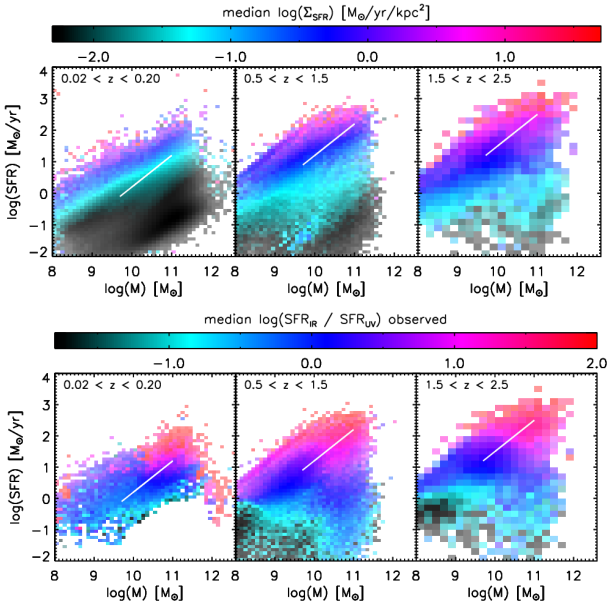
Galaxy Structure & Mode of Star Formation in the SFR-Mass Plane from z ~ 2.5 to z ~ 0.1

by Stijn Wuyts, PEP & CANDELS team

Abstract

We analyze the dependence of galaxy structure (size and Sersic index) and mode of star formation (Σ_{SFR} and SFR_{IR}/SFR_{UV}) on the position of galaxies in the SFR versus Mass diagram. Our sample comprises roughly 600.000 galaxies at z ~ 0.1, 100.000 galaxies at z ~ 1, and 25.000 galaxies at z ~ 2. Structural measurements for all but the z ~ 0.1 galaxies are based on HST imaging, and SFRs are derived using a Herschel-calibrated ladder of SFR indicators. We find that a correlation between the structure and stellar population of galaxies (i.e., a 'Hubble sequence') is already in place since at least z ~ 2.5. At all epochs, typical star-forming galaxies on the main sequence are well approximated by exponential disks, while the profiles of quiescent galaxies are better described by de Vaucouleurs profiles. In the upper envelope of the main sequence, the relation between the SFR and Sersic index reverses, suggesting a rapid build-up of the central mass concentration in these starbursting outliers. The coexistence of quiescent, moderately and highly star-forming systems over an order of magnitude or more in stellar mass presents a challenge for strict halo mass quenching if the stellar and halo mass follow a one-to-one relation. At each mass and redshift, galaxies on the main sequence have the largest size. The rate of size growth correlates with specific SFR, and so does Σ_{SFR} at each redshift. A simple model using an empirically determined SF law and metallicity scaling, in combination with an assumed geometry for dust and stars is able to relate the observed Σ_{SFR} and SFR_{IR}/SFR_{UV}, provided a more patchy dust geometry is assumed for high-redshift galaxies.

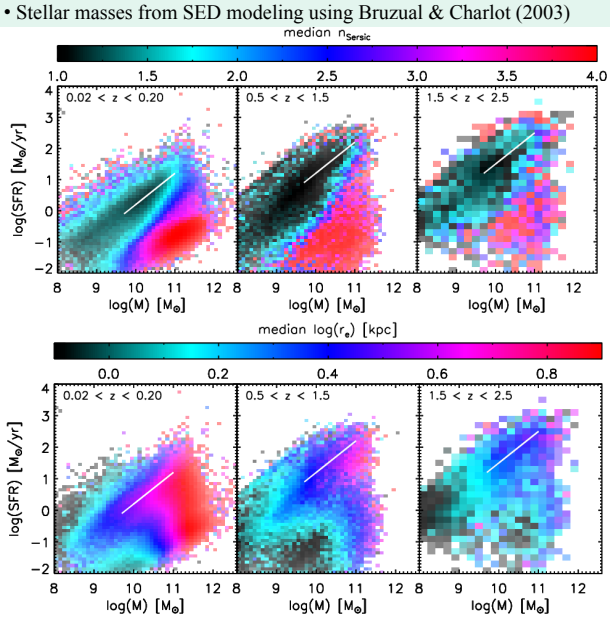


Ingredients

• Sersic profile fits to deep WFC3 H_{160} imaging in UDS and GOODS-S, and to ACS z_{850} and I_{814} imaging in GOODS-N and COSMOS respectively.

• SFRs from cross-calibrated $SFR_{UV+PACS}$, $SFR_{UV+MIPS}$, and $SFR_{SED\ modeling}$.

• Stellar masses from SED modeling using Bruzual & Charlot (2003)



Galaxy Structure

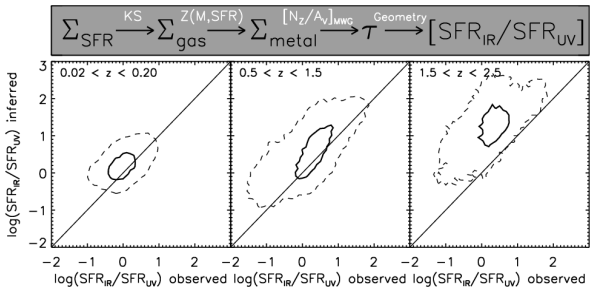
The dependence of surface brightness profile shape (n_{Sersic}) on position relative to the main sequence shows remarkable similarities over 10 Gyr of lookback time. The fact that quiescent galaxies are structurally distinct suggests that quenching and morphological transition go hand in hand.

A simple size-mass relation is inadequate to describe the entire population at a given epoch. Galaxies on the MS are the largest at a given mass.

Mode of Star Formation

At all epochs, iso-Σ_{SFR} contours run diagonally in SFR-Mass space. Σ_{SFR} correlates better with SFR/M than with SFR or M separately (see also Schiminovich et al. 2007 at z~0.1). The relative amount of obscured star formation increases as we move along the MS to higher masses, or across the MS to higher SFRs.

Using the empirical Kennicutt-Schmidt relation (Genzel et al. 2010) and fundamental SFR-Mass-Metallicity plane (Mannucci et al. 2010), we translate Σ_{SFR} to a gas, and then metal column. The IR/UV ratio inferred from the corresponding optical depth, under the assumption of an idealized homogeneous mixture of dust and stars, matches the observations well at low redshifts. At z ~ 2, galaxies are more UV transparent than our model predicts, suggesting patchier dust geometries (see also Adelberger & Steidel 2000; Daddi et al. 2007).



Conclusions

• We present evidence that a Hubble sequence is already in place at z ~ 2.

• Aside from some marked differences in the galaxy populations (e.g., size evolution and increasing zeropoint of the MS with redshift), the dependence of galaxy structure and mode of star formation on location in the SFR-Mass plane is strikingly similar at all epochs probed.

Adelberger & Steidel 2000, ApJ, 544, 218
Bruzual & Charlot 2003, MNRAS, 344, 1000
Daddi et al. 2007, ApJ, 670, 156
Genzel et al. 2010, MNRAS, 407, 2091
Mannucci et al. 2010, MNRAS, 408, 2115

For further information, please contact: swuyts@mpe.mpg.de