Colour Matters

Lensing, confusion, and the identification of counterparts to SMGs in H-ATLAS

Nathan Bourne, Institute for Astronomy, Edinburgh

Motivation & Abstract

Sensitive sub-millimetre (submm) telescopes such as *Herschel* and JCMT detect faint populations of submm galaxies (SMGs) throughout the history of the Universe, but this is a double-edged sword when the ubiquitous blending and confusion in their low-resolution images leads to ambiguous counterpart identification in multi-wavelength surveys. We find that the positional offsets between *Herschel*-ATLAS[1] SMGs and optical counterparts in SDSS[2] depend on the submm colour, and we investigate what this can tell us about the effects of lensing and confusion on the identification of true counterpart matches.

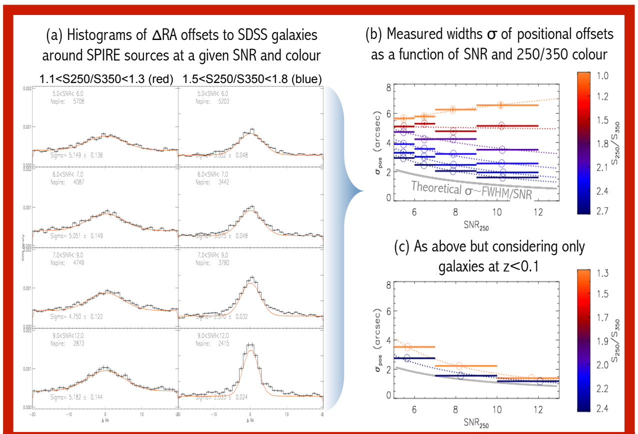


Figure 1. (a) Histograms of the offsets from each *Herschel*-SPIRE source to *all potential counterparts* at a given separation in SDSS. We create these histograms in ΔRA and ΔDec for SPIRE sources in several bins of 250μm signal-to-noise ratio (SNR) and colour (250/350μm flux ratio), fitting a Gaussian positional error function plus power-law cross-correlation. (b) The best-fitting Gaussian width (σ_{pos}) follows a smooth function of SNR and colour, yet submm positions are derived from the 250μm maps and are independent of 350μm measurements. This means that the real offsets between SMGs and associated optical galaxies behave differently depending on SMG colour. (c) The effect of considering only SDSS galaxies with photometric redshifts z<0.1.

Positional Offsets to candidate matches

We measure the offsets of all potential SDSS counterparts to H-ATLAS SMGs as shown in Fig. 1, allowing for the following contributions:

- True counterparts with offsets described by Gaussian positional errors
- Clustered galaxies with offsets described by the cross-correlation function

Theoretically we expect the width of the Gaussian to depend only on the 250μm detection: $\sigma_{pos} \sim$ FWHM/SNR,[3,4] but our results indicate an increased width for redder SMGs, suggesting either that their positional errors are larger or that there is some additional contribution to the offsets distribution that has not been considered. What could be responsible?

- Galaxies which are slightly resolved at 250μm may appear redder in point-source photometry and have larger positional errors. But we still see the effects when matching only high-redshift galaxies which cannot be resolved.
- Instrumental effects can increase positional errors. But this effect would not be stronger for redder sources selected from 250μm positions.
- Confusion could bias the colours and the positional errors. Are red sources a more clustered population which suffer greater confusion/blending at longer wavelengths and have greater positional errors as a result?
- What if the optical associations are not genuine counterparts at all? Foreground lenses which magnify high redshift (hence red) SMGs may themselves be identified as the counterpart.[5,6]

Interpretation

The only two likely explanations are that the **positional errors of red sources are increased due to clustering and confusion, or that the offset distributions are contaminated with lenses in the line of sight to distant red SMGs.**[7,8] Properties of the optical counterparts (Fig. 2) show that red sources are associated with galaxies at higher redshifts, but otherwise do not help distinguish the two scenarios. However, restricting the analysis to only galaxies at z<0.1 reduces the increased offset for red sources (Fig 1c), consistent with the expectations of a small lensing probability at low redshift.

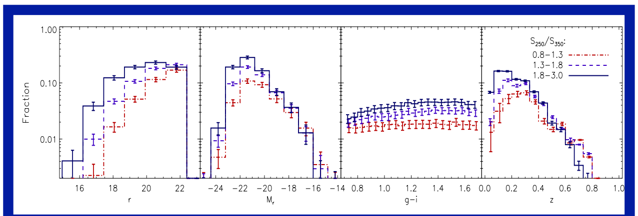
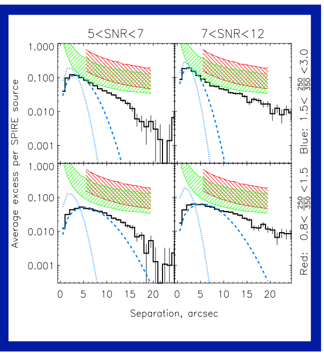


Figure 2. Distributions of r-band magnitude, absolute magnitude, g-i colour and redshift for the optical associations of SPIRE sources, as a function of submm colour.

Strong lensing is known to be common among the brightest SMGs,[5] but weak lensing is much more common and could be important for a large fraction of all high-redshift SMGs. In Fig. 3 we compare the observed offset distribution to the prediction from a simulation[9] in which randomly distributed high-z SMGs are weakly lensed by foreground SDSS galaxies and large-scale structure. **Results indicate that weak lenses comprise a strong contribution to the SDSS associations around red SPIRE sources, relative to the true counterparts.**

Figure 3. Distribution of radial offsets to SDSS associations around 250μm sources in SNR & colour bins. Blue lines indicate theoretical (dot) and measured (dash) positional error functions. Hatched regions show a range of lensing-excess predictions from the simulations for sources extracted at 350μm with limits from 5-30mJy; green=galaxy-galaxy, red=cluster-galaxy lenses. Their distribution and normalization are clearly sufficient to alter the distribution of apparent associations to red SPIRE SMGs.



Conclusions & Implications

- The positional offsets between SMGs and their optical associations show a smooth dependence on submm SNR (or flux) and colour. **Evidence suggests that weak lensing could be responsible for boosting the distribution of low-z galaxies around high-z (red) SMG positions. If this is the case then the results imply widespread lensing of SMGs of F_{250}>30mJy, consistent with recent results from correlation studies.**[9-11]
- The problem of mis-identifying a galaxy in a lensing structure as the counterpart to a higher redshift SMG may be much more common than previously thought.
- It is also possible that source clustering increases errors in the extracted positions of SMGs.
- **It is important to understand both issues to reliably identify optical counterparts to SMGs in *Herschel* and other single-dish submm surveys, and hence to correctly derive redshift distributions and luminosity functions.**

Further work is needed to simulate the effects of clustering on the colours and positional errors of SMGs and to observationally confirm the prevalence of (weak) lensing in statistical samples of red, intermediately-bright SMGs.

References:
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