I. Background

Deep near-infrared (NIR) images have opened a new era in studies of high-z galaxies (e.g. Maihara et al. 2001, Labbe et al. 2003). Very deep VLT/ISSAC images of FIRES project in the HDF-S ($K_s \simeq 26$) discover a population of old galaxies at $z \sim 3$, most of which are too faint to be identified in optical observations (e.g. Franx et al. 2003). This discovery has changed the view of galaxy formation based on star-forming Lyman break galaxies. More recently, deep NIR images are also used to identify very high-z ($z > 6$) galaxies whose detectable continuum is redshifted to near-infrared bands ($> 1\mu$m). Mobasher et al. (2005) has found one convincing candidate for $z \sim 6.5$ galaxy on the basis of the HST/NICMOS data in the HUDF. The stellar mass of the candidate estimated with Spitzer/IRAC data is very large, $\sim 5 \times 10^{10} M_\odot$, indicating that significant star-formation was triggered at very early epoch. The identification of $z > 6$ galaxies is a key to investigate the early stage of galaxy formation and to constrain on reionization of the Universe (e.g. Bunker et al. 2004). In the HUDF, Bouwens et al. (2005) select 5 possible (3σ) $z = 7 - 8$ galaxy candidates with the two-color ($z' - J$,$J - H$) diagram. However, this galaxy sample does not well constrain on luminosity function of $z = 7 - 8$ galaxies, because this sample includes only very faint ($H \simeq 27$) galaxies found in the small surveyed volume. Relatively bright ($\lesssim 26$) $z > 7$ galaxies in a large volume is extremely important to sketch the overall shape of luminosity function. In order to identify bright $z > 7$ galaxies, we have investigated the GOODS-S field which has the best deep and wide-field images taken with VLT/ISSAC as well as HST/ACS (see Giavalisco et al. 2004). We have made various combinations of two-color diagrams with z', J, H, and K images of the GOODS-S to select $z > 7$ galaxies, but found no candidate down to their shallow 5σ limit ($K \lesssim 25$). Figure 1 presents one example ($z' - J$ v.s. $J - K$) of our two-color diagrams. Thus, deeper NIR images with a wide-sky coverage are strongly requested to identify such very high-z ($z > 7$) galaxies.

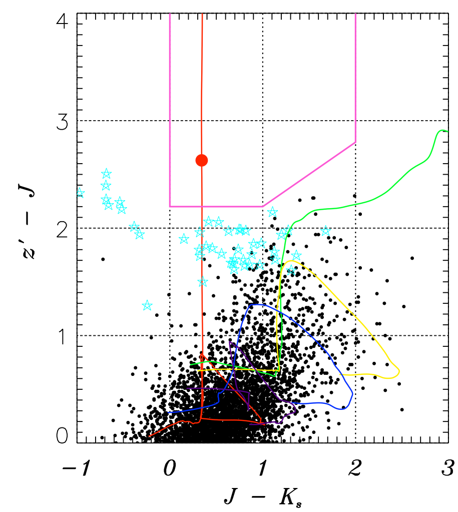

Figure 1: Two color diagram of GOODS-S objects (dots), together with model colors at various redshifts. The red, green, yellow, blue, and purple lines are estimated colors for high-z galaxies (Papovich et al. 2001), elliptical, Sbc, Scd, and Irr galaxies (Colman et al. 1980). The star marks mean for L and T dwarf stars of Knapp et al. (2004). The pink line indicates a selection window for $z = 7 - 8$ galaxies. The red circle presents the color of a galaxy at $z = 7$.

II. Our Strategy

We, MOIRCS builders, will take deep J and K images in the GOODS-N field during our Guaranteed Time (GT) in S06A. We plan to carry out deep J and K_s imaging for the central 28 arcmin^2 area (one FoV) of GOODS-N, which will achieve $J_{AB} \simeq 26.3$ and $K_{AB} \simeq 25.7$. In Figure 2, we plot the model SED of a $z = 8$ galaxy, together with detection limits of the GOODS-N images. Figure 2 shows that depths of z'(ACS) and J(MOIRCS-GT) match the shape of the $z = 8$ galaxy spectrum, but that only K_s image of MOIRCS-GT is not deep enough by ~ 0.6 magnitudes.

III. Our Proposal

We propose to take an ultra-deep K_s image in the central 28 arcmin^2 area of GOODS-N with MOIRCS. we will expose the field with K_s-band for 20 hours (net) in our 5 night observations. We will combine this deep K_s image with our MOIRCS-GT K_s image (10 hr). The co-added image will accomplish $K_{s\mathrm{AB}} = 26.3$ at a 5σ level (30-hour net exposure in total) in the wide field, which will cover a $6-7$ times larger area of sky with a depth comparable to the deepest K_s-band images of FIRES project (Labbe et al. 2003).

Our main goal is to detect the highest-z ($7 \lesssim z \lesssim 9$) galaxies, which is one of the most challenging subjects in astronomy today. We will identify $z = 7-9$ galaxies by the two-color selection of $z'-J$ v.s. $J-K_s$ (Figure 1) with the MOIRCS-GT J image ($J \simeq 26.4$) and HST/ACS z' image (2σ upper limit: $z' \simeq 28.5$). We expect to identify about 5 candidates in our 28 arcmin^2 area, assuming no evolution of luminosity function from $z = 6$ (Bunker et al. 2004). Note that, if we use the MOIRCS-GT K_s data instead of this ultra-deep K_s image, we expect only ~ 0.8 candidates. Thus our ultra-deep K_s image is critical for identifying $z \sim 8$ galaxies.

Using our $7 \lesssim z \lesssim 9$ candidates, we will derive number density of $z \sim 8$ galaxies at $K_s \lesssim 26$, and constrain on luminosity function of $z \sim 8$ galaxies, combining with the faint $z = 7-8$ galaxy candidates ($H \simeq 27$) found in the HUDF (Bouwens et al. 2004). We will obtain the cosmic star-formation rates, and give strong constraints on sources of reionization at the significantly earlier epoch than those of $z = 6$ galaxies (c.f. Bunker et al. 2004). We will estimate the stellar mass of $z \sim 8$ galaxies with the deep Sptizer/IRAC images at 3.6-8.0μm (Dickinson & Giavalisco 2002). The detection limit of Sptizer image is $m_{4.5} \simeq 25$ which will identify $z \sim 8$ galaxies with a stellar mass of $\lesssim 1.0 \times 10^{10} M_{\odot}$, if we assume the SED of typical $z = 3$ LBGs. Even our $z \sim 8$ galaxies are not detected in the Spitzer bands, we can give upper-limits on stellar mass of our $z \sim 8$ galaxies. This analysis will test whether the massive galaxy such found at $z \sim 6.5$ (Mobasher et al. 2005) is a dominant population at these redshifts, and place constraints on the formation of massive early-type galaxies for the very early epoch.

Since two-color selections are known to isolate high-z galaxies with only $\sim 10\%$ contaminants for $z = 2-6$ galaxies (e.g. Steidel et al. 1999), a negligible number of interlopers contaminates our sample of $z \sim 8$ galaxies if we carefully avoid colors of low-z galaxies and Galactic stars including L and T dwarfs (see Figure 1). Even though our galaxy sample is probably reliable, in the future we will take deep spectra for all the candidates to check whether interlopers are included at bright magnitudes, taking advantage of MOS capability of MOIRCS. We may also identify the highest-z galaxy by detecting a strong Lyα line, if any, by this future MOS spectroscopy.

Note that our ultra-deep K_s image co-added with the MOIRCS-GT image would be the deepest of all time for MOIRCS. Since this image is also quite useful for various studies, such as evolution of stellar mass function at $1 < z < 4$ and identification of faint Spitzer or Chandra sources, we will recycle our ultra-deep K_s image for these studies.

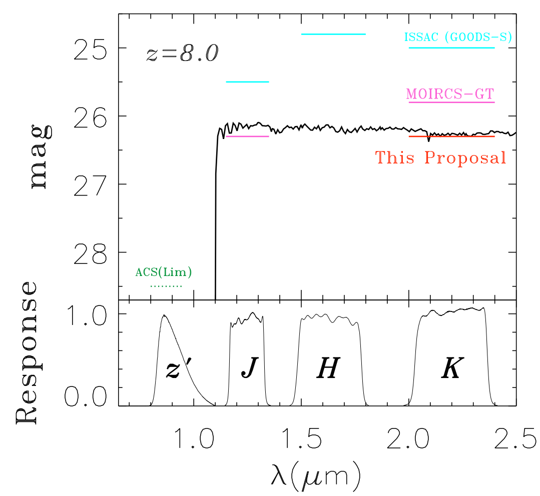

Figure 2: *Top* : The model spectrum of a z=7 LBG (black line) and detection limits. The red, pink, blue and cyan lines show the 5σ limits for surveys indicated in the legend. The green line shows the upper-limit magnitude (2σ) of the ACS in the GOODS-N. *Bottom* : Filter responses.

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