# The interplay between multicomponent charge density wave orders in kagome metal $AV_3Sb_5$ (A=Cs, Rb, K)

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The kagome metal $AV_3Sb_5$ was recently discovered to host both superconductivity and a multi-component charge density wave (CDW) order [1]. What happens to the multi-component charge density wave orders below the phase transition temperature? Do they cooperate or compete? Here, we use Raman scattering to explore this puzzle in the charge density wave phase of $AV_3Sb_5$. We identify several new phonon modes emerging in the CDW state, which are lattice vibration modes related to V and Sb atoms as well as alkali-metal atoms. The detailed temperature evolution of these modes' frequencies, half-width at half-maximums, and integrated intensities support a phase diagram with two successive structural phase transitions in $CsV_3Sb_5$: the first one with a primary-like order parameter appearing at $T_S$=94K and the second isostructural one appearing at around $T^*$=70K. Furthermore, the T dependence of the integrated intensity for these modes shows two types of behavior below $T_S$: the low-energy modes show a plateau-like behavior below $T^*$ while the high-energy modes monotonically increase below $T_S$. These two behaviors are captured by the Landau free-energy model incorporating the interplay between the primary-like and the secondary-like order parameters via trilinear coupling. Especially, the sign of the trilinear term that couples order parameters with different wave vectors determines whether the primary-like and secondary-like order parameters cooperate or compete with each other, thus determining the shape of the T dependence of the intensities of Bragg peak in x-ray data and the amplitude modes in Raman data below $T_S$. These results provide an accurate basis for studying the interplay between multiple CDW order parameters in kagome metal systems [2].

Work was done in collaboration with Brenden R. Ortiz, Hengxin Tan, Stephen D. Wilson, Binghai Yan,Turan Birol, and Girsh Blumberg. The spectroscopic work conducted at Rutgers was supported by NSF Grants No. DMR-1709161 and No. DMR-2105001.

**Key Words:** kagome metal, charge density wave, Raman scattering

**References:**

[1] B. R. Ortiz *et al.,* Phys. Rev. X 11, 041030 (2021)

[2] S. F. Wu *et al.*, Phys. Rev. B 105, 155106 (2022) Editors' Suggestion