# Environments of Luminous Infrared Radio-WISE Selected Galaxies

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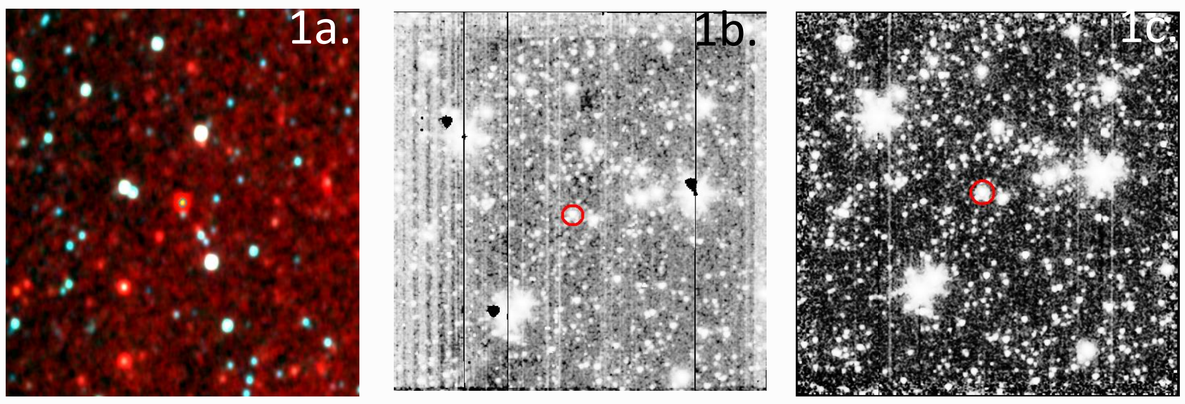
We investigate the environments of some of the most luminous infrared active galaxies in the Universe, found by combining radio and WISE mid-IR surveys. We use Spitzer imaging to measure the overdensity of companions with respect to blank fields, after using mid-IR colour selection to highlight companions plausibly at z>1.3, like the selected ultraluminous radio-WISE targets. We measure the radial distribution of potential companions around the targets, and see a significant overdensity of redder Spitzer objects in these radio-WISE selected fields, consistent with a pre-virialized cluster.

## Radio-WISE Selected Sources

Objects have been detected with steep (red) mid-infrared colours from WISE and compact radio emission from NVSS/FIRST (Lonsdale et al, 2015). These objects have high $L_{8\mu m\text{-}SCUBA2} > 10^{13}\ L_{\odot}$ (Jones et al, 2015), and are thus extremely luminous in the mid- to far-infrared.

Previous work has shown that Ultra-Luminous Infrared Galaxies (ULIRGs) and radio galaxies reside in overdense environments (Stern et al, 2003, Best et al, 2003, Galametz et al 2012, Wylezalek et al, 2014). These targets also inhabit extremely dense regions in the sub-millimetre, with overdensities of submillimetre galaxies (SMGs) of 4-6 with respect to blank fields (Jones et al 2015).

Using Spitzer's Infrared Array Camera (IRAC), we attempt to investigate the relative overdensities of fields containing these objects in the infra-red (see Fig 1).



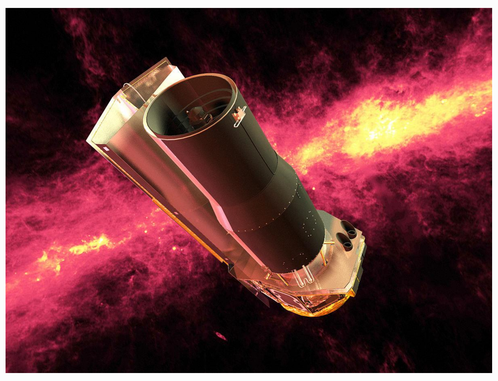

**(Fig 1a. (Left) Example WISE multi-band image centred on a radio-WISE selected object. Fig 1b. (Centre) 5'x5' IRAC1 image centred on the same radio-WISE selected object. Fig 1c. (Right) IRAC2 image of radio-WISE selected object.)**

## Spitzer's IRAC

Since the end of its cold mission, Spitzer has two operational channels, IRAC1 (3.6µm) and IRAC2 (4.5µm).

Both channels were used to target 33 fields centred on the positions of radio-WISE selected objects for 1400s each.

This produced 5'x5' fields, which could be used to determine overdensities of the environments of radio-WISE targets.



**Spitzer Space Telescope: NASA/JPL-Caltech/R. Hurt (SSC)**

## References

Best P. N., et al., 1998
Stern D., 2003
Bruzual G., & Charlot S., 2003
Papovich C., et al 2008
Galametz A., et al., 2012
Jones S. F., et al., 2015
Lonsdale C. J., et al., 2015
Penney J. I., et al 2018

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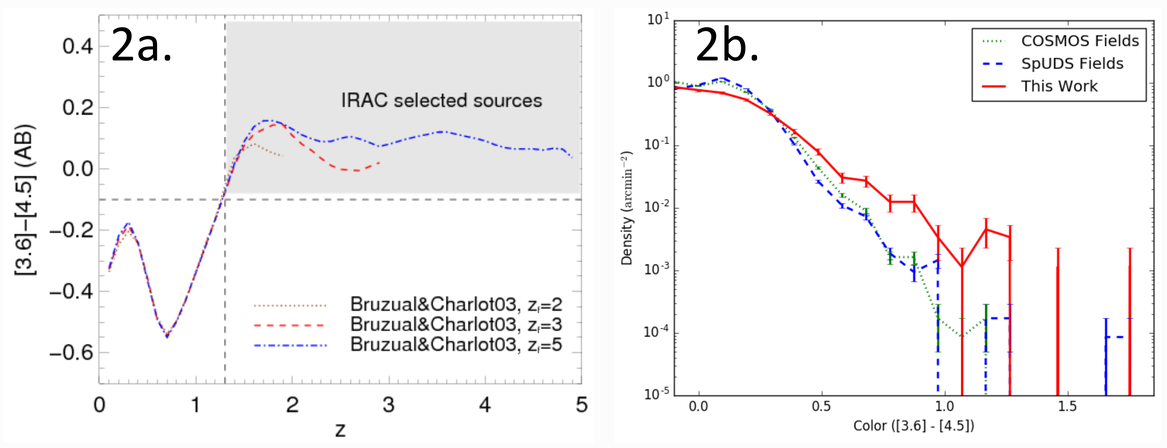
## Colour Selection and Results

Upon image reduction and source extraction, we selected objects based on the [3.6]-[4.5] colour and the completeness limits of our survey ([3.6]=21.70, [4.5]=21.44). Previous work by Papovich et al, 2008, found that most objects with [3.6]-[4.5]>-0.1 had redshifts z>1.3 (see Fig 2a.)




**(Fig 2a. (Left) Bruzual & Charlot (2003) models for the shift of the 1.6µm bump, which can be used to select galaxies with z>1.3. Fig 2b. (Right) Comparison for density of fields with respect to IRAC colour.)**

We then compared the density of objects in our fields with blank-fields from SpUDS and S-COSMOS (see Fig 2b). We see that there is a significant overdensity of redder objects ([3.6]-[4.5]>0.5) in the radio-WISE selected fields, **suggesting that these objects inhabit increasingly overdense regions of progressively redder Spitzer galaxies**.

## Clustering Results

We find no significant overdensity of [3.6]-[4.5]>-0.1 sources in the fields, however, we find that **79% of fields are denser than the average SpUDS field**, with ≳110 sources per field, suggesting that these fields are generally denser than expected.

We find a significant overdensity of [3.6]-[4.5]>0.4 sources in the radio-WISE selected fields, with **33% of fields exhibiting densities >5σ** with respect to comparison fields when fitting the SpUDS fields with a Gaussian profile, shown in Fig 3a.

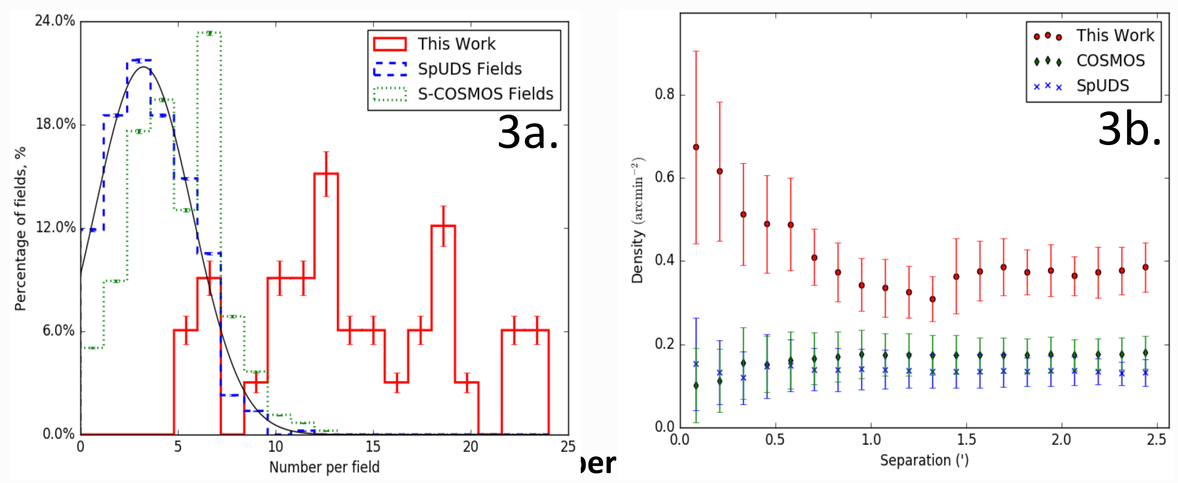



**Fig 3b. (Right) Stacked radial distribution of redder sources from the centre of the field.)**

We see a general overdensity in the radial distribution of sources across the field, with **a significant peak within 0.5' in the distribution towards the central radio-WISE selected source** (see Fig 3b). This suggests that the redder selected objects are preferentially clustering around the central sources. Interactions could be responsible for their redder features.