

Molecular Gas Excitation and Chemistry in VV 114 and NGC 1614 with ALMA

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Abstract. We present high resolution molecular line observations of dusty AGN and starburst in nearby luminous infrared galaxies (LIRGs), VV 114 (band 3/4/7) and NGC 1614 (band 3/6/7/9), with ALMA. Multi-frequency imaging from 4.8 GHz to 691 GHz of NGC 1614 allows us to study spatial properties of the radio-to-FIR continuum and multiple CO transitions, and we find the CO excitation up to $J_{\text{upper}} = 6$ can be explained by a single ISM model powered by nuclear starbursts. Our processing line imaging survey for VV 114 detected at least 30 molecular lines which show different chemical composition from region to region. Multi-molecule imaging helps us to diagnose the chemical differences of dusty ISM, while multi-transition imaging allows us to investigate gas physical conditions affected by nuclear activities directly.

Keywords. Galaxies: interaction – Galaxies: starburst – ISM: molecules

1. NGC 1614: CO SLED and Radio-to-FIR SED

NGC 1614 is one of nearby ($D_L = 68.6$ Mpc) LIRGs ($L_{\text{IR}} = 10^{11.65} L_{\odot}$; Armus *et al.* 2009), which is thought to be a minor merger remnant with an intense starburst ring (no strong AGNs; Herrero-Illana *et al.* 2014). The CO (6-5) has a completely different morphology compared with the low- J CO (Sliwa *et al.* 2014; Xu *et al.* 2015). We modeled the CO Spectral Line Energy Distribution (SLED) by RADEX (van der Tak *et al.* 2007). The observed CO SLED up to $J_{\text{upper}} = 6$ can be explained by single-phase ISM model. A modeling with PDR Toolbox (Kaufman *et al.* 2006) revealed that the CO excitations can be explained by intensities of the FUV radiation field

without any AGN contributions. This is consistent with the radio-to-FIR SED of NGC 1614 which mainly come from star-forming activities. The CO SLED of NGC 1614 is powered by starburst activities. See Saito *et al.* (2015b) submitted and Saito *et al.* (2015c) in preparation in details.

2. VV 114: 84 - 111 GHz and 127 - 154 GHz Molecular Line Survey

VV 114 is a mid-stage merger ($L_{\text{IR}} = 10^{11.71} L_{\odot}$). The eastern galaxy has a strong hard X-ray nucleus (putative AGN) surrounded by soft X-ray/MIR/Paschen α emission (Le Floch *et al.* 2002; Grimes *et al.* 2006). The western galaxy is an UV-bright galaxy because of less amounts of dust. Cycle 0 ALMA observations revealed that the eastern nucleus shows several dense gas clumps with various HCN (4–3)/HCO⁺ (4–3) ratios which are used for the extinction-free AGN diagnostic (> 1 indicates a dusty AGN signature). The CH₃OH (2_k-1_k) emission is only detected at the “overlap region” where is located between the progenitor’s disks. Our processing cycle 2 line survey preliminary detected rare species such as CCH, HNCO, HNC, CH₃OH, HC₃N, H₂CS, CH₃CCH, H₂CO, and *c*-C₃H₂. We find that these detected molecules are different from region to region (e.g., multiple transitions of CH₃OH and HNCO, which are commonly used for extragalactic shock tracers, are only detected at the overlap region), suggesting underlying chemistry is also different. Gas chemistry can distinguish the AGN at the eastern nucleus, starburst activities, and the overlap region (putative shocked region due to the collision of gas-rich galaxies) between the galaxy disks. See Iono *et al.* (2013), Saito *et al.* (2015a), and Saito *et al.* (2016) in preparation in details.

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