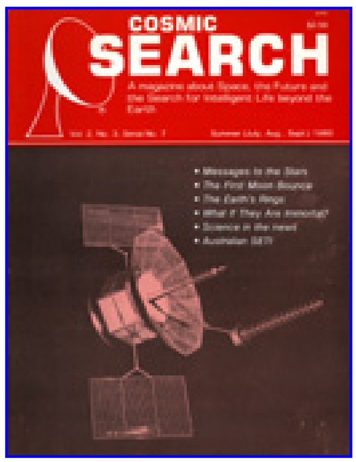
North American AstroPhysical Observatory (NAAPO)



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[Article in magazine started on page 44]

The SEnTlnel

By: Robert S. Dixon

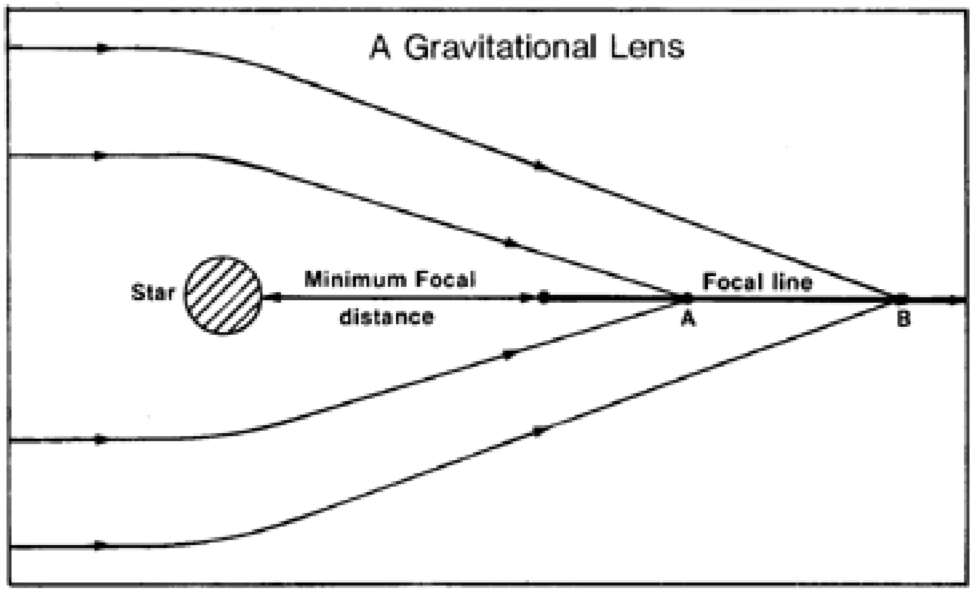
Using the Sun to Amplify Radio Waves

When a radio wave passes near a massive object such as a star, its direction of travel is bent slightly toward the star. This bending is caused by the gravitational field of the star. If the radio wave is traveling directly toward the star, then it will be bent around it equally on all sides, and brought to a focus at some point behind the star. The star may be said to act like a lens in this case. If a receiver were located at this focal point, it would receive a highly amplified version of the original wave and hence could detect much weaker and more distant waves.

This amplification effect was originally pointed out by Albert Einstein in 1936, and was recently explored in more detail by Von R. Eshleman of Stanford University.* (**Science*, Sept. 1979.) The amount of amplification is directly proportional to both the mass of the star and the frequency of the radio signal. For example, the Sun would give an amplification factor of 10 million at a frequency of 300 gigahertz (1 millimeter wavelength).

Actually, there is no single focal "point." Rather, there is a focal "line" that begins at some minimum distance behind the star, and continues radially outward to infinity. Any point along that line gives the same amplification factor. The minimum distance is inversely proportional to the mass of the object, and directly proportional to the square of its diameter. Unfortunately, this minimum distance is extremely large, which means the receiver would have to be located very remotely. For the Sun, the minimum distance is far outside the solar system, being about 15 times farther out than the planet Pluto. It would take a very long time for us to send a spacecraft out that far. There are two reasons for sending it out even farther. One is that the angular resolution, or ability to distinguish planets and even surface features on the planets where the signal originated, improves in direct proportion to the square root of the distance.

The second reason is related to the solar corona, a layer of hot gas surrounding the Sun that tends to dissipate and counteract the focusing effect of the lens. This effect becomes less serious as the distance increases, but it still prevents the use of frequencies much less than about 300 gigahertz. A distance of four times the minimum, or 56 times Pluto's distance, is required to achieve the theoretical amplification factors.



The amplification at A and B is the same but finer detail (or greater resolution) is obtained at B, since it receives waves from a larger area. Reception at B is also less affected by the star's atmosphere or corona since the waves traveling to it pass further from the star.

The spacecraft carrying the receiver would have to be capable of very precise navigation, because it must be positioned to within 24 meters of the focal line to achieve the maximum amplification factor. Due to the lack of objects to compare positions with beyond Pluto, this navigation task would be most difficult. On the other hand, if a signal were received, it would be readily possible to "home in" on it by adjusting the spacecraft position slightly to achieve maximum signal strength. The sensitivity of this system is such that the equivalent of Earth's television stations could be received from several thousand nearby stars (although a different spacecraft would be required for each star). The resolution is so great that individual transmitters on the surface of their planets could be selected for reception.

The system could be used equally well for transmitting. If both civilizations could "aim" their gravitational lenses properly at each other, communication would be possible even between distant galaxies.

Assuming that Eshleman's results hold under a wide variety of conditions, it is possible to calculate the amplification factors and minimum distances for different objects that might be used for this purpose. This has been done in the table. From the table we see that the moon is no help at all, and the planets could provide useful amplification but require huge distances (not to mention the fact that their relatively rapid orbital motion would make them almost useless from that far out). The Sun looks hopeful, and black holes even more so, for example, a classical black hole of 3 solar masses. (See next item on black holes.)

Object	**Amplification factor at 300 gigahertz**	**Minimum focal distance**
Moon	1/2	Halfway to nearest star
Earth	300	500 times Pluto orbit
Jupiter	100,000	150 times Pluto orbit
Sun	10,000,000	15 times Pluto orbit
Smallest classical black hole	30,000,000	5 kilometers
Black hole (Earth mass)	300	Less than 1 kilometer
Black hole (Jupiter mass)	100,000	Less than 1 kilometer

The amplification and focal length of various objects used as gravitational lenses.

It would appear that a primordial black hole the mass of a planet like Earth or Jupiter would be ideal, since it would provide useful amplification of 300 to 100,000, but have a shorter, and hence, more convenient focal distance, than the Earth or Jupiter would. If one could be found and brought carefully into the solar system, we could surround it with a spherical swarm of orbiting receivers, and listen to hundreds or thousands of stars all at once.

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The Two Kinds of Black Holes

Black holes are available in all colors—all of which are black, or so it would seem. Actually, all black holes are really the same but they can be born in two different ways, so we can say that there are two different kinds. This distinction has been lucidly explained by William Kaufmann in the January-February, 1980, issue of *Mercury*.

"Classical" black holes are the kind we most often hear about. They are created when stars that are at least three times as massive as the Sun collapse in on themselves in their final dying moments. The oldest classical black hole is significantly younger than the universe, since the first stars had not even formed, much less died, until the galaxies first condensed out of the big bang.

"Primordial" black holes were formed in the immediate aftermath of the big bang, as a result of the extreme temperatures and pressures that existed then. Thus, they are as old as the universe. Originally they came in all sizes, with small ones being more common than large ones. However, black holes are believed to evaporate at a rate inversely proportional to their size. The net result of this is that probably all the small primordial black holes (smaller than a small asteroid) have already evaporated. Only the bigger ones are left.

Of the two kinds, primordial black holes seem to be potentially the most useful to man, since they have all the extraordinary properties of all black holes, yet are small enough to be moved where they are needed. Examples of their use would be as an energy source and garbage dump (see the ABC's of Space in the Spring 1980 issue of **COSMIC SEARCH**), and as a gravitational lens (see preceding item).

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Metalaw: How to Get Along with an Alien

Sooner or later we may be faced with the problem of dealing with intelligent extraterrestrial beings. In doing so, we will want to choose our actions with utmost care to avoid misunderstandings. Assuming that the "shoot first and ask questions later" segment of our society can be kept under control, most people would probably try some version of the Golden Rule, "Do unto others as you would have them do unto you". One must be careful in applying this rule too literally, however, since the results might be disastrous. Giving oxygen or water to another life form might be lethal to them. Waving or extending a helpful hand might be interpreted as an insult or threat. Clearly the Golden Rule needs some clarification and generalization in this case.

Significant thought has been given to this problem in recent years, and it has been reviewed recently by G. Harry Stine in the February, 1980, issue of *Analog*. Stine has distilled the suggestions of several earlier authors into **"The Principles of Metalaw"**. They are sumarized as follows:

> I. Modified Golden Rule
> Do unto others as they would have you do unto them.
>
> II. Free Choice
> An intelligent being has the right to free choice of living style, living location and cultural system, so long as this freedom is exercised consistently with the other principles of Metalaw.
>
> III. Free Movement
> An intelligent being may move about at will provided he does not breach the Zone of Sensitivity of another intelligent being without permission of that being to do so. (The Zone of Sensitivity varies with the situation. For individual Earthing encounters, it is typically a distance of a meter or so. In other terrestrial cases it is often one's house or property. For a civilization, it might be its planet.)
>
> IV. Survival
> An intelligent being may not cause, or, through inaction, allow the destruction of another intelligent being.
>
> V. Self Defense
> An intelligent being may suspend adherence to the above Principles if necessary to defend its existence or its rights as stated above.

It is very difficult to create a set of Metalaw Principles that is even completely self-consistent, much less universally applicable. Some of the Ten Commandments appear useful in a more general sense (e.g. "Thou shalt not kill") or on the other hand, some may be less so (e.g. "Thou shalt not commit adultery"). Our first encounter will probably reveal how inadequate Metalaw is, but, nevertheless, it is important to consider such things before the fact, rather than after.

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An After-the-Fact SETI Program

It is not unusual in astronomy for observations made for one purpose to later become valuable for other purposes. For example, if a star turned into a nova or supernova and became very bright, old photographs of the region containing the star could be examined to find out about the star's past history. Many optical observatories and at least one radio observatory maintain permanent archives of all their observations for this reason.

Recently, Nathaniel Cohen of Cornell University and Matthew Malkan of the California Institute of Technology used this approach and re-examined some radio astronomical observations of globular star clusters made by themselves and others to see if they contained any signals that might have been transmitted by other civilizations.* (* National Astronomy and Ionosphere Center Report No. 111, March, 1979.) The original observations were made to search for long-period variable stars, many of which act as natural stellar masers, emitting narrowband radio radiation at the water line (1.35 centimeter wavelength) and the hydroxyl OH line (18 centimeter wavelength). Since globular clusters are known to contain long-period variable stars, they are a logical choice to search for stellar masers. Globular clusters are large spherical condensations of stars, whose stellar density varies from normal star spacings on the outside to very crowded near the center. Each globular cluster contains about 50,000 stars, and there are about 100 globular clusters in our galaxy.

Since the equipment used to search for natural narrowband radio radiation is nearly the same as would be used to search for intelligent radio radiation, the observations of Cohen and Malkan are particularly appropriate for re-examination with SETI in mind. In addition, globular clusters are not unreasonable places to look for advanced civilizations since their stars are very old (giving plenty of time for evolution and development) and not too far apart (making it easier for neighboring civilizations to discover each other and then realize that there are probably others (like us) out there somewhere). The frequencies searched were those of the water line and OH line, both of which have been suggested as possible frequencies for beacon transmitters.

A total of 25 globular clusters were observed in the data re-examined by Cohen and Malkan. The observations had been made with a variety of equipment at the Haystack Observatory in Massachussetts, at the Arecibo Observatory in Puerto Rico, and at the Parkes Observatory in Australia. Since globular clusters are closely packed, the observations encompassed about 10 million stars. No signals, either natural or artificial, were detected. This enabled Cohen and Malkan to conclude that these wavelengths are not being used for radio transmission by any civilizations of Kardashev Type II or more advanced that might live in the clusters. (Such civilizations would have at least the entire energy of their star available to them). For a few of the clusters, they can conclude that the OH line is not being used for transmission even by any Type I civilization in the cluster. Such civilizations have energy available equivalent to all the sun's radiant energy that falls on the Earth.

Cohen and Malken urge that other astronomical observations made in search of natural narrowband radio signals always be analyzed with the additional possibility of detecting intelligent signals in mind.

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A New Chain of Life Discovered

Robert D. Ballard and J. Frederick Grassle of Woods Hole Oceanographic Institute recently discovered a living oasis on the floor of the Galapagos Rift in the South Pacific which they called "all but unbelievable." These oases were found along what geologists call spreading centers (places where the rigid plates that form the hard crust of our planet are pulling apart at a rate of a few centimeters per year.)

Writing in the November, 1979, issue of the *National Geographic,* Ballard and Grassle described a process in which sea water seeps through porous rocks on the ocean floor to unknown depths and then percolates up through warm-water vents, saturated with minerals. By oxidizing solutions of hydrogen sulfide, carbon dioxide and other substances, bacteria multiply in the areas immediately surrounding these warm-water crevices. The bacteria, in turn, become the primary food source for clams, worms, mussels and crabs which also surround these vents. Ballard and Grassle estimate that the concentration of suspended food available at these deep-water cracks is 300 to 500 times greater than just outside vent areas and four times greater than in productive surface waters.

The discovery of an ecosystem based entirely on chemical synthesis overturns the conventional idea that sunlight is always the main source of energy for life, according to the authors. Since oases such as those discovered in the Galapagos Rift are expected to exist all along the Mid-Oceanic Ridge, a totally new, but quite substantial chain of life has been found. The discovery of these oases also illustrates clearly the great adaptability and versatility of life forms. A possible broad implication of this discovery is that extraterrestrial life could exist wherever there is a nearby source of energy of *any* kind (not just stellar). Such places might include the moons of Jupiter and Saturn, that are heated by tidal forces, and the neighborhoods of black holes.

Contributed by David Raub

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Computers vs. the Human Brain

The technology explosion has caused computers to increase rapidly in power, while decreasing in size and cost. A report in the March 1980 issue of *High Technology* summarizes this change and compares it to the computing power of the human brain. As can be seen in the table, the computer has already surpassed the brain in terms of speed and total computing power, and will soon do so in energy efficiency. However, it will apparently be a long time before the brain is equalled in terms of its complexity and compactness.

The implication here is that computers will become ever more important *adjuncts* to the human brain, taking over more and more of the purely computational functions. But there is no indication that the computer will in the forseeable future be able to *replace* the brain in other areas, such as judgement, intuition, and creativity.

Computer Power in Terms of Brain Power

	Year 1956	1980	1990
Speed (switches per second)	10,000	10^6	10^7
Complexity (total number of switches)	10^{-5}	10^{-5}	10^{-5}
Total Computing Power (number of switches per second)	1/10	10	100
Energy Efficiency (number of switches per joule)	10^{-4}	1/30	10,000
Switch Density (switches per cubic centimeter)	10^{-8}	10^{-6}	1/100
Memory Density (bits per cubic centimeter)	10^{-15}	10^{-13}	10^{-10}

The brain has a value of 1 for all the characteristics listed. If the computer value for a characteristic is greater than 1 then it is more "powerful, in a general sense, than the brain, and if less than 1 less powerful. For example, the top entry in column 2 (1980) is 10^6 meaning that the computer is now a million times faster than the brain but the 10^{-6} in the same column for the next to last entry means that the computer now has only one millionth the switch density (or requires one million times the volume for the same number of switches .)

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Interstellar Bibliography Moved

For a number of years a comprehensive bibliography of books, magazine articles and other published material related to interstellar communications and travel has been prepared and updated by Dr. Robert Forward of the Hughes Aircraft Co. and several of his colleagues. The bibliography and its updates have been published periodically in the *Journal of the British Interplanetary Society*, with the next update scheduled to appear in the June, 1980, issue.

Recently Dr. Forward and his colleagues announced that after the June update, they would no longer be able to continue their bibliography project. However, arrangements have been made to move the project to The Ohio State University Radio Observatory where it will be continued by David Raub and Robert Dixon. Congratulations are due Forward and his colleagues for initiating and carrying out this project for as long as they have.

Everyone is encouraged to send in lists of additions or corrections to help keep the bibliography as useful as possible. They should be sent to: Robert Dixon, The Ohio State University Radio Observatory, 2015 Neil Ave., Columbus, Ohio 43210.

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Using the Moon to Look for the Planets of Distant Stars

Present-day large optical telescopes are in principle sufficiently powerful to directly observe the planets of other stars. However, they are prevented from doing so because they are blinded by the glare of the parent stars. It's a little like trying to see a firefly sitting on the edge of a searchlight many miles away. If the searchlight were turned off, a big telescope could probably see the firefly. But if the searchlight is on, its light swamps out that of the firefly. One way of seeing the firefly even when the searchlight is on might be to position the telescope so that some large dark object like a building is between it and the searchlight. Then the telescope could be carefully shifted so that the edge of the building just barely covers up the searchlight, but not the firefly. This requires very precise alignment, and is never perfect because some of the light from the searchlight leaks (diffracts) around the corner of the building anyway. Nevertheless, it's a lot better than looking straight into the searchlight.

This same idea has been proposed by James L. Elliot of Cornell University as a means of finding the planets of distant stars.* (* **ICARUS**, volume 35, p. 156. 1978) He suggests that a dark edge of the Moon be used to cover up (occult) the parent stars, and calculates that planets the size of Jupiter could be detected out to about 30 light years distance with this technique. There are 37 suitable stars within this range. The telescope would have to be located in space, for two reasons. First, to avoid the scattering of light in the Earth's atmosphere that tends to smear out the image seen by telescopes, and second, to enable all the desired stars to be seen, since some stars are never occulted by the Moon as seen from the Earth. A dark edge (not illuminated by the Sun or sunshine reflected from Earth) of the Moon must be used, and the alignment is sufficiently critical that allowance must be made for the individual mountains and valleys on that edge of the Moon.

The telescope has to be in orbit so as to make stable observations, and the orbit must be carefully chosen so that the telescope, Moon and desired star system remain in alignment as long as possible. Elliot has calculated that to do this the telescope must orbit the Earth at a distance varying from 1 1/2 to 2 times the distance of the Moon, with the plane of its orbit tilted relative to the Moon's orbit at a different angle for each different star to be observed. This means that if we could see the telescope from Earth, it would appear to pass either above or below the Moon about once per month. With this orbit, a star can be observed continuously for about two hours with good alignment. The telescope must be positioned to within plus or minus 100 meters, a difficult navigational problem.

The NASA Space Telescope, having a 2.5 meter diameter, is large enough to carry out this project, but it will not be placed in the necessary orbit. It will be in a low Earth orbit, where suitable alignment could only be maintained for 9 seconds. Nevertheless, this would be sufficient to test the validity of the method, and pave the way for a possible future space telescope in the required orbit.

Elliot also points out that his technique could be used to study the planets in our own solar system. The diameters of all the planets, satellites and asteroids could be measured very accurately, and the atmospheres of all the planets could be studied in detail.

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Earth Life Pushed Back Another 400 Million Years

A rock was found recently in Western Australia by Malcolm Walter of the Australian Bureau of Mineral Resources, that has pushed back the date of the earliest known life on Earth by 400 million years.* (* **Reuters**, April 2, 1980.) The half meter diameter rock was chemically analyzed and its age established as 3.5 billion years, also a microscopic search revealed the presence of tiny life forms similar to bacteria. Previously the oldest known life forms were 3.1 billion years old.

Walter believes it is unlikely that any life-containing rock older than 3.5 billion years will ever be found, although others of about that same age may yet be found in Australia or South Africa. An even older rock (3.8 billion years) found in Greenland has also been analyzed and found to contain no life forms. If these two ancient rocks from Australia and Greenland are representative of life on Earth, then life must have arisen sometime between 3.8 and 3.5 billion years ago.

HOME

Designed by Jerry Ehman.
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