The Cosmos

Planets & Life

PHYS 214

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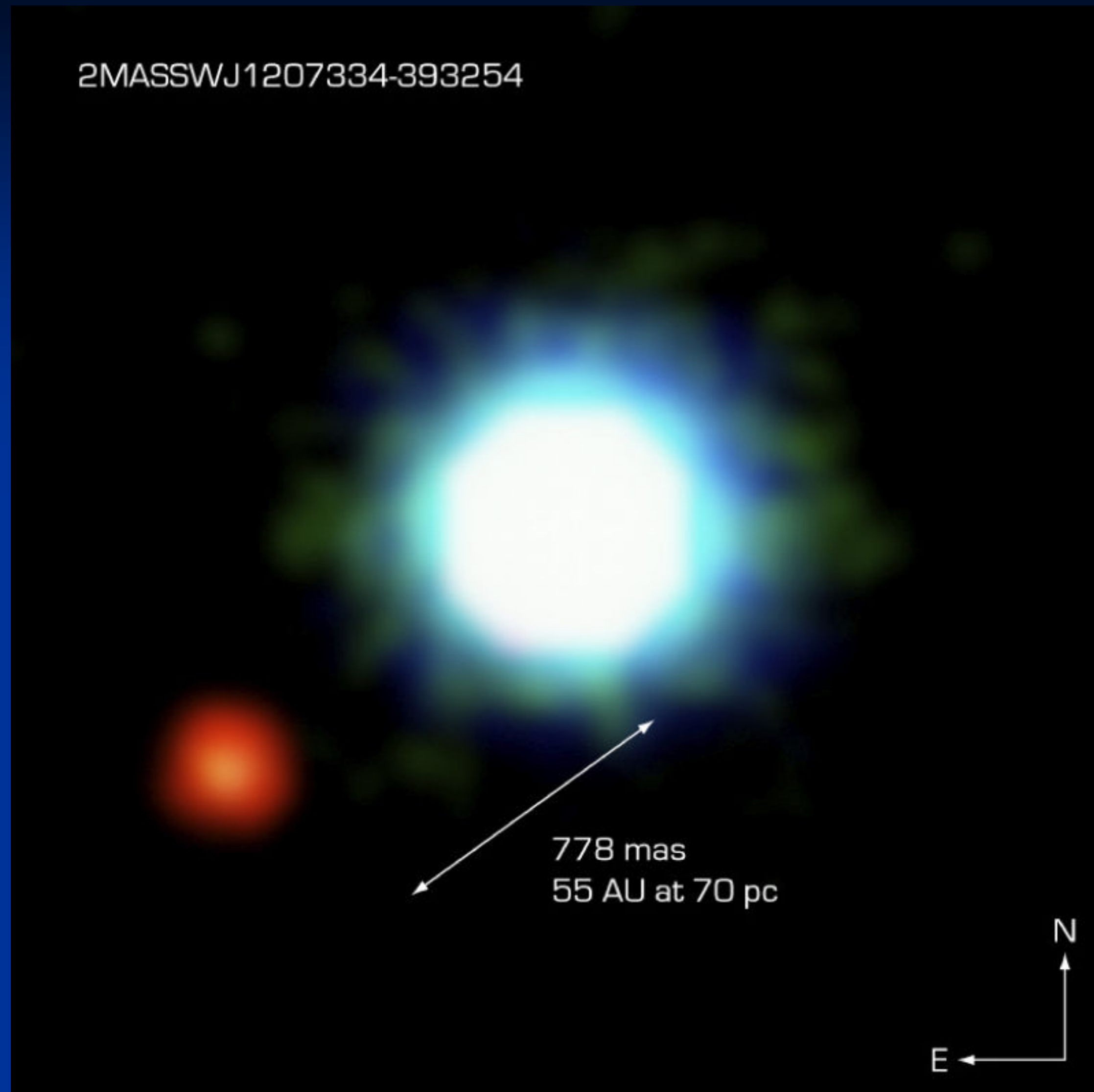
(Please start all class emails with “214:”)

What is the course really going to be about?

- Can we estimate - *scientifically* - what the total number of civilizations in the galaxy is?
  - Can we do this for the entire Universe?
- What do we need to know to estimate this number?
  - Astronomical issues
  - Biological issues

These are exciting times!

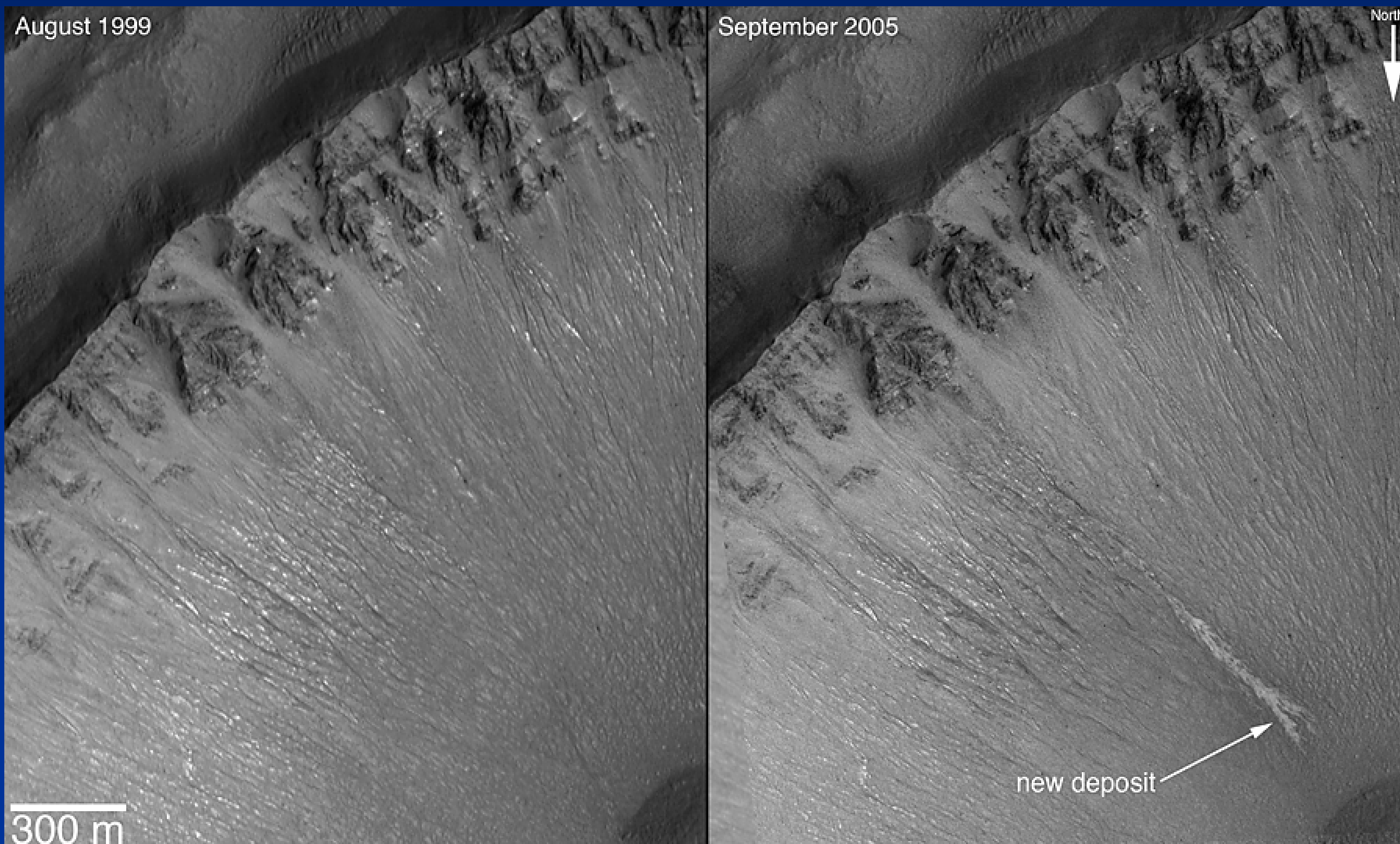
First image of an extrasolar planet



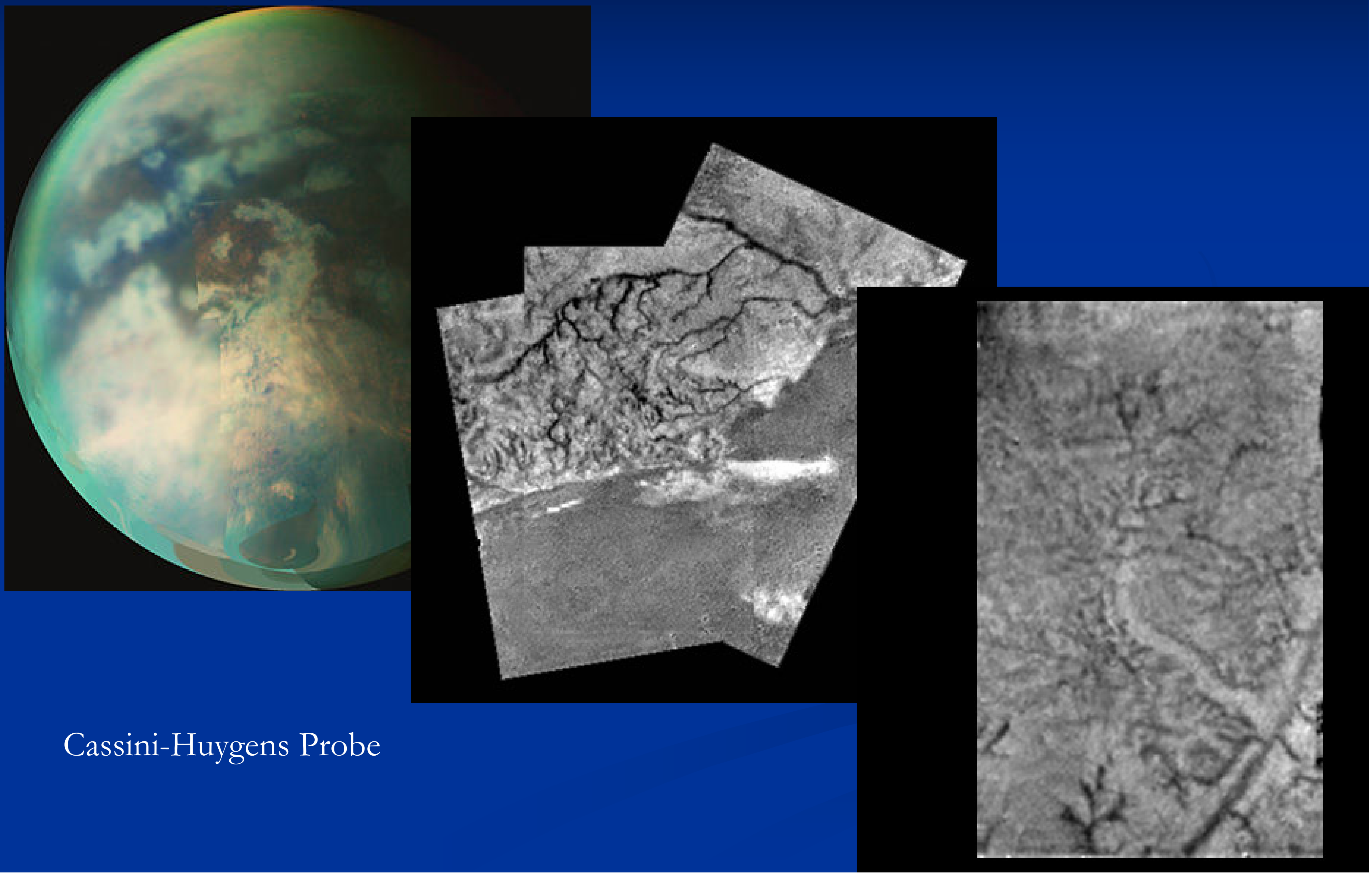
The Brown Dwarf 2M1207 and its Planetary Companion (VLT/NACO)

ESO PR Photo 14a/05 (30 April 2005)

Liquid Water on Mars?



Liquid Methane on Titan

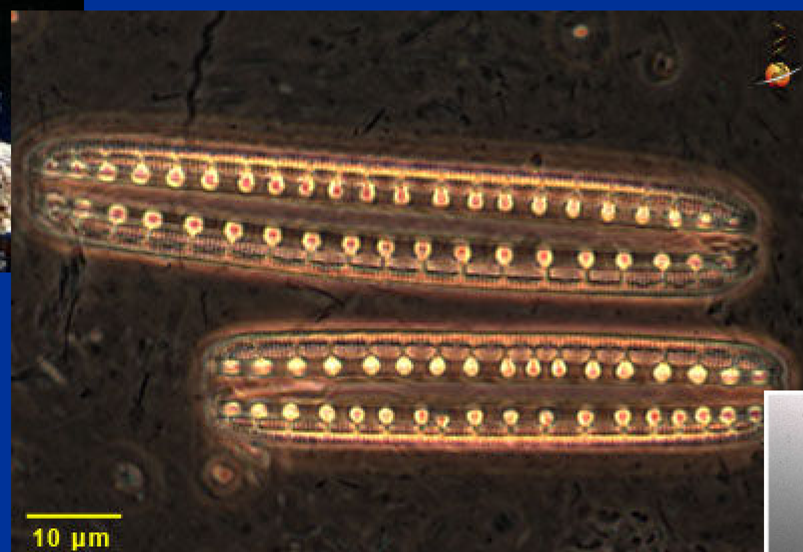


Cassini-Huygens Probe

Extremophiles: Life in the harshest environments

Life around hydrothermal vents

Diatoms surviving in extreme saline environments



Terrestrial bacteria survived (dormant) on the Moon for 3 years

Explicit course outline

Weeks 1-8

0. The Search for Extraterrestrial Life: Overview of the Drake Equation and its motivation
1. Introduction to concepts in Astronomy
2. Cosmology & the Anthropic Principle "Big ideas"

   How fundamental ideas about the Cosmos can relate to the development of life
3. Formation and Evolution of Stars

   Since we are all star dust, stars play a critical role in the development of life
4. Formation of Planets & Geophysics

Weeks 9-12

5. Development of Life

   Adaptivity and survival
6. Development of intelligence & technological issues in SETI

Marking Scheme

- 50% Final Exam
- 25% Mid term
- 20% Homeworks (4 set, approx 1 every 3 weeks)
- 5% in-class quizzes (best 3 of 5 chosen)

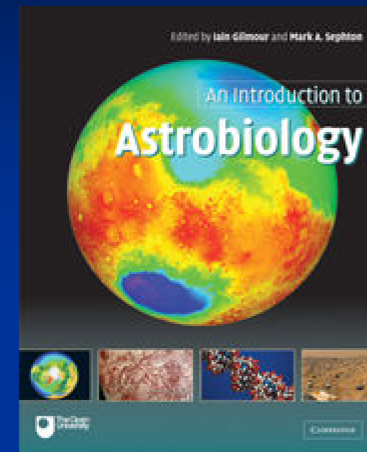
- Late assignments receive a 10% per day penalty

Course Website

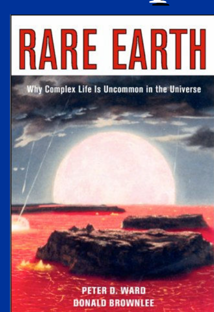
- www.astro.queensu.ca/~thacker/new/teaching/214/
- Course outline + any news
- Lecture notes will be posted there in pdf format
- Homeworks and supplementary material will be posted there

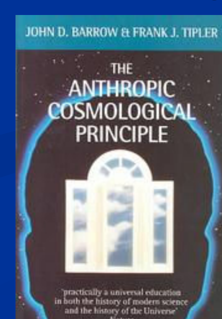
Books

- Main course text: “An Introduction to Astrobiology” Gilmour & Sephton



- Secondary texts that we will draw from (up to you whether you purchase them):
  - “Rare Earth” Ward & Brownlee
  - “The Anthropic Cosmological Principle” Barrow & Tipler





A note about the course

- I usually produce *exhaustive* presentations that should provide all you need to know about a given subject
- Unfortunately, since I am writing the presentations in tandem with teaching, I am unable to provide the presentations before the lecture
  - Although they will be available soon after class on the website
- When relevant, I'll provide additional links within the lecture for you to look at in your own time

Pseudoscience

- The concept of extraterrestrial life (and intelligence) is deeply relevant to many areas of life
  - Consequently many people are prone to over interpretation and speculation
    - Motivations may not necessarily be sinister or economic
    - Deeply flawed ideas can be hidden in an *apparently* scientific approach
      - Deep scrutiny may be required to unearth errors
      - Recent example: use of Shannon's information theory in Intelligent Design arguments by Dembski (an essay by Victor Stenger lists the errors in Dembski's arguments)

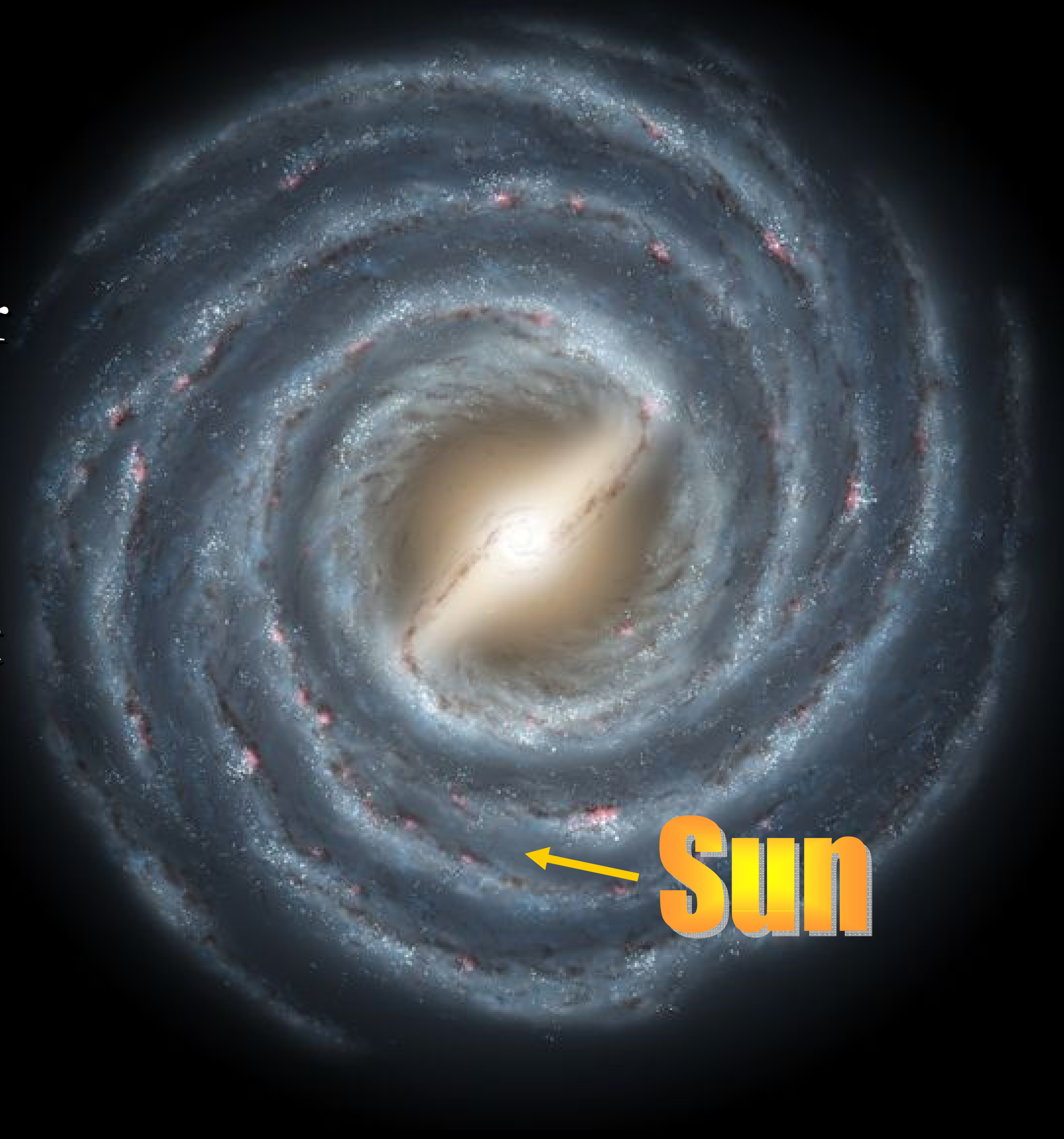
Pseudoscience

- **Classic example by an *astronomer*: Percival Lowell (1855-1916) was heavily influenced by earlier comments by Schiaparelli and interpreted optical illusions as being "canals" on Mars – directly leading to the assumption of civilization**
  - **Orson Wells then played on these assumptions with the "War of the Worlds" radio drama of 1938**
- **Carl Sagan: "*Extraordinary claims require extraordinary evidence*"**
  - **Healthy skepticism is ultimately the most natural scientific approach**

Today's Lecture

- Section 0: Prelude & Motivation: The search for extraterrestrial life & the Drake Equation
  - The Drake Equation
    - Overview of each of the terms that provides the motivation for the material we will cover in the next 12 weeks
  - Short biography of Frank Drake

- An artist's conception of our galaxy, the Milky Way
- Visible as a bright (diffuse) band overhead on a clear night



Aside – Galaxies are not static or isolated

Milky Way will collide with Andromeda galaxy in 3 billion years time – here is a simulation

Movie by John Dubinski (CITA)

Survey of your opinions!

- Three choices:
  - Number of civilizations in the Milky Way galaxy is 1
  - Number of civilizations in the Milky Way is greater than 1 but we just haven’t detected them
  - Number of civilizations in the Milky Way is greater than 1 and they are already here

- At the end of the course we’ll revisit this survey

Estimating the number of civilizations we can detect

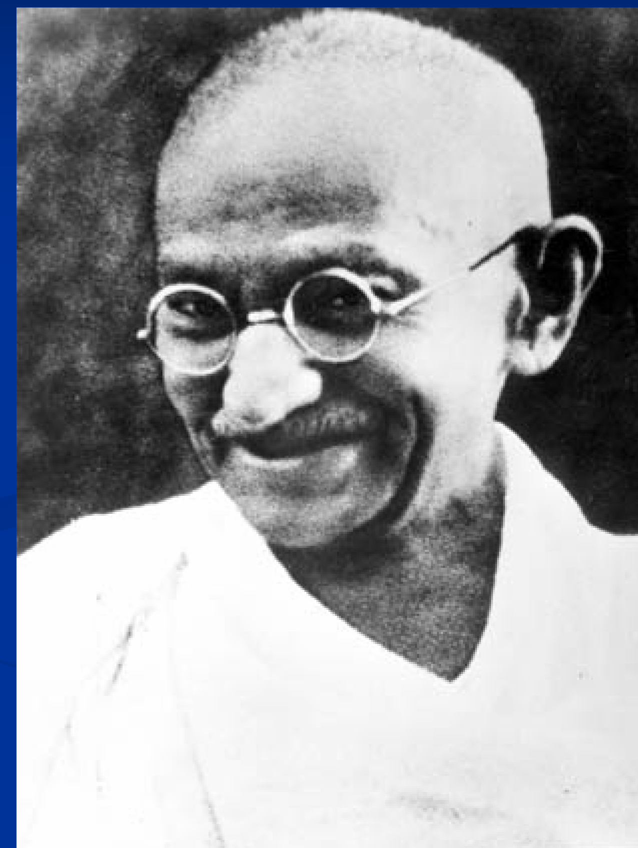
- Suppose over the *entire lifetime* of the Milky Way galaxy N_{total} civilizations are created that broadcast their existence (at different, but perhaps overlapping, times)
- Suppose civilizations broadcast for T years, and the lifetime of the Milky Way is T_{MW} years
- Each broadcast lasts a fraction T/T_{MW} of the lifetime of the Milky Way
- Thus *on average, at any one time*, we can expect to detect

  $$N = N_{total} \times (T/T_{MW}) = (N_{total}/T_{MW}) \times T = RT$$

  where we define R to be the *rate at which civilizations are created*

Humour: Definition of Civilization?

- Reporter: “What do you think of Western Civilization?”
- Ghandi: “I think it would be a good idea!”



The basis of the Drake Equation

- The simple equation $N=RT$ is starting point of the Drake Equation
- Calculation of the rate of creation of broadcasting civilizations is obviously extremely hard, and influenced by many factors
  - Number of stars in the galaxy
  - Number of habitable planets
  - Number of times life develops on these planets… among other things
- The broadcasting time of these civilizations is probably equally hard to estimate, but can be left as a single number

The Drake Equation (1961)

The Drake equation expands out the rate of creation of broadcasting civilizations as follows

$$N = RT$$

$$\Rightarrow N = R^* \times p_p \times n_E \times p_l \times p_i \times p_c \times T$$

So that R is factorized into the product

$$R = R^* \times p_p \times n_E \times p_l \times p_i \times p_c$$

Let’s look at each of these variables in the next overheads

R* – rate of formation of stars in the Milky Way

- R* is the number of stars per year formed in the Milky Way
- Not easy to measure though
  - Can’t see stars forming easily (don’t suddenly turn on)
  - Milky Way includes a lot of dust that obscures the sight lines
- We’ll examine this in detail in weeks 3-4

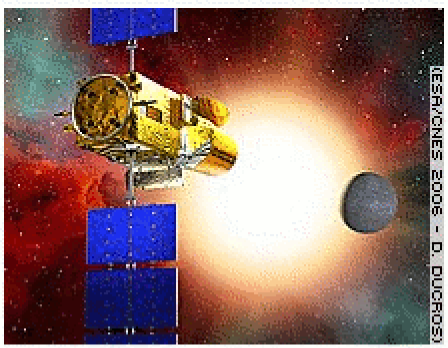
p_p – Probability of planets forming around a suitable star

- Until very recently we had little idea what this number might be
- The discovery of extrasolar planets has given us the first data relevant to estimating this variable
  - Planets are detected due to a miniscule wobble in the star as the planet orbits around it
    - So far we have only been able to detect very large planets
- The future for research in this field is exceptionally exciting!
- There is hope of building a telescope that can image Earth-sized planets around 2020
- We'll look at planets in weeks 5-8

SCIENCE & SPACE

Scientists launch 'planet hunter'

POSTED: 1621 GMT (0021 HKT), December 27, 2006



COROT will measure the light emitted by a star and detect the drop in brightness caused when a planet passes in front of it.

VIDEO — Browse/Search

COROT to hunt for extrasolar planets (:32)

PARIS, France (Reuters) -- A French-led satellite launched on Wednesday to seek out new Earth-like planets beyond the solar system and to explore the interior of stars.

The COROT project sent into orbit a telescope capable of detecting planets smaller than is currently known -- some maybe just a few times the size of Earth and rocky, rather than the larger, gaseous types, the European Space Agency (ESA) said.

"COROT will be able to find extra-solar planets of all sizes and natures, contrary to what we can do from the ground at the moment," Claude Catala, one of the researchers associated with the project, told France Info radio. (Watch the satellite launch)

"We expect to obtain a better vision of planet systems beyond the solar system, about the distribution of planet sizes," she said. "And finally, it will allow us to estimate the likelihood of there existing planets resembling the Earth in the neighborhood of the sun or further away in the galaxy."

COROT launched at 1423 GMT from Kazakhstan.

n_E – average number of suitable planets in habitable zones

- It is widely believed that planets that are “too hot” or “too cold” cannot develop life
  - As with Goldilocks & the Three Bears – things have to be *just right*
- Thus there is an expected region of space – *a habitable zone* - in which stellar radiation heats a planet up to a surface temperature that is “acceptable”
- Morrison & Cocconi (1959) formally presented the idea in an early SETI paper
- Recent discoveries of “extremeophile” creatures adapted to high temperatures have questioned the accuracy of this assumption
- We’ll come back to this in weeks 7-8

p_l – probability of life developing

- Very difficult to address this question
- Although the exact origins of life are far from clear, it is widely believed that the steps involved are
  - Origin of biological monomers
  - Origin of biological polymers
  - Evolution of molecules to cells
- We know from the Miller-Urey experiment in 1953 that we can form organic monomers in atmospheres containing water, methane, ammonia and hydrogen
- Other steps remain shrowded in controversy
- We'll look at this in weeks 9-11

p_i – probability of intelligent life developing

- Another poorly understand variable
- It may be possible that simple single cell life is extremely common, but complicated multicellular life is extremely rare due to a coincidence of circumstances required for it
  - This is really the thrust of the "Rare Earth" hypothesis
- Complex Eukaryotic cells are widely believed to be fundamental to the development of intelligent life, while the evolution from prokaryotic cells is poorly understood at best
- We'll look at this in weeks 10-11

p_c – probability of intelligent life broadcasting

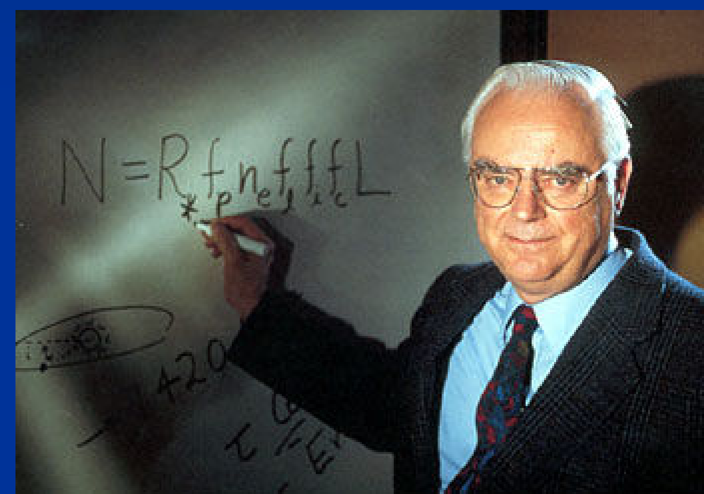
- Some advanced civilizations may not use communication equipment along the (electromagnetic) lines we envisage
- Others may be (understandably) paranoid and choose not to broadcast
- Humans have released signals purposefully, but we do not send them continuously
- We'll look at this in more detail in week ~12

T – lifetime of the broadcast

- Are intelligent civilizations destined to have a short lifetime?
- If they develop technologies to leave their planetary system does T become exceptionally large? Billions of years?
  - If they can leave their planetary system how long would they take to colonize a galaxy?
- We'll look at this issue in week ~12

Frank Drake

- Frank Drake was born in Chicago on May 28, 1930
- Graduate work at Harvard, later became professor at Cornell
- Conducted first radio search for ETI in 1960: “Project Ozma”
- Instrumental in the conversion of the Arecibo Observatory into a radio telescope for astronomy
- “The father of SETI”



How many civilizations in the observable Universe?

The standard Drake Equation assigns a probability to whether the civilization broadcasts. If we just wish to estimate the number of civilizations we can remove this factor and replace the broadcasting time, *T*, with the lifetime of the civilization, *L*.

Secondly, assuming all galaxies to be the same (which we'll see is far from true), we need to multiply by the number of galaxies in the observable Universe, *G*

$$N = GRp_b n_E p_l p_i L$$

We'll look at measuring G in the next couple of weeks.

Is the Drake Equation & the search for ETI scientific?

- It is a statistical equation
  - Not a fundamental law such as F=ma
- Is it testable?
  - No
  - Alternative proposals are equally untestable
- If we cannot test the underlying hypotheses of the Drake Equation, is searching for ETI really a science?

Summary of lecture 1

- The Drake Equation provides a useful frame work for discussing the search for ETI
  - Nonetheless, many of the parameters are difficult to measure and at worst impossible to
    - We can measure many of the astronomical parameters, such as the rate of formation of stars
    - Parameters relating to the origin of life are very uncertain

Next lecture

- Fundamental concepts in Astronomy
  - Angular measurements
  - Astronomical distances & units
  - Celestial sphere & motions