Announcements:
• Welcome!
• Pick up Syllabus, handy abundance table
• Preflight 1 due Friday Sept. 4

Today’s Agenda
★ Introductions
★ Overview and Appetizer
★ Course Mechanics: ASTR 596 NPA, ASTR 496 NPA
Nuclear and Particle Astrophysics: Overview

We are in the middle of a golden age for nuclear and particle astrophysics

Objective:
to understand the nature, and history of cosmic matter (both visible and dark) in terms of microphysical processes

Present status: turning point
major 20th century successes—tools, techniques, results lay foundations to answer 21st century questions
Whirlwind Tour: Preview of Coming Attractions
The Poor Person’s Accelerator

Major theme:

the Universe is the poor man’s accelerator
–Y. Zel’dovich

Q: meaning?

Central Example (We Hope!): Dark Matter

• both baryonic and non-baryonic
  Q: what’s a baryon?
• in fact: most cosmic matter is non-baryonic!
  Q: why is this a big deal?
• in fact: non-baryonic dark matter likely WIMPs
  Q: meaning?
Weakly Interacting Massive Particles
here: weak ⇒ scale of weak interaction
→ particle masses $m_{\text{wimp}}c^2 \sim 1\text{TeV} = 10^{12}\text{ eV}$
Q: compare: electron, proton mass?

The Search is On!
● direct detection of local dark matter
  www: UK DM search
  www: CDMS
● indirect detection: astrophysical
  Q: how could dark matter give photons?
● www: TeV gammas from Galactic center
● www: positron signal from Galactic center

current situation unclear: disputed claims of signal!
what is clear: in next 5–10 years will either
★ hit jackpot, or
★ challenge/rule out deeply held, well-tested theories.
Big Bang Nucleosynthesis

WIMPS: origin $t \lesssim$ picoseconds
move on to $t = 1$ sec: U fusion reactor/thermonuclear bomb

Big bang nuke (BBN):
first example of particle astrophysics connection
cartoon: $D$ in QSOALS–QSO, cloud, observer
www: $D$ lines (O’Meara 2001)
Q: what does this tell you?

BBN deeply connected with cosmic microwave background (CMB)
www: CMB power spectrum
will see: BBN-CMB comparison $\Rightarrow$ triumph and crisis
Messengers Beyond Photons: Neutrinos

Barely there but at the heart of it all!

Solar Neutrinos
www: Neutrino Sun

Atmospheric Neutrinos
www: IceCube Experiment, www: IceCube Sky: atmospheric neutrinos

Supernova Neutrinos
www: SN1987A discovery image

Terrestrial Neutrinos
www: geoneutrino simulated map

Cosmological Neutrinos (CNB)
tell me if you know how to detect these!
Stellar Nucleosynthesis: Supernovae

supernova explosions produce most of the diversity of heavy elements
will look at in detail
www: Cassiopeia A element map

life requires supernovae—but not too close!
www: NearbySN page
Messengers Beyond Photons: Cosmic Rays

www: Fermi gamma-ray sky
in Galactic coordinates Q: meaning?
Q: features?

www: cosmic-ray shower
www: Auger gold-plated event
www: Auger sky--cosmic ray astronomy?
The History of Cosmic Matter

Tying it all together: Galactic/cosmic chemical evolution will see how solar system, Galactic matter is a symphony of nucleosynthesis integrating big bang, supernovae, low-mass stars

www: circle of life
Laboratory Tools

just as Universe is accelerator (astro → particle)
also particle → astro connection
then accelerators act as telescopes probing early U

Q: what is most powerful accelerator today? Where?

Q: what will be the most powerful by the course’s end? Where?
the most powerful accelerator today
is in the Great State of Illinois!
\( p\bar{p} \) collision energies \( \approx 1 \) TeV

www: Tevatron
www: Fermilab tour information

coming online by the end of the semester (?)
Large Hadronic Collider (LHC)
at CERN Laboratory, Geneva Switzerland
www: LHC ATLAS webcam
Main Course Goals

• Get a sense of the **variety** and **excitement** of the field both nuke astro and particle astro

  To do this: I choose **breadth** over depth
  “short attention span” astrophysics

• Get familiarity with what is known, unknown, and boundary: **frontier** areas where breakthroughs are happening

• Understand how to use **nuke/particle tools** in other research areas (e.g., *yours*)
  e.g.: abundances, neutrinos, $\gamma$-rays, cosmic rays encode past and present history, energetics of matter applications in galaxy formation, star formation, particle physics
ASTR 496PC Addendum to Syllabus