PROCEEDINGS OF SCIENCE

Supermassive black holes and the nuclear activity in galaxies

Andrei Lobanov
Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
E-mail: alobanov@mpifr-bonn.mpg.de

Most powerful manifestations of the nuclear activity in galaxies result from galactic mergers. The nuclear activity in post-merger galaxies can be effectively connected to the evolution of binary (or multiple) supermassive black holes (SMBH) formed in the course of the merger. This connection predicts well the luminosity function and the relative abundance of major types of active galactic nuclei (quasars and Seyfert and LINER galaxies). In this scheme, the activity of the secondary black holes is rapidly quenched by an effective stripping of their accretion disks during the sinking into the center of their post-merger galactic host. The scheme reproduces the relative fractions of different types of AGN and brings a viable connection between the galactic type and the strength of the nuclear activity. Limited observational evidence in support of this scheme exists already and further tests can be done with present and future astrophysical facilities.

The tentative relation between the evolution of binary SMBH and nuclear activity in post-merger galaxies provides a very important cosmological connection between the merger history of galaxies and their nuclear activity. Testing this model requires effective means for detecting the "silent" secondaries and reconstructing the detailed relation between the nuclear activity and the central black holes in post-merger galaxies. This research will be greatly facilitated by the SKA in the radio, ELT's in the optical, and future X-ray missions.

From Planets to Dark Energy: The Modern Radio Universe
1st-5th October 2007
The University of Manchester, United Kingdom

PoS(MRU)113

1. Binary black holes and nuclear activity

Nuclear activity in galaxies believed to result from accretion onto supermassive black holes (SMBH) is a complex phenomenon regulated by a number of factors. It is widely recognized that the nuclear activity is also closely connected to galactic mergers. A merger has two most immediate effects on the environment of SMBH residing in the galactic nuclei. It perturbs substantially the dynamics of gas and stellar population in the merging galaxies, and it leads to formation of binary SMBH in the center of mass of the two galaxies merged [1].

The peak magnitude of the nuclear activity can be connected with the primary parameters of a binary SMBH system: the mass ratio and orbital separation of the two black holes [2]. The description is based on two basic quantities: the reduced mass $\tilde{M} = 2M/(M_1 + M_2)$ and the reduced separation $\tilde{r} = 1 - r_c/(r + r_c)$ of the two black holes in a binary system, where M_1 and M_2 are the masses of the two black holes, r is the actual separation between the two black holes, and r_c is the distance at which the two black holes become gravitationally bound. The peak luminosity from an AGN can be crudely estimated from

$$L_{\rm peak} = L_0 \left(1 + \frac{\tilde{M}}{2-\tilde{M}} \frac{\tilde{M}}{\tilde{r}^2}\right) ,$$

where L_0 is the luminosity of typical single, inactive galactic nuclei. This estimate predicts correctly the relative fractions of different types of AGN (Fig. 1), connects well the galactic types and the strength of the nuclear activity, and explains the luminosity evolution in the secondary SMBH in post-merger galaxies (Fig.2).

The binary black hole model explains the observed lack of galaxies with active secondary nuclei by effective disruption of accretion disks around the secondaries in BBH systems with masses of the primary smaller than $10^{10} M_\odot$ [4]. This implies that the secondary becomes "silent" even before binding to the primary, in most galaxies with typical mass of the primary of the order of $10^{10} M_\odot$. In such systems, the secondaries will be weak emitters, with X-ray luminiosities comparable to those of the brightest exragalactic ultraluminous X-ray sources.

2. A systematic study of binary SMBH in AGN

The connection between binary SMBH and nuclear activity in galaxies implied strongly by the model [1, 4] can provide a robust basis for explaining the co-evolution of SMBH and galaxies in the Universe. This connection has not been studied systematically in a sample of post-merger galaxies.

A coordinated program aimed at gathering evidence for the presence of the secondary black holes in post-merger systems and modelling the interaction between binary SMBH and the nuclear environment in post-merger systems is critically needed for establishing a physical scheme that would enable assessing the impact of binary SMBH on nuclear activity and evolution of galaxies. This connection can be studied in detail by verifying the putative connection between the nuclear activity and properties of BBH in post-merger galaxies and studying its influence on the nuclear activity and galaxy evolution. The study should be based on a two-pronged approach combining analytical and numerical modelling with an observational program to detect and study the secondary SMBH in post-merger galaxies, using X-ray and high-resolution radio imaging and 2D

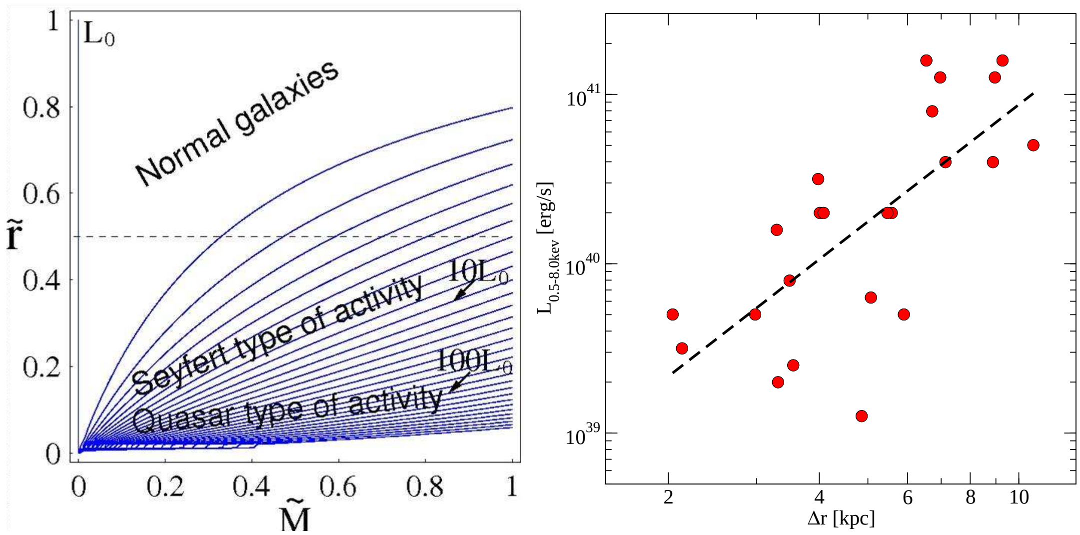

Figure 1: Left panel: AGN peak luminosities calculated for a range of values of $\tilde{M}$ and $\tilde{r}$ in pairs of SMBH in the centers of galaxies. The peak luminosity increases rapidly with increasing $\tilde{M}$ and decreasing $\tilde{r}$, and it reaches $L_{\rm peak} = 1000 L_0$ for an equal mass binary SMBH at $r \approx 0.03 r_{\rm c}$. This would correspond most likely to powerful quasars residing in elliptical galaxies. At the same reduced separation, an unequal mass binary, with $\tilde{M} = 0.15$, will only produce $L_{\rm peak} = 10 L_0$, which would correspond to a weak, Seyfert-type of active nucleus. **Right panel:** Luminosities and nuclear separations of brightest off-nuclear X-ray sources in a sample of optically bright galaxies in the Chandra deep fields [3]. The dashed line shows a fit by the binary black hole scenario, assuming that the accretion disk around the secondary black hole is stripped by tidal forces during the galactic merger, yielding the predicted dependence of the luminoisity of the secondary $L_2 \propto (r/r_{\rm c})^{9/4}$. The good agreement of the model prediction with the trend in the observed luminisities suggests that the tentative connection between off nuclear X-ray sources and secondary supermassive black holes should be investigated in more detail.

optical spectroscopy. Next generation facilities that will be operating in these domains (XEUS, SKA, and ELT) will be indispensable for this study. The observations will be complemented by investigations of empirical indicators of the evolutionary stage of the binary SMBH. This will provide a broad physical foundation for deriving a relation between the AGN power output and the state of the binary, providing a self-consistent framework for explaining the observational data, and establishing ultimately an evolutionary relation between the properties of binary SMBH and the nuclei of their host galaxies.

References

[1] M.C. Begelman, R.D. Blandford, M.J. Rees: Nature 28, 307 (1980)

[2] A.P. Lobanov, MemSAIt, 76, 164 (2005)

[3] B.D. Lehmer, et al.: AJ 131, 2394 (2006)

[4] A.P. Lobanov, in "Relativistic Astrophysics and Cosmology", eds. B. Aschenbach et al. (Springer: Heidelberg 2007), p. 242.