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 have 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 Miley & 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; Miley 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 Smail 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., Genzel et al. 2003; Greve et al. 2005), most probably the precursors of present-day ellipticals (e.g., Ivison et al. 2013) 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 HzRGs and QSOs, 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 identication 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. Lyα-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 870micron a field of a diameter of 11.0 arcmin including the proper protocluster field and its surrounding, see Fig. 1. Thus, we extended signicantly 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 (16) of SMGs down to a 3sigma peak ux of 3mJy/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 500micron 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 with a huge investment of telescope time (> 200 hrs.), including optical-NIR (VLT and Subaru), Herschel-PACS+SPIRE, Spitzer-IRAC, MIPS 24 m, deep HST and VLA 1.4GHz imaging, and VLT FORS2, ISAAC and SINFONI spectroscopy of protocluster members, see also Fig. 2.

We successfully detected Hα-line emission in four possible NIR counterparts of the LABOCA SMGs, all in the range 2.154 < z < 2.170. These results are consistent with the FIR-photometric redshifts we derived for these four SMGs. Including the radio galaxy, five of our 16 SMGs (DKB01, DKB03, DKB07, DKB12, DKB16) are spectroscopically members of the protocluster at z=2.2. In addition, we have evidence that another SMG in this field, early detected at 850miron (Stevens et al. 2003), has a counterpart exhibiting Hα and CO(1-0) emission at z=2.15 (Emonts et al. 2013). For another two SMGs our FIR-photo-z do suggest a membership as well. Our current data can exclude the membership for three sources. For the remaining five sources a judgement on membership cannot be done for the moment. Strikingly, all secure members of the protocluster structure at z=2.2 are located within a circle of 240 arcsecond diameter, corresponding to 2.0 Mpc at z=2.2. For comparison, our surface density is signicantly higher than the well known structure of six SMGs at z=1.99 in GOODS-N distributed over 7x7 Mpc^2 (Blain et al. 2004; Chapman et al. 2009). For this region, the excess of SMGs is at least a factor four higher than expected in blank fields. The facts that these SMGs are distributed within the filaments traced by the HAEs at z=2.2 but that the concentration of these massive, dusty starbursts is not centered on the HzRG may support the infalling of these sources into the cluster center.

This artist's impression depicts the formation of a galaxy cluster in the early Universe. The galaxies are vigorously forming new stars and interacting with each other. Such a scene closely resembles the Spiderweb Galaxy (formally known as MRC 1138-262) and its surroundings, which is one of the best-studied protoclusters. © ESO/M. Kornmesser

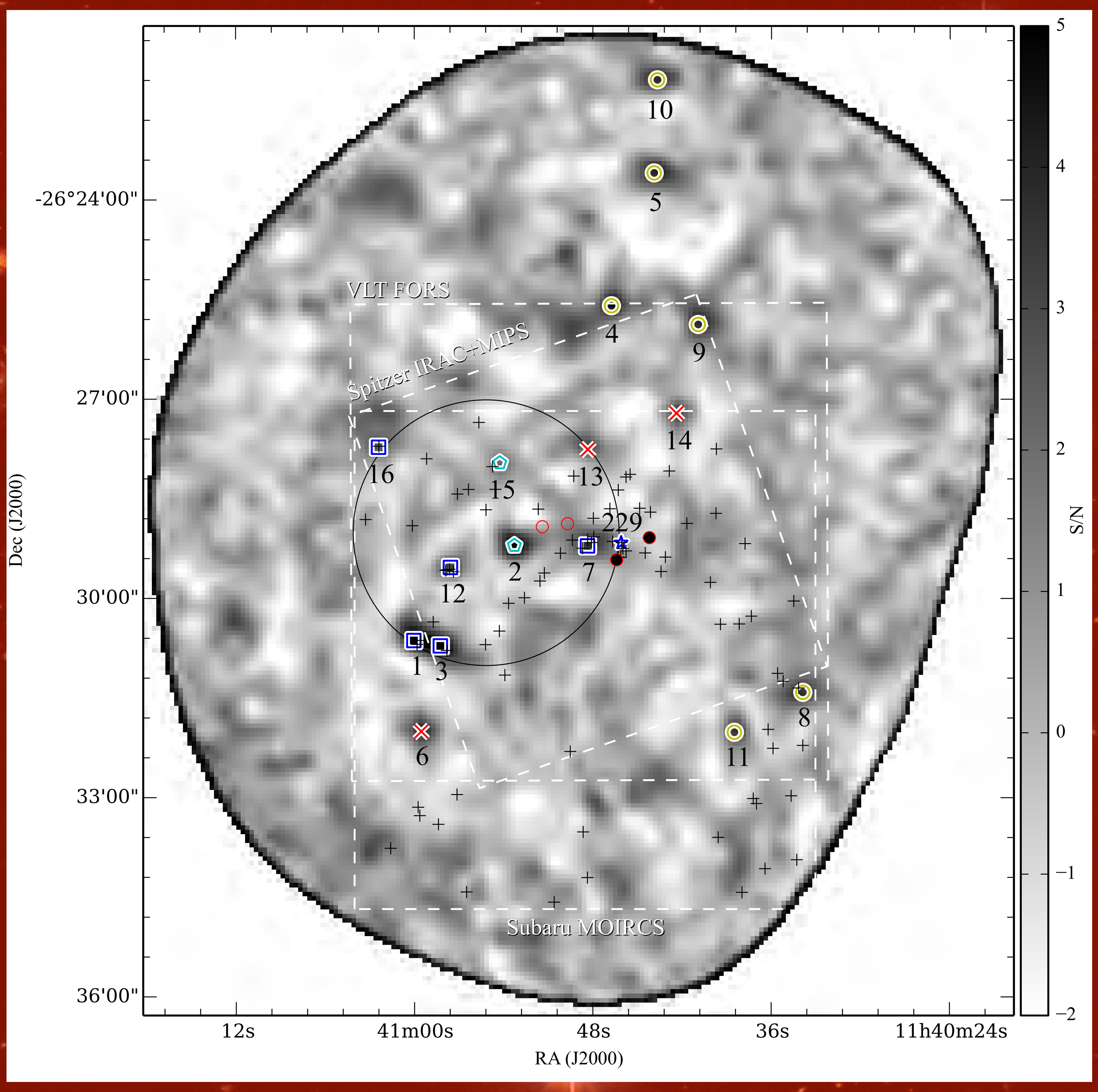

Fig. 1 – Location of 16 SMGs extracted from our LABOCA map of the field of MRC1138 on top of the LABOCA signal-to-noise map. Blue squares represent spectroscopically confirmed membership to the protocluster structure at z ≈ 2.2. The blue star is the SCUBA source at z = 2.149, also detected in CO(1–0) 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 ~240" (corresponding to a physical size 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 (Weiß et al. 2009) and not centered on the radio galaxy MRC1138 (DKB07). The spatial distribution of the SMG overdensity seems to be similar to the north-east and south-east filament-like structure traced by HAEs (plus symbols Kurk et al. 2004b; 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 Tanaka et al. 2013). In addition, we show the fields of view of our Spitzer IRAC/MIPS, VLT FORS and Subaru MOIRCS datasets. North is at the top and east is to the left.

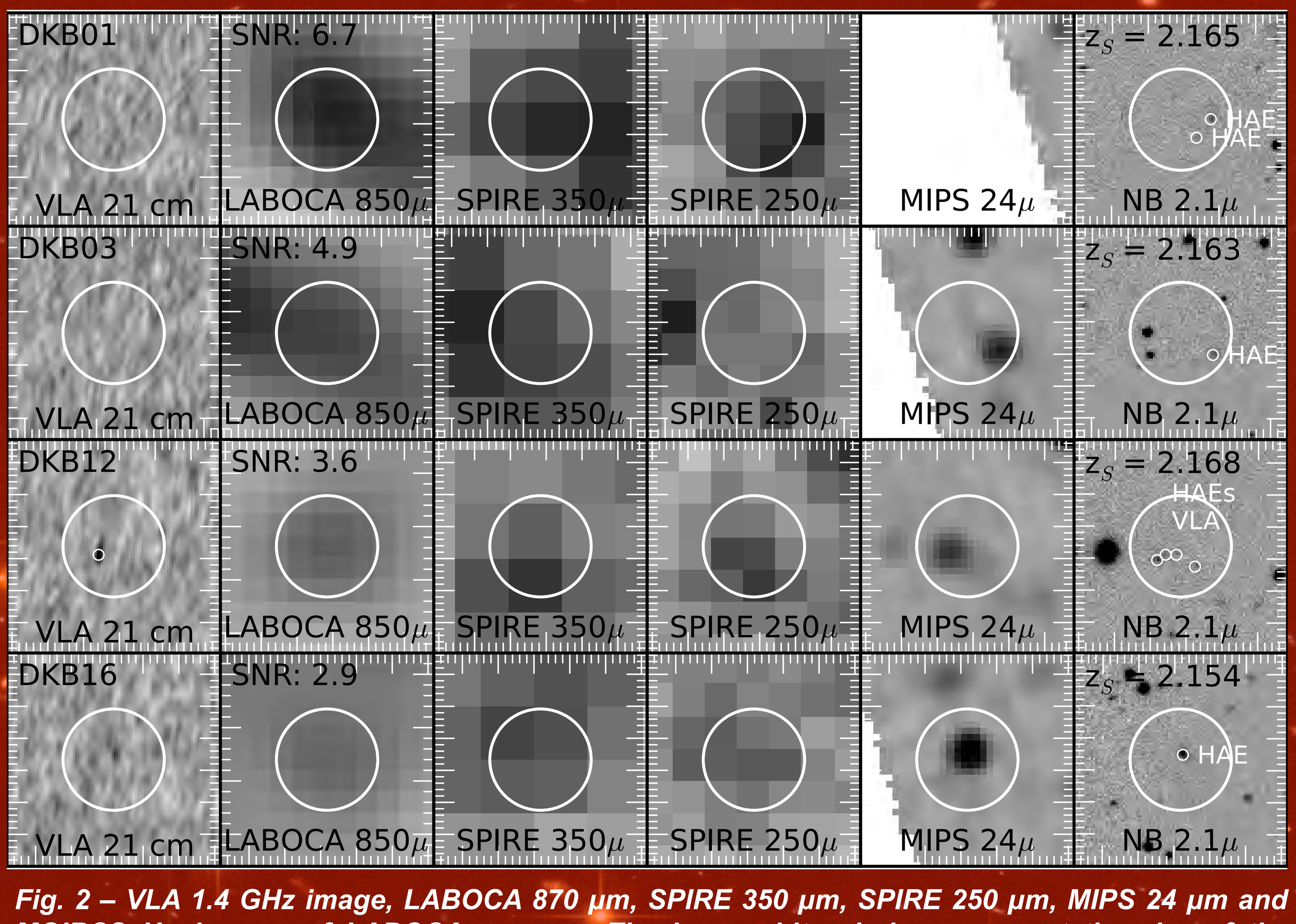

Fig. 2 – VLA 1.4 GHz image, LABOCA 870 μm, SPIRE 350 μm, SPIRE 250 μm, MIPS 24 μm and MOIRCS Hα images of LABOCA sources. The large white circles represent the size of the LABOCA beam (~11" diameter). Small white circles are VLA and/or HAE sources.

➢ **Dannerbauer H., et al., 2014, A&A, 570, 550**