# Galaxy Fun

Suppose that there are two objects in space of masses $M$ and $m$ with $M \gg m$. Also suppose that the smaller mass is rotating around the larger one. The period of the rotation, the time it takes for the smaller mass to complete one orbit around the larger mass, is given by

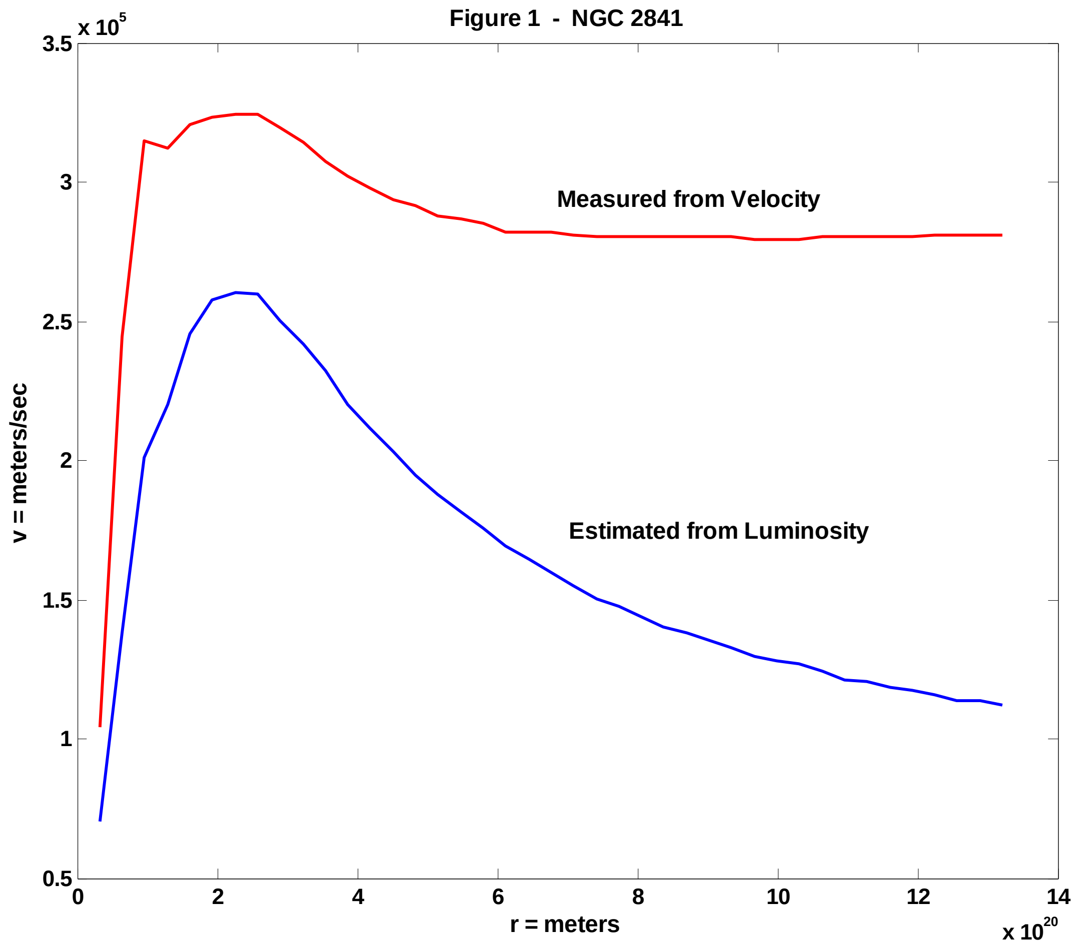
(1) $$T^2 = \frac{4\pi^2}{GM} r^2$$

where $T$ is the period, $G$ is the gravitational constant $(G = 6.67 \times 10^{-11} \frac{nt-m^2}{kg^2})$ and $M$ is the mass of the larger object. To place a satellite in a stationary position over the earth it would have to be over the equator with a period of one day. The satellite's distance above the earth can be found from equation (1) taking $T = 1\ day$ and the earth mass $M = 5.97 \times 10^{24}\ kg$. From equation (1)

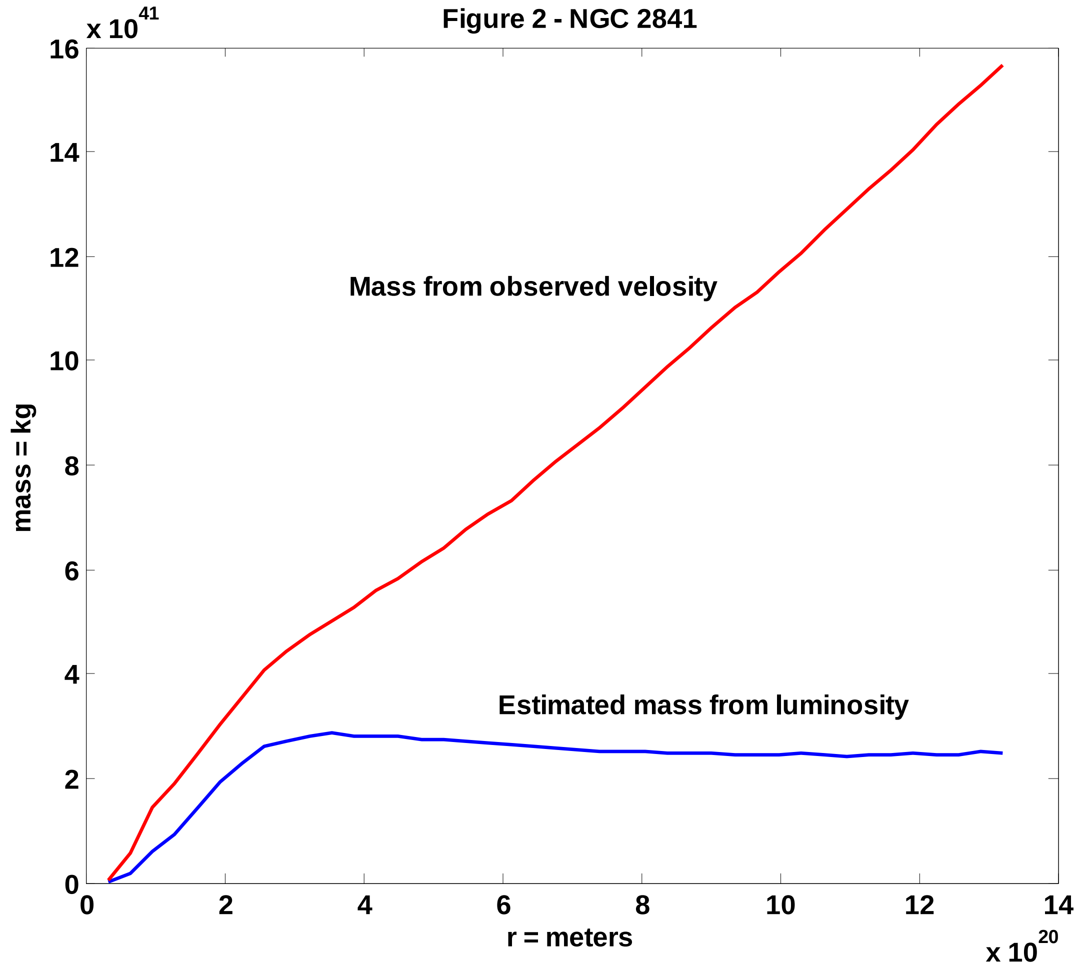
(2) $$r = \left(\frac{T^2 GM}{4\pi^2}\right)^{\frac{1}{3}}.$$

Taking $T = (23.933\ hours) \times \left(3600\ \frac{sec}{hour}\right) = 86160\ sec$, one gets $r = 35765\ km = 22214\ miles$ from the surface of the earth. This is not exact but demonstrates Equation (1).

Since the sun is much more massive than the planets, Equation (1) can be used to find the rotation rate of the planets around the sun knowing their mass. However, the rotation rate and distance a planet is from the sun is more easily measured than the mass. Having the rotation rate and the distance, Equation (1) can be used to find the mass of a planet. The same should apply to the rotation rate of stars around the center of a galaxy. Assuming a relation between the luminosity distribution and the mass distribution of a galaxy the rotation rate of a galaxy's stars can be determined. When this is done and the rotation rate of the stars measured, the measurements do not agree with what the assumed mass distribution would result in. Figure (1) shows the estimated rotation rates from luminosity mass estimates and the measured rotation rates.




From Equation 1 the mass within radius $r$ for Galaxy NGC 2841 can be plotted as in Figure 2.




The luminosity estimate looks strange. It reaches a maximum and then decreases slightly. The total mass cannot decrease as more volume encompasses the center. Looking at other galaxy data found on the internet the same feature is seen. The mass is estimated from luminosity and then the velocity from the mass. Those in the higher hills of the science world who post data on the internet are likely beyond the simplest approach taken here. The present purpose is to enjoy a walk in the lower hills of the math world and avoid such crags along the way. So this glitch will be ignored

The reason given for the observed mass curve is non-luminous mass, i.e. dark matter. There will certainly be some ordinary matter, but there could also be exotic matter. By ordinary is meant matter one can see, touch or smell. By exotic is meant unknown to senses or theory. What other phenomenon could result in the unexpected velocity curve that those in the lower hills of the math world can look at and eliminate? Perhaps the gravitational constant is not constant.

Rewrite Equation (1) as

(3) $$G = \frac{4\pi^2 r^3}{T^2 M}.$$

The period is related to the velocity by $T = \frac{2\pi}{v}$. Substituting the period $T$ into the relation for $G$ gives $G = \frac{v^2 r}{M}$. This can be written as

(4) $$g(r) = \frac{v(r)^2 r}{M(r)},$$

where the gravitational constant becomes a pseudo gravitational variable.

Assuming that the mass estimate from luminosity is correct and the observed velocity is correct Equation (3) becomes

(5) $$g(r) = \frac{v_o(r)^2 r}{M_L(r)}.$$

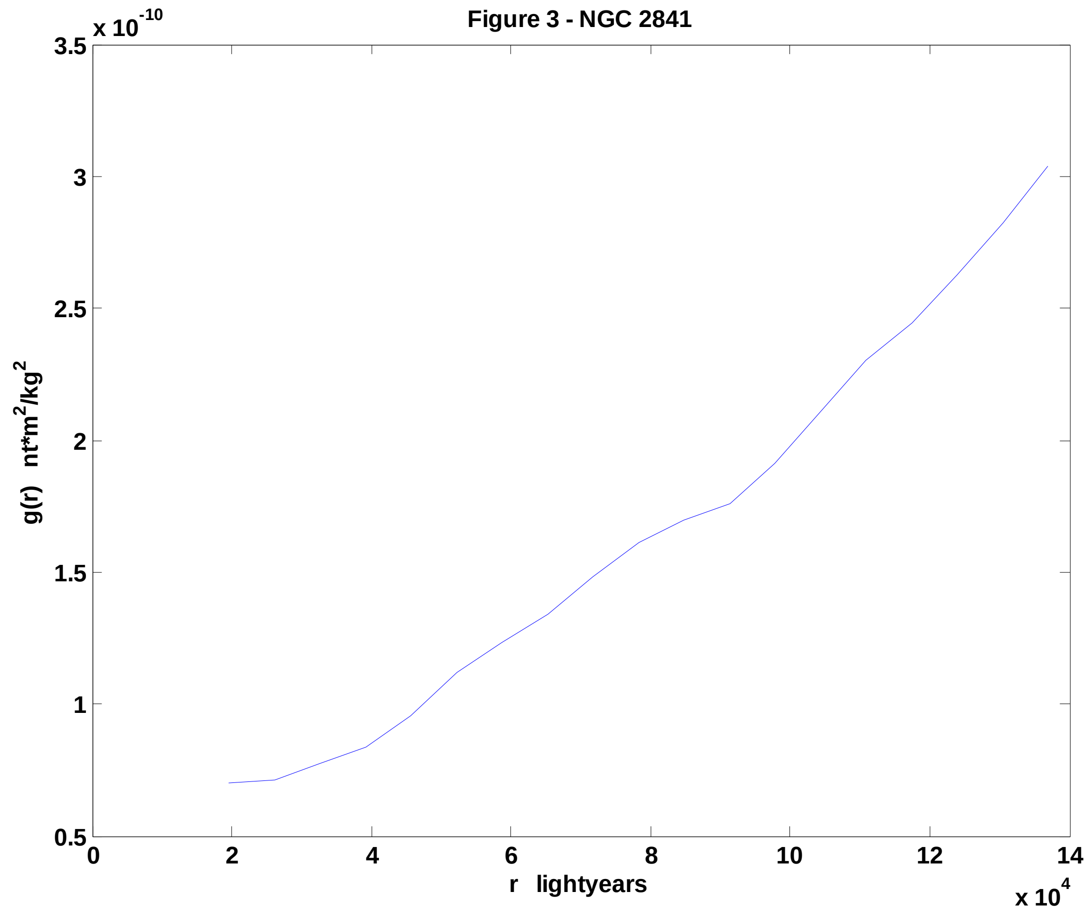
From Equation (3)

(6) $$M_L = \frac{v_L(r)^2 r}{G}.$$

Substituting Equation (6) into Equation (5) gives

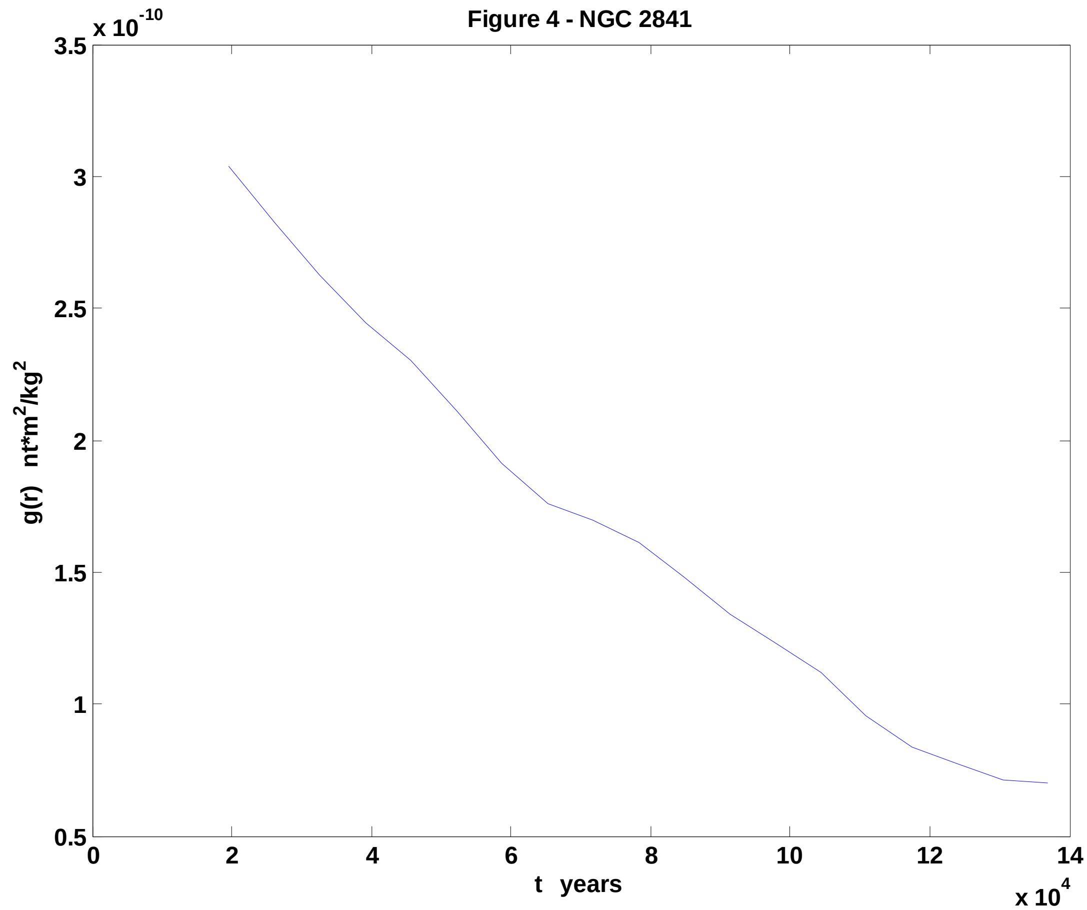
(7) $$g(r) = G * \left(\frac{v_o(r)}{v_L(r)}\right)^2.$$

Figure 3 plots $g(r)$ against $r$ for galaxy NGC 2841 taking the units for $r$ in lightyears.

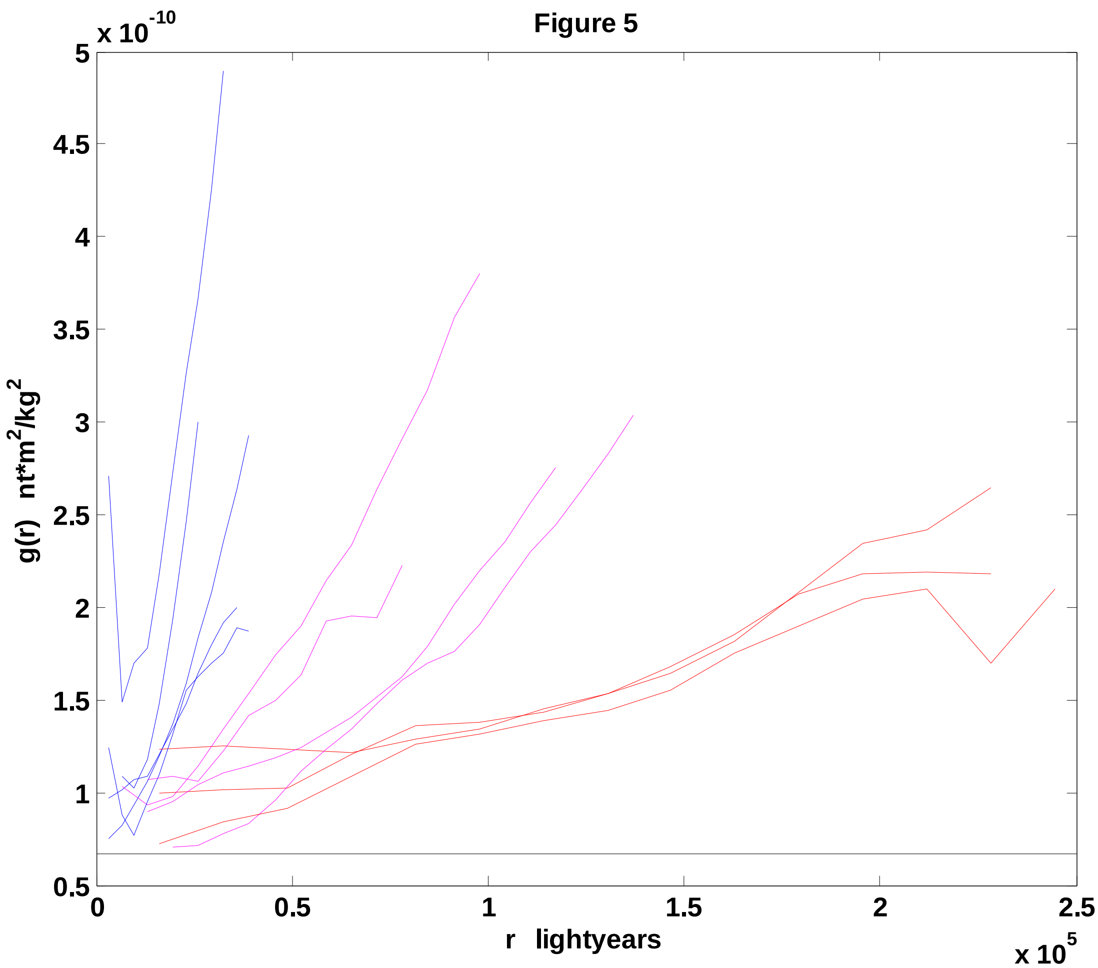



The lower values of $r$ are iffy being from data for stars closer in the galaxy center.

Assuming that the effect of gravity travels at the speed of light and making the simplifying assumption that all the mass of the galaxy is located at the center the relation between the pseudo gravitational variable factor and time is shown in Figure 4.




The gravitational constant being a gravitational variable factor changing as much as the plot shows over just 100,000 years would have had a great effect on the universe and on earth. No change in the gravitational constant over space and time has been detected to great precision. So the current hike is just a small exercise of minds and machines. Showing results for several galaxies as in Figure 5 is somewhat more interesting.




The plot shows the pseudo gravitational variable over distance from the center of each galaxy. The horizontal black line is the value of the gravitational constant. The length of each line as measured on the x-axis gives an indication of the size of each galaxy. The slopes of the lines are almost constant and clumped by galaxy size. The reader can ponder on this. As for the current hike in the lower hills of the math world, the hour is late and it is time to get off the trail and back to civilization if it can be found on the more hazardous hikes of life.

Mathdrooler 31 May2013