Dark Matter in Galaxies
IAU Symposium, Vol. 220, 2004
S.D. Ryder, D.J. Pisano, M.A. Walker, and K.C. Freeman, eds.

Nuclear Spirals and Supermassive Black Holes

H. B. Ann and Parijat Thakur

Division of Science Education, Pusan National University, Busan 609-735, Korea

Abstract. We have performed SPH simulations for the response of the gaseous disks to the imposed potentials including those from bars and SMBHs. Evolution of the nuclear regions of gaseous disks depends critically on the masses of SMBHs as well as the sound speed in the gas.

1. Introduction

Nuclear spirals are known to be preponderant in active galaxies (Regan & Mulchaey 1999; Martini et al. 2003). They have a variety of morphologies, from the grand-design symmetric two-armed spirals to chaotic ones (Martini et al. 2003). The flocculent nuclear spirals are considered to be formed by the acoustic instability proposed by Montenegro, Yuan, & Elmegreen (1998), whereas the grand-design nuclear spirals are thought to be formed by the hydrodynamical instability caused by the gas inflow driven by the non-axisymmetric potentials (Englmaier & Shlosman 2000).

It is well known that the response of a gaseous disk to the imposed non-axisymmetric potentials depends not only on the potential shape of the model galaxy but also on the hydrodynamic properties of the gaseous disk (Ann & Lee 2000; Englmaier & Shlosman 2000; Maciejewski et al. 2002). However, the effects of Supermassive Black Holes (SMBH) on the gas flow inside the ILRs have not been studied much. Here, we present some results of numerical experiments including SMBH for the formation of nuclear spirals, based on smoothed particle hydrodynamics (SPH).

2. Models and Numerical Methods

We have assumed that a barred galaxy is made up of three stellar components (bulge, disk, bar) and two dark ones (SMBH, halo). We adopt simple analytic forms for the potential generated by each component. The properties of all the potential generating components are assumed to be invariant in time. We considered mass models which are thought to resemble early type galaxies ($\sim$ SBa) by assuming bulge-to-disk mass ratios of 0.5. We assumed a strong bar which has the fractional mass of 0.2 and the axial ratio (a/b) as 3. The bar rotation period is 1.4×10^8 years. We assumed the gas to be isothermal but we explored the effect of gas temperature by varying the sound speed of the gas. We adopted $\alpha = 1.0$ and $\beta = 2.5$ for the artificial viscosity coefficients. The self-gravity of gas was also included.

https://doi.org/10.1017/S0074180900183482 Published online by Cambridge University Press

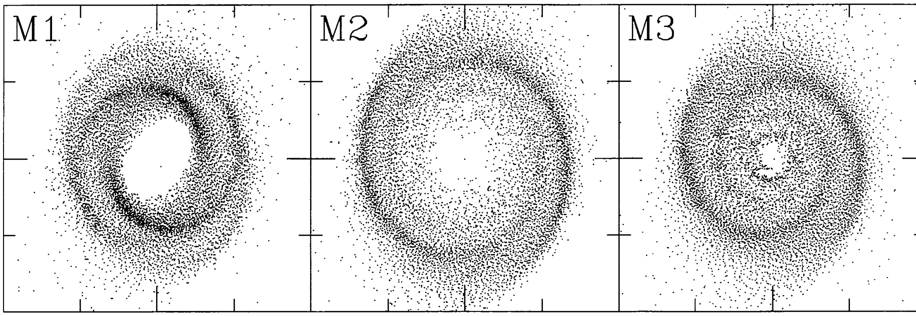

Figure 1. Snapshots of the evolution of gaseous disks at 20 bar rotations. The box size is 2 kpc in one dimension.

3. Results and Discussion

Fig. 1 shows snapshots of the evolution of the nuclear regions of gaseous disks at the evolution time of 20 bar rotations. The three models have the same mass distributions except for the central SMBHs. The model M1 has no SMBH, while the other two models (M2, M3) have a SMBH whose mass is about 1% of the total mass of the visible components (disk, bulge and bar) but different sound speeds assumed in the gas; 10 km/s for M2 and 15 km/s for M3. The sound speed in the gas of M1 model is the same as that of the model M2.

As shown clearly in Fig. 1, the nuclear regions of the gaseous disk of M1 model evolves to leading spirals between the IILR and OILR, whereas those of M2 and M3 develop trailing spirals whose detailed shapes depend on the sound speeds in the gas. The cold gaseous disk assumed in the model M2 shows ring-like spirals, while the hot gaseous disk of the model M3 shows tightly wound spirals whose innermost parts reach close to the center. Thus, it seems quite clear that the tightly wound trailing nuclear spirals can be developed in the hot interstellar medium when there is a SMBH whose mass is large enough to remove the IILR. This is the reason why nuclear spirals are frequently observed in active galaxies.

Acknowledgments. This work has been supported in part by the ARC-SEC. The computations are conducted using the facilities of KISTI.

References

Ann, H.B., & Lee, H.M. 2000, JKAS, 33, 1

Englmaier, P., & Shlosman, R.S. 2000, ApJ, 528, 677

Maciejewski, W, Teuben, P.J., Sparke, L.S., & Stone, J.M. 2002, MNRAS, 329, 502

Martini, P., Regan, M.W., Mulchaey, J.S., & Pogge, R.W. 2003, ApJ, 146, 353

Montenegro, L.E., Yuan, C., & Elmegreen, B.G. 1999, ApJ, 520, 592

Regan M.W., & Mulchaey J.S., 1999, AJ, 117, 2676

https://doi.org/10.1017/S0074180900183482 Published online by Cambridge University Press