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A NEW FORMATION MECHANISM OF NUCLEAR STARBURSTS

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RESUMEN

Se presenta un mecanismo de formación de "starbursts" nucleares basado en la idea de que estos eventos son provocados por un par binario de agujeros negros supermasivos, creados en la fase final de un "merger" galáctico. Los eventos menores dan lugar a "starbursts" nucleares y a núcleos de tipo "hot-spot", mientras que los eventos mayores originarían galaxias infrarrojas ultraluminosas.

ABSTRACT

We present a unified formation mechanism of nuclear starbursts based on an idea that all nuclear starbursts are triggered by binary supermassive black holes made in the final phase of galaxy mergers. Minor mergers cause both nuclear starbursts and hot-spot nuclei while major mergers cause ultraluminous infrared galaxies.

Key words: **GALAXIES: ACTIVE — GALAXIES: STARBURST**

1. INTRODUCTION

It has been considered that nuclear starbursts are driven by gas fueling toward the nuclear regions by bar structure or galaxy-galaxy interactions (Shlosman, Begelman, & Frank 1990; Barnes & Hernquist 1992). However, non-barred spirals account for $\simeq$ 50 % of the starburst galaxies (Balzano 1983). Also, only 30 % of the starburst galaxies have companion galaxies (Balzano 1983; Keel & van Soest 1992). It is, therefore, possible that the presence of a bar or an interacting companion may not be a prime mover of the nuclear starbursts. Another possible mechanism for the nuclear starburst is a merger with a satellite galaxy (Gaskell 1985; Hernquist 1989; Mihos & Hernquist 1994a; Hernquist & Mihos 1995). In the previous studies, however, much attention has been given to the importance of gas fueling driven by minor mergers. Recently, Taniguchi, & Wada (1996) proposed that a supermassive black hole binary formed by a merger with a nucleated satellite galaxy triggers intense star formation in the central regions of spiral galaxies in which the nuclear gas disk has already formed by the dynamical effect of the merger itself. They stressed the importance of definite triggering of the starbursts by the supermassive black hole binary relative to that of gas fueling caused by minor mergers. Their scenario is summarized as follows: As the secondary black hole approaches the nuclear gas disk, the gas disk responds to the gravitational perturbation caused by the nonaxisymmetric potential of the black hole binary, forming asymmetrical spiral patterns. This idea explains the genesis of both so-called nuclear starbursts and hot-spot nuclei: when the mass of the secondary black hole is only one tenth of the primary, the gas response is so mild that only pseudo-ring features or tightly wound spiral arms are formed in the circumnuclear region. These features then evolve into several H II-region clumps, leading to the formation of hot-spot nuclei. On the other hand, when the mass of the secondary black hole is comparable to half the primary, a very strong one-arm spiral shock appears after the close passage of the secondary to the primary in each orbital period. The gas clouds are forced to move rapidly into the central region owing to frequent collisions of gas clouds. Since the gas density is high enough to form a dense gas core in the nuclear region, the starburst is triggered near the nucleus. The estimated frequency of the starbursts by minor mergers is almost consistent with the observation ($\simeq$ 1 %). On the other hand, it is known that (ultra)luminous starburst galaxies are associated with major mergers between two gas-rich spiral galaxies (Sanders et al. 1988). Therefore, taking both minor and major mergers into account, we are able to unify the formation mechanism of starbursts from typical nuclear starbursts to ultraluminous ones (hereafter, the AZTECA unified model).

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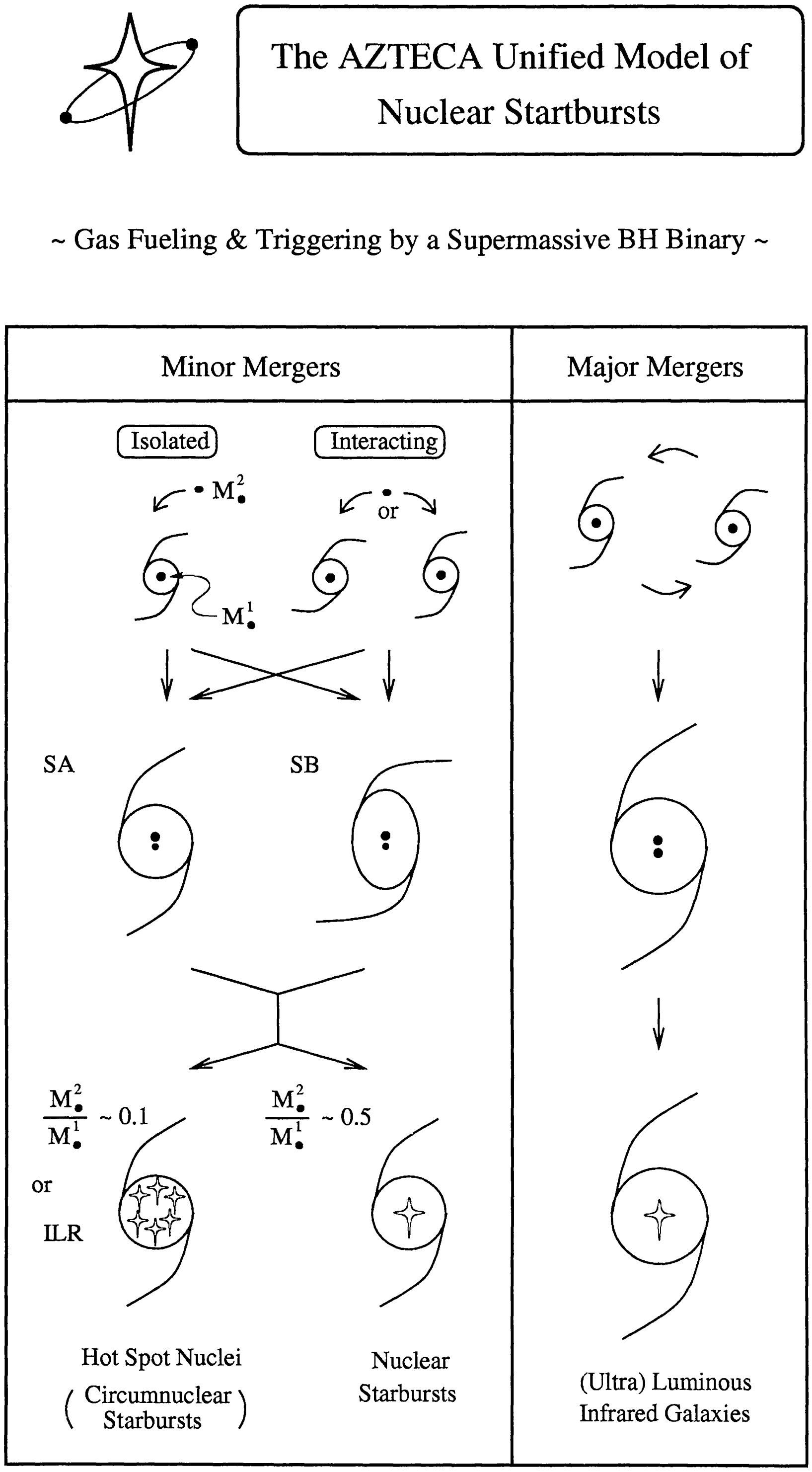

Fig. 1. The AZTECA unified model of the nuclear starbursts.

2. THE AZTECA UNIFIED MODEL OF NUCLEAR STARBURSTS

Here we summarize the merits of the AZTECA unified model of the nuclear starbursts.

- The observed frequency of the nuclear starbursts (a few %) can be explained solely by minor merger events with nucleated satellite galaxies (Taniguchi & Wada 1996).
- The efficient gas fueling occurs during the course of both major mergers (Mihos & Hernquist 1994b) and minor ones (Mihos & Hernquist 1994a; Hernquist & Mihos 1995).
- Some minor mergers may cause bar structure in the host disk galaxies. It is therefore natural to observe more starburst phenomena in the barred spirals. The formation of bar structure may depend on the mass ratio between the satellite and the host, the orbital configuration, and the dynamical properties of the host disk.
- The genesis of both nuclear starbursts and hot-spot nuclei can be understood solely by minor mergers. If the mass ratio of satellite black hole to host one[4] is relatively small ($M_\bullet^2/M_\bullet^1 \sim 0.1$), such minor mergers cause hot-spot nuclei. On the other hand, minor mergers with a relatively massive satellite ($M_\bullet^2/M_\bullet^1 \sim 0.5$) lead to the formation of nuclear starbursts (Taniguchi & Wada 1996). However, once the significant bar structure would be formed in the disk, the disk gas may be controlled dynamically by the bar structure. If a host galaxy has an inner Lindblad resonance (ILR), active star formation may occur in the ILR ring (Elmegreen 1994), leading to the formation of hot-spot nuclei.
- Minor mergers occur in both isolated and interacting galaxies. Since the timescale of dynamical friction for satellites ($\sim 10^9$ years) is shorter than the Hubble time, every isolated galaxy would experience minor mergers with its satellite galaxies several times (Tremaine 1981). Therefore, any isolated spiral galaxies have chances to host starburst nuclei in their lives. It is expected that the minor merger events are enhanced by direct capture of some satellite galaxies by the intruder. Thus the preference of starbursts for interacting galaxies is also naturally explained.
- The (ultra)luminous starbursts in major mergers can be also understood in terms of the efficient gas fueling and the definite triggering by the supermassive black hole binary. Since the binary consists of two supermassive black holes whose masses may be almost comparable, its dynamical effect on the nuclear gas disk is much stronger than the case of minor mergers, resulting in the (ultra)luminous starbursts.
- The observed diversity in starburst properties may be attributed to; 1) the mass ratio between the host and the satellite nuclei, and 2) the original gaseous contents in both the hosts and the satellites.

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[4] This mass ratio does not necessarily correspond to the mass ratio between the satellite and its host galaxy. Even if the secondary black hole is much less massive, it may become massive because of the gas accretion during the orbital decay into the nuclear region. Therefore, even in the case of $M_\bullet^2/M_\bullet^1 \sim 0.5$, the merger itself is not a major merger, but a minor one.