We could detect alien civilizations through their interstellar quantum communication

April 29 2021, by Matt Williams

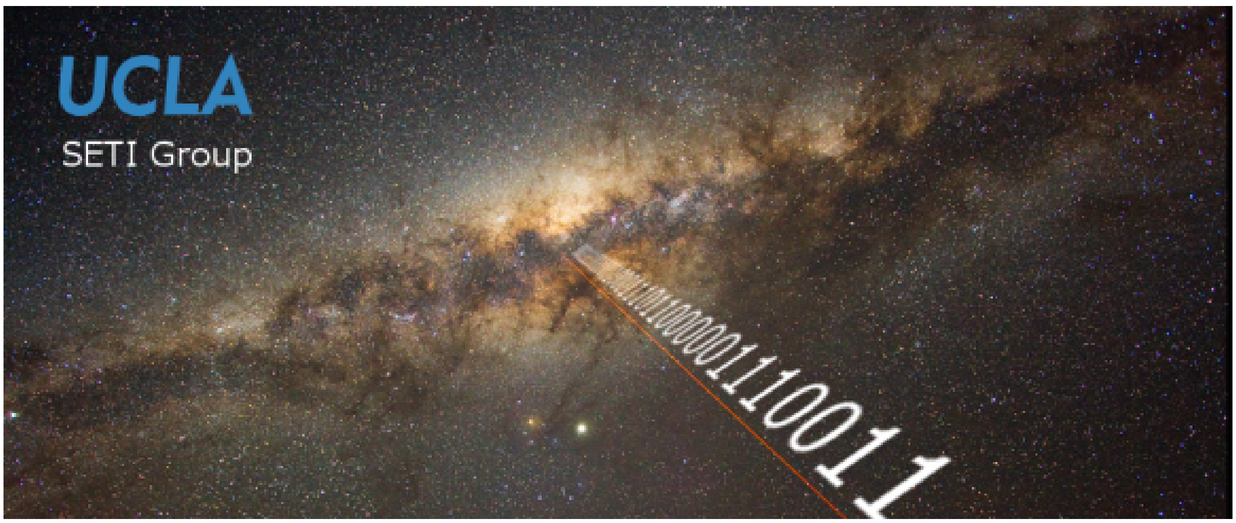


Photo of the central region of the Milky Way. Credit: UCLA SETI Group/Yuri Beletsky, Carnegie Las Campanas Observatory

Since the mid-20th century, scientists have been looking for evidence of intelligent life beyond our solar system. For much of that time, scientists who are engaged in the search for extraterrestrial intelligence (SETI) have relied on radio astronomy surveys to search for signs of technological activity (aka "technosignatures"). With 4,375 exoplanets confirmed (and counting!) even greater efforts are expected to happen in the near future.

In anticipation of these efforts, researchers have been considering other possible technosignatures that we should be on the lookout for. According to Michael Hippke, a visiting scholar at the UC Berkeley SETI Research Center, the search should also be expanded to include quantum communication. In an age where quantum computing and related technologies are nearing fruition, it makes sense to look for signs of them elsewhere.

The search for technosignatures, and what constitutes the most promising ones, has been the subject of renewed interest in recent years. This is due in large part to the fact that thousands of exoplanets are available for follow-up studies using the next-generation telescopes that will be operational in the coming years. With these instruments searching for needles in the "cosmic haystack," astrobiologists need to have a clear of what to look for.

In September of 2018, NASA hosted a Technosignatures Workshop, which was followed by the release of their Technosignature Report. By August of 2020, NASA and the Blue Marble Institute sponsored another meeting—Technoclimes 2020—to discuss concepts for future searches that would look for technosignatures beyond the usual radio signals. As someone who has dedicated his professional life to SETI, Hippke has many insights to offer.

The Search Thus Far

As he noted in his study, modern SETI efforts began in 1959 when famed SETI pioneer Giuseppe Cocconi & physicist Philip Morrison (both of Cornell University at the time) published their seminal paper, "Searching for Interstellar Communications." In this paper, Coccini and Morrison recommended searching for signs of intelligent life by looking for narrow-band signals in the radio spectrum.

This was followed two years later by R.N. Schwartz and C.H. Townes of the Institute of Defense Analyses (IDA) in Washington D.C. In their paper, "Interstellar and Interplanetary Communication by Optical Masers," they proposed that optical pulses from microwave lasers could be an indication of extraterrestrial intelligence (ETI) sending messages out into the cosmos.

But as Hippke notes, six decades and more than one hundred dedicated search programs later, surveys that have looked for these particular technosignatures have yielded nothing concrete. This is not to say that the scientists have been looking for the wrong signatures so far, but that it could be useful to consider casting a wider net. As Hippke explained in his paper:

"We are looking (and should keep looking) for narrow-band lighthouse blasts, even though we have found none yet. At the same time, it is possible to expand our search… It is sometimes argued in the hallways of astronomy departments that we 'just have to tune into the right band' and—voilà—will be connected to the galactic communication channel."

A Quantum Revolution

While virtually all attempts to create quantum processors are relatively recent (occurring since the turn of the century), the concept itself dates back to the early 1970s. It was at this time that Stephen Weisner, a of professor physics at Columbia University at the time, proposed that information could be securely coded by taking advantage of the principle of superposition.

This principle states the "spin" of an electron, a fundamental property that can be oriented "up" or "down," is indeterminate—meaning that it can be either one or both simultaneously. So while an up or down spin is similar to the zeroes and ones of binary code, the superposition principle means that quantum computers can perform an exponentially greater number of calculations at any given time.

Beyond the ability to perform more functions, Hippke identifies four possible reasons why an ETI would opt for quantum communications. These include "gate-keeping," quantum supremacy, information security, and information efficiency. "They are preferred over classical communications with regards to security and information efficiency, and they would have escaped detection in all previous searches," he writes."

The use of computers has evolved considerably over the past century, from isolated machines to the worldwide web, and possibly to an interplanetary network in the future. Looking to the future, Hippke argues that is not farfetched to believe that humanity may come to rely on an interstellar quantum network that enables distributed quantum computing and the transmission of qubits over long distances.

Based on the assumption that humanity is not an outlier, but representative of the norm (aka. the Copernican Principle) it is logical to assume that an advanced ETI would have created such a network already. Based on humanity's research into quantum communications, Hippke four possible methods. The first is "polarization encoding," which relies on the horizontal and vertical polarization of light to represent data.

The second method involves the "Fock state" of photons, where a signal is encoded by alternating between a discreet number of particles and vacuum (similar to binary code). The two remaining options involve either time-bin encoding—where early and late arrival is used—or coherent state of light encoding, where light is amplitude-squeezed or phase-squeezed to simulate a binary code.

Security and Supremacy

Of the many benefits that quantum communications would present for a technologically advanced species, Gate-Keeping is especially interesting because of the implications it could have for SETI. After all, the disparity between what we assume is the statistical likelihood of intelligent life in our Universe and the lack of evidence for it (aka. the Fermi Paradox) cries out for explanations. As Hippke puts it:

"ETI may deliberately choose to make communications invisible for less advanced civilizations. Perhaps most or all advanced civilization feel the need to keep the "monkeys" out of the galactic channel, and let members only participate above a certain technological minimum. Mastering quantum communications may reflect this limit."

The idea of quantum communication was first argued by Mieczyslaw Subotowicz, a professor of astrophysics at the Maria Curie-Sklodowska University in Lublin (Poland), in 1979. In a paper titled "Interstellar communication by neutrino beams," Subotowicz argued that the difficulties this method presented would be a selling point to a sufficiently advanced extraterrestrial civilization (ETC).

By opting for a means of communication that has such a small cross-section, an ETC would only be able to communicate with similarly advanced species. However, Hippke noted, this also makes it virtually impossible to detect entangled pairs of neutrinos. For this reason, entangled photons would not only provide for gate-keeping, but they would also be detectable by those meant to receive them.

Similarly, quantum communication is also preferable because of the security it allows for, which is one of the main reasons the technology is being developed here on Earth. Quantum key distribution (QKD) enables two parties to produce a shared key that can be used to encrypt and decrypt secret messages. In theory, this will lead to a new era where encrypted communications and databases are immune to conventional cyber attacks.

In addition, QKD has the unique advantage of letting the two parties detect a potential third party attempting to intercept their messages. Based on quantum mechanics, any attempt to measure a quantum system will collapse the wave function of any entangled particles. This will produce detectable anomalies in the system, which would immediately send up red flags. Said Hippke:

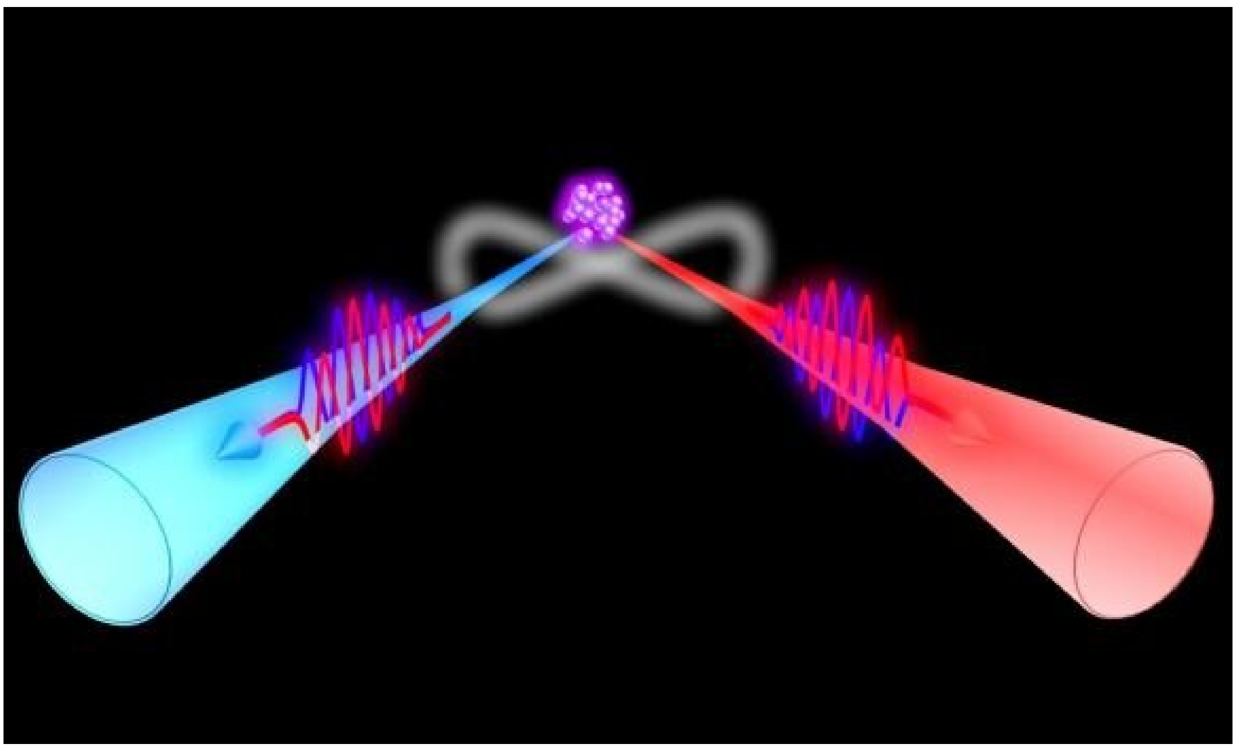
"We do not know whether ETI values secure interstellar communication, but it is certainly a beneficial tool for expansive civilizations which consist of actions, like humanity today. Therefore, it is plausible that future humans (or ETI) have a desire to implement a secure interstellar network."

Another major advantage to quantum computing is its ability to solve problems exponentially faster than its digital counterparts—what is known as "quantum supremacy." The classic example is Shor's algorithm, a polynomial-time quantum algorithm for factoring integers that a conventional computer would take years to solve, but a quantum computer could crack in mere seconds.

In traditional computing, public-key encryption (such as the RSA-2048 encryption) employs mathematical functions that are very difficult and time-consuming to compute. Given that they can accommodate an exponentially greater number of functions, it is estimated that a quantum computer could crack the same encryption in about ten seconds.

Last, but not least, there's the greater photon information efficiency (PIE) that quantum communications offer over classical channels—measured in bits per photon. According to Hippke, quantum communications will improve the bits per photon efficiency rating by up to one-third. In this regard, the desire for more efficient data transmissions will make the adoption of a quantum network something of an inevitability.

"Turned the other way around, classical channels are energetically wasteful, because they do not use all information encoding options per photon," he writes. "A quantum advantage of order 1/3 does not seem like much, but why waste it? It is logical to assume that ETI prefers to transmit more information rather than less, per unit energy."



Quantum entanglement visualized. Credit: Physics Department, HKUST

Challenges

Of course, no SETI-related pitch would be complete without mentioning the possible challenges. For starters, there's the matter of decoherence, where energy (and hence, information) is lost to the background environment. Where transmissions through interstellar space are concerned, the main issues are distance, free electrons (solar wind), interplanetary dust, and the interstellar medium—low-density clouds of dust and gas.

"As a baseline, the largest distance over which successful optical entanglement experiments have been performed on Earth is 144 km," notes Hippke. Since the mass density of the Earth's atmosphere is 1.2 kg m^{-3}, this means that a signal passing through a column 144 km (~90 mi) in length was dealing with a column density of 1.728×10^5 kg m^{-2}. In contrast, the column density between Earth and the nearest star (Proxima Centauri) is eight orders of magnitude lower (3×10^{-8} kg m^{-2}).

Another issue is the delay imposed by a relativistic Universe, which means that messages to even the closest star systems would take years. As a result, quantum computation is something that will be performed locally for the most part, and only condensed qubits will be transmitted between communication nodes. With this in mind, there are a few indications humanity could be on the lookout for in the coming years.

What to Look For?

Depending on the method used to transmit quantum information, certain signatures would result that SETI researchers could identify. At present, SETI facilities that conduct observations in the visible light spectrum are not equipped to receive quantum communications (since the technology does not exist yet). However, they are equipped to detect photons, obtain spectra, and perform polarization experiments.

As such, argues Hippke, they would be able to tease out potential signals from the background noise of space. This is similar to what Professor

Lubin suggested in a 2016 paper ("The Search for Directed Intelligence"), where he argued that optical signals (lasers) used for directed-energy propulsion or communications would result in occasional "spillover" that would be detectable.

In much the same way, "errant" photons could be collected by observatories and measured for signs of encoding using various techniques (including the ones identified in the study). One possible method Hippke recommends is long-duration interferometry, where multiple instruments monitor the amplitude and phase of electromagnetic fields in space over time and compare them to a baseline to discern the presence of encoding.

One thing bears consideration though: If by listening in on ETI quantum communications, won't that cause information to be lost? And if so, would the ETI in question not realize we were listening in? Assuming they were not aware of us before, they sure would be after all this went down! One might conclude that it would be better to not eavesdrop on the conversations of more advanced species!

More information: Michael Hippke. Searching for interstellar quantum communications. arxiv.org/abs/2104.06446
arXiv:2104.06446v1 [astro-ph.IM]

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