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Exploring the environments of SMGs: a wide-field narrowband study

I. Introduction

Submillimeter galaxies (SMGs) are massive galaxies that are extremely bright at sub-mm wavelengths. They are typically at $z \sim 2$–4 and have star formation rates of ~1000 $M_\odot$/yr.

SMG redshifts, masses, and star formation histories are consistent with them being the elusive progenitors of local massive early-type cluster galaxies. SMGs are thus expected to reside in protocluster environments, but this hasn't yet been properly tested.

Whilst previous studies have found individual SMGs in protoclusters, these were selected for follow-up due to being in overdensities and thus such studies can't tell us about the overall SMG population (e.g. Casey et al., 2015; Oteo et al., 2018). Statistical clustering measurements are promising, but are challenging to interpret due to heavy reliance on photometric redshifts and/or single-dish sub-mm surveys (e.g. Hickox et al., 2012; Wilkinson et al., 2017).

Instead, we use HAWK-I/VLT wide-field narrowband data to investigate the environments of three SMGs, selected based only on redshifts and **with no prior knowledge of their environments**.

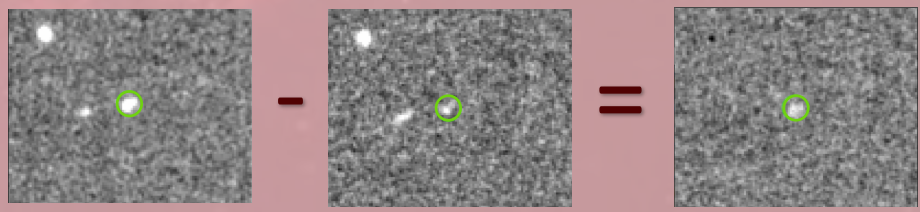
II. Data

The data cover two 7.5′×7.5′ pointings containing three ALMA-identified, spectroscopically confirmed SMGs from ALESS (Hodge et al., 2013):

- ALESS 075.2 ($z = 2.294$) } Pointing 1
- ALESS 102.1 ($z = 2.296$) }
- ALESS 005.1 ($z = 3.303$). } Pointing 2

Each pointing was observed through a broadband (BB) filter and a narrowband (NB) filter to identify Hα and [OIII] emission at $z \sim 2.3$ and $z \sim 3.3$ via their colour excess (see Figure 1).

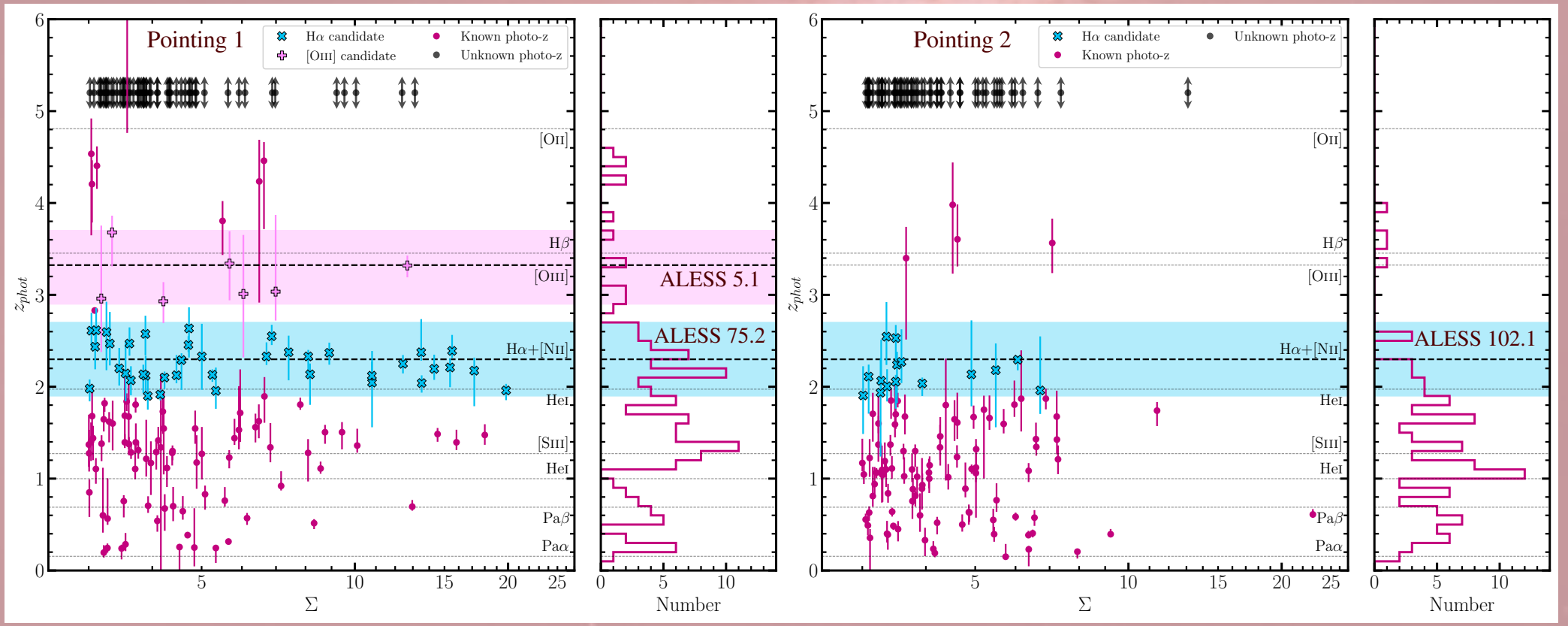
Figure 1: Example of an SMG companion selected using our NB data. Galaxies at the same redshifts as the SMGs are bright in the NB filter compared to the BB filter because of Hα emission ($z \sim 2.3$) or [OIII] emission ($z \sim 3.3$).



III. Identifying Companion Galaxies

Photometric redshifts are used to distinguish Hα and [OIII] emitters from low-redshift interlopers. Figure 2 shows the redshifts of our candidate line emitters as a function of **Σ**, which describes the significance of a source's narrowband excess based on the photometric errors (see e.g. Bunker et al., 1995).

Figure 2: Photo-*z* distributions of our line emitters in each of the two pointings. Candidate companions to the three SMGs are highlighted in blue (Hα candidates at $z \sim 2.3$) or pink ([OIII] candidates at $z \sim 3.3$). Black points indicate line emitters with no clear counterpart in the photo-z catalogue. 39 and 17 Hα candidates around ALESS 75.2 and ALESS 102.1 are identified in Pointings 1 and 2, respectively; 7 [OIII] candidates associated with ALESS 5.1 are identified in Pointing 1.



IV. Mapping the SMG Environments

To visualise the SMG environments, we plot the positions of the SMGs and their companions (see Figure 3). Whilst a typical protocluster would extend well beyond the HAWK-I field of view (see Figure 4), we can see how the companion galaxies are distributed within a few Mpc of each SMG.

Figure 3: The positions of our Hα and [OIII] candidates on the sky, as well as those of the target SMGs.

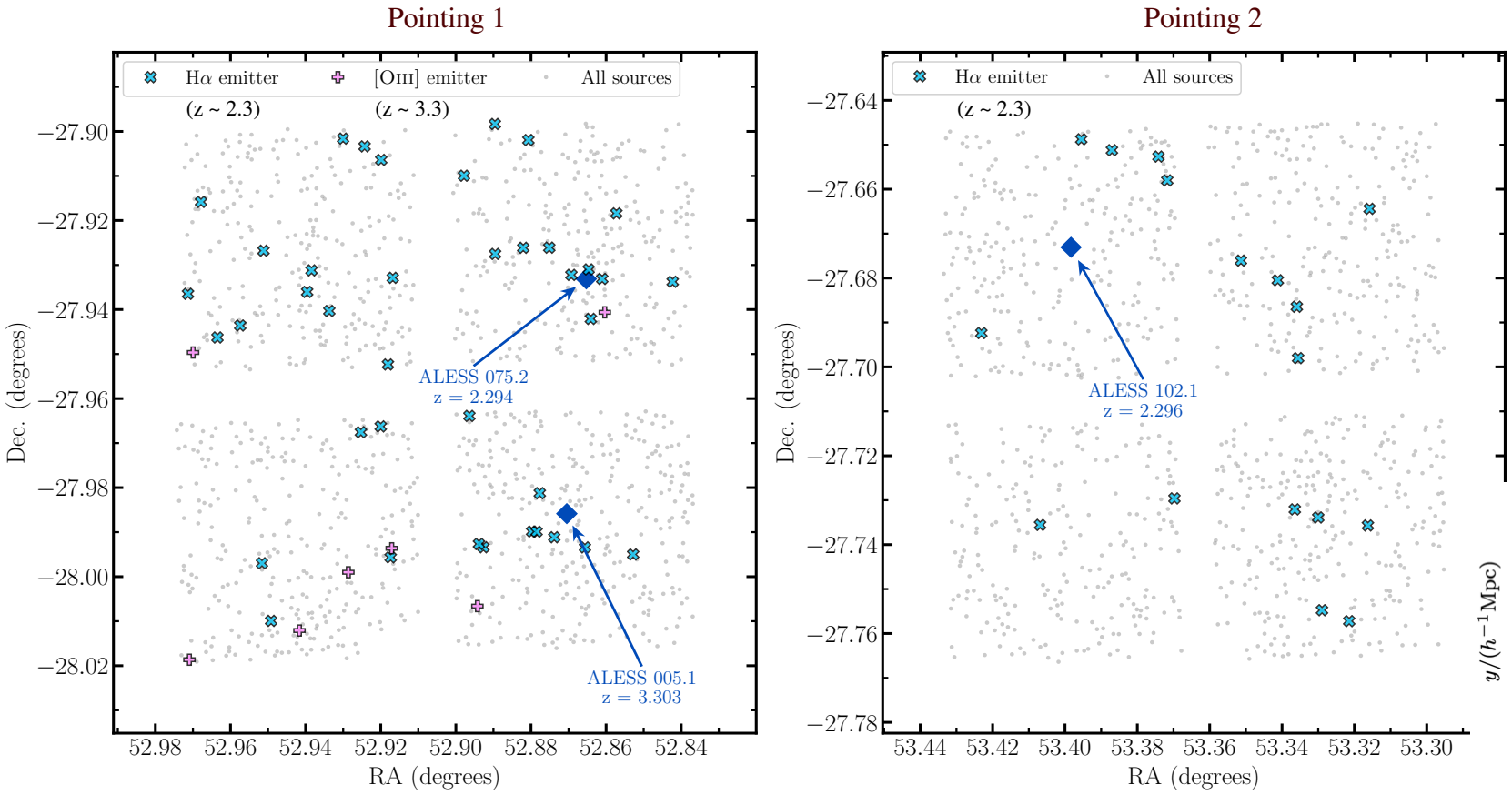
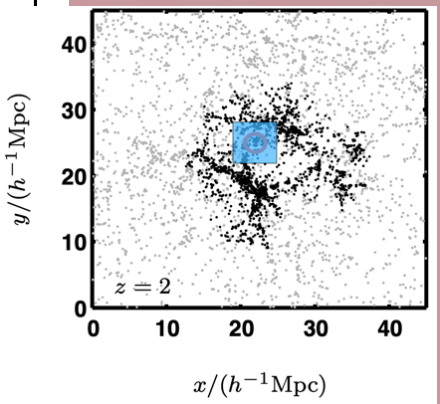


Figure 4: A simulated protocluster at z = 2 (Muldrew et al., 2015). Black points indicate member galaxies. The blue square represents the HAWK-I field of view (~8×8 Mpc at z = 2), which covers only a fraction of the protocluster.



V. Luminosity Functions

We bin our Hα and [OIII] emitters by line luminosity and compare their number densities with those obtained from blank field studies (Sobral et al., 2013; Khostovan et al., 2015; purple curves in Figure 5).

The SMG fields appear significantly ($\gtrsim$5×) denser than the blank fields, consistent with the hypothesis that SMGs are an early stage in the evolution of local early-type galaxies. Completeness corrections will likely enhance the effect.

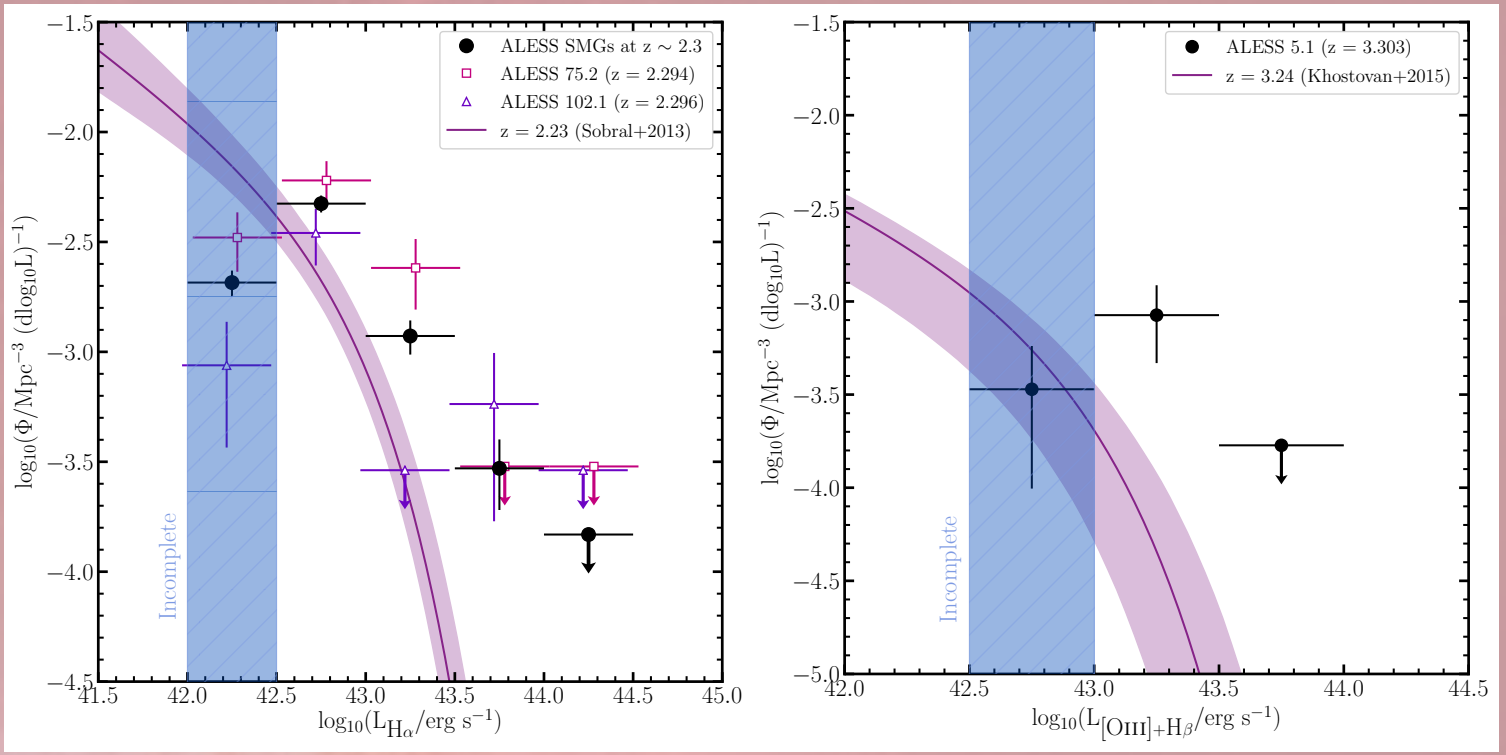


Figure 5: Luminosity functions for the Hα *(left)* and [OIII] *(right)* emitters near the target SMGs. The SMG fields appear significantly overdense compared with the blank fields.

VI. Conclusions

We have conducted a wide-field narrowband study in search of star-forming galaxies around three SMGs, with no prior knowledge of their environments.

Our results imply overdensities of star-forming galaxies around the SMGs. This suggests that SMGs do typically reside in protoclusters, and are thus consistent with being the progenitors of local massive early-type cluster galaxies.

References

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Oteo et al., *ApJ*, **856**, 72 (2018)
Sobral et al., *MNRAS*, **428**, 1128 (2013)
Wilkinson et al., *MNRAS*, **464**, 1380 (2017)