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A New Way that Planets Can Affect the Sun

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Abstract We derive a perturbation inside a rotating star that occurs when the star is accelerated by orbiting bodies. If a fluid element has rotational and orbital components of angular momentum with respect to the inertially fixed point of a planetary system that are of opposite sign, then the element may have potential energy that could be released by a suitable flow. We demonstrate the energy with a very simple model in which two fluid elements of equal mass exchange positions, calling to mind a turbulent field or natural convection. The exchange releases potential energy that, with a minor exception, is available only in the hemisphere facing the barycenter of the planetary system. We calculate its strength and spatial distribution for the strongest case ("vertical") and for weaker horizontal cases whose motions are all perpendicular to gravity. The vertical cases can raise the kinetic energy of a few well positioned convecting elements in the Sun's envelope by a factor ≤ 7. This is the first physical mechanism by which planets can have a nontrivial effect on internal solar motions. Occasional small mass exchanges near the solar center and in a recently proposed mixed shell centered at $0.16R_s$ would carry fresh fuel to deeper levels. This would cause stars like the Sun with appropriate planetary systems to burn somewhat more brightly and have shorter lifetimes than identical stars without planets. The helioseismic sound speed and the long record of sunspot activity offer several bits of evidence that the effect may have been active in the Sun's core, its envelope, and in some vertically stable layers. Additional proof will require direct evidence from helioseismology or from transient waves on the solar surface.

Keywords Convection · Solar activity · Solar interior motions · Sun – planet interactions

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1. Introduction

Although the planets raise a vertical tide on the Sun that is known to be very small (millimeters), observations cited in this section have hinted for a long time that there should exist some more interesting mechanism for planetary influence on the Sun. We will discuss a fluid perturbation that depends on the distance and velocity of a star relative to the barycenter (mass centroid) of its planetary system. This motion creates potential energy per unit mass (PE) that can be released by flows pre-existing inside the star. If some of the released energy can get promptly to the surface, one might tie its effects to the star's motion. One mechanism, whose basis is discussed in Sections 4 and 5.2, takes place in a solar-type star where an individual convection "cell" at the proper phase in its short life would release some of the PE. This would cause a local upwelling of mass and heat. If close enough to the surface, it would cause horizontal flows on the surface that have to terminate in downflows with vorticity. Spinning downflows are known to be where considerable solar activity collects and strengthens (Schatten, 2009). Thus there should be some positive correlation between the intensity of solar activity and a local burst of vertical flow energized by released PE. This will certainly not be the main reason why solar activity levels vary, but it should cause some variations because its effect on an occasional convection cell can be quite significant (Section 4).

This might explain some of the many reports of correlations between the strength of solar activity and planetary motions. The first to point out the similarity between the sunspot time series and planetary orbits was Wolf (1859b) who very briefly summarized that work in a letter to Carrington (Wolf, 1859a). With an additional century of sunspot numbers, Jose (1965) showed that there were still good correlations with the Sun's distance from the barycenter and with several derived quantities. He also found a 179-year recurrence tendency in the planetary system and pointed out two possible cycles of that period in the sunspot series. Wood (1972) found a very interesting similarity between peaks in the 11-year cycle and a function of Jupiter – Venus – Earth alignments. This result was expanded and summarized by Öpik (1972) who showed that it only had a small chance of being accidental. For much shorter-term fluctuations in solar activity, Bigg and Mulhall (1967) advocated the importance of Mercury. Fairbridge and Shirley (1987) and Landscheidt (1999) reviewed past work and sought qualitative explanations for the Sun's multi-century trends and multi-decade quiet periods such as the Maunder minimum. Landscheidt (1999) notes that two correlations between orbit properties and solar flares or sunspot numbers had very small probabilities, ~ 0.001, of being accidental.

Quantities that have been suggested to cause correlations with solar activity include tides and the Sun's distance, velocity, angular momentum, and torque with respect to the barycenter. Others including Blizard (1987) and Juckett (2000) have proposed spin – orbit coupling and Juckett (2003) showed evidence of a correlation. But there is no published mechanism, quantitatively significant in the Sun, that will convert a change in its orbital momentum into a noticeable change in its spin momentum (Shirley, 2006). Also, de Jager and Versteegh (2005) showed that the orbital acceleration is negligible compared to the accelerations measured in the tachocline where they assume a solar dynamo operates. Whatever are the main causes of observed Sun – planet correlations, the table of Bureau and Craine (1970) indicates that a significant nonlinear component would be involved.

Even though some reported correlations have limited statistical significance, there have been enough very strong ones to indicate that some real interaction exists. However, each generation of astronomers has generally dismissed or ignored such works and omitted them from their textbooks and papers, probably on the weak grounds that they were unable to imagine a quantitative physical explanation.