論文の内容の要旨

The size and angular momentum evolution of high redshift galaxies

(高赤方偏移銀河におけるサイズと角運動量の進化)

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The morphology, size, and angular momentum of galaxies are three fundamental quantities that can be used as probes for internal structure and kinematics. Studying these quantities at high-redshift provides us invaluable insights for galaxy formation and evolution.

This thesis consists of two parts. In the first part, we investigate the angular momentum evolution of disk galaxies at z ~ 2, 3, and 4. The stellar disk size of a galaxy depends on the fraction of the dark halo mass settled as disk stars, $m_\star \equiv M_\star/M_{dh}$, and the fraction of the dark halo angular momentum transferred to the stellar disk, $j_\star \equiv J_\star/J_{dh}$. Since $m_\star$ and $j_\star$ are determined in a different manner by a series of star-formation related processes such as inflows and feedbacks, measuring $j_\star$ and $m_\star$ at various redshifts is needed to understand those processes and thus the formation history of disk galaxies. However, angular momentum studies at z > 1 are still very limited because it is difficult to kinematically measure $j_\star$.

We use the 3D-HST GOODS-S, COSMOS, and AEGIS imaging data and photo-z catalog, where stellar masses and star formation rates are also given, to examine $j_\star$ and $m_\star$ for star-forming galaxies at z ~ 2, 3, and 4, when disks are actively forming. For each redshift, we divide the catalog into $M_\star$ bins and infer M_{dh} from clustering analysis and abundance matching, thus obtaining $m_\star$ for each bin. We also measure, for objects in each bin,

effective radii r_d at rest 5000Å with GALFIT which, combined with Mo et al.'s (1998) analytic disk formation model and M_{dh} and $m_\star$ measurements, gives $j_\star$ without measuring disk kinematics.

We find that the $j_\star/m_\star$ ratio is $\simeq 0.77 \pm 0.06$ for all three redshifts over the entire mass range examined, $8 \times 10^{10} < M_{dh}/h^{-1}M_\odot < 2 \times 10^{12}$, with a possible (< 30%) decrease with mass. This high ratio is close to those of local disk galaxies, descendants of our galaxies in M_{dh} growth, implying a nearly constant $j_\star/m_\star$ over past 12 Gyr. It is found that recent theoretical galaxy formation simulations predict smaller j_d/m_d than our values. We also find that a significant fraction of our galaxies appear to be unstable against bar formation. We also examine the r_d–$M_\star$ relation for our galaxies, finding shallow power-law slopes of the relation decreasing from $\simeq 0.19$ at $z \sim 2$ to $\simeq 0.08$ at $z \sim 4$. These shallow slopes less than 0.2 reflect the non-positive slopes of the $j_\star/m_\star$-M_{dh} relation, and the decrease toward $z \sim 4$ may be due to a decrease (getting more negative) in the slope of the $j_\star/m_\star$-M_{dh} relation over the same redshift range.

In the second part, we focus on the size and morphology of galaxies. We use a cosmological hydrodynamical simulation framework, FiBY, which is an updated version of Gadget-3 in order to investigate what problem would happen if we adopt the same size measurement procedure as one used in the local universe for very high-redshift galaxies at $z \sim 6$. The simulated galaxies are lensed onto the Hubble Frontier Fields (HFF) cluster image, and the sizes are measured on the mock image. By comparing the intrinsic sizes (r_{sim}) in the simulations and the observed sizes ($r_{obs,mock}$) in the mock observations, we have examined whether the surface brightness profile of the simulated galaxies is reproduced by a single S´ersic profile.

We find that our r_{sim}–luminosity relation is slightly higher than the incompleteness corrected size–luminosity relation by Kawamata et al. (2018). On the other hand, $r_{obs,mock}$ is measured two or three times smaller than r_{sim}; the $r_{obs,mock}$–luminosity relation is comparable to the incompleteness uncorrected size–luminosity relation. This is because the surface brightness limit of the HFF image is too shallow, and a single S´ersic profile can not trace the extended structure of our simulated galaxies.

For local to intermediate redshift galaxies, we can measure the accurate galaxy sizes by using the size measurement method assuming a S´ersic profile. However, our results in the second part indicate that we need special care to apply a S´ersic profile to very high-redshift galaxies at $z > 6$, because the sizes of galaxies may be underestimated by the size measurement procedure.