# Physical Laws as Invariants in Embedded Representation

Mark Tracy

## 1 Introduction

In an embedded epistemic framework, observers do not have access to the universe from an external vantage point. Instead, they encounter only observations and construct world models from those observations. Let $\Omega$ denote the universe, $D \subseteq \Omega$ the set of possible observations, and $W \subseteq \Omega$ the set of world models.

**Remark 1.** *The observation space $D$ is defined to contain exactly the observations made by embedded observers. Every element of $D$ corresponds to an observation experienced by some observer, and every observation experienced by any observer is an element of $D$. The space $D$ therefore contains all observations by all observers and nothing else.*

Observations generate models through an inference map

$$F : D \to W,$$

while models generate canonical observational implications through a map

$$g : W \to D.$$

The epistemic dynamics of the system are therefore governed by the *inference–implication loop*

$$D \xrightarrow{F} W \xrightarrow{g} D.$$

A world model is self-consistent when the loop closes on itself,

$$W = F(g(W)).$$

Within such a system, scientific theories must organize observations in a way that remains stable under repeated cycles of inference and implication.

## 2 Observational Equivalence and Quotient Structure

A world model $W$ induces a classifier

$$\pi_W : D \to Z_W,$$

which partitions the observation space into equivalence classes

$$[d]_W = \{d' \in D \mid \pi_W(d') = \pi_W(d)\}.$$

The set of these equivalence classes forms the observational quotient space

$$D/\sim_W .$$

From the standpoint of an embedded observer, relational structure in the world is detected as patterns of relations among these equivalence classes. Individual observations may vary, but the relations among classes can remain stable.

## 3 Ergodic Exploration of Observations

Observers encounter observations sequentially through interaction with the world. Let

$$d_1, d_2, d_3, \dots$$

denote the sequence of observations experienced by an observer and interpreted through the inference–implication loop.

**Remark 2.** *The sequence of observations considered here is observer-relative. Each embedded observer experiences its own sequence of observations generated through interaction with the world. The framework does not assume a global ordering of all observations in $D$.*

*Instead, the observational space $D$ is ergodic with respect to the ensemble of observers. Across the ensemble of observer trajectories, the observational space is therefore explored in its entirety, even though no individual observer need encounter all possible observations.*

Under this ensemble ergodicity, stable relational patterns among equivalence classes become visible through continued observational exploration.

Physical laws can therefore be understood as relational structures between equivalence classes that remain invariant under this ergodic exploration of observations.

## 4 Clarification of the Role of Observables

Within this framework, physical laws appear as equivalence classes of observables whose relational structure with other equivalence classes remains stable.

A physical law is therefore not a single observation but a stable relational structure between one or more equivalence classes of observables, represented by an equivalence class in the quotient space $D/{\sim_W}$.

## 5 Definition of Physical Law

**Definition 1** (Physical Law)**.** *A physical law is an observable $d \in D$, modulo a world model $W$, such that the equivalence class $[d]_W$ participates in a relational structure within the quotient space $D/{\sim_W}$ whose relations to one or more distinct equivalence classes*

$$\{[d']_W \mid d' \notin [d]_W\}$$

*remain invariant under the ergodic exploration of observations generated by the globally consistent inference–implication loop.*

**Remark 3.** *This definition characterizes physical laws as relational invariants in the observational quotient structure induced by a world model. Laws are therefore observable, model-relative, and stable under the ergodic exploration of observations produced by the self-consistent inference–implication dynamics of an embedded epistemic system.*

## 6 Persistence of Earlier Scientific Theories

The present framework also clarifies why earlier scientific theories can remain useful even after the development of more refined models.

A world model induces a particular partition of the observation space. Different scientific theories correspond to different classifiers $\pi_W$ and therefore to different quotient structures $D/{\sim_W}$.

When a later theory introduces a more refined model of the world, it typically induces a finer partition of the observation space, revealing new relational structure among observations. However, the relational invariants identified by earlier theories may still remain stable within large regions of observational space.

In this sense, earlier theories identify relational invariants that persist under the ergodic exploration of observations within a coarser observational quotient. Later theories do not necessarily invalidate these invariants; instead, they often reinterpret them as special cases within a richer relational structure.

This perspective explains the continued practical relevance of earlier physical theories. Their laws correspond to relational invariants that remain stable across large domains of observations, even when more refined theoretical frameworks become available.