SN1987A – Unfinished Business

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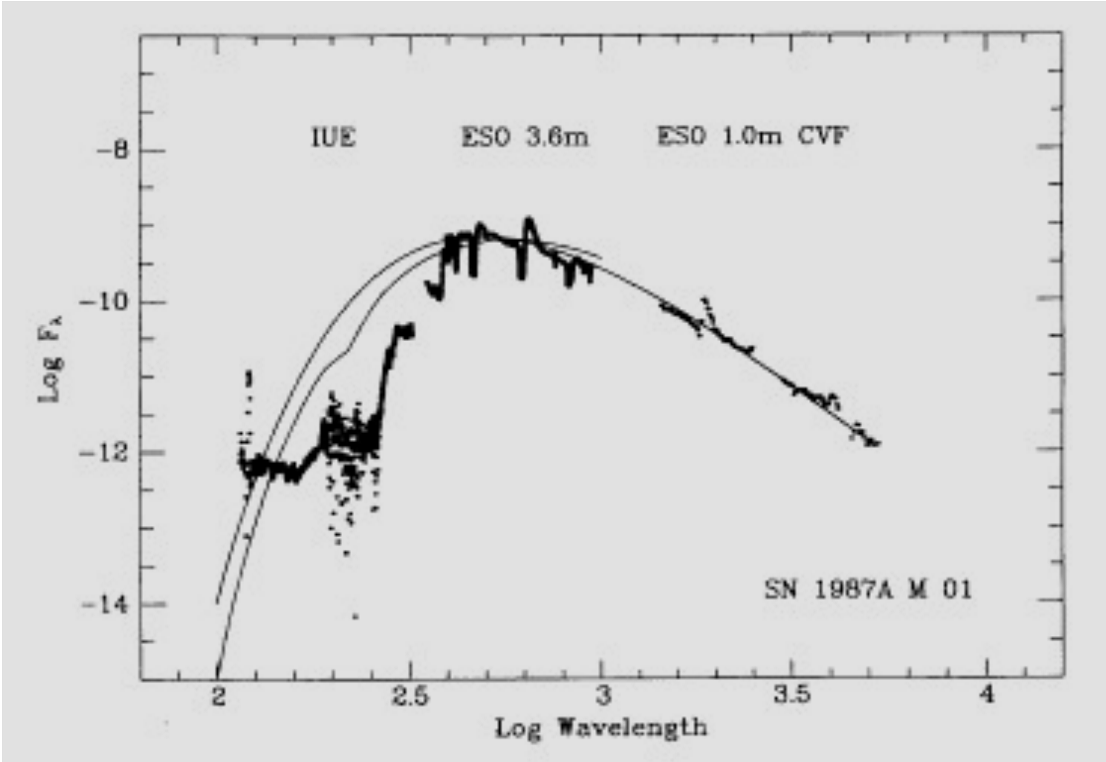
Vincent van Gogh
Arles, 1888.

Vincent van Gogh,
St.Remy, 1889.



Early full spectrum - Fosbury, Lucy etc.

Early spectra with spectrum modelling – line identification. Lucy, Fosbury etc.

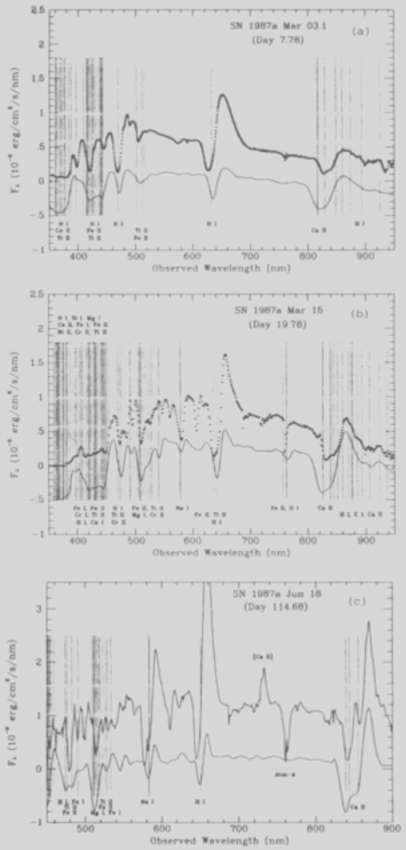
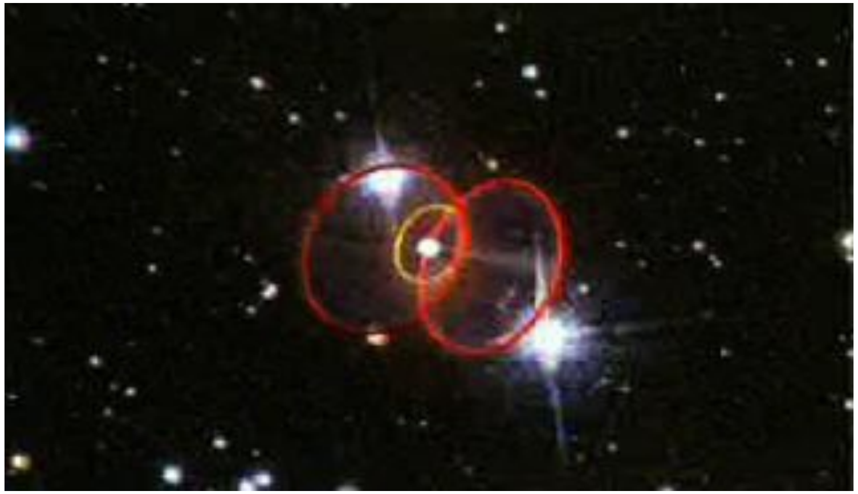


Figure 2: Comparisons between the observed and synthetic optical spectra on three dates: a) Mar 3, b) Mar 15 and c) Jun 18. Vertical indicators mark the computed positions of the absorption centroids of lines which have absorption trough equivalent widths in excess of 1 *nm* in the computed spectra All the ions which contribute lines of this strength are marked. For Mar 3 and 15, only lines with $\lambda \geq 360\,nm$ are marked.

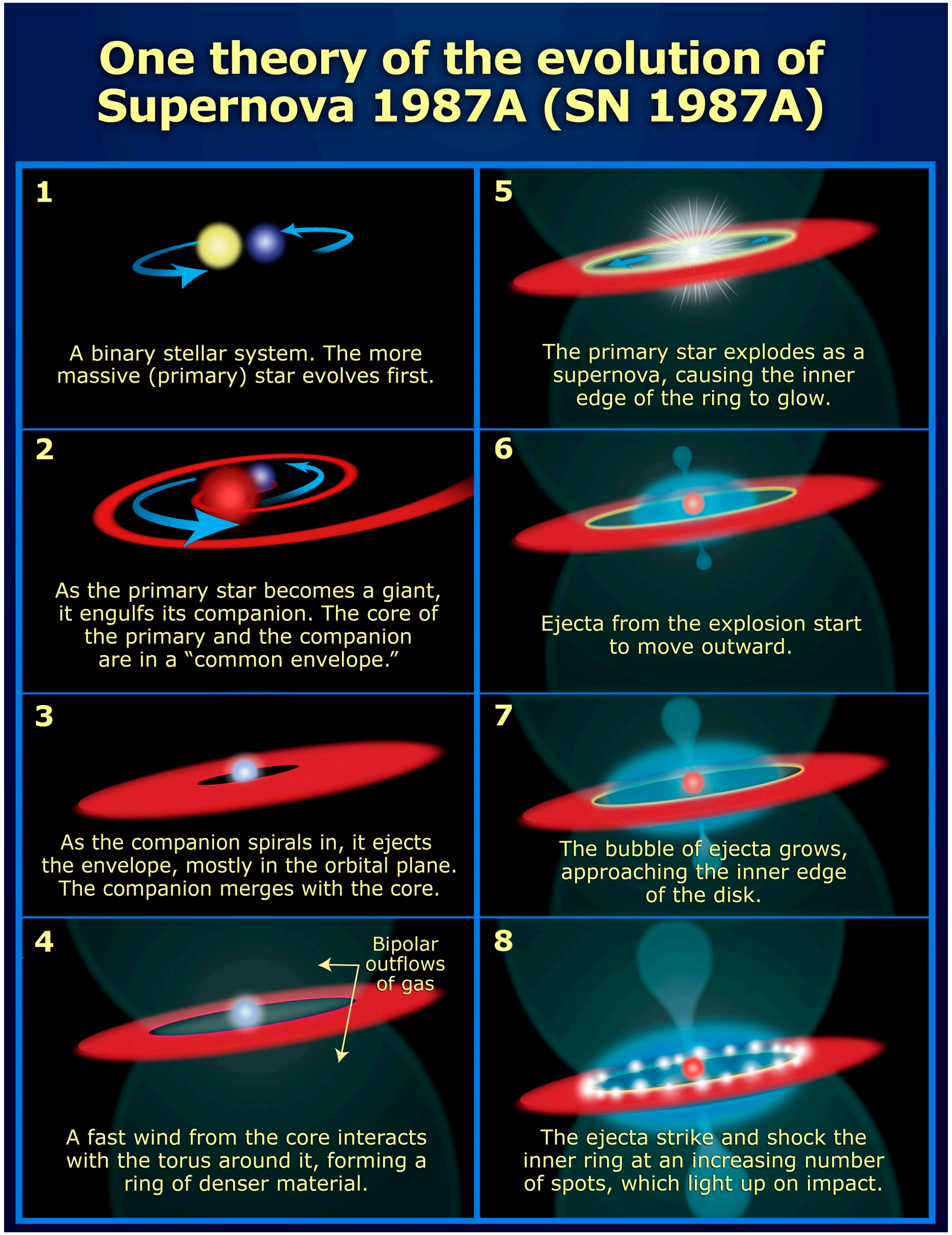
Some well established properties?

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, g -rays, Bol.LC)
4. Mass of Oxygen (~1.5Msun) - indirect
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, reverse shock).
8. Mass of dust in ejecta (~$3x10^{-4}$Msun).
9. Silicates a major component of ring dust.
10. Mass of visible dust in rings (~ 10^{-6}Msun).
11. Intrinsically faint radio burst during first few days.
12. Plus more!

The Remnant and Rings around SN1987A



Two progenitor theories
Binary star coalescence
Model Podsiadlowski et al.
Single rotating star
Model Langer et al.

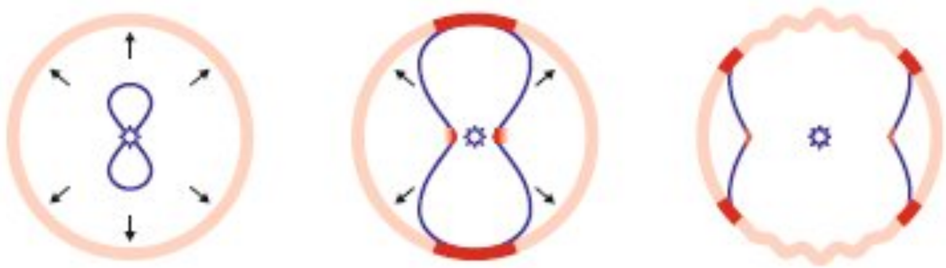


Podsiadlowski et al.

Binary – primary engulfs secondary -common envelope - secondary spirals in, merges - ejects common envelope - torus forms – merged star explodes.

Note elongation along axis perpendicular to plane.

Langer et al. 12Msun
single rotating star not
for SN1987A

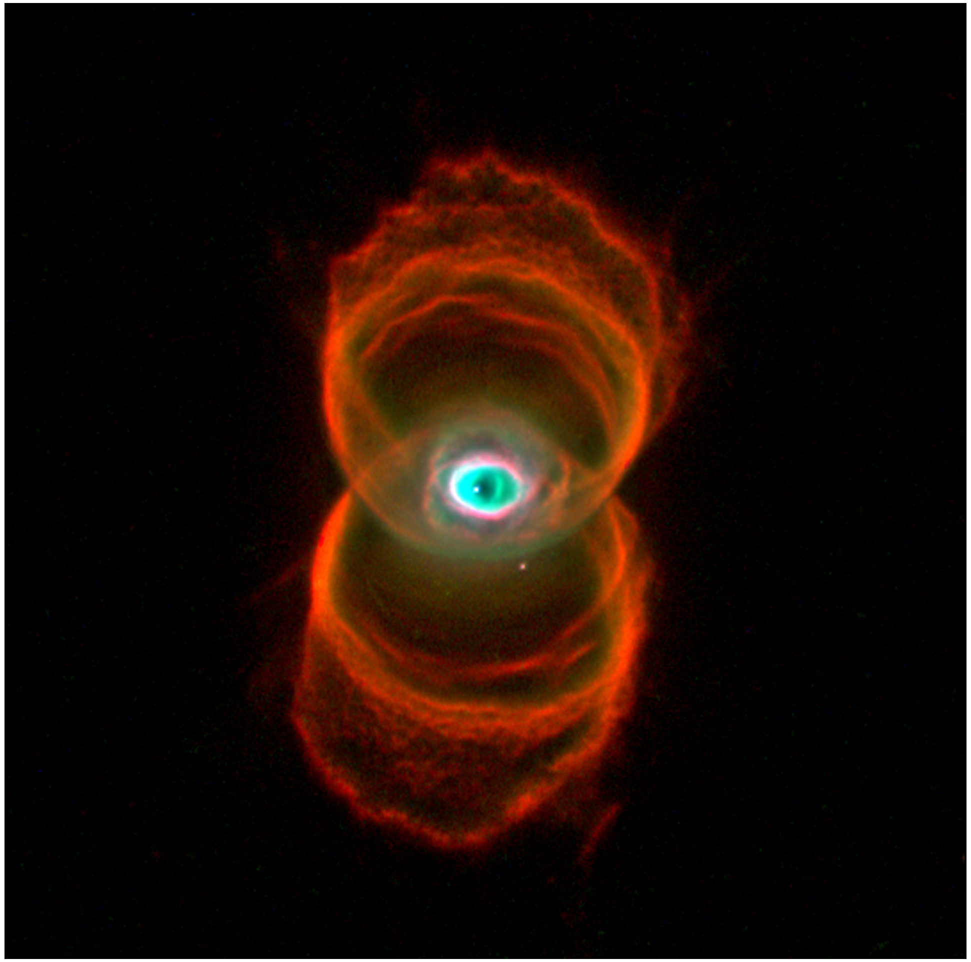


3 Winds

1. Blue Main Seq.: hot wind bubble
2. Red Supergiant: slow wind stalled by pressure of hot wind, creates stationary RSG shell.
3. Again blue SG: BSG wind creates 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

Example next

The Hourglass

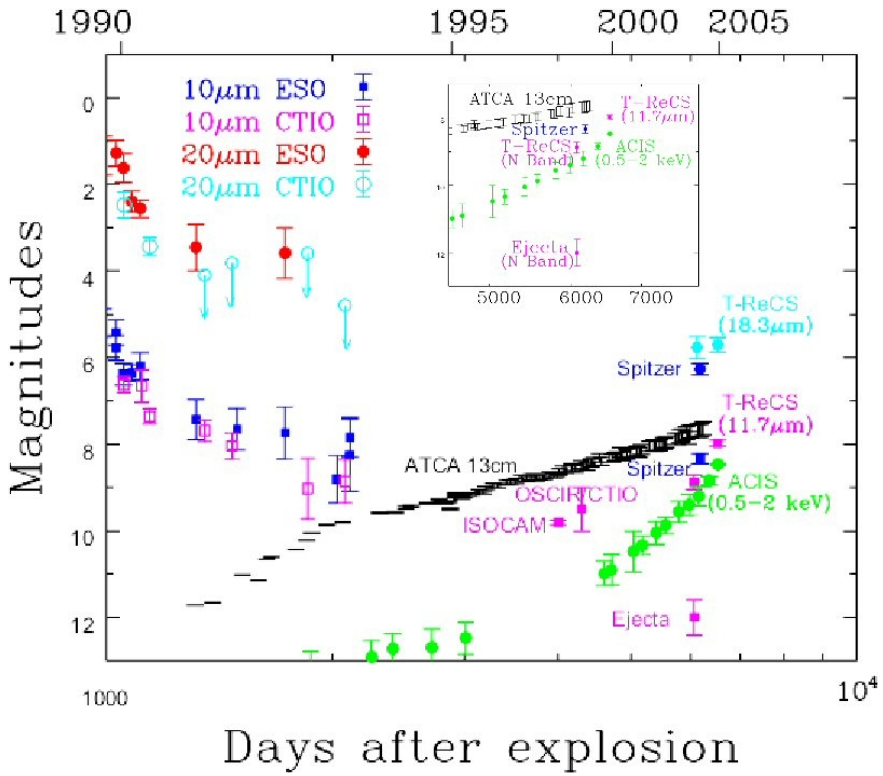


A well known PN imaged by HST.
rings apparent.

Bets allowed on which is correct

Kinetic Energy to Radiative by Shock Interaction in CSM

Light Curves at Various Frequencies

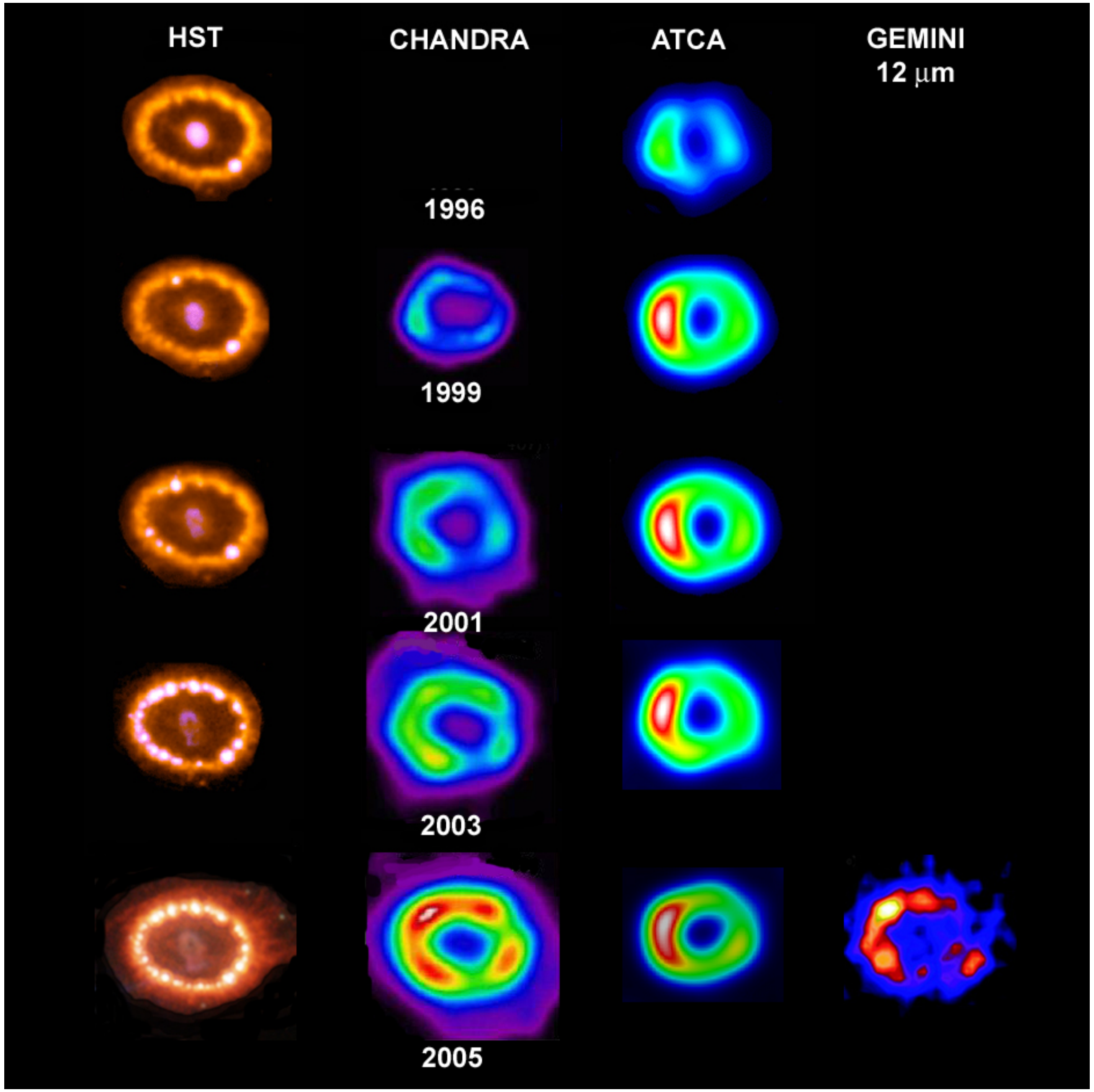


Note rapid rise in luminosity at Xray, mid-IR, radio starting near day 2000. Another increase In tempo at ~ 6000days.

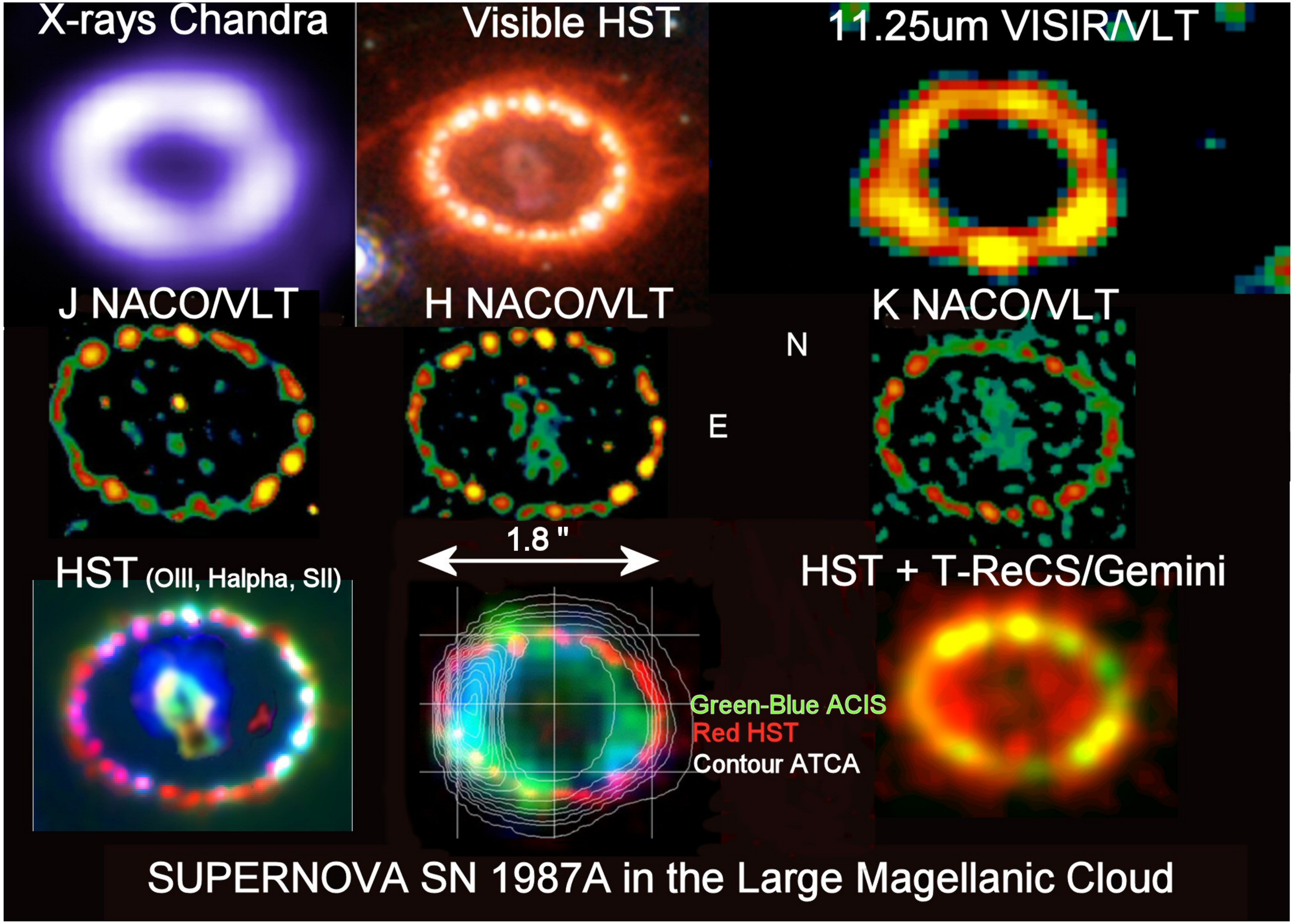
Note also big gap in mid-IR observations between ~2000 and 6000 days.
GEMINI and VLT effect

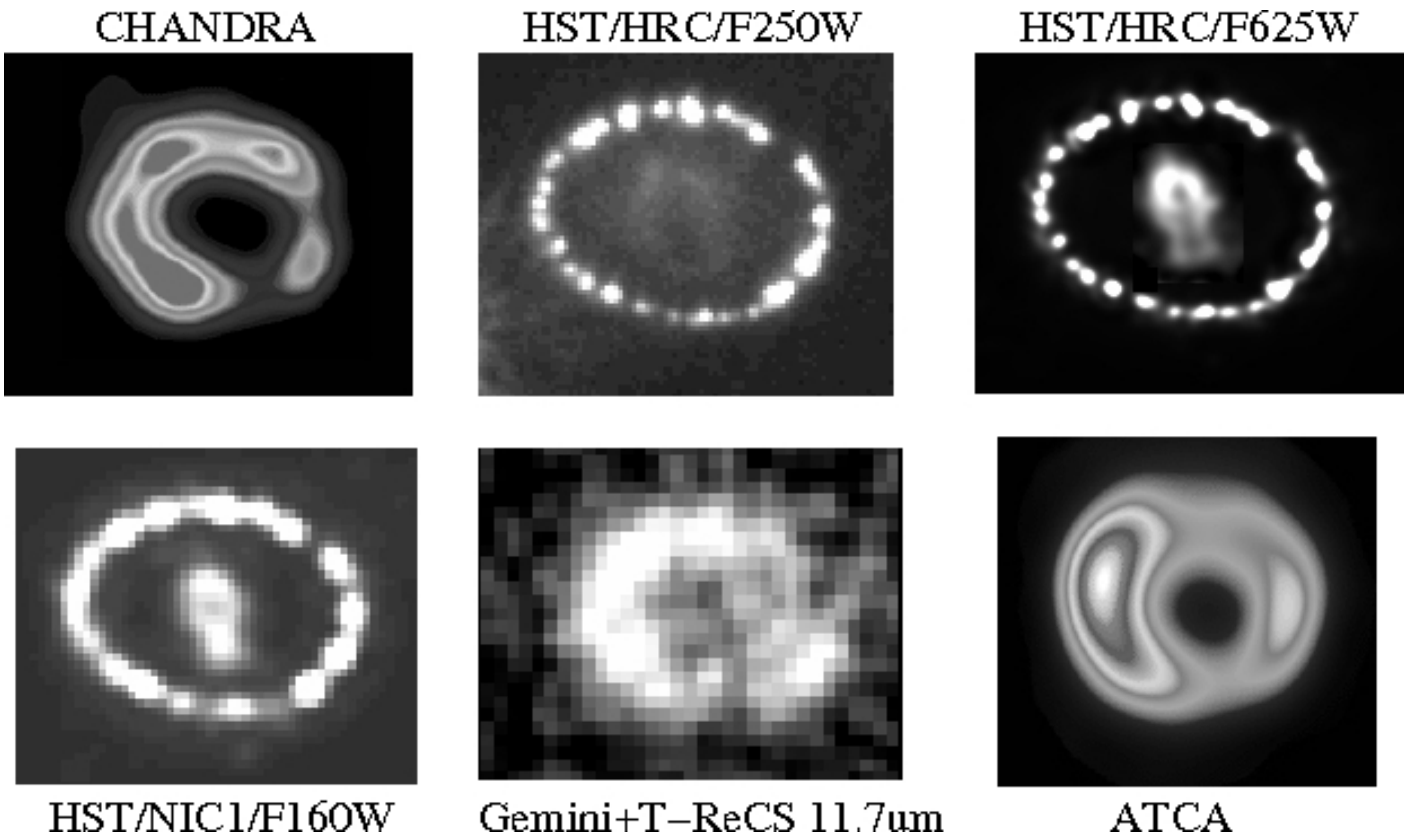
Flux increasing at all wavelengths until now!

Temporal evolution at different wavelengths

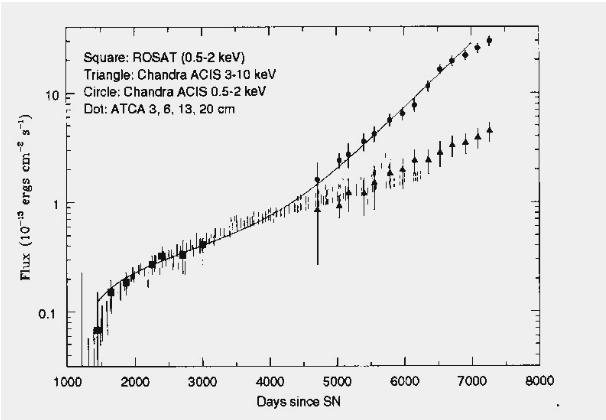


IMAGES at Comparable Epochs

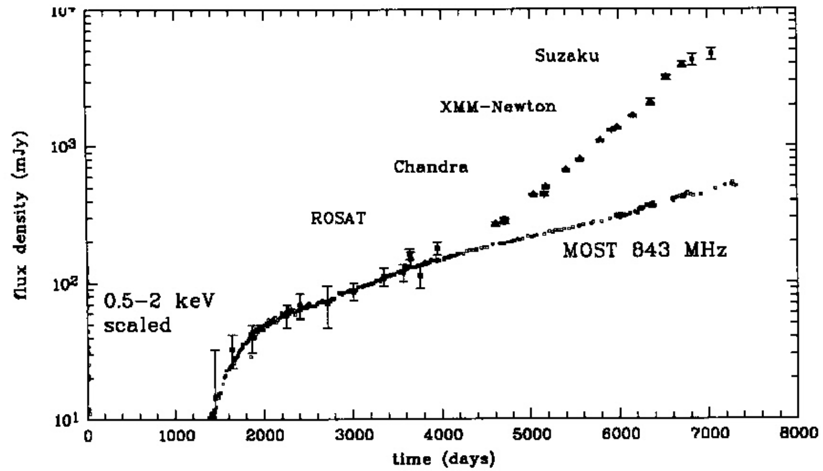



CHANDRA
HST/HRC/F250W
HST/HRC/F625W
HST/NIC1/F160W
Gemini+T−ReCS 11.7um
ATCA

Hard & Soft Xrays, ATCA Radio

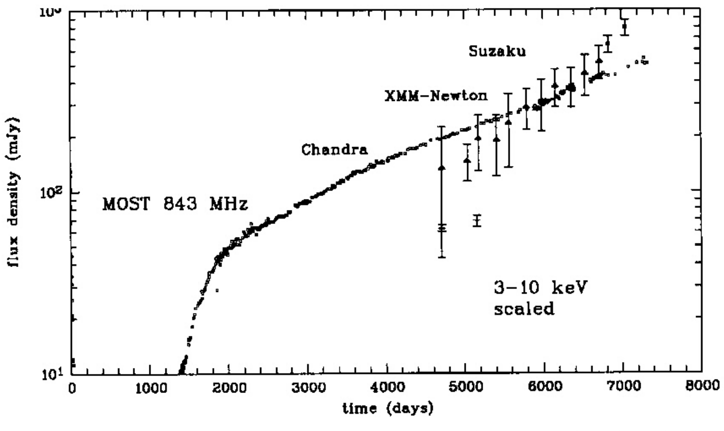


Soft Xrays, MOST low freq.Radio



rs.

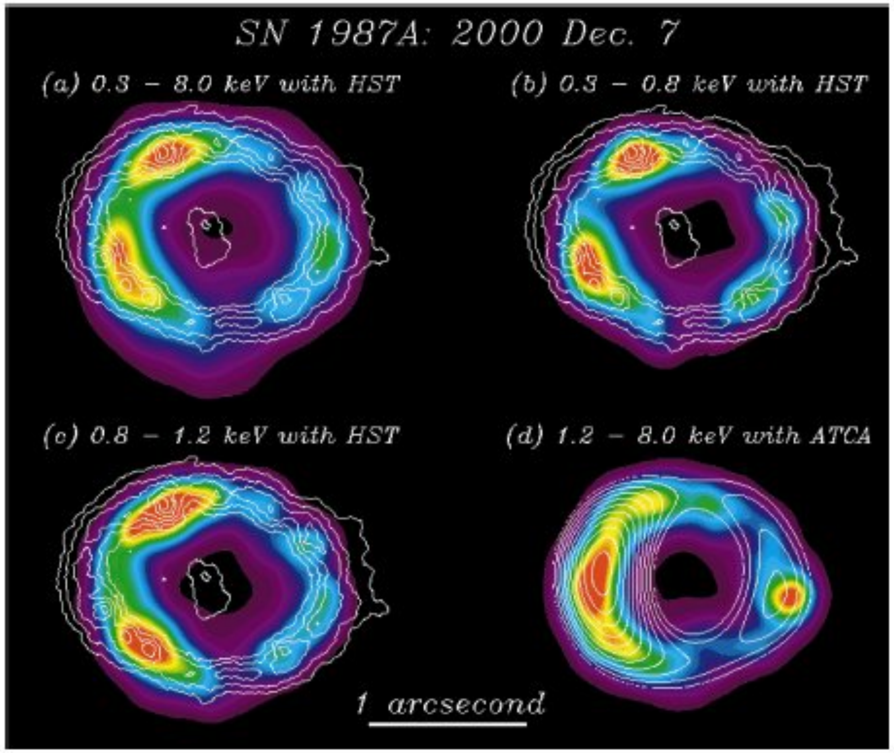
Hard Xrays, MOST low freq. Radio



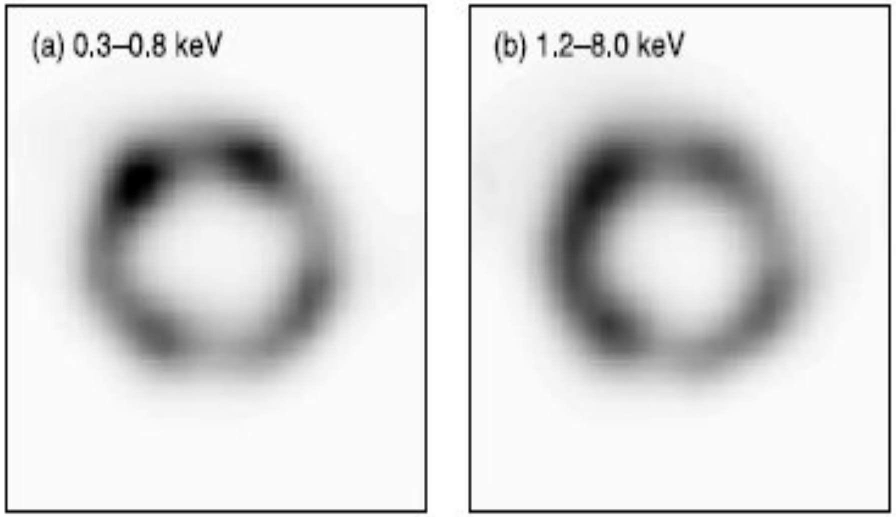
Thus Light curves for radio, hard Xrays, and soft Xrays all differ from each other implying different mecanisms and/or places of origin. Hard X and radio synchrotron associated with reverse shock, or high velocity forward blast pene-trating through ring between clumps?

Also Chandra hard & soft Xray images clearly differ. Next.

Comparisons of soft Xrays with hard Xrays, HST, ATCA radio



- Hard X and soft X differ
- Soft and HST similar
- Hard X and ATCA similar



Park et al. 2002

Park et al. 2006

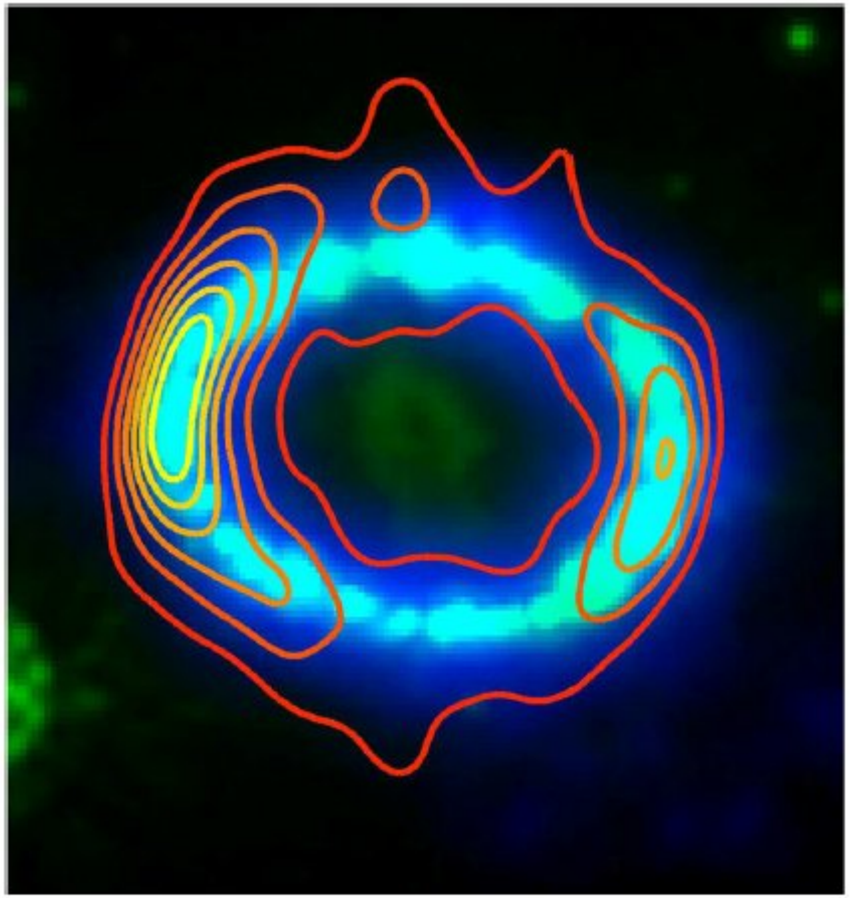


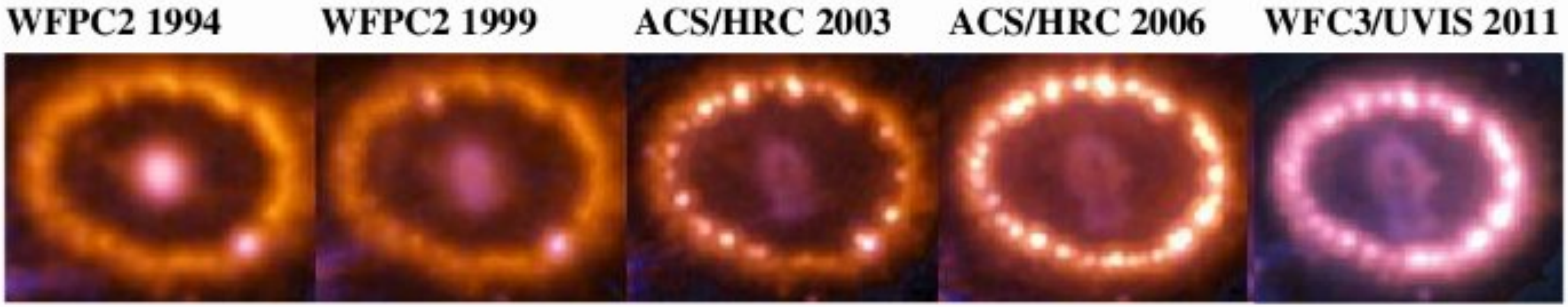
Figure 9. Overlay of the combined *HST* 2006 December 6 optical (green), *Chandra* 2008 January 9–11 X-ray (blue), and ATCA 2008 October 36.2 GHz radio images (orange-yellow contours) formed by shifting the optical and X-ray coordinate systems to center on the radio ring from the 2008 October 36.2 GHz 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

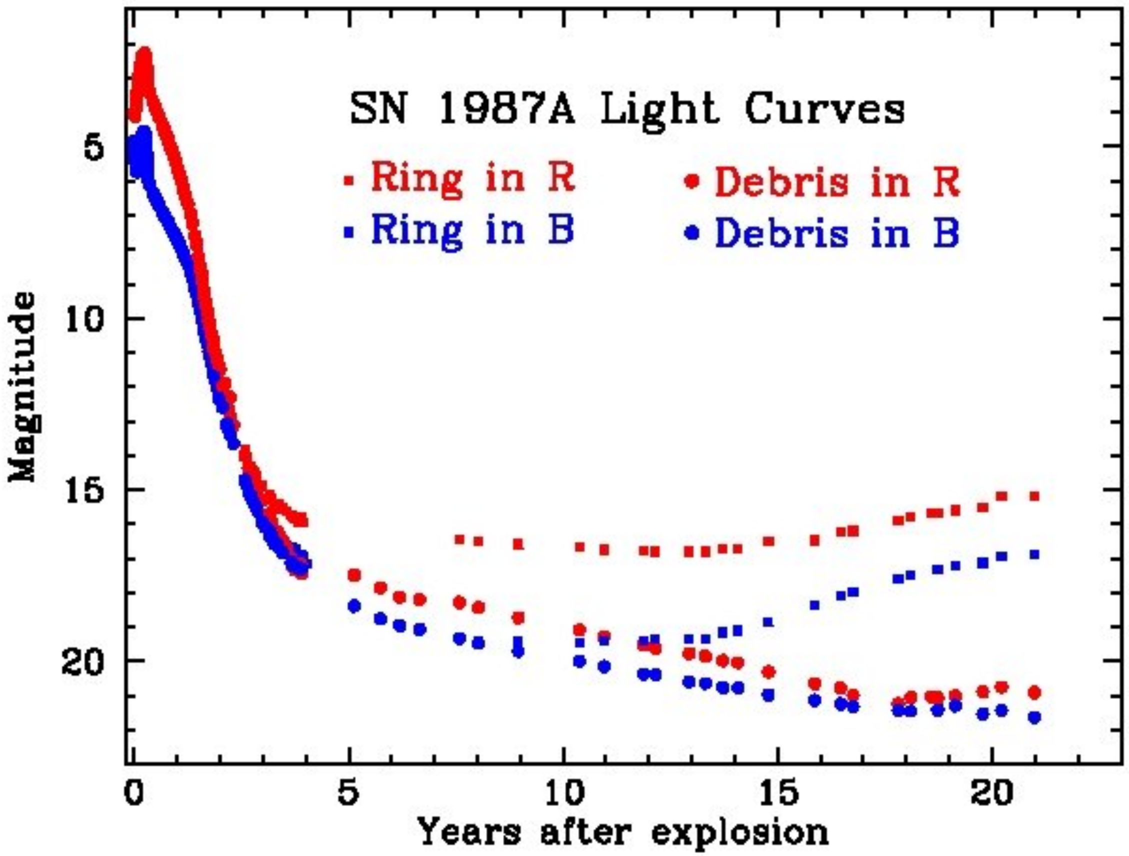
Extension of radio above and below ring caused by radio extending polar-wise out of plane of the ring

Hint of possible central source (not shown here).



Increasing elongation of asymmetric debris in
Plane of ring, orthogonal, or some other inclination.
Kjaer et al. favour plane or near plane.(collision pending?)

Dark patches dust?



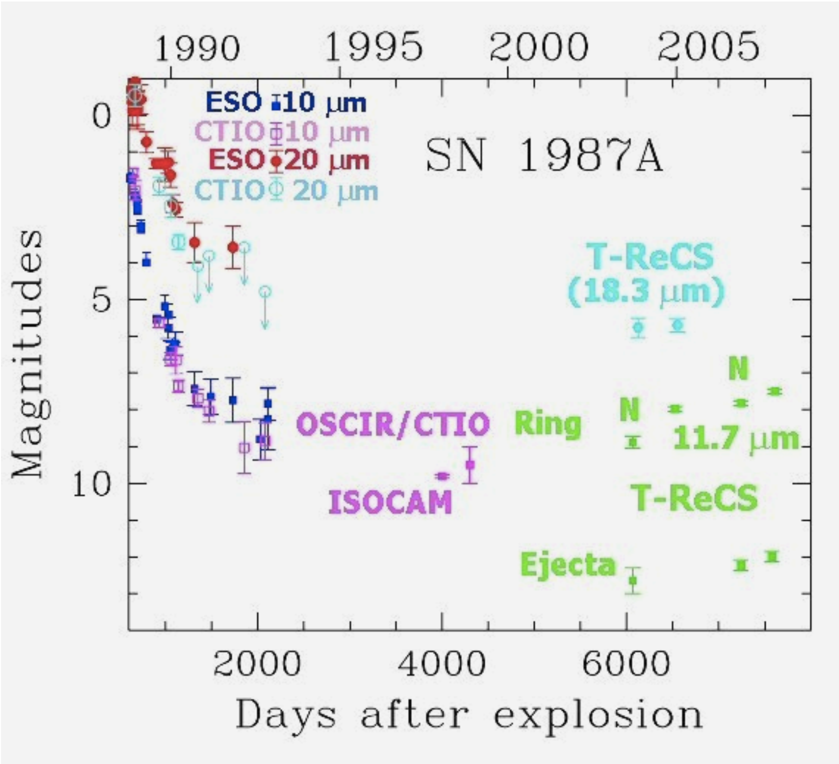
HST Light curves
for ring and
debris.
See next for IR.

Ejecta-Ring interaction.

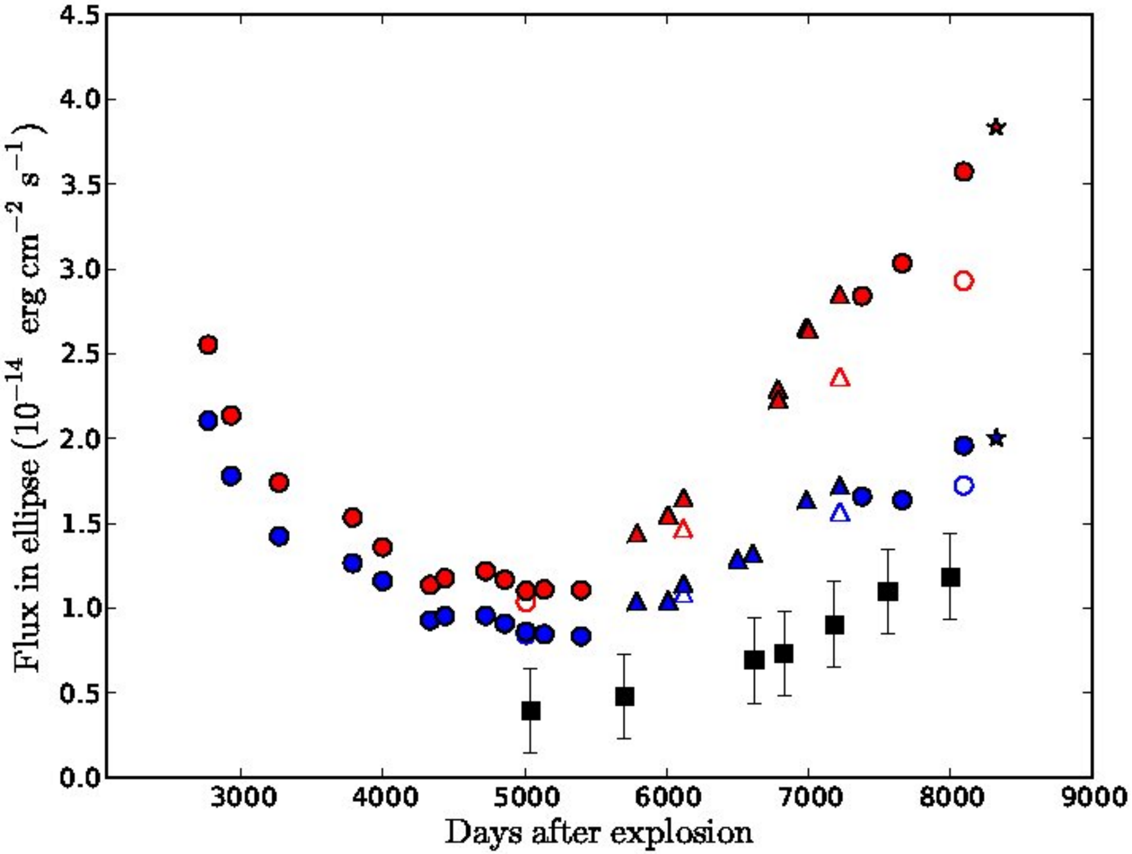
Debris (difficult to measure?)

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

MidIR Light Curves Only

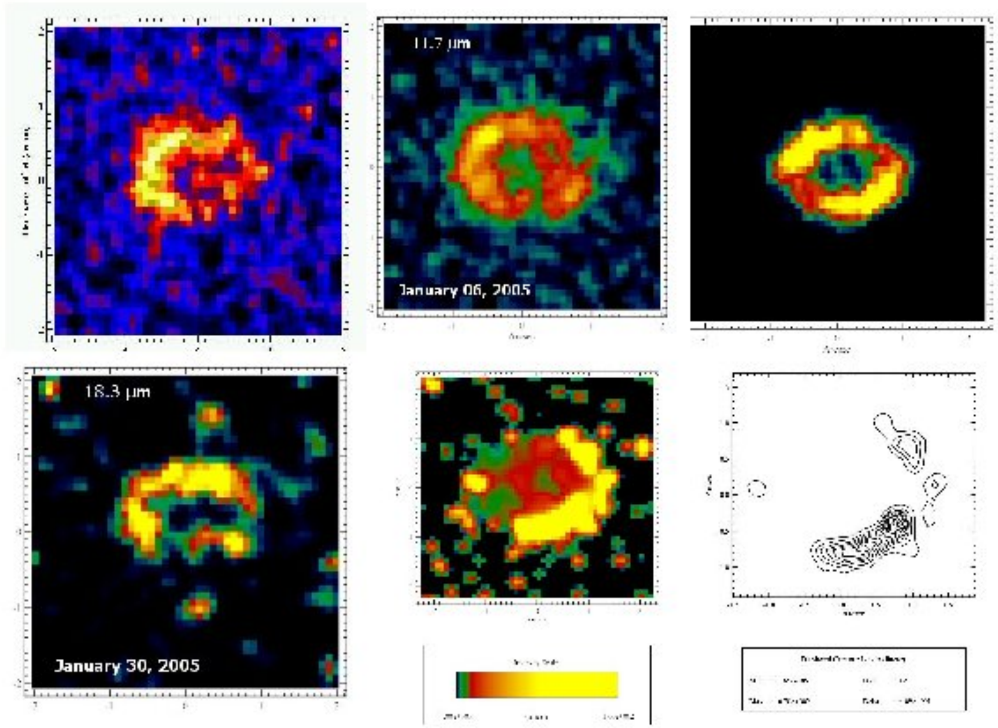


Note ejecta detected after day 6000 and increasing a little with time. Also seen in optical (previous).



Late time increase of luminosity of debris.
R and B bands shown.
Squares are [CaII]lines near 7300A.

Is the debris dust also heated?



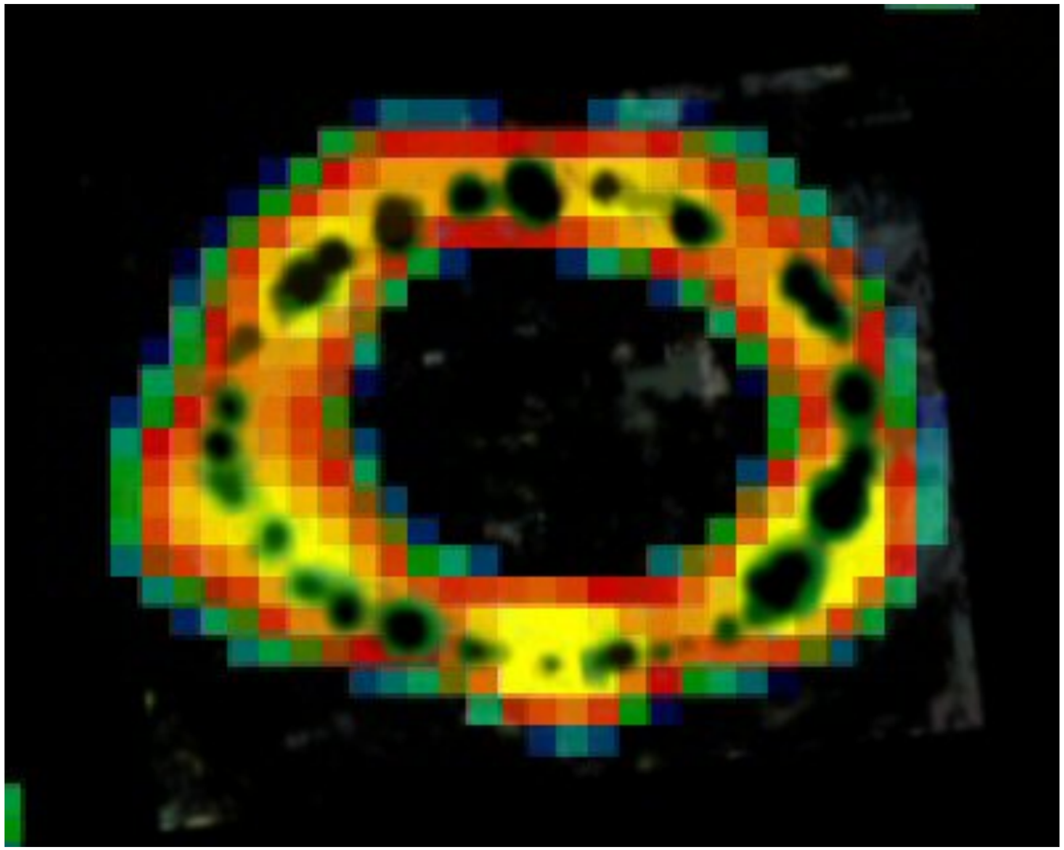
Mid IR imaging Gemini & VLT.

Brightening on NE side first, then SW side later.

Day 7241/Day 6067

10 and 18micron images give T~165K varying over ring.

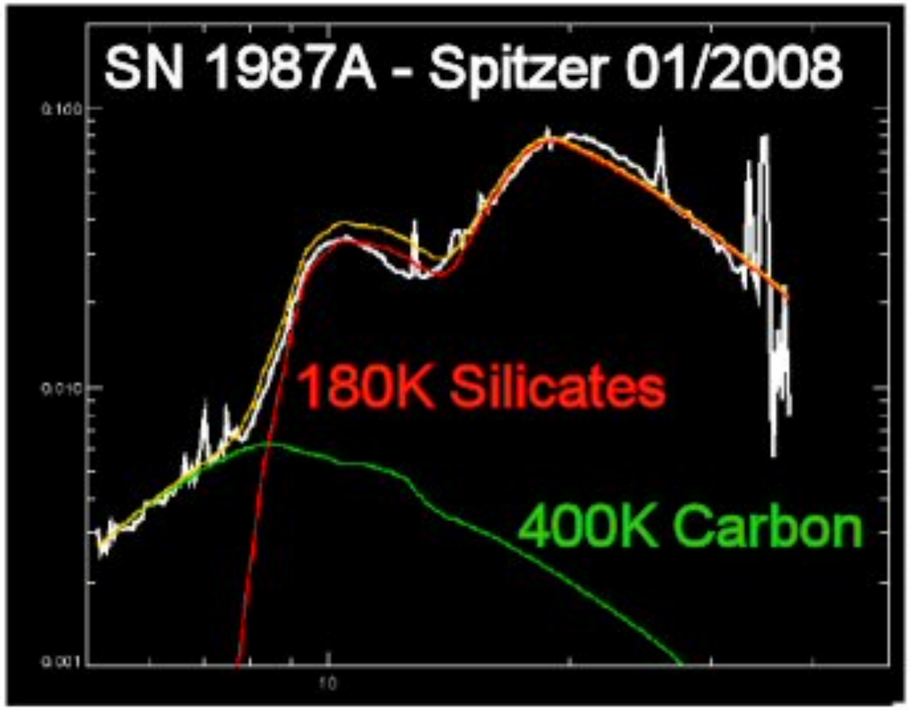
HST vs VISIR (VLT)



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.

Enter SPITZER

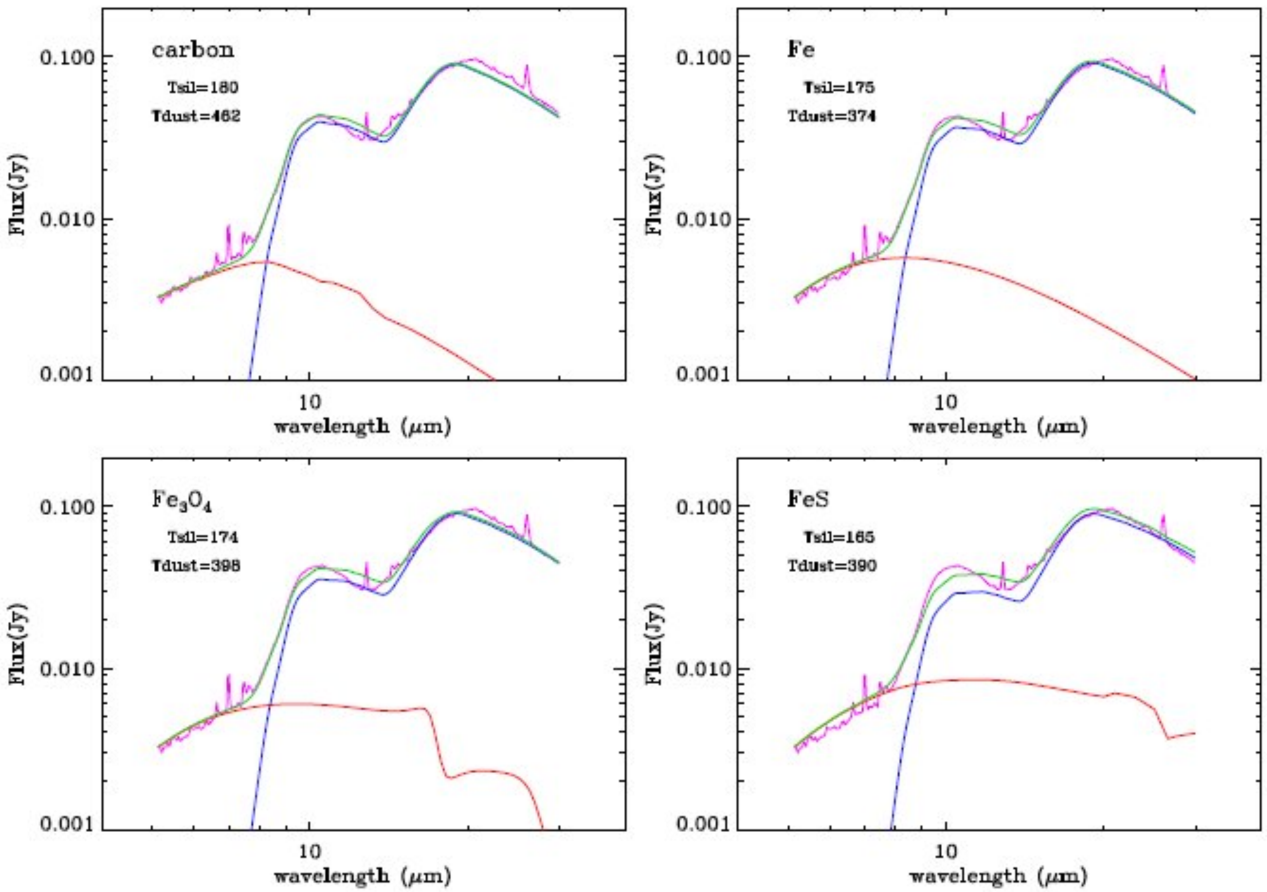


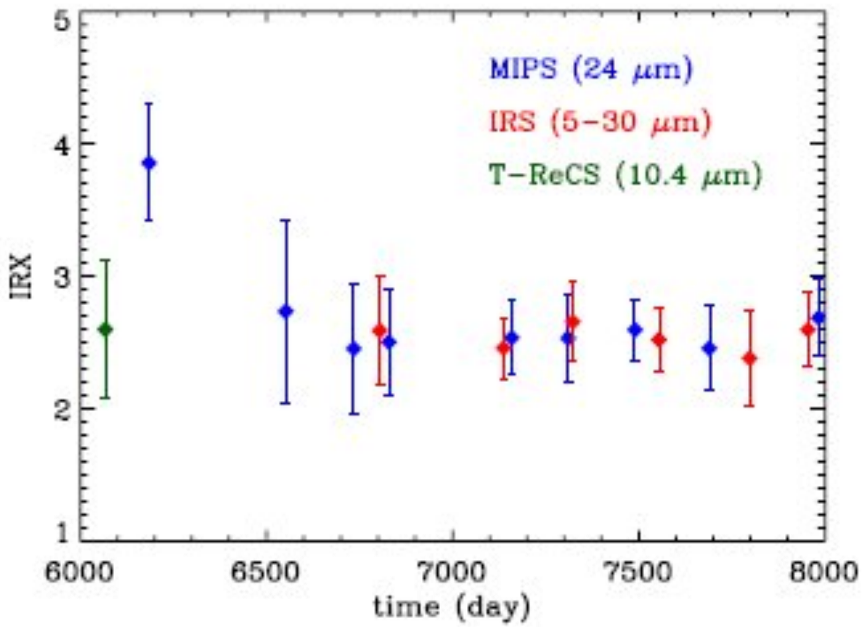
Two T components not easy to understand.
Possibly a signature of binary coalescence?

Attempts to fit 2nd component

Silicates + Carbon

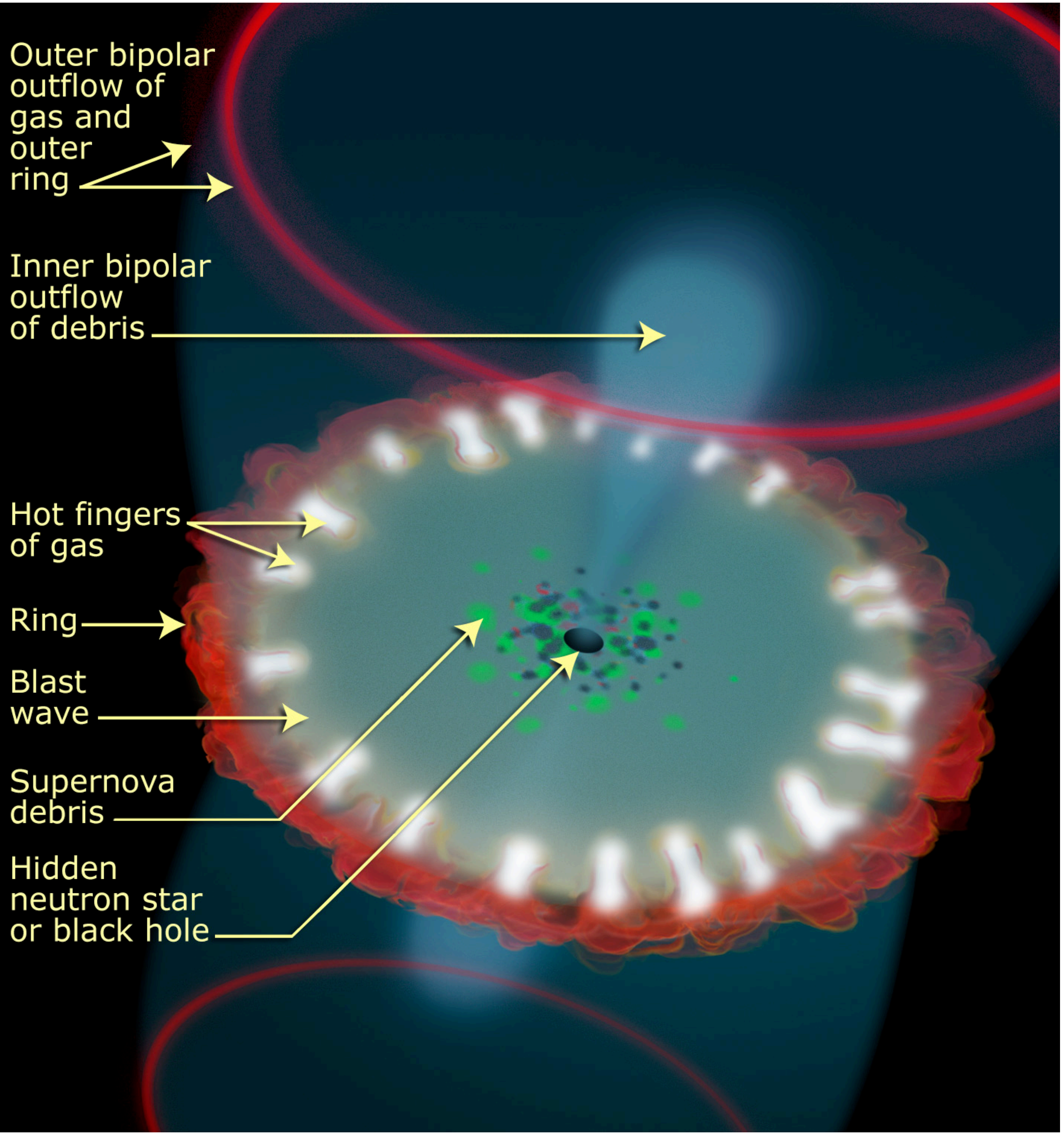
Silicates + Fe (molecules)

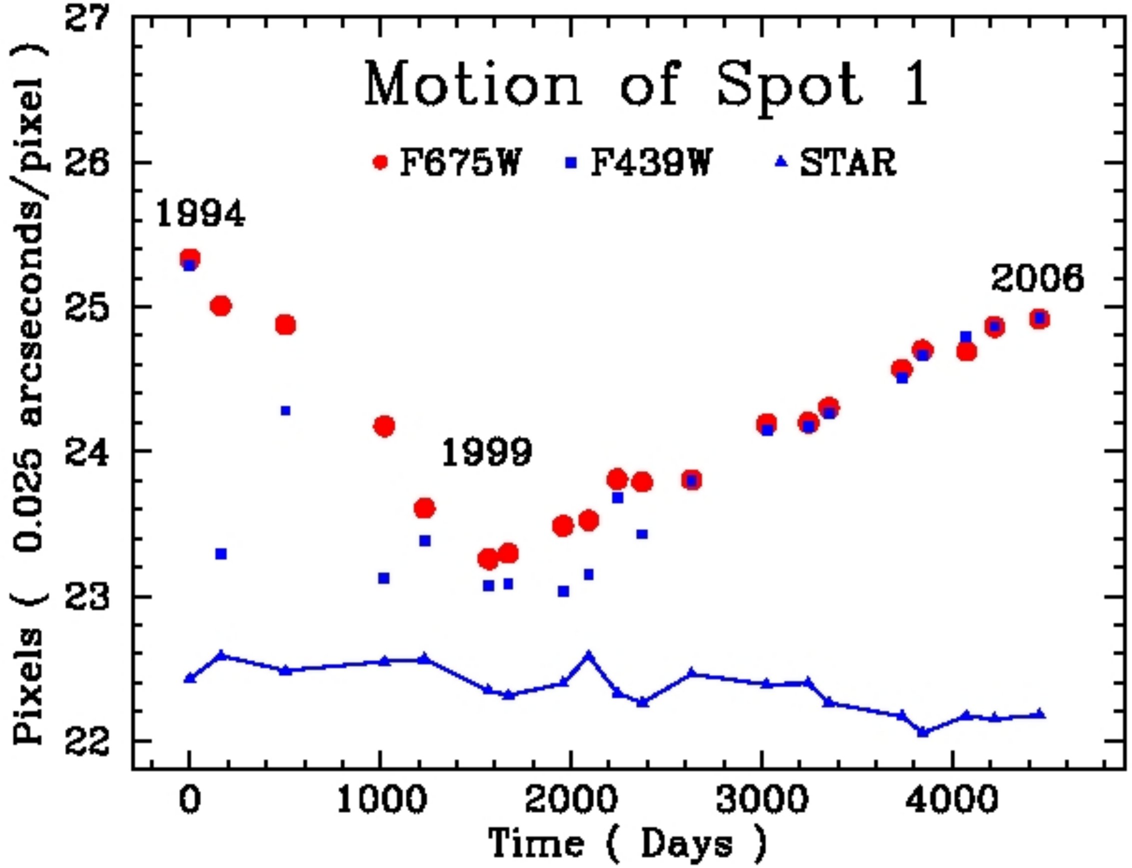




Signature of dust grain destruction in ring?
If grain destruction is occurring IR/Xray ratio should decrease.
It does not!

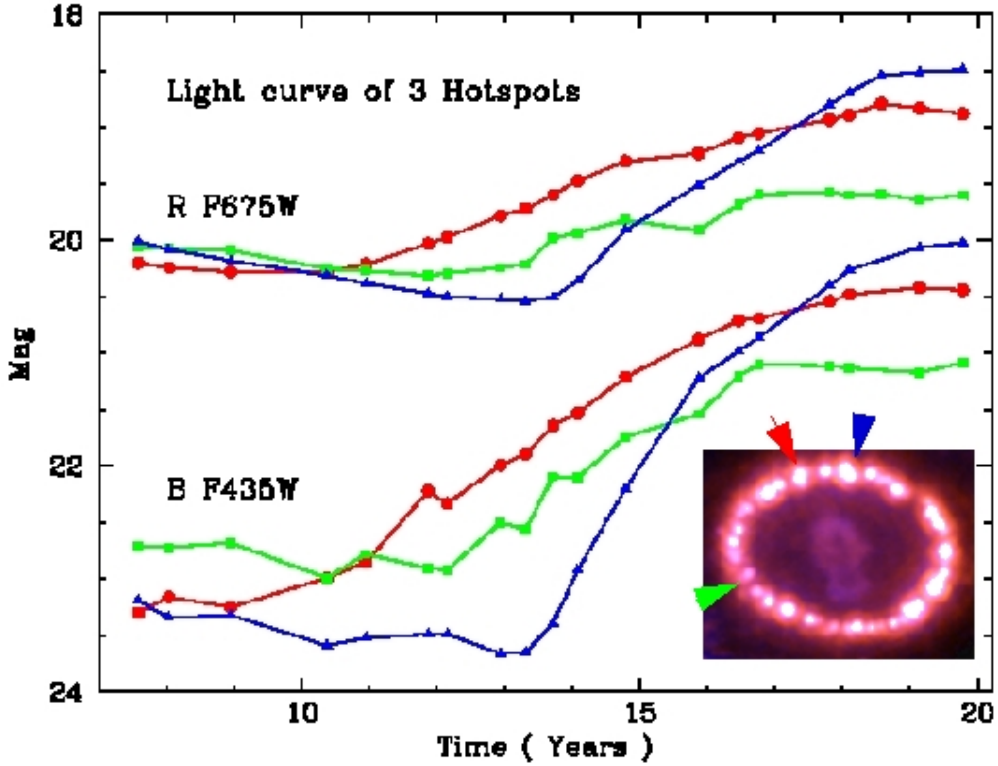
Inner debris of the Supernova 1987A (SN 1987A) ring





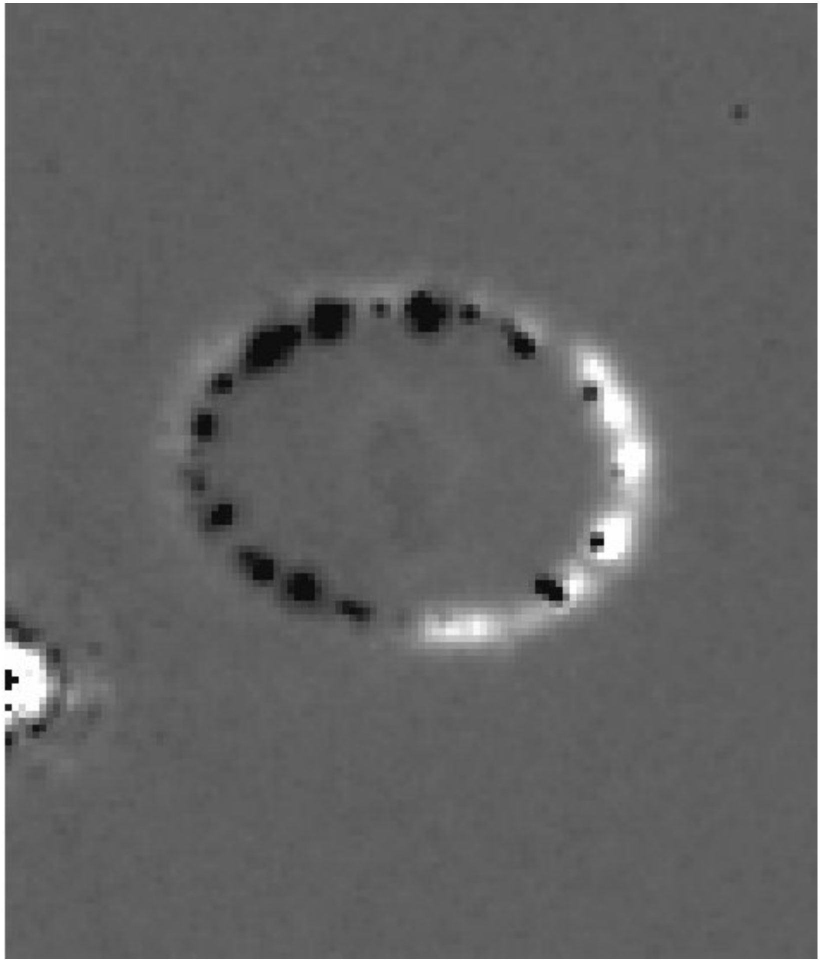
Probably not actual motion but change of position of maximum excitation of cylindrical shaped spots.

Light curves of 3 spots indicated.



Some spot brightnesses seem to have reached a maximum, others not.

Spot Development

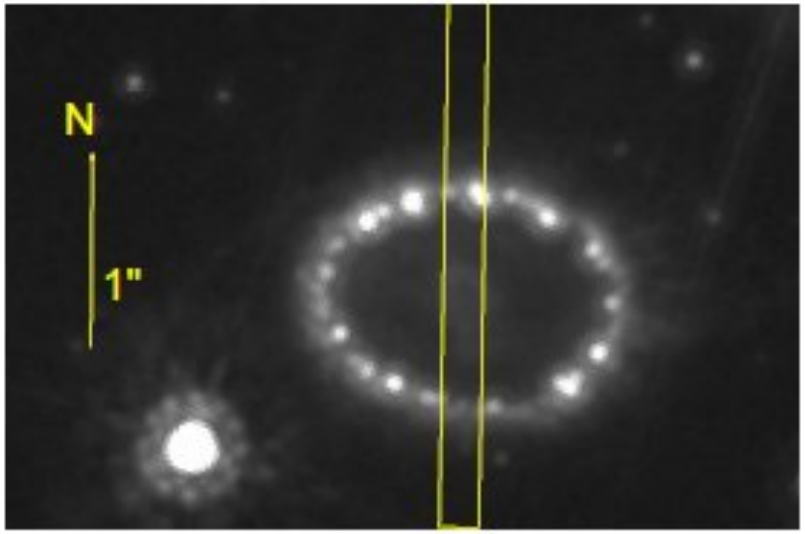


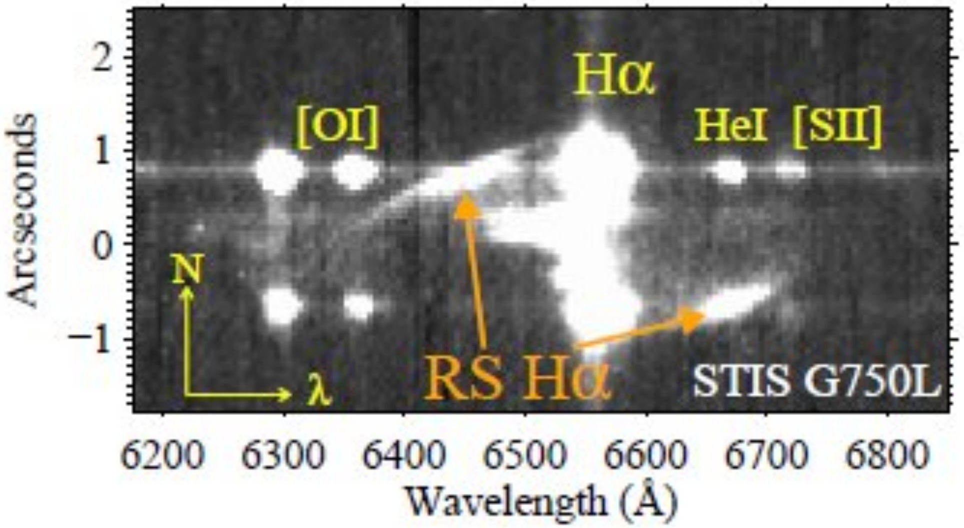
HST difference image
Jan.,2010 – July,2004.

White - brightening
Black - fading

Systematic effect not explained but also occurs for mid-IR. (see earlier).

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.

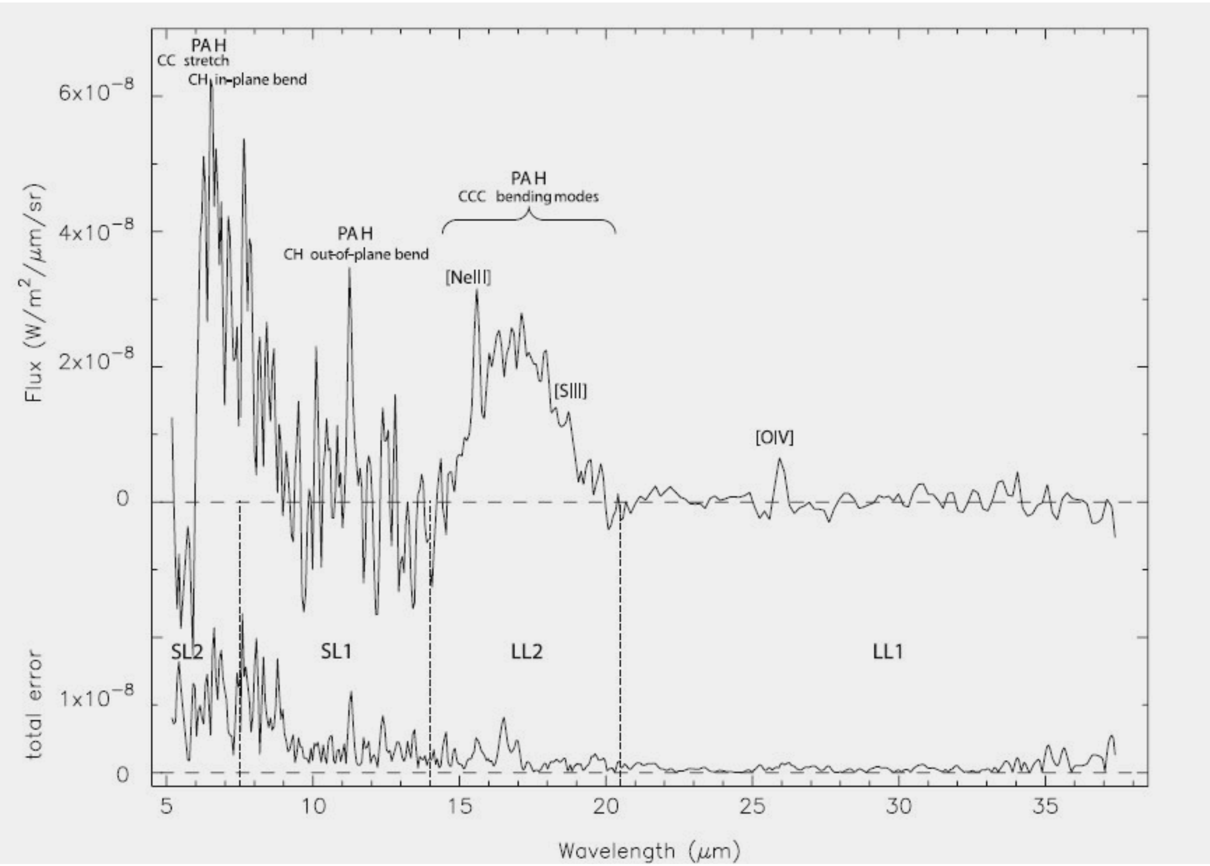
Central emission extends to blue (near side) but not to red (far side) obscured by dust.

UNFINISHED BUSINESS

- Dust composition in debris and rings: JWST
- Relation of dust to gas in rings and debris
- Why ring gas clumped in cylindrical form
- Improved location of soft and hard Xrays
- Location of radio emission: ALMA
- Nature of progenitor – single or double
- Nature of debris: HST, VLT, JWST
- Where is the dust located in debris
- Where is the reverse shock propagating
- Late time excitation of debris by soft Xrays from ring?
- Compact object formed at time of neutrino emission
- Mass of radioactive 44Ti
- Mass of non-radioactive elements: Modelling

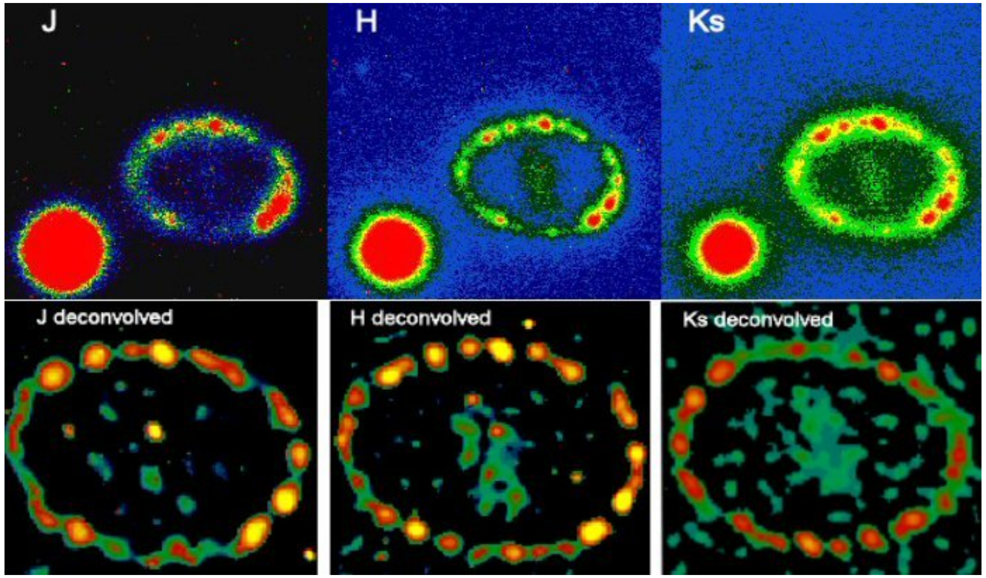
A future development in SN1987A?

N132D young O-rich SNR in LMC



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

END



VLT NACO

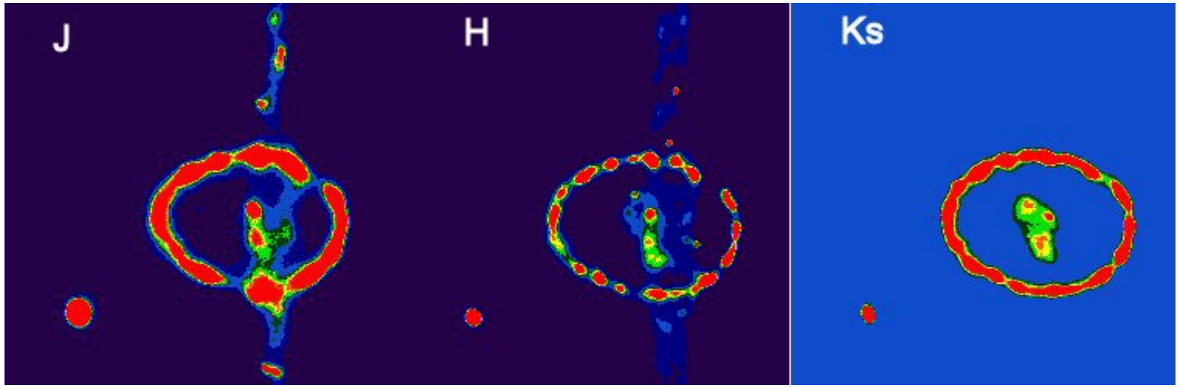
adaptive optics

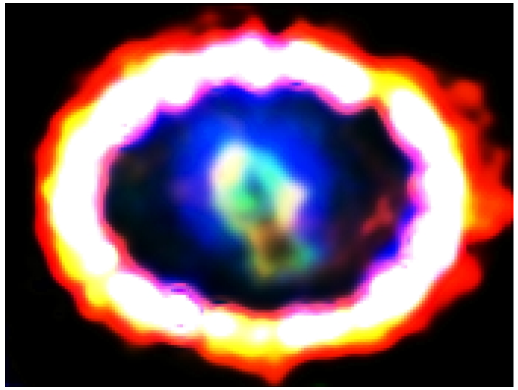
Oct.2006

original

Deconvolved
Max.Entropy

HST





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

Where is the ejecta dust located? Diameter 0.3 arcsec?