

# Institute of Cosmology and Gravitation: The Morphology of Void Galaxies

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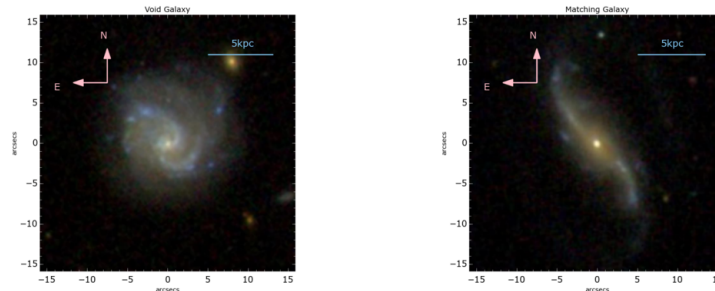
During this summer, I undertook an 8 week placement at the Institute for Cosmology and Gravitation in Portsmouth, funded by the Ogden Trust. Under the supervision of Dr Samantha Penny, I would be looking into the shape of void galaxies and seeing how they differ from ones in higher density regions of space to determine whether environment dictated how a galaxy evolves.

## **In the Beginning..**

As this was the first time I would be working in academia, I was a little apprehensive about starting the placement. How much contact would I get with my supervisor? Would I be in a shared office or alone? Would the other interns be super focussed and quiet, or friendly and chatty? One other intern was going to start the same day as me and her supervisor (who I had met over skype) organised to have two PhD students meet us and have dinner so we could chat about life at the ICG. They were really friendly and enthusiastic, so we all got along quickly, quelling a few of my nerves. I shouldn't have been worried. I was to be sharing a room with 5 other interns who after a few days were as friendly and chatty as if we had known each other for a while. My supervisor was contactable whenever I needed a gentle push in the right direction, or help with difficult coding. The other members of the ICG were great as well, with the PhD students organising talks for us on many subjects in cosmology and astrophysics.

I wasn't really sure what my internship would actually entail. I had done a little background reading on Galaxy Zoo, a citizen science project getting members of the public to determine morphological features of galaxies, and on void galaxies, but I didn't know how I was going to do the project. Turns out, with a lot of coding. After doing a Python module in my second year of university, I was fairly confident I would be okay, especially when my supervisor told me that they hadn't expected me to be able to code anyway. But a lot of it was new. I was able to get to grips with Linux, an open-source operating system, fairly quickly after being shown some commands and then my project began: find Galaxy Zoo 2 classifications for a sample of void galaxies, then

Figure 1: Example of a void galaxy with its comparison galaxy



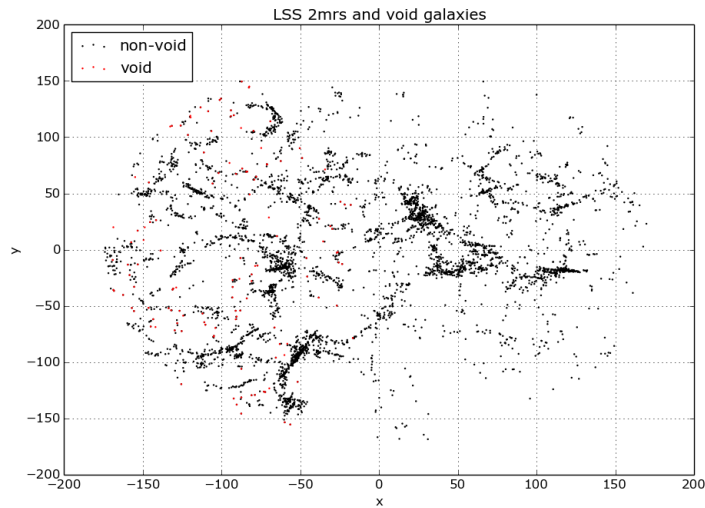
use this to find a similar comparison (non-void) galaxy for each void galaxy to compare their morphology (as shown in Figure 1). The spaces between the largest structures in the universe, filaments, are called cosmic voids. These spaces are not empty, however, they are under-dense and galaxies found within these regions are known as void galaxies. These galaxies are unique in that they have spent all of their lives in low-density environments, and so should have evolved without the influence of environment on their evolution.

## The Project

Working in an academic environment was nothing like what I had done before as I would be set a task and just left to it. I was eager to impress, so worked hard from day one to get the tasks done. Due to studying python in the past, I worked more quickly than my supervisor had expected so I had done all that was planned to be done within the first few weeks, allowing me to continue to look further into the project (not that I knew this at the time).

I was introduced to a program called TOPCAT (Tool for OPERations on Catalogues And Tables) to work with to compile my data. This graphical viewer and editor allowed me to merge tables together, combining multiple sources of information about one galaxy; do simple plots to get a rough idea of what I was working towards; and stack two sets of data together, making a larger sample. During my second week, I started to try to create the galaxy matching program, and TOPCAT was super useful for this. I practised at first with one void galaxy. I creating masks for the non-void galaxy data in python, limiting the red shift, colour ( $M_u - M_r$ ) and luminosity ( $M_r$ ) based on the void galaxies to try to find it similar comparative galaxy. Once is worked for one galaxy, I set about trying to make it work for all of them. Some galaxies didn't get a match, throwing out errors when running the code, and we needed to make sure the comparison galaxy was randomly sampled, and never chosen again if there were many matches. Once these problems were sorted, I had a fully functioning code which was used by one of the other interns as well.

Figure 2: Large Scale Structure of the Universe



Through this, I was able to compare the morphological features of the void and comparison galaxies using the Galaxy Zoo 2 data. This showed us that the void galaxies tended to be 'smooth' and non star forming. This was kind of strange because the normal way a galaxy stops forming stars is through interacting with other galaxies and hot gasses, but void galaxies are very isolated so this doesn't happen; an interesting result!

I also made a void galaxy finding program. It would take a galaxy and find firstly it's first, third and fifth nearest neighbour, and later it's sigma-5 value, based upon the surface density using the fifth nearest neighbour. For void galaxies, the third nearest neighbour would be a long distance away, allowing us to identify them. This sort of coding project would normally be done in a PhD, so I was very happy when I managed to make a code that worked! As I had understood all the concepts, my supervisor kindly made the program run quicker using KD trees, something I hadn't heard of. This also allowed me to plot the large scale structure of the universe (Figure 2).

As one of the 'Galaxy Group', we would have meetings every week or so to discuss what we had done, gathering interns, PhD students and researchers together. This was really interesting as it opened a window into what it would really be like working there full time, as well as what projects other people were undertaking.

## Final Thoughts

I have really, really enjoyed working at the ICG this summer. This internship has boosted my confidence my coding, scientific writing, and presenting skills

over the last 8 weeks. The ICG ran a summer student symposium, where we all got to present our work so far on our projects and eat pokeball cake for a member of staff's birthday! My presentation was called 'A long time ago in a galaxy far far away (from any other galaxy), getting a few laughs as the Star Wars theme played.

If any one is unsure as to if they should apply to an internship, I would tell them not to be and go for it! It has been a great experience and has opened my eyes to what the world of research is like. Thank you to the Ogden Trust and the ICG for making this happen!