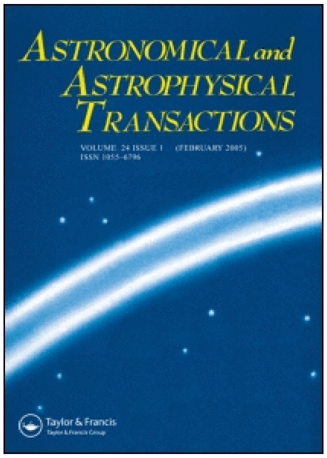


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# ON GRAVITATIONAL MODEL OF JETS†

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The motion of test particles in the gravitational field of a rotating triaxial ellipsoid with slowly varying parameters is considered as a gravitational model of jets. The polar solutions are obtained and analyzed.

KEY WORDS Celestial mechanics, stellar dynamics – orbits; jets–models

The jets – astrophysical mass outflows in the vicinity of young stars and galaxies are considered. The motion of a particle (gas, dust) in the external gravitational field of the rotating triaxial ellipsoid with slowly variable physical parameters: mass, sizes and form, is considered as dynamical model. Moreover, the ellipsoid is not only a gravitating, but also a radiating body. This model is generalized and united the non-stationary and the photogravitational cases of the problem (Bekov, 1992; Zhuravlev, 1992). The model is applicable to the description of the jets consisting of gas and dust and formed near young active stars and galaxies with star formation outbursts (Surdin and Lamzin, 1992). In this model, the gravitational interaction of the central body plays the main role and the interactions between individual particles can be neglected in comparison with the action of the central mass on them (Fridman, 1978). In this non-stationary photo-gravitational problem, families of equatorial, complanar, annular and polar solutions are obtained. The polar solutions provide the possibility of the dynamical interpretation of the astrophysical jets as a result of the mass outflow from the polar regions of young evolving stars and galaxies.

The family of the polar solutions represents the motions like bipolar outflows and large-velocity streams along the rotation axis in the external field of an ellipsoid with variable physical parameters. The case simplest for applications when the mass varies according to the united Meshtchersky's law is considered. The polar solution family consists of two classes. The class of $z$-solutions is the straight-line stream type solutions (high velocity): $x = 0$, $y = 0$, $z = z(t)$, (Bekov, 1992), and the class of the polar libration type solutions is

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$$x = 0,\ y = 0,\ z_p(t) = l_0 \frac{M_0}{M(t)} \zeta; \quad \zeta = \pm \left(\frac{\kappa}{\kappa - 1}\right)^{1/3} \pm \varepsilon \left(\frac{\kappa - 1}{\kappa}\right)^{1/3} \sigma + \ldots, \tag{1}$$

where $M(t)$ is the ellipsoid mass, $l_0$ is the characteristic length, $M_0$ is the mass at the initial moment $t_0$, $\varepsilon$ and $\sigma$ are small parameters ($\sigma$ defines a polar compression or elongation of the ellipsoid), $\kappa$ is the parameter,

$$\kappa = \frac{GqM}{l^3\omega^2}; \quad \kappa > 0, \quad 0 < q \leq 1, \tag{2}$$

and $G$ is the gravitational constant, $q$ is the reduction coefficient of the particle mass owing to the radiation pressure and $\omega$ is the angular velocity of the rotation of the ellipsoid.

The solutions (1) are particular cases of the $z$-solutions, they give a slow part of the velocity and the $z$-solutions describe a rapid part of the jet velocity. At $0 < q \leq 1$, it follows from (2), that the solutions (1) fill densely some region on the polar axis outside the ellipsoid with the characteristic length $l_0$, the length of the jet. When $q = 1$, solutions (1) become points (libration), at $q = 0$ we have a special case of the $z$-solutions: $z(t) = z_0 + \dot{z}_0 t$ fill densely the rotation axis, but these solutions are unstable.

The stability conditions for the $z$-solutions are obtained using Liapinov's $V$-function. The stability conditions for solutions (1) in the linear approximation on the $\kappa\sigma$-parameter plane are as follows:

$$6\sqrt{6}(\varepsilon|\sigma|)^{3/2} < \kappa < 1, \quad \sigma \leq 0. \tag{3}$$

In this case the gravitational interaction of the central body is dominating and a condition for a negligible role of collective effects is taken into account (Fridman, 1978).

For a typical WR star, $\dot{M}_0 = 3 \cdot 10^{-5} M_\odot/\text{year}$, $M_0 = 10 M_\odot$, $R_0 = 2 R_\odot$, $v_r = 200$ km/s and for a jet with the length $l_0 = 2 \cdot 10^{16}$ cm we obtain $\kappa/q \sim 10^{-13}$ and for the velocities, $\dot{z}_p \sim 30$ km/s and $\dot{z}(t) \sim 350$ km/s. Observational data on jets give $\dot{z}$ =200–400 km/s (Mundt, 1986).

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## DISCUSSION

*Fridman*: According to estimates, in both stellar and galactic jets the influence of gravity can be neglected. What is in your case?
*Bekov*: In this model the gravitational interaction of the central body is the main and the matching interactions are not taken into account. If we neglect the gravitation, it is necessary to consider other models of jets.