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Seeing-sorted Visible Multi-Object Spectrograph *U*-band Imaging of the GOODS-south Field*

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Abstract

We present the optimal resolution and optimal depth *U*-filter mosaics using the seeing-sorted method of Ashcraft et al. on deep, ground-based *U*-bandimaging of the Great Observatories Origins Deep Survey South field as part of the near-UV imaging program UVCANDELS. We use the *U*-band images obtained with the Visible Multi-Object Spectrograph on the

European Southern Observatory Very Large Telescope by Nonino et al. Our best resolution mosaic includes images with a seeing full-width half maximum (FWHM) ≤ 0.″8, and encompasses 50% of the data. Our best depth mosaic includes images with FWHM ≤ 1.″5, corresponding to 100% of the data. Prior to being combined, the source fluxes in each individual background-subtracted image are corrected to match a 3D-HST photometric catalog of the same field to correct variations in the *U*-band zero-points. These mosaics provide deep *U*-banddata complementary to the UVCANDELS HST WFC3 F275W and ACS F435W images. We assess the depth of both *U*-bandmosaics.

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1. Introduction

Nonino et al. (2009) presented the results of deep *U*-band and *R*-band imaging of the GOODS-south field. In the current paper, we present the seeing-sorted version of their *U*-bandimages, which also have a closer zero-point match to other GOODS multi-wavelength photometry. By utilizing a number of image processing techniques, Nonino et al. (2009) were able to create an image mosaic out of the 552 single chip images taken from the VIMOS instrument on the Very Large Telescope (VLT) in Chile. The final mosaic from this work had a full width half maximum of 0.″8 and reached a depth of $m_{AB} \simeq 29.8$ mag (Nonino et al. 2009).

Ashcraft et al. (2018) used observations from the Large Binocular Telescope image mosaics: (1) the best resolution mosaic, generated with images using seeing FWHM $\leq 0\farcs8$, and (2) the best depth mosaic, cut off at $1\farcs8$ seeing (Ashcraft et al. 2018). This stacking method is useful to mitigate atmospheric effects associated with ground-based imaging. The optimal resolution mosaic is best for studying bright galaxies, and shows structure in galaxies more clearly than the best depth mosaic. The optimal depth stack, however, is more sensitive to lower surface brightness objects and structures. Ashcraft et al. (2018) showed using galaxy number counts that the optimal depth mosaic detects more of the faintest galaxies.

The work presented here focuses on the GOODS-south field, builds on the data of Nonino et al. (2009) and uses the seeing-sorted stacking method of Ashcraft et al. (2018). An additional step was incorporated to reduce uncertainty and variability in the zero-points of individual images following a process similar to one described in T. McCabe et al. (2021, in preparation).

2. Observations

The 552 individual U_V-filter images used in this work were taken between 2004 August and 2006 October by the VIsible Multi-Object Spectrograph (VIMOS) on ESO's VLT (Nonino et al. 2009). VIMOS is a four-chip charge coupled device (CCD) camera with a pixel scale of $0\farcs205$/pixel and a field of view of 4 × 7' × 8'. In imaging mode, each chip uses a 2048 × 2440 pixels EEV 44–82 backside illuminated CCD. The chips are separated by 2' gaps. Special care was taken when dithering to get uniform coverage of the field (Nonino et al. 2009).

3. Analysis

Ashcraft et al. (2018) found a ~0.2 mag difference in the *U*-bandphotometric zero-points between their optimal resolution and optimal depth LBT/LBC mosaics. This difference was attributed to variations in transparency among different exposures and across different nights. Here, we therefore correct the flux scale of each image to match the *U*-bandphotometry in the 3D-HST photometric catalog of Skelton et al. (2014). Figures 1(e) and (f) show an example of the uncorrected and corrected flux ratios between the VIMOS images and the 3D-HST catalog for the first four nights of observations.

0.6%. After applying these *U*-bandzero-point corrections, this ratio increased to 99.8% ± 0.1%, better matching the 3D-HST catalog.

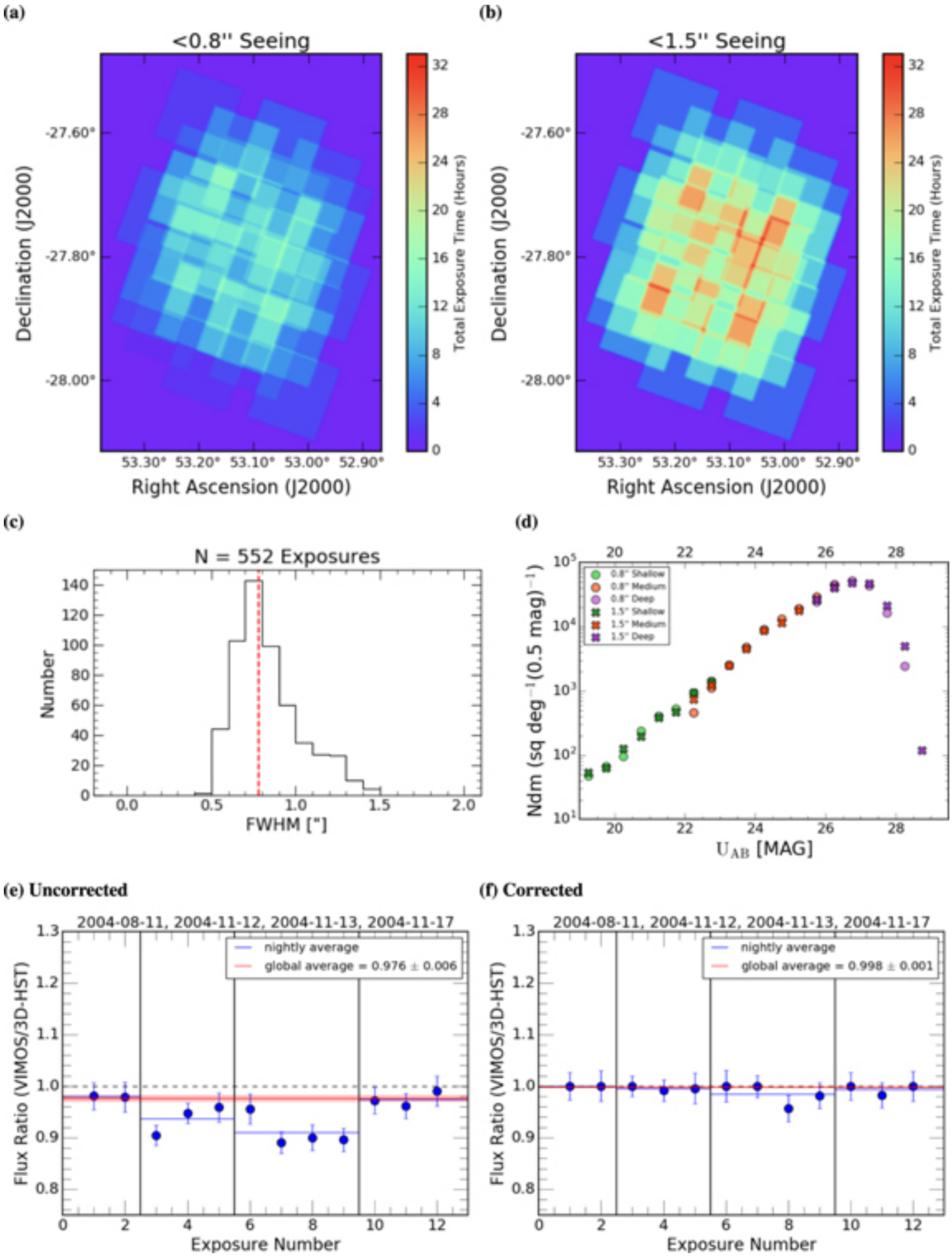

Figure 1. VLT/VIMOS U_V-filter exposure maps for the best resolution mosaic (a) and the best depth mosaic (b) in GOODS-south. The color indicates the total exposure time in hours. Figure (c) is a histogram of the seeing for the 552 single chip VIMOS images. The median seeing, FWHM ~ 0.″78, is indicated by the dashed red line. Exposures with FWHM ≤ 0.″8 are included in the best resolution mosaic. All exposures are used in the best depth mosaic. Figure (d) compares the galaxy number counts for both mosaics. The circles

correspond to the optimal resolution mosaic counts and the crosses correspond to the optimal depth mosaic. The counts are color-coded based on the exposure time areas they were taken from (i.e., shallow corresponds to least exposure time, deep corresponds to most exposure time; please magnify the PDF as needed). Figure (e) and (f) show uncorrected and corrected flux ratio distributions for the first four nights of observations, respectively. Nights are separated by solid vertical lines. The horizontal, dashed black line represents flux equal to 3D-HST (Skelton et al. 2014). The solid red line with confidence bands (shaded red) represents the global average for all 139 exposures before and after U_V zero-point corrections to match the 3D-HST U catalog.

All 552 single chip exposures were sorted based on their seeing (Figure 1(c)). SWARP (Bertin et al. 2002; Bertin 2010) was used to combine the individual images. Our best resolution mosaic, cut off at FWHM $\lesssim 0''.8$, used 288 images, just over 50% of the VIMOS U_V data (Figure 1(a)). Our best depth mosaic used images with seeing FWHM $\lesssim 1''.5$, corresponding to 100% of the VIMOS U_V data (Figure 1(b)). SEXTRACTOR (Bertin & Arnouts 1996) was used to create source catalogs of the mosaics. The mosaics shared the same SEXTRACTOR configuration parameters, which are similar to those in Ashcraft et al. (2018). The galaxies were separated from stars as described in, e.g., Windhorst et al. (2011). Figure 1(d) shows the resulting galaxy number counts from our U-bandcatalogs. The best resolution mosaic U-bandcounts start to turn over around $m_{AB} \simeq 26.8$ mag, and fall off more quickly than the best depth U-bandmosaic, which turns over at $m_{AB} \simeq 27$ mag in U-band. For examples of the differences in resolution and depth between our best resolution and best depth mosaics we refer the reader to Figures 2–5 of Ashcraft et al. (2018), which are also representative for our data.

4. Summary

We present the results of deep U-bandimaging of the GOODS-south field from VIMOS on the VLT using data and image reductions from Nonino et al.

(2009). Two image mosaics were made following the seeing-sorted stacking method of Ashcraft et al. (2018). All 552 single chip images were sorted based on FWHM. The optimal resolution mosaic was assembled using only images with FWHM ≤ $0\farcs8$. The optimal depth mosaic was made from images with FWHM ≤ $1\farcs5$. Before creating the mosaics, 139 four-chip exposures were corrected to better match the 3D-HST *U*-bandflux (Skelton et al. 2014). With the completion of these mosaics, three of the four UVCANDELS fields will have ground-based images complementary to HST data. New LBT *U*-banddata for the EGS and COSMOS fields are currently being reduced, thereby completing the seeing-sorted stacking analysis for the UVCANDELS program. In the coming years, these mosaics will complement JWST 1–5 μm observations and help us better understand galaxy assembly over the past 10 billion years. The image mosaics and source catalogs from this work will be released as part of the UVCANDELS program later this year, found at http://uvcandels.ipac.caltech.edu.

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Footnotes

* Based on data acquired using the Very Large Telescope (VLT) of the European Southern Observatory (ESO).