Cosmic, Geological, Biological and Human Timescales

- Context
- The statistics of time
- Cosmic, geological, biological & human time
- Plate tectonics, a slow dynamical process
- Periodization as a conceptual timescale tool
- Galactic time units as a conceptual timescale tool
- An origins chronology in Galactic time units
- Implications for extrasolar planets and extraterrestrial life & civilizations

Assignments for week of Dec 1

- A precept debate/discussion in the same format as last week’s
- Bring a one page brief to precept outlining your argument/views & be prepared to discuss them.
- TOPIC: Assume the existence of an extrasolar planet similar to Earth with physical conditions equally hospitable to life and of the same age. Will life exist there, and if so, how closely will it resemble terrestrial life?
- Problem Set 8 due in lecture on Dec 3
\[ N = f(p)n(e)f(l)f(i)f(c)R_\star L \]

- Radial velocity techniques have provided first direct clues about \( f(p) \), \( \geq 5 \text{ -10}\% \)
- No direct information on \( n(e) \) yet
- \( R_\star \) measured by astronomical observations
- \( f(l) \) depends on biochemistry & \textbf{cell biology}
- Depends on evolution towards complexity
- \textit{One & only one} case + no general theory
- Zero cases + no theory -> speculation
- Some lower & upper bounds/constraints

**The statistics of time**

- The greater the duration of a given phenomenon or step in a sequence of events, the proportionately more probable it is that a random sampling will yield that phenomenon or state. (This assumes a stationary, unchanging on average, situation.)
- In a fixed sequence of random events, the interval between one event and the next is inversely proportional to the probability of the 2nd event on average.
Examples of time statistics

• If you pick a Princeton undergraduate at random and determine his/her age, you are twice as likely to have chosen someone 19 or 20 years old (between 19th and 21st birthdays) as someone who is 19 years old (between 19th and 20th birthdays).

• Roll a pair of dice until you get a 7, then until you get a 2, then until you get a 12, then start over and go back to trying to roll a 7 and repeat the sequence many times. On average you will have to make 6 times more rolls to get each 2 or 12 as each 7 because 7’s are 6x more probable than 2’s or 12’s.

Cosmic Time
Geological Time

Biological Time

Multicellular life
Human/Historic Time
Plate Tectonics - The Changing Earth

GEOLOGIC TIME SCALE

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<thead>
<tr>
<th>Era</th>
<th>Period</th>
<th>Age in millions of years before present</th>
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<tbody>
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<td>4650</td>
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<td>Archean</td>
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<td>Holocene</td>
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<tr>
<td>Present</td>
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</table>
A New Set of Time Units

The orbital period of the Earth around the Sun defines the conventional, or solar, year. By analogy we can define a set of time units by the orbital period of the Sun around the center of the Galaxy. The Galactic year (Gyr) would then be about 225 million times longer than an ordinary solar year, and all other familiar time units can be scaled to the same standard (365.24 Galactic days in one Gyr, for example). This set of time units is much more suitable for discussions of origins. "Now" is assumed to be 3 PM on Dec 1, 2003 for the purposes of the following origins chronology.
Origins Chronology in Galactic Units

- **Big Bang Origin of the Universe:** 61 Gyr → 1942
- **First Galaxies & Quasars:** 60 Gyr → 1943
- **Galaxies & Quasars Begin to Fade:** 30 Gyr → 1973
- **Formation of Sun & Solar System:** 21 Gyr → 1982
- **Origin of Life on Earth:** 18 Gyr → 1985
- **Photosynthesis:** 16 Gyr → 1987

Origins Chronology in Galactic Units (cont’d)

- **O₂ Atmosphere, Eukaryotes:** 9 Gyr → 1994
- **Multicellular Life, Sex & Death:** 4 Gyr → 1999
- **Differentiated Organisms:** 3 Gyr → 2000
- **Vertebrates:** 2 Gyr → 2001
- **Amphibians:** 19 Gmonths → May, 2002
- **Seeds, Land Animals, Cont. Drift:** 16 Gmonths → August, 2002
Origins Chronology in Galactic Units (cont’d)

- **Dinosaurs**: 13 Gmonths → **Nov, 2002**
- **Mammals**: 11 Gmonths → **January, 2003**
- **Great Impact Extinction**: 15 Gwks → **Aug 18, 2003**
- **Primates**: 11 Gwks → **Sept 15, 2003**
- **Homo Erectus, Ice Age**: 5 Gdays → **Nov 26, 2003 (last Wed, previous lecture)**

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Origins Chronology in Galactic Units (cont’d)

- **Fire**: 27 Ghrs → **noon Nov 30, 2003 (yesterday)**
- **Homo Sapiens**: 5 Ghrs → **10 am Dec 1, 2003 (this morning)**
- **Humans Spread Globally**: 4-1 Ghrs → **11 am - 2 pm Dec 1, 2003 (today)**
- **Cities**: 14 Gmin → **2:46 pm today**
- **BC/AD, Roman Empire**: 5 Gmin → **2:55 pm today**
- **Middle Ages**: 2 Gmin → **2:58 pm today**
Origins Chronology in Galactic Units (cont’d)

• Renaissance, Western Colonialism: 78 Gsec → 2:58:42 pm today
• Princeton University: 36 Gsec → 2:59:24 pm today
• WW2, Nuclear Tech, Computers: 9-7 Gsec → 2:59:51-53 pm today
• Class of 2004 born: 3 Gsec → 2:59:57 pm today
• Class of 2004 HS freshmen: 1 Gsec → 2:59:59 pm today

Galactic Time Units

• 1 Gyr = 225 million years
• 1 Gmonth = 19 million years
• 1 Gweek = 4.3 million years
• 1 Gday = 620 thousand years
• 1 Ghr = 26 thousand years
• 1 Gmin = 430 years
• 1 Gsec = 7 years
Implications for extrasolar planets and extraterrestrial life & civilizations

• We are minute and isolated in the time dimension as well as the spatial ones, lost in time as well as space.
• Extrasolar terrestrial planets are much more likely to resemble the Earth’s far past or future than its present.
• Despite “appearances” it may be easy/probable to form simple (prokaryotic) unicellular life but difficult or improbable to form complex multicellular life and/or advanced intelligence and technological civilizations.
• Extraterrestrial civilizations will be either extremely rare or much older than our own.

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