A Survey for Young Metal-poor Galaxies at Intermediate Redshifts

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SUMMARY

We present a new survey that we are conducting to search for extremely metal-poor galaxies at z~0.4-0.8. We use narrow-band imaging to identify galaxies with extremely high emission-line equivalent widths (EWs). These emission lines fall outside the narrow-band filter and produce a significant excess in the broad-band photometry. The first study to use this technique was Nagao et al. (2007), who identified high-EW z~6 Lyα emitters. The technique has been confirmed with optical spectroscopy and photometric redshift. The photometric redshifts are primarily used to distinguish the emission lines causing the strong excess since their accuracy of <5% level is sufficient. Due to the rarity of such a galaxy population, we cover a wide volume by probing a large redshift range (Δz ~ 0.4) and surveying multiple independent fields, COSMOS and the Subaru Deep Field (SDF). This survey is at least a factor of ten larger than past surveys (e.g., Hu et al. 2009) in searching for metal-poor galaxies via a wider Δz and covering over 2 deg^2 in area.

1. MOTIVATION

Identifying and studying galaxies in their earliest stages of formation is an important step towards testing cosmological models of galaxy formation. Future facilities and observatories aim to search at z > 7 for these young galaxies that are thought to be responsible for cosmic reionization. These young galaxies are often characterized by extremely low metallicities (e.g., less than 0.1 Solar) and high star formation rates. While it is important to find the earliest galaxies that formed, searching for lower redshift analogs will permit detailed studies of their morphologies, gas metallicities and the states of their interstellar medium, and kinematics with existing and future capabilities. We describe a new survey and discuss the technique that we adopt to identify low-z analogs.

2. THE SAMPLE

Previous surveys have acquired deep Subaru/Suprime-Cam imaging in broad-band and narrow-band (NB) filters in several extragalactic fields. We utilize data for two of them, the SDF (0.25 deg^2; Kashikawa et al. 2004) and COSMOS (~2.0 deg^2; Scoville et al. 2007). To date, SDF has been imaged in five NB filters (NB704, NB711, NB816, NB921, and NB973) while COSMOS has imaging in NB711 and NB816. These NB data typically reach 3σ AB sensitivity between 26.0 and 26.5 mag. We illustrate in Fig. 1, the color-magnitude diagrams to select NB "depressors." By adopting conservative selection limits, we have identified in the SDF, 2900 NB704, 1900 NB711, 1200 NB816, and 950 NB921 depressors. In addition, 5800 NB711 and 3800 NB816 depressors are identified in the COSMOS field.

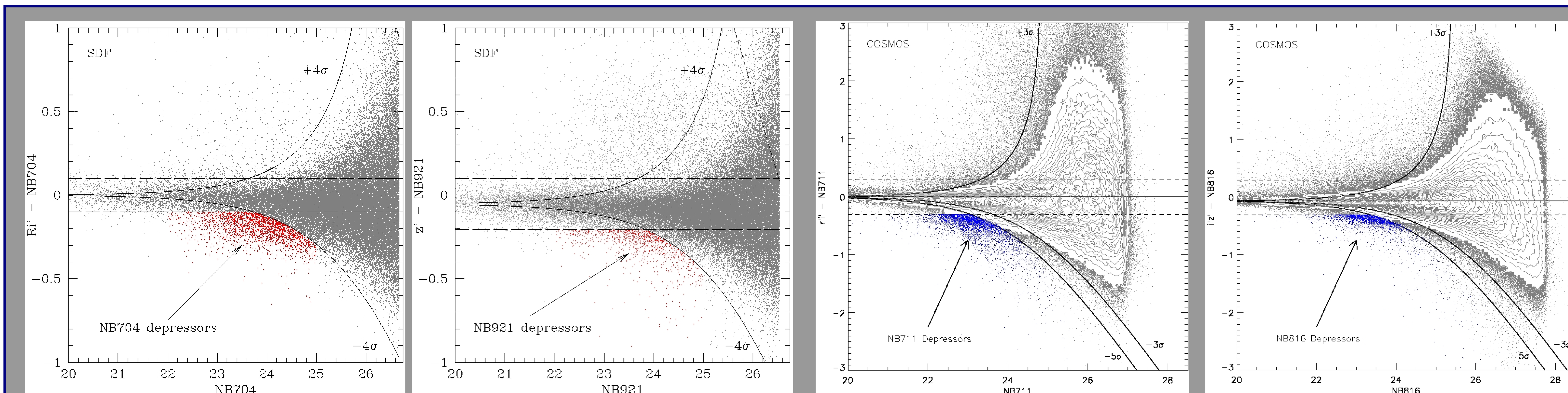

Fig. 1 – Color-magnitude plots to select a variety of NB "depressors" in the SDF (two left panels) and COSMOS (two right panels) fields. Sources shown in red and blue are those selected as NB depressors above 4σ (SDF) and 5σ (COSMOS), respectively.

3. SPECTROSCOPIC CONFIRMATIONS

If these NB depressors are indeed galaxies with high-EW emission lines, then optical spectroscopy would provide unambiguous support for the technique. For the SDF, Keck/LRIS spectroscopy (with 1-1.5 hr integration) targeted 33 NB depressors with 31 of them being identified. While we find five sources (15%) showing stellar absorption features (e.g., Balmer, CaII H&K) within the NB filters, 26 sources (79%) show high-EW emission lines. The location of the emission lines was found outside of NB filters but within broad-band filters. An illustration of this is given in Fig. 2 and a LRIS spectrum is shown in Fig. 3.

For COSMOS, we use the zCOSMOS data (i_{AB}<22.5; Lilly et al. 2007) and cross-matched this spectroscopic sample against the NB depressors. Roughly 700 of the COSMOS NB711 depressors have spectroscopic redshifts. We also find that the majority of these depressors are at a certain redshift such that emission lines are located within the broad-band filters.

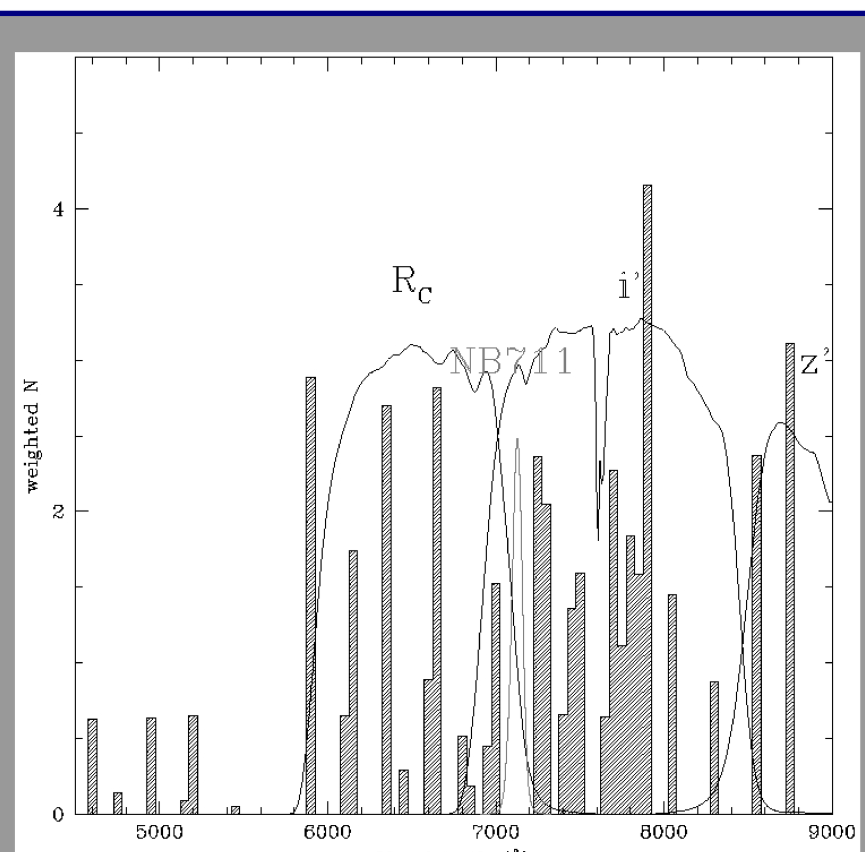

Fig. 2 – Illustration of the location of nebular emission lines. The y-axis is normalized based on the EW.

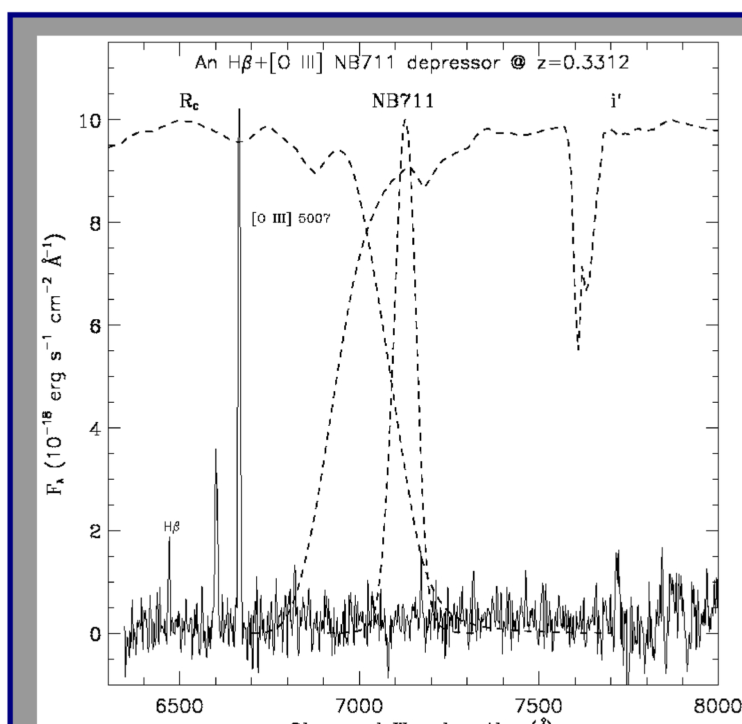

Fig. 3 – A one-hour Keck/LRIS-R spectrum of a galaxy identified using the NB depressor technique. The cause of the R$_C$-band excess is from high-EW [O III] emission line with a flux of 1x10^{-16} erg s^{-1} cm^{-2}.

4. UTILIZING PHOTOMETRIC REDSHIFT

While spectra is not available for all galaxies, we have photometric redshifts that are reliable at the 5% per (1+z) level or better. The photo-z's for the SDF were derived using the EaZy code with 20-band imaging (1500Å to 2μm; see Ly et al. 2011). The COSMOS photo-z's are those from 30-band imaging (Ilbert et al. 2009) using the *Le Phare* code. To support that these photo-z's are reliable, we compare them to available spectroscopic redshifts (See Fig. 4).

Using photo-z's, we can estimate the location of strong nebular emission lines (e.g., Hα, [O III], and [O II]), which when compared to the filter bandpasses, allows us to identify what the emission lines are responsible for the broad-band excess. This is provided in Fig. 5.

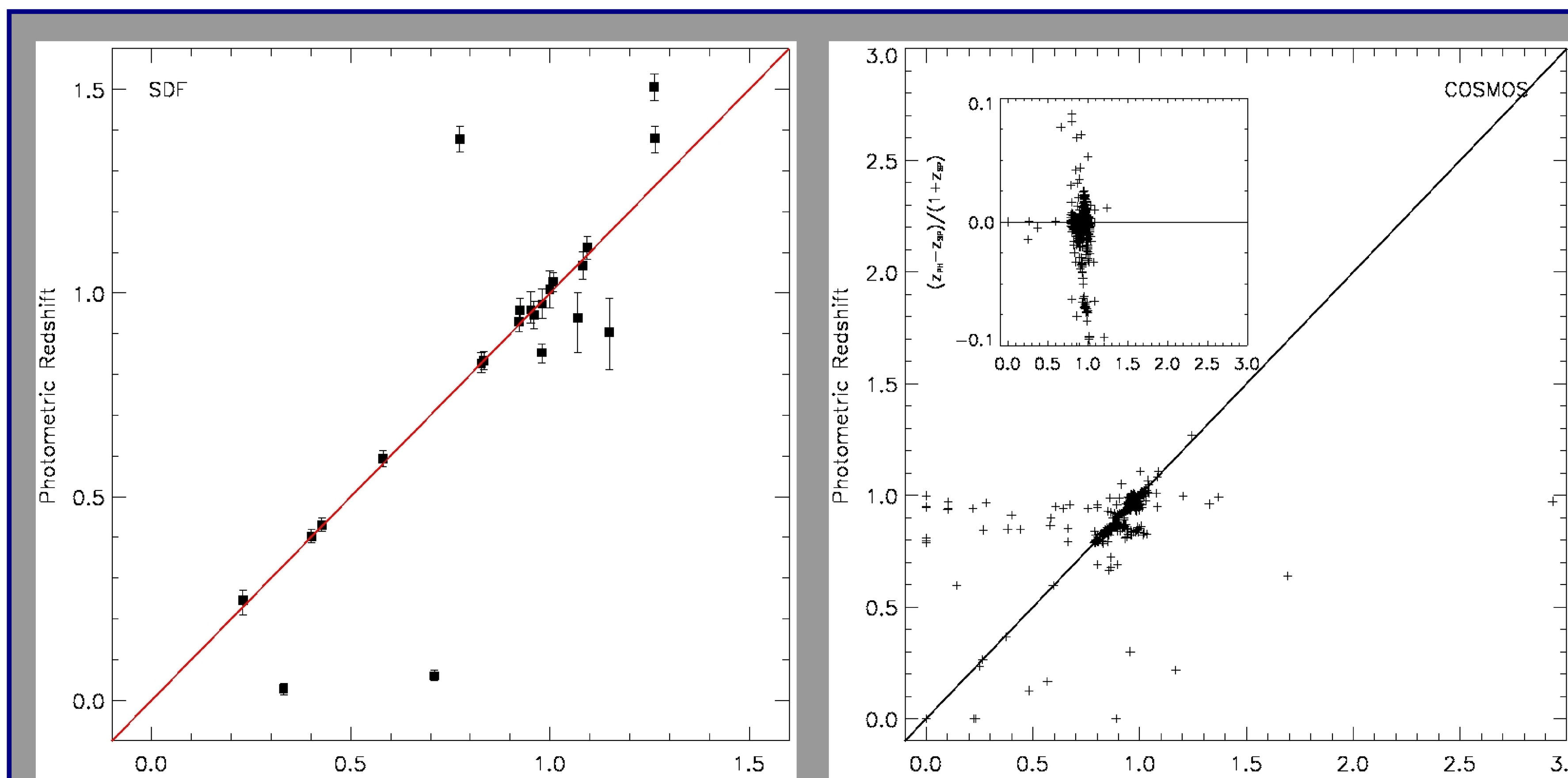

Fig. 4 – Comparison between spectroscopic and photometric redshifts for subset of galaxies in the SDF (left) and COSMOS (right). Most of the NB depressors are [O II] emitters at z ~ 1. The photo-z's are typically accurate to a few per cent; however, there are circumstances of failure due to extremely high-EW emission lines.

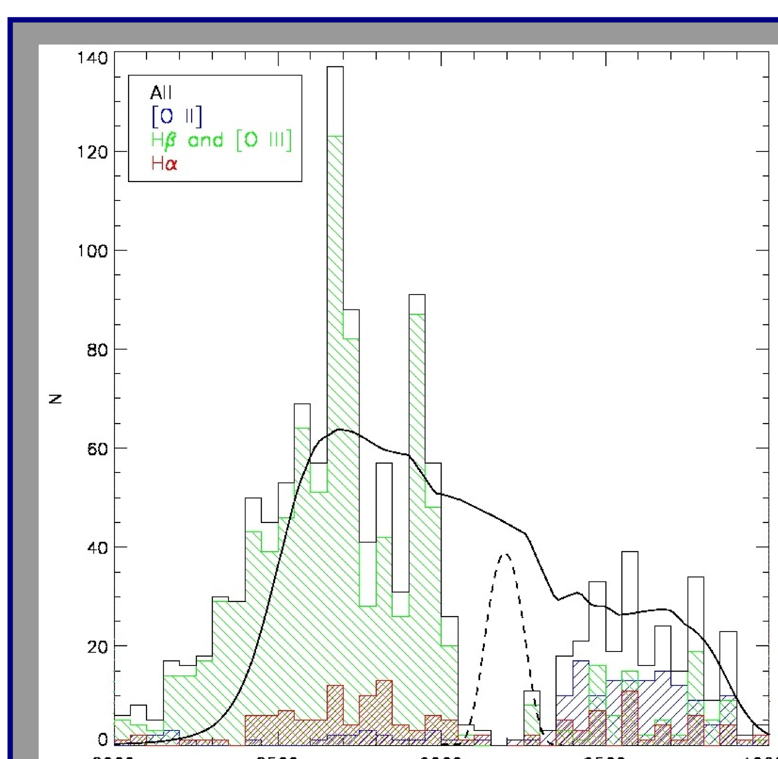

Fig. 5 – Location of emission lines based on accurate photo-z's for NB921 depressors in the SDF. These lines all are found in the z' (solid line). This allows the survey to probe a wider Δz and identify more rare galaxies with log(O/H) < 7.65.

CONCLUSIONS

We have developed a new survey to identify galaxies with high emission-line equivalent widths, which is an important characteristics of extremely metal-poor galaxies. The survey utilizes a comparison between broad-band and narrow-band filters to identify a galaxy population called "NB depressors." Thousands of these galaxies were identified in the SDF and COSMOS fields, and optical spectroscopy has indicated that the majority of them (~80%) possess strong nebular emission lines that alter the broad-band photometric measurements to cause this "depression" in the NB. We also examine reliable photometric redshifts from multi-band imaging and find further support that emission lines are entering the broad-band filters. We also find that for a fraction of our NB depressors, high-EW emission lines can alter the spectral energy distribution (SED) significantly to yield incorrect photometric redshifts. Additional spectra of this galaxy population could allow for improvements to photo-z SED templates to obtain more reliable photo-z's and reduce catastrophic failures. Future plans include multi-object spectroscopy of thousands of these sources. With estimates on stellar masses, ages, star-formation rates, and redshift from SED modeling, we will have a sample of candidate extremely metal-poor galaxies for deep follow-up spectroscopy. Existing high resolution imaging from *Hubble* will allow us to study the galaxy's morphologies and their local environment to determine if galaxy interactions are responsible for such strong nebular emission lines.

References

Hu, E., et al. (2009), *ApJ*, 698, 2014
Ilbert, O., et al. (2009), *ApJ*, 690, 1236
Kashikawa, N., et al. (2004), *PASJ*, 56, 1011
Lilly, S., et al. (2007), *ApJS*, 172, 70
Ly, C., et al. (2011), *ApJ*, 735, 91
Nagao, T., et al. (2007), *A&A*, 468, 877
Scoville, N., et al. (2007), *ApJ*, 172, 1