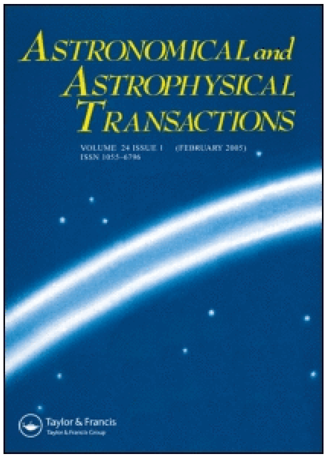

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Optical jets of SS 433

A. A. Panferov [a]
[a] Special Astrophysical Observatory RAS, Karachaevo-Cherkesia, Russia

Online Publication Date: 01 August 1999
To cite this Article: Panferov, A. A. (1999) 'Optical jets of SS 433', Astronomical & Astrophysical Transactions, 18:1, 199 - 203
To link to this article: DOI: 10.1080/10556799908203056
URL: http://dx.doi.org/10.1080/10556799908203056

Astronomical and Astrophysical Transactions, 1999, Vol. 18, pp. 199–203
Reprints available directly from the publisher
Photocopying permitted by license only

OPTICAL JETS OF SS 433

A. A. PANFEROV

Special Astrophysical Observatory RAS, Nizhnij Arkhyz, Karachaevo-Cherkesia, 357147, Russia

(Received December 15, 1996)

The precession curves of H I line intensities of the SS 433 jets in a comoving frame show an anisotropy of the jet radiation. We construct an axial by symmetric beam of radiation which has two opposite maxima and a stronger head maximum which is indined at about 40° to the jet velocity vector in the direction of precession movement.

The physical parameters of gas in the jets are derived by comparing the observed Balmer decrements with the model decrements of Drake and Ulrich (1980). We discuss the hierarchical structure of the jets. The determining factor in the dynamics of clouds and in the formation of jet radiation is the interaction between the jet and the gas of the slow wind from the accretion disk. The nature of a zone of brightening of synchrotron radio emission at distance of about 4×10^{15} cm is explained.

KEY WORDS Close binary systems, SS 433, jets, Balmer decrements, beam of radiation

The jets of the close binary system SS 433 hold a key position in the study of the nature of astrophysical jets. Two counter-directed jets of SS 433 emerge from the centre of the supercritical accretion disk with a velocity of 0.26c. The jets consist from gas clouds which radiate in H I and He I lines – a unique case for relativistic jets. We measured the intensities of the moving Balmer lines of the SS 433 jets (Panferov *et al.*, 1997) and used these intensities to diagnose physical conditions in the optical part of the jets.

1 ANISOTROPY OF JET RADIATION. RADIATION BEAM

The precession dependence of the intensities of the $H_\alpha^\pm$ lines in a comoving reference frame are given in Figure 1, in units of 10^{-10} erg cm^{-2} s^{-1}. The intensities are corrected for interstellar extinction (Cherepaschuk *et al.*, 1982). The great resemblance of the intensity curves of "–" and "+" jets is evidence for the equality of the jets and of the central symmetry of its radiation.

The precession curve of the ratio of intensities of H_α^- and H_α^+ lines is given in Figure 2. This relation is close to 1 when the jets lie in the sky plane (phases 0.34 and 0.66), and the difference maximizes at phases near 0.5 and 1.0, from which

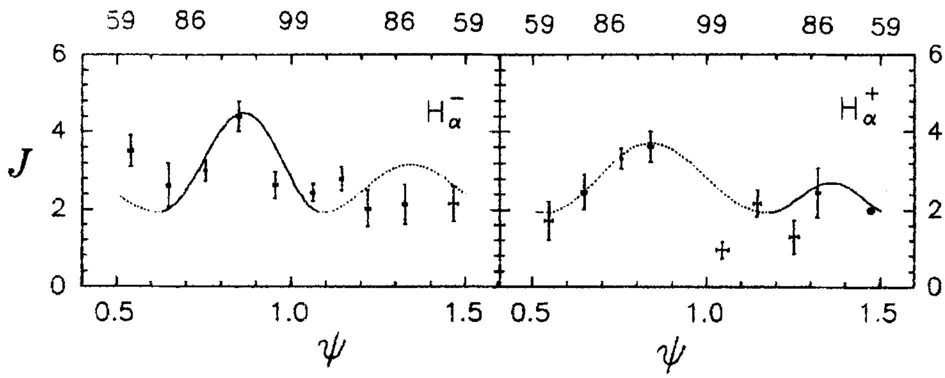

Figure 1 The H_α intensity of the SS 433 jets as a fuction of the precession phase ψ (bottom axis), or of the angle between "–" jet and the line sight (upper axis). H_α^- – jet directed towards us, H_α^+ – the counter–jet. The intensity $\mathcal{J}$ is in units 10^{-10} erg cm^{-2} s^{-1}.

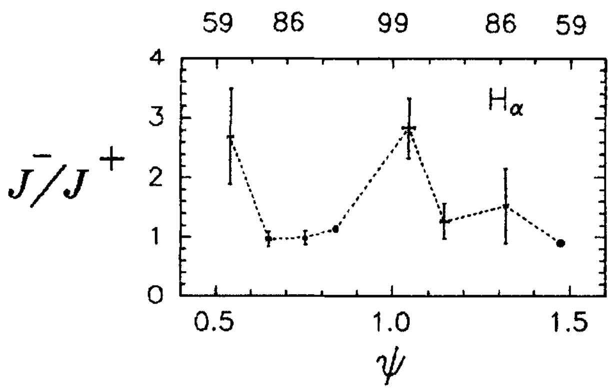

Figure 2 The ratio of the intensities of $H_\alpha^\pm$ lines of the SS 433 jets.

Asadullaev and Cherepaschuk (1986) inferred the possibility of an anisotropy of jet radiation.

The orientations of the axial by symmetric beams of radiations for both jets were derived from data from Figure 1. Relativistic aberrations were taken into account. It turned out that the beams of both jets are directed equally and the radiation axis is inclined at about 40° to the jet velocity vector in the direction of the precession movement. We simulated precession curves using the angular distribution function of such a beam: $I(\theta) = C + A\cos^2(\theta)$, where θ is the polar angle. The simulated curves are given in Figure 1 with the parameters $C_- = C_+ = 2$, $A_- = 2.5A_+ = 5$. The continuous line represents radiation from the hemisphere of the beam; the dotted line from the counter-hemisphere. The head maximum is 1.75 brighter than the back one (the observed equality of the line intensities of both jets and the difference of the widths of the curves' maxima arise from relativistic aberrations).

This angular distribution of jet radiation is possibly caused by dynamical interaction between the jet and its surroundings. Consequently dissipation of the kinetic energy of the jets may be one source of heating of the jets. The precession rotation causes the jet to continuously sweep the gas of the slow wind from the accretion disk. The jet sweeps the gas on the surface of the precession cone up to a distance beginning $P_{\rm pr}V_w \approx 3 \times 10^{15}$ cm (the zone of sweeping). The length of sweeping just equals that of the observed jet in the $H\alpha$ line (Borisov and Fabrika, 1987). Further, the jet propagates in the gas-free space, where gas was swept in previous precession cycles.

To explain the anisotropy of radiation of the SS 433 jets we propose a model of an optically thick cloud, or of a cluster of clouds, which is flattened, or the escaping of photons from which is more probable in the direction of shock waves (because of the gradient of the velocity). This interpretation accords with the conclusions below about the physical parameters of the gas clouds in the jets and about the jet structure.

2 PHYSICAL PARAMETERS AND STRUCTURE OF JETS

The precession dependences of the Balmer decrements (BDs) are given in Figure 3. For the range of interstellar extinction toward SS 433, $A_v = 7\overset{\rm m}{.}3$–$8\overset{\rm m}{.}3$, we determined the next limits of BDs: $\mathrm{H}_\alpha/\mathrm{H}_\beta = 0.66$–$2.20$, $\mathrm{H}_\gamma/\mathrm{H}_\beta = 0.61$–$1.03$, and the means (for a more probable $A_v = 7\overset{\rm m}{.}8$) are $\mathrm{H}_\alpha/\mathrm{H}_\beta = 1.3$, $\mathrm{H}_\gamma/\mathrm{H}_\beta = 0.8$. It turned out that the BDs of both jets were approximately equal, but essentially differed in different precession phases: in the phases of a maximum of intensities of moving lines (0.7–0.9), $\mathrm{H}_\alpha/\mathrm{H}_\beta = 1.6 \pm 0.2$, $\mathrm{H}_\gamma/\mathrm{H}_\beta = 0.7 \pm 0.1$; in the phases of a minimum (0.0–0.2), $\mathrm{H}_\alpha/\mathrm{H}_\beta = 0.9 \pm 0.2$, $\mathrm{H}_\gamma/\mathrm{H}_\beta = 0.8 \pm 0.1$ ($A_v = 7\overset{\rm m}{.}8$).

By comparing the observed BDs with those simulated by Drake and Ulrich (1980) the following BD parameters were derived: the number density of the gas, $n \approx 10^{13}$ cm^{-3}, the size of an emiter, $l \approx 10^8$ cm, the kinetic luminosity of the jet, $L_k \approx 10^{39}$ erg s^{-1}, and the rate of radiation in the H_β line, $\epsilon_{\mathrm{H}_\beta} \approx 1$ erg cm^{-3}. The mass of one cloud is $M \approx m_p n l^3/2 \approx 10^{13}$ g. The number of clouds in a jet is $N \approx 2L_{\mathrm{H}_\beta}/\epsilon_{\mathrm{H}_\beta} l^3 \approx 10^{12}$, where the luminosity of the jet in the H_β line is $L_{\mathrm{H}_\beta} = 7 \times 10^{35}$ erg s^{-1}. The filling factor is $q_j \approx 4L_{\mathrm{H}_\beta}/(R_m + R_d)^3 \theta_j^2 \epsilon_{\mathrm{H}_\beta} \approx 4 \times 10^{-6}$, where R_m is the distance from the jet's orgin to the region of the radiation maximum, R_d is the spatial decrement of the brightness of the jet (Borisov and Fabrika, 1987).

The physical sence of the thickness l of an emiter of moving lines depends on the structure of jet. If photons in a line are scattered in some clouds before they leave the jet, then the real size of the clouds is less l. The effective size l and the real size l_t of the cluster are connected in the following fashion:

$$l_t = 10^{12}\sqrt{L_{k39}P_2/n_{13}l_8}\ \mathrm{cm}, \tag{1}$$

where P_2 is the period in units of 100 s, n_{13} is n in units of 10^{13} cm^{-3}, l_8 is in units of 10^8 cm. Borisov and Fabrika (1987) have given a period of $\sim$ 100 s for the creation of largest structure units in the jet.

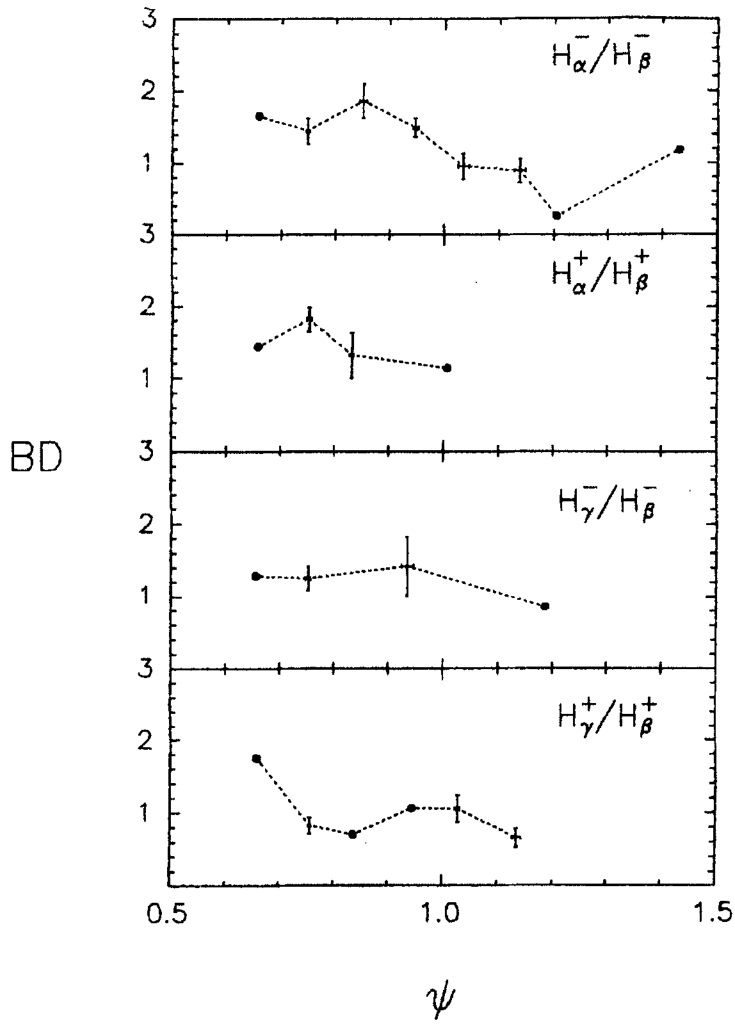

Figure 3 Balmer decrements of the SS 433 jets as a function of the precession phase ψ.

The dynamical time of the cloud is $t_s = l/c_s \approx 100$ s, which is essentially less than the radiation time of such a cloud (1–6 days). Consequently, the expansion of the clouds is restrained. We propose that in the zone of sweeping, cool clouds are restrained by the dynamical pressure of the surrounding gas. At distances above the zone of sweeping, in gas-free space, clouds are expanding rapidly and overheating and, as a result, the radiation of the clouds in the al band optic ceases.

Usually profiles of the $H_\beta^\pm$ lines do not have secondary components, but profiles of the $H_\alpha^\pm$ lines do. This is evidence for a steep decrement H_α/H_β in the remote parts of the jet and, consequently, of a decrease in the gas density in the clouds with time.

The existence of a zone of jet brightening in the radio band (the radio brightening zone), observed in VLBI maps (Vermeulen *et al.*, 1987) at a distance of 3.7×10^{15} cm (5.6 days of flight), possibly relaten to the fast evolution of clouds beyond the sweeping zone. The free expansion of clouds begins at the boundary of the sweeping zone (4.5 days of flight) and leads to the generation of relativistic electrons on the front of shock waves which manifests itself as a brightening zone of synchrotron radio emission. Between the end of the sweeping zone and the radio brightening zone, the jet truvelo for approximately one day. In the sweeping zone, clouds develop according to the laws $l \propto R^{2/3}$, $q \propto R^{-1}$. Reducing the cloud parameters from there observed, i.e., at a distance of $\approx R_m$, to there at the boundary of the sweeping zone, we find that the clouds fill the entire jet volume and, as a result, are in the shock, for a time $t = t_s/q^{1/3} \approx 1$ day, which is observed. So, our suggestions about the interaction between jets and the wind from the accretion disk and about the dynamics of clouds are in agreement with the existence of the radio brightening zone.

References

Asadullaev, S. S. and Cherepacshuk, A. M. (1986) *Soviet Astronomical Journal* **63**, 94.

Borisov, N. B. and Fabrika, S. N. (1987) *Letters in Soviet Astronomical Journal* **13**, 487.

Cherepacshuk, A. M., Aslanov, A. A., and Kornilov, V. G. (1982) *Soviet Astronomical Journal* **59**, 1157.

Drake, S. A. and Ulrich, R. K. (1980) *Astrophysical Journal Supplement* **42**, 351.

Panferov, A. A., Fabrika, S. N., and Rahimov, V. Ju. (1997) *Soviet Astronomical Journal* **74**, 392.

Vermeulen, R. C., Schilizzi, R. T., and Icke, I. *et al.* (1987) *Nature* **328**, 309.