Contribution ID: **24** Type: **Computing**

High-Performance Computing to Trace the Evolution from Massive Stars to Supernovae and Their Remnants

Tuesday 15 October 2024 14:40 (20 minutes)

The remnants of core-collapse supernovae (SNe) display complex morphologies and a highly non-uniform distribution of stellar debris. In young remnants (less than 5,000 years old), these features encode valuable information about the processes at work in the SN engine, including nucleosynthetic yields and large-scale asymmetries that arise during the early stages of the explosion. Moreover, other properties of the remnants reveal clues about the progenitor stars and their interactions with the circumstellar medium (CSM), which is shaped by the progenitor's mass-loss history. Understanding the connection between young SN remnants, their parent supernovae, and the progenitor stars is crucial for uncovering the physics of SN engines and investigating the final evolutionary stages of massive stars, as well as the elusive mechanisms driving their mass loss. In this talk, I will present a comprehensive approach that leverages the enhanced efficiency of numerical codes and the availability of advanced HPC resources to model the entire evolution from progenitor stars to supernovae, and ultimately to fully developed supernova remnants. This approach has enabled us to link the observed physical and chemical properties of SN remnants to their progenitor stars and explosions, offering fresh insights into the life cycles and deaths of massive stars.

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Session Classification: Session 6