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Supplementary Materials for

An interacting binary system powers precessing outflows of an evolved star

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S1. Radial velocity measurements of Fg 1

From April till June 2011, we obtained medium-resolution spectroscopy of the central star of Fg 1 with the FORS2 instrument attached to ESO's Very Large Telescope. The spectral coverage spanned the wavelengths from 456 to 586 nm, with a spectral resolution of 0.12 nm (full width at half maximum). These spectra were used to monitor the radial velocity of the central star (table S1): possible wavelength calibration problems and the effect of Earth's motion were corrected for by shifting all the spectra to the rest-frame of the He I nebula emission line at 587.6 nm; the radial velocities were then measured from an average of the C IV lines at 580.1 and 581.2 nm. All stellar features moved in phase with the C IV emission lines and no features of a companion could be identified. From the signal-to-noise of the spectra (between 60 and 80) and the spectral resolution, we estimate, from an extensive set of Monte Carlo simulations, an error of 3 km/s per data point. This error encompasses both the (small) error related to the position of the nebula emission line and that related to the position of the C IV line. The slit used was 0.5" and was always smaller than the seeing.

S2. Model atmosphere fit of the central star of Fg 1

We modeled our FORS2 spectra with stellar model atmospheres (plane-parallel, chemically homogeneous, in hydrostatic and radiative equilibrium) calculated with *TMAP*, the Tübingen NLTE Model Atmosphere Package (see http://astro.uni-tuebingen.de/~TMAP). *TMAP* is based on the so-called Accelerated Lambda Iteration (ALI) method and is able to account for line blanketing by metals. The best fit to the observed spectra was found to have an effective temperature, $T_{eff} = 80000 \pm 15000$ K and a surface gravity, $\log g = 5.00 \pm 0.25$ (fig. S1). The uncertainty in the temperature was evaluated by judging how well various models of different temperatures agreed with different observed features such as O V absorption lines and C IV emission lines. The uncertainty in the surface gravity was deduced from the line profiles of the hydrogen lines and their relative fluxes.

We compared these values for the temperature and gravity with evolutionary tracks for post-AGB stars from (*17*) for different values of the final mass. This leads to the result that the mass of the CSPN is $M/M_\odot = 0.56^{+0.3}_{-0.04}$ (fig. S2). The corresponding luminosity would be $\log L/L_\odot = 3.78^{+0.42}_{-0.62}$. We note that the time to reach these positions on the tracks go down to a few hundred years for masses above 0.6 solar masses. Given that the nebula is thought to be much older, a more massive CSPN than 0.56 $M_\odot$ is highly improbable.

S3. Spectrum of the central star of Fg1 at various orbital phases

In figure S3, we show VLT FORS spectra of the central star of Fg 1 taken at four representative orbital phases (0.09, 0.21, 0.38 and 0.50) in two important wavelength ranges. The spectra in the range 575-590 nm were not nebula subtracted, while the spectra in the range 460-495 nm were nebula subtracted. The dotted lines show the rest wavelengths of He I 587.6, and C IV 580.1, 581.2, and C III (464.7, 465.0), N III (463.4, 464.0) and C IV (465.8). None of the C III and N III lines are detected (any residual emission is only a result of subtracting the nebular emission), proving there are no irradiated emission lines that would indicate a main-sequence companion. The signal-to-noise ratio of the shown spectra around 470 nm are 75, 65, 60 and 60, respectively.

S4. Photometry of Fg 1

The central star of Fg 1 was monitored in consecutive 180-s *I*-band exposures on the nights of 2010 March 24, 25, 27, 28 and 30, and in consecutive 300-s *U*-band exposures on 2010 April 2 and 6 (with each series of consecutive exposures lasting for between 40 minutes and 4 hours), using the South African Astronomical Observatory (SAAO) 1.9-m Radcliffe Telescope. The STE4 CCD was used with 2 x 2 binning, resulting in a pixel scale of 0.28"/pixel. The seeing during the observations varied between 1 and 4". The data were debiased and flat-fielded using standard *Starlink* routines. Differential photometry of the central star, relative to non-variable field stars, was performed using *sextractor*. The resulting lightcurves folded on the period of the binary are shown in figure S4, clearly showing that no periodic photometric variability was detected. Any variability associated with orbital motion must therefore have an *I*-band amplitude smaller than 0.05 mag.

S5. Constraints on the binary components inside Fg1

The nebula has an observed absolute flux in the Hβ line of log(F(Hβ)) = –11.06 in cgs units, and an extinction *c* = 0.29. Assuming an electron temperature of 10,000 K, the adopted distance of 2.4 kpc, and an ionization-bounded nebula, the total number of hydrogen-ionizing photons that must be delivered by the central star is computed to be $3.06\ 10^{47}$ phot/s. Furthermore, the observed intensity ratio HeII 4686/Hβ of 0.19 requires that the number of photons above 54 eV should be $3.3\ 10^{46}$.The model atmosphere with T_{eff} = 80 kK ± 15 kK, log g = 5.00 ± 0.25, log $L/L_{\odot}$ = 3.78 yields $4.37\ 10^{47}$ photons/sec above 13.6 eV, but only $1.06\ 10^{45}$ photons above 54 eV. Thus the missing ionizing photons above 54 eV need to be supplied by the hot secondary star. Assuming a blackbody spectrum of unknown temperature for the secondary, and demanding that both stars together would deliver both required numbers of photons above 13.6 and 54 eV, one obtains several solutions. For these solutions where the temperature is any value above 120 kK, the contribution of the secondary to the visible spectrum will be sufficiently small for a non-detection. Comparison of the possible positions for the secondary with evolutionary tracks of post-AGB stars indicate that a mass of 0.6–0.7 would be plausible, which give ages of 5000 –7000 years for the 0.605 $M_{\odot}$ track, and 3500 years for 0.625 $M_{\odot}$. The 0.696 $M_{\odot}$ track would also give a solution with 900 years age and the 205 kK secondary being caught just in the rapid drop in luminosity.

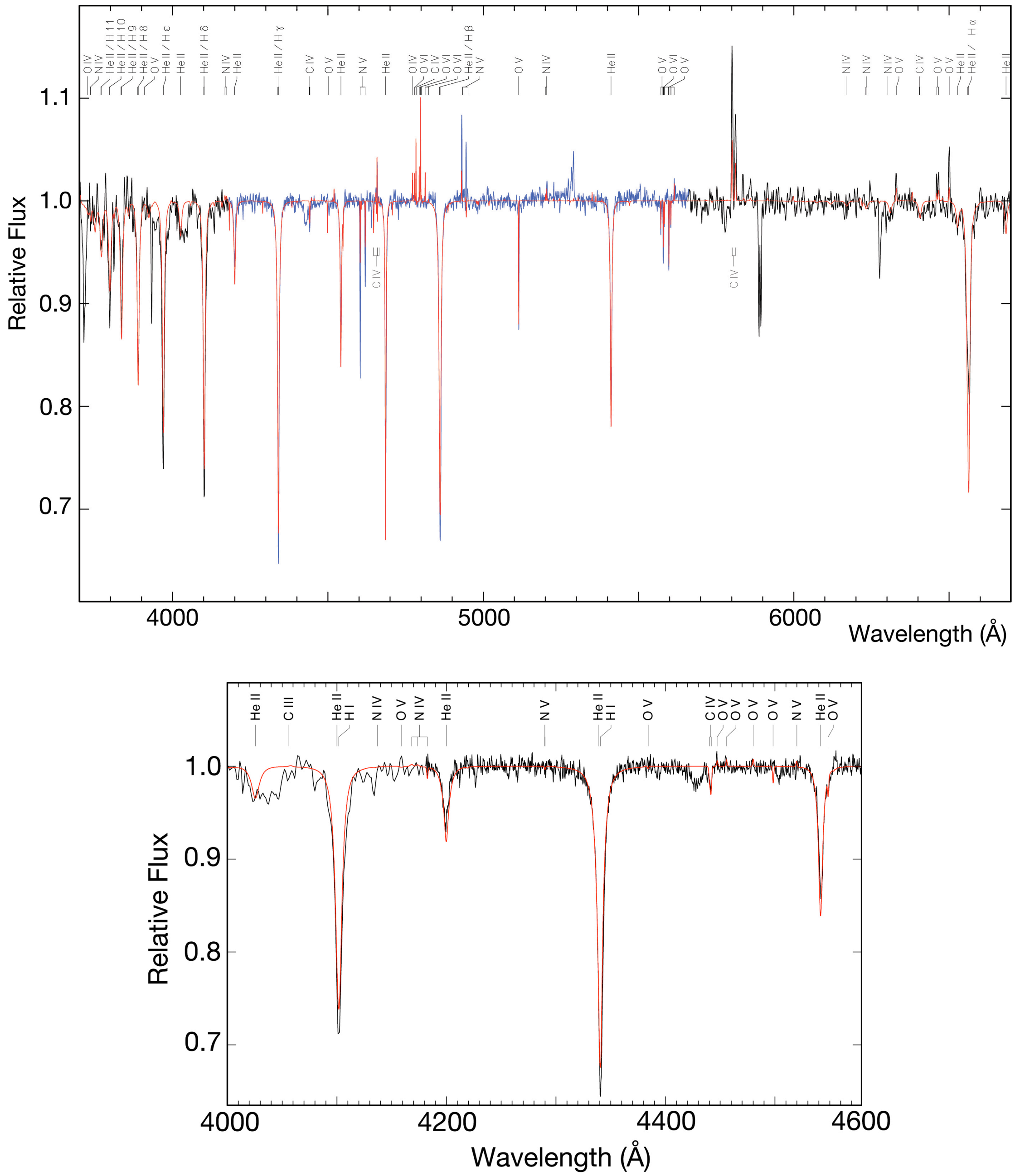

Figure S1: (top) Comparison between our best-fit synthetic spectrum (red) and the observed spectrum of Fg1 (black and blue lines). The synthetic spectrum was computed with the Tübingen NLTE Model Atmosphere Package, while the observed spectrum combines our FORS2 low and medium resolution spectra. The main features in the spectrum are identified. (bottom) A close-up of a region between 400 and 460 nm.

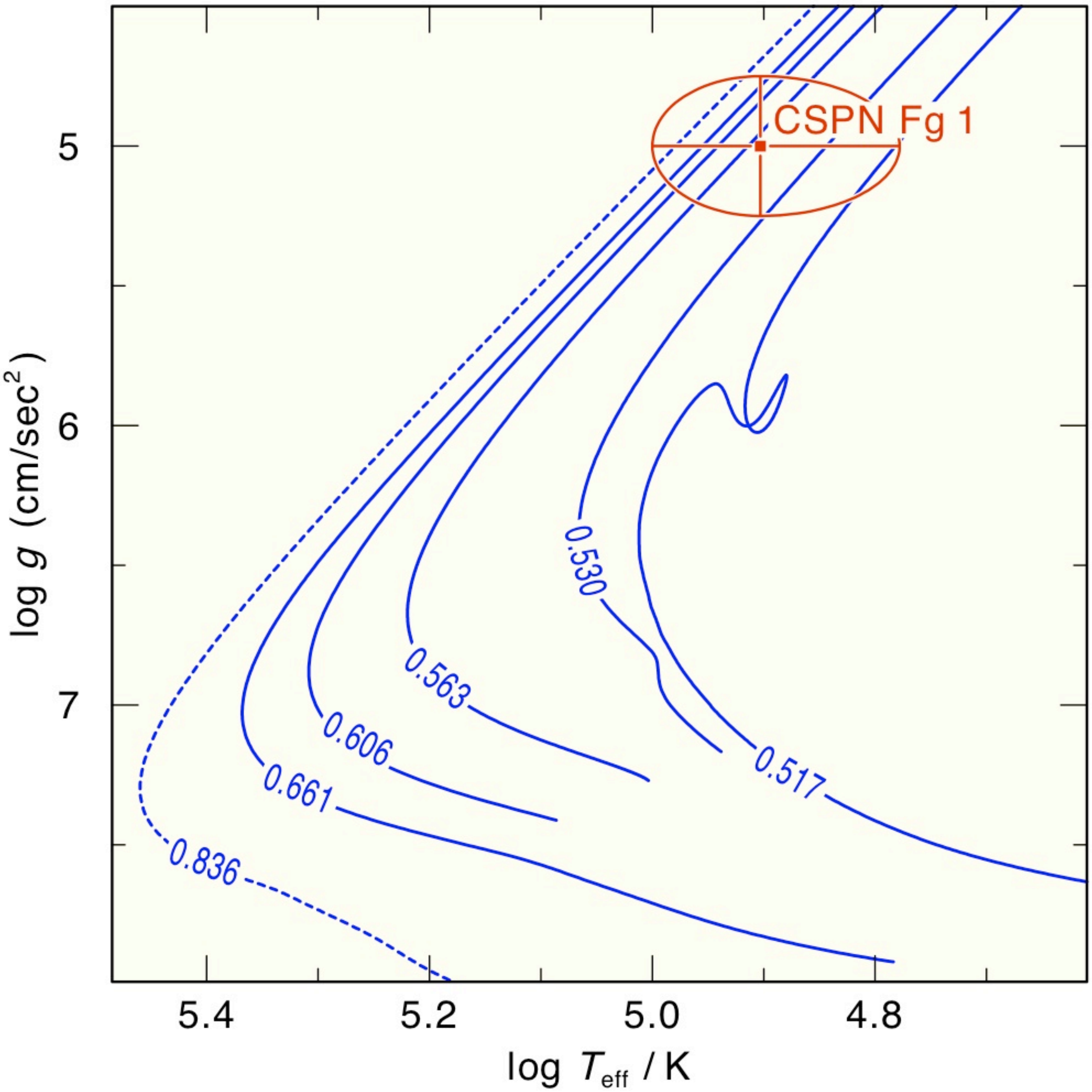

Figure S2: Position of the central star of Fg 1 in the log T_{eff} – log *g* plane, as derived from our fit to the spectra. Several evolutionary tracks from (16) are drawn for different masses (labeled in solar masses) of post-AGB stars.

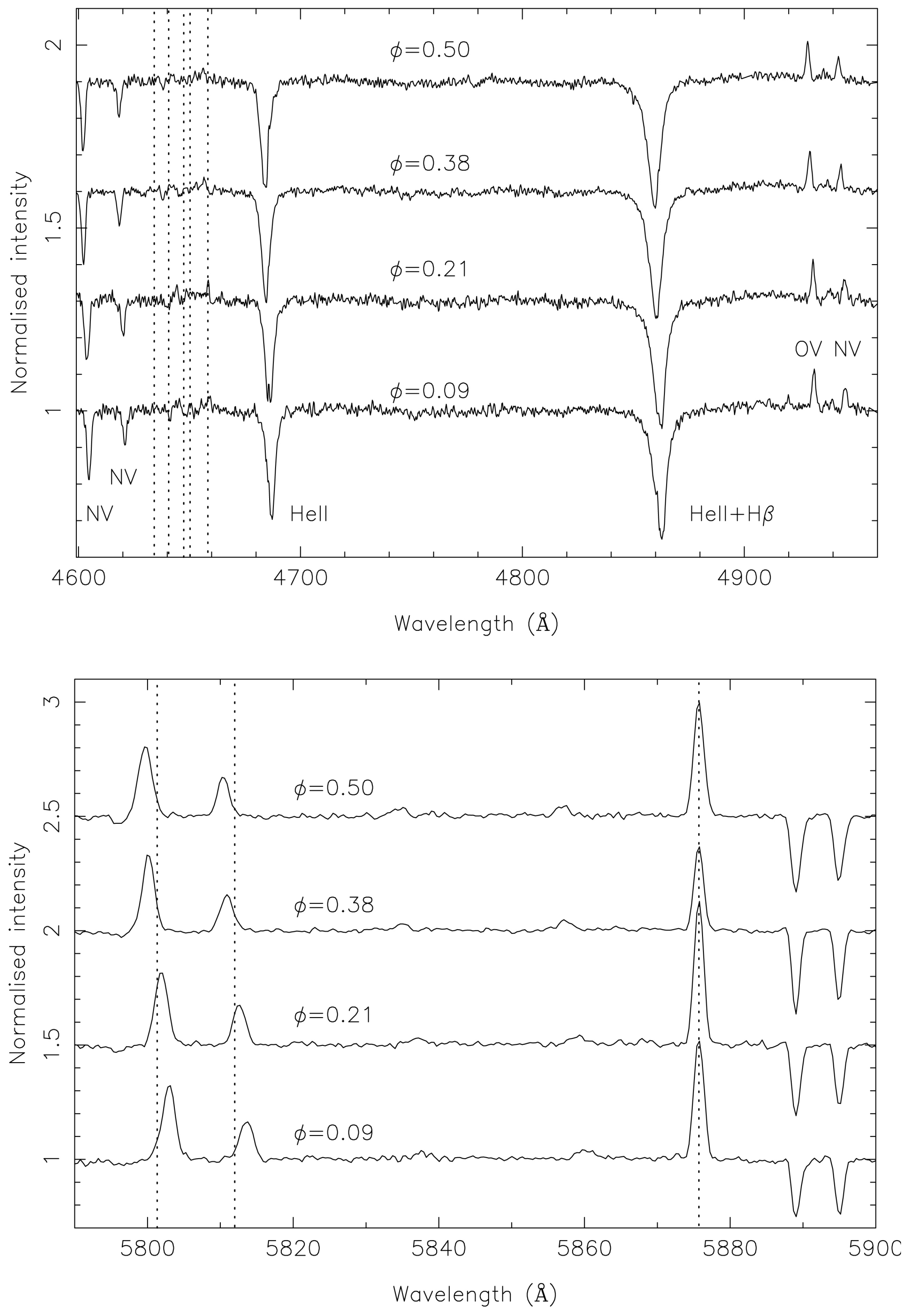

Figure S3: VLT FORS spectra taken at four representative orbital phases (0.09, 0.21, 0.38 and 0.50) in two important wavelength ranges.

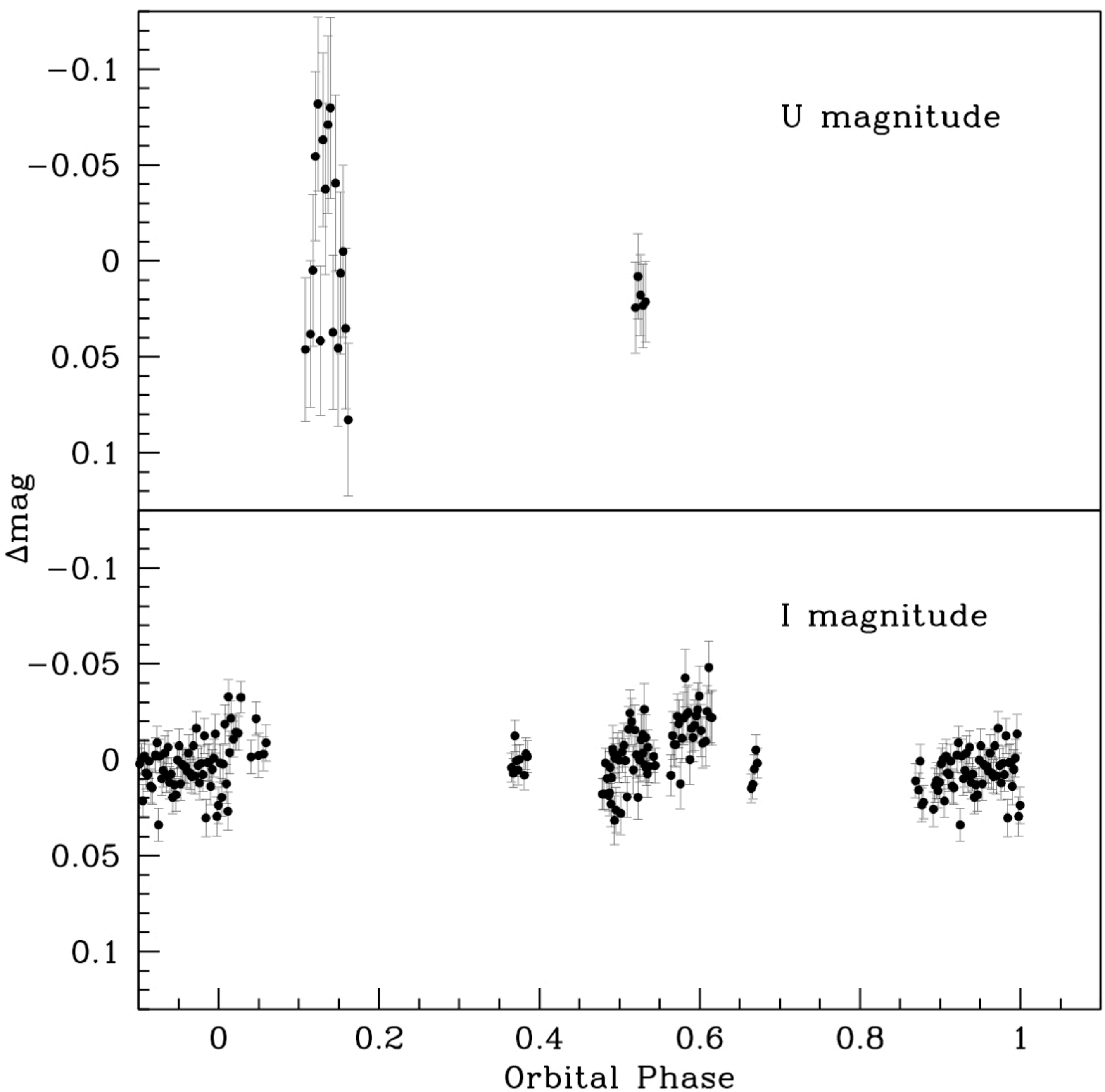

Figure S4: Time-resolved photometry of Fg 1: the top panel shows the *U*-band differential magnitude and the lower panel the *I*-band's one. The data are folded on the spectroscopic orbital phase and clearly illustrate the extremely small amplitude – if any – of the variations, hence, the absence of any irradiation in the system.

Table S1. Radial velocities of Fg 1 obtained from FORS2 spectra.

Modified Julian Date	**Orbital Phase**	**Radial Velocity (km/s)**
55671.078209	0.600	–34.6
55672.016132	0.385	–25.3
55672.029181	0.396	–23.3
55672.999103	0.207	63.6
55674.102418	0.130	97.7
55675.987399	0.707	10.3
55678.202092	0.600	–38.8
55680.207108	0.237	48.6
55682.975855	0.554	–40.3
55683.176573	0.721	27.4
55683.215418	0.754	44.4
55702.035429	0.499	–46.0
55704.044393	0.179	81.6
55704.138941	0.259	39.8
55707.034128	0.681	6.2
55708.042024	0.524	–42.9
55710.023947	0.182	76.0
55710.122714	0.265	37.2
55711.104254	0.086	120.9
55712.096820	0.916	118.9
55726.999135	0.383	–23.8

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