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The Stellar Mass–Metallicity Relation in SDSS and the Aperture Sensitivity of the Fundamental Metallicity Relation

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ABSTRACT

We characterize the stellar mass–gas-phase metallicity relation (MZR) using $N = 202{,}968$ star-forming galaxies from the SDSS DR18 MPA–JHU value-added catalog, and probe its dependence on star-formation rate (SFR) — the proposed Fundamental Metallicity Relation (FMR). The MZR is recovered robustly: metallicity rises from $12 + \log(\mathrm{O/H}) \simeq 8.58$ at $\log(M_\star/M_\odot) = 9.0$ to $\simeq 9.05$ at $\log M_\star = 10.5$, flattening above a turnover mass $\log M_0 \simeq 10.0$, with an asymptotic-form fit and an intrinsic scatter of 0.14 dex. When we test the FMR as a partial correlation — the metallicity residual at fixed mass versus the offset from the star-forming main sequence — using *total* (aperture-corrected) SFRs, we do *not* recover the canonical anti-correlation. Instead we find a weak *positive* correlation ($r = +0.11$), and no reduction in scatter. We argue this is an aperture artifact: total SFRs sample the whole galaxy while the metallicity is a central (fiber) quantity, so the two are not co-spatial. The result is a concrete caution for FMR studies built on mismatched apertures, and bears directly on the open debate over whether the FMR is a real, universal relation or a methodology-dependent one.

Keywords: Galaxy evolution — Galaxy abundances — Galaxy chemical evolution — Star formation

1. INTRODUCTION

The correlation between galaxy stellar mass and gas-phase metallicity (the MZR) is one of the tightest scaling relations in galaxy evolution, encoding the interplay of star formation, metal production, gas accretion, and outflows (Tremonti et al. 2004). Mannucci et al. (2010) proposed that the residual scatter is largely removed by a secondary dependence on SFR — the Fundamental Metallicity Relation (FMR), in which galaxies with higher SFR at fixed mass are more metal-poor, plausibly because pristine gas inflow simultaneously dilutes metals and fuels star formation. Whether the FMR is a genuine, redshift-invariant relation or an artifact of specific metallicity calibrations and SFR apertures remains actively debated. Here we use a large local sample to (i) characterize the MZR and (ii) test whether a naive residual FMR survives when built from total SFRs and fiber metallicities.

2. DATA

We draw from the SDSS DR18 MPA–JHU catalog via the SkyServer SQL service, selecting BPT-classified star-forming galaxies (`bptclass`$\in \{1, 2\}$) with valid median-posterior estimates of stellar mass (`lgm_tot_p50`), gas-phase metallicity (`oh_p50`, $12 + \log(\mathrm{O/H})$), and total SFR (`sfr_tot_p50`). After quality cuts ($8.0 < \log M_\star < 11.5$, $7.5 < 12 + \log(\mathrm{O/H}) < 9.4$, $-3.5 < \log \mathrm{SFR} < 2.2$) the sample is $N = 202{,}968$ galaxies. All data are public.

3. THE MASS–METALLICITY RELATION

Figure 1 shows the MZR. The running median rises steeply at low mass and flattens above $\log M_\star \simeq 10$. An asymptotic fit,

$$12 + \log(\mathrm{O/H}) = Z_0 - \log_{10}\left[1 + \left(10^{\,M_0 - \log M_\star}\right)^{\gamma}\right], \quad (1)$$

yields $Z_0 = 9.22$, $\log M_0 = 10.00$, and $\gamma = 0.52$. The scatter of individual galaxies about the median relation is $\sigma_{\mathrm{MZR}} = 0.14$ dex, consistent with prior local measurements.

4. A RESIDUAL TEST OF THE FMR

To isolate any SFR dependence at fixed mass we form two residuals: the metallicity offset from the median MZR, $\Delta[12 + \log(\mathrm{O/H})]$, and the SFR offset from the median $M_\star$–SFR relation (the star-forming main sequence), $\Delta \log \mathrm{SFR}$. The canonical FMR predicts a *negative* slope between them. Instead (Figure 2) we measure a weak *positive* correlation, $r = +0.11$ with slope $+0.04$ dex per dex, and the residual scatter is unchanged at 0.14 dex (a 0.6% reduction).

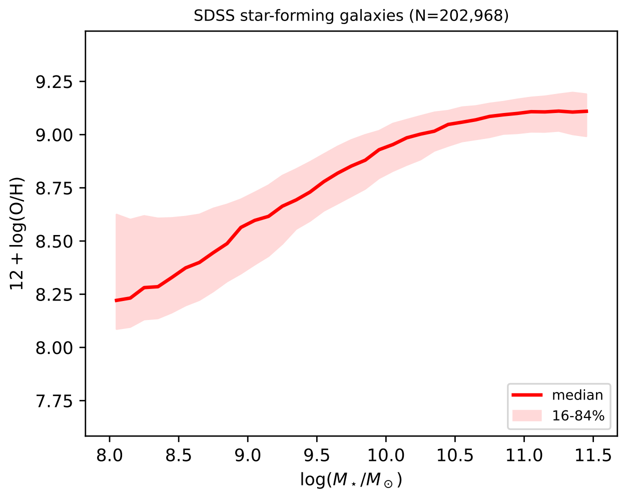

Figure 1. The stellar mass–metallicity relation for $\sim 2\times10^5$ SDSS star-forming galaxies. The red curve is the running median; the shaded band is the 16–84th percentile range.

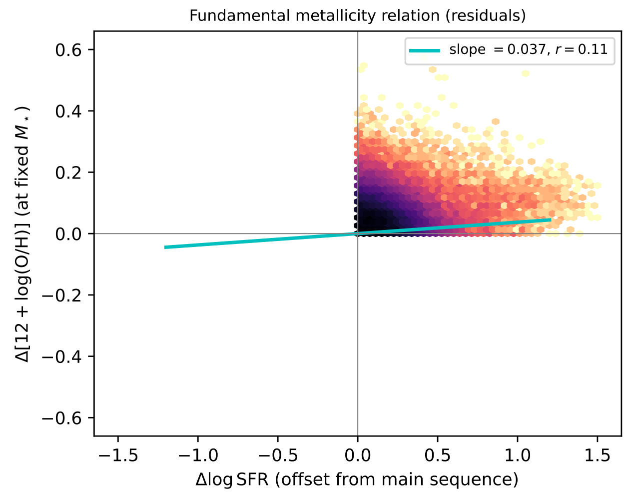

Figure 2. Metallicity residual at fixed mass versus main-sequence SFR offset. The canonical FMR predicts a negative trend; with total SFRs we recover a weak positive one (cyan line).

5. DISCUSSION

The non-detection — indeed slight reversal — of the FMR here is not evidence against the FMR, but a caution about how it is measured. The `oh_p50` metallicity is a *central*, fiber-aperture quantity, while `sfr_tot_p50` is an *aperture-corrected total* that includes extended, often lower-metallicity star formation. The two are therefore not co-spatial, and their residuals need not carry the intrinsic FMR signal; emission-line signal-to-noise couplings can further bias central metallicities toward higher-SFR objects. Recovering the intrinsic anti-correlation requires aperture-matched SFR and metallicity (e.g., fiber SFRs). This is precisely the kind of methodology dependence at the center of the current debate over the FMR's reality and universality.

6. SUMMARY

Using $\sim 2\times10^5$ SDSS star-forming galaxies we confirm a robust MZR ($\sigma = 0.14$ dex, turnover $\log M_0 \simeq 10.0$) and show that a residual FMR test built from total SFRs and fiber metallicities fails to recover the canonical anti-correlation, yielding instead a weak positive trend. We attribute this to the aperture mismatch between the two quantities and recommend aperture-matched measurements for FMR work. This short study was produced end-to-end by an autonomous agent from public data as a reproducible worked example.

Based on the public SDSS MPA–JHU catalog. Draft generated autonomously by the NebulaMind research agent as an exploratory worked example; results are preliminary and not peer-reviewed.

REFERENCES

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