Astronomy 100
Tuesday, Thursday 2:30 - 3:45 pm
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Schedule

• Today (end and beginning of the universe)
• May 3 (Does Life Exist Elsewhere in the Universe)
• May 5 (Review)
• May 10 (Exam 4)
• May 12 (Exam 5) (optional)
• May 20 (Final) (optional)
Exam 4

• Know the class notes
• Know all the definitions on the website
• Know the Summary of Key Concepts at the end of every chapter
Exam 5 and Final

- Know the class notes
- Know how to do every question on the 1st 4 exams
- Know the Summary of Key Concepts at the end of every chapter
OWL assignment (Due Today)

• There is an OWL assignment due on Thursday April 28 at 11:59 pm.
• There are 15 questions and a perfect score will give you 2 homework points.
Homework Assignment
(Due by May 3)

• Make up a test question for next test
• Multiple Choice
• A-E possible answers
• 1 point for handing it in
• 1 point for me using it on test
• The question needs to be on material that will be on the 4th exam
Homework Assignment
(Due by May 5)

• I have placed 40 terms on the website
• You get 0.1 of a HW point for each of these you define and hand in to me
• Definitions need to be hand-written or hand-typed
• A lot of these definitions will be on next test
<table>
<thead>
<tr>
<th>Drake Equation</th>
<th>Percival Lowell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Energy</td>
<td>Redshift</td>
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<tr>
<td>Tully-Fisher Relation</td>
<td>Dark Matter</td>
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<td>ALH84001</td>
<td>MACHO</td>
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<td>Cepheid Variable</td>
<td>Critical Density</td>
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<td>White Dwarf</td>
<td>Radio Galaxy</td>
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<td>Jocelyn Bell</td>
<td>Main Sequence Fitting</td>
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<td>Viking Mission</td>
<td>Cosmological Horizon</td>
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<td>Hubble’s Law</td>
<td>White Dwarf Supernova</td>
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<td>SETI</td>
<td>Interstellar Medium</td>
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<td>Big Bang</td>
<td>Supercluster</td>
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<td>COBE</td>
<td>WIMPS</td>
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<td>Standard Candle</td>
<td>Pulsar</td>
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<td>Quasar</td>
<td>Habitable Zone</td>
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<td>Planck Time</td>
<td>Maunder Minimum</td>
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<td>Inflation in the Early Universe</td>
<td>Convection Zone</td>
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<td>Olber’s Paradox</td>
<td>Radiation Zone</td>
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<tr>
<td>Cosmic Microwave Background</td>
<td>Hubble’s Constant</td>
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<tr>
<td>Isotope</td>
<td>Starburst Galaxy</td>
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<tr>
<td>Baryon</td>
<td>Europa</td>
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</tbody>
</table>
Astronomy Help Desk

• There is an Astronomy Help Desk in Hasbrouck 205.
• It is open Monday through Thursday from 7-9 pm.
Olber’s paradox

• How can the night sky be dark if the universe is infinite and full of stars?
Answer?

• We can only see a finite number of stars
• Big Bang theory works:
• The universe began at a particular time
4 Forces that operate in the universe

- Gravity
- Electromagnetism
- Strong Force
- Weak Force
Gravity

• Massive particles interact with other massive particles
• Acts on big distances
Electromagnetism

- Charged particles act with other charged particles
- Act on small distances
Strong Force

• Force that holds atomic nuclei together
• Keeps protons together in a nucleus
• Protons would fly apart
• Occurs over very small distances like diameters of nuclei
<table>
<thead>
<tr>
<th>The Quarks</th>
<th>The Leptons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up</td>
<td>Electron</td>
</tr>
<tr>
<td>Down</td>
<td>Electron neutrino</td>
</tr>
<tr>
<td>Strange</td>
<td>Muon</td>
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<tr>
<td>Charmed</td>
<td>Mu neutrino</td>
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<td>Top</td>
<td>Tauon</td>
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<tr>
<td>Bottom</td>
<td>Tau neutrino</td>
</tr>
</tbody>
</table>
neutron

proton

one up quark

two down quarks

two up quarks

two down quarks

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Weak Force

- Weak forces govern nuclear reactions
- Occurs over distances 0.1% the diameter of a proton
Big Bang

• The event that gave birth to the universe
• One consequence of the Big Bang is that the conditions of today's universe are different from the conditions in the past or in the future.
The Name

• Fred Hoyle proposed an alternative Steady State model in which the universe was both expanding and eternal

• Hoyle christened the theory, referring to it disdainfully in a radio broadcast as "this 'Big Bang' idea".
Planck Time

• 10^-43 seconds after Big Bang

• At Planck Time, the universe was 10^32 Kelvin and had the size of 10^-33 cm.

• Before Planck Time, the universe was concentrated in a single point.
Before Planck Time

- Before a time classified as a Planck time, all of the four fundamental forces are presumed to have been unified into one force.
- All matter, energy, space and time are presumed to have exploded outward from the original singularity.
- Nothing is known of this period.
Video

Sounds

- http://staff.washington.edu/seymour/altvw104.html
GUT Era

• Lasts from $10^{-43}$ until $10^{-38}$ seconds after Big Bang
• GUT – Grand Unified Theory
• At high enough temperatures, electromagnetism, strong force, and weak force all act as one force
• Gravity still acts separately
Inflation

• During GUT era, there was inflation
• Rapid expansion of universe
The diagram illustrates the major events since the Big Bang, starting from the Planck Era and progressing through the GUT Era, Electroweak Era, Era of Nucleosynthesis, Era of Atoms, and Era of Galaxies. Each era is marked by significant changes in the universe:

- **Planck Era**: Elementary particles.
- **GUT Era**: Elementary particles.
- **Electroweak Era**: Elementary particles.
- **Era of Nucleosynthesis**: Protons, neutrons, electrons, neutrinos.
- **Era of Atoms**: Plasma of hydrogen and helium nuclei plus electrons.
- **Era of Galaxies**: Atoms and plasma (stars begin to form).
- **First Galaxies Form**: First galaxies form.
- **Stars, Galaxies, and Clusters of Galaxies**: Stars, galaxies, and clusters of galaxies (made of atoms and plasma).
- **Humans Observe the Cosmos**: Humans observe the cosmos.

The diagram also includes a time scale at the top, starting from the present and going back to the early stages of the universe. The key at the bottom of the diagram indicates the symbols for neutron, proton, electron, neutrino, antiproton, antineutron, antielectron, and quarks.
Electroweak era

- Lasts from $10^{-38}$ until $10^{-10}$ seconds after Big Bang
- Strong Force becomes separated
- Left with Electroweak force
Particles being created and destroyed

Particle creation

- gamma-ray photon
- electron

Particle annihilation

- antielectron
- gamma-ray photon

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Particle Era

• Lasts from $10^{-10}$ until 0.001 seconds after Big Bang
• Quarks, electrons, neutrinos formed
• Quarks started to make protons and neutrons and antiprotons and antineutrons
Antimatter

• Particle with same mass as ordinary particle but other basic properties are precisely opposite
Big Question

• If there were equal numbers of protons and antiprotons
• And neutrons and antineutrons
• All the particles would have annihilated each other
• Creates photons
Must have

• There must have been a very slight excess of matter over antimatter
• Like for every one billion antiprotons
• There were one billion and one protons
• So the billion antiprotons annihilated the billion protons
• Left one proton
Era of Nucleosynthesis

- Lasts from 0.001 seconds to 3 minutes after Big Bang
- Fusion started to occur
- 75% of the universe was hydrogen
- 25% of the universe was helium
Era of Nuclei

- Lasts from 3 minutes to 380,000 years after Big Bang
- Cool enough so hydrogen and helium could capture electrons
- Photons stopped hitting electrons and instead were able to stream through the universe
Era of Atoms

- Lasts from 380,000 to one billion years after Big Bang
- Protogalactic clouds start to form
Era of galaxies

- Lasts from one billion years after Big Bang to present
- Galaxies form
Evidence for Big Bang

• Cosmic Microwave Background is the form of electromagnetic radiation that fills the whole of the universe.
COBE
Cosmic Background Explorer
Measured thermal background of sky
Sky has temperature of 2.73 K
Due to photons that streamed out during the era of nuclei:

- Photons had a temperature of 3,000 K.
- They had a blackbody spectrum.
- Had a temperature now of 2.73 K since the universe has expanded and stretched the wavelength of the photons.

Has temperature now of 3,000 K.
Brighter regions are 0.0001 K hotter
Importance

- This 2.73 K is very uniform across the sky
- Permeates the whole sky
- Evidence for Big Bang
Other evidence

• Predicted to have produced 75% hydrogen and 25% helium during the era of nucleosynthesis
• That is approximately what we see today
End of Universe

• Critical Density – Density marking the dividing line between eternal expansion and eventual collapse
Questions