# The rotation curve of galaxies in the "photon universe" model

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## Abstract

Using the photon universe model, as an alternative to the "missing mass" models (dark matter, MOND, etc), a theoretical derivation of the rotation curves of galaxies is proposed.

**Keywords:** dark matter, visible matter, photon-photon collision, universe model photons, galaxy, missing mass, rotation curve, Breit-Wheeler.

### 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 was given of the behavior of the rotation curves that show a "missing mass".
The "photon universe" model allows to estimate the total mass of a galaxy **[1]** (visible component and non-visible component) and to provide an estimate for the total mass of the Observable Universe **[2]**.
In this work we want to use the interpretative model for the rotation curves previously exposed **[3]** to propose a theoretical derivation of the rotation curves of galaxies.
In scientific literature there is the mathematical trend of the rotation curves **[4]** as well as the asymptotic value to which the rotation curve tends **[5]** with regard to the speed value during non-Keplerian behavior is known; in particular the limit value is known

$$V_L \sim \sqrt{4\pi\rho_{R_0} G \cdot R_0} \qquad \text{(i)}$$

Experimentally **[6]** the values of the observed limit velocities lie in the range of values with order of magnitude equal to (10 - $10^2$) *km/s*.
In the next paragraph we will use the hypotheses of the "Universe of Photons" model to derive the mathematical form of the rotation curves of galaxies and we will try to verify that the limiting speed obtained is coherent as an order of magnitude with that which can be experimentally obtained from the rotation curves of galaxies which show a "missing mass" **[5]**.

### 2. Determination of the Rotation Curve of the Galaxy in the "Universe of Photons" model.

In our work we focus our attention on the dynamic analysis of the galaxy from the *bulge* onwards: we will not, therefore, analyze the dynamics within the galactic *bulge*.
In the "photon universe" model it is assumed that due to photon-photon annihilation (Breit-Wheeler or similar) there is a mass creation that has gravitational effects on a large scale. Translating this hypothesis into mathematical language, we can write the total gravitational force of a star of mass *m* both as a result of the visible matter from the galactic *bulge* forward and as a result of the mass generated by photonic annihilation:

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

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 annihilation up to the considered distance *r*.

Using the hypothesis that matter created by photonic annihilation 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 annihilation (iii), we write

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

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

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

Assuming the motion of the star of mass *m* as circular and almost uniform around the galactic center, we can write:

$$m \cdot \left(\frac{V^2(r)}{r}\right) = \frac{G \cdot M_{VIS}(r) \cdot m}{r^2} + G \cdot \delta_{BW} \cdot \left(\frac{4\pi}{3}\right) \cdot m \cdot r$$

which, simplifying for *m* and for *r*, becomes

$$V^2(r) = \frac{G \cdot M_{VIS}(r)}{r} + G \cdot \delta_{BW} \cdot \left(\frac{4\pi}{3}\right) \cdot r^2 \qquad \text{(iv)}$$

that in a graph *V*(*r*) vs *r* allows to study the trend of the velocity as the distance varies beyond the galactic *bulge*. The last equation obtained (iv) allows to distinguish the presence of two terms:

- $\frac{G \cdot M_{VIS}(r)}{r}$ it is responsible for the Keplerian trend,
- $G \cdot \delta_{BW} \cdot \left(\frac{4\pi}{3}\right) \cdot r^2$ it is related to the mass created by photon-photon annihilation.

We have been able to introduce an interpretation of the rotation curves **[3]** and the concepts of "critical mass of a galaxy" and "limit radius of a galaxy", whereby for $r = R^L$ the mass created by annihilation reaches the total visible mass of the whole galaxy; this means that the mathematical term related to the mass created by photon-photon annihilation is greater than the term responsible for the Keplerian trend, so we can write:

$$V^2(r=R^L)\sim G\cdot\delta_{BW}\cdot\left(\frac{4\pi}{3}\right)\cdot(R^L)^2$$

hence a speed limit equal to

$$V\sim\sqrt{G\cdot\delta_{BW}\cdot\left(\frac{4\pi}{3}\right)\cdot R^L} \qquad \text{(v)}$$

The relation (v) allows us to estimate the value of the limit velocity obtainable experimentally; we use the following orders of magnitude

- $G\sim 10^{-10}\left(\frac{m^3}{kg\cdot s^2}\right)$
- $\delta_{BW}\sim 10^{-20}\left(\frac{kg}{m^3}\right)$ **[1]**
- $R^L\sim 10^{20}\,m$ **[3]**

we obtain:

$$V\sim\sqrt{10^{-10}\cdot 10^{-20}}\cdot 10^{20}\,m/s\sim 10^{-15}\cdot 10^{20}\,m/s\sim 10^5\,m/s\sim 10^2\,km/s \qquad \text{(vi)}$$

The estimate (vi) is consistent with the experimental results.

However, it is necessary to underline that the experimental rotation curves do not all look the same: in some rotation curves it seems that the Keplerian component is initially present; on the contrary in some rotation curves, after passing the galactic *bulge*, it seems that the linear regime begins immediately **[6]**: the interpretation given for this behavior is that the mass created by annihilation has already reached the critical value, at least in the curves of rotation without apparent Keplerian trend (before the limit linear regime); on the contrary in the rotation curves in which it is possible to observe a Keplerian trend before the linear trend, it happens that the critical mass is reached after (in terms of distance from the galactic center).

Wanting to schematically summarize what has just been explained, let's observe the following qualitative graph of the rotation curve:

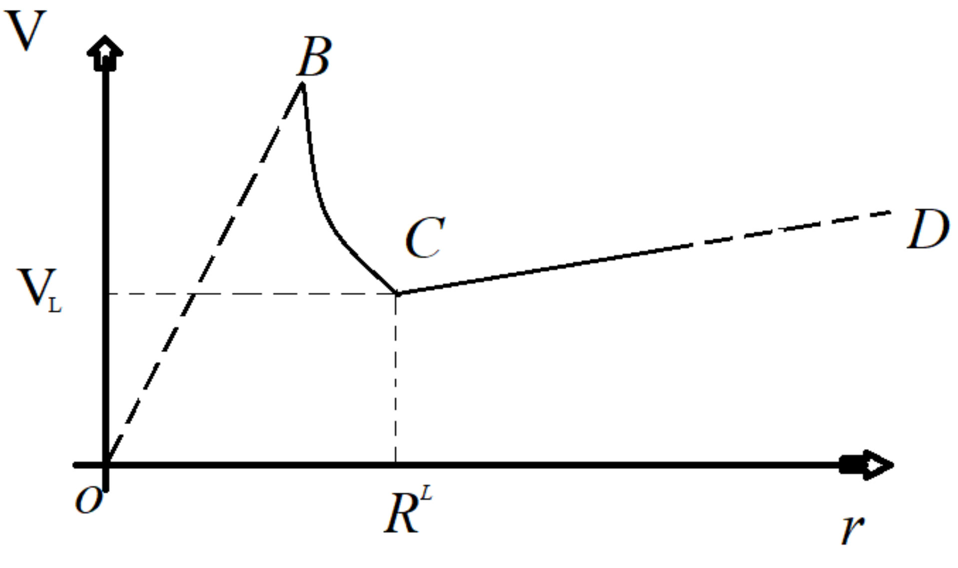

**Fig.1**: generic trend V(*r*) vs *r*

where we can observe:

- the OB path, which was not the subject of our study, is the trend in the galactic *bulge*;
- the BC path is the Keplerian trend until the limit radius is reached;
- the path CD is the linear trend observable in the experimental rotation curves.

## 3. Conclusions.

We tried to use the "Universe of Photons" model to theoretically obtain the trend of the rotation curves that show a "missing mass" in addition to the visible component (**[7]**, **[8]**).

Through the assumptions of the model (**[1]**, **[2]**, **[3]**) we have obtained the order of magnitude of the limiting speed starting from which the Keplerian trend ends and a linear trend begins: the result obtained is of the same order of magnitude of the experimental value.

An interpretation of the general behavior of the rotation curves that do not show a Keplerian trait has also been provided.

The following work must also be considered as a Fermi exercise.

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