Machine Learning Searches for ISM-Scintillated Technosignatures

Bryan Brzycki[1], Andrew Siemion[1,2,3,4]

[1]UC Berkeley, [2]SETI Institute, [3]Radboud University, [4]University of Malta

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The Search for Technosignatures

- The search for extraterrestrial intelligence (SETI) is primarily focused on searching for technosignatures, evidence of alien technology
- We search for technosignatures using radio observations for multiple reasons:
  - The assumption that alien civilizations also use radio transmissions for communication or other reasons
  - Radio frequencies pass through interstellar and intergalactic space and through Earth's atmosphere easily
  - We can use existing radio telescopes to search for artificial sources, just as we do for natural astrophysical sources
- Narrowband signals are distinguishable from natural signals, and extrasolar narrowband signals would be localized to a single position in the sky and potentially Doppler accelerated

Interstellar Scintillation and Narrowband Signals

- The brightness of radio signals coming towards us from space fluctuates, or scintillates, according to the material it passes through in the interstellar medium (ISM)
- In the direction of the galactic center, we have the highest scattering and the lowest scintillation timescales, of about 2-4 seconds
- If we can detect this characteristic scintillation in a narrowband signal, it would be compelling evidence that the signal passed through the interstellar and interplanetary media and therefore came from outside the solar system!

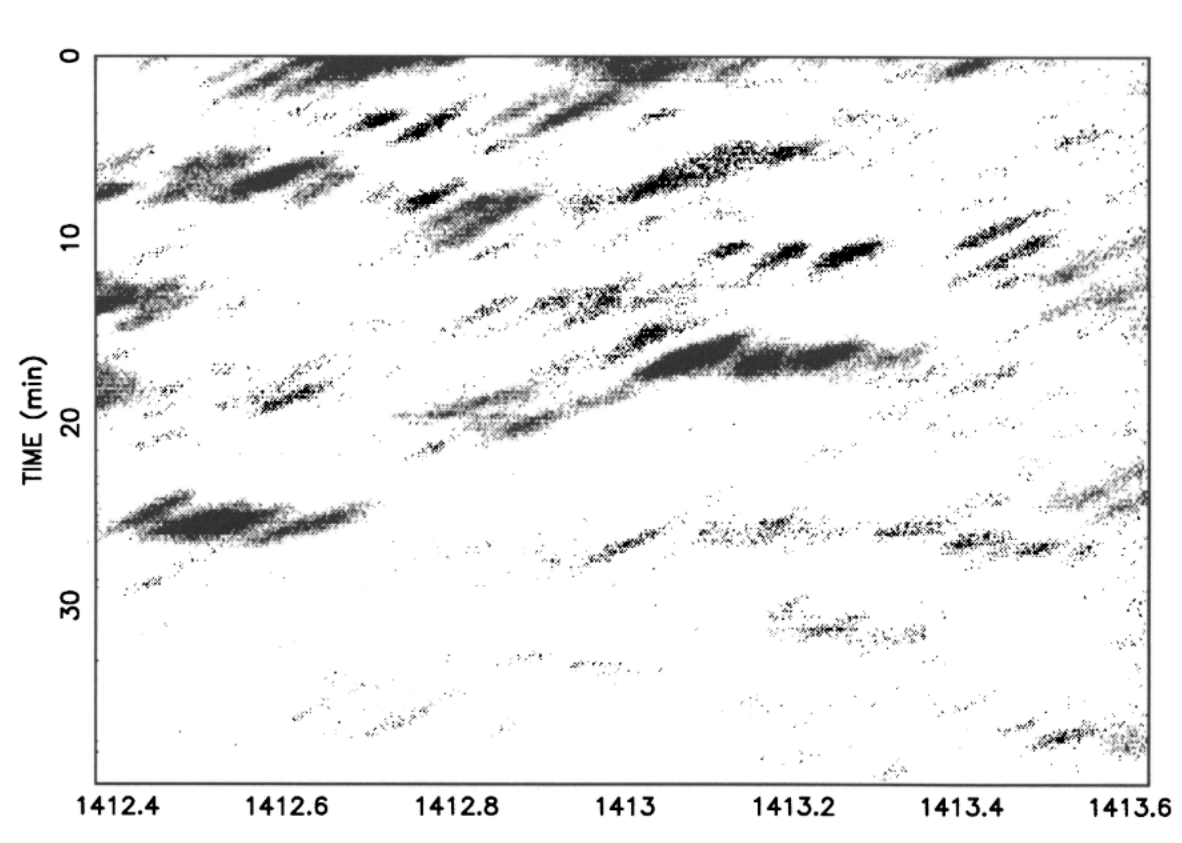

Figure 1. Dynamic spectrum of pulsar PSR 1933+16, showing scintillation from multipath propagation through the ISM. Flux ranges from -0.2 to 0.6 Jy (Cordes & Lazio 1991).

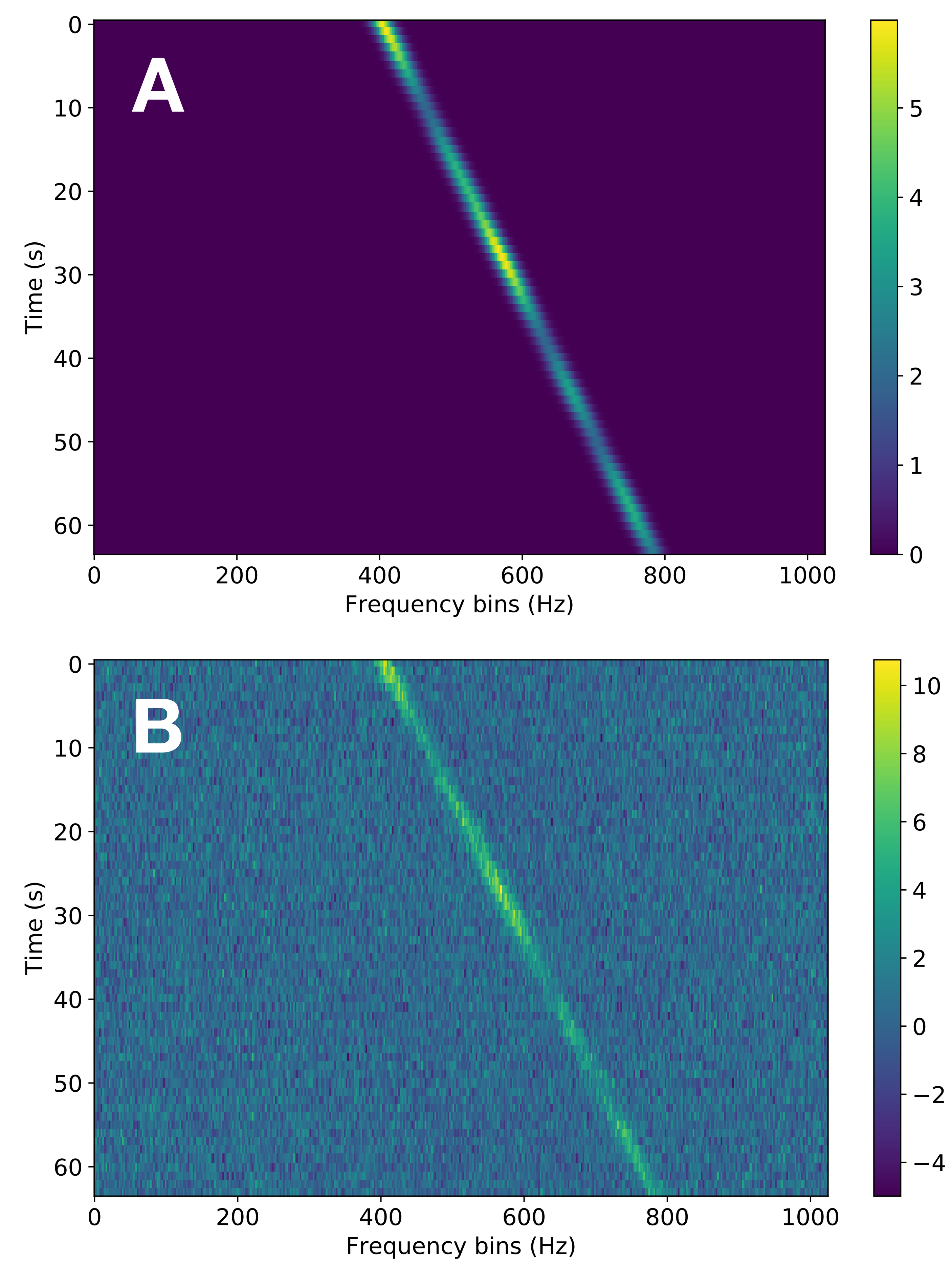

Figure 2. Synthetic narrowband signal created with Setigen. Panel A is the clean signal, and panel B is normalized by frequency with Gaussian noise. The signal has a Doppler drift rate of 6 Hz/s, a width of 10 Hz, and a scintillation timescale of 3 s.

Using Machine Learning to Detect Scintillation

- Convolutional neural networks (CNN) are a type of machine learning model used extensively in image classification and are especially effective at detecting objects based on morphology
- We needed to train CNN models with examples of time-frequency plots with and without ISM-scintillated signals
- Since we do not have natural examples of this (yet!), we developed a Python package called Setigen to generate training and test datasets with synthetic data
- With the CNN, we attempt to distinguish between scintillation, constant sources (i.e. human-made interference), and pure noise

Synthetic Narrowband Signals with Setigen

- Setigen is a flexible Python package that generates synthetic narrowband signals and interfaces closely with radio observation data products
- Time-frequency data produced from radio observations are essentially 2D arrays
- With Setigen, users can customize every aspect of a synthetic signal, including:
  - Path in time-frequency space
  - Intensity variation with respect to time
  - Spectral structure of the signal intensity throughout each timestep
  - Intensity variation over the entire bandpass
  - Add Gaussian noise
  - Normalize over the bandpass of the data in various ways

Current Work and Next Steps

- We are currently experimenting with different combinations of training data parameters (generated with Setigen) and CNN architectures
- Different training sets vary in time-frequency resolution, scintillation timescale, and amplitude of intensity change
- For each training set, we use trial and error in our CNN models with about 3 convolutional layers. We can extend our models to use residual networks, which help propagate features further into the CNN and improve accuracy overall
- We will be taking radio observations of the galactic center with very high resolution (1 Hz in frequency and 1 s in time) to search for interesting signals!

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