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Physics and Science of Matter

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Thesis subject

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Title of the thesis subject :

Bridging Cosmological and Galactic Scales: The Role of Angular Momentum in Shaping Galaxies

Keywords : - galaxies, cosmology - individual galaxies, galaxy environment, VIRGO cluster, cluster of galaxies, groups of galaxies, baryonic and dark matter, gas accretion, mergers, galaxy interaction, kinematics, dynamics, secular evolution, ionized gas, HARMONI and MOSAIC on the ELT, 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 fraction of dark matter (DM) in galaxies varies with stellar mass: massive galaxies are not dominated by DM within their optical disks, whereas dwarf galaxies are. Studying angular momentum provides insights into the relationship between baryonic and DM masses during galaxy formation and evolution. To bridge the gap between galaxies and their environments - either through mergers, gas accretion, or outflows - dynamical methods are essential. They help in establishing the signatures of those events by addressing the two-dimensional distribution of the specific angular momentum within the galactic radii in different environments.

The angular momentum **J** is a physical quantity representing the cross product of the position **R** and velocity **V** vectors multiplied by the mass M: **J** = **R** x M **V**. For a galaxy, most of the angular momentum is found within its disk [e.g. 1]. In the central bulge or in the dark matter halo, due to random motion of the components, the resulting angular momentum is lower. It is useful to consider the specific angular momentum vector **j** = **J**/M, to remove the implicit mass scaling dependence. The specific angular momentum is a universal parameter defined for all galaxies which is preserved for isolated galaxies, but which varies during galaxy formation, galaxy interaction and galaxy merger. This universality motivates the use of the angular momentum as parameter to describe and classify galaxies. In the scenario of the cold dark matter hierarchical Universe (ΛCDM), the galaxies were born in halo of dark matter from collapsing baryonic matter, and the angular momentum have been transferred by the gravitational interaction. These processes are known as the tidal torque theory and were integrated within the hierarchical framework of galaxy formation in the ΛCDM paradigm [e.g. 2,3].

The aim of this thesis is to study the spatial distribution of the stellar specific angular momentum of the warm ionised gas component, for a sample of star-forming galaxies located in different environments in the nearby universe, for which we have all the kinematical data, obtained with different integral field spectrometers. We have developed a new methodology for computing the spatial distribution of the stellar specific angular momentum and introduced a new classification scheme to tackle the physical mechanisms driving the acquisition and redistribution of angular momentum [4]. The sample is made of about 600 star-forming galaxies covering several mass bins, belonging to different environments, from isolated systems in the field to the Virgo cluster (e.g. [5, 6, 7, 8]). To test very different environments, galaxies belonging to other nearby clusters and to Hickson Compact Groups, galaxies in binary interactions, as well as low surface brightness galaxies are also part of the sample. Thirty isolated galaxies have already been selected from this sample to prove the feasibility of the method [4]. The objective will be to study the effects of the environment on the new classification on an extended sample.

This study will primarily emphasize data analysis and modeling, with potential expansions based on the PhD student's expertise and interests. The approach may incorporate numerical simulations to aid in result interpretation, multi-wavelength data mining to integrate complementary gaseous and stellar datasets, and advanced machine learning techniques to prepare for the analysis of large-scale and high-redshift galaxy observations.

The research will enhance our comprehension of galaxy dynamics and evolution, while optimizing the scientific potential of the upcoming HARMONI (https://elt.eso.org/instrument/HARMONI/) and MOSAIC (https://www.mosaic-elt.eu/) instruments on the ELT (https://elt.eso.org/). These instruments, offering comparable spatial resolution to current facilities but extending to redshifts up to z=2, will enable the study of the time evolution of two-dimensional specific angular momentum in galaxies. If the PhD student wishes to expand the scope of this thesis, the developed methods could also be applied to intermediate-redshift galaxies using existing data from the MUSE instrument on the VLT.

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