CHARACTERIZING THE LOCAL RELATION BETWEEN STAR FORMATION RATE AND GAS-PHASE METALLICITY IN MANGA SPIRAL GALAXIES

Laura Sánchez-Menguiano,[1,2] Jorge Sánchez Almeida,[1,2] Casiana Muñoz-Tuñón,[1,2] Sebastián F. Sánchez,[3]
Mercedes Filho,[4,5] Hsiang-Chih Hwang,[6] and Niv Drory[7]

ABSTRACT

The role of gas accretion in galaxy evolution is still a matter of debate. The presence of inflows of metal-poor gas that trigger star formation bursts of low metallicity has been proposed as an explanation for the local anti-correlation between star formation rate (SFR) and gas-phase metallicity (Z_g) found in the literature. In the present study, we show how the anti-correlation is also present as part of a diversified range of behaviours for a sample of more than 700 nearby spiral galaxies from the SDSS IV MaNGA survey. We have characterized the local relation between SFR and Z_g after subtracting the azimuthally averaged radial profiles of both quantities. 60% of the analyzed galaxies display a $SFR-Z_g$ anti-correlation, with the remaining 40% showing no correlation (19%) or positive correlation (21%). Applying a Random Forest machine-learning algorithm, we obtain that the slope of the correlation is mainly determined by the average gas-phase metallicity of the galaxy. Galaxy mass, $g - r$ colors, stellar age, and mass density seem to play a less significant role. This result is supported by the performed 2nd-order polynomial regression analysis. Thus, the local $SFR - Z_g$ slope varies with the average metallicity, with the more metal-poor galaxies presenting the lowest slopes (i.e., the strongest $SFR - Z_g$ anti-correlations), and reversing the relation for more metal-rich systems. The dependence seems to flatten in the metal-poor regime, hinting at a single slope for low-metallicity galaxies. Our results suggest that external gas accretion fuels star-formation in metal-poor galaxies, whereas in metal-rich systems the gas comes from previous star formation episodes.

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Вычитали азимутально усредненные металличности и SFR, смотрели на зависимость delta(Z) — delta(SFR)

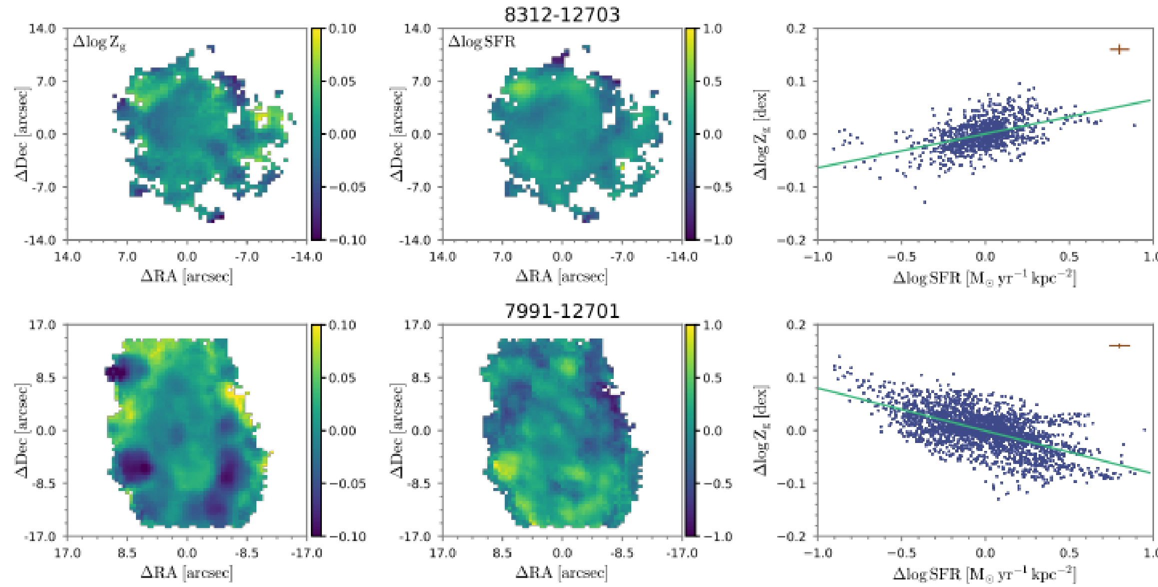
1. Galaxies with $z < 0.05$ and observed with the 91- and 127- fiber bundles (corresponding to FoV diameters of 27.5″ and 32.5″, respectively).

2. Galaxies with $b/a > 0.35$, corresponding to an inclination lower than approximately 70°. The axial ratios (b/a) were taken from the NASA Sloan ATLAS (NSA) v1_0_1 catalog and measured on the SDSS r-band images (Blanton et al. 2011).

3. Galaxies with morphological types $T \geq 1$, corresponding to Sa types and later. Morphological classifications were adopted from the MaNGA Deep Learning Morphology Value Added catalog (MDLM-VAC) described in Fischer et al. (2019). The MDLM-VAC is a morphological catalog of MaNGA DR15 galaxies obtained with Deep Learning models trained and tested on SDSS-DR7 images (see Domínguez Sánchez et al. 2018). All the T-Type values in the catalog have been eyeballed, and modified if necessary, for additional reliability (Fischer et al. 2019).

4. Finally, we discarded galaxies for which the quality of the final DRP products (3D dacubes) did not meet quality standards because of potential issues during processing, such as the presence of many dead fibers or a critical failure in one or more frames (i.e., bad flags in the field DRP3QUAL contained in the output FITS headers of the datacubes, see Law et al. 2016 for details).

$8.17 < 12 + \log(O/H) < 8.77$



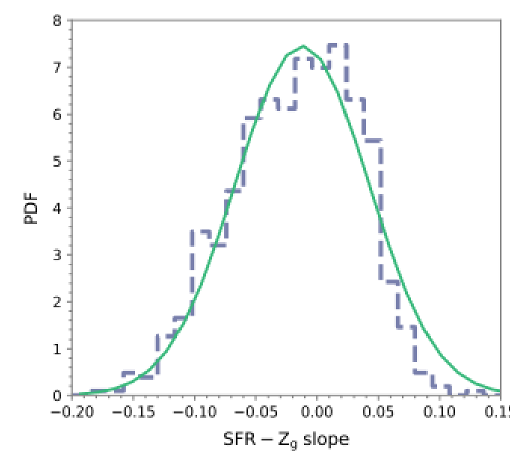


Figure 3. PDF of slopes of the correlations between SFR and Z_g residuals. Solid green line represents a Gaussian fit to the observed PDF (blue dashed line) sampled with the same bins.

Figure 5. Slopes of the local $SFR - Z_g$ relation predicted by the RF algorithm versus the measured values for the training (blue circles) and test (red triangles) samples. The dashed line indicates the one-to-one relation.

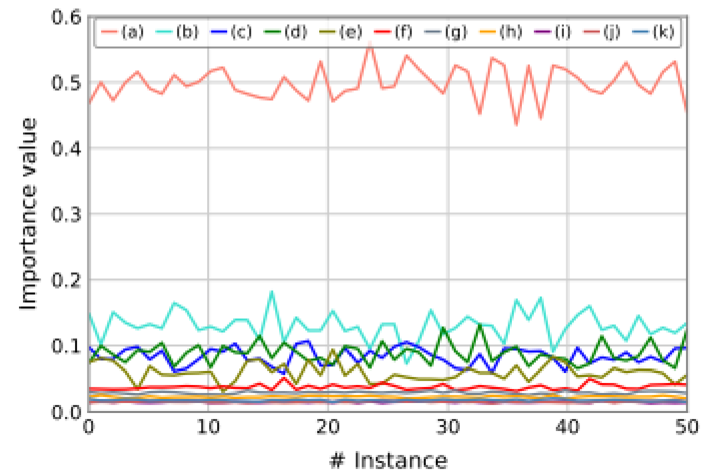
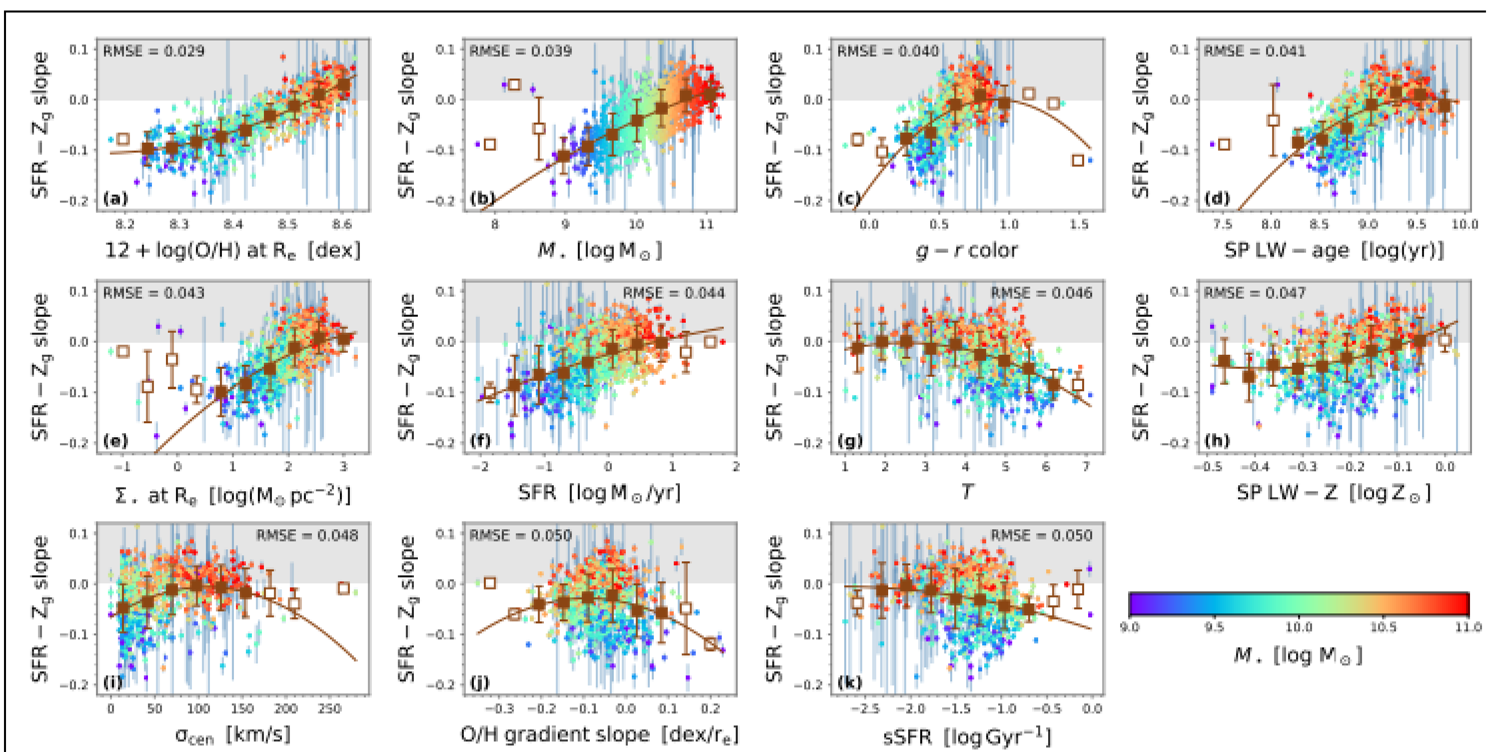


Figure 6. Relative *importance* of the input features of the RF in predicting the slope of the local $SFR - Z_g$ relation for 50 runs of the algorithm. The different solid lines correspond to: (a) $12 + \log(O/H)$ at R_e, (b) $g - r$ color, (c) $M_\star$, (d) LW stellar age at R_e, (e) average $\Sigma_\star$ at R_e, (f) integrated SFR, (g) slope of the O/H radial gradient, (h) LW stellar Z at R_e, (i) morphological type, (j) σ_{cen}, and (k) sSFR.



One scenario is the local infall of metal-poor gas that mix with pre-existing gas and trigger star formation bursts, provided that both ac- creted and pre-existing gas in each star forming region have comparable masses. Our results suggest that this could be plausible for galaxies of low-intermediate mass (< 10−10.5 logM_stars). On the contrary, for more massive systems the pre-existing gas mass may exceed the exter- nal gas mass, thus reversing the SFR−Zg relation from having a negative slope to a positive one. Alternatively,

All these results evidence that the time-scales of mixing processes taking place in spiral galaxies are large enough as to allow the durability of chemical variations for long periods of time.

In summary, this work shows the existence of a linear relation between log SFR and log Z_g at local scales (after correcting for radial trends), with the slope determined mainly by the average gas-phase metallicity of galaxies. We confirm previous studies finding an anti-correlation for dwarf galaxies, which reverses for more metal-rich (and massive) systems. As a plausible explanation, we propose a scenario in which external gas accretion fuels star-formation in metal-poor galaxies, whereas the gas comes from previous star formation episodes in metal-rich systems. Numerical simulations emerge as key in confirming this framework and provide an answer to the level of contribution of gas accretion to galaxy formation and chemical evolution.