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Can't See the Galaxies for the Stars: Improving Cross – Identification for Radio Surveys Using Ridgelines

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Abstract

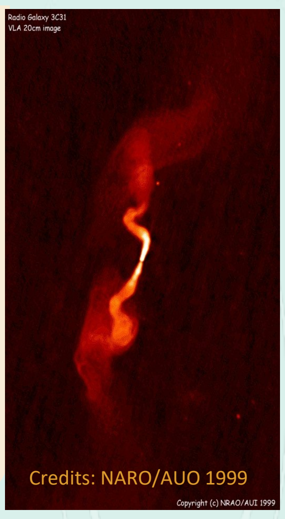
We created a code (RL-Xid) to develop an optimal likelihood ratio method for cross-identifying complex extended radio sources, incorporating spatial information from ridgelines as well as existing catalogue information.

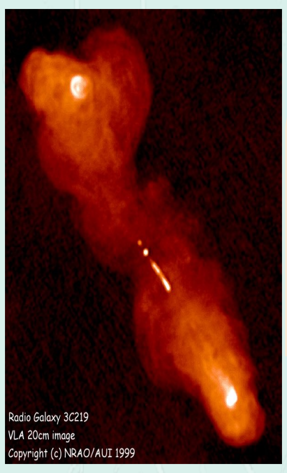
Cross-identification is the matching of radio sources with optical/infrared sources from other surveys. It can be particularly challenging for extended radio sources such as extragalactic jets. These counterparts give the redshifts which are so crucially needed for the scientific aims of many radio continuum surveys. With this information physical properties such as age and size can be characterised for extended sources. Interactions with their environment can reveal properties such as velocity, energy density and magnetic field content. From these inferences about the environments of jets can be made, and with more information about the extended radio population radio galaxy models can be properly tested.

RL-Xid successfully identifies the hosts in the LoTSS DR1 catalogue at a comparable level to the visual identification via citizen science.

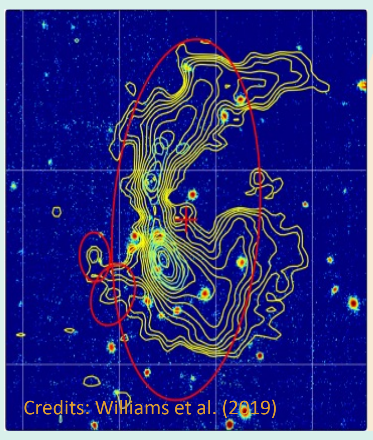
The LOFAR Two metre Sky Survey (LoTSS) data release 1 (DR1) (Shimwell et al., 2019) is a 150 MHz continuum survey covering 424 deg^2 at 6 arcsec resolution. Our sample comes from the 23,344 sources defined as radio loud AGN by Hardcastle et al. (2019) and are compared with the optical/infrared catalogue used by Williams et al. (2019).

There are two traditional morphological classes for radio loud AGN. To the right, an FRI radio jet where the peak of the brightness is near the core.





To the left an FRII where the brightness is near the edge of the lobes



LOFAR Galaxy Zoo (LGZ) is a citizen science platform where volunteers visually matched optical/infrared host galaxies to extended radio sources for which the statistical likelihood ratio method is unreliable. These were the two methods used to cross-identify in Williams et al. (2019).

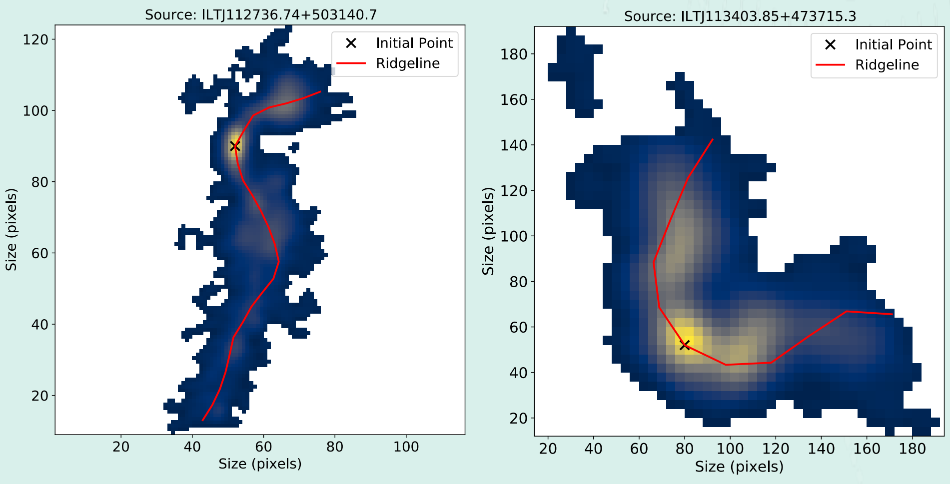
Ridgelines and Surface Brightness Profiles

Using a similar approach to Pushkarev et al. (2017), a ridgeline is the pathway of connected points of highest flux intensity; it is intended to trace the direction of fluid flow. We used RL-Xid to investigate the application of ridgelines for host identification and morphological classification.

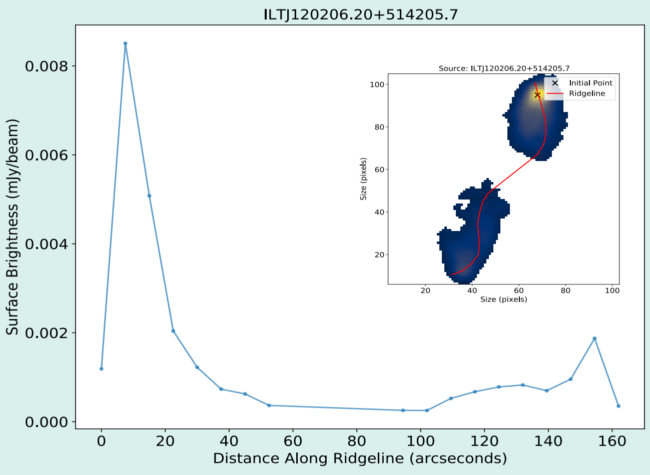
Assuming the jet is generated by the supermassive black hole residing at the galactic centre, the ridgeline should pass through the centre of the optical/infrared host. This will help with cross identification.

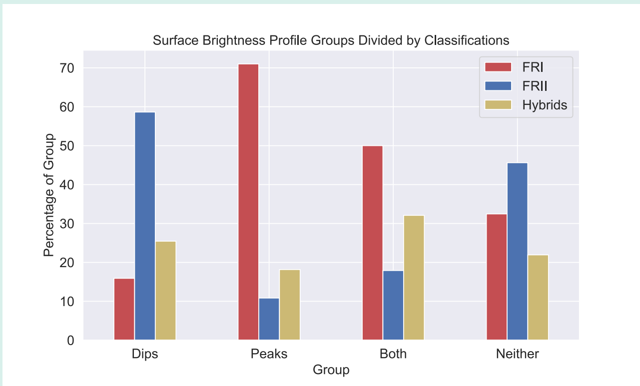
RL-Xid records the surface brightness along the ridgeline which maybe used for morphological classification.

Ridgelines can map out simple sources to the left, and more complex sources, such as the wide angle tail source to the right, and the FRII in the inset below left.



Surface brightness profiles show the changes in flux intensity along a ridgeline. These can demonstrate the difference between an FRI, with a peak near the centre of the ridgeline and an FRII (shown to the right) with at least two distinct peaks towards the ends of the ridgeline.





We compared the presence of bright central peaks and central dips in the surface brightness profiles with the results from LoMorph (Mingo, et al. 2019). This shows a link between peaks and dips with FRIs and FRIIs respectively (shown to the left).

The top row shows the percentage of sources for which RL-Xid successfully drew ridgelines. The following two rows show the number of correctly identified hosts, as a percentage of only those sources with a successfully drawn ridgeline and as a percentage of all the sources, for each flux density and size group.

	> 10 mJ y and > 15 arcsec (All sources)	> 30 mJy and > 60 arcsec (Large and Bright sources)
% Ridgelines Drawn	85.8	95.9
Ridgeline Sources	96.4	92.5
All Sources	82.6	88.7

Cross Identification Results

We used RL-Xid to compare different distance parameters in the likelihood ratio formula to see if using the distance form the ridgeline was a viable parameter.

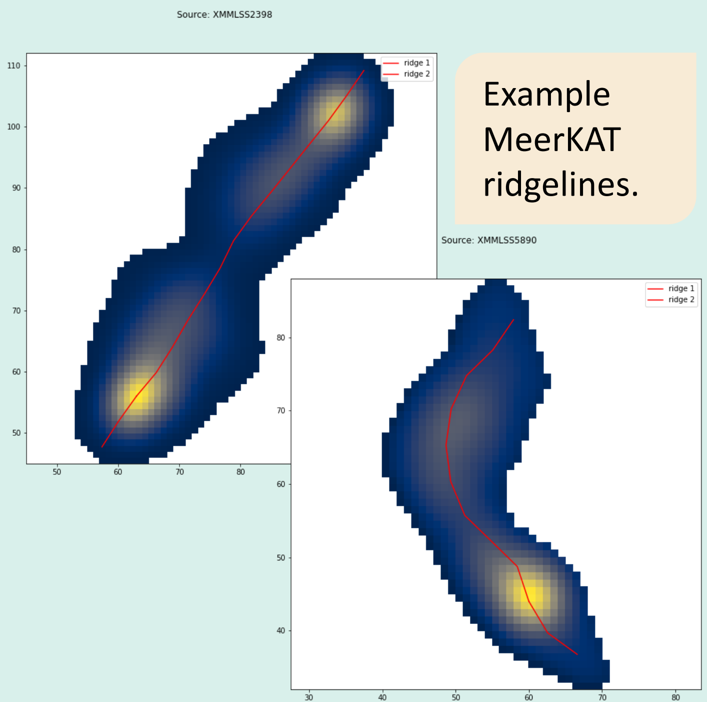
As can be seen in the table we found using a product of the probability functions of the distance to the ridgeline and a radio centroid-based distance, RL-Xid can find a comparable number of optical/infrared host galaxies to radio sources as the LGZ volunteers did.

Full results will be published in Barkus et al. (2021, *in prep*).

Future Work

Our next step forward is to apply this to data sets with no previously known hosts. Preliminary testing with LoTSS DR2 (covering 2600 deg^2) is showing good initial results, and we have started work with applying RL-Xid to a second deep radio survey, with MeerKAT sources (radio images courtesy I. Heywood).

To explore the adaptability and effectiveness of RL-Xid we have also applied our method to an observation of the XMM-LSS field from the MeerKAT International GHz Tiered Extragalactic Exploration (MIGHTEE) survey. These are deep images covering the frequency range of 900 – 1670 MHz, at a resolution of ~6 arcsec (Jarvis, 2017).



Example MeerKAT ridgelines.

Acknowledgments:
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