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RESULTS OF TWO YEARS OF SETI OBSERVATIONS WITH META II

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ABSTRACT We have conducted a two year search of the southern sky ($-80^o \leq \delta \leq -20^o$) for narrowband radio signals near the 1420 MHz line of neutral hydrogen, using an 8.4×10^6 -channel Fourier spectrometer of B = 0.05 Hz resolution and 400 kHz instantaneous bandwidth. The observing frequency was corrected both for motions with respect to three astronomical inertial frames, and for the effect of Earth's rotation, which provides a characteristic changing Doppler signature for narrowband signals of extraterrestrial origin. The total observing time was 9,000 hours. This represents nearly 1,600,000 independent spectra, among which we have found 10 candidate events.

INTRODUCTION

On October 12, 1990 we switched on the power to The Planetary Society (TPS) Instituto Argentino de Radioastronomía's project META II, an 8.4 million channel spectrum analyzer dedicated to search for extraterrestrial intelligence in the southern hemisphere. META II was built at Harvard University according to an agreement signed by TPS and IAR and approved by the National Research Council of Argentina (CONICET). It was installed at one of the two IAR 30-meter dishes in mid-1990. A similar system (META I) has been in operation since 1985 at the Harvard-Smithsonian 26-meter radio telescope at Agassiz Station. The IAR and Harvard systems have jointly surveyed the entire sky at 21 cm with similar resolution and sensitivity, looking for possible CW beacons of extraterrestrial origin.

THE META SYSTEM

META has been described in detail elsewhere (Horowitz *et al.* 1986). The main characteristics of the IAR system are the following: the radio telescope is a 30-meter parabolic reflector with an equatorial mount, but operates in a meridian transit mode for the SETI survey, being moved in declination by one half-power beamwidth every day (see Figure 1). It is in operation for 12 hours a day, while during the nights the same dish is used for conventional astronomy. The radio telescope can make a complete sky survey between ($-90^o \leq \delta \leq -10^o$) in a period of 500-700 days.

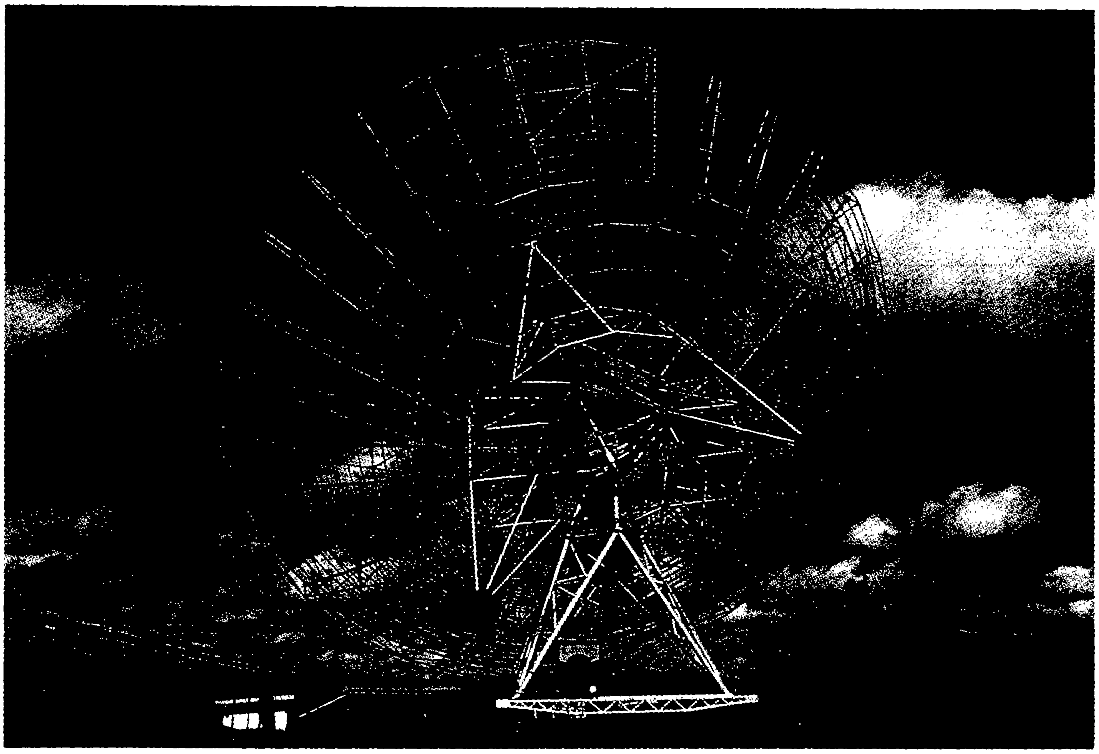

Figure 1. The Instituto Argentino de Radioastronomía's antenna No. 2 used for the search for extraterrestrial intelligence, near Buenos Aires, Argentina.

The primary feed is a corrugated horn; two orthogonal circular polarizations are obtained by mean of a turnstile junction. The first RF amplifiers are uncooled GaAs FETs, which are followed by bandpass image rejection filters. The first local oscillator (LO) is switched to receive signals at λ=21 cm referenced to the galactic barycenter, cosmic black body or LSR-heliocentric frames. The dual polarization receiver with programmable first LO, fixed second LO and swept third LO feeds a 128 point DFT implemented with an A41102 Austek Microsystems Frequency Domain Processor. It performs a multiplication between the baseband sampled signal and a selected window in the time domain. This constitutes a filter bank pre-processor for an array of 128 FFT of 64,000 points. The complex amplitudes that appear at any given DFT channel, considered as a time series, feed a corresponding ultra-narrowband array of 64,000 complex FFTs (128 in total) resulting in 8,388,608 channels covering 400 kHz.

The first IF is centered at 126.5 MHz and the second IF is centered at 30 MHz. Figure 2 shows the META II system. On-line software computes

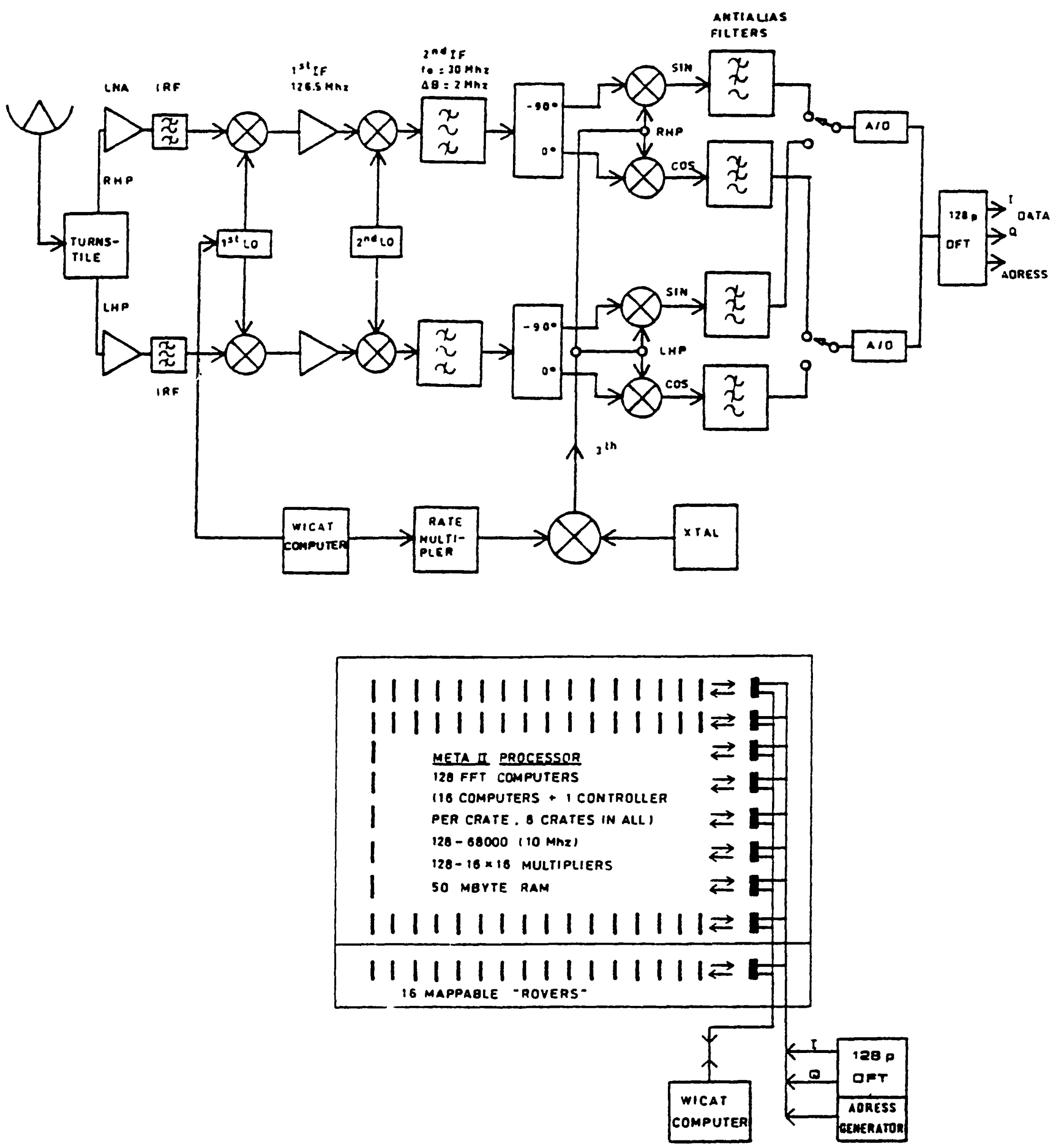

Figure 2. Block diagram of the 8.4 million channel narrowband analyzer (META II). The 128 point DFT processor is used as a preprocessor to divide the analyzer bandpass of 400 kHz into 128 contiguous baseband channels of 3.1 kHz bandwidth. An array of 128 identical processors then performs the megachannel power spectrum computation in 15 sec. An additional 16 mappable processors check the array and dynamically replace faulty processors. The array contains 50 megabytes of RAM, 16,384 blackplane pins, and half a million solder joints.

ephemeris information and controls the LO, i) setting the first LO and polarization switch at the beginning of each 20 second integration interval τ_i

($B\tau_i = 1$) such that the center of the received band corresponds to the chosen frequency as observed in the chosen reference frame, and ii) sweeping the third LO to compensate for the Doppler chirp caused by the Earth's rotation. The control computer also iii) orchestrates overall timing (frame buffering and initiation of Fourier transforms), iv) checks for processor errors using 16 redundant processors (1 million channels), v) examines the 8.4 million channel spectra for unusual signal features, and vi) archives numerical and graphical information connected with unusual signals or system malfunction.

The META strategy is to look for properly chirped narrowband signals at guessable rest frames. The chirp is necessary to compensate the Doppler shift produced by the Earth rotation and avoid spreading the signal over many channels. We use three rest frames of recognized universality: the Local Standard of Rest (LSR), the galactic barycenter, and the cosmic black body. Figure 3 shows the hardware system at the IAR's control room.

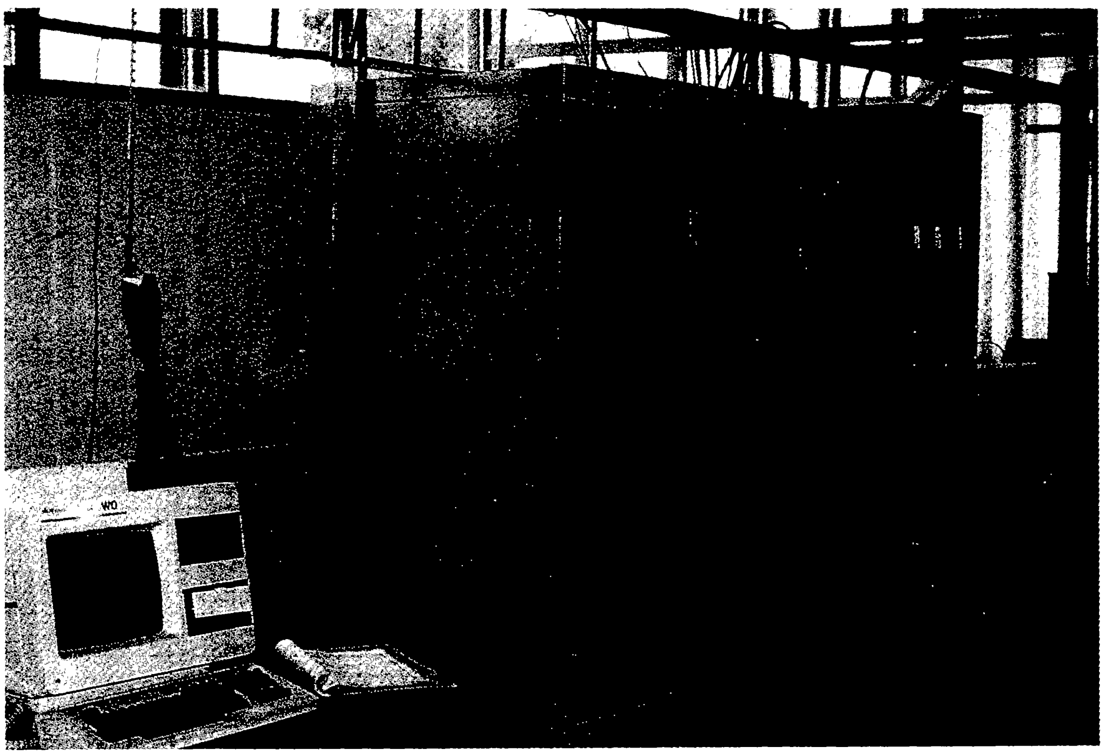

Figure 3. The META II system at the IAR's control room. The paneled rack holds the 144 processors comprising the 8.4-million-channel receiver. The control computer is to its left, with radio frequency hardware extending to the right of the picture.

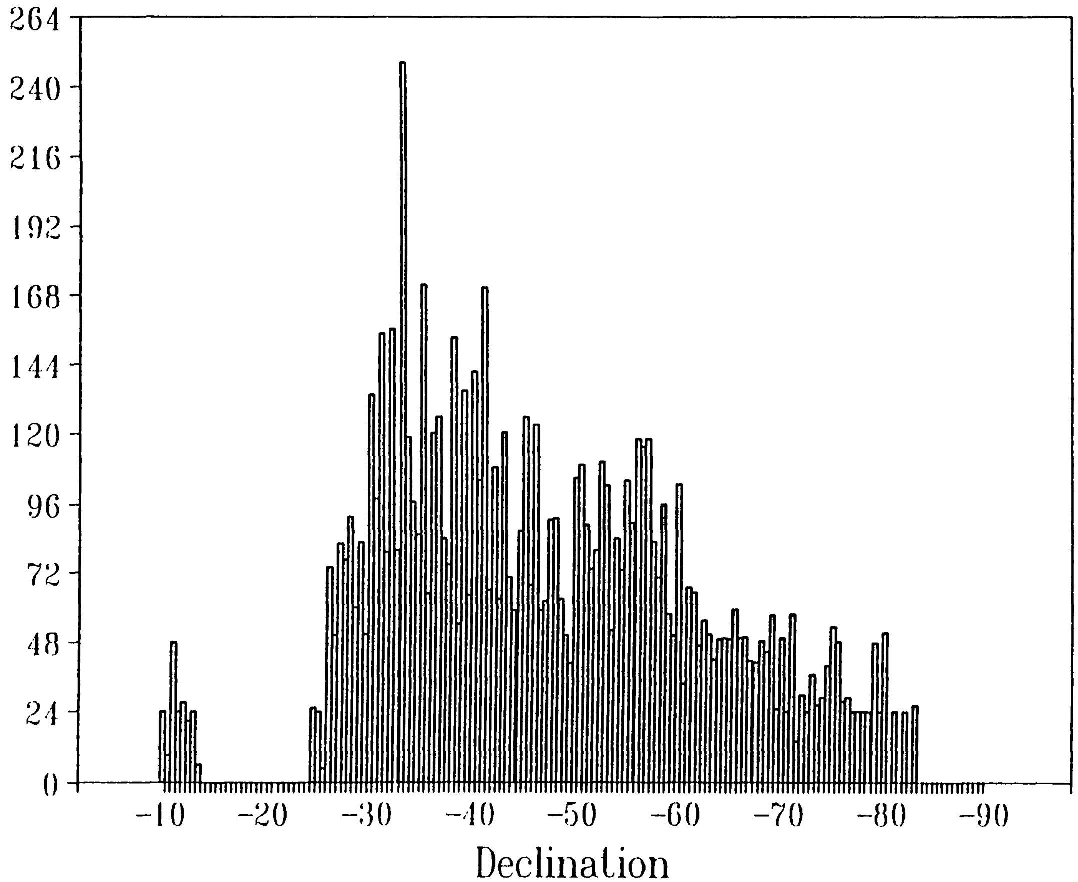

Figure 4. Total observing time as a function of the declination. Clearly the distribution increases for those declinations near the stowed position of the antenna. For high declinations the "chirp" oscillator is inefficient, while declinations between -10° and -30° were already observed by META I (Horowitz and Sagan 1993).

OBSERVATIONS

The META II system has operated successfully for more than two years and continues to operate normally, except for minor failures and some damage caused to the system by strong lightning storms, especially at the end of spring. We have covered the sky almost two times at 1,420 MHz and, for some declinations near the stowed position of the antenna ($\delta \cong -35^o$), four or more days were observed. Figure 4 shows the total observing time as a function of the declination. As a test to develop a common strategy, the declinations around -10° and -13° were observed simultaneously with META I.

The total observing time was 9,000 hours. This represents nearly 1,600,000 independent spectra, each consisting of 8.4 million channels. Only those profiles that exceed a preset threshold of 20.6 P_o (where P_o is the

Table 1. "Candidates" Detected by META II

Date	Frequency	System	P_0	R.A. (1950)	Dec (1950)
08.03.91	128.8	D	31.68	00:05:50	-34 43 48
12.11.91	-115.6	B	31.24	08:42:14	-39 51 00
29.08.92	85.9	d	28.72	08:59:05	-40 49 48
28.06.91	24.0	B	27.78	12:49:36	-46 46 12
09.09.91	26.2	e	30.76	14:01:17	-50 48 00
10.12.92	-30.4	d	29.68	14:33:26	-24 18 48
11.03.91	56.1	B	32.40	16:36:05	-30 25 12
05.07.91	63.5	E	30.74	21:02:33	-29 10 12
08.03.91	-80.6	E	31.26	21:11:14	-34 40 12
26.06.91	51.7	E	28.26	21:40:12	-37 11 24

Table 1. List of "candidates" detected by META II in 9,000 hours of observation of the southern hemisphere. In the first column we have the observing date, in the second the frequency in kHz, in the third the reference frame: (B)-Heliocenter-LSR, right polarization; (b)-Heliocenter-LSR, left polarization; (D)-Galactic barycenter, right polarization; (d)-Galactic barycenter, left polarization; (E)-Cosmic black body, right polarization and (e)-Cosmic black body, left polarization; in the fourth the peak intensity as a multiple of P_o; and in the last two columns we have the right ascension and the declination for the year 1950.

mean power per bin) were written onto disk. According to statistical analysis (Groth 1975) the normalized probability density of the power P in a frequency bin is $p(P) = (1/P_o)e^{-P/P_o}$, the probability of a power in a bin exceeding a threshold T times the mean is Probability $(P > TPo) = e^{-T}$. Thus for our daily harvest of $N = 3.3 \times 10^{10}$ independent frequency channels, the power in the largest will typically be $T = \ln N \cong 24$ times the mean power. These peaks are consistent with the statistics of random noise.

An exhaustive analysis of all the data was done among all the registered peaks over 23 P_o (about 4 events per day are expected according to the probability distribution for spectral power). A search for evidence of terrestrial interference signals (*e.g.*, point-to-point and TV stations, marching signals, local oscillators interferences, *etc.*) were carried out among all those peaks. Figure 5 shows the theoretical number of events as a function of the mean power per bin for 24 hours and 9,000 hours. All those signals that passed all our rejection criteria are also plotted in Figure 5. Only 10

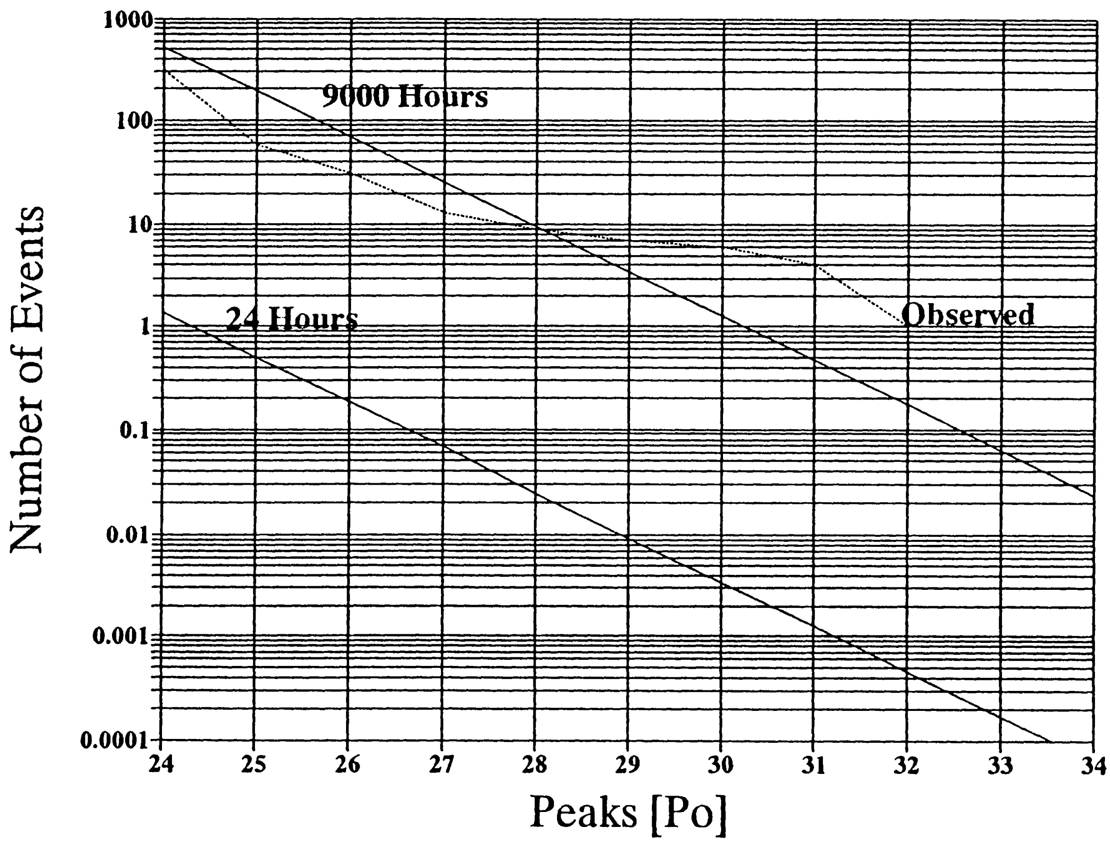

Figure 5. Theoretical and observational number of events as a function of the mean power per bin for 24 hours and 9,000 hours.

peaks above 28 P_o are over the theoretical expected value of events for the complete 9,000 hours set of data.

In Table I we have listed all these events. In each case we have a single channel peak (0.05 Hz), no instances of immediate re-detection were confirmed.

The observations were stopped in March, 1993 due to a serious interference problem caused by several (point-to-point) stations that are transmitting in the allowed band (from 1,428 to 1,550 MHz). These transmitters, primarily located at about 50 km, are saturating our receiver. Different filters for the HI line were tested and we have already begun to re-observe these candidate sources, in a tracking mode, to confirm their existence.

During the META I and II programs, the full sky was observed at 21 cm for the first time to search for ultra-narrowband signals. During the first 9,000 hours of observations, META II detected 10 "alerts" that have the expected characteristics for an ETI signal (strong, ultra-narrow, inband), none of which were observed in the immediate re-observation (2 minutes) and during a second re-observation in a transit mode. Horowitz and Sagan (1993) reported that, in a period of five years, META I has detected spectral peaks with similiar characteristics (14 peaks at 21 cm and 23 peaks at

10.5 cm). We cannot claim that these signals are of extraterrestrial intelligent origin, but if this is the case, we are still faced with the problem of their origin.

ACKNOWLEDGEMENTS

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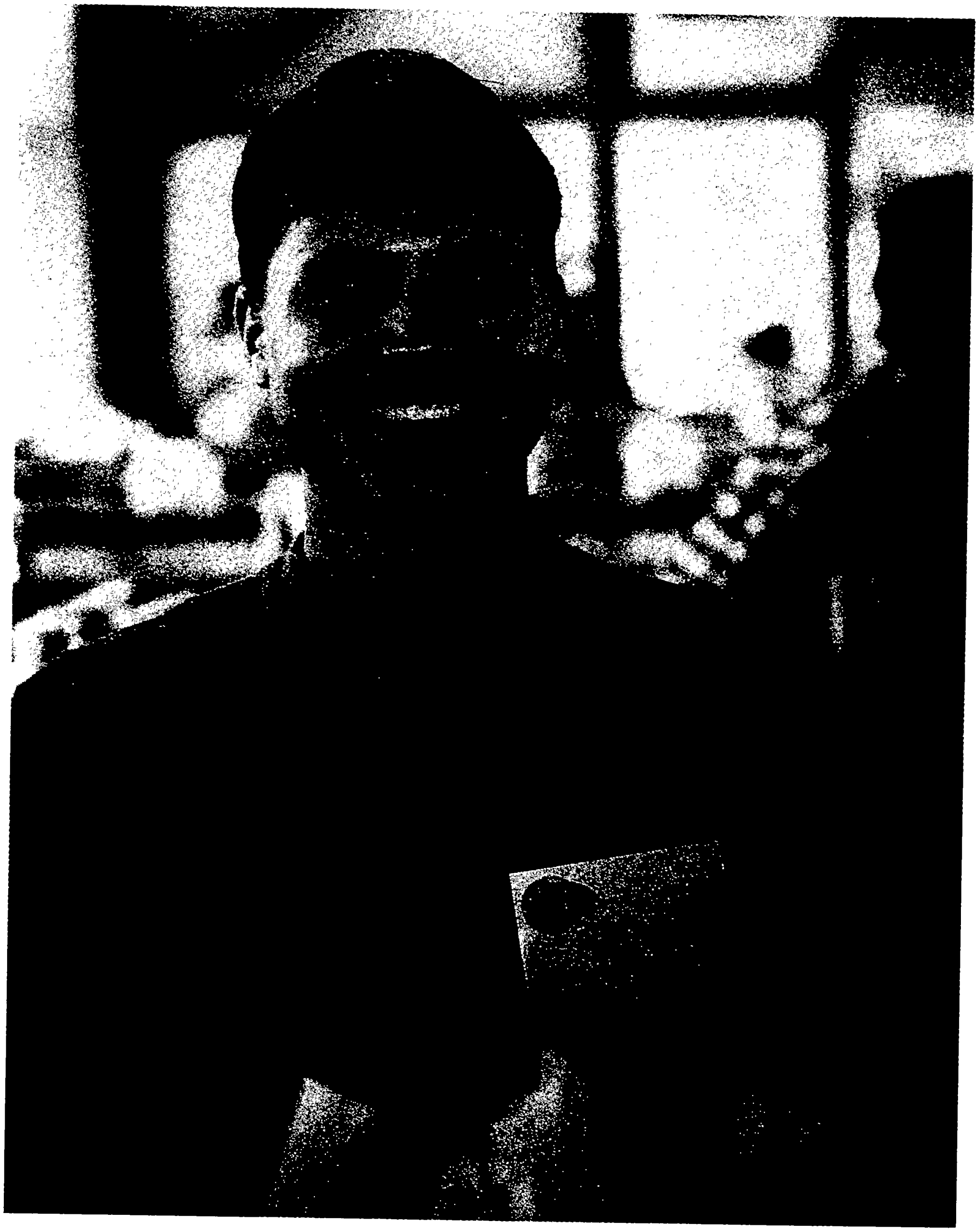
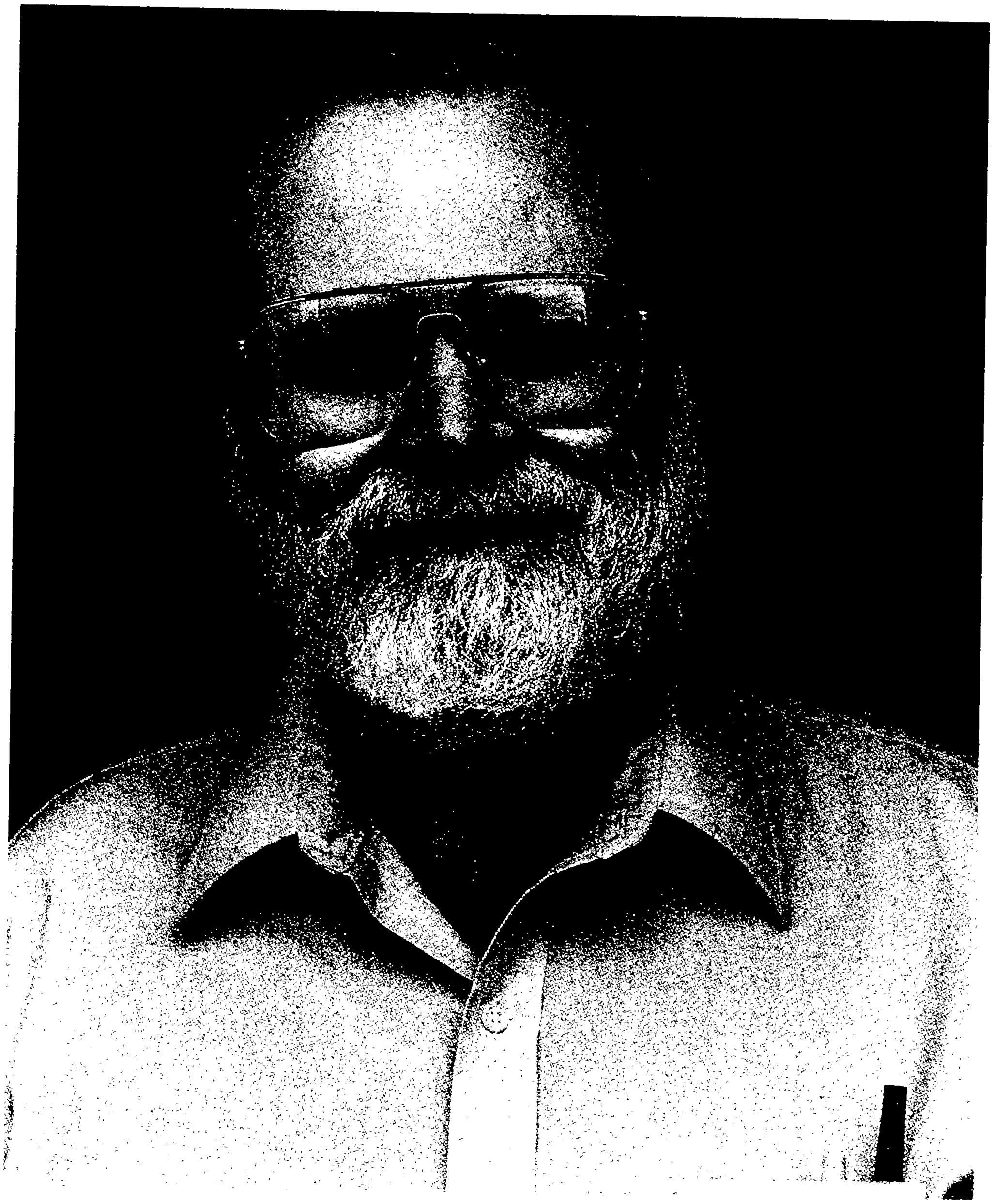


Darren Williams feigns delight in the cafeteria.



Bob Dixon argues for Argus.