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Association canadienne  
des physiciens et physiciennes

Contribution ID: 3230

Type: Oral (Non-Student) / Orale (non-étudiant(e))

## Charge Density Wave Order and Fluctuations above $T_{CDW}$ and below Superconducting $T_c$ in the Kagome Metal $CsV_3Sb_5$

Monday 6 June 2022 17:00 (15 minutes)

The phase diagram of the kagome metal family  $AV_3Sb_5$  ( $A = Cs, Rb, K$ ) features both superconductivity and charge density wave (CDW) instabilities, which have generated tremendous recent attention. Nonetheless, significant questions regarding the nature of the CDW states remain. In particular, the temperature evolution and demise of the CDW state has not been extensively studied, and little is known about the co-existence of the CDW with superconductivity at low temperatures. We report an x-ray scattering study of  $CsV_3Sb_5$  over a broad range of temperatures from 300 K to  $\sim 2$  K, below the onset of its superconductivity at  $T_c \sim 2.9$  K. Order parameter measurements of the  $2 \times 2 \times 2$  CDW structure show an unusual and extended linear temperature dependence onsetting at  $T^* \sim 160$  K, much higher than the susceptibility anomaly associated with CDW order at  $T_{CDW} = 94$  K. This implies strong CDW fluctuations exist to  $\sim 2 \times T_{CDW}$ . The CDW order parameter is observed to be constant from  $T = 16$  K to 2 K, implying that the CDW and superconducting order co-exist below  $T_c$ , and, at ambient pressure, any possible competition between the two order parameters is manifested at temperatures well below  $T_c$ , if at all. Anomalies in the temperature dependence in the lattice parameters coincide with  $T_{CDW}$  for  $c(T)$  and with  $T^*$  for  $a(T)$ .

**Primary author:** Dr CHEN, Qiang (Department of Physics and Astronomy, McMaster University)

**Co-authors:** GAULIN, Bruce (Brockhouse Institute for Materials Research, McMaster University and Department of Physics and Astronomy, McMaster University and Canadian Institute for Advanced Research); Dr FELSER, Claudia (Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany); Dr CHEN, Dong (Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany); Dr SCHNELLE, Walter (Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany)

**Presenter:** Dr CHEN, Qiang (Department of Physics and Astronomy, McMaster University)

**Session Classification:** M3-2 Unconventional superconductivity and topology (DCMMP) | Supraconductivité non conventionnelle et topologie (DPMCM)

**Track Classification:** Technical Sessions / Sessions techniques: Condensed Matter and Materials Physics / Physique de la matière condensée et matériaux (DCMMP-DPMCM)