A 1.1 to 1.9 GHz SETI Raster Scan of the Kepler Field: A Machine-Learned Search for Narrow-band Emission. I. Shivvers[1], A. Siemion[1] and D. Werthimer[1], [1]University of California at Berkeley, Dept. of Astronomy and the Berkeley SETI Research Center.

Introduction: We present the data reduction process, current progress, and initial analysis of a search for narrow-band signals (width < 5 Hz) of extraterrestrial origin arising from the Kepler field. Remarkable technological advances over the last century have given researches new insights into the fundamental question of all SETI research: namely, whether something like life occurs anywhere other than Earth. We now know that Earth-like planets are not rare in our galaxy [1;2], that there is a great diversity in the properties of planets and that many different types of planets may have liquid water on the surface [3], and that the fundamental building blocks of life (i.e. complex organic molecules) are present throughout the local galaxy [4]. In the near future we'll be able to directly image (and take spectra of) select exoplanets (e.g. the Gemini Planet Imager; [5]). The search of our galaxy for electromagnetic signals created by an intelligent, technologically advanced civilization is a complementary endeavor, and we aim, through this study and others like it, to place limits on the number of intelligent and communicative extraterrestrial civilizations within the technical limitations of our experiment, acknowledging that we are probing only a very small subset of the parameter space open to us as SETI explorers.

Experiment Overview: In early 2011 we performed a raster scan of the entire Kepler field using the Robert C. Byrd Green Bank Telescope (GBT) and the Green Bank Ultimate Pulsar Processor (GUPPI) instrument, covering a wavelength range of 1.1 - 1.9 GHz, saving coarsely channelized baseband voltage data for offline reduction and analysis. This produces a multi-terabyte dataset and requires a sophisticated set of modern computing resources and codes. Our data reduction pipeline makes use of many-core GPU machines as well as parallel CPU techniques, and we use machine-learning techniques to identify sources of interest and to understand the pernicious radio-frequency interference from terrestrial sources that contaminates any radio SETI effort. The procedures and results of a companion study with the same instrument, a targeted search for narrow-band signals from 86 Kepler stars hosting confirmed planets, was recently published (no extraterrestrial signals were found)[6].

Early Results: Analysis is ongoing, and our discussion here is extremely preliminary. First, as an overall check of our pipeline, we've produced a map of neutral hydrogen in the field: Figure 1 shows a comparison between our data and the published Leiden/Argentine/Bonn (LAB) survey data [7].

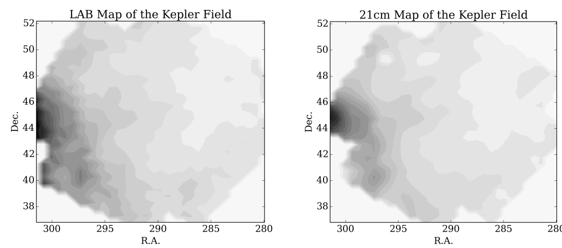

Figure 1: The H I map produced by our pipeline is in very good agreement with the LAB data.

At the time of this submission, our pipeline has discovered ~9x10^7 sources at the $\sigma \geq 10$ level. 95% of these were immediately identified as terrestrial RFI by our code and ignored, while the remaining 5% are saved for further inspection. A few examples of signals passing our first-pass RFI rejection routine are shown in Figure 2. For each candidate signal, we extract a set of ~20 features characterizing its properties and perform a Local Outlier Factor [8] search for unique signals, and we independently search for clustering indicative of signals of extraterrestrial origin. Full details to be published in forthcoming paper.

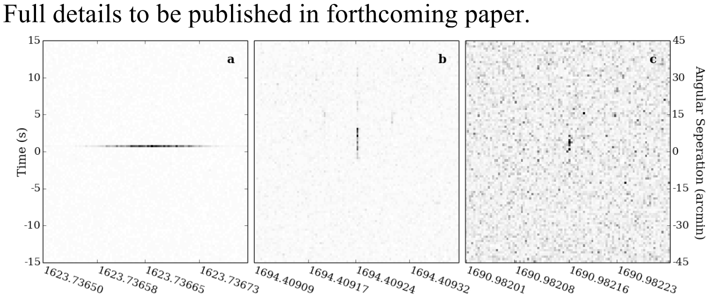

Figure 2: Waterfall plots of candidate signals.

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