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A SEARCH FOR ARTIFICIAL SIGNALS FROM THE SMALL MAGELLANIC CLOUD

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ABSTRACT

We have used the Parkes radio telescope to observe three fields in the Small Magellanic Cloud encompassing $> 10^7$ stars, looking for signals that could be ascribed to extraterrestrial intelligence. No narrow-band (≤ 1 Hz) continuous or slowly-pulsed emissions greater than ≈ 19 Jy were detected in the observed spectral band of 1.2–1.75 GHz. This limit corresponds to a transmitter power of $\approx 5 \times 10^5$ MW for a 100 m antenna at the distance of the SMC (EIRP of $\approx 1.5\ 10^{12}$ MW). © *1996 American Astronomical Society.*

1. INTRODUCTION

Until now, radio experiments in the search for extraterrestrial intelligence (SETI) have principally differed in the degree to which they explore the two major parameter domains: spectral and spatial. Projects META (McDonough 1995), SERENDIP (Werthimer *et al.* 1995, Donnelly *et al.* 1995), and the Ohio State SETI Program (Dixon 1985) survey large fractions of the celestial sphere, but sample relatively small sections of the microwave spectrum.

By contrast, the recently launched Project Phoenix, descendant of the Targeted Search component of NASA's High Resolution Microwave Survey, has wide frequency coverage (1.2–3.0 GHz) and high spectral resolution (1 Hz), but restricts spatial sampling to approximately one thousand nearby stellar systems.

Distinctions in the extent of radio spectral domain sampling of SETI experiments will slowly disappear. Rapid growth in the speed and functionality of microelectronics should allow every major search to undertake broad and detailed spectral measurements. However, while "backend" costs are dropping, the cost of additional collecting area is not. Consequently, the principal discriminant among SETI experiments will be their strategy for spatial sampling. The breadth of possibilities is enormous; a complete scrutiny of the Galaxy encompasses 10^8 as many stellar targets as the Project Phoenix search. To date, no other observational parameter, whether it be signal type, antenna area, or integration time, has approached this range of variation.

We report here a preliminary SETI survey of the Small Magellanic Cloud (SMC). We believe that this object is a felicitous choice between the extremes of a small, targeted sample and broad surveys such as all-sky searches, galactic plane scans (Sullivan & Mighell 1984), or observations of large, but distant galaxies (Sagan and Drake 1974). While the number of star systems surveyed is substantial ($> 10^7$), the distance to the SMC is only 0.1 times that to the Galaxy's principal companion spiral, M31. Additionally, we suggest that both the SMC's geometry and adjacency to the Galaxy argue for a greater-than-random chance that transmissions from the Cloud would be aimed in our direction.

2. OBSERVATIONS

Observations of three fields in the SMC were made on 1995 June 8 and 9, using the Parkes 64 m radio telescope. The beamwidth of this instrument is 14 arcmin (FWHP) at 21 cm. The fields, listed in Table 1, were chosen on the basis of high stellar density as judged from optical photographs. An additional criterion, applied to the third field listed, was the presence of a double-peaked profile in the observed H I (Hindman *et al.* 1963). This could indicate two regions of high stellar density along our line of sight, a circumstance that might encourage high-powered communications within the SMC, half of which would be beamed in our general direction.

This experiment took place during the cooperative science period offered the astronomical community following four months of observing for Project Phoenix. Consequently, the microwave and spectral analysis systems used here were identical to that for Phoenix (Backus 1996; Dreher 1996). In brief, the spectrometer consisted of two identical, 10 MHz-wide, dual-polarization spectrum analyzers. Each analyzer

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1996AJ....112..164S

TABLE 1. Observations of the Small Magellanic Cloud, 1995.

Date	α (J2000)	δ (J2000)	Frequency range (MHz)
June 8	$0^h51^m45.5^s$	-72° 53′ 42.0″	1200-1540, 1640-1750
June 9	$0^h50^m52.92^s$	-73° 01′ 50.6″	1200-1562
June 9	$0^h45^m55.0^s$	-73° 06′ 48.0″	1200-1400, 1420-1500, 1520-1540

divided this bandwidth into 14,370,048 channels per polarization. Channel separation was 0.696 Hz, and equivalent channel width was 1.0 Hz. As the two analyzers were placed "end to end," the result was a 28 million channel, dual-polarization receiver with an instantaneous bandwidth coverage of 20 MHz. The system temperature was 30 K.

Note that the frequency gaps above 1500 MHz evident in Table 1 are spectral regions where terrestrial interference was so vigorous that meaningful observations could not be obtained.

The Phoenix signal analysis systems operate in near-real time to find either continuous (or rapidly pulsed) emissions, or slowly pulsing signals (periods $\geqslant$ 2 s) that stand out above the noise. The systems can accommodate signal frequency drifts of up to $\approx \pm$ 1 Hz s^{-1}, which should be adequate to encompass the changing Doppler shift from a transmitter on a rotating planet. The current software limited the maximum integration time to 138 s. Due to the manner in which data were taken and analyzed, coherent summation of multiple integrations was not possible. Consequently, each 138 s integration had to be regarded as a separate observation. Longer coherent data summation times will clearly be important in future efforts to achieve higher sensitivity.

Thresholds were set so that, typically, the 2 or 3 strongest signals in the 20 MHz band were reported for each integration. A continually updated database of known terrestrial signals was kept in order that detections of known satellites and ground-based transmitters would not be reported. The candidate signals were sent to a special subsystem known as a Follow Up Detection Device (FUDD). The FUDD reobserved up to 16 candidate signals with the Parkes antenna to accurately characterize their frequencies, drift rates, and (if appropriate) pulse periods. This information was used to enable a confirming observation by the 22 m diameter Mopra antenna located 200 km northeast of Parkes. The precise specification of the signal, and consequent optimization of receiver parameters, compensates for the smaller collecting area of the Mopra telescope. In the event that a candidate signal was also detected by the Mopra instrument and exhibited the differential Doppler shift expected of a sidereal source, the observer would be notified by audible alarms.

Such "extraterrestrial candidates" were found in non-interference bands three times during this search. Our procedure was to immediately observe off source in case of such detections. Candidates still present in the off-source integration could be discarded as terrestrial interference. Candidates that were not found off-source prompted a series of new on-source observations.

In view of the possibility that a galaxy-wide (Doppler-corrected) beacon frequency might be in use within the Cloud, the off-source positions were chosen to be beyond the limits of this galaxy.

On the basis of this on-off procedure, none of the FUDD candidates (those confirmed by Mopra) proved to be extraterrestrial, and consequently no persistent signals greater than 19 Jy were found within the range of frequencies listed in Table 1. (Note that this sensitivity level was established pragmatically such that an on-off confirmation would be required only once in thirty observations.)

3. DISCUSSION

Our strategy in observing the SMC was to maximize the number of stellar targets while still being able to detect transmitters that do not require enormous energy sources. The former intention derives from a simple consideration: only systems within $\approx$25 light-years have had both reason and time to deliberately beam signals our way. Farther systems are only now receiving evidence of terrestrial radio technology, or will do so in the future. The probability that we are *by chance* in the beam of an interstellar transmission is small, $< 10^{-6}$ for an extraterrestrial transmitter affixed to a 100 m antenna, and is only ameliorated if isotropic beacons of large power exist or we are being targeted. This sobering thought encourages a SETI strategy in which very large numbers of stars are examined.

The SMC has optical dimensions 5°.3 × 3°.1 and color index $(B-V)=0.45$ (de Vaucouleurs *et al.* 1991). The mean surface brightness is 14.77 mag $arcmin^{-2}$, corresponding to an average luminosity of 5.5 10^5 $L_\odot$ $beam^{-1}$. However, as our search fields were chosen in the optically brighter regions of the cloud, we estimate the luminous mass in our sampled fields to be $\geqslant 10^7$ stars $beam^{-1}$.

Large stellar samples clearly increase the probability that we would, by chance, intercept an alien transmission. Additionally, some evidence suggests that the SMC is a prolate spheroid oriented nearly end-on towards us (Feast 1989). In this case, we might expect powerful interstellar transmitters to be preferentially aimed along this axis, and in our direction. Similar reasoning led us to choose one field (the third listed in Table 1) exhibiting a double-peaked H I profile, as this may indicate the presence of two stellar concentrations in our line of sight.

Another consideration favoring the SMC as a SETI target is the possibility that some Cloud inhabitants may be exchanging transmissions with civilizations in the Galaxy. As seen from the SMC, the Milky Way Galaxy subtends $\approx$ 15° × 20°, a large and obvious target. A 100 m antenna at the distance of the SMC, operating at 1.4 GHz, would illuminate $\approx 2\times10^6$ Galaxy stars (of all types). If among this relatively large number there exists a galactic civilization that has made itself known to the SMC, we would be in the beam of the SMC's response. Once again, this situation increases the likelihood of picking up a signal not deliberately targeted at Earth.

At a distance of 58 kpc (=188,000 light-years, Westerlund 1991), the SMC is 10^3 times farther than the most distant stellar targets examined by Project Phoenix. Consequently, the power requirements for detectable transmitters

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1996AJ....112..164S

are 10^6 times greater, or $\approx 1.5\times 10^{12}$ MW EIRP (Effective Isotropic Radiated Power), based on our flux density limit. Note that this is equivalent to an $\approx 5\ 10^5$ MW transmitter assuming an extraterrestrial antenna system having a total surface area equivalent to a 100 m diameter dish. This exceeds by about four orders of magnitude the peak power generated by contemporary terrestrial radars, and is obviously substantial. Nonetheless, it is $< 10^{-5}$ the solar flux on a terrestrial-sized planet, and $< 10^{-14}$ the energy output of a solar-type star.

Large phased arrays would lower the transmitter power required of detectable extraterrestrials but also, unfortunately, the chances of being in their beam.

4. CONCLUSIONS

We have examined three fields in the SMC, or $> 10^7$ stars, over the frequency range 1.2–1.75 GHz. No narrowband ($\leq$ 1 Hz) extraterrestrial signals greater than 19 Jy were found.

Despite our failure to uncover evidence for a sentient presence in the Cloud, we suggest that the approach taken in this preliminary experiment is worth future elaboration. In contrast to Project Phoenix's targeted search, our experiment traded a factor of 10^6 in detectable transmitter power for a nearly 10^6 gain in the number of stars examined. As a point of comparison, had our total observing time been comparable to that of Project Phoenix, our achieved sensitivity relative to the present search would have been greater by a factor of 2 or 3, while the number of stars examined could have been increased by an order of magnitude.

Creating a star system with a technological civilization requires a clement environment and billions of years. Such sites may be rare. But once technology has arisen, a million-fold gain in transmitter power is apparently not difficult. On Earth, this improvement has taken no more than a century. In view of this, we believe that a strategy of trading sensitivity for targets merits continued consideration.

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REFERENCES

Backus, P. 1996, Acta Astron. (in press)
Dixon, R. S. 1985, in The Search for Extraterrestrial Life: Recent Developments, edited by M. D. Papagiannis and D. Reidel (Dordrecht), p. 305
Donnelly, C., & Werthimer, D. 1995, in Progress in the Search for Extraterrestrial Life, edited by G. S. Shostak, ASP Conf. Series, 74, 293
Dreher, J. 1996, Acta Astron. (in press)
Feast, M. W. 1989, in Recent Developments of Magellanic Cloud Research, edited by K. S. de Boer, F. Spite, and G. Stasinska, A European Colloquium, Paris, 75
Hindman, J. V., Kerr, F. J., & McGee, R. X. 1963, Austr. J. Phys., 16, 570
McDonough, T. R. 1995, in Progress in the Search for Extraterrestrial Life, edited by G. S. Shostak, ASP Conf. Series, 74, 419
Sagan, C., & Drake, F. 1974, Sci. Am. 232, 80
Sullivan III, W. T., & Mighell, K. J. 1984, Icarus, 60, 675
Werthimer, D., Ng, D., Bowyer, S., & Donnelly, C. 1995, in Progress in the Search for Extraterrestrial Life, edited by G. S. Shostak, ASP Conf. Series, 74, 293
Westerlund, B. E. 1991, in The Magellanic Clouds, edited by R. Haynes and D. Milne, IAU Symp. 148 (Kluwer, Dordrecht)
Vaucouleurs, G. de, Vaucouleurs, A. de, Corwin, Jr., H. G., Buta, R. J., Paturel, G., & Fouque', P. 1991, Third Reference Catalogue of Bright Galaxies, (Springer, New York)

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