Announcements:
• Welcome!
• Pick up syllabus
• ASTR 496-ers: pick up Addendum

Today’s Agenda
★ Overview and Appetizer
★ Course Mechanics: ASTR 596PC, ASTR 496PC
Physical Cosmology: Overview

We are in the golden age of Cosmology

Present status: precision ignorance

Q: meaning?
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. Shapiro’s course!

**www:** high-z galaxy in SDSS

- relativistic cosmology
- lifestyles in an expanding universe
Part II: The Homogeneous Universe

www: SN1997D

Q: what are the objects in this image?
Q: how can you 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
  $T = 2.725 \pm 0.001$ 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 dwarf galaxy
- 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: State of Illinois micro-big-bang simulator
www: the competition abroad
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

- 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
  $\rightarrow$ seeds of supercluster, clusters, galaxies, you & me!
Part III: Inhomogeneous Universe

www: 2dF Slice
• inhomogeneities—describe, then explain

Theory:
Q: relevant physics? Q: important cosmic ingredients?

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

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

www: DES
www: SDSS
www: cosmosimulations
www: cosmic star formation
www: particle cosmology
Spoilers vs Reruns?

Last semester, several of you suffered through Astronomy 596 NPA: Nuclear and Particle Astrophysics

Q: isn’t this course a rerun of that?

A: No.
  ▶ in this course: all of cosmology
    not just early universe, not just homogeneous
  ▶ even in early U: here will discuss inflation at length
    precedes dark matter formation and nucleosynthesis

A: Well, mostly no.
  ▶ foundational material has the most overlap
    → it’s the same universe, same equations!
  ▶ primordial nuke, particle dark matter appear in both
    but here: briefer treatment
    emphasis on connection to CMB physics & formalism
ASTR 496PC Addendum to Syllabus