

## Doppler Tests Limitations

**alan:** 3.5. Tests of Second-order Doppler Effects Ives and Stilwell (1938, 1941) performed a second-order Doppler experiment that was intended to be a demonstration of time dilation. They measured the longitudinal Doppler effect in red- and blue-shifted H  $\alpha$  line emission from hydrogen atoms moving at speeds up to  $v = 0.01c$ , simultaneously in the approaching and receding directions (essentially the same effect in neon was investigated by Kaivola et al. 1985, and McGowan et al. 1993). But these results and their interpretation are also problematic: While it is true that the observed red- and blue-shift are slightly asymmetrical in the relativistic case, they are also asymmetrical in the classical Doppler effect for moving sources, only this second-order effect is actually twice as large in the classical case than it is in the relativistic case, so detection would be easier in the classical case. The existence of an asymmetry does not necessarily mean that the observed effect was relativistic. Kundig (1963) and Hasselkemp, Mondry and Scharmann (1979) claimed to have directly observed the relativistic transverse Doppler effect, however, the results and interpretation of both works are problematic. Kundig's Mossbauer rotor experiment was recently re-analyzed by Kholmetskii et al. (2008). Hasselkemp et al. did not initially detect a transverse Doppler effect, but claimed a detection after correcting for a possible misalignment. Furthermore, it is a little-known fact that a classical transverse Doppler effect is observed in acoustics, which would suggest an analog in the classical wave theory light, although no such effect is described in textbooks.

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### Assistant:

The tests of second-order Doppler effects mentioned in the text are experiments that aimed to detect relativistic effects predicted by special relativity. The first experiment performed by Ives and Stilwell in 1938 and 1941 measured the longitudinal Doppler effect in red- and blue-shifted H  $\alpha$  line emission from hydrogen atoms moving at speeds up to  $v = 0.01c$ . The experiment aimed to demonstrate time dilation, but the results and interpretation are problematic. While the observed red- and blue-shift are slightly asymmetrical in the relativistic case, they are also asymmetrical in the classical Doppler effect for moving sources. In fact, the second-order effect in the classical case is twice as large as it is in the relativistic case, making detection easier in the classical case. Therefore, the existence of an asymmetry does not necessarily mean that the observed effect was relativistic.

Kundig's experiment in 1963 and Hasselkemp, Mondry, and Scharmann's experiment in 1979 claimed to have directly observed the relativistic transverse Doppler effect. However, the results and interpretation of both works are problematic. Kundig's Mossbauer rotor experiment was recently re-analyzed by Kholmetskii et al. (2008), and Hasselkemp et al. initially did not detect a transverse Doppler effect but claimed a detection after correcting for a possible misalignment.

It is also worth noting that a classical transverse Doppler effect is observed in acoustics, suggesting an analog in the classical wave theory of light, although no such effect is described in textbooks. Overall, these experiments illustrate the difficulties in detecting and interpreting relativistic effects and the importance of carefully designing and analyzing experiments to differentiate between classical and relativistic effects.

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**alan:** In this paper it states: “Furthermore, it is a little-known fact that a classical transverse Doppler effect is observed in acoustics, which would suggest an analog in the classical wave theory of light, although no such effect is described in textbooks.”

Is this suggesting that the wave needs a medium to propagate through to produce the Doppler effect?

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**Assistant:**

No, the statement in the paper is not suggesting that the wave needs a medium to propagate through to produce the Doppler effect. The classical transverse Doppler effect observed in acoustics refers to the change in frequency of sound waves emitted by a moving source and detected by a stationary observer perpendicular to the direction of motion. This effect is analogous to the relativistic transverse Doppler effect in which the frequency of light waves emitted by a moving source is observed to change when measured by a stationary observer perpendicular to the direction of motion. The paper suggests that this classical effect in acoustics could have an analog in the classical wave theory of light, but it is not described in textbooks. However, it is important to note that the Doppler effect in electromagnetic waves, including light, does not require a medium for propagation and can occur in vacuum.

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**alan:** What is the classical wave theory of light

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**Assistant:**

The classical wave theory of light, also known as wave optics or classical optics, is a theory that describes light as a wave phenomenon that can be characterized by its wavelength, frequency, amplitude, and phase. According to this theory, light waves can undergo reflection, refraction, diffraction, interference, and polarization, and can be described by mathematical equations such as Maxwell’s equations of electromagnetism. The classical wave theory of light was developed in the 17th and 18th centuries and was widely accepted until the early 20th century when the particle nature of light was discovered and the wave-particle duality became a fundamental concept in quantum mechanics. Despite

the success of quantum mechanics, the classical wave theory of light is still widely used in many areas of optics, including the design of optical instruments and the analysis of light-matter interactions.

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**alan:** didn't maxwell's equation account for propagation speed through a medium? presupposing a medium

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**Assistant:**

Yes, you are correct. Maxwell's equations do include terms that account for the propagation of electromagnetic waves through a medium, such as a material or a vacuum. In fact, Maxwell's equations were originally developed to describe the behavior of electromagnetic waves in a hypothetical medium called the "luminiferous ether," which was believed to fill all of space and serve as the medium for the propagation of light. However, experiments such as the Michelson-Morley experiment in the late 19th century failed to detect the motion of the Earth through the luminiferous ether, leading to the eventual abandonment of the idea of a luminiferous ether and the realization that electromagnetic waves can propagate through vacuum. Despite this, Maxwell's equations still play a fundamental role in the description of electromagnetic waves and their behavior, both in a vacuum and in various materials.

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**alan:** So understanding that and going back to this part of the paper: "Furthermore, it is a little-known fact that a classical transverse Doppler effect is observed in acoustics, which would suggest an analog in the classical wave theory of light, although no such effect is described in textbooks."

Is he suggesting that there must be a medium

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**Assistant:**

No, the statement in the paper is not suggesting that there must be a medium for the classical transverse Doppler effect to occur in wave theory. The classical transverse Doppler effect observed in acoustics is caused by the motion of the source of the sound wave relative to the observer, and it is a purely wave phenomenon that can occur in a medium such as air or water. The paper suggests that this classical effect in acoustics could have an analog in the classical wave theory of light, but it is not described in textbooks. However, the Doppler effect in electromagnetic waves, including light, does not require a medium for propagation and can occur in vacuum. Therefore, the existence of a classical transverse Doppler effect in acoustics does not imply the existence of a similar effect in the classical wave theory of light that would require a medium.

**alan:** the air and water are the medium for the sound wave. The sound wave only exist because the vibration of molecules in the medium. So in that context: Furthermore, it is a little-known fact that a classical transverse Doppler effect is observed in acoustics, which would suggest an analog in the classical wave theory light, although no such effect is described in textbooks. is suggesting a medium for light

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**Assistant:**

No, the statement in the paper is not suggesting the existence of a medium for light. The classical transverse Doppler effect observed in acoustics is a phenomenon that occurs in a medium, such as air or water, and it is caused by the motion of the source of the sound wave relative to the observer. The paper is suggesting that there could be an analog of this classical effect in the classical wave theory of light, which is a wave phenomenon that can be described by mathematical equations such as Maxwell's equations. However, the Doppler effect in light waves does not require a medium for propagation and can occur in vacuum, as electromagnetic waves are self-propagating and do not require a medium for their propagation. Therefore, the statement in the paper is not suggesting the existence of a medium for light.

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**alan:** Maxwell's equations explicitly account for a medium

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**Assistant:**

Maxwell's equations were developed to describe the behavior of electromagnetic waves, including light. In the original form of the equations, there was an explicit reference to a medium, known as the luminiferous ether, which was believed to be the medium that supported the propagation of electromagnetic waves through space. However, the existence of the ether was later disproved by the Michelson-Morley experiment in 1887.

After the ether was disproved, Maxwell's equations were modified to remove the explicit reference to the ether, and they were reformulated to describe the behavior of electromagnetic waves in vacuum. The modified equations still account for the propagation of electromagnetic waves through a medium, but the medium is no longer explicitly mentioned, as the equations are valid both in a medium and in vacuum.

Therefore, while Maxwell's equations were initially developed with the idea of a medium in mind, they have since been modified and extended to describe the behavior of electromagnetic waves both in a medium and in vacuum.

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**alan:** Why can't you admit that the full context of "Furthermore, it is a little-known fact that a classical transverse Doppler effect is observed in acoustics, which would suggest an analog in the classical wave theory light, although no such effect is described in textbooks." implies an medium

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**Assistant:**

I apologize for any confusion. You are correct that the statement in the paper suggests an analogy between the classical transverse Doppler effect in acoustics and a similar effect in the classical wave theory of light. The classical transverse Doppler effect in acoustics occurs in a medium, and the analogy would suggest that there might be a similar effect in the classical wave theory of light, which would imply the existence of a medium.

However, it is important to note that this suggestion is not consistent with the modern understanding of light, which is described by the theory of electromagnetic waves. In the theory of electromagnetic waves, there is no need for a medium to propagate the waves, and the Doppler effect in light can be observed both in a medium and in vacuum. Therefore, while the suggestion in the paper may imply the existence of a medium, it is not consistent with the modern understanding of light.

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**alan:** so to be clear on the experimental results summed up by the paper, relative motion could possibly explain the relativistic effects?

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**Assistant:**

Yes, according to the paper, the experimental results that were claimed to demonstrate relativistic effects could also be explained by classical effects due to relative motion. For example, the observed asymmetry in the red and blue shifts in the longitudinal Doppler effect in hydrogen atoms could be explained by classical Doppler effect for moving sources, which would be twice as large as the relativistic effect. Similarly, the claimed detection of the relativistic transverse Doppler effect in experiments by Kundig and Hasselkemp et al. were disputed, and alternative explanations based on classical effects were suggested.

Overall, while the paper acknowledges the possibility of relativistic effects, it also highlights the importance of considering classical effects due to relative motion when interpreting experimental results.

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**alan:** Summarize the ives-stilwell experiment

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**Assistant:**

The Ives-Stilwell experiment was performed in 1938-1941 and aimed to demonstrate time dilation, a prediction of special relativity. In the experiment, the longitudinal Doppler effect in the red and blue shifts of the H  $\alpha$  line emission from hydrogen atoms moving at speeds up to  $v = 0.01c$  was measured simultaneously in both approaching and receding directions. The observed red and blue shifts were slightly asymmetrical, which was interpreted as evidence of relativistic time dilation.

However, the interpretation of the results is controversial, as the observed asymmetry could also be explained by classical Doppler effects for moving sources. The classical effect is actually twice as large as the relativistic effect, making its detection easier. Therefore, while the Ives-Stilwell experiment is often cited as evidence for time dilation, the interpretation of the results is still debated.

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