The Effect of Dwarf's Planets Pluto and Eris upon Long Period Comets

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Abstract:

The orbit of long period comets overlapped with that of dwarf's planet Pluto and Eris. The gravitational effects arise from dwarf's planets as well as the eight planets have been involved in orbits calculations. The heliocentric distance, equatorial coordinates, total energy and observed magnitude are estimated for each sample according to those conditions. Compare the results with that of two body problem exhibit that a noticeable difference in these values mentioned aforesaid. A variation in the time of a period at present work has been seen than that in previous cases.

Keywords: long period comets, orbit perturbation, dwarf planets, orbital total energy, cometry observed magnitude.

تاثير الكواكب القزمية بلوتو وايرس على المذنبات طويلة الدورة المدارية

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الخلاصة:

تعتبر مدارات المذنبات طويلة الدورة كبيرة بما يكفي لكي تتداخل مع مدار الكوكبين القزمين بلوتو وآيرس مما يؤثر على حركتها فضلا عن تأثيرات كواكب المجموعة الشمسية الثمانية حيث تم حساب هذه التأثيرات على بعد المذنب عن الشمس و الإحداثيات الاستوائية والطاقة الكلية للمدار والقدر الضوئي المرصود للمذنب ومقارنتها مع مثيلاتها في حالة انعدام هذه التأثيرات على المذنب للعينة المختارة من المذنبات وقد اظهرت النتائج وجود تباين ملحوظ في القيم سابقة الذكر فضلا عن التغير الحاصل في مدة الدورة للمذنبات.

الكلمات المفتاحية: المذنبات طويلة الدورة ،اضطراب المدار، الكواكب القزمية، طاقة المدار الكلية، القدر الضوئي المرصود للمذنب.

1. Introduction

Long period comets are subdued to several forces are the sun and eight planets gravitational forces, galaxy tide, stars, molecular clouds, hypothetical disk of matter outside the planetary orbits , non-gravitational forces resulting from outgassing , solar radiation pressure , solar wind pressure and drag [1] as short period comets nevertheless it has large orbits that reach at the end of the solar system towards Oort cloud that made it suffer to further perturbations arise from Trans Neptune objects mainly the two biggest dwarf planets Eris and Pluto [2],[3].

Where Eris are massive than Pluto and other discovered dwarfs as well as its aphelion approach to that of most of the long period comets therefor its essential to insert these effects in the orbits and period calculations to ensure more precise values.

2-The comets dynamics:

2-1 Equation of motion:

The comet equation of motion could be written without perturbation in two body problem as [4].

$$\frac{d^2\vec{r}}{dt^2} = -\frac{G(M_\odot + m)}{r^3}\vec{r} = -\frac{\mu}{r^3}\vec{r} \quad \text{----------- (1)}$$

Where $M_\odot$ and $,m$ are the mass of the sun and comet, G is the gravitational constant, $\vec{r}$ is the comet position vector relative to the sun since $m \ll M_\odot$ so $\mu = GM_\odot$, so the Kepler equation could be derived for this case as follows [5].

$$E_a - \frac{180}{\pi} e \sin E_a = M \quad \text{---------------- (2)}$$

Whereat E_a is an eccentric anomaly, e eccentricity and M is the mean anomaly $M = n(t - \tau)$ --------- (3)

Which n , t and τ are the mean motion, orbital period, instantaneous time and the time of perihelion passage.

Since the comet is facing the major planets in it’s a path so there is a considerable perturbation could affect its orbit may not comparable to the gravitational influence of the sun, but their effect on the comet orbit is remarkable especially for long period comets orbit which makes these effect cause deflection perturbed orbit that about which does not depend planetary disturbances.

It’s clearly that the long period comets (period over 200 years) are most affected than the short period comets by the dwarf planets those are speared after Pluto aphelion.

In general, we could express the perturbed motion of comet by the equation.

$$\frac{d^2\vec{r}}{dt^2} = -GM_\odot \frac{\vec{r}}{r^3} - \sum_{j=1}^{N} GM_j \left(\frac{\vec{r}-\vec{r_j}}{|r-r_j|^3} + \frac{\vec{r_j}}{|r_j|^3}\right) \quad \text{------------------------(4)}$$

Where **N** is number of the major planets and dwarf planets, $\vec{r_j}$, M_j is the position vector and mass of j object (planet or dwarf) and solving it by numerical integral using Adams–Bashforth 4th-order a method for calculating the comet's position and velocity at time t [6].

2-2 Orbital energy:

Since the comet´s velocity in its orbit changed according to the position where an increase nearest the sun as well as perturbation caused by entering the planetary region, mainly the influence of Jupiter, so the comets orbital velocity is given as [7].

$$v^2 = \mu\left(\frac{2}{r} - \frac{1}{a}\right) \quad \text{-------------------------- (5)}$$

Where v , r and a are comets velocity, heliocentric distance and semi major axis of comet orbit.

The energy of comets also changes as a result of its velocity as follows [8].

$$\boldsymbol{E} = \frac{v^2}{2} - \frac{\mu}{r} \text{ -------------------------------- (6)}$$

Where $\boldsymbol{E}$ is the total energy per unit mass of the comet.

2-3 Magnitude variations:

Where the long period comets travel to farther point in the solar system, therefore, the arriving flux will be varying accordingly, so that the total magnitude of active comet will suffer a vibration depending on its position in the solar system hence the observed magnitude of comet $\boldsymbol{m}$ is given by [9]

$$\boldsymbol{m} = \boldsymbol{H_n} + 5\,\boldsymbol{log_{10}}\,\Delta + 2.5\boldsymbol{n}\,\boldsymbol{log_{10}}\,\boldsymbol{r} \quad (7)$$

Where $\boldsymbol{H_n}$ is the magnitude of the comet when it was at (1 AU) from both the sun and earth and it's called the absolute magnitude of the comet, Δ , $\boldsymbol{r}$ are the geocentric and heliocentric distance of the comet in AU., and $\boldsymbol{n}$ is known as the photometric index and its conveniently took the value (4.0) so the equation **(7)** could be written as[10] .

$$\boldsymbol{m} = \boldsymbol{H_{10}} + 5\,\boldsymbol{log_{10}}\,\Delta + 10\,\boldsymbol{log_{10}}\,\boldsymbol{r} \text{ ---(8)}$$

3- Data:

The long period comets have been studied are divided into two groups of comets elliptical orbit and near parabolic orbit where its data are listed in tables (1),(2) [11],[12],[13].

Table (1) characteristics of long period comets with elliptical orbit

Comet	a (AU)	e	q (AU)	i (deg)	ω (deg)	N (deg)	Q (AU)	$H_{10}\,mag$
C/1861G1 (Thatcher)	55.681886	0.983465	0.920700	79.7733	213.4496	31.8674	110.44307	-
C/1887 B2 (Brooks)	99.972096	0.983694	1.630145	104.2738	159.4231	281.5113	198.31404	-
C/1937 P1 (Hubble)	71.039489	0.972499	1.953657	11.5806	147.4924	97.7957	140.12532	-
C/1974 O1 (Cesco)	67.232309	0.979579	1.372951	173.1585	176.7744	165.7415	133.09166	-
C/2005N4 Catalina)	58.555426	0.960656	2.303766	116.6303	136.5459	64.0366	114.80708	14.2
C/2010 G2 (Hill)	96.189835	0.979407	1.980773	103.7452	137.4253	246.7810	190.39889	9
C/2010KW7 (Wise)	99.841841	0.974254	2.570441	147.0608	332.3058	104.7614	197.11324	12.3
C/2014G3 (Panstarrs)	55.687748	0.915637	4.697976	155.8245	147.8033	4.5421	106.67751	6.0
C/2016 A8 (Linear)	35.070324	0.946362	1.881096	148.2119	130.2669	111.2302	68.25955	9.8

Table (2) characteristics of long period comets with near parabolic orbit

Comet	a (AU)	e	q (AU)	i (deg)	ω (deg)	N (deg)	Q (AU)	$H_{10}\,mag$
C/1965 Sl-B (Ikeya-Seki)	103.706666	0.999925	0.007778	141.8610	69.0343	346.9811	207.4055	6.2
C/1998 U5 (Linear)	102.878807	0.987981	1.236452	131.7647	51.1342	66.6506	204.5211	10.9
C/2014 C3 (Neowise)	108.416708	0.982825	1.862025	151.7843	345.8768	204.4069	214.9713	12.0

Where $\boldsymbol{a}$ is semi major axis, $\boldsymbol{e}$ is the eccentricity, $\boldsymbol{q}$ is the perihelion, $\boldsymbol{i}$ is the inclination of comet, $\boldsymbol{\omega}$ is the argument of perihelion and $\boldsymbol{N}$ is the longitude of the ascending node and Q is the aphelion.

4- Calculations and results:

Equation (2) which is the Kepler equation in the case of no perturbation of planets has been solved numerically by Newton method as well as the equation (4) solved by Adams–Bashforth 4th-order method where the dwarf planets Eris and Pluto has been involved in addition to eight planets using Pascal code [6] since the heliocentric distance, geocentric distance and the equatorial coordinates for each comet are listed in tables (1), (2) as a result.

The orbital energy has been computed by equation (6) hence the comet's magnitude was estimated by the relation (8).

The comet heliocentric distance, right ascension of the comet, the total energy of the orbit per unit mass and the observed magnitude of the comet for both perturbed and unperturbed orbits are plotted vs. the time of the period as shown in figures (1),(2),(3),(4).

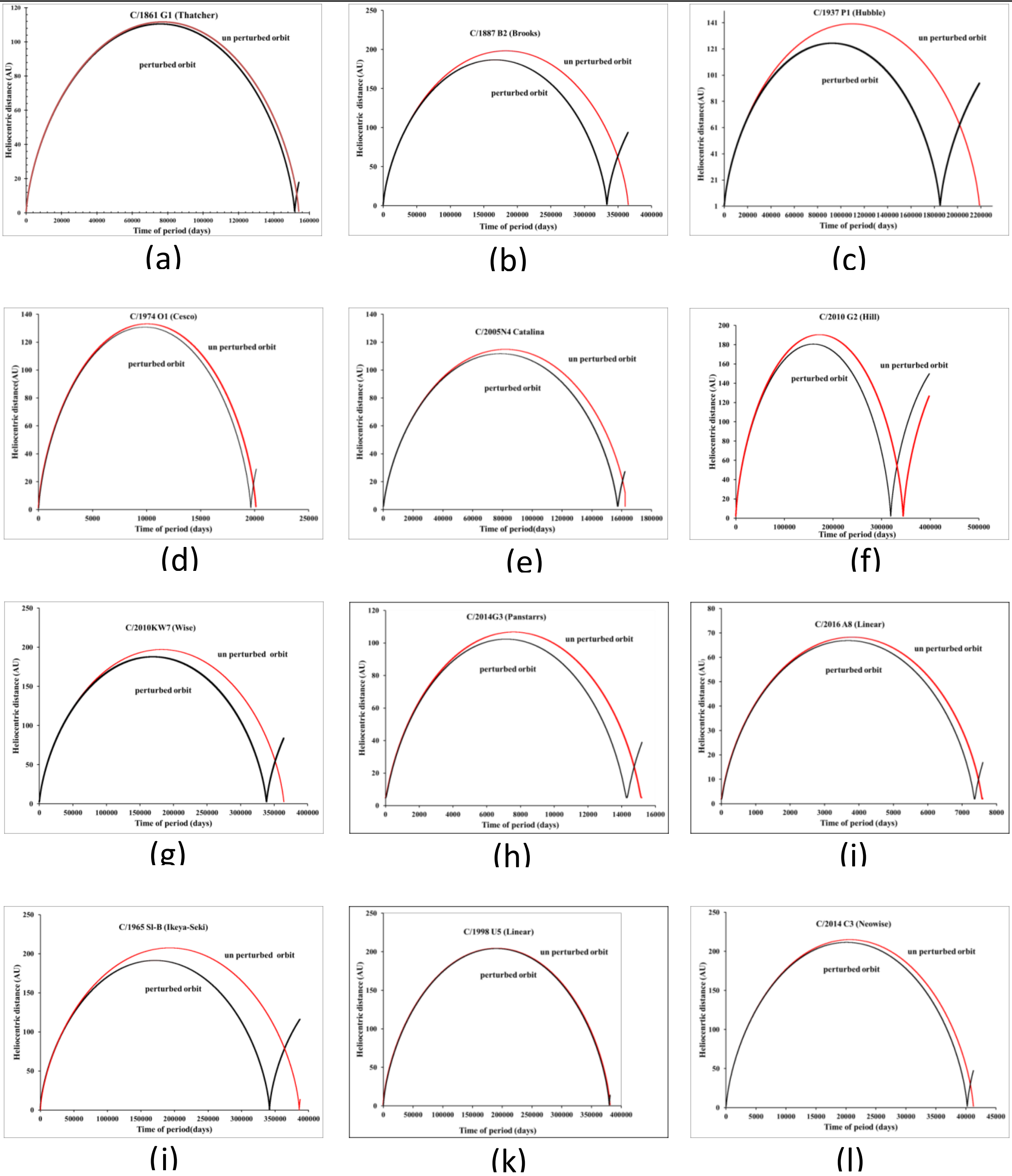


Figure (1)(*a,b,c,d,e,f,g,h,I,j,k,l*) the variation of heliocentric distance with the time of period for perturbed and unperturbed orbit for the comets listed in tables(1)&(2)

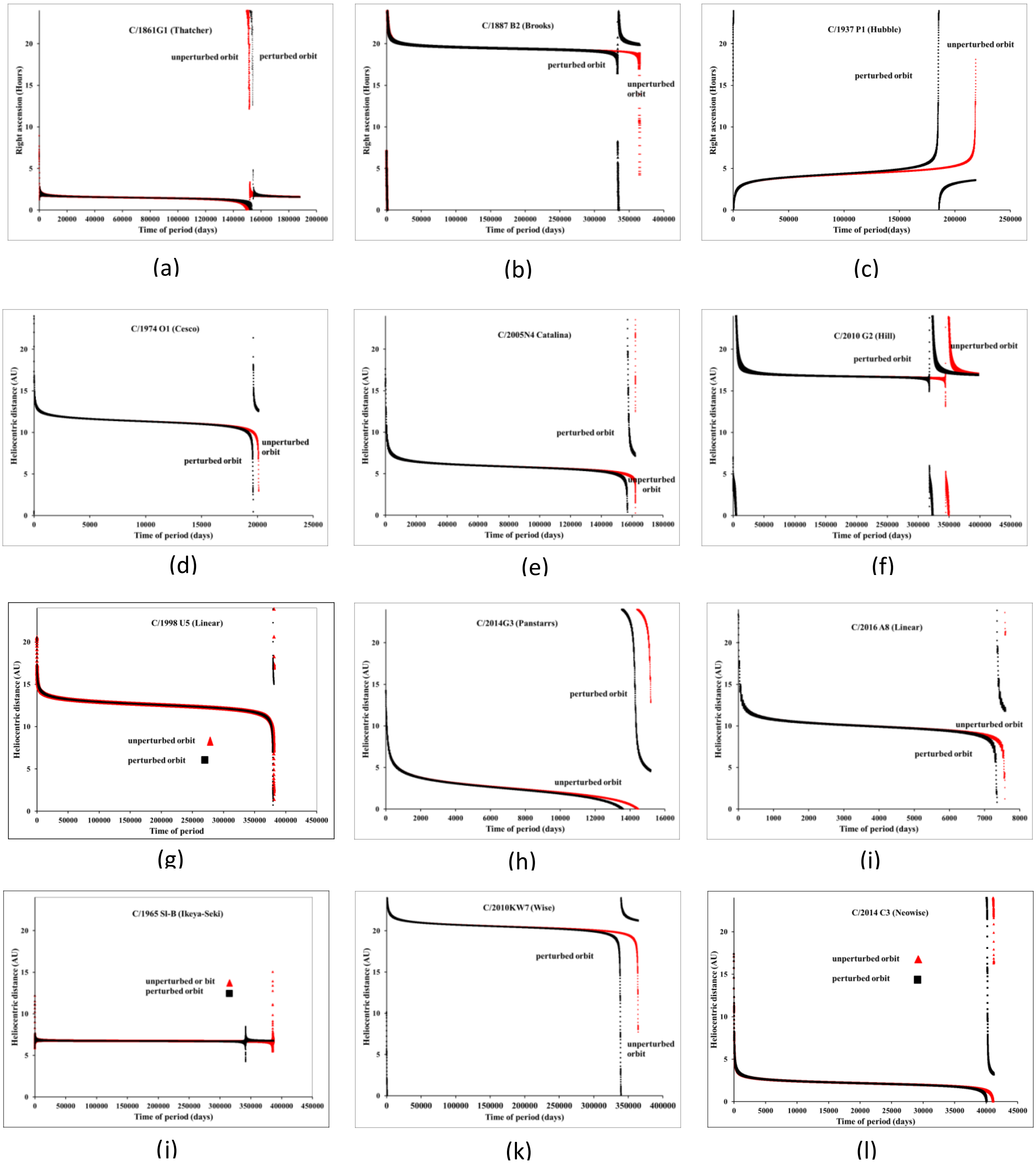


Figure (2) (a,b,c,d,e,f,g,h,I,j,k,l) equatorial coordinates the right ascension of the comets in hours vs. the time of period in days

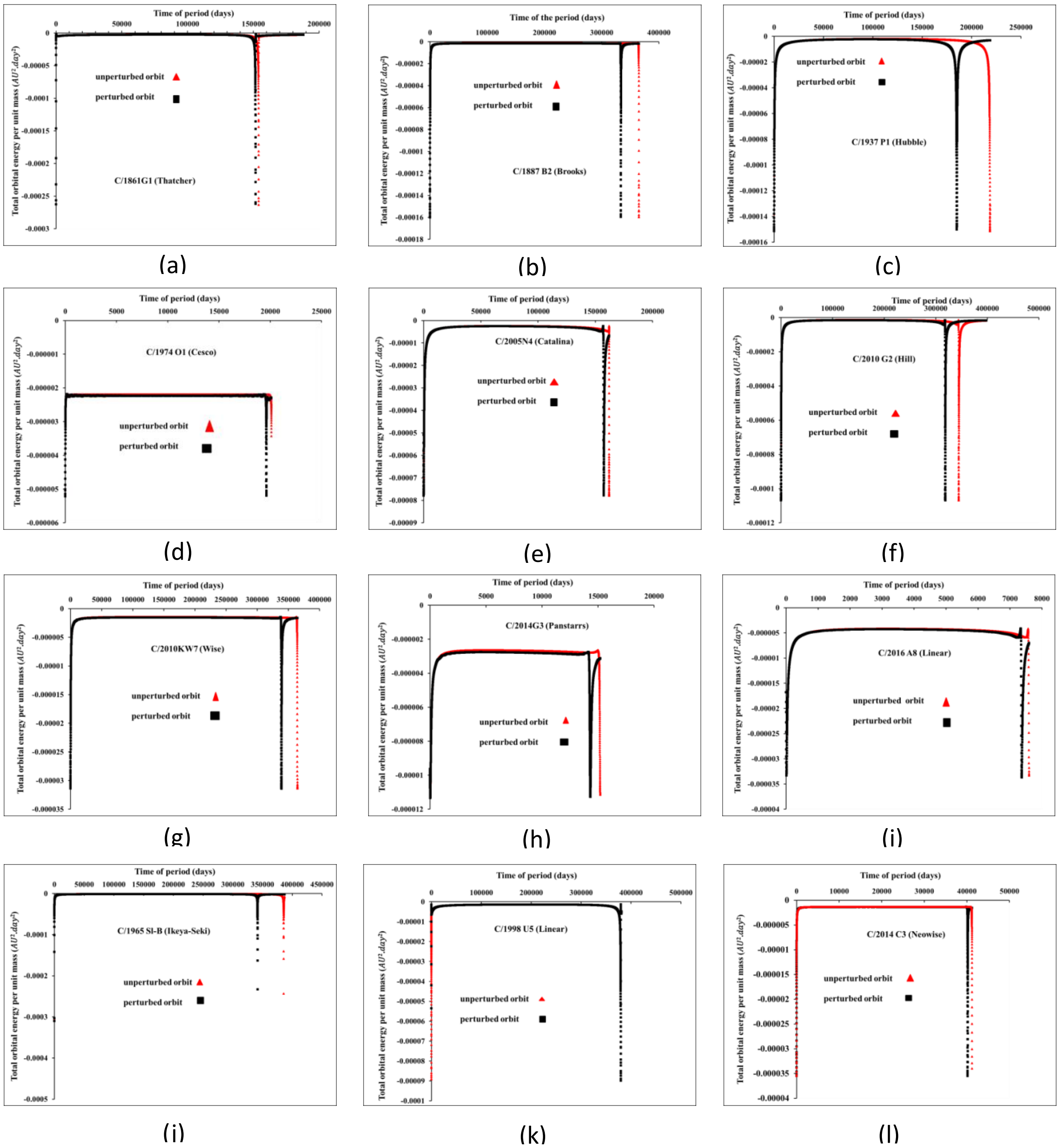
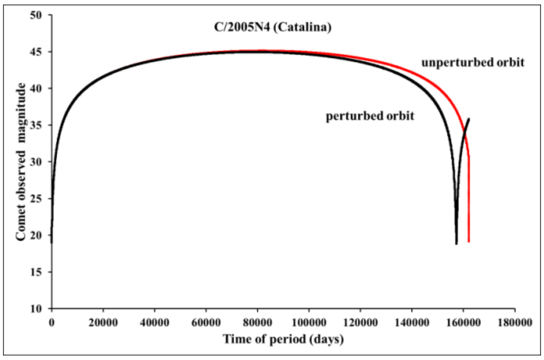
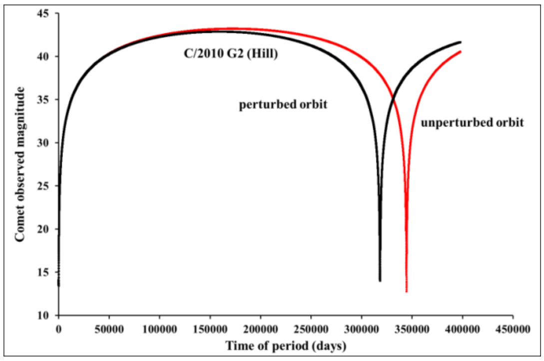


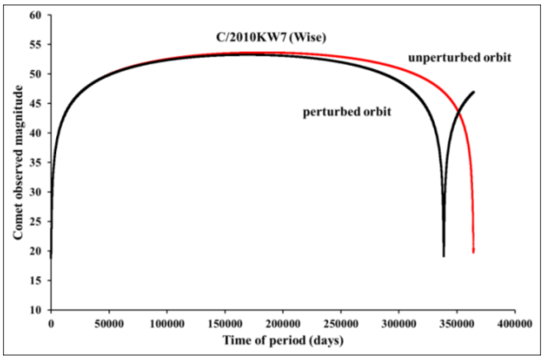
Figure (3) (a,b,c,d,e,f,g,h,I,j,k,l) the total energy per unit mass of the comet in $AU^2.day^{-2}$ as a function of the time of period in days



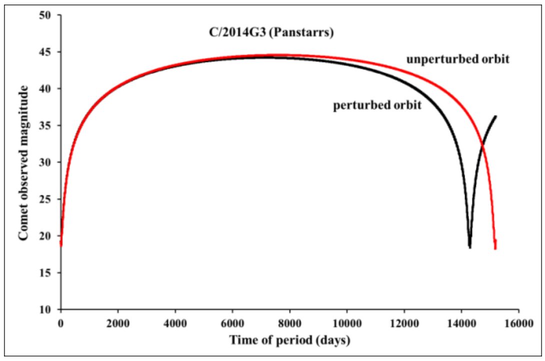
(a)



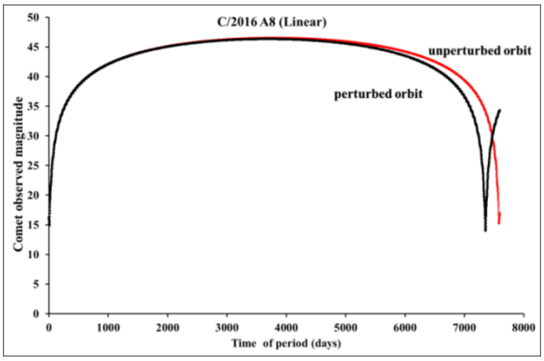
(b)



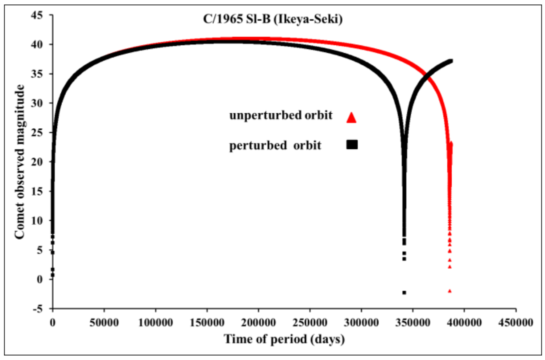
(c)



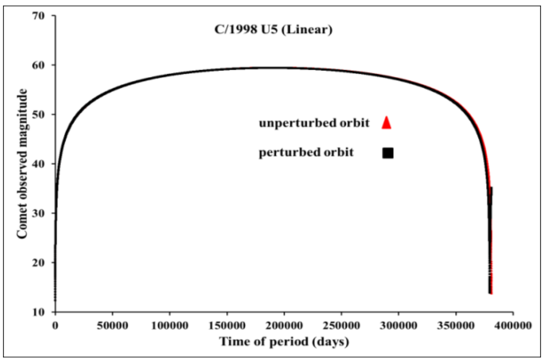
(d)



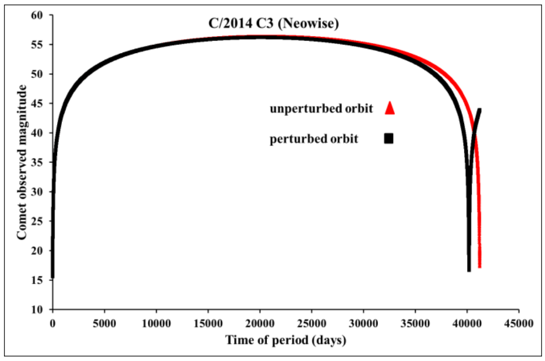
(e)



(f)



(g)



(h)

Figure (4) (a,b,c,d,e,f,g,h) the change of comet observed magnitude during the period in days

Where the heliocentric distance, the right ascension and the total orbital energy per unit mass are measured in AU, hours and $AU^2.day^{-2}$ respectively.

5- Discussion:

Since the long comet period has large aphelia which intersect with Pluto and Eris orbits so that if its disturbance has been inserted in the cometary equation of motion it will be seen a few notes.

1- Comets aphelia and perihelia become smaller than in the case of excluding the two dwarf planets.

2- The equatorial coordinates of comets show that whosoever comets become far away from the sun the difference of right ascension will be larger and vice versa.

3- The total orbital energy is negative as long as the orbit is an ellipse and this is for long period comets.

4- The estimated observed magnitude of the selected comets shows the dependence upon the comet heliocentric distance, the semi major axis as well as perihelion before and after the orbit perturbations.

6- **Conclusions**:

1- The heliocentric distance of comets as a function of time will differ for the perturbed orbit about which does not, causing a change in the period of the orbit and semi major axis and makes them less than that in the case of absent Pluto and Eris.

2- The variance in energy values increase as the comet approaching the next perihelion on other words the orbital energy is measured by the inverse semi major axis which alters according to gravitational effects.

3- The increasing of perihelion of the comet due to the perturbations will make it approach to the sun of which pushing to increase the observed magnitude.

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