



# Synchrotron radiation in Cas A: the non-linear connection

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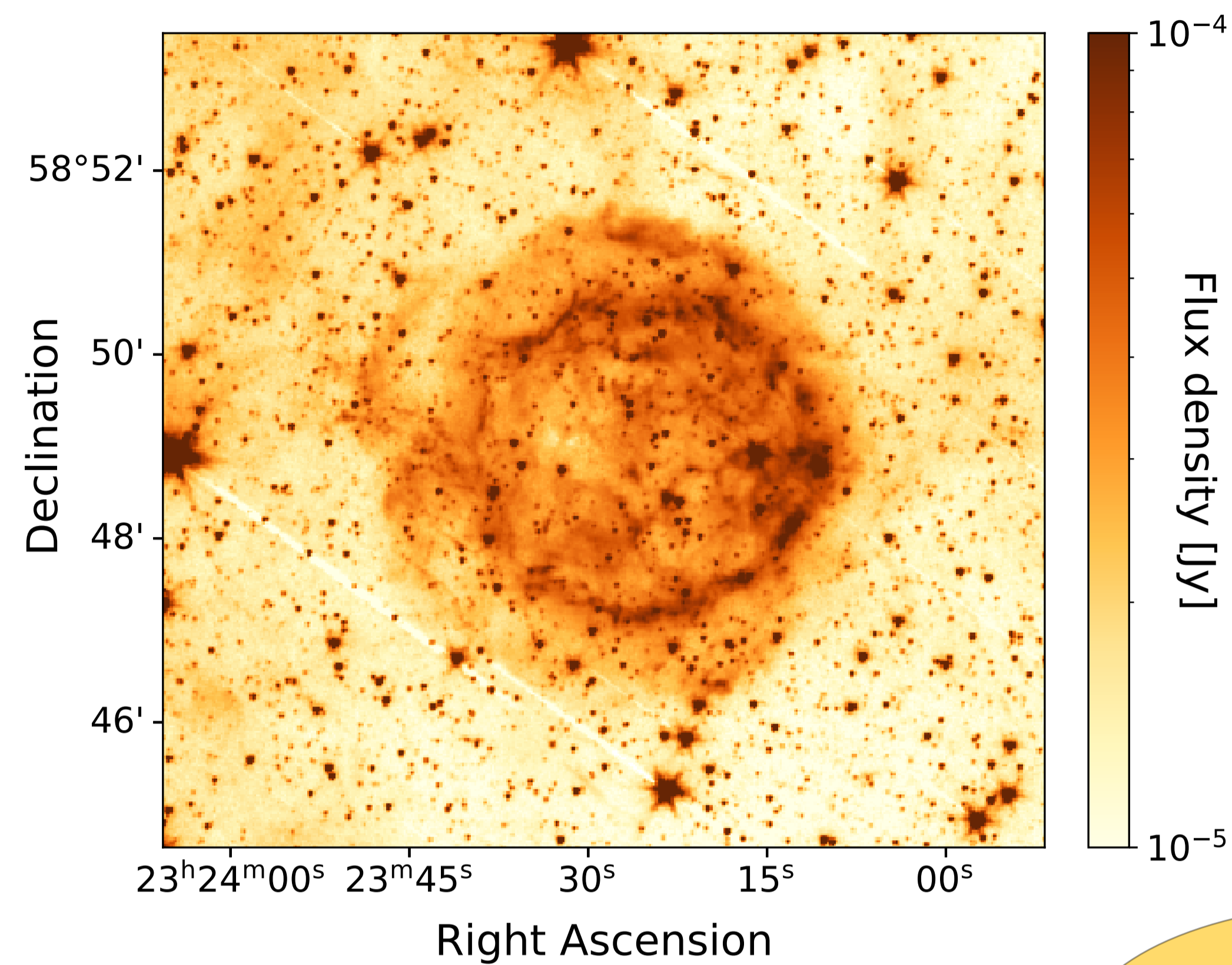
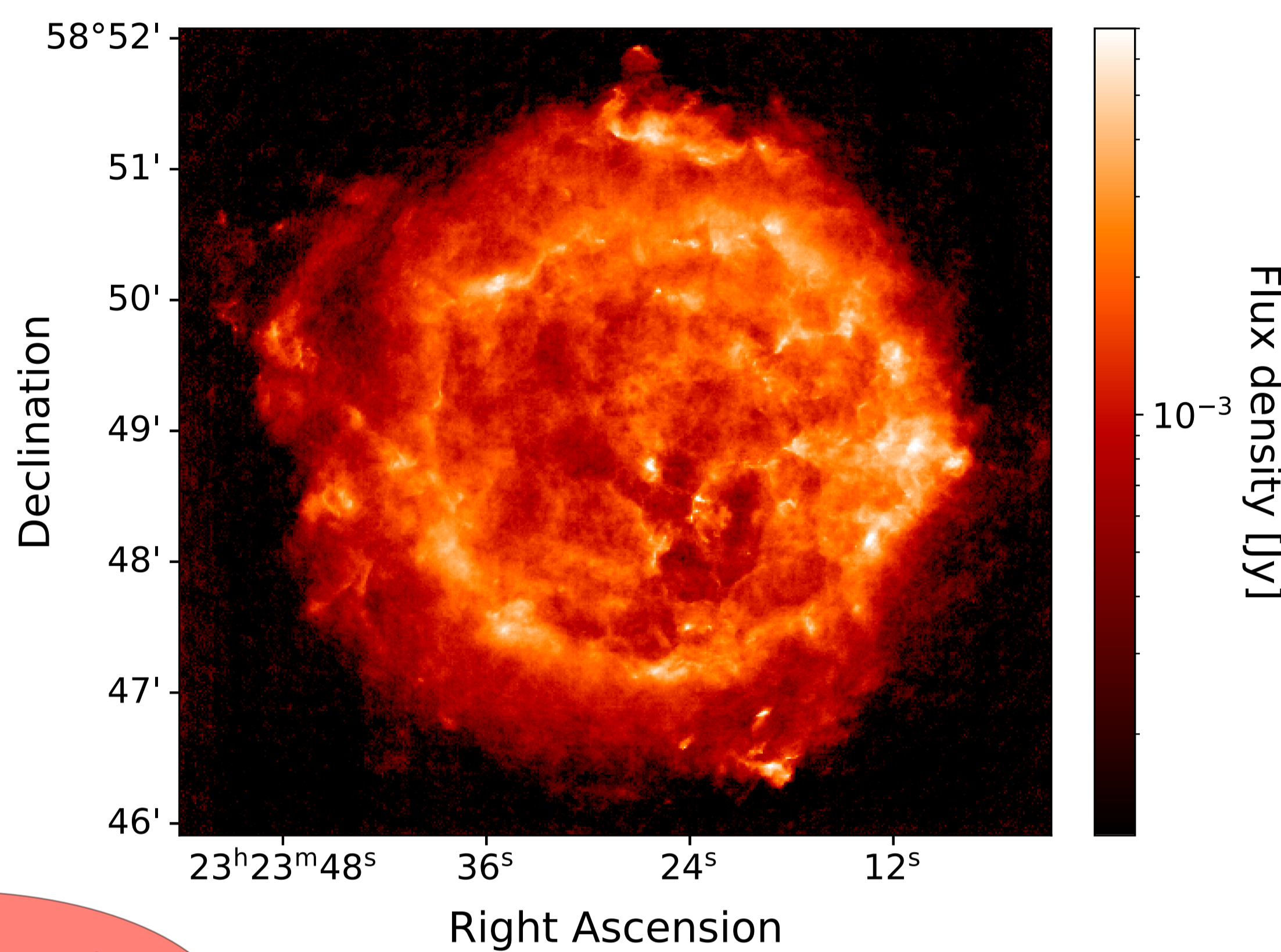
Supernova remnants (SNRs) are thought to be the dominant sources of Galactic cosmic rays (Helder+ 2012)

First evidence of that was given by the radio observations showing synchrotron emission of GeV electrons

Non-linear cosmic-ray acceleration: accelerated particles influence the shock itself

Steep spectra at low frequencies, flat at high frequencies resulting in spectral curvature (Malkov & Drury 2001)

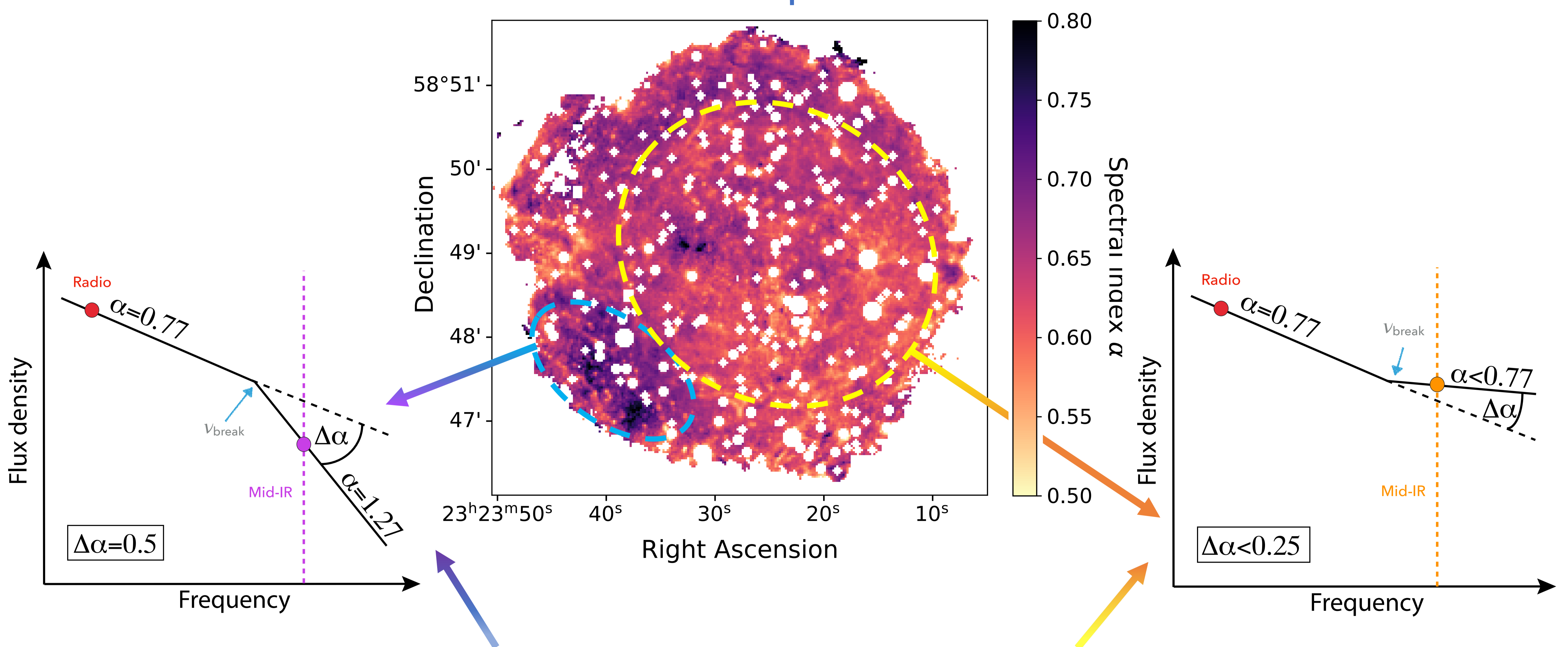
We investigate the spectral index of synchrotron radiation between radio and mid-infrared to look for this curvature



Radio – VLA\*  
4.72 GHz ( $\sim 10^9$  Hz)

Mid-IR - Spitzer,  
3.6  $\mu$ m ( $\sim 10^{13}$  Hz)

$$\alpha = \frac{\log(\text{IMG}_{\text{Spitzer}}) - \log(\text{IMG}_{\text{VLA}})}{\log(\nu_{\text{Spitzer}}) - \log(\nu_{\text{VLA}})}$$



## Spectral steepening

- Strongest in the south-east region
- One of the oldest structures in the remnant
- We estimate magnetic field upper limit from cooling break  $\rightarrow B \sim 1.2$  mG (for  $t=100$  yr)

$$\left(\frac{B}{\text{mG}}\right) \approx 10 \times \left(\frac{\nu_{\text{break}}}{7.3 \times 10^{14} \text{ Hz}}\right)^{-1/3} \left(\frac{t_{\text{age}}}{100 \text{ yrs}}\right)^{-2/3}$$

## Spectral flattening

- Observed in most of the remnant
- Stronger at the reverse and forward shock
- Weaker in-between the shock regions
- Points to non-linear acceleration

## Conclusions

- We find a good morphological correlation between the 4.72GHz and 3.6 $\mu$ m data  $\rightarrow$  synchrotron radiation
- Spectral index map shows flattening in the shocks regions ( $\alpha \sim 0.55 - 0.65$ ) and in-between ( $\alpha \sim 0.65 - 0.75$ )  $\rightarrow$  Non-linear acceleration (c.f. Jones+ 2003)
- South-east of the remnant shows signs of spectral steepening ( $\alpha \sim 0.75 - 0.85$ )  $\rightarrow$  Cooling break consistent with  $B < 1.2$  mG