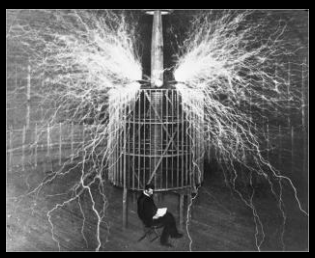
Today in Astronomy 106

- Evolution of a communicable civilization: Drake Equation input f_C.
- How long do they last? Part 1: Natural Disasters.



Nikolai Tesla: one of the inventors of radio. (Dickenson V. Alley/Burndy Library)

How many intelligent species have emerged on Earth? How many of them evolved independently?

Civilization and f_C

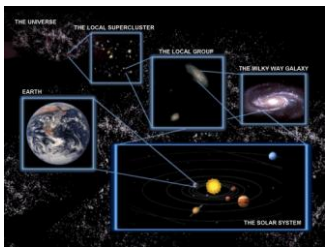
At this point the invention of writing and tools means that adaptation can be passed widely to society, and the kinds of evolution we have discussed hitherto – random experiments rewarded or punished by natural selection – come to an end.

- And we have enough information for estimating the next Drake-equation quantity,

  f_C = the fraction of occurrences of intelligence in which technological civilization capable of interstellar communication evolves
- Once intelligence evolved, the production of civilization took a **lot** less time than the evolution of life or intelligence did. And from Sumer to us is much shorter.
  - So intelligence doesn't run out of time to civilize.

Pre-requisites to Communication

- Intelligent civilizations must have technology as well as a specific worldview to develop interstellar communication:
  - Appreciation of size and nature of the universe
  - Realization of species' place in the universe
  - Belief that odds of communication are reasonable



Appreciation of Size and Nature of the Universe

- Many early cultures, for practical reasons, understood earth's natural cycles and could read the heavens
  - Evidence of a shellfish diet very early in human evolution in South Africa points to knowledge of the tides.
  - Mayans knew the length of a year to 0.001% accuracy. The start of a 14th b'ak'tun is 20 December 2012.

Appreciation of Size and Nature of the Universe (con't)

- Development of correct astronomy
  - Copernican Revolution (1540) - heliocentric worldview
  - Kepler , Galileo (1610), Newton (1687) – solar system is **big**, **predictable** and we are definitely not at the center

Realization of species' place in the universe

- Also requires correct astronomy (and physics)
  - Hubble, 1920s – we are one planet, orbiting one star in a galaxy of many stars, in a universe of many galaxies

- Correct biology
  - Lyell (mid 1800s) - Earth is 4.5 Gya
  - Darwin (1859) - Life was not a supernatural act
  - Miller-Urey (1953) - Life could arise from chemistry

Odds of communication are reasonable

- Life could be everywhere and could be trying to communicate with us
  - Sagan, Drake and others (1960s) – 1st attempt to communicate and start of SETI (more on 20 June 2011)

Arecibo message

Written by Frank Drake and Carl Saga with the help of others this 1679 binary digit message was broadcast to M13

- Globular cluster, 25,000 ly away
- 1679 is a product of prime numbers 23 and 73
- Several parts including atomic number of H, C, N, O & P, formulas for sugars and bases in DNA, graphic of DNA, a human, the solar system and the Arecibo radio telescope.
  (More in this on 20 June 2011)

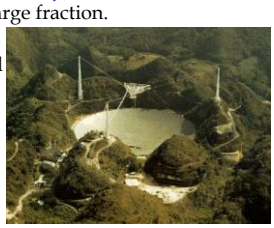
Civilization and f_C

Let us consider a "statistical" answer offered by the Earth:

- Two independent loci of intelligence developed on Earth: both mammals: one land-based (primates), one ocean-based (dolphins, whales).

Civilization and f_C

- One developed civilization capable of interstellar communication. So **f_C = 0.5**.
- This is quite uncertain, but at least it seems clear that **we should expect f_C to be larger than f_i,** and Earth offers confidence that f_C can be a large fraction.
- Drake's original guess: f_C = 0.01. There are still good arguments for small f_C but not as many as for small f_i.



Aricebo radio telescope in Puerto Rico where the first deliberate interstellar signal was send from earth in 1974.

Mid-lecture Break

- Homework #5 will be out today.

Major T.J. "King" Kong rodeo-rides an H bomb down to Siberia. (From Stanley Kubrick's *Dr. Strangelove*, 1964)

Shooting ourselves in the foot

Technological civilizations can collapse and/or lose the ability to communicate with those on other planets by two general means, **self-inflicted damage** and **natural disasters**. First we shall discuss the self-inflicted sort, of which there are four main types, listed here in increasing order of danger:

- Loss of interest in searching for other civilizations, while retaining technological capability.
- Population growth to the point of societal collapse.
- Depletion of resources within reach of the civilization.
- Destruction of the habitability of the planet(s) on which the civilization resides.

Being uncommunicative

Just because a civilization *can* communicate with others far away doesn't mean it will. Best local analogy: China.

- China has been a leading civilization, capable of exploring far past its borders, continuously for about 3500 years.
- Yet for almost all of this time she has not only denied interest in other cultures, but has been proud of that.
  - e.g. the Qing dynasty's Qianlong Emperor, in refusing the British request to exchange ambassadors in 1793: *This request is contrary to all usage of my dynasty…I set no value on objects strange or ingenious, and have no use for your country's manufactures.*

Being uncommunicative (continued)

- In the early years of the Tang Dynasty (618-907 AD), the borders of China were advanced along the Silk Road as far as the Syr Darya in modern Kazakhstan, but China lost interest in further advance after losing a battle (Talas, 751 AD) to the Arabs of the Abbasid Caliphate, never establishing permanent political relationships in the West.
- The third ruler of the Ming Dynasty, the Yongle Emperor, sent his vizier Zheng He – in a fleet of 1500-ton ships – on seven voyages of exploration and tribute collection (1405-1423 AD) that made it as far as East Africa: the only explorations in Chinese history.

So although China was capable ("$f_C = 1$"), her communicative phase was short: L = 18 years, 0.5% of the possible lifetime.

- Civilizations could have science and technology without the correct astronomy, e.g.:
  - Very cloudy planets
  - Planets in molecular clouds

Overpopulation and collapse

Thomas Malthus remarked famously (1798) that population seems inevitably to increase faster than its means of subsistence can increase:

The power of population is so superior to the power of the earth to produce subsistence for man, that premature death must in some shape or other visit the human race … should [armies] fail in [their] war of extermination, sickly seasons, epidemics, pestilence, and plague advance in terrific array, and sweep off their thousands and tens of thousands. Should success be still incomplete, gigantic inevitable famine stalks in the rear, and with one mighty blow levels the population with the food of the world.

Overpopulation and collapse (continued)

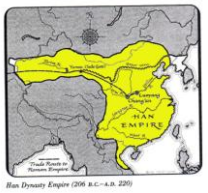
And indeed, on scales smaller than global, such collapses have crippled many cultures:

- From the early 1700s on, Ireland, with a population of 7-8 million, was on the very edge of being able to feed itself. When a blight destroyed the potato crop two years in a row (1845-46), two million died, three million emigrated, and the Irish nation was virtually destroyed.

Overpopulation and collapse (continued)

- By the end of the third century AD, both the Roman and Han Chinese empires were populated near the limit of their subsistence. Repeated epidemics, and probably a minor worsening in global climate, sent both empires into tailspins from which neither recovered; their civilizations and influence were destroyed.

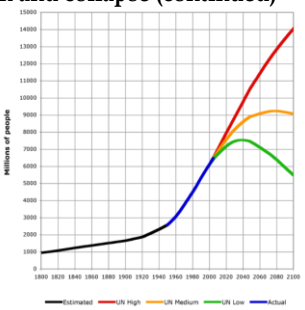
Wikimedia Commons



What other examples of overpopulation and collapse does history offer us?

Overpopulation and collapse (continued)

Earth can feed a maximum of about 20 billion; the current population is 7 billion and doubling every 55 years.



World population from 1800 to 2100, based on UN 2004 projections and US Census Bureau historical estimates.

Resource depletion and collapse

Again there are instructive micro-examples in the collapse of civilizations on Earth (Jared Diamond 2004, *Collapse*).

- Easter Island is the classic: the Polynesian colonists, unused to the timescale for tree growth in more temperate climates, systematically deforested the island and left themselves without transportation and fishing vessels. Probably about 70% population loss.
- The Greenland Norse depleted their resources by practicing forms of animal husbandry developed in Scandinavia but unsustainable on Greenland; unsustainability became catastrophic with the buildup toward the Little Ice Age in the late 15th century.

Resource depletion and collapse

Globally we are also using technology based upon access to resources we are using unsustainably, mostly in the realm of nonrenewable resources like petroleum. Petrochemicals provide, among other things,

- our highest-energy-density fuels, without which aviation would be far more difficult.
- plastics, without which modern technology is scarcely imaginable.
- fertilizers, important in maintaining the high crop yields upon which we have come to depend.

Disease and Collapse

- A 2009 epidemeological study found that an outbreak of "slow moving, cannibalistic and undead" zombies could "lead to the collapse of civilization."
- Assistant Surgeon General Ali S. Khan from the CDC posted on 16 May 2011 "Preparedness 101: Zombie Apocalypse"
  - Better safe than sorry
  - Kit includes water, food, medications, tools and supplies sanitation and hygiene, clothing and bedding, documentation and first aid supplies.

What do you think will catch us first?

A. Overpopulation. B. Exhaustion of energy resources.
C. Exhaustion of other technological necessities.
D. Nuclear destruction. E. Other.