SN1987A and its REMNANT

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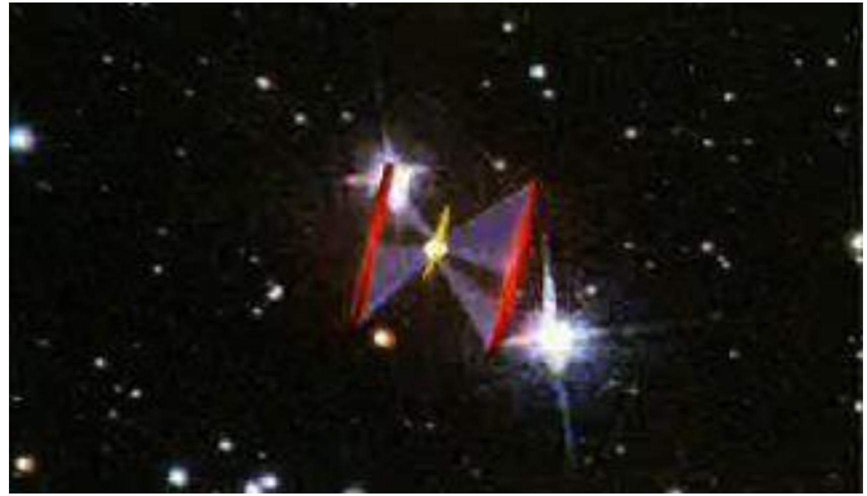
Some well established properties?

1. Neutrino luminosity $2x10^{53}$; KE ~$2x10^{51}$; radiative $2x10^{49}$ ergs.
2. Exploding star B supergiant; mass ~ 16Msun.
3. Mass of Fe (56,57) (0.075 Msun: IR lines, γ -rays, Bol.LC)
4. Mass of Oxygen (~1.5Msun).
5. Mixing in envelope (line profiles, Bol.LC)
6. Ring origin, age (20000 years) and enriched abundances (N).
7. Nature of ring excitation: aspects of shock physics (Xray, Optical, radio).
8. Mass of dust in ejecta (~$3x10^{-4}$Msun).

What follows - Senilita or as a supernova grows older

The Remnant and Rings around SN1987A



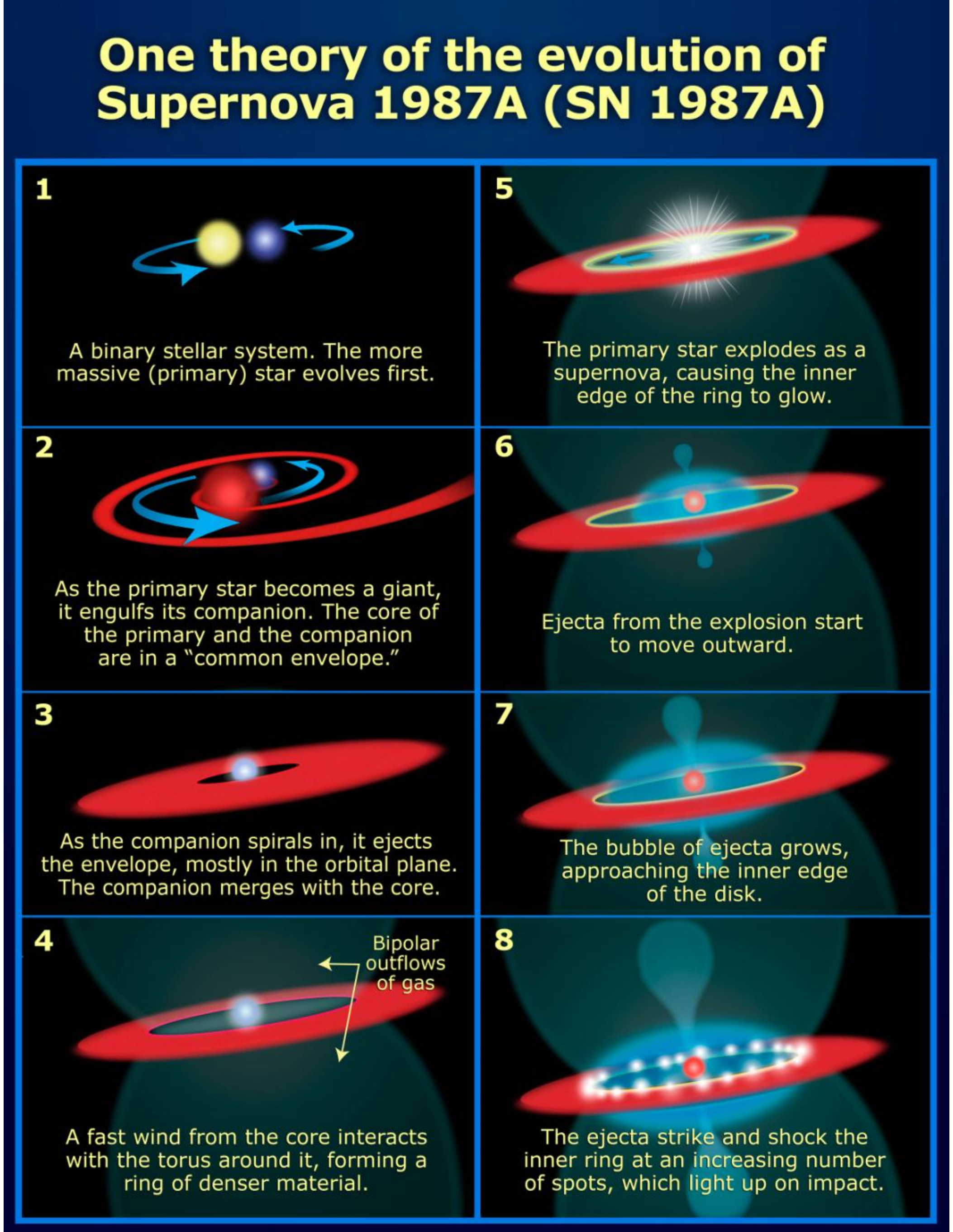
Two progenitor theories

Binary star coalescence

Model Podsiadlowski et al.

Single rotating star

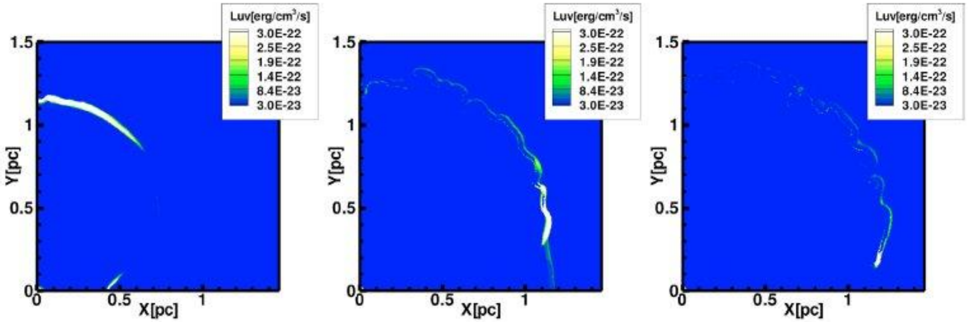
Model Langer et al.

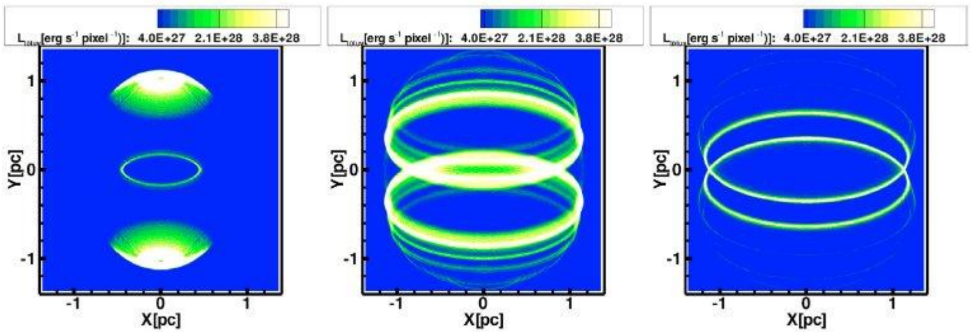


Podsiadlowski et al.

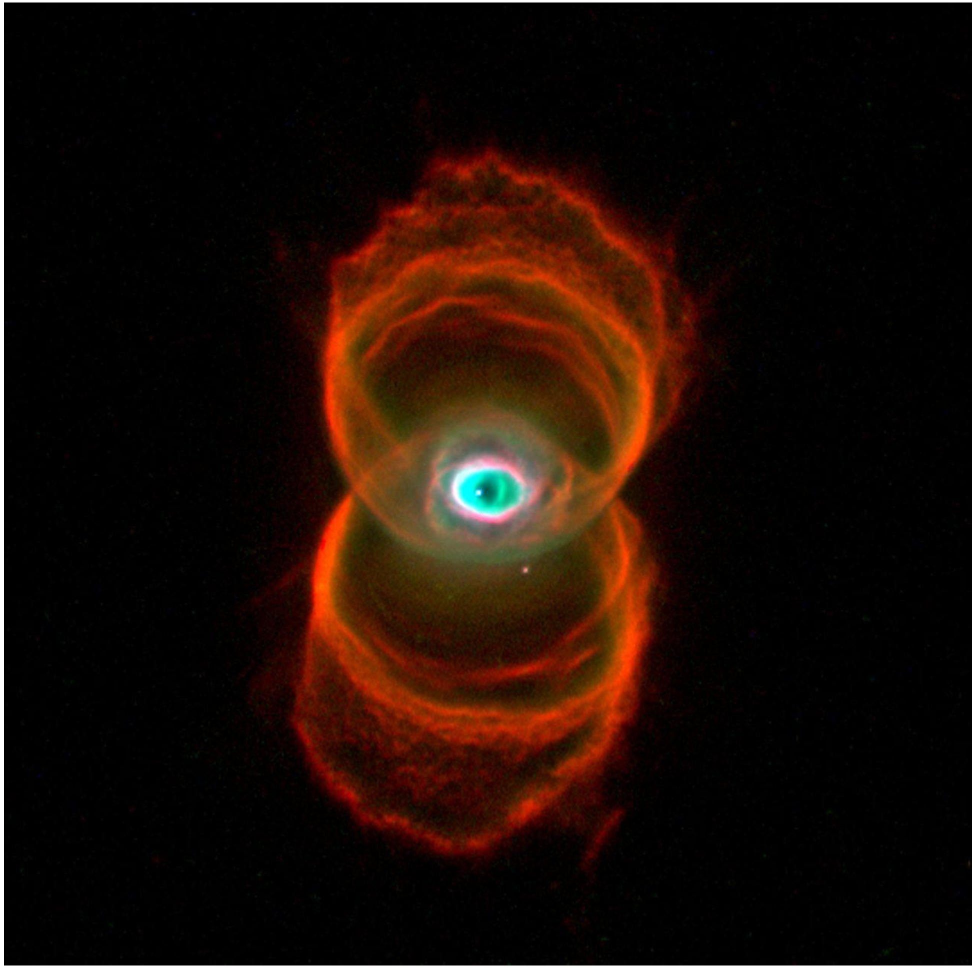
Note elongation along axis perpendicular to plane.

Langer et al. 12Msun star





Blue Main Seq.: hot wind bubble
Red Supergiant: slow wind talled by pressure of hot wind, creates stationary RSG shell.
Again blue SG: increase in wind speed creating BSG wind plowing up a BSG shell hitting the RSG shell first at the poles and inner part of equatorial plane.
Polar caps form rings moving towards plane, central ring fades

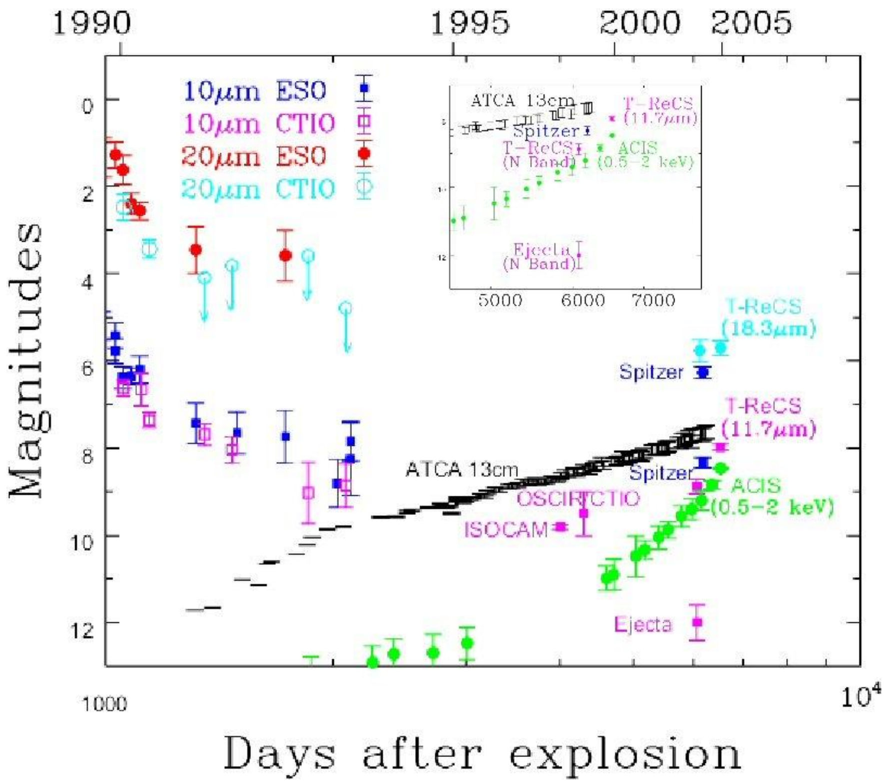


A well known PN
Imaged by HST.
Rings apparent.

Bets allowed on which is correct

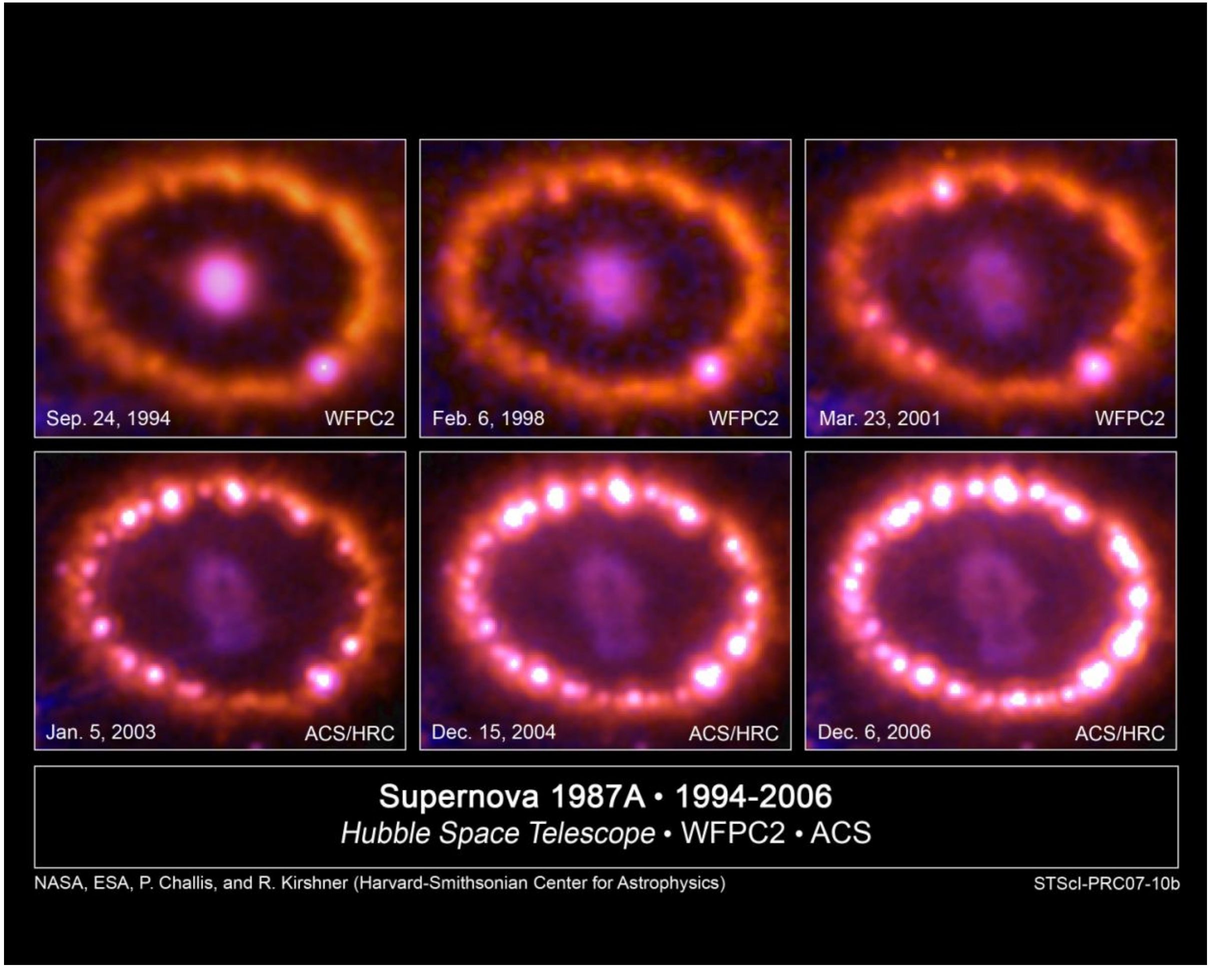
Kinetic Energy to Radiative by Shock Interaction in CSM

Light Curves at Various Frequencies



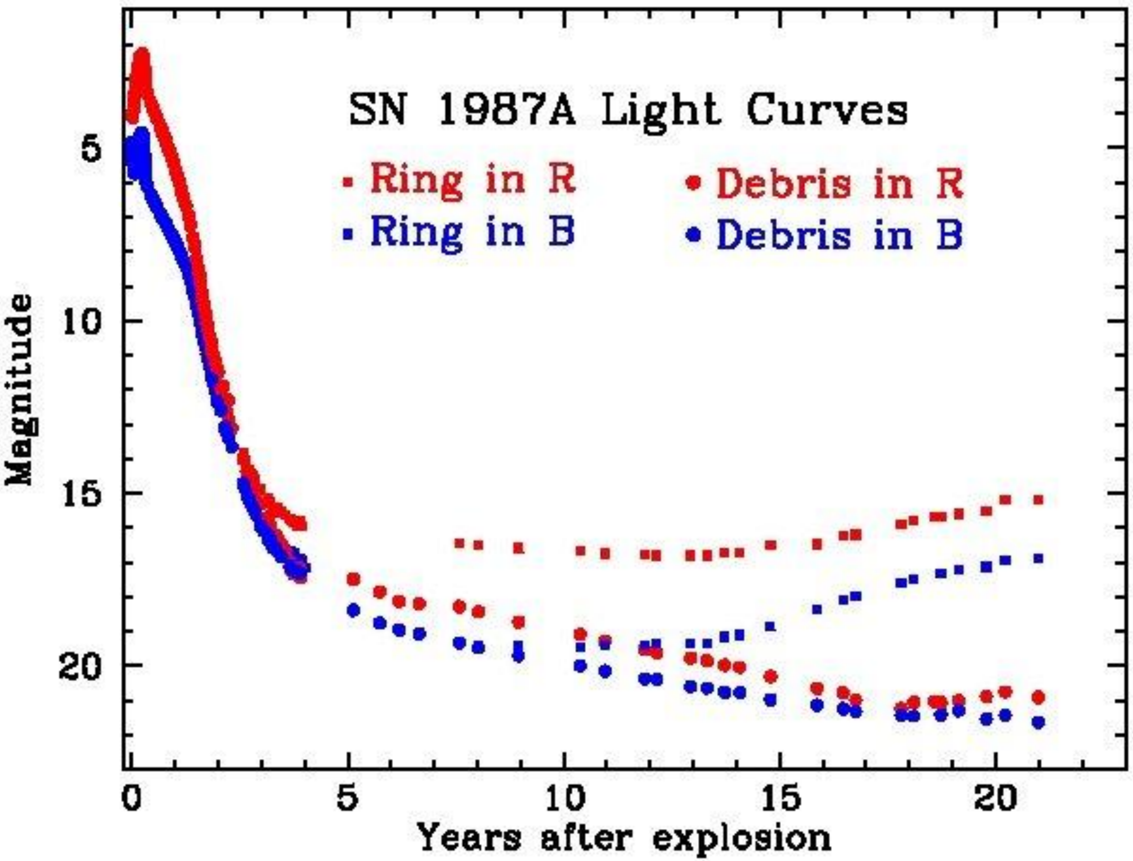
Note rapid rise in luminosity at Xray, mid-IR, radio starting near day 2000. Another increase In tempo at ~ 6000days.

Note also big gap in mid-IR observations between ~2000 and 6000 days.
GEMINI and VLT effect



Elongation of ejecta in plane of ring or perpendicular to plane?

Central dark patches due to obscuration by dust?



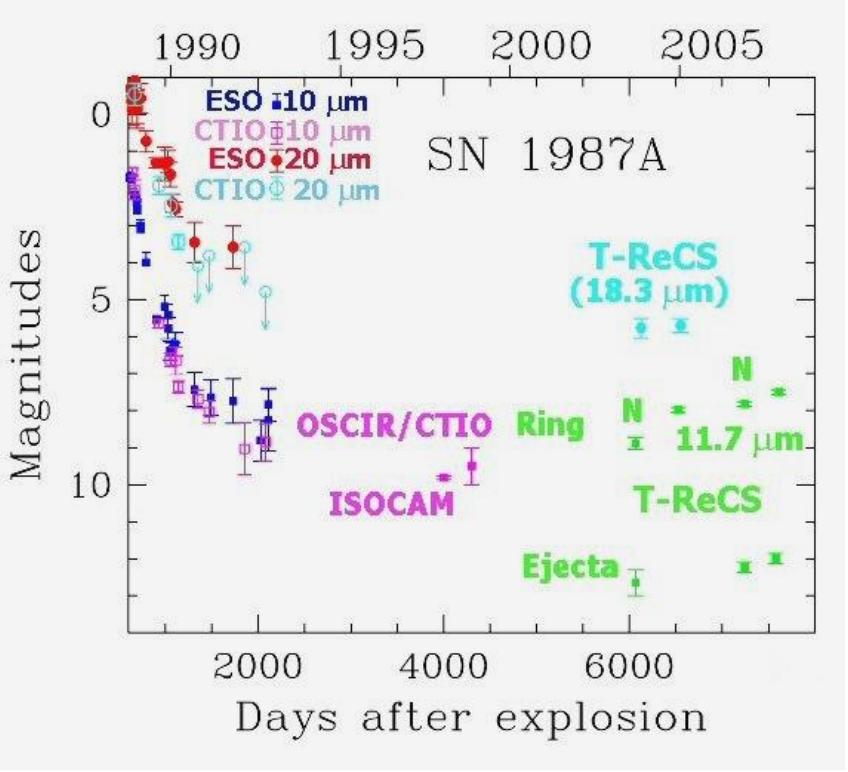
Light curves for Ring and debris. See next for IR.

Ejecta-Ring interaction.

Debris (difficult to measure?)

Slope 5-15 years too steep to mimic 44Ti decay.

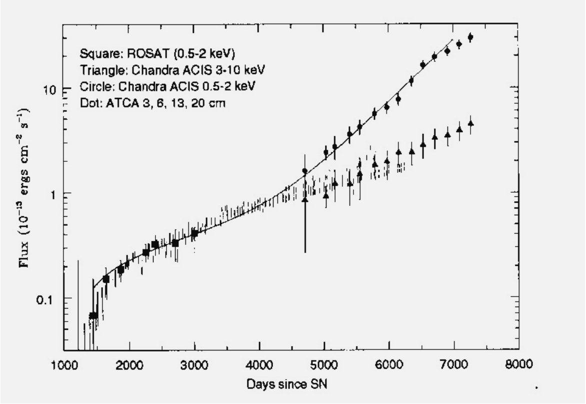
MidIR Light Curves Only

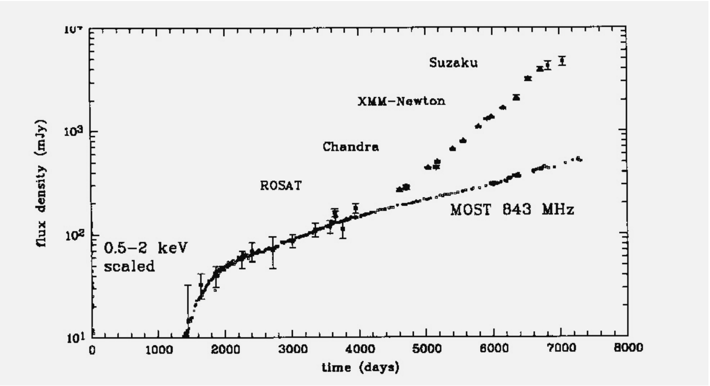


Note ejecta detected after day 6000 and increasing a little with time. Also seen In optical.

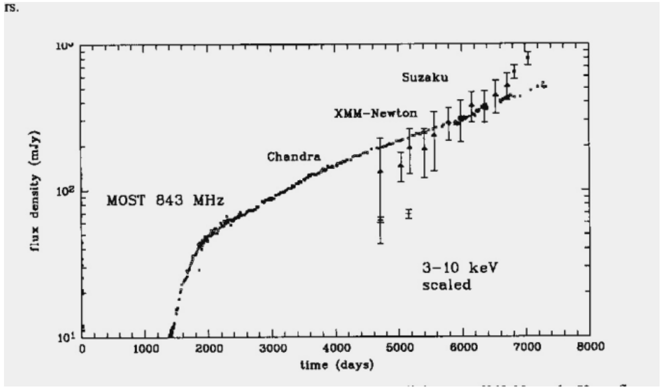
Hard & Soft Xrays, ATCA Radio

Soft Xrays, MOST low freq.Radio





Hard Xrays, MOST low freq. Radio



Thus Light curves for radio, hard Xrays, and soft Xrays all differ from each other implying different mecanisms and places of origin.

Also Chandra hard & soft Xray images clearly differ.

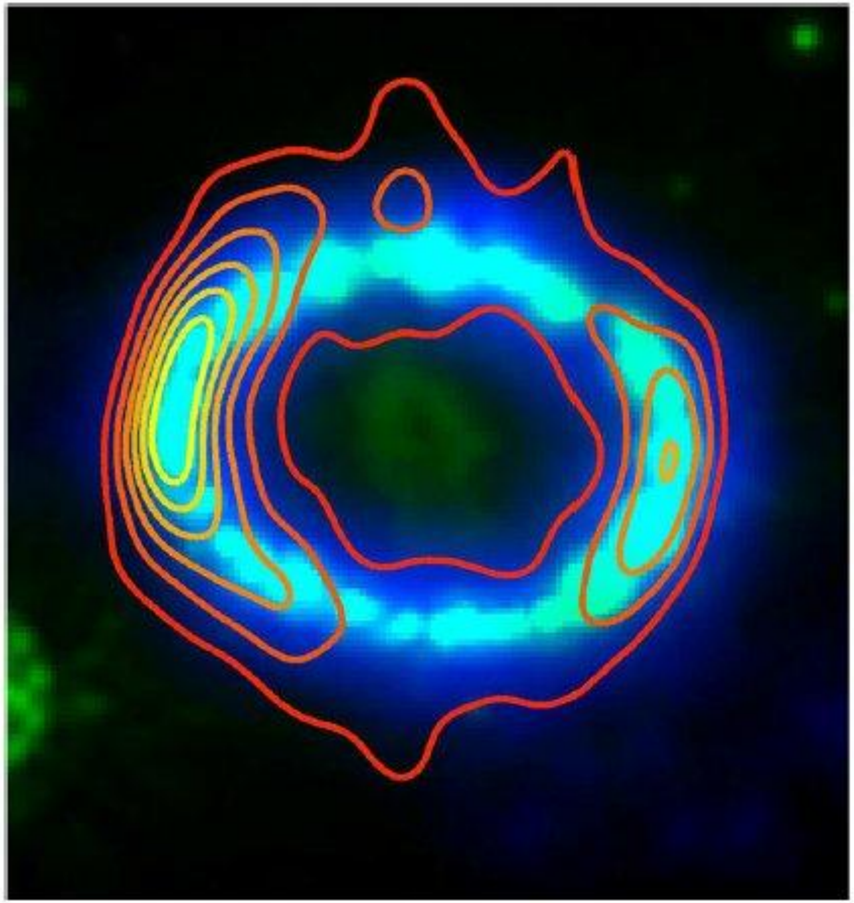


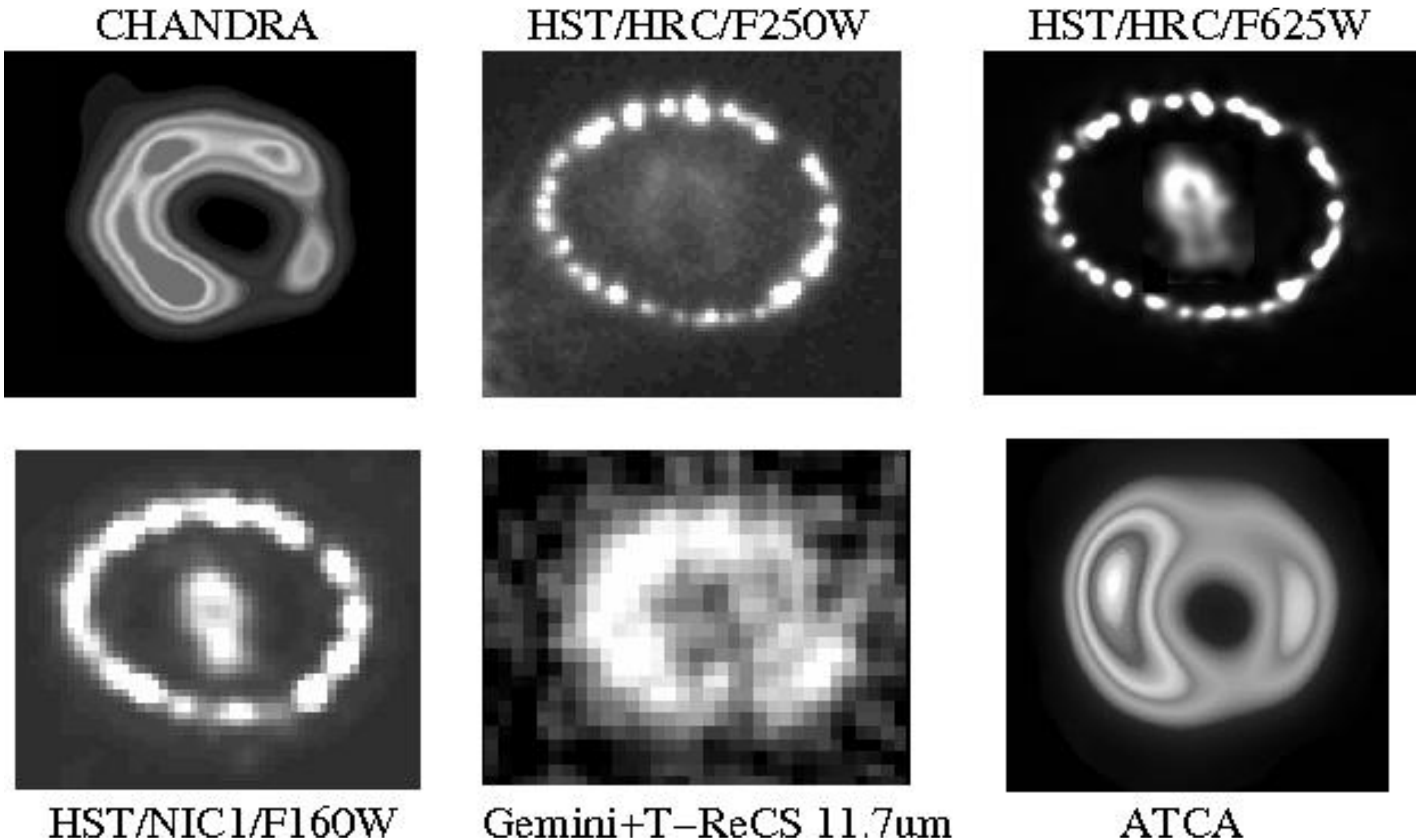
Figure 9. Overlay of the combined *HST* 2006 December 6 optical (green), *Chandra* 2008 January 9–11 X-ray (blue), and ATCA 2008 October 36.2 GHz radio images (orange-yellow contours) formed by shifting the optical and X-ray coordinate systems to center on the radio ring from the 2008 October 36.2 GHz radio image at robust = 0.5 weighting. Radio contours are at 14 (orange), 30, 40, 60, 70, and 85% (yellow) of the maximum at 2.4 mJy beam^{-1}. The outermost contour and the contour within the optical ring are at the same 14% level.

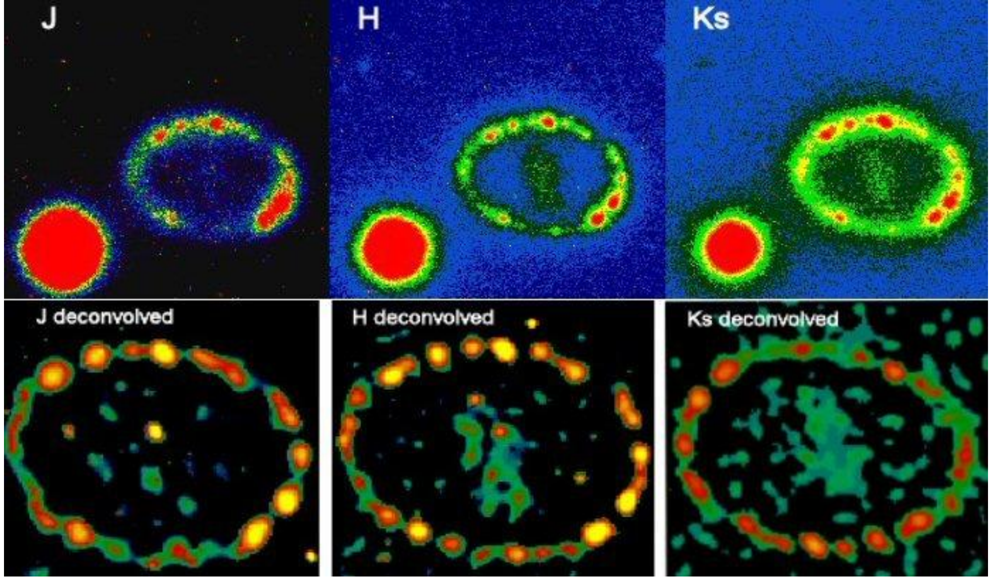
A comparison of images at Different wavelengths.

Green: HST optical
Blue: Chandra all energies
Orange-yellow: ATCA 36.2 GHz

Extension of radio above and below ring caused by radio extending polar-wise out of plane of the ring

Hint of possible central source (not shown here).


CHANDRA
HST/HRC/F250W
HST/HRC/F625W
HST/NIC1/F160W
Gemini+T−ReCS 11.7um
ATCA

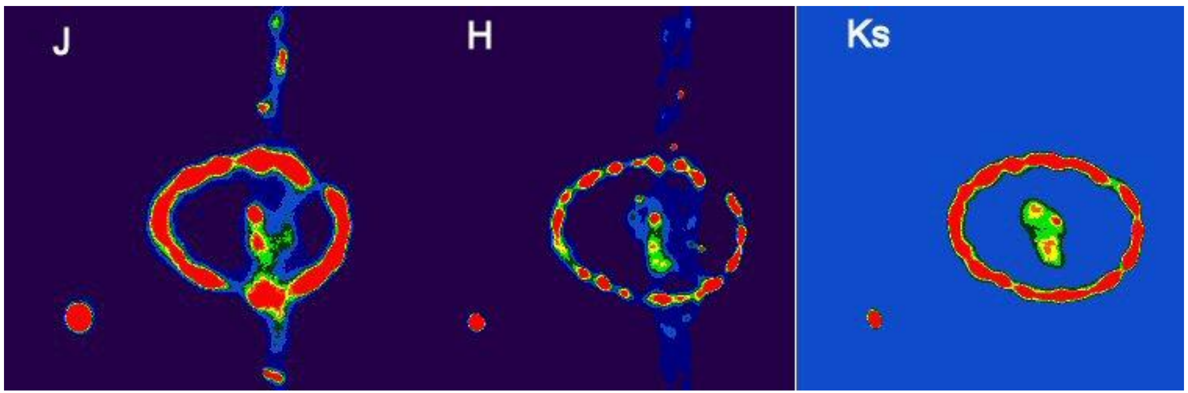


VLT NACO

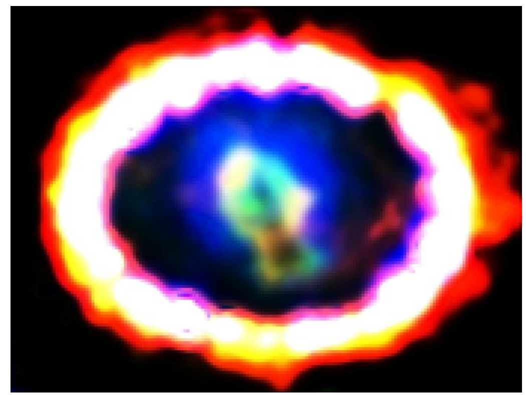
adaptive optics

original

Deconvolved
Max.Entropy

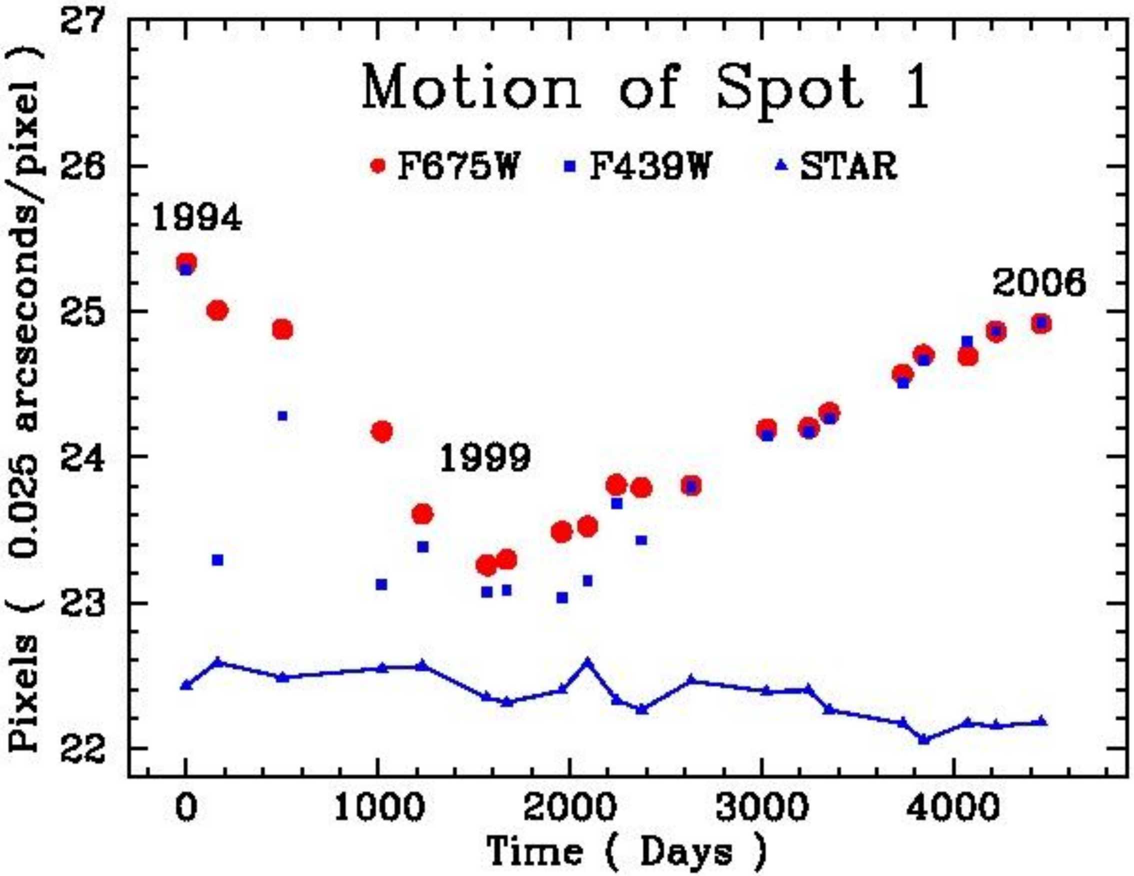


HST



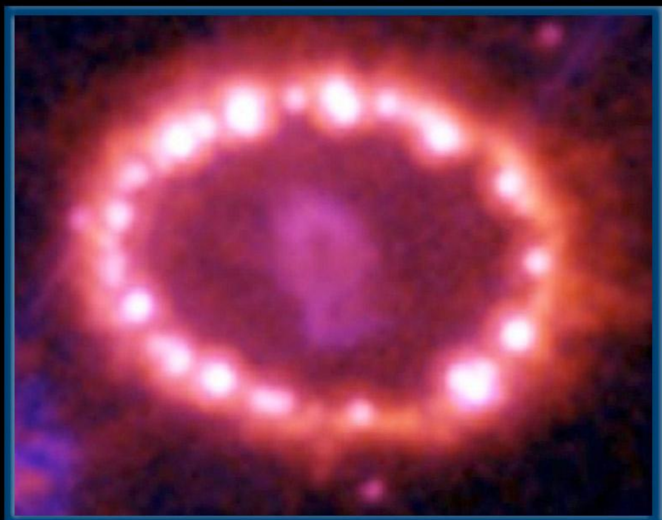
Ejecta:Note shape, intensity, some
real hot spots?

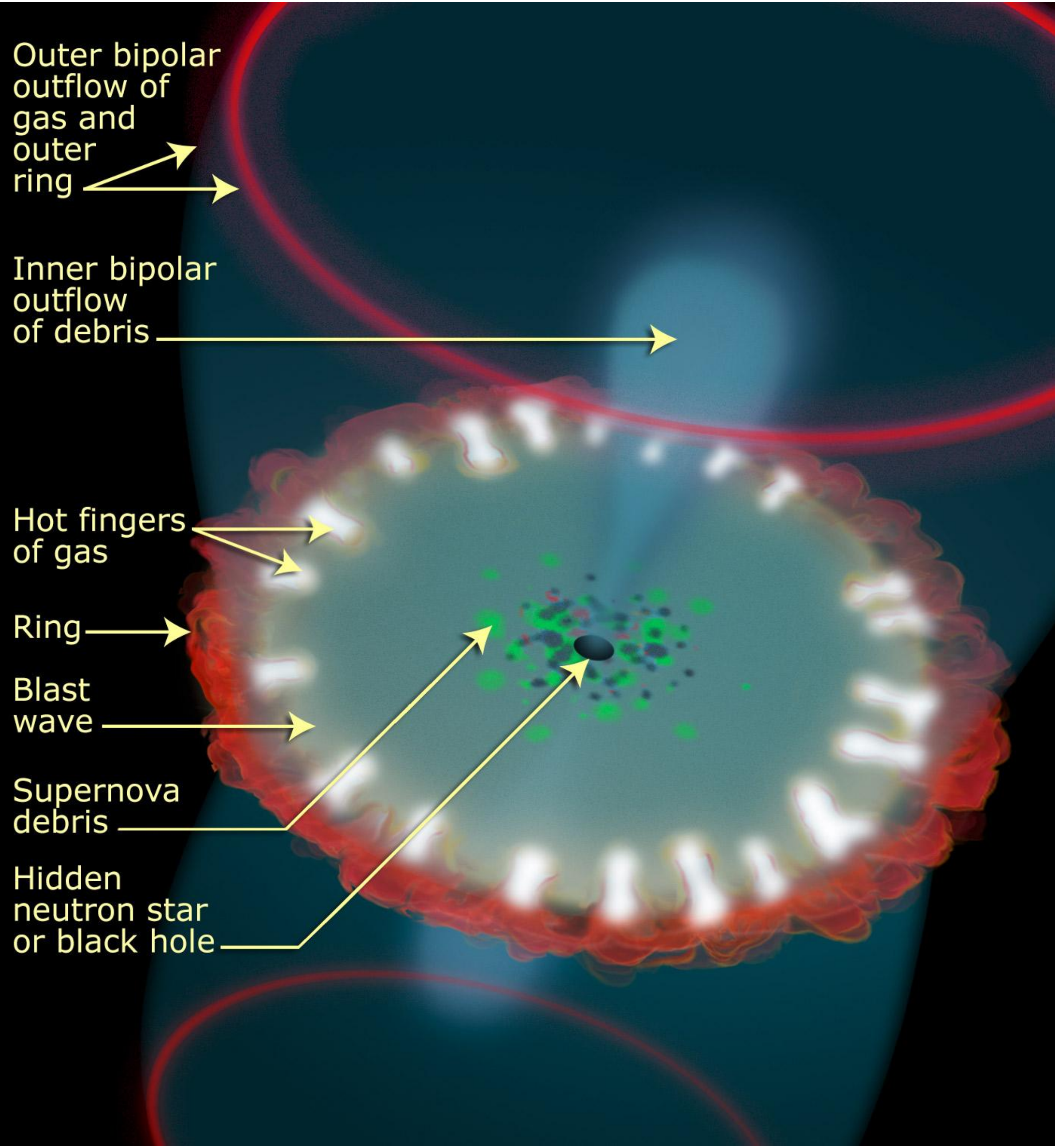
Where is the ejecta dust located? Diameter 0.3 arcsec?



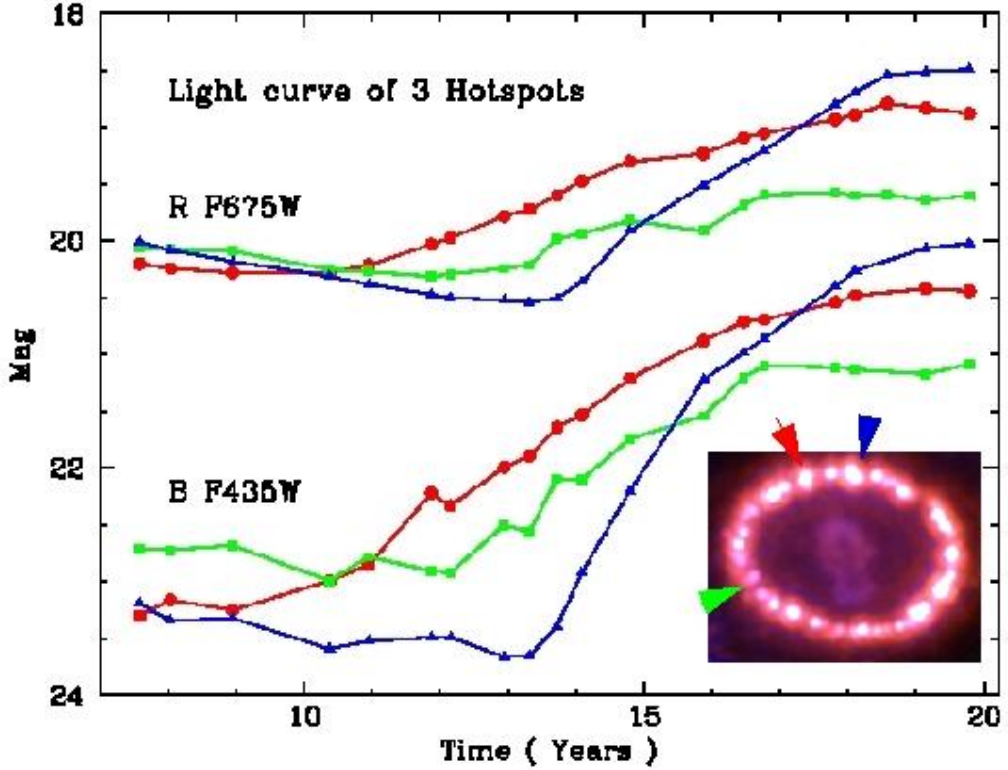
Probably not actual motion but change of position of maximum excitation of cylindrical shaped spots.

Inner debris of the Supernova 1987A (SN 1987A) ring



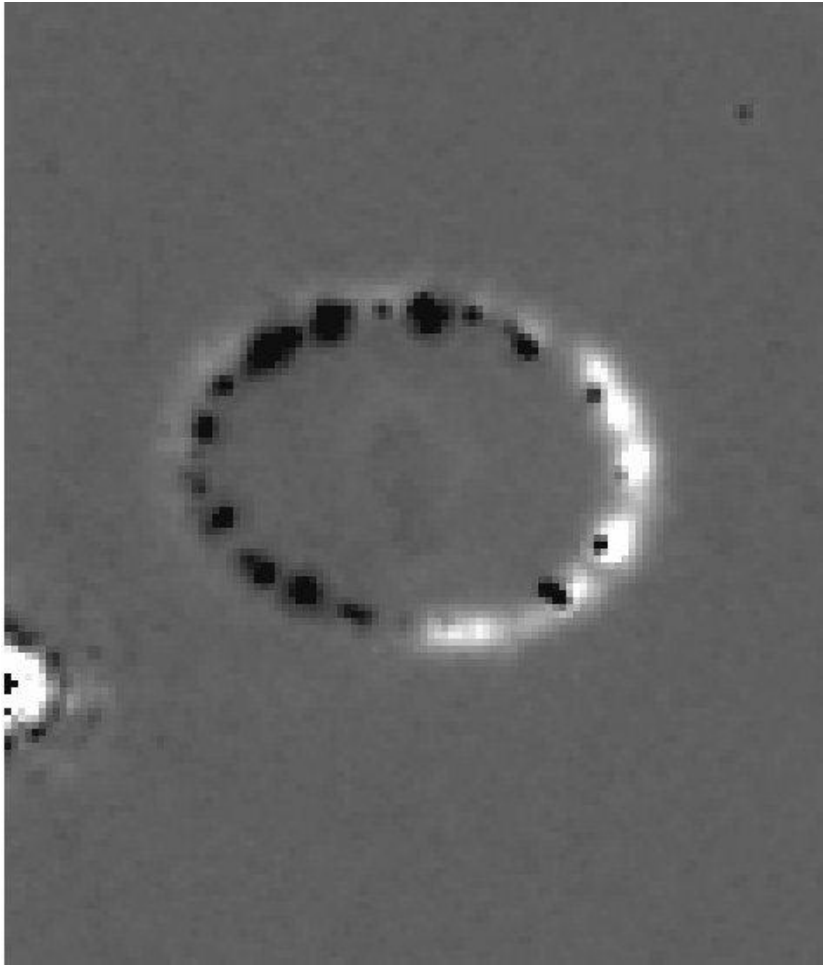


Light curves of 3 spots indicated.



Spot brightnesses seem to have reached a maximum.

Spot Development

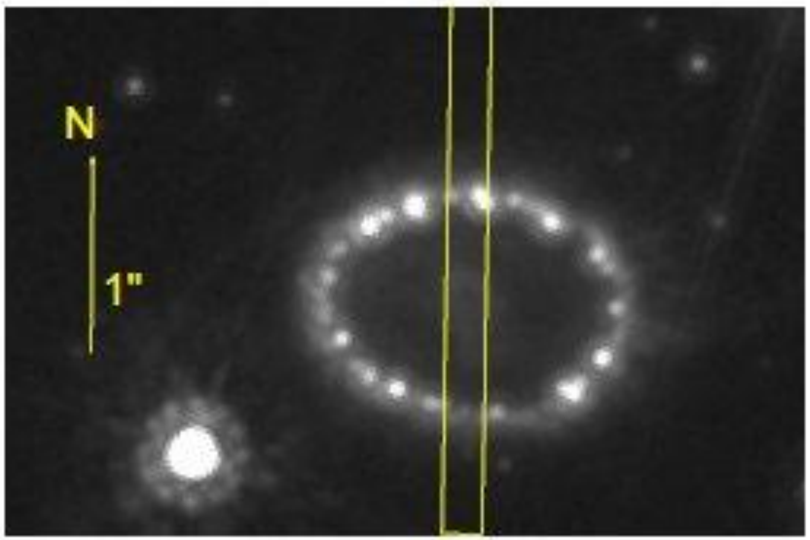


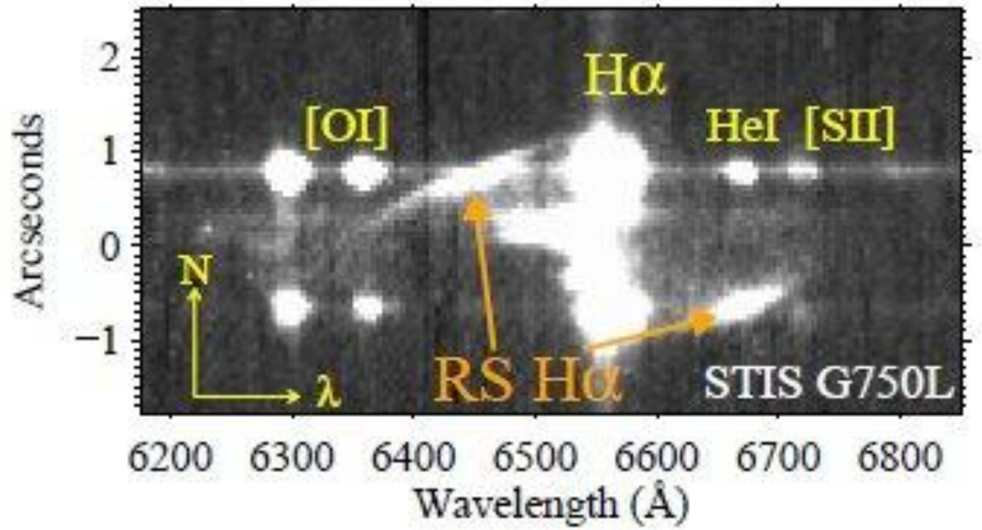
Difference image
Jan.,2010 – July,2004.

White - brightening
Black - fading

Systematic effect not explained but also occurs for mid-IR

Recent STIS Spectra





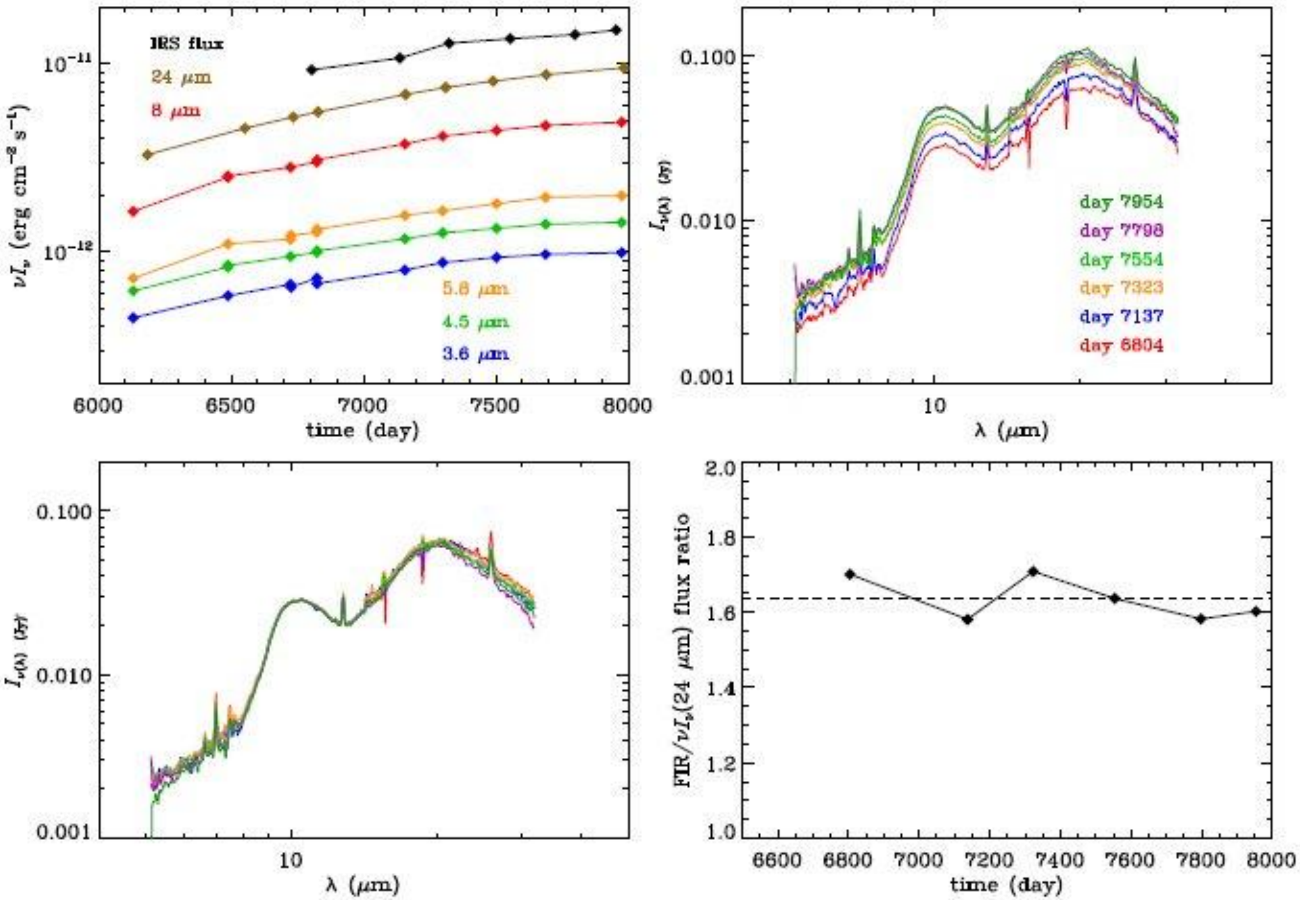
Spectral region around Halpha.
RS marks reverse shock extending to 20000km sec^{-1}
Maximum brightness just inside ring.
Reverse shock extends out of equatorial plane of ring.
French et al. In press.

What we do not know.

1. The point source at the centre.
2. Single or binary progenitor.
3. Orientation of the asymmetric debris.
4. The mass of radioactive 44Ti.
5. Nucleosynthesis of most other elements.
6. Ring spot structure and shape.

END

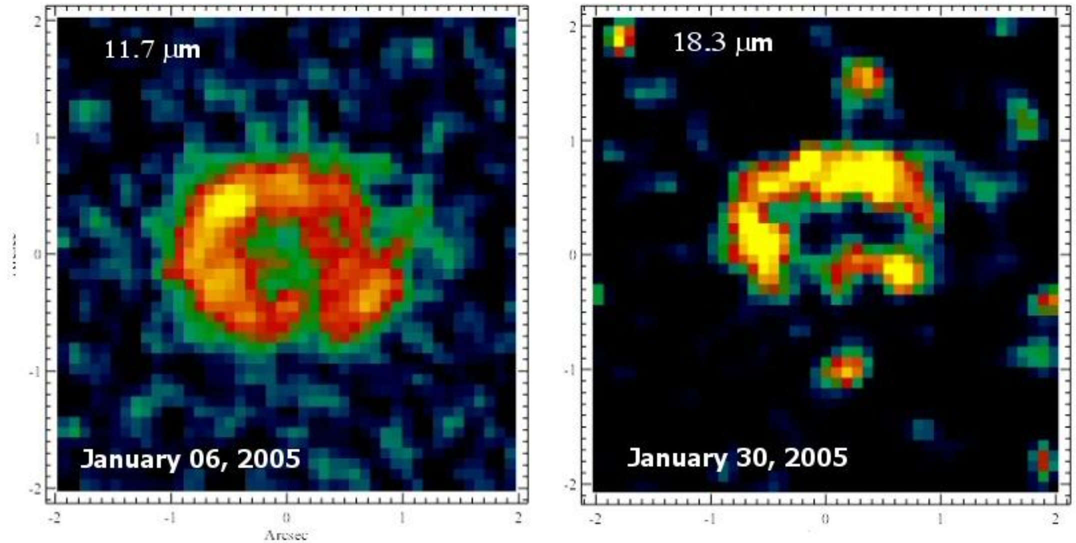
Temporal variations of Ring emission



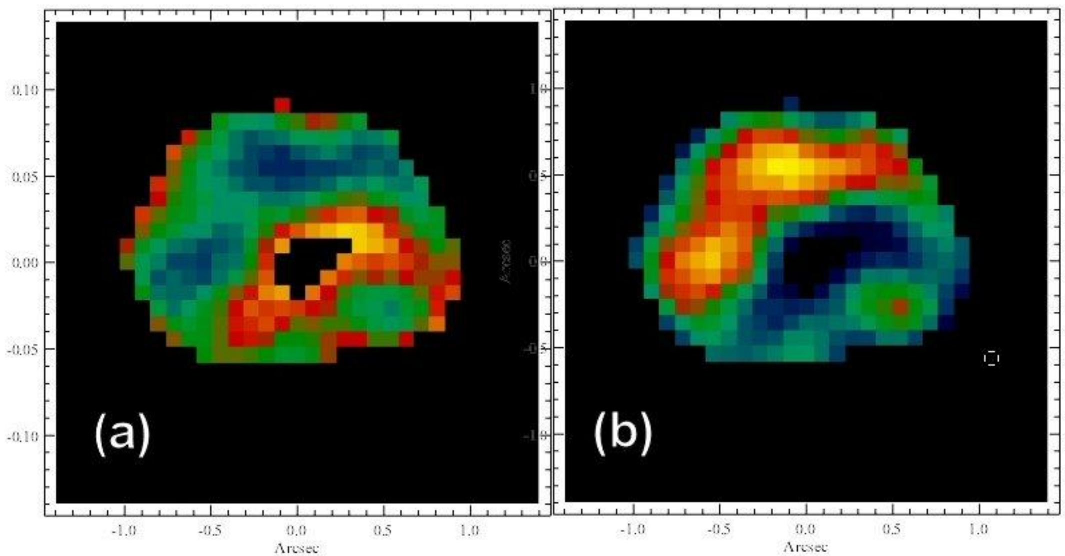
Note no change
In ratio of fluxes
of primary to
secodary
component.

Flux ratio
no change
in Temp. or
density.

MidIR imaging



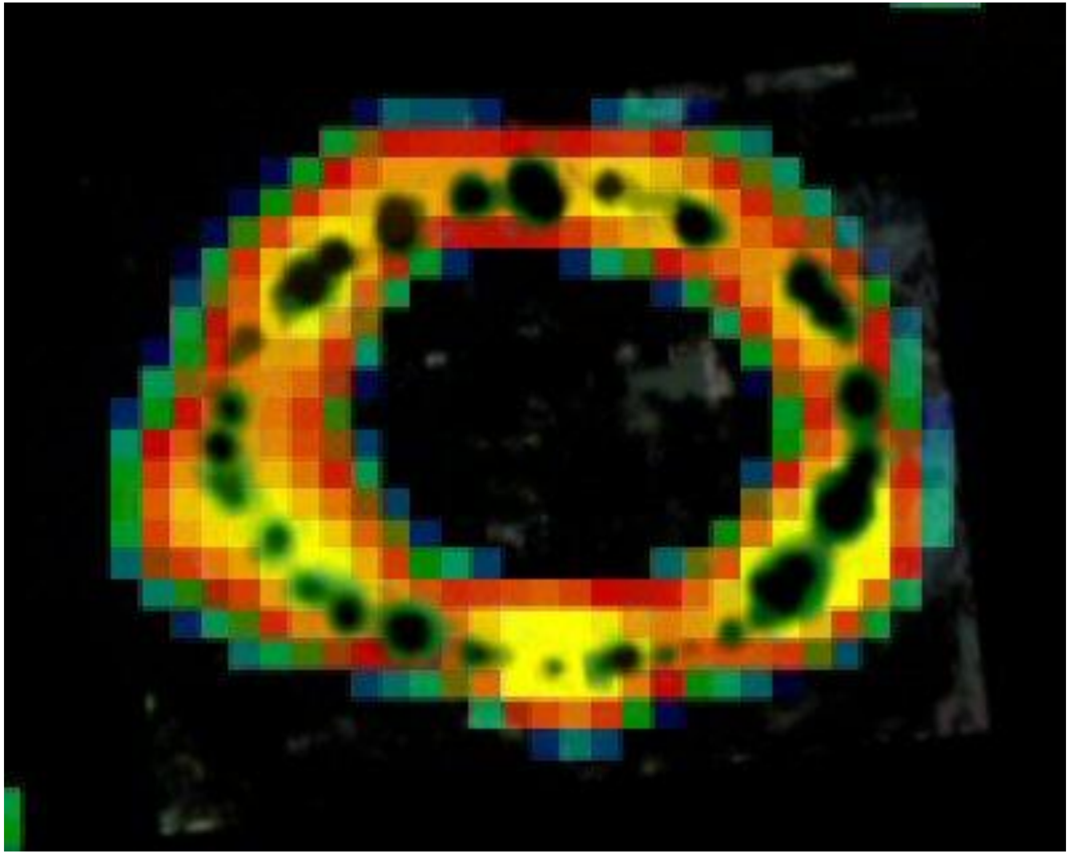
Note differences between 11.7 and 18.5❍ images leading to variations of T and emission ♦ (very small) across the image.



Average temperature of ring 180K.

Temperature Emission Optical Depth

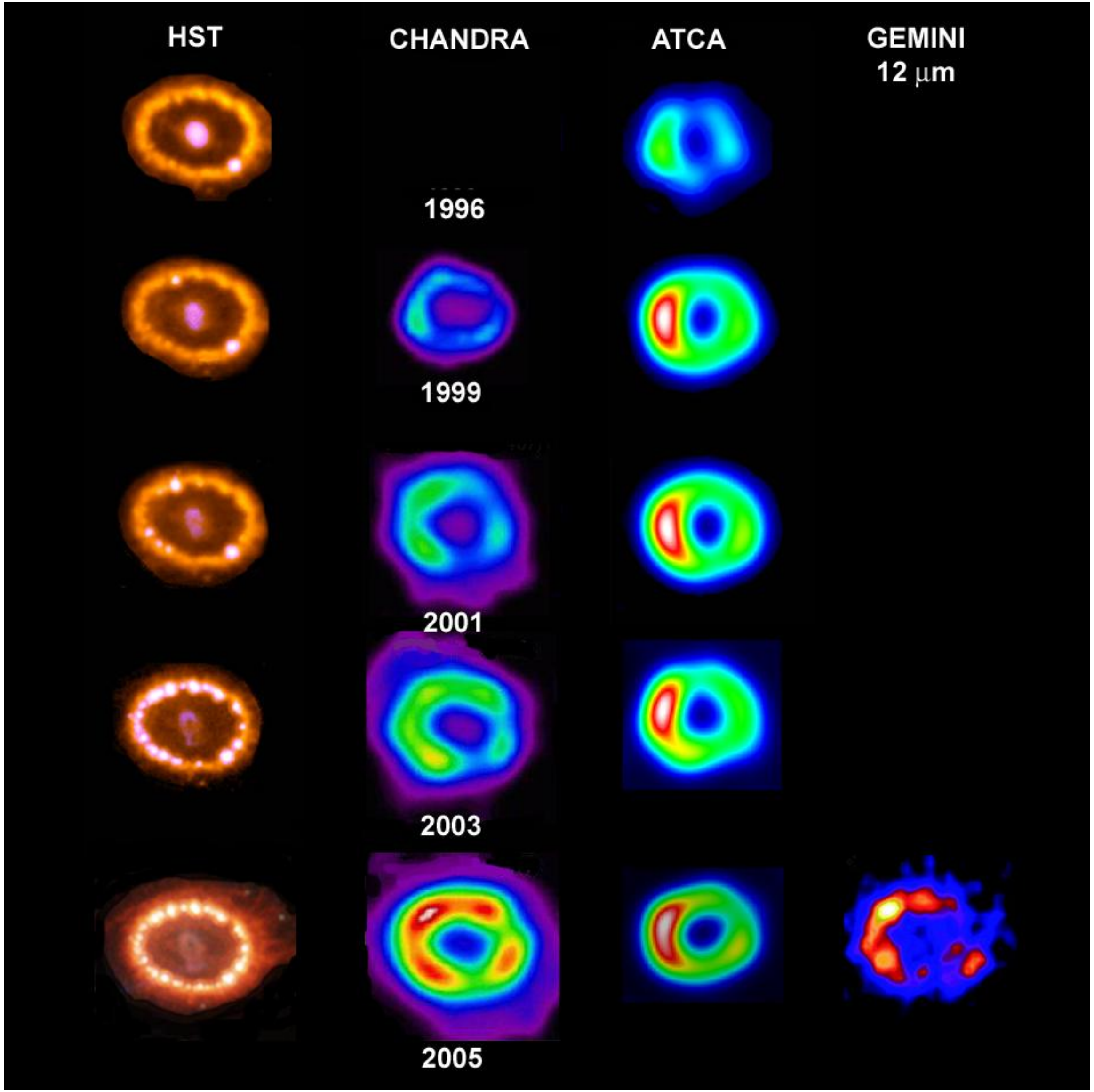
HST vs VISIR (VLT)

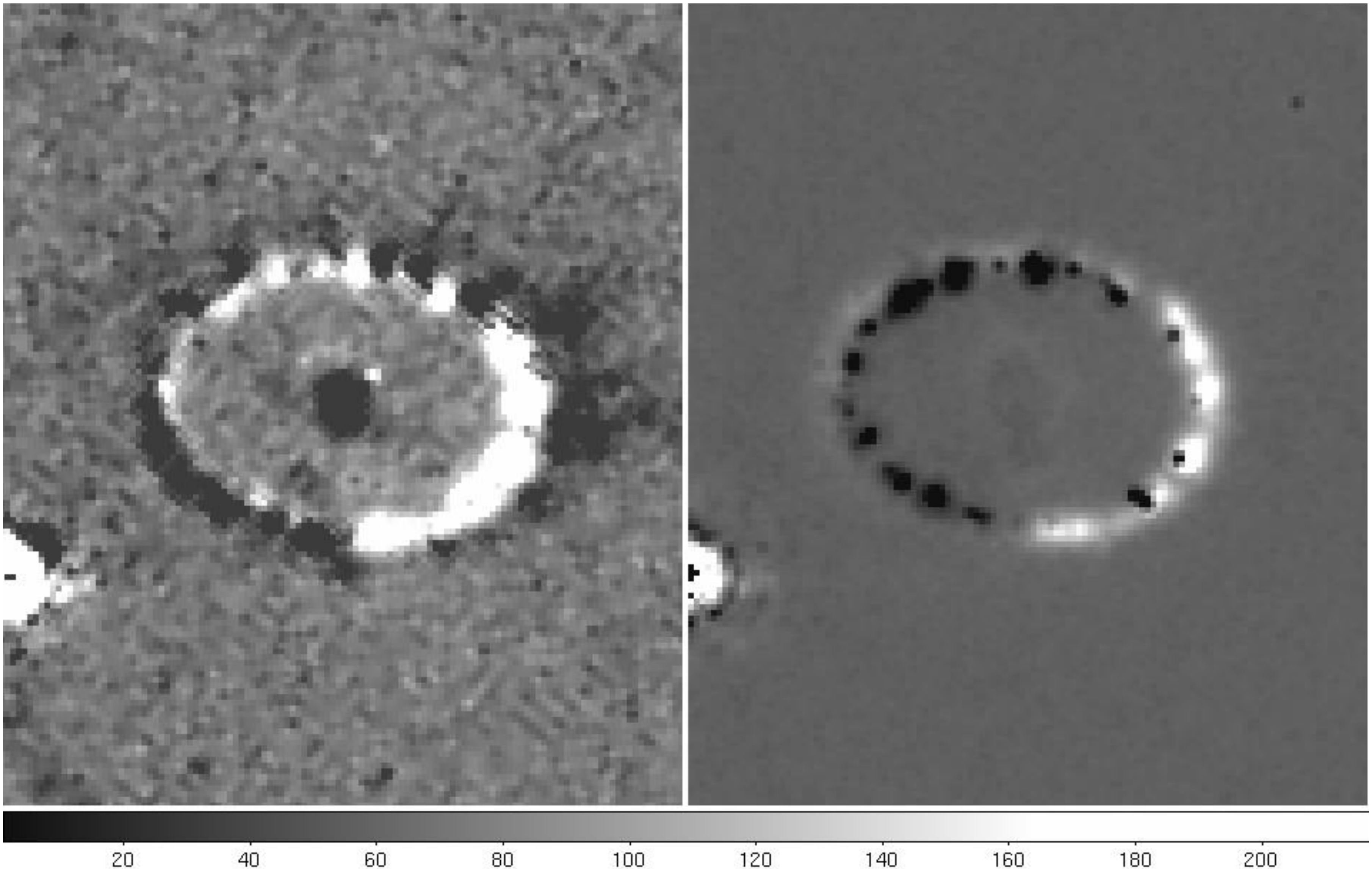


Overlay of HST (Dec2006) (black) with VISIR (red-yellow) shows correlation far from 100 percent!

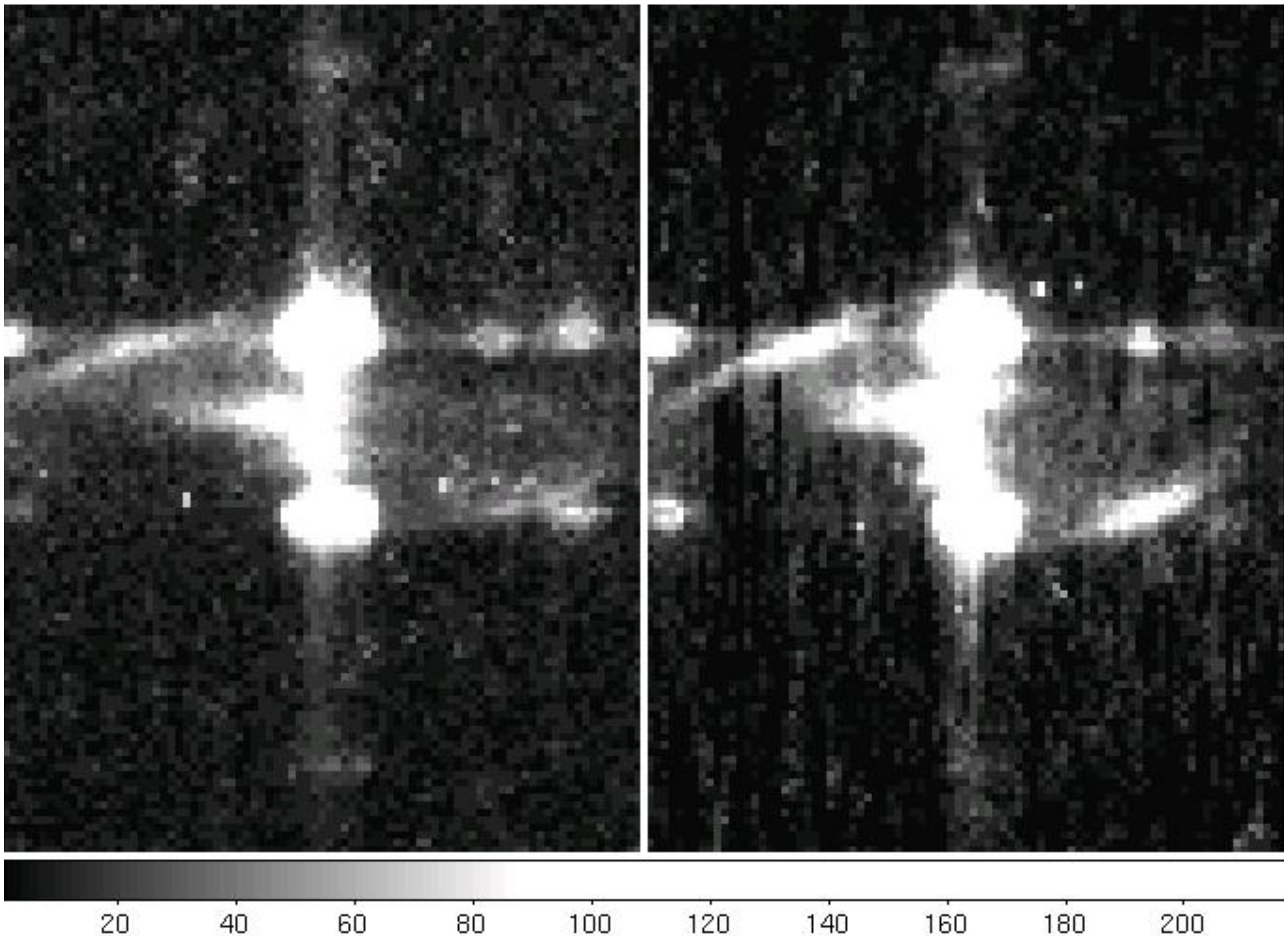
Other comparisons show dust annulus possibly (?) thicker than visual HST annulus.

Temporal evolution at different wavelengths



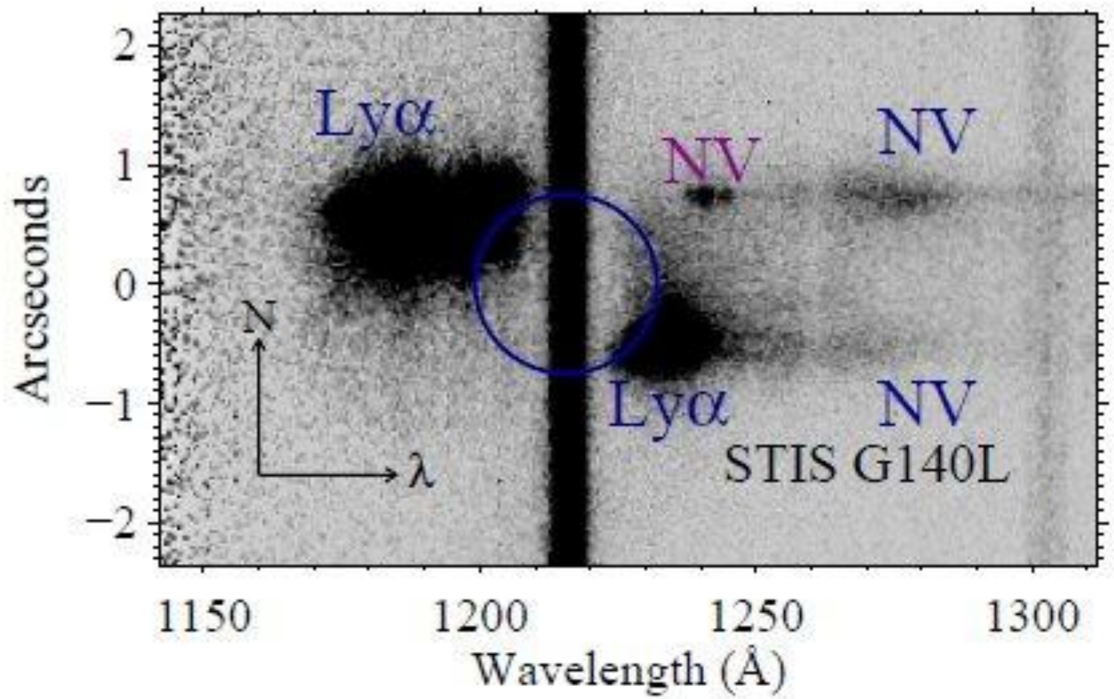

20
40
60
80
100
120
140
160
180
200

Recent STIS spectrum showing Halpha

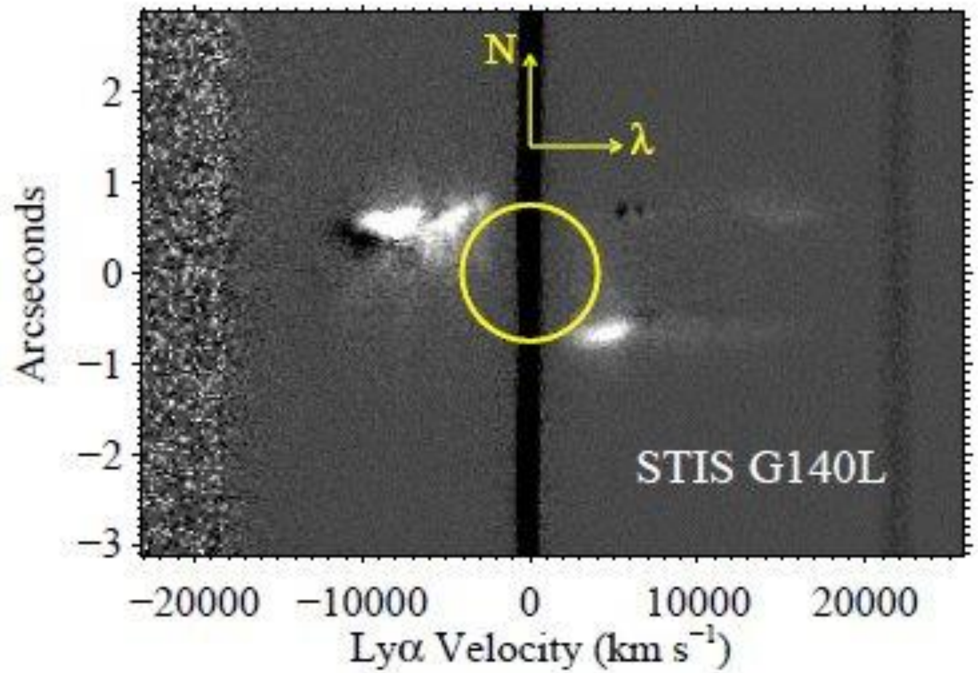


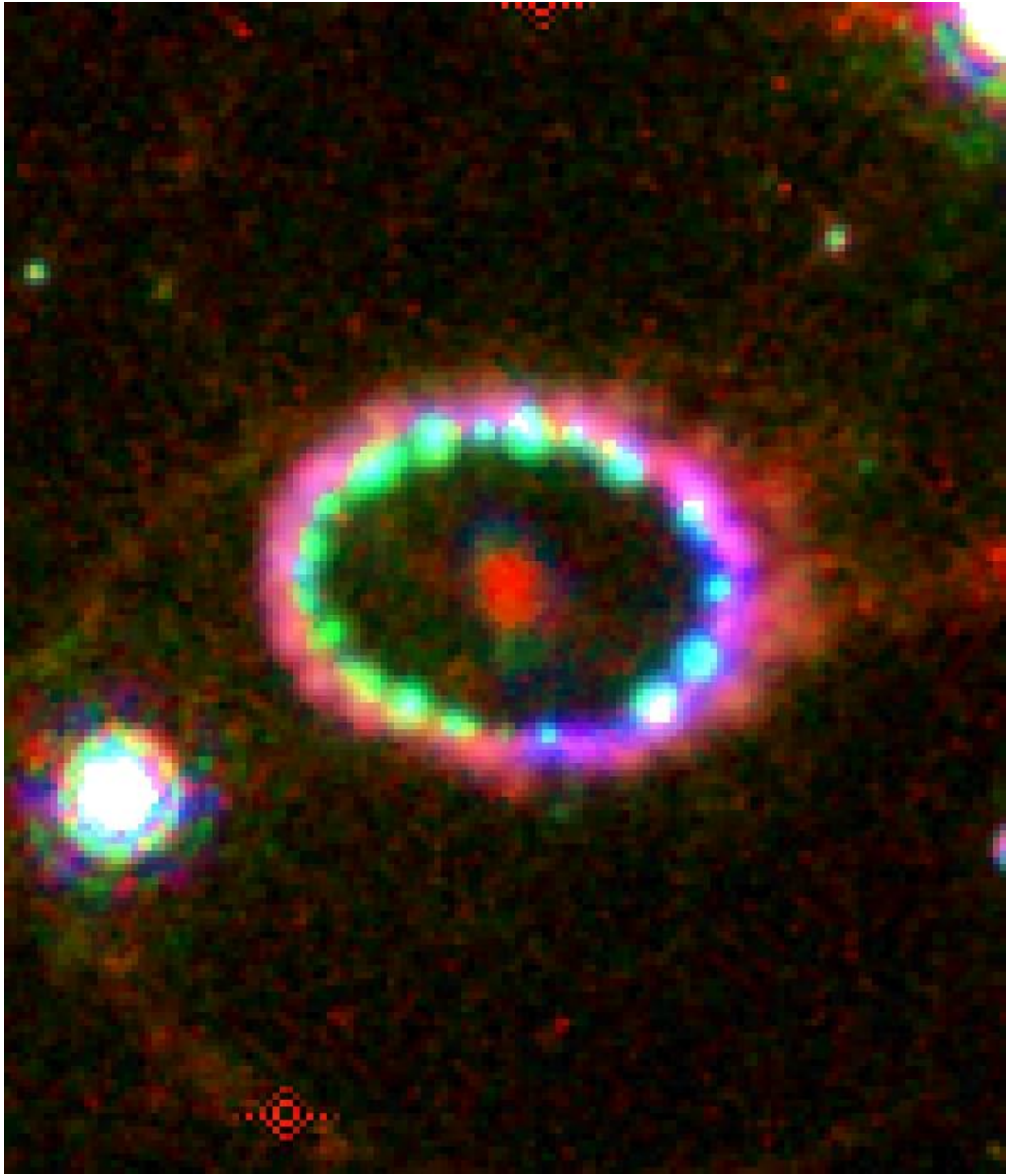
blue red

Central part (debris) shows blue (approaching) Extending to ~4000 km/s. Red extension not apparent.
Dust in ejecta?



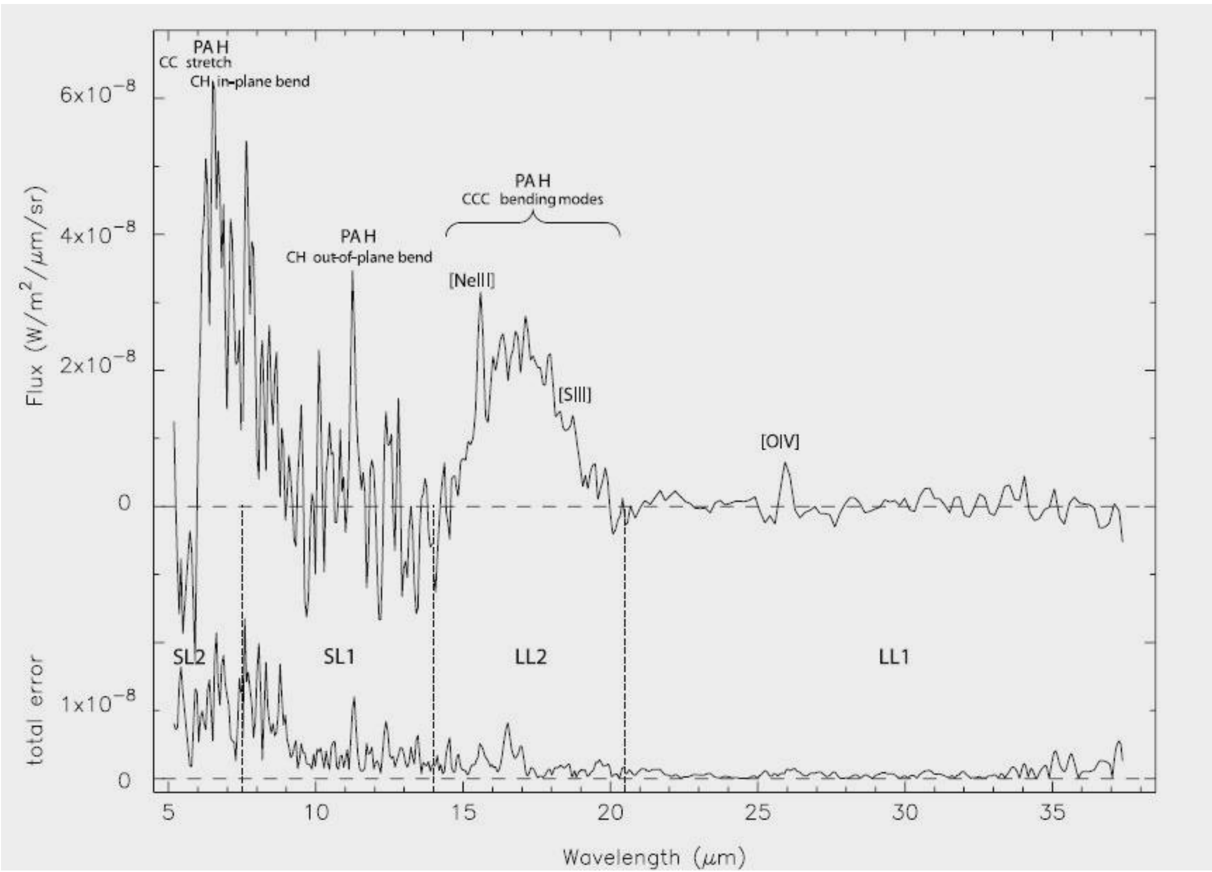
Lyα
NV
NV
Lyα
NV
N
λ
STIS G140L
Arcseconds
Wavelength (Å)


N
λ
STIS G140L
Arcseconds
2
1
0
−1
−2
−3
−20000
−10000
0
10000
20000
Lyα Velocity (km s^{-1})

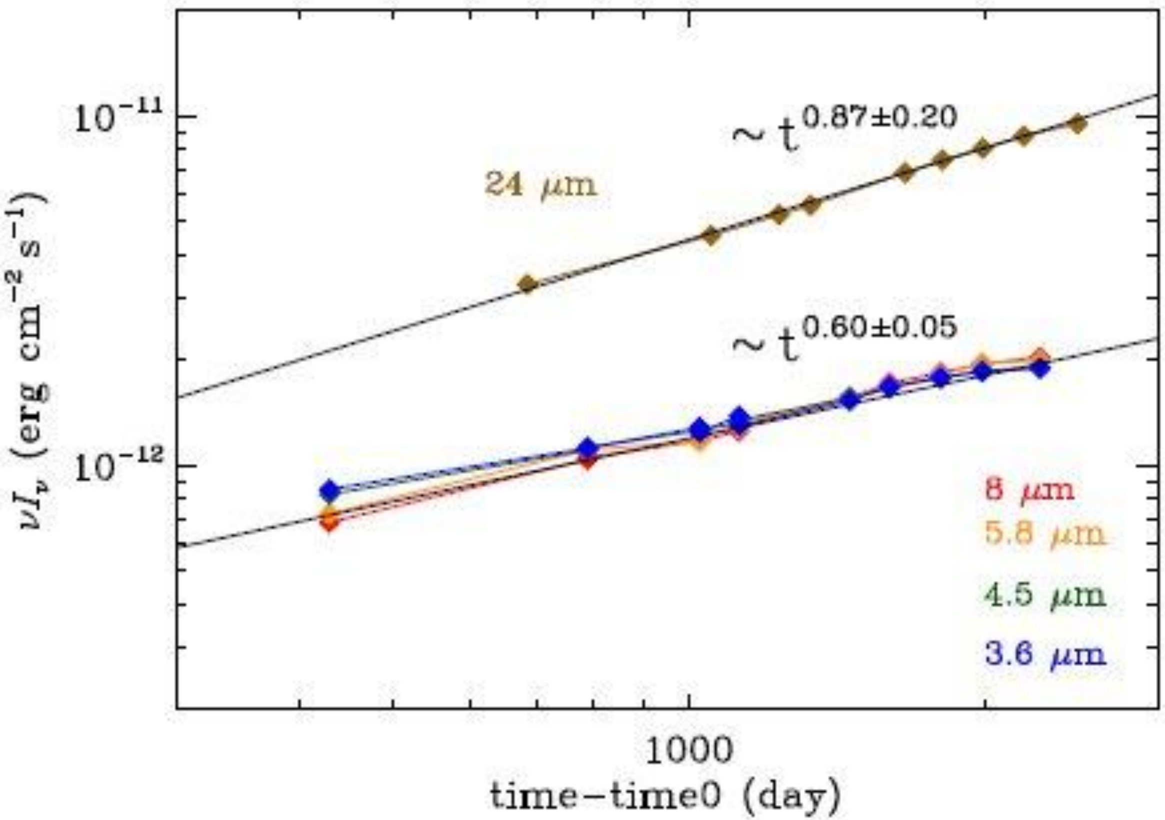


A future development in SN1987A?

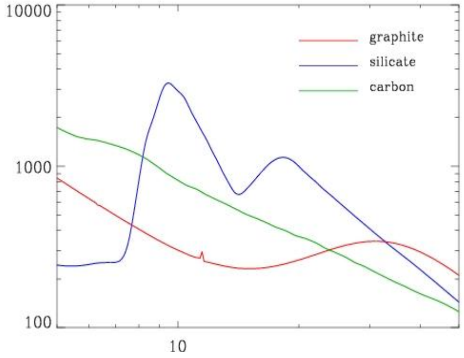
N132D young O-rich SNR in LMC



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



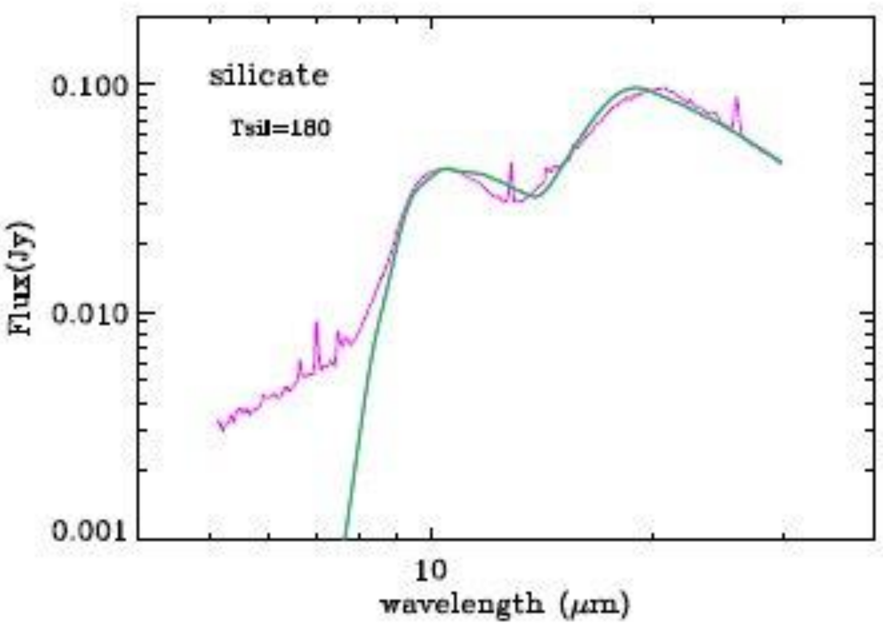
$\sim t^{0.87\pm0.20}$
24 μm
$\sim t^{0.60\pm0.05}$
8 μm
5.8 μm
4.5 μm
3.6 μm
10^{-11}
10^{-12}
νI_ν (erg cm^{-2} s^{-1})
1000
time−time0 (day)



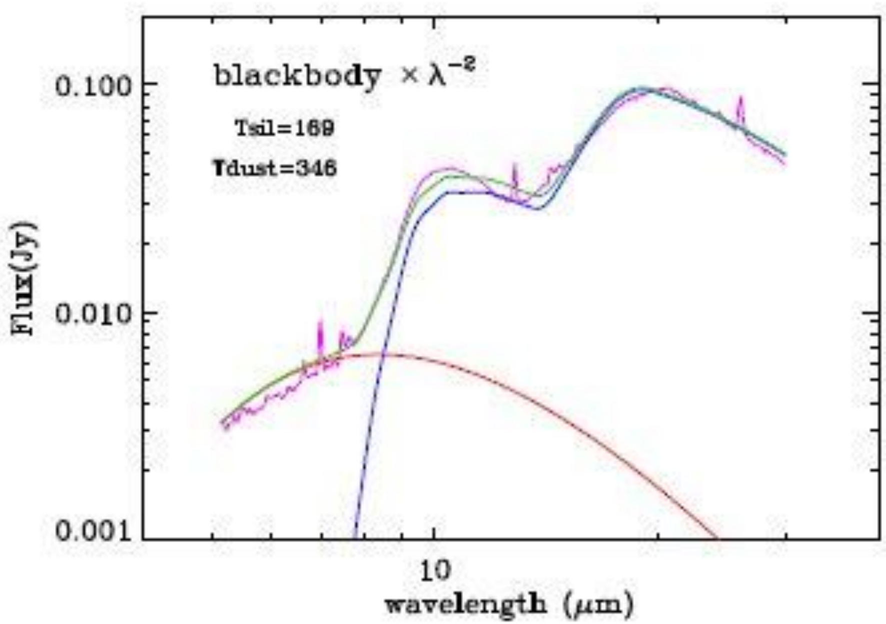
SPITZER

Grain absorption coeffs.

Silicates



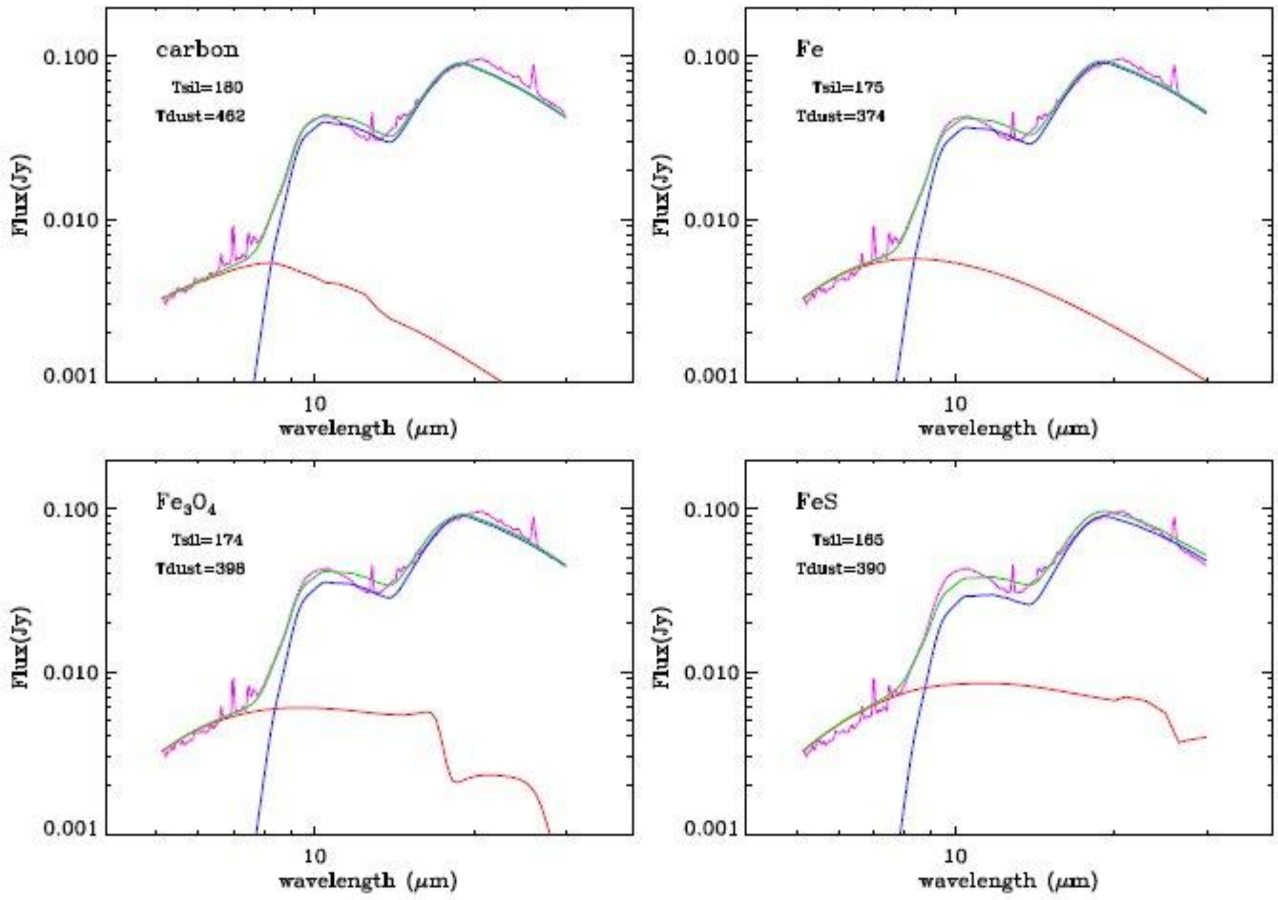
Silicates + Black body



No evidence for T ~400K in imaging photometry.
Not surprising!

Silicates + Carbon

Silicates + Fe (molecules)



IMAGES at Comparable Epochs