How radio data can support ASTRI Mini-Array Galactic science

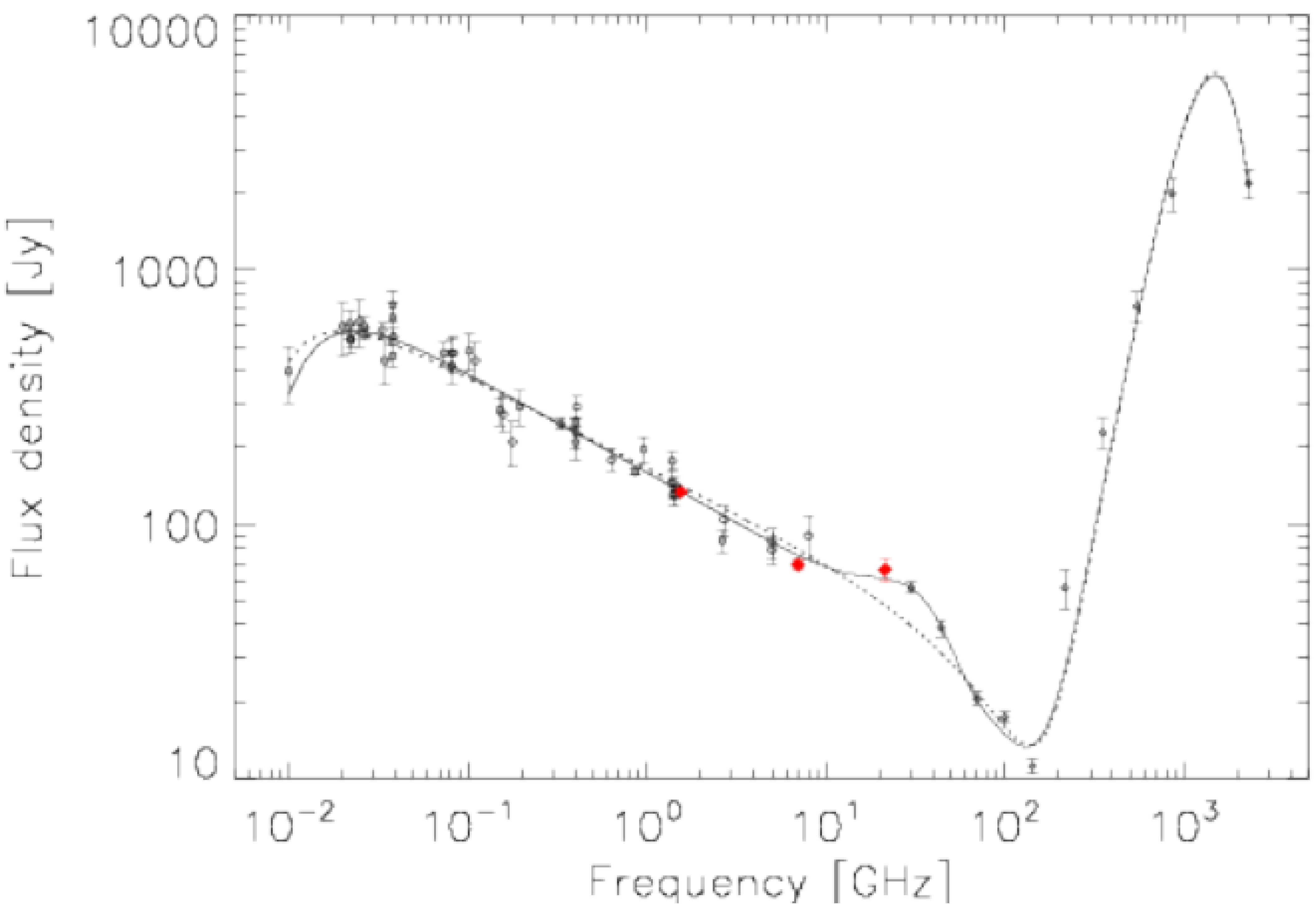
Adriano Ingallinera (INAF)
and G. Umana, S. Vercellone, G. Pareschi

for the ASTRI Project

PASTO, 06/09/2022

Supernova remnants in radio

- Among the most prominent Galactic sources at cm-wavelengths.
- Radio emission due to:
  - ➢ Synchrotron
  - ➢ Spinning dust
  - ➢ Thermal dust
  - ➢ Free-free
  - ➢ OH maser at 1720 MHz



Typical radio spectrum (cit.)

Synchrotron is the main mechanism

below ~10 GHz

Spectral slope is related to the electron energy distribution

Instrumental limits

- Low frequencies (< ~500 MHz) poorly accessible:
  - ➢ now mitigated by MWA and LOFAR -> high resolution and sensitivity

- Large spatial scales (>> ~1 arcmin) poorly recovered at 1-10 GHz:
  - ➢ now mitigated by MeerKAT and ASKAP with densely populated cores
  - ➢ baselines down to ~20 m -> structures recovered up to 30 arcmin at 1 GHz

- A few top-class instruments for frequencies above 10 GHz:
  - ➢ now mitigated by new single-dishes as SRT -> up to ~30 GHz (~100 GHz by 2025)

New and upcoming telescopes

- New and upcoming large instruments in **radio** and **gamma**
- Radio:
  - SKA precursors (MWA , MeerKAT and ASKAP)
  - High-frequency single-dishes (SRT)
  - SKA1 LOW and MID by this decade (freq. cov. ~70 MHz - ~15 GHz)
- Gamma-ray:
  - ASTRI Mini-Array (energy cov. 1 – 300 TeV)
  - CTA observatory by this decade (energy cov. 20 GeV – 300 TeV)

ASTRI Mini-Array

- Nine-element array of "Small-size telescopes"
- Telescope based on the Italian ASTRI technology
- Energy coverage: 1 – 300 TeV
- Observatorio del Teide (Canary islands)

New opportunities for Galactic synergies

ASTRI prototype at Serra La Nave

Involvement

- The radio astronomy group in Catania is involved in two major survey programs that are supplying top-level Galactic data:

  - The Evolutionary Map of the Universe (EMU) survey with ASKAP with two 40-deg^2 Galactic fields already observed

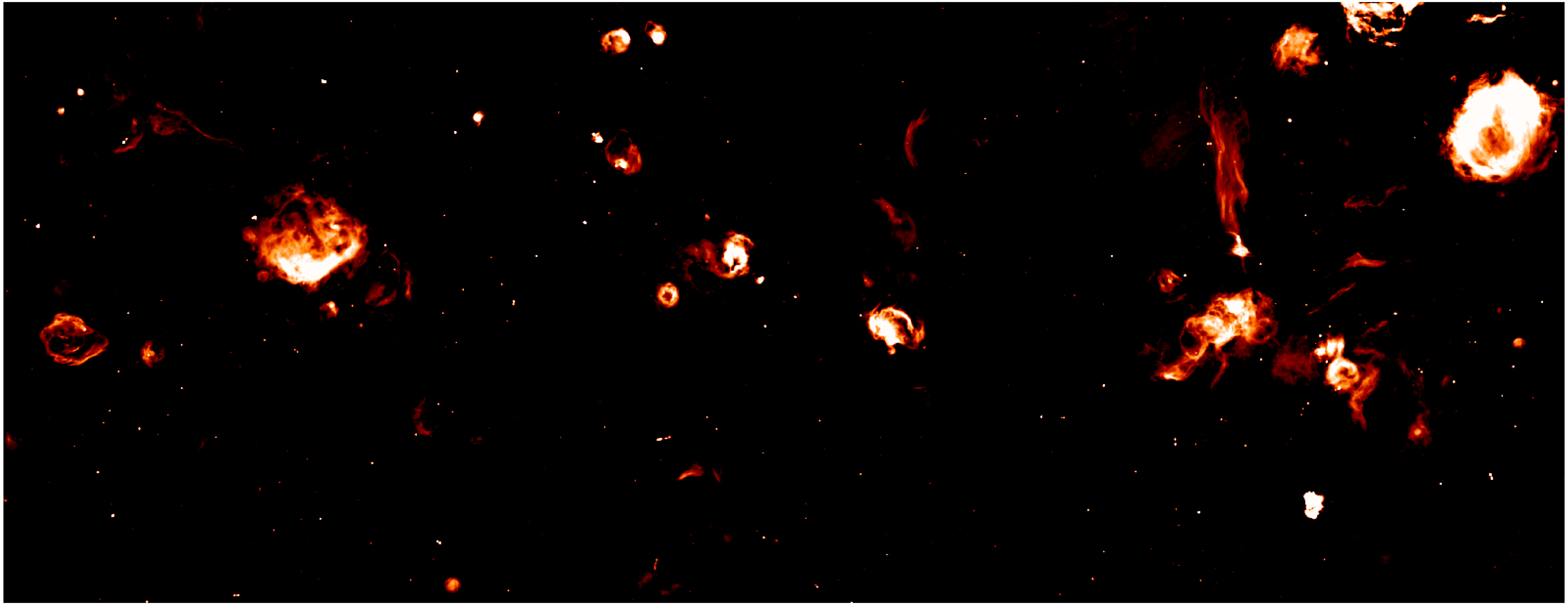
  - The MeerKAT SARAO Galactic plane survey

MeerKAT SARAO Galactic Plane Survey

- MeerKAT SARAO Galactic plane survey:
  - 250° < *l* < 60° (except *l* = 0°)
  - Observing band: 900 – 1700 MHz
  - Sensitivity: ~ 10-20 μJy/beam
  - Survey presented in Goedhart et al. in prep.

  - About 200 known SNRs, plus many new candidates
  - **New potential targets for gamma-ray follow-ups**

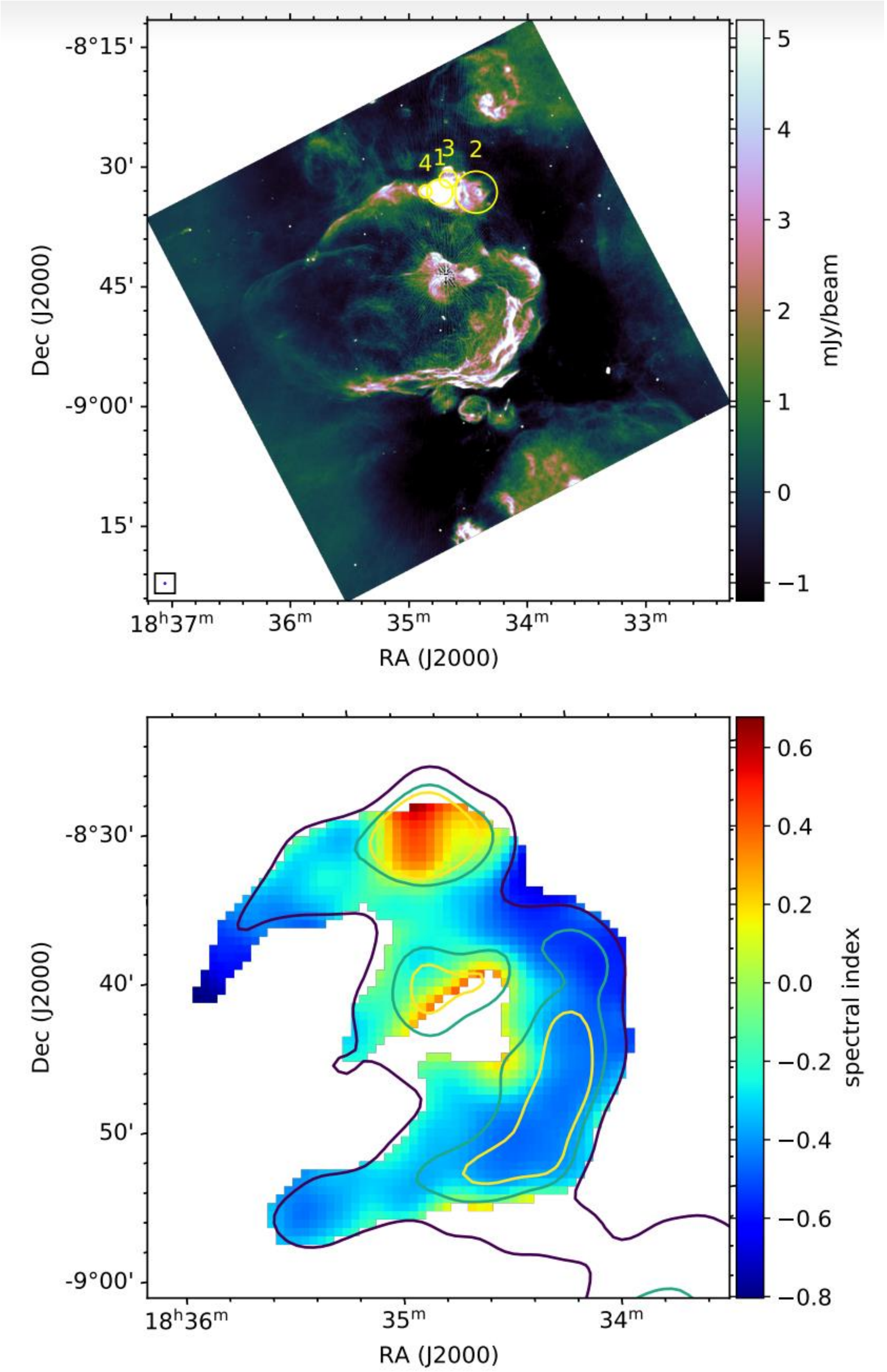
MeerKAT SARAO Galactic Plane Survey



A MeerKAT view of the Galactic plane (about 2 deg in Galactic longitude)

MeerKAT data analysis on SNRs

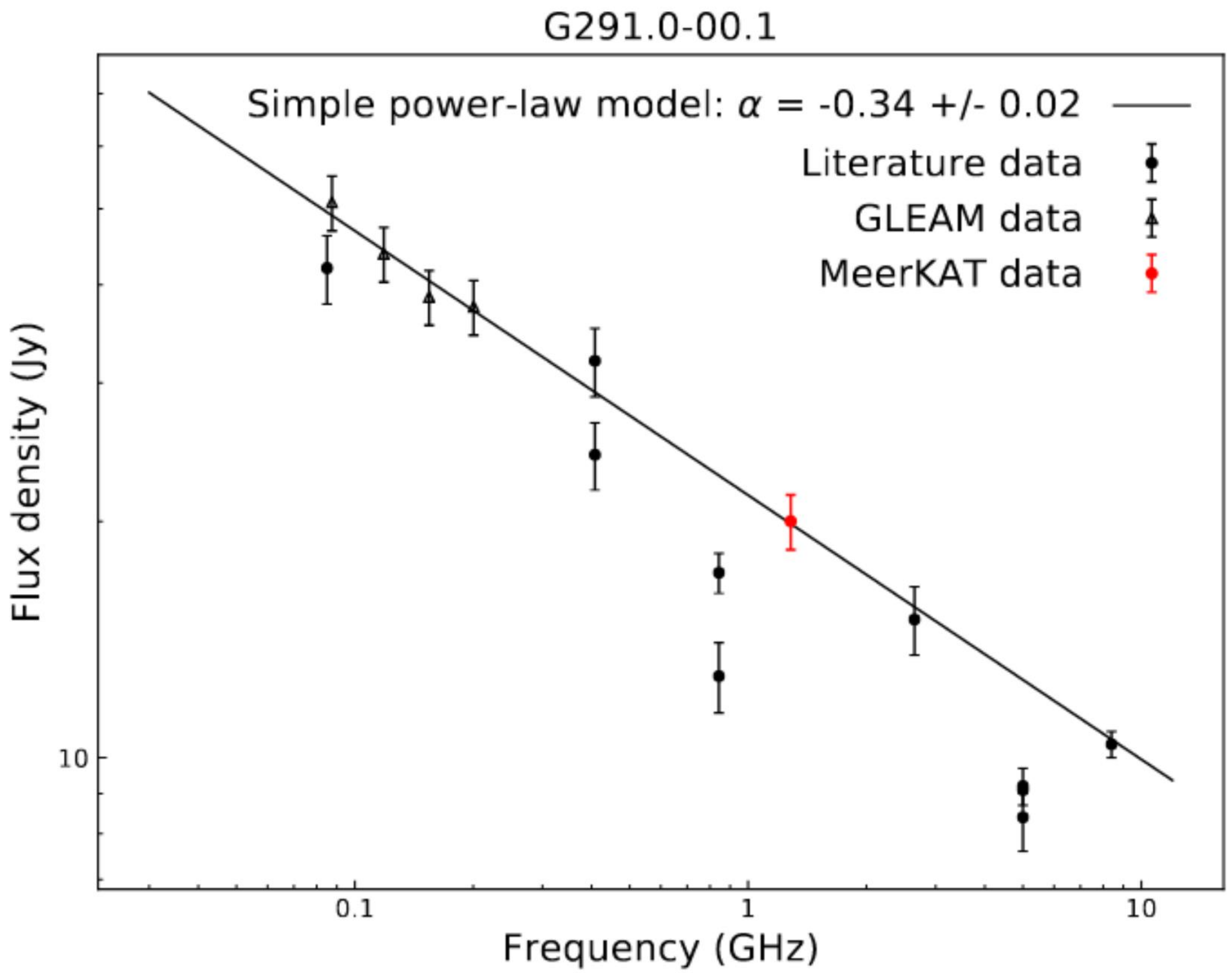
- A revised catalogue of known SNRs will be presented in Bufano et al. in prep.
- Deep spectral analysis in Loru et al. in prep.
  - Accurate flux density
  - Spectral index maps
  - Challenging literature global spectral indices



G023.3-0.3 MeerKAT and spectral index map (Loru et al. in prep.)

MeerKAT data analysis on SNRs

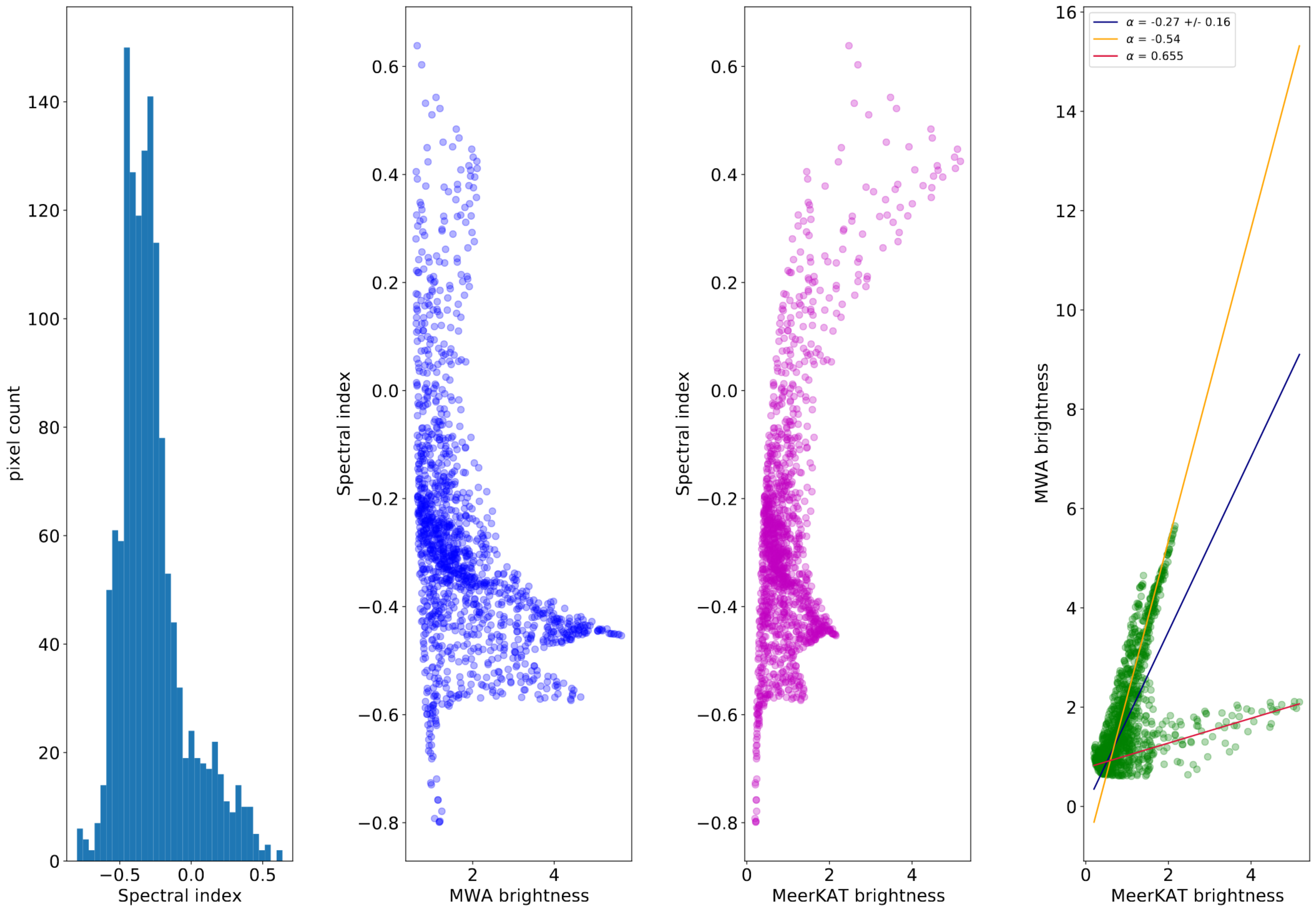
- New flux density measurements to test the literature data:
  - ➢ Using recent and homogeneous values
  - ➢ Disputing some global spectral index
  - ➢ High resolution and sensitivity to exclude possible foreground/background contamination



Literature data are confusing…

MeerKAT data analysis on SNRs

- Histograms and scatter plots to identify hidden spectral features



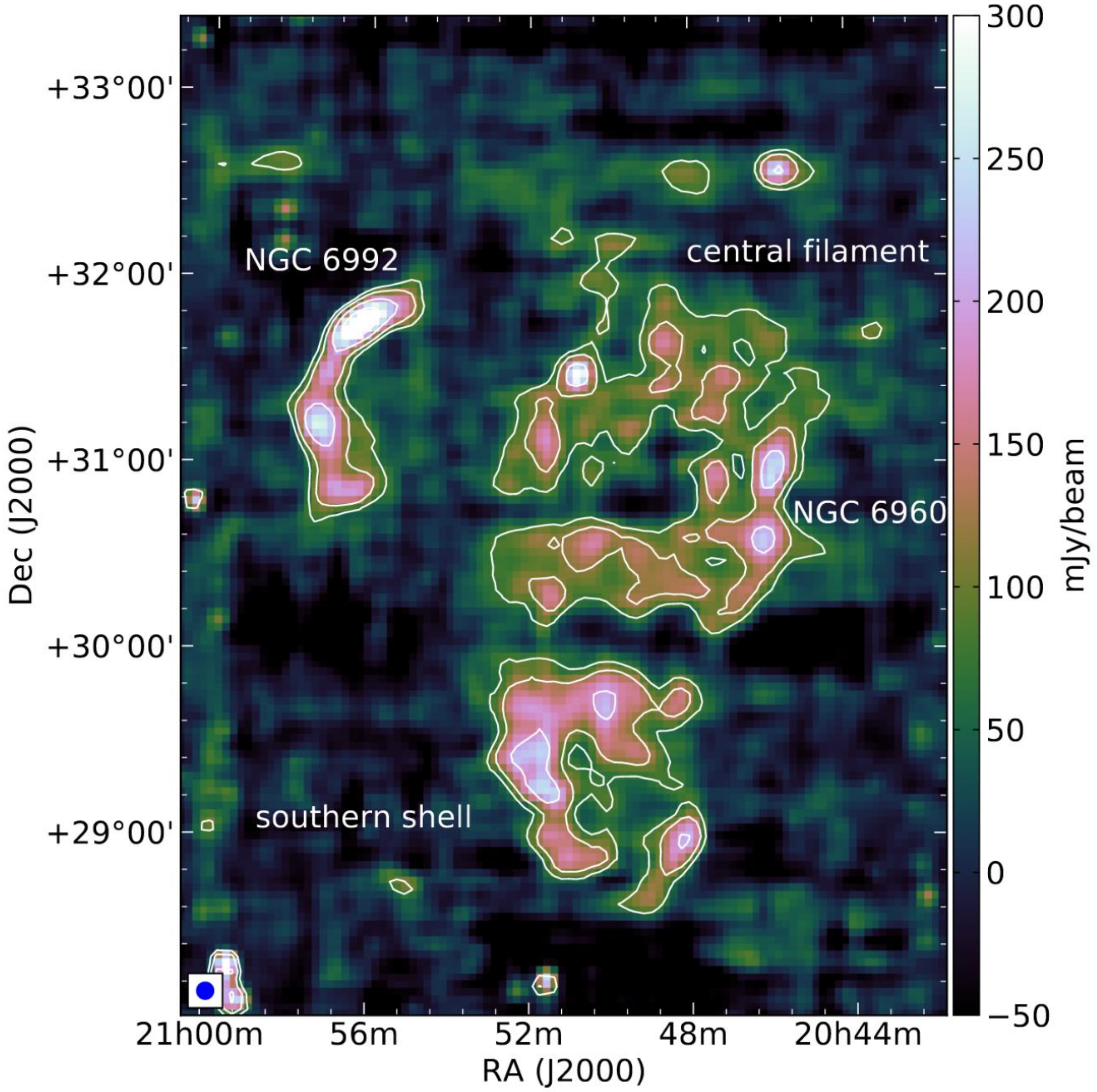
Spectral index histrogram and different scatter plot to spot spatial spectral features.

(Loru et al. in prep.)

This work is aimed at better modelling radio emission.

Cygnus Loop: radio-gamma link

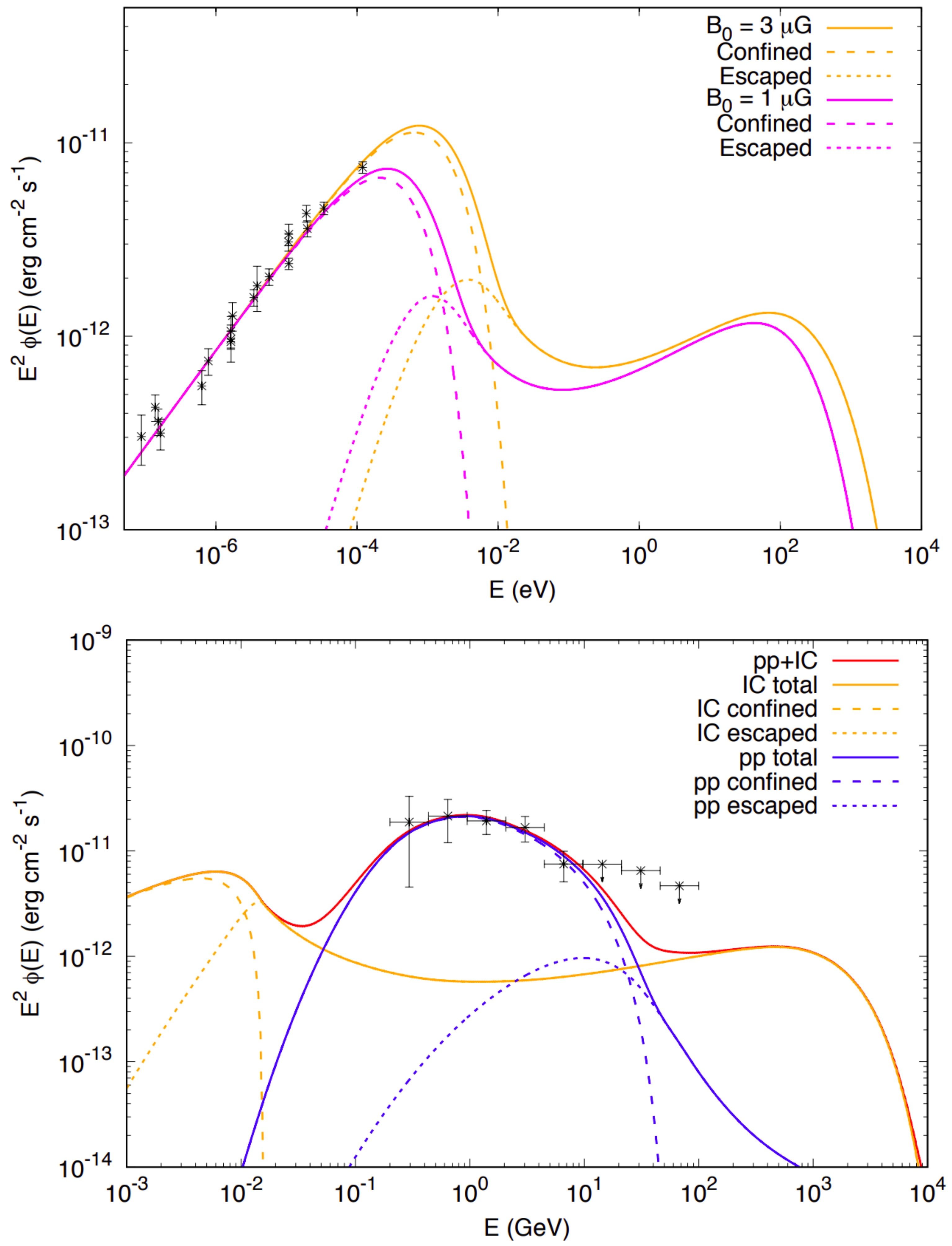
- Angular extension: ~ 4 deg!
- Observed with Medicina and SRT from 7 to 25 GHz
- Planck data at 30 and 40 GHz show a possible, inhomogeneous dust contribution



Comprehensive view of Cygnus Loop at 8 GHz (Loru et al. 2021)

Cygnus Loop: radio-gamma link

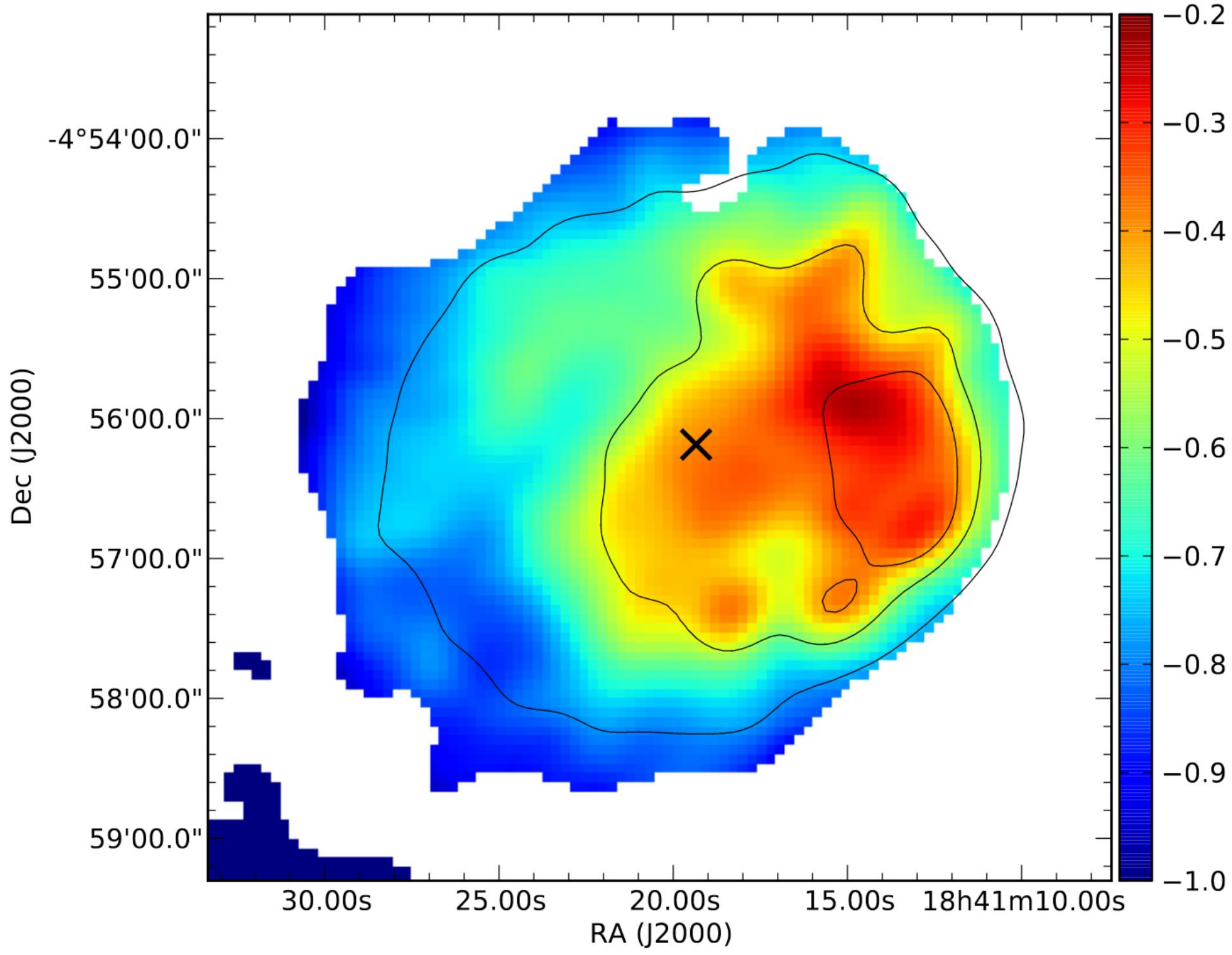
- Using our radio data and literature gamma data to model the non-thermal emission (Celli+ 2019, Morlino & Celli 2020)
- Radio data rule out spectral steepening: input constraint at "low-energy"
- The model constrains:
  - maximum particle energy (65 GeV)
  - magnetic field at shock (10 μG)
  - electron density (dominant IC above 10 GeV)
- **Need for sensitive > 1 TeV observations**
- **Pathfinder study for other SNR**



Radio and gamma-ray spectra (Loru et al. 2021)

Case study: KES 73

- Relatively small-sized: 4 arcmin
- Hosting a magnetar
- Our radio analysis shows a significant spectral index variation

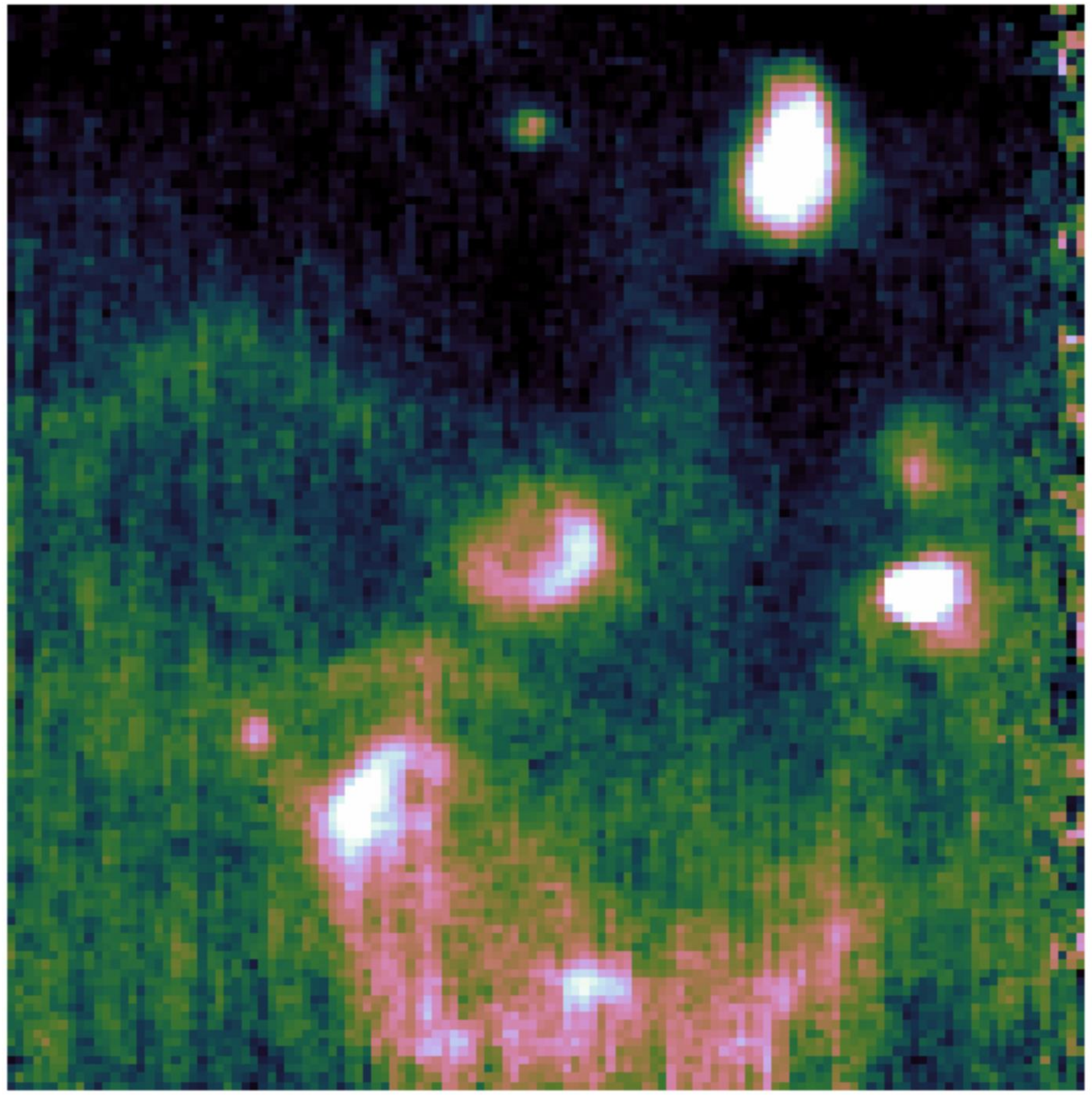


Radio spectral index map (1.4-5 GHz; Ingallinera et al. 2014)

Case study: KES 73

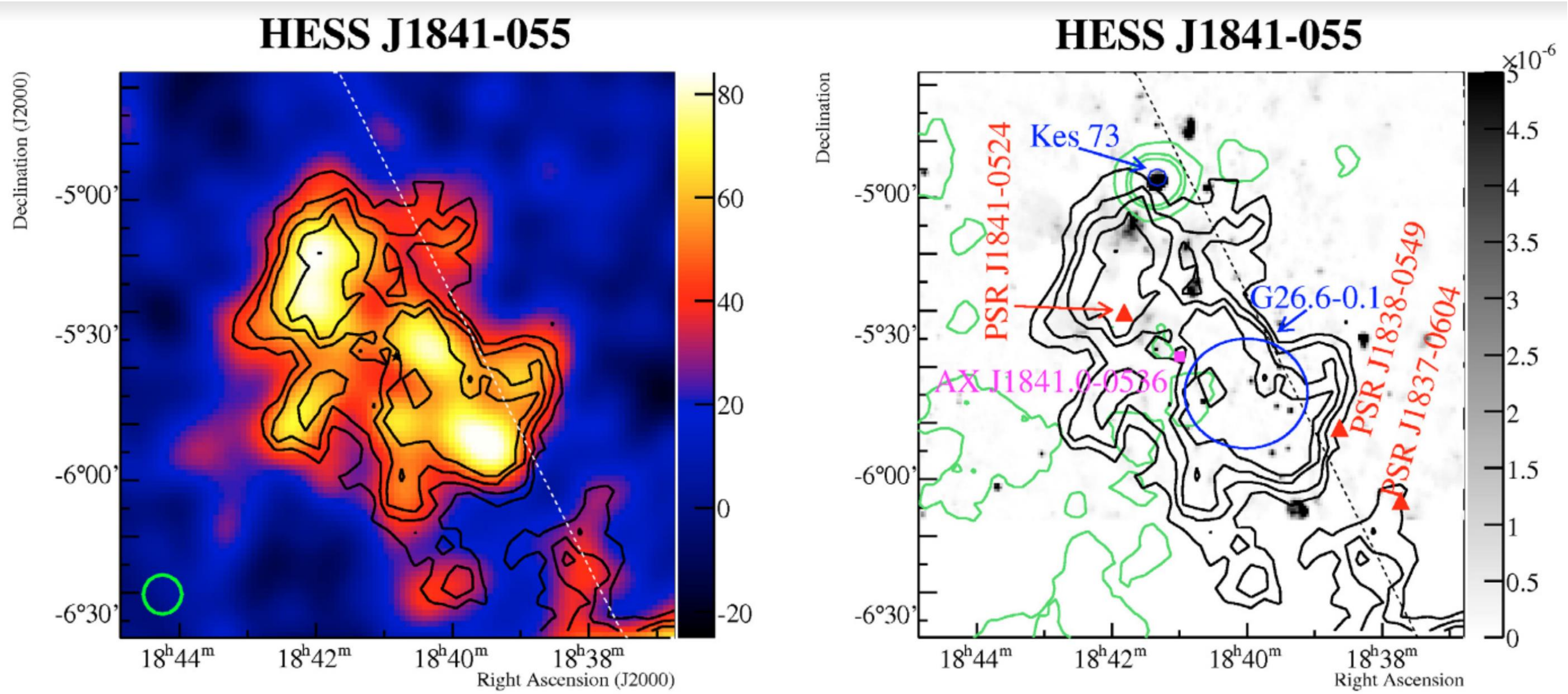
- New high-frequency data observations with SRT (PI A. Pellizzoni) are under reduction/analysis

- Spectral analysis to look for departures from a power-law synchrotron emission



KES 73 @ 18 GHz with SRT (Loru et al. in prep.)

Case study: KES 73



KES 73 with HESS (Aharonian et al. 2008)

Conclusions

- New possibilities enabled by upcoming radio and gamma-ray instruments.
- SNRs are suitable objects for radio and gamma-ray studies.
- We presented a template case that can be taken into accounts for future studies.
- A sample of SNRs is ready for observations with ASTRI Mini-Array.