Olbers's Inverse: The all-lit problem

Speculative thoughts of Auden S. Howard

Abstract

This paper explores the astrophysical hypothesis of a hypothetical planet where every line of sight from its surface ends on a star, thus creating a sky without darkness. Through a rigorous physical and mathematical framework, this study evaluates the potential for such a phenomenon, addressing both transient and permanent stellar densities, as well as the feasibility of near-complete sky coverage. The analysis concludes with implications of the findings and proposes further questions for study.

Introduction and Hypothesis

Hypothesis: A planet may exist in the universe where, due to an exceptionally high-density stellar environment, every line of sight from its surface intersects a star, leaving no trace of observable darkness.

This concept challenges our understanding of stellar distribution and cosmic scale, compelling a deeper consideration of astrophysical limits and probabilities associated with such an extreme environment.

Physical and Mathematical Analysis

To test this hypothesis, the study examines distributions of stars, calculates sky coverage across dense cosmic environments, and assesses whether transient or permanent factors could indeed yield a zero-darkness sky.

1. Stellar Distribution and Density

Average Stellar Density in the Universe

- **Total Stars:** Estimates suggest the observable universe contains between 10^{22} and 10^{24} stars[1].

- **Volume of the Observable Universe:** Approximately $V_{universe} = \frac{4}{3}\pi R^3$, with $R \approx 4.4 \times 10^{26}$ metres[2].
- **Average Stellar Density (n_{avg}):**
  - $n_{avg} = \frac{TotalStars}{V_{universe}} \approx \frac{10^{24}}{\frac{4}{3}\pi(4.4\times10^{26}m)^3} \approx 1.2 \times 10^{-58}$ stars/m^3

Densest Known Stellar Regions

- **Globular Clusters:**
  - **Characteristics:** Spherical collections containing up to 10^6 stars within a radius of about 50 light-years (5×10^{17} metres)[3].
  - **Stellar Density ($n_{cluster}$):**
    - $n_{cluster} = \frac{10^6}{\frac{4}{3}\pi(5\times10^{17}m)^3} \approx 9.5 \times 10^{-47}$ stars/m^3
- **Galactic Centres:**
  - **Characteristics:** Regions near supermassive black holes with increased stellar density[4].
  - **Stellar Density (n_{centre}):**
    - $n_{centre} \approx 3.4 \times 10^{-44}$ stars/m^3

2. Sky Coverage Calculations

Angular Size of a Star

- **Formula[5]:**
  - For small angles $(R_* \ll D)$:
    - $\theta \approx 2arctan(\frac{R_*}{D}) \approx \frac{2R_*}{D}$, where R_* is the star's radius and D is the distance.

Fraction of Sky Covered by a Single Star

- **Solid Angle (Ω) Subtended by a Star:**
  - $\Omega = 2\pi(1 - cos\theta) \approx (\frac{2R_*}{D})^2 = \frac{4\pi R_*^2}{D^2}$

Total Sky Coverage Fraction (f)

- **Formula:**

- $f = N \times (\frac{\Omega}{4\pi}) = N \times (\frac{4\pi R_*^2}{D^2 \times 4\pi}) = \frac{NR_*^2}{D^2}$, where N is the number of stars at average distance D

Example Calculation

- **Assumptions:**
  - **Number of Stars (N):** 10^6
  - **Average Distance (D):** 5×10^{17} **metres**
  - **Average Stellar Radius (R_*):** 7×10^8 **metres**
- **Calculation:**
  - $f = \frac{NR_*^2}{D^2} = \frac{(10^6)(7\times10^8 m)^2}{(5\times10^{17} m)^2} \approx \frac{(10^6)(4.9\times10^{17} m^2)}{2.5\times10^{35} m^2} \approx 1.96 \times 10^{-12}$
- **Interpretations:** Only about 0.000000000196% of the sky is covered by stars in this dense environment.

3. Assessing Temporary Zero-Darkness Scenarios

Transient Astronomical Events

- **Supernovae:**
  - **Effect:** Dramatic increase in brightness but localized to a small region[6].
  - **Limitation:** Even simultaneous supernovae would not cover the entire sky.
- **Gamma-Ray Bursts (GRBs):**
  - **Effect:** Extremely bright but short-lived and directional[7].
  - **Limitation:** Insufficient to eliminate darkness across the sky.

Collective Luminosity Impact

- **Cumulative Light Contribution:**
  - **Effect:** In dense regions, the collective light from numerous stars can increase overall sky brightness.
  - **Limitation:** Does not significantly increase sky coverage due to the vastness of space between stars.

4. Exploring Near-Complete Sky Coverage

Hypothetical Extreme Environments

- **Ultra-Dense Stellar Clusters**[8]**:**
  - **Requirement:** Star densities orders of magnitudes higher than observed.
  - **Feasibility:** Such densities are unstable due to gravitational interactions leading to stellar collisions or ejections.

Perception of Brightness

- **Observer Eye Sensitivity:**
  - Increased sky brightness might reduce the perceived contrast between stars and darkness.
  - **Limitation:** Darkness would still exist; it would just be less apparent.

Conclusion

The findings suggest that the existence of a planet where every line of sight intersects a star is improbable within the boundaries of current astrophysical understanding. Even the densest known cosmic regions show only a minimal percentage of sky coverage due to the immense distances separating stars.

Temporary events and near-complete sky coverage yield slightly more plausible scenarios but remain insufficient. Transient events are too localized to eliminate global darkness. High coverage remains physically constrained by gravitational interactions limiting extreme densities.

Further Questions

1. Could unknown cosmic phenomena or alternate physics allow such stellar densities?

Venturing beyond the Standard Model may reveal mechanisms that increase star densities or alter light propagation.

2. What would be the implications for life on a planet within an exceptionally dense stellar environment?

Exploring how such brightness affects climates, biological rhythms, and potential life adaptations may yield further insight.

References

1. Conselice, C. J., Wilkinson, A., Duncan, K., & Mortlock, A. (2016) “The Evolution of Galaxy Number Density at $z < 8$ and its Implications.” *The Astrophysical Journal*, 830(2), 83.
2. Planck Collaboration. (2020). “Planck 2018 results. VI. Cosmological parameters.” *Astronomy & Astrophysics*, 641, A6.
3. Harris, W. E. (1996). “A Catalog of Parameters for Globular Clusters in the Milky Way.” *The Astronomical Journal*, 112, 1487.
4. Genzel, R., Eisenhauer F., & Gillessen, S. (2010). “The Galactic Center massive black hole and nuclear star cluster.” *Reviews of Modern Physics*, 82(4), 3121.
5. Karttunen, H., Kröger, P., Oja, H., Poutanen, M., & Donner, K. J. (2017). *Fundamental Astronomy*, 6th ed. Springer.
6. Filippenko, A. V. (1997). “Optical Spectra of Supernovae.” *Annual Review of Astronomy and Astrophysics*, 35(1), 309-355.
7. Piran, T. (2004). “The physics of gamma-ray bursts.” *Reviews of Modern Physics*, 76(4), 1143-1210.
8. Binney, J., & Tremaine, S. (2008). *Galactic Dynamics*, 2nd ed. Princeton University Press.