An introduction to

Cosmology

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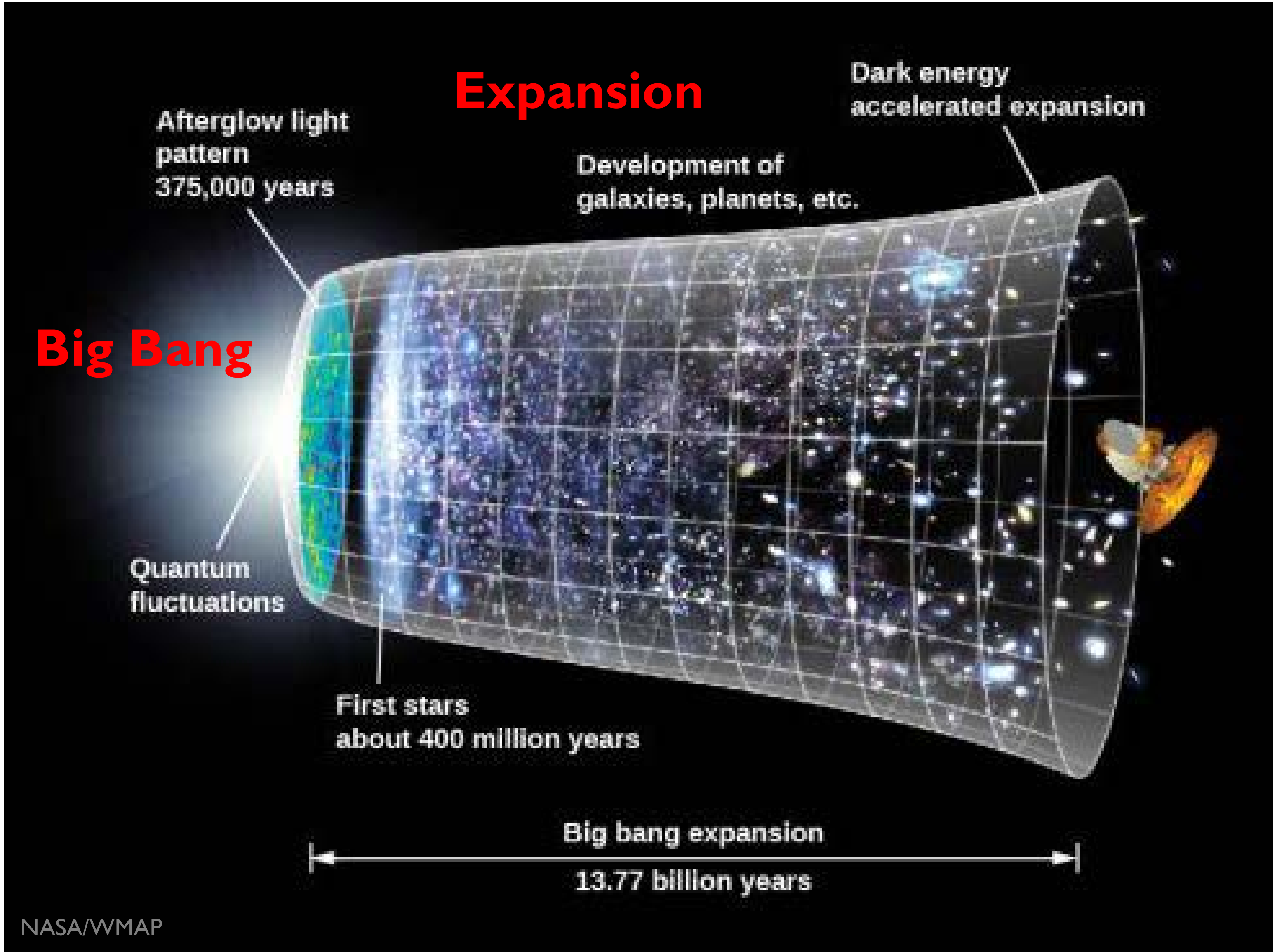
Cosmetology

Cosmology is the study of the structure of the universe over time

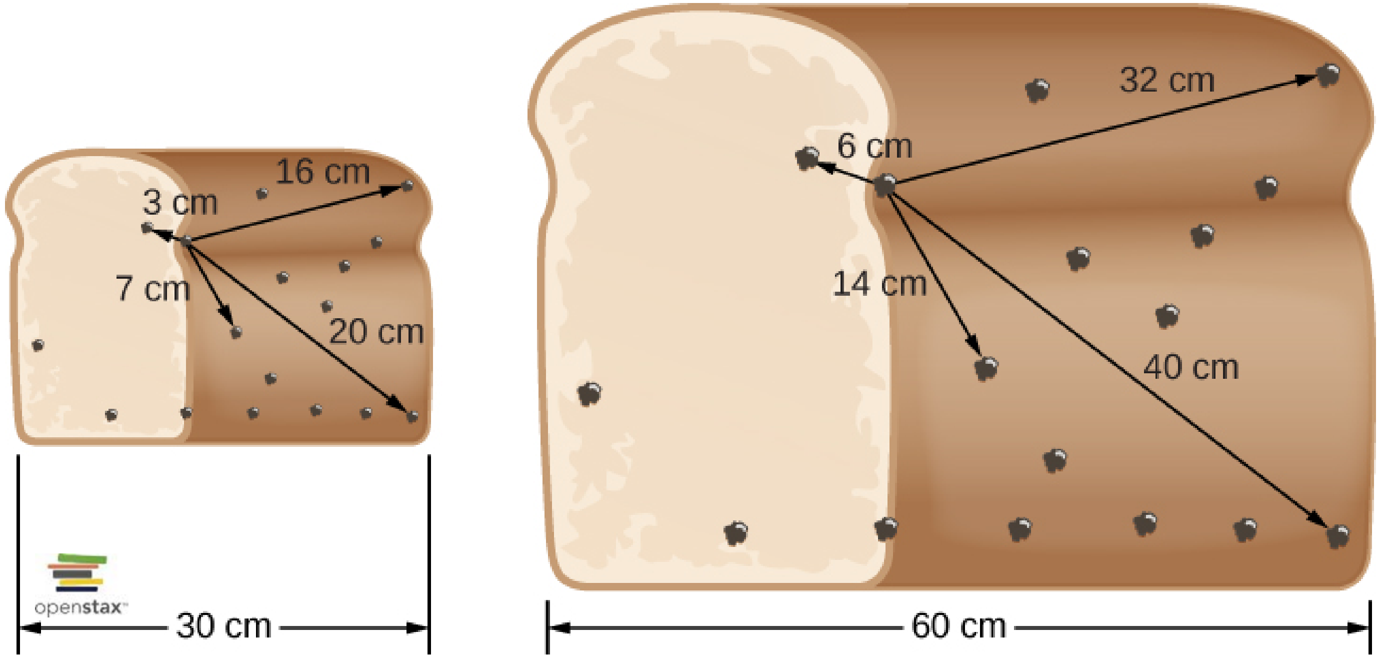


…counting from ~14Gyr ago.

- The "Big Bang" was the beginning of the universe as we know it
- Everything was an infinitesimally small point, and then began expanding suddenly
- After a rapid phase of expansion, more expansion followed
- This expansion slowed, until "recently" the expansion began to accelerate

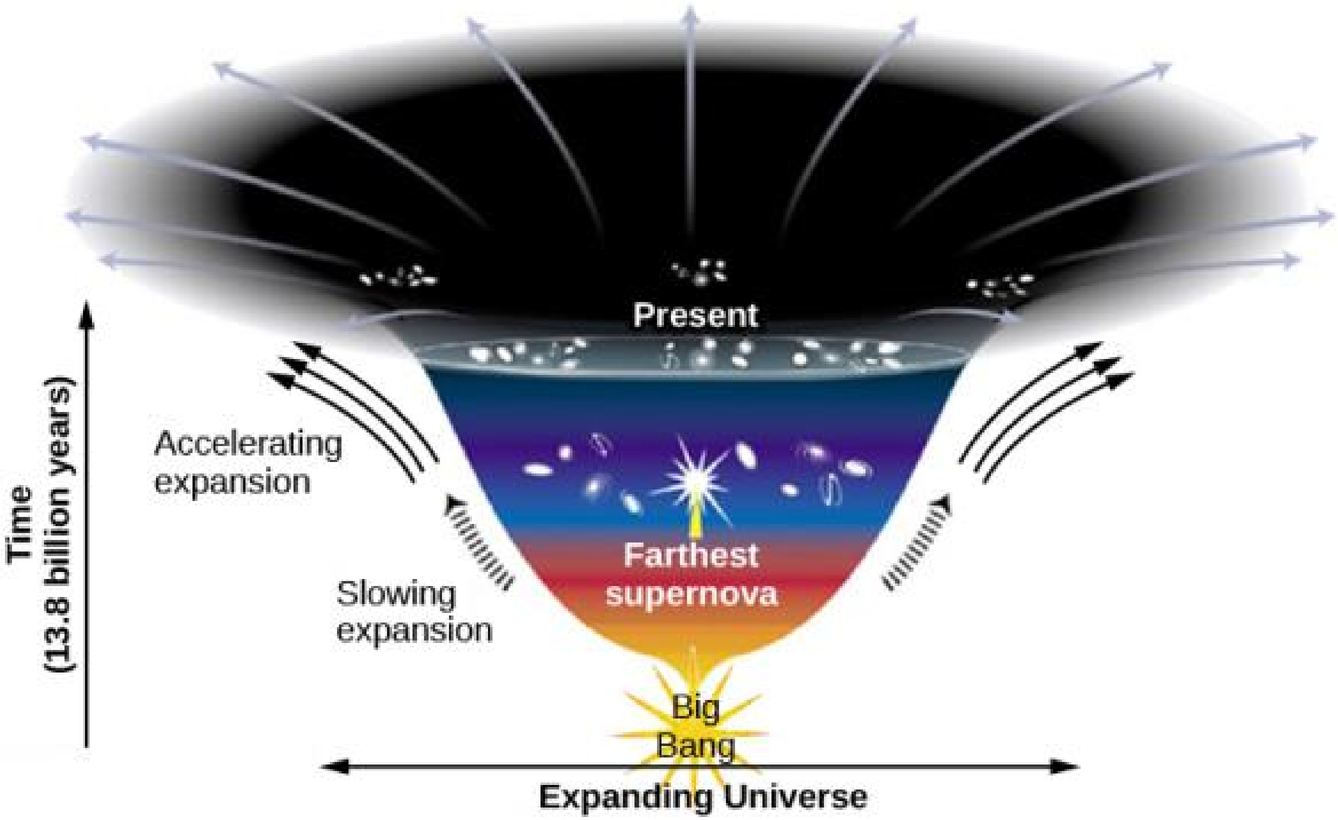
Rate of expansion

- Space itself is expanding: everything is moving away from everything else
- Like chocolate chips in a muffin, the further away one chip is from another, the faster that chip is moving away from the other
  - Consider the closest and furthest chips in the picture.
    - The closest will go from 3cm to 6cm away
    - The furthest will go from 20cm to 40cm away, **in the same amount of time**
- Therefore the velocity is related to the distance: $v = Hd$, where $H \approx 20\frac{km/s}{Mly}$ is the Hubble constant
- E.g. The Virgo cluster is ~54 Mly away and is therefore receding from us at $v \approx \left(20\frac{\frac{km}{s}}{Mly}\right)(54\ Mly)$
  $\approx 1080\ km/s$



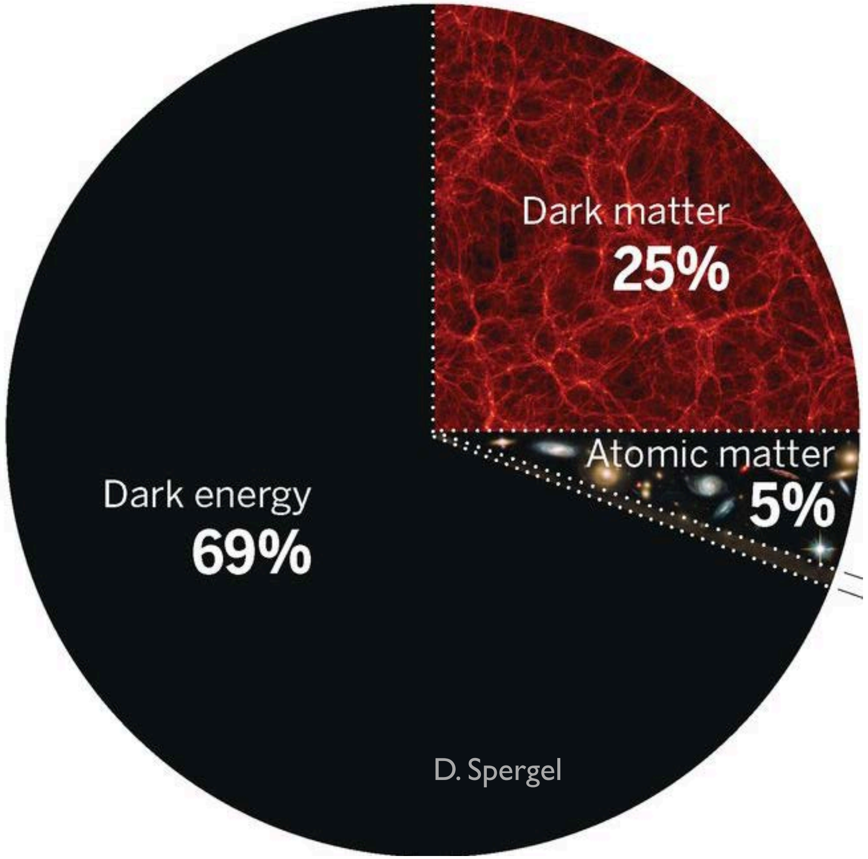
Change in Rate of Expansion

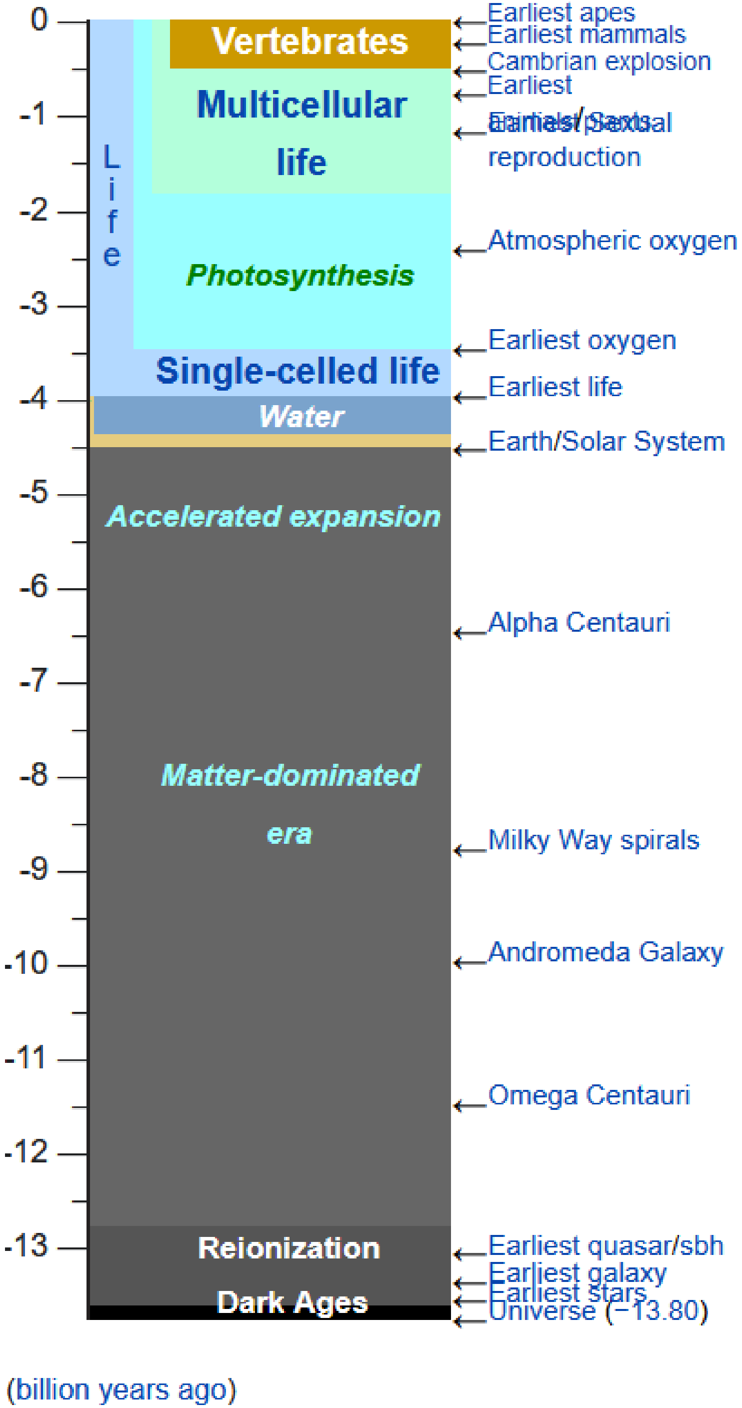
- The force of gravity means that everything with mass is attracted to everything else with mass
- So eventually, you would think that the expansion would run out of steam from the initial bang and slow down
- Instead, we see that in the past few billion years, acceleration has taken over



The Universe is Mostly Secret Sauce

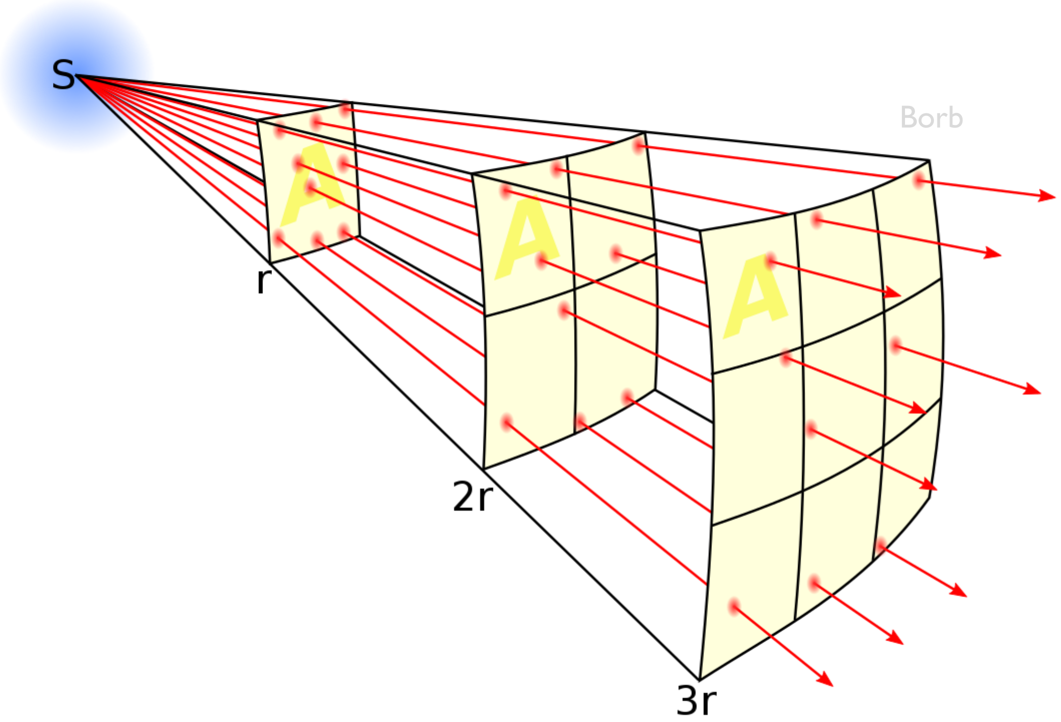
- Cosmology is largely impacted by stuff that we know almost nothing about
- "Dark matter" has mass, but doesn't interact with light
- "Dark Energy" is responsible for a repulsive force





How do we know the universe is expanding?

- Velocity from spectra (recall Introduction to Redshift lecture)
  - *Redshift is actually due to space stretching things apart!*
- Distance from "standard candles"



So what happens to everything?

One last bang (for some stuff)

…then heat death

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Black dwarf supernova in the far future

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ABSTRACT

In the far future, long after star formation has ceased, the universe will be populated by sparse degenerate remnants, mostly white dwarfs, though their ultimate fate is an open question. These white dwarfs will cool and freeze solid into black dwarfs while pycnonuclear fusion will slowly process their composition to iron-56. However, due to the declining electron fraction, the Chandrasekhar limit of these stars will be decreasing and will eventually be below that of the most massive black dwarfs. As such, isolated dwarf stars with masses greater than $\sim 1.2\,M_\odot$ will collapse in the far future due to the slow accumulation of iron-56 in their cores. If proton decay does not occur, then this is the ultimate fate of about 10^{21} stars, approximately 1 percent of all stars in the observable universe. We present calculations of the internal structure of black dwarfs with iron cores as a model for progenitors. From pycnonuclear fusion rates, we estimate their lifetime and thus delay time to be 10^{1100} yr. We speculate that high-mass black dwarf supernovae resemble accretion induced collapse of O/Ne/Mg white dwarfs while later low mass transients will be similar to stripped-envelope core-collapse supernova, and may be the last interesting astrophysical transients to occur prior to heat death.