Reduction in Gravitational Force as a Result of the Relativistic Doppler Effect

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Abstract

This paper describes the method by which the gravitational force between galaxies can be reduced and even reversed as a result of the net energy loss from photon exchange. According to the relativistic Doppler Effect, galaxies moving apart will suffer a net energy loss when exchanging photons. This energy loss reduces the total energy of the system, resulting in a reduction in gravitational attraction between the galaxies. Given sufficient velocity, emitted photon energy, and rate of photon exchange, it is shown that the attractive force between galaxies can be reversed, resulting in an accelerated expansion of the Universe.

Gravitation and the Relativistic Doppler Effect

Figure 1 depicts our galaxy in the center of the Universe with the mass of the rest of the Universe depicted as masses distributed evenly around it (the cosmological principle tells us that the Universe looks the same in all directions which means that the mass of the Universe is evenly distributed in all directions).

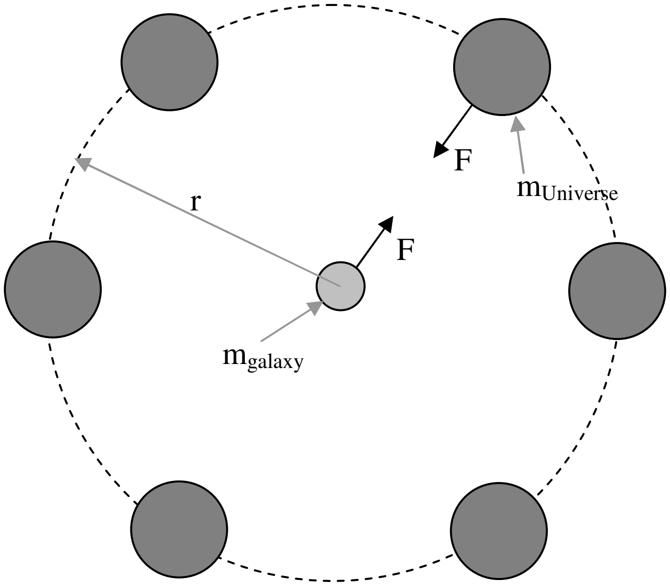

Figure 1: Gravitational Forces Between Galaxies

From Figure 1, we see that there is a gravitational force between our galaxy and the surrounding Universe acting equally in all directions. If we consider the force between our galaxy and a small portion of the Universe as shown in Figure 1, we know from Newton's law of gravity that the force acting between the galaxy and that portion of the Universe is given by:

$$F = \frac{m_{galaxy} m_{Universe} G}{r^2} \qquad \text{(Eq. 1)}$$

And this force is attractive when positive. Now let us suppose that the radius of the Universe is expanding at a constant rate ($\dot{r}$), and that there is a constant rate of exchange of photons between m_{galaxy} and $m_{Universe}$ (which we will denote $\dot{\gamma}$). We will assume that the average frequency of photons being emitted from our galaxy and the Universe are equal and denote this frequency $f_{emitted}$. Since the surrounding Universe is moving away from our galaxy at speed $\dot{r}$, there will be a Doppler shift in the frequency of the photons absorbed by our galaxy and the Universe according to the relativistic Doppler Effect:

$$f_{absorbed} = \left(\sqrt{\frac{1 - \frac{\dot{r}}{c}}{1 + \frac{\dot{r}}{c}}} \right) f_{emitted} \qquad \text{(Eq. 2)}$$

And the difference between the emitted and absorbed frequency is given by:

$$f_{\Delta} = f_{emitted} - f_{absorbed} = \left(1 - \sqrt{\frac{1 - \frac{\dot{r}}{c}}{1 + \frac{\dot{r}}{c}}} \right) f_{emitted} \qquad \text{(Eq. 3)}$$

We know from special relativity that energy and mass are equivalent and therefore a system which loses energy will behave the same as a system which loses mass. Therefore, the equivalent mass loss of the system per photon exchanged by this shift is given as:

$$m_{eq} = \frac{h}{c^2} \left(1 - \sqrt{\frac{1 - \frac{\dot{r}}{c}}{1 + \frac{\dot{r}}{c}}} \right) f_{emitted} \qquad \text{(Eq. 4)}$$

Where h is Plank's constant and c is the speed of light. In this case, as the Universe and galaxy exchange photons, the system will lose energy as a result of the Doppler shift, and the gravitational force between them will be reduced. For a single photon exchanged, the instantaneous gravitational force between the galaxy and Universe will become:

$$F = \left((m_{galaxy} - m_{eq,galaxy})(m_{Universe} - m_{eq,Universe}) \right) \frac{G}{r^2} \qquad \text{(Eq. 5)}$$

And after time t, given a constant rate of photon exchange $\dot{\gamma}$ in photons/second, the gravitational force becomes:

$$F_{t+1} = F_t - \dot{\gamma} dt \left[m_{eq,galaxy}(\dot{r}) \right] \left[m_{eq,Universe}(\dot{r}) \right] \frac{G}{r^2} \qquad \text{(Eq. 6)}$$

Note that because m_{eq} is dependant on the velocity of expansion, and therefore the force itself, the equation involves feedback and *dt* is the time difference between successive force calculations where constant velocity is assumed. Thus, we see that it is possible for the gravitational force between the galaxies to become repulsive if the energy lost from the aggregated photon exchange becomes larger than the rest energy of the Universe and galaxy, causing the expansion to accelerate. Furthermore, the amount of energy loss increases as the photon frequency increases. Thus, for times with high rates of high energy photon exchange (such as the early Universe), the force reduction may have been enough to drive an accelerated expansion.

Now suppose the Universe is closed such that a photon travelling from one point in space along an undisturbed geodesic can return to the same point. In this case, it is possible for the photon to be emitted and reabsorbed by the galaxy without any Doppler shift after traversing the entire Universe. We know that as the Universe expands, the distance between galaxies will increase, and the number of the aforementioned paths will increase. Thus, for a closed Universe, the m_{eq} will be reduced proportional to the radius of the Universe and Equation 6 must be modified:

$$\begin{aligned} m_{eff,galaxy} &= m_{eq,galaxy}(\dot{r})\left(\dot{\gamma}_{galaxy}dt - g_{galaxy}(dt, \dot{\gamma}_{galaxy}, r)\right) \\ m_{eff,Universe} &= m_{eq,Universe}(\dot{r})\left(\dot{\gamma}_{galaxy}dt - g_{Universe}(dt, \dot{\gamma}_{Universe}, r)\right) \\ F_{t+dt} &= F_t - \frac{m_{eff,galaxy}m_{eff,Universe}G}{r^2} \end{aligned} \qquad \text{(Eq. 7-9)}$$

Where $g(dt, \dot{\gamma}, r)$ is some function representing the number of photons emitted able to return to their source without a Doppler shift. So in a closed Universe evolving over time, we see that it is possible to have an accelerated expansion (given an initial velocity) for some time, followed by a contraction as $g(dt, \dot{\gamma}, r)$ becomes large and the force becomes attractive. Once the force becomes attractive, the velocities will decrease, reducing the energy loss due to the Doppler Effect, making the attractive force even stronger. And when the galaxies reverse direction and move toward each other again, the Doppler Shift will result in a net *increase* of energy, causing the attractive force to increase until the Universe completely collapses.

In the case of an open Universe, the function $g(dt, \dot{\gamma}, r)$ will become $g(dt, \dot{\gamma}, r, f_{emitted})$ and will additive to the first terms in equations 7 and 8 because any emitted photons which do not get re-absorbed will result in an energy reduction equal to the total energy of the photon emitted. Therefore, in an open Universe with an accelerating expansion, there is no possibility for a future reversal of the expansion as a result of the mechanism.

Conclusion

It has been shown that integrating the energy change resulting from the relativistic Doppler Effect between bodies with relative velocities into the law of gravitation, the accelerated expansion of the Universe can be explained given an initial expansion velocity and constant photon exchange between bodies. When the galaxies are moving apart, it has been shown that the net energy of the bodies after photon exchange decreases, which, given the correct conditions, can make the gravitational force repulsive. Furthermore, it is argued that if the Universe is closed, the acceleration will decrease as the radius of the Universe increases because the increasing distance between galaxies allows more emitted photons to return to their source without a frequency shift (and thus, no energy loss). In this case, the acceleration will eventually reverse, resulting in the collapse of the Universe.