# Modified dynamics due to forehead collisions of bodies with gravitons: Numerical modeling

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**Abstract**

The numerical modeling of a non-relativistic modification of dynamics due to forehead collisions of bodies with gravitons in the model of low-energy quantum gravity is performed. We have found too big instability of trajectories in the central field by the anomalous deceleration $w \simeq -H_0 c$. Perhaps, the most probable source of that may be backhead collisions of bodies with gravitons, not taken into account in this model up to now.

## 1 Introduction

An existence of dark matter in clusters of galaxies and in spiral galaxies, as well as its need to fit observations of remote Supernovae Ia, are accepted by the scientific community as a proven fact [1]. However, a possibility of an alternative explanation of corresponding observations remains, mainly in the direction of modifications of gravitational physics. This possibility has a remarkable example of simple and partly successful (to fit flat rotation curves of spiral galaxies) model: MOND by Mordehai Milgrom [2]. This model differs from Newton's gravity if the gravitational acceleration is less than some $a_0 \sim 10^{-10}\ m/s^2$. It is important that somewhy $a_0 \sim H_0 c$, where $c$ is the light velocity and $H_0$ is the Hubble constant. MOND does not concern the problem of dark energy.

The model of low-energy quantum gravity [3, 4] predicts small additional effects which may lead to a new approach to cosmology. As it has been shown in [5], the model fits the observational data sets of remote objects very well without dark energy and *cosmological* dark matter. It forces to think about a chance to find some tie between this model and the missing mass problem. In the model, every massive body with a non-zero velocity relative to the isotropic graviton background should experience a constant deceleration of the order of $H_0 c$. This deceleration is considered in this paper as a tentative cause of non-classical motion of bodies by very small gravitational accelerations.

## 2 Modified dynamics in the graviton background

In the model [3, 4], the deceleration of massive bodies and the redshift of remote objects have the same nature: these effects are caused by forehead collisions with gravitons of the low-temperature graviton background. Due to only forehead collisions with gravitons, the deceleration of massive bodies in this model is equal to:

$$w = -H_0 c(1 - V^2/c^2), \tag{1}$$

where $\mathbf{V}$ is a body's velocity relative to the graviton background [4]. For small velocities: $w \simeq -H_0 c$. Using the theoretical value of $H_0$ in this model: $H_0 = 2.14 \cdot 10^{-18}\ s^{-1}$, we have: $w \simeq 6.42 \cdot 10^{-10}\ m/s^2$. This deceleration is universal, and the Newtonian equation of motion of a material point with a mass $m$ should be replaced with the following one:

$$m\ddot{\mathbf{r}} = \mathbf{F} - mw \cdot \frac{\mathbf{V}}{V}, \tag{2}$$

where $\mathbf{F}$ is a classical net force acting on the point. In a gravitationally bound system of two bodies with very different masses, if we consider a motion of a smaller body (a material point) relative to its more massive partner with a velocity $\mathbf{v}$, it is necessary to take into account the force of inertia if the system moves relative to the graviton background. In the Newtonian approach, if $\mathbf{u}$ is a more massive body's velocity relative to the background, $M$ is its mass, and $\mathbf{V} = \mathbf{v} + \mathbf{u}$ is the velocity of the small body relative to the graviton background, we will have the following equation of motion of the small body:

$$\ddot{\mathbf{r}} = -G\frac{M}{r^2} \cdot \frac{\mathbf{r}}{r} + w(\frac{\mathbf{u}}{u} - \frac{\mathbf{v} + \mathbf{u}}{\mid \mathbf{v} + \mathbf{u} \mid}), \tag{3}$$

where $\mathbf{r}$ is a radius-vector of the small body, $G$ is Newton's constant. Here the force of inertia is equal to: $mw \cdot \frac{\mathbf{u}}{u}$.

This equation should have classical (or almost classical) solutions in the limit case: $GM/r^2 \gg w$. Another limit case is realized by the conditions: $GM/r^2 \ll w$ and $\mathbf{u}/u - \mathbf{v} + \mathbf{u}/\mid \mathbf{v} + \mathbf{u} \mid \to 0$ (when $\mathbf{v}$ strives to coincide in direction with $\mathbf{u}$ ); then a solution is: $\mathbf{v} \to const$. A planar motion will take place by the condition: three vectors $\mathbf{r}, \mathbf{v}, \mathbf{u}$ should lay in one plane at an initial moment of time. This case is considered here.

## 3 A numerical solution of the equation of motion of a material point in the central field

To solve Eq.(3) numerically, we can use the following recurrent equations:

$$\begin{aligned}
\mathbf{r}(t + \Delta t) &= \mathbf{r}(t) + \mathbf{v}(t) \cdot \Delta t + \mathbf{a}(t) \cdot \Delta t^2/2, \\
\mathbf{v}(t + \Delta t) &= \mathbf{v}(t) + \mathbf{a}(t) \cdot \Delta t, \\
\mathbf{a}(t + \Delta t) &= -G\frac{M}{r^3(t + \Delta t)} \cdot \mathbf{r}(t + \Delta t) + w(\frac{\mathbf{u}}{u} - \frac{\mathbf{v}(t + \Delta t) + \mathbf{u}}{\mid \mathbf{v}(t + \Delta t) + \mathbf{u} \mid}),
\end{aligned} \tag{4}$$

where we denote: $\mathbf{a} \equiv \ddot{\mathbf{r}}$, and $\Delta t$ is the time difference. We suppose here that $\mathbf{u} \simeq const$; it means that our two-body system is not closed.

A program in C++ realizing algorithm (4) has been written by two of us (A.N. and P.S.) to model the planar motion in the central field. We usually choose $\Delta t$ as: $\Delta t = 10^{-6} T/p$, where $T$ is a period of motion in the classical case of a circular trajectory by the given initial distance to the center, $p$ is an integer number. But to verify an absence of artifacts due to the discreteness, we also have used another version with $\Delta t \to \Delta t \cdot (r(t)/r(0))^{1.5}$. Parameters of 1 from every 10000 trajectory points are written into data files to build graphics later in MathCad.

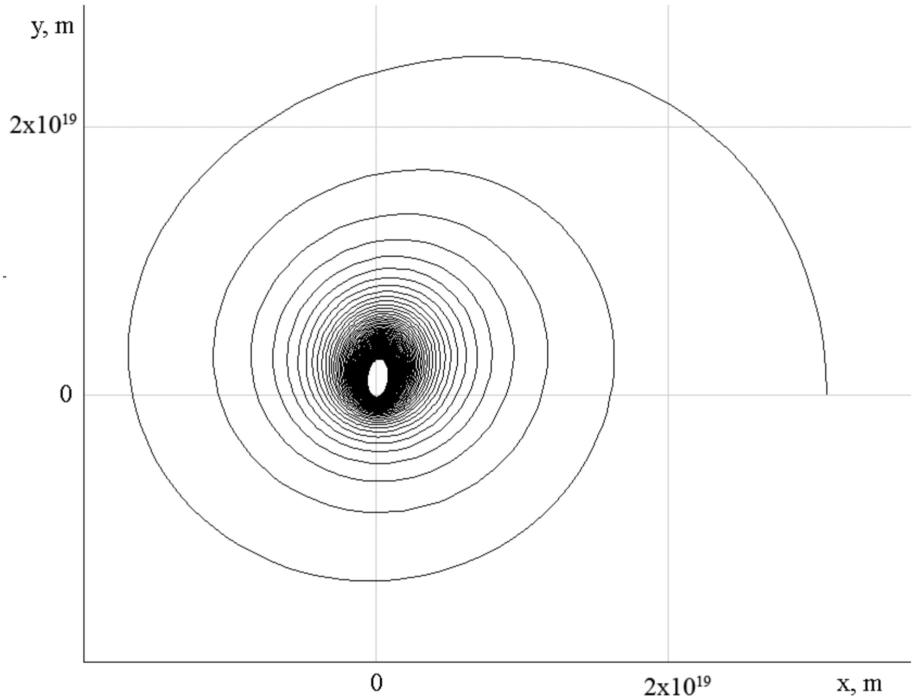


Figure 1: A star orbit in a galaxy with $M = 10^{10} \cdot M_{\odot}$ by $u = 5 \cdot 10^5$ m/s and $r(0) = 1$ kpc.

## 4 A motion in the central field by an initial velocity $v(0) = (G \cdot M/r(0))^{0.5}$

Let us consider the initial conditions by which a material point trajectory in the classical case is circular, i.e. $v(0) = (G \cdot M/r(0))^{0.5}$, and $\mathbf{v}(0) \perp \mathbf{r}(0)$. To evaluate computational errors, we have found solutions of Eq.(3) by $w = 0$ using different values of $\Delta t$. For one classical period $T$, the relative error $\Delta r/r(0)$ is equal to: $+1.184 \cdot 10^{-5}$ by $\Delta t = 10^{-7} \cdot T$, and $+1.579 \cdot 10^{-7}$ by $\Delta t = 10^{-9} \cdot T$, while $\Delta v/v(0)$ is equal to: $-5.87 \cdot 10^{-6}$ by $\Delta t = 10^{-7} \cdot T$, and $-7.896 \cdot 10^{-8}$ by $\Delta t = 10^{-9} \cdot T$.

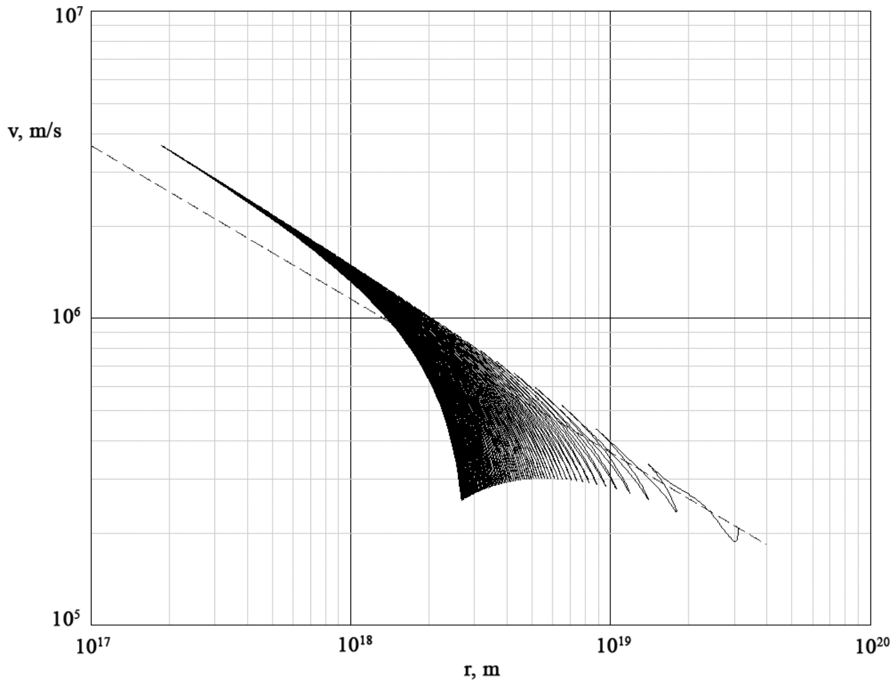


Figure 2: The graph of $v(r)$ for the star orbit in a galaxy with $M = 10^{10} \cdot M_{\odot}$ by $u = 5 \cdot 10^5$ m/s and $r(0) = 1$ kpc (solid line). For comparison, the graph of $v_0(r) \equiv (G \cdot M/r)^{0.5}$ is shown (dashed line).

Our second task was to evaluate a stability of planetary orbits in the solar system in a presence of the anomalous deceleration $w$. We have chosen $u = 2 \cdot 10^5$ m/s. In a case of the Earth-like circular orbit, i.e. by $M = M_{\odot}$, $r(0) = 1$ AU, we get by $w = H_0 c$ for the same time: $\Delta r/r(0) = +5.645 \cdot 10^{-8}$ and $\Delta v/v(0) = -2.822 \cdot 10^{-8}$ by $\Delta t = 10^{-9} \cdot T$. It means that the Earth orbit by $w = H_0 c$ would be unstable, and its radius should change on $\Delta r/r(0) \simeq 10^{-7}$ per year. This result contradicts to the estimated age of the solar system.

To consider a behavior of star orbits in a galaxy, we have chosen $u = 5 \cdot 10^5$ m/s, and $M = 10^{10} \cdot M_{\odot}$. If $r(0) = 1$ kpc, we get an orbit shown in Fig. 1, the graph of $v(r)$ is shown in Fig. 2; the vector $\mathbf{u}$ is parallel to the horizontal axis. A full time of motion is equal to $3.3 \cdot T$. In this case, the ratio $a(0)/w$ is equal to 2.17. We see that the star inspirals to the center quickly (by these conditions, we have: $T \simeq 3 \cdot 10^7$ years). It should lead to the instability of galaxies, too. It is impossible to trace the trajectory in Fig. 1 further because $v \to c$ in the

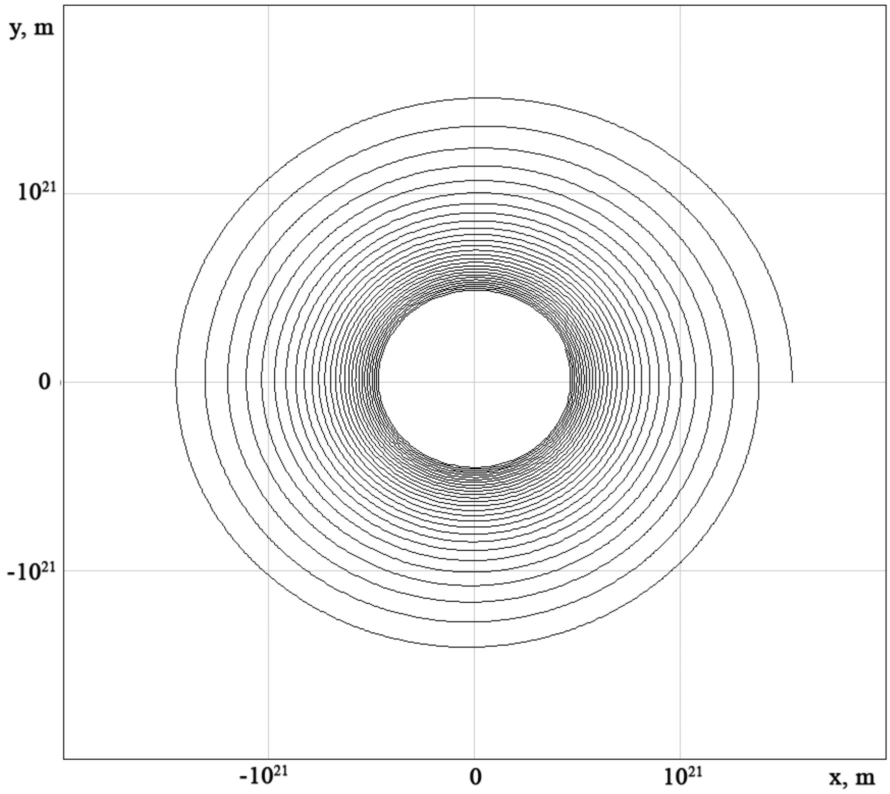


Figure 3: A star orbit in a galaxy with $M = 10^{10} \cdot M_{\odot}$ by $u = 5 \cdot 10^5$ m/s and $r(0) = 100$ kpc for the case of $w = 10^{-4} \cdot H_0 c$; $t = 300$ Gyr, the first unclosed external loop corresponds to 27.6 Gyr.

nearest to the center its points, and Eq. 3 is not valid here.

Taking into account the found instability, let us consider now $w$ to be a free parameter to evaluate an order of its magnitude leading to stable enough trajectories on both considered scales. To have $\Delta r/r(0) \simeq 10^{-11}$ per year, or $\Delta r/r(0) \simeq 0.045$ per 4.5 billion years, we should choose: $w = 10^{-4} \cdot H_0 c$. Then on the galactic scale we will have: $\Delta r/r(0) \simeq \pm 0.005$ per 6 billion years by $r(0) = 1$ kpc, $u = 5 \cdot 10^5$ m/s. For $r(0) = 100$ kpc, the trajectory is shown in Fig. 3; the full time $t = 300$ Gyr, the first unclosed external loop corresponds to 27.6 Gyr. On both scales, the instability is acceptable by this value of $w$.

# 5 Conclusion

Our numerical study of a modification of dynamics due to only forehead collisions of bodies with gravitons has shown that on planetary and galactic scales trajectories of bodies are too unstable. It is necessary to do a theoretical re-analysis of the interaction of massive bodies with gravitons in this model to understand why this anomalous acceleration should be much smaller than the value of $H_0 c$ to be consistent with observations. The most probable source of that, in our opinion, may be backhead collisions of bodies with gravitons which were not taken into account earlier.

Even by much smaller values of $w$, trajectories of bodies stay unclosed, but their stability become much higher. From our current results we do not see some connection of this modification of dynamics with the problem of dark matter on the galactic scale. In some parts of trajectories, velocities are higher than classical ones on circular orbits, but not essentially, and the ones do not have a definite limit by big distances to the center of the galaxy.

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