

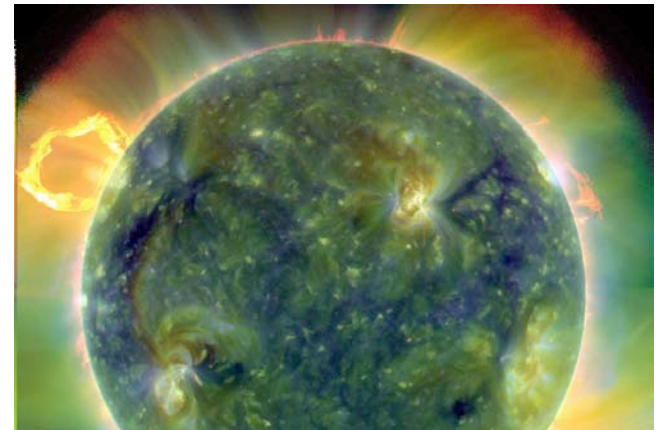
April 23, 2010

Reading - Chapter 13, 14

No office hours today, Manos doing his PhD qualifying exam.

Astronomy in the News? See picture of the day

Pic of the Day - Sun in the ultraviolet from the new Solar Dynamics Observatory.



## 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

 Gravitates

 Anti-gravitates

## 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

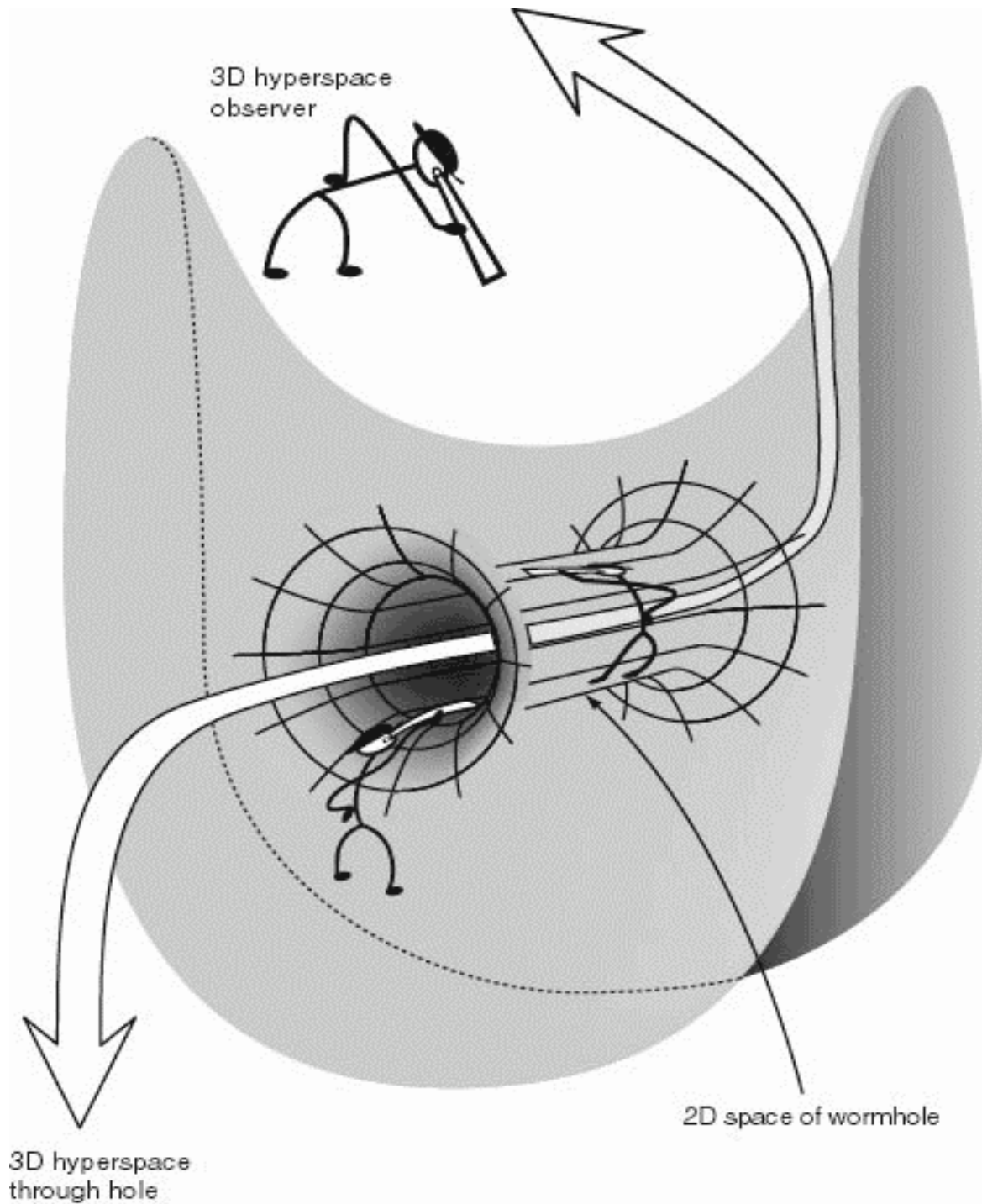
 about  $10^{-33}$  grams/cubic centimeter

 about  $10^{-43}$  grams/cubic centimeter

## 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

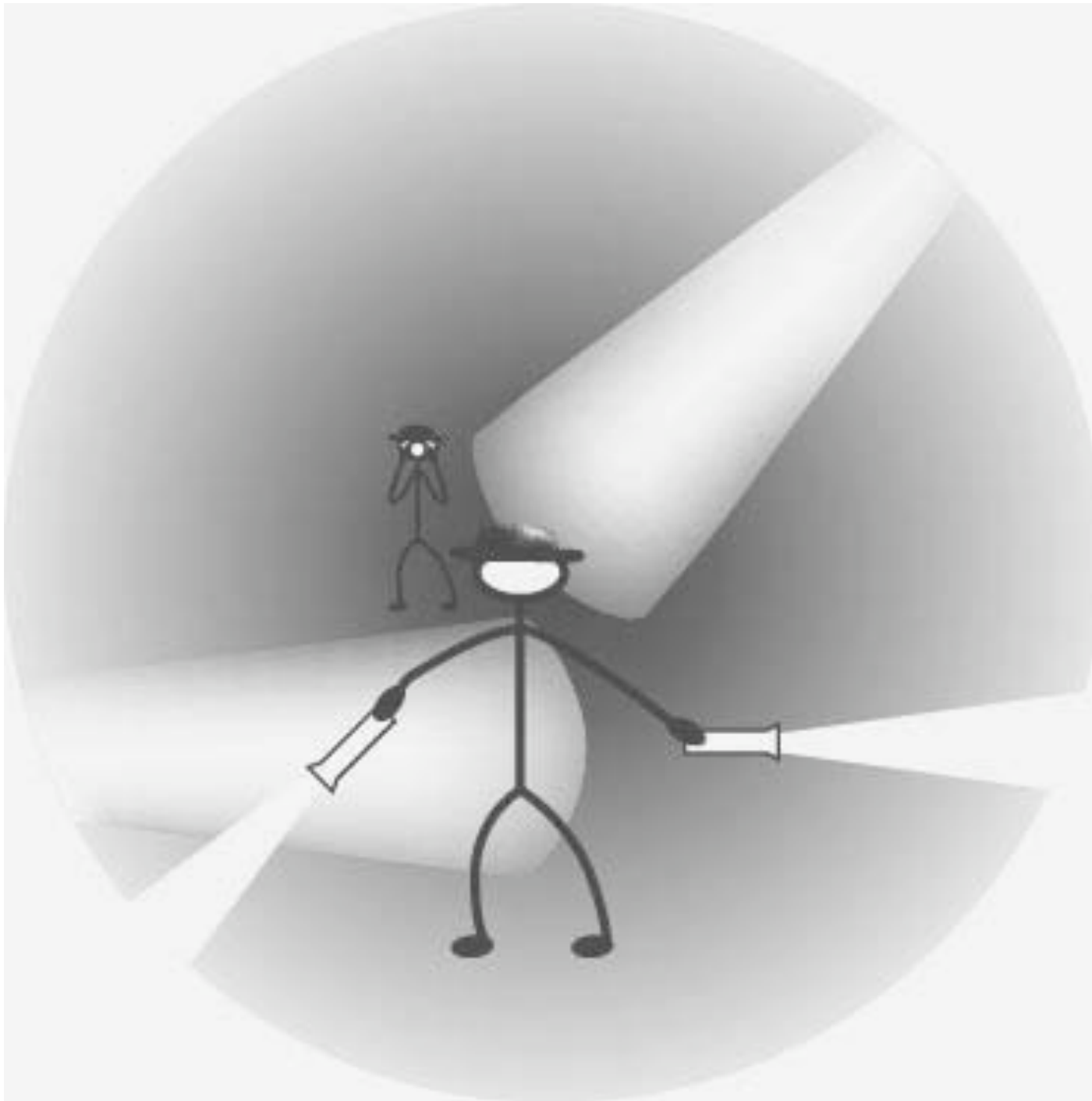


Figure 13.1


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

## One Minute Exam

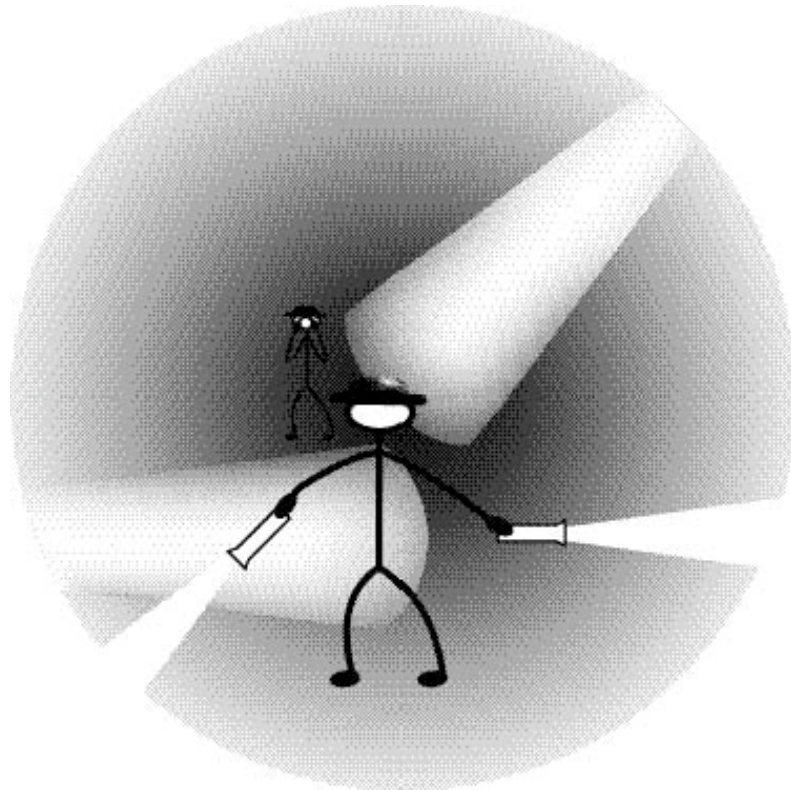
If I flew straight into a worm hole and once inside turned at 90 degrees and kept flying as straight as I could, I would

 Emerge from the other mouth of the worm hole

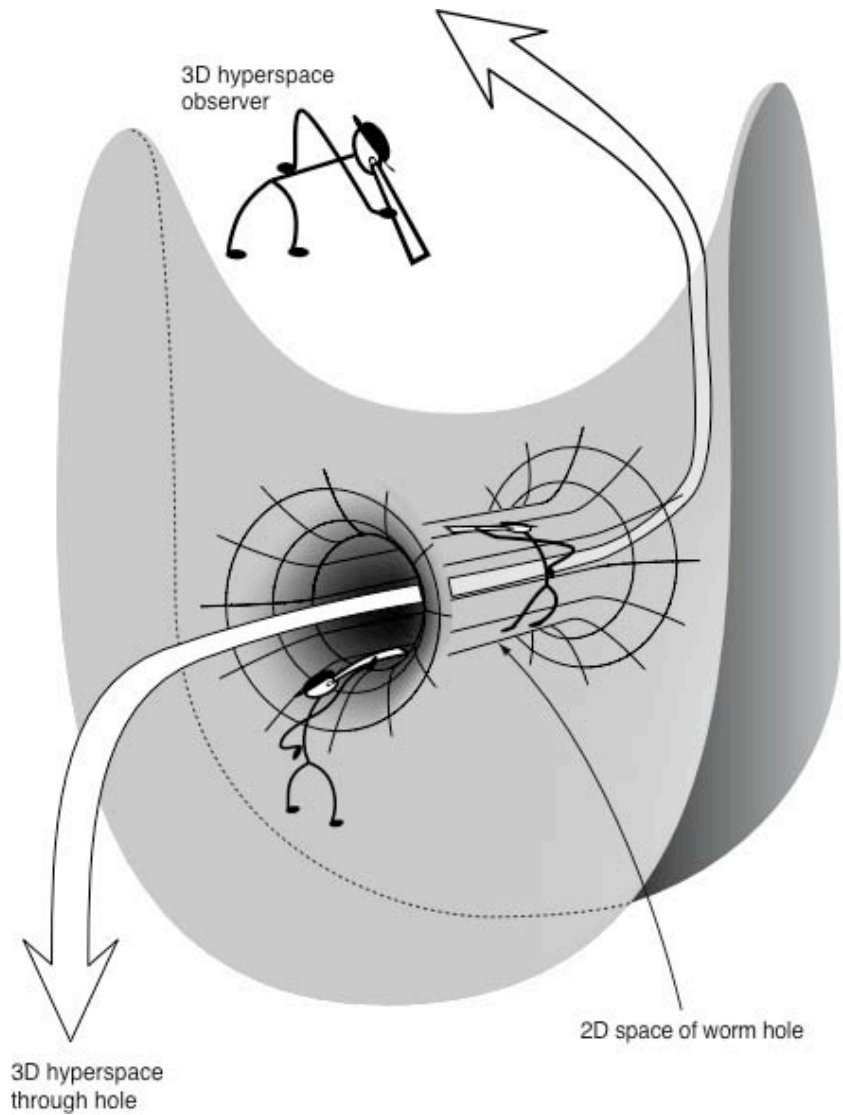
 Run into myself

 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”



Goal:

To understand how Einstein's theory predicts worm hole time machines.

Thorne went on to study worm holes (Thorne - Black Holes and Time Warps: Einstein's Outrageous Legacy)

*Worm holes are automatically time machines!*

Igor Novikov elaborated (Novikov - The River of Time)

Twin paradox - twin who accelerates out and back in space will be younger than the twin who stays behind (special relativity).

Do this (conceptually) with one mouth of a worm hole or lower one mouth into strong gravity where time runs slower.

Time “connects” differently through the wormhole and in the surrounding space - one mouth is “younger”

Thorne video

## Discussion Point:

What happens when you go into a worm hole time machine?

Can, in principle, travel back in time (but not before the time the machine is constructed)

Go in one mouth, come out in the past, go around in normal space, meet yourself before you go in.

Time travel paradoxes - Grandfather Paradox, Self-suicide

Pool Ball Paradox (purely mechanical, get people, intention, and will out of the analysis) - fire pool ball through time machine to deflect itself before it went in so could not have deflected

Novikov - there is no paradox - Physics always works out so that a paradox is avoided

Pool ball just nicks, Grandfather ducks.