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Possible existence of wormholes in the central regions of halos

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HIGHLIGHTS

- Earlier we showed possible existence of wormholes in the outer regions of halo.
- We obtain here analogous results for the central parts of the galactic halo.
- Our result is an important compliment to the earlier result.
- This confirms possible existence of wormholes in most of the spiral galaxies.

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ABSTRACT

An earlier study (Rahaman, et al., 2014 and Kuhfittig, 2014) has demonstrated the possible existence of wormholes in the outer regions of the galactic halo, based on the Navarro–Frenk–White (NFW) density profile. This paper uses the Universal Rotation Curve (URC) dark matter model to obtain analogous results for the central parts of the halo. This result is an important compliment to the earlier result, thereby confirming the possible existence of wormholes in most of the spiral galaxies.

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1. Introduction

Wormholes are hypothetical handles or tunnels in spacetime linking widely separated regions of our Universe or entirely different universes. Morris and Thorne [1] proposed the following line element for the wormhole spacetime:

$$ds^2 = -e^{2f(r)}dt^2 + \left(1 - \frac{b(r)}{r}\right)^{-1} dr^2 + r^2(d\theta^2 + \sin^2\theta\, d\phi^2), \tag{1}$$

using units in which $c = G = 1$. Here $f = f(r)$ is called the *redshift function*, which must be everywhere finite to prevent an event horizon. The function $b = b(r)$ is called the *shape function*, which has the property that $b(r_{th}) = r_{th}$, where $r = r_{th}$ is the *throat* of the wormhole. A key requirement is the *flare-out condition* at the throat: $b'(r_{th}) < 1$, while $b(r) < r$ near the throat. The flare-out condition can only be satisfied by violating the null energy condition (NEC), which states that $T_{\mu\nu}k^\mu k^\nu \geq 0$ for all null vectors and where $T_{\mu\nu}$ is the energy–momentum tensor. So given the null vector (1, 1, 0, 0), the NEC is violated if $\rho + p_r < 0$, where ρ is the energy density and p_r the radial pressure.

The possible existence of wormholes in the outer region of the halo has already been discussed in Refs. [2,3] using the Navarro–Frenk–White (NFW) density profile [4]:

$$\rho(r) = \frac{\rho_s}{\frac{r}{r_s}\left(1 + \frac{r}{r_s}\right)^2},$$

where r_s is the characteristic scale radius and ρ_s is the corresponding density. This model yields a shape function whose basic properties, such as the throat size, remain the same in the region considered [3]. It is well known that the NFW model predicts velocities in the central parts that are too low [5], but these discrepancies do not exist in the outer regions of the halo where the wormholes discussed in Refs. [2,3] are located [6,7].

In this study we are going to be primarily concerned with the region closer to the center where the Universal Rotation Curve (URC) dark matter profile is valid [8]:

$$\rho(r) = \frac{\rho_0 r_0^3}{(r + r_0)(r^2 + r_0^2)}; \tag{2}$$

here r_0 is the core radius and ρ_0 the effective core density. While the URC model is valid throughout the halo region, we assume that the outer region has already been dealt with in Refs. [2,3] using the NFW model, thereby leaving only the central region, which is the subject of this paper.

In this connection we would like to add here that the URC represents any single rotation curve in spirals of any mass and Hubble type, and it is an obvious step forward with respect to assuming a constant value. At some time, a Cored Burkert profile is a step forward with respect to NFW profile since, it is now a common fact that the latter fails to reproduce the dark matter distribution. Both the URC and the Cored profile are born empirically and find some explanation later on [9].

Therefore, our plan of the present work is as follows: In Section 2 we provide the basic equations and their solutions under the URC dark matter profile whereas Section 3 is devoted to some specific comments regarding the results obtained in the study.

2. The basic equations and their solutions

Even though we now have the density profile, other properties of dark matter remain unknown. So we are going to assume that dark matter is characterized by the general anisotropic energy–momentum tensor [10]

$$T_\nu^\mu = (\rho + p_r)u^\mu u_\nu - p_r g_\nu^\mu + (p_t - p_r)\eta^\mu \eta_\nu, \tag{3}$$

with $u^\mu u_\mu = -\eta^\mu \eta_\mu = -1$, p_t and p_r being the transverse and radial pressures, respectively. The line element for the galactic halo region is given in Eq. (1).