



# Alignment Between LIGO O4a GWOSC Open Data and Matrix Node Theory

## Executive summary

The GWOSC O4a open-data release covers GPS 1368195220 (2023-05-15) to 1389456018 (2024-01-16) and includes **Hanford (H1)** and **Livingston (L1)** strain, provided both at **16 kHz** and **downsampled 4 kHz** rates. The “final” O4a strain channels are `H1:GDS-CALIB_STRAIN_CLEAN_AR` and `L1:GDS-CALIB_STRAIN_CLEAN_AR`. <sup>1</sup>

For the **O4a\_4KHZ\_R1** archive, GWOSC states that each time-series file has fixed **4096 s** duration (HDF5 or GWF) and notes that downsampling can introduce issues near Nyquist, recommending **16 kHz** data for studies around **~1700 Hz and above**. <sup>2</sup>

Using GWOSC’s published **4 kHz HDF5 file manifest** (`strain-hdf.txt`), I reconstructed the complete O4a\_4KHZ\_R1 H1/L1 file inventory (4096 s segments) and quantified gaps. The manifest itself is available from GWOSC. <sup>3</sup>

Matrix Node Theory (MNT / Evans Node Dialect) is presented by its author as **independent research in progress, not yet peer-reviewed**, and its core documents are deposited on Zenodo (DOI: **10.5281/zenodo.17730781**). <sup>4</sup>

In the MNT-END companion, the emergent invariant propagation speed is defined as  $c = \ell_0 / \delta\tau$ , intended to recover Lorentz-invariant wave propagation at long wavelengths. <sup>5</sup>

In MNT’s Global Validation/Alignment document, the gravitational-wave sector is treated as **GR-like at leading order** (TT-gauge wave equation and quadrupole/radiation formulas), with potential **lattice-induced dispersion** constrained by existing empirical bounds. <sup>6</sup>

A key practical finding for “alignment”: the publicly released O4a data products and LVK catalog analyses to date are **consistent with GR propagation** (no detected dispersion, no confirmed non-tensor polarizations), which is broadly compatible with MNT’s *leading-order GR recovery*, while strongly constraining any MNT “correction” terms. <sup>7</sup>

A local synthesis document you provided (useful as a map of claims/sources, but not a primary source) is available here: [Download mnt\\_draft\\_v1.pdf](#).

```
flowchart TD
  A[GWOSC O4a_4KHZ_R1 manifest strain-hdf.txt] --> B[Reconstruct 4096-s file index & URLs]
  B --> C[Merge contiguous files into availability segments]
  C --> D[Quantify gaps and coverage]
  B --> E[Select representative O4a event/segment from GWTC-4.0 / O4 discovery]
```

```
releases]
E --> F[Map event GPS to containing 4096-s file segment]
F --> G[Define quantitative tests: speed, dispersion, waveform, polarization,
amplitude scaling]
G --> H[Compare expectations from MNT vs GR-consistent observations & published
constraints]
```

## GWOSC O4a\_4KHZ\_R1 data release metadata and file inventory

GWOSC's O4a release overview (run bounds, detectors, sample rates, and strain channels) is stated explicitly on the O4a release page. <sup>1</sup>

The O4a\_4KHZ\_R1 archive specifies that each file corresponds to **4096 seconds** and can be up to "half a GB". <sup>8</sup>

### Core release properties relevant to your request

O4a release time bounds and detectors:

- O4a run dates: GPS **1368975618** (2023-05-24) to GPS **1389456018** (2024-01-16), but the public release begins earlier at GPS **1368195220** for analyses of SN2023ixf and GW230518\_125908. <sup>1</sup>
- Detectors: **H1** and **L1**. <sup>1</sup>
- Sample rates: **16 kHz** original and **4 kHz** downsampled. <sup>1</sup>
- Final strain channel names: `H1 : GDS-CALIB_STRAIN_CLEAN_AR` and `L1 : GDS-CALIB_STRAIN_CLEAN_AR`. <sup>1</sup>

Technical caveats for 4 kHz data relevant to dispersion/high-frequency checks:

- For the **4096 Hz dataset**, GWOSC warns that anti-aliasing filtering affects data near Nyquist, advising **16 kHz** for studies around **~1700 Hz** or above. <sup>9</sup>
- HDF5/GWF files have **fixed 4096 s boundaries**, with padding requested during downsampling to avoid border effects; padding may not always be available, leaving "tiny border effects" in some 4 kHz files. <sup>9</sup>

### Reconstructed O4a\_4KHZ\_R1 file inventory (HDF5)

GWOSC publishes an "all 4 kHz HDF5 strain" manifest at:

- [https://gwosc.org/archive/md5/O4a\\_4KHZ\\_R1/strain-hdf.txt](https://gwosc.org/archive/md5/O4a_4KHZ_R1/strain-hdf.txt) <sup>3</sup>

From that manifest, I reconstructed the full list of 4096 s HDF5 strain files and their URLs (by prepending [https://gwosc.org/archive/data/O4a\\_4KHZ\\_R1/](https://gwosc.org/archive/data/O4a_4KHZ_R1/) to each relative path), then merged consecutive files to get contiguous "availability segments," and computed gaps.

Downloads (full tables):

- [Download: full file index \(all H1 & L1 4096 s HDF5 files, with gps\\_start, duration, sample\\_rate, url, md5\)](#)

- [Download: merged availability segments \(contiguous blocks of released data\)](#)
- [Download: gaps between availability segments](#)

Key coverage summary (derived from the manifest <sup>3</sup>):

- H1: **3901** files × 4096 s → **15,978,496 s** (≈ **184.94 days**) released; total gap time ≈ **5,283,840 s** (≈ **61.16 days**) over the full release span.
- L1: **3873** files × 4096 s → **15,863,808 s** (≈ **183.61 days**) released; total gap time ≈ **5,369,856 s** (≈ **62.15 days**) over the full release span.
- Over the release span (GPS 1368195220–1389456018 is ≈ **246.07 days**), this corresponds to about **75.15%** coverage for H1 and **74.62%** for L1 (simple fraction of released seconds over total span).

Gap characteristics (derived from the computed gaps list):

- Maximum single gap: **~117.2 hours** (≈ 4.88 days).
- Median gap: **~2.28 hours**.

Largest gaps (derived):

- H1: max gap from GPS **1368555520** to **1368977408** (421,888 s, ~117.2 h).
- L1: max gap from GPS **1368555520** to **1368973312** (417,792 s, ~116.1 h).

## Representative file segments table (H1 and L1)

The full inventory is in the downloadable CSVs above; this excerpt shows representative segments: the beginning of the release, the segment containing GW230814\_230901, and the end.

### H1 representative 4 kHz HDF5 files (4096 s):

detector	gps_start	duration_s	sample_rate_hz	url	md5
H1	1368195072	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/H-H1_GWOSC_O4a_4KHZ_R1-1368195072-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/H-H1_GWOSC_O4a_4KHZ_R1-1368195072-4096.hdf5</a>	9b63a9211
H1	1368264704	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/H-H1_GWOSC_O4a_4KHZ_R1-1368264704-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/H-H1_GWOSC_O4a_4KHZ_R1-1368264704-4096.hdf5</a>	588ecd07e
H1	1368268800	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/H-H1_GWOSC_O4a_4KHZ_R1-1368268800-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/H-H1_GWOSC_O4a_4KHZ_R1-1368268800-4096.hdf5</a>	b6b2c37ae
H1	1376088064	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1375731712/H-H1_GWOSC_O4a_4KHZ_R1-1376088064-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1375731712/H-H1_GWOSC_O4a_4KHZ_R1-1376088064-4096.hdf5</a>	2f117b73a

detector	gps_start	duration_s	sample_rate_hz	url	md5
H1	1389445120	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/H-H1_GWOSC_O4a_4KHZ_R1-1389445120-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/H-H1_GWOSC_O4a_4KHZ_R1-1389445120-4096.hdf5</a>	262a002c0
H1	1389449216	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/H-H1_GWOSC_O4a_4KHZ_R1-1389449216-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/H-H1_GWOSC_O4a_4KHZ_R1-1389449216-4096.hdf5</a>	ad123e980
H1	1389453312	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/H-H1_GWOSC_O4a_4KHZ_R1-1389453312-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/H-H1_GWOSC_O4a_4KHZ_R1-1389453312-4096.hdf5</a>	5dd6a2380

**L1 representative 4 kHz HDF5 files (4096 s):**

detector	gps_start	duration_s	sample_rate_hz	url	md5
L1	1368195072	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/L-L1_GWOSC_O4a_4KHZ_R1-1368195072-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/L-L1_GWOSC_O4a_4KHZ_R1-1368195072-4096.hdf5</a>	b500fadb1
L1	1368264704	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/L-L1_GWOSC_O4a_4KHZ_R1-1368264704-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/L-L1_GWOSC_O4a_4KHZ_R1-1368264704-4096.hdf5</a>	9782c4334
L1	1368268800	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/L-L1_GWOSC_O4a_4KHZ_R1-1368268800-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1367343104/L-L1_GWOSC_O4a_4KHZ_R1-1368268800-4096.hdf5</a>	f63317688
L1	1376088064	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1375731712/L-L1_GWOSC_O4a_4KHZ_R1-1376088064-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1375731712/L-L1_GWOSC_O4a_4KHZ_R1-1376088064-4096.hdf5</a>	d0b35a55f
L1	1389416448	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/L-L1_GWOSC_O4a_4KHZ_R1-1389416448-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/L-L1_GWOSC_O4a_4KHZ_R1-1389416448-4096.hdf5</a>	310afb345
L1	1389420544	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/L-L1_GWOSC_O4a_4KHZ_R1-1389420544-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/L-L1_GWOSC_O4a_4KHZ_R1-1389420544-4096.hdf5</a>	d13d490b4
L1	1389424640	4096	4096	<a href="https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/L-L1_GWOSC_O4a_4KHZ_R1-1389424640-4096.hdf5">https://gwosc.org/archive/data/O4a_4KHZ_R1/1389363200/L-L1_GWOSC_O4a_4KHZ_R1-1389424640-4096.hdf5</a>	0f0f1df0d5

**Visualizing availability and gaps (derived from strain-hdf.txt)**

O4a\_4KHZ\_R1 merged availability segments for H1 and L1

## Matrix Node Theory primary sources and testable GW-propagation predictions

### Primary source map

MNT/END is presented by its author as independent, not-yet-peer-reviewed work hosted at jremnt.com. <sup>10</sup>  
The MNT-END Zenodo record (DOI 10.5281/zenodo.17730781) lists the core PDFs: **MNT\_Axioms\_Ontology**, **MNT\_Global\_Validation**, **MNT\_Math\_Lexicon**, and **MNT\_Structural\_Proofs**. <sup>11</sup>

The most GW-relevant MNT primary documents used here:

- **MNT\_END\_COMPANION.pdf** (white-paper style summary; explicitly defines emergent invariant speed  $c = \ell_0/\delta\tau$ ). <sup>5</sup>
- **MNT\_Global\_Validation.pdf / Global Alignment Summary.pdf** (test suite, includes GW propagation and inspiral constraints; presents a GR-like TT wave equation and a generic dispersive correction parameterization). <sup>6</sup>
- **Auxiliary:** “Unified Matrix Node Theory of Everything (Enhanced)” (am.pdf) includes an explicit claim of “unique polarization modes” in its prediction list; this appears *outside* the core Zenodo record and should be treated as an auxiliary/unstable claim unless harmonized with the core END documents. <sup>12</sup>

### Explicit, testable MNT statements about GW propagation

The items below are phrased as **operational predictions** (things you can test against GWOSC/LVK products). Where MNT defines quantities but does not supply numerical parameter values, I flag that as a falsifiability gap.

MNT defines an emergent invariant propagation speed as the ratio of spatial and temporal discretization scales,

$$c = \ell_0/\delta\tau,$$

in the regime where the discrete Laplacian and time-step operator approximate a Lorentz-invariant wave operator at long wavelengths. <sup>5</sup>

This is intended to reproduce standard luminal propagation in the continuum limit; in practice, MNT also emphasizes that this “locked” microscopic structure must reproduce multiple observables without retuning, and explicitly identifies “compute lattice-induced corrections to gravitational wave speed and compare with LIGO/Virgo bounds” as a next step. <sup>5</sup>

In its validation write-up, MNT treats the weak-field GW sector in TT gauge with a wave equation of the GR form (schematically  $\square h_{ij}^{TT} = 0$  at leading order), i.e., **standard, nondispersive propagation at  $c$**  in the long-wavelength limit. <sup>13</sup>

MNT introduces a generic dispersive modification captured by a power-series correction to the standard dispersion relation. In one explicit parameterization, MNT discusses a “lattice dispersion” form

$$\omega^2 = c^2 k^2 \left[ 1 + \eta \left( \frac{|k|}{k_*} \right)^n + \dots \right],$$

and notes that empirical bounds require any fractional speed deviation to be extremely small (order  $10^{-15}$  in the cited discussion). <sup>13</sup>

Crucially, MNT **does not** (in these documents) supply a unique numerical prediction for  $\eta$ ,  $n$ ,  $k_*$  based on a fixed graph choice—so the prediction is *structural* (“corrections exist, suppressed by a high scale”), but not yet a fully specified model forecast.

For waveform morphology and amplitude scaling in the inspiral regime, the MNT validation material explicitly uses a GR-like TT far-field formula with  $1/r$  scaling (schematically  $h^{TT} \propto (G_{\text{eff}}/(c^4 r)) \ddot{Q}^{TT}$ ), and states that the quadrupole-inspiral energy loss behaviour is recovered at leading order once  $G_{\text{eff}}$  and  $c$  are fixed (with higher-order corrections suppressed). <sup>14</sup>

Operationally: **absent large corrections**, MNT expects CBC waveforms in the LIGO band to be GR-like (chirp + merger + ringdown), with standard amplitude-distance and phase-evolution structure, modulo small correction terms.

On polarization: the core END/Global Validation documents largely frame the GW sector in TT language (which is consistent with the two GR tensor polarizations). <sup>13</sup>

An auxiliary short document (am.pdf, 4 pages) lists “unique polarization modes predicted by  $\Lambda_{\text{EQEF}}$ ” as a testable prediction. <sup>12</sup>

This should be treated carefully: without a quantitative mapping (expected mode content, coupling, and amplitude fraction vs frequency), it is difficult to compare directly to LVK polarization constraints; and it is not reflected as a quantified prediction in the END companion or in the extracted validation formulas.

## Quantitative tests to compare O4a data with MNT-style predictions

This section translates the above MNT “prediction surface” into a set of quantitative tests that (a) GWOSC/LVK data products can support, and (b) map cleanly onto MNT parameters (especially  $c$  and any dispersion term).

### Arrival-time consistency across detectors

For two detectors separated by baseline vector  $\mathbf{b}$ , a plane GW arriving from direction  $\mathbf{n}$  gives an inter-site delay approximately

$$\Delta t \approx \frac{\mathbf{b} \cdot \mathbf{n}}{v_{\text{gw}}} + \Delta t_{\text{cal}},$$

where  $v_{\text{gw}} = c$  in GR (and  $v_{\text{gw}} = c_{\text{MNT}}$  at leading order in MNT). With two LIGO sites  $\sim 3000$  km apart, the maximum possible inter-site delay is about **10 ms**, and signals separated by more than that are vetoed as non-astrophysical. <sup>15</sup>

A practical timing-precision rule of thumb is that arrival-time resolution improves with higher SNR and higher characteristic signal frequency/bandwidth; an internal LIGO timing requirement document discusses

timing resolution scaling roughly with  $1/(f \text{ SNR})$  and gives example values from  $\sim 0.1$  ms at SNR $\sim 10$  for  $\sim$ hundreds of Hz signals, down to  $\sim$ tens of microseconds for higher-frequency cases. <sup>16</sup>

To turn O4a into a **speed test** rather than just a consistency check, you need either: - an **EM counterpart** (sky localization fixed externally), or - a sufficiently strong multi-detector localization (3+ detectors), allowing inference of **n**.

A peer-reviewed method paper illustrates the “no-EM counterpart” approach, but notes it is far less precise than the GW170817/GRB170817A bound, which is at the “one part in  $10^{15}$ ” level. <sup>17</sup>

## Dispersion and frequency-dependent group velocity

With a modified dispersion relation,  $v_g(f) = d\omega/dk$  becomes frequency-dependent. Using MNT’s generic expansion

$$\omega^2 = c^2 k^2 \left[ 1 + \eta \left( \frac{k}{k_*} \right)^n + \dots \right],$$

a small-correction expansion yields a group-velocity deviation scaling like  $(k/k_*)^n$ . <sup>13</sup>

Operational tests (ordered from most to least “O4a practical”):

- **Template-based phase residual test:** fit GR CBC waveforms; look for systematic phase residuals  $\delta\phi(f)$  consistent with a propagation dephasing term. This is the standard LVK approach in “modified dispersion relation / massive graviton” tests. (A fully rigorous implementation requires PE infrastructure and calibration uncertainty propagation.)
- **Band-to-band arrival-time test** (multi-detector): estimate  $\Delta t(f)$  in separate frequency bands via matched filtering or coherent reconstruction; look for statistically significant slope in  $\Delta t$  vs  $f$ .
- **Time-frequency ridge distortion:** measure whether the observed chirp track is consistent with GR emissions and nondispersive propagation given inferred source parameters; look for systematic frequency-dependent time shifts beyond source-model variability.

Expected tolerances depend on event SNR, effective bandwidth, and calibration phase uncertainty. GWOSC also warns that 4 kHz downsampling affects the region near Nyquist; dispersion tests targeting kHz features should use 16 kHz products. <sup>9</sup>

## Polarization content

A clean polarization decomposition generally requires **3+ detectors** with sufficiently different antenna responses; with only H1 and L1, polarization separation is fundamentally limited. The most data-driven approach uses coherent-network analyses and null streams (where possible) to constrain non-tensor modes.

Official LVK tests across GWTC-3 report **no evidence** for non-GR polarizations or dispersion in the analysed events, tightening bounds like the graviton mass constraint. <sup>18</sup>

If an MNT variant predicted additional modes at appreciable amplitude fraction, it would need to evade these constraints (or predict a very specific frequency/time structure not tested).

## Amplitude scaling with distance and “modified GW propagation” in cosmology

A key observational handle on modified propagation is whether GW amplitudes damp with distance differently than GR predicts (often parameterized as a modified GW luminosity distance).

An LVK O4a cosmology analysis explicitly includes a parameter  $\Xi_0$  (with  $\Xi_0 = 1$  recovering GR) and reports  $\Xi_0 = 1.2^{+0.8}_{-0.4}$  (68% interval; 90% interval also given), consistent with GR within uncertainties. <sup>19</sup>  
In MNT terms: if MNT’s continuum limit reproduces GR damping, it should map to  $\Xi_0 \approx 1$ ; any predicted deviation would be constrained by such results.

## Applying the tests to O4a

### Choosing a representative high-SNR O4a event

From GWTC-4.0 (which corresponds to O4a detections in GWOSC), the highest matched-filter SNR events exceed 30—including **GW230814\_230901** and **GW231226\_101520**—enabling high-fidelity waveform studies. <sup>20</sup>

The GWOSC O4 discovery-paper documentation also highlights GW230814\_230901 and states that its downloadable strain is aligned with the 4096 s run-file boundaries, giving the start GPS and the offset of the peak in the file. <sup>21</sup>

In the GWOSC event portal entry for **GW230814\_230901 (O4 discovery release, v2)**, the default PE section quotes a matched-filter SNR of about **42** (with credible interval) and the pycbc search pipeline lists **43.0**. <sup>22</sup>  
This makes GW230814\_230901 a natural “highest-SNR” exemplar for O4a.

### Event-to-file alignment in O4a\_4KHZ\_R1 (4096 s grid)

GWOSC’s O4 discovery documentation for GW230814\_230901 states:

- strain file begins at GPS **1376088064** and spans **4096 s**
- the GW signal peaks at GPS **1376089759.8**
- the peak is **1695.8 s** into the file
- files exist for both H1 and L1, but only L1 was observing at the time <sup>21</sup>

Using the O4a\_4KHZ\_R1 manifest-derived index (derived from `strain-hdf.txt` <sup>3</sup>), the containing 4 kHz 4096 s files are:

- H1: `.../H-H1_GWOSC_O4a_4KHZ_R1-1376088064-4096.hdf5`
- L1: `.../L-L1_GWOSC_O4a_4KHZ_R1-1376088064-4096.hdf5`

This is a direct “alignment” check between O4a run-file segmentation and the event portal / paper release metadata and it matches exactly (same file start and offset). <sup>21</sup>

## What can and cannot be measured from the public O4a products in this environment

Because the O4a run strain itself is distributed as **HDF5/GWF** (and event “figures data” is frequently distributed as compressed archives), and those binary/compressed downloads are not ingestible in this chat execution environment, I cannot compute new, independent values for:

- H1-L1  $\Delta t$  arrival-time offsets from strain,
- band-by-band dispersion  $\Delta t(f)$ ,
- phase residuals vs GR templates,
- polarization fractions from coherent network reconstructions.

What can be done rigorously here is:

- reconstruct and quantify the **complete O4a\_4KHZ\_R1 segmentation and gap structure** (done above), and
- use **published, citable event-level measurements and figures** (event portal values, LVK plots) to map which tests are feasible and what constraints already apply.

## Representative time-frequency view for GW230814

The LVK collaboration has published a time-series + time-frequency representation of GW230814 and its reconstruction; this image is available under CC-BY on Wikimedia Commons (sourced from arXiv:2509.07348 per the file page). <sup>23</sup>

GW230814 data timeseries and time-frequency representation (LVK figure)

This figure is the most direct, publicly citable visualization relevant to waveform morphology and (qualitatively) dispersion-like distortions: you can inspect whether the signal's time-frequency track shows gross smearing or frequency-dependent arrival consistent with strong dispersion. No such strong effect is visually apparent in the published reconstruction, which is consistent with GR-like propagation in the LIGO band (a qualitative statement; quantitative dispersion constraints require full PE). <sup>24</sup>

## A dispersion-scale illustration tied to MNT's parameterization

MNT presents a generic dispersion correction  $\omega^2 = c^2 k^2 [1 + \eta(k/k_*)^n + \dots]$ . <sup>13</sup>

Using a representative bound  $|\delta v|/c \lesssim 10^{-15}$  (motivated by the published multi-messenger constraint level and as discussed in the GW-speed literature <sup>17</sup>), you can translate this into a *heuristic* upper bound on the length scale  $\ell_* = 1/k_*$  versus power  $n$  at a representative frequency (here 100 Hz) assuming  $\eta \sim 1$ .

Heuristic dispersion-length constraint vs power  $n$  at 100 Hz

Interpretation: for higher powers  $n$ , very small fractional speed deviations allow relatively *large*  $\ell_*$  (weaker constraints), while for low powers  $n$  constraints can push  $\ell_*$  much smaller. This is not a substitute for a template-based dispersion analysis, but it does show that MNT's “suppressed by a high scale” claim is easy to satisfy if  $k_*$  corresponds to microscopic scales.

## Alignment and mismatch assessment

### Where O4a observations align with MNT

At the level MNT is currently specified in its core validation/companion documents, MNT is structurally designed to reproduce Lorentz-invariant propagation at long wavelengths with an emergent  $c = \ell_0/\delta\tau$ .

5

The gravitational-wave sector is treated in TT language and uses GR-like far-field amplitude and inspiral energy-loss relations once  $c$  and  $G_{\text{eff}}$  are fixed, implying that **standard CBC waveform morphology** should hold in the LIGO band unless correction terms become appreciable. 25

This is broadly compatible with the empirical status quo in LVK catalogs: high-SNR CBCs are well modeled by GR inspiral-merger-ringdown templates, and (as of GWTC-3 tests) there is no evidence for dispersion or non-GR polarization in the analysed sample. 18

In the specific O4a context, an LVK cosmology analysis that includes modified GW propagation via  $\Xi_0$  finds results consistent with  $\Xi_0 = 1$  (GR), which is consistent with an MNT continuum limit that does not introduce additional amplitude damping. 19

### Where MNT’s current public form is underconstrained or potentially in tension

MNT’s dispersion discussion is framed as a generic correction series with parameters  $\eta, n, k_*$ , but **does not provide a unique, fixed numerical prediction** for these parameters derived from a specific lattice/graph instantiation. 26

As a result, the theory’s GW-propagation “prediction” is presently more of a *model class* than a single falsifiable curve unless a concrete graph topology and parameter set is committed and used to compute  $k_*$  (which the END companion itself lists as a next step). 5

On polarization: an auxiliary MNT document claims “unique polarization modes predicted by  $\Lambda_{\text{EQEF}}$ ” without quantifying expected amplitudes or frequency dependence. 12

If interpreted as predicting sizeable non-tensor components in the LIGO band, that would be in conceptual tension with the LVK “no evidence for non-GR modes of polarization” result in the GWTC-3 GR test suite. 18

However, because the auxiliary document provides no quantitative mapping and this claim is not clearly integrated into the core END companion / validation parameterization, the fairest assessment is: **it is not yet testable at high confidence**, but it highlights a potential future falsification route if MNT is sharpened into a numeric forecast.

Finally, any MNT prediction that implies  $|v_{\text{gw}} - c|/c$  appreciably larger than  $\sim 10^{-15}$  would be strongly constrained by the existing GW-speed literature and multi-messenger consistency level (the latter discussed explicitly in the GW-speed measurement literature). 17

## Systematic uncertainties and alternative explanations

Any O4a-vs-theory comparison has to account for:

- **Downsampling artifacts and Nyquist-region corruption** in 4 kHz products, which can mimic or mask subtle high-frequency phase effects; GWOSC recommends 16 kHz for studies at ~1700 Hz and above. <sup>9</sup>
- **Border/padding effects** because O4a files are fixed 4096 s boundaries and padding is sometimes unavailable. <sup>9</sup>
- **Calibration uncertainty** (magnitude and phase vs frequency) and the complexities of noise subtraction—both of which feed directly into dispersion/polarization tests. <sup>27</sup>

These are sufficient to explain small discrepancies between naive “by-eye” dispersion/polarization claims and robust LVK PE-based constraints without invoking new physics.

## Recommendations and data needed to strengthen conclusions

A stronger, “analysis-grade” MNT vs O4a alignment study would need two things in parallel: (i) more specific MNT numerical predictions, and (ii) full strain-level inference on suitable O4a events.

On the MNT side, the most valuable step is to publish (or append) a single concrete “locked” graph/topology and parameter set that yields specific predicted values for  $k_*$  (or  $\Lambda_{\text{lim}}$ ),  $\eta$ ,  $n$ , and any extra polarization coupling strengths, so that the dispersion/polarization predictions become **single curves with error bars** rather than a generic series form. <sup>28</sup>

On the O4a/GWOSC analysis side, the highest leverage analyses are:

- A multi-detector, high-SNR event (e.g., GW231226\_101520) where H1-L1 timing triangulation and band-by-band group delay can be measured, enabling direct constraints on any  $v_{\text{gw}}(f)$  variation. <sup>20</sup>
- A template-based dispersion PE test (modified dispersion relation / massive graviton style), using 16 kHz strain when probing kHz features to avoid 4 kHz Nyquist artifacts. <sup>29</sup>
- A network polarization analysis using 3+ detectors (when available) and coherent subtraction/null streams, to directly target any hypothesized non-tensor component at the levels implied by an explicit MNT forecast. <sup>30</sup>
- A propagation-amplitude test using the GW luminosity distance vs EM distance framework (where EM counterparts exist) and/or catalog-level  $\Xi_0$ -style constraints, to compare MNT’s implied damping law against LVK’s O4a cosmology results. <sup>19</sup>

If you want this carried through as a full “numbers out” study, the essential additional input is access to the actual strain time series in an analysis environment that can ingest **HDF5/GWF** and (optionally) LVK PE products; GWOSC’s O4a open-data paper and technical notes provide the correct channels, formats, and caveats to implement that pipeline cleanly. <sup>31</sup>

---

<sup>1</sup> <https://gwosc.org/O4/O4a/>

<https://gwosc.org/O4/O4a/>

- 2 8 [https://gwosc.org/archive/O4a\\_4KHZ\\_R1/](https://gwosc.org/archive/O4a_4KHZ_R1/)  
[https://gwosc.org/archive/O4a\\_4KHZ\\_R1/](https://gwosc.org/archive/O4a_4KHZ_R1/)
- 3 [https://gwosc.org/archive/md5/O4a\\_4KHZ\\_R1/strain-hdf.txt](https://gwosc.org/archive/md5/O4a_4KHZ_R1/strain-hdf.txt)  
[https://gwosc.org/archive/md5/O4a\\_4KHZ\\_R1/strain-hdf.txt](https://gwosc.org/archive/md5/O4a_4KHZ_R1/strain-hdf.txt)
- 4 10 **JREMNT - Home**  
[https://jremnt.com/?utm\\_source=chatgpt.com](https://jremnt.com/?utm_source=chatgpt.com)
- 5 28 [https://img1.wsimg.com/blobby/go/24d7a457-640a-4b87-b92f-ef78824df3ec/MNT\\_END\\_COMPANION.pdf](https://img1.wsimg.com/blobby/go/24d7a457-640a-4b87-b92f-ef78824df3ec/MNT_END_COMPANION.pdf)  
[https://img1.wsimg.com/blobby/go/24d7a457-640a-4b87-b92f-ef78824df3ec/MNT\\_END\\_COMPANION.pdf](https://img1.wsimg.com/blobby/go/24d7a457-640a-4b87-b92f-ef78824df3ec/MNT_END_COMPANION.pdf)
- 6 13 24 25 26 (no title)
- 7 18 30 <https://journals.aps.org/prd/accepted/17075Qf4Z7b11729787e85f1c18faca230d51e013>  
<https://journals.aps.org/prd/accepted/17075Qf4Z7b11729787e85f1c18faca230d51e013>
- 9 27 29 [https://gwosc.org/O4/o4\\_details](https://gwosc.org/O4/o4_details)  
[https://gwosc.org/O4/o4\\_details](https://gwosc.org/O4/o4_details)
- 11 <https://zenodo.org/records/17730781>  
<https://zenodo.org/records/17730781>
- 12 [img1.wsimg.com](https://img1.wsimg.com)  
<https://img1.wsimg.com/blobby/go/24d7a457-640a-4b87-b92f-ef78824df3ec/am.pdf>
- 14 <https://img1.wsimg.com/blobby/go/24d7a457-640a-4b87-b92f-ef78824df3ec/Global%20Alignment%20Summary.pdf>  
<https://img1.wsimg.com/blobby/go/24d7a457-640a-4b87-b92f-ef78824df3ec/Global%20Alignment%20Summary.pdf>
- 15 **LIGO's Dual Detectors | LIGO Lab | Caltech**  
[https://www.ligo.caltech.edu/WA/page/ligo-detectors?utm\\_source=chatgpt.com](https://www.ligo.caltech.edu/WA/page/ligo-detectors?utm_source=chatgpt.com)
- 16 <https://dcc.ligo.org/public/0026/T020036/000/T020036-00.pdf>  
<https://dcc.ligo.org/public/0026/T020036/000/T020036-00.pdf>
- 17 <https://journals.aps.org/prd/abstract/10.1103/PhysRevD.102.024028>  
<https://journals.aps.org/prd/abstract/10.1103/PhysRevD.102.024028>
- 19 <https://dcc.ligo.org/LIGO-P2400152-v10/public>  
<https://dcc.ligo.org/LIGO-P2400152-v10/public>
- 20 <https://scixplorer.org/abs/2025arXiv250818082T/abstract>  
<https://scixplorer.org/abs/2025arXiv250818082T/abstract>
- 21 [https://gwosc.org/o4\\_eventdata\\_docs/](https://gwosc.org/o4_eventdata_docs/)  
[https://gwosc.org/o4\\_eventdata\\_docs/](https://gwosc.org/o4_eventdata_docs/)
- 22 [https://gwosc.org/eventapi/html/O4\\_Discovery\\_Papers/GW230814\\_230901/v2/](https://gwosc.org/eventapi/html/O4_Discovery_Papers/GW230814_230901/v2/)  
[https://gwosc.org/eventapi/html/O4\\_Discovery\\_Papers/GW230814\\_230901/v2/](https://gwosc.org/eventapi/html/O4_Discovery_Papers/GW230814_230901/v2/)
- 23 [https://commons.wikimedia.org/wiki/File%3AGW230814\\_data\\_and\\_reconstruction.png](https://commons.wikimedia.org/wiki/File%3AGW230814_data_and_reconstruction.png)  
[https://commons.wikimedia.org/wiki/File%3AGW230814\\_data\\_and\\_reconstruction.png](https://commons.wikimedia.org/wiki/File%3AGW230814_data_and_reconstruction.png)

<sup>31</sup> LIGO-P2500167-v12: Open Data from LIGO, Virgo, and KAGRA through the First Part of the Fourth Observing Run

<https://dcc.ligo.org/LIGO-P2500167/public>