Dying radio galaxies with LOFAR

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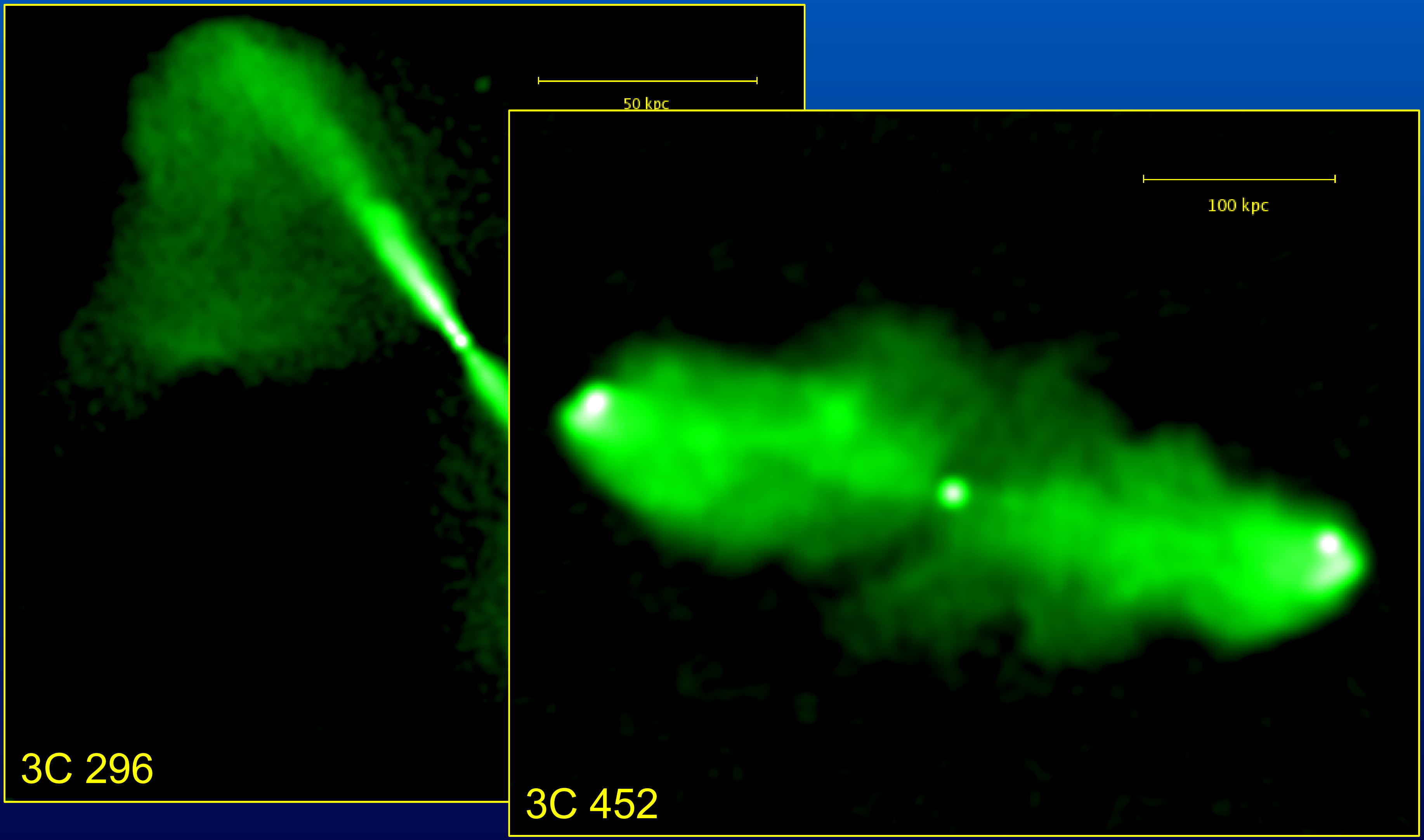
Radio galaxies: the active phase

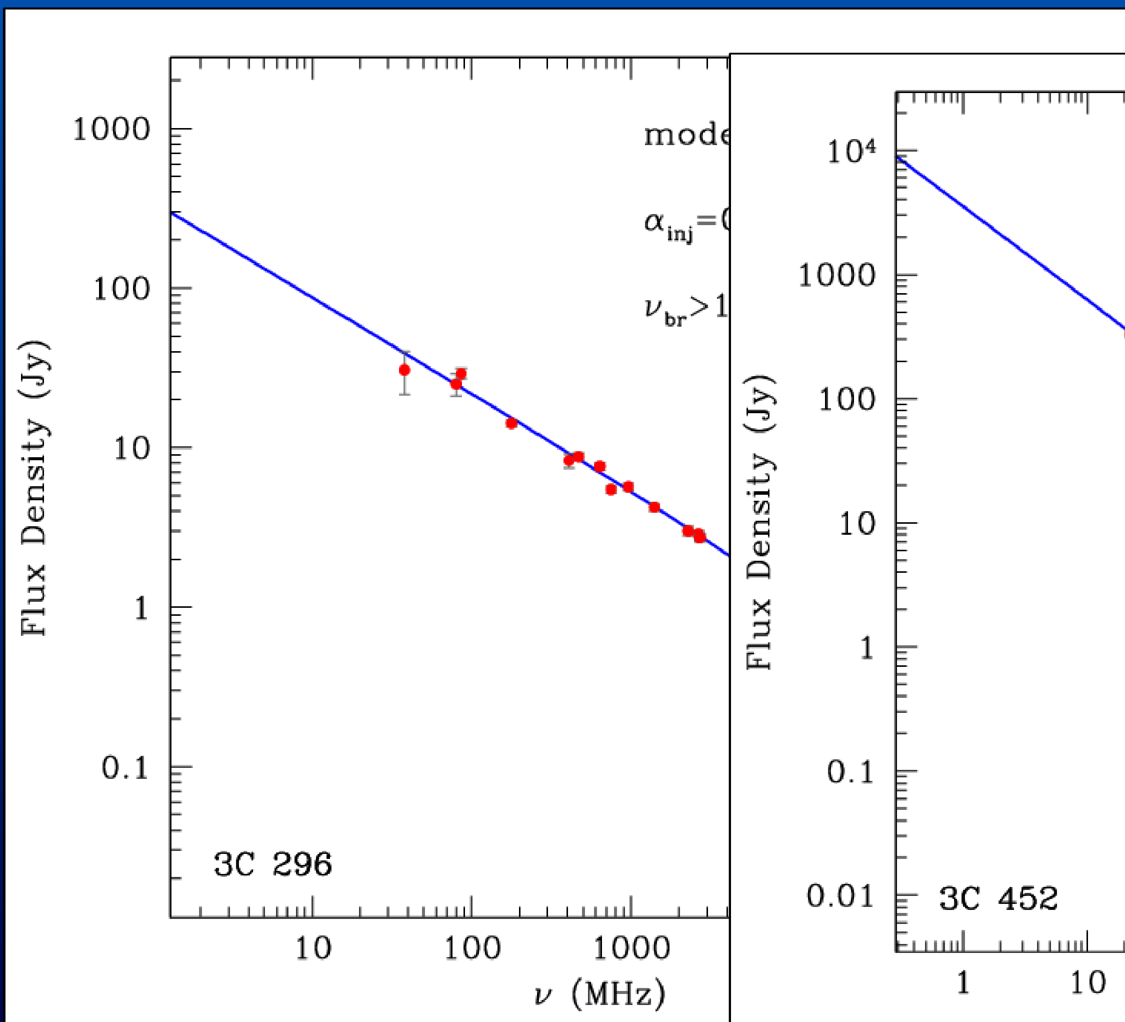
Strong radio source associated with elliptical galaxies are supplied with energy from active galactic nuclei via plasma beams.

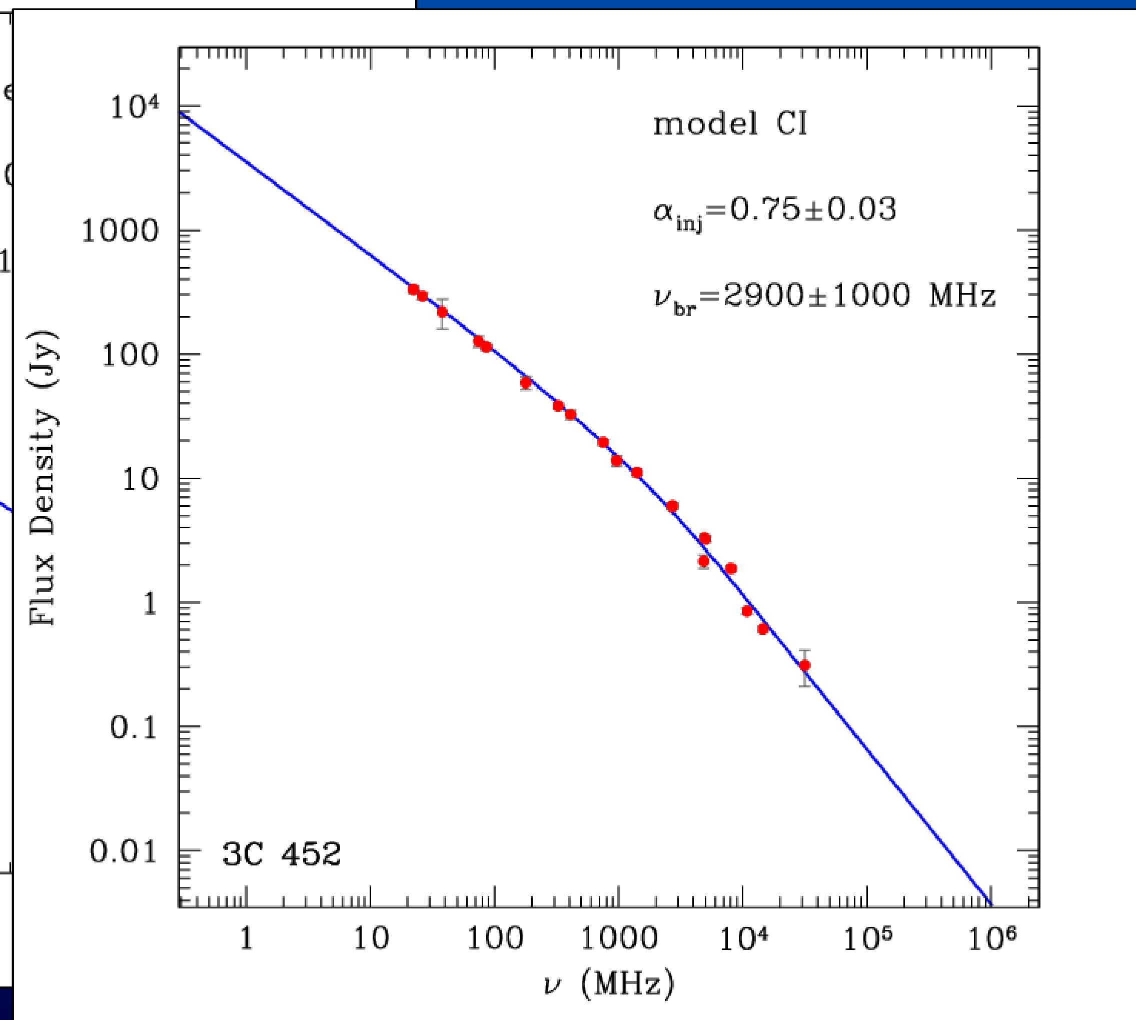


Radio cores, jets and hot spots are produced by continuous activity.

Radio galaxies: spectral properties

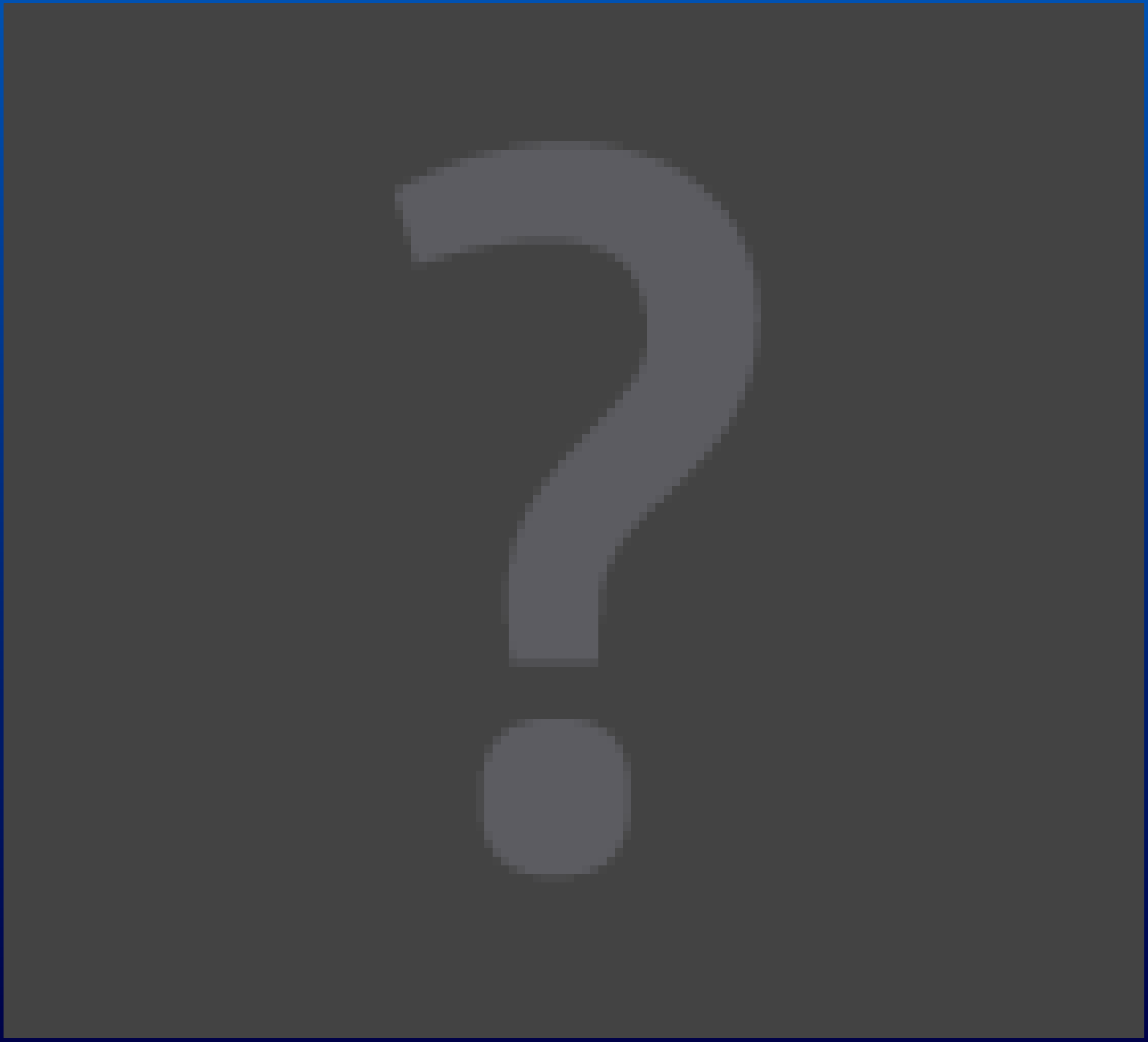
The total spectra of the active radio sources are usually well-approximated by a power law over a wide range of frequencies. Spectral breaks at high-frequency, with a moderated steepening of the spectrum are also often observed.





Spectral evolution: the CI solution

During the active phase the source is continuosly replinished of fresh particles. Due to the radiative losses, the high-frequency spectrum to steepen beyond a time-dependent break frequency: $v_b \propto t_s^{-2}$.



Dying radio galaxies

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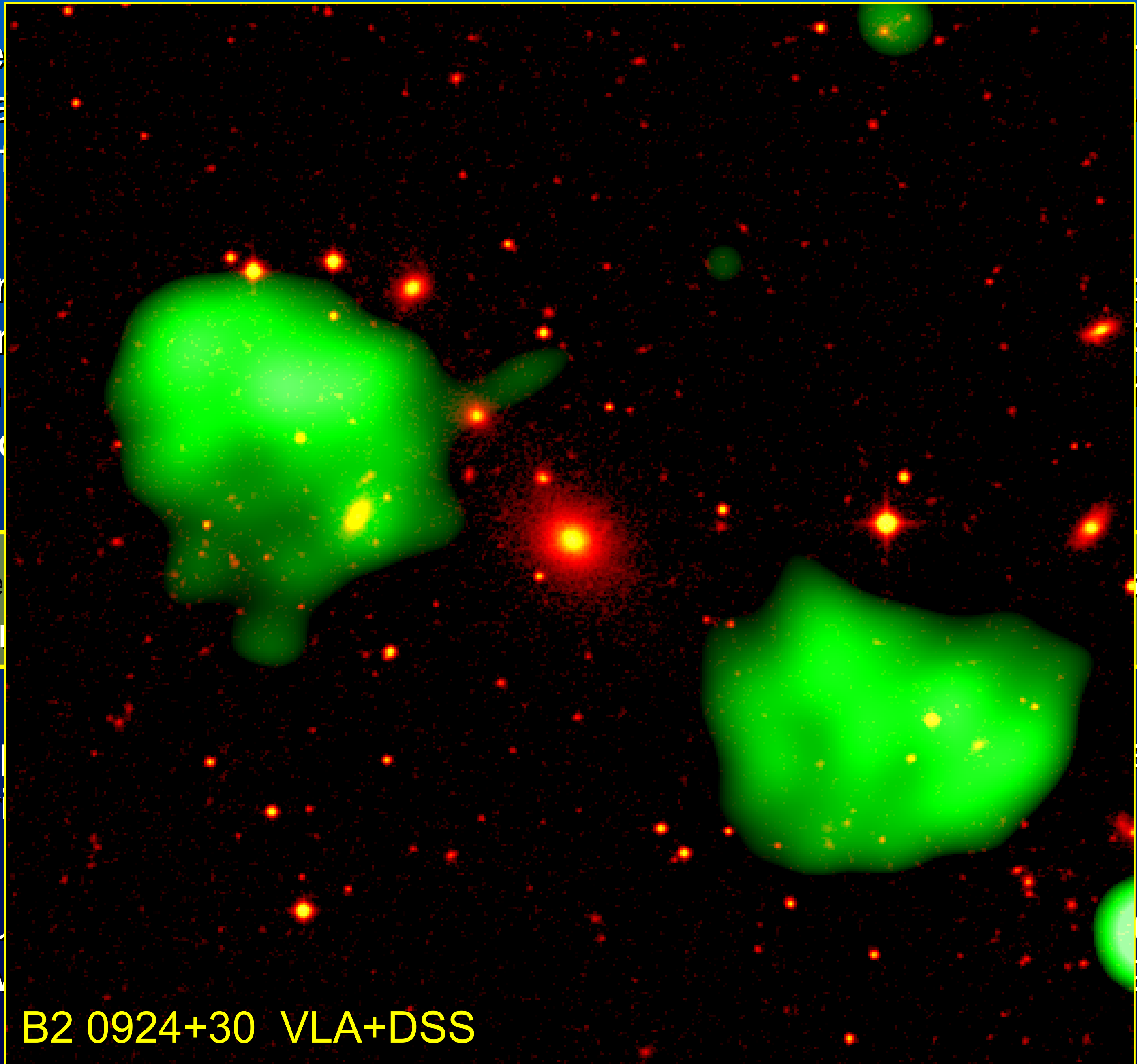

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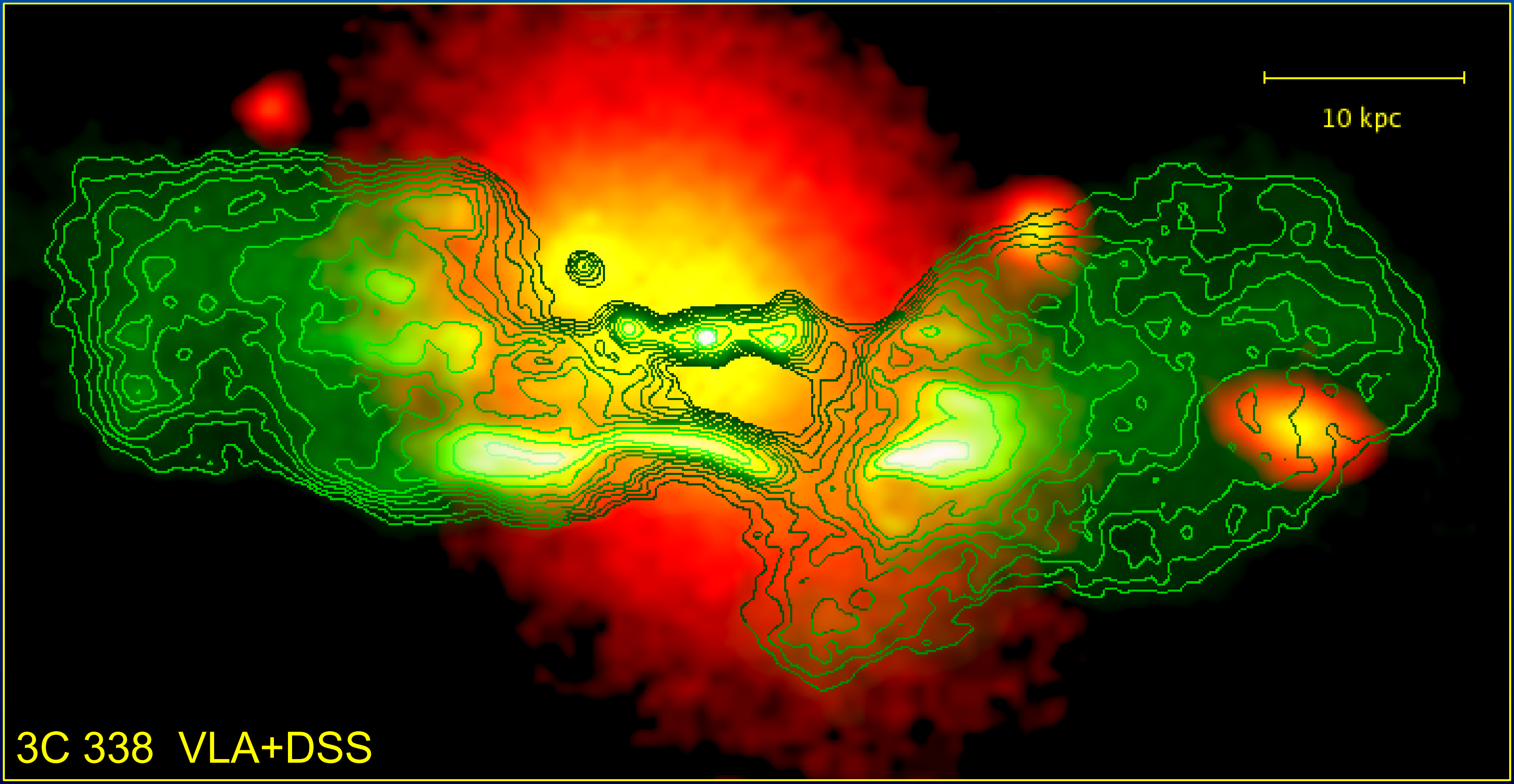
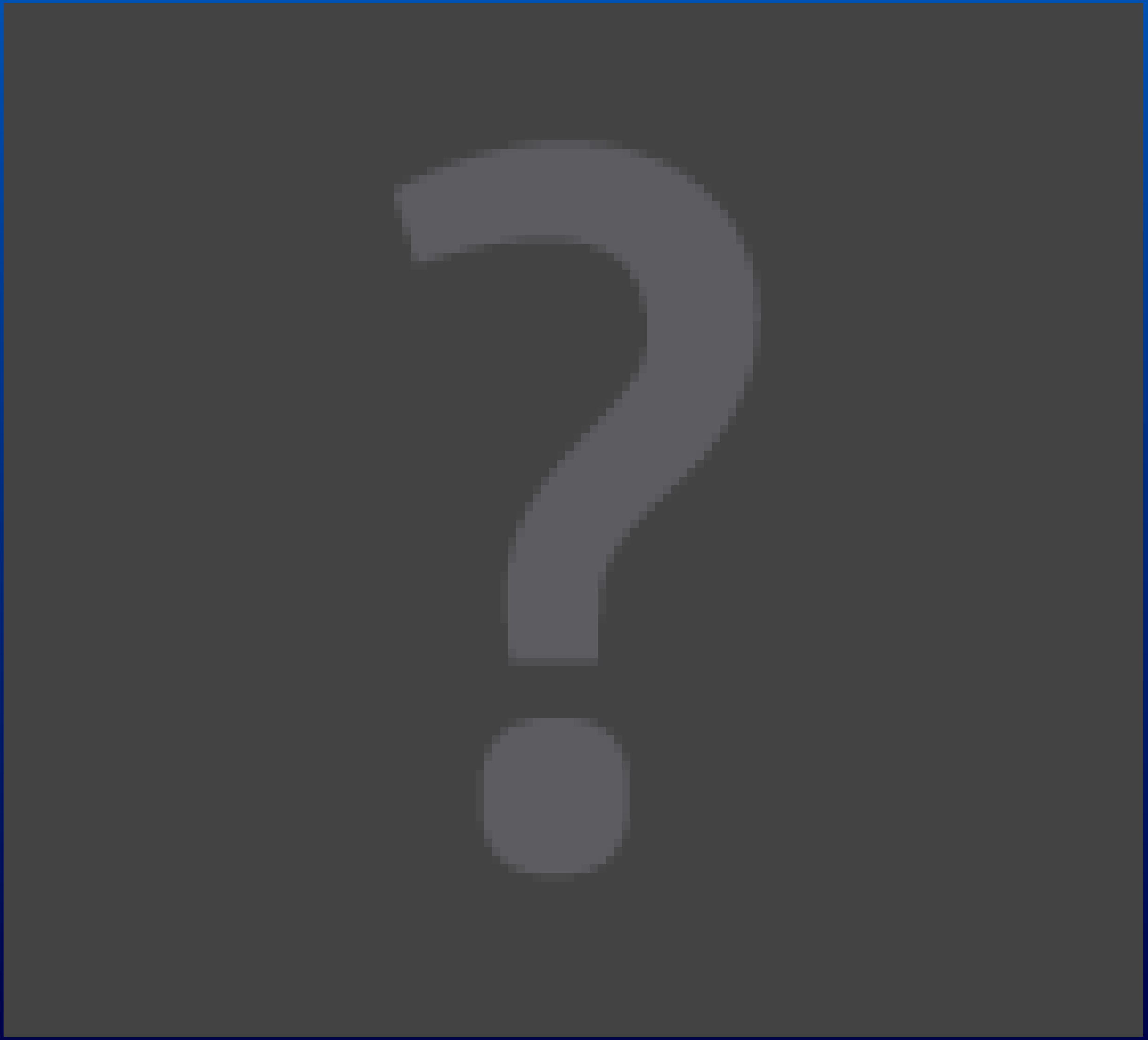
Restarting activity

It is also possible that radio galaxies may be active intermittently; in that case one may find fossil radio plasma left over from an earlier phase of activity, while newly restarted core and jets are visible as well (e.g. 3C 338)



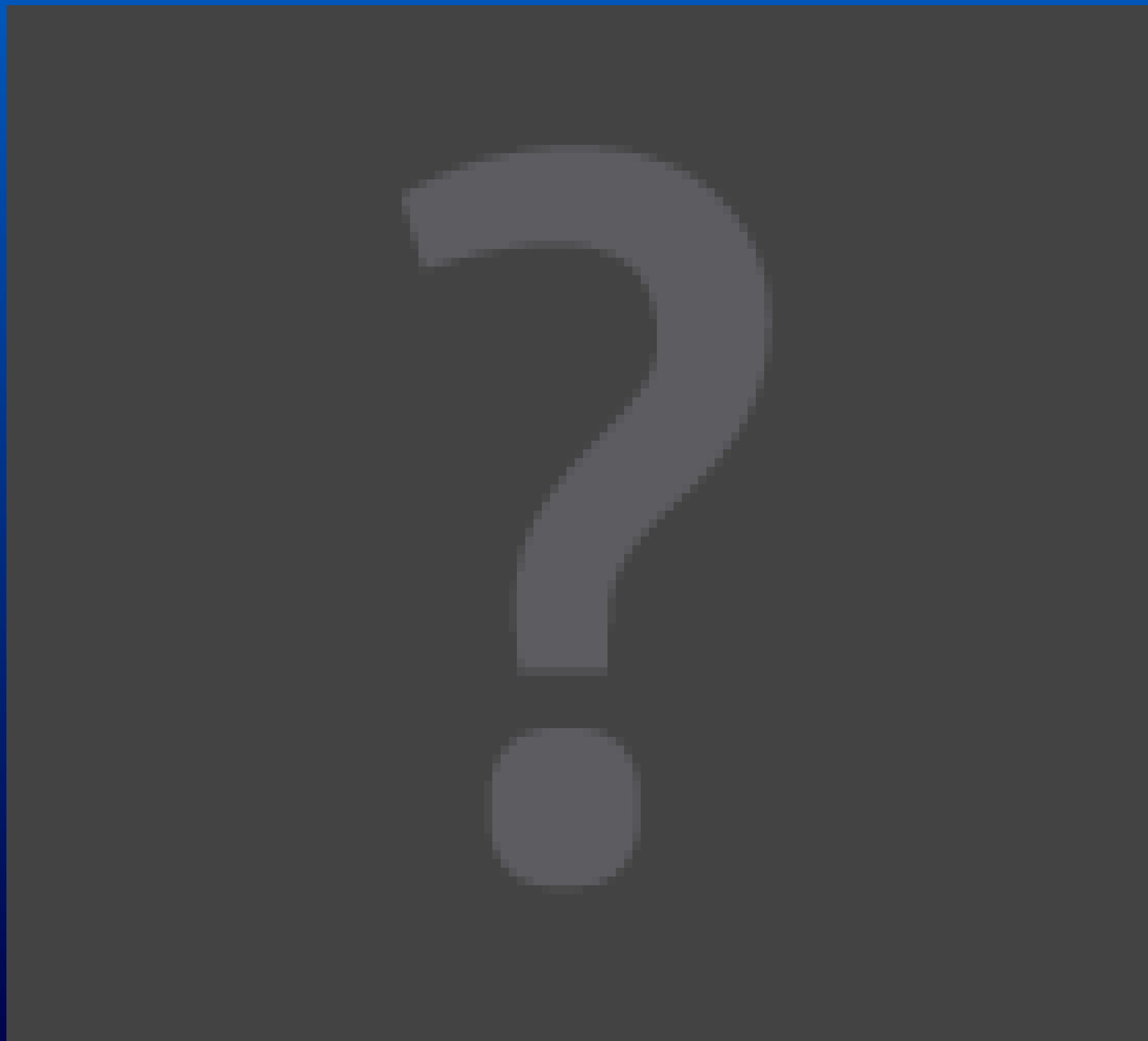
Spectral evolution: the injection switch-off

The switch-off of the injection of energetic electrons leads to a second high-frequency break, vb^h, with an exponential steepening of the total spectrum of the radio source (e.g. Komissarov & Gubanov 1994, Slee et al. 2001).



Spectral evolution: injection restarting

The injection restarting will result in an evident flattening of the total spectrum of the radio source at high-frequencies.



In search of dying radio sources in the WENSS

Dying radio galaxies are more easily detected at low radio frequencies, therefore the WENSS at 325 MHz is particularly well-suited to search for these elusive objects.

Selection criteria:

- angular size < 1 arcmin
- only sources associated with an elliptical galaxy with m_r <17
- spectral index between 325 MHz and 1400 MHz was steeper than $\alpha > 1.3$

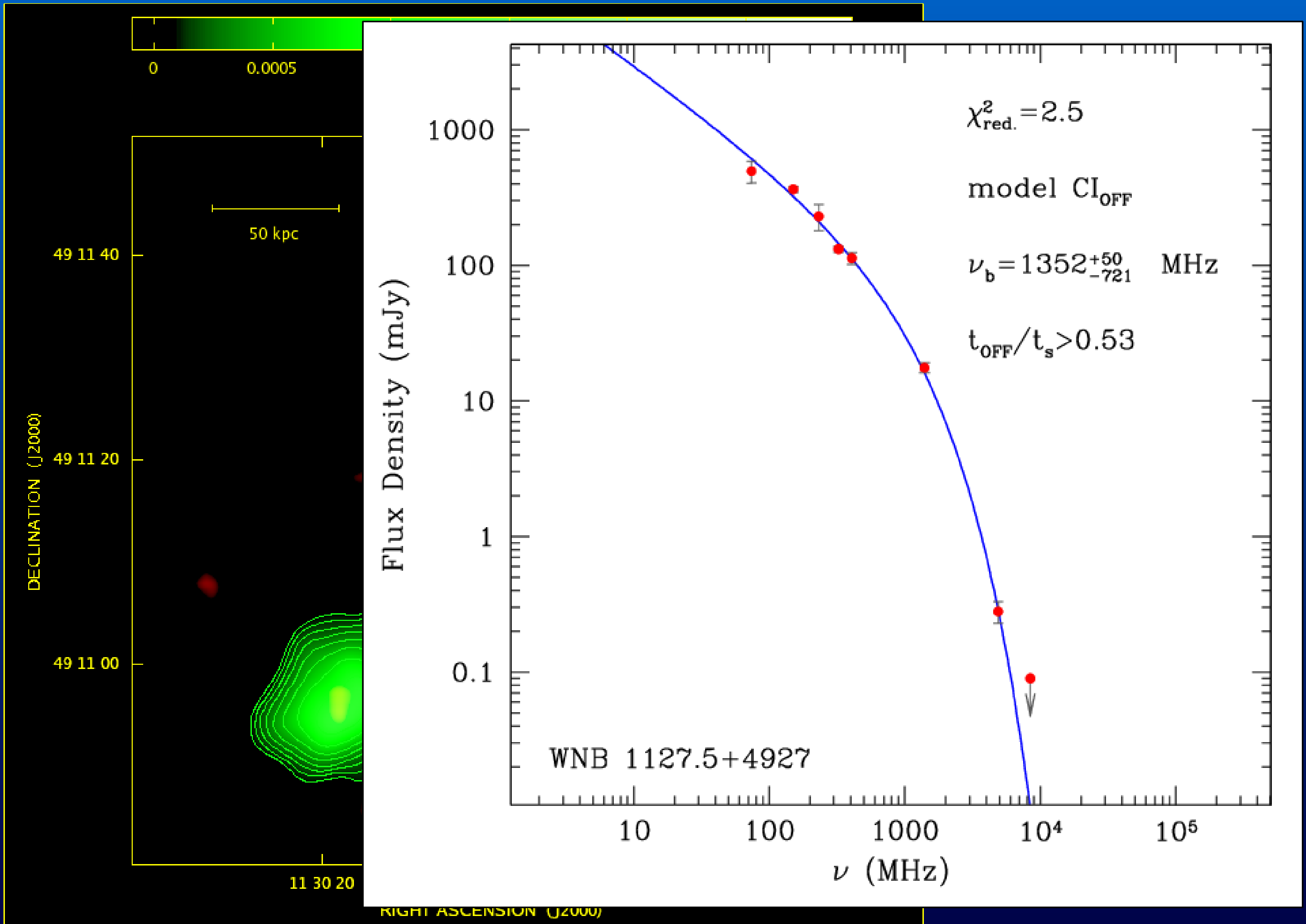
⇩

At the end, we obtained a list of 14 dying sources candidates (Murgia et al. 2005, Murgia et al. in preparation, Parma et al. submitted).

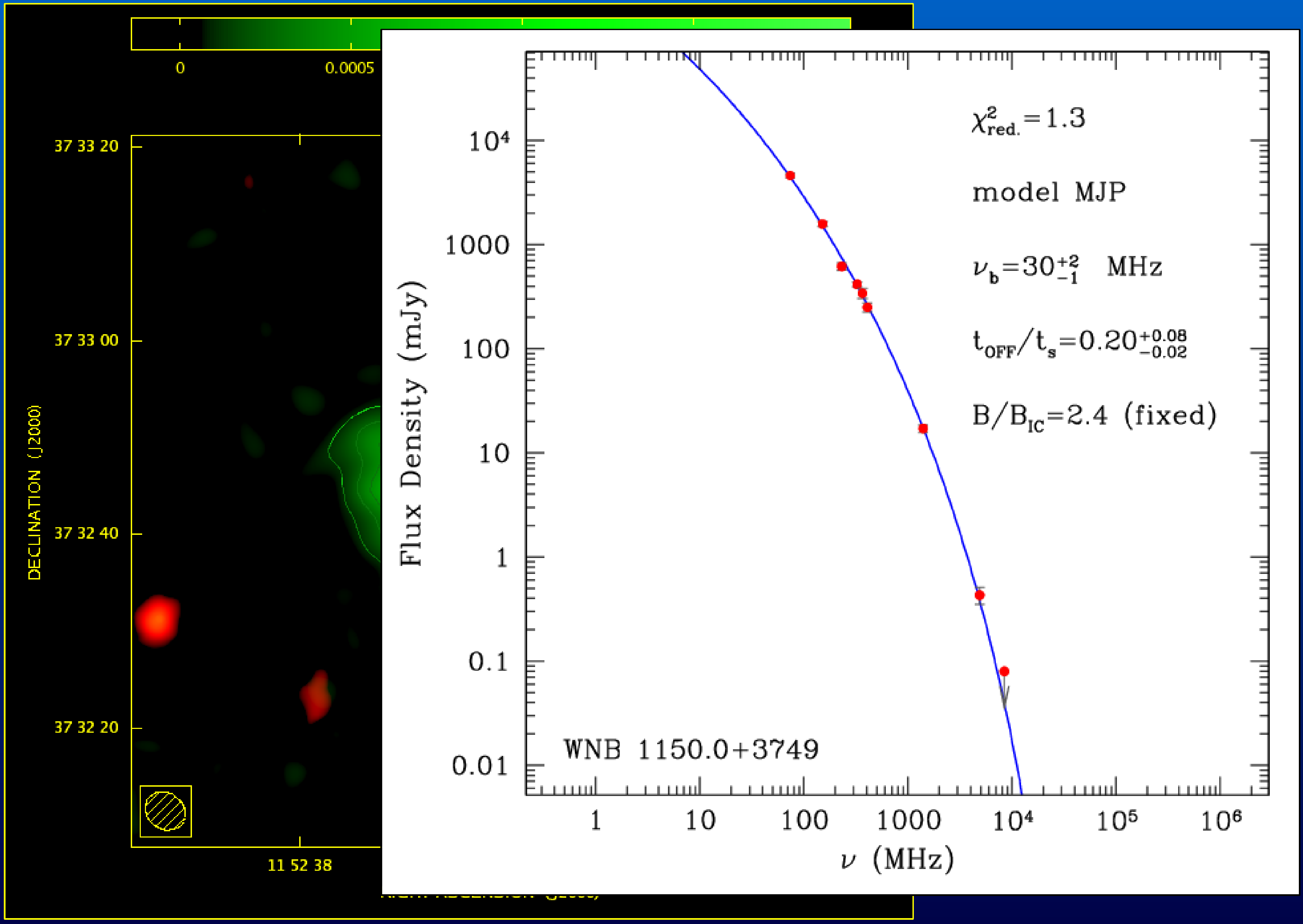
Deep VLA observations performed in various configurations and frequencies confirmed that of these canditates are:

- **8 dying radio galaxies**
- **4 restarting sources**
- **2 unresolved sources (LS<10kpc) with an anusual steep spectrum**

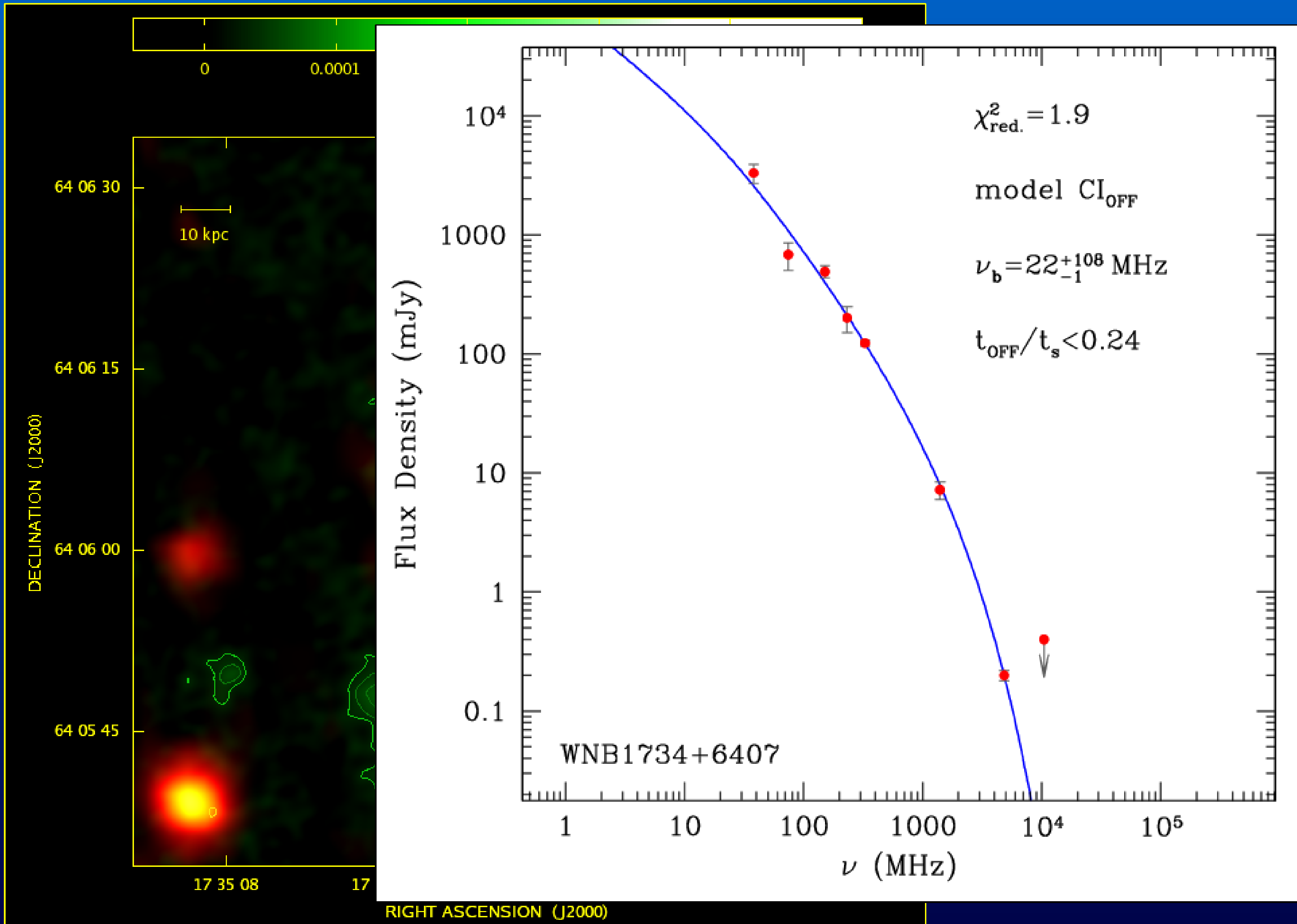
Dying sources in the WENSS: WNB 1127.5+4927



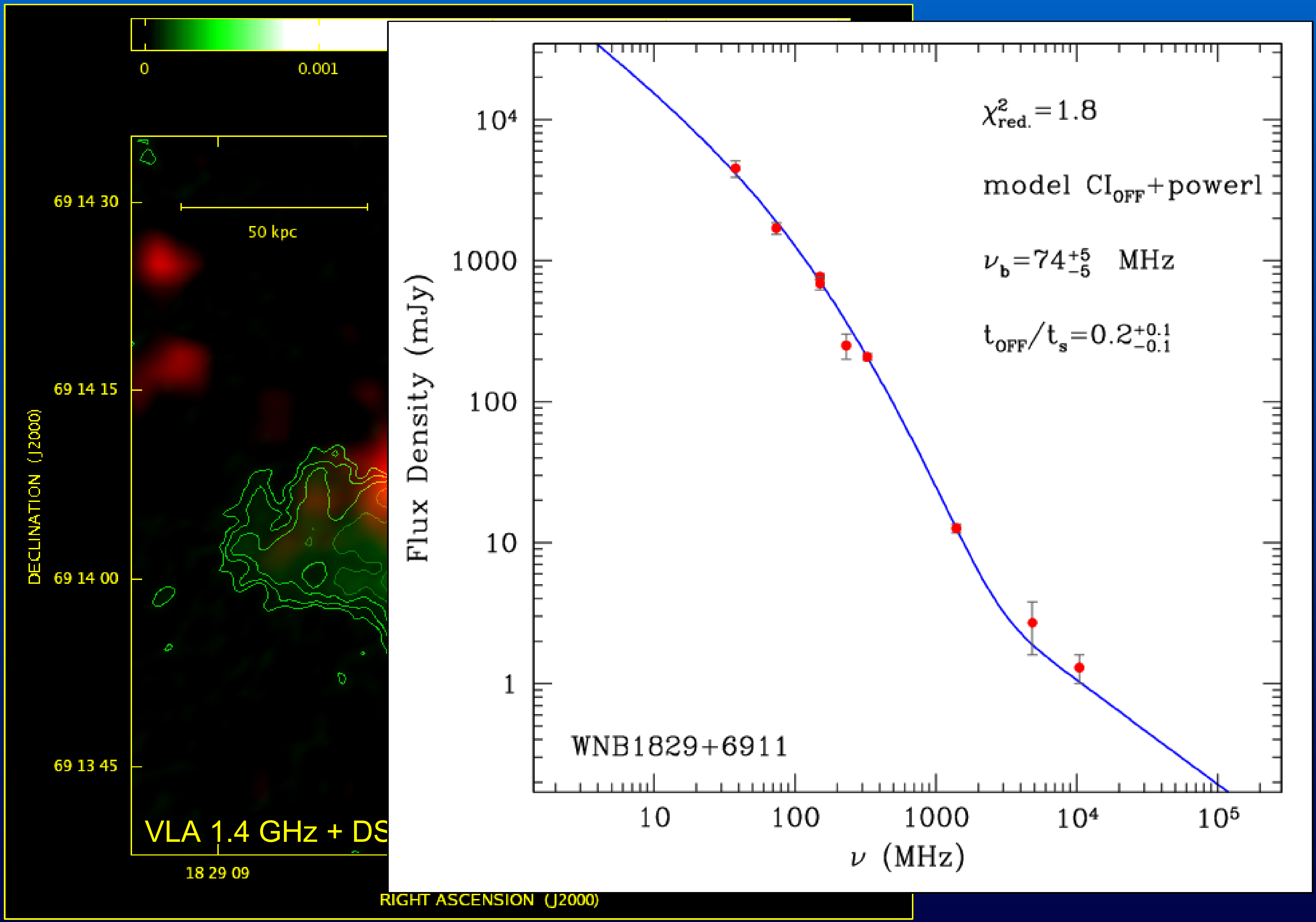
Dying sources in the WENSS: WNB 1150.0+3749



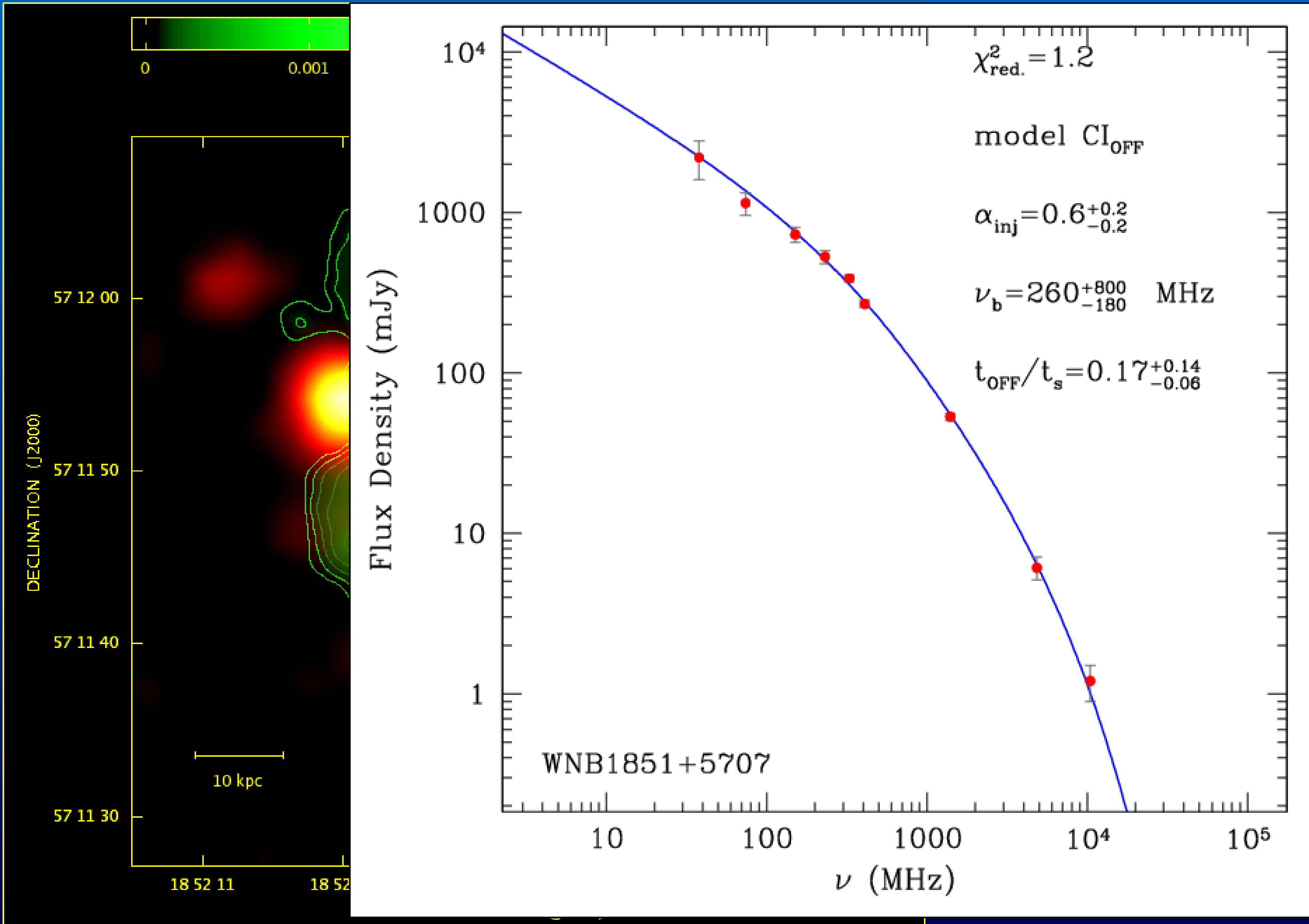
Dying sources in the WENSS: WNB 1734+6407



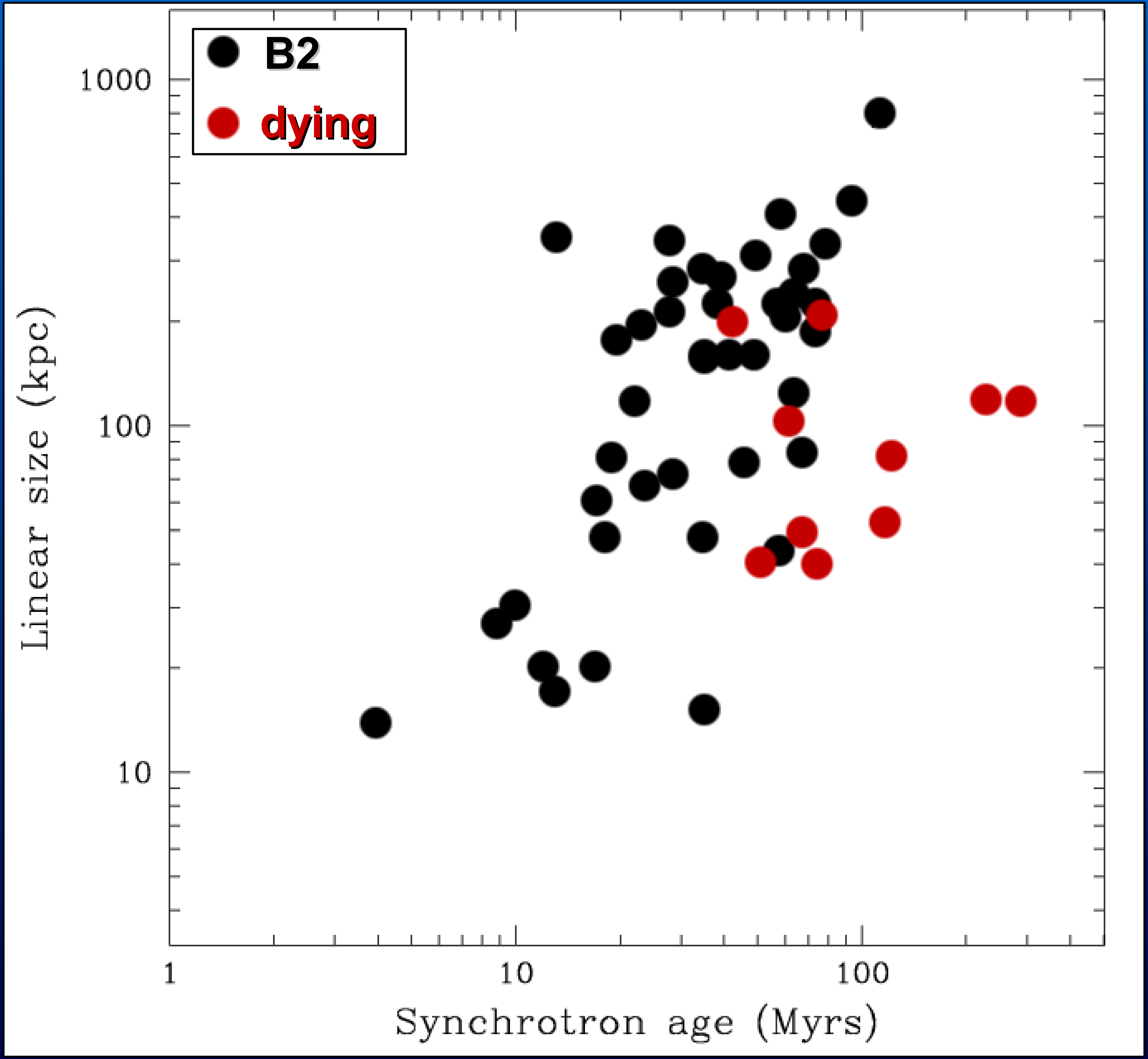
Dying sources in the WENSS: WNB 1829+6912



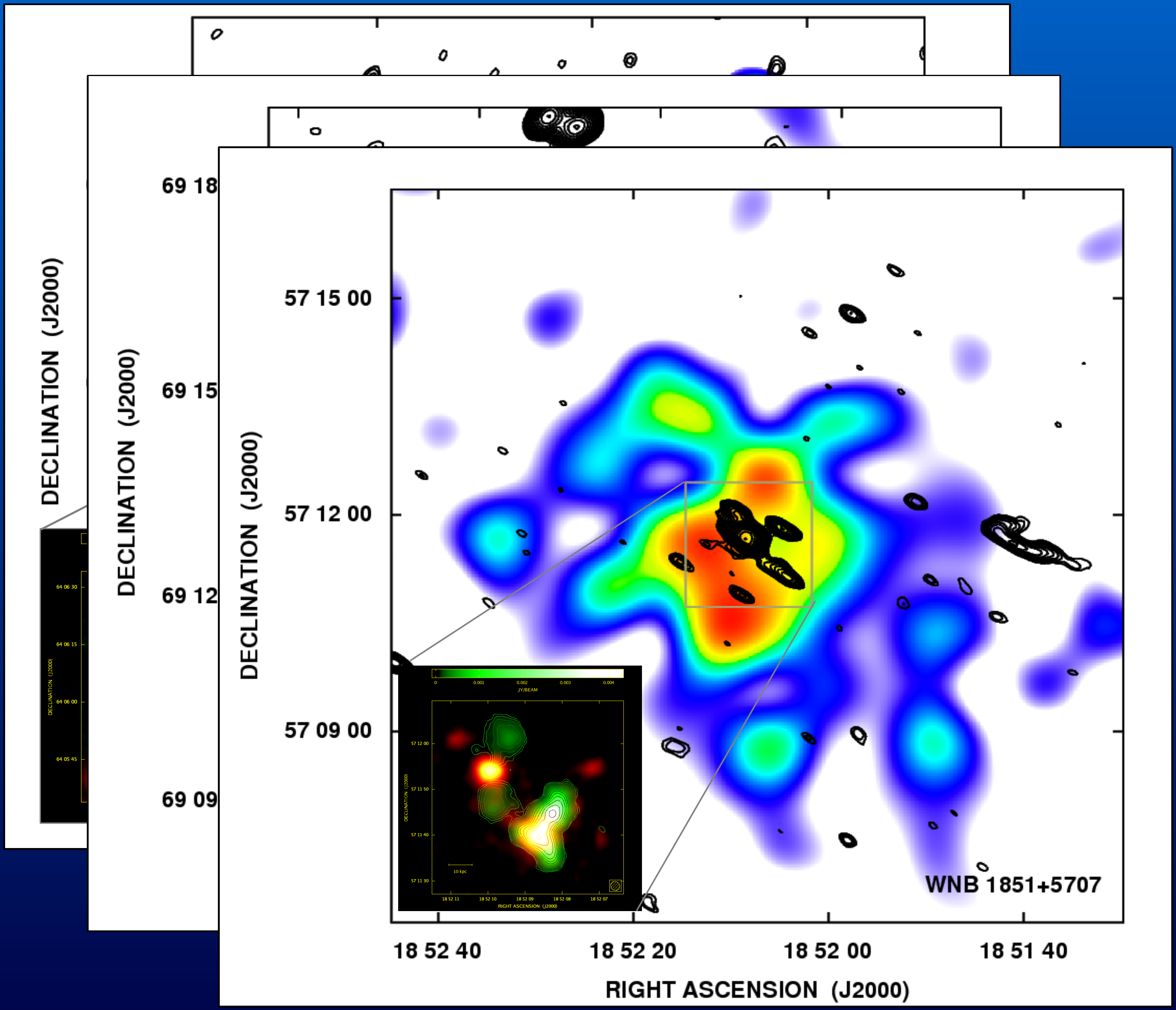
Dying sources in the WENSS: WNB 1851+5707



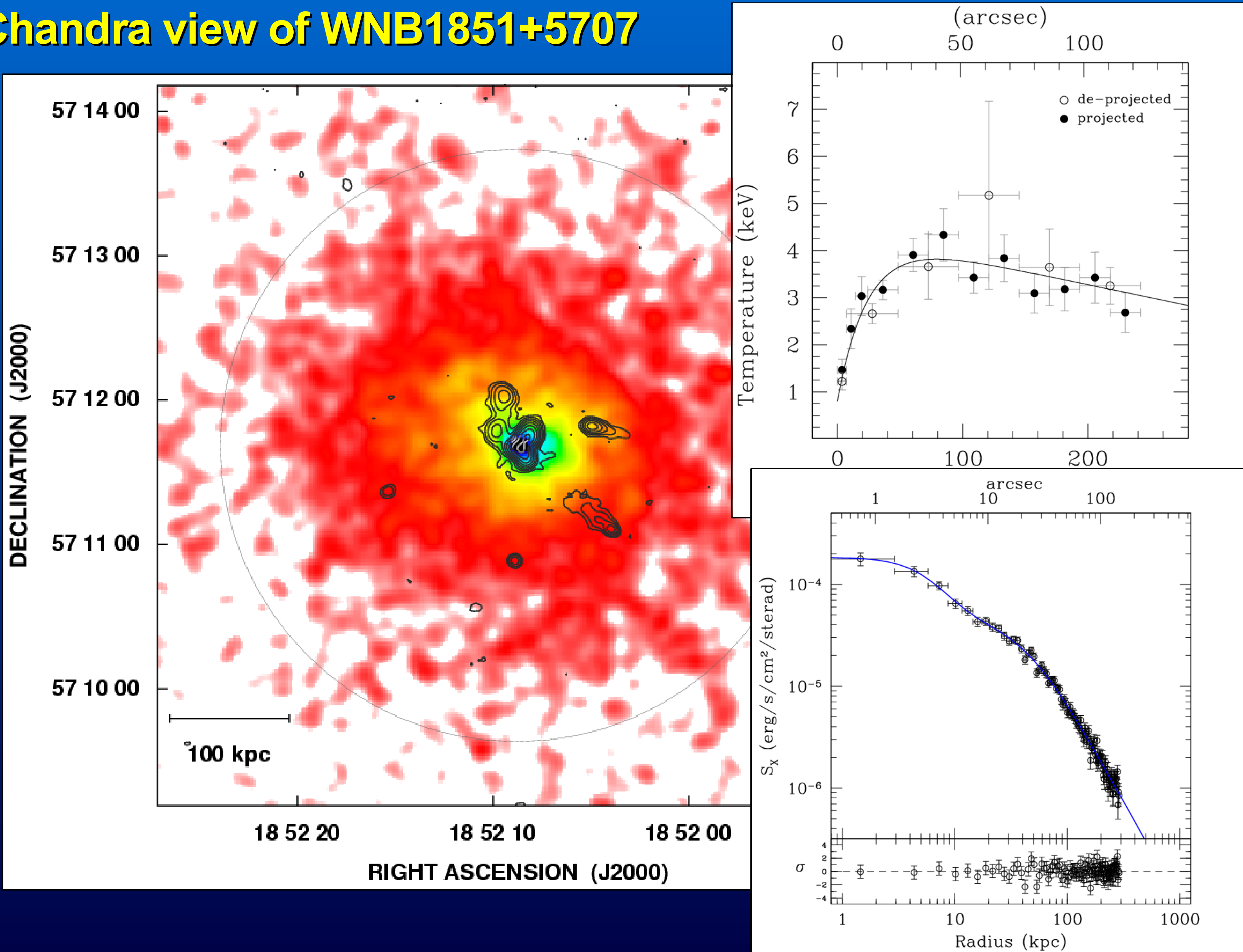
The ages of dying radio galaxies



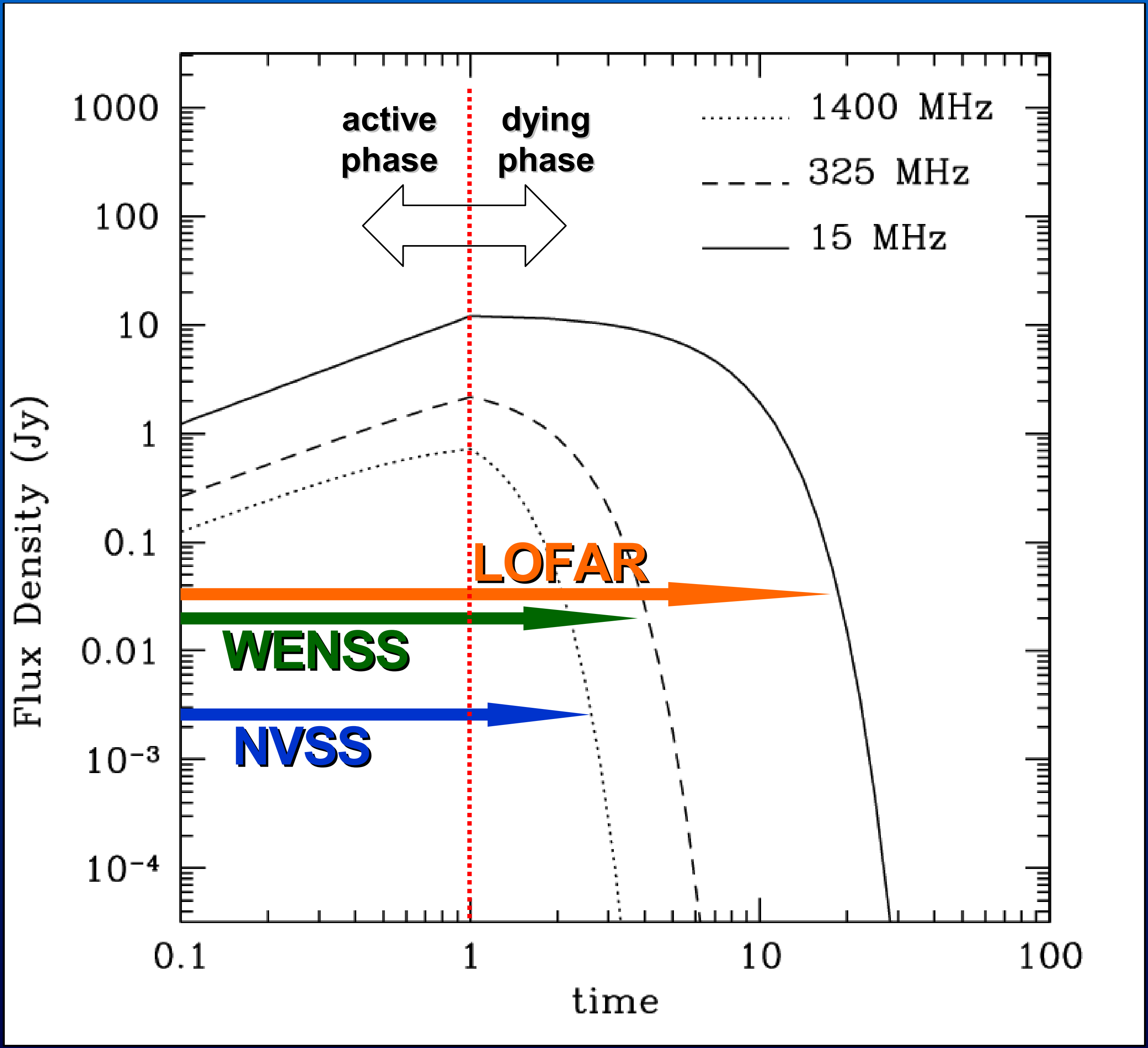
The X-ray environment of dying sources



Chandra view of WNB1851+5707



The impact of LOFAR: deep low-frequency surveys



The impact of LOFAR: spectral index imaging

According to the injection switch-off scenario, the oldest dying sources should be characterized by a very uniform spectral index distribution.

The arcsecond resolution of th
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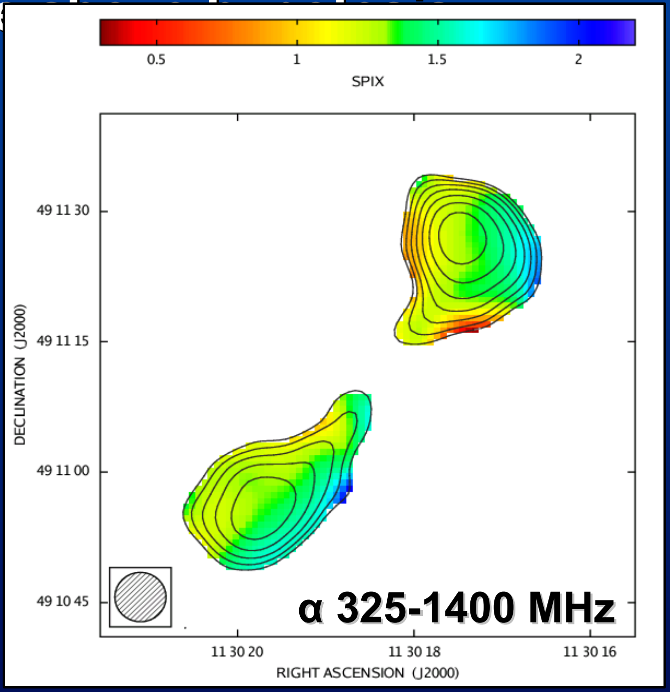

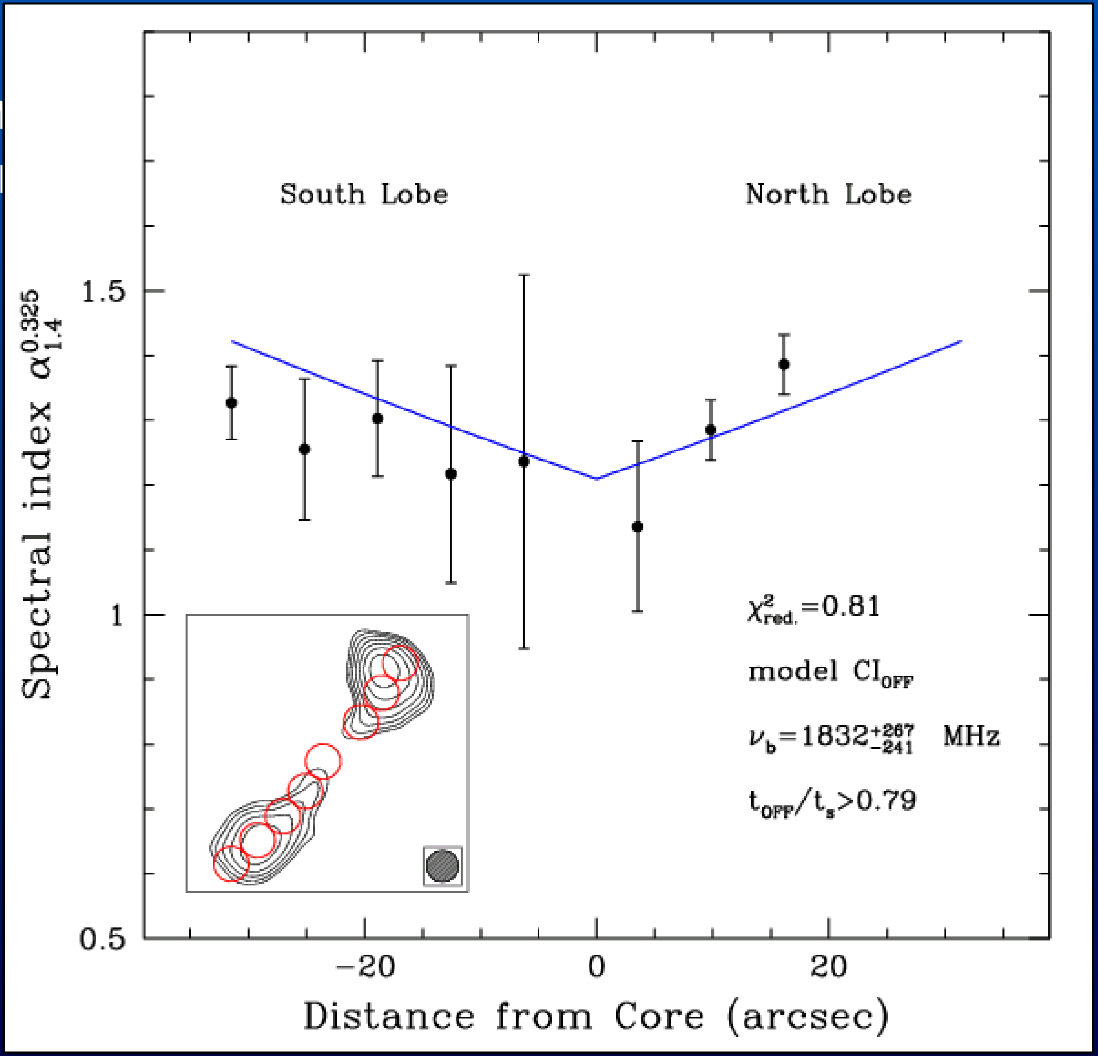

Conclusions

- We may expect the existence of a large population of dying radio sources that have been missed from the current surveys because of their very steep spectra.

- These sources are very faint at centimeter wavelenghts but should still be visible at frequency below 100 MHz if they are only subject to radiative losses.

- Due to its sensitivity and angular resolution the LOFAR represents the ideal instrument to discover and study in detail these elusive objects.

In search of dying radio sources in the WENSS

Dying radio galaxies are more easily detected at low radio frequencies, therefore the WENSS at 325 MHz is particularly well-suited to search for these elusive objects.

We have used as starting points the works done by de Breuck et al. (2000) and the WENSS *minisurvey* (de Ruiter et al. 1998). From both samples, we have considered only sources associated with an elliptical galaxy with $m_r < 17$ and we selected only those whose spectral index between 325 MHz and 1400 MHz was steeper than $\alpha > 1.3$.

At the end, we obtained a list of 14 dying sources candidates (Murgia et al. 2005, Murgia et al. in preparation, Parma et al. submitted).

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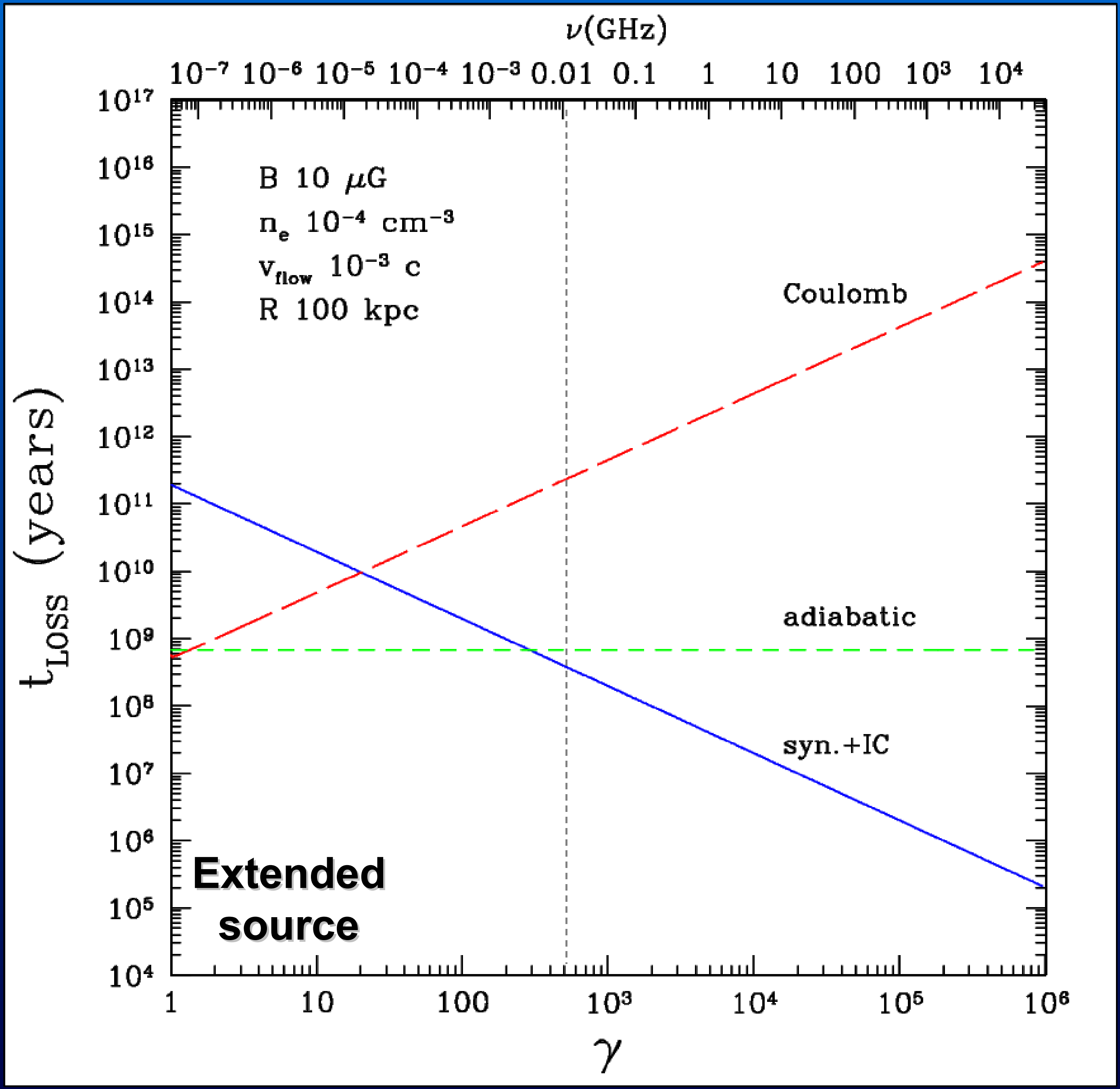
$$-\frac{d\gamma}{dt} = 1.94 \cdot 10^{-21} \left(\frac{2}{3} B^2 + B_{\rm IC}^2 \right) \gamma^2 \qquad \sec^{-1}$$

synchrotron losses

$$-\frac{d\gamma}{dt} = 9.80 \cdot 10^{-14} \left(\frac{v_{\rm flow}/c}{R_{\rm 100kpc}} \right) \gamma \qquad \sec^{-1}$$

expansion losses

$$t_{\rm LOSS} \equiv \frac{\gamma}{d\gamma/dt}$$



ν(GHz)
10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 0.01 0.1 1 10 100 10³ 10⁴
B 10 μG
n_e 10⁻⁴ cm⁻³
v_flow 10⁻³ c
R 100 kpc
Coulomb
adiabatic
syn.+IC
Extended source
t_LOSS (years)
γ
1 10 100 10³ 10⁴ 10⁵ 10⁶