PUBLICATIONS OF THE KOREAN ASTRONOMICAL SOCIETY
3: 179 ~183

EVOLUTION OF ACTIVE GALACTIC NUCLEI BASED ON THE UNIFIED THEORY

SEOK JAE PARK
Korea Astronomy Observatory
AND
ETHAN T. VISHNIAC
University of Texas at Austin, U. S. A.
(Received Oct. 15, 1993)

ABSTRACT

We analyze the evolution of active galactic nuclei for the decreasing accretion rate case. Our analysis is based on the unified theory of active galactic nuclei which entirely depends on the accretion rates of the central supermassive black holes. Our discussion leads us to conclude that active galactic nuclei may evolve from QSOs into the nuclei of Seyfert or radio galaxies.

I. INTRODUCTION

Active galactic nuclei (hereafter, AGNs) have various features from the most luminous QSOs to nuclei of the radio galaxies (see e.g., Weedman 1987). Several attempts to establish the unified theory for all the AGNs have been made during the last decade.

One of the most successful attempts was the theoretical model based on various accretion rates of the central black hole, established by Begelman (1985) and Blandford (1985) independently. In this theory the accretion of the black hole determines the type of an AGN. If the accretion is large enough that explains the observed spectra of QSOs and if small those of nuclei of radio galaxies.

Based on this unified theory we analyze the evolution of active galactic nuclei for the decreasing accretion rate case.

II. ANALYSIS AND DISCUSSION

According to the unified theory the dimensionless quantity $\dot{m}$ defined by

$$\dot{m} \equiv \frac{\dot{M}}{\dot{M}_E} \tag{1}$$

governs the structure of the AGN. Here $\dot{M}$ is the usual mass accretion rate of the central supermassive black hole and $\dot{M}_E$ is the Eddington accretion rate defined by

$$\dot{M}_E \equiv \frac{L_E}{c^2}, \tag{2}$$

where L_E is the Eddington luminosity and c is the speed of light.

If $\dot{m}$'s are close to zero AGNs have ion tori at their centers and that accounts for the nuclei of radio galaxies whose spectra are dominated by synchrotron radiation. If $\dot{m}$'s are close to or greater than unity then AGNs have radiation tori and that accounts for the QSOs whose spectra are dominated by thermal radiation. The values between null and unity are related to the spectra of the nuclei of Seyfert or BL Lacertae galaxies.

The unified theory, therefore, means that an AGN also must change the observational feature if $\dot{m}$ changes throughout its lifetime. For example, if $\dot{m}$ of an AGN has the initial value equal to or greater than unity and rapidly decreases as time goes by then the AGN must seem to be born as a QSO and evolve into a nucleus of a radio galaxy.

This is plausible if the central black hole was formed through a violent process like the gravitational collapse of a dense stellar cluster. In this case it is reasonable to suppose that the surrounding galactic nucleus becomes more dynamically stable as it ages and $\dot{M}$ consequently decreases.

The decrease of $\dot{M}$ has been analyzed by Park and Vishniac (1988, 1990 hereafter PV) based on the several observed features of AGNs. The power P extracted through the electrodynamic torque from the black hole and the accretion disk is given by (eq. [4.50] in Thorne et al. 1986)

$$P \sim 10^{45} \text{ ergs s}^{-1} \left(\frac{a}{M}\right)\left(\frac{M}{10^9 M_\odot}\right)^2 \left(\frac{B}{10^4 \text{ gauss}}\right)^2, \tag{3}$$

where a is the ratio of the angular momentum of the black hole to its mass, M is the mass of the hole, and B is the strength of the hole magnetic field.

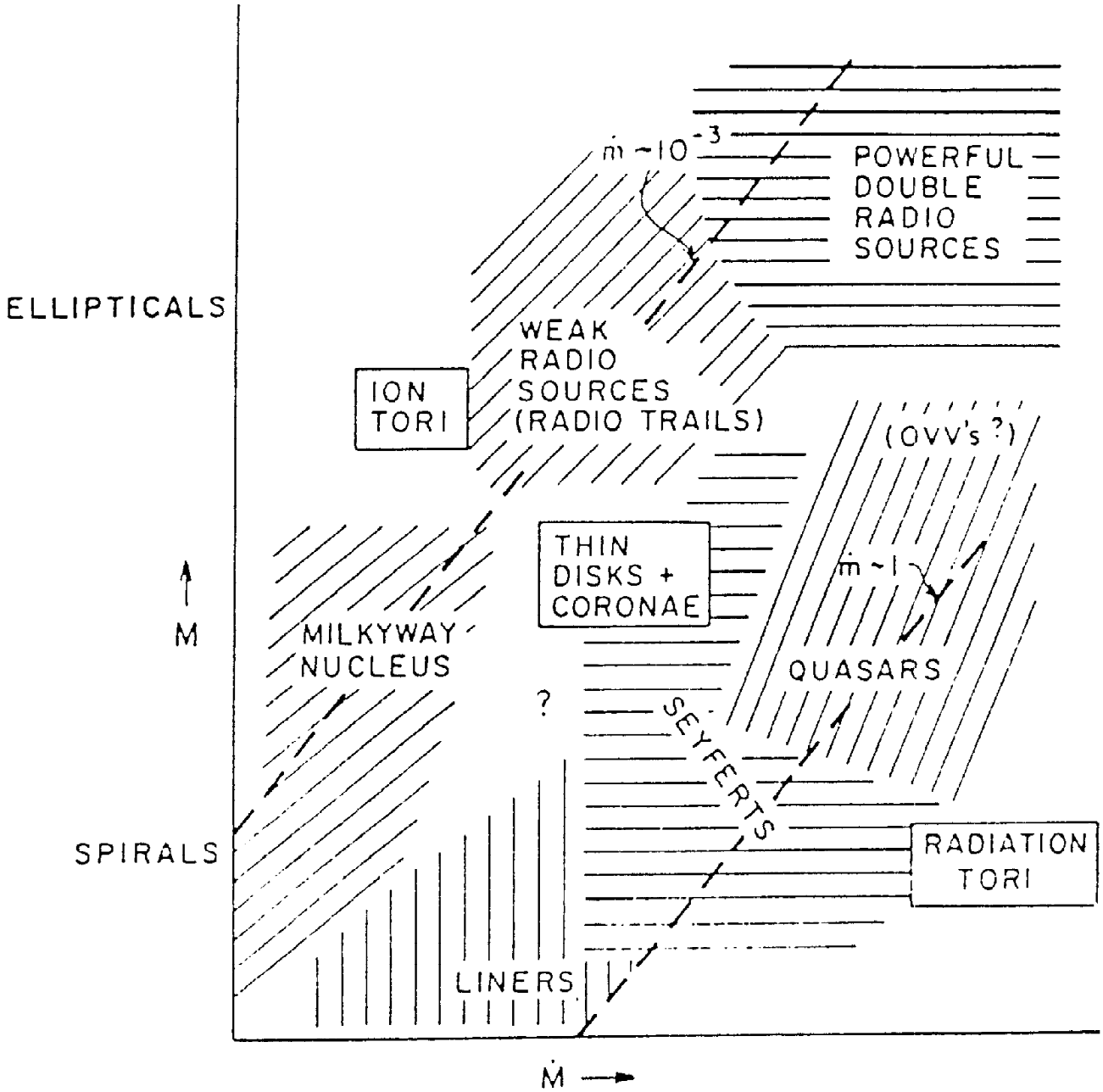

Fig. 1. A two-dimensional unified AGN scheme(adapted from Begelman 1985)

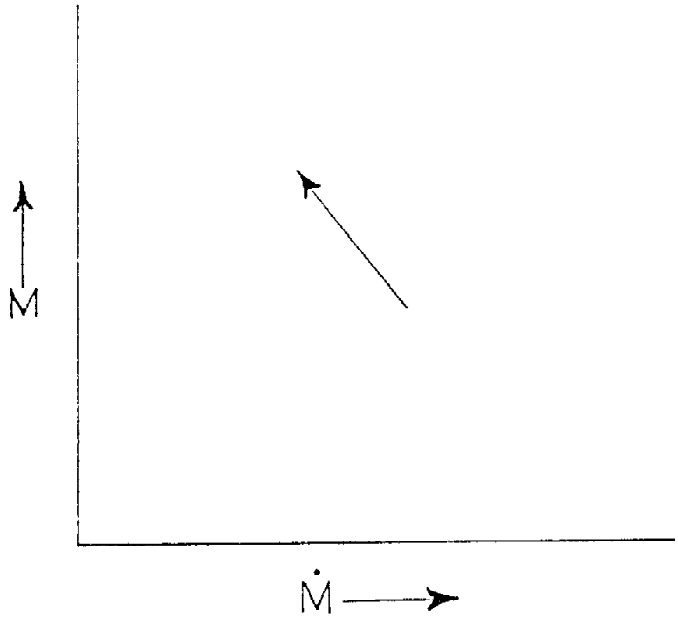

Fig. 2. A probable evolutionary track of AGNs

PV also show that if P is dominant throughout the lifetime t of an AGN then $\dot{M}$ may exponentially decrease as

$$\dot{M} \sim \dot{M}(0)e^{-\lambda t} \tag{4}$$

where $\dot{M}(0)$ is the certain initial value of $\dot{M}$ and λ is a positive number between $1.6\times10^{-17}\,s^{-1}$ and $2.1\times10^{-16}\,s^{-1}$.

The observational results of QSO statistics shows that the number of QSOs increases with the redshift z (see Weedman 1987). This tells us that QSOs may be the typical feature of galactic nuclei at the early epoch of the universe. As time goes by QSOs may lose their luminosities and finally evolve even into the nuclei of normal galaxies. Then why do we observe only few thousands of QSOs so far? Eq. (3) gives the answer for this question; AGNs only which have central black holes more massive than $\sim10^9 M_\odot$ are luminous enough.

If our scenario is correct our galaxy which may possess a $\sim10^6 M_\odot$ black hole at the center, therefore, never had a chance to be a luminous QSO in the beginning of the universe.

This manuscript was presented in the workshop *Supernovae and Galactic Evolution* held at Korea Astronomy Observatory in August 1992 by the Department of Astronomy and Space Science, Chungnam National University. It was supported in part by the Basic Research Project 93-5200-004 of the Ministry of Science and Technology through Korea Astronomy Observatory.

REFERENCES

Begelman, M. C. 1985, in Astrophysics of Active Galactic Nuclei and Quasi-Stellar Objects, ed. Miller, J. S.(Mill Valley: Univerity Science Books) p. 411

Blandford, R. D. 1985, in Active Galactic Nuclei, ed. Dyson, J.(Manchester: Manchester Univerity Press) p. 281

Park, S. J. and Vishniac, E. T. 1988, ApJ, 332, 135

---------- 1990, ApJ, 353, 103

Thorne, K. S., Price, R. H., and Macdonald, D. A. 1986, Black Holes: The Membrane Paradigm(New Haven: Yale Univerity Press)

Weedman, D. W. 1987, Quasar Astronomy(Cambridge: Cambridge Univerity Press)