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ZOONIVERSE: WEB-BASED CITIZEN SCIENCE PROJECTS

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ABSTRACT

This is a preliminary report on citizen science accounts.

Keywords: citizen science

1. INTRODUCTION

The Zooniverse citizen science platform has produced dozens of peer-reviewed papers in a wide variety of fields based on crowdsourced data. Overall descriptions of the Zooniverse and citizen science are given in Clery (2011); Fortson et al. (2012); Masters (2013); Simpson et al. (2014); Marshall et al. (2015).

2. SPACE

2.1. *Galaxy Zoo*

2.1.1. *Galaxy Zoo 1*

The original Galaxy Zoo project is described in Lintott et al. (2008), with the catalog release in Lintott et al. (2011). The techniques for the classification debiasing are described in detail in Bamford et al. (2009).

Papers using Galaxy Zoo data for population studies include those of morphology and colour on environment (Bamford et al. 2009; Skibba et al. 2009; Hoyle et al. 2012), AGN (Schawinski et al. 2010a), and mergers (Darg et al. 2010b,a, 2011; Teng et al. 2012). We have used Galaxy Zoo to identify unusual populations of red spiral (Masters et al. 2010b; Cortese 2012) and blue elliptical (Schawinski et al. 2009) galaxies. Wong et al. (2012) examine the low-mass end of post-starburst galaxies. Tojeiro et al. (2013) analyze star-formation histories of galaxies as a function of color and morphology. Masters et al. (2010a) use Galaxy Zoo data to study dust in spiral galaxies. Schawinski et al. (2014); Smethurst et al. (2015) look at star-formation histories and their effects on morphology.

Hanny's Voorwerp is a quasar light-echo discovered in the very early days of reviewing images (Lintott et al. 2009; Józsa et al. 2009; Rampadarath et al. 2010; Schawinski et al. 2010b; Keel et al. 2012b). A further class of similar objects, called Voorwepjes, appear in Keel et al. (2012a, 2015). A unique class of compact star-forming galaxies are the Green Peas, discovered by (Cardamone et al. 2009) and further studied by Amorín et al. (2010); Chakraborti et al. (2012) and Hawley (2012). Orientation data of spiral galaxies were used by Land et al. (2008), Slosar et al. (2009) and Jimenez et al. (2010).

External projects using Galaxy Zoo data include studies of polar ring galaxies identified in the forum (Finkelman et al. 2012), and overlapping galaxies in Keel et al. (2013, 2014). Photometric redshifts as a function of morphology were studied by Way (2011). Rodríguez & Padilla (2013) studied the intrinsic shapes of galaxies in SDSS.

Banerji et al. (2010) reproduce the morphologies from Galaxy Zoo with a machine-learning algorithm.

2.1.2. *Galaxy Zoo 2*

The Galaxy Zoo 2 (GZ2) project paper and data release is Willett et al. (2013).

We used GZ2 data to study bars in Hoyle et al. (2011); Masters et al. (2011, 2012); Cheung et al. (2013); Galloway et al. (2015). Dust lanes in early-type galaxies appear in Kaviraj et al. (2012b); Shabala et al. (2012); this is also related to tidal dwarf galaxies (Kaviraj et al. 2012a) and spheroidal post-mergers (Carpineti et al. 2012; Kaviraj et al. 2013). Skibba et al. (2012) studied the environmental dependence of bars and bulges in disc galaxies. Casteels et al. (2013) quantify morphological indicators of galaxy interaction, centering on loosely-wound spiral arms. Simmons et al. (2013) use GZ2 galaxies to identify a bulgeless population with actively growing black holes. Willett et al. (2015) studies the effect of disk morphology on the SF-stellar mass relation.

Davis & Hayes (2012, 2014) trained an algorithm to detect spiral-arm galaxy structure calibrated using GZ2 data. Dieleman et al. (2015) developed a convolutional neural network to replicate the results of the GZ2 catalog in conjuction with a Kaggle competition.

2.1.3. *Galaxy Zoo: Hubble*

The Galaxy Zoo: Hubble (GZH) project paper and data release is Willett et al. (2016, in prep).

Melvin et al. (2014) used early GZH data to measure the declining bar fraction as a function of redshift. Che-

ung et al. (2015) investigate the relationship between bars and AGN over the various surveys in GZH.

2.1.4. *Galaxy Zoo: CANDELS*

The Galaxy Zoo: CANDELS (GZC) project paper and data release is Simmons et al. (2016, submitted).

Simmons et al. (2014) use early GZC data to measure the bar fraction at $z \sim 2$.

2.2. *Galaxy Zoo: Supernova*

The Galaxy Zoo: Supernova project was described in Smith et al. (2011), and an improved dynamic Bayesian classification system used for data analysis in Simpson et al. (2013). GZ: Supernova results also appear in papers by Maguire et al. (2011, 2012) and Levitan et al. (2013).

2.3. *Galaxy Zoo: Mergers*

Galaxy Zoo: Mergers was a separate project from Galaxy Zoo, using simulations to characterize the dynamical effects of major mergers (Holincheck et al. 2016).

2.4. *Planet Hunters*

Planet Hunters has identified many exoplanet candidates using public archive data from the *Kepler* spacecraft. Unlike other Zooniverse papers, most publications have been explicitly numbered in a series:

(I) Fischer et al. (2012) - first two candidates (PH1, PH2) discovered by the project

(II) Schwamb et al. (2012) - inventory of Kepler short-period planets

(III) Schwamb et al. (2013) - first circumbinary planet in a quadruple star system

(IV) Lintott et al. (2013) - new candidates from Kepler Quarter 2

(V) Wang et al. (2013) - a confirmed Jupiter-size planet in the habitable zone

(VI) Schmitt et al. (2014a) - independent characterization of KOI-351 and other long-period candidates

(VII) Schmitt et al. (2014b) - discovery of new planet (PH3 c) and mass measurements of PH3 b and PH3 d

(VIII) Wang et al. (2015) - measurements of 41 long-period candidates

(IX) Boyajian et al. (2016) - "Tabby's Star", a deeply unusual object with up to 20% aperiodic dips in flux

(X) Schmitt et al. (2016) - search for nearby neighbors of 75 K2 targets

In non-numbered papers, Kato & Osaki (2014) credit Planet Hunters in helping to identify an unusually active dwarf nova. Gies et al. (2013) describes the discovery of a new cataclysmic variable.

2.5. *Solar Stormwatch*

Solar Stormwatch used citizen science data to track 2D structure of coronal mass ejections (Savani et al. 2012). They also inferred the distribution of interplanetary dust between 0.96 and 1.04 AU (Davis et al. 2012). Their coronal mass ejection catalog (Barnard et al. 2014) was compared against results from experts and automated algorithms in Tucker-Hood et al. (2014); Barnard et al. (2015).

Wilkinson et al. (2016) combines results from Solar Stormwatch and Old Weather in a novel way of measuring historical aurora activity.

2.6. *Milky Way Project*

The Milky Way project design and data release appears in Simpson et al. (2012). Kendrew et al. (2012) use this data to make a statistical study of massive star formation associated with infrared bubbles, and their proximity to cold clumps from ATLASGAL (Kendrew et al. 2016). Kerton et al. (2015) describe the compact infrared sources dubbed "yellowballs".

Beaumont et al. (2014) leverage the training set of the MWP to create Brut, an automated algorithm for identifying bubbles in infrared images of the midplane.

2.7. *Space Warps*

Results and methodology for Space Warps are given by Marshall et al. (2016) and More et al. (2016). The project discovered the "Red Radio Ring", a gravitationally-lensed hyperluminous galaxy at $z = 2.553$ (Geach et al. 2015). Users also attempted to model the mass distributions of the lensing systems (Küng et al. 2015).

2.8. *Radio Galaxy Zoo*

The project description for Radio Galaxy Zoo is Banfield et al. (2015).

2.9. *Moon Zoo*

Preliminary results on crater counts at the Apollo 17 landing site are in Bugiolacchi et al. (2016).

2.10. *Snapshot Supernova*

The Snapshot Supernova project was developed for Stargazing Live in 2015. Campbell et al. (2015); Cartier et al. (2015) made spectroscopic classifications of the newly-discovered optical transients.

2.11. *Andromeda Project*

The first catalog of stellar clusters from Andromeda is Johnson et al. (2015).

2.12. *Ice Hunters*

Parker et al. (2013) discovered 2011 HM_{102}, a high-inclination L5 Neptune Trojan, which was recovered in a parallel effort by Ice Hunters.

3. NATURE

3.1. *Whale FM*

Sayigh et al. (2013) studied repeated call types in short-finned pilot whales using Whale FM data. Shamir et al. (2014) analyzed whale calls using computer algorithms in attempt to accurately identify different species.

3.2. *Snapshot Serengeti*

The project description of Snapshot Serengeti is Swanson et al. (2015), with validation methods in Swanson et al. (2016). Data is used to estimate the spatial density of lions in Cusack et al. (2015).

4. CLIMATE

4.1. *Cyclone Center*

Hennon et al. (2014) show that the modern global tropical cyclone record is littered with uncertainty; crowdsourcing could help clean up the mess.

5. MEDICINE

5.1. *Cell Slider*

Candido dos Reis et al. (2015) describe Cell Slider and comparison of tracking estrogren receptors to experts.

6. HUMANITIES

6.1. *Ancient Lives*

Ancient Lives is a humanities project transcribing Greek papyri. This included the publication of a new volume for the Oxyrhynchus Papyri (Brusuelas 2013). The algorithms and pipeline are described in Williams et al. (2014a,b).

6.2. *Operation War Diary*

Grayson (2016) analyzes data for WWI British infantry and cavalry divisions, showing the difference in time spent in combat between the various divisions.

7. CITIZEN-SCIENCE: SOCIOLOGY, EDUCATION RESEARCH, AND MACHINE LEARNING

7.1. *Sociology and meta-studies*

Motivations of Zooniverse users were studied in Raddick et al. (2010, 2013); Jackson et al. (2015). Mankowski et al. (2011) did an interpretive study of the meanings that citizen scientists make when using Galaxy Zoo. Cox et al. (2015) defines various metrics of success for citizen science projects. Eveleigh et al. (2013); Eveleigh et al. (2014); Greenhill et al. (2014) discuss gamification and user engagement in Old Weather. Jackson et al. (2016) examines trajectories of newcomers to the Zooniverse. Jennett et al. (2013) research creativity in web-based citizen science. Luczak-Roesch et al. (2014); Mugar et al. (2014, 2015) examine online communities in Seafloor Explorer and Planet Hunters.

Kloetzer et al. (2013); Prather et al. (2013); Masters et al. (2016) examines how and what volunteers learn through participation.

Christian et al. (2012); Madison (2014) describe contributions of citizen science to astronomy research.

7.2. *Education research*

Slater et al. (2011) describe using Galaxy Zoo as a teaching tool for stimulating scientific inquiry. Borden et al. (2013) summarizes Zooniverse tools for formal and informal audience engagement.

Facilities:

Facility: SDSS,

Facility: HST,

Facility: Spitzer,

Facility: Chandra,

Facility: Kepler,

Facility: STEREO,

Facility: LRO,

Facility: CFHT,

Facility: Magellan,

Facility: VLA,

Facility: ATCA,

Facility: WISE,

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