Telescopes give us a view back in time

Relativistic space travel takes us rapidly forward in time

Administrivia...

Creative Projects are due today!

Readiness question(s):

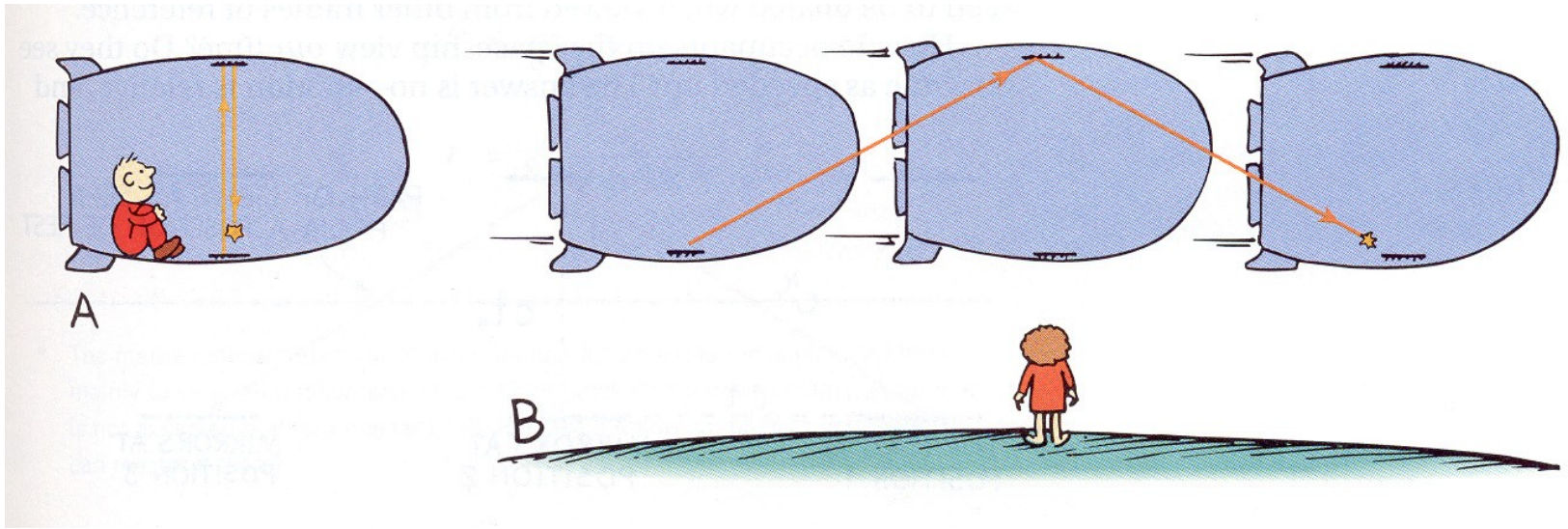
The first seriously considered (viable) craft for interstellar travel was called **what,** and in a sentence, how does it work?

Time Dilation, quantified a little bit

For the speedy traveler, time is stretched by the Lorentz factor, denoted by the greek letter 'gamma'.

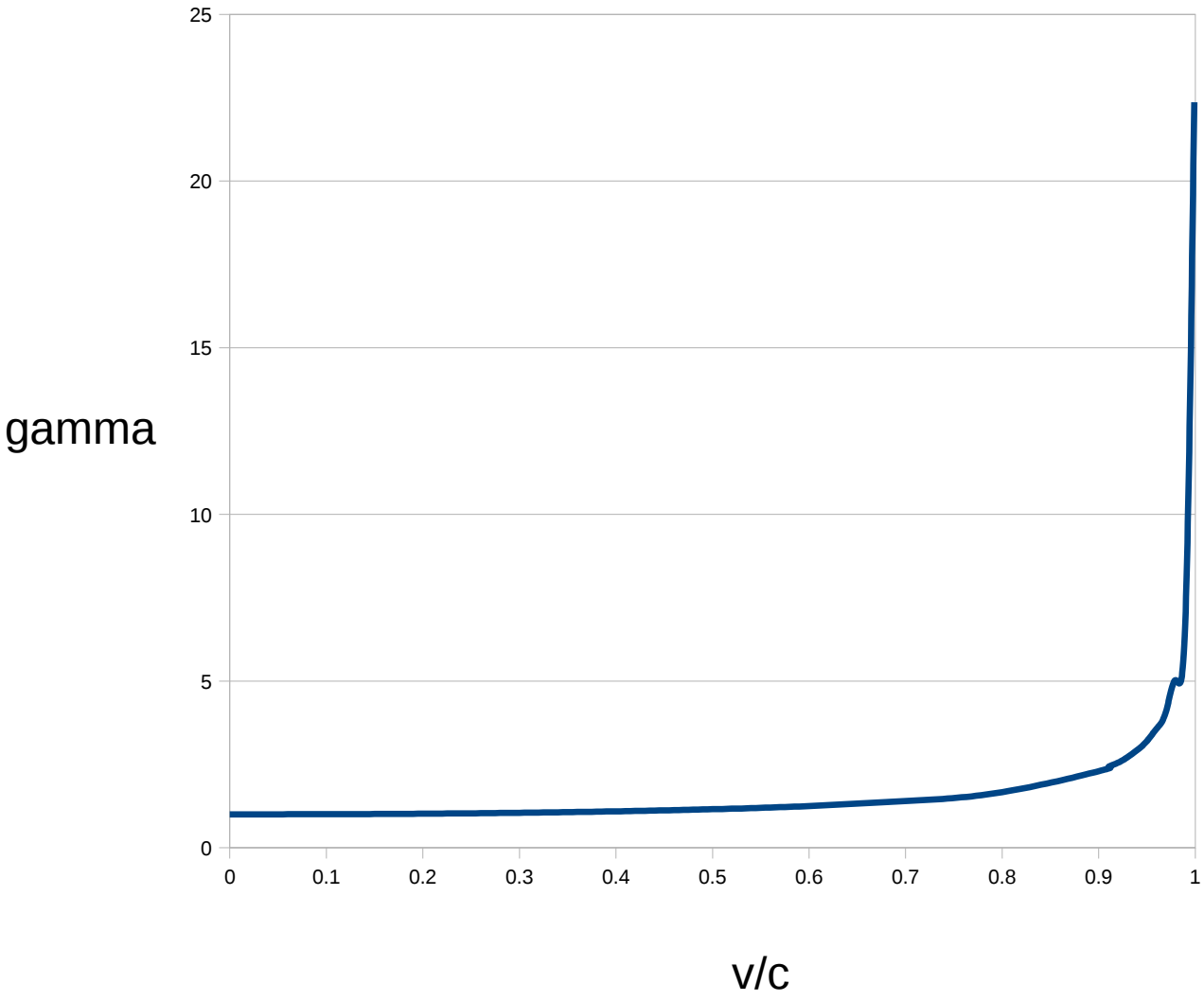
It's possible to derive it from the picture below (from the last class).

$$t = \gamma\, t_0 \quad , \quad \gamma \equiv \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$



How time dilation depends on velocity (relative to the speed of light)

v/c	gamma
0	1
0.1	1.01
0.3	1.05
0.5	1.15
0.7	1.4
0.9	2.3
0.95	3.2
0.99	7.1
0.999	22.4



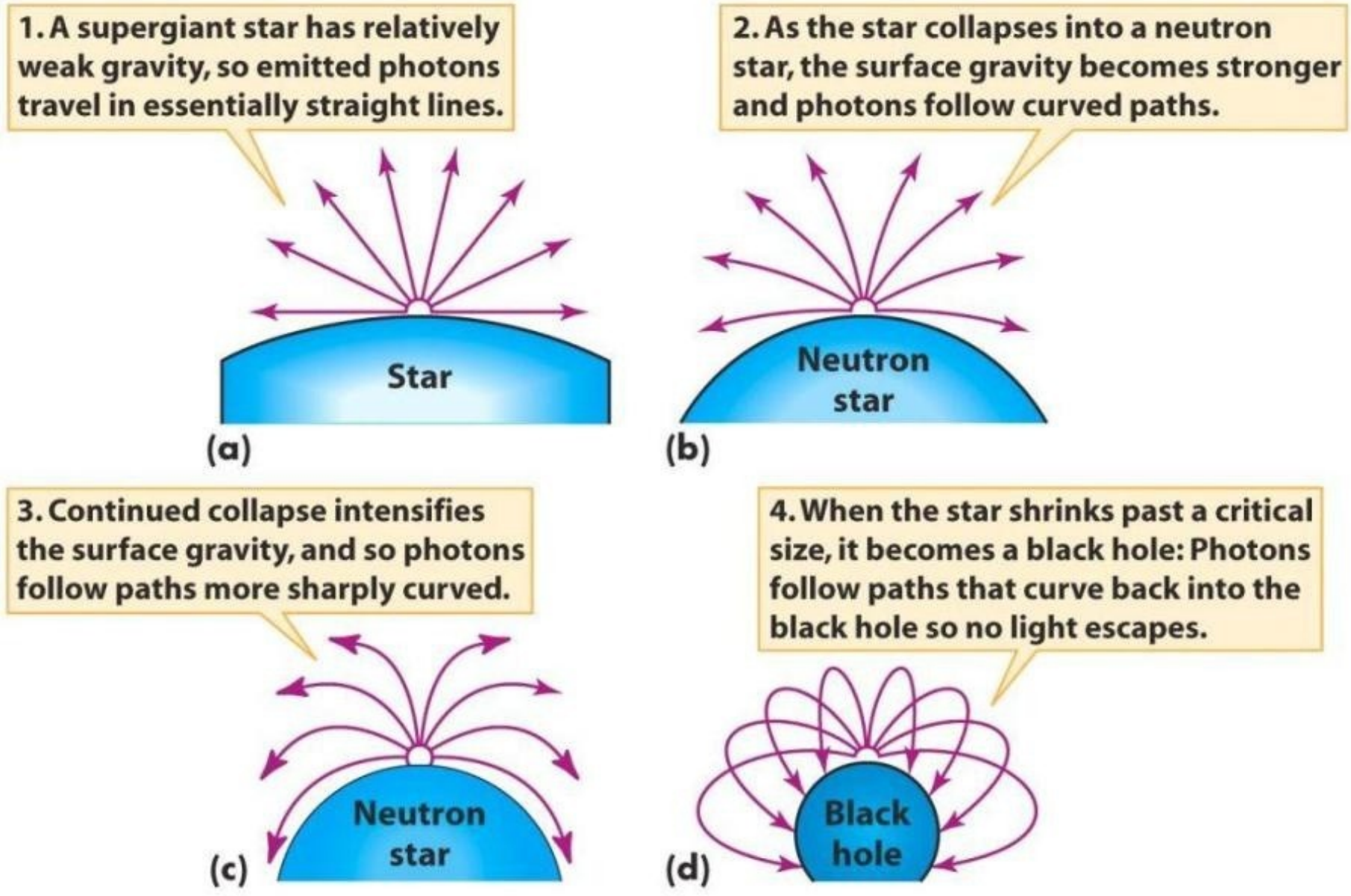
Traveling fast in space also means jumping forward in time...

Accelerating at 1g until the halfway mark, then decelerating to the destination, you could travel round-trip to...

Destination	**Traveler's watch**	**Earth time**
HR 8799	30 years	300 years
Center of Milky Way	50 years	60,000 years
Andromeda Galaxy	60 years	4,000,000 years
1 way to edge of observable universe	60 years	~14 billion years

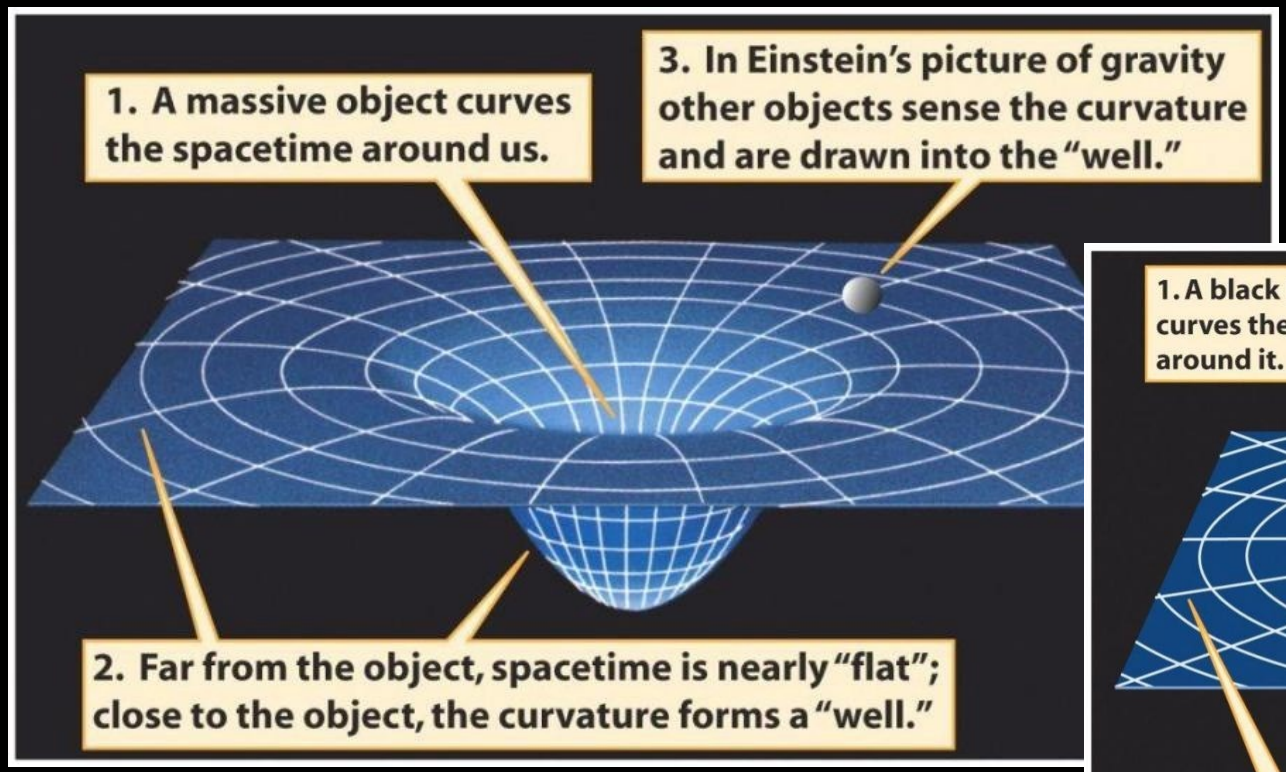
You can only travel forward in time, and only for the people making the interstellar journey! **Are there any shortcuts?**

Maybe. Look at photon paths around objects of same mass and increasing density.



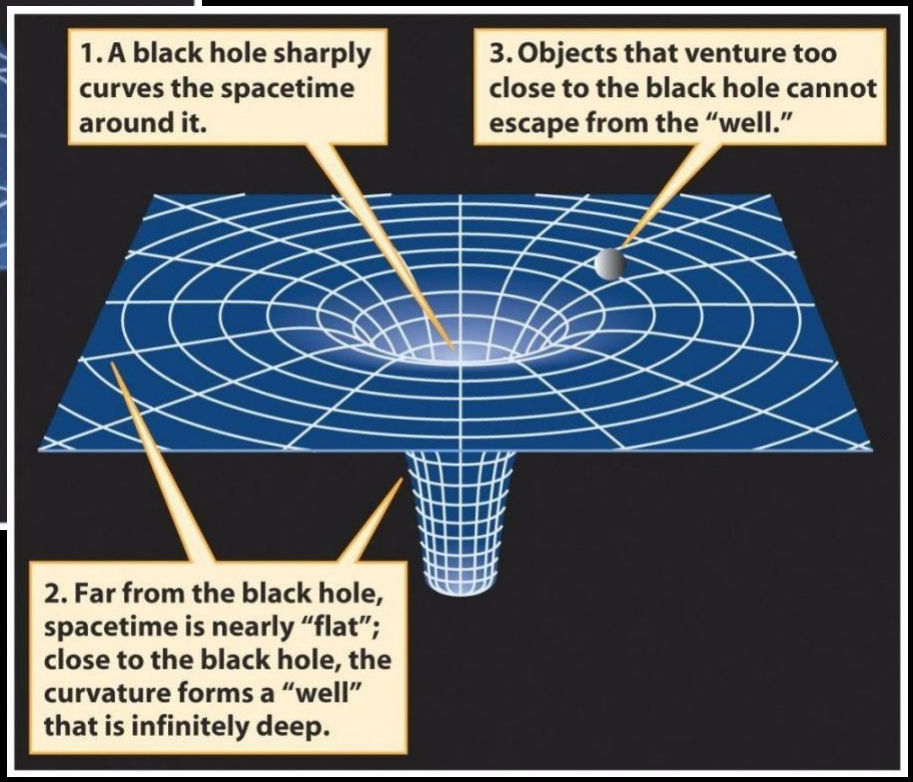
We can use curved 2-d surfaces to model curved 3-d space

The surfaces stand for the flat equatorial plane around a condensed object like a dense star or a black hole. Walking uphill (outwards) is analogous to moving radially outward from the dense object. Note that you walk a long way on the surface but the radius does not change very much. The usual formula of the circumference = 2 π R is wrong … the circumference is smaller than you expect. This is what we mean by "curved space."

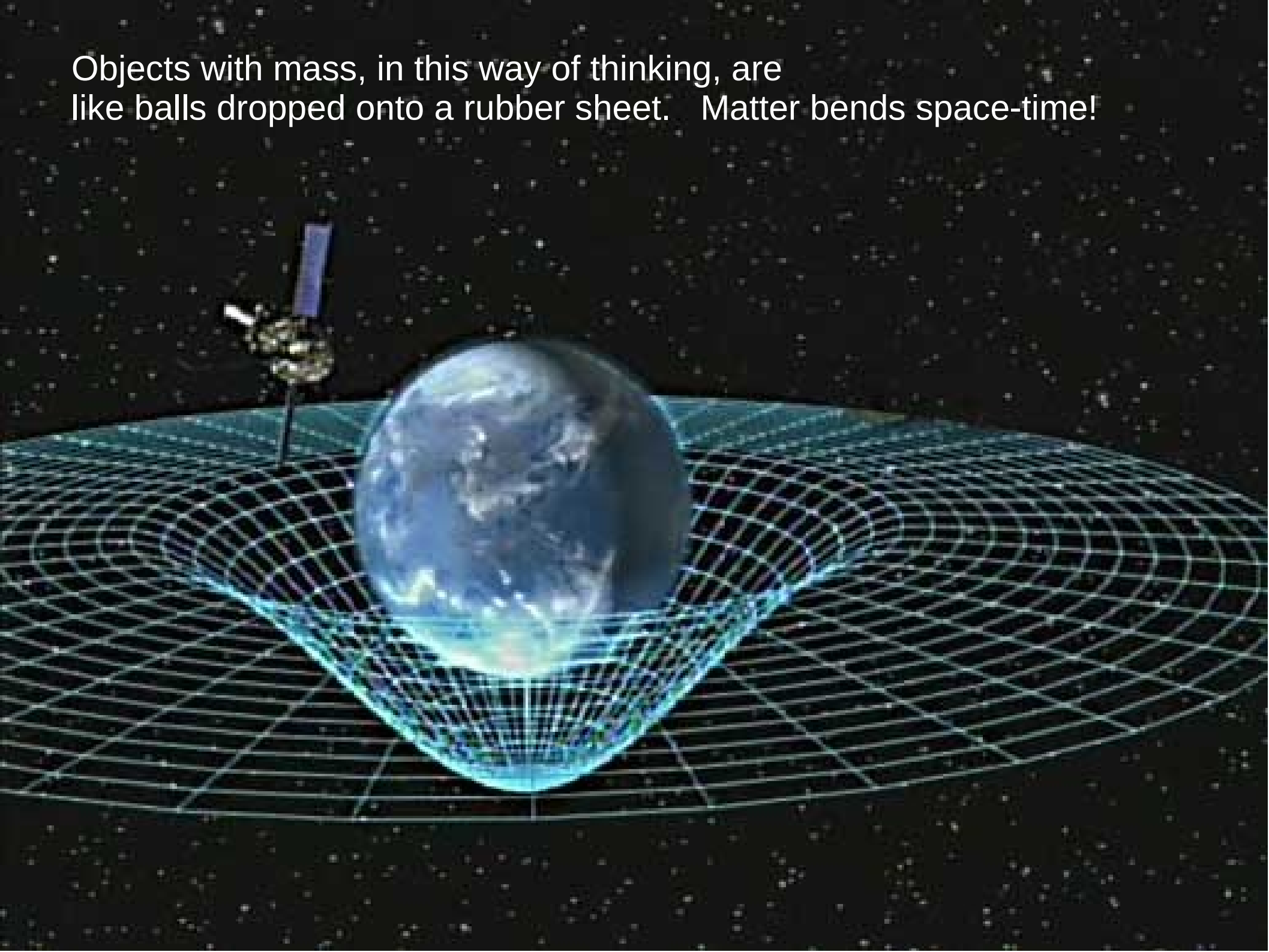


Spacetime near a dense star

Spacetime near a black hole



Objects with mass, in this way of thinking, are
like balls dropped onto a rubber sheet. Matter bends space-time!

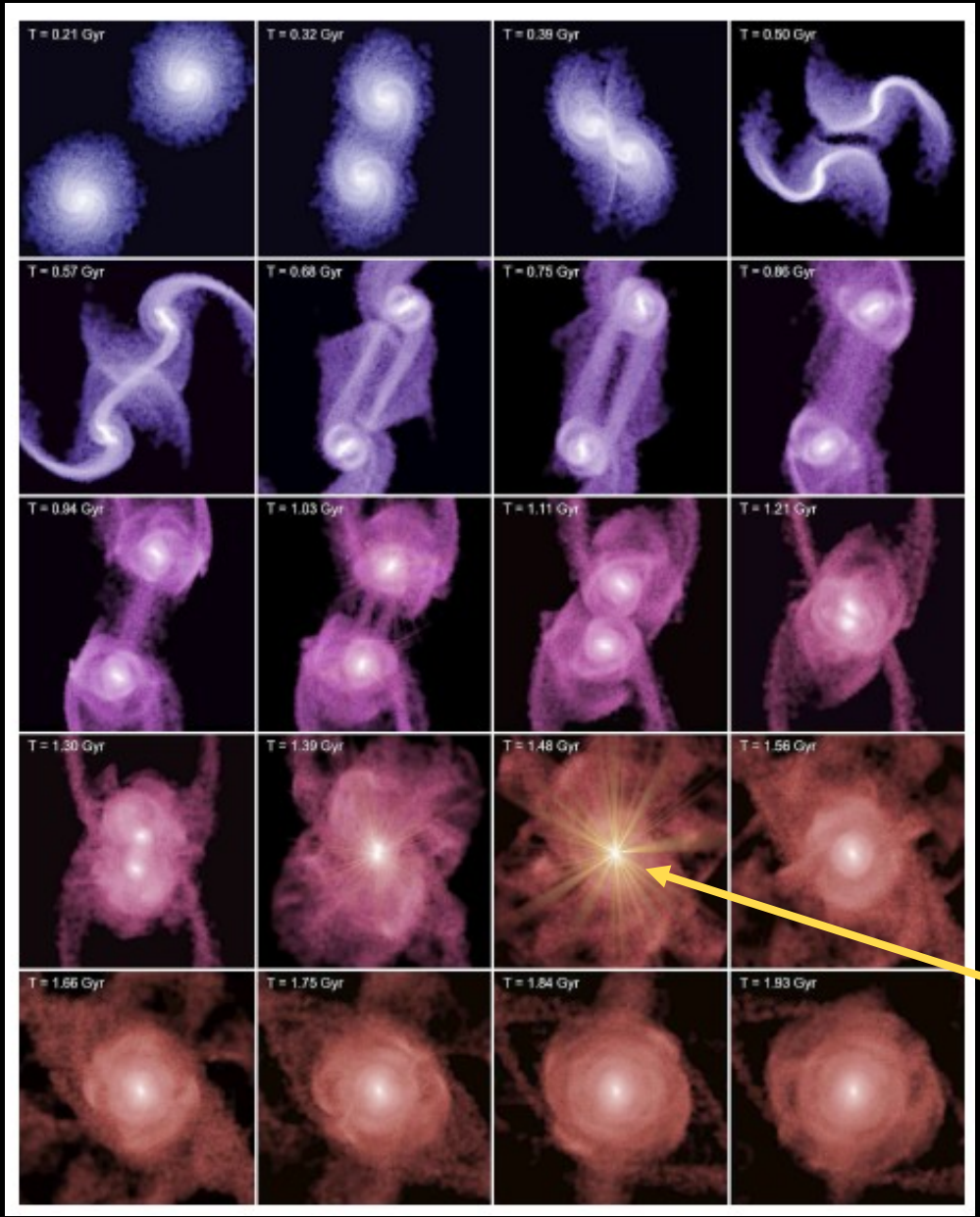


< show movie of falling into black hole, discussion of **tidal forces** around small black holes versus supermassive ones >

The centers of most galaxies host massive black holes

When gas falls onto BHs, they become brilliant **active galactic nuclei** and **quasars** which we can see across the Universe

BH's generated by galaxy collisions (*'quasar' mode)*



Sources of “feedback” during a merger:

• Gas is funneled into the central regions, fueling a starburst and creating a wind

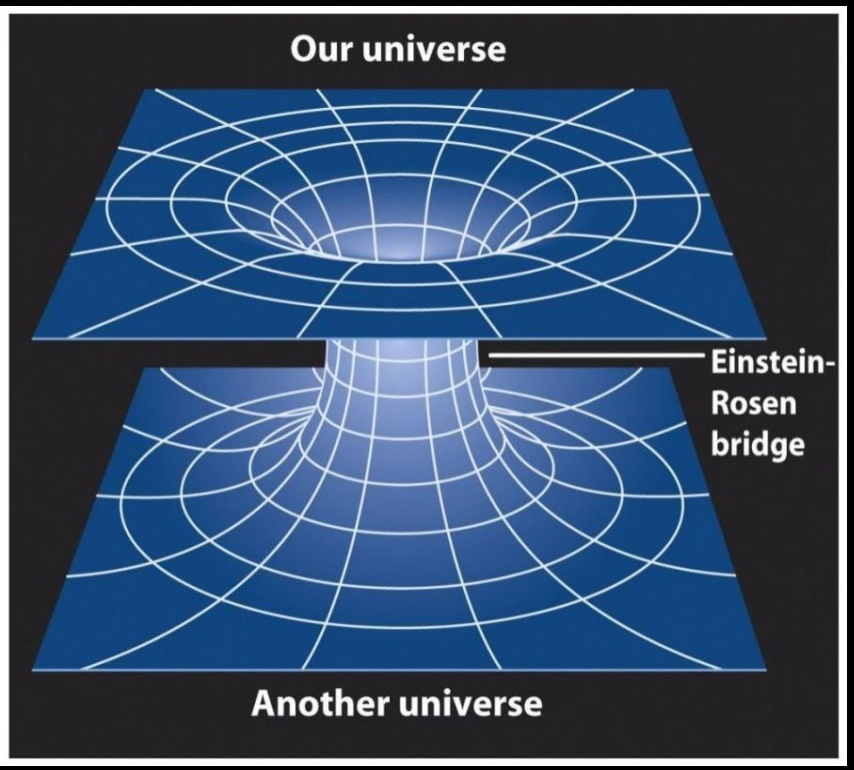
• Orbital kinetic energy is converted to heat in cloud-cloud collisions, which drives a wind

• Gas driven to the center fuels a black hole, creating a ***quasar*** whose feedback quenches further infall and star formation

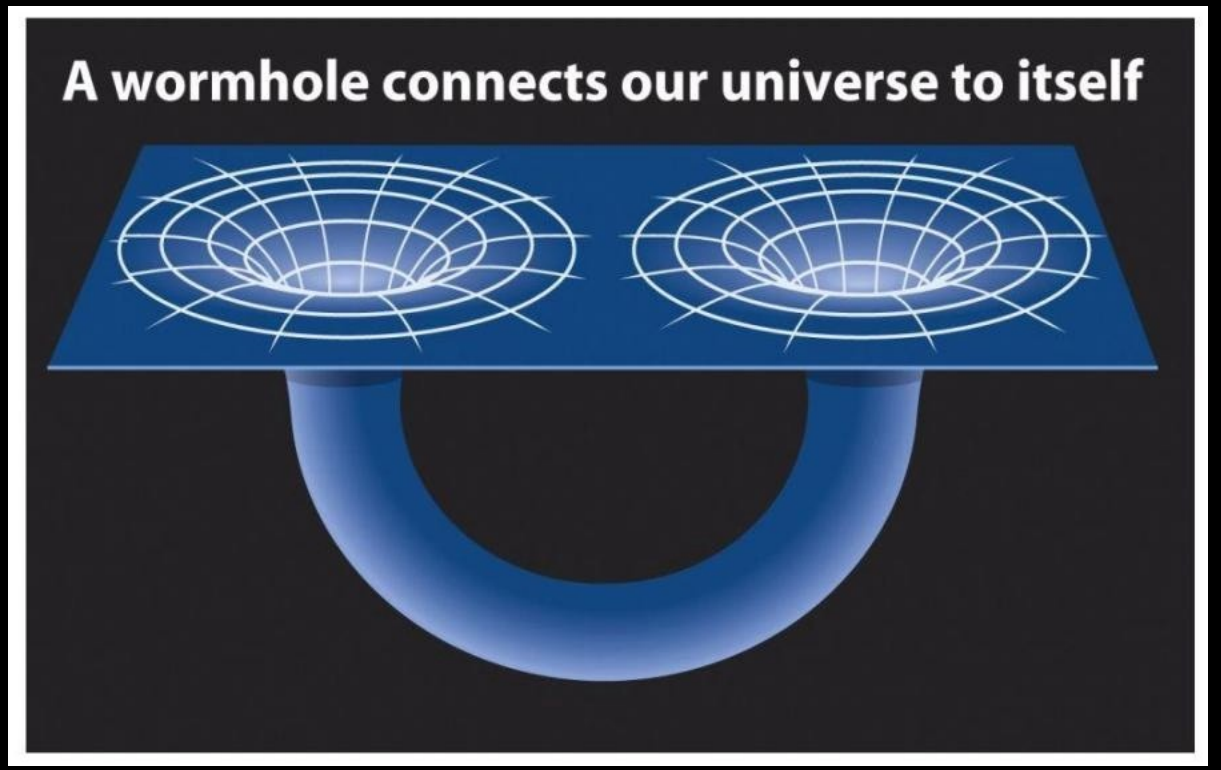
Wormholes

- Wormholes are solutions to the Einstein's general relativity equations that involve two singularities. A wormhole can be thought of as a special combination of two black holes.
- By special, we mean that the interiors of the two black holes are connected under some circumstances.
  - Remember how strongly warped space is, near and within a black hole horizon: a lot of space is contained therein, and if it weren’t so strongly curved it could reach a long way.
- A concrete example may show better what we mean …..

Wormholes are mathematical solutions to general relativity equations – that may not actually exist



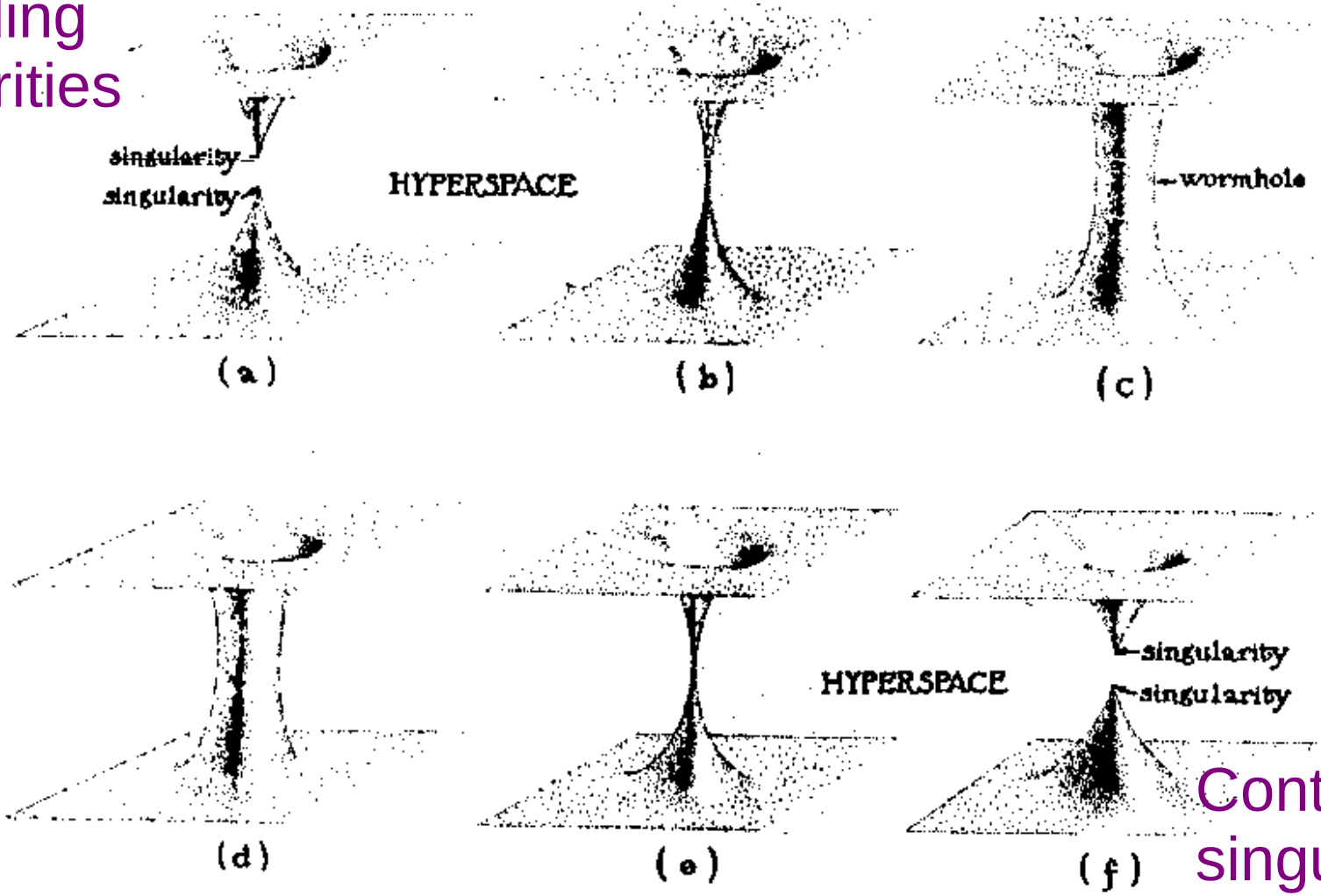
Wormhole connecting two universes



Wormhole connecting two spots in the same universe.

Construction and destruction of a wormhole.

Expanding singularities

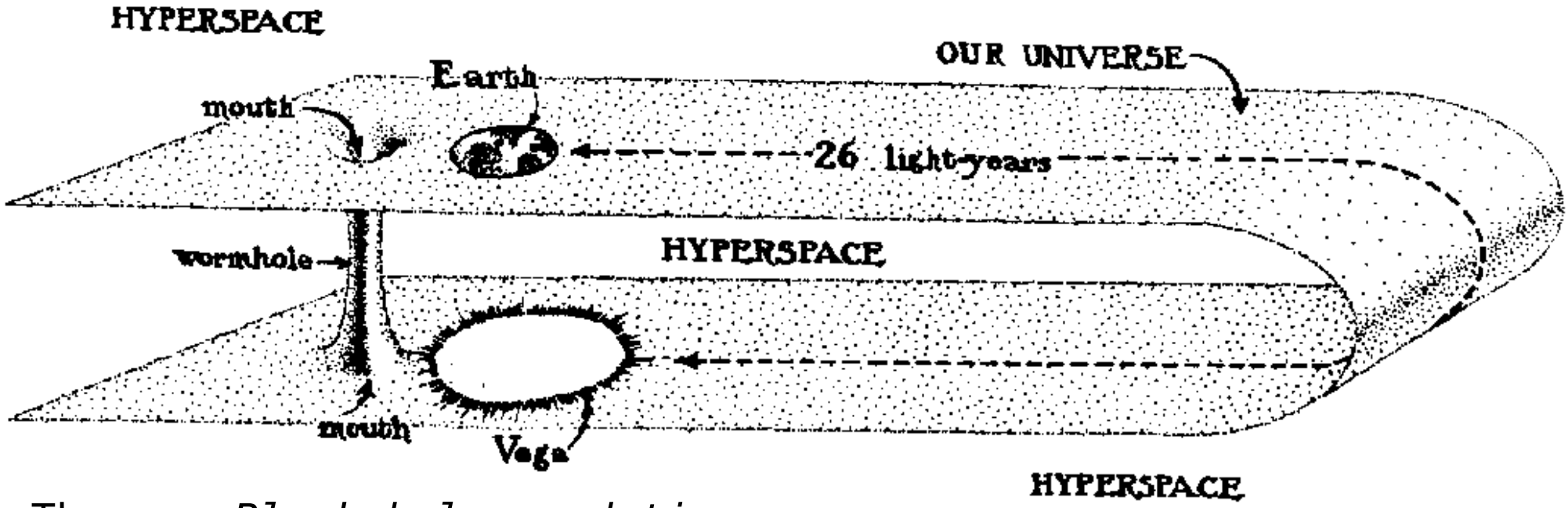


Contracting singularities

Figure from Thorne, *Black holes and time warps.*

A hyperspace shortcut *via* a wormhole.

- **Embedding diagram** of a wormhole with the properties described in Carl Sagan's novel *Contact*, that was used by the lead character, Ellie Arroway, to travel to the neighborhood of Vega and back in about eighteen hours.

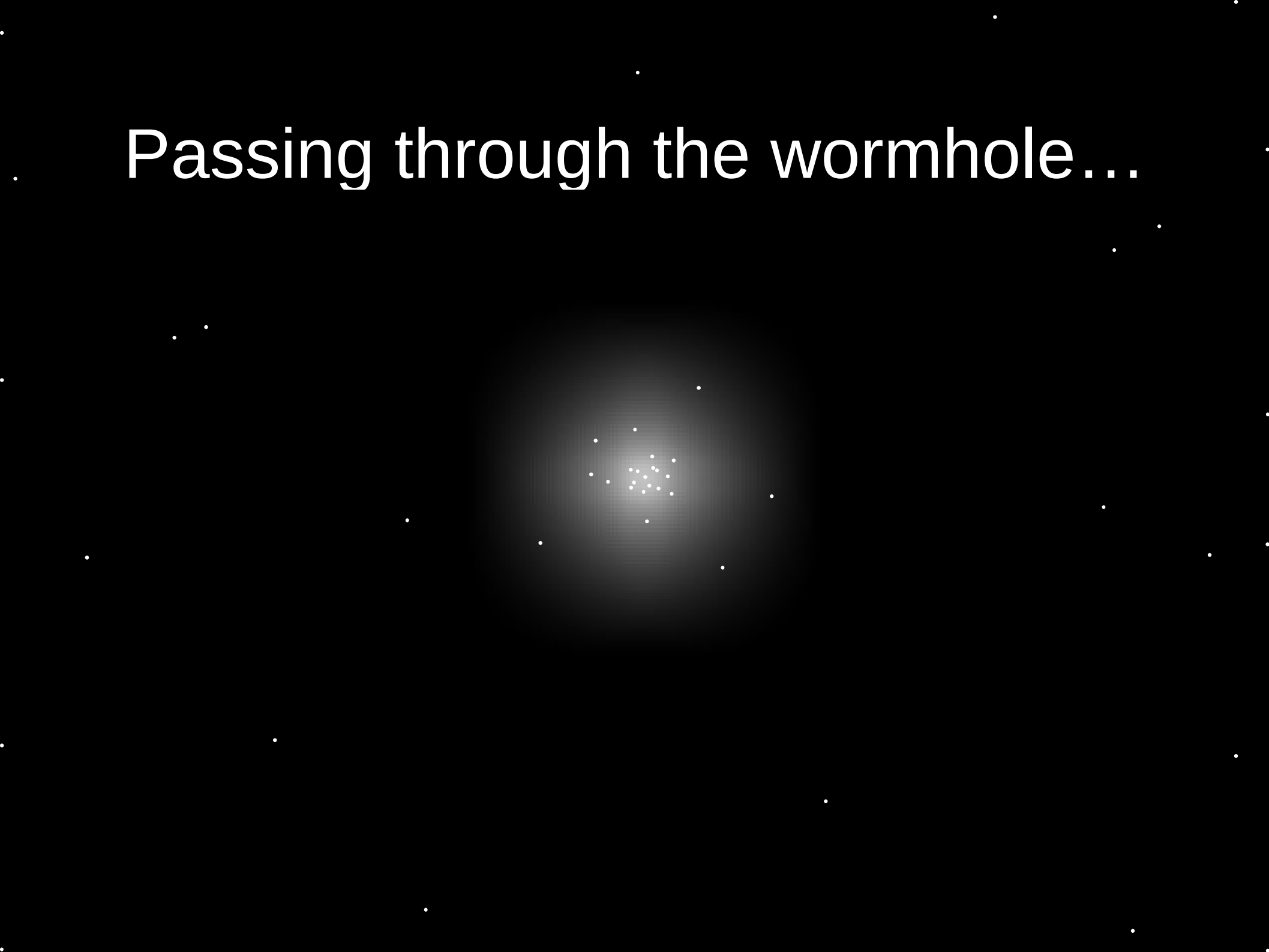


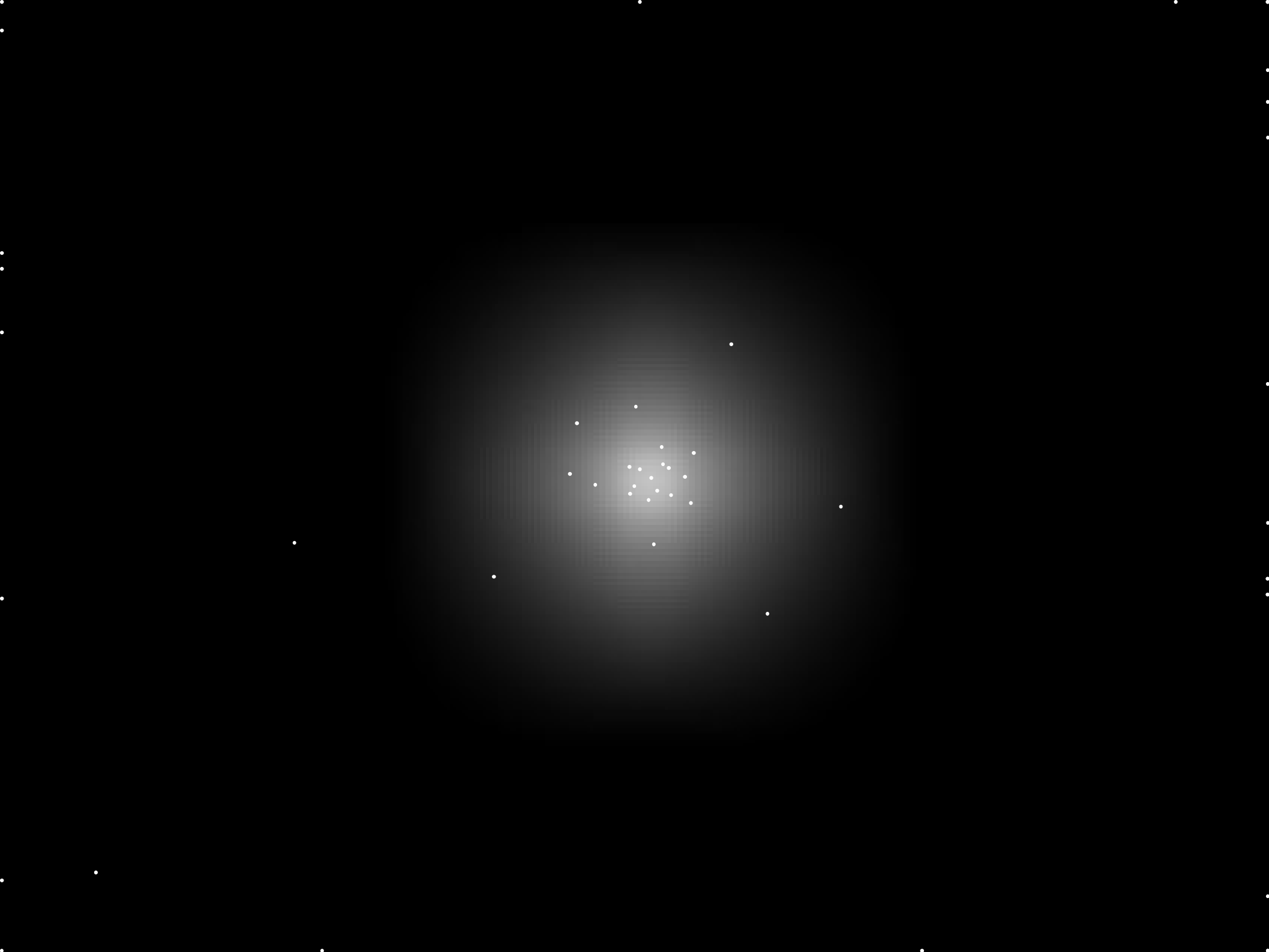
rom Thorne, *Black holes and time warps*

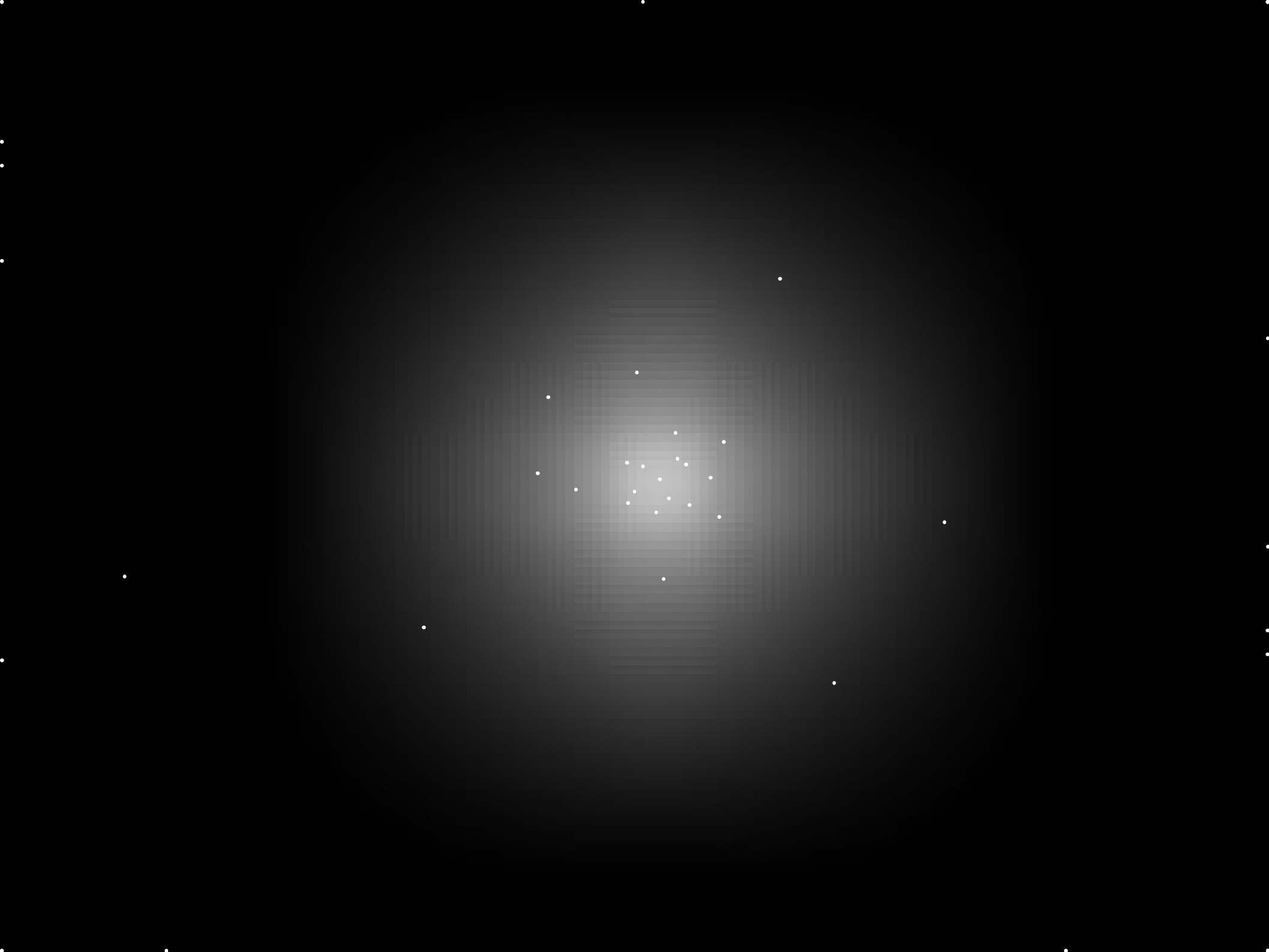
How an open wormhole might really look.

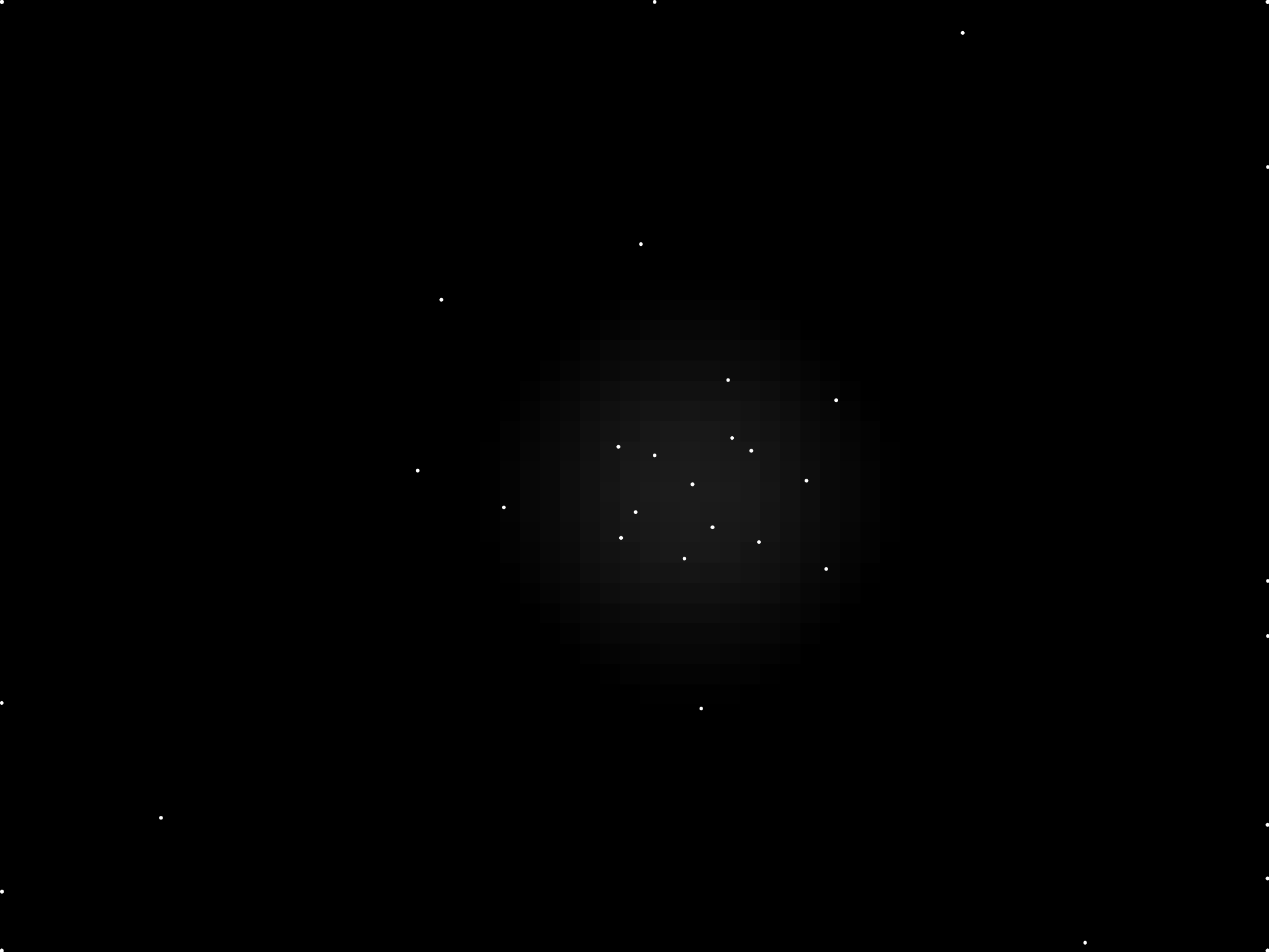
It’s spherical, and like a giant globe of the sky as seen from the *other* mouth.

Passing through the wormhole…









…and out the other side

In your rear-view mirror, you would now see a globe on which you see what was the *initial* rear view.

Use and abuse of wormholes.

- The down side: what happens if you try to enter the wormhole to employ the shortcut?
  - You are accelerated to relativistic speeds on your way through. As a result, your energy (and mass) increase dramatically, in the view of distant observers.
  - Your mass eventually becomes large enough, halfway through the wormhole, that your own gravity warps space-time, collapsing the wormhole onto you.
  - As your gravity “pinches off” the wormhole, singularities form again - but this time, they’re of the black hole type. Your energy is added to the black hole's, and the wormhole is destroyed. While you're in it. Hint: that's bad.

Use and abuse of wormholes.

- How could we prevent the collapse of the wormhole under your gravitational influence, so you could make it through unscratched?
  - By putting exotic matter into it. Exotic matter, with its negative energy density, would be “anti-gravity”: it would warp space-time in senses opposite to the way normal matter warps it.
  - In particular, adding exotic matter to a wormhole would tend to expand the diameter of its effective “hyperspace tunnel.”

Wormholes as time machines.

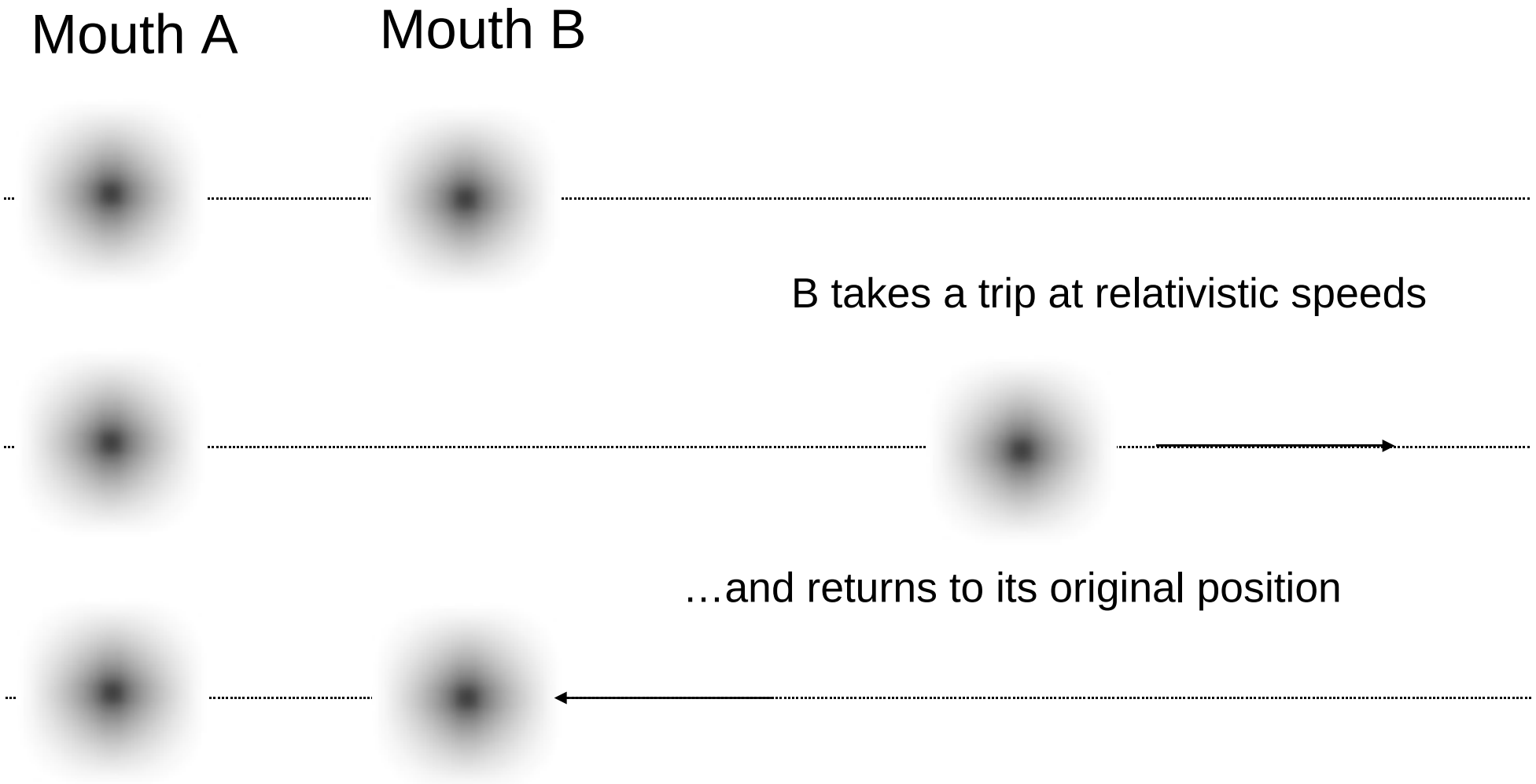
- How does time hook up inside a wormhole? Imagine a wormhole with **constant length in hyperspace**, but with the **two mouths moving with respect to each other in physical space**, with one of them experiencing acceleration.

  - Time dilation: clocks just outside the two mouths would appear to a distant observer to run at different speeds; the rates of time flow are different.

  - From the inside, though, the mouths appear at rest with respect to each other; the rates of time flow are the same.

  - This effect, the difference in time flows at the two mouths and the joining in the middle, could enable the use of a wormhole as a time machine, as follows…….

How to build a wormhole time machine.



Of course, this can create some really serious causal problems!

Maybe we should stick with the physics we know...

What would we do with a Project Daedalus-type spacecraft going 12% of *c*?

- Unmanned probes to stars w/in 100 l.y. of the Sun
- then Colonization ships
  - multi-generation ships, or need advanced medical facility to 'grow' people before arriving at the new world

Example: suppose we landed at a new world and set out again every 500 years to the next world, hopping from star to star

The human race would expand through the Galaxy at 0.016c! We'd reach the other side of the Galaxy in 5 million years, a mere blink of cosmic time...

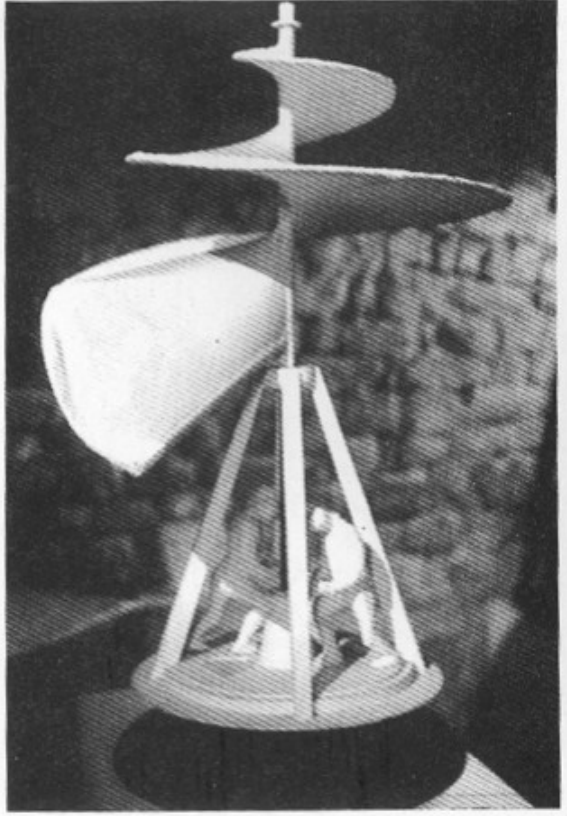
So where are they?

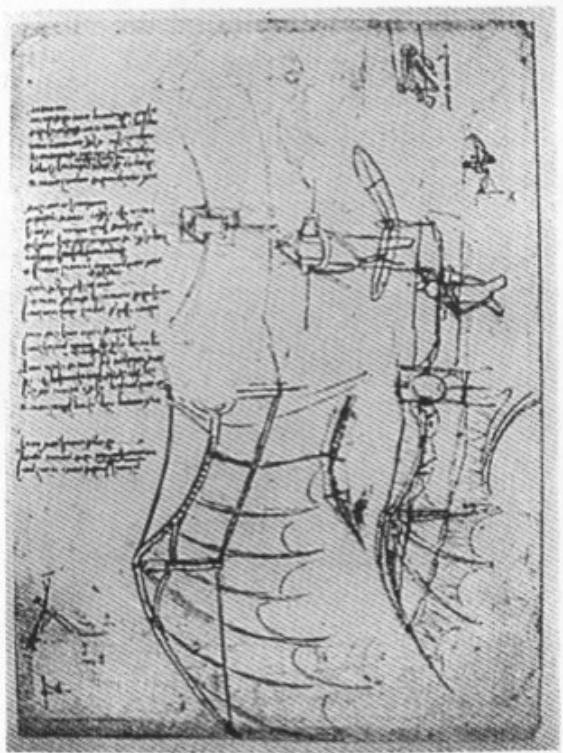
If we can imagine it, then other civilizations have thought of it too, presumably.

Even being pessimistic in the Drake equation, ~300 civilizations will have existed before us.

So where are they? One of the following may be true:

1) Space travel really isn't all that feasible.
2) Other civilizations have chosen not to colonize.
3) Other civilizations have not had time to colonize.
4) The Earth has been visited in the past, but we do not see them now.
5) There really are no other advanced civilizations in the Galaxy.





Perspectives on Space Travel

- We are probably no closer to the actual interstellar spacecraft of the future, than Da Vinci was in getting the first helicopter or airplane right.
- Still, this is the necessary first step. Early airplane designers built from knowledge of Da Vinci's work.

These notes may be found at:

http://loke.as.arizona.edu/~ckulesa/classes/astr202/