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The Evolution of Galaxies with the Square Kilometre Array

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Galaxies have been formed from a homogeneous neutral gas in the early Universe, and evolved with forming stars from the gas in them. Then the key factor of the galaxy formation and evolution is the transition from atomic to molecular hydrogen. This transition is also strongly coupled with chemical evolution, because dust grains play a critical role in molecular formation. Therefore, a comprehensive understanding of neutral–molecular gas transition, star formation and chemical enrichment is necessary to clarify the galaxy formation and evolution.

At $z \sim 0$, we try to construct a unified picture of atomic and molecular hydrogen through nearby galaxies in terms of metallicity and other various ISM properties. In previous studies, the knowledge from the ISM physics was not efficiently used in extragalactic studies, mainly because of the limitation of the angular resolution in radio observations today. The ultimately high high angular resolution of SKA at cm wavelengths will bring us the unprecedented information of the physical state of the ISM in galaxies. By SKA, we will be able to push forward the HI–H_2 transition toward significantly high-z and discuss its evolution.

Up to intermediate redshifts $z \sim 1$, we explore scaling relations including gas and star formation properties, like the main sequence and the Kennicutt–Schmidt law of star forming galaxies. To connect the global studies with spatially-resolved investigations, such relations will be plausibly a viable way. Especially in relation to the HI–H_2 topic, the Kennicutt–Schmidt law provides a unique opportunity, since this relation holds both for resolved (local) and global galaxy properties. If we can trace the evolution (or constancy) of these scaling relations, we can constrain the star formation scenarios in galaxy evolution. It is particularly important since it is the way how to connect the ISM physics and extragalactic physics and organize them on the common basis. Only SKA can achieve such observations.

At high redshift, it would be very difficult to detect the HI emission of galaxies, even with SKA2. Instead, the absorption lines of HI 21-cm line will be a very promising observable to explore the properties of gas in galaxies. We are interested in the physical processes going on during the galaxy formation. One of the ideal proves for this is a high column density system like DLAs. Though DLAs are alreacy extensively studied in the field of galaxy formation and cosmology, one possible bias was pointed out. If a DLA contains even a tiny amount of dust, it would bias the detection probability of background quasars. This plausible bias can be compensated by selecting radio-loud quasars and explore the 21-cm absorption line system. Since the cross section of such system is small, we can examine their physical properties even if the column density is extremely high. It is pointed out that such systems would have been rare at very high-zs, and clasical statistical methods would not work properly. To tackle such a problem, we designed an appropriate statistical method to analyze such small sample size data, based on the high-dimensional statistical analysis which has been developed recently.

Apart from HI, we have yet another great probe for the star formation history in the whole range of the cosmic time. The radio continuum at $\nu > 10$ GHz consists of thermal free-free and synchrotron emission. Both of these radiation processes are related to the star formation activity in galaxies, and work as a good tracer of the SFR. Since the feasibility of the radio continuum by SKA is much higher than that of HI 21-cm line, the radio continuum is very suitable for the exploration of the cosmic SFR from the very early phase of galaxy formation.

By these studies, we will surely witness the evolution of galaxies through the whole cosmic age at long-wavelength radio observation with SKA.