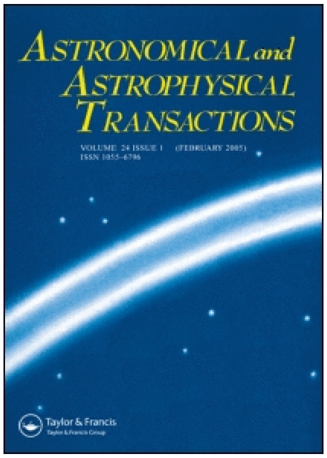

Astronomical & Astrophysical Transactions

The Journal of the Eurasian Astronomical Society

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Physical conditions in compact details of core-dominated sources

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To cite this Article: Tyul'bashev, S. A. (2007) 'Physical conditions in compact details of core-dominated sources', Astronomical & Astrophysical Transactions, 26:6, 663 - 669
To link to this article: DOI: 10.1080/10556790701610332
URL: http://dx.doi.org/10.1080/10556790701610332

Astronomical and Astrophysical Transactions
Vol. 26, No. 6, December 2007, 663–669

Physical conditions in compact details of core-dominated sources

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(Received 19 July 2007)

Spectra are built for compact details of core-dominated sources. Seventy-seven compact details in sources have cut-offs in the spectrum. The estimates of physical parameters are made for them.

By far, the majority of details show evidence of the equipartition between densities of energy of the magnetic field and relativistic particles. The constructed relationship between the density of energy of the magnetic field and the density of energy of the relativistic particles has not any satisfactory explanation for the present moment.

Keywords: Compact radio sources; Physical conditions

1. Introduction

Compact radio sources visible in VLBI observations present individual details of a source. This may be nuclei, jets, and hot spots in radio clouds. On frequent occasions, it is impossible to understand what precisely is observed in the given source. Therefore, the observations are to be perfomed at many frequencies, which allows to reveal the structure of a source, to estimate the precise angular sizes of compact details plus to build the spectra of individual details.

When investigating compact radio sources, many questions emerge, most of which do not have any unambiguous answers to the present day. Let us list some of them. Is there an equipartition of energies of the magnetic field and relativistic particles in compact details of radio sources? Is there a direct relationship between the black hole with its accreation disk and radio details, which may be at distances of fractions of parsec up to megaparsecs from the nucleus? Is there a relationship between the physical conditions in a compact radio source and the size of a radio source, or the distance of a radio source from the black hole, or its red shift? Is there a difference of physical conditions in compact details of radio sources of different classes? May an unification scheme of radio sources be constructed that is based on the physics of a nucleus and not on the geometry of a source?

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Astronomical and Astrophysical Transactions
ISSN 1055-6796 print/ISSN 1476-3540 online
http://www.tandf.co.uk/journals
DOI: 10.1080/10556790701610332

When answering these questions, we need some facility of estimating physical conditions in compact details of radio sources. We need large samples of radio sources of different classes and multifrequency observations with high angular resolution. Of prime importance are the observations at low frequencies, since the estimates of physical parameters may be obtained for those of them that have low frequency cut-offs of spectra.

The present work considers core-dominated sources.

2. Observations

Around 89 sources of complete sample [1] were taken for observations. Initial sources had steep spectra, positive declinations, and a flux density from the compact component of more than 1 Jy at 5 GHz as well, and they were extragalactic ($|b| \geq 15°$).

The observations were carried out at the Large Phased Array (LPA) at a frequency of 111 MHz, by the interplanetary scintillation (IPS) method. The bandwidth was 600 kHz, the integration time was 0.5 s, the sampling time was 10 Hz. The sensitivity of LPA for scintillating sources was 0.15–0.2 Jy.

From 6 up to 10 calibrators and from 5 up to 15 investigated sources were registrated during some session of observations. The method of reduction of observations of scintillating sources are set out in refs. [2, 3]. The accuracy of the estimates of flux density is 20% from the amount of a single flux.

The reduction of observation needed a special method created for the search of utmost weak scintillating sources [3]. This method allows to find scintillating components even in the case where fluctuations of flux density are less than the noises by nearly a factor of 2 with the used integration time. The example of such reduction is presented in figure 1a and b. The primary record of a weak scintillating source is given in figure 1a. The signal to noise ratio in the primary record is of the order of two. The same source, after the reduction of observations, appears in figure 1b. The SNR becomes equal to 23. In view of the small sizes of the work, we do not present the estimates of flux density of scintillating components and integral flux densities, they would be published in the forthcoming work. It may be noted that observations of 72 sources have been gathered altogether. The scintillations are recorded in 28 sources, and the upper limits of flux density are given for the rest of them. Among these, 24 sources also have estimates of integral flux density.

3. Estimation of physical parameters

The method described in the work by V.S. Artyukh [4] in 1988 was used for the estimation of physical parameters in compact components of sources (in the case of a low frequency cut-off of the spectrum due to synchrotron self absorption): the value of the perpendicular component of the magnetic field, the energy of the magnetic field, the density of relativistic particles, and the energy of relativistic particles.

According to the original method, the accuracy of the method is one order of the value for the magnetic field and the energy of the magnetic field [4]. As this takes place, typically the main accuracy is connected with the accuracy in evaluating the angular dimensions of a scintillating source. The error by a factor of 2 in evaluating the angular dimensions produce the inaccuracy of estimation of the magnetic field by a factor of 2^4, and since $E_{H_\perp} \sim H_\perp^2$ the fact is that the typical accuracy has become slightly more than two orders. However the estimates of angular sizes from VLBI observations were taken in the works on the investigation of compact sources

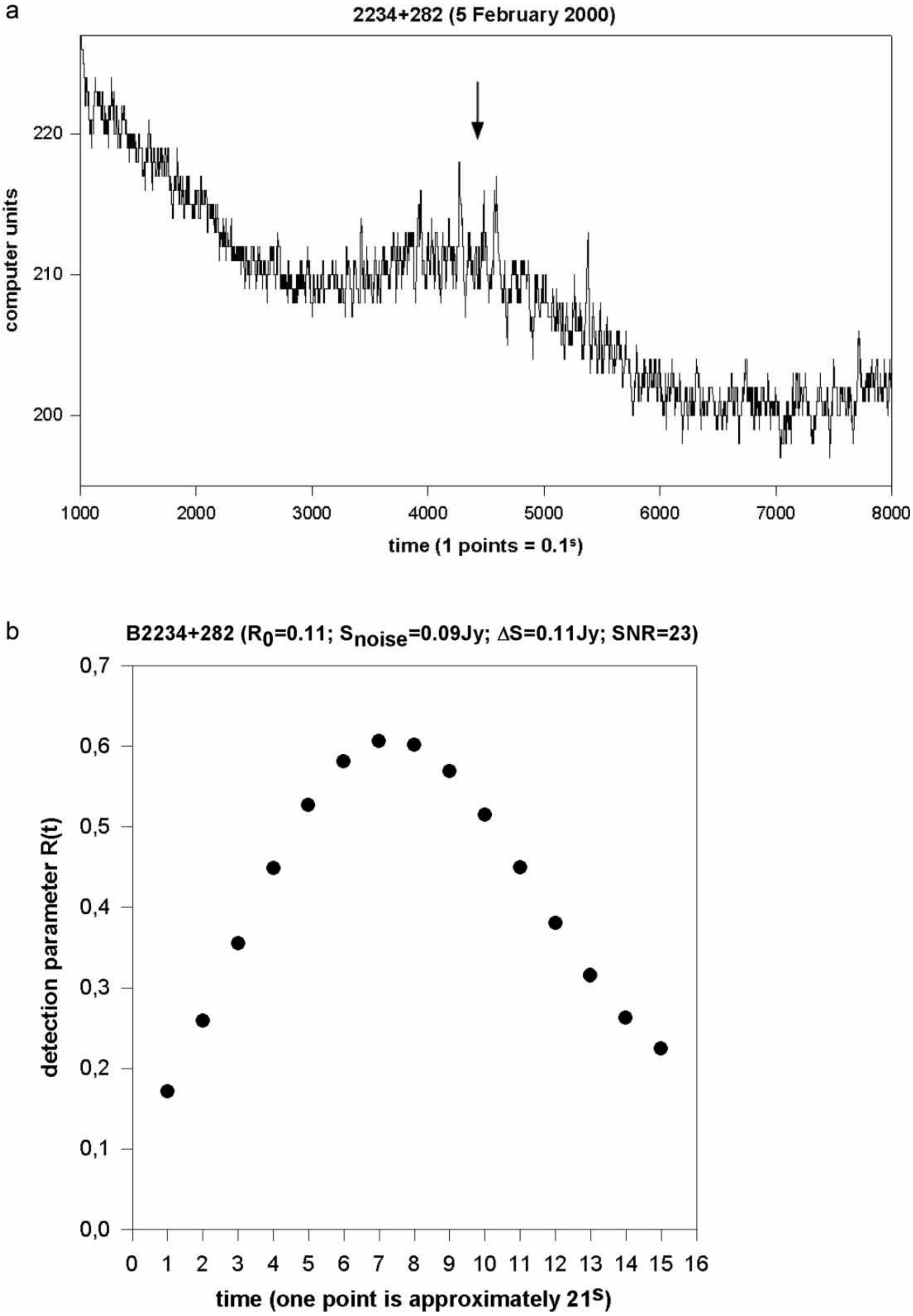

Figure 1. The weak scintillating source B2234 + 282 is marked off by an arrow it the centre of the record. A little integral flux is also seen. The source B2234 + 282 after reduction which course offers the closest possible SNR for scintillations. The parameter of detection is plotted along the vertical axis. Details of reduction in paper [3].

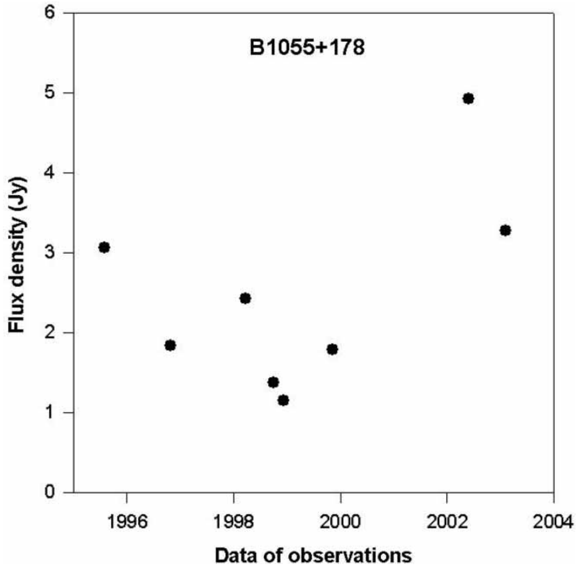

Figure 2. The figure shows the change of flux density gained from the compact component (nucleus) of the source B1055 + 178 with time. *Source*: Ref. [8].

with steep spectra by the IPS method [5, 6, 7]. The typical accuracy of the estimates of angular sizes in VLBI observations is of order 20–30%. Therefore, the accuracy of the estimates of physical parameters should increase.

Some moments are significant though, they were not given considerable attention in the original method but they are important in the work with the investigated sources. First, the investigated sources are variables (see figure 2). Therefore, considerable attention should be given to the construction of simultaneous spectra. Second, a Doppler boosting is observed in the sources. That is, the superluminal motion and temperatures exceeding the Compton limit are observed due to relativistic speeds of the motion of compact details, in a source, at a small angle to an observer [8]. In this case, it is essential to use the relativistic correction δ suggested by Marscher [9]. The estimation δ may be obtained from the formula given in the paper of Blandford [10]:

$$\delta = \left(\frac{T_\mathrm{b}}{10^{12}}\right)^{1/3}, \tag{1}$$

where T_b is the brightness temperature of a source in Kelvin, which in turn may be estimated by the formula given in the review of ref. [11]:

$$T_\mathrm{b} = 1.22 \times 10^{12} S \nu^{-2} \theta^{-2} (1 + z). \tag{2}$$

Here, S is the flux density expressed in Jansky, ν is the frequency in gigahertz by which the brightness temperature (T_b) is estimated, and θ is the angular size of a source on this frequency expressed in msec. All of the preceding leads us to the conclusion that we should be extremely carefull in gaining the estimates of physical parameters. It is imperative that we follow an accurate analysis of literature data used to gain the spectrum. Therefore, the reason that the estimates of physical conditions demanded only those spectra where a cut-off in the spectrum is seen immediately in the initial data.

After building the spectra, the estimates of physical parameters were given for those details where cut-offs in the spectrum were observed.

4. Physical conditions in compact details of sources

Consider the question of equipartition of energies of the magnetic fields and relativistic particles in the investigated sources. Should plots be constructed with the axes, where the density of energies of the magnetic field and relativistic particles would be plotted, then accordingly, at the same scales, the equipartition of these energies will be reflected in the form of a point on the line passing at an angle of 45^o to the axes. Points on either side of this line would indicate the disruption of equipartition. The predominance of points on any one side of the line would indicate that the disruption of equipartition is characterized by the greater energies of the field or particles. Such view will conveniently indicate whether there is an equipartition of energies in the compact components of quasars and BL Lac objects, which are precisely the object of a sample of sources.

The data for densities of energies of the field and particles are presented in figure 3. The grey colour is for the zone, where the distinction from equipartition makes up 2 orders of the value. By the equipartition of energies, most part of all estimates should be in the grey zone. As illustrated in the figure, the result issued directly contradicted what was expected. The overwhelming majority of the estimates of densities of energies of the magnetic fields and particles lies outside the domain of the grey zone. In addition, almost all of them lie in the realm where the density of the energy of particles exceeds the density of the magnetic field. The excess of the energy of the relativistic particles over the energy of the magnetic field in compact details over 10 orders of the value has already been intimated [12, 13 14], however a relationship between these energies was not noted.

As pointed out in the foregoing paragraph, the method of extraction of physical parameters is such that all gained estimates are ultimately connected with the estimation of the perpendicular component of the magnetic field. Therefore, probable errors in evaluating the magnetic field will reflect automatically on all other extracted parameters.

We do not have any ground for revising the accuracy of the method. The only distinction of our estimates of the magnetic field from the old method is in considering the Doppler

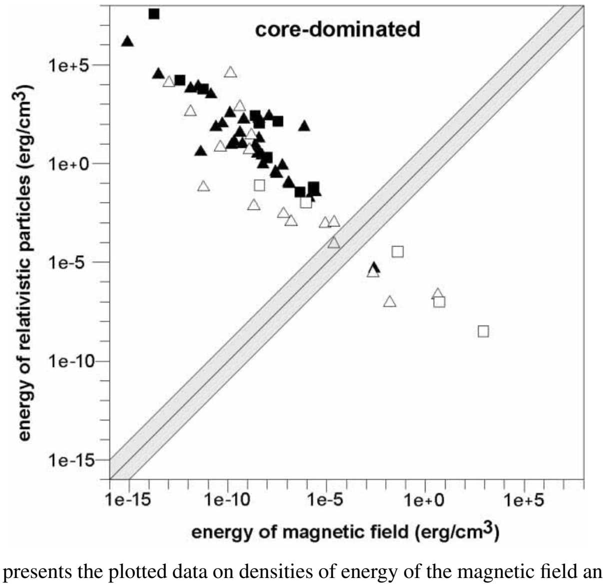

Figure 3. The figure presents the plotted data on densities of energy of the magnetic field and relativistic particles. Filled triangles are the data on nuclei of quasars, empty triangles are the data on jets of quasars, filled squares are the data on nuclei of BL Lac objects, and empty squares are the data on jets of BL Lac objects.

relativistic boosting. This may be estimated in different ways. For example, Readhead [14] demostrated that the Compton limit is not 10^{12} K but 10^{11} K. Clearly, this would show that our estimates of δ turn up to be understated and, thus, the estimates of the magnetic field would be understated, too. However, different methods of the estimates of δ would show that the final distinction do not exceed the order of the value at the field. An increase of the magnetic field by the order will not change the general view of a relationship.

It is possible that the method of estimation of physical parameters is inapplicable to real sources. The initial formulae of estimation of the magnetic field are gained in the assumption of the spherical form of sources and the homogeneous distribution of the fields and particles. The most part of the sources is non-spherical. We do not have any proof that the spectral index is equal to -2.5 in the region of the cut-off of a spectrum. Unfortunately, for the vast majority of the investigated sources points are so few in the spectrum that it is impossible to use the models of non-homogeneous sources.

Yet, the difference in densities of energies up to 20 orders suggests that the method of estimation of physical parameters may be unadequate in the work with compact sources.

One might suppose that the cut-offs in the spectra are induced by free-free absorption. Supposing that the temperature of free-free electrons was 10^4 K, one might estimate their density according the formula [15]

$$n_{\mathrm{e}} = \sqrt{\frac{T^{1.35}}{l}} \times \frac{\nu}{0.3}, \tag{3}$$

where T is the temperature of electrons in Kelvin, l is the size of a compact source, and ν is the frequency of maximum of the spectrum.

The estimates show that an explanation of the cut-off in a spectrum by free-free absorption demands the densities of electrons with the order of 10^4 particles/cm^3. If the temperature of free-free electrons is more than 10^4 K, the estimates of the density of electrons will also rise. From our point of view such densities are unlikely.

5. Conclusion

If the used method is actually applicable to sources, so: the density of energy of the magnetic field in the volume unit is inversely related to the density of energy of the relativistic particles; the energy of the relativistic particles is many orders higher than the energy of the magnetic field in the majority of compact components with the cut-off in a spectrum due to synchrotron self absorption. The typical size of the compact component therewith is not more than one parsec. For the present moment, we have no satisfactory explanation of the gained relationship. Yet, it is hardly probable that the gained relationship is an artefact.

Acknowledgements

This work was supported by RFBR (project 05-02-17011a) and Program of Russian Academy of Sciences 'Origin and evolution of stars and galaxies'.

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