Stability of planetary Systems [1]

Ingo H. Leubner
Rochester Institute for Fundamental Research - RI*ff*R
35 Hillcrest Drive, Penfield, NY 14526-2411, USA
www.RocherResearch.com

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1. Abstract

Planetary orbits increase with time because of the relative instability of the planetary orbits and solar mass loss by radiation and solar wind. A parameter free model quantifies that at the beginning of the solar systems all planets were significantly closer to the Sun, and will be more distant in the future. Consequences of the model for intra and intergalactic cohesion are discussed.

The planetary potential energy relative to the solar surface was obtained by calculating the launch energy that would be necessary to move an object from the solar surface to the planetary orbit (‘planetary launch velocity’). The planetary launch velocities range from 613.830 (Mercury) to 617.526 km/s (Eris = UB313, Xena), vs the solar escape velocity of 617.547 Km /s. The difference between solar escape and planetary launch velocities ranges from 3.7 Km/s for Mercury (0.6%) to 0.0034 Km/s for Eris (0.034%).

Solar radiative and solar wind mass (~gravity) loss cause the gravitational interaction between Sun and planets to decreases with time. This reduces the solar escape velocity, while the planetary orbital potential (=launch) energy is invariant. Changes of planetary orbits with time (+/- 4.5 Byr from present) were calculated based on the total solar mass-loss rate constant. After the formation of the solar system (-4.5 Byr**),** the orbits of Mercury and Eris were 5.61E+07 (presently 5.80E+07) and 1.47E+09 Km (10.2E+09) and the orbital periods were 0.23 (0.24) and 30.7 yr (560 yr). It is suggested that the original orbits should be used for modeling of the formation of the solar system. It is predicted that Pluto and Eris will escape the solar system in 1.3 and 0.76 billion years, respectively.

2. Introduction

The solar-planetary interaction was modeled based by the balance of planetary kinetic-potential energy with solar gravitational attraction. The calculations indicate that the planets are relatively weakly adsorbed. Solar mass and gravity decrease by radiative and solar wind mass loss. The present work explores how this mass loss affects the orbits of the solar planets. The rate of solar mass loss was quantified based on experimental data. The newly detected planet Eris (= UB313, Xena) was included into the modeling.[1]

The solar radiative mass loss has generally been considered too small to affect planetary orbits (solar radiative decay constant, k_s (M/M_0) 66.29E-06 Byr^{-1}), and because planetary orbits were assumed to be stable. No evidence could be found which quantitatively supports this assumption. This paper will show that these assumptions are erroneous. The argument based on the insignificant effect of solar mass and gravity loss on planetary orbits is not sufficient, since two forces determine planetary orbits. One is the centripedal solar gravitational attraction to the center. The other force is the centrifugal energy inherent in the planetary orbital potential energy. The present model shows that the orbital adhesion of planets is sufficiently low so that the observed solar radiative and solar wind losses will cause significant planetary orbital changes. These changes are amenable to experimental observation.

3. The Model

Figure 1 shows the concept for the modeling of the solar-planetary system. At present, the planets move in orbits around the sun because of the gravitational solar attraction. However, for a hypothetical removal of the sun, this solar attraction is missing, and the planets would move away from the solar center. While the full removal of the solar mass is a hypothetical assumption, the gradual removal of solar mass by solar radiation and solar wind is an ongoing process. Thus, the transition between the solar presence and absence is gradual.

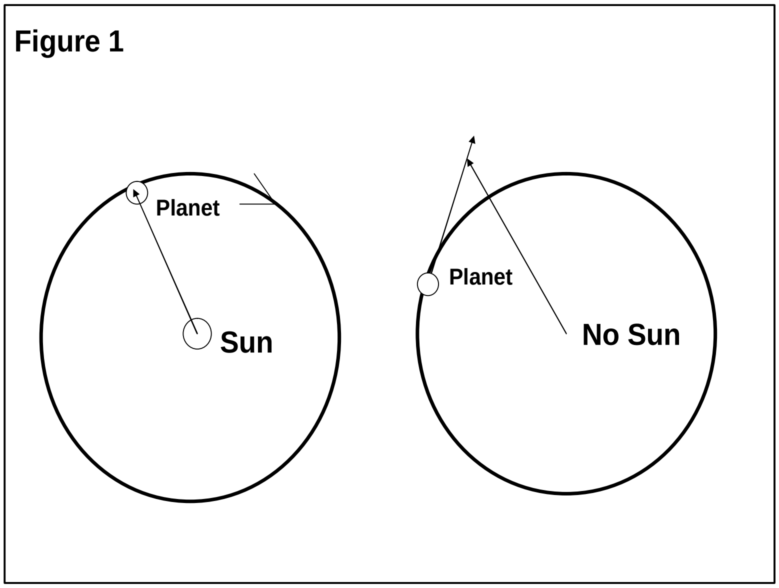


Figure 1	Model: The Planetary System +/- Sol

The change of planetary orbits and orbital periods as a function of solar mass loss is the topic of this paper. The modeling and results derived for the solar system can logically be expanded to other planetary stellar system, and to galactic, and intergalactic systems.

The solar mass-to-energy conversion follows Einstein's Equation (1) which predicts that the formation of light (photons) in stars must lead to a proportional loss of stellar mass.

	$\mathbf{E = h\nu = mc^2}$	(1)

This implies that the gravitational force of stars decreases proportionally to the radiative mass loss.

Stars decay by different mechanisms, which imply different mass-to-energy conversion (decay) rates and different rates of mass and gravity loss. For instance, it is anticipated that the solar radiative mass loss rate will change during the transition from thermonuclear hydrogen burning to helium burning. To extend the model beyond the solar system to the decay of galactic and intergalactic systems, the decay rates and the relative magnitude of different mass-to-energy conversion processes can be experimentally determined.   The overall radiative mass conversion is modeled by a sum of those first-order decay processes of stars. For the solar system, the present decay constant was calculated from published information (Lide, 2004)[2].

Newton and Einstein developed equations for the gravitational forces between masses (Giancoli, 1998, Misner, 2000)[3,4]. The modeled effects (velocities, times, rates) are well below significant relativistic effects. Relativistic corrections and refinements due to elliptic orbits are considered may be incorporated, but are not within the scope of the present paper.

3.1 Solar Radiative Mass Loss

Einstein's equation (1) gives the relationship between mass and radiated energy (hν). The radiative conversion involves only one reactant, which is the mass of the radiating object (the sun) that converts mass to free energy (the product) in form of photons. Thus, the reaction is first order, or a combination of first-order reactions (Equation (2)).

	$$M(t) = M_0 e^{-kt}$$	(2)

Here, M (t) is the mass of the radiating object at time t from a given time (t = 0). M_0 is the mass at the present time (reference, t=0), and k is the mass-loss (=decay) constant.

The decay constant of complex systems, e.g. solar transition from hydrogen to helium burning, stars, galaxies, and the universe, k_u, is a combination of first order reaction constants k_i and weighing factors n_i, which are the fraction of the total mass that is converted by a given mechanism (Equations (3,4)). Decay rates of stars may also change with time, and this can be incorporated into general modeling.

	$$k_u = \Sigma n_i k_i$$	(3)

Where

	$$\Sigma n_i = 1.0$$	(4)

The decay constant of the Sun was calculated from the radiation rate and mass as shown in Table 1. Assuming that the experimental solar wind mass loss rate is causative related to the radiative mass loss, 33% of the radiative mass loss would be added for general calculations of stars to estimate the total stellar mass loss.

Table 1 : Calculation of Solar Radiative and Solar Wind Mass Loss Rates

Name	Value	Units
Solar Radiative Constant	61.84E+09	erg/s*cm^2
Solar Radius	69.60E+09	cm
Solar Surface Area	60.86E+21	cm^2
Solar Radiative Energy Output	37.64E+32	erg/s
Solar Mass Loss Rate	41.82E+11	g/s
Solar Mass	19.91E+32	g
Radiative Decay Constant, k_s	21.01E-22	s^{-1}
Radiative Decay Constant, k_s	6.63E-05	Byr^{-1}
Universal Gravity Constant	6.67E-08	cm^3/g*s^2
Solar Wind Mass Loss	1.38E+12	g/s
Solar Wind Loss Rate, k_w	2.18E-05	Byr^{-1}
Total Solar Mass Loss Rate, k_{sw}	8.81E-05	Byr^{-1}

Conversion of mass leads to a proportional increase in energy, E (t), which consists of photons, as given by Equation (5):

	$$E(t) = M_0 c^2 (1 - e^{-k_u t})$$	(5)

For the conversion rate of matter into energy, the constant k_u and its components have positive signs. Negative signs for k_u or its components indicate mass increase. This is the case for black holes, which grow by absorption of mass and photons. Thus, negative reaction rates need to be considered when modeling complex stellar systems, like galaxies, which include black holes.

For the solar system, the conversion constant for the sun, k_s, (2.100526E-21(1.0/s), or 6.62884E-05 (1.0/billion sidereal years = Byr) was used for the radiative mass loss (Table 1) (Lide, 2004) [2].

3.2 Solar Wind

Solar (stellar) wind increases the solar (and stellar) mass loss rate beyond the radiative mass loss. Solar wind consists of ionic particles that are ejected from the sun, like electrons, protons, Helium ions, and other ions. An average value of solar wind was determined over one polar orbit by the Ulysses satellite (McComas 2000, Smith 2003). [4,5]

The radiative mass loss rate, M_r (g/s), and solar wind mass loss rate, M_w (g/s), combine to give the solar decay constant, k_{sw} (1/s), which is given by Equation (6), where M_0 is the total solar mass.

$$\mathbf{k_{sw}} = \left[\frac{\mathbf{M_r + M_w}}{\mathbf{M_0}}\right] \qquad \textbf{(6)}$$

For the solar wind a rate of 1.38E+12 g/s was used which is based on data from the first full solar polar orbit of the Ulysses solar satellite (McComas, 2000)[4].

The solar wind is a function of processes at the solar surface, and varies over a wide range of values (McComas, 2000, Smith, 2003). [4,5] Processes occurring in the solar bulk drive the surface processes and it may be assumed that the same underlying processes drive solar radiative decay and solar wind mass loss. The data show the solar wind mass loss is one third of the radiative mass loss (32.9%). It is not known if this is coincidence or a causative relationship.

3.3 Solar-Planet Interactions

Modeling is simplified by limitation to the case of gravitational interaction of masses outside a central mass with the central mass. The solar system was chosen to represent planetary star systems.

Another case, which was not considered for the present modeling, is the gravitational interaction occurring within a star, or within and between galactic systems. The concepts proposed for the solar systems may applicable; however, it might be necessary to use the gravity-radius dependence within a closed system.

The present modeling focuses on interaction between planets and their central star. The gravitational force, F_r, between a central star and a planet is given by Equation (7)

$$\mathbf{F_r} = \frac{\mathbf{G M_s M_P}}{\mathbf{R_p^2}} \qquad (7)$$

Here, G is the universal gravity constant, M_s and M_p are the masses of the star (Sun) and a planet, and R_p is the average star-to-planet distance (orbit). To demonstrate the effects, circular average orbits are used for planetary orbits, which significantly simplify the calculations vs. elliptical orbital modeling. It also is not known how the predicted changes in planetary orbits will affect their ellipticity.

The stability of a planetary orbit was determined by its energy relative to the escape energy from the Sun. The solar escape energy is traditionally expressed as the solar launch velocity from the solar surface (solar radius R_s) which moves an object to infinity. Similarly, in this work a planetary launch velocity is defined which moves an object from the solar surface to a planetary orbit. The difference between the escape and planetary launch velocity is then a measure for the stability of the planetary orbit.

In principle, any distance from the center of the Sun may be chosen as the reference for these calculations. The solar radius was chosen because it provides a convenient reference. The center of the Sun is not a useful reference, since a radius of zero will lead to singularities in the equations.

When an object of the mass m is launched vertically from the surface of the sun (at Radius R_s) with an initial velocity of v_0 (launch velocity), its velocity v_R at the distance R from the center of the sun is given by the energy balance equations (8) - (11). Here, ΔE_{kin} represents the change in kinetic energy, and ΔE_{pot} the change of potential energy of the object relative to the solar surface during ascent.

$$\Delta E_{kin} - \Delta E_{pot} = 0 \quad (8)$$

$$m\int_{Rs}^{R} v(R)dR - GmM_s \int_{R_s}^{R} \frac{1}{R^2} dR = 0 \quad (9)$$

$$\frac{m}{2}\left[v_R^2 - v_0^2\right] - mM_s G\left[\frac{1.0}{R} - \frac{1.0}{R_s}\right] = 0 \quad (10)$$

$$v_R^2 = v_0^2 - 2GM_s\left(\frac{1}{R_s} - \frac{1}{R}\right) \quad (11)$$

Traditionally, e.g., for launches from Earth, the Earth surface gravity constant, g, is used for the calculations. Similarly, for the calculation of the solar – planetary interactions, the solar surface gravity, G_s, may be used. However, the model becomes more transparent, if G_s is replaced by its definition, (equation (12)).

$$G_s = \frac{GM_s}{R_s^2} \quad (12)$$

When the highest distance (apogee), e.g. orbit ($R = R_p$), is reached, v_r is equal to zero, since all kinetic launch energy has been converted to orbital potential energy. In the case of planetary orbits, calculated launch velocities are thus a measure of the orbital potential energy relative to the solar surface, and also for the potential energy relative to the center of the Sun. For the planets with an orbit of R_p, this condition was used to calculate the launch velocities v_p for all planets (equation (13)).

$$v_p^2 = 2GM_s\left(\frac{1}{R_s} - \frac{1}{R_p}\right) \quad (13)$$

The launch velocities and the present solar escape velocity (see below) are listed in Table 2.

Table 2: Planetary Launch Speed, Orbit Separation Rate, and Separation Time

Planet	Orbit Km	Launch Speed Km/s	% Adhesion*	Separation Rate Km/yr	Separation Time Byr
Mercury	5.80E+07	613.830	0.6018	4.32E-04	133.77
Venus	1.08E+08	615.554	0.3238	1.54E-03	71.64
Earth	1.50E+08	616.112	0.2328	3.04E-03	51.53
Mars	2.28E+08	616.603	0.1530	7.30E-03	33.88
Jupiter	7.78E+08	617.270	0.0448	7.89E-02	9.92
Saturn	1.43E+09	617.396	0.0243	2.74E-01	5.39

Uranus	2.87E+09	617.472	0.0121	1.07E+00	2.69
Neptune	4.50E+09	617.499	0.0077	2.68E+00	1.71
Pluto	5.91E+09	617.510	0.0059	4.68E+00	1.30
Eris*	1.019E+10	617.526	0.0034	1.46E+01	0.76

*= UB313, Xena; Solar Escape Velocity, $v_s = 617.547$ (km/s)
Radiative: $k = k_s$; Radiative + Solar Wind (SW): $k_{sw} = 1.329k_s$; % adhesion* = $100*(v_s - v_p)/v_s$

3.3.1 Escape Velocity

The solar escape velocity v_s is the launch velocity that causes a body to leave the solar system ($R_p \to \infty$). As shown in equation (14), the escape velocity is a function of the solar mass, M_s, and the solar radius, R_s. Thus, if the solar mass decreases, v_s^2 and thus v_s decrease proportionally.

$$v_s^2 = \frac{2GM_s}{R_s} \tag{14}$$

The results in Table 2 show that the difference between the launch speed of Pluto and the present solar escape speed is only 37m/s, or a fraction of 6.0E-5. This indicates that relative small changes of the solar mass, M_s, which determines the escape velocity, can have a significant effect on Pluto's orbit, and those of its nearest neighbors.

The solar escape velocity decreases proportionally to radiative and non-radiative solar mass loss, M_s (equation (14)). In contrast, planetary launch velocities (representing the kinetic launch energy and orbital potential energy) are invariant for constant R_s.

When during the solar mass loss the solar escape velocity, v_s decreases below the planetary launch velocity, v_p ($v_s <= v_p$), the planet will escape the solar system. At this point, the centrifugal force (potential energy) of the planet exceeds the gravitational attraction of the sun, and the planet will start leaving the solar system. The excess potential energy is converted to kinetic energy and movement away from Sol.

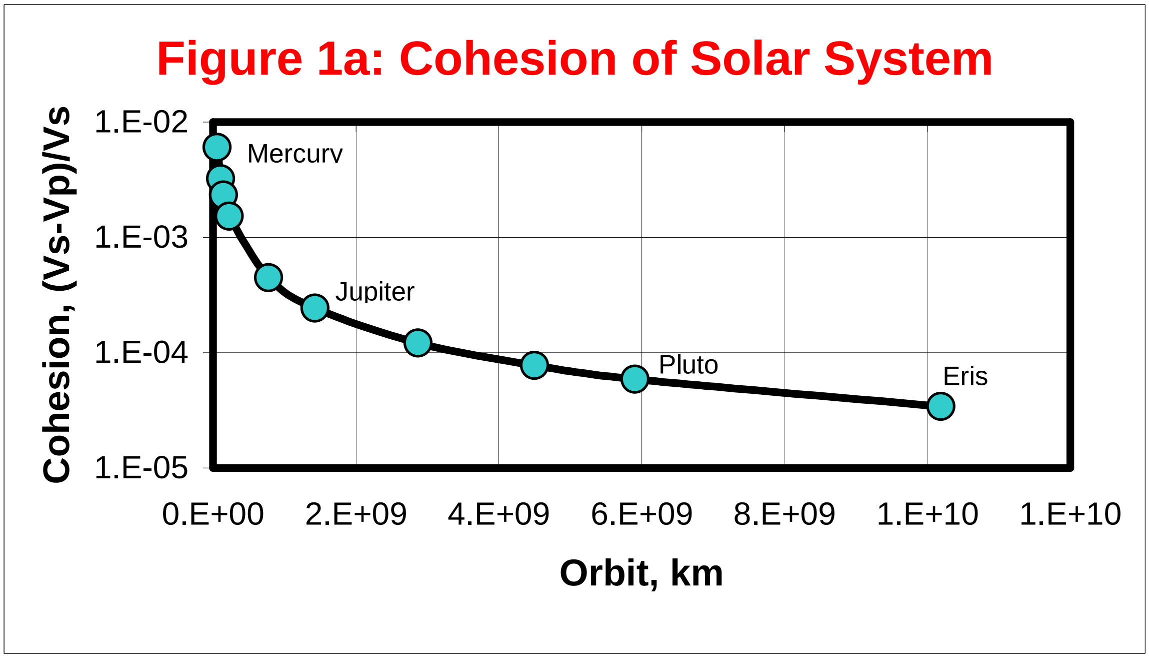
3.3.2 Cohesion of the solar System: Planetary Adhesion to the Sun

The relation between planetary launch speed, v_p, and solar escape speed, v_s, gives the planetary adhesion to the solar system, equation (15) and Figure 1a. For demonstration, percent adhesion values were calculated using equation (16). The values are listed in Table 2.

$$\mathrm{adhesion} = \frac{v_s - v_p}{v_s} \tag{15}$$

$$\%\mathrm{adhesion} = 100\frac{v_s - v_p}{v_s} \tag{16}$$

The results show that the strength of adhesion, as given by % adhesion, varies from a high of 0.60% for Mercury to a low of 0.0034% for Eris (= UB313). These results demonstrate that the planets are relatively weakly adhering to the solar system. Eris' adhesion of 3.5E-05 is thus of the same magnitude as the solar decay rate, 8.81E-05 ($\Delta M_s / M_s$ Byr).



3.3.3 Dissociation of the solar System: Solar Mass - Loss and Planetary Orbits

Changes of planetary orbits, $R_p(t)$, are calculated from the planetary launch velocity v_p, the solar mass, M_s, and the solar radius, R_s (Equation (17)). Thus, the planetary orbits are not stationary but expand with time.

$$\mathbf{R_p(t) = \frac{2GM_s(t)}{2GM_s(t)/R_s - v_p^2}} \qquad (17)$$

Since v_p is invariant, R_p varies with M_s. $M_s(t)$ is calculated from the solar mass as a function of time (Equation 2). Equation (17) shows that R_p will approach infinity when $2GM_s(t)/R_s$ becomes equal to v_p^2. Beyond this limit, the sun-planet distance must be calculated by including the planetary excess velocity above the escape velocity.

It was pointed out above, that the mass of the sun, M_s, decreases with time due to radiative processes. Equation (2) is modified for total solar mass loss rate (Equation (18).

$$\mathbf{M_s(t) = M_{s,0} e^{-k_{sw}\, t}} \qquad (18)$$

The present solar mass, solar radiative decay rate, k_s, the solar wind mass loss rate, k_w, and the combined decay constant, k_{sw}, are listed in Table 1.

From Equation (18) two additional relations can be derived that may help simplifying the calculations. (Esq. (19) and (20)):

	$G_s(t) = G_s(0)e^{-k_{sw}t}$	(19)
	$v_s^2(t) = v_s^2(0)e^{-k_{sw}t}$	(20)

Here, G_s (0) and v_s^2 (0) refer to the present solar-planet solar gravity constant and solar escape velocity.

As the time, t, increases and the solar mass, M_s, decreases the solar-planetary interaction, and the solar escape velocity, v_s, decrease. The planetary launch velocity (for constant R_s), v_p, however, is a constant. This has important consequences:

- The difference between the planetary launch velocities, v_p, and the solar escape velocity, v_s, decreases with time
- The planetary orbital distances increase with time due to the reduced mass and gravity of the sun
- When the planetary launch velocity, v_p, exceeds the solar escape velocity v_s, the planet will escape the solar system

Changes in the planetary orbits, dR_p/dt, were calculated as a function of time and solar mass loss constant, k_{sw}. The change in orbital distance with time, dR_p/dt is given by Equations (21) or (22). For convenience, equation (22) was used to calculate dR_p/dt.

	$\dfrac{dR_p(t)}{dt} = \dfrac{2kGM_0e^{-k_{sw}t}}{\left[v_{s,0}^2e^{-k_{sw}t} - v_p^2\right]}\left\{\dfrac{v_{s,0}^2e^{-k_{sw}t}}{(v_{s,0}^2e^{-k_{sw}t} - v_p^2)} - 1.0\right\}$	(21)
	$\dfrac{dR_p}{dt} = \dfrac{R_p\left(t+dt\right) - R_p\left(t\right)}{dt}$	(22)
	$d_v\left(t\right) = v_p - v_s\left(t\right)$	(23)

The difference between the launch velocity, v_p and the escape velocity is obtained using Equation (23).

For times where $d_v(t)$ is negative, the planet remains within the solar system. At the time when $d_v(t)$ becomes positive the launch velocity exceeds the escape velocity and the planet leaves the solar system. Equations (22) and (23) can be used to calculate the change of orbital distance and separation velocities.

The separation time for the planets can also be calculated from equation (24) which is derived from equation (22), where v_s is replaced by v_p, and solved for the separation time, t_{ss}

	$t_{ss} = -\dfrac{\ln(v_p^2 / v_s(0)^2)}{k_{sw}}$	(24)

The separation rates and times for the planets are included Table 2.

The same set of equations can be used to calculate planetary orbits and orbital periods before the present time, e.g., for Mars, and its transition from liquid water to ice. For this case, negative t values are used, since the present is taken as the time reference (t=0).

4. Stability of the Solar System

The solar mass loss constant, k_{sw}, for the current radiative and solar wind decay rates was chosen throughout the modeling. Thus, the modeling is strictly correct only for the time range when the sun is decaying by the current decay processes. These solar radiative decay processes are predicted to change with time, and the decay rate constant is likely be different as the processes changes. The variation of radiative decay rate is part of Equation (3). Since the times for these reaction changes are uncertain, this was ignored for the present calculations. The present modeling demonstrates the general consequences of solar mass loss on the planetary orbits. It provides predictions for the present time that can be experimentally verified.

Another unknown factor is the stability of the solar radius over time. It is shown in the above model equations that the surface solar gravity constant is proportional to $1/R_s^2$, and in the reduced equations proportional to $1/R_s$. Thus, a change in solar radius may cause planetary orbit changes. The radius of the sun is dependent on its mass. As the mass decreases, the radius may either increase or decrease.

If constant density is assumed, the volume and thus the radius of the sun decrease proportional to the mass loss. On the other hand, the mass loss also results in a decrease of gravity, which might lead to an expansion of the sun. Without further knowledge of the predominant processes, the question of future solar radius changes can presently not be answered, and for the present calculations, the solar radius was held constant as a function of time.

4.1 Orbital Changes as a Function of Decay Constant (Earth and Pluto)

Changes of the solar/stellar mass-loss mechanism have a significant effect on the solar/stellar-planet interactions. The effect of varying solar mass-loss rates, was modeled for Mercury, Earth, and Pluto, where the decay constant, k was varied from $k=k_s$ to $k=20\ k_s$ (Table 3).

Table 3: Separation Time (Byr)
as a Function of Radiative Mass-Loss Constant
(Mercury, Earth, and Pluto)

k/k_s	Mercury	Earth	Pluto
1.00	182.0	70.1	1.78
1.329*	137.0*	52.8*	1.34*
2.50	72.8	28.1	0.71
5.00	36.4	14.0	0.36
7.50	24.3	9.4	0.24
10.00	18.2	7.0	0.18
20.0	9.1	3.51	0.089

***Solar Radiative + Solar Wind Mass Loss Constant, k_{sw}**

The data show that the outer planets will separate from the solar system significantly earlier than the inner planets. Further, separation time decreases with increasing radiative mass-loss rate. Thus, stellar systems with central stars that burn at a higher rate are less likely to retain planets than those whose central star burns at a lower rate. Measuring the rate of change of planetary orbits may allow calculation of the actual mass-loss constant (radiative plus non-radiative) for the sun.

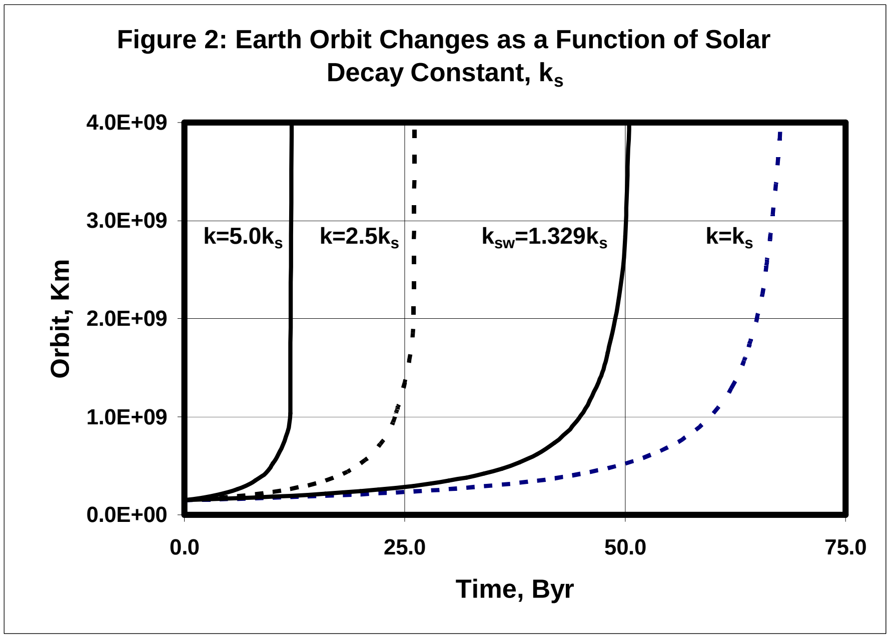


Figure 2	Earth Orbit increase as a Function of relative solar Decay Rate ($k = 1.0 – 5.0k_s$) and time

In Figure 2, the change of Earth orbital distance is shown as a function of time and k (1.0 to 5.0 k_s) until the time when escape velocity is reached. The results show that the mass loss by solar wind contributes significantly to stability of the orbit. Figure 2 shows that early during solar decay there is only a low rate of orbital change. At longer times, there is an increased rate of separation. Experimental determination of the planetary separation rates allows thus to determine the solar mass loss rate constant.

Figure 3 (equation (24)) of separation times vs. varying relative decay constant shows that for Earth and Pluto small increases of the decay constant have a more significant effect of reducing the separation time from the Sun than equivalent changes at larger constants.

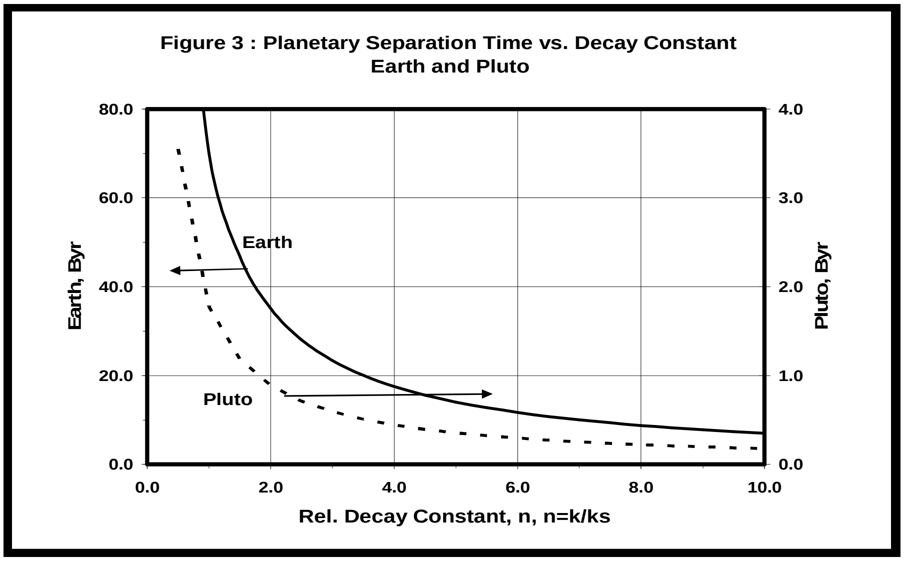


Figure 3	Earth and Pluto Separation Times as a function of Decay Constant

The modeling can be extended to times before the present. Under the assumption that $k=k_{sw}$, Earth was at the formation of the solar system, at about five billion years ago, about thirteen million km closer to the sun than at present. Since the sun at that time had a greater energy output, this and a closer orbit may have contributed to a climate with higher temperature than present for Earth and other planets. The closer orbit and higher solar energy output correctly predicts when and why Mars sustained liquid water before about 3.6 Byr ago.

4.2 Planetary Separation Distance, Velocity, and Time

The orbital increase as a function of time is shown in Figure 4 and Figure 5 for Mercury through Mars, and for Jupiter through Eris (UB313), respectively. The plots show that the planets will move away from the sun in a super-linear function of time. The curves predict that the first planet to separate will be Eris, while Mercury will be the last to show significant movement and separation from the solar system.

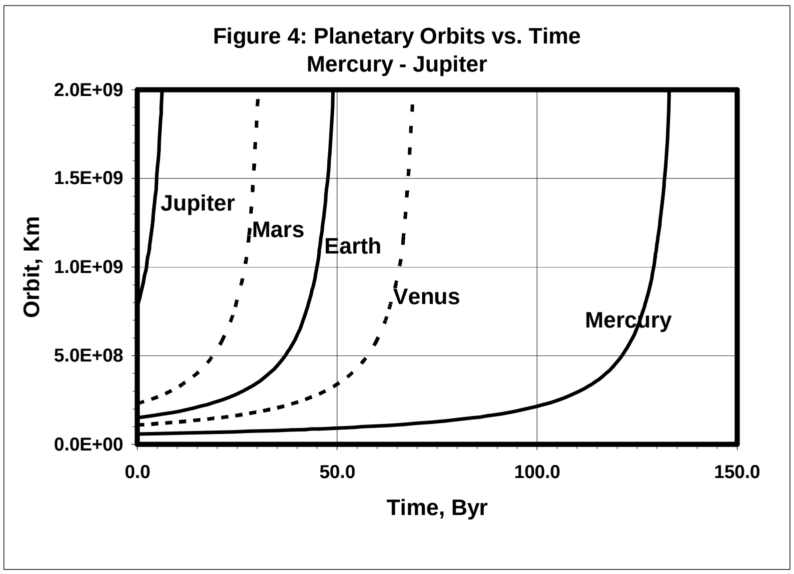


Figure 4	Mercury – Jupiter, Orbit Increase with Time

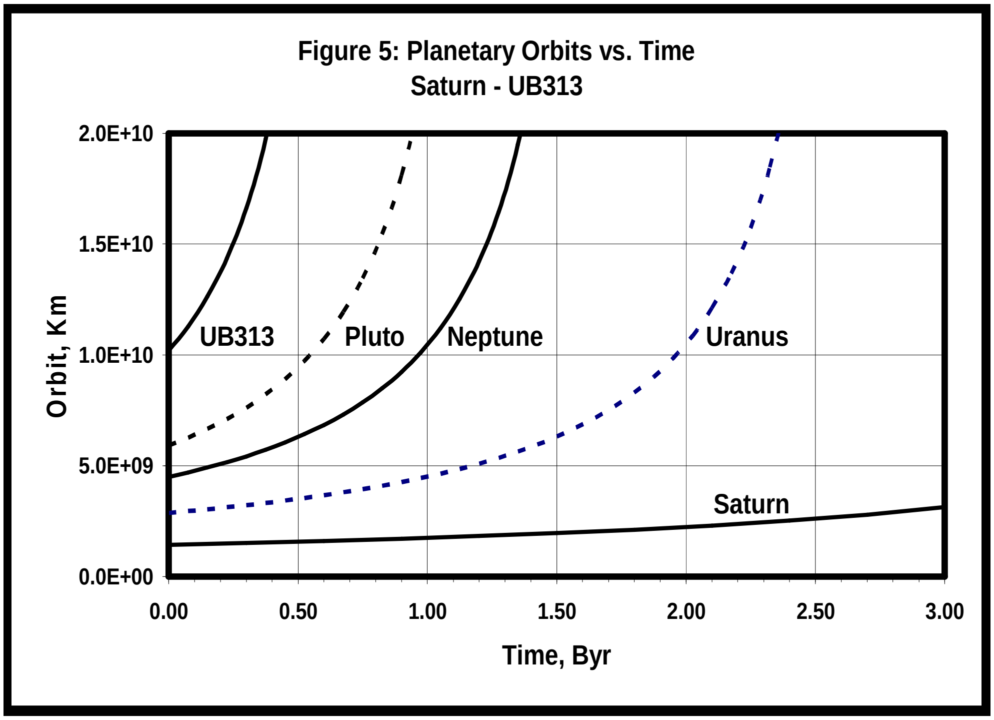


Figure 5	Saturn – Eris (UB313) Orbit Increases with Time

5. Orbital Periods

The orbital periods of the planets increase as the orbits increase due to solar mass loss. Changes of orbital periods were calculated using the relationship between orbital period and solar mass (Equation (25)):

$$T_p^2 = \frac{4\pi^2 R_p^3}{GM_s} \quad (25)$$

Here, T_p is the orbital period, R_p is the radius of the planetary orbit, G is the universal gravity constant, and M_s is the solar mass. According to Equation (25), the orbital period is a function of both planetary orbital radius R_p and solar mass M_s. Both planetary orbital radius, R_p, and solar mass, M_s, are functions of solar decay, which in turn is a function of the solar decay constant and time. For the calculations, the solar mass loss rate constant k_{sw} was chosen. The results are shown in Table 4.

Table 4 : Current annual Increase of Orbital Periods

Planet	Orbit Km	Orbital Period yr/orbit	Orbital Period Rate Increase s/yr
Mercury	5.80E+07	0.241	8.58E-05
Venus	1.08E+08	0.615	4.19E-04
Earth	1.50E+08	1.000	9.79E-04
Mars	2.28E+08	1.880	2.93E-03
Jupiter	7.78E+08	11.861	5.73E-02
Saturn	1.43E+09	29.46	2.71E-01
Uranus	2.87E+09	84.01	1.49E+00

Neptune	4.50E+09	164.78	4.69E+00
Pluto	5.91E+09	248.35	9.43E+00
Eris	1.02E+10	560.00	3.89E+01

Radiative: $k = k_{s;}$ Radiative + Solar Wind (SW): $k_{sw} = 1.329k_s$;

Changes of the orbital period for the planets are shown as function of time in Figure 6 and Figure 7 for Mercury through Jupiter, and Saturn through Eris, respectively. The figures show that the orbital periods increase super-linearly with time. Changes in planetary orbital periods increase with the planetary distance from the Sun.

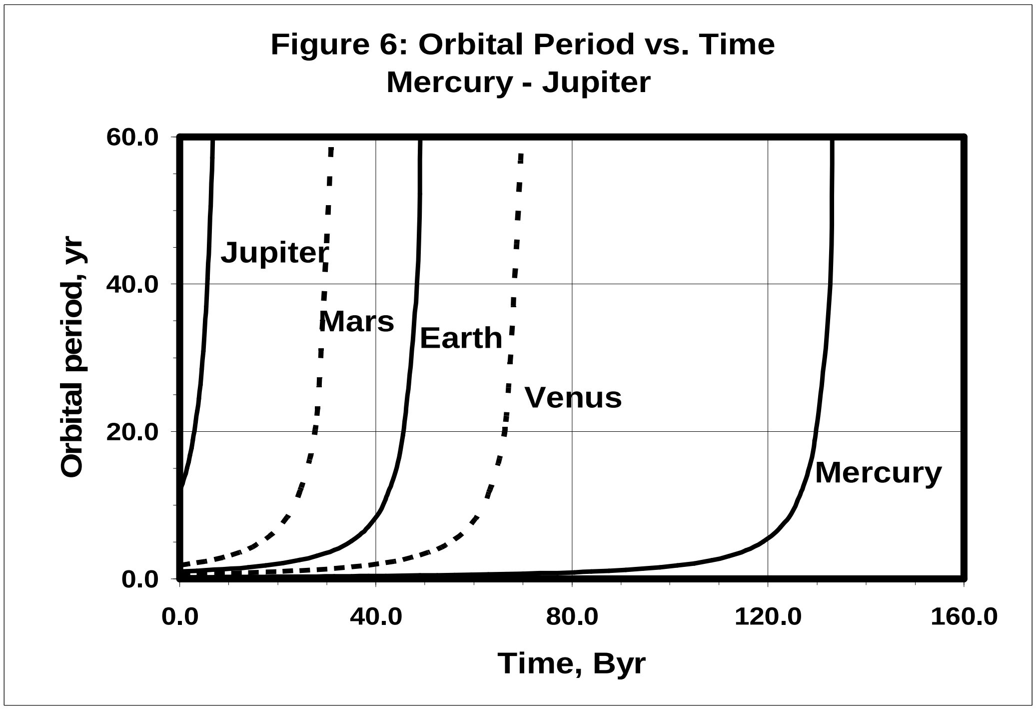


Figure 6	Mercury – Jupiter, Orbital Period Increases with Time

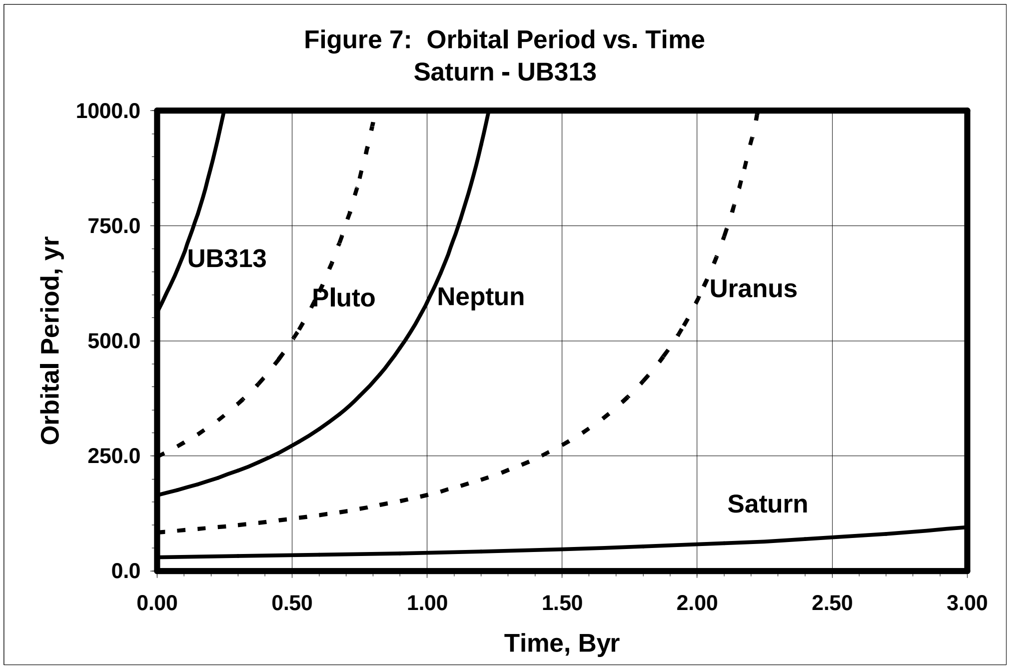


Figure 7	Saturn – Eris (UB313), Orbit Increase with Time

The current changes for the orbital periods are included in Table 2 for all planets for k_{sw}. The calculations show that the Earth year will increase by 0.91E-03 s/yr due to radiative and with solar wind mass loss. It is predicted that Pluto's orbital time will increase by 15.9 s/year, or about 64 minutes per Pluto orbital time (248yrs). It may be possible to observe these changes experimentally.

6. History of the Solar System

The model predicts both the past and the future orbits of the planets. The time of the end of formation of the solar system is given at about -4.5 billion years (Byr) from present. The orbits at -4.5, present, and +4.5 Byr are shown in Figure 8. The results are compiled in Table 5.

Table 5 : History of the Planetary System (Byr)

	Orbits, Km			Orbital Periods, yr		
Planet	R_p (-4.5)	R_p (0)	R_p (+4.5)	T_p (-4.5)	T_p (0)	T_p (+4.5)
Mercury	5.61E+07	5.80E+07	6.00E+07	0.23	0.24	0.25
Venus	1.02E+08	1.08E+08	1.15E+08	0.56	0.62	0.68
Earth	1.38E+08	1.50E+08	1.64E+08	0.88	1.00	1.15
Mars	2.01E+08	2.28E+08	2.63E+08	1.56	1.88	2.33
Jupiter	5.35E+08	7.78E+08	1.42E+09	6.8	11.9	29.3
Saturn	7.80E+08	1.43E+09	8.62E+09	11.9	29.5	437.2
Uranus	1.07E+09	2.87E+09	----	19.2	84.0	----
Neptune	1.24E+09	4.50E+09	----	23.9	164.8	----
Pluto	1.33E+09	5.91E+09	----	26.4	248.4	----
Eris	1.47E+09	1.02E+10	----	30.7	560.0	----

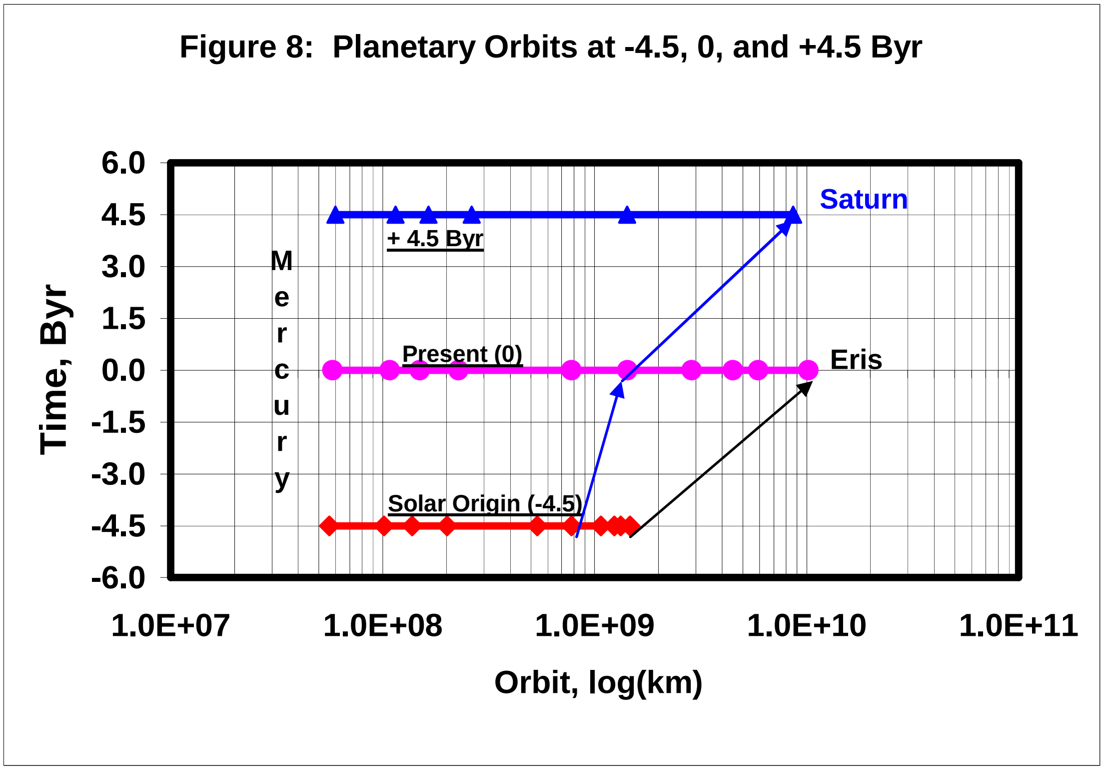


Figure 8	Orbital History of the Solar System, -4.5, Present (0), and +4.5 Byr

The plot indicates that at the origin of the solar system the planets were closer to the Sun. This is most evident for Jupiter to Eris. The orbit changes are indicated for Saturn and Eris. At +4.5By, the planets beyond Saturn are no longer part of the solar system (Figure 8). The results indicate that for studies of planet formation the orbits at the origin of the solar system must be used.

Shorter orbital periods are associated with closer orbits. This is shown in Figure 9. The results for -4.5, present, and +4.5 Byr are also compiled in Table 4.

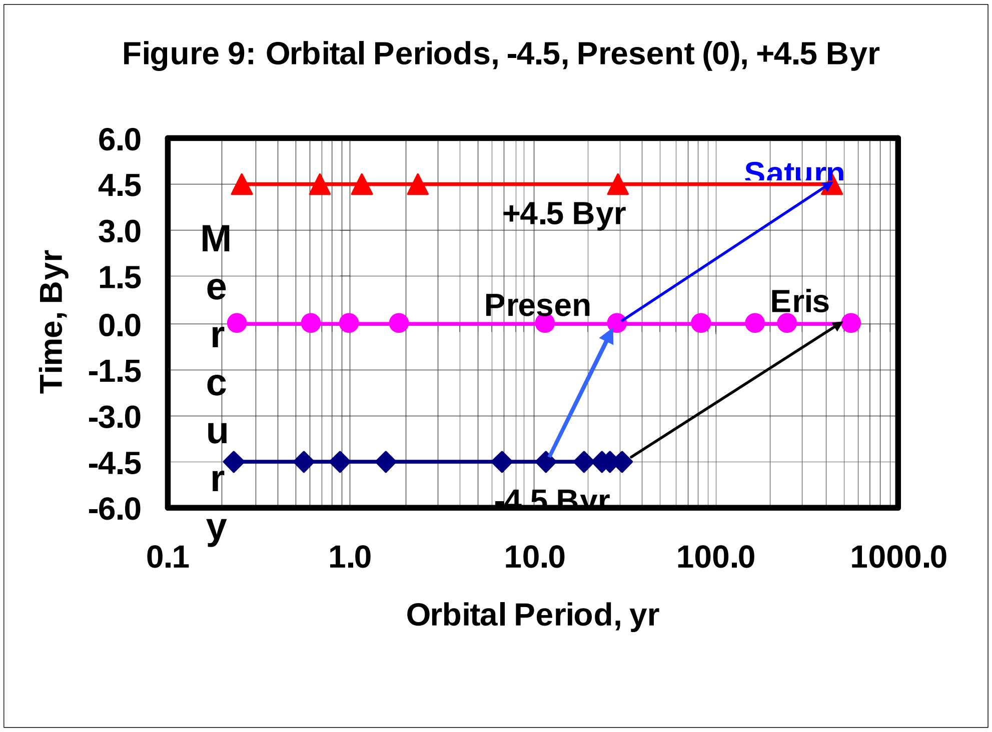


Figure 9	Orbital Period History of the Solar System, -4.5, Present (0), and +4.5 Byr

7. Hubble-Plot for Planetary Separation Rate vs. Orbit

The Hubble correlation plots the separation rate of galaxies vs. their distance from Earth. This universal Hubble plot (speed vs. distance) resulted in a linear plot. As shown, the solar system, like the Universe, is also a dissociating system. The data allow thus constructing a Hubble-type plot for the Sun (H_s) of the rate of planetary orbit changes vs. planetary orbits. The rates of the change of the planetary orbits are plotted in Figure 10 for all planets as a function of present planetary orbit.

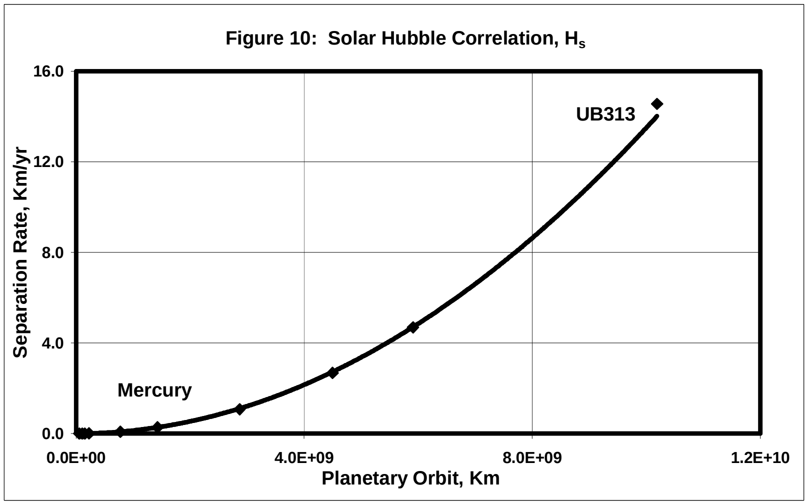


Figure 10	Solar Hubble Correlation Plot of Separation Rate vs. Distance, Mercury – Eris (UB313)

This plot shows that the separation rate for the inner planets is significantly lower than for the outer planets, which leads to a curvature of the plot close to the Sun. For the outermost planets, Neptune, Pluto, and Eris the plot approaches linearity. It might be interesting to apply the present model to spatial changes of the Universe since its origin and its possible expansion due to radiative mass loss.

8. Discussion and Conclusions

8.1 Solar System

The model quantifies how solar, or stellar, mass loss by radiative decay and solar wind causes a loss of gravitational attraction, an increase of planetary orbits, and lengthening of orbital periods. All input into the calculations are based on experimental data. Quantitative predictions are developed for the solar system, which are accessible to experimental tests.

Solar radiative and solar wind mass loss rates are available from published experimental data. It was observed that the solar wind provides about one third (32.9%) of the radiative mass loss. Since both types of mass losses depend on the internal solar radioactive processes, the value of this ratio may be significant.

The model uses the concept of (calculated, hypothetical) launch velocities for the orbital potential energy of the planets relative to the Sun's surface, which balances the solar gravitational attraction. This concept is strictly a means to quantify solar-planetary adhesion, and does not imply that planets were formed by mass ejection from the Sun. The problem of formation of planets is beyond the scope of this paper.

As the Sun loses mass, this energy balance is changed. To quantify this change, the changing solar escape velocity was related to the planetary launch velocities (= potential energy) which are considered invariant. The difference between launch and escape velocity decreases proportional to the mass loss of the Sun. When the difference becomes zero or less, planets start separating from the star system. The difference between the launch speed of Pluto and the present solar escape speed is only 37m/s, or a fraction of 0.006 percent of the present escape velocity.

The modeling predicts that Eris and Pluto will separate from the solar system in about 0.79 and 1.34 Byr, respectively. For the current solar mass loss rate, the separation time for Earth is calculated to about 53.8 and for Mercury about 137 Byr. However, these results are also dependent on changes of the solar decay mechanisms and resulting changes in solar decay rate.

In general, the mass-loss constant of stellar objects may be significantly different from the solar decay constant. This was modeled by varying the radiative decay constant using Mercury, Earth and Pluto as test cases. A tenfold increase of the decay constant predicts an approximately ten-fold reduction in separation time; however, the correlation is super-linear.

Present increases of orbital periods are predicted for Mercury to 8.35E-05 s/year, for Earth 9.79E-04s/yr, and for Pluto (Eris) 9.43 (38.9) s/year, and are reported for all planets. For Earth, this translates to a lengthening of the year of about 0.9ms/year. The changes in planetary orbit and orbital periods may be experimentally confirmed. In turn, experimentally determined values of the separation rate and changes in orbital period of planets may be used to experimentally determine the overall solar mass loss rate.

The presented model suggests high-precision determination of the orbits and orbital periods of the planets, the quantitative value of the solar wind and its relation to solar radiative activity, and application to extra-solar systems.

8.2 Implications for Extrasolar Systems

The proposed model is based on general concepts and thus it may be allowed to contemplate possible consequences beyond the solar system. Like the Sun, Stars and galaxies loose mass by radiative processes and proportional gravity losses must be assumed. Thus, the concepts and results derived for the solar system should apply to those systems.

Considering the presented results, it can be expected that expansions within galaxies and between galactic systems occur at a low rate during their early stages. The separation rate is expected to increase as the mass of these entities decreases. For an intermediate range, the separation is essentially constant, which is in agreement with the linear part of the Hubble constant. This model also anticipates that galaxy formation may have occurred before the time that is obtained by linear extrapolation of the Hubble plot.

Negative energy has been proposed to account for the separation of the galaxies and for the expansion of the universe. Negative energy is presently an experimentally unsupported concept. In contrast, the concept of radiative mass and gravity loss is firmly established and may account for the dissociation and for separation of galaxies.

The modeling shows that for stellar planetary systems the outer planets separate from the central mass prior to inner planets. Applied to galactic systems, this process suggests a similar process for the change from clustered to spiral shape, and to dissociation of galaxies. For stellar planetary systems, it is expected that older stars will have fewer planets than younger stars. In addition, the data show that stellar bodies with high radiative loss rate will lose planets in shorter times than those with lower loss rates.

It is known that the regular in the Universe will not result in a reversal of the present expansion. Thus, dark matter has been suggested to counteract the future disintegration of the universe. This matter is not visible, but has gravity; however, dark matter has not yet been experimentally confirmed. The present concept of dark matter does not account for the continuing mass loss of the Universe and no mechanism for its increase has been proposed.

In contrast, the concept of radiative and stellar wind mass-loss of stellar objects is firmly established, and the accompanying reduction of gravity leads to the logical conclusion of expansion and collapse of the universe. A solution to the problem of the future contraction of the universe is provided by Einstein's relativistic gravity doubling (RGD) (Misner, 2000; Leubner 2003)[4,6]. This effect is based on the theory of relativity and on experimental observations, which show that photons carry twice the gravity of the mass from which they originate. This was experimentally confirmed by a doubling of light bending while passing the sun vs. deflection of mass particles. Thus, the overall gravity of the universe is increasing by the radiative conversion of mass to photons.

These considerations indicate that the present model is self-consistent for a variety of problems of the solar system, and by extension to interactions within and between galaxies, and by implication to the Universe. It is

anticipated that measurements within the solar system will be able to test and confirm the present model predictions.

Acknowledgments: I am indebted to D. J. McComas for the solar wind data and to J. and G. Mitchell for editing of the manuscript.

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Tables

Table 1 : Calculation of Solar Radiative and Solar Wind Mass Loss Rates

Name	Value	Units
Solar Radiative Constant	61.84E+09	erg/s*cm^2
Solar Radius	69.60E+09	cm
Solar Surface Area	60.86E+21	cm^2
Solar Radiative Energy Output	37.64E+32	erg/s
Solar Mass Loss Rate	41.82E+11	g/s
Solar Mass	19.91E+32	g
Radiative Decay Constant, k_s	21.01E-22	s^{-1}
Radiative Decay Constant, k_s	6.63E-05	Byr^{-1}
Universal Gravity Constant	6.67E-08	cm^3/g*s^2
Solar Wind Mass Loss	1.38E+12	g/s
Solar Wind Loss Rate, k_w	2.18E-05	Byr^{-1}
Total Solar Mass Loss Rate, k_{sw}	8.81E-05	Byr^{-1}

Table 2: Planetary Launch Speed, Orbit Separation Rate, and Separation Time					
Planet	Orbit Km	Launch Speed Km/s	% Adhesion*	Separation Rate Km/yr	Separation Time Byr
Mercury	5.80E+07	613.830	0.6018	4.32E-04	133.77
Venus	1.08E+08	615.554	0.3238	1.54E-03	71.64
Earth	1.50E+08	616.112	0.2328	3.04E-03	51.53
Mars	2.28E+08	616.603	0.1530	7.30E-03	33.88
Jupiter	7.78E+08	617.270	0.0448	7.89E-02	9.92
Saturn	1.43E+09	617.396	0.0243	2.74E-01	5.39
Uranus	2.87E+09	617.472	0.0121	1.07E+00	2.69
Neptune	4.50E+09	617.499	0.0077	2.68E+00	1.71
Pluto	5.91E+09	617.510	0.0059	4.68E+00	1.30
Eris*	1.019E+10	617.526	0.0034	1.46E+01	0.76

*Eris = UB313, Xena; Solar Escape Velocity, $v_s = 617.547$ (km/s)
Radiative: $k = k_s$; Radiative + Solar Wind (SW): $k_{sw} = 1.329k_s$; % adhesion* = $100*(v_s – v_p)/v_s$

Table 3: Separation Time (Byr) as a Function of Radiative Mass-Loss Constant (Mercury, Earth, and Pluto)			
k/k_s	Mercury	Earth	Pluto
1.00	182.0	70.1	1.78
1.329*	137.0*	52.8*	1.34*
2.50	72.8	28.1	0.71
5.00	36.4	14.0	0.36
7.50	24.3	9.4	0.24
10.00	18.2	7.0	0.18
20.0	9.1	3.51	0.089

*Solar Radiative + Solar Wind Mass Loss Constant, k_{sw}

Table 4 : Current annual Increase of Orbital Periods

Planet	Orbit Km	Orbital Period yr/orbit	Orbital Period Rate Increase s/yr
Mercury	5.80E+07	0.241	8.58E-05
Venus	1.08E+08	0.615	4.19E-04
Earth	1.50E+08	1.000	9.79E-04
Mars	2.28E+08	1.880	2.93E-03
Jupiter	7.78E+08	11.861	5.73E-02
Saturn	1.43E+09	29.46	2.71E-01
Uranus	2.87E+09	84.01	1.49E+00
Neptune	4.50E+09	164.78	4.69E+00
Pluto	5.91E+09	248.35	9.43E+00
Eris	1.02E+10	560.00	3.89E+01

Radiative: $k = k_{s;}$ Radiative + Solar Wind (SW): $k_{sw} = 1.329k_s$;

Table 5 : History of the Planetary System (Byr)

Planet	Orbits, Km			Orbital Periods, yr		
	R_p (-4.5)	R_p (0)	R_p (+4.5)	T_p (-4.5)	T_p (0)	T_p (+4.5)
Mercury	5.61E+07	5.80E+07	6.00E+07	0.23	0.24	0.25
Venus	1.02E+08	1.08E+08	1.15E+08	0.56	0.62	0.68
Earth	1.38E+08	1.50E+08	1.64E+08	0.88	1.00	1.15
Mars	2.01E+08	2.28E+08	2.63E+08	1.56	1.88	2.33
Jupiter	5.35E+08	7.78E+08	1.42E+09	6.8	11.9	29.3
Saturn	7.80E+08	1.43E+09	8.62E+09	11.9	29.5	437.2
Uranus	1.07E+09	2.87E+09	----	19.2	84.0	----
Neptune	1.24E+09	4.50E+09	----	23.9	164.8	----
Pluto	1.33E+09	5.91E+09	----	26.4	248.4	----
Eris	1.47E+09	1.02E+10	----	30.7	560.0	----

Table 6 Glossary of Terms

Byr	Billion Years
c	Velocity of Light
E	Energy
F_r	Gravitational Force
G_s	Surface gravity constant
G	Gravity constant, universal
k_i	Specific decay rate, stellar
k_s	Solar radiative decay constant
k_u	Overall stellar decay rate
k_w	Solar wind loss constant
k_{sw}	Solar total mass loss rate
M_0	Solar mass, present
M_p	Mass, planetary
M_s	Mass, stellar / solar
M_s (t)	Mass, Solar/stellar f (time)
n_i	Fraction of specific decay rate
R_p	Planetary orbit
R_s	Radius, solar / stellar
t_{ss}	Time of planetary separation
T	Planetary orbital Period
v_p	Planetary launch velocity
v_s	Solar escape velocity

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