Poster nr.

Galaxy Rotation Curves from Self-Consistent Gravitational Energy Distributions

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Main finding:
New solutions to the Einstein Field equations reveal the existence of stable entities (called geons), offering a solution to the missing mass problem.
These new solutions , made of vacuum energy , can have any size; from particle size to the size of a galaxy (galactic geons).
We find that galaxies, embedded in galactic geons can explain the galaxy rotation curves.
The galactic geons have mass (due to their vacuum energy), but do not contain any material particles.

$$G_{\mu\nu} + \Lambda\, g_{\mu\nu} = 8\,\pi\, T_{\mu\nu}$$

$$ds^2 = -e^{2\Phi(r)}dt^2 + e^{2\Lambda(r)}dr^2 + r^2(d\theta^2 + sin^2\theta\, d\phi^2)$$

Assume spherical symmetry
Use tt-component (energy density), rr-component (radial pressure, $\theta\theta$- or $\phi\phi$-component (angular pressure)
No rotation: Eliminates cross terms like $G_{t\theta}$

$$T_{\mu\nu} = \text{diag}\left(\rho e^{2\Phi}, p_r e^{2\Lambda}, p_t r^2, p_t r^2 sin^2\theta\right)$$

Geon density profile $\rho(r) = \rho_0 e^{-r^2/R^2}$

The tt equation becomes: $\frac{1}{r^2}\frac{d}{dr}[r(1-e^{-2\Lambda})] = 8\pi\rho_0 e^{-r^2/R^2}$

Define the mass function: $m(r) = \frac{1}{2}r(1-e^{-2\Lambda})$

$$m(r) = 4\pi\rho_0\left[\frac{\sqrt{\pi}R^3}{4}\, erf\!\left(\frac{r}{R}\right) - \frac{R^3}{2}e^{-r^2/R^2}\right]$$

Taking the integral from 0 to infinity, the integral becomes:
$M_{geon} = \pi^{3/2}\rho_0\, R^3$ which is the total “dark mass” of the geon.

$$e^{-2\Lambda} = 1 - \frac{2m(r)}{r}$$

$$\frac{2}{r}\Phi'(r)e^{-2\Lambda} - \frac{1}{r^2}(1-e^{-2\Lambda}) = 8\pi p_r(r)$$

$$\frac{2}{r}\Phi'(r)\left(1-\frac{2m(r)}{r}\right) - \frac{1}{r^2}\left(\frac{2m(r)}{r}\right) = 8\pi p_r(r)$$

$$\Phi'(r) = \frac{r}{2\left(1-\frac{2m(r)}{r}\right)}\left(8\pi p_r(r) + \frac{2m(r)}{r^3}\right)$$

$\nabla_\nu T^{\mu\nu} = 0$ (conservation equation)

$\frac{dp_r}{dr} = -(\rho + p_r)\frac{d\Phi}{dr} + \frac{2}{r}(p_t - p_r)$ (radial component)

Use equation of state $p_r = -\rho$

$$p_t = -\rho\left(1 - \frac{r^2}{R^2}\right)$$

Note:
This is the simplest possible solution. In reality, the geon will rotate, leading to a more complex derivation.
Furthermore, the geon might not be spherical symmetric but an oblate spheroid.

Note:
The existence of this solution was already predicted **27 years ago** [2];
«From a more classical point of view, these bubbles should correspond to non-linear stable solutions of the EFE in which the source of the curvature is the curvature itself».

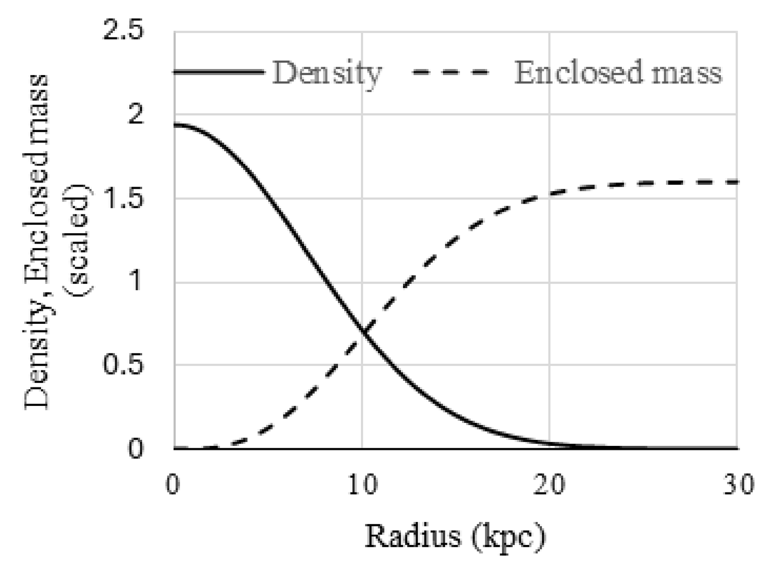

Figure 1. Density and enclosed mass of the geon. The units are scaled; The density (in kg/m³) is obtained by multiplying the scaled values by 10^{-21}. The enclosed mass (in solar masses) is obtained by multiplying the scaled values by 10^{11}. The scale length R = 9 kpc. Total mass of geon = 1.6 10^{11} $M_\odot$.

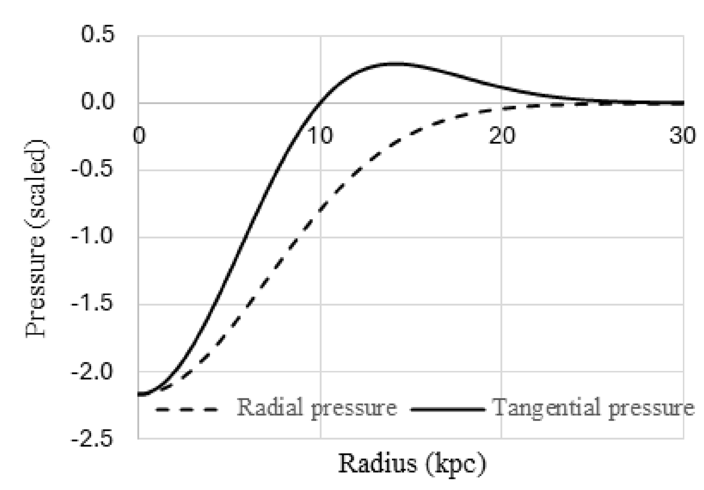

Figure 2. Radial and tangential pressure profiles of the geon. The units are scaled; the pressures (in Pa) are obtained by multiplying the scaled values by 10^{-38}.

Solution to the missing mass problem

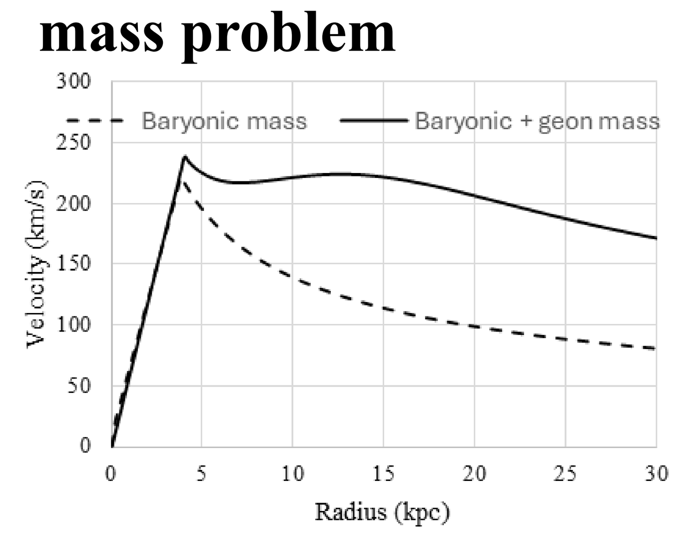

Figure 3. Calculated velocity profiles for the Milky Way (simplistic model), showing the Newtonian decay and the relatively flat profiles obtained by the additional force of the geon.

Solution to the core-cusp problem

Nearly all simulations form dark matter halos have "cuspy" dark matter distributions, with density increasing steeply at small radii, while the rotation curves of most observed dwarf galaxies suggest that they have flat central dark matter density profiles ("cores"). *Here, **geons with a Gaussian density profile** could provide a natural solution since the gradient of the density becomes zero at the center.*

Explanation for Early galaxy formation

Recent observations from the James Webb Space Telescope (JWST) of massive, mature galaxies at only 250–300 million years after the Big Bang seem to challenge the ΛCDM model . Geons could form seconds to minutes after the Big Bang, far earlier than the formation of large dark matter halos (between 100000 yr to 300 Myr years after the Big Bang). ***Geons** forming almost immediately after inflation, could begin clustering well before recombination and lead to much earlier galaxy formation.*

Conclusions

1. Stable gravitational vacuum energy solutions of the EFE found
2. The equation of state is given by $p_r = -\rho$
3. The size of these geons can range from particle to galactic size
4. The presence of galactic geons can solve several problems;
   1) missing mass (dark matter), 2) core-cusp problem, 3) Early galaxy formation.

References

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