

Warped Space-Time and Pants



Jim Pivarski
October 20, 2011

Limited goal for this talk

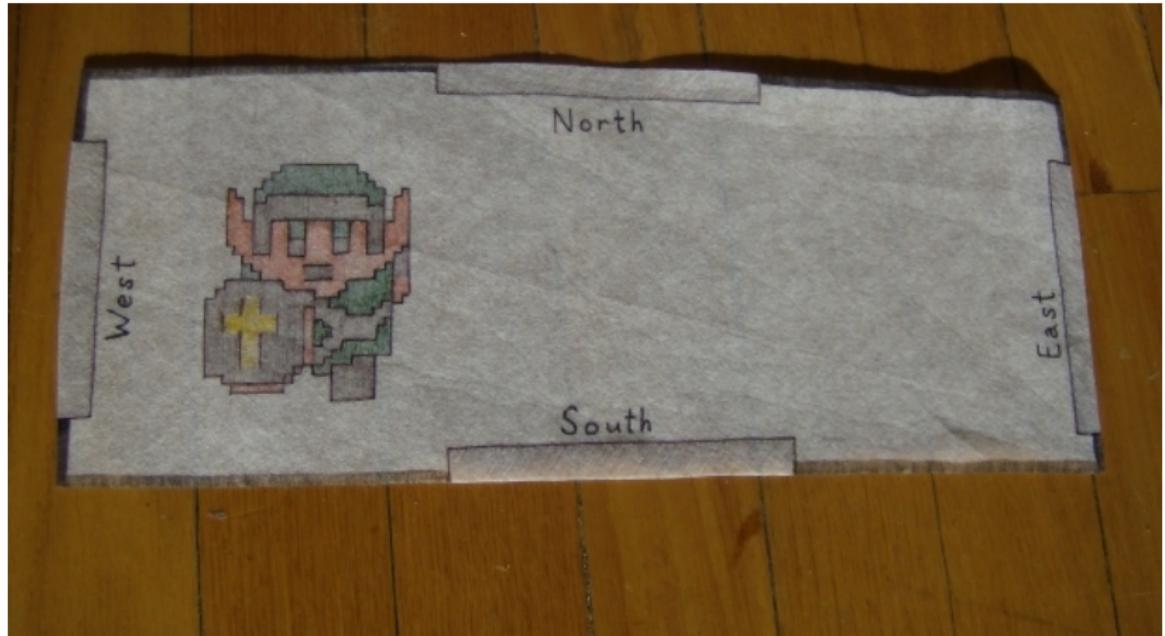
- ▶ To understand what it means for space-time to be “curved”

Limited goal for this talk

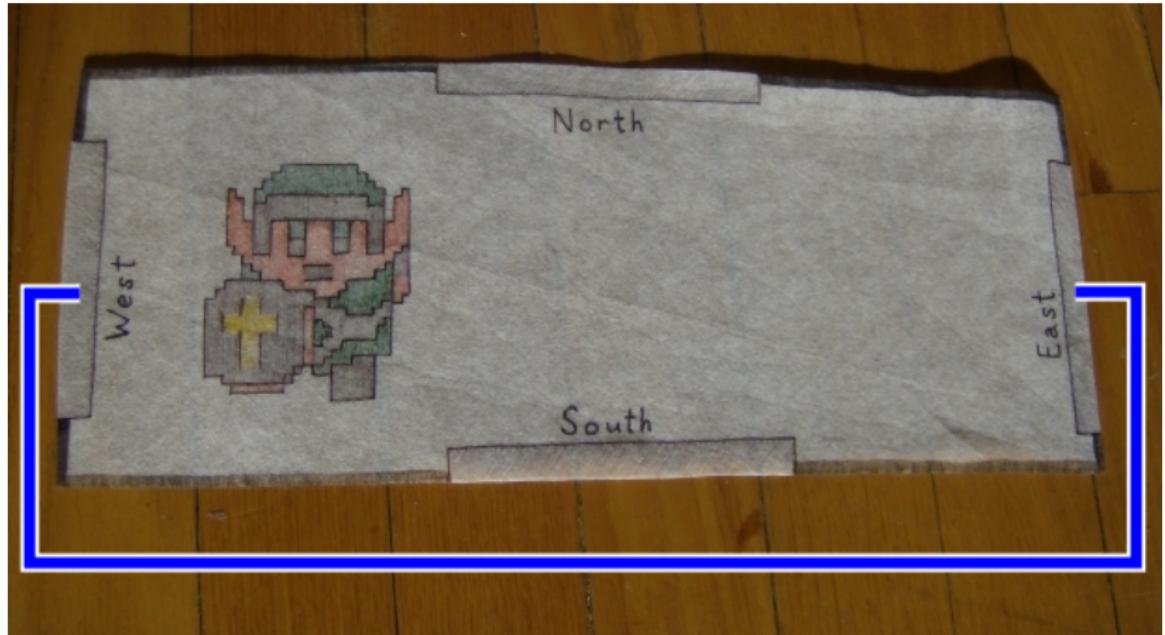
- ▶ To understand what it means for space-time to be “curved”
- ▶ If you already know all about this, enjoy the beer

Global Topology

Global topology



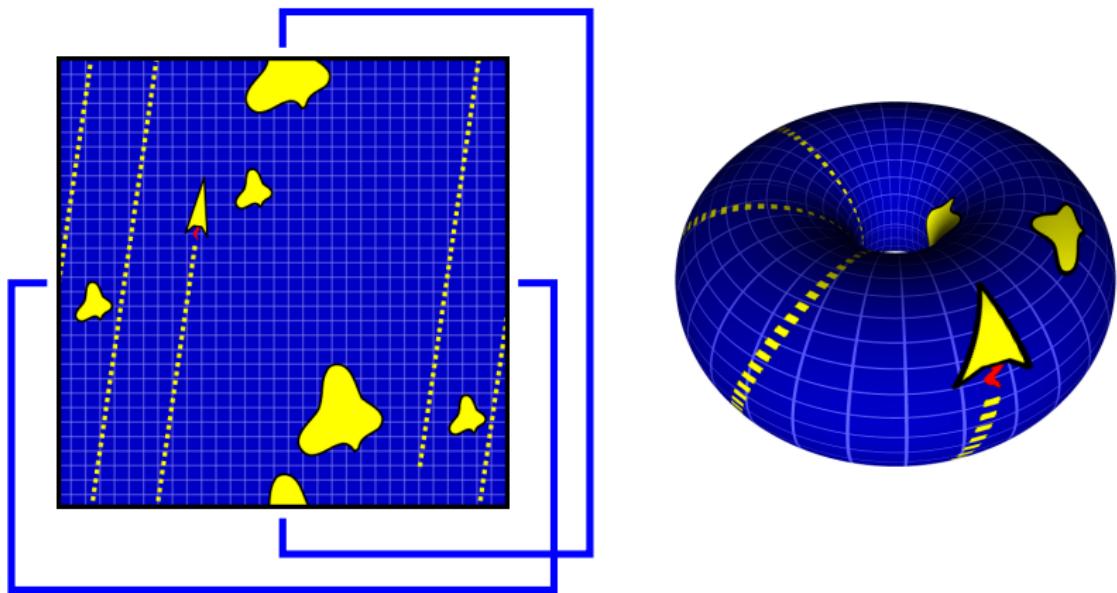
Global topology



Global topology

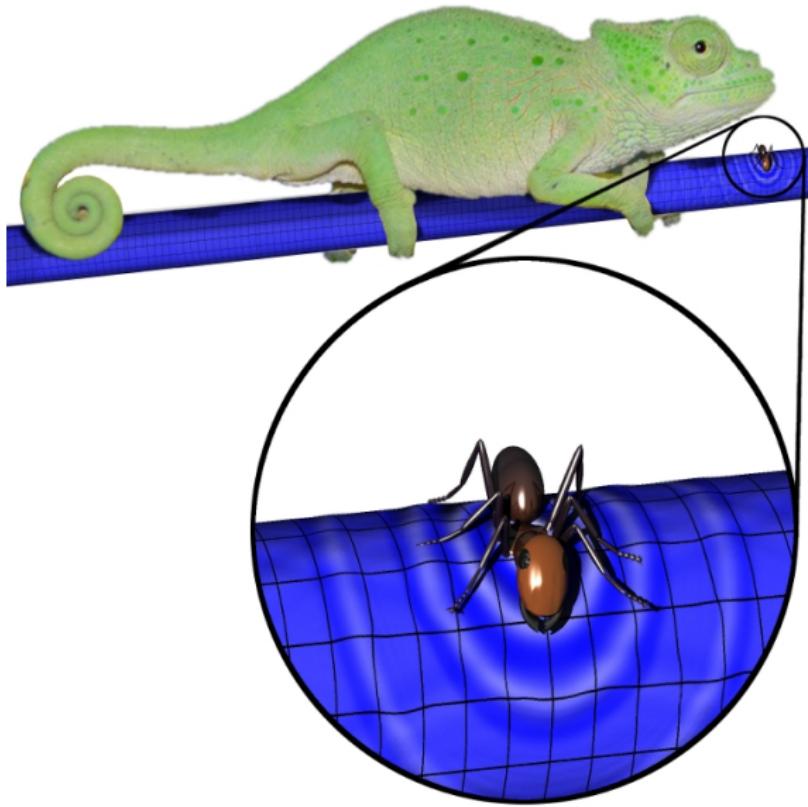


It may be visualized in a larger-dimensional space



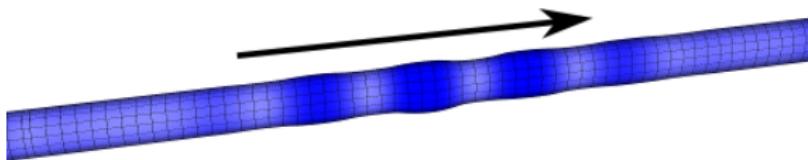
But it doesn't have to be: only the connections matter

Microscopic dimensions

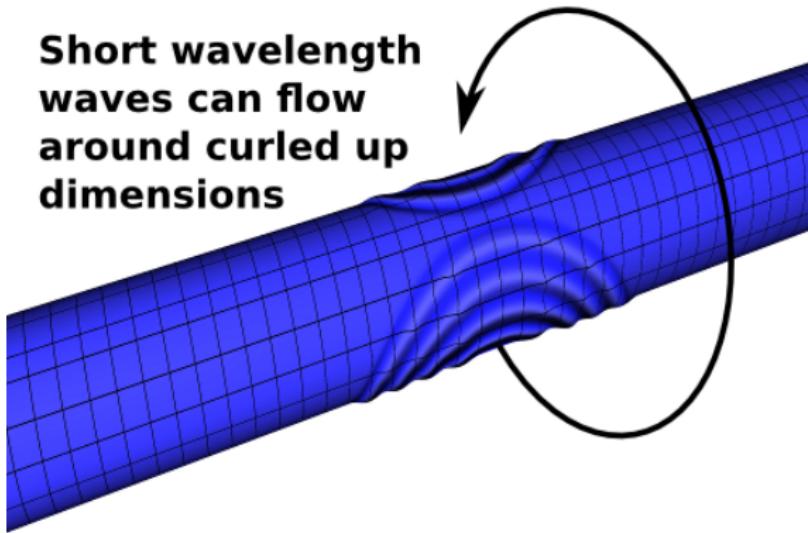


Microscopic dimensions (earlier version of the graphic)

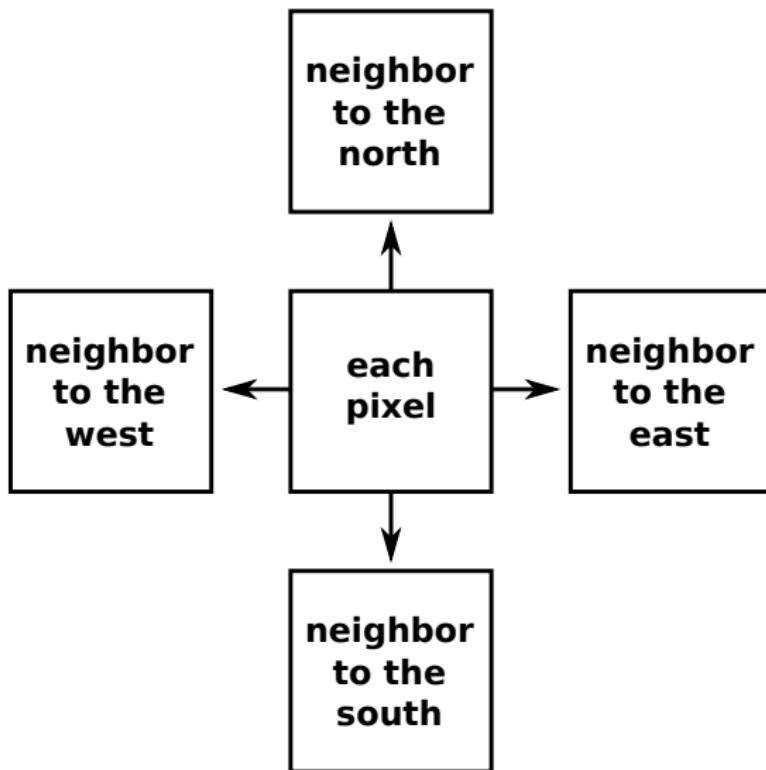
**Long wavelength waves only
flow along large dimensions**



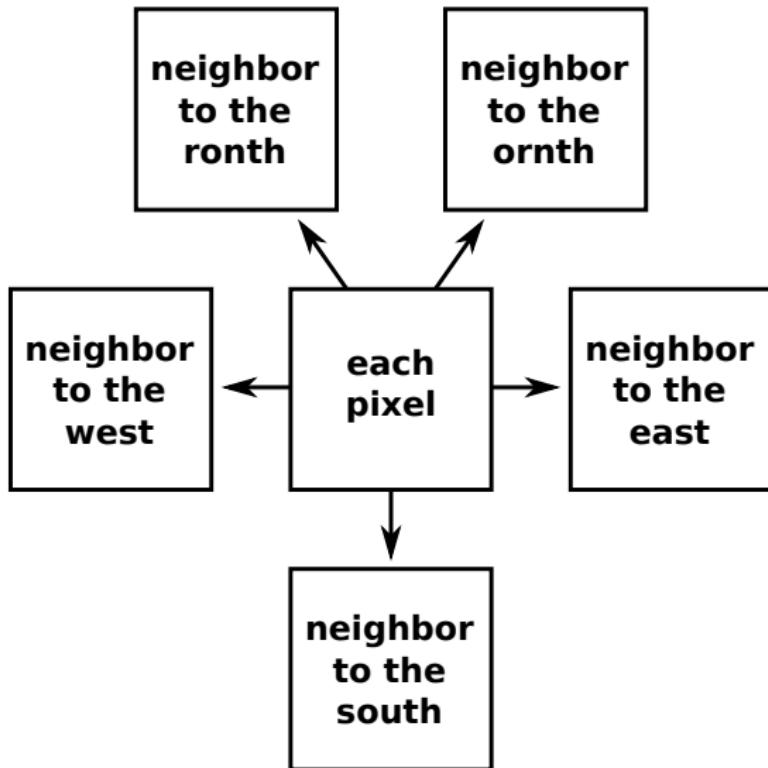
**Short wavelength
waves can flow
around curled up
dimensions**



Easier to think of connections in a discrete space



Suppose we instead change space in a local way

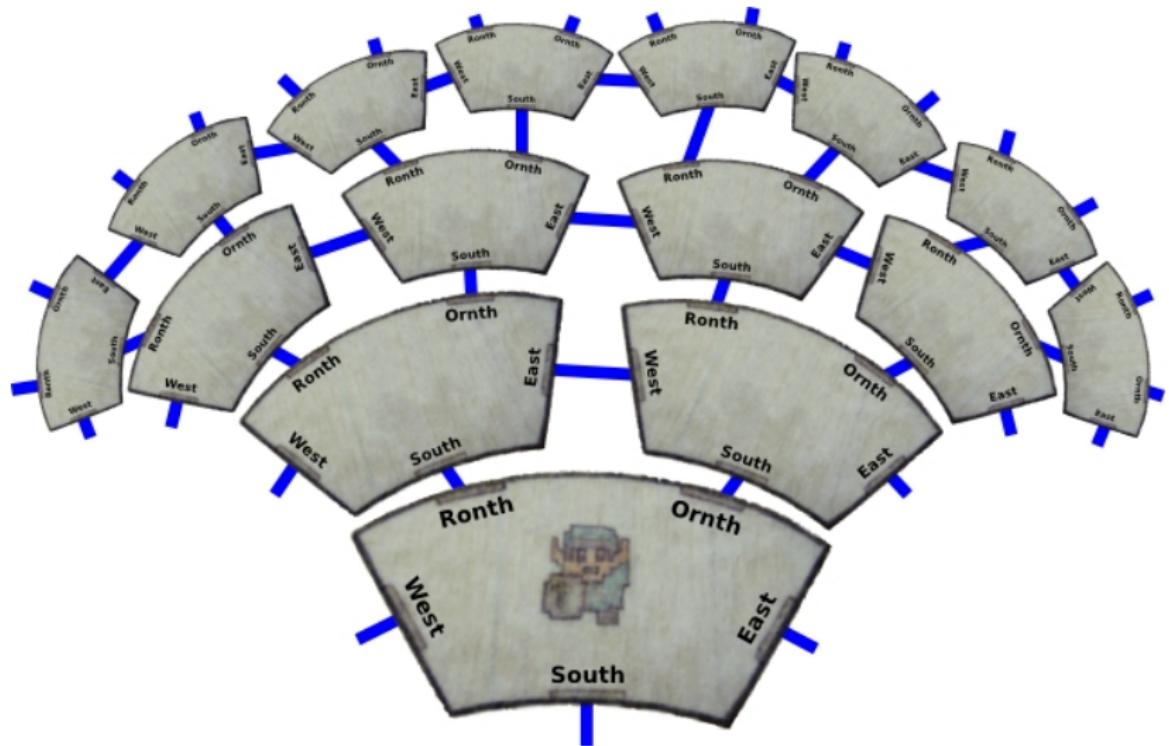


Space Curvature

Crochet model of a curved space by Daina Taimina



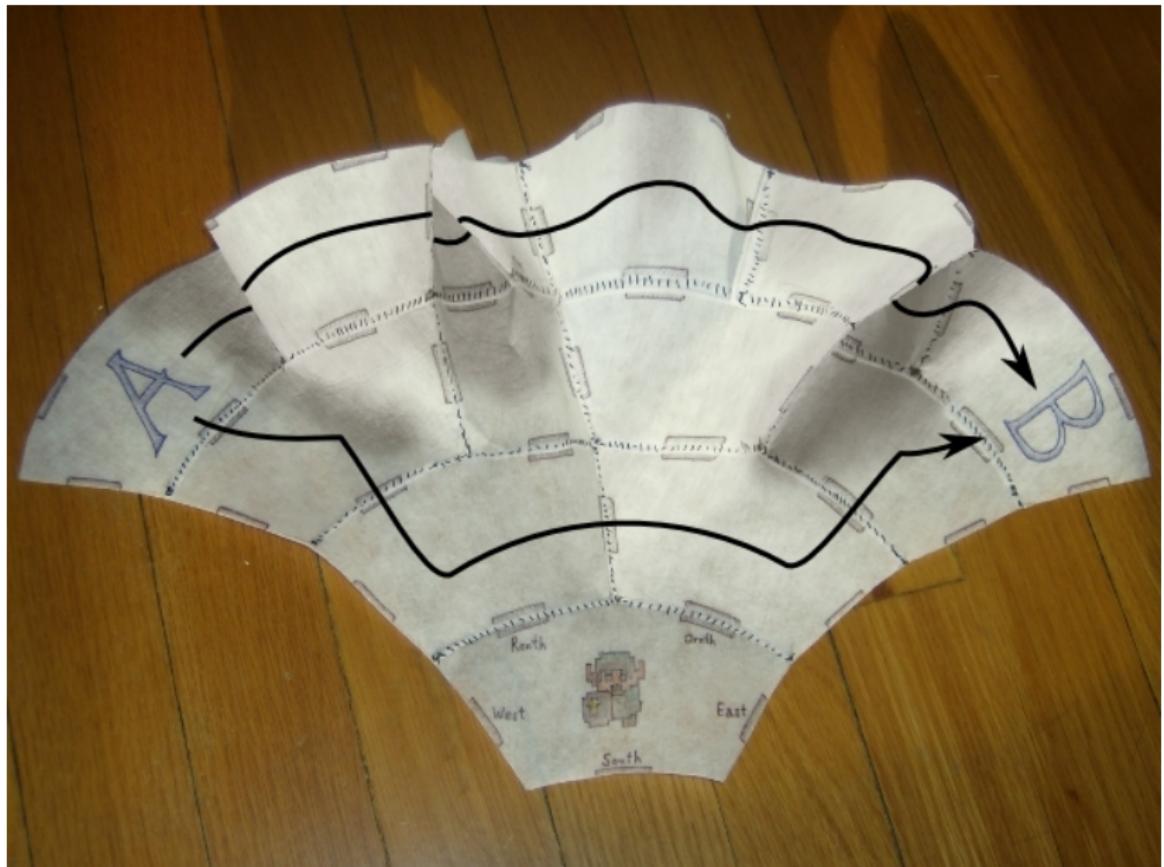
Map of a curved dungeon



Representing a curved space in 3-D



Shortest distance in curved space



Shortest distance in curved space



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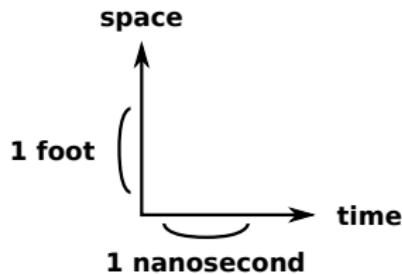
Space-Time Curvature

Time is a dimension like space

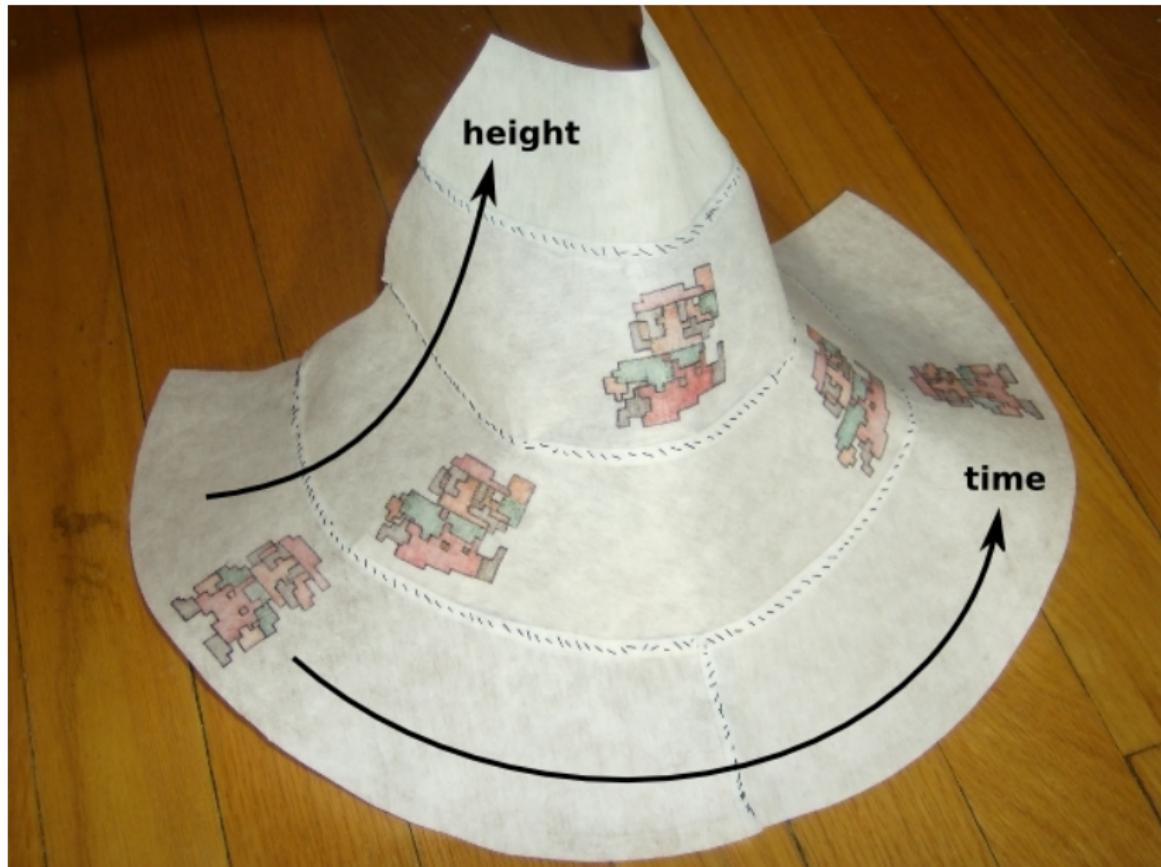
Time and space can be expressed in the same units

$$\begin{aligned}\text{conversion constant: } c &= 2.998 \times 10^8 \text{ meters/second} \\ &= 0.984 \text{ feet/nanosecond}\end{aligned}$$

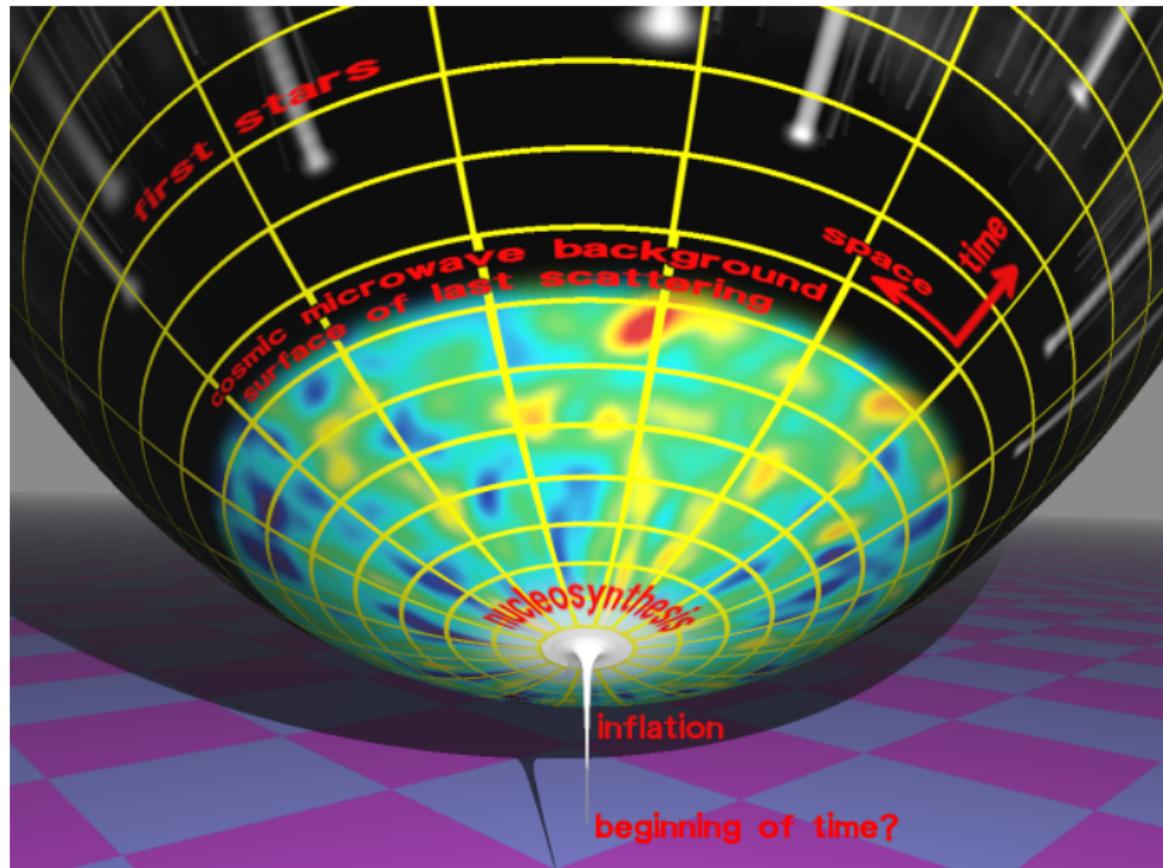
Light, electronics signals, etc. travel at speed = 1



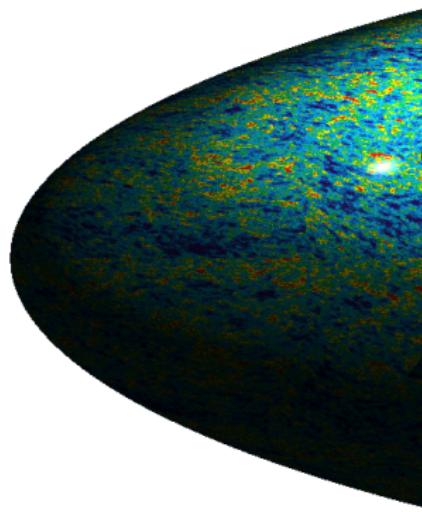
Space-time curvature



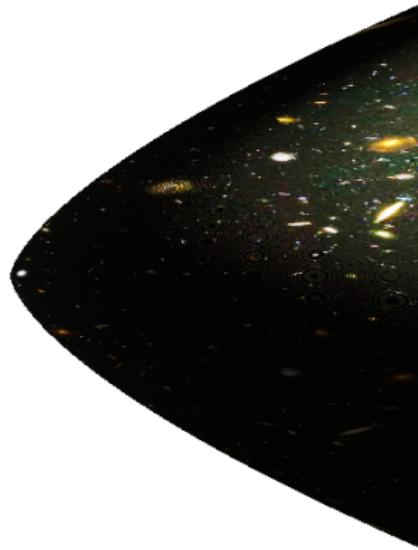
Space-time curvature on a cosmic scale



Space-time curvature on a cosmic scale



Radiation dominated early
universe: size \propto time $^{1/2}$



Matter dominated later
universe: size \propto time $^{2/3}$

Space-time curvature on a cosmic scale



Cosmological constant-dominated now: size $\propto e^{\text{time}}$
(and perhaps at the beginning, too, though that was called “inflation”)

Shameless Plug



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Standing on a Crunchy Star

14 Oct 2011

A voyage to the sun would not be a pleasant trip. While still a million miles away, the tungsten hull of our spacecraft would start to melt. At half a million miles, it evaporates. A little farther and we'd be nothing but swirling plasma, mixing into a nuclear furnace so vast that "oceans" would be an understatement.

Though we could never touch the sun, there are stars that you can touch—former stars, anyway—and one has recently been discovered [[link to paper](#)]. It is only four thousand light-years away (16.1 years traveler time; see "We Can Get There from Here"). This star has been transformed by its neighbor into a hunk of cold diamond. Since it's solid, some astrophysicists are calling it a planet, but it's not clear that the word applies to an object with such a bizarre history.

Suppose that we take the 16-year trip to visit this world: what would it look like? Could we really stand on the heart of a dead star?



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Letters to the Editor



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- [Dimensions of color](#) Jim Pivarski

We Can Get There From Here

23 Sep 2011

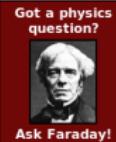
"Have you heard about this? Opera says neutrinos travel faster than light!"

I was in a conversation at Fermilab yesterday when I first heard about it. "Is that like one of those things where astrophysicists say that quasar jets travel faster than light, but only because they're leaving out some projection effect?" I said.

"No, this is for real. Except—I think so. I can't really tell; the article doesn't say very much."

I shrugged. I have no nose for news. It was only when my wife asked me about it that I knew it was a big story. She usually hears too much physics from me, so she doesn't actively seek it out. By that point, it was in all the newspapers, the experimenters made their paper public, and CERN's director general sent out a general e-mail.

If it's true that neutrinos travel faster than light, it would be a huge upset. Some may take it to mean that relativity is overturned, Einstein rolls in his grave, and there's no longer any limitation on the speed of future spaceships: we can get to distant stars in weeks, rather than decades. However, the implications run a lot deeper than that.



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