Analysis of Quasar Environments using a Galaxy and Quasar Formation Model

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We construct a unified semi-analytic model that includes both galaxy and quasar formation based on a hierarchical clustering scenario and apply this model to investigate environment of quasars, i.e. relations between quasars and underlying mass distribution, and relations between galaxies and quasars.

We assume that a supermassive black hole (SMBH) is fueled by accretion of cold gas and that it is a source of quasar activity during a major merger of the quasar host galaxy with another galaxy. Our semi-analytic model for the galaxy formation can reproduce not only observations of galaxies in the local universe, such as luminosity functions and the cold gas mass fraction in spiral galaxies, but also galaxy number counts and redshift distributions of galaxies in the Hubble Deep Field. We incorporate a quasar formation model in this galaxy formation model. Our quasar formation model can reproduce the observed relation between a SMBH mass and a spheroid luminosity, the present black hole mass function and the quasar luminosity functions at different redshifts. Using this model, we investigate environmental properties of quasar.

First, we analyze the mean numbers of quasars and galaxies in a dark halo, which provide the relations among galaxies, quasars and dark halos. We find that the dependence of the mean numbers of quasars on halo mass is different from the dependence of the mean numbers of galaxies. Then, using the mean numbers, we calculate the bias parameters of quasars and galaxies because the spatial distributions of galaxies and quasars depend on the mean number of galaxies and quasars in a dark halo, respectively. We find that the evolution of the bias parameters of quasars is different from that of galaxies. In our model, both the formation efficiency of galaxies and quasars depends on the cold gas mass fraction and the galaxy merger rate in a dark halo. However, the quasar formation efficiency depends on galaxy merger rate more strongly and ,furthermore, depends on quasar lifetime.

Next, we show the galaxy number distribution function around quasars. At lower redshifts ($0.2 \lesssim z \lesssim 0.5$), most halos with quasars have at most several galaxies. This indicates that most quasars reside in groups of galaxies. On the other hand, at higher redshifts ($1 \lesssim z \lesssim 2$), the number of galaxies in a dark halo with quasars is from several to dozens; quasars reside in ranging from small groups of galaxies to clusters of galaxies. These results show that most quasars at higher redshifts reside in more various environments than at lower redshifts. In our model, we assume that galaxy major merger triggers quasar activity. Since galaxy merger rate has a maximum in halos corresponding to groups of galaxies, $\sim 10^{13} M_{\odot}$, our model predicts that most quasars populate in groups.

Finally, we analyze the spatial cross-correlation between quasars and galaxies. To do this, we combine our semi-analytic model of our galaxy and quasar formation with cosmological N-body simulation. Comparison of the quasar-galaxy cross correlation functions with the galaxy two-point correlation functions shows that quasars populate in a similar environment to the galaxies with $M_B - 5\log(h) < -19$ even in high redshifts.

Comparing these predictions with observations in the future will enable us to constrain our quasar formation model and the processes of galaxy merging.

References

[1] Enoki, M., Nagashima, M. & Gouda, N, 2003, PASJ, 55, 133