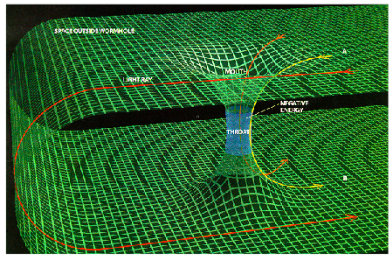

Parallel Worlds

in Science & Science Fiction

Geoffrey A. Landis

~~NASA Glenn Research Center~~

www.geoffreylandis.com

I'm not here in my "official" role as a NASA scientist; I was invited here to give a [erspective as a science fiction writer. So none of the things I say here should be considered "official" NASA positions.

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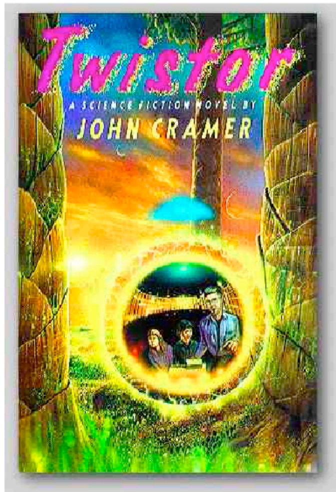
John Cramer:
Living in Parallel worlds

Prof. John G. Cramer, physicist

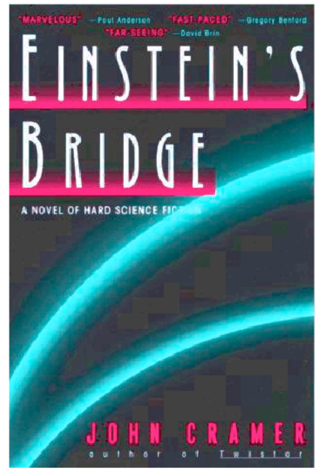
\- John Cramer, SF writer

Image shamelessly stolen from Kathryn Cramer's Flickr account! If you didn't want me to steal it, you shouldn't have put it up!

It occurred to me, when I titled this talk, that "parallel worlds" could be a metaphor for John Cramer's parallel lives in science and in science fiction, but actually, this slide is as far as I'm going to go with this metaphor



Twistor (1989)



Einstein's Bridge (1997)

I want to talk about some of the background in science and science fiction for John's two novels– both of which, in different ways, talk about the physics of parallel worlds.

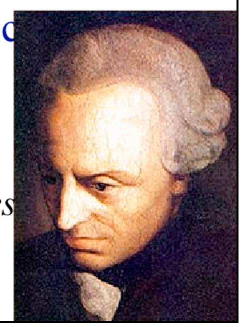
I want to talk not just about the science, or the science fiction, but to link the science and the SF, show how they are, in their own ways, parallel development of the same scientific concepts

"That **everywhere space has three dimensions and that space in general cannot have more dimensions** is based on the proposition that not more than three lines can intersect at right angles in one point. This proposition cannot at all be shown from concepts, but rests immediately on intuition and indeed on pure intuition *a priori* because it is apodictic (demonstrably) certain."

--Immanuel Kant,

Prolegomena to any Future Metaphysics

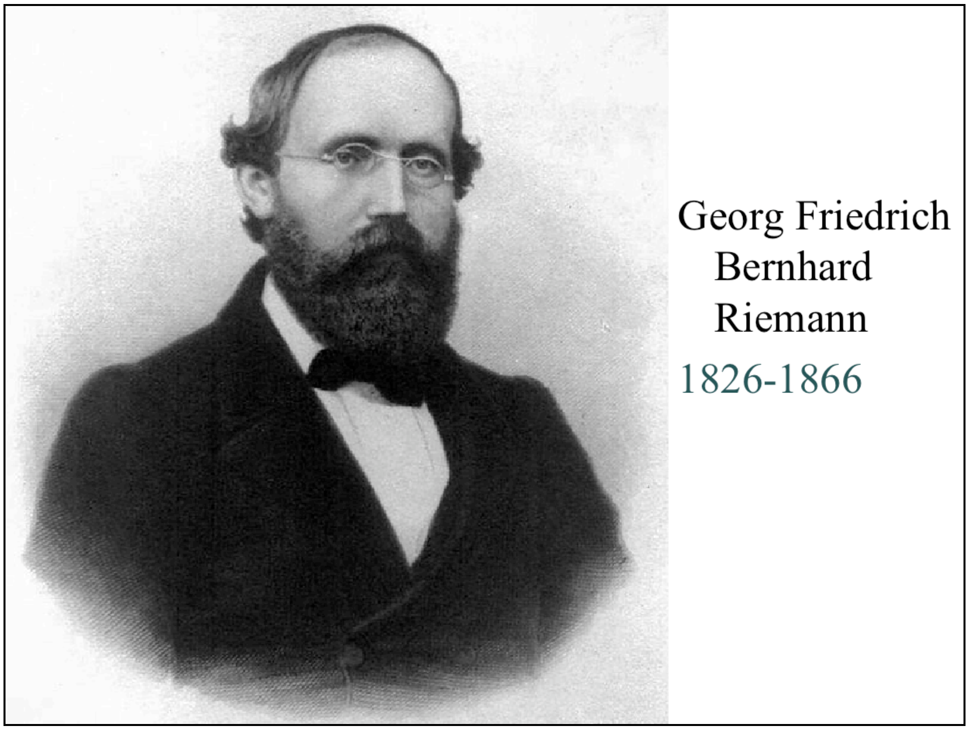
1783.



Well, it's pretty clear, just from looking around, that the world we live in has only three dimensions. In fact, here's Kant saying that this is intuitively obvious.

Boy, was he wrong.

Quoted from Wikipedia http://en.wikipedia.org/wiki/Dimension



The fourth dimension

We can verify the fact that the world has only three dimensions, for example, by noticing that things don't appear and disappear (as they could, if the world we saw was a three-dimensional “plane” embedded in a universe with four (or more) spatial dimensions. And even more notable, the long-range forces are 1/r2 forces. That's the signature of three dimensions.

But is this logically necessary?

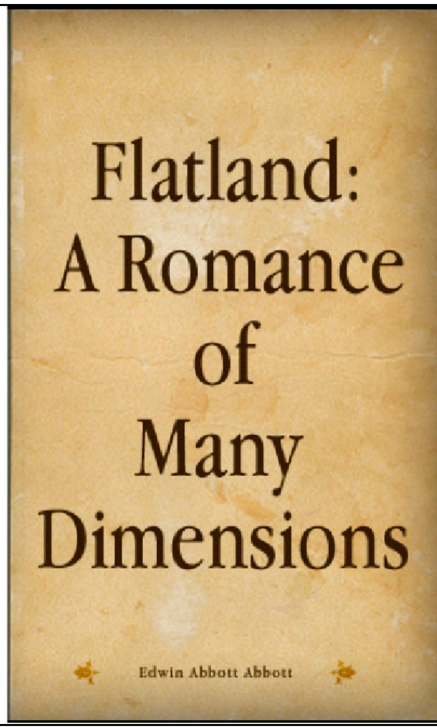
Around the early 19th century, mathematicians started thinking about our three dimensional world. It's clear and obvious that there are three dimensions to our world, just look around. But in the 18th century, mathematicians started to question the obvious. IS it really obvious? Can you prove it? What about more than three dimensions? What would a fourth dimension be like?

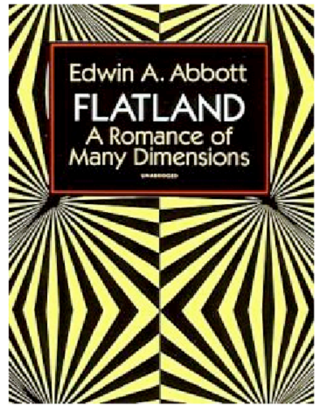
A number of mathematicians began to consider this concept, and the question of what “intuitively obvious” things actually are mathematically true– that is, true because they are logically necessary– and which ones just happen to be true, but don’t’ have to be true. Many people looked at this, but Bernhard Riemann really was the major figure here, in his thesis “On the assumptions that lie at the ground of mathematics.”

The mystics and theosophy immediately picked up on the idea of higher dimensions. It provided a convenient “scientific” vocabulary to talk about how the world could have unseen elements, ghosts, spirits, and such, that can be there but unseen, can see everything interior and exterior at once. Even now mysticism continues to use vocabulary such as talking about ”rising into another plane,” higher and lower planes of existence, the "astral plane,” and so on.

- **Edwin A. Abbott**

Edwin Abbott (several years before Einstein) wrote a book elucidating the concepts of higher dimensions, entitled *Flatland*. 1884





Flatland (1884)

Flatland: A Romance of Many Dimensions
by Edwin Abbott Abbott

Flatland. 1884

Abbot’s book pointed out some of the "impossible" things that a three-dimensional being could do in a two-dimensional world (like appear and disappear)-- and by analogy, what a four dimensional being could do in our three dimensional world.

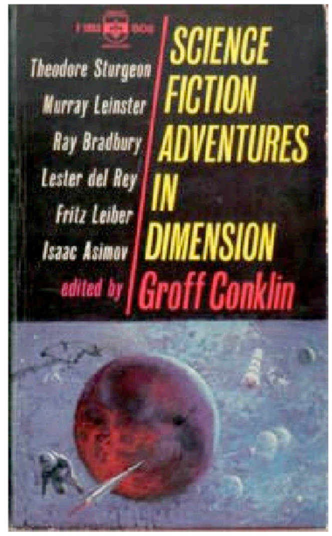
The ideas of other dimensions was picked up by science fiction in the early 20th century

Unlike some other science fiction concepts like trips to the moon, and time travel, there wasn't a "first" canonical novel that introduced and defined the concept.

The fourth dimension (and higher dimensions) represents a direction in which one can travel– an ideal speculation for science fiction. Surprisingly, though, the idea of travelling into other dimensions actually crept into science fiction slowly.

A lot of the early SF using the fourth dimension was gimmick stories. Lovecraft's "Dreams in the witch house," for example, where the condemned witch disappears from confinement by moving through the fourth dimension. In Murray Leinster's "Fifth dimensional catapult," by the way Leinster noted that the fourth dimension is time, and so the title is just making it explicit that was talking about a fourth *spatial* dimension.

- **Science-Fiction Adventures in Dimension** (1953), edited by **Groff Conklin**



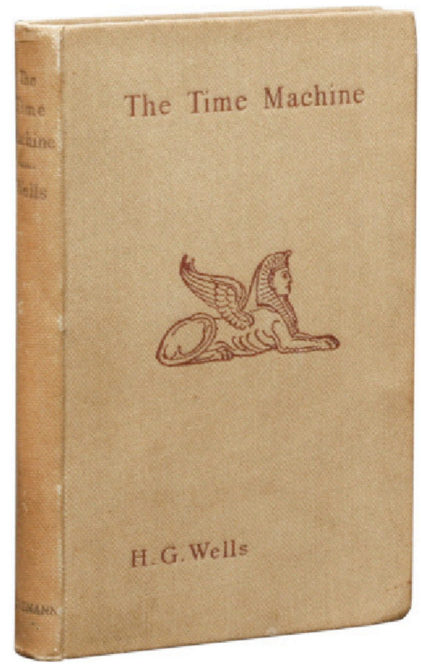
By Groff Conklin's anthology *Science-Fiction Adventures in Dimension* (1953) the idea of "other dimensions" seemed to be canonical enough for science fiction that the word “dimension” in the title was enough. (the title echoes the Raymond J. Healy and J. Francis McComas 1947anthology *Adventures in Space and Time*).

A Wrinkle in Time (1962)

Madeleine L'Engle's classic childrens/young-adult book *A Wrinkle in Time* was the first introduction to concepts of embedding and higher dimensions for a large number of readers.

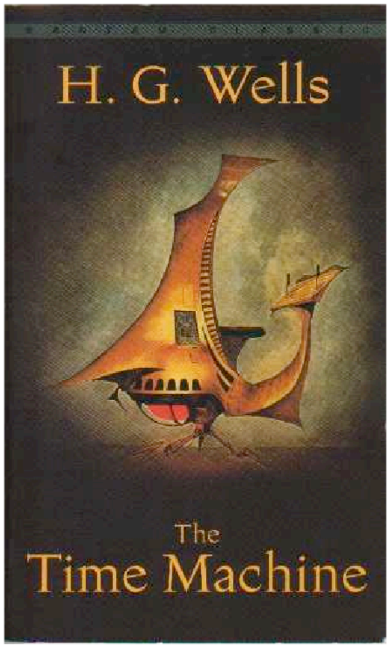
H. G. Wells

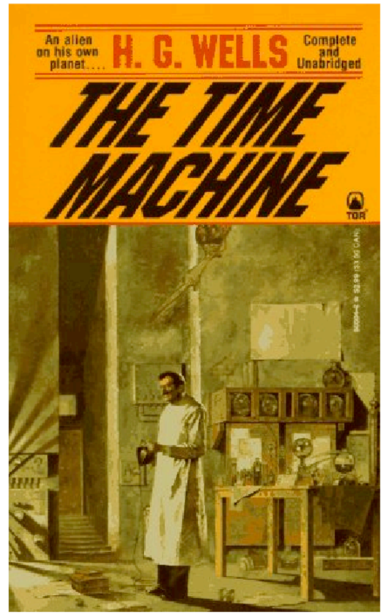
Moving back a little, let’s talk about H.G. Wells. In 1888, at age 21, he came up with a different concept about the fourth dimension, one that ended up influencing physics directly.



The Time Machine

In his novel *The Time Machine*, (first serialized in 1888) H.G. Wells wrote, "There is no difference between time and any of the three dimensions of space except that our consciousness moves along it." The introductory section, in which the Time Traveler explains why time is a dimension, remains one of the most clear and concise explanations of the nature of time as a dimension ever written.

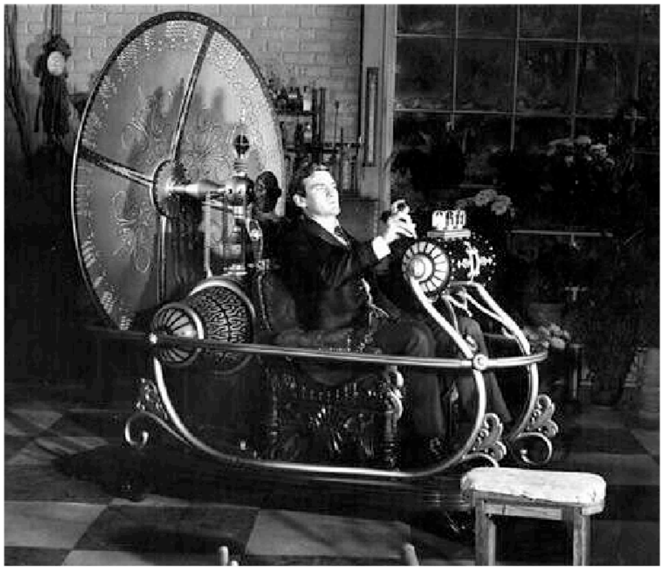




The Time Machine

The *Time Machine* was Wells' first book. It's a very odd story. The main character is simply known as "the time traveler." The book was, in addition to being an adventure story, a forum for his ideas on society, and evolution-- but also a remarkable book about the nature of time.

Classics Illustrated version of Time Machine
Movie version of Time Machine



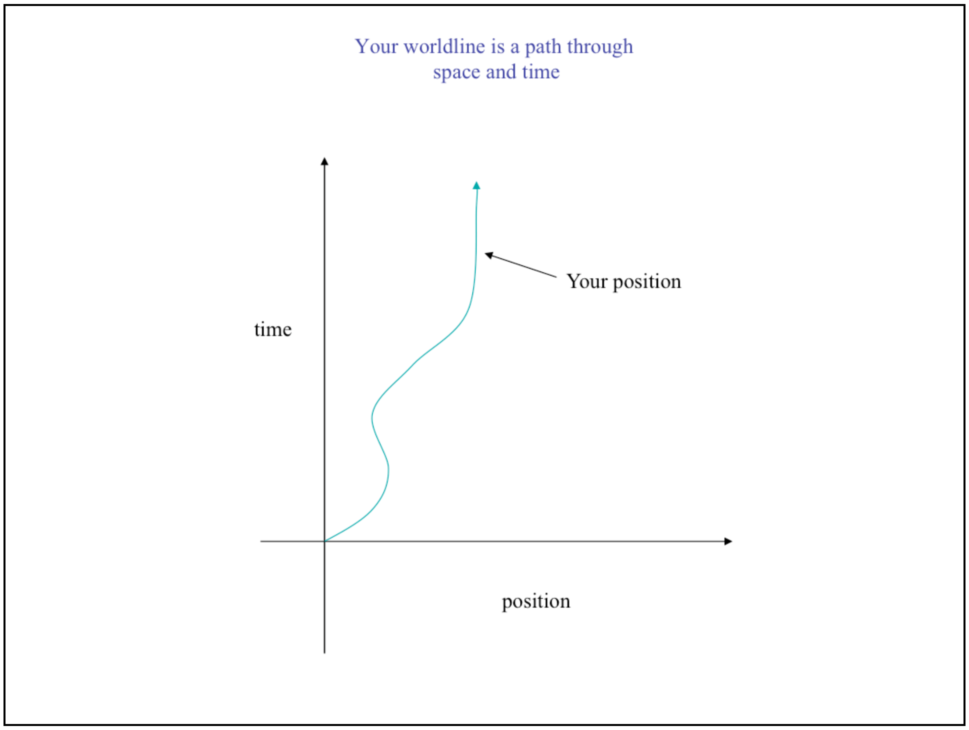
Time Machine, from the movie

George Pal’s visualization of a very Victorian time machine (from the movie).

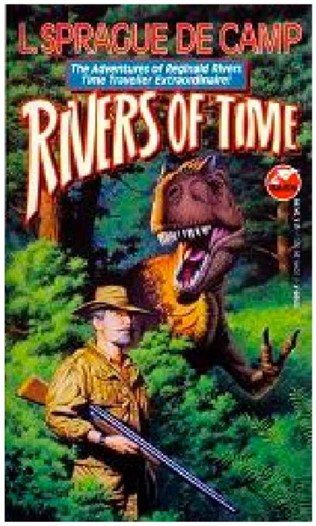
Albert Einstein in 1905

The idea of time is simply a dimension underlies the theory of relativity (at least, after Minkowski explained it). Space and time do not exist separately, only a merged, four dimensional manifold, “spacetime”.

(Of course, it’s actually a bit more complicated than that.)



In the four dimentions view, your existence is a line through space and time– a “worldline”.

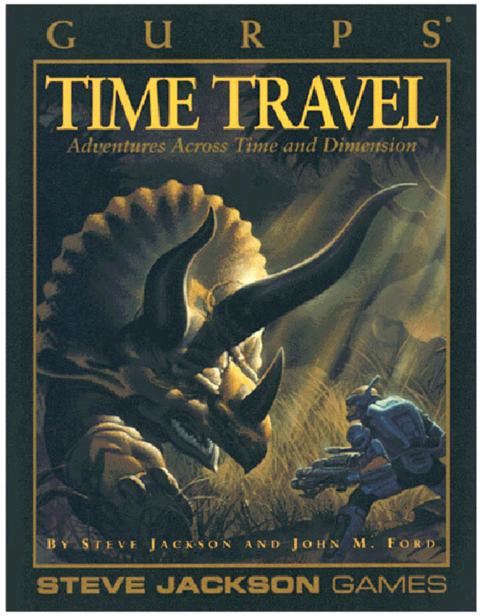


L. Sprague DeCamp
"A Gun for a Dinosaur"

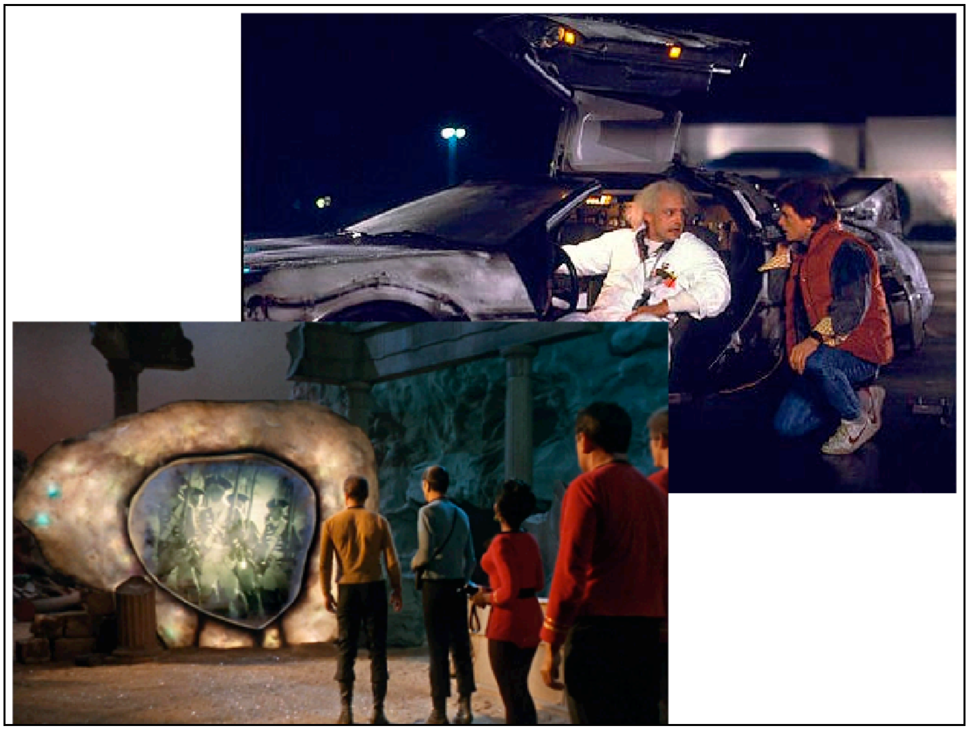
"By His Bootstraps", Robert A. Heinlein
(writing as Anson MacDonald)

Wells' insight was picked up as an underlying basis for a lot of science fiction. There were a lot of kinds of stories possible– the time travel adventure story, the time travel paradox story.


Edited by Bill Adler, Jr.
TIME MACHINES
THE BEST TIME TRAVEL STORIE
Featuring Isaac Asimov,
Rod Serling, H.G. Wells, and
Time Machines: The Best time Tr
Stories Ever Written
TIME PATROL
POUL ANDERSON
BAEN
"Go back to a wonderful world and have a wonderful time doing it!"
NEW YORK TIMES
Time and Again
An illustra
y Jack
TIME-SCAPE
A novel by the author of
"IN THE OCEAN OF NIGHT"
Gregory Benford

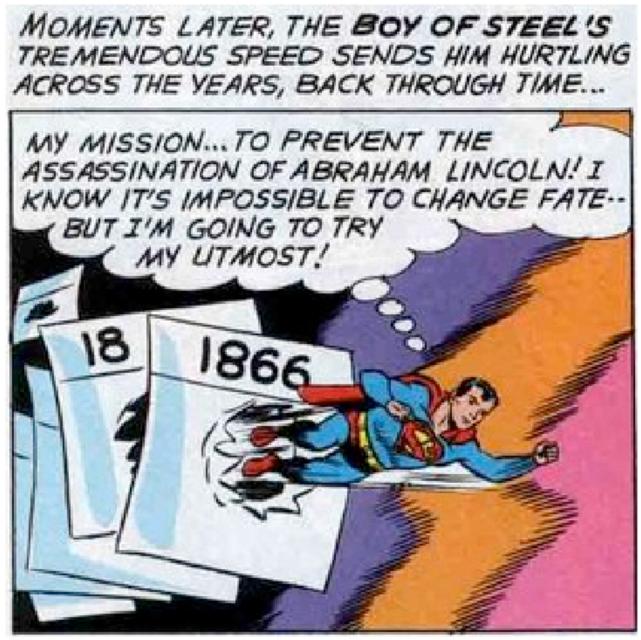


GURPS Time Travel

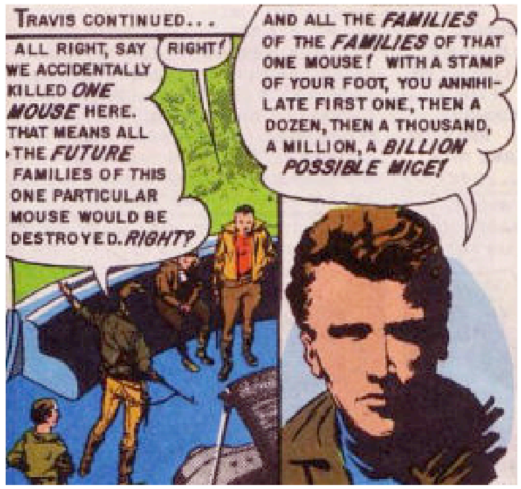


Also in science fiction movies and television.

In “The City on the Edge of Forever,” McCoy inadvertantly changed the past, and the Star Trek episode was about trying to avoid the alternate future where the Nazis take over the world.



But, what happens if you change the past?



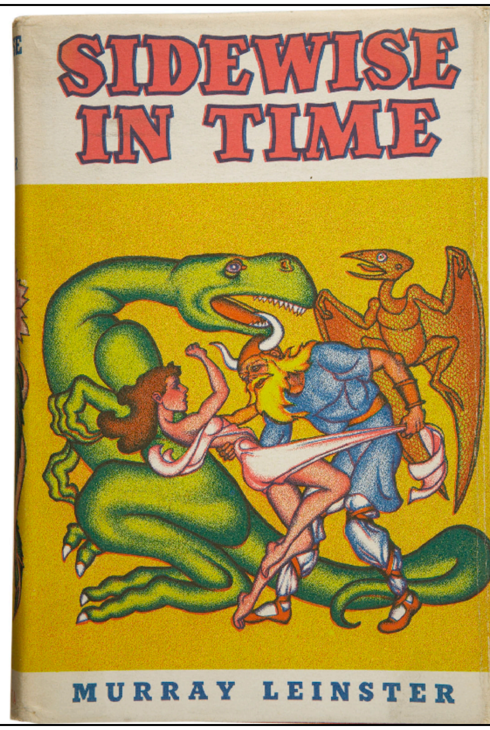
Bradbury, "A Sound of Thunder"

Does a change in the past make another universe, in which everything is changed? If the past can be changed, then a time travel story is about alternate universes

"Sidewise in Time"

Murray Leinster

- June 1934

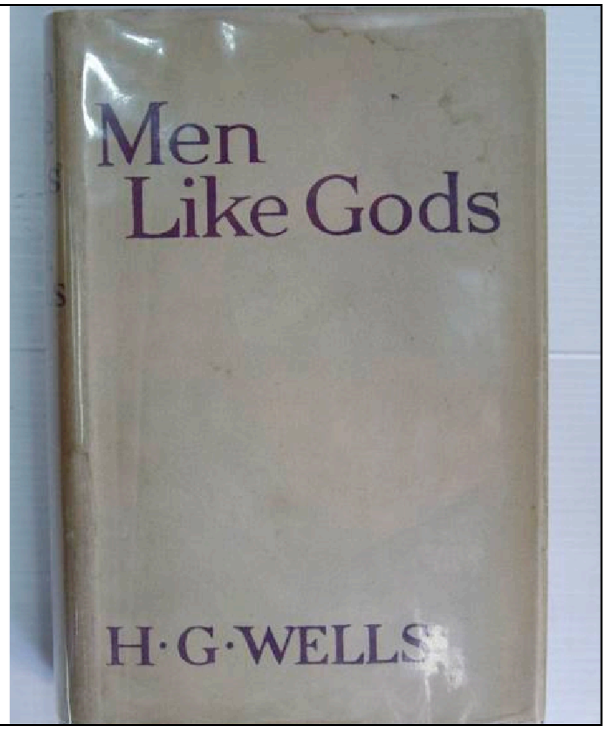


Leinster severed the parallel universe idea from time travel– talked about alternate versions of the world without explicitly causing the variation with time travel.

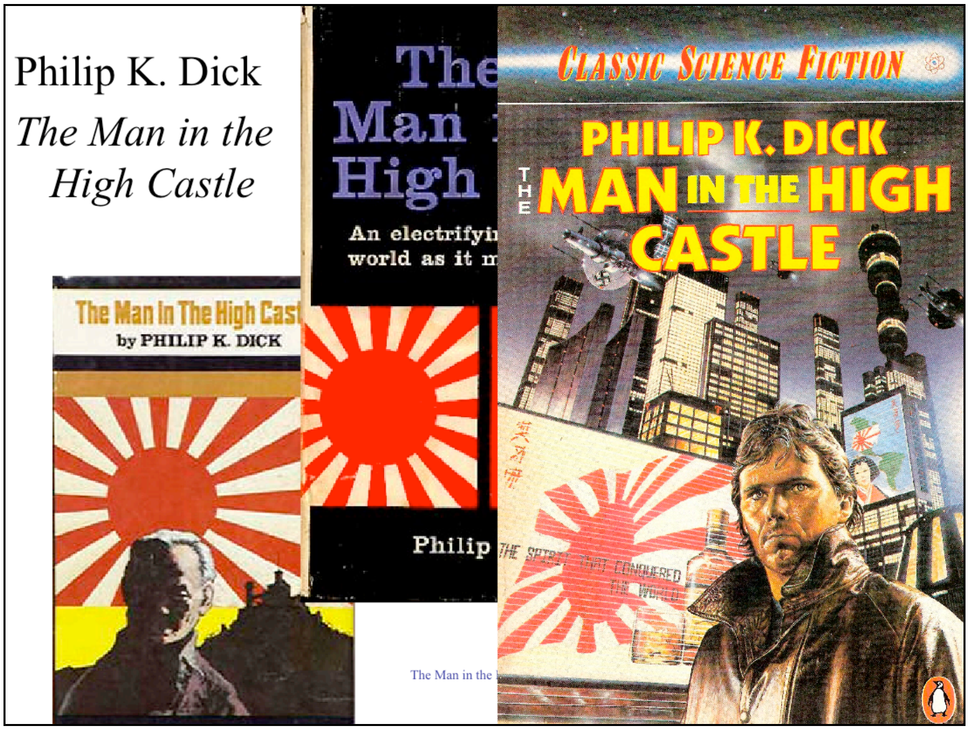
H. Beam Piper, Paratime Books (first story, 1948)

Travel across alternate realities was picked up by many science fiction writers.

H.G. WELLS,
MEN LIKE GODS:
London, Cassell and Company, 1923. First Edition.

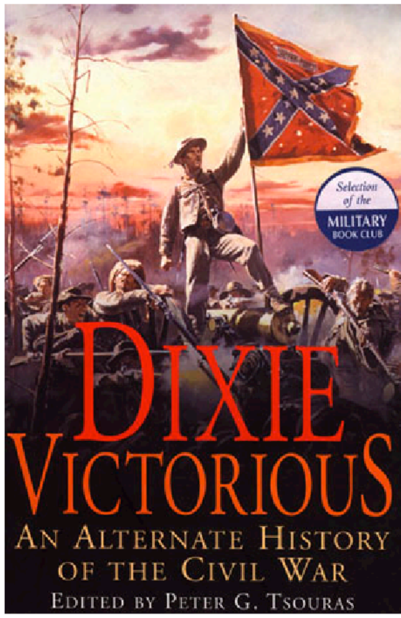


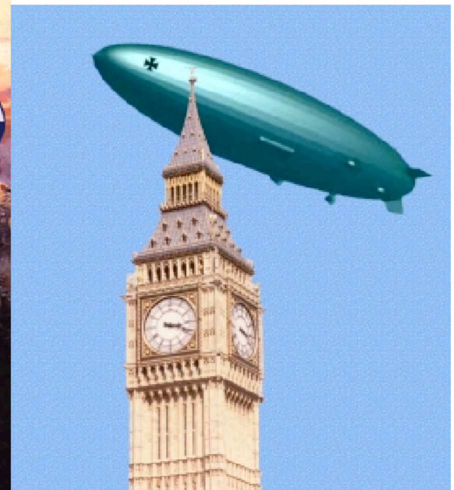
H. G. Wells' *Men Like Gods"* is a very early story about travel to a parallel world.



Dick's classic *The Man in the High* Castle, an alternate world story.

http://www.sfreviews.com/displays/Philip%20K.%20Dick_1962_The%20Man%20In%20The%20High%20Castle.htm





Alternate history

Alternate history stories (what historians call “counterfactuals”). Actually, alternate history has a history older than science fiction– goes back to Livy.

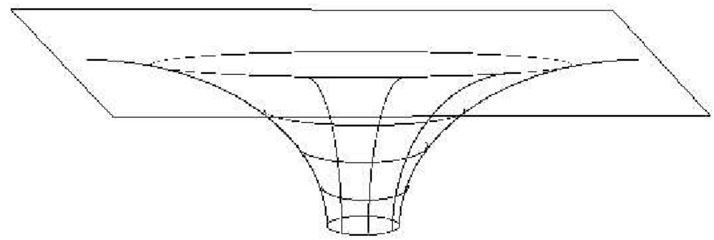
3mpub.com/rhodes/

Let’s get back to physics. I talked at little about special relativity, but now let’s talk about general relativity..

Special relativity is defined in Euclidean space, but General Relativity is non-euclidean. It’s been known for ages that general relativity does not necessarily require topology variation, but non-trivial topology is allowed in general relativity.

When he introduced his field equations, Einstein apologized that, in his opinion, they were "so complicated I'm afraid no one will ever find an exact solution.”

-for all his brilliance, Einstein was actually not a meticulous mathematician. It took about six months for Schwartzschild to publish the first exact solution.



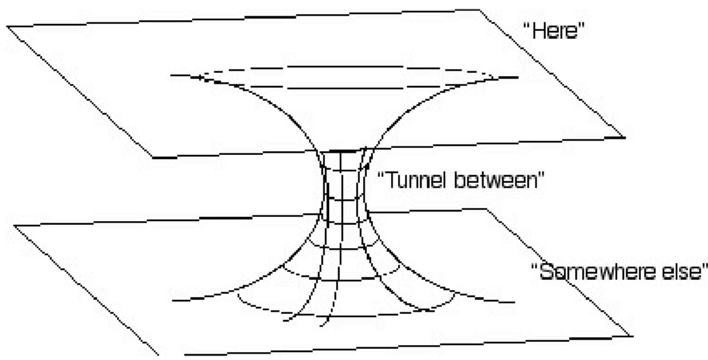
Black hole - embedding diagram

This picture is an embedding diagram, a “flatland” version of a black hole, the people living in the two-dimensional world can go through this “hole” in their space, and find themselves far away.

Ludwig Flamm first showed that Schwartzschild metric can be exactly mapped to an embedding. The embedding in the (nonexistent) third dimension h is a square root function (h = SQRT[R-Rs])

I like embedding diagrams, because I find it hard to visualize noneuclidean geometry, but I do have to point out that embedding diagrams can be misleading. The third dimension is not real.

Extend this square root further downward, to the negative square root and the embedding opens out again on the bottom, to another asymptotically flat region of space. That’s an “Einstein Rosen Bridge.”

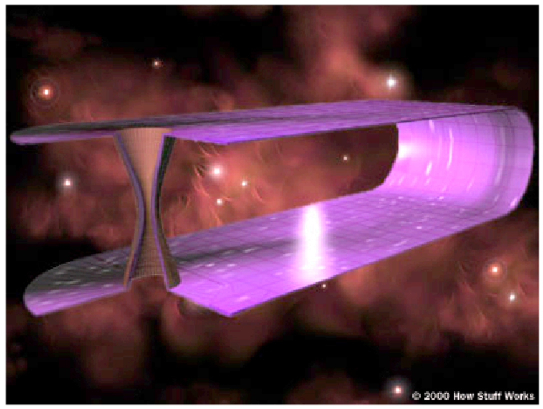


Maximally extended Flamm embedding:
the Einstein-Rosen wormhole connects to another
asymptotically flat region "elsewhere"

Turns out, that analytical extension was a false alarm– black holes are not really wormholes. However, the extension did introduce the idea.

No reason in particular that a wormhole leads to somewhere else in *this* universe. It leads to another place, but the equations don't really say where.

(I'll mention *Einstein's Bridge* here.)



Wormhole: connecting two places
separated in (space)

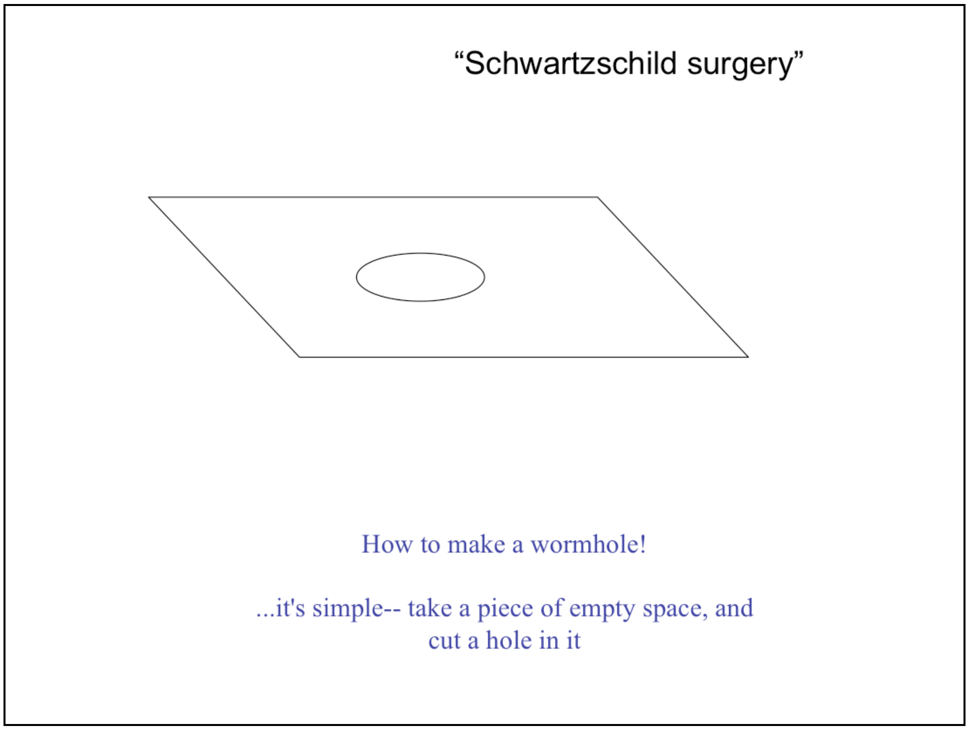
Here's a prettier picture of a hypothetical wormhole.

This picture is a "flatland" version of a wormhole, the people living in the two-dimensional world can go through this "hole" in their space, and find themselves far away.

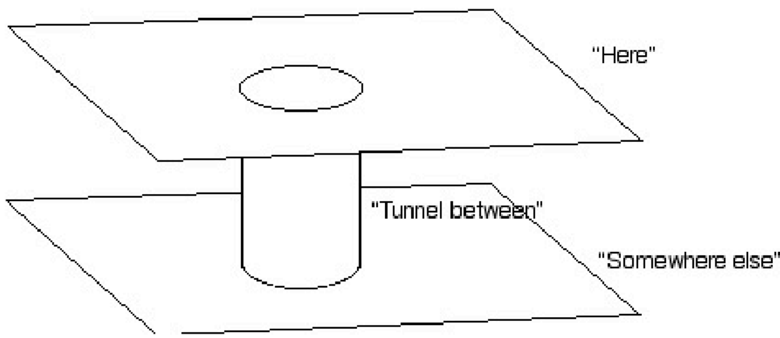
Mike Morris and Kip Thorne, at the request of Carl Sagan (who was writing a science fiction book, *Contact*) explicitly calculated what would go into a wormhole that could be traversed. They discovered it needs exotic matter (Negative energy density matter-- not the same as antimatter, by the way). Turns out, though, that for all that it seems to be contradictory, negative matter can exist in quantum mechanics

Negative-energy-density material has very odd properties– F = ma, so you push it this way, it goes that way

Later, Matt Visser figured out a somewhat simpler polyhedron version of a wormhole.



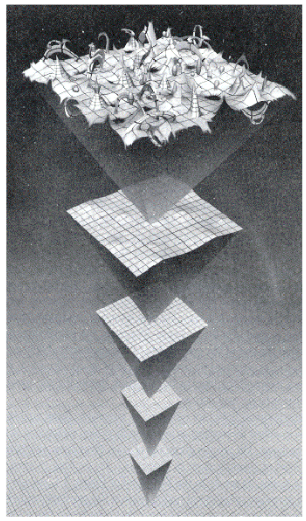
But, how do you make a wormhole? Well, conceptually, it's simple. You just need to be able to cut and glue spacetime.



And then just sew the edges of that hole to the corresponding edges of a piece cut out somewhere else.

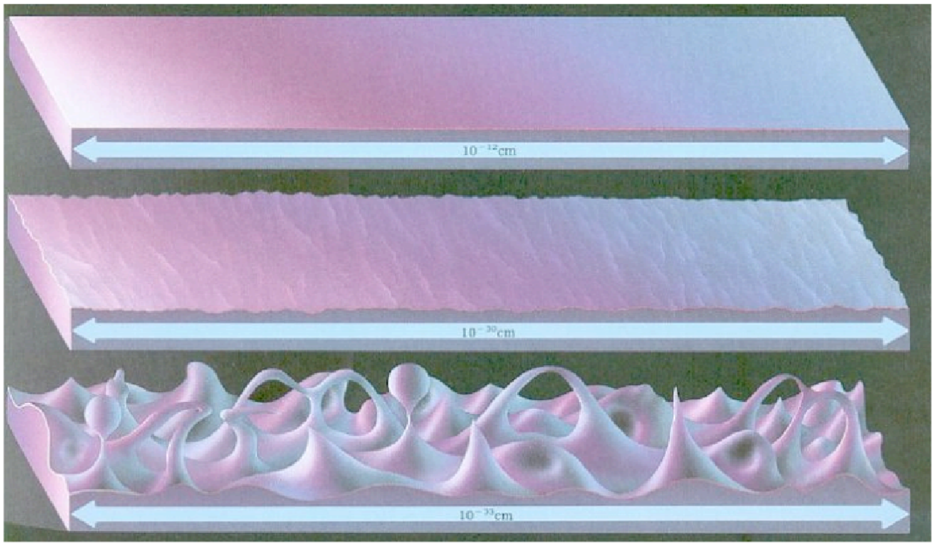
But, of course, in the real world we have no idea how to cut and paste spacetime!

Exercise for the student: show that this requires negative matter. (Hint: use parallel lightlight geodesics traversing through the hole).



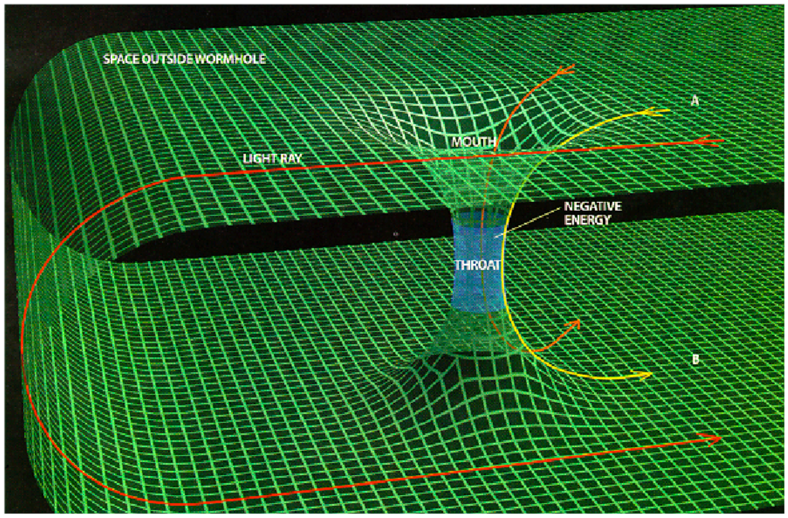
Quantum foam

Look at the world in successively higher magnification, until you get to the Planck level, where quantum fluctions of vacuum energy are significant.



Quantum foam

At the Planck level, the vacuum fluctuations are so large that, if quantum mechanics and general relativity both apply, spacetime itself is highly curved. This is the “quantum foam.” The quantum foam may include non-trivial topology– wormholes at the Planck length scale!



John Cramer, Robert L. Forward, Michael Morris, Matt Visser, Gregory Benford and Geoffrey A. Landis, "Natural Wormholes as Gravitational Lenses," ***Physical Review D,*** *15 March 1995, 3124-3127.*

I should mention this paper while I'm here.

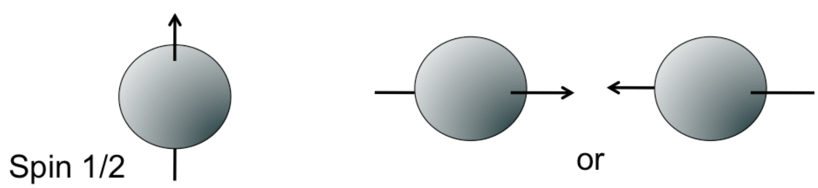
This came from a NASA workshop. In the work, we simplified Visser's wormhole geometry to use just a piece of cosmic string (a geometrical defect in space-time, thought to be a relic of the early universe). Since there could, in principle, be wormholes left over from the Early universe (when the density was very high) we calculated that such a wormhole could have effective negative mass, and proposed that you could detect one using gravitational lensing effect.

This was a NASA workshop with a more or less freewheeling discussion, coming up with the properties of natural wormholes essentially from the basic properties of conservation of momentum, and at the end of the discussion, we said, more or less, well, we ought to do the calculation and write a paper.

The next day of the workshop, John showed up and said, well I went back to my hotel room and did the calculations, here are the graphs showing the signatures of gravitational lensing.

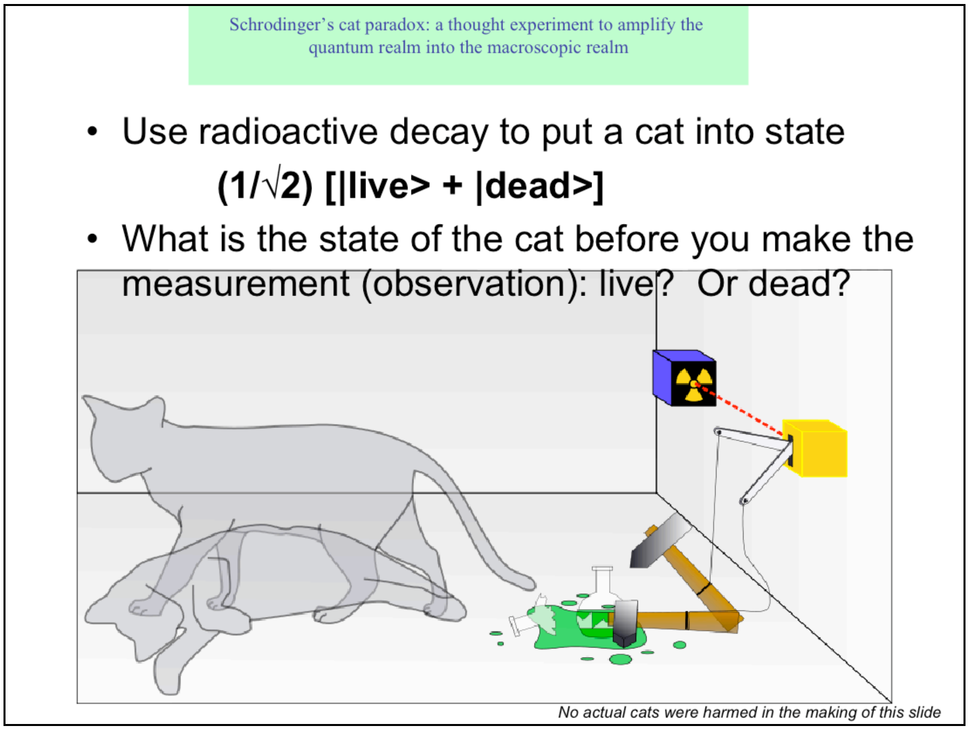
The Quantum Measurement Problem

- Particle in state $(1/\sqrt{2})\ \left[|A\rangle + |B\rangle\right]$
- Measurement: A or B?
  - Result: A
- Particle has been projected into state $|A\rangle$



And now switching topics for a moment, to something (apparently) completely different: quantum measurement.

Some details left out



Schrodinger's cat paradox: really just a way of amplifying the quantum realm into the macroscopic realm

- Hugh Everett III
- "Many Worlds" Interpretation of Quantum Mechanics
- 1957

Everett's "relative states" formulation– soon tagged the "many worlds" version of quantum mechanics

Everett-Wheeler “relative states” interpretation: the most misinterpreted theory in quantum mechanics?

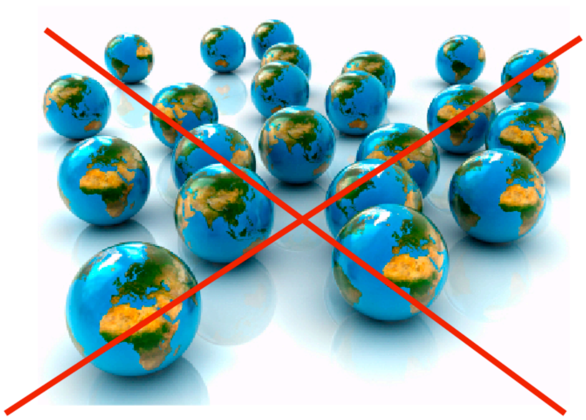
- Many-worlds interpretation: the science fiction version:
  - *When you make the measurement, **the entire universe** splits in two*

Science fiction really jumped on this! A (pseudo?) scientific justification for alternate histories!

- Many-worlds interpretation: Everett’s relative-state formulation:
  - When you make the measurement, your quantum state is entangled in the state that is measured. If you make a measurement of a state |**A**> + |**B**>, the final state is

    |you observing A> + |you observing B>
  - The “real world” is a superposition of both states– but they cannot interact with each other

- The Many-worlds interpretation is not actually “many worlds” at all– it’s one world, with innumerable states superimposed on each other



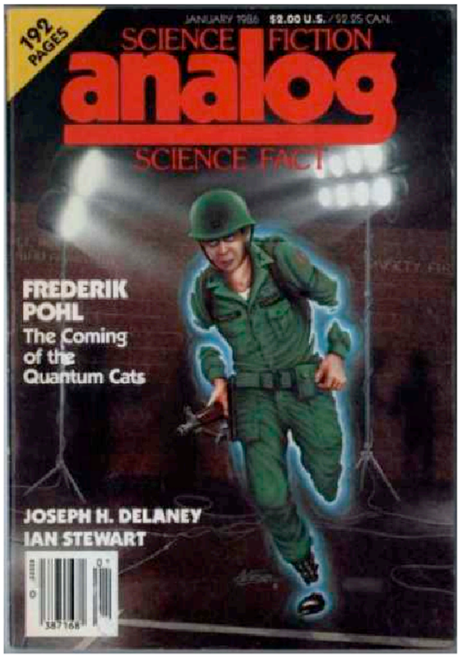
This is actually far weirder than the idea that the universe splits.

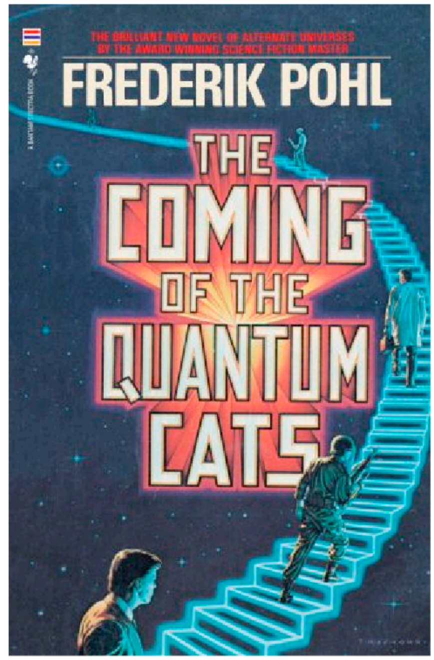
This is actually far weirder than the idea that the universe splits.

(It really begins to sound like new age philosophy.)

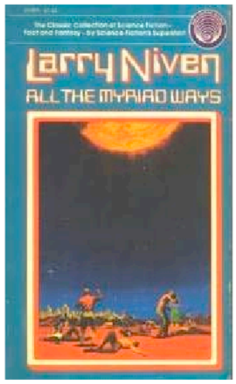
--Does bring up the question of what constitutes a measurement. The relative states have no obvious connection with time travel, with alternate history, or even with consciousness.

Image: iStockphoto / Sirin Buse.

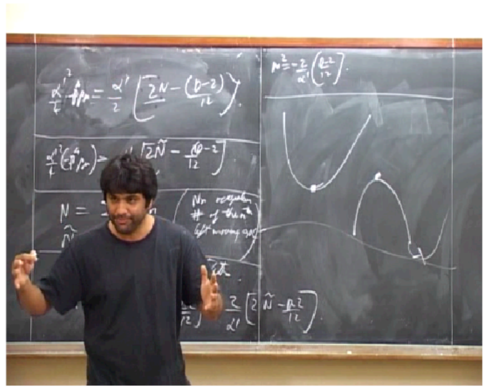




“Many Worlds” interpretation in science fiction” Frederik Pohl’s *The Coming of the Quantum Cats*

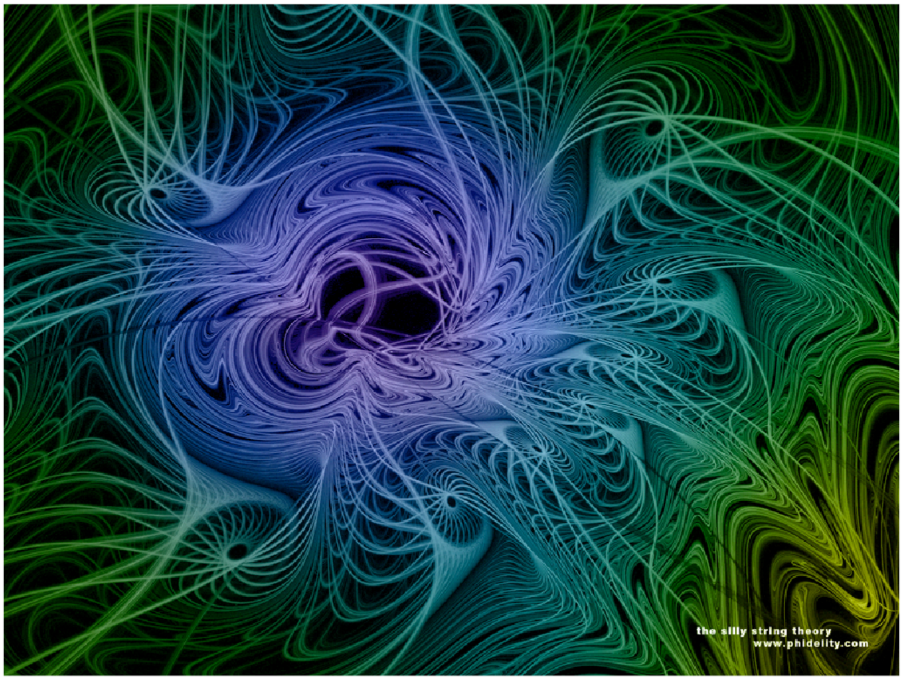


- Larry Niven, “All the Myriad Ways”



String theory: Shiraz Minwalla.

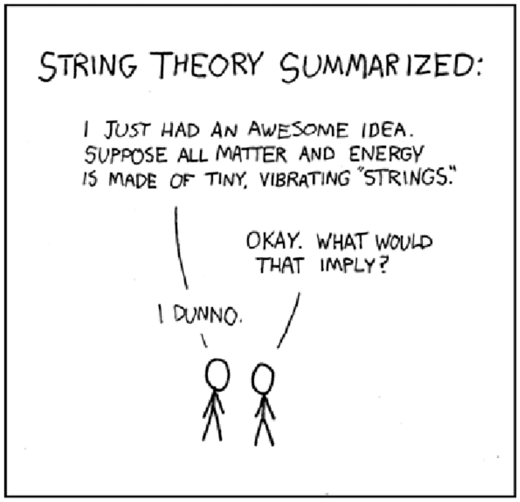
I’m not going to talk very much about string theory, because very rapidly I get to the point where it’s obvious that I don’t know what I’m talking about.



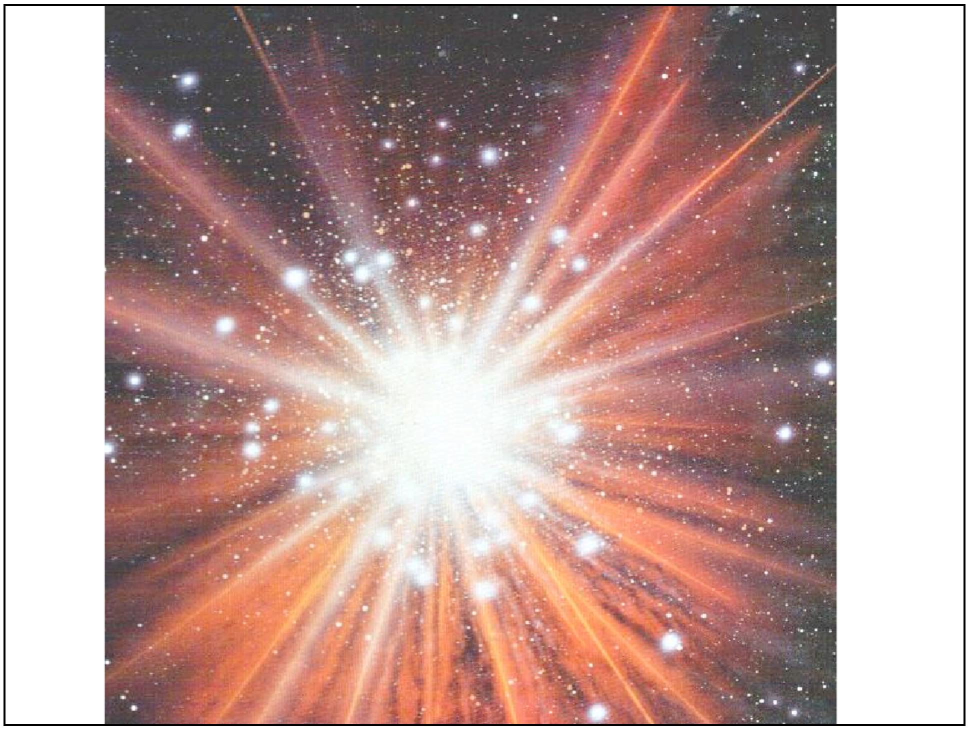
http://www.phidelity.com/photos/v/Artwork/Wallpaper/sillystringTheory.jpg.html

Except to mention that string theory takes that science-fictiony notion of higher dimensions and directly incorporates it as a necessary part of the mathematics to make the theory work.

Score one for science fiction.



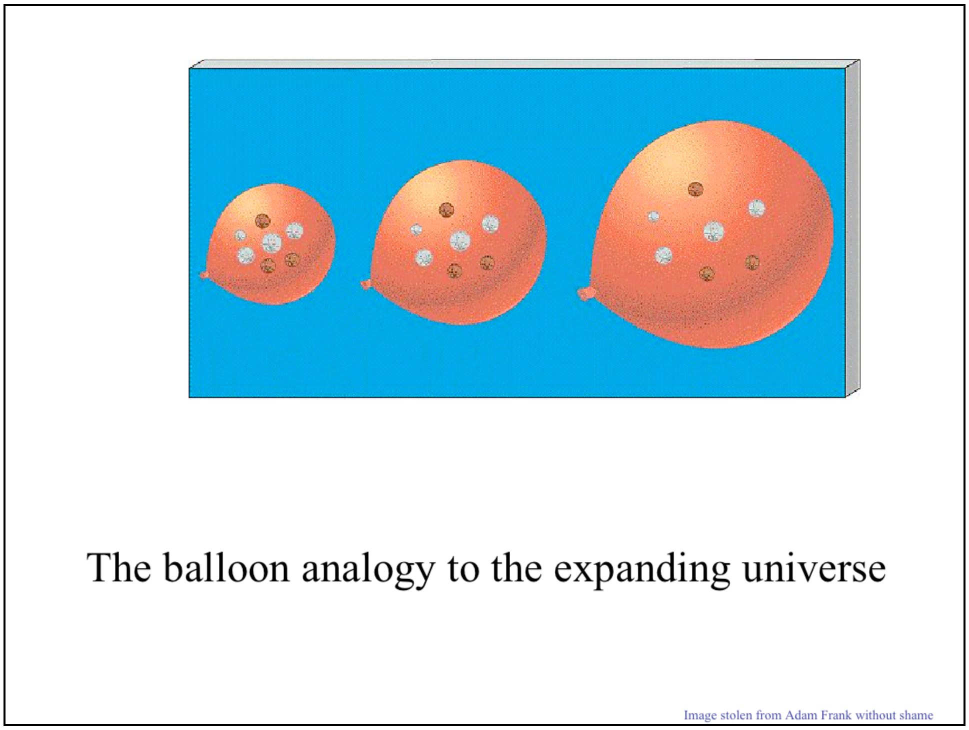
http://xkcd.com/171/



So let’s get back to the big bang.

We're all familiar with the "balloon" analogy for the big bang.

balloon



The Balloon Analogy is so easy to visualize, so easy to explain, that it's a real pity that it's completely misleading.

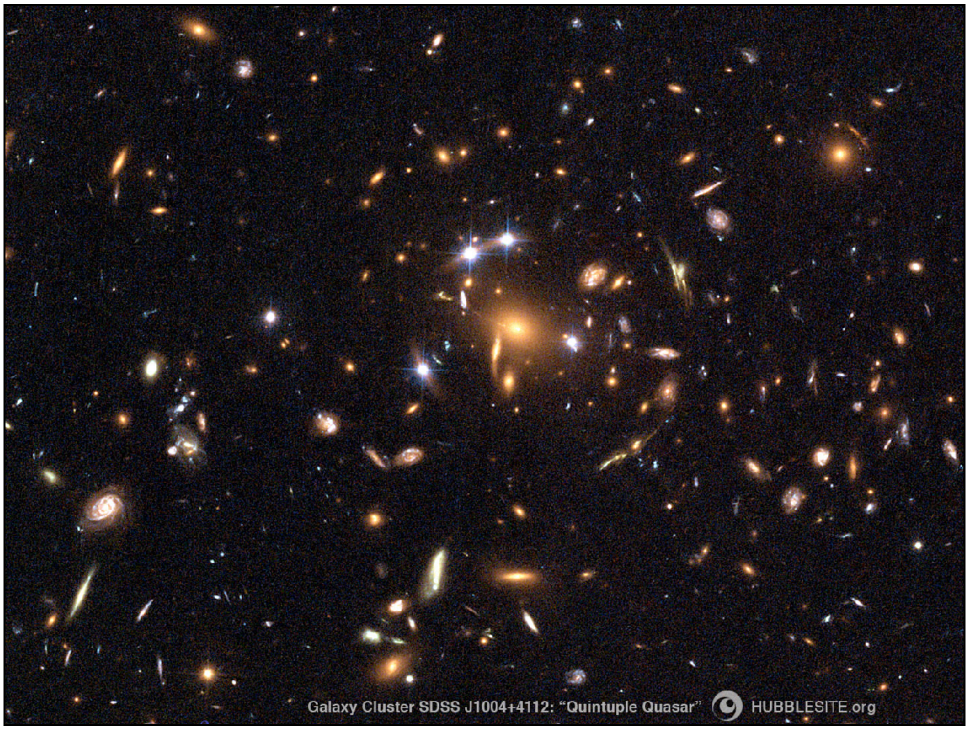
We have very good observational evidence now to show that the Universe is open (not closed, like a balloon), and is infinite in extent.

Too bad– the science fiction writers really liked the oscillating universe theory, where after the big bang comes the big crunch, and after that you get another big bang, and another universe.

A closed universe is closed in time and finite in space. An open universe is infinite in (future) time, and infinite in space.

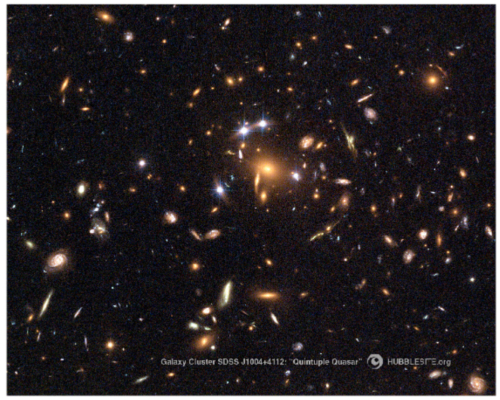
Image from Adam frank, http://www.pas.rochester.edu/~afrank/A105/LectureXVI/LectureXVI.html

Astro 105: The Milky Way Lecture XVI: A Short Course on Cosmology



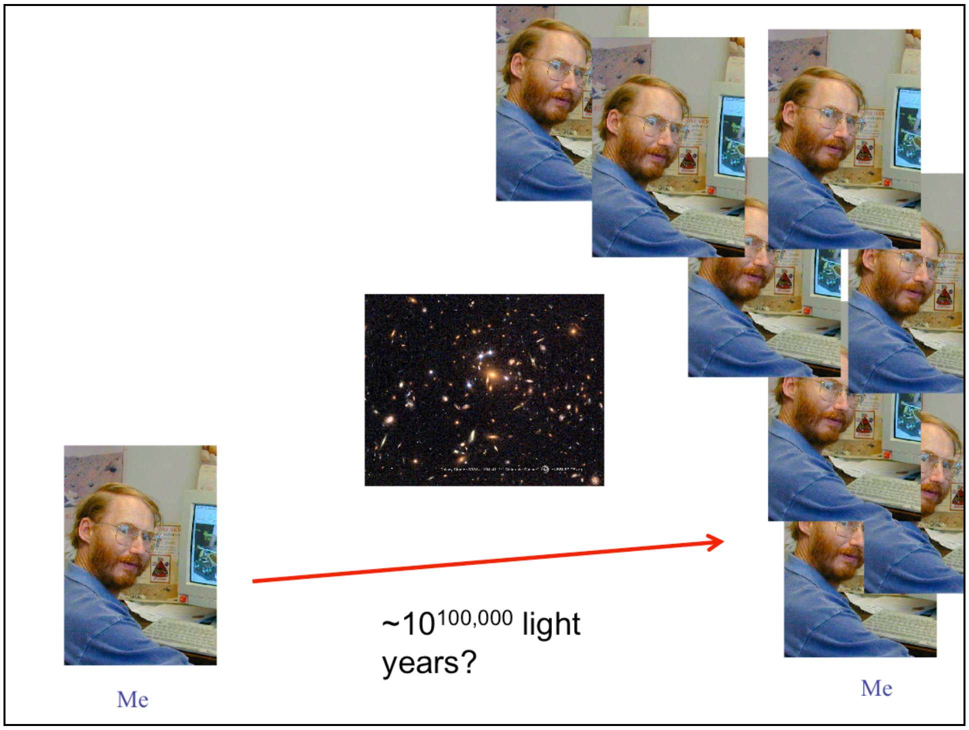
Universe did not expand from a point-- an infinite universe is always infinite, even at the “beginning” when it had infinite density it was still infinite

Infinite in all directions



We're living in an infinite universe!

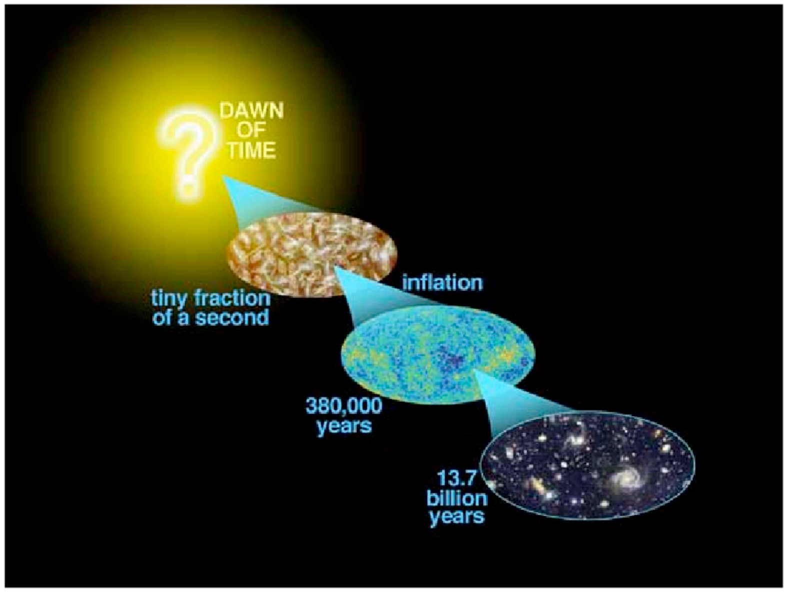
Universe did not expand from a point-- an infinite universe is always infinite, even at the “beginning” when it had infinite density it was still infinite



You don't really "need" parallel universes– our own universe is infinite!

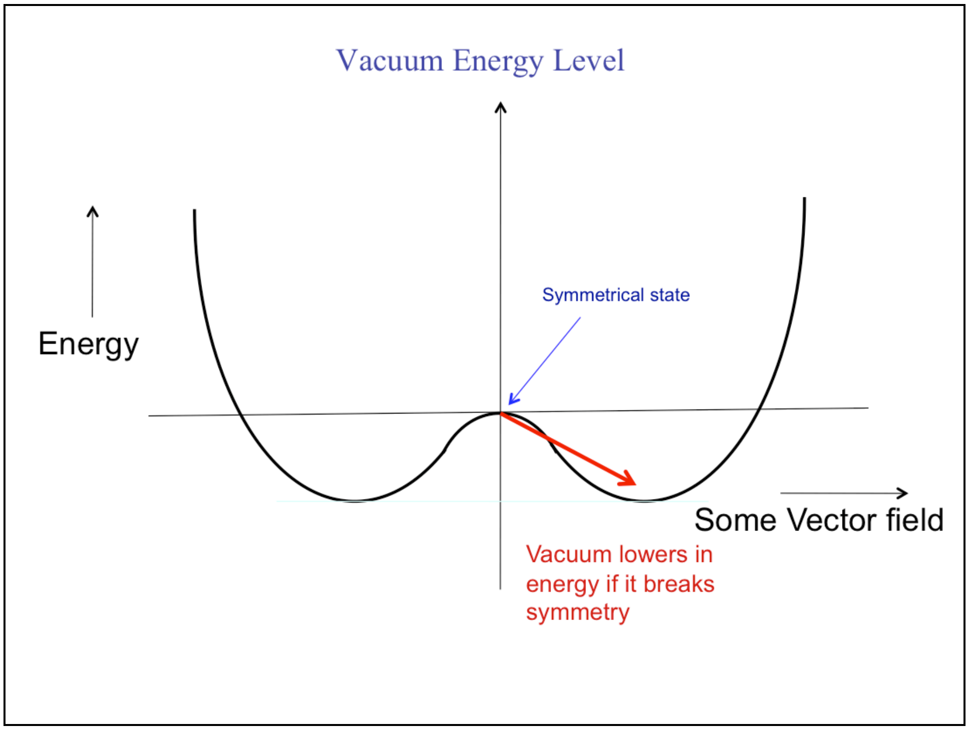
My quick estimate is that the nearest me is something like 10^100,000 light years away (depends on how you do the calculation– could be as far away as 10^(10^27) light years, to find another "me" with a complete replication of every atom in my brain.)

(note that "infinite" doesn't mean that anything is possible. Reference Niven's story "All the myriad Ways.")



Inflation

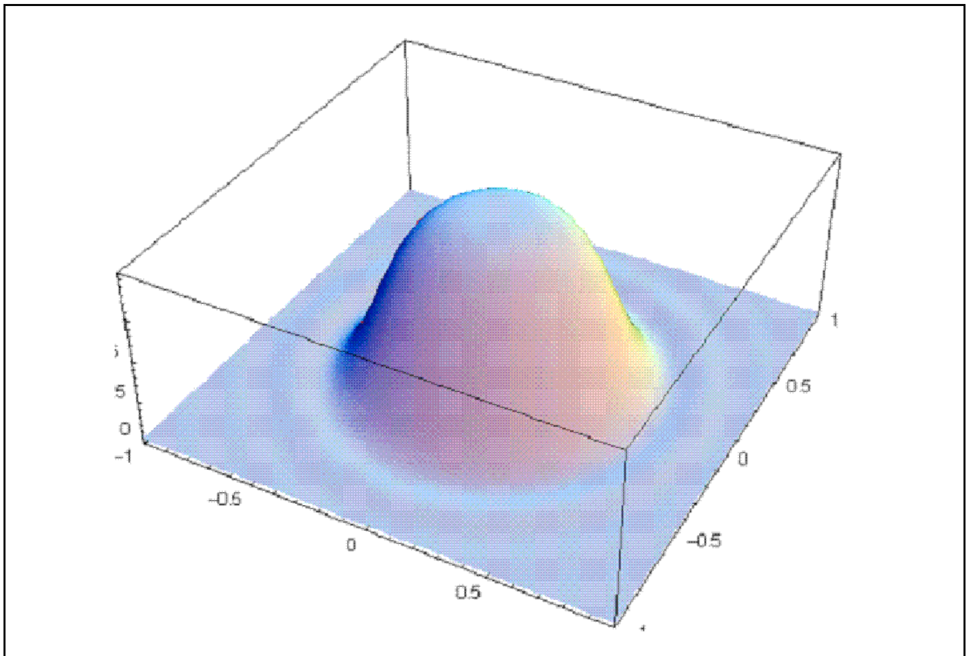
http://mbscientific.com/mediawiki/mediawiki-1.11.1/images/BigBang.jpg



Analogy is pencil balanced on its tip

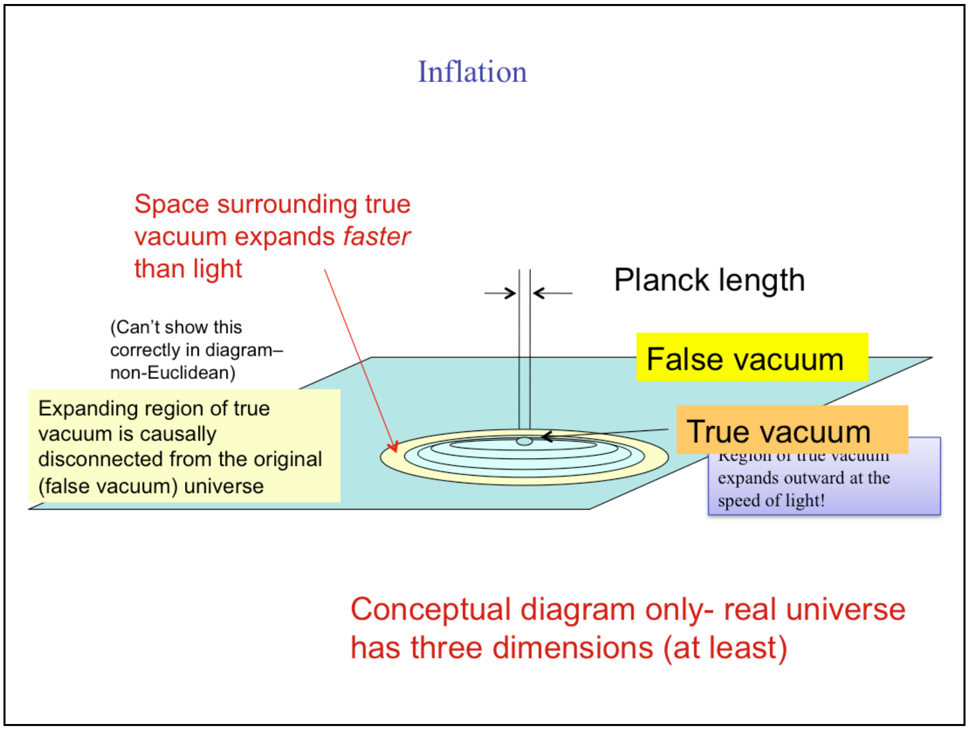
Original thought was that this could be the Higgs field

Original symmetrical state is metastable.

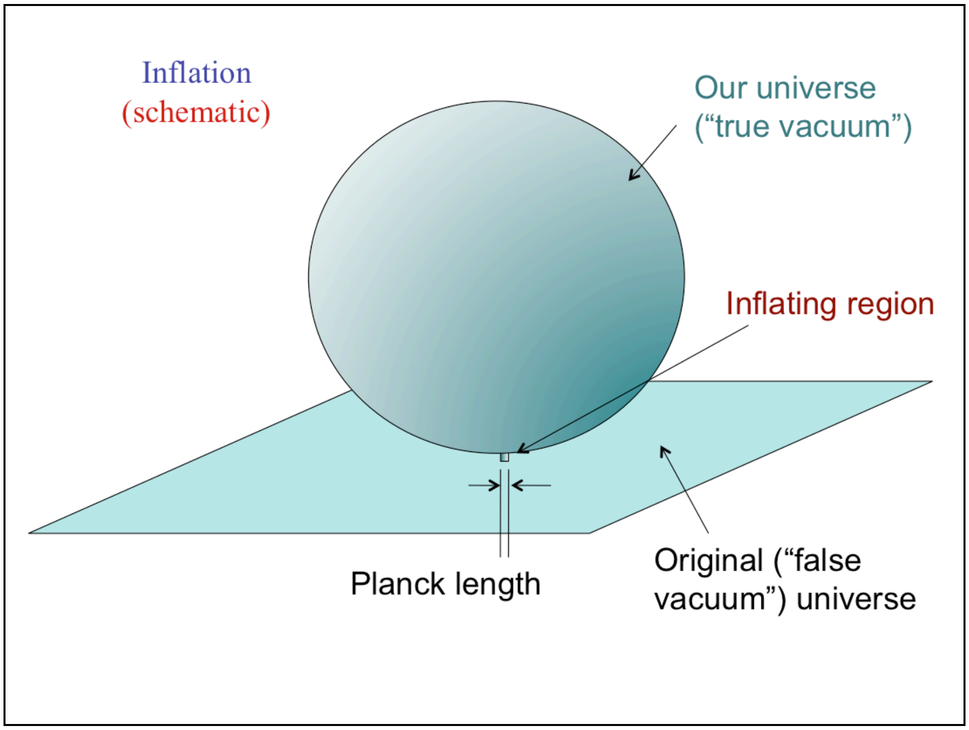


Energy Versus vector field

Actually in more than 1-dimension



Like a TARDIS, it's bigger on the inside than on the outside



Note: schematic only-- embedding diagrams can be misleading “child” universe budding from a parent universe via a false-vacuum bubble

Image from Alan H. Guth,
The inflationary universe: the quest for a new theory of cosmic origins

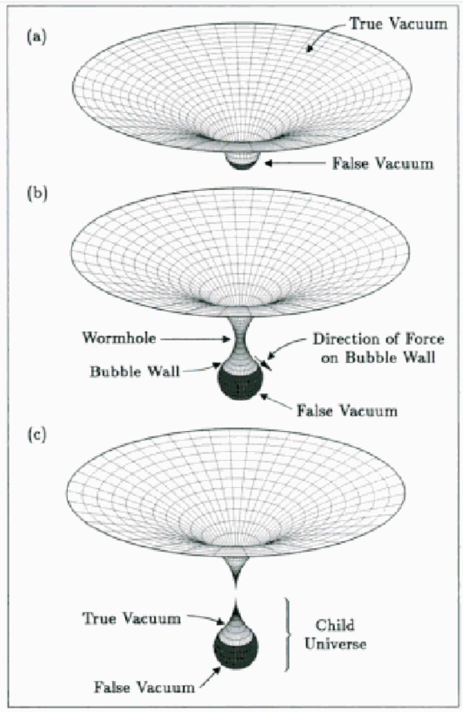
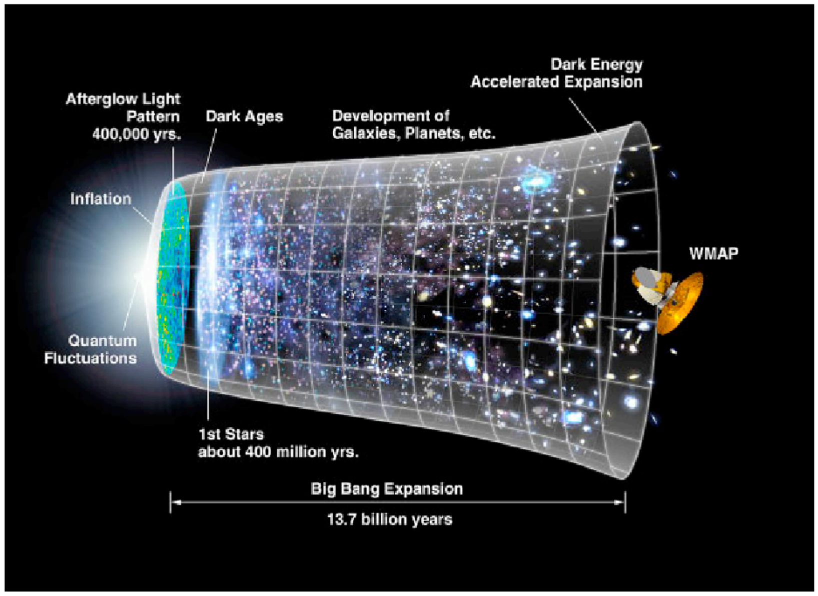


Image from Alan H. Guth, page 262



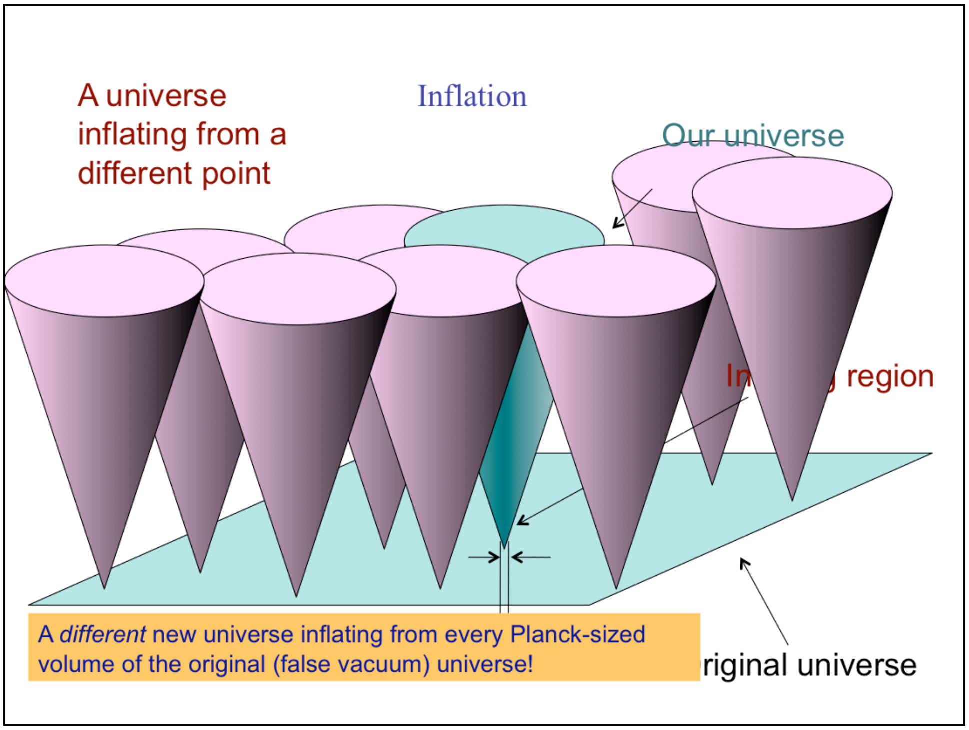
The big bang, with inflation

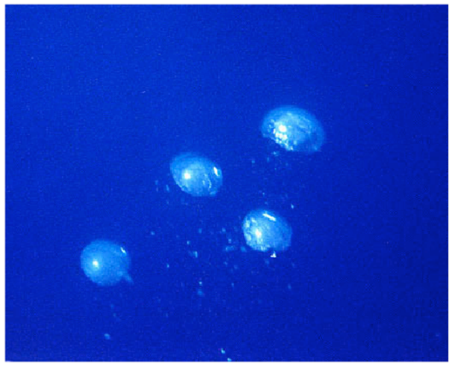
Notes!

1. distances are on log scale!
2. The universe is actually open, not closed

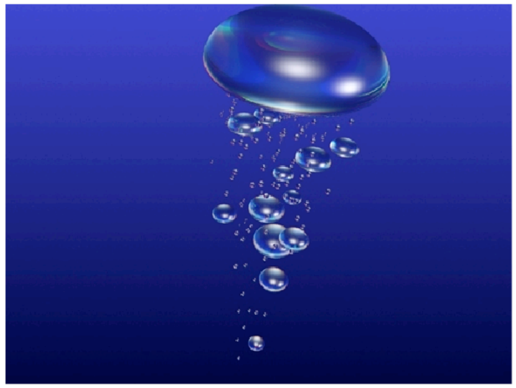
Inflation

http://wildwildweather.com/forecastblog/category/time/


A universe inflating from a different point
Inflation
Our universe
In
region
A *different* new universe inflating from every Planck-sized volume of the original (false vacuum) universe!
riginal universe



Myriad universes like separate, disconnected bubbles



Richard Jennings 1997

http://www.shaders.co.uk/graphics_factory/renders/bubble.jpg

But– can we get there?
We are causally disconnected

http://farm3.static.flickr.com/2047/2060200428_1b4bd19cd9.jpg?v=0

Conclusions

- Science and Science fiction have, in parallel, developed the concepts of parallel worlds
- Many concepts that seemed "science fiction" in the past have been adopted into mainstream physics
  
  - Spatial dimensions >3
  - Time as a fourth dimension
  - Wormholes
  - Alternate Universes ("Many worlds" hypothesis)
  - Parallel universes (Inflationary universe)
- will the parallel lines of science and science fiction ever meet?