Prediction HI-Void-001: Radial Hydrogen Gradient in Cosmic Voids

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1. Statement

The interiors of large cosmic voids are predicted to exhibit a measurable radial gradient in the density of diffuse neutral hydrogen (HI). Specifically, the hydrogen density increases from the void center toward a maximum located near 0.6 times the void radius (R_void), with the possibility of flattening or declining beyond that point.

2. Functional Form

Let $\rho_H(r)$ denote the diffuse neutral hydrogen density at radial distance $r \in [0, R_{void}]$ from the void center. Then:

$$\rho_H(r) \propto \exp(-m_H^2 / \gamma(r))$$

where:

- • m_H is the mass of the hydrogen atom
- • $\gamma(r)$ is a geometric or field-related scalar function that increases with radial distance up to a maximum near $r \approx 0.58\ R_{void}$, and may plateau or decline beyond.

An approximate analytic form for $\gamma(r)$ in the rising phase is:

$$\gamma(r) = \gamma_{min} + (\gamma_{max} - \gamma_{min}) \cdot (r / (0.58\ R_{void}))^2 \text{ for } r \leq 0.58\ R_{void}$$

with:

- • $\gamma_{min} \approx 0.56$ at $r = 0$
- • $\gamma_{max} \approx 0.944$ at $r = 0.58 \cdot R_{void}$

For $r > 0.58\ R_{void}$, $\gamma(r)$ may plateau or decrease, leading to a corresponding flattening or decline in $\rho_H(r)$.

3. Interpretation

The proposed profile is intended as a testable hypothesis regarding large-scale hydrogen structure. It is not derived from a specific cosmological model but reflects a possible correlation between large-scale curvature gradients and hydrogen distribution. The scalar function $\gamma(r)$ is introduced to encode any field, geometric, or environmental parameter that may regulate hydrogen density across voids. The functional form offers a falsifiable shape hypothesis: rising hydrogen density from the void center to a shell at $r \approx 0.6\ R_{void}$, with potential leveling or decline beyond. The behavior of $\gamma(r)$ outside this region is left empirically unconstrained.

4. Observational Prediction

Upcoming or future 21 cm intensity mapping surveys should detect this hydrogen gradient within void interiors. Stacked void profiles at redshifts $z < 0.2$ are expected to show a statistically significant increase in HI brightness temperature $T_b(r)$ from the center to $\sim 0.6\ R_{void}$, potentially followed by a plateau or decline.

5. Falsifiability Criteria

This prediction will be falsified if either of the following is observed:

1. 1. The radial hydrogen profile in voids is flat or decreasing from center to $\sim 0.6\ R_{void}$
2. 2. No statistically significant HI brightness gradient is detected in a sufficiently large, high-resolution void stack (e.g., using SKA, CHIME, MeerKAT, or equivalent).

6. Novelty Statement

To the best of our knowledge, no prior cosmological model has predicted this specific radial hydrogen density structure inside voids, independent of galaxy distribution. This prediction is testable, falsifiable, and formally timestamped via cryptographic hash.

7. Theoretical Addendum

While the prediction is framed independently of any particular theory, its mathematical structure is not arbitrary. The exponential suppression form $\rho_H(r) \propto \exp(-m_H^2 / \gamma(r))$ reflects a generic functional class found in physical systems where energy thresholds or coherence gradients regulate density. The shape of $\gamma(r)$, including its minimum and maximum values, corresponds to a hypothesized curvature profile motivated by dimensional analysis and previous theoretical work on field-gradient scaling in low-density environments.

This addendum serves to signal that the functional form is not curve-fitted to data but is instead intended to encode deeper physical principles that may emerge from a unified theoretical framework, to be articulated separately.

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