

# Calculation of the Gravitational Limits and the Hubble Constant for the Local Group

by  
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## Abstract

This paper presents the equations for the calculation of the gravitational limits and Hubble constant for celestial bodies according to the Reciprocal System of physical theory developed by D. B. Larson. It then applies these equations to calculate the gravitational limits and the Hubble Constant for the Local Group of galaxies and compares the results to observation. It is shown that the Hubble Constant is not a fixed structural value of the universe; rather it is different for each stellar aggregate and is a function of mass.

**keywords:** gravitation, space-time, Hubble Constant, Reciprocal System, Local Group

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## Introduction

The Reciprocal System of physical theory is described in the books by Dewey B. Larson, such as Ref. [1], [2], [3]. In this theory two oppositely-directed basic motions exist, the space-time

progression and gravitation. Both are scalar, not vectorial or tensorial. The gravitational motion is inward, or negative, whereas the space-time progression is outward, or positive, in regard to macroscopic phenomena. The gravitational motion is attenuated with distance by the inverse-square law, whereas the space-time progression is not. Therefore, Larson concludes that "...the gravitational limit of a mass is the distance at which the inward gravitational motion of another mass toward the mass under consideration is equal to its outward motion due to the progression of the natural reference system relative to our stationary system of reference." (Ref. [3], p. 105). This is the first gravitational limit. The second gravitational limit is reached at the point where gravitation is eliminated entirely, and the mass entity recedes at the speed of light, the full speed of the progression. The Hubble Constant relates to the increase in speed of the mass entity between the two gravitational limits. Expanding on the work presented in Ref. [4], this paper is runnable as a *Mathcad* program, so the equations are more detailed than they otherwise would be.

## Nomenclature

$a_g$  = acceleration of arbitrary mass due to gravity of mass M, dynes/gm or  $\text{cm/s}^2$

$a_p$  = acceleration of arbitrary mass due to the space-time progression, dynes/gm or  $\text{cm/s}^2$

$a_n$  = net acceleration of arbitrary mass due to gravity and the space-time progression, dynes/gm or  $\text{cm/s}^2$

$b_1$  = constant of integration for gravitational velocity

$b_2$  = constant of integration for velocity due to space-time progression

$c$  = speed of light,  $\text{cm/s}$

$\text{conv}_{\text{cmtoly}}$  = factor to convert cm to lightyears

$\text{conv}_{\text{lytoMpc}}$  = factor to convert lightyears to Mpc (megaparsecs)

$\text{conv}_{\text{Mpc to km}}$  = factor to convert Mpc to km

$\text{conv}_{\text{stoyear}}$  = factor convert seconds to years

$d_0$  = gravitational limit at which gravitation equals the space-time progression, cm

$d_{0n}$  =  $d_0$ , natural space units

$d_{0ly}$  =  $d_0$ , lightyears

$d_{0\text{Mpc}}$  =  $d_0$ , Mpc

$d_{0ly\text{LG}}$  =  $d_0$  for Local Group, lightyears

$d_{0\text{Mpc}\text{LG}}$  =  $d_0$  for Local Group, Mpc

$d_1$  = gravitational limit at which gravitation is eliminated entirely, cm

$d_{1ly}$  =  $d_1$ , lightyears

$d_{1\text{Mpc}}$  =  $d_1$ , Mpc

$d_{1ly\text{LG}}$  =  $d_1$  for Local Group, lightyears

$d_{1\text{Mpc}\text{LG}}$  =  $d_1$  for Local Group, Mpc

$G$  = universal constant of gravitation, dynes  $\text{cm}^2/\text{gm}^2$

$H$  = Hubble Constant, km/sec per Mpc

$H_{\text{LG}1}$  = Hubble Constant for Local Group based on "observed mass", km/sec per Mpc

$H_{LG2}$  = Hubble Constant for Local Group based on calculated mass, km/sec per Mpc

$H_{LG3}$  = Hubble Constant for Local Group based on  $d_{0MpcLG}$  and  $d_{1MpcLG}$

$H_x$  = Hubble "Constant" as function of x close to  $d_0$

$I_{d0}$  = rotational ratio, dimensionless

$I_{d1}$  = inter-regional ratio, dimensionless

$M$  = mass of celestial body, gm (except in Figures, where it's expressed in solar units)

$M_n$  = mass of celestial body, natural mass units

$M_s$  = mass of the sun, gm

$M_{LGobs}$  = observed mass of Local Group of galaxies, gm

$M_{LGcalc}$  = calculated mass of Local Group of galaxies, gm

$M_{LGobsol}$  = observed mass of Local Group of galaxies, in solar units

$M_{LGcalcsol}$  = calculated mass of Local Group of galaxies, in solar units

$m_u$  = natural unit of mass, gm

$P$  = universal constant of the space-time progression, dynes/gm or  $cm/s^2$

$s_u$  = natural unit of space, cm

$t$  = time, s

$v_g$  = velocity of arbitrary mass due to gravitation, inside first gravitational limit, cm/s

$v_{g0}$  = velocity of arbitrary mass due to gravitation, outside first gravitational limit, cm/s

$v_n$  = net velocity of arbitrary mass, inside first gravitational limit, cm/s

$v_{n0}$  = net velocity of arbitrary mass, outside first gravitational limit, cm/s

$v_0$  = speed of arbitrary mass due to space-time progression at first gravitational limit, cm/s

$v_{0km}$  = speed of arbitrary mass due to space-time progression at first gravitational limit, km/s

$v_p$  = velocity of mass due to the space-time progression, inside first gravitational limit, cm/s

$v_{p0}$  = velocity of mass due to space-time progression, outside first gravitational limit, cm/s

$x$  = distance from celestial body to arbitrary mass, cm

$y$  = ratio of  $x$  to first gravitational limit, dimensionless

Note: A black square in the upper right of an equation means that the equation is disabled from running in *Mathcad*. This is done because not all variables in the equation have, as yet, been given numerical values.

## Unit Conversions and Physical Constants

$$\begin{aligned} \text{conv}_{\text{cmtoly}} &:= 1.0571 \times 10^{-18} & \text{conv}_{\text{lytoMpc}} &:= 3.0674 \times 10^{-7} \\ \text{conv}_{\text{Mpctokm}} &:= 3.084 \cdot 10^{19} & \text{conv}_{\text{stoyear}} &:= 3.169 \cdot 10^{-8} & c &:= 2.997925 \cdot 10^{10} \text{ cm/s} \\ \underline{\underline{G}} &:= 6.67 \cdot 10^{-8} \text{ dynes cm}^2 / \text{gm}^2 \\ M_{\text{S}} &:= 2 \cdot 10^{33} \text{ gm} & M_{\text{LGobs}} &:= 2.3 \cdot 10^{12} \cdot M_{\text{S}} & M_{\text{LGobs}} &= 4.6 \times 10^{45} \text{ gm} \quad (\text{Ref. [5]}) \\ m_{\text{U}} &:= 1.65979 \cdot 10^{-24} \text{ gm} & s_{\text{U}} &:= 4.558816 \cdot 10^{-6} \text{ cm} \quad (\text{Ref. [1], p. 160}) \end{aligned}$$

## Motion Inside the First Gravitational Limit

The acceleration of a body of arbitrary mass due to the gravitational force of a celestial body of mass  $M$  a distance  $x$  away (outside of it) is given by

$$a_{\text{g}} := \frac{-GM}{x^2} \quad \text{dynes/gm or cm/s}^2 \quad (1)$$

The acceleration of a body of arbitrary mass due to the force of the space-time progression is

$$a_{\text{p}} := P \quad \text{dynes/gm or cm/s}^2 \quad (2)$$

Therefore, the net acceleration of the mass at a distance  $x$  from mass  $M$  is

$$a_n := P - \frac{G \cdot M}{x^2} \quad \text{dynes/gm or cm/s}^2 \quad (3)$$

The first gravitational limit occurs when the net acceleration is zero. To calculate the distance at which this occurs,  $d_0$ , we will have to temporarily revert to using the natural units of the Reciprocal System. With these units, there is no need to use the conversion factor  $G$ , and the value of  $P$  is 1. Thus

$$\frac{M_n}{d_{0n}^2} := 1 \quad (4)$$

But Ref. [3], p. 196, shows that the gravitational motion is distributed over  $2.1475 \times 10^9$  units, only one of which is acting against the the outward progression. Larson terms this number the "rotational ratio."

$$l_{d0} := 2.1475 \cdot 10^9 \quad (5)$$

Equation 4 then becomes

$$\frac{M_n}{l_{d0} \cdot d_{0n}^2} := 1 \quad (6)$$

Solving for  $d_{0n}$ , we obtain

$$d_{0n} := \left( \frac{M_n}{I_{d0}} \right)^{.5} \quad (7)$$

In terms of conventional units

$$d_0 := \left( \frac{M}{m_u} \right)^{.5} \cdot s_u \quad (8a)$$

$$d_0 := 76.3588 \cdot M^{.5} \quad \text{cm} \quad (8b)$$

$$d_{0ly} := 3.6099 \cdot \left( \frac{M}{M_s} \right)^{.5} \quad \text{lightyears} \quad (8c)$$

$$d_{0Mpc} := 2.476 \cdot 10^{-23} \cdot M^{.5} \quad \text{Mpc} \quad (8d)$$

Knowing  $d_0$  we can now obtain the value for  $P$  in conventional units:

$$P := \frac{G \cdot M}{d_0^2} \quad P := \frac{G \cdot M}{76.3588^2 M} \quad P := \frac{G}{76.3588^2} \quad (9)$$

$$P = 1.144 \times 10^{-11} \quad \text{dynes/gm}$$



And, knowing the accelerations, we can now derive the speeds due to the gravitational and space-time progression accelerations. For gravitation:

$$a_g = dv_g/dt = (dv_g/dx) * v_g = -G * M / x^2 \quad (10)$$

Separating variables and integrating,

$$\int v_g dv_g = \int \frac{-G \cdot M}{x^2} dx \quad (10a)$$

we obtain

$$v_g^2 = 2 * G * M / x + b_1 \quad (11)$$

For the acceleration due to the space-time progression:

$$a_p = dv_p/dt = (dv_p/dx) * v_p = P \quad (12)$$

$$\int v_p dv_p = \int P dx \quad (12a)$$

$$v_p^2 = 2 * P * x + b_2 \quad (13)$$

At the first gravitational limit, where  $x = d_0$ , the net speed is zero, so  $v_p^2 = v_g^2$ .

$$2 * G * M / d_0 + b_1 = 2 * P * d_0 + b_2$$

$$b_1 - b_2 = 2 ( P * d_0 - G * M / d_0 ) = 2 * d_0 ( P - G * M / d_0^2 ) = 0 \quad (14)$$

In the limit as  $x$  goes to zero,  $v_p$  should go to zero, or close to zero. Therefore  $b_1$  is zero, or close to zero, which by eq. 14 makes  $b_2$  zero, or close to zero, as well. Note that we are treating the masses here as essentially point masses, and therefore not including any differential gravitational effects. Also, note that if we were merely dealing with two atoms approaching each other, rather than huge aggregations of matter, the progression and gravitation would reverse directions at unit space. Right at the boundary of unit space between the two atoms, the progression is zero. Considering all of this, we will take  $b_1$  and  $b_2$  to be zero in what follows.

K. Nehru, Ref. [4], terms the progression speed of the mass aggregate at  $d_0$  the "zero-point speed",  $v_0$ .

$$v_0 := (2 \cdot P \cdot d_0)^{.5} \quad (15a)$$

$$v_0 := 4.1797 \cdot 10^{-5} \cdot M^{.25} \quad \text{cm/s} \quad (15b)$$

$$v_{0\text{km}} := 4.1797 \cdot 10^{-10} \cdot M^{.25} \quad \text{km/s} \quad (15c)$$

If we let  $y = x / d_0$ , the distance in non-dimensional form, we can express both of the speeds in compact form:

$$v_g = -(2 * G * M / x)^{.5} = -(2 * G * M / d_0)^{.5} * (d_0 / x)^{.5} = -v_0 / y^{.5} \text{ cm/s} \quad (16)$$

$$v_p = v_0 * y^{.5} \text{ cm/s} \quad (17)$$

Then the net velocity,  $v_n$ , applicable from  $x$  equal zero (or near zero) to the first gravitational limit, is:

$$v_n = v_p + v_g = v_p - |v_g| = v_0 * (y^{.5} - 1 / y^{.5}) \text{ cm/s} \quad (18)$$

Here's a plot of  $v_{0\text{km}}$  (km/s) as a function of mass (gm) for galaxies or associations considerably smaller to considerably larger than the Milky Way.

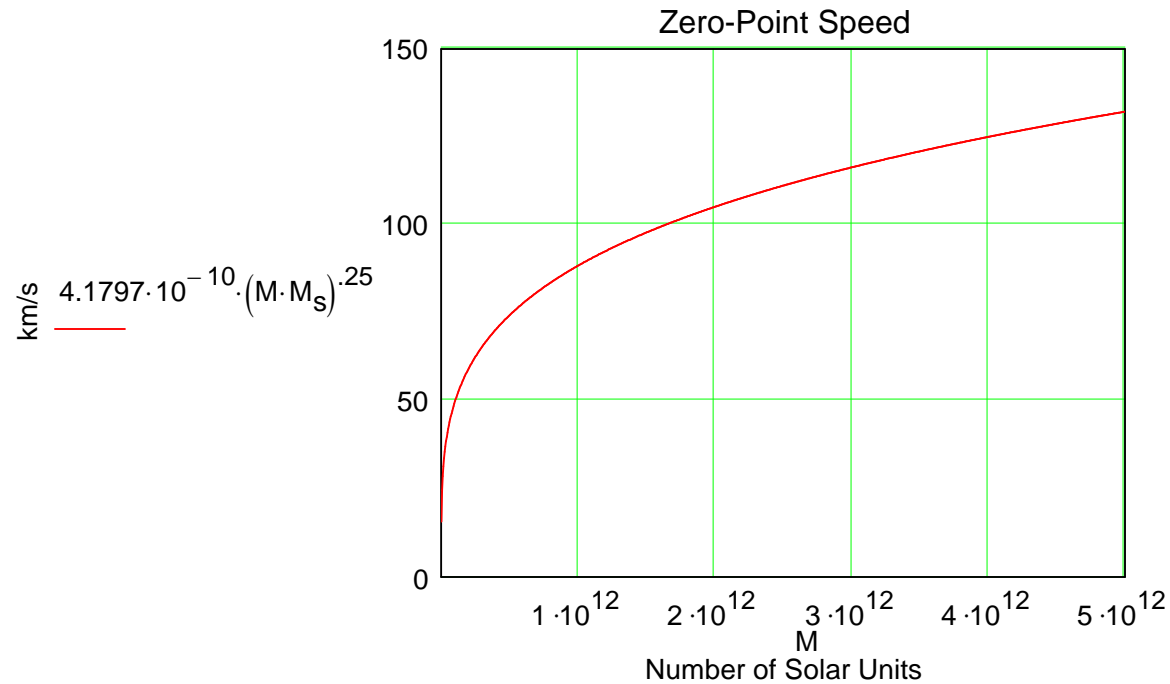


Figure 1. Zero-Point Speed as a Function of Mass

For the Local Group, the zero-point speed is (after converting to km/s)

$$v_{0LGkm} := 4.1797 \cdot 10^{-10} \cdot M_{LGobs}^{.25} \quad v_{0LGkm} = 108.8515 \quad \text{km/s}$$

And here's a plot of the speed due to the space-time progression, the speed due to gravitation, and the net speed of an arbitrary mass as a function of distance from  $y$  ( $= x/d_0$ ) equal to .05 to  $y = 1$  for the Local Group, using the above equations. (Below approximately  $y = .05$ , local and differential gravitational effects cannot be ignored.)

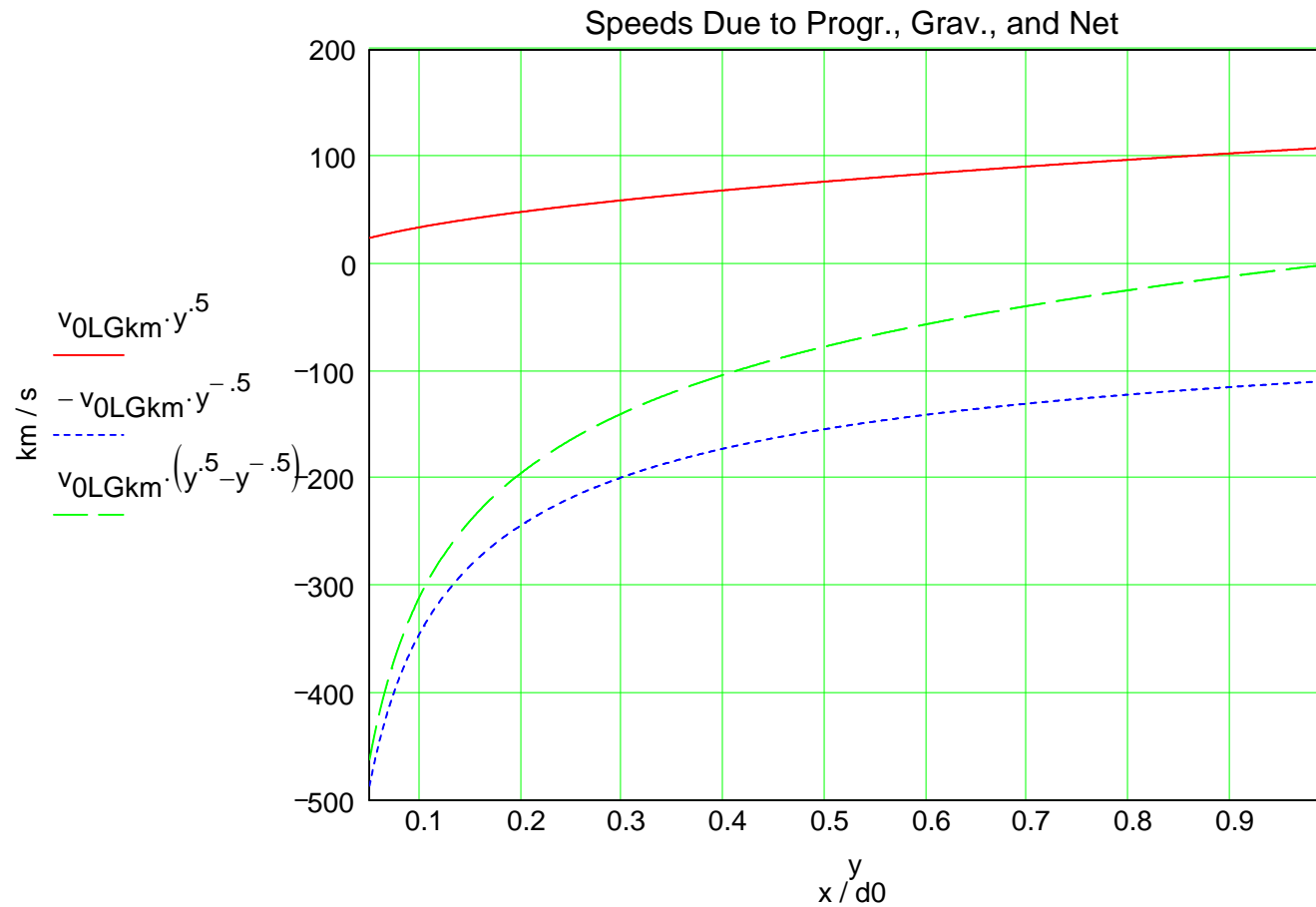


Figure 2. Speed Components of Arbitrary Mass Toward Local Group as a Function of Distance in Terms of First Gravitational Limit

Also of great importance is the first gravitational limit as a function of mass. Here's the plot:

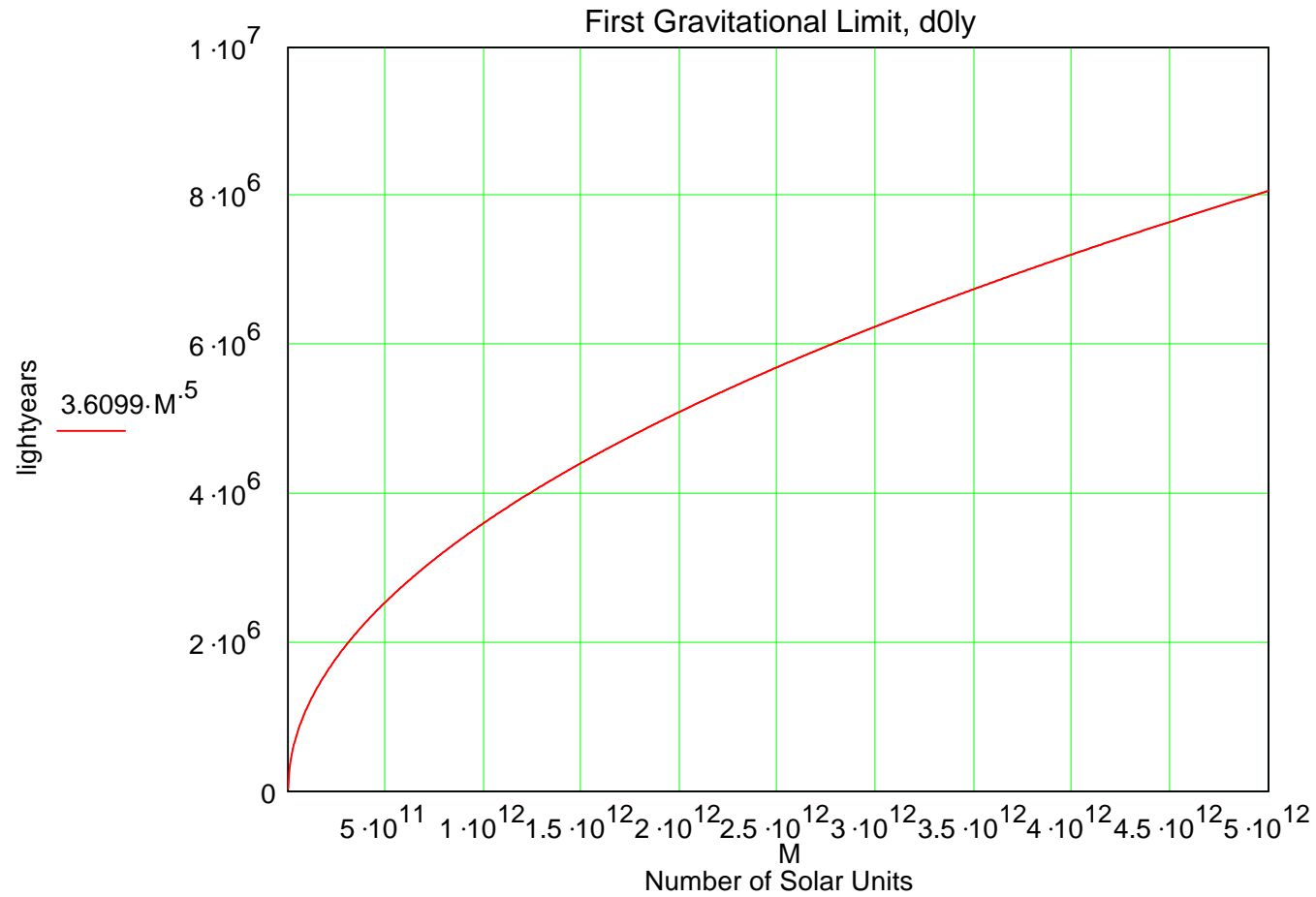


Figure 3a. First Gravitational Limit,  $d_{0ly}$ , as a Function of Mass

For the Local Group,

$$d_{0lyLG} := 3.6099 \cdot \left( \frac{M_{LGobs}}{M_S} \right)^{.5} \quad d_{0lyLG} = 5.4747 \times 10^6 \text{ lightyears}$$

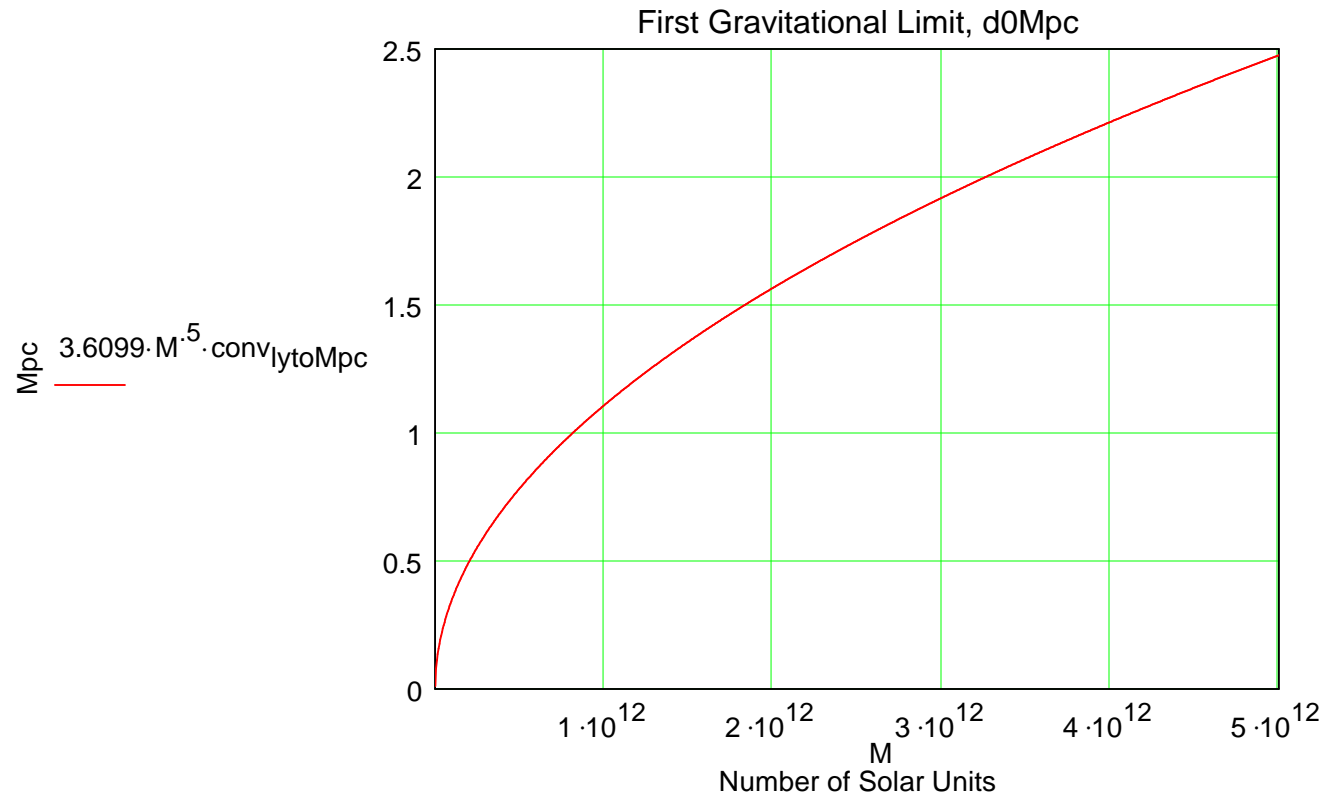


Figure 3b. First Gravitational Limit,  $d_{0\text{Mpc}}$ , as a Function of Mass

For the Local Group,

$$d_{0\text{MpcLG}} := 3.6099 \cdot \left( \frac{M_{\text{LGobs}}}{M_{\text{S}}} \right)^{.5} \cdot \text{conv}_{\text{lytoMpc}} \quad d_{0\text{MpcLG}} = 1.6793 \text{ Mpc}$$

Ref. [5] says that "the zero-velocity surface, which separates the Local Group from the field that is expanding with the Hubble flow, has a radius  $R_0 = 1.18 \pm 0.15$  Mpc." Our result thus appears a bit high, but this is based on the observed mass--also as reported in Ref. [5]. If, instead, we take  $d_{0\text{MpcLG}} = 1.18$ , we would then calculate the mass of the Local Group to be,

$$M_{\text{LGcalcsol}} := \left( \frac{1.18}{\text{conv}_{\text{lytoMpc}} \cdot 3.6099} \right)^2 \quad M_{\text{LGcalcsol}} = 1.1356 \times 10^{12}$$

or about half that "observed." Given that it's probably easier to determine  $d_{0\text{MpcLG}}$  than  $M_{\text{LGobs}}$ , the second result is probably the more accurate one. Ref. [5] also states that "The galaxies NGC 3109, Antlia, Sextans A and Sextans B appear to form a distinct grouping...that is located beyond the LG zero-velocity surface at a distance of 1.7 Mpc from the Local Group centroid." Both 1.18 Mpc and 1.6793 Mpc are consistent with this observation.

## Motion Outside the First Gravitational Limit and Inside the Second Gravitational Limit

Beyond the first gravitational limit, the motion changes. Larson states that "...the three-dimensional region of space extends only to the gravitational limit...beyond this limit...the gravitational effect of the aggregate is in equivalent space rather than in actual space." (Ref. [3], p. 197). All quantities in equivalent space (whether within a single unit of space or outside the first gravitational limit) are second power expressions of those in ordinary space--"...if we measure the quantity  $a$  in the outside region, it is essential that the equation be expressed in the correct regional form:  $a = b^2 c^2$ ." (Ref. [1], p. 155).

First we divide the gravitational speed of the arbitrary mass,  $v_g$ , by the the zero-point speed  $v_0$ , square it, and then multiply by  $v_0$ . So



$$v_{go} := -\left(\frac{v_g}{v_0}\right)^2 \cdot v_0 \quad \text{cm/s} \quad (19a)$$

Substituting from eq. (16),

$$v_{go} := \frac{-v_0}{y} \quad \text{cm/s} \quad (19b)$$

Second we divide the speed of the arbitrary mass due to the space-time progression,  $v_p$ , by the zero-point speed  $v_0$ , square it, and then multiply by  $v_0$ .

$$v_{po} := \left(\frac{v_p}{v_0}\right)^2 \cdot v_0 \quad \text{cm/s} \quad (20a)$$

Substituting from eq. (17)

$$v_{po} := v_0 \cdot y \quad \text{cm/s} \quad (20b)$$

Eq. (18) then becomes

$$v_{no} = v_{po} + v_{go} = v_{po} - |v_{go}| = v_0 \cdot (y - 1/y) \quad \text{cm/s} \quad (21)$$

For distances large compared with the first gravitational limit,  $d_0$ , eq. (21) reduces to

$$v_{no} := v_0 \cdot y \quad \text{cm/s} \quad (22)$$

Substituting for  $v_0$  and  $y$ , we get

$$v_{\text{no}} := \left( \frac{2 \cdot P}{d_0} \right)^{.5} \cdot x \quad \text{cm/s} \quad (23)$$

Substituting for  $d_0$ , and simplifying, we get

$$v_{\text{no}} := 5.4739 \cdot 10^{-7} \cdot M^{-.25} \cdot x \quad \text{cm/s} \quad (24)$$

By inspection, we can see that Hubble's Constant is

$$H := 5.4739 \cdot 10^{-7} \cdot M^{-.25} \quad \text{s}^{-1} \quad (25)$$

Converting to the normal units for Hubble's Constant (using  $\text{conv}_{\text{Mpc to km}}$ ), we finally obtain

$$H := 1.6882 \cdot 10^{13} \cdot M^{-.25} \quad \text{km s}^{-1} \text{ Mpc}^{-1} \quad (26)$$

For the Local Group of galaxies, the result is

$$H_{\text{LG1}} := 1.6882 \cdot 10^{13} \cdot M_{\text{LGobs}}^{-.25} \quad H_{\text{LG1}} = 64.8238 \quad \text{km s}^{-1} \text{ Mpc}^{-1}$$

If we use the calculated mass for the Local Group, instead, we get

$$H_{\text{LG2}} := 1.6882 \cdot 10^{13} \cdot (M_{\text{LGcalcsol}} \cdot M_{\text{s}})^{-.25} \quad H_{\text{LG2}} = 77.3318 \quad \text{km s}^{-1} \text{ Mpc}^{-1}$$

Either of these values of the Hubble Constant for the Local Group is within the range of current estimates by astronomers. Ref. [6] states "Many astronomers are working hard to measure the Hubble Constant using a variety of different techniques. Until recently, the best estimates ranged from 65 km/sec/Megaparsec to 80 km/sec/Megaparsec, with the best value being about 72 km/sec/Megaparsec." But, please note that H is not a single and fixed structural constant of the universe. From the above equations, it clearly is a function of mass of the celestial body. A plot will be helpful.

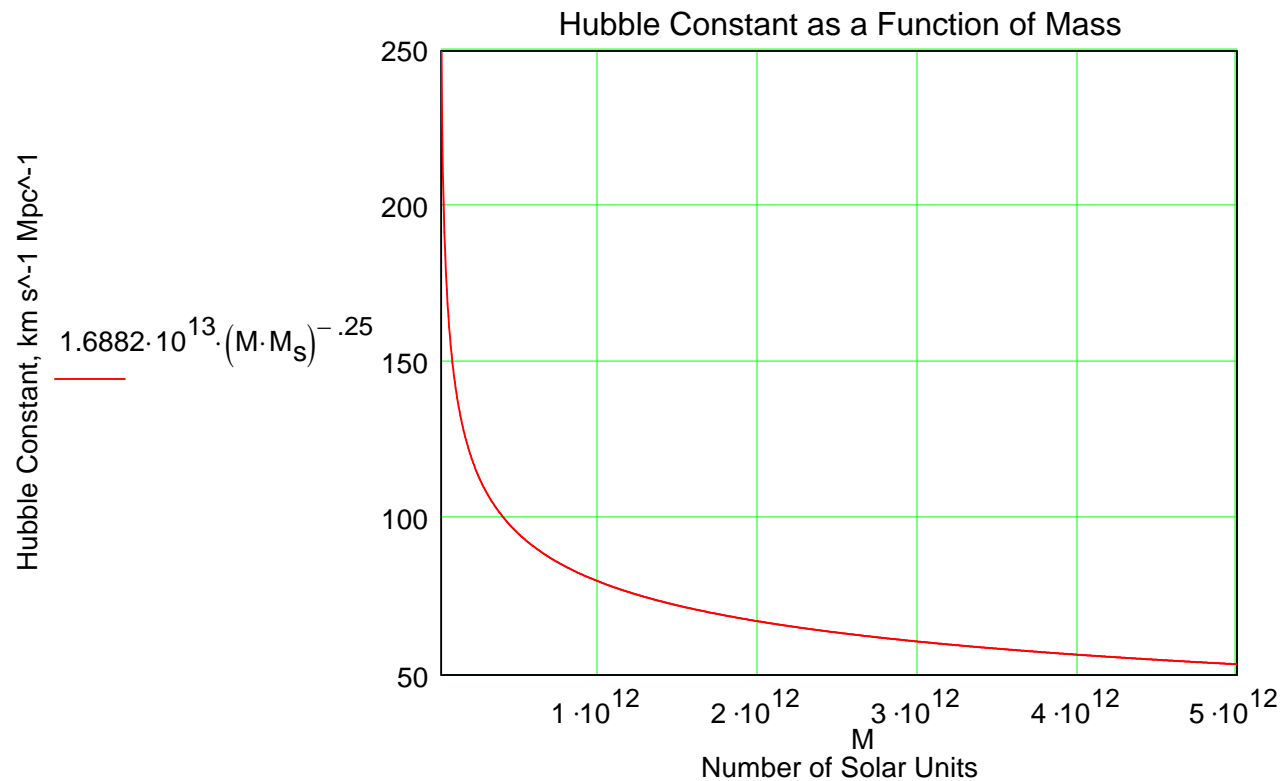


Figure 4. Hubble Constant as a Function of Number of Solar Units

The gravitational motion should not be neglected close to the first gravitational limit ( $< 10 \cdot d_0$ ). Let's plot the speeds (converted to km/s) due to the gravitational force, the space-time progression, and the net speed for an arbitrary mass in relation to the Local Group.

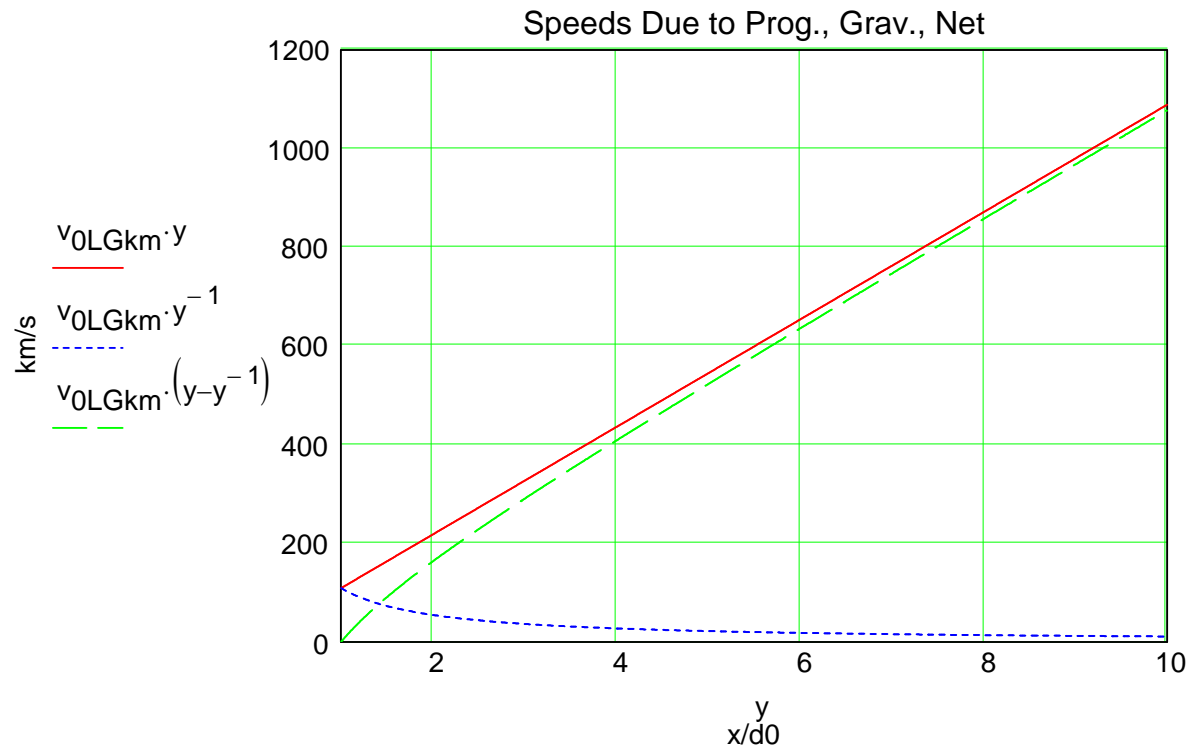


Figure 5. Speed Components of Mass Away from Local Group as a Function of Distance in Multiples of First Gravitational Limit

Obviously, close to the first gravitational limit the value of Hubble's Constant is really not constant. This can be seen by writing eq. (21) as

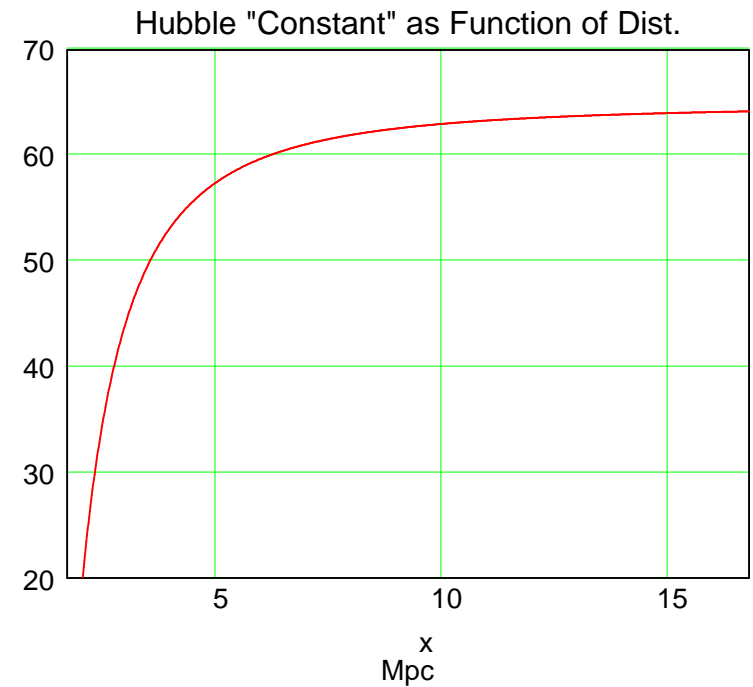
$$H_x \cdot x := v_0 \cdot \left( \frac{x}{d_0} - \frac{d_0}{x} \right)^2 \quad (27)$$

Solving for  $H_x$  as a function of  $x$  we get

$$H_x := 4.1797 \cdot 10^{-10} \cdot M^{.25} \cdot \left( \frac{1}{2.476 \cdot 10^{-23} \cdot M^{.5}} - \frac{2.476 \cdot 10^{-23} \cdot M^{.5}}{x^2} \right)^2 \quad (28)$$

For the Local Group this plots as follows.

$$\text{km/s} \quad 4.1797 \cdot 10^{-10} \cdot M_{\text{LGobs}}^{.25} \cdot \left( \frac{1}{2.476 \cdot 10^{-23} \cdot M_{\text{LGobs}}^{.5}} - \frac{2.476 \cdot 10^{-23} \cdot M_{\text{LGobs}}^{.5}}{x^2} \right)^2$$



## Second Gravitational Limit

Larson states (Ref. [3], pp.200-201), "The net outward speed increases with the distance, but it cannot continue increasing indefinitely. Eventually the attenuation of the gravitational motion by distance brings it down to the point where the remaining motion of each mass unit is sufficient to cover the distribution over the dimensional units involved in direct one-dimensional contact between motion in space and motion in time. Less than this amount...does not exit. Beyond this point, therefore, the gravitational effect is eliminated entirely, and the recession takes place at the full speed of light." Larson then goes on to derive the value of this second gravitational limit,  $d_1$ , by a method similar to that for  $d_0$ . He substitutes  $l_{d1} = 156.44$  (the inter-regional ratio) for  $l_{d0}$  in our eq. (6).

We can also calculate  $d_1$  from the the previous net velocity equation as follows.

$$c = v_0 * (y_1 - 1/y_1) \quad \text{cm/s} \quad (27)$$

Note that relativistic corrections are not necessary since we're working in equivalent space, not ordinary space!

This is a simple quadratic equation. The solution is

$$y_1 := \frac{c}{2 \cdot v_0} + \left( \frac{c^2}{4 \cdot v_0^2} + 1 \right)^{.5} \quad (28)$$

Therefore

$$d_1 := y_1 \cdot (76.3588 \cdot M^5)^{\frac{1}{5}} \quad \text{cm} \quad (29a)$$

$$d_{1ly} := y_1 \cdot \left[ 3.6099 \cdot \left( \frac{M}{M_S} \right)^5 \right]^{\frac{1}{5}} \quad \text{lightyears} \quad (29b)$$

$$d_{1Mpc} := y_1 \cdot (2.476 \cdot 10^{-23} \cdot M^5)^{\frac{1}{5}} \quad \text{Mpc} \quad (29c)$$

For the Local Group (and switching to km/s):

$$y_{1LG} := \frac{c \cdot 10^{-5}}{2 \cdot v_{0LGkm}} + \left[ \frac{(c \cdot 10^{-5})^2}{4 \cdot v_{0LGkm}^2} + 1 \right]^{\frac{1}{5}} \quad y_{1LG} = 2.7541 \times 10^3$$

Therefore

$$d_{1lyLG} := y_{1LG} \cdot d_{0lyLG} \quad d_{1lyLG} = 1.5078 \times 10^{10} \quad \text{lightyears}$$

$$d_{1MpcLG} := y_{1LG} \cdot d_{0MpcLG} \quad d_{1MpcLG} = 4.625 \times 10^3 \quad \text{Mpc}$$

Now the plots:

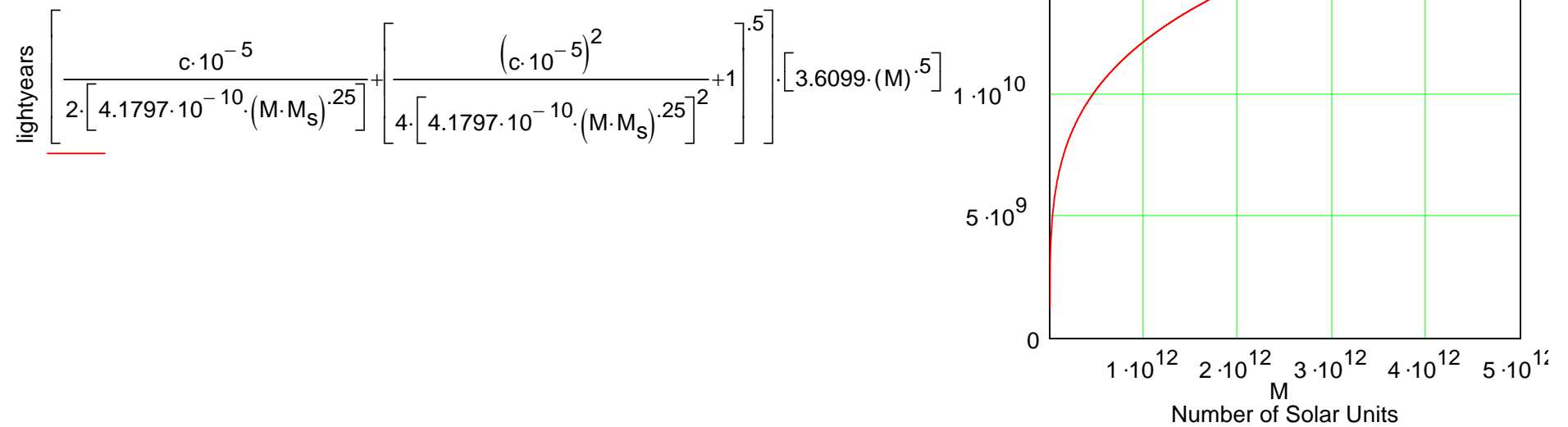


Figure 7. Second Gravitational Limit, lightyears



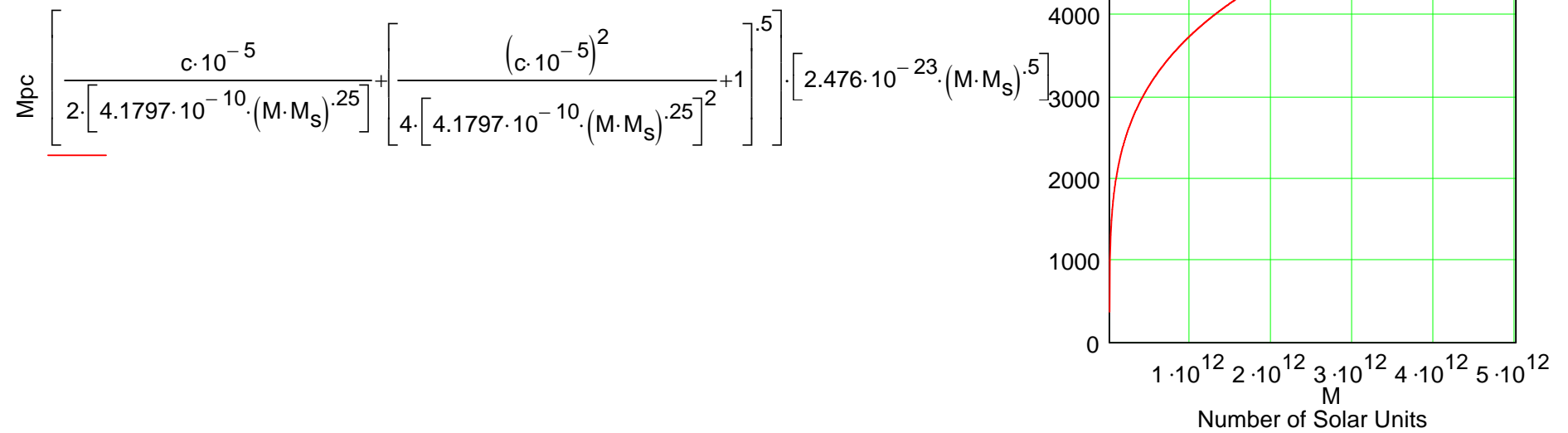


Figure 8. Second Gravitational Limit, Mpc

Knowing both the first and second gravitational limits, we have another way to calculate Hubble's Constant for the Local Group, using  $M_{LGobs}$ .

$$H_{LG3} := \frac{(c \cdot 10^{-5})}{(d_{1MpcLG} - d_{0MpcLG})} \quad H_{LG3} = 64.8429 \quad (30)$$

which is similar to the previous result  $H_{LG1}$ .

## Discussion

As the above equations show, Hubble's Constant is a function of mass. It is not a fixed structural constant of the universe. It's also a function of distance close to the first gravitational limit of our Local Group of galaxies. Both the first and second gravitational limits are a function of mass, as well. The space-time progression is the source of the expansion.

Conventional astrophysical theory posits that the universe is expanding because of a big bang explosion which occurred at  $1/H$  seconds ago. According to Ref. [6], if the universe has a very low density of matter then the age of the universe is extrapolated to (If  $H$  is taken to be 72 km/s/Mpc)

$$\left( \frac{72}{\text{conv}_{Mpc \rightarrow km}} \right)^{-1} \cdot \text{conv}_{\text{stoyear}} = 1.3574 \times 10^{10} \quad \text{years}$$

or 13.6 billion years. But, if the universe is flat and composed mostly of matter then the age of the

$$\left( \frac{3.72}{2 \cdot \text{conv}_{\text{Mpctokm}}} \right)^{-1} \cdot \text{conv}_{\text{stoyear}} = 9.0493 \times 10^9 \quad \text{years}$$

or about 9 billion years. This latter calculation puts astronomers into a conundrum because that's less than the age of the oldest stars!

Ref. [6] concludes that *if* the second calculation were correct then either 1) our measurement of the Hubble Constant is incorrect, 2) the Big Bang theory is incorrect, or 3) that we need a form of matter like a cosmological constant that implies an older age for a given observed expansion rate.

Ref. [6] then says that NASA's WMAP satellite has come to the rescue and measured the expansion rate such that the first calculation is correct.

None of this affects the Reciprocal System of theory. The Hubble Constant is not, in fact, a determinate of the age of the universe. The observed expansion is due to the space-time progression overpowering gravitation at the first gravitational limit and causing the mass to accelerate to the speed of light at the second gravitational limit. There was no cosmic egg that exploded 13 billion years ago.

## Acknowledgments

I wish to thank Dr. Rainer Huck of ISUS for commissioning this paper.

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