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Gravitational Acceleration Constant

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The gravitational force between two astronomical objects having masses m and M is given by Newton's law of gravity, which says that the attractive force between them is proportional to the product of their masses and inversely proportional to the square of the distance between their centers. This law can be expressed in the equation

$$F_G = G(mM)/R^2 \quad \ldots (1)$$

where F_G is the gravitational force, G is the gravitational constant (equal to 6.67×10^{-11} $m^3\ kg^{-1}\ sec^{-2}$)[1]. For the sake of simplicity, we will assume that the mass of the more massive astronomical object M (hereinafter the M object) is much greater than the mass of the less massive astronomical object (hereinafter the m object) or M >> m.

According to Newton's second law of motion, the acceleration of an object (a) equals the net force (F) acting on it divided by its mass (*m*). This can be represented by the equation

$$a = F/m \quad \ldots (1).$$

In this case, we have

$$F_G = ma_G \quad \ldots (2)$$

where a_G is the gravitational acceleration of the m object received due to the gravitational force F_G acting on it. From the eqn. (2), we find that the gravitational acceleration is equal

$$a_G = GM/R^2.$$

Special relativity limits the acceleration of the m object with the speed of light c ($\approx 3 \times 10^8$ *m sec*$^{-1}$) and it must be $a_G << c/1$ *sec* [1, 2].

Indeed, suppose $a_G = c/1$ *sec*. In expression,

$$a_G = c \times sec^{-1} (\approx 3 \times 10^8\ m\ sec^{-2})$$

or

[1] To avoid confusion in further text, the SI units are given in italics.

$$GM/R_c^2 = c \times sec^{-1}.$$

This is the minimum possible distance between the m and M objects or $R > R_c$.

Hence,

$$M/R_c^2 = c \times sec^{-1}/G.$$

Substituting known values of $c \times sec^{-1}$ and G into this inequality, we obtain

$$M/R_c^2 = 4.5 \times 10^{18} \text{ (expressed in } kg\ m^{-2}) \quad \ldots (3).$$

$M/R_c^2 = c \times sec^{-1}/G = 4.5 \times 10^{18}$ $kg\ m^{-2}$ represents its maximum value obtained assuming that the gravitational acceleration $a_G = c \times 1\ sec^{-1}$. We name it as the gravitational acceleration constant $\gamma = 4.5 \times 10^{18}$ $kg\ m^{-2} > M/R^2$.

Using eqn. (1) and after a bit of algebra, we have the following expression for the distance R_c

$$R_c = 4.7 \times 10^{-10}\sqrt{M} \quad \ldots (4),$$

Example: Venus has a nearly circular orbit with an eccentricity of 0.007. Its mass is about 4.87×10^{24} *kg* and it is much smaller than the mass of the Sun. Introducing the mass of the Sun of about 1.989×10^{30} *kg* into eqn. (4), we find that $R_c = 670$ *km*. In contrast, the radius of the Sun is much larger about 7×10^5 *km*.

The Milky Way's mass is about 6×10^{42} *kg* and, although the mass of a galaxy is difficult to estimate with any accuracy. Currently, it appears the Segue 2 in the Aries constellation is the one closest to the Earth orbiting the Milky Way. It is a dwarf galaxy with a mass of about 2.2×10^{36} *kg*. Using eqn. (4), we estimate that R_c would be about 1.15×10^{12} *km*. In contrast, the Milky Way's radius is much larger about 4.75×10^{17} *km*.

Reference

[1] P. I. Premović, *Acceleration of a non-relativistic astronomical objects and the speed of light*. The General Science Journal.

[2] P. I. Premović, *Gravitational acceleration and the speed of light*. The General Science Journal.