Introduction

• Today’s (r=1) massive clusters of galaxies are made of passive “red and dead” galaxies. Going to earlier times the fraction of star-forming galaxies in dense regions increases [eg Elahi-07, Popesso-12]. The SPIE density peaks at r=2-3 (Hopkins & Beacom 04), but we cannot talk about clusters from an observational point of view as they are still forming and not yet in shape to be easily detected [eg of Virginal].

• Different signposts are used as tracers of these protoclusters: powerful radio galaxies and QSOs [Allley & Breckin 2008 for a review] or submm detected (S(G)K)S galaxies (eg Chapman-09).

• To confirm a protocluster a number density excess of galaxies at a similar redshift to the radio galaxy/QSO or SMG is reported: galaxies identified using lma for other redshifts (or optical, Kunz-04, Koynay-14), narrow band imaging or NIR colour selections (eg Haga-11), submm imaging (Ganguly-15).

• The high-redshift and the foreground/background contamination make the search for protoclusters in bands impossible.

• If there is no colour information, spectroscopy or accurate photometric redshift. None of the protoclusters known to date can be visually identified in a broad band map from Spitzer or other ground-based or space facilities.

• Overdensities of star-forming galaxies in broad-band maps should exist, based on the physically motivated framework: Protoclusters of galaxies and overdensities of star-forming sources in the environment of the peak (see Fig.3).

• Protocluster fields, especially those around the peak of the SPIE density, are the natural location to search for such overdensities.

The Spiderweb protocluster

• Herschel PACS and SPIRE imaging as part of the HER (guaranteed time P1-2, Altieri).

• PACS maps at 100 and 160 µm and 500 µm cover only ~5’’ around the radio galaxy.

• SPIRE maps in 250, 350 and 500 µm cover a larger region: ~20’’ radius, down to the extragalactic confusion noise. There are also 12 SPIRE observations in the larger field [see Right+11].

• Standard SPIRE map making with HiPE v10, using the deteriorator and also including the telescope tumbler data.

• SPIRE maps were inflated to match Spitzer/MIPS 24µm acrosstet (only in the centre).

• SPIRE maps depths: 68, 8.3, 7.4 Jy beam’’ (250, 350, 500 µm close to WIPAC-10 limits).

• SPIRE source detection: using SExtractor (STF, Smith-12). In the Spiderweb field we detect 871 sources in 250 µm map, above a signal-to-noise ratio of 3. There are 366 sources at relative abundance above 50%.

• SPIRE 250 µm sources are used as priors on the SXT map on 250 and 500 µm maps.

• SPIRE extragalactic control fields:

  • GOODS-North, Lockman, COSMOS and UDF from Herschel [see Oliver-12 for overview],
  • Trimmed down to the same depth (same map repetitions) and applying the same map making and source detection with SExtractor.

Overdensity of SPIRE 250 µm sources

Serendipitously identified as a visually compelling clump of a large number of 250 µm sources in the Spiderweb field at ~7’ south of the radio galaxy [see Fig.1]. Only the SPIRE data available and shallow all sky survey data from WISE (Kirk-10).

• To quantify it we make use of an adaptive kernel density estimate (ADE), as PseudoW and compare it with ADE from fields of randomly distributed sources, as well as the ADE results from the four control fields.

• Results:

  • ADE peak is at 5.5 to with respect to the background
  • 2 of 100 fields of randomly distributed sources we detect similar or higher significance ADE peak (range from 3 to 5.5). We do not check the size of the 2.5 > 0.01%
  • No ADE peaks at similar contrast in the control fields, the max ADE at 4.6 in Lockman. None of the ADE results above 2.5 come from known protostructures.

  • Definition of the overdensity: ADE peaks at (1.15, 5.5, 44.1, 26.5, 31.5, 0.03), size = 3.5’’ (for contours). For the analysis we use slightly offset centre (11.0, 39.5, 3.25, 31.5) and radius of 4’’ (the red circle in Fig. 3).

Surface density excess

• There are 76 (85% of 250 µm sources within the overdensity ~ 1.5±0.17 arcmin’’

• There are 41 at 250 - 30 µm > 5.5±0.69 arcmin’’

• Protoclusters: PACS at 100 (2 arcmin’’ at 4’’ radius) with 250 > 20 µm. This is a factor of 3.4 excess of the overdensity vs the fields.

• From control fields: in 100 random regions of 4’’ radius max number of sources with 250 > 250 - 10 µm are 42 in COSMOS (15 in GOODS-North, 31 in UDS and 31 in Lockman, on average 20+4 in 4’’ regions, still a factor of 2 excess.

• Control fields: 4’’ regions with smaller number of sources can be found, but they do not correspond to ADE peak above 1.5σ – the overdensity is more centrally concentrated.

Results

• Surface density excess

- The same SPIE distribution of some control fields as well as with the number counts from Beltzer-12 indicates a marginal excess in the 30-40 µm bins: while we detect 4, 4.2±0.2 in the fields (and 4.3±0.1 from Beltzer-12).

• FIR colours and dust reddening

- With m 3.7 FIR photometric priors the detection of photo-z is challenging (eg. Lapi, Galametz-13).

- We fit a modified blackbody with a fixed dust temperature (~25 K, Ganguly-12). Examples are shown in Fig. 6.

- The best fit reddening and the observed IR flux density distribution (Fig. 5) is consistent with a fixed dust temperature.

Discussion and conclusions

• Serendipitous detection of a significant (>5σ) overdensity of 250 µm sources.

- First report on such a discovery, more to come.

- Herschel follow up of Planck sources revealed that some of them are also overdensities of sources (Clements+11), in 4 out of 16 Planck sources.

- Detection of two overdensities in 26 fields around powerful radio galaxies (Clements+13).

- No similar structures are identified in four wellknown extragalactic control fields.

- Similar AKDE peak occurs in 2 out of 100 simulated fields with randomly distributed sources (same number and same field geometry).

- Close to a known protocluster, at ~7’ south (~10 Mpc comoving).

- If we fix Td to 38 K then zbb peak will be at 2.2 (z-t degeneracy).

- There is already a reported large-scale filament (10 Mpc comoving) North of the Spiderweb (Koyama-13), can this be a southern extension?

- Other possibilities:

  • Chance alignment of star-forming galaxies?

  But then the colours (by means of the zbb), the significant surface density excess and the space distribution are quite unusual. <= follow up needed.

- Protocluster complex with no link to the Spiderweb to spectrally needed.

- Too scarce multi-wavelength data to make any strong statement but none of these hypotheses can be discarded with the currently available data. Follow-up needed to make any progress.