Approach to Calculate the Sunspot Cycle: 10.38 years

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Abstract: Relativistic matter wave was rewritten in terms of ultimate acceleration. If there is an ultimate acceleration $\beta$, nobody’s acceleration can exceed this limit $\beta$, in the solar system, $\beta=2.961520e+10$ (m/s$^2$). Because this ultimate acceleration is a large number, any quantum effect connecting to $\beta$ will become easy to test, including quantum gravity test. In this paper, the relativistic matter wave in gravity with the ultimate acceleration establishes an approach which shows that the sunspot cycle is mainly determined by the ultimate acceleration $\beta$. As an application, the sunspot cycle is calculated out to be 10.38 years, the result agrees well with the experimental observation. Using the same approach, the radius of the Sun is calculated out to be $r=7e+8$ (m) with a relative error 0.72%; the radius of the Earth is calculated out to be $r=6.4328e+6$ (m) with a relative error 0.97%.

1. Introduction

In 1843, German pharmacist H.S. Schwabe found that the growth and decline of sunspots had a period of about 10 years through his own observation records of sunspots for more than 20 years. In 1848, J.R. Wolf calculated the monthly sunspot relative number to 1749, thus affirming that the average cycle length of sunspot activity was 11.1 years. In 2019, there are 288 days without sunspots, and 40 consecutive days ahead. On December 25, 2019, two new sunspots appeared in the southern hemisphere of the sun, indicating the arrival of the 25th sunspot cycle, which is expected to reach its peak in July 2025. Although it is known that the cycle of sunspot activity is about 11 years, what drives this non-stop pattern is still a mystery.

In general, some quantum gravity proposals [1,2] are extremely hard to test in practice, as quantum gravitational effects are appreciable only at the Planck scale [3]. In the present paper, relativistic matter wave was rewritten in terms of ultimate acceleration. If there is an ultimate acceleration $\beta$, nobody’s acceleration can exceed this limit $\beta$, in the solar system, $\beta=2.961520e+10$ (m/s$^2$). Because this ultimate acceleration is a large number, any quantum effect connecting to $\beta$ will become easy to test, including quantum gravity test. It was found that ultimate acceleration can enhance the quantum gravity effects for test. In this paper, the relativistic matter wave in gravity with the ultimate acceleration establishes an approach which shows that the sunspot cycle is mainly determined by the ultimate acceleration $\beta$. As an application, the sunspot cycle is calculated out to be 10.38 years, the result agrees well with the experimental observation.

2. How to connect the ultimate acceleration with quantum theory

In the relativity, the speed of light $c$ is an ultimate speed, nobody's speed can exceed this limit $c$. 

1
The relativistic velocity \( u \) of a particle in the coordinate system \( (x_1,x_2,x_3,x_4=ict) \) satisfies
\[
\frac{\dot{u}_1^2 + \dot{u}_2^2 + \dot{u}_3^2 + \dot{u}_4^2}{c^2} = -1.
\] (1)

No matter what particles (electrons, molecules, neutrons, quarks), their 4-vector velocities all have the same magnitude: \( |u|=ic \). All particles gain equality because of the same magnitude of their 4-velocity \( u \). The acceleration \( a \) of a particle is given by
\[
a_1^2 + a_2^2 + a_3^2 + a_4^2 = a^2; \quad (a_4 = 0; \quad x_4 = ict)
\] (2)

Assume that particles have an ultimate acceleration \( \beta \) as limit, no particle can exceed this acceleration limit \( \beta \). Subtracting the both sides of the above equation by \( \beta^2 \), we have
\[
a_1^2 + a_2^2 + a_3^2 - \beta^2 = a^2 - \beta^2; \quad a_4 = 0
\] (3)

It can be rewritten as
\[
\left[ a_1^2 + a_2^2 + a_3^2 + 0 + (i\beta)^2 \right] \frac{1}{1-a^2/\beta^2} = -\beta^2
\] (4)

Now, the particle subjects to an acceleration whose five components are specified by
\[
\alpha_1 = \frac{a_1}{\sqrt{1-a^2/\beta^2}}; \quad \alpha_2 = \frac{a_2}{\sqrt{1-a^2/\beta^2}}; \\
\alpha_3 = \frac{a_3}{\sqrt{1-a^2/\beta^2}}; \quad \alpha_4 = 0; \quad \alpha_5 = \frac{i\beta}{\sqrt{1-a^2/\beta^2}};
\] (5)

where \( \alpha_5 \) is the newly defined acceleration in five dimensional space-time \( (x_1,x_2,x_3,x_4,x_5) \). Thus, we have
\[
\alpha_1^2 + \alpha_2^2 + \alpha_3^2 + \alpha_4^2 + \alpha_5^2 = -\beta^2; \quad \alpha_4 = 0
\] (6)

It means that the magnitude of the newly defined acceleration \( \alpha \) for every particle takes the same value: \( |\alpha|=i\beta \) (constant imaginary number), all particle accelerations gain equality for the sake of the same magnitude.

How to resolve the velocity \( u \) and acceleration \( \alpha \) into \( x, y, \) and \( z \) components? In realistic world, a hand can rotate a ball moving around a circular path at constant speed \( v \) with constant centripetal acceleration \( a \), as shown in Fig.1(a).
In analogy with the ball in a circular path, consider a particle in one dimensional motion along the $x_I$ axis at the speed $v$, in the Fig.1(b) it moves with the constant speed $|u|=ic$ almost along the $x_I$ axis and slightly along the $x_I$ axis, and the constant centripetal acceleration $|\alpha|=|\beta|$ in the $x_S$ axis at the constant radius $iR$ (imaginary number); the coordinate system $(x_I,x_S=ict,x_5=iR)$ establishes a cylinder coordinate system in which this particle moves spirally at the speed $v$ along the $x_I$ axis. According to usual centripetal acceleration formula $a=v^2/r$, the acceleration in the $x_I-x_5$ plane is given by

$$a = \frac{v^2}{r} \Rightarrow i\beta = \frac{|u|^2}{iR} = \frac{c^2}{iR} = \frac{c^2}{R} .$$

Therefore, the track of the particle in the cylinder coordinate system $(x_I,x_S=ict,x_5=iR)$ forms a shape, called as acceleration-roll. The faster the particle moves, the longer the spiral step is.

As like a steel spring which contains elastic wave, the track in the acceleration-roll in Fig.1(b) can be described by a wave function whose phase changes $2\pi$ for one spiral step. The wave function phase changes $2\pi$ for one spiral circumference $2\pi(iR)$, then the small displacement of the particle on the spiral track is $|u|d\tau=icd\tau$ in the 4-vector $u$ direction, thus this wave phase along the spiral track is given by

$$phase = \int_0^\tau \frac{2\pi}{2\pi(iR)} icd\tau = \int_0^\tau \frac{c}{R} d\tau .$$

Substituting the radius $R$ into it, the wave function $\psi$ is given by

$$\psi = \exp(-i \cdot phase) = \exp(-i \int_0^\tau \frac{c}{R} d\tau) = \exp(-i \frac{\beta}{c} \int_0^\tau d\tau) .$$

In the theory of relativity, we known that the integral along $d\tau$ needs to transform into realistic line integral, that is

$$d\tau = \frac{c^2}{c^2} d\tau = (u_1^2 + u_2^2 + u_3^2 + u_4^2) \frac{d\tau}{c^2} .$$

Therefore, the wave function $\psi$ is evaluated by

$$\psi = \exp(-i \frac{\beta}{c} \int_0^\tau d\tau) = \exp(i \frac{\beta}{c} \int_0^\tau (u_1dx_1 + u_2dx_2 + u_3dx_3 + u_4dx_4)) .$$
This wave function may have different explanations, depending on the particle under investigation. If the $\beta$ is replaced by the Planck constant, the wave function of electrons is given by

$$\psi = \exp \left( \frac{i}{\hbar} \int_0^x (\mu_t dx_i + \mu_x dx x_2 + \mu_y dx x_3 + \mu_z dx x_4) \right)$$

where $\mu_t dx_x = -Edt$, it strongly suggests that the wave function is just the de Broglie’s matter wave [4,5,6]. In Fig.1(b), the acceleration-roll of particle moves with two distinctions: right-hand chirality and left-hand chirality. The direction of the angular momentum $J$ would be slightly different from the $x_1$ due to spiral precession. It is easy to calculate the ultimate acceleration $\beta$, the radius $R$ and the angular momentum $J$ in the plane $x_1-x_5$ for a spiraling electron as

$$\beta = \frac{c^3 m}{\hbar} = 2.327421e+29 \text{ (M/s}^2\text{)}$$

$$R = \frac{c^2}{\beta} = 3.861593e-13 \text{ (M)}$$

$$J = \pm |u| iR = \mp \hbar$$

Considering planets in the solar system, no Planck constant can be involved. But, in a many-body system with the total mass $M$, data-analysis (in the next section) tells us that the ultimate acceleration can be rewritten in terms of Planck-constant-like constant $\hbar$ as

$$\psi = \exp \left( \frac{i}{\hbar M} \int_0^x (u_1 dx_1 + u_2 dx_2 + u_3 dx_3 + u_4 dx_4) \right)$$

The constant $\hbar$ will be determined by experimental observations. In next section we shall try to use this wave function as the planetary scale waves in the solar system to explain quantum gravity effects for the planets and satellites, the wave function represents the relativistic matter wave generalized in gravity, called as the acceleration-roll wave.

Tip: actually, ones cannot get to see the acceleration-roll of particle in the relativistic spacetime ($x_1,x_2,x_3,x_4=ict$); only get to see it in the cylinder coordinate system ($x_1,x_4=ict,x_5=iR$).[28]

3. The relativistic matter wave in planetary scale

In the Bohr’s orbit model for planets or satellites, as shown in Fig.2, the circular quantization condition is given in terms of relativistic matter wave in gravity by
\[
\frac{\beta}{c^3} \int_L v_L dl = 2\pi n \\
\Rightarrow \sqrt{r} = \frac{c^3}{\beta GM} n; \quad n = 0, 1, 2, \ldots 
\] (15)

Fig. 2 A planet 2D orbit around the sun, an acceleration-roll winding around the planet.

The solar system, Jupiter's satellites, Saturn's satellites, Uranus' satellites, Neptune's satellites as five different many-body systems are investigated with the Bohr's orbit model. After fitting observational data as shown in Fig.3, their ultimate accelerations are obtained in Table 1. The predicted quantization-blue-lines in Fig.3(a), Fig.3(b), Fig.3(c), Fig.3(d) and Fig.3(e) agree well with experimental observations for those inner constituent planets or satellites.
The orbital radii are quantized for inner constituents. (a) the solar system with $h = 4.574635 \times 10^{-16} \text{ m}^2\text{s}^{-1}\text{kg}^{-1}$). The relative error is less than 3.9%. (b) the Jupiter system with $h = 3.531903 \times 10^{-16} \text{ m}^2\text{s}^{-1}\text{kg}^{-1}$). Metis and Adrastea are assigned the same quantum number for their almost same radius. The relative error is less than 1.9%. (c) the Saturn system with $h = 6.610920 \times 10^{-16} \text{ m}^2\text{s}^{-1}\text{kg}^{-1}$). The relative error is less than 1.1%. (d) the Uranus system with $h = 1.567124 \times 10^{-16} \text{ m}^2\text{s}^{-1}\text{kg}^{-1}$). $n=0$ is assigned to the Uranus. The relative error is less than 2.5%. (e) the Neptune system with $h = 1.277170 \times 10^{-16} \text{ m}^2\text{s}^{-1}\text{kg}^{-1}$). $n=0$ is assigned to the Neptune. The relative error is less than 0.17%.

Table 1  Planck-constant-like constant $h$, $N$ is constituent particle number with smaller inclination.

<table>
<thead>
<tr>
<th>system</th>
<th>$N$</th>
<th>$M/M_{\text{Earth}}$</th>
<th>$\beta$ (m/s)</th>
<th>$h$ (m$^2$/kg$^{-1}$)</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar planets</td>
<td>9</td>
<td>333000</td>
<td>2.961520e+10</td>
<td>4.574635e-16</td>
<td>Fig.3(a)</td>
</tr>
<tr>
<td>Jupiter's satellites</td>
<td>7</td>
<td>318</td>
<td>4.016793e+13</td>
<td>3.531903e-16</td>
<td>Fig.3(b)</td>
</tr>
<tr>
<td>Saturn's satellites</td>
<td>7</td>
<td>95</td>
<td>7.183397e+13</td>
<td>6.610920e-16</td>
<td>Fig.3(c)</td>
</tr>
<tr>
<td>Uranus's satellites</td>
<td>18</td>
<td>14.5</td>
<td>1.985382e+15</td>
<td>1.567124e-16</td>
<td>Fig.3(d)</td>
</tr>
<tr>
<td>Neptune's satellites</td>
<td>7</td>
<td>17</td>
<td>2.077868e+15</td>
<td>1.277170e-16</td>
<td>Fig.3(e)</td>
</tr>
</tbody>
</table>

Besides every $\beta$, our interest shifts to the constant $h$ in Table 1, which is defined as

$$h = \frac{c^3}{M \beta} \Rightarrow \sqrt{r} = h \sqrt{\frac{M}{G^n}}.$$

In a many-body system with the total mass $M$, a constituent particle has the mass $m$ and moves at
the speed $v$, it is easy to find that the wavelength of de Broglie's matter wave should be modified for planets and satellites as

$$\lambda_{\text{de-Broglie}} = \frac{2\pi \hbar}{mv} \Rightarrow \text{modify} \Rightarrow \lambda = \frac{2\pi \hbar M}{v}. \quad (17)$$

where $\hbar$ is a Planck-constant-like constant. Usually the total mass $M$ is approximately equal to the central-star's mass. It is found that this modified matter wave works for quantizing orbits correctly in Fig.3 [28,29]. The key point is that the various systems have almost same Planck-constant-like constant $\hbar$ in Table 1 with a mean value of $3.51\times10^{-16}$ m$^2$s$^{-1}$kg$^{-1}$, at least have the same magnitude! The acceleration-roll wave is a generalized matter wave as a planetary scale wave.

In Fig.3(a), the blue straight line expresses the linear regression relation among the Sun, Mercury, Venus, Earth and Mars, their quantization parameters are $\hbar M=9.098031\times10^{14}$m$^2$s. The ultimate acceleration is fitted out to be $\beta=2.961520\times10^{10}$ (m/s$^2$). Where, $n=3,4,5,..$ were assigned to solar planets, the sun was assigned a quantum number $n=0$ because the sun is in the central state.

4. Optical model of the central state

The acceleration-roll wave as the relativistic matter wave generalized in gravity is given by

$$\psi = \exp\left(\frac{i}{\hbar M} \int_0^s v_j dl\right); \quad \lambda = \frac{2\pi \hbar M}{v_j}. \quad (18)$$

In a central state $n=0$, if the coherent length of the acceleration-roll wave is long enough, its head may overlap with its tail when the particle moves in a closed orbit in the space time, as shown in Fig.4, the interference of the acceleration-roll wave between its head and tail will occur in the overlapping zone. The overlapped wave is given by

$$\psi(r) = 1 + e^{i\delta} + e^{i2\delta} + ... + e^{i(N-1)\delta} = \frac{1-\exp(iN\delta)}{1-\exp(i\delta)}. \quad (19)$$

where $N$ is the overlapping number which is determined by the coherent length of the acceleration-roll wave, $\delta$ is the phase difference after one orbital motion, $\omega$ is the angular speed of the sun rotation. The above equation is a multi-slit interference formula in optics, for a larger $N$ it is called as the Fabry-Perot interference formula.

![Fig.4](image.png) The head of the acceleration-roll wave may overlap with its tail.
The acceleration-roll wave function $\psi$ needs a further explanation. In quantum mechanics, $|\psi|^2$ equals to the probability of finding an electron due to Max Burn’s explanation; in astrophysics, $|\psi|^2$ equals to the probability of finding a nucleon (proton or neutron) *averagely in astronomic scale*, because all mass is mainly made of nucleons, we have

$$|\psi|^2 \propto \text{nucleon\_density}.$$  \hspace{1cm} (20)

It follows from the multi-slit interference formula that the interference intensity at maxima is proportional to $N^2$, that is

$$N^2 = \left| \frac{\psi(0)_{\text{multi-wavelet}}}{\psi(0)_{\text{one-wavelet}}} \right|^2.$$  \hspace{1cm} (21)

What matter plays the role of “one-wavelet” in the solar core or Earth core? We choose vapor above the sea on the earth surface as the “reference matter: one-wavelet”. Thus, the overlapping number $N$ is estimated by

$$N^2 = \left| \frac{\psi(0)_{\text{multi-wavelet}}}{\psi(0)_{\text{one-wavelet}}} \right|^2 \approx \frac{\text{core\_nucleon\_density}_{n=0}}{\text{vapor\_above\_sea\_density}}.$$  \hspace{1cm} (22)

Although today there is not vapor on the solar surface, the solar core has a maximum density of $1.5e+5\text{kg/m}^3$ [31], comparing to the vapor density $1.29 \text{ kg/m}^3$ on the earth, the solar overlapping number $N$ is estimated as $N=341$. The Earth core density is $5.53e+3\text{kg/m}^3$, the Earth’s overlapping number $N$ is estimated as $N=65$.

For the Sun, Earth and Mars, their central densities and their reference matter density are given in the Table 2. Thus, their overlapping numbers are estimated also in this table.

**Table 2** Estimating the overlapping number $N$ by comparing solid core and reference matter, regarding protons and neutrons as basis particles.

<table>
<thead>
<tr>
<th>object</th>
<th>Solid core, density (kg/m$^3$)</th>
<th>Reference matter, density (kg/m$^3$)</th>
<th>Overlapping number $N$</th>
<th>$\beta$ (m/s$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>$1.5e+5$ (max.)</td>
<td>$1.29$ (vapor above the sea)</td>
<td>341</td>
<td>$2.961520e+10$</td>
</tr>
<tr>
<td>Earth</td>
<td>5530</td>
<td>$1.29$ (vapor above the sea)</td>
<td>65</td>
<td>$1.377075e+14$</td>
</tr>
<tr>
<td>Mars</td>
<td>3933.5</td>
<td>$1.29$ (vapor above the sea)</td>
<td>55</td>
<td>$2.581555e+15$</td>
</tr>
<tr>
<td>Jupiter</td>
<td>1326</td>
<td></td>
<td></td>
<td>$4.016793e+13$</td>
</tr>
<tr>
<td>Saturn</td>
<td>687</td>
<td></td>
<td></td>
<td>$7.183397e+13$</td>
</tr>
<tr>
<td>Uranus</td>
<td>1270</td>
<td></td>
<td></td>
<td>$1.985382e+15$</td>
</tr>
<tr>
<td>Neptune</td>
<td>1638</td>
<td></td>
<td></td>
<td>$2.077868e+15$</td>
</tr>
<tr>
<td>Alien-planet</td>
<td>5500</td>
<td>$1.29$ (has water on the surface)</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>

Sun’s rotation angular speed at the equator is known as $\omega=2\pi/(25.05*24*3600)$, unit s$^{-1}$. Its mass $1.9891e+30$ (kg), radius $6.95e+8$ (m), mean density $1408$ (kg/m$^3$), the solar core has a maximum density of $1.5e+5\text{kg/m}^3$ [31], the ultimate acceleration $\beta=2.961520e+10$ (m/s$^2$), the constant $hM=9.100745e+14$ (m$^2$/s). According to the $N=341$, the matter distribution of the $|\psi|^2$ is calculated out in Fig.5, it agrees well with the general description of the sun’s interior. The radius of the Sun is calculated out to be $r=7e+8$ (m) with a relative error $0.72\%$ in the Fig.5, it indicates that the sun radius strongly depends on the sun self-rotation.
The matter distribution $|\psi|^2$ around the Sun has been calculated in radius direction. 

5. Earth central state and space debris distribution

Applying the acceleration-roll wav to the Moon, as illustrated in Fig.6(a), the Moon has been assigned a quantum number of $n=2$ in author’s early study [28]. According to Eq.(15), the ultimate acceleration is fitted out to be $\beta=1.377075e+14$ (m/s$^2$) in the Earth system. Another consideration is to take the quasi-satellite's perigee into account, for the moon and 2004_GU9 etc., as shown in Fig.6(b), but this consideration requires further understanding to its five quasi-satellites [28].
int main() { N=2; M=5.97237E24; r_unit=1.495978707e8; for(i=0;i<N;i+=1) {x=orbit[i]; y=e[i]; z=x*(1+sqrt(1-y*y))/2;r_ave[i]=z;//average_radius D[i+i]=qn[i]; D[i+i+1]=sqrt(z); } DataJob("REGRESSION,2",D,dP); b=dP[0]; a=dP[1]; SetAxis(X_AXIS,0,0,3,"n;0;1;2;3;"); SetAxis(Y_AXIS,0,0,3," #if#rsr#t (average radius unit:0.001AU);0;1;2;3;"> SetPen(2,0xff0000); Plot("OV ALFILL,0,2,XY ,3,3,",D); for(i=0;i<N;i+=1) {nP[0]=TAKE;nP[1]=i;TextJob(nP,Stars,str); x=qn[i]+0.2;y=sqrt(orbit[i]) - 0.05; TextHang(x,y,0,str); } x=GRAVITYC*M*r_unit;z=sqrt(x); H=z*a; B = -z*b; TextAt(100,450,"#ifH#t=%e  #ifB#t=%e",H,B); for(i=0;i<N;i+=1) { y=b+a*qn[i]; D[i+i]=qn[i]; D[i+i+1]=y; } SetPen(1,0x0000ff); Polyline(N,D,0.5,2.2,"quantization");//check }}

Now let us talk about the central state of the earth, the earth’s rotation angular speed is known as \(\omega = 2\pi/(24 \times 3600)\), unit s\(^{-1}\). Its mass 5.97237e+24(kg), radius 6.371e+6(m), core density 5530(kg/m\(^3\)), the ultimate acceleration \(\beta = 1.377075e+14\)(m/s\(^2\)), the constant \(hM = 1.956611e+11\)(m\(^2\)/s).

We have estimated that the wave overlapping number in the central state of the earth is \(N=65\), the matter distribution \(|\psi|^2\) in radius direction is calculated out as shown in Fig.7(a), where the self-rotation near its equator has the period of 24 hours:

\[
\delta(r) = \frac{1}{hM} \int_L (v_j) dl = \frac{2\pi r}{hM} \omega r .
\]

There is a central maximum of matter distribution at the earth heart, which gradually decreases to zero near the earth surface, then rises the secondary peaks and attenuates down off. The radius of the earth is calculated out to be \(r = 6.4328e+6\) (m) with a relative error 0.97% using the interference of its acceleration-roll wave. Space debris over the atmosphere has a complicated evolution [7,8], has itself speed

\[
v_j = \sqrt{\frac{GM}{r}} ;\quad \delta(r) = \frac{1}{hM} \int_L (v_j) dl = \frac{\beta}{c^3} \int_L (v_j) dl = \frac{2\pi \beta}{c^3} \sqrt{GMr} .
\]

The secondary peaks over the atmosphere up to 2000km altitude is calculated out in Fig.7(b) which agrees well with the space debris observations [16]; the peak near 890 km altitude is due principally to the January 2007 intentional destruction of the Fengyun-1C weather spacecraft while the peak centered at approximately 770 km altitude was created by the February 2009 accidental collision of Iridium 33 (active) and Cosmos 2251 (derelict) communication spacecraft [16,18]. The observations based on the incoherent scattering radar EISCAT ESR located at 78°N in Jul. 2006 and in Oct. 2015 [21,22,23] are respectively shown in Fig.7(c) and (d). This prediction to secondary peaks also agrees well with other space debris observations [24,25].
6. Mars and Jovian planets

The Mars and its satellites are quantized very well by its ultimate acceleration $\beta$ as shown in Fig.8(a). Now let us talk about the Mars in the central state with quantum number $n=0$, its ultimate acceleration is $\beta=2.581555\times10^{15}$ (m/s$^2$) in the Mars system. We have estimated the Mars overlapping number $N=55$ in Table 2, the matter distribution $|\psi|^2$ around the Mars can be calculated out in radius direction as shown in Fig.8(b), where the self-rotation at equator has the period of 24 hours.

The radius of the Mars is calculated out as $r=1.6\times10^6$ (m) with a relative error 52.79%, no further attempt was made to improve the calculation, because of limited knowledge about the Mars history.

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**Fig.7** (a) The radius of the Earth is calculated out $r=6.4328\times10^6$ (m) with a relative error 0.97% by the interference of its acceleration-roll wave; (b) The prediction of the space debris distribution up to 2000km altitude; (c) The pace debris distribution in Jul. 2006, Joint observation based on the incoherent scattering radar EISCAT ESR located at 78°N [21]; (d) The space debris distribution in Oct. 2015, Joint observation based on the incoherent scattering radar EISCAT ESR located at 78°N [21].
But one thing is certain, the Mars has frequently bombarded with smaller objects, in fact, consequently with the inclination of 25.2 degrees, so that its self-rotation is unstable or incorrect for its formation in a sense. At very beginning, the Mars self-rotation should have a period of 100 hours.

Thanks to the Mars for safeguarding the Earth.

In order to extend the quantization rule to the Jovian planets (Jupiter, Saturn, Uranus and Neptune), it is necessary to further study the magnet-like components of gravity [28], the issue beyond the scope of this paper.

7. Sunspot cycle

In the solar convective zone, adjacent convective arrays form a top-layer flow, a middle-layer gas and a ground-layer reverse flow, (like the concept of molecular current in electromagnetism). Considering one convective ring at the equator as shown in Fig.9, there is an apparent velocity difference between the top-layer flow and the middle-layer gas, where their acceleration-roll waves are denoted respectively by

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Fig. 9 One convective ring at the equator, the speed difference causes a beat frequency.

Their wave interference leads to a beat phenomenon

$$|\psi|^2 = |\psi_{\text{middle}} + \psi_{\text{top}}|^2 = 2 + 2 \cos \left[ \frac{2 \pi}{\lambda_{\text{beat}}} \int_L dl - \frac{2 \pi}{T_{\text{beat}}} t \right]$$

$$\frac{2 \pi}{T_{\text{beat}}} = \frac{\beta}{c^3} \left( \frac{c^2}{1 - v_{\text{top}}^2 / c^2} - \frac{c^2}{1 - v_{\text{middle}}^2 / c^2} \right) = \frac{\beta}{c^3} \left( \frac{v_{\text{top}}^2 - v_{\text{middle}}^2}{2} \right).$$

Their speeds are calculated by

$$v_1 = \omega_{\text{middle}} = 2017 \text{ (m/s)} \quad \text{(sun rotation)};$$

$$v_2 \approx 6200 \text{ (m/s)} \quad \text{(≈ observed in Evershed flow)}$$

There are three ways to estimate the top-layer flow speed $v_2$. (1) regarding the Evershed flow as the eruption of the top-layer flow, about 6km/s speed was reported [31]. (2) regarding the prominences as the eruption of the top-layer flow; the prominence turbulent speeds are reported [31] in the range 2-10km/s. (3) Alternatively, since the thermal equilibrium gas in a convective zone supplies the flow speed $v_2$, where the temperature $T=5700^\circ \text{K}$, the flow consists of 73.46% hydrogen atoms and 24.85% helium atoms; these atoms are approximately regarded as in 1D circular flow: $mv^2/2 = kT/2$. Thus,
the top-layer speed \( v_2 \) can be estimated out by

\[
v_2 \approx 0.7346 \sqrt{\frac{kT}{m_{\text{hydrogen}}}} + 0.2485 \sqrt{\frac{kT}{m_{\text{helium}}}}.
\]

\( = 6244 \text{ (m/s)} \) (28)

Their beat period \( T_{\text{beat}} \) is calculated out to be a very remarkable value 10.38 (years), in agreement with the sunspot period value (say, mean 11 years).

\[
T_{\text{beat}} = \frac{4\pi c^3}{\beta (v_2^2 - v_1^2)} = 10.38 \text{ (years)}.
\]

The relative error to the mean 11 years is 5.6% for the beat period calculation using the acceleration-roll waves. This beat turns out to be a density wave that undergoes to drive the sunspot evolution. Comparing to the beat wavelength \( \lambda_{\text{beats}} \) in order of magnitude, only the beat period is easy to be observed.

In the above calculation, although this seems to be a rough model, there is an obvious correlation between solar radius, solar rotation, solar density, ultimate acceleration and Planck-constant-like constant \( h \).

8. Conclusions

In the present paper, relativistic matter wave was rewritten in terms of ultimate acceleration. If there is an ultimate acceleration \( \beta \), nobody’s acceleration can exceed this limit \( \beta \) in the solar system, \( \beta = 2.961520e+10 \text{(m/s^2)} \). Because this ultimate acceleration is a large number, any quantum effect connecting to \( \beta \) will become easy to test, including quantum gravity test. It was found that ultimate acceleration can enhance the quantum gravity effects for test. In this paper, the relativistic matter wave in gravity with the ultimate acceleration establishes an approach which shows that the sunspot cycle is mainly determined by the ultimate acceleration \( \beta \). As an application, the sunspot cycle is calculated out to be 10.38 years, the result agrees well with the experimental observation. Using the same approach, the radius of the Sun is calculated out to be \( r=7e+8 \text{ (m)} \) with a relative error 0.72%; the radius of the Earth is calculated out to be \( r=6.4328e+6 \text{ (m)} \) with a relative error 0.97%.

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