

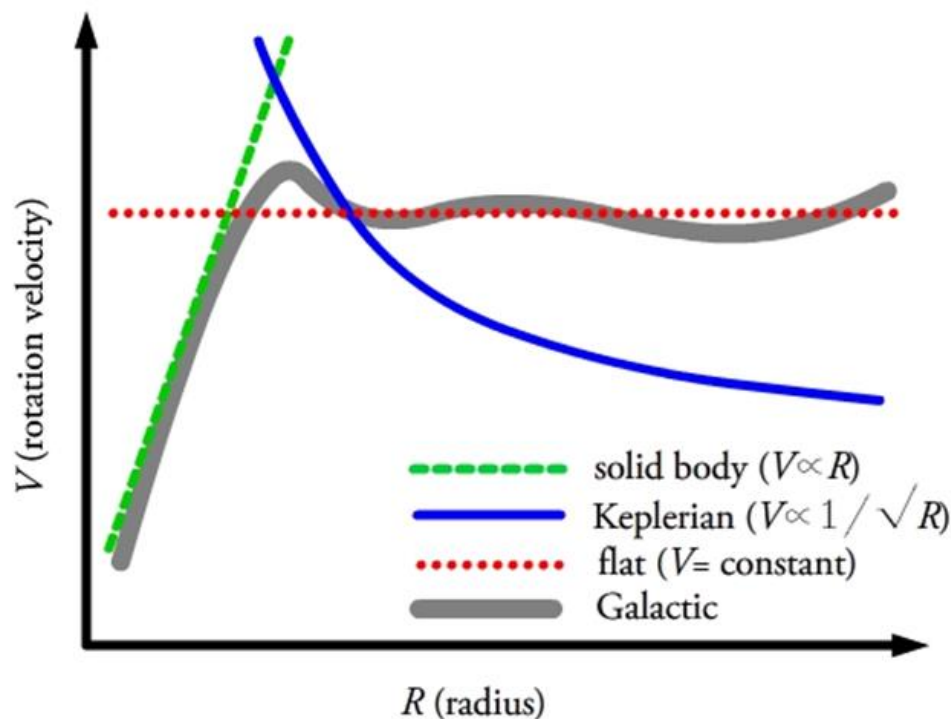
# Is Molecular Hydrogen (H<sub>2</sub>) the ‘Dark Matter’ that Explains the Galactic Rotation Anomaly?

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Molecular hydrogen (H<sub>2</sub>), virtually undetectable from space, has long been a viable candidate for the alleged ‘dark matter’ supposedly accountable for the ‘flattening’ of the galactic (tangential) rotation curves. Presented here is a simplified analysis, assuming such molecular hydrogen is uniformly distributed throughout the Milky Way Galaxy’s disk, that examines the plausibility of such ‘dark matter’ providing a definitive gravitational explanation for the observed rotational behavior.

## 1. Introduction

As discussed in [1]: “Dark matter was postulated by Jan Oort in 1932, ... to account for the orbital velocities of stars in the Milky Way and by Fritz Zwicky in 1933 to account for evidence of ‘missing mass’ in the orbital velocities of galaxies in clusters. Adequate evidence from galaxy rotation curves was discovered by Horace W. Babcock in 1939, but was not attributed to dark matter. The first to postulate dark matter based upon robust evidence was Vera Rubin in the 1960s–1970s, using galaxy rotation curves [see Figure 1] ... Together with fellow staff-member Kent Ford, Rubin announced ... that most stars in spiral galaxies orbit at roughly the same speed, which implied that the mass densities of the galaxies were uniform well beyond the regions containing most of the stars (the galactic bulge), a result independently found in 1978 ... Eventually other astronomers began to corroborate her work and it soon became well-established that most galaxies were dominated by ‘dark matter’ ... [B]y the 1980s most astrophysicists accepted its existence.”



**FIGURE 1.** Galactic (Tangential) Rotational Curves [2]

In 1966, Varsavsky observed that “... the appearance of the rotation curve of the [Milky Way] Galaxy implies that molecular hydrogen could have an abundance comparable, or actually higher by a factor of about four, to that of atomic hydrogen ... Molecular hydrogen, if present, would have a considerable influence on many astronomical problems ... [If] a large fraction of the unseen mass is gas distributed near the plane of the Galaxy, [and] this gas ... can be molecular

hydrogen, we could postulate an abundance of molecular hydrogen up to five times larger than the abundance of atomic hydrogen and still satisfy all the observations of the motions of the stars.” [3]

In 1989, P. Marmet and Reber commented that “[t]he largest fraction of gases in space cannot be atomic hydrogen, but possibly can be H<sub>2</sub> [molecular hydrogen]. Such a large amount of H<sub>2</sub> would be undetectable in the 21-cm radio receivers of radio astronomers [i.e., the wavelength at which atomic hydrogen absorbs and emits radiation] ... H<sub>2</sub>, having no dipole moment, cannot emit any measurable amount of radio-frequency signal ... it is extremely difficult to detect. Therefore, H<sub>2</sub> is a serious candidate that might form the important component of invisible matter in space.” [4]

In 1995, Marmet offered an alternative explanation for the Cosmic Microwave Background (CMB) instead of the Big Bang. “Astronomical observations show that there is a very large quantity of atomic hydrogen (H) in the universe ... It is well known in basic physics and chemistry that atomic hydrogen H is quite unstable. Spectroscopy reveals that when one has a given quantity of atomic hydrogen in a given volume, these atoms react between themselves to form molecular hydrogen (H<sub>2</sub>) ... Molecular H<sub>2</sub> is extremely stable at normal pressure down to the most extreme vacuum. One can expect that, after billions of years, an important fraction of atomic hydrogen H in the universe is already combined to form the extremely stable molecular hydrogen (H<sub>2</sub>) ... Molecular H<sub>2</sub> is among the most transparent gases in the universe. Consequently, one cannot hope to detect free H<sub>2</sub> in space by usual spectroscopic means.

“Since we are fully surrounded by the matter of the universe, it is well known that Planck’s radiation observed from inside our local volume of space at 3 K (during the last billion years) must be perfectly isotropic. This is in perfect agreement with observational data. It is inconceivable that the matter in space around us (a billion light years around us) would not emit Planck’s radiation ... [If] the region of the heavens around the earth [is] filled with molecular H<sub>2</sub> at 3K, [and] such a gas emits 3 K Planck’s radiation in all directions, this leads to the 3 K isotropic radiation as observed in space. However, on the contrary, the primeval radiation [from the Big Bang] has been calculated to be non-isotropic.” [5]

Molecular hydrogen has been a leading candidate for ‘dark matter,’ at least within a galaxy, for 50 years or more, not to mention Marmet’s conjecture that it could be an explanation for the CMB. At least traces of it have been identified in ours and other galaxies, fairly remarkable given its extreme difficulty to detect. [6,7] If molecular hydrogen is indeed the majority of the alleged ‘dark matter’ that permeates throughout our Milky Way Galaxy and causes its anomalous rotation, an analysis of its gravitational effects might lend some evidence to the validity of this postulate.

## 2. Estimating Gravity and Rotational Speed within the Milky Way Galaxy

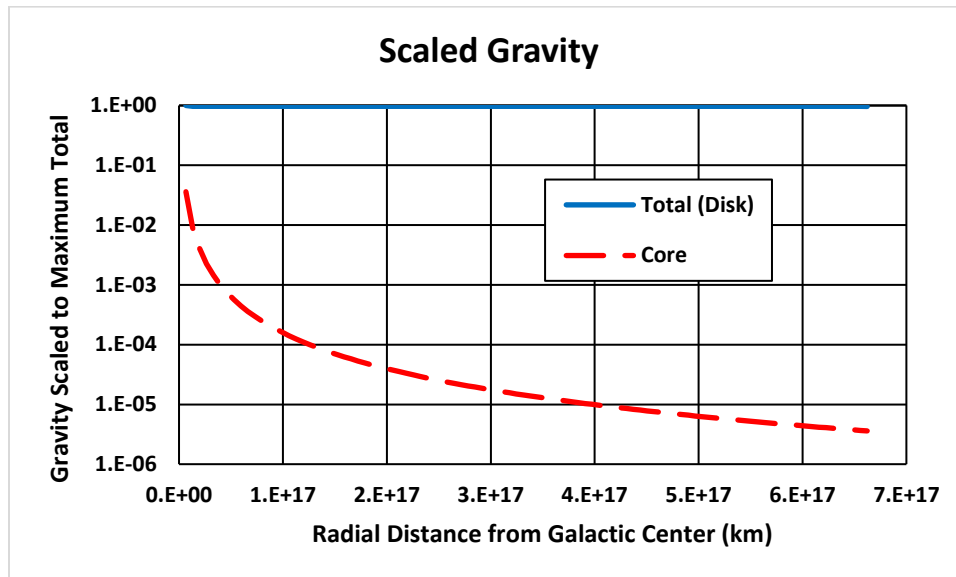
Assume the Milky Way Galaxy is circular of uniform density (due to presence of molecular hydrogen [H<sub>2</sub>] as ‘dark matter’), with the galactic core at the center. Assume a star with the sun’s mass is located in the disk a distance ‘r’ from the center. Based on similarity for the gravitational force inside a solid sphere of uniform density at radius r [8], assume that the gravitational force from the galactic disk at r arises solely from that portion of the disk < r.<sup>1</sup> Since the mass of the disk < r is proportional to r<sup>2</sup>h, where ‘h’ is the thickness of the disk, and the gravity at r is proportional to 1/r<sup>2</sup>, when combined the dependence on r disappears, implying that the gravity throughout the disk (from the disk only) is constant. If the mass of the galaxy is ‘M’ and the star has the sun’s mass ‘m,’ the gravitational force on the star will be  $F_{disk} = \frac{GMm}{R^2}$ , where ‘R’ is the galactic radius.

Now including the gravitational force from the galactic core,  $F_{core} = \frac{G\mu m}{r^2}$ , where ‘μ’ is the mass of the core, the total gravitational force on the star (scaled to its maximum value) as a function of r is just the sum, as shown in Figure 2 (constants are M = 2.29E+42 kg, μ = 8.55E+36 kg, m = 1.99E+30 kg, h = 1.89E+13 km, R = 6.62E+17 km, G = 6.67E-20 km<sup>3</sup>/kg-s<sup>2</sup> [9]). From this, equating the total gravitational force to the centripetal force at r, we obtain  $F(r)_{total} = \frac{mv(r)^2}{r}$ , which implies  $v(r) = \sqrt{rF(r)/m}$ , where v(r) is the tangential speed at r. As indicated by Figure 3, the tangential speed continues to rise out to the edge of the galaxy, despite the fact that the gravitational force is essentially

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<sup>1</sup> As shown there, gravitational force rises linearly from zero at the center of the solid sphere to its maximum value at the sphere’s surface. This follows readily from gravity arising only from the portion of the sphere < r, for which the enclosed mass is proportional to the cube of the radius, while the gravitational force at r is proportional to the inverse square of the radius. Combined, these yield a linear dependence of gravity with r.

constant throughout. However, after a quick initial drop, the angular speed  $\omega(r) = v(r)/r$  levels off, declining gradually with distance. Note that both speeds are scaled to their individual maxima.



**FIGURE 2. Gravitational Force on Star vs. Radial Distance from Galactic Center<sup>2</sup>**

The tangential speed across the galactic disk in Figure 3, if anything, most nearly resembles that of the ‘solid body’ in Figure 1. This is reinforced by the tendency for the angular speed to level off with radial distance, although still showing some gradual decrease. Thus, it appears that, from this highly simplified analysis, assuming uniformly distributed ‘dark matter’ throughout the galactic disk falls somewhat short of explaining the galactic rotation anomaly by itself.

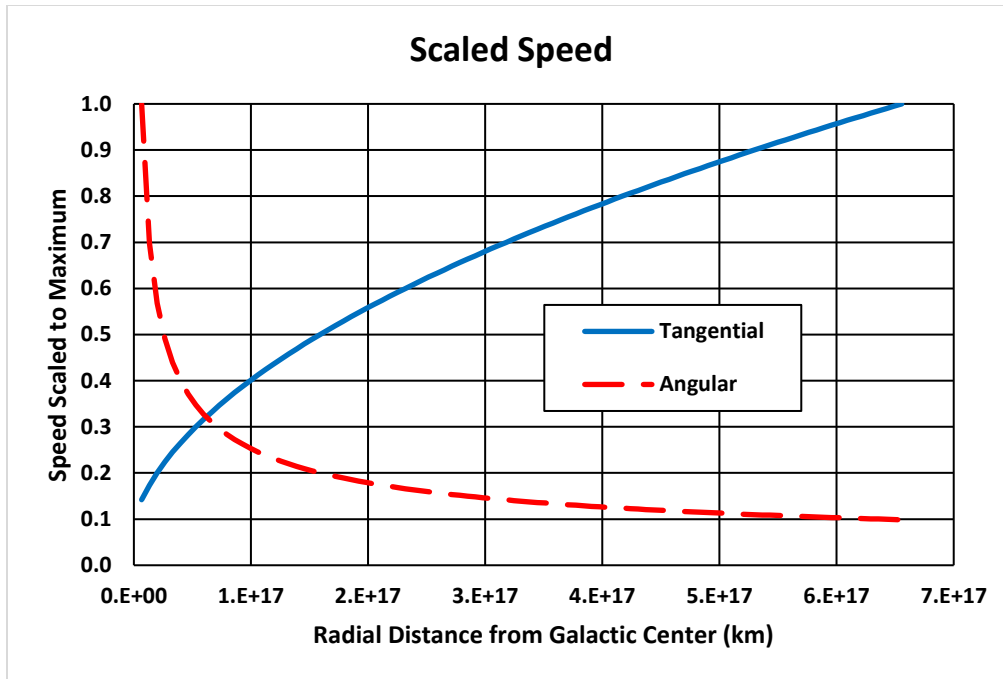
### 2.1 Alternate or Supplemental Considerations

As an alternative or supplement to the ‘dark matter’ explanation, electromagnetic phenomena have been proposed as mechanisms that account for the flattening of the galactic (tangential) rotation curve. Among these are ones that exclusively invoke Electric/Plasma Universe Theory and even one of the author’s own. [10-12] Another that, while providing a strictly gravitational explanation still leaves room for the possibility of electromagnetic effects, is that from L. Marmet: “Given the rotation curve, the intrinsic angular momentum, the maximum radius and a smooth mass distributions as boundary conditions, a unique mass distribution is obtained. The mass distribution is finite and does not have to fit a simple analytical function. The additional mass needed to obtain an agreement with the observed mass-to-luminosity ratio is provided by baryonic matter most likely to be molecular hydrogen and condensed matter ... Also, calculations with plasmas also produce matter distributions which explain galaxy dynamics. It would be important to know which fraction of interstellar matter is a plasma and contributes as such.” [13]

### 3. Conclusion

While molecular hydrogen appears as a plausible candidate for ‘dark matter,’ at least within galaxies, if such actually exists, the simple analysis here suggests that it alone may not be sufficient to explain the galactic rotation anomaly of the ‘flattening’ of the tangential speed curve with radial distance. If distributed uniformly throughout the disk of a galaxy, ‘dark matter’ does not produce the observed flattening, but suggests more of a ‘solid body’ (pinwheel) rotational behavior, also suggested by the angular speed variation. At least one alternative that assumes a ‘double mass’ distribution of molecular hydrogen as the ‘dark matter’ within a galactic disk has been proposed by Marmet to rectify the ‘failure to flatten,’ although it does not dismiss the possibility of electromagnetic effects contributing as well.

<sup>2</sup> Since the gravity from the disk dominates over that from the core, both the core and total gravity are shown as a single line.



**FIGURE 3.** Tangential and Angular Speed of Star vs. Radial Distance from Galactic Center

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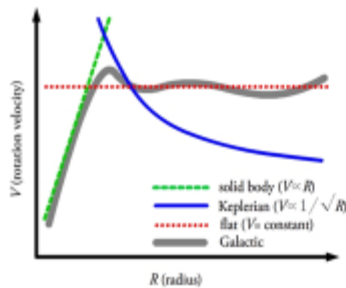
# DOES MOLECULAR HYDROGEN (H<sub>2</sub>) = 'DARK MATTER?'

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4<sup>th</sup> Annual John Chappell Natural Philosophy Society Conference

Storrs, CT (UConn)  
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## GALACTIC ROTATION ANOMALY



"Dark matter was postulated by Jan Oort in 1932 ... to account for the orbital velocities of stars in the Milky Way and by Fritz Zwicky in 1933 to account for evidence of 'missing mass' in the orbital velocities of galaxies in clusters ... The first to postulate dark matter based upon robust evidence was Vera Rubin in the 1960s–1970s, using galaxy rotation curves ... [M]ost stars in spiral galaxies orbit at roughly the same speed, which implied that the mass densities of the galaxies were uniform well beyond the regions containing most of the stars ... Eventually other astronomers began to corroborate her work and it soon became well-established that most galaxies were dominated by 'dark matter' ... [B]y the 1980s most astrophysicists accepted its existence." ([http://en.wikipedia.org/wiki/Dark\\_Matter](http://en.wikipedia.org/wiki/Dark_Matter))

## MOLECULAR H<sub>2</sub> = DARK MATTER? (1)

- In 1966, Varsavsky observed that "... the appearance of the rotation curve of the [Milky Way] Galaxy implies that molecular hydrogen could have an abundance comparable, or actually higher by a factor of about four, to that of atomic hydrogen ... [If] a large fraction of the unseen mass is gas distributed near the plane of the Galaxy, [and] this gas ... can be molecular hydrogen, we could postulate an abundance ... up to five times larger than ... atomic hydrogen and still satisfy all the observations of the motions of the stars." (*The Detectability of Molecular Hydrogen in Interstellar Space*, Space Science Reviews, No. 5, pp. 419-434)

## MOLECULAR H<sub>2</sub> = DARK MATTER? (2)

- In 1989, P. Marmet and Reber commented that "[t]he largest fraction of gases in space cannot be atomic hydrogen, but possibly can be [molecular] H<sub>2</sub> ... undetectable in the 21-cm radio receivers [the wavelength at which atomic hydrogen absorbs and emits radiation] ..." (*Cosmic Matter and the Non-expanding Universe*, IEEE, Transactions on Plasma Science, 17(2): 264-269)
- In 1995, Marmet offered the emission of 3°K Planck radiation isotropically in all directions from molecular H<sub>2</sub> as an alternative to the Big Bang to explain the Cosmic Microwave Background (CMB).
  - "Astronomical observations show that there is a very large quantity of atomic hydrogen (H) in the universe ... [which] is quite unstable ... [T]hese atoms react between themselves to form molecular H<sub>2</sub> ... [which] is extremely stable ... down to the most extreme vacuum ... [A]fter billions of years, an important fraction of atomic hydrogen H in the universe is already combined to form ... molecular hydrogen (H<sub>2</sub>) ..., among the most transparent gases in the universe. Consequently, one cannot hope to detect free H<sub>2</sub> in space by usual spectroscopic means." (*The Origin of 3 K Radiation*, Apeiron, Vol. 2, No. 1)

## MOLECULAR H<sub>2</sub> = DARK MATTER? (3)

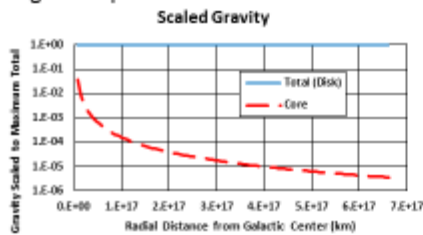
- Molecular hydrogen has been a leading candidate for 'dark matter,' at least within a galaxy, for 50 years or more, not to mention Marmet's conjecture that it could be an explanation for the CMB.
- At least traces of it have been identified in ours and other galaxies, remarkable given its extreme difficulty to detect.
- If molecular hydrogen is indeed the majority of the alleged 'dark matter' that permeates throughout our Milky Way Galaxy and causes its anomalous rotation, an analysis of its gravitational effects might lend some evidence to the validity of this postulate.

## GRAVITY & GALACTIC ROTATION (1)

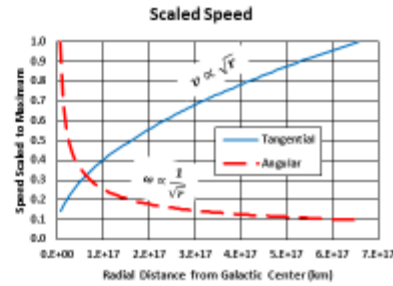
- Milky Way = circular disk, uniform density (due to presence of molecular H<sub>2</sub> as 'dark matter')
  - Core at center and star of Sun mass 'm' at radius r
- For solid sphere of uniform density, gravity increases linearly with r from zero at center to maximum at surface ( $\frac{mass [\propto r^3]}{distance [\propto r^2]} \propto r$ ), arising solely from spherical mass < r
  - Analogy for disk  $\rightarrow \frac{mass [\propto r^2]}{distance [\propto r^2]} \propto constant$ 
    - Throughout galactic disk, gravity from disk at any r is constant  $=GMm/R^2$ , for galactic mass 'M', galactic radius 'R' and star mass 'm'

## GRAVITY & GALACTIC ROTATION (2)

Including the gravitational force from the galactic core,  $F_{core} = \frac{G\mu m}{r^2}$ , where ' $\mu$ ' is the mass of the core, the total gravitational force on the star as a function of  $r$  is just the sum. From this, equating the total gravitational force to the centripetal force at  $r$ , we obtain  $F(r)_{total} = \frac{mv(r)^2}{r}$ , which implies  $v(r) = \sqrt{rF(r)/m}$ , where  $v(r)$  is the tangential speed at  $r$ .



The tangential speed continues to rise out to the edge of the galaxy, despite the fact that the gravitational force is essentially constant throughout. However, after a quick initial drop, the angular speed  $\omega(r) = v(r)/r$  levels off, declining gradually with distance.



## GRAVITY & GALACTIC ROTATION (3)

- The tangential speed across the galactic disk, if anything, most nearly resembles that of the 'solid body,' if that line had a much more gradual slope.
- This is reinforced by the tendency for the angular speed to level off with radial distance, although still showing some gradual decrease.
- It appears that, from this highly simplified analysis, assuming uniformly distributed 'dark matter' throughout the galactic disk falls somewhat short of explaining the galactic rotation anomaly by itself.



## OTHER EXPLANATIONS?

- Electromagnetic phenomena have been proposed as mechanisms that account for the flattening of the galactic (tangential) rotation curve, including ones that exclusively invoke Electric/Plasma Universe Theory and even one of the author's own ("Who Needs Dark Matter? An Alternative Explanation for the Galactic Rotation Anomaly," 3<sup>rd</sup> Annual Chappell Natural Philosophy Society Conference, 2017).
- Another that, while providing a strictly gravitational explanation still leaves room for the possibility of electromagnetic effects, is that from L. Marmet ("Rotation Dynamics of a Galaxy with a Double Mass Distribution," [arXiv:1210.1998](https://arxiv.org/abs/1210.1998) [astro-ph.GA] 2012):
  - "Given the rotation curve, the intrinsic angular momentum, the maximum radius and a smooth mass distributions as boundary conditions, a unique mass distribution is obtained ... [which] is finite and does not have to fit a simple analytical function. The additional mass ... is provided by baryonic matter most likely to be molecular hydrogen and condensed matter ... Also, calculations with plasmas also produce matter distributions which explain galaxy dynamics. It would be important to know which fraction of interstellar matter is a plasma and contributes as such."

## CONCLUSION

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