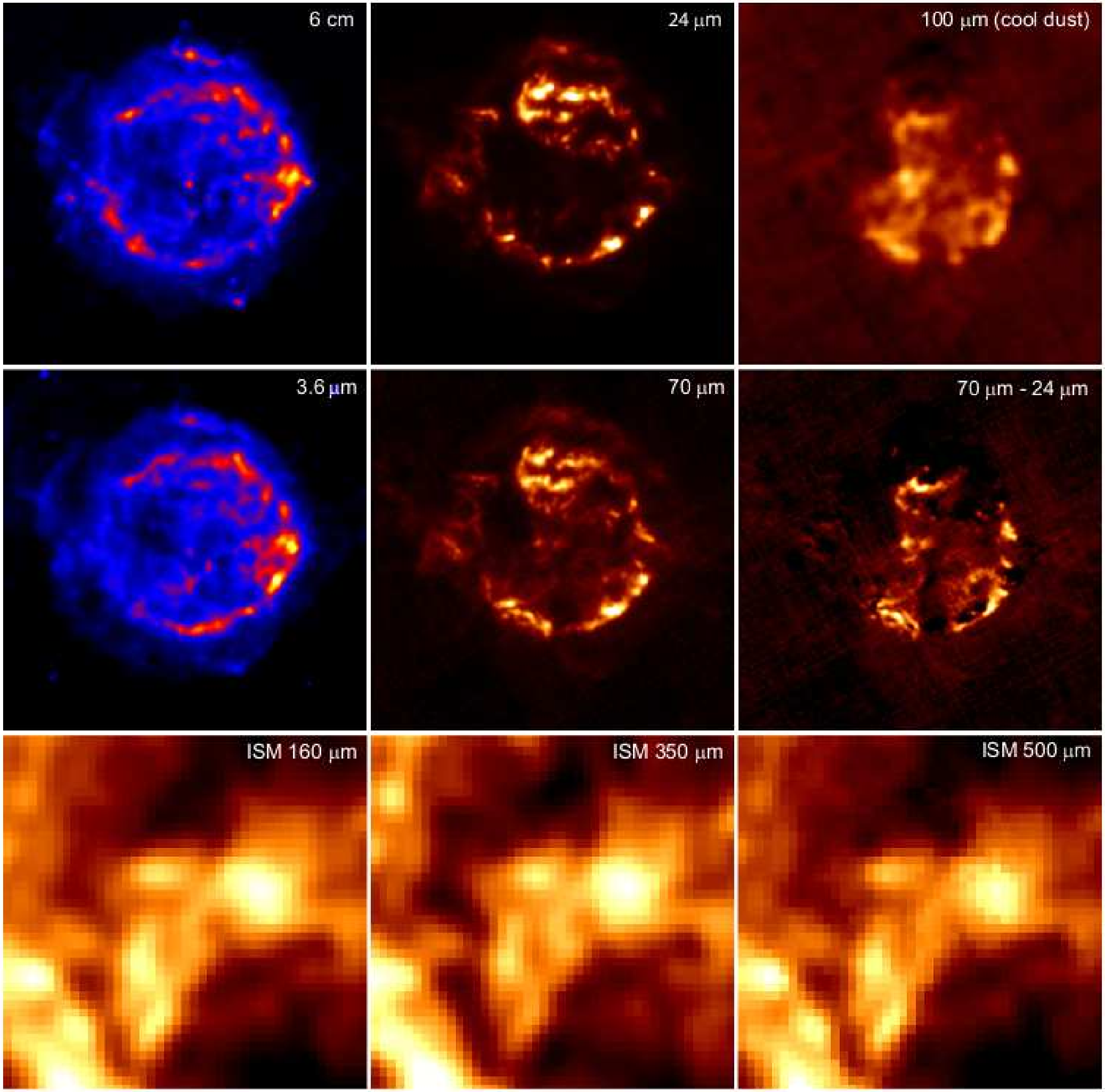


Most evolved star circumstellar shells are difficult to detect in line emission; but easy to detect via their far-IR dust emission

To account for the huge quantities of dust found in many very high redshift galaxies, models indicate that ~ 0.1-1.0 Msun of dust needs to be formed by each core-collapse supernova.

Spitzer studies of young core-collapse supernova ejecta in the local Universe (SN ages < 5 yrs) found only relatively small quantities of warm dust emitting at mid-IR wavelengths, typically ~ 10^{-3} Msun per supernova.

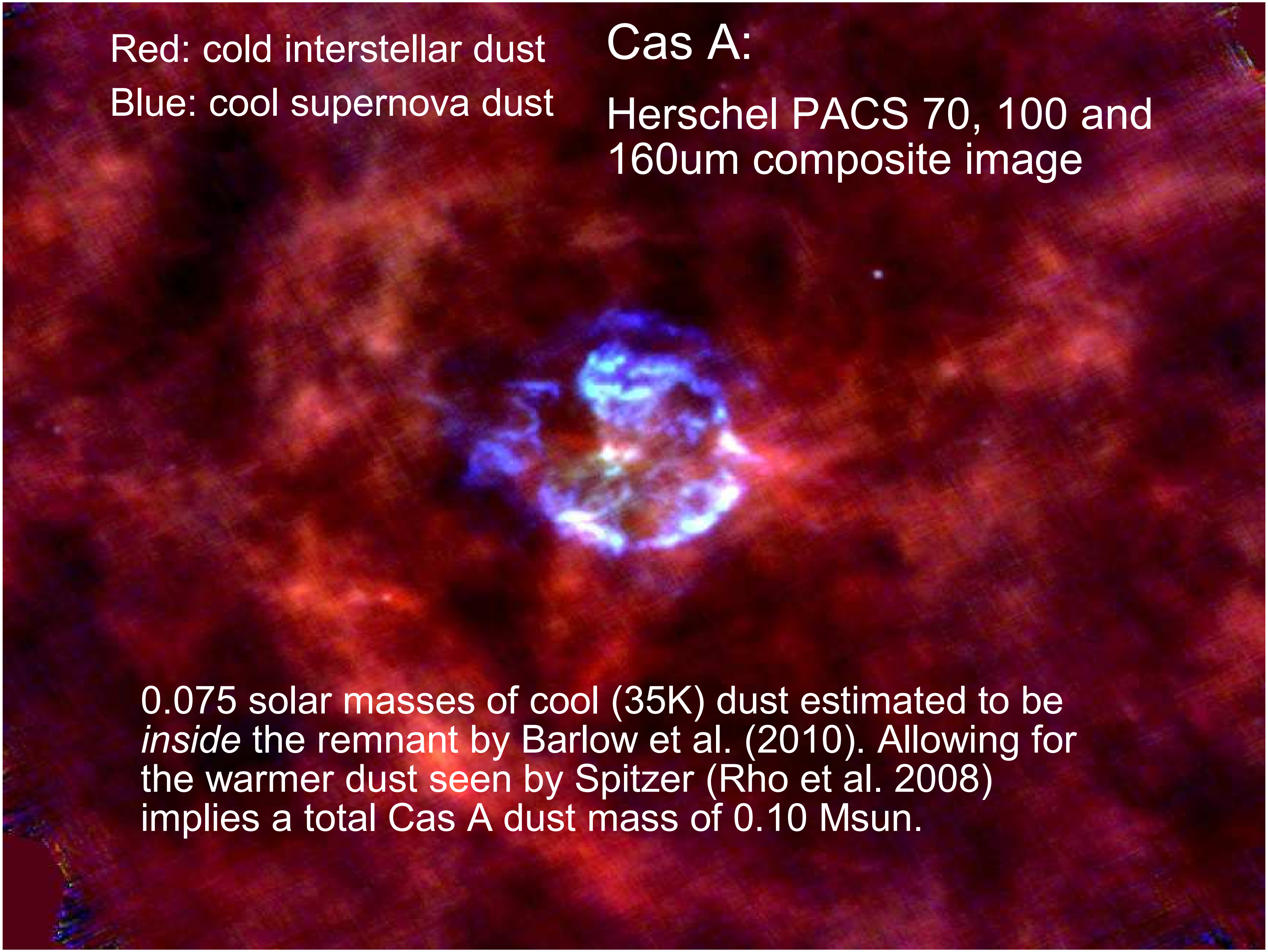
The advent of Herschel enabled emission from much cooler dust to be probed



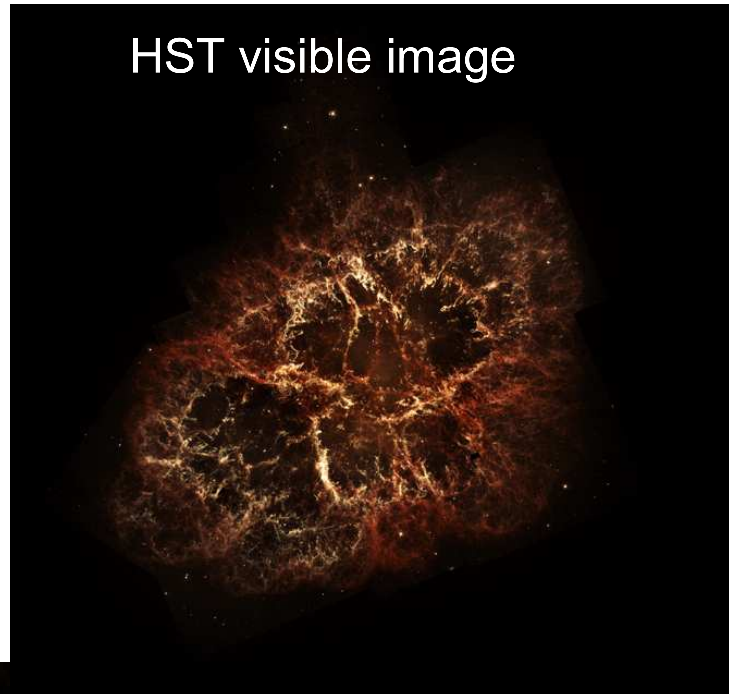
Cas A

near-IR/far-IR/ radio

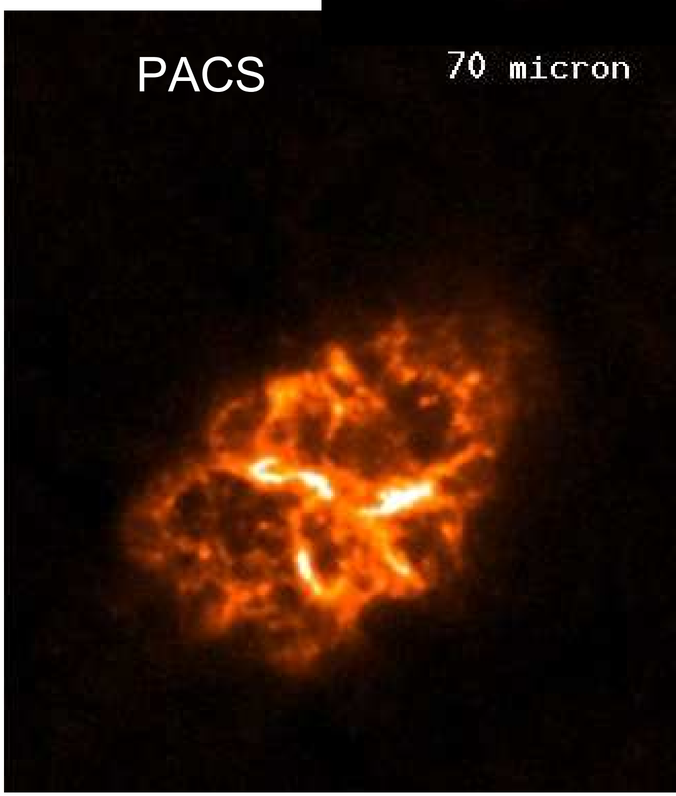
Barlow et al. (2010)

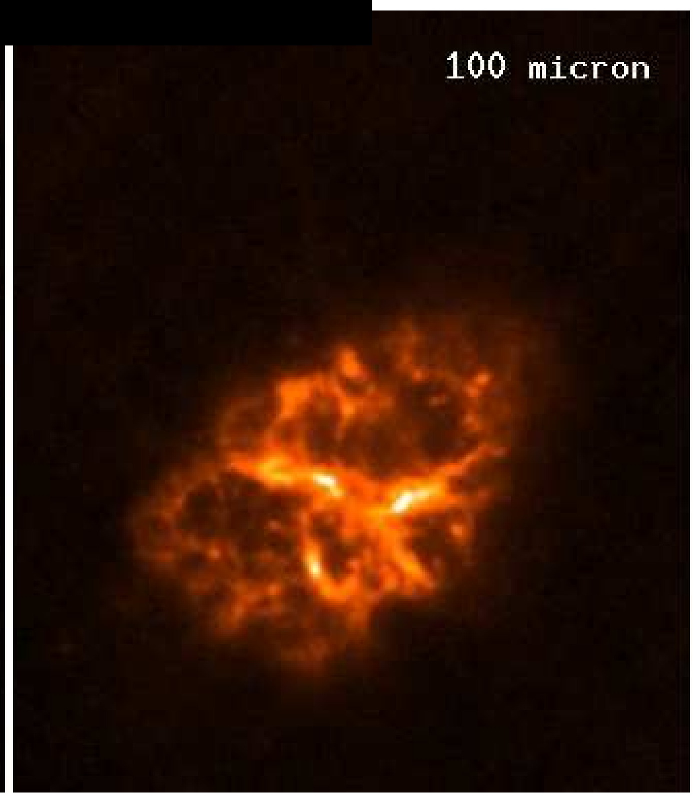

Red: cold interstellar dust
Blue: cool supernova dust
Cas A:
Herschel PACS 70, 100 and 160um composite image
0.075 solar masses of cool (35K) dust estimated to be *inside* the remnant by Barlow et al. (2010). Allowing for the warmer dust seen by Spitzer (Rho et al. 2008) implies a total Cas A dust mass of 0.10 Msun.

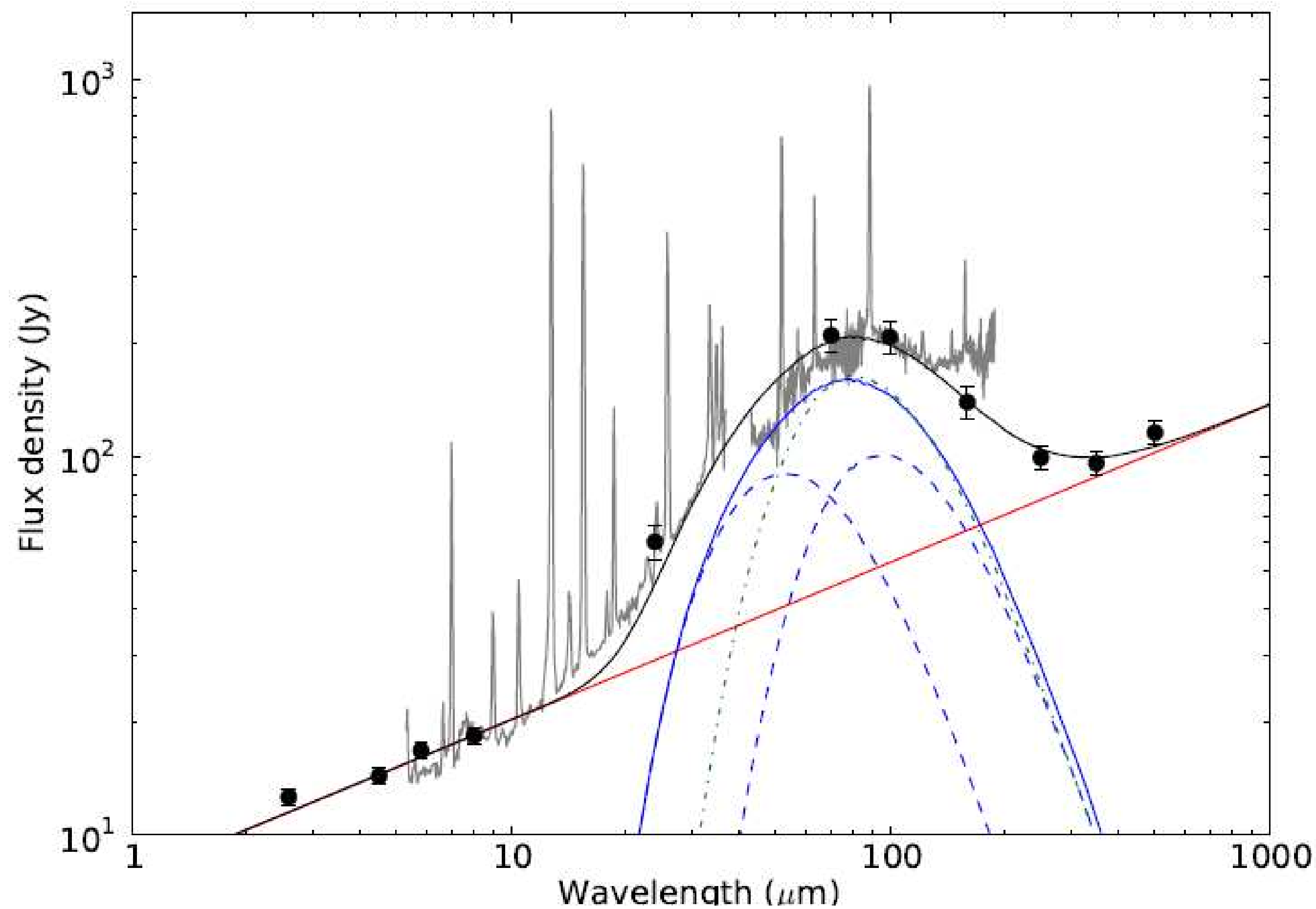
The Crab Nebula: the remnant of a Type II SN



Near the Galactic anti-centre, so interstellar dust emission is relatively low.



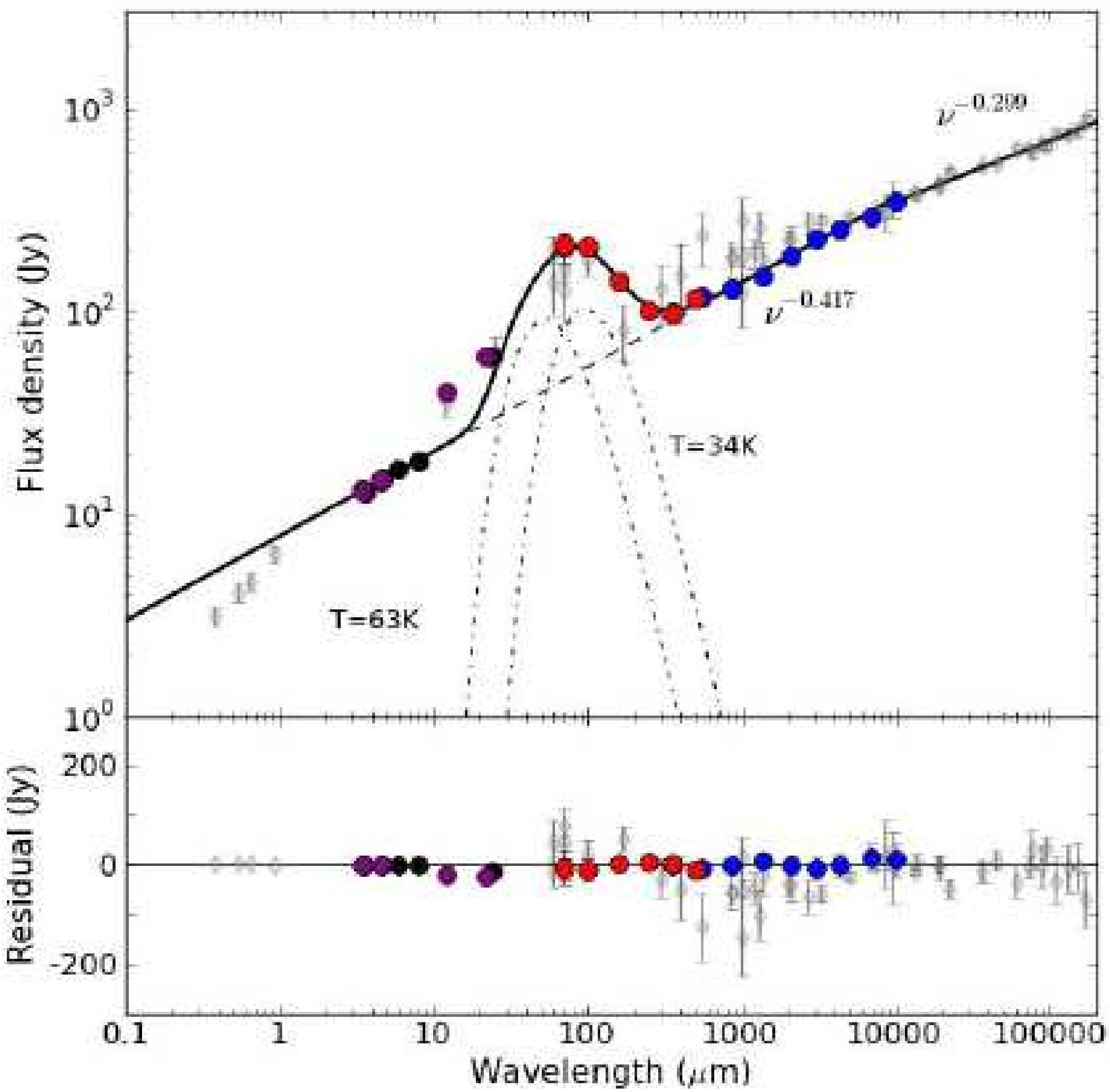




Gomez et al. (2012b)

λ (μm)	Line contribution in band (%)				average
24 (*Spitzer* [a])	..	27	54	48	43
70 (*ISO*)	6.6	4.2	5.4	4.4	4.9
100 (*ISO*)	12.9	5.6	9.6	6.7	9.9

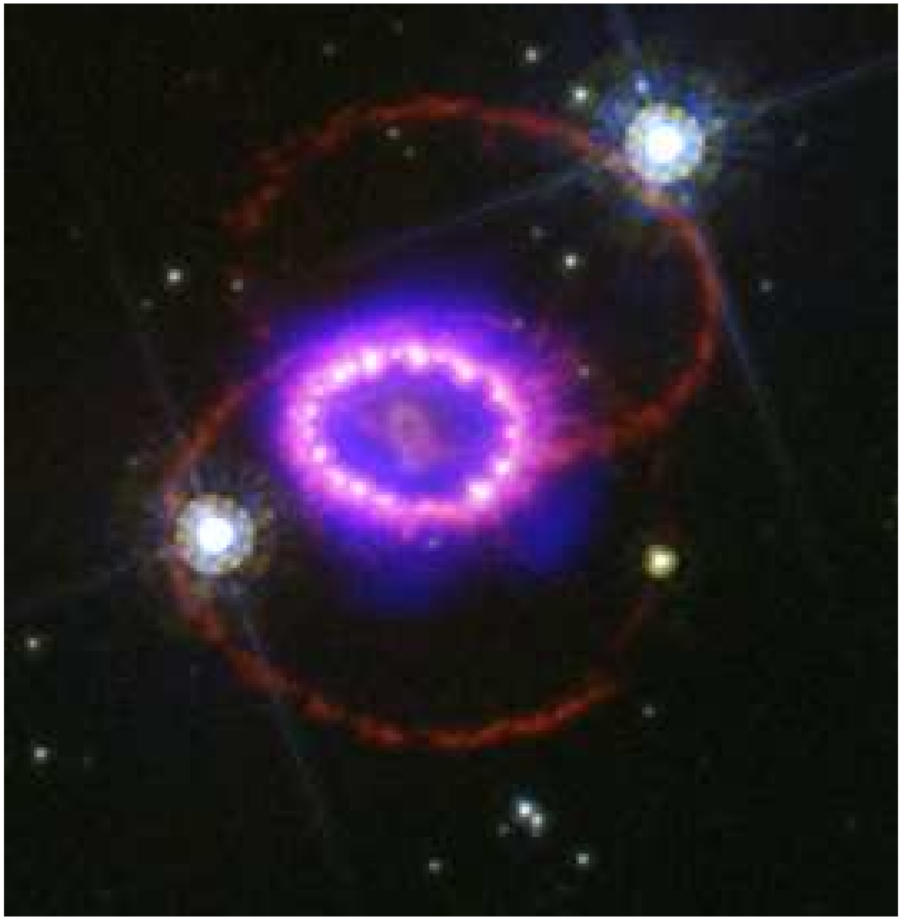
Table 4: The contribution in each *Spitzer* and *Herschel* band from the line emission at different points across the remnant . The *ISO* points refer to regions #1-4 (Fig. 1). [a] - Temim et al. (2012).



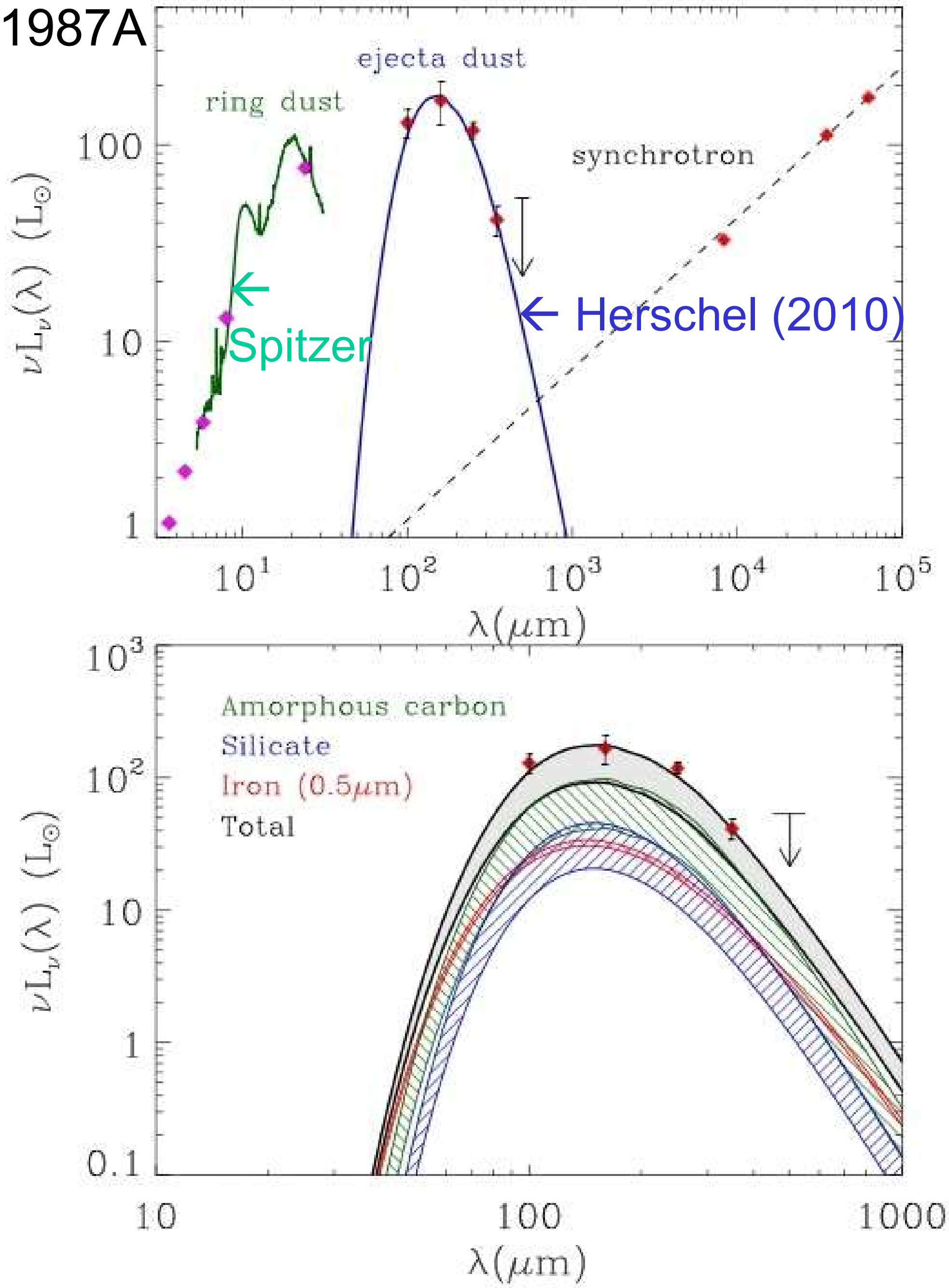
The mm-wave Planck data points (in blue) yield a steeper slope for the nonthermal synchrotron component than did the (longer wavelength) VLA radio data points. This increased the fractions of the 70-250um Herschel fluxes (in red) attributable to cool dust emission.

Gomez et al. (2012b)

Figure 5. The SED of the Crab Nebula from the IR-radio including *Herschel* (red points) and *Spitzer* (black), WISE (purple) photometry and *Planck* fluxes (*Planck* Collaboration 2011, blue points). Previous fluxes from the literature (see Table A1 and references therein) are shown with grey diamonds. The synchrotron law fitted to the $3.6-10^4$ μm data points is the dashed black line.

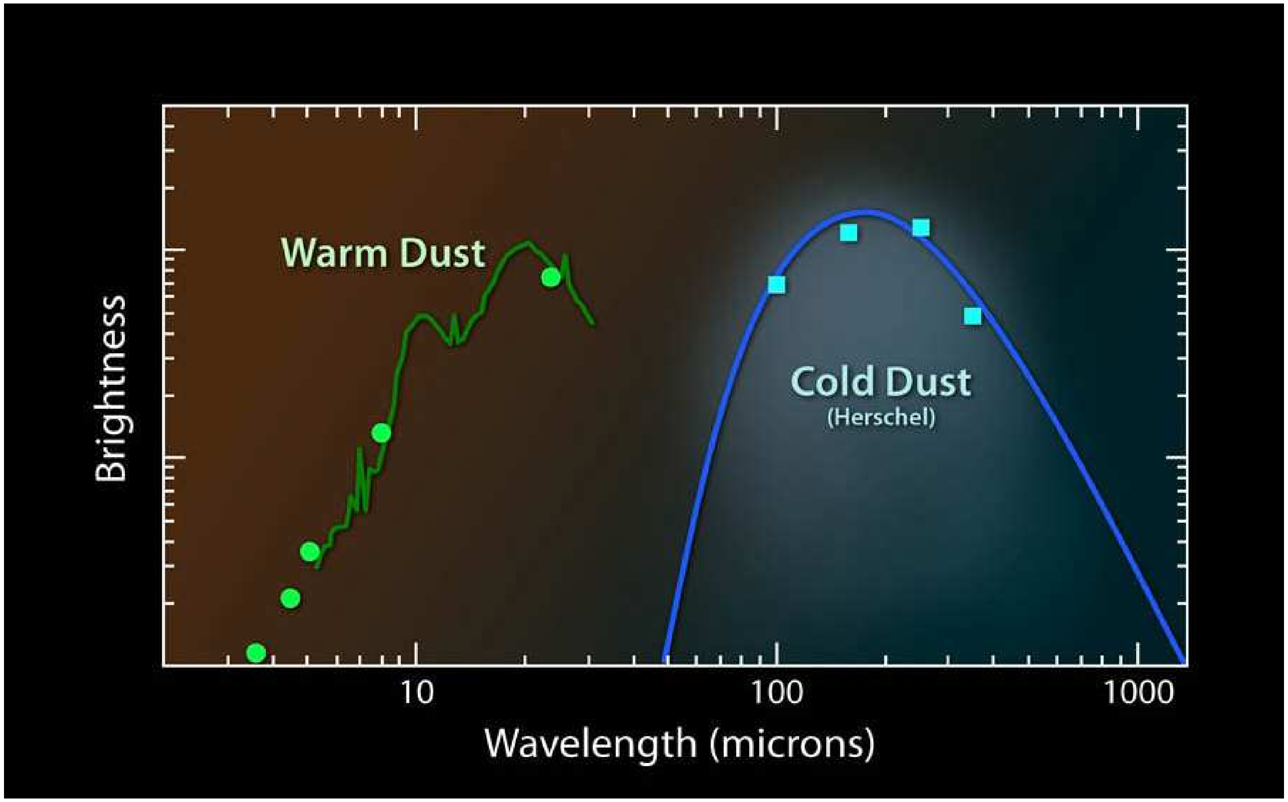


Matsuura et al. (2011) spectrum of SN 1987A



Supernova 1987A in 2005:

Hubble image showing the faint inner ejecta and the brightening ring of material that was ejected before the supernova event.



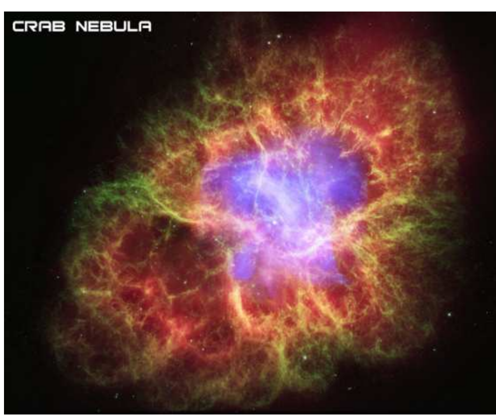
The dust that was discovered by Herschel in SN 1987A's ejecta is so cold (~22 K) that a very large dust mass is needed to fit the observed emission.

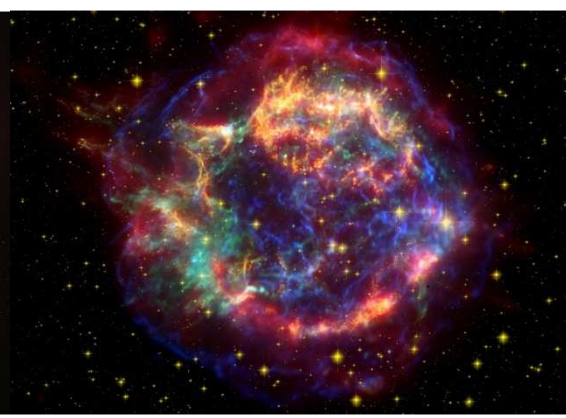
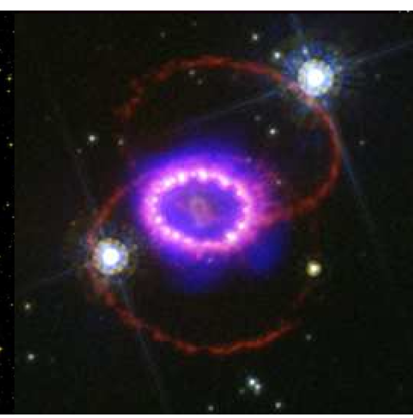
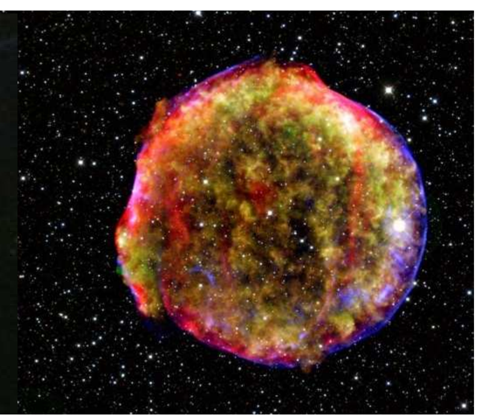
The mass of dust made by SN 1987A was estimated by Matsuura et al. (2011) to be 0.7 solar masses (230,000 Earth masses)

Herschel Supernova Results:

			M(dust) (T_d<50K)	
1680	IIb	Cas A	**0.10 Msun**	**Barlow et al. (2010)**
1054	II	Crab	**0.10-0.24 Msun**	**Gomez et al. (2012b)**
1987	II	SN 1987A	**0.7 Msun**	**Matsuura et al. (2011)**

The growing angular diameter of the SN1987A ejecta, currently ~0.9 arcsec, and the ongoing interaction with the surrounding ring system, make it an ideal target for FIRI. However, the LMC is near the South Ecliptic Pole, which according to the SPIRIT definition documents would require significant additional boom shielding for observations to be possible.



Prospects for detecting dust emission from distant core-collapse SNRs:

Cas A dust: F(70um) = 138 Jy; F(100um) = 139 Jy @ 3.4 kpc @ 342yrs

$\Rightarrow$ 1.8 μJy @ 30 Mpc => 9σ in a deep field exposure with SPIRIT specs.

(ang. diam. = 0.034” at 30 Mpc, i.e. point source for SPIRIT)

Crab dust: F(70um) = 213 Jy F(100um) = 215 Jy @ 2.0 kpc @ 967yrs

$\Rightarrow$ 2.2 μJy @ 20 Mpc => 11σ in deep field exposure (5σ if at 30 Mpc)

SN 1987A: F(100um) = 43 mJy F(160um) = 181 mJy @ 50 kpc @ 25yrs

=> @ 10 Mpc: 1.1 μJy @ 100um (5σ/deep) and 4.5 μJy @ 160um (23σ)

Galaxies at 10-30 Mpc would be well-resolved, so SNRs similar to these should be easily distinguishable in SINGS-type surveys of local galaxies.

Future Prospects:

A combination of mid-IR and far-IR observations will be needed to properly characterize the dust SED evolution of future core collapse SNe, in order to derive reliable masses for warm and cold dust components.

The MIRI 5-30um instrument onboard the JWST (launch date 2018) will be 50x more sensitive than Spitzer's IRAC and MIPS, with its 8x larger aperture than Spitzer's leading to drastically reducing confusion limits. However, JWST will only be sensitive to warm dust.

The cooled 3.5m telescope to be used for the proposed JAXA/ESA mid/far-IR SPICA would offer a similar sensitivity gain at far-IR wavelengths, when compared to Herschel, but it will still have the same confusion limits as Herschel.

The 10x higher angular resolution of FIRI greatly reduces backgrounds/confusion, leading to very deep sensitivity limits for point sources. Ideal for detecting dust emission from the ejecta of distant young supernovae.

With a 60" field of view, FIRI could image shells and discs around Milky Way evolved stars with exquisite detail, just as for debris discs.