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

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Published August 2021 - © 2021. The Authors. Published by the American Astronomical Society.

Abstract

We present the optimal resolution and optimal depth U-band mosaics using the seeing-sorted method of Ashcraft et al. on deep, ground-based U-band imaging 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) ≤ 0.9”, 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-band data complementary to the UVCANDELS HST WFC3 F125W and ACS F435W images. We assess the depth of both U-band mosaics.

1. Introduction

Nonino et al. (2009) presented the results of deep U- and R-band imaging of the GOODS-south field. In the current paper, we present the seeing-sorted version of their U-band images, 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 55 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 0.9” and reached a depth of $m_{AB} = 29.1$ mag (Nonino et al., 2009).

Ashcraft et al. (2013) used observations from the Large Binocular Telescope of the GOODS-North field and used a sub-stacking method to create two image mosaics: (1) the best resolution mosaic, generated with images using seeing FWHM ≤ 0.9”, and (2) the best depth mosaic, cut off at 1.5” seeing (Ashcraft et al., 2013). 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. (2013). 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 55 individual U-band 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 0.035/pixel and a field of view of $4' \times 4'$. In Imaging mode, each chip uses a 2048 x 2440 pixels EVG 48-82 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. (2013) found a ~0.2 mag difference in the U-band photometric zero-points between their optimal resolution and optimal depth U-band 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-band photometry in the 3D-HST photometric catalog of Skelton et al. (2014). Figures 3(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. Prior to these corrections, the average ratio across all nights was 97.6% ± 0.6%. After applying these U-band zero-point corrections, this ratio increased to 99.8% ± 0.1%, better matching the 3D-HST catalog.

![Image](image.png)

Figure 1. VLT/VIMOS U 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 = 0.79 arcsec is indicated by the dashed red line. Exposures with FWHM < 0.79 arcsec 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 mosaics 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 longest exposure time, deep corresponds to shortest exposure time; please magnify the PDF as needed). Figures (e) and (f) show uncorrected and corrected flux ratio distributions for the first four nights of observations, respectively. Hists are separated by solid vertical lines. The horizontal, dashed black line represents flux equal to 3σ in HST (Kelson et al. 2014). The solid red line with confidence bands (shaded red) represents the global average for all 139 exposures before and after U-$\lambda$ zero-point corrections to match the 3D-HST U catalog.

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All 552 single chip exposures were sorted based on their seeing (Figure 1c), swan (Bertin et al. 2002; Bertin 2013) was used to combine the individual images. Our best resolution mosaic is cut off at 1.35 FWHM X-9% used 289 images, just over 50% of the VIMOS U-λ data (Figure 1a). Our best depth mosaic used images with seeing FWHM ≤ 1.5′′, corresponding to ~100% of the VIMOS U-λ data (Figure 1b). 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. (2013). Figure 1d shows the resulting galaxy number counts from our U-λ data catalogs. The best resolution mosaic U-bandcounts start to turn over at mg~28.8 mag and fall off more quickly than the best depth U-band mosaic, which turns over at mg~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-band imaging of the GOODS-south field from VIMOS on the VLT using data and image reductions from Nomoto 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 ≤ 0.79′′. The optimal depth mosaic was made from images with FWHM ≤ 1.5′′. Before creating the mosaics, 139 four-chip exposures were corrected to better match the 3D-HST U-band flux (Kelson et al. 2013). With the completion of these mosaics, three of the four UVCANDELS fields will have ground-based images complementary to HST data. New LBT U-band data 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://uvcandeles/pascaltip.edu.

This work used data from the 3D-HST Treasury Program (HST-GO-12177 and 12329). We also acknowledge support from the NSF/NOAO grant NSF-0941505 awarded to Satalay through the Gauss.
Footnotes

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