INVESTIGATING DUAL AGN/SMBH: A STUDY OF DUAL AGN MRK739 IN HIGH ENERGY ASTROPHYSICS

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ABSTRACT

Active Galactic Nuclei (AGN) are energetic centers of galaxies, driven by supermassive black holes (SMBHs). While most galaxies contain a single AGN, some have **dual AGN systems**, which arise due to mergers of massive galaxies. Dual AGN can evolve into **binary AGN**, which may later emit **gravitational waves**.

This study focuses on **image analysis of the dual AGN system Mrk 739 (Markarian 739)**, utilizing **Swift, NuSTAR, XMM-Newton, and Chandra** observations. We estimate the **projected nuclear separation** of Mrk 739's AGN components to be **~3.6 kpc**. A comparative study of observatory capabilities and a discussion of similar systems, such as **NGC 6240**, provide insights into **galaxy evolution and SMBH dynamics**.

Dual ACTIVE GALACTIC NUCLEI

What are Dual AGN?

•AGN are powered by SMBH accretion in galaxies.

•Dual AGN form when **two massive galaxies merge**, bringing their SMBHs into proximity.

•These systems are **key laboratories for studying SMBH interactions and galaxy mergers**.

Why Mrk 739?

•Mrk 739 is a **confirmed dual AGN** system. (Koss et al. 2011)

•Studying it helps understand **AGN feedback and SMBH growth mechanisms**.

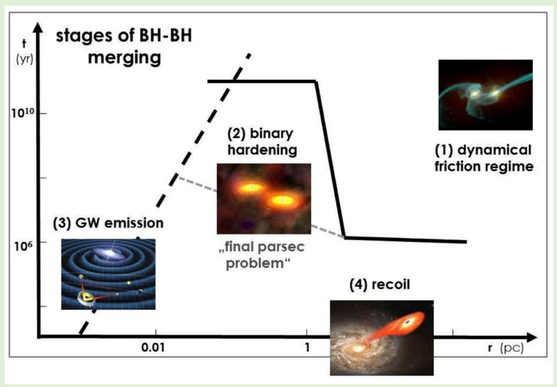


Fig: Stages of AGN/SMBH/BH-BH Merging http://arxiv.org/abs/1502.05720

METHODOLOGY

Data Acquisition: Retrieved Swift, NuSTAR, XMM-Newton, Chandra data from archives.

Preprocessing: Used HEASoft, SAS, CIAO for image calibration & corrections.

Coordinate Conversion: RA & Dec (HH:MM:SS → Decimal Degrees) conversion applied.

Angular Separation: Calculated using spherical law of cosines & Pythagorean approximation.

Physical Distance: Used Hubble's Law to estimate 3.6 kpc separation

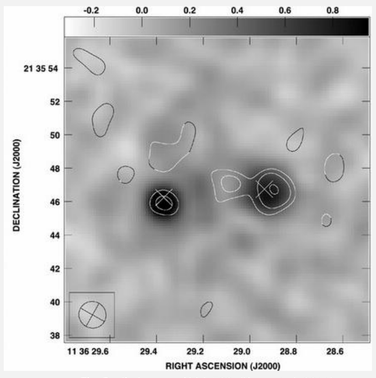


Fig. Radio Image of Mrk 739. (Koss et al. 2011)

DATA TAKEN FROM

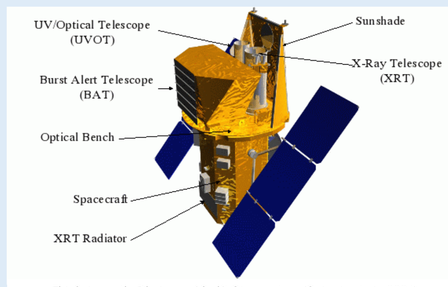


Fig: Schematic Diagram of Swift Observatory (Gehrels et al., 2004)

📌 **Neil Gehrels Swift Observatory**

•**XRT, 0.3–10 keV**: Provides **spectral and positional information** of AGN. Angular Resolution: **18 arcsec (FWHM)**

•**BAT, 15–150 keV**: Operates as a wide-field, ongoing sky monitor. Angular Resolution: **~17 arcminutes (FWHM)**

•**UVOT, 170–600 nm**: Observes **UV/optical afterglows** of AGN Angular Resolution: **2.5 arcseconds(FWHM)**

📌 **NuSTAR**

• **hard X-rays (3–79 keV)**.

•Enables studies of **heavily obscured AGN** and BH accretion.

•Features **twin focal plane modules (FPMA & FPMB)** for better localization & noise reduction.

•**Resolution: ~58 arcseconds** (FWHM), **~18 arcseconds** (HPD)

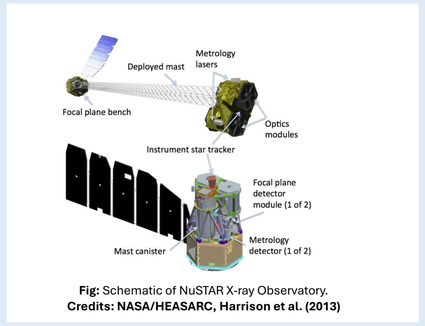


Fig: Schematic of NuSTAR X-ray Observatory.
Credits: NASA/HEASARC, Harrison et al. (2013)

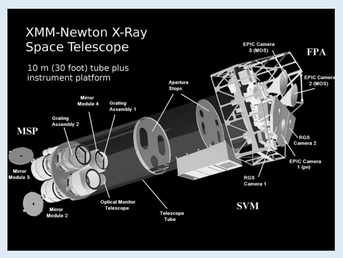


Fig: Schematic of XMM-Newton X-ray Observatory.
Credits: ESA/XMM-Newton (XMM-Newton Users Handbook, 2021)

📌 **XMM-Newton**

•Observes **black holes, neutron stars, and AGN** in X-rays. **0.15 – 15 keV**

•**Large collecting area** for high-sensitivity observations.

•**Simul. optical/UV & X-ray imaging** for multi-wavelength studies.

•**Resolution:** EPIC MOS**: ~6 arcseconds** (FWHM), (EPIC PN): **~15 arcseconds.** OM: **~1.0–1.2 arcseconds** (FWHM)

📌 **Chandra**

•Observes **supernova remnants, galaxy clusters, and black holes**. **0.1 – 10 keV**

•**Sub-arcsecond resolution** enables detection of **distant AGN & dual AGNs**

•**Resolution:** Chandra/ACIS-S**: ~0.5 arcseconds** (FWHM), **highest resolution** among X-ray telescopes.

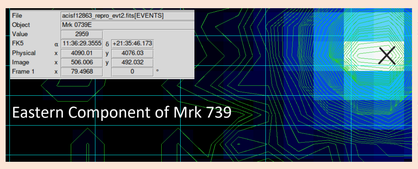
Fig: The Chandra X-ray Observatory.
Credits: NASA/Chandra

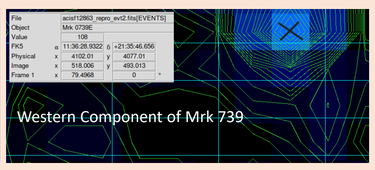
DATA ANALYSIS, RESULTS AND CONCLUSION

IMAGE ANALYSIS

Calculating the Nuclear Separation of the Dual AGN -

Choosing Coordinates:
Using DS9 and applying contours, the accurate RA and Dec can be found of the centre of a single AGN





Coordinate Conversion:

$$\text{Decimal Degrees} = (HH + \frac{MM}{60} + \frac{SS}{3600}) \times 15$$ — Coordinate Conversion for RA

$$\text{Decimal Degrees} = DD + \frac{MM}{60} + \frac{SS}{3600}$$ — Coordinate Conversion for Dec

For Calculating Angular Separation,

$$d = \sqrt{(\Delta RA \cdot \cos(\bar{Dec}))^2 + (\Delta Dec)^2} \qquad \cos(d) = \sin(\delta_1)\sin(\delta_2) + \cos(\delta_1)\cos(\delta_2)\cos(\Delta\alpha)$$

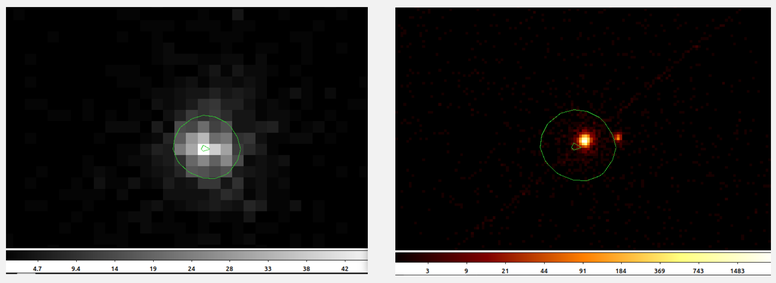
Conversion to Physical Units Assumption: **Lambda Cold Dark Matter (ΛCDM) model**

$$D = \frac{c \cdot z}{H_0} \qquad L = 2 \cdot D \cdot \sin\left(\frac{d}{2}\right)$$

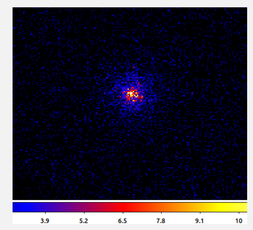
L — Physical distance between to AGN in parsec

IMAGE RESULTS

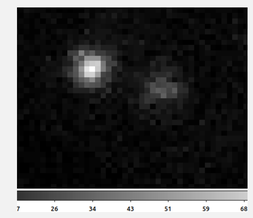
Mrk 739 Observations -



Swift's low resolution (LHS) cannot resolve the two AGN, but Chandra's superior angular resolution (RHS) clearly distinguishes them.

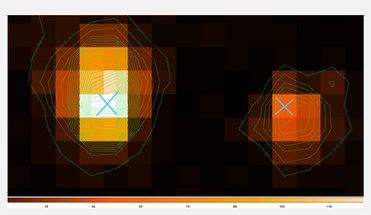


NuSTAR Observation

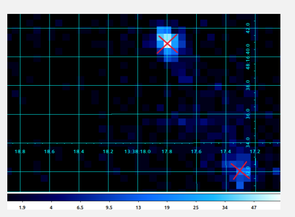


XMM Newton/OM Observation

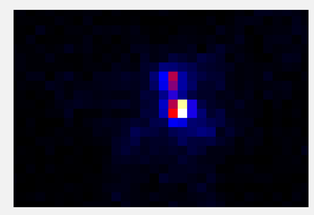
Other dual AGN observed by Chandra —



Mrk 463



Mrk 266



NGC 6240

CALCULATED PROJECTED NUCLEAR SEPARATION

Object	Redshift (z)	Nuclear Separation (kpc)
Mrk 739	0.0297	**3.6 kpc**
NGC 6240	0.0245	**0.9 kpc**
Mrk 463	0.0508	**3.7 kpc**
Mrk 266	0.0227	**5.9 kpc**

Using the methodology demonstrated above, we calculated these values by selecting dual AGN from the SDSS. (Rosa et al., 2022)

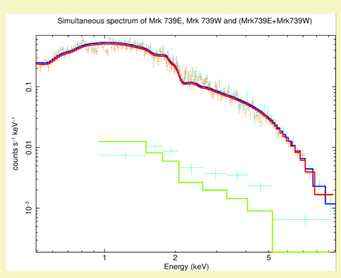
BIBLIOGRAPHY

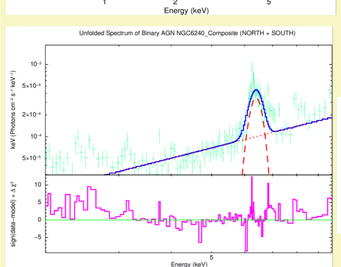
- Koss M., Mushotzky R., Veilleux S., Winter L., 2011, ApJ, 739, 57
- Rose M., Hogg D. W., Sanders J. S., 2022, MNRAS, 516, 4345
- Gehrels N., Chincarini G., Giommi P., et al., 2004, ApJ, 611, 1005

CONCLUSION

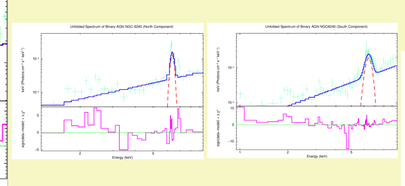
- Conducted image and spectral analysis of the dual AGN Mrk 739.
- Determined projected nuclear separation for Mrk 739 and other dual AGN.
- Demonstrated Chandra's high resolution in distinguishing dual AGN structures.
- Analyzed X-ray spectra, revealing key features, including a broad iron line in NGC 6240, requiring further investigation.

SPECTRAL RESULTS





- We generated a simultaneous spectrum of Mrk 739, showing photon counts from multiple X-ray telescopes (0.5–10 keV).
- Additionally, Chandra spectra of other dual AGN, like NGC 6240, revealed a broad iron line (Fe Kα).
- Further research is needed for definitive conclusion.



Scan here for more details —