An Excess of Dusty Starbursts at z=2.2

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1. Motivation:
Understanding when and how did present-day galaxy cluster form at high redshifts has been the science driver for the extensive search, especially at optical and near-infrared wavelengths, for protoclusters of galaxies in the distant universe in the past decade. Powerful high-redshift radio galaxies (see for more details the review by Milly & De Breuck 2008) are considered to be the most promising signposts of massive clusters in formation. The VLT survey of Lyα-emitters (LAEs), Hα-emitters (HAEs), Lyman Break Galaxies and Extremely Red Objects in seven fields containing radio galaxies at redshifts up to 5.2 provided in almost all cases evidence for galaxy overdensities associated with the central galaxy (e.g., Kurk et al. 2000, 2004ab; Pentericci et al. 2000; Venemans et al. 2007; Overzier et al. 2006; Milly et al. 2004).

2. Dust Star Forming Galaxies:
However, we note that these optical/NIR techniques mainly trace (rather low-mass) galaxies with unobscured star formation, making up only 50% of the cosmic star formation activity (Dole et al. 2006). In the last decade (sub)millimeter surveys have revolutionized our understanding of the formation and evolution of galaxies, by revealing an unexpected population of high-redshift, dust-obscured galaxies which are forming stars at a tremendous rate. Submm galaxies (see the review by Blain et al. 2002), first discovered by Small et al. (1997), have intense star formation, with rates of a few hundred to several thousands solar masses per year. These dusty starbursts are massive (e.g., Hatch et al. 2011), and excellent tracers of mass density peaks and thus of protoclusters. Studying SMGs offer us an unique opportunity to explore episodes of bursting star formation in a critical epoch of galaxy formation. Several studies has been carried out in the field of Hα-emitters and SMGs, all of them reporting excesses of SMGs (e.g., Stevens et al. 2003, 2010; De Breuck et al. 2004; Greve et al. 2007). However, in none of these cases the obligatory and time consuming identification work was properly done for the individual sources and presumably cluster members.

3. Results:
One of the best-studied large scale structures so far, is the protocluster associated to the HzRG MRC1138-262 at z = 2.16. Lying-imaging and Hα-imaging of this field revealed an excess of LAEs and HAEs compared to blank fields (Kurk et al. 2000, 2004ab; Pentericci et al. 2000; Hatch et al. 2011). Using the bolometer camera LABOCA at the APEX telescope, for a total of 40 hours of ESO-MPG time, we observed at 870µm a field of a diameter of 11.0 arcmin including the proper protocluster field and its surrounding, see Fig. 1. Thus, we extended significantly previous SCUBA observations by Stevens et al. (2003), who observed only the inner 2.0 arcmin part of the protocluster structure (covering a radius of only half a Mpc) and detected 3 sources. We detected a large number (18) of SMGs down to a 3σ noise level of 35µJy/beam, up to a factor 4 more than expected from blank field surveys as e.g. LESS at these wavelengths (e.g., Weiss et al. 2009). This excess is consistent with an excess of SPIRE 500µm sources in the same field of the radio galaxy reported by Rigby et al. (2014). We emphasize that the field of MRC1138 has an exquisite multi-wavelength dataset, close in quality to ECDFs and shows the region where all eight SMGs at z = 2.2 are located. The SMG overdensity is at least a factor four higher than expected from blank fields (Weiss et al. 2009), – based on six sources with identified tentative detections – with flux densities in the 149µm band of the protocluster structure at z = 2.2. The blue star is the SCUBA source at z = 2.149, also detected in CO(1–0) by Emonts et al. (2013). Cyan pentagons show possible protocluster members. In the case of yellow circles, no reliable judgment on the cluster membership can be made. Red crosses are sources that can be securely excluded from the protocluster. The large circle has a diameter of 33′′ (corresponding to a physical size 0.2 Mpc) and shows the region where all eight SMGs at z = 2.2 are located. The SMG overdensity is at least a factor four higher than compared to blank fields (Wolf et al. 2009) and not contained on the radio galaxy MRC1138 (DKB07). The spatial distribution of the SMG overdensity seems to be similar to the north-east and south-west filament-like structure traced by HAEs (plus symbols Kurk et al. 2004a; Koyama et al. 2013a) and in contrast to the location of passive quiescent galaxies clustered within 0.5 Mpc around the radio galaxy (red circles, filled if spectroscopically confirmed see Tacconi et al. 2013). In addition, we show the fields of view of our Spitzer IRAC MIPS, VLT FORS and Subaru MultiRS datasets. North is at the top and east is to the left.

References:

This artist's impression depicts the formation of a galaxy cluster in the early Universe. The galaxies are represented as blurred and interacting with each other. Such a scene closely resembles the Spiderweb Galaxy (formally known as M51) which is thought to be another formation of protoclusters. © ESO/M. Kornmesser