The X-ray – Globular Cluster Connection in NGC 3256

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Abstract

During the merging of galaxies, strong X-ray point sources can be detected. The properties of the detected X-ray sources suggest that they originate in massive black holes. Although single stars emit X-rays, many of these detected sources are too strong to be characteristic of them. It has been proposed that these X-ray sources come from bright globular star clusters, which would enable them to come from an overlap of the stars where the overall accretion disk of the black hole would be emitting very strong X-rays. The purpose of this project is to show that the strong X-ray point sources from the merging NGC 3256 galaxy do in fact originate in the bright star clusters detected there.

Globular Cluster Systems:

Globular cluster systems are densely packed groups of thousands upon millions of stars. They are roughly spherical in shape and they primarily exist around the centers of galaxies. Globular cluster systems formed at the time of the formation of their host galaxies. One of the proofs of this assertion is in the systems' general lack of more massive O through F stars on the main sequence (according to the classification system in which stars are distinguished based on their temperatures). These stars must have long since depleted their early hydrogen rich nuclear fuel and vanished from the main sequence of stars. This means that the stars in these star clusters must be very old and therefore contain the oldest stars known for that particular galaxy. The stars in the globular systems are about the same age. These systems are studied because of their unique properties of providing a fossil record of the galaxy's early life. They are the remnants of the early stage of a galaxy's life. Studying globular cluster systems gives insight to the conditions surrounding a galaxy's inception.

Globular clusters also provide environments, which are conducive to studying stellar evolution and stellar dynamics. Since they are housed in such a compact environment, it is possible to study their interactions with each other.

NGC 3256 Merger:

This galaxy is an example of two spiral galaxies colliding. When these galaxies come in contact with each other, new globular clusters are formed and strong X-ray sources can be detected. A full image of the galaxy taken with the Wide Field and

Planetary Camera 2 (WFPC2) on the Hubble Space Telescope (HST) can be seen in Figure 1. A blowup of the central region of the galaxy from the same camera can be seen in Figure 2.

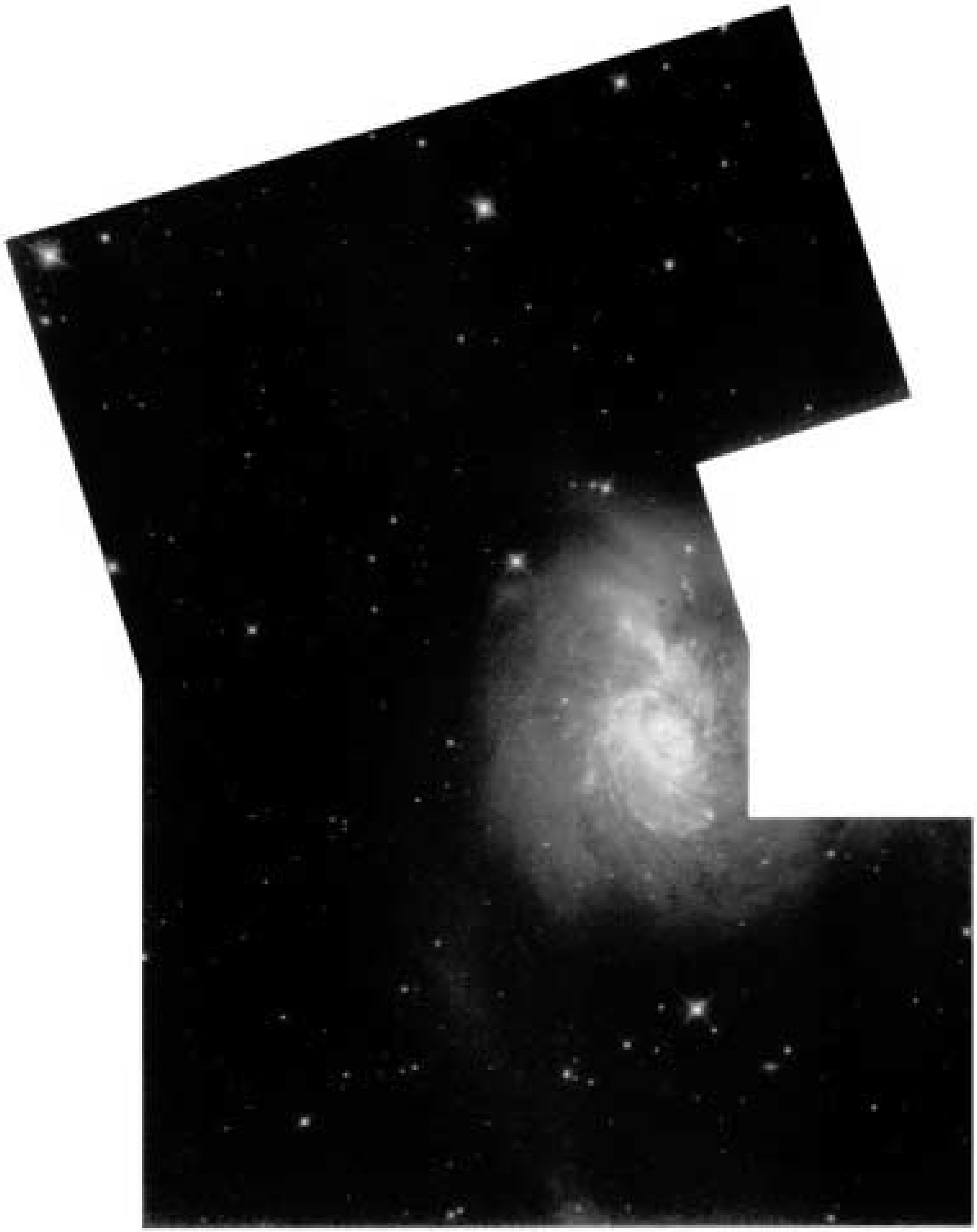

Figure 1: Image of full NGC 3256 galaxy merger

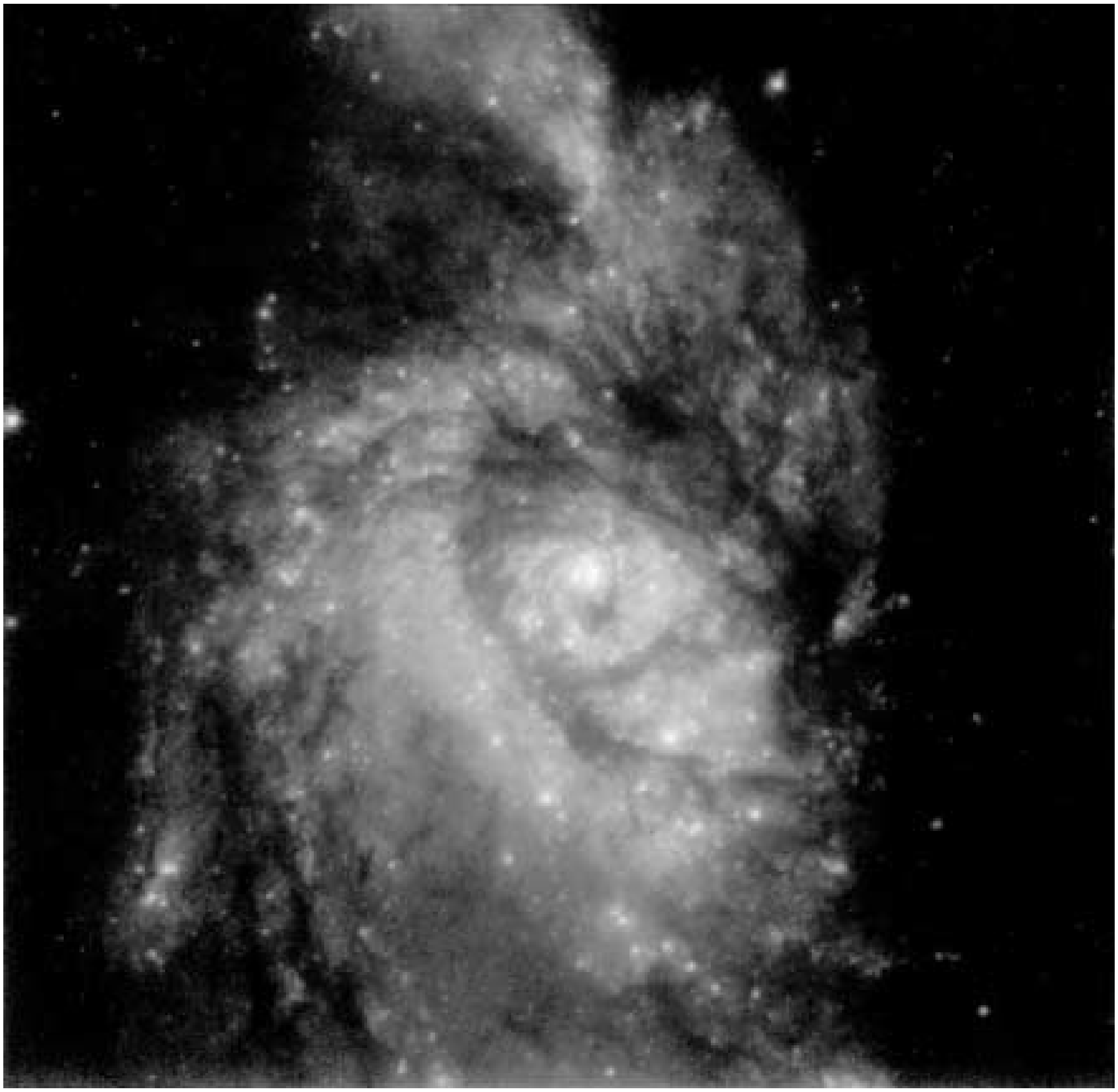

Figure 2: Blowup of central region of NGC 3256

Proposed Problem:

The proposed question in this project is do the strong X-ray point sources from NGC 3256 coincide with the brighter globular clusters? The data involved in this project is both optical and X-ray coming from the HST and Chandra Observatory respectively.

The two sets of data were combined to see if a correlation existed that agreed with the hypothesis.

Data Reduction Process:

Both the optical and X-ray data were obtained from their respective distributors. A program called Image Reduction and Analysis Facility (IRAF) was used to reduce both sets of data. The optical data from HST was specifically two images of NGC 3256, one focusing on the galactic center (Figure 2) and the other on an outer region of the galaxy. A single WFPC2 exposure is obtained as 4 images, one from each CCD chip on the camera. Two exposures were taken for each region each using a different color filter for comparison purposes later. The raw images were first combined using an IRAF task that used coincidence techniques to eliminate cosmic rays and combined them to create a final image. Once this task was completed, four images were created, one for each filter in both regions. Next another task was used in IRAF which identified the globular clusters from the newly formed images. A photometric task was then used to find the amount of light coming from each of these detected globular clusters. The data corresponding to the list of globular clusters from one image was then compared to that in the list corresponding to the different filter for the same region so as to compile one complete list for each region. A single observations file was then created with this list of globular clusters.

Next the X-ray data was reduced. This data was taken from Chandra as a list of 39 X-ray sources in the galaxy as well as an X-ray image of the galaxy. The list of 39 sources was provided giving their right ascensions and declinations, which was different from how the optical data was given. These positions had to be converted to the same format as the optical data so that they could be compared. When this was done, 18 of the total 39 sources were found to lie in the central region of the galaxy. The coordinates of each were able to be determined in the same format as the optical data so that they could be compared. When they were compared, seven of the X-ray sources were found to have optical counterparts. This entire process for the central region can be seen in Figure 3 with the red points marking out the globular clusters and the purple circles showing the X-ray sources. The seven total sources can be seen from this image where the circles and points line up.

Figure 3: X-Ray Source Overlay (red are optical GC sources, purple are x-ray-optical matches)

Data Analysis:

The next step in the project is determining what the overall difference is between the seven globular clusters with X-ray counterparts and the remaining globular clusters in the galaxy. Histograms were made of the two sets of data in order to compare them and determine if the proposed hypothesis, that the X-ray sources came from brighter globular clusters, was accurate. The histograms plot the optical data in question and their corresponding magnitudes. Both sets of data have been scaled so as to measure the counts between zero and one rather than the total number. This has been done because the number of clusters with X-ray counterparts is about 0.96% the number of total clusters. This difference makes it difficult to accurately compare the sets of data without scaling both of them in some way.

The first histogram is a plot of all the optical globular cluster data and their corresponding magnitudes and can be seen in Figure 4. The magnitude number goes in order of least luminous to most luminous on the x axis while the number of globular clusters observed at that magnitude is on the y axis. The drop off on the left side of the plot which corresponds to the fainter clusters exists because of the decreased detection at these magnitudes. Optical data at this magnitude is more difficult to detect so the results look like they drop off dramatically where in reality they should not. A Gaussian fit was applied to the histogram and it was determined that the peak was at a magnitude of roughly 18.558 with a standard deviation of 1.8564. The second histogram (Figure 5) shows the results from only the seven clusters housing X-ray sources as well. When a Gaussian fit was applied to this set of data, the peak was clearly shifted towards the more luminous region at 16.961 with a standard deviation of 1.856. The results of this histogram procedure clearly agree with the hypothesis that the clusters with strong X-ray counterparts are on average more luminous than the entire population of clusters.

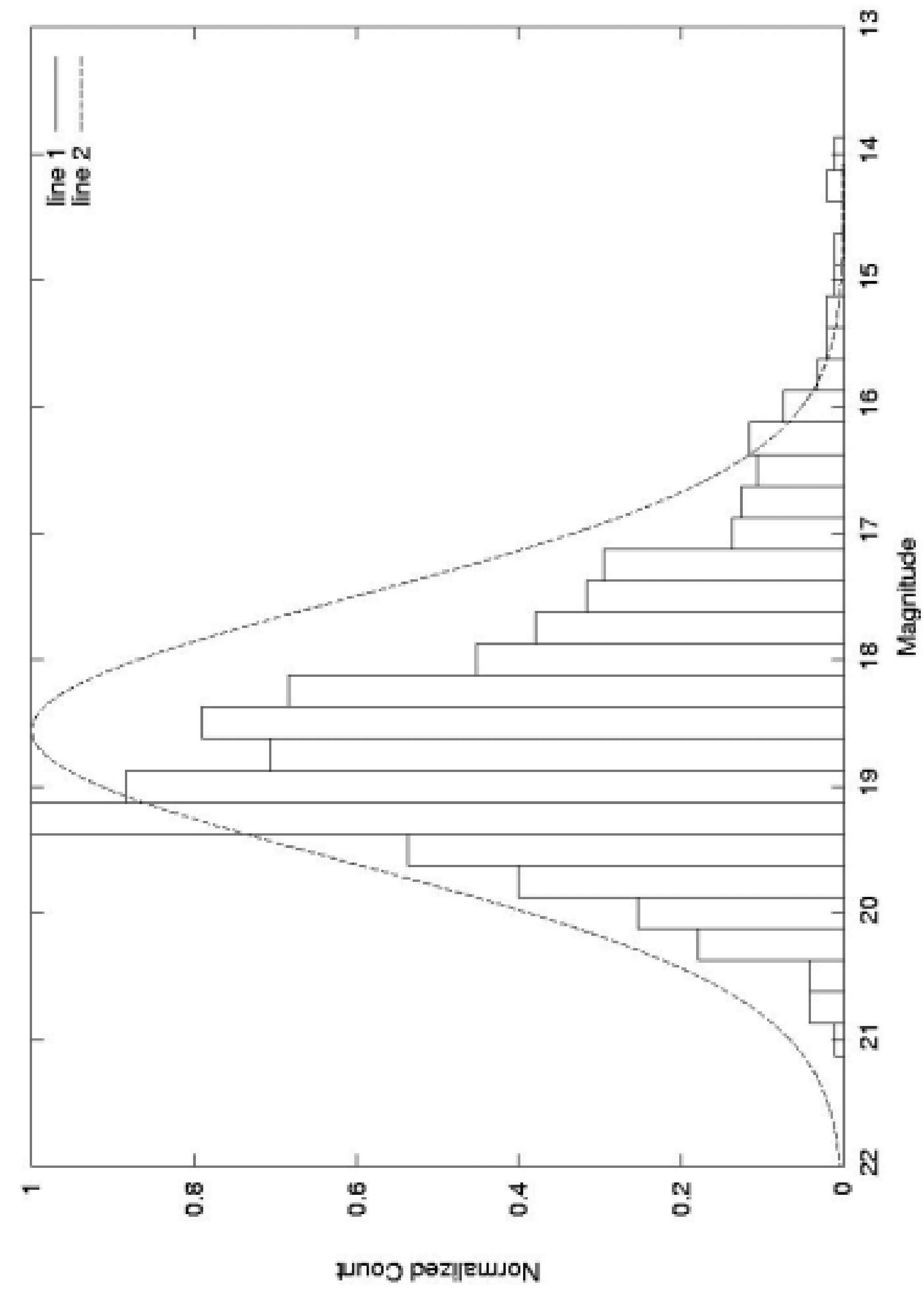

Figure 4: Histogram of all optical data with Gaussian fit

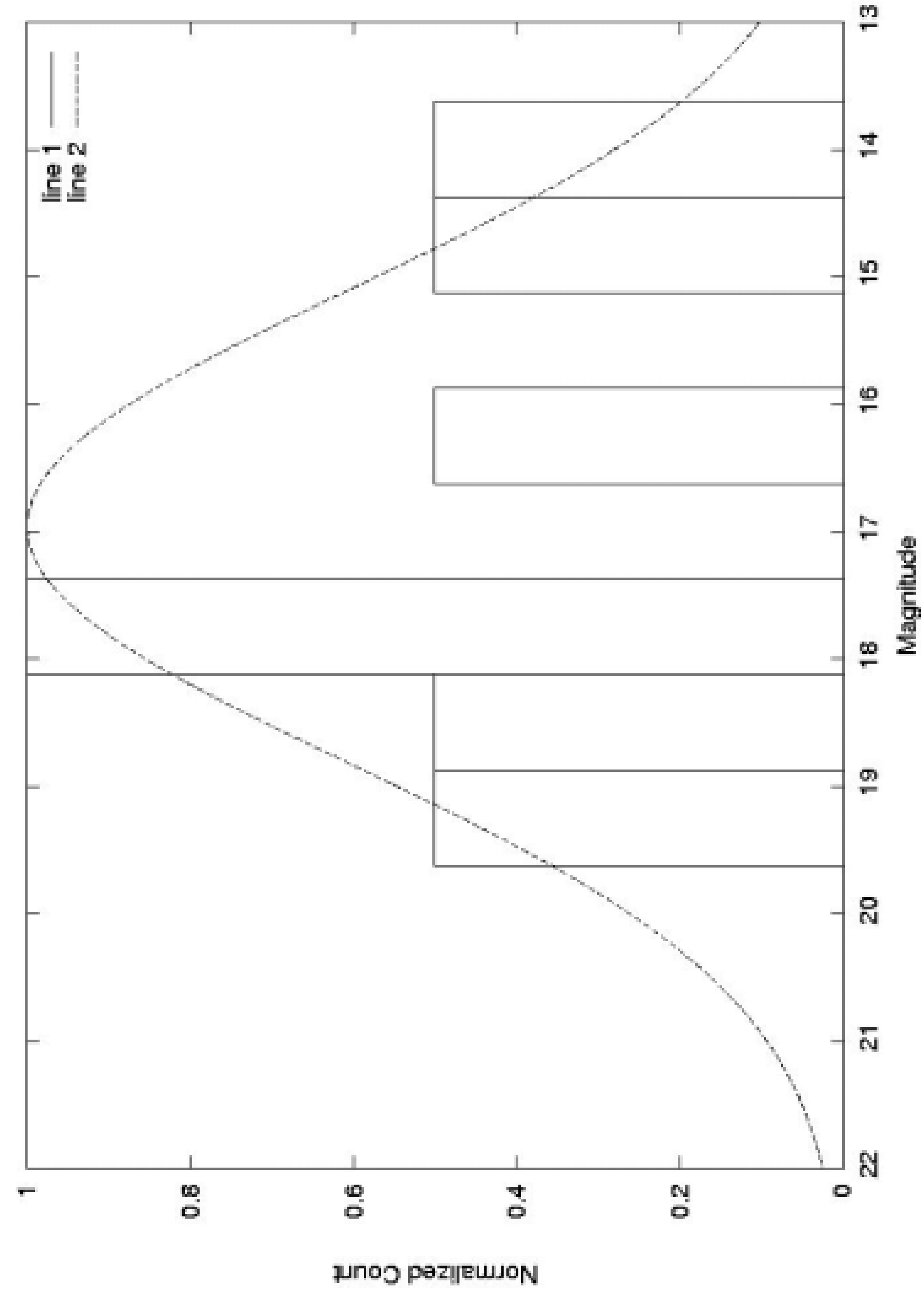

Figure 5: Histogram of X-ray – globular cluster
matches with Gaussian fit

Results and Conclusions:

Based on the histogram plots, the hypothesis of the project was determined to be correct. The globular clusters that were determined to coincide with the strong X-ray sources were brighter on the whole than the spectrum of clusters. One of the problems encountered with this project was specifically with the X-ray data that was taken from Chandra. The data region that was used did not seem to show the strong point sources in detail. Essentially, the data seemed somewhat messy and not well defined in areas. The detection algorithm used to find these strong points may not have been successful with this messy region. It may have purely been designed for a well-defined region in which case the sources could have been somewhat skewed. To compensate for this unknown, the X-ray image was analyzed by hand so as to see where the strong sources were coming from and this leaves room open for human error in the process.

The expected result in the project could be accounted for by relating the luminosity of the clusters with their mass. The scope of this project can be applied to studying different galaxies to see if the results are similar. Different types of galaxies besides mergers, for example pure spirals or ellipticals, can also be studied more to see how the results vary.

References:

Ashman, K. M., & Zepf, S. E. 1998, Globular Cluster Systems (Cambridge: Cambridge University Press)

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