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Megachannel Extraterrestrial Assay Candidates: No Transmissions from Intrinsically Steady Sources

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Abstract. This paper reports new, more sensitive observations of nine of the eleven extrastatistical signals in the Megachannel Extraterrestrial Assay (META). These extrastatistical signals had all of the expected characteristics of extraterrestrial transmissions, except that they did not repeat. Cordes, Lazio, & Sagan (1997) showed that this lack of repeatability could be explained by interstellar scintillation of intrinsically steady sources. We use their methodology and our observations to exclude the scintillation hypothesis at a confidence level of at least 97.8% (for the case of an intrinsically weak source) to a level in excess of 99% (if the source strengths are comparable to that favored by Cordes, Lazio, & Sagan 1997). We also demonstrate that gravitational microlensing cannot account for the initial detection of these candidates nor is microlensing likely to play a role in future SETI programs. We conclude that the META candidates do not reflect a large population of powerful beacons.

1. Introduction

Various searches for extraterrestrial intelligence (SETI) have found signals having all of the expected characteristics of hypothesized ET transmissions, except one: the candidate signals do not repeat during follow-up observations. By contrast it is easy to imagine that received signals might be intermittent. Cordes, Lazio, & Sagan (1997, hereinafter CLS97) analyzed the impact of one cause of signal intermittency—natural, extrinsic modulation of ETI sources—on SETI surveys, with an emphasis on interstellar scintillation (ISS), motivated by the following considerations. First, it is a simple, testable mechanism for producing transients from otherwise steady signals. Second, ISS is important at centimeter wavelengths, which are used commonly in SETI surveys.

CLS97 showed that ISS *by itself* is sufficient to explain the lack of confirmation of ETI candidates in surveys. They also predicted the sensitivities required to rule out the ISS modulation hypothesis.

We have obtained new observations of nine of the eleven candidates from the Megachannel Extraterrestrial Assay (META, Horowitz & Sagan 1993, hereinafter HS93). Here, we summarize the META candidates and demonstrate that neither ISS nor gravitational microlensing explains the non-repeatability of these candidates (see also Lazio, Tarter, & Backus 2002, hereinafter LTB02).

2. The Extrastatistical META Candidates

META conducted three northern sky surveys at the frequency 1420 MHz and two at 2840 MHz. At each sky position observed, two polarizations were searched in each of three reference frames—the Local Standard of Rest, the Galactic barycenter, and the cosmic microwave background. Of the roughly 6×10^{13} observations acquired, eleven could not be explained as due to either noise or processor failure. HS93 identified these eleven extrastatistical signals, four at 1420 MHz and seven at 2840 MHz, as candidate ETI transmissions.

During the surveys, the online software could halt the observations and acquire reobservations on "interesting" signals within 40 s of detection. In no case was a candidate reacquired. Additional, unsuccessful followup observations were conducted over the five-year META.

With the exception of the lack of reobservation, the candidates had all of the characteristics expected of ETI transmissions: narrowband signals in a celestial reference frame. The eleven extrastatistical candidates were also at low Galactic latitudes, consistent with that expected for a Galactic population.

3. Observations

We observed nine of the eleven META candidates as part of Project Phoenix (Cullers 2000). Coordinated observations were conducted with the 43 m (140 ft) NRAO telescope at Green Bank, WV, and a 30 m telescope in Woodbury, GA. Initial observations were conducted with the NRAO telescope, and signals passing a power threshold were reobserved subsequently with lower thresholds at both telescopes. A signal had to be detected at both telescopes with the correct Doppler offsets in order to be considered a celestial signal.

The (1σ) sensitivity was 1.4×10^{-27} W m^{-2}, and the initial detection threshold for the NRAO telescope was 7σ. For comparison the typical META sensitivity (1σ) was 5.7×10^{-25} W m^{-2}, and the threshold for the extrastatistical candidates (§2.) was 31.7σ.

CLS97 normalized intensities to the mean noise level $\langle N\rangle$ in the META spectrometer. Thus, the various observational thresholds become $\eta = I/\langle N\rangle = 31.7$ for META, $\eta = 0.018$ for the NRAO telescope, and $\eta = 0.0045$ for the telescope at Woodbury. An important quantity is the dynamic range between the initial candidate detection level η_1 and the subsequent reobservation threshold η_T. For our observations, $\eta_1/\eta_T \sim 10^3$, whereas $\eta_1/\eta_T \sim 2$ for the META reobservations.

4. Interstellar Scintillation

Compact sources observed at centimeter wavelengths (e.g., pulsars) scintillate. The signal from an intrinsically steady, distant source of flux density S will have an observed flux density of gS. The probability density function of the ISS gain is $p(g) = e^{-g}$, with $g \geq 0$. Cordes & Lazio (1991) and CLS97 emphasized that ISS can render an otherwise undetectable signal detectable, but as the most probable gain is $g = 0$, ISS will more likely render a signal undetectable.

CLS97 showed that the META candidates could be explained as rare combinations of a gain $g > 1$ *and* a noise spike. ISS has a decorrelation time scale of minutes to days. The spectrometer noise decorrelated in the time required to compute a fast Fourier transform ($\simeq 20$ s). The failure of the immediate reobservations to detect a candidate could be understood as due to a reobservation threshold that was too high coupled with the noise decorrelating; later reobservations had the additional complication that the ISS gain had also decorrelated.

CLS97 quantified the probability of redetecting a source with the conditional probability $P_{2\mathrm{d}}(\eta_T|\eta_1;\zeta,\rho)$ (see also LTB02). Here a source of intrinsic strength $\zeta \equiv S/\langle N\rangle$ is detected initially at a level η_1. At a later time, for which the ISS gain correlation coefficient is ρ ($0 \leq \rho \leq 1$), the source is reobserved with a reobservation detection threshold of η_T.

Should we have redetected the META candidates? We consider first our coincidence detection procedure. The initial observation threshold is that of the NRAO telescope, $\eta'_1 = 0.018$, and the reobservation threshold is that of the telescope at Woodbury, $\eta'_T = 0.0045$. If the ISS is uncorrelated completely, $\rho = 0$, then $P_{2\mathrm{d}}(\eta_T|\eta_1;\zeta,\rho = 0) = e^{-\eta_T/(1+\zeta)}$. In order to explain the META candidates as scintillating sources, CLS97 also found that $\zeta \sim 3$. Thus, $P_{2\mathrm{d}}^{(P)}(\eta'_T|\eta'_1;\zeta \sim 3,\rho = 0) \simeq 0.999$. A similar result occurs for $\rho = 1$. A *lower* limit to the detection probability is obtained by setting $\zeta = 0$ (i.e., no source is present!) for which $P_{2\mathrm{d}}^{(P)} \geq 0.996$.

For the META reobservations (10 yr later), the reobservation threshold is that of the NRAO telescope, $\eta_T = 0.018$. Thus, $P_{2\mathrm{d}}^{(M)}(\eta_T|\eta_1;\zeta \sim 3,\rho = 0) = 0.996$, and the lower limit is $P_{2\mathrm{d}}^{(M)} \geq 0.982$.

The overall probability of detection is $P_{2\mathrm{d}} = P_{2\mathrm{d}}^{(P)}P_{2\mathrm{d}}^{(M)}$. The strict lower limit to the overall redetection probability ($\zeta = 0$) is 97.8%, while it is in excess of 99.5% for a source strength comparable to that estimated by CLS97.

5. Gravitational Microlensing

Gravitational microlensing has been detected toward stars along a number of lines of sight (e.g., Udalski et al 1994; Alcock et al. 1995; Ansari et al. 1996). In this scenario, the continuous transmissions of an ETI transmitter are amplified briefly by a foreground object passing close to the line of sight. This scenario was not covered by CLS97.

The requisite microlensing amplifications are $A \sim 100$. Like ISS, the decorrelation time of microlensing is much longer than the time for the immediate reobservations to occur, so the noise in the META spectrometer would have played a key role in the initial detections. Thus, microlensing need not account for the full dynamic range η_1/η_T.

The probability for the microlensing amplification to exceed a value $A_0 \gg 1$ is $P_{\mathrm{gl}}(A > A_0) \simeq \tau A_0^{-2}$, where τ is the microlensing optical depth (Paczyński 1986). Toward the inner Galaxy, $\tau < 10^{-6}$ (Kiraga & Paczyński 1994).

If $A_0 \sim 100$, then $P_{\rm gl}(A > A_0) \sim 10^{-10}$. On average, in order to obtain an amplification as large as A_0, the number of ETI transmitters must be $NP_{\rm gl} \sim 1$ or $N \sim 10^{10}$. HS93 estimate that if all of the META candidates represent real signals, the Galactic population of transmitters is roughly 2×10^6. The number of candidates is insufficient, by orders of magnitude, for them to be explained as microlensed transmitters.

In order for microlensing to be important, the number of transmitters within the inner Galaxy must be $N \sim \tau^{-1} \sim 10^6$. Equivalently, the average distance between transmitters must be roughly 0.6 pc. Given that programs such as the SETI Institute's Project Phoenix have not detected any transmissions from nearby stars, this surface density is far higher than the actual surface density. Gravitational microlensing is unlikely to play an important role in modulating signals from ETI transmitters within the Galaxy.

6. The Number of Civilizations

HS93 derived limits on various populations of transmitters. These limits can be revisited in light of our results: There is no more than 1 Kardashev Type II civilization broadcasting isotropically near the H I line or its second harmonic within the nearest 10^3 galaxies. There are no more than 10^4 Kardashev Type I civilizations broadcasting isotropically within the Galaxy and no more than 1 such civilization with a transmitter having a 30 dB gain. More stringent limits on weaker transmissions will have to await future surveys.

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References

Alcock, C., et al. 1995, ApJ, 445, 133

Ansari, R., et al. 1996, A&A, 314, 94

Cordes, J. M., Lazio, T. J. W., & Sagan, C. 1997, ApJ, 487, 782

Cordes, J. M., & Lazio, T. J. 1991, ApJ, 376, 123

Cullers, K. 2000, in ASP Conf. Ser. 213, Bioastronomy '99: A New Era in the Search for Life, ed. G. Lemarchand & K. Meech, 451

Horowitz, P., & Sagan, C. 1993, ApJ, 415, 218

Kiraga, M., & Paczyński, B. 1994, ApJ, 430, L101

Lazio, T. J. W., Tarter, J., & Backus, P. 2002, AJ, 124, 560

Paczyński, B. 1986, ApJ, 304, 1

Udalski, D., Szymanski, M., Kaluzny, J., Kubick, M., Mateo, M., & Krzeminski, W. 1994, ApJ, 426, L69