325 and 610 MHz radio counterparts of SNR G353.6-0.7 a.k.a HESS J1731-347

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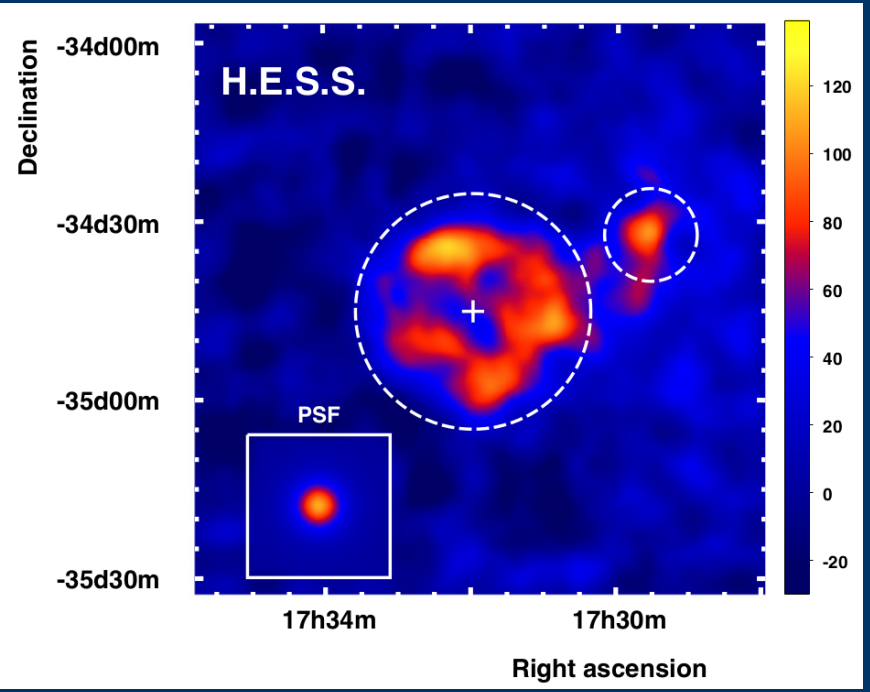
Plan of talk

- Introduction – TeV SNRs and HESS J1731-347.
- Motivation
- GMRT observations and Data Analysis.
- Results – Low frequency radio images of the SNR.
- Discussions – Morphological comparison with VHE emission.
- Summary
- Future Directions

Introduction

- Cosmic rays are energetic particles of energies ~ 0.1 to $10^{8\text{-}9}$ GeV discovered by victor Hess in 1912. *(Blandford & Eichler 1987)*
- Shocks of SNRs have been suggested as major acceleration sites of GCRs. *(Blasi 2013)*
- Only five spatially resolved shell-like VHE sources firmly identified as SNRs *(Acero et al. 2015)*



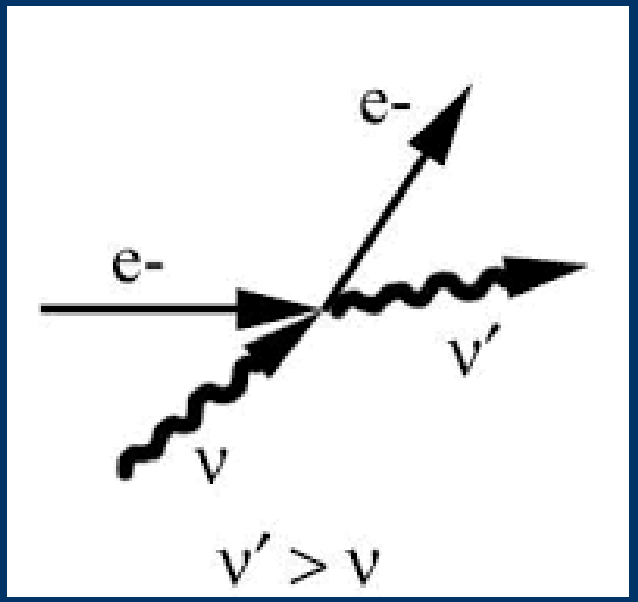
Introduction

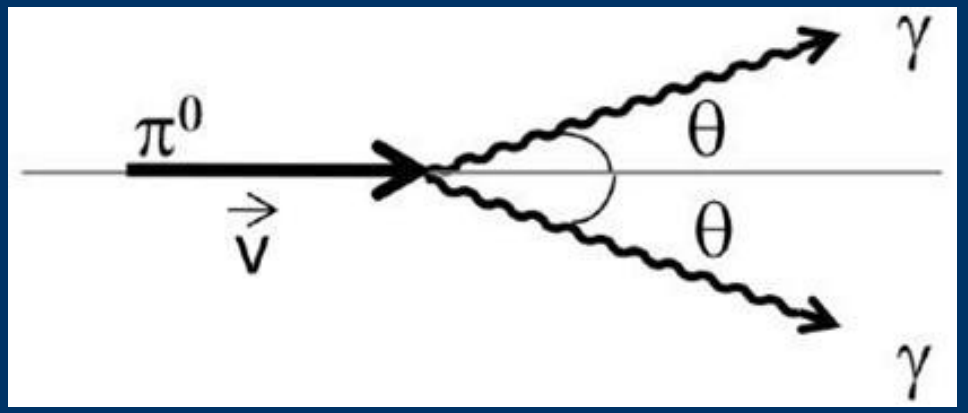
- Multiwavelength study of TeV remnants helps to understand the acceleration mechanism.

- TeV emission can be explained by two models.

  Leptonic model – via inverse compton scattering.

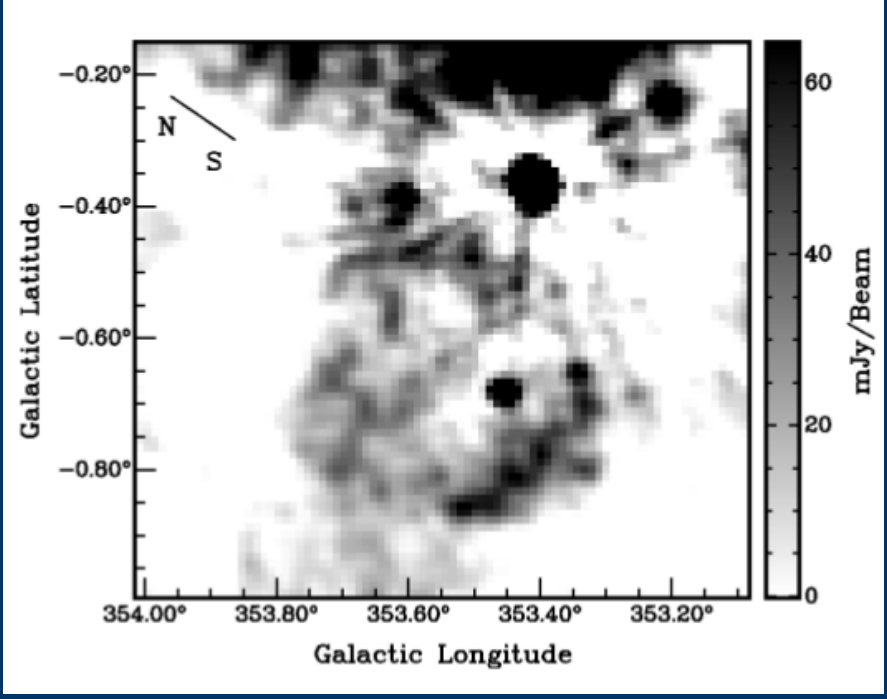
  Hadronic model – via decay of neutral pions.

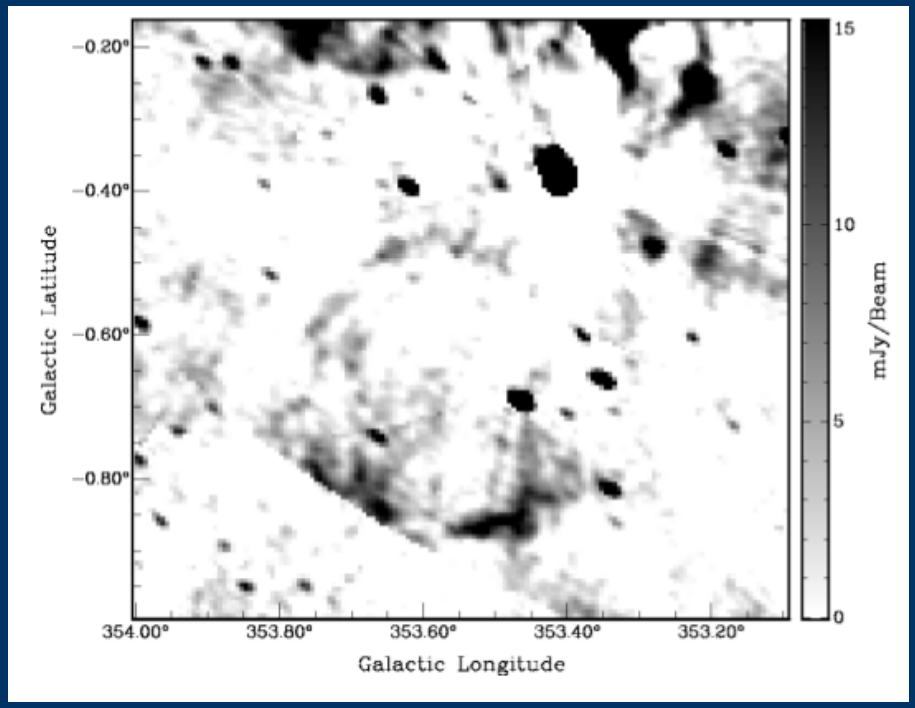




HESS J1731-347

- First seen in HESS Galactic plane survey. *(Aharonian et al. 2008)*
- SNR G353.6-0.7 was discovered in spatial coincidence at 1.4 GHz (SGPS) and 843 MHz (MOST). *(Tian et al. 2008)*
- X-rays are purely non-thermal ----> CR electrons are accelerated up to TeV energies. *(Acero et al. 2009, Bamba et al. 2012)*





HESS J1731-347

- Presence of a central compact object (CCO) in X-rays.

  (Halpern & Gotthelf 2010)

- No radio counterpart for the CCO at 1.4 GHz SGPS map and 843 MHz MOST map.

- Range of age estimations in the literature -- 2000 to 27000 kyr

  (Tian et al. 2008, Abramowski et al. 2011, Fukuda et al. 2014, Acero et al. 2015)

- A distance of 3.2 ± 0.8 Kpc was suggested. *(Tian et al. 2008)*

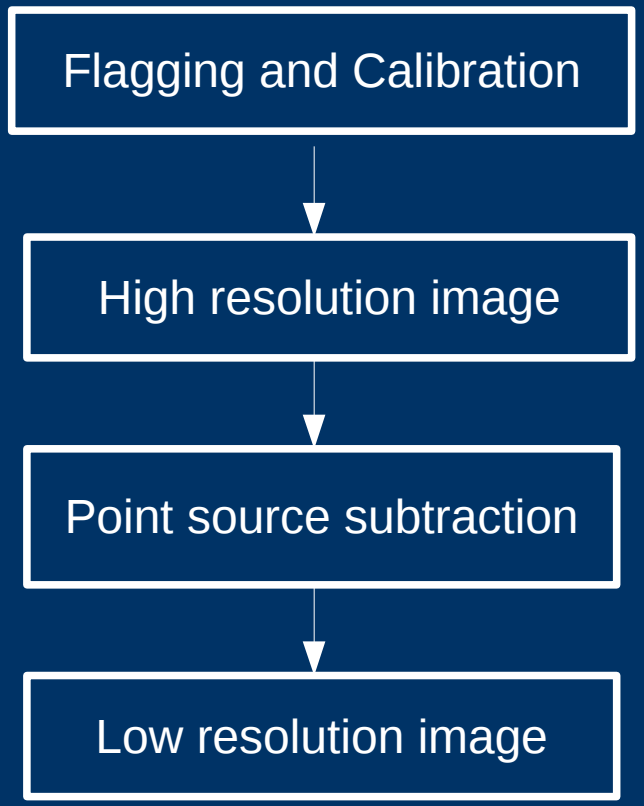
Motivation

- Detect and study the radio morphology of the SNR at low radio frequencies.
- Compare radio morphology with that of VHE emmison.
- Study particle acceleration in SNR shocks.
- Attempt to constrain the particle acceleration models.

GMRT Observations

- Giant Metrewave Radio Telescope located at Narayangaon, India.
- GMRT -- 30 antennas each of 45 m diameter.
- 14 antennas in central 1 km and remaining spread over 25 km.
- Observing Frequencies – 150, 235, 325, 610 and 1390 MHz.
- uGMRT – seamless coverage from 150 – 1450 MHz, 2.5 times better sensitivity.

Data Analysis



SNR was detected at 325 MHz and 610 MHz

Non-detection at 1390 MHz

325 MHz GMRT map of the SNR

S_{int} = 1.84 +- 0.15 Jy
at 325 MHz

S_{int} = 0.88 Jy
Derived flux density at 1390 MHz

$S_{int(1.4)}$ = 2.2 +- 0.9 Jy
Previously reported value
(Tian et al. 2008)

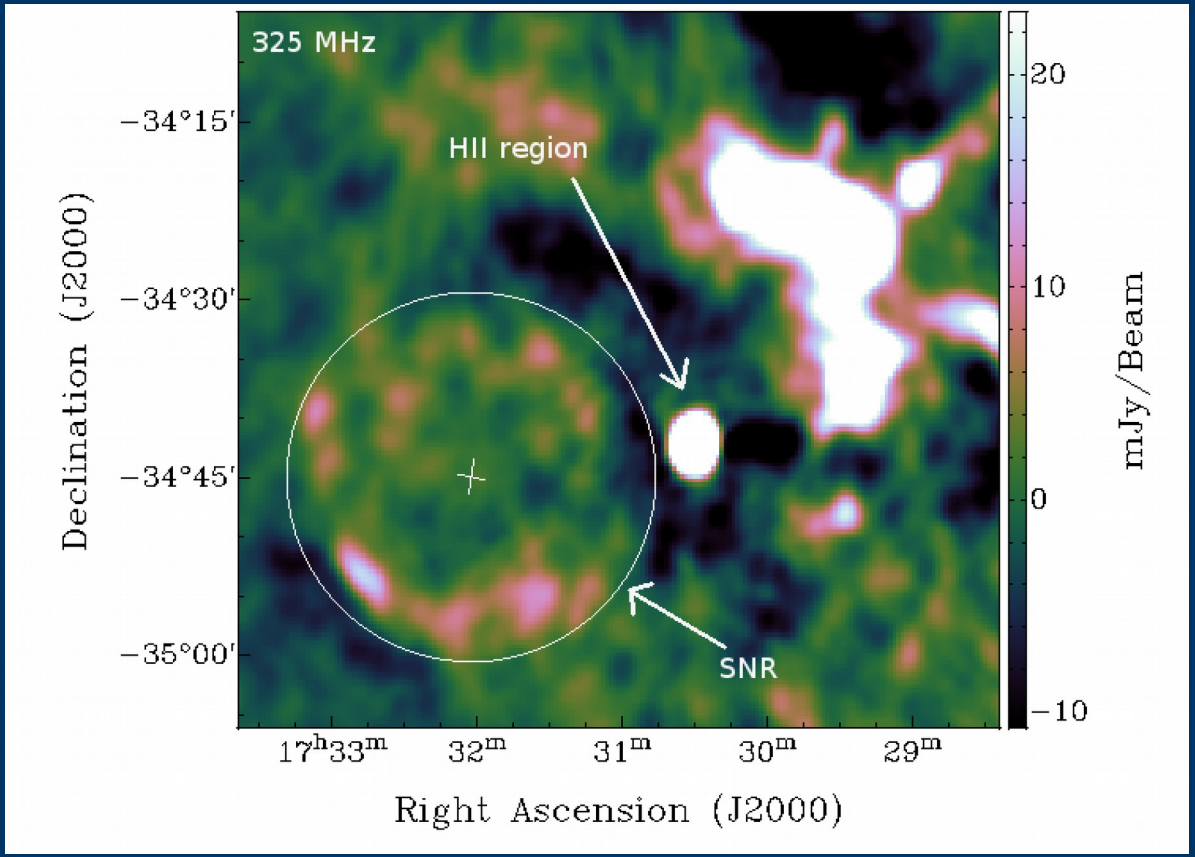
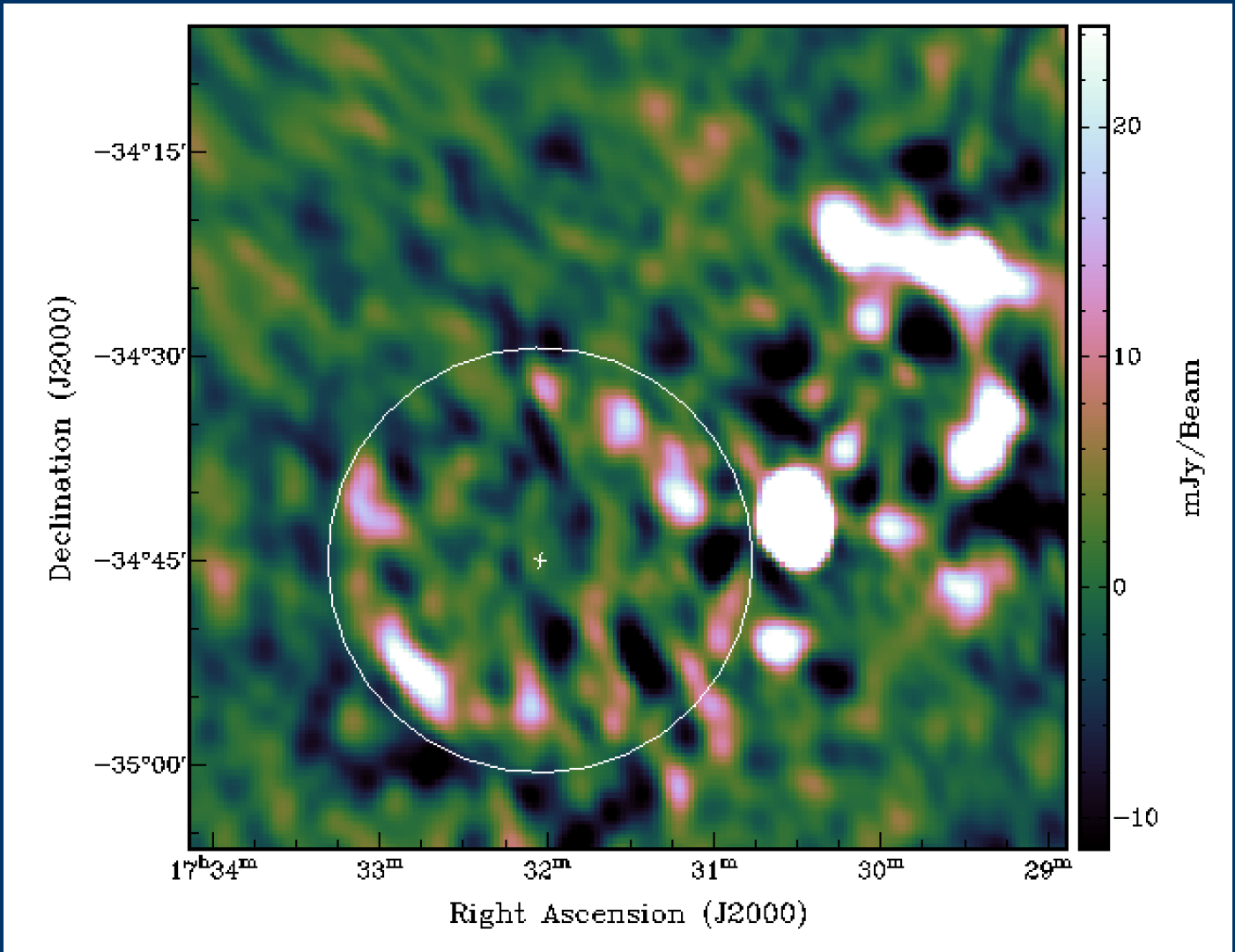


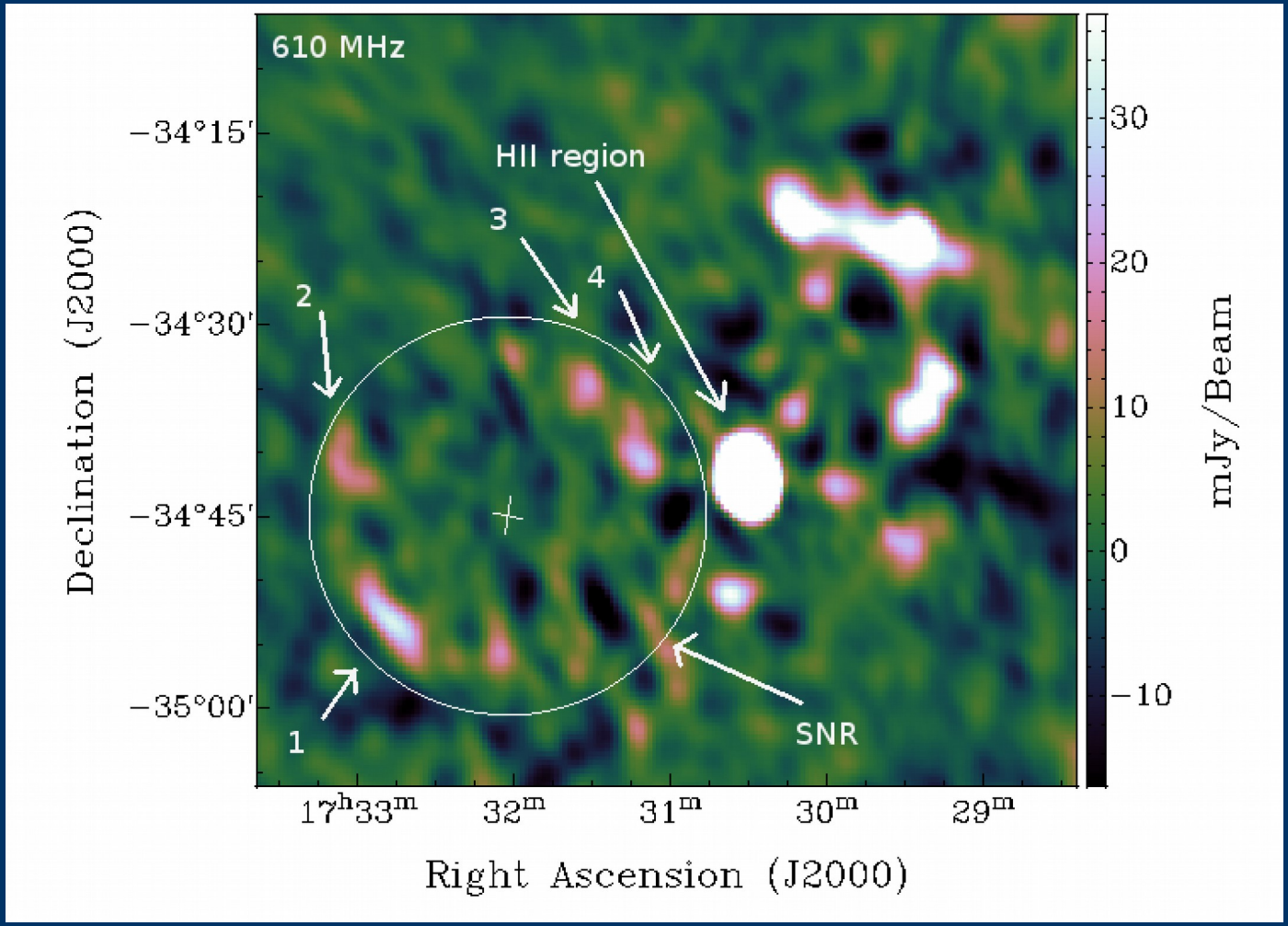
Figure: GMRT low resolution map of the G353.6-0.7 FoV at 325MHz. Map resolution is 135"×97", rms=4.8 mJy/beam *Nayana et al. 2017*

610 MHz GMRT map of the SNR



GMRT low resolution map of the G353.6-0.7 FoV at 610MHz. Map resolution is 150”×105”, rms=4 mJy/beam Nayana et al. 2017

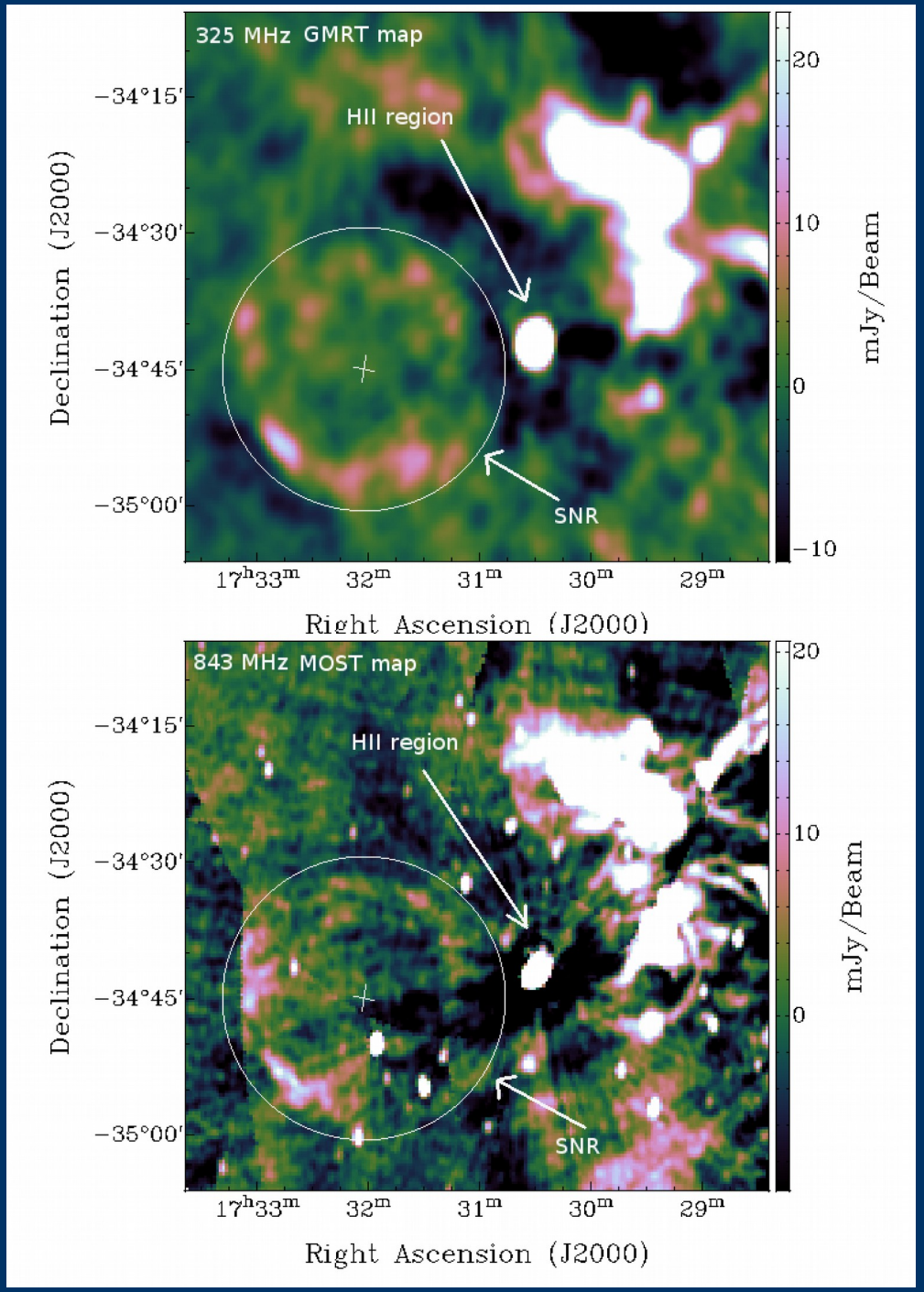
Spectral index of four filaments

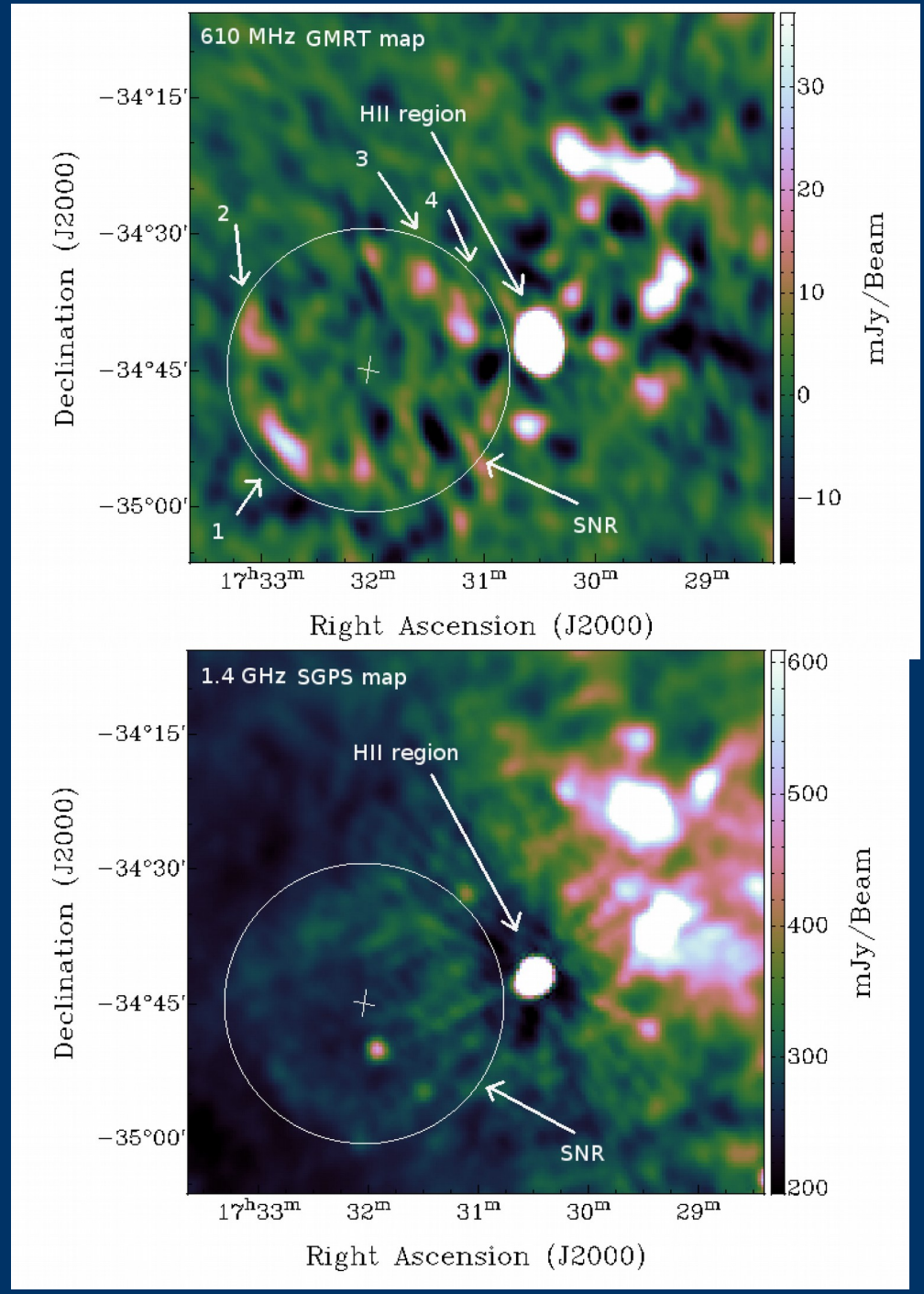


Filament 1 $\alpha = -0.70 \pm 0.19$; Filament 3 $\alpha = -0.50 \pm 0.30$

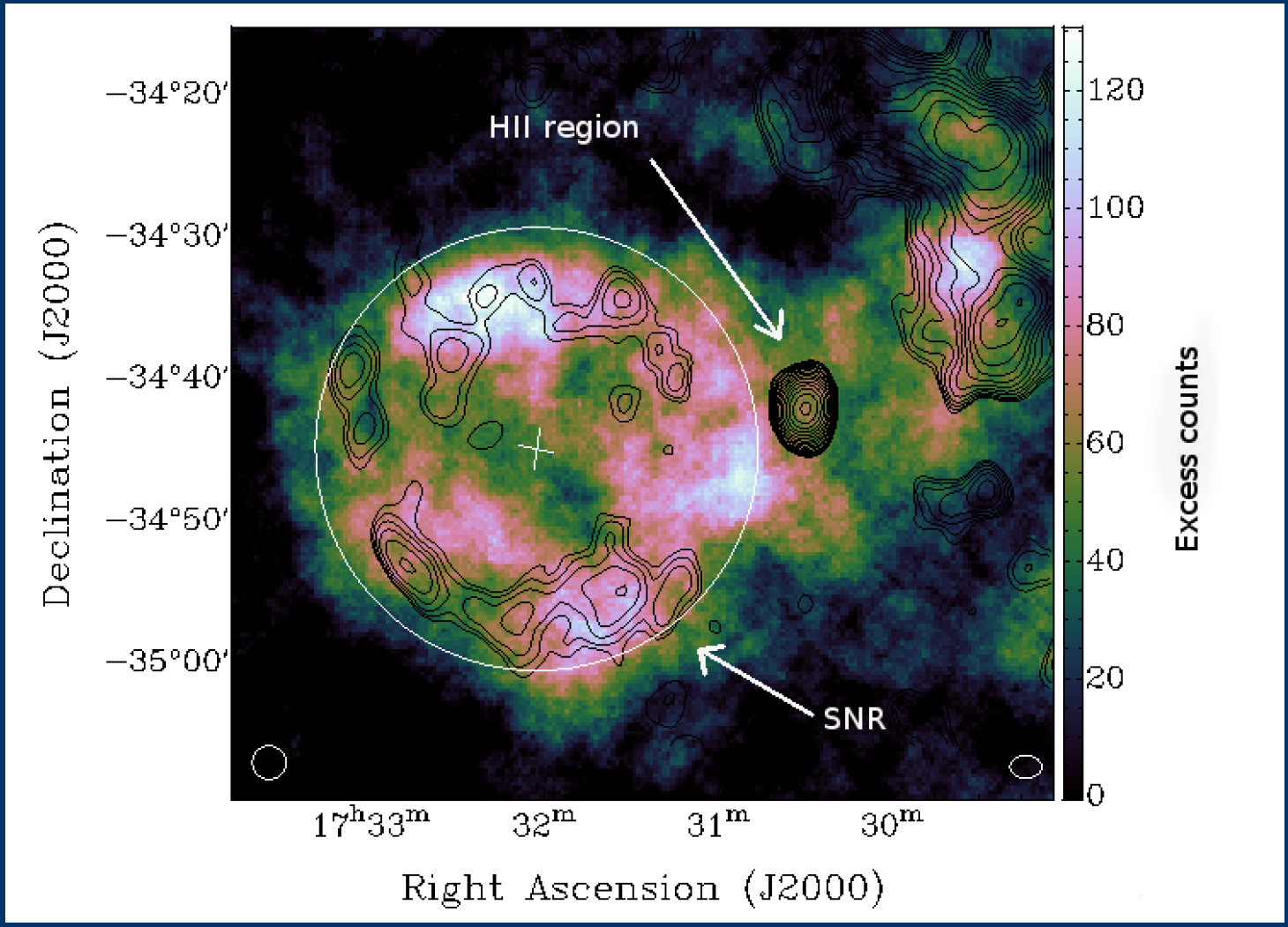
Filament 2 $\alpha = -1.11 \pm 0.22$ Filament 4 $\alpha = -0.15 \pm 0.32$

SNR at different frequencies





Comparison with VHE emission



TeV gamma ray excess map (Abramowski et al. 2011) overlaid with the GMRT 325 MHz map contours (Nayana et al. 2017).

Discussion

- Variation in radio brightness can be explained by the presence of non uniform magnetic field.
- Radio brightness increases with magnetic field as $B^{3/2.}$
- If VHE emission is of leptonic origin, the electrons corresponding to VHE emission have energies $E \sim E_{max}$ and experience substantial radiative losses. $dE/dt \sim E^2B^2$
- Lower IC brightness and higher radio brightness in SNR regions with larger magnetic fields.
- Much steeper spectral index of filament 2 (-1.11) can be due to synchrotron cooling, suggestive of higher B in that region.

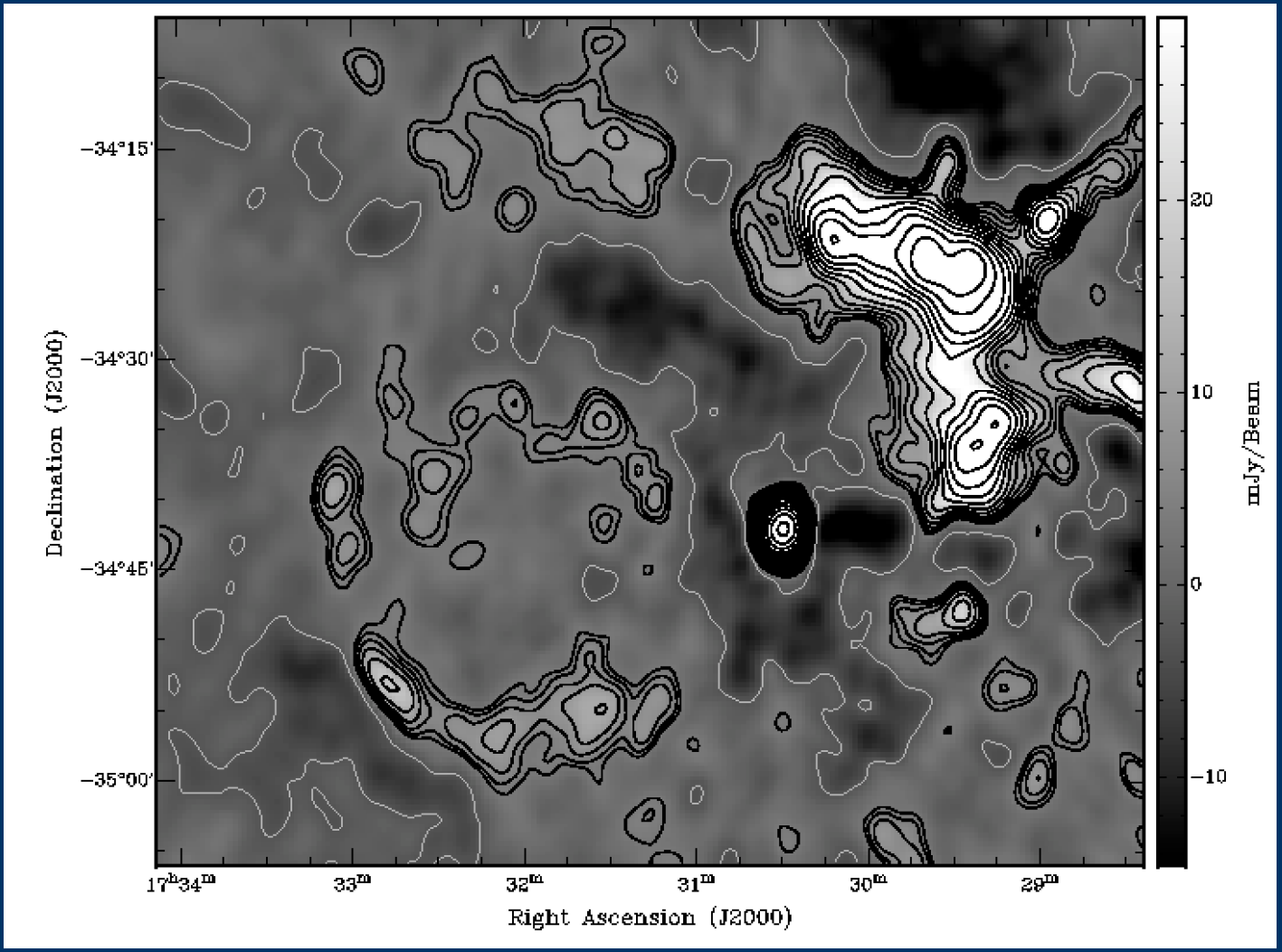
Summary

- We detect radio morphology of SNR G353.6-0.7 at 325 and 610 MHz.
- The spectral indices of different filaments vary from -1.11 to -0.15 and are consistent with the non-thermal radio emission.
- We derive integrated flux density at 1.4 GHz as 0.88 Jy and this value is 1.5 σ lower than previously reported value by Tian et al. 2008.
- The brightest feature in radio correspond to the faintest in the VHE emission and viceversa.
- The faintest filament in VHE shows a steep spectral index of -1.11 ± 0.22; suggestive of synchrotron cooling in that region of the SNR.
- The anti-correlated emission favours a leptonic scenario.

Future Directions

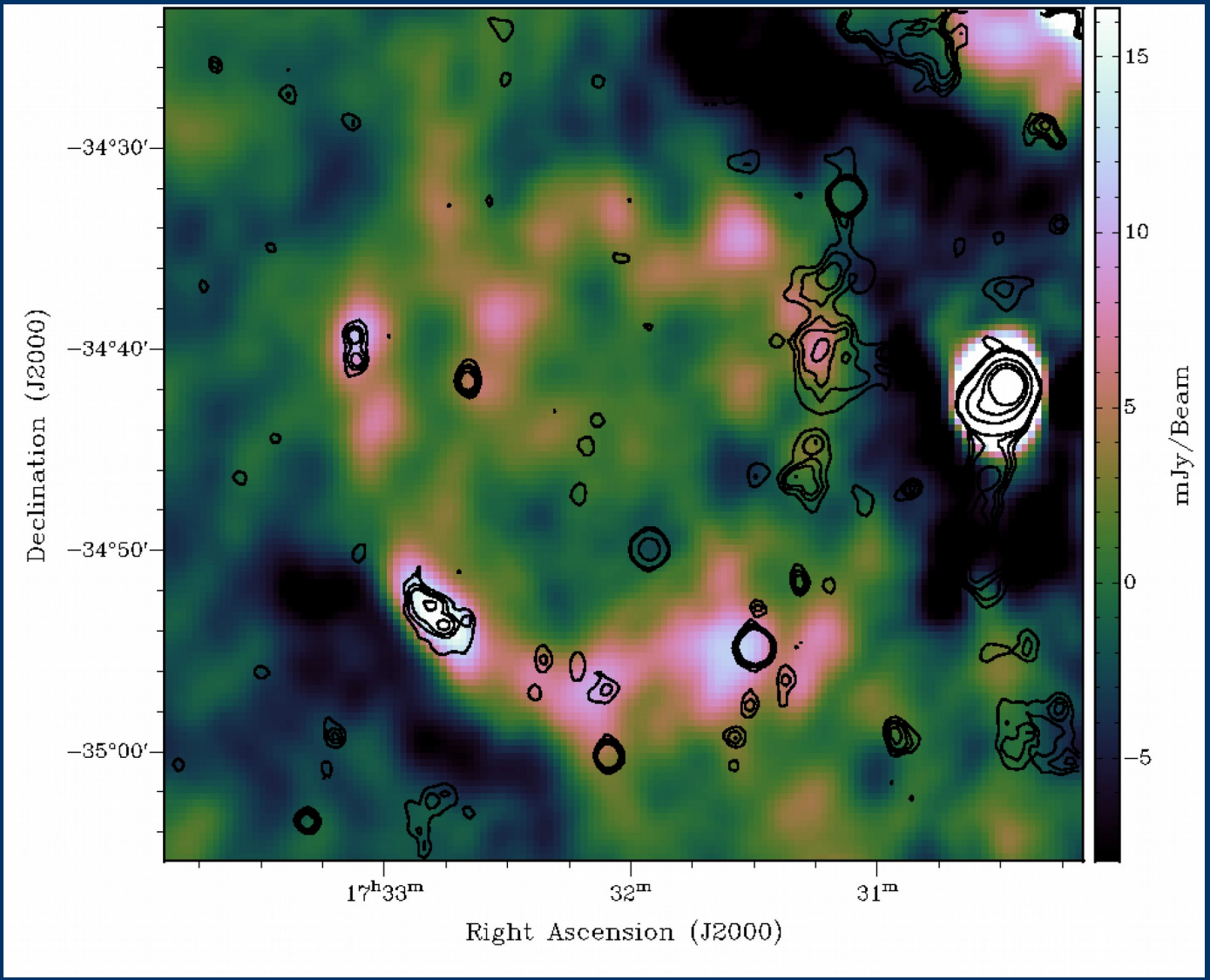
- Study the spectral structure of individual filaments with wide frequency range observations; 250 MHz to 2 GHz.
- uGMRT observations with 200 MHz bandwidth will provide 2.5 times better sensitivity and excellent uv coverage.
- 250-500 MHz observations are yet to happen in mid March.
- Accepted proposal - JVLA observations in its D array in the frequency band 1- 2 GHz.

325 MHz GMRT map of the SNR

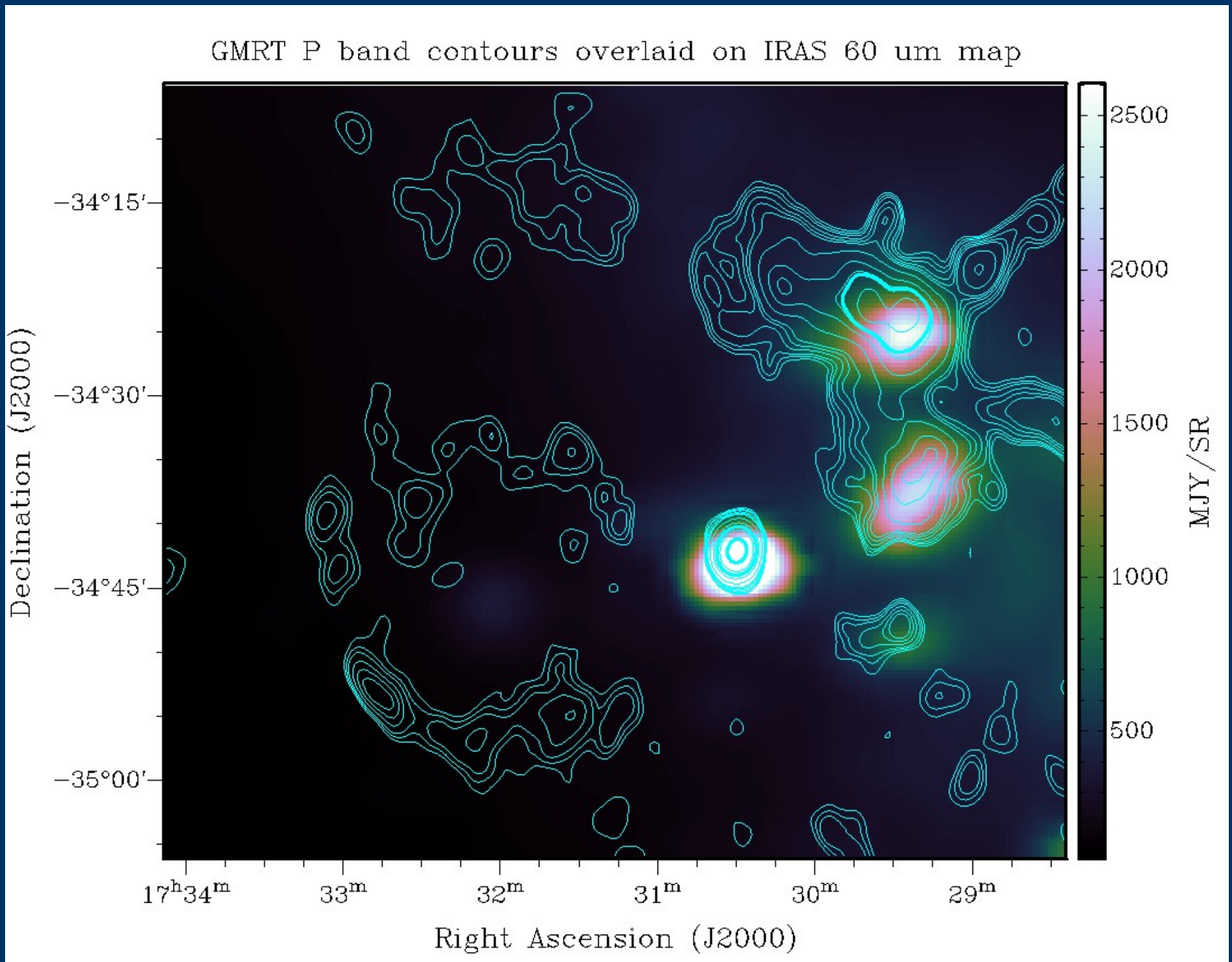


Map resolution is 135”×97”. The contours are ± √2^n σ (σ=1.5 mJy/beam) (n = 2,3,4. . .) with negative contours in grey colour *Nayana et al. 2017*

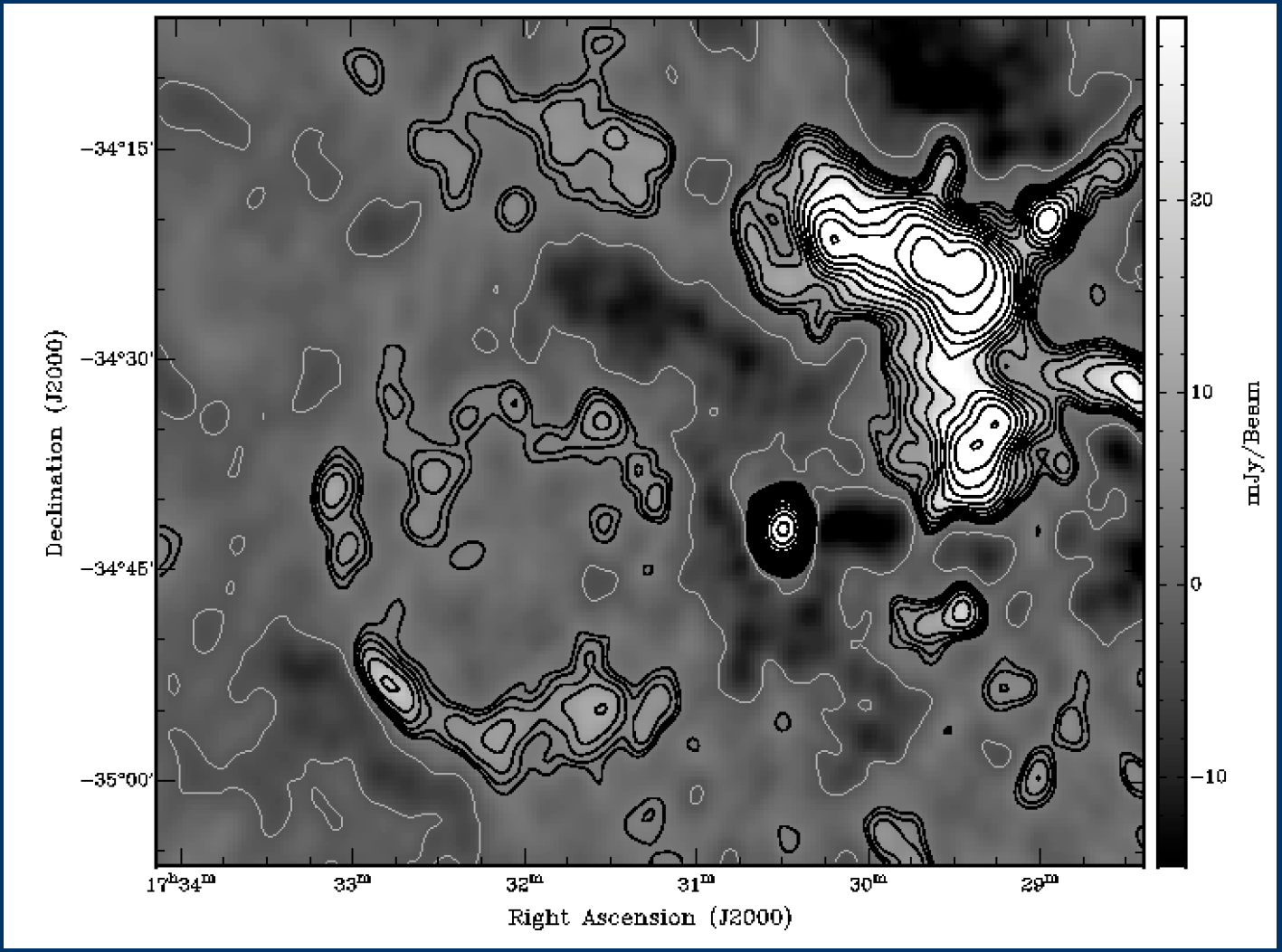
SNR in the NVSS map



Map resolution is 45”×45”. The contours are n σ (σ=1.5 mJy/beam) (n = 3,4,5,6)


GMRT P band contours overlaid on IRAS 60 um map
−34°15′
−34°30′
−34°45′
−35°00′
Declination (J2000)
17h34m
33m
32m
31m
30m
29m
Right Ascension (J2000)
2500
2000
1500
1000
500
MJY/SR

325 MHz GMRT map of the SNR



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