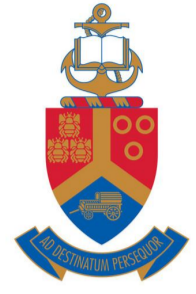


# Investigating the Scarcity of X-shaped Radio Galaxies: Distinct Origin or Detection Constraints?



UNIVERSITEIT VAN PRETORIA  
UNIVERSITY OF PRETORIA  
YUNIBESITHI YA PRETORIA

Dr Kshitij Thorat (Email: [kshitijthorat.astro@gmail.com](mailto:kshitijthorat.astro@gmail.com)), University of Pretoria

With Dr Gourab Giri (INAF-IRA, Bologna), Etienne Bonnassieux (OASU/Laboratoire d'Astrophysique de Bordeaux, Bordeaux), Leon Mtshweni (University of Pretoria) and William Rasakanya (University of Witwatersrand)

## Problem Statement:

X-shaped radio galaxies (XRGs), a subclass of winged sources, can be characterised by the presence of two pairs of radio lobes that are aligned at a substantial angle to each other (on an average  $\sim 75$  degrees, giving them a distinct X-shape. One pair of jet lobes, where hotspots are often observed is known as the active lobe, while the other pair, typically faint, diffuse, and edge-darkened, is known as the wing. Depending on the study, the fraction of X-shaped radio galaxies among extended radio sources is estimated to be 3–10% range seen in literature (Leahy & Williams 1984; Leahy & Parma 1992; Joshi et al. 2019). Given the proposed mechanisms for the origin of XRGs : spin-flip in the jet axis resulting from SMBH mergers or especially backflows aren't very rare, why are these sources so rare?

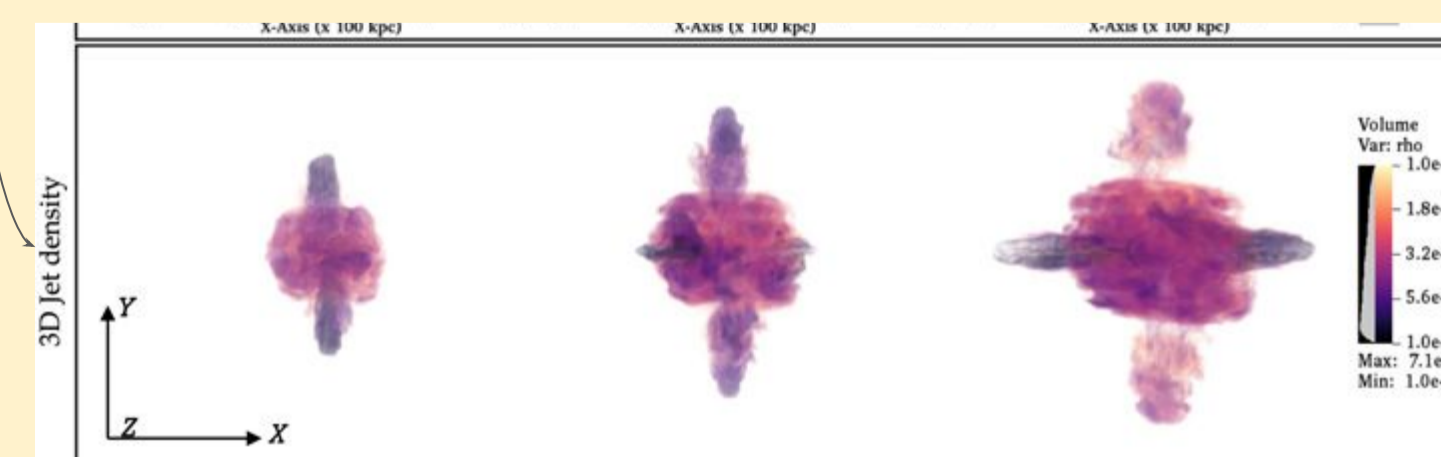
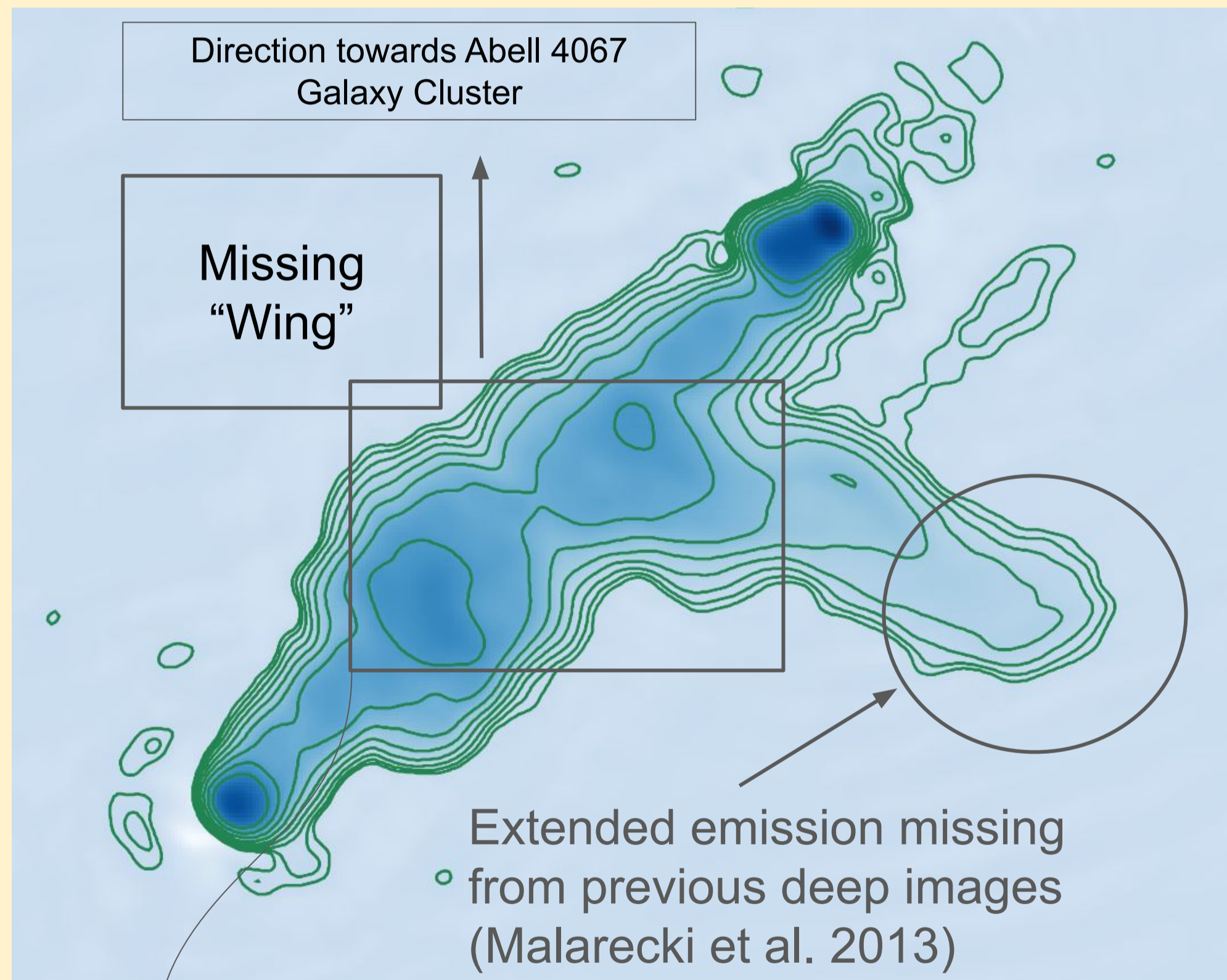
## Methodology and Observations:

To check if the observed rarity is an issue of sensitivity to diffuse emission (see Bruni et al. 2021, Mahatma et al. 2023, Yang et al 2019) or real - both have wider implications including for the nanoHertz gravitational wave background - we proposed a MeerKAT UHF band survey of a small sample of prominent XRG "candidates" - sources which have been seen in shallower surveys like TGSS / RACS to have off-axis emission but with very small "wing" sizes to see if MeerKAT's superior surface brightness sensitivity reveals extended emission in the wings. All sources were chosen from the relatively unexplored southern sky. **Here we present a particularly interesting source from this sample, PKS 2356-61 ( $z = 0.09$ ).**

The observations were carried out at UHF band (544–1087 MHz) with 2 Hours of on-source time with the standard cadence of bandpass and gain calibrators. All data for these observations are reduced with a combination of MeerKAT pipelines (CARACal, SDP pipelines) and custom Stimela- based imaging where required. PKS 2356-61, with a total flux density of 34.8 Jy at UHF band this is one of the brightest radio sources in the southern sky.

**PKS 2356-61**, MeerKAT UHF band image with rms noise of 0.2 mJy/beam with a beam of 14.17" X 9.9". Octave contours start from 10 sigma.

Central boxy structure hints at rapid reorientation of jet axis



MHD simulation plot taken from Giri et al. 2023

## Results and Questions:

PKS 2356-61 is a truly fascinating radio galaxy - being a candidate XRG, a Giant Radio Galaxy (GRG), a candidate for rapid jet reorientation.

Salient takeaway points:

1. "Missing wing" remains missing in deep MeerKAT observations - suggesting that the emission there is non-existent rather than at low surface brightness levels.
2. We recover emission missing from previous deep observations of the source (Malarecki et al 2013) with much better structural information than contemporary observations (RACS).
3. The culprit for the missing wing is expected to be the gas in the cluster/filament in that direction (agreeing with Malarecki et al 2013) - see Kumari et al. 2024 for a similar case in the northern sky.
4. Morphological details suggest rapid reorientation scenario - supported by spectral index map (not shown, from Rasakanya et al. in prep) which does not support a hydrodynamic backflow origin.
5. In summary, this supports our hypothesis that XRGs may be miscounted due to interactions with the environments or due to low surface brightness sensitivity, however a larger sample study is needed before conclusiv

## Acknowledgements:

The MeerKAT telescope is operated by SARAO, a facility of the National Research Foundation (NRF), which is an agency under the Department of Science, Technology and Innovation (DSI). We also acknowledge the use of the ilifu cloud computing facility ([www.ilifu.ac.za](http://www.ilifu.ac.za)), a partnership between the University of Cape Town, the University of the Western Cape, Stellenbosch University, Sol Plaatje University, and the Cape Peninsula University of Technology. The ilifu facility is supported by contributions from the Inter-University Institute for Data Intensive Astronomy (IDIA), a partnership between the University of Cape Town, the University of Pretoria, and the University of the Western Cape; the Computational Biology division at UCT; and the Data Intensive Research Initiative of South Africa (DIRISA). Additionally, this work made use of the CARTA (Cube Analysis and Rendering Tool for Astronomy) software (DOI: 10.5281/zenodo.3377984 - <https://cartavis.github.io>)