DUST in SUPERNOVAE

John Danziger

Main Collaborators concerning dust

P.Bouchet
L.Lucy
E.Dwek
J.DeBuizer
R.Arendt

IAP Paris 29 July 2010

Dust hypothesized before unambiguous observations in SNe by: Cernuschi et al., Hoyle & Wickramasinghe, Dwek.

Importance: Mass and Composition in Milky Way et al.
Large IR Fluxes at Cosmological Distances.

In this talk SN1987A provides a prototype because it resulted in the best quality and longest temporal coverage of the phenomenon.

How does the presence of dust manifest itself?

There are several ways in which the presence of dust may be shown to be associated with supernovae. Each individually may not be unequivocal concerning its precise location and time of origin. This is mainly due to the fact that dust forms in the ejecta, but it may form or be already present in the CSM.
SN1987A provided the means of examining these methods.

Possible dust indicators.

1. Early presence of molecules
2. Blueward line shifts.
3. Decrease in visual light curves.
4. Increase in IR emission.
5. Effects on Bolometric light curve.

Dust in or near other SNe has used some but never all these methods.

SN1987A

Dust preceded by molecule formation. CO, SiO <150 days

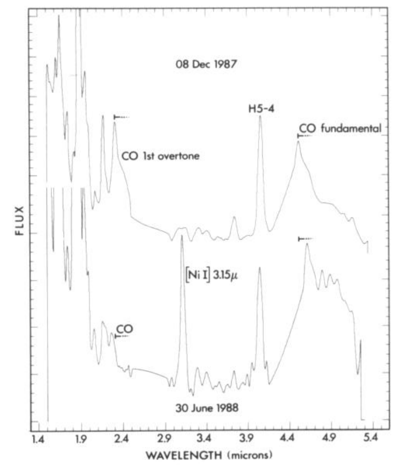
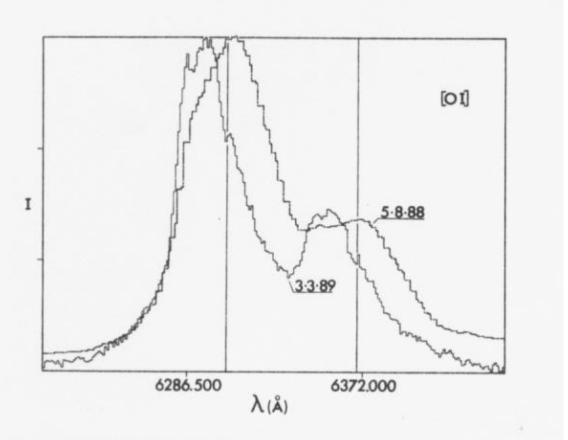


Fig. 7. CVF spectra from 1.4–5.4 μ of SN 1987A at 2 epochs. Note the temporal evolution of the strength of the fundamental and first overtone bands of CO, and the way in which the strength of the [Ni I] 3.12 μ has changed.

Molecular CO Fundamental and 1st overtone bands in IR.

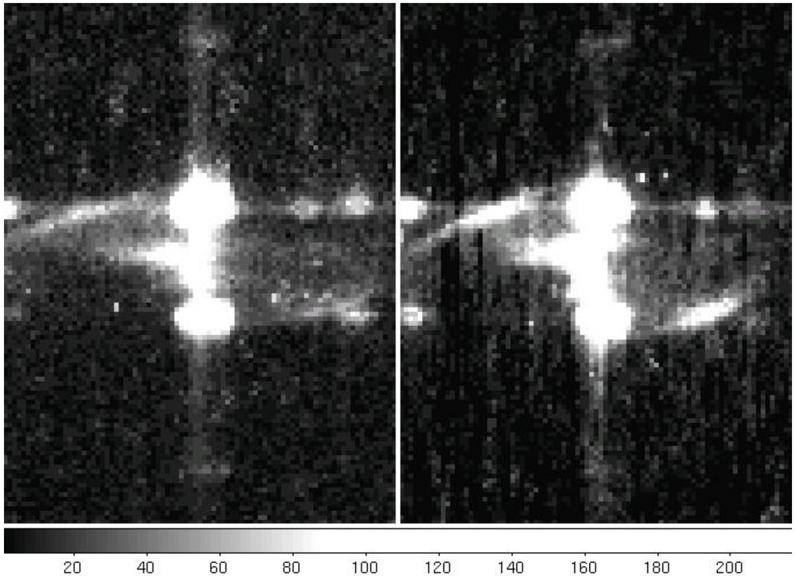
Blueward lime shifts



Apparent line shift caused by blocking of red side of profile.

Spectra give: grain size, optical depths, duration of dust formation, radial location of dust, possible clumping.

2009 STIS spectrum of SN87A showing Halpha region



July,2004 Jan.,2010

Central debris shows blue (approaching) extends to ~4000 km/s. Red extension not apparent.

Dust in ejecta blocks far side!

SN1957D in M83 Type Ib/c,II

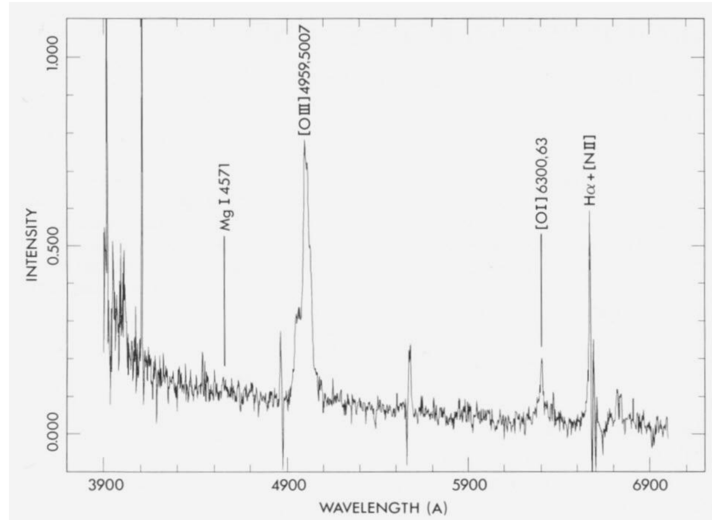


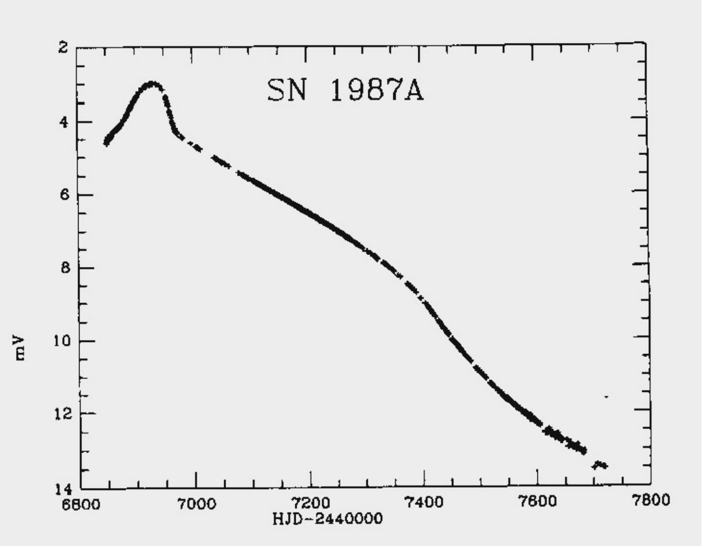
Figure 2: *Spectrum of SN 1957d. Wavelength identifies features discussed in the text, since the redshift of M83 is only 500 km s^{-1}.*

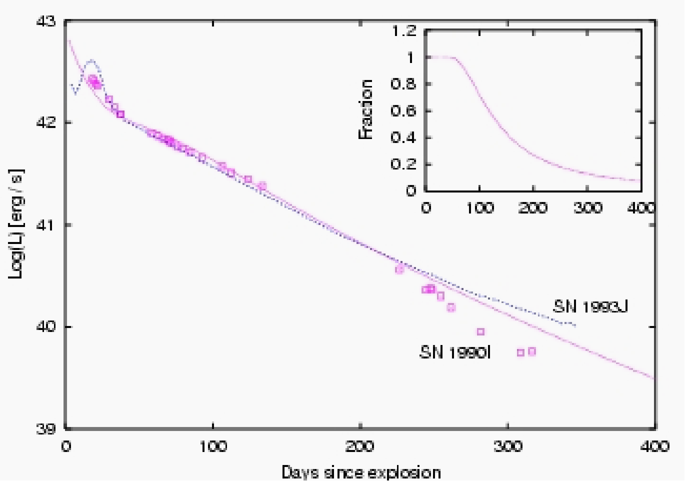
Blue shift 650km/s of [OIII]
Dust remains after 30 years?
Point source hides 2D detail seen in 87A!

Another example

SN1990I Type Ib SN.

Geneva Photometry Shows dust formation near day 530

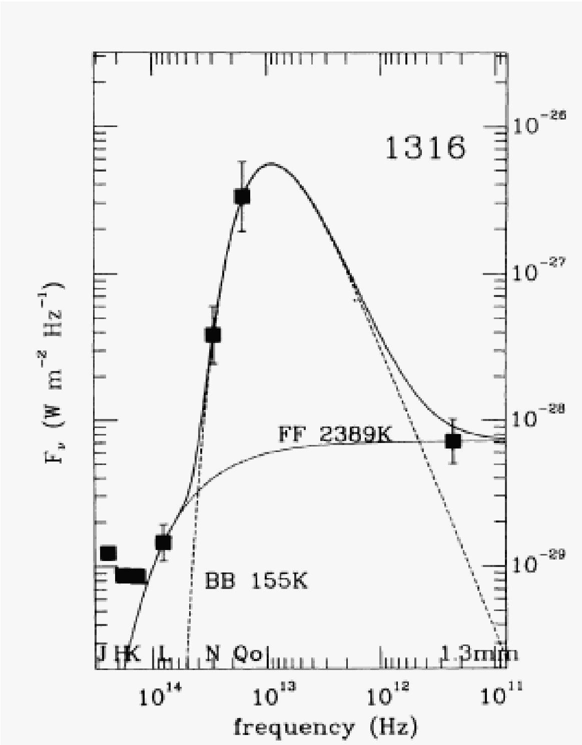




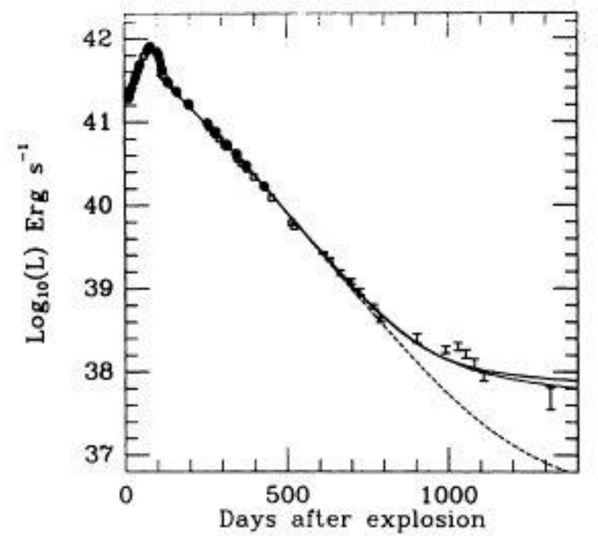
Dust formation d. 530

Dust formation slows ~ d. 750

Both light curve and blue line shifts support dust formation near 230 days. Earlier than in SN87A because more metal rich?



IR Spectrum at
day 1316.
Note M, Q fluxes.
IR excess gives: mass of
radiating dust ~3x10^{-4}Msun.
Type of dust -silicates, C. Fe molecules?
Not certain! Wooden, Colgan, Ercolano.



Accurate
bolometric light
curve gives: outward
mixing of radioactive
source (56Co).

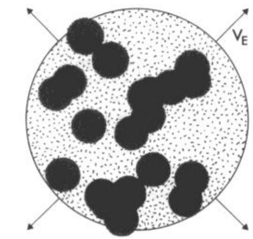


Fig. 7. Opaque clouds – diffuse dust model. Here the number of clouds $n = 20$ and have radii such that $\tau_* = 0.4$.

Opaque clumps
minimize dust
mass determination

Observational

SNe suggesting possible evidence of dust.

Spectra +	IR
SN1987A	1979C
SN1999em	1985L
SN1990I	
SN1998S	1994Y
SN1980K NB	1997ab
SN2003gd NB	1999el
SN2002hh	2006jc NB
SN2005bf	2004dj
SN2005ip	
SN2004et	2005af
SN1957D !	

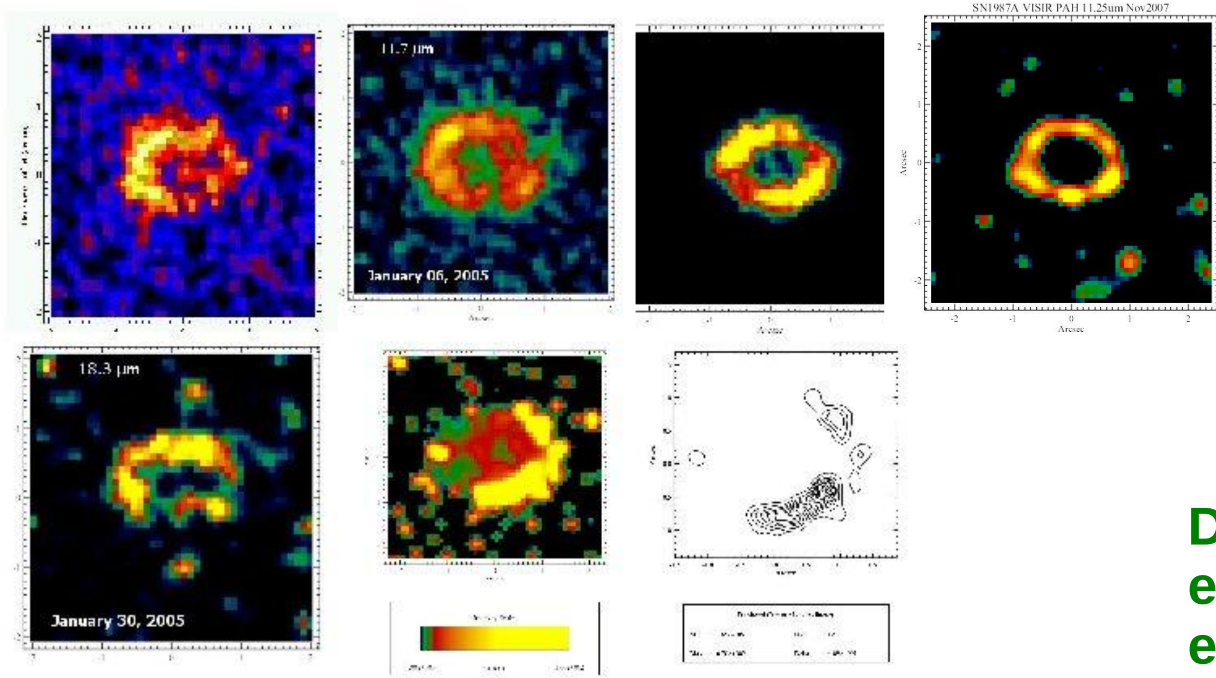
Most of above but not all SNIIP

Theoretical

Attempts to show how very large masses of dust are produced in SNe to explain the high z IR luminosities. (e.g. Kozasa, Todini)

Historical & young SN Remnants showing IR emission from possibly associated dust:
Tycho, Kepler, Crab, CasA, IC443
N132D (LMC), 1E0102-72.3(SMC)
+ because of SPITZER.

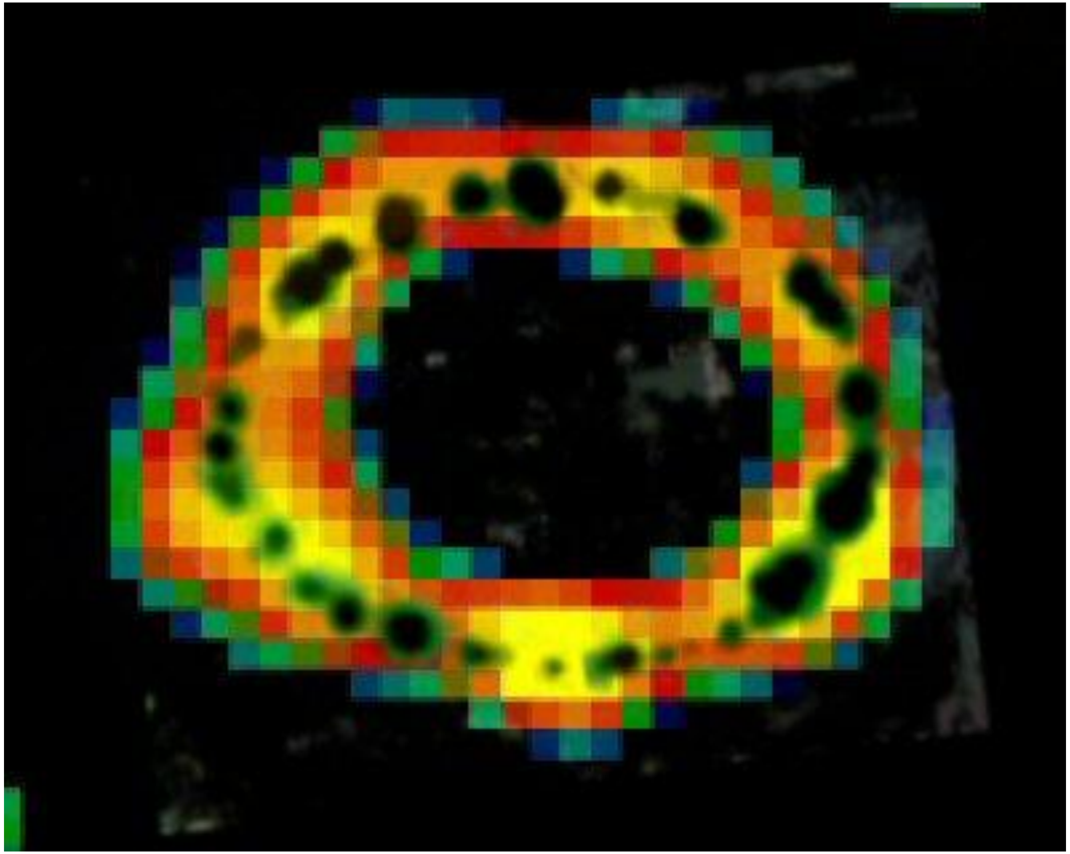
Now Circumstellar Dust



Dust present before explosion now heated by ejecta-ring interaction!

Mid-IR images at different epochs.
Top left to right. N-band at day 6067,
11.7❍ day 6526, N-band day 7241, 11.7❍ day 7569.
Bottom left to right. Q-band at day 6526,
ratio of N-bands day 7241/6067, this ratio contoured.

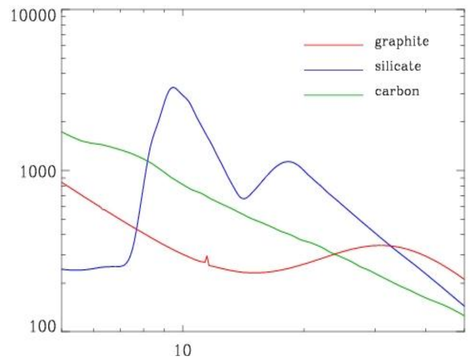
HST vs VISIR (VLT)



Overlay of HST (Dec2006) (black) with VISIR (red-yellow) shows correlation far from 100 percent!

Other comparisons show dust annulus possibly (?) thicker than visual HST annulus.

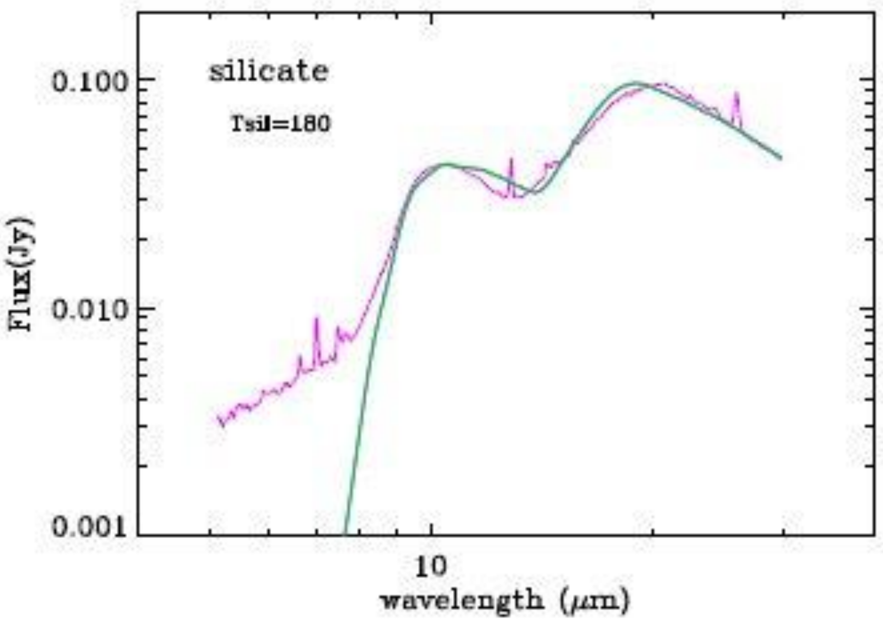
SPITZER

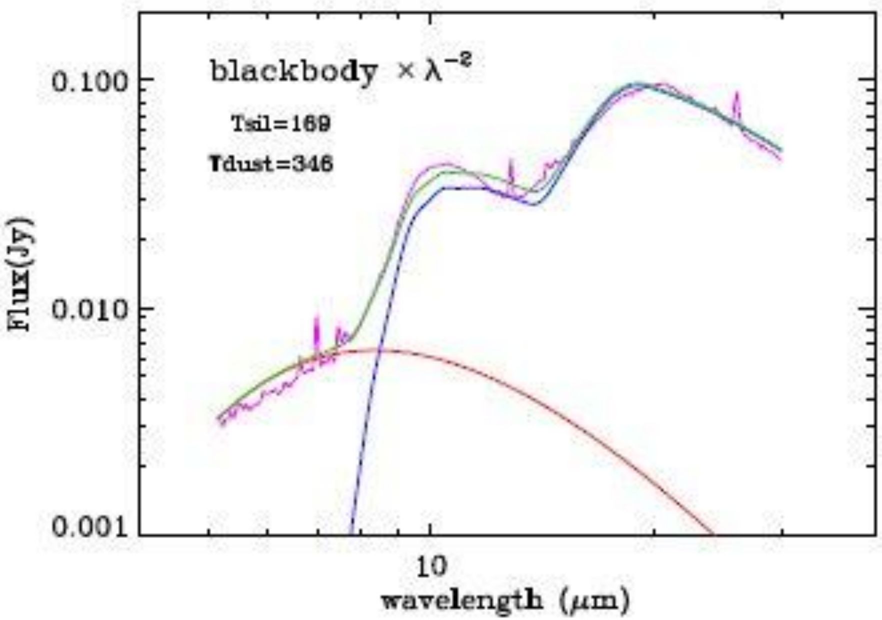


Grain absorption coeffs.

Silicates

Silicates + Black body



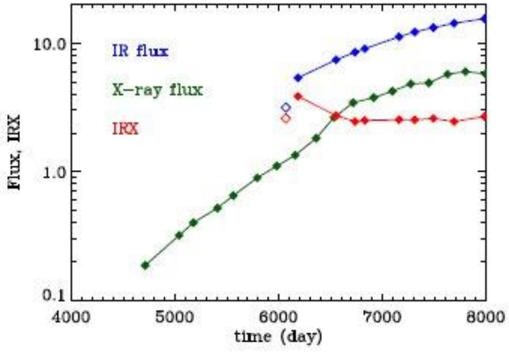


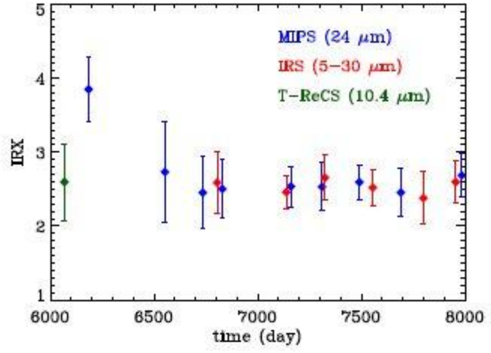
Black body = mystery contributor. Carbon and Fe molecules require much higher T to fit spectrum. No temporal change of spectral shape

A clue to binarity of progenitor ?

No Obvious Dust Destruction Yet

IR vs Soft Xray Flux



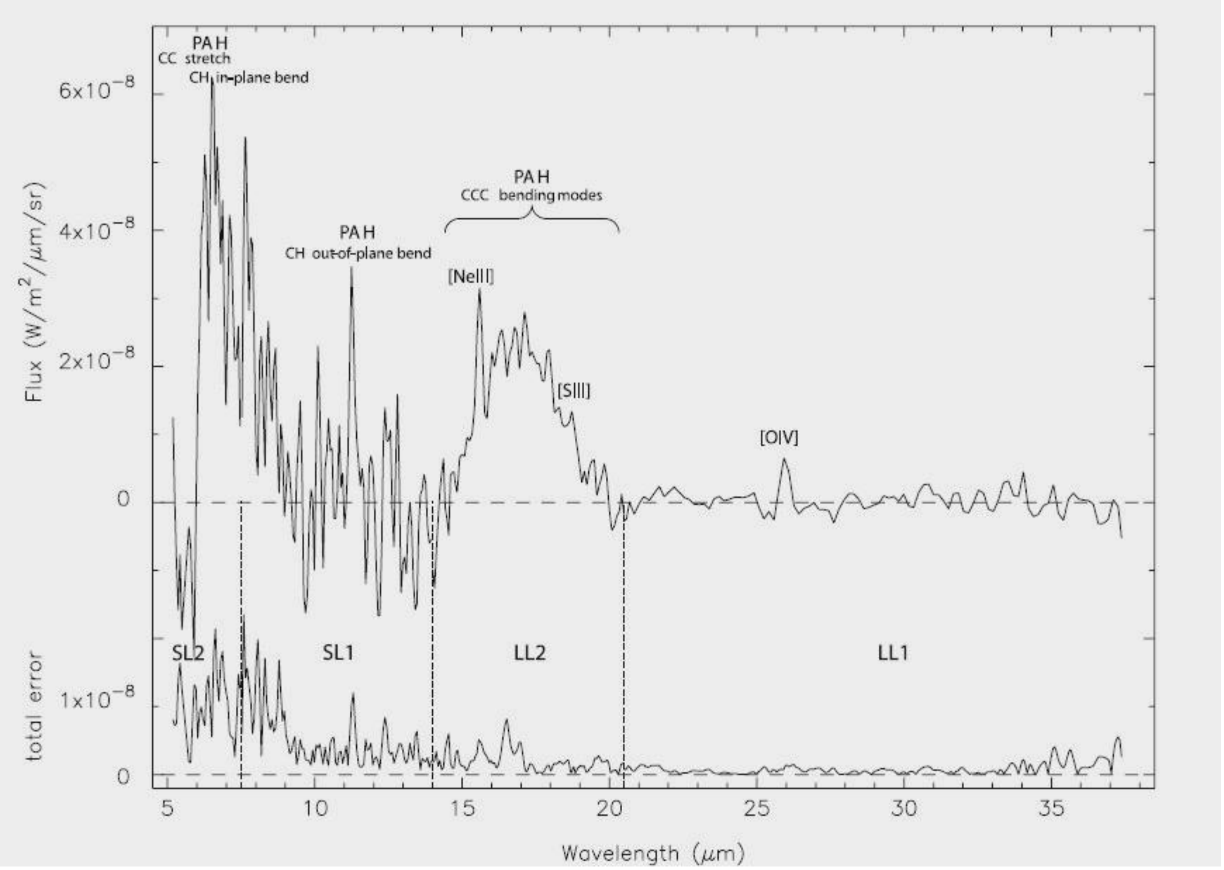


No decrease in IR/Xray ratio suggests no dust destruction!

Mass of radiating dust in ring = ~10^{-6} Msun

As a Supernova Ages

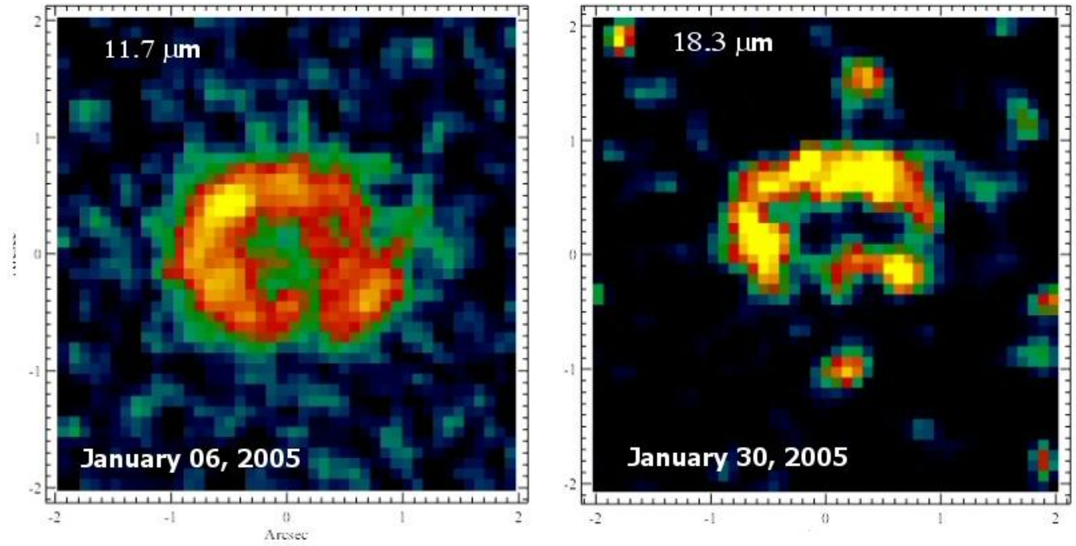
N132D young O-rich SNR in LMC



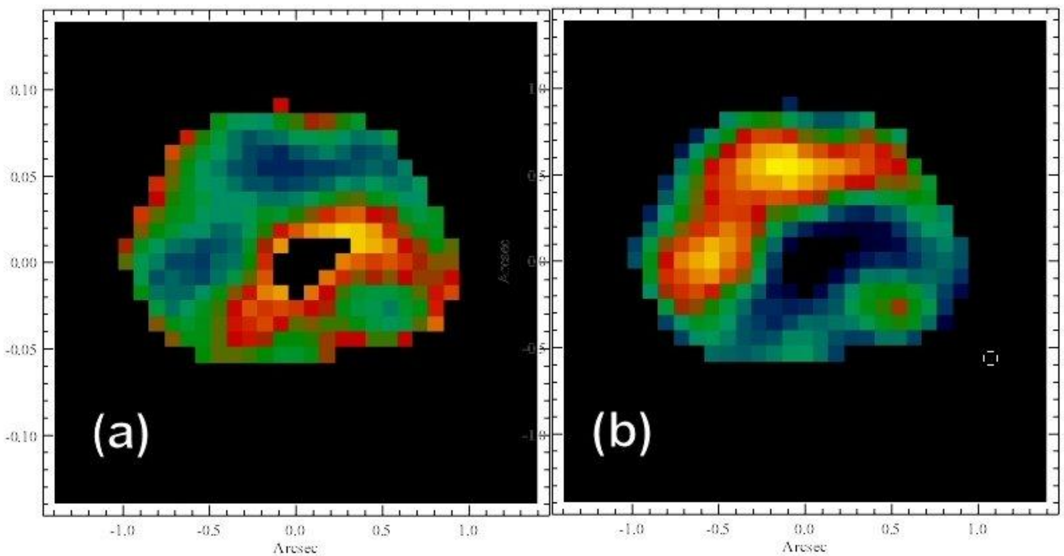
Swept up dust grains and PAH in blast wave. (Tappe et al.) Polyaromatic hydro-carbons

THE END

MidIR imaging



Note differences between 11.7 and 18.5❍ images leading to variations of T and emission ♦ (very small) across the image.

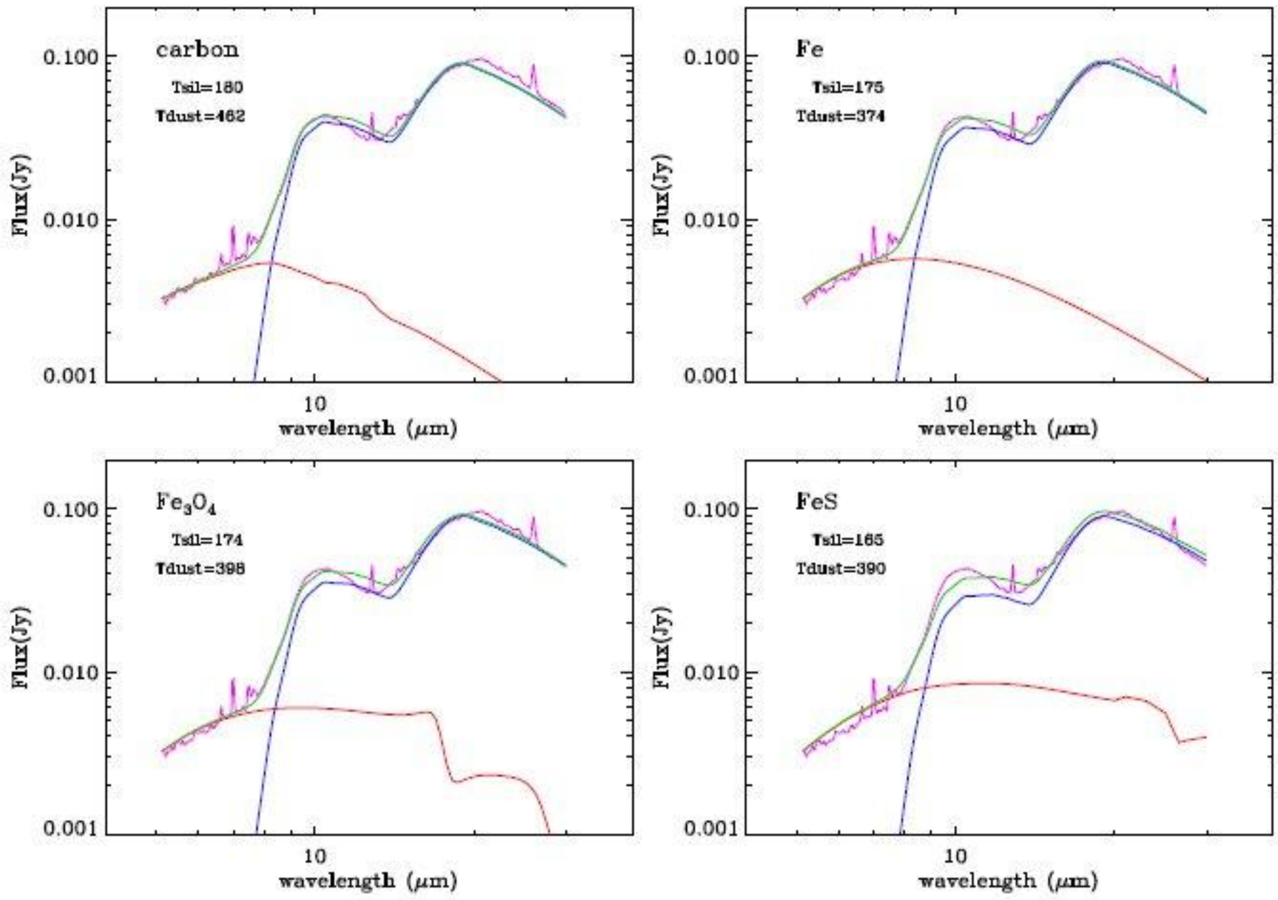


Average temperature of ring 180K.

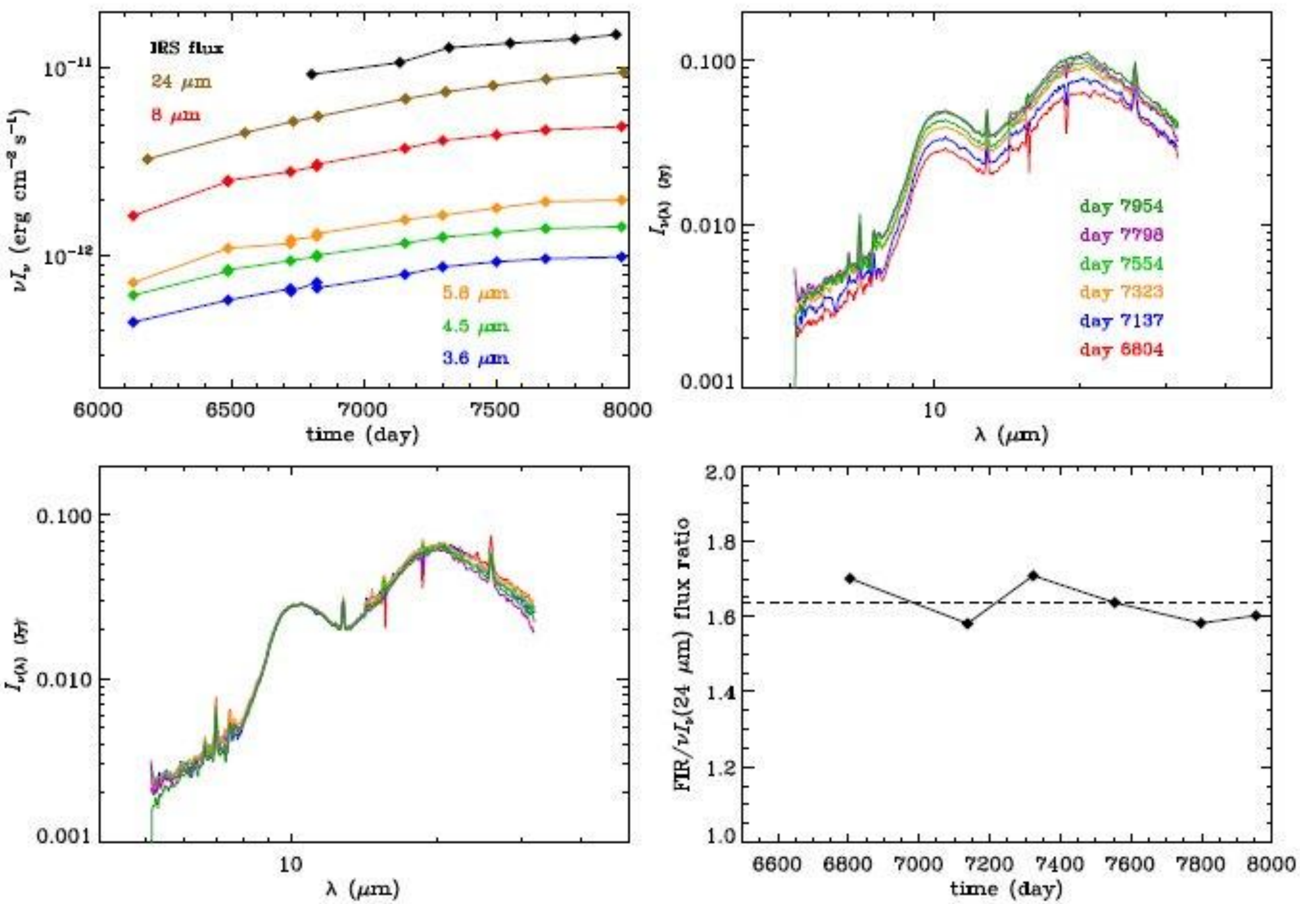
Temperature Emission Optical Depth

Silicates + Carbon

Silicates + Fe (molecules)



Temporal variations of Ring emission



Note no change
In ratio of fluxes
of primary to
secodary
component.

Flux ratio
no change
in Temp. or
density.

Conclusions concerning grain properties

1. Higher temperature of second component >350K suggests grain radii or or IR emissivities significantly smaller than those of silicates (a > 0.2 ❍✆. Sputtering (by ions) lifetimes would be shorter than silicates. But the ratio of the 2 components Is constant over the period observed.

2. If there is a mixture of grain types within the ring or between ring and internal debris this suggests progenitor type favours a binary coalescence origin. Hence important to understand.