LARGE-SCALE FRAGMENTATION OF GAS CLOUD ROTATING AT THE GALACTIC CENTER

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ABSTRACT. A rotating and slowly-contracting gas cloud is followed in the deep gravitational potential of the galactic center. When the gas density increases as high as $(10^2 - 10^3) H_2 \ cm^{-3}$, which is more than twenty times as large as the background matter density, the self-gravity of the cloud becomes dominant to govern its dynamical structure. The cloud elongates and then splits into two separated objects, as observed at the centers of IC342, NGC6946, and Maffei 2 where we have two symmetric peaks on the major axis of the ^{12}CO (J=1-0) cloud.

1. Elongation of Gaseous Ellipsoid Rotating at the Galactic Center

A self-gravitating uniform gaseous ellipsoid rotates and contracts slowly in the potential $\Phi = AX^2 + BY^2 + CZ^2$, where X, Y, and Z denote the coordinates referred to the galactic center, and A, B, and $C > 0$. When $A < B$, Φ represents a bar-like potential elongated in the X-direction in the galactic plane. When Φ rotates slowly, it would mimic a central gravitational potential of the barred spiral. By applying a method developed by Tatematsu and Fujimoto (1990), we can follow the flattening and elongation of a uniform gaseous ellipsoid as in figure 1, where a_1, a_2 are the principal axes of the ellipsoid on the equatorial plane and a_3 is the one coincident with the galactic

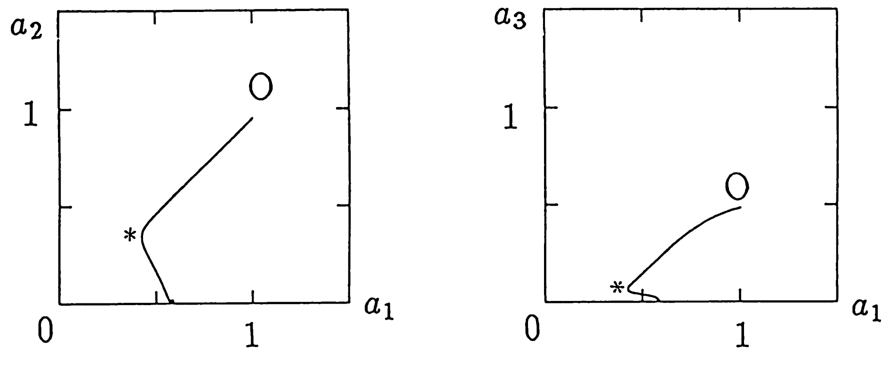

Fig. 1. Elongation and flattening of a contracting homogeneous gaseous ellipsoid.

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axis. The gaseous ellipsoid, which was circular initially, elongates quickly at $*$s where $\rho \geq 20\rho_b$, with ρ and ρ_b the gas density of the ellipsoid and the background matter density $(A+B+C)/2\pi G$. The direction of the major axis of the ellipsoid (a_1 in figure 1) is not parallel to that of the background bar potential of $(B-A)/A = 0.1$: The ellipsoidal configuration rotates freely against the background bar-potential.

2. Large-Scale Fragmentation of Elongated Gas Cloud at the Galactic Center

When the nonaxisymmetric contraction proceeds beyond the point $*$ in figure 1 where $\rho > 20\rho_b$, the gaseous ellipsoid spins up and is ever more dynamically subject its gravity and rotation. Then the third-order (pear-shaped) perturbation grows when $a_2/a_1 < 0.33$ (Chandrasekhar 1969), leading to a large-scale fragmentation (fission) of the elongated cloud. Since the density ratio ρ/ρ_b and the axis ratios of the molecular clouds at the centers of IC342 (Lo et al. 1984), NGC6946 (Ball et al. 1985) and Maffei 2 (Ishiguro et al. 1989) exceed these theoretical values, the dumbbell-like distribution of ^{12}CO (J=1-0) line intensity would be due to the fission of high-density, $(10^2-10^3)H_2$ cm^{-3}, gas clouds accreted onto and elongated at the galactic center.

3. Numerical Simulation for the Fission of Elongated Gaseous Cloud

In order to see the fission of the elongated gas cloud in figure 1, we use a fluid-particle simulation for following the motion of gaseous component (Fujimoto, Tatematsu and

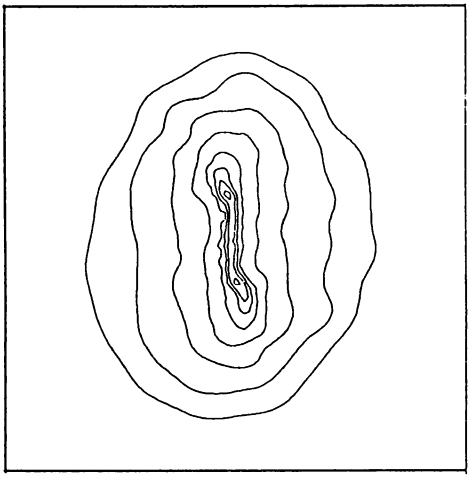

Figure 2

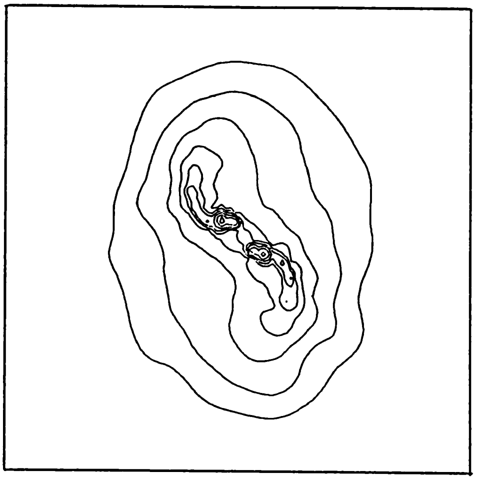

Figure 3

Fig.2. Shocked condensation of gas along the bar-like potential. Note that this potential is due to the self-gravity of the gas.

Fig.3. Fission of the elongated gas cloud.

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Miyama 1990). Figure 2 shows that when gas crosses over the major axis of the elongated cloud, it hits the bar-like potential and is compressed as a shock wave along the major axis. Although the background gravitational force stabilizes the gas cloud, the self-gravity due to the strongly compressed gas becomes dominant to divide it into two objects (figure 3). As the contraction proceeds in each fragment, it becomes a gravitationally more bound object and spins up due to the local conservation of angular momentum.

4. Inflow of Gas Clouds into the Galactic Nucleus

When the fission proceeds and each fragment condenses into a more-bound object, it moves as a ballistic particle in the background potential Φ. Since the fragment mass, M_f, is $(10^7 - 10^8)M_\odot$, the dynamical friction due to the background stars, η, is so large that it spirals in towards the center. The decay time, τ, of the orbital motion or the dynamical lifetime of the fragment is estimated as

$$\tau \sim \frac{1}{\eta}$$
$$\sim 2.5 \times 10^7 \left(\frac{r}{1\ kpc}\right)^3 \left(\frac{M_f}{10^8\ M_\odot}\right)^{-1} \left(\frac{\Omega}{100\ km\ s^{-1}\ kpc^{-1}}\right) yr$$

where $\Omega \sim \sqrt{2A}$ is the angular velocity of the rigid rotation curve of the galactic center. Thus the supply of mass to the center is estimated as $M_f/\tau \sim 1 M_\odot$ yr^{-1}.

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