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Galaxy Zoo: Two modes of black hole growth driven by star formation

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ABSTRACT

Two modes of black hole growth in early and late type galaxies but no correlation to mechanisms. New Bayesian SFH tool STARPYlet's us investigate the SFH as two parameters $[t, \tau]$ and investigate the AGN fraction, duty cycle and average AGN luminosity across this parameter space. We find that rapid quenching mechanisms give rise to high luminosity AGN and slow quenching mechanisms to low luminosity AGN.⋆

1 INTRODUCTION

There is clearly a relationship between central black hole and evolution of galaxy. Magorrian relation shows this as do simulations and observations of feedback.

This effect seems to be strongest during AGN phase of black hole growth.

Previous studies shown that two different modes of black hole growth in late types and early types.

Largest fraction of AGN found in green valley suggesting some link to the process of quenching star formation in order for a galaxy to progress from the blue cloud to the red sequence.

Here we try to link the star formation history of galaxies to the presence of AGN with the use of novel new code implementing a Bayesian method; STARPY which, given NUV and optical colours and using SSP models, can effectively describe the SFH of a galaxy with two parameters.

2 DATA

2.1 STARPY

STARPY is a PYTHON code which allows the user to derive the quenched star formation history of a galaxy through a Bayesian Markov Chain Monte Carlo method through the input of two observed photometric colours and a redshift. This quenched star formation history is described by two parameters $[t_q, \tau]$ where t is the time at which the onset of quenching begins $[Gyr]$ and τ is the exponential rate at which quenching occurs $[Gyr]$. The SFH if one assumes that all galaxies formed at $t = 0$ Gyr with an initial burst of star formation can therefore be described as:

$$SFR = \begin{cases} i_{sfr}(t_q) & \text{if } t < t_q \\ i_{sfr}(t_q) \times exp\left(\frac{-(t-t_q)}{\tau}\right) & \text{if } t > t_q \end{cases} \quad (1)$$

where i_{sfr} is an initial constant star formation rate dependent on t_q. A smaller τ value corresponds to a rapid quench, whereas a larger τ value corresponds to a slower quench. The probabilistic fitting methods to this SFH for an observed galaxy are described in detail in Smethurst et al. (2015) wherein the STARPY code was run on a sample of 126,316 galaxies from the Galaxy Zoo project.

2.2 AGN Selection

Schawinski et al. (2010) selected a sample of 942 narrow line AGN galaxies from a parent magnitude limited sample of 47,675 SDSS galaxies with $0.02 < z < 0.05$ and $r < 17$ AB mag and $M_{z,Petro} < -19.5$ AB mag with morphological classifications from Galaxy Zoo. They further select AGN galaxies by measuring the emission line fluxes of each galaxy using GANDALF (Sarzi et al. 2006) and utilising emission line diagrams (see Figure 2 of Schawinski et al. 2010 of the narrow line flux ratio's of $[OIII]/H\beta$, $[NII]/H\alpha$, $[SII]/H\alpha$ and $[OI]/H\alpha$. This is the same as the method outlined previously in Schawinski et al. (2007).

2.3 Galaxy Zoo 2

In this investigation we use visual classifications of galaxy morphologies from the Galaxy Zoo 2[1] citizen science project (Willett et al. 2013), which obtains multiple independent classifications for each optical galaxy image; the full question tree for each image is shown in Figure 1 of Willett et al. 2013.

The Galaxy Zoo 2 (GZ2) project consists of 304,022 images from the SDSS DR8 (a subset of those classified in Galaxy Zoo 1; GZ1) all classified by *at least* 17 independent

⋆ This investigation has been made possible by the participation of more than 250,000 users in the Galaxy Zoo project. Their contributions are individually acknowledged at `http://authors.galaxyzoo.org`

[1] `http://zoo2.galaxyzoo.org/`

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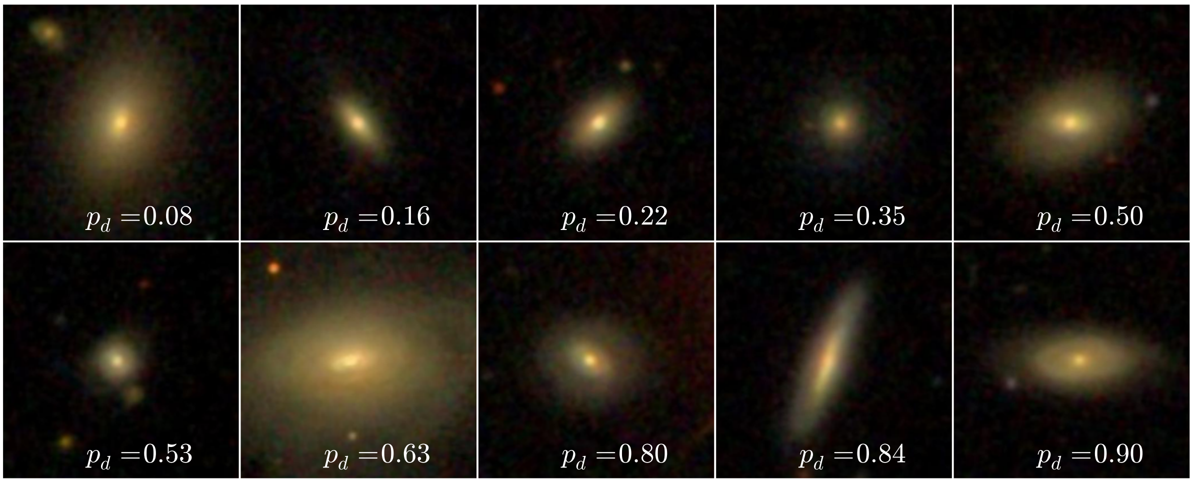

Figure 1. Randomly selected SDSS *gri* composite images from the sample of 439 narrow-line AGN showing the continuous probabilistic nature of the Galaxy Zoo sample from a redshift range $0.040 < z < 0.045$. The debiased 'disc or featured' vote fraction (see Willett et al. 2013) for each galaxy is shown. The scale for each image is 0.099 arcsec/pixel.

users, with the mean number of classifications standing at ~ 42.

Further to this, we required NUV photometry from the GALEX survey, within which $\sim 42\%$ of the GZ2 sample were observed, giving a total sample size of $126,316$ galaxies. The completeness of this subsample of GZ2 matched to GALEX is shown in Figure 2 of Smethurst et al. (2015) with the u-band absolute magnitude against redshift for this sample compared with the SDSS data set. Typical Milky Way L_* galaxies with $M_u \sim -20.5$ are still included in the GZ2 subsample out to the highest redshift of $z \sim 0.25$; however dwarf and lower mass galaxies are only detected at the lowest redshifts.

This sample of $126,316$ galaxies was then matched to the AGN sample from Galaxy Zoo 1 selected by Schawinski et al. (2010) to give $21,713$ galaxies with morphological classifications from GZ2 and SFH parameters from starpy. This resulted in a sub-sample of 439 narrow-line AGN giving a lower limit on the AGN fraction of 2%, as we do not include LINERS, obscured AGN or broad-line AGN, as in Schawinski et al. (2010).

3 RESULTS

Here are all the ridiculous amounts of plots I made condensed down into 1 or 2 easy to understand plots that gets the point across.

4 DISCUSSION

Rapid quench results in high luminosity AGN.

Slow quench results in low luminosity AGN.

Majority of disc galaxies with AGN found at slow quenching timescales but with low luminosity AGN.

Small fraction of AGN are in smooth galaxies found at rapid quenching timescales with high luminosity AGN.

Two modes of black hole growth clearly highlighted.

5 CONCLUSION

AGN and SFH linked. Rapid == high luminosity but there's not a lot of those. Slow == low luminosity and there's loads of those.

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Chinese Academy of Sciences (LAMOST), Los Alamos National Laboratory, the Max-Planck-Institute for Astronomy (MPIA), the Max-Planck-Institute for Astrophysics (MPA), New Mexico State University, Ohio State University, University of Pittsburgh, University of Portsmouth, Princeton University, the United States Naval Observatory, and the University of Washington.

This publication made extensive use of the Tool for Operations on Catalogues And Tables (TOPCAT; Taylor 2005) which can be found at `http://www.star.bris.ac.uk/~mbt/topcat/`. Ages were calculated from the observed redshifts using the *cosmolopy* package provided in the Python module *astroPy*[2]; Robitaille et al. 2013). This research has also made use of NASA's ADS service and Cornell's ArXiv.

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[2] `http://www.astropy.org/`

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