J. Astrophys. Astr. (2011) **32,** 193–196

X-ray Radiation Mechanisms and the Beaming Effect of Hot Spots and Knots in AGN Jets

Jin Zhang[1,*], Jin-Ming Bai[2], Liang Chen[2] & Enwei Liang[3]

[1]*College of Physics and Electronic Engineering, Guangxi Teachers Education University, Nanning 530001, China.*

[2]*National Astronomical Observatories/Yunnan Observatory, Chinese Academy of Sciences, Kunming, China.*

[3]*Department of Physics and GXU-NAOC Center for Astrophysics and Space Sciences, Guangxi University, Nanning 530004, China.*

[*]*e-mail: zhang.jin@hotmail.com*

Abstract. The observed broadband spectral energy distributions (SEDs) of 22 hot spots and 45 knots are modelled with single-zone lepton models. Considering the sources at rest, the X-rays of some hot spots can be explained by the SSC model with magnetic field being consistent with the equipartition magnetic field in magnitude of order 1, but at the same time an unreasonably low magnetic field is required to model the X-rays for all knots. When considering the relativistic bulk motion of the sources, the IC/CMB model well explains the X-ray emission for most of them under the equipartition condition. We show that the ratio of observational luminosity R_L is tentatively correlated with the co-moving equipartition magnetic field $B'_{\rm eq}$ and the beaming factor δ. These facts suggest that the observational differences of the X-rays from the knots and hot spots may be mainly due to the differences in the Doppler boosting effect and the co-moving magnetic field of the two kinds of source.

Key words. Galaxies: jets—magnetic fields—radiation mechanisms: non-thermal—X-rays: galaxies.

1. Introduction

Hot spots and knots in large-scale jets have been observed in many active galactic nuclei (AGNs). It is generally believed that their radio and optical emission is produced by the synchrotron radiation (Roser & Meisenheimer 1987; Lahteenmaki & Valtaoja 1999). However, the origin of X-ray emission is highly debating. Systematical analysis on the SEDs in the radio and X-ray bands of hot spots, knots, and lobes were presented by Hardcastle *et al*. (2004) and Kataoka & Stawarz (2005). Note that the optical data are critical to characterize the SEDs and may give more constraints on the models. In this paper, we compile a large sample of 35 AGNs containing 22 hot spots and 45 knots, and fit their broadband SEDs with various models in order to study the radiation mechanisms of the X-rays and to reveal the differences of the two kinds of sources. For a full version of our paper refer to Zhang *et al*. (2010).

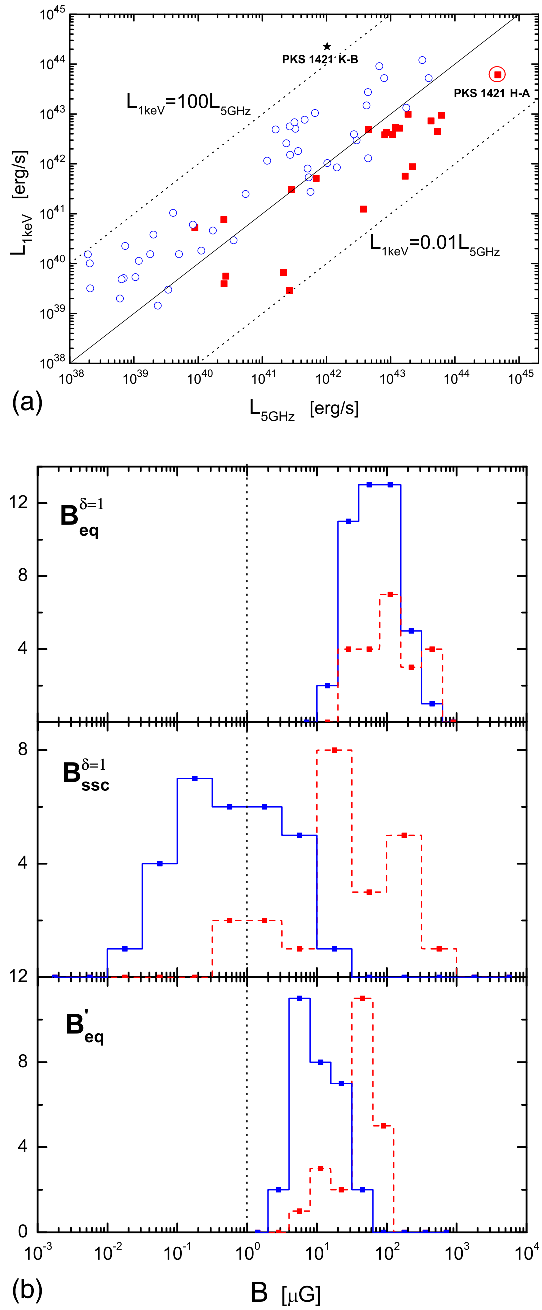

Figure 1. (**a**) Luminosity at 1 keV as a function of that at 5 GHz for the knots (squars) and hot spots (circles). (**b**) Distributions of the magnetic field strength for the knots (solid line) and hot spots (dashed line) in cases of (1) assuming equipartition condition and $\delta = 1$, (2) derived from the SSC model by assuming $\delta = 1$, and (3) considering the beaming effect. The vertical dotted line is the magnetic field strength for the interstellar medium, i.e., $B = 1\mu G$.

2. Model and results

The tight $L_{5\mathrm{GHz}}$–$L_{1\mathrm{keV}}$ correlation (as shown in Fig. 1) indicates that the radiations in the two energy bands may be produced by the same electron population. Therefore, we fit these SEDs with single-zone synchrotron + IC scatting models. Firstly, we fit the observed SEDs in the radio-optical band with the synchrotron radiation model to calculate the equipartition magnetic field $B_{\mathrm{eq}}^{\delta=1}$. Assuming that the sources are at rest, we fit the SEDs with the synchrotron + SSC model and derive the magnetic field strengths $B_{\mathrm{ssc}}^{\delta=1}$. It is found that the deriving magnetic fields of the knots are much smaller than that of the hot spots. Considering the beaming effect under the

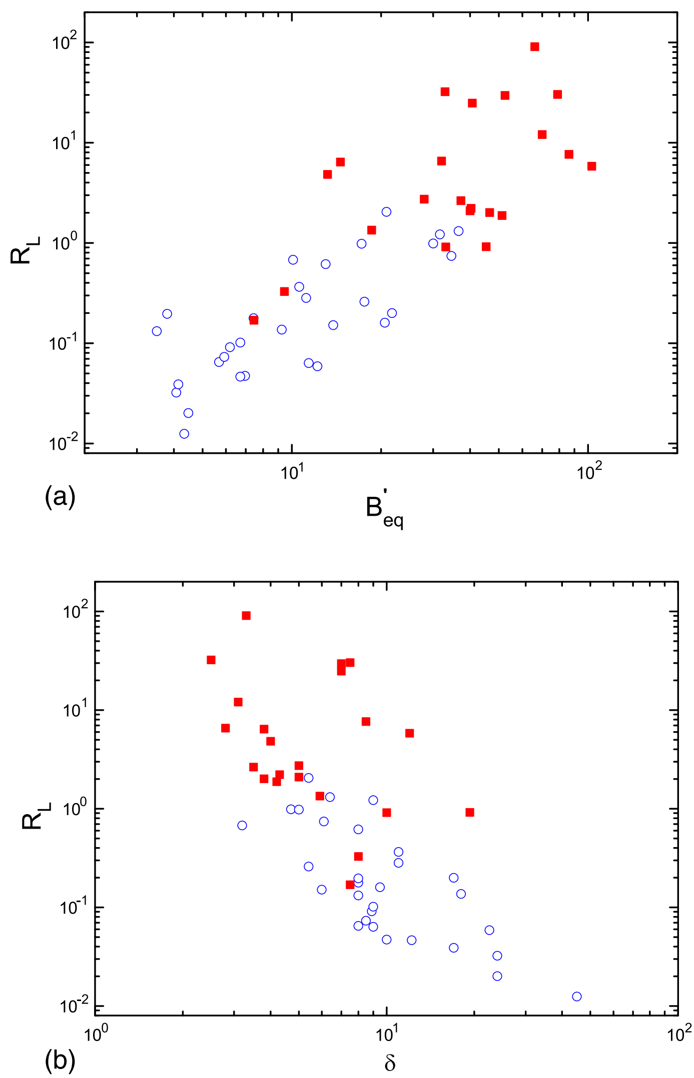

Figure 2. Correlations of R_L with B'_{eq} (**a**) and δ (**b**) for the knots and hot spots. The symbol styles are the same as in Fig. 1.

equipartition condition, the X-ray emission for most of the sources can be explained by IC/CMB model. Fitting results show that, in average, $\delta \sim 10$ for most of the knots and $\delta \sim 5$ for most of the hot spots. The distributions of equipartition magnetic field with comparison to $B_{\rm ssc}^{\delta=1}$ and $B_{\rm eq}^{\delta=1}$ are shown in Fig. 1.

3. Discussion and conclusion

The SED fits show that the mechanisms of the X-rays are diverse. While the X-ray emission of a small fraction of the sources is a simple extrapolation of the synchrotron radiation for the radio-to-optical emission, the IC component may dominate the observed X-rays for most of the sources. Without considering the relativistic bulk motion, the SSC model can explain the X-rays for some hot spots with the fitting magnetic field being consistent with the equipartition magnetic field in order 1 of magnitude, but at the same time an unreasonably low magnetic field strength is required in modelling the X-rays for all knots with this model. When considering the relativistic bulk motion of the sources, the IC/CMB dominated model well explains the X-ray emission for most of them under the equipartition condition.

The ratio R_L is an intrinsic characteristic of the sources, which is found to be correlated with $B_{\rm eq}^{'}$ and δ (as shown in Fig. 2). These facts suggest that, under the equipartition condition, the differences on the X-ray observations for the knots and hot spots would be mainly due to the differences of the Doppler boosting effect and the co-moving magnetic field.

Acknowledgements

This work is supported by the National Natural Science Foundation of China (Grants 11078008, 11025313, 10873002), the National Basic Research Program (973 Programme) of China (Grant 2009CB824800), China Postdoctoral Science Foundation, Guangxi Science Foundation (2011GXNSFB018063, 2010GXNSFC013011), and Guangxi SHI-BAI-QIAN project (Grant 2007201).

References

Roser, H. J., Meisenheimer, K. 1987, *Astrophys. J.*, **314**, 70.
Lahteenmaki, A., Valtaoja, E. 1999, *Astrophys. J.*, **117**, 1168.
Hardcastle, M. J. *et al.* 2004, *Astrophys. J.*, **612**, 729.
Kataoka, J., Stawarz, L. 2005, *Astrophys. J.*, **622**, 797.
Zhang, J. *et al.* 2010, *Astrophys. J.*, **710**, 1017.