

LIGHT ECHOES FROM HISTORIC SUPERNOVAE

Armin Rest (Harvard)

SuperMACHO & EHS collaboration

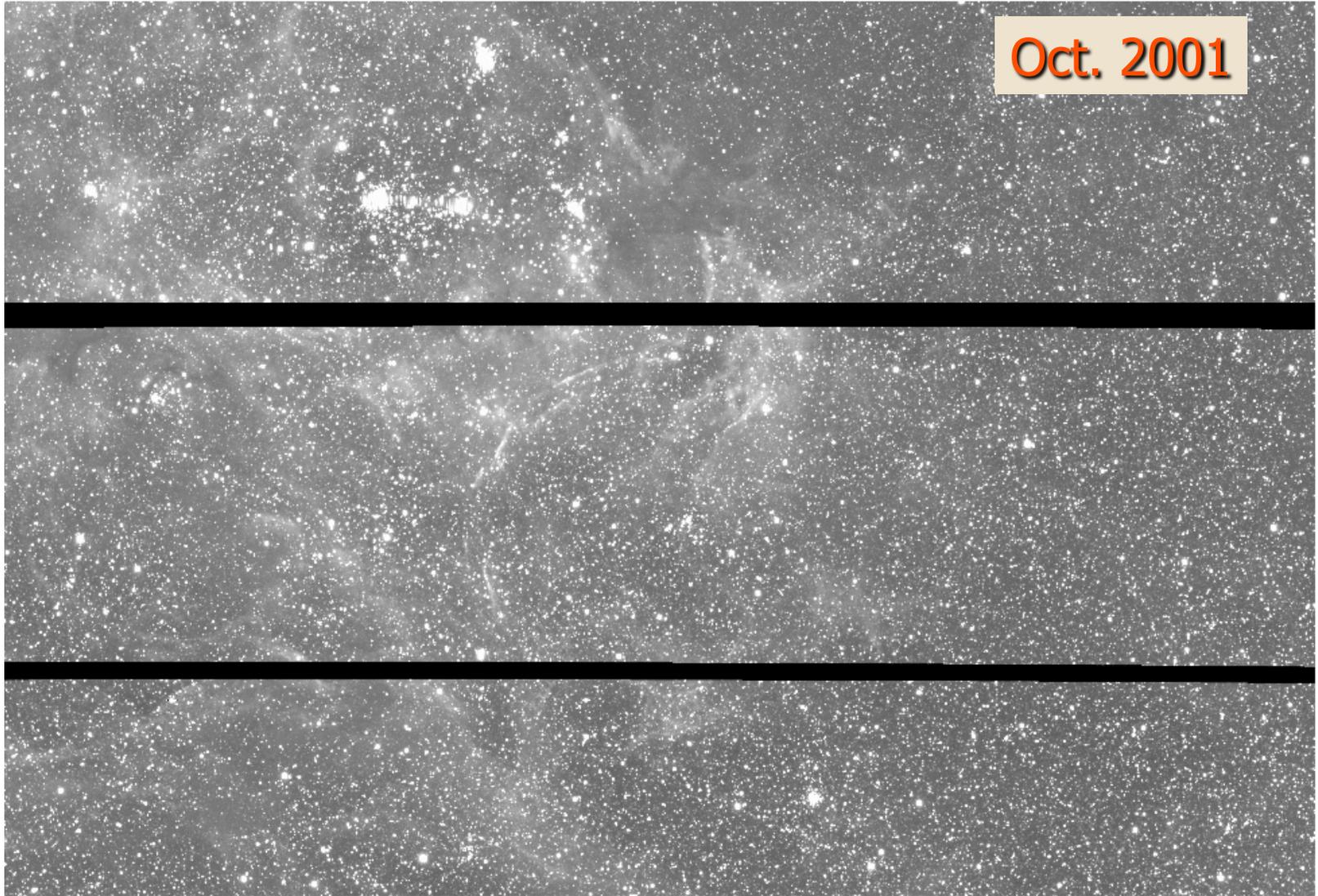
Outline



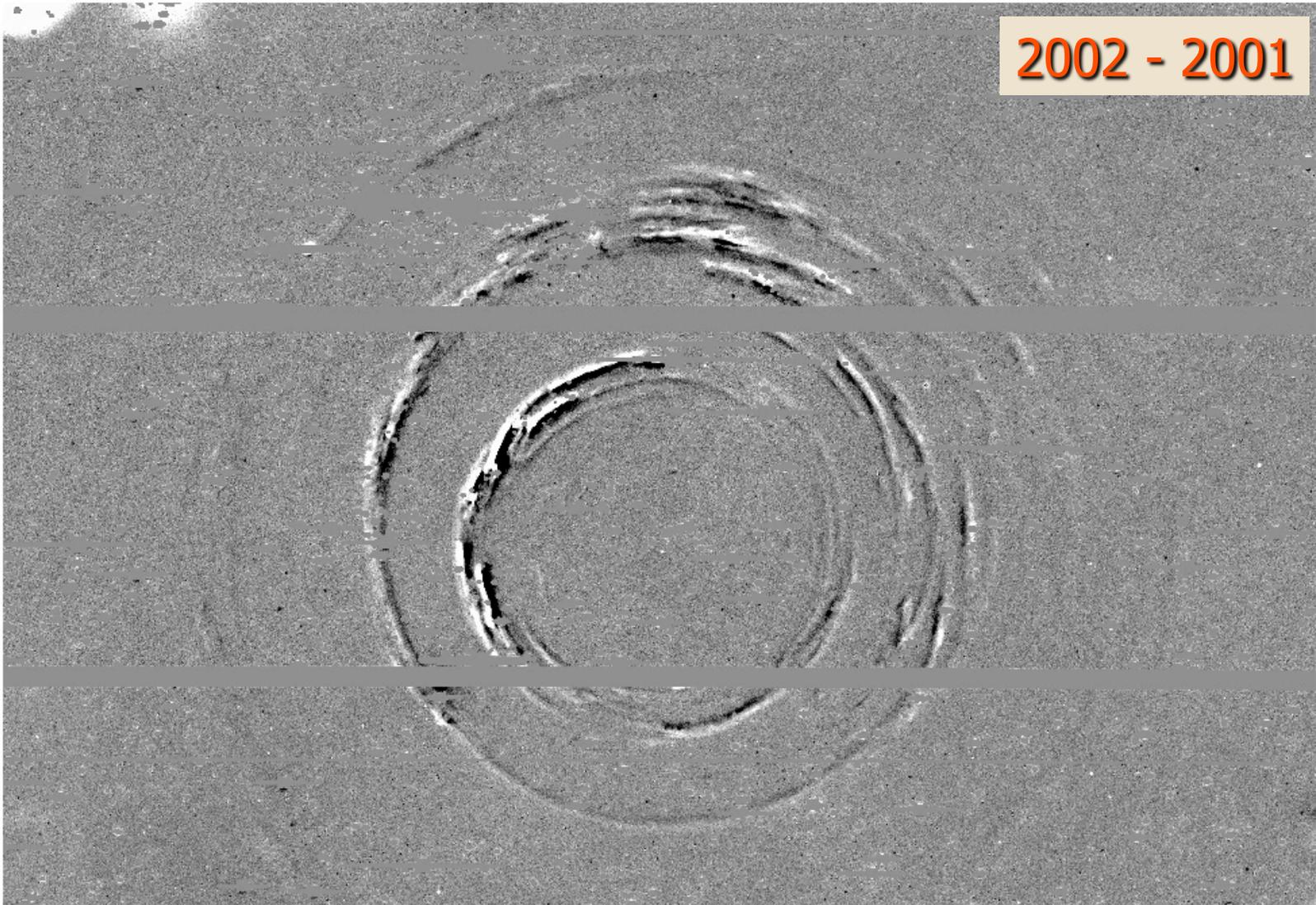
- Background
 - What are light echoes
- Light Echoes of SNe
 - SN 87A
 - SNe in LMC
 - Galactic SNe
- Future

Microlensing alerts????

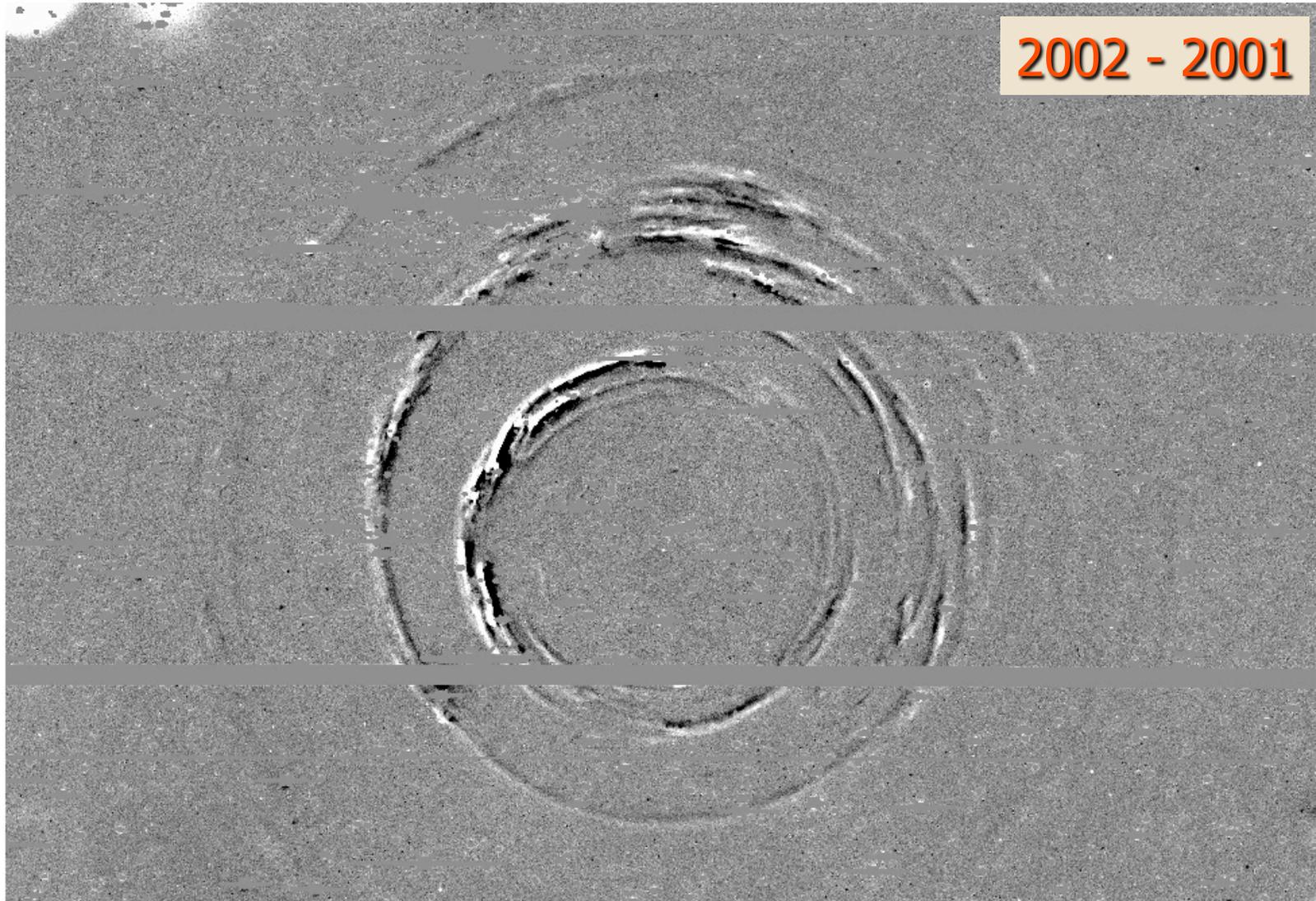
Oct. 2001



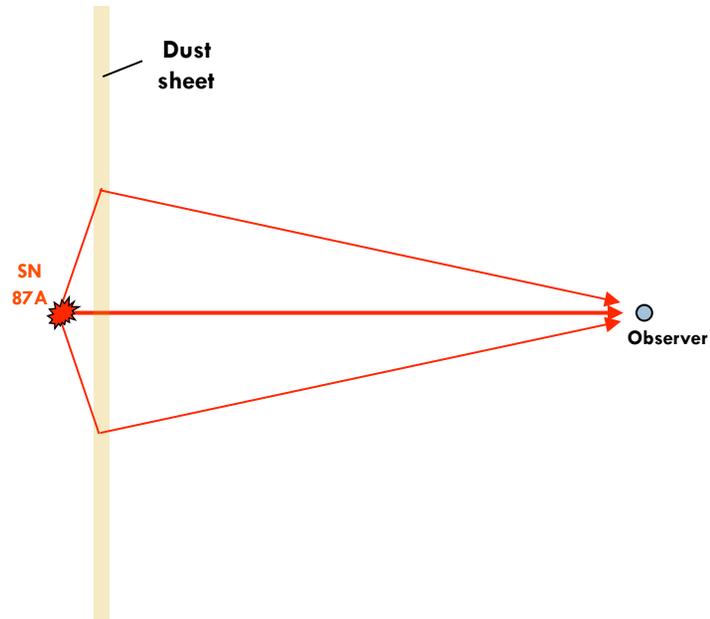
2002 - 2001



The Well-known Light Echoes of SN 1987A!

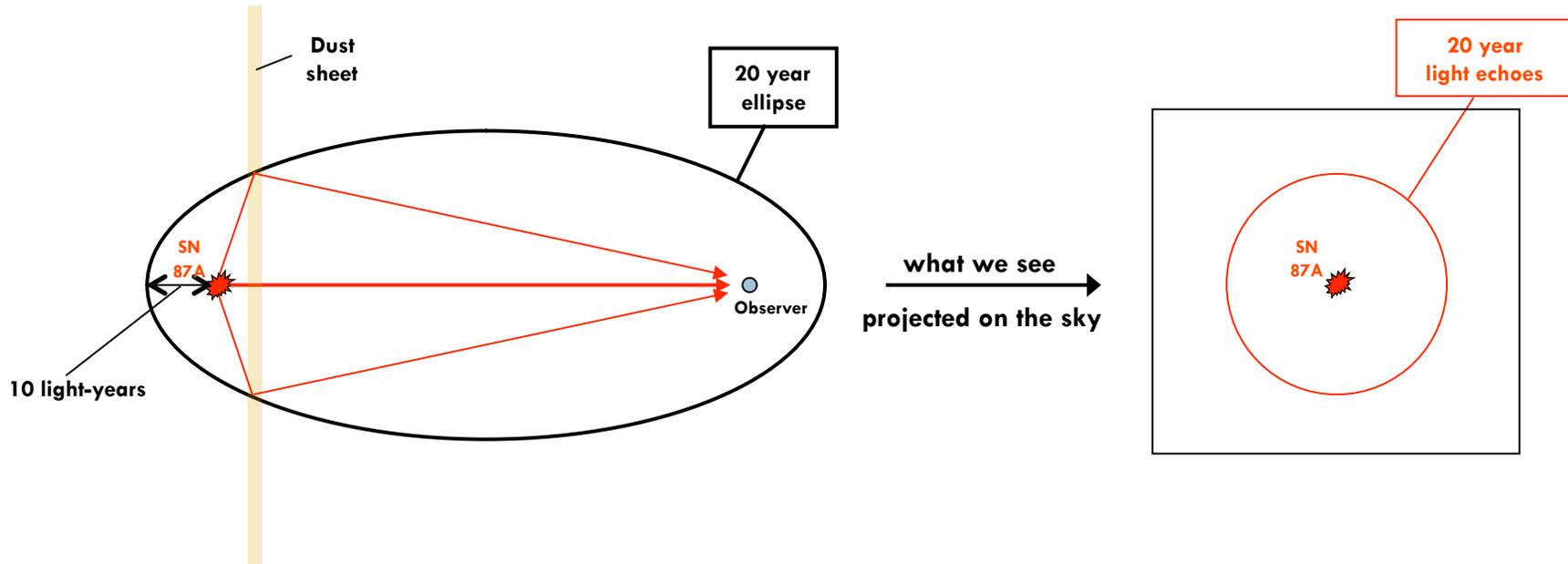


Geometry of Light Echoes



Geometry of Light Echoes

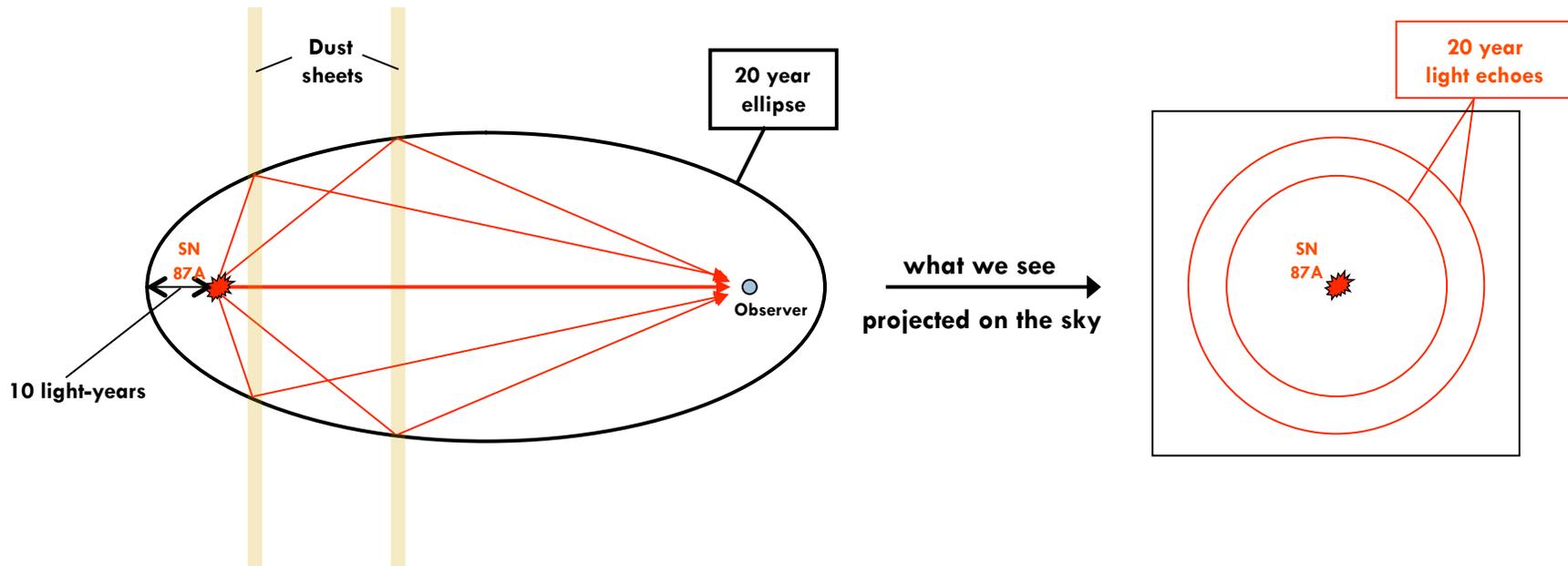
Ellipsoids trace out surfaces of constant arrival time



Extra path: 2×10 light years \rightarrow Light echo after 20 years

Geometry of Light Echoes

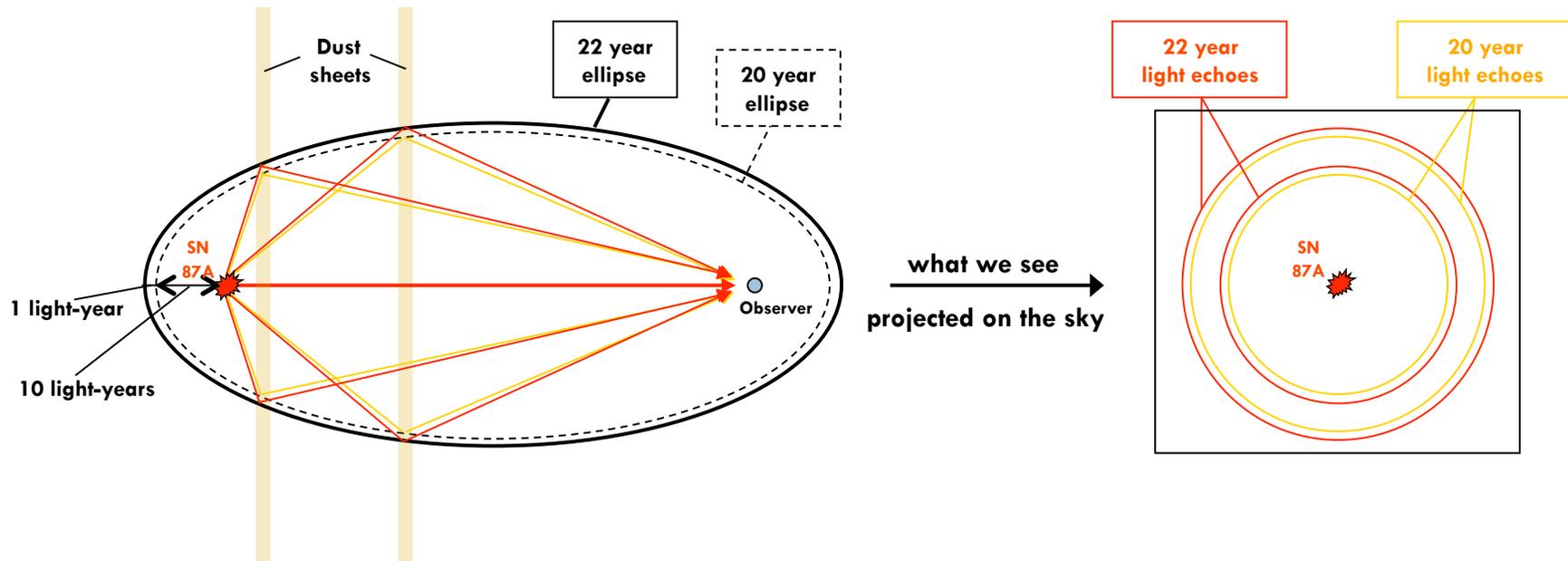
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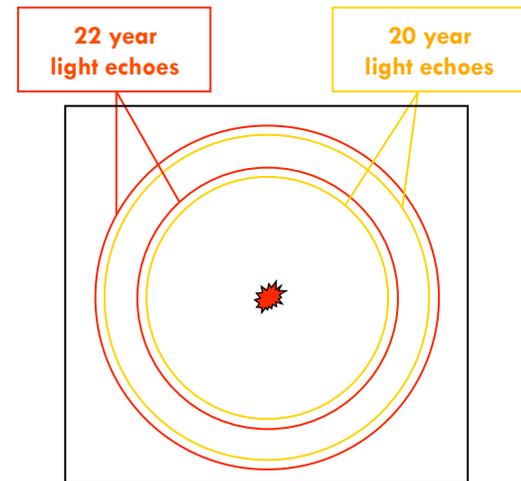
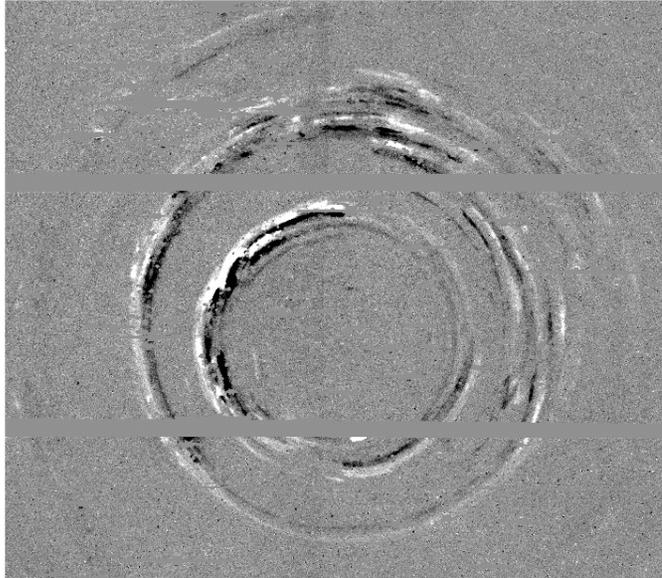
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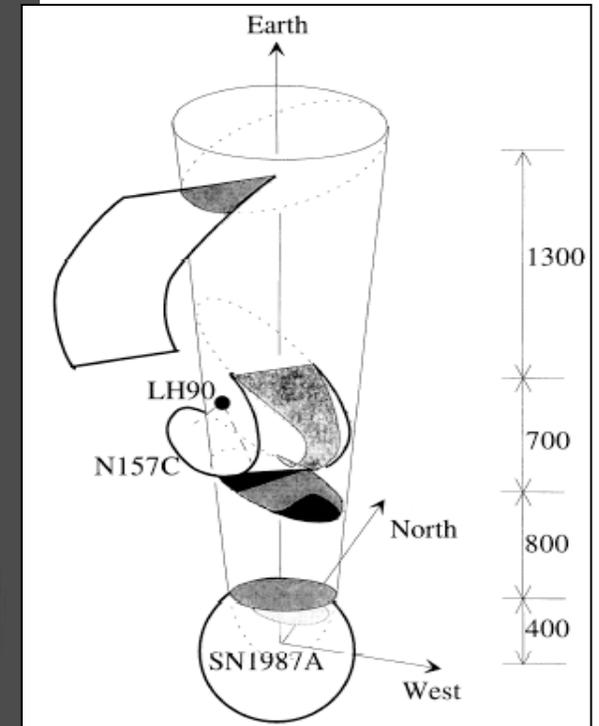
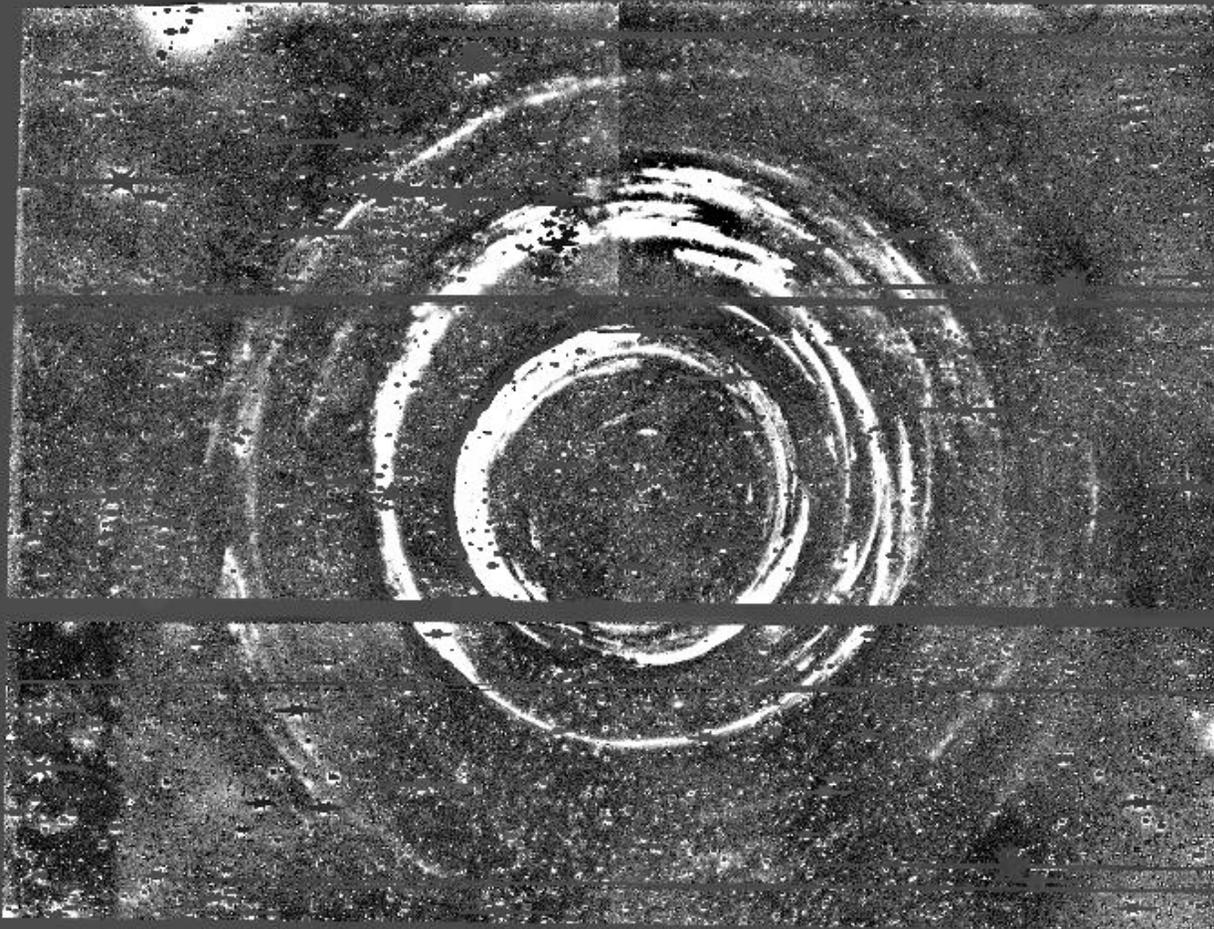
Extra path: 2×10 light years \Rightarrow Light echo after 20 years
Extra path: 2×11 light years \Rightarrow Light echo after 22 years

Geometry of Light Echoes

SuperMACHO difference image, 2003-2001



SN 87A Light Echoes with NN2 Difference Imaging (each season combined and smoothed)

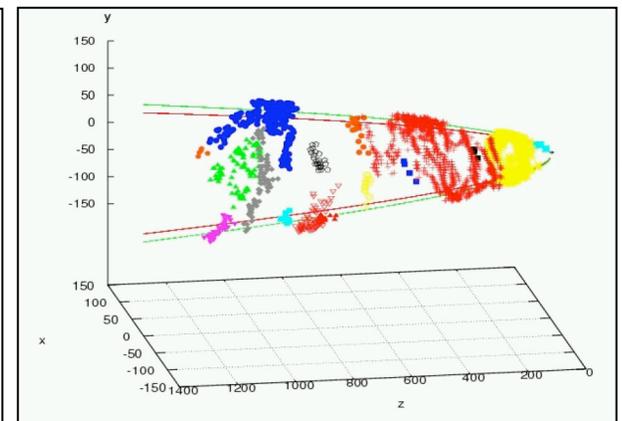
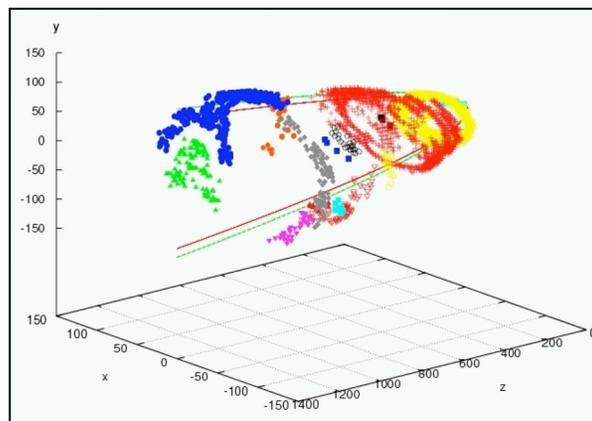
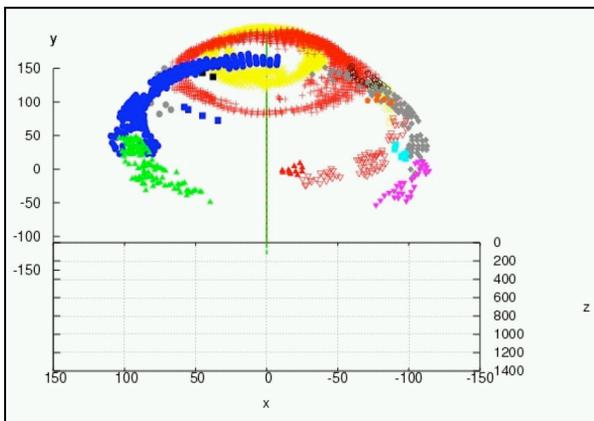
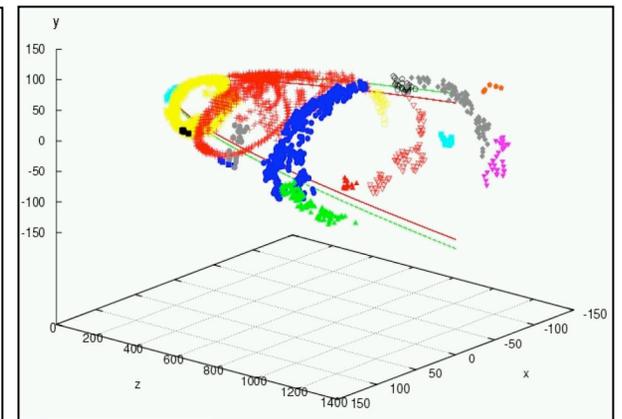
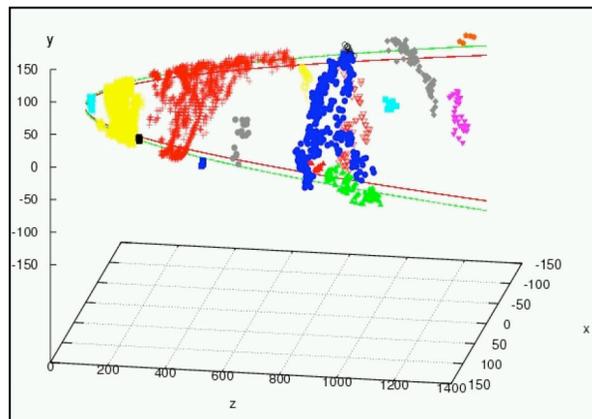
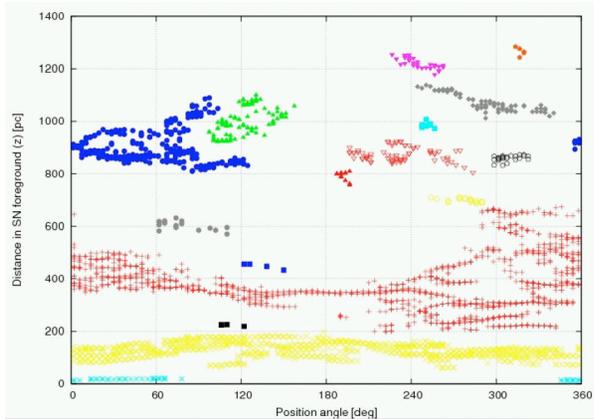


Xu, Crofts, & Kunkel (1995)

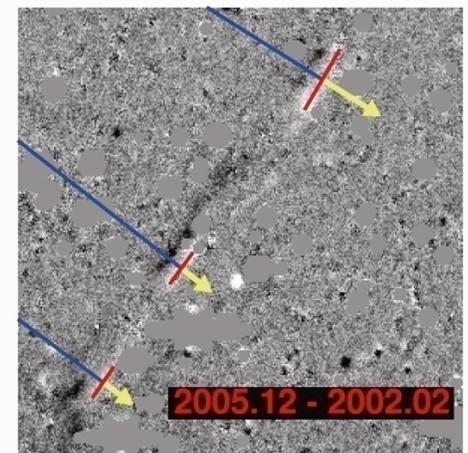
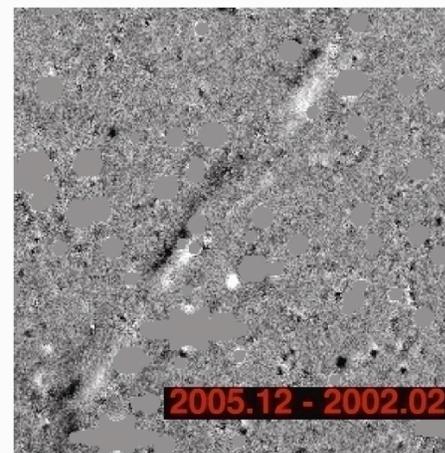
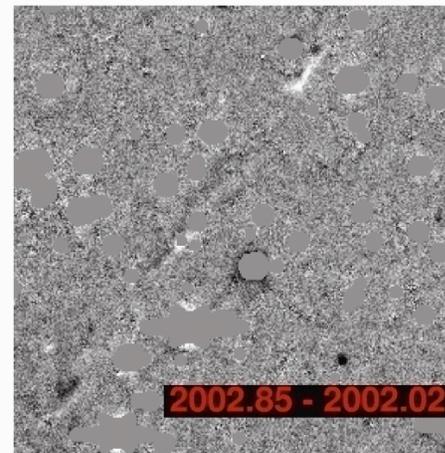
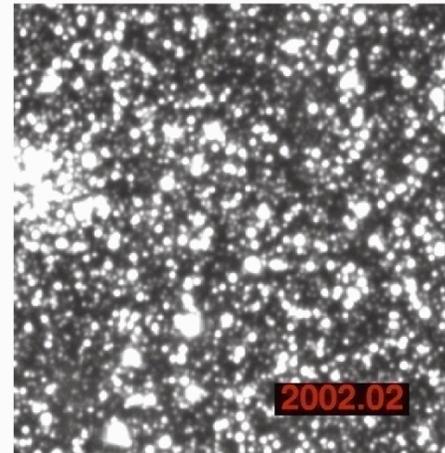
Newman & Rest, in preparation

The Outer Light Echo Ring of SN 87A

(Newman & Rest, in preparation)



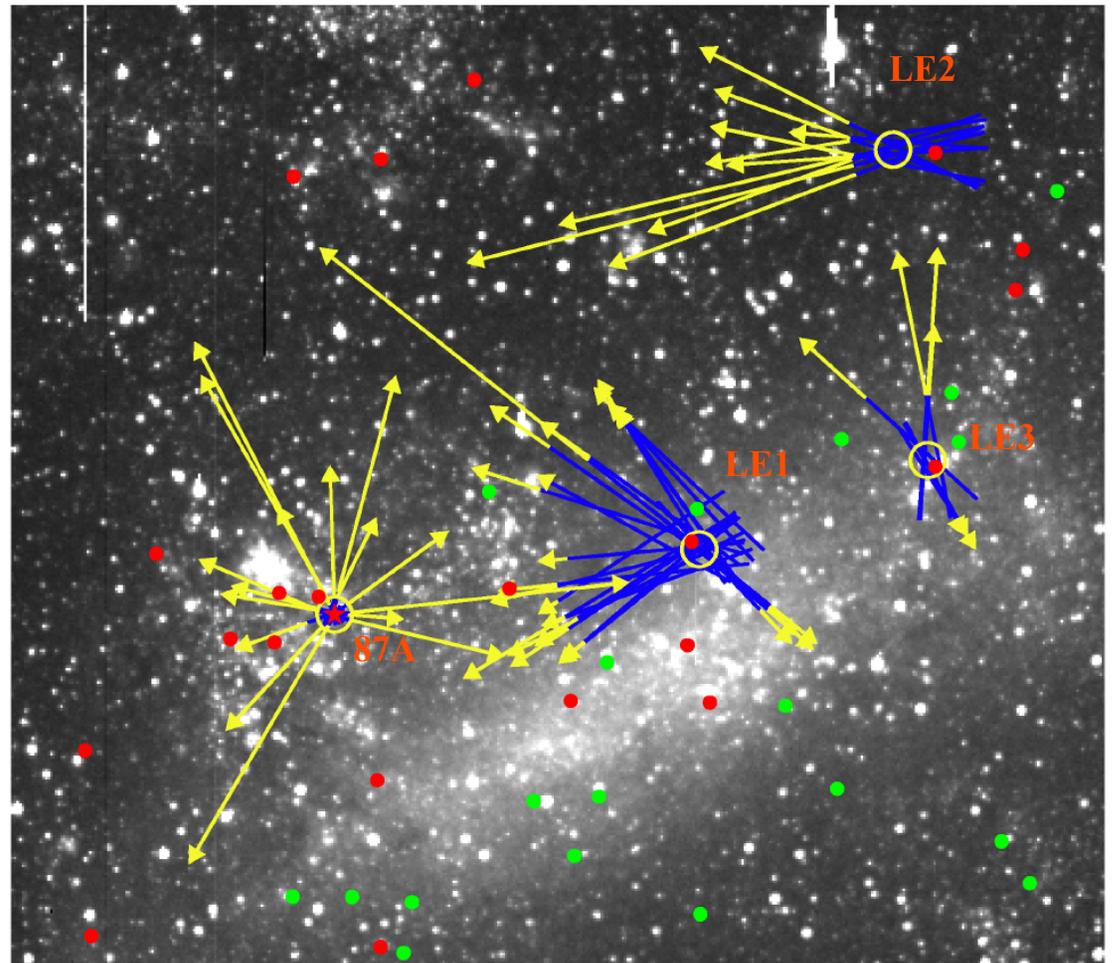
Light Echoes from a source other than SN 1987A?



Light Echoes from Ancient Supernovae in the LMC

- Three distinct light echo groups
- Apparent proper motion: between $0.7c$ and $1.8c$
- R magnitudes between 22.5 and 24.0

Rest et. al., 2005, Nature, 438, 1132



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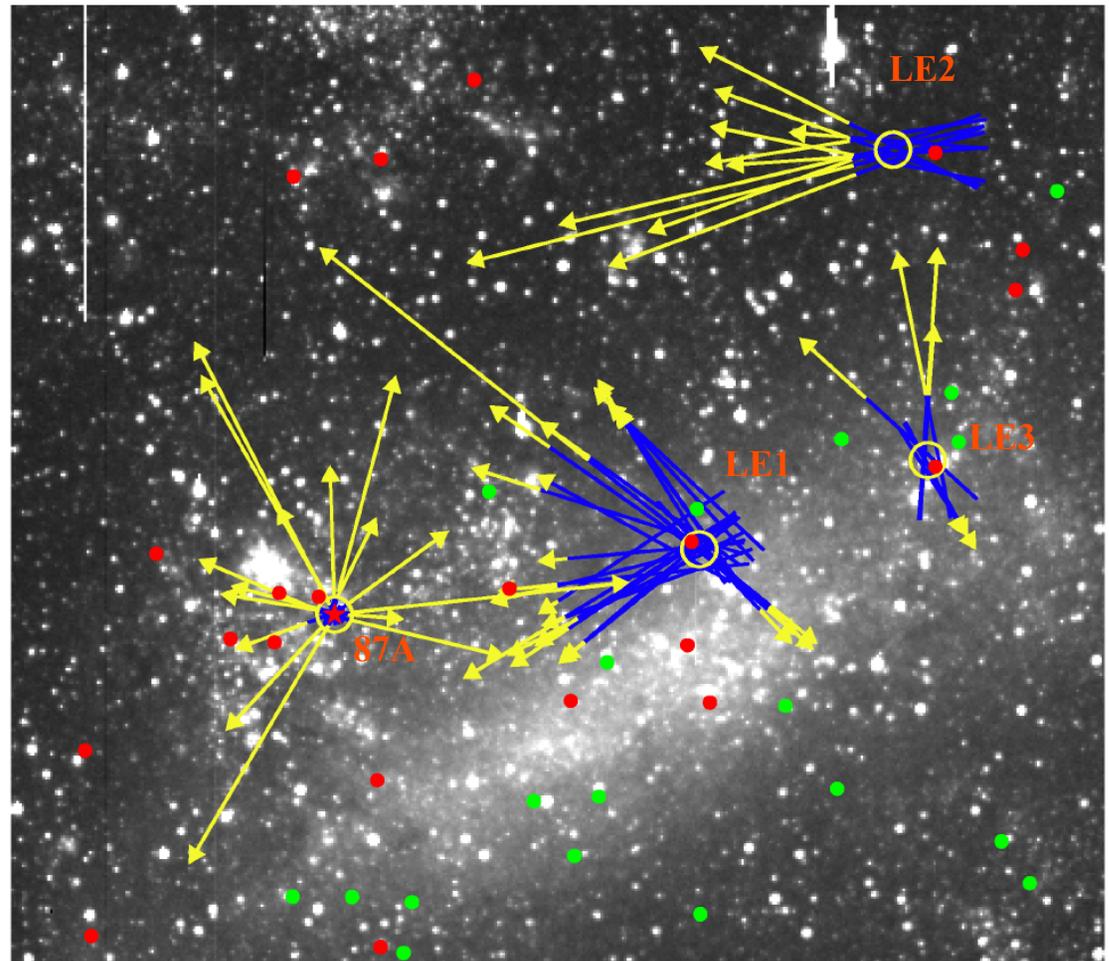
TABLE 1

THE SMALLEST SUPERNOVA REMNANTS
IN THE LARGE MAGELLANIC CLOUD

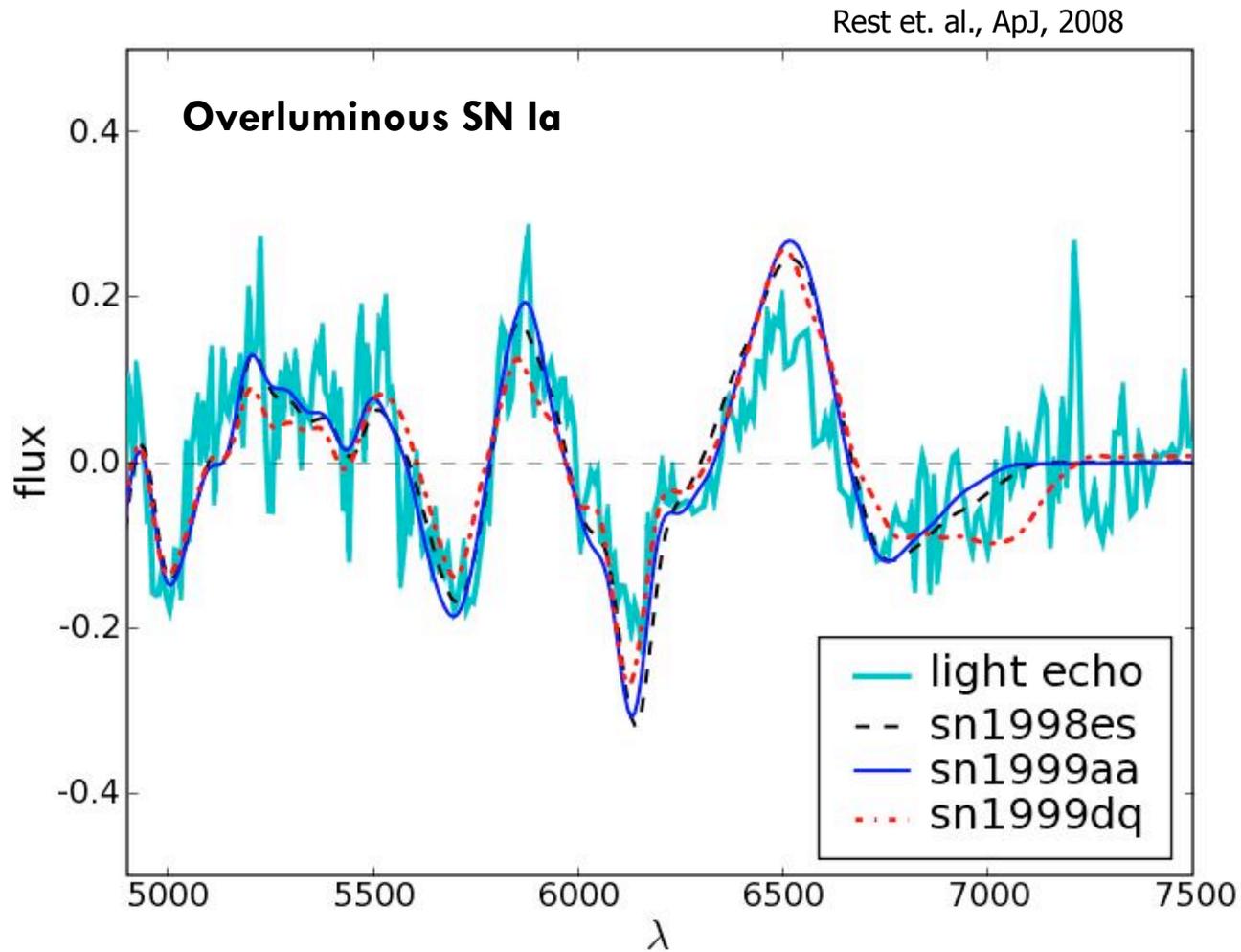
SNR Name	Age or Radius	SN Type	
SN 1987A	8 yr	II	
0540-69.3	1.5 pc	II	
N157B	1.8 pc	(II)?	
N103B	3.0 pc	Ia	LE3
0509-67.5	3.3 pc	Ia	LE2
0519-69.0	3.6 pc	Ia	LE1

Hughes et. al. (1995)

Rest et. al., 2005, Nature, 438, 1132



Overluminous SNe Ia correlating best with LE2 spectra



The Type of SNR 0509-67.5

Rest et. al., 2008, ApJ, 680

Light echo spectrum: The SN of SNR 0509-67.5 was an overluminous SN Ia with a $\Delta m_{15} < 0.9$

Badenes et. al., 2008, ApJ, 680

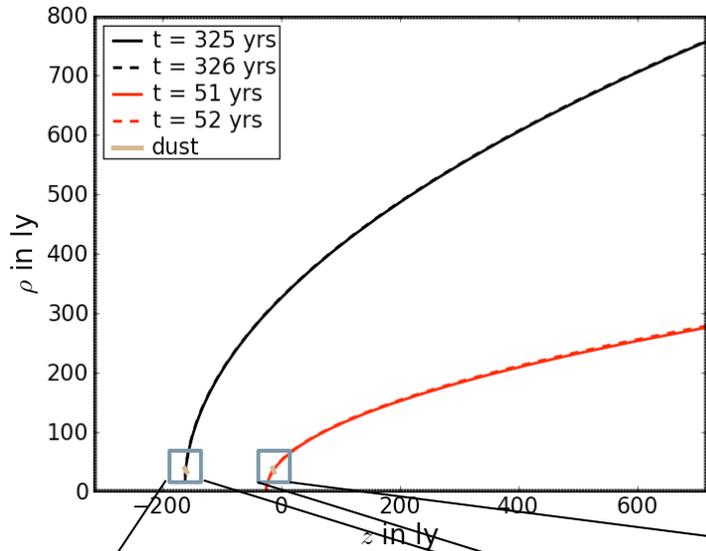
X-Ray spectrum of SNR 0509-67.5: Hydrodynamic non-equilibrium ionization models favor bright, highly energetic SN Ia

Rosetta stone for SN: First time the origin event of a SNR is directly determined, placing stringent constraints on the explosion mechanism and hence on the interpretation of X-ray spectra of the remnant

IR echoes of Cas A

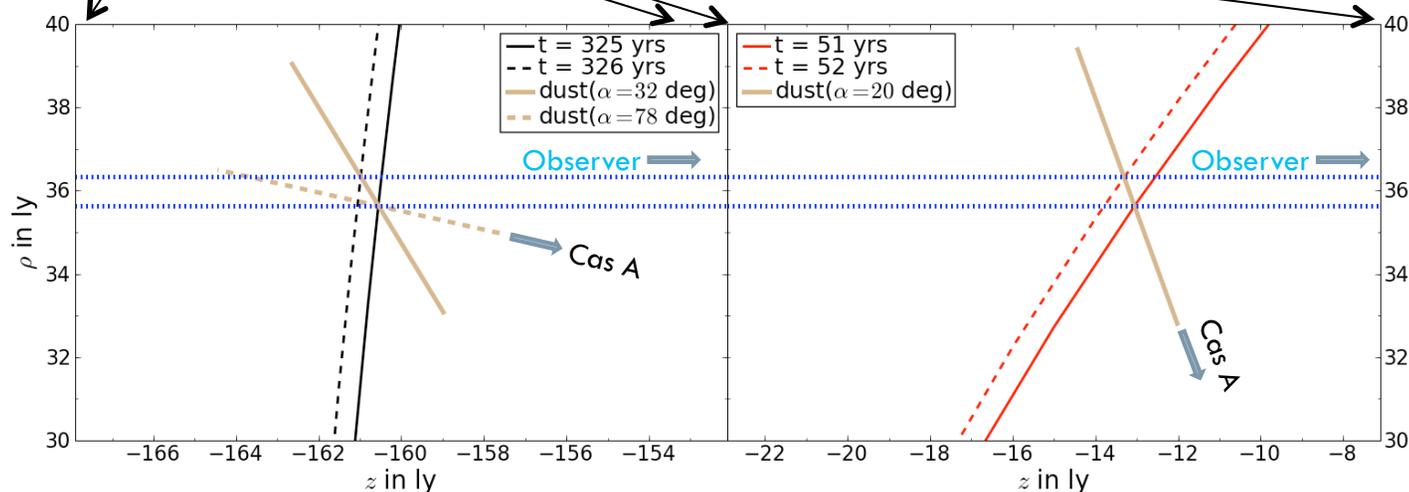
- Krause et al. 2005: Spitzer IR echoes
- Apparent motion: $v = 0.7c$
- Claim:
 - ▣ observed IR echo apparent motion evidence for X-ray flare in 1953 \pm 2.5 days
 - ▣ Need strong magnetic field
 - ▣ Magnetar

IR echoes of Cas A

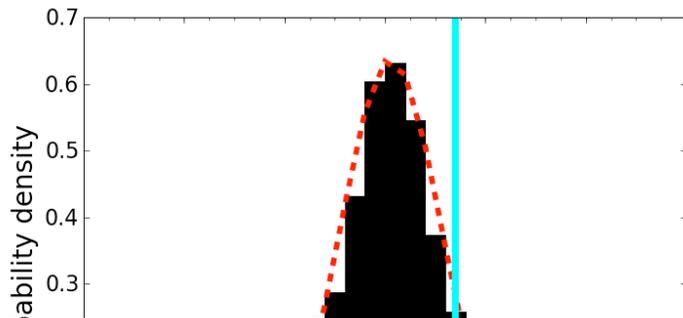


□ Krause et al. 2005:

- If Cas A SN source: angle of incidence of the heating flash relative to plane of sky ~ 75 degree.
- Therefore: much smaller apparent motion than observed
- Cas A SN can't be source of IR echoes



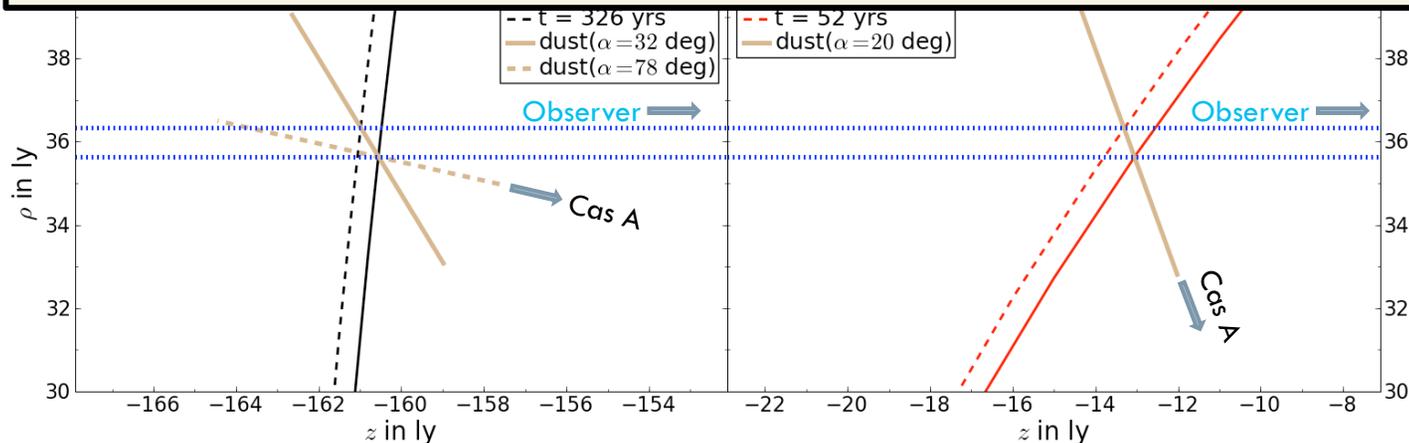
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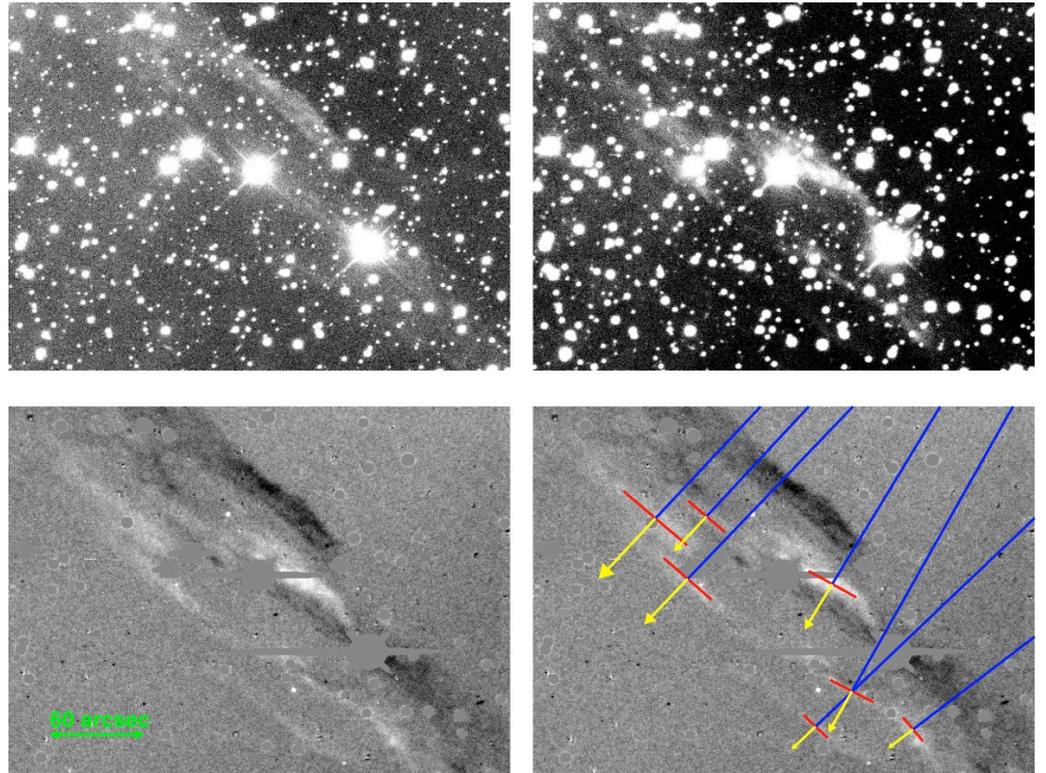
Mythbuster:

There has never been any evidence based on light echoes indicating that the Cas A remnant hosts a magnetar



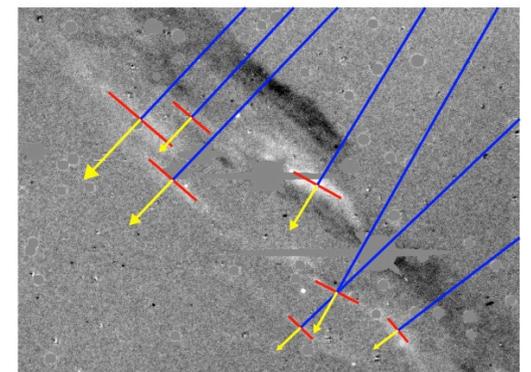
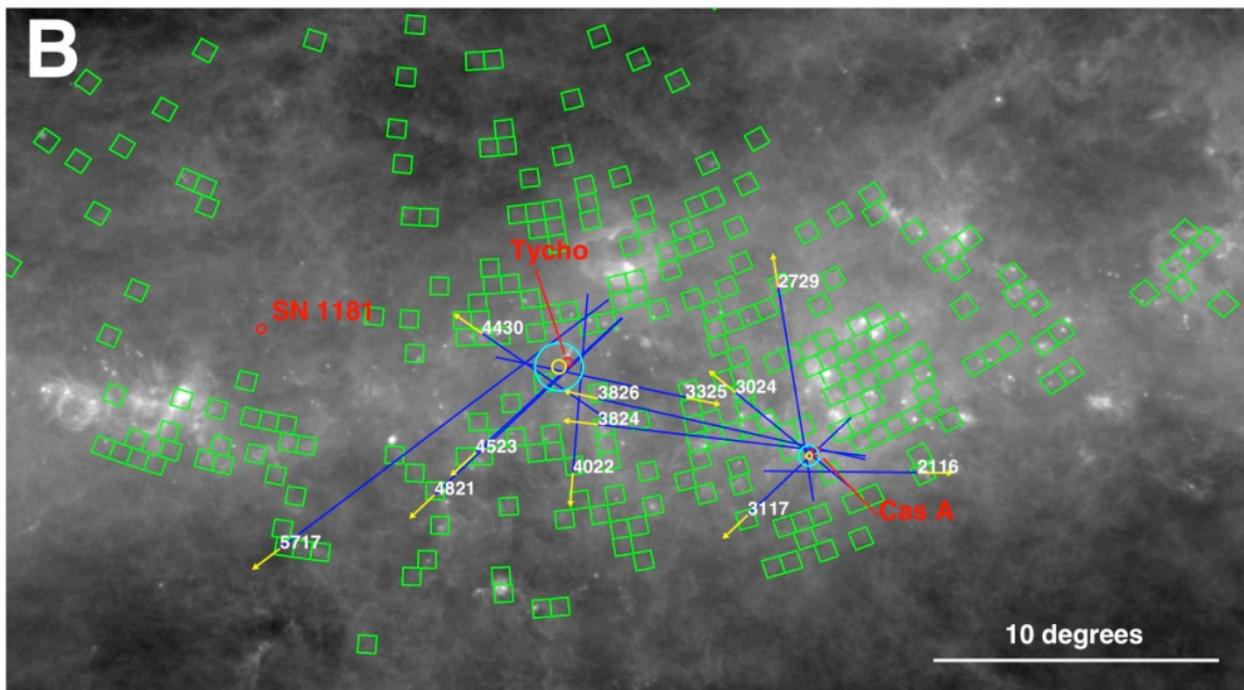
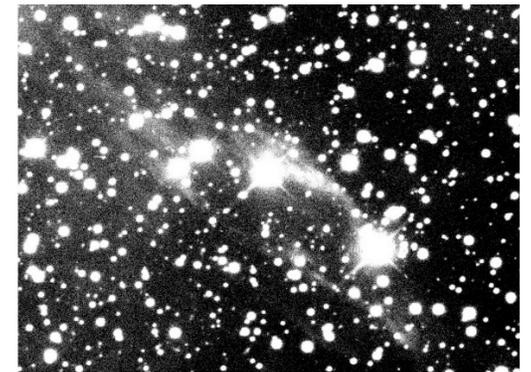
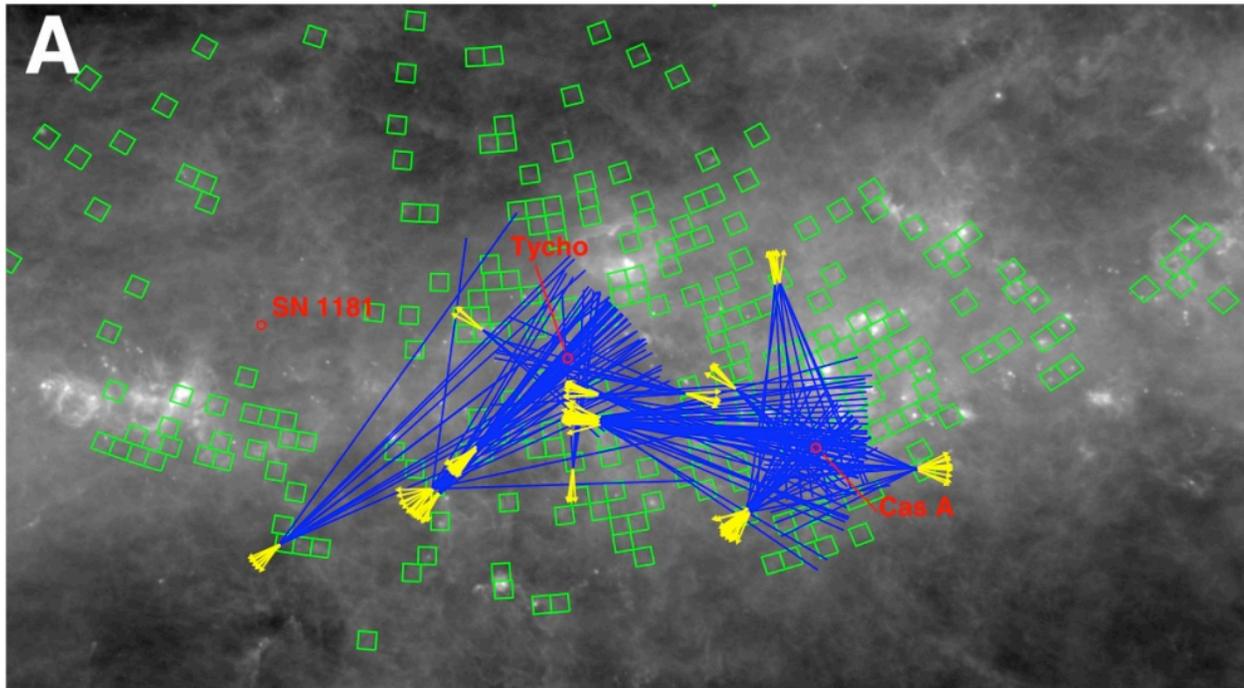
Light Echoes of Galactic SNe

- KPNO Mosaic imager
- 200 fields
- 12 light echo candidate groups
- Surface brightness $V \sim 24 \text{ mag/arcsec}^2$



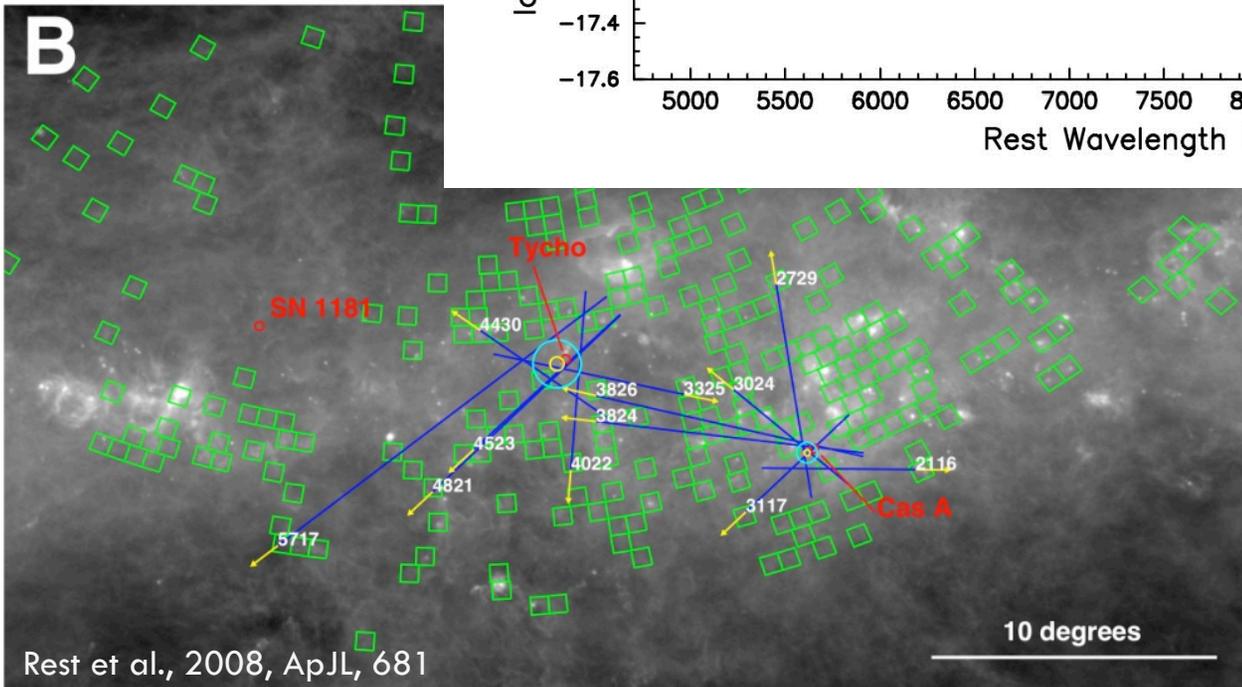
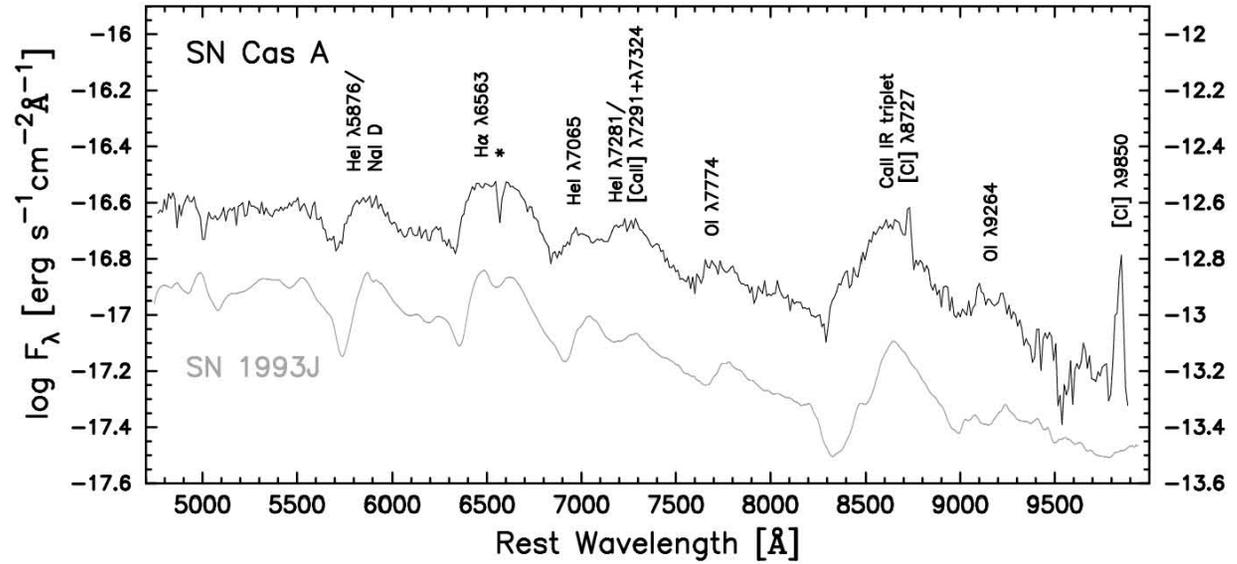
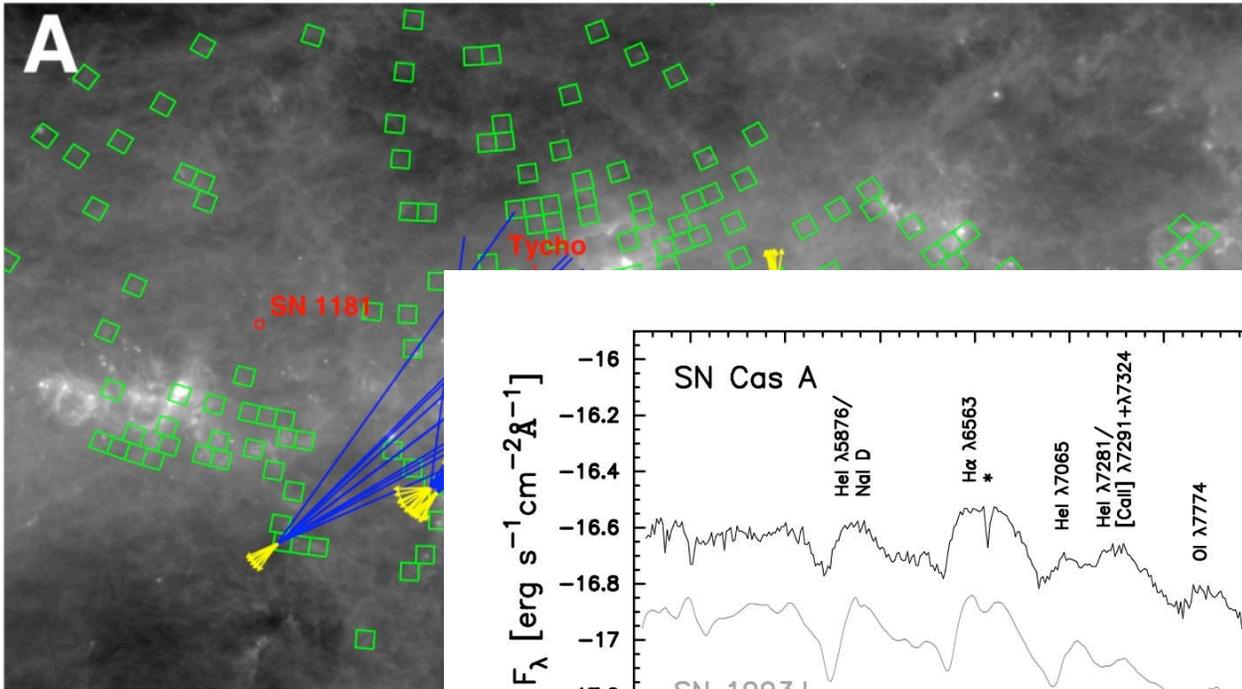
Rest et al., 2008, ApJL, 681

Tycho SN (1572) and Cas A (1680)



Rest et al., 2008, ApJL, 681

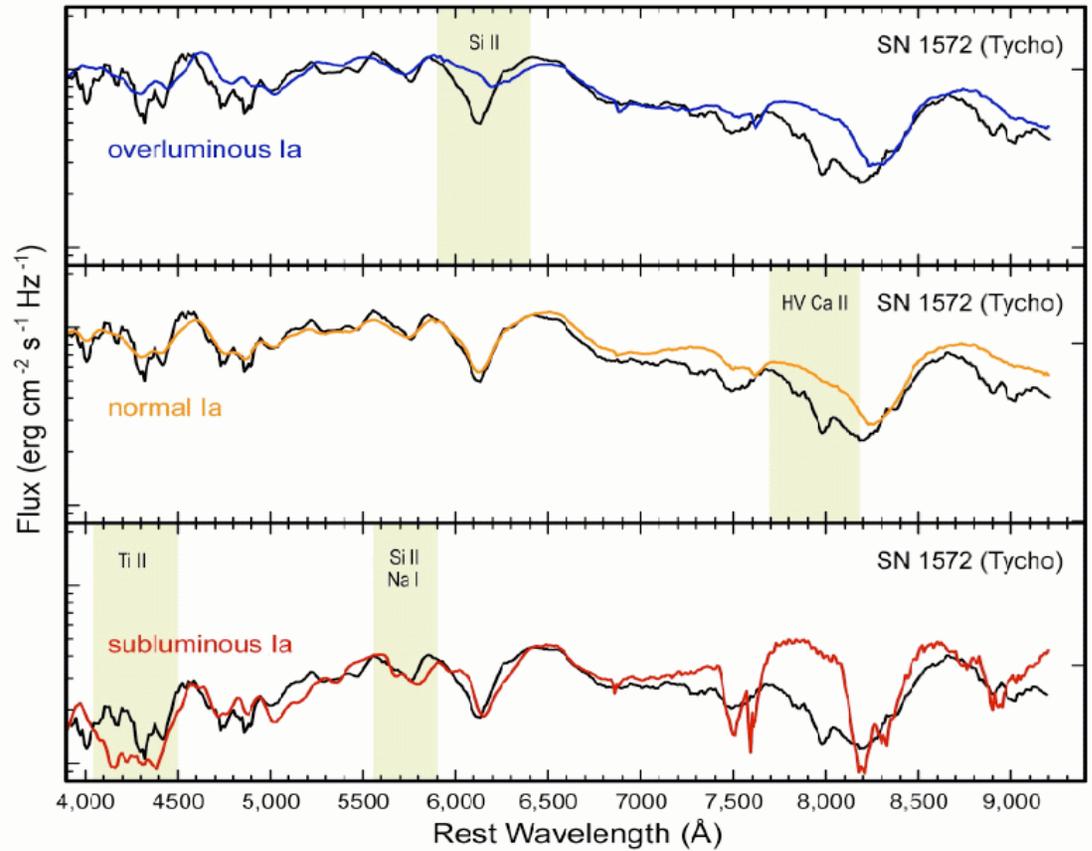
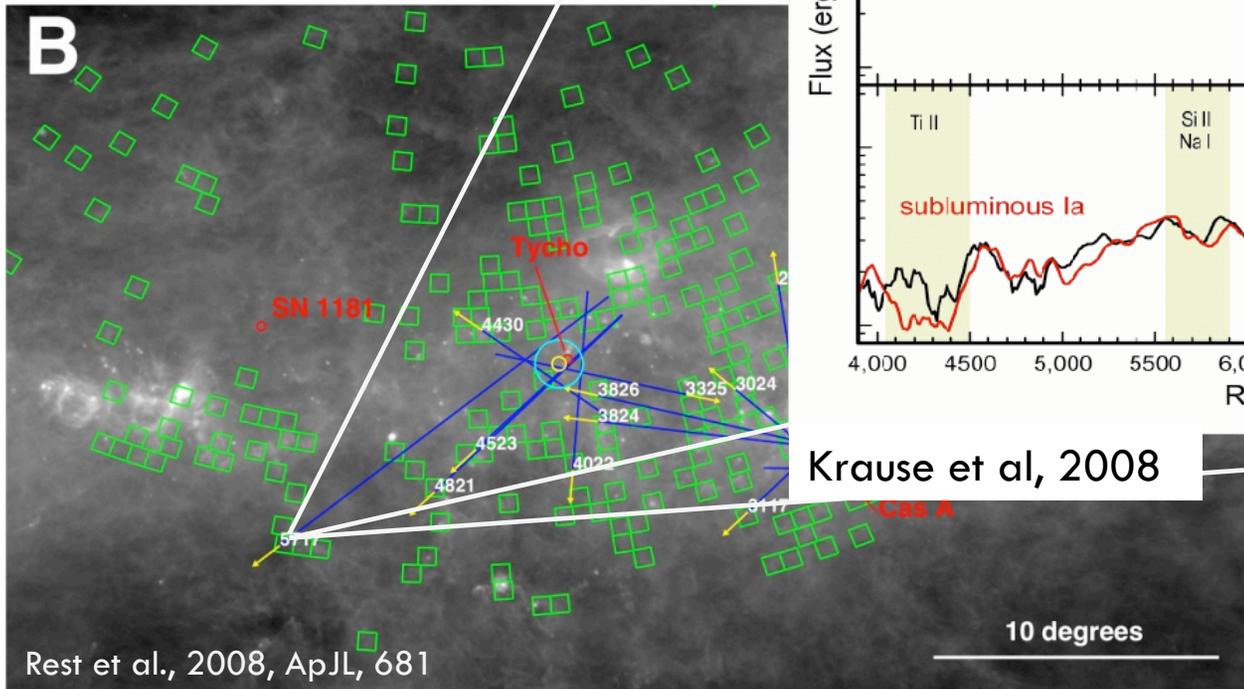
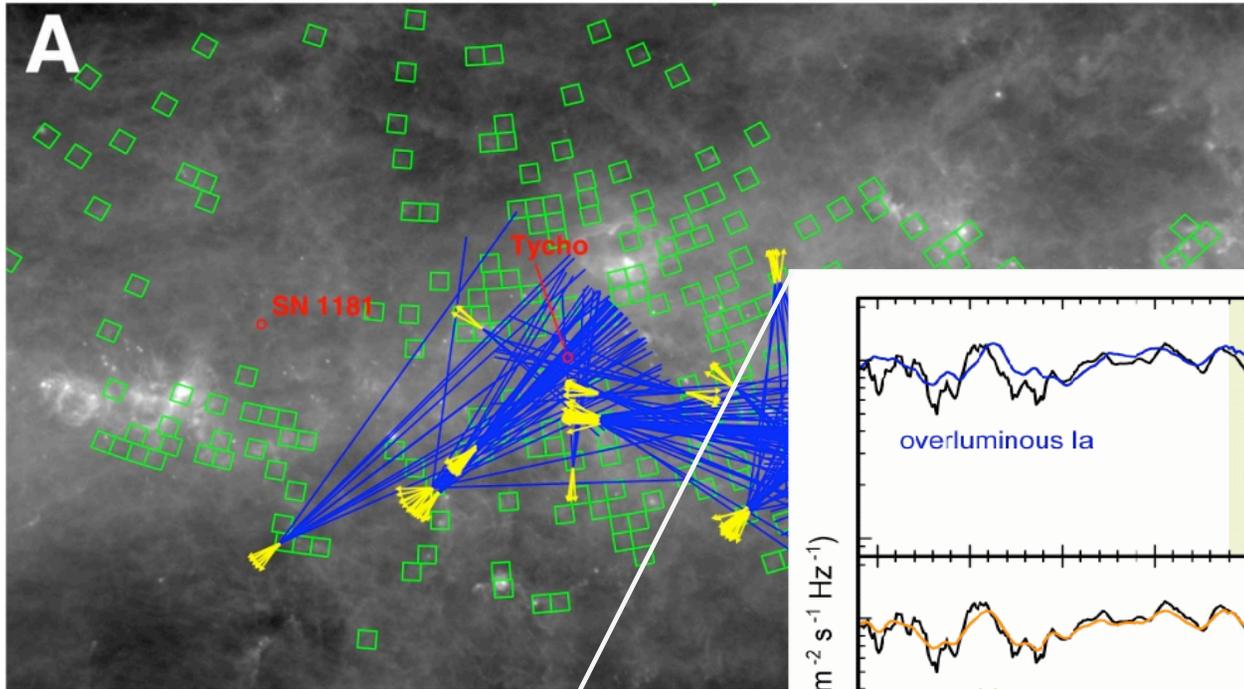
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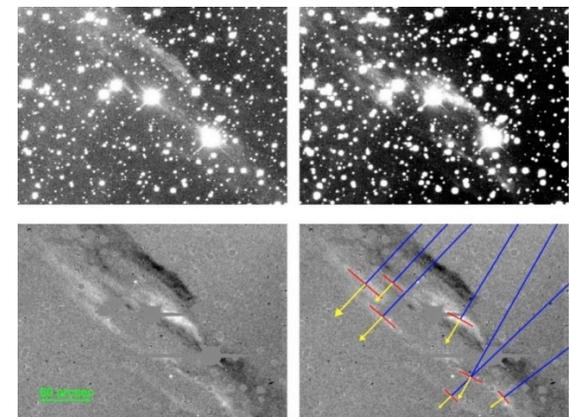
Rest et al., 2008, ApJL, 681

Galactic SNe light echoes:

Future surveys

- 7 known SNe in last 2000 years
- PanSTARRS, Skymapper, LSST,
- Visual inspection not possible!
- New detection package needed
 - ▣ Not centrally peaked like stars/galaxies
 - ▣ Low surface brightness, but 10s or arcsec wide/long

SN name	Date	Type
Cas A	1680 AD?	SN Ib?
Kepler	1604 AD	SN Ia/b?
Tycho	1572 AD	SN Ia
SN 1181	1181 AD	?
SN 1006	1006 AD	SN Ia
Crab Nebula	1054 AD	SN II
RCW 86	0185 AD	SN II?



Conclusions

- Light echoes from SNe are visible 100s of years
- 3-D dust structure
- Typing of ancient SN based on light echo spectrum (SNR 0509-67.5, Cas A, Tycho)
- Rosetta stone!
- 3D spectroscopic view of SNe possible!
Asymmetries!
- PanSTARRS, LSST, Skymapper: possibility to find light echoes of more SNe