ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

DIPARTIMENTO DI FISICA E ASTRONOMIA
Department of Physics and Astronomy - DIFA

PhD project in ASTROPHYSICS

Title of the Project: ***A Big Model for Big Data: Forward Modeling the Colors of Millions of Galaxies***

Supervisor : Sirio Belli
Co-Supervisors : Lucia Pozzetti

Scientific Case: Recent observations with the James Webb Space Telescope (JWST) have discovered a population of massive galaxies that are already "red and dead" (i.e., have stopped forming new stars) at redshift $z > 4$, when the universe was still young and rich in gas. This discovery opens up fundamental questions about the population of quiescent galaxies: when did they first form? What physical processes are responsible for turning off their star formation in the early universe? What is the role played by mergers in shaping the properties of galaxies? So far, the study of the most massive, and therefore rare, galaxies at high redshift has been limited by the lack of both wide and deep surveys. Luckily, a new generation of observatories are rapidly providing enormous amounts of data that can be used to study all types of galaxies, including the ones belonging to rare populations. Space missions are finally mapping the universe in the near-infrared, which is crucial for the study of distant galaxies: JWST has already observed more than half a million galaxies between the local universe and the epoch of reionization; and Euclid is currently observing about a million galaxies *every single day*. Space-based infrared data will be complemented by optical observations from ground-based facilities such as the Vera Rubin Observatory, which will start science operations soon.

Outline of the Project: The student will analyze galaxy photometry using observations from JWST (at high redshift), Euclid and Rubin (at low to intermediate redshift). The first step will be the measurement of number densities for different galaxy populations selected on the basis of their physical and observational properties (such as mass, redshift, and colors). Next, the student will develop a comprehensive empirical model with a small number of free parameters that is able to reproduce, for each bin in mass and redshift, the number density of galaxies with different colors, thus capturing the diversity of galaxies from quiescent (red) to star-forming (blue), including all the intermediate stages. Finally, the empirical model will be evolved forward in time, accounting for the most important physical mechanisms: gas inflows, galaxy mergers, stellar evolution, star-formation quenching, etc. The effect of these processes on the colors of galaxies will be derived from theoretical studies and numerical simulations. Finally, using state-of-the-art statistical and computational methods, the evolved model will be fit to observations at different redshifts, resulting in a comprehensive picture of the processes driving galaxy evolution, with an emphasis on the formation and evolution of quiescent galaxies.

The student will be part of the Bologna-based, ERC-funded *Red Cardinal* project, and will also work in collaboration with an international network of colleagues.

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