Thesis subject

Laboratory : **LAM**

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Title of the thesis subject :

Bridging Cosmological and Galactic Scales: The Role of Gas and Dark Matter in Galaxy Evolution

Keywords : - galaxies, cosmology - individual galaxies, baryonic and dark matter, gas accretion, mergers, kinematics, dynamics, neutral gas, SKA, data analysis, numerical simulations, data mining, machine learning.

Description of the thesis subject:

While significant progress has been made in understanding cosmological mass accretion through galaxy mergers and gas inflows, both numerical simulations and observations struggle to trace gas down to kiloparsec scales within galaxies. Meanwhile, probing dark matter (DM) at large radii remains a major challenge. In the nearby universe, the DM fraction in galaxies decreases with stellar mass: massive galaxies like the Milky Way are not DM-dominated within their optical disks, unlike dwarf galaxies.

To bridge the gap between galaxies and their environments—whether through mergers, gas accretion, or outflows—dynamical methods are essential. They help in establishing the signatures of those events by addressing the structure of DM halos and disk-halo degeneracies at small galactic radii inherent to varying mass-to-light ratios of stellar disks.

Neutral hydrogen (HI) gas is uniquely capable of mapping the connection to the cosmic web, linking cold and warm gas features ($10^3<T<10^4$ K), extended UV disks, and faint optical emissions. It also enables rotation curve measurements beyond the optical disk, offering critical insights into the mass distribution of disks.

The Square Kilometre Array Observatory (SKAO, https://www.skao.int/en), the world's largest radio telescope, will offer an unprecedented view of the neutral gas universe from the epoch of reonization to the present day. Construction of SKA1-Mid, featuring 197 dishes, is currently underway in South Africa, with early science operations expected in the early 2030s. Among its keystone surveys, SKAO will trace HI gas across cosmic time, allowing shallow and deep surveys at various angular resolutions that will probe the physics of the neutral Hydrogen reservoir at various scales inside the disks and in the circumgalactic and intergalactic media.

SKA pathfinders and precursors, such as MeerKAT, a 64-antenna radio telescope, are already conducting high-sensitivity surveys (https://www.sarao.ac.za/science/meerkat/about-meerkat/). Notably, the MHONGOOSE survey (MeerKAT HI Observations of Nearby Galactic Objects: Observing Southern Emitters) delivers ultra-deep, spatially resolved HI observations of 30 nearby galaxies, spanning a wide range of stellar and HI masses [1]. This is a pilot survey for SKAO and the HI reservoir in and out galaxies, as it reveals the structure and kinematics of the faintest HI gas ever detected around nearby galaxies, down to very low surface densities ($5\ 10^{17}\ cm^{-2}$, e.g. [2,3,4]). The observations were completed at the end of 2024, and the survey data are available within the collaboration of which we are a part.

This thesis will investigate specific angular momentum distributions [5] and gas velocity anisotropies [6] using high-quality HI data from the MHONGOOSE survey. It will examine how non-circular motions—revealed through non-axisymmetric and anisotropic features in velocity and angular momentum—shape the distribution of baryonic and dark matter, as well as gas accretion in galaxies. The methodology will combine data analysis and modeling, with potential extensions based on the PhD student's interests and skills. This may include: numerical simulations to interpret results; multi-wavelength data mining to access complementary gaseous and stellar data; and machine learning techniques to prepare for large-scale data exploitation with SKA.

This work will deepen our understanding of galaxy dynamics and evolution, helping to maximize the scientific potential of the upcoming SKA1-Mid facility and prepare for its full scientific exploitation.

References:

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[6] Adamczyk, P.; Amram, P.; Chemin, L. et al., 2023, A&A, 678, 5.