Thesis subject

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Subject's title: Unveiling the high-z galaxy demography through deep JWST surveys

Subject description:

The context is the James Webb Space Telescope (JWST) successfully launched into orbit Dec. 25, 2021, and currently acquiring data since mid-July 2022. This infrared observatory is revolutionizing our knowledge of the unobserved first galaxies in the cosmic era when the Universe was in the process of being reionized by these primordial sources. This critical epoch remains largely unexplored, and its study will lead to new constraints on galaxy formation and on the properties of these distant sources.

The thesis project will be centered on discovering, analyzing, and interpreting the galaxies of the young Universe through unprecedented observations of deep field imaging during JWST Cycle 1 observations. Those will be obtained through two Treasury Programs on the well-known extragalactic deep fields (COSMOS & UDS) with pre-existing information acquired through various facilities (HST, VLT, ALMA, Spitzer, …), that is the PRIMER and COSMOS-Web Large Programs.

The objective is the PhD project is to exploit these new and original JWST data. It will focus on one of the scientific goals of PRIMER, that is unveiling and studying galaxies in the epoch of reionization at $z>7$, one of the most challenging topics with JWST. Out of the two targeted extragalactic fields by PRIMER, COSMOS/HST and UDS/HST, we will primarily analyze the COSMOS field observed with MIRI+NIRCam. The high-z epoch remains largely unexplored and poorly understood, our goal is to set new observational constraints on galaxy formation and evolution, with statistically significant high photometric redshift datasets (and not in the competition of the highest redshift), in deriving number counts, luminosity/mass functions, and the physical properties derived from their spectral energy distribution shape.

We will have furthermore the opportunity to combine these data and results with COSMOS-Web. In fact, the later will be wider thus brighter than PRIMER, and is suited to acquire massive/bright galaxies at high-z due to their much lower number density. Thus COSMOS-Web and PRIMER are fully complementary to study on one side the bright high-z galaxy population, and on the other side the faint high-z galaxy population. In this project, we will pursue our seminal work (Kauffmann, et al. 2022) on high-z galaxies in COSMOS field. In this publication, we identified 17 new candidate sources and confirm 15 previously published ones at $7.5<z<10$ and we derived the galaxy UV luminosity functions in three redshift bins and confirmed the no clear evolution of the brightest galaxies. Thanks to the JWST exquisite imaging resolution and sensitivity in near-to-mid infrared, PRIMER will enable us to gather more numerous and more secure candidate sources for the long-awaited detection of representative galaxy populations at $z>>7$. From 2024, we should have also the opportunity to follow-up high-z candidate sources with the spectrograph PFS/Subaru as part of our LAM GTO allocation time.

Planning and methodology:

Step 1 /1st year will consist in careful source detection and photometry measurements adapted to high-z sources (z >> 4 – 12) over MIRI images using tools as, e.g., SourceXtractor (Bertin et al. 2020), and to cross-matching with the COSMOS2020 catalogues, which include CFHT/Megacam, Subaru/HSC, UlltraVISTA and Spitzer/IRAC multi-band information.
Step 2 / 1st year will be devoted to the measurement of their photometric redshifts, using tools as, e.g., LePhare (Ilbert et al. 2006), EASY (Brammer et al. 2008). The photometric redshifts will be vastly improved with JWST information. This step will also be a preparation for the PFS/Subaru high-z observations.
Step 3 / 2nd year is the measurement of several fundamental physical properties of the high-z galaxies (stellar masses, star formation rates, dust attenuation, star formation histories, etc.) using specific tools as, e.g., BEAGLE (Chevallard & Charlot, 2016), Cigale (Boquiem et al., 2019), LePhare (Ilbert et al. 2006). Stellar mass at these redshifts using rest-frame optical, will be enabled, which is currently impossible.
Step 4 / 3rd year is to estimate the luminosity/mass function evolution from COSMOS data and confront the results with prediction of simulations of the early Universe. In this step, the representativity and the completeness of the datasets is fundamental to establish meaningful statistical estimations, thus a study using both PRIMER and COSMOS-Web sources at the end of reionization (z >> 6 - 10) will be critical.

Data Acquisition:

- PRIMER will obtain deep JWST imaging in 10 bands: F090W, F115W, F150W, F200W, F277W, F356W, F444W and F410M with NIRCam, and F770W and F1800W with MIRI. The COSMOS field will start to be observed with MIRI, acquiring F770W and F1800W imaging in the planned observation windows: COSMOS-2 from Nov 18, 2022, to Jan 7, 2023 (24 visits), And COSMOS-1 from Apr 6, 2023, to May 27, 2023 (24 visits). These 48 visits cover 111.5 arcmin^2, with a 25.53 AB mag depth F770W expected.
- COSMOS-Web will start with NIRCam imaging in 2023-2024 and will be longer to complete since observations cover a much larger area than PRIMER, that is covering 0.6 deg^2 with NIRCam and 0.2 deg^2 with MIRI.

Work environment:

The PhD student will work within a fruitful environment expert team in deep fields, ranging from observations, analyses, interpretations, and simulations, and involved in several JWST programs related to deep fields (e.g., GTO-MIRI, COSMOS-Web, PRIMER), in the ANR Image (2022-2026, PI Ilbert (LAM) and co-PI Laigle (IAP), dedicated to the emergence of massive high-z galaxies in COSMOS-Web), and in the GTO allocation time of PFS/Subaru.

References:

Kauffmann, O. et al. COSMOS2020: UV-selected galaxies at z ≥ 7.5, A&A, 2022, 667, 55
JWST: https://www.jwst.fr/ (French site) https://jwst.nasa.gov/ (NASA site)
PRIMER: https://ui.adsabs.harvard.edu/abs/2021jwst.prop.1837D/abstract Dunlop et al. 2021, GO 1837 Cycle 1 Large Program
COSMOS-Web: https://ui.adsabs.harvard.edu/abs/2021jwst.prop.1727K/abstract Kartaltepe et al. 2021, GO 1727 Cycle 1 Large Program
ANR Image: https://collaborations.lam.fr/iMAGE/

— PRIMER (Public Release IMaging for Extragalactic Research) Treasury Program: 189.4 hours awarded on NIRCam+MIRI (λ=0.9-18μm) JWST instruments. PRIMER pointings: in COSMOS

and UDS CANDELS extragalactic fields, with 8-band NIRCam imaging over 400 arcmin^2 of which 2-band MIRI imaging over 230 arcmin^2. These data will unveil the Universe in its time of reionization thanks to the discovery of a large, homogenous samples of galaxies paving this cosmic epoch, that cannot yet be access with our current facilities. We expect ~13000 galaxies at z=7, ~500 at z=8, ~150 at z=9, and ~50-100 at 10<z<12.

— COSMOS-Web (The Web Cosmic Origins Survey) Treasury Program will map a larger area over the COSMOS field of 0.6 deg^2 in 4-band NIRCam imaging, and 0.2 deg^2 with MIRI. These shallower data will enable to eliminate cosmic variance from smaller field of views, to identify rarer sources, and to relate the sources to their large-scale environment.