Astro 507: Physical Cosmology

Lecture 1

Jan 22, 2014

Announcements:

- Welcome!
- Pick up syllabus
- cosmology talk today: Brad Benson, U. Chicago
  "Exploring Fundamental Physics through Measurements of the Cosmic Microwave Background"
  Physics Colloquium, 4pm, Loomis 141

Today's Agenda

★ Overview and Appetizer

★ Course Mechanics

★ ASTR 596/496 RF

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: 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

Breaking News

closest/brightest SN Ia in decades discovered *yesterday*

`www: blink image of starburst galaxy M82`

`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 $\rightarrow$ matter in "good thermal contact"
  $\rightarrow$ 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
  $\rightarrow$ 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?

$\star$ 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?

$\star$ 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:  SPT
www:  dark matter and non-gaussianity
www:  cosmosimulations
www:  supernova cosmology
www:  inflation
www:  cosmic star formation
www:  particle cosmology
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Syllabus

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!

ASTR 596 RF: Supernovae and Dark Energy

Instructor: Prof. Ryan Foley
Time: Thursdays and Fridays, 2:00–3:30pm

Q: Wait, isn't that the same as this course?

A: No.

- this course much broader: all of cosmology
- even when overlap exists, perspectives different
  Prof. Foley is an observer, I'm not
- This course is more traditional: lecture, discussion, HW
  A596RF: no HW! readings, presentations, group research paper

A: Well, mostly no.

- foundational material has the most overlap
  $\rightarrow$ it's the same universe, same equations!
- *courses are complimentary:* dark energy, supernovae in both
  here: briefer treatment, broader context