The Interplay among Black Holes, Stars and ISM in Galactic Nuclei
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Formation of obscuring clouds by circumnuclear Starbursts

Y. Watabe[1] **and M. Umemura**[1]

[1]Center for Computational Science, University of Tsukuba, Ten-nodai, 1-1-1 Tsukuba, Ibaraki 305-8577, Japan, JP email: watabe@rccp.tsukuba.ac.jp

Abstract. We pursue the dynamics of dusty gas clouds that are blown out of circumnuclear starburst regions, taking into consideration the growth of clouds by inelastic cloud-cloud collision and the resultant change of the optical depth. As a result, we find that the clouds originating in the circumnuclear starburst can contribute to the obscuration to produce type 2 Seyfert galaxies. Also, it is shown that, if the AGN luminosity overwhelms the starburst one, almost all clouds are ejected from the galaxy by the radiation pressure of the AGN, resulting in the formation of quasar-like objects.

1. Introduction

Recent observations on circumnuclear regions of AGNs have gradually revealed that Seyfert 2 galaxies are more frequently associated with starbursts than Seyfert 1 galaxies (Heckman et al. 1989). In contrast, quasars are mostly observed as type 1 AGNs, regardless of the star formation activity in their galaxies (Solomon et al. 2004). It seems beyond understanding based on the picture of the unified model in which the dichotomy is caused by the orientation toward the nuclear surrounded by an obscuring torus.

Ohsuga & Umemura (2001) have obtained the equilibrium configuration of dusty gas around an AGN accompanied by a circumnuclear starburst, taking the radiation force into account. However, the origin of the dusty gas and the dynamical behavior of the gas have not been considered. Recently, Wada & Norman (2002) have solved the dynamical evolution of the gas ejected from the starburst region. But, their simulations have not included the radiation force by the starburst as well as an AGN, which make a noticeable component of force on the dusty gas. In this paper we examine the dynamics of gas clouds that are blown out through starburst-driven superbubbles in circumnuclear starburst regions, including the radiation force by a starburst as well as an AGN. We solve the radiative transfer for dusty clouds, taking into account the change of cloud size and optical depth by inelastic cloud-cloud collisions.

2. Model : Radiation, gravitatinal fields and gas clouds

Recent high-resolution observations of Seyfert nuclei have established circumnuclear starburst regions, which frequently exhibit ring-like features (Pogge 1989). Here, we assume the starburst region has a ring configuration. The duration of the star formation is assumed to be 10^7yr (Efstathiou et al. 2000). Also, as another radiation source, we consider an AGN. As for the gravitational fields, we consider the starburst ring, the central black hole and the bulge. Dusty gas clouds are postulated be blown out from the starburst ring at a given mass loss rate. We assume that the cloud-cloud collisions are inelastic and the density of the cloud is constant after the collision. When the gas cloud radius is over the Jeans radius, we regard the gas cloud as collapsing cloud, which cannot contribute to the obscuration.

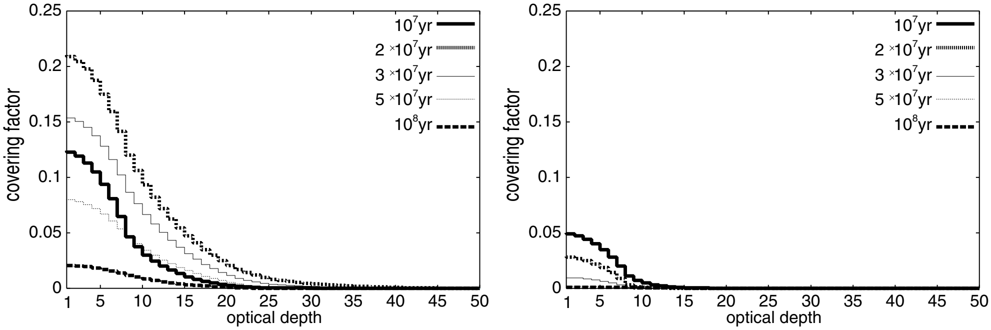

Figure 1. The covering factor of the area whose line-of-sight optical depth is greater than a given optical depth in the horizontal axis. The left panel shows the results for $L_{\rm AGN} = 10^{10}{\rm L}_\odot$, while the right panel is for $L_{\rm AGN} = 3 \times 10^{11}{\rm L}_\odot$. The evolution of the covering factor is shown at 1, 2, 3, 5, and 10 $\times 10^7$ yr.

3. Results and Summary

Figure 1 shows the time evolution of covering factor. We regard an AGN as obscured if the line-of-sight optical depth is greater than unity. The left panel in Fig. 1 shows the results for $L_{\rm AGN} = 10^{10}{\rm L}_\odot$ (left figure), which is lower than the starburst luminosity until $\sim 3 \times 10^7$ yr. In this case, at $\sim 10^7$ yr, gas clouds are accelerated by the radiation pressure of the starburst, the covering factor for obscuration becomes $\sim 13\%$. At $\sim 2 \times 10^7$ yr, gas clouds with large optical depth are formed by cloud-cloud collisions and they fall back owing to the reduced radiation pressure per unit mass. The large gas clouds eventually are distributed around the equatorial plane, the covering factor becomes a maximum as $\sim 20\%$. After that, most of the gas clouds fall back as the luminosity of starburst declines. In this phase, since many gas clouds repeat collisions, some of their radius are beyond the Jeans radius. Thus the number of gas clouds that can obscure the AGN decreases.

On the other hand, when $L_{\rm AGN} = 3 \times 10^{11}{\rm L}_\odot$ (right figure), the luminosity is close to the Eddington luminosity for the total mass of the galaxy. Hence, the dusty gas clouds are rapidly accelerated and ejected from the galaxy by the radiation pressure of the AGN, so that most of the gas clouds cannot contribute to the obscuration of the AGN. Eventually, the covering factor becomes very low and takes a maximum $\sim 5\%$ at 10^7 yr. This AGN-dominant case may correspond to quasars.

The present results are summarized as follows: In the starburst-dominant case, the gas clouds can obscure the AGN, so that the type of AGN is divided into two, type 1 and 2. This corresponds to Seyfert-like galaxies. On the other hand, in the AGN-dominant case, most gas clouds are blown out by the radiation pressure of the AGN. So the AGN is almost always observed as a type 1. This corresponds to quasar-like objects.

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