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THE EMISSION-LINE DUSTY OBJECT IRAS 07080+0605: EVIDENCE FOR BINARITY

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Abstract. FS CMa–type stars are interacting binaries that show the B[e] phenomenon and strong infrared excess from dusty circumbinary material. We present a high-resolution spectroscopic study of IRAS 07080+0605 (A0–A1 II) to measure its orbital motion and test a common-envelope (CE) origin. Our dataset comprises 20 echelle spectra from FEROS, REOSC, Gecko, and ESPaDOnS (R ≈ 18 000–100 000; 3900–10 150 Å). Radial velocities were obtained via cross-correlation in IRAF/RVSAO; periodicities were identified with a Lomb–Scargle periodogram; orbital elements and their uncertainties were derived via Bayesian inference implemented with the MCMC method. We find a short-period solution with P = 23.97 ± 0.01 days and a semi-amplitude K1 = 10.45 ± 1.70 km × s^{-1}. The mass function together with literature constraints on M1 and inclination from SED modeling, implies a low-luminosity secondary consistent

with a compact or low-mass main-sequence companion. The combination of a short orbital period and a persistent dusty disk is incompatible with a full AGB envelope and instead points to recent CE evolution that ejected the envelope and shrank the orbit to weeks. IRAS 07080+0605 thus emerges as a short-period FS CMa binary in a transitional post-AGB state, providing a benchmark for studying dust production and angular-momentum loss in non-conservative mass transfer and for testing CE-driven pathways to compact binaries.

Key words: spectroscopy; binary stars; B[e] stars; common envelope; stellar evolution; IRAS 07080+0605

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IRAS 07080+0605 ЭМИССИЯЛЫҚ ОБЪЕКТІ: ЕКІЖҰЛДЫЗДЫҚ ЖҮЙЕНІҢ ДӘЛЕЛІ

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Аннотация. FS CMa типті жұлдыздар — B[e] феномені мен шаңды циркумбинарлық ортадан туындайтын күшті инфрақызыл артығы бар өзара әрекеттесетін қос жұлдыздар. Біз IRAS 07080+0605 (A0–A1 II) нысанына жоғары айырымды спектроскопиялық зерттеу ұсынамыз, оның мақсаты — орбиталық қозғалысын өлшеу және жалпы қабық (CE) сценарийін тексеру.

Мәліметтер жиыны FEROS, REOSC, Gecko және ESPaDOnS құралдарымен алынған 20 эшелле-спектрден тұрады (R ≈ 18 000–100 000; 3900–10 150 Å). Сәулелік жылдамдықтар IRAF/RVSAO ортасындағы кросс-корреляция әдісімен анықталды; периодтылықтар Ломб–Скаргла периодограммасымен табылды; орбиталық элементтер мен олардың белгісіздіктері Байесдік қорытындылау арқылы, MCMC әдісімен алынды. Қысқапериодты шешім алынды P = 23.97 ± 0.01 тәулік және жарты амплитудасы K1 = 10.45 ± 1.70 км × с$^{-1}$. Массалық функция, әдебиеттегі M1 шектеулері және SED-модельдеуден алынған орбита еңкеюімен бірге, төмен жарқыраулы екінші компонентті меңзейді; ол ықтимал компакті объекті немесе аз массалы бас тізбек жұлдызына сай келеді. Қысқа период пен тұрақты шаңды дискінің қатар байқалуы толық AGB қабығын сақтаумен сыйыспайды және, керісінше, жақында өткен жалпы қабық кезеңін, онда жұлдыз қабығы тасталып, орбита апталар шамасындағы периодтарға дейін қысқарғанын көрсетеді. Осылайша IRAS 07080+0605 өтпелі post-AGB күйіндегі қысқапериодты FS CMa жүйесі ретінде көрінеді және масса беруінің неконсервативті режімінде шаң түзілуі мен бұрыштық импульс жоғалуын, сондай-ақ CE-мен қалыптасатын компакті қос жүйелердің эволюциялық жолдарын зерттеуге үлгі нысан болып табылады.

Түйін сөздер: қос жұлдыздар, B[e] жұлдыздары, жалпы қабық, жұлдыздардың эволюциясы, IRAS 07080+0605

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ЭМИССИОННЫЙ ПЫЛЕВОЙ ОБЪЕКТ IRAS 07080+0605: ДОКАЗАТЕЛЬСТВО ДВОЙНОЙ ПРИРОДЫ

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Аннотация. Звезды типа FS CMa – это взаимодействующие двойные системы, демонстрирующие феномен B[e] и выраженный инфракрасный избыток от пылевого циркум бинарного вещества. Мы представляем высококачественное спектроскопическое исследование IRAS 07080+0605 (A0–A1 II) с целью измерения её орбитального движения и проверки сценария общей оболочки (CE). Набор данных включает 20 эшелле-спектров, полученных на FEROS, REOSC, Gecko и ESPaDOnS (R ≈ 18 000–100 000; 3900–10 150 Å). Лучевые скорости определены методом кросс-корреляции в IRAF/RVSAO; периодичности выявлены периодограммой Ломба–Скаргла; орбитальные элементы и их неопределенности получены через байесовскую статистику, реализованную через метод MCMC. Найдено короткопериодическое решение с P = 23.97 ± 0.01 суток и полуамплитудой K1 = 10.45 ± 1.70 км × с$^{-1}$. Функция масс в сочетании с литературными ограничениями на M1 и наклон орбиты из SED-моделирования указывает на вторичную компоненту, с низкой светимостью, совместимую с компактным объектом или маломассивной звездой главной последовательности. Сочетание короткого периода и устойчивого пылевого диска несовместимо с сохраненной полной AGB-оболочкой и, напротив, указывает на недавнюю фазу общей оболочки, во время которой оболочка была сброшена, а орбита сократилась до периодов порядка недель. IRAS 07080+0605 тем самым предстает короткопериодной FS CMa-системой на переходной пост-AGB стадии и служит ориентиром для изучения пылеобразования и потерь углового момента при неконсервативной передаче массы, а также для проверки CE-управляемых путей формирования компактных двойных.

Ключевые слова: спектроскопия; двойные звезды; B[e]-звезды; общая оболочка; эволюция звёзд; IRAS 07080+0605

Introduction. The FS CMa-type objects demonstrate features of the B[e] phenomenon (presence of forbidden emission lines and IR excess). These stars were singled out as a separate new group by Prof. Miroshnichenko (2007). A leading hypothesis of the nature of the FS CMa objects are binary evolution with non conservative mass transfer, according to the confirmed results of the analysis (Miroshnichenko et al., 2023).

IRAS 07080+0605 is an emission-line star that was first noted in an Hα survey by Kohoutek & Wehmeyer (1999). It was later classified as an FS CMa-type star by Miroshnichenko et al. (2007) based on its prominent B[e] characteristics, including strong permitted (e.g. H I, Fe II) and forbidden (e.g. [O I], [Ca II]) emission lines and a significant infrared excess. Classified as approximately A0-A1: II (Condori, 2019), it has attracted considerable attention in the context of stellar evolution due to its distinctive characteristics. IRAS 07080+0605 shows pronounced emission lines and a strong infrared excess similar to that seen in FS CMa stars. The dust component consists of carbonaceous compounds rather than silicates, which distinguishes the object from classical B[e] stars. However, its exact evolutionary status remains uncertain. Previous observations by Khokhlov (2022) made it possible to determine the object's basic

physical parameters, detect photometric variability with cyclic changes in brightness, and rule out a young stellar nature. Moreover, a number of its properties resemble those of the well-known binary system Red Rectangle, which possesses a developed dusty disk. This similarity has prompted the hypothesis that IRAS 07080+0605 could represent an earlier evolutionary stage of objects like the Red Rectangle. IRAS 07080+0605 is characterized by the fundamental parameters Teff = 8500 K ± 500 K, log g = 2.0, and L = 216 L⊙, with a corresponding radius of R = 6.8 R⊙. Parameters were determined through synthetic spectrum modeling using SPECTRUM. The resulting spectrum demonstrates a high degree of agreement with the observed data, confirming the reliability of these estimates (Khokhlov et al., 2022).

The present study aims to further investigate IRAS 07080+0605, particularly by determining its orbital parameters, estimating the mass of the secondary component. These objectives will help deepen our understanding of how stars in close binary systems interact and how such processes contribute to dust production in our Galaxy. The new insights gained from this object may also shed light on the broader class of B[e] stars and their significant role in stellar evolution.

Methods and materials. Before any quantitative analysis, all spectra underwent standard preliminary reduction procedures using the IRAF environment. The reduction included continuum normalization, cosmic ray removal, and correction for instrumental effects. These steps ensured spectral consistency across different epochs and improved the reliability of subsequent radial velocity (RV) determinations.

To derive the RV of the stellar component, we employed the cross-correlation method, which identifies the Doppler shift between an observed spectrum and a reference template by maximizing their similarity. We used 20 high-resolution optical spectra of IRAS 07080+0605 obtained with FEROS at ESO (R = 48,000), REOSC at SPM (R = 18,000), and Gecko and ESPaDOnS at CFHT (R = 100,000 and 65,000). The spectral range spans 3900–10150 Å. The analysis was carried out using the xcsao task from the RVSAO package (Mink, 1998) within IRAF. This task computes the cross-correlation function (CCF) between a target and a reference spectrum, locates its peak, and determines the wavelength shift $\Delta\lambda$. The resulting shift is then converted into a RV using the Doppler formula. As a template, we selected one of the highest-quality spectra from our dataset to ensure consistency in line profiles and instrumental characteristics. Additionally, xcsao provides formal errors in the measured velocities based on the peak's sharpness and symmetry.

The resulting RV measurements, obtained at multiple epochs, were used to characterize the orbital motion of the system. Assuming Keplerian motion, the RV curve was approximated by the standard model:

$$Vr = \gamma + K \cdot (cos(v + \omega) + e \cdot cos\omega) \quad (1)$$

Where Vr is the RV, K is the RV semi-amplitude, v is the true anomaly, e is the orbital eccentricity, and ω is the argument of periastron. In the special case of a circular orbit

(e = 0), this expression reduces to a simple sinusoidal function dependent on the orbital phase.

To investigate the periodic behavior of the RV variations and spectral line shifts, we applied a Lomb–Scargle periodogram analysis. This technique is particularly well-suited for unevenly spaced observational data, such as those commonly found in ground-based spectroscopic monitoring campaigns. The Lomb–Scargle periodogram is particularly well-suited for the analysis of unevenly sampled time series, as it preserves the native temporal structure of the data without requiring resampling or interpolation (Scargle, 1982). Its formulation enables the robust detection of sinusoidal or quasi-periodic signals, even in datasets affected by observational gaps or substantial noise. Using this method, we identified the dominant frequency in the RV data, corresponding to the orbital period of the binary system. The derived period was adopted as an input parameter in the final orbital model fitting, described further below.

To determine the orbital parameters of the binary system IRAS 07080+0605, we developed a specialized Python-based software framework designed for the analysis of RV measurements obtained over multiple epochs. The framework integrates several widely used scientific libraries: NumPy (1.26.4) for numerical computations, Pandas (2.0.3) for structured data processing, Matplotlib (3.8.4) for visualization, and scipy. optimize (1.13.0) for nonlinear least-squares fitting. For statistical inference and uncertainty estimation, we employed the emcee package, which implements the affine-invariant ensemble sampler for Markov Chain Monte Carlo (MCMC) analysis (Foreman et al., 2013).

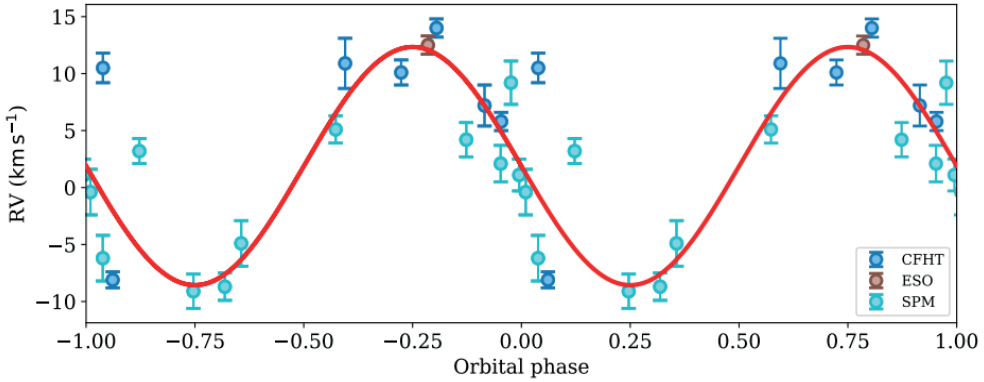
The analysis was carried out in two primary stages. First, we performed a nonlinear least-squares fit using scipy.optimize to obtain initial estimates for the orbital period (P), systemic velocity (γ), and RV semi-amplitude (K). These preliminary values served as starting points for the MCMC procedure. To refine parameter estimates and rigorously assess their uncertainties, we adopted a Bayesian framework using emcee. The posterior probability distribution was constructed as the product of a Gaussian likelihood function—assuming normally distributed observational errors—and physically motivated priors. We adopted uniform priors within plausible bounds based on initial fits and physical constraints (e.g., positive semi-amplitudes and periods). The MCMC sampler was initialized with multiple walkers and run for a sufficiently large number of iterations to ensure convergence and adequate sampling of the posterior.

Once the orbital period was established, observational epochs were converted into orbital phases. We constructed the phase-folded RV curve and overlaid the best-fit model to evaluate the quality of the solution. The reference phase (zero-point) was defined at time T_0, corresponding to the point where the RV crosses the systemic velocity from above—facilitating comparison with theoretical predictions and analogous systems.

This methodology provides a consistent and statistically robust determination of the orbital parameters P, γ, K, and T_0, along with credible uncertainty estimates. These results lay the groundwork for subsequent dynamical modeling and interpretation of the system's evolutionary stage.

Results. To characterize the orbital motion of IRAS 07080+0605, we constructed a RV curve using the measured velocities and corresponding heliocentric Julian dates (HJD) obtained from our spectroscopic dataset. The RV points were plotted as a function of orbital phase, calculated based on the period derived from the Lomb–Scargle periodogram analysis. This resulting phase-folded RV curve is shown in Fig. 1.

Figure - 1. RV variations based on spectral line measurements. The red curve folded with the best-fit orbital period.



Based on the inclination angle of i = 79° and the primary component's mass of approximately 3 ± 0.2 M⊙, both derived from spectral energy distribution (SED) modeling (Khokhlov et al., 2022), the mass of the secondary component was estimated using the standard mass function. For the adopted inclination, the resulting mass is 0.327 ± 0.020 M⊙ (Fig. 2). The primary mass value accounts for luminosity attenuation caused by circumstellar dust, which also explains the observed significant optical dimming and the infrared excess due to dust re-emission.

Table №1 - Comparison of orbital parameters

	Elements	Value
1	P (days)	23.97 ± 0.01
2	T_0 (HJD)	3376.45 ± 0.70
3	γ (km × s^{-1})	1.89 ± 1.47
4	K_1 (km × s^{-1})	10.45 ± 1.70
5	f(m), M⊙	0.003 ± 0.002
6	N	20

Parameters listed are as follows (line number): 1—orbital period, 2—periastron (elliptical) or superior conjunction (circular), HJD – 2,450,000., 3—systemic velocity, 4—semi-amplitude of the RV variation of the visible component, 5—mass function, and 6—number of spectra used in the orbit calculation.

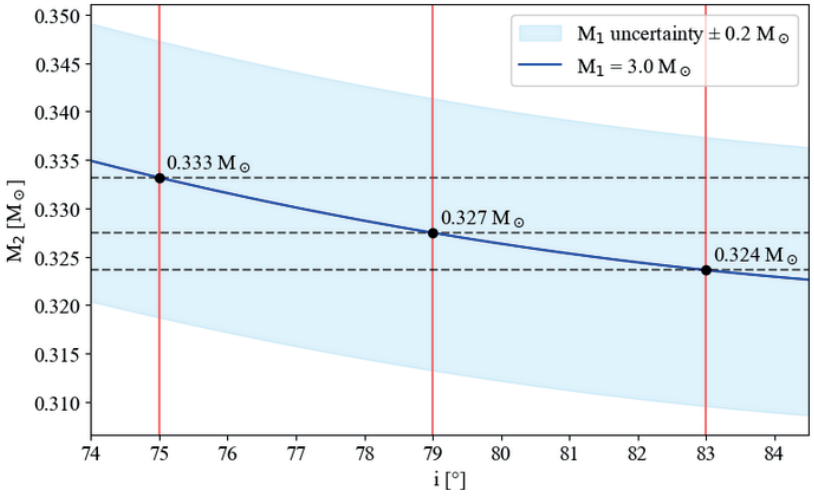
This estimated companion mass suggests that the system likely contains a compact object, such as a low-mass main-sequence star, a white dwarf, or another degenerate

companion. Importantly, to assess the robustness of this estimate, we considered a range of inclination angles, varying it within i = 79 ± 4°. This range reflects the uncertainty associated with the disk inclination derived from SED fitting and directly affects the derived secondary mass. When recalculating the mass function over this interval, the secondary mass was found to vary between approximately 0.31 and 0.35 M , which still excludes a luminous companion and reinforces the interpretation that the secondary is a compact, low-luminosity object.

Furthermore, no spectral signatures attributable to a secondary component were detected in the optical spectrum, lending additional support to the scenario of a faint or degenerate companion. If the secondary were a luminous giant or an intermediate-mass star, its spectral contribution would likely be detectable in high-resolution spectra or manifest in significant photometric variability inconsistent with the observed light curve.

Taken together, the derived mass function, the inclination constraints from SED fitting, and the spectroscopic non-detection of the secondary all converge toward a consistent picture in which the companion is a low-mass, compact object. These findings are consistent with expectations for post-common-envelope binaries, where a substantial portion of the envelope mass has been lost and the secondary star remains in a tight orbit following the interaction.

Figure - 2. Secondary mass M_2 as a function of orbital inclination i for the IRAS 07080+0605.



Dependence of the secondary mass M_2 on the orbital inclination angle i (Fig. 2), assuming a fixed primary mass of $M_1 = 3.0\ M\Theta$ and an observed mass function $f(m) = 0.003\ M\Theta$. The solid blue curve represents the best-fit solution for M_2, while the light blue shaded region corresponds to the uncertainty caused by ± 0.2 MΘ variation in M_1. Vertical red dashed lines indicate selected inclination angles (75°, 79°, and 83°) used for comparison.

IRAS 07080+0605 is considered a system transitioning towards the post-AGB phase. Our analysis of RV has revealed an orbital period of ~24 days, which is significantly shorter than the typical orbital periods observed in most post-AGB binary systems, which usually range from several hundred to several thousand days (Bollen et al., 2022; Kluska et al, 2022)

Such a compact orbit is too small to accommodate a fully expanded AGB star, implying that the primary's envelope was shed during a CE phase. In a CE event, a companion is engulfed by the giant's extended envelope, and the two cores spiral inward while orbiting inside a single envelope. Dynamical friction (drag forces) within the envelope transfers orbital energy and angular momentum from the binary's orbit to the envelope gas. This process leads to a rapid orbital decay: the released orbital energy heats and accelerates the envelope. If sufficient energy and momentum are deposited to overcome the envelope's binding energy, the envelope is ejected, leaving behind a close binary system; otherwise the two stars may merge. (Ropce et al., 2022).

In the case of IRAS 07080+0605, the observed ~24-day orbit and low radial-velocity amplitude (only ~10 km s^{-1}) indicate the presence of a low-mass secondary star that likely survived the spiral-in phase within a common-envelope interaction. The drastic shrinkage from a giant-star radius separation down to an orbit of only ⊖0.2 AU strongly suggests a common-envelope ejection as the mechanism for forming this close pair (Oomen et al., 2018; Izzard et al., 2012).

During the CE phase, the expanding envelope of the AGB star engulfs its close companion, and intense drag forces within the shared envelope cause the companion to spiral inward. As a result, orbital energy and angular momentum are transferred to the envelope gas, leading to a dramatic reduction in orbital separation. This process lays the groundwork for the formation of compact binaries with short-period orbits of only a few days (Izzard et al., 2012), as well as close pairs of white dwarfs, neutron stars, X-ray binaries, and other compact systems (Webbink, 2007; Ropce et al., 2022). CE evolution is considered one of the most important yet least understood processes that determine the formation of close pairs of compact objects (Ivanova, 2011).

Discussion. IRAS 07080+0605 appears to be an unusual post-AGB object in that its orbital period (~24 d) is extremely short compared to most known post-AGB binaries. In contrast, binaries that do pass through a common envelope typically end up with periods of only a few days (Oomen et al., 2018). For example, many close binary central stars of planetary nebulae (the products of CE ejection on the AGB) have orbital periods of hours to days. Surveys of planetary nebula nuclei in the Galactic bulge show a clustering of periods shorter than 1 day, with a tail up to a few days – these systems are essentially the lower-mass analogues of IRAS 07080+0605, where the primary has already become a hot white dwarf core. A notable case is the binary core of the PN Hen 2-428, which has a period of only 0.17 days and is believed to be a double-degenerate system formed via CE evolution (Miszalski et al., 2009).

According to classical models (Webbink, 2007), when a companion spirals into the envelope of a red giant or AGB star, orbital energy and angular momentum are transferred

to the envelope. If the deposited energy exceeds the envelope's binding energy, it may become unbound and ejected from the system, forming either a wide outflow or a bound equatorial disk — the latter often seen in systems like IRAS 07080+0605. The presence of such a bound disk, as opposed to a freely expanding outflow, serves as additional evidence supporting a common-envelope evolution scenario in this system.

Recent 3D hydrodynamic simulations (Ricker et al., 2012) support this scenario. They demonstrate that CE interactions can naturally produce post-AGB binaries with short-period orbits on the order of 0.2–1 AU, surrounded by residual disk-like structures, especially when the ejection is asymmetric. Post-AGB stars still burning helium (or hydrogen) in a shell, like IRAS 07080+0605, are rarely seen with periods as short as a few tens of days because they evolve quickly: after envelope ejection, the core contracts and heats up to become a planetary nebula nucleus on timescales of 1000-10000 years . The properties of IRAS 07080+0605 (B[e]-type emission, a dusty disk) point to an object that has recently shed its envelope and has not yet fully heated up.

Another noteworthy analog is HD 101584, a binary system that underwent a premature termination of its giant phase. ALMA observations of HD 101584 reveal a complex bipolar and equatorial outflow structure; this is interpreted as the result of a common-envelope ejection that halted just before merger, leaving a subgiant core and a companion with a circumbinary nebula. The estimated kinematic age of the outflows is approximately 770 years (assuming a distance of 1 kpc), suggesting that the envelope ejection occurred relatively recently. This timescale supports the interpretation of HD 101584 as a system caught in a transitional post-common-envelope phase (Olofsson et al., 2019). HD 101584 thus provides rare direct evidence of a common-envelope interaction caught in progress, where the anisotropic envelope ejection was likely driven by a spiral-in companion. Such dynamics are highly consistent with the morphology and orbital configuration inferred for IRAS 07080+0605, suggesting that it too may represent an outcome of an incomplete or stalled CE phase. These examples reinforce the interpretation that short-period binaries like IRAS 07080+0605 are best understood as post-common-envelope systems – analogous to close binary central stars of planetary nebulae, but observed at an earlier evolutionary stage.

Conclusion. Our study of IRAS 07080+0605 reveals a remarkable example of a binary star emerging from an episode of strong binary interaction. The object is characterized by an A-type luminous component embedded in a dusty circumstellar disk, and a close companion in a ~24-day orbit. It exhibits significant dust-driven variability (190-day quasi-cycle) and shows evidence of substantial extinction along the line of sight. Notably, IRAS 07080+0605 does not show the heavy-element depletion seen in many post-AGB binaries with dusty disks (no evidence of the photospheric metal deficiency that is common in evolved post-AGB stars), and no extended nebula is detected around the system. These findings suggest that while the star has left AGB, it has undergone a different evolutionary pathway than the canonical stable post-AGB mass transfer scenario.

We propose that IRAS 07080+0605's properties can be consistently explained by a

recent CE event in this binary system. The short orbital period and presence of a compact circumbinary envelope are consistent with a common-envelope ejection scenario, wherein the primary star's envelope was shed as the companion spiraled inward. This process would naturally produce a tight binary remnant with a period of only a few weeks, as observed, and can account for the formation of the dust-rich circumbinary disk. Our interpretation aligns with theoretical expectations and other studies of CE evolution: a common-envelope phase is expected to create close binaries out of initially wider systems, leaving behind two stellar cores in a tight orbit. In the case of IRAS 07080+0605, the primary star appears to be on the cusp of the post-AGB stage, having had its evolution truncated by the CE event before it could develop a typical extended planetary nebula. This system thereby bridges the gap between classical post-AGB binaries with long-period orbits and the close binary central stars of planetary nebulae that result from common-envelope interactions.

In summary, the evidence points toward IRAS 07080+0605 being a post-common-envelope binary system. Although the common-envelope phase in this system cannot be confirmed with certainty, the available evidence – including orbital characteristics and analogies with other post-interaction binaries – is consistent with such a scenario. Continued observations and modeling efforts will be essential to evaluate this possibility further. IRAS 07080+0605 stands out as a promising system for probing the dynamics of binary interaction and post-AGB evolution.

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