High-Redshift Superclustering of Galaxies around a QSO Cluster at z=1.1(Abstracts of Doctoral Dissertations,Annual Report(from April 1999 to March 2000))

High-Redshift Superclustering of Galaxies around a QSO Cluster at z=1.1

Makoto Tanaka

Astronomical Institute, Graduate School of Science

Recent development achieved in the study of the large-scale structures of galaxies in the nearby universe, as well as in searching and identifying the high redshift galaxy population is remarkable. Clearly, one of the important next steps is to trace the evolution of the large-scale structures directly toward high redshift, and to figure out how the galaxy evolutionary process relates with the environmental evolution in such superclusters. In this thesis, we try to identify the 'supercluster' of galaxies at $z \sim 1.1$; it is one of the first attempts to provide a rare example of the well-defined large-scale structure of galaxies observed at $z > 1$. We believe that this pioneering effort would provide a base for further fruitful studies of high-redshift galaxy clustering.

We conducted deep wide-field imaging observations to search for the direct signature of a postulated supercluster structure of galaxies associated with a close clustering of five QSOs, part of a "QSO cluster" known to exist at $z = 1.1$. The drift-scanning mode (TDI mode) observations, with the 3.5-m telescope at the Apache Point Observatory, allow us to construct a very homogeneous R- & I-band catalog of galaies across the $48' \times 9'$ area down to the nominal completeness limit of $I = 23.5$. We have detected several 'clumps', where the faint ($I > 21$) and very red ($R - I > 1.2$) galaxies are strongly clustered, over the region where the members of the "QSO cluster" lie. One of the most prominent clustering structures of red galaxies is the known cluster associated with the QSO B2 1335+28 at $z \sim 1.1$, which was identified through our previous optical and near-infrard observations and published in Yamada et al. (1997) and Tanaka et al. (2000). These galaxies, that comprises the other clumps, also have similar $R - I$ colors and magnitudes to the cluster members around B2 1335+28, which implies that they are likely to be at similar redshift of $z \sim 1$. As the expected number of the clusters of galaxies with Abell richness class $R \geq 0$ at $z \gtrsim 0.7$ is less than unity, we argue that the detection of several clumps of faint red galaxies implies that this field is not only a unique high density region of QSOs but also of faint red galaxies.

In order to establish that this supercluster-scale clustering of galaxies is possibly associated with the QSO concentration at $z \sim 1.1$, we have made two statistical analysis, namely, a detailed cell count analysis and a two-point correlation analysis. First, we select the galaxies that are in the color and magnitude range that expected for those at $z = 1.1$ and performed a cell count analysis to identify 5 or more clumps with a significance larger than 2.5σ. Especially, the number density of the detected clumps is higher in the region of the southern half of our survey area that contains four of the five QSO cluster members

(called the 'A-Scan' region). We then measure the two-point auto-correlation function for galaxy samples selected by various color and magnitude ranges as well as the cross-correlation function among these samples. We find that faint red galaxies in the A-Scan region show an unusually strong auto-correlation signal compared with those in the control region (the northern half of our survey area), or with those for the bluer galaxies. Further analysis shows that these faint galaxies in that region also show a strong cross-correlation signal between those with the reddest ($1.3 < R - I < 2.0$) and the moderately redder ($0.9 < R - I < 1.3$) galaxies. The galaxy evolutionary models show that those colors correspond to the early-type ($1.3 < R - I < 2.0$) and the normal disk ($0.9 < R - I < 1.3$) galaxies at $z \sim 1.1$. Interestingly, the signal does not disappear even after we exclude the area that contains high-density clumps of red galaxies, while the auto-correlation signal fells down after that. We speculate on this very curious feature as the implication of the following: The observed field may contain a fairly extended supercluster-scale structure elongated along the east-west direction, loosely associated with the distribution of these $z = 1.1$ QSOs, where early-type and late-type galaxies are both clustered in common but the clustering of early-type galaxies is stronger to form discrete clusters/groups to be detected as clumps in our survey. Absence of such a signal in the northern control field implies again that the QSO cluster may work as a signpost of the underlying large-scale structure of galaxies.

Through the study, we have revealed the spatial and color distribution of the optically-selected galaxies around a tight clustering of five QSOs at $z = 1.1$ and succeeded to detect a very plausible and encouraging signature of the superclustering of galaxies that may be associated with the QSO cluster. If confirmed, the area will be the most distant large-scale ($\gtrsim 20$ Mpc) structure of normal galaxies traced by such QSO clusters at high redshifts. Considering that our surveyed area is only a part of the whole QSO cluster region, a more extended survey will be expected to reveal a possible ~ 100 Mpc–scale structure. With further near-infrared imaging and the deep spectroscopic observations planned in the near future, we expect to prove and establish the supercluster to study the evolution of such structures and the evolution of galaxies in the structure.