Monday, November 25, 2013

Reading: Chapter 12 – all; Chapter 13 – all

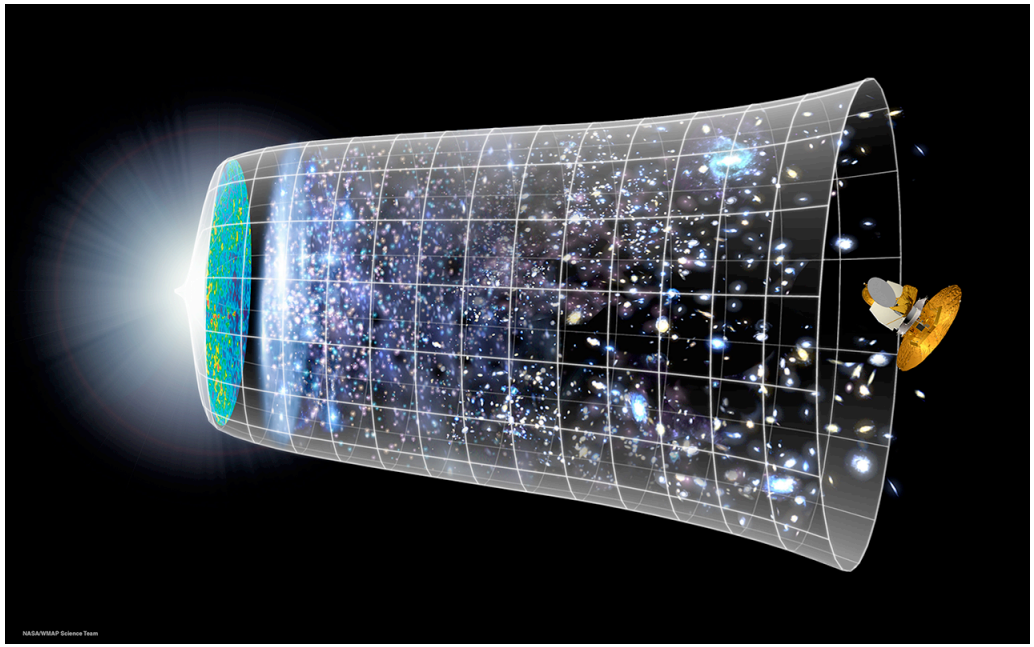
There will be class on Wednesday

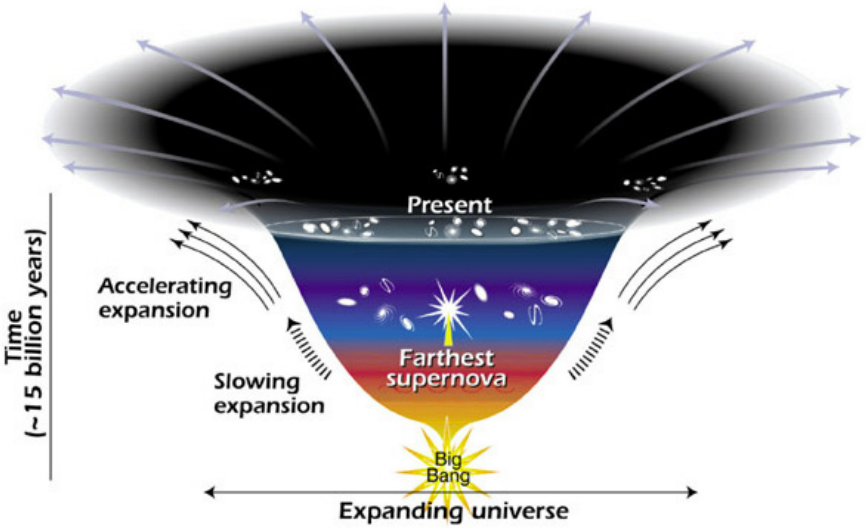
Astronomy in the news?

Goal:

To understand what the Dark Energy implies for the shape and fate of the Universe.

"Space-time diagrams" illustrate how the Big Bang led to inflation, then deceleration, and now acceleration





The Fate of the Universe?

If the acceleration stays constant, the fate is rather dismal: galaxies will be pulled infinitely far apart, then even small mass, long-lived stars age and die, protons, neutrons and electrons will decay to photons, black holes will evaporate by Hawking radiation.

The result would be an empty Universe filled with dilute radiation.

We know so little about the Dark Energy, that it could do other things.

It could get stronger, leading to a ***Big Rip*** with atoms and the very fabric of space being pulled apart (most physicists think this unlikely)

It could reverse sign and gravitate, leading to the recollapse of the Universe in a ***Big Crunch***.

Goal:

To understand how physicists are attempting to cope with the existence and nature of the acceleration of the Universe driven by Dark Energy.

Einstein's theory of the behavior of the Universe contained a "Cosmological Constant" that could be positive, negative, or zero.

Einstein first argued it was positive in order to provide an anti-gravitating force to counteract gravity to keep the Universe from expanding or contracting. Then the expansion of the Universe was discovered and he called it a "blunder."

Current results on the expansion are consistent with the Dark Energy behaving in accord with Einstein's Cosmological Constant.

Even if true, we still need to know what it is, physically! Why does this "constant" have the value it does? Sort of like asking why the speed of light has the value it does.

Theories of **quantum fields** suggest that the Dark Energy could or should vary with time and space.

One theory called "quintessence" (the fifth essence, after the Greek earth, air, fire, and water) would have that property.

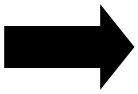
Other theories call for interaction with other 3D Universes "elsewhere" in hyperspace.

The race is on to determine whether the Dark Energy is constant (Einstein's cosmological constant) or not (some quantum field).

Texas astronomers will be doing the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) starting next winter for three years to try to answer this question.

One Minute Exam

As an explanation for the Dark Energy, a quantum field would be different from Einstein's Cosmological Constant because a quantum field would


Be constant in space


Vary in time


Gravitate


Anti-gravitate

Goal:

To understand why we need a new theory of Quantum Gravity and the ideas involved in the attempt to construct that theory.

Quantum Gravity - The Final Frontier

The remainder of the class will be spent exploring various aspects of the most fundamental issue of modern physics: reconciling ***Einstein's theory of gravity*** as curved space with the ***quantum theory*** of how things behave at a fundamental microscopic level.

The problem - each of these great theories of 20th century physics contradict one another at a fundamental level.

Einstein's theory predicts ***singularities*** at the beginning of the Big Bang and in the centers of black holes where matter is crushed to a point with infinite density, time and space come to a halt. Quantum theory says the position of nothing, not even a singularity, can be specified exactly (the Uncertainty Principle applied to singularities).

Quantum theory is designed to work in flat, or gently curving space. It does not make sense when the curvature of space is tighter than the "wavelength," the uncertainty in position, of a particle.

Each great theory of 20th century physics contradicts the other!

Can use current theories to "predict" the conditions for which the theoretical collision occurs, where the theory of quantum gravity is most crucially needed, effectively the **scale of length where quantum uncertainty and space-time curvature are equal**.

Planck length - about 10^{-33} centimeters, vastly smaller than any particle, but still not zero!

Planck density - about 10^{93} grams/cubic centimeter, huge, but not infinite!

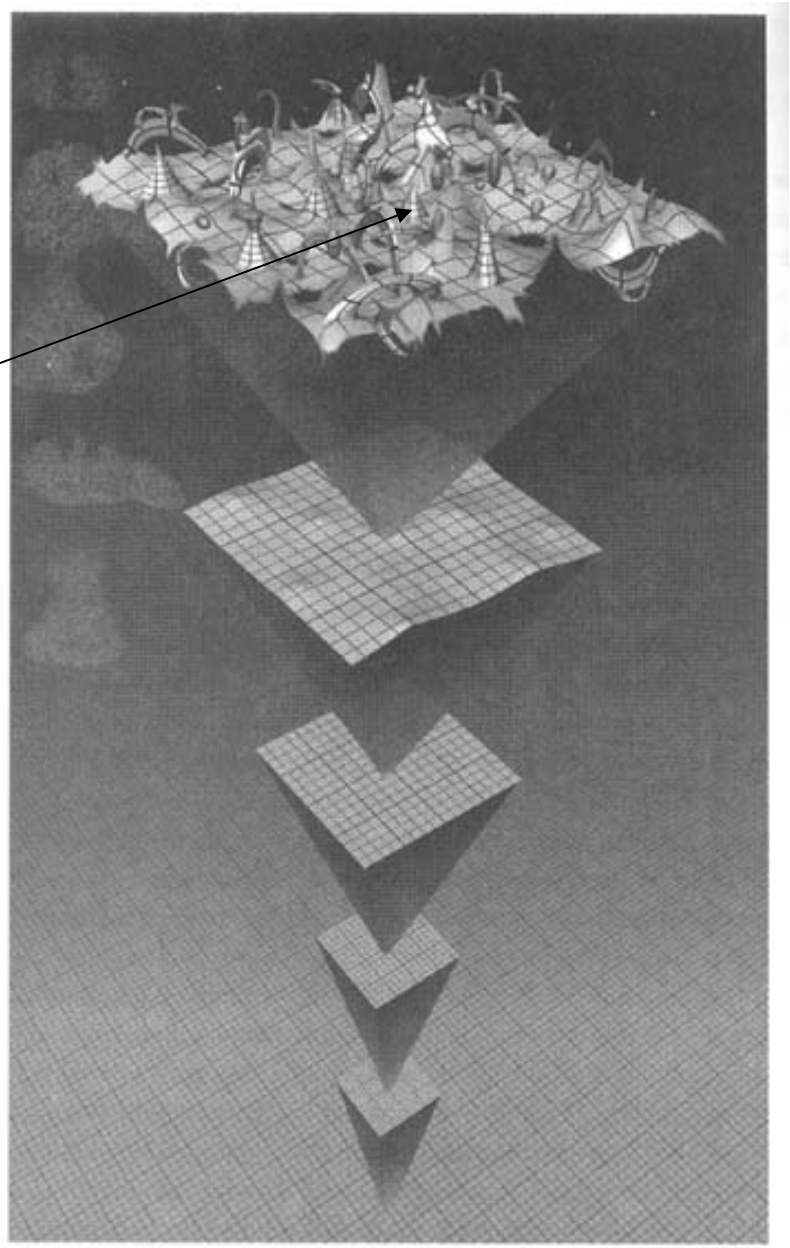
Planck time - about 10^{-43} seconds, short, but not zero! Cannot predict earlier times in the Big Bang.

On the Planck scale, not just that the position of things would be uncertain in space, but that space and time themselves could be quantum uncertain, "up" "down" "before" "after" difficult if not impossible to define.

Spacetime becomes a "quantum foam" (a poetic concept without a mathematical/physical framework).

Quantum Foam

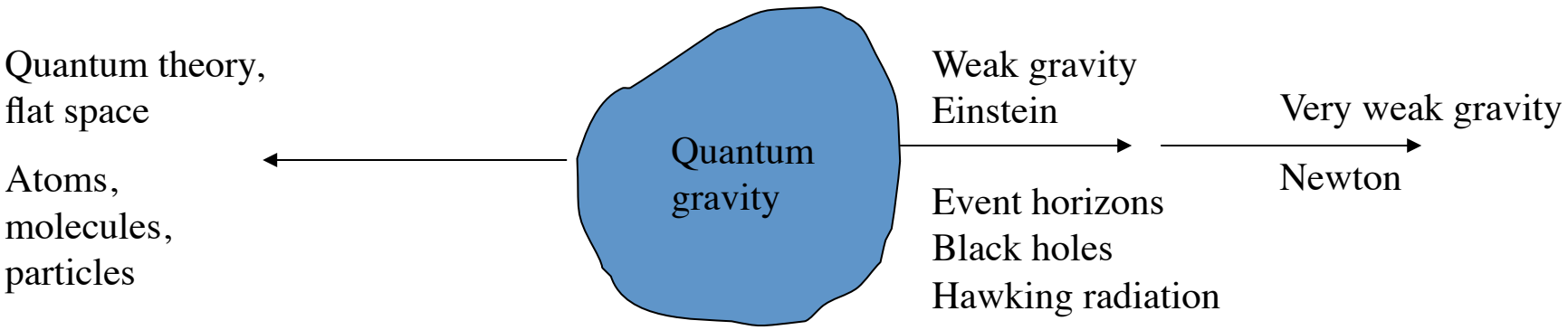
At the Planck length scale



From Brian Greene

The Elegant Universe

We need an embracing theory of ***quantum gravity*** that will reduce to ordinary gravity and ordinary quantum theory where they work well (away from singularities and with non-severe curvature - same thing!), but will also tell us what a "singularity" really is.

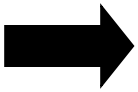


The world of the small

The world of the large

One Minute Exam

In a theory of quantum gravity, the singularity in a black hole would have a density of



infinity

about 10^{93} grams/cubic centimeter

about 10^{-33} grams/cubic centimeter

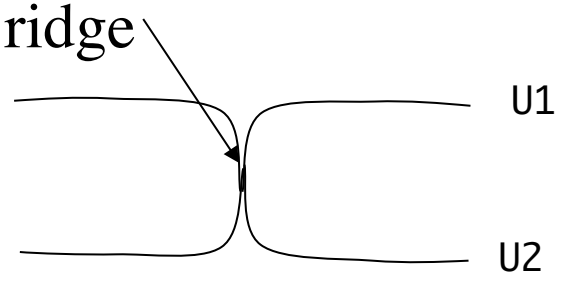
about 10^{-43} grams/cubic centimeter

Goal:

To understand how Einstein's theory predicts worm holes and time machines and how we need a theory of quantum gravity to understand if those are really possible.

Backstory: Sagan/Thorne CONTACT

Sagan wanted "connection" through Einstein-Rosen Bridge



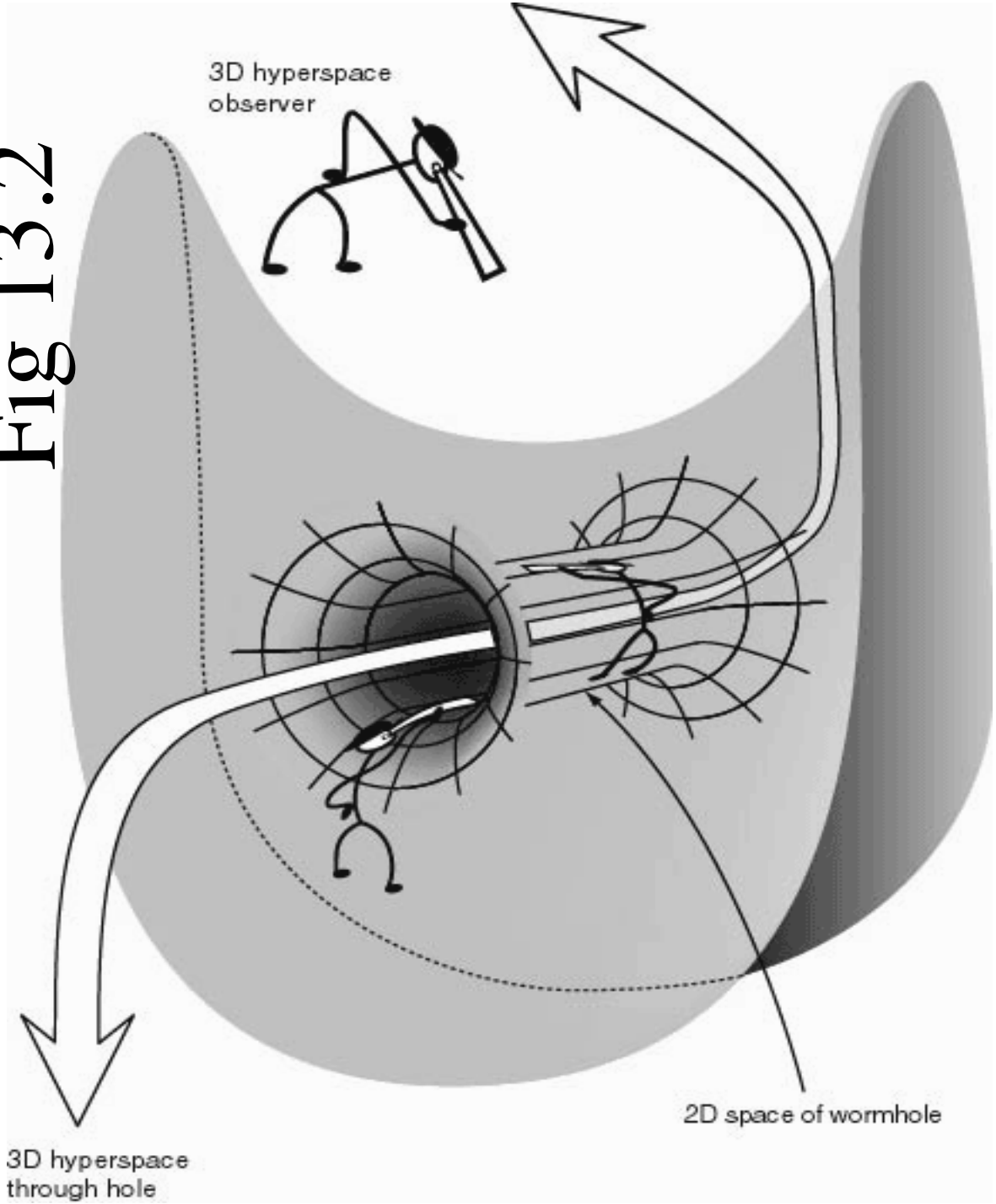
Thorne - Jodie Foster will die a screaming death by noodleization in singularity - no good. He worked out a new theory.

Could open a "mouth" to make a worm hole, strongly curved space but **no singularity**, but would be unstable, would slam shut.
In principle, could stabilize with "Exotic Matter," anti-gravity stuff like Dark Energy.
Not ruled out by physics - good enough for Sagan, book and film

Discussion Point:

What would it look like to go into a worm hole?

Fig 13.2



2D Analogy - Embedding Diagram

Can go "through" wormhole, but also once deep inside can turn "sideways," parallel propagate - return to point of origin

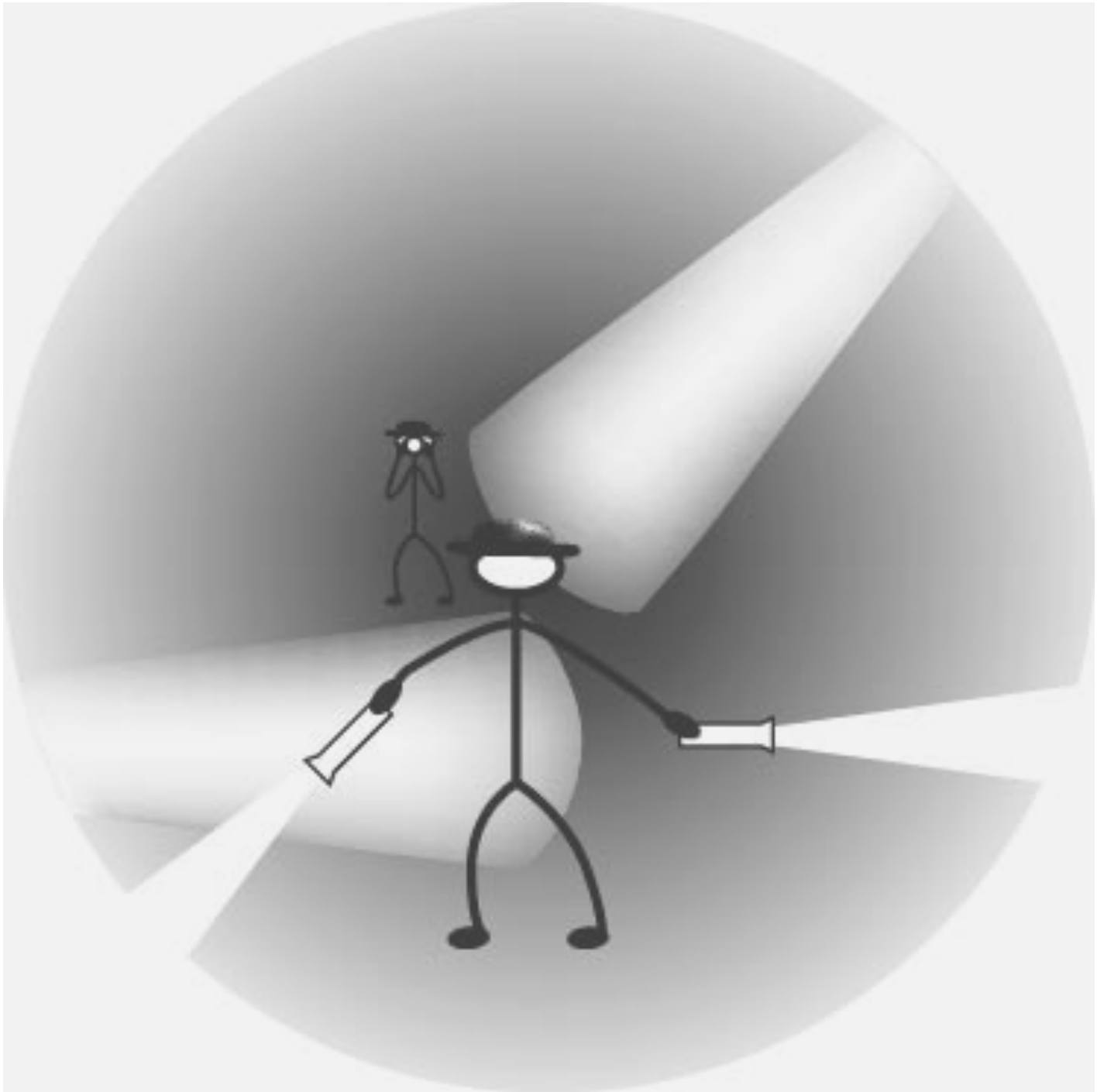
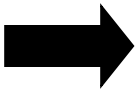


Figure 13.1

In principle, a light beam would travel "around" the interior of a worm hole. You could also see through the wormhole.

One Minute Exam

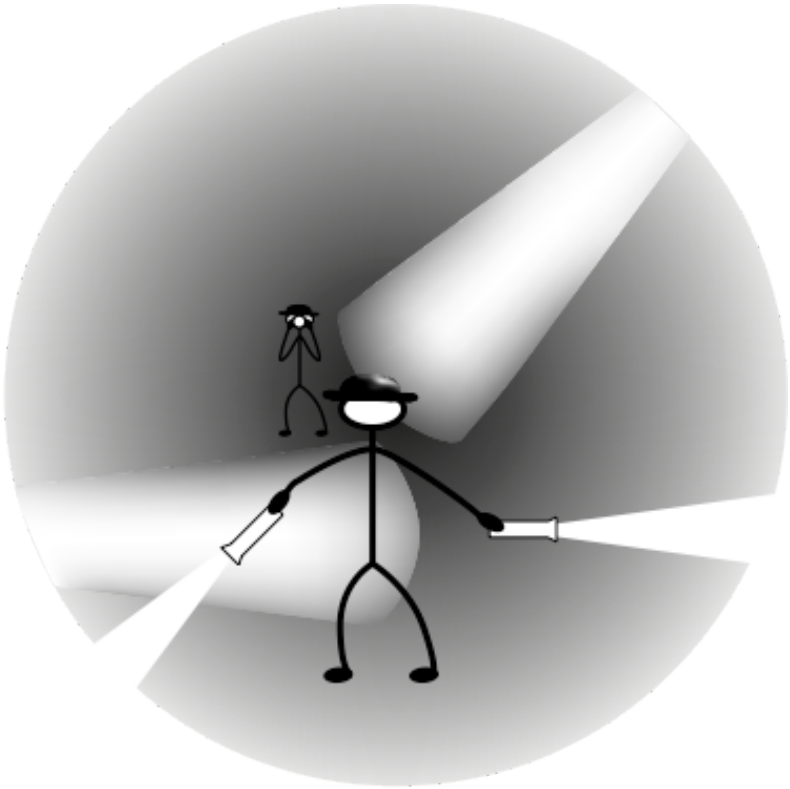
If I flew straight into a worm hole and once inside turned at 90 degrees and kept flying as straight as I could, I would

 Emerge from the other mouth of the worm hole

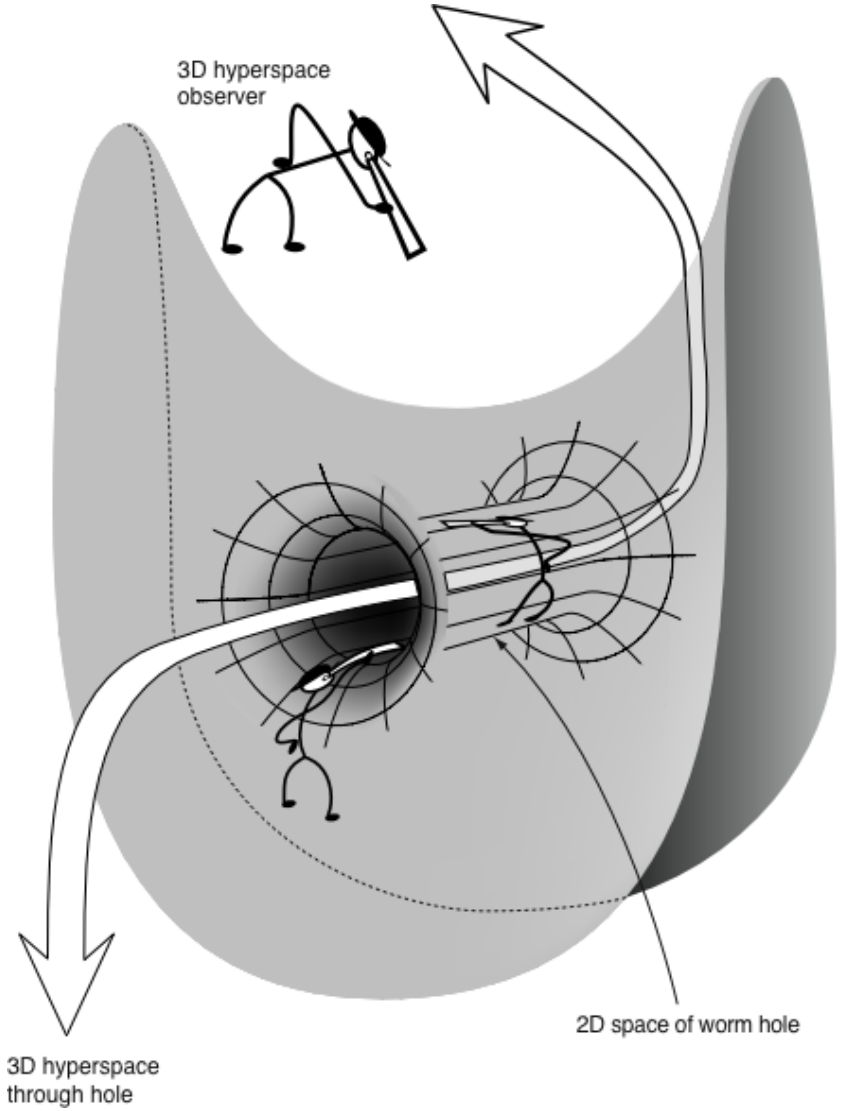
 Run into myself

 Be in hyperspace

 return to the point where I made the turn



The mouth of a worm hole would be a 3D “object,” the space inside highly curved.



Embedding diagram of a worm hole in an “open” universe

Do not confuse the “tunnel” through the middle of an embedding diagram representation of a worm hole (that is hyperspace!) with the tunnel-like aspect of the real three dimensional space.

Stargate - two dimensional “opening” not “realistic”