

Unification: The Missing Arrow of Time

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November 14, 2025

Abstract

Using only elementary mechanics, we show that the decomposition of force into parallel and orthogonal components reveals two distinct physical interactions. In idealized systems these components are lossless, but real systems contain constraints that produce dissipation. Since quantum mechanics and general relativity are both constraint-free theories describing a universe full of coupled subsystems, any unification must necessarily incorporate dissipation and the arrow of time.

1 Force, Momentum, and the Two Components of an Interaction

In classical physics, a force represents nothing but an *instantaneous change of momentum*:

$$\frac{d\vec{p}}{dt} = \vec{F}.$$

This relation is fully vectorial. It implies that every force—regardless of its origin—always has two physically distinct components whenever there is a moving *mass* (and, as shown in Appendix A, this applies equally to radiation):

- a component *parallel* to the velocity: changes the magnitude of the momentum;
- a component *orthogonal* to the velocity: changes the direction of the momentum.

Both components represent real physical interactions. Neither of them “disappears”: each corresponds to a fundamentally different way in which a force influences motion.

These two components are described exactly by the two geometric products:

$$\text{dot product: } \vec{F} \cdot \vec{v} \quad \text{and cross product: } \vec{F} \times \vec{v}.$$

The dot product measures the *parallel* contribution of the force, while the cross product measures the *orthogonal* one. Each has a distinct physical meaning.

1.1 The Dot Product: Parallel Momentum Change and Work

The parallel component of the force is

$$F_{\parallel} = \vec{F} \cdot \hat{v}.$$

This component changes the *magnitude* of the momentum and hence the kinetic energy. Energy transfer follows from

$$\frac{d}{dt} \left(\frac{1}{2} m v^2 \right) = \vec{F} \cdot \vec{v}.$$

Work is therefore nothing but the *integral of the parallel momentum change along the path*:

$$W = \int \vec{F} \cdot d\vec{x}.$$

What the dot product is in geometry (a parallel projection) becomes energy transfer in physics.

1.2 The Cross Product: Orthogonal Momentum Change and Torque

The orthogonal component of the force changes the *direction*, not the magnitude, of the momentum:

$$F_{\perp} = |\vec{F} \times \hat{v}|.$$

Because this component is perpendicular to the velocity, it performs no work:

$$\vec{F}_{\perp} \cdot \vec{v} = 0.$$

Still, it is physically essential. It produces all phenomena where the direction of motion changes without changing speed:

- centripetal force in circular motion,
- Lorentz force on a charged particle ($\vec{F} = q\vec{v} \times \vec{B}$),
- Coriolis force on a rotating Earth.

The cross product measures exactly this component. In rotational dynamics, it underlies torque:

$$\vec{\tau} = \vec{r} \times \vec{F},$$

the oriented area element that determines rotational motion.

1.3 Example 1: Pulling a Sled at an Angle

A person pulls a sled with force \vec{F} under an angle θ with respect to the horizontal direction of motion.

The decomposition is:

$$F_{\parallel} = |\vec{F}| \cos \theta, \quad F_{\perp} = |\vec{F}| \sin \theta.$$

Parallel component. This component performs work; it determines the acceleration (or overcoming friction).

Orthogonal component. This component performs no work on the translation, but it has clear physical effects:

- it presses the sled deeper into the snow,
- increases the normal force,
- increases friction,
- produces microscopic deformation and heat.

Nothing about the orthogonal force “disappears”: it acts through the contact with the ground and governs the dissipative forces. The parallel/orthogonal decomposition therefore captures two distinct interaction mechanisms.

1.4 Example 2: A Planet in Orbit — Purely Orthogonal Interaction

A planet with velocity \vec{v} experiences gravitational force \vec{F} directed toward the centre:

$$\vec{F} = -\frac{GMm}{r^2}\hat{r}.$$

Since \vec{v} is always perpendicular to \hat{r} in a stable orbit,

$$\vec{F} \cdot \vec{v} = 0.$$

Gravity performs no work; the kinetic energy remains constant.

Yet the interaction is decisive:

$$\frac{d\vec{p}}{dt} = \vec{F}_\perp.$$

The cross product characterizes this motion:

$$\vec{L} = \vec{r} \times \vec{p}$$

remains constant because $\vec{F} \times \vec{r} = 0$.

The planet “falls” continuously toward the Sun, but its momentum simply rotates.

1.5 Conclusion

The decomposition

$$\vec{F} = F_\parallel \hat{v} + \vec{F}_\perp$$

is not merely a mathematical property of vectors, but reflects two fundamentally different physical processes:

- **Parallel** — energy transfer, work, change of speed:

$$\vec{F} \cdot \vec{v}.$$

- **Orthogonal** — change of direction, curvature of the path, rotation:

$$\vec{F} \times \vec{v}.$$

Both are equally real forms of interaction. The dot and cross product—derived geometrically from projections and area elements—gain a direct, deep physical meaning. They describe two complementary aspects of momentum change underlying every force.

2 Dissipation and the Arrow of Time from Elementary Mechanics

A force always decomposes relative to the velocity:

$$\vec{F} = F_\parallel \hat{v} + \vec{F}_\perp,$$

where F_\parallel acts along the motion and \vec{F}_\perp acts perpendicular to it.

With only elementary mechanics we can see how this decomposition produces the distinction between *lossless* and *dissipative* systems, and thus the emergence of an arrow of time.

2.1 Ideal Lossless Systems

Consider first simplified systems without friction or drag.

Example 1: A block on a frictionless track. A block moves over a perfectly smooth track under a force along the path. The force is purely parallel:

$$\vec{F} = F_{\parallel} \hat{v}.$$

Work

$$W = \int \vec{F} \cdot d\vec{x}$$

goes entirely into changing kinetic energy $\frac{1}{2}mv^2$. No heat or dissipation occurs. Reversing the velocity runs the motion backward exactly. The system is *time-reversible* and lossless.

Example 2: A planet in orbit. A planet moves in a circular orbit under gravity toward the centre. The force is perpendicular to the velocity:

$$\vec{F} \cdot \vec{v} = 0.$$

No work is done; the speed remains constant. Again the motion is reversible.

In both cases: a purely parallel or purely orthogonal force in an ideal system produces no dissipation.

2.2 Real Systems Always Contain Constraints

In reality nothing moves in perfect freedom. Examples include:

- a sled on snow,
- a block on a table,
- a cart on rails,
- a pendulum in air.

These systems contain *constraints*: surfaces, pivots, connections. Constraints introduce *reaction forces* and often *friction*.

A portion of the force's effect is absorbed by the environment and emerges as heat, sound, or internal deformation. This is *dissipation*.

2.3 Revisiting the Pulled Sled

The decomposition is

$$F_{\parallel} = |\vec{F}| \cos \theta, \quad F_{\perp} = |\vec{F}| \sin \theta.$$

Parallel component. This produces work along the path.

Orthogonal component. This increases the normal force. The ground responds with:

$$F_{\perp} + F_{\text{normal}} = 0.$$

The sled's velocity perpendicular to motion does not change, but physically:

- pressure increases,
- friction increases,
- microscopic deformations occur,
- heat is generated.

Thus the orthogonal component is fully *dissipative* in a constrained system.

2.4 Free vs. Constrained Systems

- A *free* system with no constraints is lossless; the motion is reversible.
- A *constrained* system produces dissipation due to reaction forces and friction.

2.5 The Arrow of Time from Classical Mechanics

Many everyday processes—rolling friction, air drag, warm tires—end in heat. Reversing them would require reassembling microscopic motion into macroscopic order, which never occurs spontaneously.

Thus:

- Fundamental Newtonian motion is time-reversible.
- Dissipation arises from constraints and material properties.
- Dissipation produces an arrow of time.

3 Cosmic Dissipation and the Unification of GR and QM

The classical insights above have surprising reach. Applying the same parallel/orthogonal decomposition to the pillars of modern physics—quantum mechanics (QM) and general relativity (GR)—reveals that dissipation in the cosmos arises from constraints and couplings of subsystems. Each theory alone is lossless, but their interaction is not.

3.1 GR and QM Individually Are Non-Dissipative

The governing equations of both theories contain no arrow of time:

- The Schrödinger equation $i\hbar \partial_t \psi = H\psi$ describes *unitary*, reversible evolution.
- The Einstein equations $G_{\mu\nu} = 8\pi T_{\mu\nu}$ describe *geometric*, reversible evolution of spacetime.

Neither theory on its own produces dissipation.

3.2 In the Real Universe, Systems Interact with Constraints

Examples:

- quantum systems interacting with environments (decoherence),
- information lost to horizons (black holes, cosmological horizons),
- energy redistributed across degrees of freedom (thermalization),
- fluctuations amplified in the early universe by expansion.

Subsystem couplings produce dissipation—just as in the sled example.

3.3 Parallel and Orthogonal Interactions in Cosmology

- In GR, interactions primarily change *direction* (orthogonal components): curvature of trajectories.
- In QM, interactions primarily change *energy* (parallel components): amplitudes, phases, frequencies.

Constraints prevent these components from evolving independently. Coupling forces dissipation.

3.4 Why Any Unification Must Contain Dissipation

A theory unifying QM and GR must necessarily include a mechanism permitting dissipation. A fully lossless unification is impossible because the universe consists of coupled subsystems that impose constraints.

Existing unification attempts often fail because they combine two reversible systems to describe an inherently dissipative universe.

3.5 Conclusion

- QM and GR are individually reversible and lossless.
- The universe contains constrained, interacting subsystems.
- Constraints make dissipation unavoidable.
- A successful unification must incorporate dissipation.

For the complete mathematical implementation of this principle—incorporating dissipation into the Einstein-Hilbert action and deriving explicit field equations—see [Dissipative Quantum Hydrodynamics: A Symmetric Interaction Between QM and GR](#):

From Philosophy to Formalism The elementary insight that constraints produce dissipation translates directly into field theory. In the relativistic quantum-hydrodynamic framework, the quantum current J^μ represents the flow, while spacetime geometry provides the constraint. Their coupling via a dissipative term $\propto \|J\|^m$ in the action implements exactly the constraint-induced dissipation derived above from classical mechanics.

A Radiation, Momentum, and the Two Components of Photon Interaction

Radiation carries momentum:

$$\vec{p} = \frac{h\nu}{c} \hat{k}.$$

Any interaction of light with matter or fields can be expressed as a change of momentum:

$$\frac{d\vec{p}}{dt} = F_{\parallel} \hat{p} + \vec{F}_{\perp}.$$

A.1 Parallel Component: Energy Change of Light

A parallel momentum change modifies the photon frequency:

$$F_{\parallel} = \frac{d|\vec{p}|}{dt}.$$

This appears as:

- Doppler shifts,
- gravitational redshift,
- cosmological redshift,
- (inverse) Compton scattering.

A.2 Orthogonal Component: Deflection of Light

An orthogonal momentum change alters direction, not energy:

$$F_{\perp} = |\vec{F}_{\text{eff}} \times \hat{p}|.$$

This explains:

- gravitational lensing,
- refraction,
- directional change in Compton scattering.

The orthogonal component is the photon analogue of centripetal force.