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The Moon, Sun and Jupiter coordinates and distances variation through 100 years

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Abstract

In this research calculate the ecliptic and equatorial coordinates for the Moon , Sun and Jupiter through 100 years and calculate the distances between the Moon and the Earth , the Sun and the Earth , Jupiter and the Sun, Jupiter and the Earth . From Calculation and discussion the changes in the equatorial coordinate were: $\Delta\delta m = (28.23 + 27.36 , 27.78 + 27.78)$, Δ δ_J = (22.73+21.93, 23.28+22.99) , and the maximum values and minimum values for the Moon were: $R_{m(min)}$ = 0.00239,0.00240 and $R_{m(max)}$ = 0.0027,0.00272 , and Jupiter $R_{J(min)}$ = 4.99077,4.99966 and $R_{J(min)}$ = 5.44469,5.45057 , and the periods change preface to calculate the conjunction of the Moon and Jupiter.

Keywords: Moon orbit, Jupiter orbit, Sun-Moon distance, Jupiter-Earth distance.

التغيرفي الاحداثيات والمسافات للقمر،الشمس والمشتري خلال 100عام

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الخلاصة

تم في هذا البحث حساب الاحداثيات البروجية والاستوائية للقمروالشمس وكوكب المشتري خلال مئة عام وحساب المسافات بين القمروالارض والشمس والارض والمشتري والشمس والمشتري والارض وتمت حساب ومناقشة تغيرات الاحداثيات = Δ δ_J , $\Delta\delta m = (28.23 + 27.36 , 27.78 + 27.78)$ (22.73+21.93, 23.28+22.99) والمسافات اعلاه وحسبت القيم العظمى والصغرى للقمر وكانت $R_{m(min)}$ = $R_{m(max)}$ = 0.00239,0.00240 0.0027,0.00272 وللمشتري $R_{J(min)}$ = 4.99077,4.99966 , $R_{J(min)}$ = 5.44469,5.45057 ودورات التغير فيها تمهيدا لحساب الاقتران بين كوكب المشتري والقمر.

1. Introduction

The Earth revolves around the Sun in an elliptical orbit, and its Moon follow elliptical orbits around the Earth also, this is called lunation [1]. The Moon rotates in the same direction as the Earth rotates around the Sun [2]. The Moon ellipse orbit with a mean eccentricity $^{(e)}$ which is defined as the ratio of the difference between the major and minor axis to the major axis is 0.055[3], (0.056 or 0.0549) [4] or 0.058 [5].Inclination of the lunar orbit to the ecliptic plane is about 50(varies from 4 059' to 50 17') [6,7]. The orbit of the Moon is inclined from the Earth orbit about (5^0.9'), it's intersects with Earth's orbit in two points, these points are called the ascending node and descending node, according to the

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motion of the Moon south or north for the Earth orbit [8]. The distance between the Moon and the Sun is between (147×10^6-152×10^6 km)[9].

The moon mean orbital velocity is 1.023 km/s [10], its moves relative to the stars 1.0248 km/s (our calculation).

The orbit of Jupiter, like that of all the planets, is elliptical instead of circular around the Sun. The elliptical orbit of Jupiter is inclined 1.303° compared to the Earth. The orbit eccentricity is 0.048498. Jupiter's mean distance from the sun is 5.2 AU At perihelion (closest approach) Jupiter comes within 740.55 million km, or 4.95 (AU) of the Sun. At its most distant point, called aphelion, Jupiter is 817 million km, or 5.46 AU from the Sun. The average between perihelion and aphelion is called the semi-major axis. Jupiter's semi-major axis is 778.299 million km, or 5.202 AU [11- 13].

In this work the coordinates and distances of the Moon and Jupiter are calculated and discussed there orbital elements and its variation with time as an introduction to study the conjunction between them.

2. The Sun and the Moon Coordinates Calculation:

2.1. Coordinates of the Moon

The Moon's longitude (λ_m) and latitude (β_m) is given by [14]:

$$\lambda_m = 218.316 + 481267.881\, T_2 + 6.29 \sin(134.9 + 477198.85\, T_2) - 1.27 \sin(259.2 - 413335.38\, T_2) + 0.66 \sin(235.7 + 890534.23\, T_2) + 0.21 \sin(269.9 + 954397.7\, T_2) - 0.19 \sin(357.5 + 35999.05\, T_2) - 0.11 \sin(186.6 + 966404.05\, T_2) \quad (1)$$

$$B_m = 5.13 \sin(93.3 + 483202.03\, T_2) + 0.28 \sin(228.2 + 960400.87\, T_2) - 0.28 \sin(318.3 + 6003.18\, T_2) - 0.17 \sin(217.6 - 407332.2\, T_2) \quad (2)$$

Where:

T_2 : The number of Julian centuries from the epoch J2000 as in [15, 16].

The Moon ecliptic coordinate (λ_m , B_m) converted to equatorial coordinate (α_m,δ_m) as in [15].

2.2. The Earth Moon distance

The Moon's distance from the center of the Earth can be calculated as the following empirical formula [14, 15].

$$R_m = 385000.56 - 20905.355 \cos M - 3699.111 \cos(2D - M) - 2956.968 \cos(2D) - 569.925 \cos(2M) + 48.888 \cos(M_s) - 3.149 \cos(2F) + 246.158 \cos(2M - 2D) - 152.138 \cos(M + M_s - 2D)\ (km) \quad (3)$$

Where:

$$M = 134°.96292 + 477198°.86753\, T_2 + 0°.0087414\, T_2^2 \quad (4)$$

M: The Moon's mean anomaly.

$$M_s = 357°.52543 + 35999°.04944\, T2 - 0°.0001536 T2^2 \quad (5)$$

M_s: The Sun's mean anomaly.

$$D = 297°.85027 + 445267°.11135\, T_2 - 0°.0018819 T_2^2 \quad (6)$$

D: The difference between the mean longitudes of the Sun and the Moon.

$$F = 93°.27209 + 483202°.01752\, T_2 - 0°.0036539\, T_2^2 \quad (7)$$

F: The Moon's argument of latitude.

2.3. The Sun coordinate and the Earth Sun distance

The longitude of the Sun on the epoch J1900.0 was 280.46, and the rate at which the Earth is going round the Sun is 0.985647359 per day (from equinox to equinox), the Mean longitude of the Sun is given by [17]:

$$L_s = 279°.69668 + 36000°.76892\, T + 0°.0003025\, T^2 \quad (8)$$

T: The number of Julian centuries elapsed since midday of beginning of 1st January 1900 as in [15, 16].

The Sun's equation of the center C_s is given as [14] [15]:

$$C_s = 1°.914602 - 0°.004817\, T_2 - 0°.000014 T_2^2 \sin(M_s) + (0°.019993 - 0°.000101 T_2) \sin(2M_s) + 0°.000289 \sin(3M_s) \quad (9)$$

The Sun true longitude (λs) can be calculated using this equation [14, 15].

$\lambda s = L_s + C_s$. (10)

For more accuracy some correction adding to the (λs) [15].

$$A = 153.23 + 22518.7541\, T \quad (11)$$

$$B = 213.57 + 45037.5082 T \quad (12)$$

$$C = 312.69 + 32964.3577\, T \quad (13)$$

D=350.74+445267.1142 T-0.00144 T^2 (14)
E=231.19+20.20 T (15)
$\lambda s'$ = 0.00134 COS (A) + 0.00154 COS (B) + 0.00200 COS (C) + 0.00179 SIN (D) + 0.00178 SIN (E) (16)
The correction adding to (λs) is given by:
$\lambda s = \lambda s + \lambda s'$ (17)
Without an error the Latitude (β*s)* of the Sun can be considered zero as it remains on the ecliptic.
The Sun's true anomaly Vs is given as [14, 15].
$Vs=Ms+ Cs$ (18)
The distance between the centers of the Sun and the Earth, expressed in Astronomical Units (A.U.), is given as [14, 15]:
$R_s= 1.000001018(1-e^2) / (1+e \cos V_s)$ (19)
Where
e :The eccentricity of Earth orbit calculated as [14]:
$e = 0°.016708634 – 0°.000042037\ T_2 – 0°.0000001267\ T_2^2$ (20)
For more accuracy some correction adding to the (Rs) [15].
R_s' = 0.00000543 sin (A) + 0.00001575 sin(B) + 0.00001627 sin (C) + 0.00003076 cos (D) + 0.00000927 sin (H) (21)
Where:
H=353.40+65928.7155T (22)
$R_S = R_S + R_S'$ (23)

3. Jupiter calculation:

3.1. Jupiter distance from the Sun

The distance of Jupiter from the Sun its can be calculated by using the orbital elements (Inclination (i), Longitude of the ascending node (Ω), Argument of the perigee (ω), Semi-major axis (a) , Eccentricity (e) ,Jupiter mean anomaly(M_J)) for can be calculated from these equations [15].
L = 238.049257 +3036.301986 T + 0.000 3347 T^2 – 0.00000165 T^3 (24) Where:
L=mean longitude of the planet, a= 5.202561 (25)
e = 0.04833475 + 0.000164180 T – 0.0000004676 T^2 - 0.00000000010 T^3 (26)
i = 1.305288 – 0.0022374 T_2 + 0.000 02942T_2^2 +0.000000127 T_2^3 (27)
ω = 273.329584 +0.0478404 T_2 -0.00021857 T_2^2 + 0.000008999 T_2^3 (28)
Ω = 100.287838 + 0.1659357 T_2 +0.00096672T_2^2 – 0.000012460 T_2^3 (29)
M = L – ω – Ω (30)
Use the planet's mean anomaly (M_J) to calculate Eccentric anomaly (E) by using the kepler equation [18].
$$E = M + e_o \sin E \quad (31)$$
This equation is called Kepler's equation, where e convert from radians into degrees which is denoted by e_o.
$$e_o = e \times \frac{180}{\pi} \quad (32)$$
Equation (31) iterated to accuracy 0.00000001.
The distance of Jupiter from the Sun is calculated as [15]:
$$r = a(1 - e\cos E) \quad (33)$$
The true anomaly (f) of Jupiter is calculated as [19].
$$\tan\frac{f}{2} = \sqrt{\frac{1+e}{1-e}}\,\tan\frac{E}{2} \quad (34)$$

3.2. Jupiter coordinates from the Earth

The planet's argument of latitude calculates as [15].
$U = L + f - M - \Omega$ (35)
The ecliptic longitude (l') is calculated as [15]:
Tan ($l' – \Omega$) = Cos (i) tan (U) (36)
The planet's ecliptic latitude (b_J) is calculated as [15]:
Sin b_J= sin (U) sin (i), With $-90 < b_J < +90$. (37)

Then we find the planet's geocentric longitude (λ_J):

$N = r\cos b_J \sin(l' - \lambda s)$ (38)

$D = r\cos b_J \cos(l' - \lambda s) + R_S$ (39)

$\tan(\lambda_J - \lambda_s) = \frac{N}{D}$ (40)

λs: The sun true longitude.

R_S: The distance between the centers of the Sun and the Earth.

N: Numerator.

D: Denominator.

3.2. Jupiter distance from the Earth

The Jupiter distance to the earth (Δ) calculated in (A.U) as [15].

$\Delta^2 = N^2 + D^2 + (r \sin b_J)^2$ (41)

4. The Results and discussions:-

The equatorial coordinates of the Moon, Sun and Jupiter are calculated through 100 years. The maximums and minimums of distances variation are plotted and discussed.

As the follow in the Table-1 the distances of the Moon, Earth and Jupiter are calculated and plot with Julian date through 100 years.

Table 2- The limited distances of the Moon , Sun and Jupiter.

Sky body	Perihelion (A.U)	Aphelion (A.U)	a (A.U)	Δr100% (A.U)
Moon	0.00239	0.00272	0.002555	0.129
Sun	0.9838	1.01516	0.99948	0.0313
Jupiter	4.99966	5.45057	5.225115	0.08629

$\Delta r = \frac{Aphelion - Perihelion}{a}$ (42)

The distance of the Moon variation with Julian date through many periods through the dates (2000 – 2100). The minimum values distance (Perihelion) change between (0.00239, 0. 00240) A.U, and the maximum values distance (Aphelion) change between (0.0027, 0.00272) A.U. As show in Figure- (1a, b) the distance of the Moon varies quickly because it's have a small period (27.3) days respect to star, the reasons of the change the perihelion and aphelion are the effect of the others body attraction as the Sun and near planets.

The declination of the Moon with Julian date through many periods through the dates (2000 – 2100). The minimum values change between ($^-$27.36, $^-$27.78) degree, and the maximum values change between (28.23, 27.78) degree, as show in Figure- (2 a, b).

The right ascension of the Moon with Julian date through many periods through the dates (2000 – 2100). The minimum values change between (0.89, 1.08) hour, and the maximum values change between (23.48, 23.78) hour. The right ascension of the Moon varies between (0 – 24) hour, every 3 months the minimum and maximum values changed as show in Figure- (3 a, b).

The variation in the declination and right ascension mean the inclination of the Moon orbit are change by the attraction of the Sun and other planets.

The distance of the Sun variation with Julian date through many periods through the dates (2000 – 2100). The minimum values distance change between (0.9833, 0.9838) A.U, and the maximum values distance change between values distance n (1.01504, 1.01516) A.U, as show in Figure-4. The reason of this variation is the near planets on the Earth.

The variation of Jupiter distance from the Sun with Julian date through many periods through the dates (2000 – 2100) .The minimum values distance change between (4.99077, 4.99966) A.U, and the maximum values change between (5.44469, 5.45057) A.U, as show in Figure-5.

The declination of Jupiter with Julian date through many periods through the dates (2000 – 2100).The minimum values change between (-21.93,-22.99) degree, and the maximum values change between (22.73, 23.28) degree. The declination of Jupiter varies between (-23.5, +23.5) degree, as show in Figure-6.

The right ascension of Jupiter with Julian date through many periods through the dates (2000 – 2100).The minimum values change between (1.93, 2.4) hour, and the maximum values change from (23.73, 23.93) hour, as show in Figure-7.

The distance of Jupiter from the Earth with Julian date through nine periods through the dates (2000 – 2100).The minimum values distance change between (4.4131123, 4.4261544) A.U, and the maximum values change between (6.1031682, 6.1303146) A.U, there is some variation in the maximum and minimum values distances from one period to another, as show in Figure-8.

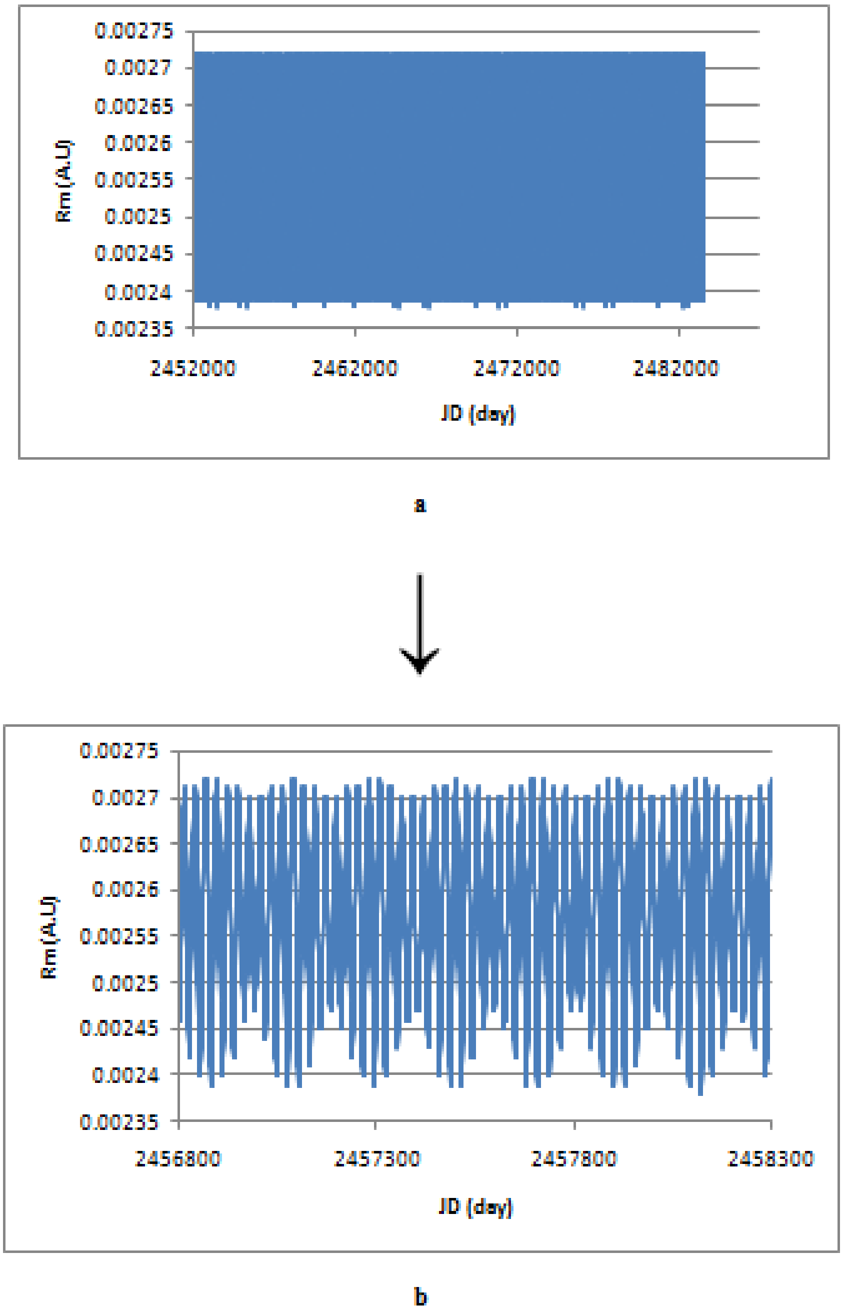
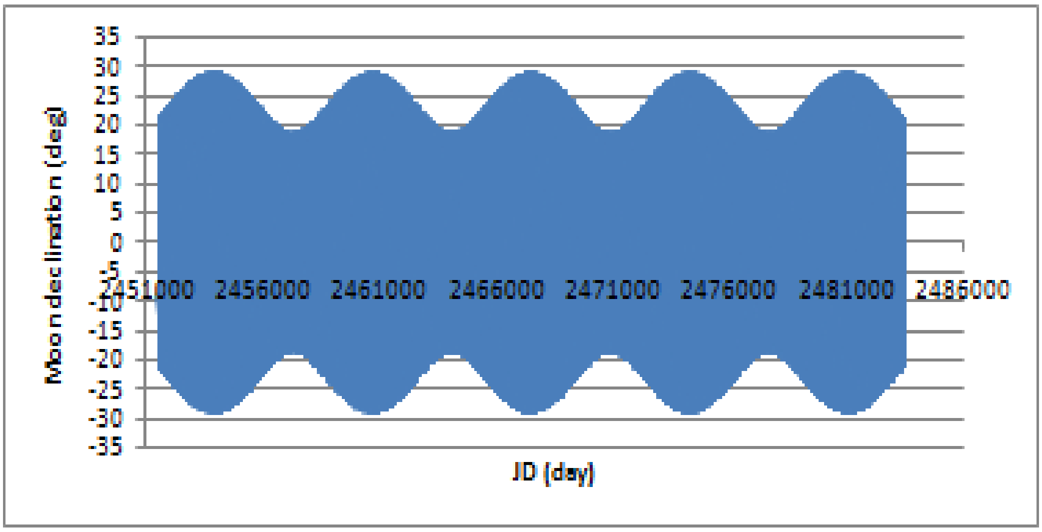
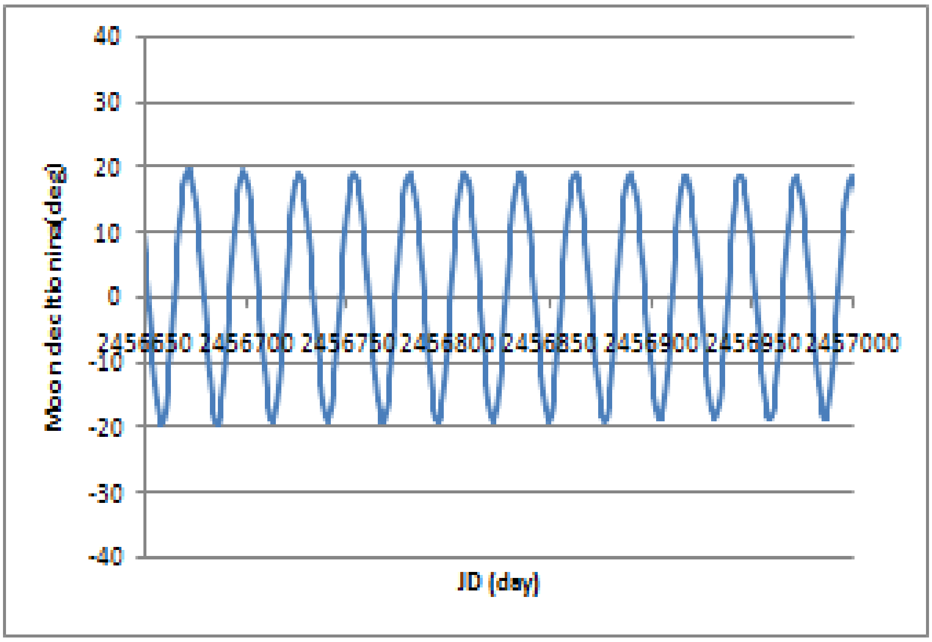


Figure 1- a,b The variation of the Moon's distance with Julian date through 100 years.

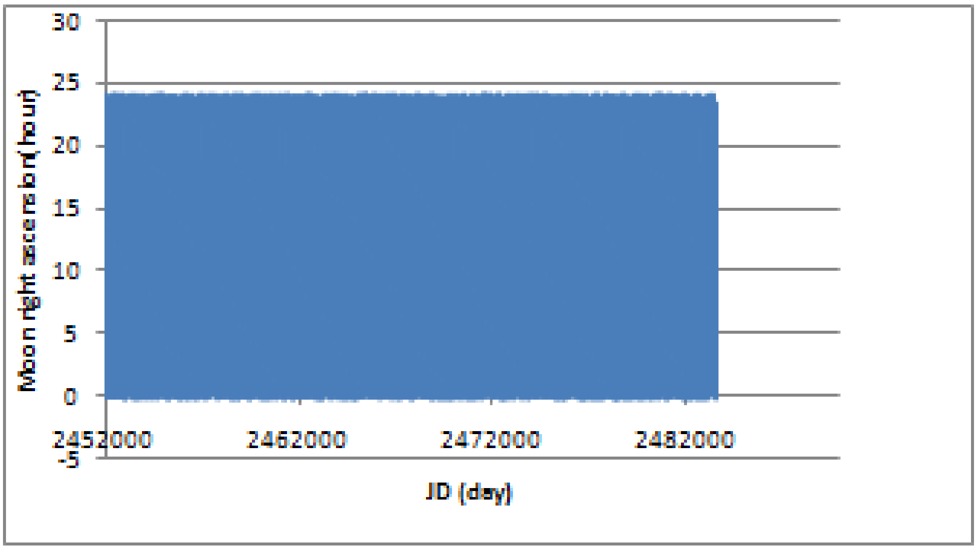


a

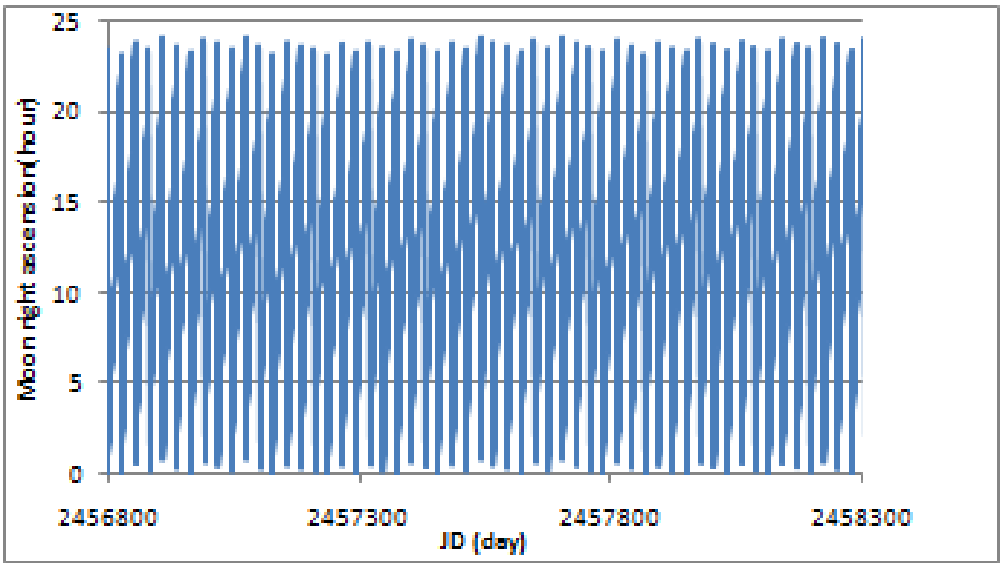


b

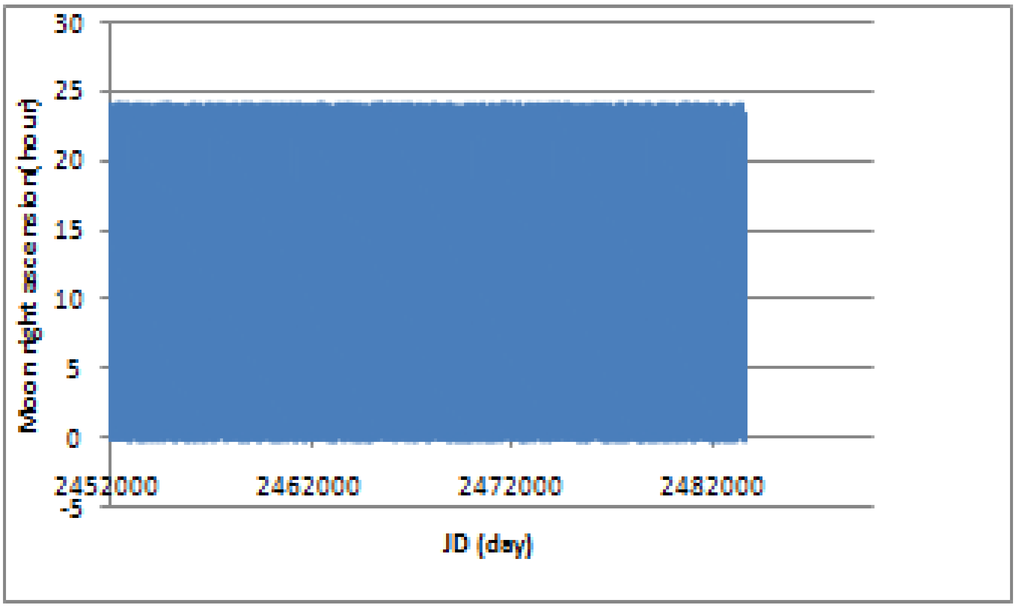
Figure 2- a,b The variation of Moon declination with Julian date through 100 years.


30
25
20
15
10
5
0
-5
Moon right ascension(hour)
2452000
2462000
2472000
2482000
JD (day)

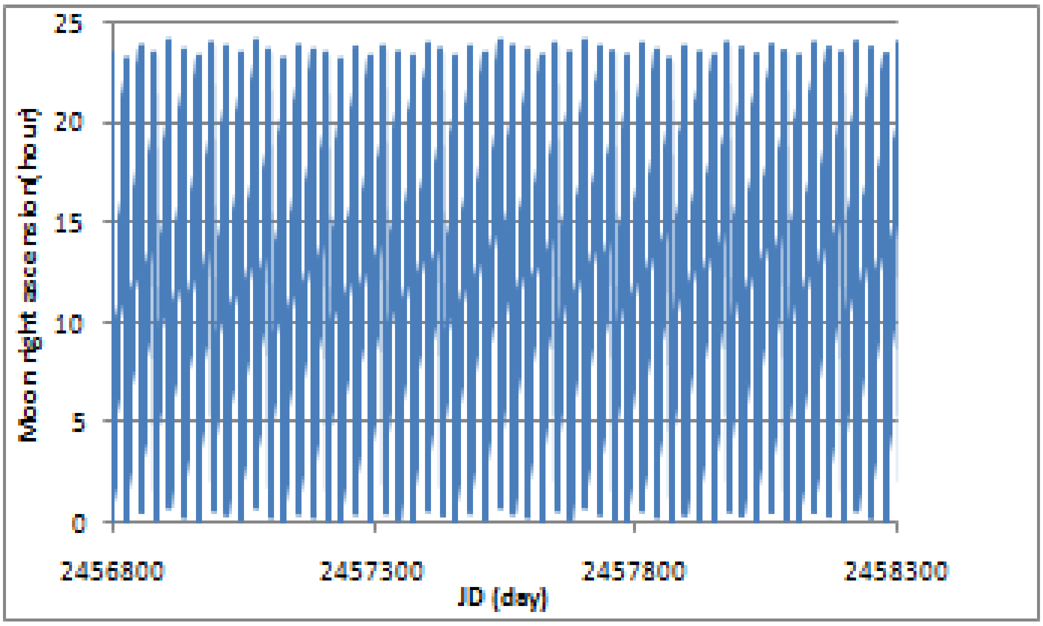
a


25
20
15
10
5
0
Moon right ascension(hour)
2456800
2457300
2457800
2458300
JD (day)

b

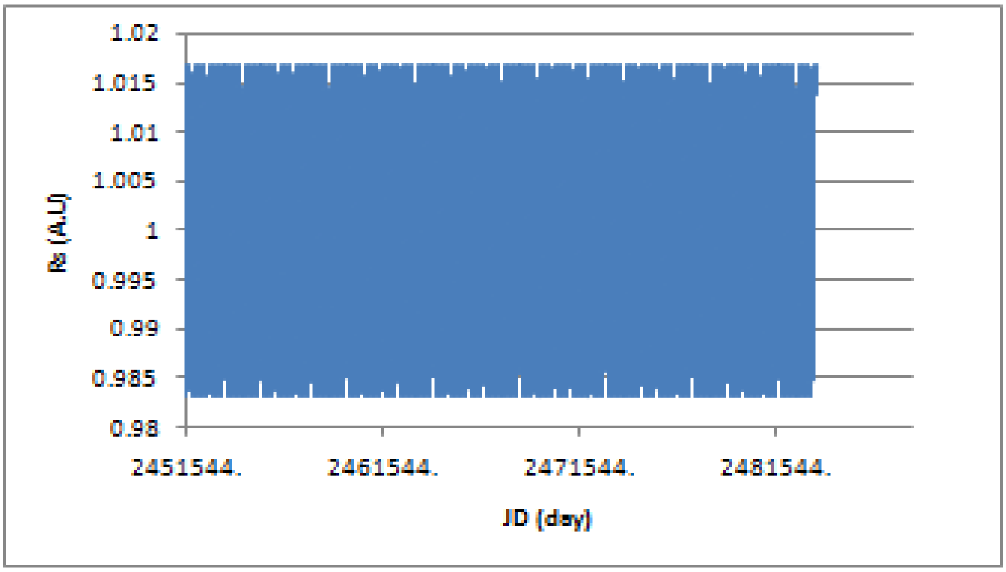


a

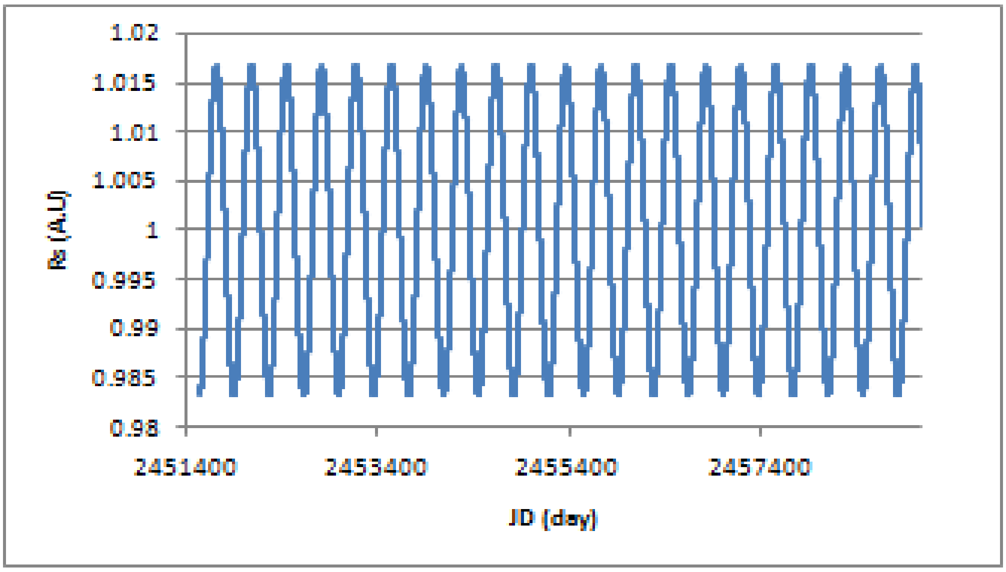


b

Figure 3- a,b The variation of the moon right ascension with Julian date through 100 years.



a



b

Figure 4- a,b The variation of the Sun's distance with Julian date through 100 years .

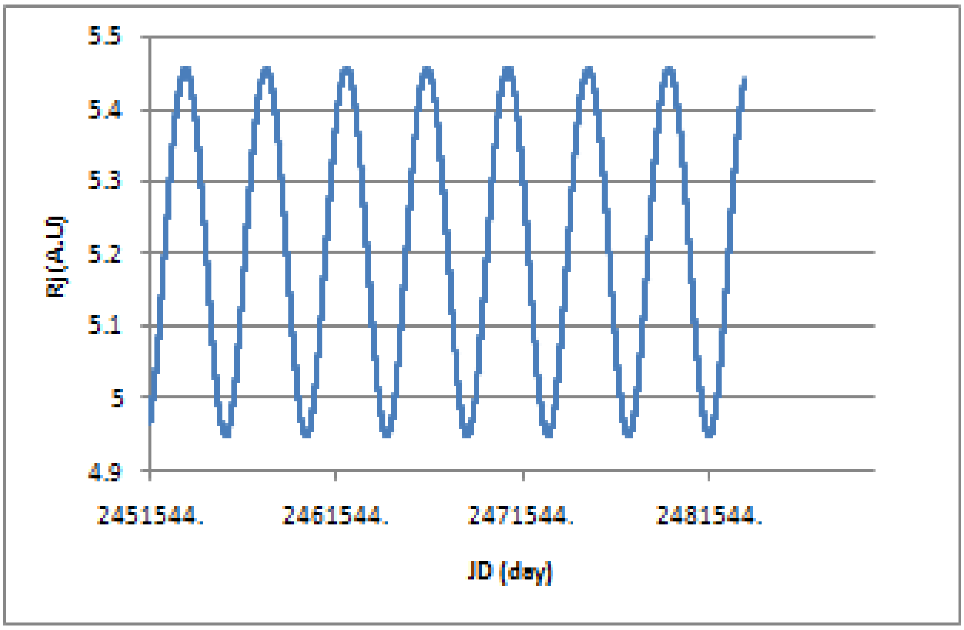


Figure 5 - The variation of Jupiter's distance with Julian date through 100 years.

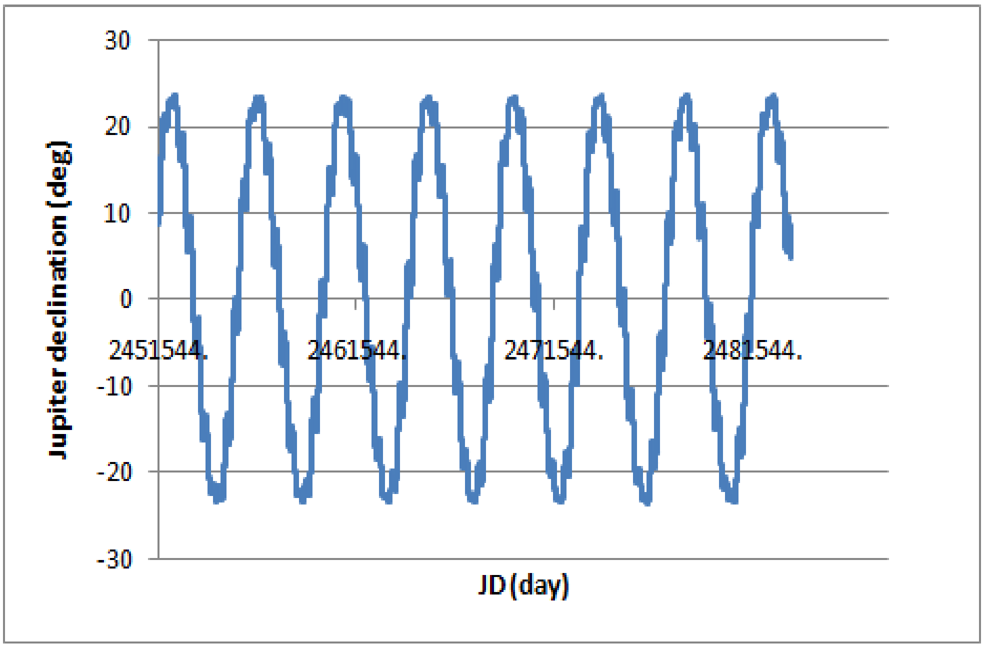


Figure 6- The variation of the Jupiter's declination with Julian date through 100 years.

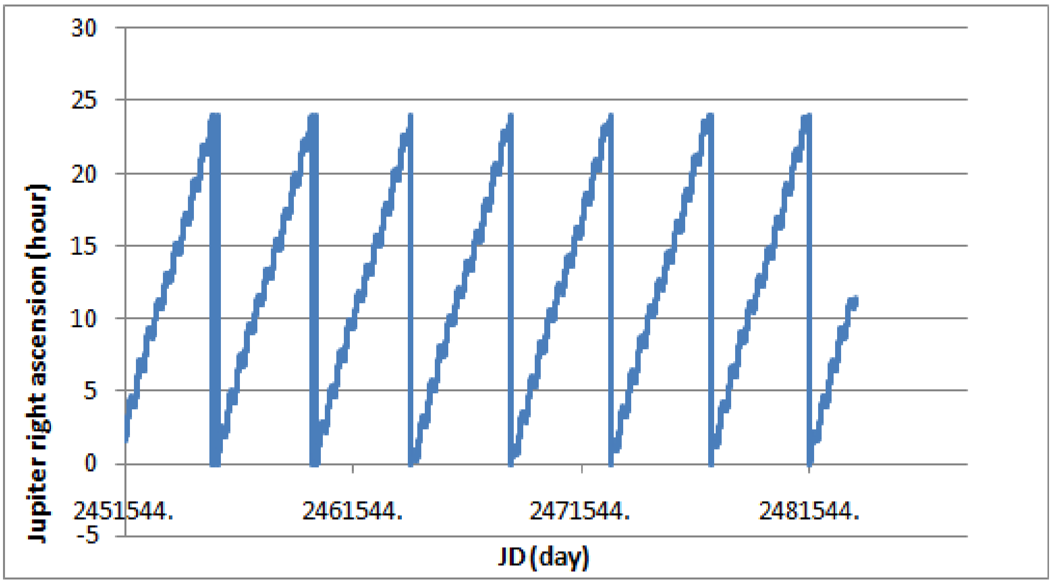


Figure 7- The variation of the Jupiter's right ascension with Julian date through 100 years .

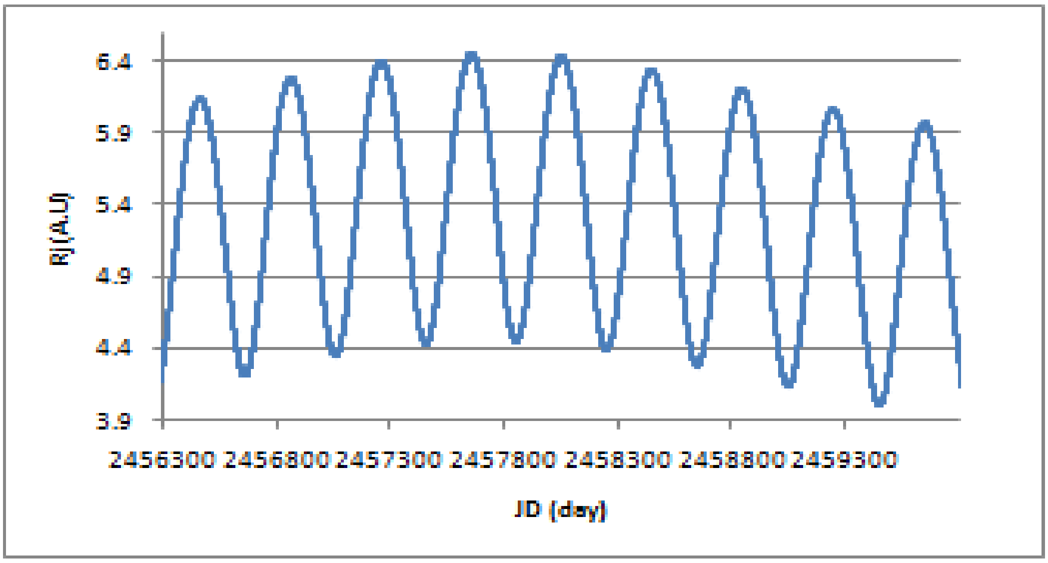


Figure 8- The variation of Jupiter distance from the Earth with Julian date through 100 years.

5- Conclusions

In this work we can conclude the following :

1- The maximum and minimum values for the coordinates of the Moon and Jupiter $\Delta\delta m = (28.23 + 27.36\,,27.78 + 27.78)$ and $\Delta\ \boldsymbol{\delta}_J$ = (22.73+21.93, 23.28+22.99).

2- The perturbation that appear in the distance of Jupiter and it's coordinates caused by the effect of the inner planets as for example the effect ration of the gravity of mars on Jupiter to the gravity of the Sun >/ 0.00000046.

3- The Jupiter-Earth distance have small period (2000 – 2088) years and long period greater than 100 years.

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