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Combing the WISE W4 catalogue and the Gaia Data Release 1: Searching for Infrared bright, optically faint objects across the full sky

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ABSTRACT
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Key words: galaxies: clustering – luminous red galaxies: general – cosmology: observations – large-scale structure of Universe.

PREAMBLE

All the code and plotting packages, and smaller catalogues are available at `https://github.com/d80b2t/WW4C`. The .tex and PDF file can be found `here`.
The four 'obvious' files that aren't on the GitHub are::
GaiaDR1xWISEw4_10as_noDupes_sorted.csv (1.1G);
WISE_W4_DecOrdered.dat (1.4GB);
WISE_W4_cat_with_GaiaNull.csv (2.6GB);
WISE_W4_cat_with_Gaia.csv (3.2GB).

1 INTRODUCTION

Extremely Red Quasars (ERQs; Ross et al. 2015; Hamann et al. 2017) are a unique obscured quasar population with extreme physical conditions related to powerful outflows across the line-forming regions (Zakamska et al. 2016; Alexandroff et al. 2017). These sources are the signposts of the most extreme form of quasar feedback at the peak epoch of galaxy formation, and may represent an active "blow-out" phase of quasar evolution. The energetics of luminous AGN, i.e. quasars, is thought to be a major ingredient and physical process in galaxy formation and evolution, vital for suppressing, or "quenching" star-formation and leading to the population or red galaxies seen in the local Universe. As such, a great deal of effort has gone into identifying the sites of the so-called "AGN feedback" , (e.g., Cano-Díaz et al. 2012; Page et al. 2012; Maiolino et al. 2012; Cicone et al. 2014; Harrison et al. 2014; Zakamska & Greene 2014; Harrison 2017) and (Fabian 2012; Kormendy & Ho 2013; Heckman & Best 2014; Netzer 2015; King & Pounds 2015; Naab & Ostriker 2017) for relevant reviews. Motivated by the ERQs, we are interested in finding further infrared bright, optically faint, high-z quasars.

The WISE W4 23μm band is shallow. Therefore, anything that is detected in W4, and is *not* a Milky Way star, or nearby e.g. dusty spiral galaxy, is going to be intrinsically very luminous. Furthermore, objects that are also detected in W4, but are faint/non-detected in the optical, or in the shorter WISE W1/W2 bands also have very interesting properties, (e.g., Assef et al. 2015; Tsai et al. 2015; Lonsdale et al. 2015; Assef et al. 2016; Díaz-Santos et al. 2016; Ricci et al. 2017; Wu et al. 2017; Jones et al. 2017; Farrah et al. 2017). The WISE W4 band is also crucial in the discovery and characterization of the "Extremely Red Quasar" population, using a colour selection of $r_{\rm AB} W4_{\rm Vega} > 14.0$ (Ross et al. 2015; Zakamska et al. 2016; Hamann et al. 2017). The WISSH Quasars project (Bischetti et al. 2017; Duras et al. 2017; Martocchia et al. 2017) is also focusing on WISE/SDSS selected "hyper-luminous" broad-line quasars at $z \approx 1.5 - 5$.

Singal et al. (2016) LaMassa et al. (2017) Toba et al. (2015) Toba & Nagao (2016) Toba et al. (2017)

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Note, the W4 channel effective wavelength was recalibrated from the original 22μm by Brown et al. (2014).

2 MATCHING THE GAIA DR1 AND WISE W4 CATALOGS

2.1 WISE

The Wide-field Infrared Survey Explorer (WISE) mission description and initial on-orbit performance is described in Wright et al. (2010). We use the `AllWISE Data Release`.

There are 40,939,966 objects, with $> 2\sigma$ detections at WISE W4 in the AllWISE Catalog. The W4 PSF is 12", but the centroid positions should be good to $\lesssim 2''$ (WISE HelpDesk, priv. comm.). Figure 1 shows the sky distribution of these 40.9M objects. The WISE scanning pattern can clearly be `seen`.

2.2 Gaia DR1

We use the `Gaia Data Release 1`. (Gaia Collaboration et al. 2016,?)[1]

The Gaia DR1 magnitude histogram peaks around 20th magnitude in G-band. The G-band is a very wide filter, that covers the wavelength range frthat covers the wavelength range from about 350 to 1000nm, with the maximum energy transmission at ∼715 nm and the full width at half maximum of 408 nm. (Jordi &. Carrasco, 2007, ASPC, 364, 215).

There are 1,142,679,769 sources in total in the Gaia DR1.

2.3 Matching

We match the two catalogues with a matching radius of 2" and 10". This is done using some v. nice and quick code from R. Collins [More details required here]. The results are given in Figure 2 and Figure 4. Figure 3 shows the WISE W4 Unique ID (UID; which isa a proxy for object declination) versus the Gaia DR1 Source ID.

3 RESULTS OF MATCHING

The matched 10" GaiaDR1xWISEW4 catalogue returns 71,593,922 objects since one-to-many (WISE-to-Gaia) matches are allowed. The Python `numpy unique` command is used to return the sorted unique elements of this catalogue. 24,671,865 WISE W4 objects have a unique match with a Gaia source within 10".

Thus, 16,268,101 objects in the WISE W4 catalogue do not have a

Figure 4 shows the matching radius separation histograms for objects, with and without duplicates.

Figure 5 (top) shows the all-sky distribution for the full 40.9M objects that are detected in WISE W4 (same as Figure 1 but with a different colour-scale). Figure 5 (middle) shows the all-sky distrubtion of objects that were matched to a Gaia DR1 source. The overdensity of the Milky Way is clearly seen. Figure 5 (bottom) shows the 16.3M objects that do *not* have a match in the Gaia DR1.

Name	Mean	σ	Min.	Max.
W4_no	2.0469982E7	1.181835E7	0	40939965
RA	198.89731	98.82655	1.9600E-5	359.9998663
Decl	-4.5770774	41.878914	-89.9769927	89.9673322
uid	2.4711034E7	2.592262E7	-1.0	7.1593991E7
Gaia_ID	2.42485497E18	2.43082065E18	-1.0	6.917528718403911
radius	-0.35169324	0.52868944	-1.0	0.16666666

Table 1. WISE_W4_cat_with_Gaia. $N_{\rm Good} = 40939966$.

[1] I don't know how to fix this citation.

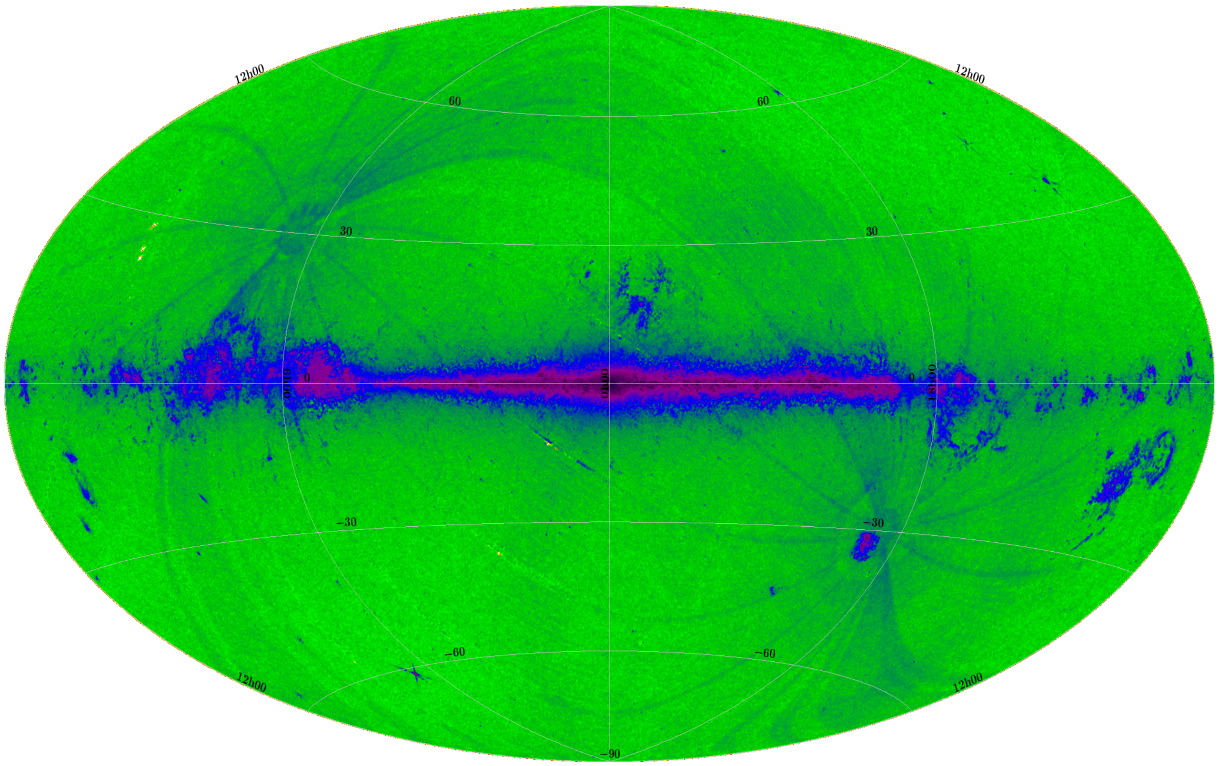

Figure 1. The all-sky distribution of the 40.9M objects in the AllWISE W4 catalog. The WISE scanning pattern can clearly be seen.

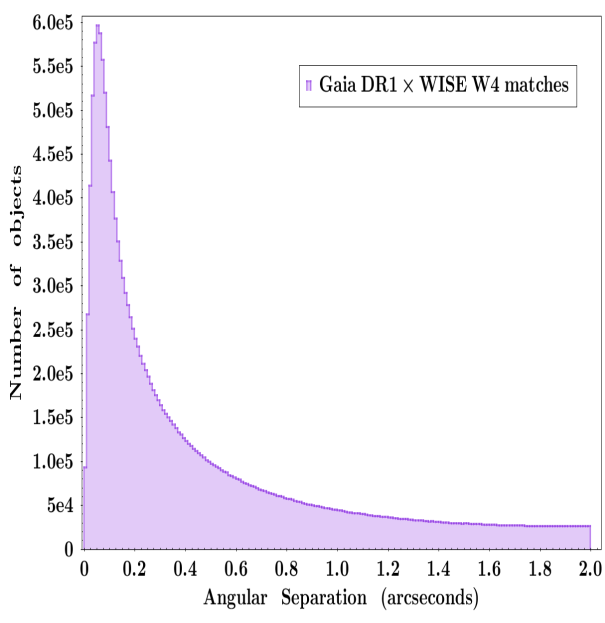

Figure 2. The matching radius separation histograms for objects, when a 2" matching radius is applied.

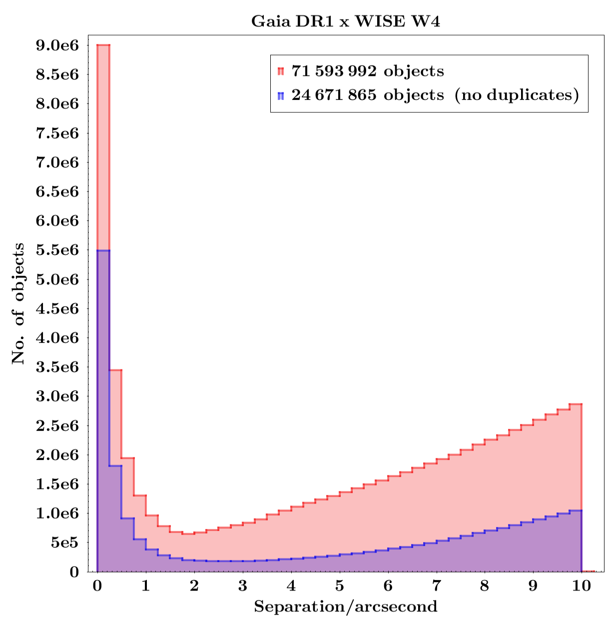

Figure 3. The matching radius separation histograms for objects, when a 10" matching radius is applied, with and without duplicates.

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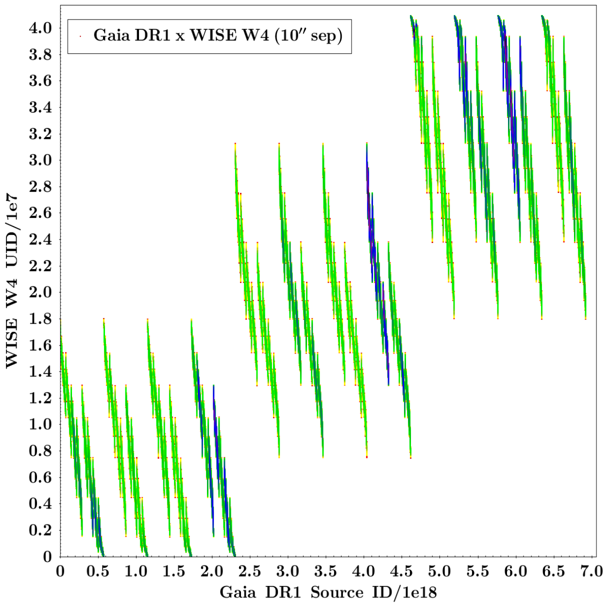

Figure 4. The WISE W4 Unique ID (UID; which isa a proxy for object declination) versus the Gaia DR1 Source ID.

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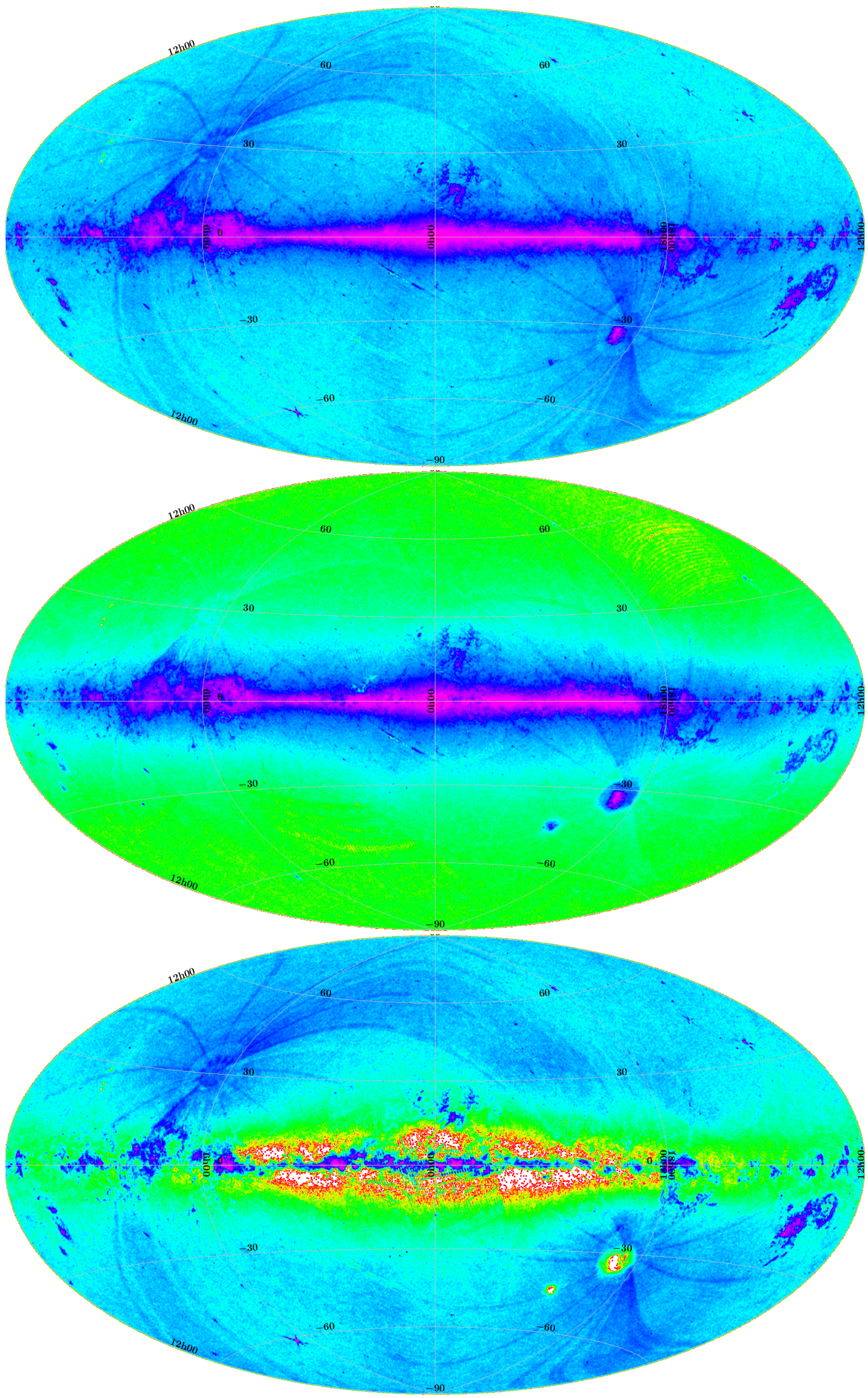

Figure 5. Three aitoff projects for the Gaia DR1×WISE W4 matched catalog. *Top:* The full 40.9M objects that are detected in WISE W4. *Middle:* The 24.7M WISE W4 objects that are matched to a Gaia DR1 source. *Bottom:* The 16.3M WISE W4 objects that are not matched to a Gaia DR1 source.