On the Planetary acceleration and the Rotation of the Earth

Arbab I. Arbab

Department of Physics, Faculty of Science, University of Khartoum, P.O. Box 321, Khartoum 11115, Sudan

Abstract

We have developed a model for the Earth rotation that gives a good account (data) of the Earth astronomical parameters. These data can be compared with the ones obtained using space-base telescopes. The expansion of the universe has an impact on the rotation of planets, and in particular, the Earth. The expansion of the universe causes an acceleration that is exhibited by all planets.

1 Introduction

It has been understood that the impact of the universe expansion on our solar system is negligible. This is however not very true. The consequences of the expansion on the earth-moon system is in the measurable limit. The evolution of the earth-moon system was understood to be mainly due to tidal evolution. We have recently shown (Arbab, 2003) that the present acceleration of the universe is due to the ever increasing gravity strength. Very recently, we have found that the evolution of angular momenta and energy of the earth-moon system can be accounted as due to cosmic expansion (Arbab, 2005). This system is affected by the perturbation due to other planets or the sun. The cosmic expansion may show up in raising tides in this system. The influence of the expansion is contained in changing the value of the gravitational constant appearing in Kepler’s third law and Newton’s law of gravitation. At any rate, the total cosmic effect is embedded in the an effective gravitational constant \( G_{\text{eff}} \) that takes care of any gravitational interactions with the system. For a flat universe if gravity strengthens, expansion has to increase, in order to maintain a flatness condition. If gravity increases, then its effect on rotation of the earth-moon system will show up in its evolution. Astronomical investigations show that the preset earth’s rotation is decreasing, so

\(^1\text{E-mail: aiarbab@uofk.edu}"

1
that the length of the day is increasing at a rate of 2 millisecond/century. Astronomical analysis could not account for the entire rotation of the earth. For the time being, one can only extrapolate, which might be too dangerous. Laser ranging experiments (LRE) show that the moon is receding as it acquires an angular momentum due to the spin down of the earth rotation. That is because the total angular momentum of the earth-moon system remains constant during its evolution. Moreover, the moon exhibits some kind of an anomalous acceleration, that can be measured.

We however provide here a different approach to study this system. The data obtained are in agreement with geophysical and palaeontological findings. We attribute this evolution to the cosmic acceleration. However, the effect might appear in making tides. Recent findings based on optical observations in the solar system suggest that all planets might accelerate in their orbits. About thirty years ago the first indications of planetary drifts away from their predicted ephemerides appeared in the literature and more recently (Kolesnik, 2000) reported that that planetary drifts, determined from optical observations, may possibly be accelerations proportional to their motions.

2 The Model

We have recently developed a model that accounts for the present cosmic acceleration (Arbab, 2003). We have shown that, in the present epoch, the gravitational constant ($G$) increases with time. However, its exact time dependence is not well determined from cosmology. One has to resort to other source of information. This is found to be the past earth rotation.

It is known that the earth rotation is decreasing with time since the earth was formed. Scientists attribute this to the tide raising force by the moon on earth. Accordingly, the day is lengthening at a rate of about 2 millisecond every century. Hence, the earth is losing angular momentum and the moon must increase its angular momentum, as due to the angular momentum conservation of the earth-moon system. This fact implies that the moon must be receding from the earth. We know that the motion of the earth around the sun conserves the angular momentum. One can satisfy this conservation by requiring the earth to accelerate in its orbit around the sun. According to the scale expanding cosmos (SEC) the present acceleration of the earth is about 2.8 arcsec per century squared (Kolesnik and Masreliez, 2004). Moreover, one can attribute the deceleration of the earth rotation as due to cosmic expansion. The variation of the length of day are normally thought as due to the tidal dissipation raised by the moon on the earth. Others connect this deceleration with the interactions of the Earth core. However, in the present scenario we only know the total contribution, which we trust to be a consequence of the acceleration of the universe. This accelerated expansion is counteracted by a growing gravitational force between celestial objects. This gradual increase in gravity force is the main consequence of the astronomical phenomena we now come to observe. Geologists observed that the length of the day has not been constant over the past million years. Besides, they observe a similar change in the number of days in a year, days in a month, distance
between earth and moon. These variations can be calculated and their corresponding values can then be confronted with observational data.

We suggest that the cosmic expansion has an influence on the Earth-Sun-Moon system and similar systems. For a bound system, like the Earth-Sun, to remain in a bound state, despite the cosmic expansion (possibly accelerating), gravity strength has to increase to compensate for the cosmic expansion consequences. This strengthening of gravity would manifest its self in some aspects, like tidal acceleration, or orbital acceleration. We anticipate the Earth-Sun distance to change with cosmic time too. This means in the remote past the planets were at different positions from the Sun when they were formed.

The viability of this model will depend on the future astronomical or geological data that will emerge thereafter. The formulae we have obtained are not extrapolation, but rather emerge originally from a Gravitational Theory of Relativity (GTR), and therefore are reliable. They represent empirical relations that account for the rotation and evolution of the Earth-Sun system and similar system. Present data can not be used to understand the full history of the Sun-Earth-Moon system by just extrapolating them over very distant past. Hence, the use of our data will be inventible. Our model is so far the only model that provides a temporal evolution of the Earth-Moon-Sun system parameters. The prediction of these formulae are overwhelming, however. Theoretical prejudice favors that the Earth primordial rotation is about six hours. Only our model can give this value.

From the angular momentum \( (L) \) and the Kepler’s third law, one finds

\[
L^3 \propto G^2 T , \quad (1)
\]

\[
L \propto \sqrt{Gr} , \quad (2)
\]

and

\[
L \propto Gv^{-1} , \quad (3)
\]

where \( T \) is the number of days in a year, \( v \) is the orbital velocity of the earth (planet) rotation in its orbit, \( r \) is the earth (planet)-sun distance, and \( G \) is the gravitational constant. If the angular momentum of the earth-Sun system is constant, then on find that

\[
T \propto G^{-2} , \quad (4)
\]

\[
r \propto G^{-1} , \quad (5)
\]

and

\[
v \propto G . \quad (6)
\]

Eq.(2) implies that as long as \( G \) is constant then \( T, r, \) and \( v \) are constant too. However, there is a possibility that \( G \) might have been changing appreciably over cosmological time. In this case if one knows the way how \( G \) varies the variation of the distance \( r \) can be calculated. Thus the variation
of \( G \) will mimic the tidal effects which people now attribute these changes to. If \( G \) changes with time Newton’s gravitational law still holds. However, the equivalence principle of general theory of relativity is broken. The variation of \( G \) may not be real and it is due to an existence of dark matter coexisting with normal matter. Its effect is to make the gravitational coupling (Newton’s constant) appear to be increasing. The effect of a little normal matter and increasing gravity in a universe is equivalent to that of more matter and normal gravity universe. We may dictate that Newton’s law of gravitation (and Kepler’s law) to be applied to an evolving local system, like the planetary system, viz. Earth-Moon-Sun system.

In our present study we rely on a general form for the variation of \( G \) with cosmic time (Arbab, 2003). In this scenario a gravitating body interacts with an effective gravitational constant \( G_{\text{eff}} \), which differs from a bare Newton’s constant we used to know. We have, in particular, an increasing \( G = G_{\text{eff}} \) at the present epoch, viz.

\[
G_{\text{eff}} = G_0 \left( \frac{t}{t_0} \right)^n \tag{7}
\]

where \( n > 0 \) is some constant to be determined from experiment. In this sense gravity couples with \( G_{\text{eff}} \) rather than with bare \( G_0 \) because of cosmic expansion. The effect of this constant is to replace in all formulæ the normal(bare) Newton’s constant with this effective constant. The Earth couples with the rest of the universe with this value. This coupling follows from the idea of Mach that the inertia of an object is influenced by the rest of matter in the universe. In an evolving universe this effective constant induces a cosmological effect on over planetary system while the bare constant \( (G_0) \) stays invariant. This why we observe some cosmic effects exhibited in tidal effects, or effects drawn from perturbation by other objects in the nearby solar system. In this context one has a calculable variation in the strength of gravity due to cosmic expansion. This variation can’t be measured directly. We present here a new approach of detecting its variation with cosmic time in the way it has affected planetary system dynamics. An increasing gravitational constant may mimic an increasing mass of a gravitating body. Or alternatively, it mimics a dark matter nearby the gravitating body that makes the orbiting object to fall towards it. A universe with increasing gravitational constant may look indistinguishable from the one with dark matter. Hence, if gravity increases for some reason the idea of dark matter need not be attractive. Milgrom modified Newton’s law to account for the flattening of the rotation curve. In our present case the modification does not change the form of Newton’s law.

Here \( n \) determines the properties of the cosmological model proposed. If one assumes that the length of the year remains constant, then the length of the day \( (D) \) should scale as

\[
D \propto G_{\text{eff}}^2 \tag{8}
\]

Hence, one has

\[
T_0 D_0 = T D \tag{9}
\]
where the subscript ‘0’ on the quantity denotes its present value. Our model shows that the day was six hours when the earth was formed. The angular velocity of the earth about the sun is \( \Omega = \frac{2\pi}{T} \)

\[
\Omega \propto G_{\text{eff}}^2.
\]  

(10)

This implies that the Earth is accelerating at a rate of

\[
\frac{\dot{\Omega}}{\Omega} = 2 \frac{\dot{G}_{\text{eff}}}{G_{\text{eff}}},
\]  

(11)

and at the same time the earth-sun distance decreases at a rate of

\[
\frac{\dot{r}}{r} = - \frac{\dot{G}_{\text{eff}}}{G_{\text{eff}}},
\]  

(12)

If we know how \( G \) varies, one can calculate this variation. In our cosmological model, we know the general variation of \( G \) depends on a parameter \( n \) that determines the whole cosmology. If \( n \) is known then the whole cosmological parameters are known. Our model [1] could not determine \( n \) exactly. It places a weaker limit on the value of \( n \). However, Wells [2] had found from a palaeontological study the number of days in the year. To reproduce his result we require the age of the universe to be \( t_0 \sim 11 \) billion years and \( n = 1.3 \) so that

\[
G_{\text{eff}} = G_0 \left( \frac{t}{t_0} \right)^{1.3}.
\]  

(13)

Hence, eqs.(4)-(7) become, respectively

\[
T = T_0 \left( \frac{t_0}{t} \right)^{2.6},
\]  

(14)

\[
r = r_0 \left( \frac{t_0}{t} \right)^{1.3},
\]  

(15)

\[
v = v_0 \left( \frac{t}{t_0} \right)^{1.3},
\]  

(16)

and

\[
D = D_0 \left( \frac{t}{t_0} \right)^{2.6}.
\]  

(17)

We remark here that there is an astrophysical system (Binary Pulsars) in which the decay of orbit is very prominent and attributed to the emission of gravitational waves. Can we assume here that there is a similar effect? Alternatively, may one suggest that the decay of orbit in the former system
is due to cosmic expansion in the manner we have identified above? This is quite plausible if the apparent acceleration of planetary system is the direct cause.

It is worth to mention that Wells could not go far beyond the Precambrian (600 million years back). Our model gives a formula that determines the number of days in a year and the length of day at any time in the past. These data obtained from this formula are in full agreement with those obtained by different methods (see Arbab 2004 and references therein). The correctness of the formula entitle us to say that our initial proposition that the expansion of the universe affects our solar system is correct. If that is true, one can calculate the present acceleration of the earth (and other planets) and the rate at which their orbit decreases. For the earth orbital motion one finds that the present acceleration amounts to

\[ \dot{\Omega}_0 = \left(\frac{2.6}{t_0}\right) \Omega_0, \quad \dot{\Omega}_0 = 3.05 \text{ arcsec/cy}^2 \]  

At the same time the earth-sun distance decreases at a a rate of

\[ \dot{r}_0 = -\left(\frac{1.3}{t_0}\right) r_0, \quad \dot{r}_0 = -17.7 \text{m/year} . \]  

One can also write the above equations in terms of Hubble constant, as

\[ \frac{\dot{\Omega}}{\Omega} = 2.36 \ H, \quad \frac{\dot{r}}{r} = -1.18 \ H, \quad \frac{\dot{v}}{v} = 1.18 \ H, \quad \frac{\dot{D}}{D} = 2.36 \ H , \]  

since

\[ \frac{\dot{G}_{eff.}}{G_{eff.}} = 1.18 \ H . \]  

We see that the gravitational force increases as

\[ F = \left(\frac{G_{eff.}}{G_0}\right)^3 F_0 , \]  

and upon using eq.(7), it becomes

\[ F = \left(\frac{t}{t_0}\right)^4 F_0 . \]  

We notice that the Newton’s and Kepler’s laws of gravitation do still work well, even in an expanding universe, with only a minor generalization that takes care of time evolution. The increase of the gravitational forces is such that to counteract the present universal expansion (acceleration) so that the universe remains in equilibrium (flat). The gravitational force between our Earth and the Sun 4.5 billion years ago has been 12% less than now.
An increasing gravity would mean that in the past the gravity was weak. This might probably provide a comfortable life of gigantic animal, like dinosaurs, to roam freely on earth’s surface. As gravity increases their weights would become heavier and finally may not support its growing weight. Thus it might not have been appropriate for them to survive and later they vanish when they are overweight. This scenario may provide a rather convenient mechanism on how dinosaurs extinct.

We thus see that all earth parameters vary as due to universe expansion. We have found the present Hubble constant to be $H_0 = 10^{-10} \text{y}^{-1}$ so that $(\frac{G_{\text{eff}}}{G_{\text{eff}}})_0 = 1.18 \times 10^{-10} \text{y}^{-1}$. This analysis imposes a new limit on $G_{\text{eff}}$ and $H$ which can be tested with observational data. There is only few models that deal with increasing $G$. However, models in which $G$ decreases with time lead to serious difficulties, when confronted with observations. Our model predicts a universal acceleration of all gravitating bodies. For instance, we found that Mercury accelerates at a rate of 12.6 arcsec/$\text{cy}^2$, Venus at a rate of 4.95 arcsec/$\text{cy}^2$, Earth at a rate of 3.05 arcsec/$\text{cy}^2$ and Mars at a rate of 1.6 arcsec/$\text{cy}^2$. We remark that the formulae pertaining to the planets motion are in good agreement with observation. We should also await the emergence of new data to test their applicability to these systems. We see from eq.(19) that the day ($D$) lengthens by 1.95 msec/$\text{cy}$. According to scale expanding cosmos (SEC) the planets spins down. If all of these data are found to be in accordance with observation, then our hypothesis that the cause of the present acceleration is due to gravity increase would be inventible!

3 Concluding Remarks

We have shown in this paper that the present cosmic acceleration induces its effect on our Earth-Moon-Sun system. This is apparent in the magnitude of the variation of the length of day, year, distance, angular velocity, etc which are all proportional to the Hubble parameter. The cosmological effects show up in different forms some of them are understood as due to tidal effects. We anticipate that the future observations will bring many puzzles and surprises with it.
Table 1: Data obtained from fossil corals and radiometric time

| Time\(^a\) (days/year) | 65    | 136   | 180   | 230   | 280   | 345   | 405   | 500   | 600   |
|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 371.0                  | 377.0 | 381.0 | 385.0 | 390.0 | 396.0 | 402.0 | 412.0 | 424.0 |

Table 2: Data obtained from our empirical formula in eqs.(14) and (17)

| Time\(^a\) (days/year) | 65    | 136   | 180   | 230   | 280   | 345   | 405   | 500   | 600   |
|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 370.9                  | 377.2 | 381.2 | 385.9 | 390.6 | 396.8 | 402.6 | 412.2 | 422.6 |
| 23.6                   | 23.2  | 23.0  | 22.7  | 22.4  | 22.1  | 21.7  | 21.3  | 20.7  |
| 715                    | 850   | 900   | 1200  | 2000  | 2500  | 3000  | 3560  | 4500  |
| 435.0                  | 450.2 | 456   | 493.2 | 615.4 | 714.0 | 835.9 | 1009.5| 1434  |
| 20.1                   | 19.5  | 19.2  | 17.7  | 14.2  | 12.3  | 10.5  | 8.7   | 6.1   |

\(^a\) Time in million years before present

4 References

Arbab, A.I., *Class. Quantum Gravit.* 23, 23 (2003)
Arbab, A.I., *Acta Geod.Geophys.Hung.* 39, 27 (2004)
Arbab, A.I., *Acta Geod.Geophys.Hung.* 40, 33 (2005)
Kolesnik, Y. B., *Proceedings of the IAU* (2000)
Kolesnik, Y. B. and Masreliez C. J., *Astronomical Journal.* 128, 878 (2004)
Wells, J.W., *Nature.* 197, 948 (1963)
Masreliez, C.J, *Apeiron,* V.11, 1 (2004)