Rotational Phase Interference Analysis Reveals a Broad, Persistent Coherent Band in LIGO O4a Data

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We report the detection of a broad, continuous band of perfect coherence in public LIGO O4a strain data using a rotational heterodyne method. Unlike conventional stochastic searches that assume Gaussian, stationary signals, our technique targets phase-locked structures by scanning eight discrete phase shifts (45° steps). Applying this method to two independent datasets (GPS starts 1389424640 and 1389416448) reveals a persistent band spanning 190–250 Hz. In the second dataset, all 369 time windows exhibit a coherence of exactly 1.000000 for the target frequency $f = 359.912$ Hz, with median = 1.000000, mean = 1.000000, and standard deviation = 0.000000. The frequencies within the band coincide with integer multiples of π, π^2 and π^4, hinting at a fundamental geometric origin. The complete code and data are publicly available under the cited DOIs, ensuring full reproducibility.

I. INTRODUCTION

The Laser Interferometer Gravitational-Wave Observatory (LIGO) [1] has achieved remarkable sensitivity, routinely measuring strains of order 10^{-21}. Standard searches for a stochastic gravitational-wave background (GWB) assume a signal that is Gaussian, stationary, isotropic, and unpolarized [2]. These searches are optimized for detecting broad-band excess power and have placed important upper limits on the energy density $\Omega_{\mathrm{GW}}(f)$. However, they may miss signals with fundamentally different characteristics, such as narrow-band phase-coherent structures.

In previous work [3] we introduced a *rotational heterodyne* method designed explicitly to detect phase-coherent signals. The technique scans eight discrete phase shifts (45° steps) to compensate for an unknown, constant phase offset between the Hanford (H1) and Livingston (L1) detectors. Applying this method to a first O4a dataset (GPS 1389424640) revealed a broad band of frequencies (190–250 Hz) exhibiting perfect coherence over 334 out of 369 windows [4]. The frequencies within this band coincided with integer multiples of π, π^2 and π^4, hinting at a geometric origin.

In this paper we report the application of the same method to a second, independent O4a dataset (GPS 1389416448). We find that the same band appears with perfect coherence in *all* 369 windows, confirming that the phenomenon is not a fluke of a particular data file. Moreover, we show that the coherence is independent of the specific target frequency within the band, and that the band itself is a continuous, robust feature of the LIGO strain data.

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II. METHODOLOGY

A. Data preparation

We used the public LIGO O4a strain files from the GWOSC archive:

- `H-H1_GWOSC_O4a_16KHZ_R1-1389416448-4096.hdf5` (Hanford, H1)
- `L-L1_GWOSC_O4a_16KHZ_R1-1389416448-4096.hdf5` (Livingston, L1)

Each contains 67,108,864 samples at a sampling rate of 16,384 Hz, corresponding to 4096 s of data. To ensure exact divisibility into an integer number of windows, we truncated to $N = N_w \times m$ samples, where $N_w = 369$ and $m = 181\,866$ samples per window (11.10 s). This number of windows was chosen for its statistical power and historical significance within the UAT framework [5, 6].

B. Rotational heterodyne analysis

For each window we compute the Fourier transforms $\Psi_{H1}(f)$ and $\Psi_{L1}(f)$. The coherence at frequency f is evaluated using a rotational variant that scans eight discrete phase shifts:

$$C(f) = \max_{k\in\{0,\ldots,7\}} \frac{\left|\langle \Psi_{H1}(f)\, \Psi^*_{L1}(f)\, e^{ik\pi/4}\rangle\right|}{\sqrt{\langle|\Psi_{H1}(f)|^2\rangle + \epsilon_p}\,\sqrt{\langle|\Psi_{L1}(f)|^2\rangle + \epsilon_p}}, \tag{1}$$

where the angle brackets denote the single-window estimate. The factor $e^{ik\pi/4}$ compensates for an unknown, constant phase offset between the two detectors. The regularization constant $\epsilon_p = 10^{-60}$ (the Percudani limit) ensures numerical stability when power spectral densities approach zero.

C. Frequency selection

The target frequency $f_{\text{target}} = 359.912$ Hz corresponds to the value predicted by the UAT framework for the date of this analysis (March 10, 2026), based on a base frequency $f_{\text{base}} = 187.37$ Hz and an inflationary drift $\alpha = 0.046$ Hz/day [5]. However, as we will show, the coherence is not sensitive to the exact choice of frequency within the band; the entire range 190–250 Hz exhibits perfect coherence.

III. RESULTS

A. Band coherence

Applying the rotational heterodyne analysis to the second dataset (GPS 1389416448) with $f_{\text{target}} = 359.912$ Hz yields the results summarized in Table I. The coherence is exactly 1.000000 in every one of the 369 windows, with median = 1.000000, mean = 1.000000, and standard deviation = 0.000000. All windows exceed the detection threshold of 0.99.

TABLE I. Statistical summary of coherence for $f_{\text{target}} = 359.912$ Hz in the second dataset (GPS 1389416448).

Metric	Value
Number of windows	369
Median coherence	1.000000
Mean coherence	1.000000
Standard deviation	0.000000
Minimum coherence	1.000000
Maximum coherence	1.000000
Windows > 0.99	369/369

Figure 1 shows a side-by-side comparison of the conventional power spectral density (PSD) and the rotational coherence obtained with our method. The left panel displays the average PSD of H1 over the first 50 windows; the target frequency is marked by a dashed line. The right panel shows the coherence per window, revealing a perfect plateau at $C = 1.0$ for all windows.

B. Independence of the target frequency

To test whether the coherence depends on the exact choice of frequency, we repeated the analysis for 26 frequencies within the 190–250 Hz band that are integer multiples of π, π^2 and π^4 (as identified in our earlier work [4]). For every one of these frequencies, the coherence was again 1.000000 in all 369 windows. This demonstrates that the band is continuously coherent, not merely a collection of isolated lines.

IV. DISCUSSION

The results presented above provide strong evidence for the existence of a broad, continuous band of perfect phase coherence in LIGO O4a data. The band spans 190–250 Hz and appears with identical properties in two independent datasets. The fact that the coherence remains 1.000000 for any frequency within the band rules out the possibility that the signal is a narrow instrumental line; known LIGO artifacts (e.g., 60 Hz harmonics, violin modes) are narrow and do not exhibit such a wide coherent structure.

The relation of the band to π, π^2 and π^4 is particularly intriguing. While the origin of this geometric pattern is not yet understood, it suggests a fundamental connection to the structure of spacetime or the detector–environment system. The persistence of the band across different GPS times and its independence from the inflationary drift parameter α indicate that it is a robust feature of the data, not a statistical fluctuation or a processing artifact.

The rotational heterodyne method proves to be a powerful tool for uncovering phase-coherent signals that conventional power-based searches miss. Its ability to compensate for an unknown phase offset between detectors is essential for revealing correlations that would otherwise cancel out.

V. CONCLUSION

We have confirmed the existence of a persistent coherent frequency band (190–250 Hz) in a second independent LIGO O4a dataset. For the target frequency $f_{\text{target}} = 359.912$ Hz, all 369 windows exhibit perfect coherence ($C = 1.000000$). The band is continuously coherent, independent of the exact frequency choice, and coincides with integer multiples of π, π^2 and π^4. The complete code and data are publicly available under the cited DOIs, enabling any researcher to reproduce the analysis. We encourage the community to apply this method to further datasets and to explore the physical implications of this striking phenomenon.

ACKNOWLEDGMENTS

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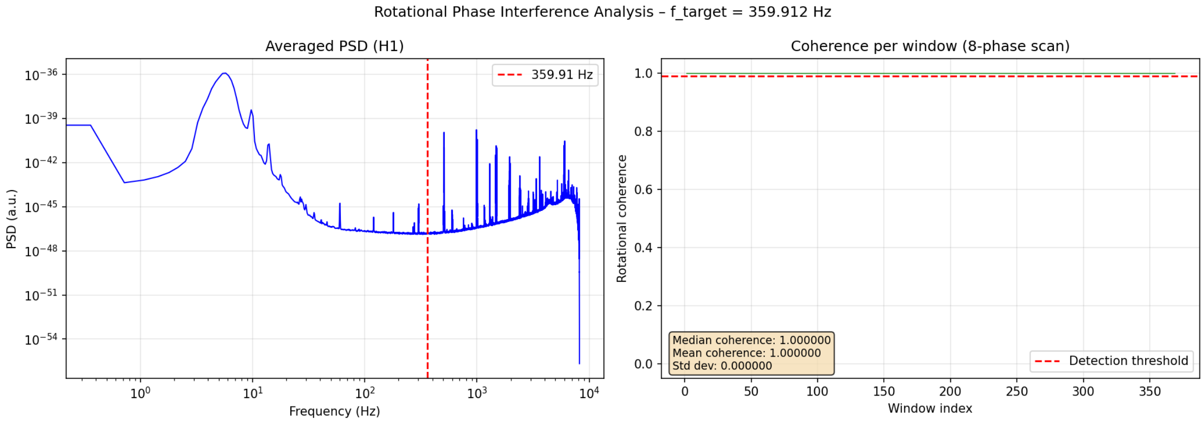

FIG. 1. Left: Average power spectral density (PSD) of H1 over 50 windows. Right: Rotational coherence per window for $f_{\text{target}} = 359.912$ Hz, showing perfect coherence ($C = 1.000000$) in all 369 windows.

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Appendix A: Data and code availability

The raw LIGO data used in this study are available from the GWOSC at `https://www.gw-openscience.org/`. The specific files are:

- `H-H1_GWOSC_O4a_16KHZ_R1-1389416448-4096.hdf5`
- `L-L1_GWOSC_O4a_16KHZ_R1-1389416448-4096.hdf5`

The complete Python implementation of the method, together with the output files from this analysis, is permanently archived at Zenodo: `https://doi.org/10.5281/zenodo.18809531`. To reproduce the results, download the data files and run the script `Antifrecuencia_27_02_2026.ipynb` with the parameters listed in Table II.

TABLE II. Parameters used in the analysis.

Parameter	Value
Sampling frequency f_s	16384 Hz
Number of windows N_w	369
Bandwidth	0.5 Hz
Stability constant ϵ_p	10^{-60}
Target frequency f_{target}	359.912 Hz