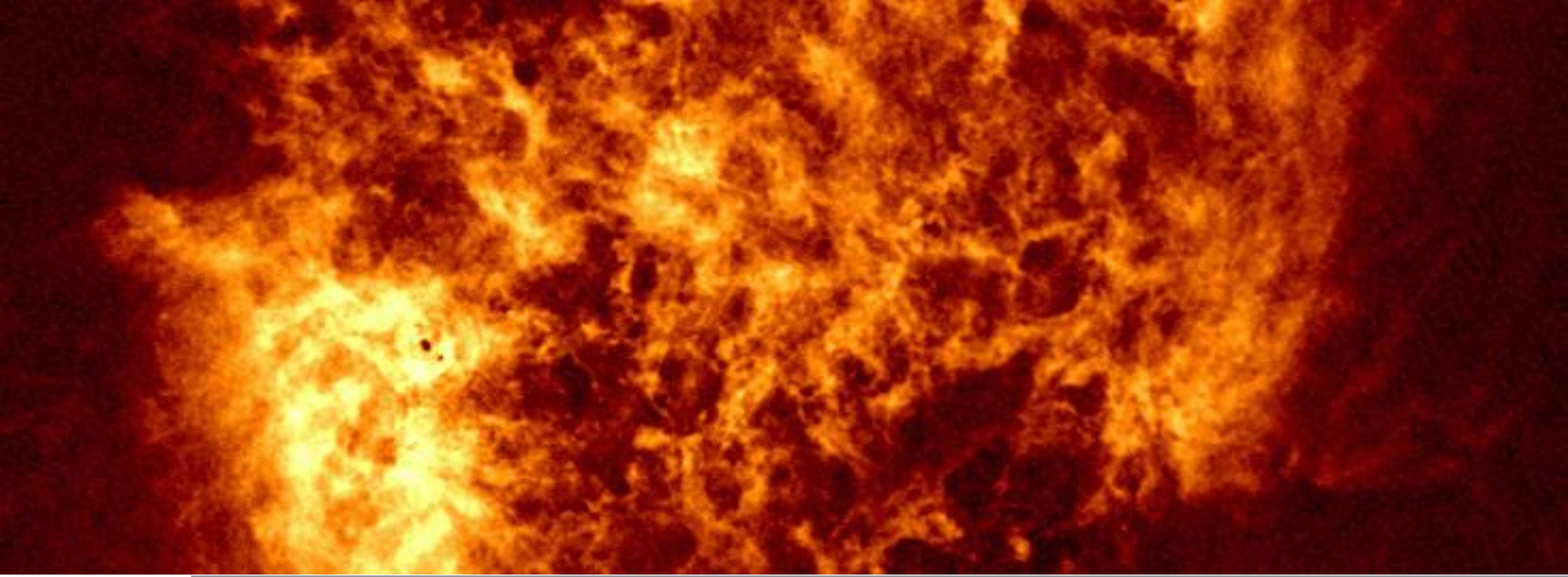
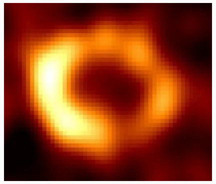


The Radio Evolution of SN1987A

Lister Staveley-Smith

University of Western Australia



Collaborators

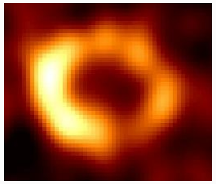
Lewis Ball (ATNF)

Bryan Gaensler (University of Sydney)

Mike Kesteven (ATNF)

Dick Manchester (ATNF)

Tasso Tzioumis (ATNF)



Summary of Early Radio Observations

Prompt SN outburst lasting ~5 days

- Optically thick RSN phase (Turtle et al. 1987)
- Initial expansion rate >19,000 km/s (Jauncey et al. 1987)

Re-emergence as a radio source on day 1200

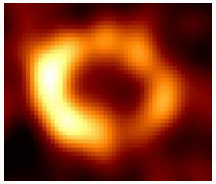
- Optically thin SNR phase (Staveley-Smith et al. 1992)
- Expansion rate ~3000 km/s (Gaensler et al. 1997)
- Accelerating flux increase near day 4600 (Manchester et al. 2002)

Low Radio Luminosity

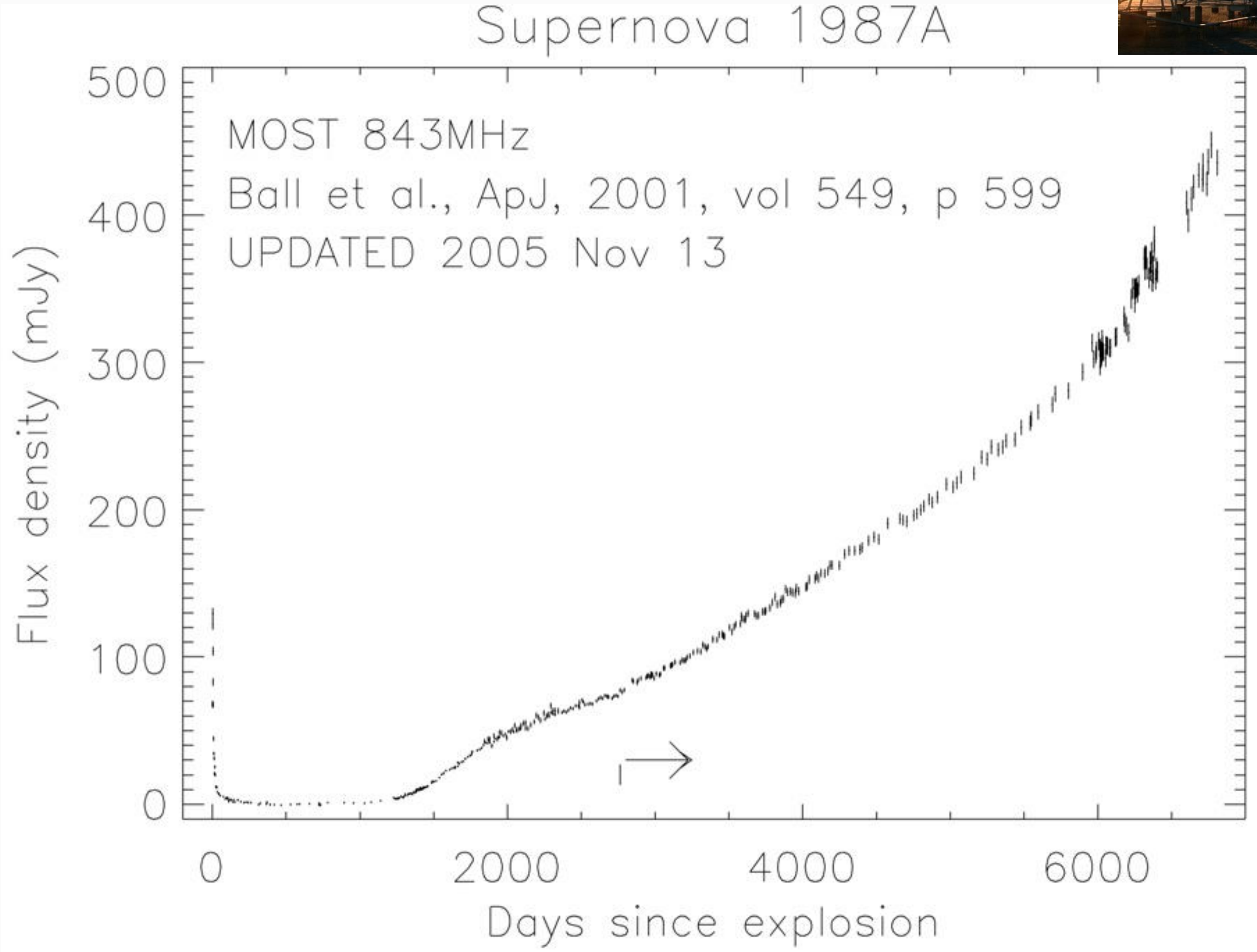
- 10^{-4} times luminosity of SN1993J at maximum

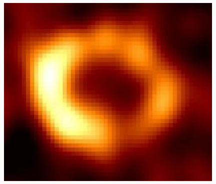
Unusual Evolution

- Circumstellar model of Chevalier & Dwarkadas (1995) and CR shock acceleration model of Duffy, Ball & Kirk (1995) provided some explanation.

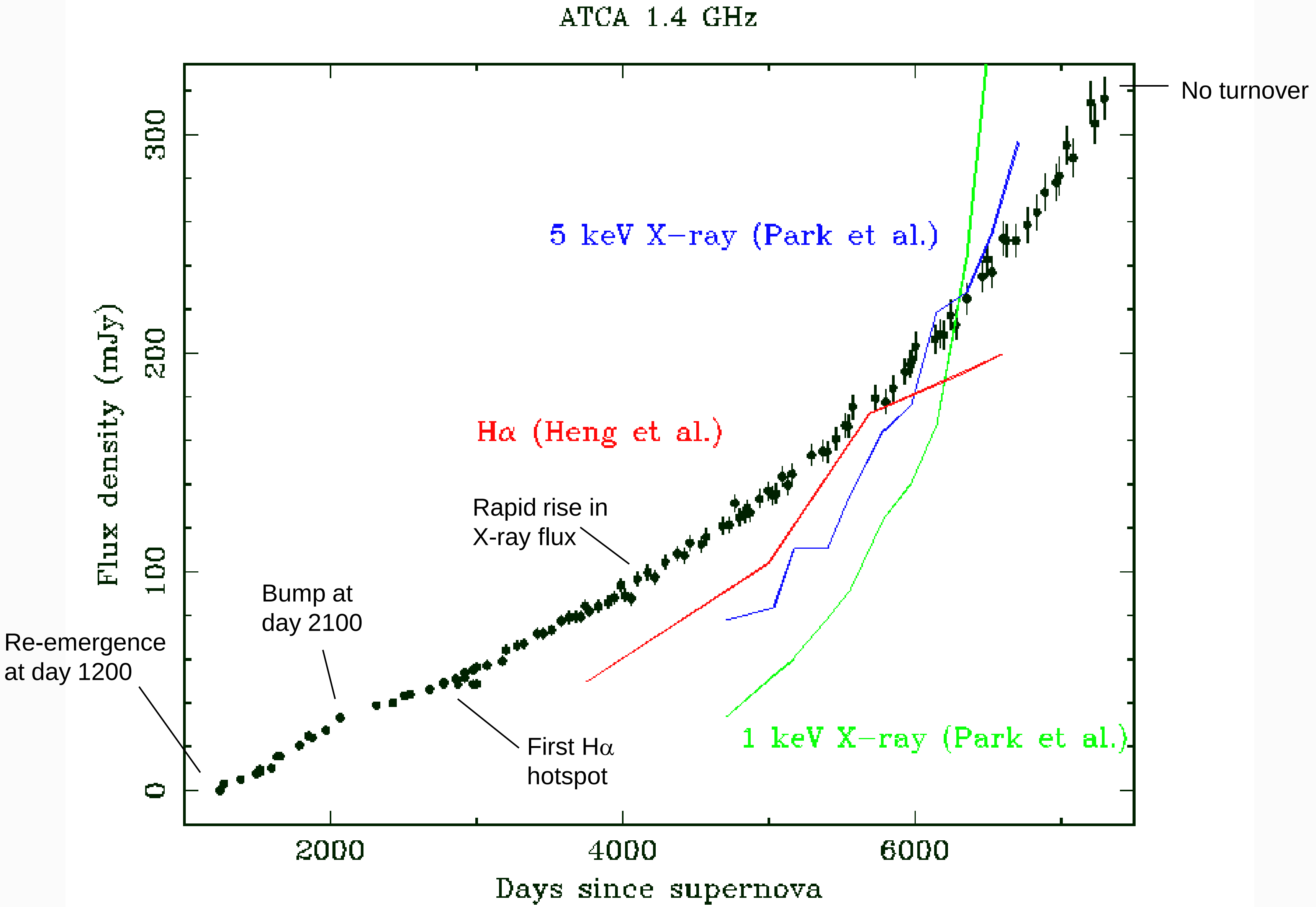


MOST 843 MHz Light Curve

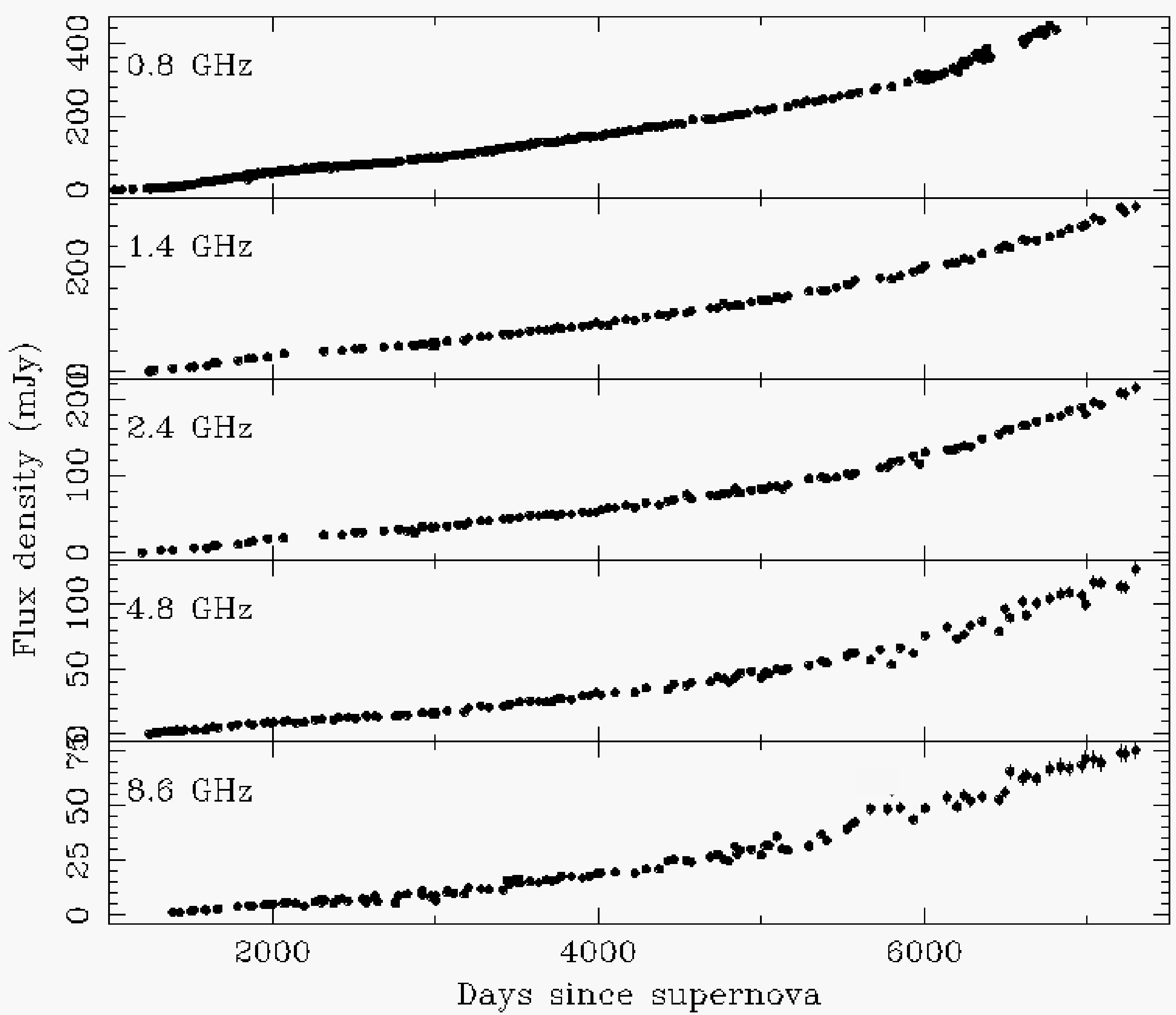


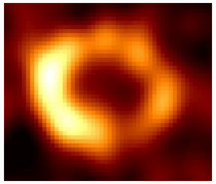


ATCA 1.4 GHz light curve to day 7297 (2007 Feb 15)

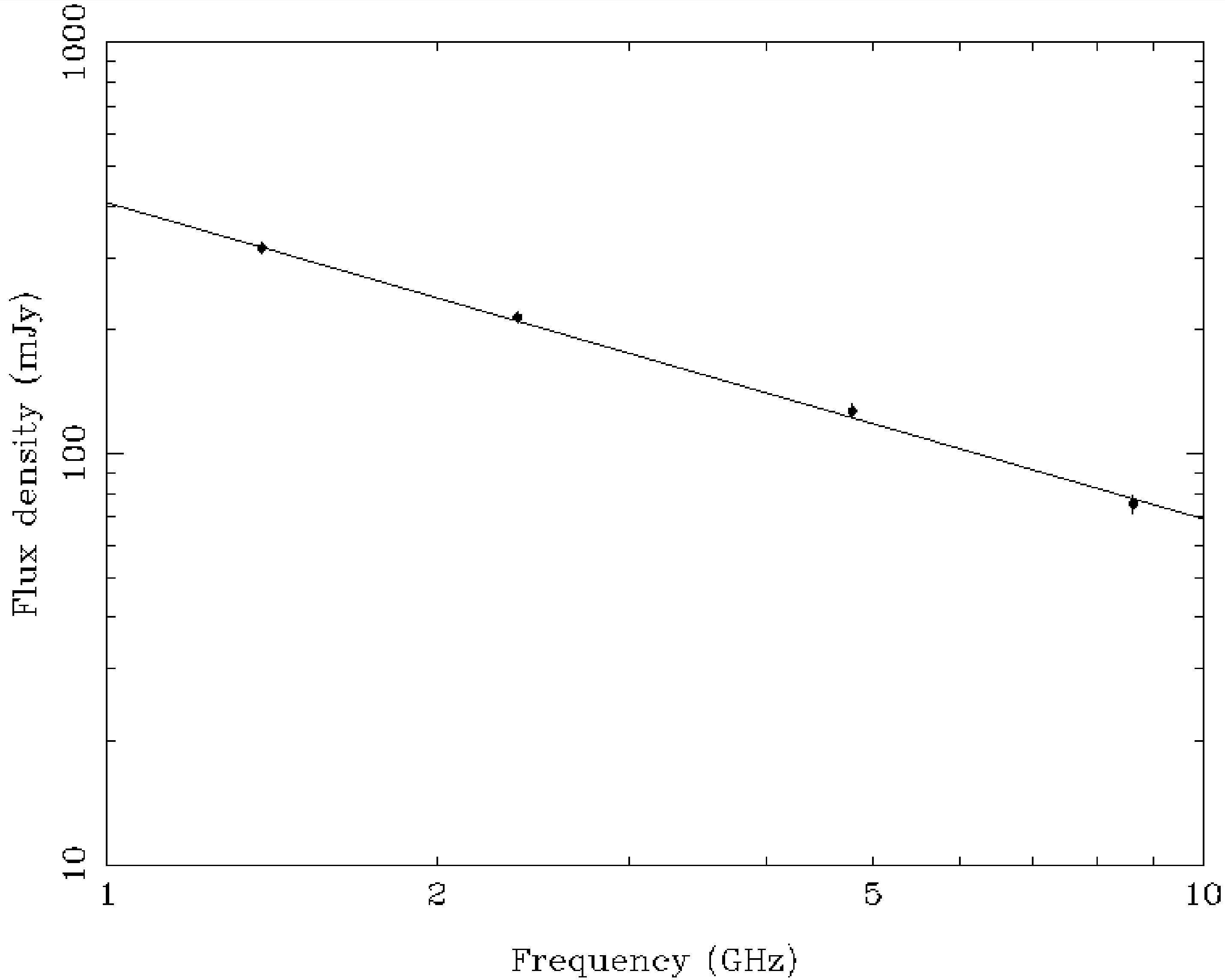


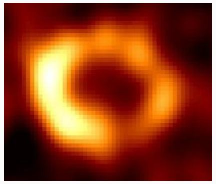
Spectral Evolution





Day 7300 radio spectrum



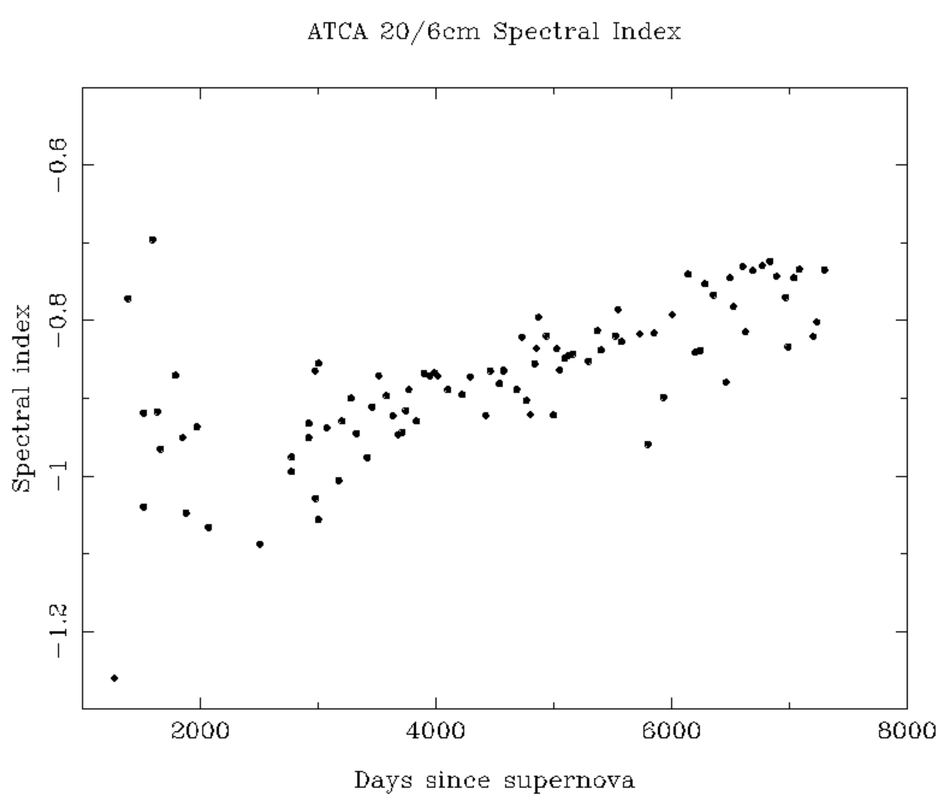


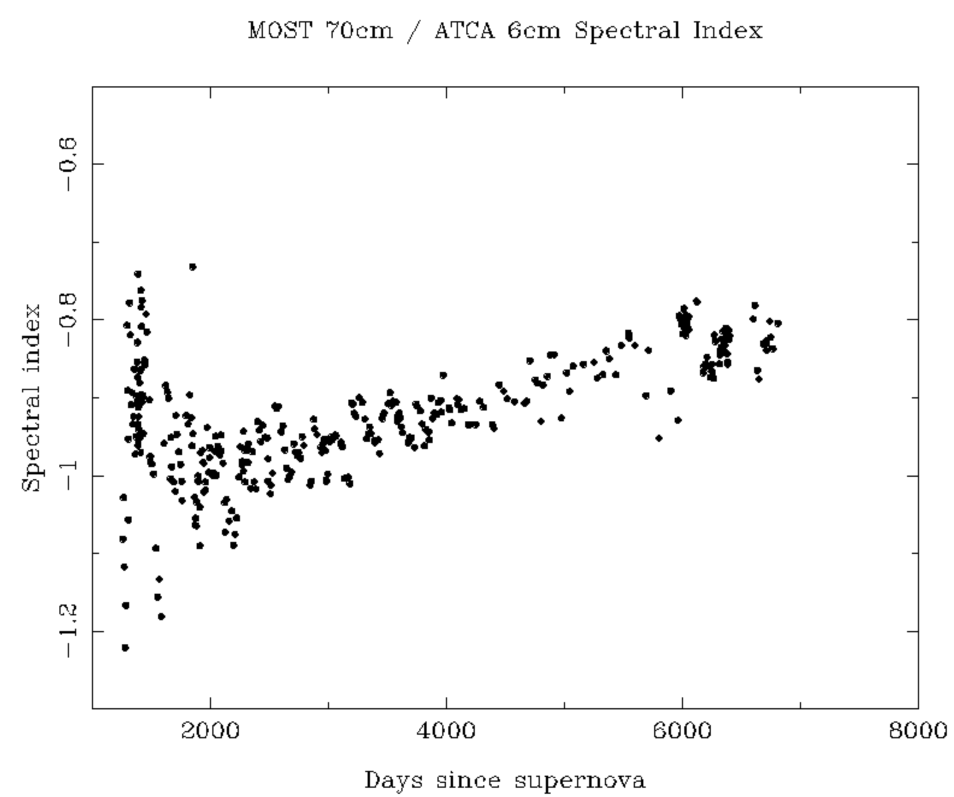
Spectral Evolution

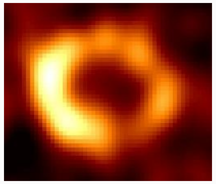
Spectral index ($S \propto \nu^{\alpha}$) is now α=-0.75

Flattening at a rate $\Delta\alpha$=+0.02/yr, will reach canonical SNR spectral index (-0.5) in 2020

Electron energy spectral index is -2.5

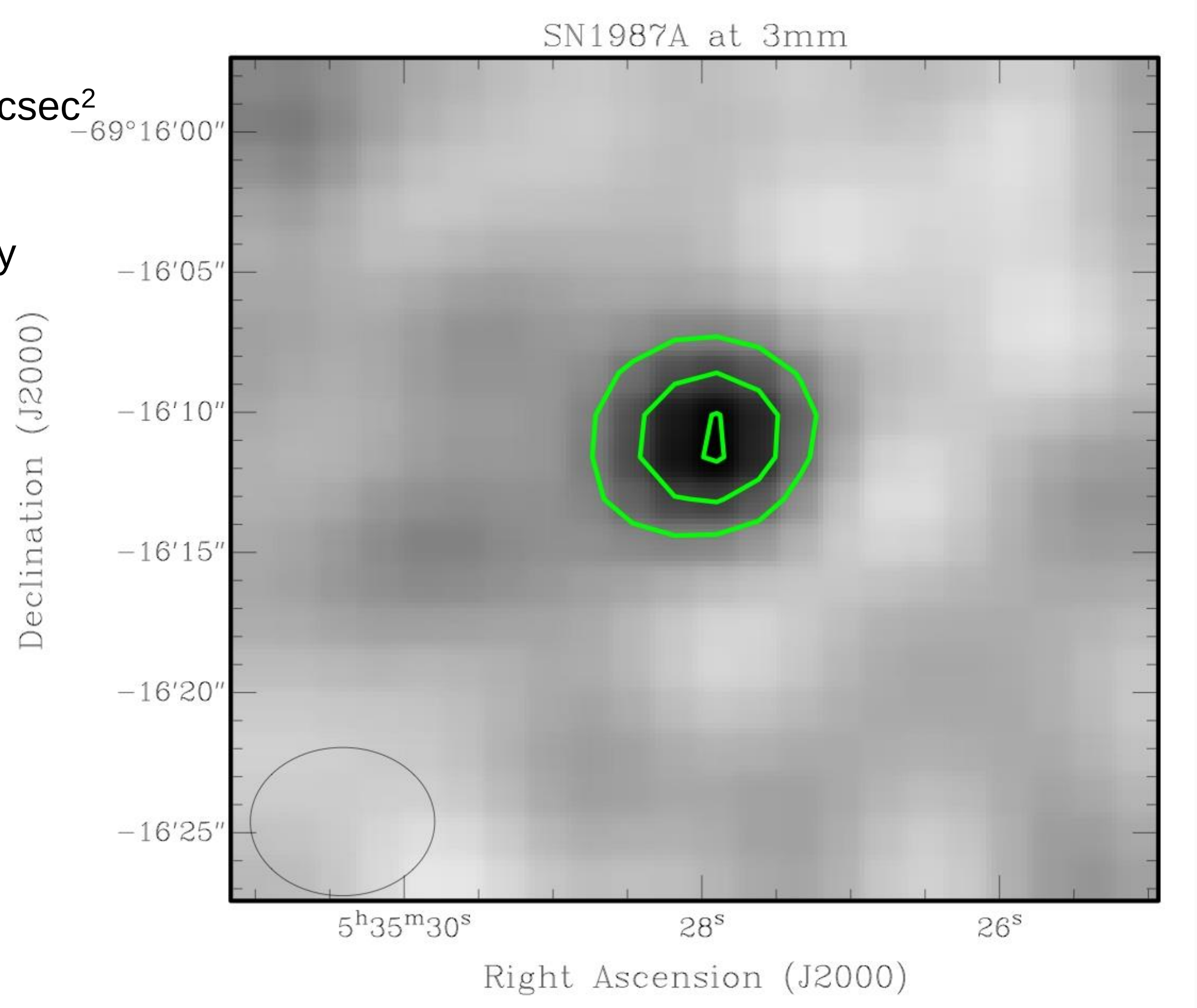


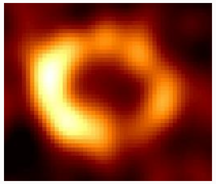




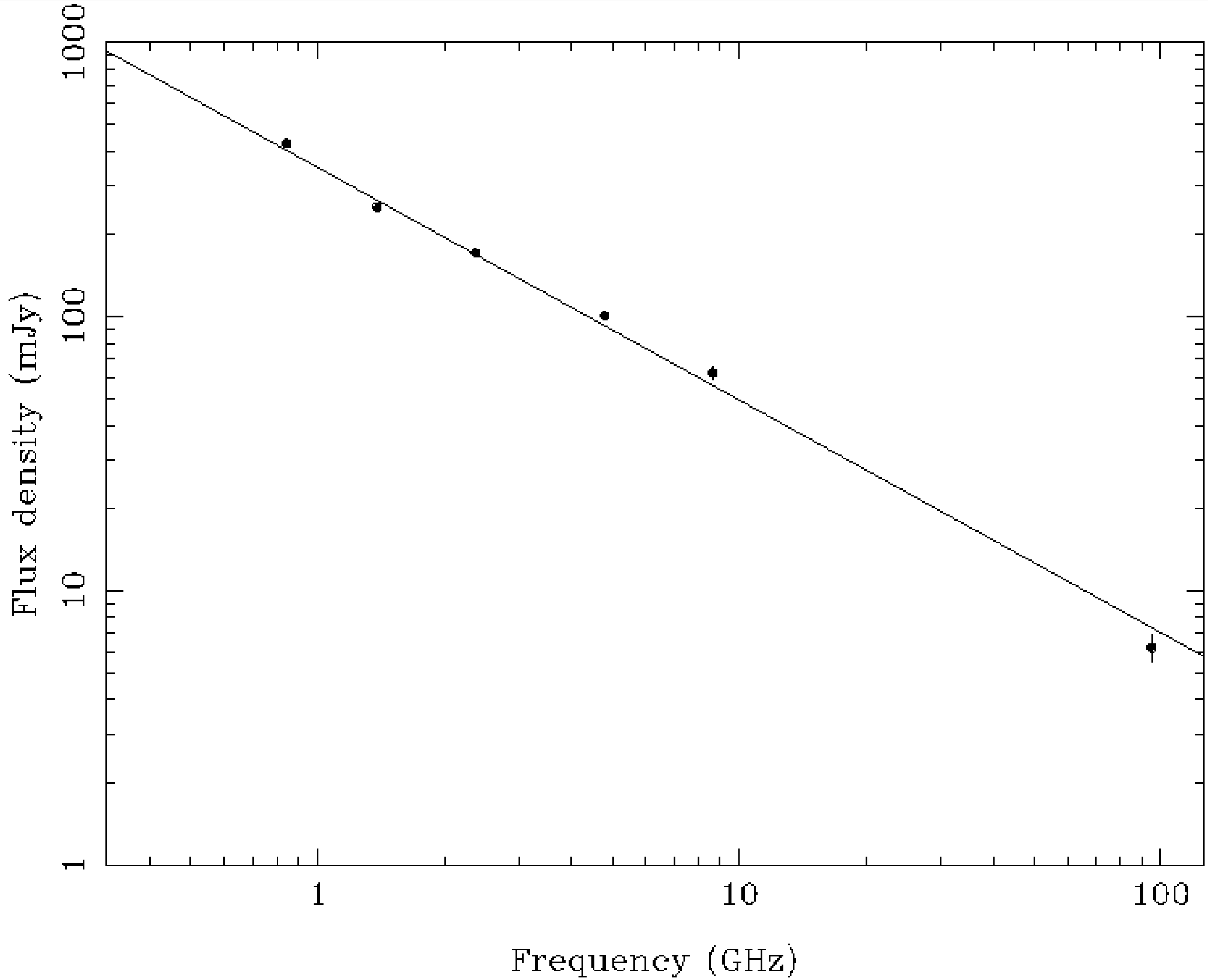
First ATCA millimeter detection

- Day 6710:
- H75 array - 6 x 5 arcsec^2
- 94 GHz
- Flux density 6.2 mJy





0.8-100 GHz Spectrum - day 6710



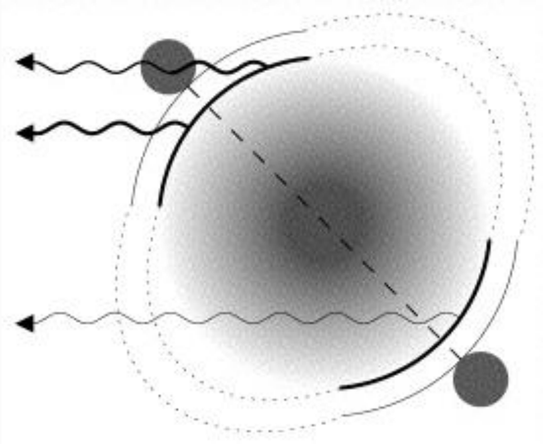
Radio emission mechanism

Cosmic rays accelerated in an CR-modified shock (Ball & Kirk 1992, Duffy et al. 1995).

Interaction with magnetic field produces synchrotron radiation

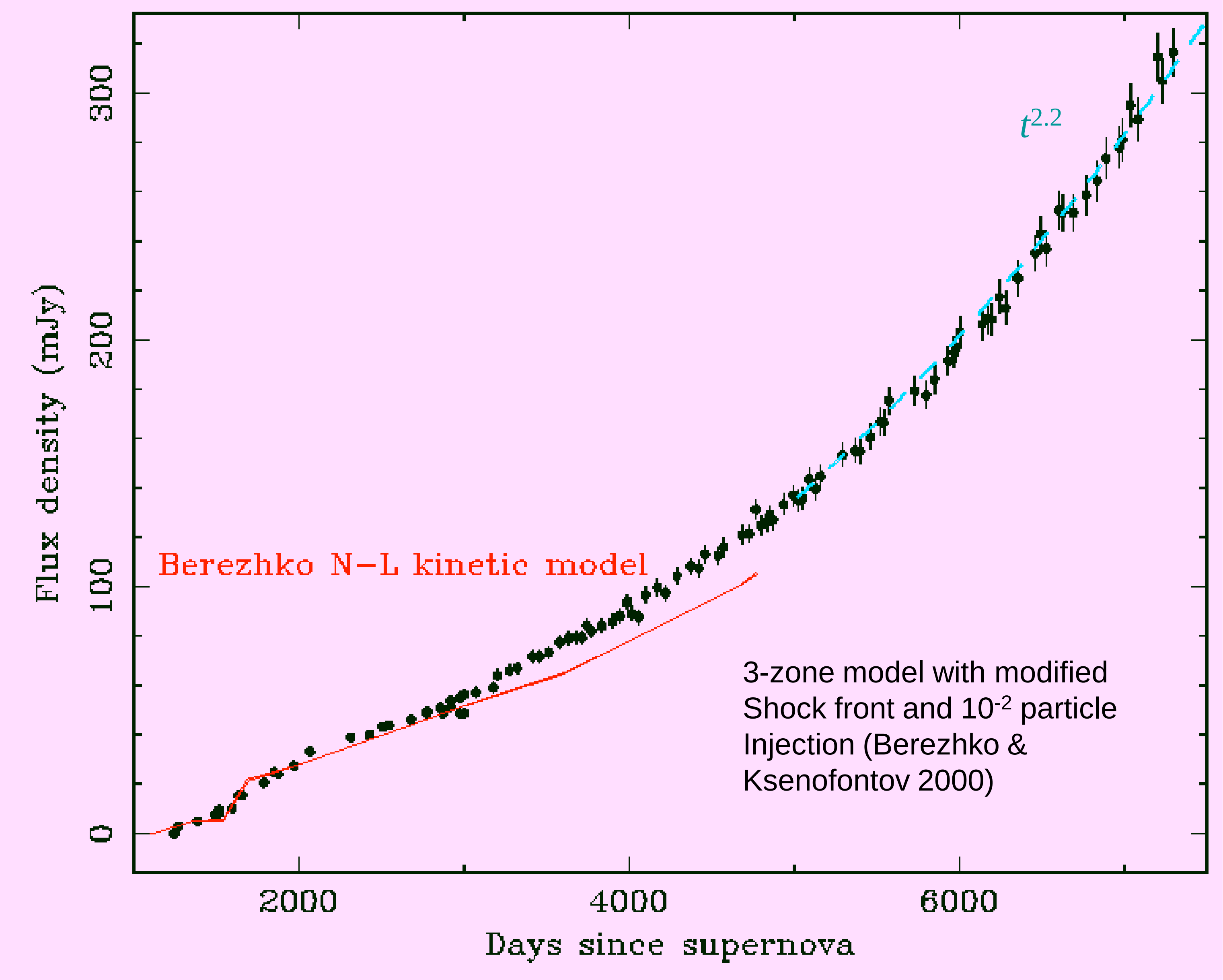
Toroidal geometry and slow expansion suggestive of production of CRs in reverse shock.

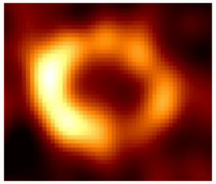
However B field and CR energy density probably too low in reverse shock for efficient emission (Dorfi 1991, Berezhko & Ksenofontov 2000)



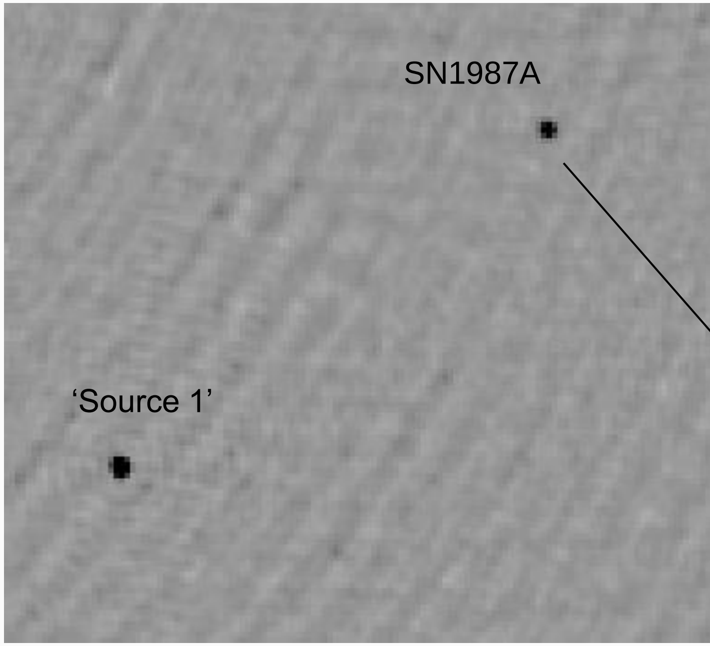
Michael et al. (2003)

Application to ATCA 1.4 GHz Light Curve

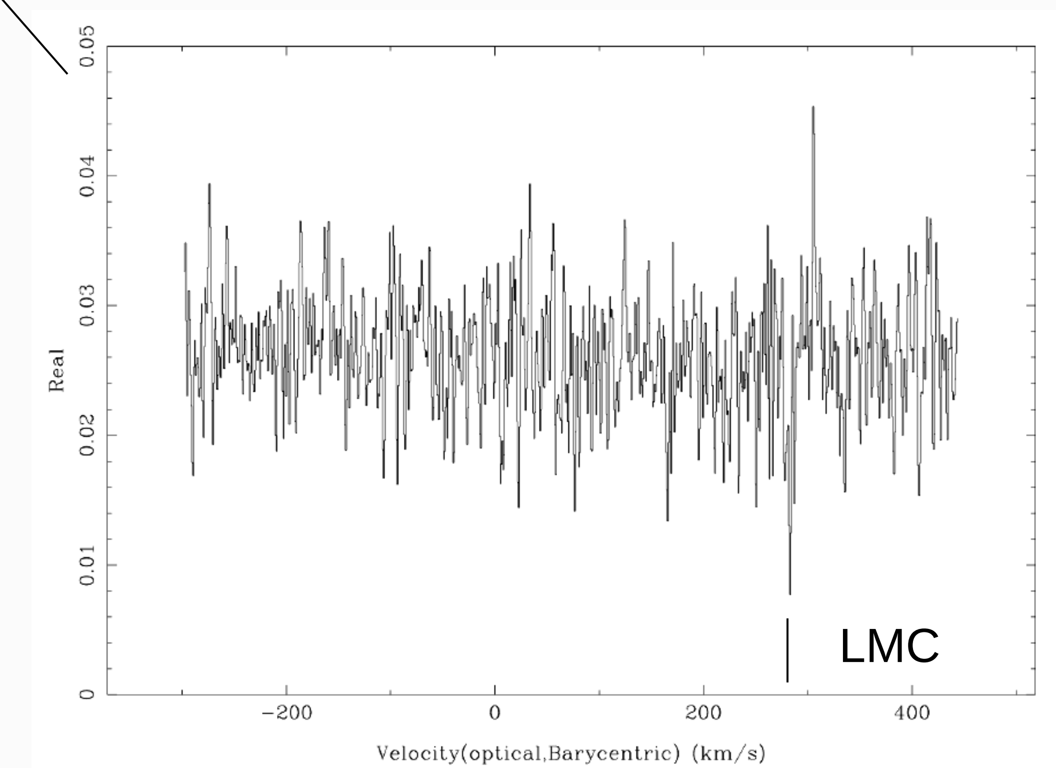


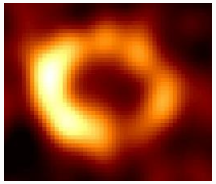


SN1987A as a new probe of the LMC

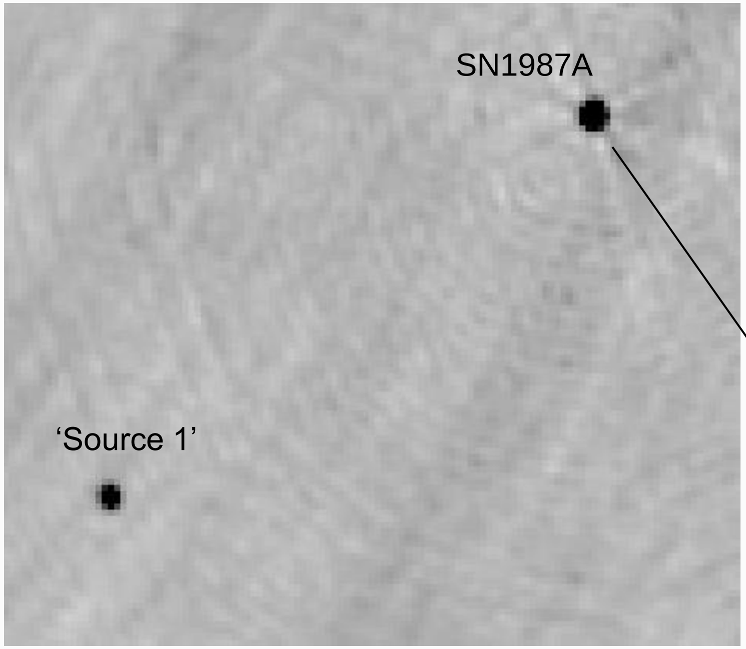


1992 ATCA image/spectrum at 1.4 GHz (21cm HI)

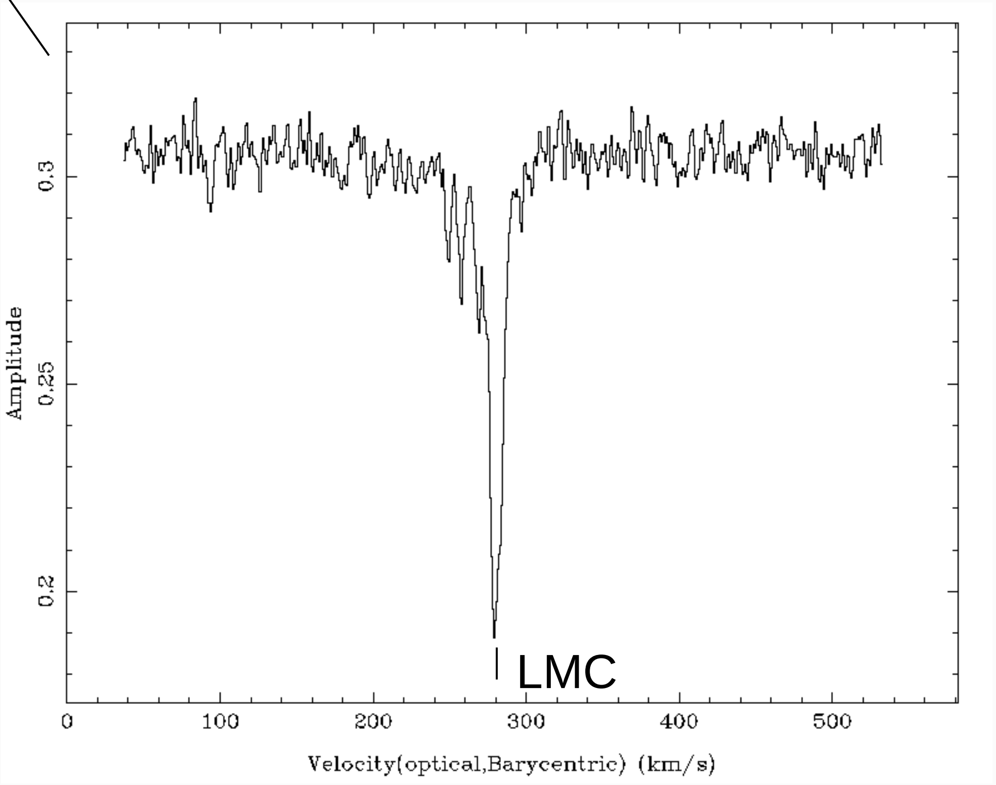


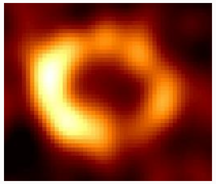


SN1987A as a new probe of the LMC

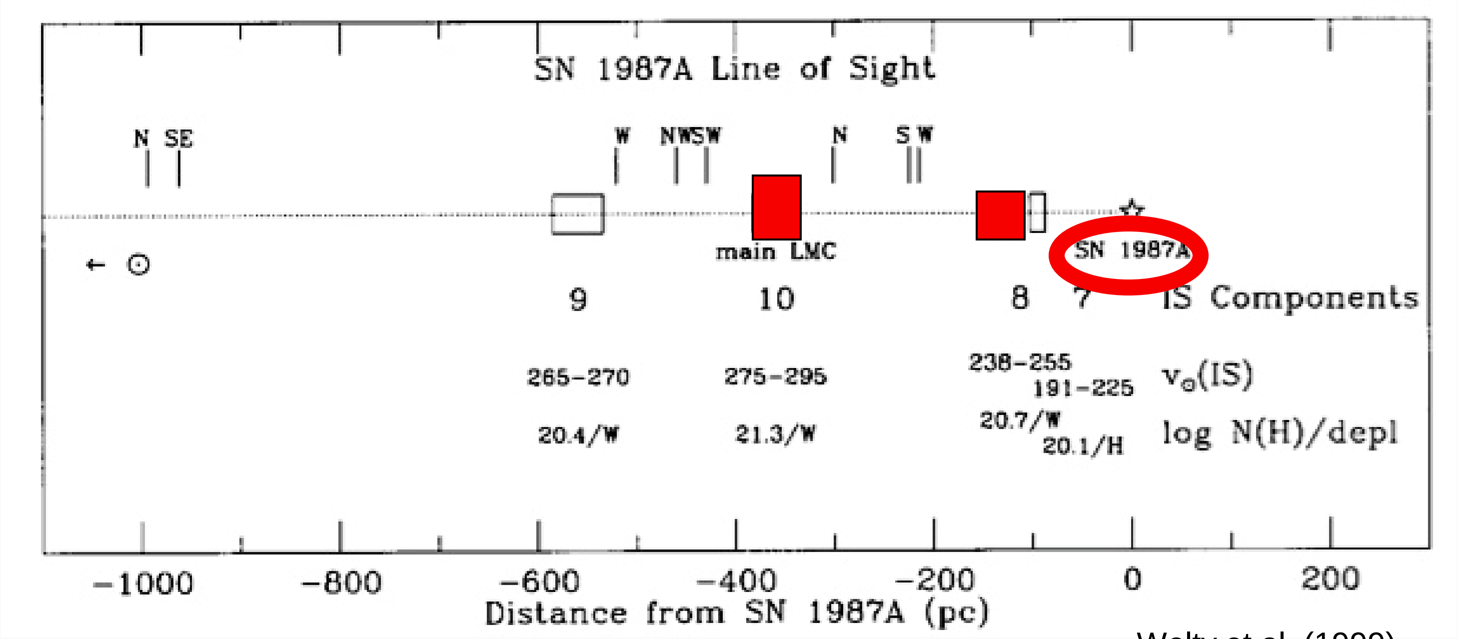


2006 ATCA image/spectrum at 1.4 GHz (21cm HI)



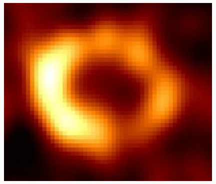


Line of sight absorption components

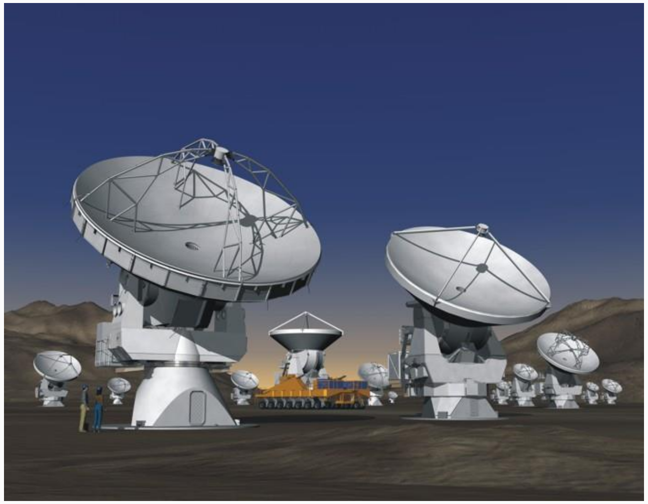


Welty et al. (1999)

- τ_{HI}(280 km/s)=0.48
- T_{HI}(280 km/s)=36K and N_{HI}=2.37x10^{21} cm^{-2} from emission spectrum
- $\Rightarrow$Tspin(280 km/s)<94K
- SN1987A behind bulk of the LMC's disk which has more cool gas than the Milky Way



Implications for ALMA and SKA



ALMA (2012)

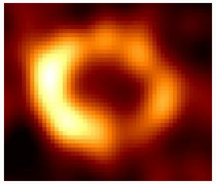
- Resolution 0.1 arcsec at 100 GHz
- Mean S/N~3 per beam area at present flux density (8 hr observation)

SKA Phase 1 (2014)

- Resolution 0.1 arcsec at 6 GHz
- Mean S/N~4 per beam area at present flux density (8 hr observation)

SKA (2020)

- Resolution 0.01 arcsec at 1 GHz
- Mean S/N~100 per beam area, even at present flux density (8 hour observation)
- Detailed, spatially resolved structure at all frequencies 0.1-20 GHz



Summary

- Rapid increase of flux density at all radio frequencies - lately $S \propto t^{2.2}$
- No evidence of recent turning over of radio flux densities
- Spectral index becoming flatter - now at -0.75
- First millimeter (95 GHz) detection
- Some progress in modelling - but large number of poorly known variables (B field, shock velocity, CR acceleration efficiency, geometry and density profile)
- SNR 1987A now strong enough to be a useful probe of the foreground ISM