# Supernovae and Clusters of Galaxies as Probes for the High Redshift Universe

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**Abstract:**
This thesis includes investigations of high redshift supernovae and clusters of galaxies, two important observational probes for the evolution of star formation and large scale structure.

From observed star formation rates we calculate the expected rate of different supernova types to redshifts $\gtrsim 5$. We use these rates together with assumptions about peak magnitudes, light curve shapes and dust extinction to calculate the number and redshift distribution of supernovae that should be detectable in different filters, and at different limiting magnitudes. The calculations can be used to optimise supernova searches when it comes to limiting magnitudes and filter choices for the redshift range of interest. We include estimates for existing and future telescopes, in particular the NGST. We show that a large number of high redshift SNe will be detected in future surveys, opening up a new window of the high redshift Universe, including a direct study of the nucleosynthesis and the energy input into galaxies. With observational results in hand, these calculations can also be used to infer the underlying star formation rate, which can be compared with independent estimates based on e.g., the UV luminosity of high redshift galaxies.

A main concern for deep supernova searches is to determine the redshift of the supernovae. The large number of expected supernovae, and their faint magnitudes, makes spectroscopy infeasible. We show that colours of supernovae, and in particular colours of their host galaxies, can be used to determine redshifts of the supernovae, or alternatively

to select high redshift supernova candidates for subsequent spectroscopic and photometric follow-up.

Using photometric redshifts we investigate the galaxy populations of the clusters Cl0016+16 at $z = 0.55$, Cl1600+41 at $z = 0.54$, Cl1601+42 at $z = 0.54$ and MS1008-1224 at $z = 0.31$. We show that the photometric redshift technique applied to clusters significantly reduces the contamination from the field, compared to the standard background subtraction technique. The photometric redshift technique also determines galaxy type of each individual object based on colour information. With this information we investigate the galaxy population divided into early-type and late-type galaxies separately.

We have for the first time determined the cluster luminosity function (LF) down to the dwarf population at redshift $z \sim 0.55$. We find no evidence for a universal shape of the cluster LF at high redshift. When we divide the galaxies into different populations we find that early-type galaxies have a Gaussian shaped LF peaking at intermediate magnitudes, while the LF of the late-type galaxies can be described by a Schechter function with a steep faint-end slope. The relative normalisation of these populations is the main reason for the varying total LFs in our sample, implying that a cluster with an abundant population of late-type galaxies has a total LF with a steep faint-end slope.

We find that a fading of the late-type population by $\sim 2$ mag and the early-type population by $\sim 1$ mag describes the evolution from $z = 0.55$ to $z = 0$ well. This evolution suggests that the total LFs of high-$z$ clusters become more similar to the LFs of rich local clusters, as they get dynamically older.

We find that the radial gradient of the fraction of early-type galaxies in our sample is steeper than in low redshift clusters, consistent with the hierarchical infall scenario.

The fraction of blue galaxies varies between the clusters, but is generally higher than locally, consistent with the Butcher-Oemler effect. The blue fraction depends on radius and limiting magnitude, which is a consequence of the different radial distributions and LFs of the early-type and late-type galaxies.

The cluster Cl0016+16 is atypical in the sense that many of its properties, such as the blue fraction and early-type gradient, is similar to local clusters. This indicates that Cl0016+16 is dynamically old despite its high redshift.

In MS1008-1224 we find two distinct populations of dwarf galaxies, consistent with dwarf ellipticals and dwarf irregulars. We find that the dwarf irregulars dominate over dwarf ellipticals, which is contrary to nearby clusters where dwarf ellipticals dominate.

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