# A magnetic field mechanism for the origin of planetary motion

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Calculations are made of the paths of earth-sized ejected matter from a star or sun, under the influence of gravitational, electrostatic and magnetic forces, assuming an electric potential of the sun and earth, and that the sun has a very large dipole magnetic field. Generally such paths are a large loop, ending back in the sun. However, if the ejected body has a particular ejected velocity appropriate to its mass and is ejected in the equatorial plane of the sun, it can attain a circular orbit around the sun, as in planetary motion. Furthermore, the magnetic forces on the electrical charges on the planet are such as to produce planetary spin. However, extremely large magnetic fields and plasma potentials are required, similar or greater than those of neutron stars.

## 1. Introduction

Conventional theories such as the "Nebular Condensation Theory" for the origin of planetary motion, for example as in our Solar System, are developments of the original theory of Laplace [1]. The planets and the sun are regarded as having formed together from the condensation of rotating interstellar material falling towards the central sun under the influence of gravity. There are many details in which the nebular condensation theory is incomplete. (a) The formation of the initial rotating disks and planetesimals from the interstellar material has not been worked out [2]. (b) It is difficult to explain why the planets have 98% of the angular momentum of the system with only 0.2% of the total mass [3]. (c) The orbits of the planets are remarkably regular; seven out of eight planets are coplanar to within several degrees and are very closely circular with eccentricities of less than 0.02. (d) It is difficult for the nebular hypothesis to explain the origin of planetary spin [2].

In the present paper we examine the possibility of planets originating from the ejection of material from the sun and being captured into an orbit around the sun. Such ejected material would be fully ionised due to its high temperature and thus would be a plasma, as also would the sun. We consider that the sun and the ejected mass have an electric potential appropriate to their temperature, due to influences such as ambipolar diffusion. We also consider the sun to have a large dipole magnetic field. We do numerical calculations of the paths taken by various masses ejected from the sun's surface under the influence of gravitational, electrostatic, and magnetic forces. Of particular interest is the Lorentz or magnetic force on the ejected material, which will be perpendicular to its motion and tend to make its path curved. If the ejection is in the equatorial plane of the sun we show that the planet can be captured into orbit.

The magnetic field can also explain planetary spin. While a planet is being ejected and travelling away from the sun, negative charges flow towards the sun if it is positively charged, leaving positive charges on the side of the planet away from the sun. The influence of the magnetic field on these opposite charges exerts a torque to induce planetary spin. Once the planets rotate around the sun, there is a similar but weaker torque, tending to rotate the axis of rotation of the planets. Thus there would be a qualitative explanation for the axes of Venus to be inverted and for Uranus to be on its side.

The big problem of the present mechanism is that the magnetic field that is required on the sun is extremely large, being of the same order or larger than the magnetic fields on neutron stars. Nevertheless the mechanism is of interest for a number of reasons. (1) Recently it has been found that some neutron stars have planets [4], so that this mechanism may have relevance to planetary formation in neutron stars. (2) The mechanism may have relevance to the formation of planetary systems in other galaxies. (3) It is possible that such extremely large magnetic fields may have been present millions of years ago at the formation of our own solar system. (4) The mechanism is of philosophical interest in that highly ordered properties of planetary motion arise after random isotropic mass ejections from a central star. Physical systems usually result in increased randomisation.

## 2. Theory

We have done calculations for various planetary masses ejected from various positions and angles on the surface of the sun, for various values of electrostatic potential of the sun and planet, and also for various values of the sun's magnetic dipole. The motion of the ejected material from the sun is represented in Cartesian co-ordinates.

$$\frac{d\boldsymbol{s}}{dt} = \boldsymbol{v} \quad \text{and} \quad \frac{d\boldsymbol{v}}{dt} = \boldsymbol{a}. \qquad (1)$$

The vector $\boldsymbol{s}$ represents the position *(x, y, z)* relative to the centre of the sun, the vector $\boldsymbol{v}$ represents the velocity of the mass with components $v_x$, $v_y$, and $v_z$, the vector $\boldsymbol{a}$ is the acceleration of the mass, and $t$ is the time from the ejection of the mass, initially at the surface of the sun.

The acceleration, $\boldsymbol{a}$, is given by Newton's Law in terms of the force $\boldsymbol{F}$ acting on the ejected mass, where $\boldsymbol{F}$ has contributions due to gravity $\boldsymbol{F_g}$, electrostatic forces $\boldsymbol{F_e}$, and magnetic forces $\boldsymbol{F_m}$

$$\boldsymbol{a} = \boldsymbol{F}/m = (\boldsymbol{F_g} + \boldsymbol{F_e} + \boldsymbol{F_m})/m; \qquad (2)$$

$m$ is the mass of the ejected material. The gravitational force, which is in the radial direction, is given by Newton's Law of Gravitation:

$$\boldsymbol{F_g} = -\boldsymbol{i}\, GmM/r^2 \qquad (3)$$

where $G$ is the gravitational constant, $m$ is the mass of the ejected material, $M$ is the mass of the sun, $r$ is the radial distance between the mass and the centre of the sun and $\boldsymbol{i}$ is a unit vector in the radial direction. The electrostatic force, also in the radial direction, is given by:

$$\boldsymbol{F_e} = \boldsymbol{i}\, q_1\, q_2/(4\pi\varepsilon\, r^2) \qquad (4)$$

where $q_1$ and $q_2$ are the charges of the ejected mass and the sun respectively, and $\varepsilon$ is the permittivity of free space.

The magnetic force, known as the Lorentz or "**J**×**B**" force, is perpendicular to both the direction of motion of the mass and also the magnetic field. This force is given by

$$\boldsymbol{F_m} = \boldsymbol{J}\times\boldsymbol{B}, \qquad (5)$$

where $\boldsymbol{J} = q_1\boldsymbol{v}$ is the "current" represented by the charge on the moving planetary mass, and $\boldsymbol{B}$ is given by the sum of the field from the two poles of the magnetic dipole representation of the sun's magnetic field, i.e.

$$\boldsymbol{B} = \frac{\boldsymbol{i_1} Cp}{r_1^2} - \frac{\boldsymbol{i_2} Cp}{r_2^2}. \qquad (6)$$

$C$ is a physical constant, $p$ is the strength of the dipole for the sun's magnetic field, $r_1$ and $r_2$ are the radial distances from the two dipoles within the sun to the ejected mass; $\boldsymbol{i_1}$ and $\boldsymbol{i_2}$ are unit vectors in the direction of $r_1$ and $r_2$. The magnetic field from the dipole is similar to that of a conventional magnet.

We have solved the above equations to obtain the path of the ejected mass as a function of time, given by $\boldsymbol{s}$ of equation (1), in three dimensions. We have used a numerical integration scheme where the step size in time is controlled and varied throughout the integration according to the rates of change of the variables. This procedure results in a considerable reduction of computation time, as much larger step sizes can be used at distances far from the sun. Checks were made on numerical accuracy by changing the control parameter to reduce the step size.

Apart from the masses of the sun, $M$, and the ejected planet, $m$, the parameters needed for any calculation are the initial speed, position and angle of the ejected mass on the surface of the sun, the plasma potential of the sun and planet which determines their net electrostatic charges $q_1$ and $q_2$, and the strength of the magnetic dipole of the sun. The electrostatic force of equation (4) is very much less than the gravitational force of equation (3). Also the Lorentz force, being perpendicular to the motion of the mass, does no work on the mass to change its speed.

Electrons from any isolated plasma tend to escape from the plasma by ambipolar diffusion until the plasma, in this case the sun and planet, reaches a positive potential to prevent the further escape of electrons. The plasma potential is thus determined by the maximum temperature, and thus the maximum energy, of electrons in the plasma. Taking this temperature to be that required for thermonuclear reactions, i.e. ~ 10,000,000 K, the corresponding potential is about 1 kV, using the relation that potential, $V = kT/e$ where $e$ is the electronic charge, $T$ is the temperature and $k$ is Boltzmann's constant. This potential is approximately consistent with the energy required to produce the sun's corona [5]. It is possible that electrons of high energy from deep within the plasma of the sun, can escape to the sun's surface due to the effect of "run-away electrons" [6], resulting from the rapid reduction of the Coulomb cross-section with increasing energy. Knowing the potential of the sun and ejected mass, the charges $q_1$

and $q_2$ on each body can be determined from the electrostatic relationship

$$V = q/(4\pi\varepsilon R) \qquad (7)$$

where $R$ is the radius of the planet or sun.

The magnetic field of the sun is subject to significant uncertainty, particularly for conditions millions of years ago. The purpose of our investigation has been to determine if the $\boldsymbol{J}\times\boldsymbol{B}$ force could cause capture of an ejected mass under any conditions, so we have chosen the magnitudes of this magnetic dipole of the sun by trial.

## 3. Numerical Results

We find that the ejected "planet" takes a curved path, due to the magnetic field, but generally returns to the sun due to the influence of the gravitational field of the sun. If the ejected velocity is larger than the escape velocity, the planet is lost from the sun. However, for very large magnetic fields on the sun, and for planets ejected in the equatorial plane of the sun, and ejected at just the right velocity appropriate to the magnetic field, the planet can be captured into orbit around the sun. Then the planets fulfil the properties of the present solar system as they are only captured, if and only if they are ejected in the sun's equatorial plane. All other projections end in the planet crashing back into the sun under the influence of the sun's gravity.

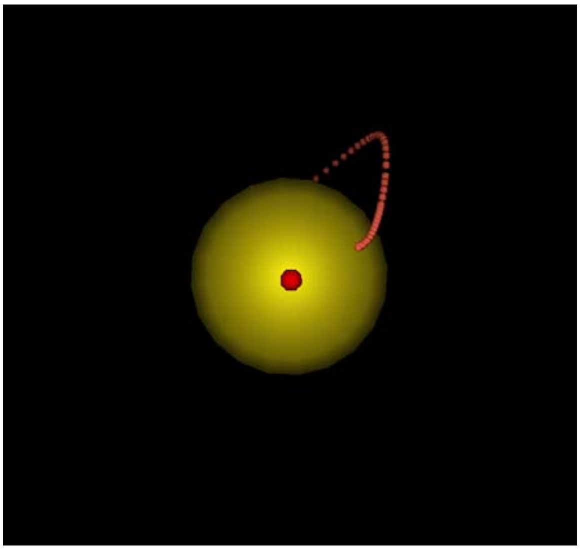

Fig. 1 Usual "orbit" is a loop ending in the sun.

Fig. 1 shows such a curved path, for an earth mass ejected at 45 degrees to the equatorial plane of the sun at a velocity of 500 km/s. The curvature of the orbit is due to the Lorentz plasma force and the path ends at the sun's surface.

For masses ejected at the equator of the sun, the effect of the magnetic field is particularly strong as the magnetic field lines are perpendicular to the motion. We find that for ejected velocities at just below the escape velocity of the sun, for just the right planetary mass appropriate to the sun's magnetic field, the mass can traverse a circular planetary orbit as shown in Fig. 2. We obtained this orbit by adjustment of the strength of the magnetic dipole of the sun, keeping the mass of the planet equal to the current mass of the earth.

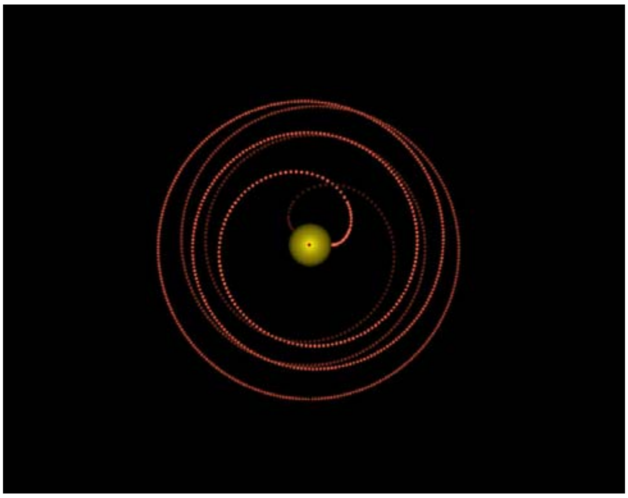

Fig. 2 Ejection at sun's equator can lead to a circular orbit.

The number of revolutions of the sun that we obtain before the numerical solution again ends in the surface of the sun is very sensitive to the value of the magnetic field, the ejection velocity, and also the numerical accuracy of the calculations. The calculations of Fig. 2 indicate the possibility of such ejected material from the sun being collected into a circular orbit around the sun due to the influence of the Lorentz force.

## 4. Discussion

The magnetic mechanism is remarkable in that it can explain, at least qualitatively, many of the features of the solar system. (a) All planets rotate in the same plane, that of the sun's equator. (b) The planetary orbits are closely circular, elliptical orbits being unstable due to the magnetic field. (c) All ejected masses that are captured rotate in the same direction around the sun. (d) The magnetic field mechanism does not have the classical problem of the Laplace theory to conserve angular momentum. The magnetic mechanism requires a very large magnetic field and thus a very large speed of rotation of the sun. Production of the planets through ejection from the sun would reduce this angular momentum. If the sun's rotation is reduced to zero, there would be little or no magnetic field and no further capture of ejected planets into a circular orbit.

The plasma mechanism also provides an explanation for the planetary spin. Electrons in the ejected mass, which is a plasma, will be attracted to the side of the planet facing the positively charged sun, leaving an excess of positive charges on the opposite side of the planet away from the sun. The net positive charge of the planet will also reside on this side of the planet. The sun's magnetic field, which is perpendicular to the planet's motion away from the sun, exerts opposite forces on the positive and negative charges, tangential to the planet, which constitute a torque inducing planetary spin, as is illustrated in Fig. 3. The direction of this spin is anti-clockwise looking down on the north pole of the sun, consistent with the direction of rotation of six out of the eight major planets. Once planets are spinning they will continue to spin even though all plasma charges may be lost and there is no longer a torque to produce acceleration of the spin.

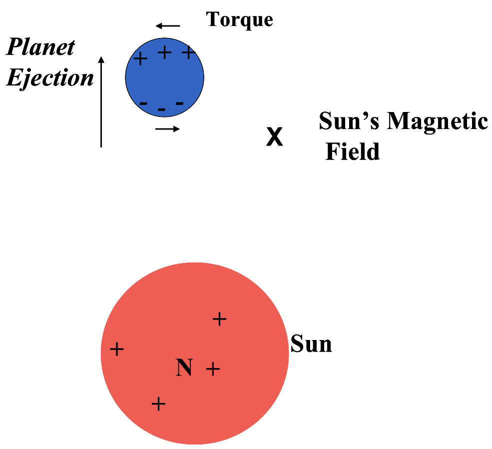


Fig. 3 The sun's magnetic field induces planetary spin due to electric charges on the planet.

When the planet is in orbit around the sun, if it is still a plasma, there will be a similar torque on the planet, but smaller because it is further from the sun. In this case, the planet's motion around the sun is still perpendicular to the magnetic field, but the magnetic forces are radial to the planet in a line through the centre of the planet. The forces are not exactly equal and opposite as the planet will have a net positive charge. Any lack of balance of these forces will act to turn the axis of rotation, thus giving an explanation why the axes of spin of the planets are generally tilted, the axis of Uranus being on its side, and the axis of Venus being completely inverted so that its rotation is retrograde to most of the other planets.

However, the magnetic mechanism requires an extremely large magnetic field at the surface of the sun necessary for capture of a planet into a circular orbit. The calculations of Fig. 2 for a mass equal to that of the earth ejected from the surface of the sun at 600 km/s, close to the escape velocity on the sun of 617 km/s, with plasma potentials of the sun and the earth of 1 kV, requires a magnetic field at the surface of the sun of $1.92\times10^{22}$ T.

The magnetic fields for planetary capture are dependent on the plasma potentials and the radii of the planet and sun. For a plasma potential of 100 MV instead of 1 kV, and increased radii of the earth and sun by a factor of 100 due, for example to complete vaporisation of the earth, the required magnetic field for capture of an earth mass is reduced to $10^{11}$ T, which are the magnetic fields and potentials believed to be present in neutron stars called "Soft Gamma-Ray Repeaters" [7].

## 5. Summary

The present paper indicates that very large magnetic fields and potentials of the sun could provide a plasma mechanism for the formation of planets, explaining regular features of the solar system that the major planets all rotate around the sun in the same direction, have orbits that are closely circular rather than elliptical, and are all closely in the same plane. The mechanism also provides explanations for the formation of planetary spin, why axes of spin can be tilted, and the lack of angular momentum in the sun. But the magnetic fields that are required are extraordinarily large, being generally greater than those of neutron stars.

## 6. References

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