Вісник Астрономічної школи / Astronomical School's Report

ISSN 1607–2855

Том 7 • № 1 • 2011 С. 70 – 73

UDC 524.7

The X-ray and radio structure of extragalactic jets

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The internal structure of jets from active galaxies is explored using the X-ray and radio data. The transverse intensity distributions of X-ray knots in jet are calculated and compared with corresponding intensity distributions for radio knots. It is shown that for selected active galaxies the internal structure of radio knots can be resolved while X-ray knots are almost point-like.

СТРУКТУРА ПОЗАГАЛАКТИЧНИХ СТРУМЕНІВ НА ОСНОВІ РЕНТГЕНІВСЬКИХ ТА РАДІО ДАНИХ, Марченко В.В., Сукач К., Соколов Д., Комок І., Сущов О. — В роботі досліджується внутрішня структура струменів від активних галактик, використовуючи рентгенівські та радіо дані спостережень. Було отримано поперечний розподіл інтенсивності випромінювання в рентгенівських вузлах в струмені та порівняно їх з відповідними радіо вузлами. Показано, що для вибраних активних галактик внутрішня структура радіо вузлів може бути досліджена, проте рентгенівські вузли майже точкові.

СТРУКТУРА ВНЕГАЛАКТИЧЕСКИХ СТРУЙ НА ОСНОВЕ РЕНТГЕНОВСКИХ И РАДИО ДАННЫХ, Марченко В.В., Сукач К., Соколов Д., Комок И., Сущев А. — В работе исследуется внутренняя структура струй от активных галактик, используя рентгеновские и радио данные наблюдений. Было получено поперечное распределение интенсивности излучения в рентгеновских узлах в струе и проведено сравнение их с соответствующими радио узлами. Показано, что для выбранных активных галактик внутренняя структура радио узлов может быть исследована, однако рентгеновские узлы почти точечные.

Ключевые слова: внегалактические струи; интенсивность излучения в рентгеновском и радиодиапазоне.

Key words: extragalactic jets; emission intensity in X-ray and radio range.

1. INTRODUCTION

In spite of great progress in exploring active galactic nuclei (AGN) these objects remain one of the most interesting and remarkable issues in modern astrophysics [1]. One of the representations of AGN activity is the existence of extragalactic jets that constitute the longest collimated structures in the Universe [2]. The detailed study of extragalactic jets in all wavelengths is important task for modeling of different astrophysical processes that are believed to take place in jets; namely, acceleration of ultra high energy cosmic rays, generation of electromagnetic radiation of different wavelengths, neutrino generation etc.

Extragalactic jets are widely believed to be the cosmic rays accelerators up to the ultra high energies due to Fermi acceleration mechanisms [4, 5]. At the same time acceleration on the jet boundary can lead to efficient acceleration of particles [6]. In this mechanism acceleration on tangential discontinuity between jet and surrounding medium is taken into account. In some papers two-zone inverse Compton emission model for internal jet structure is discussed [7]. In this model the jets have highly relativistic spines to produce the X-ray emission via upscattering of cosmic microwave background photons with outcontributing significant radio synchrotron emission. The slower sheath around the spine produces the bulk of radio synchrotron emission. According to this model acceleration on the jet boundary can be more efficient due to existence of two tangential discontinuities: between spine and sheath and between sheath and surrounding medium. The purpose of this research is to analyze the X-ray structure of the jet and to compare it with radio data of the same region.

2. OBSERVATIONAL DATA

In this research we explore some active galaxies with clearly seen jet structure in both X-ray and radio wavelengths. We consider core-dominated quasar (CDQ) 3C 273 and Fanaroff & Riley type I radio galaxy (FRI RG) 3C 274. For further analysis of jet structure we have chosen some bright knots in these galaxies, namely, knots A1 and B1 in 3C 273 and knots D and A in 3C 274. The X-ray data for these objects were obtained by Chandra X-ray Observatory and radio data were get by Very Large Array (VLA). The X-ray and radio images of 3C 273 and 3C 274 with selected knots are presented in Figure 1.

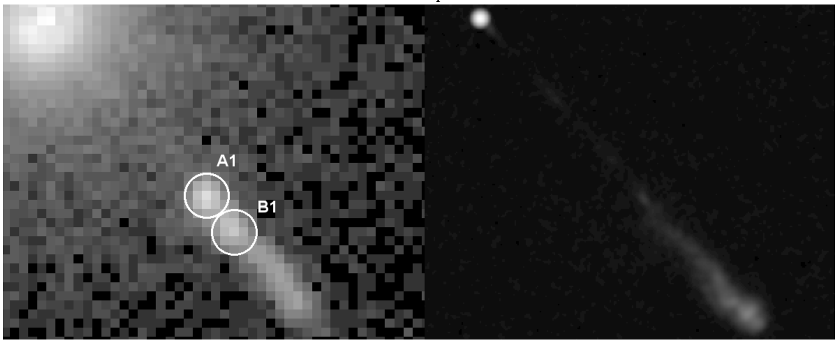
3. RESULTS AND CONCLUSIONS

The X-ray data analysis was processed with CIAO 4.2 — a software package for Chandra interactive analysis of observations [8]. The distribution of intensity across the knot, i.e. transverse profiles, were

Table 1. Parameters of radio data

Object	z	Class	Pixel size (″/px)	BMAJ (″)	BMIN (″)	BPA (deg)
3C 273	0.1583	CDQ	0.075	0.35	0.35	0
3C 274	0.00427	FRI RG	0.02	0.17	0.15	30.45

Core-dominated quasar 3C 273



Fanaroff & Riley type I radio galaxy 3C 274

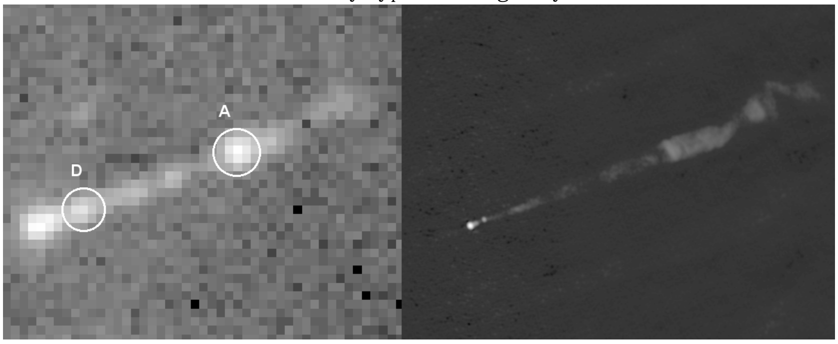


Fig. 1. X-ray (left) and radio (right) images of 3C 273 and 3C 274.

investigated for X-ray and radio data. In order to estimate the real size of knots one have to analyze the point spread function (PSF) for these objects. To perform simulations of the Chandra PSF for selected knots the Chandra Ray Tracer (ChaRT) was used [9]. The final best available PSF were get with the combination of ChaRT and MARX 4.5 — a suite of programs for detailed ray-trace simulation.

The PSF for radio data were modeled with Gaussian function:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right),$$

where $\sigma = L_{\text{beam}}/2.355$, L_{beam} is a full width at half maximum (FWHM) of the beam width, which can be calculated knowing major and minor axes of a beam and its position angle (see Table 1). The parameters for radio data are presented in Table 1. In this table the parameters BMAJ and BMIN are the major and minor axes of a beam (FWHM), BPA — the position angle of a beam measured from North through East.

The transverse intensity distributions for all knots are presented on Figures 2 and 3. Also these figures contain the corresponding PSF profiles for X-ray and radio. One can see that for the radio images in some cases the PSF profiles are narrower than radio knot transverse intensity distributions. It makes possible the exploration of internal structure of radio emitting region in knot. While for X-ray images the PSF profiles have almost the same shape as X-ray knot intensity distributions. One can conclude that for the selected X-ray knots the resolution is not enough to explore the detailed internal structure of X-ray knots and they are visible for us almost as point-like source.

The obtained results determine the upper limit for the size of X-ray emitting region in knots. These results can be used in modeling the particle acceleration in the jet's surrounding medium up to ultra high energies and subsequent propagation of accelerated particles in galactic and extragalactic magnetic fields, in interpretation of electromagnetic radiation from AGN jets etc.

Acknowledgments. The authors acknowledge to Michal Ostrowski (Astronomical Observatory of Jagiellonian University, Poland), Lukasz Stawarz (Japan Aerospace Exploration Agency, Japan) and Dan Harris (Harvard-Smithsonian Center for Astrophysics, USA) for assistance and fruitful discussions.

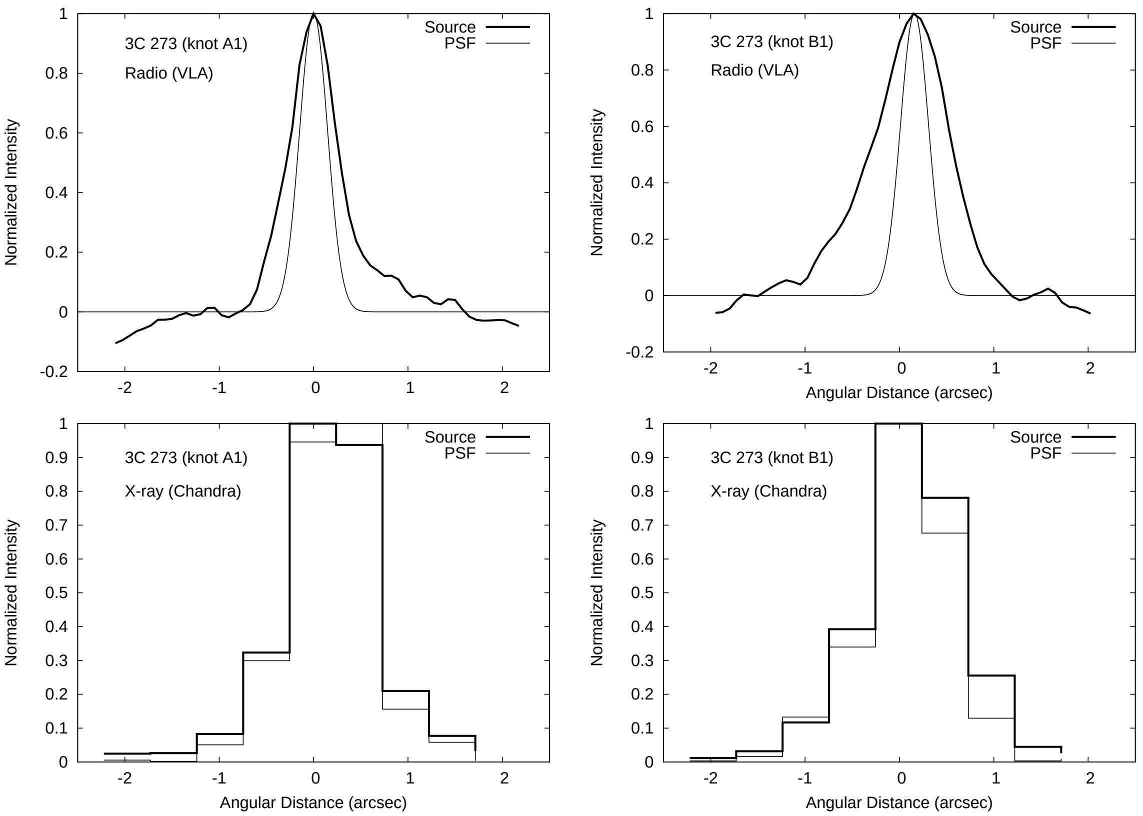


Fig. 2. X-ray and radio profiles of knots in 3C 273.

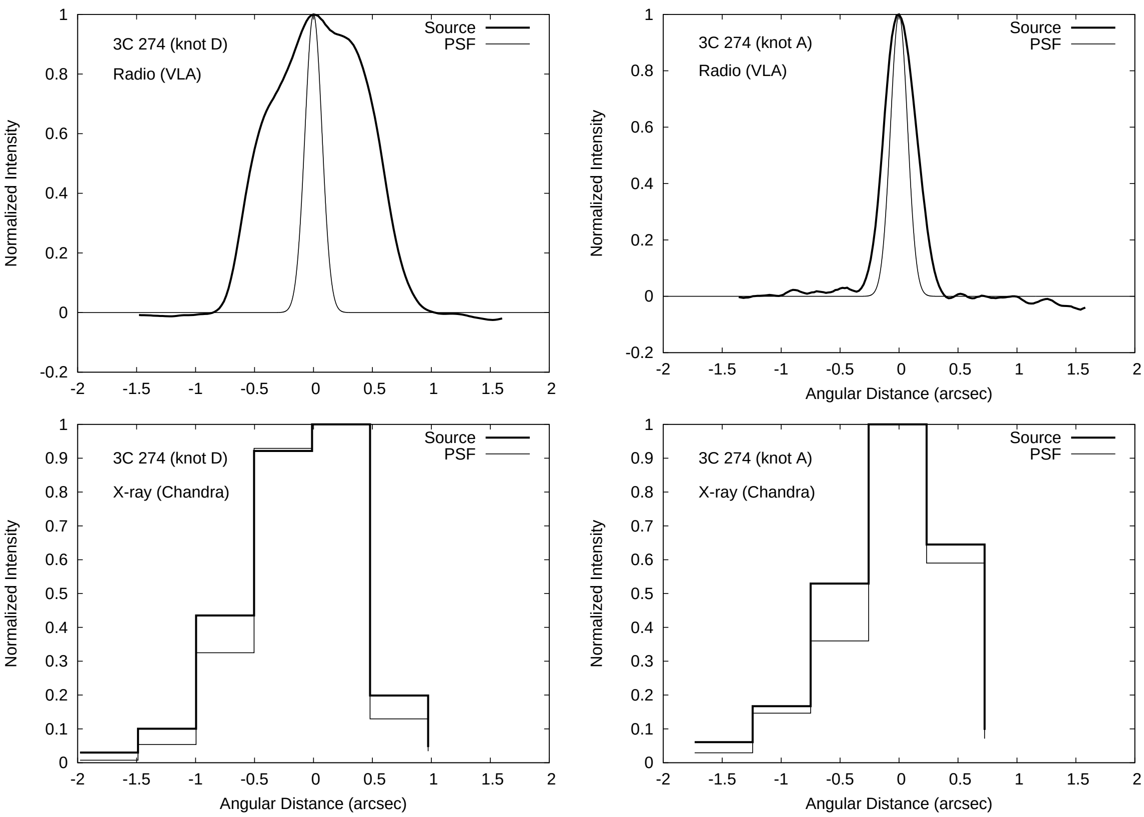


Fig. 3. X-ray and radio profiles of knots in 3C 274.

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Received 23.11.2011