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Identification of a transition from stochastic to secular star formation around $z = 9$ with JWST.

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ABSTRACT

Star formation histories (SFH) of early ($6< z <12$) galaxies have been found to be highly stochastic in both simulations and observations, while at $z \lesssim 6$ the presence of a main sequence (MS) of star-forming galaxies imply secular processes at play. In this work, we aim at characterising the SFH variability of early galaxies as a function of their stellar mass and redshift. We use the JADES public catalogue and derive the physical properties of the galaxies as well as their SFH using the spectral energy distribution modelling code CIGALE. To this aim, we implement a non-parametric SFH with a flat prior allowing for as much stochasticity as possible. We use the SFR gradient, an indicator of the movement of galaxies on the SFR-M_* plane, linked to the recent SFH of galaxies. This dynamical approach of the relation between the SFR and stellar mass allows us to show that, at $z > 9$, 87% of massive galaxies, ($\log(M_*/M_\odot) \gtrsim 9$), have SFR gradients consistent with a stochastic star-formation activity during the last 100 Myr, while this fraction drops to 15% at $z < 7$. On the other hand, we see an increasing fraction of galaxies with a star-formation activity following a common stream on the SFR-M_* plane with cosmic time, indicating that a secular mode of star-formation is emerging. We place our results in the context of the observed excess of UV emission as probed by the UV luminosity function at $z \gtrsim 10$, by estimating σ_{UV}, the dispersion of the UV absolute magnitude distribution, to be of the order of 1.2 mag and compare it with predictions from the literature. In conclusion, we find a transition of star-formation mode happening around $z \sim 9$: Galaxies with stochastic SFHs dominates at $z \gtrsim 9$, although this level of stochasticity is too low to reach those invoked by recent models to reproduce the observed UV luminosity function.

Выборка

2. The sample

In this work, we use the JWST Advanced Deep Extragalactic Survey (JADES, Bunker et al. 2023; Eisenstein et al. 2023; Hainline et al. 2023) initial data release of the Hubble Ultra Deep Field covering $26'^2$ presented in Rieke & the JADES Collaboration (2023). This catalogue combines 9 broad filters from JWST/NIRCam, 5 NIRCam medium bands from the JEMS survey (Williams et al. 2023), and existing HST imaging, for a total of 23 photometric bands. The reddest NIRCam filter where all the galaxies are detected (F444W) allows us to probe the 0.63 μm and 0.34 μm rest frame at $z = 6$ and $z = 12$, respectively. The catalogue includes sources detected in the F200W NIRCam filter and photometry performed in a set of apertures.

Our sample comprises 5,601 galaxies, for which we show the stellar mass of galaxies as a function of their redshift in Fig. 1. Selected galaxies have at least 2 JWST bands with an SNR larger than 3. We separate the galaxies in three redshift bins: $6 < z < 7$, $7 < z < 9$, and $9 < z < 12$, spanning 150, 220, and 180 Myr, respectively. They include 3,197, 1,883, and 521 galaxies, respectively.

Главные последовательности…

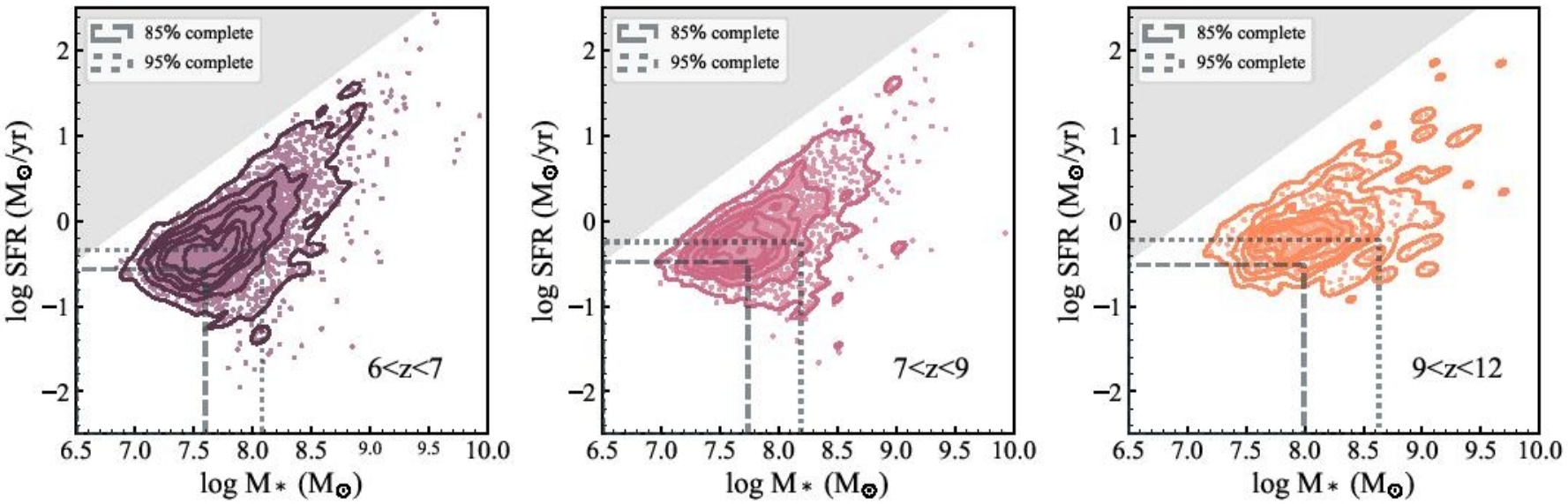

Fig. 4: SFR as a function of M_* in three bins of redshift. The positions of JADES galaxies are indicated by the coloured points and contours. The grey dotted and dashed lines indicate where the sample is 95% and 85% complete, respectively. The grey regions indicate part of the SFR-M_* plane not covered by the models used to do the SED fitting.

… в терминах корреляции

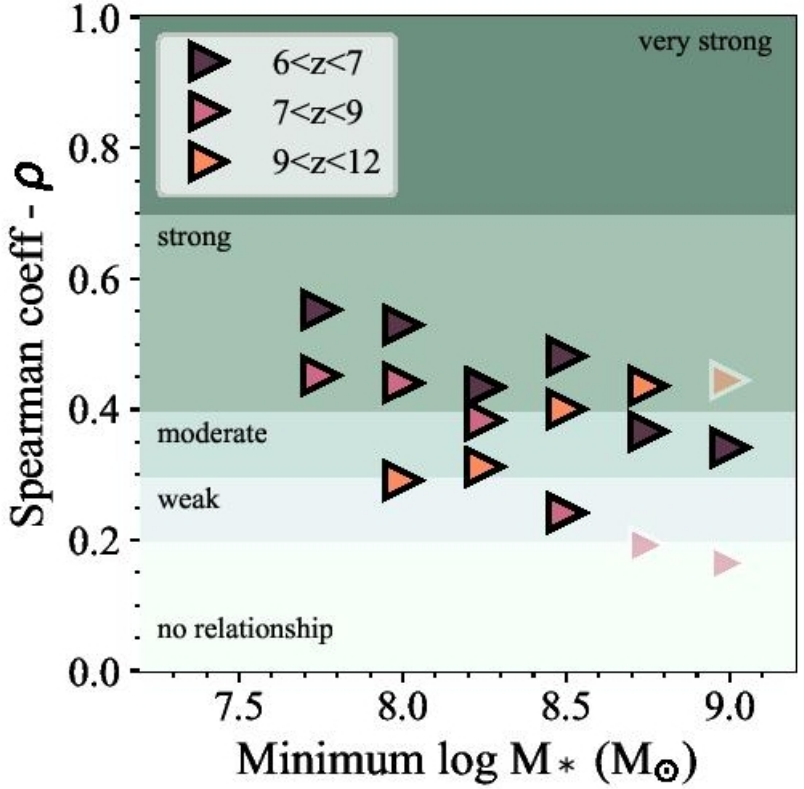

Fig. 5: Spearman coefficient as a function of the minimum stellar mass used to compute it. Symbol colours indicate the redshift range of the galaxies considered. Those with black contours are considered reliable coefficient value since associated with p-value lower than 0.05. The green shaded regions indicate the interpretation scale.

Расхождение с LCDM моделями

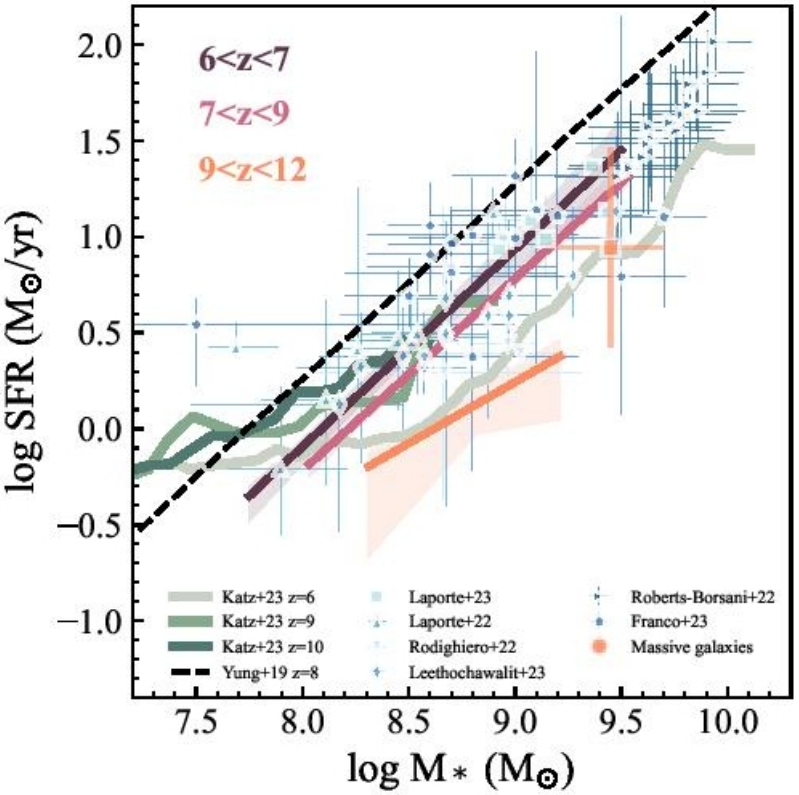

Fig. 6: SFR as a function of stellar mass. The relations found in the redshift bins studied in this work are shown with the solid lines and shaded regions. They are compared to samples of the literature. Relations from simulations are shown in dashed black line (Yung et al. 2019) and green solid lines (Katz et al. 2023). SFR and masses from the literature have been converted to Salpeter (1955) IMF dividing by 0.63 from a Chabrier (2003)

Переходим к исследованию истории SF за последние 100 Myr

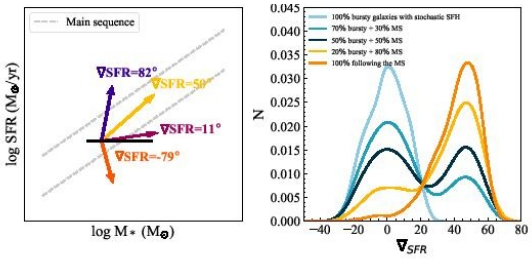

Fig. 7: Left panel: Schematic example of the definition of ∇SFR. The gradient corresponding to each arrow is indicated with the same color and show the path that galaxies followed recently. The point of the arrow indicate the position of the galaxy when observed. The black line is the reference from which the angle of the gradient is computed. The grey dashed lines mark the position of the MS with its the dispersion. Right panel: Mock distributions of ∇SFR obtained from simple modelling.

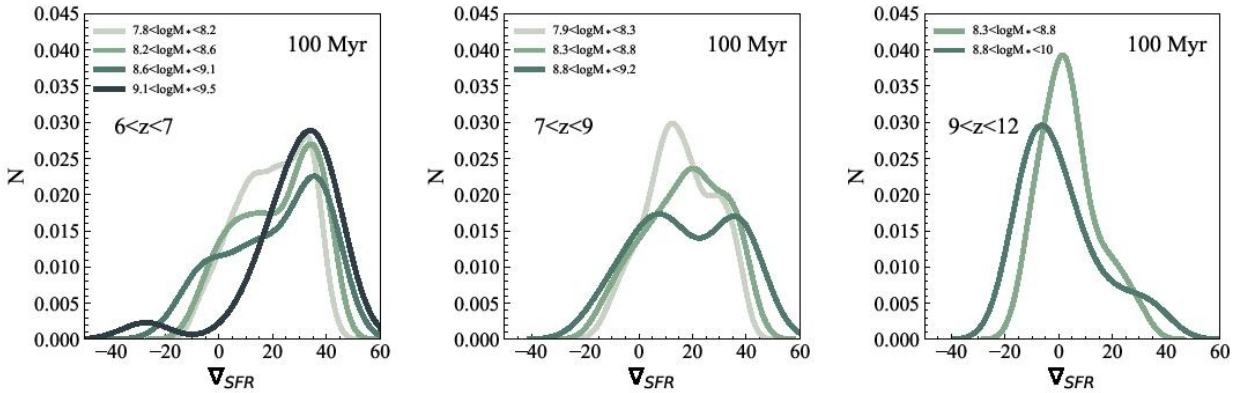

Fig. 8: Distribution of ∇SFR computed over 100 Myr in the three redshift bins. The different colors indicate different stellar mass bins.

Вспышечность слева, ламинарность справа

z>8: даже в массивных галактиках звездообразование идет вспышками

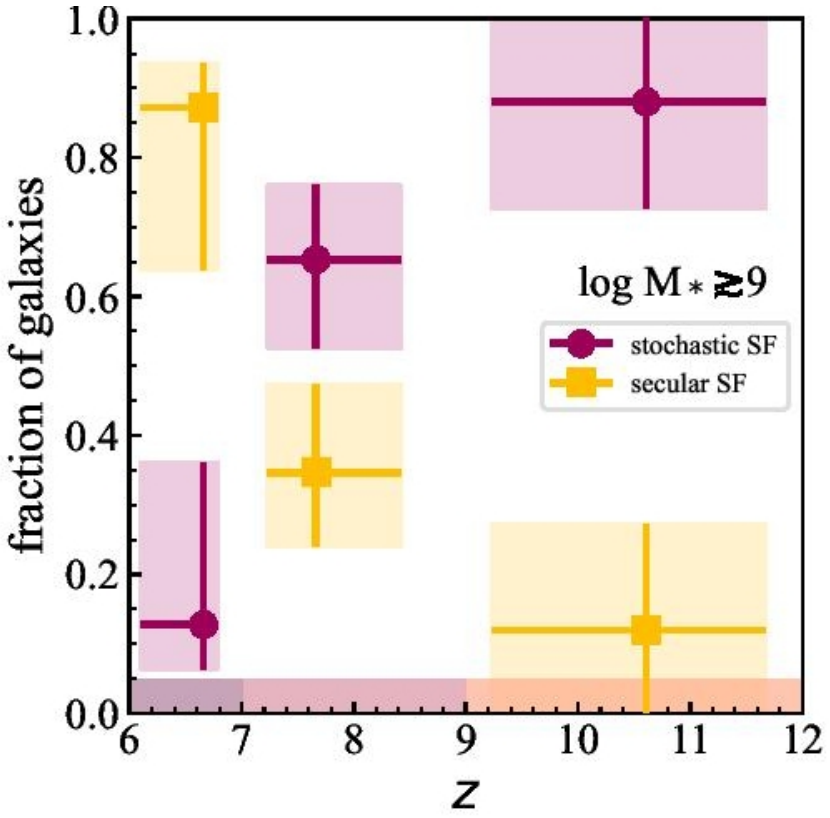

Fig. 9: Fraction of galaxies in the secular SFH gradient distribution (peak around 40°, yellow squares) and in the stochastic SFH distribution (peak around 0°, purple circles) as a function of redshift.

И тем не менее…

- Такого контраста амплитуд вспышек звездообразования недостаточно, чтобы объяснить избыток (по данным JWST) ультрафиолетовых (в рестфрэйме) галактик на z>10