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Galaxy Zoo: Detailed Morphological Classifications for 48,000 galaxies from CANDELS*

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ABSTRACT

To be rewritten, probably last.

Galaxies are sometimes really far away. The distant ones are pretty cool, because they tell us what the Universe was like back when it was just a kid, or maybe a teenager. You really have to look hard to see these galaxies, but once you do, what you do see tells you a whole lot. I mean, it's not exactly a WYSIWYG type of thing: there's a lot of work to figure out what the faint stuff you see really means. We did a bunch of work, and we think we did pretty well. Also, we compared to others who have done different kinds of work to try and answer some of the same questions. But we have a unique way of answering them, so here are those answers, and you can use them to answer other questions about the Universe.

Key words:
galaxies: general — galaxies: evolution — galaxies: morphology — galaxies: structure

1 INTRODUCTION

Outline:
Galaxy morphologies trace physics & dynamics and are therefore important.

They have a long history and there are many types, including those that use proxies [which are useful but not without problems] and those that reduce a galaxy and its billions of stars to a single number [same]. Visual morphologies are in many ways still ideal as they are able to provide incredibly detailed information about galaxies.

Visual morphologies have a scale problem without many eyes, and they're often not quantified. Galaxy Zoo to the rescue.

Galaxy Zoo started in 2007 and has provided robust, quantified visual classifications for more than 1,000,000 galaxies to $z \sim 1$.

Much use has been made of these, including [summarize and include non-GZ papers].

Here we present the visual morphologies of galaxies imaged by the *HST* treasury survey CANDELS.

Section summary and cosmology.

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2 OBSERVATIONAL DATA

2.1 Images

The Cosmic Assembly Near-infrared Extragalactic Legacy Survey (CANDELS; Grogin et al. 2011; Koekemoer et al. 2011) is an *HST* Treasury programme combining optical and near-infrared imaging from the Advanced Camera for Surveys (ACS) and Wide Field Camera 3 (infrared channel; WFC3/IR) across five well-studied survey fields (GOODS-North and -South, Giavalisco et al. 2004; EGS, Davis et al. 2007; UDS, Lawrence et al. 2007, Cirasuolo et al. 2007; and COSMOS, Scoville et al. 2007) using a two-tiered "deep" and "wide" approach. Each of the wide fields (UDS, COSMOS, EGS and flanking fields to the GOODS-S and GOODS-N deep fields) are imaged over 2 orbits in WFC3/IR, split in a 2:1 ratio between filters F160W and F125W, respectively, with parallel exposures in F606W and F814W using ACS. Each of the deep fields (GOODS-S and GOODS-N) are imaged over at least 4 orbits each in both the F160W and F125W filters and 3 orbits in the F105W filter, with ACS exposures in F606W and F814W in parallel. These are reduced and combined to produce a single mosaic for each field in each band, with drizzled resolutions of $0.03''$ and $0.06''$ per pixel for ACS and WFC3/IR, respectively (a process described in detail by Koekemoer et al. 2011).

Here we use the CANDELS ACS and WFC3/IR images from within the first set of data to be classified within the Galaxy Zoo interface. Those data cover the COSMOS, GOODS-South, and UDS fields. The 4th release of Galaxy Zoo included all detections with $H \leqslant 25.5$ from these 3 combined fields, comprising 49,555 unique images. These were shown to visitors to the website galaxyzoo.org[1] starting on the 10th of September, 2012.

The images shown to the public are colour composites of ACS I ($F814W$), WFC3 J ($F125W$), and WFC3 H ($F160W$) filters for the blue, green and red channels, respectively. The angular sizes of the images in different filters are matched, and the native point-spread functions (PSFs) are used. The images are combined with an asinh stretch (described in detail in **?**) with a non-linearity value of 3.0.

Sources in the dataset vary greatly in size and surface brightness, and therefore a single set of values for channel scalings is not adequate to capture the variety of features across the images. We therefore use a variable scaling based on the magnitude and size of each target source. For each image the R, G, and B channels have a fixed ratio of [not sure; must get this from Jeyhan], and the multiplier can vary between A and B. Figure **??** shows examples of these colour composites across a wide range of source fluxes and sizes.

Each colour image is 424 pixels square. The angular size of the image varies, such that the colour image encompasses at least 3 times the 80% flux radius of the target source, with a minimum screen-to-WFC3 zoom ratio of 1:10 and a maximum ratio of 3:1. The Galaxy Zoo interface loads the normal colour images by default, and the user may choose to display an inverted colour image, but may not otherwise change the image scaling or size within the software while performing the classification.

2.2 Photometry

Brief description of photometric catalogs. Focus on IJH because that's all the images consider. Do mention all the extra stuff available, but note that the classifications themselves don't depend on them.

2.3 Redshifts

Some of them have speczs. Lots of them have photzs, including CANDELS, 3D-HST and several previous surveys.

Comparison of photozs and speczs; might be able to just reference the other papers.

What do we do about those without redshifts? We use them with caution, I guess.

2.4 Simulated Images

Describe simulations and what we'll use them for.

3 CLASSIFICATION DATA

3.1 Decision Tree

Details on the decision tree, plus a table mapping questions and answers to unique tasks and answers, like the one in Willett et al. 2013.

[1] Archived at zoo4.galaxyzoo.org

3.2 Raw classifications

Basic details on raw classifications, including the start and end dates considered in this paper, how many classifications which galaxies have, why some have less than others and some more.

How many users participated, and the distribution of classifications (typical number per person, number signed in and not, maybe that square diagram Old Weather uses).

3.3 User Weighting

Note: we may discuss other weighting if that proves useful.

3.3.1 Consensus Weighting

3.3.2 IBCC

4 COMPARISON TO OTHER CLASSIFICATIONS

Kartaltepe et al. 2014

CAS? Gini? M20?

5 SOME KIND OF INITIAL RESULT

Hubble Sequence, maybe?

6 SUMMARY

Galaxies! We have galaxies!

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REFERENCES

Cirasuolo M. et al., 2007, MNRAS, 380, 585
Davis M. et al., 2007, ApJ, 660, L1
Giavalisco M. et al., 2004, ApJ, 600, L93
Grogin N. A. et al., 2011, ApJS, 197, 35
Koekemoer A. M. et al., 2011, ApJS, 197, 36
Lawrence A. et al., 2007, MNRAS, 379, 1599
Scoville N. et al., 2007, ApJS, 172, 1

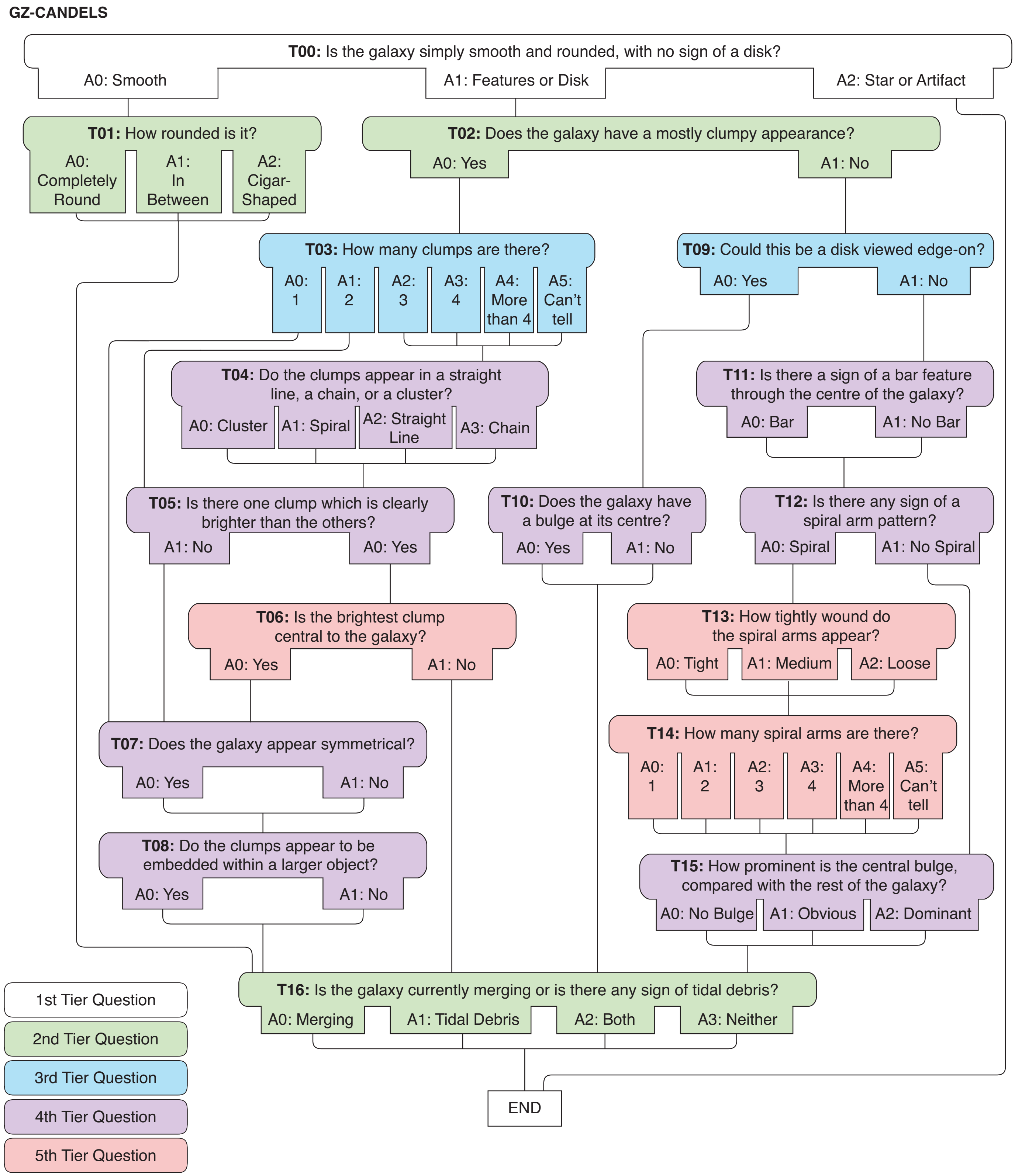

Figure 1. The Decision Tree for Galaxy Zoo: CANDELS