Multiple periods and semi-periodicities in the magnetic symbiotic FN Sgr

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The lightcurves

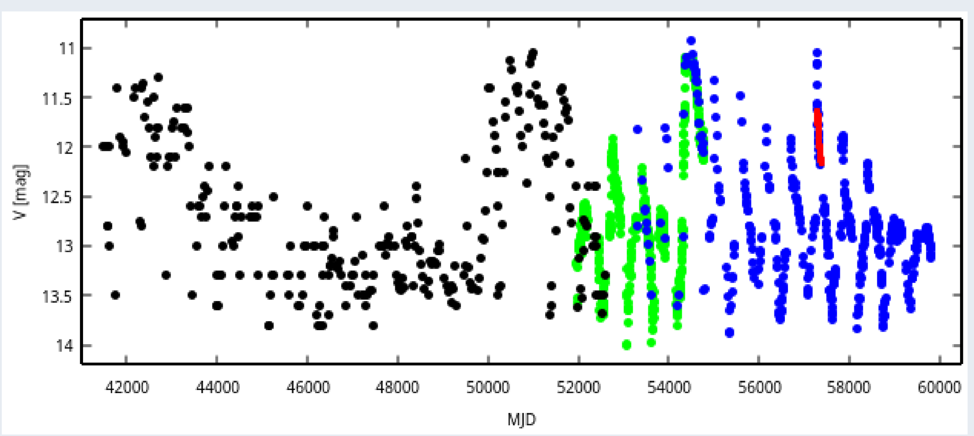

Figure 1:≃ 55 years optical light curve of FN Sgr: black: from Brandi et al. 2005, green: ASAS, blue: new data. Kepler light curve in red, offset vertically by 12 mag.

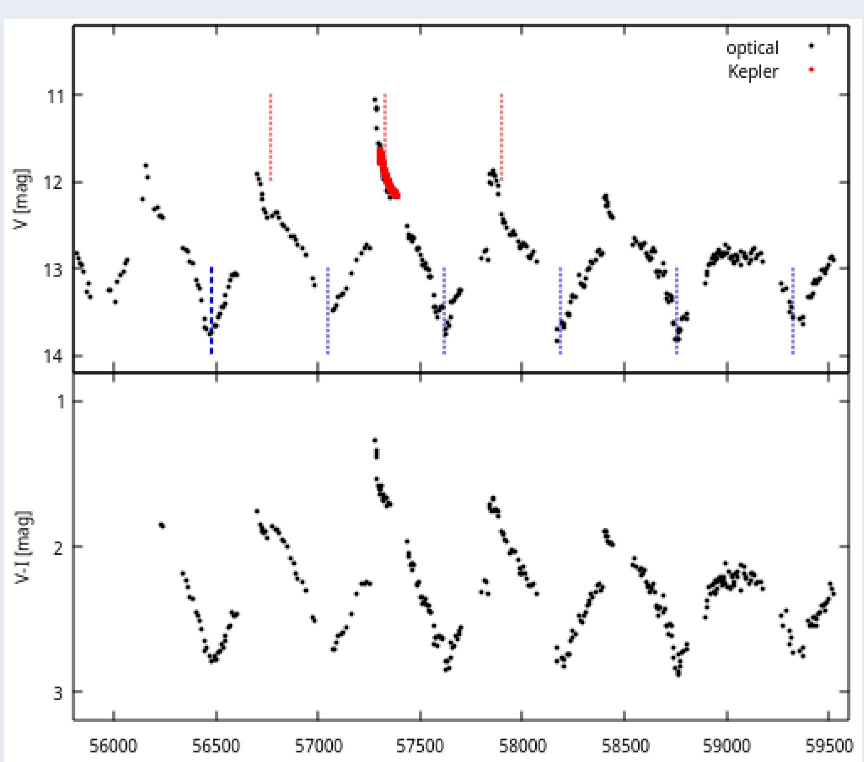

Figure 2:Selected time interval from Fig. 1, and corresponding V-I index. Blue dashed lines: inferior conjunction, red lines: superior conjunction of the red giant. Blue thick dashed line: reference optical minimum (by polynomial fitting).

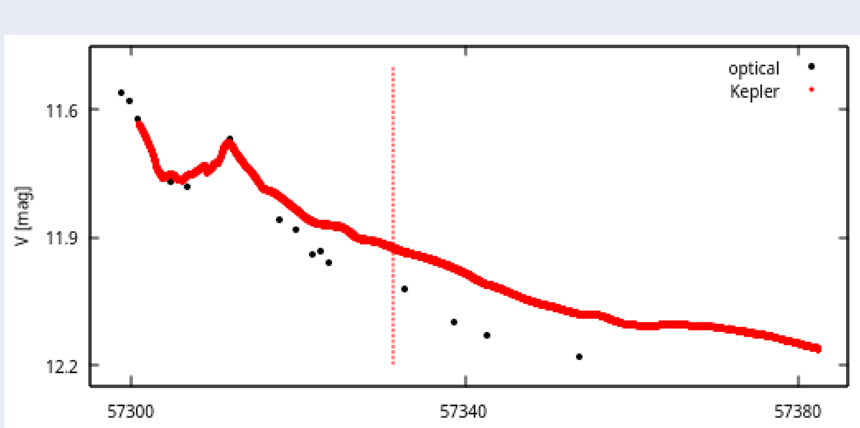

Figure 3:81 days Kepler high cadence light curve (red points). In black, points from Fig. 1. Red dashed line: the superior conjunction of the red giant.

A well studied symbiotic at ≃7 kpc

- Like many symbiotic binaries, composed of a red giant and a white dwarf
- M5-type giant of 1.5 $M_\odot$; white dwarf of 0.7 $M_\odot$.
- Orbital inclination 80°.
- E(B-V)=0.2±0.1
- Orbital period of 568.3 days.
- Spectroscopic studies indicate presence of an accretion disk and Roche-lobe overflow, given a binary separation 1.6 AU.
- These data are from Brandi et al. 2005 and references therein, the period was revised by us.

Three short periods

In the Kepler light curve we discovered three frequencies with sidebands. We attribute a stable frequency of 127.5 d^{-1} (corresponding to a **11.3 minutes period) to the white dwarf rotation**. We measured also a second frequency close to 116.9 d^{-1} (corresponding to **about 137 minutes), which is is much less stable**. Finally, there is a **third unstable frequency** that appears to correspond to the **beating** between the rotation and the second frequency.

The photometric data

We investigated the optical variability of this symbiotic binary, taking advantage also of the previous optical monitoring done over tens of years. The ≃ 55 years light curve is shown in Fig. 1. We examined optical data in the V and I bands from the All-Sky-Automated Survey (see Gromadzki et al. 2013) and new photometry we obtained with the 35cm Meade RCX400 telescope at the Kleinkaroo Observatory using a SBIG ST8-XME CCD camera and V and Ic filters. The new V light curve we obtained starts at MJD 53308, but the Ic data cover a shorter period, starting at MJD 56233. Each observation was the result of several individual exposures, calibrated (dark-subtraction and flat-fielding) and stacked. The magnitudes were derived from differential photometry, with nearby reference stars, using the single image mode of the AIP4 image processing software. The photometric accuracy of the derived magnitudes is better than 0.1 mag. Since a detailed light curve with high resolution was missing, we proposed to obtain a high cadence (almost one minute) Kepler light curve, which could be measured over 81 days, between 2015 October and December, in Kepler K2 field 7. It is shown in Fig. 2. **The results of a Lomb-Scargle timing analysis and a full discussion will be available in a refereed paper led by J. Magdolen.**

Recurrent mini-outbursts

As Fig. 2 shows, small amplitude flares, **mini-outbursts of amplitude 0.5-1 mag**, different from the 1997-1998 event, **occurred between 2001 and 2019** and seem to have ceased in 2020-2021. There is always have a sharp rise (∼ 10 days) and slower decline, and they seem to be orbital-phase-locked, with rise near phase 0.3 and never after phase 0.5. The bottom panel of Fig. 2 shows that the the peak wavelength was shifted toward higher energies, with V-I increasing during the flares. Since 2019 the light curves in addition to the deep eclipses show secondary minima, most likely due to ellipsoidal variability and particularly evident in the I light curve, in which the red giant significantly contributes to the continuum. This confirms that the red giant fills, or almost fills, its Roche lobe, so **a persistent accretion disc should be present in this system**.

Conclusions

If the stable period of 11.3 minutes is the white dwarf rotation period, as we suggest, it is detected because **the white dwarf accretes through a magnetic stream, like in intermediate polars**. We examined **the possibility of the mini-outbursts being due a "non-ejecting nova" or to localized thermonuclear burning, confined by the magnetic field**, like recently inferred in some cataclysmic variables, although the bursts' timescales and amplitudes are different (Scaringi et al. 2022a and 2022b).

The "unstable" period of 137 minutes may be due to **rocky detritus** around the white dwarf, **or to inhomegeinity in the accretion disk**, and in the article we discuss why this second possibility is more likely. We suggest that the region of the inhomogeneities is luminous being the end-point of the trajectory of an accretion stream from the L_1 point, which impinges the geometrically thick disk, penetrating it and generating the inhomogeneities at the inner disk edge.

References

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- Gromadzki, M., Mikolajewska, J., & Soszynski, I. 2013, Acta Astron., 63, 405
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