Eight-Component Quasi-Periodic Train and a Candidate $\sqrt{5}$ Damping Ratio in FRB 20190122C

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Abstract

Using the published component-level pulse table for FRB 20190122C (Xiao et al., arXiv:2601.03950), we measure an eight-component millisecond pulse train with quasi-period $P = 0.933 \pm 0.063$ ms. Fitting a post-peak exponential envelope yields $\tau = 2.179 \pm 0.052$ ms, giving $\tau/P = 2.334 \pm 0.167$, consistent with $\sqrt{5} = 2.236$ within uncertainties. We compare an unconstrained exponential envelope to a constrained model with τ fixed to $\sqrt{5}\,P$. The constrained model is not rejected (likelihood-ratio $p = 0.068$), though the unconstrained model is weakly preferred as expected for an additional free parameter. Both envelope fits exhibit large χ^2 values, indicating that a single-τ exponential is an imperfect phenomenological model for these component amplitudes; we therefore treat model-comparison p-values as heuristic. We also report secondary ratios (e.g., A_4/A_5) as exploratory observations and provide an illustrative Monte Carlo null model to calibrate coincidence rates under simple assumptions (not a formal p-value). Definitive conclusions require replication on independent high-component events (e.g., FRB 20201014B) and validation from raw baseband/intensity data products.

1 Introduction

Fast Radio Bursts (FRBs) are millisecond-duration radio transients of unknown origin. A subset show sub-burst structure and, in rare cases, quasi-periodic oscillations (QPO-like morphology) on millisecond timescales. FRB 20190122C is notable for a reported eight-component morphology separated by $\sim$1 ms with an overall damped envelope (Xiao et al., arXiv:2601.03950).

Motivation: if FRB sub-burst trains are produced by an underlying oscillator or clock-like process, the component count and damping ratio τ/P become key invariants to compare across physical models. This draft documents a fully reproducible measurement of these quantities from the published component table and provides a minimal statistical test of the constraint $\tau = \sqrt{5}\,P$, which arises as a parameter-free prediction in the Recognition Science (RS) framework.

This manuscript is intentionally split into: (A) empirical measurements from published data tables, and (B) an interpretation layer (RS) clearly separated from (A).

2 Data

We use Extended Data Table 1 from Xiao et al. (arXiv:2601.03950), transcribed into `data/FRB_20190122C_pulses.c` Columns: `tick, time_ms, amplitude, amplitude_err, width_ms`.

This analysis does not use raw baseband voltages; it is therefore a secondary analysis of published fit products. Replication from baseband/intensity data is a priority.

3 Methods

3.1 Period estimation

We estimate the quasi-period P by linear regression:

$$t_n = t_0 + nP$$

where n is the component index (0..7) and t_n is the reported arrival time (ms). We report P_{fit} (slope) and P_{mean} (mean adjacent interval) as a descriptive statistic.

3.2 Exponential envelope fit

We fit a damped envelope from the peak onward using:

$$A(t) = A_0\, e^{-t/\tau}$$

where t is time since the peak component. The fit is weighted by the reported amplitude uncertainties.

3.3 RS constrained model test (nested model comparison)

We compare:

- Free model: $A(t) = A_0 e^{-t/\tau}$ (parameters: A_0, τ)
- RS constrained: $A(t) = A_0 e^{-t/(\sqrt{5}\,P)}$ (parameter: A_0; τ fixed)

We compute χ^2 for both models on the same post-peak points, then evaluate $\Delta\chi^2$ and report ΔAIC and ΔBIC.

Important caveat. In this event, the phenomenological envelope fit yields very large χ^2 values ($\chi^2/\text{dof} \gg 1$), suggesting underestimated uncertainties and/or model misspecification. Therefore, likelihood-ratio p-values should be interpreted qualitatively (as a plausibility check), not as definitive statistical significance.

3.4 Secondary ratio checks

We compute τ/P with propagated uncertainty and A_4/A_5 (using tick indices 4 and 5) with propagated uncertainty.

4 Results (FRB 20190122C)

All results below are generated by `scripts/frb_model_comparison.py`, which writes `data/FRB_20190122C_model_`

4.1 Eight-component morphology

The event exhibits exactly $N = 8$ components in the published decomposition.

4.2 Period and damping

From the published component times:

$$P_{\text{fit}} = 0.933452 \pm 0.063195 \text{ ms}$$

and $P_{\text{mean}} = 0.952857$ ms (std over intervals: 0.283885 ms).

From a weighted post-peak exponential fit:

$$\tau_{\text{free}} = 2.179045 \pm 0.051607 \text{ ms}$$

Ratio:

$$\tau/P_{\text{fit}} = 2.334393 \pm 0.167429, \qquad \sqrt{5} = 2.236068$$

This is consistent within $\sim 0.59\sigma$ under Gaussian error propagation.

4.3 RS constrained vs free model comparison

Using $\tau_{\text{RS}} = \sqrt{5}\,P_{\text{fit}}$ gives $\tau_{\text{RS}} = 2.087263$ ms. Goodness-of-fit (post-peak, 6 points):

$$\chi^2_{\text{free}}(\text{dof} = 4) = 132.721, \qquad \chi^2_{\text{RS}}(\text{dof} = 5) = 136.062$$

$$\Delta\chi^2 = 3.341 \quad (1 \text{ dof}) \quad \Rightarrow \quad p \approx 0.0676$$

Information criteria:

$$\Delta\text{AIC}(\text{RS} - \text{free}) = +1.341, \qquad \Delta\text{BIC}(\text{RS} - \text{free}) = +1.549$$

Interpretation: the RS constraint $\tau = \sqrt{5}\,P$ is plausible given these data and this envelope model, but the unconstrained fit is (weakly) preferred. Note the very large χ^2 values, indicating that a single-τ exponential does not fully describe the component amplitudes and that quoted p-values should be treated as heuristic.

4.4 Secondary ratios (exploratory)

Amplitude ratio (ticks 4 and 5):

$$A_4/A_5 = 2.277283 \pm 0.367061, \qquad \sqrt{5} = 2.236068$$

4.5 Illustrative null model Monte Carlo (not a formal p-value)

We assess whether the joint observation of $\tau/P \approx \sqrt{5}$ and $A_4/A_5 \approx \sqrt{5}$ could arise by chance under a toy null model where these quantities are independent and have no special relationship to $\sqrt{5}$ (see `scripts/frb_null_model_mc.py`, output `data/FRB_20190122C_null_model_mc.json`). This exercise is intended to calibrate plausibility, not to produce a definitive statistical significance level.

5 Population context and replication targets

Microsecond morphology analyses (Curtin et al., arXiv:2411.02870 source tables) suggest that high-component bursts are rare. Within that dataset, only one additional eight-component burst was identified: FRB 20201014B (repeater FRB 20200202A), $N_{\text{components}} = 8$.

A key replication test is whether FRB 20201014B exhibits a comparable constrained ratio $\tau/P \approx \sqrt{5}$ when analyzed with the same pipeline. Replication on independent events is essential to control a posteriori pattern risk and to establish generality.

6 Discussion (interpretation layer)

6.1 Conventional interpretations

An eight-component damped millisecond train can arise from several physical processes (e.g., magnetospheric oscillations, emission windowing, propagation effects). A complete astrophysical model should jointly explain: component count distribution, period stability, envelope damping, frequency dependence and scattering, and repetition statistics.

6.2 Recognition Science hypothesis (clearly labeled)

In RS, discrete "ledger" update structure forces an 8-step cycle and a ϕ-geometry that implies $\sqrt{5} = \phi + 1/\phi$. Under this hypothesis, rare FRB events may transiently expose this structure, producing: $N = 8$ component trains, τ/P clustering near $\sqrt{5}$, and additional ϕ-related scaling in secondary observables.

This manuscript does not claim RS is established by one event; it documents a concrete, falsifiable set of predictions and a replication program.

6.3 Limitations and threats to validity

- Measurements are derived from a published component table (fit products), not direct re-processing of raw voltages.
- Component identification and indexing can be analysis-dependent; alternative decompositions could shift amplitudes/times.
- The exponential envelope is a phenomenological simplification; the large χ^2 indicates unmodeled structure.
- The toy Monte Carlo null model is not a population model and does not account for selection effects.
- Because FRB 20190122C is a singled-out rare event, independent replication (e.g., FRB 20201014B) is the most important next test.

7 Reproducibility / artifacts

Repository artifacts used:

- `data/FRB_20190122C_pulses.csv`
- `scripts/frb_rs_analysis.py` (general RS checks; corrected to fit τ in ms)
- `scripts/frb_model_comparison.py` (nested model comparison + uncertainty propagation)
- `scripts/frb_null_model_mc.py` (null model Monte Carlo, 100k simulations)
- `data/FRB_20190122C_rs_analysis.json`
- `data/FRB_20190122C_model_comparison.json`
- `data/FRB_20190122C_null_model_mc.json`

- `data/FRB_RS_Analysis_Report.txt`

Minimal reproduction commands:

```
python3 scripts/frb_model_comparison.py
python3 scripts/frb_null_model_mc.py
```

8 References

- Xiao, S., Jiang, J., & Li, D. (2025). arXiv:2601.03950. "Evidence for a Damped Millisecond Quasi-Periodic Structure in FRB 20190122C." (Title as listed on arXiv.)
- Curtin, A. P., et al. (2024). arXiv:2411.02870. "Morphology of 35 Repeating Fast Radio Burst Sources at Microsecond Time Scales with CHIME/FRB."
- CHIME/FRB Collaboration et al. (2023). CHIME/FRB Baseband Catalog 1. Data citation DOI: 23.0029.

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