The Cosmos

Planets & Life

PHYS 214

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Please start all class related emails with "214:"

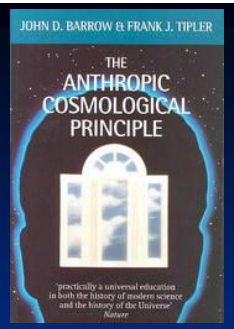
Today's Lecture

- Life in Cosmos: The Anthropic Cosmological Principle
  - We'll discuss a number of philosophical issues today
- (Next week we'll start working from the book)

If you want to make an apple pie from scratch,
you must first create the universe.

Carl Sagan

Preface



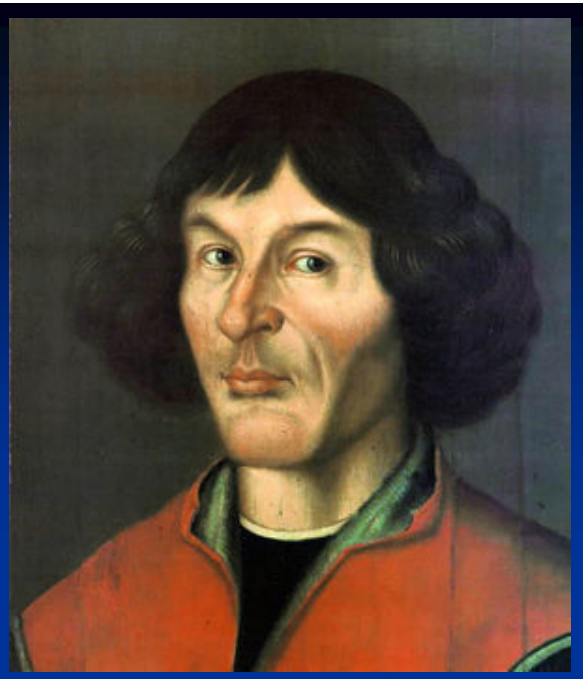
- Science has been phenomenally successful at explaining the features of the observed Universe in the last 40 or so years
  - DNA
  - Big Bang… and so on…
- We now (tend to) believe that there is a fully scientific explanation for anything we observe…
- Yet, as we'll see in this course, certain aspects of the Universe appear strongly at odds with the idea that humanity is "average"
- Some of the ideas in this lecture may seem totally crazy – that's OK, some of them *are*

Ptolemaic Cosmology

- This is a geocentric view of the Universe
- Planets, Sun, stars *etc.* are all viewed as revolving around the Earth
- Actually predicting orbits was very difficult in this model because it is obviously wrong
- Nonetheless, its moderate successes made it attractive for hundreds of years

Earth at the center, the Moon Mercury, Venus, Sun, Mars, Jupiter, Saturn and lastly the fixed Stars

The Copernican Principle



- Prior to the 16th century the philosophical view of the Cosmos was *Ptolemaic*
  - Placing the Earth at the centre of the Universe also influenced philosophical thought about how special the Earth was
- Nicolaus Copernicus (1473-1543) is credited advancing the idea that the Earth is *not special*
  - This idea lead to him showing the motions of the planets could be explained by a Solar System with the Sun at its center
  - The step lead to the "Copernican Revolution"
- The same idea can be extended to Cosmology, and is partially motivation for the Cosmological Principle

(Copernicus was a Catholic Cleric)

Mediocrity Principles

- The philosophy underlying the Copernican revolution can be extended
  - There is nothing special about the Human Race
  - There is nothing special about the Earth
  - There is nothing special about the Sun
  - There is nothing special about the Milky Way
  - and so on…
- Most scientists like to adopt this stance
  - Implying we aren't special means that we expect physical laws we derive to be typical of elsewhere

The fundamental constants of nature

- There are many (unexplained) constants used in the equations for the physical forces
  - *e.g.* G, Newton's gravitational constant, or the unit of charge on the electron, e
- If any of these values were changed - by even a small amount - stars would not form
- Since the formation of stars is a precursor to the formation of life, ***is the Universe in fact tuned to form life?***

Are we, in fact, special in some way?

Selection effects

- Before drawing conclusions from any scientific process we must always be aware of possible *observational biases*
- Suppose a ratcatcher tells you that all rats are longer than six inches…
  - Your first reaction should be to check the size of his traps!
- Similarly, just because your highest probability of seeing an elephant is in a zoo…
  - Doesn't mean all elephants are in zoos
  - Or even that most elephants are in zoos

Suppose the fundamental constants were slightly different

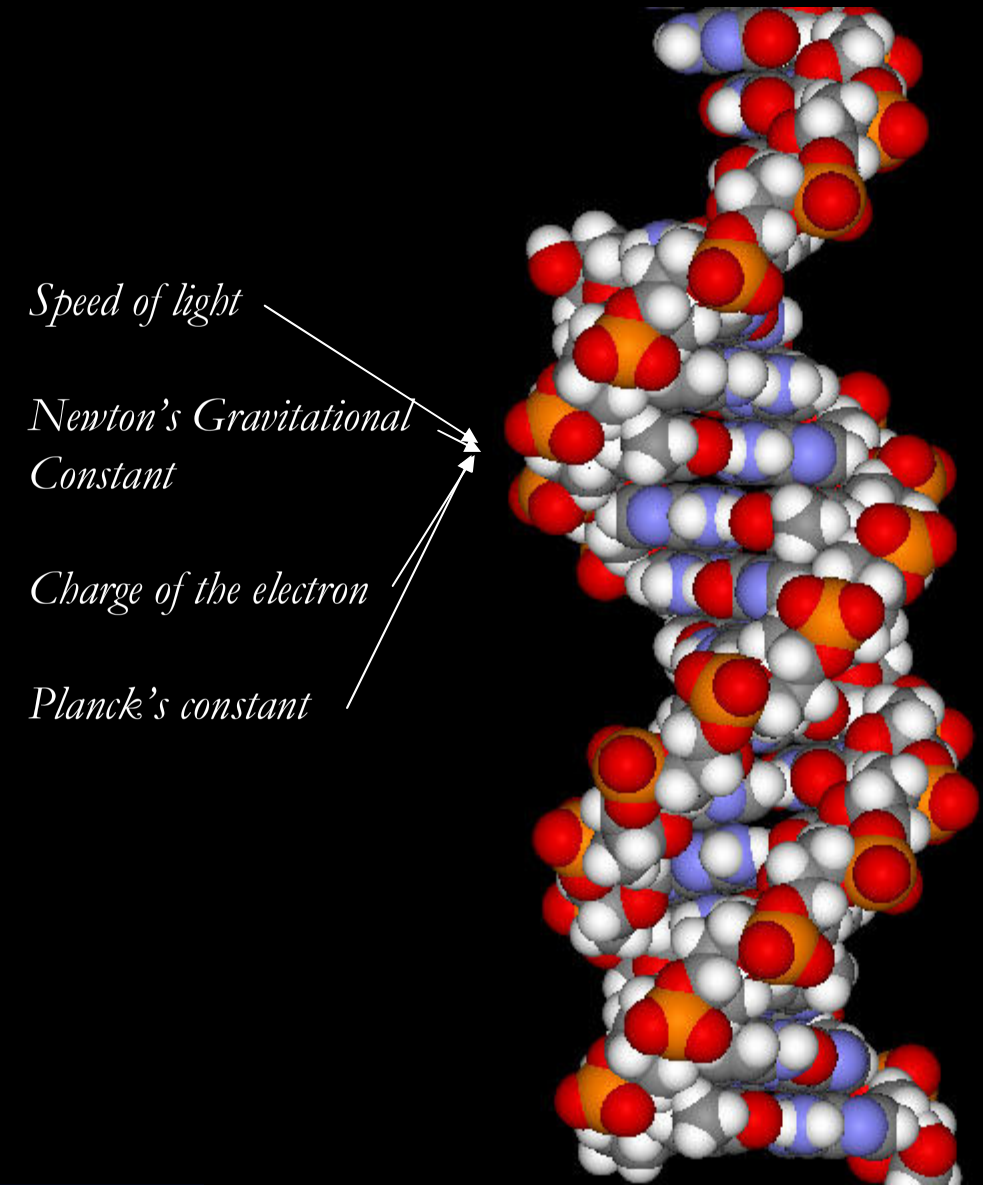
- If gravity was weaker, stars wouldn't collapse as fast or get as hot
- If electromagnetism was different matter might repel too strongly to form stars
- If we can't form stars we can't form elements "heavier" than **He**, such as **O,Si,Al,Fe** that make up much of the Earth
- Without the Earthlike planets *we can't form life as we know it*
- Thus if we change the constants *we won't be here to see them*

What about the age of the Universe?

- After we have formed **H,He** following the Big Bang the only place hot enough left to form heavy elements is the center of stars
- **H** and **He** are fused into progressively heavier elements (we'll talk about this later in the course)
- The most massive stars die in supernova explosions that distribute the heavy elements into the space between stars
  - This material can later be used to form planets
- Scientists estimate this has to take between 4-8 billion years
- By this time the Universe has to be extremely large
  - Another selection effect!

A more biological perspective

- Aside from the formation of stars, the chemistry that results from the values of the fundamental constants is responsible for the formation of DNA



So let's think about ourselves for a second…

- We are a carbon-based lifeform that was produced via evolution
- Living on an Earthlike planet
- Revolving around a yellow dwarf star
- Revolving around the center of a spiral galaxy
- Evolving in a Universe capable of forming structures like stars and galaxies
- In a universe with roughly 10 H atoms for each He

A pretty strong set of selection effects

The Weak Anthropic Principle(WAP)

"The observed values of all physical and cosmological quantities are not equally probable but they take on values restricted by the requirement that there exist sites where carbon-based life can evolve and by the requirements that the Universe be old enough for it to have already done so."

Barrow & Tipler

An immediate consequence

- The possibility of biological evolution is strongly dependent upon the global structure of the Universe
  - This is really a restatement of the apple pie statement!
- The existence of life may be no more, but no less, remarkable than the existence of the Universe

Common Sense

- At the end of the day, the Weak Anthropic Principle is merely a statement of common sense
  - "If things were different, we wouldn't be here to see them"
- This fact has frustrated some researchers, here is a statement from a famous book on cosmology:

"*It is unclear to one of the authors how a concept as lame as the "anthropic idea" was ever elevated to the status of a principle.*"

Fun Frank Zappa Joke

"Some scientists say that the major building block of the universe is hydrogen because it's the most plentiful element, but my theory is that the universe is made out of stupidity, because it is more plentiful than hydrogen"

Explaining the values of the fundamental constants

- One of the major goals of fundamental physics is to explain the values held by these constants
- That said, no accepted scientific theory has been able to explain these values with any success
- In response to this, and the fact that the formation of stars is so finely tuned, one cosmologist (Brandon Carter) has suggested that

  "*The Universe must be such as to admit the creation of observers within it at some stage*"

The Strong Anthropic Principle(SAP)

"***The Universe must have those properties which allow life to develop within it at some stage in its history***"

Barrow & Tipler

Implications of the SAP

- There are at least three possible interpretations of what the SAP might mean
- The first is a classic design argument
- *"There exists one possible Universe 'designed' with the goal of generating and sustaining 'observers.'"*
- This implies that the purpose of the Universe is to give rise to intelligent life, with the laws of nature set to ensure that life as we know it will emerge
- This is of course strongly counter to most modes of scientific thought and as a scientist you should really feel uncomfortable with this statement

SAP Implications II

- *"Observers are necessary to bring the Universe into being."*
- This is an apparently crazy idea stemming from quantum mechanics – I won't discuss it further
- *"An ensemble of other different universes is necessary for the existence of our Universe."*
- Many different "parallel" Universes have to exist to create our particular Universe

Why so much interest in this idea?

- Scientists studying the Big Bang (such as Stephen Hawking) have a very hard time making sense of the mathematics involved
- The invocation of an Anthropic Principle may help to simplify the math
  - i.e. we only allow this range of numbers and not a larger one
- Some theories associated with the Big Bang start with as many as 11 dimensions and an Anthropic Principle seems to be the only way of throwing away all those useless dimensions and leaving us with the 4 we have

Problems, problems…

- Design arguments seem to always be a last resort in science
- When we do not understand something, a natural reaction is to suggest something must be that way because of an underlying purpose
- This bears similarities to Intelligent Design ideas, although the Anthropic Principles try to strongly resist the idea of any "higher being"

Even more unusual…

- Before we finish I'll present two final Anthropic Principles
- One is moderately interesting, the last one is an amusing poke at the whole concept

Final Anthropic Principle (FAP)

"Intelligent information-processing must come into existence in the Universe, and, once it comes into existence, it will never die out"

Barrow & Tipler

Humour: The Completely Rediculous Anthropic Principle (CRAP)

- The mathematician Martin Gardner quoted the last two lines of the book by Barrow & Tipler
- "***At the instant the Omega Point is reached, life will have gained control of*** all ***matter and forces not only in a single universe, but in all universes whose existence is logically possible; life will have spread into*** all ***spatial regions in all universes which could logically exist, and will have stored an infinite amount of information, including*** all ***bits of knowledge which it is logically possible to know. And this is the end.***"

Summary of lecture 6

- When conducting any scientific experiment you must always be careful to avoid selection effects
- The Weak Anthropic Principle is merely the statement that we see things the way they are because if they were any other way we wouldn't be here to see them
- The Strong Anthropic Principle can be interpreted as a design argument
  - It is usually a last resort when there appears to be no argument for why a particular system should be the way it is
  - Its value is strongly contested
- It is nonetheless amazing that interpretation of the mathematics of the Big Bang can be influenced by the possibility of life
- The remaining anthropic principles are far more speculative and of less significance

Next lecture

- Stars