Investigation of a Possible Uncatalogued Seyfert 2 in the FOV of SNR 3c 397 Using Archival Data

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Abstract

The point of this is to investigate an interesting X-ray point source in other wavelengths to further prove that is it indeed a Seyfert II type AGN. In 2005, Safi-Harb and her team identified a point source during a 3c 397 project to be a possible Seyfert II type galaxy. X-ray spectra seem to support that theory given that it is heavily absorbed, has a strong iron line at 6.4 keV, and suffers from high energy cut off. Seyfert II’s tend to have similar x-ray spectra, especially the Seyfert II’s that I have looked at in a separate paper by L. Hernandez-Garcia et al. In addition, this object is radio quiet, as in high profile papers involving radio images like Dyer Reynolds or Rudnick have not mentioned it. Checking the NRAO archive confirms that this object is radio quiet even in the more sensitive beam widths. Seyfert II’s can be radio quiet. Optical is promising as well, as Seyfert II’s tend to be luminous in the Infrared, which is true looking at images in the 2MASS archives. Furthermore, the University of Wyoming is going to try and take optical spectra of this object to further solidify this claim, as Seyfert II’s tend to have distinct optical spectra.

Introduction

A point source behind 3c 397 was briefly investigated in the X-ray by Dr. Safi-Harb and her colleagues in 2005. Dr. Safi-Harb concluded that it may be a possible Seyfert 2 due to its spectra in the X-ray exhibiting a strong iron line around 6.4 keV and heavily absorbed spectra. I used Chandra to take X-ray spectra of the point source and piggybacked off Dr. Safi-Harb’s models for the point source. I have also tried to document this source in other wavelengths like, infrared, hard X-ray, radio, and optical spectrums. Subsequently it shows up in the optical with a V mag of 13.5 and shows bright in the infrared with magnitudes ~6.5-9.5. The point source fails to show up in the radio even with higher resolution and lower flux densities. XMM newton did not have the resolution to distinguish the point source between the SNR 3c 397. The original purpose of this project was to use CIAO to investigate the SNR 3c 397 instead of focusing solely on the point source. However, when I read that Dr. Safi-Harb and her colleagues would follow up on the point source and haven’t done yet. I’ve decided to pick up where they left off and try getting a definitive answer.

It is better to explain what a Seyfert galaxy is. A Seyfert galaxy is a class of AGN (active galactic nuclei) with starlike qualities, as their cores are very luminous and often obscure the spiral arms of their outer edges. Seyferts are far more activity than more normal types of galaxies and produce substantial amounts of radiation from their engine (supermassive blackhole). They are one of the more intensely studied objects in modern astronomy and so far, account for 10% of all types of galaxies. It is also worth noting that there are two distinct classes of Seyfert’s, namely type I and type II which may have in-between types depending on how they are oriented in space. The defining feature between both major types depends on. how wide the mission peak is for the h beta line in the optical spectrum.

As for resources used this was primarily done with archival data, pictures, and previous papers on SNR 3c 397. Chandra was used to complete the X-ray data analysis and create spectra for this object. XMM Newton was also used through CIAO to make region files for the object, but I could not follow through due to SNR 3c 397 overshadowing the object in those images. Data bases like 2MASS and NRAO had images that were also used to help and classify the object. Some of my own data also came from Skynet using the Prompt 5 telescope of the Cerro Tololo Observatory.

Methods and Materials

Originally, this project was just going to involve X-ray astronomy, this is where most of my work has occurred working with this possible Seyfert galaxy. I extracted a region file of just the point source. The background was very quiet, so I decided to exclude a background file. As I extracted the spectra, I noticed that the spectra were heavily absorbed, had a strong iron line ~6.4 keV and may have a calcium emission line ~3.7 keV. As well as having distinct emission lines and being heavily absorbed I noticed that around ~8 keV the spectra suffer from high energy cut off. These features seem to be like other spectra taken from other Seyfert 2 galaxies, which tend to have high energy cutoff, heavily absorbed spectra, and a distinct iron line around ~6.4 keV. I made a color image of SNR 3c 397 using the dmextract feature in Unix in order to make a DS9 RGB image.

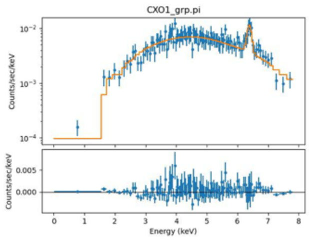

Fig. 1 Folded model of the point source southeast of SNR 3c 397. Residuals were plotted and were limited to 8 keV as there was not much data present beyond that range.

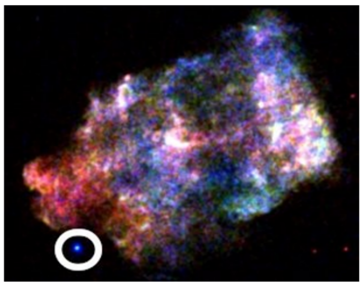

Fig. 2 X-ray color image of SNR 3c 397. Red is in the 0.5:1.5 keV range**,** green is in the 1.5:2.5 keV range, and blue is in the 2.5:8 keV range. The point source is circled and appears blue due to it being a hard X-ray source.

This is spectra I took using Chandra, mirroring Safi-Harbs work on the source, a 1d power law plus a 1d gaussian seems to produce an adequate fit to the spectra. This model would be described as xsphabs * (powerlaw1d + gauss1d). My parameters were also in the ballpark of Safi-Harbs.

Parameter	Value
$N^H \approx$	$4.76\times10^{22} cm^{-2}$
$\Gamma \approx$	-0.151
$Norm^a \approx$	6.47×10^{-5}
$E_0 \approx$	$6.39\ keV$
$EW^b(eV) \approx$	395
$Norm^c \approx$	1.85×10^{-5}
$\chi_\nu^2 \approx$	0.508
$\upsilon \approx$	73

Table. 1 Point source parameter table. Some values are similar to Safi-Harbs, though my Norm parameters are little higher.

As in a paper by L. Hernandez-Garcia et al, there seems to be correlation between their spectra and the spectra that I took of the point source outside of 3c 397. Their primary investigation was to study the variation in spectra of several Seyfert 2's as well as near Seyfert 2 objects. Their spectra are not only variable over time, but are also heavily absorbed, contain strong iron lines at ~6.4 keV, and tend to have high energy cut off. However, L. Hernandez-Garcia's example Seyferts had column densities that seemed to be lower than the point source (on the order of 10^{22}).

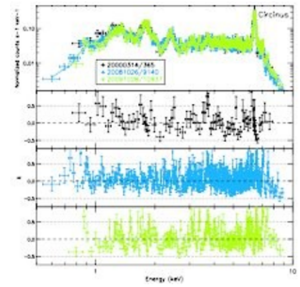

Fig. 3 Their Chandra X-ray spectra of the Circinus galaxy. This Seyfert 2 seems to be most similar the point source but has better defined emission lines.

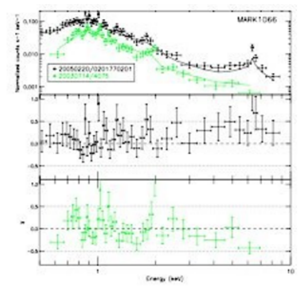

Fig. 4 Their Chandra X-ray spectra of Markian 1066, another Seyfert 2 galaxy. In addition, it seems that Seyfert 2 X-ray spectra can differ drastically because they tend to be variable.

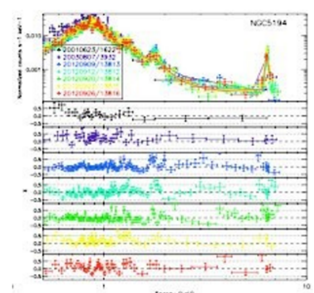

Fig. 5 Their Chandra X-ray spectra of NGC5194. Likewise, it can be variable. Once again an iron line is present, has heavily absorbed, and has high energy cut off.

In addition to accessing Chandra data, I had set out to gather XMM Newton fits files and make region files from them to start my own investigation in the harder X-rays (past 14 keV. Though when I opened up several fits' files in DS9 I could not distinguish between the point source and the SNR 3c 397 due to its proximity to the southeast of it. Therefore, I could not use Chandra to plot spectra and models of the point source in the harder X-rays due to lack of distinction between the point source and the bright SNR 3c 397. In these pictures there was not enough picture quality to discern the object from the X-ray bright SNR. It is also worth noting that this object may not really have data in the higher X-ray ranges due to the spectra suffering from high energy cutoff, which seems to be a symptom of Seyfert 2's, particularly in the X-ray spectrum.

This object does not appear to be associated with the supernova remnant 3c 397. There are a couple reasons for that, namely that the spectra is unlike any object to be associated with SNR 3c 397, they seem to be distinct from one another. More importantly, the X-ray spectra does not match that of any magnetars, pulsars, or other cataclysmic variables (Fig. 1). Spectra extracted from this point source tend to support that of a non-stellar source, such as a Seyfert galaxy. It is worth noting that the column density for this object is also not correlated with column densities associated with SNR 3c 397, which tends to have a column density $\sim 3.2 \times 10^{22} cm^{-2}$ (Safi-Harb 2005). This object has a column density ~$4.76 \times 10^{22} cm^{-2}$(Table 1), depending on the models, which is higher than that of SNR 3c 397. Safi-Harb also dismissed this object being associated with SNR 3c 397 because of its distance, which is around ~40mpc. In addition, an object of that distance is not going to have a similar velocity to SNR 3c 397 (~1300 km/s), as it is ~10kpc away and estimated to be ~5300 years old x`by Safi-Harb and her team.

I started my radio investigation by using the NRAO archive to access pictures of 3c 397 in various beam widths and resolution. However, even in the VLA band and at ~200-400 mJy flux densities. I could not find the point source. I was told by Dr. Bloom, a professor at Sydney that specializes in AGN, that it is possible for a Seyfert galaxy to be quiet in the radio. Infact, there are many Seyferts that tend to be radio quiet, so this is not an unusual conclusion for the radio investigation. Likewise, papers involving radio imaging of 3c 397 have not mentioned anything about the point source. It is not mentioned in the Dyer-Reynolds paper nor is it mentioned in the Anderson-Rudnick paper. It would have been favorable if it was at least somewhat visible in the radio and had clearly visible radio jets, but that would still be hard to see due to its proximity to the SNR 3c 397, which is a radio bright SNR. Moreover, this doesn't concretely conclude that this is a Seyfert galaxy. This information is relevant information to note, as this is not out of the ordinary for this kind of object.

One other useful tool was looking at archival data in the optical and wavelengths just before or beyond that (like infrared). As I have mentioned before, this object tends to be very bright in the infrared as it has a magnitude ~6.8-9.5 magnitude throughout the j-k band passes in the 2MASS catalog. It is worth noting that type II Seyferts tend to appear brighter when viewed through infrared wavelengths.

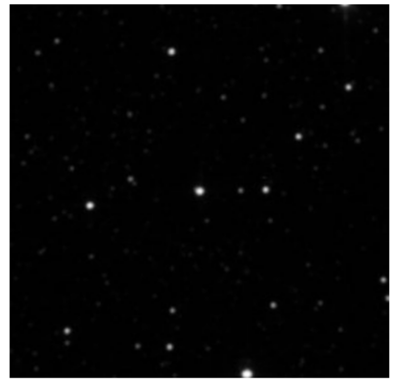

Fig. 6 K-Band 2MASS image of the point source at 19:07:41.3, +7:06:50 (it is the object in the very center of the image). It has a magnitude of 6.8 which is consistent with Seyfert 2's appearing brighter in the infrared as opposed to visible wavelengths just like normal optical spectrum.

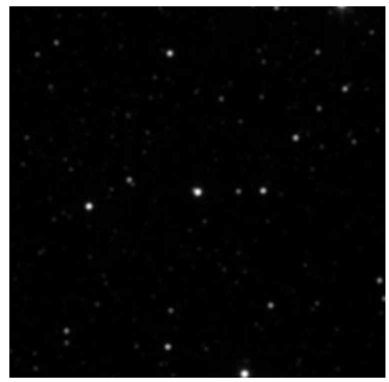

Fig. 7 H-Band 2MASS image of the point source. It has a magnitude of 7.7 in this bandpass. It is also interesting to note that objects in the background seem to get far dimmer while the point source still appears to remain bright, some even appear brighter while the point source appears dimmer.

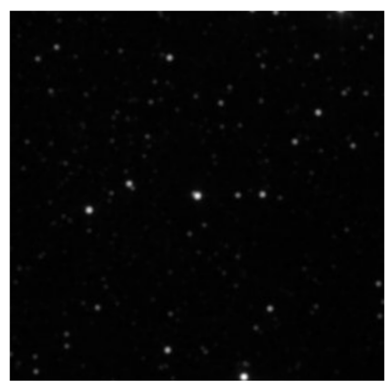

Fig. 8 J-Band 2MASS image with a magnitude of 9.8. Magnitude seems to drop off the most in this band.

In addition to using archival data, I have also used Skynet to get data of my own and pictures of this object. I used a clear filter because I was not concerned with color of the object, just what it looked like. The goal of this was to purposely boost signal to noise ratio in order to capture the arms of a spiral galaxy. 90 observations were made all with 10 second exposure lengths on the same filter on the Prompt 5 telescope. The images were then stacked and aligned. I used a rainbow color map to help visualize the point source. Although there is poor pixel quality with the Prompt 5 telescope, quality this object looks non-stellar, it is clearly slightly elongated and does not have double lobed quality when looking at the plotter tool graph. This is probably the object that is also visible in the X-ray and with it not being double lobed, may rule out the possibility of it being an X-ray binary. X-ray binaries also have an accretion disk and a companion star that is in the process of getting stripped of its materials.

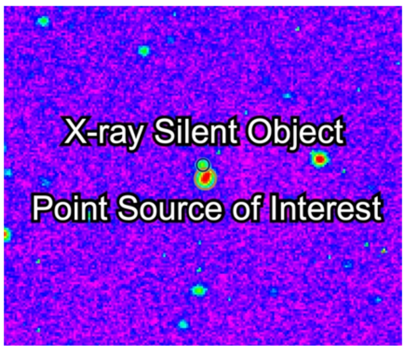

Fig. 9 Skynet image of the point source. It is ~6.5 arcseconds in length, ~4-5 arcseconds in width, and appears to be oriented at a slight angle. A ring also appears around what appears to be a brighter slightly elongated core. Another object is also visible in the optical and it is much smaller in size ~1-2 arcseconds with a magnitude of 11.5. Could be a star in front of the possible Seyfert 2. Optical spectra should be taken of it to be safe.

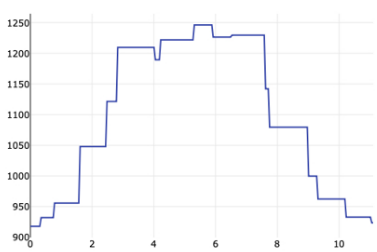

Fig. 10 Plotter tool graph. Pixels are displayed in the x-axis. Density is plotted in the Y-axis. Much denser in the center than the outer ring. Graph also displays a single curve, so it is probably a single object.

What would really crack this case is getting optical spectrum, as Seyfert IIs have distinct optical spectrum. Currently I am waiting for the Wyoming University telescope to be active again. A friend of Dr. Bloom, Michael Brotherton, who specializes in AGNs is going to try and get an optical spectrum of this object since they have the capabilities. Though I am not sure how soon I will get this information back, this may be after this paper is already written as per requirements. The most important part I am looking for in this optical spectrum is the H beta emission line that is present with Seyferts. A narrower line means that it is a Seyfert II, if it is broad then it is a Seyfert I. That tends to be the discernable feature between the two types, although there are in-betweens like type 1.5s and 1.8s.

Discussion

This point source is not likely to be associated with super nova remnant 3c 397 nor is it associated with any cataclysmic variables tied to super nova remnant 3c 397. This point source also has a lot of similarities to a Seyfert II type galaxy thus far. It appears brighter in the infrared, clearly has a non-stellar shape in the visible spectrum, has typical x-ray spectra of a Seyfert II galaxy, and is a radio quiet object. I am not going to classify this object as a Seyfert II until I get optical spectrum from Dr. Blooms friends at University of Wyoming. If optical spectrum is consistent with a Seyfert II galaxy then I will try and update my findings and try and formally classify it as such. Moreover, I should visit the X-ray models again and get more quantitative data as the redshift for this object and temperature for this object both remain unresolved. The object next to it that only appears in the optical and infrared spectrum may just be a star in front of the point source, but I can't come to that conclusion unless I get more data on it. I will try and request spectral analysis from that object as well just to be safe

Acknowledgements

I wanted to personally thank Dr. Safi-Harb for putting in the effort and doing a fantastic job on this point source even though their investigation was focused on 3c 397. I want to thank Dr. Bloom and his friend Danny (as well as Micheal Brotherton) at Wyoming State University for the advice on AGN's and the pending optical spectrum that will be taken, once their telescope is in working order. I bid them good luck. I also want to thank my advisor Dr. Keohane for helping me learn the ropes of X-ray astronomy and the importance of digging up archival data. I would also like to thank my undergraduate colleague Matthew Toman for working hard on his X-ray analysis of Keplers SNR. Lastly, I would like to thank Dr. Wolyniak who leads the Hampden-Sydney summer research program.

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