Title: From galaxy to core collapse: An overview from the theoretical astrophysics group of Cologne.

Abstract:

Introduction: The interstellar medium (ISM) is an essential component of our galaxy, consisting of gas, dust and radiation. The ISM is the birthplace of stars and constantly evolving due to stellar feedback and chemical evolution.

Method: In the Cologne theoretical astrophysics group we use the 3D magneto-hydrodynamic (MHD) adaptative mesh refinement (AMR) grid code FLASH (Fryxell et al. 2000) to simulate the ISM over a wide range of environments from au up to kpc scales. The group and its collaborators have extended the FLASH code to include several relevant processes to follow the evolution of the ISM. This includes MHD solvers (e.g. Derigs et al. 2018), non-equilibrium chemical networks to follow the evolution of several chemical species (Walch et al. 2015), self-gravity (Wünsch et al. 2018), radiation transport (Wünsch et al. 2021), a Hermite integration scheme for sink particles (Dinnbier and Walch 2020) and especially stellar feedback from massive stars (Gatto et al. 2017, Peters et al. 2017, Rathjen et al., 2021, 2024, 2025, Klepitko et al. 2023, Brugaletta et al. 2025).

Results: The "SImulating the LifeCycle of molecular Clouds" (SILCC) project simulates the evolution of molecular clouds in a patch of a Milky Way-like galaxy. The simulations provide an extensive set of data focusing on different aspects of the ISM: effects of stellar feedback, chemical evolution, magnetic fields, and metallicity. Each new generation of simulation aims to better understand observations (e.g. through the SFE and Kennicutt-Schmidt relation) by adding more phyiscal processes. In addition to the simulations of the SILCC project, the group also studies other environments: e.g formation of massive stars in collapsing dense cores (Zimmermann et al. 2025), evolution of HII regions and their comparison with observations (Dannhauer et al. 2025), tracing supernova remnants in simulations (Makarenko et al. 2020, 2023, 2024), formation of cores and clumps in colliding flow simulations (Weis et al. 2024), and many other topics.

Conclusion: The theoretical astrophysics group of Cologne aims to improve physical models across many spatial scales to better understand the evolution of the ISM, its role in the formation of stars as well as observations of the ISM.