FISSION OF A MASSIVE ELONGATED GAS CLOUD ROTATING AT THE GALACTIC CENTER

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ABSTRACT. A uniform gaseous ellipsoid in external force field is applied as a dynamical model for massive gas cloud rotating at the galactic center of deep gravitational potential. An initially oblate ellipsoid elongates and rotates end-over-end when its contraction proceeds and the gas density becomes more than twenty times as large as the background matter density. A condition for third-order (pear-shaped) deformation of the gaseous cloud is easily satisfied, suggesting its split into two parts, separated on diametrically opposite sides of the center. Numerical simulations were made to confirm the fission: The two symmetric peaks observed in the ^{12}CO (J=1-0) gas cloud on the galactic center (IC342, NGC6946, and Maffei 2) seem to be the result of the elongation and subsequent fission of a massive (10^7 to $10^8 M_\odot$) high-density (10^2 to 10^3 H_2cm^{-3}) gas cloud accreted onto the galactic center.

1. Gravitational Contraction of Gaseous Ellipsoid Rotating at the Galactic Center

A self-gravitating uniform gaseous ellipsoid rotates in the background potential well $\Phi = AX^2 + BY^2 + CZ^2$, where A, B, and $C > 0$, and X, Y, and Z denote the external coordinates referred to the galactic center (Tatematsu and Fujimoto 1990; Fujimoto et al. 1990). The origin $X = Y = Z = 0$ coincides with that of the ellipsoid. When Φ of $A \neq B$ rotates slowly, it represents a bar-like background potential. Figures 1 shows the elongation and flattening of a gaseous ellipsoid which was initially circular at O: a_1 and a_2 are the principal axes of the ellipsoid on the equatorial plane $Z = 0$ and a_3 is the one parallel to the galactic axis. The elongation develops at *s when the density of the ellipsoid, ρ, becomes twenty times as large as the background matter density, $\rho_b = (A + B + C)/2\pi G$, or when $T/|W|$=0.36, the ratio of the rotation energy to the potential energy which includes partly the background potential Φ. As shown in figure 2, when $\rho \geq 8\rho_b$, the elongated configuration rotates freely independent of the direction of the major axis of Φ.

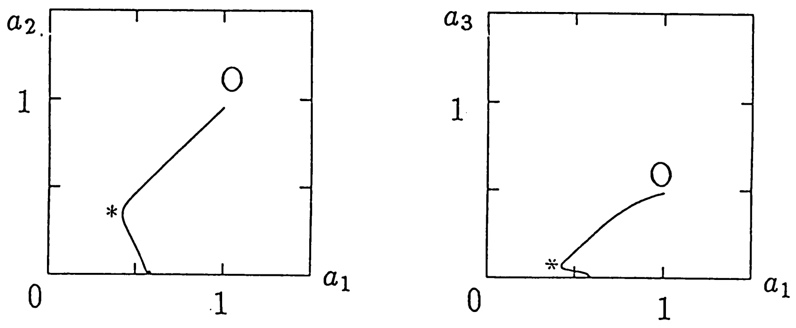

Fig. 1. Elongation and flattening of a contracting homogeneous gaseous ellipsoid.

F. Combes and F. Casoli (eds.), Dynamics of Galaxies and Their Molecular Cloud Distributions, 278–280.

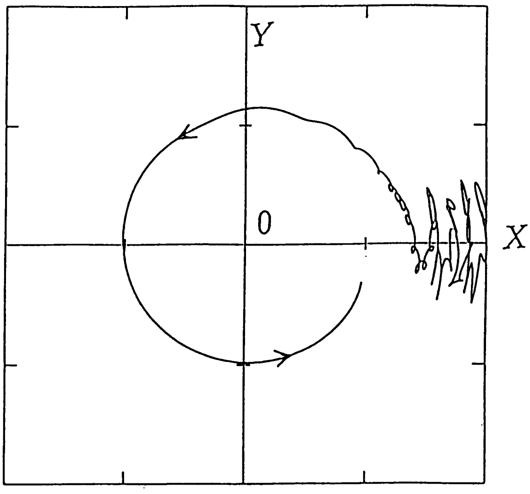

Fig. 2. A locus tracing the outer end of the major axis of a contracting gaseous ellipsoid in the (X, Y) plane. The background bar potential Φ is elongated in the X-direction with $B/A = 1.1$.

2. Fission of Elongated Gaseous Cloud in the Central Region of the Galaxy

When the nonaxisymmetric contraction proceeds beyond the point * in figures 1, the gaseous ellipsoid spins up and is ever more dynamically subject to its gravity and rotation. Then a third-order (pear-shaped) perturbation grows when $a_2/a_1 < 0.33$ (Chandrasekhar 1969), leading to fission of the elongated gas cloud. Since the observed axis ratios of the molecular clouds in the galactic centers exceed these theoretical values (Lo et al. 1984; Ball et al. 1985; Ishiguro et al. 1989), the dumbbell-like distribution of gas or the symmetric peak intensities of ^{12}CO (J=1-0) line on the major axis would be due to the fission of an elongated high-density (10^2 to 10^3 $H_2 cm^{-3}$) gas cloud rotating at the galactic center.

3. Numerical Simulations for Fission of Elongated Gaseous Objects

In order to see the fission of rotating elongated gas cloud, we apply the fluid-particle simulation for the gaseous ellipsoid in figures 1 (Fujimoto, Tatematsu and Miyama 1990). When the elongation proceeds, shock compression occurs in gas along the major axis of its own gravitational potential (Fujimoto and Sørensen 1977). Although the tidal force stabilizes the rotating gas cloud against its deformation, the high density due to the shock becomes gravitationally dominant to divide it into two objects along the major axis (Figure 3).
As the contraction proceeds in each fragment, it becomes gravitationally more-bound system and spins more rapidly due to the conservation of angular momentum. Figure 4 gives the global distribution of the radial velocity to be observed along the major axis joining the two split objects. We observe more-steeply inclined rotation curves in the fragments, superimposed on the globally rigid rotation curve.

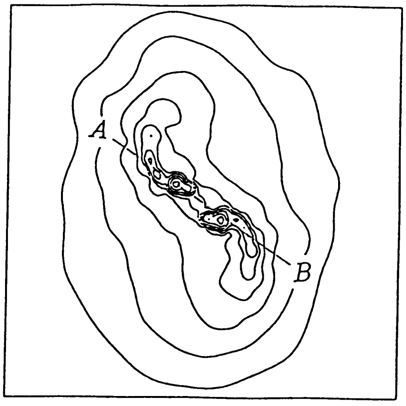

Figure 3

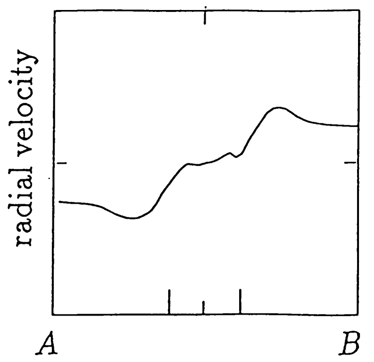

Figure 4

Fig. 3. A particle-fluid simulation for fission of an elongated gas cloud.
Fig. 4. Radial velocity distribution on the line joining the two fission fragments in figure 3.

4. Discussion and Conclusion

We have discussed that the self-gravity and rotation cooperate to elongate the gas cloud and to split it into two objects when the density becomes more than twenty times as large as the background matter density and the axis ratio a_1/a_2 at the elongation exceeds ~ 3. The data concerning the molecular cloud at the centers of IC342 (Lo et al. 1984), NGC6946 (Ball et al. 1985) and Maffei 2 (Ishiguro et al. 1989) satisfy these conditions: We can make a dynamical model in which a massive gas cloud accreted to the galactic center rotates, contracts and then elongates by its own gravity and splits into two objects. When the fission proceeds and each fragment condenses to a gravitationally bound object, it spirals in toward the center due to dynamical friction caused by the background stars and supplies a large amount of gas to the nucleus within a very short time of 10^7 yrs.

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