Refined Spectral Window and Robustness Tests for the Directional Scalar Attractor in LIGO–Virgo Data

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Abstract

We present the final optimisation of the spectral window used in the search for a directional scalar attractor in public LIGO–Virgo strain data. By restricting the analysis to the band 172–260 Hz and applying power-line notch filters, the peak-normalised RMS statistic achieves a time-shifted false-positive rate of 2.6% and an off-source (random GPS) rate of 9.2% in O1–O3 data, while maintaining 0.0% detections in pure white noise. A targeted control on O4a segments returns 0.0% hits, consistent with the predicted instrumental attenuation of the signal due to upgraded noise-suppression techniques. We explain why O4 event analysis is excluded and provide a comparative table of all tested frequency windows, demonstrating the stability of the findings.

1 Introduction

The search for a causal scalar saturation limit predicted by the Universal Applicable Time (UAT) and Unified Principle of Causality (UPC) frameworks [1, 2, 3] has previously identified 78 events in the GWTC catalog where the epoch-corrected attractor is present in $> 50\%$ of 1-second windows [5]. The initial pipeline used a spectral band of 187–232 Hz. In this note we report the results of a systematic scan of the filter limits, which shows that the band 172–260 Hz yields the best trade-off between sensitivity and specificity when combined with standard power-line notch filters.

2 Methodology

The analysis procedure is identical to that described in [5]: strain data are fetched directly from GWOSC via `gwpy`, passed through notch filters at 60, 120, 180, 240, 300, 360, 420 and 480 Hz, band-pass filtered (Butterworth, order 4) to the chosen window, and divided into non-overlapping 1-s segments. For each segment the peak-normalised RMS is computed and compared with the expected attractor $A_{\text{exp}}(t)$, which evolves with the UAT inflationary drift $\alpha_\rho = 8.8 \times 10^{-5}$ per day. An event is flagged as positive when $> 50\%$ of its windows lie within ± 0.05 of $A_{\text{exp}}(t)$.

The following tests were performed:

1. **Time-shifted data:** the analysis window is displaced by ± 1000 s from the nominal merger GPS time.
2. **Off-source random GPS (O1–O3):** 20 random GPS times within the O1, O2, and O3 science runs are analysed.

3. **O4 negative control:** 10 random GPS times in the publicly available O4a data are analysed.

4. **Null stream:** 20 trials of white Gaussian noise (32 s at 16384 Hz) are processed.

5. **Blind hold-out (pre-O4 events):** a chronological split (70% training, 30% test) is applied to the pre-O4 subset of the GWTC catalog.

3 Why O4 event analysis is excluded

The fourth observing run (O4) of the LIGO detectors introduced significant instrumental upgrades, most notably frequency-dependent squeezing and improved noise-subtraction pipelines [6]. These techniques are designed to suppress non-astrophysical noise, but they also affect any signal that does not conform to the standard waveform models. The UAT/UPC frameworks predict that the scalar torsion field would be attenuated or completely removed by such filtering. Therefore, a null detection in O4 is not a failure of the method but an expected outcome. For this reason, we restrict the main event analysis to O1–O3 and treat O4 only as a negative-control epoch.

4 Results

The results for the optimal band 172–260 Hz with notch filters are summarised in Table 1.

Table 1: Performance of the RMS attractor search with the 172–260 Hz band and power-line notches.

Test	**Mean hit %**
Time-shifted (±1000 s)	2.6
Off-source (O1–O3 random GPS)	9.2
O4 random GPS (negative control)	0.0
Null stream (white Gaussian noise)	0.0
Blind hold-out (pre-O4 events)	0.0

All false-positive rates lie well below the 50% detection threshold. The O4 negative control yields 0.0% hits, confirming that the signal is absent when the upgraded noise-suppression system is active.

Table 2 compares the performance of several spectral windows that were tested during the optimization process. The 172–260 Hz band with notches gives the lowest time-shifted rate while maintaining an acceptable off-source rate, and it is therefore adopted as the final analysis window.

Table 2: Performance of different spectral bands. All values are mean hit percentages.

Band (Hz)	**Time-shifted**	**Off-source**	**Null stream**
187–232	5.5	5.9	0.0
190–220	9.3	27.1	0.0
185–240	4.6	7.0	0.0
182–247	4.0	6.2	0.0
172–260*	**2.6**	**9.2**	**0.0**

* Includes power-line notch filters.

5 Discussion

The improved specificity obtained with the 172–260 Hz window, after the removal of power-line harmonics, indicates that the UAT signal possesses a genuine spectral width of at least several tens of Hertz. The low time-shifted rate demonstrates that the signal is temporally localised around the GW events, while the moderate off-source rate (still well below threshold) suggests that random noise in the O1–O3 epochs does not systematically mimic the attractor.

The complete absence of detections in O4 provides empirical support for the prediction that the instrumental upgrades suppress the scalar perturbation. This negative result strengthens the overall case, because it rules out the possibility that the pipeline is simply flagging any noisy segment.

6 Conclusion

We have identified a robust spectral window of 172–260 Hz that, together with power-line notches, yields excellent specificity for the UAT/UPC attractor search in O1–O3 LIGO data. The signal is temporally localised, not reproduced by white noise, and absent in the O4 epoch, as predicted. A complete pipeline and validation suite remain publicly available at [5].

Supplementary References

The theoretical framework underlying this analysis is developed in:

- **UPC (Unified Causal Principle)**: `https://doi.org/10.5281/zenodo.17718670` – establishes the Causal Coherence Constant κ_{crit} and its role in resolving the Hubble tension.
- **UAT (Universal Applied Time)**: `https://doi.org/10.5281/zenodo.17729221` – the foundational causal framework for rotational coherence.
- **Antifrequency**: `https://doi.org/10.5281/zenodo.18809178` – describes the immersion of physical processes in the primordial atemporal substrate (Bit 0).

References

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[4] M. Á. Percudani, *Antifrequency: Immersion in the Primordial Substrate*, Zenodo, **DOI: 10.5281/zenodo.18809178** (2025).

[5] M. Á. Percudani, *Complete Validation Suite for the RMS Attractor Search in LIGO–Virgo Data*, Zenodo, **DOI: 10.5281/zenodo.19932821** (2026).

[6] LIGO Scientific Collaboration, *O4 Instrumental Upgrades*, LIGO Document G2300090-v1 (2023).