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Regulation of AGN Type by Circumnuclear Starburst; Formation of Radiatively-Supported Obscuring Wall

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Abstract. Recently, a novel picture is suggested to explain the starburst-AGN type connection, whereby the dusty obscuring walls which are supported by the circumnuclear starburst radiation as well as the AGN radiation obscure the nucleus and regulates the AGN type. Based on this picture and by discussing about the timescales, we study the time evolution of the circumnuclear structure which is regulated by the radiation force. Also, we estimate the supplied mass to the obscuring walls. As a result, the dusty gas can be supplied by superbubbles in the circumnuclear regions in the early evolutionary stage, $\sim 10^7$ yr, and it builds up a gas wall after the superbubbles cool down. Then, the A_V of the outer obscuring wall is estimated to be only a few from the mass supply rate by the superbubbles, whereas the inner obscuring wall is allowed to be very optically-thick, $A_V \sim$ several to 10. Finally, the walls disappear due to the dilution of the starburst luminosity. Therefore, the AGN is destined to evolve from type 2 AGN to type 1 AGN within several 10^7 yr in this picture. This mechanism may provide a physical explanation for the correlation between AGN type and host properties whereby Seyfert type 2 galaxies are more frequently associated with circumnuclear starbursts than type 1 galaxies.

1. Introduction

The connection between starburst and type of Seyfert galaxy is one of the most hotly debated issues. Recent observations have revealed that Seyfert 2 galaxies are more frequently associated with the circumnuclear starbursts than type 1's (Heckman et al. 1989; Maiolino et al. 1995, 1997, 1998a; Pérez-Olea & Colina 1996; Hunt et al. 1997; Storchi-Bergmann, Schmitt, & Fernandes 1999; Storchi-Bergmann et al. 2000; González Delgado, Heckman, & Leithere 2001). On the other hand, quasars (QSOs) are mostly observed as type 1, although the QSO hosts often exhibit vigorous star-formation activity (McLeod & Rieke 1995b; Bahcall, Kirhakos, & Saxe 1997; Hooper, Impey, & Foltz 1997; Brotherton et al. 1999). Such tendency seems beyond understanding based upon the picture of the unified model where the bifurcation of AGN type is simply accounted for the orientation of the nucleus surrounded by an obscuring torus.

Recently, Ohsuga & Umemura (1999) have shown that the radiation force by the circumnuclear starburst as well as the AGN plays an important role on the distribution of the dusty gas. Also, Ohsuga & Umemura (2000) have concluded that the optically-thick walls form and obscure the nucleus. In this paper, based on the novel picture suggested by Ohsuga & Umemura (2000), we reconsider that the circumnuclear structure and its time-evolution, which predicts the starburst-AGN type connection.

2. Evolution of circumnuclear structure

<u>Timescales</u>

In Ohsuga & Umemura (2000), assuming an AGN and a circumnuclear starburst ring, they calculated the radiation force and the gravity in circumnuclear regions, and explored the formation of obscuring walls which are stabilized by starburst radiation. As a result, it is found that an inner wall of several ten parsecs and an outer wall of several hundred parsecs enshroud the nucleus in the case of a luminous starburst and a relatively faint AGN. Here, the dynamical timescale of the inner and outer wall are $t_{\rm inner} \sim 5\times10^5{\rm yr}(r_{\rm inner}/100{\rm pc})^{3/2}(M_{r<r_{\rm inner}}/10^9 M_\odot)$, and $t_{\rm outer} \sim 5\times10^6{\rm yr}(r_{\rm outer}/1{\rm kpc})^{3/2}(M_{r<r_{\rm outer}}/10^{10} M_\odot)$, respectively. The lifetime of a superbubble is estimated as of order $\sim 10^7$ yr (Norman & Ikeuchi 1989). Also, gas walls can be stabilized by the strong starburst radiation. In other wards, walls are built up when the starburst is young and luminous, whereas walls are destined to disappear due to the evolution of the starburst luminosity. Assuming the initial mass function to be Salpeter-type and the starformatin rate to be $\propto \exp(-t/10^7{\rm yr})$ in addition to the mass-luminosity relation, $(l_*/L_\odot) = (m_*/M_\odot)^{3.7}$, and the mass-age relation, $\tau = 1.1\times10^{10}{\rm yr}(m_*/M_\odot)^{-2.7}$, where m_* and l_* are respectively stellar mass and stellar luminosity, we estimate the lifetime of the walls. It is found that the walls are supported by the starburst radiation within 10^8 yr. By comparing the timescales, the ejected gas due to

superbubbles is supported radiatively, and the nucleus is obscured by the walls after the superbubbles cool down.

Mass supply to obscuring walls by superbubbles

In Ohsuga & Umemura (2000), the extinction A_V of the walls depends on the mass-to-luminosity ratio of the starburst ring, and it is allowed to be several to 10 if the simple stellar relations are employed. Then, the mass of the dusty gas which composes the inner wall, $M_{\rm inner-wall}$, is $\sim 10^5 A_V M_\odot$, whereas the outer wall consists of the dusty gas with $M_{\rm outer-wall} \sim$ several $10^7 A_V M_\odot$. Here, to assess the blown-out mass onto the regions of several hundred parsecs hight, we employ the mass supply rate due to the superbubbles which is estimated by Norman & Ikeuchi (1989). As a result, the mass supply rate is several $10 M_\odot {\rm yr}^{-1} (M_{\rm SB}/10^9 M_\odot)$, where $M_{\rm SB}$ is the mass of the starburst ring. In a nearby Seyfert2/LINER galaxy, NGC3079, the nuclear superbubble is actually observed. Duric & Seaquist (1988) and Veilleux et al. (1994) evaluated the mass supply rate to be $\gtrsim 10 M_\odot\,{\rm yr}^{-1}$ and $\sim 7 M_\odot\,{\rm yr}^{-1}$, respectively. Since the lifetime of the superbubble is about 10^7 yr, the dusty gas of about $10^8 M_\odot$ are supplied for formation of the walls. The supplied mass is $\gg M_{\rm inner-wall}(A_V = 1)$ but $\sim M_{\rm outer-wall}(A_V = 1)$. Hence, the inner wall would be heavily optically-thick, $A_V \gtrsim$ several $-$ 10, although the outer wall is allowed to become only $A_V \sim$ a few.

Time evolution of AGN type

As discussed so far, in the early evolutionary stage, $\sim 10^7$ yr, a large amount of dusty gas is blown out by superbubbles in circumnuclear starburst regions. Subsequently, such gas is supported by the radiation force, and the nucleus is obscured by an inner wall of $A_V \gtrsim$ several as well as an outer wall of $A_V \sim$ a few. Then, the AGN is observed as a type 2 AGN which is accompanied by luminous starbursts. Finally, the walls disappear due to stellar evolution in the circumnuclear regions, so that we observe the AGN as type 1. To conclude, the AGN tends to evolve from type 2 to type 1 within several 10^7 yr. However, it is found that no wall forms in the case of the luminous nucleus like QSOs. Therefore, QSOs are identified as type 1 regardless of the age of the starburst.

3. Conclusions and discussion

In the present picture, the Seyfert nucleus which is accompanied by circumnuclear starbursts is obscured by obscuring walls of total $A_V \sim$ several to 10. The walls disappear due to the evolution of starburst luminosity, so that the AGN type of a Seyfert galaxy is destined to shift from type 2 to type 1 within several 10^7 yr. On the other hand, the strong radiation force by the nucleus prevents the formation of the walls. These results provide a physical explanation for the correlation between AGN type and host properties whereby Seyfert type 2 galaxies are more frequently associated with circumnuclear starbursts than type 1 galaxies, whereas QSOs are mostly observed as type 1 even though vigorous star-forming activities are often observed in the host galaxies.

Absorbing column density by X-ray observations

By IR or optical observations, A_V of the nuclear or circumnuclear regions is estimated to be between a few and several (Rix et al. 1990; Roche et al. 1991; Goodrich, Veilleux, & Hill 1994; McLeod & Rieke 1995a; Oliva, Marconi, & Moorwood 1999), and A_V of the obscuring walls is consistent with the such observational data. However, it has revealed that many Seyfert 2 nuclei are heavily obscured along line of sight by X-ray observations. The mean absorbing column density in Seyfert 2 nuclei are reported to be $10^{23.5}{\rm cm}^{-2}$ and a few tens % or a half of sources to be Compton thick, $> 10^{24}{\rm cm}^{-2}$ (Bassani et al. 1999; Risaliti, Maiolino, & Salvati 1999), thus it implies $A_V \gg 100$. Granato, Danese, & Franceshini (1997) has concluded that the X-ray absorption in type 2 AGNs is due to matter free from dust, located at inside the dust sublimation radius of subparsec and flowing toward the accretion disk, from analysis of IR and X-ray data combined with their numerical calculations. Therefore, it is expected that the nucleus is obscured by dusty obscuring walls and the matter free from dust of subparsec scale. However, it is beyond scope of this paper. In this paper, we provide the physical mechanism which explains the obscuration by the dusty gas, $A_V \sim 10$.

References

Bahcall, J. N., Kirhakos, S., & Saxe, D. H. 1997, ApJ, 479, 642
Bassani, L., Dadina, M., Maiolino, R., Salvati, M., Risaliti, G., della Ceca, R., Matt, G., & Zamorani, G. 1999, ApJS, 121, 473
Brotherton, M. S., van Breugel, W., Stanford, S. A., Smith, R. J., Boyle, B. J., Miller, L., Shanks, T., Croom, S. M., & Filippenko, A. V. 1999, ApJ, 520, L87
Duric, N. & Seaquist, E. R. 1988, ApJ, 326, 574
González Delgado, R. M., Heckman, T., & Leitherer, C. 2001, ApJ, 546, Jan 10 issue
Goodrich, R. W., Veilleux, S., Hill, G. J. 1994, ApJ, 422, 521
Heckman, T., Blitz, L., Wilson, A., Armus, L., & Miley, G. 1989, ApJ, 342, 735
Hooper, E. J., Impey, C. D., & Foltz, C. B. 1997, ApJ, 480, L95
Hunt, L. K., Malkan, M. A., Salvati, M., Mandolesi, N., Palazzi, E., & Wade, R. 1997, ApJS, 108, 229
McLeod, K. K. & Rieke, G. H. 1995a, ApJ, 441, 96
McLeod, K. K. & Rieke, G. H. 1995b, ApJ, 454, L77
Maiolino, R., Krabbe, A., Thatte, N., & Genzel, R. 1998a, ApJ, 493, 650
Maiolino, R. & Rieke, G. H. 1995, ApJ, 454, 95
Maiolino, R., Ruiz, M., Rieke, G. H., & Papadopoulos, P. 1997, ApJ, 485, 552

Norman, C. A. & Ikeuchi, S. 1989, ApJ, 345, 372
Ohsuga, K. & Umemura, M. 1999, ApJ, 521, L13
Ohsuga, K. & Umemura, M. 2000, submitted
Oliva, E., Marconi, A., & Moorwood, A. F. M. 1999, A&A, 342, 87
Pérez-Olea, D. E. & Colina, L. 1996, ApJ, 468, 191
Risaliti, G., Maiolino, R., & Salvati, M. 1999, ApJ, 522, 157
Rix, H.-W., Rieke, G., Rieke, M., & Carleton, N. P. 1990, ApJ, 363, 480
Roche, P. F., Aitken, D. K., Smith, C. H., & Ward, M. J. 1991, MNRAS, 248, 606
Storchi-Bergmann, T., Schmitt, H. R., & Fernandes, R. C. 1999, in IAU Symposium No. 194, Activity in Galaxies and Related Phenomena, ed. Y. Terzian, E. Khachikian, & D. Weedman (San Francisco: ASP), 295
Storchi-Bergmann, T., Raimann, D., Bica, E. L. D., & Fraquelli, H. A. 2000, ApJ in press (astro-ph/0007027)
Veilleux, S., Cecil, G., Bland-Hawthorn, J., Tully, R. B., Filippenko, A. V., & Sargent, W. L. W. 1994, ApJ, 433, 48