Structural Analysis of Potential Dual Quasar Pairs Using Galactic Modeling Software

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Abstract

The study of dual quasar systems has recently been of heightened interest. Quasars are actively accreting supermassive black holes residing in the center of massive galaxies and they play an important role in galactic evolution theory, and dual quasar systems have implications of altering their host galaxy properties. In this project, Hubble Space Telescope images of several selected candidate dual quasar systems will be thoroughly analyzed using GALFIT, a morphological modeling program. Point Source Functions will be built for each source to account for optical aberrations in the various cameras aboard the Hubble Space Telescopes. Through GALFIT analysis, candidates will either be accepted as true dual quasars, or rejected as gravitational lenses, minor galaxy mergers, or other systems falsely resembling dual quasars. In addition, I will explore whether these dual quasars candidates appear to reside in a single shared host galaxy, or whether each source still retains its own host. Wither finding will set constraints on models of galaxy mergers that trigger quasar activity.

I. INTRODUCTION

Interest in the study of quasars has been consistently growing for decades. Since their discovery in the 1950s through radio astronomy, they have quickly become some of the most studied astronomical objects. Their physical characteristics give them unique properties that allow us to peer deeper into space. Through quasars, we can learn about about the large scale structure of the universe, the nature of dark matter, and the morphological evolution of galaxies. They are some of the most luminous and oldest known interstellar objects. The wealth of knowledge that quasars hold is vast, and we have only begun to skim its surface.

Quasars are comprised of an accretion disk surrounding a supermassive black hole at the center of a galaxy. The mass of these black holes can range from millions to billions of times the mass of the sun. Gas, dust, and other local matter accrete around the black hole, bound by the black hole's immense gravitational force. While only a fraction of the accreted matter falls directly into the black hole, the matter has an induced angular momentum, causing it to form a rotating disk. These accretion disks are generally — to — parsecs across. The gravitational force from the black hole accelerates the accreting matter to relativistic speeds. The friction between the accelerated matter produces huge amounts of energy, leading to extreme luminosities, ranging from 10^{45} – 10^{47} ergs s^{-1}. Quasars are excellent at converting matter into energy as the process of accretion of matter onto the black hole is energy efficient – the gravitational energy release by accretion has an efficiency of 32%.[5] For reference, the nuclear fusion of hydrogen in stars has an energy release efficiency of only 0.7%. The immense luminosities from the high energy release efficiency of accreting matter is one of the unique characteristics of quasars that make their study so worthwhile. Extremely distant sources are detectable due to their high absolute magnitudes.

While all quasars have accretion disks, there are a number of morphological factors that vary between individual quasars. Some quasars have a dust torus radially beyond the accretion disk. These tori can significantly obscure the light emitted from accretion disks – especially when the quasar has an inclination angle so that the plane of the disk and torus is parallel to our line-of-sight from Earth. Some quasars also have radio synchrotron radiation jets and optical jets – narrow beams of particles travelling away from the central black hole at relativistic speeds. The matter accelerated through these jets can travel up to a megaparsec, or roughly 3×10^{20} km. While the precise cause of jets is disputed, it is generally agreed that these jets provide a feedback mechanism for quasars. Also present in some quasar systems are large radio lobes ballooning out from the central black hole.

While certain components of quasars vary, their spectra are generally consistent and distinct. Inherent in quasar spectra are a number of characteristic absorption and emission lines corresponding to different regions of the quasar. There are recognizably broadened spectral lines and sharp, resolved spectral lines produced by broad line and narrow line regions respectively. Additionally, some quasars, known as radio loud quasars, have strong radio emission, sourcing from radio jets and lobes. There is also significant x-ray emission from the accretion disk. Quasars are tend to be old and distant objects, resulting in large redshifts of spectral lines. As quasars are old, luminous, spectrally recognizable, and regularly distributed throughout the universe, they are ideal objects for determining distance and redshifts of regions of space. Like lighthouses scattered all around us, they provide a standard of measure and scale of the biggest dimensions. Where the light from most objects of the early universe would be too dim to detect, the extreme luminosity of quasars enables us to see traces of the distant past.

The facet of interest in quasars for this study is the morphological evolution of galaxies. Every quasar is hosted by a galaxy. These galaxies are usually giant ellipticals, but there have been examples of other morphological types.[2] These galaxies tend to be large so that they can continually feed the accretion disk of the quasar. A small galaxy would not have enough disposable matter to fuel a live quasar. Additionally, as quasars tend to be at high redshifts, their host galaxies are generally older, and elliptical galaxies are thought to be one of the last stages of galactic development. There is also speculation into the role of early-stage galactic mergers in the origin of massive elliptical galaxies.[6]. The confirmation of this theory would fill an important gap in our understanding of galaxy evolution. A tangential theory draws connections between Active Galactic Nuclei (AGN) and galaxy mergers. AGN are a class of galaxies that have an ultra-luminous nucleus due to matter accreting onto a supermassive black hole. Quasars are the most luminous subcategory of AGNs. It has been shown that AGN can turn "on" or "off" much like a flashlight, transitioning between a dormant state and an actively accreting state.[1] While it is not fully understood what causes these changes, theories suggest that galaxy mergers can introduce new matter and trigger star formation that reignite dormant AGN.[3]

Dual quasar systems are an excellent tool in uncovering the mechanisms behind these theories. Dual quasars (DQSOs) are two gravitationally bound quasars in close proximity. In order to be deemed a DQSO, the two quasars must have a separation of 10 pc to 10 kpc – systems with a separation of < 10 pc are considered binary quasars.[4] These two quasars orbit around each other, and depending on their separation and host galaxy diameters, will share accreting matter. While research on DQSOs is limited, it is speculated that they form with the merger of two quasar housing host galaxies. If this theory were to be true, DQSO systems would be an important stage in galactic development, and would give critical insight into the effect of galaxy mergers on AGN activity. Observing galaxy mergers between non active galactic nuclei can be difficult, but with the increased luminosity of quasars we can pinpoint galaxy mergers at much higher redshifts. This effectively deepens our view, increasing the number of visible subjects. Additionally, with the wealth of knowledge that exists within quasar spectra, we can make more detailed speculations based on emission and absorption lines into the timelines and physical conditions of specific mergers. This information would be invaluable in clarifying galactic merger and AGN activation theories.

This past summer I worked on a research project with Glikman, Ph.D. of Middlebury College and Lindsay Graham of Wellesley College searching for DQSO systems at high redshifts. There have been relatively few confirmed DQSO systems detected to date, and the theorized density of dual quasars in space suggested the existence of many undiscovered DQSO systems. We suspected that many DQSO systems had been overlooked, and had been incorrectly labeled as single quasars. We built an algorithm that analyzed archival Hubble Space Telescope data containing the coordinates of known quasars. This image data was inspected and we ultimately found 21 strong candidate dual quasar systems. Using available volume calculations we determined that approximately 1% of the space analyzed contained a DQSO system.[7] If these candidates were to be confirmed as DQSO systems, our theory would be supported, proving that many DQSO systems have simply been overlooked. Increasing the number of known DQSOs enhances our ability to conduct research into the mechanisms behind AGN activity and long-term galaxy evolution.

In this project, four (?) DQSO candidates were selected from the 21 candidates proposed in this summer's research. In order to accept or deny the DQSO nature of these candidates, point source functions were generated for each system, and used for mathematical luminosity modelling through GALFIT.

II. METHODS

discuss candidate selection process – promising candidates and single HST camera with a tested method for generating PSFs

what is TinyTim, and how it works

what is GALFIT, and how it works. chi-squared minimization and Levenberg-Marquardt algorithm

III. RESULTS

best models using GALFIT, table of iterations for each source.

f-test

IV. CONCLUSION

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[1] Comerford. (2017) .An Active Galactic Nucleus Caught in the Act of Turning Off and On

[2] Courbin. (2006). The Host Galaxies of the Brightest Quasars: Gas-Rich Galaxies, Mergers, and Young Stars (incomplete citation)

[3] De Rosa. (2016). Unveiling multiple AGN activity in galaxy mergers

[4] Frey. (2012). Two in one? A possible dual radio-emitting nucleus in the quasar SDSS J1425+3231

[5] Lambourne, Robert J. A. (2010). Relativity, Gravitation and Cosmology (Illustrated ed.). Cambridge University Press. p. 222.

[6] Naab. (2006). Properties of Early-Type, Dry Galaxy Mergers and the Origin of Massive Elliptical Galaxies

[7] Our summer research! Not sure how to cite this...