A Search for Submillimeter Galaxy Counterparts

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Abstract

In this paper, we look to find counterparts to our 450μm sources found in our SCUBA-2 imaging of the Chandra Deep Field – South (CDF-S). We chose sources greater than 4σ and found 21 sources. We then matched the sources to a published 850μm ALMA catalog. We matched the sources within a 4 arcsecond radius and found 12 matches to our 450μm sources. Using the fluxes from the SCUBA-2 CDF-S map and the ALMA 850μm fluxes from the catalog. We created a 450μm to 850μm flux ratio versus redshift plotted against an Arp220 spectral energy distribution (SED) at varying temperatures.

1. Introduction

Submillimeter galaxies (SMGs) are some of the most powerful star forming galaxies in the universe. The use of deep imaging with the Submillimeter Common-User Bolometer Array (SCUBA: Holland et al. 1999) on the 15m James Clerk Maxwell Telescope (JCMT) brought these faint galaxies into view for astronomers. They found these newly discovered galaxies to be distant, but dusty and extremely luminous (e.g. Smail et al. 1997; Barger et al. 1998), indicating high star formation rates (SFRs). Because of this, they are significant contributors to the star formation history (Barger et al. 2014; Chapman et al. 2005; Casey et al. 2013; Cowie et al. 2017), making them critical in understanding galactic evolution.

In 2013 SCUBA was replaced by the second-generation camera SCUBA-2 (Holland et al. 2013). This new instrument vastly improved ground-based submillimeter astronomy by achieving a field of view of 50 arcmin^2, 16 times larger than its predecessor, and an angular resolution of ~14 arcseconds at 850μm and ~7 arcseconds at 450μm, far better than any other single-dish submillimeter telescope. Even with the advancements in SCUBA-2, SMG observations still suffer from unresolved and blended sources. In order to combat this problem, astronomers often pair single-dish imaging with multi-dish array observations like with Atacama Large Millimeter/submillimeter Array (ALMA) in order to properly identify the positions of these sources.

These accurate positions become significantly important when searching for other wavelength counterparts for these SMGs. Multiwavelength studies are needed to better understand critical properties of these galaxies. For example, radio is used to estimate redshift while also pushing to extremely high redshifts. X-ray can determine star formation activity as well as if the galaxy has an active galactic nuclei. Since SMGs are major factors in galactic evolution history, we must examine these galaxies as broadly as possible.

Our study aims to find counterparts to these galaxies in order to better constrain their properties. We began our search for 850μm counterparts for our sample of 450μm sources. Our sources come directly from our SCUBA-2 imaging of the Chandra Deep Fields – South (CDF-S). We chose this field because of its extensive and deep multiwavelength study. We set our detection limit to 4σ for accurate detections and perform a match process with a 4 arcsecond radius with the 850μm ALMA source catalog in Cowie et al. (2018).

2. Methods

The observations of the CDF-S have been a continual process since 2011. This is necessary in order to obtain the depths required for the submillimeter astronomy. At the time of this study, we have ~100 hours of observation time on the CDF-S, giving us a RMS value of 2.64 mJy/beam. Our reduction process is described in greater detail in Jenness et al. (2011) so we refer the reader these papers for more information on the reduction process. Generally, we download our proprietary SCUBA-2 imaging from the CADC archive and begin the reduction process. Using the Dynamic Iterative Map Maker (DIMM) in the SMURF package from the STARLINK software developed by the Joint Astronomy Centre. Going through this process reduces the background noise while bringing out potential sources.

As for the data analysis, we used Python coding and packages. We used a package created within our group to extract sources from our SCUBA-2 maps as well as commonly used astronomy Python packages such as AstroPy and SkyCoord to complete our data analysis. Other coding was self-written.

3. Key Results

After completing the image reductions, we moved to the data analysis process which we completed in Python. We first selected our 450μm sources from the created CDF-S maps. To make sure that we were picking our definite galaxies, we limited the source detection to 4σ or above, being sensitive to a flux of ~10.5 mJy or higher. With that restriction we picked up 21 sources with fluxes ranging from ~12mJy to ~31mJy.

Next, we matched our 21 450μm to the 850μm source catalog in Cowie et al. (2018). Their sources come from ALMA survey, meaning if we match our sources to theirs, we will have an extremely accurate position for our sources. Positional accuracy is key when searching for counterparts. In Python we ran compared the positions of each source to the ALMA catalog. We restricted our separation to 4 arcsecs due to SCUBA-2's angular resolution. With those restrictions, we found that 12 of the 450μm sources had an 850μm counterpart.

We extracted fluxes from the 450μm sources by converting our maps to pixel coordinates and lifting the central pixel value from the image. This is possible by the nature of our data reductions which keep the actual source flux intact. Fluxes for the 850μm ALMA sources come from the same catalog.

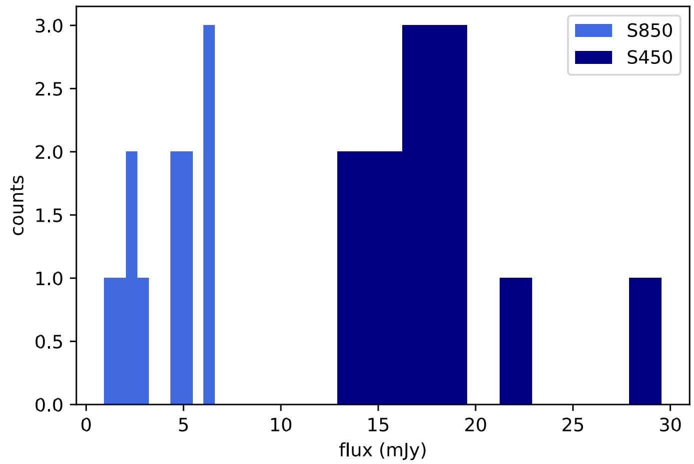

Figure 1: A histogram of the 450μm (dark blue) and 850μm (light blue) flux of the sources with ALMA counterparts.

4. Discussion

Just finding counterparts is not enough. In order to better understand the sources that we found in the CDF-S, we created a flux versus redshift plot to see if these galaxies, theorized to be high redshift analogs to Ultra-Luminous Infrared Galaxies (ULIRGs), and plot it against the spectral energy distribution (SED) of a low redshift ULIRG, Arp220. This SED evolves over redshift at varying temperatures so that we can see if these galaxies match Arp220.

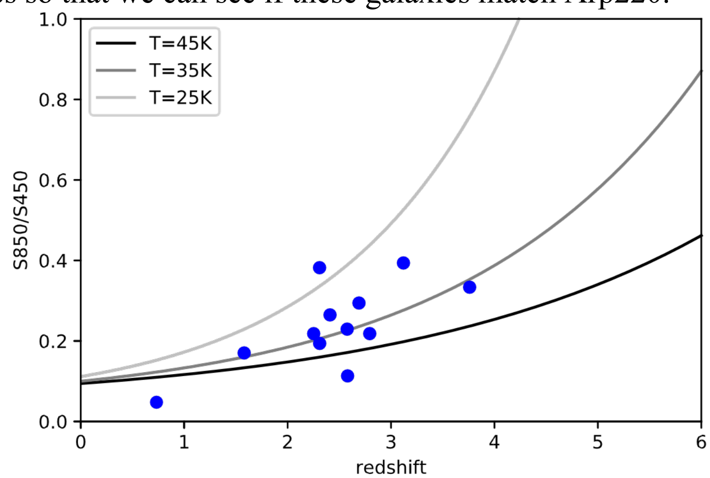

Figure 2: Flux ratio vs redshift. In blue arethe sources with matches. Plotted behind is an Arp220 SED are varying temperatures.

We expected to find more sources than we did in the CDF-S, but this is a limitation of the depth of our imaging and possible cosmic variance. We will next look to the CDF-N where we have far deeper imaging, meaning that we will have a larger sample of sources. We will compare these sources to the catalog in Cowie et al. (2017) and repeat the same process we did for the CDF-S.

After repeating this in the CDF-N, we will look to other wavelengths to gather more data on these SMGs. In particular, we will look to the radio in order to give us redshift estimations of our sources. X-ray will give us interesting information of star formation and active galactic nuclei. SMGs are known to be invisible in the optical so checking that our sources match the key characteristic is very important.

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