High-redshift Galaxy Clusters at z~1

Team Redshift:
Merrill Butler, Orange County Astronomers
Adam Keeton, North High School, Eau Claire, WI
Shefali Mehta, Haddam-Killingworth High School, Higganum CT

Tim Spuck, Oil City High School, Oil City, PA and NSF Fellow
Varoujan Gorjian, Spitzer Research Scientist, SSC/JPL
Audrey Galametz, INAF/Astronomical Observatory of Rome
Mark Abajian, Software Engineer, NExScI/IPAC

Abstract

We propose to study galaxy clusters around Active Galactic Nuclei (AGN) at a high redshift range of 0.7<z<1.2. In order to accomplish this we will utilize data from the *Spitzer Space Telescope* compiled by Falder et al (2010). We propose to identify galaxy clusters by using simple IRAC color selection which has been found to be effective at unraveling high redshift galaxies (A. Galametz et al. 2011). Using a counts-in-cell analysis, we will identify a field as being overdense if 15 or more IRAC sources are found within 1' (ie., 0.5 Mpc at 1<z<3) of the targeted galaxy to the 5 sigma flux density limits of the IRAC data that was targeted. Also using the color selection criteria developed by Stern et al (2005) we will seek out other AGN surrounding the originally targeted source. The number of our sample is 168 and we plan on both rediscovering previously known clusters and protoclusters as well as discovering new galaxy cluster candidates. The researchers further hope to create some statistical sampling which would further confirm suggestions that high redshift radio AGN with high radio luminosity lie in some of the densest regions in the Universe.

Background

Galaxy clusters are the largest structures in the universe (on the order of 10^{15} solar masses) and are often home to hundreds of galaxies covering an enormous swath of space (several Mpc). It is important to observe many of these clusters at a specific cosmic time allowing for the study of the evolution and formation of galaxies within them. Research using X-ray satellites has confirmed the presence of galaxy clusters with a redshift up to z ~ 1.5. Although this approach is extremely useful, searching for high redshift clusters becomes increasingly difficult as the X-ray emissions produced begin to fade. There are, however, other methods that scientists can employ in order to efficiently measure and locate high-redshift galaxy clusters. Using the Infrared Array Camera (IRAC) on the *Spitzer Space Telescope*, we can employ color selection techniques to not only identify cluster candidates in an efficient manner but also any additional Active Galactic Nuclei (AGN) that are members of the cluster.

One approach to using the color selection technique involves using a high-redshift AGN as a useful and powerful marker to begin the process of determining whether an AGN is surrounded by galaxies that occupy the same redshift and therefore might qualify as a cluster. The goal of the project will be to evaluate and observe a large sample of radio loud and radio quiet quasars as well as a sample of radio loud galaxies at a similar redshift. By observing these targeted AGN, we hope to identify other galaxies which, because of their unique color and over-density, can be classified as potential cluster members. It is surmised that additional AGN will be located as well within identified clusters. Once a cluster has been discovered and its members defined, TRS hopes to further investigate the clusters by using other measurement techniques in order to answer some of the questions posed at the end of the "Proposed Project" section. Specifically, we will be searching for other AGN and the presence of a light signature that is characteristically emitted by "warm dust" accreting around the AGN black hole. This serves to both identify clusters that the sources might inhabit, as well as whether the galaxies within the potential cluster may be also AGN.

Proposed Project

We plan to study a large sample of mid-IR selected galaxy clusters at z~1 by targeting the surroundings of high-redshift AGN also at that redshift range. We will also study the AGN population within these high-z structures. In order to accomplish our objective, we will be employing some varied techniques. Archival IRAC data will provide our team with the data necessary to study our targeted AGN that have a known redshift of $0.7<z<1.2$ to see if they reside within a cluster. Additionally, it will allow us to confirm the presence of additional AGN as cluster members. Using *Spitzer* archival data, a selection criterion has been created in order to single out high-redshift galaxy clusters. One of the features that has been studied in order to locate high-redshift galaxies is the 1.6 micron “bump.” This bump, created by the Ionized Hydrogen found in cooler stars, typically redshifts into the 3.6 and 4.5 micron IRAC bands (Fig 1), thus altering the colors of background sources vs. foreground, sources which are not redshifted. It should be pointed out that this change in colors creates a clear distinction between sources that are red shifted and within the desired z range, and those that are not. Therefore, any object whose light does not fall within the prescribed range of IRAC1 and IRAC2 is an object which does not meet our criteria for cluster membership. Further, by using another color selection technique first proposed by Stern, et al (2005) we will determine whether the sources identified as members of the cluster surrounding the targeted AGN are themselves AGN. Since AGN accretion warms the dust near its galactic core, an excess of longer wavelength light will be seen (ie, at 4.5 microns) (Fig 2). Once candidate sources around the chosen AGN are identified, the surface density of those sources will be calculated using a counts-in-cell analysis which will identify a field as being overdense if 15 or more IRAC sources are found within 1' (ie. 0.5 Mpc at $1<z<3$) of the targeted galaxy to the 5 sigma flux density limits of the IRAC data that was targeted. If the surface density criterion is met, then the target AGN is deemed to be a member of a cluster and that cluster is at the redshift of the target AGN.

Further, the study of clusters around AGN has led to additional and useful data in studying high-z clusters. Galametz, et al. (2009) identified AGN populations in a very large sample of clusters at a cosmic distance less than $z \sim 1.5$. This research identified an excess of AGN within a distance of 0.5 Mpc of the cluster centers. Galametz, et al (2009) also determined that the AGN activity in clusters was stronger in the past with the number of AGN decreasing as z decreases. This begs the question as to what role AGN play in cluster formation and evolution.

Our sample will be compiled from a preliminary investigation of cluster membership done by Falder, et al (2010) who used radio data supplied by radio observatories and the 3.6 micron data for 168 AGN to see if they were potentially members of clusters. They did not, however, use the color selection technique to better identify cluster members, nor did they use the other IRAC colors to determine if the candidate cluster members were AGN. The target list is attached at the end of the proposal.

Through this research, we hope to accomplish the following:

1. Using the color selection technique, identify a new sample of galaxy clusters using IRAC observations of the targeted AGN at $z \sim 1$.

2. Study the characteristics of the (mid-IR selected) cluster population in clusters at $z \sim 1$ and determine whether other AGN reside in the same cluster.

3. Try to correlate cluster member spatial distribution with existence of additional AGN (ie. filamentary or clumped).

Analysis Plan

Students, teachers, and amateur astronomers on Team Red Shift will engage directly in a literature search in an effort to find out what scientists currently know about AGN and high red shift galaxy clusters. This process will require the effective use of online search skills, an increased understanding of science and technical information, and the use of the SAO/NASA Astrophysics Data System, the NASA Extragalactic Database (NED), and various Internet search engines. This process will significantly enhance the literature search skills for students, teachers, and amateur astronomers.

Also, members of Team Red Shift will have direct access to *Spitzer* archival data, specifically the 3.6-8.0 micron images in the target list for analysis purposes.

The group will use the Aperture Photometry Tool (APT) developed by *Spitzer* Scientist Russ Laher. APT will be used to measure intensity and subsequent magnitude values for targets in each of the images. Microsoft Excel will then be used to generate color-color diagrams in an effort to identify members of potential galactic clusters and AGN candidates. Team members will also use NED to explore additional published data (e.g. redshift, galaxy type, size, etc.) on potential members of these high-redshift galaxy clusters. This process will provide an opportunity for students, teachers, and amateur astronomers to experience authentic astronomy research and enhance their data analysis and interpretation skills.

Education and Public Outreach

Our research team is comprised of an amateur astronomer in Southern California Mr. M. Butler, and two science educators, Mr. A Keeton from Eau Claire, WI and Mrs. S. Mehta from Middletown, CT with a veteran educator/researcher and lead teacher, Mr. T. Spuck from Oil City, PA and currently an NSF Einstein Distinguished Educator Fellow. Our goals and desires in this research may vary, but the dedication we all have towards better understanding our universe is consistent. Along with the working professionals there will also be approximately 6-8 high school aged students involved in the research and presentation process as well. Their role will be similar in nature to our own, but supported to reflect their age level and what we desire them to gain from this experience.

Upon completion of this research process, Team Red Shift members will work collaboratively to produce both a science and an education poster summarizing their work. These posters will be presented at the 2012 American Astronomical Society Winter Meeting in Austin, Texas

Beyond the official research process the group will engage in a variety of education and public outreach activities. Presentations will be made by Team Red Shift teachers and amateur astronomers at local, regional, state, and national science gatherings (e.g. NSTA, AAS, Astroblast, school professional development, astronomy club monthly meetings, etc.). Teachers and students will also develop related classroom activities that can be utilized with their own students as well as shared with other teachers and students across the United States. These activities will be disseminated broadly via the NITARP Wiki and website, and through educational presentations.

Specific locations and opportunities for each educator are presented below:

Merrill Butler:

Being an amateur astronomer, I am very familiar with the interests of the amateur community. I have seen over the years how the interest has changed from taking "pretty pictures" to engaging in real science. There are a great many amateurs who are very active in measuring binary and variable stars. There are others who are now employing the tools of photometry as well as spectroscopy in order to achieve their scientific goals. But, in my experience I have not encountered any amateur groups which are using the incredible amount of archived data to support any form of astronomical research. I view this as a "Golden Opportunity" for outreach.

My outreach plan will be comprised of two components. One will be to schedule presentations of my participation in NITARP and how by doing scientific research (this proposal) I was able to access and learn about the incredible depth of the archives. I plan to lead the participants through every major step in the process and thereby show them how they too can access these archives for their own research. These presentations will be made at the monthly meetings of the many Astronomy Clubs here in Southern California. I plan to identify one to two people which will be my key people inside the club and with whom I can have further discourse and will be the ongoing contacts at each club. Two will be to establish a competition for the participating clubs such that there will be some award established for the best research project presented. The judges will be the current science staff at NITARP and Spitzer Science Center. I plan on accessing my contacts at Meade and Celestron to see if they will donate a telescope to be awarded to the winning research project. I think by creating some competition we will get some very enthusiastic participation. Here is a list of the Amateur Astronomy clubs that I initially hope to make presentations to:

1. Orange County Astronomers
2. Los Angeles Astronomers
3. Andromeda Astronomical Society
4. Antelope Valley Astronomy Club
5. Astronomical Society of the Desert
6. Bear Valley Astronomy Society
7. Central Coast Astronomical Society
8. China Lake Astronomical Society
9. Excelsior Telescope Club
10. Kern Astronomical Society

Adam Keeton

Presentations to state and national science organizations as well as school district staff development opportunities will be used to demonstrate the work that students, teachers and scientists have completed. I will also be creating various national and state standards-based activities related to the research conducted that connect current research investigations (with an emphasis on archival data) to topics taught in introductory astronomy courses. These activities will be made available to all science teachers across not only the Eau Claire Area School District, but also the United States. Students involved in the research process will also be required to apply to the University of Wisconsin Eau Claire's Student Research Day. This two day event showcases research being done by students in the area in various disciplines, not just science.

Shefali Mehta

In order to share what we have accomplished through this project, I plan on involving additional students as well as the community. Within the classroom, I will be incorporating activities in which students can continue learning how to conduct data or image analysis. Within Regional School District #17, I plan on offering professional development opportunities to teach other teachers how to include data and image analysis into their classes. I also plan on working with The Children's Museum in West Hartford, The Copernican Observatory and Planetarium at CCSU, and the Astronomical Society of Greater Hartford to teach others about the research as well as to showcase the students' work throughout the community.

Tim Spuck

I will be making presentations about TRS to amateur astronomers and educators at Astroblast 2011 and 2012. I will make at least one presentation here at the National Science Foundation to program officers and Einstein Fellows about TRS/NITARP. I will also work to involve Oil City students as well as DC students in various aspects of the research process, and hope to deliver a presentation on TRS and the NITARP program at the 2011 American Geophysical Union meeting.

References

Falder, J. T. et al. 2010, MNRAS, 405, 347
Galametz, A. et al. 2009, ApJ, 694, 1309
Stern, D. et al. 2005, ApJ, 631, 163

Target List

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#ID17; PI Fazio 3C184
#XFLS RSDSS171732.94+594747.7 RSDSS172130.96+584404.1 RSDSS172310.35+595105.6
#Too close to edge of XFLS RSDSS171145.53+601318.4
0.9643 0.9348 0.9562 1.0935 1.1004 0.9983 0.9087 1.0264 1.0139 1.0113 0.9923 0.9088 0.9744 1.0516
1.079
0.9940
1.0596 1.0001 0.9899
0.9804
10:35:25.06 10:38:29.75 10:38:55.34 10:41:14.19 10:41:56.52 10:42:39.67 10:43:55.47 10:46:59.38
10:48:59.68 10:49:30.47 16:09:13.18 16:32:25.56 16:33:06.12 16:39:30.82

17:24:18.96 07:39:24.26
17:17:32.94 17:21:30.97 17:23:10.35
17:11:45.54
+58:03:35.6 +58:52:04.1 +57:58:14.7 +59:02:19.5 +59:36:11.3 +58:32:31.0 +59:30:54.1 +57:30:55.9
+56:56:48.6 +59:20:32.7 +53:54:29.6 +41:18:52.4 +40:17:47.5 +41:00:13.7
+50:57:40.32
+70:23:11.01
+59:47:47.5 +58:44:04.7 +59:51:05.7
+60:13:18.6