PITCH ANGLES OF CLUSTERED SPIRAL GALAXIES IN THE CHANDRA DEEP FIELD SOUTH.

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Introduction: We have examined a set of 125 galaxies lying in the Chandra Deep Field South for which we have redshifts and pitch angles from previous work. Upon cross-referencing this set with the larger COMBO-17 survey, we have found a cluster that is confirmed by recent literature. When comparing the pitch angle of galaxies in and out of clustered regions, there seems to be little to no difference, suggesting no environmental effect of clusters on pitch angle

Background: Recent studies by the AGES (Arkansas Galaxy Evolution Survey) collaboration (of which the current authors are members) [1] have shown that there is a strong correlation between the pitch angle of spiral galaxies and the mass of the black hole that lies in the middle of every galaxy studied [2]. Spiral structure (and therefore pitch angle) are, to date, best described by the wave-density theory, but it is not yet clearly understood how disk galaxy morphology may be affected by environmental factors.

For this reason, the reliability of pitch angle is very important in measuring black hole mass in different environments. For instance, clusters are thought to provide many insights into galactic evolution and therefore structure [3], [4]. Furthermore, galaxies in clusters are more susceptible to galaxy harassment and the effects of dark matter than galaxies in the field. If the black hole mass-pitch angle relationship is not direct, then environmental pressures such as those that exist in clusters may have an effect on pitch angle.

Investigation: The Chandra Deep Field South, although an excellent source of objects with available photometric redshifts (63,501 total), was actually chosen due to the lack of local clusters in our line of sight in order to enable a "deep" telescopic look. Since we were unsure of finding a strictly defined cluster, and we don't have the full range of instrumentation necessary for defining each aspect of clustering (X-ray luminosity, spectroscopic velocity distribution, etc.), we decided to initially concentrate on the relative density of galaxies. At the same time, we looked in the literature for pre-existing relations between clustering and spiral galaxy structure to provide context.

Programing. The definition of a cluster has evolved somewhat from the initial understanding of being simply an overdensity of galaxies to the more complex Abell system of cluster categories to the use of X-ray luminosity, galaxy velocities, gravitational lensing, etc. to confirm optical observations [3]. However, a general definition of clustering is simply a count of 1000 galaxies or more within a 10 Mpc radius [5]. With this number in mind, we wrote a program in Fortran to give us the number of neighbors that one galaxy had within a certain radius by comparing Seigar et al's set to the comprehensive COMBO-17 survey [6]. To avoid false neighbors (those appearing close-by due to small angle separation), we placed a virtual cylinder around each galaxy with a redshift range limiting the length (or line-of-sight distance). The redshift "length" of the cylinder was determined by the radius, which was varied between 1 and 10 Mpc.

Literature. We found several sources discussing the evolution of disk galaxies in clustering regions, specifically the morphology from spiral to S0 (lenticular) galaxies [4], [7]. All sources consulted agreed that galaxies appear to change from spiral to S0 over time (higher to lower redshift), and so we speculated that this could mean a pitch angle that concurrently evolved lower and lower (or gradually tightening spiral arm structure). However, this could also mean that we might expect a higher number of galaxies and therefore more pitch angle data at higher redshifts from Seigar et al's sample.

We also found sources outlining the discovery of clusters in the CDFS at various redshifts, and especially one towards the high end of our sample's range (z~1) [8].

Results: Our program produced data that confirmed the cluster at z~1 found by Trevese et al. Forty-three of Seigar et al's galaxies had 1000 neighbors or more within a cylinder of radius 10 Mpc (several of these had 1000 neighbors starting at 5 Mpc cylinders). When we plotted these galaxies' right ascension and declination versus redshift (Figures 1 and 2), they showed an average redshift of about 1.04.

However, when we compared the average pitch angles of the clustered and non-clustered galaxies (Table 1), the pitch angle didn't vary by more than 0.4 degrees. A plot of pitch angle versus neighbor count (Figure 3) confirmed little to no correlation between the two.

Discussion and Further Work: Our preliminary results seem to indicate that there is no difference between the pitch angles of galaxies in and out of clusters, but there are several aspects that we wish to pursue further.

The first one would be to determine more about this cluster we have found. For instance, we know which of Seiger et al's galaxies are in the cluster, but not which of the COMBO-17 galaxies. We assumed that our 125 galaxies were spread evenly throughout the GOODS-S and so their location was representative of the greater cluster, but this may not be so. We will work on a more comprehensive version of our program so as to obtain a map of galaxy density, which may lead to different results or simply confirm what we have found.

We will also compare our data to Trevese et al.'s data to find out what areas of cluster determination we did not use but they did (i.e., X-ray luminosity), and how we may further future work with clusters with a better understanding of all defining quantities.

Finally, another part of Seigar et al's data comes from the Hubble Deep Field North. The data for this field is not as comprehensive as the CDFS, containing only 4396 objects (1811 galaxies), but there is a chance of clustering also occurring here, and so we'd like to look at pitch angles in this area of the sky.

Figures:

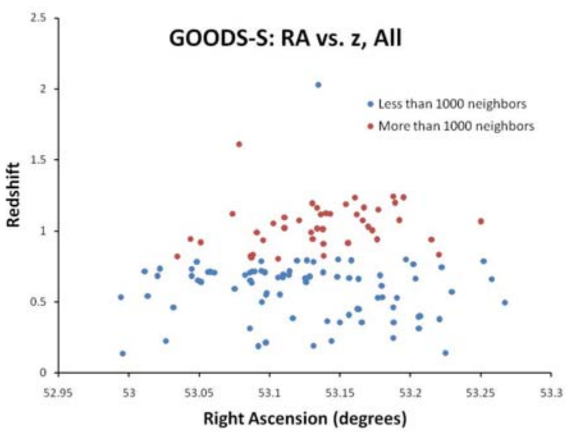

Figure 1: Right ascension vs. redshift

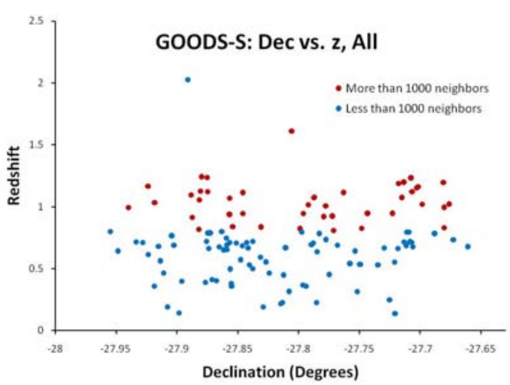

Figure 2: Declination vs. redshift

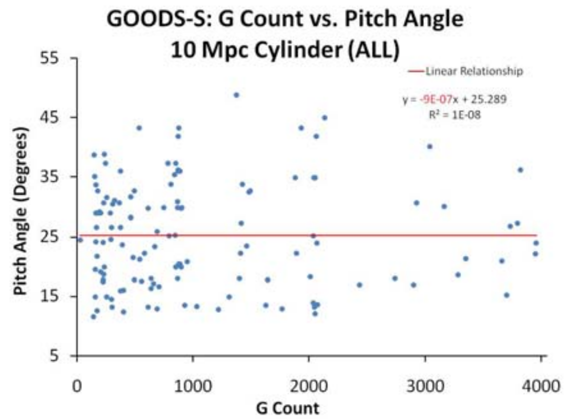

Figure 3: Neighbor count vs. pitch angle

GOODS-S 10 Mpc Cylinder: Comparing Numbers			
G Count	<550	>550, <845	>845
Avg. Pitch Angle	25.2	25.6	25.1
# of Galaxies in Bin	41	42	42
Avg. z	0.493	0.697	1.046

Table 1: Pitch angle, neighbor count, and redshift by bins.

References: [1] The Arkansas Galaxy Evolution Survey, http://dafix.uark.edu/~ages/ [2] Seigar M. S., et al. (2008) *ApJ.*, *678*, 93-96. [3] Voit G. M. (2005) *Rev. Mod. Phys.*, *77*, 207-258. [4] Moore B. et al. (1999) *Mon. Not. R. Ast. Soc.*, *304*, 465-474. [5] Berrier J. (2009) Private Communication. [6] Wolf C. et al. (2004) *Astro. and Astrophys.*, *421*, 913-936. [7] Poggianti B. M. et al. (2009) *ApJ.*, *697*, 137-142. [8] Trevese D. et al. (2009) *AIP Conf. Proc.*, *1126*, 125-127.