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SUB-MILLIMETER GALAXIES: DUSTY, CLUMPY AND MESSY STARBURSTS IN THE DISTANT UNIVERSE

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We present the first spatially-resolved observations of the Hα emission in three $z \sim 2$ sub-millimeter selected galaxies (SMGs) using the Keck OH-Suppressing Infrared Imaging Spectrograph (OSIRIS) with Laser Guide Star Adaptive Optics (LGS-AO). With the unprecedent kpc-scale resolution – up to ten times that achieved with previous seeing-limited studies – and the kinematic insight that these observations provide, we unveil a clumpy Hα structure and reveal velocity offsets that suggest these systems are in an advanced merging phase. The spatially-resolved spectral information also allows us to disentangle the Hα emission arising from an active galactic nucleus (AGN) from that associated with star formation.

Ultra-luminous infrared (IR) galaxies ($L>10^{12}$ $L_\odot$; Sanders & Mirabel 1996) are locally rare, but appear to dominate the co-moving energy density at $z > 2$ (e.g., Caputi et al. 2007). Many are optically-faint, dust-obscured galaxies that have been identified by the detection of their thermal dust emission redshifted into the submillimeter wavelengths (e.g., Hughes et al. 1998). With extreme characteristics – including high star-formation rates (SFRs $\sim 10^2 - 10^3$; Swinbank et al. 2004) and large stellar masses ($<M_{\rm stellar}> = 7 \times 10^{10} M_\odot$; e.g., Hainline et al. 2009) – and the presence of AGN signatures in the majority of these systems (see Menéndez-Delmestre et al. 2009 and references therein), these sub-millimeter galaxies (SMGs) could build the stellar bulk of a massive galaxy (and its underlying supermassive black hole, SMBH) in under a few $\sim 10^8$ yrs. These findings suggest that the submm phase may represent a dust-obscured pre-quasar period in the evolutionary scenario that leads to the formation of today's massive ellipticals.

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With OSIRIS we are able to explicitly distinguish between compact AGN-dominated regions of broad Hα emission (FWHM $>$ 1000 km/s) from more extended regions exhibiting narrow Hα emission (FWHM $<$ 500 km/s) and thus likely dominated by star formation activity. We observe that the distribution of star formation in these objects is characterized by multiple Hα-bright kpc-scaled clumps, each presenting high SFR surface densities, with values similar to that of local extreme sources, such as circumnuclear starbursts and luminous infrared galaxies. However, in contrast to these local environments, SMGs appear to be undergoing such intense activity on significantly larger spatial scales as revealed by extended Hα emission over 4-16 kpc. The estimated clump masses and specific SFRs set SMGs off the main-sequence of star-forming objects at $z \sim 2$. The Hα kinematics reveal no evidence of ordered global motion as would be found in a disk, but rather large velocity offsets ($\sim$ few $\times 100$ km/s) between the distinct clumps. Assuming that the broad Hα emission identifies a SMBH likely at the dynamical center of system, we interpret both the velocity offsets between the observed clumps and their asymmetric distribution around the broad Hα region as an indication that these are not likely to reside in a regular potential well structure. Although a clumpy disk structure has been suggested in other populations of star-forming galaxies at similar redshifts, the merger interpretation is likely the most accurate scenario for the SMGs in our sample. However, the final test of whether an underlying disk structure is present will come from detailed studies of the cold molecular gas at the high spatial resolutions possible with ALMA. For more details, we refer the reader to Menéndez-Delmestre et al. 2013.

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