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Concerning the historical background of pulsed, broadband, targeted-beam beacons for interstellar communication

Dear Professor Cady,

I am writing in regard to the two papers published in the June issue of *Astrobiology* authored by G. Benford, J. Benford, and D. Benford entitled "Searching for cost optimized interstellar beacons" and "Messaging with cost optimized interstellar beacons."(1, 2) Both discuss the advantages of using pulsed, broadband, targeted beacons for extraterrestrial communication as opposed to the discrete frequency continuous-broadcast-type signals traditionally searched for in ongoing SETI programs. I found both papers interesting to read. However, I wanted to bring to the reader's attention that the concept of pulsed, broadband, directed-beam, ETI communication which their papers discuss is not new. I had first proposed this concept at the spring 2000 American Astronomical Society meeting.(3) A video of this oral presentation has been available as a DVD since 2001.(4) Also I had described this broadband, directed-beam concept in considerable detail in my book, *The Talk of the Galaxy*, published in 2000, which was reprinted in 2006 as an updated second edition with the title, *Decoding the Message of the Pulsars*.(5,6) These ideas were referenced and further discussed in a paper by G. Zeitlin published in a 2002 issue of the journal *New Frontiers in Science*.(7)

For someone doing research on the subject of interstellar communicator beams, information about my work is not hard to find. A google search of the keywords "ETI, beam, beacon" turns up many links that discuss my work. Also the keywords "ETI, communicator, beam" or "broadband, ETI, communicator, beam" turn up a Google Books link that allows a person a free preview of three chapters and Appendix B of my book which discuss in considerable detail the concept of pulsed, broadband, targeted beam beacons. These illustrate and discuss one method in which we might construct such a beacon and also explore an alternate method in which an alien civilization having interstellar flight capability might generate such a communication beam by manipulating the cosmic ray electron flux emitted by a natural stellar source. In addition, the Amazon.com listing for my book has a "Look Inside" feature which allows a partial preview of chapter 1 and Appendix B, all of which discuss the idea of directed beam beacons for interstellar communication. Over the past ten years, stories about my work on pulsed directed-beam ETI communication have appeared in several lay magazines, have been discussed in various websites,(8) and presented at numerous conferences and radio talk shows.

In my book I propose the idea that radio pulsars may actually be artificially engineered beacons that project pulsed stationary beams for interstellar communication and navigation. In particular, I discuss a subset of the pulsar population which exhibit a combination of various attention-getting features such as giant pulses, optical pulses, pulse glitching, unusual brightness or luminosity, or unusual orbital features. I found that the sky positions of this pulsar subset, or in some cases the relative lengths of their pulse periods, portray certain geometrical relations such as pi, the phi ratio, the location of the Galactic center (GC) using the geometric one-radian concept, the location and orientation of the Earth's ecliptic plane, and the locations of the two young supernova remnants that happen to be situated closest to our solar system, i.e., the Crab and Vela remnants. Furthermore, I had uncovered what I believe is an intelligible message being broadcast specifically to us which appears to be notifying us about an energetic outburst from the Galactic core and consequent cosmic ray volley that moved radially outward at a relativistic speed and passed our solar system around 14,000 years ago. Admittedly, the past occurrence of such a "galactic superwave" would be a logical topic for interstellar communication since this is something that would have affected all civilizations in the Galaxy.

I had suggested that these apparent intelligent pulsar arrangements may be interpreted in three possible ways. Either a) we may attribute them as being due to chance arrangements, which means we must be prepared to live with very large improbabilities, e.g., of the order of up to 1 chance in 10^{28}, b) we may presume that the universe as a whole is intelligent and is trying to communicate with us by psychokinetically organizing natural processes in such a way as to produce these nonrandom relationships, or c) we may infer that these pulsar signals have been engineered by civilizations of substantial technical advancement that have mastered the ability to navigate the Galaxy at superluminal speeds and have developed the ability to engineer the high-energy particle emissions from stars so as to generate the observed pulsed signals. More than anything, it was the deciphering of an intelligible Galactic core explosion "message" that swayed me to consider this third alternative. It is not the purpose of this letter to engage in any debate over the authenticity of this message. I only wish to mention here that considering its potential importance, I decided in 1979 to investigate this core explosion hypothesis in a critical manner as the topic of my Ph.D. dissertation.(9, 10) The evidence I gathered, in my opinion, seems to suggest that the core explosion/superwave phenomenon does occur in our galaxy, as well as in others, and that one particular intense event originating from our own galactic core had passed through our solar system about 11,000 to 16,000 years ago. Since the time of that study, this hypothesis has had more than 12 a posteriori confirmations.(11)

I am aware that not everyone is prepared to admit the existence of extraterrestrial civilizations that have mastered interstellar space travel, which is why I had offered the first and second options for skeptics. Indeed there may be those who believe in the validity of the paradox that Fermi stated back in 1950 in regard to the lack of any evidence of alien visitation and that in the 60 years since that time no further such evidence has emerged. But it is not my intention here to engage in a debate about the existence or nonexistence of alien visitations or of civilizations possessing advanced space propulsion technology. The central issue here concerns that of idea priority on the concept of pulsed broadband, directed beam beacons for ETI communication. I bring this up partly because there had been a large number of news articles discussing the findings of the Benfords' *Astrobiology* papers and proclaiming these authors as being the first to come up with the idea of directed-beam communication, even referring to these communicators as "Benford beacons." As noted below, there are differences between the directed-beam technology they have proposed and those that I had earlier proposed. But, if one considers the general concept of broadband interstellar beam communication, to my knowledge I was the first to elaborate this idea as distinguished from the conventional SETI idea of isotropic discrete frequency signal broadcast. The current misrepresentation of the historical facts came about partly because the Benford papers omitted reference to my prior work, and partly because the media were not adequately informed of the historical context of the idea.

The method that the Benfords have proposed for creating their directed beam involves using an array of microwave antennas fed by high-power gyrotrons and networked to operate as a phased array so as to emit a pulsed microwave beam in a particular direction. In one of their examples, they consider a 5.1 km diameter antenna array consisting of 3000 gyrotrons, each capable of emitting a few megawatts of power. They figure a total power of 6.9 GW and antenna gain of $\sim 10^9$ to produce an effective isotropic radiated power (EIRP) of 10^{19} watts.

This is emitted as a beam having an angular width of about 10^{-4} radians which is able to communicate over a distance of ~6000 light years. They propose transmitting at a frequency of ~1 GHz and estimate a bandwidth of about 1 megahertz for the oscillator power levels they consider, this frequency spread being determined by the physics of microwave oscillation in gyrotron cavities.

I proposed a substantially different method for producing a targeted communication beam, namely a particle beam device that operates much like a free-electron laser. In this design, a linear particle accelerator produces a continuous beam of ultra relativistic electrons which, in turn, are directed into a wiggle field modulator consisting of transverse magnetic fields generated by a series of superconducting magnets.[5, 6] These wiggle fields cause the electrons to emit a beam of synchrotron radiation. Due to the relativistic beaming effect, this emitted radiation would be confined to a forward-directed conical beam having an aperture of $2/\gamma$ radians and a luminosity that would scale as $8\gamma^3$, where γ is the Lorentz factor of the cosmic ray electrons. By varying the power to the wiggler fields, the communication beam intensity may be modulated in periodic fashion to produce highly precise, attention-getting pulses.

I had considered the case of a communicator beam transmitting radiation having a median frequency of f = 400 MHz and bandwidth of Δf = 400 MHz that could produce a 0.8 Jansky signal at a distance of 6000 light years, hence one that would produce a signal strength equal to that coming from the Crab pulsar. The calculations given in Appendix B of my book indicate that this would require a particle accelerator capable of producing a 1 megawatt beam of 50 Gev electrons having a Lorentz factor of $\gamma = 2 \times 10^5$. The beam width calculates to be a ~10^{-5} radians, which produces a beam diameter of about 4000 AU at a distance of 6000 light years. Choice of a lower γ for the particle beam increases the beam angular aperture and reduces the Doppler boosting of the synchrotron emission so that an increased relativistic particle energy flux would be needed to maintain an equivalent target signal intensity.

I had conservatively estimated an efficiency of 1% for converting electric power to relativistic electron power and in turn into synchrotron beam power. Hence I estimated that the communicator would require an input power of 100 MW to operate. ~~This is~~ So it would use about 70 times less power than what the Benfords estimate for their phased array communicator and would produce a beam having a 50 fold lower EIRP. ~~But since the radiation beam is confined within a 10 times smaller conical aperture, in terms of watts per steradian, it delivers a signal at the target location of an intensity comparable to what the Benfords' beam produces. The synchrotron beam example would amount to an EIRP of 10^{18} watts, which is about an order of magnitude less than that of the Benfords' gyrotron communicator beam.~~ I did not estimate a cost for constructing the proposed particle beam communicator, but I believe it would not be much more than \$5 B, the cost of constructing the Large Hadron Collider. One must consider that the cost of accelerator technology has progressively dropped over the years with the advent of beat wave and wake field accelerators used in producing free electron lasers. So I expect the construction cost would be substantially less than the \$41 billion that the Benfords estimate for their 6000 light-year pulsed beam communicator.

The Benfords refer to their phased array communicator as *broadband*, as distinguished from the prior notion of discrete frequency communication. I also had used the term broadband to refer to the particle beam communicators I was proposing. However, since such beacons would produce a much broader frequency spread than those that the Benfords have proposed ($\Delta f > 100$ MHz as compared with $\Delta f \sim 1$ MHz), they might be more appropriately termed *ultra-broadband*. It is generally agreed that a beacon that spans a greater bandwith is desirable from the standpoint of ETI communication since this increases the chance of the beacon being detected by a target civilization.

The other method I had proposed for creating a targeted beam for interstellar communication is beyond our current capabilities since it presupposes the development of interstellar space travel and the ability to travel close to a stellar cosmic ray source such as a neutron star or X-ray star. I had proposed that an alien civilization could position a maser phase conjugate resonator near such a stellar cosmic ray source and use it to project normal and phase conjugate maser beams to (and from) an ionized region near the star's surface. By the proper choice of frequencies, it would be possible to create a field grating pattern in the ionized region which would act as wiggler fields that would locally decelerate the outgoing relativistic electron flux and produce an outward directed synchrotron beam. By manipulating this projected field pattern, a rather complex outgoing pulsed communication signal may be created similar to the signals we observe coming from pulsars. Such microwave phase conjugate resonator technology has been developed mainly for military use.(5, 6, 12) In some respects, this concept resembles that employed in the HARRP project which attempts to create a field grating region in Earth's ionosphere for influencing EM wave transmission.

This method, which utilizes a much greater spectrum of relativistic particle energies than those produced in a particle accelerator, would necessarily produce a very broadband synchrotron beam spanning many decades of the radio frequency spectrum and in some cases could extend up to optical X-ray, and gamma ray wavelengths. Compared to the more "low-tech" earth-based particle accelerator communication beam technology, this star-engineering beam technology would have a much lower energy demand. An initial investment of energy would be needed to power up the maser phase conjugate resonator to create the projected field grating pattern. But once the phase-conjugate beam was activated, no additional energy would be needed to operate the system since the soliton beam would be able to entrain energy from the impinging stellar core cosmic ray flux. That is, energy from the outgoing cosmic rays would transfer to the maser soliton beam within the grating wiggler field interface thereby allowing the maser beam to be essentially self-powered. Also it is characteristic of phase conjugate resonators that they have relatively low energy losses.

Unlike the Benfords' suggestion that pulsed beams might be retargeted to a series of different directions in a repeating cycle, the beams that I describe would remain on their targets continuously. I suggest that from a given stellar core an advanced civilization could be generating a large number of stationary, synchrotron beams that they continuously target to a variety of galactic locations. We would only be aware of the existence of those beams being targeted directly towards us. In my opinion, pulsar signals are our detection of beams being targeted toward our Galactic neighborhood. In this regard, I have come to abandon the conventional lighthouse model since it fails to account for the varied characteristics of a given pulsar in a consistent manner.(5, 6)

One other point I would like to bring up concerns the Benfords' discussion of the transient pulsed radio source GCRT J17445-3009 as being a possible ETI beacon candidate.(2) In my book I had also called attention to this source, suggesting that it might be an ETI beacon.(6) I considered it a candidate for several reasons. First, it was unusually bright. At 1500 milliJanskys, it was the second brightest pulsed radio source in the sky, when observed in 2003. Second, as a transient source, it was very unusual since no other transient radio source has been observed to produce pulses with such regularity. A third feature that prompted me to single it out, was its proximity to the Galactic center, something that the Benfords also comment on in their paper. The source lies just 1.1° southwest of the GC and at about the same distance. Prior to the discovery of this source in 2002, I had proposed that certain pulsars were conveying a message that made careful reference to the Galactic center. These included the Millisecond Pulsar that was pointing out the location of the GC using the one radian geometrical concept, the Eclipsing Binary Millisecond Pulsar which is positioned close by and also calls attention to this one-radian marker point, and the Vela and Crab pulsars which appear to make reference to a cosmic ray volley that originated from the core of our Galaxy and passed the Earth around 14,000 years ago. So the discovery of an unusual radio source this close to the GC definitely peaked my interest and prompted me to consider it as being of artificial origin, possibly one additional warning marker purposely set up to call attention to the pulsar superwave message. Since then a few pulsars have been located which have sky positions closer to the GC. But no unusual characteristics have been reported that would make them stand out like this particular transient radio source.

The Benfords do not take a position on whether or not pulsars might be artifactual. Their proposal is far less paradigm shifting. They simply argue that, compared with the current concept of sending narrow frequency, nonfocused transmissions, it is more cost effective and energy efficient for a civilization to send pulsed, broadband signals via targeted beams. Nevertheless their conclusions are generally supportive of the pulsed broadband beam method I have suggested is currently being used by Galactic civilizations to communicate with us. I feel that their papers have made an important contribution by capturing the imagination of the public and spreading the idea that pulsed, broadband, targeted beam communication may be the more rational method of interstellar communication. Nevertheless, I believe that more has to be done to investigate the possible ETI origin of pulsars and the message they may be conveying.

Sincerely,

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