QuasarCodex: Quantifying AGN Feedback in High-Redshift Quasars Through Outflow Kinematics

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Quasars are the brightest objects in the universe and the most energetic subclass of active galactic nuclei (AGN), resulting from the accretion of gas and dust within a rapidly rotating disk in supermassive black holes (SMBH). As matter falls into these SMBH, energy converts into electromagnetic radiation, driving intense gas outflows impacting star formation and galaxy evolution. AGN feedback is critical for galaxy morphology, yet the kinematics and energetics of quasar-driven outflows at high redshifts ($z > 2$), remain uncertain, hindering our understanding of early universe feedback. To address this, I developed QuasarCodex, a machine learning model classifying AGN outflows using spectral features by employing QUILT (Quasar Ultraviolet and Ionized Line Tracer), an algorithm automating the extraction of spectral features from emission lines (like [O III], PV, and CIV). QUILT enables more accurate measurement of velocity shifts, ionization states, and chemical abundances, improving redshift and outflow parameterization estimates by fitting lines with Gaussian models. QuasarCodex transforms spectroscopic data into numerical feature space, automating outflow detection via Principal Component Analysis (PCA) and enabling high-speed processing with statistical significance for large datasets of outflow signatures. This is exemplified within the Sloan Digital Sky Survey DR16Q catalog, where a strong correlation ($r = 0.85$, $p < 0.01$) between outflow velocity and quasar luminosity was found, suggesting radiation pressure as a driver of wind generation. QuasarCodex advances AGN feedback models and can be applied to further datasets focused on processing more diverse AGN and quasar spectra to improve the understanding of feedback mechanisms in galaxy evolution.

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