Summary

Machines to Learn the Multi-scale Physics of Galaxies

COORAY Nawalage Suchetha Manakal

Galaxies are an aggregation of stars, gas, dust, and dark matter that evolve through external interactions (merging, gas accretion) and internal processes (star formation, feed- back). These processes extend over a vast length-scale range, from AU scales ($\sim 10^{11}$m) to hundreds of Megaparsec scales ($\sim 10^{24}$m). Therefore, a comprehensive multi-scale theory that combines cosmology and baryonic physics is necessary to understand the working of galaxies. In this thesis, we explore the use of machines to get a step closer to such an understanding of multi-scale galaxy physics.

Astronomical observations are often incomplete. The challenge to deal with them is that these problems are also often ill-posed, meaning that no one unique solution exists that satisfies the observation. We recognize three areas where such reconstruction of the signal is paramount. Firstly, astronomical images are smeared with unnecessary fore- ground objects, artifacts, or bad pixels. In Cooray et al. (2020), we introduced a flexible, cost-effective algorithm for treating incomplete images of the CO Multi-line Imaging of Nearby Galaxies (COMING) Project. We Secondly, magnetism is vital for galaxy forma- tion but is very difficult to observe. A new technique called Faraday tomography shows potential but is interrupted by an ill-posed problem. We developed CRAFT (Cooray et al. 2021) and CRAFT+WS (Cooray et al. 2022a), which solves the Faraday tomogra- phy problem with the highest fidelity compared to existing methods. Successful Faraday tomography will deepen our understanding of the magnetized Universe.

Growing astronomical data may also be over-complete. The key idea is that all the high-dimensional data we obtain of the Universe should derive from a much lower- dimensional process or a physical theory. Therefore, dimensionality reduction provides a natural way for machines to extract physical information from data by transforming the high-dimensional data into a lower-dimensional representation. In Cooray et al. (2022b), we reported the discovery of a two-dimensional Galaxy Manifold within the 11-dimensional luminosity space provided in the RCSED (Chilingarian et al. 2017) catalog. Considering that the manifold represents the possible parameter space, we analyzed the evolutionary tracks. We found that gas accretion onto galaxies may be the driver for the existence of the Galaxy Manifold. Thus through data scientific methods, we have built a comprehensive picture of multi-scale galaxy physics that combines cosmological gas inflow, galaxy evolution, and cosmic magnetism.