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Causal Relationship Between Geological Catastrophes and Spiral Potential

——New Eviderce from Modern Astronomy, Fossil Records and Geological Survey

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Abstract: The Modern astronomic theory of the Milky Way Galaxy is called ' Density wave theory' . Density wave theory is used to make attempt in explaining the catastrophes and paleontological records. Coincidentally, but still disputed, each time solar system entered into the spiral arms corresponds to impact events, respectively. Furthermore, earth was heated up while traversing the spiral arms. Therefore, warmed climate would reach its climax at the end of a traversing. Calculations revealed that the spiral arms would impose an influence on earth and the solar system, which is astronomically slight but biologically considerable. Fossil records and geological survey corroborated such statement. Both abnormal events during the transition of Perseus Arm and Scutum-Crux Arm are discovered in this article. Research on lunar vestiges and craters is under process, in order to compensate earth's geologic process which might efface records.

Key words: density-wave theory; impact event; geological catastrophe; paleontological clock

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1 Introduction

Geological catastrophes, which seem to be unexplainable, had great influence on earth and shaped our biosphere. A more puzzling question is that why those catastrophes, such as many bolide impacts, volcanic activities, marine regression, and tectonic activities, were always appearing at the same time. This manuscript mainly tried to explain this point by density wave theory.

Density wave theory or the Lin-Shu density wave theory is a theory proposed by C. C. Lin and Frank Shu[1-4] in the mid-1960s to explain spiral arm structure of spiral galaxies. Their theory introduces the idea of long-lived quasistatic density waves, which are the sections of the galactic disk which have greater mass density (about 10% ~ 20% greater). The theory has also been successfully applied to Saturn´s rings.

Originally, astronomers had the idea that the arms of a spiral galaxy were material. However, if this was the case, then the arms would become more and more tightly wound, since the matter nearer to the center of the galaxy rotates faster than the matter at the edge of the galaxy. The arms would become in-

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distinguishable from the rest of the galaxy after only a few orbits. This is called the winding problem.

Lin and Shu proposed in 1964 that the arms were not material in nature, but instead made up of areas of greater density instead. In the galaxy, stars, gas, dust, and other components move through the density waves, are compressed, and then move out of them.

Their hypothesis pointed out following suggestions:

(1) the spiral arms are quite young, and are continuously appearing and dying (chaotic spiral model);

(2) the spiral pattern may be a temporary phenomenon resulting from a recent violent disturbance such as an encounter with another galaxy (tidal model);

(3) the spiral arms are some sort of wave pattern that propagates through the galactic disk.

More specifically, the density wave theory argues that the "gravitational attraction between stars at different radii" prevents the so-called winding problem, and actually maintains the spiral pattern. The density wave theory gives a constant pattern speed $\Omega_p \approx 13.5\ \mathrm{kpc} \cdot \mathrm{sec}^{-1}$.

The Lin-Shu density wave model can explain most of the features seen in spiral galaxies, i. e., the prevalence of trailing arms and two-armed spirals. And now this hypothesis is proved to be true by Zheng et. al[5]'s latest observation. They have measured the distance to the massive star-forming region W_3OH in the Perseus spiral arm of the Milky Way to be 1.95 ± 0.04 kiloparsecs ($5.86 \times 1\,016$ km). This resolves the long-standing problem that there is a discrepancy of a factor of 2 between different techniques used to determine distances. The reason for the discrepancy is that this portion of the Perseus arm has anomalous motions. The orientation of the anomalous motion agrees with spiral density-wave theory.

2　The Lin-Shu hypothesis (QSSS)

Here are some brief conceptions of Quasi-stationary Spiral Structure hypothesis[1]:

(1) Pattern rotates at constant speed: it is a growing mode of oscillations

(2) Waves are of 4 types (S. T., S. L., L. T., L. L.)

(3) They propagate in a part of the galaxy bordered by resonances and/or turning-points which deflect (refract) waves in a differentially rotating disk.

(4) That part acts as a resonant cavity for waves

(5) Waves are growing in the stellar disk, but do not reach large amplitude (arm-interarm contrast) before saturating.

(6) Saturation is due to the transfer of wave energy to gas disk

(7) Gas disk is colder kinematically and responds much more vigorously to the gravitational forces of the spiral wave in a stellar disk than that disk itself. As a consequence, gas waves steepen into shock waves: non-linear, easily-visible waves we see.

(8) Waves grow between the Inner Lindblad Resonance and Corotational Res.

(9) Waves can propagate beyond Corotation to Outer LR.

(10) CR region acts as an amplifier of waves due to over-reflection.

As a first step, we shall neglect the velocity dispersion altogether. One then has the following set of equations:

$$\mu_t + r^{-1}[r(\mu u)_r + (\mu v)_\theta] = 0, \tag{1}$$

$$u_t + uu_r + (v/r)u_\theta - v^2/r = \phi_r, \tag{2}$$

$$v_t + uv_r + (v/r)v_\theta + uv/r = \phi_\theta/r, \tag{3}$$

$$\phi_{rr} + \phi_r/r + \phi_{\theta\theta}/r^2 + \phi_{zz} = -4\pi G\mu(r,\theta)\delta(z). \tag{4}$$

The solution is a spiral form. Potential perturbation:

$$V_1(r, \phi, t) = A(r)\exp(i(\omega t - m\phi + \Psi(r))), \tag{5}$$

where: ω real part is pattern speed $m\ \Omega_p$; m: number of spiral arms, in most cases (including the Milky Way), $m=2$; $A(r)$: amplitude of spiral; $\Psi(r)$: shape of spiral.

What's more, according to the Boltzman equation and the Poisson equation,

$$\frac{\partial \Psi}{\partial t}+\frac{\pi\partial \Psi}{\partial \omega}+\frac{\Theta}{\omega}\frac{\partial \Psi}{\partial \Theta}+Z\frac{\partial \Psi}{\partial z}+\left(\frac{\Theta}{\omega}-\frac{\partial V}{\partial \omega}\right)\frac{\partial \Psi}{\partial \omega}-\frac{1}{\omega}\left(\pi\Theta+\frac{\partial V}{\partial \theta}\right)\frac{\partial \Psi}{\partial \Theta}-\frac{\partial V}{\partial z}\frac{\partial \Psi}{\partial Z}=0,$$

$$\frac{\partial^2 V}{\partial \omega}+\frac{1}{\omega}+\frac{\partial V}{\partial \omega}+\frac{1}{\omega}+\frac{\partial^2 V}{\partial \theta^2}+\frac{\partial^2 V}{\partial z^2}=4\pi G\rho. \qquad (6)$$

where ρ is the density of the galaxy.

3 The Influence on Earth and a Great Cycle

To clarify the phenomenon in earth's history, one must bear in mind the following important environment of the Solar system, as presented in fig. 1, the locations of the galactic center, sun (a small circle), and spiral arms are indicated.

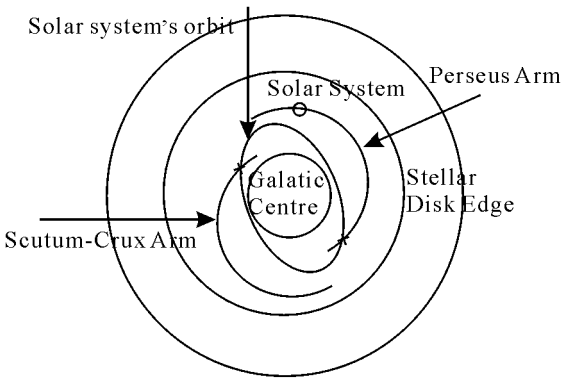

Fig. 1 "Plan View" of the Milky Way as Seen from Its North Pole

The position of the solar system is figured out in this figure. Because the velocity of the spiral arms is just half of the solar system, 520 Ma is just the time our Solar System needs to pass the four major swing arms once. Therefore if we take the spiral pattern as the reference system, it will take the solar system 520 Ma to form a circle. Based on the recent survey[6], the Milky Way also has 2 main spiral arms like all the other galaxies. Most spiral galaxies have two arms and approximate twofold symmetry. Actually it is also effective for the Milky Way. Observations presented by Benjamin[6] proved that the Milky Way also possesses only two major stellar arms: the Perseus arm and the Scutum-Centaurus arm. The rest of the arms are minor or adjunct arms.

From the current position we can infer that 65 million years ago the solar system is very likely to be in the Scutum-Crux Arm, and 250 million years ago in the Perseus Arm. (According to the density wave theory, the solar system's orbit is an incoaxial eclipse.) The period of the solar system's period of movement in the Milky Way can be divided in the following manner, as presented in Fig. 2.

The time Solar System needs to move around the galaxy once is called a cosmic year, nearly 250 Myr. While the Solar System is moving, the spiral arms of the galaxy are circling round as well. Furthermore, the velocity of the screwy gravitational field was just half of the Solar System's velocity: $\omega = 13.5\ \mathrm{kms^{-1}kpc^{-1}}$, while the solar system's $\omega = 25\ \mathrm{kms^{-1}kpc^{-1}}$. Hereby the final result is ——the time our Solar System needs to pass all the major spiral arms once is neither more nor less than 2 cosmic years[7].

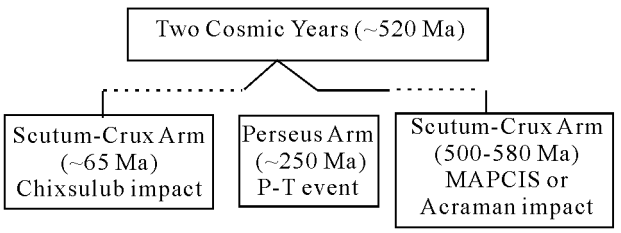

Fig. 2 Solar System's Movement in the Milky Way Since Late Precambrian.

According to (5), there is a strong extra gravitational field in spiral arms. The Solar System is a 2-body system. A planet only has gravitational operation with the Sun. The gravitation between planets is trivial. All 2-body celestial systems have analytic state and its macroscopical state can be calculated. But

when the Solar System passes the abnormal gravitational field, its strong force works, resulted in a 3-body celestial system. A 3-body gravitational system is a state of chaos. The state is confused and impacts become possible.

This is why many events, including impacts, volcanisms and marine regression, occurred at the same time. For instance, the possible P-T impact[8-9] is accompanied with great volcano activities.

Moreover, another well-known K-T impact[10], is also accompanied with Deccan Trap volcanism[11-12], Maastrichtian sea-level regression[13] and many other impacts: several other craters also appear to have been formed about the time of the K-T boundary. This suggests the possibility of near simultaneous multiple impacts, perhaps from a fragmented asteroidal object, similar to the Shoemaker-Levy 9 cometary impact with Jupiter. In addition to the 180 km Chicxulub Crater, there is the 24 km Boltysh crater in Ukraine (65.17 ± 0.64 Ma), the 20 km Silverpit crater, a suspected impact crater in the North Sea (60~ 65 Ma), and thecontroversial and much bigger 600 km Shiva crater. Any other craters that might have formed in the Tethys Ocean would have been obscured by tectonic events like the relentless northward drift of Africa and India[14-16].

4 Paleontological Evidence for Perseus Arm Event

Growth lines of organisms are result of the physiological activity in responding to some cyclic change of the physical conditions, such as diurnal light intensity, monthly tidal fluctuation and seasonal temperature transition, etc., recorded in the epicecae of the organisms. Wells´ pioneer work[27] on the growth rhythm of fossil corals reveals that the ancient year had more days than today, indicating that the earth rotation was slow down through geologic time, which fits the astronomic observation well, and stimulates considerable interest in "paleontological clocks".

In addition, Pannella[18] discussed the temporally geologic environments and astronomic periods by distinguishing different types of periodic growth increments. Berry and Barker discovered a hierarchy of growth increments in present-day bivalve shells along the eastern coast of the USA. Berry and Barker[28] considered that there are 15 increments in a rhythm period that reflects the local tidy rhythm.

Data on specimens of particularly good preservation like figure 3 have been summarized. Also, many former researches' data are plotted together in fig. 4.

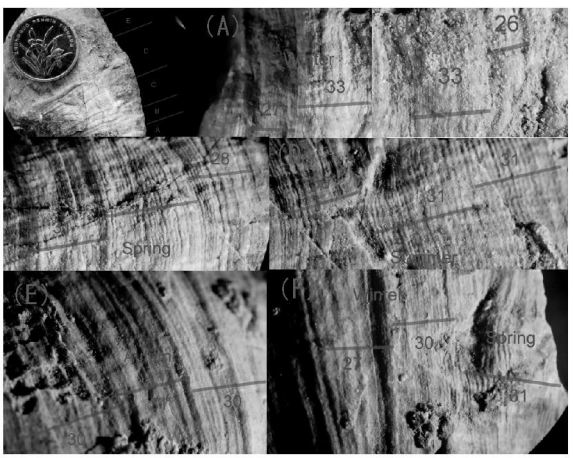

Fig. 3　An Overview of Fossil Coral Specimen GMPKU-XJ-30-16 and Enlargements of Each Part on Coral Epitheca

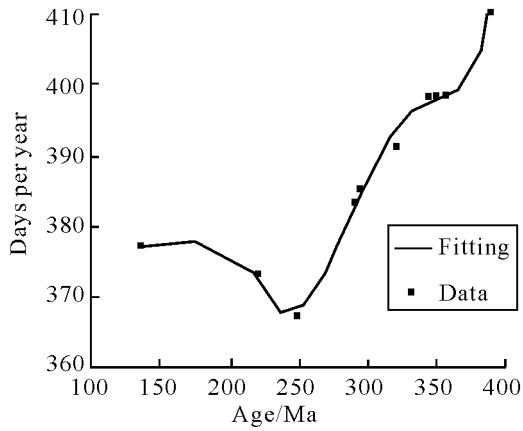

Fig. 4　Variations of Synodic Months Per Year During P-T Boundary

Synthesize new data with former achievements[17-35], this paper provides a detailed curve of ancient variations of days per year, presented in Figure 4.

It is shown in the curve that P-T boundary is a critical in earth's slowdown pattern. This means that

earth's astronomical situation was affected during the transition of the Perseus Arm. Though this may also be a coincidence.

5 Geological Survey on MAPCIS (Scutum-Crux Arm Event)

MAPCIS (Massive Australian Precambrian/Cambrian Impact Structure) is the largest known terrestrial impact structure and is dated to approximately 545 Ma. MAPCIS is a complex multiple ring impact structured with the buried center located at 25°32′55.66″S, 131°23′21.50″E approximately equidistant between Uluru/Ayers Rock and Mt. Conner. The 2000km outermost ring was visualized from a 2007 satellite Google earth image after a rare rainy season in central Australia transformed the usual monochrome reddish desert to a multihued bloom which temporarily highlighted the crater ring. There are significant concentric magnetic[37] and gravitational anomalies[38] at the center consistent with impact origin that lies underneath a central MASCON. On the 2002 magnetic intensity map of the Uluru/Ayers Rock region[39] there is a comet shaped excavation in the crystalline basement that runs NNE to SSW ending at contact with the Musgrave Block. Regional geology, lineaments, forbidden zones and smaller coeval impacts[40] are consistent with a NNE to SSW trajectory of an oblique impact.

Large pseudotachylite deposits are considered diagnostic evidence, for the biggest impacts[41] as are evident at the Vredefort and Sudbury impacts. Pseudotachylite deposits in the direct downrange angle of MAPCIS center are the largest known in the world. The pseudotachylite stretches over 300 km from the Tomkinson Ranges in Western Australia to Mt. Cuthbert where it enters the Northern Territories, with widths up to 2 km. The Pseudotachylite deposits can be found in arcuate deposits around MAPCIS center and in radial deposits which converge at MAPCIS center.

The pseudotachylite postdates all other lithologies and structures and is not associated with any single fault or structure[42].

The dating of MAPCIS is based on regional stratigraphic relationships and on individual crystals located directly downrange between MAPCIS center and the pseudotachylite[43]. The basement target rock of 1 Ba Grenville age was violently exhumed, activating all the faults in the Musgrave block, which reset ages around these faults to dates between the original age and approximately 545 Ma. The Neoproterozoic beds of Mt. Conner survive the impact and are evidence of the age of the target rock. Acraman ~ 590 Ma ejecta layer is missing at MAPCIS center and directly downrange, yet is intact in protected forbidden zones or deep trenches[44]. Soft bodied Ediacaran fauna of South Australia are preserved in the protected areas at the time of the mass extinction at the end of the Precambrian. MAPCIS is centered in post impact Cambrian Kalkarindji Event flood basalts.

This is but a brief synopsis of the most salient information pertaining to MAPCIS. Whose stroctigraphic diagram is presented as fig. 5. As a newly discovered impact, there is still much to be done.

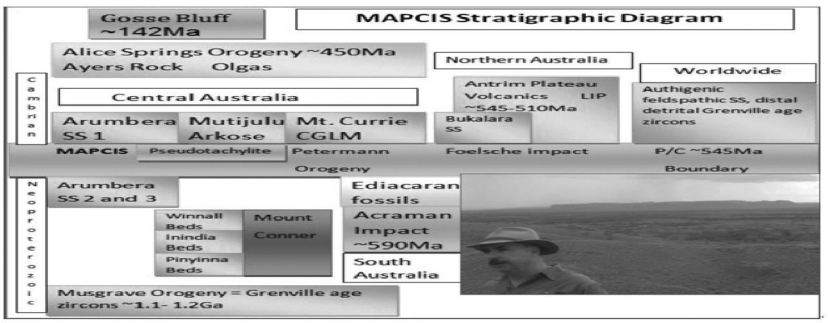

Fig. 5 MAPCIS Stratigraphic Diagram. MAPCIS Probably Occurred Just Before the Precambrian/Cambrian Boundary

Further research is needed to refine this dating. The photo presents a corner of MAPCIS and the third author as a scale.

Also, in the Precambrian shales of Adelaide, South Australia (~ 600 Ma), and the impact ejecta deposits can be traced back to 260 km. A solitary layer of shattered crustal rock fragments has been traced over a distance of 260 kilometers within folded 600-million-year-old Precambrian marine shales of the Adelaide Geosyncline, South Australia. The fragments consist entirely of acid to intermediate volcanics (approximately 1 575 million years old) displaying shattered mineral grains, shock lamellae in quartz, and small shatter cones. Fragments reach 30 centimeters in diameter and show evidence of vertical fall emplacement. Available evidence points to derivation of the rock fragments from a distant hypervelocity impact into the Gawler Range Volcanics at Lake Acraman, approximately 300 kilometers west of the Adelaide Geosyncline. To our knowledge, this is the first record of widely dispersed coarse impact ejecta preserved in a pre-Cenozoic sedimentary sequence.

6 The Slight Decrease of the Great Cycle

According to McCrea[36]'s calculation, when passing across each spiral arm, the solar system will stay in the arm for several million years.

In the first place, the spiral potential:

$$f = A(r)\cos[2\phi + \Psi(r)], \tag{7}$$

maybe played the most important role. We choose the galaxy as an inertial frame. Spiral arms will form at the minimal potential position and give a spiral pattern like above.

According to the desity wave theory, when the solar system is moving across a spiral arm, it will generate a radical velocity. The solar system will move toward the galactic center while the celestial bodies in the interarm region are moving away from it. We shall use the term systematic motion to refer to that part of the gas motion which results from the presence of the spiral gravitational field of a traveling pattern in addition to the mean circular motion. This motion has a tangential component as well as a radial component, where (ω, θ) are the cylindrical coordinates with the origin located at the galactic center and θ is measured clockwise from the radius passing.

We consider a spiral potential of the form:

$$v_1 = A(\omega)\cos[2(\Omega_p t - \theta) + \Phi(\omega)]. \tag{8}$$

Where the amplitude $|A|$ is a slowly varying function of ω, t is the time, and $\Phi(\omega)$ is the phase term, so that the spiral pattern at any instant is given by

$$-2\theta + \Phi(\omega) = \text{constant}. \tag{9}$$

The spiral potential also caused an extra gravitational field. Because the mass density of the spiral arm is several times larger than the outer space, the extra gravitational field will have an influence on the solar system.

When the solar system is approaching the spiral arm's low density part, the gravitational field of the latter worked and accelerated the solar system. The energy increased equals the work done by the spiral arm,

$$W = \int_{\infty}^{1/2\Delta r} \frac{GM_{\text{Arm's low-density part}} M_{\text{Sun}}}{r^2} \mathrm{d}r = -\frac{GM_{\text{Arm's low-density part}} M_{\text{Sun}}}{1/2\Delta r}, \tag{10}$$

meaningfully, when the solar system is leaving the arm, which attracted it is the high density part, comparatively. The energy decreased equals the work done by the spiral arm,

$$W = \int_{1/2\Delta r}^{\infty} \frac{GM_{\text{Arm's high-density part}} M_{\text{Sun}}}{r^2} \mathrm{d}r = \frac{GM_{\text{Arm's high-density part}} M_{\text{Sun}}}{1/2\Delta r}, \tag{11}$$

certainly, $M_{\text{Arm's high-density-part}} > M_{\text{Arm's low-density-part}}$, total energy decreased.

$$\Delta E_{\text{Sun}} = \frac{G(M_{\text{Arm's high-density-part}} - M_{\text{Arm's low-density-part}})M_{\text{Sun}}}{1/2\Delta r} = K \cdot M_{\text{Sun}}. \tag{12}$$

For other celestial systems, based on the same process we can deduct $\Delta E = K \cdot M$. So the net result is a net mechanical energy loss.

Based on recent measurements and McCrea[36]'s data, $\Delta r \approx 10^{19}$ m; $M_{\text{Milky Way}} \approx 1 \times 10^{12} M_{\text{Sun}}$, $M_{\text{Spiral Arm}} \approx 1 \times 10^{11} M_{\text{Sun}}$; Not the whole spiral arm works, and we should notice that the "high density" or "low density" are merely comparative conceptions. So the part which crossed by the solar system can be symbolized as $(a \cdot M_{\text{spiral arm}}(a \approx 10^{-4})$. Finally we estimate that,

$$K = a \cdot \frac{GM_{\text{spiral arm}}}{\Delta r} \approx a \cdot 10^{11} \approx 10^{7}. \tag{13}$$

Then let's discuss the compact effect and its result. We may find out that only the secondary celestial system suffered severely.

(1) For the Sun:

$$\Delta E = K \cdot M, \tag{14}$$

therefore,

$$E = \frac{GMm}{-2A}\downarrow \Rightarrow A \downarrow \Rightarrow T \downarrow. \tag{15}$$

Thus we can estimate the total decreased ratio of Sun's axis:

$$\frac{K \cdot M_{\text{Sun}}}{(\frac{GM_{\text{Galactic center}}}{A}) \cdot M_{\text{Sun}}} \approx \frac{10^{7}}{10^{11}} \approx 0.01\% \sim 0.02\%. \tag{16}$$

According to Kepler's third law, such decreased ratio of the Solar system's orbital axis indicates the decrease of the Great Cycle itself.

(2) For the earth-Moon system. We can write down the solutions of earth's orbit follows:

$$\begin{cases} \frac{d}{dt}(\frac{\partial L}{\partial \dot{\theta}}) - \frac{\partial L}{\partial \theta} = 0, \\ \frac{d}{dt}(\frac{\partial L}{\partial \dot{r}}) - \frac{\partial L}{\partial r} = 0 \end{cases} \Rightarrow \begin{cases} \ddot{r}r + \dot{r}^2 + r^2\ddot{\theta} + 2r\dot{r}\dot{\theta} = 0, \\ \ddot{r} + r\dot{\theta} = r\dot{\theta}^2 + r\dot{\theta} - \frac{GM}{r^2}. \end{cases} \tag{17}$$

and the Binet's formula,

$$\frac{1}{2}mc^2[(\frac{du}{d\theta})^2 + u^2] + V(\frac{1}{u}) = E, \tag{18}$$

where $c = r^2\dot{\theta}$, $u = \frac{1}{r}$. Reasonably, we choose the Sun-earth system to be our study object, then

$$T = \frac{1}{2}(M + m) \cdot v^2 + \frac{1}{2}mv'^2 = \frac{1}{2}Mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}mv'^2. \tag{19}$$

$$V = V_{\text{Sun}} + \frac{GMm}{-r}. \tag{20}$$

Therefore both Laplace function and Hamiltion function are obtained as follows,

$$L = T - V = \frac{1}{2}Mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}mv' - (V_{\text{Sun}} + \frac{GMm}{-r}). \tag{21}$$

$$H = \sum p\dot{q} - L = \frac{1}{2}Mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}mv'^2 + V_{\text{Sun}} + \frac{GMm}{-r}. \tag{22}$$

Similarly, one can derive the expression for the Moon's kinetic energy and potential energy as,

$$T = \frac{1}{2}(M + m + m_m) \cdot v^2 + \frac{1}{2}(m + m_m)v'^2 + \frac{1}{2}m_m v''^2, \tag{23}$$

$$V = V_{\text{Sun}} + \frac{GM(m + m_m)}{-r} + \frac{Gmm_m}{-r'}. \tag{24}$$

And the Laplace function and the Hamilton function as,

$$L = \frac{1}{2}Mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}m_m v^2 + \frac{1}{2}mv'^2 + \frac{1}{2}m_m v''^2 - \left(V_{\text{Sun}} + \frac{GMm}{-r} + \frac{GMm_m}{-r} + \frac{Gmm_m}{-r'}\right), \tag{25}$$

$$H = \sum p\dot{q} - L = \Delta(\text{Sun's mechanical energy}) + \left[\Delta\left(\frac{1}{2}mv^2\right) + \Delta\left(\frac{GMm}{-2a}\right)\right] + \frac{1}{2}m_m(v^2 + v'^2) + \frac{GMm_m}{-r'} + \left(\frac{1}{2}m_m v''^2 + \frac{Gmm_m}{-r''}\right). \tag{26}$$

As a result,

$$\Delta\left(\frac{Gm}{-2a'}\right) = 0 \Leftrightarrow \Delta\left(\frac{Gmm_m}{-2a'}\right) = 0. \tag{27}$$

In conclusion, the Great Cycle itself is slightly decreasing though the earth-Moon distance will not be affected. This is supported by modern astronomical observations[7].

7 Conclusions

In this manuscript, density wave theory is used to attempt to explain geological catastrophes and global warming. Coincidentally, although still disputably, each time the solar system enters into the spiral arms, events happen. And the mechanism of these events seems to be consistent with geological records. Calculations reveal that the spiral arms of the Milky Way exert an influence on the earth and the solar system, which is astronomically slight but biologically considerable. Fossil records and geological survey corroborated such statement. Both abnormal events during the transition of Perseus Arm and Scutum-Crux Arm were discovered in this article.

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地质灾难与螺旋势场间的关系

——来自现代天文学和化石记录及地质调查的新证据

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摘　要: 现代的银河系天文理论即密度波理论被应用以试图解释地质历史上的灾变与化石的纪录. 太阳系穿越银河系中主旋臂的时间分别对应于 K-T 陨击事件, P-T 陨击事件与前寒武- 寒武纪交界事件. 计算表明: 旋臂的引力场将对地球与太阳系产生影响, 在天文学角度看并不大但对于生物圈的影响已经足够达到所谓灾变. 同时, 来自化石记录和地质考察的证据对这一机理提供了有力的支持, 当太阳系穿越英仙座旋臂和半人马座旋臂时发生的异常事件都得到了支持. 为了解决地质运动造成地球地质记录不完整的问题, 针对月球表面记录的研究工作也已经展开.

关键词: 密度波理论; 撞击事件; 地质灾难; 古生物钟

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