

Attempts to Salvage the Ether

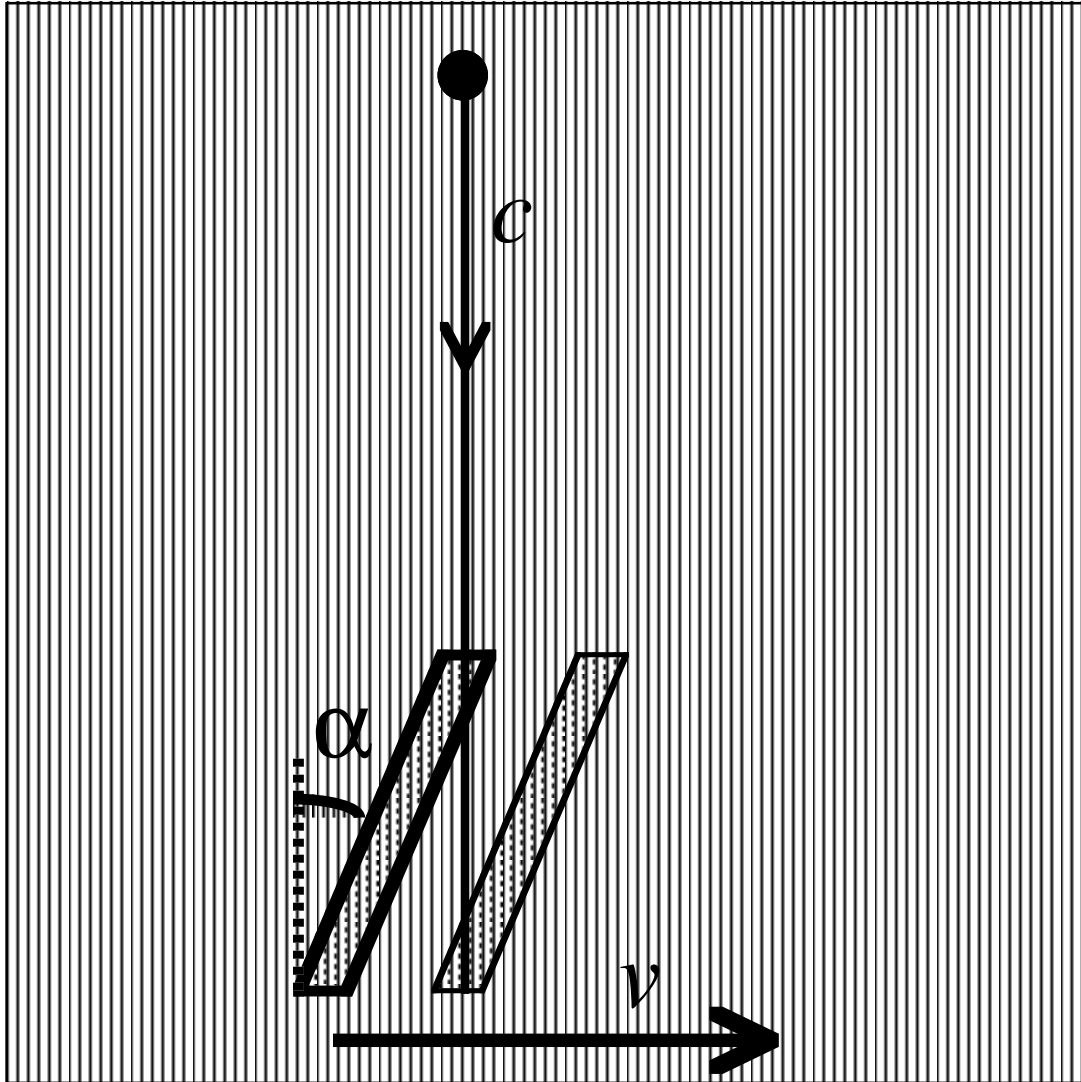
MM implies that the speed of light in the earth's frame is always the same along both arms of the interferometer, no matter how the instrument is oriented

Ether Drag

- Proposed before MM
- Full/partial
- ☞ Partial drag is inconsistent with MM.
- ☞ Full drag conflicts with the observations on stellar aberration.

Stellar Aberration

- The change in the apparent direction of a star caused by the earth's orbital motion around the sun.
- First detected and explained by James Bradley in 1725
- Analogy: When driving through a rainstorm, raindrops falling vertically appear to be moving obliquely.
- Forces the observer to tilt her telescope slightly in the direction of the earth's orbital motion to be able to see the stars (small effect).

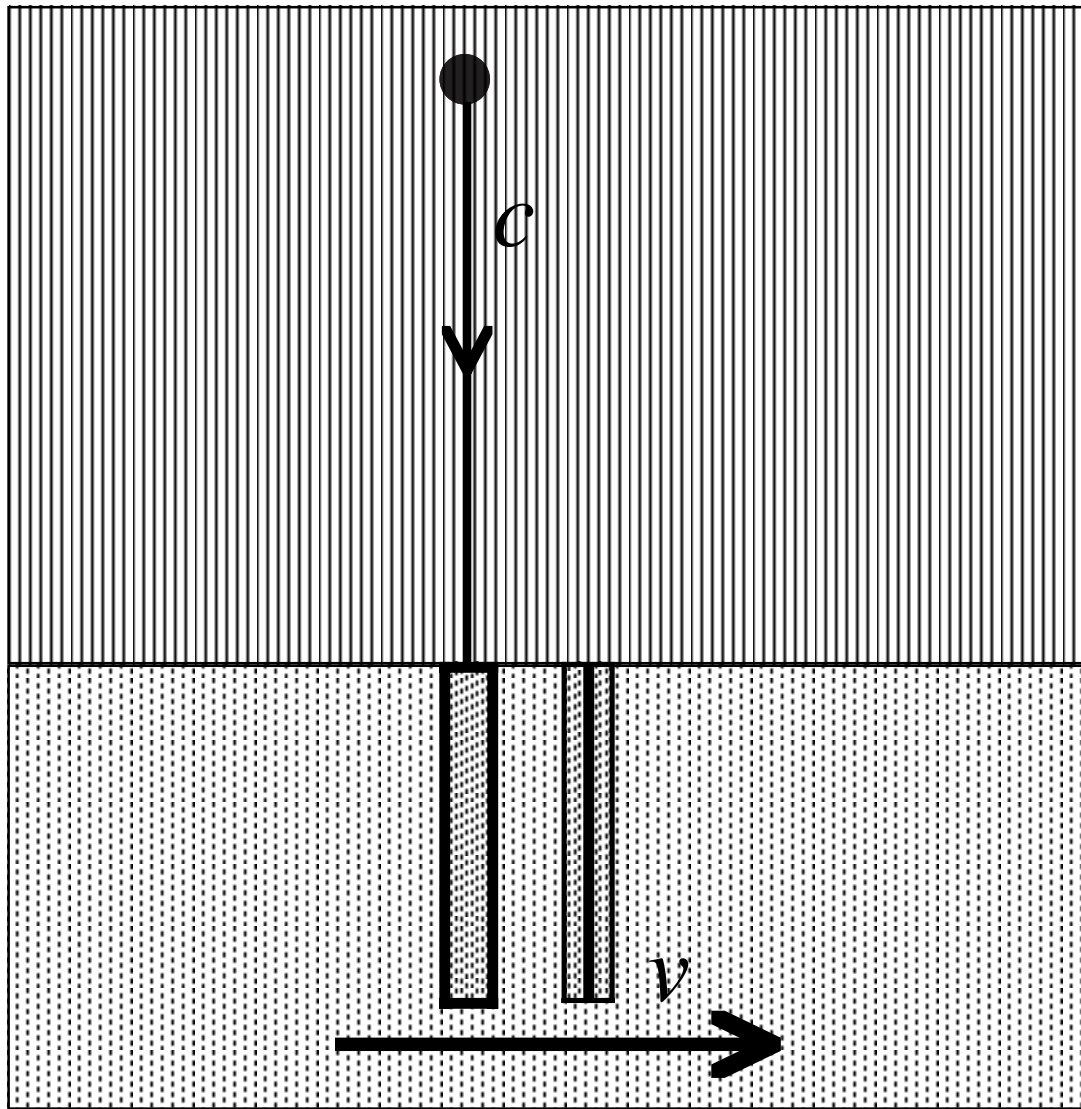


$v \approx 30 \text{ km/sec}$

$\tan \alpha = v/c \approx 10^{-4}$

$\alpha \approx 20''$ of arc

No drag aberration (observed)



Ether drag (full)
observation)

no aberration (contrary to

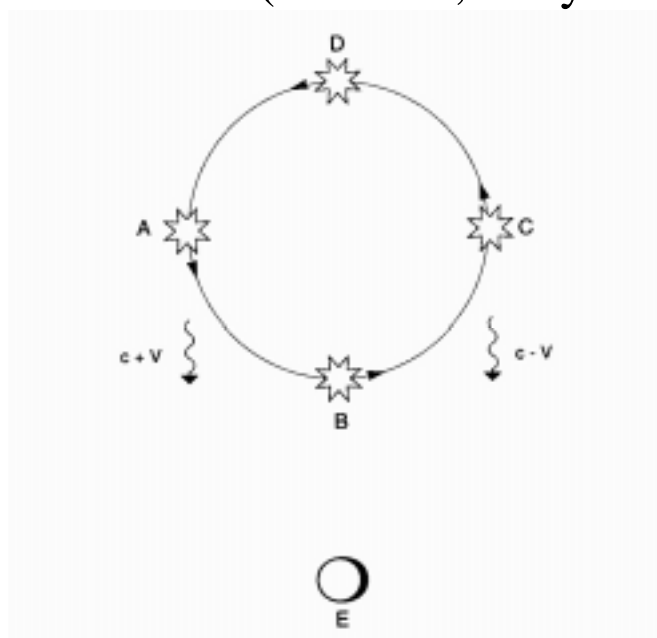
The Emission Theory

- The speed of light is c relative to the source of the light, not to the ether
- The velocity of the reflected light is c relative to the mirror

☞ Direct refutation:

- Pion decays
- MM with extraterrestrial sources of light

☞ Indirect refutation (de Sitter, early 1920's (?))



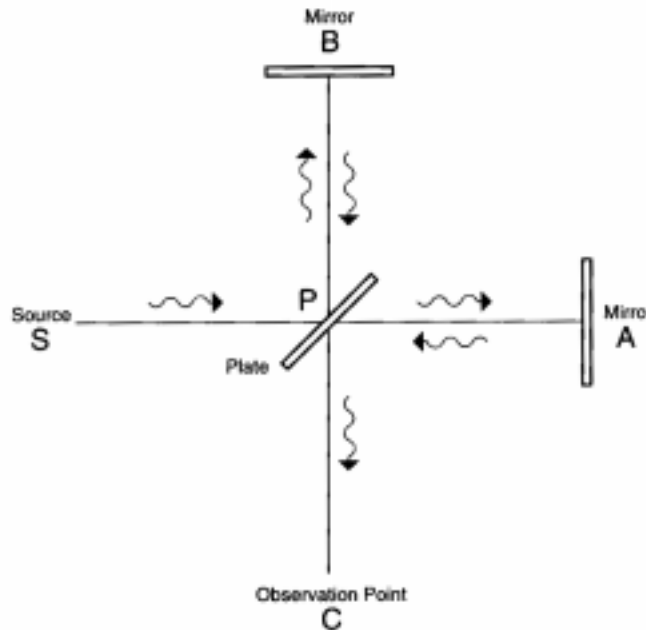
[Sartori, Fig. 2.7, p. 42]

The FitzGerald-Lorentz Contraction

☞ The dimensions of all material bodies contract by

$$\gamma \equiv \frac{1}{\sqrt{1 - \frac{u^2}{c^2}}} \text{ in the direction of motion through the ether.}$$

- Proposed after MM but long before relativity.



$$T_{SPAPC} - T_{SPBPC} = \frac{2L}{c} \left(\frac{1}{1 - \frac{u^2}{c^2}} - \frac{1}{\sqrt{1 - \frac{u^2}{c^2}}} \right) \approx \frac{L}{c} \left(\frac{u}{c} \right)^2$$

L_{PA} is contracted: L $\frac{L}{\gamma} = L \sqrt{1 - \frac{u^2}{c^2}}$ in the first factor

$$T_{SPAPC} - T_{SPBPC} = 0$$

- Kennedy-Thorndike (1932): $L_{PA} \neq L_{PB}$

$$T_{SPAPC} - T_{SPBPC} = \frac{2}{c} \left(\frac{L_{PA}}{1 - \frac{u^2}{c^2}} - \frac{L_{PB}}{\sqrt{1 - \frac{u^2}{c^2}}} \right)$$

L_{PA} is contracted: $L_{PA} \frac{L_{PA}}{\gamma} = L_{PA} \sqrt{1 - \frac{u^2}{c^2}}$

- $T_{SPAPC} - T_{SPBPC} = \frac{2(L_{PA} - L_{PB})}{c \sqrt{1 - \frac{u^2}{c^2}}} \approx \frac{2(L_{PA} - L_{PB})}{c} \left(1 + \frac{1}{2} \left(\frac{u}{c}\right)^2\right)$

- Does NOT change when the apparatus is rotated.
- BUT: Does change with change of u , in particular, due to the earth's orbital motion around the sun.*

*Sartori makes KT to fight a straw man. In 1905, Lorentz proposed that, in addition to length contraction, *clocks moving through the ether retard by γ* . On this hypothesis his theory becomes, FAPP, *fully equivalent to SR*. In particular,

$$T_{SPAPC} - T_{SPBPC} \text{ (as measured by retarded clocks) =}$$

$$\frac{2(L_{PA} - L_{PB})}{c}$$

Implications for Scientific Method: How Theories are Refuted by Evidence

- Naïve model:

A theory makes an empirical prediction

The prediction is disconfirmed by experiment

The theory is thereby refuted and thrown away.

- In reality:

The theory can almost always be modified to accommodate adverse evidence, e.g. by adding suitable “auxiliary” hypotheses.

- The Duhem-Quine Thesis:

A theory is tested *as a whole*; different parts of a theory *cannot* be tested *separately*. Consequently, one can always save any part of a theory, in light of adverse evidence, by making appropriate adjustments “elsewhere in the system.”

“The totality of our so-called knowledge or beliefs, from the most casual matters of geography and history to the profoundest laws of atomic physics or even of pure mathematics and logic, is a man-made fabric which impinges on experience only along the edges. Or, to change the figure, total science is like a field of force whose boundary conditions are experience. A conflict with experience at the periphery occasions readjustments over some of our statements. Truth values have to be redistributed over some of our statements. Reevaluation of some statements entails reevaluation of others, because of their logical interconnections. . . . But the total field is so underdetermined by its boundary conditions, experience, that there is much latitude of choice as to what statements to reevaluate in the light of any single contrary experience. No particular experiences are linked with any particular statements in the interior of the field, except indirectly through considerations of equilibrium affecting the field as a whole....

Any statement can be held true come what may, if we make drastic enough adjustments elsewhere in the system.

[W. Quine, “Two Dogmas of Empiricism”]

- Example: One can save the ether in light of MM by making suitable adjustments “elsewhere in the system”: by introducing an auxiliary hypotheses of the ether drag (Stokes), or light emission (Ritz), or contraction (Lorentz).

- Disastrous consequences of the Duhem-Quine thesis for scientific method: How to distinguish between a right and a wrong theory?
- Proposal for saving scientific method: consider *multiple* evidence

Around 1900, there were several different ether theories that could successfully accommodate Michelson's null result:

- Stokes's hypothesis of ether drag
- Ritz's emission theory
- Lorentz-FitzGerald's contraction hypothesis.

BUT:

- Stokes's hypothesis can accommodate Michelson's result, but not this result *together* with the data on the aberration of light from stars
- Ritz's theory can also explain Michelson's experiment alone, but it cannot be reconciled with the results of this experiment *and* other evidence, e.g., the observed kinematics of binary stellar systems.
- Etc.

- Under the pressure of multiple adverse evidence, a wrong theory is forced to make multiple modifications which eventually “tear” the theory “apart.”
- One can adhere to a wrong theory only “at the price of continual repairs and many tangle-up stays” in the attempt to preserve “the worm-eaten columns of a building tottering in every part, when by razing these columns it would be possible to construct a simple, elegant, and solid system.”

[Pierre Duhem, *The Aim and Structure of Physical Theory*. Princeton, Princeton University Press, 1954, p. 217.]