Does the relativity principle hold for all situations in relativistic physics?

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Eötvös University, Budapest

L.E. Szabó (2004): On the meaning of Lorentz covariance
Foundations of Physics Letters **17**, 479

M. Gömöri and L.E. Szabó (2011): On the formal statement of the special principle of relativity
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(available from: http://phil.elte.hu/leszabo)

As we have seen in Márton's lecture, the following conceptual plugins are necessary for the RP:

- Physical quantities in K
- The operational counterparts in K'
- Distinction between the quantities in K and K'
- Admissible values of physical quantities
- Putting primes ($P_{\mathbf{V}}$)
- Transformation law ($T_{\mathbf{V}}$)
- Description of a phenomenon (F)
- Physical equations ($\mathcal{E} \ni F$)
- Primed solution ($P_{\mathbf{V}}(F)$)
- Same solution expressed in primed variables ($T_{\mathbf{V}}(F)$)
- The same but in different state of motion ($M_{\mathbf{V}}(F)$)

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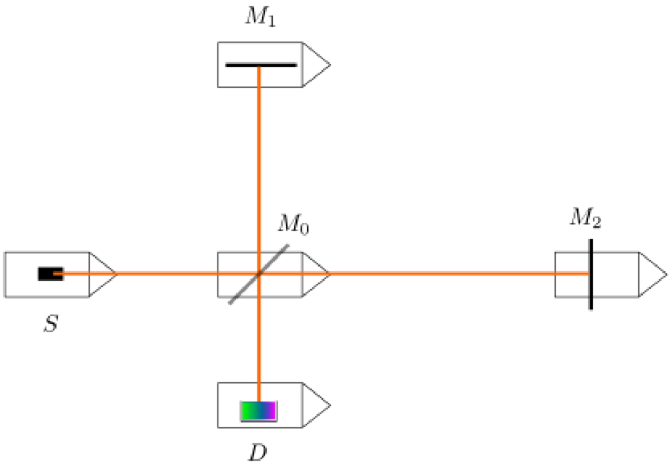
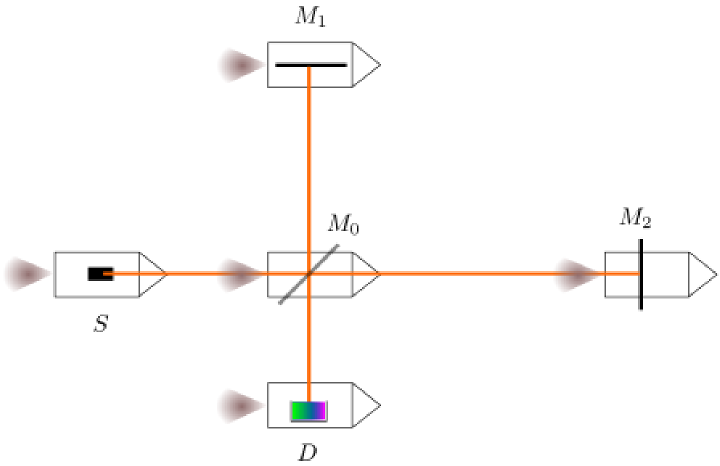


M_1
M_0
M_2
S
D


M_1
M_0
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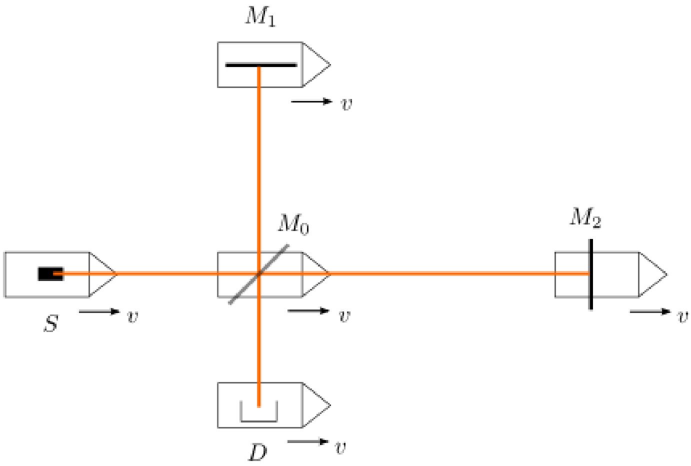
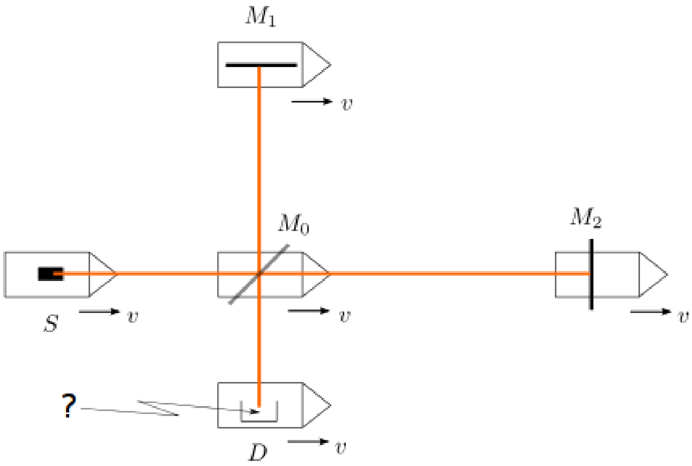
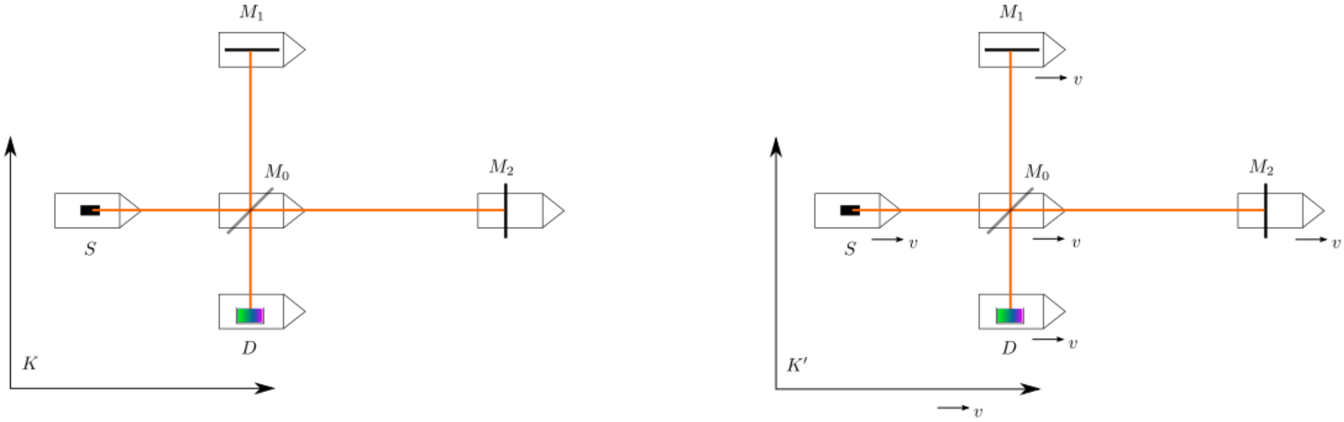
S
D



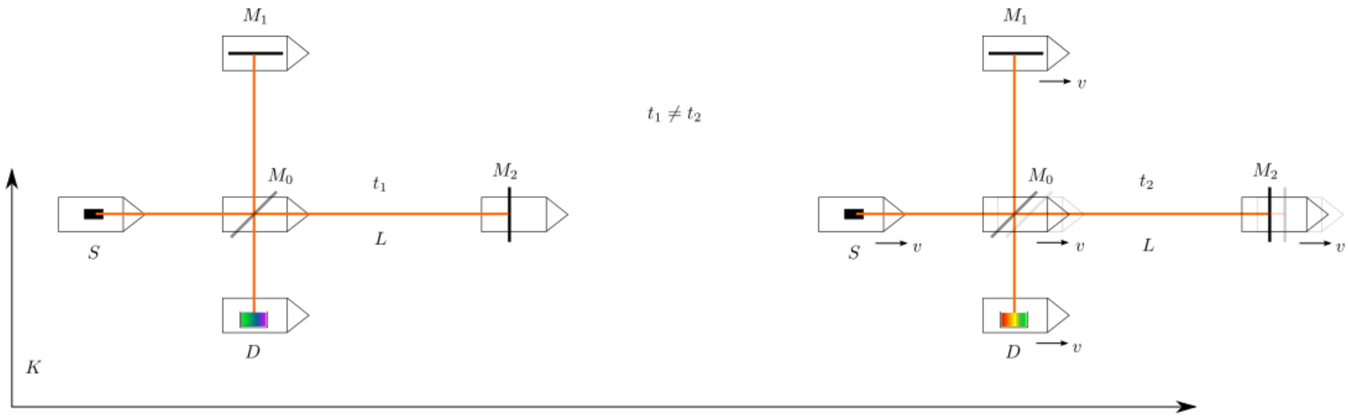
M_1
v
M_0
M_2
S
v
v
v
D
v



M_1
v
M_0
M_2
S
v
v
v
?
D
v



M_1
M_0
M_2
S
D
K
M_1
v
M_0
M_2
S
v
v
v
D
v
K'
v



M_1
$t_1 \neq t_2$
M_1
v
M_0
t_1
M_2
M_0
t_2
M_2
S
L
S
v
v
L
v
D
D
v
K

Which one is the correct answer?

The Relativity Principle states:

$$M_v(F) = T_v^{-1}\left(P_v(F)\right)$$

The same physical system exhibiting the same phenomenon as the one described by F, *except that the system is in motion* with velocity v relative to K, that is, co-moving with inertial frame K'

The "Lorentz boosted" F: The inverse Lorentz (Galilean, etc.) transformation of the "primed" F, that is, of the same formula as F but in the primed quantities of K'

For example:

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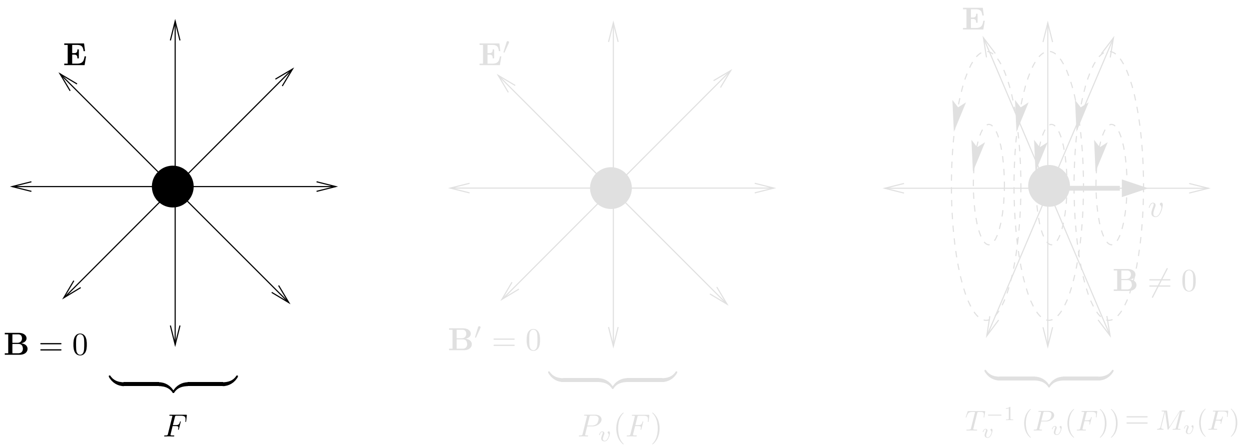

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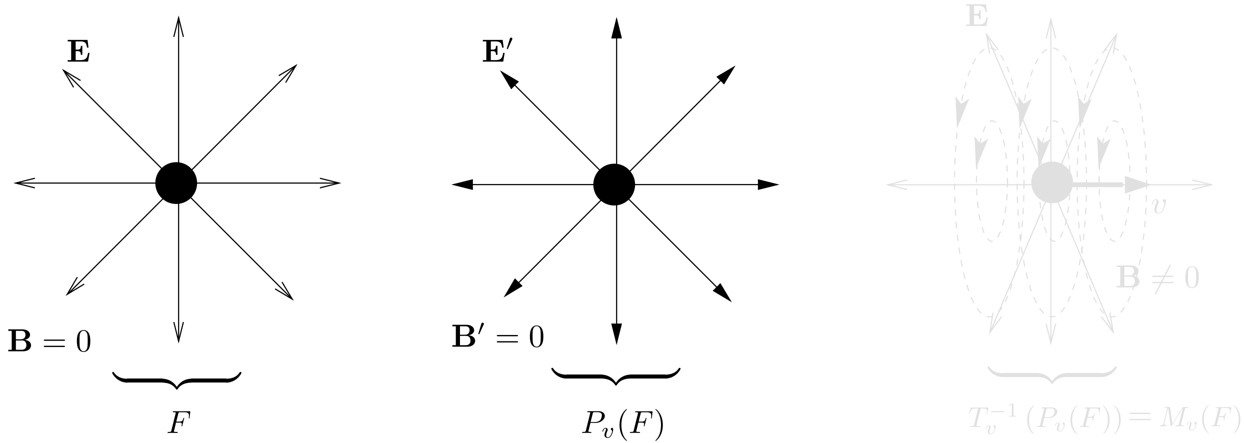

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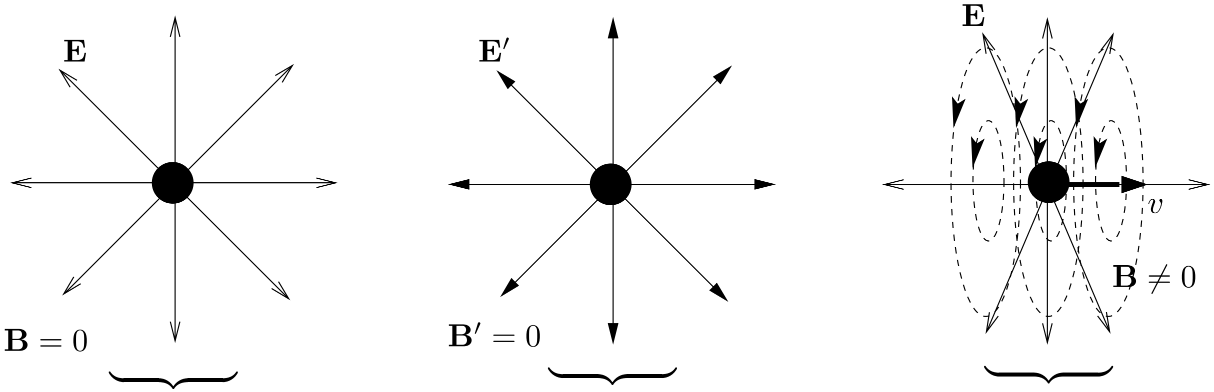

F $\qquad$ $P_v(F)$ $\qquad$ $T_v^{-1}\left(P_v(F)\right) = M_v(F)$

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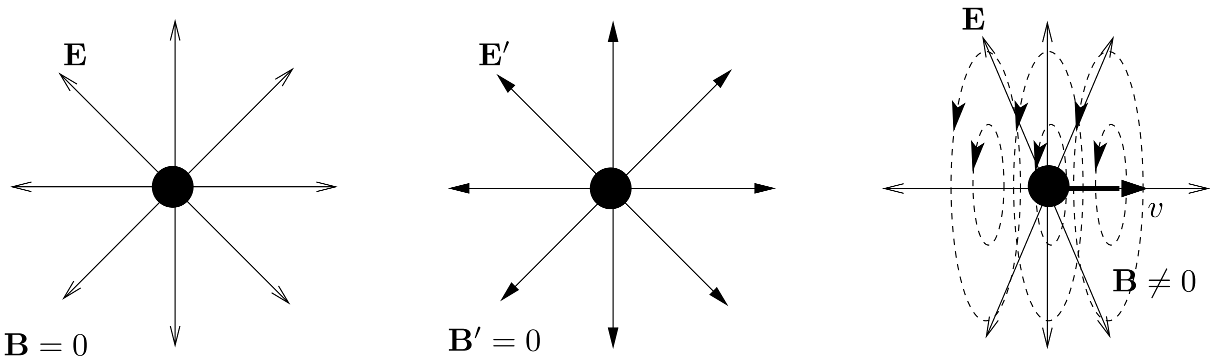

$\underbrace{\qquad}_{F}$ $\underbrace{\qquad}_{P_v(F)}$ $\underbrace{\qquad}_{T_v^{-1}\left(P_v(F)\right) = M_v(F)}$

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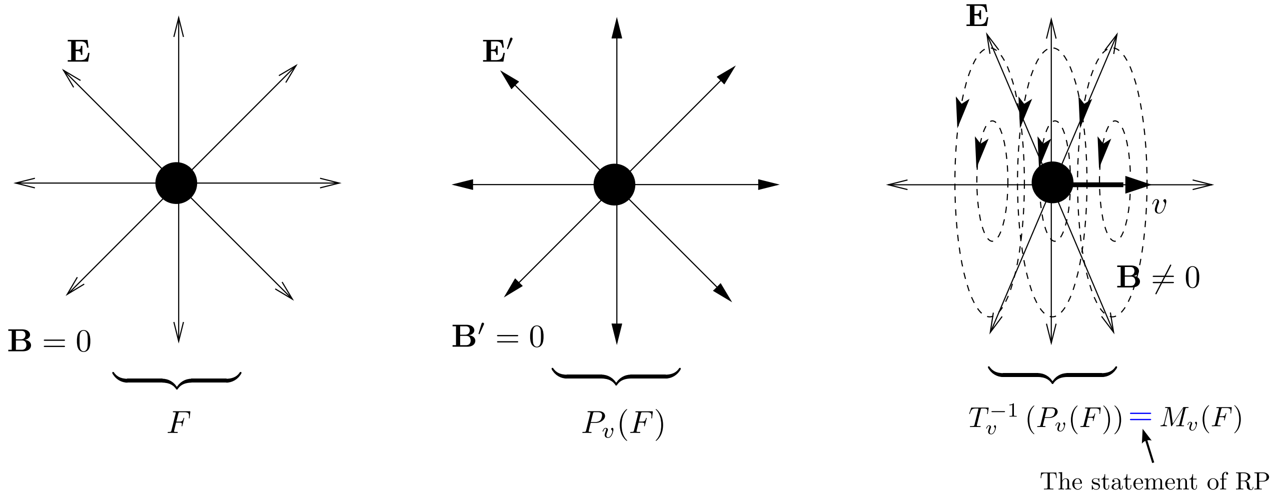
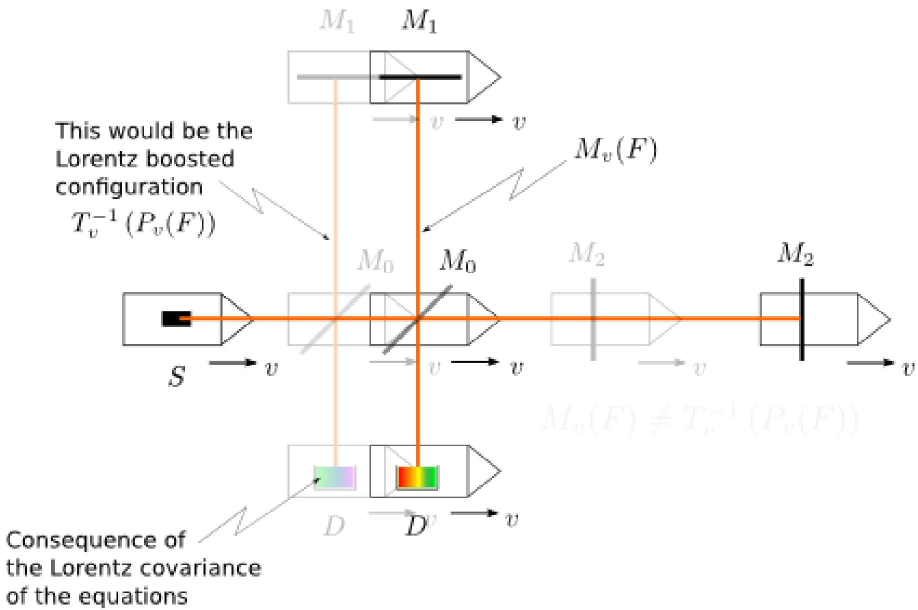
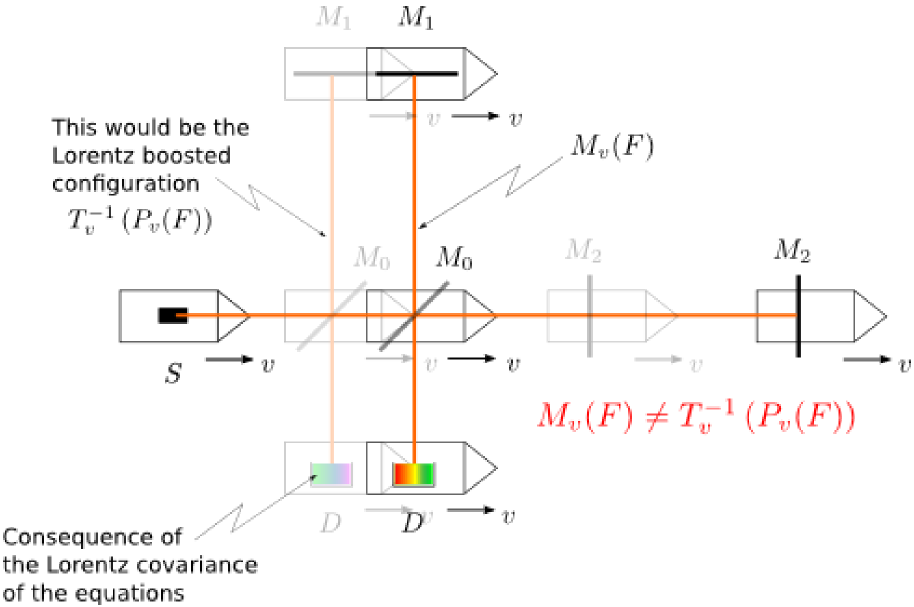
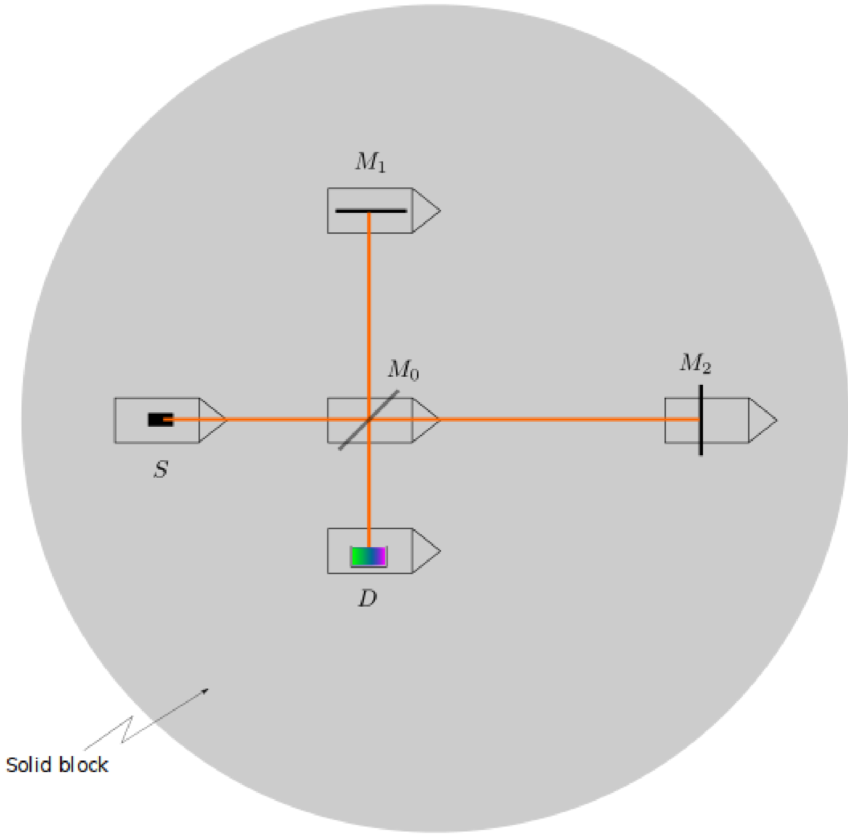


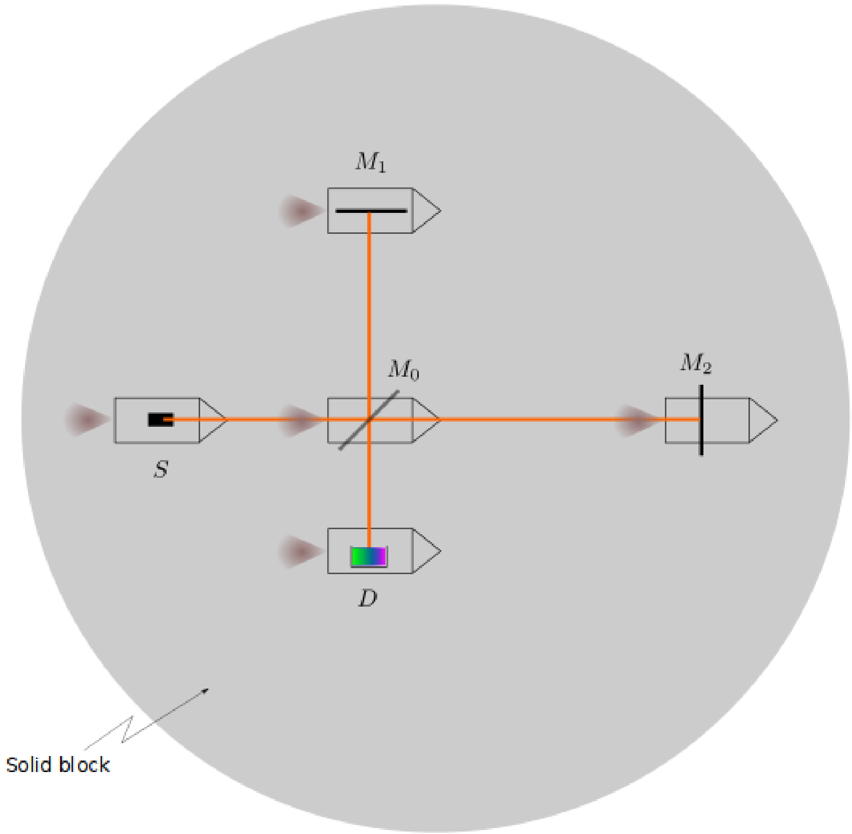


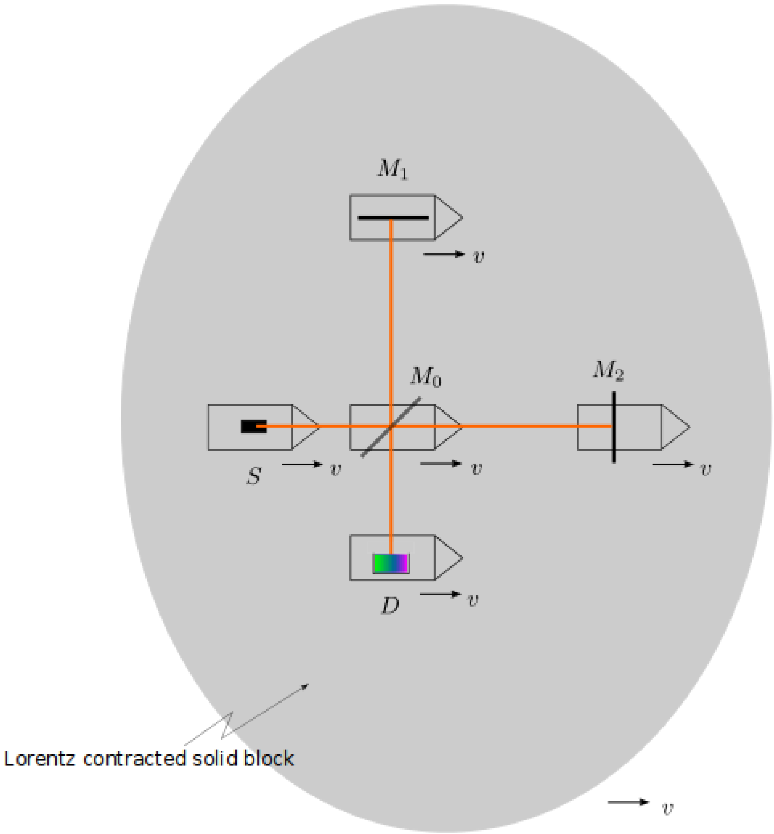
M_1
M_1
v
v
This would be the
Lorentz boosted
configuration
$T_v^{-1}(P_v(F))$
$M_v(F)$
M_0
M_0
M_2
M_2
S
v
v
v
v
v
$M_v(F) \neq T_v^{-1}(P_v(F))$
D
D
v
Consequence of
the Lorentz covariance
of the equations


M_1
M_1
v
v
This would be the Lorentz boosted configuration $T_v^{-1}(P_v(F))$
$M_v(F)$
M_0
M_0
M_2
M_2
S
v
v
v
v
v
$M_v(F) \neq T_v^{-1}(P_v(F))$
D
D
v
v
Consequence of the Lorentz covariance of the equations

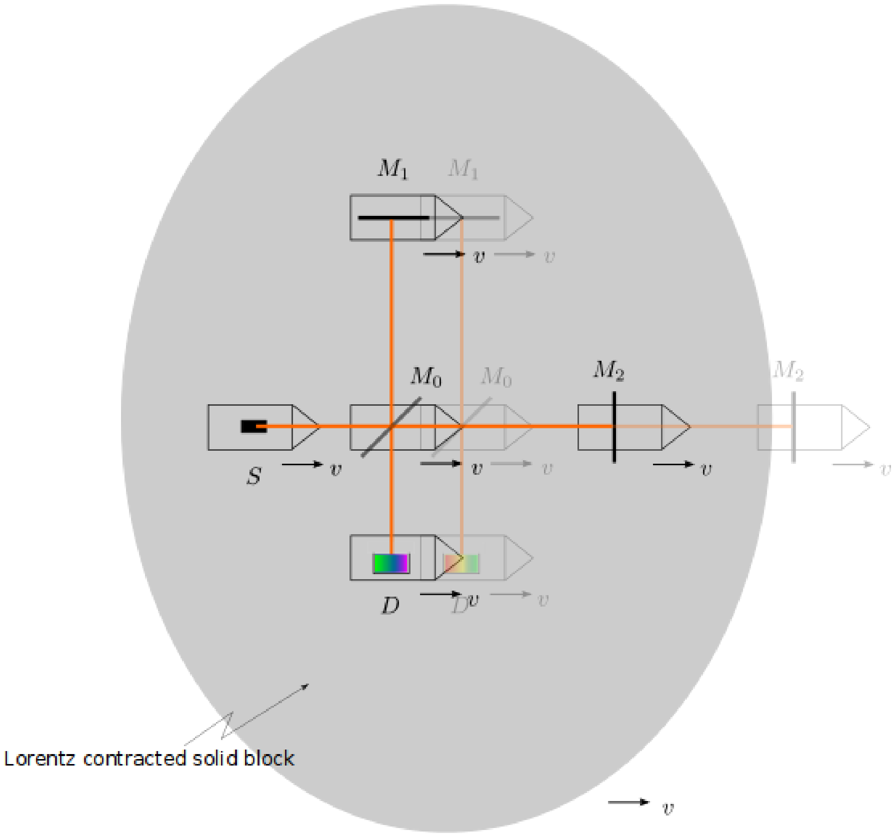


M_1
M_0
M_2
S
D
Solid block

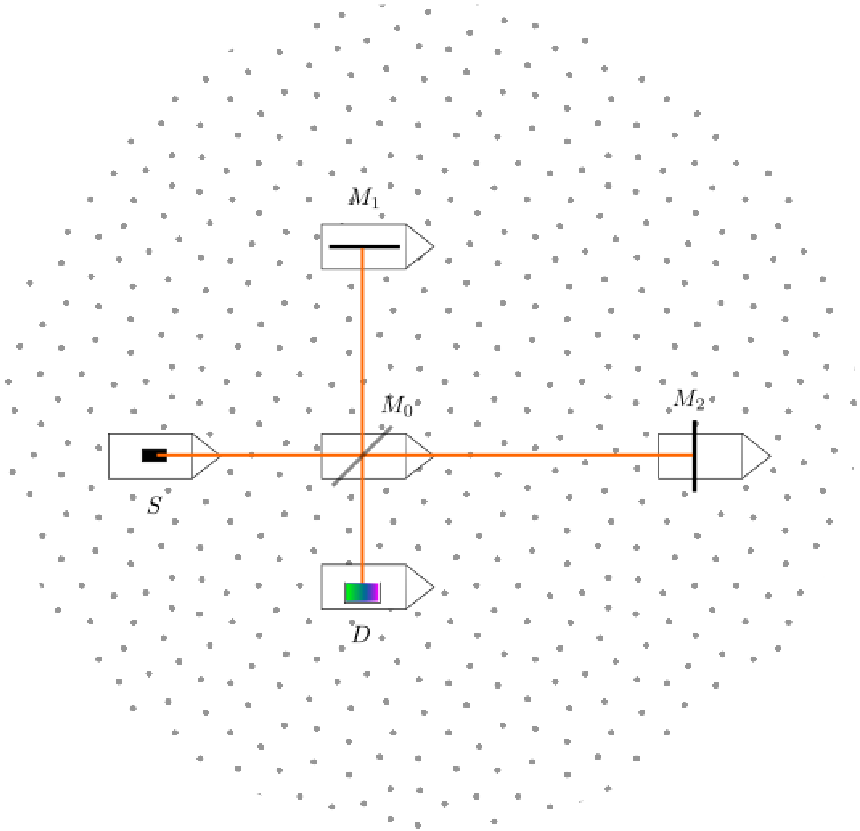

M_1
M_0
M_2
S
D
Solid block

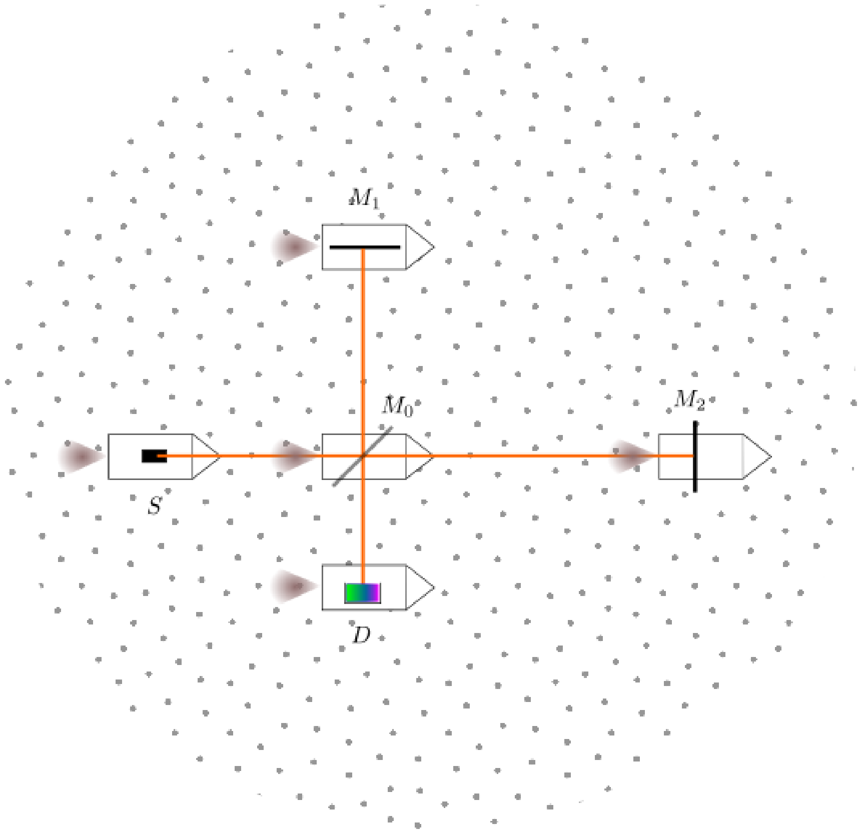


M_1
v
M_0
M_2
S
v
v
v
D
v
Lorentz contracted solid block
v

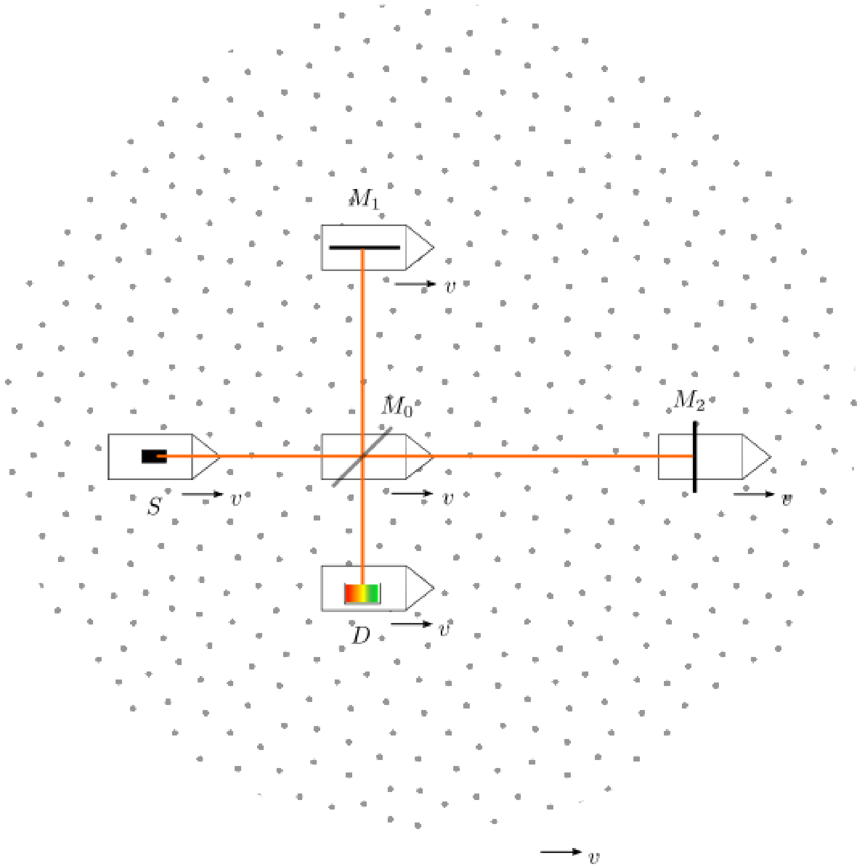


M_1
M_1
v
v
M_0
M_0
M_2
M_2
S
v
v
v
v
v
D
D
v
v
Lorentz contracted solid block
v


M_1
M_0
M_2
S
D



M_1
M_0
M_2
S
D



M_1
v
M_0
M_2
S
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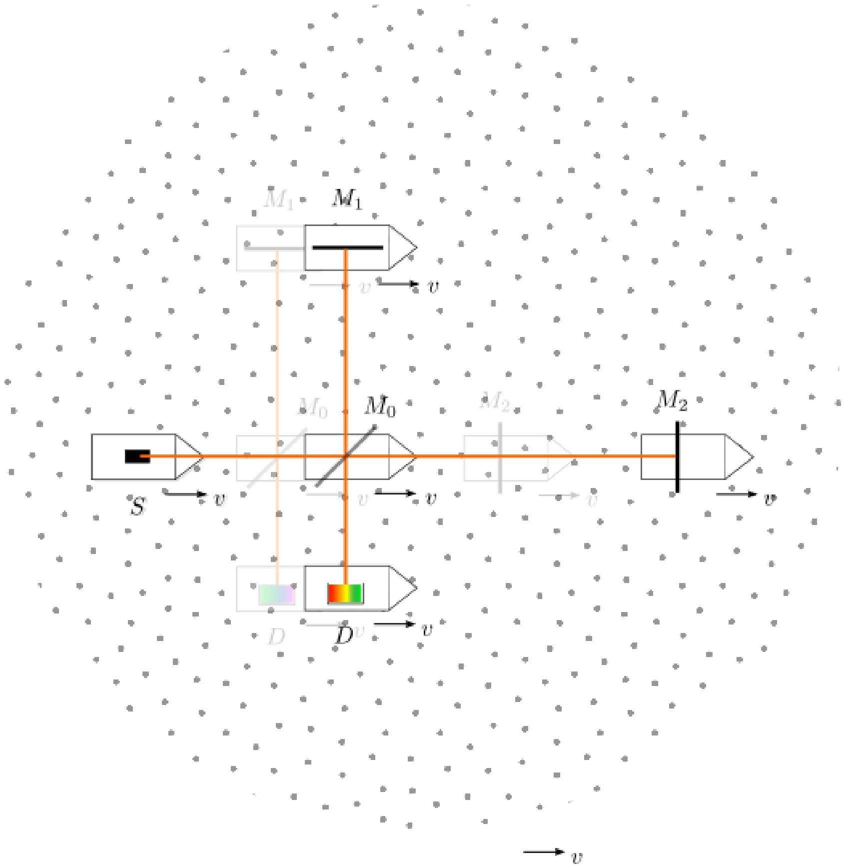

M_1
M_1
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M_0
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M_2
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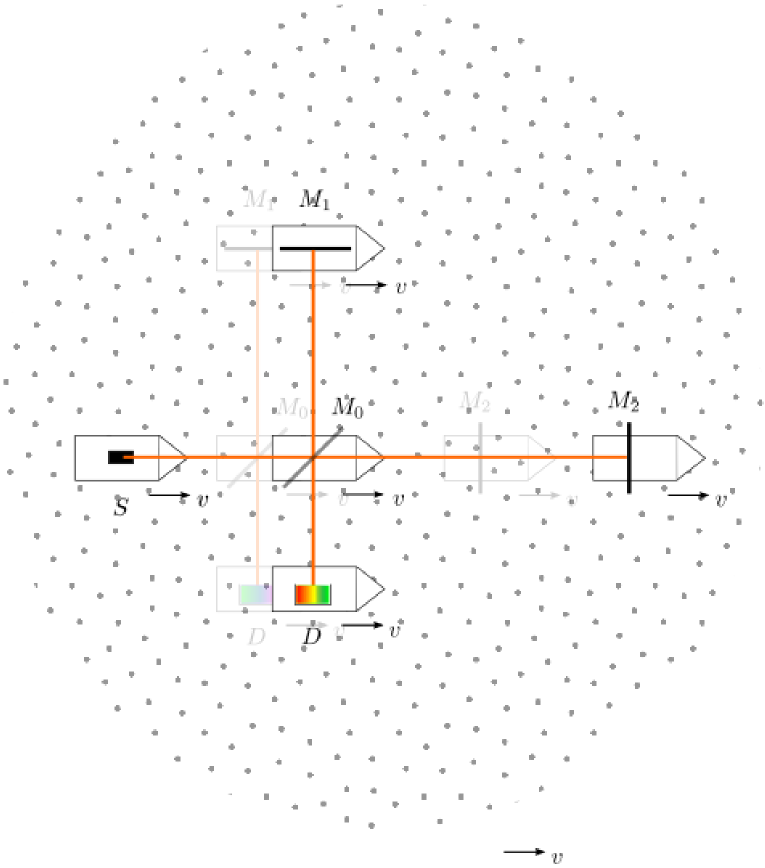
v



M_1
M_1
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M_0
M_0
M_2
M_2
S
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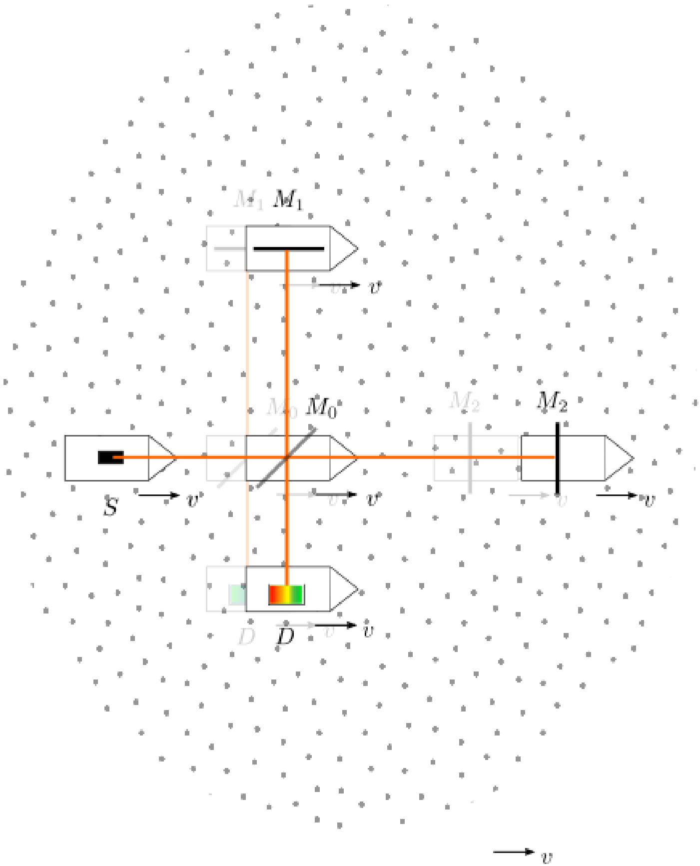
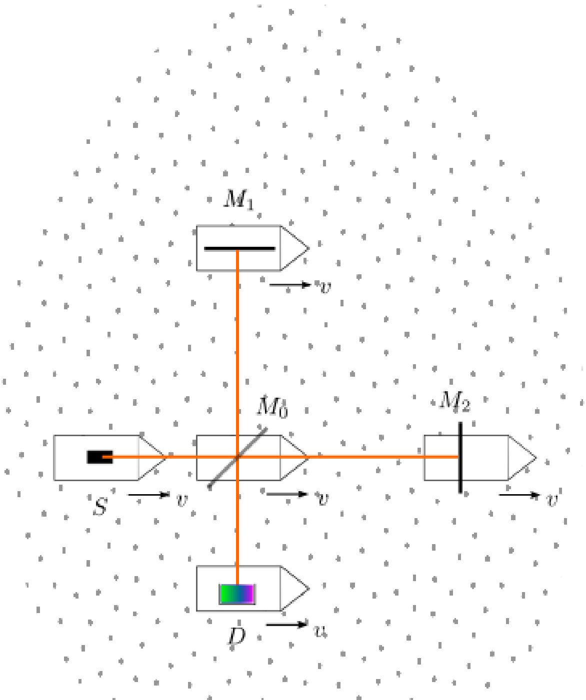
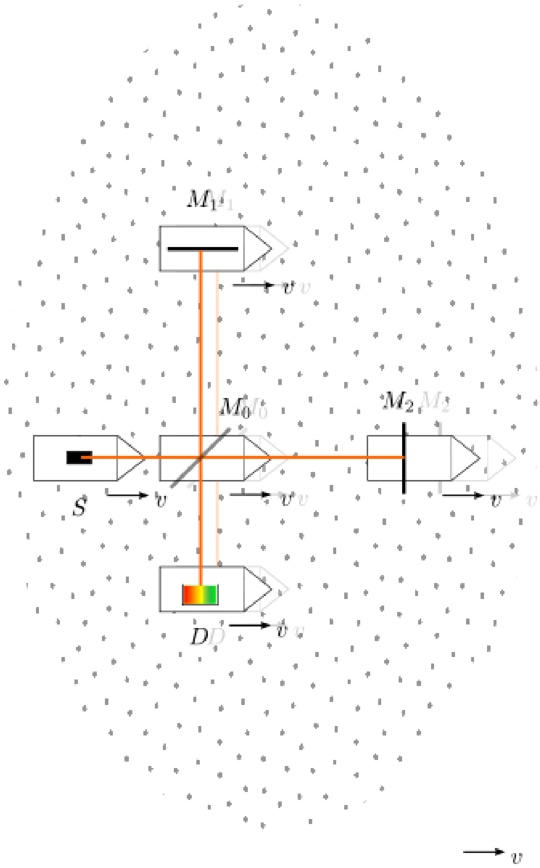


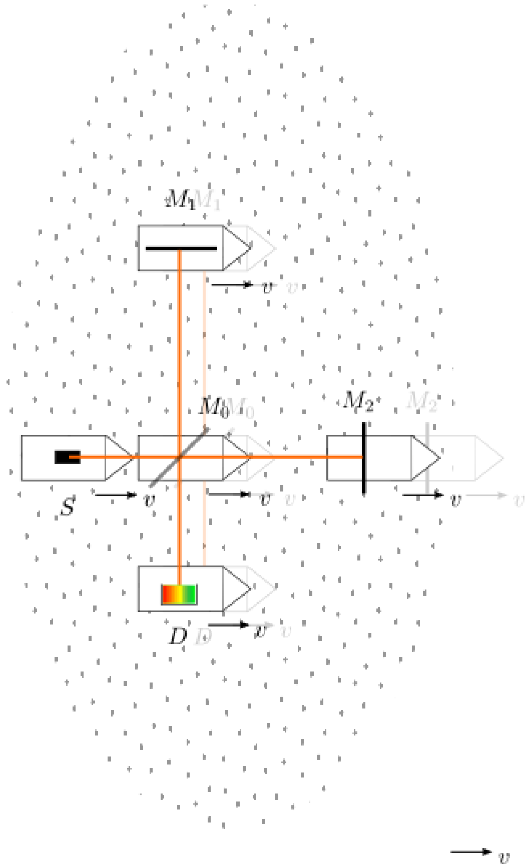
M_1
v
M_0
M_2
S
v
v
v
D
v
v



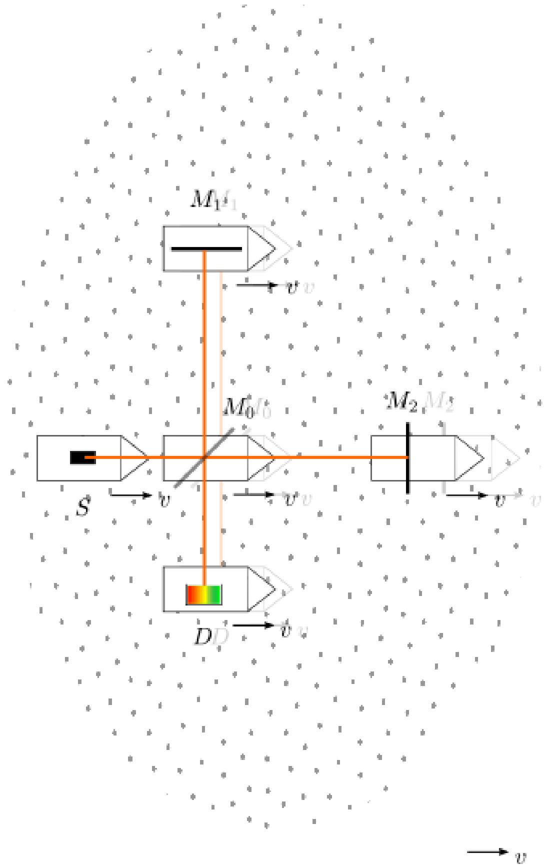
This is the state predicted by the relativity principle!



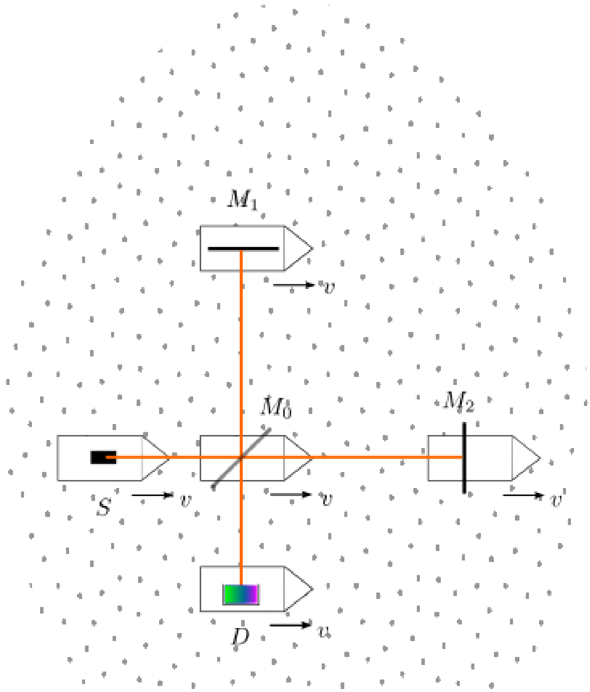
M_1
v
M_0
M_2
S
v
v
v
D
v
v



M_1
M_0
M_2
S
D
v



M_1
v
M_0
M_2
S
v
v
v
D
v
v



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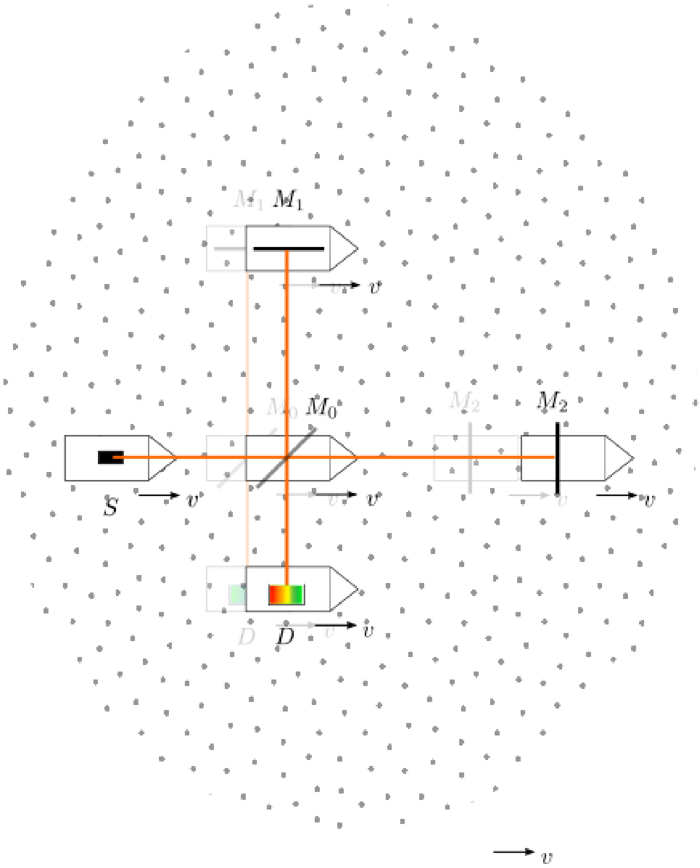
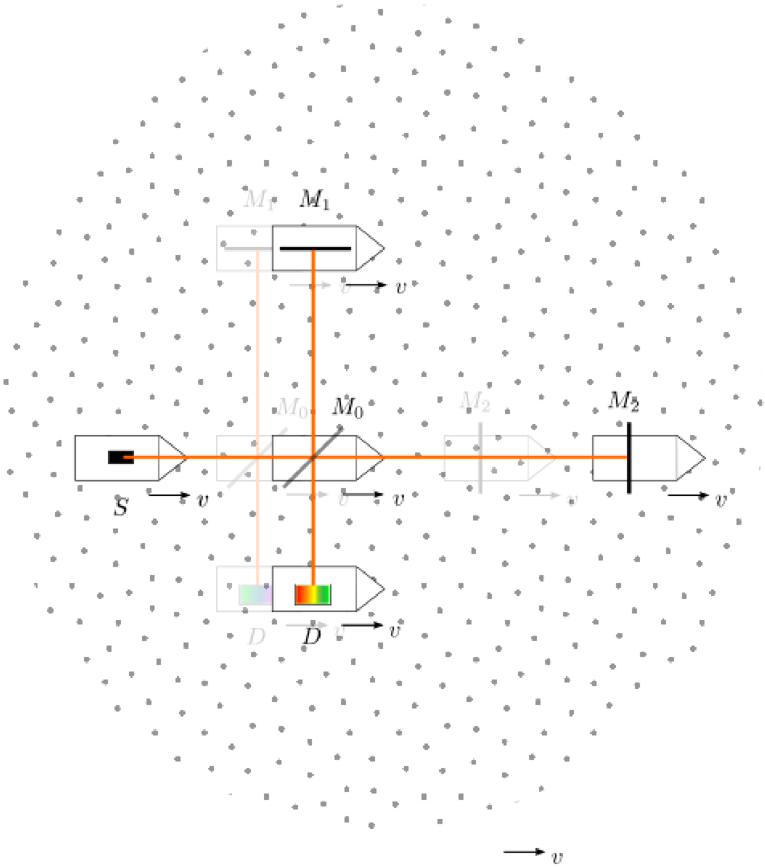


M_1
M_1
v
v
M_0
M_0
M_2
M_2
S
v
v
v
v
v
D
D
v
v
v



M_1
M_1
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M_0
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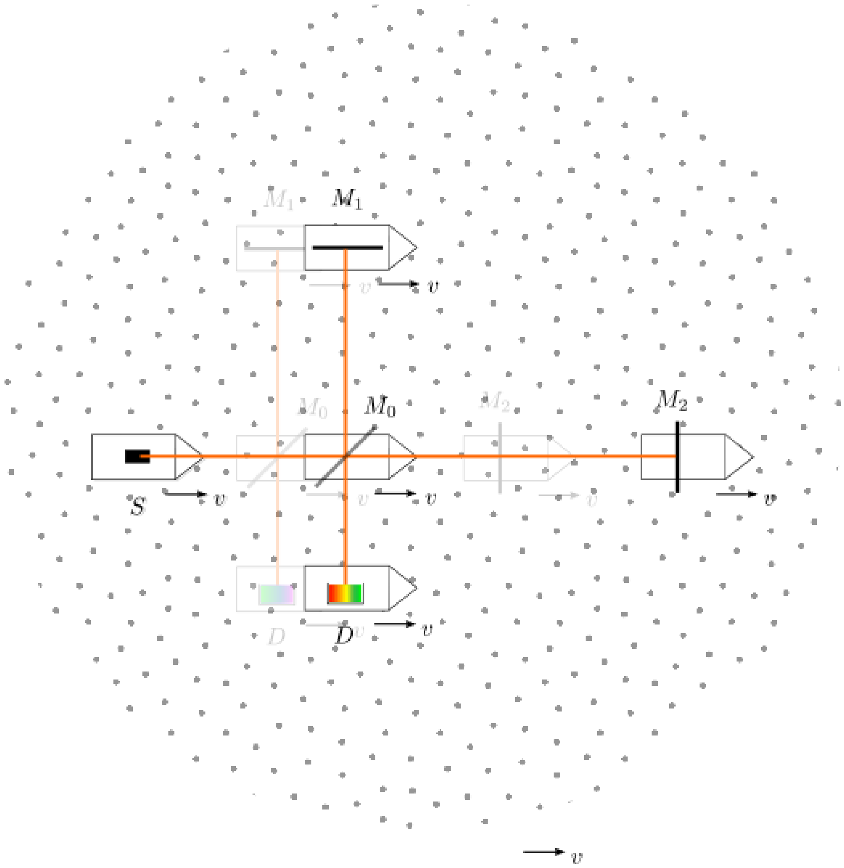

M1
M1
v
v
M0
M0
M2
M2
S
v
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D
D
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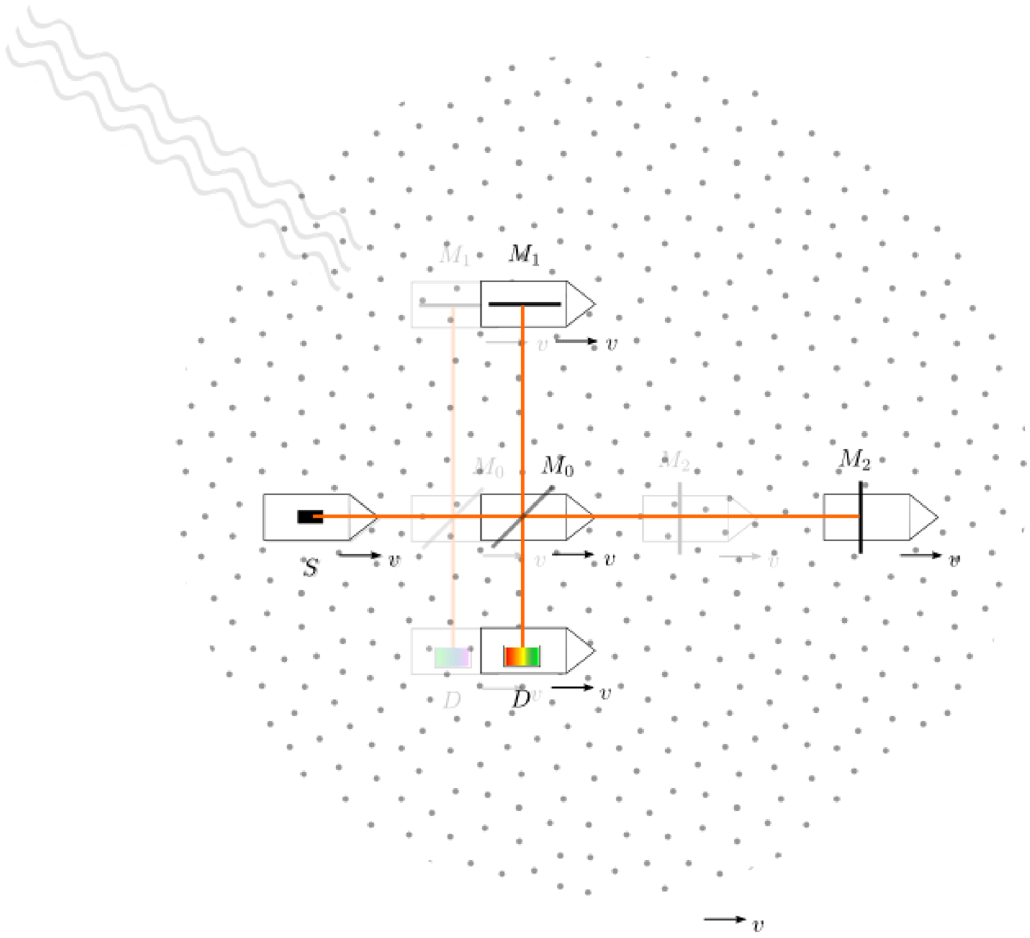
v



M_1
M_1
v
v
M_0
M_0
M_2
M_2
S
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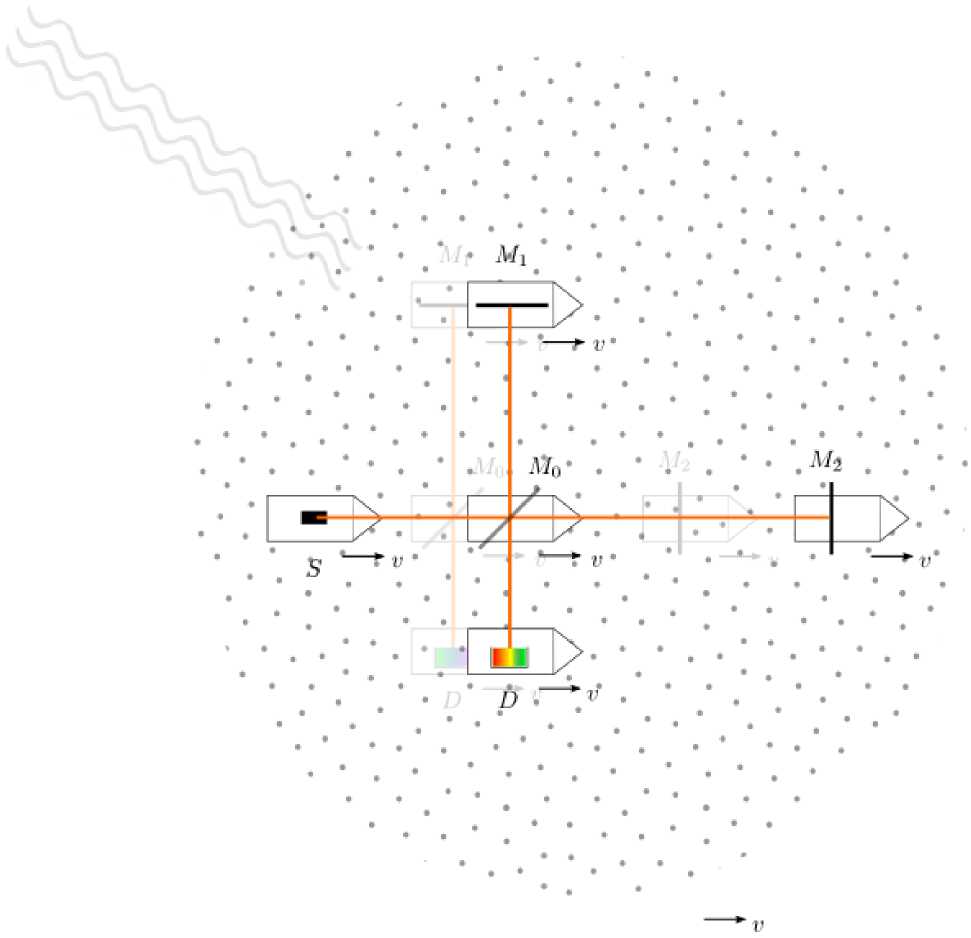

M_1
M_1
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M_0
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M_2
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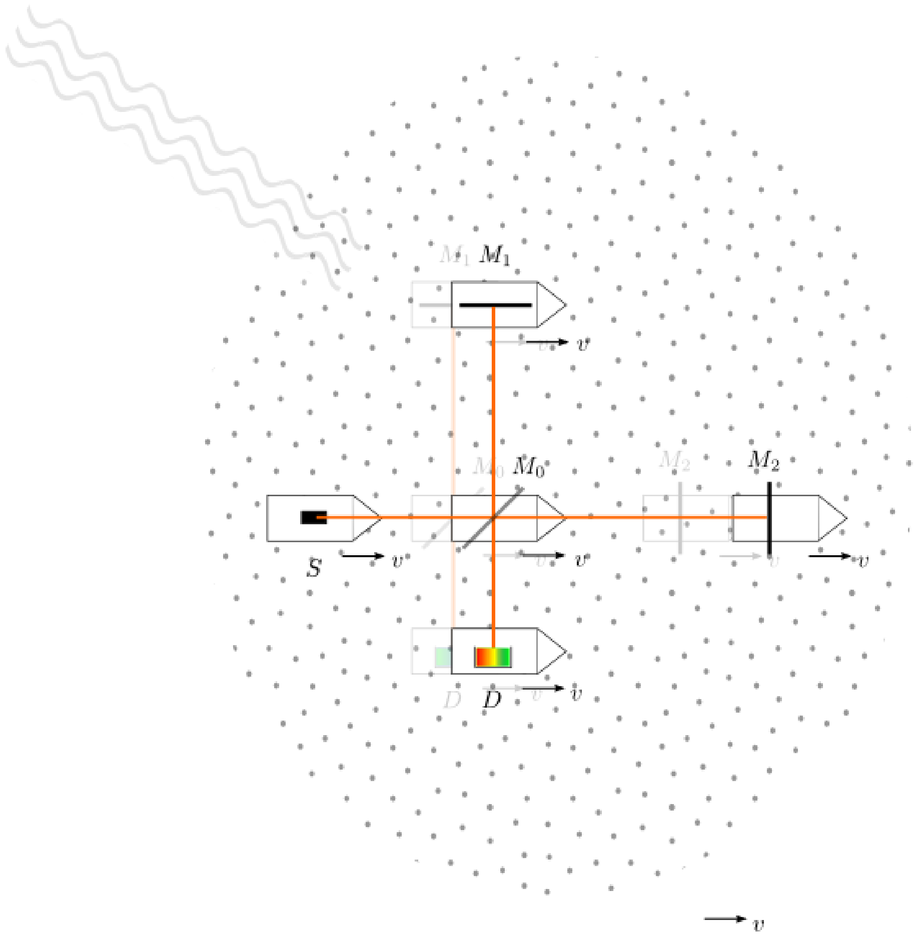

M_1
M_1
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M_0
M_0
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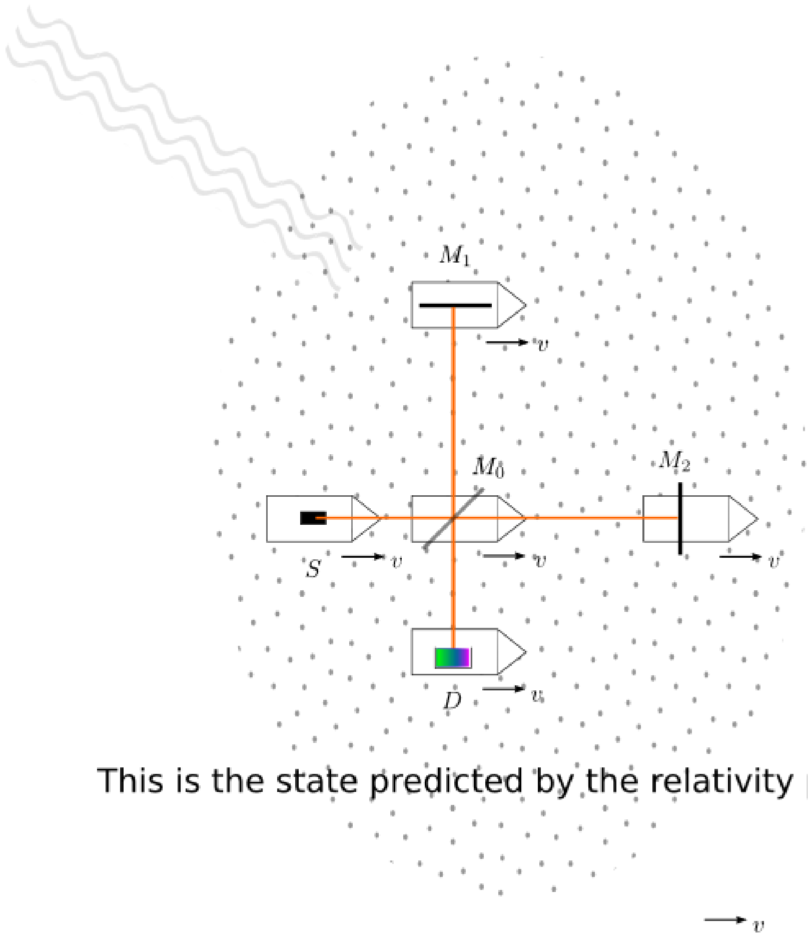

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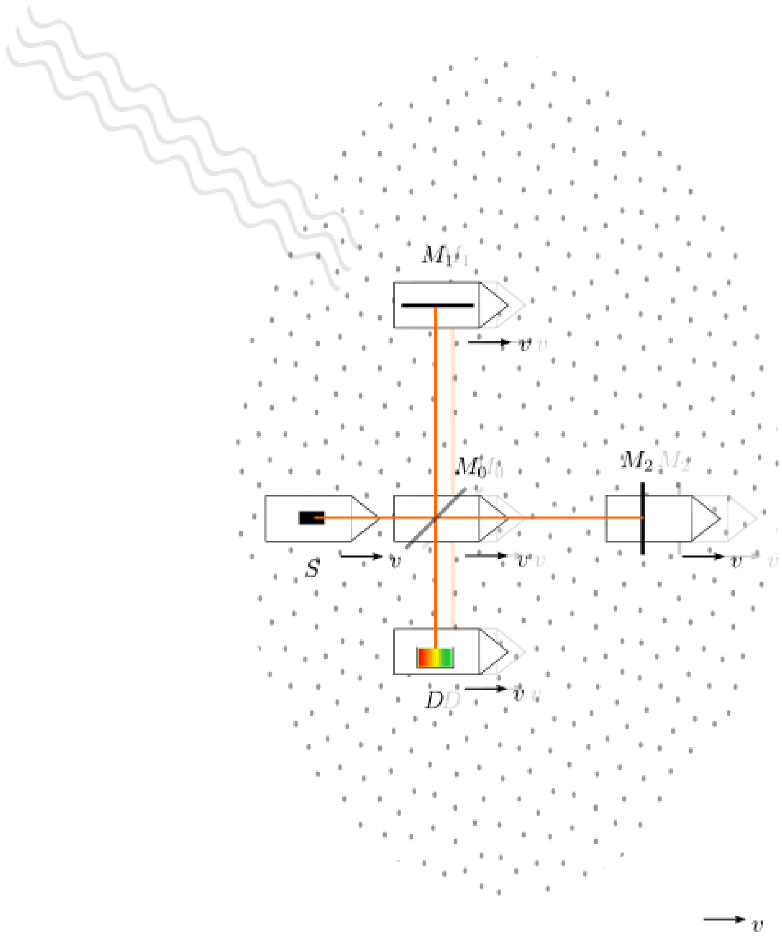

M_1
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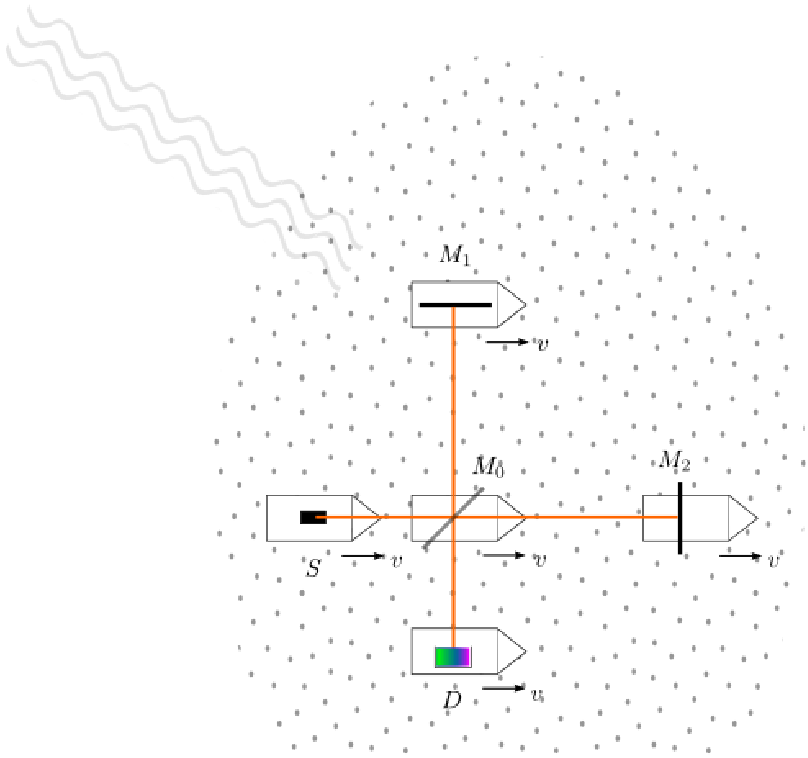

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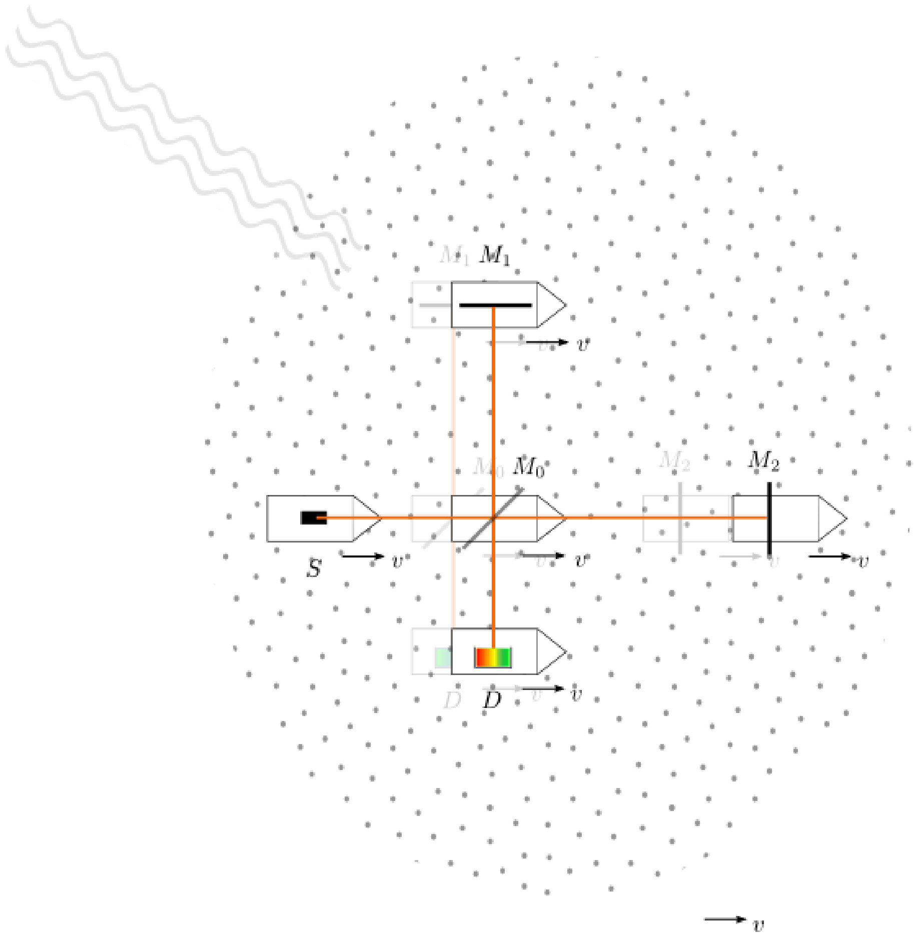

M_1
M_1
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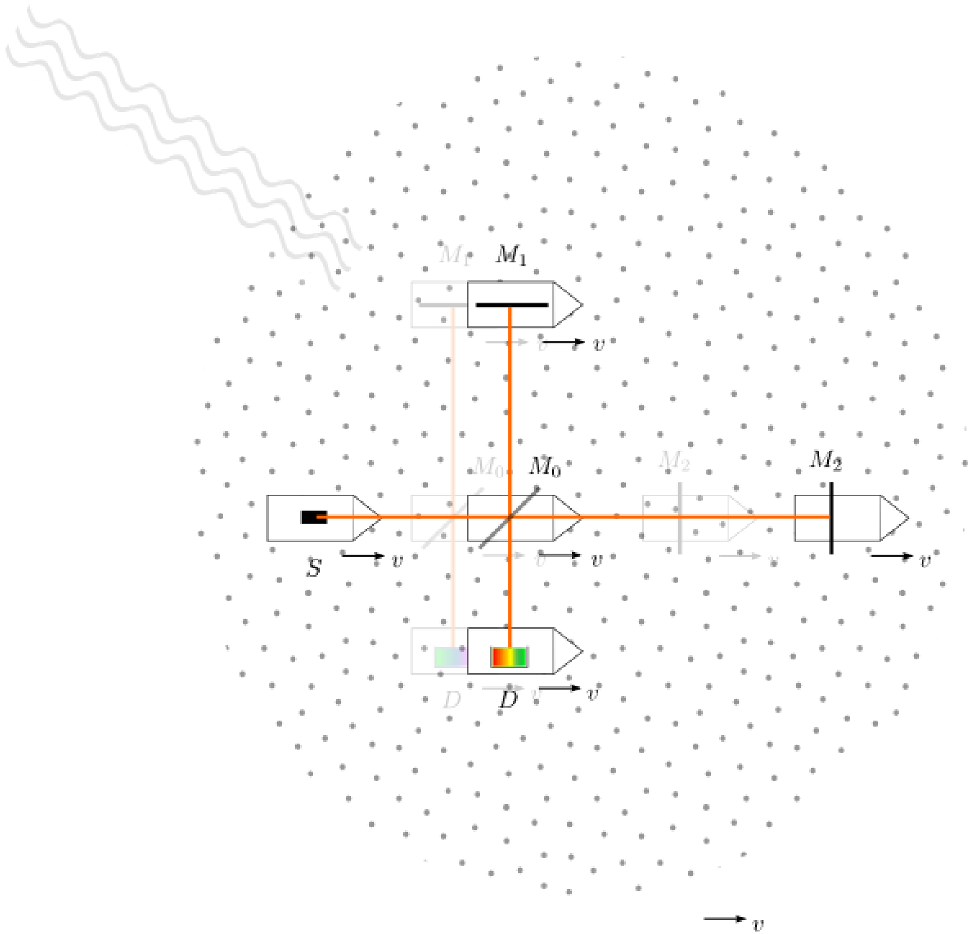

M_1
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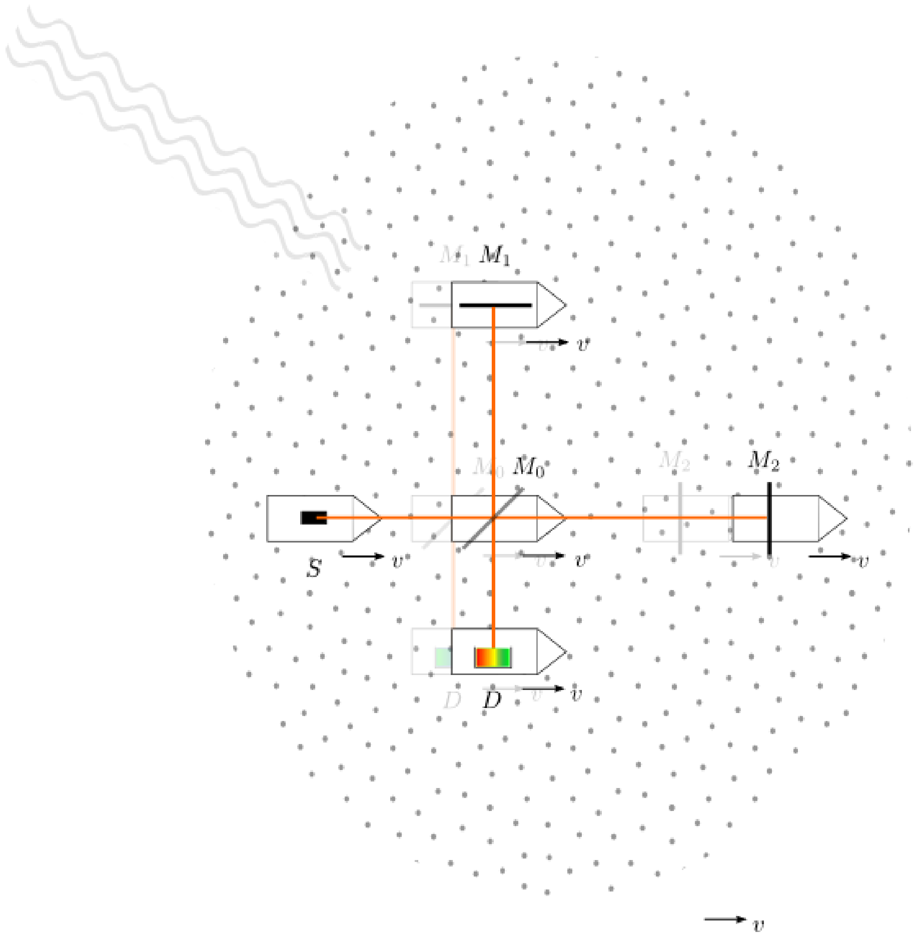
v



M_1
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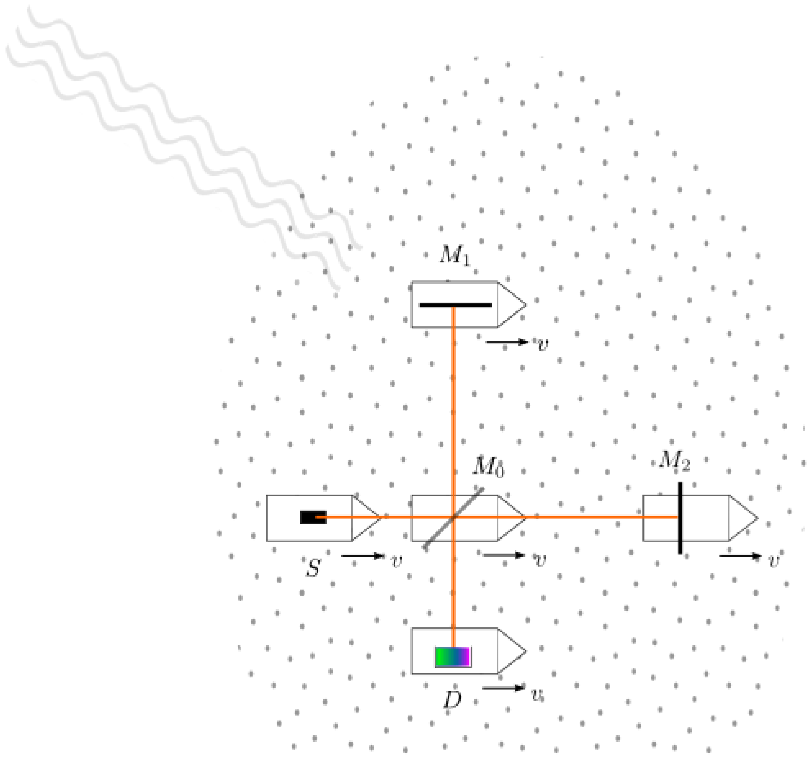

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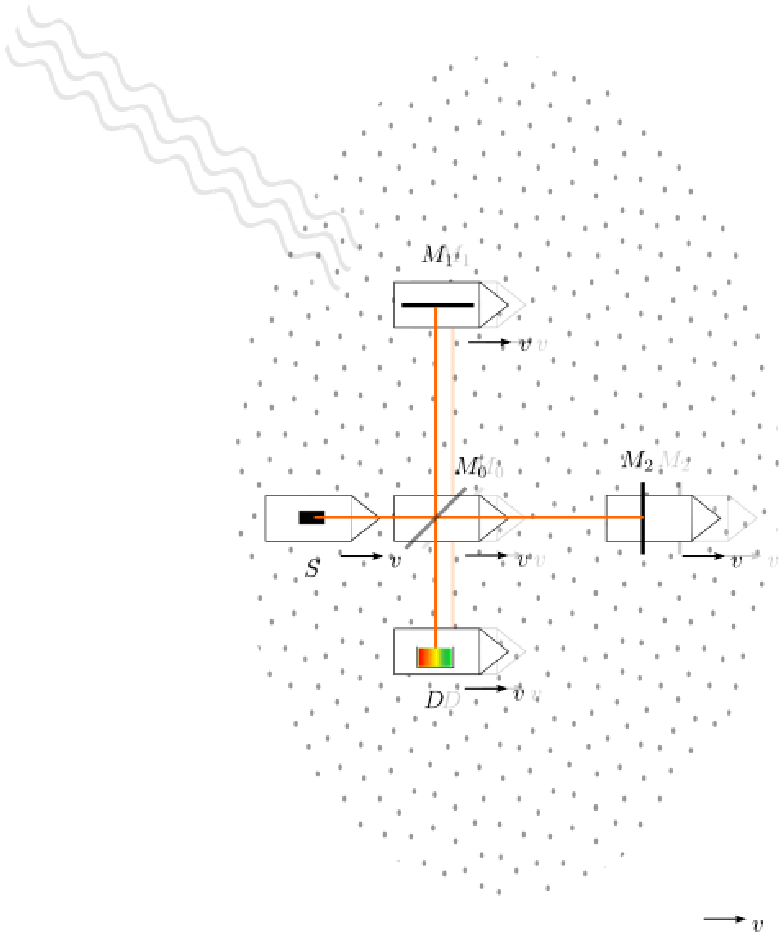
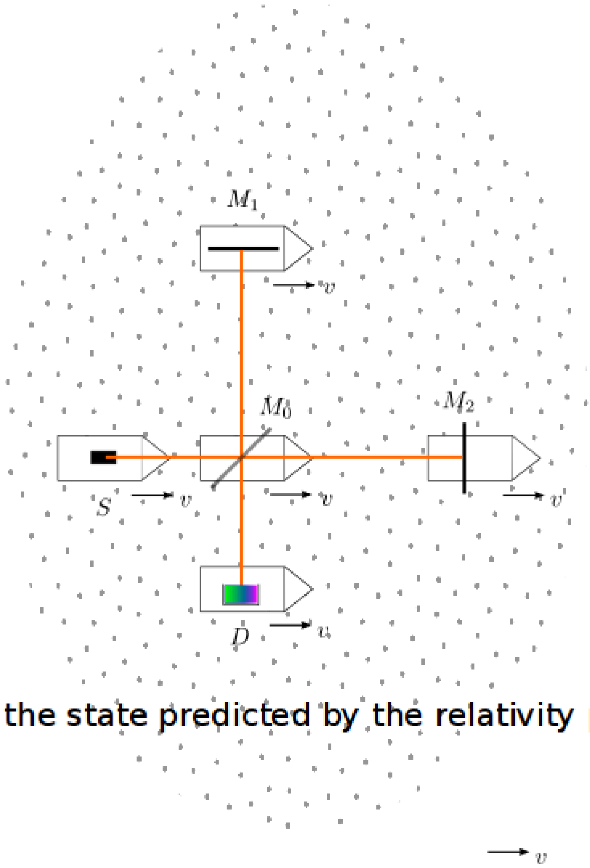


M_1
v
M_0
M_2
S
v
v
v
D
v
v



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Conclusions

- There is more to the RP than the simple requirement of the covariance of the physical equations. In fact, covariance says nothing about whether the RP is true or not.

- The meaning of the RP is relative to the concept of $M_{\mathbf{V}}(F)$. But, there seems no unambiguous meaning of $M_{\mathbf{V}}(F)$ in relativistic physics. (It would be completely untenable to claim that $M_{\mathbf{V}}(F) \stackrel{def}{=} T_{\mathbf{V}}^{-1}(P_{\mathbf{V}}(F))$, by definition. The RP would become a tautology!)

- Therefore, *in general, the RP is not an unambiguous statement, the validity of which could be empirically tested.*

- In some situations, *with absolutely reasonable understanding of* $M_{\mathbf{V}}(F)$, *the RP proves false!* Typically, it fails during the "relaxation process" of relativistic deformations.

- The RP is not a universal principle. It does not hold for the whole range of validity of the Lorentz covariant laws of relativistic physics.

- Hypothesis: *The RP only holds for the equilibrium quantities characterizing the equilibrium states of dissipative systems.*

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