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A Mosaic of TESS images Acquired Near The South Ecliptic Pole

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1. SCIENTIFIC MOTIVATION AND SUMMARY

The primary goal of the two-year Transiting Exoplanet Sky Survey (TESS) mission is to discover new, nearby exoplanet systems (Ricker et al. (2015). The mission acquires images every 30 minutes, through a single broadband filter and with four cameras. It offers a unique opportunity to study the diffuse Universe. Holwerda (2018) showed it can in principle allow studies of topics such as the derivation of the halo mass profiles of nearby galaxies (essentially those in the NGC and UGC catalogs); tests of Lambda-CDM galaxy formation scenarios; derivation of stellar halo fractions for galaxies of different masses and morphologies; identification of local stellar streams that cross over multiple TESS observing sectors and other galaxy cannibalism leftovers; detection of ultra-diffuse galaxies as companions to bigger galaxies; and searches for supernovae remnants and planetary nebulae.

With such science goals in mind, we have constructed a first-look, science-ready mosaic of a subset of the images released by TESS, to inform the processing and storage requirements of a mosaic of the southern sky, planned for Fall 2019. The mosaic covers the continuous viewing zone near the south ecliptic pole. In response to community requests, the mosaic is freely available at https://doi.org/10.26134/ExoFOP4 along with tools for downloading the data. This paper describes the creation of the mosaic and its characteristics.

2. CREATING THE MOSAIC

TESS is equipped with four 2048×2048 CCD cameras, which in Mission Year 1 have observed the sky in swaths 24°×96° in size, stretching from the south ecliptic pole to ecliptic latitude $\beta - 6°$. The satellite observes 13 partially overlapping swaths, or sectors, for a total of 27.5 days each. This strategy generates a sky coverage in the southern hemisphere where the south ecliptic pole is observed continuously for 351 days, and the sectors nearest the ecliptic equator are observed for 27.5 days. Full frame images (FFIs) for successive sectors are released at regular intervals through the mission archive at the Mikulski Archive for the Space Telescope (MAST).

We have created a mosaic of all FFIs acquired by Camera 4, which covers the south ecliptic pole, for Sectors 1 through 5. Figure 1 shows this mosaic, downsampled by ×10 for presentation. The mosaic was created with the Montage image mosaic engine (Berriman and Good 2017). It preserves the calibration and astrometric fidelity of input FITS images, models smoothly varying image backgrounds across images, and rectifies these backgrounds to a common level. Montage is to our knowledge unique in using this approach to handling backgrounds. The processing required 2.5 days running on a 2.4 GHz 4-core Linux server, and created a 64-bit mosaic 20 TB in size. The mosaic over-samples the original images at 3.5× the original pixel size of 21 arcseconds to preserve all information in the overlaps between images.

3. CHARACTERISTICS OF THE MOSAIC

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Figure 1 presents the resulting mosaic. The most prominent feature is the Large Magellanic Cloud, in the bottom right quadrant. Even after background rectification two artifacts remain: a nearly symmetric ring of light near $\beta = -83°$, most likely due to scattering in the instrument and to extended red emission from high-latitude clouds (Witt et al. 2008); and scattering at the image edges (localized stripes associated with the CCD strapping are not visible in Figure 1). A custom approach is therefore needed to account for the effects of the artifacts on the science content of the mosaics; we plan to investigate such approaches. The most productive approach may well be to identify objects of interest in the mosaics, then analyze the background features in individual images and use the multiple measurements to deduce high-quality statistics on them. The exact noise reduction that can be achieved will depend on the science case and the precision with which stellar contaminants can be removed for that use case. Finally, Stripes associated with the strapping in the CCDs—not visible in Figure 1—are localized to specific pixel columns, and a one-dimensional smooth background removal should leave the extended objects unaffected.

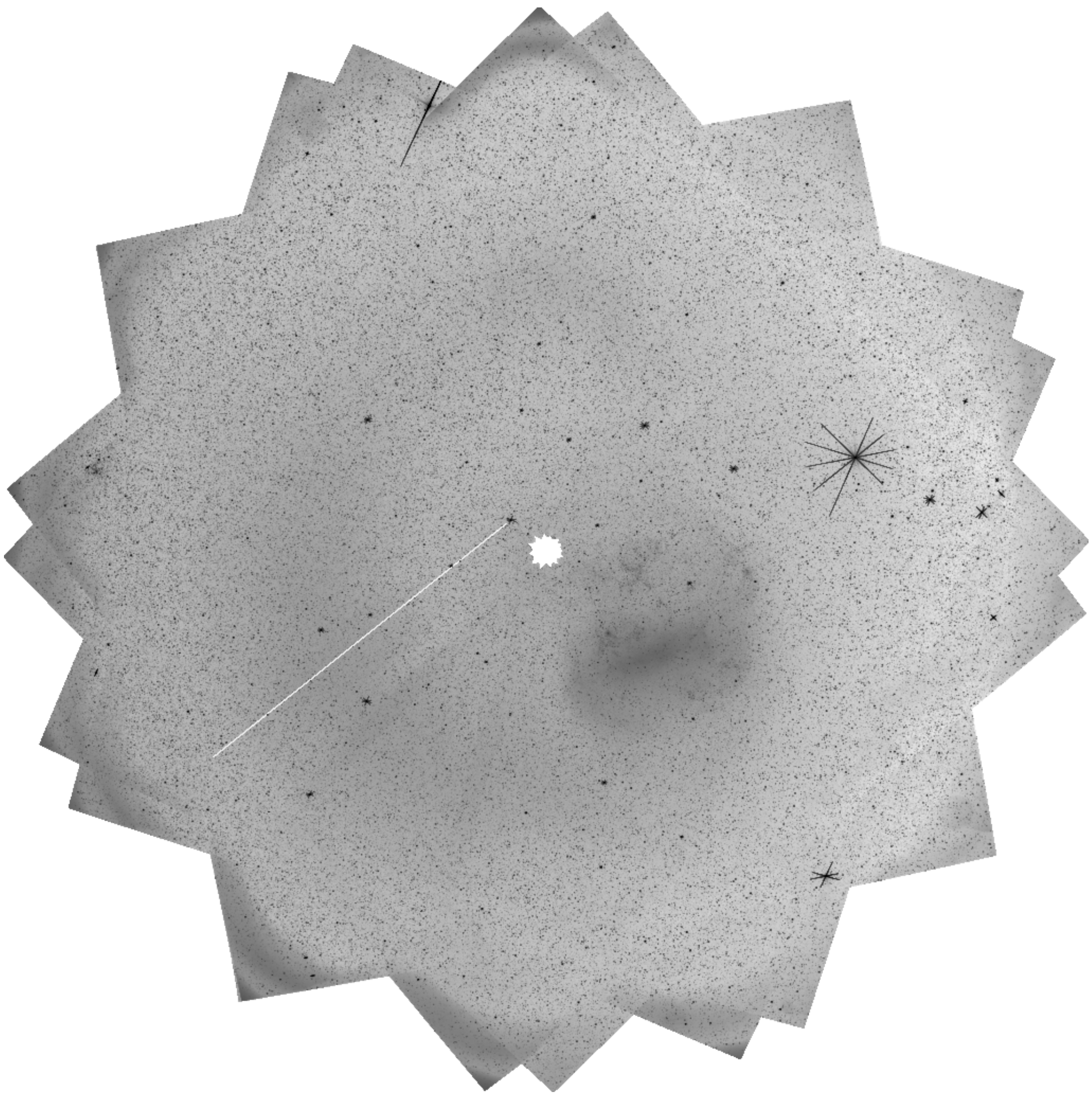

Figure 1. Mosaic of FFIs with background rectification for Sectors 1–5 in camera 4, centered on the south ecliptic Pole. The Large Magellanic Cloud is clearly seen below and to the right of center. The mosaic is freely available at NASA ExoFOP-TESS.

This paper includes data collected with the TESS mission, obtained from the MAST data archive at the Space Telescope Science Institute (STScI). Funding for the TESS mission is provided by the NASA Explorer Program.

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Software: The Montage image mosaic engine; code repository at https://github.com/Caltech-IPAC/Montage.

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