The NEWFIRM Medium-Band Survey: Filter Definitions and First Results

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ABSTRACT. Deep near-infrared imaging surveys allow us to select and study distant galaxies in the rest-frame optical, and have transformed our understanding of the early Universe. As the vast majority of K- or IRAC-selected galaxies are too faint for spectroscopy, the interpretation of these surveys relies almost exclusively on photometric redshifts determined from fitting templates to the broadband photometry. The best-achieved accuracy of these redshifts, \( \Delta z/(1 + z) \gtrsim 0.06 \) at \( z > 1.5 \), is sufficient for determining the broad characteristics of the galaxy population but not for measuring accurate rest-frame colors, stellar population parameters, or the local galaxy density. We have started a near-infrared imaging survey with the NEWFIRM camera on the Kitt Peak 4-m telescope to greatly improve the accuracy of photometric redshifts in the range \( 1.5 \lesssim z \lesssim 3.5 \). The survey uses five medium-bandwidth filters, which provide crude “spectra” over the wavelength range 1–1.8 \( \mu \text{m} \) for all objects in the 27.6\( \times \)27.6\( \mu \text{m} \) NEWFIRM field. In this first paper, we illustrate the technique by showing medium-band NEWFIRM photometry of several galaxies at 1.7 < \( z < 2.7 \) from the recent near-infrared spectroscopic sample of Kriek et al. The filters unambiguously pinpoint the location of the redshifted Balmer break in these galaxies, enabling very accurate redshift measurements. The full survey will provide similar data for \( \sim 8000 \) faint K-selected galaxies at \( z > 1.5 \) in the COSMOS and AEGIS fields. The filter set also enables efficient selection of exotic objects such as high-redshift quasars, galaxies dominated by emission lines, and very cool brown dwarfs; we show that late T and candidate Y dwarfs could be identified using only two of the filters.

1 INTRODUCTION

It has become clear that the Universe at \( 1.5 < z < 3.5 \) saw a much greater diversity of galaxies than the Universe today. This epoch is often characterized as one of rapid change, as many galaxies were experiencing strong and presumably short-lived star formation (Steidel et al. 1996; Blain et al. 2002), significant merging activity, and rapid black hole growth (e.g., Daddi et al. 2007). At the same time, a substantial population of quiescent galaxies already existed (e.g., Kriek et al. 2006). These galaxies have spectra characterized by strong Balmer or 4000 Å breaks and no detected H\( \alpha \) emission. They also have very compact morphologies, which implies they must undergo significant subsequent evolution (e.g., Trujillo et al. 2006; Cimatti et al. 2008; van Dokkum et al. 2008).

Given the diversity and rapid changes in the galaxy population at this epoch, it is important to secure and study large, uniformly selected samples of galaxies at \( 1.5 < z < 3.5 \) in a homogeneous way. Unfortunately, it is difficult to obtain such samples, as familiar rest-frame optical spectral features are shifted into the near-infrared. As a consequence, most studies of high-redshift galaxies have focused on blue star forming galaxies, as they are relatively bright at observed-optical (rest-frame ultraviolet) wavelengths (e.g., Steidel et al. 1996, 1999). Although this approach is very efficient, it misses galaxies that are relatively red: as shown in van Dokkum et al. (2006), the majority of galaxies with masses \( > 10^{11} M_\odot \) at \( 2 < z < 3 \) would not be selected by traditional Lyman break criteria. Studying samples that are complete to a rest-frame optical limit, or to a stellar mass limit, implies a compromise: one either works with small, bright samples for which it is possible to obtain spectra (Cimatti et al. 2002; Kriek et al. 2008), or one relies on photometric redshifts derived from broadband photometry (e.g., Dickinson et al. 2003; Fontana et al. 2006, and many other studies). These photometric redshifts are generally assumed to be sufficiently accurate for determining broad characteristics of the galaxy population, such as the luminosity function. However, redshift errors can lead to biases (see, e.g.,

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Marchesini et al. 2007, Reddy et al. 2008), and these redshifts cannot be used to measure accurate rest-frame colors, stellar population parameters, or the local galaxy density. Furthermore, their random errors typically have a non-Gaussian distribution (leading to so-called “catastrophic failures”) and they can have significant systematic uncertainties (see, e.g., Brammer et al. 2008, and references therein).

Inspired by the successful COMBO-17 optical medium-band imaging survey at redshifts $0 < z < 1$ (Wolf et al. 2003), we are undertaking a project that will provide a sample of $K$-selected galaxies with accurate redshifts in the range $1.5 < z < 3.5$ that is several orders of magnitude larger than what is available today. We designed and manufactured a set of five medium-bandwidth near-infrared (near-IR) filters, which provide “spectra” with a resolution of $R \sim 10$ from 1–1.8 μm. The filters are designed to isolate the location of the redshifted Balmer or 4000 Å break for galaxies at $1.5 < z < 3.5$. A set of these filters was manufactured for the NEWFIRM camera (Probst et al. 2004) on the Kitt Peak 4 m, and the NEWFIRM Medium Band Survey (NMBS; an NOAO Survey Program) began in March 2008. This paper describes the characteristics of the filters, outlines the survey strategy, and shows results from a short pilot program that we executed in the Spring of 2008. The survey will be described more extensively in a forthcoming paper (K. Whitaker et al., in preparation).

2. FILTER CHARACTERISTICS

The filters are shown in Figure 1. The $J$ band is split in three filters $J_1$, $J_2$, and $J_3$, and the $H$ band is split in two filters $H_1$ and $H_2$. Each filter consists of two physically separate components: a transmission filter and a blocking filter, which both need to be mounted in the two filter wheels of NEWFIRM. The blocking filters are needed because of the long-wavelength sensitivity of NEWFIRM’s InSb arrays, and are the cause of the roll-off in sensitivity toward shorter wavelengths and the wiggles in the transmission curves of (particularly) $J_2$ and $J_3$. The $J_1$ filter has its own blocking filter, $J_2$ and $J_3$ share a blocking filter, and $H_1$ and $H_2$ share a blocking filter. Mounting all five filters in NEWFIRM therefore requires eight filter slots.

Central wavelengths and 50% cut-on and cutoff wavelengths for the five filters are listed in Table 1. The $J_1$ filter is somewhat redder and broader than the $Y$ filter used by, e.g., the United

![Fig. 1.—Medium-bandwidth filters designed for NEWFIRM and used in the NMBS. The throughput of the filters ranges from $\approx 70\%$ for $J_1$ to $\approx 90\%$ for $H_2$ (excluding effects of the atmosphere). The top panel shows the atmospheric transmission spectrum, for two different water columns: the broken line is for a column of 1.6 mm and the solid line is for 3.0 mm.](image)
Kingdom Infrared Telescope (UKIRT) Infrared Deep Sky Survey, whose cut-on and cutoff wavelengths are 0.97 and 1.07 μm, respectively. The \( J_3 \) filter is narrower and redder than the \( J_s \) (“J-short”) filter used in, e.g., HAWK-I on the Very Large Telescope. The wavelength range covered by the \( J_s \) filter contains an atmospheric \( H_2O \) absorption feature, and the red edge of the \( J_3 \) filter pushes slightly into the \( H_2O \) band between the \( J \) and \( H \) windows. The atmosphere leads to a decrease in throughput of up to \( \approx 10\% \) in the \( J_2 \) and \( J_3 \) filters. Figure 1 and Table 1 demonstrate the effects of varying the \( H_2O \) column between 1.6 and 3.0 mm; for all filters the variations in throughput due to variations in the water column are \( \approx 2\% \).

Transformations from the Vega to the AB system were calculated by integrating the Vega spectrum, using filter curves that include atmospheric absorption. The uncertainties in the AB offsets listed in Table 1 are \( \approx 0.02 \), and are dominated by uncertainties in the absolute calibration of Vega.

### 3. SURVEY STRATEGY

The goal of the NMBS is to obtain high-quality spectral energy distributions (SEDs) and redshifts for galaxies down to a limit of \( K \approx 21.5 \). In practice, we aim to secure medium-band photometry with a 1 σ uncertainty of \( \approx 2 \times 10^{-20} \) ergs s\(^{-1}\) cm\(^{-2}\) Å\(^{-1}\). This constant limit in \( F_\lambda \) should provide >8 σ photometry in bands redward of the Balmer break for most galaxies with \( 1.5 < z < 3.5 \) and \( K < 21.5 \) (Vega; \( K_{AB} < 23.3 \)). This limit allows us to select and study samples that are >95% complete for galaxies with stellar masses \( >10^{11} M_\odot \) out to \( z \sim 3 \) (van Dokkum et al. 2006). The required integration times strongly depend on conditions, and are typically \( \sim 40 \) hr per band.

We are targeting two fields: a single 27.6’ × 27.6’ NEWFIRM pointing within the COSMOS field (Scoville et al. 2007) and a single pointing overlapping with part of the All-Wavelength Extended Groth Strip International Survey (AEGIS) strip (Davis et al. 2007). The center of the COSMOS pointing is at \( \alpha = 9^h59^m53.3^s, \delta = +02^d24^m08^s \) (J2000); it overlaps with the extensive data sets at other wavelengths that are available for this field, including the \( z \) COSMOS deep redshift survey (Lilly et al. 2007) and the upcoming UltraVISTA survey.\(^3\) The AEGIS pointing is centered at \( \alpha = 14^h18^m00^s, \delta = +52^d36^m07^s \) (J2000). It overlaps with about 50% of the deep ACS and Spitzer imaging in AEGIS and with the “Westphal” field, which contains 188 spectroscopically confirmed Lyman break galaxies (see Steidel et al. 2003). For both fields public optical ugriz data are available from the Deep Canada-France-Hawaii Telescope Legacy Survey.\(^3\) These data are of uniform quality (at least over the extent of the NEWFIRM fields) and very deep, reaching typical 10 σ AB limits of \( \sim 25.5 \) for point sources.

These two fields are observed whenever they are available and conditions are good. In mediocre conditions, we observe backup fields to much shallower depth. The goal is to obtain several of these fields over the course of the survey, as they play an important role in calibrating photometric redshifts, constraining the bright end of the luminosity and mass functions, and in providing targets for follow-up spectroscopy. In the following we report on observations of the first of these backup fields, the Multiwavelength Survey by Yale-Chile (MUSYC) SDSS 1030+05 field.

### 4. OBSERVATIONS AND REDUCTION OF THE MUSYC SDSS 1030+05 FIELD

The first run of the NMBS comprised a contiguous block of 24 nights, 2008 March 24–April 16. A detailed description of the observations in our primary COSMOS and AEGIS fields will be presented in K. Whitaker et al., in preparation. Here we discuss observations in the bad weather backup field MUSYC SDSS 1030+05 (see Quadri et al. 2007; Blanc et al. 2008). This is one of the four 30’ × 30’ fields surveyed by MUSYC (Gawiser et al. 2006). It is centered on \( \alpha = 10^h30^m27.1^s, \delta = +05^d24^m55^s \) (J2000), and contains the \( z = 6.3 \) QSO SDSSp J103002.71+052455.0 (Becker et al. 2001).

We chose this field because it contains 14 objects from a sample of spectroscopically confirmed \( K \)-selected galaxies at \( z \sim 2.3 \) (Kriek et al. 2008). The Kriek et al. sample is unbiased with respect to observed-optical flux, as it was selected on the basis of \( K \)-magnitude and photometric redshift only. Furthermore, rest-frame optical continuum spectroscopy is available for the entire sample (see Kriek et al. 2008). The NMBS observations in this field therefore effectively serve as a small pilot program, allowing us to assess whether the medium-band filter technique can indeed provide reliable SEDs and redshifts for optically faint sources. Even though there are thousands of spectroscopic redshifts available in our primary survey fields

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\(^\text{1}\)Information on the UltraVISTA survey can be found online at http://www.eso.org/sci/observing/policies/PublicSurveys/.

\(^\text{2}\)The Web site for the Deep Canada-France-Hawaii Telescope Legacy Survey is http://www.cfht.hawaii.edu/Science/CFHTLS/.

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\( \lambda_{\text{cen}}^a \) Includes atmosphere, with 3.0 mm water column.

\( \lambda_{\text{blue}}^b \) 50% cut-on/cutoff wavelengths; includes atmosphere.

\( \lambda_{\text{red}}^c \) Transmission of the atmosphere for different water columns.

\( \Delta \text{AB}^d \) Synthetic AB magnitudes of Vega.
(AEGIS and COSMOS), they are almost exclusively for optically bright, low redshift galaxies.

Because the SDSS 1030+05 field served as a bad weather backup field the data quality is relatively poor (as compared to the main survey fields). The seeing was typically in the range 1.4′′–1.8′′ when we observed the field, and the background was often relatively high. Total integration times were 2.3 hr in J1, 1.1 hr in J2, 2.5 hr in J3, 1.1 hr in H1, and 1.6 hr in H2. The data were processed using a new reduction package, which was developed by one of us (L.L.). The heart of the code is similar to the popular IRAF XDIMSUM package, but it incorporates many of the changes that we have developed over the years (see Labbé et al. 2003; Quadri et al. 2007). The code was completely rewritten in the IDL programming environment, automated, and optimized for NEWFIRM.

The data were calibrated by repeated observations of six different near-IR spectrophotometric standards. Synthetic magnitudes of these stars were calculated by integrating their observed (HST/NICMOS) spectra in our filters. We verified that this method reproduces the (independently calibrated) broadband J-, H-, and K-band magnitudes of these stars. Based on the observed variation of zero points derived from different stars and on different photometric nights, we estimate that the zero-point uncertainties are ≤0.02 mag. The stars and their synthetic magnitudes are listed in Table 2, along with stars that were not observed during the March/April run. The achieved 5 σ depths in the SDSS 1030+05 field are J1 = −22.2, J2 = −21.5, J3 = −21.4, H1 = −20.8, and H2 = −20.9 (total Vega magnitudes for point sources).

The medium-band images were combined with UBVRIC photometry from the MUSYC survey. A general description of the MUSYC optical imaging is given in Gawiser et al. (2006); specific aspects of the SDSS 1030 field are provided in Quadri et al. (2007) and Blanc et al. (2008). The methodology for PSF-matching of the optical- and near-IR data and the procedures for creating a K-selected catalog are the same as used in Labbé et al. (2003) and Quadri et al. (2007). We also included Spitzer Infrared Array Camera (IRAC) imaging in the analysis, which are described in Marchesini et al. (2008). The final product is a K-selected catalog with accurate UBVRICzJ1J2J3H1H2K + IRAC fluxes.

5. RESULTS

5.1. Spectral Energy Distributions

Of the 14 galaxies in the SDSS 1030 field that overlap with the Kriek et al. (2008) sample, four have an average signal-to-noise ratio (S/N) in the H1 and H2 filters that exceeds our survey criterion of 8. The broad + medium-band photometry of these galaxies is shown in Figure 2, along with the (binned) Gemini Near-Infrared Spectrograph (GNIRS) spectra from Kriek et al. (2008) (shown in light gray).

The medium-band photometry is consistent with both the GNIRS continuum spectroscopy and with the broadband J and H data. The medium bands sample the SEDs more finely than the broad bands and capture the overall shape of the SEDs as traced by the GNIRS spectra. In particular, there are obvious breaks in the medium-band photometry, making it possible to pinpoint the location of the redshifted Balmer or 4000 Å break within the J band window (or between J3 and H1 for objects 1531 and 1813). This is a significant advance: the medium bands sample the SED with a spectral resolution of R = 10–11, whereas standard broadband near-IR photometry corresponds to R = 3–4.

The ability to detect breaks obviously depends on a combination of the intrinsic strength of the break and the S/N of the photometry. Galaxy 181310 has a very strong break between J3 and H1, which would also have been detected in shallower exposures. The breaks in the other galaxies are weaker, and the ability to measure accurate redshifts will depend sensitively on the quality of the photometry. The average S/N in H1 and H2 ranges from 8 to 15 for the four galaxies shown in Figure 2;

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Table 2. Spectrophotometric Standards

| ID         | α         | δ         | J1   | J2   | J3   | H1   | H2   | K   |
|------------|-----------|-----------|------|------|------|------|------|-----|
| G191B2     | 05°05′30.6″ | +52°49′53.6″ | 12.44 | 12.52 | 12.54 | 12.62 | 12.67 | 12.75 |
| GD71       | 05°52′27.5″ | +15°3′16.6″  | 13.66 | 13.72 | 13.75 | 13.82 | 13.87 | 13.95 |
| GD153      | 12°57′02.4″ | +22°01′56.0″ | 13.99 | 14.06 | 14.09 | 14.16 | 14.21 | 14.29 |
| P041C      | 14°51′57.9″ | +71°23′13.0″ | 11.08 | 10.94 | 10.85 | 10.60 | 10.57 | 10.55 |
| P177D      | 15°50′13.6″ | +47°36′40.0″ | 12.49 | 12.33 | 12.22 | 11.96 | 11.92 | 11.90 |
| P30E       | 10°31′13.6″ | +30°38′48.0″ | 12.02 | 11.86 | 11.76 | 11.49 | 11.45 | 11.42 |
| 1740346    | 17°40′03.7″ | +65°27′15.0″ | 12.18 | 12.12 | 12.09 | 12.02 | 12.02 | 12.00 |
| 1805292    | 18°05′29.3″ | +64°27′52.1″ | 12.10 | 12.07 | 12.06 | 12.02 | 12.02 | 12.00 |
| 1812095    | 18°12′09.6″ | +63°29′42.3″ | 11.43 | 11.39 | 11.37 | 11.31 | 11.30 | 11.28 |
| KF0671     | 17°57′58.5″ | +66°52′29.3″ | 11.89 | 11.84 | 11.61 | 11.31 | 11.30 | 11.29 |

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The numbering follows Kriek et al. (2008), who give coordinates, K magnitudes, and other information for these galaxies.
the goal of the main survey is to reach a S/N > 8 in the bands redwards of $\lambda_{\text{rest}} = 4000$ Å for all galaxies with $K < 21.5$ in our NEWFIRM fields.

5.2. Photometric Redshifts

Redshifts are measured with the photometric redshift code EAZY (Brammer et al. 2008), which is optimized for situations where complete spectroscopic calibration samples are not available. The default template set and rest-frame template error function were used, and the default magnitude and redshift priors (appropriate for the $K$ band). Although not of great consequence in the present context, the CHI2_SCALE parameter was set to 0.5 in order to provide more realistic error bars.\footnote{We find that the default EAZY uncertainties slightly overestimate the errors; as discussed in Brammer et al. (2008), the exact interpretation of the uncertainties can vary between data sets.}

The photometric redshifts are compared to the Gemini/GNIRS redshifts from Kriek et al. (2008) in Figure 3. There is excellent agreement for the four galaxies, with the biweight scatter in $(z_{\text{phot}} - z_{\text{spec}})/(1 + z_{\text{spec}})$ only 0.010. This value is not very robust given the small sample size (the normalized median absolute deviation is 0.020, and the rms is 0.011), but it is substantially better than what has so far been achieved at these redshifts. As an example, Grazian et al. (2006) and Brammer et al. (2008) find a scatter of 0.06–0.07 at $z > 1.5$ using state of the art broadband data in the CDF-South field. Similarly, Ilbert et al. (2008) find a scatter of 0.06 (with 20% catastrophic outliers) at $1 < z < 3$ in COSMOS using 30 photometric bands (including GALEX, IRAC, and 18 medium-bandwidth optical filters from Subaru).

Open symbols in Figure 3 have a S/N less than our survey criterion of 8 in the $H_1$ and $H_2$ bands. Interestingly, they nevertheless show relatively small scatter as well, and the scatter in the full sample of 14 galaxies is $\approx 0.023$ in $\Delta z/(1 + z)$. The sample is obviously too small to investigate the exact behavior of the redshift uncertainty as a function of the S/N, but the presently available information suggests that uncertainties of $\approx 0.02$ in $\Delta z/(1 + z)$ can be achieved with a S/N of 6–10 in filters redward of the redshifted Balmer or $4000$ Å break.

The dark gray spectra in Figure 2 are the best-fitting EAZY model SEDs. These templates fit the observed photometry well, and all four galaxies have acceptable best-fit $\chi^2$ values (partly owing to the template error function; see Brammer et al. 2008). The dark gray model spectra fit the binned GNIRS spectra remarkably well; the only significant deviation is a $\approx 20\%$ underprediction of the flux at $\approx 2.2$ $\mu$m for galaxy 301.

\footnote{Each template is actually a linear combination of six “base” templates, and these six base templates are themselves linear combinations extracted from a large template library—see Brammer et al. (2008) for details.}
6. OTHER APPLICATIONS: SELECTING THE COOLEST BROWN DWARFS

The medium-band filters were designed to improve redshift estimates and stellar population constraints for distant galaxies but can also be used for other purposes, in particular when used in a wide, relatively shallow survey. Among these other applications are the identification of objects with extremely bright emission lines; improved star/galaxy separation; identification and characterization of high-redshift galaxies and QSOs; and finding cool brown dwarfs. In the following we expand on the latter application.

As illustrated for a T7 dwarf in Figure 4, the spectra of very late-type dwarfs (beyond the L/T boundary) are characterized by strong H$_2$O and CH$_4$ absorption. The subtype within the T class is determined by the strengths of these absorption bands, which in turn are thought to be closely correlated with the effective temperature (see Burgasser et al. 2002). The most dramatic change going from T1 to T9 is in the broad methane absorption at $\sim$1.7 $\mu$m, which is weak at the L/T boundary and almost complete for the coolest T dwarfs.

Finding the coolest dwarfs typically involves a multistage process: the initial selection uses $JHK$ photometry from Two Micron All Sky Survey (2MASS; e.g., Burgasser et al. 2002) or $iz$ photometry from the Canada-France-Hawaii Telescope Legacy Survey (CFHTLS; e.g., Delorme et al. 2008); follow-up broadband near-IR imaging is used to weed out interlopers and spurious sources and to obtain accurate $J-H$ and $H-K$ colors; and near-IR spectroscopy provides the spectral type.

Interestingly, the medium-band filters offer an extremely efficient way to select ultracool stars, as the $H_2$ filter coincides almost exactly with the location and width of the CH$_4$ feature at $\sim$1.7 $\mu$m. As a result, the $H_1-H_2$ color is a very strong function of spectral class (and hence effective temperature) for the coolest dwarfs. In Figure 5 we show the relation between the $H_1-H_2$ color and spectral type for the T dwarfs of Burgasser et al. (2002). The colors are not based on models but were calculated by integrating the observed near-IR spectra of these dwarfs.

There is a clear relation between T subclass and $H_1-H_2$ color, with $H_1-H_2$ progressively bluer for later types. The relation shown by the broken line has the form $T_{\text{eff}} = 4.2 - 2.7(H_1 - H_2)$; it has an rms of less than one subclass. The histogram shows the distribution of $H_1-H_2$ colors for all objects in the SDSS 1030 field; dwarfs with spectral type $\geq$T5 can be uniquely identified by their extremely blue $H_1-H_2$ color. Also included is the coolest dwarf known to date, which may be a T/Y boundary object (Delorme et al. 2008). This object falls on the same relation as the other T dwarfs.

It is interesting to speculate whether the $H_1-H_2$ color could also be used to select stars with $T_{\text{eff}} < 700$ K, the elusive “Y” class (e.g., Kirkpatrick et al. 1999). The CH$_4$ band saturates near the T/Y boundary, which limits its utility for spectral classification. Nevertheless, the recently discovered T/Y transition object CFBDs J005910.90–011401.3 (Delorme et al. 2008) falls on the same relation as the late T dwarfs (see Fig. 5). It may therefore be possible to select Y dwarfs by the simple criterion $H_1-H_2 < -1.5$.

Fig. 4.—Observations in $ugrizJHK$ (black) and the medium-band filters (blue; obtained in twilight) for the T7 dwarf 2MASS 1553+1532. The spectrum is from Burgasser et al. (2002). This cool dwarf has a unique signature in the medium-band filters, particularly in the $H_1-H_2$ color.

Fig. 5.—Relation between $H_1-H_2$ color and T subclass, as derived from near-IR spectra of cool dwarfs from Burgasser et al. (2002). The histogram shows the distribution of $H_1-H_2$ colors for all objects in the SDSS 1030 field; dwarfs with spectral type $\geq$T5 can be uniquely identified by their extremely blue $H_1-H_2$ color. Also included is the coolest dwarf known to date, which may be a T/Y boundary object (Delorme et al. 2008). This object falls on the same relation as the other T dwarfs.

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13 Obtained from http://web.mit.edu/ajb/www/tdwarf/#spectra.
7. CONCLUSIONS

We have developed a medium-bandwidth filter system in the near-IR, providing a compromise between spectroscopy and broadband imaging. Installed in the wide-field NEWFIRM camera on Kitt Peak, the filters enable us to obtain high-quality redshifts and spectral energy distributions for large, complete samples of galaxies with far greater efficiency than is possible with spectroscopy. The NMBS aims to obtain redshifts of \( \approx 40 \) 000 galaxies with \( K < 21.5 \), some 8000 of which are expected to be at \( z > 1.5 \). To put this in context, with a multiobject near-IR spectrograph such as FLAMINGOS-2 on Gemini it would require \( \approx 2500 \) hr to obtain redshifts for 1000 galaxies to this limit (scaling from Kriek et al. 2008).

Although the initial results reported here are promising, the accuracy of the redshift measurements needs to be verified. The medium-band technique relies on the presence of a break in the rest-frame optical, and the improvement in photometric redshift estimates will therefore depend on galaxy type. Very young stellar populations with ages \( \lesssim 300 \) Myr do not have a significant Balmer break, and the accuracy of the redshifts of many Lyman break and “BM/BX” galaxies (Steidel et al. 2004) may therefore not be much better than can be derived from broadband optical photometry alone. Similarly, very dusty galaxies can have featureless red SEDs.

With larger samples of galaxies with spectroscopic redshifts, we will be able to quantify these and other effects (such as the presence of bright emission lines, and the redshift dependence of redshift errors). Such spectroscopic samples will obviously not be representative of our entire sample, but they can be used to assess the reliability of the uncertainties given by the EAZY code. If accuracies of 0.01–0.02 turn out to be typical for galaxies down to our survey limit, the NMBS will establish the relations between redshift, color, and density at \( 1.5 < z < 3.5 \) with excellent statistics. Reduced images, catalogs, and derived redshifts, stellar population parameters, and rest-frame colors will be publicly released after the survey is completed. Finally, we note that the \( H_1 \) and \( H_2 \) filters enable very efficient searches for late T and candidate Y dwarfs.

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