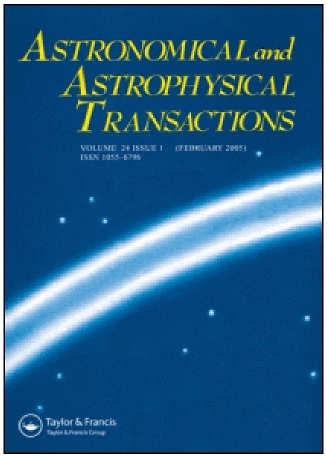

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ON THE SHOCK WAVE THEORY OF 'SUPERLUMINAL' RADIO JETS

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Superluminal parsec scale components of jets in an AGN are considered as being parts of a shock front excited by a flare (explosion) in the vicinity of the nucleus and moving at small angles to the direction of sight. The influence of laminar flows (accretion and wind) is discussed, as well as pumping from the flare region.

KEY WORDS Quasars, flares, superluminal jets, relativistic shocks

1 INTRODUCTION

The nature of 'superluminal' parsec scale jets is still not clear in spite of their discovery long ago. Most researchers are agreed that in this phenomenon we are dealing with ultra-relativistic motion at a small angle to the line of sight. However, what exactly moves is still the subject of discussion. The widespread model is ejection of separate components, which merge at the kiloparsec scale into a continuous stream. Here we investigate another possibility of treating superluminal components as parts of a shock front moving towards an observer from a flare in the AGN vicinity. We find a basis for such interpretation in the observed correlation (Babadzhanyanz and Belokon', 1985; 1993; reviews in Vermeulen, Cohen, 1994; Zensus, 1997) between optical (X, γ) flares in quasars and other types of AGN and the separation of consecutive superluminal components. In this consideration we also take into account the stream and accretion flows in the medium which the blast wave is moving through.

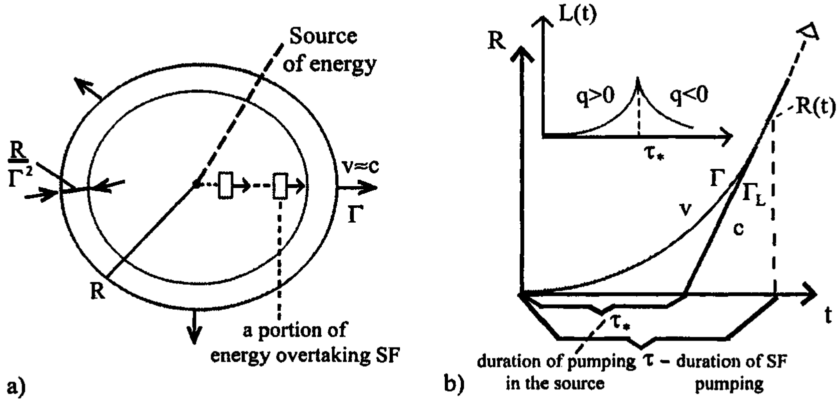

Figure 1 a, The pumping scheme from the point energy source; b, The duration of the flare and of the pumping of the shock front.

Some consequences of the model are discussed in the present report.[†]

As we have shown earlier (Kontorovich and Pasyuga, 1999), if the relativistic medium near a massive compact object (black hole) is in hydrostatic equilibrium then the apparent velocity of the SF β_{app} is asymptotically constant and proportional to the energy of explosion. Here we discuss the influence of the motion of the medium and pumping from the region of explosion on the velocity β_{app}. We also show that the correlation between the acceleration time of components and the flare duration finds a natural explanation in the framework of the model.

2 DISCUSSION

(1) We start with the boundary conditions at the SF that bound the Lorentz-factors of the medium and SF. For the asymptotical approach in the Kompaneets approximation (strong explosion, equipartition of pressure along the SF and its proportionality to the density of the energy of explosion $E/V(t)$) the ultra-relativistic relation (Blandford and McKee, 1976; Shapiro, 1979) for the Γ-factor of the leading point of the SF is sufficient to discuss the results:

$$\Gamma^2 = \lambda E / w_1 V. \tag{1}$$

[†] During periods between flares, AGNs radiate at a quite high level that indicates continuous accretion. However, as follows from recent works (Ustyugova, Lovelace, Romanova *et al.*, 2000 and the references therein) a jet seems necessary to take away the momentum of the accretion media from the small vicinity of the AGN and, thus, to keep the accretion efficient. The idea is also confirmed by the universal presence of jets in phenomena of quite different scales and energies (Lada, 1985; Mirabel and Rodriges, 1999). Therefore, the scenario where superluminal components are not real ejecta but processes developing in the medium with continuous flows is attractive. Such a process could be the propagation of an (ultra) relativistic shock front (SF) initiated by the explosive release of energy in a flare.

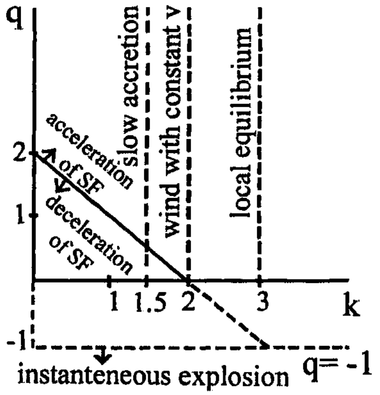

Figure 2 The acceleration of the shock front conditions in the pumping and surrounding medium – inhomogeneous case.

Here w_1 is the enthalpy of the medium equal to ρc^2 if the temperature of the medium is not too high, $V(t) = 4\pi R^3/3$ with the radius of the SF $R = ct$. The apparent velocity $\beta_{\text{app}} \equiv v/c \approx 2\alpha\Gamma^2$, where α is a small angle of sight, $(\Gamma\alpha)^2 \ll 1$. In the case of interest the hydrostatic equilibrium corresponds to $w_1 \propto R^{-3}$, from where the independence of β_{app} from coordinates, as well as its proportionality to the energy of explosion (Kontorovich and Pasyuga, 1999) follow, that corresponds to the data of (Babadzhanyanz and Belokon', 1985; 1993).

(2) For non-relativistic flows the value of β_{app} mainly depends on the appropriate density distribution near the AGN. For example, for constant velocity of the flow (wind) we have $w_1 \propto 1/R'^2$ (the prime corresponds to the frame of AGN, the distance is measured from the centre of the nucleus). For β_{app} at $R \gg R_0$, where R_0 is the coordinate of the flare, it follows that $\beta_{\text{app}} \propto E/R$. For slow accretion (ADAF, see Blandford, 1999) at $w_1 \propto (R')^{-3/2}$ we have $\beta_{\text{app}} \propto ER^{-3/2}$ (at $R \gg R_0$). The relation (1) is valid locally, i.e. in the framework of the 'sector' approximation. Due to the relativistic aberration the mechanism of radiation is not important. The radiation comes from the part of the SF moving towards the observer. For simplicity we consider the part near the upper leading point (see diagram in Figure 1 from Kontorovich and Pasyuga, 1999).

(3) Pumping energy into the SF from the central source (point of explosion) for power $L(t)$ and Γ-factor $\Gamma_L \gg \Gamma$ can be taken into account according to Blandford and McKee (1976) (see Figure 1*a*). Taking into account the relativistic time dilation and the power law $L(t_*) = L_0 t_*^q$, where t_* and t are measured in the frameworks of the source and SF, accordingly (see Figure 1*b*), we have (for $q + 1 > 0$):

$$t_* = t/2\Gamma^2(t), \quad E(t) = \int^t L(t)\,\mathrm{d}t, \quad \Gamma^2 = \frac{3\lambda L_0 t^{q+1}}{4\pi w_1(ct)(ct)^3\Gamma^{2(q+1)}}. \qquad (2)$$

Solving the last relation for Γ^2 we find $\Gamma^2(t)$, which at $w_1 \propto (R')^{-k}$, accounting

Table 1. The durations of flares and accelerations in 3C 345.

Components	*Duration of s-flare*	*Duration of f-flare*	*Duration of pumping (SF acceleration)*
C3	$\simeq 2$ years	20 days	< 2.22 years
C3a	$\simeq 2$		< 2.29
C4	$\simeq 2$		≥ 1.06 (≤ 2.84)

*For components C5,6,7 the duration of the acceleration phase is $\leq$6.03, <1.84, 1.5 years, accordingly.

for the power law inhomogeneity of the medium, can be given as: $\Gamma^2 \propto t^m, m = (q+k-2)/(q+2), (m < 1)$. In Figure 2 the regions of acceleration $(q+k > 2)$ and deceleration $(q+k < 2)$, as well as the corresponding regimes of flows are shown for different exponents.

(4) Note that as is seen in the diagram in Figure 1*b* the duration of pumping in the source and in the SF are significantly different. However, for a distant observer the duration of acceleration is equal to that of pumping, which can also be seen from Fig.1b. We carried out a preliminary comparison of results by Zensus, Lobanov *et al.* (see Figure 5 in the review Zensus, 1997) with data for flare duration (Babadzhanyanz and Belokon', 1993; Zensus, 1997). From Table 1 a rough correspondence is seen of the duration of component acceleration (within the first mas) with the duration of corresponding optical flares.

3 CONCLUSIONS

Thus, even the preliminary analysis of data on the correlation of optical flares and motion of superluminal components results in the conclusion that the model of an ultra-relativistic shock wave may be in a good correspondence to the physics of processes in the nuclei of active galaxies such as quasars and radio galaxies.

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