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# A new era of the fine structure constant measurements in the early universe

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In some modern theories, fields of the Standard Model of particle physics are allowed to interact with dark matter and dark energy. Such interactions, if they exist, may give rise to temporal evolution of the fine structure constant ($\alpha$) or its spatial variations. Consequently, stringent constraints on such theories can be placed by searching for any possible $\alpha$ variation. Recent advancements in astronomical instrumentation and a newly developed spectral analysis tool based on Artificial Intelligence (AI) allow for unprecedented precision in measuring the value of $\alpha$ from newly acquired astronomical spectra.

I will present major developments based on the high-resolution spectrograph ESPRESSO (mounted on the Very Large Telescope) and on the new AI spectral modelling tool, AI-VPFIT. The former provided the highest quality data yet and the latter provided a tool for objective, robust, and reproducible measurements derived from spectroscopic data. Combined, these advancements allowed us to identify and quantify several new systematic effects important for $\alpha$ (and similar) measurements, associated both with the astrophysical objects (e.g. non-terrestrial isotopic abundances) and with the measurement process (e.g. model non-uniqueness). More importantly, they also allowed us to remove them, ushering a new era of fundamental physics measurements in the early universe.

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