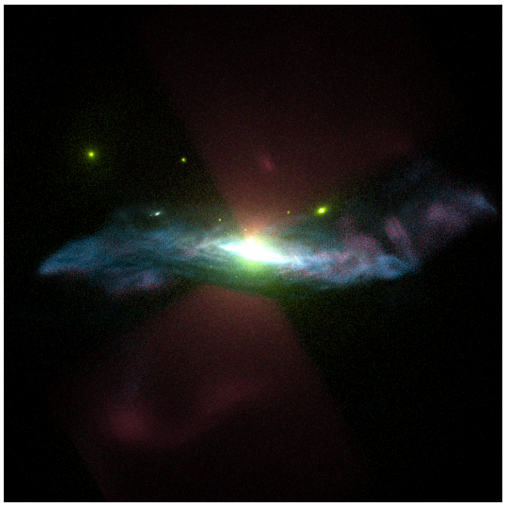
The Mochima cosmological simulations: The interplay between supernovae and a central AGN

Arturo Núñez-Castiñeyra
Email: arturo.nunez@cea.fr
CEA Saclay
Emmanuel Nezri (LAM), Yohan Dubois (IAP), Sebastien Peirani (OCA)

The star formation rate in galaxies is regulated by various energetic processes that inject energy into the interstellar medium (ISM). This energy acts as pressure support, countering gravitational collapse, which initiates star formation. In low mass galaxies $< 10^{12} M_{\odot}$, supernova explosions are the primary source of energy injection. Conversely, in high mass galaxies $> 10^{12} M_{\odot}$, energy injection is predominantly from active galactic nuclei (AGN). Given the Milky Way's position at the boundary of these two regimes, the combined influence of AGNs and supernovae on its evolution remains unclear. To investigate these scenarios, the Mochima suite of cosmological simulations has been expanded (refer to arXiv:2004.06008 and arXiv:arXiv:2301.06189) by incorporating AGN feedback into certain existing runs. Various combinations of multi-freefall models of star formation, delayed cooling feedback, or mechanical-feedback, alongside AGN feedback from a central black hole, are tested. A resolution of 35 pc within a zoom-in box of 36 Mpc is achieved using the RAMSES code, which includes the implementation of gas turbulence over time and tracks the local hydrodynamical features of star-forming gas. Comparisons are made between galaxies at redshift 0 and global and interstellar medium observations in the Milky Way and local spiral galaxies, with the simulations showing successful alignment with observations. The implementation of varied numerical strategies leads to diverse galactic morphologies, affecting not only the distributions of stellar and gaseous components but also modifying the dark matter distribution due to the stellar evolution of the galaxy. The addition of AGN feedback mitigates problems observed in the original Mochima suite, where certain simulations were excessively efficient at forming stars. This highlights the essential role of the interplay among different feedback sources and their impact on gas turbulence and temperatures, which in turn affects the ability to form spiral arms and star-forming clusters. Such findings underline the critical need for detailed modeling of star formation and feedback processes, particularly with the enhancement of simulation resolution.



Postprocessing RGB image of the Mochima galaxy featuring a central AGN. Different bands are simulated using SKIRT to depict the luminosity of stars and their scattering in the gas across various SDSS bands, with X-ray emissions represented in red to illustrate the hot gas ejected by the AGN.