Eat Your Veggies: Green Pea Galaxy Abundance at Redshifts of 1.0 – 2.3

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Abstract

We investigate starbursting, compact Green Pea galaxies at redshifts of 1.0 − 2.3 using the ZFOURGE Survey conducted on the 6.5 m Magellan Baade telescope. Little is understood about these Green Pea galaxies that are classified by their strong [OIII] lines (4959Å and 5007Å). We model the theoretical colors of starbursting sources, using the Starburst99 stellar population synthesis model, where we add the effects of nebular emission. We then select objects that have broad-band colors indicative of having a strong emission line in one of the bands. We search for Green Peas in color-color space using the *J*1, *J*2, *J*3, *Hs*, and *Hl* bands from ZFOURGE, effectively identifying galaxies with strong emission lines, from z = 1.0 to 2.3 down to stellar masses of $10^8 - 10^{9.5}\ M_\odot$. We find that these Green Peas are much more isolated in low-mass galaxies typically ranging from masses of $10^8 - 10^{9.5}\ M_\odot$.

Introduction

What is a Green Pea Galaxy?

- A Green Pea (GP) appears optically green because when we show an RGB image, and we place the band with the strong emission line in the G(reen) color of the image, it makes them look green.
- They are compact, star forming galaxies typically have stellar masses ranging from $10^{8.5}$ - $10^{10} M_\odot$ (Amorín et al. 2010).
- Because they're undergoing intense star formation processes, they have very strong [OIII] lines.

ZFOURGE Survey

- The ZFOURGE Survey was conducted on the Magellan Baade telescope at Las Campanas Observatory.
- It is a broad and narrow band survey that focuses on the infrared (IR) part of the spectrum constraining photometric redshifts at a range of $1 < z < 4$.
- This survey consists of three 11' x 11' fields: CDFS, UDS, and COSMOS in 5 IR bands – *J*1, *J*2, *J*3, *Hs* and *Hl.*

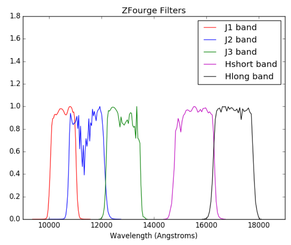
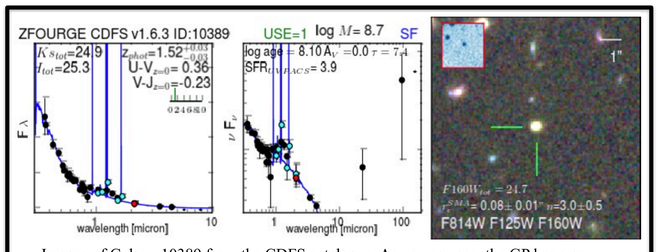


Figure 1: This figure shows the 5 filters we used from the ZFOURGE Survey and shows the transmission and wavelengths each filter spans.

Table 1: The different redshifts for the five ZFOURGE filters where the [OIII] lines will be best detected. The z on is the redshift where the transmission is 50% of the peak on the left side of the filter. The z off is the redshift where the transmission is 50% of the peak on the right side of the filter.

Filter	Z On	Z Off
J1	1.009	1.205
J2	1.146	1.418
J3	1.433	1.681
Hs	1.950	2.250
Hl	2.252	2.548



Images of Galaxy 10389 from the CDFS catalogue. As you can see, the GP has a green appearance in the optical and the spectra show a spike through the J filters – how we determine if they're GPs.

Importance of Studying Green Peas

- Little is known about how Green Peas form, why they have such high levels of star formation, and what causes their starbursting phase.
- Green Peas at higher redshifts could be a component in the reionization of the universe, so understanding them at lower redshifts is critical (Jaskot et al. 2013).

Process of Selecting Green Peas

Finding the Filter Depending on Redshift:

- A redshifted spectrum will change which filter the [OIII] lines peak in, so in order to find which filter to use for a certain redshift, we had to redshift our simulated spectrum.

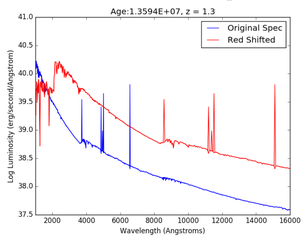


Figure3: This shows how the different emission and absorption lines change with a redshift of 1.3 – we specifically wanted to find which filter the [OIII] lines fell in when redshifted.

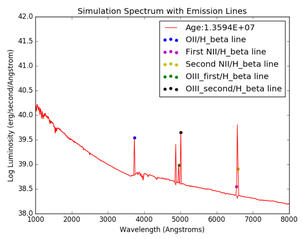


Figure 2: A graph of a simulated spectrum produced from Starbrust99 showing which emission and absorption lines and their strengths that we used. This spectrum has not been redshifted.

Starburst99:

- "We used Starburst99, a program that simulates star formation in galaxies, to produce our simulated spectra. We did this in order to find which redshift to use per color and to produce our continuum.

Creating the Simulated Continuum:

- We produced a continuum that would indicate how to select our Green Peas from a color-color plot.
- Creation: We found the average flux across the ZFOURGE Survey bands for varying redshift and age. From there, we plotted the continuum on our color-color plots. When we plotted it, we kept the redshift constant and varied the age.
- Figure 5 shows two separate lines over plotted on the color-color diagrams – the continuum and the continuum + the emission lines. Both were used to select our green peas based on the most extreme galaxies (Van Der Wel et. al, 2011).
- We are sort of averaging the continuum – for example, for the emission line in the J2 band, we are assuming that the J1 - J3 color is ~flat (so J1 - J3 = 0) in which case the J1 - J2 and J2 - J3 colors give us an estimate of the emission line strength. We did this for all of the plots.

Selecting Green Peas:

- We created three different color-color plots using all three data sets (UDS, COSMOS, and CDFS) with the selection values shown in Table 2. Plots can be found in Figure 5.

Colors	Redshift	Selection Criteria	Number of GPs
J1- J2 vs. J2 – J3	1.146 < z < 1.418	J1 – J2 > 0.5 mags J2 – J3 < -0.5 mags	50
J2 – J3 vs. J3 - Hs	1.433 < z < 1.680	J2 – J3 > 0.5 mags J3 – Hs < -0.7 mags	40
J3 – Hs vs. Hs - Hl	1.950 < z < 2.250	J3 – Hs > 0.5 mags Hs – Hl < -0.8 mags	65

Table 2: This table shows the values used for selecting the Green Peas for the different filters and redshifts, as well as the total number of GPs found.

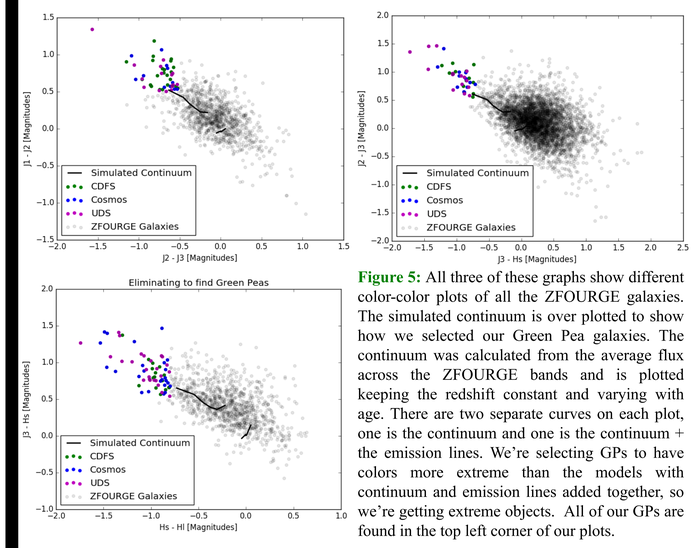


Figure 5: All three of these graphs show different color-color plots of all the ZFOURGE galaxies. The simulated continuum is over plotted to show how we selected our Green Pea galaxies. The continuum was calculated from the average flux across the ZFOURGE bands and is plotted keeping the redshift constant and varying with age. There are two separate curves on each plot, one is the continuum and one is the continuum + the emission lines. We're selecting GPs to have colors more extreme than the models with continuum and emission lines added together, so we're getting extreme objects. All of our GPs are found in the top left corner of our plots.

Conclusions

- Our data shows that Green Peas are found to be lower mass and have higher star formation rates (Figure 6). This makes sense as GPs are theorized to be low mass, compact, and starbursting galaxies (Amorín, et al. 2010). Our GP data is consistent with previous studies.

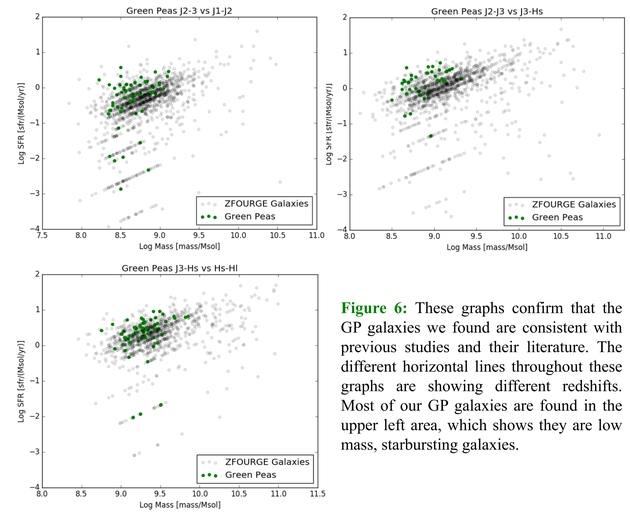


Figure 6: These graphs confirm that the GP galaxies we found are consistent with previous studies and their literature. The different horizontal lines throughout these graphs are showing different redshifts. Most of our GP galaxies are found in the upper left area, which shows they are low mass, starbursting galaxies.

- We have determined that GP galaxy abundance is significantly higher at lower masses. Our GP galaxies typically are found in a mass range of $10^8 - 10^{9.5}\ M_\odot$. We found that there are no GPs above $10^{10}\ M_\odot$ - in agreement with Amorín et al. 2010.

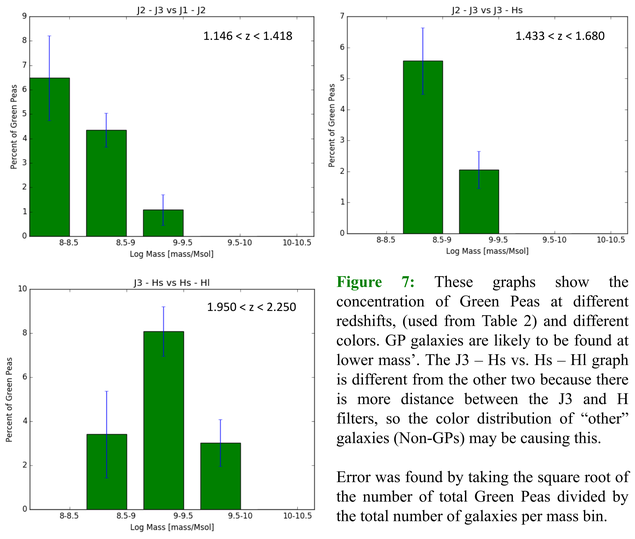


Figure 7: These graphs show the concentration of Green Peas at different redshifts, (used from Table 2) and different colors. GP galaxies are likely to be found at lower mass'. The J3 – Hs vs. Hs – Hl graph is different from the other two because there is more distance between the J3 and H filters, so the color distribution of "other" galaxies (Non-GPs) may be causing this.

Error was found by taking the square root of the number of total Green Peas divided by the total number of galaxies per mass bin.

Future Work

- We want to look through the SDSS Catalogues to find the fraction of Green Peas per mass to see if our results are in agreement with other data sets.
- We also want to look through the SDSS catalogues to find Green Pea abundance at higher redshifts since the ZFOURGE data doesn't go deep enough to find GPs at higher redshifts.
- It is unknown as to whether Green Pea galaxies played a role in the reionoization of the universe, but we can study the characteristics of the GP galaxies that are at lower redshifts to learn more about their ionization characteristics.

References:

- Amorín, R. et al., 2010, APJ, 715
- Jaskot, A. et al., 2013, APJ, 766, 91
- Van Der Wal, A. et al., 2011, APJ, 742, 2
- Starburst99 – run through Space Telescope Science Institute

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GMT

HETDEX Hobby-Eberly Telescope Dark Energy Experiment — Illuminating the Darkness

LSST Large Synoptic Survey Telescope

DARK ENERGY SURVEY

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