

UHF OBSERVATIONS OF THE TAIL LIKE REGION OF THE HYDRA A RADIO GALAXY.

In collaboration with Andrew Chen

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HYDRA A BACKGROUND

Hydra A is a powerful FR-I radio galaxy located at the center of the Abell 780 cluster with a redshift of $z=0.054$. Previous observations of the galaxy were conducted at radio and X-ray frequencies and these helped shed light on its morphology. The galaxy is composed of: (a) Bright central core, (b) Pair of relativistic jets, (c) Pair of inner and outer radio lobes, (d) Tail-like extension from southern outer lobe and (e) Three pairs of X-ray cavities. The tail-like region was investigated by Naidoo (2023) [1] using VLA and MeerKAT's L-band (856-1711 MHz). Key findings were that the spectral index of the region was much steeper than its counterparts and its spectral age via the Kardashev-Pacholczyk (KP) model. The spectral break was located in a gap between the two observations meaning it could not be directly measured thus possibly affecting spectral age calculations.

AIMS OF STUDY

- Conduct observations in MeerKAT's UHF band (544-1087 MHz) in order to directly determine the spectral break and further constrain the KP model.

RESULTS

SPECTRAL ANALYSIS

- Two datasets: Including UHF observations and Excluding UHF observations (used by [1] for preliminary analyses).
- KP model selected due to presence of spectral break.
- Multi-layered Python code used for the KP model which determined the best fit magnetic field (B) and spectral age (T) values via a grid search for the pair which produces a minimum χ^2 .
- Best fit B and T values from [1] were optimized using LMFIT to further constrain the model.

Northern Lobe Optimal Parameters	VLA data	L-band data	UHF exclusive data	UHF inclusive data
Logscale normalization factor (h)	10	19 ± 0.69	10.00 ± 1.00	
Magnetic field (μG)	17.11 ± 0.99	25.30 ± 0.12	25.11 ± 0.51	
Spectral age (Myrs)	8.75 ± 1.25	8.75 ± 0.55	8.75 ± 0.33	

Southern Lobe Optimal Parameters	VLA data	L-band data	UHF exclusive data	UHF inclusive data
Logscale normalization factor (h)	10	10.60 ± 1.76	9.96 ± 2.74	
Magnetic field (μG)	10.90 ± 0.49	10.90 ± 0.17	10.90 ± 0.19	
Spectral age (Myrs)	50 ± 1.25	49.89 ± 1.56	49.89 ± 1.60	

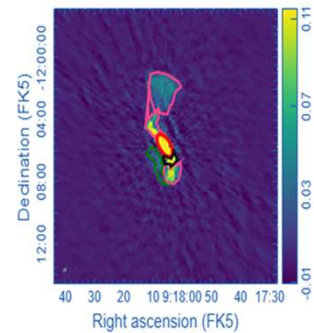
Tail Region Optimal Parameters	VLA data	L-band data	UHF exclusive data	UHF inclusive data
Logscale normalization factor (h)	10	9.81 ± 0.68	11.11 ± 0.66	
Magnetic field (μG)	1.99 ± 0.49	1.97 ± 0.20	1.93 ± 0.13	
Spectral age (Myrs)	138.75 ± 2.5	138.81 ± 5.71	138.45 ± 4.31	

METHODOLOGY

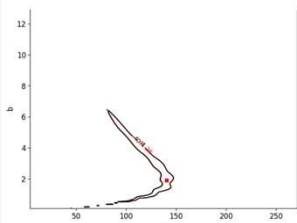
- Three observations epochs whose data was stored in corresponding measurement set files.
- Data reduction occurred via CARACal pipeline [2] with the implemented steps being flagging, cross-calibration and self-calibration.

DATA ANALYSIS

- The data was split into four frequency channels with central frequencies of 612, 748, 884 and 1020 MHz.
 - The flux densities were measured using the CARIA software with the corresponding errors being determined using [3]
- $$\Delta S_{\nu} = \sqrt{\sigma_{\text{amp}}^2 S_{\nu}^2 + \sigma_{\text{rms}}^2 N_{\text{beam}}}$$
- Due to three measurement sets being available, the weighted flux and its corresponding error were calculated for each of the regions of interest which were:
 - Northern Lobe [Top magenta]
 - Southern Outer Lobe [Bottom magenta]
 - Tail region [Green].

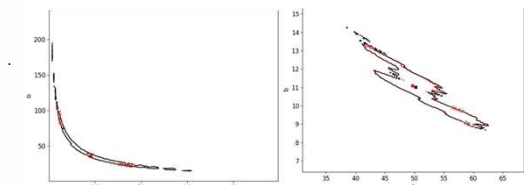


UHF EXCLUSIVE (BLACK) AND UHF INCLUSIVE (RED) 3σ CONTOUR PLOT COMPARISON FOR THE TAIL REGION.

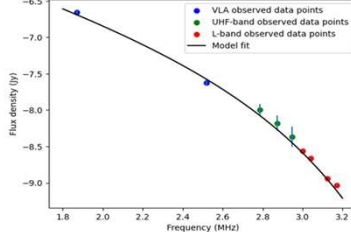


68% and 99% confidence contours plotted for UHF inclusive and exclusive datasets to help visualize the new (B-T) parameter space and evaluate success of constraining the model.

UHF EXCLUSIVE (BLACK) AND UHF INCLUSIVE (RED) 3σ CONTOUR PLOT COMPARISON FOR THE NORTHERN LOBE AND SOUTHERN OUTER LOBE RESPECTIVELY.

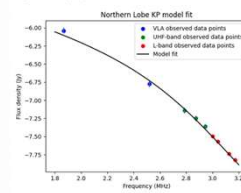


Tail Region KP model fit

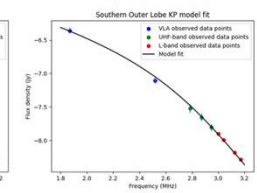


- Accompanying the confidence plots was a mini-grid search to find the best (B-T) pair (for both UHF inclusive and exclusive datasets) which fully encompass the 99% contour with these being our final best fit values.
- The optimal B and T for both datasets was 1.91 μG and 140.24 Myrs respectively.
- KP model was fitted onto the best B and T values from the UHF inclusive dataset.

NORTHERN LOBE OPTIMAL B AND T: (35.70 μG, 9.14 Myrs)



SOUTHERN OUTER LOBE OPTIMAL B AND T: (11.08 μG, 49.68 Myrs)



FUTURE WORK

- Further observations using the UHF band to confirm the obtained results.
- Break degeneracy by conducting independent magnetic field observations through polarization measurements.
- Determine spectral age with Tribble model.

[1] 2023afas.confE_54N
 [2] 2022ASPC_532_447J
 [3] 2020MNRAS.499_404P

