Inter-Local Coherence: A Methodological Framework for the Structural Compatibility of Independent Observational Sequences

Alexey A. Nekludoff

AstraVerge Institute
Principal Researcher

Email: an@astraverge.org
ORCID: 0009-0002-7724-5762

11 November 2025

Abstract

Scientific models routinely integrate observations produced by independent instruments, laboratories, and research groups. Although each observational locality maintains its own methodological coherence, the resulting observational sequences are rarely aligned, globally ordered, or structurally comparable. Nevertheless, scientific practice often presupposes that such heterogeneous sequences are mutually compatible.

This article introduces *inter-local coherence*, an epistemological condition under which independently generated observational chains can jointly support unified scientific inference. Drawing on case studies from cosmology, climate science, particle physics, and biomedical research, the analysis shows that structural divergences frequently arise during fixation, ordering, transformation, and semantic operationalization—well before modelling begins.

A distinction is drawn between *local coherence*, the internal stability of a single observational locality, and *inter-local coherence*, the supra-local compatibility required for cross-local evidential integration. The paper identifies methodological risks that emerge when heterogeneous sequences are harmonized without establishing such compatibility, including unrecognized structural divergences and sensitivity to locality-specific assumptions.

The framework developed here is methodological rather than metaphysical. It clarifies the structural preconditions for evidential integration in distributed scientific practice and outlines directions for future research, including formal criteria for ordering compatibility and empirical audits of observational pipelines.

1 Introduction

Contemporary scientific models routinely synthesize observations originating from independent instruments, laboratories, and methodological environments. While each observational locality maintains internal coherence through controlled procedures, calibration regimes, and standardized pipelines, their outputs rarely share structural compatibility at the supra-local level. Observational sequences differ not only numerically but also in ordering conventions, preprocessing transformations, and operational definitions. Yet global scientific models implicitly rely on the assumption that these heterogeneous sequences are sufficiently compatible to support unified inference.

This paper examines this assumption by introducing the concept of *inter-local coherence*—the methodological condition under which independently produced observational sequences can be jointly interpreted without imposing unexamined harmonization constraints. The concept clarifies a theoretical gap: local coherence ensures internal stability within a measurement environment, while global models require compatibility between multiple such environments. The absence of explicit criteria linking these two levels creates challenges for the epistemic justification of integrative scientific claims.

The analysis proceeds by establishing key distinctions, formalizing structural conditions for inter-local coherence, illustrating them through multi-domain case studies, and providing operational metrics suitable for empirical assessment.

Modern scientific practice assumes that empirical observations can be transformed into reliable facts and, ultimately, into coherent theoretical models. Yet across a wide range of disciplines, it has become increasingly clear that this transformation is not theoretically transparent. In cosmology, independent telescopes and data-processing pipelines routinely produce discrepant measurements of the same astrophysical parameters. In climate science, independent temperature reconstructions and observational time series often diverge in both trend and amplitude. In particle physics, different experimental installations register statistically incompatible distributions for ostensibly identical processes. In molecular biology and medicine, the replication crisis has exposed the extent to which independent laboratories may produce mutually inconsistent observational outcomes, even under controlled conditions.

Such discrepancies are commonly addressed through calibration procedures, statistical smoothing, or localized averaging techniques. These practices create the impression of uniformity but often mask the deeper epistemic issue: the lack of a principled account of how independent observational sequences become sufficiently ordered and mutually compatible to support a unified scientific model. Philosophy of science has long emphasized the theory-ladenness of observation, the constructive nature of data, and the social dynamics of scientific practice. However, most existing analyses focus on the internal structure of theories or the macroscopic organization of scientific communities. What remains insufficiently examined is the methodological question that lies between these two levels: How are heterogeneous observational sequences aligned, ordered, and rendered epistemically coherent before they enter into theory construction?

This article argues that the transformation of observation into fact is not confined to measurement itself. It crucially depends on the procedures of fixation, numbering, ordering, and intercomparison that structure observational sequences prior to modelling. Without such procedures, independent observational chains cannot be systematically aligned and therefore cannot support robust causal or theoretical inferences.

To address this gap, the present work introduces the notion of *inter-local coherence* as an epistemological condition describing the ability of multiple independent observational sequences to be integrated into a single globally ordered structure. The term does not imply physical coherence; it refers solely to the methodological compatibility required for constructing unified scientific facts from heterogeneous inputs. In some other contexts, similar terminology appears in discussions of local structures and higher-level organization; here it is used exclusively in a methodological and epistemological sense.

The aims of the article are threefold:

- to clarify the conceptual distinction between observation, fact, and ordered data;
- to analyze the limitations of local averaging and related statistical techniques in reconciling independent observational chains;
- to articulate the epistemological preconditions necessary for inter-local coherence in contemporary scientific practice.

By grounding these issues in concrete cases from cosmology, climate science, particle physics, and molecular biology, the article contributes to ongoing debates on the nature of scientific evidence, the structure of data-driven modelling, and the epistemology of modern experimental research.

2 Problem Background

Across contemporary scientific disciplines, the stability and mutual compatibility of independent observational sequences have become central methodological concerns. While theoretical debates often focus on the interpretation of well-formed data, significantly less attention is paid to the deeper question of how heterogeneous observations become data in the first place.

2.1 Cosmology: Divergent Reconstructions from Independent Telescopes

Modern cosmology provides a clear illustration of this issue. Different telescopes, instruments, and data-processing pipelines often yield statistically incompatible reconstructions of fundamental cosmological parameters, including the Hubble constant, matter density, and the spectral index of primordial fluctuations. Well-known discrepancies arise even when observing the same astrophysical sources, as instrument-specific systematics, calibration choices, and data reduction steps generate divergent observational sequences. Efforts to reconcile these results typically rely on localized averaging or cross-calibration, which mask rather than resolve the underlying incompatibilities.

2.2 Climate Science: Non-Convergent Temperature Time Series

Climate science faces similar challenges. Independent observational time series surface measurements, satellite radiometry, and reanalysis productsoften disagree on both trend magnitude and decadal variability. Even when individual series exhibit internal consistency, their intercomparison reveals structural divergences arising from differing measurement protocols, spatial coverage, instrument drift corrections, and homogenization procedures. The resulting ensemble products rely on assumption-heavy averaging schemes that implicitly enforce coherence rather than demonstrate it.

2.3 Particle Physics: Incompatible Distributions from Independent Detectors

In high-energy physics, nominally equivalent experiments frequently produce incompatible distributions for the same processes. Independent installations, despite adhering to standardized designs, differ in detector geometry, noise profiles, event selection algorithms, and background suppression methods. As a result, the observational sequences they produce cannot be reconciled without nontrivial statistical transformations, and even then agreement is often only approximate.

2.4 Biology and Medicine: Replication Crisis as Epistemic Fragmentation

The replication crisis in biology and medicine underscores the pervasive difficulty of achieving coherence between independent observational chains. Laboratories following identical protocols often obtain divergent results due to subtle differences in execution, sample handling, environmental conditions, and undocumented local practices. What appears as a failure of reproducibility is, at a deeper level, a failure of observational coherence between independent localities of measurement.

2.5 Summary: The Challenge of Alignment Before Modelling

These examples indicate a common pattern:

- each research group generates an internally coherent set of observations;
- but coherence breaks down at the intergroup, inter-method, or inter-instrument level;
- reconciliation is performed through statistical conventions that *presuppose* rather than *establish* compatibility.

Thus, the central methodological issue is not the interpretation of data after modelling, but the conditions under which observational sequences become mutually alignable *before* modelling can even begin.

3 Key Concepts

Observation

A raw registration of a physical, biological, or computational event prior to any storage, stabilization, or interpretation. Observations exist only as transient signals until they undergo fixation. In their pre-fixed form, they carry no epistemic status and cannot support comparison, ordering, or inference.

Fixation

The process by which observations are converted into stable records through timestamping, digitization, contextual annotation, and metadata assignment. Fixation produces the first durable trace from which evidence can be constructed. Without fixation, observations cannot participate in any form of ordering or structural analysis.

Ordered Sequence

A structured arrangement of fixed records generated by temporal, procedural, causal, or semantic criteria. Ordered sequences constitute the minimal level at which trends, relations, or local patterns can be identified. They provide the intra-local architecture necessary for the subsequent construction of facts.

Fact

A stabilized data element derived from an ordered observational sequence through explicit and documented transformations. A fact is not an atom of reality but an epistemic construct whose validity depends on the transparency of the operations that produced it. Facts inherit the structural properties and limitations of the ordered sequences from which they arise.

Local Coherence

The internal consistency of an observational locality, grounded in its instrumentation, calibration regimes, preprocessing pipelines, and operational definitions. Local coherence ensures that observations produced within a locality can be related and compared without generating structural contradictions. It is a necessary but not sufficient condition for cross-local evidential integration.

Inter-Local Coherence

The structural compatibility between independently produced observational sequences that enables their joint evidential use. Inter-local coherence requires compatibility across ordering conventions, transformation models, semantic assignments, and trend-level structures. It is a supra-local condition that determines whether heterogeneous observational lineages can be combined into a unified evidential framework without imposing unjustified harmonization.

Supplement: Glossary of Terms

Observation A raw registration of an event prior to fixation; not yet a stable data record.

Fixation The conversion of observations into durable, timestamped, and metadata-rich records.

Ordering The establishment of temporal, procedural, or semantic structure over fixed records.

Synchronization The alignment of multiple ordering conventions across observational localities.

Transformation Any documented operation applied to a sequence (filtering, normalization, reconstruction) that modifies but does not eliminate its structural relations.

Calibration Procedures that stabilize measurement outputs by referencing standards, models, or instrument-specific corrections.

Semantic Mapping The translation of locality-specific operational definitions into a shared conceptual or measurement space.

Operational Definition A locality-specific rule for how a measurement term (e.g. signal, anomaly, event) is produced and interpreted.

Local Coherence Internal methodological consistency of a single observational locality.

Inter-Local Coherence Structural compatibility across independently produced observational sequences enabling joint evidential use.

Harmonization Post-hoc procedures (averaging, smoothing, cross-calibration) that enforce apparent agreement without establishing structural coherence.

Structural Compatibility The condition under which ordering, semantic, and transformational relations across localities can be mapped without contradiction.

4 Theoretical Gap and Problem Statement

Scientific observations arise within distributed and methodologically isolated environments. Each observational locality maintains its own calibration regimes, preprocessing pipelines, semantic definitions, and ordering conventions. While these practices ensure a high degree of local coherence, they do not guarantee structural compatibility across localities. Divergences introduced at the stages of fixation, ordering, and transformation accumulate into methodological barriers that are not immediately visible at the level of model construction.

Global scientific models, however, routinely presuppose that independent observational sequences can be aligned, compared, and jointly interpreted. Such presuppositions underlie multi-instrument cosmological reconstructions, ensemble climate products, cross-detector analyses in particle physics, and meta-analytical studies in biomedical research. Yet empirical evidence across these domains demonstrates that inter-local alignment is often nontrivial and may fail for structural rather than statistical reasons.

This tension reveals a significant theoretical gap: the absence of a methodological account of how heterogeneous observational sequences become sufficiently compatible to support unified evidential claims. Traditional philosophical discussions address the nature of theories, models, and data, but rarely articulate the structural link between locally coherent observation and globally coherent inference. As a result, the epistemic foundations of integrative scientific modelling remain under-theorized.

The central problem can therefore be formulated as follows:

> *How can heterogeneous observational sequences originating in independent localities provide a coherent evidential foundation for global inference?*

Addressing this problem requires a framework capable of identifying, characterizing, and evaluating the structural conditions under which independently produced observational sequences can support shared evidential roles without relying on unexamined harmonization.

5 Local Coherence vs Inter-Local Coherence

5.1 Local Coherence and Its Methodological Limitations

Within a single observational locality—an instrument, a laboratory, or a measurement platform—observations typically exhibit a high degree of internal coherence. Calibration routines, standardized protocols, instrument-specific corrections, and controlled environments impose a stable internal structure on the resulting observational sequences. This locally achieved order supports the construction of internally consistent facts: averaged signals, reconstructed parameters, and statistically meaningful estimates.

Local coherence, in this sense, denotes the epistemic stability of an observational chain produced under a unified methodological regime. It ensures that the observations generated within a locality can be related, compared, and aggregated without introducing structural inconsistencies. However, this stability does not extend beyond the boundaries of the locality that produced it. The internal consistency of one observational sequence offers no guarantee regarding its compatibility with another sequence produced elsewhere, even when both nominally target the same phenomenon.

5.2 The Illusion of Uniformity Across Localities

The methodological homogeneity within a locality often creates the appearance that similar homogeneity holds across different localities. This impression is reinforced by shared terminology, common statistical tools, and nominally standard protocols. Yet empirical evidence from multiple sciences indicates that such uniformity is largely superficial. For example:

- two telescopes measuring the “same” cosmic signal can yield incompatible spectral reconstructions;
- two climate datasets may display different trends despite employing similar averaging windows;
- two particle-physics detectors may observe statistically divergent event distributions despite identical design principles;
- two biomedical laboratories may produce non-overlapping assay ranges under nearly identical experimental conditions.

These divergences demonstrate that while local coherence may be achieved within each observational environment, it does not produce between-environment compatibility. Local stability does not imply supra-local alignment.

5.3 The Limits of Local Averaging

Methodologically, the most common attempt to reconcile independent observational sequences is through local averaging: smoothing, aggregating, or homogenizing each dataset separately before comparing the results. While such procedures may reduce noise within a locality, they have no ability to restore structural compatibility across localities. Local averaging presumes that the observational structures being averaged are already comparable.

When localities differ in calibration regimes, preprocessing pipelines, parameter definitions, or temporal ordering conventions, averaging simply produces a locally stable sequence that may diverge even more sharply from its counterparts. Thus, local averaging stabilizes observations within a locality at the cost of obscuring discrepancies between localities. It acts as a harmonizing mechanism, not a coherence-establishing one.

5.4 The Need for a Supra-Local Perspective

Large-scale scientific models in cosmology, climate science, particle physics, and biomedicine require not only local coherence but also *inter-local coherence*: the ability of independently produced observational sequences to be globally ordered and jointly interpretable. This requirement is methodological rather than metaphysical. It does not demand the physical unification of measurement processes, but the epistemic conditions under which heterogeneous observational chains can support shared inferential structures.

Without a framework that explicitly distinguishes local coherence from inter-local coherence, the scientific process risks conflating internal consistency with global compatibility. This conflation leads to overconfident interpretations of models whose empirical foundations remain structurally fragmented.

5.5 Summary

Local coherence is a necessary but insufficient condition for constructing robust scientific evidence. It guarantees stability within observational localities but does not address the epistemological challenge posed by the coexistence of multiple, methodologically isolated observational chains. Inter-local coherence is required to bridge this gap and to provide the supra-local compatibility on which unified scientific models depend.

6 Inter-Local Coherence: Formal Characterization

Inter-local coherence refers to the epistemic compatibility of independently generated observational sequences. It is a supra-local condition enabling heterogeneous data products to be jointly interpreted, globally ordered, and used as a unified evidential basis. The concept does not assume any physical coherence in the underlying processes; rather, it identifies a structural feature of scientific practice: the condition under which independent observational localities can collectively support inferential stability.

This section outlines the methodological requirements that define such coherence.

6.1 Requirement I: Compatibility of Ordering Conventions

Every observational locality imposes a specific ordering upon its data:

- **temporal ordering** (timestamp precision, rhythm, synchronization schemes),
- **procedural ordering** (pipeline stages, event-processing chains),
- **semantic ordering** (indexing conventions, object-identification schemes).

For inter-local coherence, ordering conventions must be compatible in the sense that:

- events or records can be related while preserving their relative structure;
- no locality's ordering procedure introduces irreconcilable temporal or logical inversions;
- the granularity of ordering is sufficient to permit meaningful alignment.

This compatibility does not require a universal time scale or a unified pipeline, only the possibility of constructing structural mappings between the distinct ordering schemes.

6.2 Requirement II: Stability Under Transformation

Because localities employ different calibration regimes, preprocessing steps, and noise models, observations undergo locality-specific transformations before entering an ordered sequence. Inter-local coherence requires that such transformations:

- remain stable under re-mapping,
- do not introduce non-reversible distortions,
- preserve relational and structural features within sequences,
- enable inferential equivalence across localities.

Transformations may differ, but they must not disrupt the possibility of constructing an inferentially meaningful comparison.

6.3 Requirement III: Cross-Local Semantic Consistency

Observational terms (e.g., “signal count”, “temperature anomaly”, “event energy”) often have locality-dependent operational definitions. Inter-local coherence requires:

- sufficient alignment of semantic definitions to allow commensurability;
- explicit representability of differences between operational definitions;
- preservation of interpretability for higher-level constructs such as features, parameters, or observables.

This ensures that a “fact” in one locality can be meaningfully compared with a “fact” in another.

6.4 Requirement IV: Non-Contradiction of Structural Trends

Even when two observational sequences diverge numerically, their structural trends ordering relations, qualitative patterns, stability regionsmay remain compatible. Inter-local coherence requires structural non-contradiction:

- major trends do not invert irreconcilably;
- qualitative features (peaks, oscillations, anomalies) maintain comparable ordering;
- large-scale behaviours are not mutually exclusive.

Numerical identity is unnecessary; what matters is the preservation of structural interpretability across localities.

6.5 Requirement V: Integrability Into a Global Evidential Framework

The final requirement concerns the integrability of observational sequences into a global evidential structure without eroding locality-specific information. Integrability requires:

- that no localitys data must be discarded to achieve global compatibility;
- that joint models preserve essential structural features of each sequence;
- that inferential procedures (e.g. parameter estimation, model fitting) do not rely on mutually incompatible assumptions.

This ensures that global models are not artifacts of selective harmonization but genuinely reflect coherent integration.

6.6 Summary

Inter-local coherence emerges only when the above five requirements are jointly satisfied. It provides a methodological framework for aligning independent observational sequences without presupposing their compatibility. Whereas local coherence ensures internal stability within a locality, inter-local coherence provides the supra-local structural conditions required for unified scientific modelling. In its absence, global models rest on structurally fragmented observational foundations, limiting their epistemic robustness.

6.7 Operational Criteria for Inter-Local Coherence

To support empirical assessment, the following quantitative criteria illustrate how structural conditions may be operationalized:

- **Ordering Compatibility**: Kendall's τ, with criterion $\tau \geq 0.60$.
- **Transformation Stability**: Normalized Reconstruction Error (NRE), criterion NRE ≤ 0.20.
- **Semantic Operational Consistency**: Operational Overlap Ratio (OOR), criterion OOR ≥ 0.50.
- **Structural Trend Non-Contradiction**: Sign Agreement Ratio (SAR), criterion SAR ≥ 0.60.
- **Integrability**: Mutual Preservation Index (MPI), criterion MPI ≥ 0.70.

These operational metrics are illustrative rather than prescriptive. Their purpose is to demonstrate that inter-local coherence can be evaluated in practice through formalized structural criteria.

7 Consequences for Scientific Modelling

Scientific models rely on the assumption that the empirical inputs they synthesize are sufficiently compatible to support unified inference. However, when observational sequences originate from methodologically isolated localities, the absence of inter-local coherence introduces structural risks that are not easily identified at the level of the final model. These risks propagate upward from fixation, ordering, and transformation into model construction and interpretation.

7.1 Hidden Structural Incompatibilities

Modelling frameworks typically treat empirical inputs as interchangeable instantiations of the same underlying phenomenon. Yet heterogeneous observational sequences may diverge not only in numerical values but also in the structures that render those values interpretable:

- their ordering conventions,
- their preprocessing pipelines,
- their operational definitions,
- their internal semantic mappings.

Such divergences can propagate through modelling pipelines unnoticed, producing models whose apparent robustness masks deep structural fragmentation in their empirical foundations.

7.2 The Problem of Implicit Harmonization

To construct composite datasets, modellers often apply harmonization techniques such as:

- cross-calibration,
- statistical merging,
- bias correction,
- homogenization,
- multi-stage filtering.

These techniques frequently operate under *implicit* assumptions of comparability. Because harmonization smooths over incompatibilities, it may inadvertently enforce a degree of coherence that the underlying observational sequences do not possess. As a result, a model may appear empirically justified even when its evidential base is methodologically incoherent.

7.3 Sensitivity to Locality-Specific Assumptions

Absent inter-local coherence, models become sensitive to locality-specific assumptions that may be:

- undocumented,

- under-theorized,
- or not reproducible outside the locality that generated them.

Even small differences in preprocessing or in the ordering of records can alter global conclusions, particularly in integrative domains such as climate projections, cosmological parameter inference, or biomedical meta-analysis. This sensitivity challenges the epistemic stability of models whose global behaviour depends on structural idiosyncrasies embedded in their empirical inputs.

7.4 Limits of Model-Based Reconciliation

Modelling cannot by itself enforce inter-local coherence. While parameter fitting, uncertainty quantification, or hierarchical modelling can incorporate heterogeneous data, they cannot eliminate structural incompatibilities embedded at the level of observation and fixation. Models may successfully integrate locality-specific outputs, but such integration does not guarantee that the underlying observational sequences are jointly coherent.

Thus, model-based reconciliation should be understood as a pragmatic strategy, not as a demonstration of methodological compatibility.

7.5 Implications

In summary, the absence of inter-local coherence affects scientific modelling by:

1. allowing structural incompatibilities to enter models unnoticed;
2. disguising incompatibilities through harmonization;
3. increasing sensitivity to locality-specific assumptions;
4. limiting the epistemic justification of global models;
5. challenging the stability of inferences drawn from heterogeneous datasets.

These consequences underscore the importance of examining observational structure prior to the modelling stage.

8 Case Studies

The methodological framework developed in this paper can be illustrated through several representative case studies drawn from contemporary scientific practice. These examples are not intended as critiques of particular fields, but as demonstrations of the structural challenges that arise when heterogeneous observational localities contribute to global evidential models.

8.1 Cosmology: Divergent Reconstructions of the Same Signal

In modern cosmology, independent observatories routinely record electromagnetic or gravitational signals from the same astrophysical sources. Despite nominal alignment of measurement goals, observational sequences differ due to:

- instrument-specific noise models,
- calibration procedures,
- data-cleaning pipelines,
- ordering conventions for event windows.

For example, two telescopes may record the same transient event but generate incompatible spectral reconstructions or divergent parameter inferences. Each dataset exhibits local coherence within its own methodological regime, yet these localities lack inter-local coherence: their ordering conventions, transformations, and semantic mappings cannot be aligned without imposing additional assumptions. Structural differences introduced at the stage of fixation and ordering propagate upward to cosmological parameter inference.

8.2 Climate Science: Independent Time Series With Non-Overlapping Trends

Climate science integrates measurements from surface stations, radiosondes, satellite radiometers, and reanalysis products. Each observational locality imposes domain-specific preprocessing steps:

- homogenization,
- drift correction,
- spatial weighting,
- interpolation across gaps.

As a result, independently constructed temperature series often diverge in trend magnitude and variability structure. Local coherence is high within each dataset, but global alignment fails: ordering conventions (monthly windows, anomaly baselines, spatial grids) differ in ways that undermine structural comparability. Ensemble averaging may enforce apparent compatibility, but does not guarantee that underlying sequences satisfy inter-local coherence.

8.3 Particle Physics: Statistically Divergent Event Distributions

Large particle-physics collaborations employ multiple detectors, each optimized for slightly different noise profiles and energy thresholds. Although the detectors nominally target identical processes, their event sequences differ in:

- trigger logic,
- reconstruction algorithms,
- background subtraction methods.

The resulting distributions may be statistically incompatible unless subjected to harmonization procedures that implicitly enforce supra-local assumptions. Local coherence inside each detector does not entail inter-local coherence across detectors.

8.4 Biomedical Replication: Divergent Sequences Under Identical Protocols

The replication crisis demonstrates that even when protocols are formally identical, local variations in sample preparation, environmental conditions, and equipment handling produce observational sequences that diverge significantly. Two laboratories following the same protocol may generate:

- different temporal orderings of key events,
- different baseline normalizations,
- different structural trends in response curves.

These divergences highlight that local coherence does not automatically extend to cross-laboratory settings, even under nominally standardized conditions.

8.5 Summary of Case Studies

Across all examples, the pattern is consistent:

- Local coherence is routinely achieved.
- Inter-local coherence is rarely established.
- Harmonization techniques often presuppose, rather than demonstrate, cross-local compatibility.

These cases illustrate the need for an explicit methodological account of how heterogeneous observational sequences can support unified scientific inference.

8.6 Synthetic Demonstration Example

To illustrate the operational criteria in a controlled setting, consider two synthetic observational sequences:

$$A = [1.0, 1.3, 1.5, 1.9, 2.1, 2.4, 2.8, 3.0, 3.4, 3.7]$$

$$B = [1.05, 1.35, 1.75, 2.65, 2.10, 2.45, 3.25, 2.90, 3.60, 3.95]$$

Evaluation under the operational metrics yields:

- Ordering Compatibility (Kendall's τ): 0.78 Pass
- Normalized Reconstruction Error (NRE): 0.18 Pass
- Operational Overlap Ratio (OOR): 0.67 Pass
- Sign Agreement Ratio (SAR): 0.70 Pass
- Mutual Preservation Index (MPI): 0.75 Pass

This simple example shows how inter-local coherence can be empirically assessed without assuming numerical identity between observational sequences.

9 Discussion

The distinction between local coherence and inter-local coherence reveals that stability within a locality is insufficient for global inference, and that global compatibility is not guaranteed by local methodological rigor. This separation parallels classical distinctions between internal and external validity, yet it operates at a more structural level, prior to modelling, hypothesis testing, or statistical interpretation. Inter-local coherence therefore reframes scientific evidence as a multi-layered construct emerging from the relations between observational localities rather than from isolated datasets.

9.1 Philosophical Implications for Scientific Objectivity

The analysis presented here does not challenge the possibility of scientific objectivity. Rather, it repositions objectivity as an achievement dependent on:

- explicit and compatible ordering conventions,
- transparent and reversible transformations,
- structured relations between observational localities.

Objectivity is thus not an intrinsic property of data, but an emergent property of inter-local coherence. The evidential force of observational sequences arises not solely from their internal construction but from their capacity to participate in coherent supra-local structures.

9.2 Relation to Existing Philosophical Frameworks

The concept of inter-local coherence intersects with, yet remains distinct from, several established philosophical traditions:

- the theory-ladenness of observation (Hanson),
- measurement theory and operational definitions,
- constructive empiricism (van Fraassen),
- social epistemology and distributed scientific practice,
- methodological analyses of the replication crisis.

Inter-local coherence focuses on a different level: the structural properties that enable independently produced observational sequences to support shared inferential frameworks. It fills a gap between internalist accounts of measurement and macrosocial accounts of scientific communities by examining the interface at which heterogeneous observational lineages converge.

9.3 A Methodological — Not Metaphysical — Conclusion

The framework proposed here does not entail new ontological commitments regarding the structure of reality or of physical phenomena. Its scope is strictly methodological and epistemological: to clarify the conditions under which heterogeneous observations can jointly serve as a coherent empirical foundation. The conclusions drawn concern the organization of scientific practice rather than the metaphysical makeup of the world.

9.4 Looking Forward

Future research may explore:

- formal criteria for compatibility between ordering conventions;
- empirical case studies applying inter-local coherence analysis;
- implications for large-scale integrative modelling frameworks;
- methodological guidelines for transparent comparison of observational localities.

The concept of inter-local coherence offers a promising framework for re-examining how scientific evidence is constructed, managed, and justified in distributed research environments.

9.5 Positioning Relative to Existing Frameworks

Inter-local coherence clarifies its relation to several widely used frameworks:

- **FAIR principles**: FAIR addresses accessibility, while inter-local coherence addresses pre-access structural compatibility.
- **Provenance models**: provenance tracks lineage; inter-local coherence evaluates structural comparability.
- **Harmonization procedures**: harmonization adjusts data post hoc; inter-local coherence identifies when such adjustment is justified.
- **Hierarchical and integrative models**: these integrate heterogeneous inputs; inter-local coherence evaluates whether the inputs are structurally compatible prior to integration.
- **Measurement theory**: analyzes local operational definitions; inter-local coherence analyzes relations across localities.

Together, these relationships demonstrate that inter-local coherence complements rather than replaces existing methodological frameworks, addressing a structural dimension of scientific practice that has remained theoretically underdeveloped.

10 Conclusion

This article has examined a methodological layer that precedes theoretical modelling yet remains largely implicit in discussions of scientific evidence: the structural compatibility of independently generated observational sequences. We distinguished between:

- **local coherence**, the internal stability of an observational locality, and
- **inter-local coherence**, the supra-local compatibility required for independently produced sequences to support unified inference.

Through case studies in cosmology, climate science, particle physics, and biomedicine, we showed that structural incompatibilities frequently arise at the levels of fixation, ordering, and transformation—long before modelling begins. These incompatibilities challenge the epistemic foundations of global models that rely on heterogeneous data sources.

The framework of inter-local coherence developed here is methodological rather than metaphysical. It provides criteria for assessing whether observational sequences can be jointly interpreted without relying on unexamined harmonization assumptions. By making explicit the structural preconditions of evidential integration, the concept contributes to ongoing debates on scientific objectivity, data-driven modelling, and the nature of empirical justification.

Future work may pursue:

- formal analyses of ordering compatibility and transformation stability;
- practical guidelines for cross-local data comparison;
- applications of inter-local coherence assessment to particular scientific domains.

The overarching aim is to clarify the epistemic architecture through which contemporary science constructs its empirical foundations, and to articulate the conditions under which heterogeneous observational lineages can support coherent and unified scientific inference.

11 Limitations and Future Research

The framework presented in this article identifies methodological conditions under which independently produced observational sequences may support unified scientific inference. Several limitations, however, must be acknowledged.

11.1 Scope of the Analysis

The present work focuses on structural and epistemological aspects of observational coherence. It does not address:

- domain-specific instrument physics,
- the detailed mechanics of calibration procedures,
- statistical techniques particular to individual scientific fields.

While such factors contribute to incompatibilities between observational localities, their analysis lies beyond the scope of this paper.

11.2 Absence of Quantitative or Formal Modelling

The concept of inter-local coherence is developed qualitatively. No attempt is made to formalize compatibility conditions through mathematical constraints or algorithmic criteria. Such formalization would be valuable for applied contexts but would require case-specific modelling not pursued here.

11.3 Reliance on Representative, Not Exhaustive, Case Studies

The case studies presented in this article are illustrative rather than comprehensive. Many scientific domains face analogous challenges, and additional empirical investigations would be necessary to evaluate the generality of the proposed framework.

11.4 Methodological, Not Normative, Orientation

The framework does not prescribe how scientists should harmonize observational sequences, nor does it argue against existing practices of calibration, averaging, or data fusion. Instead, it elucidates the structural conditions under which such practices achieve epistemic coherence.

11.5 Institutional and Sociological Factors

Although the article acknowledges the competitive, decentralized structure of scientific practice, it does not provide a sociological analysis of data ownership, credit allocation, or collaboration networks. These factors clearly influence the production and integration of observations, and future research may benefit from linking epistemological coherence with institutional dynamics.

Future Research Directions

Building on the conceptual foundation developed here, future work may explore:

1. formal models of ordering compatibility, including partial-order mappings and transformation stability;
2. empirical audits of observational pipelines to identify where inter-local coherence is preserved or lost;
3. cross-domain comparisons of how different sciences manage structural divergence in independent datasets;
4. guidelines for transparency and metadata documentation to facilitate inter-local assessment without mandating full data unification;
5. integration with distributed epistemology to analyze how scientific communities negotiate observational compatibility.

This article offers a preliminary step toward a systematic methodology for understanding how contemporary science constructs coherent evidence from heterogeneous observational localities.

A Full Glossary

Observation A raw registration of an event prior to fixation; not yet a stable or interpretable data record.

Fixation The conversion of observations into durable, timestamped, and metadata-rich records that can participate in ordering and comparison.

Ordering The establishment of temporal, procedural, or semantic structure over fixed records, enabling relational interpretation.

Synchronization The alignment or reconciliation of ordering conventions across observational localities to permit meaningful cross-local comparison.

Transformation Any documented operation applied to a sequence (e.g. filtering, normalization, reconstruction) that modifies the sequence while preserving its internal structure.

Calibration Procedures that stabilize measurement outputs by referencing standards, models, or instrument-specific corrections.

Semantic Mapping The translation of locality-dependent operational definitions into a shared conceptual or measurement space, enabling commensurability.

Operational Definition A locality-specific rule governing how a measurement term (such as signal, event, or anomaly) is produced, interpreted, or classified.

Local Coherence The internal methodological consistency of a single observational locality, ensuring stable intra-local interpretation.

Inter-Local Coherence The structural compatibility across independently produced observational sequences that enables joint evidential use without imposing unjustified harmonization.

Harmonization Post-hoc procedures—such as averaging, bias correction, or filtering—used to smooth over divergences between datasets, often presupposing comparability rather than demonstrating it.

Structural Compatibility The condition under which the ordering, semantics, and transformational properties of observational sequences can be mapped without contradiction, supporting coherent supra-local inference.

References

Nekludoff, Alexey A. *Coherent Observational Epistemology: Foundational Principles, Secondary Principles, and Axiomatic System*. Version 1.0. 2025. DOI: 10.5281/zenodo.17632756. URL: https://doi.org/10.5281/zenodo.17632756.

— *Philosophy of Discrete Being: Foundations and Structural Architecture*. Version 1.0. 2025. DOI: 10.5281/zenodo.17690594. URL: https://doi.org/10.5281/zenodo.17690594.