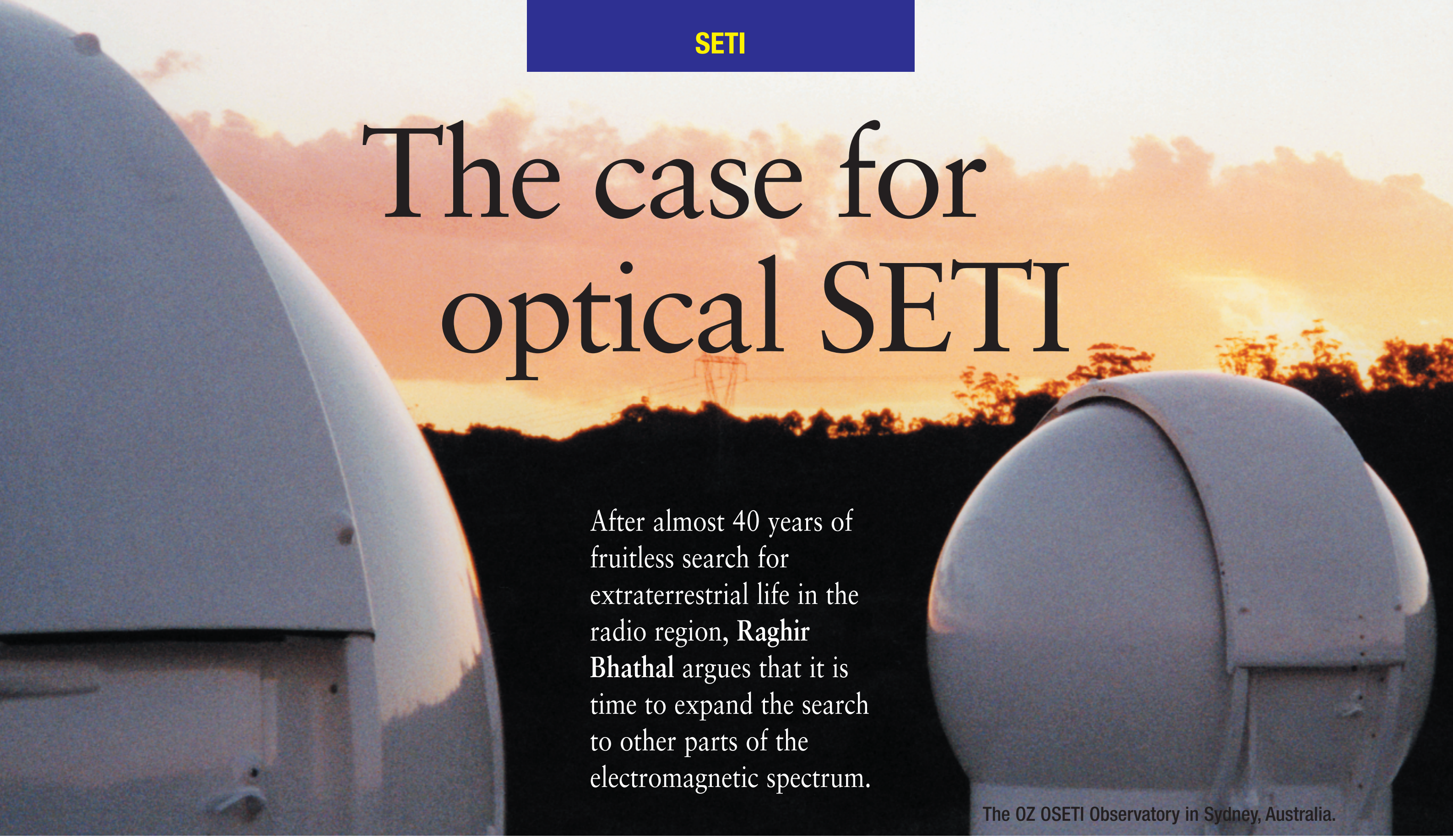
The case for optical SETI

After almost 40 years of fruitless search for extraterrestrial life in the radio region, **Raghir Bhathal** argues that it is time to expand the search to other parts of the electromagnetic spectrum.



The OZ OSETI Observatory in Sydney, Australia.

The search for extraterrestrial life has fascinated humankind for centuries. But it was only in the 1960s that the search was put on a scientific footing by a young astronomer Frank Drake, now president of the SETI Institute, the largest organization devoted to the search and promotion of life on other planets. Speculation and philosophy gave way to science. In an unprecedented and bold move in 1960, the young Drake turned the Green Bank radio telescope onto two nearby stars – Tau Ceti and Epsilon Eridani – to search for signals from extraterrestrial intelligence (ETI) (Drake 1961). Called Project Ozma, it searched for 150 hours but found no evidence of strong signals from these stars. By performing that experiment Drake initiated new fields of study in astronomy and the social sciences which are now slowly finding their way into mainstream academic studies and university courses (Bhathal 1999).

Seminal papers

Almost 40 years ago *Nature* published two seminal papers (Cocconi and Morrison 1959, Schwartz and Townes 1960) regarding the possibility of searching for signals from extraterrestrial intelligence. The papers advocated different search strategies, radio and optical. Since large radio telescopes were coming on line in the 1960s, Cocconi and Morrison advanced the view that the search for ETI could be carried out using radio telescopes in the region around the 21 cm (1420 MHz) line or what has come to be termed the "water hole" region. Their advocacy that "if we never search, the chances of success is zero" spawned a number of microwave searches around the world. Further advocacy of the water hole region by Bernard Oliver in the Cyclops project (Sagan and Drake 1975) set the scene for search strategies confined mainly to that region. But after almost 40 years of fruitless search, there is still no answer to Fermi's question: where are they?

This has prompted new thinking amongst SETI researchers who believe that the search strategy needs to be expanded to include other parts of the electromagnetic spectrum where there are clear windows for the passage of electromagnetic waves, such as the windows at 12 000–10 000 nm, 1100–1000 nm and 900–400 nm. In fact, the optical strategy is not new. In the second and now almost forgotten *Nature* paper, Schwartz and Townes argued that a search be made for interstellar laser signals. They suggested two laser systems which at that time had yet to be built. System A used a single continuous wave (CW) laser while System B used a group of 25 lasers in a star configuration with the same laser characteristics as System A. System A used a laser with a power level of 10 kW at a wavelength of 500 nm. The diameter of the reflector at the source was taken as 5 m (the maximum size of telescopes on Earth at that time).

A back-of-the-envelope calculation shows that the apparent magnitudes of the ETI star and ETI CW laser at a distance of ten light years from us would be about 2 and 21 (small astronomical magnitudes are brighter). The latter source could just be picked up by the 200 inch telescope at Mt Palomar Observatory. However, to ensure that the ETI laser signal could be picked up we need to increase the power of the laser by several orders of magnitude than that proposed by Schwartz and Townes. Their proposals were not taken up by the scientific community.

Renewed interest

Since Schwartz and Townes' paper, three developments have taken place. First, there has been a tremendous increase in radio frequency noise and in the coming years it is going to become exceedingly difficult to carry out the search in the microwave spectrum. Secondly, the discovery of a number of important microwave lines at various frequencies in interstellar clouds makes a choice of "magic frequencies" less obvious. Thirdly, the power of lasers has been rising exponentially from the milliwatt lasers of first-year university laboratories of the 1960s to lasers in the megawatt power range in the 1980s and 1990s. The development of high-power lasers has been motivated by the requirements of the military and interest in imploding pellets of hydrogen to produce nuclear fusion. Pulsed solid-state lasers have achieved terawatts, albeit for about a nanosecond. It is expected that the National Ignition Facility at the Lawrence Livermore National Laboratory will deliver 500 TW pulses lasting 3 to 5 ns when it begins operating in the next couple of years. These developments in high-power lasers give credence to the search for ETI signals in the optical spectrum. Incidentally, it will give Graham Bell's terrestrial photophone a new lease of life in 21st century interstellar communication with laser light.

The high directionality and tight beam makes lasers ideal devices for attention-getting beacons and for communication purposes. According to Ross (1965), information theory shows that at optical frequencies, narrow pulse, low duty-cycle systems can convey more information per received signal photon than radio waves.

In the 1980s, Townes (1983) made another appeal for searching for laser signals. It is normally assumed that searches for ETI should concentrate on attempts to receive signals in the microwave region. The reason for this is that communication there uses minimum broadcast power. Townes questioned this assumption. He said: "Such a conclusion is shown to result only under a restricted set of assumptions. If generalized types of detection are considered – in particular, photon detection rather than linear detection alone – and if advantage is taken of the directivity of telescopes at short wavelengths, then somewhat less power is required for communication at infrared wavelengths than in the microwave region." Furthermore, for distances less than 1000 light years, extinction and smearing of pulsed laser signals due to interstellar grains are not a serious problem (Cordes 1999).

Earliest proposals

Despite these developments and arguments for an optical SETI search there have been very few searches in the optical spectrum. Some of the earlier and more recent ones are reported below.

Some of the earliest proposals of using light beams were proposed by Karl Gauss and Charles Cross in the 19th century (Crowe 1986). In 1822 Gauss had proposed using "100 separate mirrors each of 16 square feet" to send a "good heliotrope-light to the Moon". He felt that if we could get in touch with our neighbours on the Moon, it would be a "discovery greater that that of America". Forty-seven years later Cross suggested that light could be focused by parabolic mirrors so as to be visible to inhabitants on Mars. Periodic flashes could be used for sending messages to them.

In the 1970s, Shvartsman (1977) conducted experiments to search for optical variability in peculiar objects with a 6 m telescope. Called the MANIA (Multichannel Analysis of Nanosecond Intensity Alterations) experiment the main aim was to study superfast variability of different objects using an extremely high resolution of about 10^{-7} s. The observations also included the search for extraterrestrial signals. They observed about 60 peculiar and Sun-like stars but did not find any ETI signals (Beskin 1997). Betz's (1986) analysis showed that for specified transmitter and receiver locations, communications at infrared and radio frequencies could be equally effective. On this basis he searched for extraterrestrial signals at infrared wavelengths. He searched for CO_2 laser signals from 200 nearby solar-type stars. Earlier, Demming and Mumma (1983) had suggested that CO_2 in the atmosphere of Mars exhibited laser behaviour which could be channelled into a powerful SETI beacon.

One of the most ardent advocates of the optical SETI search has been Stuart Kingsley who runs the Columbus Optical SETI Observatory in the USA. More than anyone else he has been plugging away to get more scientists both professional and amateur to be involved in the OSETI search. Conservative calculations carried out by Kingsley (1996) at a wavelength of 550 nm show that light from a pulsed ETI laser would outshine the ETI star by seven orders of magnitude. For a pulsed ETI laser beacon system with a 1 Hz repetition rate and a peak power of 10^{18} W he predicted that the magnitudes of the ETI laser and the ETI star at a distance of 10 light years would be ~15 and 2. Sources of these magnitudes can be easily picked up by small telescopes. However, it would be advisable to use at least a 0.4 m or larger telescope to ensure that one is able to detect the laser signal.

Kingsley's advocacy for OSETI searches has paid off. Over the past couple of years two more groups in the USA (led by Dan Werthimer at the University of California and Paul Horowitz at Harvard University) and one in Australia (the OZ OSETI Project) have taken up his challenge (Beatty 1999). All three groups will be searching for nanosecond pulses with specially built very fast detectors. The University of California group will be searching in the 300–700 nm range and will be looking for signals from F, G, K and M stars including a few globular clusters and galaxies. The OZ OSETI project will be targeting southern Sun-like circumpolar stars, southern globular clusters and a few galaxies. It will be using two telescopes placed 20 m apart to ensure that extraneous signals are minimized when the same target star is observed. The search will be conducted in the 300–700 nm range but centred on 550 nm. The Harvard group is searching in the 160–850 nm range with the search centred on 420 nm. They are using hybrid avalanche photodiodes and have plans to carry out the search with two telescopes at different locations. The Harvard group is well ahead of the other two groups, having already observed more than 1000 nearby stars but with no success in detecting any ETI laser signals. They are also planning to carry out an all-sky optical SETI search.

Another search at the University of California by Geoffrey Marcy and Paul Butler will search 1000 stars for continuous laser signals which will manifest themselves in very sharp lines in their high-resolution spectra of target stars. In essence they will be mining the data from their ongoing planet search for any tell-tale signatures. In Arizona, Monte Ross is developing plans to build two large collectors made up of 18 (12.8 cm diameter) spherical mirror segments on each collector. These will serve as photon buckets. According to Ross, photon buckets can be used in this experiment because: "The signal energy in a short pulse can overcome the generated noise by the star's spectrum. Exact optical frequency knowledge is not required because of the high background discrimination of the short-pulse approach." He has proposed that we search for strong Fraunhofer lines, especially the H α line (656.3 nm).

Rather than searching for pulsed laser signals there is a suggestion that we should look for technological activities that generate infrared radiation. This idea was suggested by Dyson (1960) who echoed Tsiolkovskii's predictions made in the 19th century. He proposed that intelligent civilizations could build thin shells around stars to trap radiation and extract their energy for use. The heat generated would radiate away in the infrared. Jugaku and Nishimura (1997) searched for Dyson spheres associated with 50 solar-type stars of spectral class F, G and K within 25 pc of the Sun. However, they found no evidence of Dyson spheres.

Conclusion

After several years of neglect it would appear that optical SETI (both visible and infrared) may finally find a growing niche in ETI searches. Over the next few years we will see the exploitation of a greater part of the electromagnetic spectrum for ETI searches. Even if we do not find ETI we may find very fast astronomical phenomena that have yet to be discovered. Who knows what the future holds. ●

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