Universe of photons and MOND

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Abstract

Using the photon universe model, as an alternative to models for the explanation of some rotation curves (dark matter, MOND), we propose a comparative analysis of the "photon universe" model with the MOND model.

Keywords: dark matter, visible matter, photon-photon collision, model universe photons, galaxy, hidden mass, rotation curve, MOND.

1. Introduction.

In the previous articles (**[1]**, **[2]**) the "photon universe" model was introduced as an exercise by Fermi (1901-1954); in the third article **[3]** an interpretation of the behavior of the rotation curves that highlight a "hidden mass" was given and in the fourth article **[4]** a theoretical derivation of these rotation curves was proposed.

In this work we want to use the interpretative model for the rotation curves previously exposed to obtain:

(a) a theoretical estimate of the visible mass of a galaxy;

(b) a theoretical derivation of the characteristic parameter of the MOND theory.

2. Theoretical estimate of the visible mass of a galaxy

Experimentally, through the analysis of the rotation curve of a galaxy, it is possible to extract its limit radius **[3]**, the definition of which is given below:

definition: **Limit Radius of a galaxy**

the "Limit Radius of a galaxy", R_L, is defined as the distance from the galactic center for which the mass created by the photon-photon collision (within the volume of the limit radius) is equal to the total visible mass of a galaxy, $\mathbf{M_{BWC}} \sim \mathbf{M_{BW}}(\boldsymbol{r}=\boldsymbol{R_L})$**.**

This parameter allows to indirectly estimate the total visible mass of a galaxy:

$$M_{VIS} \sim \delta_{BW} \cdot R_L^3 \qquad \text{(i)}$$

where:

- $\delta_{BW} \sim 10^{-20} \left(\frac{kg}{m^3}\right)$ is the quantity of mass per cubic meter produced by the photon-photon collision (as an order of magnitude);
- R_L is the limit radius that can be experimentally obtained from the rotation curve (for those galaxies that open up to the problem of "hidden mass").

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As an example we propose the analysis of two systems (in the following table):

	Limit radius experimental (m)	**Total visible mass estimated with the "universe of photons" model (kg)**	**Total visible mass (scientific literature) (kg)**
NGC 1097 **[5], [6]**	10^{20}	10^{40}	$5 \cdot 10^{39}$
NGC 1068 **[7], [8], [9]**	10^{19}	10^{37}	10^{37}

The comparison makes it possible to verify that the expected theoretical value is of the same order of magnitude as the tabulated value in scientific literature. It should be emphasized that this method can only be used in rotation curves that show a typical trend of the "hidden mass".

3. Theoretical derivation of the characteristic parameter of the MOND theory

MOND theory (**[10]**, **[11]**) introduces the parameter *ad hoc* $a_0=1{,}2\cdot 10^{-10} m/s^2$ with the intent to modify the second Newtonian law of motion.

Using the "universe of photons" model, we want to show how it is possible to obtain, as an order of magnitude, an acceleration that is comparable with the value of the MOND and that we can associate with the acceleration due to the creation of mass (or energy) due to the effect of photon-photon collision. What in the MOND theory is an *ad hoc* parameter, in the “universe of photons” model is instead a obtainable quantity: remember that in our model there is no modification of the Newtonian second law of motion.

Let's start from equation **[4]** which allows us to write the total gravitational force of a star of mass *m* both due to the effect of the visible matter from the galactic *bulge* forward and to the effect of the mass generated by photon-photon photoproduction:

$$F_g=\frac{G\cdot(M_{VIS}(r)+M_{BW}(r))\cdot m}{r^2} \qquad \text{(ii)}$$

where:

- m, mass of a star beyond the galactic *bulge*;
- G, universal gravitational constant;
- r, distance from the galactic center but beyond the galactic *bulge*;
- $M_{VIS}(r)$, visible matter contained by the *bulge* and up to the considered distance r;
- $M_{BW}(r)$, matter created by photon-photon photoproduction up to the considered distance r.

Using the hypothesis that the matter created by photonic photoproduction can be expressed in a spherical symmetry with the following **[3]**:

$$M_{BW}(r)=\delta_{BW}\cdot\left(\frac{4\pi}{3}\cdot r^3\right) \qquad \text{(iii)}$$

we can then write

$$F_g=\frac{G\cdot(M_{VIS}(r)+M_{BW}(r))\cdot m}{r^2}=\frac{G\cdot M_{VIS}(r)\cdot m}{r^2}+\frac{G\cdot M_{BW}(r)\cdot m}{r^2}$$

and replacing in the equation the relation concerning the mass component created by photoproduction (iii), we write

$$\frac{G\cdot M_{VIS}(r)\cdot m}{r^2}+\frac{G\cdot\delta_{BW}\cdot(\frac{4\pi}{3}\cdot r^3)\cdot m}{r^2}=\frac{G\cdot M_{VIS}(r)\cdot m}{r^2}+G\cdot\delta_{BW}\cdot(\frac{4\pi}{3})\cdot m\cdot r \quad \text{(iv)}$$

The equation for the overall gravitational force on a star of mass *m* due to the visible component from the galactic *bulge* onwards and to the contribution of the mass created by photonic photoproduction can be expressed as follows:

$$F_g=\frac{G\cdot M_{VIS}(r)\cdot m}{r^2}+G\cdot\delta_{BW}\cdot(\frac{4\pi}{3})\cdot m\cdot r \quad \text{(v)}$$

Equation (v) can be rewritten in the form:

$$F_g=a(r)\cdot m+a_{BW}(r)\cdot m \quad \text{(vi)}$$

where:

- $a(r)=\frac{G\cdot M_{VIS}(r)}{r^2}$ is the acceleration which the mass *m* is affected by due to the visible mass at distance *r*;
- $a_{BW}(r)=G\cdot\delta_{BW}\cdot(\frac{4\pi}{3})\cdot r$ is the acceleration of the mass *m* due to the effect of the mass created at the distance r from the photon-photon photoproduction phenomenon.

Definition: **Limit acceleration of a galaxy**
the "Limit Acceleration of a galaxy" is defined as the acceleration of a mass m due to the mass created by photon-photon photoproduction at the distance of the limit radius, $a_L=a_{BW}(R_L)=G\cdot\delta_{BW}\cdot(\frac{4\pi}{3})\cdot R_L$

Let us try to estimate the order of magnitude of a limiting acceleration using the typical value for the limiting radius $R_L\sim 10^{20}\,m$ getting:

$$a_L=a_{BW}(R_L)=G\cdot\delta_{BW}\cdot(\frac{4\pi}{3})\cdot R_L\sim G\cdot\delta_{BW}\cdot R_L\sim 10^{-10}(\frac{m^3}{kg\cdot s^2})\cdot 10^{-20}(\frac{kg}{m^3})\cdot 10^{20}m\sim 10^{-10}m/s^2$$

In the "universe of photons" model it is not imagined to modify the second Newtonian law of motion but the value of the acceleration introduced *ad hoc* in the MOND theory is interpreted as the value (order of magnitude) reached by the acceleration which acts on the mass *m* by effect of the mass (or energy) created by photon-photon photoproduction: once the limit radius of the galaxy is reached, the order of magnitude of the limit acceleration is equal to that of the parameter introduced *ad hoc* by MOND theory.

3. Conclusion.

We tried to use the "photon universe" model to theoretically obtain the value of the parameter $a_0=1{,}2\cdot 10^{-10}m/s^2$ introduced *ad hoc* in the MOND model.
Our interpretative model of the rotation curves of galaxies that highlight the problem of "hidden mass" (**[12]**, **[13]**, **[14]**)
(a) does not modify the Newtonian law of motion (contrary to the MOND theory),
(b) does not use an unknown phenomenology (or particle) as the source of the "hidden mass" (or energy) but hypothesizes a photon-photon photoproduction (contrary to the theory of dark matter).
The following work must also be considered as a Fermi exercise.

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