# THE EFFECT OF THE GRAVITY OF A CIRCUMSTELLAR TORUS ON BIPOLAR JETS

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We examine the hydrodynamical wind-type jet in the funnel formed along a rotational axis of accretion tori surrounding a proto star, taking into account the gravitational field produced by torus-gas (Fukue and Yamamoto, in press, 1986). In the current models (e.g. Fukue 1982, 1983), an astrophysical jet was assumed to be accelerated along the funnel considering only the gravitational field of the central object.

The following is assumed: the jet is steady, one-dimensional (r) flow along the funnel; inviscid and adiabatic; no magnetic funnel's cross-sectional area A is proportional to $r^n$; almost all the torus-gas is distributed in a thin ring (wire approximation for the gravitational field generated by torus-gas); and the Newtonian approximation is adopted.

Under the above assumptions, the basic equations governing the funnel jet are reduced to the familiar wind equation of adiabatic solar wind except for the cross-sectional area and the additional gravitational potential $\psi$ produced by torus-gas:

$$\frac{dM^2}{dr} = \frac{M^2 \; N(r, M^2; n, \gamma, a, m/m_*; E)}{M^2 - 1}$$

where

$$N = [(\gamma-1)M^2+2]A'/A - (\gamma+1)[M^2/2+1/(\gamma-1)](\phi' + \psi')/(E-\phi-\psi),$$

$$\phi = -1/r, \quad \psi = -m/m_*/(r^2+a^2)^{\frac{1}{2}} \quad ,$$

and the prime denotes the differentiation with respect to r. Here we have introduced the Mach number M = v (jet velocity)/c (sound speed). $\phi$ is the gravitational potential of the central star while $\psi$ is that of the torus/wire. The parameters are n, $\gamma$(polytropic index), a (radius of the torus-center), $m/m_*$(the ratio of mass of torus-gas m to that of the central star $m_*$), and E (specific energy of the jet). The quantities are normalized by $r_*$ (radius of the central star) and $v_* = (Gm_*/r_*)^{\frac{1}{2}}$.

The nature of the funnel jet is determined by the behaviour of a solution near a critical point. A linear analysis of the wind equation for the present model shows that the topology around the critical point is always saddle (X-type) or center (O-type).

In conclusion, the behaviour of the jet flow is drastically changed due to the effect of gravity of torus-gas; that is:

1. For a large value of $m/m_*$, multiple (three) critical points appear within some range of E; i.e., inner(X), middle (O), and outer (X) critical points.

2. For the hot boundary (large E), the jet flow passes through the inner critical point. For the cold boundary (small E), it passes through the outer one. A slight change in E leads to a drastic transition of

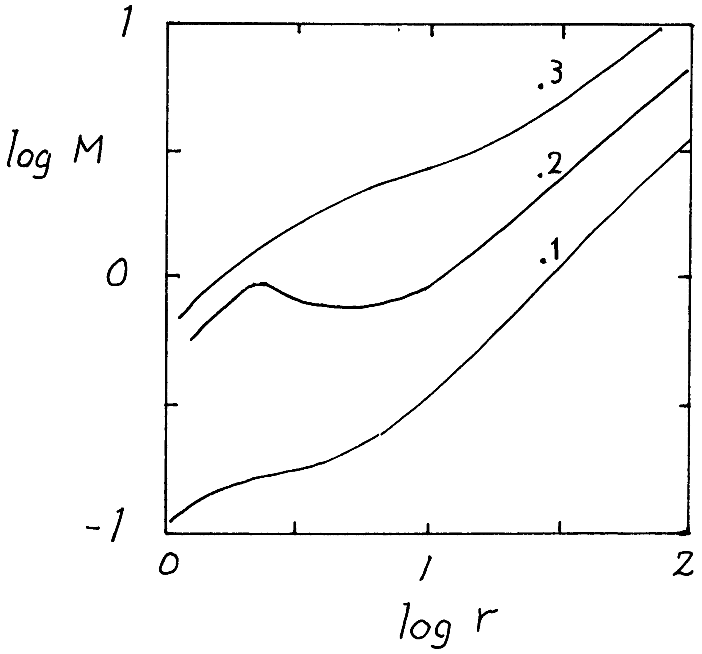


Fig. 1. Critical solutions for several values of E. Other parameters are fixed as n = 1, $\gamma = 5/3$, a = 5, $m/m_* = 2$. In this case, the transition of location of critical points occurs near E = .2. That is, when $E \lesssim .2$, $r_c \sim 10$, while $r_c \sim 2.3$ when $E \gtrsim .2$.

the location of the critical point.

Other effects are:

3. The terminal speed $v_\infty$ of the jet decreases for a fixed set of boundary conditions as $m/m_*$ increases.

4. On the other hand, the gravity of torus-gas attracts the gas toward the equator. As a result, the funnel widens. This geometrical effect also changes the jet velocity field.

## REFERENCES

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