



The Radio Supernova Remnant of SN 1987A at 20 Years of Age

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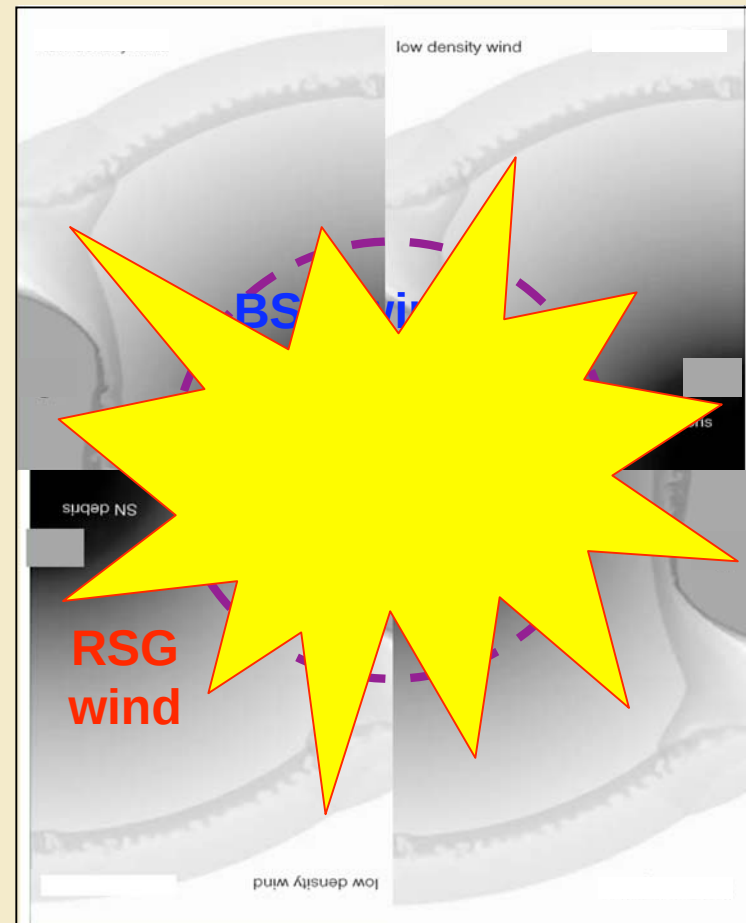




Circumstellar Structure

- Dense slow red supergiant wind, concentrated into equatorial plane
- High-velocity low-density isotropic blue supergiant wind for final $\sim 20\,000$ yr
- Blue supergiant photoionises red supergiant wind (Chevalier & Dwarkadas 1996)

HST WFPC2 (Pete Challis / SAINTS)



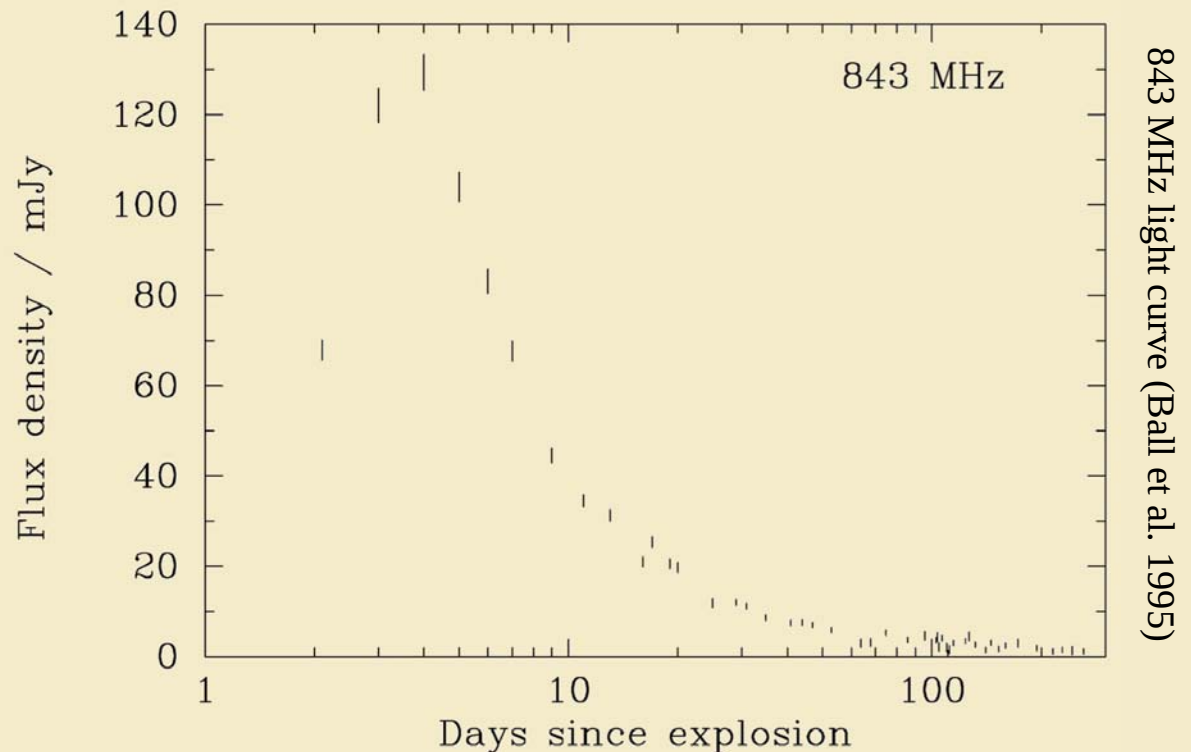
Hydro simulation (Michael et al. 2003)



Prompt Phase

- Core collapse on 23 Feb 1987
- Burst of radio emission seen by MOST on day 2; peaked on day 4 (Turtle et al. 1987)
- Power law decay; faded by day 150
- Synchrotron in BSG wind ($\rho \propto r^{-2}$) (Storey & Manchester 1987; Chevalier & Fransson 1987)
- $H\alpha$, VLBI: $V \sim 19000 - 30000$ km/s (Hanuschik & Dachs 1987; Jauncey et al. 1988)

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Birth of a Supernova Remnant

- MOST, & then ATCA, redetected radio emission in mid-1990 (day ~ 1200)

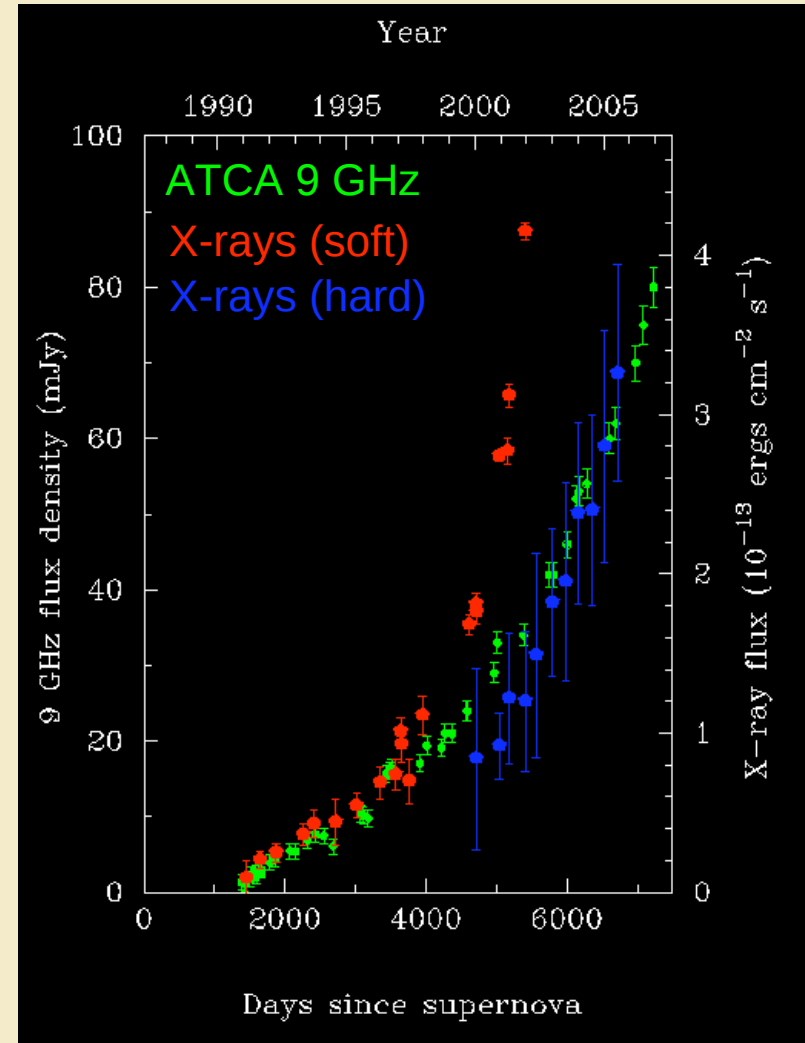
MOST (Douglas Bock)



ATCA (ATNF/CSIRO)



- Steady increase in flux over 17 years
- 9 GHz ATCA data ($\theta \approx 0.9''$) showed source was extended (Staveley-Smith et al. 1992, 1993)
- Track size vs. time in u - v plane: first-order fit to thin spherical shell (Staveley-Smith et al. 1993; Gaensler et al. 1997, 2007)

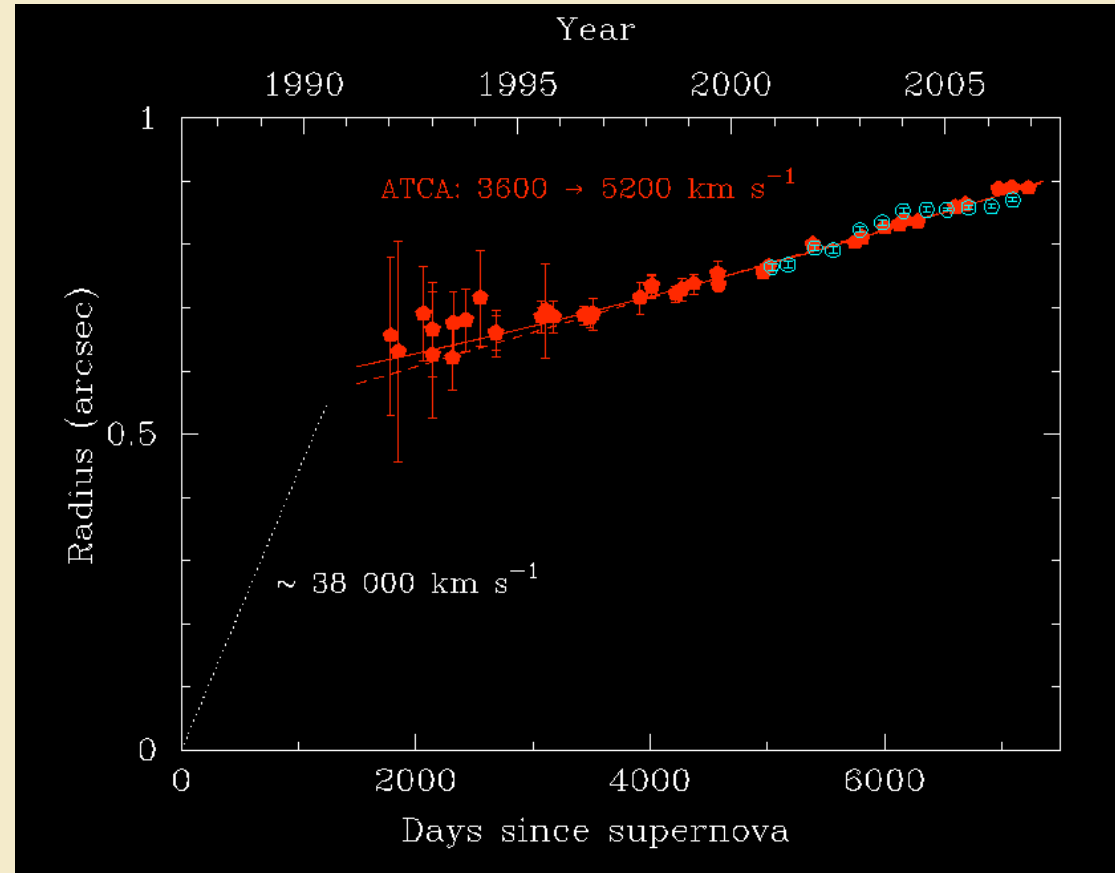


Staveley-Smith et al. (2007)



Expansion

- Shell was $\sim 1.3''$ (0.3 pc) across at day ~ 1800
→ mean expansion
 $\sim 38\,000$ km/s (1987-1992)
- Since day 1800,
approx. constant
expansion at
 $V = 4700 \pm 100$ km/s
→ rapid deceleration
→ slightly better fit:
quadratic increase from
3600 km/s to 5200 km/s



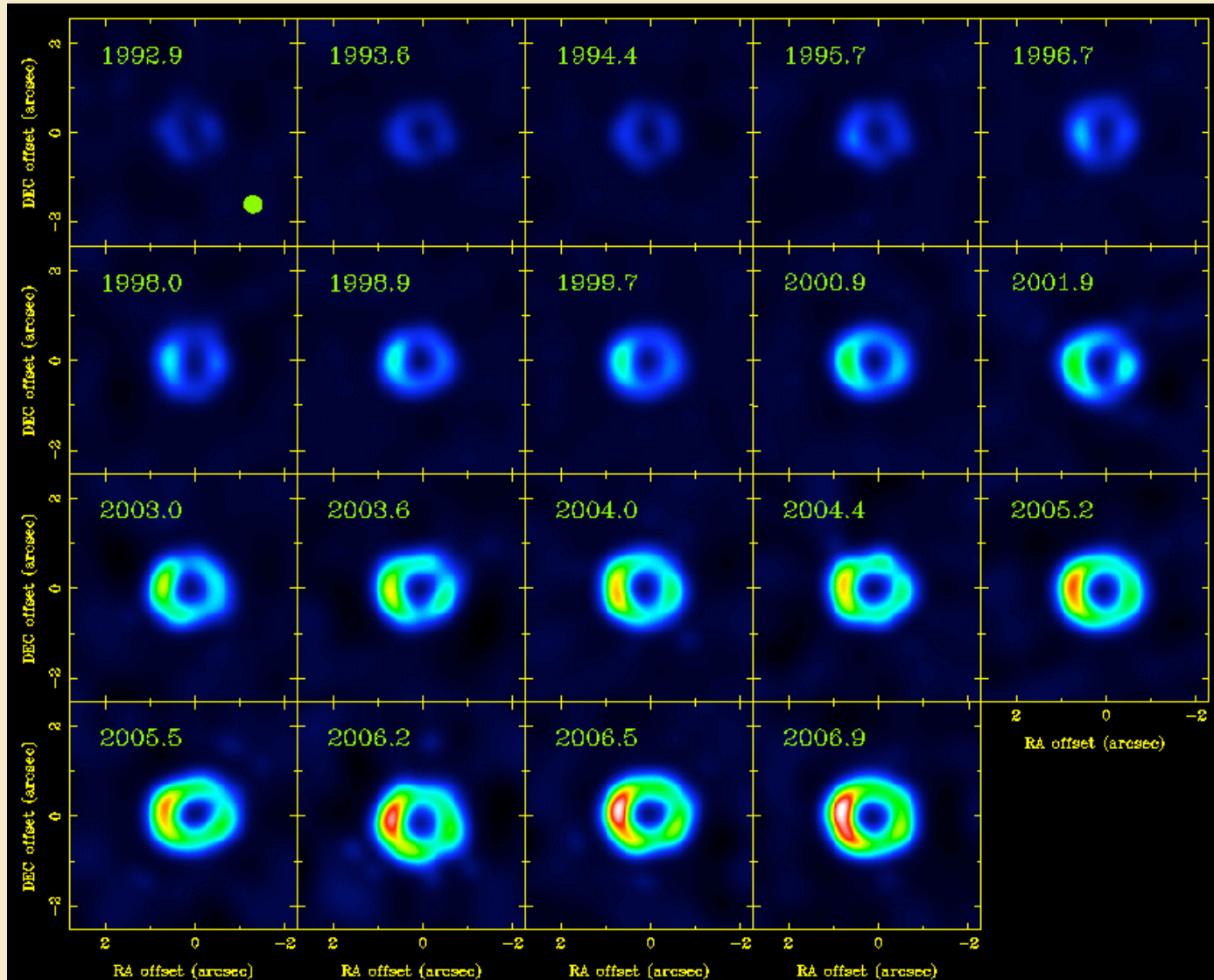
Gaensler et al. (2007)

- Source now same size as optical ring
- Radius & velocity match *Chandra* X-ray data (Park et al. 2004, 2006, 2007)



Imaging & Super-Resolution

Gaensler et al. (2007)

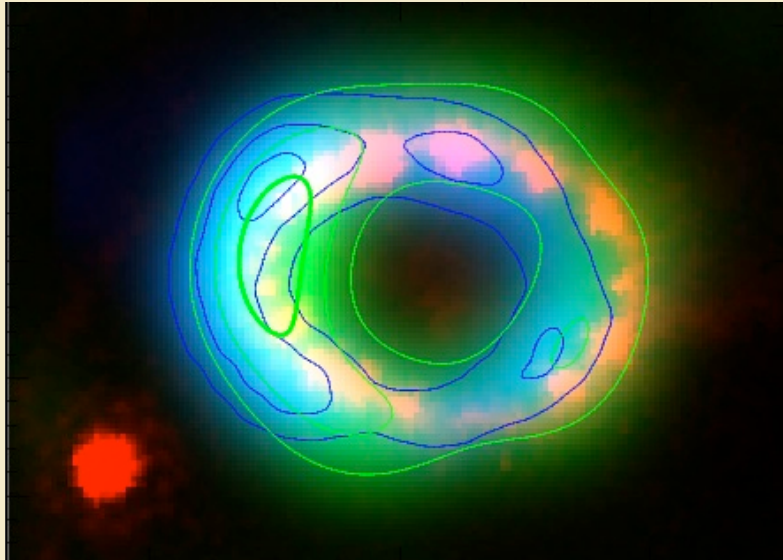


- Limb brightened
- Bright lobes to east and west
- Eastern lobe brighter than western lobe, & brightening faster

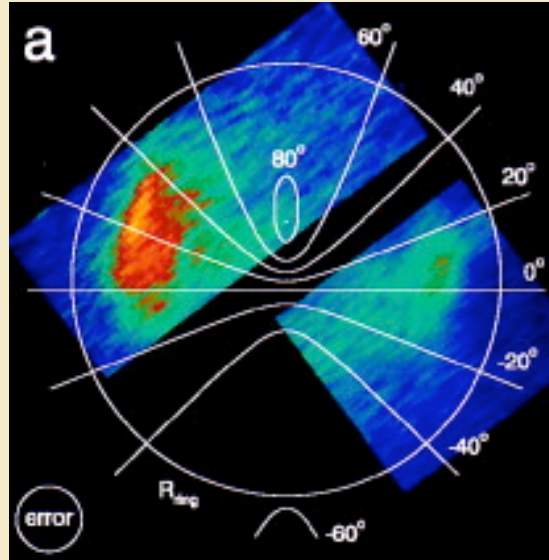
ATCA 9 GHz super-resolution (0.5 arcsec)



Multi-Wavelength Comparison

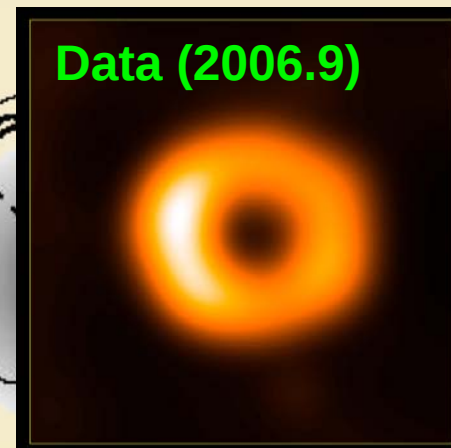
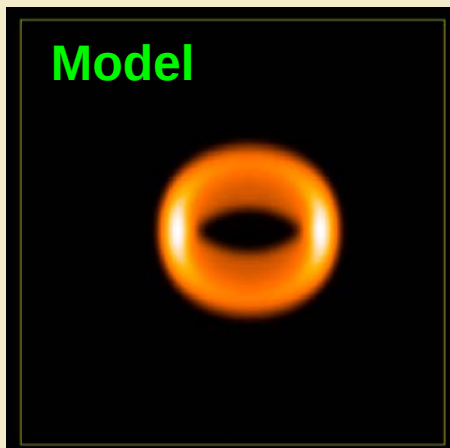


ATCA / *Chandra* / *HST* (day 6300)



STIS Ly α (Michael et al. 1998)

- Two-lobed structures seen in radio, hard X-rays, optical
- Lobes align with major axis of ring
- True morphology is likely a tilted ring
- Brighter lobe is at larger radius
- Asymmetry in explosion/ejecta

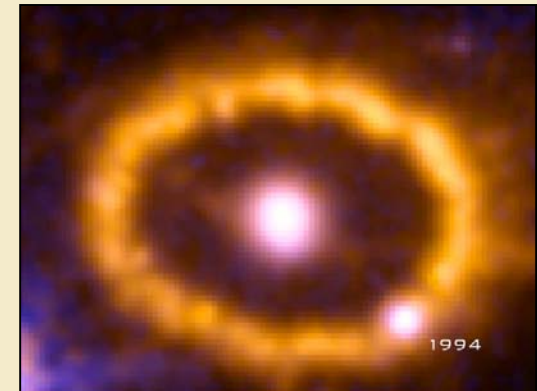


Michael et al. (2003)

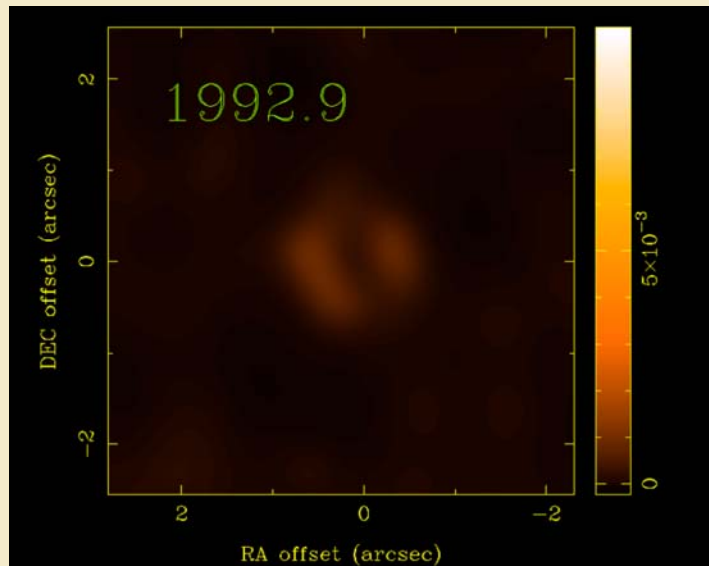


Conclusions

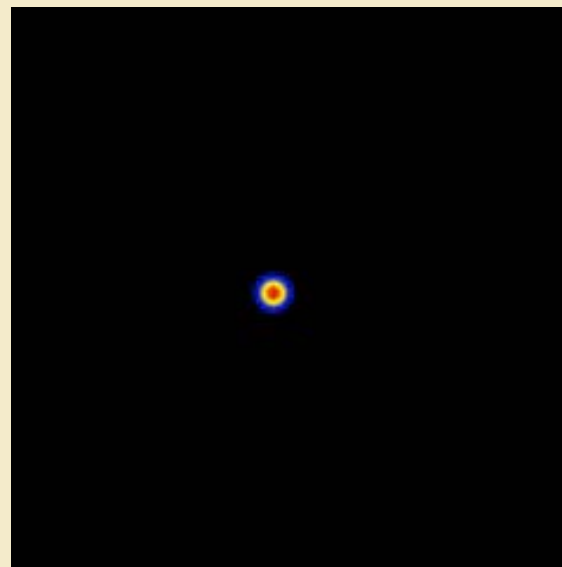
- Turn-on & deceleration of radio source due to impact with dense RSG wind
- Radio remnant of Supernova 1987A continues to steadily expand & brighten
- Consistent multi-wavelength picture of reverse-shock region:
 - limb-brightened shell expanding at $V \sim 5000$ km/s
 - interaction is with stellar wind in equatorial plane
 - collision of ejecta piston with dense optical ring now upon us!
- The Future: ALMA, ASKAP, SKA



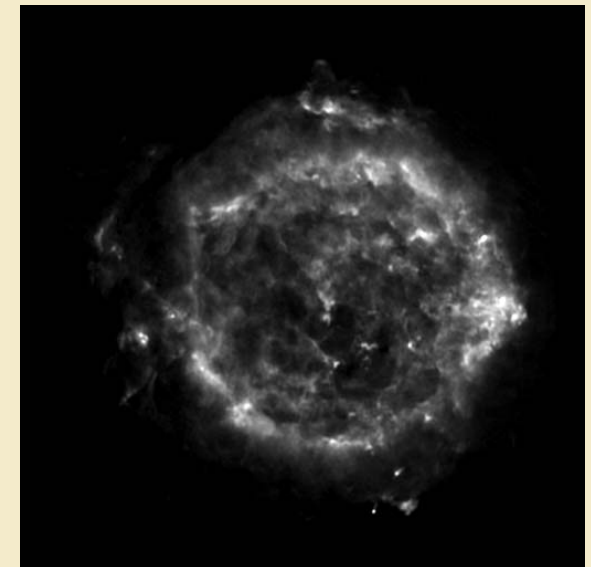
NASA / ESA / G. Bacon



9 GHz images of SN 1987A, 1992 to 2007



SN 1993J (Bietenholz et al. 2003)



Cas A (L. Rudnick / T. Rector)