Spiral galaxies rotation curves with a logarithmic corrected newtonian gravitational potential

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Abstract We analyze the rotation curves of 10 spiral galaxies with a newtonian potential corrected with an extra logarithmic term. The logarithmic correction can have its origin from fundamental frameworks, like string theories or effective models of gravity due to quantum effects. There is also a connection with some toy models resulting from TeVeS. We represent the spiral galaxies as a thin disk. There is a new constant associated with the extra term in the potential. The rotation curve of the chosen sample of spiral galaxies is well reproduced for a narrow range of the new constant. The compatibility of this correction with local physics is discussed.

Keywords Dark matter · Rotation curves · Gravitation

1 Introduction

The observed features of the rotation curves of gravitationally bound objects, like stars or gas clouds, in spiral galaxies is one of the most important evidence to the existence of dark matter. Spiral galaxies is composed essentially of a very dense central bulge and a flat disc containing spiral arms. At large distance from the center of the galaxy, the keplerian orbits of stars or gas clouds should exhibit velocities decreasing with
the distance to the center. However, observations indicate that the velocities become constant (or even increase slightly) at very large distances to the center of the galaxy. This feature seems to be universal, and it can not be explained by the visible matter present in the galaxy, neither by an additional amount of invisible baryonic matter (baryonic dark matter). It is largely accepted today in the astrophysics community that the only consistent explanation for this anomalous behavior of the rotational curve of spiral galaxies is the existence of a large amount of non-baryonic dark matter, which composes a huge halo around the galaxy extending for a distance many times larger than the visible radius of the galaxy. The reader is addressed to the reviews articles on the subject for a detailed analysis of the evidences for the existence of non-baryonic dark matter and for the candidates to represent it [1,2]. For specific models concerning the dark matter hypothesis, see [3].

Among the candidates to form this “dark halo” around the spiral (and perhaps even the elliptic) galaxies, the most frequently quoted are the axion and the neutralinos. Axions are relics of a “grand unified theory” (GUT) phase in the primordial universe. Axions are particles with small mass, \( m_A \sim 5 \text{ eV} \), but with a very small cross section. Hence, a gas of axions may be approximated by a pressureless, non-relativistic, fluid in spite of its small mass. Neutralinos are the less massive, electrically neutral, stable supersymmetric particles. Both axions and neutralinos have all the characteristic one can ask for a non-baryonic dark matter: they do not emit electromagnetic radiation, having at the same time a very small cross section, behaving essentially as a cold (pressureless) fluid. Cosmologically, they are also asked to play an important role in the structure formation process since they must decouple very early from the radiative gas that dominates, at that moment, the dynamics of the universe. In this way, they can suffer the process of gravitational instability even during the radiative phase, generating the potential well where baryons will later fall. Without such a mechanism is very difficult to understand the actual characteristics of the large scale structures observed in the universe.

In spite of its many success in describing the dynamics of galaxies, and even cluster of galaxies, the dark matter model has, for the moment, a major drawback: no one of its candidates comes from a experimentally tested theory. Axions and neutralinos, in special, remain theoretical proposals. This fact legitimates the search of alternatives to the dark matter model. One of them is to suppose that the ordinary laws of gravity are not valid from galactic scales on. This alternative is quite attractive since the proportion of dark matter, with respect to baryonic matter, required to explain the dynamics of virialized structure like galaxies and clusters of galaxies increases as the scales of the structures increase: clusters of galaxies ask for a much higher proportion of dark matter than galaxies, see, for example, [4]. A recent analysis of supercluster dynamics suggests the possibility of a new long range force [5]. Another possibility is to keep the gravity theory intact, but to modify the law of inertia, as it has been done by the MOND theory, which modifies the Newton second law [6], introducing a critical acceleration parameter \( a_0 \). This proposal has been particularly successful in reproducing the rotation curves of spiral galaxies [7]. The application of MOND to clusters of galaxy is more problematic. But, as we will see later, it is possible to map the MOND formulations in modified gravity models. However, the equivalence of both approach for specific problems has some restrictions.