

Astro 507: Physical Cosmology

Lecture 1

Jan 22, 2020

Announcements:

- Welcome!
- Pick up syllabus

Today's Agenda

- ★ Overview and Appetizer
- ★ Prerequisites
- ★ Course Mechanics

Physical Cosmology: Overview

We are in the golden age of Cosmology

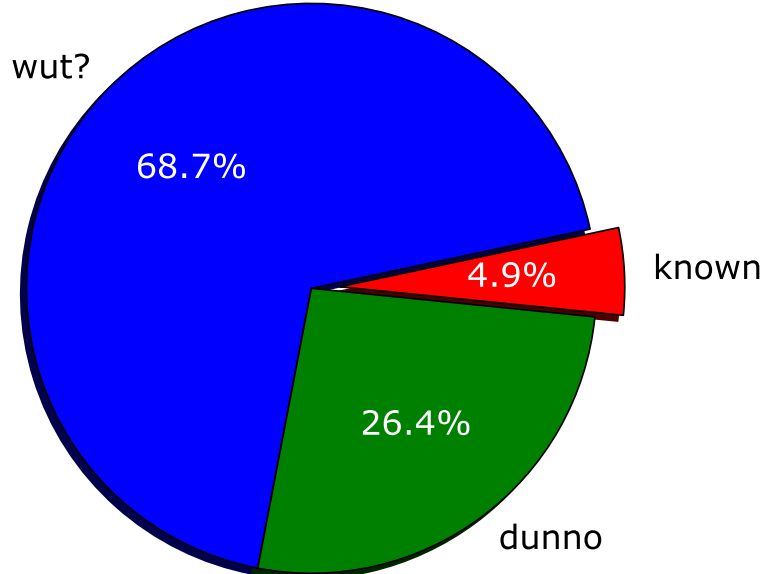
Present status:

precision ignorance

Q: meaning?

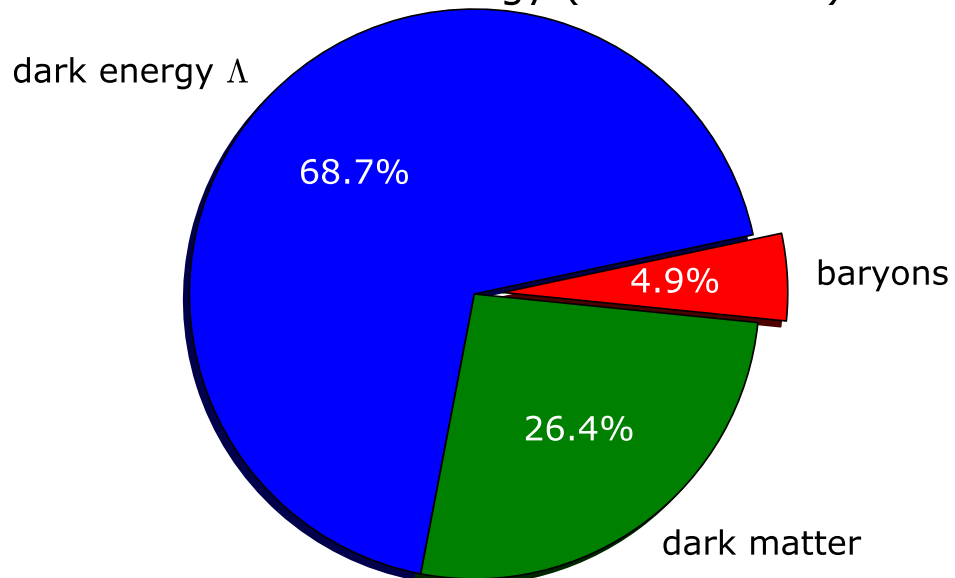
The Universe Today: Ingredients

Cosmic Mass-Energy (Planck 2018)



ω Q: fancier names for these components?

Cosmic Mass-Energy (Planck 2018)



Methods to the Madness

My goals:

you will come away with appreciation for

- ★ great cosmo successes and their far-reaching implications and how these lead to
- ★ profound open questions
e.g., pointing to new and fundamental physics:
elementary particles, quantum gravity.
- ★ interplay between observation and theory
- ★ cosmologists' toolbox: concepts, methods, lingo

Course Title:

Q: *why “physical cosmology” and not just “cosmology”?*

...more than one reason...

Whirlwind Tour: Preview of Coming Attractions

Part I: Foundations—Cosmological Pushups

www: Hubble

Q: how many spectroscopic redshifts to date? blueshifts?

- Hubble's law, expanding universe
- rough-and-tumble quasi-Newtonian analysis

www: Einstein

- General Relativity – quick overview
mostly conceptual, sketch of key elements
for the real deal: take Prof. Yunes's course!

www: lensed high-z galaxies

- relativistic cosmology
- lifestyles in an expanding universe

Part II: The Homogeneous Universe

www: SN1997D

Q: what are the objects in this image?

Q: for experts—how to tell SN type from image alone?

- determining expansion history
- evidence for cosmic acceleration

Q: caused by?

- grasping for explanation, and perhaps
a challenge to Einstein and a glimpse at quantum gravity

www: CMB Monopole

- cosmic microwave background: a perfect blackbody: thermal

$$T = 2.725 \pm 0.001 \text{ K}$$

∞

Q: implications for cosmic history?

★ Cosmic Microwave Background

- U. once thermalized → matter in “good thermal contact”
→ early U hot, dense!
- if hot enough: ionized! opaque!
- CMB: fossilized at (“re”)combination of $p + e \rightarrow H$
- “atomic age” of the Universe

www: helium in metal-poor galaxy *Q: for experts—em or abs line?*

- stars make He, but also “metals” in roughly equal amounts
- but (baryonic) U mostly H, He in nearly uniform abundances
Q: implications for cosmic history?

★ Big Bang Nucleosynthesis

- $t \sim 1$ sec, $kT \sim 1$ MeV: U was nuclear reactor
→ created light elements.
- “nuclear age” of the Universe

Q: what if earlier U achieved higher T?

Q: microphysical conditions?

Q: where are these recreated on Earth today

www: [micro-big-bang simulator](#)

Q: what other fossils might this leave behind?

★ Particle Dark Matter

- dark matter as stable particles from early universe production and candidates (e.g., Supersymmetry) detection, direct and indirect

www: Cryogenic Dark Matter Experiment

www: CMB Monopole

- T uniform on sky to few parts in 10^5

Q: implications?

www: high contrast CMB: fluctuations

Q: implications?

★ Inflation

- T on opposite sides of sky agrees to 4th decimal place
this. is. weird. *Q: why?*
- CMB T uniformity (isotropy) seemingly acausal
 T coordinated beyond apparent light cones
(i.e., $\gtrsim 1^\circ$ on CMB sky)
- inflation: explains T isotropy
- ...also a mechanism for anisotropy
→ seeds of supercluster, clusters, galaxies, you & me!

Part III: Inhomogeneous Universe

www: 2dF Slice

- inhomogeneities—describe, then explain

combine in model – “cold dark matter”

will sketch in analytic terms, but then also sims:

www: simulation still

www: simulation movie

Structure Formation

cosmological structures hierarchical

Q: which means?

Q: how might this come about? two logical possibilities!

www: evidence for one of these

www: M101 Galaxy

Q: what makes the blue light? the magenta?

Q: recall the CMB results—implications?

www: implications

structure formation and galaxy formation

somehow linked to **black hole** formation

14 www: Sgr A*

www: HST quasar

Cosmology and Illinois

Illinois is center for cosmology

you'll get an idea of what goes on here

how it fits into larger context of Physics & Astronomy

Facilities:

www: DES, www: SPT, www: Spider/Keck Array, www: LSST

Science Areas:

www: cosmic microwave background

www: dark matter and non-gaussianity

www: cosmosimulations

www: supernova cosmology

www: inflation

www: cosmic star formation

www: particle cosmology

Prerequisites

Not required (but great if you've had)

- cosmology, astrophysics
- general relativity
- nuclear and/or particle physics

Required (should be fine for 1st year grad students)

- classical mechanics
- basic special relativity
- E&M (particularly Poisson equation)
- basic quantum mechanics (Bohr atom; bosons and fermions)
- basic thermodynamics (ideal gasses, blackbody radiation)
- Fourier transforms

ASTR 406 veterans: you should be fine

if in doubt—don't panic, but ask me!

Syllabus