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Hidden Correlations of Reionization Optical Depth in Cosmology

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The reionization optical depth $\tau_{\rm reio}$ has interesting connections to existing cosmological anomalies. As first studied in the context of the Hubble tension in our previous paper, a larger $\tau_{\rm reio}$, which could be achieved by removing the Planck low-ℓ polarization data, could boost H_0 slightly, resulting in a mild reduction of the tension between the early- and late-universe determinations of H_0. It has been shown later that a larger $\tau_{\rm reio}$ could also relieve other anomalies including: the tension between BAO and CMB data, the neutrino mass tension, and the latest DESI plus supernovae data's tension with the standard cosmological constant scenario. In this paper, we systematically analyze the correlations between $\tau_{\rm reio}$ and relevant cosmological parameters in the existing cosmic observation anomalies. In addition to Pearson correlation coefficients extracted directly from the covariance matrix, we also study partial correlation coefficients which measure intrinsic relationships between pairs of parameters removing the influence of other parameters. Introducing these methods of partial correlations to cosmology,
we show that $\tau_{\rm reio}$ has weak intrinsic correlations with the parameters responsible for the tensions and anomalies discussed. The large direct Pearson correlations that allow larger $\tau_{\rm reio}$ inferences to alleviate the cosmological tensions each arise from complicated networks through multiple parameters. As a result, the relationships between $\tau_{\rm reio}$ and each anomaly are not independent of other parameters. We also introduce causal inference methods to cosmological data analyses, computing correlations to clarify the impact of large scale polarization data and the effects of CMB observations from ACT and SPT.

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