IMPACT OF A ROTATING VACUUM ON GALAXY ROTATION CURVES

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Abstract

Assuming that the vacuum surrounding a galaxy takes part in its rotational motion, it is shown in this paper that an additional inward force is generated, resulting in flat galaxy rotation curves. The rotation of the vacuum results in an increase of the vacuum pressure such that the galaxy is effectively contained in a so-called vacuum bubble (i.e. slight local change of the vacuum pressure). The coupling of the rotation of matter and vacuum ensures that the galaxy rotation curves always look similar.

1. Introduction

It is generally believed that the observed [1] flat rotation curves as observed in most galaxies are due to some form of invisible dark matter that surrounds the galaxies. It was shown however by the author [2] that if one assumes that the galaxies are located in so-called vacuum bubbles (slight depression in the quantum vacuum pressure) it is no longer required to invoke dark matter to explain the flat rotation curves. In this case, the vacuum itself provides an additional radial inward force. A weakness of the proposed theory was however that no satisfactory reason could be offered why the vacuum bubble had to be there in the first place and secondly, why its properties were so closely related to the mass contained within them. It is the objective of this paper to demonstrate that these two questions can be answered by assuming that the vacuum in and around the galaxy takes part in the rotational motion of the galaxy.

2. Effect of vacuum rotation

At the quantum level, virtual particles are allowed to pop in and out of existence because of the Heisenberg uncertainty principle. Normally, one thinks of this soup of particles as having zero average net momentum. Nevertheless, nothing prevents us from assuming that these zero-point fluctuations can have a mean net velocity, just like ordinary matter. Because of the interaction of matter and vacuum, it is therefore not unreasonable to assume that the velocity of the vacuum is coupled to that of the moving matter. Recently [3,4], space-time has been considered to be a kind of superfluid which can be set into rotational motion around a collapsing star, resulting eventually in a so-called gravastar. So, the abstract concept of space-time is being moved more in the realm of a physical entity. If the motion of the vacuum is coupled to the motion of matter and the motion of matter to that of the vacuum, it is clear that we have to solve the dynamical behavior in a self-consistent way.

Since the galaxy rotation curves are often found to be very similar in shape, it can be suspected that there exists an underlying simple and basic principle which forces the rotation curves to the shape as observed. This underlying principle should also not depend too strongly on the detailed mass distribution within the bulge of the galaxy. Therefore, the following analysis will be based on the most simple galaxy description characterised by a central bulge with uniform mass density and an outer region with negligible mass density.

In [5], it was argued that mass distorts the surrounding vacuum energy pressure and that the gravitational force results from a non-cancelled vacuum pressure exerted on matter. Note that in this framework, the vacuum energy density ρ (however large) is non-gravitating since gravity in this model is only based on gradients of ρ. The magnitude of the gravitational force on a test mass m can then be expressed as [5]

$$F = V_m \cdot \left(\frac{dp}{dr} \right) \tag{1}$$

in which the equivalent volume $V_m = m\,c^2 / \rho_V$ where ρ_V is the unperturbed vacuum energy density. When the disturbance (at a distance r) of the vacuum pressure due to a mass M is given by

$$p(r) = \rho_V \cdot \left(1 - \frac{G \cdot M}{c^2 \cdot r} \right) \tag{2}$$

in which G is the gravitational constant, one reproduces Newton's law of gravitation, using equation (1).

If the vacuum itself is in motion (rotation), the vacuum energy density is actually increased, similar to the increase of a particle's energy by its kinetic energy. Based on dimensional considerations, one expects a vacuum kinetic pressure term ($p_{kinetic}$) of the form

$$p_{kinetic} = \alpha\, \rho_V\, (v_{vac}^2 / c^2) \tag{3}$$

in which v_{vac} is the rotational velocity of the vacuum and α a dimensionless constant which we set equal to one. It is this term which will provide the vacuum bubble (local depression in vacuum energy) as mentioned first in [2].

The total vacuum pressure profile is then given by

$$p_{tot} = \rho_V\, ((1 - GM/(c^2 r)) + \rho_V\, (v_{vac}^2 / c^2) \tag{4}$$

We will designate the bulge radius by r_b and define a normalized radius (R) and a normalized velocity (V) by

$$R = r / r_b \tag{5}$$

$$V = v \Big/ \sqrt{\frac{G \cdot M}{c^2 \cdot r_b}} \tag{6}$$

The force balance equation (for a test particle of mass m) then becomes

$m\, v^2 / r = (m\, c^2 / \rho_V)\, (d\, p_{tot} / dx)$ (7)

We will assume zero vacuum rotation in the galaxy centre. We assume further that the vacuum rotation increases up to some large radius and then decreases again to zero. This can most easily be modeled by a sine function (limited to the argument interval - π/2 to π/2):

$v_{vac} = d \,.\, \sin (r/a)$ (8)

Converting this into normalized distance and velocity (equations (5,6)) results in

$V_{vac} = D \,.\, \sin(R/A)$ (9)

From the force balance equation, one then obtains for the region outside the bulge

$$V = \sqrt{\frac{1}{R} + \frac{D^2}{A} \cdot \sin\left(\frac{2 \cdot R}{A}\right)} \tag{10}$$

and for the region inside the bulge one obtains

$$V = \sqrt{R^2 + \frac{D^2}{A} \cdot \sin\left(\frac{2 \cdot R}{A}\right)} \tag{11}$$

The velocity profile corresponding to the case without vacuum rotation corresponds to setting D = 0 in the above two equations.

Choosing A = 16 (location of maximum vacuum rotation at R =25) and D = 3, one obtains the rotation profiles shown in Figure 1.

The choice of the sine function is of course somewhat arbitrary. The real vacuum velocity profile could of course be different, though it should still exhibit similar features such as zero velocity in the center, a smooth increase up to a maximum and a subsequent decrease down to zero. In equation (3) on the other hand, we just assumed α to be equal to one (thus not used as fitting parameter). The value of A is motivated by the observed flat rotation curves up to large values of R, though the flatness of the rotation curve does not depend strongly on it for 10 < A < 25. The dependence of the rotation curve on D (which corresponds to the maximum normalized vacuum velocity) is stronger but it is remarkable that D is of order one, meaning that it is of similar magnitude as the normalized velocity at R = 1, namely V = 1.

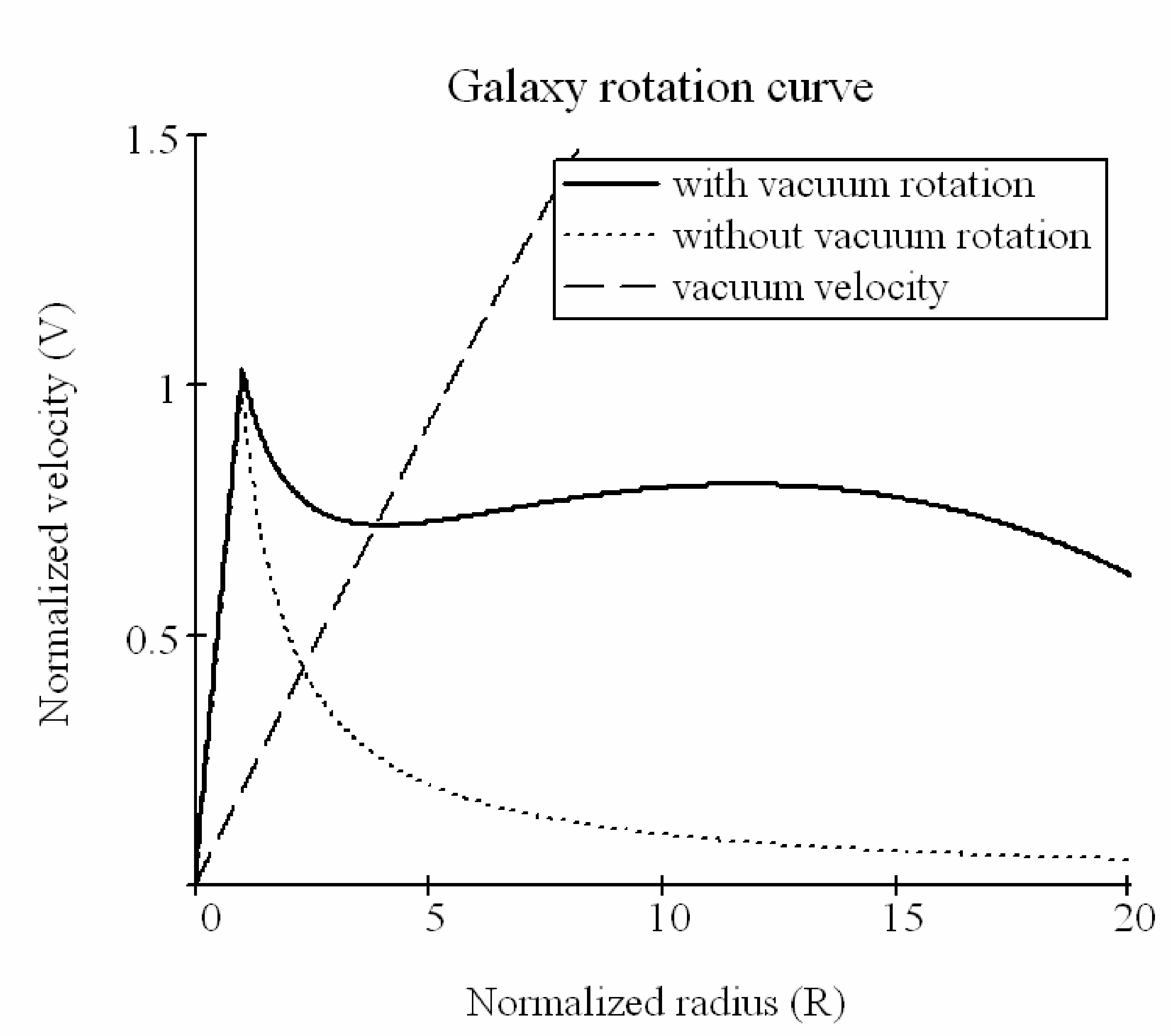

Fig.1 : Normalized galaxy rotation curves, including the profile of the vacuum velocity.

Conclusion

If one assumes that there exists a ring of rotating vacuum around galaxies, in which the vacuum velocity is coupled to the velocity of the rotating matter, it is possible to explain the observed flat galaxy rotation curves.

References

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