A study of the relationship between comets and solar activity

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Abstract. It is suggested that some comets originated from solar activity and were ejected by the sun in late period. In order to verify this point of view, the new star ejected from the sun’s surface is regarded as a particle, and the orbital evolution problem is simplified to the problem of a particle moving around a sphere, whose motion is disturbed by the asteroid belt and planets. By analyzing the influence of gravity, Coriolis force and viscous force on the trajectory of the new star, the trajectory of the new star is obtained. The results show that the orbits of small objects ejected from the surface of the sun are very similar to those of comets, which also explain the rotation of comets along the direction of the sun’s rotation, etc., indicating the physical rationality of the comet hypothesis.

1. The introduction

The question of whether the origin of comets is closely related to the formation of stars and planets, or whether they formed in dense regions of interstellar space, is one of the oldest unsolved astronomical questions[1]. In order to study the formation mechanism of comets, many theories on the origin of comets have been proposed and a lot of work has been done on the basis of observation. The most widely accepted hypothesis is that comets were born in the Oort Cloud, proposed in 1950[2]. However, recent observations have found that comets contain minerals that form at extremely high temperatures, which cannot be explained by the Oort Cloud hypothesis[3]. In 1982, Zhongwei Hu[4] et al. proposed that most of the planetesimals from the Jupiter region to Neptune formed large planets, while a small part of the remaining coma became comets; In 2001, due to the observation of crystalline olivine on comets, Kevin D.McKeegan[5] et al. proposed that comets were formed and thrown out by the dynamic interaction between the protostar and its disk accretion. But so far, these explanations are not convincing enough, and the origin of comets has yet to be explained.

Combined with the solar wind, strong activity on the surface of the sun and the presence of many more impact craters on the surface of Mercury than on other planets, this paper proposes a different view on the origin of comets: in the early days, the sun was more active, and may have ejected lumps of hot material, which formed small stars in space. These small bodies are affected by the sun, the planets and the asteroid belt, etc., their orbits gradually become elliptical, forming comets.
2. Force analysis of comet evolution

2.1. Solar jets and gravitational effects
According to the Oort Nebula hypothesis, the primordial comets were mainly concentrated in the proto-comet cloud region, which was about 20 to 100,000 astronomical units away from the Sun. Due to the perturbed motion of nearby stars, a very small number of proto-comet comets entered the region of the planets to form comets. But that doesn’t explain why Mercury has so many craters on its surface. Because if comets came from the procometary cloud region, then outer planets like Neptune should have the highest density of impact craters. For this evolution process, this paper proposes a different view: the sun may have ejected large chunks of hot material in the early stage, forming some small stars, these stars by the sun, planets and asteroid belts, etc., their orbits gradually become elliptical, forming comets.

Firstly, the initial normal velocity of the solar ejecting new stars should be greater than the rotational speed, and secondly less than the velocity parameter of the solar wind. This is because the new star that formed the comet is small. If it is traveling at less than rotational speed, it will be attracted to the sun and hit it again. The solar wind is a stream of high-energy particles ejected by the sun. Compared with the small star, the particle stream has a lower mass and accelerates more when subjected to the same force. Therefore, the small star generally does not exceed the particle stream.

In the process of ejecting a new star, it is being pulled by a variety of objects, including the sun and planets. But for the solar system, the sun occupies 99.8 percent of the mass of the entire solar system, the mass of other planets is very small, can be ignored, only consider the gravitational effect of the sun. Therefore, when analyzing the motion of a new star, it can be regarded as a two-body problem in mechanics.

2.2. Asteroid belt disturbances
As the jet’s orbit evolves into an ellipse, it is perturbed by the asteroid belt and other planets, acting as a viscous force. Take the asteroid belt, for example, when a small star approaches the asteroid belt, the force it experiences is similar to viscous force. If the star is moving faster than the belt, it will be dragged by the belt. If the star is moving faster than the belt, there will be a pull on the belt, causing the star to accelerate. This viscous force is actually caused by the gravity of small stars in the asteroid belt, which is a component of the gravity of small stars.

2.3. Rotation of stellar accretion disk
The stellar accretion disk is a rotating system outside the sun composed of eight planets and asteroids. The diffuse material of the solar system revolves around the center, so the inertial forces need to be taken into account when considering the orbit formation of comets.

Consider two ways of supplying the inertial forces, uniform acceleration and uniform rotation. Since the uniformly accelerated motion of the stellar accretion disk provides the same inertial acceleration for each star, it cannot have an impact on the evolution of the comet orbit. Therefore, only the influence of uniform rotation on the comet orbit is considered here. Therefore, the inertial force provided by the uniformly rotating stellar accretion disk to the comet body is the Coriolis force.

2.4. Mathematical model with universal gravitation and viscous force and its solution
Since \( \vec{F}_g \) is the universal attraction of the sun on the comet in the two-body problem, it can be written according to the formula

\[
\vec{F}_g = -G \frac{M m}{r^3} \vec{r}
\]

(1)

Where G is the gravitational constant, and \( r \) is the distance between the jet star and the sun, which changes with the orbital movement of the new star.

The viscous force is the component of the universal gravity of a large number of small stars in the
comet when it moves in the asteroid belt. When the velocity of the comet is greater than that of the asteroid belt, the viscous force is the resistance. When the velocity of the comet body is less than that of the asteroid belt, its velocity is shown as a pulling force. It is assumed that the viscous force is proportional to the velocity difference between the comet and the asteroid belt. The viscous force of the ejecting comet can then be written as:

\[ \vec{F}_v = m\eta \nabla^2 \vec{v} \]  

Where, \( \eta \) is the viscosity coefficient

In the viscous force \( \nabla^2 \vec{v} \) represents the velocity difference between the cometary body and the asteroid belt. We can further express it in terms of differential velocities

\[ \vec{F}_v = m\eta (\vec{v}_k - \vec{v}) \]  

Where \( v_k \) is the speed of the asteroid belt.

According to the above \( \vec{F}_g \) universal gravitation formula and \( \vec{F}_v \) the viscous force formula of the asteroid belt on the comet body, the acceleration expression of the comet body can be obtained and the equation can be obtained by orthogonal decomposition of the coordinate axis:

\[ a_x = G \frac{M}{r^2} x + \eta \nabla (\vec{v}_x - \vec{v}) \]  

\[ a_y = G \frac{M}{r^2} y + \eta \nabla (\vec{v}_y - \vec{v}) \]  

The following is to estimate the viscosity coefficient from the perspective of particle collision:

During the movement of the particle in the asteroid belt, the star body will have elastic collision with the particle, giving (or taking away) part of the energy of the particle, that is:

\[ \frac{1}{2} M v_x^2 + \frac{1}{2} M v_y^2 = \frac{1}{2} M v_1^2 + \frac{1}{2} m v_2^2 \]  

Where, \( M \) is the example mass and \( m \) is the average mass of the star.

The energy difference before and after particle collision is:

\[ \Delta E = \frac{1}{2} M \left[ v^2 - v_1^2 \right] \]  

And because stars are distributed in space at a certain density, the energy gained (or lost) in the asteroid belt can be calculated by taking into account the length of the path traveled by the particle. This part of the impact energy is equivalent to the energy generated by the viscous force of the ejecting comet body mentioned above, so:

\[ n\Delta ES = n \frac{1}{2} M \left[ v^2 - v_1^2 \right] S = \vec{F}_v \cdot \vec{S} = m\eta \nabla^2 \vec{v} \cdot \vec{S} \]  

Where, \( n \) is the number density of stars in space, and \( S \) is the length of the path passed by particles. In this way, the path length \( S \) is eliminated, and the estimation formula of the viscosity coefficient can be obtained:

\[ \eta = \frac{nM \left[ v^2 - v_1^2 \right]}{2m\nabla^2 \vec{v}} \]  

2.5. Mathematical models including universal gravitation, viscous force and Coriolis force and their solutions

Think of the solar system as a rotating non-inertial system. The rotation of the accretion disk exerts
inertial forces -- Coriolis forces -- on the jet comet bodies. Generally speaking, the Coriolis force refers to the reference frame (inertial frame) of its own rotation like the earth. The object moving in a straight line will keep its original motion state due to its inertia. In the reference frame of its own rotation, it seems to be subjected to an external force that deviates from the direction of motion, which is the Coriolis force. Therefore, it can be expressed by the following formula:

$$F_c = -2m\omega \times \vec{v}$$ \hspace{1cm} (10)

Where $\omega$ is the angular velocity of the rotation of the solar system background.

Under the condition of accretion disk rotation, the universal gravitation, Coriolis force and viscous force equations of the comet body are given, and then the acceleration of the small star is orthogonal decomposed to obtain the equations, i.e.

$$a_x = G\frac{M_x}{r^2} - 2(\omega v)_x + \eta \times (\vec{v}_x - \vec{v}_c)$$ \hspace{1cm} (11)

$$a_y = G\frac{M_y}{r^2} - 2(\omega v)_y + \eta \times (\vec{v}_y - \vec{v}_c)$$ \hspace{1cm} (12)

To sum up, the ejecting comet is subject to universal gravitation, viscous force and inertial force (Coriolis force) in the process of motion, so the resultant force on the ejecting comet can be expressed as

$$\vec{F} = \vec{F}_g + \vec{F}_v + \vec{F}_c$$ \hspace{1cm} (13)

Among them, $\vec{F}_g$ is the universal gravitation of the sun by the comet body, $\vec{F}_v$ is the viscous force of the asteroid belt by the comet body, $\vec{F}_c$ is the Coriolis force by the comet body.

3. Simulation and analysis of comet evolution trajectory

3.1. Numerical simulation and calculation results

In order to simulate the orbital change of the comet subjected to the universal gravitation and viscous force, this paper substituted the real data of the initial conditions into, by consulting the data, the angular velocity and radius of the sun’s rotation are $\omega = 2.97 \times 10^6$ rad/s, $R = 6.95 \times 10^8$ m. Since the range of $v_0$ is limited above, that is, between the speed of the solar wind and the speed of the solar wind, that is, $1 < \frac{v_0}{R\omega} < 645$ (the speed of the solar wind is between 300 and 500km/s, which is 645 to 1075 times the speed of the sun). In this range, we traverse the values of $v_0$ to find the $v_0$ that can change the motion of the jet comet body into an elliptical motion around the sun. And it turns out that at $v_{x0} = 282.25R\omega$, $v_{y0} = 22.3R\omega$ (That’s 283.13 times the speed of the sun), the orbit of the comet subject to the universal gravity and viscous force becomes elliptical. The movement trajectory of the comet was obtained by solving the differential equation in Matlab, as shown in Figure 1.
Fig. 1: Particle trajectories of gravitational and viscous forces at $\vec{v} = (282.25 R_w, 22.3 R_w), \vec{F} = (0, R)$

In Figure 1, the red line is the location of the asteroid belt (the asteroid belt is 30AU from the Sun). Comets are affected by viscous forces that fine-tune their orbits every time they complete an orbital cycle.

Through the above simulation analysis, it is concluded that the orbital change of the comet body after ejecting from the sun is caused by the viscous force of the asteroid belt at a long distance. The orbit of the new body is also similar to the elliptical orbit of a comet, with its orbit slowly expanding outward.

Fig. 2: Particle trajectories of gravity, viscous forces and Coriolis forces at $\vec{v} = (282.25 R_w, 22.3 R_w), \vec{F} = (0, R)$

In order to simulate the universal gravitation, viscous force and Coriolis force of the comet, as above, the initial conditions were substituted into the comet orbit simulation equation. Taking 10s as the iteration step and 126.84 years as the iteration time, the results were obtained as shown in Fig. 2.

In the process of numerical simulation above, it can be concluded that under the action of the three forces, the new star still rotates around the sun in an elliptical shape, and its rotation period is 112.75 years, which is similar to the rotation period of the known short-period comet.

3.2. Result analysis and inference

One, through calculation, the sun material under the action of the original accretion disk, evolved into a comet eccentricity larger motion around the sun, which indicates that the comet can form in the injection material, also explains the most comets to the same direction and the direction of the sun’s rotation, comets orbit Angle to the sun the planets orbit plane Angle is not big, etc. These phenomena. This suggests the possibility that comets evolved from solar ejections. Otherwise, if the comet is interstellar
material formed by the gravitational pull of the sun, the rotation direction and the angle between the orbital plane should have an equal probability distribution.

Second, the comets' orbits evolved towards the circle under the disturbance of the accretion disk, that is, the comets gradually evolved into the asteroids and other planets' orbits, thus making the stellar accretion disk grow stronger. These materials should have played an important role in the evolution of the planets in the very early solar system.

Thirdly, on the basis of the above conclusions, there are two important conclusions as follows:

1. Planets are likely to be important products of stellar material evolution, which is the result of the long tail effect of solar ejections. Which is a decreasing eccentricity of the material that the sun ejects out, and the material clumps together to form planets. In other words, planetary systems should be common around stars, as stars evolve to produce planets around them even without the help of interstellar matter.

2. Various elements, inorganic matter, water and simple organic matter on the original planet should all be produced in the process of solar jet, that is, solar nuclear reaction is the basic source of the original material on the planet.

4. The conclusion

In this paper, the physical mechanism of the new star motion is firstly analyzed, and then the orbital evolution model of the new star subjected to universal gravitation, Coriolis force and viscous force is established. Numerical simulation by MATLAB found new stars trajectory is similar to the comet orbits the sun, and comets originated in view of the sun itself helps to explain why a large number of meteorite craters on mercury and comet has high temperature to form ore material, these all indicate that some comets originated in solar activity view in physics has rationality, at the same time, it shows that even without the participation of interstellar matter, because of the long tail ejected material, stars will be through their own evolution form the rest of the stars within them.

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