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Calculation the Venus orbital properties and the variation of its position

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Abstract

Venus orbit around the Sun is an ellipse inside the Earth orbit. The elements of Venus orbit and its position are affected by the gravitational force of near planets therefore the elements were determined with Julian date through ten years 2011-2020. The orbital elements used to calculate Venus distance from the Sun, the heliocentric and geocentric equatorial coordinates. From the results the orbit of Venus and its position were described and show the gravity effect of near planets on it. The results get the values and their variation through ten years for the eccentricity, semi-major axis, inclination, longitude of ascending node, argument of perihelion, mean anomaly and distance from the Sun. The variation is very small through 10 years. The values of eccentricity variation are from 0.0067678 to 0.0067630 and inclination from 3º.39537 to 3º.39529 and argument of perihelion from 54º.634 to 54º.663 and longitude of ascending node from 76º.927 to 76º.899 and the mean anomaly increases at a uniform rate from 0º to 360º every one orbital period which mean value equal to 224.73 days. All variations were calculated through about 16 orbital periods and they are secular variation and may show more value through many hundred years due to perturbation from the Sun and planets especially the Earth, Mercury and Jupiter. The equatorial coordinates show that Venus has apparent retrograde motion as seen from Earth and that is because the Earth and Venus orbital periods around the Sun are different as well as the Venus orbit inside the Earth orbit. The distance between the Sun and Venus is various between minimum value 0.71843 AU and maximum value 0.72822 AU.

Keywords: Venus orbit, Julian Date, orbital elements, Kepler equation.

حساب خصائص مدار كوكب الزهرة والتغير في موقعه

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الخلاصة

مدار الزهرة حول الشمس هو قطع ناقص داخل مدار الارض. عناصر مدار الزهرة وموقعها تتأثر بقوة الجاذبية للكواكب القريبة وبالتالي حسبت العناصر مع التاريخ الجولياني خلال 10 سنوات 2011-2020. العناصر المدارية استخدمت في حساب بعد الزهرة عن الشمس والاحداثيات من مركز الشمس والاحداثيات الاستوائية من مركز الارض. من النتائج تم وصف مدار الزهرة وموقعه واظهرت تأثير جاذبية الكواكب القريبة عليه. النتائج اعطت القيم وتغيرها خلال عشر سنوات للشذوذ المركزي ونصف المحور الرئيسي والميل وخط طول العقدة الصاعدة وازاحة الحضيض ومتوسط الشذوذ والمسافة عن الشمس. وكان التغيير صغير جدا خلال 10 سنوات. قيم الشذوذ المركزي تتغير من 0.0067678 الى 0.0067630 والميل من 3º.39537 الى 3º.39529 وازاحة الحضيض من 54º.634 الى 54º.663 و خط طول العقدة الصاعدة من 76º.927 الى 76º.899 ويزداد الشذوذ المتوسط بمعدل منتظم من 0º الى 360º كل دورة مدارية واحدة والتي تساوي معدل 224.73 يوما. تم حساب كل هذه التغييرات خلال 16 دورة مدارية وهي تغييرات غير دورية وربما تظهر قيمة أكبر خلال مئات السنين بسبب الاضطرابات الناجمة عن الشمس والكواكب خاصة الارض وعطارد والمشتري.الاحداثيات الاستوائية تظهر بأن الزهرة تمتلك حركة تراجعية ظاهرية عندما تشاهد من الارض وذلك بسبب ان الفترة المدارية للارض والزهرة حول الشمس مختلفة وكذلك بسبب ان مدار الزهرة

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داخل مدار الارض. المسافة بين الشمس وكوكب الزهرة تختلف بين القيمة الادنى 0.71843 وحدة فلكية والقيمة الاعلى 0.72822 وحدة فلكية.

1. Introduction

Venus is the third brightest object in the sky, after the Sun and the Moon [1]. It is the second planet from the Sun and the sixth largest planet in the solar system in size and mass. Venus called Earth's twin due to their similarities in size, mass, density and chemical compositions and in relative location in the solar system [2]. It was named by the ancient Roman goddess of beauty and love. It is an inferior planet with orbit smaller than Earth's orbit. Therefore, Venus sees in Earth's sky at the same direction as the Sun. At some days of the year the planet appears as a morning star in the hours before sunrise. At other days it appears as an evening star in the hours after sunset [3].

The diameter of Venus is about 12,092 km .Its mass is 4.867×10^{24} kg, a mass 81.5% that of the Earth [4], and it has an average density of 5.204 g/cm³. Gravity of the Venus surface at equator is 90% that of the Earth's and its escape velocity is 10.46 km/s. Venus does not have any moon [5].

Venus rotates very slowly, with a period of 243 days and rotates from east to west. The westward rotation of planet is called retrograde rotation [6]. Its axis of rotation is inclined relative to the plane of its orbit; the obliquity is 177.3º [1, 7]. It has no measurable internally magnetic field. If rotation rate is an essential factor in generating a magnetic field of the planets, the very slow retrograde rotation rate of Venus might be the reason for the lack of its magnetic field [8].

Venus's orbit has an orbital eccentricity of 0.006773[9], making it the most nearly circular orbit around the Sun, therefore Venus' average orbital velocity of 36.020 km/s, nearly equal a maximum orbital velocity at perihelion (36.259 km/s) and the minimum orbital velocity at aphelion (35.784 km/s). At its closest, Venus approaches the Earth to a minimum distance of 0.26 AU. At its furthest, Venus recedes to the other side of the Sun to a maximum a distance of 1.744 AU [5].

The average distance between Venus and the Sun is 0.723 AU. While the actual distance varies from 0.7184 AU at perihelion and 0.7282 AU at aphelion. The orbital period of Venus is 224.7 days, and orbital inclination to the ecliptic is 3.39º [9, 7]. Venus shows phase changes when observed from Earth, because the orbit of Venus is closer to the Sun than the Earth does. Its phases are similar to the Moon's phases. Venus some days appears as a crescent and other days as a half or full disk and about every 584 Earth days It completes one cycle of phases [3]. Venus has the most massive atmosphere of the planets in the inner solar system [2]. Its surface temperature is 450 °C [8].

2. Calculation of Julian Date (JD) and Julian Centuries

A calendar date entered in the program as consecutive numbers, the year (y) first, then the month number (m), and finally the days of month with decimals (D.d) = day + ut /24
Where ut: is the universal time in hours.

The program starts with a procedure separating the numbers of year, month and days.
In what follows, suppose that this separation has been performed.
y=y-1 and m=m+12 at m < 3
If the number y, m, and D.d is after 15/10/1582 (that is, in the Gregorian calendar), then calculate [10]

A_{Ju}=INT (y/100) (1)

B_{Ju}=2-A+Int (A_{Ju}/4) (2)

Before the date 15/10/1582, B_{Ju}equal to zero.

The required Julian Day is calculated as following [10, 11]

JD = INT (365.25 y) + INT (30.6001 (m+1)) + D.d + 1720994.5+ B_{Ju} (3)

T_1 refers to the time measured in Julian centuries of 36525 ephemeris days from the epoch 1900 January 0.5 [10]

T_1= (JD-2415020.0) / 36525 (4)

and T_2 from the epoch J2000.0 [11]

T_2 = (JD-2451545.0) / 36525 (5)

3. Calculation the Orbital elements of Venus

The mean longitude of Venus orbit (l) calculated as the following [10]:

l = 342.767053 + (58519.21191 T_1) + (0.0003097 T_1^2) (6)

The semi major axis (a) of the orbit (it is a constant for each planet), for Venus it is equal to 0.7233316 AU [10].

The eccentricity of the orbit (e) calculated as the following [10]:

$$e = 0.00682069 - (0.00004774\ T_1) + (0.000000091\ T_1^2) \quad (7)$$

The inclination of the orbital plane respect to the ecliptic plane (i) calculated as the following [10]:

$$i = 3.395459 - (0.0007913\ T_2) - (0.00003250\ T_2^2) + (0.000000018\ T_2^3) \quad (8)$$

The argument of perihelion (w) calculated as the following [10]:

$$\omega = 54.602827 + (0.2892764\ T_2) - (0.00114464\ T_2^2) - (0.000000794\ T_2^3) \quad (9)$$

The longitude of ascending node (n) calculated as the following [10]:

$$\Omega = 76.957740 - (0.2776656\ T_2) - (0.00014010\ T_2^2) + (0.000000769\ T_2^3) \quad (10)$$

The mean anomaly of Venus (m_n) can be calculated from [10]:

$$m_n = l - \omega - \Omega \quad (11)$$

The eccentric anomaly (E) calculated using equation of kepler [10, 11]

$$E = m_n + e \sin E \quad (12)$$

Generally, (e) and (m_n) are given, and the equation solved for (E). The above equation cannot be solved directly. To solve Kepler equation there are many methods can be used, in this research the second method is used for finding (E). The second method takes as a very good approximation solution. A better iteration formula used a better value (E_l for E) is [10, 11]:

$$E_1 = E_0 + \frac{m_n + e_0 \sin E_0 - E_0}{1 - e \cos E_0} \quad (13)$$

Where (E_o) is the last obtained value for (E) and e_0==e*180/ π . All quantities in this formula are expressed in degrees.

From the value of eccentric anomaly E , calculate the true anomaly *(v*) from the following formula[10, 11]

$$\tan \frac{v}{2} = \sqrt{\frac{1+e}{1-e}} \tan \frac{E}{2} \quad (14)$$

All the parameters (l, i, ω, Ω, m_n, E, v) are in degree.

The radius vector of the Venus (r), or the distance between the centers of the Sun and Venus, can be calculated by the following formulae [10, 11]:

$$r = a\,(1 - e \cos E) \quad (15)$$

The Venus's argument of latitude (u) calculated as the following [10]:

$$u = l + v - m_n - \Omega \quad (16)$$

4. Calculation the Heliocentric Ecliptical Coordinates of Venus

The ecliptical longitude (L) can be deduced from (L-Ω), as follow [10]:

$$\tan (L-\Omega) = \cos i \tan u \quad (17)$$

When a program calculator is used, in order to avoid the use of tests, formula (17) can better be written as follows [10]:

$$\tan (L-\Omega) = \frac{\cos i \sin u}{\cos u} \quad (18)$$

Its value ranging from 0º to 360º

The ecliptical latitude (b) is given by [10]

$$\sin b = \sin u \sin i \quad (19)$$

Its value between ± 90º

5. Calculation the Distance of the Sun

The sun's geometric mean longitude (L_s), referred to the mean equinox of the date calculates as following [10]:

$$L_s = 279^o.69668 + 36000^o.76892\ T_1 + 0^o.0003025\ T_1^2 \quad (20)$$

The mean anomaly of the sun (m_s) calculated as follow [10]:

$$m_s = 358^o.47583 + 35999^o.04975\ T_1 - 0^o.000150\ T_1^2 - 0^o.0000033\ T_1^3 \quad (21)$$

Where the mean anomaly of the Sun and the Earth are the same [11].

The eccentricity of the Earth's orbit (e_e) calculated as follow [10]:

$$e_e = 0.01675104 - 0.0000418\ T_1 - 0.000000126\ T_1^2 \quad (22)$$

The sun's equation of the center (C) calculate as [10]:

$$C = (1^o.91946 - 0^o.004789\ T_1 - 0^o.000014\ T_1^2) \sin m_s + (0^o.020094 - 0^o.0001\ T_1) \sin (2\ m_s) + 0^o.000293 \sin (3\ m_s) \quad (23)$$

Then the sun's true longitude (ʘ) calculated as follow [10]:

$$\odot = L_s + C \quad (24)$$

A better accuracy can be obtained as follows. The angles A1, B1, C1, D1, E1, F1 are calculated by the following expression, where all numerical values are in degrees and decimals

A1 = 153.23 + 22518.7541 T_1 (25)

B1 = 216.57 + 45037.5082 T_1 (26)

C1 = 312.69 + 32964.3577 T_1 (27)

D1 = 350.74 + 445267.1142 T_1 - 0.00144 T_1^2 (28)

E1 = 231.19 + 20.2 T_1 (29)

F1 = 353.4 + 65928.71550000001 T_1 (30)

Then the following corrections added to the sun's longitude (ʘ):

+ 0.00134 cos A1 +0.00154 cos B1 + 0.00200 cos C1 + 0.00179 sin D1 + 0.00178 sin E1

the Sun's true anomaly (v_s) calculated as following [10]:

$v_s = m_s$ + C (31)

The Sun's radius vector (R_s), or the distance between the centers of the Sun and the Earth, expressed in astronomical units, obtained by the following expression [10]:

$$R_s = \frac{1.0000002\ (1-e_e^2)}{1+e_e \cos v_s} \quad (32)$$

The following corrections added to the sun's radius vector R_s :

+ 0.00000543 sin A1 +0.00001575 sin B1+0.00001627 sin C1+0.00003076 cos D1 + 0.00000927 sin F1

The terms involving A1 and B1 are due to the effect of Venus, the terms with arguments C1 and F1 are due to Jupiter, the terms with D1are due to the Moon, and the term involving E1 is an inequality of long period [10].

The obliquity of the ecliptic (ε), is given by [10]

ε = 23.452294 - 0.0130125 T_1- 0.00000164 T_1^2 + 0.000000503 T_1^3 (33)

6. Calculation the Geocentric Ecliptic Coordinates of Venus

The geocentric longitude of Venus (λ) can be deduced from (λ-ʘ), which is given by [10]

$$\tan(\lambda - \odot) = \frac{r \cos b \sin(L-\odot)}{r \cos b \cos(L-\odot)+R_s} = \frac{N}{D} \quad (34)$$

The Venus's distance to the Earth (d_v), in astronomical units, given by [10]

$$d_v = N^2 + D^2 + (r \sin b)^2 \quad (35)$$

The geocentric latitude of Venus (β), given by [10]

$$\sin \beta = \frac{r}{d_v} \sin b \quad (36)$$

7. Calculation the Equatorial Coordinates of Venus

Venus's ecliptical coordinates (λ, β) convert to equatorial coordinates (α, δ) using the following formula [10]:

$$\tan \alpha = \frac{\sin\lambda \cos\varepsilon - \tan\beta \sin\varepsilon}{\cos\lambda} \quad (37)$$

$$\sin \delta = \sin\beta \cos\varepsilon + \cos\beta \sin\varepsilon \sin\lambda \quad (38)$$

where,

α : the right ascension of Venus.

δ : the declination of Venus.

ε : the obliquity angle.

8. Results and Discussion

The orbit of Venus has a constant value of semi major axis and very small changes in eccentricity, inclination, argument of perihelion and longitude of ascending node, and increasing in mean anomaly at a uniform rate as the planet executes its fixed orbit. Its orbit has also small changes in distance to the Sun and in equatorial coordinates. The main effects on Venus orbit is the Sun attraction and attraction of near planets like earth and mercury, these attraction forces depend on distances between Venus and the other bodies and their masses.

The orbital elements of Venus were calculated through 10 years 2011-2020 at 6 universal time and the results were plotted in Figures-(1, 2, 3, 4 and 5). The other results were the Venus distance from the Sun and its equatorial coordinates with time through 10 years 2011-2020 as in Figures-(6, 7and 8).

Figure-1 shows the variation of eccentricity (e) of Venus orbit with Julian date through 10 years, its value is linearly decreasing from 0.006767811 to 0.006763061, and it's expected to decrease by 4.75×10^{-6} every 10 years. The results prove that Venus orbit is tending to be circular in future. This small change in eccentricity is due to gravitational attractions of the Sun and the planets. The small eccentricity gives Venus the smallest range of aphelion and perihelion distances of the planets which gives the smallest variation in orbital speed.

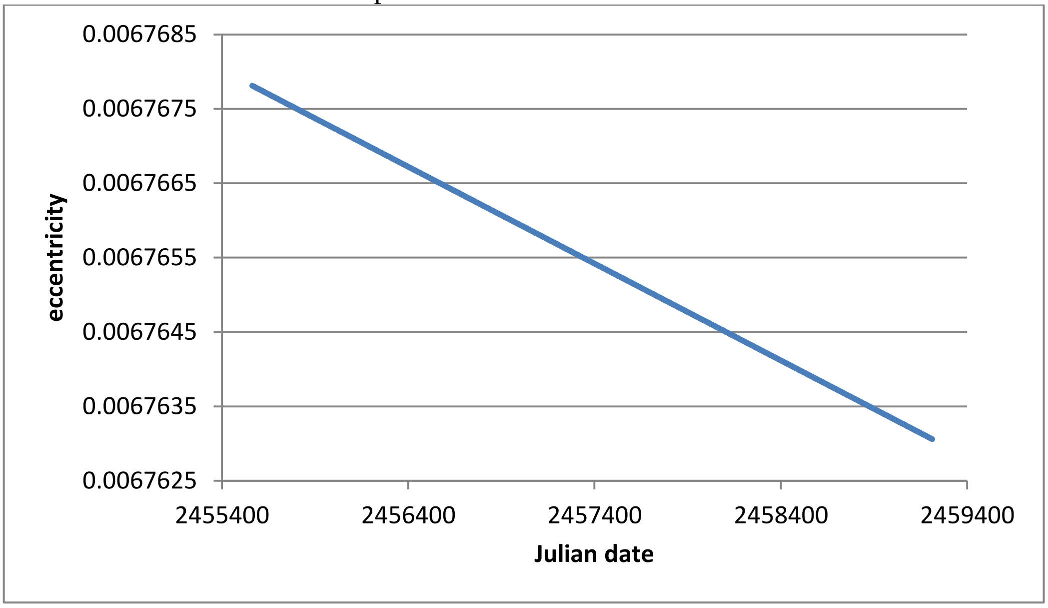

Figure 1- The eccentricity of Venus orbit with J.D. through 10 years.

Figure-2 shows the inclination (i) of Venus orbit with Julian date through 10 years. The figure shows long-term non-periodic variation of values needing millions of years to exhibit obvious changes. The orbital inclination to the ecliptic has value linearly decreasing from 3.395371564 degree to 3.395291449 degree and it's expected to decrease by $8.011499999983\times10^{-5}$ degree every 10 years and complete 180 degree during 22467702.677449 years.

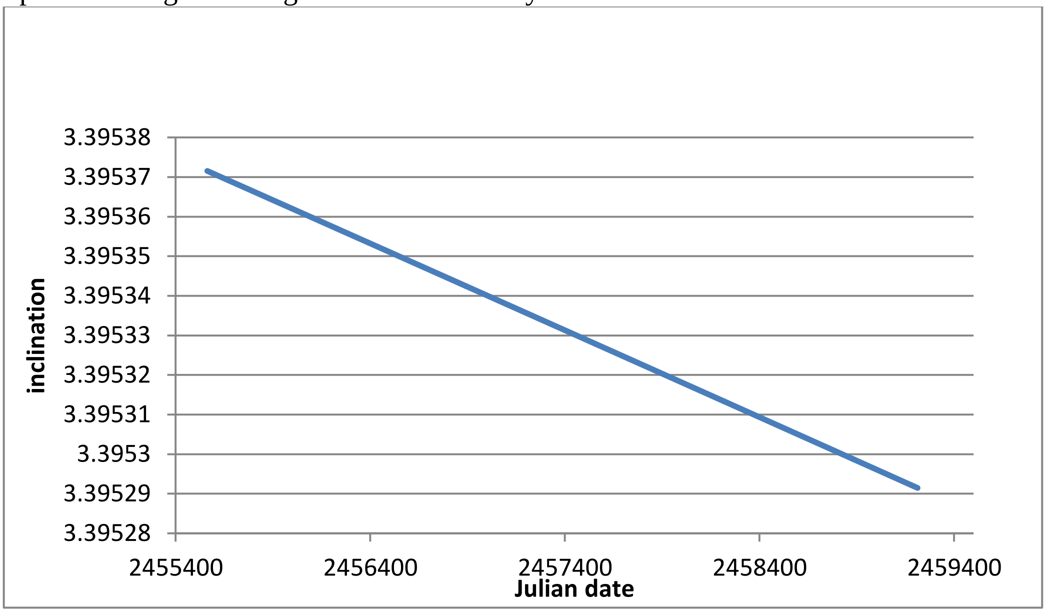

Figure 2-The inclination (degree) of Venus orbit with J.D. through 10 years.

Figure-3 shows the argument of perihelion (ω) of Venus orbit with Julian date through 10 years, its value linearly increases and varies from 54.63463355 degree to 54.66350479 degree and it's expected to increase by 0.028871240000001 degree every 10 years and complete 360 degree during 124691.56156784 years. This type of variation is secular variation due to perturbations from the Sun and planets especially the Earth, Mercury and Jupiter.

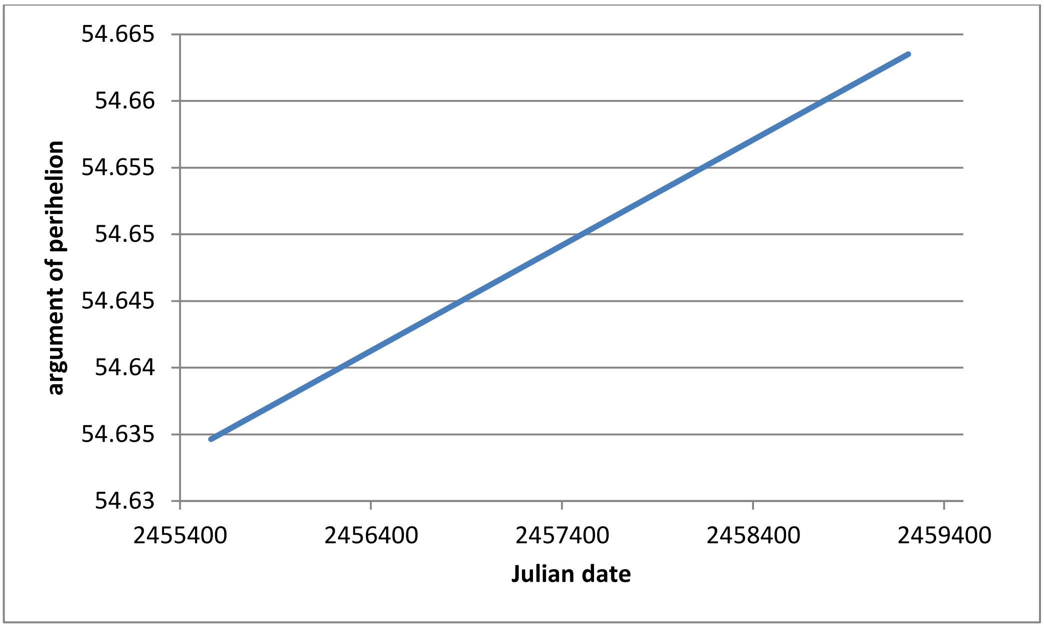

Figure 3-The argument of perihelion (degree) of Venus orbit with J.D. through 10 years.

Figure-4 shows the longitude of ascending node (Ω) of Venus orbit with Julian date through 10 years, its value linearly decreases and varies from maximum 76.92719509 degree to minimum 76.89944306 degree and it's expected to decrease by 0.027752030000002 degree every 10 years and complete 360 degree during 129720.24028512 years.

Figure 4-The longitude of ascending node (degree) of Venus orbit with J.D. through 10 years.

Figure-5 shows the mean anomaly (m_n) of Venus orbit with Julian date through 10 years. It increases at a uniform rate from 0 to 360 degree every one orbital period which mean value equal to 224.73 days.

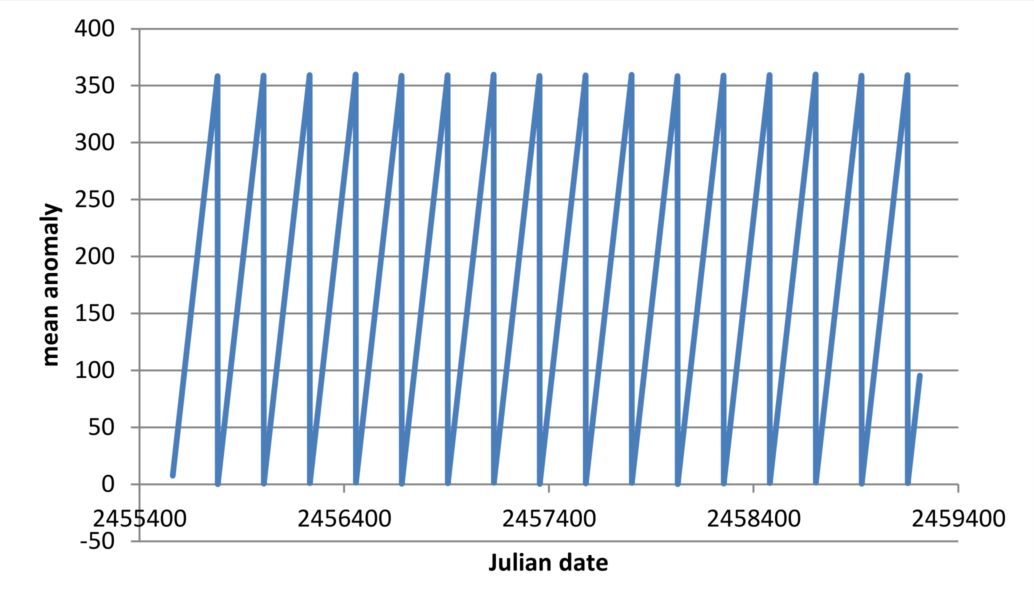

Figure 5-The mean anomaly (degree) of Venus orbit with J.D. through 10 years.

Figure-6 shows the distance (r) between Venus and Sun with Julian date through 10 years. The figure shows that the distance various between the minimum at perihelion and maximum at aphelion through one orbital period and through many periods the minimum distances values are nearly 0.71843 AU and the maximum distances values are nearly 0.72822 AU through 10 years (2011-2020) because the planet orbit around the Sun is an elliptical so the distance varies depending on the position of planet in the orbit. The mean distances are 0.72333 AU where this value is agreed with the semi-major axis of Venus orbit. The time between two minimum or two maximum values represent the time of period for Venus orbit around the sun which mean value equal to 224.73 days. The minimum and maximum distances values are not constant, they vary through the time and this variation is because of the perturbation effect of other planets.

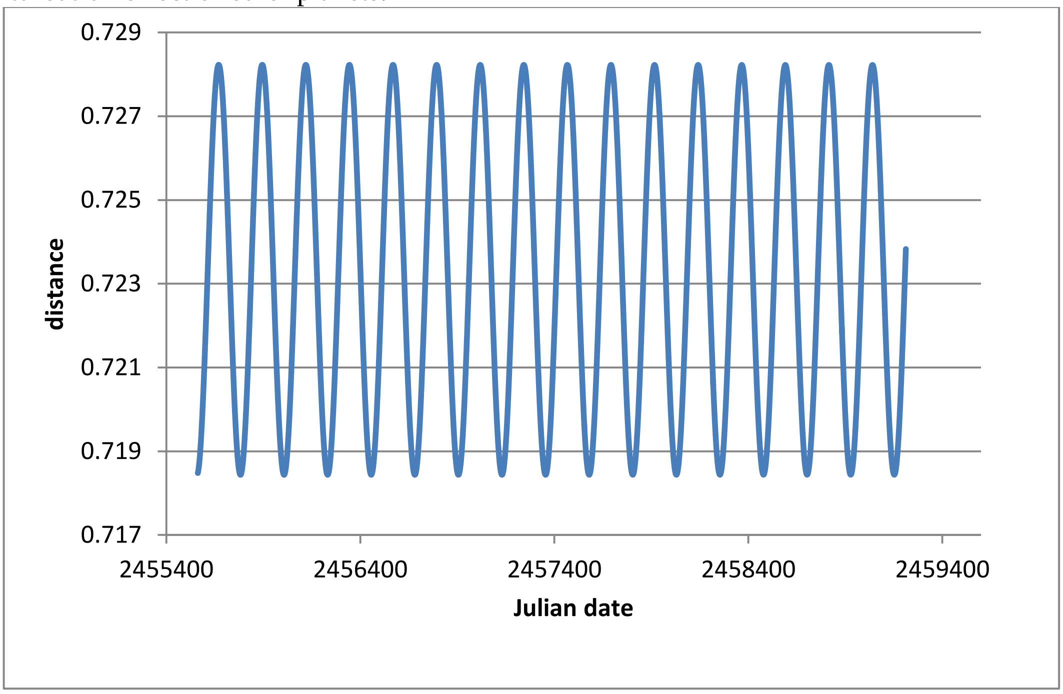

Figure 6-The distance (AU) between Venus and Sun with J.D. through 10 years

Figure-7 shows the right ascension (α) of Venus with Julian date through 10 years. The figure shows that the right ascension changes from 0 hr to 24 hr and shows that there are sudden decreases due to the apparent retrograde motion of Venus as seen from Earth because the Earth and Venus orbital periods or velocities around the sun are different, where Venus is faster than Earth as well as because Venus orbit is inside the Earth orbit. The retrograde values occur nearly every 584 days when Venus is close to the inferior conjunction and last nearly 40 days. In this figure there is a sudden jump in value of right ascension between 0 hr and 23.9 hr, in fact these two values are near of each other.

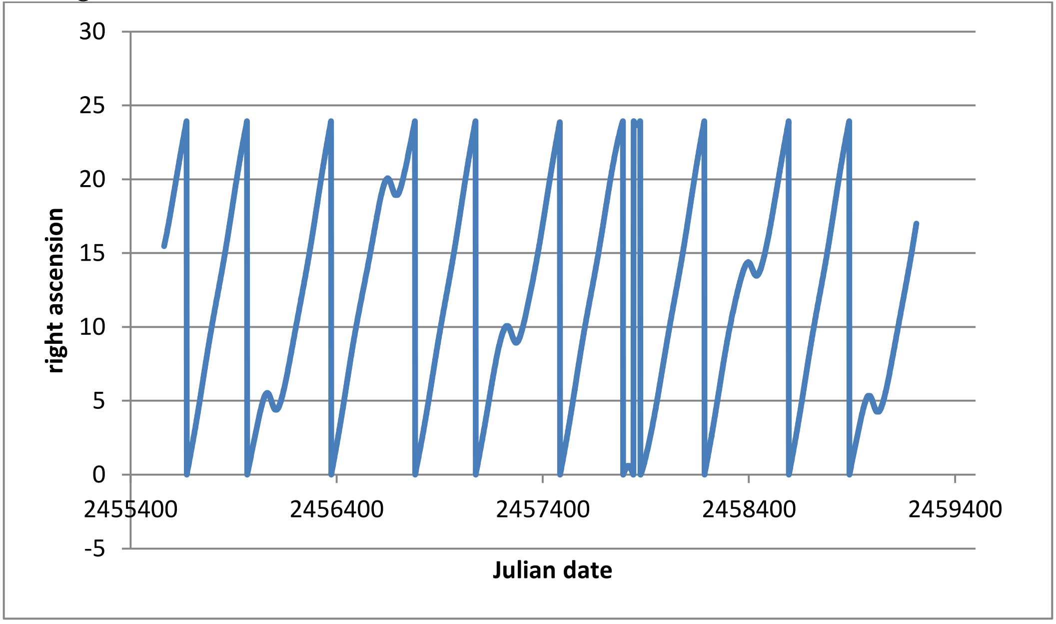

Figure 7-The right ascension (hr.) of Venus with J.D. through 10 years.

Figure-8 shows the declination (δ) of Venus with Julian date through 10 years. The figure shows that the declination various from -28 to 28 degree through many periods and shows that the maximum and minimum declination values of Venus are not constant, they are changing from period to another because of the variation in the gravity effect of the planets on Venus because the continuous positions change. The figure also shows sudden changes due to the motion of Venus as seen from Earth because the Earth and Venus periods around the sun are different and also because Venus orbit is inside the Earth orbit, these sudden changes occur approximately every 584 days due to the apparent retrograde motion.

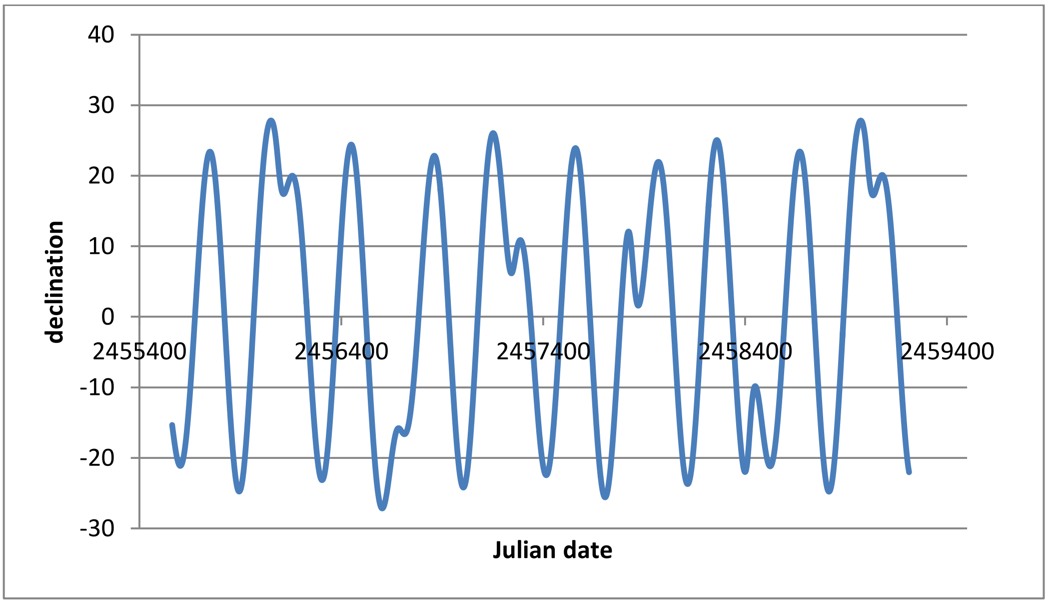

Figure 8-The declination (degree) of Venus with J.D. through 10 years.

9. Conclusion

The main important conclusion that gets through 10 years 2011-2020 from this research could be summarizing as follows:

1- The variation of orbital elements of Venus is secular variation affected by the gravitational attraction of the Sun and planets.
2- The eccentricity (e) is linearly decreasing from 0.006767811 to 0.006763061.
3- The inclination (i) is linearly decreasing from 3º.395371564 to 3º.395291449.
4- The argument of perihelion (ω) is linearly increasing from 54º.63463355 to 54º.66350479.
5- The longitude of ascending node (Ω) was is linearly decreasing from 76º.92719509 to 76º.89944306.
6- The mean anomaly (m_n) is increasing at a uniform rate from 0º to 360º every 224 or 225 days.
7- The results have proved that the stability of Venus orbit is high.
8- The equatorial and horizontal coordinates of Venus have showed an apparent retrograde motion occurs every 584 years and lasts nearly 40 days.
9- The distance between Venus and the Sun changed through many periods between the minimum value of 0.71843 AU to maximum value of 0.72822 AU and the mean distance was 0.72333 AU where was agreed with the semi-major axis of Venus orbit.

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