MIM JOURNAL 2018 illuminate your work

Made in Millersville Journal | www.mimjournal.com

X-Ray Properties of the Galactic Black Hole H 1743-322

Stephen Beegle

Abstract

H 1743-322 is a well-studied X-ray black hole binary first discovered in 1977. All previous analysis of X-ray spectra has determined that the system lies 8.5 kpc from Earth, near the galactic center, and is a standard transient system. This means that it goes through a periodic increase in X-ray luminosity, before returning to a long period quiescent state. The goal of this paper to understand the nature of black holes and their accretion disks through previous theoretical work, then use data from Chandra X-ray Observatory and the Swift X-ray Telescope component to analyze the spectrum of H 1743-322 while it is moving into an outburst state. After completing data reduction and spectral analysis of Chandra observations, it will be shown by the luminosity values that H 1743-322 did enter an outburst state in 2015. Then, using Swift observations, the findings will be verified.

Black Holes

Black holes are an important component in understanding the evolution of stars and galaxies. They provide important insight into accretion disk physics, relativistic radio jets, and are a natural laboratory for testing relativity and quantum mechanics. They were first conceived by John Mitchell in 1783 (Carroll & Ostlie, 2007). Mitchell reasoned, using Newton's conclusion that light was a stream of particles, that gravity of a large enough star could trap light. Using an escape velocity equal to the speed of light, he came to the conclusion that a star 500 times larger than the Sun, but just as dense, would have enough gravitational influence to trap light emitted at the surface of the star.

Fast forward almost 200 years to 1939, where J. Robert Oppenheimer & G.M. Volkoff explored this idea more using Einstein's Theory of General Relativity. Building off the predictions made by Baade & Zwicky (1934); that after the fusion in a massive star ceases, it will undergo gravitational core collapse, then explode as a supernova, leaving behind a stellar remnant; Oppenheimer & Volkoff (1939) found that a stellar remnant of 2.3-2.9Mo (Mo = 1.99x1030 kg) is the limit that one type of remnant, neutron stars, could remain stable. This was the first calculation and modeling to be done for neutron stars (NS) using Einstein's Theory of General Relativity, and the quantum mechanical description of a bulk number of fermions, or a Fermi gas (Carroll & Ostlie, 2007; Oppenheimer & Volkoff, 1939). The limit of ~2.9 Mo came to be known as the Tolman-Oppenheimer-Volkoff limit (TOV).

Later the same year that Oppenheimer & Volkoff (1939) determined the limit, Oppenheimer & Hartland Snyder asked what would happen if a remnant exceeded the TOV. The result was the definition of an object unable to maintain equilibrium, causing it to collapse indefinitely due to gravity. One of the consequences of this collapse is that any light emitted experiences an infinite gravitational red-shift (Oppenheimer & Snyder, 1939). Time is moving so slowly near the objects surface, that light becomes frozen in time due to the gravitational field. This highlights the obvious difficulty when it comes to studying these objects: black holes themselves appear invisible to observation inside a certain radius, the event horizon.

X-Ray Binary Systems

Anything that we know about black holes comes from observing how they interact with the space around them. This is because the black holes themselves emit no radiation. X-ray binaries offer one way of studying black holes, and the system H 1743-322 is no exception.

An X-ray binary is a system where, at first, two stars orbit one another as a close binary system. If one of the stars has a sufficient mass, >~25 Mo, it will eventually collapse and explode as a supernova, leaving behind a remnant that exceeds the TOV limit, becoming a black hole (Carroll & Ostlie, 2007). If the second star survives the explosion, it will remain in orbit with the newly formed black hole.

As the second star, called the donor star, evolves and expands, it begins to accrete matter onto the black hole. This mass transfer creates a disk of material around the black hole, known as an accretion disk. In this disk, friction from angular momentum and particle collisions heat the disk of material up. As this disk grows and heats, a critical point is reached in the mass transfer, which results in the disk dramatically increasing in luminosity. Specifically, in the X-ray part of the spectrum.

X-Ray State Evolution

Study of multiple black hole and neutron star binaries in X-rays has provided a frame work for what are called X-ray states. There are currently three understood states that most X-ray binaries go through over their lifetime. The mechanism for the state changes is the accretion disk around the compact object.

In the outburst state, the accretion disk has reached its critical mass limit, and the X-ray luminosity increases dramatically. Observations show that the hot disk dominates the spectrum, and is so bright that it drowns out the donor star. Another state is the quiescent state, where X-ray luminosities are low, and the disk is cooler and less dominant, allowing for the study of the donor star. In this state, powerful radio jets are observed coming from the magnetic poles of the compact object, as matter in the disk begins to fall onto the object. Finally, there is the steep power-law state, which is a period when there is both a dominate disk and powerful radio jets observed. The steep power-law state is considered a transition state, where the system is transitioning between outburst and quiescence.

X-ray Binary H 1743-322

The system H 1743-322 is a black hole X-ray binary (BHXB), located at J2000 coordinates RA 17h 46m 15.61s and DEC -32° 14" 00.6'. Observations thus far have shown that this is a typical BHB, which shows a large increase in X-ray luminosity for a short period of time, and then decays into a low luminosity state that can last for months at a time. First discovered in 1977, H 1743-322 (H1743) entered an outburst state that the *Ariel V* and High Energy Astronomical Observatory 1 were able to observe (Kaluzienski & Holt, 1977). Other outbursts have occurred through the years, where one such outburst event occurred in 2003. During that observation period, the distance, *d* = 8.5+/-0.8 kpc from Earth, and an orbital inclination, *i* = 75°+/-3° were verified (Steiner et al., 2011). This was the first occasion that *Chandra* X-ray Observatory was used to observe the system.

Another luminosity increase occurred in 2008, where the *Chandra* X-ray Observatory was pointed to the location of H1743 again. Plotkin et al. (2013) analyzed the observations made between 2 March and 24 March 2008 following what they deemed a failed state transition from quiescence to outburst. It was determined that X-ray luminosity started at 2.52x1033 erg s-1 (1 erg s-1 = 10-7 W), and by the end of observational period in late March, X-ray luminosity had decayed to 1.01x1032 erg s-1. This shows that H1743 was moving back into a hard X-ray state, or quiescence, after failing to reach full outburst. It is also important to note that these luminosities fall within the range set by Remillard & McClintok (2006) of 1030.5-33.5 erg s-1 for BHXBs in a quiescent state.

Data

Chandra and *Swift* observations of the 2015 outburst were downloaded from the High Energy Astrophysics Science Archive Research Center, HEARSARC. Observation IDs 16738, 17679, 17680, 16739, and 16741 were downloaded for *Chandra*. Then 00031441029, 00031441031, 00031441032, 00080797003, and 00080797004 were downloaded for *Swift-XRT*. The observations took place between June and August of 2015, with a total exposure time of 85,940s for *Chandra*, and 11,181s for *Swift-XRT*.

The data reduction process for *Chandra* was done using the latest version of Chandra Interactive Analysis of Observations, *CIAO* 4.9. The *chandra_repro* script was applied to the level 1 events files downloaded from *HEARSARC*, as recommended in the *CIAO* data analysis guides. This produced a new level 2 event file, from which the RMF, ARF, and pha2 files were extracted. From those files, the first-order grating spectra from the HEG and MEG arms were extracted, then loaded into *Sherpa*, a modelling and fitting software package. Absorption and power-law models were then applied, with an interstellar absorption density of *hcol* = 2.60 x 1022 cm-2. The models provide a suitable fit.

Swift-XRT data reduction was done using *the HEASOFT* software bundle, and applying the *xrtpipeline* data reduction script to extract the appropriate files. At the due date for this article, *Swift-XRT* data reduction was not complete, and will be left for a later report. When the spectrum is extracted, spectral analysis will be done using XSPEC, an X-ray spectrum modelling and fitting program, where absorption and power-law models will be also be applied.

Results and Discussion

The *Chandra* observations done at high resolution show a steady increase in luminosity over time. When compared to one another chronologically, each observation shows that the accretion disk around the black hole is emitting more energy as it progresses into its outburst state. This is consistent with the findings of Neilsen et al. (2015) during the original observational period.

Future work will include the verification from *Swift* observations, followed up with a comparison of the elemental lines in the extracted spectra with those found in labs on Earth. This is an effort to verify a feature of black hole binaries; a broadened florescent line of iron in the area of 6.4 keV.

References

Baade, W. & Zwicky, F. 1934. *Phys. Rev.* 46, 76

Barret, D., McClintock, J. E., & Grindlay, J. E. 1996. *ApJ*, 473(2), 963-973. *Chandra* Data Analysis Threads. Grating Spectroscopy, HETG/ACIS-S Grating Spectra

http://cxc.harvard.edu/ciao/threads/spectra_hetgacis/ Carroll, B. W., & Ostlie, D. A. (2007). An Introduction to Modern Astrophysics (2nd ed.).

San Francisco, CA: Pearson Addison Wesley. Kaluzienski, L. J., and Holt, S. S. 1977. IUAC 3099:3 McClintock, J. E., Remillard, R. A., Rupen, M. P., Torres, M. A., Steeghs, D., Levine, A. M.,

& Orosz, J. A. 2009. *ApJ*, 698(2), 1398-1421. Neilsen, J., Motta, S., Coriat, M., Fender, R., Ponti, G., Corbel, S., Sanna, A. (2015). ATel #7652,

The Astronomer's Telegram Oppenheimer, J. R., & Volkoff, G. M. 1939. *Phys. Rev.*, 55(4), 374-381. Plotkin, R. M., Gallo, E., & Jonker, P. G. 2013. *ApJ*, 773(1), 59. Remillard, R. A., & McClintock, J. E. 2006. *Annu. Rev. Astronomy and Astrophysics*, 44, 49-92. Steiner, J. F., McClintock, J. E., & Reid, M. J. 2011. *ApJ, 745*(1). Tananbaum, H., Gursky, H., Kellogg, E., Giacconi, R., & Jones, C. 1972. *ApJ*, 177.

Recommended Citation
Beegle, S. (2018). X-ray properties of the galactic black hold h 1743-322. *Made in Millersville Journal*, 2018. Retrieved from https://www.mimjournal.com.