On the Broadband Radio Technosignature Searches

Vishal Gajjar
SETI Institute and UC Berkeley

gajjarvishal.com

Bridging Multi-Messenger Astronomy and SETI , Jan 26, 2025

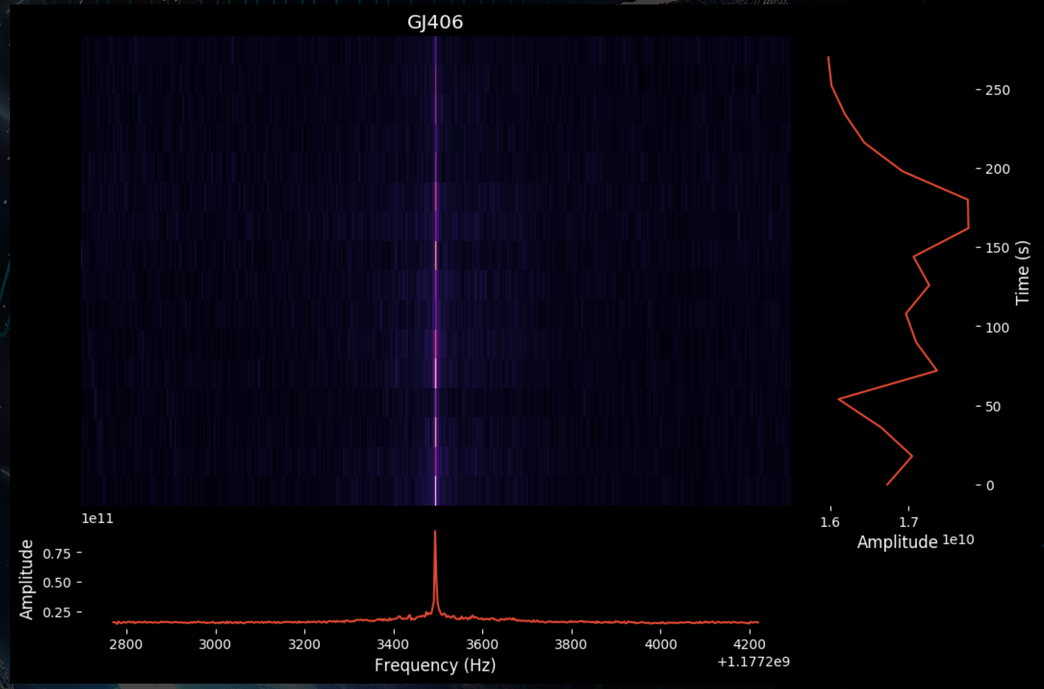
SETI INSTITUTE

BREAKTHROUGH LISTEN

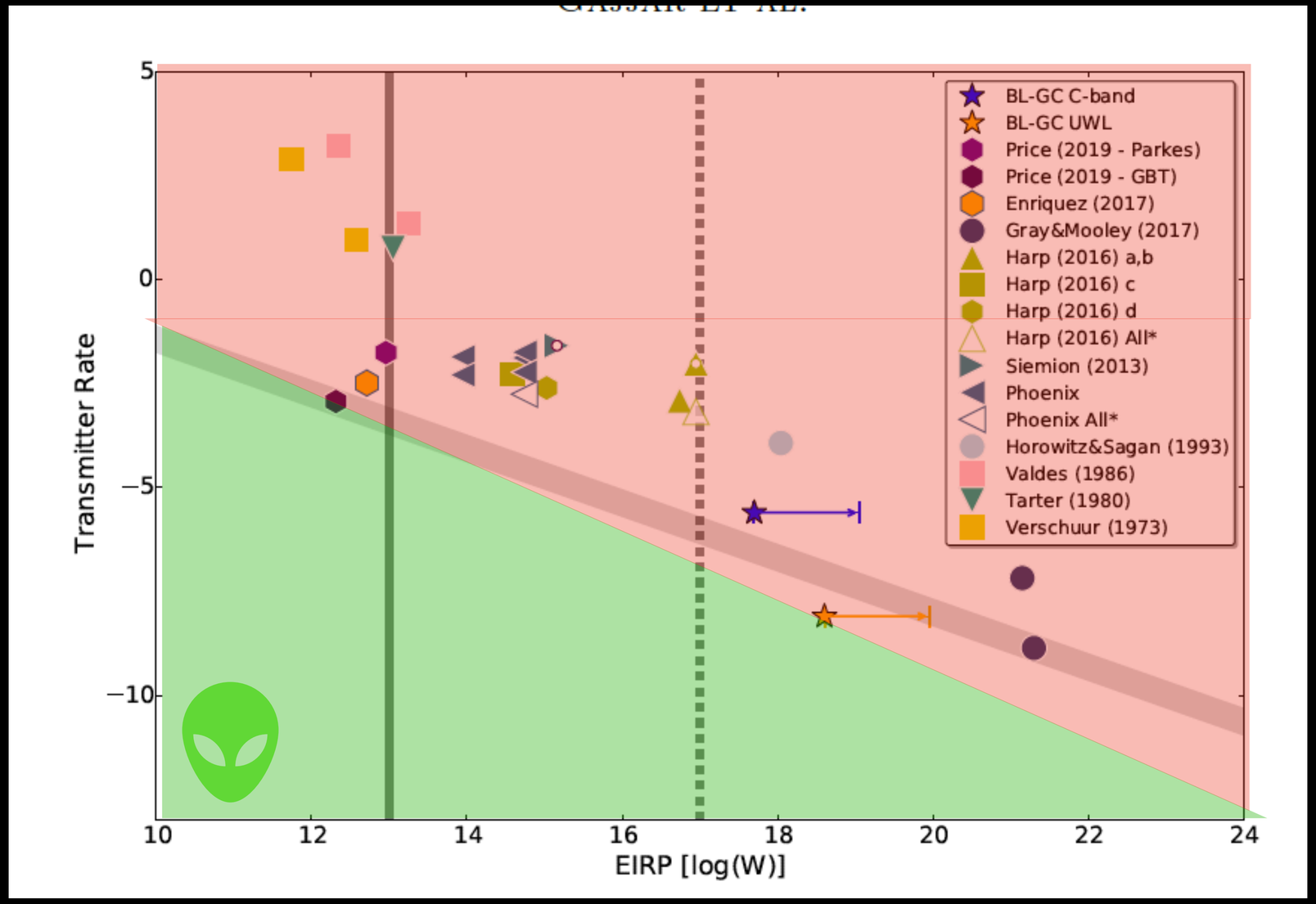
SETI Signal Searches

- Almost all of the previous SETI surveys searched for narrow-band drifting signals across a limited part of the radio spectrum.

  (Drake 1960; Verschuur 1973; Tarter et al. 1980; Valdes & Freitas 1986; Horowitz & Sagan 1993; Siemion et al. 2013; Harp et al. 2016; Tingay et al. 2016, 2018; Enriquez et al. 2017; Pinchuk et al. 2019; Price et al. 2019; Sheikh et al. 2020; Traas et al 2021; Gajjar et al 2021)



Transmitter Occurrence Space



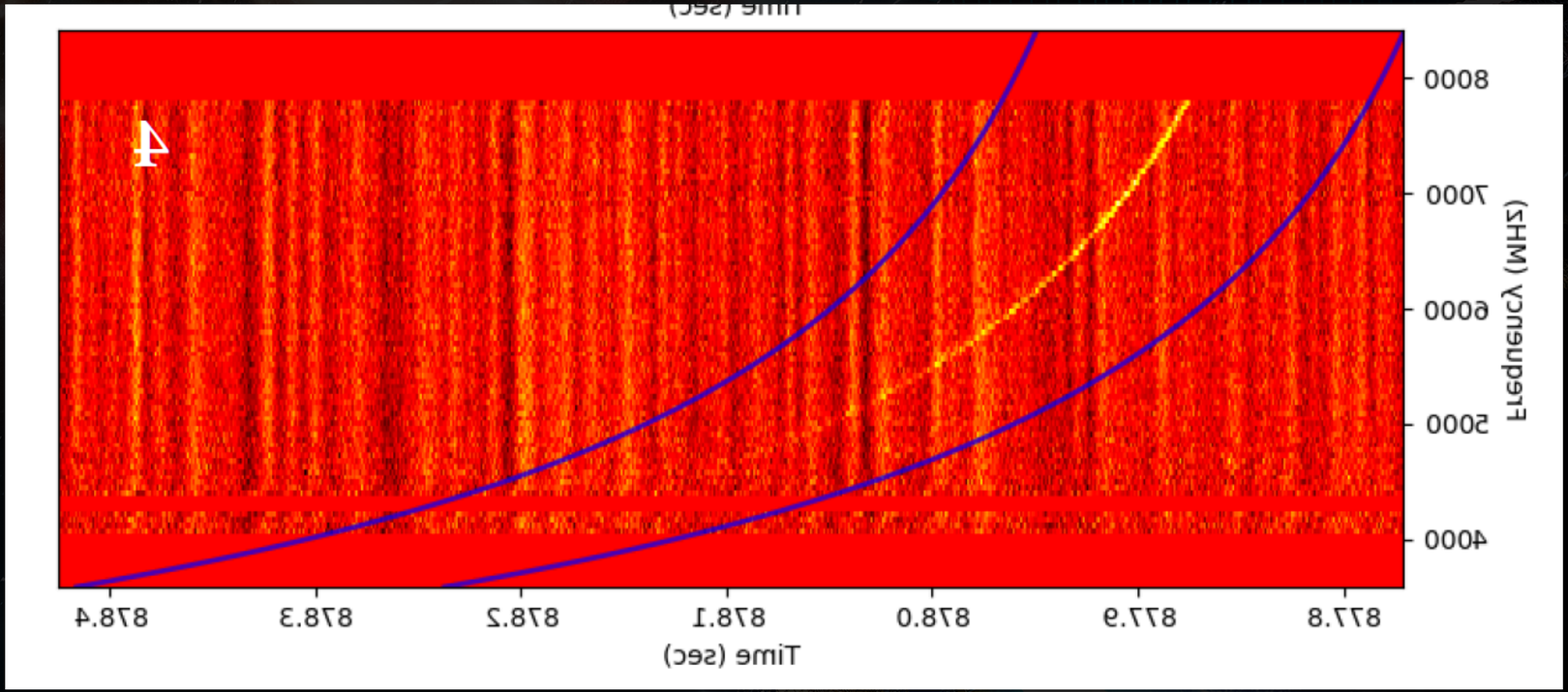
Multidimensional Parameter Technosignature Search

- 1 - time
- 1 - sensitivity
- 2 - polarization
- 2 - space
- 1 - frequency
- 1 - modulation scheme

Source : Jill Tarter

Broadband Pulsed Beacon

Pulses with Artificial Dispersion as beacons from ETIs



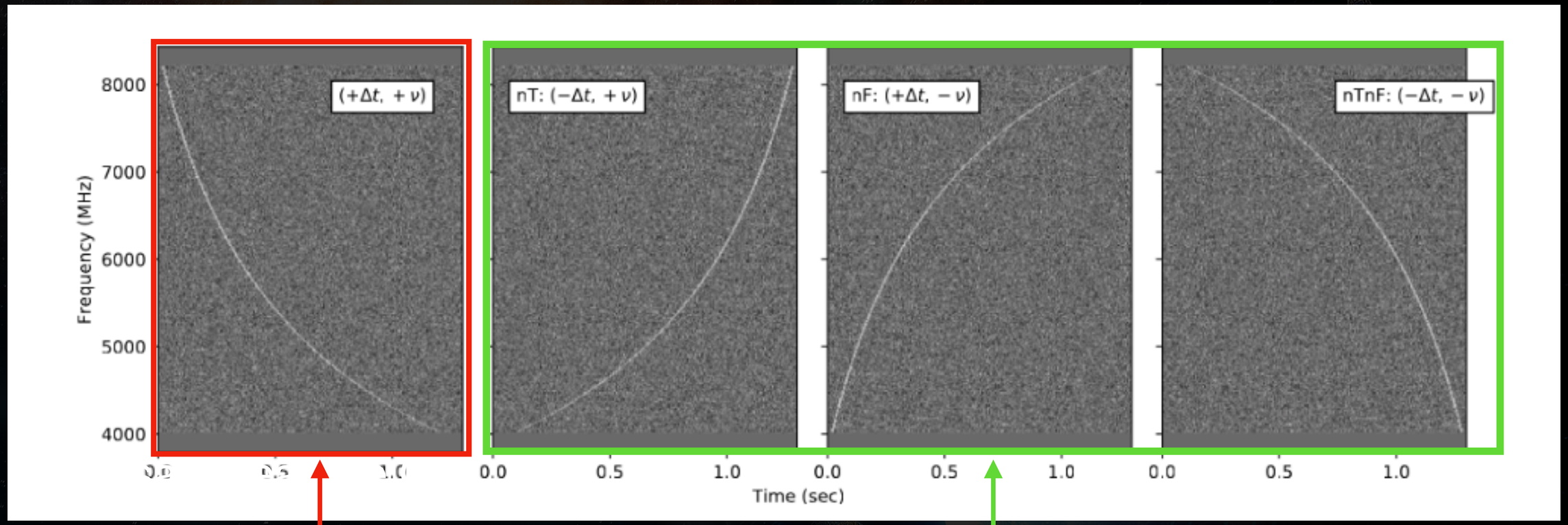
$$\Delta t \;=\; 4.15 \times 10^{6} \times DM \times \left(\nu_l^{-2} - \nu_h^{-2}\right)\; msec$$

$$\Delta t(DM, \nu) \;\propto\; \frac{DM}{\nu^2}$$

Broadband Pulsed Beacon Suggestions

- Oliver 1985 argued that regular train of pulses have more advantage over the CW transmitter. If the train of pulses can exhibit altering circular polarization, that would mimic artificiality of the signal.
- ”The most rational ET signal would be a series of pulses that would be evidence of intelligent design” (Drake 1990)
- Extremely narrow pulses with positive and negative dispersion from ETI (Siemion et al. 2013)
- ASTROPULSE (Von Korff et al. 2016)
- Pulsar as beacon for SETI (Vidal 2019; Haliki 2019; etc)

Broadband Pulsed Beacon

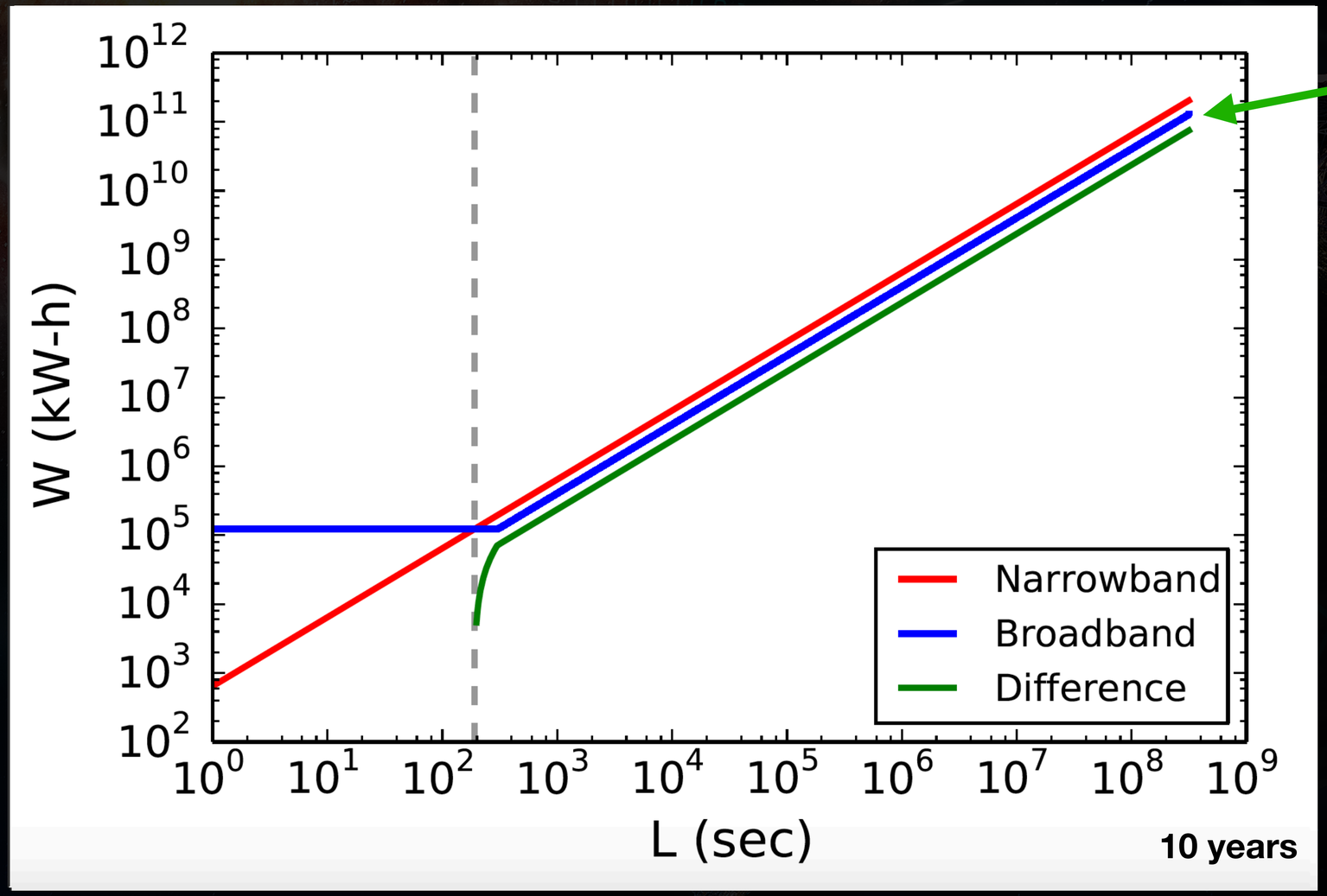


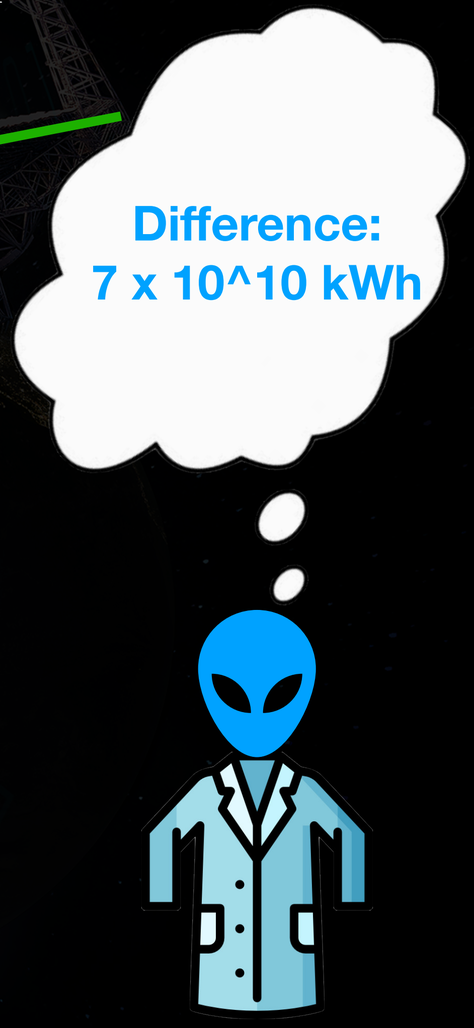
Positive DM (pDM)
From natural sources

Artificial DM (aDM)
From non-physical sources

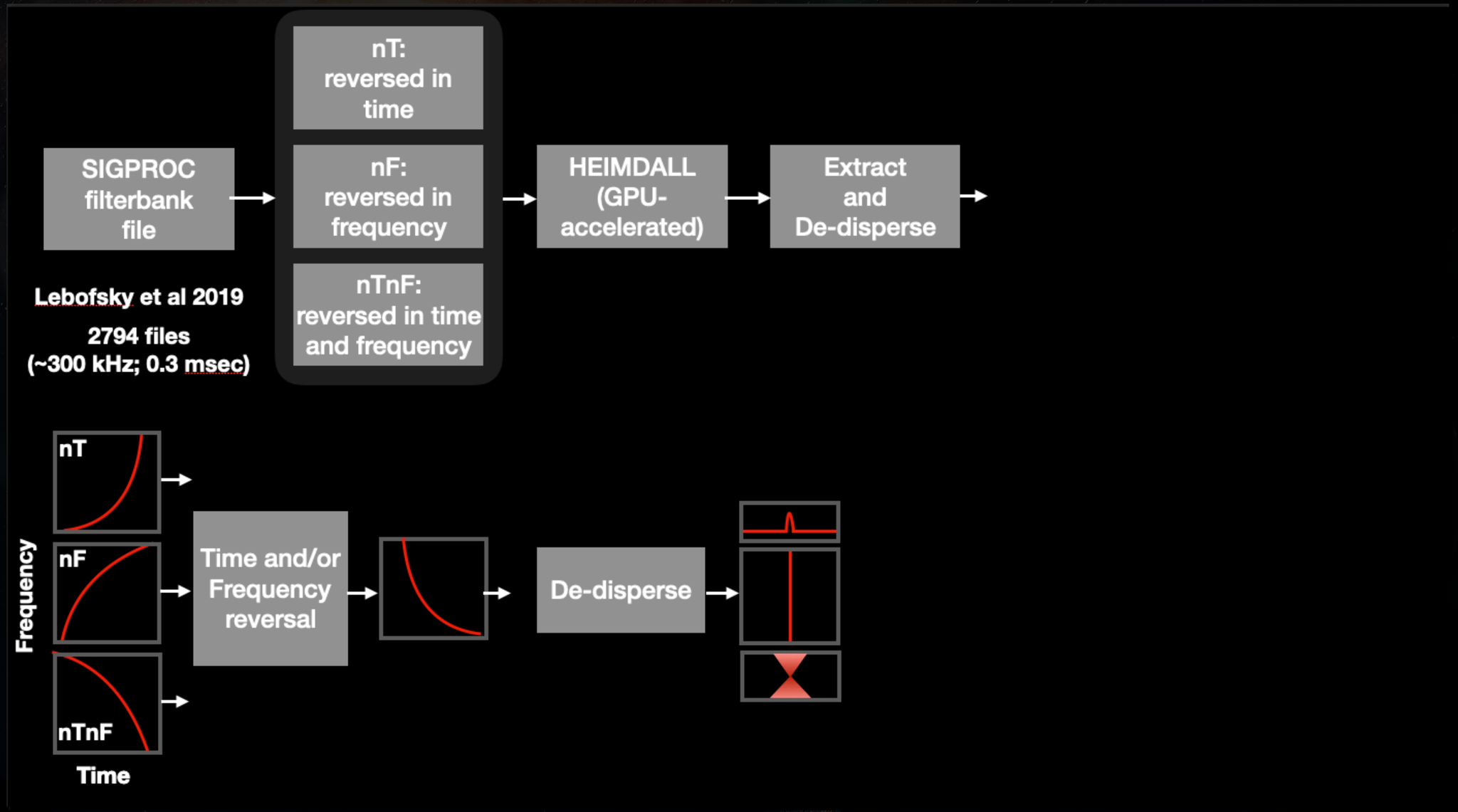
Power-Budget of an ETI transmitter

$$W_{min} = P_{ET,min}\, \nu_{ET}\, L \quad \text{kWh}.$$

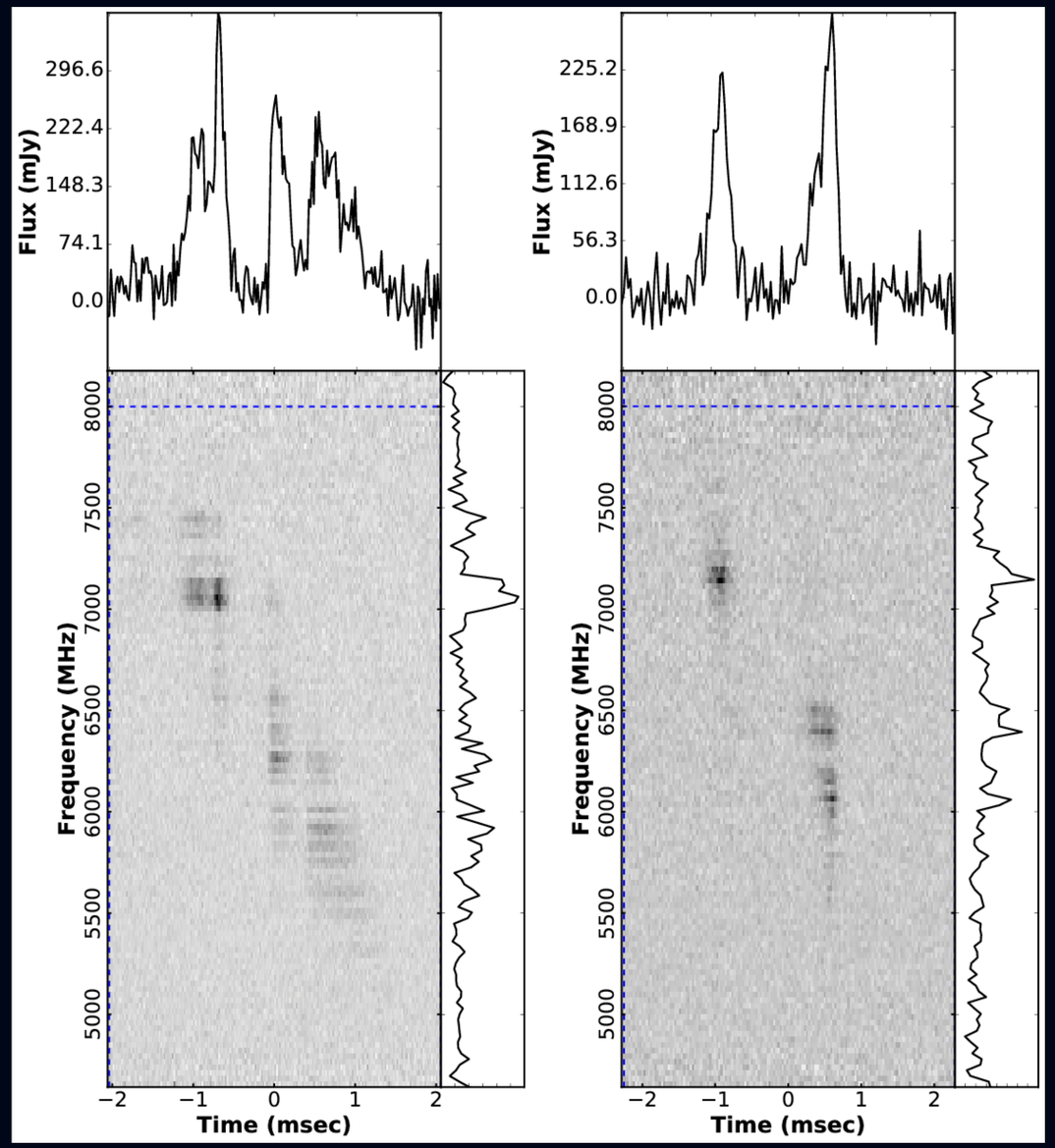




SPANDAK Pipeline



First and only highest-frequency FRB detection with SPANDAK



Gajjar et al. ApJ 2018

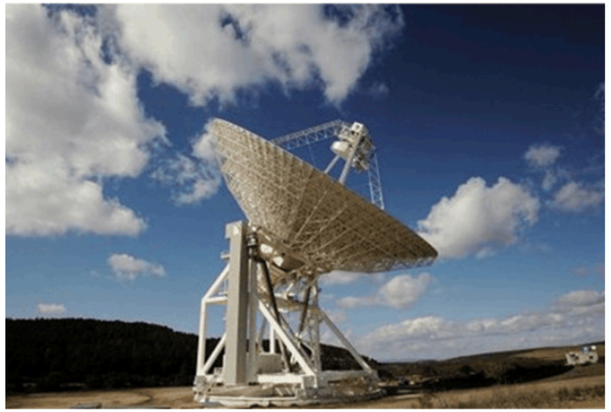
AAS Press conference, Washington DC Jan 2018

Michilli + Gajjar et al. Nature 2018

SPANDAK is being/have been used to search FRBs at the following radio telescopes across the globe

GBT, USA (Gajjar et al 2018)

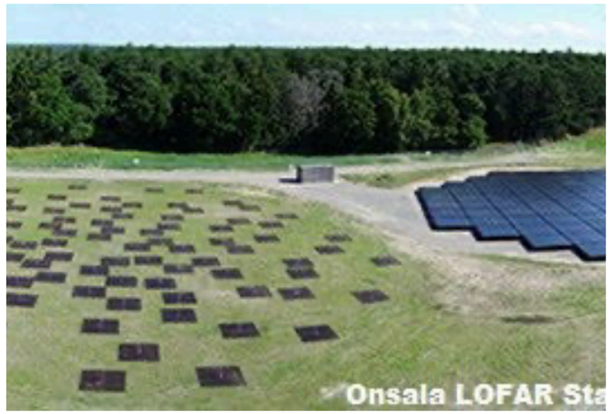
GMRT, India (Sand et al. 2021)



SRT, Italy (Pilia et al. 2020)

NRT, Italy (Trudu et al. 2022)

LOFAR, Ireland

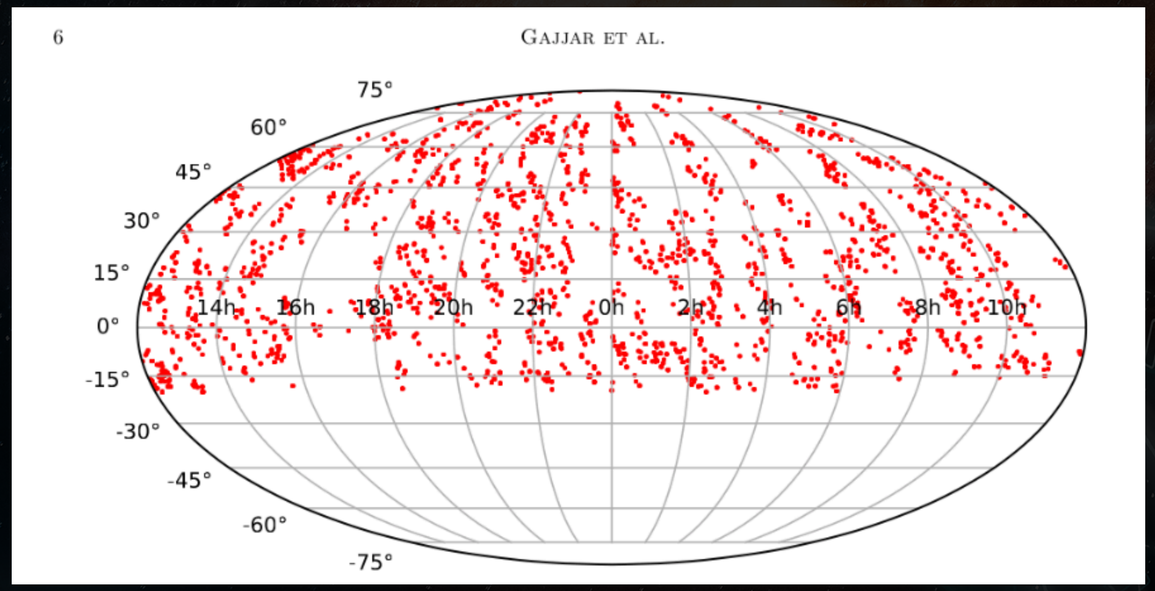


LOFAR, Sweden

ATA, USA

FAST, China

Observations of Nearby Stars



- 232 hours of total observations across 4 — 8 GHz with the Breakthrough Listen Digital backend (MacMahon et al. 2018) from July 2017 and June 2018.
- 1884 stars observed
  - 584 primary targets and 1300 secondary targets (Isaacson et al. 2017).
- Beacon search parameters using SPANDAK
  - Artificial DM : 0 to 5000
  - W : 0.3 to 42 msec
  - S/N > 10

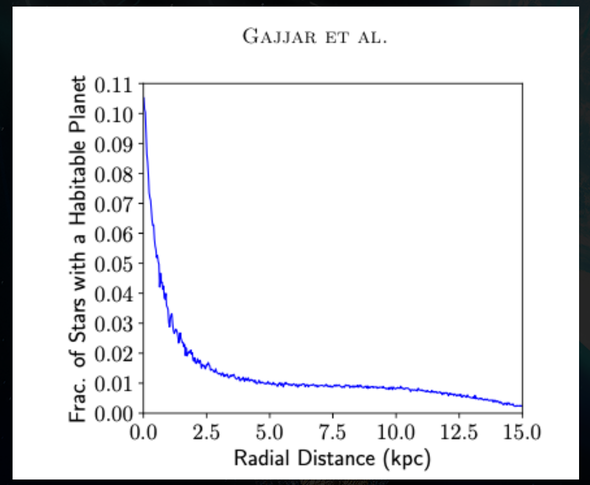
Observations of Galactic Center

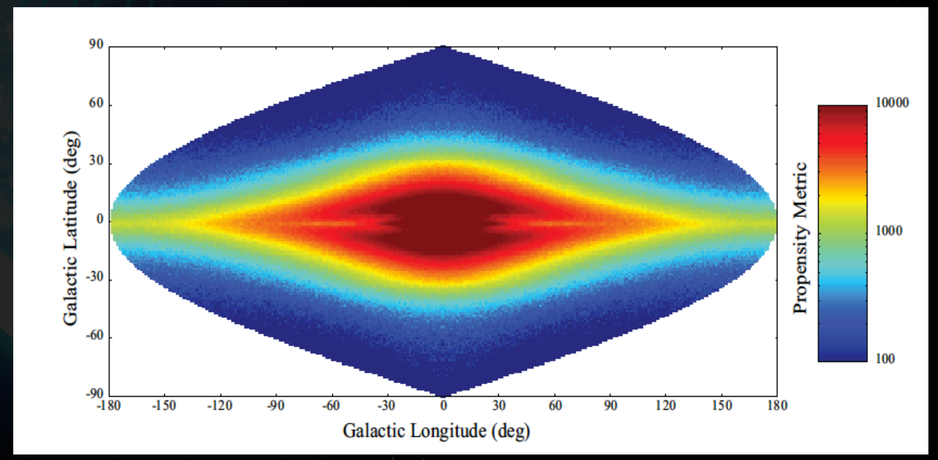
1. Higher propensity of habitable planets near and towards the Galactic Center.

2. Schelling Point

3. Spacefaring Civilizations

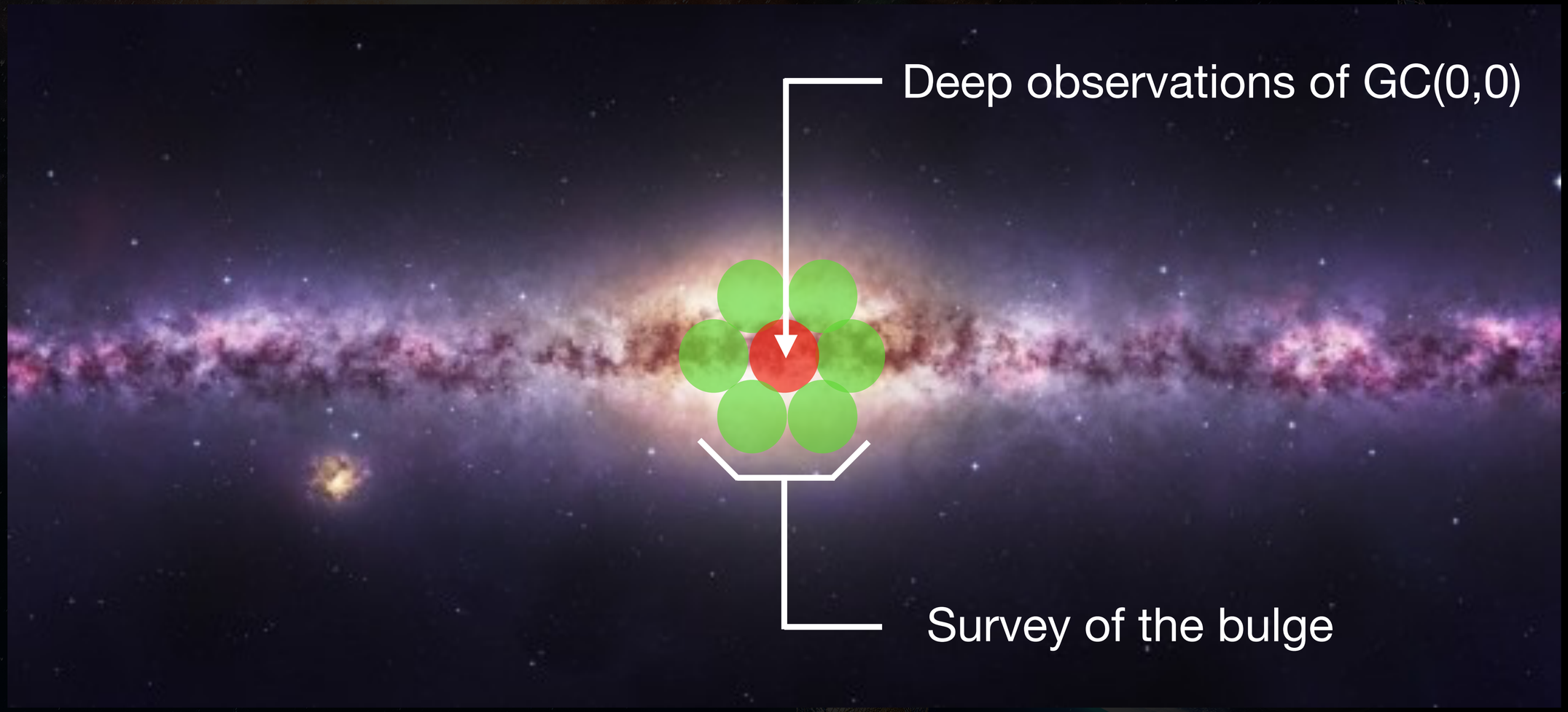
4. Plethora of exotic astrophysical objects



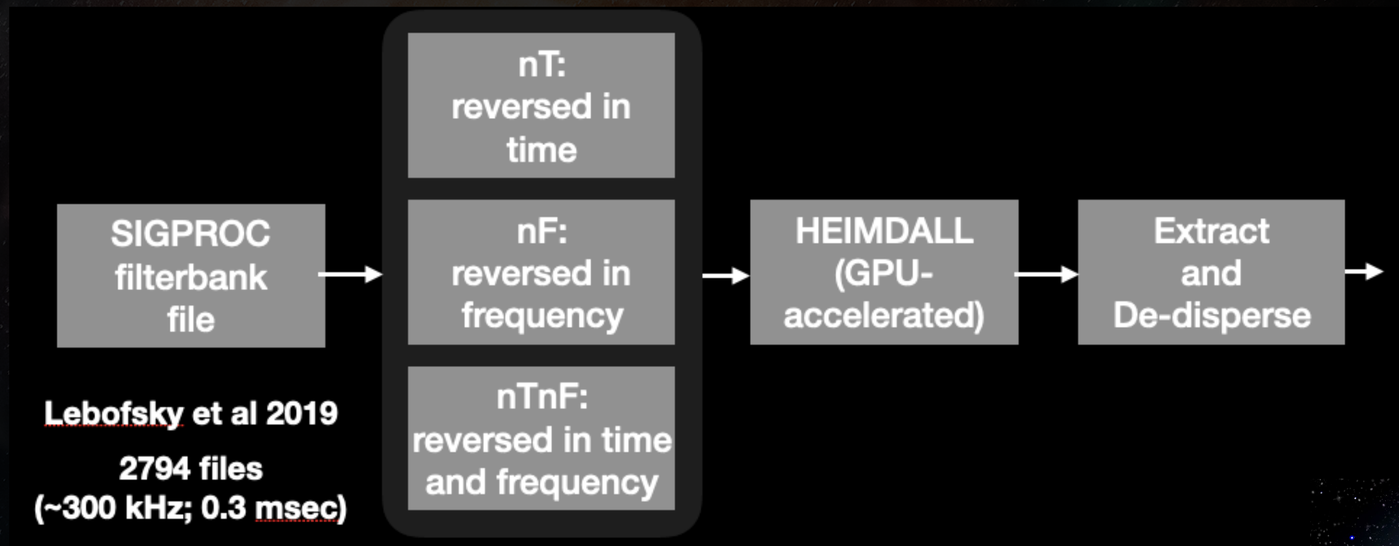


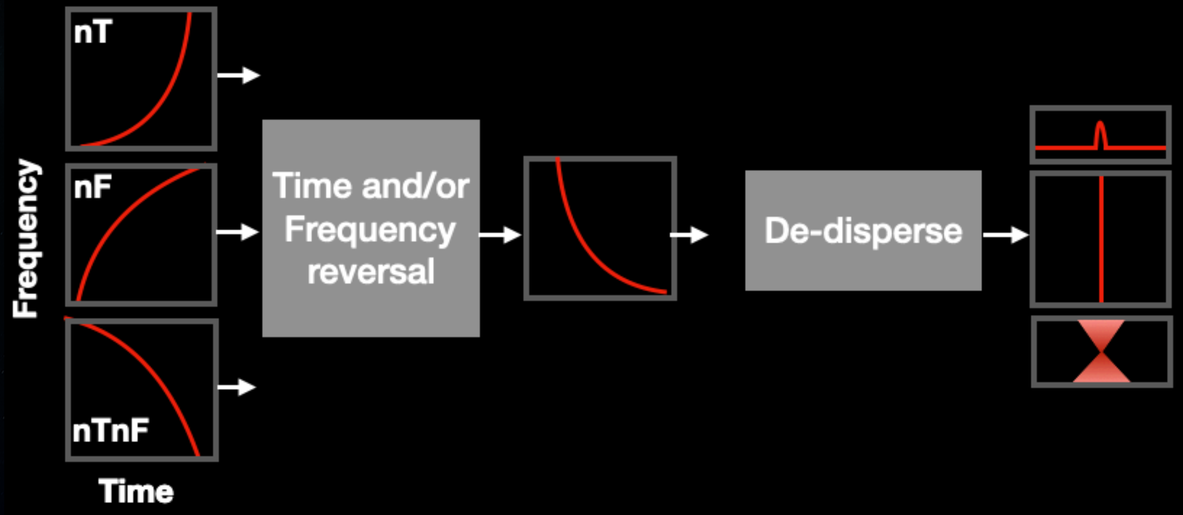
Siemion et al. 2014; Morrison and Gowanlock 2015

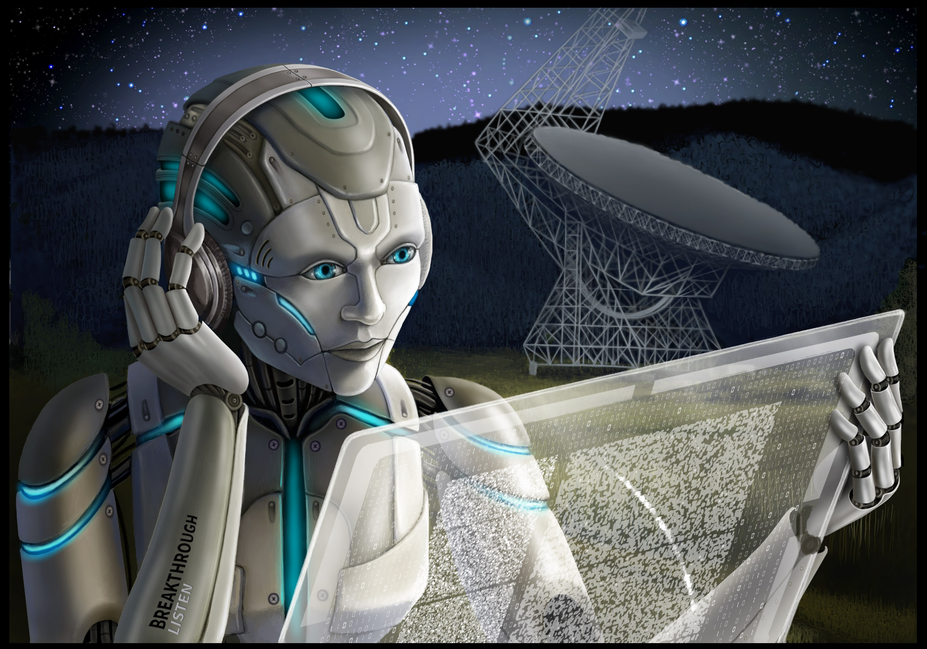
Observations Strategy



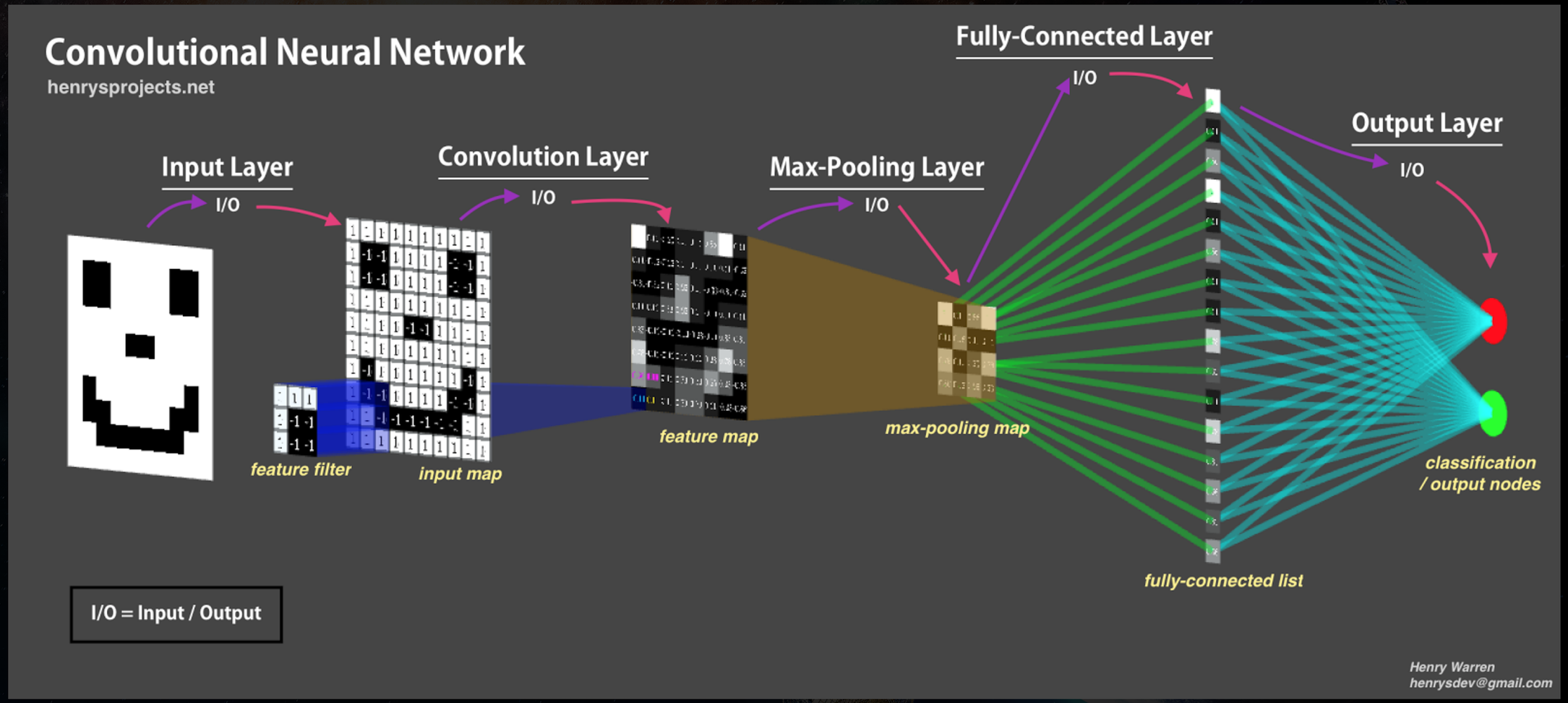
Applying SPANDAK Pipeline on Observations



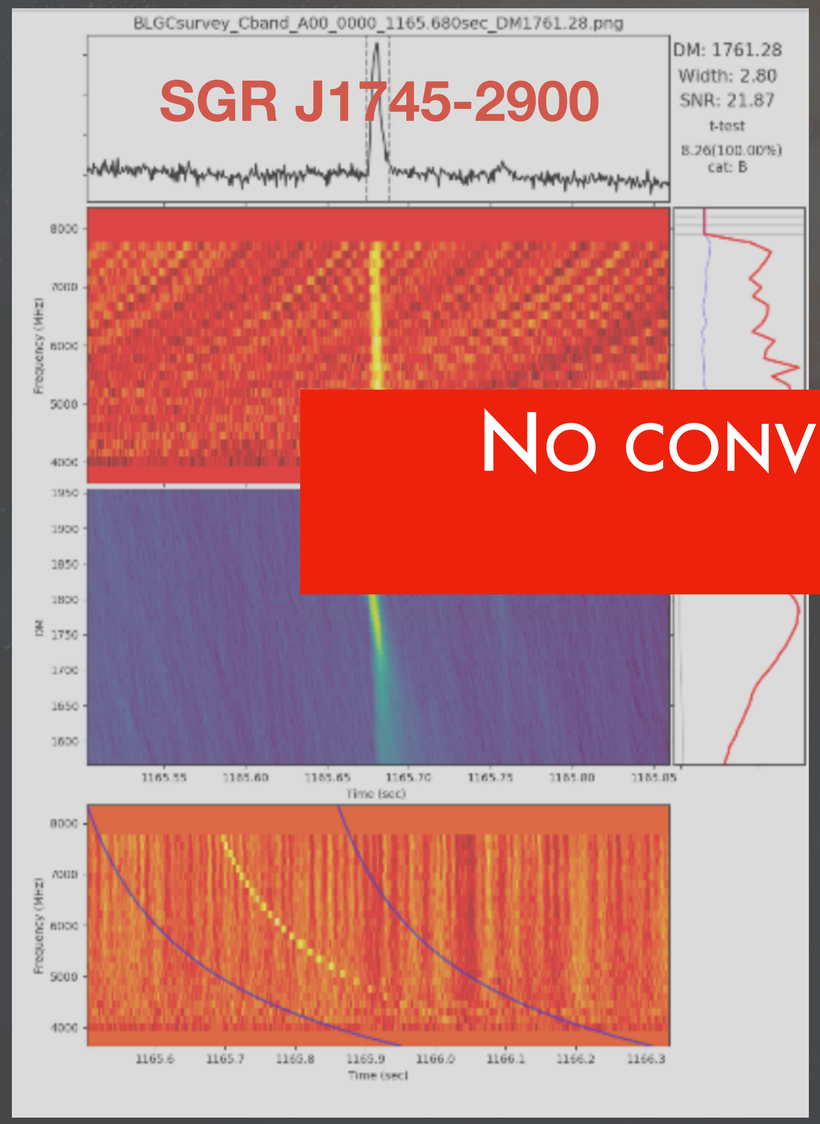


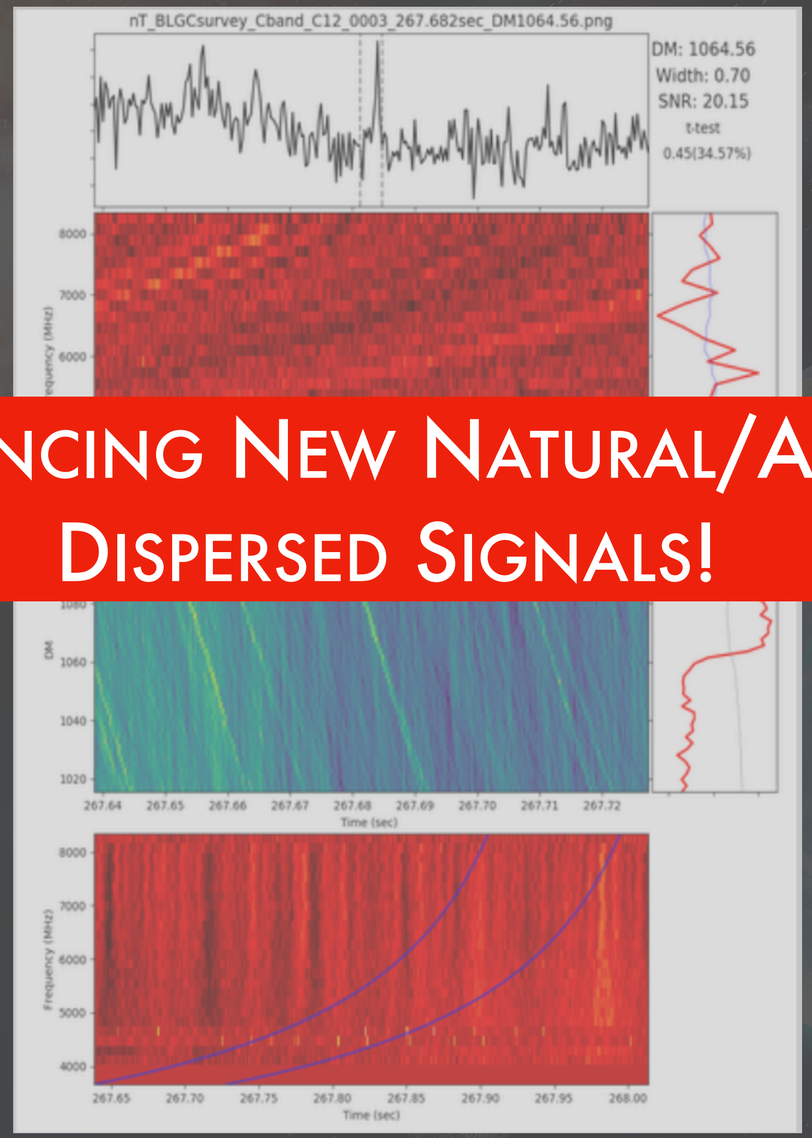


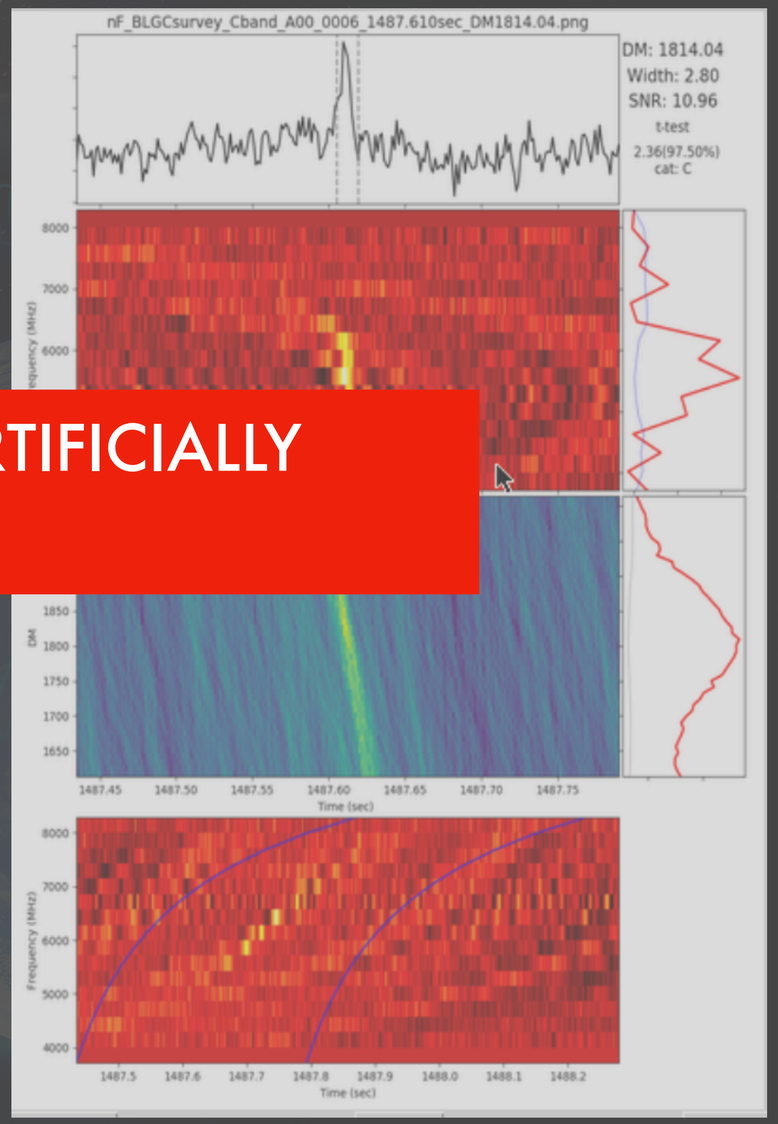
Convolution Neural Network



Transient Signal Searches: Interesting candidates!







No convincing New Natural/Artificially Dispersed Signals!

Total Number of Stars Surveyed

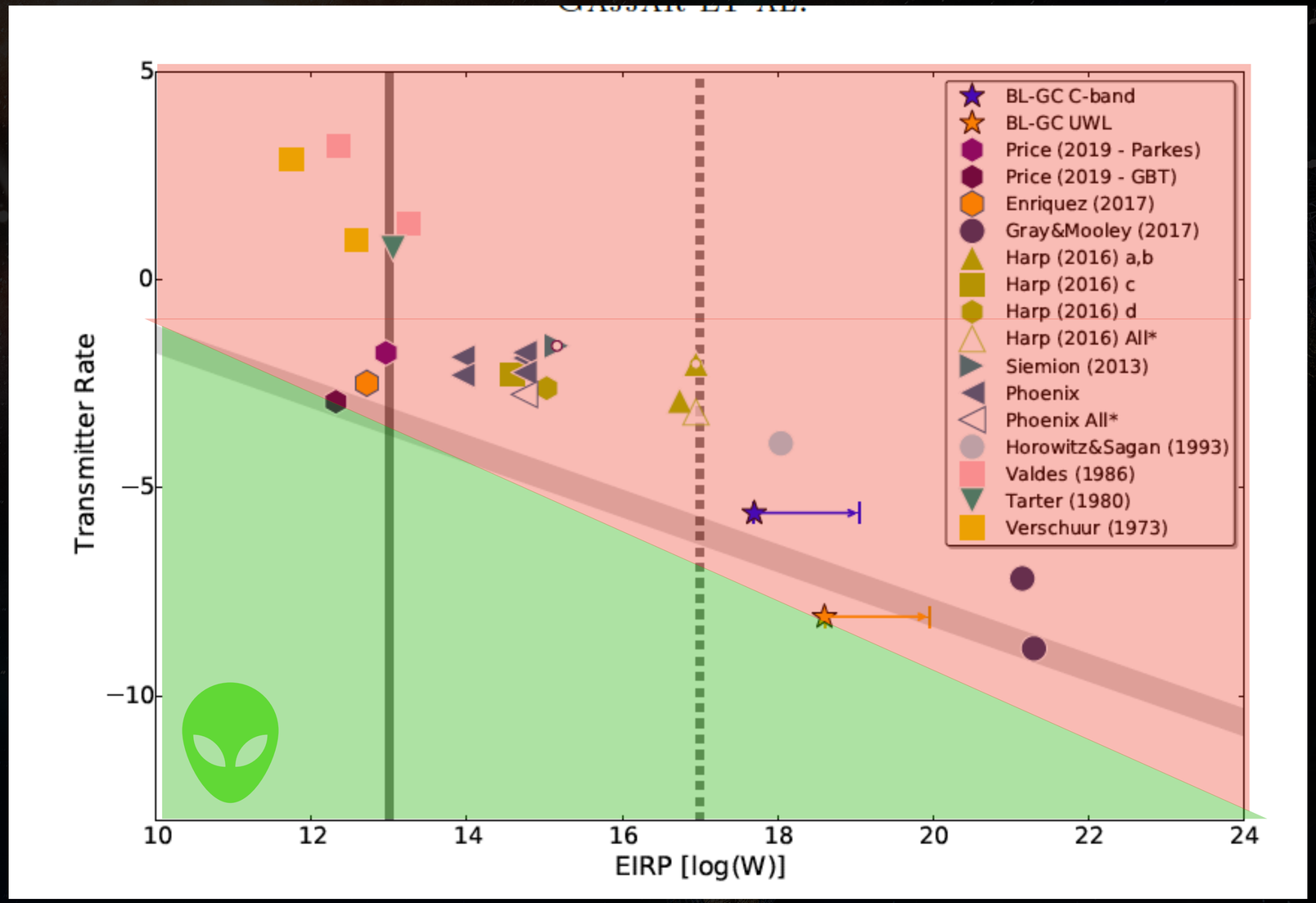
$$n(Z,R) = n_0 \left(e^{-Z/Z_{thin}} + 0.085 e^{-Z/Z_{thick}}\right) e^{-R/h_R} \text{ stars/pc}^3$$

(Carroll & Ostlie 2007)

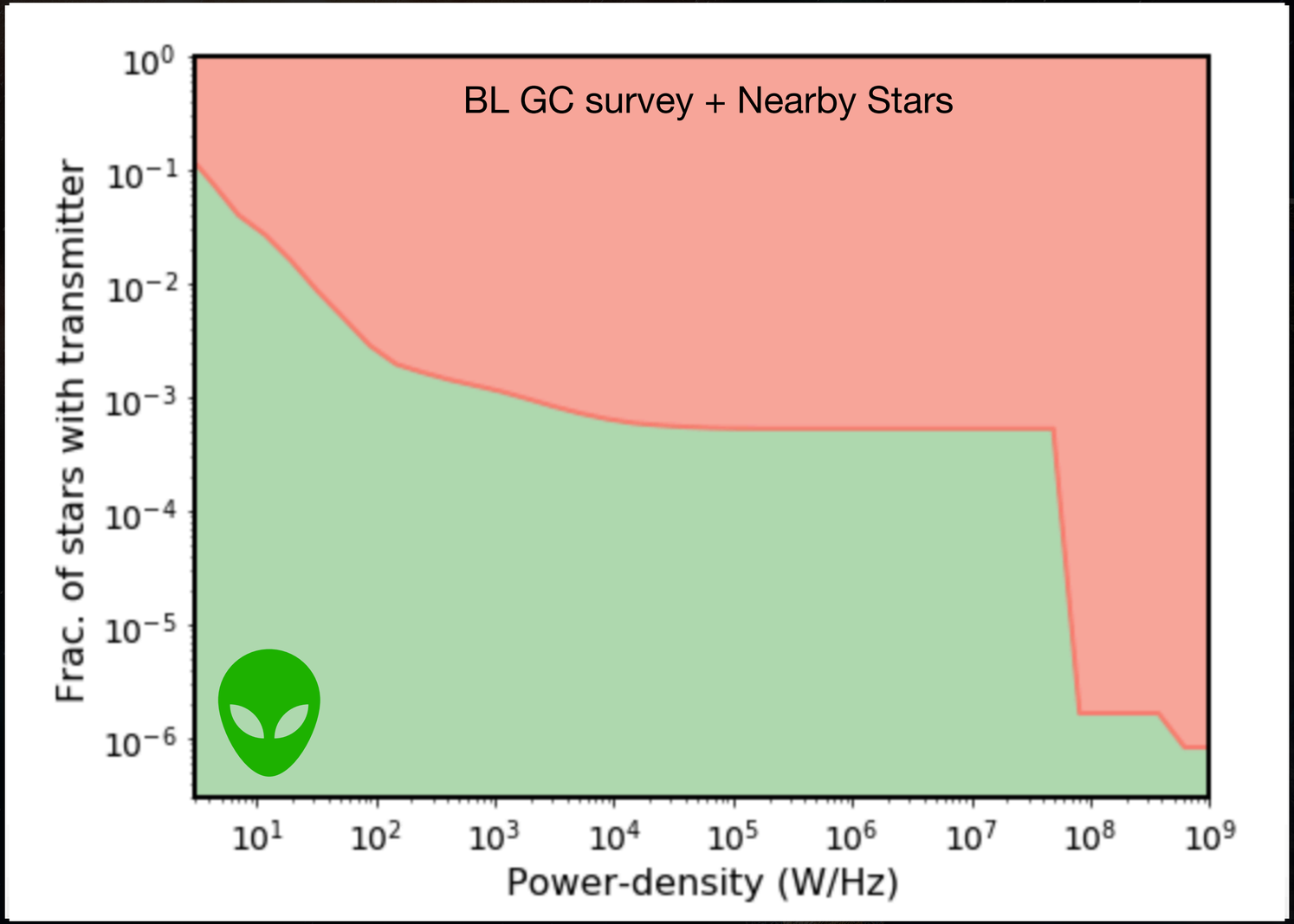
$Z_{thin} = 350\ pc$ $\quad Z_{thick} = 1000\ pc$ $\quad h_R = 2.25\ kpc$

- GBT C-band (4' x 4') : **0.6 million stars**
- Parkes UWL (30' x 30') : **60 million stars**

Transmitter Occurrence Space for Narrowband Beacons



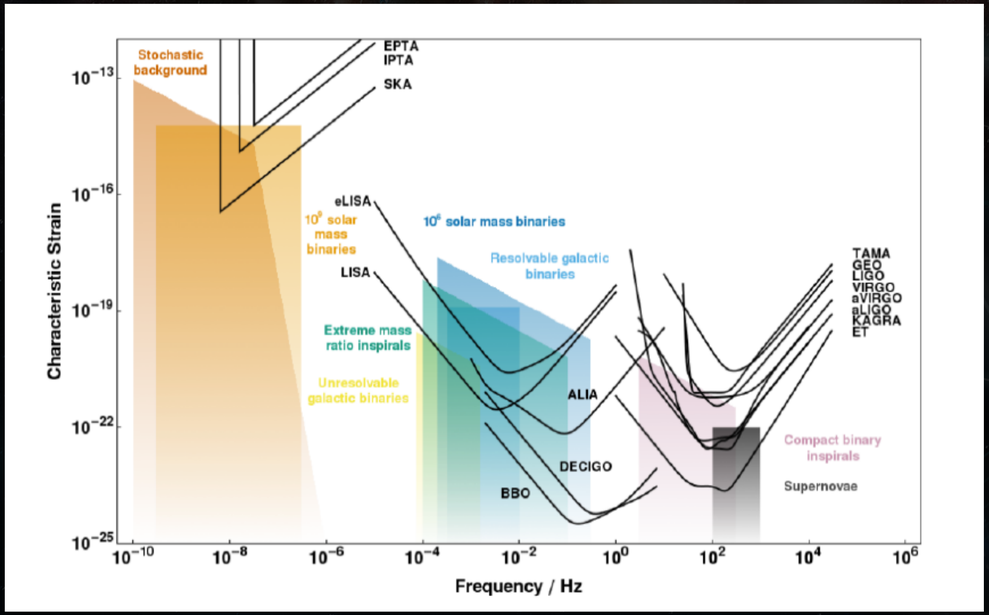
Transmitter rate for Broadband Signals vs. EIRP



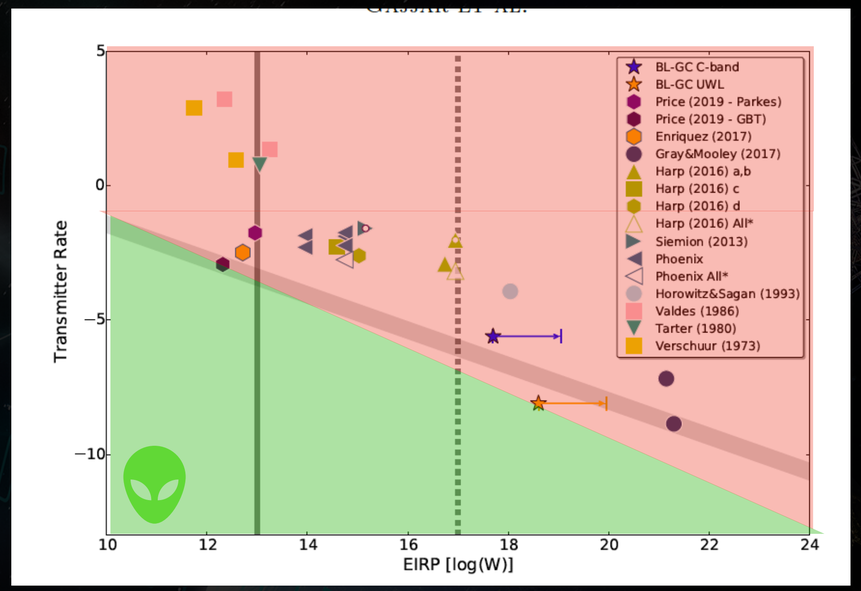
Gajjar et al. 2022

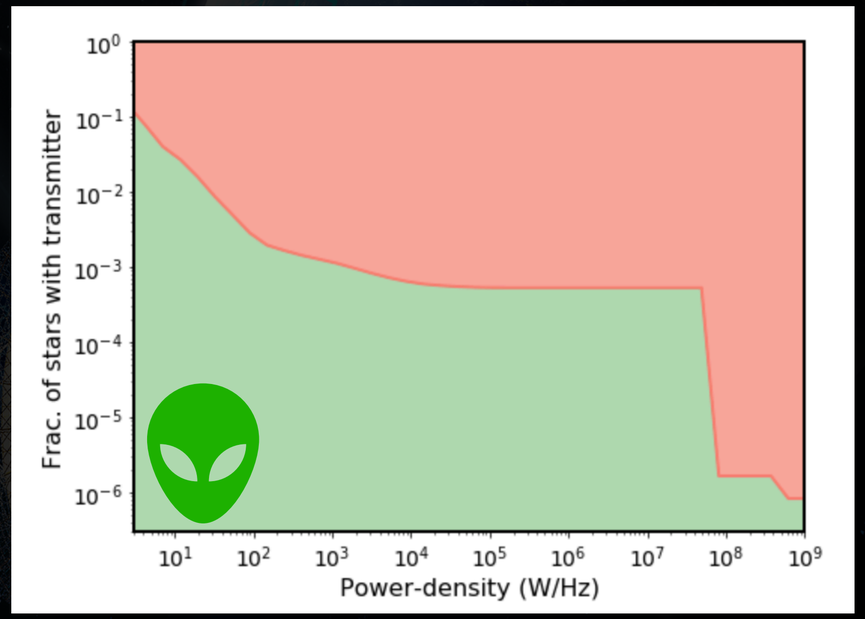
Gajjar et al. 2021

Parameter Space Limits



Historical GW detector limits





Summary

- Broadband pulsed signals with artificial dispersion are unique class of beacon which are easy to identify and can travel across large interstellar distances
- We observed close to 2000 stars and Galactic Center, across 4 to 8 GHz with the Breakthrough Listen program on GBT.
- Three different types of broadband pulsed beacons were searched using a locally developed GPU-enable signal detection pipeline named SPANDAK. We developed and trained a CNN based classifier to reduce the number of false positives. This is the first time ML has been actively used in for a large scale SETI survey.
- For the first-time we were able to constrain presence of broadband pulsed beacons in the solar neighborhood.