The Impact of Dust Dynamics and Grain Properties on Star Formation: Insights from Radiation-Dust-MHD Simulations

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Cosmic dust is integral to the evolution of giant molecular clouds (GMCs) and star formation. Conventional models often overlook the intricate dynamics and variations in dust properties, assuming a constant dust-to-gas ratio (DTG) and canonical Mathis, Rumpl, & Nordsieck grain size distribution (GSD). However, the DTG likely fluctuates locally within star-forming regions and the GSD likely significantly varies across environments. Crucially for star formation, these variations have non-linear impacts on interstellar medium (ISM) thermochemistry, dynamics, and radiative transfer.

In this presentation, I introduce radiation-dust-magnetohydrodynamic (MHD) simulations of star formation within the STARFORGE project, advancing previous models by explicitly modelling the dynamics of a diverse size spectrum of live dust grains. These simulations incorporate radiation, drag, Lorentz forces, and dust heating and cooling. I also investigate how changes in the GSD, while maintaining fixed dynamic range and dust mass, affect star formation.

My findings emphasize the significant impact of the GSD on GMC thermochemistry. Specifically, when increasing grain size at fixed dust mass, the dominant effect is a reduction in opacity. As the maximum grain size increases from 0.1μm to 10μm, photons penetrate deeper through the cloud, heating the gas and reducing star formation efficiency by an order of magnitude. Furthermore, I find that radiation-dust interactions strongly influence the properties of gas surrounding and accreting onto massive stars. As stars exceed a critical mass ($\sim 2 - 5\mathrm{M}_\odot$), radiation expels dust, forming $\sim$ 100 AU dust-evacuated zone surrounding by a "dust shell". This leads to a reduction in the DTG by up to 1-2 orders of magnitude within circumstellar environments, consequently impacting the composition of massive stars and their circumstellar discs.

In summary, this presentation highlights the essential role of detailed dust modeling in enhancing our understanding of the processes governing the ISM and star formation.