Evidence for dark matter in the inner Milky Way...Really?

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The following is a comment on the recent letter by Iocco, Pato, and Bertone (2015) where the authors claim to have found "...convincing proof of the existence of dark matter...". The letter in question presents a compilation of recent rotation curve observations for the Milky Way, together with Newtonian rotation curve estimates based on recent baryonic matter distribution measurements. A mismatch between the former and the latter is then presented as "evidence for dark matter". Here we show that the reported discrepancy is the well known gravitational anomaly which consistently appears when dynamical accelerations approach the critical Milgrom acceleration \( a_0 \sim 1.2 \times 10^{-10} \text{ m s}^{-2} \). Further, using a simple modified gravity force law, the baryonic models presented in Iocco, Pato, and Bertone (2015), yield dynamics consistent with the observed rotation values.

Keywords: Galactic Dynamics; Relativity and gravitation; Modified theories of gravity; Milky Way

The claim of “Evidence for dark matter” on a recent letter to Nature Physics (Iocco, Pato, and Bertone 2015) appears excessive. The authors have convincingly shown that the baryonic matter distribution in our galaxy cannot account for the observed rotation curve of our galaxy, at scales somewhat shorter than those of the \( \sim 8 \text{ kpc} \) solar radius. This result extends towards the inconsistency between the observed baryonic matter and the measured rotation curve, already well known at large radii. Two generic ways to deal with this discrepancy are currently under discussion in the scientific literature: (a) To keep Newton’s gravity unchanged and make up any dynamical mismatch through the addition of as much hypothetical non-baryonic dark matter as required. And (b) To search for a modified theory of gravity under which no such discrepancies appear. The latter requires a transition away from Newton’s gravity and experience dynamical friction, or it will not work. Further, using a simple modified gravity force law, the baryonic models presented in Iocco, Pato, and Bertone (2015) can be reproduced from the baryonic models these same authors use.

The history of gravitational anomalies extends back to almost 200 years; when reporting on the observed residuals in the orbit of Neptune, Bouvard (1821) correctly concluded that either (i) the effect of the Sun’s gravity, at such a great distance might differ from Newton’s description, or (ii) the discrepancies might simply be observational error; or (iii) perhaps Uranus was being pulled, or perturbed, by an as-yet undiscovered planet. On that occasion option (iii) proved correct, not so however in the following instance, where the observed peculiarities in the orbit of Mercury turned out not to signal “dark matter”, but indeed, marked the end of the validity regime of Newtonian gravity towards high velocities.

It is important to note that the difference between the two points of view is far from merely semantic: both reflect fundamentally distinct ideas of reality, either space is teeming with unseen particles far outnumbering the detectable universe, or it is not. Both lead to distinct predictions in a number of cases, e.g. black hole growth rates will be affected by the accretion of dark matter, or not (Hernandez and Lee 2010). A satellite galaxy orbiting within a dark matter halo will gravitationally interact with countless dark matter particles, lose energy and experience dynamical friction, or it will not (Sánchez-Salcedo, Reyes-Iturbide, and Hernandez 2006). Any theory where the driving causal entity is something no one has ever seen, (e.g. Cartesian vortices, phlogiston, caloric or the electromagnetic aether) should be treated, at best, as a temporary working hypothesis.

In summary, Iocco’s (2015) conclusion for “...a convincing proof of the existence of dark matter...” is misleading, specially given that they fail to mention that

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FIG. 1. On the log-log angular frequency vs. galactocentric radius plot of the upper panel from figure (2) of Iocco, Pato, and Bertone (2015), we have superimposed blue curves of constant acceleration $a = a_0, 2a_0, 3a_0, 4a_0$, from bottom to top respectively. The cross shaded region bound in green, shows the angular frequencies which the gray baryonic models of the above authors result in, using a MOND model (Mendoza et al. 2011) where the gravitational force per unit mass in units of $a_0$ is given by $f(x) = (x^3 + x^2 + x)/(x + 1)$, where $x^2 := GM(R)/a_0R^2$ and $G$ is Newton’s gravitational constant, $R$ the galactocentric distance and $M(R)$ the enclosed mass. Note that the Newtonian gravitational regime is recovered for $x \gg 1$.

their analysis is restricted to a small subset amongst the many theories of gravitation currently under consideration in the scientific literature.

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