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An Alternative Approach for Investigating Extra Solar Planets through Two Elective "Water Holes"

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ABSTRACT: *There is a serious limitation in the methods of detecting extrasolar planets. Any planet is an extremely faint light source compared to its parent star. Light from the parent star causes a glare that washes it out. For this limitation only a very few extrasolar planets have been detected directly. Generally, the life, which originates outside the earth, signified as extraterrestrial life. Tentative types of extraterrestrial life are in the range between sapient beings to bacterial life. Since convincing evidence of life is not extensively acknowledged by the scientific community, its existence is still hypothetical. Scientists and general public have realized that probably we are not the only civilization in our galaxy. There may even contain dozens or hundreds of civilizations scattered among its 1011 stars. Gallup pools find that 50% of adults believe there is intelligent life beyond the earth. In fact, efforts of radio astronomy to detect a signal or message from another civilization are increasing rapidly. Reasonably the top priority in the current agenda of our civilization is to seek contact and to prepare for successful interaction with intelligent life from somewhere else in our galaxy. The purpose of this paper is to present a method of new radio technique and an outline of the instruments required for the purpose that can be implemented for interstellar studies.*

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I. INTRODUCTION

Astronomical measurements from space can be more sensitive than measurements done from the ground, as the distorting effect of the Earth's atmosphere is removed and the instruments can view in infrared wavelengths that do not penetrate the atmosphere. These space probes even have the capability of detecting planets similar to our Earth [1-3]. If the hydrogen line and the water line are considered, we find that the hydrogen (H) line is at 21 cm whereas the hydroxyl radical (OH) line is at 18 cm. When hydrogen is combined with hydroxyl radical, it produces water (H2O) whose wavelength lies between 18 cm and 21 cm. This window is selected as the first water hole. To make radio link this window can be exploited by galactic civilizations and also our own civilization with each other. Again, there is a water molecule which starts from 2mm extend up to 14 mm line and this may be considered as a second "water hole" [4-8]. The two water holes considered have frequencies 1.67 to 1.43 GHz (first water hole) and 21.43 to 150.00 GHz (second water hole) respectively. In order to calculate d, we assumed that the dish diameter of the receiving antenna on the earth is identical and their aperture efficiency is 50% with the system temperature at the earth station. From the calculation we find that depending on the transmitted power and hence on the radius (in Ly) the numbers of stars vary. It is interesting to note that when the radius is significantly small, the number of stars may even be less than one. This indicates that a minimum value of the transmitted power is essential for detecting and identifying any star [1, 9]. The Microwave Window, where natural noise is at a minimum, is a favored region for conducting radio astronomy research, including SETI. Low frequencies are obstructed by galactic noise, primarily due to synchrotron radiation while high frequencies are subject to quantum-effect emissions and the whole continuum experiences a 3 Kelvin background radiation level from the residual radiation of the Big Bang. These natural radiation sources limit our ability for detecting artificial emissions.

II. METHODS FOR DETECTING EXTRASOLAR PLANETS

Out of many attempts so far, the following indirect methods have revealed successful results. Established detection methods are: (i) Astrometric Method, (ii) Radial Velocity or Doppler Method, (iii) Pulsar Timing Method, (iv) Transit Method, (v) Gravitational Microlensing Method, (vi) Circumstellar Disks Method and (vii) Direct Imaging Method.

2.1 Astrometric Method

Astrometry is the method of measuring the position of a star in the sky and precisely observing how that position changes with time. One great advantage of this method is that it is highly sensitive to planets with large orbits. This makes astrometric method complementary to other methods that are most sensitive to planets with small orbits. However, long observation times required – may be years and even possibly decades [10].

2.2 Pulsar Timing Method

A pulsar is a small, ultra-dense remnant of neutron star. It is a star that has exploded as a supernova. Pulsars emit radio waves regularly as they rotate. As the intrinsic rotation of a pulsar is regular, slight anomalies in the timing of its observed radio pulses can be used for tracking its motion [11].

2.3 Gravitational Microlensing Method

Gravitational Microlensing happens in principle when the gravitational field of a star acts like a lens, magnifying the light of a distant background star (Fig .1). The effect occurs only when the two stars are almost aligned. Lensing events are brief, lasting for weeks or days, as the two stars and the Earth are all moving related to each other.

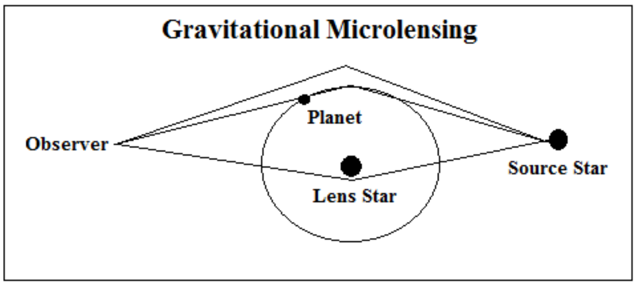

Fig. 1 Illustration of the principle of Gravitational Microlensing [12]

2.4 Circumstellar Disks Method

Disks of space dust (called debris disks), surround many stars. This dust can be detected as it absorbs ordinary starlight and re-emits it as infrared radiation. Even if the dust particles have a total mass sufficiently less than that of the earth, they can still have a considerably large total surface area that they outshine their parent star in infrared wavelengths. The Hubble Space Telescope is capable of observing dust disks with the help of NICMOS (Near Infrared Camera and Multi Object Spectrometer) instrument [13].

2.5 Direct Imaging Method

Current Telescopes are capable of directly imaging planets, e.g. the Gemini Telescope, the Subaru Telescope and the VLT etc. Direct imaging is possible when the planet is especially large (considerably larger than the Jupiter) and widely separated from its parent star. A group of astronomers used the European Southern Observatory's very large telescope array in 2004 and 2005 and also in 2007 to produce images of exoplanets.
Future Detection Methods are: (i) Observations from space, (ii) Eclipsing binary minima timing, (iii) Orbital phase reflected light variations and (iv) Polarimetry.

2.6 Observations from Space

Astronomical measurements from space can be more sensitive than measurements done from the ground, as the distorting effect of the Earth's atmosphere is removed and the instruments can view in infrared wavelengths that do not penetrate the atmosphere. These space probes even have the capability of detecting planets similar to our Earth [4, 5, 6, 10, 14, 15, 16, 17]. NASA has cut funding for the Terrestrial Planet Finder in 2007 and the funding has gone towards the Kepler Mission. This is mainly because the transit method will be used by the Kepler Mission to scan a hundred thousand stars simultaneously and thus will be able to collect statistics on the numbers of planets around sun like stars [18].

2.7 MOP and Phoenix

The main objectives of the Microwave Observing Program [3, 4, 19] abbreviated as MOP, were the following: (i) "Targeted Search" Program, (ii) 800 Specific nearby Stars & General Sky Survey, (iii) Radio Dishes associated with NASA and (iv) A 43-meter dish at Green Bank. Signals were to be analyzed by Spectrum Analyzers each with a capacity of 15 million Channels.

On the other hand, Project "Phoenix" (1995) was largely engaged in: (i) "Targeted Search" Program, (ii) Studying about 1000 nearby Sun-like Stars, (iii) Phoenix conducted observation at the 64-meter Parks Radio Telescope in Australia and (iv) A 140-ft Telescope of the National Radio Astronomy Observatory in West

Virginia, USA. The project observed 800 Stars over the available channel in the frequency range from 1200 to 3000 MHz.

III. EARLY SEARCHES AND CONFIRMED EXTRASOLAR PLANETS

At N.R.A.O., Green Bank, with a radio telescope (diameter of antenna 26 m) Drake [20] took first attempt to search extraterrestrial life. With a single tunable channel of 100 Hz bandwidth at the hydrogen line corresponding to 1.4 GHz, it was a 'Targeted Search' for two stars, 'Tau Ceti' and 'Epsilon Eridani'. At Ohio State University with 110 m radio telescope Dixon [21] continued observation for the same purpose while with 26 m radio telescope an ultra-narrow band multi-channel search was made by Horowitz and Forster [22]. The summary of all these early attempts is presented in Table 1.

Table 1. Summary of early attempts of interstellar communication

Type of search	Location	Scientist	Year	Antenna Diameter
Targeted search	N.R.A.O., Green Bank	Frank Drake	1960	26m
All sky search	Ohio State University	Robert Dixon	1985	110m
All sky search	Harvard University	Paul Horowitz & J. Forster	1985	26m

A list of confirmed extrasolar planets as discovered during the last twenty years are presented in Fig. 2 in the form of histogram while Table 2 provides the exoplanets discovered during 2009 and up to July 2010.

Table 2. Exoplanets discovered during 2009 and 2010

Year of Discovery	Star	Planet	Mass (Compared to Jupiter)	Radius (Compared to Jupiter)	Orbital period (days)	Inclination (in degree)
2009	WASP-18	b	10.43	1.165	0.9414518	86
2009	COROT-7	b	0.0151	0.150	0.853585	80.1
2009	COROT-7	c	0.0264	-	3.698	-
2009	WASP-19	b	1.15	1.31	0.7888399	80.8
2009	HAT-P-12	b	0.211	0.959	3.2130598	-
2009	WASP-16	b	0.855	1.008	3.1186009	85.22
2009	Gliese 581	e	0.006104	-	3.14942	≥ 30
2009	WASP-17	b	0.49	1.66	3.7354417	87.8
2009	GJ 1214	b	0.0179	0.2415	1.5803925	88.62
2009	MOA-2008-BLG-310L	b	0.23	-	-	-
2009	OGLE-2007-BLG-368L	b	0.0694	-	-	-
2009	COROT-6	b	2.96	1.166	8.887	-
2009	HAT-P-11	b	0.081	0.422	4.8878162	88.5
2010	WASP-26	b	1.02	1.32	2.7566	82.5
2010	HAT-P-16	b	4.193	1.289	2.77596	86.6
2010	HD 15082	WASP-33b	< 4.1	1.497	1.2198669	87.67
2010	WASP-22	b	0.56	1.12	3.53269	89.2
2010	HAT-P-15	b	1.946	1.072	10.863502	89.1
2010	2M J044144	b	7.5	-	-	-
2010	COROT-12	b	0.917	1.44	2.828042	85.48
2010	COROT-13	b	1.308	0.885	4.03519	88.02
2010	COROT-14	b	7.6	1.09	1.51214	79.6
2010	WASP-25	b	0.58	1.26	3.76483	87.7
2010	WASP-24	b	1.032	1.104	2.3412083	85.71
2010	HAT-P-14	b	2.232	1.15	4.6267669	83.5
2010	COROT-11	b	2.33	1.43	2.99433	83.17
2010	COROT-9	b	0.84	1.05	95.2738	>89.9
2010	Kepler-8	b	0.603	1.419	3.52254	84.07
2010	Kepler-4	b	0.077	0.357	3.21346	89.76

2010	Kepler-7	b	0.433	1.478	4.885525	86.5
2010	COROT-10	b	2.75	0.97	13.2406	88.55
2010	COROT-8	b	0.22	0.57	6.21229	88.4
2010	Kepler-6	b	0.669	1.323	3.23423	86.8
2010	Kepler-5	b	2.114	1.431	3.54846	86.3
2010	Gliese 876	e	0.046	-	124.26	59.5
2010	WASP-21	b	0.30	1.07	4.322482	88.75
2010	WASP-28	b	0.91	1.12	3.408821	89.1
2010	WASP-29	b	0.248	0.74	3.923	87.96

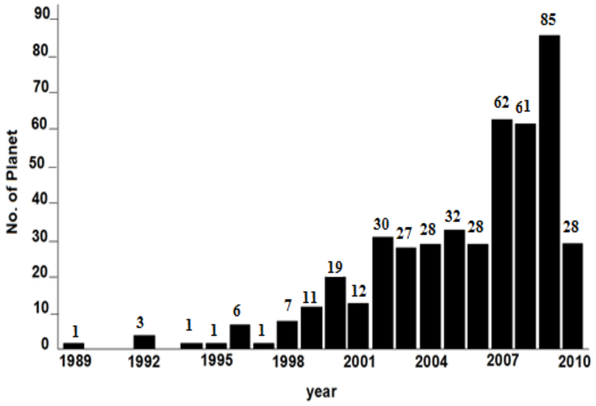

Fig. 2 Confirmed exoplanets during 1989 to 2010

IV. PRESENT APPROACH AND THEORETICAL CONSIDERATION

Considering the sky noise windows of the atmosphere we are suggesting the radio communication approach here. A sky noise diagram, indicating sky noise temperature against frequency, is shown in Fig. 3. If the hydrogen line and the water line are considered, we find that the hydrogen (H) line is at 21 cm whereas the hydroxyl radical (OH) line is at 18 cm. When hydrogen is combined with hydroxyl radical, it produces water (H_2O) whose wavelength lies between 18 cm and 21 cm. This window is selected as the first water hole. To make radio link [23] this window can be exploited by galactic civilizations and also our own civilization with each other. Again, there is a water molecule which starts from 2mm extend up to 14 mm line and this may be considered as a second "water hole". Let us consider a radio transmitter installed at earth's surface, isotopically radiates a power P_t over a transmitter bandwidth B_t. Fig. 4(a) illustrates the principle of the radio communication link, while Fig. 4(b) reveals a block diagram of the spectrograph including low noise amplifier, transmitter and receiver.

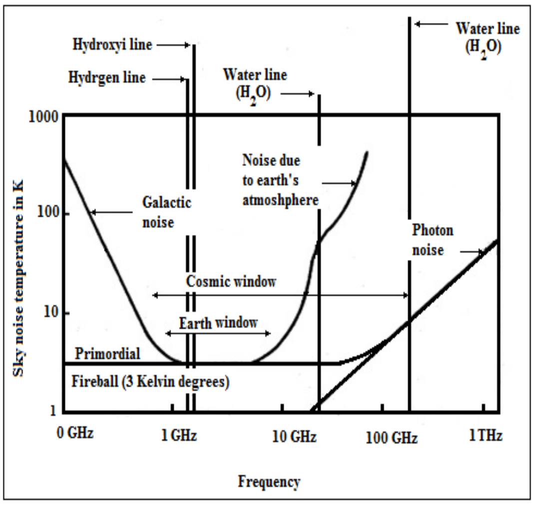

Fig. 3 Sky noise windows ("water holes"), may be taken as most appropriate for interstellar communications

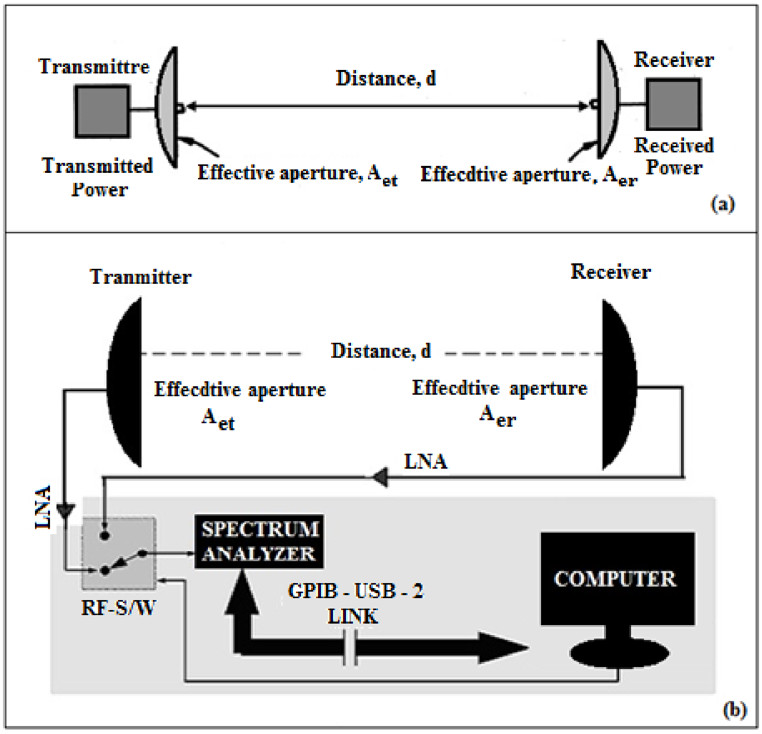

Fig. 4(a) Principle of radio transmission and reception for exoplanet link, (b) Suggested technique to be implemented

The flux density generates at a distance *d* is $(P_t/4\pi d^2 B_t)$. Let A_{er} be the effective aperture of the receiving antenna, then power it receives at a distance d is

$$P_r = \frac{P_t A_{er} B_r}{4\pi d^2 B_t} \qquad \ldots (1)$$

Where, B_r = receiving bandwidth

If the directivity of the transmitting antenna be *D*, the received power becomes,

$$P_r = D\frac{P_t A_{er} B_r}{4\pi d^2 B_t} \qquad \ldots (2)$$

Now the value of *D* is,

$$D = \frac{4\pi A_{et}}{\lambda^2} \qquad \ldots (3)$$

Putting the value of *D*, we have,

$$P_r = \frac{4\pi A_{et}}{\lambda^2} \cdot \frac{P_t A_{er} B_r}{4\pi d^2 B_t} = \frac{A_{et} P_t A_{er} B_r}{\lambda^2 d^2 B_r} \qquad \ldots (4)$$

where, A_{et} = effective aperture of the transmitting antenna, λ = wavelength

The received power is suitable for communication or not, determined by measuring signal to noise power ratio *S/N*. Applying Nyquist relation, the noise power can be written as,

$$P_n = kT_{sys}B_r \qquad \ldots (5)$$

where, *k* = Boltzmann constant and T_{sys} = system temperature

Now taken the ratio of equations (4) and (5) we get,

$$\frac{P_r}{P_n} = \frac{A_{er} P_t A_{et} B_r}{kT_{sys} B_r \lambda^2 d^2 B_t} \qquad \ldots (6)$$

Now according to statistical point of view, the noise can be making smaller by integrating over the bandwidth B_r for a time t, which can be expressed as $\sqrt{B_r t}$. Therefore, from equation (6) we have,

$$\frac{S}{N} = \frac{P_r}{P_n/\sqrt{B_r t}} = \frac{A_{et} P_t A_{er} \sqrt{B_r t}}{k T_{sys} B_r \lambda^2 d^2 B_t} \qquad \ldots (7)$$

If in such case, when the bandwidths of the communicative signal which transmitted by the earth are matched with the extragalactic receiver, i.e. $B_r = B_t$ and the corresponding duration of pulses are matched to bandwidth, i.e. $B_r t = 1$ then the value of *S/N* is,

$$\frac{S}{N} = \frac{A_{et} P_t A_{er}}{k T_{sys} B_r \lambda^2 d^2} \qquad \ldots (8)$$

Hence, the distance of the radio communication link *d* can be derived from,

$$d = \sqrt{\frac{P_t A_{et} A_{er}}{k T_{sys} (S/N) \lambda^2 B_r}} \qquad \ldots (9)$$

From above equation we see that the range of *d* will be increased with the decreased value of B_r. Therefore, for better communication the small bandwidth should be used. From some significant considerations, Drake and Helou [24] concluded that due to time broadening by multiple scattering of the interstellar medium, a minimum usable bandwidth is 0.1 Hz approximately.

V. INTERSTELLAR LINKS TO EXTRATERRESTRIAL CIVILIZATION

Let us consider a hypothetical interstellar communication link for the purpose of extraterrestrial observations. We choose two dishes of diameters 75 m and 150 m respectively for using signal transmission and reception independently for two different situations. The effective apertures of the antennas can be calculated from: Aet= Aer= 0.125π (diameter of the dish) 2. If we take, 1, k = 1.38 x 10-23 JK-1, T_{sys} = 10 K and Br = 0.1 Hz, then from equation (9), we can calculate the maximum distance of the transmitted signal in terms of the wavelength (λ). This is shown in the Table 3.

Table 3 Dish diameters, transmitted powers and corresponding distances

Dish Diameter (in m)	$A_{er} = A_{et}$ **(in m^2)**	**Transmitted power (P_t) (in W)**	***d* from equation (9) (×10^{16}) (in m)**
75	2208.9	10^7	$\frac{188.0}{\lambda}$
		10^5	$\frac{18.8}{\lambda}$
150	8835.7	10^7	$\frac{752.1}{\lambda}$
		10^5	$\frac{75.2}{\lambda}$

We choose the two water holes, as indicated in Fig. 3, for the selection of frequency. The wavelengths (also the corresponding frequencies) and distances of the radio link for the two holes are specified in Table 4. From this table it is clear that the two water holes have frequencies 1.67 to 1.43 GHz (first water hole) and 21.43 to 150.00 GHz (second water hole) respectively. In order to calculate d, we assumed that the dish diameter of the receiving antenna on the earth is identical. And their aperture efficiency is 50% with the system temperature at the earth station. Take this system temperature T_{sys} is 10 K with the corresponding bandwidth 0.1 Hz.

Table 4. Water holes and the corresponding frequencies

Feature	Wavelength (in λ)	Frequency (in GHz)	Dish Diameter (in m)	Transmitted power (P_t) (in w)	Distance(d) of radio link (in m) ($\times 10^{16}$) [using Table 3]
First water- hole	18cm	1.67	75	10^7	1044.6
				10^5	104.7
			150	10^7	4178.6
				10^5	417.8
	21cm	1.43	75	10^7	895.4
				10^5	89.5
			150	10^7	3581.6
				10^5	358.2
Second water-hole	2mm	150.00	75	10^7	94018.5
				10^5	9401.5
			150	10^7	376073.0
				10^5	37607.0
	14mm	21.43	75	10^7	13431.2
				10^5	1343.1
			150	10^7	53724.7
				10^5	5372.4

Now 1 Ly being equal to 1016 m (approximately), the corresponding distances become 1044.65 Ly, 104.46 Ly, 4178.59 Ly, 417.85 Ly (for wavelength18 cm); 895.41 Ly, 89.53 Ly, 3581.65 Ly, 358.16 Ly (for wavelength 21 cm); 94018.50 Ly, 9401.50 Ly, 376073.00 Ly, 37607.00 Ly (for wavelength 2 mm) and 13431.21 Ly, 1343.07 Ly, 53724.71 Ly, 5372.43 Ly (for wavelength 14 mm). If for simplicity we take the uniform star density as 0.01 per Ly3 then by measuring the volume for different radii and directivities of corresponding antenna we can calculate the number of stars to be recognized by the proposed antenna beam. The probable number of stars as derived from this suggested technique is presented in Table 5.

Here volume, $V = \frac{4}{3}\pi$ (Radius in Ly) 3

And directivity of the transmitting antenna, $D = \frac{4\pi A_{et}}{\lambda^2}$

Therefore, number of stars = Volume/Directivity

$$= \frac{V}{D} = \frac{(Radius\ in\ Ly)^3 \times \lambda^2}{3A_{et}}$$

Table 5. The probable number of stars to be identified from the suggested technique

Wavelength (λ)	Radius (in Ly)	Number of stars = Volume/Directivity
18cm	1044.6	55
	104.5	0.05*
	4178.6	891
	417.8	0.89*
21cm	895.4	47
	89.5	0.05*
	3581.6	764
	358.2	0.76*
2mm	94018.5	5016
	9401.5	5
	376073.0	80262
	37607.0	80
14mm	13431.2	716
	1343.1	0.72*
	53724.7	11466
	5372.4	11

In the above calculation we find that depending on the transmitted power and hence on the radius (in Ly) the numbers of stars vary. It is interesting to note that when the radius is significantly small, the number of stars may even be less than one (as shown by * marks) in the table. This indicates that a minimum value of the transmitted power is essential for detecting and identifying any star.

VI. CONCLUSION

Within this so-called Microwave Window, photons (the substance of electromagnetic communication) travel relatively unimpeded through the interstellar medium, at the speed of light. This is, in fact, the fastest possible speed making photons the fastest spaceships known to man. Thus, the Microwave Window, where natural noise is at a minimum, is a favored region for conducting radio astronomy research, including SETI [25, 26]. Low frequencies are obstructed by galactic noise, primarily due to synchrotron radiation while high frequencies are subject to quantum-effect emissions and the whole continuum experiences a 3 Kelvin background radiation level from the residual radiation of the Big Bang. These natural radiation sources limit our ability for detecting artificial emissions. Moreover, the Earth's own ocean of air generates spectral absorption and emission lines to draw a further curtain across our sky. However, there are a few relatively clear windows on the cosmos. Our eyes evolved to operate in two such windows. These windows will allow us to observe the stars and planets hopefully, if the proposed experiment can be performed with utmost care [1, 9, 17, 26].

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