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SPECTRAL-AGEING ANALYSIS OF SELECTED DISTANT GIANT RADIO GALAXIES

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Abstract. Very deep 4.9 GHz observations with the VLA are used to supplement available radio maps at the frequencies of 325 MHz (WENSS survey) and 1.4 GHz (NVSS survey) in order to study the synchrotron spectra and radiative ages of relativistic particles in the extended lobes of distant giant radio galaxies selected from the sample of Machalski et al. (2001).

Key words: galaxies: active – radio continuum: galaxies

1. INTRODUCTION AND THE SAMPLE

Our analysis of spectral ages of radiating particles in the opposite lobes of faint giant radio galaxies follows the classical spectral-ageing method used to estimate radiative ages and expansion speeds in a large set of powerful 3CR sources as well as in samples of low- and medium-luminosity radio galaxies. Those sources were used by Machalski et al. (2004a, b) as the observational base for a statistical study of the dynamical evolution of the population of FRII-type radio sources (cf. also Machalski et al. 2005).

Three sources from the sample of Machalski et al. (2001) were selected for the present spectral analysis; their basic data are given in columns 2, 3, 4 and 5 of Table 1. The spectral analysis of the radio lobes of the above sources is based on the radio maps at 325 and 1400 MHz available from the surveys: WENSS (Rengelink et al. 1997) and NVSS (Condon et al. 1998). For the low-frequency extent of the radio spectra the flux density data provided in the 7C catalogs (Riley et al. 1999) were used. There was a lack of relevant data at frequencies higher than 1.4 GHz, so we aimed to observe the above giant radio galaxies at 5 GHz with the VLA in its D-array.

2. 4.9 GHz MAPS AND RADIO SPECTRA OF THE THREE 'GIANTS'

The observations were carried out in February of 2003. During the total exposure time from 50 to 70 min for each of the two extended radio lobes, the rms noise level varied from about 32 to 20 μJy beam^{-1}. The calibrated brightness distribution of both lobes, corrected for the 'primary beam' attenuation and convolved to the common angular resolution of $20'' \times 20''$, has been combined into the final maps. The maps are shown in Figures 1 (a,b,c). The sensitivity achieved allowed us to detect a weak radio core in J0912+3510, which was crucial to confirm the host galaxy identification for this source.

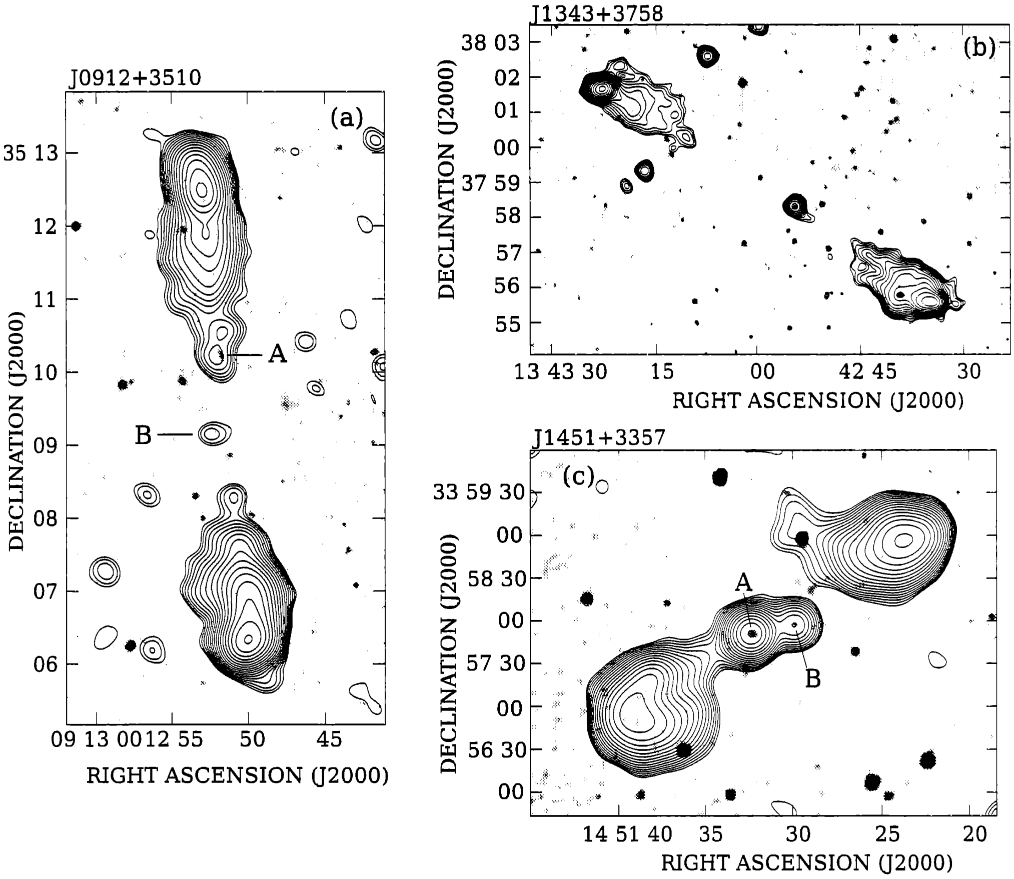

Fig. 1. 4.9 GHz VLA contour maps overlayed on the optical DSS fields. The identified host galaxies are marked with 'A'. The faint compact components unrelated to the investigated sources are marked with 'B'

3. SPECTRAL AGEING ANALYSIS

For the spectral analysis, the maps at all frequencies were convolved to the common beamwidth of 60″. Then the spectrum in different parts of the lobes has been determined by integration of the total intensity along strips perpendicular to the source axis. The strips are one common beam across providing independent data points. In each lobe the spectrum steepening is clearly visible.

The time elapsed since the particles were last accelerated is calculated assuming the Jaffe & Perola (1973) model. The magnetic field strength in the lobes, B_{eq}, is calculated on the assumption of minimum energy using the method outlined by Miley (1980). Their total radio luminosity is integrated between 10 MHz and 100 GHz. The volume of the lobes is calculated assuming a cylindrical geometry with the base diameter equal to the average width of the lobes measured on the WENSS and NVSS maps (column 5 of Table 1).

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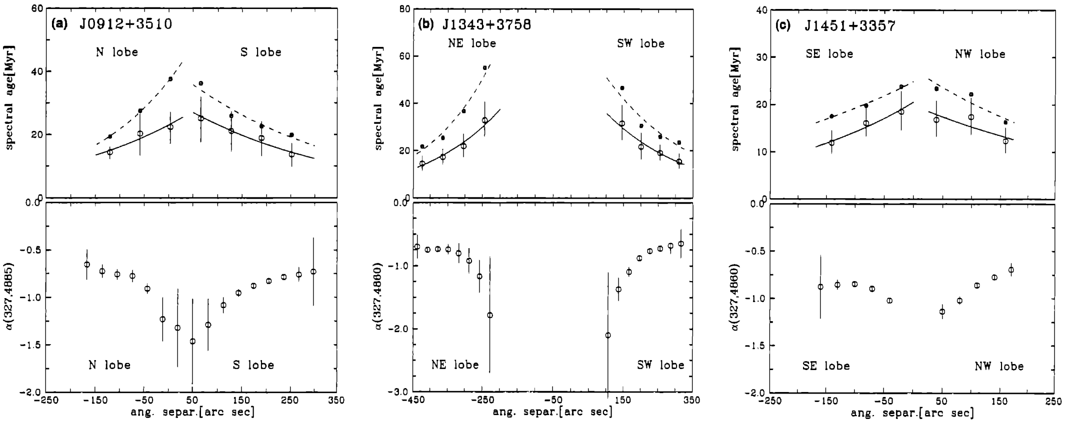

Fig. 2. Spectral index (lower panel) and radiative age (upper panel) are plotted along the source axis for J0912+3510 (panel a), J1343+3758 (panel b) and J1451+3357 (panel c). The solid curves show the best fit to the data points, while the dashed curves indicate the upper limit of the radiative (synchrotron) age (see the text)

Table 1. The basic data of selected radio galaxies calculated for $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0.5$, and their radiation ages vs. dynamical age estimates, as well as the resultant expansion velocity; (*) – taken from Machalski et al. (2004a,b).

Source	z	$\log L_{1.4}$ (W Hz^{-1} sr^{-1})	D (Mpc)	b (kpc)	$t_{\rm rad}$ (Myr)	$t_{\rm dyn}$ (Myr)	$\frac{t_{\rm dyn}}{t_{\rm rad}}$	v_h/c
J0912+3510	0.2489	24.55	1.84	372	25	91	3.6	0.033
J1343+3758	0.2267	24.42	3.14	502	33	94*	2.8	0.054
J1451+3357	0.3251	24.74	1.41	344	19	80	4.2	0.029

The results of this analysis are shown in Figures 2 (a, b, c), where for each lobe of the investigated sources the spectral index between 325 and 4885 MHz and the radiative age have been plotted against distance measured along the source axis from the hotspot. The best fits to the age data points are shown by solid curves. The dashed curves mark the best fits to an upper limits of the particle age calculated with a substitution of $B_{\rm MBR}/\sqrt{3}$ instead of $B_{\rm eq}$, where $B_{\rm MBR}$ is the magnetic field equivalent of the 2.7 K microwave background radiation. This corresponds to the phase in which a lobe is no longer overpressured in respect to an external pressure of the intergalactic medium.

A comparison of these synchrotron ages of the oldest particles with the dynamical age estimates provided by Chyży et al. (2005) is given in Table 1 (columns 6, 7, 8). The radiative ages of the oldest particles range from about 15 to 40 Myr, and are similar to relevant ages of normal-size radio galaxies at comparable redshifts. A comparison of the above ages and the dynamical ages derived as above suggests that the mean backflow velocity is 1–3 of the mean advance velocity of the jet's head with respect to the surrounding intergalactic medium, i.e., the dynamical age of a giant radio galaxy can be 2–4 times higher than the synchrotron age of the oldest radiating particles.

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