ALESS67.1 : Morphological dissimilarity between cold dust and CO, HII regions, and stars

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The Big Question

In the spatially-unresolved analyses, it is normally assumed that the spatial distributions among different energy tracers, in particular dust and CO, are similar. But is this assumption true?

1. Background

Spatially-resolved, multi-wavelength observations are key to fully understand not only the physical processes that are driving the extreme star-forming conditions in SMGs, but also their role under the current framework of galaxy formation and evolution.

However, obtaining these data is also the most difficult due to the requirement of high (~0.1") spatial resolution, as well as the low surface density of SMGs. Consequently, the detailed SMG studies to date have either focused on the UV/optical/NIR or the FIR/(sub-)millimeter.

Recently, the need to combine spatially-resolved UV/optical/NIR and FIR/submillimeter imaging on individual SMGs has been driven by the significant differences sometimes found when comparing results from the two types of study, on subjects such as the dynamics, IRX-β, and dust extinction. These examples illustrate that having spatially-resolved panchromatic data with both photometry and spectroscopy on the same galaxies is the key to make further progress.

2. ALESS67.1

Here we present such a study of the z = 2.12 SMG ALESS67.1, where we have collected sub-arcsecond UV-to-NIR continuum from the HST, NIR IFU from the AO-aided SINFONI observations, and 870 μm continuum and ^{12}CO(J=3-2) from ALMA. ALESS67.1 is part of the ALESS sample (Karim et al. 2013; Hodge et al. 2013), a Cycle 0 ALMA survey targeting a flux-limited sample of 126 submillimeter sources detected by a LABOCA 870 μm survey in the Extended Chandra Deep Field South (ECDFS) field (LESS survey; Weiss et al. 2009).

ALESS67.1 is one of the few SMGs so far that is covered by all the necessary follow-up observations, and it is representative of the ALESS sample; ALESS67.1 has a redshift, a SFR of 500 $M_\odot yr^{-1}$ and a stellar mass of ~2×10^{11} $M_\odot$ that match to the averaged properties of SMGs. It is also detected by Chandra, however the relatively low X-ray luminosity suggests that the FIR luminosity is dominated by star formation.

3. Size and morphology

In Figure 1, we show thumbnails of ALESS67.1 in 870 μm continuum, Hα, CO(3-2), and NIR imaging from HST, highlighting ***the spatial offsets between dust continuum and Hα and stellar components, as well as the size difference specifically shown in Figure 2 between dust and all the other tracers, including CO***. The physical interpretation of these results, especially the mismatch between CO and dust, needs to be explored further, both theoretically and observationally. It could be that the rest-frame 280 μm continuum still misses a significant amount of cold, optically thin dust, which requires higher surface brightness sensitivity and is better traced by optically-thick CO. Deeper ALMA observations in millimeter wavelengths coupled with hydrodynamical simulations implemented with detailed radiative transfer treatment might shed more light on this issue.

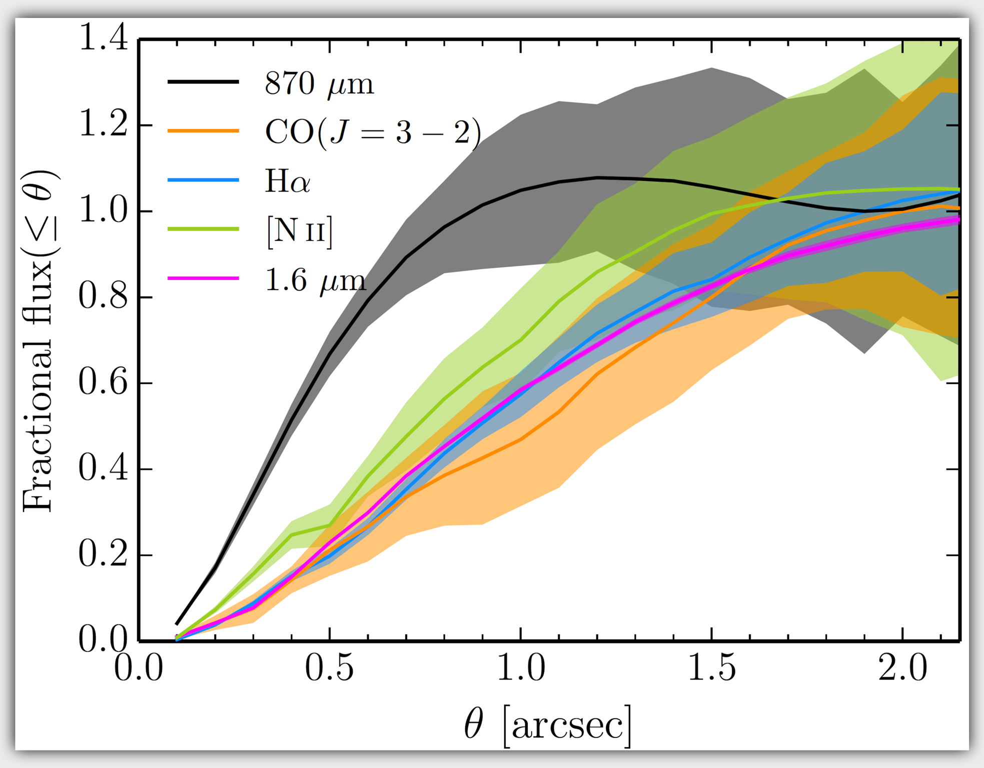
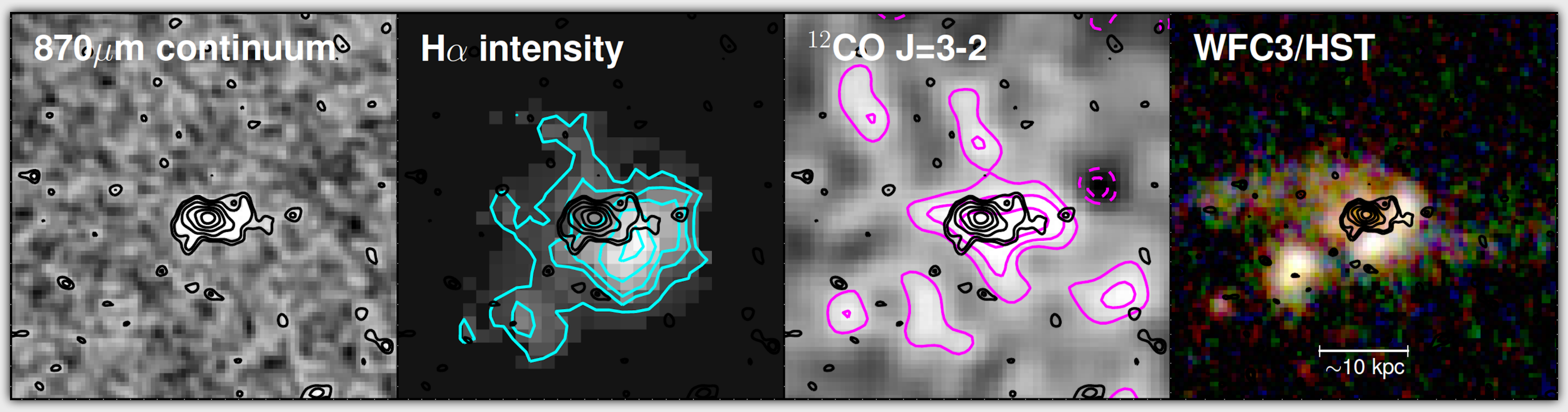


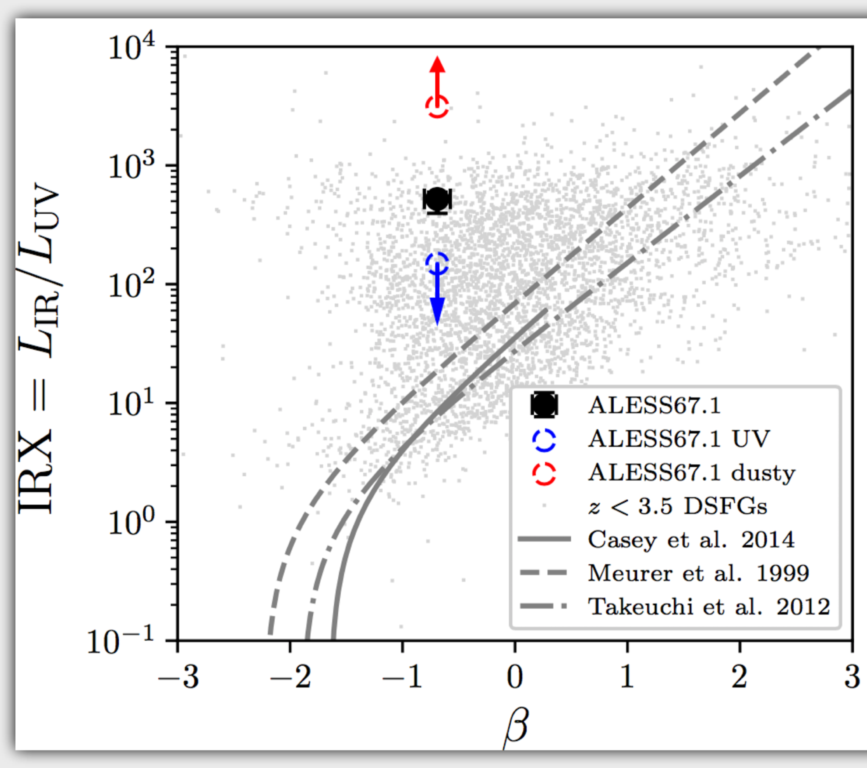
Figure 2:
The curve-of-growth diagram with all the tracers plotted. All the maps are convolved with the CO beam to make the spatial resolution comparable. Note the size difference between 870 μm and the rest of the tracers, especially CO. *Our results caution against assumptions in any model or analyses that adopt a single geometry for all the tracers in SMGs.*

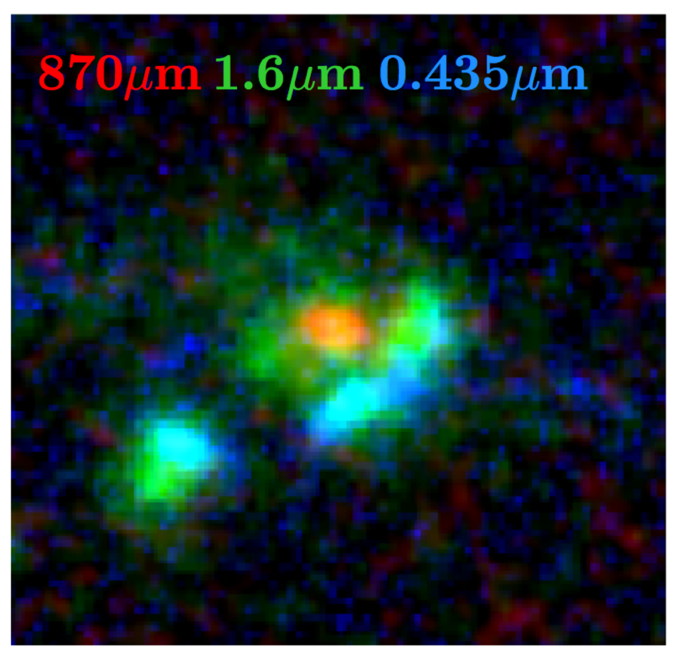
Figure 1:
Thumbnails of ALESS67.1 in 870 μm continuum, Hα, CO, NIR HST r-g-b (F160W-F125W-F105W) imaging, with black contours showing the high-resolution 870 μm continuum.

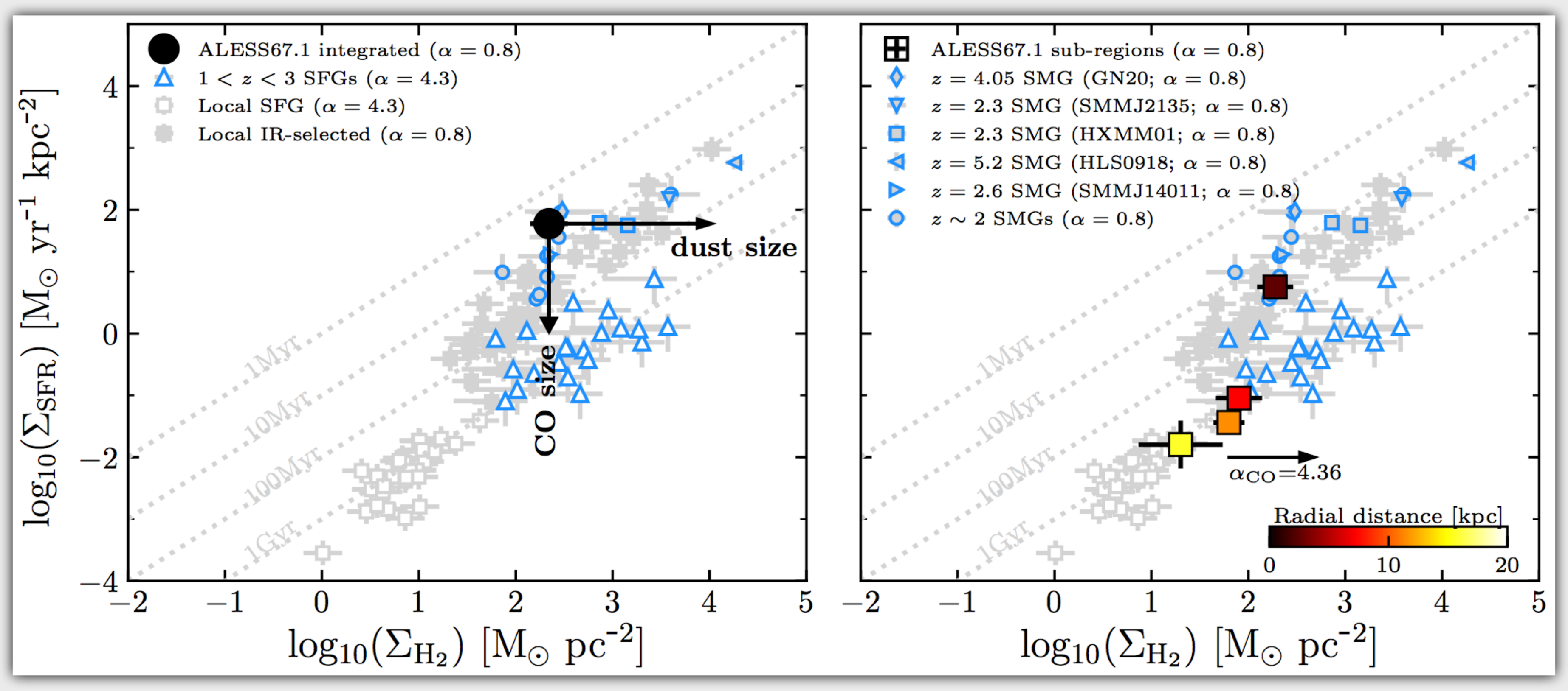


4. Implications on IRX-β and Schmidt-Kennicutt relationship

The IRX-β diagram shown in the left panel with the black point representing ALESS67.1 and grey dots are z < 3.5 DSFGs (Casey et al. 2014). The various correlations found in the local SFGs are also plotted. ALESS67.1 as a whole is significantly bluer (more IR luminous) compared to the local relationships, but locating at the locus of the z < 3.5 DSFGs. We also plot the limits of both dusty regions revealed by the 870 μm continuum and UV-emitting regions as red- and blue-dashed circle, respectively, by fixing to the same β for the dusty regions. Right panel shows ***a complete mismatch between cold dust and UV emitting regions, supporting the postulation that geometrical effect is part of the reason causing the deviation of DSFGs on the local IRX-β correlations.***







The Schmidt-Kennicut diagram shown in both panels, comparing ALESS67.1 to the literature values on local SFGs, (U)LIRGs (Kennicutt 1998), z = 1-3 SFGs (Tacconi et al. 2013), z~2 SMG (Bothwell et al. 2010; Danielson et al. 2011; Fu et al. 2013; Sharon et al. 2013; Rawle et al. 2014), and a z~4 SMG (GN20; Hodge et al. 2015). The left panel shows ALESS67.1 if we consider the galaxy as a whole, whereas in the right panel the sub-regions are shown in squares color coded by the radial distance from the peak of 870 μm continuum. In the left panel the downward(rightward) arrows demonstrates where would the data point be if we instead adopt CO(dust) size to measure the SFR(molecular gas) density. In the right panel the rightward arrow indicates the 0.7 dex shift if we instead adopt galactic CO = 4.3. The diagonal dotted lines show the gas consumption time derived by dividing gas density by SFR density. *Under the assumption of CO = 0.8 the central part of ALESS67.1 (≲5 kpc) agrees with the physical conditions of local (U)LIRGs and other SMGs, whereas the outskirts (≳5 kpc) of the galaxy follow closely with both local and z~2 SFGs, suggesting different star-formation efficiencies within one galaxy.*

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