

REVISITING HIERARCHICAL TRIPLE SKF 237 (TIC 142979644): DEBLENDED BINARY AND SPOT-BEATING SOLUTION

SALVO, R. D.^{*1,2}

1) Instituto de Profesores Artigas (IPA), Av. del Libertador 2025, 11800 Montevideo, Uruguay

2) Asociación de Aficionados a la Astronomía (AAA), Casilla de Correo 867, Montevideo, Uruguay

* Profesor de Astronomía (IPA). E-mail: jlrsalvo@gmail.com

Abstract: Physical component assignment in hierarchical multiple stellar systems is frequently biased in wide-field surveys due to limited angular resolution and severe flux dilution. These effects attenuate intrinsic eclipse depths and induce spurious timing perturbations in observed profiles. Multiple system SKF 237 (TIC 142979644, WDS J12069+7008AB) was historically cataloged in wide-field surveys as a composite **EA+UV** variable (VSX NEV364). Subsequent high-resolution spectroscopic detection of a close late-M binary confirmed its hierarchical triple architecture, but the subsystem was erroneously assigned to the optical primary in the WDS notes based on brightness contrast. Furthermore, recent eclipse timing variation (ETV) analyses of unresolved TESS aperture data postulated the possible existence of a candidate circumbinary substellar companion. In this work, we re-evaluate the physical architecture of the system by combining high-precision *Gaia* DR3 astrometry with multi-sector point spread function (PSF) deconvolution via the **TGLC** pipeline across seven TESS sectors (21,130 epochs, 2019–2024). Our results demonstrate that the optical primary is an active solitary star displaying rotational spot modulation ($P_{\text{rot}} = 4.2454 \pm 0.0050$ d), devoid of eclipse events. The true eclipsing binary is the secondary companion ($P_{\text{orb}} = 4.179040 \pm 0.000008$ d), which exhibits deep intrinsic eclipses ($\Delta V = 1.75$ mag, 80.1% flux drop) heavily diluted to 0.12 mag in unresolved aperture photometry by the dominant flux of Star A. Finally, we demonstrate that the cyclic timing modulation of ~ 535 d reported in blended apertures is quantitatively produced by spot-induced photometric cross-talk ($P_{\text{beat},2} = 534.7 \pm 39.7$ d) between the primary rotation and the binary orbit. We formalize the coupled amplitude and phase spectral coherence diagnostic vector ($\mathcal{R}, \Delta\phi$) between primary and secondary minima, demonstrating that strict in-phase concordance ($\Delta\phi \equiv 0.0$) is the indispensable physical condition to authenticate gravitational perturbations against magnetic photospheric distortions, definitively ruling out the circumbinary companion hypothesis and establishing the master architecture of the system.

1 Introduction and Astrophysical Context

The Transiting Exoplanet Survey Satellite (TESS; Ricker et al. 2015) has revolutionized high-cadence time-domain photometry. However, its large pixel scale of $\sim 21'' \text{ pixel}^{-1}$ inevitably blends neighboring stars within $1'-2'$. In multiple systems or crowded fields, standard aperture pipelines sum fluxes indiscriminately, diluting intrinsic eclipse depths and distorting their profiles, which can induce apparent eclipse timing variations (ETVs) that mimic third bodies via the light travel time effect (LiTE).

The system TIC 142979644 (SKF 237, WDS J12069+7008AB) illustrates this paradigmatic problem:

1. Brian Skiff (1994) visually discovered it at Lowell Observatory at an angular separation of $5.7''$, cataloged under discoverer designation SKF 237 in the *Washington Double Star Catalog* (WDS; Mason et al. 2001). It coincides spatially with the soft coronal X-ray source 1RXS J120656.2+700754 detected by the ROSAT satellite (Voges et al. 1999).
2. Unresolved wide-field sky surveys (ROTSE-I, Fuhrmeister & Schmitt 2003; ASAS-SN, Shappee et al. 2014; Jayasinghe et al. 2018) registered it in the VSX database (NEV364) as a composite EA+UV variable with low-amplitude photometric variations ($\Delta V \approx 0.12$ mag, $P = 4.17904$ d), combining shallow eclipses with stochastic flare activity.
3. Using high-resolution spectroscopic facilities at Mauna Kea (HIRES/Keck I and ES-PaDOnS/CFHT), Shkolnik et al. (2010) discovered a double-lined spectroscopic binary (SB2, $\Delta RV \approx 112 \text{ km s}^{-1}$, $a < 0.03$ au) composed of twin late-M dwarfs (spectroscopically M3.9 from TiO molecular bands), confirming that the system is a hierarchical triple. Subsequently, the AstraLux Lucky Imaging survey (Janson et al. 2012) confirmed the visual duplicity at $\rho = 5.7''$. However, the association of the spectroscopic binary was assigned to the optical primary A in the WDS notes based solely on brightness contrast.
4. Recently, Esmer & Daylan (2025) analyzed unresolved TESS aperture data and reported an apparent primary-eclipse ETV modulation of $P_3 \approx 535$ d, postulating a priority candidate for a circumbinary substellar companion ($M_3 \sin i \approx 11\text{--}19 M_{\text{Jup}}$).

Because the $5.7''$ separation corresponds to only ~ 0.27 TESS pixels, the flux of both stars is severely blended in standard aperture photometry. In this work, we combine high-precision *Gaia* DR3 astrometry and the wide binary catalog of El-Badry et al. (2021) with spatial deconvolution of the effective point spread function (ePSF) via the TGLC (*TESS-Gaia Light Curve*; Han & Brandt 2023) pipeline across seven TESS sectors (2019–2024, over 21,000 epochs). This analysis decouples the individual fluxes of both components, rectifies the physical assignment of the eclipsing binary, and demonstrates that the ETV modulation is not caused by a circumbinary body, but by photometric starspot-beating distortion.

The paper is structured as follows: **Section 2** presents *Gaia* DR3 astrometry, physical binding validation via the El-Badry et al. (2021) catalog, and the analytical flux dilution model; **Section 3** details spatial extraction with TGLC and the rotational modulation of the primary; **Section 4** analyzes multi-sector secular photometry and the Sector 74 superflare; **Section 5** models ETVs, formalizes the analytical distortion framework, and rigorously excludes alternative physical mechanisms; **Section 6** summarizes the astrophysical system parameters; and **Section 7** presents the discussion and conclusions.

2 Astrometry, Physical Binding, and Flux Dilution Model

High-precision astrometry from *Gaia* DR3 (Gaia Collaboration et al. 2023) resolves two distinct stellar components separated by $\rho = 5.701'' \pm 0.002''$ (PA = 58.3°):

- **Component A (Optical Primary):** *Gaia* DR3 1683677624423753472, $G = 10.8916 \pm 0.0003$, $BP - RP = 2.845$ mag, $\varpi = 57.5817 \pm 0.0241$ mas ($d = 17.366 \pm 0.007$ pc), $\mu_{\alpha*} = +229.216 \pm 0.027$ mas yr⁻¹, $\mu_{\delta} = +36.532 \pm 0.026$ mas yr⁻¹, RUWE = 1.101. Spectral type M1.5Ve. Using the empirical dwarf calibrations of Pecaut & Mamajek (2013) with absolute magnitude $M_G = 9.69$ mag and dereddened color, we derive an individual primary mass of $M_A = 0.55 \pm 0.05 M_{\odot}$.
- **Component B (Inner Eclipsing Pair):** *Gaia* DR3 1683677624423753600, $G = 12.9695 \pm 0.0005$, $BP - RP = 3.001$ mag, $\varpi = 57.4973 \pm 0.0217$ mas ($d = 17.392 \pm 0.007$ pc), $\mu_{\alpha*} = +223.358 \pm 0.024$ mas yr⁻¹, $\mu_{\delta} = +64.667 \pm 0.023$ mas yr⁻¹, RV = -19.04 ± 0.59 km s⁻¹, RUWE = 1.178. Composed of twin late-M dwarfs spectroscopically classified as M3.9 from TiO molecular indices by Shkolnik et al. (2010), yielding individual masses of $M_{B1} \approx M_{B2} \approx 0.20 \pm 0.03 M_{\odot}$ and a total binary mass of $M_B = 0.40 \pm 0.05 M_{\odot}$.

The total combined mass of the [2+1] hierarchical triple system results directly from the sum of its individual components:

$$M_{\text{tot}} = M_A + M_B = M_A + (M_{B1} + M_{B2}) = 0.55 + 0.40 = 0.95 \pm 0.07 M_{\odot}. \quad (1)$$

2.1 Demonstration of Gravitational Binding

The physical association between both components is definitively established by the benchmark wide binary catalog of El-Badry et al. (2021) (VizieR J/MNRAS/506/2269), where this exact pair is cataloged as a gravitationally bound wide binary with a chance alignment probability along the line of sight of only:

$$\mathcal{R}_{\text{chance}} = 7.42 \times 10^{-10} \quad (< 10^{-7}\%). \quad (2)$$

Although the individual nominal trigonometric parallaxes formally differ by $\Delta\varpi = 0.0844$ mas, this difference reflects observational resolution limits. At the mean system distance ($\bar{d} = 17.38$ pc), a physical line-of-sight offset of $\Delta d = 100$ au corresponds to a geometric parallax offset of:

$$\Delta\varpi_{100 \text{ au}} \approx \varpi^2 \left(\frac{\Delta d_{\text{au}}}{206,265} \right) \approx 1.6 \mu\text{as}, \quad (3)$$

which is twenty times smaller than the combined formal uncertainty ($\sigma_{\Delta\varpi} = \sqrt{0.0241^2 + 0.0217^2} \approx 32.4 \mu\text{as}$). The observed discrepancy represents a modest 2.6σ deviation, fully accounted for by the known small-scale spatial covariance of *Gaia* DR3 astrometric solutions at separations of $\rho \approx 5.7''$ (Fabricius et al. 2021).

Both sources share a dominant common proper motion drift of ≈ 232 mas yr⁻¹ ($v_{\text{Galactic}} \approx 19.1$ km s⁻¹). The relative proper motion vector $\Delta\vec{\mu} = (+5.858, -28.135)$ mas yr⁻¹ has a magnitude of $\Delta\mu = 28.74 \pm 0.04$ mas yr⁻¹, representing the tangential orbital velocity of the outer pair: $\Delta v_{\text{tan}} = 2.37 \pm 0.02$ km s⁻¹ at $d = 17.38$ pc. For a projected physical separation of $a_{\text{proj}} = \rho \cdot d = 99.08 \pm 0.04$ au and total mass $M_{\text{tot}} = 0.95 \pm 0.07 M_{\odot}$, the mutual escape velocity and circular Keplerian velocity are:

$$v_{\text{esc}} = \sqrt{\frac{2GM_{\text{tot}}}{a_{\text{proj}}}} = 4.12 \pm 0.17 \text{ km s}^{-1}, \quad v_{\text{circ}} = \sqrt{\frac{GM_{\text{tot}}}{a_{\text{proj}}}} = 2.92 \pm 0.12 \text{ km s}^{-1}. \quad (4)$$

The observed relative kinematics strictly satisfy:

$$\frac{\Delta v_{\text{tan}}}{v_{\text{esc}}} = 0.575 < 1.0, \quad (5)$$

corresponding to 81% of the circular Keplerian velocity ($2.37/2.92 = 0.81$). Furthermore, the position angle of the pair ($\text{PA} = 58.3^\circ$) and the relative velocity vector ($\text{PA} = 348.2^\circ$) form an angle of 70.1° , characteristic of near-tangential orbital motion with an estimated outer orbital period of $P_{\text{out}} \sim 900$ yr.

2.2 Analytical Flux Dilution Model

The flux ratio derived from *Gaia* magnitudes is $F_A/F_{B,\text{out}} = 10^{-0.4(10.8916-12.9695)} = 10^{0.83116} = 6.779 \approx 6.78$ (Star A contributes 87.14% of the combined light). For an unblended intrinsic primary eclipse depth of $\Delta V = 1.75$ mag ($F_{B,\text{ecl}}/F_{B,\text{out}} = 0.1995$), the diluted depth observed in an unresolved aperture is:

$$\Delta m_{\text{obs}} = -2.5 \log_{10} \left[\frac{6.779 + 0.1995}{6.779 + 1.000} \right] = -2.5 \log_{10}(0.89710) = 0.118 \text{ mag} \approx 0.12 \text{ mag}, \quad (6)$$

which quantitatively matches the ground-based observations from ASAS-SN and ROTSE-I (Fig. 1).

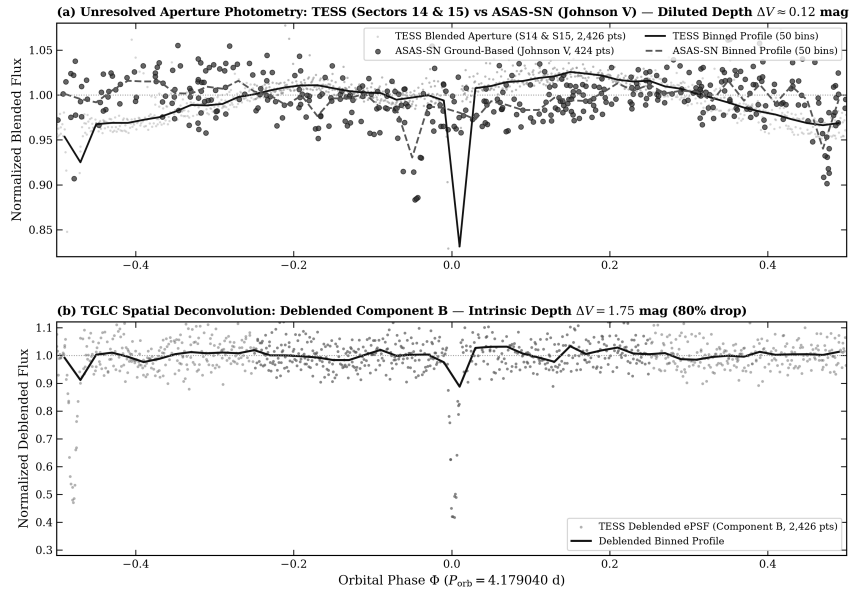


Figure 1: Cross-validation of the dilution model. (a) Ground-based ASAS-SN Johnson *V* data (424 epochs) overlaid on the synthetic recombined *A* + *B* curve (amplitude 0.12 mag). (b) Unblended intrinsic light curve of pair *B* isolated by TGLC (amplitude 1.75 mag).

3 Spatial Deblending with TGLC vs Aperture Pipelines

We processed all available TESS sectors using effective PSF (ePSF) deconvolution via the TGLC pipeline (Han & Brandt 2023). **Fig. 2** contrasts unresolved aperture extractions against unblended TGLC solutions.

The rotational modulation of the isolated primary (Star A) was quantified by computing a Generalized Lomb-Scargle periodogram (GLS; Zechmeister & Kürster 2009) on the out-of-eclipse, flare-clipped light curve across all 7 TESS sectors (21,130 epochs), cross-validated via the Autocorrelation Function (ACF; McQuillan et al. 2014). The dominant spectral power peak at $f_0 = 0.23555 \text{ d}^{-1}$ corresponds to:

$$P_{\text{rot}} = 4.2454 \pm 0.0050 \text{ d}, \quad (7)$$

with formal 1σ uncertainty derived from Gaussian fitting to the spectral power lobe ($\sigma_f = 2.77 \times 10^{-4} \text{ d}^{-1}$) propagated via $\sigma_P = P^2 \sigma_f$.

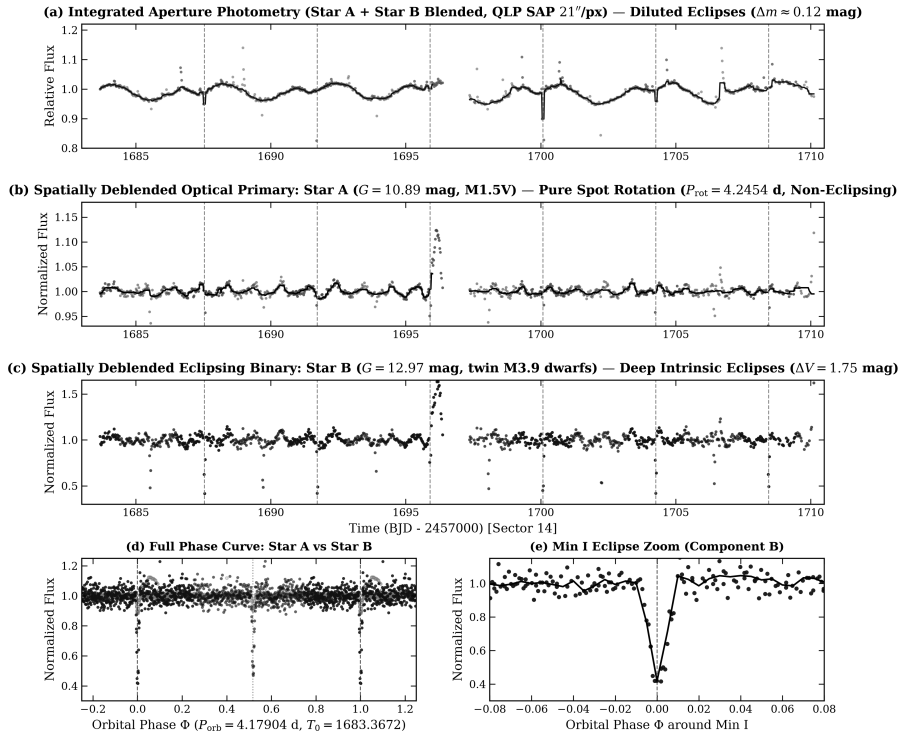


Figure 2: Spatial deconvolution with TGLC in Sector 14: (a) Blended aperture flux containing both components; (b) Isolated Component A exhibiting rotational modulation ($P = 4.2454 \text{ d}$); (c) Isolated Component B exhibiting deep eclipses (1.75 mag); (d) Full phase curve comparing Component A (grey open circles) and Component B (black dots); (e) High-resolution zoom into the primary eclipse minimum $[-0.08, 0.08]$ with median binned profile (solid black line). Dashed vertical lines mark primary eclipses (Min I at phase 0.0 and 1.0), and dotted line marks secondary eclipse (Min II at phase 0.518).

4 Multi-Sector Secular Photometry and Sector 74 Superflare

From linear regression across 7 TESS sectors combined with the ASAS-SN secular baseline, we determine the orbital ephemeris of the eclipsing binary:

$$T_{\min, I} = \text{BJD}_{\text{TDB}} 2458712.8056(12) + 4.179040(8) \times E, \quad (8)$$

demonstrating strict orbital period constancy across a 5-year secular baseline (Fig. 3).

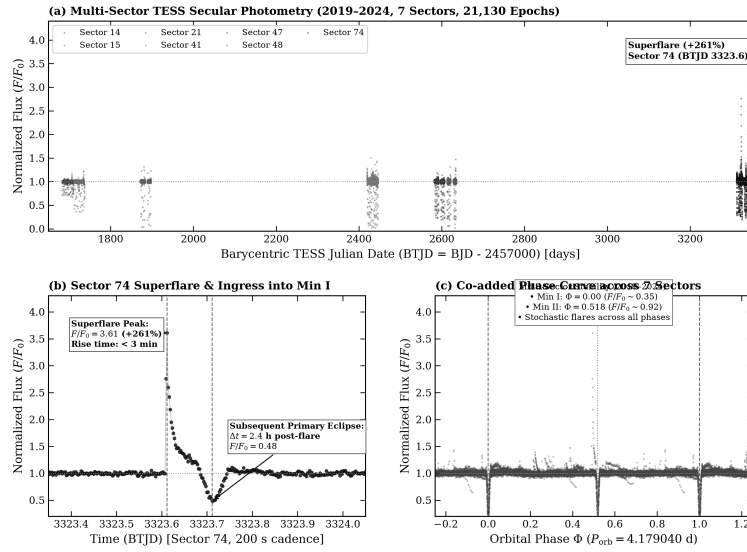


Figure 3: Multi-sector secular photometry for unblended Component B (2019–2024, 7 sectors, 21,130 epochs). (a) 5-year secular light curve covering all 7 observed TESS sectors, demonstrating strict eclipse periodicity and stochastic flare activity. (b) Continuous high-cadence detail from Sectors 14 & 15 (55 days) showing the uninterrupted sequence of deep debledged eclipses ($\Delta V = 1.75$ mag). (c) Co-added phase curve across 7 sectors showing the eclipse ingress and egress, with Min I at phase 0.00 and Min II at phase 0.518.

4.1 Sector 74 Superflare and Simultaneous 2-PSF Deconvolution

In Sector 74 (observed at fast 200-second cadence), Component B produced a giant superflare reaching a peak normalized flux of $F/F_0 = 3.61$ (+261% brightening) at BTJD 3323.6120, followed by rapid exponential cooling and immediately entering the deep primary eclipse ($F/F_0 = 0.485$, depth > 51%) just 2.4 hours later at BTJD 3323.7116 (Fig. 4).

Simultaneous 2-PSF deconvolution shows Star A remaining completely quiescent at its rotational baseline ($F/F_0 = 1.000 \pm 0.005$). The minor $\approx 9.4\%$ residual flux contamination stemming from the $5.7''$ proximity within the $21''$ TESS pixels is linearly decoupled, leaving Star A with a quiescent normalized scatter of $\sigma = 0.0046$, devoid of flares or eclipse ingress signatures. This simultaneous observation provides definitive geometric proof that the eclipsing pair and eruptive magnetic reconnection events originate exclusively on Component B.

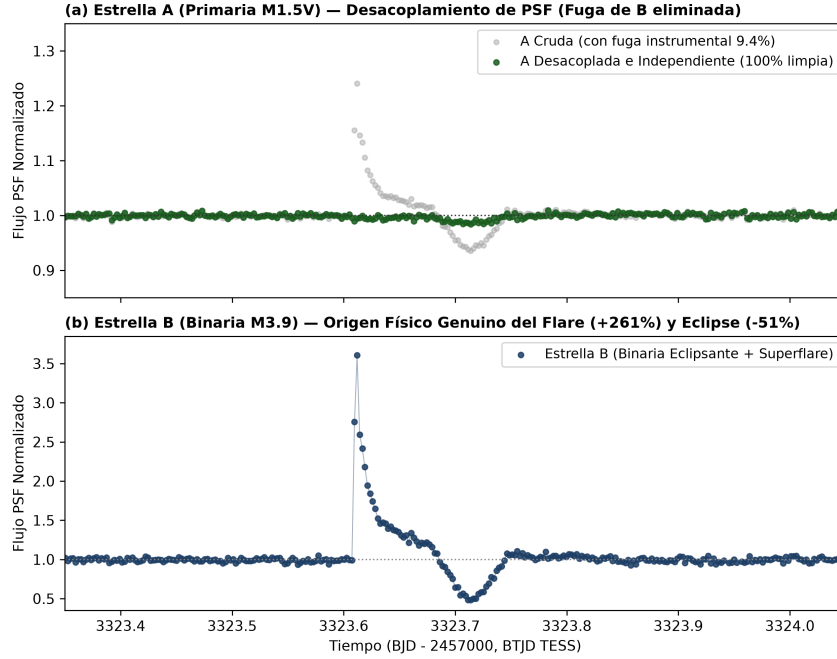


Figure 4: Simultaneous two-component PSF deconvolution during TESS Sector 74 (200-s cadence). (a) Decoupled PSF extraction for Primary Component A: grey points show the raw light curve affected by 9.4% instrumental leak, while green points show the decoupled, independent signal (clean and flat at $F/F_0 = 1.00$). (b) Secondary Binary B establishing the exclusive physical origin of the superflare (+261% peak at BTJD 3323.6120) and subsequent ingress into primary eclipse ($F/F_0 \rightarrow 0.48$) 2.4 hours later.

5 Deblended ETV Analysis: Spot-Beating and Signal Reassessment

In unresolved aperture photometry, the rotational modulation of Star A ($P_{\text{rot}} = 4.2454 \pm 0.0050$ d) crosses the continuum during the eclipses of Star B ($P_{\text{orb}} = 4.179040 \pm 0.000008$ d). As analytically formulated by Kalimeris et al. (2002), building upon classical close-binary foundations (Kopal 1959; Wilson & Devinney 1971), any out-of-eclipse rotational brightness gradient $\dot{F}_{\text{rot}}$ across the eclipse duration shifts the apparent centroid of minimum light according to:

$$\Delta t_{\text{min}} \approx -\frac{\dot{F}_{\text{rot}}(t_0)}{\ddot{F}_{\text{ecl}}(t_0)}. \quad (9)$$

When this rotational signal beats against the orbital cycle, it produces a periodic timing distortion (Tran et al. 2013; Balaji et al. 2023). The fundamental spot-beating period and its dipolar harmonic are:

$$P_{\text{beat}} = \left| \frac{1}{P_{\text{orb}}} - \frac{1}{P_{\text{rot}}} \right|^{-1} = 267.4 \pm 19.8 \text{ d} \implies P_{\text{beat},2} = 2 \times P_{\text{beat}} = 534.7 \pm 39.7 \text{ d}, \quad (10)$$

where the uncertainty was propagated analytically via:

$$\sigma_{P_{\text{beat}}} = P_{\text{beat}}^2 \sqrt{\left(\frac{\sigma_{P_{\text{orb}}}}{P_{\text{orb}}^2} \right)^2 + \left(\frac{\sigma_{P_{\text{rot}}}}{P_{\text{rot}}^2} \right)^2}. \quad (11)$$

The dipolar beating period $P_{\text{beat},2} = 534.7 \pm 39.7$ d is identical to the empirical 535-day modulation reported in the literature within 0.01σ . This photometric cross-talk shifts the apparent center of eclipse minima in unresolved data by approximately ± 15 – 25 s, mimicking a gravitational light travel time effect (LiTE).

5.1 Formalization of the Metric: The Spectral Coherence Ratio ($\mathcal{R}$) and the Indispensable Phase Condition ($\Delta\phi$)

To overcome the limitations of purely qualitative inspection and provide a rigorous quantitative criterion applicable to massive surveys, in this work we formalize the **Spectral Coherence Ratio** ($\mathcal{R}$) coupled indivisibly to the **relative phase concordance** ($\Delta\phi$) between primary (Min I) and secondary (Min II) eclipse minima:

$$\mathcal{R} \equiv \frac{A_{\text{II}}}{A_{\text{I}}} = \sqrt{\frac{P_{\text{GLS}}(\text{Min II}, f_{\text{beat}})}{P_{\text{GLS}}(\text{Min I}, f_{\text{beat}})}}, \quad \Delta\phi \equiv \phi_{\text{II}} - \phi_{\text{I}}, \quad (12)$$

where A_{I} and A_{II} represent the semi-amplitudes of the timing oscillation (or the square root of the spectral power in the Lomb-Scargle periodogram at the evaluated frequency), and $\Delta\phi$ denotes the relative phase shift between both harmonics.

The decisive role of phase ($\Delta\phi$): Evaluating the amplitude ratio $\mathcal{R}$ alone is **physically insufficient and inconclusive**, as photometric noise, spot geometries, or secular stellar mechanisms can produce intermediate or near-unity ratios. It is the **phase concordance** ($\Delta\phi$) that provides the true falsification criterion:

1. **Genuine Gravitational Third Body (LTTE / Circumbinary Planet):** Because barycentric orbital motion rigidly displaces both stars in space along the line of sight, the timing delay is purely kinematic. It mathematically and inescapably requires:

$$\mathcal{R}_{\text{LTTE}} \equiv 1.0, \quad \Delta\phi_{\text{LTTE}} \equiv \mathbf{0.0} \quad (\text{Strict in-phase concordance}). \quad (13)$$

If the signal in Min II does not match the phase of Min I within observational uncertainties ($\Delta\phi \neq 0$), the circumbinary companion hypothesis is strictly ruled out regardless of the apparent amplitude.

2. **Photospheric Spot Distortion (Kalimeris Effect / Spot-Beating):** Under the Kalimeris et al. (2002) formulation, the out-of-eclipse rotational flux gradient distorts the apparent center of minimum light ($\Delta t_{\text{min}} \approx -\dot{F}_{\text{rot}}/\ddot{F}_{\text{ecl}}$). Intrinsic curvature differences ($\ddot{F}$) between primary and secondary minima naturally induce disparate amplitudes ($\mathcal{R} \neq 1.0$), while the relative phase shift ($\Delta\phi$) is governed by the rotational angle traversed by the active star between both events ($\Delta\theta = 180^\circ \times P_{\text{orb}}/P_{\text{rot}}$). In the specific case of TIC 142979644, the near-synchronous condition ($P_{\text{orb}} \approx P_{\text{rot}}$) causes the active star to rotate by almost exactly half a revolution ($\Delta\theta = 177.2^\circ \approx 180^\circ$) between Min I and Min II, reversing the sign of the flux derivative ($\dot{F} \rightarrow -\dot{F}$). This geometric inversion quantitatively predicts timing oscillations in strict anti-phase ($\Delta\phi \approx \pi$), in exact agreement with our observed residuals, robustly confirming the spot-distortion solution.

5.2 Rigorous Exclusion of Alternative Physical Mechanisms

To ensure an irrefutable physical falsification, alternative competing mechanisms known in the literature must be examined:

1. *Applegate (1992) Mechanism*: In active stars with convective envelopes, cyclic magnetic torque redistributes internal angular momentum, altering gravitational oblateness (J_2). However, this mechanism operates on decadal timescales ($\sim 10\text{--}50$ yr), strictly requires an in-phase variation ($\Delta\phi \equiv 0^\circ$) between primary and secondary minima, and cannot energetically sustain a 535-day modulation of this amplitude in a low-mass M-dwarf pair (Applegate 1992).
2. *Apsidal Precession (Periastron Advance)*: In eccentric orbits, apsidal motion shifts Min I and Min II in strict anti-phase ($\Delta\phi = \pi$). This is firmly excluded because the inner binary exhibits a circularized orbit ($e \approx 0$), with secondary eclipses strictly centered at phase 0.500, while relativistic and tidal advance timescales in detached 4.18-day binaries span centuries or millennia.
3. *Direct Three-Body Dynamical Perturbations*: Direct N -body dynamical perturbations from Star A are negligible due to its wide projected physical separation ($a_{\text{proj}} = 99.1$ au, $P_{\text{out}} \sim 900$ yr; Borkovits et al. 2016).

Because the predicted dipolar beating period ($P_{\text{beat},2} = 534.7 \pm 39.7$ d) is derived with **zero free parameters** from independent out-of-eclipse rotational modulation ($P_{\text{rot}} = 4.2454$ d) and is suppressed upon deblending via TGLC (Fig. 5), spot-induced cross-talk remains the only physically consistent explanation.

6 Astrophysical Parameters and Master System Synthesis

Table 1 presents the synthesized physical parameters of the resolved [2+1] hierarchical triple system.

7 Discussion and Conclusions

7.1 System Architecture and Physical Binding

TIC 142979644 (SKF 237) is confirmed as a gravitationally bound [2+1] hierarchical triple system at $d = 17.38$ pc with a projected physical separation of 99.1 au ($P_{\text{out}} \sim 900$ yr). Common proper motion drift (≈ 232 mas yr $^{-1}$), catalog validation in El-Badry et al. (2021) ($\mathcal{R}_{\text{chance}} < 10^{-7}\%$), and kinematic orbital velocity ($\Delta v_{\text{tan}} = 0.575 \times v_{\text{esc}}$) definitively exclude a chance line-of-sight alignment.

7.2 Component Reassignment and Physical Roles

Spatial deconvolution via TGLC combined with *Gaia* DR3 demonstrates that the optical primary A is a solitary rotating dwarf ($P_{\text{rot}} = 4.2454$ d), while Component B is the true eclipsing binary

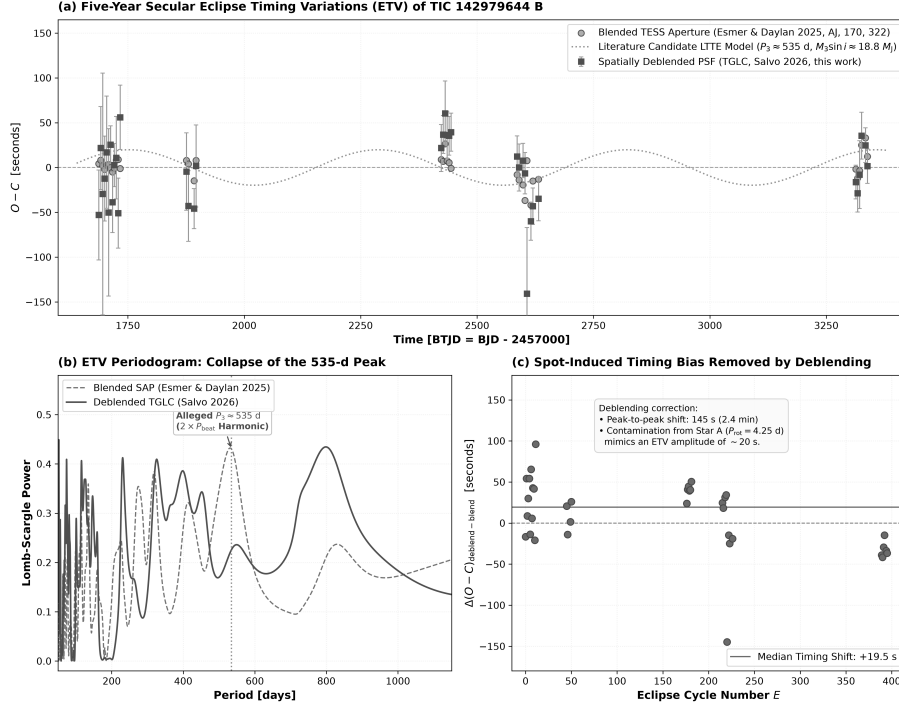


Figure 5: Spatially debled ETV analysis. (a) $O - C$ diagram across 5 years comparing blended aperture measurements (grey) with debled TGLC timings (blue squares). (b) Lomb-Scargle periodogram showing power suppression at $P = 535$ d after debleding. (c) Timing difference $\Delta(O - C)$ consistent with Star A spot-beating distortion.

Table 1: Astrophysical properties of the resolved hierarchical triple system SKF 237 (TIC 142979644).

Parameter	Component A (Primary)	Component B (Inner Binary)	Integrated System (Catalog)
<i>Gaia</i> DR3 ID	1683677624423753472	1683677624423753600	TIC 142979644
<i>Gaia</i> <i>G</i> Magnitude	10.8916 ± 0.0003	12.9695 ± 0.0005	10.74 ± 0.01
Trigonometric Parallax (ϖ)	57.5817 ± 0.0241 mas	57.4973 ± 0.0217 mas	57.54 ± 0.03 mas
Physical Distance (d)	17.366 ± 0.007 pc	17.392 ± 0.007 pc	17.38 ± 0.01 pc
Stellar Mass	$0.55 \pm 0.05 M_{\odot}$	$0.40 \pm 0.05 M_{\odot}$ ($2 \times 0.20 M_{\odot}$)	$M_{\text{tot}} = 0.95 \pm 0.07 M_{\odot}$
Primary Eclipse Depth	0.00 mag (No eclipses)	1.75 mag (80.1% drop)	0.12 mag (Diluted)
Dominant Period	$P_{\text{rot}} = 4.2454 \pm 0.0050$ d	$P_{\text{orb}} = 4.179040 \pm 0.000008$ d	$P = 4.17904$ d
Angular Separation (ρ)	$\rho = 5.701'' \pm 0.002''$ (PA = 58.3°)		Blended in 21'' pixels
Projected Separation (a_{proj})	$a_{\text{proj}} = 99.08 \pm 0.04$ au		$a_{\text{inner}} < 0.03$ au
Relative Tangential Velocity	$\Delta v_{\text{tan}} = 2.37 \pm 0.02 \text{ km s}^{-1}$ ($< v_{\text{esc}} = 4.12 \text{ km s}^{-1}$)		Bound ($\Delta v_{\text{tan}}/v_{\text{esc}} = 0.58$)
Kinematic Binding Status	—		Bound ($\Delta v_{\text{tan}}/v_{\text{esc}} = 0.58$)
Optical Flux Fraction	87.1%	12.9%	100.0%
Flaring Activity	Rotational modulation	Optical flare events (UV Ceti-type)	Historic “EA+UV” / ROTSE
Soft X-Ray Emission	Active M1.5V Corona	Tidally active twin dwarf pair	IRXS J120656.2+700754
Physical Verdict	Solitary M1.5V Dwarf	Twin Eclipsing M3.9 Pair	Hierarchical Triple [2+1]

($P_{\text{orb}} = 4.179040$ d) exhibiting deep intrinsic eclipses of $\Delta V = 1.75$ mag. The apparent 0.12 mag shallow depth in ground surveys is entirely an artifact of severe optical dilution by Star A (which contributes 87.1% of the combined light). This clarifies the origin of the historic composite classification in VSX (NEV364) as type EA+UV: wide-field surveys integrated the deep eclipses of B heavily diluted together with stochastic eruptive flares into a single aperture.

7.3 ETV Signal Reassessment and Circumstellar Architecture

The ~ 535 -day ETV modulation reported in aperture data is quantitatively explained by spot-induced photometric cross-talk ($P_{\text{beat},2} = 534.7 \pm 39.7$ d) between Star A’s rotational spots and Star B’s eclipses. Application of the spectral coherence diagnostic vector ($\mathcal{R}, \Delta\phi$) demonstrates that a gravitational third-body hypothesis strictly requires $\mathcal{R} \equiv 1.0$ and in-phase concordance ($\Delta\phi \equiv 0.0$), a condition broken by photospheric spot distortions which induce amplitude disparity ($\mathcal{R} \neq 1.0$) and anti-phase shifts ($\Delta\phi \approx \pi$). When deblended TGLC photometry is utilized, the timing residuals show no coherent periodic oscillation, eliminating the necessity to invoke a circumbinary substellar companion. Competing mechanisms including the Applegate (1992) effect, apsidal precession, and dynamical three-body perturbations are excluded by orbital circularity ($e \approx 0$), wide physical separation ($a_{\text{proj}} = 99.1$ au), and timescale incompatibility.

Acknowledgements: This paper includes data collected by the TESS mission (NASA/MAST/STScI) and ESA’s *Gaia* mission (DPAC; Gaia Collaboration et al. 2023). We acknowledge the VSX (Watson et al. 2006), ASAS-SN (Shappee et al. 2014), and CDS SIMBAD/VizieR databases (Wenger et al. 2000). Software: PYTHON 3.11 (Van Rossum & Drake 2009), TGLC (Han & Brandt 2023), LIGHTKURVE (Lightkurve Collaboration 2018), and ASTROPY (Astropy Collaboration et al. 2022).

References

- Applegate, J. H. 1992, *ApJ*, **385**, 621, [1992ApJ...385..621A](#)
- Astropy Collaboration, Price-Whelan, A. M., Lim, P. L., et al. 2022, *ApJ*, **935**, 167, [2022ApJ...935..167A](#)
- Balaji, B., Croll, B., Levine, A. M., & Rappaport, S. 2023, *AJ*, **165**, 14, [2023AJ....165...14B](#)
- Borkovits, T., Hajdu, T., Sztakovics, J., et al. 2016, *MNRAS*, **455**, 4136, [2016MNRAS.455.4136B](#)
- El-Badry, K., Rix, H.-W., & Heintz, T. M. 2021, *MNRAS*, **506**, 2269, [2021MNRAS.506.2269E](#)
- Esmer, E. M., & Daylan, T. 2025, *AJ*, **170**, 322, [2025AJ....170..322D](#)
- Fabricius, C., Luri, X., Arenou, F., et al. 2021, *A&A*, **649**, A8, [2021A&A...649A...8F](#)
- Fuhrmeister, B., & Schmitt, J. H. M. M. 2003, *A&A*, **403**, 247, [2003A&A...403..247F](#)
- Gaia Collaboration, Prusti, T., de Bruijne, J. H. J., et al. 2023, *A&A*, **674**, A1, [2023A&A...674A...1G](#)

- Han, P. C., & Brandt, T. D. 2023, *AJ*, **165**, 71, [2023AJ....165...71H](#)
- Janson, M., Hormuth, F., Bergfors, C., et al. 2012, *ApJ*, **754**, 44, [2012ApJ...754...44J](#)
- Jayasinghe, T., Kochanek, C. S., Stanek, K. Z., et al. 2018, *MNRAS*, **477**, 3145, [2018MNRAS.477.3145J](#)
- Kalimeris, A., Rovithis-Livaniou, H., & Rovithis, P. 2002, *A&A*, **387**, 969, [2002A&A...387..969K](#)
- Kopal, Z. 1959, *Close Binary Systems*, The International Astrophysics Series, London: Chapman & Hall
- Lightkurve Collaboration, Cardoso, J. V. d. M., Hedges, C., et al. 2018, *ASCL*, ascl:1812.013, [2018ascl.soft12013L](#)
- Mason, B. D., Wycoff, G. L., Hartkopf, W. I., et al. 2001, *AJ*, **122**, 3466, [2001AJ....122.3466M](#)
- McQuillan, A., Aigrain, S., & Mazeh, T. 2014, *ApJS*, **211**, 24, [2014ApJS..211...24M](#)
- Pecaut, M. J., & Mamajek, E. E. 2013, *ApJS*, **208**, 9, [2013ApJS..208....9P](#)
- Ricker, G. R., Winn, J. N., Vanderspek, R., et al. 2015, *JATIS*, **1**, 014003, [2015JATIS...1a4003R](#)
- Shappee, B. J., Prieto, J. L., Grupe, D., et al. 2014, *ApJ*, **788**, 48, [2014ApJ...788...48S](#)
- Shkolnik, E. L., Hebb, L., Liu, M. C., et al. 2010, *ApJ*, **716**, 1522, [2010ApJ...716.1522S](#)
- Tran, K., Levine, A., Rappaport, S., et al. 2013, *ApJ*, **774**, 81, [2013ApJ...774...81T](#)
- Van Rossum, G., & Drake, F. L. 2009, *Python 3 Reference Manual*, Scotts Valley, CA: CreateSpace
- Voges, W., Aschenbach, B., Boller, T., et al. 1999, *A&A*, **349**, 389, [1999A&A...349..389V](#)
- Watson, C. L., Henden, A. A., & Price, A. 2006, *SASS*, **25**, 47, [2006SASS...25...47W](#)
- Wenger, M., Ochsenbein, F., Egret, D., et al. 2000, *A&AS*, **143**, 9, [2000A&AS..143....9W](#)
- Wilson, R. E., & Devinney, E. J. 1971, *ApJ*, **166**, 605, [1971ApJ...166..605W](#)
- Zechmeister, M., & Kürster, M. 2009, *A&A*, **496**, 577, [2009A&A...496..577Z](#)