

AGB Post-Mass-Transfer Spectroscopic Ratios as WD tracers

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INTRODUCTION

When a star ascends the asymptotic giant branch (AGB), dredge-up brings s-process elements (Ba, Sr, La, etc.) to its surface. In a binary, part of this enriched wind can be accreted by the companion before the donor becomes a white dwarf (WD). The recipient preserves this contamination as a fingerprint: a permanent spectroscopic signature of its history.

These post-mass-transfer systems include Ba, CH, and CEMP-s stars, all products of past AGB enrichment. Barium dwarfs are the unevolved primarily F- and G-type subset, defined by $[s/Fe] \geq +1$ and mild carbon enhancement (Roriz et al. 2024), and are the subject of this study.

RESULTS

Using Gaia DR3 radial-velocity amplitudes and sampling statistics, we derived period ranges and lower-limit companion masses for 62 barium dwarfs. Even with these lower-limit assumptions, a small fraction (11%) of systems reach the canonical white-dwarf mass range (0.5–0.8 M_{\odot}), illustrating that some companions must be compact objects. The majority have smaller lower-limit masses, consistent with inclination or sampling effects that bias Gaia DR3 toward underestimation.

Spectral-energy-distribution (SED) fits using VOSA reveal several stars with a distinct near-UV flux excess above their main-sequence model. This excess provides an independent *fingerprint* of a hot companion, consistent with a white dwarf that contributes primarily in the ultraviolet while remaining undetectable in the optical or infrared. The SED fits are robust, however, VOSA’s derived radii and masses are only approximate and should not be interpreted as physical values. Their main utility lies in identifying stars whose photometric profiles suggest a WD companion.

Together, the radial-velocity amplitude modeling and the ultraviolet SED excess provide complementary diagnostics for detecting hidden white dwarfs and tracing the legacy of AGB mass transfer. The upcoming Gaia DR4 release, expected in 2026, will supply full time-series radial-velocity data, enabling direct orbital reconstruction and more accurate mass-ratio estimates. Combined with future spectroscopic and photometric cross-matching, these methods will form a consistent diagnostic framework for identifying and characterizing post-AGB binary systems.

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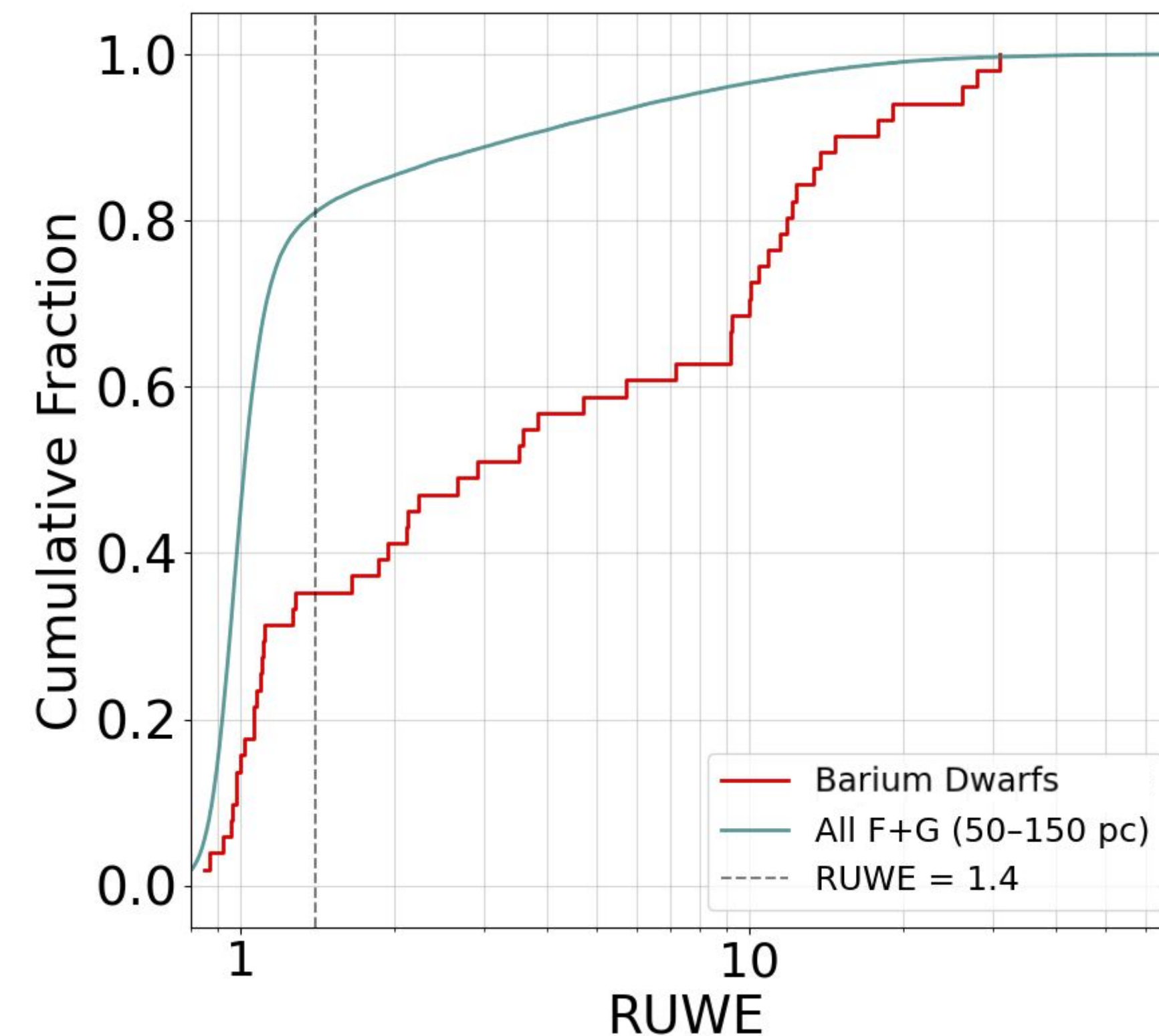


Fig. 1: Renormalized Unit Weight Error (RUWE) describes the “wobble” in Gaia’s single-star astrometric model; values greater than 1.4 indicate unresolved orbital motion. Among barium dwarfs, 64.7 % have $RUWE \geq 1.4$, compared to only 19.1% of field F + G stars. The RUWE distribution of barium dwarfs show an excess relative to normal field stars, suggesting many exhibit hidden orbital motion from WD companions.

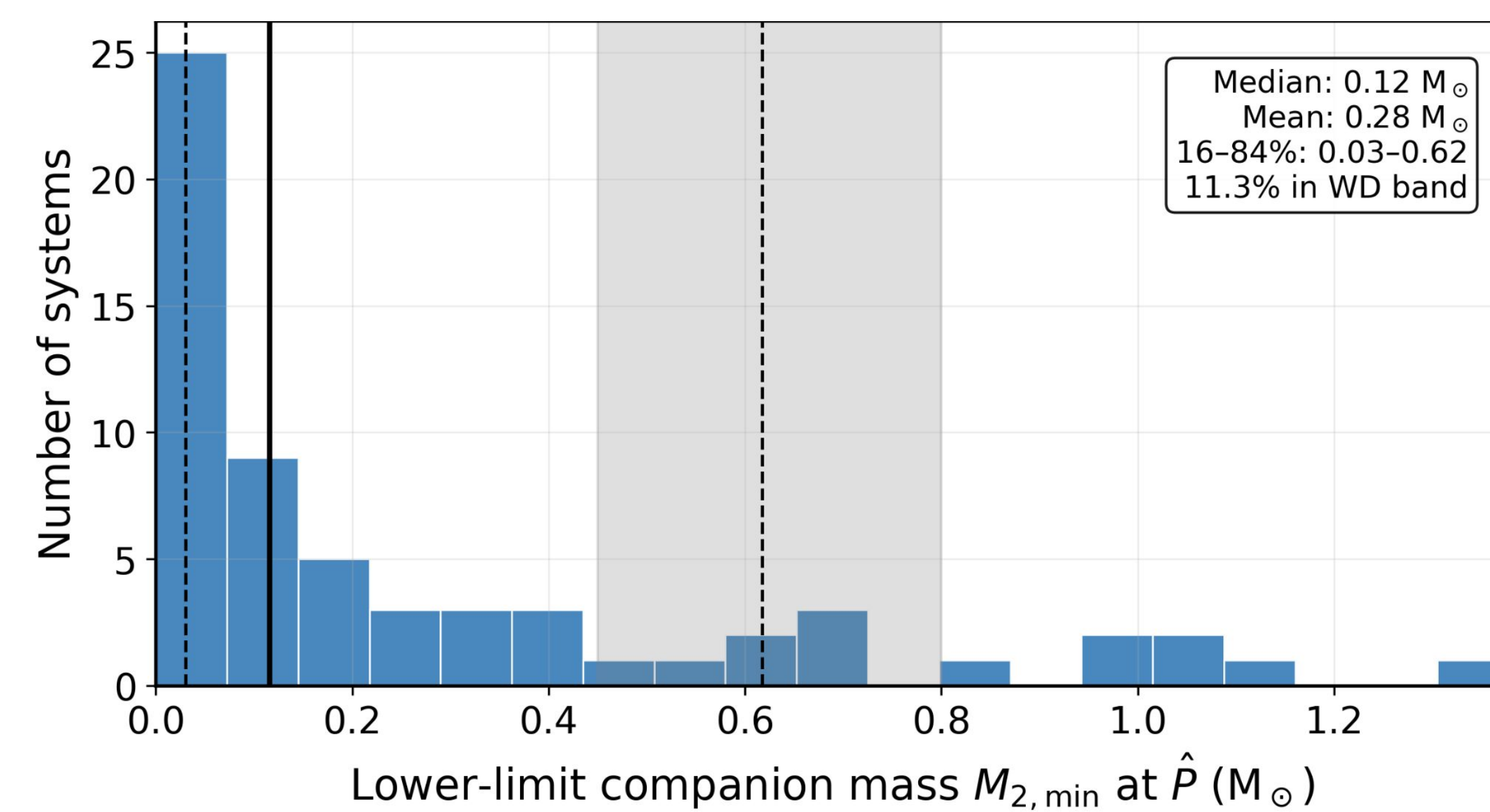


Fig. 2: Distribution of lower-limit companion masses $M_{2,min}$ at the most probable period P . The shaded region (0.45–0.8 M_{\odot}) marks the white-dwarf mass range. Only 11% of systems fall within this band, though true companion masses are likely higher once inclination effects are considered.

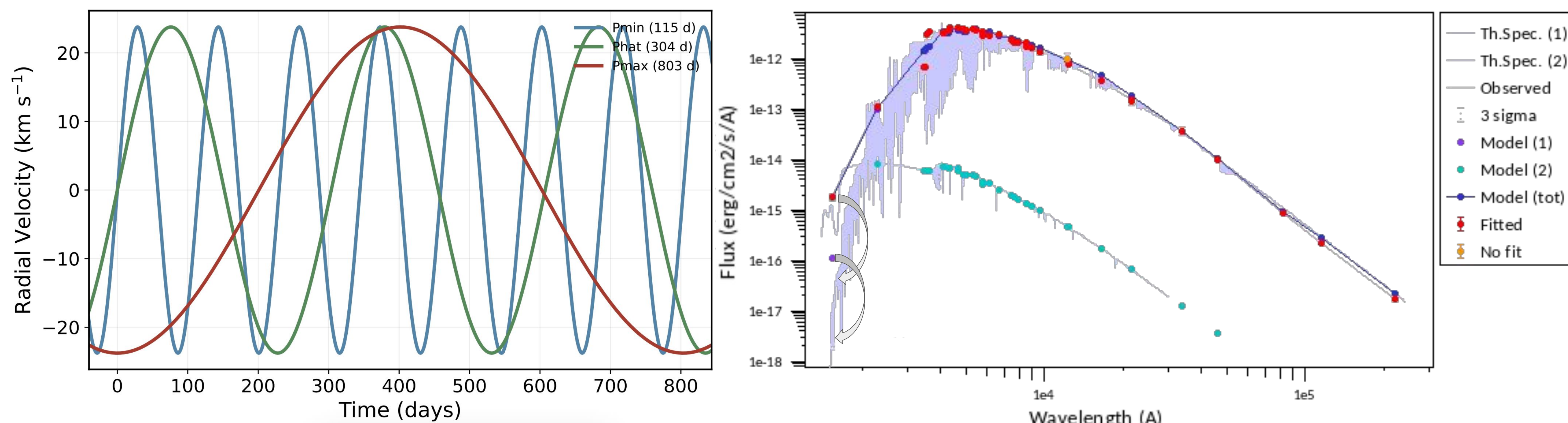


Fig. 3: Synthetic Gaia RV sinusoids (left) and VOSA two-component SED fit (right) for HD 89948. Using Gaia DR3 summary parameters ($K=23.8$ km s $^{-1}$, $T=803.4$ d, $N=15$), we infer orbital period limits of $P_{min}=115$ d, $P^{\wedge}=304$ d, and $P_{max}=803$ d. The corresponding companion-mass estimates are $M_{2,min}=0.80, 1.31, 2.30 M_{\odot}$ for the three periods, assuming $M_1=1 M_{\odot}$. The RV curves illustrate how different sampling-based period assumptions translate to plausible orbital motion. The SED fit (right) combines a BT-Settl main-sequence model ($T_{eff}=5700K$) with a Koester WD model ($T_{eff}=9250K$), showing a clear near-UV excess consistent with a white-dwarf companion.

CONSTRAINING THE ORBIT

To uncover hidden companions, we combine data from Gaia DR3 and multiple spectroscopic and photometric surveys (GALEX, GALAH, ESO, 2MASS, WISE, and others). Gaia’s astrometry constrains orbital motion via the Renormalized Unit Weight Error (RUWE) to flag binary, and while its radial-velocity statistics provide lower-limit mass functions. Meanwhile, NUV photometry from GALEX reveals hot WDs blended within the primary’s SED.

We analyze 71 spectroscopically confirmed barium dwarfs from Roriz et al. (2024) to search for evidence of unseen WD companions using Gaia DR3 radial-velocity statistics. For each star, Gaia provides the robust radial-velocity amplitude (K), observing baseline (T), and number of transits (N). From these, we estimate plausible orbital periods. The limits on the orbital period (P_{min}, P_{max}) are derived from the sampling pattern, and the most probable period (P) is taken as the geometric mean of these upper and lower bounds.

$$P_{min} = 2T / (N-1)$$

$$P_{max} = T$$

$$P = \sqrt{P_{min}P_{max}}$$

$$f(M) = PK^3 / (2\pi G) = M_2^3 / (M_1 + M_2)$$

Using these parameters, we calculate the spectroscopic mass function $f(M)$, which relates the period, semi-amplitude, and companion mass. Assuming a primary mass of $1 M_{\odot}$, circular orbits, and an edge-on orientation, we obtain the minimum companion mass ($M_{2,min}$) and the corresponding mass ratio ($q = M_2/M_1$). The sine waves modeled from K , P_{min} , P_{max} , and P , representing synthetic radial velocity, illustrate how Gaia DR3’s limited data still provides meaningful orbital information, allowing for lower bounds on WD mass estimates to be estimated.

MODELING NUV EXCESS

We then construct spectral-energy distributions (SEDs) for each target using the VOSA toolkit (Bayo et al. 2008), compiling photometric data from GALEX, Gaia DR3, Tycho, Hipparcos, 2MASS, WISE, NEOWISE, and AKARI. Each SED is modeled with two components: a BT-Settl CIFIST main-sequence model (Baraffe et al. 2015; $4 \leq \log g \leq 5$) representing the visible primary, and a Koester (2010) WD atmosphere model ($5000 \leq T_{eff} \leq 80\,000$ K; $6.5 \leq \log g \leq 9.5$) representing the hot companion. VOSA minimizes χ^2 by adjusting T_{eff} , $\log g$, and scaling factor. A near-ultraviolet (NUV) excess in the combined fit, especially when flux rises above the BT-Settl curve in GALEX bands, signals a likely WD contribution. The primary star dominates in the optical and infrared, while a close, hot WD companion adds a measurable rise in the NUV component of the primary’s SED.

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