# CGA-influence:
# Giant Planets Acting on Small Planets

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**Abstract:** It seems that up to now researchers have not fully and systematically taken into consideration the gravitational influence of the giant planets on the small ones in our solar system. The main purpose of the present work is to show that, while the intensity of the giant planets' influence is certainly very weak compared to that of the Sun, it cannot be completely neglected. In this research paper we have qualitatively and quantitatively studied such effects in order to clarify, for example, the possible causal origin of the unexpected secular increase of the Astronomical Unit. The approach uses the concept of Combined Gravitational Action (CGA).

**Keywords:** Combined gravitational action; dynamic gravitational field-force; CGA-influence; Jovian planets; terrestrial planets

## 1. Introduction

In previous work relating to the CGA [1,2], we have explained and calculated the CGA-influence of the Sun, as principal gravitational source, on Pioneer10 and on all the planets. For example, the CGA predicted that the dynamic gravitational field-force, $(\mathbf{\Lambda}, \mathbf{F}_{\mathrm{D}})$, causes secular perihelion precession in the orbit of each planet, mostly the inner ones. Now, we are particularly interested in knowing about the CGA-influence of giant plants on the small ones, and its consequence as, for instance, the secular increase of the mean radial distance between a giant and a small planet, because such a consequence may help us to understand the possible causal origin of the observed secular increase of the astronomical unit (AU) [3].

In this work, the CGA predicts some very small orbital perturbations induced gravitationally by a giant planet on the nearest small ones. These orbital perturbations may be manifested in the form of an extra-orbital precession of the small planet's orbit.

As we presently understand the Solar System (SS), the Sun is the principal gravitational source $A$, and each planet plays the role of an orbiting test-body $B$.

In the present research paper, we select from our SS an idealized system for further investigation. We have the four terrestrial (inner) planets, namely Mercury, Venus, Earth, and Mars, as test-bodies. Since the Jovian (outer) planet (Jupiter) is the biggest planet, it serves as the principal gravitational source other than the Sun.

So we mentally and momentarily give the Sun an abstracted existence, and we focus our attention on the system $\{M_i, M_{\mathrm{J}}\}$ where $M_i$ is the terrestrial planet mass, for $i = 1,2,3,4$ corresponding to the order in the SS, and $M_{\mathrm{J}}$ is Jupiter's mass. Thus in such configuration Jupiter should play the role of the principal gravitational source $A$ and each terrestrial planet (TP) plays the role of the test-body $B$. Therefore in this case and under direct CGA-influence of Jupiter, each TP should see its proper elliptical orbit rotate very slowly in the orbit's plane with respect to the barycenter of system

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$\{M_i, M_J\}$. That is to say, during its orbital revolution, the elliptical orbit of the TP precesses in its own plane by very small amount, $\Delta\varphi$, which is exactly the expected rate of this orbital precession.

## 2. Terrestrial Planets

Since Earth is the main massive planet of the group of TP's, and Jupiter is the major massive one in the group of Jovian planets, and the ratio of Earth's mass $M_{i=3} = M_{\oplus}$ to Jupiter's mass $M_J$ is $q = M_{\oplus}/M_J = 3.145643\times10^{-3} << 1$; it follows from the CGA [2] that we can use the CGA-formula (32.7), which is herein numbered and expressed as follows:

$$\Delta\varphi(\text{rad/rev}) = \frac{1}{2}\left[\frac{GM_J P}{r_{\text{mean}}^2 c_0}\right]^2 , \qquad (1)$$

where $\Delta\varphi$ is the expected rate of orbital precession of TP expressed in *radian per revolution*, $G$ is Newton's gravitational constant, $M_J$ is Jupiter's mass, $P$ is the relative orbital period of TP, $r_{\text{mean}}$ is the mean radial distance between Jupiter and TP, and $c_0$ is the speed of light in local vacuum.

The orbital and physical parameters of the four TP's relative to the Sun, as given by Wikipedia, are listed in Table 1.

Table 1: Orbital and Physical Parameters of TP's Relative to the Sun

| **TP** | $P$ (days) | $r_{\text{max}}$ (AU) | $r_{\text{mean}}$ (AU) | $r_{\text{min}}$ (AU) | $e$ | $M$ $(M_{\oplus})$ |
|---|---|---|---|---|---|---|
| **Mercury** | 87.970 | 0.466697 | 0.387098 | 0.307499 | 0.2056 | 0.055 |
| **Venus** | 224.700 | 0.728231 | 0.723332 | 0.718432 | 0.0068 | 0.815 |
| **Earth** | 365.256 | 1.016713 | 1 | 0.983291 | 0.0167 | 1 |
| **Mars** | 686.971 | 1.665861 | 1.523679 | 1.381497 | 0.0933 | 0.107 |

In Table 1, column 1 gives the name of each TP: Mercury (Merc.), Venus, Earth, Mars; columns (2-7) give, respectively, the orbital period; the radial distances maximum, mean, and minimum between the Sun and each TP; the orbital eccentricity; and the mass. Here, we have adopted the values: $1\text{AU} = 1.49597870\times10^{11}\ \text{m}$; and $M_{\oplus} = 5.976\times10^{24}\ \text{kg}$.

## 3. Jupiter

Jupiter is a gas giant with a mass slightly less than one-thousandth of the Sun's mass, but 2.5 times that of the entire set of other planets in our SS combined. This is so massive that its barycenter with the Sun lies above the Sun's surface at 1.068 solar radii from the Sun's center. Jupiter's mass, $M_J$, is often used as a unit to describe masses of other celestial objects, particularly extrasolar planets and brown dwarfs. So, for example, the extrasolar/exoplanet HD 209458b has a mass of $0.69 M_J$, while COROT-7b has a mass of $0.015 M_J$. Jupiter is classified as a gas giant, along with Saturn, Uranus and Neptune. Together, these four outer planets are sometimes referred to as the 'Jovian planets'.

### 3.1. Orbital and physical parameters of Jupiter relative to the Sun

Aphelion: $r_{\max} = 5.458104\,\mathrm{AU}$; Perihelion: $r_{\min} = 4.950429\,\mathrm{AU}$; Semi-major axis: $a = 5.204267\,\mathrm{AU}$; Mass: $M_{\mathrm{J}} = 317.9\,M_{\oplus}$; the ratio of Jupiter's mass $M_{\mathrm{J}}$ to the Sun's mass $M_{\mathrm{S}} = 1.9891\times10^{30}\,\mathrm{kg}$ is: $q = M_{\mathrm{J}}/M_{\mathrm{S}} = 9.546584\times10^{-4}$.

### 3.2. Orbital and Physical Parameters of TP's Relative to Jupiter

In Table 2 are listed the orbital and physical parameters of TP's relative to Jupiter. It is worthwhile to note that, to calculate the relative eccentricity and period of each TP with respect to Jupiter, we can use the two following well-known formulae:

$$e = (r_{\max} - r_{\min})(r_{\max} + r_{\min})^{-1}\ , \tag{2}$$

and

$$P(\text{seconds}) = 2\pi\, r_{\text{mean}} \left[\frac{r_{\text{mean}}}{GM_{\mathrm{J}}}\right]^{1/2} . \tag{3}$$

Table 2: Orbital and Physical Parameters of TP's relative to Jupiter

| **TP** | $P$ (years) | $r_{\max}$ (AU) | $r_{\text{mean}}$ (AU) | $r_{\min}$ (AU) | $e$ | $q$ |
|---|---|---|---|---|---|---|
| **Mercury** | 341.9497 | 4.991407 | 4.817169 | 4.642930 | $3.6170\times10^{-2}$ | $1.7301\times10^{-4}$ |
| **Venus** | 306.7802 | 4.669871 | 4.480935 | 4.231997 | $4.9189\times10^{-2}$ | $2.5637\times10^{-4}$ |
| **Earth** | 278.6392 | 4.435828 | 4.204267 | 3.969251 | $5.5511\times10^{-2}$ | $3.1456\times10^{-3}$ |
| **Mars** | 228.3759 | 3.792243 | 3.680588 | 3.568932 | $3.0336\times10^{-2}$ | $3.3784\times10^{-4}$ |

In Table 2, column 1 gives the name of each TP; columns (2-7) give, respectively, the relative period; maximal; mean and minimal radial distance between Jupiter and each TP ; relative eccentricity; and mass ratio.

## 4. Precession of TP Orbits Caused by the CGA-Influence of Jupiter

In reality, the orbital precession of TP orbits caused by the CGA-influence of Jupiter is very similar to the secular perihelion advances of the all planets caused by the Sun. So, according to the CGA [2], and in terms of field, Jupiter as principal gravitational source $A$ (the Sun is mentally and momentarily excluded *via* abstraction) is exerting on each PT as test-body $B$ two fields, namely the static, $\boldsymbol{\gamma}$, and the dynamic, $\boldsymbol{\Lambda}$, gravitational fields *via* the combined gravitational field, $\mathbf{g} = \boldsymbol{\gamma} + \boldsymbol{\Lambda}$, which is their resultant. The classical and relativistic gravitational theories ignored or missed the phenomenological and/or conceptual existence of $\boldsymbol{\Lambda}$. Consequently, according to the CGA [1], such an omission implies $\mathbf{g} = \boldsymbol{\gamma}$ and what, among other things, has provoked the Pioneer10 anomaly.

However, if we take into account the motion of the test-body, *i.e.*, when the velocity vector $\mathbf{v} \neq \mathbf{0}$, in this case $\boldsymbol{\gamma}$ and $\boldsymbol{\Lambda}$ together become the main components of $\mathbf{g}$, and consequently $\boldsymbol{\Lambda}$, appearing its effects. Further, the dynamic gravitational field (DGF), $\boldsymbol{\Lambda}$, is in reality an induced field, it is more precisely a sort of gravitational induction due to the relative motion of the material body in the vicinity of the gravitational source, that is why we have the adjective 'dynamic', because according to the CGA [1,2], the magnitude of this gravitational induction is phenomenologically depending on the modulus of 3D-position vector $\mathbf{r}$, 3D-velocity vector $\mathbf{v}$ and kinematical parameter $w$. Certainly, the static gravitational field $\boldsymbol{\gamma}$ is in general always stronger than DGF, but $\boldsymbol{\Lambda}$ has its proper role and effects, which are summarized in the expression: 'CGA-influence'. Therefore, in the system $\{M_i, M_{\mathrm{J}}\}$, the expected extra-orbital precession of each TP's orbit is mainly due to $\boldsymbol{\Lambda}$ that behaves as an additional gravitational field.

Now in order to determine qualitatively and quantitatively the expected extra-orbital precession of each TP's orbit with respect to the barycenter of the system $\{M_i, M_{\mathrm{J}}\}$, firstly, we must use the parameters listed in Table 2 to calculate the numerical values of the factors contained in the CGA-formula (1), and after substitution into (1), we get the value of the expected rate $\Delta\varphi$ for each TP's orbit. The computed values are listed in Table 3.

Table 3: Expected rate of Orbital Precession of TPs' Orbits

| **TP** | $\Delta\varphi$ (rad/rev) | $\Delta\varphi$ (rad/cy) | $\Delta\varphi$ (arcsec/cy) |
|---|---|---|---|
| **Mercury** | $3.859056\times10^{-11}$ | $1.128545\times10^{-11}$ | $2.328972\times10^{-6}$ |
| **Venus** | $4.148629\times10^{-11}$ | $1.352313\times10^{-11}$ | $2.790761\times10^{-6}$ |
| **Earth** | $4.423448\times10^{-11}$ | $1.587518\times10^{-11}$ | $3.276152\times10^{-6}$ |
| **Mars** | $5.050752\times10^{-11}$ | $2.211596\times10^{-11}$ | $4.564058\times10^{-6}$ |

In Table 3, column 1 gives the name of each TP; columns (2-4) give, respectively, the expected rate $\Delta\varphi$ of orbital precession of each TP's orbit expressed in rad/rev; rad/cy and arcsec/cy in that order. We have used the Earth time and for the physical constants we have adopted the values: $G = 6.67384\times10^{-11}\ \mathrm{m^3\ kg^{-1}\ s^{-2}}$ and $c_0 = 299\,792\,458\ \mathrm{m\,s^{-1}}$.

## 5. Possible Explanation of Secular Increase of the AU in the Context of the CGA

In this Section we try to determine the secular increase of the mean radial distance between each TP and Jupiter as a direct consequence of the orbital precession of each TP orbit in its own plane with respect to barycenter of the system $\{M_i, M_{\mathrm{J}}\}$.

### 5.1. Problematic

Several researchers have recently reported an unexpected secular increase of the AU, the length scale of the SS (Krasinsky and Brumberg [3]; Standish [4]; Pitjeva [5]). The AU is without doubt one of the most important scales in astronomy: it characterizes the scale of the SS and the standard of the cosmological distance ladder. AU is also the fundamental astronomical 'constant' that associates two length units: one (m) in International System (SI) of Units and one (AU) in Astronomical System of Units.

In the field of fundamental astronomy, *e.g.*, the planetary ephemerides it is one of the most important subjects to evaluate AU from the observation data. Further, the appearance of planetary radar and spacecraft ranging techniques has led to great improvement of determination of AU. Contemporary observations of the major planets, including the planetary exploration spacecrafts such as Martian Landers and Orbiters, make it very possible to check the value of AU within the accuracy of one mater or even better! Now, the best-fit value of AU is obtained as (Pitjeva [5]):

$$1\,\mathrm{AU} = \mathrm{AU(m)} = 1.495978706960 \times 10^{11} \;\pm\; 0.1\ \mathrm{(m)}\,. \tag{4}$$

However, Krasinsky and Brumberg [3] reported the positive secular variation in AU as:

$$\frac{d}{dt}\mathrm{AU} = 15 \pm 4\ \mathrm{m/cy}\,, \tag{5}$$

from the analysis of radar ranging of inner planets and Martian Landers and Orbiters [3,4]. As already mentioned, the value of AU is presently obtained within the error of one meter or even better, so that the reported secular variation (5) seems to be in excess of current determination error of AU. It is worthwhile to note that this secular increase of AU was discovered from the following formula:

$$t_{\mathrm{theo}} = \frac{d_{\mathrm{theo}}}{c_0}\left[\mathrm{AU} + \frac{d\mathrm{AU}}{dt}\,(t - t_0)\right], \tag{6}$$

in which $t_{\mathrm{theo}}$ is the theoretical value of round-trip time of radar signal in the SI second, $d_{\mathrm{theo}}$ is interplanetary distance obtained from ephemerides in the unit of (AU), $c_0$ is the light speed in local vacuum, AU and $d\mathrm{AU}/dt$ are, respectively, the astronomical unit as (4) and its variation with time, and $t_0$ is the initial epoch of ephemerides, $t$ is compared with the observed lapse time of observed signal $t_{\mathrm{obs}}$, and the AU, $d\mathrm{AU}/dt$ are fit by the least square method. However, many attempts have already been made to explain this secular increase of AU, including, *e.g.*, the effects of the universe's expansion [3,6,7]; mass loss of the Sun [3,8], the time variation of gravitational constant [3], the influence of dark matter [9] and so on. But unfortunately so far none of them seems to be successful.

In this research paper, we will try to approach another viewpoint and propose a possible causal origin for this secular increase of AU, based on the secular orbital precessions of TP orbits in their own planes with respect to barycenter of the system $\{M_i, M_{\mathrm{J}}\}$. To this end, let us consider the following scenario: The above mentioned secular orbital precessions of TP orbits caused by the CGA-influence of Jupiter which should induce a certain time variation of the mean radial distance, $r\,\mathrm{(m)}$, between each TP and Jupiter. The rate, $\dot{r}\,\mathrm{(m/cy)}$, of such a radial variation with time should be very approximately related to the amount, $\Delta\varphi\,\mathrm{(rad/cy)}$, of the secular precession of each PT's orbit by the relation:

$$\dot{r}\,r^{-1} = f(e)\,\Delta\varphi, \tag{7}$$

where $f(e)$ is a function of the relative eccentricity of TP and defined by the expression

$$f(e) = (1+e)^2(1-e)^{-2}\ . \tag{8}$$

### 5.2. Calculation of the rate $\dot{r}$ (m/cy)

With the help of Tables 2 and 3, and by using the relation (7), we can calculate the rate $\dot{r}$ (m/cy) for each TP. The values are listed in Table 4.

Table 4: Expected Rate of Mean Radial Distance Variation

| TP | $r$ (m) | $f(e)$ | $\Delta\varphi$ (rad/cy) | $\dot{r}$ (m/cy) |
|---|---|---|---|---|
| **Mercury** | $7.206382\times10^{11}$ | 1.155742 | $1.128545\times10^{-11}$ | 9.399333 |
| **Venus** | $6.703383\times10^{11}$ | 1.217640 | $1.352313\times10^{-11}$ | 11.0 3799 |
| **Earth** | $6.289490\times10^{11}$ | 1.248911 | $1.587518\times10^{-11}$ | 12.46997 |
| **Mars** | $5.506881\times10^{11}$ | 1.129055 | $2.211596\times10^{-11}$ | 13.75075 |

Above, column 1 gives the name of each TP; columns (2-5) give, respectively, the mean radial distance; the eccentricity function; the rate of orbital precession; and the rate of the mean radial distance variation with time for each TP.

Finally, if we take into account the universality of the homogeneity and isotropy of space and the uniformity of time, thus in such case we can affirm without hesitation that the calculated values of the rate $\dot{r}$ of the mean radial distance variation with time are real or at least are very near to the reality. This affirmation is reinforced by the fact that the estimated $d\mathrm{AU}/dt$ in different data is distributed within the range $7.9 \pm 0.2$ to $61.0 \pm 6.0$ (m/cy), see Table 2 of Krasinsky and Brumberg [3]. Further, the arithmetic mean of the four values listed in our Table 4, namely 11.66451 m/cy is in good agreement at 77.76 % with the value $15 \pm 4$ m/cy reported by [3]. Therefore, we can finally conclude that the causal origin of the secular increase of the AU may be due to the CGA-influence of Jupiter on the TP's.

## 6. Conclusions

In this research work, we have shown that the CGA-model [1,2] can be used to determine qualitatively and quantitatively the CGA-influence of Jupiter –as a major giant planet in the SS– on the small ones. This CGA-influence has provoked a very small precession for each terrestrial planet's orbit in its own plane with respect to barycenter of the system $\{M_i, M_J\}$. In turn, this extra-orbital precession has induced the secular increase of the mean radial distance between each terrestrial planet and Jupiter, which may be interpreted as the causal origin of the reported secular increase of the astronomical unit (AU).

**Dedication:** This research paper is dedicated to the Palestinian and Syrian Children.

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