FRB Morphology as a (Possible) Indicator of Multiple Populations

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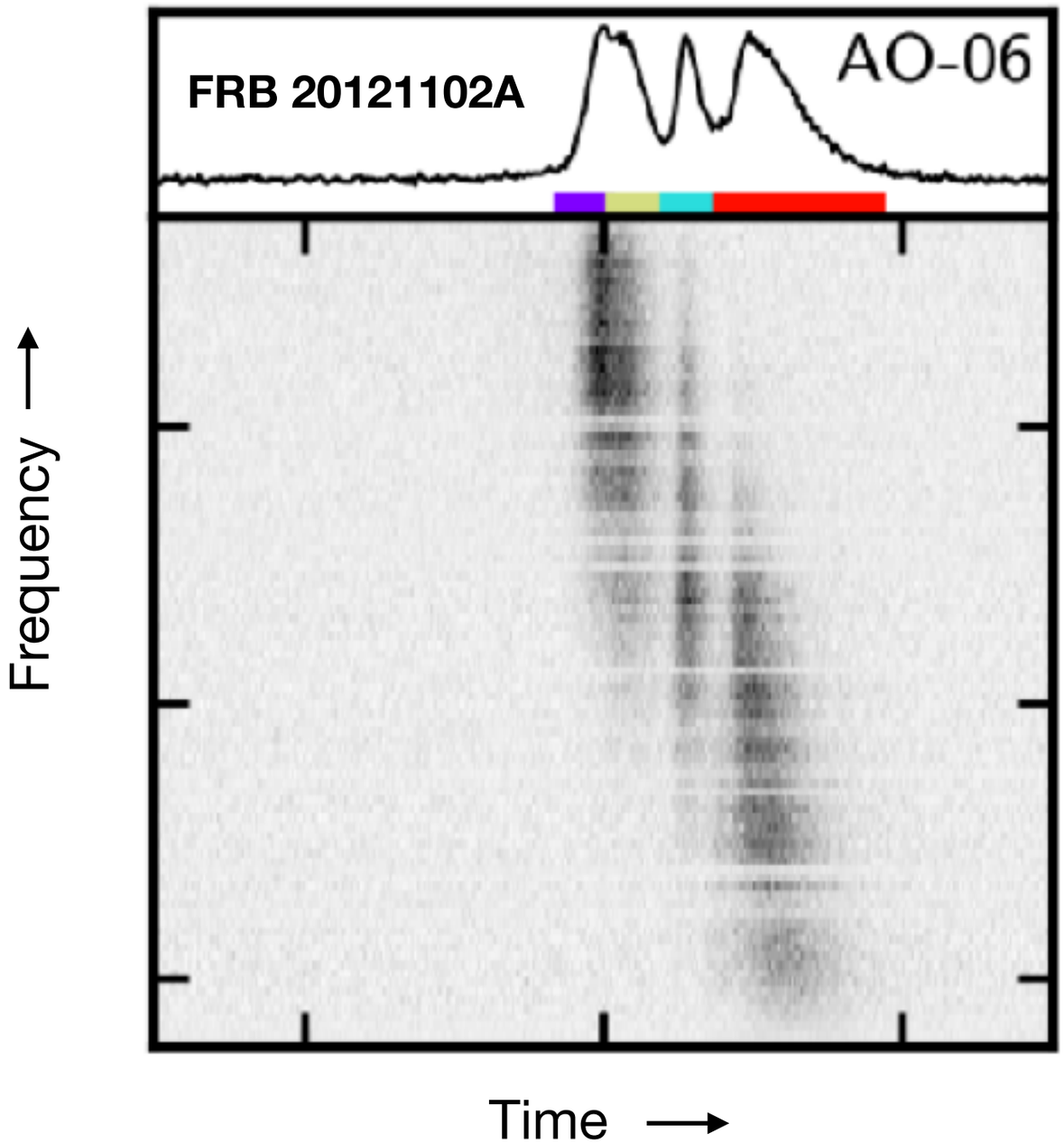
Cornell FRB Workshop
10-11 October 2022

Spectro-temporal Behavior of Repeating FRBs

- Analysis of high-S/N bursts from the first repeating FRB —> features in dynamic spectra that are unique amongst other radio-transient phenomena.

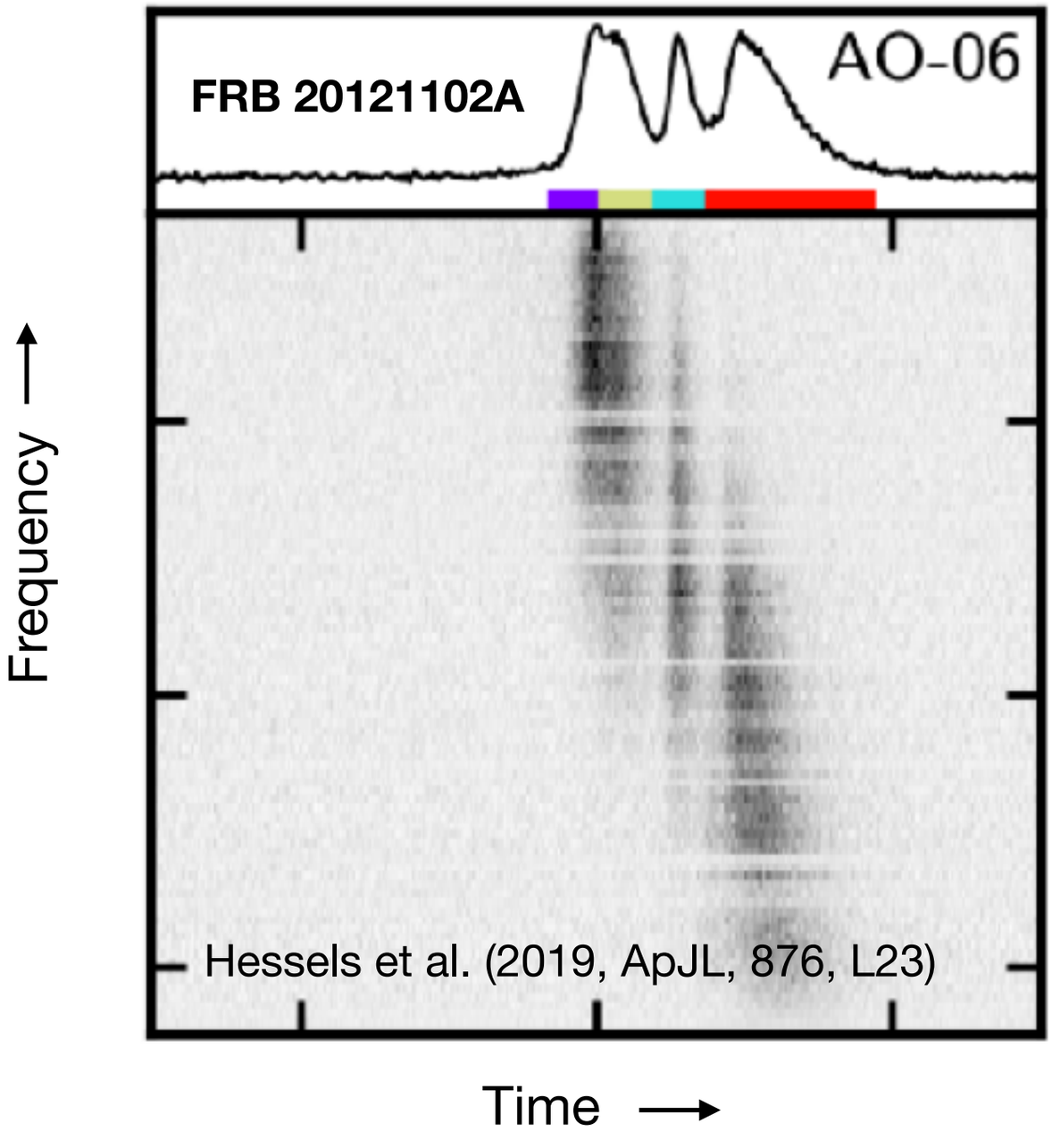
- Distinct bursts from “repeaters” similar in temporal widths to “apparently non-repeating” FRBs, but are band-limited.

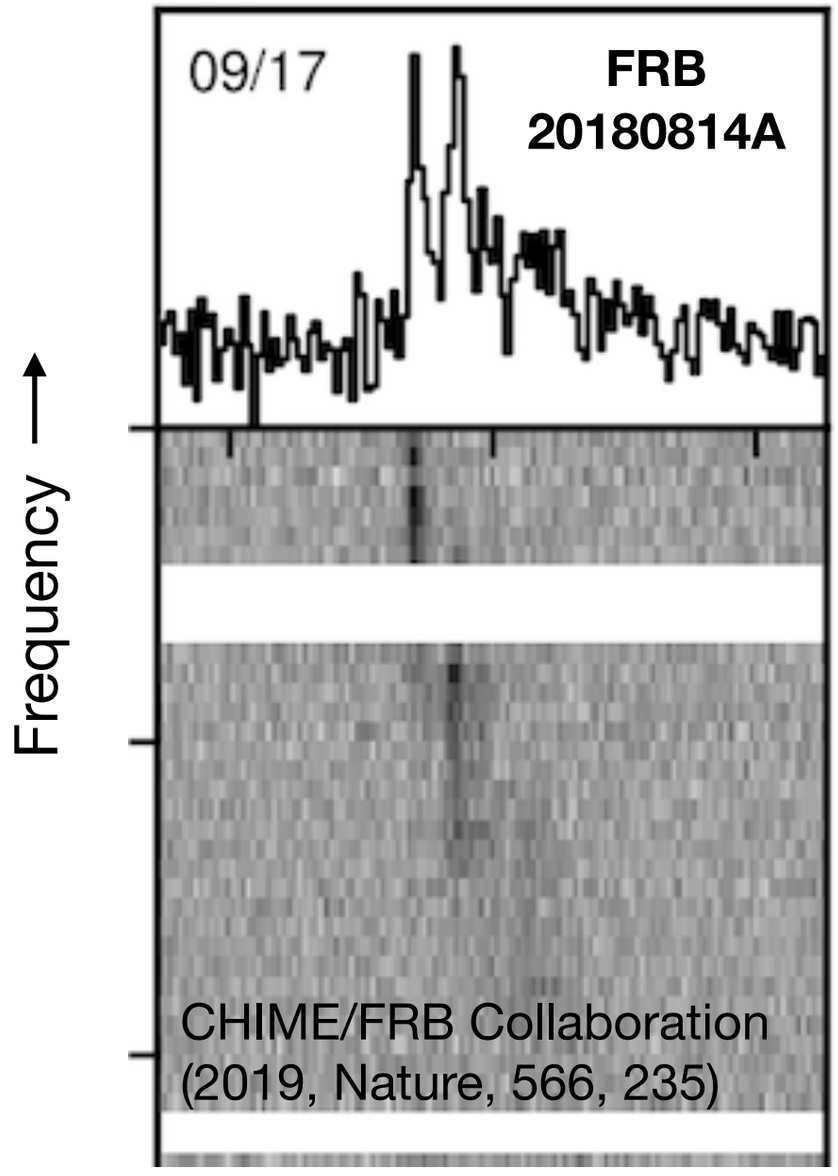
- Most striking feature —> “downward drifting” substructure (see right).



Hessels et al. (2019, ApJL, 876, L23)

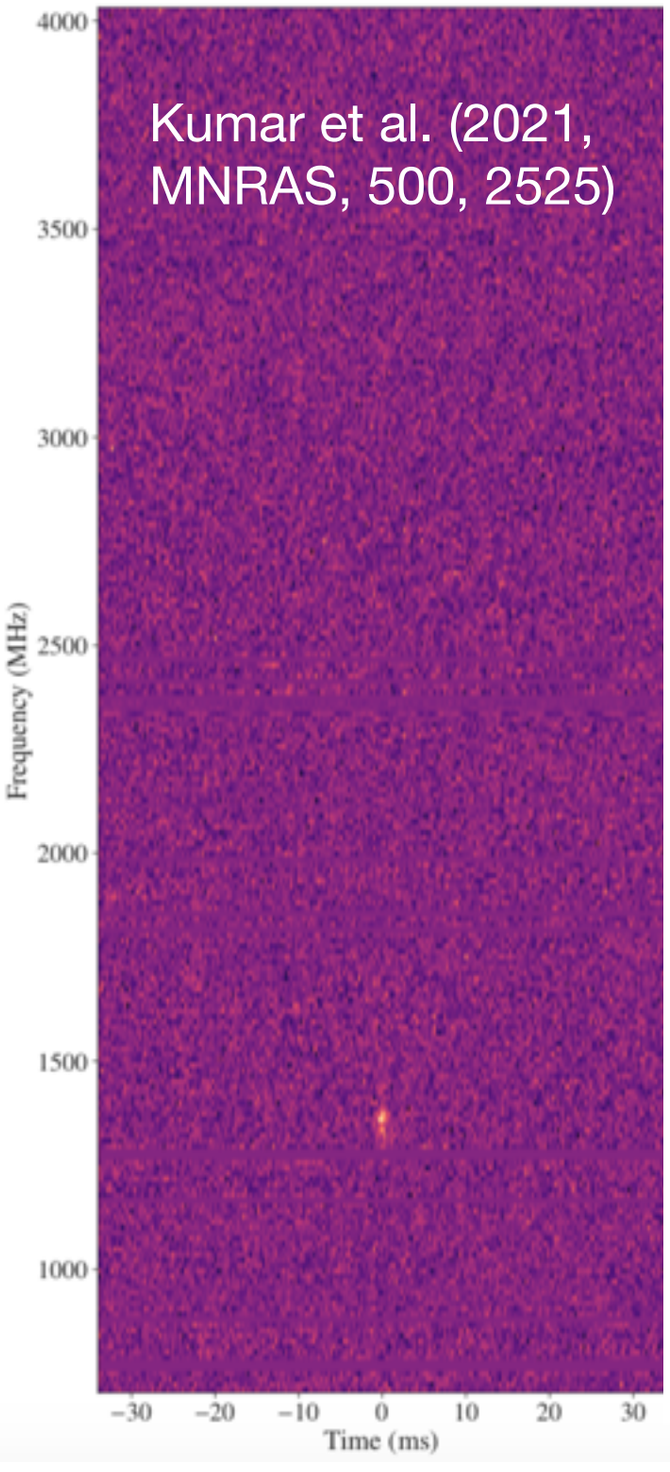
Similarities in Repeating Behaviour

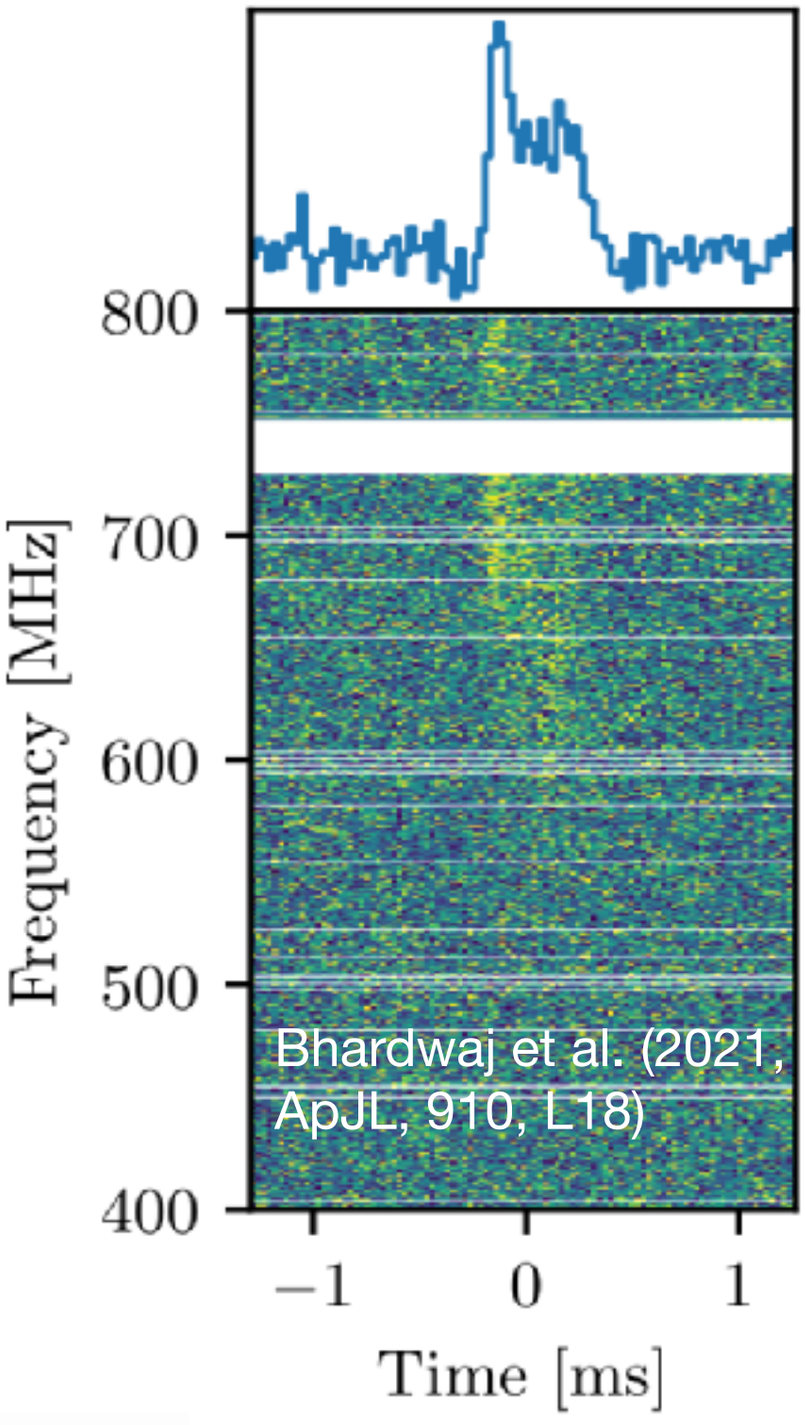




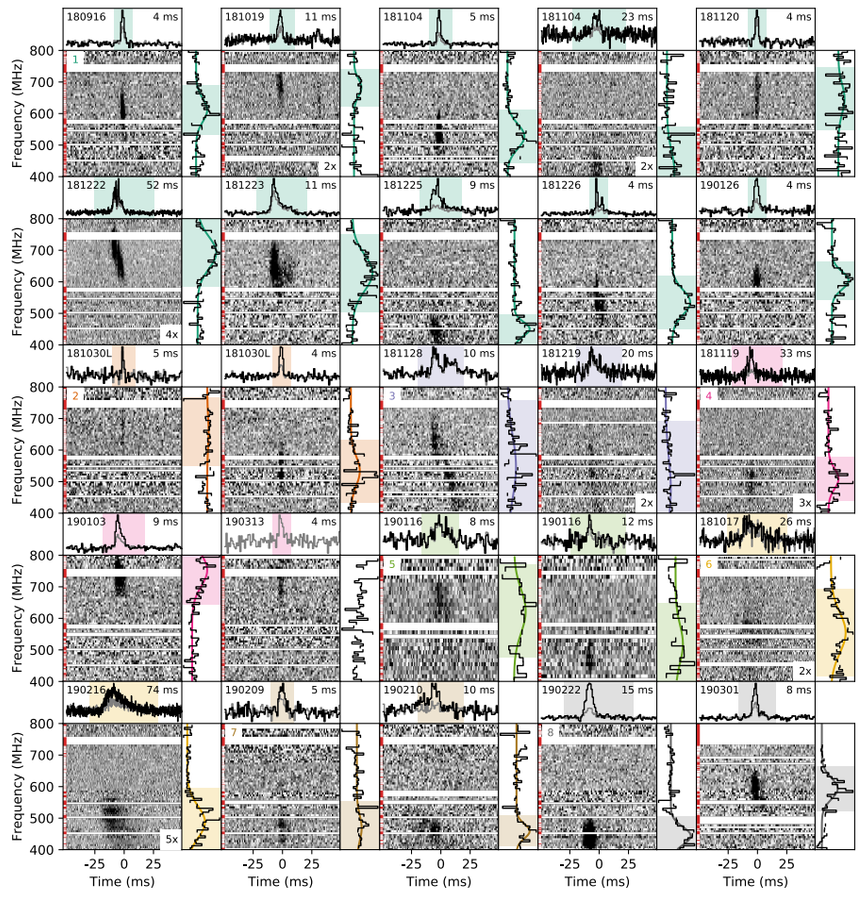
The second repeating FRB source demonstrated the same, dramatic behavior first seen in FRB 20121102A —> similar environments and/or progenitors?

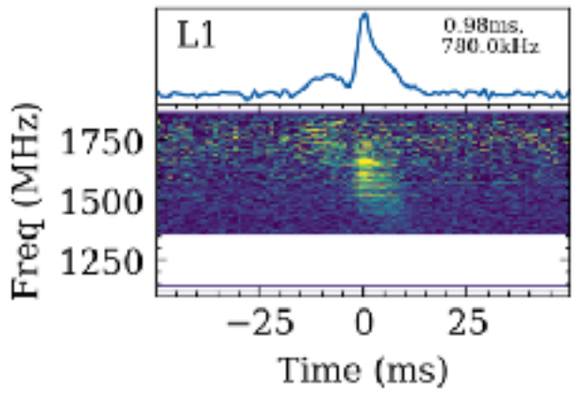
Many Repeaters found in the Last 4 Years





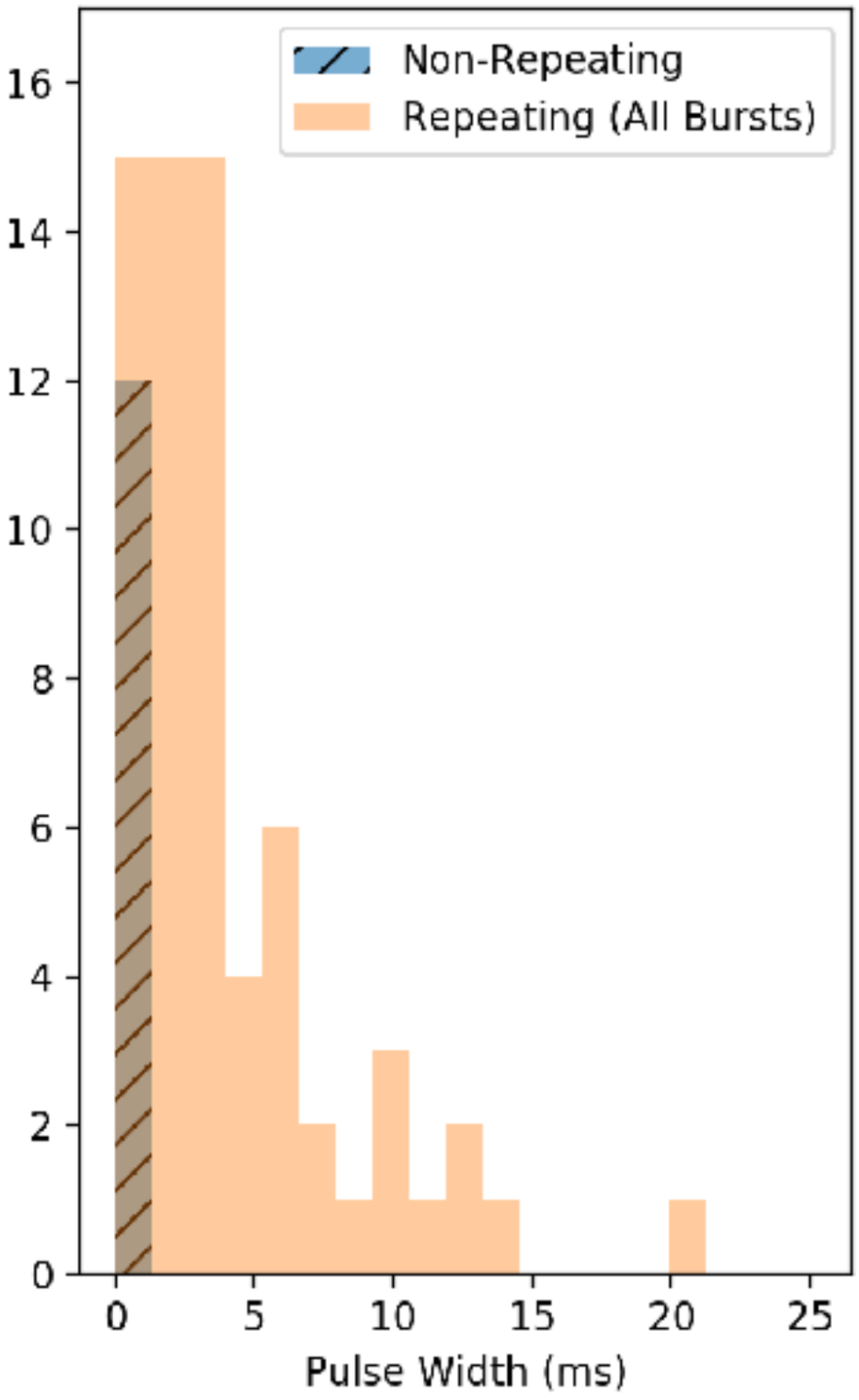
CHIME/FRB Collaboration (2019, ApJL, 885, L24); Fonseca et al. (2020, ApJ, 891, L6); and **see talk contribution by Ziggy Pleunis**!

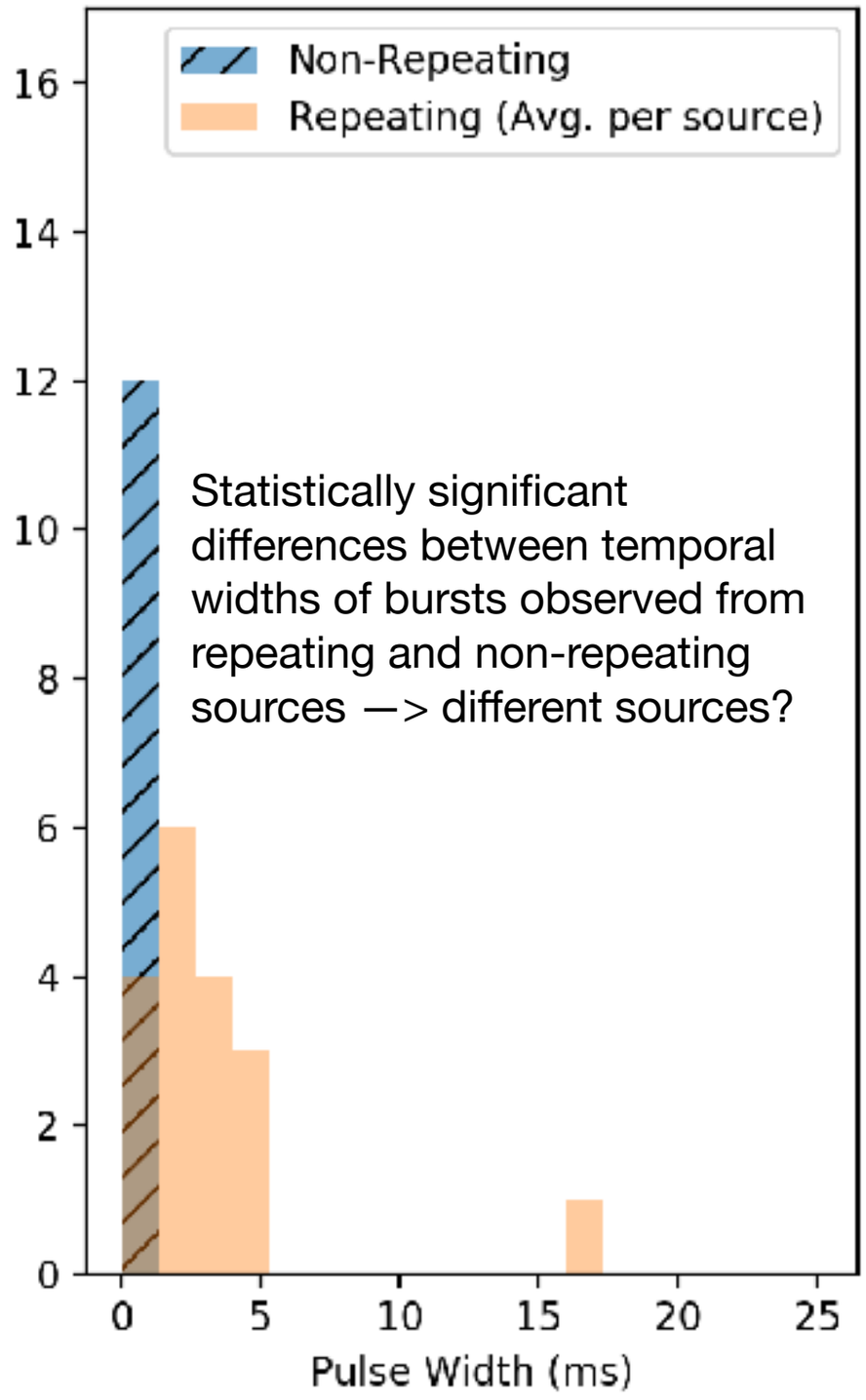




Anna-Thomas et al. (2022, arXiv: 2202.11112)

First Hints of Different FRB Populations





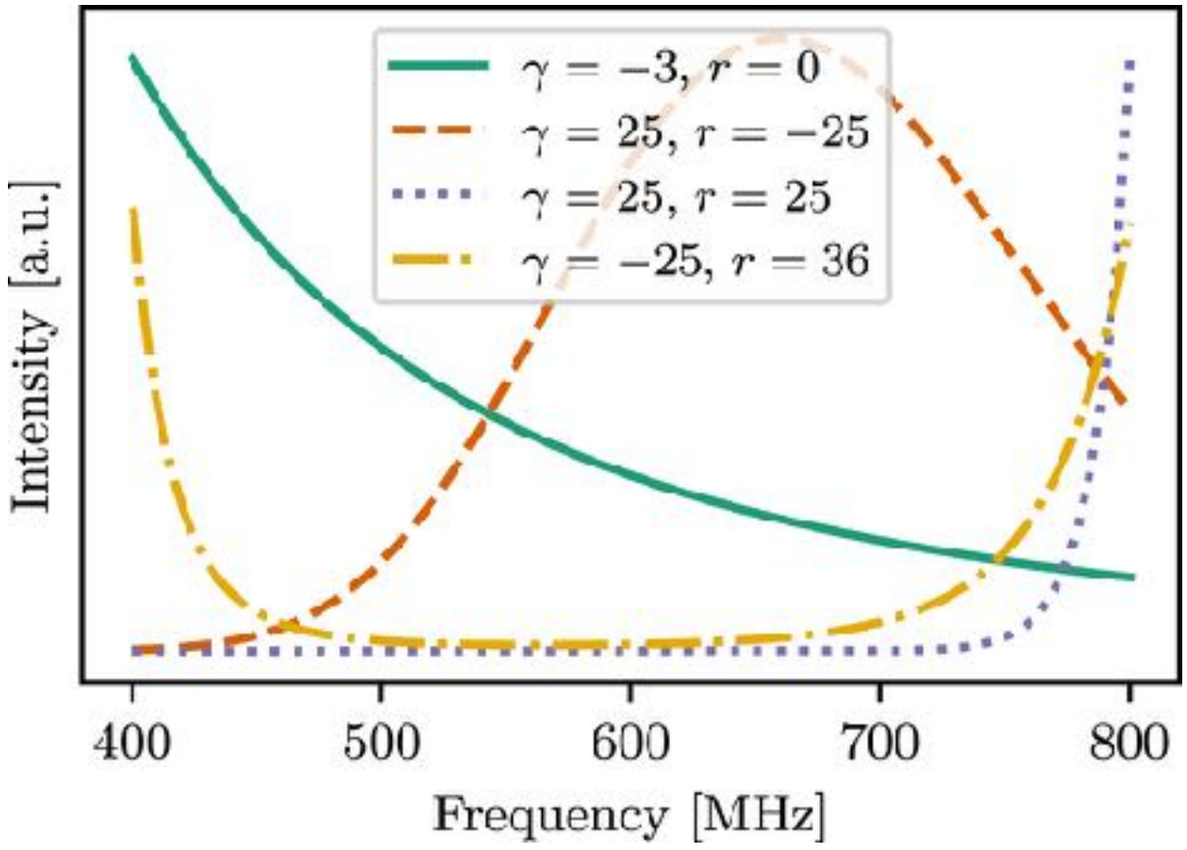
Fonseca et al. (2020, ApJL, 891, L6)

Characterizing FRB Morphology

- There are several different frameworks to generate toy models of FRB dynamic spectra:
  - Ravi et al. (2019, MNRAS, 482, 1966)
  - Aggarwal et al. (2021, ApJ, 922, 115)
  - CHIME/FRB et al. (2018–2022); Pleunis et a. (2021, ApJ, 923, 1); Fonseca et al. (in prep); Masui et al. (2015, Nature, 528, 523)

- CHIME/FRB uses a “running power-law” model for spectral-energy distribution:

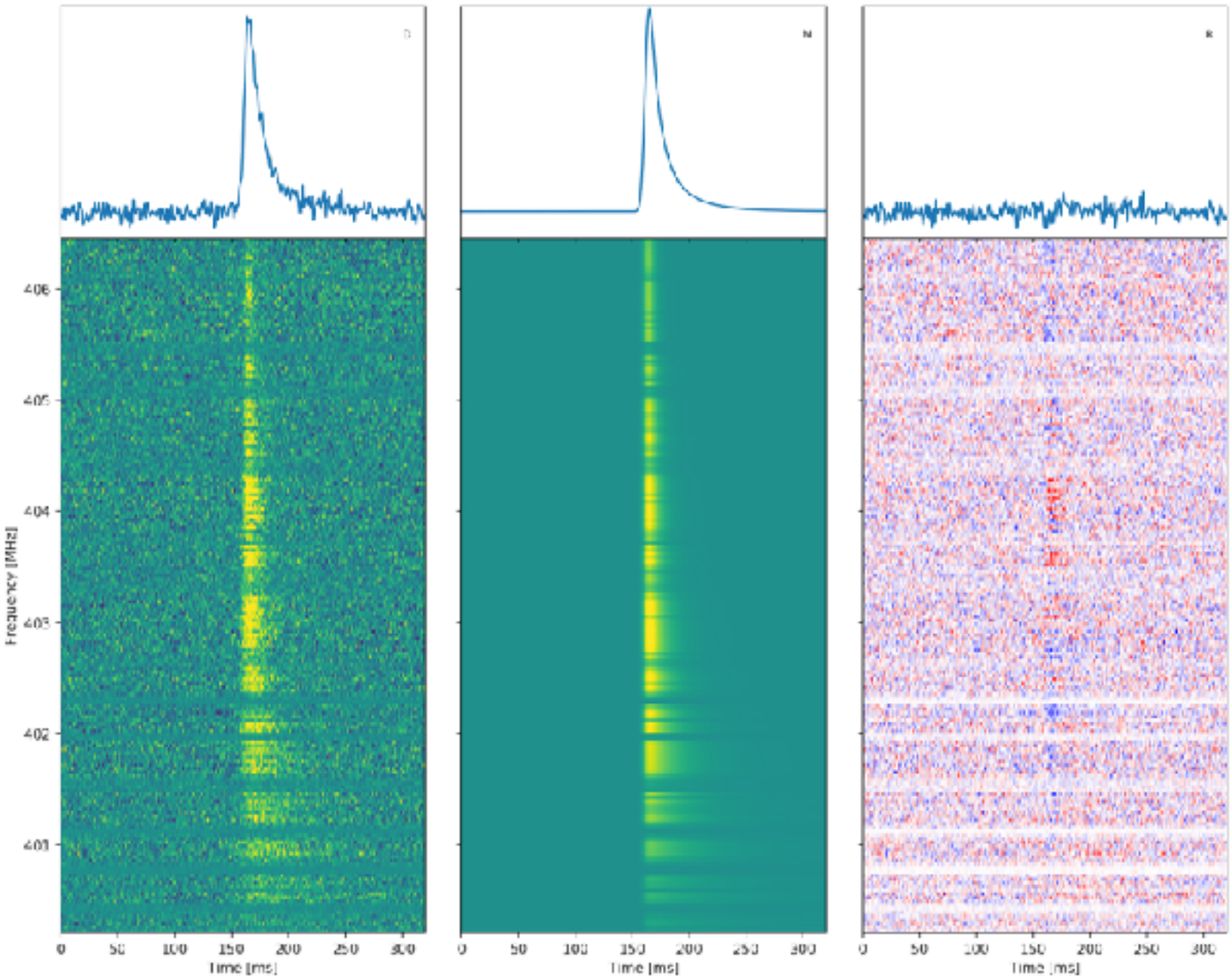
$$I(\nu) = \left(\frac{\nu}{\nu_0}\right)^{\gamma + r\,\ln(\nu/\nu_0)}$$



Different combinations of spectral index (γ) and running (r) parameters lead to different SED shapes.

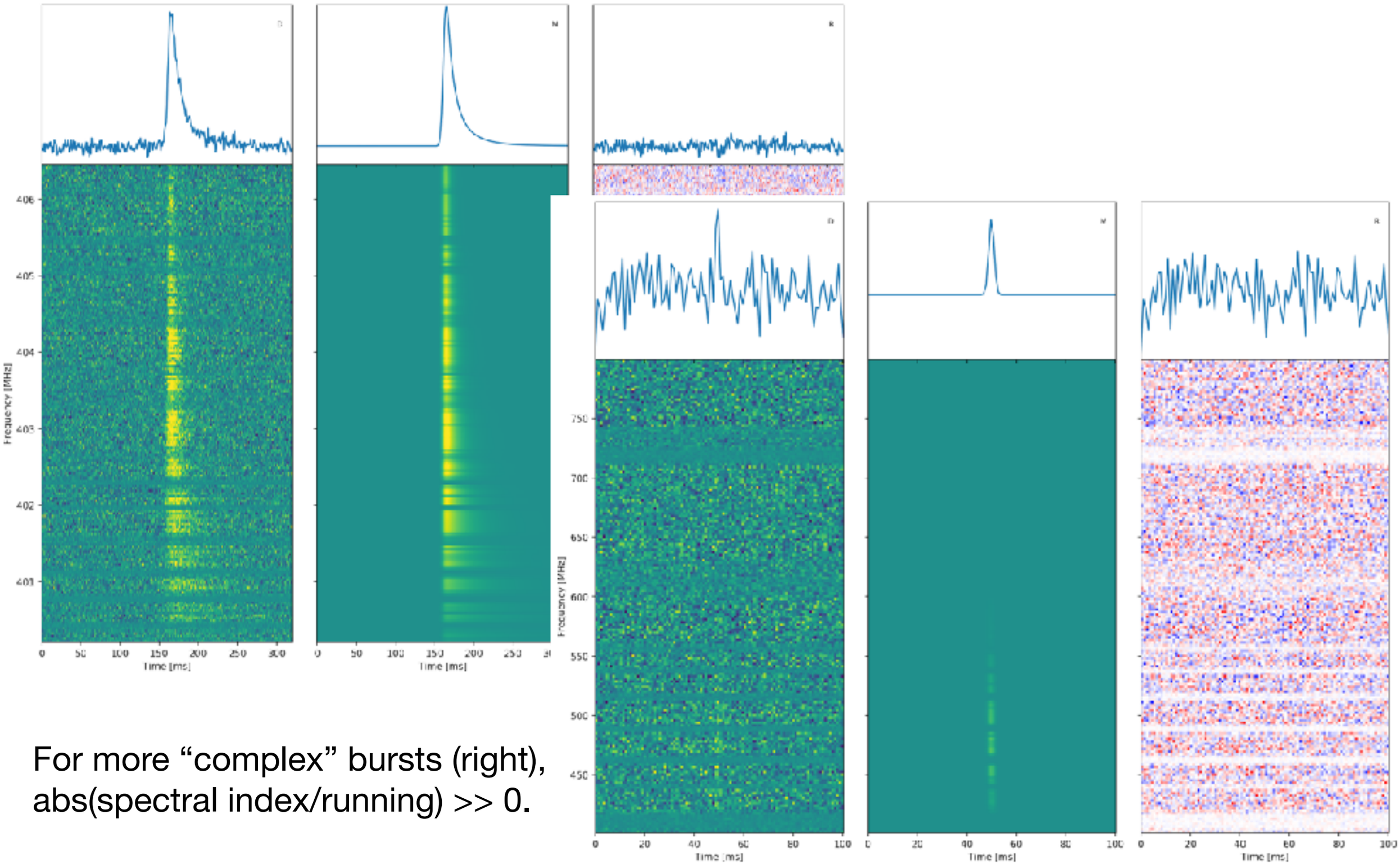
Taken from Pleunis et al. (2021, ApJ, 923, 1)

CHIME/FRB Spectra Models w/ fitburst



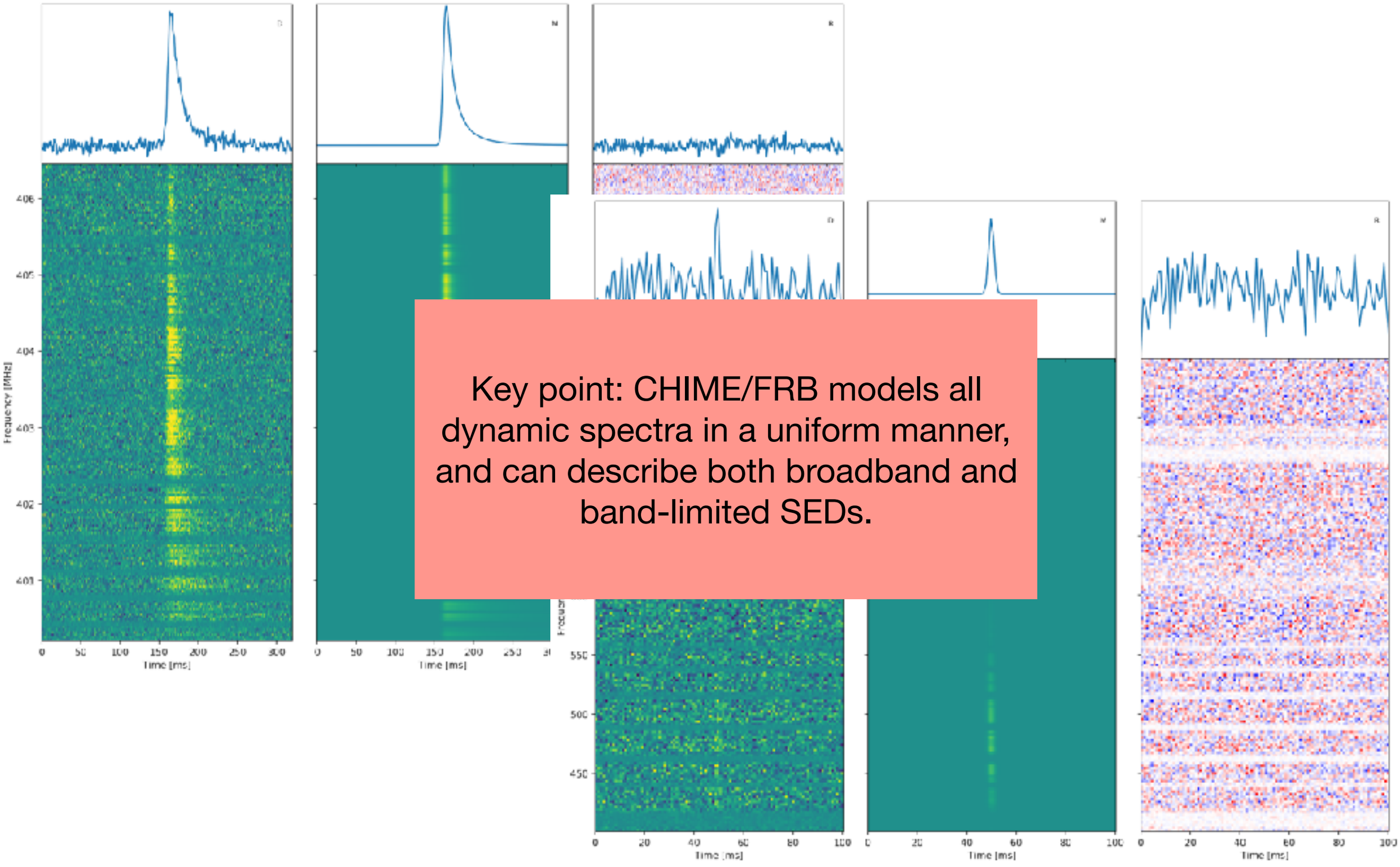
For “classic” burst shapes (e.g., left), dynamic spectra are characterized with “typical” values of the spectral index (~ -3 < gamma < 0), and spectral “running” —> 0.

CHIME/FRB Spectra Models w/ fitburst



For more “complex” bursts (right), abs(spectral index/running) >> 0.

CHIME/FRB Spectra Models w/ fitburst



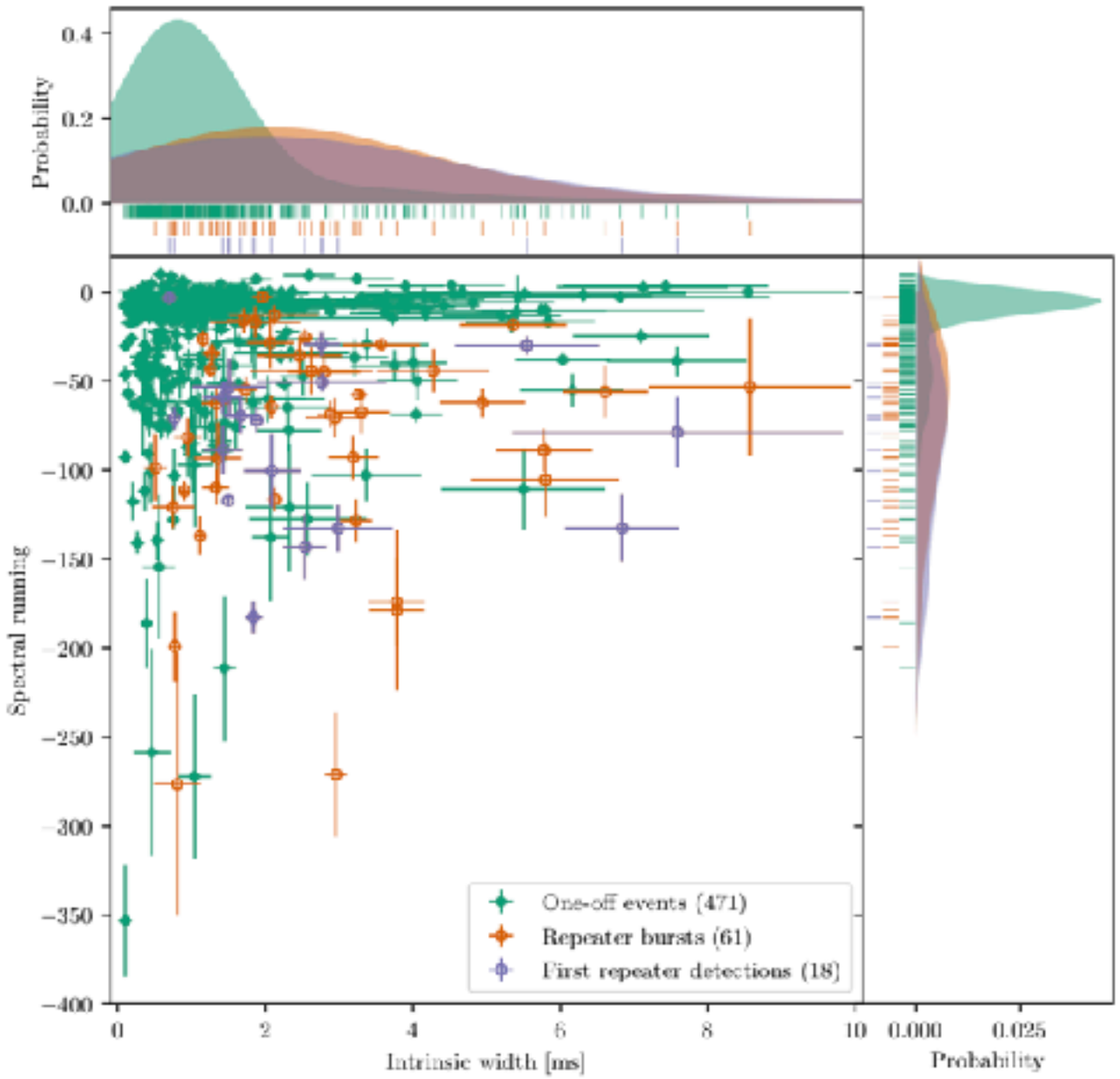
Key point: CHIME/FRB models all dynamic spectra in a uniform manner, and can describe both broadband and band-limited SEDs.

Summary of CHIME/FRB Modeling for Catalog 1

- In the first CHIME/FRB catalog, (2 + 5 * N) parameters for each burst, where N = number of distinct components.

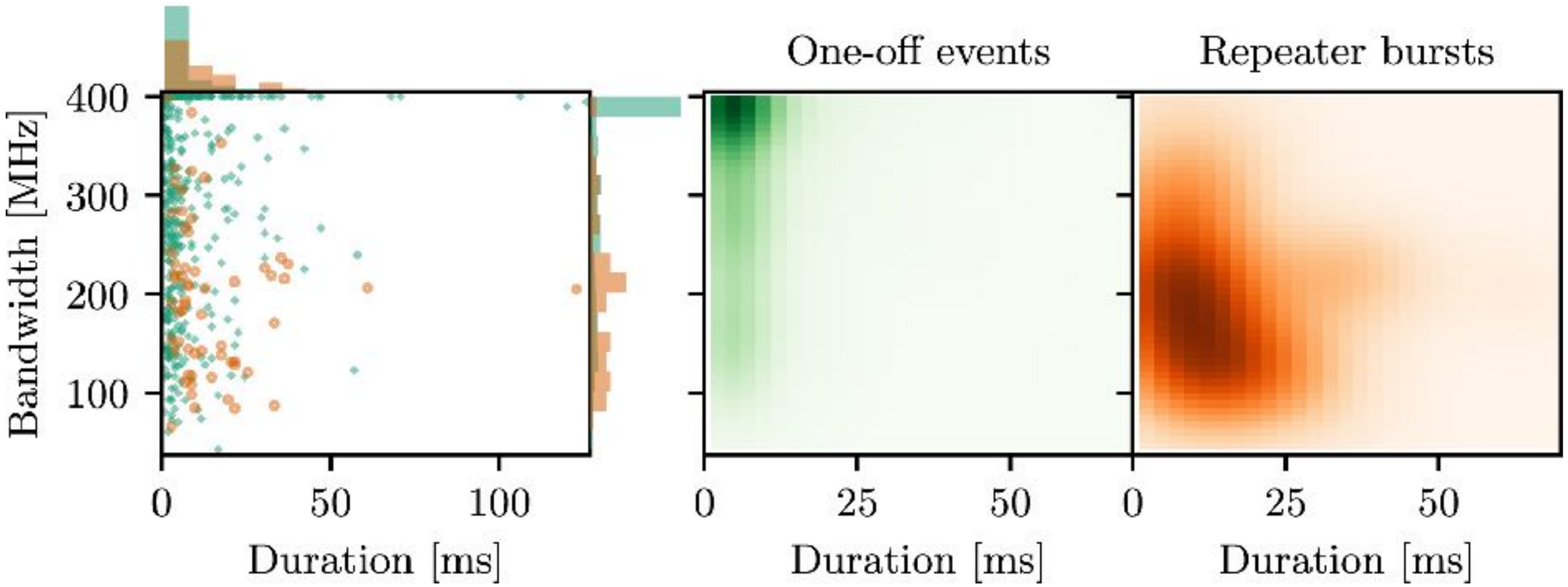
- Despite uniformity in modeling, FRBs from“apparently non-repeating” sources are significantly different than confirmed repeaters in terms of spectral properties (see right).

- This framework yields several implications that may be useful on various fronts.



Pleunis et al. (2021, ApJ, 923, 1)

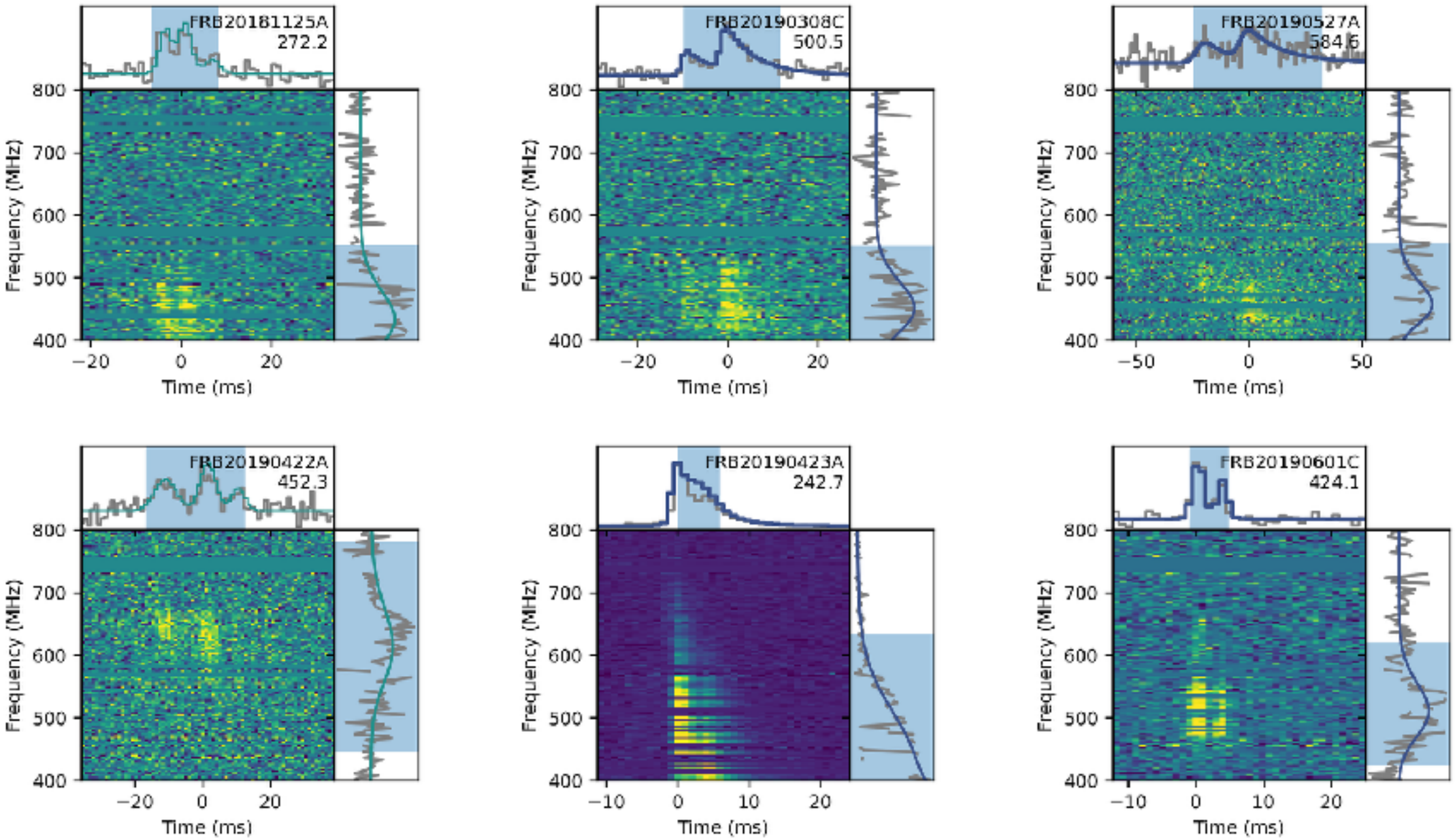
Implication #1: Preferred Phase Spaces in FRB Spectra Modeling



Confirmed repeaters occupy different portions of the parameter phase space in comparison to apparently non-repeating sources.

Do current models of FRB emission predict one or more of these preferred regions of spectro-temporal phase spaces? Are there models that predict both broadband and band-limited/repeater-like bursts?

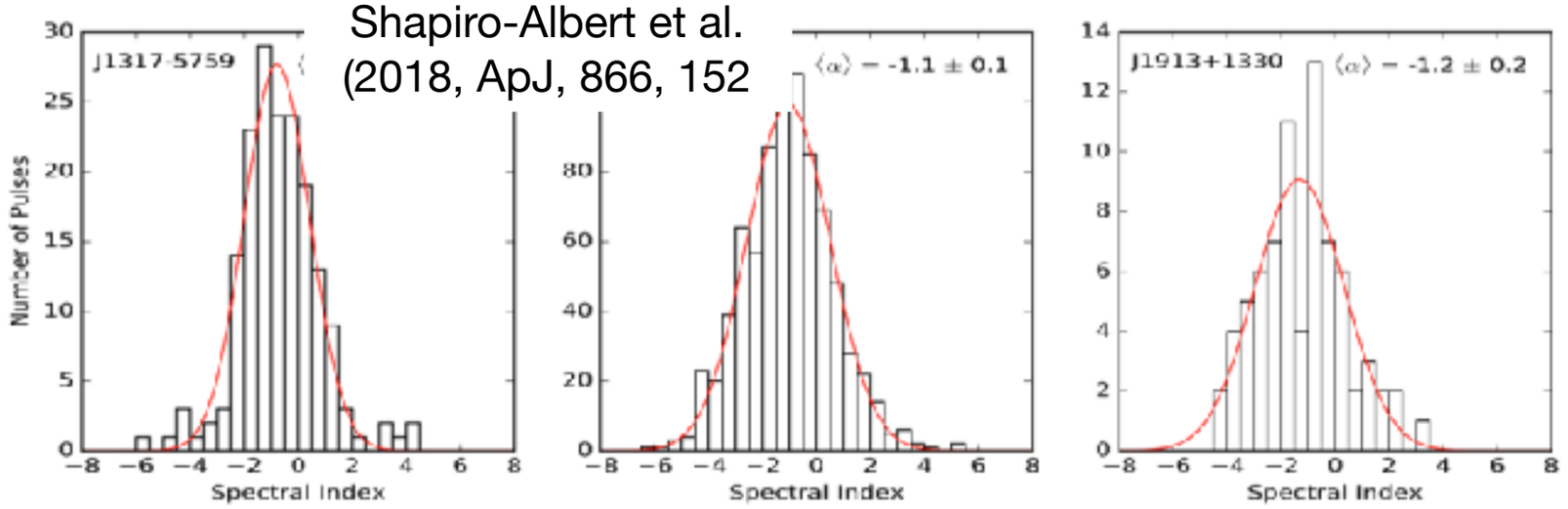
Implication #2: Repeatability based on Morphology



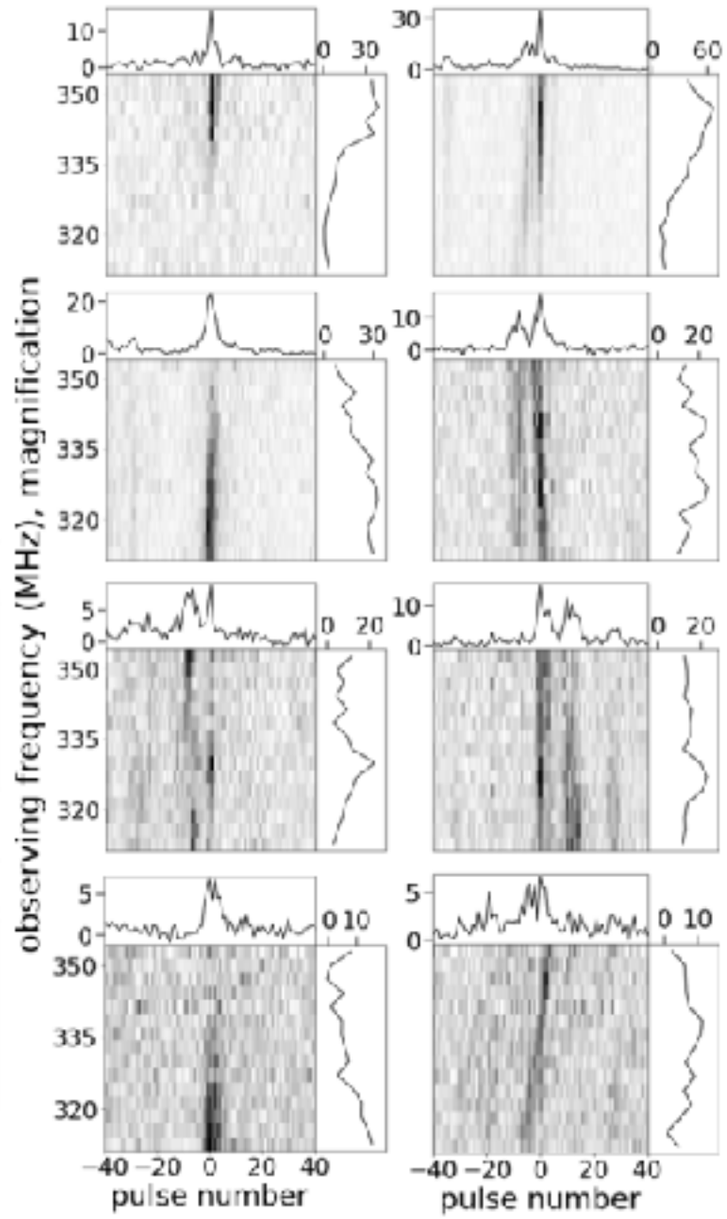
Pleunis et al. (2021) noted that six FRBs in CHIME/FRB's Catalog 1 satisfy criteria for "likely repetition" (based on morphology, multiple components, etc.)

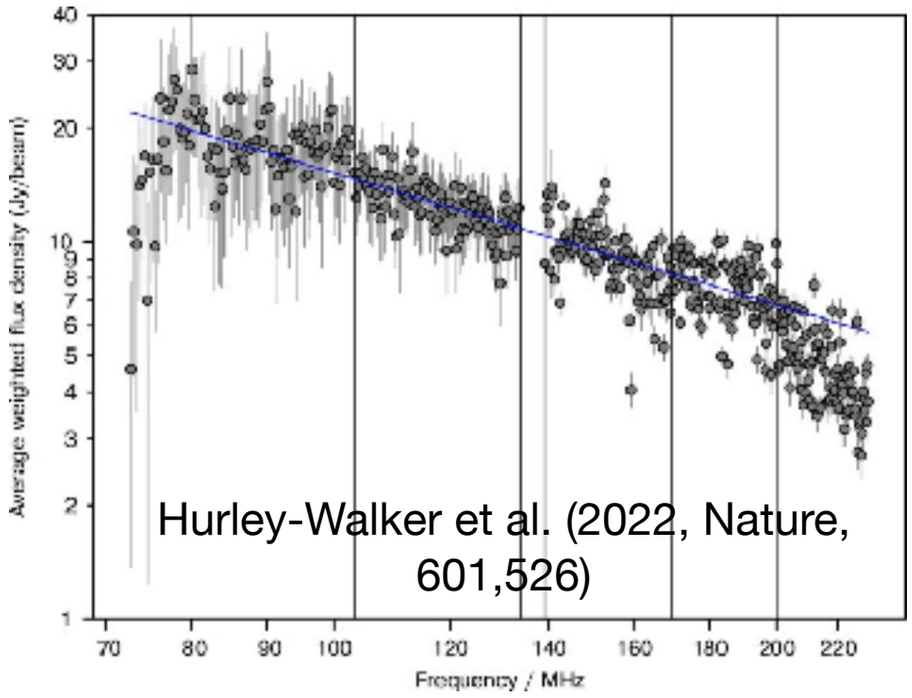
Implication #3: (Lack of?) Similarity with Galactic Sources

Shapiro-Albert et al. (2018, ApJ, 866, 152

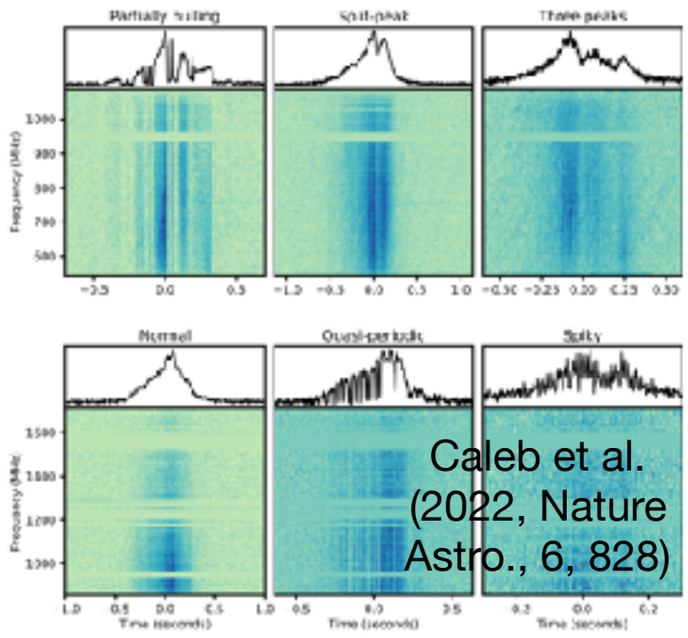


Main et al. (2022, Nature, 557, 522)





Hurley-Walker et al. (2022, Nature, 601,526)



Caleb et al. (2022, Nature Astro., 6, 828)

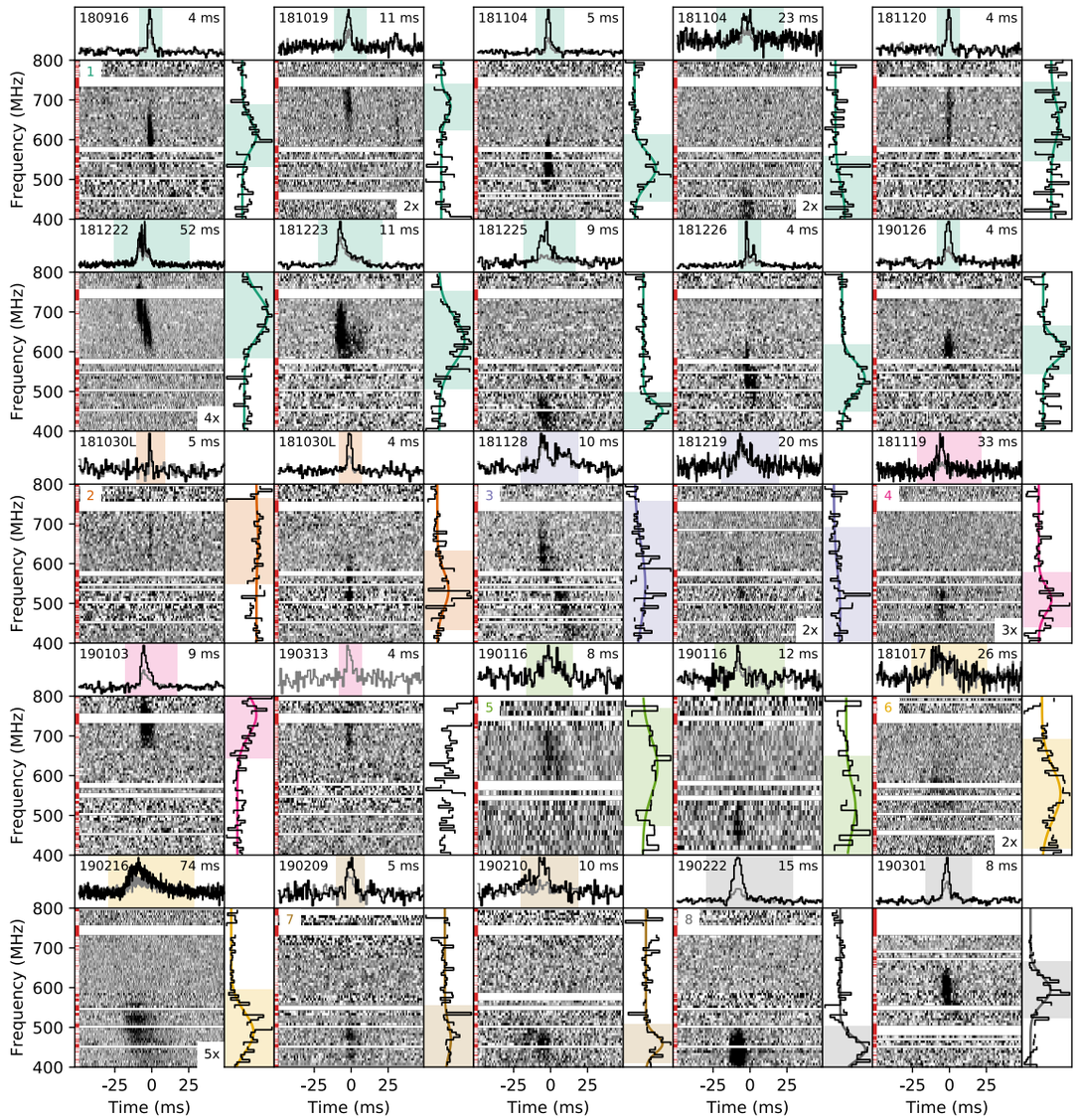
Direct modeling of dynamic spectra —> meaningful comparisons between FRBs and radio-transient sources in the Milky Way, such as pulsars (right), RRATs (top), and recently-discovered slow transients (bottom).

Summary + Food for Thought

- Increasing population of observed FRBs —> apparent dichotomy in burst morphology.

- Uniform methods of modeling FRB spectra yield preferred (phenomenological) phase spaces for repeaters.

- A variety of implications for both observers and theorists to ponder over!



Thank You!