# HW 4: Galaxy to cloud scales Summary

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Using large-scale simulations has enabled the resolution of the multiphase interstellar medium (ISM), molecular clouds, and other feedback processes such as supernovae. The author presented a review of simulations of molecular cloud formation and evolution, star formation, and the role of galactic structure. Afterward, 2D hydrodynamical simulations of isolated galaxies were made with a degree of accuracy in cooling and heating, molecular chemistry, and stellar feedback that can hold up even today.

Simulations of isolated galaxies and kiloparsec-scale phenomena have significantly advanced our understanding of the multiphase interstellar medium (ISM), molecular cloud dynamics, star formation, and the impact of galactic structures like spiral arms and bars. These simulations, particularly those from the last 15 years, have employed sophisticated computational techniques such as grid or Adaptive Mesh Refinement (AMR), Smoothed Particle Hydrodynamics (SPH), and moving mesh codes to explore the complexities of galactic environments. Early works focused on galactic structure development and cloud-cloud collisions, while more recent studies have delved into the intricate processes of molecular cloud formation and evolution, driven by gravitational instabilities, supernova feedback, and interactions within galactic structures. These simulations not only replicate observed galactic phenomena but also predict the formation of giant molecular clouds (GMCs) through various instabilities and feedback mechanisms. The review highlights the progression from simple models to comprehensive simulations that incorporate a wide range of physical processes, suggesting future research could explore stellar clusters and galaxy modeling in an extragalactic context to further unravel the mysteries of galaxy formation and evolution.

Instabilities and perturbations in the interstellar medium (ISM), particularly in the cold, stable HI phase, drive the formation of denser structures and clouds through thermal instabilities, largely independent of gravity or magnetic fields. Simulations have shown that such instabilities, along with converging flows from phenomena like spiral arms or supernovae, can accumulate thermally unstable gas, leading to cloud formation. The process is further influenced by turbulence, gravity, and magnetic fields, with gravity causing cloud collapse to form stars and strong magnetic fields potentially suppressing structure formation. Additionally, Parker instabilities, while not significantly enhancing density on their own, can seed further instabilities that contribute to molecular cloud formation.

Galaxy-scale events, such as cloud-cloud collisions, are more common in spiral arms and can gather large volumes of gas, although their direct impact on star formation rates varies. Various instabilities and collisions, including effects from supernovae, play roles in molecular cloud formation, with large-scale simulations suggesting a complex interplay of processes influencing gas distribution and the properties of giant molecular clouds (GMCs), with gravitational instabilities and cloud-cloud collisions being key in forming massive clouds.

The evolution of Giant Molecular Clouds (GMCs) within galaxies is closely linked to the large-scale properties of the interstellar medium (ISM), including the distribution of gas across different phases, the scale heights of these phases, and the overall structure of the ISM. Observational data, although varied and uncertain, suggest that in spiral galaxies like the Milky Way, about one-third of the ISM mass is in molecular form, with the rest divided among cold, unstable, and warm atomic phases. Simulations of Milky Way-like galaxies have largely confirmed these proportions, indicating a dependency on factors such as dust content, chemical processes, and the impacts of supernova feedback and cosmic rays on heating and cooling mechanisms. These simulations also highlight that the scale heights of gas phases exceed those expected from thermal sound speed alone, reflecting the influence of turbulence, magnetic fields, and feedback mechanisms in shaping the ISM. While cosmic rays and magnetic fields moderately affect gas phase transitions and scale heights, feedback from supernovae plays a critical role in determining the distribution and state of the interstellar gas, thereby influencing the formation and evolution of GMCs within the galactic environment.

## References

[1] Clare Dobbs, *2a Results: Galaxy to cloud scales*, frontiers/arXiv:2312.01854.