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Leveraging HPC for the modeling of supernova remnants and their interaction with the inhomogeneous interstellar medium

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Supernova remnants (SNRs) are expanding nebulae which in general show a rather complex morphology reflecting the interaction of the supernova (SN) blast wave with the circumstellar/interstellar medium (CSM/ISM), and the physical processes associated to the SN explosion and the internal structure of the progenitor star. The CSM/ISM into which the SNR expands is likely to be quite anisotropic as it has been strongly modified by the wind of the progenitor. In some cases, SNRs expand into a highly inhomogeneous environment, interacting with molecular and atomic clouds. This interaction leads to a significant slowdown of the forward shock as it collides with dense clouds and, consequently, a strengthening of the reverse shock traveling through the ejecta resulting in highly asymmetric morphologies.
Combining observations with 3D hydrodynamical (HD) models offers new insights into the mechanisms which produce the diversity of observed SNRs. However, accurately simulating such complex interactions demands substantial computational resources. Here, we present some examples of 3D HD models that describe the evolution of a SNR and its interaction with the inhomogeneous CMS/ISM parametrized according to observations. We discuss the role of the inhomogeneous CSM/ISM in shaping the remnant morphology, and emphasize the necessity of using high-performance computing (HPC) to handle the complexity and scale of these simulations.

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