EXPLORING THE RADIO PROPERTIES OF AGN USING THE MILLION QUASAR CATALOGUE

Luís Barroso[a,b], José Afonso[a,b], Israel Matute[a,b].
(a) Instituto de Astrofísica e Ciências do Espaço, Universidade de Lisboa. Portugal.
(b) Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Portugal.

Our Goal

Powerful Active Galactic Nuclei (AGN), key to understanding galaxy formation and evolution, are powered by accretion onto supermassive black holes (SMBHs). Different accretion modes have been identified: quasar mode, corresponding to a high accretion rate and generating strong optical and X-ray emission; radio mode, typical of slower accretion rates and producing radio powerful outflows; merger mode, where SMBH growth results from the merger of two galaxies. Understanding the evolution of AGN requires comprehensive studies of AGN samples, at all wavelengths. And while optical and near-infrared observations have been frequently used in the past, they can only offer a partial view of the accretion phenomena. In particular, radio observations are witnessing a renewed interest, as new methods of reaching the highest redshifts have been developed, and the perspective of the direct study of the neutral Hydrogen at the Epoch of Reionization by the upcoming Square Kilometre Array (SKA) prompts for a deeper knowledge of the radio AGN population.
In this work, we have explored the radio properties of AGN in the Million Quasar Catalogue (MQC) , using the LOFAR Two-metre Sky Survey (LoTSS, 150 MHz); the Rapid ASKAP Continuum Survey (RACS, 888 MHz); the VLA Sky Survey (VLASS, 3 GHz). We identify specific radio AGN types, associated with young radio emission and/or very dense environments, for example (GPS, inverted or flat radio spectrum sources). By using the resulting dataset, we can now start to develop a better understanding of the radio emission from powerful AGN, and how to better explore next-generation radio observations with the so-called SKA-pathfinders (namely ASKAP and MeerKAT, where an active participation of our team exists) and, in the future, for the SKA itself.

The MQC Sample:

The MQC[1] is a catalogue composed of 1.4 million quasars, and it is one of the largest catalogues of powerful AGNs available. The redshifts of this sample of quasars range between 0 and 8.

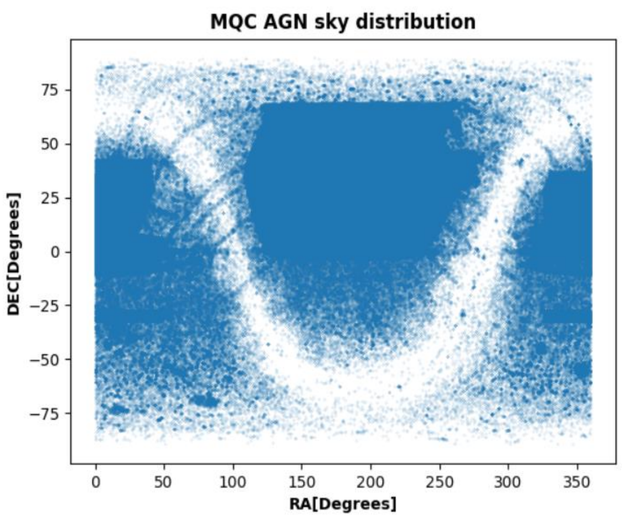

Figure 1 : Sky distribution of MQC AGN. The density of sources has various peaks, not due to intrinsic AGN clustering, but rather reflecting deeper observations from specific surveys (for example, the XXX survey at 12h, +25º. The Milky Way “zona of avoidance” is also evident.

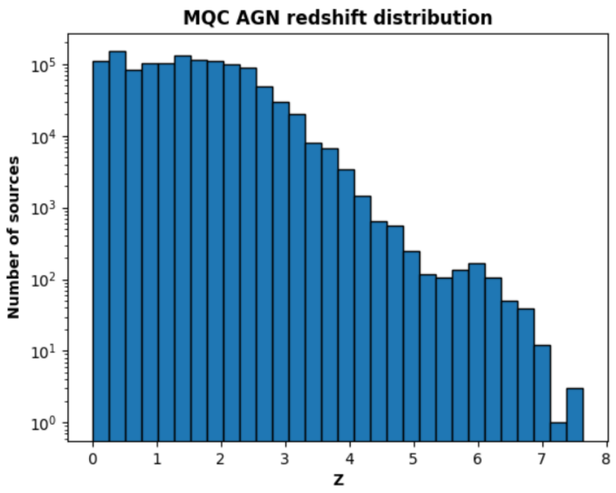

Figure 2: The redshift distribution for more than 1.4 million AGN with distance estimates in the MQC. Even at very high redshifts (z>5) the catalogue includes several hundred AGN, allowing for studies targeting the high redshift regime.

Radio observations of MQC sources:

Due to their depth and size, we made use of the observations of three state-of-the-art wide-area radio surveys: LoTSS, RACS and VLASS.

Figure 3: The Very Large Array Sky Survey (VLASS) has covered the entire sky north of -40º (over 30000 sq deg) at ~3GHz with the VLA radio telescope, in New Mexico (USA). It reaches a sensitive of ~200 uJy.

Figure 4: The LOFAR Two-metre Sky Survey (LoTSS) covers (data release 2) 5700 sq degree at 150 MHz, down to a radio flux sensitivity of ~80 uJy. It has been produced by the LOFAR radio telescope, located in the Netherlands.

Figure 5: The Rapid ASKAP Continuum Survey (RACS) is the first large-area survey performed with the Australian Square Kilometre Array Pathfinder (ASKAP) telescope. It covers over 34000 sq deg of the sky at ~888 MHz, down to a sensitivity level of ~300 uJy.

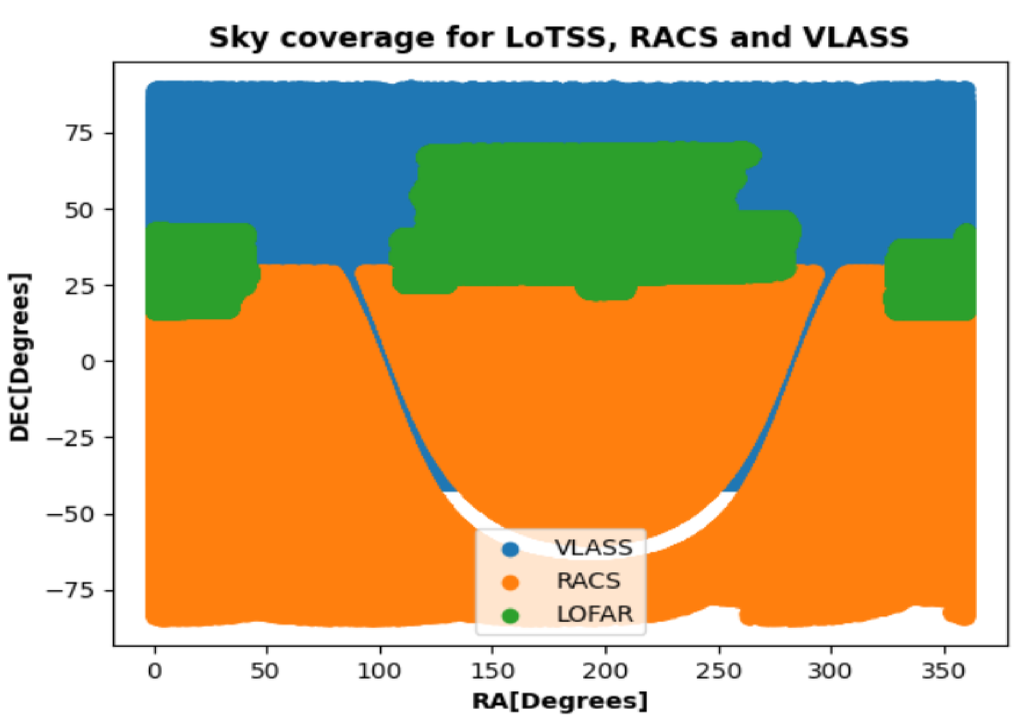

Figure 6: The coverage for all three radio surveys used in this work. The overlapping area, covered by all surveys, where radio information will be more complete, still covers more than 2000 MQC AGN.

First Results:

By correlating the MQC with LoTSS, RACS and VLASS, we can begin characterizing the radio emission for thousands of AGN. As an example, we can immediately identify almost 300 Gigahertz Peaked Sources (GPS), 181 Inverted Spectrum and 60 Flat-spectrum radio sources (examples are given below. These peculiar radio-spectral types have been long discussed to trace young radio emission and/or unusually dense environments near the origin of the radio emission. The identification and study of these sources is fundamental to understand the radio emission mechanisms associated with AGN.

Type of source	Number of sources
GPS	275
Inverted spectrum	181
Flat spectrum	60
Others	2220

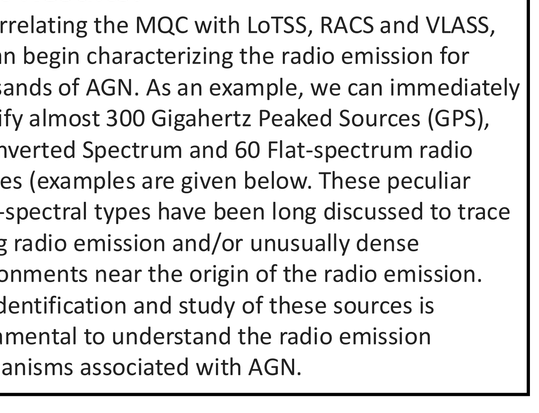

Figure 7: The MQC source J0720+2538, an example of a GPS source, with its peak flux emission at the RACS frequency.

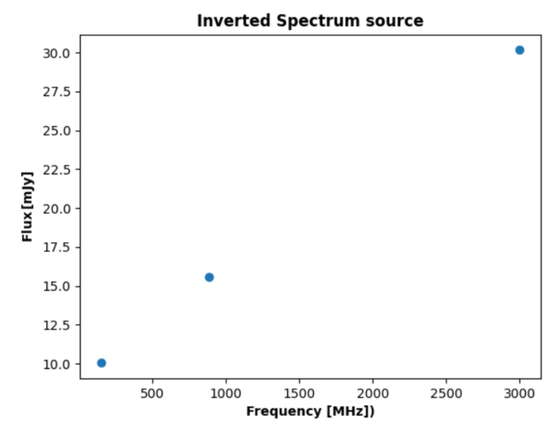

Figure 8: SDSS J0901+2754, an inverted spectrum radio source in the MQC.

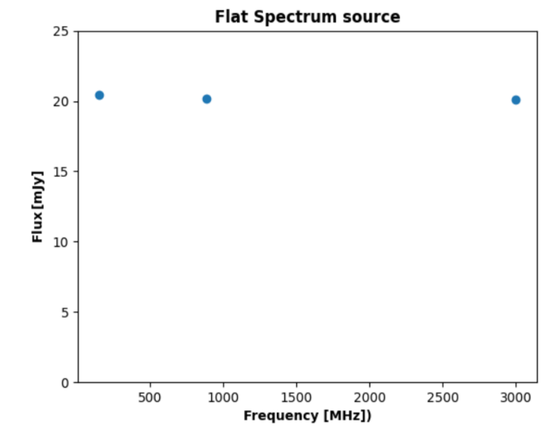

Figure 9: As the name suggests, the MQC source SDSS J0824+251105 reveals very similar fluxes at 150, 888 and 3000 MHz.

References:

[1] E. W. Flesch, 2021 “The million quasars (milliquas) v7. 2 catalogue”, arXiv:2105.12985, 2021.

[2] Y. A. Gordon et al., 2021, “A quick look at the 3 ghz radio sky. i.source statistics from the very large array sky survey”, ApJS 255, 30

[3] D. McConnell et al., 2020 “The rapid askap continuum survey i: design and first results”, PASA, 37, 2020.

[4] T. Shimwell et al., 2022 “The LOFAR Two-metre Sky Survey V. Second data release” A&A, 659, A1 (2022)

Radio information from the recent LoTSS, RACS and VLASS radio surveys can be used to study the long-wavelength emission from powerful AGN. This will be used, in the future, to better understand the accretion mechanisms in radio AGN, and how to use radio observations to identify even distant SMBHs, even at the Epoch of Reionization - in particular with upcoming radio surveys being developed for the Square Kilometre Array, later in this decade.

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