Radio-loud AGN through the eyes of 3XMM, WISE and FIRST/NVSS

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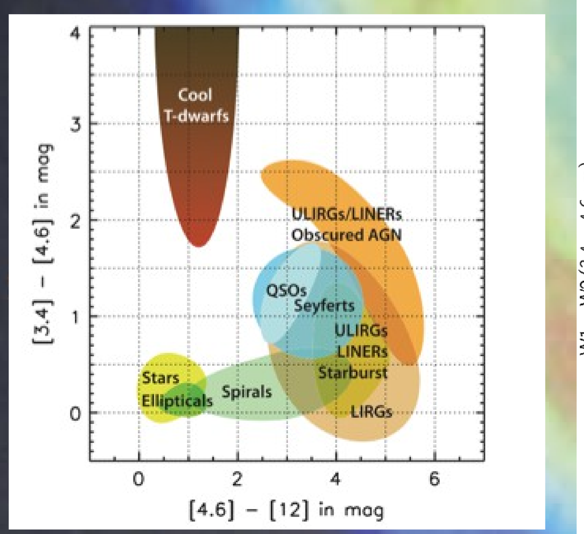
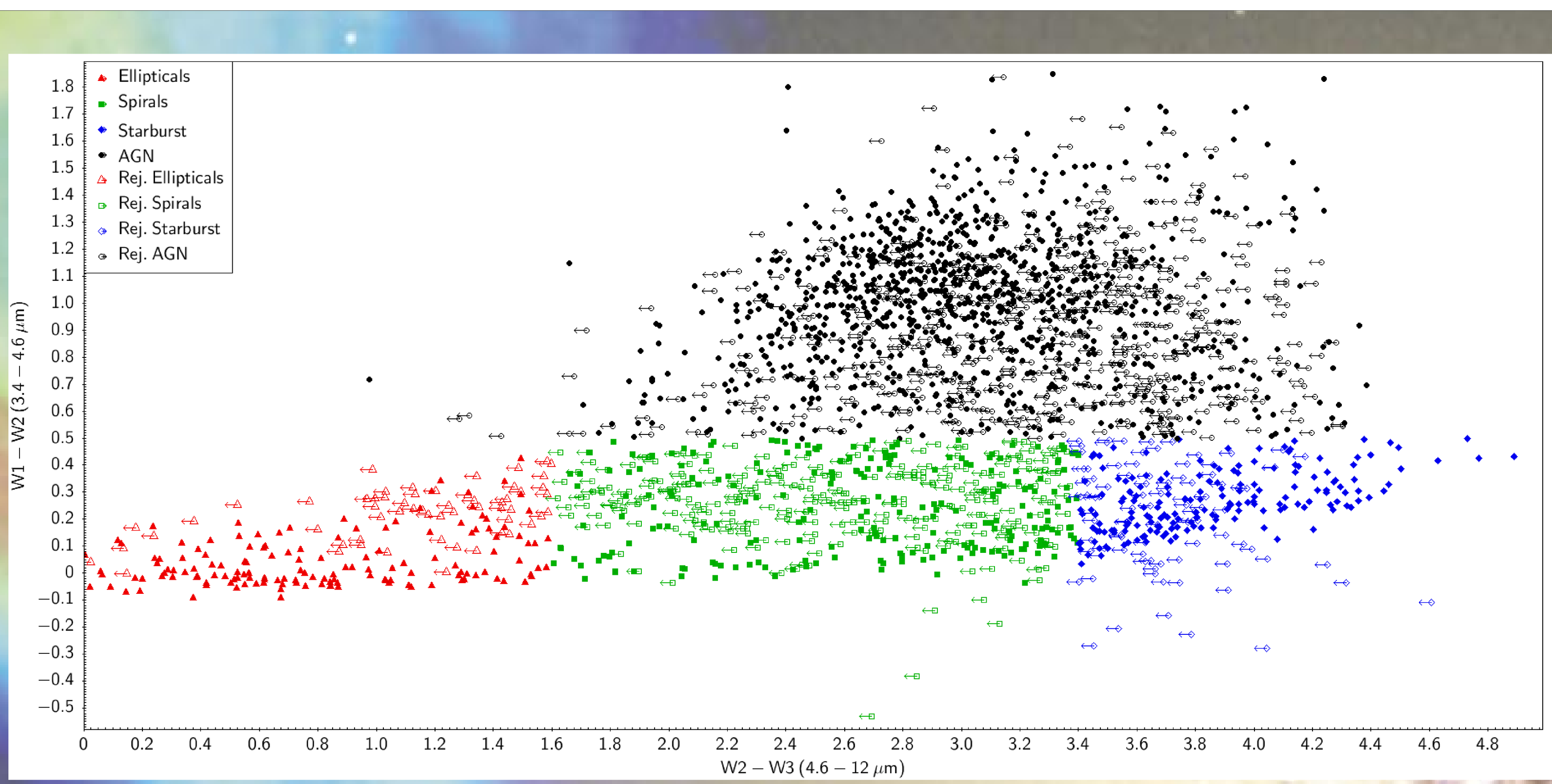
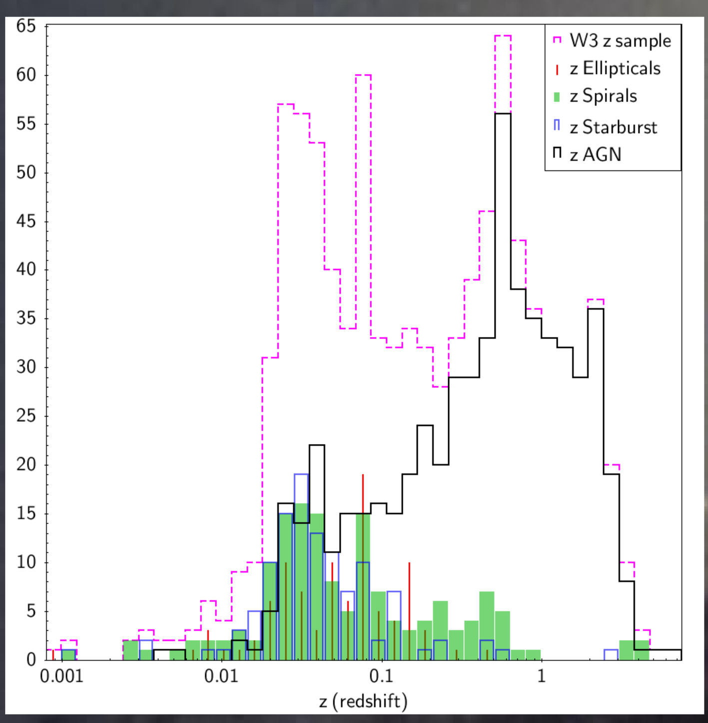
Although radio-loud AGN only constitute 10-20% of the sources we observe, evidence suggests that most, if not all AGN, have undergone a radio-loud phase. It is in this phase that the AGN most dramatically affects its environment (see e.g Bower et al. 2006 MNRAS 370 645; Croton et al. 2006 MNRAS 365 11). This is particularly relevant for low-power sources, including Seyferts, where the AGN can deposit up to 10^6 supernovae worth of energy into the ISM of the host galaxy in the span of a few million years, with the potential to dramatically affect the dynamics and star formation rate of the host (see e.g Croston et al. 2008 ApJ 688 190; Mingo et al. 2011 ApJ 731 21; Mingo et al. 2012 ApJ 758 95).

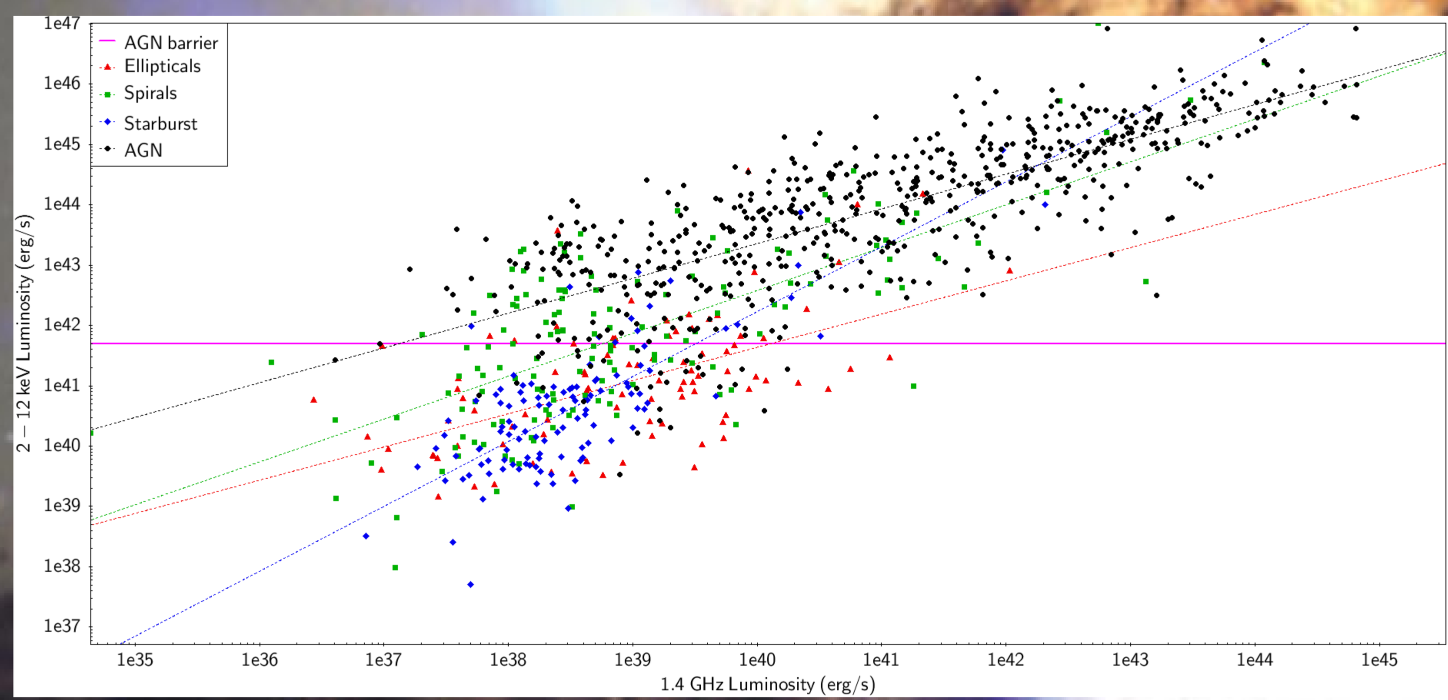
Radio-loud AGN are also fundamental to understand accretion, as it is not yet clear what regulates jet production. Although we know that the jet and radiative output of an AGN must be related by accretion, the wide scatter in radiative output observed for a given jet power, and vice versa, suggest that there must be an intervening mechanism mediating between the two (see e.g. Mingo et al 2014 MNRAS 440 269).



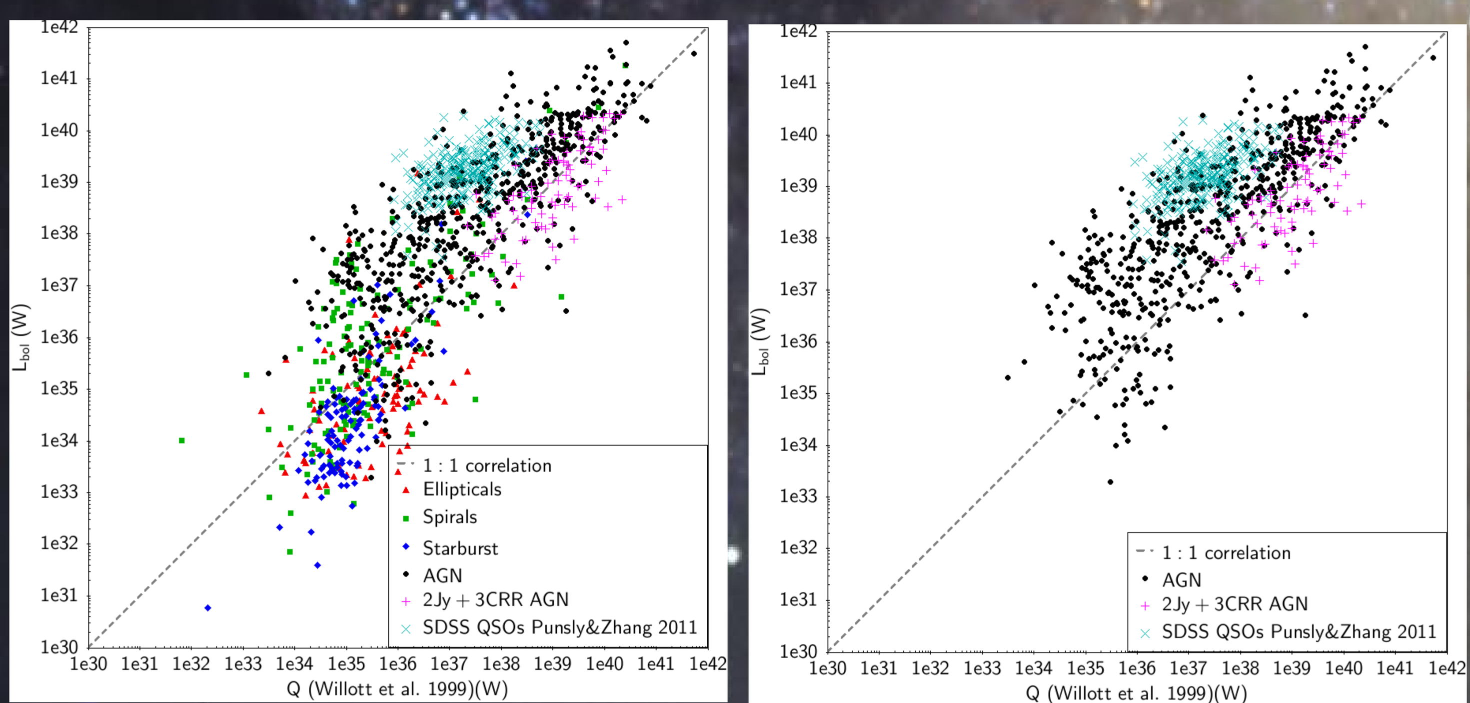


Above Left: WISE c/c diagram from Lake et al. (2012, AJ 143 7), illustrating the expected colours (from synthetic SEDs) for different sources.
Above Right: WISE c/c diagram for our selected sample, with qualitative classifications derived from the diagram on the left. Empty symbols represent the upper limits for the sources that do not pass the W3 S/N>3 cut





Above Left: z distribution for the sources in each population type (that pass the W3 S/N cut). From an initial sample of ~2500 sources that pass all the cuts but W3, ~40% percent are eliminated in the W3 cut, and a further 40% by requiring SDSS redshifts. The final sample contains 94 ellipticals, 149 spirals, 114 starburst, and 577 AGN.
Above Right: X-ray 2-12 keV luminosity versus radio 1.4 GHz luminosity, with the best fitting correlations for each source type. This plot illustrates the dangers of IR colour-based classifications, as many "spiral" sources harbour powerful AGN. It is clear here that ellipticals host radiatively inefficient AGN, as their X-ray luminosities are comparable to those of star-forming objects, while having substantially larger radio emission. Starburst sources follow a well defined correlation. AGN show a large scatter in radio luminosity, reinforcing the conclusion that jet and radiative power are not correlated (Punsly & Zhang 2011, ApJ, 735, L3; Mingo et al. 2014, MNRAS 440 269).



Left: jet power versus radiative output for all the sources (1) and only those classified as AGN (2). The sources from Mingo et al. 2014 and Punsly & Zhang 2011 are added for comparison. These plots demonstrate the large scatter between Q and L_bol.

The sample

The ARCHES project (http://www.arches-fp7.eu/) is an EU/FP7 collaboration between five institutions (University of Leicester, Universidad de Cantabria, Universite de Strasbourg, Instituto Nacional de Tecnica Aeroespacial, and Leibniz Institut für Astrophysik Potsdam). ARCHES aims to produce well-characterised multi-wavelength data for large samples of sources drawn from the 3XMM serendipitous source catalogue.

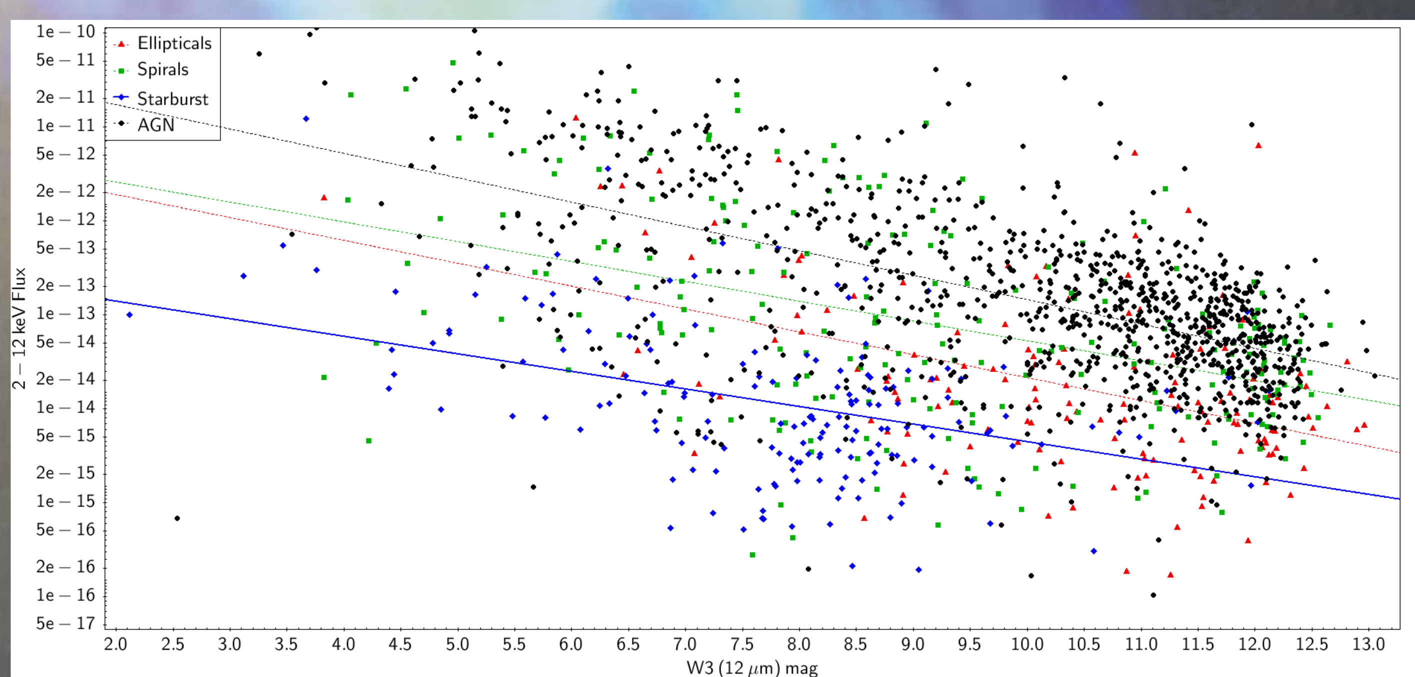
In this context, we have selected a sample that combines radio (FIRST+NVSS), mid-IR (WISE) and X-rays (3XMM), to characterise a large sample (~1000 sources) of radio-loud AGN and star forming galaxies.

We combine FIRST and NVSS sources into a single catalogue, which is cross-correlated with WISE and 3XMM using a Bayesian Chi-square based cross-match tool developed by F.-X. Pineau (Pineau et al. 2015, in prep., see also Pineau et al. 2011 A&A 527 126). We excluded extended X-ray sources and those with low Galactic latitude (|Bii|<20) to minimise confusion. Then imposed quality constraints for 3XMM (DET_ML>10), WISE (S/N>5 for W1, W2, S/N>3 for W3), and FIRST/NVSS (sidelobe probability <0.1). We then cross-correlate with SDSS to get redshifts.

The presence of radio emission allows us to cleanly select both AGN and star forming objects, discriminating against the far more numerous, "passive" galaxies. We are selecting fainter AGN where the host colours dominate in the c/c WISE plot, and the fainter, soft X-ray emission might not pass the luminosity and hardness ratio cuts commonly required in X-ray selected samples.

Star formation also produces radio emission, albeit at a much fainter level. This allows us to select a population of nearby star forming galaxies, and explore the correlations for both star formation and AGN activity in the three selected bands.

The mid-IR data allow us to best constrain the AGN luminosity, and the X-ray selection allows us to probe deeper, and with less bias on terms of line classification, than an optically selected sample would do.



Above: 3XMM 2-12 keV flux versus WISE 12 micron magnitude diagnostic plot, illustrating that, even without redshifts, it's possible to triage sources into distinct populations.
AGN-dominated and SF-dominated sources appear on two clearly distinct branches. Objects with spiral galaxy mid-IR colours (probably radio-loud Seyferts) bridge the gap between both populations. Most of the objects with elliptical colours are systematically fainter in both bands; these objects are likely to harbour LINER-like (radiatively inefficient, or ADAF) sources.

Conclusions

In our preliminary results we observe clear trends in the AGN radio/X-ray, radio/mid-IR and mid-IR/X-ray correlations. We observe similar results for the expected SF correlations, allowing us to disentangle both contributions for different populations in our sample and create diagnostics that can be used even when redshifts are unavailable.

We also observe the expected scatter in the jet/radiative output that clearly points towards a mediating mechanism that regulates the jet, and we are able to identify a group of X-ray and mid-IR faint, radio-bright sources which are most likely LINER-like (ADAF). These results could not be achieved with standard AGN selection criteria.