A TEST FOR THE INTERSTELLAR CONTACT CHANNEL HYPOTHESIS IN SETI

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ABSTRACT

This paper describes a SETI research programme which commenced in 1990 in Australia. The project is intended to be a specific test for the existence of definable interstellar contact channels. The rationale for the choice of interstellar contact frequency is described. In the initial observations 100 targets were searched, down to a flux limit of 2 Jy.

1. INTRODUCTION

The Drake equation (1980) yields a relationship between the number of concurrent electromagnetically telecommunication civilizations (ETCs) in the galaxy, N, and their mean lifetime L. Optimistic scenarios for the number of suitable planets and for the inevitability of life, evolution and technology lead to several questions. If L is large, especially if indefinite survival of an ETC is possible, then N could be very large. For example, if L $\sim 10^8$ years we could expect the mean spacing between ETCs to be less than 50 light-years (Blair,1985). The question arises, where are they? Tipler has argued (1980) that since they have not shown themselves, we are alone: N=1.

An alternative hypothesis is that technological civilization is an extremely short-lived manifestation of the evolution process. Thus L is very small, and consequently N is very small. The nearest ETC could be a minimum of several thousand light-years away for L = 100 years.

A third possibility, on which this work is based, does not do away with the idea that L is large and consequently that N is very large. Instead it assumes that physical laws make interstellar travel impractical. They are out there, but they do not travel. They communicate by radio. Detectable signals may be expected on an interstellar beacon frequency. (Blair, 1986, Bracewell 1974). A search on an interstellar beacon frequency, of several hundred stars, will allow significant restrictions on the basic hypotheses.

The initial search described here is to our knowledge the first in the southern hemisphere (Papagiannis,1985). It covers 100 southern stars, and includes 40 nearby solar type stars south of declination 40°. The search tests specifically the interstellar contact channel hypothesis, and a null result will allow limits to be placed on at least one of the hypotheses, which are described below.

2. FIVE HYPOTHESES

To place the tests described here on a rigorous logical footing, we present five hypotheses which outline an optimistic and specific scenario for extraterrestrial intelligence in the galaxy. A modest observation program can significantly constrain the hypotheses, especially hypotheses 1, 4 and 5.

Hypothesis 1. Life and Technology : Inevitable and Abundant. That the evolution of life and, ultimately, technological civilization is an inevitable outcome of physical laws and occurs profusely throughout the galaxy.

Hypothesis 2. Temporal Mediocrity. That the Earth is mediocre in its time development and civilizations far advanced with respect to ours exist in the galaxy, it is not the first and the time range for formation is a moderate fraction of the age of the galaxy.

Hypothesis 3. Non-existence of Superscience and Hyperdrives. That the physical laws, energy sources and phenomena known to physics today represent a complete approximation to the laws of nature and that consequently interstellar travel is impractical. In particular the relationships between mass, energy, velocity and distance known today, can not be radically violated. "Completeness" implies the non-existence of radical new laws, while "approximation" refers to the fact that they are not necessarily exact, and that future science may refine our understanding. Thus while technological development may carry far beyond our own there is no radical new physics.

Hypothesis 4. Exploration by Data Exchange on Universal Contact Frequencies. That physical laws make interstellar exploration by spacecraft non-viable (Olivier,1981). That is, communication and exchange of information constitutes the one viable means of exploring life in the galaxy. Radio communication in the 1-20 GHz range is ordained by noise and energy considerations and interstellar contact channels can be universally defined.

Hypothesis 5. The Galactic Club Exists and Welcomes and Assists Members. That civilizations far ahead of us (say 500 million years ahead) have already developed communications and chosen beacon channels based on universality and logic. That target stars and planets are known through advanced astronomy and that beacons are directed at likely systems and are designed to attract ETCs at their most primitive stage. The goal is to spread and acquire knowledge and possibly even to assist emerging civilizations during dangerous phases of possible self-destruction.

3. CHOICE OF INTERSTELLAR CONTACT CHANNEL (ICC)

It has been frequently shown that the range 1-20 GHz represents the minimum energy band (MEB) for interstellar communication (Papagiannis, 1985). On the low side galactic synchrotron radiation creates a broadband background. On the high side the quantum limit and photon energy imposes an energy barrier, since each photon can convey a maximum of 1 bit of information. Water

absorption limits the upper frequency to 10 GHz below the atmosphere. A logical choice of frequency, independent of anthropocentric bias can be defined as follows :

a) Choose a base frequency, f_B. It should be near or in the MEB, it should be universal, it should be the 'number 1' of our frequency scale. The natural choice is the 1420 MHz hydrogen line, F_H, since H is element number 1.

b) Choose a Civilization Signature Constant (C_{SC}). This should be non-integer so that no natural source can mimic the frequency through harmonic generation. The product $C_{SC} \times f_B$ defines the interstellar communication band, f_I modified only by possible Doppler shifts. The number π is the natural choice of C_{SC}, since it is fundamental to civilization, is universal, is irrational, and places the ICC in the middle of the MEB at 4.462336275 GHz. While π^{-1} could be equally universal, it translates the ICC to too low a value (0.45 GHz). Arguments could be made regarding other irrationals such as 'e' or the golden mean. They may be secondary choices but from our perspective π is the first choice.

c) It is worth considering the optimum choice for the type of beacon which might be used. An omni-directional beacon could be considered to reduce the numbers of antennas required, but this would be at an enormous energy cost. Such a beacon, however, would be unable to correct for local Doppler shifts, and hence would be less able to allow receiving civilizations to home-in on the ICC. It would also use very high powers. Secondly the beacon could be directed but time shared between targets. This would represent a huge loss of duty cycle, greatly reducing the probability of successful detection. The only efficient type of beacon, therefore is the directed beacon. While it requires multiple antennas, it minimizes energy usage and maximizes the probability of successful contact. For this reason we consider the directed beacon, corrected for local Doppler shifts from the source, to be the most likely choice.

d) We are unable to determine the correct choice of reference frame for Doppler corrections. In this present search we have chosen to observe in three frequency bands. The first assumes that the beacon is broadcast at f_I in the target barycentre reference frame. The second assumes that the beacon is broadcast in the solar barycentre reference frame. The third assumes sufficient knowledge of the earth's orbit, and the solar system distance to broadcast in the Earth geocentre reference frame. In future searches we intend to use also the reference frame defined by the relic cosmic microwave radiation. This universal frame could well be a much better choice as it is independent of both the source and receiver local conditions. Unfortunately the frame is not known to sufficient accuracy to be useful given the present bandwidth of our spectrum analyzers.

4. OBSERVATION

The Parkes radio telescope was used in a configuration as illustrated in Figure 1. The Parkes correlator was used to give two 512 channel, 100 Hz resolution spectrum analyzers. An additional

spectrum analyzer HP 3582A provided another 256 channels with the same resolution. The latter was interfaced by GPIB to the Parkes VAX 750 to enable long averages, and the display of multiple spectra.

While all data was archived, the intention of this search was to undertake real time processing of all data, allowing immediate repeats for confirmation of possible spectral lines. Observations took place from 10.00 UT on 7 May 1990, to 2300 on 9 May 1990.

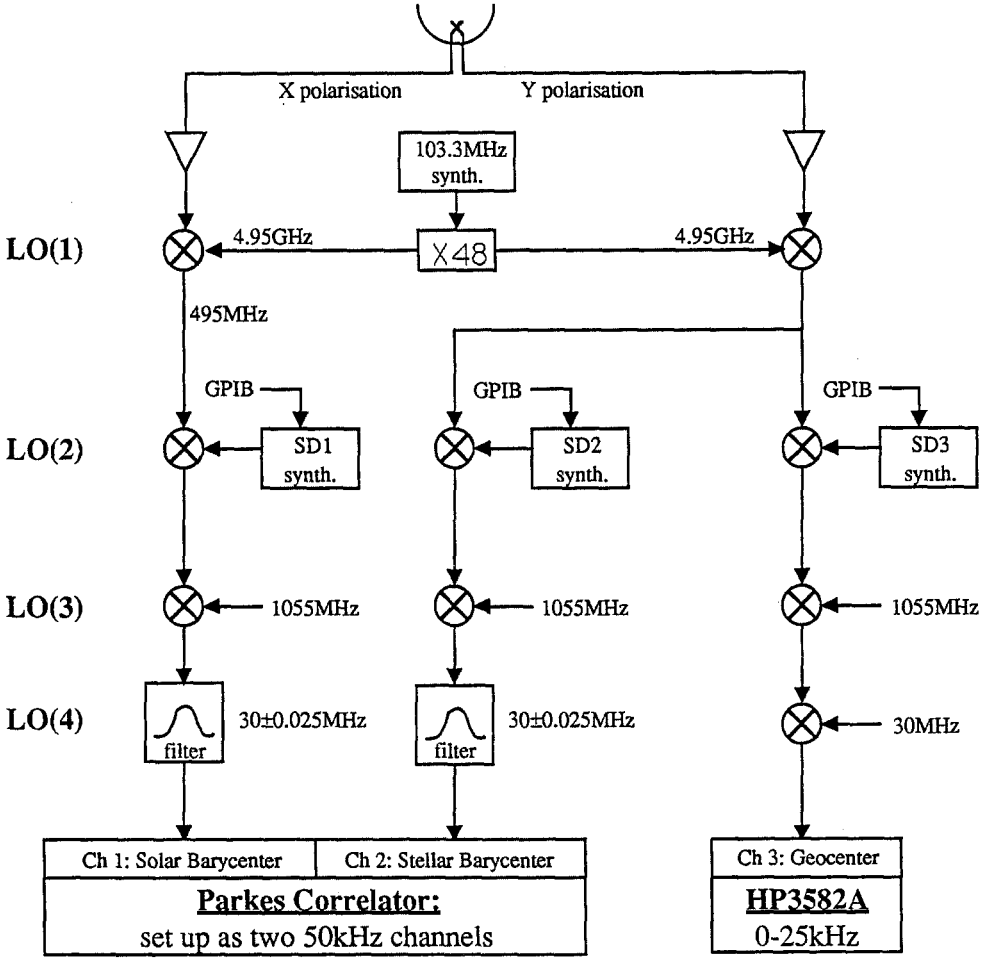

Figure 1: Set-up for SETI observations at 3 Doppler correction frequencies.

TARGET STARS

Target stars are chosen from the bright star catalog (Hoffleit) and are listed in Table 1. All were F,G, and K main sequence stars in the solar neighborhood. Reference spectra were taken several times in each 24 hour period, and these were used to normalize the observed spectra. The system noise temperature was consistently ~30 K, and the 3σ detection limit was less than 2 Jy for all sources examined. Table 1 lists the observational parameters of the 100 stars examined. Results are expressed as the threshold power detectable from a beamed narrow band beacon from a 1km dish. Threshold powers are within the range of terrestrial transmitters, as illustrated in figure 2. All stars were searched in 50kHz bands centered on the ICC in the target barycentre and solar barycentre reference frames. Most stars were also examined in a 25kHz band centered on the geocentre reference frame (see Table 1). Radial velocity data rounded to 1 km/s implied that the ICC should appear within 7 kHz of bandcentre.

The system sensitivity was tested by using standard calibrators, and the spectral analysis was tested using calibration signals injected at the feed. There was a surprising lack of interference and false alarms. Only one source yielded data worthy of repeat observation. A narrow line was seen while observing HR 6171 in the target barycentre reference frame. It was present for a period of about 1 hour, from UT1420 to UT1520 during 5 succesive observations on the 9th of May. In the following hour it was absent. It was initially thought to be interference from a geosynchronous satellite. However this is unlikely as it persisted while the RA of a satellite would have shifted 15°. It was absent when the telescope moved off source. Note also that while HR6171 has declination -2°19', a geosynchronous satellite by parallax appears well north of the equator. After an hour a new reference spectrum was taken, and thereafter the line was not seen. The line was not strong however, its amplitude was about 2Jy.

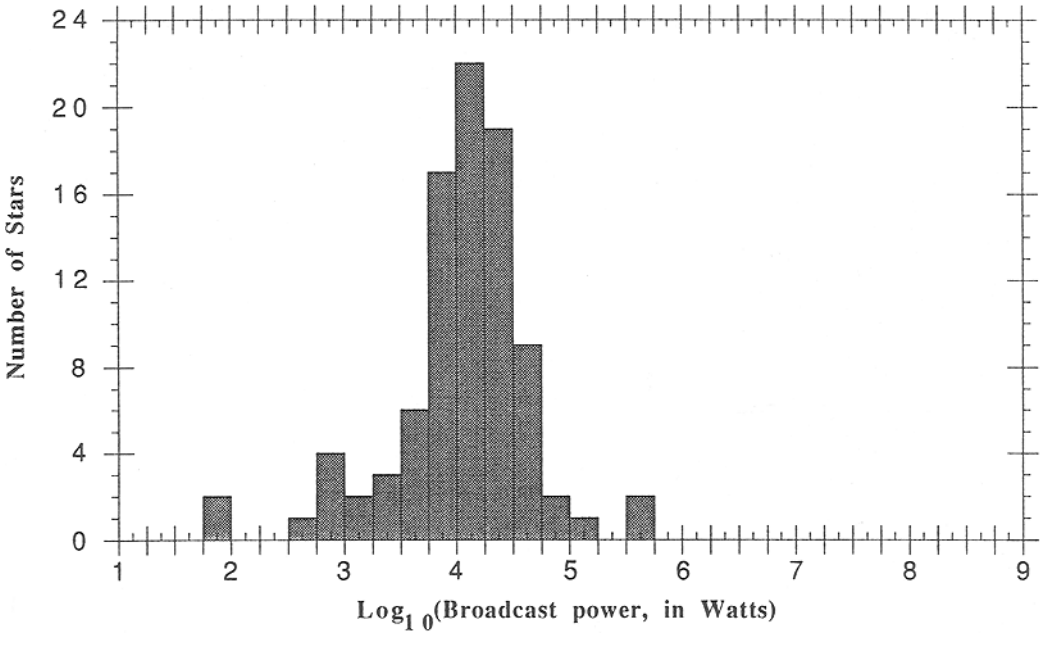

Figure 2: Threshold power histogram for 1 km transmitters.

Table 1: List of target stars, mostly taken from the Bright Star Catalog. Both the HD and HR catalog numbers are given, where known, as well as the radial velocities (RV) in km/sec. The distances (in parsecs), and the spectral type, where listed, are taken from 'Sky Catalogue 2000.0' (Hirshfeld). Asterisked stars were not searched in the Geocenter reference frame.

HR#	HD#	RA	DEC	VMAG	TYPE	Dist.	RV	IntTime	
33	693	0 11 15.8	-15 28 5	4.89	F7V	18	14	240	
77	1581	0 20 4.2	-64 52 30	4.23	F9V	7.1	9	240	
159	3443	0 37 20.6	-24 46 2	5.57	G8V	13	17	240	
176	3823	0 40 26.4	-59 27 16	5.89	G1V	20	2	360	
209	4391	0 45 45.5	-47 33 6	5.80	G1V	33	-11	240	
210	4398	0 46 11.7	-22 31 19	5.50	G3V	100	-15	360	
370	7570	1 15 11.1	-45 31 54	4.96	F8V	15	12	360	
486	10360	1 39 47.4	-56 11 53	5.86	K0V	-	23	240	
506	10647	1 42 29.3	-53 44 26	5.52	F8V	17	13	240	
509	10700	1 44 4.0	-15 56 15	3.50	G8V	3.6	-16	480	
512	10800	1 37 55.6	-82 58 30	5.87	G2V	17	-5	240	
650	13612	2 12 47.4	- 2 23 37	5.54	F8V	22	-3	240	
695	14802	2 22 32.5	-23 48 59	5.20	G1V	14	18	240	
810	17051	2 42 33.4	-50 48 1	5.41	G0V	17	16	240	
962	19994	3 12 46.4	- 1 11 46	5.06	F8V	18	18	240	
963	20010	3 12 4.2	-28 59 14	3.87	F8V	14	-21	240	
1006	20766	3 17 46.1	-62 34 32	5.54	G3-5V	13	12	240	
-	20794	3 17	-43 16	4.26	G5	6.2	87	240	
1010	20807	3 18 12.8	-62 30 23	5.24	G2V	12	12	240	
1084	22049	3 32 55.8	- 9 27 30	3.73	K2V	3.3	16	240	
1111	22713	3 39 1.0	- 5 37 34	5.96	K1V	21	40	240	
1232	25069	3 58 52.3	- 5 28 12	5.83	G9V	11	36	240	
1325	26965	4 15 16.3	- 7 39 10	4.43	K1V	4.3	-42	240	
1532	30495	4 47 36.2	-16 56 4	5.51	G1V	15	23	240	
1536	30562	4 48 36.3	- 5 40 26	5.78	F8V	22	79	240	
1538	30606	4 48 32.4	-16 19 47	5.77	F6V	23	35	480	
1608	32008	4 59 50.4	-10 15 48	5.38	G4V,K0III	110	-12	240	*
1665	33093	5 7 24.9	-12 29 26	5.97	F7V	-	50	240	
1674	33262	5 5 30.6	-57 28 22	4.72	F7V	13	-2	240	
1747	34721	5 18 50.4	-18 7 49	5.96	G0V	20	40	240	
2007	38858	5 48 34.9	- 4 5 40	5.97	G4V	24	29	480	
2022	39091	5 37 8.8	-80 28 9	5.65	G1V	15	9	240	
2086	40151	5 56 14.2	-22 50 25	5.96	K0V	10	34	240	
2186	42443	6 9 47.8	-22 46 27	5.71	F6V	25	22	480	
2261	43834	6 10 14.6	-74 45 11	5.09	G6V	8.7	35	240	
2313	45067	6 25 16.4	- 0 56 46	5.87	F8V,dF0V	33	44	240	
2400	46569	6 31 18.2	-51 49 34	5.60	F8V	19	16	240	
2667	53705	7 3 57.2	-43 36 29	5.54	G3V	13	86	240	
2866	59380	7 29 25.6	- 7 33 4	5.86	F8V	22	9	240	
-	61421	7 37	+5 21	0.37	F5V	3.5	-3	240	

HR#	HD#	RA	DEC	VMAG	TYPE	Dist.	RV	IntTime	
3018	63077	7 45 34.8	-34 10 23	5.37	G0V	17	103	240	
3064	64096	7 51 46.2	-13 53 53	5.17	G0V:	15	-18	240	
3259	69830	8 18 23.8	-12 37 55	5.98	G7.5V	11	30	480	
3677	79807	9 14 57.1	-37 36 9	5.86	G0V	-	-2	480	
3750	81809	9 27 46.7	- 6 4 16	5.38	G2V	15	54	480	
4158	91889	10 36 32.3	-12 13 49	5.70	F7V	23	-6	480	
4413	99453	11 25 43.2	-63 58 22	5.17	F7V,dF3V	22	-5	480	
4443	100286	11 32 16.0	-29 15 48	5.76	F8V	-	10	480	
4444	100287	11 32 16.3	-29 15 40	5.64	F8V	19	4	240	
4458	100623	11 34 29.4	-32 49 53	5.98	K0V	9.5	-23	480	
4488	101198	11 38 40.0	-13 12 7	5.48	F7V,dF5V	23	-24	480	
4523	102365	11 46 31.0	-40 30 1	4.91	G5V	10	15	240	
4548	103026	11 51 41.5	-30 50 5	5.85	F7V	26	33	240	
4788	109409	12 34 42.3	-44 40 23	5.77	G1V	33	18	480	
4903	112164	12 54 58.4	-44 9 7	5.89	G1V	38	32	480	
4979	114613	13 12 3.1	-37 48 11	4.85	G3V,dG5V	13	-15	480	
4995	114946	13 14 10.8	-19 55 51	5.33	G6V,dG5IV	30	-45	240	
5019	115617	13 18 24.2	-18 18 41	4.74	G6V	8.4	-9	240	
5257	122066	14 0 0.0	-25 0 37	5.77	F7V,F3V	14	-17	480	
5317	124425	14 13 40.7	- 0 50 44	5.91	F7Vw,F6IV	54	18	480	
5459	128620	14 39 36.2	-60 50 7	-0.01	G2V	1.3	-25	480	(α Cen)
5460	128621	14 39 36.2	-60 50 7	1.33	K1V	1.3	-21	240	
5698	136351	15 22 8.2	-47 55 40	5.00	F8V,dF5V	20	-11	480	
5699	136352	15 21 48.1	-48 19 3	5.65	G2-5V	16	-69	480	
5700	136359	15 23 10.3	-60 39 25	5.67	F7V,F5V	27	6	480	
5954	143333	16 0 19.5	-16 32 0	5.47	F8V	20	-25	240	
6060	146233	16 15 37.1	- 8 22 11	5.50	G2Va	17	11	240	
6094	147513	16 24 1.2	-39 11 35	5.40	G5V	15	10	480	
6098	147584	16 28 28.1	-70 5 4	4.91	F9V,G0V	12	9	480	
6171	149661	16 36 21.3	- 2 19 29	5.75	K2V,K0V	11	-15	2880	
6269	152311	16 53 25.1	-20 24 56	5.88	G3V,G5IV	22	-17	240	
6314	153580	17 3 8.6	-53 14 13	5.29	F6V,F8V	19	7	240	
6401	155885	17 15 20.9	-26 36 10	5.33	K1V	-	0	480	
6402	155886	17 15 20.7	-26 36 5	5.29	K0V	5.4	-1	480	
6748	165185	18 6 23.6	-36 1 11	5.95	G5V	14	13	480	*
6761	165499	18 10 26.1	-62 0 8	5.49	G0V,G3IV	23	30	240	
6907	169830	18 27 49.4	-29 48 59	5.92	F9V,G0V	19	-17	240	
6998	172051	18 38 53.3	-21 3 7	5.86	G4V,G5IV	34	36	240	
7161	175986	19 3 29.7	-68 45 19	5.88	F8V,dG0V	19	-	240	
7213	177171	19 6 19.8	-52 20 27	5.16	F7V,dF2V	21	2	240	
7226	177474	19 6 25.0	-37 3 48	5.01	F8V	12	-52	240	
7227	177475	19 6 25.0	-37 3 48	5.01	F8V	-	-52	240	
7597	188376	19 55 50.3	-26 17 58	4.70	G5V	11	-21	240	
7631	189245	20 0 20.2	-33 42 14	5.66	F7V	23	-8	240	
7637	189340	19 59 47.3	- 9 57 30	5.88	F8V,G0V	22	23	240	
7715	191862	20 12 25.8	-12 37 3	5.85	F7V	26	23	360	

HR#	HD#	RA	DEC	VMAG	TYPE	Dist.	RV	IntTime	
7722	192310	20 15 17.3	-27 1 58	5.73	K0Vv	8.3	-54	1440	
7776	193495	20 21 0.6	-14 46 53	3.08	F8V+A0	32	-19	360	
7875	196378	20 40 2.4	-60 32 56	5.12	F8V	21	-32	240	*
8013	199260	20 56 47.2	-26 17 47	5.70	F7V	22	-16	360	
8323	207129	21 48 15.6	-47 18 13	5.58	G0V,G2V	15	-7	240	*
8387	209100	22 3 21.3	-56 47 10	4.69	K4-5V	3.4	-40	480	*
8501	211415	22 18 15.4	-53 37 40	5.37	G3V,G1V	14	-14	240	*
8635	214953	22 42 36.8	-47 12 39	5.98	G0V	19	17	240	*
8843	219482	23 16 57.6	-62 0 5	5.66	F7V	22	-9	240	*
8883	220096	23 21 15.4	-26 59 13	5.64	G4V	11	13	240	*
8935	221420	23 33 19.5	-77 23 7	5.81	G2V,K0V	-	26	480	*
-	delta Pav	20 8 43.3	-66 10 56	3.56	G5IV	5.7	-22	240	*
-	Sag. A	17 43 00	-28 50 00	-	-	7000	-	240	
-	moon	- -	- -	-				480	

5. CONCLUSION

We have searched 100 target sources at a proposed interstellar communication channel frequency. Three of four possible Doppler corrections have been used. At the frequencies of observation no narrow band signals were detected above 2 Jy. A narrow spectral line was seen while observing HR6171, which is worthy of repeat observation. Future searches will concentrate on using improved spectral resolutions, additional southern stars, over a broader range of spectral class, and an ICC frequency defined in the cosmic microwave background reference frame. Present results do not disprove the hypotheses on which this work is based, but if the choice of ICC was correct, and the sensitivity was high enough, would imply a limit to the duration of ETCs $\sim 10^8$ years.

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Discussion

J. HEIDMANN: **With respect to your comments about which frequencies to start first, I reached the same strategy for referenced frequencies based on remarkable pulsars (J. Heidmann, C. R. Acad. Sc. Paris, II, 306, 1988, 1441; Planetary Soc. 1988 International SETI Conf., Univ. of Arizona Press, in press; IAA 89-642, 40th Intern. Astronaut. Congress of the IAF, 1989).**

D. BLAIR: The proposal of πf_H was first made by me in a letter to nature in 1986, but it was possibly made by Bracewell and others much earlier. The fact that several people independently made similar suggestions should perhaps give us confidence that we may in fact be able to guess the extraterrestrial strategy.

B. CAMPBELL: Do you allow for the fact that Doppler velocity due to surface convective motions of dwarf stars differs from the center of mass velocity by typically 0.5 kms^{-1}?

D. BLAIR: No, we have only used catalog values. Our bandwidth of 50 kHz per reference frame is sufficient to encompass almost 2 km per second error.

F. DRAKE: Please define the golden mean.

D. BLAIR: The golden mean is obtained from the Fibonacci number. It is the limit of the ratio of F_{n+1}/F_n, where F is defined by the series 1, 1, 2, 3, 5, 8, 13..... i.e.: $F_{n+1} = F_{n-1}+F_n$. The Fibonacci series predicts the structure of numerous living structures, and the golden mean has been used to define the "most beautiful" shape for paintings and sculpture.

Editor's Note: The series converges to 1.61803399.....