3.3 A glimpse of my projects

What do we really know about star formation across the universe and what does it tell us about galaxy formation and evolution? If nearby galaxies can provide us with terrific insight to answer this question, we also need to look beyond the nearby universe and expand our detailed exploration of star formation to distant galaxies. For this endeavor, Euclid will play a central role in combination with the broad range of space-borne and ground-based instruments coming online over the next decade. In particular, Euclid will provide us with unmatched catalogs in terms of breadth, depth, and spatial resolution. My extensive experience on star formation in nearby galaxies will put me in an ideal position to lead really unique investigations with these state-of-the-art instruments, and answer this major question.

In the meantime, in preparation for these large surveys at the end of the decade, several key questions on star formation have to be answered. And we can do that now. Because the SFR and the stellar mass distribution functions are key elements to constrain galaxy evolution models, it is crucial that we can estimate these parameters without bias. Failure to do so will in turn mechanically bias our understanding of the baryonic matter cycle and the mass build-up of galaxies. Unfortunately, we have strong hints that some biases as indeed at play. To be concise, I present here only three of my research projects on this topic. They will be stepping stones for the full exploitation not only of Euclid but also major instruments of the era, including ALMA, SKA, WISH (for which I am part of the French team), or the JWST. They will also have a broader impact on diverse topics such as dust production at high redshift, the evolution of the escape fraction of Lyα or the discovery of extreme stellar populations.

1. With the stellar mass, the SFR is a key parameter to constrain galaxy evolution models. To obtain an accurate measurement, it is of utmost importance that the presence of the dust is corrected for. Unfortunately, necessary data are not always available. For instance, Euclid will detect many millions of galaxies emitting in Hα. In this context, the most direct way to correct for the attenuation is to exploit the Balmer decrement between Hα and Hβ lines. Because the Hβ line is both weaker and at shorter wavelength, many of these galaxies will not have Hβ fluxes readily available. Yet, we need to obtain reliable SFR for these galaxies if we want to fully exploit Euclid to understand galaxy evolution. Worse, similar problems also plague other instruments when a range of multi-wavelengths data are not available. My first project at Institut d'Astrophysique de Paris would be to provide next-generation SFR estimators, statistically corrected for the presence of dust based on a broad range of different parameters. In the context of Euclid, I could for instance provide estimators parametrized on the morphology and mass of galaxies, as the VIS imager will provide us with images at $z = 1$ (a redshift at which Euclid will not be able to provide Hβ detections) matching the spatial resolution of SDSS data at $z = 0.1$. This work would be extended to 1) more relevant parameters, and 2) major facilities that can be used to measure star formation, from ALMA to the JWST.

2. In complement to Euclid, WISH will provide deep, wide near-infrared photometry in the 1–5 μm range. This will directly probe the UV emission of high-redshift galaxies. However, because metals rapidly build-up, we can find solar metallicity galaxies at $z \sim 3$ (Sommariva et al. 2012). This shows that even at high z, we absolutely need to correct the rest-frame UV emission for the presence of dust if we want to be in position to constrain young stellar populations properties. One key ingredient to do so is the shape of the attenuation curve. It is unlikely that the starburst attenuation curve determined on a handful of nearby galaxies (Calzetti et al. 1994) can directly apply to all galaxies detected at high-redshift with Euclid, WISH, or the JWST (e.g. Buat et al. 2012). To provide universal attenuation laws across cosmic times and across wavelengths, I am involved in various projects either as a PI (e.g. HST program 13313, observations are currently being carried out) or as a co-I. These new laws will allow for a more accurate correction for the presence of dust and as a consequence a more precise estimate of the SFR. This in turn will have a direct impact on our ability to properly constrain galaxy evolution models.

3. Upcoming instruments will not only provide us with large samples of high redshift galaxies, they will also be in position to detect the first generations of galaxies. Yet, some of the basic assumptions to estimate their physical parameters are *necessarily* invalid for high redshift galaxies. This is because we expect their SFR to vary strongly on short timescales. Such variations combined with the little time elapsed since the formation of the first stars induce strong redshift-dependent biases not only on the SFR but also on the stellar mass of galaxies, blurring our understanding of galaxy assembly. To constrain galaxy evolution models, we need accurate SFR and mass luminosity functions of high redshift galaxies which we cannot reasonably provide at the moment. To solve this issue, I propose to combine the CIGALE model that I am co-developing with state-of-the-art hydrodynamical simulations of galaxies with violent variations of their SFR. From this combination, I will explore how and to which precision we can measure galaxy properties from their spectral energy distribution, and in particular I will examine what the exact impact of the star formation history is. This will allow us to reassess SFR and mass distributions of high-redshift galaxies.

These projects would be developed not only within my research group at Université Pierre & Marie Curie and Institut d'Astrophysique de Paris, but also as part of several large international collaborations I either already belong to or that I intend to instigate over the upcoming decade. To fund these projects, I will develop proposals to obtain grants from national and European funding agencies. In particular, I aim at obtaining an ERC consolidator grant in the first years of my tenure.