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# UNVEILING GALAXY EVOLUTION WITH THE COSMOS-WEB SURVEY

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**Abstract.** Since the beginning of the observations in 2022, JWST has revealed the faintest and furthest galaxies ever observed. However, to push forward our understanding of early mass assembly and processes driving star formation efficiency, there is a need for wider extragalactic surveys, large enough to eliminate cosmic variance and probe the filamentary large-scale structures. The COSMOS-Web survey is the largest imaging program in JWST's first cycle of observations, with a contiguous coverage of 0.54 $\text{deg}^2$ in the COSMOS field. Thanks to its deep and high-resolution photometry in near and mid infrared and the combination of multiwavelength data available in COSMOS, it will provide a valuable resource for the study of the evolution of galaxies and their environments back to the universe's earliest epochs. We present an overview of this survey and discuss the creation process of the COSMOS-Web catalog, from the detection of sources in the images to the determination of galaxy properties such as their magnitude, redshift or stellar mass. We highlight the catalog's first results, including remarkable depth, redshift coverage and precision, surpassing those obtained by previous deep surveys of similar area. Furthermore, we demonstrate how this key resource can be used to investigate galaxy evolution, such as the study of galaxy clustering across the cosmic web.

Keywords: galaxy evolution, galaxy catalog, photometry, observations, galaxy clustering, galaxy environment

## 1 Introduction

One of the fundamental goals in galaxy evolution is to unravel the link between star formation and the environment of galaxies, back to the earliest epochs of the universe. To explore this connection, it becomes essential to investigate the influence of galaxy environment at various scales, ranging from dark matter halos hosting galaxies to the largest cosmic structures.

At the scale of the halo or smaller scales, galaxy growth is regulated by cold gas inflows and mergers, that can provide fuel for star formation. In the other hand, a spectrum of phenomena arises, such as feedback processes (AGN or stellar feedback) or ram pressure stripping, capable of inducing quenching of galaxies. At larger cosmic scales, it has become evident that not only do immediate galactic surroundings play a role over star formation, but also the filamentary cosmic web and the underlying dark matter density field has influence on galaxy evolution. These cosmic structures, which are the large-scale gas reservoir, can for example determine key parameters such as the accretion rate of galaxies.

Thus, the goal of our investigation is to answer this fundamental question: What is the role of the environment, spanning from the largest cosmic scales to the smallest galaxy neighborhood, in determining galaxy evolution up to the early universe? To answer these questions, the COSMOS-Web survey emerges as a valuable tool, enabling us to study a broad array of different galaxies and their environments at various scales.

## 2 The COSMOS-Web survey

### 2.1 Overview of the survey

COSMOS-Web is the largest extragalactic survey conducted during the first cycle of observations with JWST (Casey et al. 2023). It covers an expansive region of 0.5 square degrees situated within the well-known COSMOS

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field. The survey operates across four NIRCam filters (F115W, F150W, F277W, F444W) in the near-infrared spectrum, alongside one MIRI filter (F770W) at longer wavelength. Thanks to prior observations in the COSMOS field by various telescopes, a wealth of multi-band data from HST or ground-based telescopes as HSC, UltraVISTA, and Spitzer is also available. This multi-wavelength dataset allows us to probe a diverse range of galaxies, including those at high redshift, quiescent or dusty galaxies. COSMOS-Web offers this unique combination of wide spatial coverage, high-resolution and deep infrared imaging, and multi-band resources.

Figure 1 shows the first observations conducted in January 2023, representing only 5% of the final area of the survey. Despite this limited coverage, we have already identified intriguing objects, including gravitational lenses and a large sample of galaxies at the highest redshifts (Franco et al. 2023; Mercier et al. 2023). This mosaic is already accessible to the public. Recently, in April, half of the survey field has been observed, while the remaining area is scheduled for December 2023.

It is worth noticing the significant contribution of MIRI data at 7.7 microns. Over 35% of the COSMOS-Web field is covered by MIRI observations, marking a notable advancement compared to prior mid-infrared surveys such as Spitzer IRAC observations. The depths in COSMOS-Web reaches impressive limits, with the $5\sigma$ depth of extended objects for NIRCam reaching approximately 28 magnitude (AB) and around 25 magnitude for MIRI.

The COSMOS-Web survey is driven by several primary scientific objectives. Firstly, it aims to detect and study galaxies from the epoch of reionization and map the large-scale structure during the Universe's first billion years. Additionally, the wide and multi-band coverage (including optical/NIR data from on-ground facilities) of the survey allows to identify and explore the characteristics of rare massive quiescent galaxies, and constrain their star formation history. Furthermore, the survey seeks to investigate the relationship between galaxy evolution and dark matter halos thanks to the statistical power offered by its large galaxy sample.

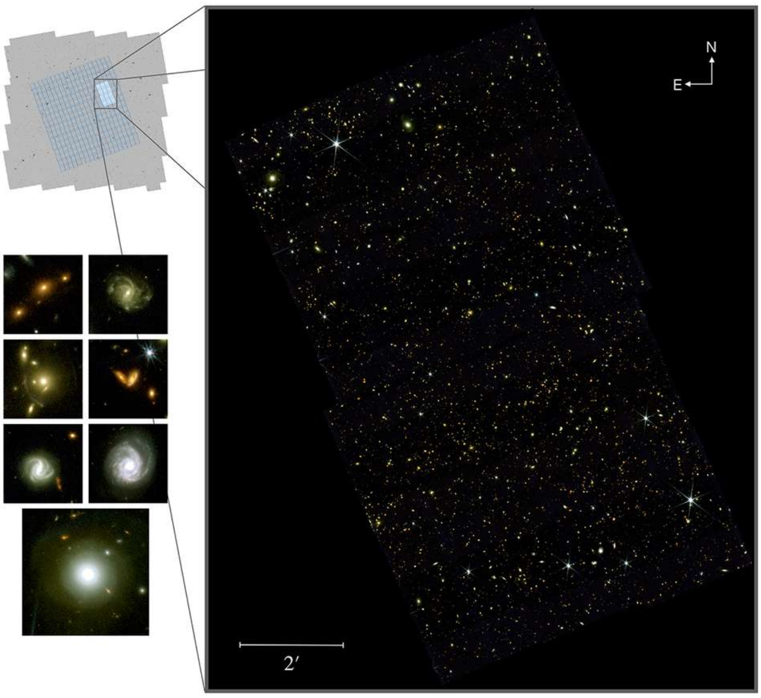


**Fig. 1.** COSMOS-Web first mosaic of NIRCam images, representing 5% of the total intended survey area, observed in January 2023. Figure from Casey et al. (2023).

### *2.2 Building COSMOS-Web catalogs*

In COSMOS-Web, a significant challenge to create photometric catalogs arises from the necessity to merge high-resolution data from JWST with low-resolution data from ground-based telescopes within the COSMOS field. This implies dealing with varying PSFs and resolutions across the datasets, making it impractical to consistently extract photometric measurements as typically done in previous studies or in JWST surveys with a wide range of filters. To overcome this challenge, we use a model-fitting code named `SourceXtractor++`, based upon the well-known detection algorithm `SExtractor`. This approach begins by the initial detection of all sources within the NIRCam images. Then, a morphological model is fitted to each source across the wavelength bands, and fluxes will be measured based on these models.

In addition to the model-fitting catalog, we also produce a more conventional catalog based on `SExtractor` aperture photometry on PSF-homogenized images. This catalog, created on only JWST and HST data, serves both as validating the SE++ catalog and as a complementary alternative for accurate color measurements or the study of high-redshift sources that may be more complicated to model.

Following detection and photometry procedures, we employ SED fitting codes, `LePhare` and `Eazy`, to derive photometric redshift estimates. Our analysis indicates an average accuracy of approximately 3%. For the determination of galaxy physical parameters, including stellar mass, star formation rate and others, the code CIGALE using non-parametric SFH is employed. A comprehensive description of these catalogs will be provided in a forthcoming paper by Shuntov et al. (in prep.), and these catalogs will be made accessible to the scientific community within the year.

## 3 First scientific results with COSMOS-Web

### *3.1 Galaxy clustering*

We present a preliminary analysis of galaxy clustering in the COSMOS-Web field, that will be extended and described in the forthcoming paper Paquereau et al. (in prep.). Galaxy clustering is a measurement of the number of galaxy pairs in excess, compared to a random distribution, across the observed field. This is a valuable tool for constraining various aspects of galaxy evolution and even cosmological parameters. For instance, it helps us inferring dark matter halos masses and investigating how galaxy environment influences star formation activity.

In essence, clustering is the two-point correlation function between galaxy positions. In our preliminary analysis, we used the Landy-Szalay estimator, which involves comparing our observed galaxy catalog with a randomly distributed one. It is important to note that the measurements presented here are based on the initial 50% of the total survey area, but it still offers a strong demonstration of the potential of JWST data in this context.

Figure 2 presents preliminary results, with clustering measurements from COSMOS-Web and previous result from the catalog COSMOS2020 before the inclusion of JWST data, in one redshift bin. COSMOS-Web measurements agrees well with previous work, but a notable achievement here is our ability to measure clustering at exceptionally small scales, smaller than what was previously attainable. These scales are much smaller than the typical size of dark matter halos that host galaxies, meaning that this high-resolution data from JWST enable the study of how galaxies are distributed within a single halo and how they connect.

Our next steps involve exploring which types of galaxies or populations are found within these halos and what their physical properties indicate, as their star formation rate or morphology. For example, the second panel in Figure 2 depicts the difference in clustering between quiescent and star-forming galaxies, suggesting that the environment of galaxies has an impact on star formation. Additionally, we aim to identify galaxy satellites and examine the processes that lead to their quenching, to answer how their environment influences their evolution.

### *3.2 Other contributions*

Furthermore, it should be noted that several papers based on COSMOS-Web observations have already been submitted at the time of this presentation, while more are currently in preparation. Two of these forthcoming papers will delve into the study of dusty galaxies. For instance, the work conducted by (Akins et al. 2023) is about the discovery of two exceptionally massive, compact, and dust-obscured galaxies around redshift 8. This discovery has the potential to significantly advance our understanding of dust buildup and star formation processes in the early universe.

Another upcoming paper will present a sample of EoR bright galaxies observed within the COSMOS-Web survey (Franco et al. 2023). According to preliminary findings, it suggests that the stellar populations of these galaxies were formed within an already metal-enriched environment, even at the higher redshifts.

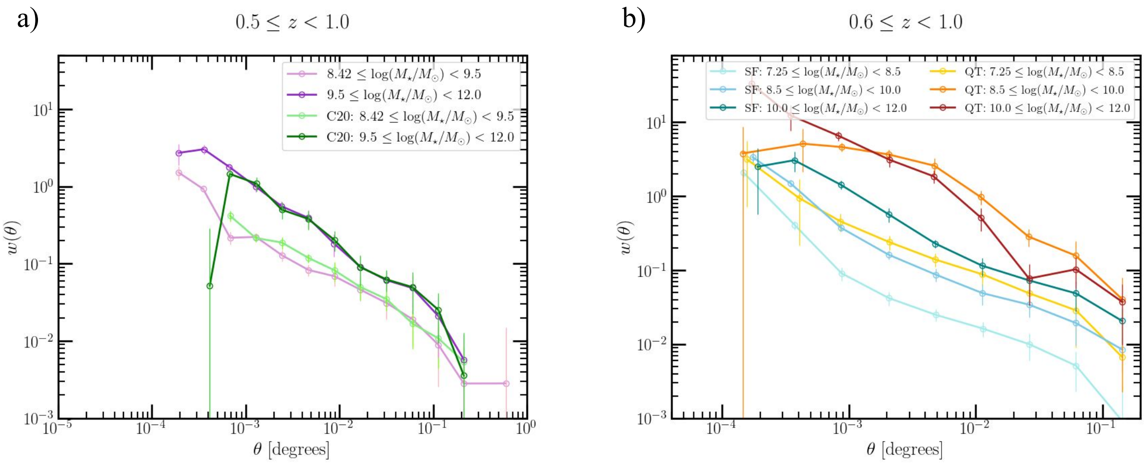


**Fig. 2.** Preliminary clustering results from half of the COSMOS-Web survey, in one redshift bin and different stellar mass bins. Panel (a) shows clustering of all COSMOS-Web galaxies in purple, compared to the COSMOS2020 catalog's measurements (before JWST data), in the same area, in green. The second panel (b) shows the variations in clustering for star-forming galaxies (noted SF) and quiescent galaxies (QT) in COSMOS-Web.

## 4 Conclusions

In summary, our study focuses on the link between the environment and galaxy evolution, spanning from the scales of dark matter halos to the largest cosmic web structures. We explored this connection using the COSMOS-Web survey, which is the largest extragalactic survey in the first cycle of observations of JWST.

Our preliminary findings indicate that COSMOS-Web offers unprecedented opportunities for studying galaxy clustering, at scales smaller than typical dark matter halo sizes. This high-resolution data allows us to investigation of how galaxies are connected within a single halo, as well as studying the influence of large cosmic web structures on star formation. Moving forward, our research will expand to explore the types of galaxies found within these halos, their morphologies or star formation rate, and the identification of galaxy satellites. We aim to uncover the processes that lead to the quenching of satellite galaxies and how their environment at various scales influences their evolution.

Furthermore, COSMOS-Web has already generated significant scientific interest, with several papers submitted and more in preparation. First discoveries include the study of massive dust-obscured galaxies at high redshifts, or samples of EoR bright galaxies. These findings mark just the beginning of the exploration of COSMOS-Web observations, with a lot more discoveries yet to come.

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Shuntov, M., Paquereau, L., et al. in prep.