

11/22/04

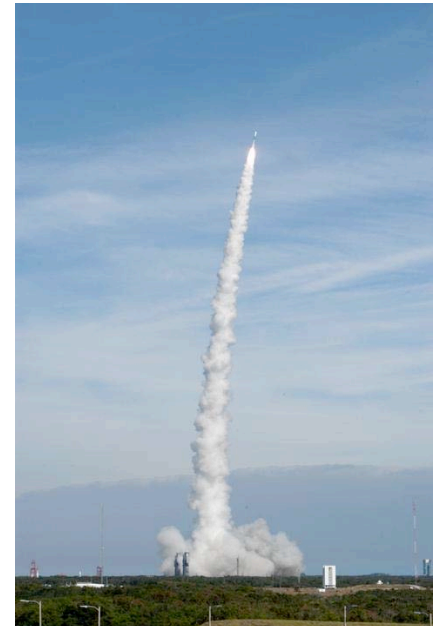
Test 4 back Wednesday

Film on Wednesday: Worm Holes and Time Machines

News? Swift gamma-ray burst satellite successfully launched Saturday (brief delay to replace fail-safe destruction button, flown in from California).

Dark energy under aggressive study (Maryland meeting Tuesday), NASA in turmoil adjusting to Presidents Exploration Initiative to go to Mars (California meeting, Wed - Fri)

Pic of the day: Swift headed for orbit!



Final - Saturday, December 11, 7:00 PM

Extra credit sky-watch reports are due by 5 PM on Monday, December 6. Crummy weather is part of the game for astronomers!

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 smaller than the “wavelength,” the uncertainty in position, of a particle.

Can use current theories to “predict” where 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!

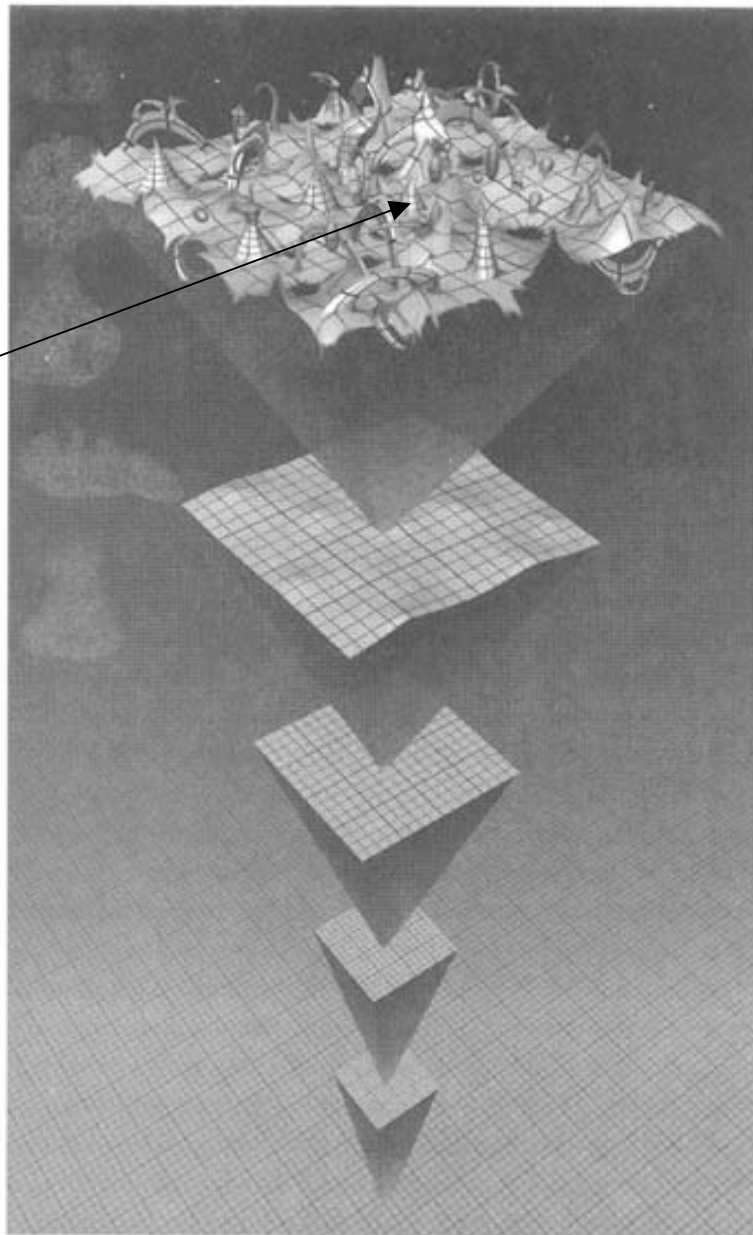
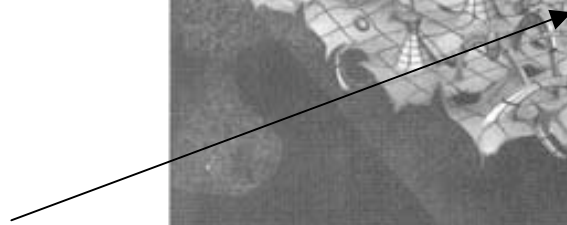
Planck density - about 10^{93} grams/cubic centimeter, huge, but not infinite!

On the Planck scale, space and time themselves would be quantum uncertain, “up” “down” “before” “after” difficult if not impossible to define

Spacetime becomes a “quantum foam” (a poetic concept without yet a mathematical/physical framework, need quantum gravity to say what quantum foam is).

Quantum Foam

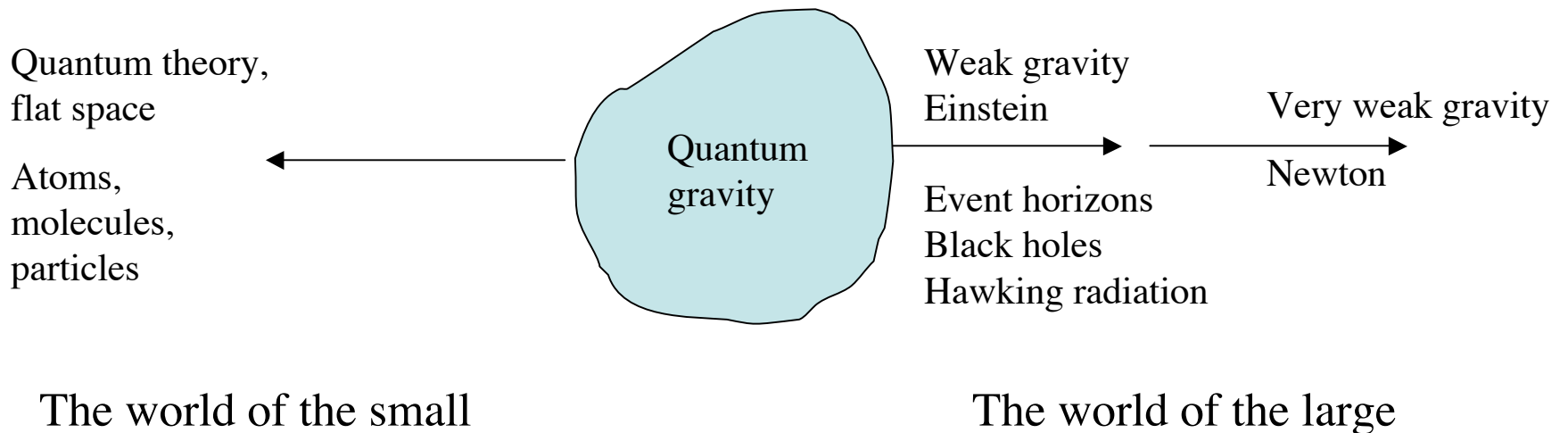
At the Planck length scale



From Brian Green

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.



Wormholes & Time Machine

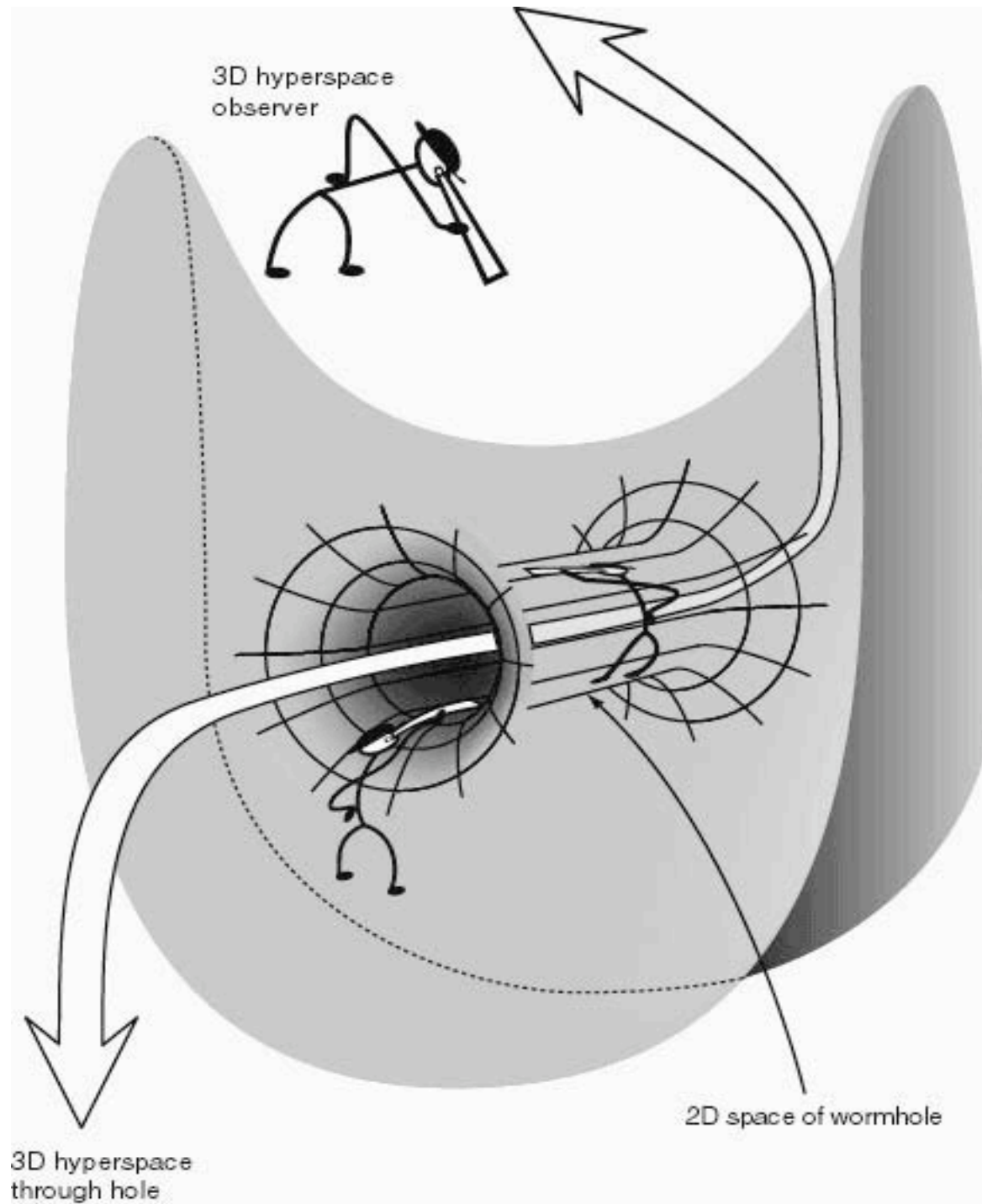
Serious physics lesson - leads to need for quantum gravity

Wormhole - connection from one place in 3D space to another
(through hyperspace? Do not need to know to reconstruct 3D solution)

Result - highly curved space, but no event horizon, no singularity
(Thorne diagram)

Use 2D Embedding Diagram to help picture what is going on in 3D space **balloon (but can't connect)**

Fig 12.2



2D Analogy - Embedding Diagram

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

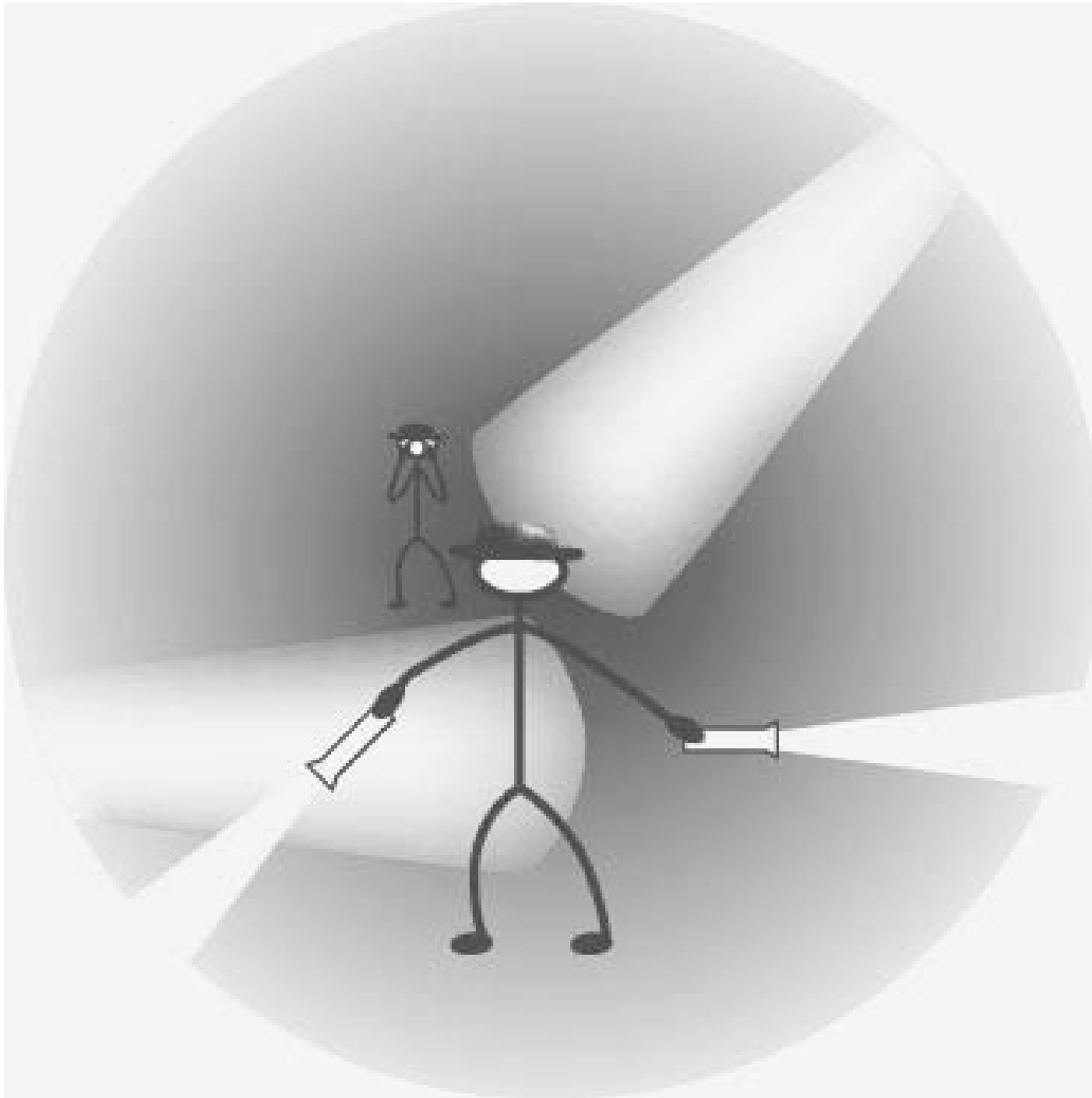


Figure 12.1

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

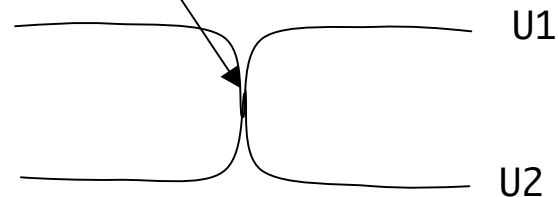
Do not confuse the “tunnel” through the middle of an embedding diagram representation of a worm hole (that is hyperspace!) with the tunnel-like aspect of the real three dimensional space.

Stargate



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



Could open mouth to make worm hole, 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 and film

Thorne & Co. went on to study (Thorne - Black Holes and Time Warps: Einstein's Outrageous Legacy)

Worm holes are automatically time machines!

Igor Novikov elaborated

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”