The Exochronous Universe:

a timeless metric as a possible alternative to Dark Matter

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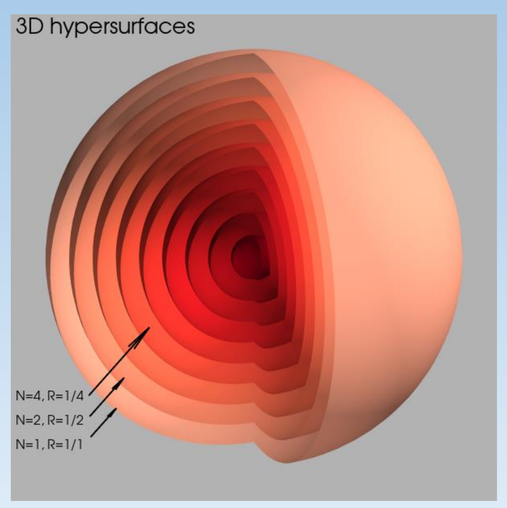
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1. Introduction

The ΛCDM cosmological model, in combination with the FLRW metric, provides solutions to the Friedman equations that govern the dynamics of the universe. However, it requires the existence of Dark Energy and Dark Matter in addition to normal baryonic mater for it to agree with cosmological observations. We introduce here an alternative timeless (exochronous) metric that reproduces the effects of these two elusive ingredients on cosmic dynamics.

2. The Exochronous Metric

$$ds^2 = \frac{\mathrm{d}R^2}{\mathrm{n}(R)} + R^2\left(\frac{\mathrm{d}r^2}{1-kr^2} + r^2\mathrm{d}\theta^2 + r^2\sin^2\theta\,\mathrm{d}\phi^2\right)$$

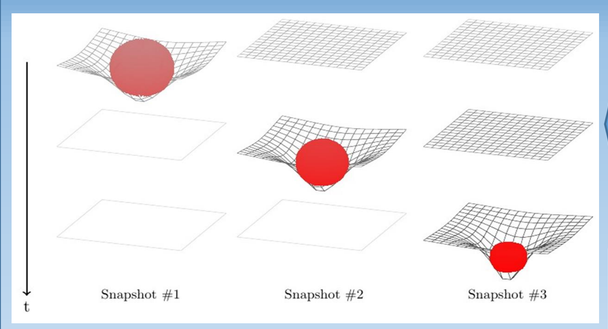


Results in a static solution to the Einstein gravitational field equations:

$$R = \frac{1}{n}\sqrt{\frac{3c^2}{8\pi G\rho}}$$

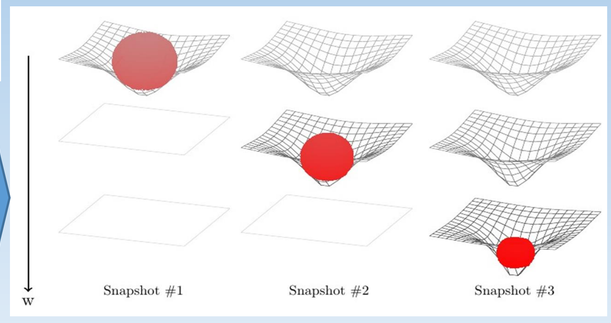
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3. Time In The Exochronous Universe



In the standard picture of time the gravitational curvature induced by matter is transitory and disappears once the original matter has moved on.

In the exochronous universe, distortions in the metric of 4D space persist even after the original matter that caused them is no longer present.



4. The Poisson Equation

- Lagrangian density for Newtonian gravity

$$\mathcal{L}(\vec{x},t) = -\rho(\vec{x},t)\phi(\vec{x},t) - \frac{1}{8\pi G}(\nabla\phi(\vec{x},t))^2$$

- Solving the Euler-Lagrange equation gives Gauss law of gravity

$$4\pi G\rho(\vec{x},t) = \nabla^2\phi(\vec{x},t)$$

- Replacing $t \equiv x_0 \rightarrow w$ gives the modified 4D Poisson equation

$$\Phi(r,w) = -\frac{4\pi G}{r}\int_0^r\int_0^w r'^2\rho(r',w')dr'\,dw'$$

5. Gravitational Collapse of Gas Cloud

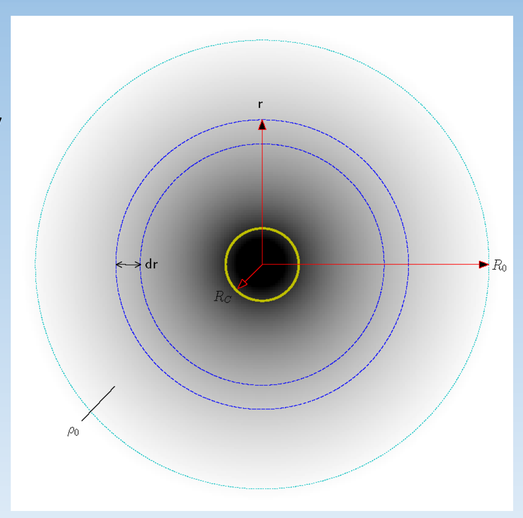
$$\rho(w) = \rho_0\left(\frac{R_0}{r(w)}\right)^3$$

$$\Phi_{shell}(R,r) = -\frac{4\pi G}{R}r^2\int_{w_1}^{w_2}\rho(r',\mathrm{w}')\mathrm{d}w'dr'$$

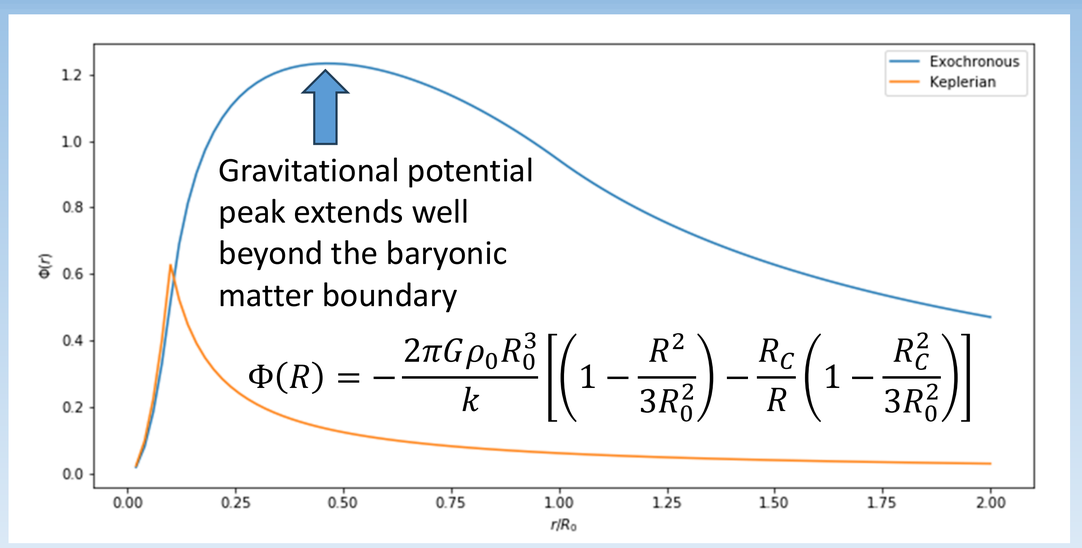
$$\Phi_{shell}(R,r) = -\frac{4\pi G\rho_0 R_0^3}{kR}\int_r^{R_0}\frac{1}{r'^3}\mathrm{d}r'$$

$$\Phi_{shell}(R,r) = -\frac{2\pi G\rho_0 R_0^3}{kR}\left(\frac{1}{r^2} - \frac{1}{R_0^2}\right)$$

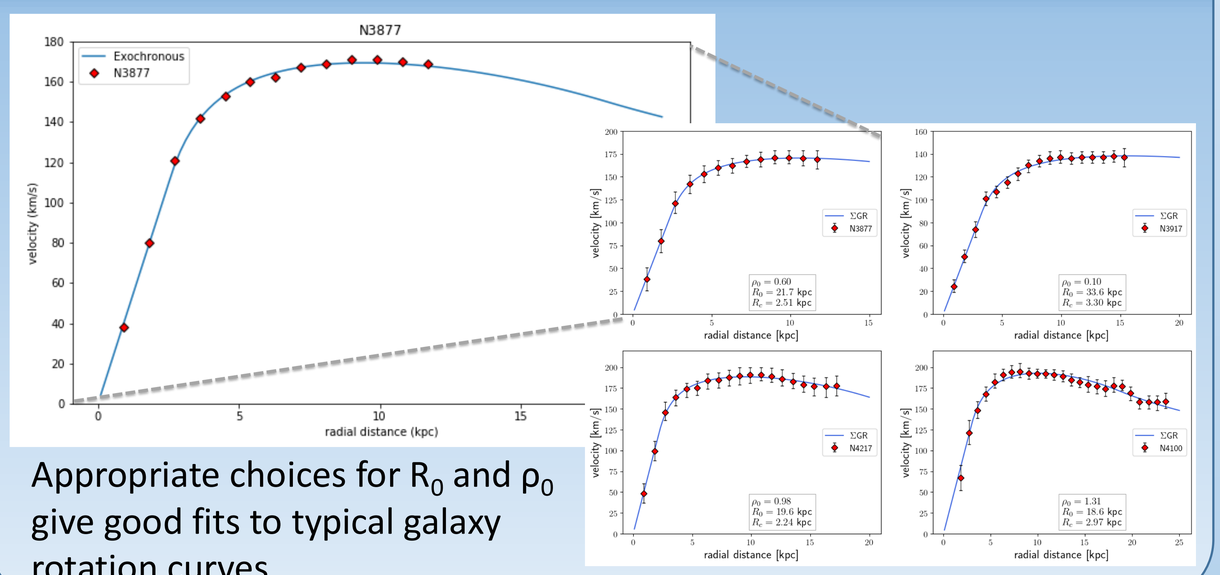
$$\Phi_{tot}(R) = -\frac{2\pi G\rho_0 R_0^3}{kR}\int_{R_C}^{R}1 - \frac{r^2}{R_0^2}dr$$



6. The Exochronous Potential

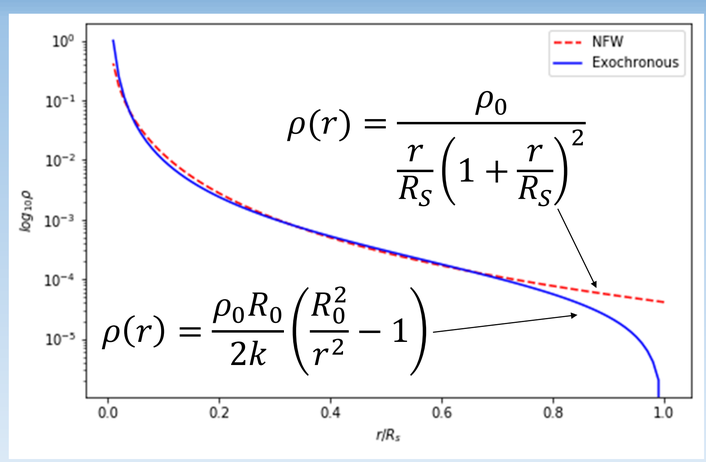


7. Galaxy Rotation Curves



Appropriate choices for R_0 and ρ_0 give good fits to typical galaxy rotation curves

8. The Navarro-Frenk-White Density Profile

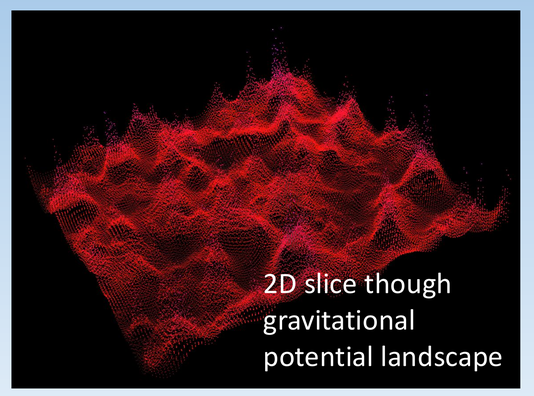


The analytically derived exochronous density profile is similar in form to the empirically derived and commonly employed NFW profile, but features a cut-off at r = R_0

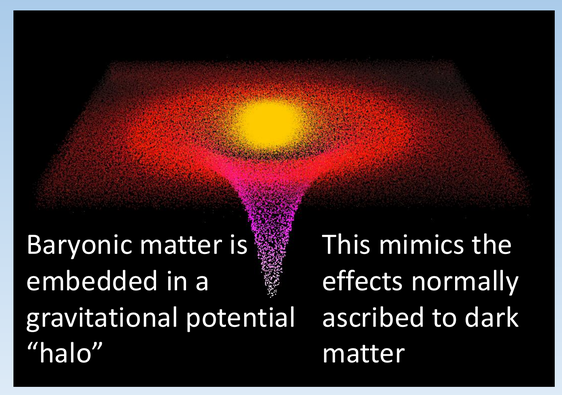
9. N-body Simulations

Use cumulative version of Poisson solver:

$$\Phi_n = \Phi_{n-1} + 4\pi G\rho_n + \omega\left(\overline{\Phi} - \Phi\right)$$



2D slice though gravitational potential landscape



Baryonic matter is embedded in a gravitational potential "halo"

This mimics the effects normally ascribed to dark matter

10. Conclusions

The exochronous (timeless) metric:

- results in a gravitational potential that accounts for the observed shape of galaxy rotation curves, without the need for dark matter
- provides an analytic derivation for the NFW density profile
- when applied to N-body simulations, replicates the effects currently ascribed to Dark Matter

References

1. R.A.J.Booth, *arXiv preprint 2201.13120* (2022)

2. R.A.J.Booth, Galaxies 12(3):21 (2024)