Multiple Jets Driving AGN Feedback in the Seyfert NGC 2639

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MOTIVATION

- Active galactic nuclei (AGN) regulate galaxy growth by injecting energy into the surrounding gas which has the effect of either heating and/or expelling star-forming material ('negative feedback') or facilitating localized star-formation ('positive feedback').
- Seyfert galaxies: "radio-quiet" (RQ) AGN (having radio luminosity $21 \leq \log[L_{6GHz}] \leq 23$).
- Most Seyferts possess sub-parsec or parsec scale radio emission and ≳ 40% display kpc-scale radio structures.
- Seyfert activity episodes typically have a shorter duration than the minimum statistical lifetime of Seyfert activity in a particular galaxy ($3 - 7 \times 10^8$ yr), implying that the nuclei evolve through at least a 100 recurring activity episodes.
- Different Seyferts episodes occur due to distinct accretion events onto the central black hole
- Despite theoretical estimates, it is rare to find Seyferts with three or more episodes. But, the rarity of multiple episodes may not be due to a true absence but rather due to observational constraints such as low surface brightness of lobes and small spatial extents.
- Using multi-frequency, multi-scale/resolution observations, we report the discovery of a Seyfert galaxy NGC 2639, which shows four AGN jet activity episodes and analyse the effects of these jets on their environment.

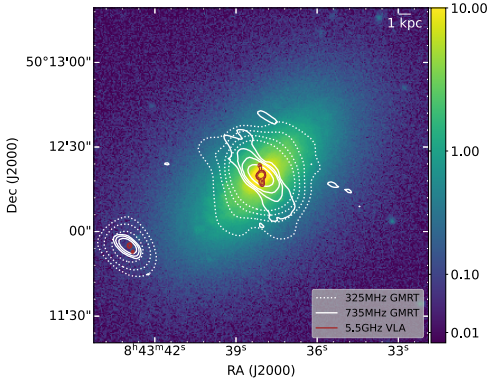


Fig: SDSS r-band image of NGC 2639 overlaid with radio contours at 325 MHz, 735 MHz, and 5.5 GHz. Two jet-lobes are clearly seen in this image

DATA ANALYSIS

Imaging:

- NGC 2639 observed using GMRT band-4 at 735 MHz and imaged using CAPTURE continuum imaging pipeline on CASA, revealing the ~9kpc jet feature.
- VLA 5.5 GHz image showing 1.5kpc north-south jet, VLA 5GHz image showing ~360 parsec east-west jet, and VLBA 8.3GHz image showing a ~3 parsec jet were also available.

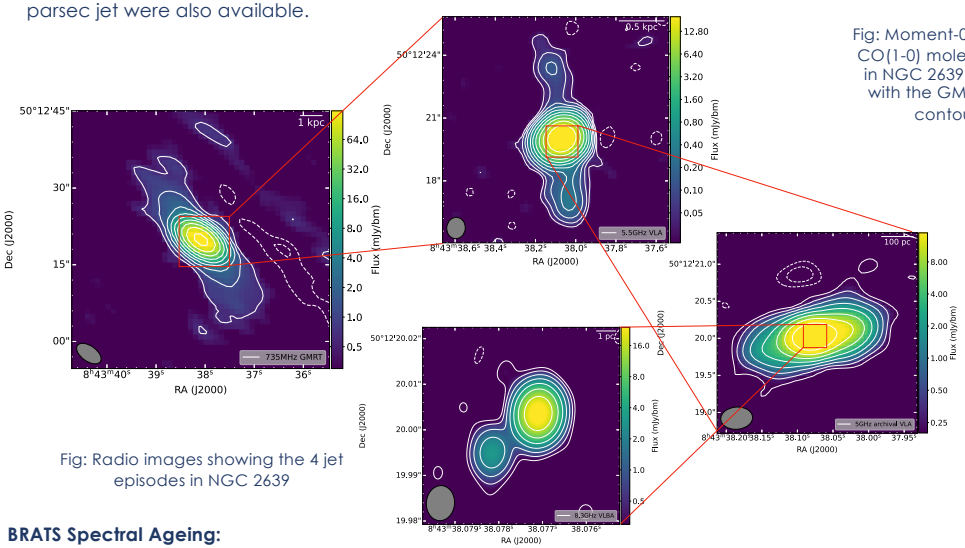
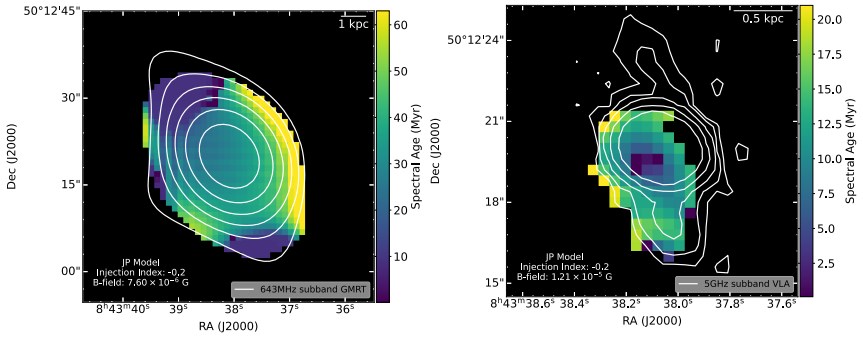


Fig: Radio images showing the 4 jet episodes in NGC 2639

BRATS Spectral Ageing:

- Archival GMRT and VLA images at 325 MHz and 1.5 GHz which partially resolved the largest two jets were available. The higher resolution counterparts were regridded and smoothed to fit the resolution of these lower resolution images. These images were fed to the BRATS software.
- Magnetic fields of the two jets were estimated assuming equipartition and injection index of the jets were taken to be -0.2 (the spectral index around the core)
- The spectral age maps from BRATS with radio contours overlaid, are shown below



RESULTS

- Mean spectral age of the largest ~9kpc GMRT jets are 34(+4,-6) Myr. That of the ~0.8kpc southern VLA jet and core are 11.8(+1.7,-1.4) Myr and 2.8(+0.7,-0.5) Myr, respectively.
- In the scenario where gas accretion from minor mergers are responsible for the multiple jets (Sebastian et al. 2019), spectral age results indicate minor mergers occurred every 9-22 Myr apart in the last ~30 Myr

- The Moment-0 image from CARMA-EDGE representing CO intensity shows a clear depletion of CO(1-0) molecular gas in the central ~6kpc of NGC 2639 (image below)

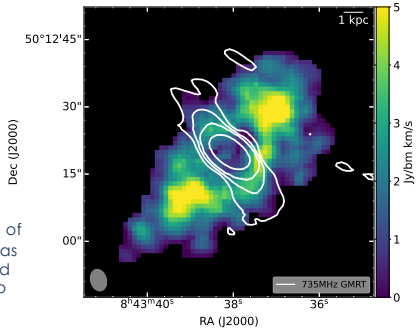


Fig: Moment-0 image of CO(1-0) molecular gas in NGC 2639 overlaid with the GMRT radio contours

- Moment-2 map of CO(1-0) also shows significant velocity dispersion around the GMRT jet edges.
- Jet power estimates reveal <1% of the mechanical power of each jet is sufficient to create the molecular gas depletion.
- GALEX data also shows a deficiency of near UV emission in the central ~6kpc (image below). The NUV band directly traces star formation in the last 200 Myr.
- Estimates of overall star formation rate surface density are also 5-18 times lower than the global Schmidt law for star forming galaxies, indicating star formation quenching.

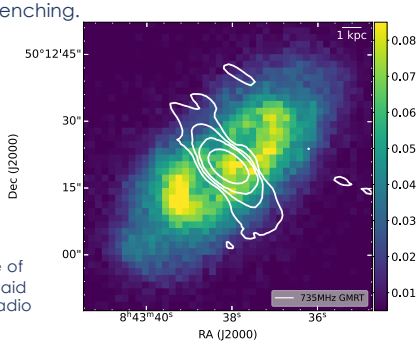


Fig: NUV image of NGC 2639 overlaid with the GMRT radio contours

CONCLUSIONS

- The Seyfert NGC 2639 exhibits four episodes of AGN jet activity as evidenced by 735 MHz, 5.5 GHz, and 8.3 GHz frequency observations via GMRT, VLA, and VLBA telescopes, respectively.
- The estimated minor merger timescale from jet spectral ageing agrees with the cosmological estimate of ~10 Myr.
- CO(1-0) morphology and NUV emissions indicate strongly towards star formation quenching by "negative AGN feedback". Given the jet power estimates and the collimated and directional nature of the jets, creation of the molecular gas ring probably required several jet episodes to occur.