Star-Planets Tidal Interactions: Study for the Solar System

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ABSTRACT: A development of the Sun tide-generating potential (STGP) to an accurate harmonic series over 30,000 years is made. The analysis of the series is done in order to verify the existence of a tidal forcing of ≈ 11.0-yr period able to excite the solar-activity cycle, following a rather debatable hypothesis. Our results do not show any ≈ 11.0-yr (nor the doubled ≈ 22.0-yr) period in the STGP spectrum. An ≈ 11.0-yr tidal period with a direct physical relevance on the 11-year-like solar-activity cycle is highly improbable.

I. INTRODUCTION

Our solar system and stars with exoplanets are natural laboratories for learning the dynamical interactions in complex star-planets systems. There is a long-running hypothesis that the planetary tides may have a modulating effect on the solar magnetic activity (the solar cycles). Specifically, several recent studies assume that certain quasi-alignments between Venus, Earth and Jupiter ("V-E-J configurations") provide a basic periodicity of ≈ 11.0 yr, and the operation of solar dynamo can be synchronized with these configurations. Nevertheless, the evidence behind this proposed tidal forcing is still debatable.

II. OUTLINES OF METHOD

In this context we have developed, apparently for the first time, the Sun tide-generating potential (STGP) in terms of accurate harmonic series. The series are built over 13,000BC – 17,000AD, they clearly identify and separate the effects of various planetary configurations on the STGP. The expansion is done by using a modification of the spectral analysis method devised by Kudryavtsev (*J. Geodesy*, **77**, 829, 2004; *Astron. Astrophys.*, **471**, 1069, 2007). The latest long-term planetary ephemeris DE-441 (Park et al., *Astron. J.*, **161**, 105, 2021) is used as a source.

The series represents the STGP value, $V(t)$, at an arbitrary point $M(r, \phi, \lambda)$ on the Sun's surface (see Fig.1) as follows:

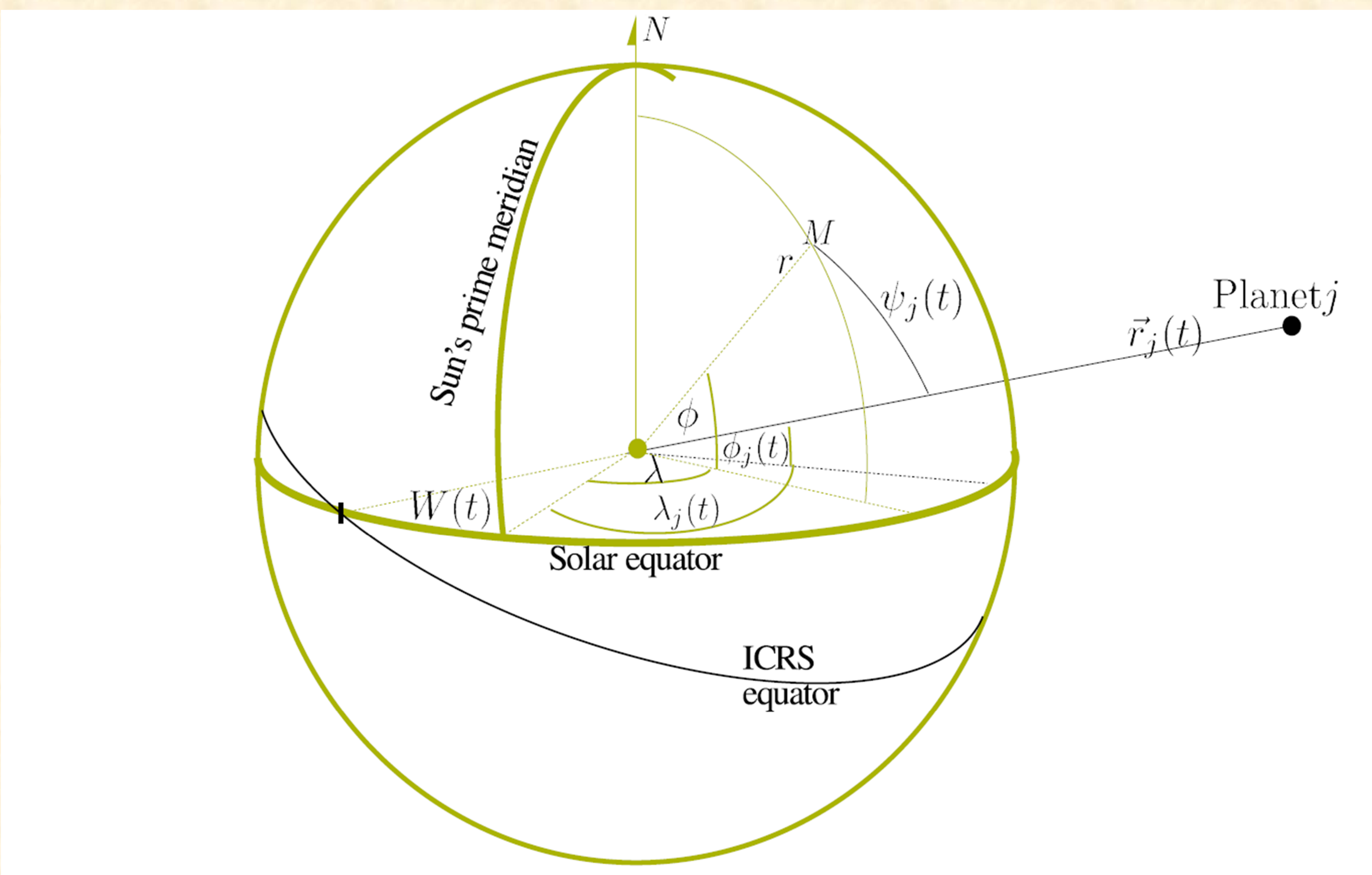

Figure 1. Coordinate system where the STGP was developed

$$V(t) = \sum_{n=1}^{n_{max}} \left(\frac{r}{R_{Sun}}\right)^n \sum_{m=0}^{n} \bar{P}_{nm}(\sin\phi)$$
$$\times \sum_{i=1}^{i_{max}(n,m)} \left[C_{nm_i}(t)\cos A_{nm_i}(t) + S_{nm_i}(t)\sin A_{nm_i}(t)\right],$$

where $\bar{P}_{nm}$ are normalized associated Legendre functions of degree n and order m and R_{Sun} is the Sun equatorial radius. As a result of the development procedure, we get amplitudes C_{nm_i}, S_{nm_i} of the series terms (as the 3rd degree polynomials of time t) at various arguments A_{nm_i}

$$A_{nm_i}(t) = m[W(t) + \lambda] + \sum_{j=1}^{8} k_{ij}\, l_j(t),$$

which are linear combinations of integer multipliers k_{ij} of mean mean longitudes $l_j(t)$ of eight major planets and the Sun rotational angle $W(t)$.

III. RESULTS

Finally, we obtained a catalogue of 713 harmonic terms precisely characterizing the STGP (http://sai.msu.ru/neb/ksm/tgp_sun/STGP.zip). In this STGP catalogue we looked for tidal forcings related to various V-E-J configurations and specifically for terms with periods of ≈ 11.0 yr and ≈ 22.0 yr. Although the tidal periods we identified range from ≈ 1000 yr to 1 week, we did not find any ≈ 11.0-yr period. The V–E–J configurations do not produce any significant tidal term at this or other periods. No term with an ≈ 22.0-yr period is found either. The 11-yr spectral band is explicitly dominated by Jupiter's orbital motion (period ≈ 11.86 yr). The V-E-J configurations do not produce any discernible terms in the STGP spectrum. The planet that contributes the most to the STGP in a three planets configuration, along with Venus and Earth, is Saturn.

IV. CONCLUSIONS

An ≈ 11.0-yr tidal period with a direct physical relevance on the 11-year-like solar-activity cycle is highly improbable. A similar estimation procedure can be used to study possible tidal interactions inside the dynamical systems of exoplanets and their parent stars more generally.

Reference: Rodolfo G. Cionco, Sergey M. Kudryavtsev, Willie W.-H. Soon (2023), *Solar Physics*, **298**:70. https://doi.org/10.1007/s11207-023-02167-w