Searching for Galaxy Clusters Around AGN at z~1 Using Spitzer Archival Imaging Data

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Abstract

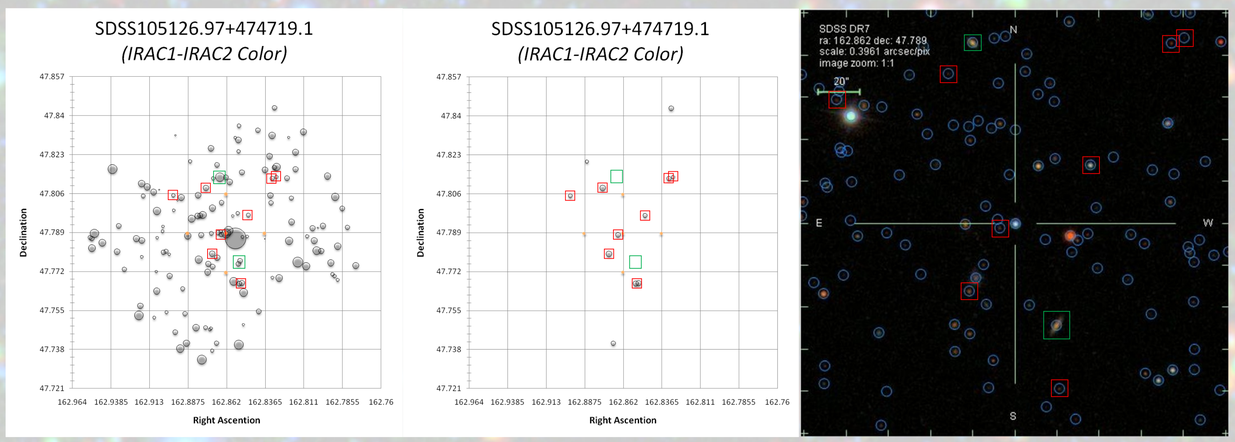
We used Spitzer Space Telescope archival data from the Infrared Array Camera (IRAC) at 3.6 and 4.5 microns to locate galaxy clusters at *z*~1. 168 fields that targeted Active Galactic Nuclei (AGN) at *z*~1 were taken from the archive, and a [3.6] - [4.5] color selection was applied to all sources in each field. At a *z*~1 the peak of a galaxy's stellar emission is redshifted into the 3.6 micron band, making those galaxies "bluer" (within the IR range) than foreground galaxies. If an overdensity of sources with the appropriate color was detected around the AGN, then the field was marked as having a potential cluster around the AGN and will be followed up for spectroscopic confirmation.

Introduction

Some of the most massive structures in the Universe are galaxy clusters. Finding a large number of them and studying them at specific redshifts can illuminate the evolution of galaxies and the evolution of structure in the Universe. One method of finding clusters is to locate Active Galactic Nuclei (AGN) at a particular redshift and then search their surroundings for a cluster.

Finding Clusters at a z~1

The Spitzer archive contains images of the surroundings of 168 AGN at a *z*~1, most imaged originally for a research project conducted by Falder, et al. (2010). The photometry of the sources surrounding each AGN was analyzed using a color selection technique similar to one described by Galametz et al. (2009), which involved comparing magnitudes in the IRAC1 and IRAC2 images (*Figure 4)*. Photometric sources at a *z*~1 were isolated by using a *Spitzer* [3.6] – [4.5] color ratio between -0.1 and -0.4 (Popovich 2008, *Figure 3*). All sources near the AGN within the -0.1 to -0.4 color range were then plotted with bubbles sizes mapped to color (*Figures 1 & 2)*. Cluster candidates were identified if the AGN was surrounded by 3-5 sources of similar color within a 1' radius, which corresponds to the typical core size of ~0.5 Mpc of clusters at *z*~1 (Galametz, et al. 2009). After selecting candidate clusters, the plots were compared to Sloan Digital Sky Survey (DR7) images of the AGN and the surrounding area to improve the confidence in the cluster candidates.



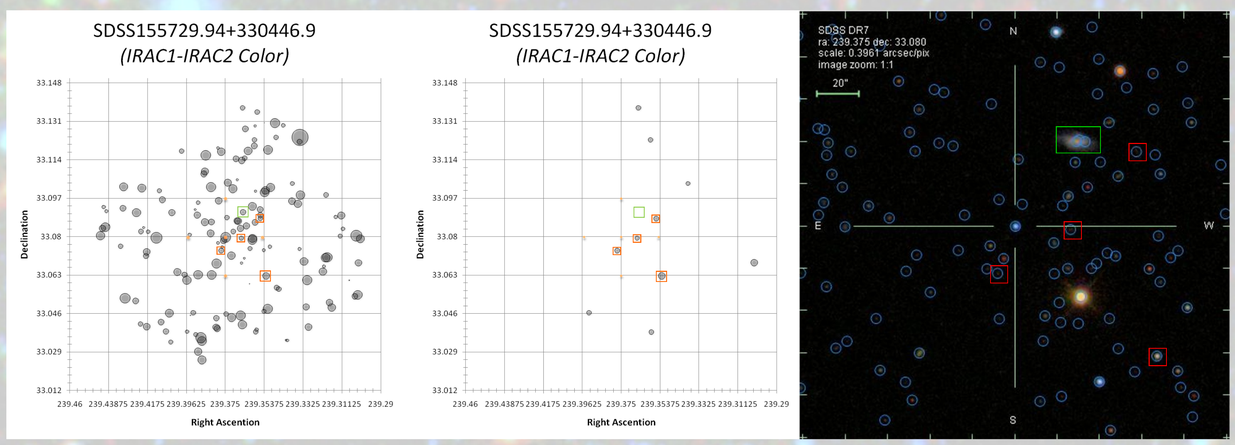
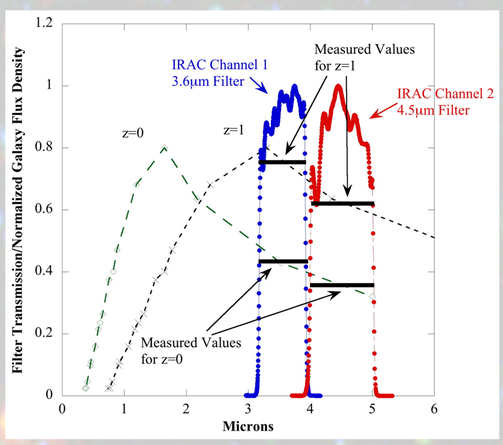


Figure 1 (Upper Left) & Figure 2 (Lower Left)

Left Images: Plot showing one AGN with all photometric sources before using the color selection technique. The 1' radius is shown as a cross of four small orange points around the AGN, which is in the center. Green boxes indicate locations of some foreground galaxies identifiable by their extended nature in the higher resolution optical image. Red boxes identify remaining sources surrounding the AGN.

Center Images: Plot of the same AGN after using the color selection technique. Note that extended foreground galaxies (green boxes) have been removed using the color selection technique.

Right Images: Sloan Digital Sky Survey image of the same AGN (centered). Green boxes identify foreground galaxies. Red boxes indicate correlation with sources in center image based on RA/Dec. Some sources appear red, which may be due to the redshift of the sources.



Results

After conducting the color analysis and reviewing the density of the objects within a radius of 1' of the AGN, ten cluster candidates were identified out of the original 168. Each candidate had 3-5 objects within the -0.1 to -0.4 color range and the 1' radius. The Sloan Digital Sky Survey assisted in verifying the objects by morphology and color (redder usually indicating higher redshift). Further research will involve additional spectroscopic imaging and analysis of the cluster candidates to confirm whether they are galaxy clusters. This will also assist in confirming these methods that have been used to identify the galaxy clusters.

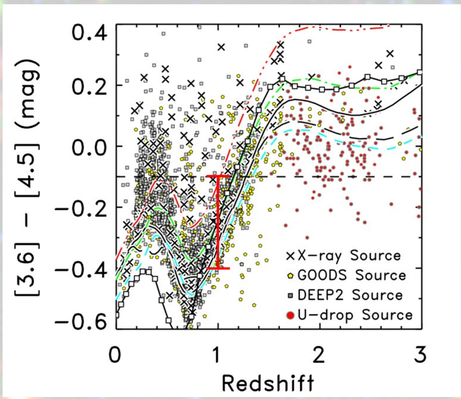


Figure 3 (Above)

Observed color ranges for objects at redshifts from 0 to 3. AGN studied in the research project were z~1, so a color range of –0.1 to –0.4 was used (marked with a red line). Credit: Popovich, 2008

Figure 4 (Left)

Spectral energy distributions of a galaxy at a z=0 compared to one at a z=1. Transmission curves for IRAC Channel 1 (blue) and 2 (red) are plotted for reference. Note the ratio in measured values at z=1 is larger than the ratio at z=0, making the galaxy "bluer."

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