Generation Mechanism for the Sun's Poloidal Magnetic Field

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There was established a sequence of physical processes forming the cause-and-effect relationship between the observed alternating poloidal magnetic field of the Sun and a non-electromagnetic factor external to the Sun. It has been shown that nonuniformity of the Sun's orbital motion about the Solar system barycenter promotes emergence inside the Sun of the conditions for generation of the alternating poloidal component of the Sun's magnetosphere having a period of about 20 years.

Keywords: Sun's poloidal magnetic field, inversion, flip, Jupiter, Saturn.

1 Problem definition

In 1908, in studying sunspot radiation spectra, American astronomer G.E. Hale revealed manifestations of the Zeeman effect [1], thus being the first who established the presence of magnetic field on the Sun's surface; in 1953, American astronomers H. D. Babcock and H. W. Babcock found out weak poloidal magnetic field of the Sun [2, 3, 4] by using a magnetograph they had developed. Since that time and up today, the scientific community continues systematically studying various aspects of the Sun's magnetosphere, including the alternating poloidal magnetic field. However, there is still no clear common concept of a mechanism for this field generation, namely, what indeed underlies this phenomenon, either factors external to the Sun or internal processes inside the Sun itself.

Fig. 1 presents a schematic layout of the Sun's geographic poles $\mathbb{N}$ and $\mathbb{S}$ and local normals $\underline{n}_{\mathbb{N}}, \underline{n}_{\mathbb{S}}$. For these points, magnetic-field strength vectors $\underline{B}_{\mathbb{N}}$ and $\underline{B}_{\mathbb{S}}$ are determined. These vectors are co-directional and lie on the axis of the Sun's own rotation which passes through the Sun's center of mass A. Hereinafter, we use open observations on the Sun's magnetic field furnished by the Wilcox Solar Observatory (*Polar Field Observations*) [5].

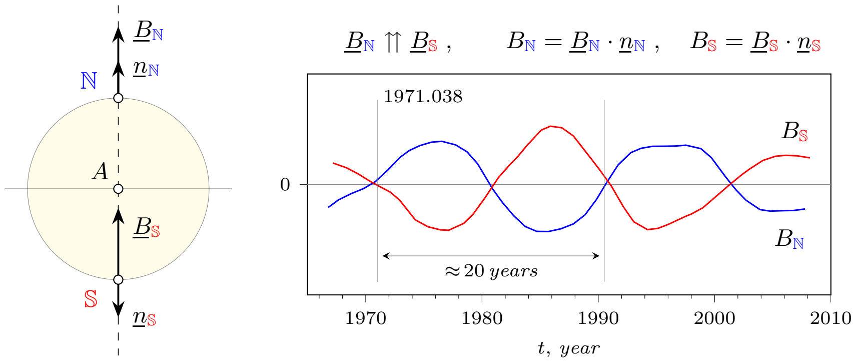


Figure 1. Polidal magnetic field strengths at the Sun's poles.

The right panel of the figure demonstrates time series $B_{\mathbb{N}}(t)$ and $B_{\mathbb{S}}(t)$ exhibiting antiphase oscillations in the strength of the Sun's magnetosphere poloidal component. One can see that the period of inversion of the magnetic field polarity is approximately 10 years. Taking $B_{\mathbb{N}}$ as an example, this periodicity may be represented as

$$\ldots \to B_{\mathbb{N}}\underbrace{>0 \to \overbrace{\mathbf{0} \to B_{\mathbb{N}}<0 \to \mathbf{0}}^{\approx 10\text{ year}} \to B_{\mathbb{N}}>0}_{\approx 20\text{ year}} \to \overbrace{\mathbf{0} \to B_{\mathbb{N}}<0 \to \mathbf{0}}^{\approx 10\text{ year}} \to \ldots \tag{1}$$

The sequence of events at the south geographic pole of the Sun may be constructed in a similar way.

The goal of this work was to find out a sequence of cause-and-effect relationships between non-electromagnetic factors external to the Sun and the observed Sun's alternating poloidal magnetic field.

2 The external factor in the poloidal alternating magnetic field of the Sun

In the framework of a heuristic approach to the problem under consideration, let us combine on the same time scale (Fig. 2), two physically different processes associated with the Sun, namely, the Sun's orbital speed variation Δv and time series demonstrating poloidal magnetic field strengths $B_{\mathbb{N}}$, $B_{\mathbb{S}}$ at the north and south solar poles, respectively. The time series reflecting the Sun's orbital speed variation was constructed by using open ephemeris data from *NASA JPL Horizons* [6].

Fig. 2 demonstrates a high extent of the temporal consistency of the variation in the Sun's orbital speed Δv with oscillations in the magnetic field

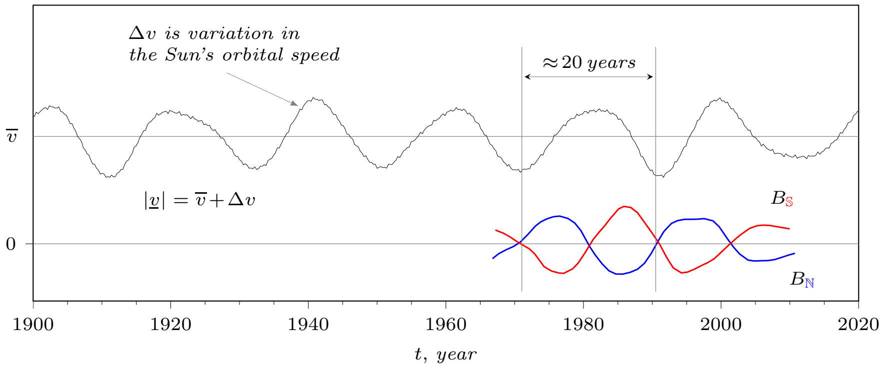


Figure 2. Comparison of the Sun's orbital speed variation Δv with oscillations in poloidal magnetic field strengths $B_{\mathbb{N}}$, $B_{\mathbb{S}}$ at the respective solar poles.

strengths $B_{\mathbb{N}}$, $B_{\mathbb{S}}$. The poloidal configuration of the Sun's magnetosphere repeats approximately every 20 years. This process is associated with regular inversions of the field (pole flips), when the poloidal magnetic field strength becomes zero at both solar poles simultaneously, i.e. $B_{\mathbb{N}} = B_{\mathbb{S}} = 0$. The inversion occurs every moment the Sun's orbital speed $|\underline{v}|$ reaches its local extremum (minimum or maximum) . And when the Sun's orbital acceleration $|\dot{\underline{v}}|$ reaches its extremum, the solar poles exhibit the maximal strengths of the poloidal magnetic fields. The obvious relationship between the processes illustrated in Fig. 2 allows us to surely assume that

> *oscillations in the Sun's poloidal magnetic field are governed exclusively by the 20-year speed variation Δv of the Sun's orbital motion about the Solar System barycenter.*

Indeed, remaining in the framework of classical mechanics, it is hardly possible to assume otherwise, namely, that the intrasolar processes are able to affect the non-uniformity of the Sun's own orbital rotation about the Solar System barycenter.

Consider the external factor that induces a well-pronounced 20-year variation in the Sun's orbital speed. The Solar System is a closed system of gravitating bodies staying in dynamic equilibrium. The Sun's orbital speed variation Δv about 20 years in period is, undoubtedly, a result of gravitational interaction of all the Solar System material bodies except for "dark matter" [7]. Based again on heuristic principles, let us restrict the number of gravitating Solar System bodies to only those that, to our opinion, can significantly affect the Sun's orbital speed. Let them be the Jupiter (J) with the period of 11.86 years and Saturn (S) with the period of 29.45 years. Notice that the solar mass is 99.86% of the Solar System mass, while the share of the Jupiter and Saturn in the remaining 0.14% is about 88%.

Let us consider characteristic time moments of the mutual spatial arrangement of the chosen planets and the Sun by using their ephemerides [6]. Fig. 3 illustrates the interrelation between spatial-temporal configuration of the Sun, Jupiter and Saturn, and the observed magnetic field strengths $B_{\mathbb{N}}$ and $B_{\mathbb{S}}$ at the respective solar poles. Mutual arrangement of the Jupiter and Saturn is characterized by function $L(t)$ that is the inversed squared distance between these planets and also by angular distance $\Delta\lambda$ between them in the barycentric frame of reference. Time moments t_A, t_C, t_E fix the state of the magnetic field inversion (pole flip), while moments t_B, t_D, t_F correspond to the maximal solar-pole strengths of the poloidal magnetic field. The red line indicates the instantaneous direction of the centrifugal force applied to the Sun's center of mass A.

Thus, analysis of the mutual arrangement of the Sun, Jupiter and Saturn shows that inversion of the Sun's magnetosphere poloidal component is a regular process with the period of about 10 years. This allows establishing that:

> *the Sun's poloidal magnetic field is absent when angular distance $\Delta\lambda$ between the Jupiter and Saturn in the barycentric frame of reference is $0°$ or $180°$. When $\Delta\lambda = 90°$, the poloidal magnetic field at the solar poles reaches its extremum.*

Table 1 presents the key time moments for the Sun – Jupiter – Saturn system with indicating the angular distance between the Jupiter and Saturn and the state of the Sun's magnetosphere. Superscripts (+) and (−) at $B_{\mathbb{N}}$ and $B_{\mathbb{S}}$ indicate whether the respective extremum is positive or negative. Thus, based on all the above we can assume that the mere existence of the

Table 1. Time moments fixing specific states of the Sun's magnetosphere. L, $\Delta\lambda$ are the parameters of the Jupiter – Saturn mutual configuration; JD and GD are the Julian and Gregorian dates, respectively.

—	JD	GD	$B_{\mathbb{N}}, B_{\mathbb{S}}$	$L(t)$	$\Delta\lambda$, *град*	
t_A	JD 2440966.5	19710115	0	*min*	178.8	(180)
t_B	JD 2442816.5	19760208	${B_{\mathbb{N}}}^+, {B_{\mathbb{S}}}^-$		89.9	(90)
t_C	JD 2444706.5	19810412	0	*max*	1.1	(0)
t_D	JD 2446546.5	19860426	${B_{\mathbb{N}}}^-, {B_{\mathbb{S}}}^+$		90.1	(90)
t_E	JD 2448076.5	19900704	0	*min*	179.6	(180)
t_F	JD 2450026.5	19951105	${B_{\mathbb{N}}}^+, {B_{\mathbb{S}}}^-$		90.2	(90)
t_G	JD 2451716.5	20000621	0	*max*	1.2	(0)

Sun's alternating poloidal magnetic field (Fig. 2) is caused by the 20-year cyclicity of the Jupiter and Saturn mutual arrangement with respect to the

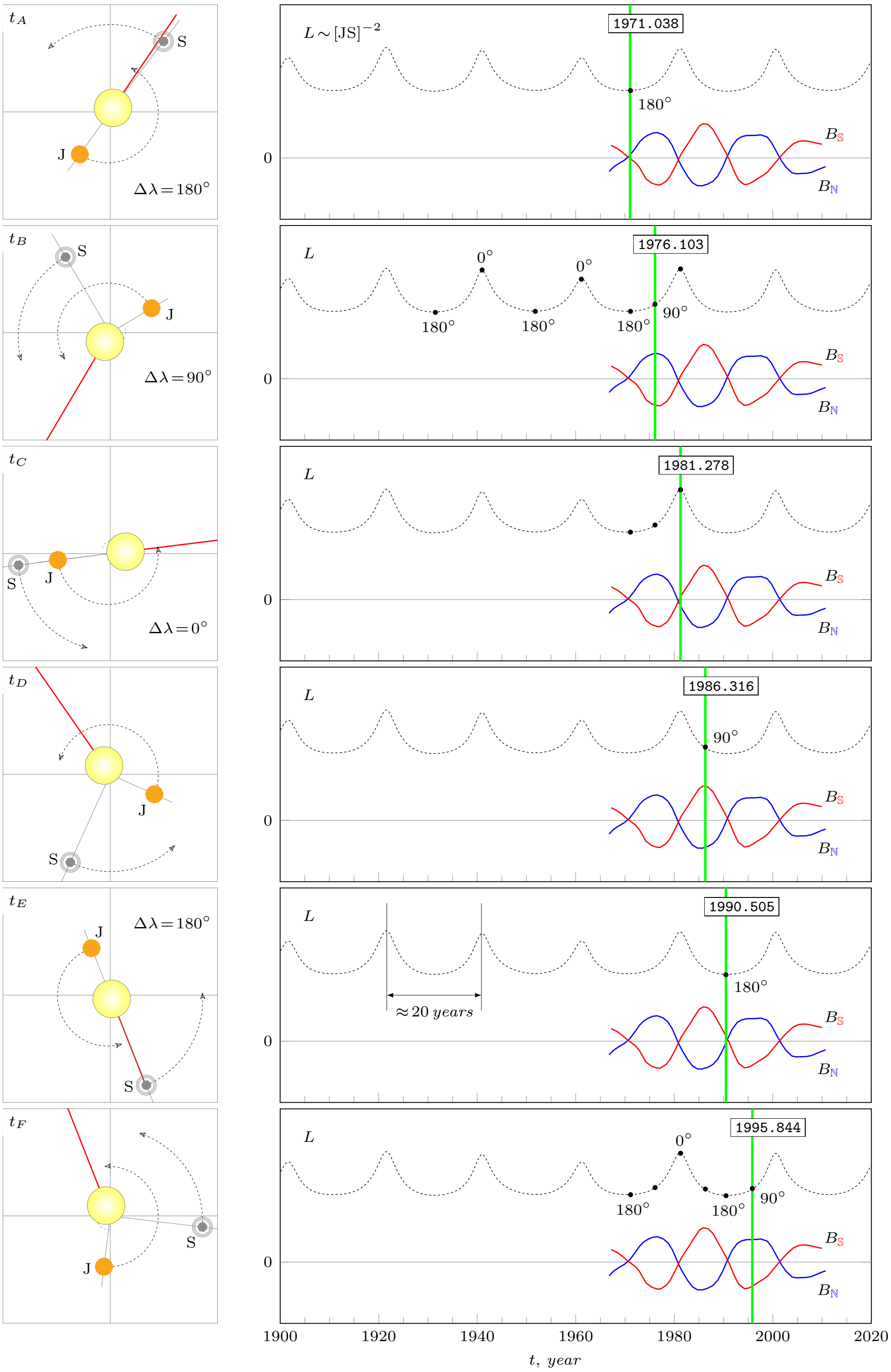


Figure 3. The relationship between the variation in the magnetic field strength in the Sun's north and south hemispheres (yellow disk) and Jupiter (J) – Saturn (S) spatial configuration expressed via angular distance $\Delta\lambda$.

Solar System barycenter. The sufficiency of accounting for only the Jupiter and Saturn is considered in more details in [8].

3 Generation mechanism for the Sun's poloidal magnetic field

Long-term observation over the Sun's magnetic field [5] enabled formation of time series (Fig. 1) exhibiting the dynamics of the poloidal magnetic field strengths $B_{\mathbb{N}}$, $B_{\mathbb{S}}$ at the north and south solar poles.

As Fig. 2 shows, variation Δv in the Sun's orbital speed has the same 20-year period as oscillations in the alternating poloidal magnetic field. Assume that inside the Sun there should exist a mechanism via which the variation in the Sun's orbital speed initiates a process promoting generation of the alternating poloidal magnetic field.

Let us put into consideration a space-fixed Cartesian frame of reference $Oxyz$ (Fig. 4) where origin O is located at the Solar System center of mass, while plane Oxy coincides with the ecliptic. Assume that the axis

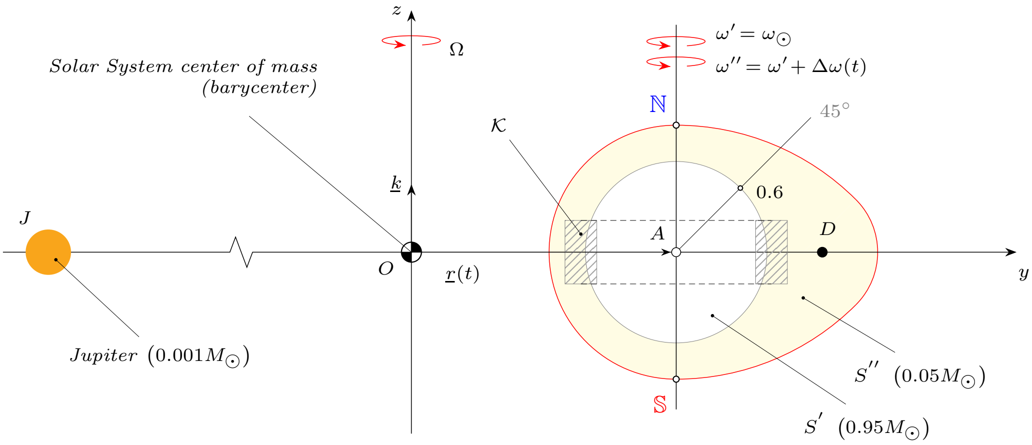


Figure 4. Meridional section of the Sun with plane Oyz. Deformed region S'' as a result of action of centrifugal forces during the Sun — Jupiter pair rotation about the Solar System barycenter O with angular speed Ω.

of the Sun's own rotation is parallel to axis Oz. Let us assign to axes Ox, Oy, Oz unit orts $\underline{i}$, $\underline{j}$, $\underline{k}$. The instantaneous position of the Sun in the $Oxyz$ system, i.e. its center of mass A, is taken from the Sun's ephemeris [6], which means that radius-vector $\underline{r}(t)$ is known.

The Sun is a deformable body and, as per [8, 9], it may be structurally represented by two characteristic regions. The first one, a rigid region S' with the mass of $0.95M_\odot$, includes the Sun's core and radiative-transport zone. The other one, deformable region S'', is an adjacent spherical layer $0.05M_\odot$ in mass which consists of the convective-transport zone and photosphere. Thus, the Sun is represented as a non-uniformly orbiting (orbiting with a periodically changing speed) solid rigid body S' surrounded by deformable region S''.

Angular speed Ω of the Sun's orbital motion about barycenter O corresponds to the period of 11.86 years. This period is mainly defined by the Sun — Jupiter system rotation about the barycenter in the ecliptic plane Oxy. At the same time, the Sun is subject to centrifugal forces deforming the outer region S'', which manifests itself as formation of a gravitational anomaly [9] or, in other words, of a centrifugal bulge. Let us designate this bulge as point D located in the equatorial plane at some distance from the axis of the Sun's own rotation (Fig. 4).

If the Sun is assumed to orbit uniformly (circular motion), centrifugal bulge D in region S'' is fixed with respect to S'. Adding the Saturn to the Sun – Jupiter system results in appearance of the 20-year variation Δv in the Sun's orbital speed, which is a basic reason for the emergence of forced tangential oscillations of centrifugal bulge D in region S'' relative to the Sun's central part with angular speed $\Delta\omega(t)$. Define angular speeds ω' and ω'' for the S' and S'' regions, respectively, as follows:

$$\omega' = \omega_\odot \ , \quad \omega'' = \omega' + \Delta\omega(t) \ . \tag{2}$$

Additional angular speed $\Delta\omega$ stems from the Sun's orbital speed variation Δv. We believe that generation of the poloidal alternating magnetic field is to occur in the equatorial region at the $S' - S''$ interface because, to our opinion, only there the solar plasma *reverse rotation* gets fully realized with the about 10-year interval due to forced tangential oscillations of the region S'' centrifugal bulge D in the Sun's equatorial plane. For this purpose, let us separate out in the Sun's equatorial region at the interface between rigid Sun's central part S' and deformable spherical layer S'' a torus-like region $\mathcal{K}$ (Fig. 4) with the axis of symmetry coinciding with the Sun's own rotation axis.

What does occur in region $\mathcal{K}$? Let us consider the Sun's equatorial cross section by ecliptic plane Oxy (Fig. 5). The torus-like region $\mathcal{K}$ is hatched. This is the region of transition from the Sun's central part S' to outer region S''. Due to forced oscillations of the region S'' centrifugal bulge D relative to S', plasma vortices get formed mechanically; rotation planes of the vortices are mainly parallel to the Sun's equatorial plane. The rotation

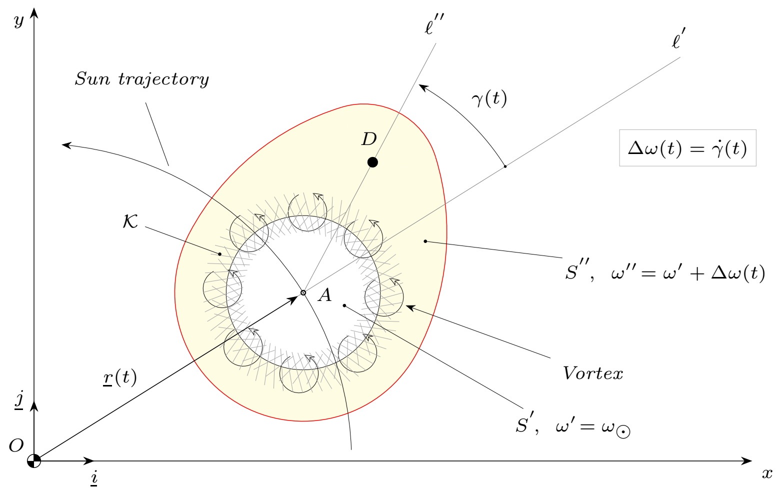


Figure 5. The Sun's equatorial cross section. Region S'' deformed by centrifugal forces. Symbol l' designates ray $[OA)$, it indicates the direction of the centrifugal force applied to Sun's center of mass A. l'' is ray $[AD)$ defining the angular position of centrifugal bulge D relative to direction l'.

sense of the vortices is defined exclusively by the difference between angular speeds ω' and ω'', namely, by the sign of relative angular speed $\Delta\omega = \dot{\gamma}$. Forced oscillations of the region S'' centrifugal bulge D with respect to ray l' initiate sequential changes in the rotation sense of the region $\mathcal{K}$ *localized solar plasma vortices* with the period of about 10 years.

Generation of the alternating magnetic field. We assume that the alternating poloidal magnetic field of the Sun is defined by the sum of magnetic fields of all the vortices which have emerged in region $\mathcal{K}$. Let us characterize magnetic field b of each individual vortex by magnetic field strength vector $\underline{b}$ in the vortex rotation center.

Consider the vortex formation process from the point of view of an Observer looking from the north solar pole. Fig. 6 demonstrates the key moments of the process of vortex generation from generation to disappearance during the time interval 10 years long from t_A to t_C . To compare characteristic positions of the region S'' centrifugal bulge D relative to the Sun's central part, we have added a 20-year variation Δv in the Sun's orbital speed and time series demonstrating the poloidal magnetic field strengths $B_{\mathbb{N}}(t)$, $B_{\mathbb{S}}(t)$ at the respective solar poles. Emphasize three characteristic time moments:

$\boldsymbol{t_A}$**:** the moment of inversion ($B_{\mathbb{N}} = B_{\mathbb{S}} = 0$).
/ *The onset of generation of the subsequent poloidal magnetic field.* /
Angular speed $\dot{\gamma} = 0$.
The Sun's orbital speed $|\underline{v}| = min$;

$\boldsymbol{t_B}$**:** the magnetic field strength is maximal, i. e. $|\underline{B}_{\mathbb{N}}| = |\underline{B}_{\mathbb{S}}| = max$.
Angular speed $|\dot{\gamma}| = max$.

$\boldsymbol{t_C}$**:** the moment of inversion ($B_{\mathbb{N}} = B_{\mathbb{S}} = 0$).
/ *The onset of generation of the subsequent poloidal magnetic field.* /
Angular speed $\dot{\gamma} = 0$.
The Sun's orbital speed $|\underline{v}| = max$;

In our case, analysis of the Sun's orbital speed variation within the time interval from t_A to t_C shows that angular rotation speed ω'' is lower than angular rotation speed ω'. This initiates formation of clockwise vortices. Since we *a priori* know from observations the direction of magnetic field vector $\underline{B}_{\mathbb{N}}$ at the north solar pole, the following condition should be fulfilled for each clockwise vortex generating local magnetic field b :

$$\underline{b} \upuparrows \underline{B}_{\mathbb{N}} \ . \tag{3}$$

The plasma vortex combines current rings consisting of both positive (p) and negative (e) particles (electrons). Each charged particle forms a current ring and induces magnetic field b that is characterized, depending on the charged particle sign, by a vector of the magnetic field strength $\underline{b}^p$ or $\underline{b}^e$ in the current ring rotation center. Mutual influence of the current rings is not considered at this stage of investigation.

Thus, the vortex magnetic field b is defined by a combination of magnetic fields of all its current rings, i.e., the total magnetic field strength vector $\underline{b}$ may be represented for the considered vortex as follows:

$$\underline{b} = \sum \underline{b}^p + \sum \underline{b}^e \ , \quad \text{where} \qquad \left|\sum \underline{b}^e\right| > \left|\sum \underline{b}^p\right| \ . \tag{4}$$

Such a relation between the magnetic fields of current rings follows from the Biot – Savart – Laplace law under the condition of elevated electron concentration in the Sun's equatorial region at the interface between the zones of radiative and convective transport. This condition stems from the consistency of the vortex magnetic fields b with the observed direction of the strength vector $\underline{B}_{\mathbb{N}}$.

Thus, in region $\mathcal{K}$ there arise a great number of vortices with co-directed vectors of magnetic field strength $\underline{b}$ merely which form the observed alternating poloidal magnetic field of the Sun. Inversion of the vortex rotation sense leads to inversion of the Sun's poloidal magnetic field.

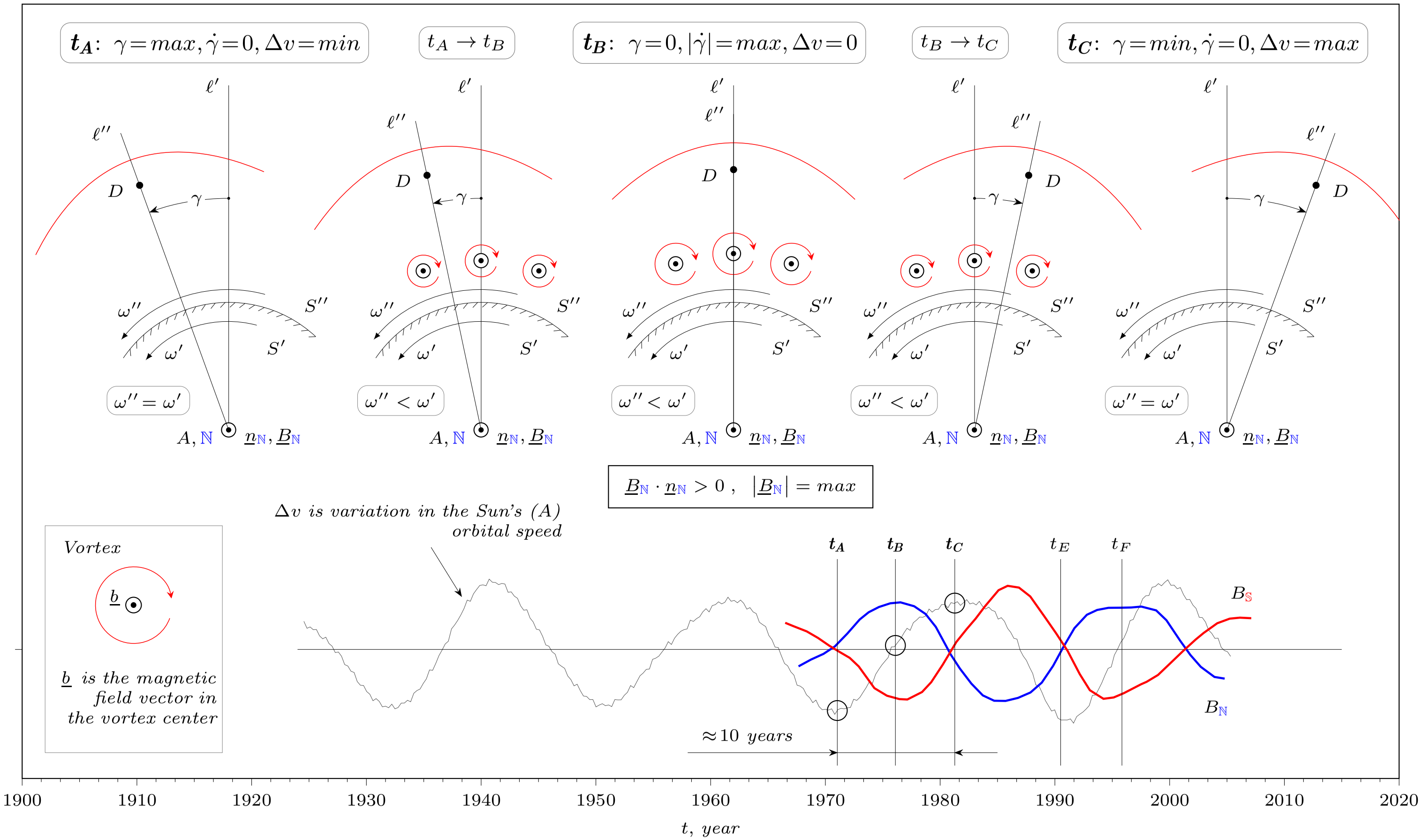


Figure 6. Formation of vortices generating the Sun's poloidal magnetic field in the interface layer $\mathcal{K}$ between the radiative-transport zone $S^{'}$ and convective-transport zone $S^{''}$ due to the difference in their angular speeds ω' and ω'', where $\omega'' = \omega' + \dot\gamma$.

Fig. 7 demonstrates the configuration of force lines of the Sun's magnetosphere poloidal component, which corresponds to the time moment when the poloidal magnetic field strengths at the solar poles reach their maxima.

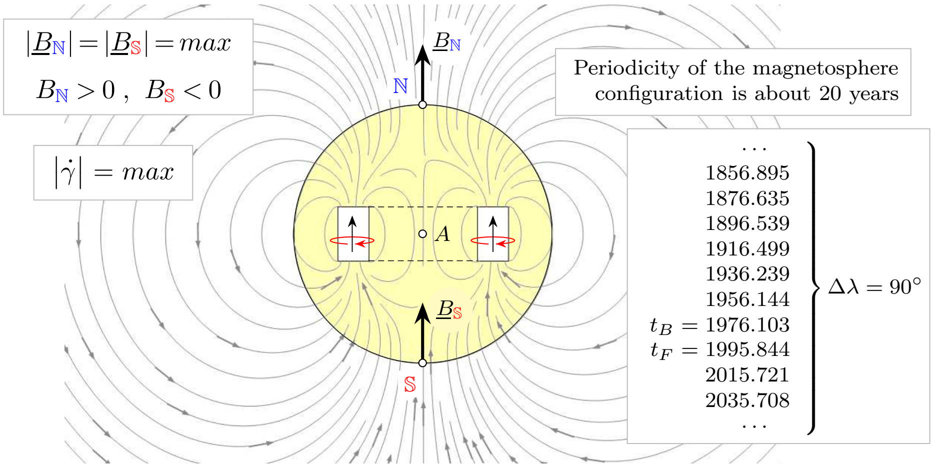


Figure 7. Characteristic configuration of force lines of the Sun's poloidal magnetic field at the moment of its maximal intensity.

Time series shown in Fig. 6 point to the defining role of the 20-year variation Δv in the Sun's orbital speed in formation of the Sun's alternating poloidal magnetic field. Thus, we have established an unambiguous cause-and-effect relationship between different-physical-nature processes participating in generation of the Sun's poloidal magnetic field.

4 Simulation of the reverse motion of the Sun's centrifugal bulge.

Let us consider the mechanical nature of forced tangential oscillations of centrifugal bulge D in region S'' with respect to the Sun's central rigid part S' taking as an example the pendulum with the kinematic excitation of the base (Fig. 8). The pendulum is a weightless rigid rod AD with length h, which is hinged at point A on a mobile weightless element able to move friction-less along a weightless guide (ray l') hinged at fixed point O.

Radius-vector $\underline{r}_D$ assigns the current position of point D with mass m which executes forced oscillations in plane Oxy relative to ray l'. Ray l' indicates the direction of the resulting centrifugal force $\underline{F}_A$ applied to point A, which arises due to the Sun – Jupiter – Saturn system rotation about barycenter O. The centrifugal bulge mass m is generally dependent on the trajectory of the Sun's rotation about the barycenter. Assume that $m = const$, since

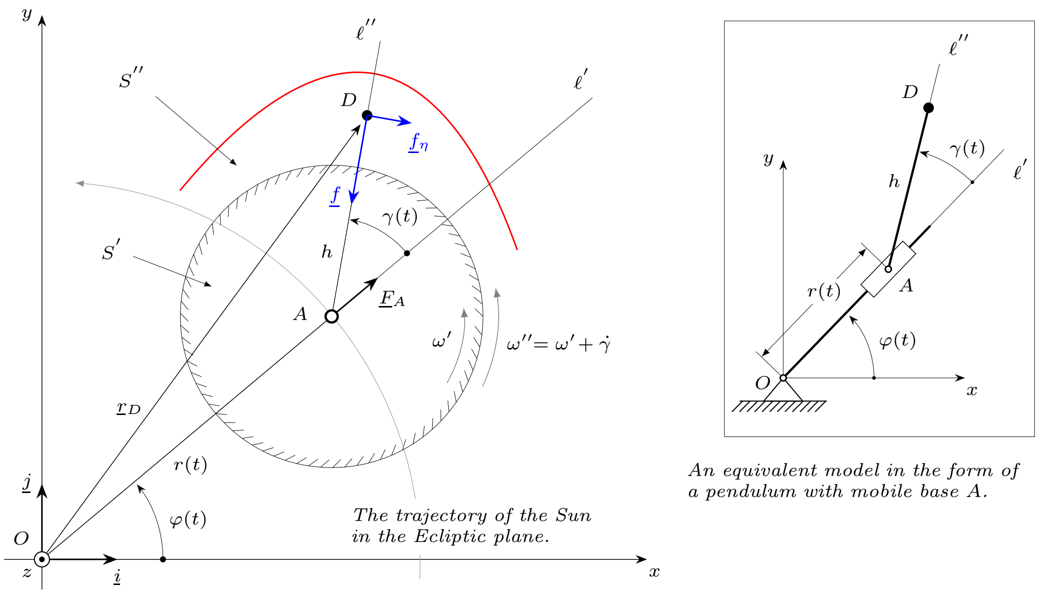


Figure 8. The oscillation model of the centrifugal anomaly D in region S''.

our task is to demonstrate only the mechanism of couplilng the Sun's orbital speed variation with tangential oscillations of centrifugal bulge D.

Kinematics of the pendulum base (point A) is defined by the solar ephemeris [6], namely, by radius-vector $\underline{r}(t)$ in barycentric frame of reference $Oxyz$. Thus, the point A motion is determined via distance $r(t)$ and angle $\varphi(t)$. Nonuniformity of the point A orbiting results in relevant tangential oscillations of deformable region S'' relative to S'. Deviations of the region S'' centrifugal bulge D is characterized by angle $\gamma(t)$ between rays l' and l''. Assume that $\gamma > 0$ in the case of the counterclockwise deviation; otherwise, $\gamma < 0$.

Dynamics equation. Assume that point D is subject to only two forces. These are retaining force $\underline{f}$ acting along ray l'' towards point A and generalized "viscous" friction force $\underline{f}_\eta$. We take friction force $\underline{f}_\eta$ to mean all that hinders relative motion of the region S'' centrifugal bulge D. The force balance equation for material point D in Fig. 8 will be written as follows:

$$m\,\ddot{\underline{r}}_D = \underline{f} + \underline{f}_\eta\,, \quad \text{where} \qquad \underline{r}_D = x(t)\,\underline{i} + y(t)\,\underline{j} + \overset{0}{\cancel{z(t)}}\,\underline{k}\,. \tag{5}$$

Here $x(t), y(t), z(t)$ are the instantaneous coordinates of material point D with mass m in barycentric frame of reference $Oxyz$.

As a result of appropriate algebraic transformations of equation (5), obtain a second-order differential equation with respect to angle $\gamma(t)$:

$$\boxed{h\ddot{\gamma} = -\frac{\eta}{m}\, h\dot{\gamma} - h\ddot{\varphi} + \left(\ddot{r} - r\dot{\varphi}^2\right)\sin\gamma - \left(2\dot{r}\dot{\varphi} + r\ddot{\varphi}\right)\cos\gamma\ .} \tag{6}$$

This equation does not contain retaining force f, which makes simpler solution of task (5), i.e., determination of the angle $\gamma(t)$ variation character for the initially specified trajectory of point A (the Sun's center of mass).

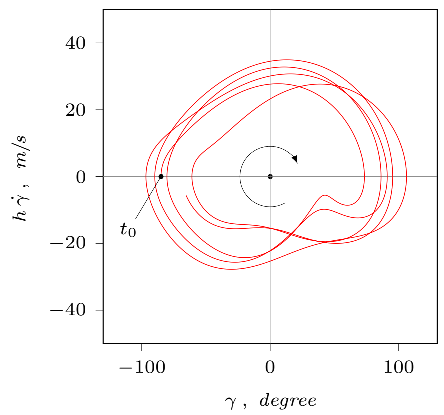
Let us define for the second-order differential equation (6) the Cauchy problem with the following initial conditions:

$$\boxed{\gamma(t)\Big|_{t=t_0} = \gamma_0\ , \quad \dot{\gamma}(t)\Big|_{t=t_0} = 0\ .} \tag{7}$$

The ray l'' periodical forced deviation (characterizing the position of centrifugal bulge D) by angle γ leftward or rightward with respect to l' is governed by the 20-year variation Δv in the Sun's orbital speed. However, there is a specific fact: the angle γ_0 initial value, as well as settings of parameters h and η of the pendulum under consideration, is unknown. However, we know that when the deviation angle is maximal ($\gamma = \gamma_0 > 0$), the Sun's orbital speed $|\underline{v}|$ is minimal. Hence, processes $\gamma(t)$ and $\Delta v(t)$ are opposite in phase, while the moments of inversion (when $B_{\mathbb{N}} = B_{\mathbb{S}} = 0$) correspond to the moments of their local extrema. All the above allows defining a quantitative criterion for selecting angle γ_0 from the range of $-\pi/2$ to $\pi/2$ and optimal parameters h and η for the model considered here.

The problem was solved as follows. As initial time moment t_0, let us choose the moment corresponding to the magnetic field inversion. Then let us specify initial values of the pendulum parameters, such as h, η and initial γ_0. The obtained solution of differential equation (6) is compared with the Sun's orbital speed variation Δv via correlation coefficient $\mathcal{R}$ which is to tend to -1 because eventually these processes are opposite in phase. Then the process is to be repeated with new refined values of γ_0, h, η . In our case, the iterative process of solving the problem was terminated when stable centrifugal bulge oscillations about 20 years in period were achieved. Actually, the problem has got reduced to searching for the global extremum with respect to several parameters [10].

Simulation results. The considered model showed the possibility of the existence of forced oscillations of the region S'' centrifugal bulge D relative to the Sun's central part as a consequence of the 20-year variation Δv in the Sun's orbital speed. The character of the obtained solution of equation (6) with initial conditions (7) is illustrated by the phase-plane trajectory



t_0 = JD 2422926.5 (1921.646)
$m = 1\ kg$
$\eta = 0.00005979 \cdot m$
$h = 2.2887 \cdot R_\odot$
$\gamma_0 = -84°58'$
$T_\gamma = 20\ year$
$\mathcal{R} = -0.932$

Figure 9. Phase trajectory of the region S'' centrifugal bulge D oscillations as a result of solving equation (6) with initial conditions (7).

in Fig. 9. In the considered time interval about 100 years long, the phase trajectory exhibits a stable character of the centrifugal bulge D oscillations.

Table 2 lists the values of angular distance $\Delta\lambda$ between the Jupiter and Saturn in the barycentric frame of reference, deviations of the Sun's orbital speed variation Δv from mean $\bar{v}$ and centrifugal bulge D deviation angle γ determined for key moments $t_A, t_B, t_C, \ldots$.

Table 2. Key moments of the state of the Sun's alternating poloidal magnetic field.

	BD	$B_\mathbb{N}, B_\mathbb{S}$	$\Delta\lambda$, *degree*		Δv, *m/s*	γ, *degree*
t_A	1971.038	0	178.8	(180)	-3.5	99.8
t_B	1976.103	${B_\mathbb{N}}^+, {B_\mathbb{S}}^-$	89.9	(90)	0.8	-6.5
t_C	1981.278	0	1.1	(0)	2.0	-94.3
t_D	1986.315	${B_\mathbb{N}}^-, {B_\mathbb{S}}^+$	90.1	(90)	0.4	13.8
t_E	1990.505	0	179.6	(180)	-2.8	89.0
t_F	1995.844	${B_\mathbb{N}}^+, {B_\mathbb{S}}^-$	90.2	(90)	-0.1	22.9
t_G	2000.471	0	1.2	(0)	3.2	-83.3

The obtained results clearly show that the existence of the poloidal component of the Sun's magnetosphere is fully defined by the 20-year Sun's orbital speed variation Δv which is just that initiates relevant forced tangential oscillations of the region S'' centrifugal bulge D with respect to the Sun's central rigid part S'.

Fig. 10 presents the numerical solution of equation (6) in the form of a time series $\gamma(t)$, which is compared with the Sun's orbital speed variation Δv, oscillations of the solar-pole magnetic field strengths $B_\mathbb{N}$ and $B_\mathbb{S}$ and parameter $L(t)$ characterizing the mutual arrangement of the Jupiter and Saturn. Notice that these time series are absolutely consistent with each other.

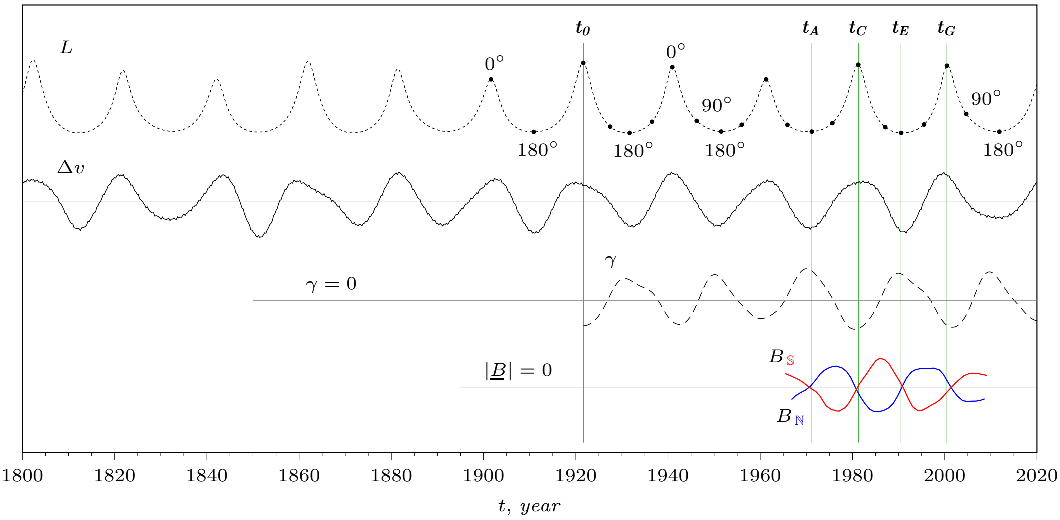


Figure 10. Comparison of variations Δv in the Sun's orbital speed, deviation angle γ of centrifugal bulge D, poloidal magnetic field strengths $B_{\mathbb{N}}$, $B_{\mathbb{S}}$ and parameter L reflecting the mutual arrangement of the Jupiter and Saturn. t_A, t_C, t_E, t_G are the moments of inversion.

5 Conclusions.

The nature of the Sun's alternating poloidal magnetic field is defined exclusively by the periodicity of the Jupiter and Saturn spatial configuration in the barycentric frame of reference, which is illustrated in the following diagram:

$$\overbrace{\quad L \quad}^{\textit{Jupiter} - \textit{Saturn}} \longrightarrow \overbrace{\Delta v \longrightarrow \gamma \longrightarrow \begin{matrix} B_{\mathbb{N}}{}^{\pm} \\ B_{\mathbb{S}}{}^{\mp} \end{matrix}}^{\textit{Sun}}$$

The diagram demonstrates a unidirectional relation between the Jupiter – Saturn mutual configuration $L(t)$ and Sun's orbital speed variation Δv which, in its turn, initiates forced oscillations in the Sun's centrifugal bulge which are expressed via angle γ and result in generation of the Sun's alternating poloidal magnetic field. In addition, notice that the Sun's own rotation does not affect the generation of the Sun's alternating poloidal magnetic field but only introduces a static correction to deviation angle γ of centrifugal bulge D.

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