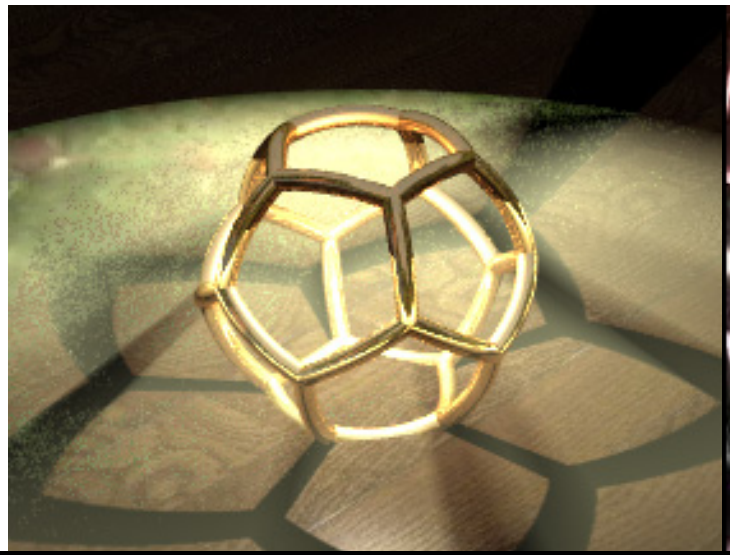
Geometry of our Universe: Historical and Recent Ideas

- Platonic solids: universe = finite dodecahedron
- Earth centered
- 19th century: elusive luminiferous ether
- Einstein theory of relativity: Riemann's curved space
- Recent: Wraparound universe like a dodecahedron? Dark matter?



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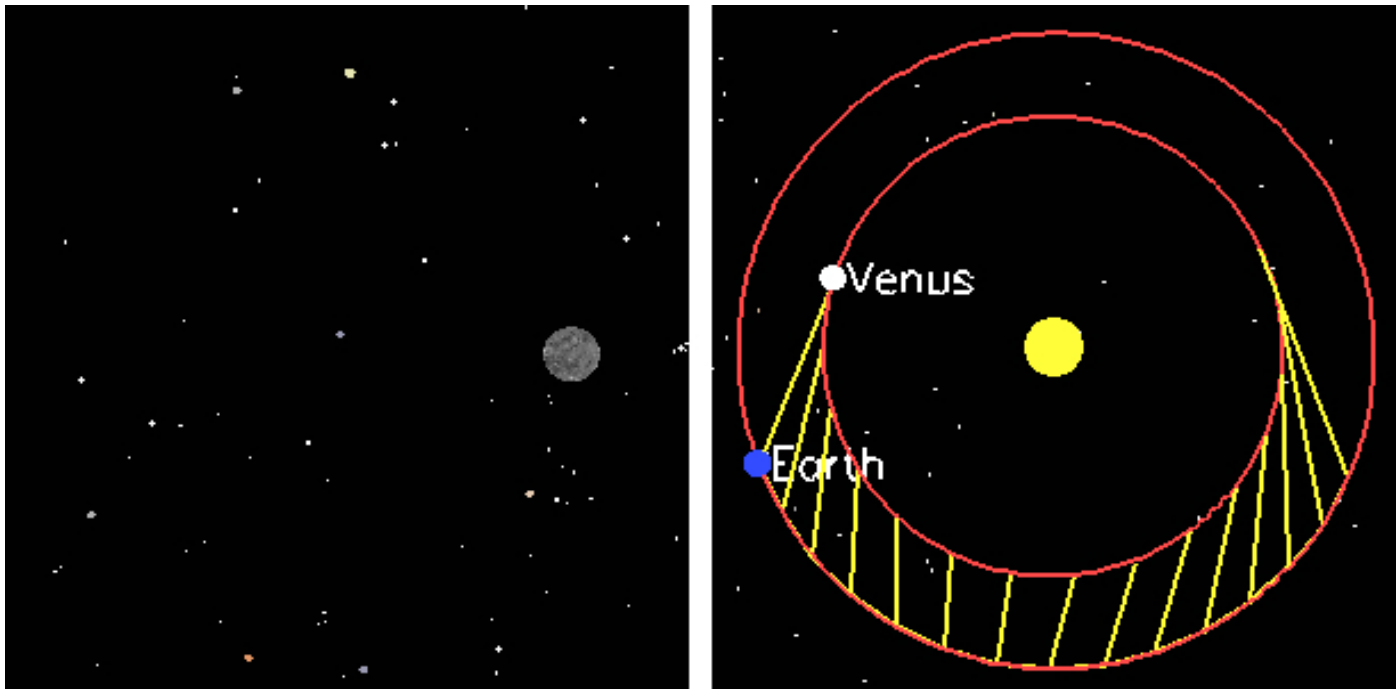
Scientific & Mathematical Breakthroughs

- They require imaginative leaps
- Understanding what we are seeing is complicated by filters

Nicolaus Copernicus (1473-1543): Heliocentric Model



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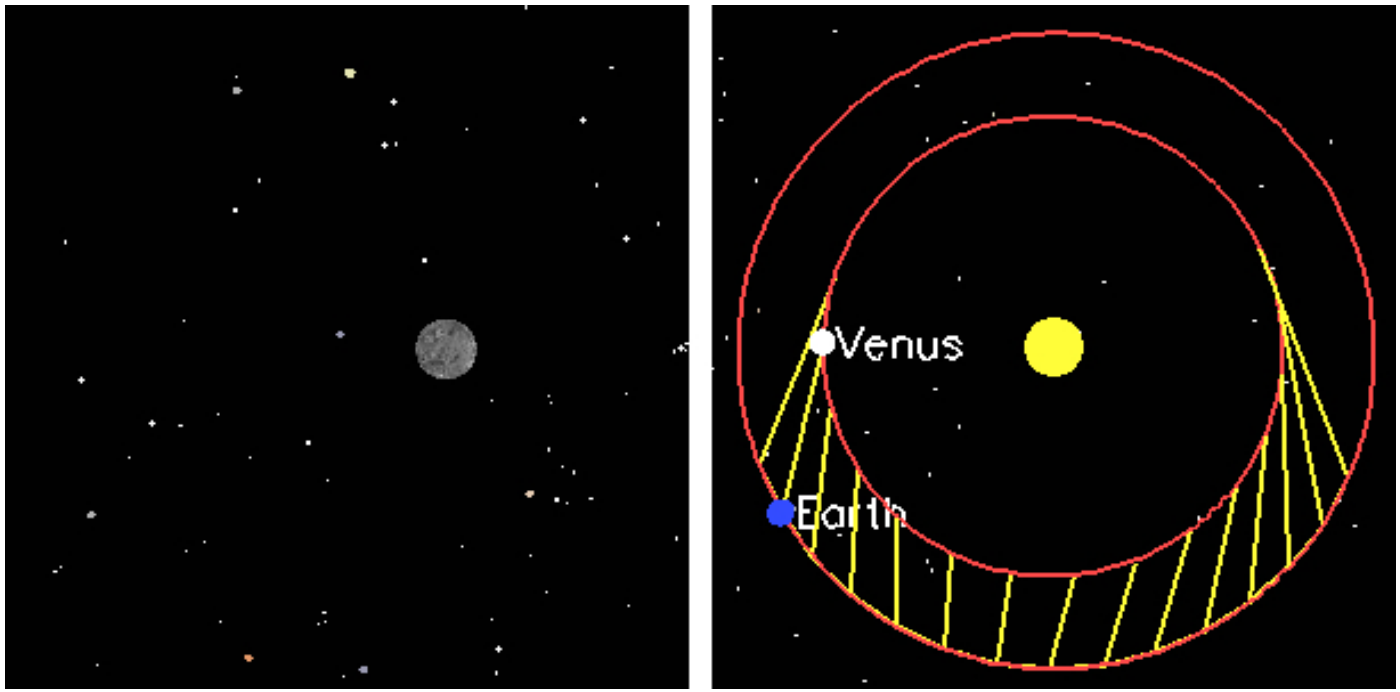

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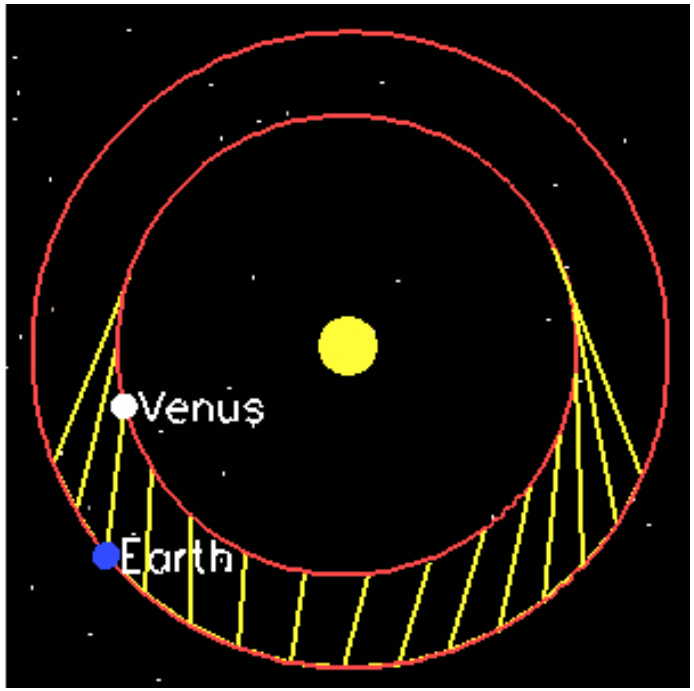

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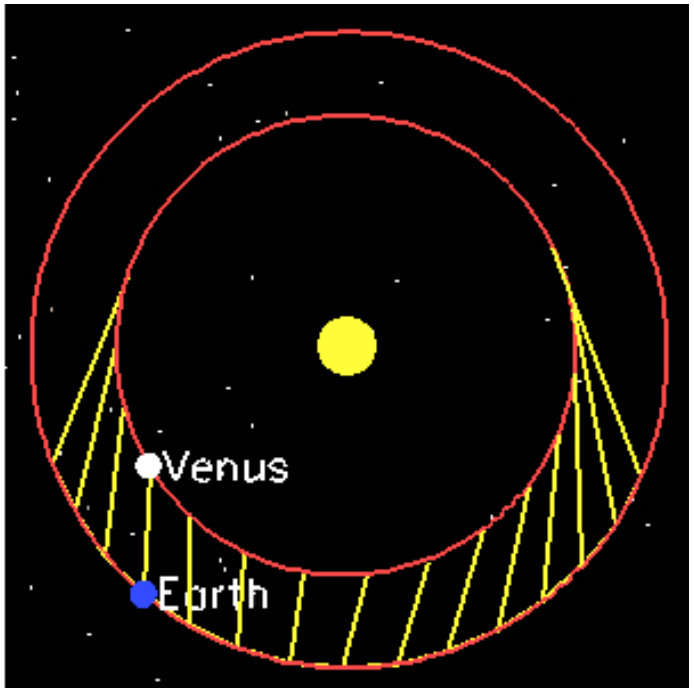

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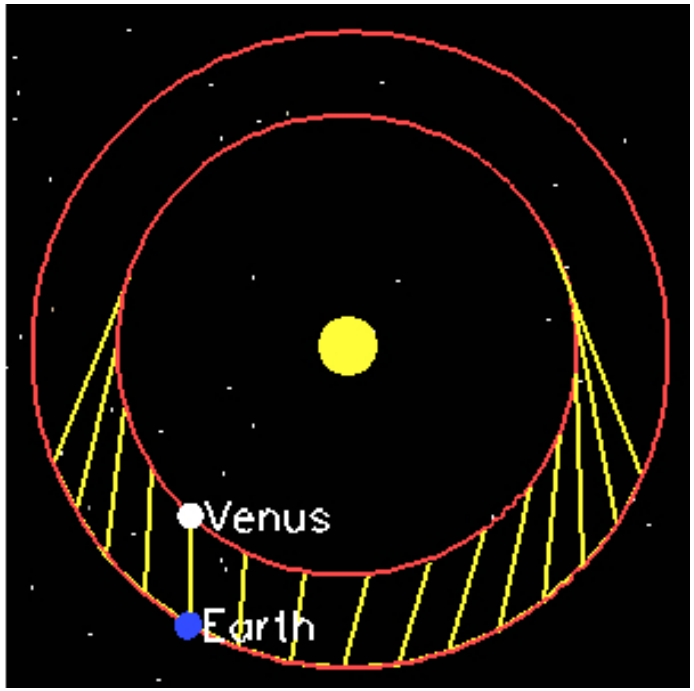

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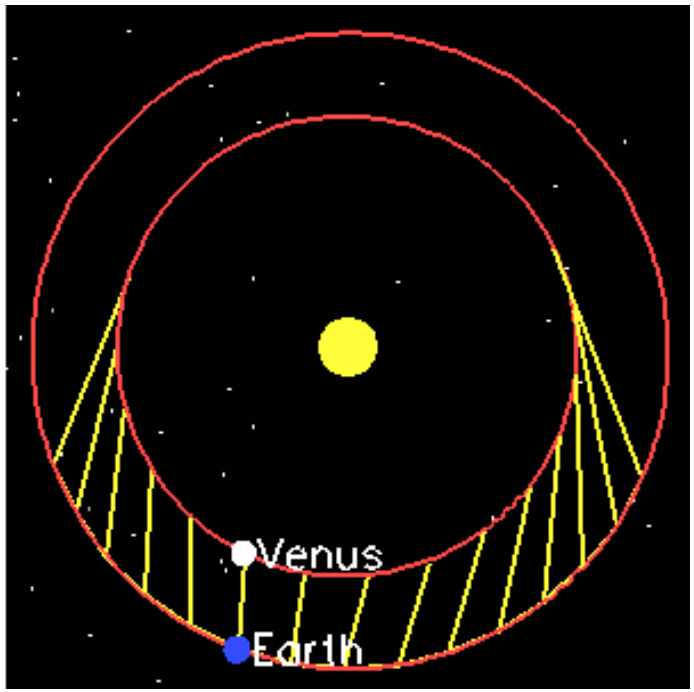

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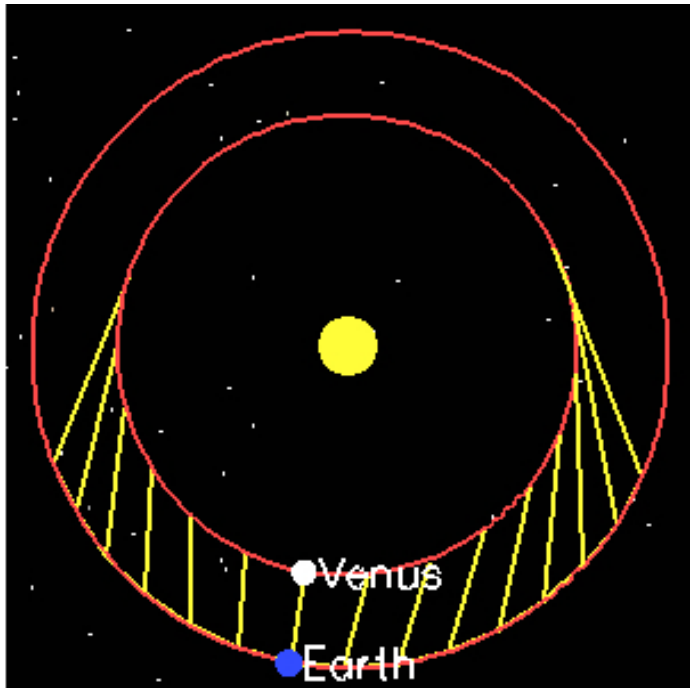

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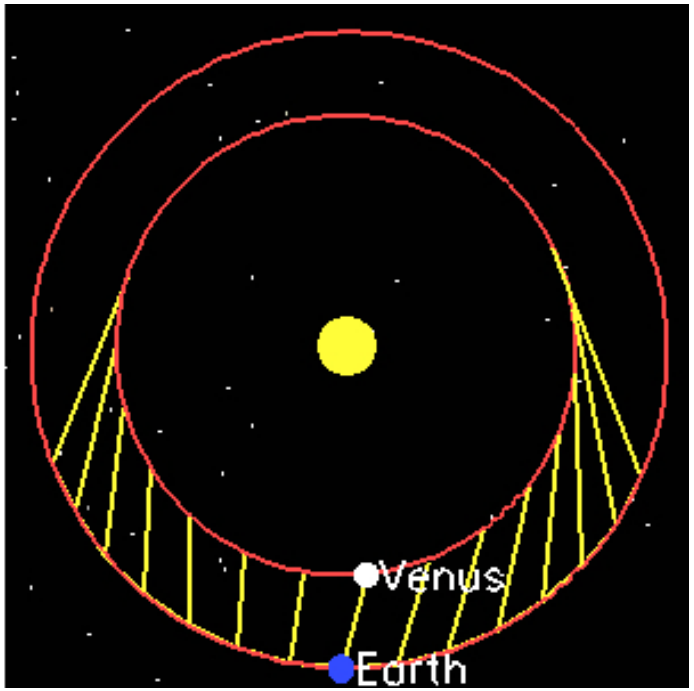

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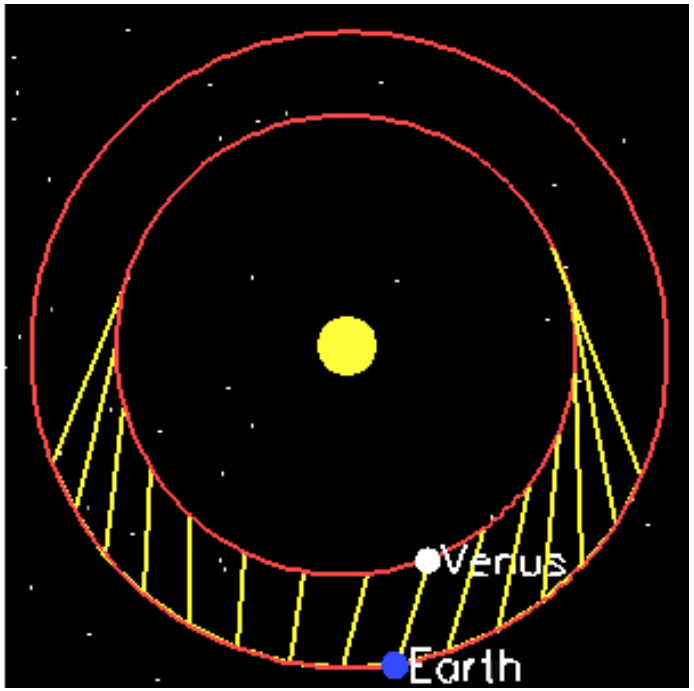

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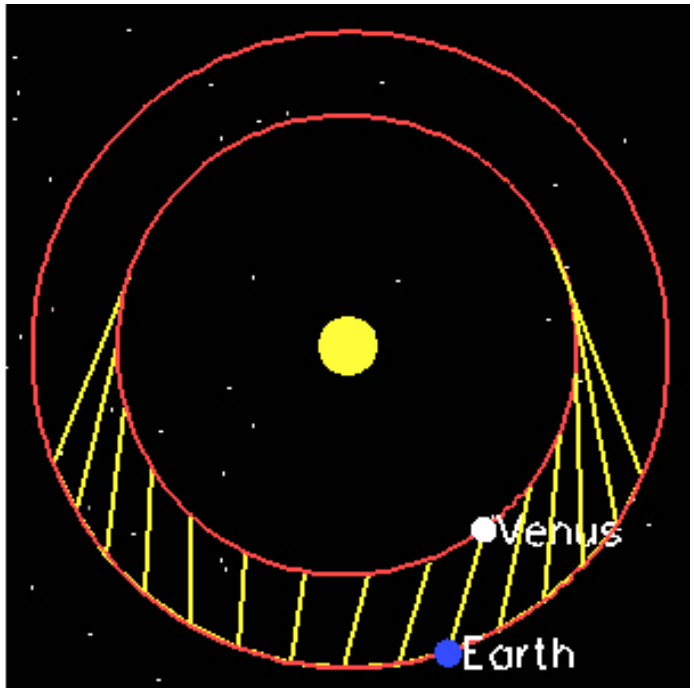

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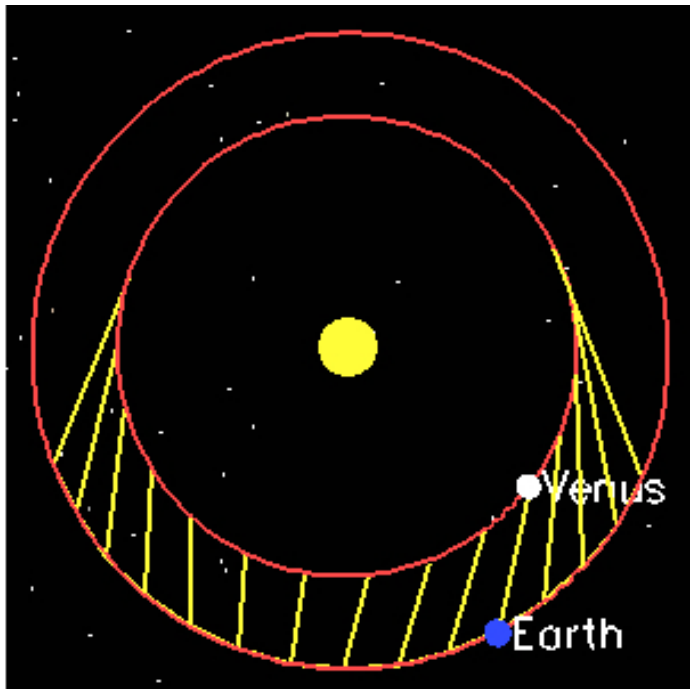

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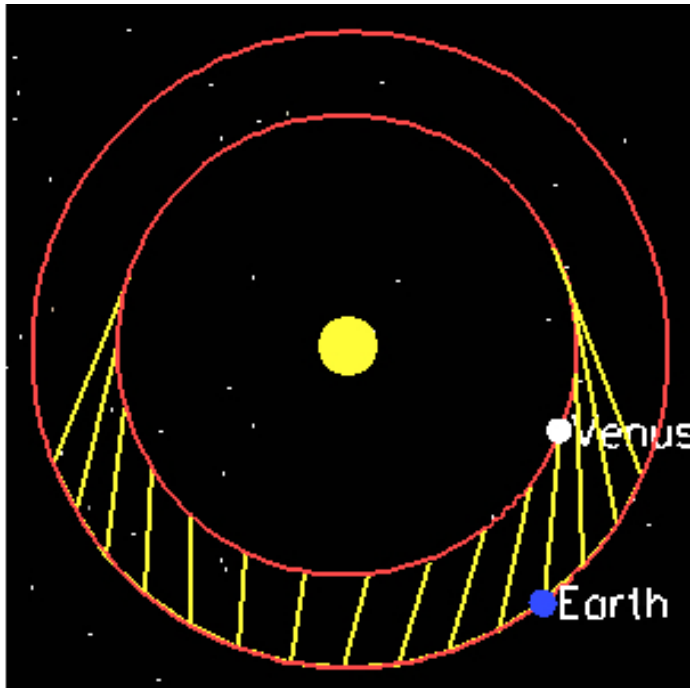

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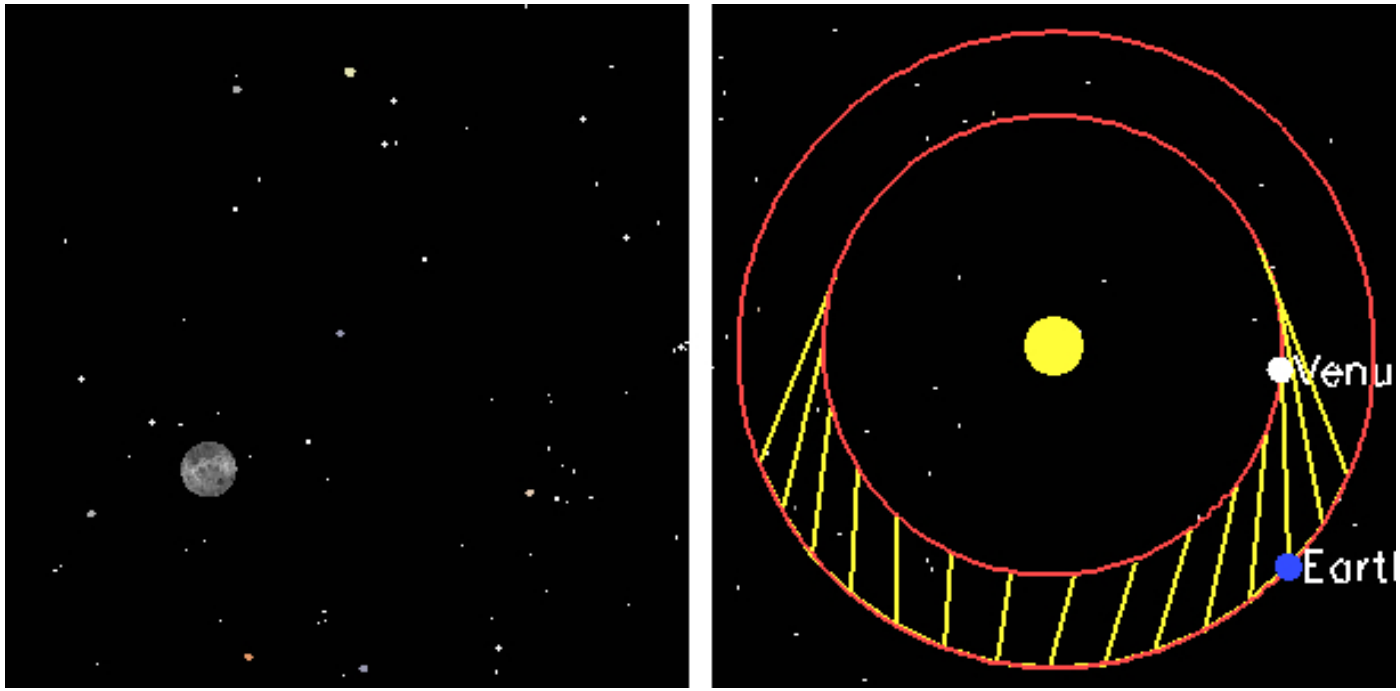

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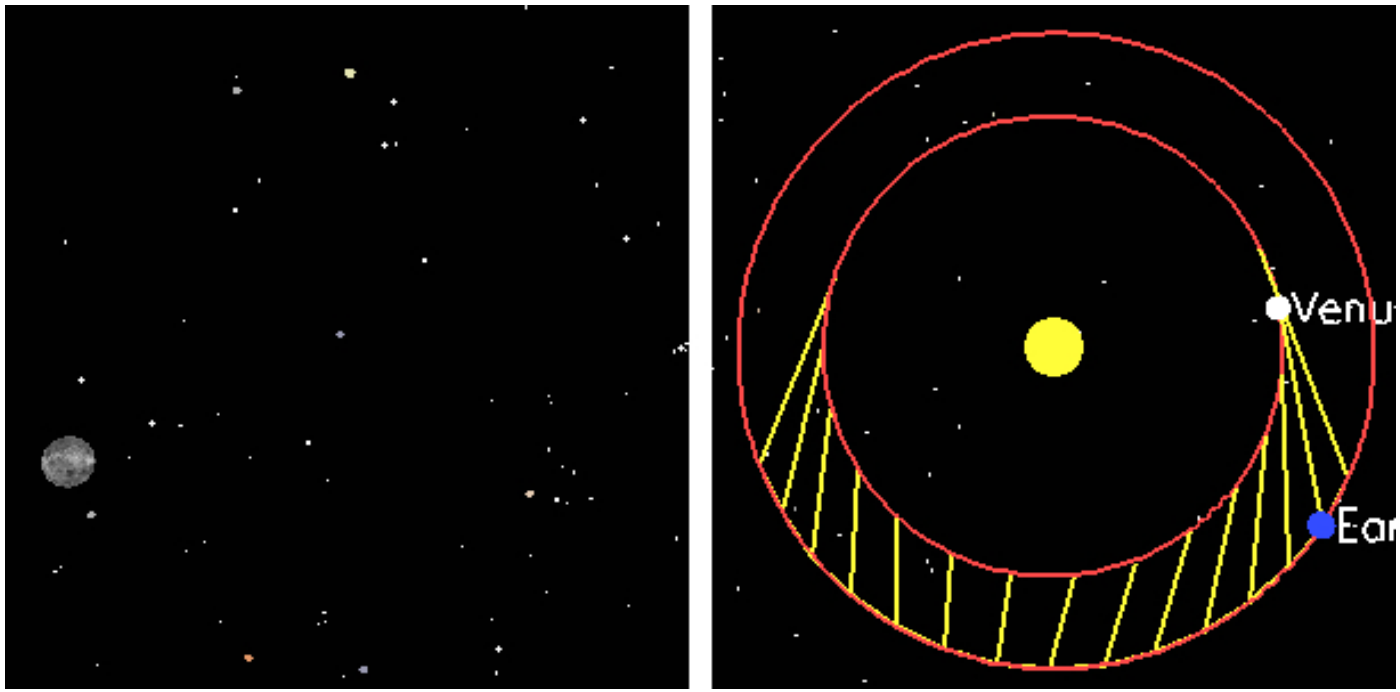

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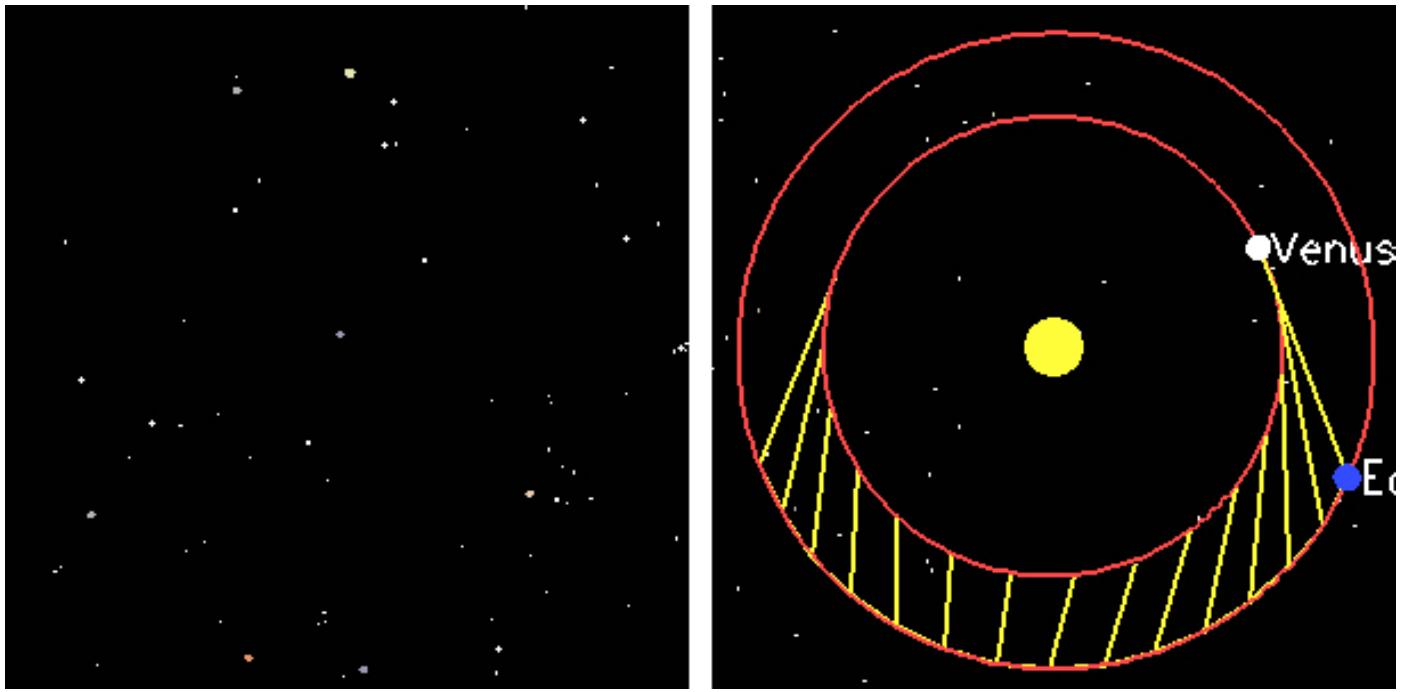

Is our Universe Finite Without Edges?

Euclidean (Pythagorean thm, 180° angle sum, 1 parallel)

- Klein bottle: 1882; Pac-Man 1980
- 3-torus with 96 stars
- An apartment in *Futurama: I, Roommate*
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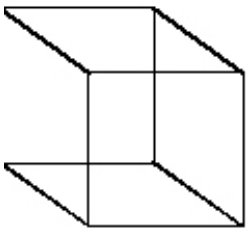
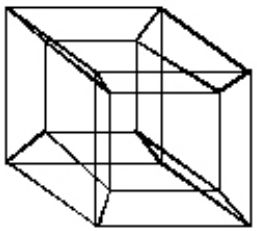
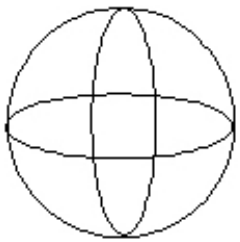
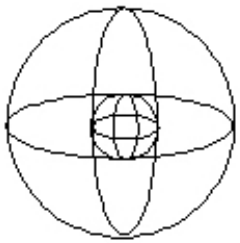
- Looking for repeated star patterns—Critiques: light takes times to reach us and changes the view, recognize?

Spherical ($a^2 + b^2 > c^2$, angle sum $> 180°$, no parallels)


CUBE


HYPERCUBE


SPHERE


HYPERSPHERE

Angle Sum: Euclidean, Spherical, Hyperbolic or Mix?

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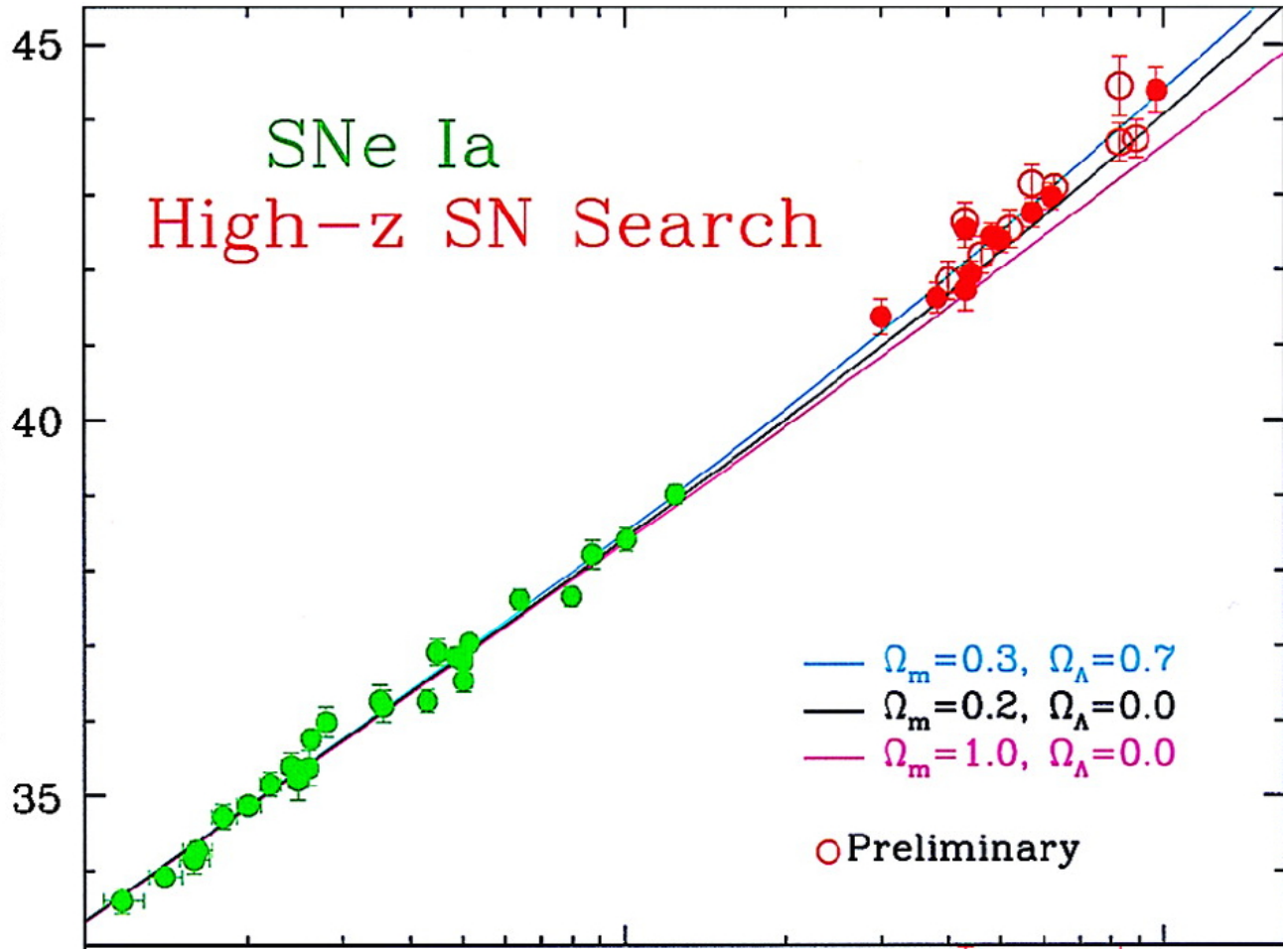
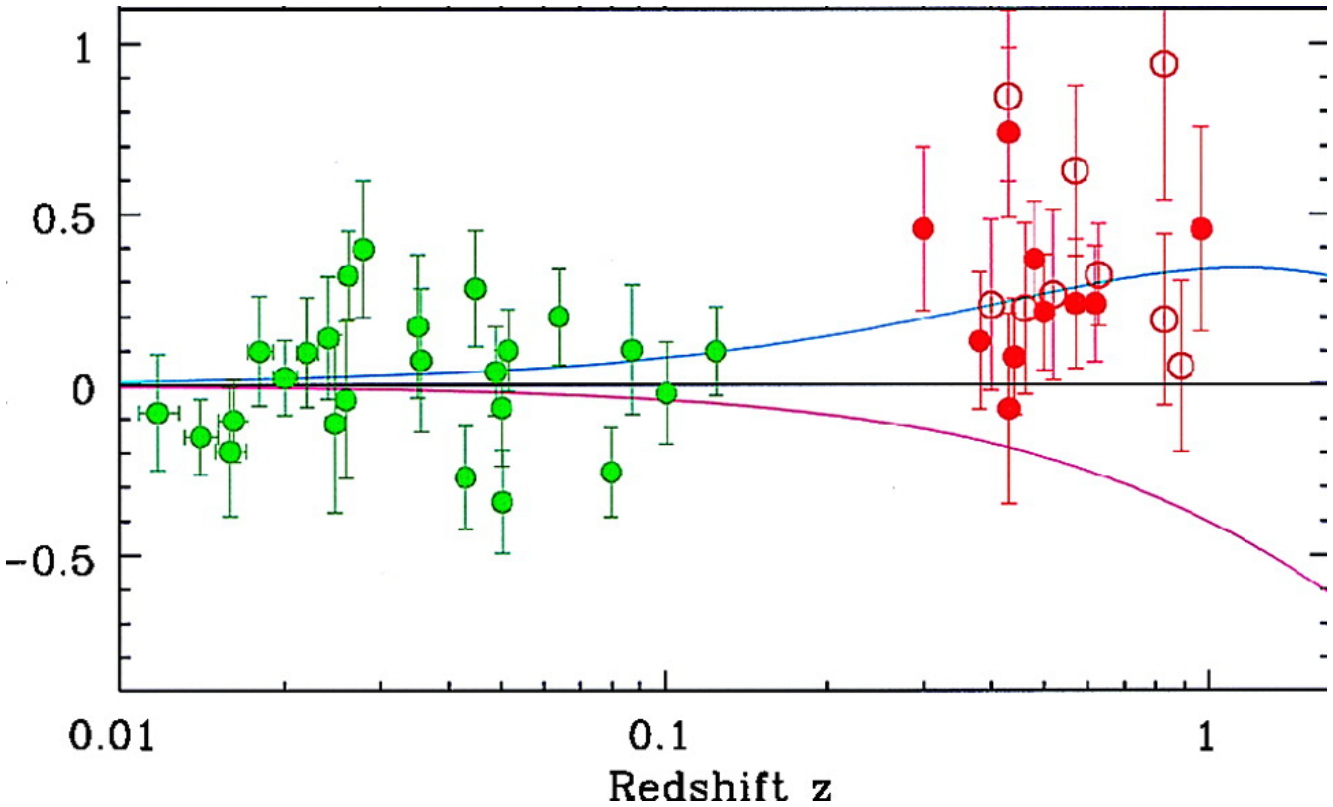
  Euclidean=180°, spherical$> 180^\circ$, hyperbolic$< 180^\circ$
- Critiques: Experimental error, light rays bend with gravity, triangles too small, convenience sample

Supernova Experiments



Euclidean inverse square law: brightness $\sim \frac{1}{\text{distance}^2}$



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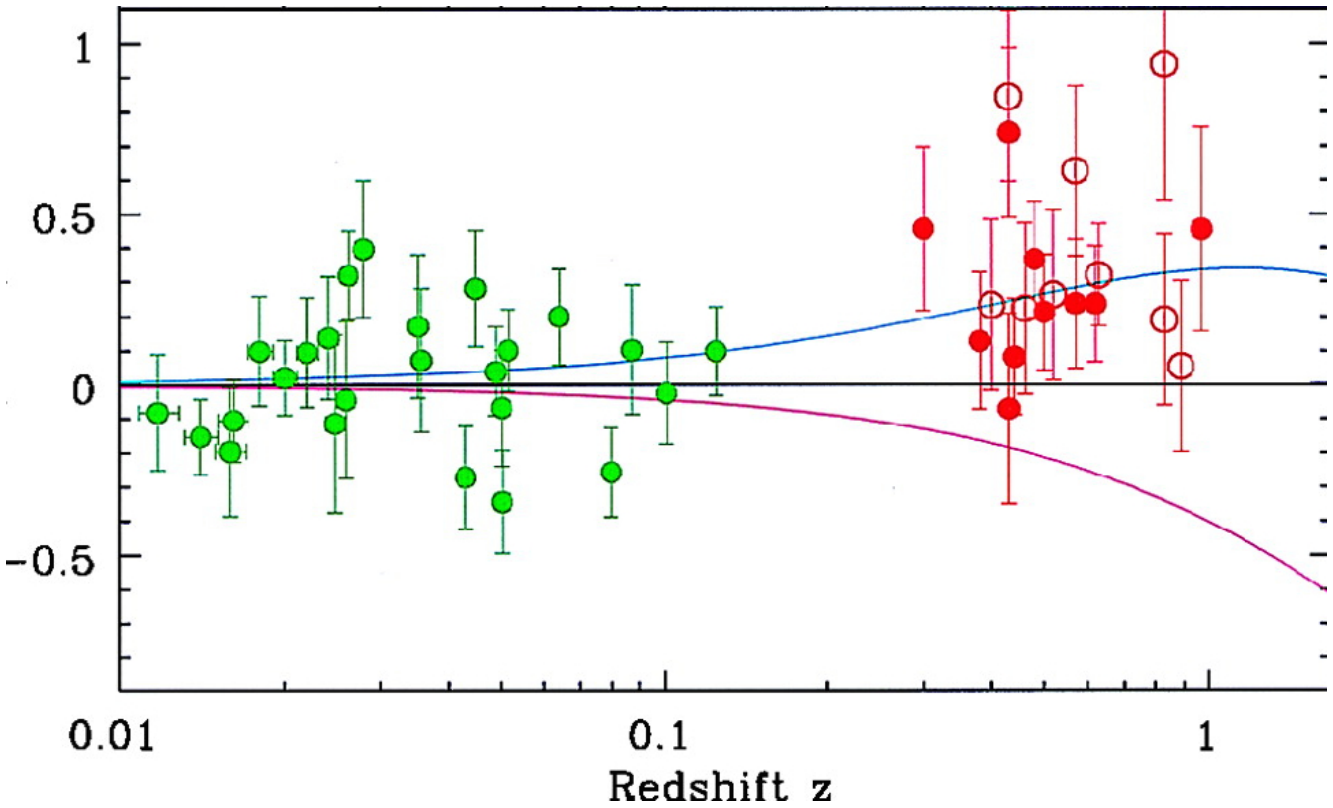

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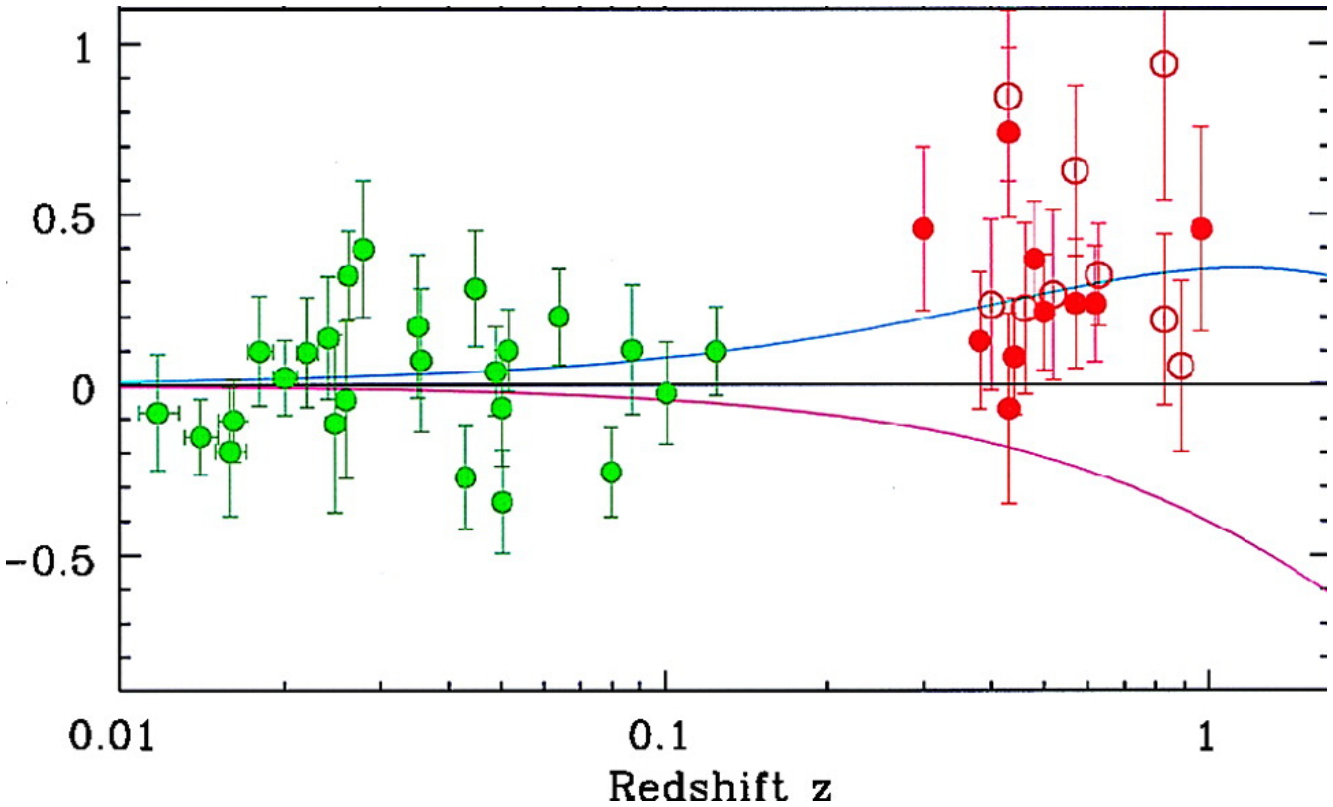

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Critiques: Experimental error, no perfect model, not necessarily exploding at the same brightness

Density Experiments: WMAP & Planck

- Cosmic Microwave Background: small temperature fluctuations due to primordial plasma density
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- Critiques: convenience samples, observable, experimental error, difficulty agreeing on the meaning of the data, neutrino mass, dark energy, speed of light?

“Shape of the Universe” Web Search

Further Readings

- Cowen, Ron (2013), “Universe may be curved, not flat: Anomalies in relic radiation could contradict the evidence for a level cosmos.” Nature. http://www.nature.com/news/universe-may-be-curved-not-flat-1.13776
- European Space Agency (2013), “Space Science: Planck.” http://www.esa.int/Our_Activities/Space_Science/Planck
- – (2005), “The Shape of the Universe.” Mathematics Awareness Month Theme Essay. http://www.mathaware.org/mam/05/shape.of.universe.html
- – (2013), “Classroom Activities on the Geometry of the Earth and Universe.” http://cs.appstate.edu/~sjg/talks/earthanduniverse.html
- Kragh, Helge (2012), “Is Space Flat? Nineteenth-Century Astronomy and Non-Euclidean Geometry.” Journal of Astronomical History and Heritage 15(3), pp. 149 - 158. http://www.narit.or.th/en/files/2012JAHHvol15/2012JAHH...15..149K.pdf
- NASA (2010), “Universe 101: Our Universe.” http://wmap.gsfc.nasa.gov/universe/universe.html
- Simanek, Donald E (2006), “The Flat Earth.” https://www.lhup.edu/~dsimanek/flat/flateart.htm
- Weeks, Jeffrey (2004), “The Poincare Dodecahedral Space and the Mystery of the Missing Fluctuations.” Notices of the AMS 51(6), pp. 610-619. http://www.ams.org/notices/200406/fea-weeks.pdf
- Weeks, Jeff (2012), “The Shape of Space.” Museum of Mathematics. https://www.youtube.com/watch?v=5u7hFQy9Mt0&feature=relate