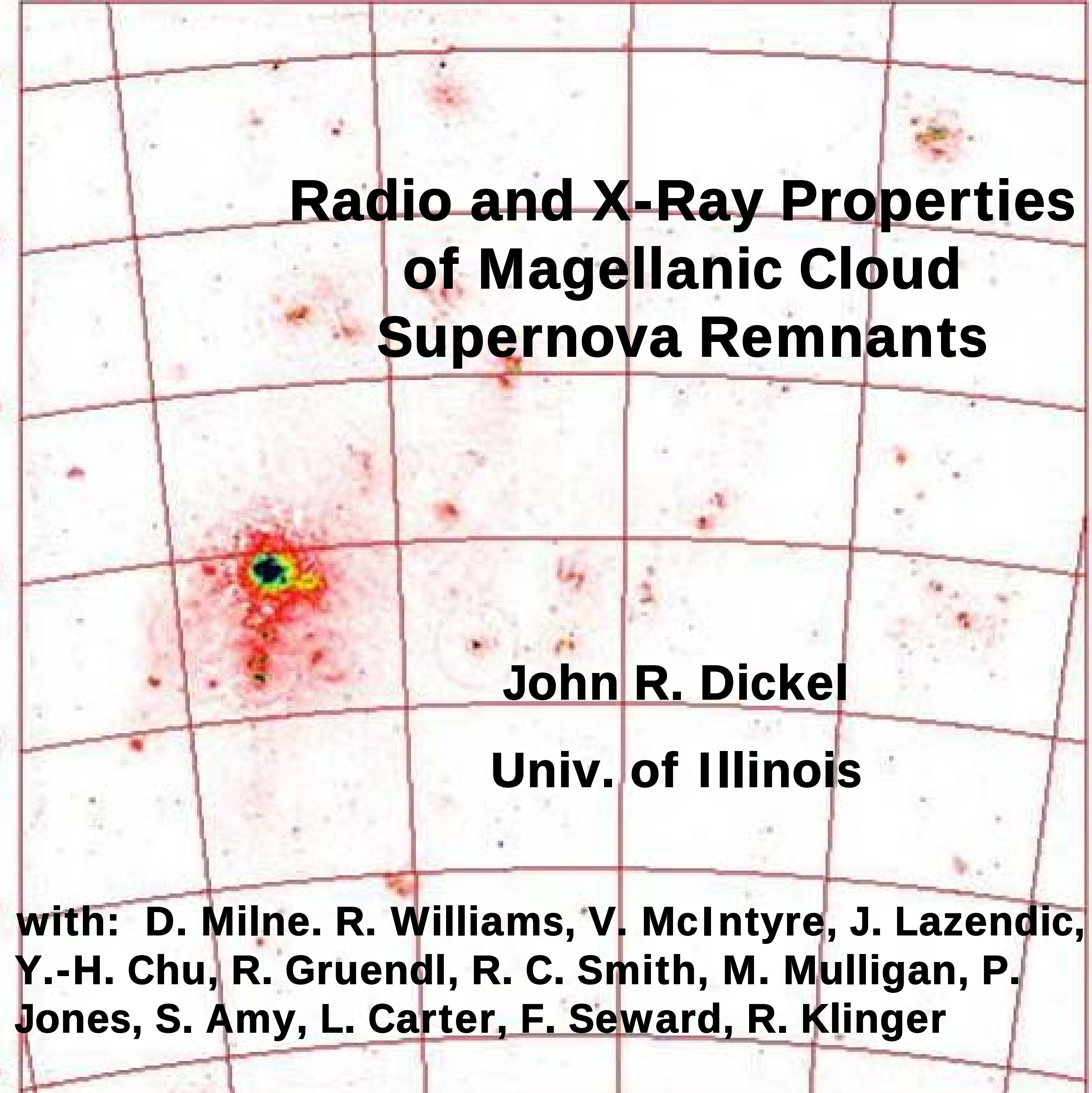


Radio and X-Ray Properties of Magellanic Cloud Supernova Remnants

John R. Dickel

Univ. of Illinois

with: D. Milne. R. Williams, V. McIntyre, J. Lazendic, Y.-H. Chu, R. Gruendl, R. C. Smith, M. Mulligan, P. Jones, S. Amy, L. Carter, F. Seward, R. Klinger

Emission Processes

* Shells

Radio - synchrotron

Tells us about: morphology, relativistic particle content, and magnetic fields (polarization)

X-Ray – mostly thermal from shocked gas at about 10^7K (keV) with spectral lines

Tells us about: morphology, temperatures, abundances (of ejecta in young remnants and of the CSM and ISM in older ones)

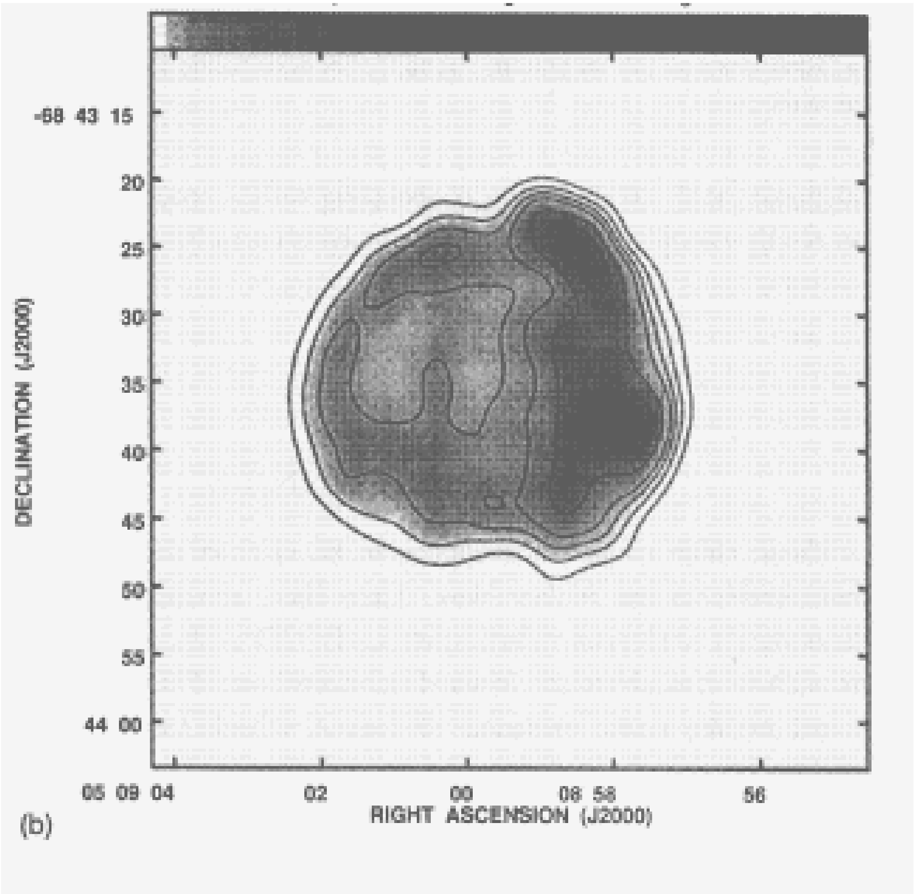
* Pulsar wind neublae

Synchrotron at both radio and X-Ray wavelengths

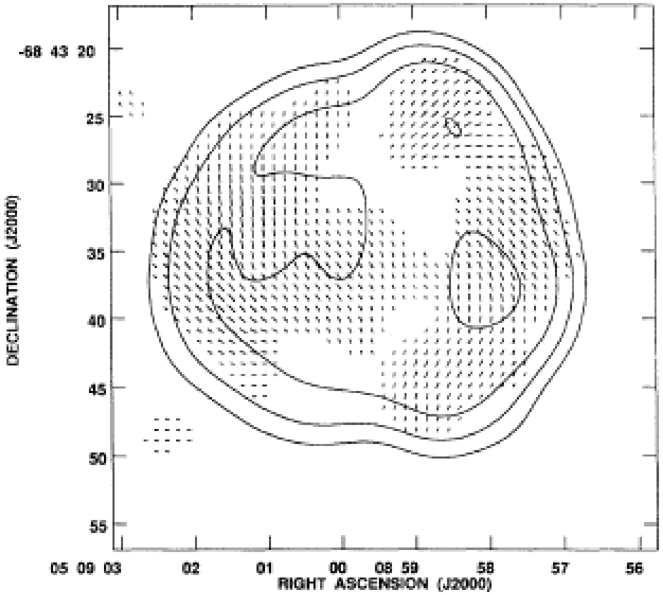
Tells us about: pulsar powering and particle energy decay

N103B a young SNR in the LMC

6-cm image

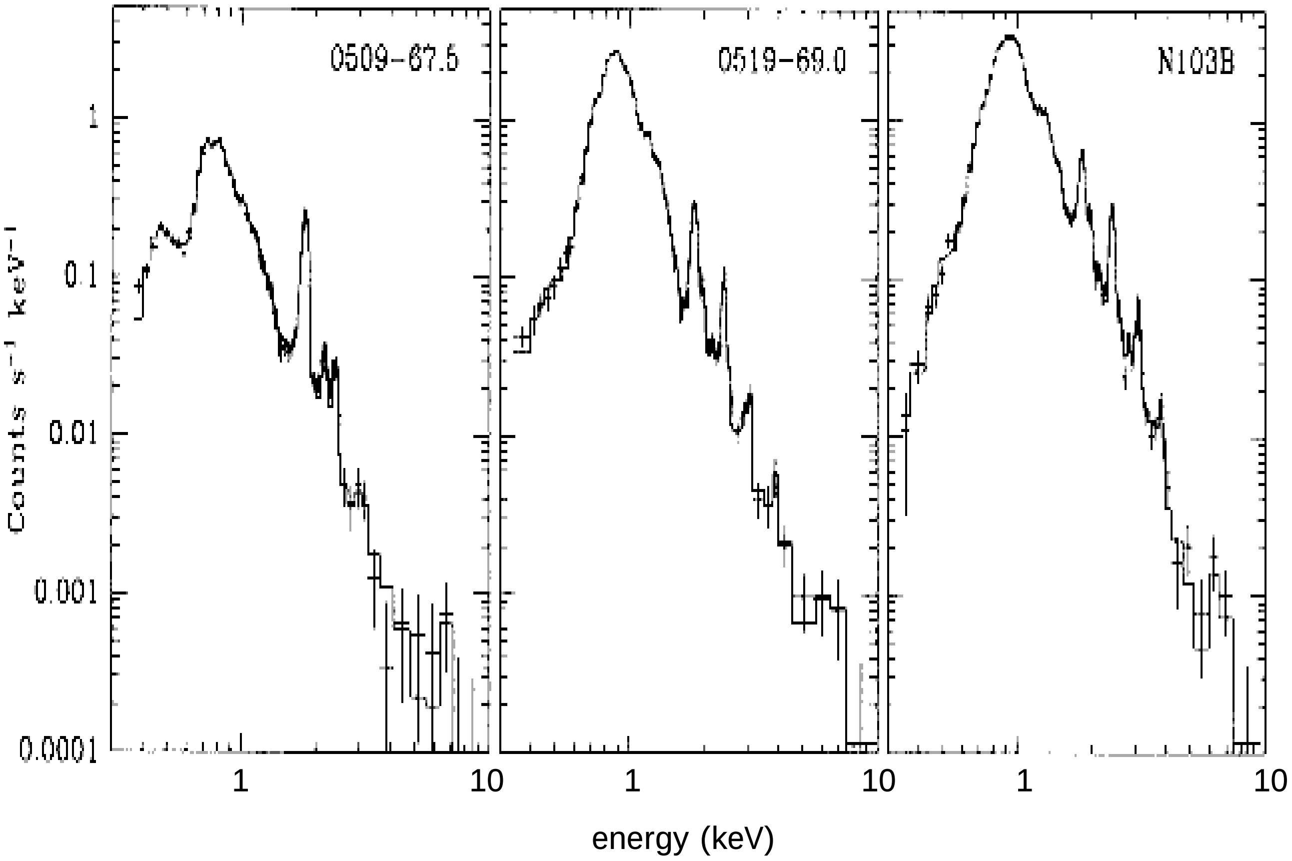


smoothed 6-cm image with polarized vectors



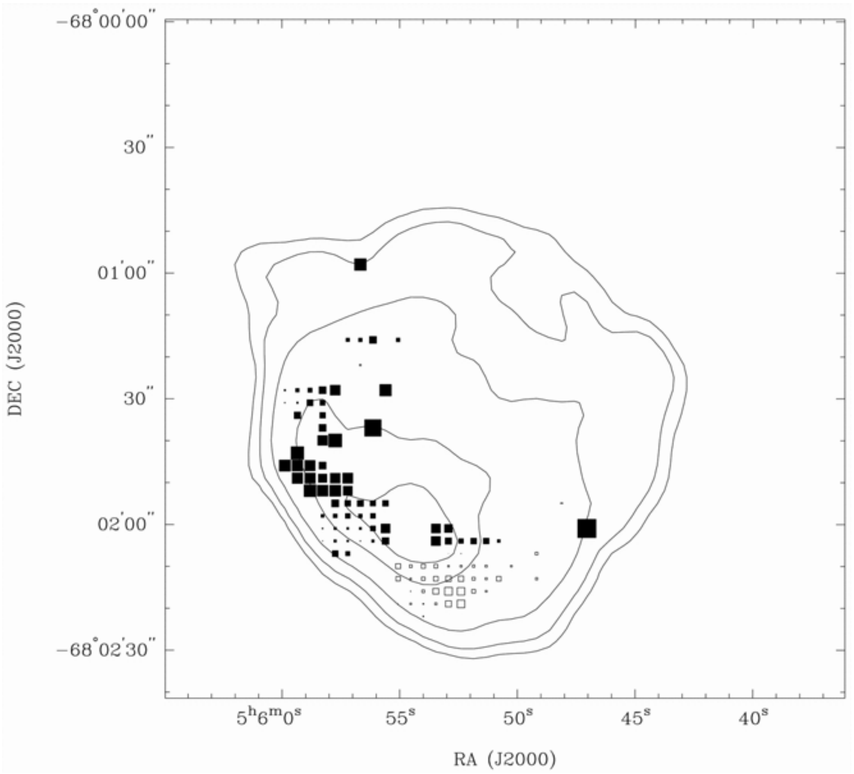
An H II region to the west is probably responsible for the asymmetry. The magnetic field vectors are approximately perpendicular to the ones shown suggesting a dominantly radial field.

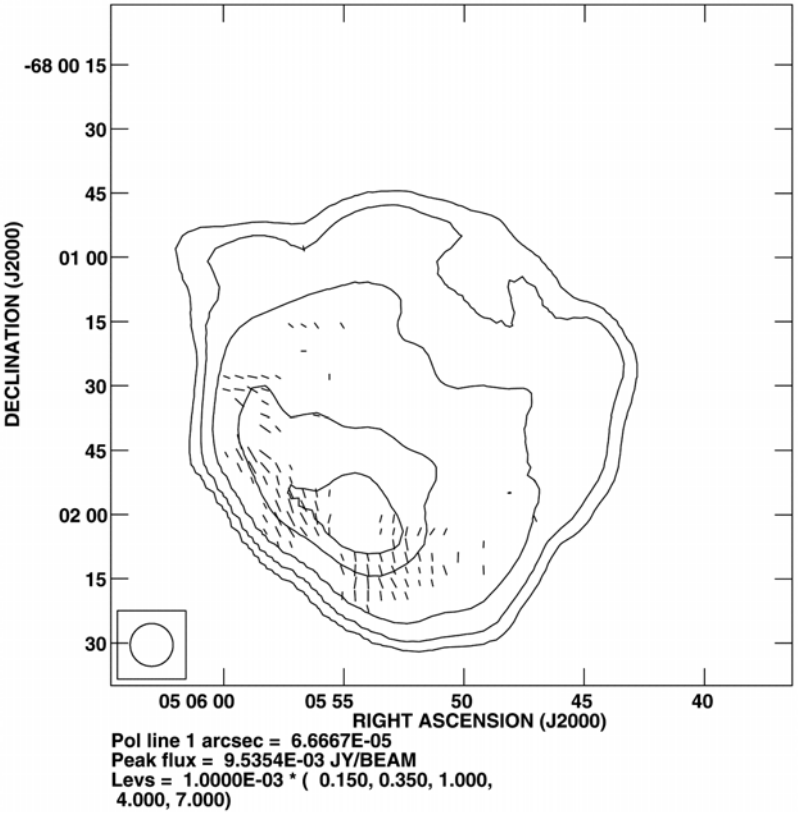
X-ray spectra of three young LMC SNRs



They show the characteristic L shell iron emission along with lines of several metals. These are characteristic of Type Ia SNRs.

Magnetic fields in the mature SNR N23



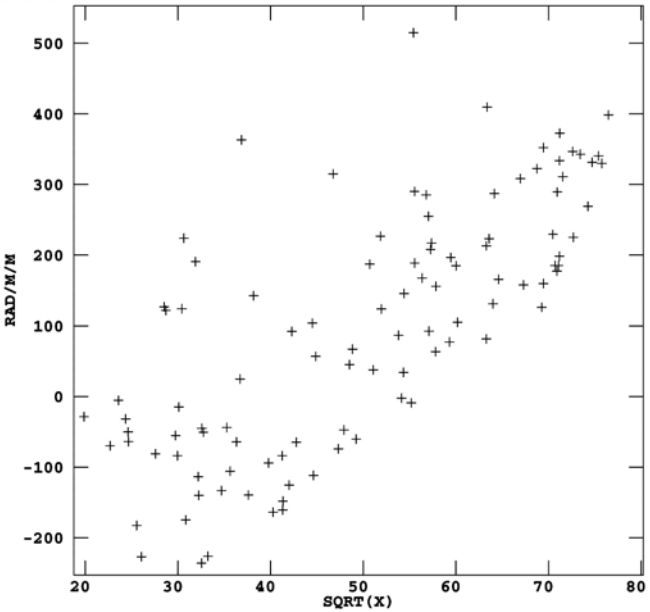


Faraday rotation gives a change in position angle of the polarized emission proportional to frequency^2 so it can be determined by polarized position angle differences between two frequencies and then the resultant magnetic field directions can be found.

Determination of magnetic field strength of N23

Faraday rotation α N_e x B

X-Ray emission α N_e^2



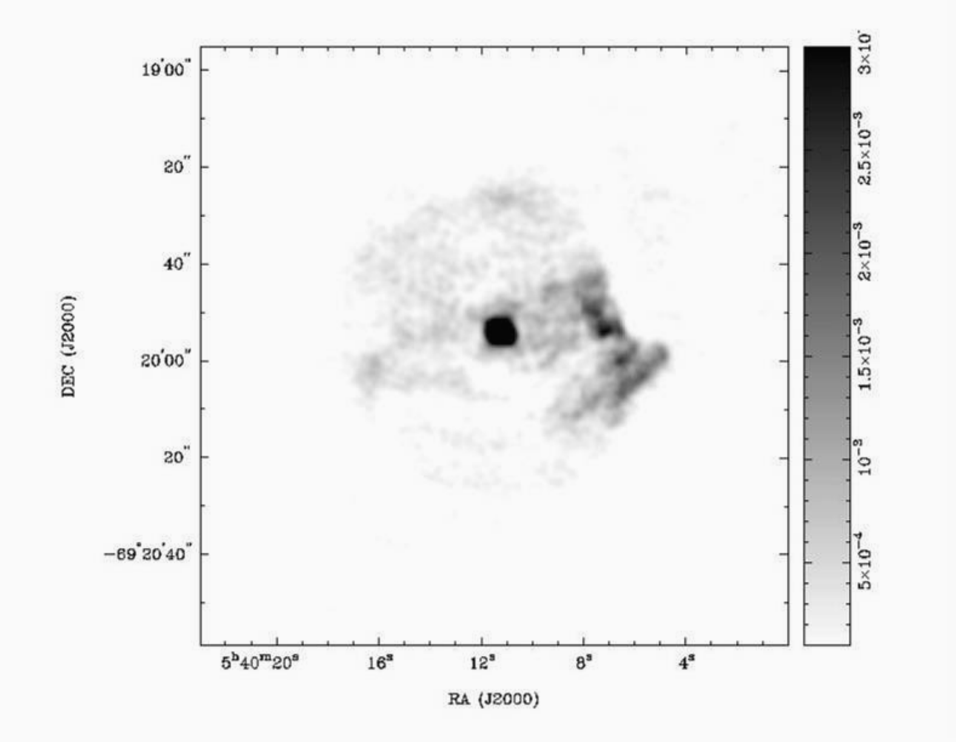
So we can use the X-Ray flux to determine the electron density and then use that in the the Faraday rotation to determine the magnetic field strength along the line of sight.

With some approximations for projections, we find a magnetic field strength of ~ 15 μGauss. This gives approximately ¼ of the relativistic particle energy or close to equipartition.

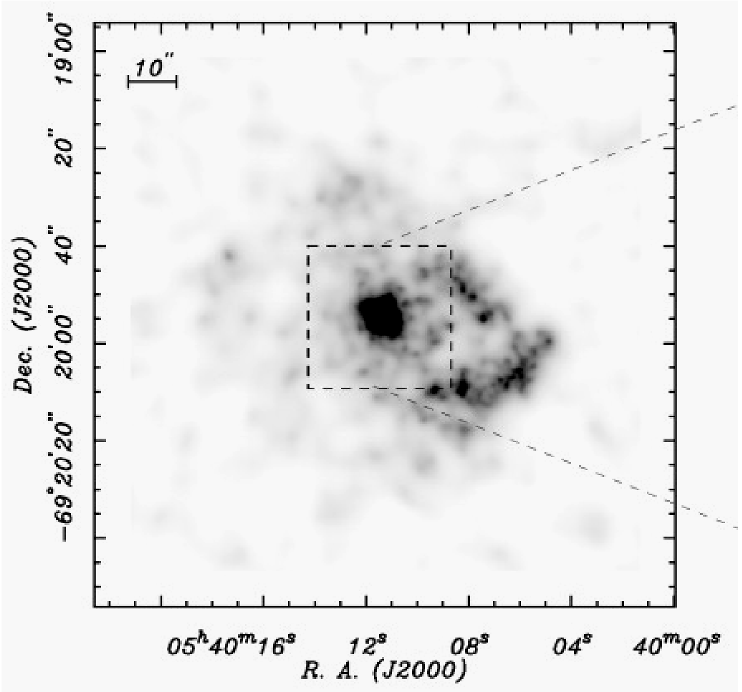
(This requires a small and reasonably uniform external Faraday rotation so the internal effects are correlated as seen here.)

The composite SNR 0540-693

The very broken, irregular shell is caused by a complex environment only ~ 17 arcmin (250 pc) from the huge 30 Doradus complex.



6-cm radio image

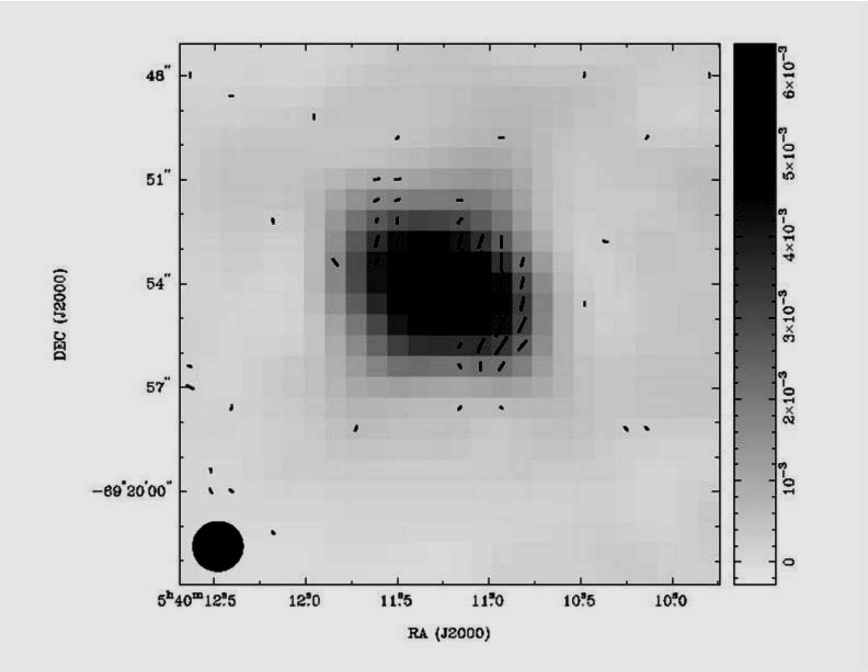


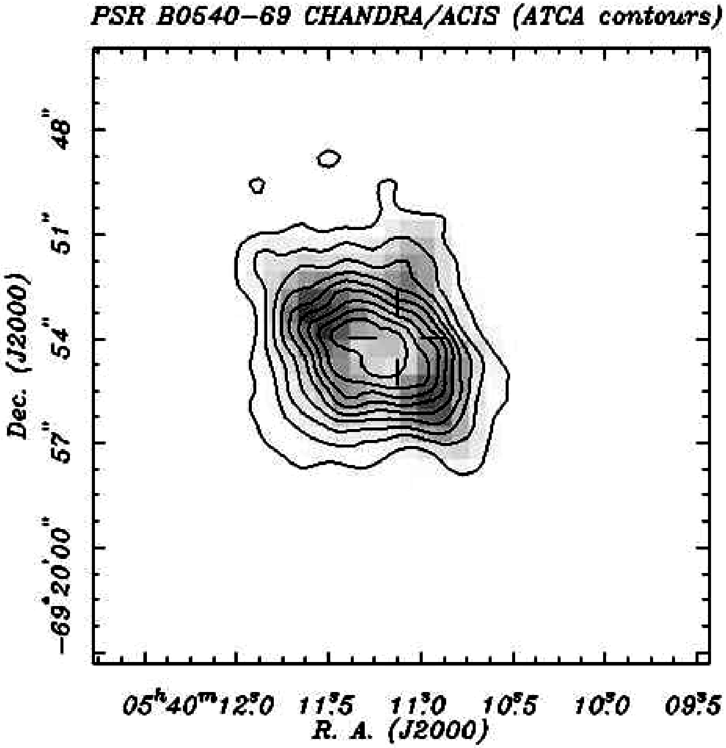
Chandra x-ray image

The central pulsar wind nebula in 0540-693

50-msec pulsar at the position of the cross

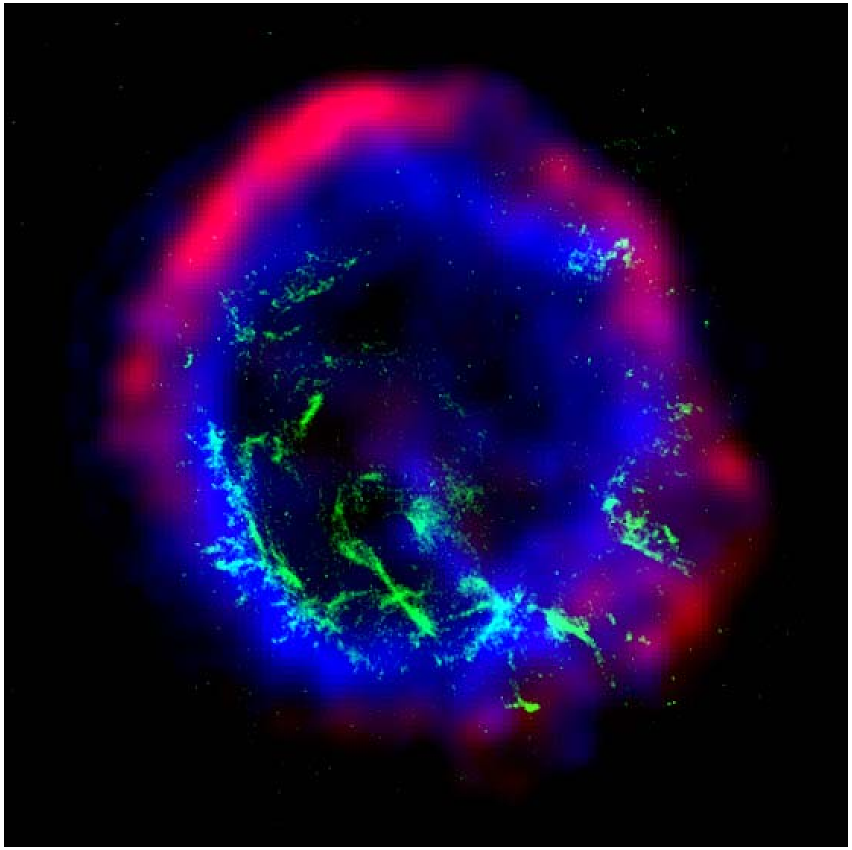
ATCA 3.5-cm image with magnetic field vectors





- **Some interesting problems from comparisons of radio and X-Ray images**

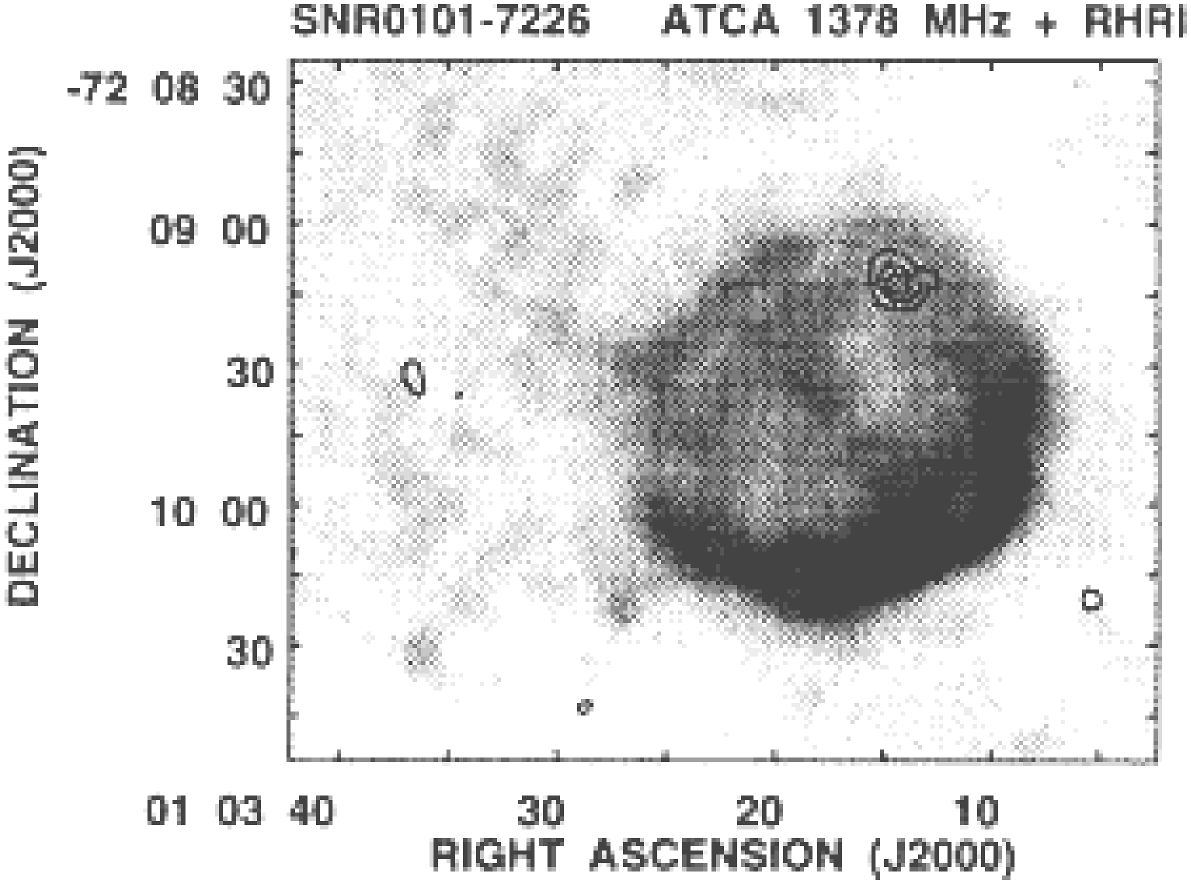
SNR 1E0102.2-7219



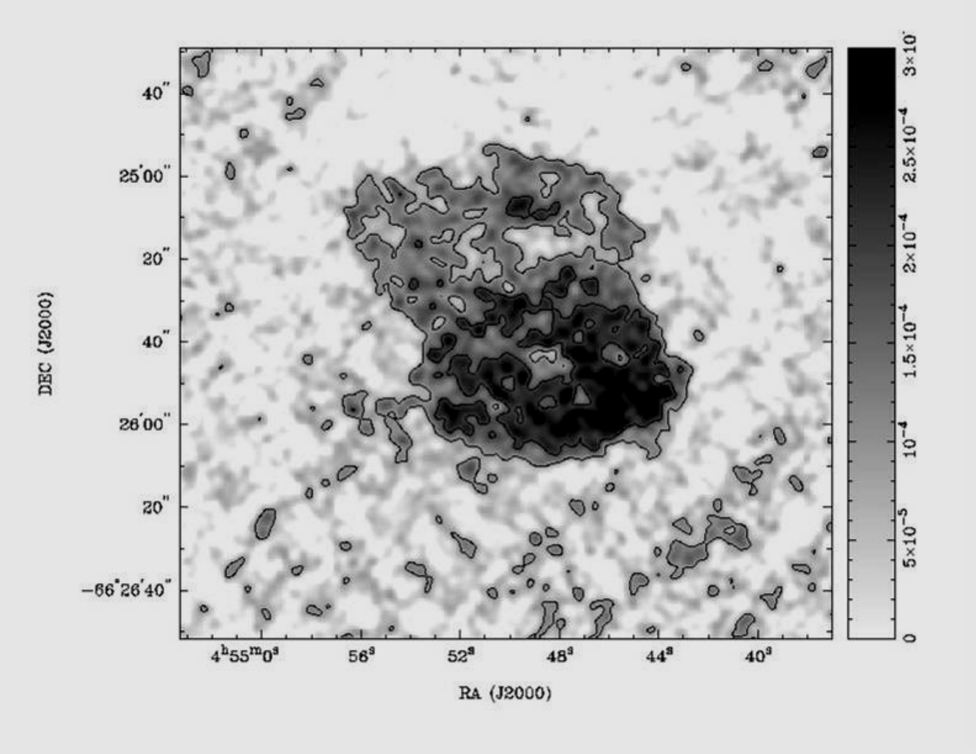
The radio emission sits <u>outside</u> the X-ray emission which is not seen in any other SNR. Theory also suggests that the X-Rays should be caused by the gas heated by the outer shock and that much of the radio emission should be created further in by the reverse shock and turbulence at the interface of the ejecta and the swept-up material.

A good radio SNR but the only X-Ray emission within its boundaries is from an unrelated Be star.

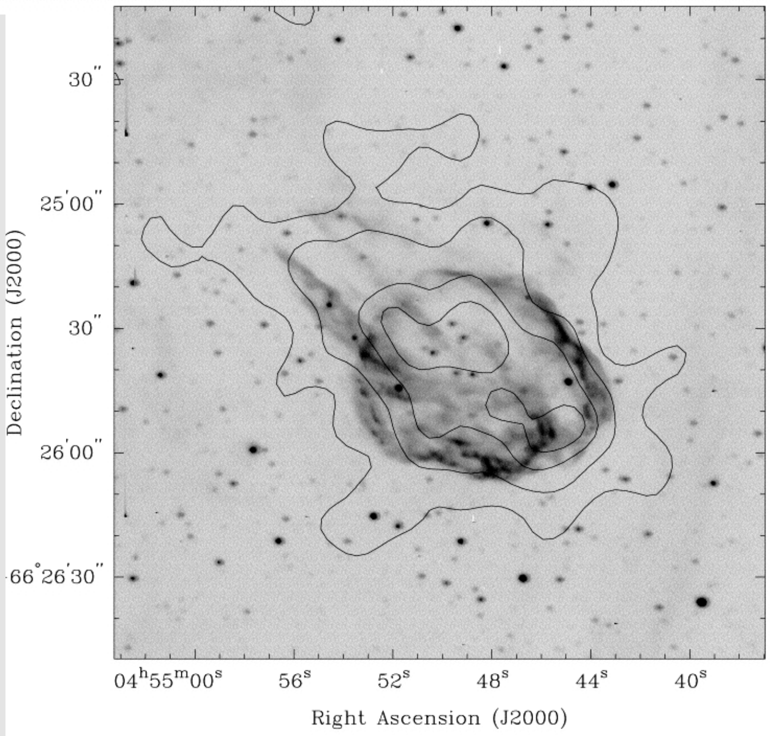
Why?



The shell SNR N11L in the LMC with an unusual “jet” and tail structure visible with varying structures at all wavelengths



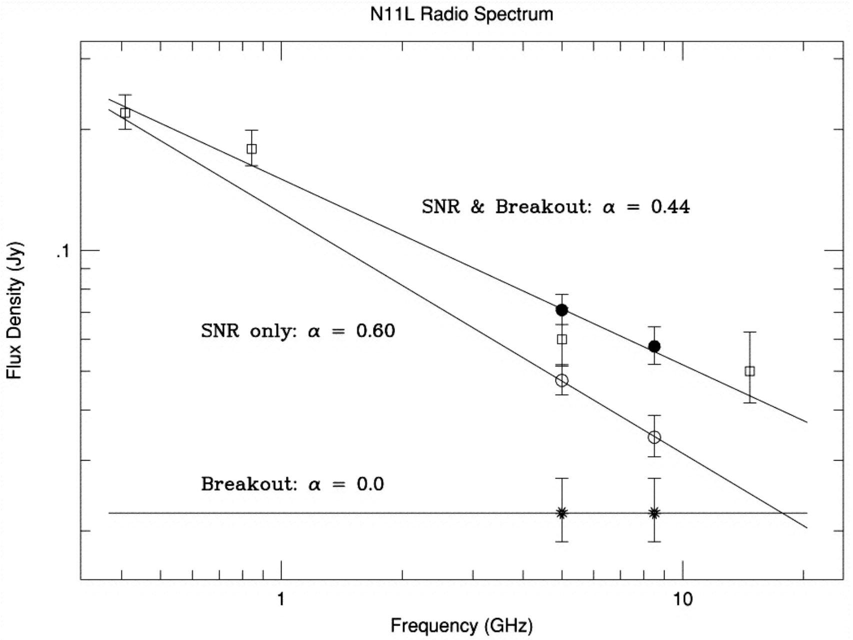
6-cm radio emission

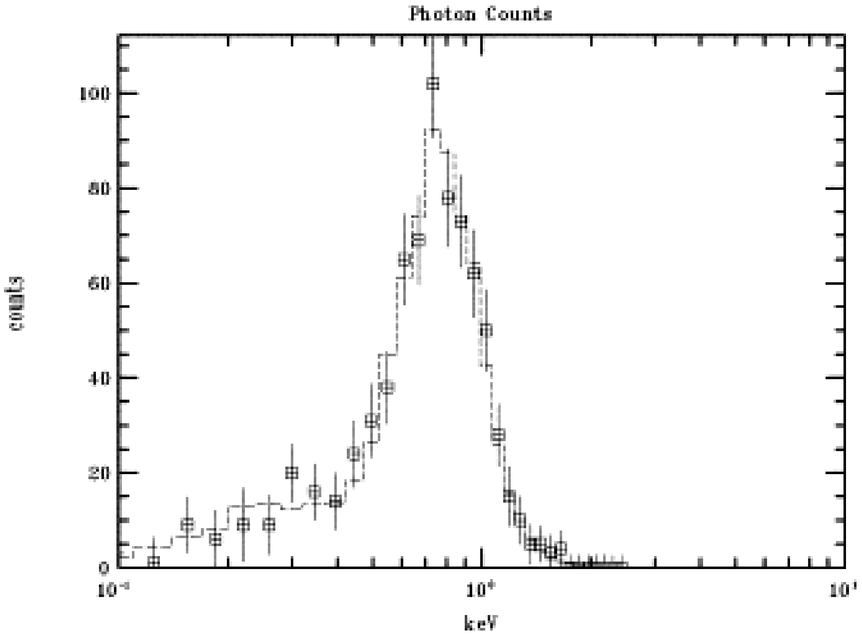


X-ray contours on an Hα image

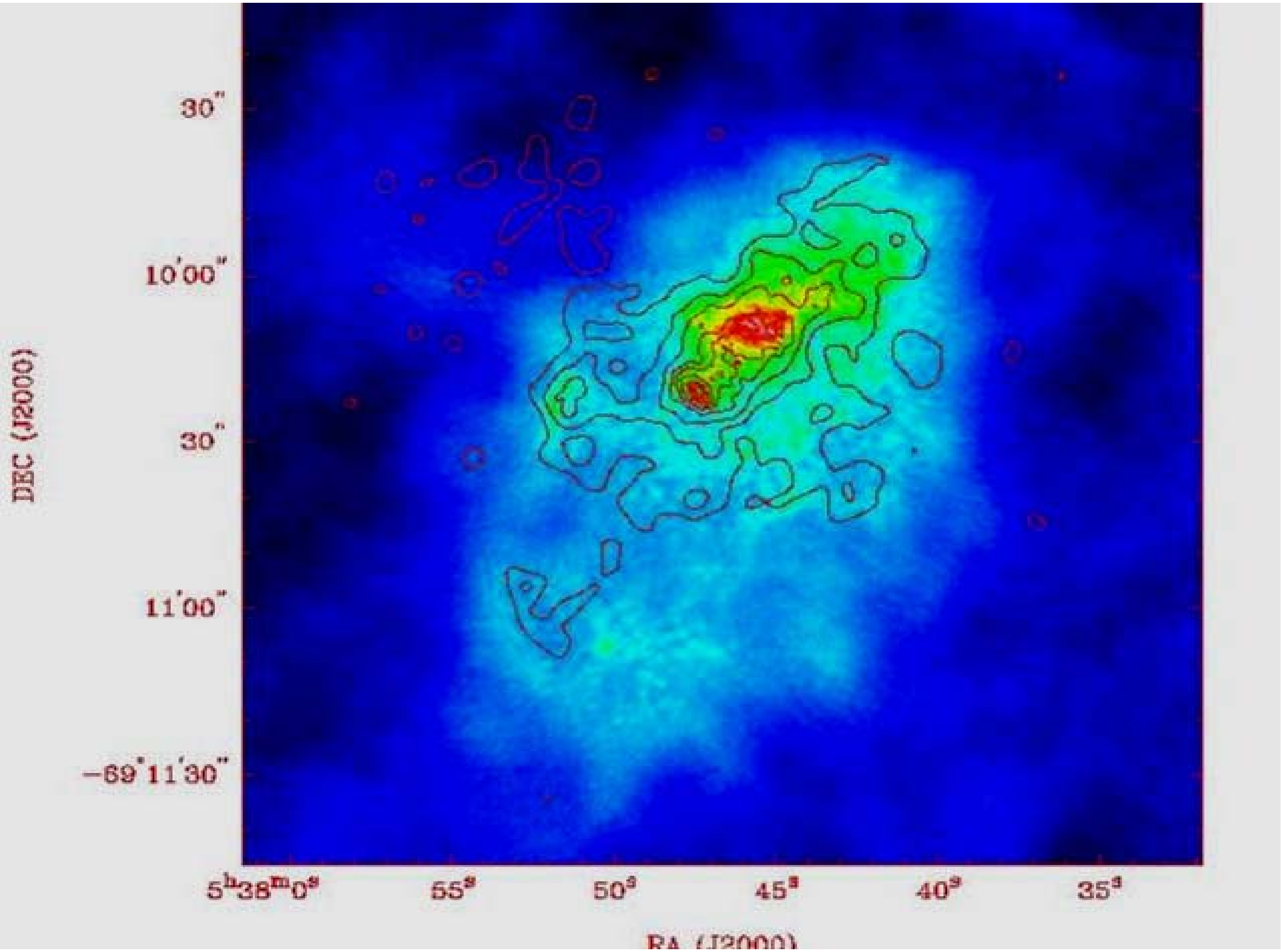
The radio spectrum of N11L shows that the breakout region has a flat spectrum and could be thermal whereas that of the SNR is steeper and more like that of synchrotron emission form a relatively young SNR.

The X-ray spectrum of N11L is thermal. The breakout and tail are too faint to be individually measured.

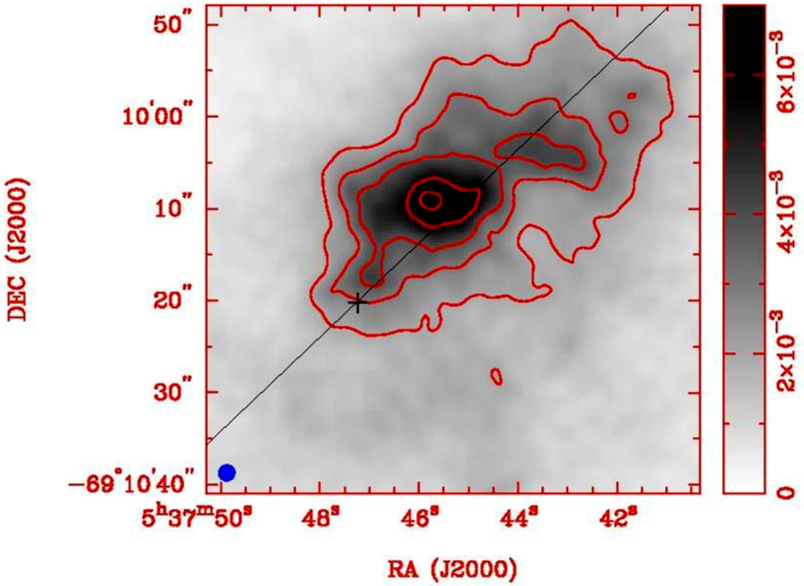




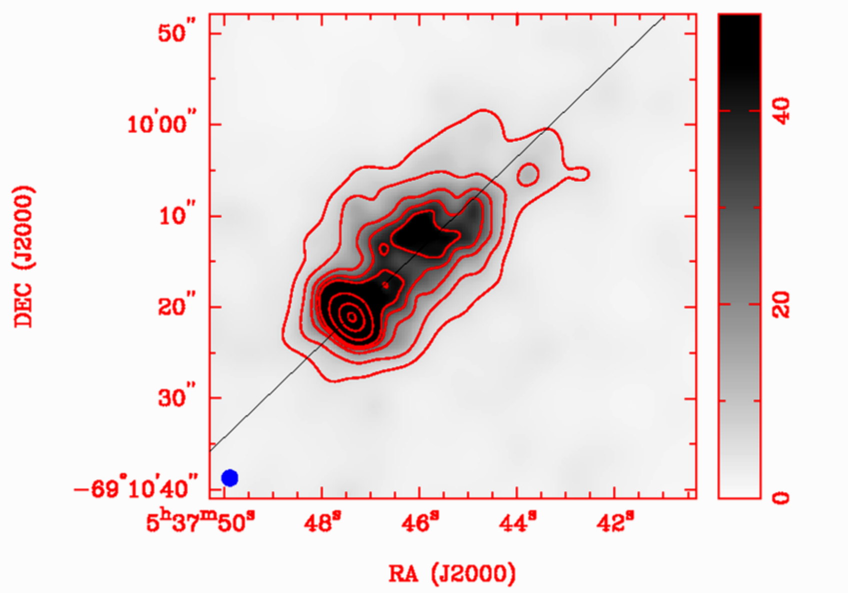
Radio image and X-Ray contours of the SNR N157B which is just becoming a composite remnant.



The pulsar wind nebula component of N157B. The radiation in both cases is synchrotron.

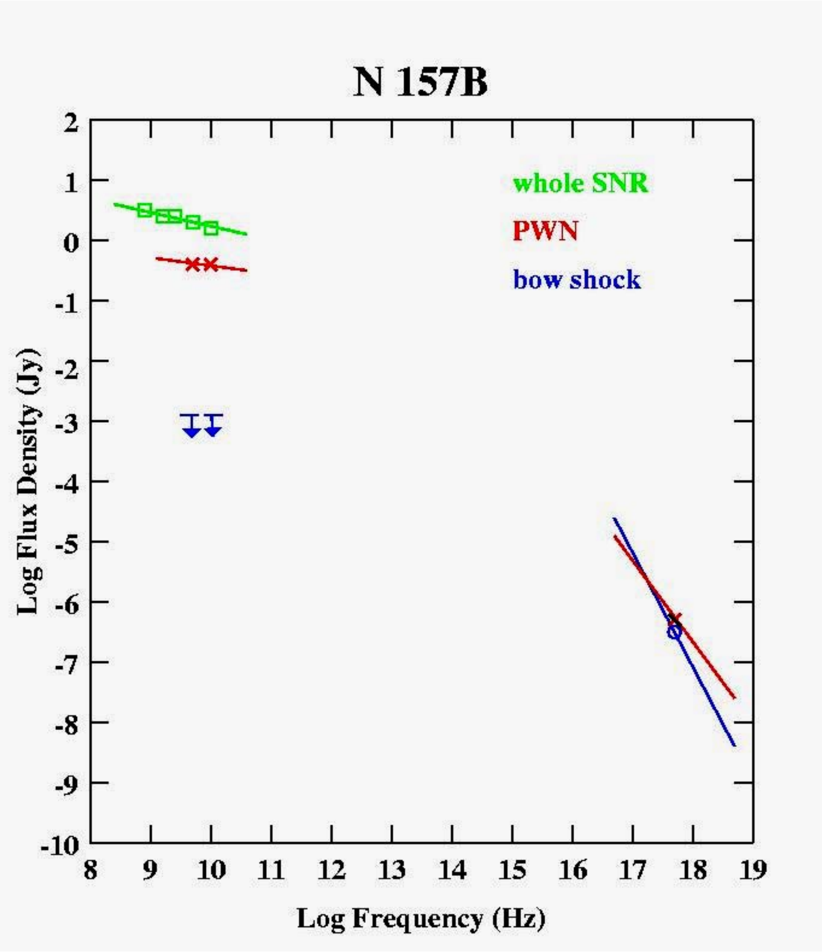


radio – contours are 2,3,4,6,7 mJy/beam



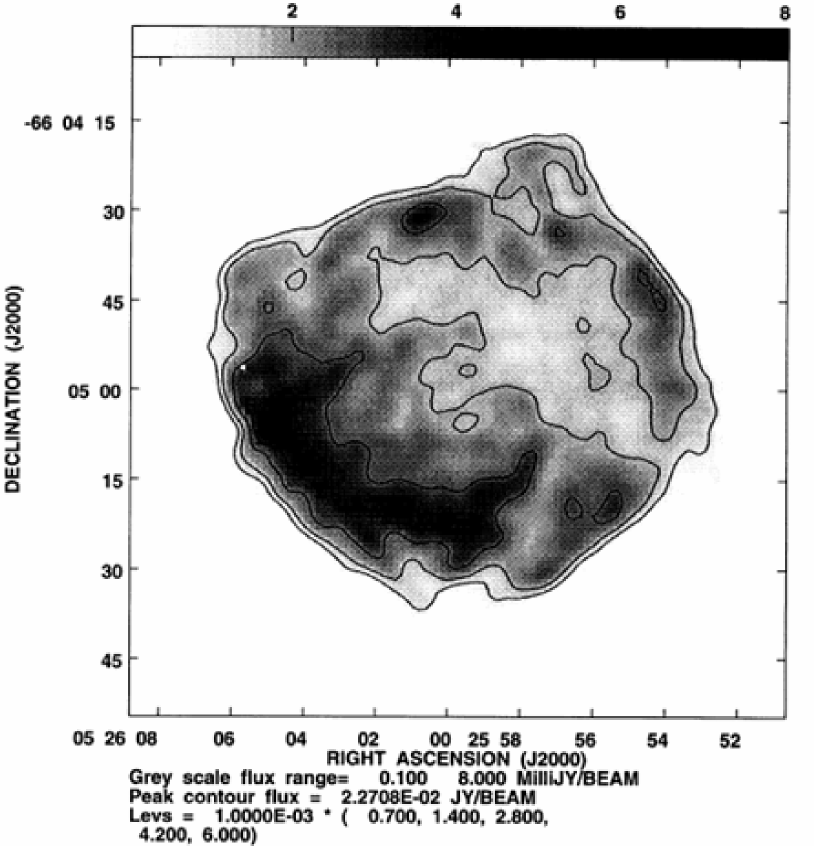
X-ray – contours are 5,10,20,30,40,100,300,600 counts from 0.1-10 keV

The 16-msec X-Ray pulsar is at the center of the bright X-Ray contours and at the position of the cross in the radio image.

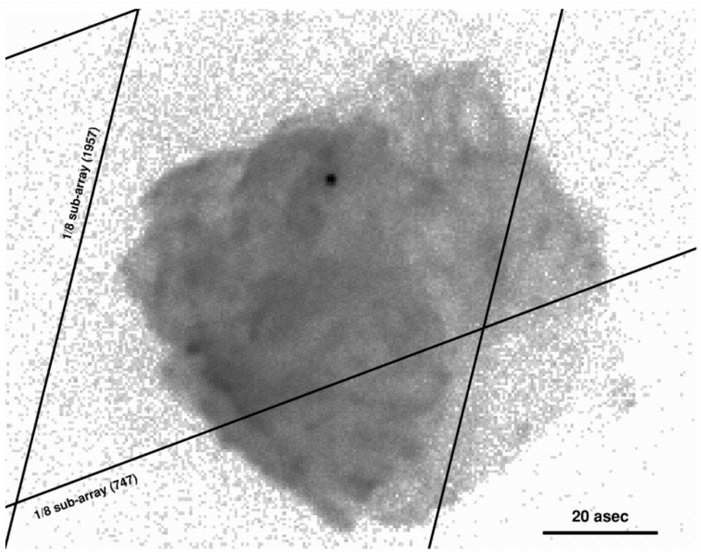


The power-law spectra of the synchrotron emission from N157B show that the X-ray emission from the bow shock region around the pulsar is relatively much too bright. The particles injected from the pulsar must receive additional acceleration from the shocks.

Radio and X-ray images of N49 showing the point X-ray source at the position of the Soft Gamma Ray Repeater 0525-66

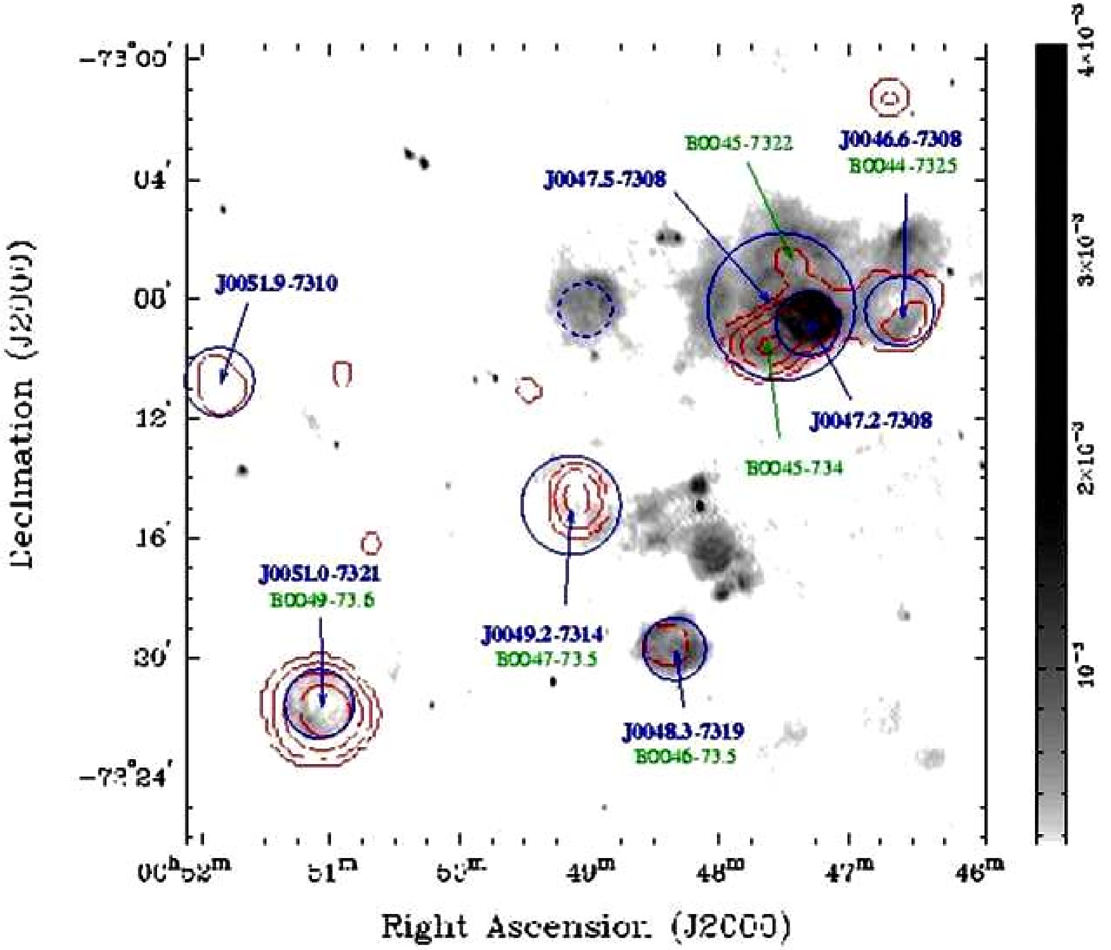


3-arcsec resolution radio image at 13 cm



1-arcsec Chandra image

Sometimes instrumental limitations of sensitivity and resolution do not allow us to separate the SNRs and H II regions such as in this complex area N19 near $00^h47.2^m$ and -73°08’ in the SMC



greyscale – radio

Rosat contours

old source designations

new source designations
MCRX Jhhmm.m-ddmm

So, what about the future?

We certainly need greater sensitivity and resolution at both radio (SKA) and X-Ray (Con-X and Gen-X) wavelengths.

- **To separate the H II region and SNR candidates in complex regions**
- **To get X-Ray spectra of individual clumps to see the detailed interactions with the surroundings**
- **To get radio Faraday rotation measures of more objects to compare with the X-Ray brightnesses to get magnetic field energies**
- **To improve synchrotron spectra of PWNs to examine the decay of the relativistic electron populations**
- **To better measure expansions (longer time baselines are important for this, too)**
- **To look for evolution**