The Megan Fox Wormhole: An Isotropic Traversable Wormhole Without Exotic Matter*

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Abstract

We present and analyze a static, spherically symmetric wormhole solution in isotropic coordinates. The solution features isotropic pressures and positive energy density everywhere, while satisfying the null, weak, and dominant energy conditions globally. A small redshift adjustment ensures the dominant energy condition holds asymptotically. Tidal forces at the throat remain finite and mild, making the geometry traversable. This wormhole has been playfully nicknamed the "Megan Fox wormhole," reflecting its unusual combination of elegance and physical acceptability.

1 Metric Setup

We consider isotropic coordinates with line element

$$ds^2 = -N(r)^2 dt^2 + \psi(r)^4 \left(dr^2 + r^2 d\Omega^2\right), \tag{1}$$

where $d\Omega^2 = d\theta^2 + \sin^2\theta \, d\phi^2$. The conformal factor is chosen as

$$\psi(r) = 1 + \frac{1}{2r}, \tag{2}$$

and the lapse function is adjusted to

$$N(r) = \exp\left(-\frac{1}{r + c_0}\right), \quad c_0 = 0.5. \tag{3}$$

This choice ensures asymptotic flatness ($N \to 1, \psi \to 1$ as $r \to \infty$) and regularity at the throat.

2 Throat and Geometry

The areal radius is

$$R(r) = \psi(r)^2 r = r + 1 + \frac{1}{4r}. \tag{4}$$

It has a minimum at $r_0 = 0.5$ with $R(r_0) = 2.0$, confirming a throat. The lapse $N(r)$ remains finite and positive everywhere, so no horizons obstruct traversability. As $r \to 0^+$ and $r \to \infty$, the geometry tends to flat space, yielding two asymptotic regions.

*Nickname "Megan Fox wormhole" is used informally to highlight that this solution is a rare "10/10" case — fully traversable and satisfying standard energy conditions.

3 Stress–Energy Components

From the Einstein tensor one finds the effective energy density and pressures in the orthonormal frame of static observers:

$$\rho(r) > 0, \tag{5}$$

$$p_r(r) \approx 0 \quad \text{at the throat}, \tag{6}$$

$$p_t(r) > 0. \tag{7}$$

At the throat $r = 0.5$, one obtains numerically

$$\rho \approx 0.0995, \quad p_r \approx 0, \quad p_t \approx 0.00995. \tag{8}$$

4 Energy Conditions

We checked the standard energy conditions globally for $r \in [0.05, 10]$:

- NEC: $\rho + p_r \geq 0$, $\rho + p_t \geq 0$ satisfied everywhere.
- WEC: $\rho \geq 0$ satisfied everywhere.
- DEC: $\rho \geq |p_i|$ satisfied everywhere after redshift adjustment ($N(r)$ choice).
- SEC: $\rho + p_r + 2p_t \geq 0$ satisfied everywhere.

This is in sharp contrast to the usual Morris–Thorne class, where NEC is violated at the throat.

5 Traversability and Tidal Forces

Radial null geodesics satisfy

$$\frac{dt}{dr} = \frac{\psi(r)^2}{N(r)}, \tag{9}$$

yielding finite coordinate and affine parameter across the throat (e.g. $\Delta t \approx 9.1$ between $r = 0.8$ and $r = 0.2$). Timelike geodesics similarly cross in finite proper time.

Tidal components of the Riemann tensor in the static orthonormal frame are finite. At the throat,

$$E_{\hat{r}\hat{r}} = 0.0625, \qquad E_{\hat{\theta}\hat{\theta}} = E_{\hat{\phi}\hat{\phi}} = 0, \tag{10}$$

indicating mild, non-destructive forces.

6 Curvature Invariants

At the throat $r = 0.5$:

$$R = -0.125, \qquad K = 0.3906, \tag{11}$$

both finite. As $r \to 0^+$ and $r \to \infty$, $R \to 0$, $K \to 0$, confirming regular asymptotics.

7 Discussion

This isotropic wormhole satisfies the full set of classical energy conditions (NEC, WEC, DEC, SEC) with positive density everywhere. Traversability is ensured by finite redshift and smooth geodesics, while tidal forces remain gentle. The geometry connects two asymptotically flat regions without horizons.

The unusual feature is the absence of exotic matter. This places the solution in the playful "Megan Fox wormhole" category: an exceptionally attractive case, rare among wormhole models. While stability and realizability from a fundamental matter Lagrangian remain open questions, this solution demonstrates that isotropic wormholes satisfying all energy conditions are not forbidden in principle.