Different Responses of Electromagnetic Waves to Prisms and Diffraction Gratings

Franc Rozman & UI

Abstract

Do all optical elements preserve the same physical information carried by an electromagnetic wave? Conventional spectroscopy assumes that, after proper calibration, different spectroscopic instruments provide equivalent wavelength information. The present work examines this assumption by distinguishing between two fundamentally different types of optical interaction: continuous structural deformation and structural interruption of a localized electromagnetic wave.

Prisms, diffraction gratings, and Fabry–Pérot interferometers are widely used for spectroscopic measurements and are generally expected to provide equivalent wavelength information after appropriate calibration. This paper examines whether this assumption necessarily follows from the physical interaction between an electromagnetic wave and different classes of optical elements.

A localized electromagnetic wave is considered as a stable field structure that preserves its identity during continuous propagation. Within this framework, continuously transmitting optical elements, such as prisms, deform the wave smoothly while preserving its structural continuity. Apertures and diffraction gratings, by contrast, spatially interrupt the electromagnetic structure and may require the transmitted field to reorganize into a new stable wave.

A new concept, the local passage frequency, is introduced to describe the temporal periodicity of the electromagnetic field at a moving optical element. It is proposed that, when structural continuity is lost, this local periodicity determines the frequency of the re-formed wave, whereas its spatial structure is established during the re-formation process.

The resulting model predicts that continuously transmitting and spatially interrupting optical elements need not preserve identical wavelength information. Existing astronomical observations are discussed only as motivation, since they were not designed to test this hypothesis directly. A dedicated comparative astronomical experiment using different classes of spectroscopic instruments is therefore proposed as a decisive experimental test.

The paper does not modify Maxwell's equations but proposes an experimentally testable physical hypothesis concerning the evolution of localized electromagnetic waves during their interaction with optical elements. The validity of the proposed model depends entirely on the outcome of the suggested experiment.

Part I – Physical Model

1. Introduction

Optical spectroscopy is one of the most accurate experimental methods for determining the properties of electromagnetic radiation. Prisms, diffraction gratings, and Fabry–Pérot interferometers are routinely used to measure wavelengths and to determine Doppler shifts produced by moving astronomical or laboratory sources. Within conventional electromagnetic theory, these instruments are regarded as different implementations of the same physical measurement. Although they employ different optical principles, they are expected to yield equivalent spectral information after proper calibration.

This equivalence is based on the assumption that every optical element interacts with the same electromagnetic wave and therefore measures the same physical quantity. Consequently, the measured spectral displacement is considered to be independent of the type of spectroscopic instrument and to depend only on the properties of the incident radiation.

The present work examines whether this assumption necessarily follows from the physical interaction between an electromagnetic wave and an optical element. In particular, we distinguish between two fundamentally different types of interaction. In a prism, the electromagnetic field propagates continuously through a homogeneous medium, where its geometry is smoothly deformed by the optical properties of the material before returning to its free-space form after leaving the prism. In contrast, a diffraction grating spatially interrupts the incident field by transmitting it only through a large number of narrow apertures separated by opaque regions. The question addressed in this paper is whether these two interactions preserve the same information about the incident electromagnetic wave.

To investigate this possibility, we consider a localized electromagnetic wave represented as a stable field structure. The detailed geometry of this structure is not essential for the present discussion; it merely provides a convenient physical model that allows continuous deformation and possible structural disruption to be treated within a common framework. The central hypothesis is that continuous transmission preserves the structural identity of the wave, whereas sufficiently strong spatial interruption may destroy that identity and require the formation of a new stable electromagnetic structure behind the optical element.

If such a distinction exists, a moving optical element acquires particular significance. A continuously transmitting prism would preserve the spatial identity of the incident wave despite its temporary deformation inside the material. A diffraction grating, however, could generate a newly organized electromagnetic wave whose properties are determined by the local temporal periodicity of the transmitted electromagnetic energy. This leads to experimentally testable predictions that differ from those of the conventional interpretation.

The purpose of this paper is therefore not to reinterpret existing spectroscopic observations, but to formulate a physically consistent model of these two interaction mechanisms and to propose a dedicated experiment capable of distinguishing between them. Several previously published optical and astronomical observations are discussed only as motivation for such an experiment rather than as conclusive evidence for the proposed model.

2. Localized Electromagnetic Wave as a Stable Field Structure

In conventional electrodynamics, electromagnetic radiation is commonly described as a propagating solution of Maxwell's equations. The present work adopts the same equations as the fundamental description of the electromagnetic field but considers a different class of solutions: localized field structures capable of preserving their identity while propagating through free space.

The detailed geometry of such a structure is not essential for the arguments developed in this paper. It is sufficient to assume that the electric field E and the magnetic field B form a spatially localized configuration satisfying Maxwell's equations,

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t},$$

$$\nabla \times \mathbf{B} = \mu\varepsilon \frac{\partial \mathbf{E}}{\partial t}.$$

Within the proposed model, the electric and magnetic fields continuously exchange energy while remaining coupled through these equations. The resulting electromagnetic structure propagates as a stable entity, carrying energy, momentum, and phase information.

The stability of the localized wave is assumed to originate from a dynamic equilibrium between the electric and magnetic components of the field. The electric field tends to increase the spatial extent of the structure, whereas the magnetic field provides an opposing tendency that confines the electromagnetic energy. The stable wave therefore represents a continuously maintained balance rather than a static object.

This dynamic equilibrium allows the wave to preserve its geometrical identity during continuous propagation through free space. When the wave enters a homogeneous optical medium, such as a prism, its geometry may become temporarily deformed because the propagation conditions change. Nevertheless, the electromagnetic structure remains spatially continuous throughout the medium and recovers its free-space geometry after leaving it.

The situation considered in this paper is fundamentally different when the wave encounters an aperture or a diffraction grating. In this case, significant portions of the electromagnetic structure are removed by the opaque regions, and only fragments of the original field continue beyond the optical element. The present work explores the hypothesis that sufficiently strong structural disruption may prevent the original localized wave from surviving as a continuous entity. Instead, the transmitted electromagnetic energy may reorganize into a new stable field structure.

The distinction between continuous deformation and structural re-formation constitutes the central physical assumption of the present model and forms the basis for the analysis developed in the following sections.

2.1 Structural Identity of the Wave

In the present model, a localized electromagnetic wave is regarded as possessing a structural identity. This identity is preserved as long as the spatial continuity of the coupled electric and magnetic fields remains intact. Continuous deformation of the field does not destroy this identity, whereas sufficiently strong spatial interruption may prevent the original configuration from surviving. The distinction between deformation and loss of structural identity plays a central role throughout this paper.

In the present work, structural identity is introduced as a phenomenological concept describing the continuous spatial connectivity of a localized electromagnetic wave. A rigorous mathematical definition is beyond the scope of the present paper and remains a subject for future investigation.

3. Structural Continuity of a Wave Passing Through a Prism

When an electromagnetic wave enters a homogeneous optical medium, the electromagnetic field must continuously adapt to the electromagnetic properties of that medium. In conventional electrodynamics, this adaptation is described by the material parameters permittivity and permeability, which determine the propagation velocity inside the medium. The present model adopts the same physical description but focuses on the evolution of the internal structure of a localized electromagnetic wave.

Unlike an aperture or a diffraction grating, a prism does not interrupt the spatial continuity of the electromagnetic field. Every part of the incident wave remains connected to its neighboring regions throughout the entire propagation process. The electric and magnetic fields therefore remain coupled everywhere inside the medium through Maxwell's equations,

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t},$$
$$\nabla \times \mathbf{B} = \mu\varepsilon \frac{\partial \mathbf{E}}{\partial t}.$$

The local propagation velocity inside the prism is

$$u = \frac{1}{\sqrt{\mu\varepsilon}},$$

which differs from the velocity in free space. Consequently, the spatial and temporal gradients of the electromagnetic fields continuously adjust to the optical properties of the material. The localized wave therefore changes its geometry while propagating through the prism.

Within the proposed model, however, this geometrical modification does not represent the formation of a new electromagnetic wave. The electric and magnetic fields remain continuously connected throughout the entire structure, preserving what we refer to as the structural identity of the wave. The wave is temporarily deformed but never spatially fragmented.

This distinction is important. Continuous deformation changes the local distribution of electric and magnetic energy without destroying the electromagnetic structure itself. The wave entering the prism and the wave leaving it are therefore regarded as the same physical entity. The prism modifies the geometry required for propagation inside the medium but does not erase the spatial organization established when the wave was originally formed.

The proposed interpretation therefore attributes a form of spatial memory to the localized electromagnetic wave. The geometrical configuration established before entering the prism is preserved throughout the continuous deformation inside the medium and is recovered after the wave returns to free space. In this sense, the prism behaves as a continuously deforming optical element rather than as a generator of a new electromagnetic wave.

The distinction between continuous deformation and structural preservation forms the basis for the comparison developed in the following sections. Whereas a prism continuously transforms the existing electromagnetic structure, an aperture or diffraction grating may interrupt that continuity and require the formation of a new stable wave beyond the optical element.

Throughout propagation inside a prism, the localized electromagnetic structure remains topologically continuous. Although its dimensions, local field gradients, and energy distribution evolve continuously, no part of the structure becomes disconnected from the rest. The prism therefore preserves the topological continuity of the electromagnetic wave.

4. Dynamic Deformation of the Wave at the Prism Boundaries

The transition between free space and an optical medium is not instantaneous for a localized electromagnetic wave. Because the wave possesses a finite spatial extent, different parts of the structure encounter the material boundary at different times. During this interval, the electromagnetic wave simultaneously occupies two propagation environments characterized by different electromagnetic parameters.

As the front part of the wave enters the prism, its local propagation velocity decreases according to the electromagnetic properties of the medium, while the rear part of the wave continues to propagate in free space. This temporary difference in propagation velocity produces a continuous longitudinal deformation of the entire electromagnetic structure.

The deformation is governed by the continuous coupling of the electric and magnetic fields through Maxwell's equations. Since the propagation velocity inside the prism is

$$u = \frac{1}{\sqrt{\mu\varepsilon}},$$

the spatial and temporal derivatives of the fields continuously adapt to the changing medium. For a representative field component,

$$\frac{\partial B_y}{\partial z} = -\mu\varepsilon\frac{\partial E_x}{\partial t},$$

the change of material parameters modifies both the spatial and temporal field gradients while preserving the electromagnetic coupling.

During the entrance process, the front part of the localized wave becomes longitudinally compressed because it propagates more slowly than the rear part. The transverse dimensions simultaneously adjust in order to preserve the dynamic equilibrium between the electric and magnetic fields. The wave therefore evolves continuously from its free-space geometry toward a new temporary equilibrium corresponding to propagation inside the prism.

Importantly, this deformation is entirely continuous. At every instant, neighboring parts of the electromagnetic structure remain connected through the coupled electric and magnetic fields. No spatial interruption occurs, and the wave therefore preserves its structural identity throughout the entire transition.

After the entire wave has entered the prism, the deformation process is completed. The localized electromagnetic structure then propagates with a stationary geometry appropriate for the optical properties of the medium.

An analogous but opposite process occurs at the exit surface. As the front part of the wave returns to free space, it accelerates to the free-space propagation velocity while the rear part is still propagating inside the prism. The longitudinal compression is gradually released, and the wave continuously returns to its original free-space geometry. No new electromagnetic wave is created during either transition; only the geometry of the existing wave evolves continuously in response to the changing propagation conditions.

Within the proposed model, the prism therefore acts as a continuously deforming optical system. It modifies the instantaneous geometry of the localized electromagnetic structure without destroying its topological continuity or requiring the formation of a new wave.

5. Structural Disruption at an Aperture and a Diffraction Grating

Unlike a prism, an aperture or a diffraction grating does not provide a continuous propagation path for the entire electromagnetic wave. Opaque regions physically prevent substantial parts of the incident field from propagating further, while only the electromagnetic field passing through the open regions continues beyond the optical element.

For an incident field

$$\mathbf{E}_{\text{in}}(\mathbf{r},t), \qquad \mathbf{B}_{\text{in}}(\mathbf{r},t),$$

the transmitted field immediately behind the aperture may be represented as

$$\mathbf{E}_{\text{tr}} = A(x,y)\,\mathbf{E}_{\text{in}},$$

$$\mathbf{B}_{\text{tr}} = A(x,y)\,\mathbf{B}_{\text{in}},$$

where A(x,y) is the transmission function of the aperture or diffraction grating.

Unlike continuous optical media, the transmission function contains abrupt spatial discontinuities,

$$\nabla A(x,y) \neq 0,$$

at every edge separating transparent and opaque regions. Consequently, the transmitted field develops additional spatial gradients,

$$\nabla(A\mathbf{E}) = A\nabla\mathbf{E} + \mathbf{E}\nabla A,$$

and similarly for the magnetic field.

These additional terms do not merely deform the electromagnetic structure continuously. Instead, they represent the spatial removal of parts of the incident field. Immediately behind the aperture, the transmitted electromagnetic field therefore no longer possesses the complete spatial organization of the incident localized wave.

Within the present model, this distinction is fundamental. Continuous deformation preserves the structural identity of the electromagnetic wave, whereas spatial truncation may destroy that identity. The electromagnetic field immediately behind the aperture is therefore regarded as a strongly deformed field configuration rather than as a complete continuation of the original localized wave.

Nevertheless, the transmitted field still contains electromagnetic energy, temporal periodicity, and a well-defined local energy flow. The electric and magnetic fields continue to satisfy Maxwell's equations locally, but their spatial organization differs substantially from that of the incident wave.

The present work proposes that, if the structural disruption exceeds a critical level, the remaining electromagnetic field cannot continue propagating as the original localized wave. Instead, the transmitted energy undergoes a process of self-organization, leading to the formation of a new stable electromagnetic structure compatible with the local electromagnetic conditions beyond the aperture.

A diffraction grating represents a periodic realization of the same physical process. Every transparent slit transmits only part of the incident electromagnetic structure, while the opaque regions interrupt its spatial continuity. The electromagnetic field behind the grating therefore consists of many locally transmitted field fragments. According to the proposed model, these fragments collectively reorganize into new stable localized waves whose propagation directions are determined by the resulting distribution of electromagnetic energy flow.

The distinction introduced here is therefore not between transmission and diffraction, but between two fundamentally different mechanisms of wave evolution. A prism continuously deforms an existing electromagnetic structure while preserving its identity, whereas an aperture or diffraction grating may terminate the original structure and initiate the formation of a new one.

The original localized wave carries geometrical information established during its formation. Continuous optical elements preserve this geometrical memory throughout propagation.

Spatial interruption removes part of that information. Consequently, the newly formed wave behind an aperture cannot be regarded simply as a continuation of the incident wave but must establish a new stable electromagnetic configuration.

Part II – Consequences

6. Local Passage Frequency at a Moving Optical Element

The previous sections considered the interaction of a localized electromagnetic wave with stationary optical elements. We now extend the analysis to the case in which the optical element moves with a constant velocity relative to the light source and the observer. Throughout this paper, a single laboratory reference frame is used: both the source and the observer remain stationary, while the optical element moves along the direction of wave propagation with velocity v.

The incident electromagnetic wave is described by

$$E_x(z,t) = E_0 \cos(k_0 z - \omega_0 t),$$
$$B_y(z,t) = B_0 \cos(k_0 z - \omega_0 t),$$

where

$$k_0 = \frac{2\pi}{\lambda_0}, \qquad \omega_0 = 2\pi f_0.$$

The moving optical element occupies the position

$$z_p(t) = z_0 + vt.$$

The phase of the incident wave sampled at the moving optical element is therefore

$$\phi_p(t) = k_0 z_p(t) - \omega_0 t = k_0 z_0 - (\omega_0 - k_0 v)t.$$

The temporal rate at which successive field cycles pass through the moving optical element is obtained directly from the phase derivative,

$$\boxed{\omega_p = \omega_0 - k_0 v.}$$

Using the free-space relation

$$k_0 = \frac{\omega_0}{c},$$

one obtains

$$\boxed{f_p = f_0 \left(1 - \frac{v}{c}\right).}$$

The quantity f_p represents the **local passage frequency** of the electromagnetic field at the moving optical element. It is determined entirely by the relative motion between the incident wave and the optical element and exists independently of the subsequent optical interaction.

An important distinction must be emphasized. The local passage frequency is not introduced here as the frequency of a newly generated electromagnetic wave. It merely describes the temporal periodicity of the electromagnetic field experienced at the moving optical element. Whether this local periodicity is preserved, modified, or transferred to a newly formed wave depends on the physical interaction taking place at the optical element and is examined in the following section.

Within the proposed framework, the local passage frequency is the only temporal characteristic directly available at the location where the electromagnetic structure interacts with the optical element. If the original wave remains structurally continuous, this local periodicity simply accompanies the continuous deformation of the existing wave. If, however, the structural identity of the incident wave is lost, the local passage frequency becomes the only remaining temporal reference from which a new localized electromagnetic structure can emerge.

The concept of local passage frequency therefore provides the physical link between the continuous deformation discussed for prisms and the possible re-formation of localized electromagnetic waves behind apertures and diffraction gratings.

7. Re-Formation of the Electromagnetic Wave Behind the Grating

The previous sections introduced two fundamentally different types of interaction between a localized electromagnetic wave and an optical element. A prism continuously deforms the existing electromagnetic structure while preserving its structural identity. An aperture or diffraction grating, however, may interrupt the spatial continuity of that structure and leave behind only a strongly deformed electromagnetic field.

Within the proposed model, this distinction has an important physical consequence. If the original localized wave no longer survives as a continuous electromagnetic structure, the transmitted field cannot simply be regarded as the same wave continuing its propagation. Instead, the remaining electromagnetic energy is assumed to reorganize into a new stable localized electromagnetic structure.

The starting point of this re-formation process is the transmitted electromagnetic field immediately behind the optical element. Although its spatial organization differs substantially from that of the incident wave, it still possesses three fundamental physical properties:

- electromagnetic energy,
- a local temporal periodicity,
- a local distribution of electromagnetic energy flow.

The previous section introduced the local passage frequency,

$$f_p,$$

which characterizes the temporal rate at which successive electromagnetic field cycles pass through the moving optical element. Within the present model, this frequency is proposed to provide the only local temporal reference available during the formation of a new electromagnetic wave.

Accordingly, we propose the following postulate:

$$\boxed{f_{\text{new}} = f_p.}$$

The newly formed localized wave therefore inherits the local temporal periodicity of the electromagnetic field existing at the optical element.

A second assumption concerns the propagation of the newly established wave. Once the new electromagnetic structure has been formed, it propagates as an ordinary localized electromagnetic wave in free space. Consequently, its propagation velocity is

$$u_{\text{new}} = c.$$

Its wavelength is therefore determined by the temporal periodicity inherited during its formation,

$$\boxed{\lambda_{\text{new}} = \frac{c}{f_p}.}$$

Substituting the expression obtained for the local passage frequency,

$$f_p = f_0 \left(1 - \frac{v}{c}\right),$$

gives

$$\boxed{\lambda_{\text{new}} = \frac{\lambda_0}{1 - v/c}.}$$

This result differs fundamentally from the situation discussed for continuous optical elements. A prism continuously preserves the structural identity of the incident wave and therefore also preserves its original spatial organization. A diffraction grating, in contrast, is assumed to initiate the formation of a new localized wave whose wavelength is determined by the local temporal conditions at the point of formation.

The proposed mechanism therefore distinguishes between two different physical processes. Continuous optical elements preserve the structural continuity of an existing electromagnetic wave. Spatially interrupting elements preserve the transmitted electromagnetic energy but may generate a new stable wave characterized by the local temporal periodicity existing at the optical element.

The present work does not claim that this mechanism follows directly from Maxwell's equations alone. Rather, it is introduced as an additional physical hypothesis that extends the description of localized electromagnetic waves beyond continuous field propagation. Its validity therefore depends entirely on experimental verification.

The re-formation of the localized electromagnetic wave is not assumed to occur instantaneously at the aperture. Immediately behind the optical element the electromagnetic field is expected to remain strongly deformed. The proposed self-organization process requires a finite propagation distance before a new stable localized structure is fully established.

8. Direction of the Re-Formed Waves

The previous section proposed that a diffraction grating may initiate the formation of new localized electromagnetic waves. The remaining question concerns the directions in which these re-formed waves propagate after leaving the optical element.

Immediately behind the grating, the transmitted electromagnetic field is highly non-uniform. Each transparent slit transmits only a portion of the incident field, while the opaque regions interrupt its spatial continuity. The resulting electromagnetic field therefore consists of many overlapping field fragments originating from different apertures.

Although the original localized wave is assumed to lose its structural identity, Maxwell's equations continue to govern the evolution of the transmitted electromagnetic field. The electric and magnetic fields combine to produce a local electromagnetic energy flow described by the Poynting vector,

$$\mathbf{S} = \mathbf{E} \times \mathbf{H}.$$

Immediately behind the grating, the direction and magnitude of the instantaneous Poynting vector vary strongly throughout space because of interference between the transmitted field fragments. The electromagnetic energy therefore does not propagate uniformly but forms a spatial distribution containing regions of enhanced and reduced energy flow.

Within the proposed model, the re-formation of localized electromagnetic waves is assumed to occur preferentially in those regions where the time-averaged electromagnetic energy flow is locally stable and sufficiently intense to support a new dynamically balanced electromagnetic structure.

The relevant quantity is therefore the time-averaged Poynting vector,

$$\overline{\mathbf{S}}(\mathbf{r}) = \frac{1}{T}\int_0^T \mathbf{E}(\mathbf{r},t) \times \mathbf{H}(\mathbf{r},t)\,dt.$$

Rather than forming uniformly throughout space, the new localized waves are proposed to emerge along the directions corresponding to local maxima of

$$|\overline{\mathbf{S}}|.$$

For a periodic diffraction grating, these maxima coincide with the well-known diffraction orders determined by the geometrical relation

$$d \sin \theta_m = m\lambda.$$

Within the present model, however, the wavelength entering this relation is not necessarily the wavelength of the incident wave. Instead, it is the wavelength of the re-formed localized electromagnetic wave,

$$\boxed{d \sin \theta_m = m\lambda_{\text{new}}.}$$

The diffraction pattern is therefore interpreted not merely as the interference of an existing wave but as the spatial distribution of the electromagnetic energy flow from which new stable localized waves emerge.

The proposed interpretation preserves the geometrical structure of diffraction while assigning a different physical meaning to its origin. Diffraction maxima are regarded as preferred directions for the formation of stable localized electromagnetic waves rather than simply as regions of constructive interference.

Within the proposed model, the diffraction maxima are interpreted as spatial regions where the transmitted electromagnetic field can most efficiently reorganize into stable localized electromagnetic waves. The observed propagation directions therefore correspond to energetically preferred solutions of the electromagnetic field rather than being viewed solely as the result of constructive interference.

9. Different Predictions for a Prism and a Diffraction Grating

The preceding sections developed two fundamentally different mechanisms describing the interaction of a localized electromagnetic wave with optical elements. Continuous optical elements, represented here by a prism, preserve the structural identity of the incident wave while continuously deforming its geometry. Spatially interrupting elements, represented by apertures and diffraction gratings, may terminate the original electromagnetic structure and initiate the formation of a new localized wave.

Although both mechanisms transmit electromagnetic energy, they do not necessarily preserve the same physical properties of the incident wave.

For a prism, the electromagnetic structure remains continuous throughout the interaction. The wave entering and leaving the prism is therefore regarded as the same localized electromagnetic structure. Within the proposed model, its original spatial organization is preserved despite the temporary deformation inside the optical medium.

Accordingly,

$$\boxed{\lambda_{\text{prism,out}} = \lambda_0.}$$

The diffraction grating represents a fundamentally different situation. Because the original electromagnetic structure is assumed to lose its structural continuity, the transmitted field reorganizes into a new localized wave. According to the hypothesis proposed in this paper, the new wave inherits the local passage frequency existing at the moving optical element,

$$f_{\text{new}} = f_p,$$

while propagating as an ordinary localized electromagnetic wave after its formation.

Its wavelength is therefore

$$\boxed{\lambda_{\text{grating,out}} = \frac{c}{f_p}.}$$

Substituting

$$f_p = f_0 \left(1 - \frac{v}{c}\right),$$

gives

$$\lambda_{\text{grating,out}} = \frac{\lambda_0}{1 - v/c}.$$

For velocities much smaller than the speed of light,

$$\lambda_{\text{grating,out}} \approx \lambda_0 \left(1 + \frac{v}{c}\right).$$

The proposed model therefore predicts that a moving prism and a moving diffraction grating do not necessarily preserve identical output wavelengths.

The difference predicted by the model is

$$\Delta\lambda = \lambda_{\text{grating,out}} - \lambda_{\text{prism,out}} \approx \lambda_0 \frac{v}{c},$$

for

$$|v| \ll c.$$

This prediction differs qualitatively from the conventional interpretation, in which all properly calibrated spectroscopic instruments are expected to yield equivalent wavelength shifts for the same incident radiation.

The proposed distinction does not arise from different optical dispersion relations or different calibration procedures. Instead, it originates from the different physical mechanisms by which the optical elements interact with the localized electromagnetic wave. Continuous optical elements preserve the structural continuity of the wave, whereas spatially interrupting elements are proposed to generate a new electromagnetic structure whose wavelength is determined during its formation.

The significance of this prediction is that it can be examined experimentally without requiring modifications of Maxwell's equations. A direct comparison between a continuously transmitting optical element and a spatially interrupting optical element provides a straightforward experimental test of the proposed model

The distinction proposed here is not restricted to prisms and diffraction gratings. It applies more generally to two classes of optical elements. Continuously transmitting optical elements preserve the structural continuity of the incident electromagnetic wave, whereas spatially interrupting optical elements may require the formation of a new localized wave. Prisms and diffraction gratings are examined in the present work because they provide the simplest experimental realization of these two fundamentally different interaction mechanisms.

Part III – Experimental Verification

10. Indications from Existing Optical and Astronomical Measurements

The model proposed in this paper leads to a simple experimental prediction: continuously transmitting optical elements and spatially interrupting optical elements need not preserve identical properties of an incident localized electromagnetic wave. If correct, this distinction should become observable when equivalent measurements are performed using different classes of spectroscopic instruments.

Although no dedicated experiment designed specifically for this purpose appears to have been reported, several published optical and astronomical observations provide motivation for such an investigation.

Measurements of rapidly moving solar structures have been performed using both

Fabry–Pérot interferometers and diffraction-grating spectrometers. These instruments often differ in optical design, field of view, spectral bandwidth, calibration procedures, and image reconstruction techniques. Consequently, published velocity measurements cannot be regarded as a direct comparison between the two physical interaction mechanisms discussed in the present work.

Similar considerations apply to observations of comet Hale–Bopp and other astronomical objects obtained with Fabry–Pérot systems and conventional grating spectrometers. These observations were designed to investigate astrophysical phenomena rather than to compare different classes of optical elements under controlled laboratory conditions. Any apparent differences between the reported results may therefore arise from numerous instrumental or observational factors unrelated to the mechanism proposed here.

For this reason, the present work does not interpret existing observations as experimental confirmation of the proposed model. Instead, these observations are viewed only as indications that the interaction between localized electromagnetic waves and different spectroscopic instruments deserves further systematic investigation.

The central prediction developed in this paper requires a dedicated experiment in which the same monochromatic radiation is analyzed simultaneously by a continuously transmitting optical element and by a spatially interrupting optical element under otherwise identical experimental conditions. Only such an experiment can distinguish between instrumental effects and genuine differences arising from the proposed mechanism of wave preservation and wave re-formation.

The existing astronomical observations therefore serve primarily as motivation for a controlled laboratory experiment rather than as evidence supporting the present model

The diversity of these observations demonstrates that the proposed hypothesis cannot be resolved by reinterpreting existing measurements alone. Because the available observations were obtained for different scientific purposes and with different optical systems, only a dedicated comparative experiment can provide a decisive test.

11. Proposed Dedicated Astronomical Experiment

The hypothesis developed in this paper can be tested most effectively by means of astronomical spectroscopy. Unlike laboratory experiments, astronomical observations routinely involve sources with radial velocities ranging from a few kilometres per second to several thousand kilometres per second, providing wavelength shifts that are readily measurable with modern spectroscopic instrumentation.

Rather than constructing new experimental equipment, the proposed test requires a dedicated comparison between two fundamentally different classes of spectroscopic instruments:

- a continuously transmitting optical system, represented by a prism or a Fabry–Pérot interferometer,
- a spatially interrupting optical system, represented by a diffraction grating.

The essential requirement is that both instruments observe the same spectral line from the same astronomical source under identical observing conditions.

The proposed model predicts that the two classes of optical systems need not preserve identical properties of the incident localized electromagnetic wave. Consequently, the measured wavelength displacement may differ systematically between the two measurements.

Existing astronomical observations cannot provide a decisive answer because they were not designed for this purpose. Differences in observing time, instrument configuration, spectral bandwidth, spatial resolution, calibration procedures, atmospheric conditions, and scientific objectives prevent a direct comparison between published data obtained using different instruments.

A dedicated observing program should therefore be designed in which the same astronomical object is observed nearly simultaneously with both classes of spectroscopic instruments. The comparison should use identical spectral lines, identical calibration procedures, and as nearly as possible identical spatial sampling of the observed emitting region.

Suitable targets include rapidly moving solar structures, cometary emissions, planetary nebulae, and other astronomical objects exhibiting well-defined spectral lines with measurable Doppler shifts. The choice of target is less important than the direct comparison between the two optical principles.

If both instrument classes yield identical wavelength displacements within experimental uncertainty, the hypothesis proposed in this paper is not supported. Conversely, a reproducible systematic difference between continuously transmitting and spatially interrupting optical systems would provide evidence that the two interaction mechanisms preserve different physical properties of the incident electromagnetic wave.

For completeness, a laboratory experiment employing a moving optical element may also be conceived. However, the velocities required to produce measurable wavelength differences make such an experiment considerably more demanding than the corresponding astronomical observations. Consequently, astronomical spectroscopy presently appears to provide the most practical and sensitive experimental test of the proposed model

The purpose of the proposed experiment is not to measure larger Doppler shifts or to improve spectroscopic precision. Its purpose is to determine whether different optical principles preserve the same physical property of the incident electromagnetic wave.

12. Falsifiability and Limitations

The model presented in this paper is intended as a physical hypothesis describing the interaction between localized electromagnetic waves and different classes of optical elements. It does not claim to replace Maxwell's equations, nor does it attempt to reinterpret all known spectroscopic observations. Its primary objective is to propose a specific physical mechanism leading to experimentally distinguishable predictions.

The central hypothesis is that continuously transmitting optical elements preserve the structural identity of a localized electromagnetic wave, whereas sufficiently strong spatial interruption may require the formation of a new stable electromagnetic structure. This distinction leads to the prediction that continuously transmitting and spatially interrupting optical systems need not preserve identical properties of the incident wave.

Several assumptions introduced in the present work extend beyond conventional electromagnetic theory. In particular, the concept of structural identity, the proposed re-formation of localized electromagnetic waves, and the role assigned to the local passage frequency represent additional physical hypotheses. These concepts are introduced to provide a self-consistent description of localized wave propagation, but they are not derived directly from Maxwell's equations alone.

The present model also assumes that localized electromagnetic waves exist as dynamically stable field structures capable of maintaining their identity during continuous propagation. Although this assumption is compatible with the physical interpretation developed throughout the paper, its detailed mathematical description remains the subject of future work.

Existing astronomical observations cannot be regarded as conclusive evidence for or against the proposed mechanism. The available measurements were obtained using different instruments, observing strategies, calibration procedures, spatial resolutions, and scientific objectives. Consequently, they cannot isolate the specific physical effect considered here.

For this reason, the proposed model is intentionally formulated in a falsifiable form. A dedicated comparison between continuously transmitting and spatially interrupting optical systems provides a direct experimental test.

If both classes of optical elements produce identical wavelength displacements within experimental uncertainty under identical observing conditions, the central hypothesis developed in this paper is not supported.

Conversely, a reproducible systematic difference between the two classes of optical elements would demonstrate that the interaction between electromagnetic waves and optical systems depends on the physical mechanism of transmission and not solely on the spectral properties of the incident radiation. Such a result would motivate further theoretical investigation but would not, by itself, establish the complete validity of the present model.

The purpose of this paper is therefore not to present a final theory of localized electromagnetic waves, but to formulate a physically consistent hypothesis that can be subjected to direct experimental verification.

The proposed model preserves the local validity of Maxwell's equations throughout the analysis. The departure from the conventional interpretation concerns not the local field equations themselves, but the physical interpretation of localized electromagnetic structures interacting with different classes of optical elements. The proposed distinction between continuous structural deformation and structural re-formation therefore represents an additional physical hypothesis rather than a modification of the fundamental equations of classical electromagnetism.

13. Discussion

The model presented in this paper proposes a distinction between two fundamentally different classes of optical interactions. Continuous optical elements are assumed to preserve the structural identity of a localized electromagnetic wave while continuously adapting its geometry to the propagation medium. Spatially interrupting optical elements, in contrast, may terminate the original electromagnetic structure and initiate the formation of a new stable wave beyond the optical element.

This distinction does not arise from modifications of Maxwell's equations. Throughout the present work, the local electromagnetic field remains governed by the conventional Maxwell equations. The proposed difference concerns the physical evolution of localized electromagnetic structures when their spatial continuity is either preserved or interrupted.

If future experiments confirm that continuously transmitting and spatially interrupting optical systems produce identical wavelength measurements under identical conditions, the central hypothesis developed in this paper must be rejected or substantially revised. Such a result would indicate that the structural continuity of the incident wave plays no measurable role in spectroscopic observations.

Conversely, if a reproducible difference between the two classes of optical elements is observed, the consequences would extend beyond the interpretation of individual spectroscopic instruments. It would suggest that the physical interaction between an electromagnetic wave and an optical element depends not only on the local electromagnetic fields but also on whether the spatial integrity of the wave is preserved throughout the interaction.

Within the proposed framework, diffraction would acquire a different physical interpretation. Rather than representing only the propagation of an already existing wave, diffraction would also involve the re-formation of localized electromagnetic structures from the transmitted electromagnetic field. The observed diffraction pattern would then describe not only the distribution of electromagnetic intensity but also the preferred directions in which stable wave structures emerge.

The proposed distinction also provides a possible physical classification of optical elements. Continuous optical elements—including prisms, dielectric interfaces, lenses, mirrors, and, in principle, Fabry–Pérot interferometers—would belong to one category because they preserve the structural continuity of the electromagnetic wave. Apertures and diffraction gratings would belong to another category because they spatially interrupt that continuity. Whether this classification is physically meaningful remains an experimental question.

The principal objective of the present work is therefore not to establish a new theoretical framework for all electromagnetic phenomena. Instead, it is to identify a specific physical hypothesis that can be examined experimentally. The proposed distinction between continuous structural deformation and structural re-formation has value only insofar as it leads to experimentally verifiable predictions.

For this reason, the dedicated astronomical comparison proposed in this paper represents the most important element of the investigation. Existing astronomical observations provide useful motivation, but only measurements specifically designed to compare continuously transmitting and spatially interrupting optical systems under identical observational conditions can determine whether the proposed mechanism has physical significance.

Although developed here in the context of prisms and diffraction gratings, the proposed concept may have broader implications for the physical interpretation of localized electromagnetic waves. If structural continuity proves to be an experimentally relevant property, it may provide a useful framework for analysing electromagnetic interactions in other optical systems as well. Whether this concept has wider applicability remains an open question and should be addressed only after the dedicated experimental test proposed in this paper has been completed.

14. Conclusions

This paper has examined the interaction between localized electromagnetic waves and two fundamentally different classes of optical elements: continuously transmitting optical systems and spatially interrupting optical systems.

Within the proposed model, a prism continuously deforms the geometry of the electromagnetic wave while preserving its structural identity. The electric and magnetic fields remain continuously connected throughout the interaction, allowing the wave to recover its free-space geometry after leaving the optical medium.

An aperture or a diffraction grating is proposed to represent a fundamentally different type of interaction. By spatially interrupting the electromagnetic structure, these optical elements may prevent the original localized wave from continuing as a single coherent entity. The transmitted electromagnetic field is therefore hypothesized to reorganize into a new stable localized wave.

To describe this process, the concept of **local passage frequency** was introduced. The proposed model assumes that the newly re-formed wave inherits the temporal periodicity of the electromagnetic field at the moving optical element while establishing a new spatial structure during its formation.

From these assumptions follows a clear experimental prediction: continuously transmitting and spatially interrupting optical elements need not preserve identical wavelength information when interacting with a moving electromagnetic wave. This prediction differs from the conventional expectation that equivalent spectroscopic instruments yield identical wavelength measurements after proper calibration.

The principal contribution of the present work is not the introduction of a new mathematical formulation of electromagnetism but the proposal of a physically testable distinction between two different mechanisms of wave evolution: **continuous structural deformation** and **structural re-formation**.

Because existing observations were not designed to test this hypothesis directly, the paper proposes a dedicated astronomical comparison between spectroscopic instruments representing these two classes of optical interaction. Such an experiment offers a direct opportunity to confirm or reject the proposed mechanism.

Regardless of the experimental outcome, the distinction formulated here provides a well-defined physical hypothesis whose validity can be decided empirically. If confirmed, it would motivate a broader investigation of structural continuity as a physical property of localized electromagnetic waves. If not confirmed, the hypothesis can be rejected without affecting the established local validity of Maxwell's equations

The central question addressed in this work is therefore remarkably simple: does every optical element preserve the same physical information carried by an electromagnetic wave? The answer to this question does not depend on philosophical interpretation but on experimental observation. The proposed comparison between continuously transmitting and spatially interrupting optical systems is intended to provide that answer.