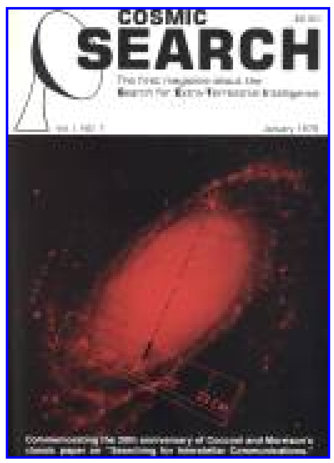
North American AstroPhysical Observatory (NAAPO)



Cosmic Search: Issue 1
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[Article in magazine started on page 32]

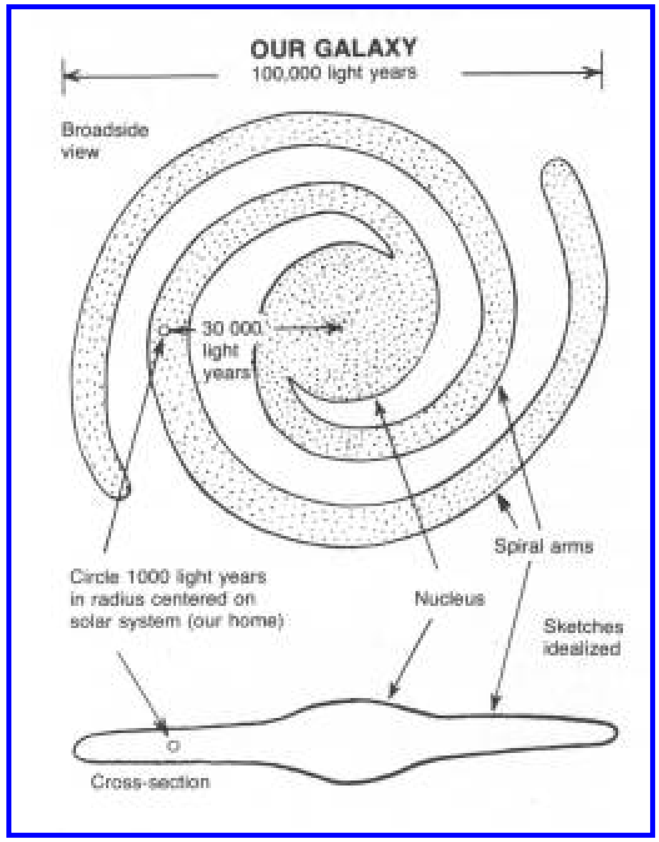
ABCs of SETI

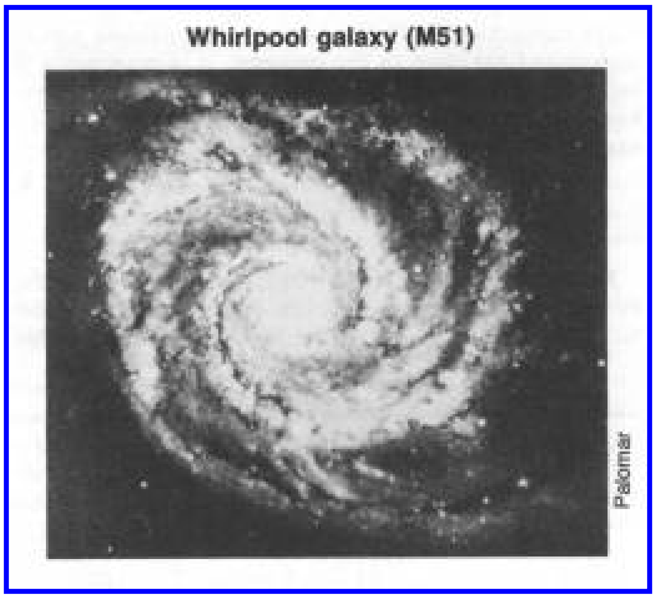
By: John Kraus

D The Wavelength Picture (The "Waterhole")

A The Galactic Perspective.

To appreciate the full significance of searching for extraterrestrial intelligence we must shift our thinking far beyond our solar system to other stars of our galaxy and even galaxies beyond our own. As a first step, in this issue, let's consider our own galaxy and how we relate to it.





Whirlpool galaxy (M51)

Our galaxy is an aggregation of perhaps 100,000 million stars arranged like a flat wheel or disc 100,000 light years across, turning around once in about 300 million years. It has a nucleus with spiral arms radiating from it as suggested by the accompanying sketch (to the right). It may not look too different than the Whirlpool galaxy (M51) in the photograph alongside (to the left). The stars are more numerous in the spiral arms than between them and even thicker in the nucleus. It is believed that a cross-section would appear similar to that of the galaxy (NGC 4565) in the photograph (below).

Galaxy in Coma Berenices (NGC 4565)

We (that is the sun, the earth and the sun's other planets) are situated in a spiral arm some

30,000 light years from the center of the galaxy or about two-thirds of the way from the center to the edge — in the galactic boondocks or outback. The little circle at our location in the two sketches has a radius of 1000 light years. Within a sphere of this size there are about one million stars. A sphere of 1000 light year radius is really enormous yet it constitutes less than one-hundredth of one percent of our galaxy! And beyond our galaxy are some 100,000 million more galaxies.

Summary:

- Stars have planets (at least one star, the sun, does).
- Galaxies have stars.
- Our galaxy is a flat disc (100,000 light years in diameter).
- Our galaxy turns around once in 300 million years.
- We are located 2/3 of the way to the edge of our galaxy in a spiral arm.
- A sphere 1000 light years in radius occupies a very small part of our galaxy (0.01 of 1 percent).
- There are about 100,000 million (10^{11} or ten to the eleventh power) stars in our galaxy.
- There are about 100,000 million (10^{11} or ten to the eleventh power) galaxies in the universe.
- Therefore, there are about 10,000 million million million (10^{22} or ten to the twenty second power) stars in the universe.
- Within 1000 light years of the sun there are about one million stars and perhaps 1/5 of these are sun-like (similar in age, size and composition and may have planets).

- **Notes:**

- *One light year* equals the distance light travels in one year (300,000 kilometers times the number of seconds in a year or about 10^{13} or ten to the thirteenth power kilometers).
- M51 stands for object number 51 in the list of Charles Messier, a French astronomer (1730-1817).
- NGC4565 stands for object number 4565 in the New General Catalog of astronomers. J. L. E. Dryer [sic; Dreyer] (1852-1926) of Denmark and Great Britain.

B The Cosmic Perspective.

Our universe began to form about 15,000 million years ago with the explosion of a primorial [sic; primordial] fireball (The Big Bang). The **Cosmic Calendar** lists events that have occurred since that time. We note that our advanced technology (even mankind for that matter!) has only been around for a very short time. It is apparent that we are a very young, emerging civilization.

Light, radio or other electromagnetic waves travel 300,000 kilometers per second in empty space. This is the top speed at which anything can travel. We can express astronomical distances using this velocity. See **Distance Table**. Thus, the distance to the moon in light travel time is about one second, to the nearest star (other than the sun) about 4 years and to the limit of our universe about 15,000 million years.

The waves (light or radio) from some galaxy 2 million light years distant (same as 2 million years light-travel time) are 2 million years old when they get here. This means we see or observe the galaxy as it was 2 million years ago. Like cosmic archeologists, we are looking back in time 2 million years. The farther out we look the farther back in time we see. Thus, in a very real sense time and distance are closely inter-related.

```
   Age of universe (T) = 15 billion years
Radius of universe (R) = 15 billion light years
                     R = cT
               where c = velocity of light
                       = 300,000 kilometers per second
```

Summary:

- The universe is 15,000 million years old.
- Our technological civilization is very young.
- The farther out we look the farther back in time we see.
- Time and space are inter-related.

C Numbers and the SETI Probability Game.

How likely is it that there are other civilizations in our galaxy capable of communication? If you consider all of the factors you can write a simple relation, as done by Frank Drake, for estimating the probability. I use the word "estimate" intentionally because our knowledge of most of the factors is so poor that we are really only guessing. Your guesses may be as good (or bad) as the next person's so why not play the probability game and see what number you come up with?

The relation, known as *Drake's Equation*, involves 7 factors as follows:

```
|Number of     |   |Rate      |   |Fraction|   |Number   |   |Fraction|
|civilizations|   |of        |   |of stars|   |of       |   |of       |
|in our galaxy|   |star      |   |with    |   |planets  |   |planets |
|capable of    | = |formation| X |planets | X |per star| X |on which|
|communiaction|   |(per      |                  |with     |   |life     |
|now           |   |year)     |                  |suitable|   |appears |
                                                  |environ-|
                                                  |ment     |

     |Fraction|   |Fraction |   |Longevity    |
     |of life |   |of        |   |of each      |
     |bearing |   |intelli- |   |technology  |
   x |planets | X |gent      | X |in           |
     |on which|   |societies|   |communi-     |
     |intelli-|   |which     |   |cative       |
     |gence   |   |develop   |   |mode (years)|
     |emerges |   |communi- |
                  |cation    |
                  |ability   |
```

Worked Example:

```
|Number of     |   |1   |
|civilizations|   |per |
|in our galaxy| = |year| X  1/5 X 2 X 1 X 1 X 1/10 X 1000 = 40
|capable of    |
|communication|
|now           |
```

Suppose you guessed that stars in our galaxy form at the rate of one per year (probably not a bad estimate), that 1/5 of the stars have planets (no one knows), that there are 2 planets with stable environments (a guess), that life appears on each (fraction = 1), that intelligence emerges on each of these (fraction = 1), that 1/10 of these develop communication capability and that these remain in this state for 1000 years. Then, it works out that the number is 40 (as above).

According to this estimate, there would be 40 civilizations in our galaxy capable of communication, or about one per trillion (10^{12} or ten to the twelfth power) cubic light years so that the nearest one might be something like 10,000 light years away. However, if it is in a communicative mode for only 1000 years, as assumed, it will be extinct long before its signals are received at the earth. The longevity time (last factor) is very uncertain. Is it 10 years or one million? In this example we have assumed 1000 years.

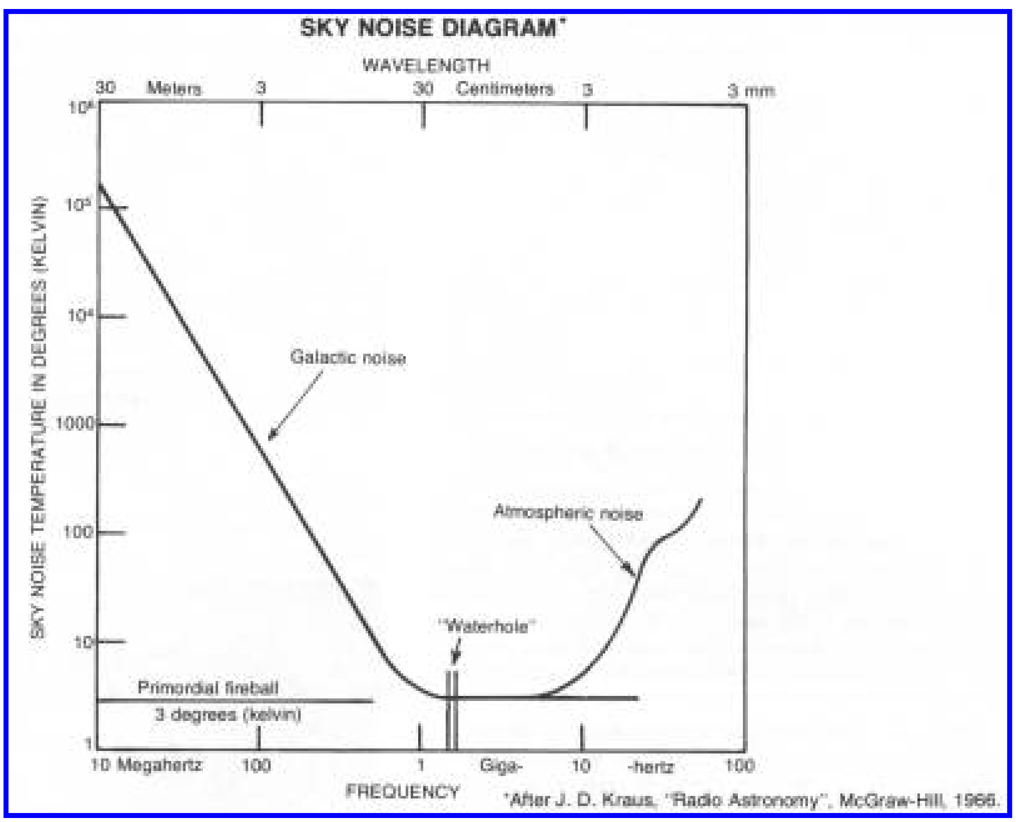
Now, *you* play the SETI game by writing down your numbers. Who knows? Your result may be the right one.

Summary:

- The SETI probability numbers are very uncertain because in all the universe we know of only one example of a civilization, us!

D The Wavelength Picture.

Even if we believe that there may be other civilizations, in which direction should we look and, if we use radio, on what wavelength (or frequency) should we listen? Let us answer the last part of this question now, leaving the rest for a later issue.



The most abundant element in the universe is hydrogen (H). It emits a natural radio signal, called the hydrogen line, at a wavelength of 21 centimeters (or frequency of 1420 megahertz). An advanced extra-terrestrial civilization would certainly be aware of this hydrogen radiation and if they chose to attract attention to themselves with a beacon signal they might choose to use this wavelength or one close to it. Also 21 centimeters is near a minimum of the background noise from the galaxy (and beyond) and is relatively free of absorption by the interstellar medium and by our atmosphere and the probable atmosphere of other planets (see **Sky Noise Diagram** to the right). Therefore, a beacon should be detectable at a greater distance at 21 centimeters or thereabouts. This is the general line of reasoning used by Cocconi and Morrison in 1959 (see lead article of this issue).

There is also natural emission from the hydroxyl (OH) radical at 18 centimeters. Now if you combine hydrogen (H) with the hydroxyl radical (OH) you get water (H_2O), so the wavelength region between 18 and 21 centimeters is often referred to as the "waterhole", in further allusion to the fact that galactic civilizations might (like radio amateurs) gather around this "waterhole" to chat like different species of animals gather around an African waterhole to drink.

Summary:

- Interstellar hydrogen (H) emits at 21 centimeters.
- Interstellar hydroxyl (OH) emits at 18 centimeters.
- The wavelength region between 18 and 21 centimeters is called the "waterhole".
- Many SETI searches are made in the "waterhole".

Notes:

Waterhole wavelengths:

- Hydrogen line (H): 21.1 centimeters (1420 megahertz)
- Hydroxyl lines (OH): 18.3 centimeters (approximately 1638 megahertz)

In the next issue of **COSMIC SEARCH** the above topics will be pursued further and other facets of SETI will be considered. Many books for further reading are listed in "Off the Shelf" (elsewhere in this issue). The ones by Drake, Sagan, and Sullivan are good as an introduction.

HOME

Last modified: September 5, 2006.