Readings for Prof. Michael J. Crowe's Two Sessions on The Expanding Universe Theory and Its Relation to Catholicism in the 2016 PLS Summer Symposium

Greetings:
All your readings for these two classes are included in this set of documents. I have put together these materials specifically for these two classes. In addition, I will show a PowerPoint presentation in the two classes drawing these materials together. Our topic is a challenging one, but it should be accessible to you. This unit will give you an up-to-date understanding of what may be the most important theory every worked out in physical science. On one level, it is certainly the broadest in scope. But it is also quite accessible.

The readings are in four sections. **Section One** provides a short statement of the theory and also provides the remarkable history of our universe that has been derived from it and that is fundamental for such areas as geology and biological evolution. **Section Two** uses a historical format covering a number of developments in stellar astronomy. In reading it, you may wish to turn to the internet for discussions of any terms or ideas that you do not understand. **Section Three** discusses some religious issues related to the Expanding Universe Theory. I believe you will find some of the information provided here both remarkable and quite different from the patterns of interaction that have occurred in most other areas of science. **Section Four** provides a bibliography of the sources I have used. It also contains references to other sources that you may wish to consult, including internet sources. It would be wise to read over this bibliography before you begin the readings. You may want to start by viewing some of the excellent internet sources.

The three parts of the readings along with the bibliography total about 25 pages.
If you have any questions about these materials, I can be contacted at crowe.1@nd.edu.

Looking forward to seeing you this summer!

Professor Michael J. Crowe
Cavanaugh Professor Emeritus
Program of Liberal Studies

Section One/Crowe/Expanding Universe

The Expanding Universe Theory; History of Our Universe (Prof. Michael J. Crowe)

What Is the Expanding Universe Theory (aka Big Bang Theory)?

It is the theory that the universe that we know began about 13.8 billion years ago with an extraordinarily strong explosion in a single extremely minute region of space. The object thus produced has continued to expand over the subsequent ca. 13.8 billion years. This explosion eventually produced all that we presently see in the universe. The objects that we see, for example, our solar system were a gradual result of this explosion. This universe is to be explained in terms of the materials and processes that are part of this initial explosion. Striking as this theory's claims are, they are a fundamental part of science and have come to be nearly universally accepted.

The History of Our Universe[1] According to the Expanding Universe Theory

What's to be learned from these materials?

It is relevant and worth noting that nearly all history courses (which usually begin no earlier than about four thousand years ago) treat only 3 millionths of the past. To put it differently, if all of human history were mapped onto a yearlong calendar, the pyramids would have been built on Dec. 31 at 11.59.50 p.m.[2] The goal of what follows is to remedy (we will be brief) that deficiency by beginning at the beginning. We will have to pass over some details (nary a king or even country will be mentioned). And some of the dates may be off slightly (hopefully none are off by more than a billion years or so), but the information may still be interesting and useful and reveal something about the atom of time (as William Whewell would say) that humans occupy.

When did the universe begin?

13.8 billion years ago now seems to be the consensus figure, down from 15 billion years ago, which seemed usual five or so years ago. At the beginning, the temperature of the fireball was ca. 50,000,000°C and its size was almost infinitely small.

What happened the previous day?

A book by John Farrell on the history of the big bang idea provides an answer in its title: *The Day without Yesterday: Lemaître, Einstein, and the Birth of Modern Cosmology*. Another answer is that no one knows. Yet another answer is that time began with the Big Bang, so that the question makes no sense.

What happened next?

Maybe not next, but "0.00000000000000000000000000000000001 seconds after the Big Bang": "The universe began with a vast explosion that generated space and time, and created all the matter and energy in the universe. What triggered this sudden expansion remains a mystery. Astronomers believe it involved a runaway process called 'inflation,' in which a peculiar type of energy that existed in the vacuum of space was suddenly mobilized. The inflationary expansion ended only when this energy was transformed into more familiar forms of matter and energy."[3]

When did the first molecules form?

About 300,000 years after the big bang (at which time the temperature of the universe was about 3000°C), protons and neutrons begin to come together to form molecules of hydrogen and helium, this taking place through thermonuclear fusion.[4]

When did the stars and galaxies first begin to form?

About 1 billion years after the big bang (by which time the temperature of the universe had dropped to about -250°C), the first stars and galaxies begin to form.[5]

When did the higher order chemical elements begin to form?
About 6 billion years after the big bang, supernova events begin to occur: explosions of huge stars, These explosions, which involve thermonuclear fusion, lead to the formation of such heavier elements as oxygen, carbon, nitrogen, calcium, and iron.[6]

When did the solar system begin to form? What is the age of oldest meteorite (i.e., formation of the solar system)?
The oldest known meteorite is dated as having formed 4.566 billion years ago, which is taken as the time when the solar nebula formed from interstellar gas and dust.[7]

When did the Earth begin to form?
About 4.5 billion years ago.[8] From its formation until about 3.9 or 3.8 billion years ago, the Earth experienced a Hadean or Heavy Bombardment period during which asteroids and comets bombarded the Earth, making it intensely hot, and probably preventing the formation or at least preservation of any life forms.

When did the Moon form?
About 4.47 billion years ago.[9] Another source: 4.2 billion years ago.[10] The now widely accepted theory of the Moon's origin is the Giant Impactor Theory according to which a body the size of Mars impacted Earth with the materials dividing in such a way that the Earth and Moon formed.

When did the earliest forms of life appear on Earth?
3.8 billion years ago.[11] Another estimate: 4.0 billion years ago.[12]

When did photosynthesis begin and what problem did it create?
3 billion years ago. As a waste product, photosynthesis formed a gas that was poisonous to nearly all then existing organisms, which led to the evolution of organisms that could tolerate, indeed make good use of this toxic gas, which is named oxygen. The establishment of photosynthesis was so productive because it opened up a way to access energy from the Sun.[13]

When did complex cells first appear? Put differently, what date is assigned to the oldest eukaryotic fossils?
About 1.8 billion years ago.[14] Another site suggests 2.1 billion years ago.[15]

When was sex invented?
About 1.2 billion years ago.[16] This had the effect of speeding up evolution.[17]

When did the first multicellular organisms develop?
Around 1 billion years ago.[18]

When did primitive animals begin to appear?
About 700 million years ago, primitive life forms begin. These were "flat worms, jellyfish and algae. By 570 million years ago, large numbers of creatures with hard shells suddenly appear."[19]

When did the Cambrian Extinction or Cambrian Explosion occur?
550 million years ago. At this time the first extensive preservation of fossils occurs.[20] Sometimes referred to as geology's "Big Bang," the Cambrian Explosion is actually an extended period in which an immense number of new species arose. Stephen Webb comments on the Cambrian Explosion: "The Cambrian extinction (actually two extinctions) occurred 540 to 500 million years ago. Their precise cause is uncertain, but in some ways they were the most serious of the mass extinctions. During the Cambrian Explosion, a time of immense biological innovation, Nature experimented with many different body plans; perhaps as many as a hundred different animal phyla evolved. All the animal phyla we are familiar with emerged during the Cambrian explo-

sion, and no new phyla have evolved since. But during the Cambrian extinctions some of these phyla—each containing species that seem bizarre and even nightmarish to our eyes—died out."[21]

When did the great extinction at the Permian-Triassic boundary occur?
250 million years ago.[22] Stephen Webb comments: "The Permian extinction 250 million years ago was even more severe than the Cambrian extinction. Perhaps more than 90% of mature species became extinct; eight of the 27 orders of insects were lost; the loss was devastating."[23]

When did mammals begin to appear on Earth?
About 200 million years ago.[24]

When did the dinosaurs disappear?
65 million years ago, when an "An asteroid or comet slams into the northern part of the Yucatan Peninsula in Mexico. This world-wide cataclysm brings to an end the long age of the dinosaurs, and allows mammals to diversify and expand their ranges."[25] This is known as the Cretaceous-Tertiary or C-T Boundary or as the K-T Boundary (the K coming from the German word for Cretaceous: Kreide). Actually, I believe it is now thought that the dinosaurs did not die out ca. 65 million years ago; rather some survived. These are now known as birds.[26]

When did Supernova 1987A explode?
About 170,000 years ago. "A star explodes in a dwarf galaxy known as the Large Magellanic Cloud that lies just beyond the Milky Way. The star, known in modern times as Sanduleak 69-202, is a blue supergiant 25 times more massive than the Sun. Such explosions distribute all the common elements such as Oxygen, Carbon, Nitrogen, Calcium and Iron into interstellar space

where they enrich clouds of Hydrogen and Helium that are about to form new stars. They also create the heavier elements (such as gold, silver, lead, and uranium) and distribute these as well. Their remnants generate the cosmic rays, which lead to mutation and evolution in living cells. These supernovae, then, are key to the evolution of the Universe and to life itself."[27]

When did the first animals in the genus homo appear?
Ca. 6 million years ago, there existed a small African ape, whose descendants eventually became chimpanzees and humans, which are now the only descendants of this ape. It was about 2 million years ago that the first animals now classified as Homo appeared.[28]

When did *Homo sapiens* appear?
"Emergence of modern *homo sapiens* occurs about 120,000 years ago."[29] Another source says 200,000 years ago.[30]

What is the date of the first Cro-Magnon cave paintings?
About 25,000 years ago.[31]

What is the date of the founding of Rome?
753 BCE.[32]

When did the human population reach 150 million?
About year 1 C.E.[33]

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[1]This chronology is based on many sources, not all of which agree. Some of the main sources are:
Monica Grady, *Astrobiology* (Washington, D. C.: Smithsonian Institution Press, 2001).
Stuart Ross Taylor, *Destiny or Chance: Our Solar System and Its Place in the Cosmos* (Cambridge: Cambridge Univ. Press, 1998).
Jeffrey Bennett, Seth Shostak, and Bruce Jakosky, *Life in the Universe* (San Francisco: Addison Wesley, 2003).
Kevin Plaxco and Michael Gross, *Astrobiology: A Brief Introduction* (Baltimore: Johns Hopkins Press, 2006), esp. p. 144.
Some of the main internet sources are:
http://www.pbs.org/deepspace/timeline/
The website for the television series called *Origins*: http://www.pbs.org/wgbh/nova/origins/universe.html
For the history of the Earth, see http://en.wikipedia.org/wiki/History_of_Earth
There is an excellent DVD called *History of the World in Two Hours*. Another good source is *How the Earth Was Made*.
[2] See http://visav.phys.uvic.ca/~babul/AstroCourses/P303/BB-slide.htm, which is Carl Sagan's Cosmic Calendar.
[3]As quoted from http://www.pbs.org/wgbh/nova/origins/univ-nf.html
[4]Grady, *Astrobiology*, 6.
[5]Grady, *Astrobiology*, 6 (but see Grady, p. 5 where she sets the time as 2 billion years after the big bang). The *Origins* website uses the 1 billion year figure, but http://www.pbs.org/deepspace/timeline/ sets the time as 300,000 years after the big bang.
[6]*Origins* site says: "600,000,000 years after the big bang: Within galaxies, as stars were being born, others died...often in enormous cataclysmic explosions. These explosions, called supernovae, are important to the evolution of galaxies because they distribute all the common elements such as oxygen, carbon, nitrogen, calcium, and iron into interstellar space. Explosions of especially massive stars also create and distribute heavier elements such as gold, silver, lead, and uranium. The supernova pictured here is of a smaller type, used by astronomers to determine distance. This one appears to us now as it looked when the universe was about five billion years old."
[7]Taylor, *Destiny*, xv.

[8]Taylor, *Destiny*, xv.
[9]Taylor, *Destiny*, xv.
[10]Plaxco and Gross, *Astrobiology,* 145.
[11]According to http://www.pbs.org/deepspace/timeline/
[12]Taylor, *Destiny*, xv.
[13] http://en.wikipedia.org/wiki/Timeline_of_evolution
[14]Taylor, *Destiny*, xv. See also Plaxco and Gross, *Astrobiology*, 145.
[15]http://en.wikipedia.org/wiki/Timeline_of_evolution
[16]Plaxco and Gross, *Astrobiology,* 145.
[17]http://en.wikipedia.org/wiki/Timeline_of_evolution
[18]http://en.wikipedia.org/wiki/History_of_Earth
[19]Quoted from http://www.pbs.org/deepspace/timeline/
[20]http://www.pbs.org/deepspace/timeline/
[21]Stephen Webb, *If the Universe Is Teeming with Aliens…, Where Is Everybody? Fifty Solutions to the Fermi Paradox and the Problem of Extraterrestrial Life* (New York: Copernicus Books, 2002), 176.
[22]Taylor, *Destiny*, xv.
[23]Webb, *Where Is Everybody?* 177.
[24]Taylor, *Destiny*, xv.
[25]As quoted from http://www.pbs.org/deepspace/timeline/
[26] See http://www.ucmp.berkeley.edu/diapsids/avians.html and http://www.abc.net.au/science/slab/dinobird/story.htm
[27]As quoted from http://www.pbs.org/deepspace/timeline/
[28]http://en.wikipedia.org/wiki/History_of_Earth
[29]Taylor, *Destiny*, xv.
[30]http://en.wikipedia.org/wiki/History_of_Earth
[31]Taylor, *Destiny*, xv.
[32]Taylor, *Destiny*, xv.
[33]http://en.wikipedia.org/wiki/Timeline_of_evolution