Our Cosmic History*

Lecture #2 - April 8, 2010

"Early History of the Cosmos"

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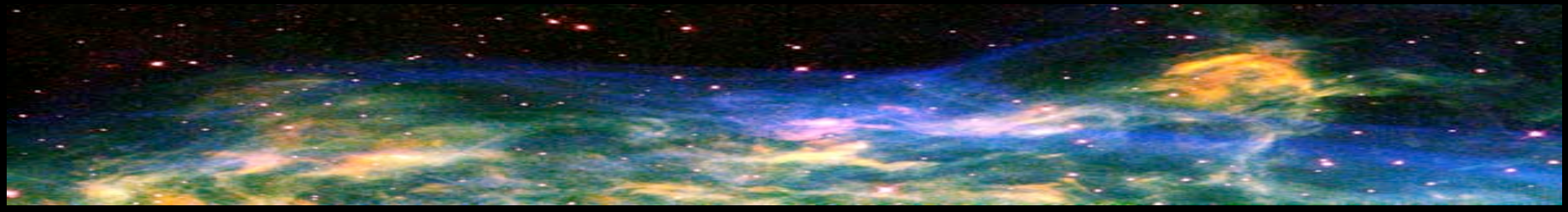
(Some slides contributed by Aparna Venkatesan, U of San Francisco)

* *Lecture series sponsored by the PSU Center for Science Education & the Science Integration Institute, and made possible by a generous grant from the Oregon Dept. of Education*



Themes of the series…

- Reflecting on what it means to be *you*, in this moment, within the context of the universe as we currently understand it. What is the cosmic *story* we are part of?
- Gaining perspective on how we connect to the universe: we are children of the *whole cosmos*, not just our immediate surroundings
- Framework for teachers and students to see how the details of science fit into a big picture that gives meaning and context to those details

Series Web Site…

…for schedule, resources, & continuing discussion…

http://oregonteacherscholars.pbwiki.com/Our-Cosmic-History

(or link from www.scienceintegration.org)

Upcoming…

Lecture #3:

"Earth: Geology, Chemistry, & Origins of Life"

April 15th at 7 pm

(same location - 71 Cramer)

Warmup Activity: Make a timeline of about 10 key events in your own life

Some things to think about…

-Where should your timeline begin? Birth? Conception? Arrival somewhere? A landmark ancestor in your family tree?

-What kinds of events/transitions will you choose as milestones? Changes in appearance? Behavior? Permanent changes or temporary ones?

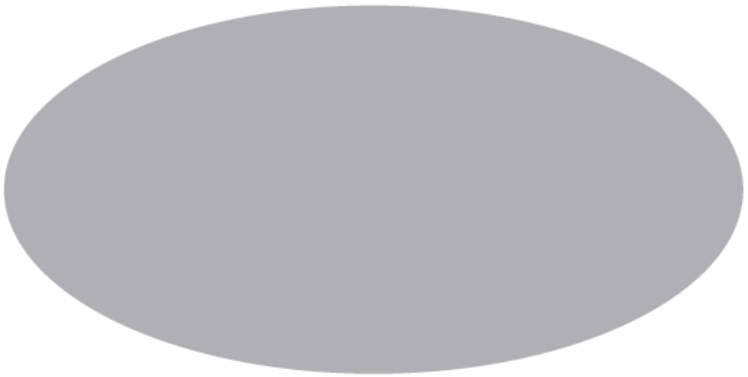
-How will you space events in time? For example, you might want to space them evenly, but perhaps significant events occur more rapidly at some times in life than others?

** This will help us appreciate the issues involved in picking events to highlight in the early history of the universe**

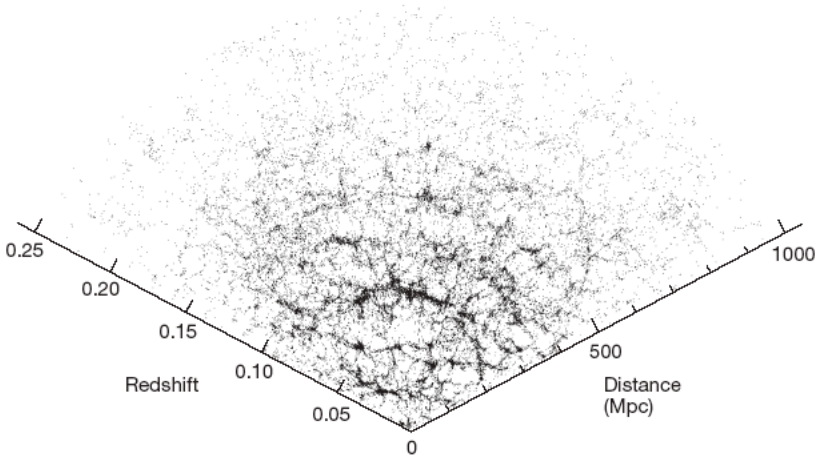
Timeline of events in the early universe

General trend: “smooth and simple” ---> “clumpy and complex”

tured form today. The smooth early universe revealed by the CMB:



became the lumpy modern universe revealed by galaxy surveys:



Source: Duncan & Tyler, *Your Cosmic Context*,
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"From so simple a beginning endless forms most beautiful and most wonderful."

– Charles Darwin (The Origin of Species)

History in Astronomy – Light as a Time Machine

Because light does not travel infinitely fast, *looking out in space means looking back in time!!*

For example, an observer in a galaxy 70 million light years away from here could be looking at the Earth *right now* through a super-powerful telescope. Can they peek in on this lecture?

What do they see? …

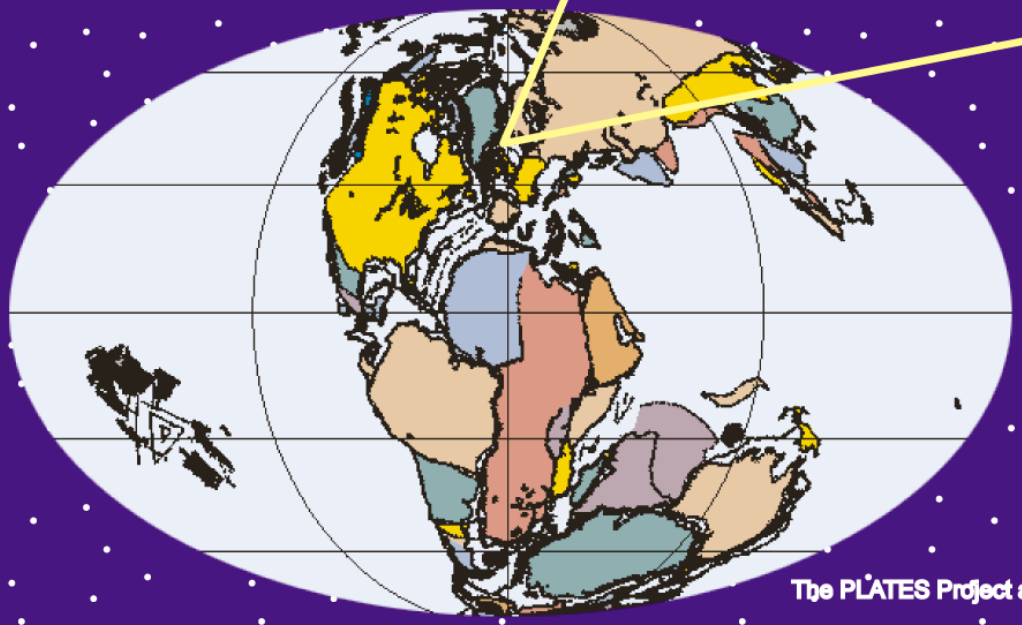
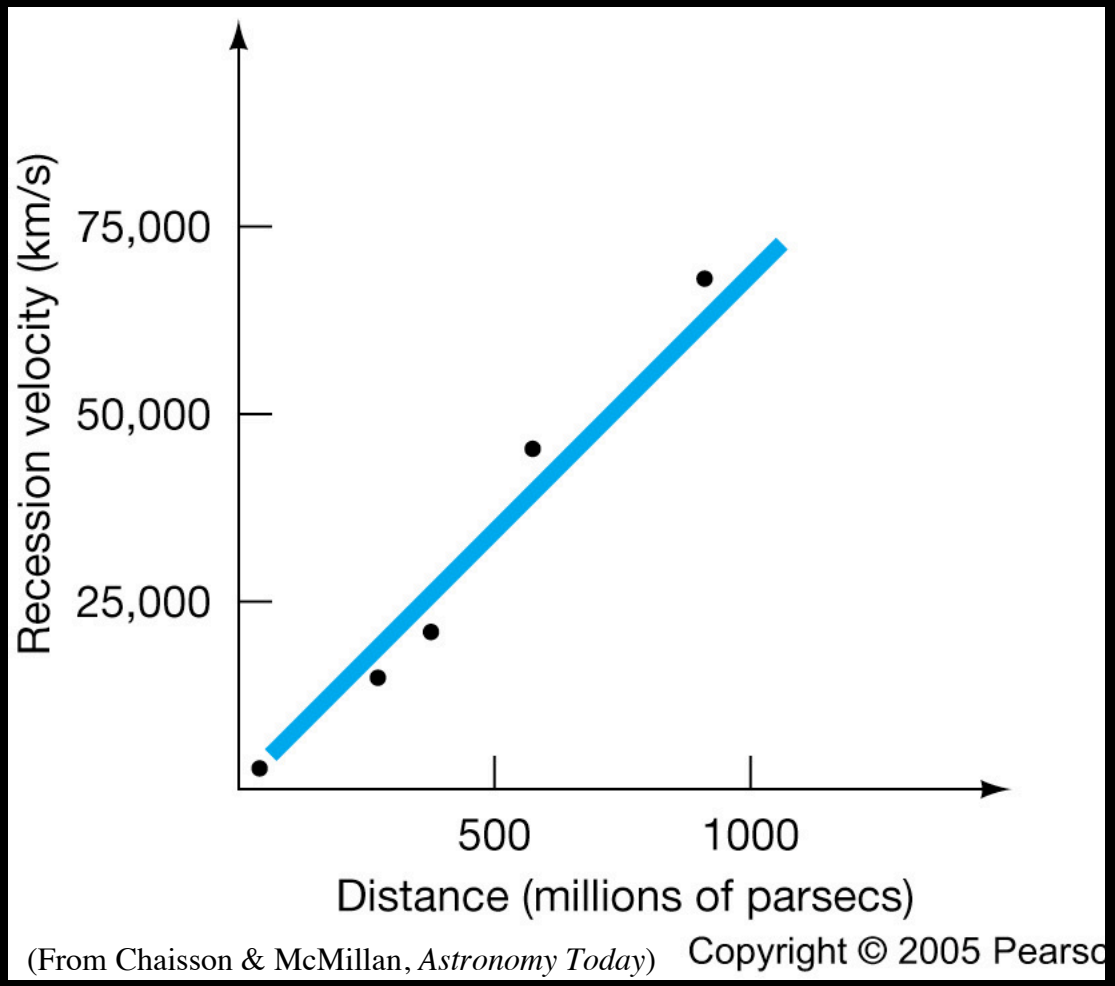


Figure Credit: Angela Lowman

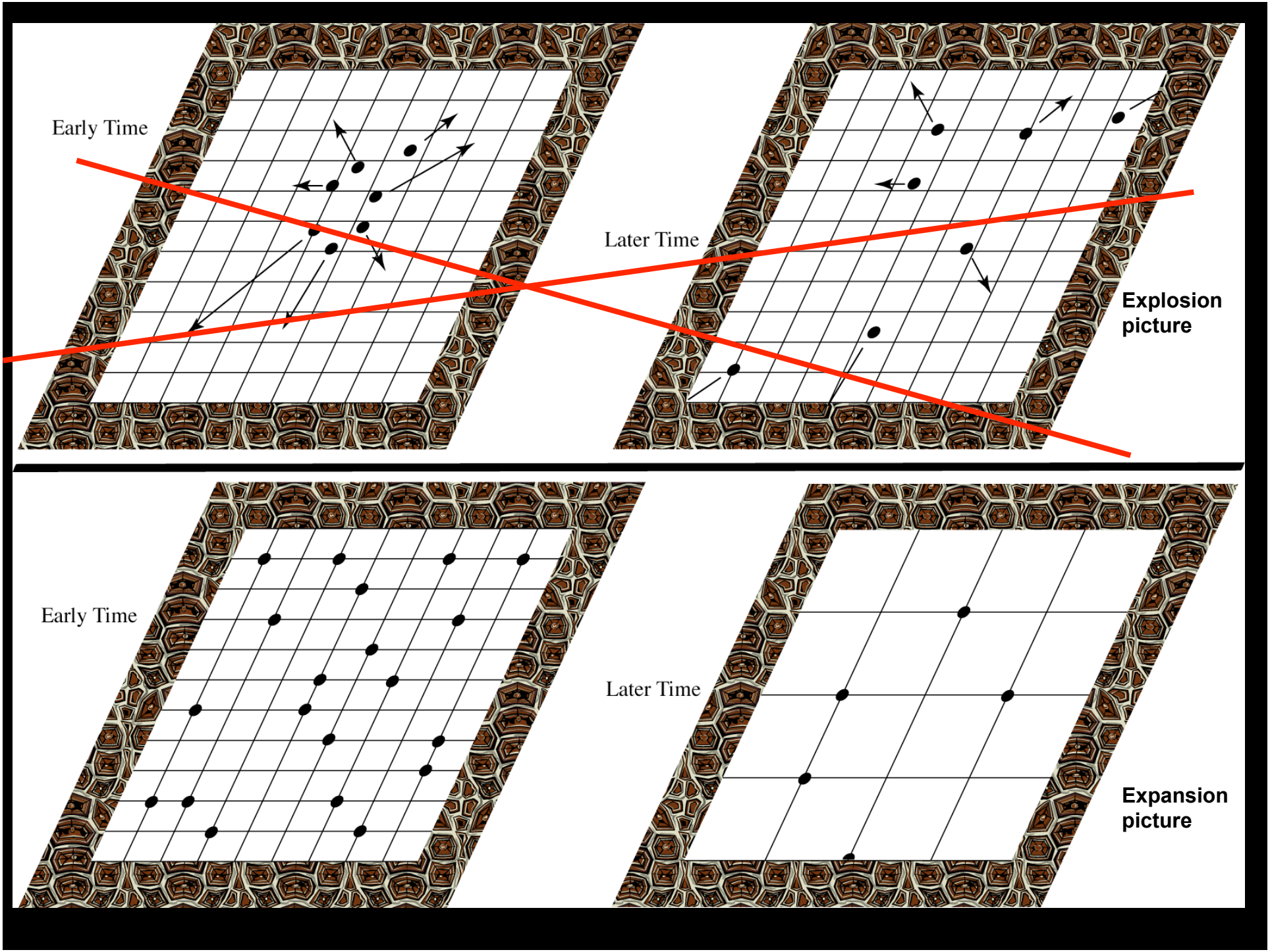
Expanding Space ("Big Bang") Framework for History

- *Space is expanding* – the physical distance between *galaxies* is increasing with time, at a rate of about 2 x 10^{-18} km/s per km (about 70 in units usually quoted). So things have to be *very* far apart before it amounts to much.
- *The universe was hotter and denser in the past.* About 13.7 billion years ago, everything in the currently observable universe was compressed to extremely high density and temperature (the "big bang").
- *The big bang happened everywhere* (including here – the space right here in this room was once glowing hot!!)

Hubble Law Evidence for Expansion of Space



(From Chaisson & McMillan, *Astronomy Today*) Copyright © 2005 Pearso


Early Time
Later Time
Explosion picture
Early Time
Later Time
Expansion picture

The Ultimate Mystery – Origins…

Why is there something rather than nothing?

(Is that even a meaningful question?? Why do we assume "nothing" is a more natural state than "something"?)

Can we even imagine true nothingness? (*Rig Veda* example – 3,000 year-old Indian hymn)

Does time itself have a "beginning"? What does that mean???

Worth remembering that everything is frozen creation, and embodies the ultimate mystery of existence itself.

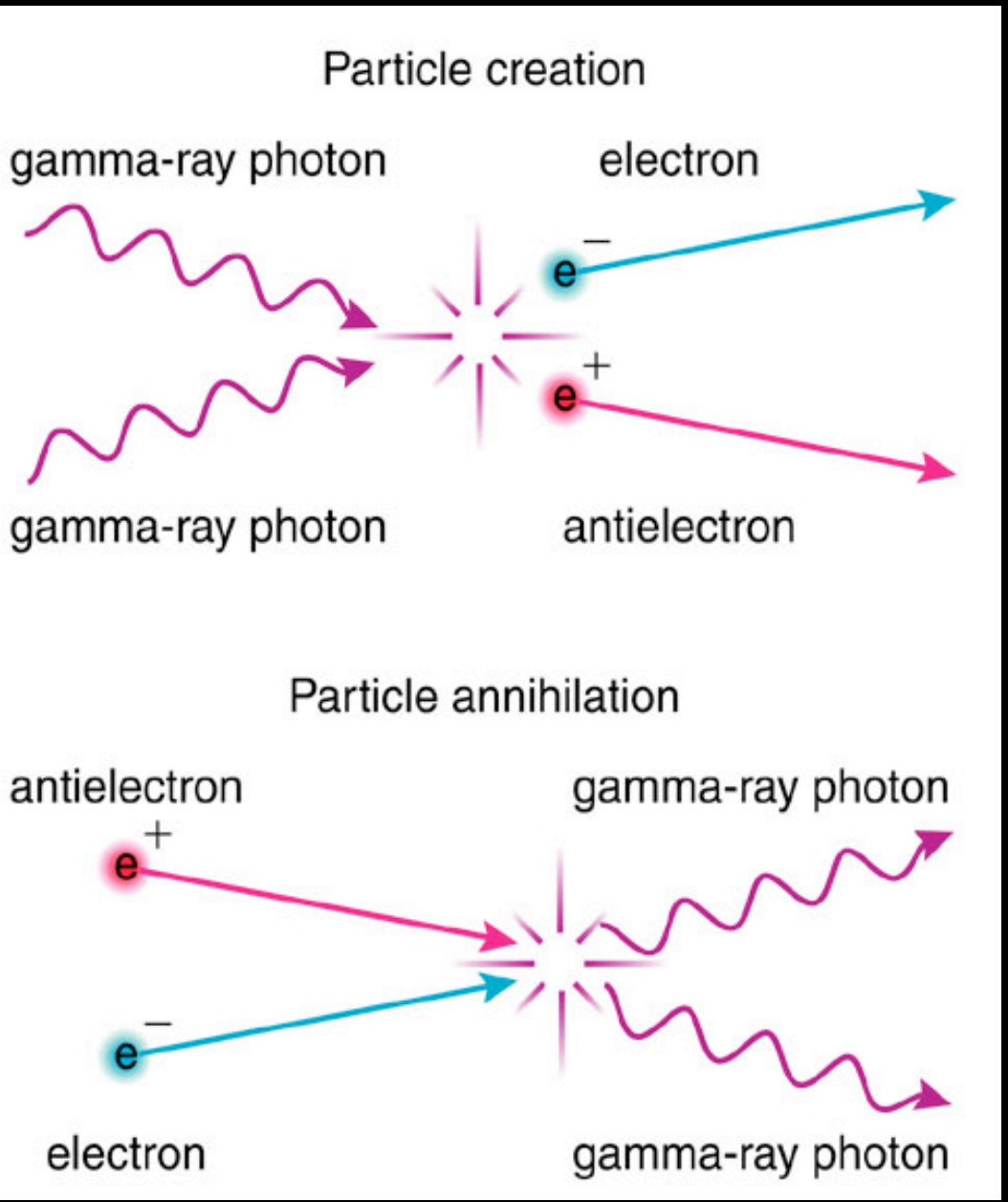
Nothing in the universe is more mysterious and wonderful than the simple fact that anything exists, in this moment.

(A pencil, a mote of dust, a tax form…)

Time = “0” (13.7 billion years ago)

Extremely hot, dense, uniform “primordial soup” of energy - if you could survive the conditions you’d be immersed in a very hot, glowing fog

Temperature at the earliest times was more than we can create in particle accelerators (LHC recently got closer). Cosmology at early times is explored via particle physics! (connection between the very small and the very large)



Photons can be converted into particle-antiparticle pairs and vice-versa

$$E = mc^2$$

Early universe was full of particles and radiation because of its high temperature

Source: Bennett et al *The Cosmic Perspective,* © Pearson Addison-Wesley

Time = a few minutes
“Big Bang Nucleosynthesis”

protons and neutrons --> hydrogen (~1/4), helium (~3/4) and traces of lithium (hot enough for fusion but cools rapidly so no time to make heavier elements, for which electrical repulsion is stronger)

very simple periodic table at this point - only 3 elements!!

all atoms ionized -- still too hot for electrons to stay bound to protons

Cosmic Elements

Source: NASA Imagine the Universe project

http://imagine.gsfc.nasa.gov/docs/teachers/elements/elements.html

White - Big Bang

Pink - Cosmic Rays

Yellow - Small Mass Stars

Green - Large Mass Stars

Blue - Supernovae

Time = 72,000 years
“Era of matter domination” begins

Key event because gravity can start to form structures

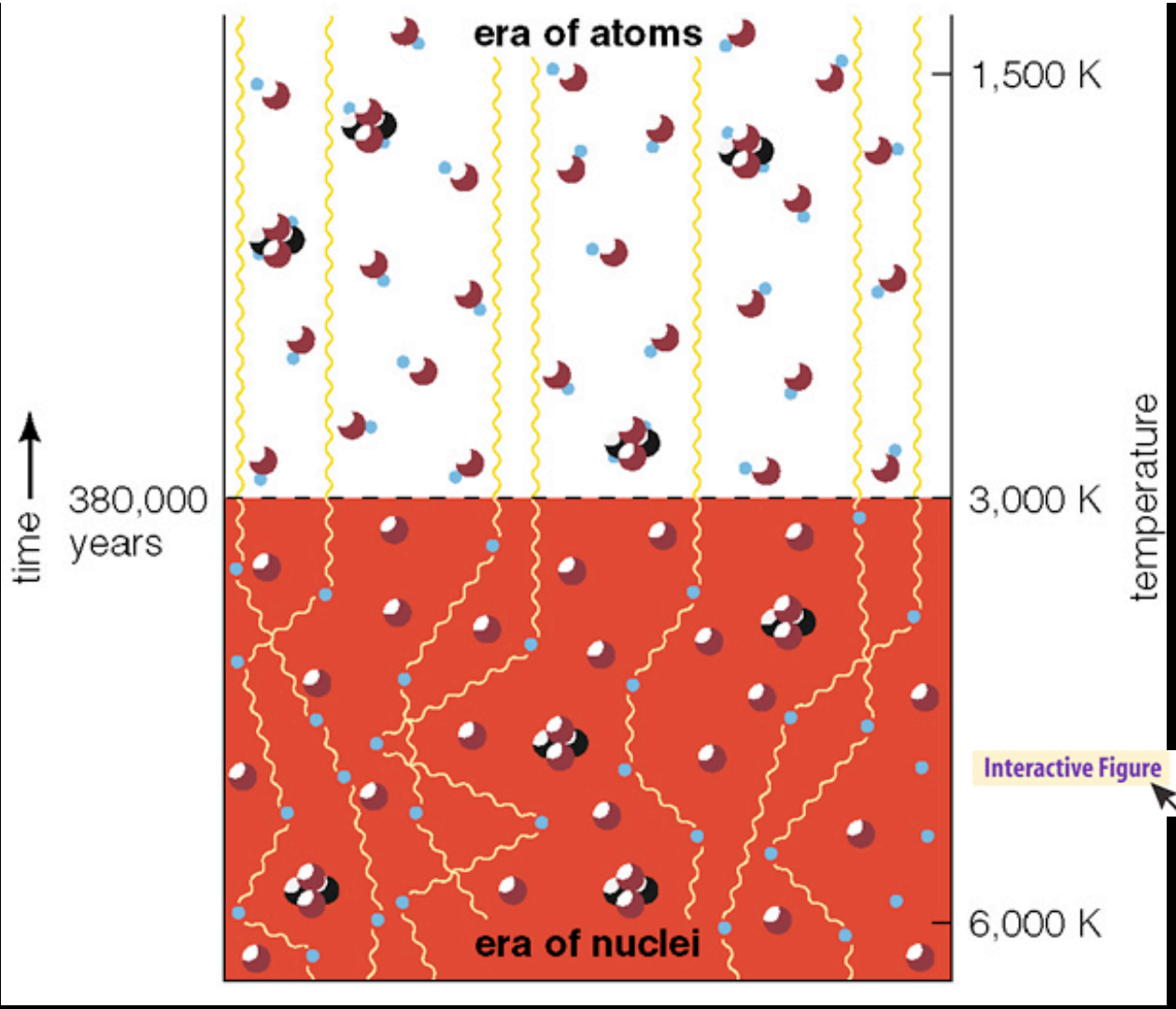
Only exotic dark matter (WIMPS?) able to start forming structures at this point -- baryonic matter still feeling pressure from light, which keeps it from clumping

Time = 380,000 years
First Neutral Hydrogen --> CMB forms

- Free electrons now bound in atoms --> universe becomes transparent -- would be like fog lifting if you were around to watch the transition

- The light that is now free travels through space mostly unimpeded, carrying information about the conditions of the last electron it scattered off of. We see this light now as the CMB (but redshifted by expansion -> microwaves)

- “Dark ages” before stars form (CMB redshifted so not visible)



Source:
Bennett et al
The Cosmic Perspective,
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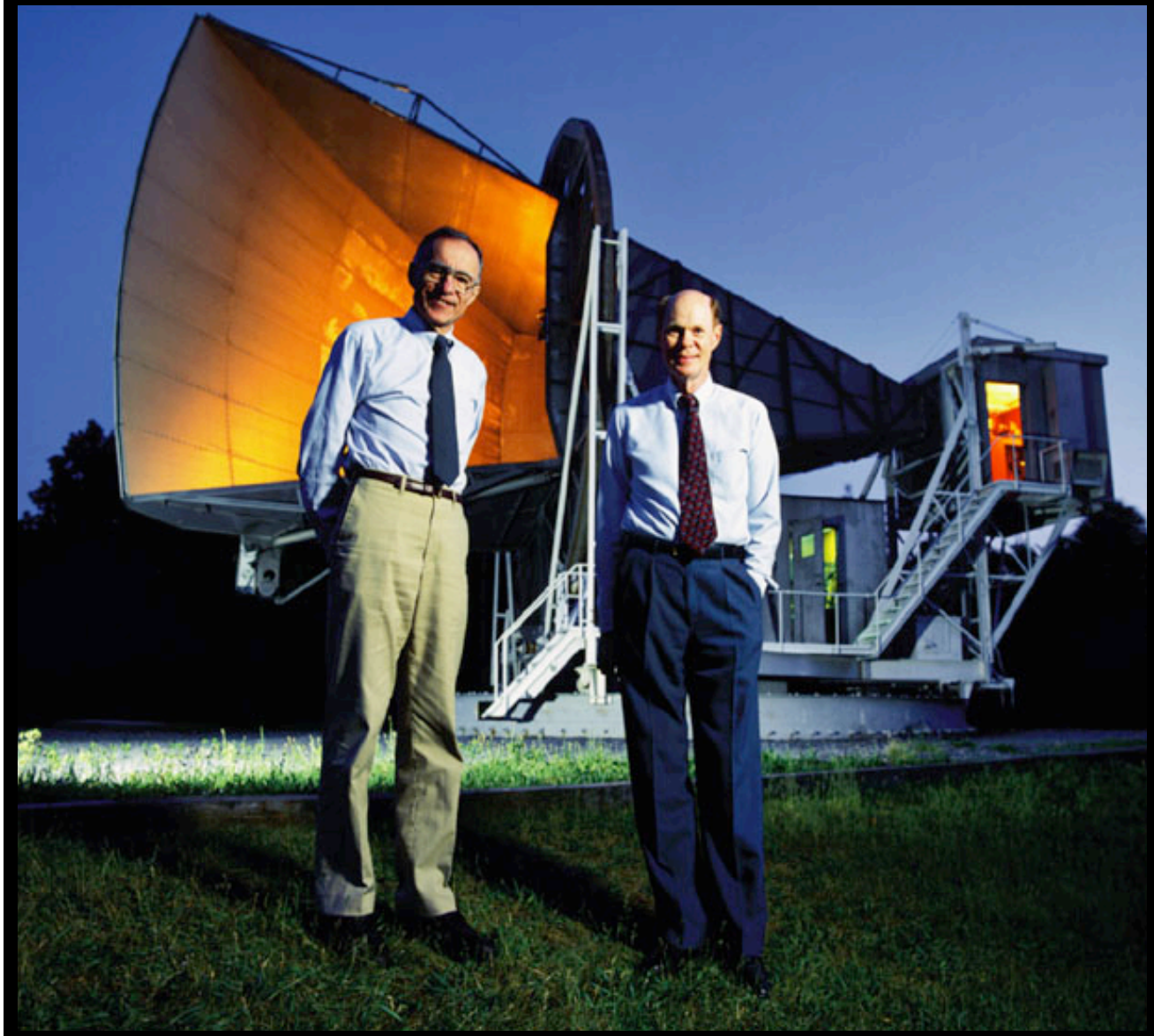
Background radiation from Big Bang has been freely streaming across universe since atoms formed at temperature ~ 3,000 K: *visible/IR* (but redshifted by factor of ~1000 by expansion since then)

Why we see microwaves…

The universe has expanded by a factor of about 1000 since the peak wavelength was 1000 nm. So its current wavelength is about 1 mm, in the microwave range.

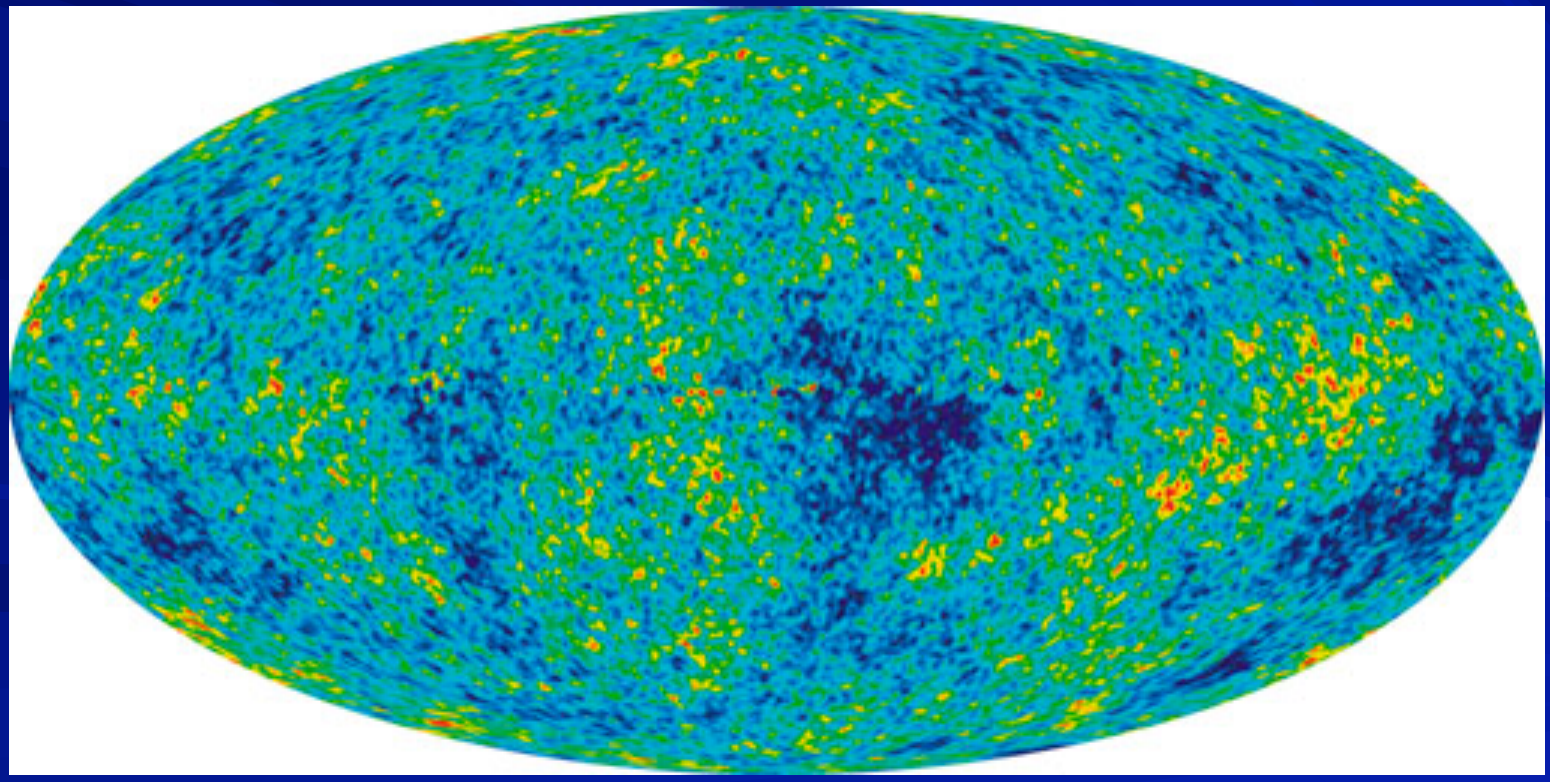
Source: Chaisson & McMillan *Astronomy Today,* © Pearson Addison-Wesley



The ***cosmic microwave background*** – the radiation left over from the early hot universe – was detected by accident by Penzias & Wilson in 1965 with a radio telescope

Source: Bennett et al *The Cosmic Perspective,* © Pearson Addison-Wesley

A snapshot of infant universe: Patterns of structure in the CMB observed by WMAP show us the “seeds” of galaxies in universe today; these seeds were only ~1 part in 100,000 different from the average at cosmic age 380,000 yr, but this was enough to make everything we see!



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- Oregon Dept. of Education Math/Science Partners Grant (primary funding for this lecture series)
- Portland State University Center for Science Education
- Beaverton and Hillsboro School Districts
- Pacific University
- Science Integration Institute

References/Suggested Reading

- Christian, *Maps of Time*, ch 1 (2004)
- Duncan & Tyler, *Your Cosmic Context*, chs 10-12 (2009)
- * Collected resources: http://www.scienceintegration.org
  (click on our cosmic history series link)