Time and Time Travel

- time *requires* at least a 2-object universe
- physics on the **micro** scale
  - + ⇔ - distance okay
  - + ⇔ - time okay too
- BUT we sense directionality (if not speed) absolutely
  - water spills (mechanical)
  - wood burns (chemical)
  - milk spoils (chemical)
  - you just *know*

3 kinds of time

1. **psychological** (looks, feels "right")
2. **cosmological** (Hubble Law, expanding univ.)
3. **thermodynamic** (2nd law of thermodynamics)
   - things get more disordered when left alone
   - takes energy ("purpose") to assemble things
   - energy generates heat that produces disorder elsewhere

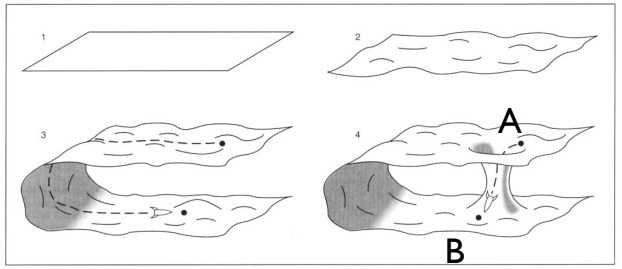
- Hawking:
  - 1 and 3 are related
  - cognition is an ordered biochemical state
  - ordered at the expense of brain heat
  - "food for thought"
  - disorder increases with time because that is the direction by which we perceive
  - we remember the past defines "past"

can we travel in time?

- **Forwards?**
  - no problem, especially at 1 s/s
  - fast forward via special relativity
    - the twin paradox
    - Planet of the Apes
- **Backwards?**
  - *instant* logical inconsistencies: the "kill your grandfather" paradox
  - must solve paradox(es) to justify pursuit of time travel
  - ways "out" - infinite, parallel universes, restricted free will, ...

a "wormhole" time machine

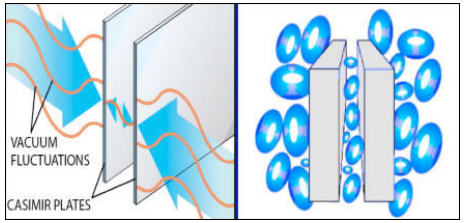
- wormhole: a theoretical connection between distinct locations in (otherwise flat) space-time
- allows *apparent* faster-than-light travel
- can exist briefly as a black hole forms, but is rapidly closed off



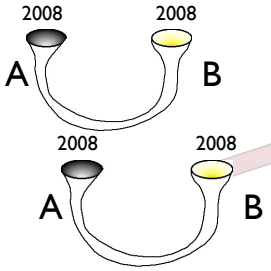
How to sidestep the speed of light. Empty, four-dimensional space-time is shown here as a flat, two-dimensional sheet (*1*). Matter distorts or curves space (*2*), and very dense concentrations can bend it drastically (*3*). A wormhole connecting two regions that lie far apart in space might let a spaceship take a shortcut (*4*) and apparently travel faster than light.

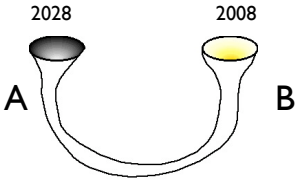
stabilizing wormholes: the Casimir effect

- exploit the energy density of the vacuum
- curved space ⇔ acceleration ⇔gravity
- need "antigravity" = pressure
- parallel plates, close together, smaller vacuum energy because Δx gets small
- use *negative refractive materials* - reverse the sign of the force, making it repulsive



wormhole time machine





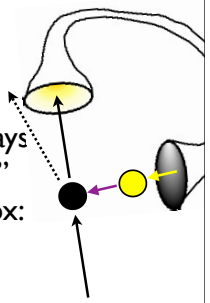
- start: A, B in 2008
- Take B, move at near *c* for 20 years, then return
- Now B is a gateway back to 2008 in 2028
- in 2028:
  - walk from A to be and look "in"
  - see A as it was in 2008
  - Hop into B, emerge from A in 2008, shake hands with the young "old" you!

what about the pardoxes?

- the two of you both jump in - now there are 4 of you!
- Grandfather paradox:

  Igor Novikov's Billiard Balls

  - "Principle of least action"
  - of all the paths available, the path taken is always one that minimizes the quantity called "action"
  - A simplified version of the grandfather paradox:
  - compute **action** for such a path
  - **NOT** a path of least action!
  - **NOT** allowed!



- why not? Why the 2nd law? Why gravity?
- Free will isn't entirely free - we can't violate physical laws despite our will to do so. Why should grandpa paradox be any different?