Studying the selected FR-II radio galaxies with the extended KDA model

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KDA EXT model – grounds and methodology

We present the preliminary results of the extension (hereafter: KDA EXT model) of the analytical model of Kaiser et al. (1997, MNRAS, 292, 723),originally assuming `continuum injection' process in the jet-IGM interaction, towards a case of the jet's termination. We analyze the P-D diagrams and other characteristics of the extended model like adiabatic changes expected in the radio lobes and their spectra, in expansion speed of the jet's head and internal pressure within the lobes – after the jet termination. Following approach of Kaiser et al. (1997) and Kaiser & Cotter (2002), we propose effective formulae describing the dynamics and luminosity evolution of the lobes during an absence of the jet flow, and present resulting diagrams for the source characteristics.

Using new numerical algorithm similar to that of Machalski et al. (2007, A&A, 462, 43), we fit KDA EXT model to few exemplary double-double/giant radio galaxies (including sources with so-called restarting activity with very steep radio spectra of the outer lobes) and compare predicted radio spectra of their lobes to the observed ones, proving that these fits are better than the best fit spectra provided with the original continuum injection' Kaiser et al.'s model.

KDA

Lobe's length evolution:

$$L_{\rm jet}(t) = c_1 \left(\frac{Q_{\rm jet}}{\rho_0 a_0^\beta}\right)^{1/(5-\beta)} t^{3/(5-\beta)}$$

Lobe's luminosity evolution:

$$P_\nu(t) = \int_{t_{\rm min}}^{t} dt_{\rm i} \frac{\sigma_T c\, r}{6\pi\nu(r+1)} Q_{\rm j} n_0 (P_{\rm hc})^{(1-\Gamma_{\rm c})/\Gamma_{\rm c}} \times \frac{\gamma^{3-p} t_{\rm i}^{a_1/3(p-2)}}{[t^{-a_1/3} - a_2(t,t_{\rm i})\gamma_{\rm i}]^{2-p}} \left(\frac{t}{t_{\rm i}}\right)^{-a_1(1/3+\Gamma_{\rm B})},$$

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Lobe's length evolution:

$$D(t,t_{\rm br}) = \begin{cases} c_1 \left(\frac{Q_{\rm j}}{\rho_0 a_0^\beta}\right)^{1/5-\beta} t^{3/5-\beta}, & t < t_{\rm br} \\ D(t_{\rm br}) \left(\frac{t}{t_{\rm br}}\right)^{\frac{2(\Gamma_{\rm c}+1)}{\Gamma_{\rm c}(7+3\Gamma_{\rm c}-2\beta)}}, & t \geq t_{\rm br} \end{cases}$$

Lobe's luminosity evolution:

$$P_\nu(t) = \begin{cases} P_\nu(t_{\rm min}, t_{\rm br}) + P_\nu(t_{\rm br}, t) & for\ t_{\rm br} > t_{\rm min} \\ P_\nu(t_{\rm min}, t) & for\ t_{\rm br} \leq t_{\rm min} \end{cases}$$

KDA EXT

$$P_\nu(t_{\rm br}, t) = \frac{\sigma_T c}{6\pi\nu} \frac{r}{r+1} Q_{jet} P_{\rm hc}^{\frac{(1-\Gamma_{\rm c})}{\Gamma_{\rm c}}} \int_{t_*}^{t} G(t_{\rm i}) H(t_{\rm i}) dt_{\rm i},$$

$t_* = t_{br}$ if $t_{br} > t_{min}$ and $t_* = t_{min}$ if $t_{br} \leq t_{min}$,

$$H(t_{\rm i}) = n_0(t_{\rm i}) \frac{\gamma^{3-p} t_{\rm i}^{a_1/3(p-2)}}{\{t^{-a_1/3} - a_2(t,t_{\rm i})\gamma_{\rm i}\}^{2-p}} \left(\frac{t}{t_{\rm i}}\right)^{-a_1(1/3+\Gamma_B)},$$

$$G(t_{\rm i}) = \frac{\int_0^1 F(\frac{\nu/\nu_{\rm br,CI}}{x^2}) x^{-p}(1-x)^{p-2} dx}{\int_0^1 F(\frac{\nu/\nu_{\rm br,CI}}{x^2}) x^{-(p+1)}\{1-(1-x)^{p-2}\} dx + \int_1^\infty F(\frac{\nu/\nu_{\rm br,CI}}{x^2}) x^{-(p+1)} dx},$$

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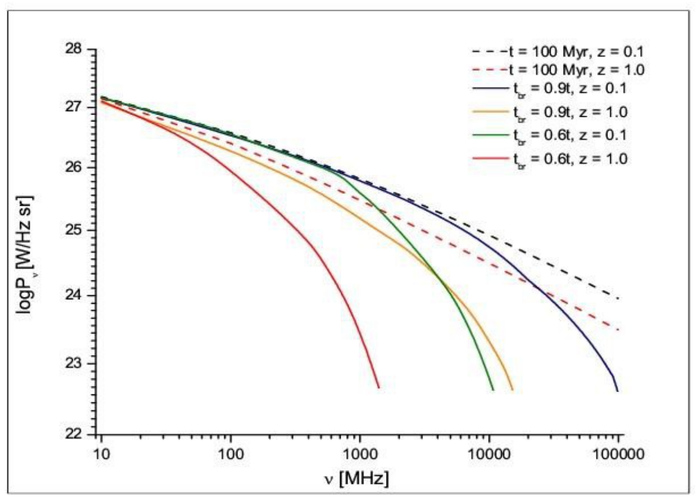
Where

$$F_{\rm CI} = (\nu/\nu_{\rm br,CI}/x^2)$$

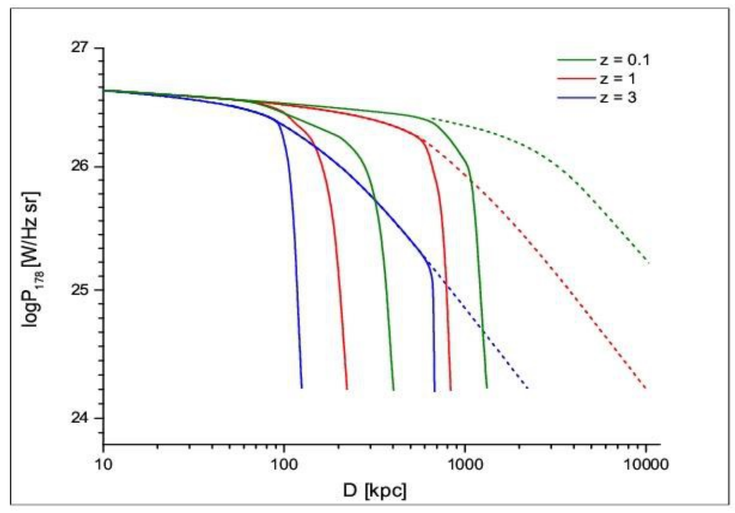
$$F_{\rm JP} = (\nu/\nu_{\rm br,JP}/x^2)$$

are the kernel synchrotron spectrum of a single relativistic particle in both: Continuum – injection and Jaffe – Perola models.

Predictions of the KDA EXT model

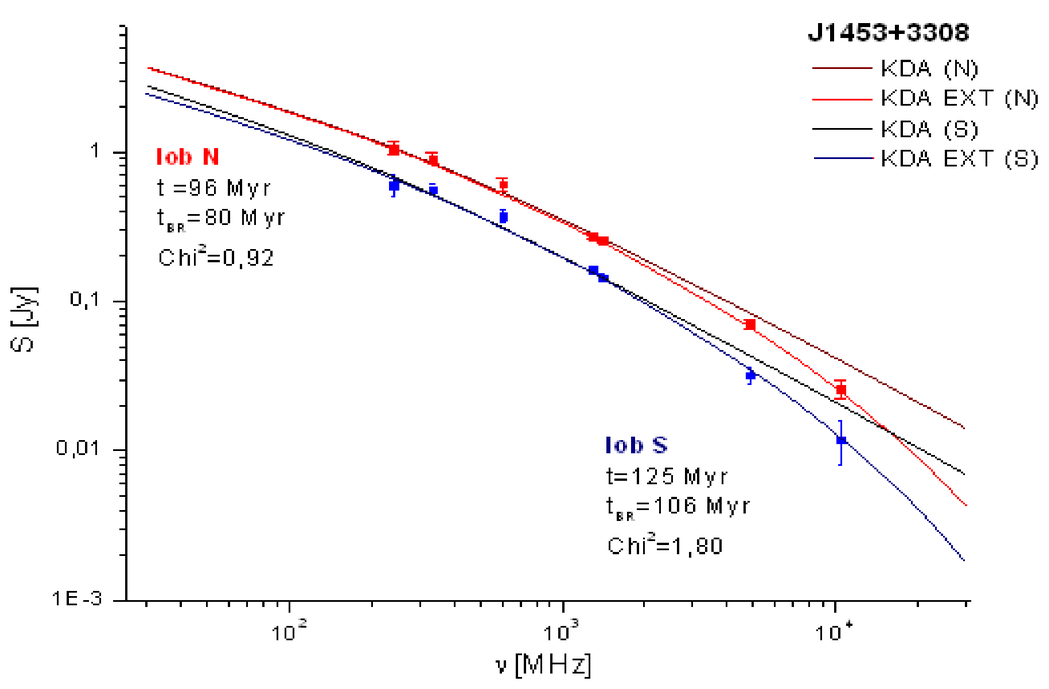


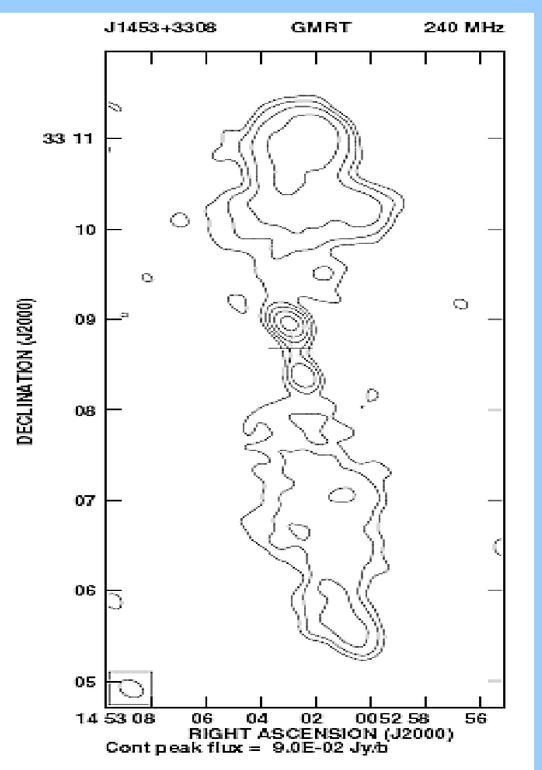
Radio power spectra for a fiducial radio source with a set of fixed parameters (αinj = 0.5, Rt = 3, β = 1,5, k' = 0, a0 = 10 kpc, for a different values of tbr and z. Dotted lines correspond to the KDA results and the solid curves correspond to the KDA EXT model



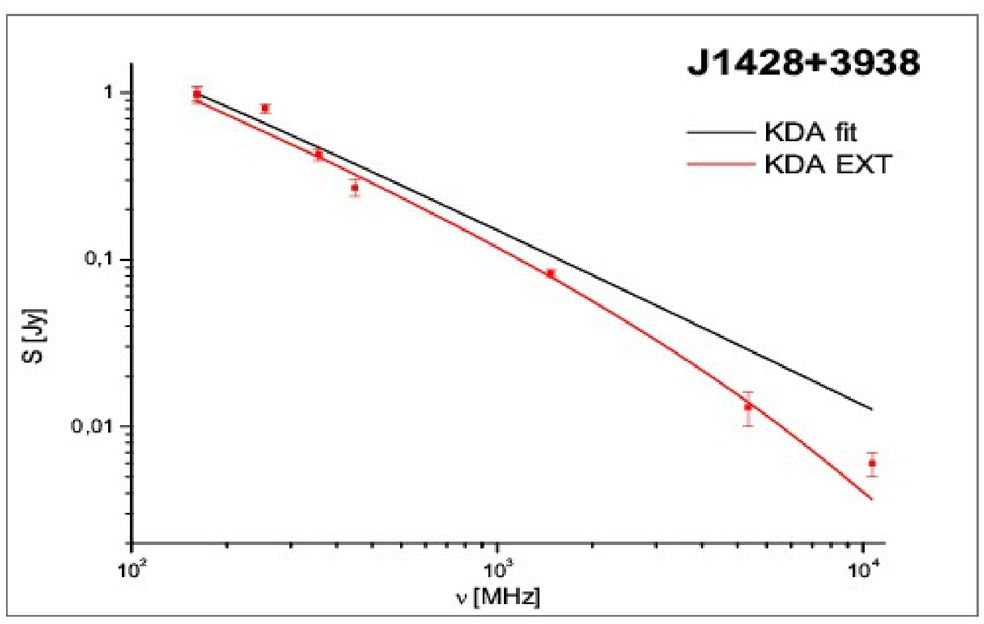
P-D diagram for a fiducial source with same parameters, for different values of redshift. Dotted curves correspond to the KDA model and solid curves show sources evolution with time in the KDA EXT model with terminated jet activity

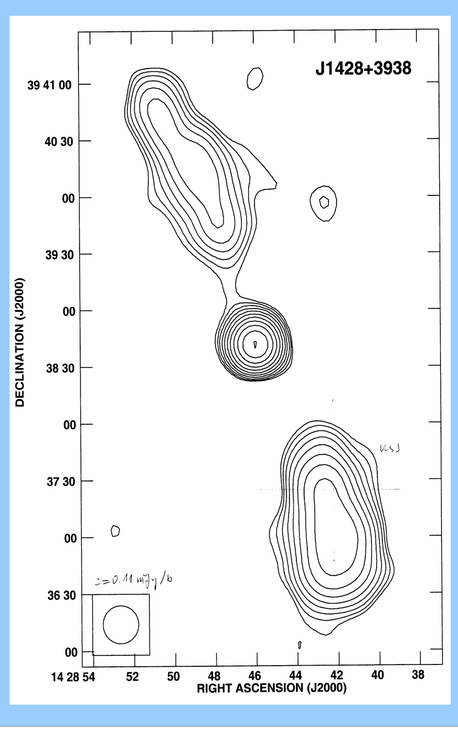
Application of the KDA EXT model to the exemplary sources





An example of FR II type DDRG radio galaxy J1453+3308 - GMRT map of total structure at 240 MHz (Konar et al. 2006)





Radio galaxy J1428+3938 - 4860 MHz, Machalski et al. (2006)