Disk Growth in GOODS-S Galaxies at Redshifts 0.5 ≤ z ≤ 3.0

Matthew Nichols[1], Lutz Haberzettl[1], Matthew Lehnert[2], Gerard Williger[1], James Lauroesch[1], Brian Leist[1]

1) University of Louisville, Louisville, KY; 2) Institut d'Astrophysique de Paris

ABSTRACT

Despite having observed thousands of star forming galaxies (SFGs) at z~3-5, and millions of galaxies at z~0, the evolution of SFGs and their disks at z~1 at the peak of the star formation history of the Universe remains an understudied regime. Recent analyses of the Milky Way and progenitor-like galaxies suggest that a turbulent thick disk thins as successive stellar populations develop. The thin disk is then allowed to form from the accreting material, beginning a new, younger era of star formation within the galaxy. Such activity would create gradient patterns in color maps based on orientation to the line of sight. Here we present preliminary results of an examination into the distribution of stellar populations in galaxies with spectroscopic redshifts 0.5 ≤ z ≤ 3.0. Using deep, high resolution HST ACS optical and NIR data to create color maps, we examine subsets of edge-on and face-on galaxies within the GOODS-S to trace the development of their disks.

INTRODUCTION

The redshift regime surrounding the global peak in the star formation rate reveals many changes to SFGs. At z~3, some SFGs become ellipticals (Guo & White 2009), while 75% of SFGs are disk galaxies by z~1 (Burgarella et al. 2006). Within these galaxies, both disk and bulge growth occur during this time, with the disk eventually dominating the bulge at redshifts z < 1 (van Dokkum 2013). The redshift regime of 0.8 < z < 1.5 represents the time period of development of the thin disk (Snaith et al. 2014, Haywood et al. 2013).

Recent computer simulations and measurements of the Milky Way and Milky Way progenitor galaxies show that early stellar populations grow quickly and cause a turbulent, alpa-enriched ISM (Snaith et al. 2014, Lehnert et al. 2014). The turbulence leads to stars with high velocity dispersion. As the thick disk's gas fraction declines, star formation slows, eventually moving to a more extended disk now enriched by type I SN (van Dokkum et al. 2013, Lehnert et al. 2009, 2013, Swinbank et al. 2011). As development of the thin disk occurs, a pseudo-bulge near the center of the galaxy may develop, as is thought to be the case for the Milky Way (Ness et al. 2013, Di Matteo et al. 2014). Viewed from the side, edge-on galaxies would develop vertical color gradients in the UV/optical, while face-on galaxies would reveal radial patterns, with evidence of two disk components.

Using high resolution HST UV, optical, and NIR data (see Giavalisco et al. 2003 and the CANDELS team), we plan to use the color gradients as a way to trace the development of the thick and thin disk and bulge of SFGs as a function of redshift. We also plan to derive dust masses and star formation histories and rates using additional data from Herschel, Spitzer, and GALEX, as well as ground-based data. As a proof of concept, we chose to begin with the F850LP and F435W filter bands.

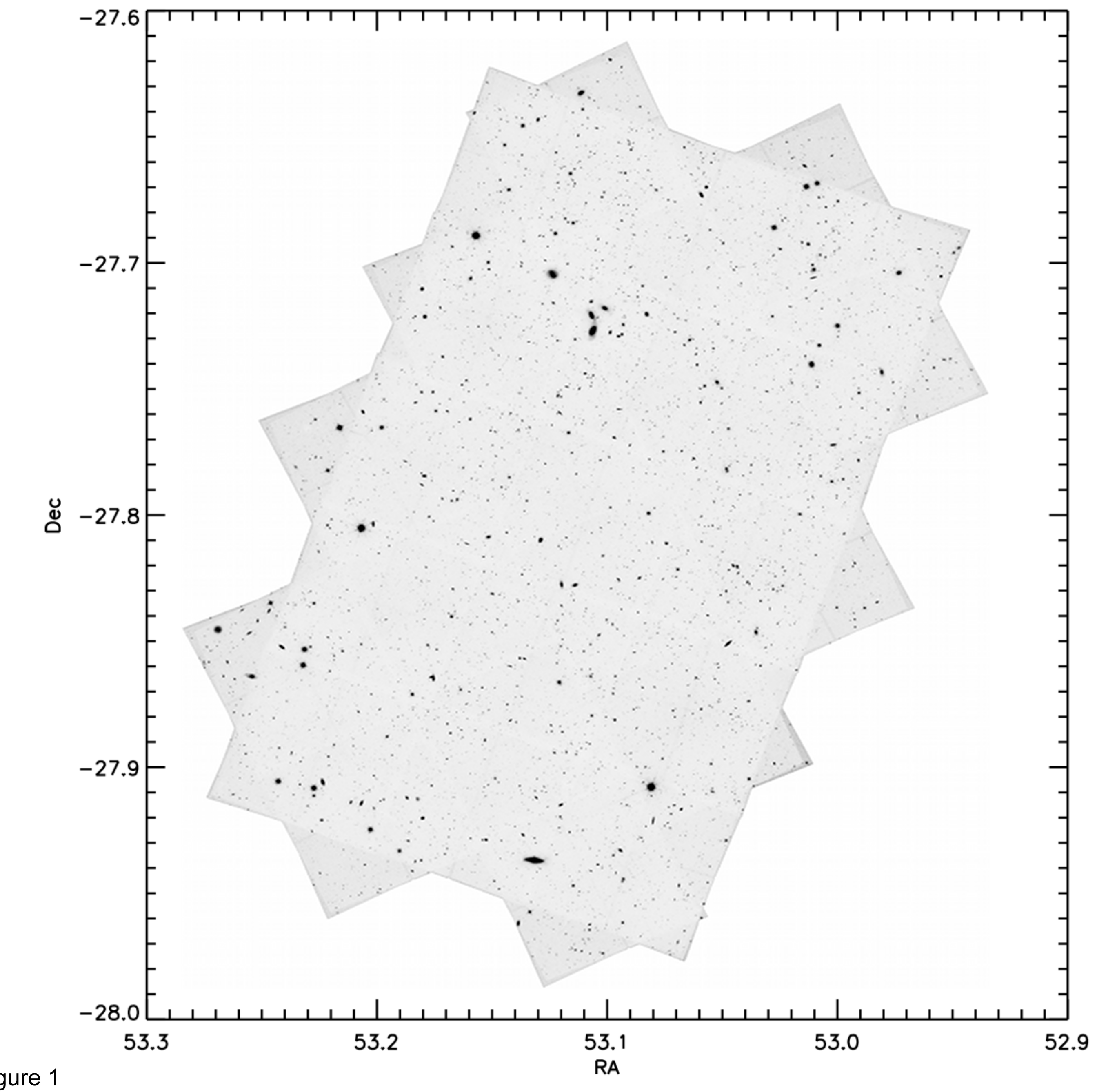


Figure 1
The F850LP dataset of the GOODS-S field provided by the Hubble Legacy Archive (Giavalisco et al. 2003)

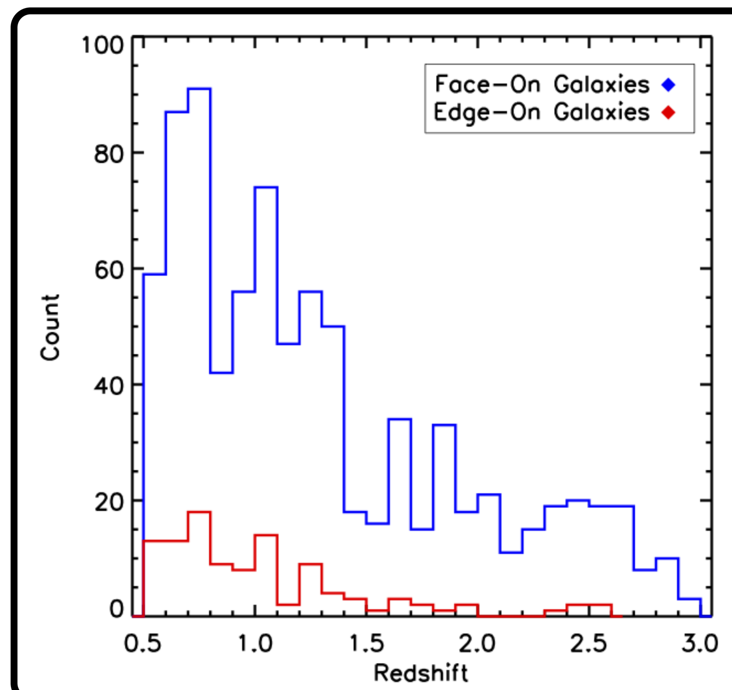
DATA AND SAMPLE SELECTION

To search for color gradients, we used high resolution HST data taken with the Advanced Camera for Surveys (ACS). The data are publicly available as a part of the Great Observatories Origins Deep Survey South (GOODS-S). We used the F850LP/z-filter (rest frame optical) and the F435W/B-filter (rest frame UV) to trace the more evolved and younger stellar components in the galaxy disks (Fig. 1). Each band covers roughly 160 sq. arcmin. and has been observed by Giavalisco et al. (2003).

For the redshifts, we used a spectroscopic redshift catalog compiled by the European Southern Observatory, which includes ~7500 redshifts from 19 different surveys, including FORS2 and VIMOS. We also used spectroscopic redshifts from the 3D-HST Survey (Skelton et al. 2014) covering the HUDF located within the GOODS-S.

After creating a catalog of detections in the F850LP and F435W filter bands, we matched redshifts with objects and selected those with 0.5 ≤ z ≤ 3.0. We selected subsamples with ellipticities greater than 0.7 (edge-on) and less than 0.3 (face-on). Our final sample consists of 841 face-on and 107 edge-on candidates. Their magnitude and flux radius distributions can be seen in Fig. 3.

For a preliminary look, we sorted the objects into redshift bins with dz=0.5. This selection allows us a first basic trace of possible evolution in color and appearance of the galaxies over our target redshift range. Typical objects from each of the redshift bins can be seen in Fig. 2.



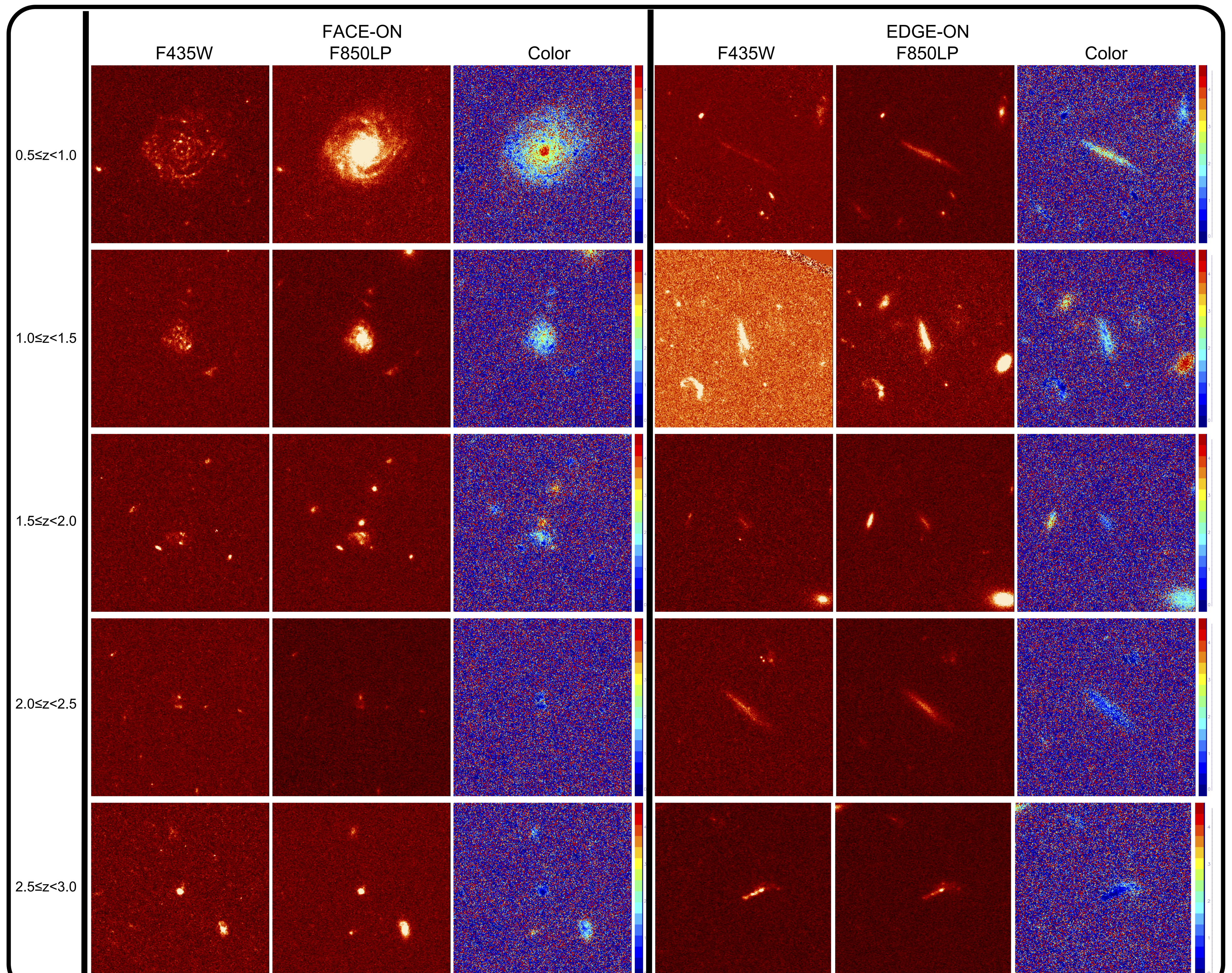


Figure 2
LEFT: Distribution of redshifts for our samples of edge-on and face-on galaxies with spectroscopic redshifts between 0.5 ≤ z ≤ 3.0.

RIGHT: These 20'' x 20'' stamps represent the galaxy as seen in the F435W (left column), the F850LP (middle column), and the color maps (F435W-F850LP, right column), where the scale runs from 0 mag. (blue) to 5 mags. (red). The left and right sets show typical face-on and edge-on objects, respectively. Each row of images represents a different redshift bin (dz=0.5), ranging from z=0.5 to z=3.0.

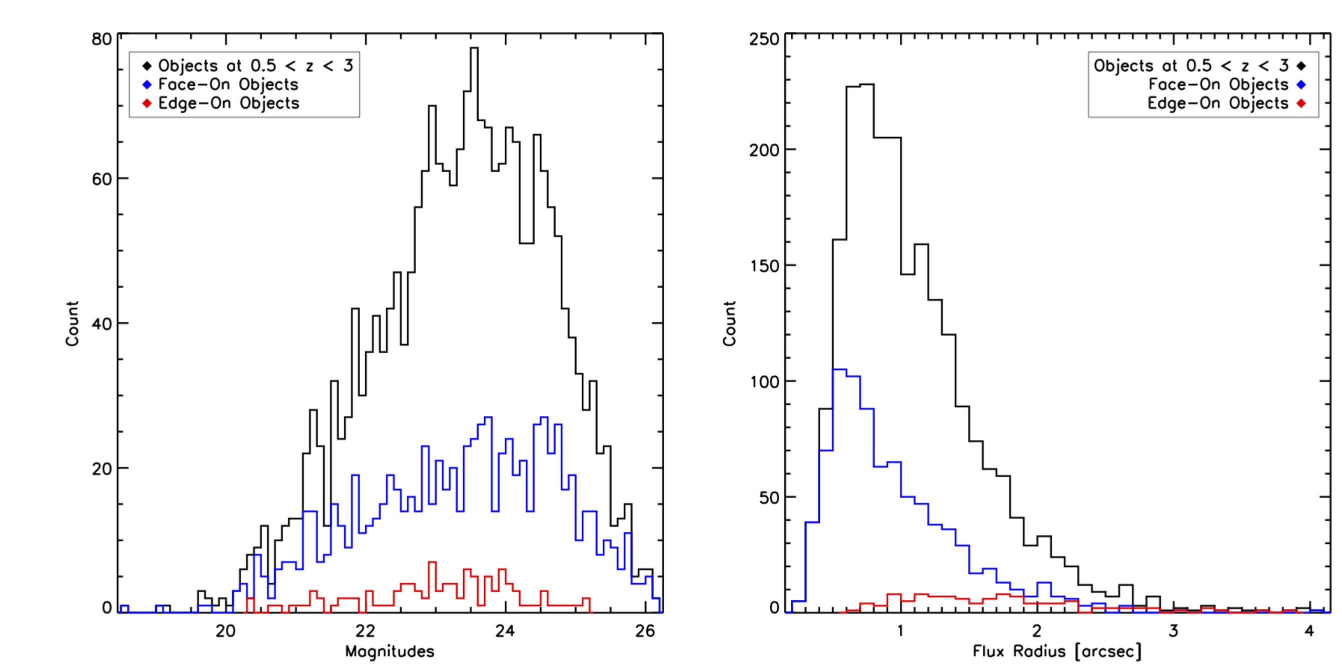


Figure 3
LEFT: Distribution of the magnitudes of all objects within the redshift range in black, face-on objects in blue, and edge-on objects in red. *RIGHT:* Distribution of the flux radius (90% as measured by SExtractor) of all objects within the redshift range in black, face-on objects in blue, and edge-on objects in red.

CONCLUSIONS

Preliminary results show that the datasets available for the GOODS-S have high enough resolution to effectively detect variations in color within both edge-on and face-on galaxies. Though still in the initial stages with no final conclusions yet drawn, these early results seem promising for tracing the evolution of disk galaxies during the era of peak star formation in the Universe.

REFERENCES

Burgarella et al. 2006, A&A, 450, 69; Di Matteo et al. 2014, arXiv 1404.0304; Giavalisco et al. 2003, ApJ 600 L93; Guo & White 2009, MNRAS, 396, 39; Haywood et al. 2013, A&A 560, A109; Lehnert et al. 2014a; ApJ, submitted; Lehnert et al. 2013, A&A, 555, A72; Lehnert et al. 2009, ApJ, 699, 1660; Ness et al. 2013, MNRAS, 430, 836; Skelton et al. 2014, ApJ, submitted; Snaith et al. 2014, ApJ, 781, L31; Swinbank et al. 2011, ApJ, 742, 11S; van Dokkum et al. 2013, ApJ, 771, L35; ESO catalog: http://www.eso.org/sci/activities/garching/projects/goods/MasterSpectroscopy.html