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Coexistence of Chromatic Flares and an Achromatic QPO in the Gamma-ray Blazar PG 1553+113

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Abstract

The physical origin of quasi-periodic oscillations (QPOs) in blazars remains debated, with geometric and plasma-driven scenarios as the main competing interpretations. Discriminating between them requires probing variability beyond flux periodicity. We study the spectral evolution of the BL Lac object PG 1553+113 over its 2.2-year gamma-ray QPO cycle to constrain the mechanism driving the oscillation. In particular, we test whether the variability is chromatic (coupled to spectral changes) or achromatic (independent of spectral shape), allowing us to distinguish between plasma-driven and geometric scenarios. We analyze 17 years of Fermi-LAT data (2008-2025) with 30-day binning. To mitigate red-noise effects, we apply Singular Spectrum Analysis (SSA) to remove slow baseline trends and use a Block Bootstrap approach to quantify correlations between photon flux and photon index while preserving temporal dependence. We find a robust softer-when-brighter chromatic trend, atypical for high-synchrotron-peaked blazars such as PG 1553+113 and which, based on our analysis, physically corresponds to softer-when-flaring episodes, that persists after detrending and accounting for temporal autocorrelation. In contrast, no significant correlation is detected between the photon index and the QPO phase, indicating that the periodic modulation is effectively achromatic. The coexistence of plasma-driven chromatic flares and an achromatic QPO disfavors scenarios in which the periodicity arises from intrinsic jet processes. Instead, the results support a geometric origin for the QPO modulation, such as jet precession, where Doppler-factor variations modulate the flux without altering the intrinsic particle energy distribution.

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