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INITIAL ANALYSIS OF CROWDSOURCED MORPHOLOGICAL CLASSIFICATIONS OF DECALS IMAGES

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ABSTRACT

Abstract.
Keywords: keywords

1. SELECTION CRITERIA

Galaxy Zoo 2 — main spectroscopic sample

- Galaxy in MGS or Stripe 82
- spectroscopic redshift available
- $0.0005 < z_{spec} < 0.25$
- $m_r < 17.0$
- `petro90_r` $> 3''$
- flag is not SATURATED, BRIGHT, or BLENDED

Galaxy Zoo 2 — Stripe 82 coadd

- version 1 of coadded data
- same as MGS with exception of $m_r < 17.77$

Dark Energy Camera Legacy Survey (DECaLS)

- Galaxies in NASA-Sloan (Extended) Atlas
- Good-quality measurements in g, r, z bands as of Jun 2015
- NSA: `brick_primary` = 1
- NSA: `decam_anymask` = 0
- NSA: `decam_nobs` ≥ 1
- $\theta_r > 10''$
- no magnitude cutoff

So the Sloan and DECaLS samples definitely were not selected in the same manner. However, all the relevant parameters are stored in the NASA-Sloan Atlas if we wanted to cut on that. More specifically, we can do a simple match (ideally through previously matched catalogs, but if necessary through a tight positional match) to directly compare morphological measurements for *the same galaxies* (Table 2).

There are 32,429 images of galaxies in GZ-DECaLS.

2. DATA

There is some overlap between the existing morphological classifications from Galaxy Zoo 2 (Willett et al. 2013). Most of the difference comes from the fact that SDSS was located at Apache Point Observatory in the Northern Hemisphere (latitude 32.780278°), while the DECaLS camera is mounted on the Blanco 4-m telescope at CTIO in the Southern Hemisphere (–30.169661°). They can cover a significant fraction of the same portion of the sky, but DECaLS will be limited at high northerly latitudes. Figure 1 shows the overlap between the NASA-Sloan ATLAS[1] (derived from SDSS) and DECaLS DR1.

Morphologies for this analysis are taken from the published GZ2 tables in Willett et al. (2013) for SDSS. The DECaLS morphologies have been collated and weighted, but not systematically debiased to account for changes in morphological fraction as a function of apparent size and brightness. Therefore, we only compare *weighted vote fractions* ($f_{w,morph}$) for galaxies in each sample.

In the GZ2 main spectroscopic sample (243,500 galaxies), we matched galaxies within a $3''.0$ radius and find 9,281 subjects appearing in both catalogs. We match a further 5,800 subjects using the same radius for the Stripe 82 data. There is overlap of 2,814 bright Stripe 82 galaxies that are included in both. The unique total of 12,267 subjects is only 38% of the GZ-DECaLS catalog, despite the fact that the original SDSS Legacy sky coverage (Strauss et al. 2002) overlaps with all of the current DECaLS bricks.

Part of the mismatch comes from the limited spatial coverage of the Stripe 82 region in SDSS, which only covered a declination range of $-1.26° < \delta < +1.26°$ (Annis et al. 2014). The DECaLS imaging bricks have NSA targets in a larger area, extending between roughly $-2.5° < \delta < +2.5°$ (Figure 2). These are presumbly targets imaged in SDSS DR8 or later, since otherwise they would have been included in the original GZ2 selection.

However, there are many DECaLS galaxies in the imaging area covered by the main Legacy survey. Galaxies in DECaLS but *not* GZ2 have $\langle m_r \rangle = 17.27$ mag, $\langle r_{petro} \rangle = 6''.64$, $\langle z \rangle = 0.093$. Galaxies in *both* DECaLS and GZ2 are on average brighter ($\langle m_r \rangle = 16.29$ mag), larger ($\langle r_{petro} \rangle = 7''.99$), and lower-redshift ($\langle z \rangle = 0.080$). The vast majority of the DECaLS images with no GZ2 counterpart are galaxies with $17.0 < m_r < 17.77$ — the fainter magnitude limit is that set by the GZ2 main sample, and the brighter was the spectroscopic targeting limit for SDSS (required for a redshift and inclusion in the NSA; Figure 3). The few remaining galaxies brighter than 17.0 mag but not in GZ2 may be the result

[1] http://www.nsatlas.org/

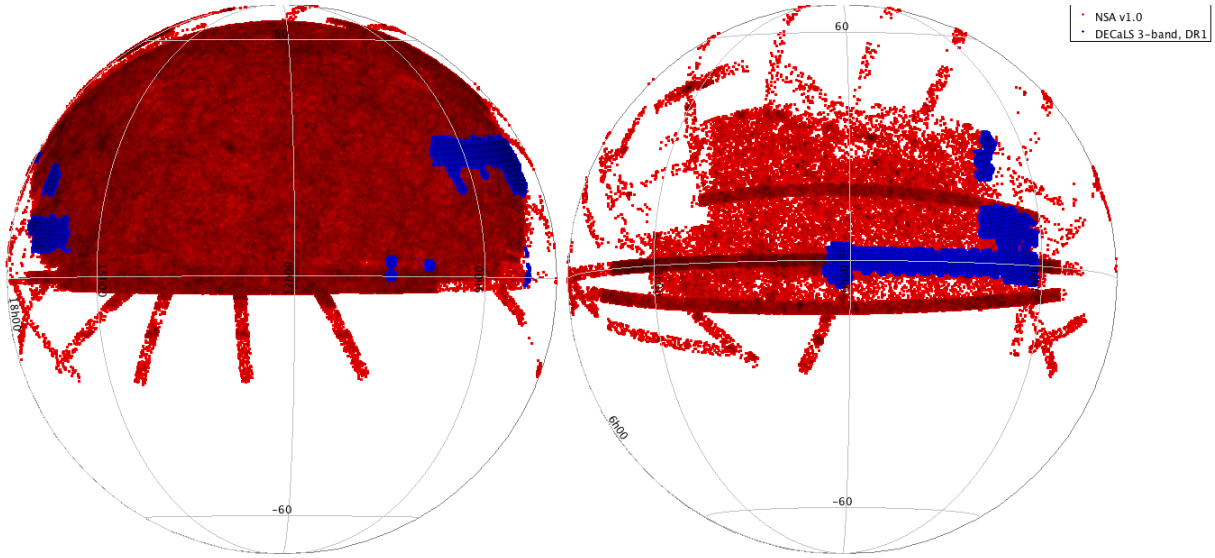

Figure 1. Overlap between galaxies in the NASA-Sloan Atlas (red) and selected targets for Galaxy Zoo from DECaLS DR1 (blue).

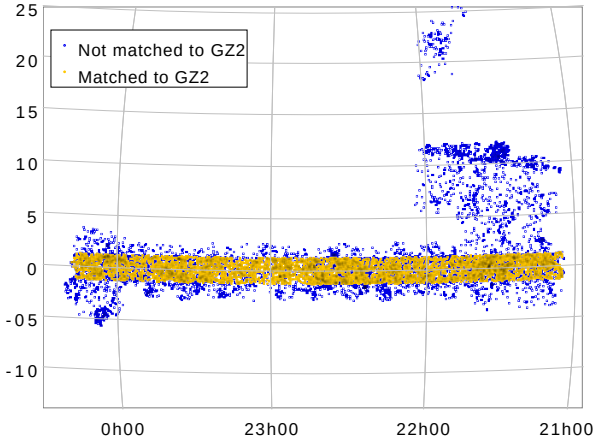

Figure 2. GZ-DECaLS galaxies in the Stripe 82 region. Galaxies with a match in the main GZ2 sample are shown the filled yellow symbols. Galaxies without a GZ2 match (open blue symbols) are due to a combination of lying outside the SDSS DR7 footprint and/or being fainter than the $m_r = 17.0$ magnitude limit for GZ2.

of positional matching errors, very low-redshift ($z < 0.0005$) galaxies or targets with a large angular size that were shredded in the initial SDSS pipeline.

Summary: roughly 40% of the DECaLS galaxies have morphological measurements from GZ2, and can be used for direct comparison. We believe we understand the reasons for the remainder of DECaLS images that are not matched to GZ2; these will be valuable scientific additions as new targets, and can serve as independent checks on the accuracy of the classifications.

3. ANALYSIS

Acknowledgments.

REFERENCES

Annis, J., Soares-Santos, M., Strauss, M. A., et al. 2014, ApJ, 794, 120
Strauss, M. A., Weinberg, D. H., Lupton, R. H., et al. 2002, AJ, 124, 1810
Willett, K. W., Lintott, C. J., Bamford, S. P., et al. 2013, MNRAS, 435, 2835

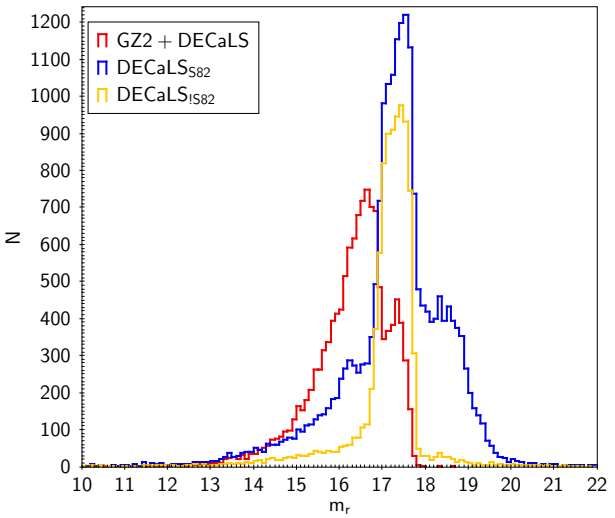

Figure 3. GZ-DECaLS galaxies in the Stripe 82 region. Galaxies with a match in the main GZ2 sample are shown the filled yellow symbols. Galaxies without a GZ2 match (open blue symbols) are due to a combination of lying outside the SDSS DR7 footprint and/or being fainter than the $m_r = 17.0$ magnitude limit for GZ2.

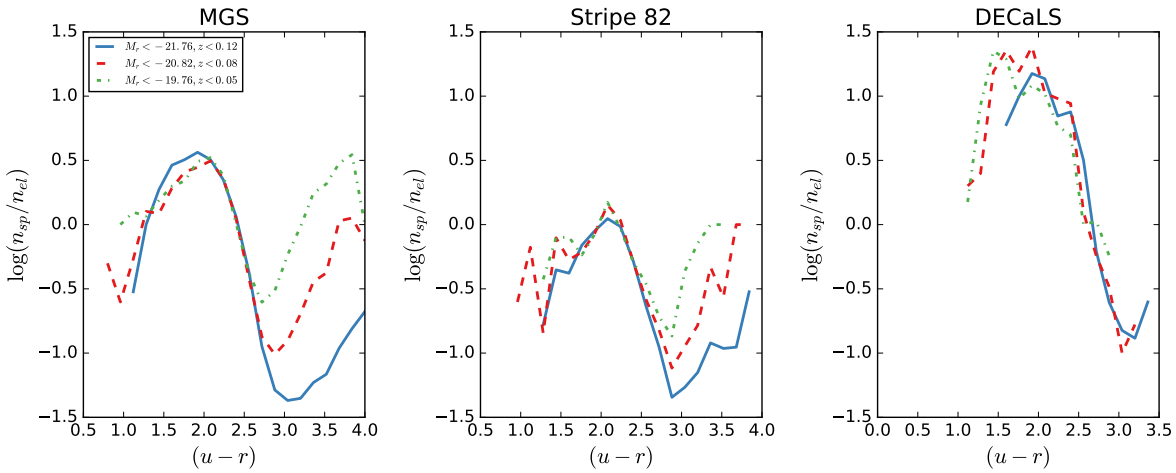

Figure 4. Average spiral-elliptical ratio for various galaxy samples as a function of optical $(u-r)$ color. From left to right, curves are for the GZ2 main spectroscopic sample, the deeper Stripe 82 coadded images, and the DECaLS images. Colors/linestyles show different volume/absolute magnitude limits for each sample.

Table 1
Galaxy Zoo morphological demographics for low-z optical imaging — all galaxies

Task	SDSS main sample			Stripe 82 coadd			DECaLS		
	N_{tot}	f_{tot}	$f_{prevtask}$	N_{tot}	f_{tot}	$f_{prevtask}$	N_{tot}	f_{tot}	$f_{prevtask}$
smooth	179153	0.74	0.74	16209	0.82	0.82	23292	0.72	0.72
features/disk	64067	0.26	0.26	3346	0.17	0.17	7967	0.25	0.25
star/artifact	280	< 0.01	< 0.01	210	0.01	0.01	1170	0.04	0.04
edge-on	9932	0.04	0.16	624	0.03	0.19	1726	0.05	0.22
not edge-on	54135	0.22	0.84	2722	0.14	0.81	6241	0.19	0.78
barred disk	14366	0.06	0.26	801	0.04	0.29	1174	0.03	0.19
no bar	39887	0.16	0.74	1932	0.10	0.71	5167	0.15	0.81
spiral	45462	0.19	0.84	2520	0.13	0.92	4973	0.15	0.80
no spiral	8791	0.04	0.16	213	0.01	0.08	1368	0.04	0.20
tight spiral arms	17322	0.07	0.39	1113	0.06	0.45	2279	0.07	0.46
medium spiral arms	20691	0.08	0.46	981	0.05	0.40	1637	0.05	0.33
loose spiral arms	6821	0.03	0.15	388	0.02	0.16	871	0.02	0.18
1 spiral arm	1879	0.01	0.04	119	0.01	0.05	237	< 0.01	0.05
2 spiral arms	26413	0.11	0.59	1602	0.08	0.65	3566	0.10	0.72
3 spiral arms	3025	0.01	0.07	188	0.01	0.08	625	0.01	0.13
4 spiral arms	837	< 0.01	0.02	51	< 0.01	0.02	192	< 0.01	0.04
5+ spiral arms	758	< 0.01	0.02	44	< 0.01	0.02	167	< 0.01	0.03
?? spiral arms	11922	0.05	0.27	478	0.02	0.19	—	—	—
no bulge	3962	0.02	0.07	103	0.01	0.04	593	0.01	0.10
noticeable bulge	34139	0.14	0.63	1139	0.06	0.42	—	—	—
obvious bulge	15791	0.06	0.29	1321	0.07	0.48	5316	0.16	0.85
dominant bulge	361	< 0.01	0.01	170	0.01	0.06	432	0.01	0.07
round edge-on bulge	6506	0.03	0.66	524	0.03	0.85	1244	0.03	0.76
boxy edge-on bulge	173	< 0.01	0.02	5	< 0.01	0.01	53	< 0.01	0.03
no edge-on bulge	3135	0.01	0.32	84	< 0.01	0.14	329	0.01	0.20
round elliptical	62308	0.26	0.35	6092	0.31	0.38	9279	0.28	0.39
in-between elliptical	91284	0.37	0.51	8331	0.42	0.51	11369	0.35	0.48
cigar-shaped elliptical	25561	0.10	0.14	1786	0.09	0.11	2644	0.08	0.11
odd feature	23795	0.10	0.10	1713	0.09	0.09	—	—	—
no odd features	219425	0.90	0.90	17842	0.90	0.91	—	—	—
ring	4099	0.02	0.18	178	0.01	0.11	317	0.01	0.01
lens/arc	155	< 0.01	0.01	17	< 0.01	0.01	4	< 0.01	< 0.01
disturbed	720	< 0.01	0.03	47	< 0.01	0.03	—	—	—
irregular	5761	0.02	0.25	113	0.01	0.07	44	< 0.01	< 0.01
other	4919	0.02	0.21	589	0.03	0.38	14	< 0.01	< 0.01
merger	7018	0.03	0.31	599	0.03	0.39	—	—	—
dust lane	220	< 0.01	0.01	6	< 0.01	< 0.01	141	< 0.01	< 0.01
overlapping	—	—	—	—	—	—	52	< 0.01	< 0.01
nothing	—	—	—	—	—	—	979	0.03	0.03
merger	—	—	—	—	—	—	1543	0.04	0.04
tidal debris	—	—	—	—	—	—	343	0.01	0.01
merger and tidal debris	—	—	—	—	—	—	141	< 0.01	< 0.01
neither	—	—	—	—	—	—	29232	0.93	0.93

Table 2
Galaxy Zoo morphological demographics for low-z optical imaging — overlaps only

Task	SDSS main sample			Stripe 82 coadd			DECaLS		
	N_{tot}	f_{tot}	$f_{prevtask}$	N_{tot}	f_{tot}	$f_{prevtask}$	N_{tot}	f_{tot}	$f_{prevtask}$
smooth	179153	0.74	0.74	16209	0.82	0.82	23292	0.72	0.72

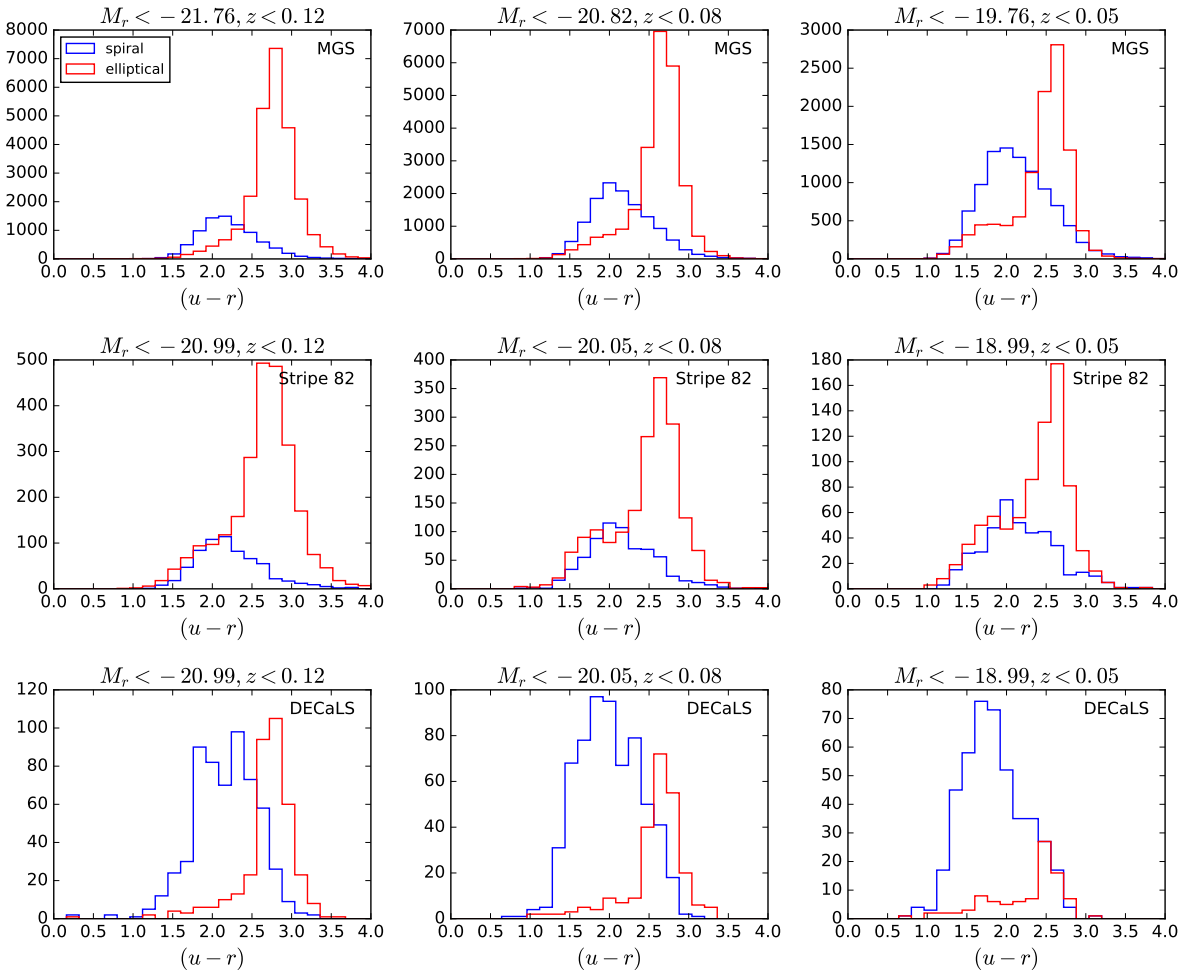

Figure 5. Histograms of the optical $(u-r)$ color distribution for various volume-limited and sample choices, separated by highly-confident ($p >= 0.8$) morphological classifications into spiral and ellipticals. Galaxies with intermediate morphologies ($0.2 < p < 0.8$) are not shown. **Top row**: GZ2 main spectroscopic sample. **Middle row**: Stripe 82 coadded. **Bottom row**: DECaLS.