AST 309L Search for Life in the Universe

Instructor: John Scalo

Teaching Assistant: Ross Falcon

Class Website: ➡

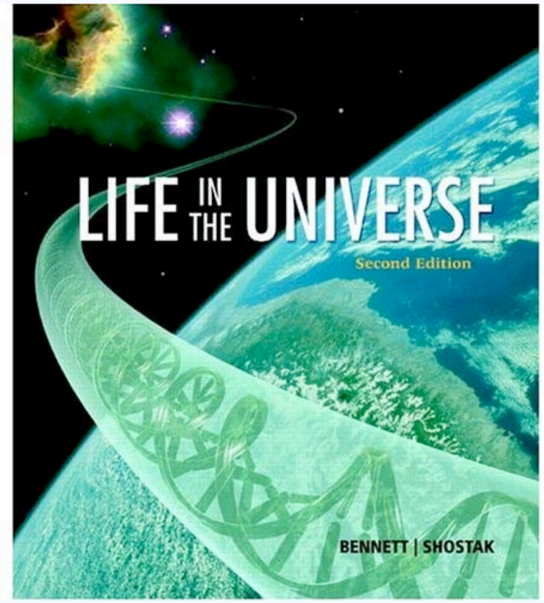
http://www.as.utexas.edu/astronomy/education/fall08/scalo/309l.html

- Download course syllabus in Word format (linkable)
- Notice calendar chapters to be read (not same order as book) and exam dates
- Outline of most class lectures will be available for download as pdf versions of ppts--these are only outlines!
- Handouts, suggested end-of-chapter questions, review sheets for exams, etc. will be located here.
- Contains link to eGradebook for checking exam scores, and to textbook ➡"Student Companion Website."
- Will contain external links for "homework assignments"

Textbook: Life in the Universe (*2nd edition)*
by J.O. Bennett & S. Shostak

Co-op: Price unknown ??
New: Amazon $98, Barnes & Noble $109
Used: As low as $78 + shipping + time
Don't buy 1st edition!

Assignment: By Tuesday Sept. 2, skim entire textbook in order given on the Reading Assignments list, not really reading, just noting topics, illustrations. *If you have a good overview of the material we are covering and why, you will do better in the course.*



There is no study guide, cdrom, or other "extras".
Most of the extras you need are at :

Student Companion Website:
http://wps.aw.com/aw_bennett_liu_2

Inside you will find tutorials, movies, interactive figures,links, glossary, flashcards, calculator and periodic table (the last two are unnecessary). "Links" is particularly valuable.

Features of textbook website

Links: Well-organized, up-to-date, and easy to navigate.

Flash cards: Could be surprisingly useful. Use for chapters as we cover them, to *become as comfortable as possible with terminology*.

Tutorials: Only four of them, but appear to be very useful.

Two assignments (do them by Tuesday) within textbook website:

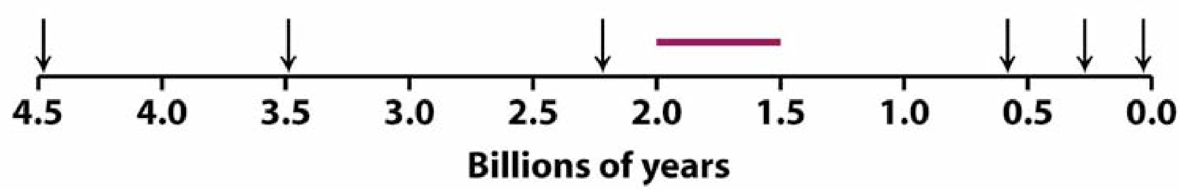
A. Read in Links: A Universe of Life, Link to simple math review in Chemistry Basics Reminder (sends you to Chem Tutor web site), Numbers and Math, only Measured Numbers…, Scientific Notation, Significance and Rounding, then Proportionality. I will cover "Units…" in class; ignore material you find here.

B. Read in Links: A Universe of Life, the material on Light Years. Which unit does your textbook use, light years or parsecs? Use opportunity to review any other astronomy topics that are relevant (see list there).

Math and numbers

You will be asked to manipulate the *simplest* of formulas, and very rarely. I will give examples in class and in handouts. There are also only a few numbers that you will have to memorize, and I will tell you what they are.

An example: You will be expected, by the end a particular section of the course, to be able to name the events in the history of the Earth, that are believed to have taken place at the times marked with the arrows:



➡ However, you *will* be expected to understand the concepts, ideas, and reasoning behind all the material, and should be able to articulate them.

Some math you should practice

Scientific notation: you don't have to *use* it, just be able to *read* it.

Simplest of **logarithms**, **base 10**. So we can make graphs of things that vary by many orders of magnitude.

Simply related to scientific notation above

Graphs: If you are uncomfortable with graphs, do some review immediately. Make one yourself! Find some in our textbook.

Wander through these for familiarity

Class website

http://www.as.utexas.edu/astronomy/education/fall08/scalo/309l.html

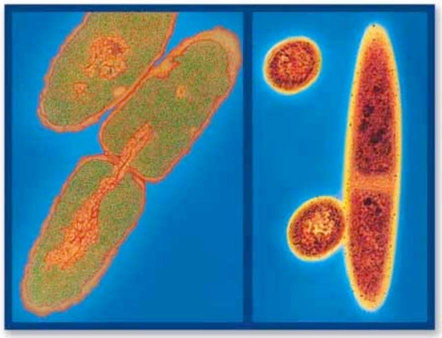
Textbook website

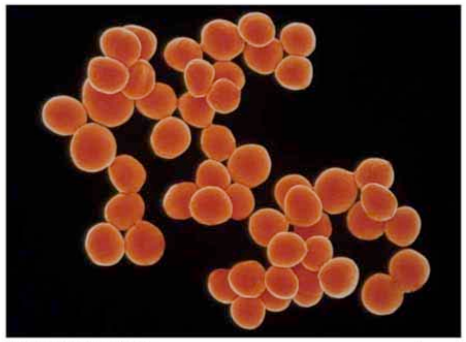
http://www.as.utexas.edu/astronomy/education/fall08/scalo/309l.html

For homework and in case you want alternative presentation of some material

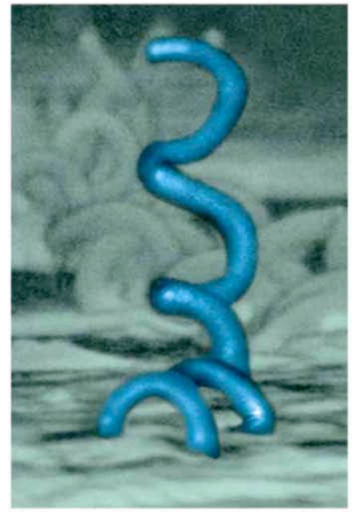
www.astrobionet.com

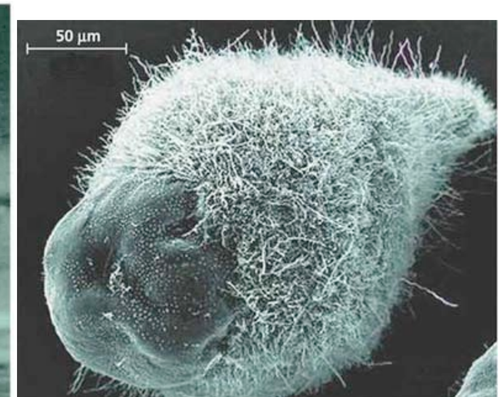
What are we looking for?
Where should we look?

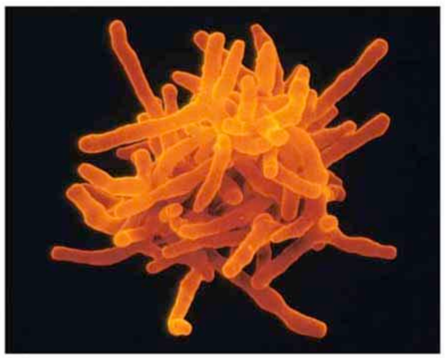




Staphylococcus aureus 1 µm

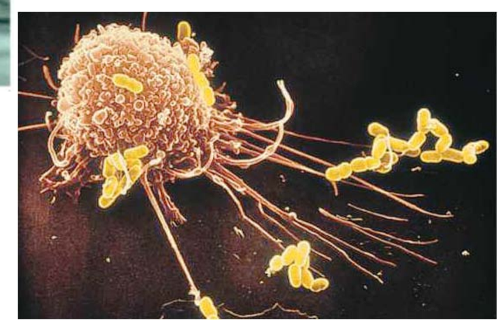


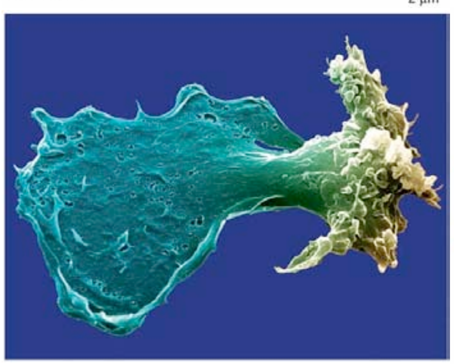


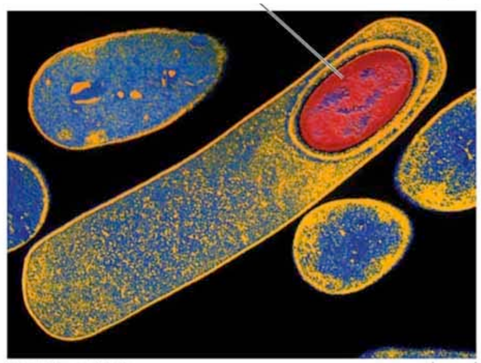


Actinomyces sp. 2 µm

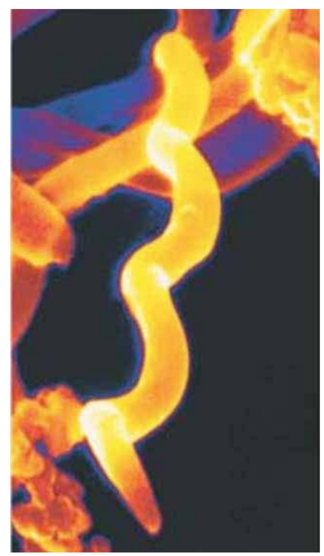
Mycoplasma gallisepticum 0.4 µm

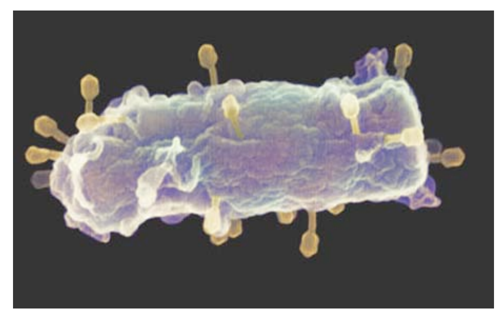






Clostridium difficile 0.3 µm



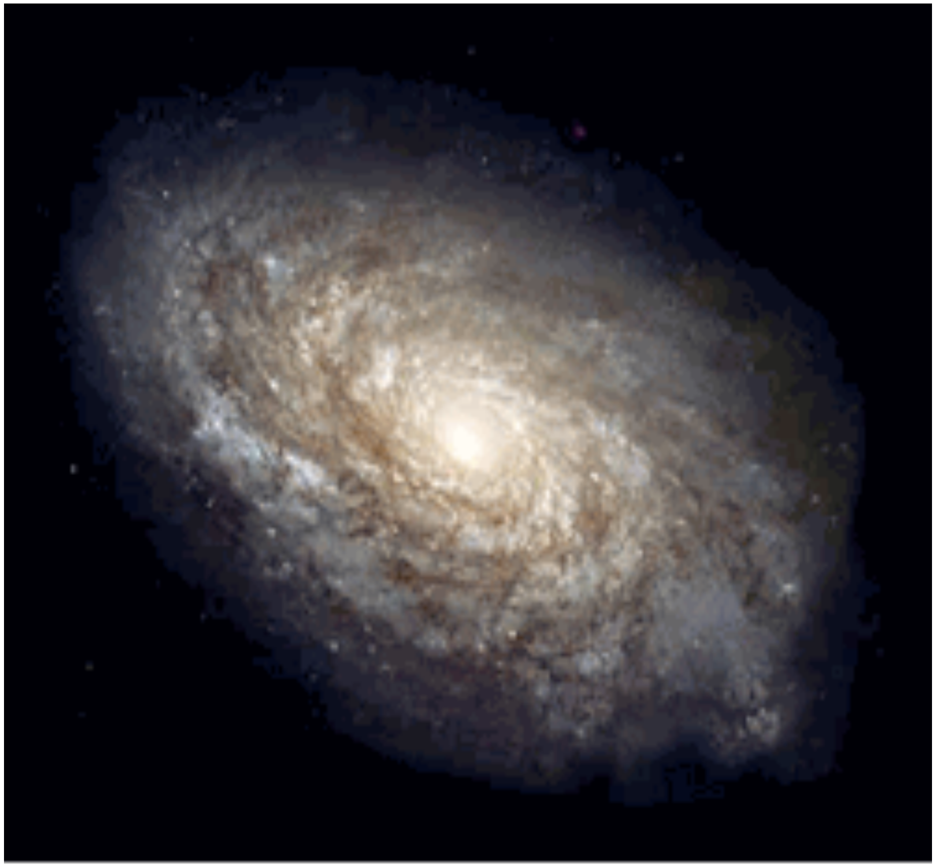


AST 309L

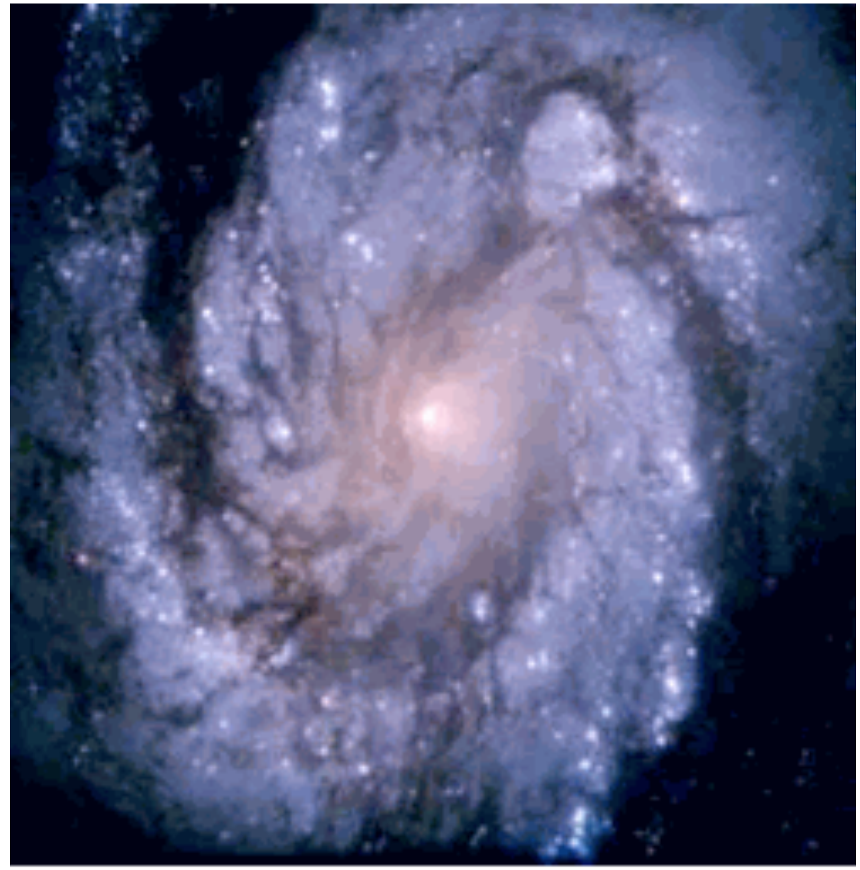
The Drake Equation as organizing tool, and its implications

(9/2/08)

Galaxies like ours: How many of these 100 billion stars might have planets, with life, or with "intelligent" life? We can organize the issues we have to address with the "**Drake equation**." (Sec. 12.1)



NGC 4414



M 100

Q: Why shouldn't we search for life in these galaxies?

How do we search? What is required to have life? Complex life?
Life we could communicate with?
The "Drake Equation" simply organizes these supposed requirements into separate factors, sort of a list of possibilities for our consideration

- **star**--about 10^{11} in our galaxy. Average separation is **a few light years**. (Compare with size of Galaxy: about 100,000 light years)
- **planet**--indirect arguments from theory as well as direct observations of extrasolar planets suggest *giant* planets may be very common. But Earth-like (much smaller, rocky) planets? *The Drake equation question: What is the probability that a star has a planet?*
- ***habitable* planet**--requires a liquid? Liquid water? Nearly everyone agrees this is fundamental (we'll discuss why later). Requires special temperature range, and so only certain range of distances from star.

Probably additional factors for habitability, like planetary mass (for atmosphere, geology,...)
Drake question: What are chances that a planet will be habitable?

- **life**--How probable or improbable? Need to understand how life arose and developed on Earth (our only example). We will spend the 2nd part of this course discussing the many theories, experiments, and types of evidence related to this. *What are chances life will develop on a habitable planet?*
- **intelligence**--What does this mean? Are there different "types"? Why think that extraterrestrials would share our forms of cognition? Compare cross-cultural, cross-species, cross-historical cognition.What is probability that life elsewhere develops "intelligence?
- **communication**—representation, language. How likely? Other forms?
- **length of time spent communicating**—we expect any *nearby* civilizations to have had a *long* lifetime. (We'll see why this is so shortly.)

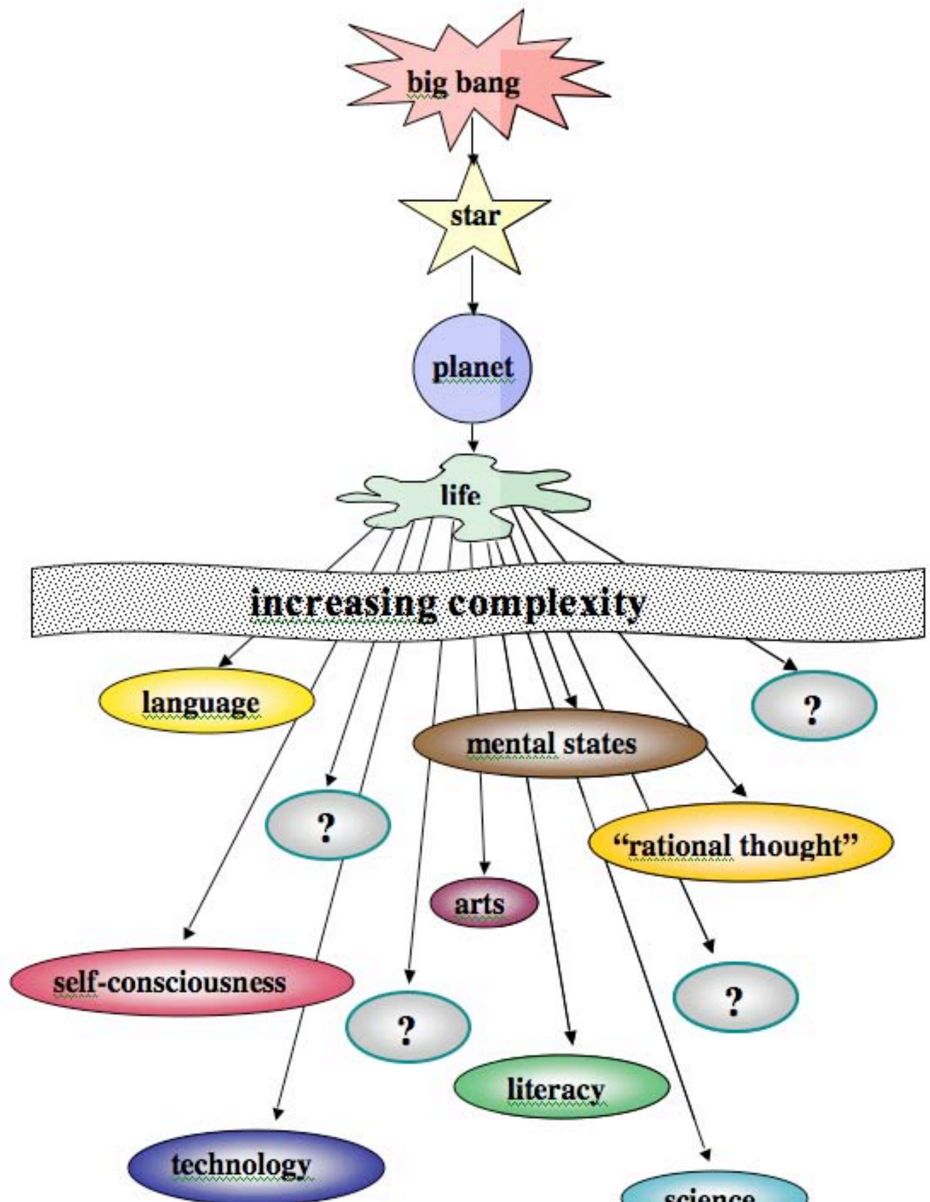
Now we just assign a symbol for each one of these, representing its probability of occurrence, and multiply all of them together. *See pp. 400-401*

Another way to see the main idea in terms of *convergence* and *contingency*

What is the likelihood or probability that the sequence of events shown to the righ will occur, ending up with the peculiar group of phenomena listed at the bottom branching? And are there many other possible branchings that we haven't thought of, or are incapable (for, say, biological reasons) of imagining?

Convergence is related to determinism, inevitability. If it occurred in one place, it was probably useful, and will arise elsewhere

Contingency is related to randomness, uncertainty, sensitivity to slight changes in conditions. Basically, a fairly complex event depends sensitively to all the events and conditions that preceded it.



Another way of looking at the sequence of events required (symbolically) represented by the Drake equation: *Look at timeline*

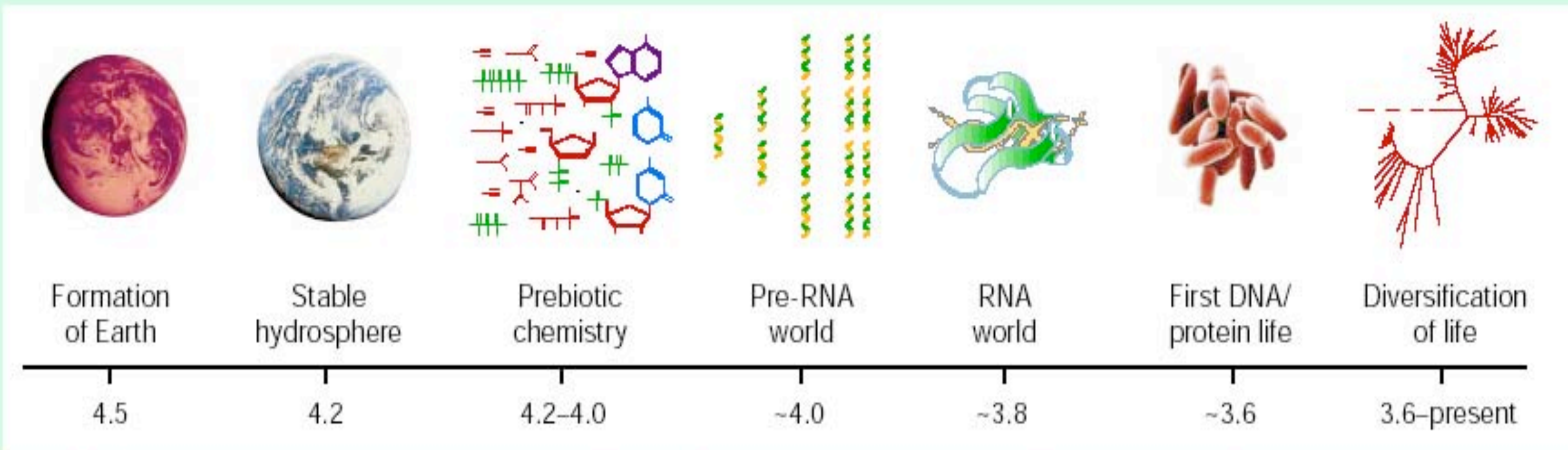
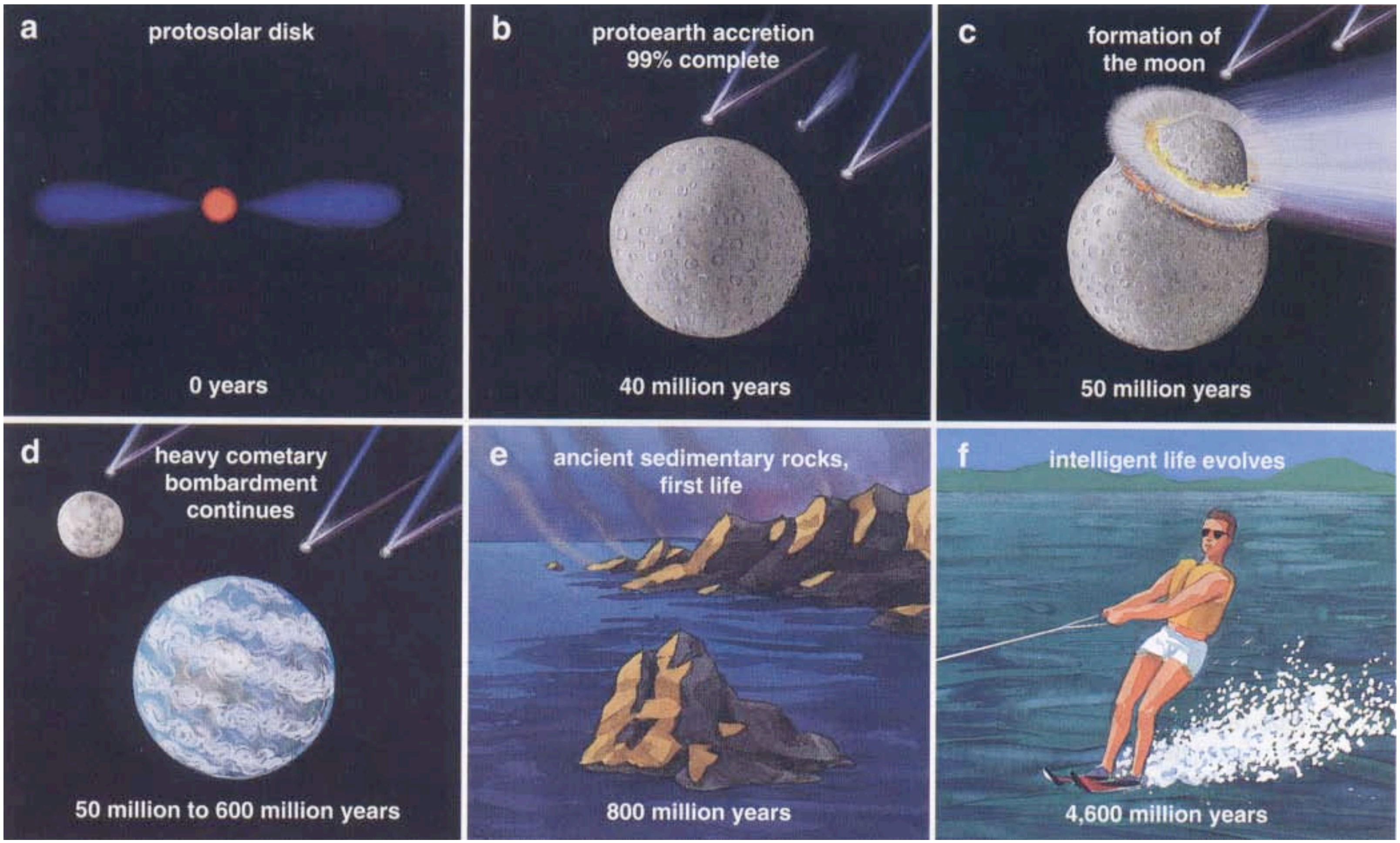


Figure 1 Timeline of events pertaining to the early history of life on Earth, with approximate dates in billions of years before the present.

The Drake equation is just a symbolic way of asking what the probabilities are that a sequence of events like those below (and more) might occur in other planetary systems.



The "Drake equation"

This is the version discussed on p. 402 of your textbook.

Multiply together the separate probabilities for:

star, planet, habitable planet, life, intelligence, technology

to obtain an estimate of the number of communicating civilizations in our galaxy N:

$$N = N_{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot (L/L_{Galaxy})$$

where N_{*} is the number of stars in our Galaxy (~10^{11}), L is the average lifetime spent in the phase in question (e.g. technological and communicative) and L_{Galaxy} is the age of our Galaxy (~10^{10} yr).

Look at example on page 401 of text. We'll try it in class.

Now estimate number of planets with *life* in our Galaxy (not number with *intelligent, communicating* life

If we leave out f_i and f_c (i.e. assume they are unity—all life forms develop our kind of intelligence and technology and try to communicate), we are calculating the number of life-bearing planets in our Galaxy at any given time (like now). We know there has been life on our planet for 3 billion years, so take L = 3 billion. Let's be optimistic about f_P (0.1), n_P (1), and f_L= (0.1). Then

$$N_{life} \sim 10^{11} \times 0.1 \times 1 \times 0.1 \times (3 \text{ billion}/10 \text{ billion}) = 300 \text{ million}$$

300 million planets with life in our Galaxy! That's roughly1 out of 1000 stars. This means that the nearest life-bearing planet might only be 10-100 light years away, close enough that in the future *we may be able to detect such planets and obtain their spectra* (that is the primary goal of astrobiology space missions for the next decade).

➡This result is a major reason for exerting most of our effort toward detecting signatures of biochemistry in the spectra of planets orbiting nearby stars. You will be reading and hearing a lot about "biosignatures" in this class soon!

Now try number of planets with *communicating* life

But if we are interested in planets with *communicating life*, even if f_i and f_c = 0.1 (optimistic!), we only get

➡ $N_{comm} \sim 10^{11} \times 0.1 \times 1 \times 0.1 \times 0.1 \times 0.1 \times L_{comm} / 10$ billion $= 10^{-3} L_{comm}$(yr)

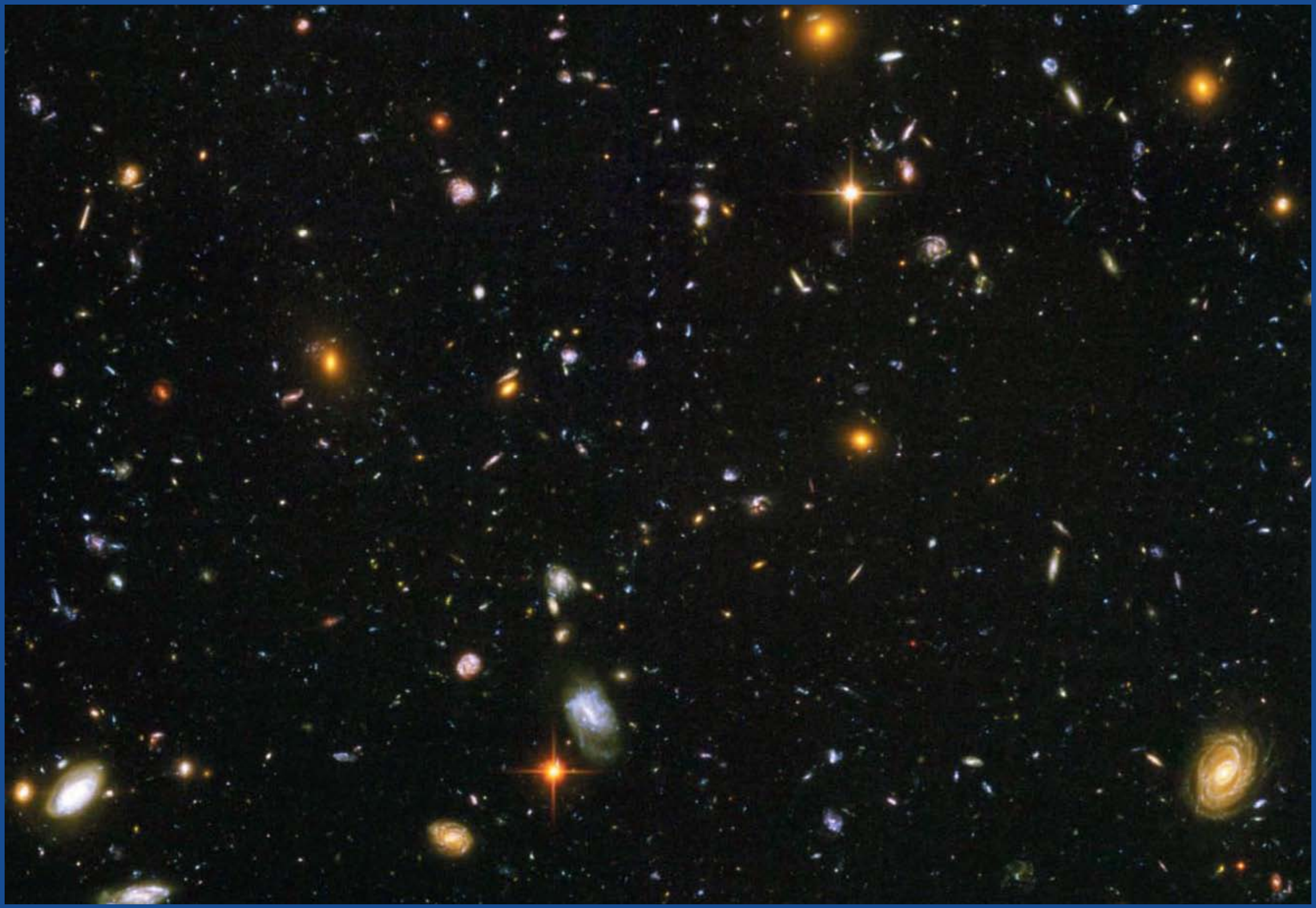
If L_{comm} is only 1000 yr (roughly 10 times our age), then $N_{comm} \sim 1$ (unlikely to be *any* others: we are essentially alone). And this is the "optimistic case" with large values of the various Drake equation probabilities, where we are getting N = L. Many people think it is very likely that $N \sim 10^{-4}$ L or even much smaller. (See later pictures.)

⇒So for communicating civilizations to be numerous, L must be very large, e.g. 10^6 years!

➡ ***Any civilization we contact will very likely be extremely advanced compared to us***

Try reading the dense "Cosmic Calculations 12.1" on p. 404 of textbook: "The distance between signaling societies." Remember, you won't have to do such a calculation yourself--it is just to appreciate a basic point…

Where to look? Answer will be: as nearby as possible
Why?

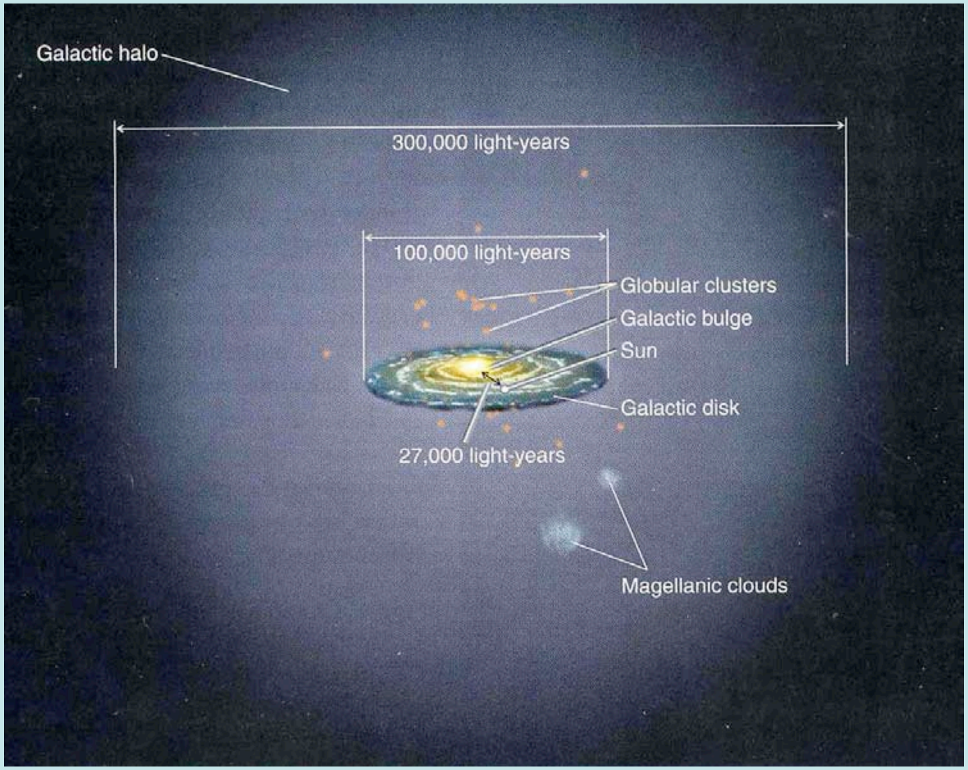


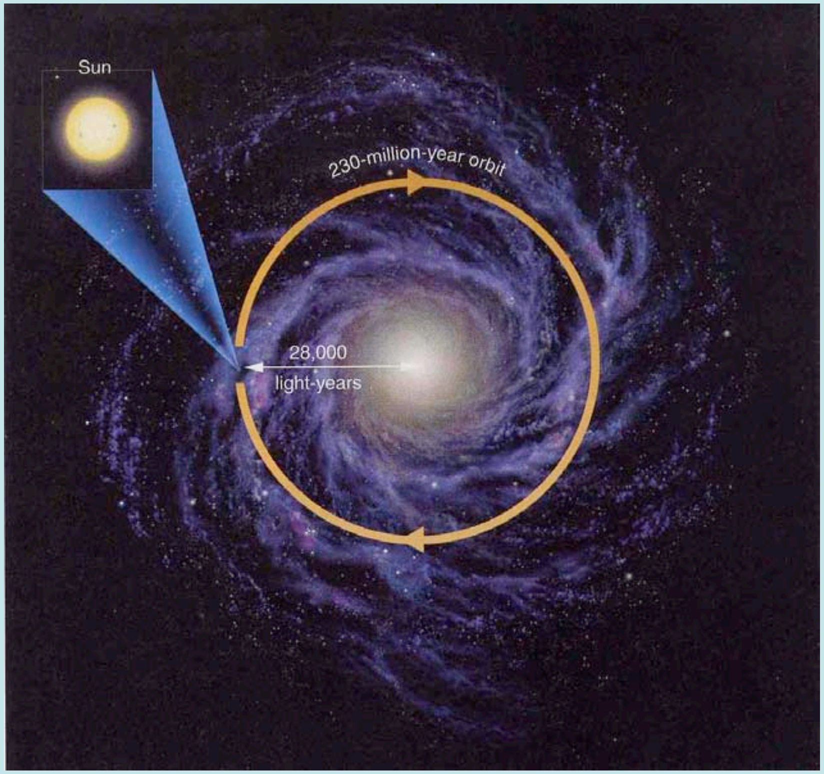
Our place in the Galaxy

The disk is ~100,000 l.y. across, Sun is about 30,000 l.y. from center.

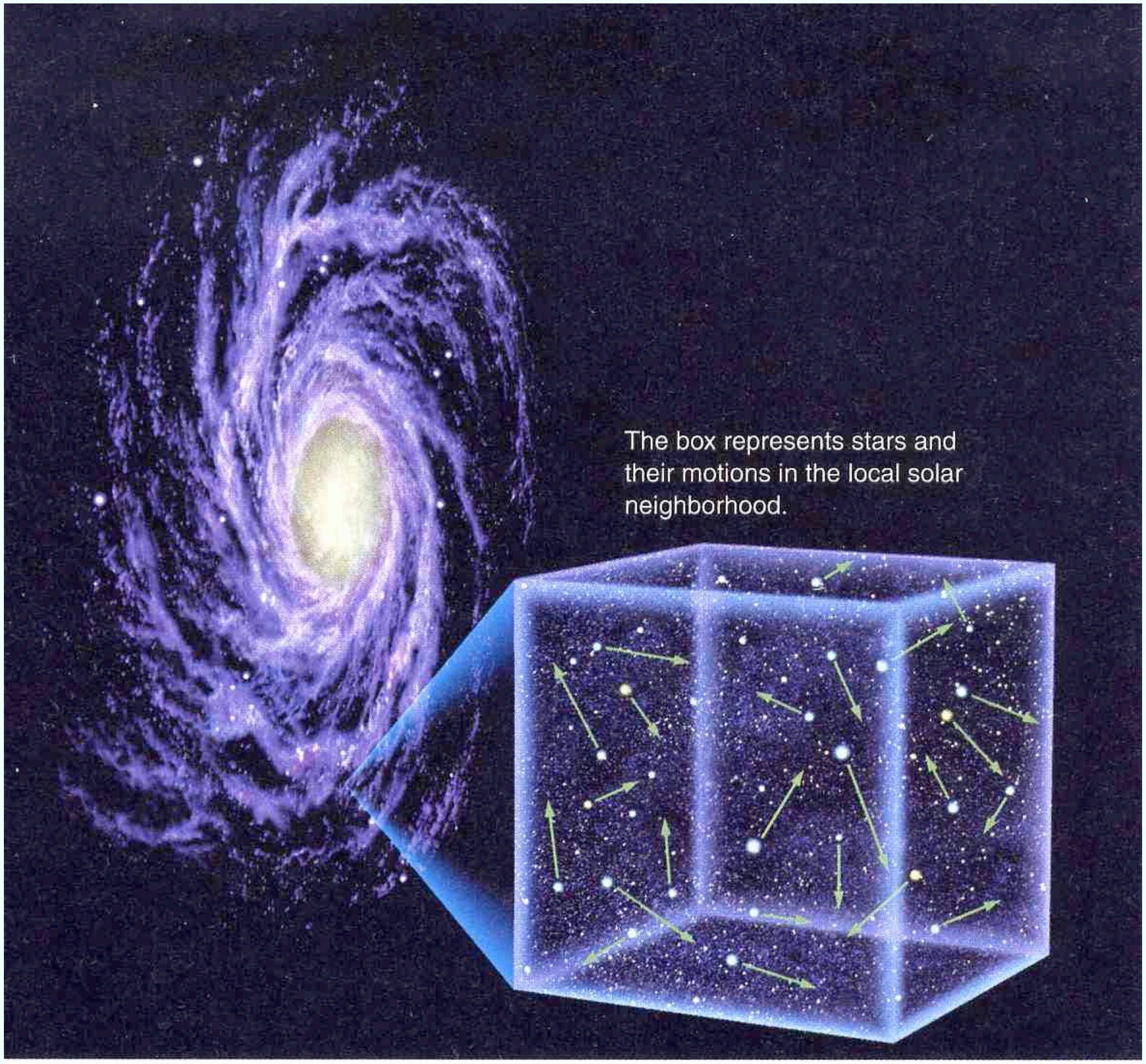
➡Think about times for communication at the speed of light!

Clearly we can only search for life among the nearest stars, and *for that to be successful, it has to be that a significant fraction of all stars must have life, "N" must be very very large* (later we will see just how large, and what this implies).

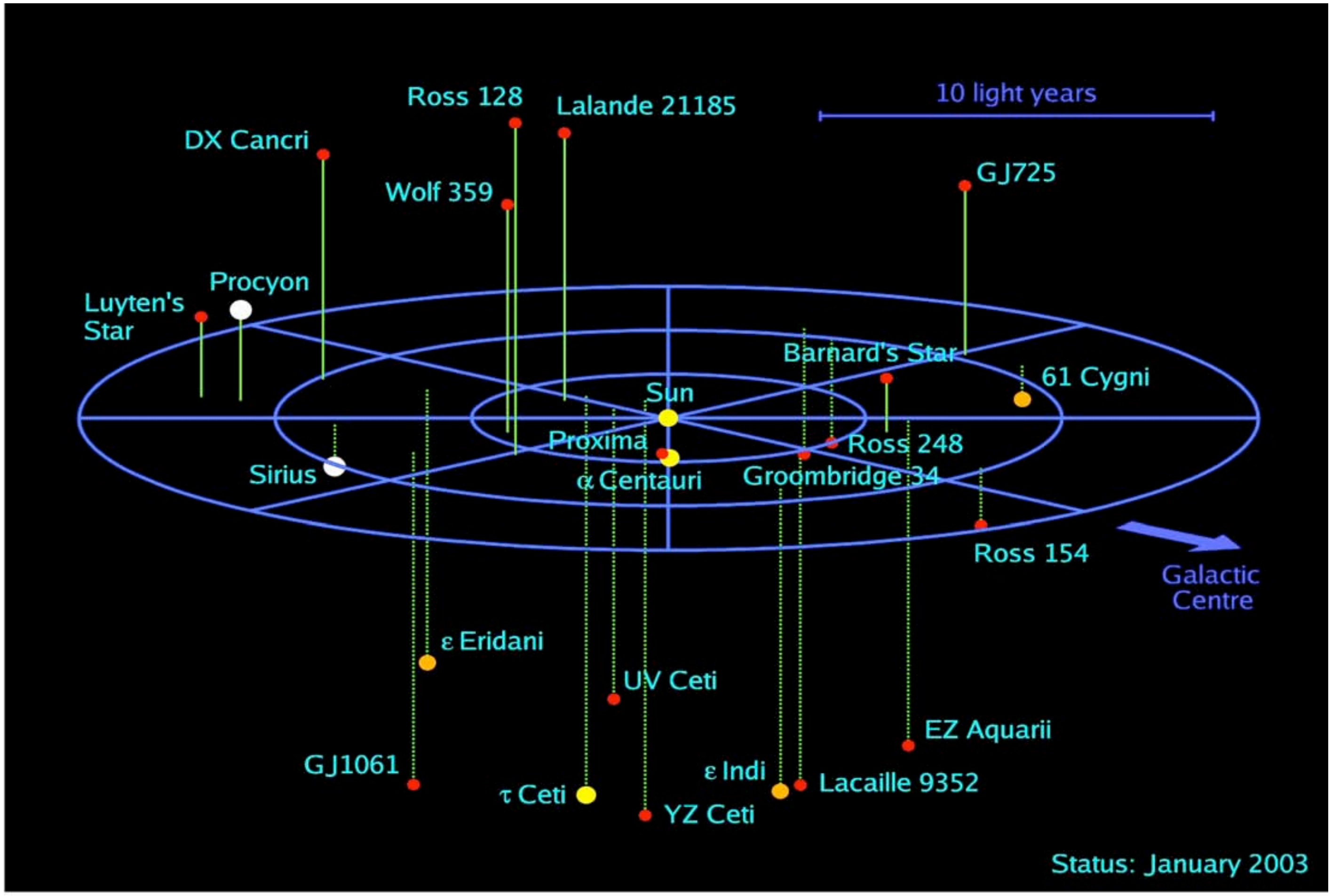




Because of the enormous size of our Galaxy and the finite speed of light, we have to concentrate on detecting signs of life, or communicating life, from stars less than about 100 light years distant.

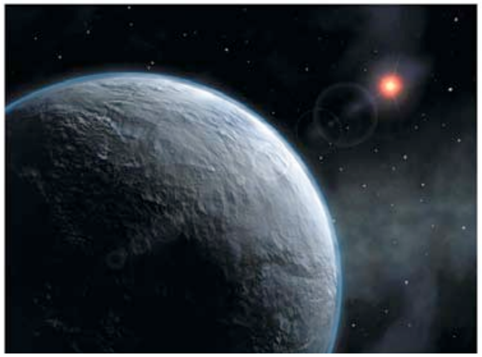


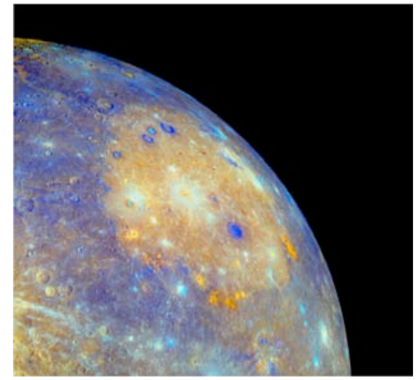
The nearest stars to the Sun--out to about 15 light years



3D Map of Known Stellar Systems in the Solar Neighbourhood

After review of physics and survey, our first serious business will have to do with the likelihood of Earth-like planets orbiting other stars.





Next time: We will cover overview (Ch. 1), then “physics you need,” and how it relates to astrobiology (Chaps. 2, 3 in reading assignments