

Analysis of the Formation Mechanisms of Various AGNs

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Abstract. As a matter of fact, investigation of Active Galactic Nuclei (AGNs) is quite important in analysis of galaxy formation in cosmology and astrophysics. On this basis, in this paper, the intricate world of AGNs and their profound implications for the understanding of galaxy formation and universe evolution has been shown. AGNs, fueled by gas accretion produced by stars clashing with central supermassive black holes (SBH), stand as some of the most luminous objects in the night sky, emitting energy surpassing the ordinary galaxies. This paper underscores the vital role of AGNs in unraveling the cosmic models. The cosmological evolution of AGN luminosity functions offers a historical perspective on SBH formation, intimately tied to the universe's history. The paper conducts a comprehensive analysis of diverse AGN types, with particular emphasis on Type I AGNs such as Quasars, Type II AGNs, and Radio Galaxies. Underscoring profound connection between AGN activity, galaxy morphology, and star formation dynamics.

Keywords: AGNs; galaxy formation; active galaxy.

1. Introduction

The physics behind galaxy formation is one of the biggest challenges in modern cosmology. AGN's powering mechanism is accretion on to the central SBH [1-5]. Understanding AGN, which refers to active galaxy nuclei that are powered by gas accumulating by the central black hole in the middle of the galaxy, is a crucial factor in this process. Active galaxy is widely known as one of the brightest objects in the night sky, the SBH in the galaxy nuclei provides more energy and light than the normal fusion galaxies. AGNs are also commonly high red shifted, this proves that they are formed in the very early stage of the universe. As the universe expands over time, the Doppler effect causes the wavelength of the wave it emits to increase, resulting in the huge amount of redshift. By studying these celestial bodies, this study is able to catch a sight and try to understand the formation of the universe and how it works [6].

Studying AGNs is vital to learn the history of the universe and understand how the universe works. However, the history of AGN research has just been initially discovered in the early 20th century [7]. The current exploration of their complex nature, highlights their significance as cosmic phenomena, driven by factors such as SBH and accretion of gas, yet despite substantial progress, a comprehensive understanding remains a work in progress, with this summary providing a foundational overview of key developments in AGN research [8].

The cosmological evolution of the AGN's luminosity function can show the history of formation of the SBH due to its direct link of universe accretion history [1]. The first discovery of Quasars in 1963 by Maarten Schmidt brings a deeper understanding of the universe. An evolutionary role in the star formation is played by the energy feedback of AGNs [2]. AGNs are classified based on their optical, X-ray, radio, and infrared emissions. The classification of AGNs is primarily determined by their spectral features and the presence of certain characteristics [7]. There is increasing observational support for the idea that black holes, through AGN feedback, have played a significant role in shaping the baryonic matter in the Universe at low redshifts. This discovery has profound implications for the comprehension of the evolution of galaxies, groups, and clusters. It also has repercussions for the precision of cosmological studies that rely on galaxy observations [8]. AGN feedback emerges as a crucial element in understanding the intricate dynamics of the baryonic Universe.

This study will be explaining the formation of AGNs of different types. The different types of AGNs and how they are linked to galaxy formation will be analyzed. This study will mainly focus on type I AGNs (like Quasars, Seyfert Galaxies) type II AGNs and Radio Galaxies. In previous papers,

evidence is provided strongly that AGN activity in central galaxies is closely dependent on the morphology and star-forming activity of their hosts, which is based on both the galaxies' internal properties and their surrounding environments [3].

2. Different types of AGN galaxies

2.1. Type I

Galaxies such as Seyfert Galaxies that are less luminous have formed later than the more luminous ones like quasars. In high-stellar-mass central galaxies, the fraction of Seyfert galaxies increases with galaxy morphology. Suggesting a link between AGN feedback and galaxy morphology. In addition, low-mass galaxies have a lower fraction of Seyfert nuclei, regardless of morphology or environment. The Seyfert fraction varies systematically with the movements of star formation in their host galaxies. The peak depends on environmental richness and stellar mass. Following that, the proportion of Seyfert galaxies diminishes as these galaxies undergo a transition into the sequence. This suggests that AGN feedback plays an important role in the regulation and suppression of star formation [3]. Observationally, there is limited direct evidence that AGNs like Seyferts in the local universe are producing theoretical large-scale outflows. However, high-velocity winds have been observed in a small number of very powerful AGN with luminosities exceeding 10^{45} erg/s, both in ionized and molecular gas. These outflows have typical speeds of 400–1000 km/s, translating to outflow rates of 700–1000's solar masses per year, potentially capable of achieving the feedback effect needed. This study compares galaxies without AGN (left image) to those with AGN (Seyfert, right image) identified via the BPT diagram [3]. The findings indicate that the presence of an AGN has little impact on the host galaxy's morphology.

There are two proposed mechanisms for AGN "feedback." The first proposal, often called "quasar" mode feedback, is associated with both classical luminous quasars and less powerful AGNs that emit strongly in optical and X-ray wavelengths. In this mode, AGN activity is fueled by the efficient accretion of cold gas through the accretion disk, resulting in the powerful emission of waves across a broad electromagnetic spectrum from ultraviolet to X-ray. Around the central black hole and accretion disk, there is a dusty torus structure that obscures emissions at specific wavelengths when viewed from large polar angles (as proposed by Antonucci in 1993 and related studies [10]).

In the local universe which refers to the redshift range from 0.03 to 0.3, AGN in the 'quasar' mode become more radio-loud as a shallow function of the mass of their host galaxies, ranging from approximately $\sim 0.002\%$ at $10^{10.7}$ solar masses to 0.1% at $10^{11.7}$ solar masses, according to research

[3]). Feedback in this context happens mainly due to high-velocity winds accelerated by the AGN. These winds can result from thermal heating of gas or radiation pressure on dust and effectively remove gas from the host galaxy. Once the available fuel supply is depleted, star formation halts. One possible assumption is that the energy supplied to these winds, as part of the "feedback" process, is proportionate to the mass and luminosity of the central black hole. Hence, feedback becomes effective above a certain mass threshold where the momentum of the outflow overcomes the black hole's gravitational potential, ceasing accretion. Quasars are believed to be triggered by galaxy mergers that lead to the rapid inflow of gas. This gas enables both the appearance of the intense star formation and the rapid black hole accretion [3].

2.2. Type II

Radio galaxies have been differentiated by Fanaroff and Riley in 1974. Additionally, the classification into type I and type II is determined by the ratio between the distance of the highest surface brightness areas on opposite sides of the central galaxy and the measurement of the source's extent taken from the lowest surface brightness. In literatures, they are frequently called FR I (ratio <0.5) and FR II (ratio >0.5) [4]. They are also separated by radio luminosity verses optical host galaxy luminosity plane by Ludlow and Owen in 1996 (seen from Fig. 1) [4]. Additional morphological

categories frequently mentioned in the literature point to the curved or distorted shapes of radio galaxies (e.g., wide-angle tail, narrow-angle tail, X-shaped radio galaxies; refer to Fig. 1).

3. Limitations & Future outlooks:

The formation of different types of Active Galactic Nuclei is a very complex and ongoing area of research in astrophysics. The limitations could be as following:

Limited Observational Data. The Lack of direct observational data on the early stages of AGN formation. AGNs are often detected when they are already highly active, causing the challenge of understanding their initial conditions and triggers.

Theoretical Challenges. The theoretical models of AGN formation are a set of complex physical processes, including accretion, black hole growth, and feedback mechanisms. These models are computationally intensive and may not capture all the relevant physics accurately.

Variability. AGNs can be highly variable in their activity levels, which can make it difficult to study their formation and evolution consistently over long time scales.

Sample Bias. Many observations of AGNs come from biased samples, which may not be representative of the entire AGN population. This can lead to potential biases in the understanding of AGN formation and evolution.

Redshift Dependence. Understanding the formation of high-redshift AGNs, such as quasars, can be particularly challenging due to the limitations of observing distant objects and the effects of cosmic evolution.

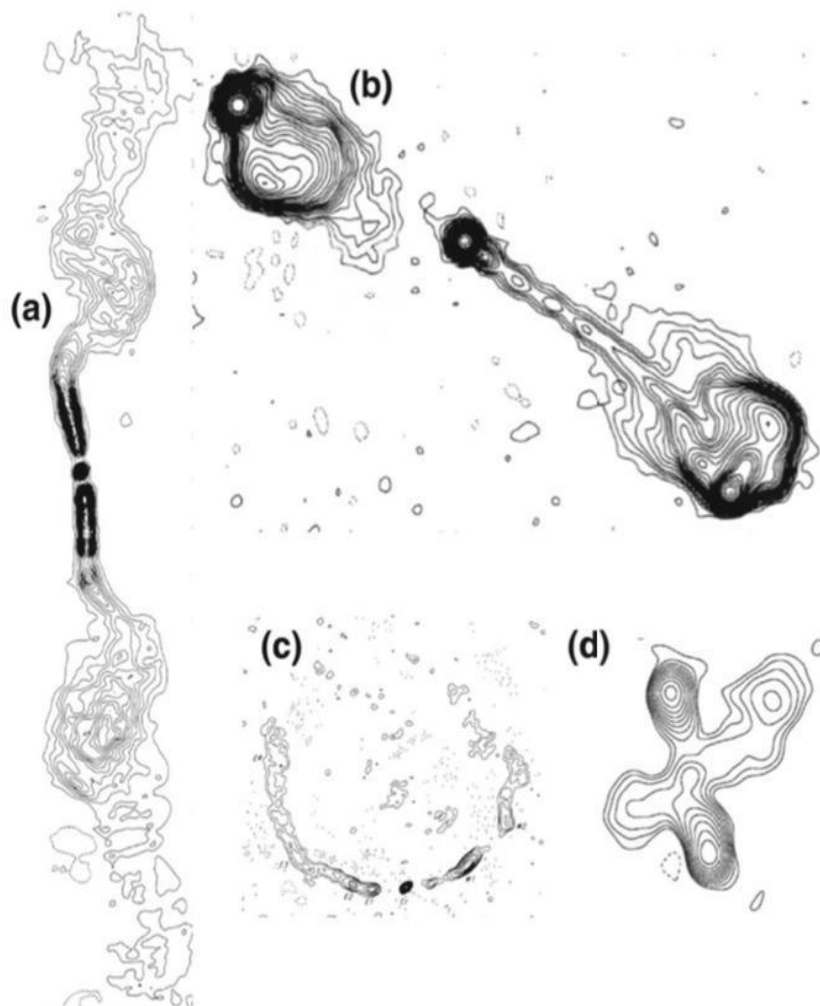


Fig. 1 Examples of FR I, FR II, wide-angle tail, and X-shaped RGs.

Future prospects are listed as follows:

Advanced Observations. Future space telescopes and ground-based observatories, such as the James Webb Space Telescope (JWST), might provide more detailed and extensive data on AGNs at various redshifts. This will help refine the understanding of their formation.

Simulations. High-resolution computer simulations of galaxy formation and AGN feedback will continue to improve, allowing researchers to explore AGN formation in more detail and make predictions that can be tested with observations.

Multi-wavelength Studies. Combining data from various wavelengths, including radio, infrared, X-ray, and optical, will provide a more comprehensive view of AGNs and their formation processes.

Time-Domain Astronomy. Studying AGNs over long time scales through time-domain surveys will help capture their variability and understand the triggers for their activity.

Cosmic Dawn and Reionization. Future studies may focus on the formation of AGNs during the cosmic dawn and the epoch of reionization, providing insights into the early universe and the role of AGNs in shaping it.

Large Surveys. Ongoing and upcoming large-scale sky surveys, such as the Legacy Survey of Space and Time (LSST), will identify a large number of AGNs, allowing for statistical studies of their formation and evolution.

In summary, the study of AGN formation is a dynamic field with ongoing advancements in both observations and theoretical models. Overcoming current limitations and addressing future challenges will continue to enhance the understanding of these fascinating cosmic phenomena.

4. Conclusion

To sum up, this study introduces the significance of AGN and their role in understanding galaxy formation and evolution. AGN, powered by gas accretion onto central SBH, are discussed as some of the brightest objects in the night sky, with their energy output exceeding that of typical galaxies. Their prevalence at high redshifts suggests they formed early in the universe's history due to the redshift caused by cosmic expansion. Studying AGNs is essential for unraveling the universe's history. The evolution of AGN luminosity functions can shed light on the history of SBH formation, directly linked to cosmic accretion history. AGNs also influence star formation through energy feedback.

The paper explores different types of AGNs, with a focus on Type I AGNs like Quasars, Type II AGNs, and Radio Galaxies. It emphasizes the connection between AGN activity and galaxy morphology and star formation. Observationally, there's growing evidence that AGNs, through feedback, have significantly impacted the baryonic matter in the Universe at low redshifts, which has profound implications for galaxy, group, and cluster evolution and cosmological studies. In summary, the text introduces AGNs as powerful cosmic phenomena, discusses their relevance to understanding the universe's history and mechanisms, and highlights their connection to galaxy evolution and cosmology. It also teases the upcoming exploration of different AGN types, focusing on their role in shaping galaxies.

References

- [1] Ueda Y, Akiyama M, Ohta K, et al. Cosmological evolution of the hard X-ray active galactic nucleus luminosity function and the origin of the hard X-ray background. *The Astrophysical Journal*, 2003, 598(2). 886.
- [2] Padovani P, Alexander D M, Assef R J, et al. Active galactic nuclei. what's in a name? *The Astronomy and Astrophysics Review*, 2017, 25. 1-91.
- [3] Sampaio V M, Aragón-Salamanca A, Merrifield M R, et al. The co-evolution of strong AGN and central galaxies in different environments. *Monthly Notices of the Royal Astronomical Society*, 2023, 524(4). 5327-5339.
- [4] Clavijo-Bohórquez W E, Pino E M, Melioli C. AGN and Star Formation feedback in the evolution of galaxy outflows. arXiv preprint arXiv.2306.11494, 2023.

- [5] Marziani P, Sulentic J W, D’Onofrio M. An introduction to 50 years of research on quasars. Fifty Years of Quasars. from early observations and ideas to future research, 2012. 1-10.
- [6] Beckmann V, Shrader C. Active galactic nuclei. John Wiley & Sons, 2012.
- [7] Boselli A. A panchromatic view of galaxies. John Wiley & Sons, 2012.
- [8] Shields G A. A brief history of active galactic nuclei. Publications of the Astronomical Society of the Pacific, 1999, 111(760). 661.
- [9] Shlosman I, Begelman M C, Frank J. The fuelling of active galactic nuclei. Nature, 1990, 345(6277). 679-686.
- [10] McAlpine K, Prandoni I, Jarvis M, et al. The Interplay between SF and AGN Activity, and its role in Galaxy Evolution. arXiv preprint arXiv.1412.5771, 2014.