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Black Holes, Wormholes, and Extra Dimensions

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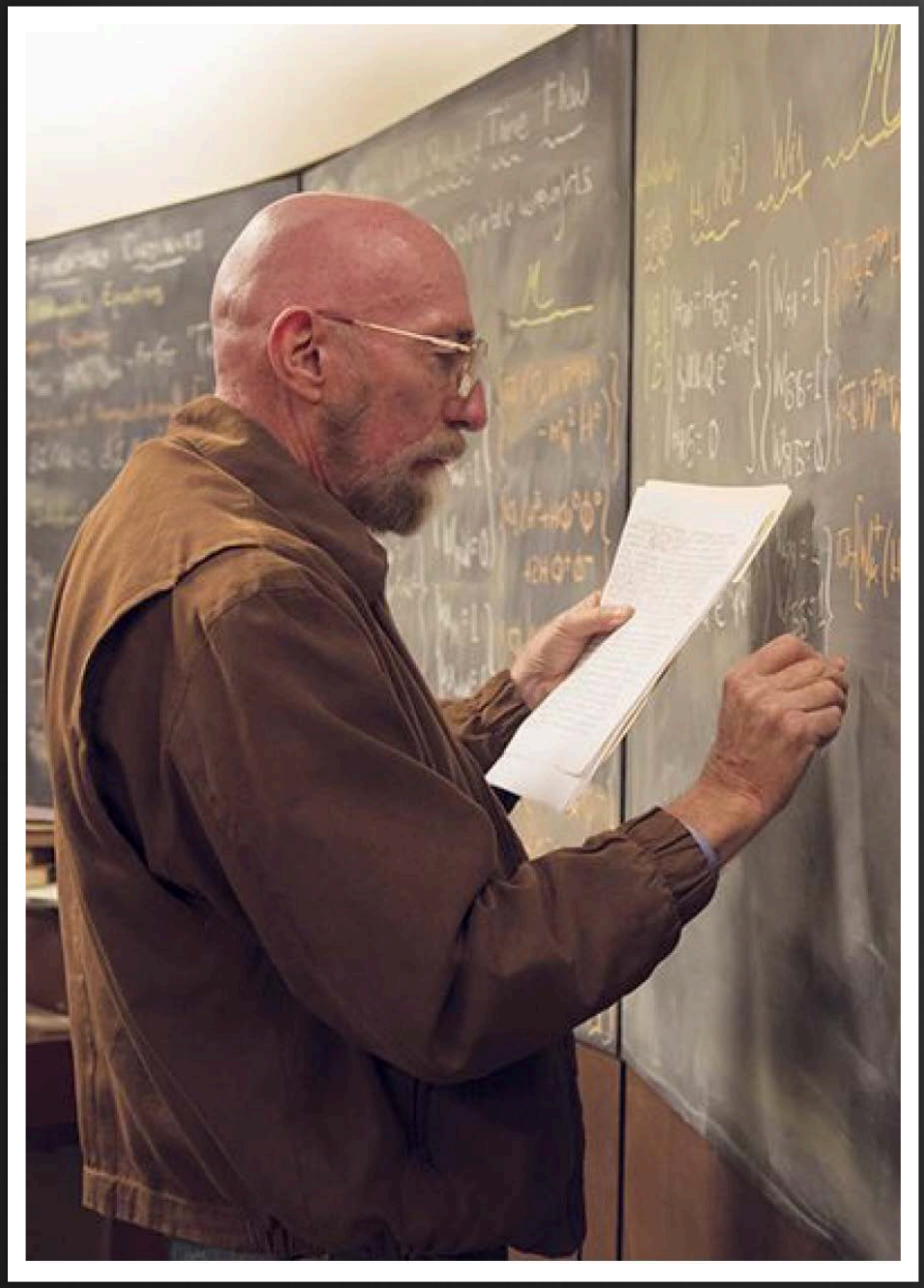
Google Talk
Dec. 10, 2015

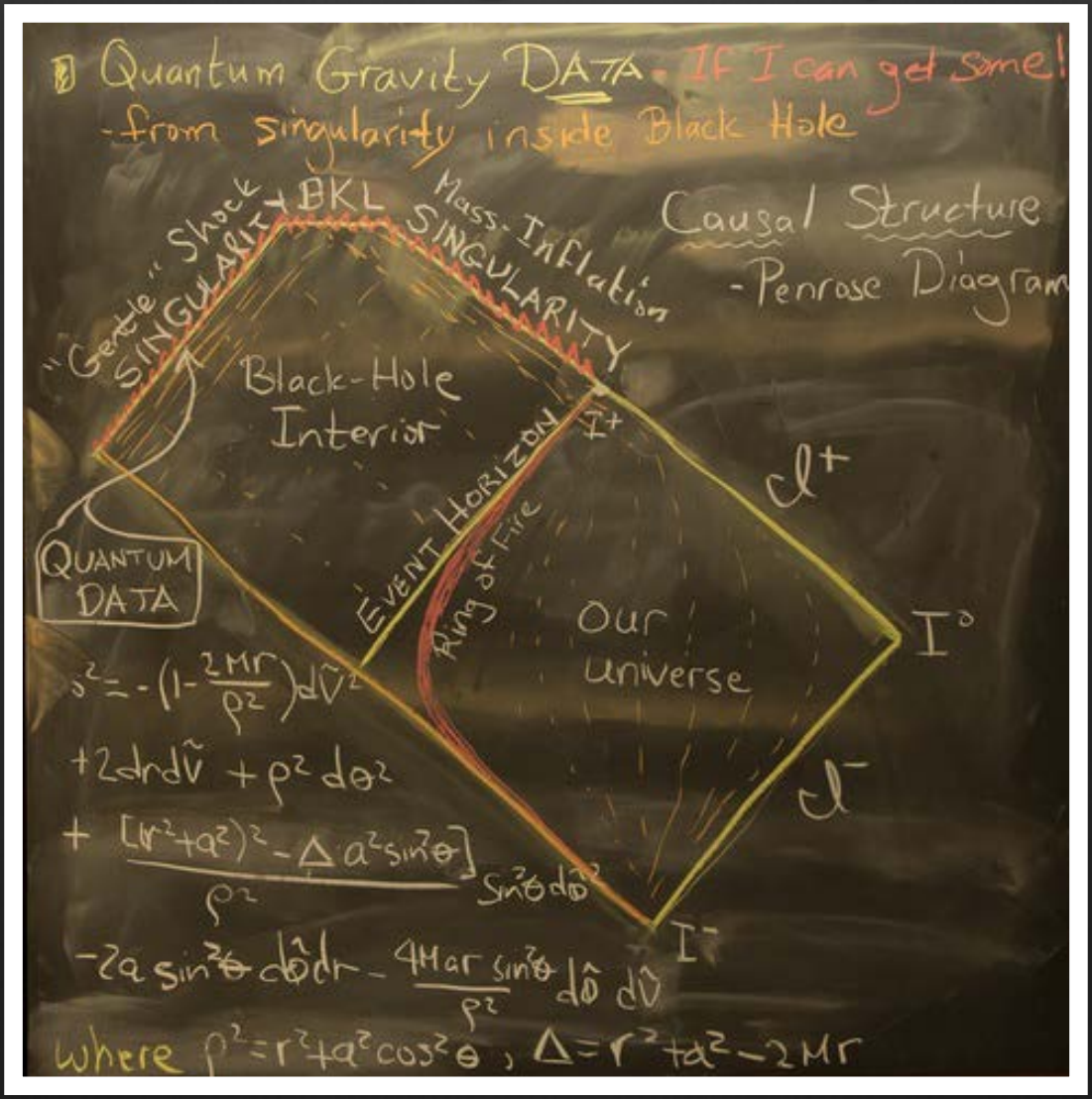
Theoretical astrophysics and cinematographic art



The Professor

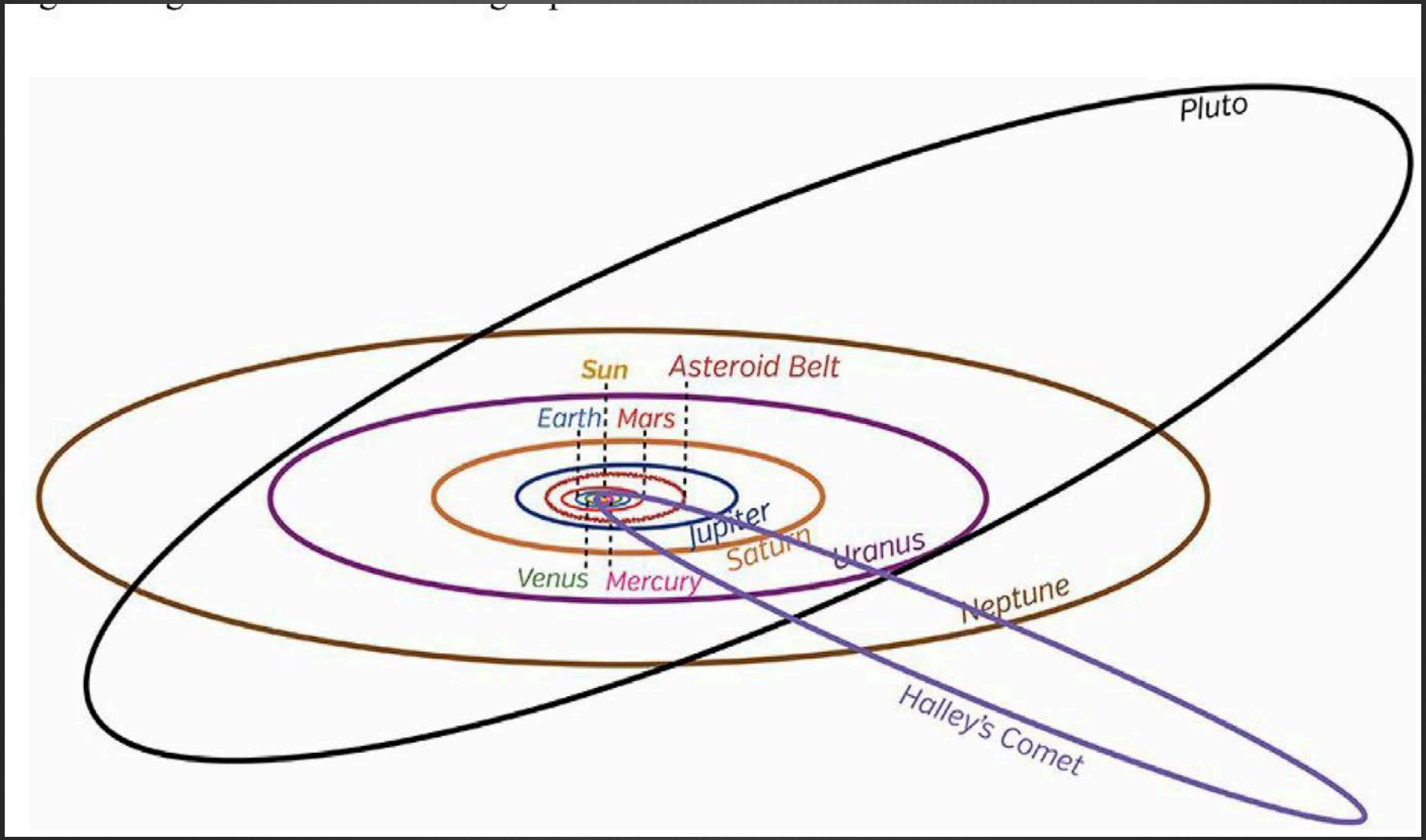
- Kip Thorne co-producer
- The search for the equation of everything that unifies gravity with quantum fields.
- If solved, the equation could to control gravity and make interstellar travel possible.

Solving Gravity



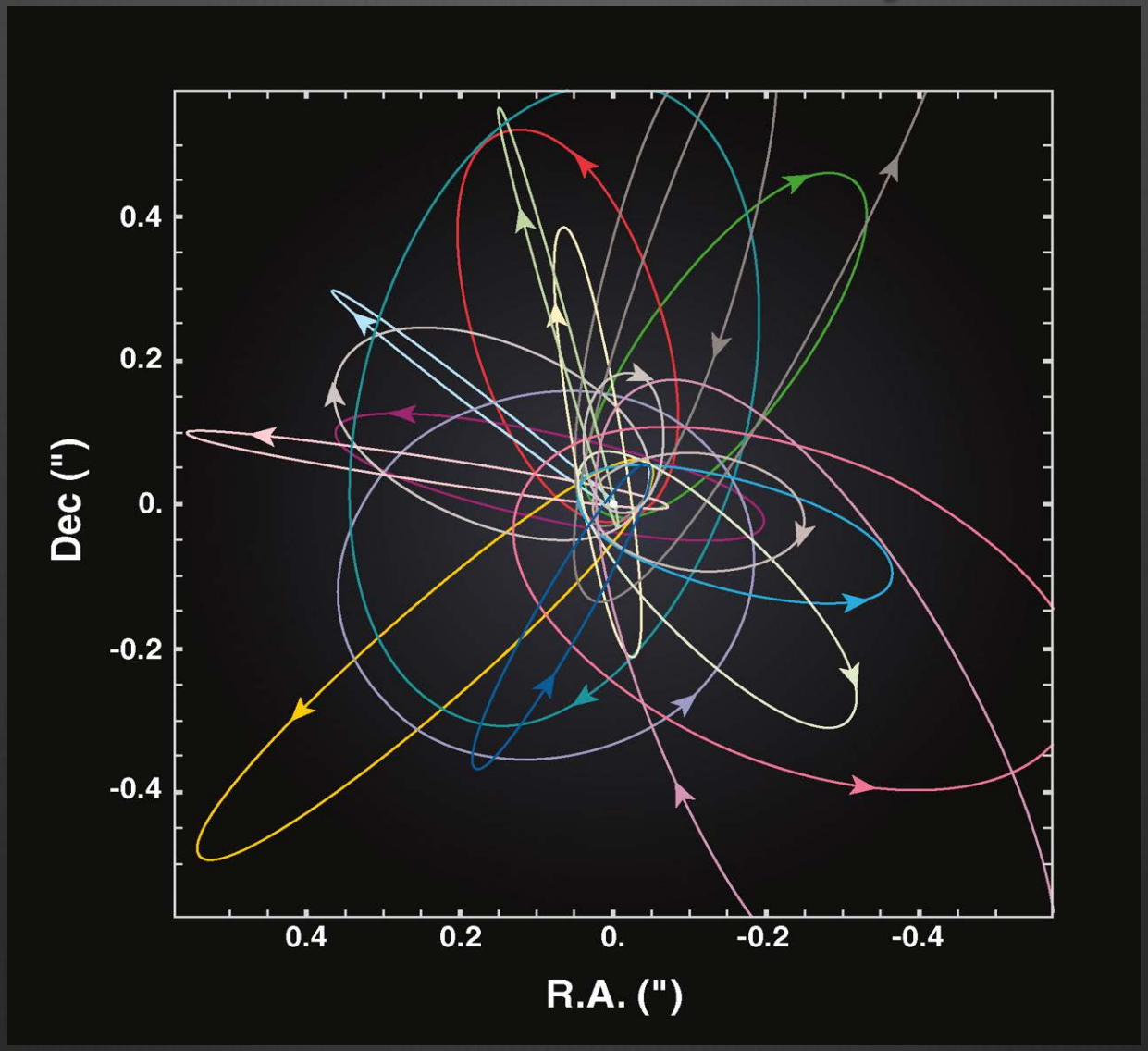
Gravitational anomalies might reveal quantum fields.
What he needs is quantum data from the singularity inside the black hole.

Newtonian Gravity



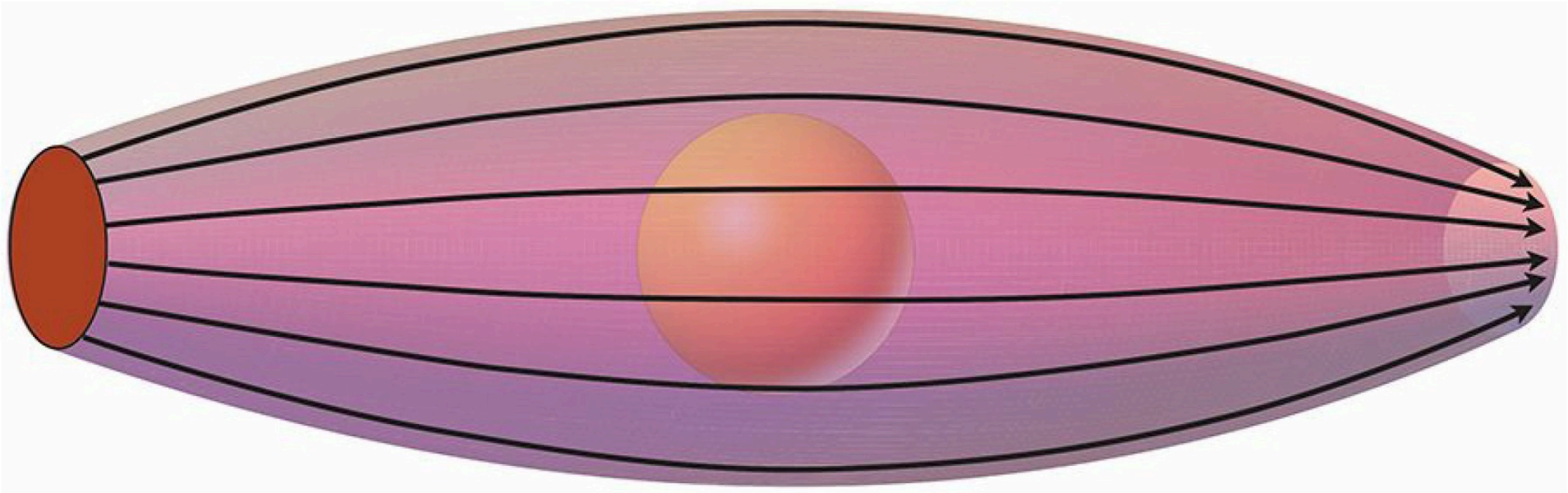
Our solar system is held together by the gravity of the Sun.
The orbits of the planets and comets are ellipses, described by Newton's law of gravity.

Einstein Gravity



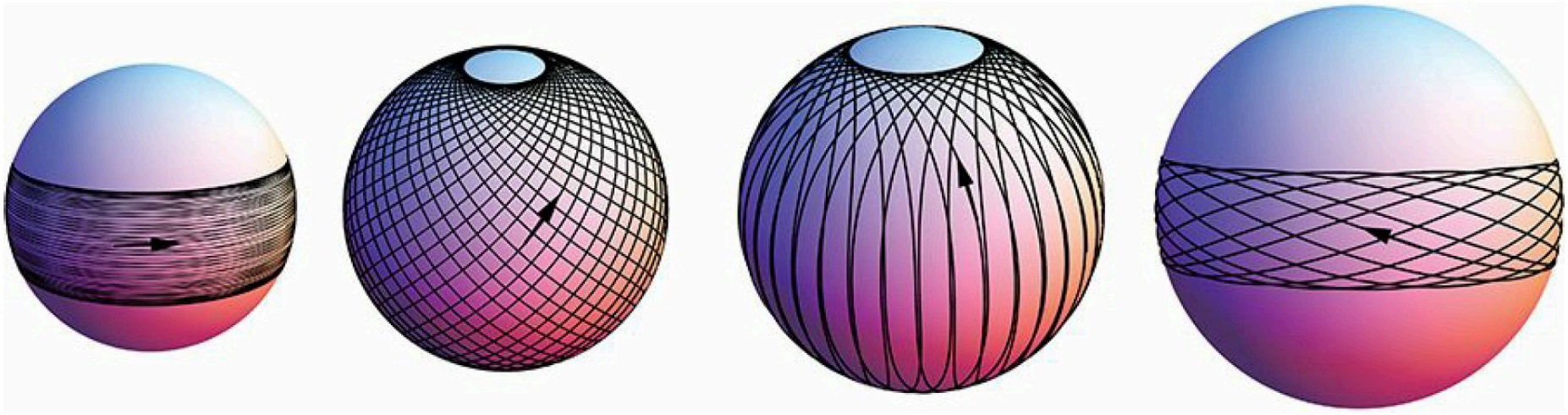
Our galaxy is held together by a supermassive black hole, 4 million times that of the Sun. The orbits of stars around the black hole is complicated.

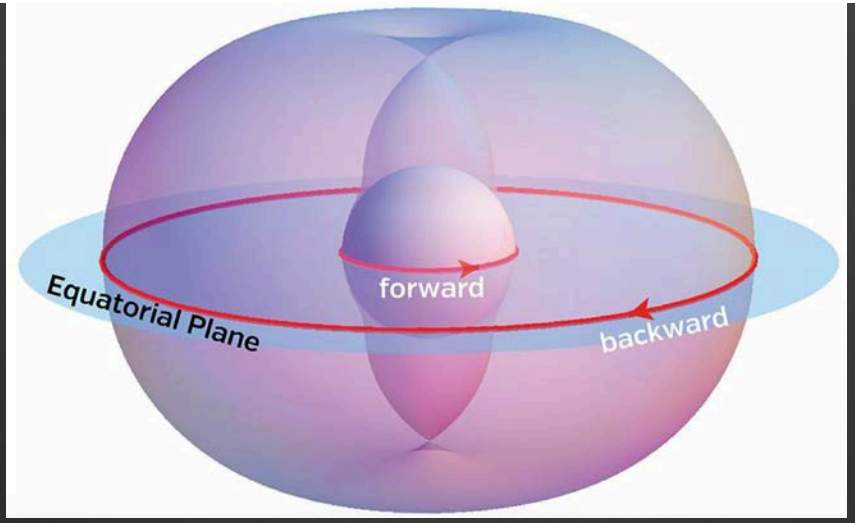
Gravity and Light



The Sun or a black hole bends a beam of light inward, according to Einstein's law of gravity. The space itself is bent and warped by matter.

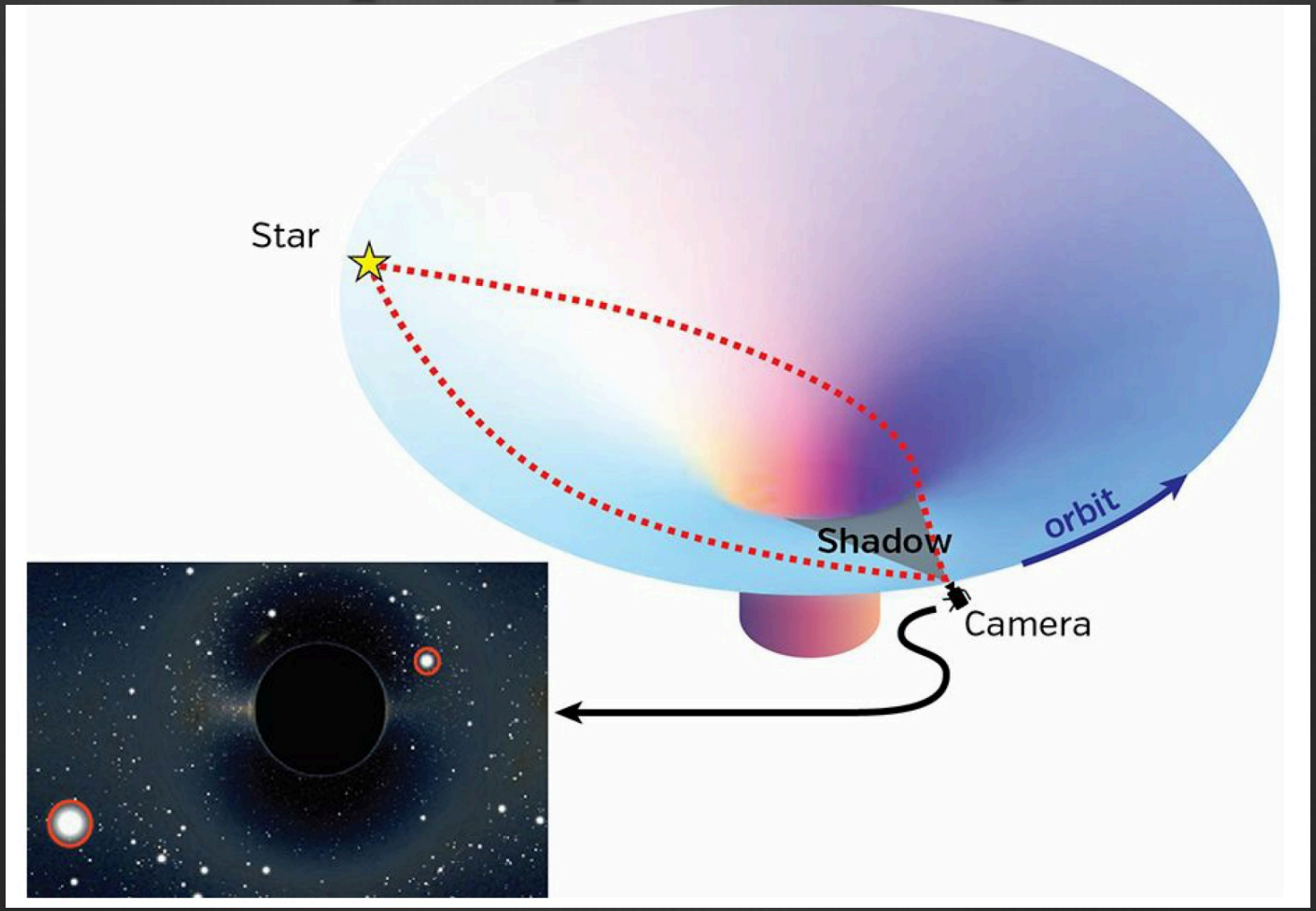
Trapped Light Rays





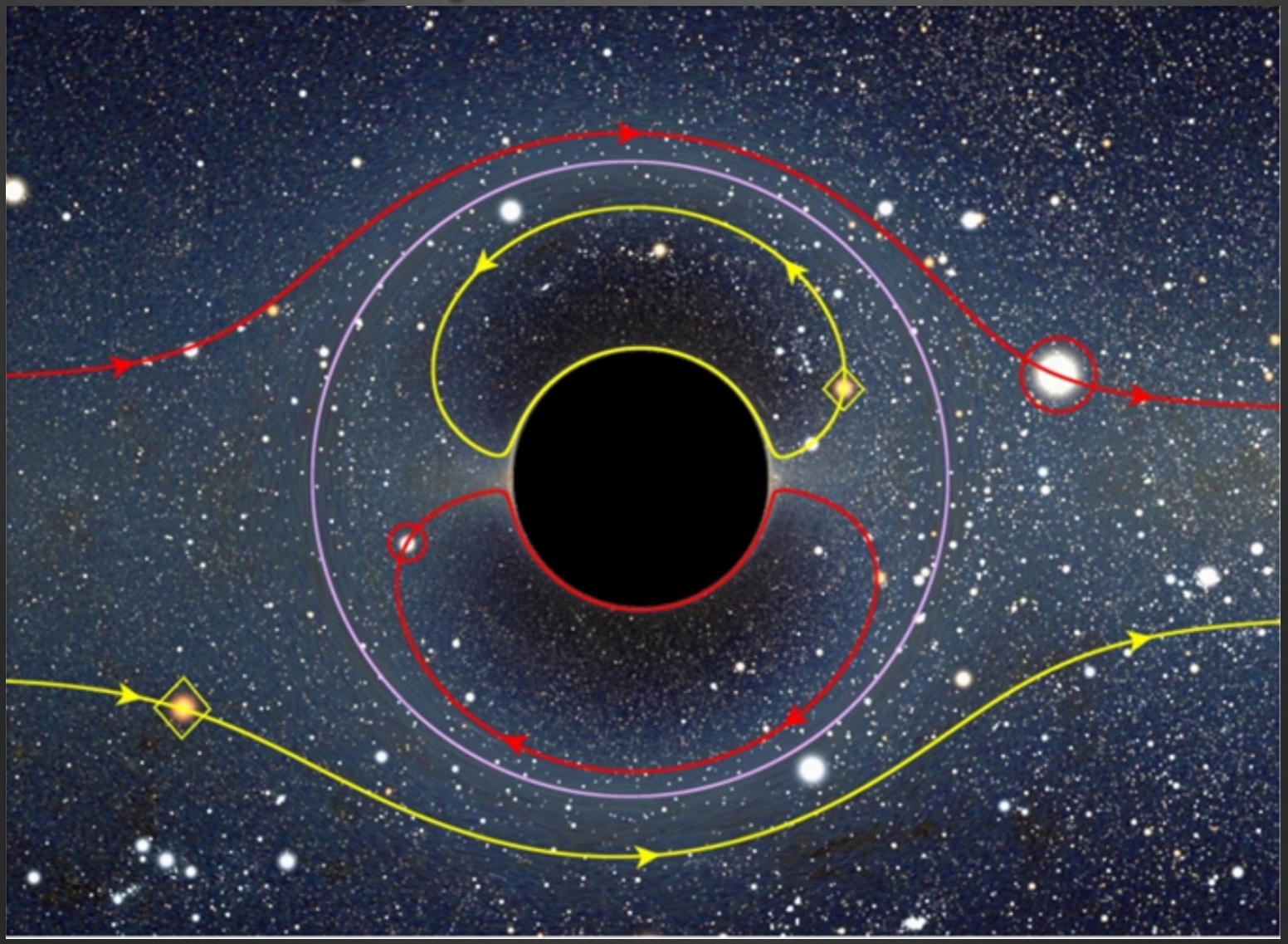
Temporarily trapped, unstable, photon orbits just outside the horizon of a black hole.
For a maximally spinning black hole, the paths of the photons form two “shells of fire”.

Warped Space and Light



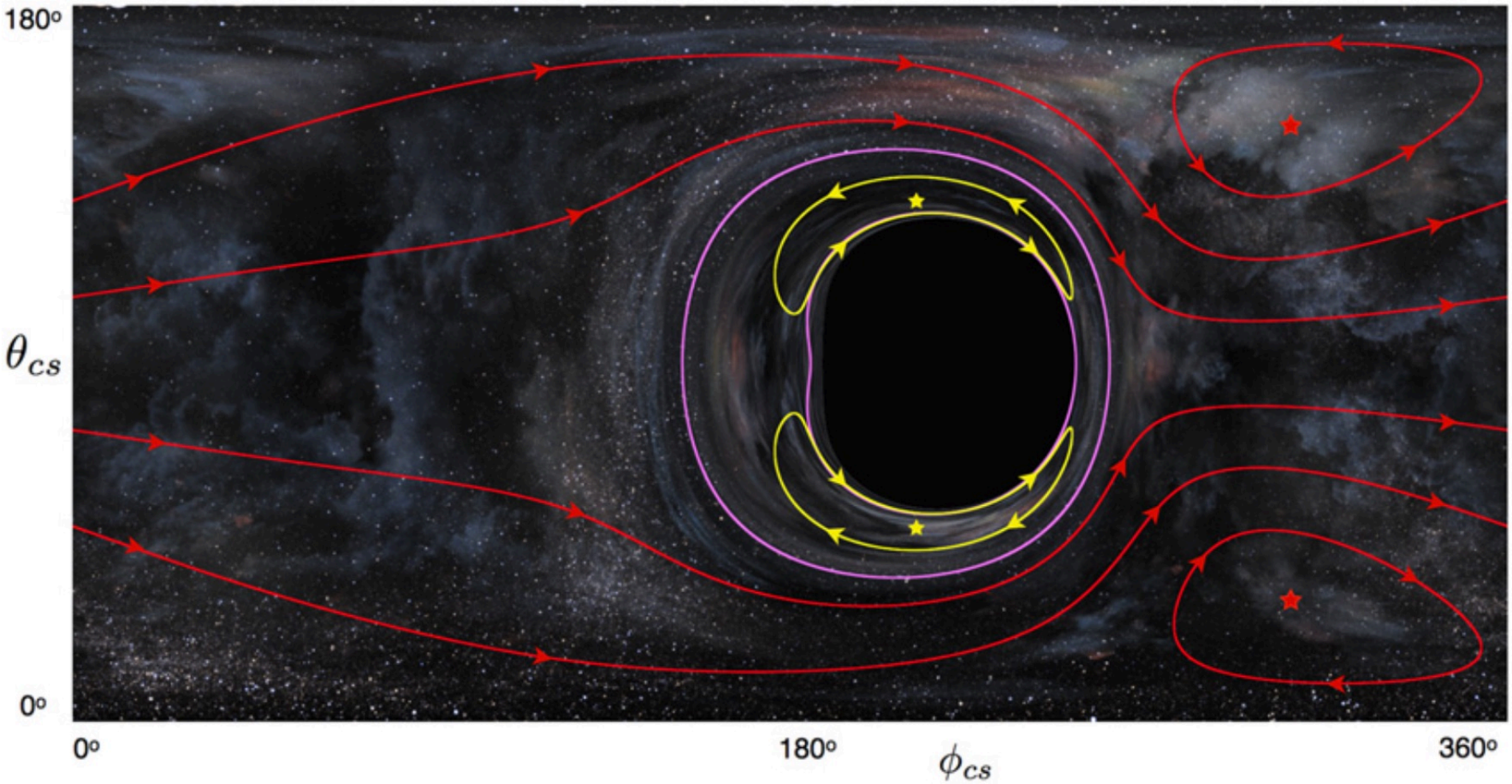
Up: the warped space around a non-spinning black hole bends two rays that travel through the warped space from a star to the camera. Bottom: camera sees two images of the star

Lensing by Static Black Hole



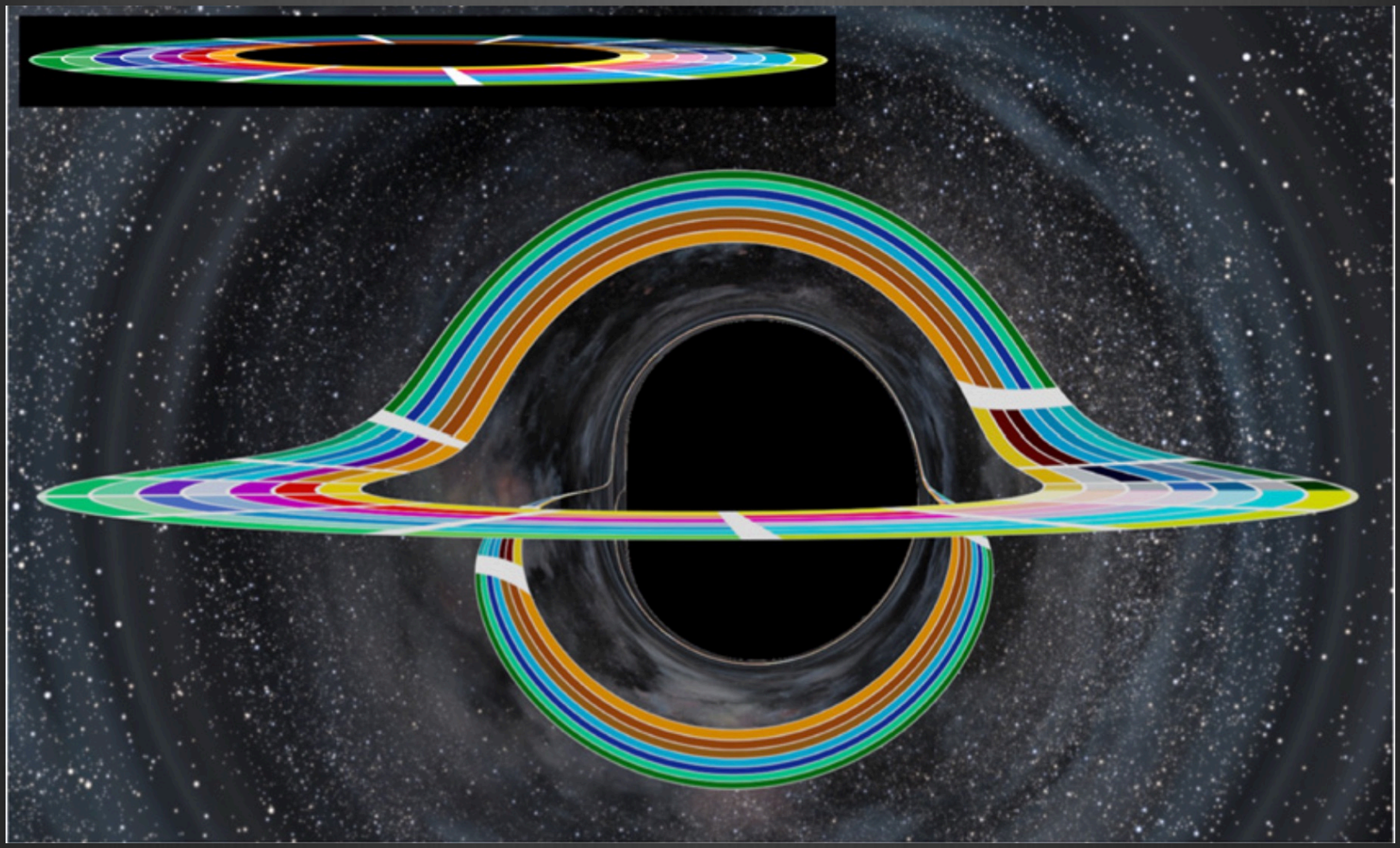
Two stars gravitationally lensed by a non-spinning black hole. Each star has
A primary image outside the Einstein ring, and a secondary inside the ring

Lensing by Spinning Black Hole



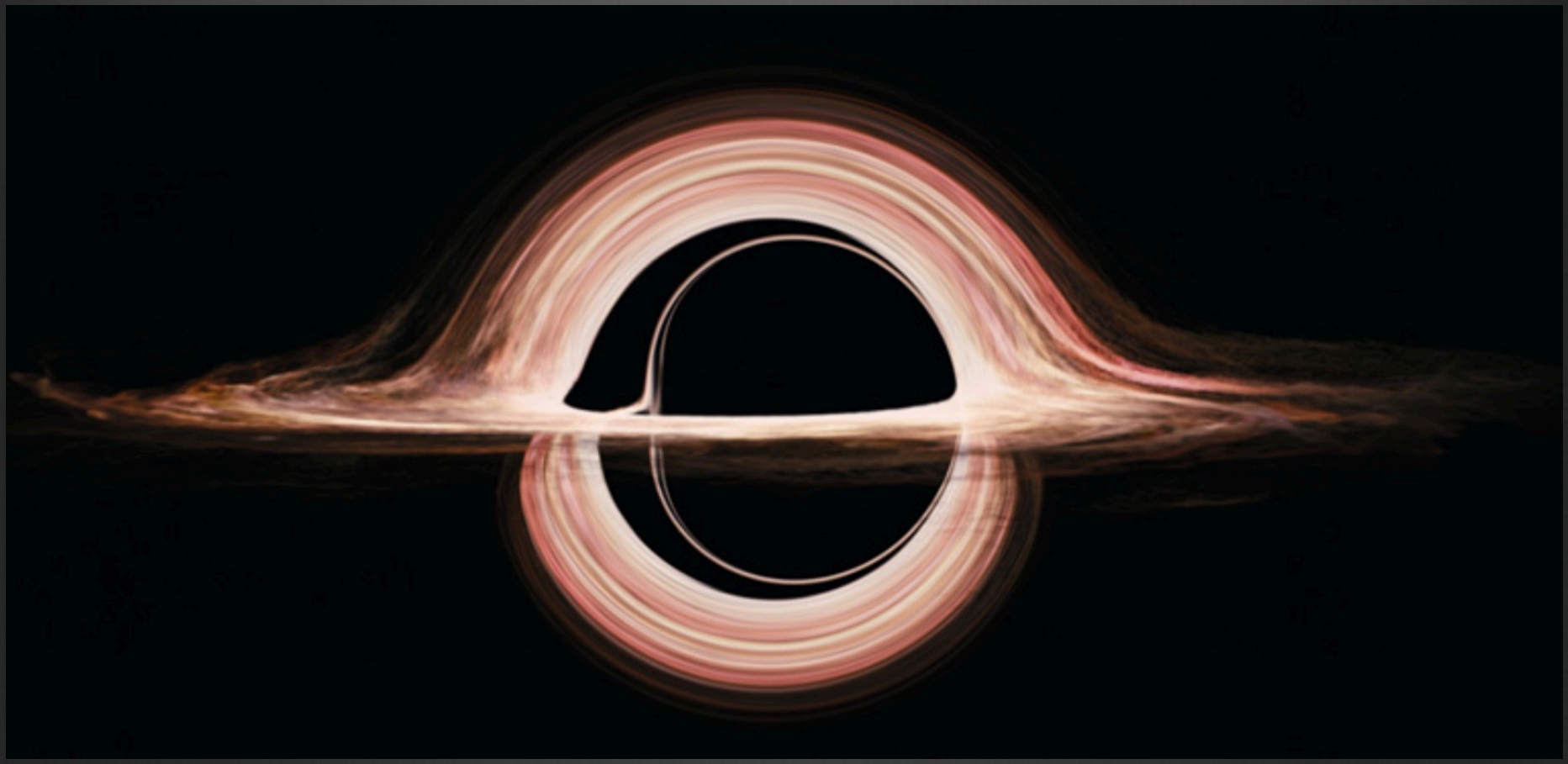
Gravitational lensing by a maximally spinning black hole The purple curves show that Einstein ring splits in two. The red curves are the trajectories of the primary images, and the yellow curves are the trajectories of secondary images from distant stars.

Lensing of the Accretion Disk



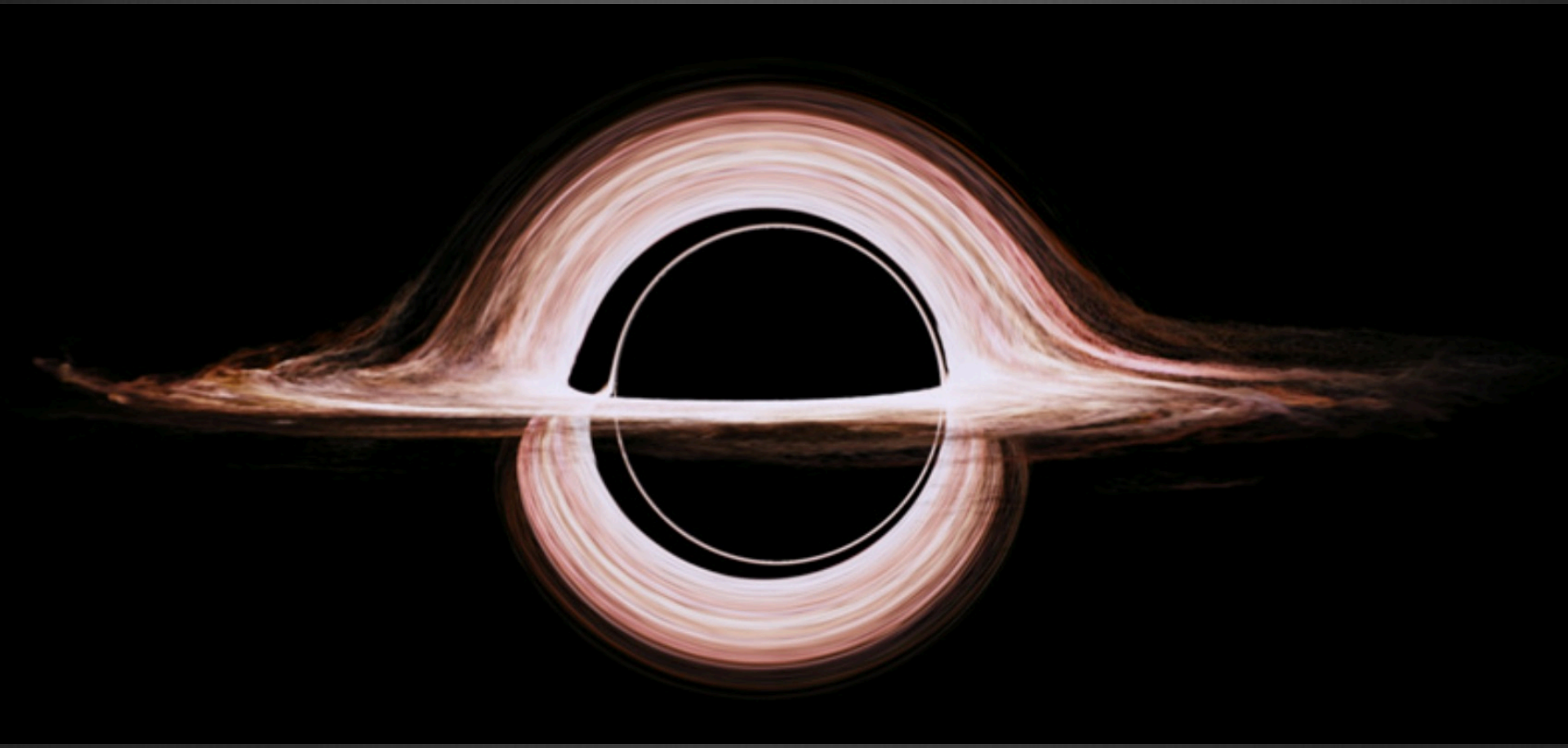
Accretion disk, placed in the equatorial plane around a maximally rotating black hole, ignoring frequency shifts, associated color, and brightness changes, and lens flare.

Black Holes Can See Their Back



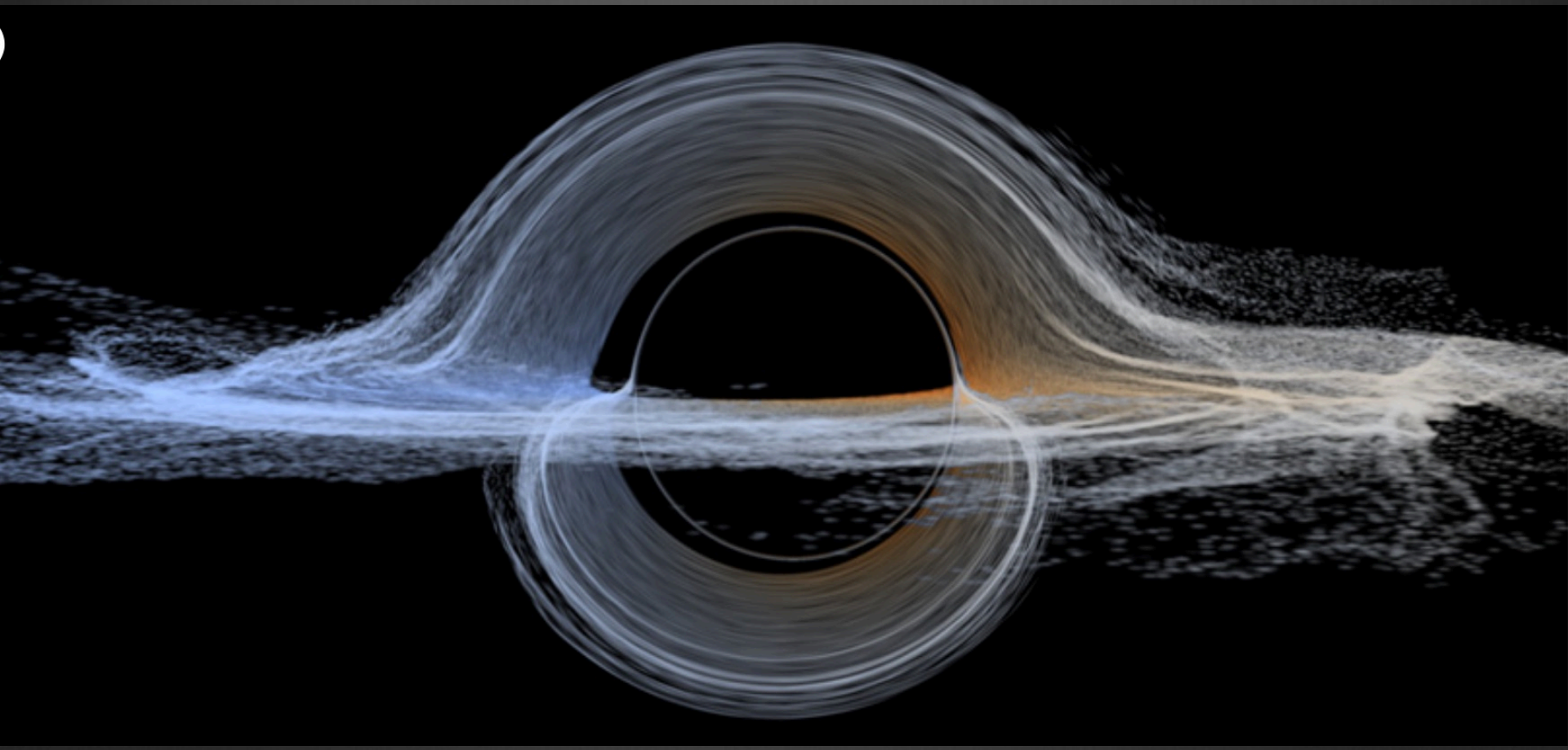
The light rays from the disk's top face from behind the hole, are wrapped over the shadow and pass up over the top of the hole. The light rays emitted by the lower face of the disk behind the hole, travel under the hole and back upward to the front.

Lensed Disk for a Slow Black Hole



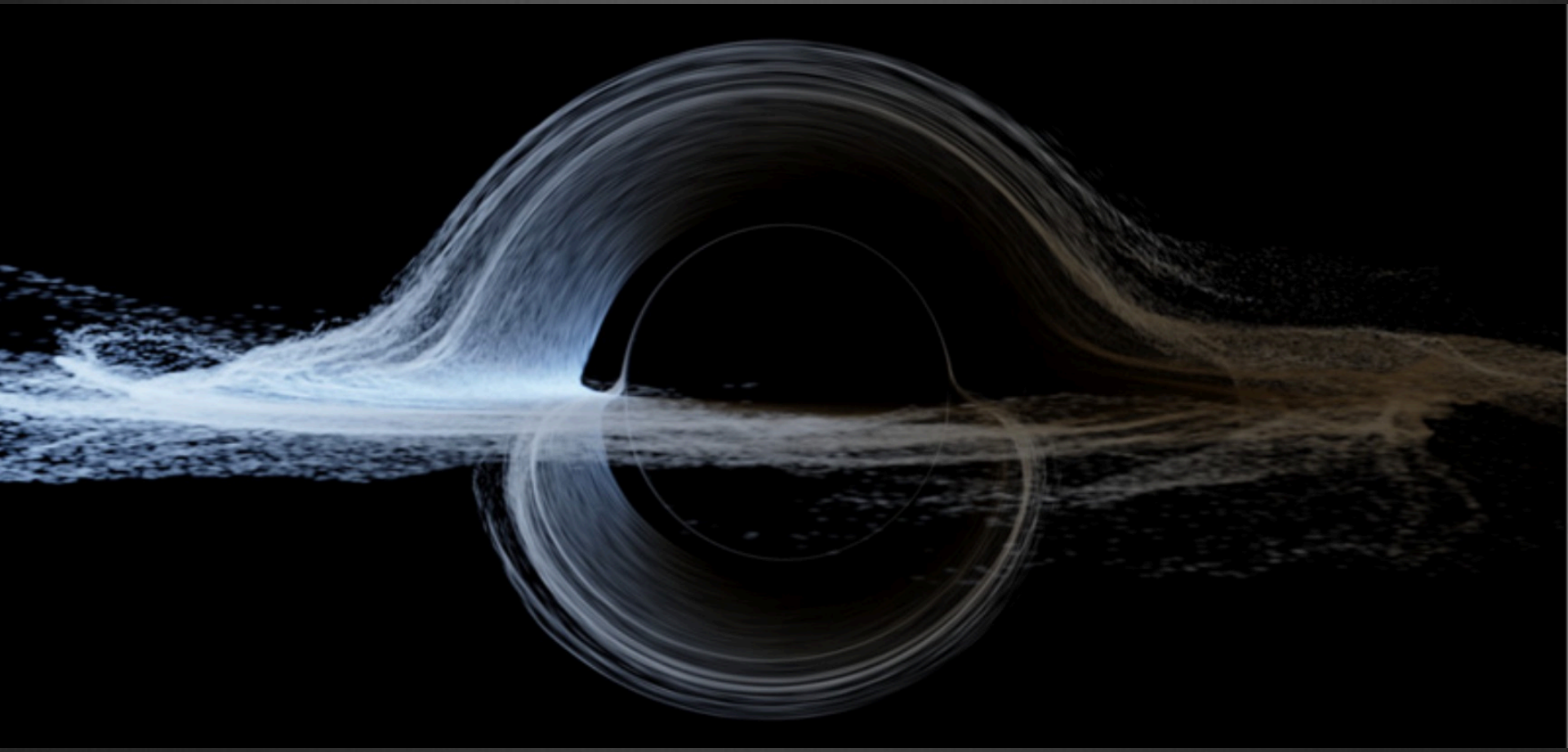
A moderately realistic accretion disk with the black rotating at half maximal speed. The left edge of the black-hole shadow become un-flattened.

Lensed Disk with Color Change



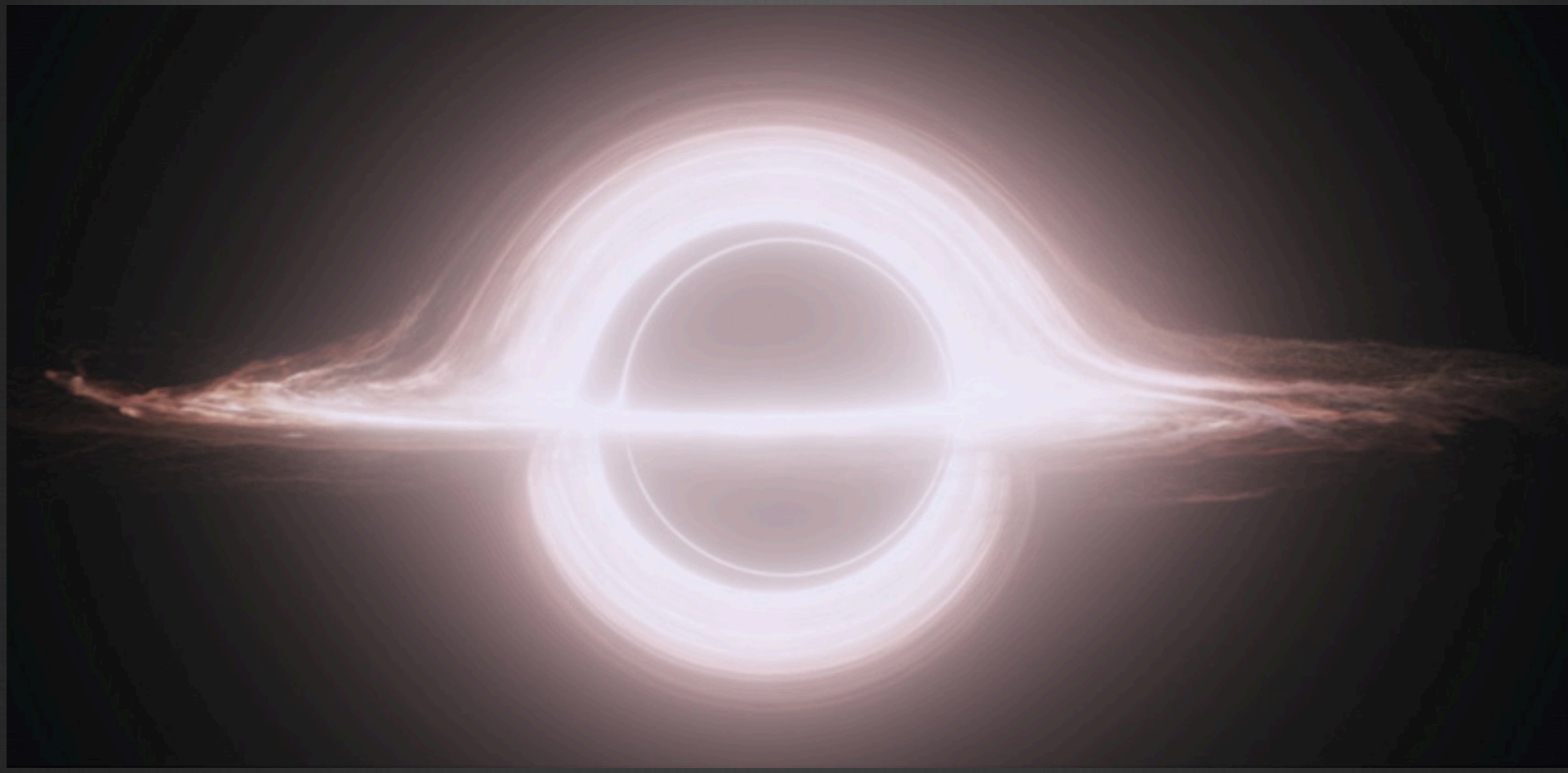
The same disk with its colors Doppler shifted and gravitationally shifted. The left side of the disk is moving towards us and the right side away with half the speed of light. The light gets blue-shifted towards us on the left by about one and a half, and red-shifted by receding on the right, by a half.

Lensed Disk with Brightness Change



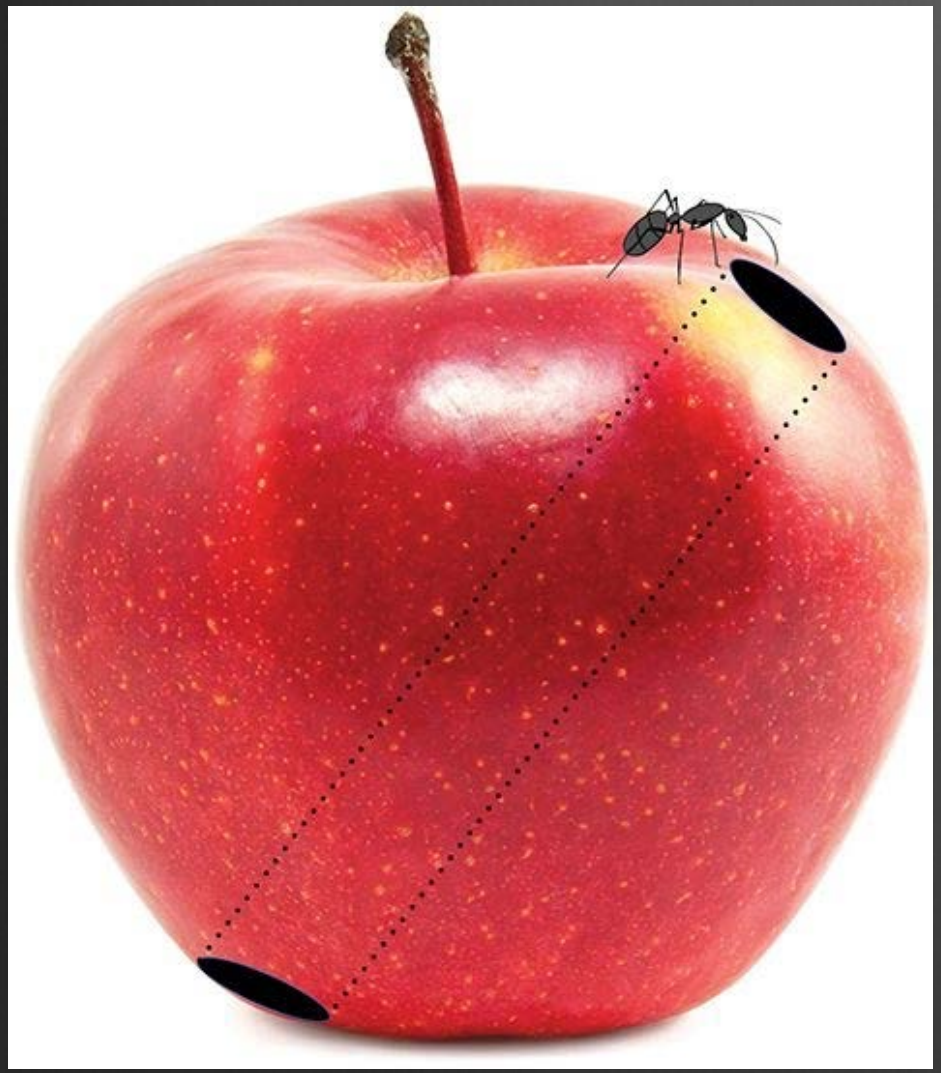
The same disk with its specific intensity (brightness) also shifted. The disk's left side, moving towards us, is very bright, while the right side, moving away, is very dim. This is similar to jets, emerging from quasars: one jet, moving toward Earth is bright, while the other, moving away, is too dim to be seen.

Lensed Disk, Director's Cut



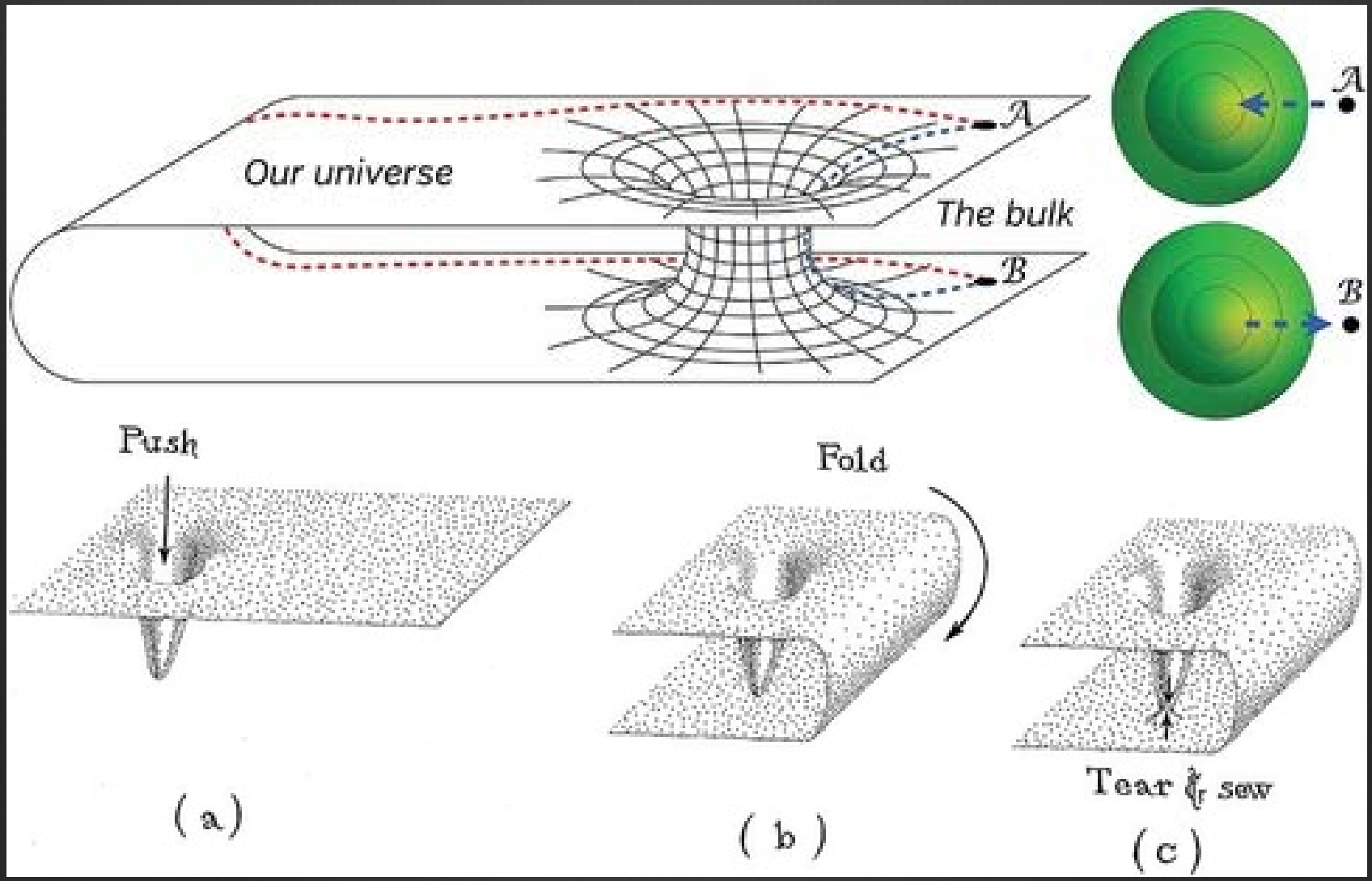
The accretion disk with no color or brightness shifts, but with lens flare added ('veiling flare'), characteristic of IMAX camera lenses. This is a variant of the accretion disk seen in Interstellar.

Wormholes



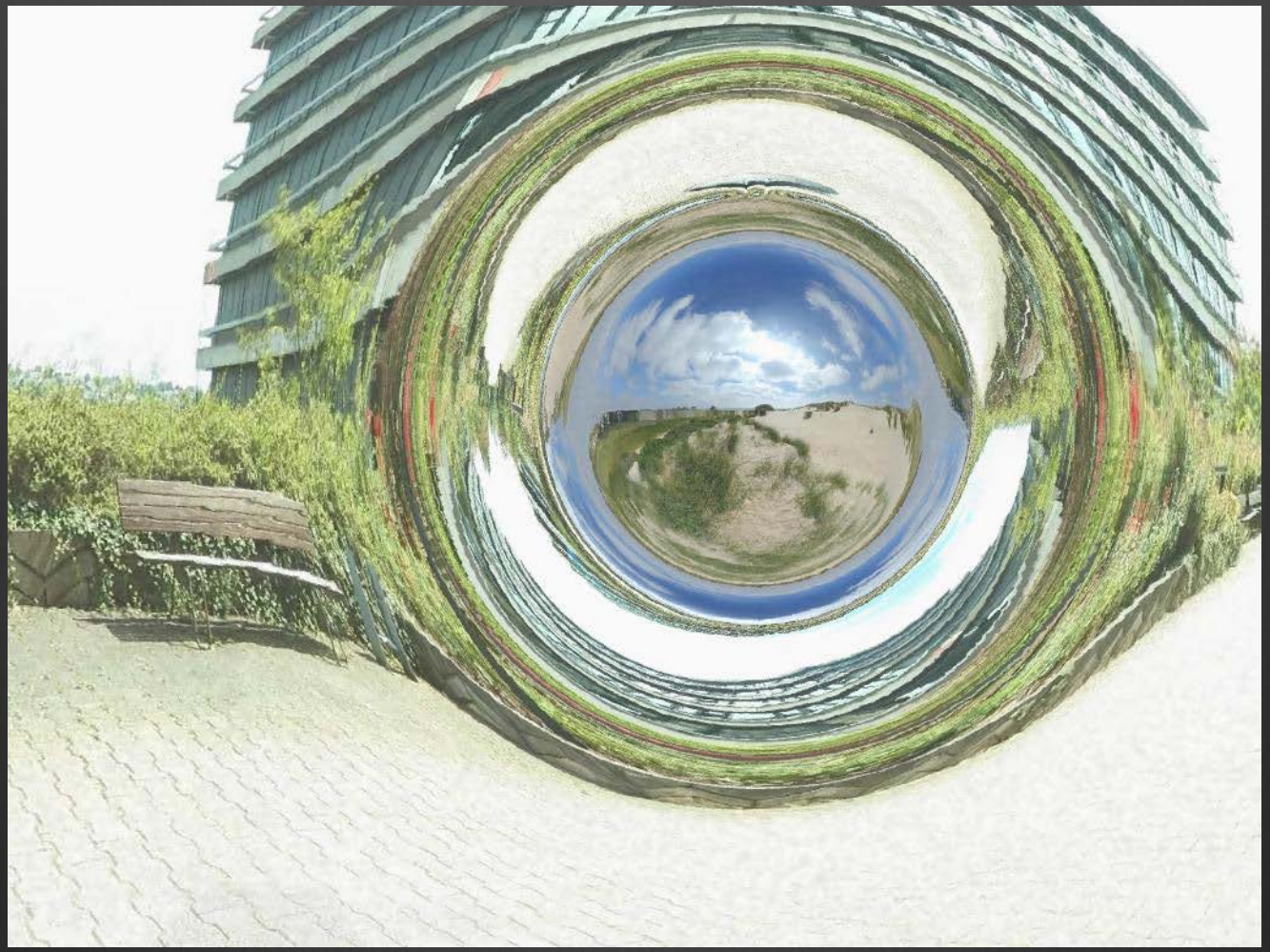
- The wormhole is a shortcut through the core (bulk).
- The ant can travel across the bulk, from one point in its universe to another.
- The wormhole is not part of ant's universe
- The wall has the same dimensionality as the ant's.

Recipe for Creating Wormholes



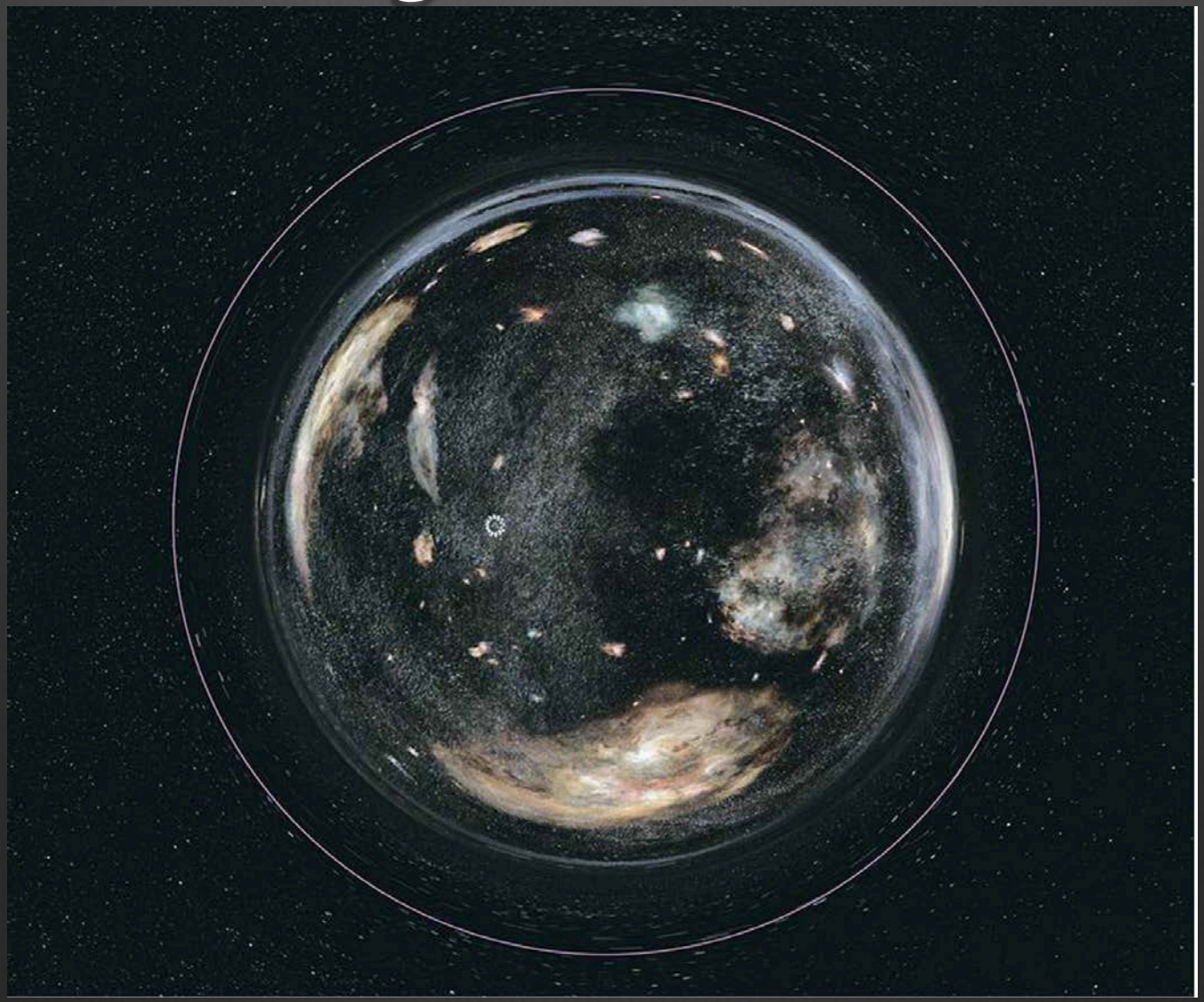
The only hope for forming them is artificially, by an ultra-advanced civilization.

Keeping the Wormhole Open



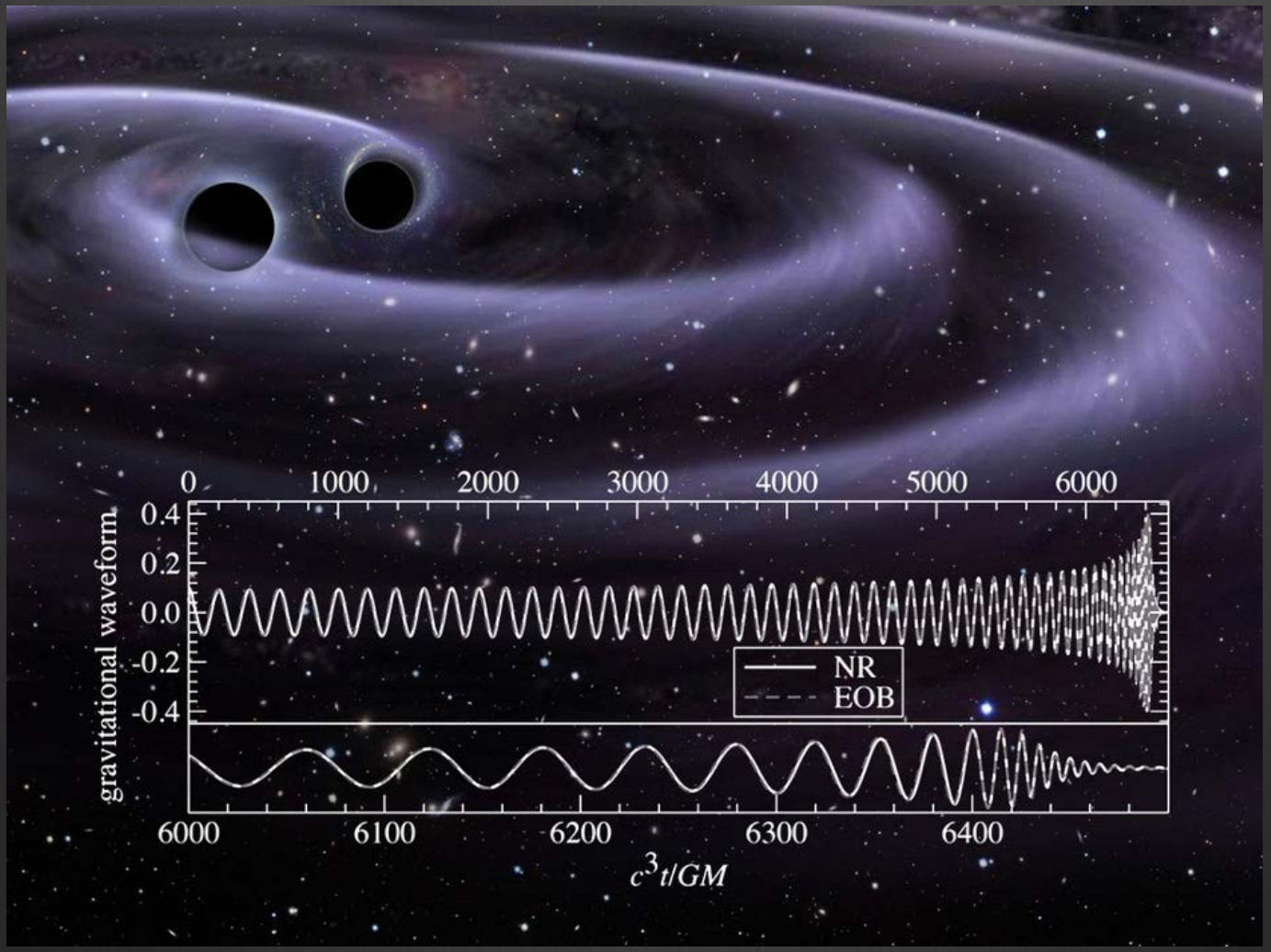
A wormhole bends light outwards, so must be made by mass with negative energy.
A wormhole is traversable only if it is threaded by ”exotic matter”.
Decades of research indicate that traversable wormholes are impossible.

Looking for a Wormhole



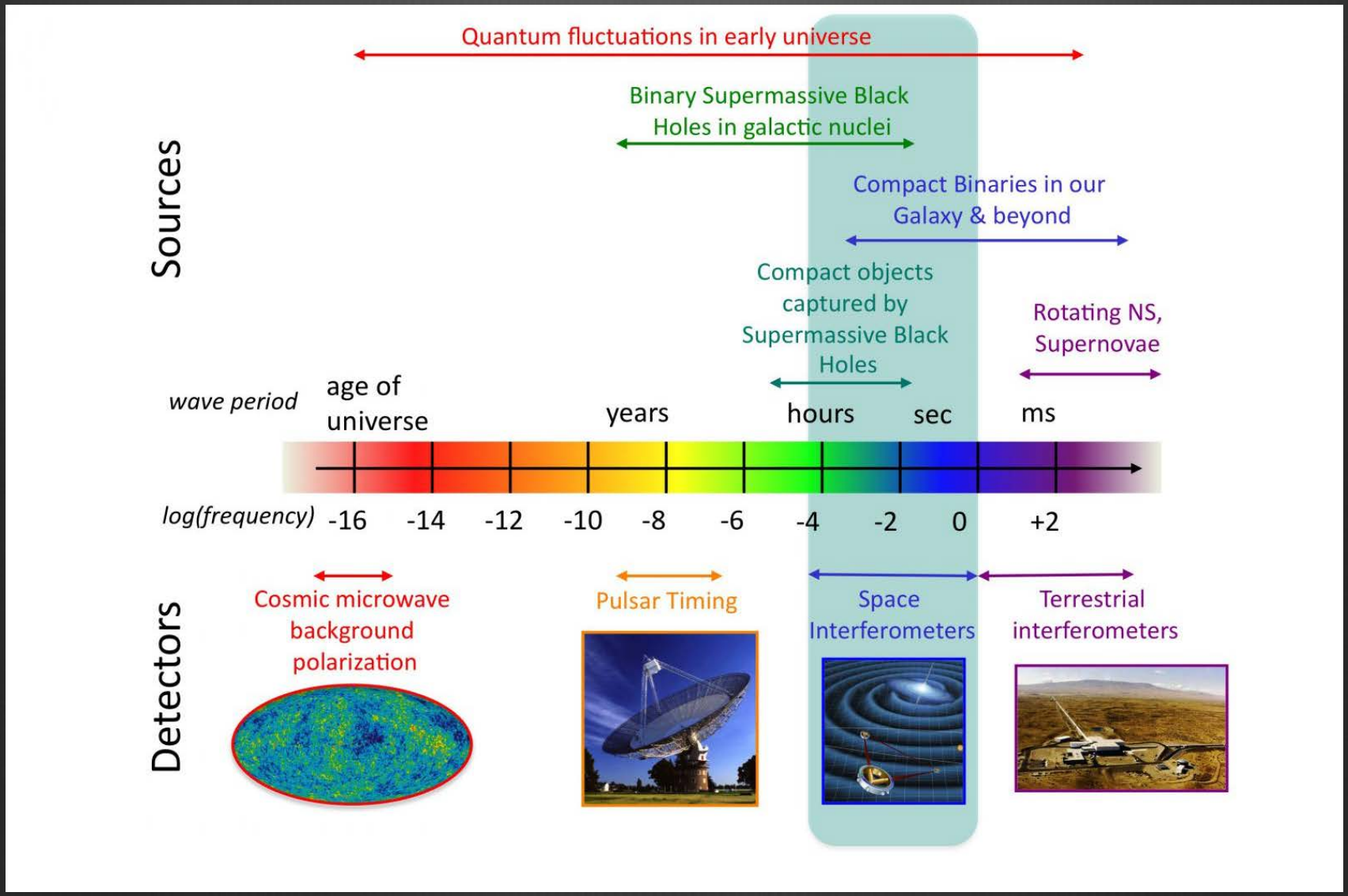
A wormhole would look as a non-spinning black hole with the Einstein ring around it. Through it you can see images of gravitationally lensed distant stars and galaxies.

Gravitational Waves



Gravitational waves are emitted as ripples in the fabric of space when black holes merge. The upper graph shows the waveforms of calculated according to numerical relativity. The lower panel shows the final few cycles, including the merger of the two black holes.

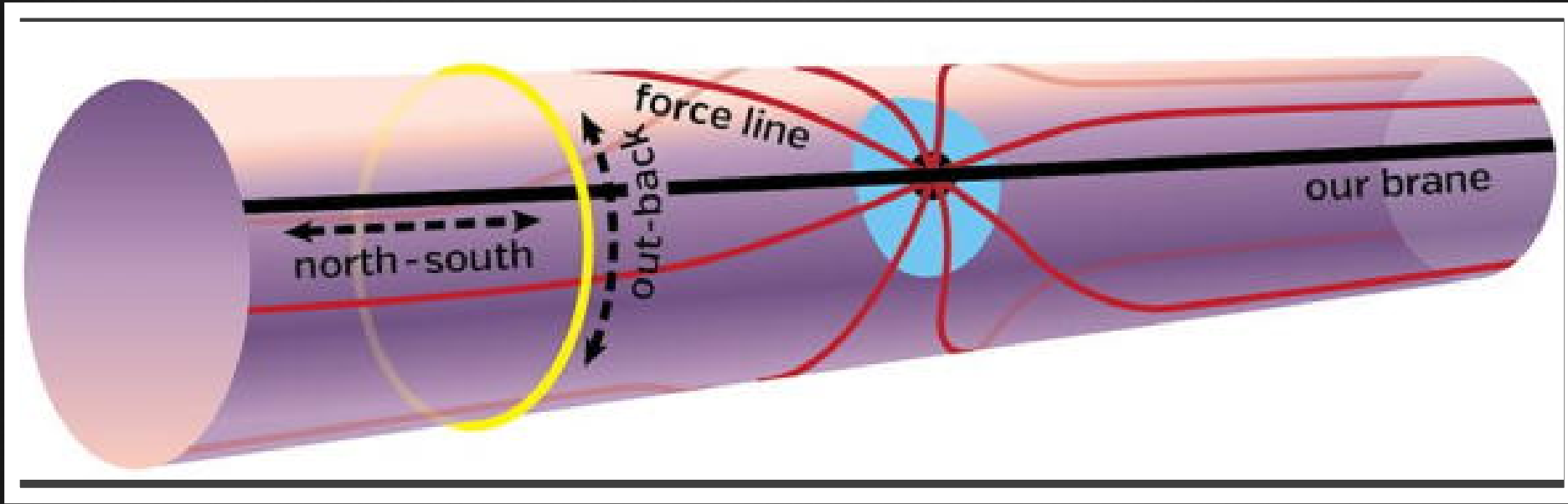
Gravitational Waves Detectors



New Window on the Universe

- Determine the role of massive black holes in galaxy evolution
- Understand supernovae, relativistic jets, or ultra-compact stars
- Study the early universe and found how it came into being
- Solve the quantum gravity puzzle and probe for extra dimensions

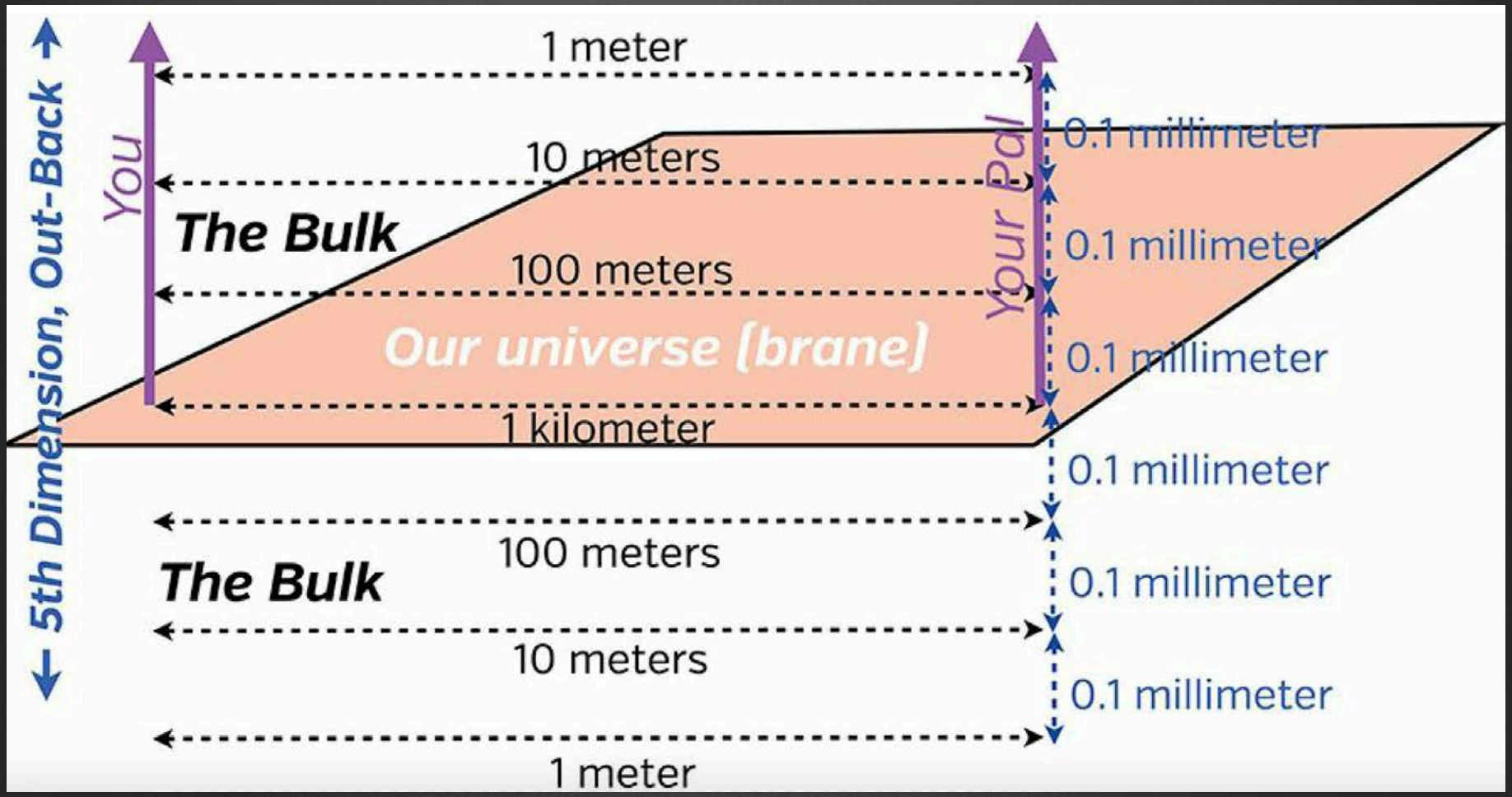
Extra Dimensions



- Gravity leaks into the extra dimensions.
- Newton's inverse square law would break.
- Curl the extra dimensions (yellow).
- Contain the spreading of gravitational force lines (*red*) to a small region (blue).
- Gravity cannot spread far outside the blue circle.

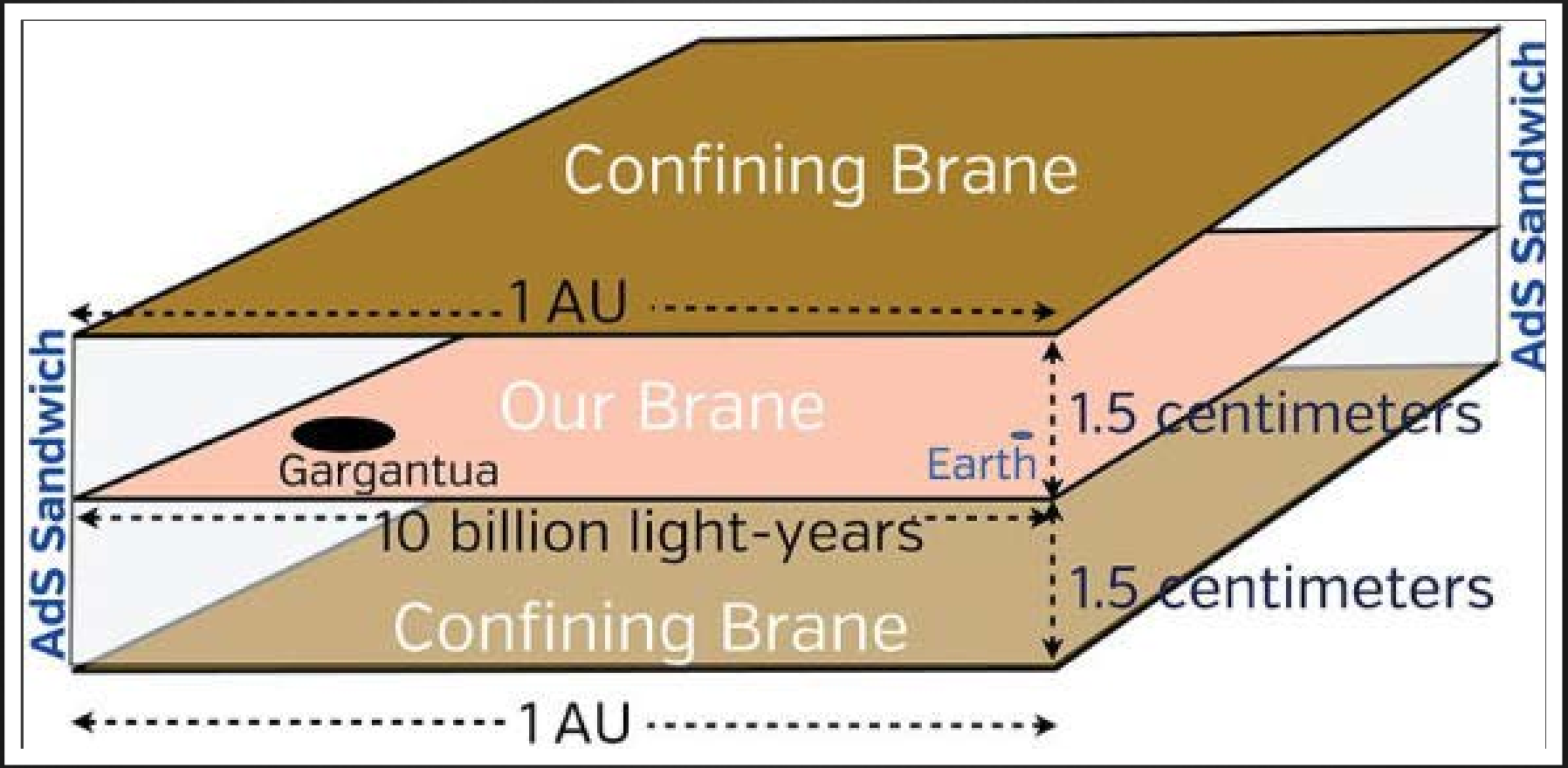
Newton law is restored!

The Bulk and Confined Gravity



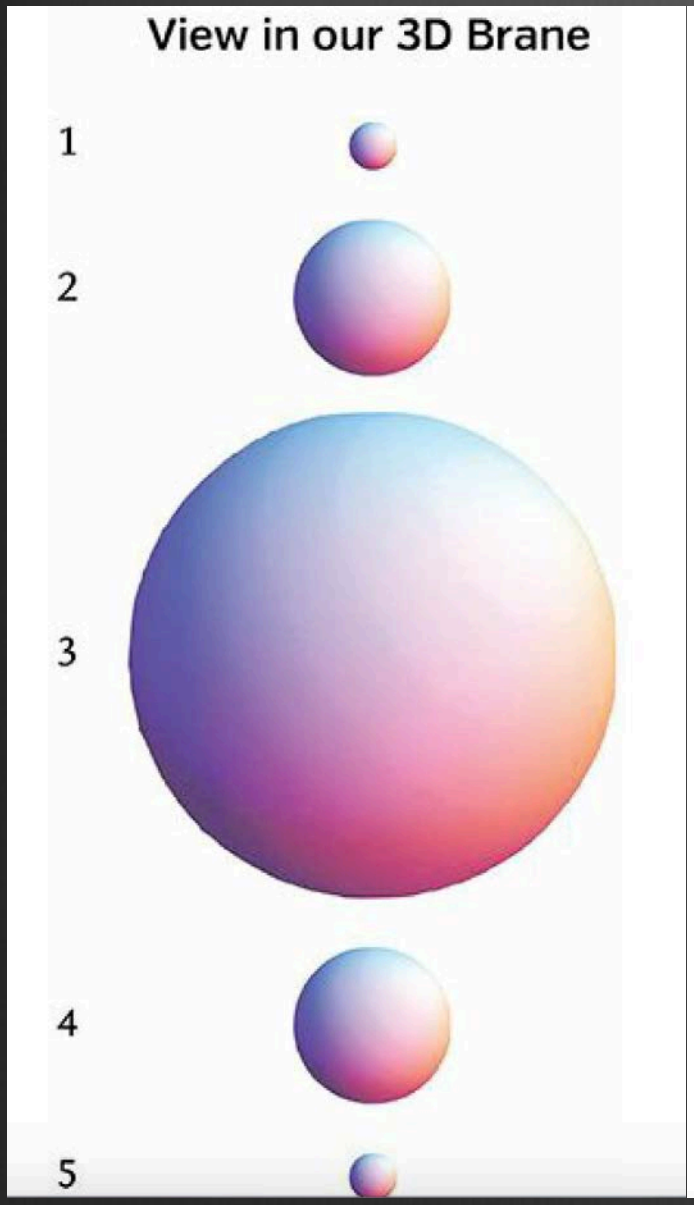
- Shrinkage of distances parallel to our brane.
- Anti-de-Sitter warping of the bulk
- Far from the brane there is very little volume in which to spread
- Gravitational force lines bend parallel to our brane.

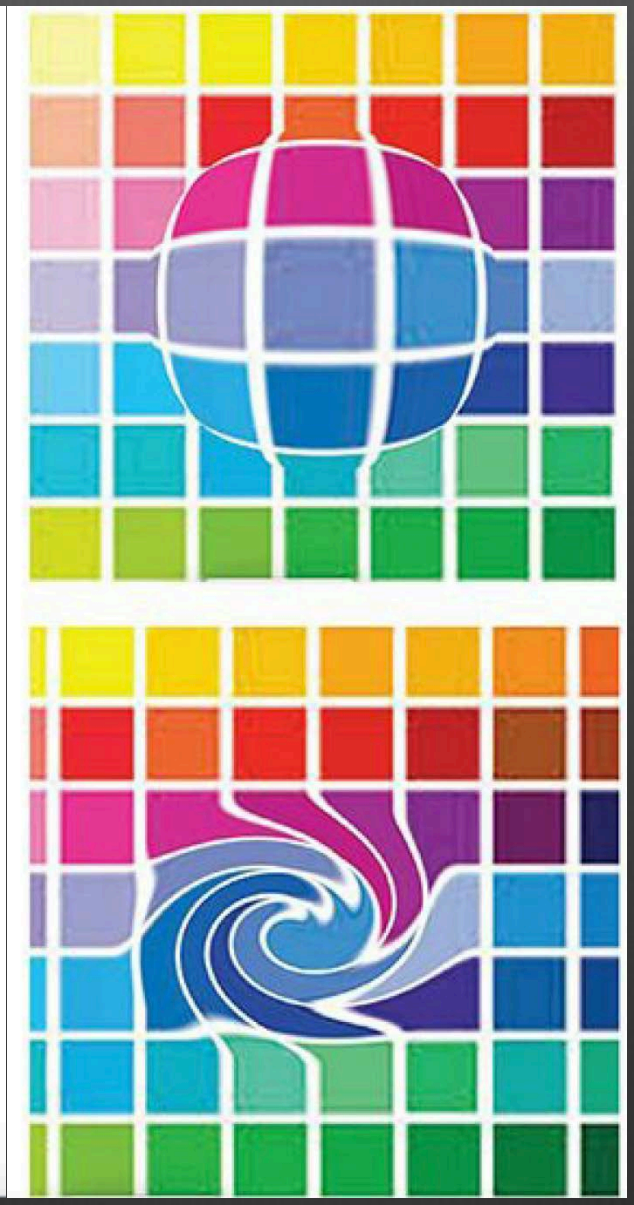
A Sandwich in 5 dimensions



- How to make enough space for bulk-based adventures?
- Confine the AdS warping to a thin layer around our brane, a "sandwich."
- Outside the sandwich, the bulk is totally un-warped.
- As you travel from our brane to a confining brane, distances parallel to our brane shrink by fifteen powers of ten: a thousand trillion!

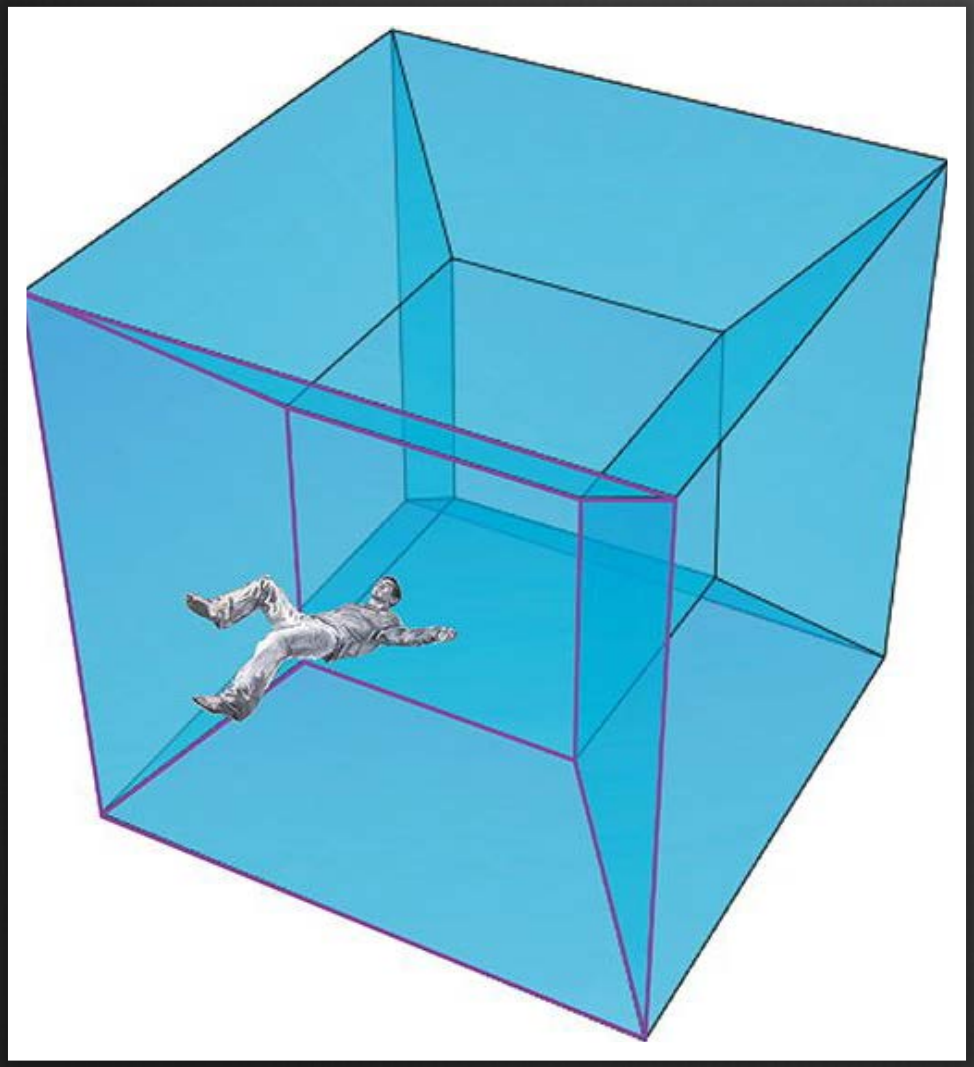
Extra-dimensional travel





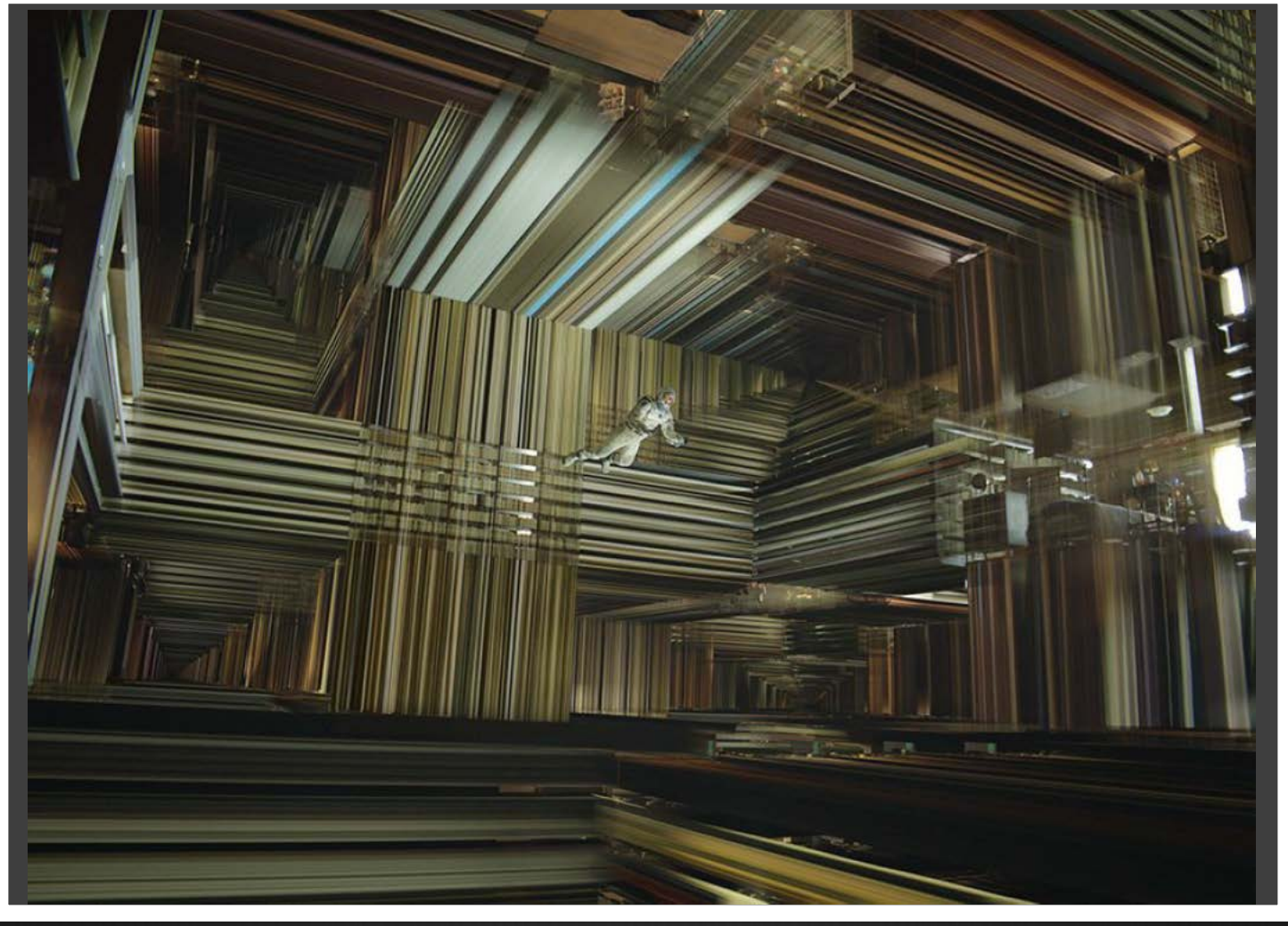
- We can't travel into the fifth dimension.
- Only gravity can.
- Bulk being can travel to us
- We can't see them
- We'd feel very weird

The Tesseract



- A cube in an extra dimension.
- Has eight faces; each are cubes.
- Its projection in our brane looks like two cubes, nested inside.
- We are confined to one of the tesseract's three-space-dimensional faces (cubes).

Interstellar's Famous Tesseract



Cooper floating in Nolan's complexified tesseract

Escher's Waterfall

Escher's famous waterfall drawing. The water wheel is powered by the falling water, then it flows up to the top and back down to the wheel.

You could not see a single mistake yet it dose not make sense logically.