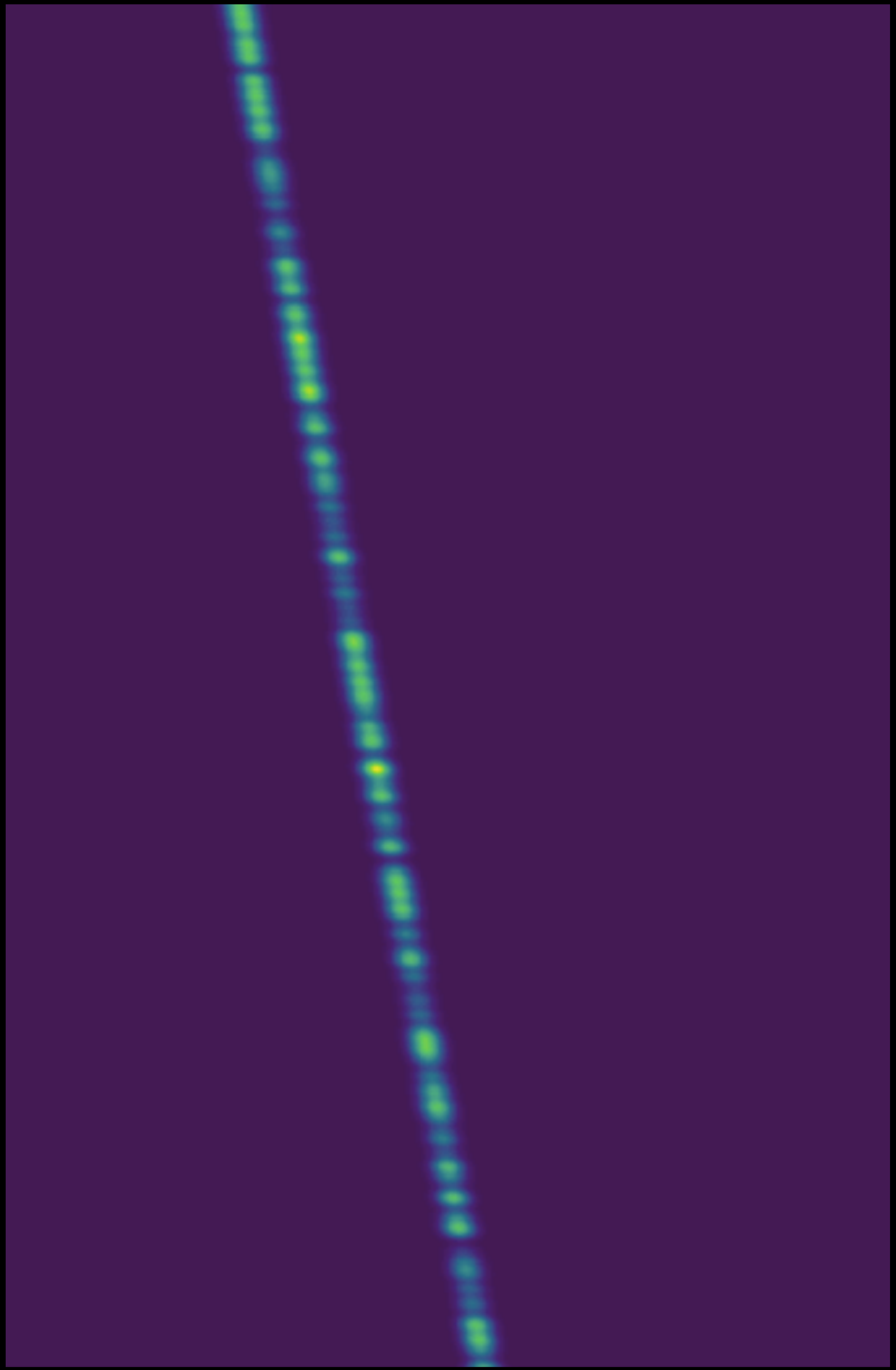

BREAKTHROUGH
LISTEN

Searching for ISM-Scintillated Technosignatures

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BERKELEY SETI
RESEARCH CENTER

INTERSTELLAR SCINTILLATION

- When we look through our galaxy, light passes through the interstellar medium (ISM)
- Radio waves interact with the ionized parts of the ISM, resulting in scattering
  - Scintillation, broadening
- We readily observe these effects in dynamic spectra of pulsars
- Typically, scintillation in SETI has been viewed as an effect that either diminishes or enhances SNR for potential technosignatures
- We claim that ISM scintillation could be used as a discriminant for *detecting* technosignatures!

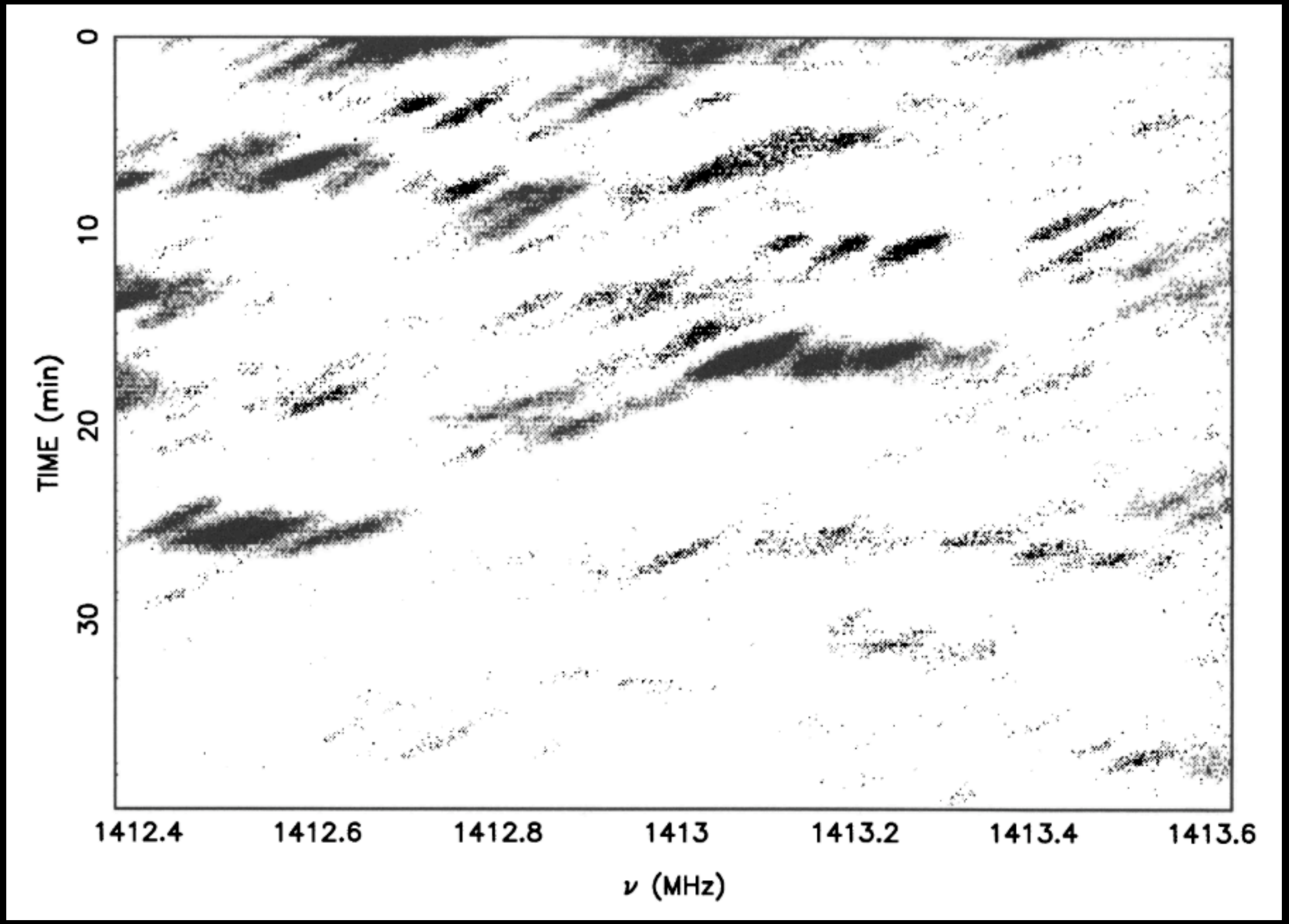

Figure 1. Dynamic spectrum of pulsar PSR 1933+16, showing scintillation from multipath propagation through the ISM. Flux ranges from -0.2 to 0.6 Jy (Cordes & Lazio 1991).

Interstellar Scintillation: Smoking Gun for Technosignatures?

- Distinguishing ETI candidates from human-made radio-frequency interference (RFI) is hard
- Technosignatures would (presumably) have to travel through a long ISM column to reach us
- So, a detection of an ISM scintillated narrow-band signal would imply that it originated outside of our solar system!
- For similar reasons, the interplanetary medium (IPM) also potentially could be used as a discriminant against RFI
- We drew lots of inspiration from works by Jim Cordes and Joe Lazio on effects of scintillation on narrow band signals

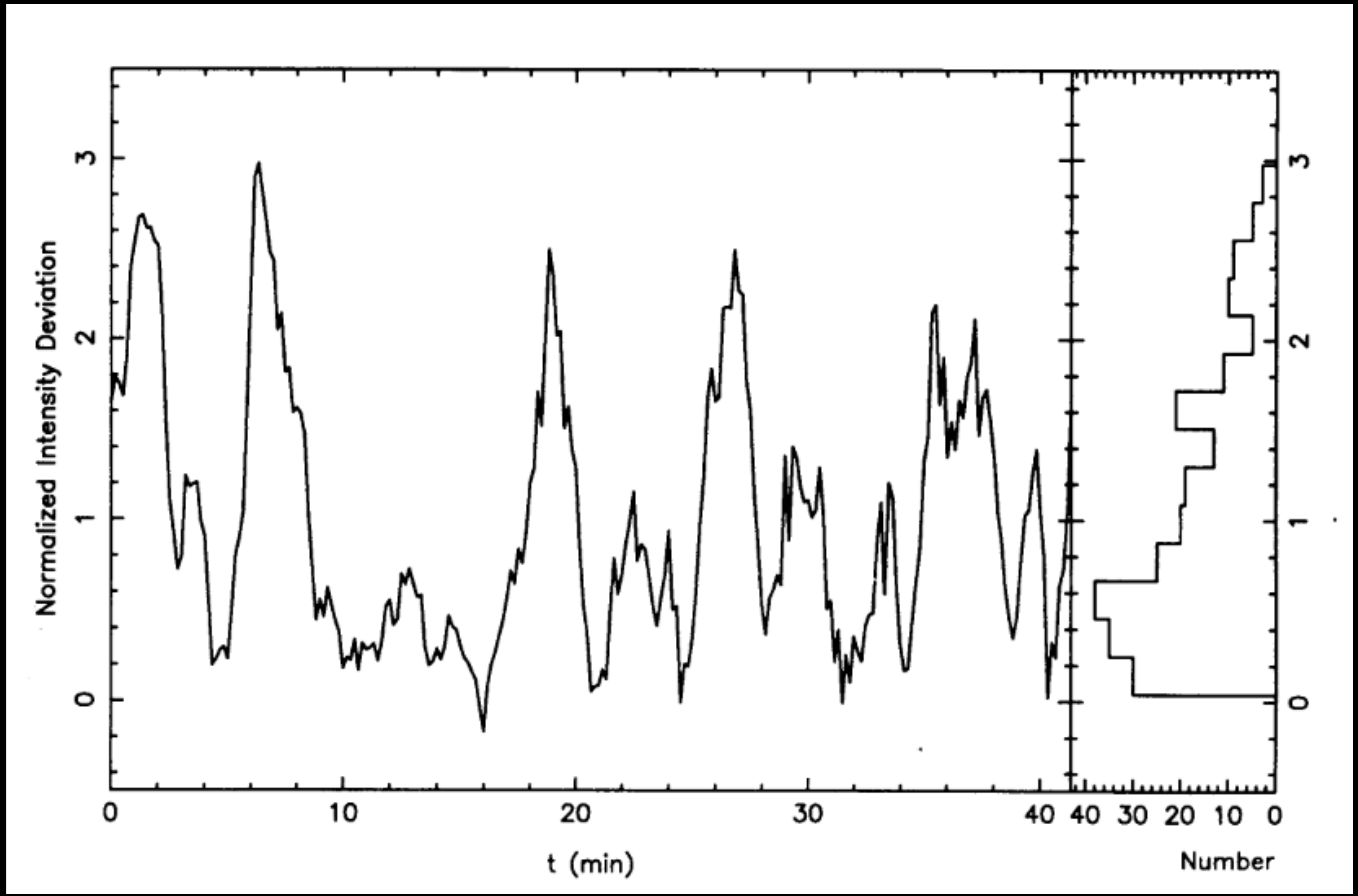

Figure 2. Left panel: Intensity vs. time for pulsar PSR 1933+16. Right panel: histogram of intensity values, showing an exponential-like distribution (Cordes & Lazio 1991).

OBERVING TARGETS: GALACTIC CENTER (GC)

- GC is a great SETI target for many reasons
- Since we're looking through the disk of our galaxy, light passes through a significant amount of ISM in the direction of the GC compared to other pointings
  - This could provide the best likelihood for detecting ISM scintillations
- Look in C-band (4-8 GHz)
  - Not as much RFI to worry about
  - Relatively unexplored
- Estimated a scintillation timescale of about 3 seconds looking out to 8 kpc

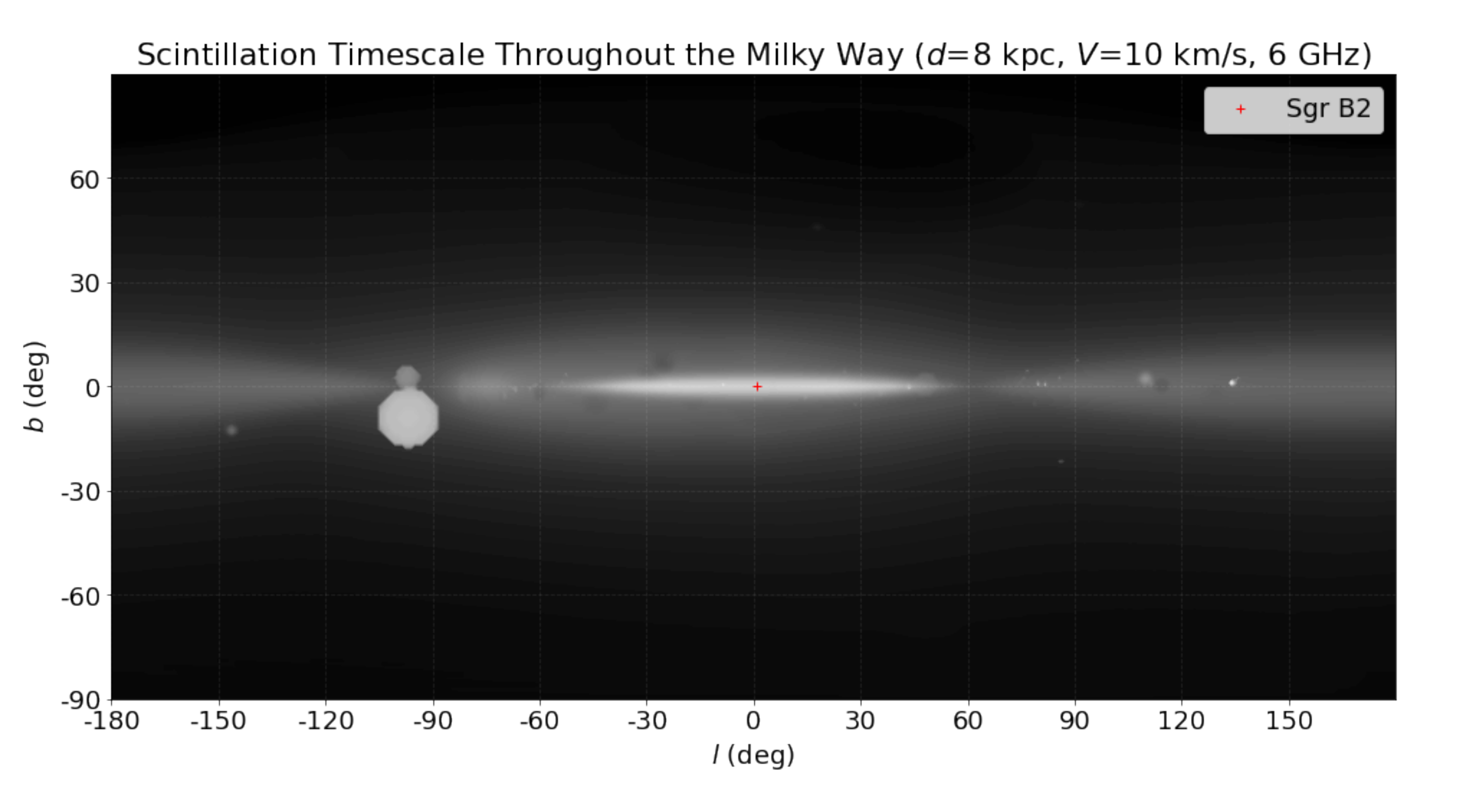

Figure 3. Map of scintillation timescales for 6 GHz out to 8 kpc using the NE2001 model (Cordes & Lazio 2002). Taking V = 10 km/s. Colormap is log scale, with a minimum timescale of about 3 s at GC.

Oberving Targets: Near the Sun

- Sources close to the Sun in the sky are expected to undergo strong scintillation from the IPM
- We plan to take observations of downlinks from solar system probes at various angles close to the Sun
  - To better understand these effects on narrow-band signals
  - To pinpoint the best way to search for these scintillated signals in general

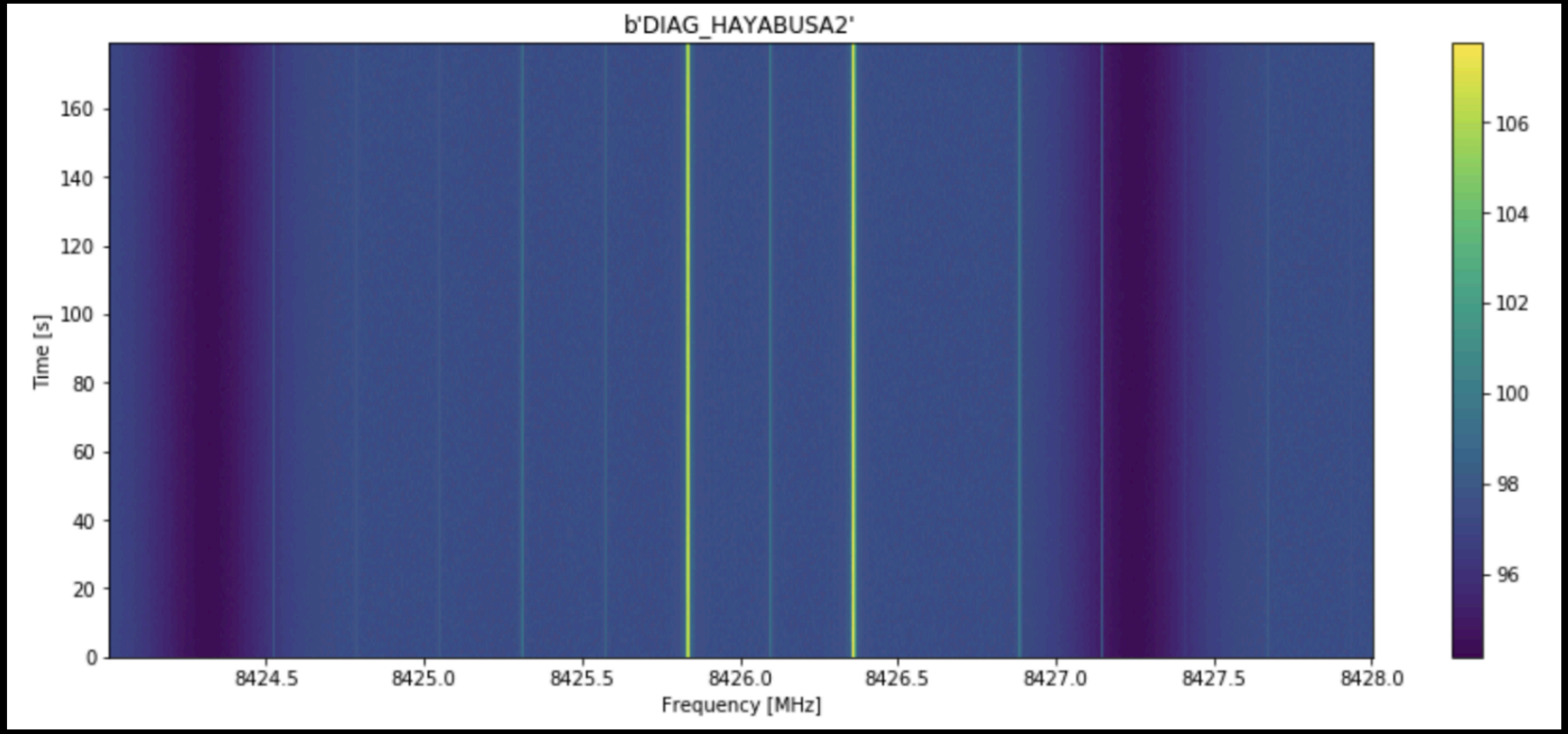

Figure 4. Recent detection of downlink from Hayabusa 2 in X-band

Search Technique: Machine Learning

- Major advances in machine learning with respect to image classification
- Computer vision techniques are good at classifying images based on morphological features
- We can visualize BL data as waterfall plots (spectrograms), of intensity as a function of frequency and time
- There is a lot of potential in machine learning for identifying scintillation features!

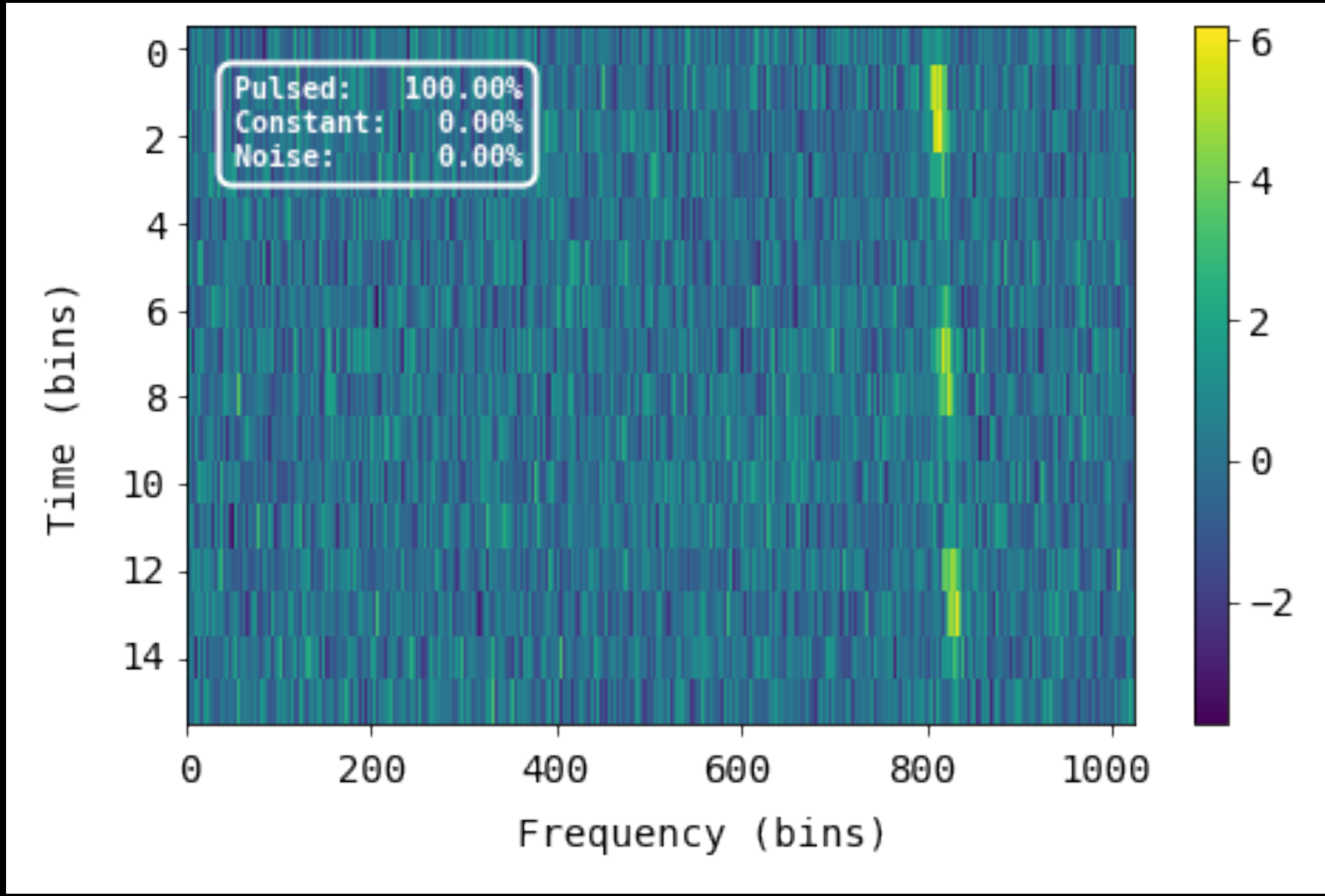

Figure 5. Simple example of ML classification (between noise, constant intensity, or pulsed) with a synthetic signal

ML: Lack of Natural Training Data

- We don't have any examples of ISM-scintillated narrow-band signals
- To train a machine learning model, we need to generate our own synthetic signals!
  - Similar to Zhang et al. 2018's approach for FRB detection
- Two-part problem:
  - We'd like to simulate scintillated signals as closely as possible to reality (based on theory and other observed signals)
  - We'd like to create a robust machine learning classifier that accurately classifies narrow-band signals

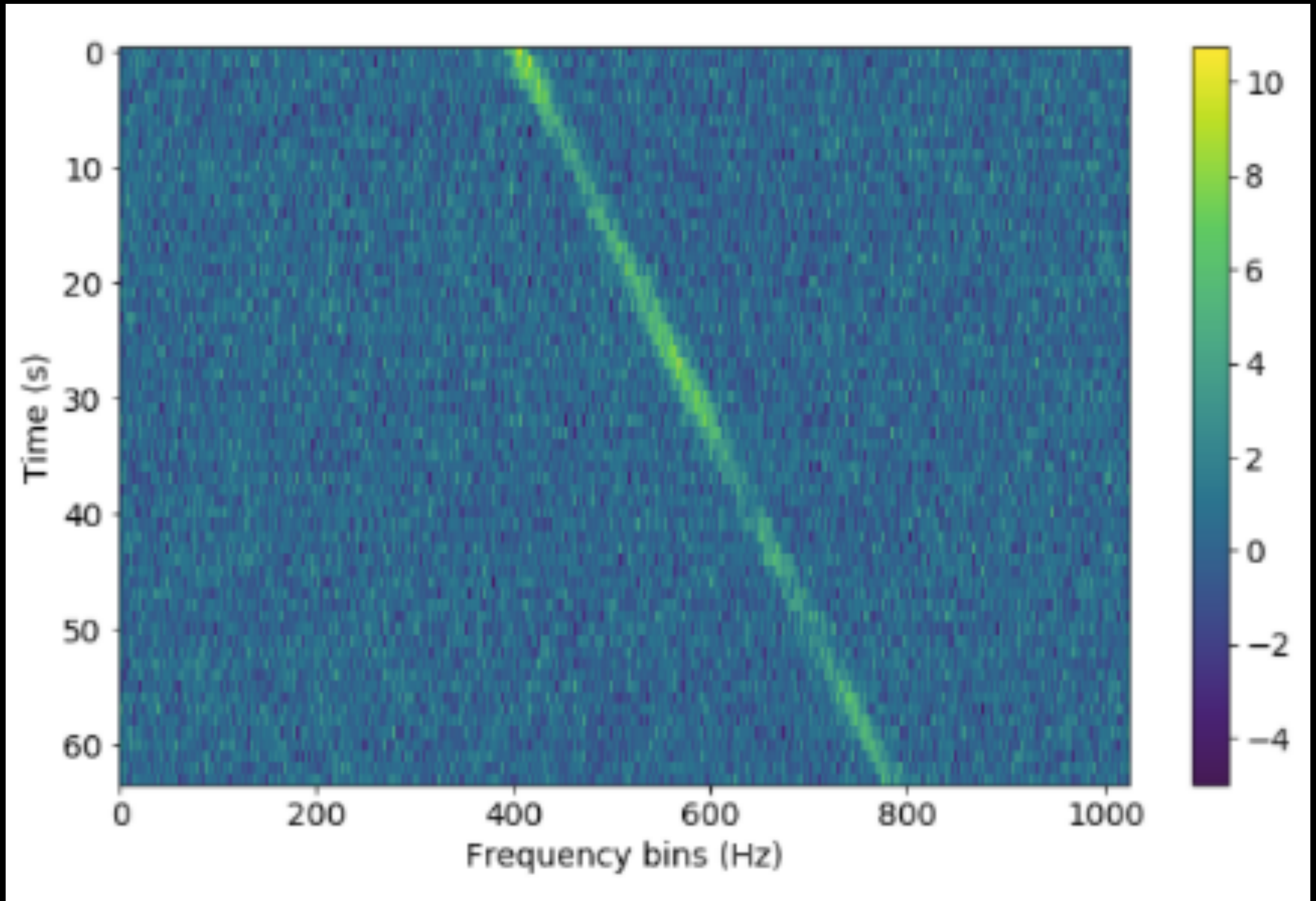

Figure 6. Example of one of the first synthetic 'scintillated' signals we created

In the Works

- Lots of exploration:
  - Simulating the scintillated signals themselves and testing different possibilities
  - Machine learning classification; what is a good set of classes to compare and distinguish against scintillation?
    - RFI is a challenge, as always
  - Handling crowded data frames with multiple signals; object localization and detection with ML?

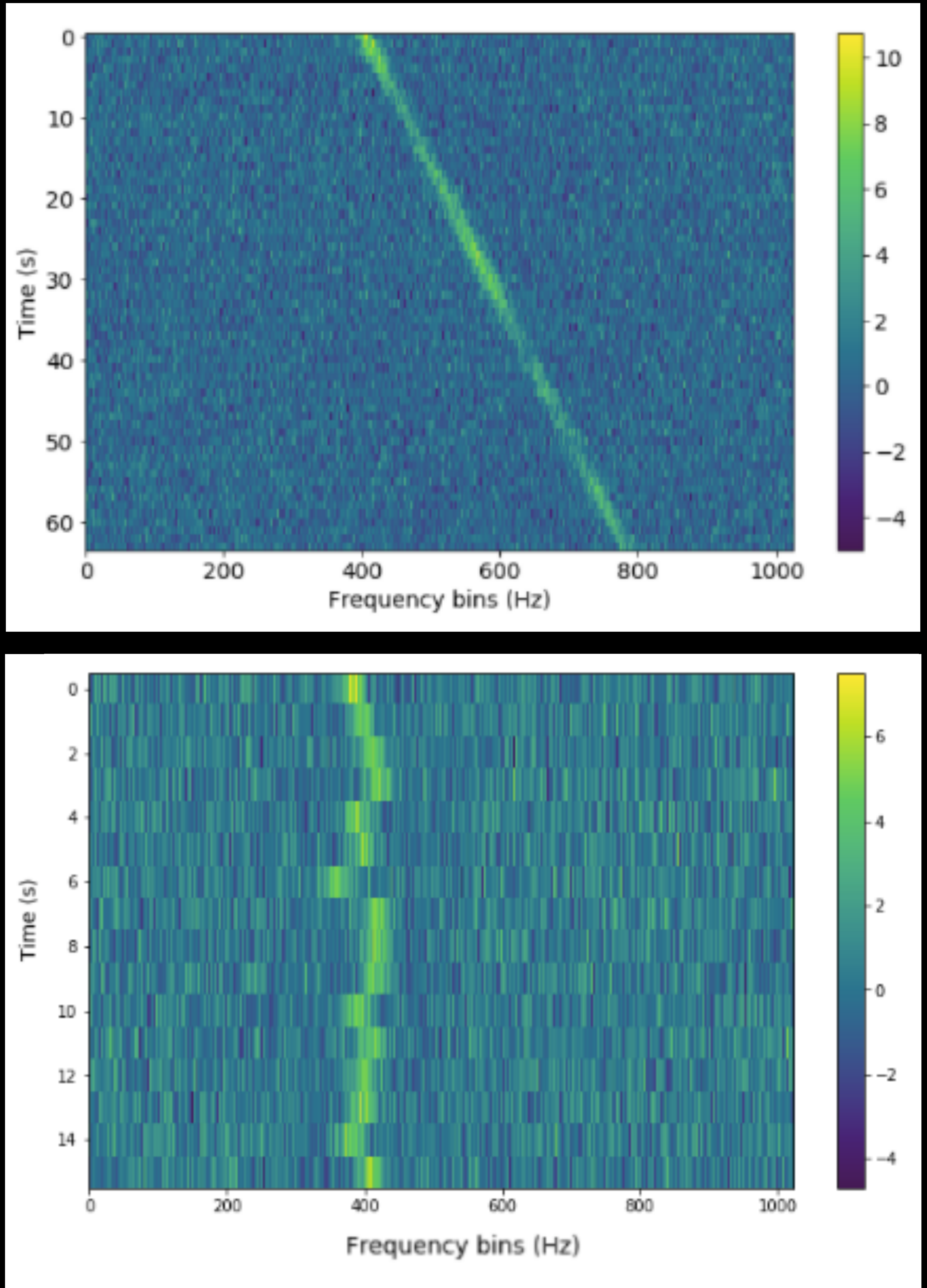

Figure 7. Top: Synthetic scintillation signal. Bottom: Synthetic RFI signal.

Thank you!

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- Cordes, J. M. & Lazio, T. J. 1991, ApJ
- Cordes, J. M. & Lazio, T. J., Sagan, C. 1997, ApJ
- Cordes, J. M. & Lazio, T. J. W. 2002, arXiv, astro-ph
- Zhang et al. 2018, ApJ, submitted

Thank you!