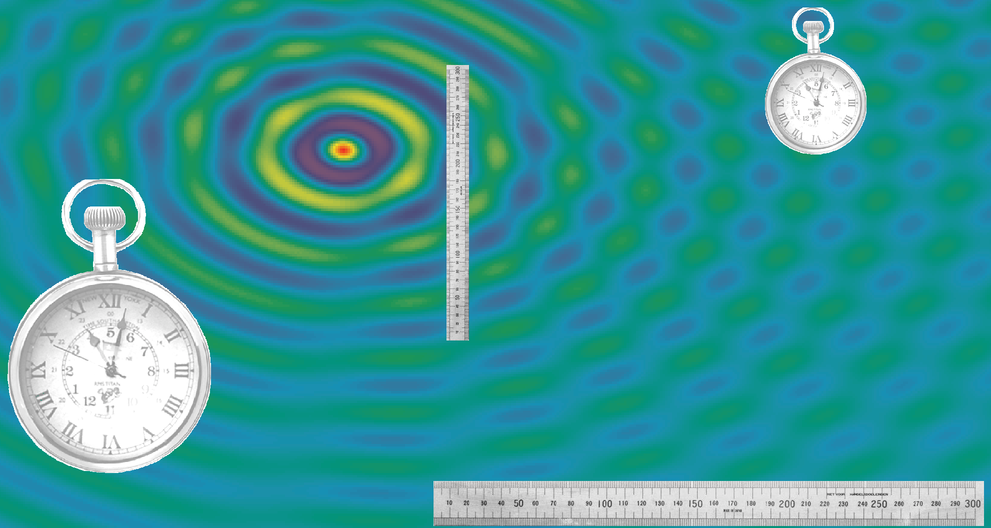
On the derivation of measurement relativity

V.-O. de Haan



Cover photograph:

In the ether the precise definition of clocks and rulers are the key elements to understand *measurement relativity*.

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In remembrance of

Jacob Pieter and Arnold Hugo,

with love

Contents

Preface

This book has been born from the research of the author into the possible experimental difference between the Lorentz ether theory and Einstein's special relativity theory. Lorentz himself regards both theories as giving the same results for the description of moving electro-magnetic systems or even more general for all systems.

There seem to be no established experiments in contradiction of special relativity theory, although quite a few authors report on such experiments, which as far as the author knows have never been accepted by main stream physics, nor have these experiments have had any influence on our daily lives.

The discovery of Wigner rotation inherent after two non-co-linear Lorentz transformations resulting in Thomas precession should have triggered a renewed interest in the search for possible differences, including the performance of accurate experiments. Unfortunately to the best of the author knowledge no such interest has emerged.

The aim of this book is therefore to arouse this interest and to give a theoretical background for the comparison of both theories.

Chapter 1

Introduction

Since at the end of the 19^{th} century methods became accurate enough to measure the speed of light, experiments were devised to measure the anisotropy of the speed of light at the Earth surface. This was sought to be done by so-called first order experiments, where the effect depends in first order on the ratio v/c , where v is the velocity of the observer with respect to a preferred rest frame and c is the speed of light in this frame. When Fresnel [1] introduced his famous Fresnel drag coefficient it was believed that all possible first order effects were compensated by an ether drag. Then Maxwell [2] came along with the notion of second order experiments, where the effect depends in second order on the same ratio. Although at the time Maxwell thought it beyond any means of experimental methods to measure a second order effect one year later in 1881 Michelson [3] devised an apparatus that should be able to measure the change of the velocity of the observer very accurately. The apparatus is now known as a Michelson-Morley interferometer. After some comments on the experiment by Lorentz in 1886 [4] Michelson and Morley [5, 6] increased the sensitivity of the apparatus with almost a factor of ten overcoming the accuracy objections of Lorentz. The accuracy of the apparatus was further increased with a factor of 6 by Morley and Miller [7],[8] and by Miller in a series of experiments between 1905 and 1930 [9, 10, 11, 12]. In all these experiments the expected magnitude of the effect was never observed. This is explained by the Lorentz contraction [13, 14] or by Einstein's special relativity theory [15].

However, Miller in his elaborate series of experiments, always claimed that he measured a small second order effect and also a first order effect. The second order effects were quite small with respect to the expected magnitude for the effect, but larger than the experimental error. He analyzed these second order effects by combining measurements at different epochs. Assuming the Sun moves relative to the preferred rest frame he was able to find a preferred direction in space and a velocity. The first order effect depended very much on the detailed experimental settings and were not analyzed to find an anisotropy.

In February 1927 a conference on the experiment and theoretical background was held at the Mount Wilson Observatory [16]. This conference did not succeed in finding a flaw in either experiment or theory, leaving the discrepancy intact. In view of this discrepancy some researchers tried to find experimental evidence of first or second order effects in Michelson-Morley interferometer type instruments. This has been done by, for instance, Piccard [17, 18, 19], Illingworth [20] and Joos [21]. All these authors report the absence of the expected magnitude of the effect.

In 1955 Shankland, a former pupil of Miller, re-analyzed Miller's data [22] and concluded that the second order effects do exist and remarks that they remain essential constant in phase and amplitude through periods of several hours and are then associated with a constant temperature pattern in the observation hut. Assuming that during several hours the second order effect should change considerably, he then concludes that there is no second order effect and contributes any other changes to temperature effects. However, it was already shown by Miller [12] that during several hours changes could be very small depending on the sidereal time and the epoch. Hence, the conclusion of Shankland is unsupported and the discrepancy between Miller's results and theoretical expectations remains.

In the following chapters a method is developed that can be used to find possible deviations from the expectations of special relativity theory and Lorentz ether theory. In literature it is often stated that Lorentz ether theory and special relativity give the same experimental results. Here it is shown that although in many cases this is true, it does not hold in general and hence an experiment can be devised to enable the choice between the one or the other.

Chapter 2

Waves in ether

2.1 Huygens principle

Many ether theories (the simple and more complicated ones) yield wave equations like

$$\frac{\partial^2 u}{\partial t^2} - c^2 \nabla^2 u = S(\vec{r}, t) \tag{2.1}$$

where t represents time flow, $\vec{r}$ is the location vector, u is either a scalar or a vector representing the essence of the wave (for instance a location of a particle with respect to its rest position, or the electric or magnetic field according to the Maxwell equations). c is a constant with the dimensions of a velocity and can be identified as the *wave velocity*. The function S corresponds to the source term.

If $S = 0$ the solution of the wave equations can be described by means of plane waves

$$u(\vec{r}, t) = \hat{u} \cos\left(\omega t - \vec{r} \cdot \vec{k} + \phi\right)$$

where $\hat{u}$ is called the *amplitude* of the wave, ω is called the *frequency*, $\vec{k}$ is called the *wave vector* and ϕ is the *phase* of the wave for $t = 0$ and $\vec{r} = 0$. This function is periodic in time with a *period*, $T = 2\pi/\omega$ and periodic in space with a *wavelength*, $\lambda = 2\pi/k$. Inserting this solution of the wave equation in equation (2.1) yields

$$\omega = kc \quad \text{or} \quad \lambda = cT$$

which is known as the *dispersion relation* for ether waves.

Waves can only be created by a source term different from 0. If this source term $S(\vec{r}, t)$ can be approximated by a Dirac delta function $\hat{S}\delta(\vec{r}, t)$ the solution of the wave equation is given by the Green function

$$u(\vec{r}, t) = \hat{S}\frac{\delta\left(t - \frac{r}{c}\right)}{4\pi r} \tag{2.2}$$

	Source 1	Source 2
Period	$T_1 = 1/c$	$T_2 = 1/c$
Velocity	$\vec{\beta}_1 = (0.5\ 0\ 0)^{\mathrm{T}}$	$\vec{\beta}_2 = (0\ 0.5\ 0)^{\mathrm{T}}$
Position	$\vec{R}_1 = (0\ 4\ 0)^{\mathrm{T}}$	$\vec{R}_2 = (0\ -4\ 0)^{\mathrm{T}}$
Start time	$t_1 = 0$	$t_2 = 0$

Table 2.1: Parameters of the two sources used in the examples.

which corresponds to a spherical wavefront expanding from its origin with the wave velocity. This is the basis for the Huygens principle put forward in his *Traité de la lumière* of 1690 [23].

2.2 Moving sources

Following Huygens principle, suppose that a wavefront is created in an Euclidean space R^3 at regular time intervals T_k, by point source k moving through the ether with velocity $c\vec{\beta}_k$, where c is the wave velocity in the ether. Here, *point source* means that the size of the source is much smaller than the emitted wavelength, λ_k, related with the time intervals T_k by the dispersion relation of the ether $\lambda_k = cT_k$. The first wavefront starts at t_k (ether time reference), the second at $t_k + T_k$ and in general the $(i+1)^{\mathrm{th}}$ wavefront at $t_k + iT_k$. When $\vec{R}_k$ is the position (ether coordinate system) of the source when the first wavefront is emitted, the position of the wavefront at a certain time t is given by

$$\begin{array}{lll} t < t_k + iT_k & : & \vec{r}_i = \vec{R}_k + c(t - t_k)\vec{\beta}_k \\ t \geq t_k + iT_k & : & \vec{r}_i = \vec{R}_k + icT_k\vec{\beta}_k + c(t - t_k - iT_k)\vec{\zeta}(\phi, \theta) \end{array} \tag{2.3}$$

where $i \in N$ and

$$\vec{\zeta}(\phi, \theta) = \begin{pmatrix} \cos\phi\sin\theta \\ \sin\phi\sin\theta \\ \cos\theta \end{pmatrix},$$

is a unit vector in an arbitrary direction. ϕ can vary between 0 and 2π, θ between 0 and π. The first line corresponds to the location of the source itself. There is no emitted wavefront, it is assumed to exist latent inside the source. Only after the creation at time $t_k + iT_k$, a real wavefront is present at locations given by the second line. Hence, this position corresponds to the location where the Green function given in equation (2.2) is non-zero.

As an example for two sources 1 and 2 with parameters as given in table 2.1 the wavefronts at different times are shown in figure 2.1. From left to right the time increases with steps of the period of source 1, starting from the pulse start time of source 1. Observe that the first point of contact of the wavefronts of source 1 and 2

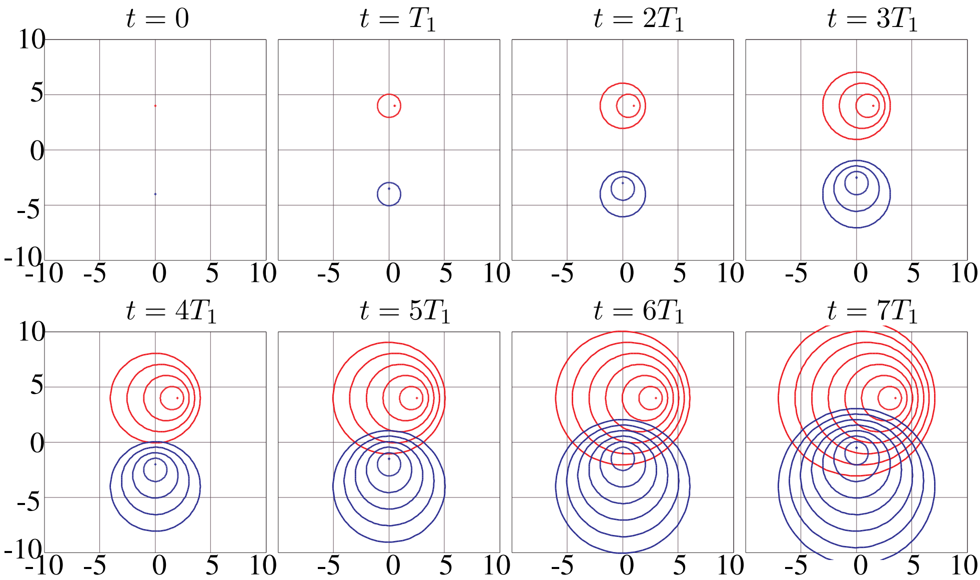

Figure 2.1: Position of wavefronts of sources 1 (red) and 2 (blue) for $z = 0$ with parameters shown in table 2.1 in the ether.

is at $t = 4T_k$ at the origin. As source 1 moves to the right, the center of the smaller circles representing ever younger wavefronts are shifted ever further to the right. The same occurs for source 2 albeit in a different direction according to the velocity of source 2.

2.3 Doppler effect

One can see in figure 2.1 that in the direction of motion the wavefronts are closer together than in the opposite direction. This is the well-known Doppler effect. The time difference between the sequential arrival of wavefronts emitted by the source at the observer location in the origin is defined by $T_o = t(\vec{r}_{i+1} = 0) - t(\vec{r}_i = 0)$. It is a measure for the Doppler effect. By eliminating $\zeta(\phi, \theta)$ from equation (2.3) one finds

$$t(\vec{r}_i = 0) - t_k = iT_k + a_i T_k$$

where $\vec{a}_i \lambda_k = \vec{R}_k + i\vec{\beta}_k \lambda_k$ equals the location of the source when the detected wavefront was emitted. The propagation direction of the wavefronts at the observers location, $\vec{\kappa}_i$ is the direction in which the location of a wavefront $\vec{r}_i$ changes when the time is increased by dt, hence by definition

$$\vec{\kappa}_i = \frac{\vec{v}_i}{v_i} \tag{2.4}$$

where $\vec{v}_i$ is the velocity of the wavefront, given by

$$\vec{v}_i = \frac{d\vec{r}_i}{dt} = c\vec{\zeta}(\phi, \theta) = -c\vec{a}_i/a_i$$

so that $\vec{\kappa}_i = -\vec{a}_i/a_i$. Now,

$$\frac{T_o}{T_k} = 1 + |\vec{a}_i + \vec{\beta}_k| - |\vec{a}_i|$$

T_o obviously depends on T_k and $\vec{\beta}_k$, but in general also depends on $\vec{R}_k$ and i. If the origin of the emitted wavefronts is far away from the observer so that $a_i >> 1$, then the wavefronts can locally be approximated by planes moving in direction $\vec{\kappa}_i$. The above equation reduces to

$$\frac{T_o}{T_k} = 1 - \vec{\kappa}_i \cdot \vec{\beta}_k + \frac{1}{2a_i}\left(\beta_k^2 - (\vec{\kappa}_i \cdot \vec{\beta}_k)^2\right) + O^2(1/a_i) \tag{2.5}$$

where the first two terms correspond to the Doppler effect for plane waves emitted by a moving source in a medium with a limited wave velocity. The third term is due to the curvature of the wavefront and is in normal situations negligible.

Chapter 3

Infinite signal speed

3.1 Galilean transformation

When an observer, being at ether time t_o at a location $\vec{R}_o$ in the ether coordinate system, is moving with respect to the ether with a velocity $\vec{\beta}_o$, then the wavefronts have a location with respect to the observer given by the Galilean transformation

$$\vec{r}^g = \vec{r} - \vec{R}_o - c(t - t_o)\vec{\beta}_o \tag{3.1}$$

and the observers reference time is

$$t^g = t - t_o \tag{3.2}$$

Hence, when the observer moves along with the first point source and he would be able to *instantly* observe the ether disturbances, he would observe the position of the wavefronts of a source k according to

$$\begin{array}{lcl} t^g < t_k^g + iT_k^g & : & \vec{r}_i^g = \vec{R}_k^g + c(t^g - t_k^g)\vec{\beta}_k^g \\ t^g \geq t_k^g + iT_k^g & : & \vec{r}_1^g = \vec{R}_k^g + icT_k^g\vec{\beta}_k^g + c(t^g - t_k^g - iT_k^g)(\vec{\zeta}(\phi,\theta) - \vec{\beta}_o) \end{array} \tag{3.3}$$

where the velocity of the source with respect to the observer

$$\vec{\beta}_k^g = \vec{\beta}_k - \vec{\beta}_o$$

is the *Galilean velocity composition law* and $\vec{R}_k^g = \vec{R}_k - \vec{R}_o - c(t_k - t_o)\vec{\beta}_o$, $t_k^g = t_k - t_o$ are the Galilean transformations of the source point location and time when the source emits its first wavefront. Here it is assumed that the period of the source does not depend on its velocity with respect to the ether, $T_k^g = T_k$.

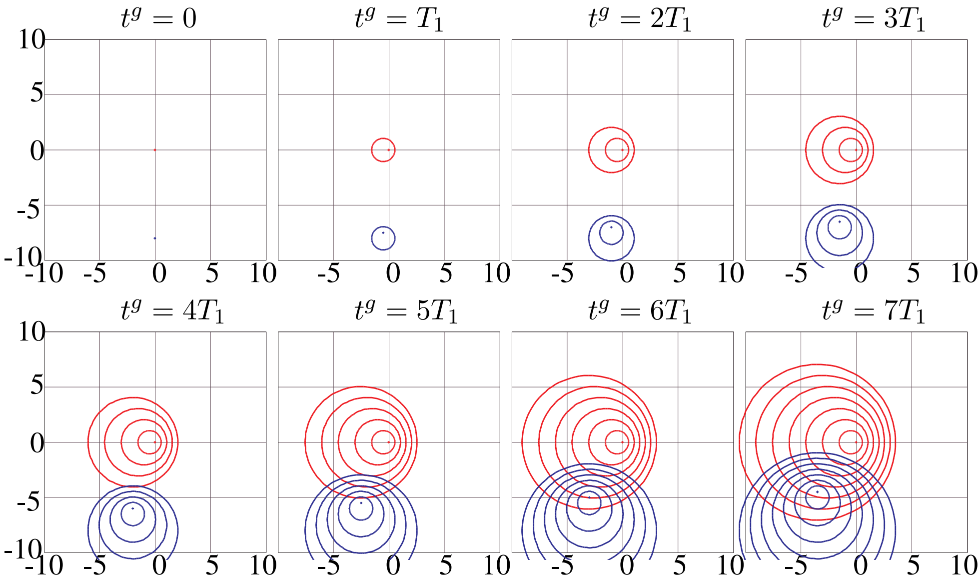

Figure 3.1: Position of wavefronts of sources 1 (red) and 2 (blue) for $z = 0$ with parameters shown in table 2.1 as would be observed by an observer moving along with source 1 when he would be able to *instantly* observe the ether disturbances.

3.2 Co-moving observer

Now let us return to figure 2.1. For the observer co-moving with source 1 $\vec{\beta}_1^g = 0$, and hence the wavefronts are always emitted from the same point with respect to the observer. After that, the wavefronts seem to 'drift away' to a direction opposite to the observers velocity direction. This is shown in figure 3.1 for the example system. The first point of contact is for $t^g = 4T_1$ the same as before, but the location is shifted to the right due to the motion of the observer with respect to the ether. Again as both sources are moving in the ether the wavefronts in the direction of motion are closer together than in the opposite direction.

3.3 Doppler effect

The Doppler effect for these sources can be defined is a similar way as before: $T_o^g = t^g(\vec{r}_{i+1}^g = 0) - t^g(\vec{r}_i^g = 0)$. By eliminating $\zeta(\phi, \theta)$ from the above equation one finds

$$t^g(\vec{r}_i^g = 0) - t_k^g - iT_k^g = |(t^g(\vec{r}_i^g = 0) - t_k^g - iT_k^g)\vec{\beta}_o - \vec{R}_k^g/c - iT_k^g\vec{\beta}_k^g|$$

or

$$t^g(\vec{r}_i^g = 0) = t_k^g + iT_k^g + \gamma_o T_k^g \left(\sqrt{\left(\gamma_o \vec{\beta}_o \cdot \vec{a}_i^g\right)^2 + (a_i^g)^2} - \gamma_o \vec{\beta}_o \cdot \vec{a}_i^g \right)$$

where $\gamma_o = 1/\sqrt{1-\beta_o^2}$ and $\vec{a}_i^g \lambda_k^g = \vec{R}_k^g + i\vec{\beta}_k^g \lambda_k^g$ equals the location of the source with respect to the observer at the moment that the detected wavefront was emitted. The propagation direction of the wavefronts at the observers location, $\vec{\kappa}_i^g$ is defined by equation (2.4). For the observer the velocity of the wavefront is given by

$$\vec{v}_i^g = \frac{d\vec{r}_i^g}{dt^g} = c(\vec{\zeta}(\phi,\theta) - \vec{\beta}_o) = -c \frac{\vec{a}_i^g}{\gamma_o \left(\sqrt{\left(\gamma_o \vec{\beta}_o \cdot \vec{a}_i^g\right)^2 + (a_i^g)^2} - \gamma_o \vec{\beta}_o \cdot \vec{a}_i^g \right)}$$

so that $\vec{\kappa}_i^g = -\vec{a}_i^g / a_i^g$. Now,

$$\frac{T_o^g}{T_k^g} = 1 - \gamma_o^2 \vec{\beta}_o \cdot \vec{\beta}_k^g + \gamma_o \left(\sqrt{\left(\gamma_o \vec{\beta}_o \cdot \vec{a}_{i+1}^g\right)^2 + (a_{i+1}^g)^2} - \sqrt{\left(\gamma_o \vec{\beta}_o \cdot \vec{a}_i^g\right)^2 + (a_i^g)^2} \right)$$

which of coarse depends on T_k^g and $\vec{\beta}_o$ and $\vec{\beta}_k^g$, but in general also depends on $\vec{R}_k^g$ and i. If the origin of the emitted wavefronts is far away from the observer so that $a_i^g >> 1$, then the wavefronts can locally be approximated by planes propagating in direction $\vec{\kappa}_i^g$. Up to first order in $1/a_i^g$ the above equation reduces to

$$\frac{T_o^g}{T_k^g} = \frac{1 - \vec{\zeta} \cdot (\vec{\beta}_k^g + \vec{\beta}_o)}{1 - \vec{\zeta} \cdot \vec{\beta}_o} = \frac{1 - \vec{\zeta} \cdot \vec{\beta}_k}{1 - \vec{\zeta} \cdot \vec{\beta}_o} \tag{3.4}$$

where

$$\vec{\zeta} = \vec{\beta}_o + \vec{\kappa}_i^g \left(\sqrt{1 - \beta_o^2 + (\vec{\beta}_o \cdot \vec{\kappa}_i^g)^2} - \vec{\beta}_o \cdot \vec{\kappa}_i^g \right)$$

is a unit vector indicating the propagation direction of the wave at the observer position as determined by *an observer at rest with respect to the ether* as it is defined by

$$\frac{\vec{\zeta} - \vec{\beta}_o}{|\vec{\zeta} - \vec{\beta}_o|} = \vec{\kappa}_i^g$$

3.4 Aberration

Equation (3.4) gives the Doppler effect for waves emitted by a moving source and detected by an observer moving in a medium with a limited wave velocity. It is usual assumed to be the classical Doppler effect for wave propagating through a medium like air or ether. However, from the above it is clear that the propagation direction

Figure 3.2: Absolute (Left) and relative (Right) rays due to motion of their source in the ether. The angle of aberration, α is the angle between the normal on the wavefronts and their propagation direction.

of the wave as observed by the moving observer is not $\vec{\zeta}$, but $\vec{\kappa}_i^g$. This difference was well known in the past as the difference between *absolute* and *relative* rays (see figure 3.2). For absolute rays the wavefront is perpendicular to the propagation direction. For relative rays the difference between these two directions is what is known as *aberration*. The angle of aberration can be found by

$$\alpha = \text{acos}(\vec{\zeta} \cdot \vec{\kappa}_i^g) = \text{asin}\,(\beta_o \sin \alpha_k)$$

where $\alpha_k = \angle(\vec{\beta}_o, \vec{\kappa}_i^g)$, equals the angle between the observers velocity and the propagation direction of the wavefront.

3.5 Transverse Doppler effect

When the source is rotated around the observer, obviously both $\vec{\zeta}$ and $\vec{\kappa}_i^g$ make a complete revolution. Hence, the minimum and maximum of the Doppler effect is not affected but the shape of the curve as function of the position of the source with respect to the observer can be quite different for source velocities close to the wave velocity. In figure 3.3 an example is shown of the relative frequency change as determined by an observer moving with respect to a source stationary in the ether as function of the angle between $\vec{\kappa}_i^g$ and $\vec{\beta}_o$ (left) or $\vec{\zeta}$ and $\vec{\beta}_o$ (right) for $\beta_o = 0.1, 0.5$ and 0.9. The functions in the right graph are just cosine functions of the angle. The amplitude is determined by β_o. The functions in the left graph are almost the same when β_o is small. For larger velocities the functions change shape, for $\gamma_o >> 1$ changing to

$$\begin{array}{lcl} \cos\angle(\vec{\kappa}_i^g, \vec{\beta}_o) \geq 0 & : & \frac{\Delta f}{f} = -1 + \gamma_o^{-2}/2 + O^4(1/\gamma_o) \\ \cos\angle(\vec{\kappa}_i^g, \vec{\beta}_o) < 0 & : & \frac{\Delta f}{f} = -1 + 2\cos^2\angle(\vec{\kappa}_i^g, \vec{\beta}_o) + O^2(1/\gamma_o) \end{array}$$

where the frequency for an observer moving away from the source becomes very small: the waves take much longer time to pass the observer.

When $\vec{\beta}_o \perp \vec{\kappa}_i^g$ then

$$\frac{T_o^g}{T_k^g} = 1 - \gamma_o \vec{\beta}_k^g \cdot \left(\gamma_o \vec{\beta}_o + \vec{\kappa}_i^g\right)$$

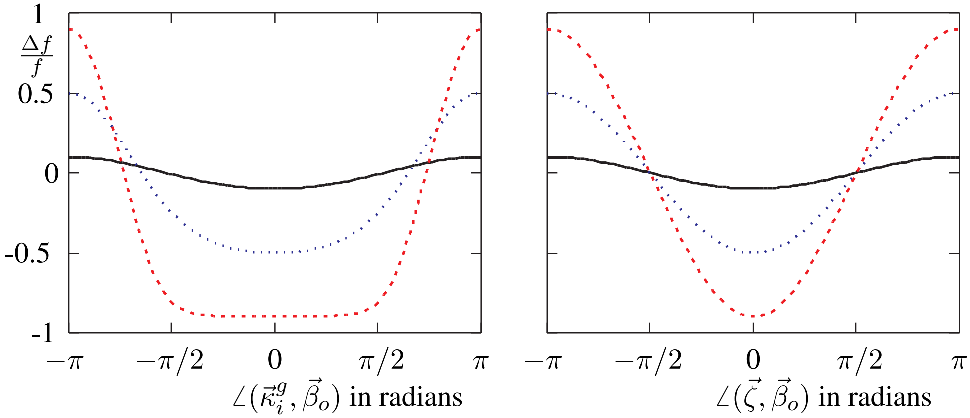

Figure 3.3: Relative frequency change, $\Delta f / f$ as determined by an observer moving with respect to a source stationary in the ether as function of the angle between $\vec{\kappa}_i^g$ and $\vec{\beta}_o$ (left) or $\vec{\zeta}$ and $\vec{\beta}_o$ (right) for $\beta_o = 0.1$ (black full line), 0.5 (blue dotted line) and 0.9 (red dashed line).

If the source is stationary with respect to the ether this reduces further to

$$\frac{T_o^g}{T_k^g} = \gamma_o^2$$

a transverse Doppler effect. However, if in such a case there is a small angle between $\vec{\beta}_o$ and $\vec{\kappa}_i^g$ so that their inner product is $-\beta_o^2/\sqrt{1+\beta_o^2}$ the transverse effect is completely vanished making the detection virtually impossible.

Chapter 4

Finite signal speed

When the observer has to use the ether waves themselves to determine the position of the ether disturbances, he has to take into account his own velocity with respect to the ether to determine the actual position of the wavefronts in the ether at a certain ether time. However, if he assumes he is stationary with respect to the ether (or equivalent that light travels in all directions with a constant velocity c), then he assumes that the wavefronts of a source (stationary and coinciding with respect to the observer) propagate with uniform velocity away from him. This constitutes his coordinate system. Note that this is only an imaginary system based on the *assumption* that his own velocity with respect to the ether is 0.

4.1 Observer time unit

According to the International System of Units [24] the second is

the duration of 9 192 631 770 periods, T_{Cs} of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the Cesium 133 atom.

A calibration of the observer time unit entails the observation of this period of radiation. What is not defined in this system of units is the velocity of the Cesium atom with respect to the ether, $c\vec{\beta}_o$. However, when ether would exists it is possible that this velocity might influence the period of the radiation [25], [26],[27],[28],[29]. Without detailed knowledge of the interaction between ether and the Cesium atom, it is impossible to assume that the period will be independent of the velocity. However, when the ether is homogeneous and isotropic, only the magnitude of the velocity can be of influence. Therefor it is assumed that the period of the Cesium atom varies with its velocity with respect to the ether according to the following relation

$$T_{Cs}(\beta_o) = \frac{T_{Cs}(0)}{\tau_o(\beta_o)} \tag{4.1}$$

Under this assumption the (in-)famous clock paradox introduced by Langevin in 1911 [30] and extensively discussed by for instance Dingle [31] does not occur, as there is no symmetry. The effect is due to the velocity with respect to the ether, not due to the velocity with respect to the observer.

4.2 Observer distance measurement

According to the same International System of Units [32] the meter is

the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second

It follows that the speed of light in vacuum is exactly 299 792 458 meters per second, c = 299 792 458 m/s. Hence, when an observer wants to determine a distance, he measures the time, Δt^o of a forth and back trip by means of his Cesium atom clock and calculates the distance as $c\Delta t^o$, so that automatically the speed of light is constant.

Let us take two observers and two equivalent sources, stationary with respect to each other, but moving with a velocity $c\vec{\beta}_o$ with respect to the ether. Observer 1 and source 1 are located at $\vec{R}_1$ in the ether at time, $t = t_1$ source 1 starts pulsing with a period of T. According to equation (2.3) the wavefronts emitted by source 1 are at location

$$\begin{array}{lcl} t < t_1 + iT & : & \vec{r}_1 = \vec{R}_1 + c(t - t_1)\vec{\beta}_o \\ t \geq t_1 + iT & : & \vec{r}_1 = \vec{R}_1 + icT\vec{\beta}_o + c(t - t_1 - iT)\vec{\zeta}(\phi, \theta) \end{array} \tag{4.2}$$

Observer 1 and 2 have agreed that observer 1 would start source 1 first and when the first ether disturbance of source 1 would reach observer 2, observer 2 would start source 2. Hence, the wavefronts emitted by source 2 are at location

$$\begin{array}{lcl} t < t_2 + iT & : & \vec{r}_2 = \vec{R}_2 + c(t - t_1)\vec{\beta}_o \\ t \geq t_2 + iT & : & \vec{r}_2 = \vec{R}_2 + c(t_2 - t_1 + iT)\vec{\beta}_o + c(t - t_2 - iT)\vec{\zeta}(\phi, \theta) \end{array} \tag{4.3}$$

where $\vec{R}_2$ is the location of source 2 at $t = t_1$ and t_2 is the ether time when source 2 starts pulsing. Hence,

$$\vec{R}_2 - \vec{R}_1 = c(t_2 - t_1)(\vec{\zeta}(\phi, \theta) - \vec{\beta}_o)$$

Eliminating $\vec{\zeta}(\phi, \theta)$ gives

$$c(t_2 - t_1) = \gamma_o^2 \vec{\beta}_o \cdot (\vec{R}_2 - \vec{R}_1) + \gamma_o \sqrt{(\gamma_o \vec{\beta}_o \cdot (\vec{R}_2 - \vec{R}_1))^2 + |\vec{R}_2 - \vec{R}_1|^2} \quad (4.4)$$

where again $\gamma_o = 1/\sqrt{1 - \beta_o^2}$. The wavefront emitted by source 2 reaches observer 1 again at an ether time $t = t_1 + \tau_{121}$ so that

$$\vec{R}_2 - \vec{R}_1 = c(t_2 - t_1 - \tau_{121})(\vec{\zeta}(\phi, \theta) - \vec{\beta}_o)$$

Again eliminating $\vec{\zeta}(\phi, \theta)$ gives

$$c(t_2 - t_1 - \tau_{121}) = \gamma_o^2 \vec{\beta}_o \cdot (\vec{R}_2 - \vec{R}_1) - \gamma_o \sqrt{(\gamma_o \vec{\beta}_o \cdot (\vec{R}_2 - \vec{R}_1))^2 + |\vec{R}_2 - \vec{R}_1|^2}$$

so that

$$\frac{\tau_{121}}{2} = \frac{\gamma_o}{c} \sqrt{(\gamma_o \vec{\beta}_o \cdot (\vec{R}_2 - \vec{R}_1))^2 + |\vec{R}_2 - \vec{R}_1|^2} \quad (4.5)$$

This is also the time difference if observer 2 would start pulsing and observer 1 would react, so that $\tau_{212} = \tau_{121}$. Of coarse this can be generalized by a multitude of observer and source pairs by using the appropriate values for $\vec{R}_1$ and $\vec{R}_2$.

4.3 Observer coordinate system

To define an Cartesian coordinate system in 3-dimensional Euclidean space, measurements of 6 distances between 4 points are needed. For instance the length of the edges of a regular tetrahedron of which all four faces are equilateral triangles. Then all distances between the points are equal. It is also possible to use four points of a corner of a cube. Then there are 3 distances with the length of an edge length a and 3 distances with a length of $a\sqrt{2}$. The advantage is that the vectors along these edges are perpendicular to each other, constituting a Cartesian coordinate system (see figure 4.1).

Let 4 of the above mentioned observer and source pairs arrange themselves with respect to each other so that the distances between them are constant and correspond to figure (4.1) and table 4.1. Note that $\vec{R}_{mn} = \vec{R}_m - \vec{R}_n$. Actually the observers do not measure the distance but the time Δt^o it takes for an ether disturbance to move forth and back between the points (see chapter 4.2). They measure a time difference according to their Cesium atom clock Δt^o and assume that the ether disturbances propagate with the speed of light, so that $a = c\Delta t^o \tau_o$, where τ_o is the time ratio defined by equation (4.1).

The observers have agreed that the direction between observers 1 and 2 should be their x-axis represented in the ether coordinates by $\vec{u}_x$, and so on. Hence, according to the co-moving observers, a point represented by coordinates (x^o, y^o, z^o) is at a location represented by vector $x^o \vec{u}_x + y^o \vec{u}_y + z^o \vec{u}_z$, where they assume that $\vec{u}_x$, $\vec{u}_y$ and $\vec{u}_z$ are unit vectors which constitute a Cartesian coordinate system.

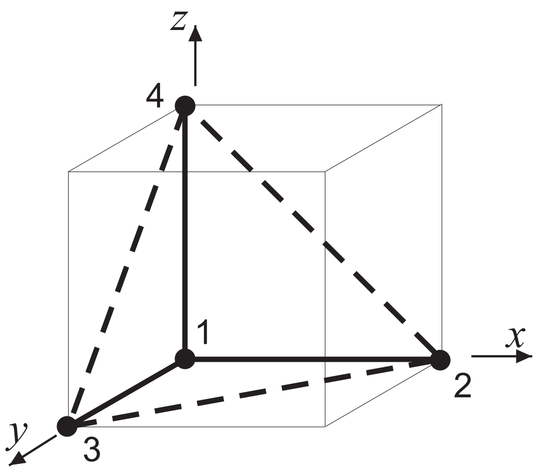

Figure 4.1: Four points of a corner of a cube with 3 distances with the length of an edge length a (full lines) and 3 distances with a length of $a\sqrt{2}$ (dashed lines). The vectors along the edges are perpendicular to each other, constituting a Cartesian coordinate system.

In reality and in general these vectors are neither of unit length neither are they perpendicular to each other. However, by measuring distances these observers have no way of knowing their wrong assumptions.

In ether coordinates the same point is represented by

$$\vec{R} = \vec{r} - ct\vec{\beta}_o \tag{4.6}$$

where $\vec{R} = (x\ y\ z)^{\mathrm{T}}$ is used as a reference to the point moving through the ether according to $\vec{r} = \vec{R} + ct\vec{\beta}_o$.

To find a linear mapping between (x^o, y^o, z^o) and (x, y, z) a scaling law is assumed due to *the properties of homogeneity that we attribute to space and time* as Einstein put it [15]. There is just one fixed direction $\vec{\beta}_o$, so that a different scaling in the direction parallel and perpendicular to $\vec{\beta}_o$ is used. Then

$$\begin{gathered} \vec{R^o}_\perp = \xi \vec{R}_\perp \quad \text{and} \quad \vec{R^o}_\| = \psi \vec{R}_\| \\ ((R^o)^2 - \xi^2 R^2)\beta_o^2 = (\psi^2 - \xi^2)(\vec{\beta}_o \cdot \vec{R})^2 \\ (\vec{\beta}_o \cdot \vec{R^o}) = \psi(\vec{\beta}_o \cdot \vec{R}) \end{gathered} \tag{4.7}$$

where $\vec{R^o} = (x^o\ y^o\ z^o)^{\mathrm{T}}$, $\vec{R}_\| = (\vec{\beta}_o \cdot \vec{R})\vec{\beta}_o/\beta_o^2$ and $\vec{R}_\perp = \vec{R} - \vec{R}_\|$. ψ and ξ can be found by inserting this equation in the relations shown in table 4.1 and remembering that $\vec{R}_{21}$ corresponds to $\vec{R^o} = (c\Delta t^o\ 0\ 0)^{\mathrm{T}}$ (and similar relations for $\vec{R}_{31}$ and $\vec{R}_{41}$),

First	Second	Direction	Time measured = Ether time
1	2	$\vec{u}_x$	$\Delta t^o \tau_o = \frac{\gamma_o}{c}\sqrt{(\gamma_o \vec{\beta}_o \cdot \vec{R}_{21})^2 + R_{21}^2}$
1	3	$\vec{u}_y$	$\Delta t^o \tau_o = \frac{\gamma_o}{c}\sqrt{(\gamma_o \vec{\beta}_o \cdot \vec{R}_{31})^2 + R_{31}^2}$
1	4	$\vec{u}_z$	$\Delta t^o \tau_o = \frac{\gamma_o}{c}\sqrt{(\gamma_o \vec{\beta}_o \cdot \vec{R}_{41})^2 + R_{41}^2}$
2	3	$\vec{u}_x - \vec{u}_y$	$\Delta t^o \tau_o \sqrt{2} = \frac{\gamma_o}{c}\sqrt{(\gamma_o \vec{\beta}_o \cdot \vec{R}_{32})^2 + R_{32}^2}$
2	4	$\vec{u}_z - \vec{u}_x$	$\Delta t^o \tau_o \sqrt{2} = \frac{\gamma_o}{c}\sqrt{(\gamma_o \vec{\beta}_o \cdot \vec{R}_{42})^2 + R_{42}^2}$
3	4	$\vec{u}_y - \vec{u}_z$	$\Delta t^o \tau_o \sqrt{2} = \frac{\gamma_o}{c}\sqrt{(\gamma_o \vec{\beta}_o \cdot \vec{R}_{43})^2 + R_{43}^2}$

Table 4.1: Time difference measured between 4 observer and source pairs to constitute a Cartesian coordinate system as the corner points of a cube shown in figure 4.1.

yielding

$$\begin{array}{c} ((c\Delta t^o)^2 - \xi^2 R_{12}^2)\beta_o^2 = (\psi^2 - \xi^2)(\vec{\beta}_o \cdot \vec{R}_{21})^2 \\ \text{or} \\ (\gamma_o^2 - (\xi\tau)^2)\beta_o^2 R_{12}^2 = ((\psi\tau_o)^2 - (\xi\tau_o)^2 - \gamma_o^4\beta_o^2)(\vec{\beta}_o \cdot \vec{R}_{21})^2 \end{array} \tag{4.8}$$

which is satisfied if and only if

$$\xi = \gamma_o/\tau_o \qquad \text{and} \qquad \psi = \gamma_o^2/\tau_o$$

so that

$$\begin{aligned} \vec{R^o} &= \tfrac{\gamma_o}{\tau_o}\left(\vec{R}_\perp + \gamma_o \vec{R}_\parallel\right) \\ &= \tfrac{\gamma_o}{\tau_o}\left(\vec{R} + (\gamma_o - 1)\vec{R}_\parallel\right) \\ &= \tfrac{\gamma_o}{\tau_o}\left(\vec{R} + \tfrac{\gamma_o^2}{1+\gamma_o}(\vec{\beta}_o \cdot \vec{R})\vec{\beta}_o\right) \\ (\vec{\beta}_o \cdot \vec{R^o}) &= \tfrac{\gamma_o}{\tau_o}\gamma_o(\vec{\beta}_o \cdot \vec{R}) \\ R^o &= \tfrac{\gamma_o}{\tau_o}\sqrt{R^2 + \gamma_o^2(\vec{\beta}_o \cdot \vec{R})^2} \end{aligned} \tag{4.9}$$

or inverse

$$\begin{aligned} \vec{R} &= \tfrac{\tau_o}{\gamma_o}\left(\vec{R^o}_\perp + \tfrac{1}{\gamma_o}\vec{R^o}_\parallel\right) \\ &= \tfrac{\tau_o}{\gamma_o}\left(\vec{R^o} + \tfrac{1-\gamma_o}{\gamma_o}\vec{R^o}_\parallel\right) \\ &= \tfrac{\tau_o}{\gamma_o}\left(\vec{R^o} - \tfrac{\gamma_o}{1+\gamma_o}(\vec{\beta}_o \cdot \vec{R^o})\vec{\beta}_o\right) \\ (\vec{\beta}_o \cdot \vec{R}) &= \tfrac{\tau_o}{\gamma_o^2}(\vec{\beta}_o \cdot \vec{R^o}) \\ R &= \tfrac{\tau_o}{\gamma_o}\sqrt{(R^o)^2 - (\vec{\beta}_o \cdot \vec{R^o})^2} \end{aligned} \tag{4.10}$$

In the case of sound waves the clock rate is not affected, so that $\tau_o = 1$ and these equation are comparable to the Prandtl-Glauert transformations used in aerodynamic calculations in a uniform moving air flow [33],[34].

The 6 equations of table 4.1 can be rearranged to express the following relations between $\vec{u}_x$, $\vec{u}_y$, $\vec{u}_z$ and $\vec{\beta}_o$

$$\begin{aligned}
&|\vec{u}_x|^2 = \tau_o^2(1-\beta_o^2) - \gamma_o^2(\vec{\beta}_o \cdot \vec{u}_x)^2 \\
&|\vec{u}_y|^2 = \tau_o^2(1-\beta_o^2) - \gamma_o^2(\vec{\beta}_o \cdot \vec{u}_y)^2 \\
&|\vec{u}_z|^2 = \tau_o^2(1-\beta_o^2) - \gamma_o^2(\vec{\beta}_o \cdot \vec{u}_z)^2 \\
&\vec{u}_x \cdot \vec{u}_y + \gamma_o^2(\vec{\beta}_o \cdot \vec{u}_x)(\vec{\beta}_o \cdot \vec{u}_y) = 0 \\
&\vec{u}_y \cdot \vec{u}_z + \gamma_o^2(\vec{\beta}_o \cdot \vec{u}_y)(\vec{\beta}_o \cdot \vec{u}_z) = 0 \\
&\vec{u}_z \cdot \vec{u}_x + \gamma_o^2(\vec{\beta}_o \cdot \vec{u}_z)(\vec{\beta}_o \cdot \vec{u}_x) = 0
\end{aligned} \tag{4.11}$$

It can be checked that all relations of equation (4.11) are satisfied by transformation (4.9). These equations can be used to determine the distance measured between an observer and source pair at $x_1^o\vec{u}_x + y_1^o\vec{u}_y + z_1^o\vec{u}_z$ and one at $x_2^o\vec{u}_x + y_2^o\vec{u}_y + z_2^o\vec{u}_z$ as given by equation (4.5)

$$|(x_1^o - x_2^o)\vec{u}_x + (y_1^o - y_2^o)\vec{u}_y + (z_1^o - z_2^o)\vec{u}_z| = \tag{4.12}$$

$$\sqrt{(x_1^o - x_2^o)^2 + (y_1^o - y_2^o)^2 + (z_1^o - z_2^o)^2}$$

which is the correct value for the norm in a Euclidean space represented by a Cartesian coordinate system.

4.4 Clock synchronization

When an observer B wants to synchronize his clock with another observer A, the distance measurement as described in chapter 4.2 is used to calculate the time that the first pulse was emitted. The observers *assume* that both time intervals for traveling forth and back are equal and half the measured time. Hence, the observer B thinks that the time that the first pulse of source A was emitted as determined by the observer B is

$$t'_B = t_A + \gamma_o^2 \frac{\vec{\beta}_o \cdot (\vec{R}_B - \vec{R}_A)}{c} \tag{4.13}$$

which differs from t_A

To generalize this, the time delay with respect to $\vec{R}_A = 0$ (i.e. the location of the ether origin at $t = 0$) can be included into the time coordinate of any co-moving observer, so that

$$t' = t - \gamma_o^2 \frac{\vec{\beta}_o \cdot \vec{R}}{c}$$

using equation (4.6)

$$t' = \gamma_o^2 \left(t - \frac{\vec{\beta}_o \cdot \vec{r}}{c} \right)$$

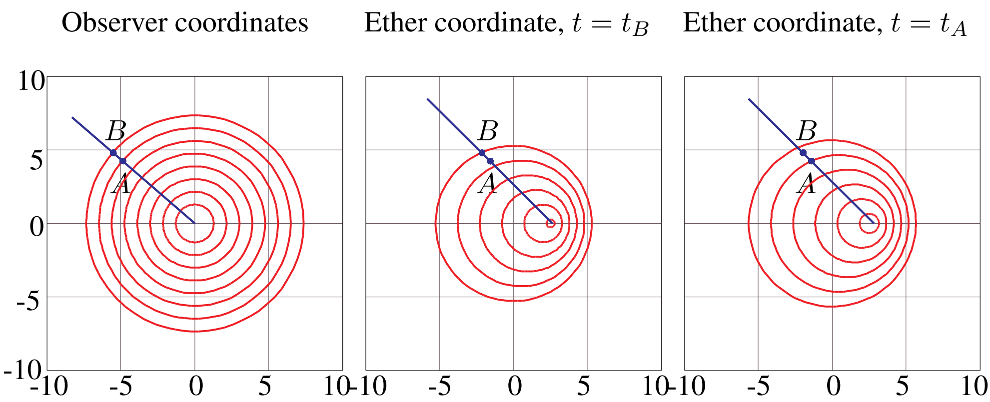

Figure 4.2: Location of source, wavefronts and observers A and B for wavelength measurement. Left: In observer coordinates, Middle: In ether coordinates at the moment the first wavefront reaches observer B. Right: In ether coordinates at the moment the second wavefront reaches observer A. The blue line goes trough the position of the observers and the source.

The observed time is measured by the clock of the observer, for which holds $dt^o = dt'/\tau_o$, so that the observed time becomes

$$t^o = \frac{\gamma_o^2}{\tau_o}\left(t - \frac{\vec{\beta}_o \cdot \vec{r}}{c}\right) \tag{4.14}$$

This can be denoted as the *local time* as was done for instance by Lorentz [35]. His initial interpretation of this time was that it could be used as an auxiliary variable reducing the complexity of the equations. After 1905 he realized that this local time is indistinguishable from the time as measured by the observer. Here, it is stressed that the local time is due to the change of clock rate (according to equation (4.1) and the way the clocks are synchronized using ether disturbance propagation under the a-priory assumption that the observer is stationary with respect to the ether.

4.5 Wavelength measurement

Two observers A and B agree to measure the distance between two sequential wavefronts emitted by a source at the origin of the observer's coordinate system. This corresponds to the wavelength of the waves emitted by the source. Hence, they position themselves in line with the source in such a way that they observe *simultaneously* the passing of the wavefronts emitted by the source (see figure 4.2). The first observer is at location $\vec{r_A^o}$ or in ether coordinates $ct\vec{\beta}_o + \vec{r}_A$, where $\vec{r}_A$ is calculated according to equation (4.10). The second observer is at location $(1+\alpha)\vec{r_A^o}$

or in ether coordinates, $ct\vec{\beta}_o + (1+\alpha)\vec{r}_A$. The observers will measure a distance of αr_A^o, while an observer at rest with respect to the ether will measure a distance of αr_A. What observers A and B interpret as simultaneous is not at the same time in the ether coordinates as was shown in chapter 4.4. The ether time difference between the second and first observer is given by equation (4.13)

$$t_B - t_A = \frac{\alpha}{c}\gamma_o^2\vec{\beta}_o \cdot \vec{r}_A$$

The time, t_A is determined by the arrival time of the second wavefront emitted by the source at the origin at the location of the first observer, so that using equation (4.4)

$$t_A = T + \frac{\gamma_o}{c}\left(\gamma_o\vec{\beta}_o \cdot \vec{r}_A + \sqrt{(\gamma_o\vec{\beta}_o \cdot \vec{r}_A)^2 + r_A^2}\right)$$

and the time, t_B is determined by the arrival time of the first wavefront emitted by the source at the location the second observer, so that again using equation (4.4)

$$t_B = \frac{\gamma_o(1+\alpha)}{c}\left(\gamma_o\vec{\beta}_o \cdot \vec{r}_A + \sqrt{(\gamma_o\vec{\beta}_o \cdot \vec{r}_A)^2 + r_A^2}\right)$$

so that

$$\alpha\gamma_o\sqrt{(\gamma_o\vec{\beta}_o \cdot \vec{r}_A)^2 + r_A^2} = cT$$

or using equation (4.15)

$$\alpha r_A^o = \frac{cT}{\tau_o} = cT^o$$

where $T^o = T/\tau_o$ is the period of the source as measured by the observers. Hence, the wavelength measurement is exactly the same as if the observers would have been at rest with respect to the ether. This could have been expected as it is a direct consequence of the definition of the observer coordinate system in section 4.3.

4.6 Lorentz transformation

Equation (4.14) and equation (4.6) inserted in equation (4.9) yield

$$\begin{aligned} \vec{R}^o &= \tfrac{\gamma_o}{\tau_o}\left(\vec{r} + \gamma_o\left(\tfrac{\gamma_o}{1+\gamma_o}(\vec{\beta}_o \cdot \vec{r}) - ct\right)\vec{\beta}_o\right) \\ t^o &= \tfrac{\gamma_o^2}{\tau_o}\left(t - \tfrac{\vec{\beta}_o\cdot\vec{r}}{c}\right) \end{aligned} \tag{4.15}$$

or inverse

$$\begin{aligned} \vec{r} &= \tfrac{\tau_o}{\gamma_o}\left(\vec{R}^o + \gamma_o\left(\tfrac{\gamma_o}{1+\gamma_o}(\vec{\beta}_o \cdot \vec{R}^o) + ct^o\right)\vec{\beta}_o\right) \\ t &= \tau_o\left(t^o + \tfrac{\vec{\beta}_o\cdot\vec{R}^o}{c}\right) \end{aligned} \tag{4.16}$$

These equations were already derived by Lorentz and Einstein. They both tried to find the function τ_o. Lorentz found it by means of the Maxwell equations and the electro-magnetic mass of an electron in his electron theory [35]. He found $\tau_o = \gamma_o$. Einstein derived the same function for it, by applying his primary assumption that all physical laws should be independent of the inertial motion of the system [15]. This means that equations (4.15) and (4.16) should be exactly the same, yielding directly $\tau_o = \gamma_o$. Poincaré used a mathematical argument from group theory for this assumption [36]. He found that under this condition co-linear transformations formed a group.

Here, it is assumed that τ_o is unknown and it will be remembered that if $\tau_o = \gamma_o$ the equations (4.15) are exactly the same as the Lorentz transformations, where the location $\vec{r^l}$ with respect to the observer is given by

$$\vec{r^l} = \vec{r} - \vec{R}_o + \gamma_o \left(\frac{\gamma_o}{1+\gamma_o} \vec{\beta}_o \cdot (\vec{r} - \vec{R}_o) - c(t - t_o) \right) \vec{\beta}_o \tag{4.17}$$

and the observers time reference would be

$$t^l = \gamma_o(t - t_o) - \gamma_o \vec{\beta}_o \cdot (\vec{r} - \vec{R}_o)/c \tag{4.18}$$

4.7 Location of wavefronts of a moving source

To get a picture of the wavefronts emitted by a moving source in the coordinates of the observer, the location of the wavefronts have to be calculated at a constant observer time t^o. So first, the observer time is transformed to the ether time using equation (4.16). So that in ether coordinates, the observer time corresponds to ether time

$$t = \frac{\tau_o}{\gamma_o^2} t^o + \frac{\vec{\beta}_o \cdot \vec{r}}{c} \tag{4.19}$$

the same as equation (4.14). Then, the position of the wavefronts in the ether are calculated by inserting it in (2.3). When

$$\frac{\tau_o}{\gamma_o^2} t^o + \frac{\vec{\beta}_o \cdot \vec{r}_i}{c} < t_k + iT_k$$

then

$$\vec{r}_i = \vec{R}_k + \left(\frac{\tau_o}{\gamma_o^2} ct^o + \vec{\beta}_o \cdot \vec{r}_i - ct_k \right)) \vec{\beta}_k$$

or otherwise

$$\vec{r}_i = \vec{R}_k + icT_k \vec{\beta}_k + \left(\frac{\tau_o}{\gamma_o^2} ct^o + \vec{\beta}_o \cdot \vec{r}_i - ct_k - icT_k \right) \vec{\zeta}(\phi, \theta)$$

Here it is assumed that the source period behaves like a Cesium atom clock (see chapter 4.1) so that T_k is the period of clock while moving through the ether with velocity β_k. By eliminating $\vec{\beta}_o \cdot \vec{r}_i$ this can be rewritten. When

$$\frac{\tau_o}{\gamma_o^2} t^o < t_k + iT_k(1 - \vec{\beta}_o \cdot \vec{\beta}_k) - \vec{\beta}_o \cdot \vec{R}_k / c$$

then

$$\vec{r}_i = \vec{R}_k + \frac{\vec{\beta}_o \cdot \vec{R}_k + \frac{\tau_o}{\gamma_o^2} ct^o - ct_k}{1 - \vec{\beta}_o \cdot \vec{\beta}_k} \vec{\beta}_k$$

or otherwise

$$\vec{r}_i = \vec{R}_k + icT_k\vec{\beta}_k + \frac{\vec{\beta}_o \cdot (\vec{R}_k + icT_k\vec{\beta}_k) + \frac{\tau_o}{\gamma_o^2} ct^o - ct_k - icT_k}{1 - \vec{\beta}_o \cdot \vec{\zeta}(\phi, \theta)} \vec{\zeta}(\phi, \theta)$$

This has to be transformed to the observer reference coordinate system using the transformation (4.15)

$$\vec{R_i^o} = \frac{\gamma_o}{\tau_o} \vec{r}_i - \left(\frac{\gamma_o^2}{\tau_o(1 + \gamma_o)} \vec{\beta}_o \cdot \vec{r}_i + ct^o \right) \vec{\beta}_o$$

so that

$$\begin{array}{lll} t^o < t_k^o + iT_k^o & : & \vec{R_i^o} = \vec{R_k^o} + c(t^o - t_k^o)\vec{\beta_k^o} \\ t^o \geq t_k^o + iT_k^o & : & \vec{R_i^o} = \vec{R_k^o} + icT_k^o\vec{\beta_k^o} + c(t^o - t_k^o - iT_k^o)\vec{\eta}(\phi, \theta) \end{array} \tag{4.20}$$

where

$$\vec{R_k^o} = \frac{\gamma_o}{\tau_o} \left(\vec{R}_k + \gamma_o \left(\frac{\gamma_o}{1 + \gamma_o} \vec{\beta}_o \cdot \vec{R}_k - ct_k \right) \vec{\beta}_o \right)$$

is the transformation according to equation (4.15) of $\vec{R}_k$,

$$t_k^o = \frac{\gamma_o^2}{\tau_o} \left(t_k - \frac{\vec{\beta}_o \cdot \vec{R}_k}{c} \right)$$

is the local time at the source origin according to equation (4.14) and

$$\vec{\beta_k^o} = \frac{\vec{\beta}_k / \gamma_o + \left(\gamma_o / (1 + \gamma_o) \vec{\beta}_k \cdot \vec{\beta}_o - 1 \right) \vec{\beta}_o}{1 - \vec{\beta}_k \cdot \vec{\beta}_o} \tag{4.21}$$

is the velocity of the source in the observers coordinates, corresponding to the *relativistic velocity addition law*. Similar

$$\vec{\eta}(\phi, \theta) = \frac{\vec{\zeta}(\phi, \theta) / \gamma_o + \left(\gamma_o / (1 + \gamma_o) \vec{\zeta}(\phi, \theta) \cdot \vec{\beta}_o - 1 \right) \vec{\beta}_o}{1 - \vec{\zeta}(\phi, \theta) \cdot \vec{\beta}_o}$$

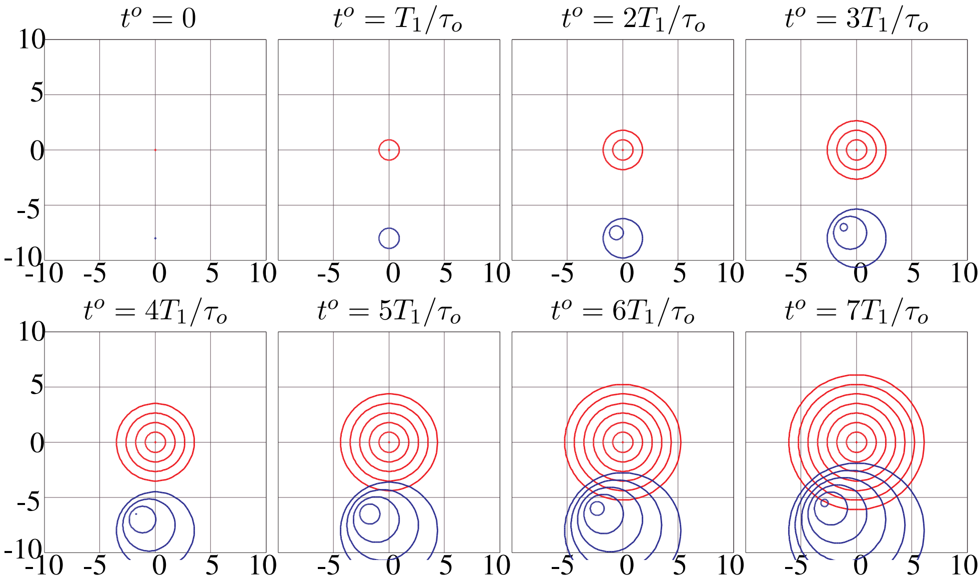

Figure 4.3: Position of wavefronts of sources 1 (red) and 2 (blue) for $z = 0$ with parameters shown in table 2.1 as observed by an observer moving along with source 1 when he uses light to observe the ether disturbances and assumes he is stationary with respect to the ether.

equal to equation (4.21) if $\vec{\zeta} = \vec{\beta}_k$ and $\beta_k = 1$. Hence, it gives the direction of the velocity of the ether disturbance as measured by the observer moving with a velocity $c\vec{\beta}_o$ with respect to the ether, when the ether disturbance moves in direction $\vec{\zeta}$ in the ether. Note that $|\vec{\eta}| = 1$, so that ether disturbances seem to move with velocity c also when they are measured by observers moving with respect to the ether.

T_k^o acts as the apparent period of the source and is equal to

$$T_k^o = T_k \frac{\gamma_o^2}{\tau_o} \left(1 - \vec{\beta}_o \cdot \vec{\beta}_k\right) \tag{4.22}$$

The results for source 1 and 2 are shown in figure 4.3. Comparison with figures 2.1 and 3.1 shows that the wavefronts appear to be at different locations. The first point of interaction between the wavefronts of source 1 and 2 appears to be at a different location and at a different time, although the physical situation is exactly the same as before. This is similar to what occurs in figure 4.2. Although the observer *measures* the wavefronts to be distributed like figure 4.3 the actual situation is depicted in figure 2.1. This is due to dependence of local time on the position with respect to the observer.

Chapter 5

Kinematic effects

Equation (4.20) is completely equivalent to equation (2.3), so that for a source moving with respect to the ether the wavefronts appear to be completely spherical to the (moving) observer, independent of the velocity of the source. This is due to the special properties of the derived transformations. It is this property that inhibits the detection of the velocity of the observer with respect to the ether by means of standard interferometric experiments, as all wavefronts seem to move with a constant velocity independent of the velocity of the observer with respect to the ether. Further, it is shown below that many observable effects only depend on the velocity of the source with respect to the observer as *measured* by the observer.

Up to now we have discussed what an observer *measures* when using the propagation of ether disturbances to define his coordinate system. Some of these effects are described above. As these effects do not influence the object under observation but are due to the observers measurements only these can be referred to as *kinematic effects*.

5.1 Doppler shift

Source 1 is moving with the same velocity through the ether as the observer (i.e. $\vec{\beta}_1 = \vec{\beta}_o$) so that the wavefronts of source 1 are observed as simple spheres. This is shown in figure 4.3. In such a case $T_1^o = T_1/\tau_o = T$ exactly the period as should be observed according to equation (4.1). Hence, the effect for source 1 is gone due to the impossibility to measure the increased pulse time without knowing ones velocity in the ether. A Doppler effect for a source moving with respect to the observer remains. The apparent period is not only time dilated (indicated by the factor γ_o^2/τ_o), but there is an additional change in period due to the absolute motion of the observer and of the source in the ether (a relative change of $\vec{\beta}_k \cdot \vec{\beta}_o$). Note that this is not the classical Doppler effect measured as a change in the time that wavefronts pass the observer as elucidated in chapter 3, but an actual change in the measured period time of the source, due to the assumed motionlessness of the observer.

The above equation (4.22) can be rewritten

$$T_k^o = T_k \frac{\gamma_o}{\tau_o} \frac{\gamma_k^o}{\gamma_k} = T \frac{\gamma_o}{\tau_o} \frac{\tau_k}{\gamma_k} \gamma_k^o \tag{5.1}$$

where $\tau_k = \tau(\beta_k)$, $\gamma_k = 1/\sqrt{1-\beta_k^2}$ and $\gamma_k^o = 1/\sqrt{1-(\beta_k^o)^2}$. In case of Lorentz transformation ($\tau = \gamma$) this reduces to the standard time dilatation $T_k^o = T\gamma_k^o$. Hence, in such a case it is impossible to determine the observers velocity with respect to the ether by measuring the change in period time from any other moving or stationary point source.

There are several papers describing experiments of Doppler shift measurements. Ives and Stilwell [37, 38] measured the Doppler shift of light emitted by fast-moving hydrogen molecules. Later these results were confirmed by similar experiments by Hasselkamp [39] in 1979. Similar Mössbauer rotor experiments done by Hay [40], Champeney [41, 42], Kündig [43] are all in agreement with this relation. All these measurements show that $\tau = \gamma$, although only up to first order accuracy in γ. For the rotation measurements one should be careful because a Doppler shift is not always observed as was shown by Champeney [44] and Thim [45]. Further reanalysis of Kündig's experiment by Kholmetskii [46] and new experiments by his team indicate that there might be a discrepancy between the expected shift and observed shift, which can not be explained by this relationship.

5.2 Apparent Lorentz contraction

Let us assume an observer A moves with velocity $c\vec{\beta}_o$ through the ether, and two observers B and C moving with velocity $c\vec{\beta}_k$ through the ether. Observer A measures the velocity of B and C as $c\vec{\beta}_k^o$ given by equation (4.21)

$$\vec{\beta}_k^o = \frac{\gamma_k}{\gamma_k^o}\vec{\beta}_k - \frac{\gamma_o(\gamma_k + \gamma_k^o)}{\gamma_k^o(1+\gamma_o)}\vec{\beta}_o$$

where is was used that

$$\vec{\beta}_k \cdot \vec{\beta}_o = 1 - \frac{\gamma_k^o}{\gamma_k \gamma_o}$$

From this one can derived the useful relations

$$\vec{\beta}_k = \frac{\gamma_k^o}{\gamma_k}\vec{\beta}_k^o + \frac{\gamma_o(\gamma_k + \gamma_k^o)}{\gamma_k(1+\gamma_o)}\vec{\beta}_o$$

$$\vec{\beta}_o \cdot \vec{\beta}_k^o = \frac{\gamma_k}{\gamma_k^o \gamma_o} - 1$$

$$\vec{\beta}_o^k = \frac{\gamma_o}{\gamma_o^k}\vec{\beta}_o - \frac{\gamma_k(\gamma_o + \gamma_o^k)}{\gamma_o^k(1+\gamma_k)}\vec{\beta}_k$$

$$\gamma_o^k = \gamma_k^o$$

A complete list of such useful relation is given in appendix A.

Observers B and C are attached to both sides of a rod that has the direction $\vec{L}^k = \vec{R}_B^k - \vec{R}_C^k$ as measured by the observers B and C at locations $\vec{R}_B^k$ and $\vec{R}_C^k$. The locations and times in the ether can be found by applying the inverse transformation (4.16)

$$\vec{r} = \frac{\tau_k}{\gamma_k}\left(\vec{R}^k + \gamma_k\left(\frac{\gamma_k\vec{\beta}_k \cdot \vec{R}^k}{1+\gamma_k} + ct^k\right)\vec{\beta}_k\right)$$

$$t = \tau_k\left(t^k + \frac{\vec{\beta}_k \cdot \vec{R}^k}{c}\right)$$

And the locations and times as observed by observer A can be found by applying transformation (4.15) yielding

$$\vec{R}^o = \frac{\gamma_o}{\tau_o}\left(\vec{r} + \gamma_o\left(\frac{\gamma_o\vec{\beta}_o \cdot \vec{r}}{1+\gamma_o} - ct\right)\vec{\beta}_o\right)$$

$$t^o = \frac{\gamma_o^2}{\tau_o}\left(t - \frac{\vec{\beta}_o \cdot \vec{r}}{c}\right)$$

so that

$$\vec{R}^o = ct^o\vec{\beta}_k^o + \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\times \tag{5.2}$$

$$\left\{\vec{R}^k - \frac{\gamma_o\vec{\beta}_o \cdot \vec{R}^k}{1+\gamma_o}\vec{\beta}_o + \gamma_o\left(\vec{\beta}_o \cdot \vec{R}^k - \frac{\gamma_k\vec{\beta}_k \cdot \vec{R}^k}{1+\gamma_k}\right)\left(\vec{\beta}_k^o + \vec{\beta}_o\right)\right\}$$

$$t^o = \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\gamma_k^o\left(t^k - \frac{\vec{R}^k \cdot \vec{\beta}_o^k}{c}\right)$$

The last term at the right hand sides shows that the observer A sees the rod moving with a velocity $\vec{\beta}_k^o$ with respect to him, just as it should. Observer A measures the rod BC as

$$\vec{L}^o = \vec{R}_B^o - \vec{R}_C^o =$$

$$\frac{\gamma_o\tau_k}{\tau_o\gamma_k}\left\{\vec{L}^k - \frac{\gamma_o\vec{\beta}_o \cdot \vec{L}^k}{1+\gamma_o}\vec{\beta}_o + \gamma_o\left(\vec{\beta}_o \cdot \vec{L}^k - \frac{\gamma_k\vec{\beta}_k \cdot \vec{L}^k}{1+\gamma_k}\right)\left(\vec{\beta}_k^o + \vec{\beta}_o\right)\right\}$$

from which it can be inferred that

$$\vec{L}^o \cdot \vec{\beta}_o = \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\frac{\gamma_k}{\gamma_k^o}\left\{\frac{\gamma_k^o - \gamma_k\gamma_o}{\gamma_o(1+\gamma_k)}\vec{\beta}_k \cdot \vec{L}^k + \vec{\beta}_o \cdot \vec{L}^k\right\}$$

$$\vec{L^o} \cdot \vec{\beta_k^o} = \frac{\gamma_o \tau_k}{\tau_o \gamma_k} \frac{\gamma_o}{(\gamma_k^o)^2} \left\{ \frac{\gamma_k(\gamma_k^o + \gamma_o)}{\gamma_o(1+\gamma_k)} \vec{\beta}_k \cdot \vec{L^k} - \vec{\beta}_o \cdot \vec{L^k} \right\}$$

$$\vec{L^k} \cdot \vec{\beta_o^k} = -\frac{\tau_o \gamma_k}{\gamma_o \tau_k} \gamma_k^o \vec{L^o} \cdot \vec{\beta_k^o}$$

so that

$$L^o = \frac{\gamma_o \tau_k}{\tau_o \gamma_k} L^k \sqrt{1 - (\beta_o^k)^2 \cos^2 \theta^k}$$

or

$$L^o \sqrt{1 + (\gamma_k^o \beta_k^o)^2 \cos^2 \theta^o} = \frac{\gamma_o \tau_k}{\tau_o \gamma_k} L^k$$

where $\cos\theta^k = \vec{L^k} \cdot \vec{\beta_o^k}/(L^k \beta_o^k)$ so that θ^k is the angle between the rods direction and the velocity of observer A as measured by observers B and C and $\cos\theta^o = \vec{L^o} \cdot \vec{\beta_k^o}/(L^o \beta_k^o)$ so that θ^o is the angle between the rods direction and its velocity as measured by observer A.

It is clear that observer A measures a rod that is shorter than the one measured by the observers B and C co-moving with the rod. This is based on the calibration of the equipment according to chapters 4.1 and 4.2, the rod has not changed its dimensions at all. This is why it is called *apparent* Lorentz contraction.

Note that in case of the Lorentz transformation ($\tau = \gamma$) these equations only contain the angles measured in the coordinates of the observer and the magnitude of their relative velocity (remember that $\beta_k^o = \beta_o^k$). The relation between the angles can be found by dividing the above equations, yielding

$$\cos\theta^o = -\frac{\cos\theta^k}{\gamma_k^o \sqrt{1 - (\beta_k^o)^2 \cos^2 \theta^k}}$$

Hence, also be measuring the apparent Lorentz contraction or the angle between the direction of the rod and its apparent velocity, it is impossible to determine the velocity with respect to the ether. Obvious, here it does not matter whether or not the rod is really contracted because one compares the length or direction of the rod as measured by observers B and C with the measurements of the same rod by observer A.

5.3 Wigner rotation

In case the observer A is moving with respect to the ether he will measure points B and C moving independently from A as given by transformation (5.2). This transformation looks quite complicated and hard to understand. However, Wigner [47] was able to find a simple interpretation of this transformation and it is now known as a *boost* defined by transformation (4.15), followed by a rotation around an axis *at the observer's location*. This rotation is known as the *Wigner rotation*. By using $\vec{\beta}_k^o$ and $\vec{\beta}_o^k$ equation (5.2) can be rewritten as

$$\vec{R}^o = ct^o\vec{\beta}_k^o + \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\left\{\vec{R}^k - \frac{\gamma_k^o\vec{\beta}_o^k\cdot\vec{R}^k}{\gamma_k^o-1}\vec{\beta}_k^o - \frac{(\vec{\beta}_o^k-\vec{\beta}_k^o)\cdot\vec{R}^k}{(1+\cos\Omega_k^o)(\beta_k^o)^2}(\vec{\beta}_o^k-\vec{\beta}_k^o)\right\} \tag{5.3}$$

where Ω_k^o is the angle between vectors $\vec{\beta}_k^o$ and $\vec{\beta}_o^k$ know as then Wigner rotation angle given by

$$\cos\Omega_k^o = -\frac{\vec{\beta}_k^o\cdot\vec{\beta}_o^k}{\beta_o^k\beta_k^o} = \frac{(1+\gamma_k^o+\gamma_o+\gamma_k)^2}{(1+\gamma_k^o)(1+\gamma_o)(1+\gamma_k)} - 1 \tag{5.4}$$

Using the results of appendix B this can be rewritten as

$$\vec{R}^o = \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\Re\left\{\frac{\vec{\beta}_k\times\vec{\beta}_o}{|\vec{\beta}_k\times\vec{\beta}_o|},\Omega_k^o,\vec{R}^k - \frac{\gamma_o^k\vec{\beta}_o^k\cdot\vec{R}^k}{1+\gamma_o^k}\vec{\beta}_o^k\right\} + ct^o\vec{\beta}_k^o \tag{5.5}$$

$$t^o = \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\gamma_k^o\left(t^k - \frac{\vec{R}^k\cdot\vec{\beta}_o^k}{c}\right)$$

where the function

$$\Re(\vec{n},\Omega,\vec{R}) = \vec{R} + \vec{n}\times\vec{R}\sin\Omega - (\vec{R}-\vec{n}(\vec{n}\cdot\vec{R}))(1-\cos\Omega)$$

is known as the Rodrigues vector rotation formula rotating the vector $\vec{R}$ around a unit vector $\vec{n}$ over an angle Ω according to the right hand rule. Note that

$$\vec{n} = \frac{\vec{\beta}_o\times\vec{\beta}_k}{|\vec{\beta}_o\times\vec{\beta}_k|} = \frac{\vec{\beta}_k^o\times\vec{\beta}_o^k}{|\vec{\beta}_k^o\times\vec{\beta}_o^k|}$$

so that $\vec{\beta}_o$, $\vec{\beta}_k$, $\vec{\beta}_k^o$ and $\vec{\beta}_o^k$ all lie in the same plane and the above rotation has the effect that the vector $\vec{\beta}_o^k$ is rotated into the vector $-\vec{\beta}_k^o$, which has been discussed by Ungar [48]. This has been depicted in figure 5.1. More useful notations of the Rodrigues vector rotation formula are given in appendix B.

A boost with a velocity $\vec{\beta}_o^k$ followed by a Wigner rotation over an angle Ω_k^o around an axis $(\vec{\beta}_k^o\times\vec{\beta}_o^k)/|\vec{\beta}_k^o\times\vec{\beta}_o^k|$ at the location of the observer, gives

$$\vec{R}^o = \frac{\gamma_k^o}{\tau_k^o}\Re\left\{\frac{\vec{\beta}_k^o\times\vec{\beta}_o^k}{|\vec{\beta}_k^o\times\vec{\beta}_o^k|},\Omega_k^o,\vec{R}^k + \gamma_o^k\left(\frac{\gamma_o^k\vec{\beta}_o^k\cdot\vec{R}^k}{1+\gamma_o^k} - ct^k\right)\vec{\beta}_o^k\right\}$$

$$t^o = \frac{\gamma_k^o}{\tau_k^o}\gamma_k^o\left(t^k - \frac{\vec{\beta}_o^k\cdot\vec{R}^k}{c}\right)$$

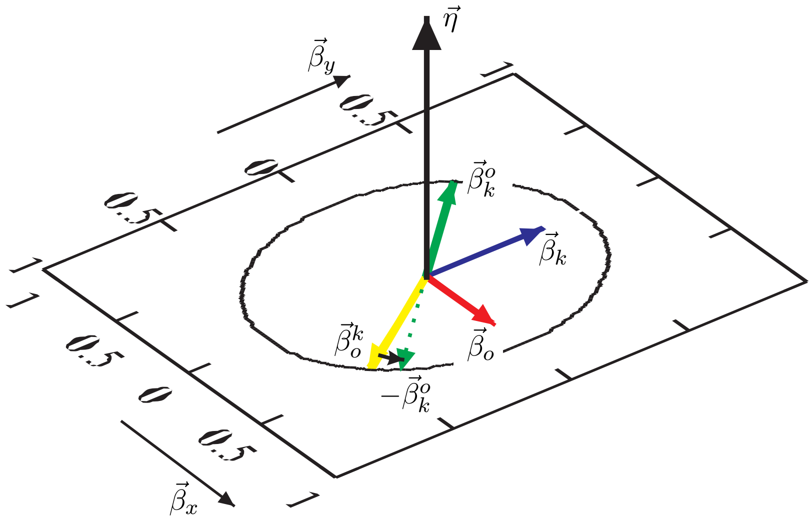

Figure 5.1: Direction of velocities in velocity space and the normal to the velocity plane. $\vec{\beta}_o$, $\vec{\beta}_k$, $\vec{\beta}_k^o$ and $\vec{\beta}_o^k$ all lie in the same plane and the Wigner rotation has the effect that the vector $\vec{\beta}_o^k$ is rotated into the vector $-\vec{\beta}_k^o$. The circle denotes the length of $\vec{\beta}_k^o$.

which is exactly the same as equation (5.5) under the condition $\tau = \gamma$. This is the reason why the apparent Lorentz contraction does not reveal the ether as discussed in the previous chapter.

If the boost velocity $\vec{\beta}_o^k$ is small, then $\gamma_k^o \approx 1$ and if in addition $\Omega_k^o << 1$ the above relations simplify to

$$\vec{R^o} \approx \vec{R^k} + \vec{\Omega}_k^o \times \vec{R^k}$$

$$t^o \approx t^k - \frac{\vec{\beta}_o^k \cdot \vec{R}^k}{c}$$

where

$$\vec{\Omega}_k^o = \frac{\vec{\beta}_k^o \times \vec{\beta}_o^k}{(\beta_k^o)^2}$$

5.4 Apparent Thomas precession

By many authors [49, 50, 51, 52] Thomas precession is defined by the rate of change of the Wigner rotation angle. The exact expression for this rate depends on the clock rate in the coordinate system of the observer.

However, as has been shown in the previous sections within one coordinate system it is impossible to measure the Wigner rotation angle nor its change in time.

To be able to determine this angle, there must be a direction in the ether which can be used as a reference. Let this direction be a rod between two points B and C in rest with respect to the ether. When an observer A moving with velocity $c\vec{\beta}_k$ with respect to the ether measures the locations $\vec{R}^k$ at a local time t^k according to the transformations (4.16) the location and time in the ether are

$$\vec{r} = \frac{\tau_k}{\gamma_k}\left(\vec{R}^k + \gamma_k\left(\frac{\gamma_k}{1+\gamma_k}(\vec{\beta}_o \cdot \vec{R}^k) + ct^k\right)\vec{\beta}_k\right)$$

$$t = \tau_k\left(t^k + \frac{\vec{\beta}_k \cdot \vec{R}^k}{c}\right)$$

At local time t_0^k the observer A experiences an acceleration so that it takes a very small time interval Δt^o to reach the velocity $c\vec{\beta}_o$ with respect to the ether. His velocity with respect to the ether changes from $c\vec{\beta}_k$ to $c\vec{\beta}_o$, which is measured after the acceleration as $c\vec{\beta}_o^k$. Then he measures the locations again according to transformation (4.15), but now with $c\vec{\beta}_o$ so that

$$\vec{R}^o = \frac{\gamma_o}{\tau_o}\left(\vec{r} + \gamma_o\left(\frac{\gamma_o}{1+\gamma_o}(\vec{\beta}_o \cdot \vec{r}) - ct\right)\vec{\beta}_o\right)$$

$$t^o = \frac{\gamma_o^2}{\tau_o}\left(t - \frac{\vec{\beta}_o \cdot \vec{r}}{c}\right)$$

yielding exactly the same results as equation (5.5) in chapter 5.3

$$\vec{R}^o = \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\Re\left\{\frac{\vec{\beta}_k \times \vec{\beta}_o}{|\vec{\beta}_k \times \vec{\beta}_o|}, \Delta\Omega_k^o, \vec{R}^k - \frac{\gamma_o^k\vec{\beta}_o^k \cdot \vec{R}^k}{1+\gamma_o^k}\vec{\beta}_o^k\right\} + ct^o\vec{\beta}_k^o$$

When $\vec{\beta}_o^k$ is small, the angle $\Delta\Omega_k^o$ is small and using the results of appendix B this can be approximated up to first order in β_o^k by

$$\vec{R}^o \approx \vec{R}^k + \Delta\vec{\Omega}_k^o \times \vec{R}^k + ct^o\vec{\beta}_k^o \tag{5.6}$$

where

$$\Delta\vec{\Omega}_k^o = \frac{\vec{\beta}_k^o \times \vec{\beta}_o^k}{\beta_k^o\beta_o^k} \approx \frac{\gamma_o}{1+\gamma_o}\vec{\beta}_o \times \vec{\beta}_k^o$$

Dividing both sides by Δt^o yields

$$\frac{\Delta\vec{\Omega}_k^o}{\Delta t^o} = -\frac{\gamma_o}{1+\gamma_o}\vec{\beta}^o \times \vec{a}_k^o \tag{5.7}$$

where $\vec{a}_k^o = \vec{\beta}_k^o/\Delta t^o$ is the acceleration of the observer as measured by the observer. Note that this rotation of vector $\vec{R}^o$ with respect to vector $\vec{R}^k$ is a purely kinematic effect as it is only due to an acceleration of the observer, not influencing any part of the rod. Note also that this rotation does not only depend on $\vec{a}_k^o$ but also on $\vec{\beta}^o$ so that it enables the detection of the rods coordinates. In many textbooks this formula is quoted as the Thomas precession, because such a phenomenon was first studied by Thomas [53, 54] and was used to explain the anomalous value of the magnetic moment of the electron.

Chapter 6

Dynamic effects

Another question all together is *"What happens to the dimensions and clock rates of objects when their velocity is changed?"*. This question is part of *dynamical effects* due to a change in the velocity of the object. One of those effects has already been encountered in section 4.1. Another one of these effects is the contraction of objects when their velocity changes, which has been proposed by Fitzgerald [13] and Lorentz [14] to explain the null result of the Michelson-Morley experiment. A third dynamical effect is the so-called *Thomas precession*, proposed by Thomas [53, 54] in 1926 to explain the reduced Zeeman splitting found in atomic spectra.

6.1 Time dilatation

If the experiments of section 5.1 are interpreted as proof for $\tau = \gamma$, then the clocks really needs to slow down when they are moving with respect to the ether. Bailey [55] observed the lifetimes of particles in storage rings and confirmed the increased lifetimes of these particles. Hafele and Keating [56, 57, 58] measured the different readings between Cesium atom clocks in relative rest with respect to the Earth and Cesium atom clocks transported around the Earth by means of planes flying in eastward and westward directions. However, the clocks did not move in inertial systems hence no final conclusions about reduction of clock tick rate in inertial flight can be obtained from these experiments. However, they have shown that the periods of Cesium atom clocks do vary with their velocity with respect to the ether and that such measurements are in practice possible with sufficient accuracy.

Let us assume two Cesium atom clocks, the first one stationary with respect to the surface of the Earth, the second one moving over a great circle around the Earth (see figure 6.1). The Earth axis is denoted as $\vec{n}_e^o$ and the direction of the normal to the great circle is $\vec{n}_{12}^o$. The velocity of clock 1 and clock 2 with respect to the observer is denoted as $c\vec{\beta}_1^o$ respectively $c\vec{\beta}_2^o$. The location of clock 1 with respect to

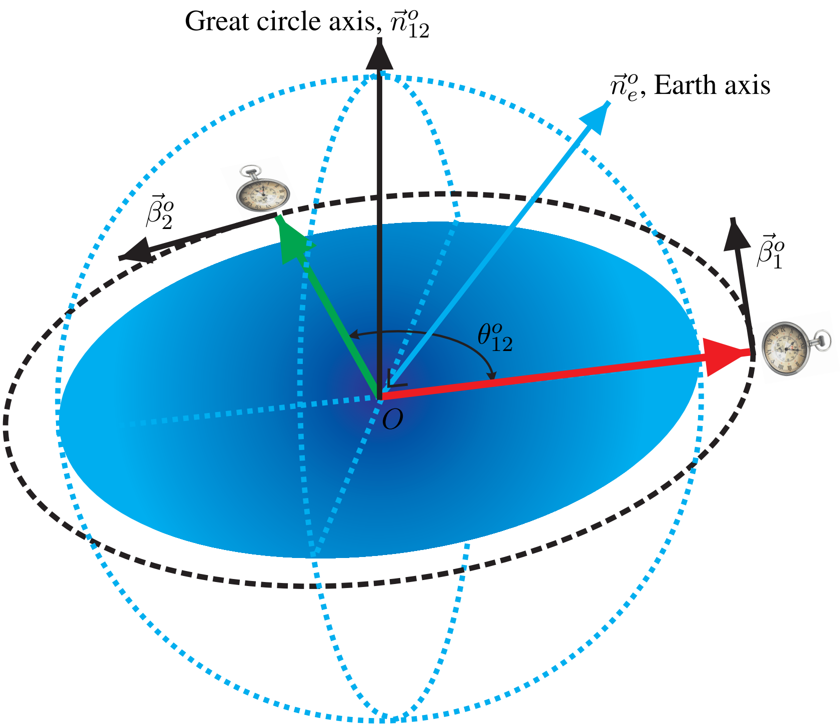

Figure 6.1: Two Cesium atom clocks moving over a great circle around the Earth. One stationary with respect to the surface of the rotating Earth, the other moving with respect to this surface.

the observer is given by

$$\vec{R}^o_1(t^o) = \Re\left\{\vec{n}^o_e, \omega^o_e(t^o - t^o_0), \vec{R}^o_1(t^o_0)\right\}$$

where ω^o_e is the rotation frequency of the Earth, t^o_0 is the time the second clock starts moving with respect to the first clock's initial position $\vec{R}^o_1(t^o_0)$. The velocity of clock 1 with respect to the observer can be found by differentiating with respect to t^o

$$\vec{\beta}^o_1(t^o) = \frac{1}{c}\frac{d\vec{R}^o_1(t^o)}{dt^o}$$

Clock 2 has a fixed velocity with respect to clock 1 and the surface of the Earth and rotates around axis $\vec{n}^o_{12}$. If the Earth would be stationary with respect to the observer, its location with respect to the observer's coordinate system can be found by

$$\vec{R}^*_2(t^o) = \Re\left\{\vec{n}^o_{12}, \theta^o_{12}, \vec{R}^o_1(t^o_0)\right\}$$

where θ_{12}^o is the angle between the positions of clock 1 and 2 as seen by the observer (see figure 6.1). When ω_{12}^o is the rotation frequency of clock 2 with respect to clock 1 as seen by the observer in the center of the Earth, then $\theta_{12}^o = \omega_{12}^o(t^o - t_0^o)$. After a complete revolution around the great circle during time interval ΔT^o the second clock returns to the position of the first, so that $\omega_{12}^o = 2\pi/\Delta T^o$. However as the Earth rotates around it's axis, the observer finds the clock at location

$$\vec{R}_2^o(t^o) = \Re\left\{\vec{n}_e^o, \omega_e^o(t^o - t_0^o), \vec{R}_2^*(t_0^o)\right\}$$

The velocity of clock 2 with respect to the observer can be found by differentiating with respect to t^o

$$\vec{\beta}_2^o(t^o) = \frac{1}{c}\frac{d\vec{R}_2^o(t^o)}{dt^o}$$

Using equation (5.1), under the condition that $\tau = \gamma$, the observed period of the Cesium atom clock 1 is given by $T_1^o = T\gamma_1^o$ and the total number of periods for clock 1 is given by

$$N_1 = \int_{t^o=t_0^o}^{t^o=t_0^o+\Delta T^o} \frac{1}{T_1^o} dt^o = \frac{1}{T}\int_{t^o=t_0^o}^{t^o=t_0^o+\Delta T^o} (\gamma_1^o)^{-1} dt^o$$

and a similar relation for clock 2. The observer time difference between clock 2 and clock 1 is

$$\Delta t_{2,1}^o = T(N_2 - N_1) = \int_{t^o=t_0^o}^{t^o=t_0^o+\Delta T^o} \left\{(\gamma_2^o)^{-1} - (\gamma_1^o)^{-1}\right\} dt^o$$

Because $\beta_1^o << 1$ and $\beta_2^o << 1$ this can be approximated as

$$\Delta t_{2,1}^o \approx \frac{1}{2}\int_{t^o=t_0^o}^{t^o=t_0^o+\Delta T^o} \left\{(\beta_1^o)^2 - (\beta_2^o)^2\right\} dt^o$$

When the initial location of clock 1 is fixed by its longitude ϕ_1^o and latitude λ_1^o and clock 2 should move along a great circle (the center of the circle is the center of the Earth), then when the latitude of $\vec{n}_{12}^o$ is chosen as λ_{12}^o, its longitude is fixed according to $\cos(\phi_1^o - \phi_{12}^o) = -\tan\lambda_1^o \tan\lambda_{12}^o$, as $\vec{R}_1^o(t_0^o) \perp \vec{n}_{12}^o$. In such a case the time difference can be calculated as

$$\frac{\Delta t_{2,1}^o}{\Delta T^o (R_1^o/c)^2} \approx \left\{\left((\omega_e^o)^2 + (\omega_{12}^o)^2\right)\left(\cos^{-2}\lambda_1^o - \cos^2\lambda_1^o\right) - (\omega_e^o)^2\right\}\left(\frac{\sin\lambda_{12}^o}{2}\right)^2 +$$

$$-\omega_e^o\omega_{12}^o\cos^2\lambda_1^o\sin\lambda_{12}^o + \frac{(\omega_e^o)^2\cos(2\lambda_1^o)}{4} - \frac{(\omega_{12}^o)^2}{2}$$

For a great circle around the equator (i.e. $\lambda_1^o = 0$ and $\lambda_{12}^o = \pm\pi/2$) this reduces to

$$\frac{\Delta t_{2,1}^o}{\Delta T^o} \approx -\beta_{12}^o\left(\pm\beta_e^o + \frac{\beta_{12}^o}{2}\right)$$

where $\beta^o_{12} = \omega^o_{12} R^o_1/c$, the velocity of clock 1 relative to the surface of the Earth and $\beta^o_e = \omega^o_e R^o_1/c$, the velocity of the Earth surface with respect to the observer at the center of the Earth. The time difference is identical to the one derived by Hafele and Keating [56, 57] when the gravitational effect is ignored. Note that the time difference is not the same when clock 2 moves with the rotation of the Earth instead of against it. Hafele and Keating had to involve the general theory or relativity to obtain the same results, while here they are obtained by assuming the existence of the ether.

For a great circle around the poles (i.e. $\lambda^o_{12} = 0$) this reduces to

$$\frac{\Delta t^o_{2,1}}{\Delta T^o} \approx \frac{(\beta^o_e)^2 \cos(2\lambda^o_1) - 2(\beta^o_{12})^2}{4}$$

In this case the time difference depends on the latitude of clock 1 and varies between $-((\beta^o_e)^2 + 2(\beta^o_{12})^2)/4$ for $\lambda^o_1 = \pm\pi/2$ and $((\beta^o_e)^2 - 2(\beta^o_{12})^2)/4$ for $\lambda^o_1 = 0$. Hence when starting at the equator the magnitude of the time difference is smallest. This is due to the fact that the velocity of the clock fixed to the surface of the Earth is largest at the equator.

6.2 Lorentz contraction

Lorentz [25] explained that contraction would occur due to the electro-magnetic nature of the forces between the molecules or atoms of the rods. Hence, the rod only contracts due to the dynamical rearrangement of its molecules or atoms due to the change in electro-magnetic forces induced by the changed velocity of the rod with respect to the ether. This gives us another clue how to measure Lorentz contraction.

For instance, take two neutral objects with the same mass at some fixed distance from each other and stationary in the ether. Accelerate them by means of two identical but independent rockets into the same direction, with the same acceleration until the same end velocity is reached. As there are no forces between the objects and they undergo the same acceleration, the distance between the objects remains perfectly the same as before. However, when they measure their distance after the acceleration they will measure a different one, because their measurement system is Lorentz contracted.

Detailed analysis of such a possible experiment shows that there are three possibilities. Firstly, one can assume that the objects are accelerated at the same *local* time. Secondly, one can assume that at the moment the first object accelerates it also sends a signal using ether disturbances (i.e. the velocity of the signal is c) to the second object. The second object will accelerate at the moment it receives the signal. Thirdly, one can assume that the signal sent by the first observer propagates with infinite velocity in the ether, hence the acceleration of both objects occurs an the same *ether* time. The first two possibilities are in concord with Lorentz ether theory or special relativity theory. The third possibility requires an infinite signal speed, prohibited by special relativity theory but (maybe) possible in quantum mechanics.

So, let us assume observers B and C moving with velocity $c\vec{\beta}_k$ through the ether at locations $\vec{R}^k_{B,<}$ and $\vec{R}^k_{C,<}$ with respect to the origin of their co-moving coordinate system. The subscripts $_<$ denote values before the acceleration. They have synchronized their clocks with respect to the origin so that they have the same local time. Let observer B accelerate (in a very short time) at local time $t^k_{B,0}$ to ether velocity $c\vec{\beta}_o$. Observer C will accelerate in exactly the same way at local time $t^k_{C,0}$. After the accelerations the observers will be stationary again with respect to each other as they moved with the same initial velocity.

An observer A already moves with velocity $c\vec{\beta}_o$ with respect to the ether. His observation of the locations of B and C before they have accelerated can be found from the results in chapters 5.2 and 5.3 as summarized in equation (5.5)

$$\vec{R^o}_{B,<} = \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\Re\left\{\frac{\vec{\beta}_k\times\vec{\beta}_o}{|\vec{\beta}_k\times\vec{\beta}_o|}, \Omega^o_k, \vec{R^k}_{B,<} - \frac{\gamma^k_o\vec{\beta}^k_o\cdot\vec{R^k}_{B,<}}{1+\gamma^k_o}\vec{\beta}^k_o\right\} + ct^o\vec{\beta}^o_k \tag{6.1}$$

and similar for C, so that before the acceleration, the distance between B and C as measured by observer A is given by

$$L^o_< = \frac{\gamma_o\tau_k}{\tau_o\gamma_k}\sqrt{(L^k_<)^2 - \left(\vec{L}^k_<\cdot\vec{\beta}^k_o\right)^2}$$

where $\vec{L}^k_< = \vec{R}^k_{C,<} - \vec{R}^k_{B,<}$ and $\vec{L}^o_< = \vec{R}^o_{C,<} - \vec{R}^o_{B,<}$.

Before the acceleration, the location and time of observer B in the ether can be found by applying the inverse transformation (4.16)

$$\vec{r}_{B,<} = \frac{\tau_k}{\gamma_k}\left(\vec{R}^k_{B,<} + \gamma_k\left(\frac{\gamma_k\vec{\beta}_k\cdot\vec{R}^k_{B,<}}{1+\gamma_k} + ct^k\right)\vec{\beta}_k\right)$$

$$t_{B,<} = \tau_k\left(t^k + \frac{\vec{\beta}_k\cdot\vec{R}^k_{B,<}}{c}\right)$$

At the moment of the acceleration (denoted by subscripts $_0$) the local or observer B time $t^k = t^k_{B,0}$ and the location of observer B in the ether is

$$\vec{r}_{B,0} = \frac{\tau_k}{\gamma_k}\left(\vec{R}^k_{B,<} + \gamma_k\left(\frac{\gamma_k\vec{\beta}_k\cdot\vec{R}^k_{B,<}}{1+\gamma_k} + ct^k_{B,0}\right)\vec{\beta}_k\right)$$

This is also the location of observer B directly after the acceleration, as it is assumed to be very large. His ether time is

$$t_{B,0} = \tau_k\left(t^k_{B,0} + \frac{\vec{\beta}_k\cdot\vec{R}^k_{B,<}}{c}\right)$$

which depends on its position $\vec{R}^k_{B,<}$. Hence, the ether times that observers B and C start their accelerations differ by

$$t_{C,0} - t_{B,0} = \tau_k \left(t^k_{C,0} - t^k_{B,0} + \vec{\beta}_k \cdot (\vec{R}^k_{C,<} - \vec{R}^k_{B,<})/c \right) \tag{6.2}$$

After the acceleration the velocity with respect to the ether is $c\vec{\beta}_o$ and hence the location of observer B with respect to the ether is

$$\vec{r}_{B,>} = \vec{r}_{B,0} + c\vec{\beta}_o(t - t_{B,0})$$

And the locations and times as observed by observer A co-moving with observers B and C after the acceleration can be found by applying transformation (4.15) with the velocity $c\vec{\beta}_o$ yielding

$$\vec{R}^o_{B,>} = \frac{\gamma_o}{\tau_o} \left(\vec{r}_{B,>} + \gamma_o \left(\frac{\gamma_o \vec{\beta}_o \cdot \vec{r}_{B,>}}{1+\gamma_o} - ct \right) \vec{\beta}_o \right)$$

$$t^o = \frac{\gamma_o^2}{\tau_o} \left(t - \frac{\vec{\beta}_o \cdot \vec{r}_{B,>}}{c} \right) \tag{6.3}$$

So that, by inserting the above equations

$$t = \tau_o t^o - (\gamma_o^2 - 1) t_{B,0} + \gamma_o^2 \frac{\vec{\beta}_o \cdot \vec{r}_{B,0}}{c}$$

and

$$\vec{R}^o_{B,>} = \frac{\gamma_o}{\tau_o} \left(\vec{r}_{B,0} + \frac{\gamma_o^2 \vec{\beta}_o \cdot \vec{r}_{B,0}}{1+\gamma_o} \vec{\beta}_o - \gamma_o c t_{B,0} \vec{\beta}_o \right)$$

yielding by using $\vec{\beta}^o_k$ and $\vec{\beta}^k_o$

$$\vec{R}^o_{B,>} = \frac{\gamma_o \tau_k}{\tau_o \gamma_k} \times \tag{6.4}$$

$$\left\{ \gamma^o_k c t^k_{B,0} \vec{\beta}^o_k + \vec{R}^k_{B,<} - \frac{(\gamma^o_k)^2 \vec{\beta}^k_o \cdot \vec{R}^k_{B,<}}{\gamma^o_k - 1} \vec{\beta}^o_k - \frac{(\vec{\beta}^k_o - \vec{\beta}^o_k) \cdot \vec{R}^k_{B,<}}{(1 + \cos \Omega^o_k)(\beta^o_k)^2} (\vec{\beta}^k_o - \vec{\beta}^o_k) \right\}$$

where Ω^o_k is the Wigner rotation angle as defined by equation (5.4). This equation can be interpreted as a boost with $c\vec{\beta}^k_o$ by applying transformation (4.15)

$$\vec{R}^o_{B,>} = \frac{\gamma^o_k}{\tau^o_k} \left(\vec{R}^k_{B,<} + \gamma^o_k \left(\frac{\gamma^o_k}{1+\gamma^o_k} (\vec{\beta}^k_o \cdot \vec{R}^k_{B,<}) - c t^k \right) \vec{\beta}^k_o \right)$$

$$t^o_{B,0} = \frac{(\gamma^o_k)^2}{\tau^o_k} \left(t^k_{B,0} - \frac{\vec{\beta}^k_o \cdot \vec{R}^k_{B,<}}{c} \right)$$

at $t^k = t^k_{B,0}$, followed by a rotation over Wigner rotation angle Ω^o_k around an axis $(\vec{\beta}^o_k \times \vec{\beta}^k_o)/|\vec{\beta}^o_k \times \vec{\beta}^k_o|$ at the location of origin of the observer, giving almost same result (see also appendix B). The difference is that the factor $\frac{\gamma_o \tau_k}{\tau_o \gamma_k}$ is replaced by $\frac{\gamma^o_k}{\tau^o_k}$. This yields the same result when $\tau = \gamma$.

Directly after the acceleration the local time measured by observer A of the acceleration moment of B is given by equation (6.3)

$$t^o_{B,0} = \frac{\tau_k \gamma_o}{\gamma_k \tau_o} \gamma^o_k \left(t^k_{B,0} - \frac{\vec{R}^k_{B,<} \cdot \vec{\beta}^k_o}{c} \right)$$

and a similar relation for C so that the time difference between C and B is

$$\Delta t^o = t^o_{C,0} - t^o_{B,0} = \frac{\tau_k \gamma_o}{\gamma_k \tau_o} \gamma^o_k \left(t^k_{C,0} - t^k_{B,0} - \frac{\vec{L}^k_< \cdot \vec{\beta}^k_o}{c} \right) \tag{6.5}$$

where $\vec{L}^k_< = \vec{R}^k_{C,<} - \vec{R}^k_{B,<}$ so that in general the clocks of observers B and C are not synchronized anymore after the acceleration. Note that

$$\vec{L}^k_< \cdot \vec{\beta}^k_o = -\frac{\gamma_k \tau_o}{\tau_k \gamma_o} \gamma^o_k \vec{L}^o_< \cdot \vec{\beta}^o_k$$

where $\vec{L}^o_> = \vec{R}^o_{C,>} - \vec{R}^o_{B,>}$, so that the time difference between the acceleration of C and B as observed by A can also be written as

$$\Delta t^o = \frac{\tau_k \gamma_o}{\gamma_k \tau_o} \gamma^o_k \left(t^k_{C,0} - t^k_{B,0} \right) + (\gamma^o_k)^2 \frac{\vec{L}^o_< \cdot \vec{\beta}^o_k}{c} \tag{6.6}$$

By using equation (6.4), after the acceleration the difference between locations B and C as measured by observer A is given by

$$\vec{L}^o_> = \frac{\gamma_o \tau_k}{\tau_o \gamma_k} \times$$

$$\left\{ \gamma^o_k c (t^k_{C,0} - t^k_{B,0}) \vec{\beta}^o_k + \vec{L}^k_< - \frac{(\gamma^o_k)^2 \vec{\beta}^k_o \cdot \vec{L}^k_<}{\gamma^o_k - 1} \vec{\beta}^o_k - \frac{(\vec{\beta}^k_o - \vec{\beta}^o_k) \cdot \vec{L}^k_<}{(1 + \cos \Omega^o_k)(\beta^o_k)^2} (\vec{\beta}^k_o - \vec{\beta}^o_k) \right\}$$

which can be rewritten as

$$\vec{L}^o_> = \vec{L}^o_< + c \Delta t^o \vec{\beta}^o_k$$

Hence, observer A will notice that the acceleration of B and C is not simultaneously and will notice that the distance between B and C changes. When $\Delta t^o > 0$ corresponds to the distance moved by C after B has accelerated or when $\Delta t^o < 0$ corresponds to the distance moved by B after C has accelerated. Below the details of the three possibilities as discussed above are given.

6.2.1 Equal local time

If it is assumed that the objects are accelerated at the same *local* time, we will have $t^k_{B,0} = t^k_{C,0}$ and hence according to equation (6.6)

$$\Delta t^o = (\gamma^o_k)^2 \frac{\vec{L}^o_< \cdot \vec{\beta}^o_k}{c}$$

When $\vec{L}^o_< \perp \vec{\beta}^o_k$, there is no time difference and hence no change in L^o. When $\vec{L}^o_> // \vec{\beta}^o_k$ then the distance $L^o_>$ is equal to

$$L^o_> = (\gamma^o_k)^2 L^o_<$$

which differs form the apparent Lorentz contraction by a factor of γ^o_k. Unfortunately it is very difficult to perform such an experiment, so that this difference is not observed yet. Both this time difference and distance can be measured and gives information about $\vec{\beta}^o_k$, but is not directly dependent on the velocity with respect to the ether.

The question arises what happens when, like in the previous chapter, the points B and C are ridged connected to a rod. Can this rod change its velocity at every location at the same local time? When a force is applied at one point of the rod, dynamical action will prevent a direct start of the complete rod, especially if one assumes that no signal can travel faster than ether disturbances. Hence, when this time difference is measured it gives information about the dynamical aspects of the matter the rod is constructed of.

6.2.2 Ether signal synchronization

Let us assume that at the moment object B accelerates ($t^k = t^k_{B,0}$) a signal is send to object C using ether disturbances (i.e. the velocity of the signal is c). This signal will reach object C at the *local* time

$$t^k_{C,0} = t^k_{B,0} + \frac{L^k_<}{c}$$

because as it was shown in chapter 4.7, according to the observers B and C, ether disturbances seem to move with velocity c also when they are moving with respect to the ether. Hence according to equation (6.6)

$$\Delta t^o = \frac{\tau_k \gamma_o}{\gamma_k \tau_o} \frac{\gamma^o_k L^k_<}{c} + (\gamma^o_k)^2 \frac{\vec{L}^o_< \cdot \vec{\beta}^o_k}{c}$$

which can be rewritten as

$$\Delta t^o = \frac{\tau_k \gamma_o}{\gamma_k \tau_o} \gamma^o_k \left(\frac{L^k_< - \vec{L}^k_< \cdot \vec{\beta}^k_o}{c} \right)$$

corresponding to the time difference it takes for the ether disturbance to travel the distance between objects B and C as observed by observer A. Note that $\Delta t^o > 0$ so that also according to observer A, the second object will always accelerate after the first object. In observer's A coordinates this becomes

$$\Delta t^o = \gamma_k^o \frac{\sqrt{(L_<^o)^2 + \left(\gamma_k^o \vec{L}_<^o \cdot \vec{\beta}_k^o\right)^2} + \gamma_k^o \vec{L}_<^o \cdot \vec{\beta}_k^o}{c}$$

When $\vec{L}_<^o \perp \vec{\beta}_k^o$, the time difference is equal to $\Delta t^o = \gamma_k^o \frac{L_<^o}{c}$, so that it seems that the time interval is dilated. When $\vec{L}_>^o // \pm \vec{\beta}_k^o$ then the time difference is equal to

$$\Delta t^o = \frac{L_<^o}{c \mp c\beta_k^o}$$

so that

$$L_>^o = L_<^o \left(1 + (\gamma_k^o)^2 \beta_k^o (1 \pm \beta_k^o)\right)$$

Again both time difference and distance can be measured and gives information about $\vec{\beta}_k^o$, but does not directly depend on the velocity with respect to the ether.

6.2.3 Infinite speed signal synchronization

If it is assumed that the signal sent by the first observer propagates with infinite velocity *in the ether*, then the acceleration of both objects occurs at the same *ether* time. In that case the time difference is given by equation (6.2)

$$t_{C,0}^k - t_{B,0}^k = -\frac{\vec{\beta}_k \cdot \vec{L}_<^k}{c}$$

so that by using equation (6.5)

$$\Delta t^o = -\frac{\tau_k \gamma_o}{\gamma_k \tau_o} \gamma_k^o \frac{\vec{L}_<^k \cdot \left(\vec{\beta}_k + \vec{\beta}_o^k\right)}{c}$$

Here it is clear that the velocity $\vec{\beta}_k$ enters into the time difference. So, that in principle it should be detectable by such a measurement. If $\beta_o^k << 1$ then

$$\Delta t^o \approx -\frac{\vec{L}_<^o \cdot \vec{\beta}_k}{c}$$

so that the change in distance becomes

$$\vec{L}_>^o \approx \vec{L}_<^o - \left(\vec{L}_<^o \cdot \vec{\beta}_k\right) \vec{\beta}_k^o \approx \vec{L}_<^o + \left(\vec{L}_<^o \cdot \vec{\beta}^o\right) \vec{\beta}_k^o$$

Hence, the distance between the points C and B changes due to the acceleration proportional to first order in β_k^o and β_k or β^o, enabling the detection of the velocity of the ether with respect to observer A, $\vec{\beta}^o$, by changing the orientation of $\vec{L}_<^o$ with respect to it.

6.3 Thomas precession

Lets have an electron moving with velocity $c\vec{\beta}_k^o$ with respect to an observer A. The observer moves with velocity $c\vec{\beta}_o$ with respect to the ether. The electron moves with $c\vec{\beta}_k$ with respect to the ether. Let us assume that the magnetic moment of the electron is initially directed in a direction $\vec{S}^k$ in the electrons rest system. The direction in the ether co-ordinate system can be found by applying inverse transformation (4.16)

$$\vec{S} = \frac{\tau_k}{\gamma_k}\left(\vec{S}^k - \frac{\gamma_k \vec{\beta}_k \cdot \vec{S}^k}{1+\gamma_k}\vec{\beta}_k\right)$$

and the direction in observer's A co-ordinate system by equation (5.5)

$$\vec{S}_k^o = \frac{\gamma_o \tau_k}{\tau_o \gamma_k}\Re\left\{\frac{\vec{\beta}_k^o \times \vec{\beta}_o^k}{|\vec{\beta}_k^o \times \vec{\beta}_o^k|}, \Omega_k^o, \vec{S}^k - \frac{\gamma_o^k \vec{\beta}_o^k \cdot \vec{S}^k}{1+\gamma_o^k}\vec{\beta}_o^k\right\}$$

which can be rewritten as

$$\vec{S}_k^o + \frac{(\gamma_o^k)^2 \vec{\beta}_k^o \cdot \vec{S}_k^o}{1+\gamma_o^k}\vec{\beta}_k^o = \frac{\gamma_o \tau_k}{\tau_o \gamma_k}\Re\left\{\frac{\vec{\beta}_k^o \times \vec{\beta}_o^k}{|\vec{\beta}_k^o \times \vec{\beta}_o^k|}, \Omega_k^o, \vec{S}^k\right\} \tag{6.7}$$

and reversed

$$\vec{S}^k = \frac{\gamma_k \tau_o}{\tau_k \gamma_o}\Re\left\{\frac{\vec{\beta}_k^o \times \vec{\beta}_o^k}{|\vec{\beta}_k^o \times \vec{\beta}_o^k|}, -\Omega_k^o, \vec{S}_k^o + \frac{(\gamma_o^k)^2 \vec{\beta}_k^o \cdot \vec{S}_k^o}{1+\gamma_o^k}\vec{\beta}_k^o\right\}$$

Then at a certain instance, the electron's velocity with respect to the ether changes to $c\vec{\beta}_m$, and hence with respect to the observer the velocity becomes $c\vec{\beta}_m^o$. The question arises what happens to the direction of the magnetic moment when the velocity of the electron changes? Of coarse this depends on how the velocity change is imparted. Two special cases are the assumptions that the direction in the ether does not change or that the direction in the electron's rest system does not change.

6.3.1 Stationary direction in ether

In case the direction of the magnetic moment of the electron does not change in the ether, the direction with respect to the observer does not change either as the velocity of the observer with respect to the ether is constant. Hence, in such a case only the interaction of the magnetic moment with the self-field of the electron is changed. In quantum mechanics this self-field is ignored and hence, no change in interaction occurs and hence this can not explain the anomalous value of the magnetic moment of the electron in quantum mechanics.

6.3.2 Stationary direction in electron's rest system

In case the direction of the magnetic moment of the electron does not change in its rest system, both the direction of the magnetic moment with respect to the ether as the one observed by observer A changes, as the velocity of the electron with respect to the ether changes. Now again, the direction in the ether co-ordinate system can be found by applying inverse transformation (4.16) and the direction in observer's A co-ordinate system by equation (5.5)

$$\vec{S}^o_m = \frac{\gamma_o \tau_m}{\tau_o \gamma_m} \Re \left\{ \frac{\vec{\beta}^o_m \times \vec{\beta}^m_o}{|\vec{\beta}^o_m \times \vec{\beta}^m_o|}, \Omega^o_m, \vec{S}^m - \frac{\gamma^m_o \vec{\beta}^m_o \cdot \vec{S}^m}{1+\gamma^m_o} \vec{\beta}^m_o \right\}$$

and reversed

$$\vec{S^m} = \frac{\gamma_m \tau_o}{\tau_m \gamma_o} \Re \left\{ \frac{\vec{\beta}^o_m \times \vec{\beta}^m_o}{|\vec{\beta}^o_m \times \vec{\beta}^m_o|}, -\Omega^o_m, \vec{S}^o_m + \frac{(\gamma^m_o)^2 \vec{\beta}^o_m \cdot \vec{S}^o_m}{1+\gamma^m_o} \vec{\beta}^o_m \right\}$$

As it is assumed that the magnetic moment of the electron does not change direction in the electron's rest system $\vec{S}^m = \vec{S}^k$ and hence by using equation (6.7) $\vec{S}^o_m$ can be expressed in $\vec{S}^o_k$, according to

$$\frac{\gamma_m \tau_k}{\tau_m \gamma_k} \Re \left\{ \frac{\vec{\beta}^o_m \times \vec{\beta}^m_o}{|\vec{\beta}^o_m \times \vec{\beta}^m_o|}, -\Omega^o_m, \vec{S}^o_m + \frac{(\gamma^m_o)^2 \vec{\beta}^o_m \cdot \vec{S}^o_m}{1+\gamma^m_o} \vec{\beta}^o_m \right\} =$$
$$\Re \left\{ \frac{\vec{\beta}^o_k \times \vec{\beta}^k_o}{|\vec{\beta}^o_k \times \vec{\beta}^k_o|}, -\Omega^o_k, \vec{S}^o_k + \frac{(\gamma^k_o)^2 \vec{\beta}^o_k \cdot \vec{S}^o_k}{1+\gamma^k_o} \vec{\beta}^o_k \right\}$$

If we assume that the electrons velocity with respect to the observer is in all cases much smaller than c the second terms in the rotation function arguments can be neglected and the above reduces to

$$\frac{\gamma_m \tau_k}{\tau_m \gamma_k} \Re \left\{ \frac{\vec{\beta}^o_m \times \vec{\beta}^m_o}{|\vec{\beta}^o_m \times \vec{\beta}^m_o|}, -\Omega^o_m, \vec{S}^o_m \right\} = \Re \left\{ \frac{\vec{\beta}^o_k \times \vec{\beta}^k_o}{|\vec{\beta}^o_k \times \vec{\beta}^k_o|}, -\Omega^o_k, \vec{S}^o_k \right\}$$

Further, when both $\Omega^o_k << 1$ and $\Omega^o_m << 1$, then $\frac{\gamma_m \tau_k}{\tau_m \gamma_k} \approx 1$ and using the results of appendix B

$$\vec{S}^o_m = \vec{S}^o_k + \frac{\vec{S}^o_k \times \left(\vec{\beta}^o_k \times \vec{\beta}^k_o\right)}{(\beta^o_k)^2} - \frac{\vec{S}^o_m \times \left(\vec{\beta}^o_m \times \vec{\beta}^m_o\right)}{(\beta^o_m)^2}$$

Note that both sides of this equation contain $\vec{S}^o_m$. However, by inserting this equation in itself the last term disappears, as the cross product of two parallel vectors is 0, yielding

$$\vec{S}^o_m = \vec{S}^o_k + \vec{S}^o_k \times \left(\frac{\vec{\beta}^o_k \times \vec{\beta}^k_o}{(\beta^o_k)^2} - \frac{\vec{\beta}^o_m \times \vec{\beta}^m_o}{(\beta^o_m)^2} \right) - \frac{\left\{\vec{S}^o_k \times \left(\vec{\beta}^o_k \times \vec{\beta}^k_o\right)\right\} \times \left(\vec{\beta}^o_m \times \vec{\beta}^m_o\right)}{(\beta^o_k)^2 (\beta^o_m)^2}$$

or expressed in the coordinate system of the observer

$$\vec{S}^o_m = \vec{S}^o_k + \vec{S}^o_k \times \left\{ \left(\alpha^o_m \vec{\beta}^o_m - \alpha^o_k \vec{\beta}^o_k \right) \times \vec{\beta}_o \right\} - \alpha^o_k \alpha^o_m \left\{ \vec{S}^o_k \times \left(\vec{\beta}^o_k \times \vec{\beta}_o \right) \right\} \times \left(\vec{\beta}^o_m \times \vec{\beta}_o \right)$$

where

$$\alpha^o_k = \frac{\gamma_o \gamma^o_k (1 + \gamma_o + \gamma_k + \gamma^o_k)}{(1 + \gamma_o)(1 + \gamma_k)(1 + \gamma^o_k)}$$

and a similar expression for α^o_m.

If $\beta^o_k << 1$, $\beta^o_m << 1$, then $\alpha^o_k = \alpha^o_m = \gamma_o/(1 + \gamma_o)$ and hence

$$\vec{S}^o_m = \vec{S}^o_k + \Delta\vec{\Omega}^o_{m,k} \times \vec{S}^o_k$$

where

$$\Delta\vec{\Omega}^o_{m,k} = -\frac{\gamma_o}{1 + \gamma_o} \vec{\beta}^o \times \left(\vec{\beta}^o_m - \vec{\beta}^o_k \right)$$

Dividing both sides by Δt^o yields

$$\frac{\Delta\vec{\Omega}^o_{m,k}}{\Delta t^o} = -\frac{\gamma_o}{1 + \gamma_o} \vec{\beta}^o \times \vec{a}^o_{k,m} \tag{6.8}$$

where $\vec{a}^o_{k,m} = \left(\vec{\beta}^o_m - \vec{\beta}^o_k \right) / \Delta t^o$ is the acceleration of the electron as measured by the observer. Note that this rotation of vector $\vec{S}^o_m$ with respect to vector $\vec{S}^o_k$ depends on the velocity of the observer and hence (in the used approximation) of the electron with respect to the ether. The only approximations used are that $\beta^o_k << 1$ and $\beta^o_m << 1$, so that this equation is still valid even if both observer and electron move through the ether with a velocity close to the speed of light.

6.3.3 Discussion

The result (6.8) is completely analogue to equation (5.7), although here the electron changes its velocity instead of the observer. The difference is that here the observer's velocity with respect to the ether does not change, hence he is actual able to measure the rotated vector. In the case leading to equation (5.7) the whole coordinate system of the observer is rotated and hence he was not able to detect the rotated vector directly. It was only possible to detect the rotated vector if a reference vector in the ether coordinate system was assumed to remain fixed and hence the observer was able to measure the rotation of his coordinate system with respect to this reference vector.

Under the same conditions (i.e. the magnetic moment of the electron does not change in its rest system and small velocities) according to special relativity theory there is a Wigner rotation due to the difference between $\vec{\beta}^o_k$ and $\vec{\beta}^o_m$. The axis of this rotation is perpendicular to $\vec{\beta}^o_k$ and $\vec{\beta}^o_m$ [49, 59] given by

$$\frac{\Delta\vec{\Omega}^o_{m,k}}{\Delta t^o} = -\frac{(\gamma^o_k)^2}{1 + \gamma^o_k} \vec{\beta}^o_k \times \vec{a}^o_{k,m}$$

This equation is different from the one in equation (6.8) by the factor in front of the cross product. In case of velocities small with respect to c, this difference is very small. However, in the cross product instead of the velocity of the observer (or electron) with respect to the ether, the velocity of the electron with respect to the observer enters. In this way it should be possible to discriminate between the theories leading to these equations.

According to many authors the Thomas precession is the cause of the anamolous electron g-factor. If the above equation is correct it might be that very high precision measuermetns of the electron g-factor could also reveal annual variations during the earth's orbit around the sun [27].

One should keep in mind that the derivation critically depends on the reaction of the electron moment on the velocity change of the electron. The electron can only change its velocity be means of forces applied to it. In case of electro-magnetic forces one has to be careful how these forces are created as electro-magnetic forces are also subject to Lorentz transformations. It might be that a torque free force in one coordinate system results in a torque on the electron in its rest system, thereby not only changing the velocity of the electron, but also the direction of the magnetic moment in the electron's rest system. This also has been stressed by Kholmetskii [60, 61].

Chapter 7

Possible experiments

7.1 Classification of experiments

Simply one can divide the experiments to determine the absolute motion of the reference frame (or in other terms ’of the ether’) into two categories: first order or second order experiments, where the observed effect should be proportional to the appropriate order of the ratio of the velocity of the laboratory frame relative to the speed of light.

Bradley aberration [62] and the cosmic microwave background signal [63] are the most famous ones of the first category. The observation of a dipole distribution in the cosmic microwave background radiation [63] is an important experiment. By special relativity theory it is interpreted as the remnants of the initiation of the universe. For others it is a clear indication of a preferred reference frame and for some it has triggered renewed interest in the old ether concept. If it is interpreted as the frame in which the ether is at rest, another conclusions must be drawn from the observation of the dipole: A first order effect is possible. This is in direct contrast to the popular believes of the 20th century.

The Michelson-Morley experiment [3] is the most famous one for the second category. Because of the large speed of light and the smallness of velocity of the laboratory, in the 19th and first half of the 20th century, measurements were restricted to interference techniques (polarization measurement can also be interpreted as an interference technique). The attention changed from first order experiments to second order experiments when at the end of the 19th century the Fizeau drag effect was used to explain why first order experiments were not able to detect the absolute velocity of the earth. Nowadays, a further distinction into two other categories can be made: interference measurements and non-interference experiments.

In table 7.1 the categories with some examples are shown. Some of these experiments have been performed, but never repeated. Others are proposals based on theoretical analysis. The listing is typical, but incomplete. In the following, first the history of the second order interference experiment is discussed. This type of experiment is not a perfect candidate for a possible experiment to find deviations from special relativity theory because of the smallness of the effect: they are second order effects and the deviations are very small.

First order interference experiments as proposed by Múnera [64], Spavieri [65] and Wesley [66] and performed by Silvertooth [67, 68] and De Haan [69] are therefore better candidates. It is argued that time-of-flight measurements might do a better job as claimed via experiments by Marinov [70] and De Witte [71] and proposed by Kozynchenko [72] and Sardin [73] and in progress by Ahmed [74].

	Experiment	Proposal
Interference First order	Silvertooth (Standing waves) Galaev (Dynamic) De Haan (Gas-filled)	Wesley (Adapted Sagnac) Spavieri (Material-filled) Múnera (Gas-filled) Christov (Correlator)
Interference Second order	Michelson-Morley Demjanov (Material-filled) Múnera (Stationary) Cahill (Optical fiber) De Haan (Optical fiber)	Consoli (Gas-filled)
Non-Interfer. First order	Bradley aberration Cosmic Microwave Backgr. Marinov (Coupled shutters) De Witte (Time difference)	Ahmed (Coupled shutters) Kozynchenko (Time diff.)
Non-Interfer. Second order		Sardin (Time difference) Phipps, Jr. (Bradley aber.)

Table 7.1: Categories and possible experiments to test special relativity theory

The question arises under which conditions an ether theory and special relativity theory might give different results compared to the Lorentz ether theory. A possible answer has already been given by Helmholtz in 1858 [75] and was based on a remark by Euler in a publication of 1757 [76]. This was made to draw attention to limitations of velocity potentials to describe fluid motion. Triggered by this, Helmholtz showed that some type of fluid motion can not be generated or destroyed by conservative forces. He related this kind of fluid motion to vortex motion. Santilli [77] discovered a similar shortcoming in the modern use of Lagrangian and Hamiltonian dynamics, where standard all non-conservative forces are neglected. Santilli [77] describes two conditions under which these neglects are not detrimental. The first one is the *closure condition*: The system can be considered as isolated from the rest of the universe in order to permit the conservation laws of the total mechanical energy, the total physical linear momentum, the total physical angular momentum, and the uniform motion of the center of mass. The second one is the *selfadjointness condition*: The particles can be well approximated as massive points moving in vacuum along stable orbits without collisions, in order to restrict all possible forces to those of action-at-a-distance, potential type. Hence, the search for experiments to invalidate special relativity theory should be based on considerations whether or not these experiments violate these conditions. Todays examples of such experiments are (among many others) the superluminal tunneling experiments [78] and the rotational Mössbauer experiments [46].

7.2 Second order interference experiments

In chapter 1 the history of the most famous second order interference experiment, the Michelson-Morley experiment has been discussed. All experimentalist authors report the absence of the sought for effect. However, according to Múnera [79, 80] these experiments all have results comparable with those of Miller. Hence, experimental evidence is not conclusive whether or not some first or second order effect exists. Recently, it has been argued by Cahill [81] and Consoli [82] that the Miller effect [12], together with all other Michelson-Morley interferometer experimental results [17, 18, 19, 20, 21], could be due to a reduction of ether drag. This drag would depend on the difference of the refractive index of 1, which for atmospheric air is approximately 3×10^{-4}, for atmospheric helium 4×10^{-5} and for vacuum 0. This would also explain why modern-day vacuum experiments all give much lower limits for the anisotropy. Experiments performed by Demjanov [83] and Galaev [84] seem to confirm these predictions, but they have never been repeated. Cahill [85] used a fiber optic interferometer and claimed a positive result. This experiment was repeated by De Haan [86] under (almost) the same conditions yielding a result compatible with special relativity theory. The idea that the drag would depend on the medium (or is time-dependent as assumed by Galaev) can also be explained by a violation of one of the Santilli's conditions mentioned earlier.

New interests in the theory and experiment of the interferometric method to determine the anisotropy (or its absence) of the speed of light at the Earth surface emerged at the end of the last century. Múnera [79] discovered systematic errors in the data reduction of the measurements. He showed that the interpretation of the amplitude and phase of the second order effect should be done for each rotation of the interferometer separately, not by averaging on forehand. Further, following Hicks [87, 88] and Righi [89, 90, 91] De Miranda Filho describes possible first order effects in a Michelson-Morley interferometer [92]. Recently Múnera [80] reported an experiment claiming to see second order effects. He used a Michelson-Morley interferometer being stationary in the laboratory frame. The rotation of the Earth was used to change the direction of the velocity of the apparatus with respect to the preferred frame. This idea was followed by Cahill [85] using a fiber optical version of the interferometer. In these experiments the influence of the temperature on the signal was acknowledged. Múnera corrects his data for it and Cahill claims that the temperature can not influence the signal significantly. De Haan [86] copied the set-up of Cahill, with a stabilized temperature. He found a second order signal, but no sidereal dependence.

The Michelson-Morley experiment [5, 6] and its successors show that a moving rod changes its length according to the Lorentz transformations. Otherwise it would be possible to observe a shift in the interference pattern upon rotation of the instrument. This is a real dynamical effect in the arms of the interferometer, occurring completely unnoticed because the length measurements are distorted in the same way.

In 1968 Demjanov [93] repeated the Michelson-Morley experiment and discovered that the effect dependents on the material used as optical path. In vacuum the effect is absent and in air it is reduced by a factor of about 40. He also derived the same conclusion from the Fresnel drag coefficient formula and taking into account Lorentz contraction. Unfortunately, by that time, special relativity theory had reached dogma status and his findings are being ignored by mainstream physics until this day [83]. By now, the claim of a reduced sensitivity is followed by Spavieri [65], Consoli [82] and Cahill [81].

In view of the history of the experiment described above and the new insight of its reduced sensitivity it is of paramount importance that the Michelson-Morley experiment is repeated. This modern day repetition should copy as close as possible its original form under temperature controlled conditions with a fully-automated data acquisition. The knowledge of systematic errors in the data reduction of previous experiments must be used for the data reduction procedure.

7.3 First order interference experiments

Due to the smallness of second order effects many have devised experiments that should give a first order effect. Successful candidates are experiments which incorporate a violation of Santilli's conditions. This could be due the interaction of light with matter as discussed in the previous section.

According to Múnera [64] and Spavieri [65] the second order effects mentioned could be transformed into a first order effect by using an a-symmetric Mach-Zehnder interferometer. One arm of the interferometer contains over a path length L a material with refractive index n_1 and the other arm over the same length a material with refractive index n_2. Spavieri calculates a change in traveling time difference in the two arms upon rotation of the setup of $\Delta t = 2vL(n_1^2 - n_2^2)/c^2$ where v is the velocity of the ether wind, c the speed of light. He then argues that this will yield a fringe shift proportional to first order and would result in an easy obtained detection limit for v of some meters per second. A fiber optical version of this experiment was performed by De Haan [69]. In one arm a glass tube was inserted with a length of 100 mm that could be filled with atmospheric air or helium. When the glass tube was filled with air, upon rotation a fringe shift was observed corresponding to a maximum velocity of 64(6) km/s, about twice the velocity of Earth in its orbit around the Sun. However, the azimuth of the maximum of the first order effect was in the North to South direction and did not depend on sidereal time. When the air was replaced by helium this shift remained almost the same, casting doubts on the validity of Consoli's assumption of the reduction of ether drag. Another possible explanation would be that the ether velocity is dependent by the height above the surface of the Earth. This effect is mentioned by Miller [12] as a possible explanation for his reduced effect. Galaev [84] introduces such an effect to explain his measurements results with an asymmetric Mach-Zehnder interferometer. Such an effect could also depend on the medium surrounding the experiment, for it is not known to what extension the ponderable matter might influence the ether velocity. For definite conclusions these experiment need to be repeated with higher accuracy and at several altitudes.

Wesley [66] describes an interesting possibility that (as far as the author is aware) has never been performed. He uses a Mach-Zehnder type of interferometer and analyzes the resulting intensities of independent beams passing in opposite directions through the interferometer in a frame that is both rotating and translating. The novelty is in the comparison of intensities produced by counter propagating waves at two different locations. There might be a connection to the experiment performed by Silvertooth [67, 68]. He used a very thin transparent photo detector [94] to detect the nodes of the standing wave created by two counter propagating waves in a Sagnac type of interferometer. Silvertooth claimed a positive result but the theoretical background of the experiment was never explained satisfactorily [95, 96, 97, 98, 99, 100]. The experiment was repeated by Marinov twice. First with a similar result [101] and later after adaptation of the experiment with a negative result [102]. The adaptation was the replacement of the standing wave detector by a transparent mirror, changing the interference from counter propagating waves into interference of waves traveling into the same direction. This indicates that the use of counter propagating waves is crucial. The connection between Wesley's proposal and Silvertooth experiment can be made by the Wang's description of a Generalized Sagnac effect [103] as due to any moving part of the experiment. In Silvertooth experiment, the rotation of the earth would be used to create the rotational motion additional to the translation of the solar system. The possible accuracy of Silvertooth experiment makes it a very attractive option to reproduce.

7.4 Second order non-interference experiments

Interference techniques are regarded as the most accurate ones for the detection of the preferred frame. However, standard interference techniques use interference between light waves traveling in the same direction to obtain intensity fluctuations or fringes due to travel distance differences and not due to travel time differences. If the wave character of light is taken into account, light reflected from a moving mirror obtains in general a different frequency. If the Doppler effect is taken into account, this complicates the calculations. Further complications arise due to the aberration effect. Under these conditions it might be considered that Lorentz contraction and/or time dilatation does not occur in reality. Based on this reasoning, Sardin [73] proposed to measure the actual time difference of the travel time of the light beams through the two arms of a Michelson-Morley interferometer. With current state-of-the-art pulsed lasers and an interferometer as large as LIGO with multiple reflections yielding an effective arm length of 120 km the expected time difference is some nanoseconds. It was considered not feasible by LIGO staff [104].

7.5 First order non-interference experiments

In 1728 Bradley [62] discovered that some stars exhibited an aberration depending on the velocity of the earth around the sun. This is now known as Bradley aberration. Its explanation in the framework of special relativity theory is disputed in literature (see for instance [105]), especially since De Sitter [106] showed that binary stars (moving with a different velocity at approximately the same location in the sky) have the same aberration independent of the velocity of the stars. The discrepancy can be mended up to first order if the wave character of light is taken into account. Phipps [107] proposes that higher order terms might be observable by Very Long Base Line interferometry.

In the 1970-80's Marinov [108, 70] performed several first order experiments which (he claimed) gave positive and similar results. They were all based on a so-called Newtonian time synchronization. The idea that a Newtonian time synchronization can be obtained is strengthened by the well-known clock paradox or twin paradox. It has been and still is discussed by many authors. It is closely related to the question whether time dilatation is a dynamical process or not. According to special relativity theory the observer's time scale is changed when he moves with respect to a clock. According to compatible ether theories the time scale is fixed (Newtonian) and the clock set in motion changes its rate. Based on the idea that Newtonian time synchronization is achieved, Kozynchenko [72] proposes to look for a sidereal period in the time-of-flight measurements of laser pulses between two distant locations on the Earth surface.

The Newtonian time synchronization as realized by Marinov is based on shutters or mirrors mounted on two rotating discs connected by a rigid axis. Ives [109] showed that such a system, subjected to Lorentz contraction, cannot be used as a Newtonian time synchronization. However, Lorentz contraction is based on conservative forces and it could be that contact forces in the axis and discs (violating the second Santilli condition) would enable a Newtonian time synchronization. Again to the author knowledge Marinov's experiments have not been repeated until now, but an attempt is in progress [74].

In 1991 De Witte [71] performed a first order experiment by measuring a phase delay of a 5 MHz electro-magnetic signal through a 1.5 km long cable. The novelty of this experiment was that he did not use an interference technique to determine the time delay, but he directly measured the phase of the waves. He measured for 178 days and claimed to have observe a sidereal dependence on the occurrence of the maximum time delay. The experiment was never repeated in this way. Based on this experiment Cahill claimed to measure a similar effect [110], but it is based on very limited data.

Christov [111] uses this idea of phase comparison in a novel way. Instead of measuring the local intensity of interfering counter propagating light beams he proposes to measure the correlation between the electro-magnetic fields at different locations. The correlation between the electro-magnetic fields should exhibit a clear first order effect, varying with the distance between the locations. The maximum effect occurs if the ratio between the wavelength of the used light and the distance between the locations is equal to the ration of the expected velocity and the speed of light, i.e. 1/1000. For visible light the frequency is too high to be able to measure the temporal characteristics of the electro-magnetic field. For lower frequencies down to radio waves this is possible. However, the associated wavelengths are much larger, which results in distances of the order of several meters to hundreds of meters to obtain accurate enough results. With the use of Terahertz waves (sub mm) the dimensions could be kept below 1 m. Another approach to measure the correlation between two distant locations, could be to use superluminal tunneling [78, 112, 113] or other non-propagating transfer mechanisms, like for instance a standing wave crossing an absorber [114].

7.6 New experiments

It has been shown that a growing number of experimentalists are considering the possibility of detecting deviations from special relativity theory.

To be able to experimentally test a theory a good understanding of its range of applicability is needed. An alternative theory that does not deviate in its experimental predictions can only be preferred or rejected by its meta-philosophical content. An alternative extended theory is needed to be able to device experiments to discriminate between them. The Lorentz ether theory extends special relativity theory (although it predates it too) as it uses absolute velocities, i.e. velocities relative to the frame in which the ether is at rest. However, as long as this extension is not experimentally verified is has no practical use and can be disregarded.

Another extension has been realized by Santilli by incorporating contact forces or extended particles and non-locality. Contact forces can give rise to superluminal velocities which, when incorporated in a suitable experiment, should be able to expose the velocity of the ether. That is why in the above the considered experiments were focused on the detection of the ether rest frame.

The above list is far from complete and only addresses certain experiments in which a possible violation of Santilli's conditions for the validity of special relativity theory is considered. Some experimentalists claim to have observed such a deviation. Unfortunately the reproduction of most of these experiments is either not documented or not performed. This omission clearly hinders scientific progress. On the one hand, if the reported deviations are experimentally confirmed, special relativity theory should have been replaced by a more extended theory. On the other hand, if they were experimentally dismissed, efforts could have been spent into other scientific endeavors.

The most important experiments that needs to be reproduced are the first order experiments because of the expected magnitude of the effect. The interference measurements with counter propagating beams and a standing wave detector as performed by Silvertooth should be reproduced. The adapted Sagnac experiment as proposed by Wesley could be related to this experiment, however it does not use a standing wave detector so it is technically not too complicated. The novel experiment as proposed by Christov is interesting, not only to detect the ether rest frame, but also in studies where relative velocities are considered or when superluminal velocities are involved.

A proposal for the repetition of the Demjanov experiment has been made by de Haan [115].

As we have seen in the previous chapters that if it exist, the ether is masked due to clock rate and length changes due to the velocity with respect to this ether. This is based on the effect that ether disturbances move with a maximum velocity. If there is a means that a signal is transported faster than the speed of light, then also is will be possible to detect ones motion through the ether as these signals can be used to synchronize clocks. This is the basis for the proposal of Rembielinski [116] to perform an Einstein-Podolsky-Rosen-type experiment with a pair of observers staying in the same inertial frame and with use of elementary particles to find a preferred (or ether) frame. Some authors [117, 118, 119, 120, 121] propose that the existence of *fast light* really means that ether disturbances move faster than light through the ether, if it exists such phenomena can be used to detect the ether frame.

Chapter 8

Conclusions

It is impossible to detect a difference between an observer at rest or an observer in motion with respect to the ether when the period of all sources depend on their velocity with respect to the ether as indicated by equation (4.1) and the assumption that $\tau = \gamma$. Einstein's basic axiom that all physical laws should be the same regardless of the observer's velocity [15] gives this result directly. This can be interpreted as due to ignorance of ones own velocity with respect to the ether.

If this should also be the case in general, then this means that all objects should contract according to the Lorentz transformation (4.17) and periodic events should be time dilated according to equation (4.18). Lorentz [25] proved this for all electromagnetic phenomena for which the Maxwell equations hold and he proposed this could be valid for all natural phenomena. He called this his *theorem of corresponding states*.

Here, this is interpreted as the result of a measurement system distorted in such a way that it is impossible to detect one's velocity with respect to the ether as long as the clocks and measurements rods are affected by this velocity in the way as discussed above. This can be called *measurement relativity*, because it is due to the distortions in the measurement equipment due to the velocity with respect to the ether.

However, a growing number of experimentalists are considering the possibility of detecting deviations from special relativity theory.

An alternative extended theory is needed to be able to device experiments to discriminate between them. The Lorentz ether theory extends special relativity theory (although it predates it too) as it uses absolute velocities, i.e. velocities relative to the frame in which the ether is at rest.

Another extension has been realized by Santilli by incorporating contact forces or extended particles and non-locality. Contact forces can give rise to superluminal velocities which, when incorporated in a suitable experiment, should be able to expose the velocity of the ether. A proposal based on this possibility is the repetition of the Demjanov experiment [115].

Some authors [117, 118, 119, 120, 121] propose that the existence of *fast light* really means that ether disturbances move faster than light through the ether, if it exists such phenomena can be used to detect the ether frame.

The experiment based on Thomas Precession at relatively small velocities as described in chapter 6.3 should be able to give information about the reference system in which the torque on the electron magnetic moment is 0 or negligible. This might be the ether frame, although this is not in general the case. It is a first order experiment, so it should be able to give reasonable accurate results.

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Appendix A. Useful relations

Variables without superscript denote quantities as measured in the ether. Variables with a superscript o or k denote quantities as measured in a coordinate system as defined in chapter 4.3 for an observer moving with a velocity $c\vec{\beta}_o$ or $c\vec{\beta}_k$ with respect to the ether. In all cases $\gamma = 1/\sqrt{1-\beta^2}$.

The velocity of coordinate system k as measured by an observer in coordinate system o is given by the velocity addition formula (4.21) as derived in chapter 4.7

$$\vec{\beta}^o_k = \frac{\vec{\beta}_k/\gamma_o + \left(\gamma_o/(1+\gamma_o)\vec{\beta}_k \cdot \vec{\beta}_o - 1\right)\vec{\beta}_o}{1 - \vec{\beta}_k \cdot \vec{\beta}_o}$$

which can be rewritten as

$$\vec{\beta}^o_k = \frac{\gamma_k}{\gamma^o_k}\vec{\beta}_k - \frac{\gamma_o(\gamma_k + \gamma^o_k)}{\gamma^o_k(1+\gamma_o)}\vec{\beta}_o$$

where is was used that

$$\vec{\beta}_k \cdot \vec{\beta}_o = 1 - \frac{\gamma^o_k}{\gamma_k \gamma_o}$$

and a similar relation for

$$\vec{\beta}^k_o = \frac{\gamma_o}{\gamma^k_o}\vec{\beta}_o - \frac{\gamma_k(\gamma_o + \gamma^k_o)}{\gamma^k_o(1+\gamma_k)}\vec{\beta}_k$$

A special case exists if one takes $\beta_k = 0$, i.e. the velocity of the ether as measured by an observer moving with respect to the ether with velocity $c\vec{\beta}_o$

$$\vec{\beta}^o = -\vec{\beta}_o$$

From this one can derived the useful relations

$$\gamma^k_o = \gamma^o_k$$

$$\vec{\beta}_k = \frac{\gamma^o_k}{\gamma_k}\vec{\beta}^o_k + \frac{\gamma_o(\gamma_k + \gamma^o_k)}{\gamma_k(1+\gamma_o)}\vec{\beta}_o$$

$$\vec{\beta}_k = -\frac{(1+\gamma_k)\left(\gamma_k^o \vec{\beta}_o^k + \gamma_o \vec{\beta}_o\right)}{\gamma_k(\gamma_o + \gamma_k^o)}$$

$$\vec{\beta}_k = -\frac{\gamma_k^o(1+\gamma_k)\left((\gamma_k + \gamma_k^o)\vec{\beta}_o^k + (1+\gamma_k^o)\vec{\beta}_k^o\right)}{\gamma_k(\gamma_k^o - 1)(1+\gamma_o+\gamma_k+\gamma_k^o)}$$

and

$$\vec{\beta}_o = \frac{\gamma_k^o}{\gamma_o}\vec{\beta}_o^k + \frac{\gamma_k(\gamma_o+\gamma_k^o)}{\gamma_o(1+\gamma_k)}\vec{\beta}_k$$

$$\vec{\beta}_o = -\frac{(1+\gamma_o)\left(\gamma_k^o \vec{\beta}_k^o + \gamma_k \vec{\beta}_k\right)}{\gamma_o(\gamma_k + \gamma_k^o)}$$

$$\vec{\beta}_o = -\frac{\gamma_k^o(1+\gamma_o)\left((1+\gamma_k)\vec{\beta}_o^k + (\gamma_o + \gamma_k^o)\vec{\beta}_k^o\right)}{\gamma_o(\gamma_k^o - 1)(1+\gamma_o+\gamma_k+\gamma_k^o)}$$

so that

$$\vec{\beta}_k^o \cdot \vec{\beta}_o = \frac{\gamma_k}{\gamma_o\gamma_k^o} - 1$$

$$\vec{\beta}_o^k \cdot \vec{\beta}_o = \frac{(\gamma_o+\gamma_k^o)^2}{\gamma_o\gamma_k^o(1+\gamma_k)} - \frac{1+\gamma_o\gamma_k^o}{\gamma_o\gamma_k^o}$$

$$\vec{\beta}_k^o \cdot \vec{\beta}_k = \frac{(\gamma_k+\gamma_k^o)^2}{\gamma_k\gamma_k^o(1+\gamma_o)} - \frac{1+\gamma_k\gamma_k^o}{\gamma_k\gamma_k^o}$$

$$\vec{\beta}_o^k \cdot \vec{\beta}_k = \frac{\gamma_o}{\gamma_k\gamma_k^o} - 1$$

Also

$$\vec{\beta}_o = -\frac{\gamma_k^o(1+\gamma_o)\left((1+\gamma_k)\vec{\beta}_o^k + (\gamma_o + \gamma_k^o)\vec{\beta}_k^o\right)}{\gamma_o(\gamma_k^o - 1)(1+\gamma_o+\gamma_k+\gamma_k^o)}$$

and

$$\vec{\beta}_k = -\frac{\gamma_k^o(1+\gamma_k)\left((\gamma_k + \gamma_k^o)\vec{\beta}_o^k + (1+\gamma_o)\vec{\beta}_k^o\right)}{\gamma_k(\gamma_k^o - 1)(1+\gamma_o+\gamma_k+\gamma_k^o)}$$

The Wigner rotation angle is

$$\cos\Omega_k^o = -\frac{\vec{\beta}_o^k \cdot \vec{\beta}_k^o}{\beta_o^k \beta_k^o} = \frac{(1+\gamma_o+\gamma_k+\gamma_k^o)^2}{(1+\gamma_o)(1+\gamma_k)(1-\gamma_k^o)} - 1$$

which can be rewritten by using $\cos\theta = \vec{\beta}_k \cdot \vec{\beta}_o/(\beta_k\beta_o)$ as

$$\cos\Omega_k^o = 1 - \frac{(\gamma_o-1)(\gamma_k-1)\sin^2\theta}{1+\gamma_o\gamma_k(1-\beta_o\beta_k\cos\theta)}$$

and also

$$\sin\Omega_k^o = \gamma_o\beta_o\gamma_k\beta_k\sin\theta\frac{(1+\gamma_o+\gamma_k+\gamma_k^o)}{(1+\gamma_o)(1+\gamma_k)(1+\gamma_k^o)}$$

Appendix B. Rodrigues vector rotation formula

The function

$$\Re(\vec{n}, \Omega, \vec{R}) = \vec{R} + \vec{n} \times \vec{R} \sin\Omega - (\vec{R} - \vec{n}(\vec{n} \cdot \vec{R}))(1 - \cos\Omega)$$

is known as the Rodrigues vector rotation formula rotating the vector $\vec{R}$ around a unit vector $\vec{n}$ over an angle Ω according to the right hand rule.

In case of Wigner rotation the vector $\vec{n}$ can be expressed by means of the velocities $c\vec{\beta}_o$ and $c\vec{\beta}_k$ where

$$\vec{n} = \frac{\vec{\beta}_o \times \vec{\beta}_k}{|\vec{\beta}_o \times \vec{\beta}_k|}$$

and the angle Ω can be expressed as

$$\cos\Omega = \frac{1}{(1+\gamma_o)(1+\gamma_k)} \left(\frac{\gamma_o + \gamma_k}{1 + \gamma_o\gamma_k(1 - \vec{\beta}_o \cdot \vec{\beta}_k)} + 1 \right)^2 - 1$$

or

$$\sin\Omega = \sin\theta \frac{\gamma_o\beta_o\gamma_k\beta_k}{(1+\gamma_o)(1+\gamma_k)} \left(\frac{\gamma_o + \gamma_k}{1 + \gamma_o\gamma_k(1 - \beta_o\beta_k\cos\theta)} + 1 \right)$$

where θ is the angle between $\vec{\beta}_o$ and $\vec{\beta}_k$.

When the velocities $c\vec{\beta}_k^o$ and $c\vec{\beta}_o^k$ are used instead then

$$\vec{n} = \frac{\vec{\beta}_k^o \times \vec{\beta}_o^k}{|\vec{\beta}_k^o \times \vec{\beta}_o^k|}$$

and

$$\cos\Omega = -\frac{\vec{\beta}_k^o \cdot \vec{\beta}_o^k}{\beta_k^o \beta_o^k}$$

so that $\vec{\beta}_o$, $\vec{\beta}_k$, $\vec{\beta}_k^o$ and $\vec{\beta}_o^k$ all lie in the same plane and the above rotation has the effect that the vector $\vec{\beta}_o^k$ is rotated into the vector $-\vec{\beta}_k^o$.

Note that

$$\sin\Omega = \frac{|\vec{\beta}_k^o \times \vec{\beta}_o^k|}{\beta_k^o \beta_o^k}$$

so that

$$\vec{n} = \frac{\vec{\beta}_k^o \times \vec{\beta}_o^k}{\beta_k^o \beta_o^k \sin\Omega}$$

Using these relations, the Wigner rotation can be rewritten as

$$\Re(\vec{n}, \Omega, \vec{R}) = \vec{R}\cos\Omega + \vec{n} \times \vec{R}\sin\Omega + \vec{n}(\vec{n} \cdot \vec{R})(1 - \cos\Omega)$$

$$\Re(\vec{\beta}_k^o, \vec{\beta}_o^k, \Omega, \vec{R}) = \frac{(\vec{\beta}_k^o \times \vec{\beta}_o^k) \times \vec{R} - (\vec{\beta}_k^o \cdot \vec{\beta}_o^k)\vec{R}}{(\beta_k^o)^2} + \frac{(\vec{\beta}_k^o \times \vec{\beta}_o^k)\left((\vec{\beta}_k^o \times \vec{\beta}_o^k) \cdot \vec{R}\right)}{(1 + \cos\Omega)(\beta_k^o)^4}$$

which can be rewritten as

$$\Re(\vec{\beta}_k^o, \vec{\beta}_o^k, \Omega, \vec{R}) = \vec{R} - \frac{2\vec{\beta}_k^o(\vec{R} \cdot \vec{\beta}_o^k)}{(\beta_k^o)^2} - \frac{(\vec{\beta}_k^o - \vec{\beta}_o^k)\left(\vec{R} \cdot (\vec{\beta}_k^o - \vec{\beta}_o^k)\right)}{(\beta_k^o)^2(1 + \cos\Omega)}$$

If $\Omega << 1$, Rodrigues vector rotation formula can be approximated by

$$\Re(\vec{n}, \Omega, \vec{R}) = \vec{R} + \vec{\Omega} \times \vec{R}$$

where $\vec{\Omega} = \Omega\vec{n}$, so that

$$\Re(\vec{\beta}_k^o, \vec{\beta}_o^k, \vec{R}) = \vec{R} + \frac{\left(\vec{\beta}_k^o \times \vec{\beta}_o^k\right) \times \vec{R}}{(\beta_k^o)^2}$$

or when both $\beta_o << 1$ and $\beta_k << 1$

$$\Re(\vec{\beta}_k^o, \vec{\beta}_o^k, \vec{R}) = \vec{R} + \frac{1}{2}\left(\vec{\beta}_o \times \vec{\beta}_k\right) \times \vec{R}$$

Summary

Based on the principle of Huygens that an ether disturbance moves away with a finite constant velocity in a spherical shell, it is possible to derive Lorentz-like transformations that reduce to Lorentz transformations when it is assumed that the period of the ether disturbance is dependent on its velocity with respect to the ether. A moving observer using these ether disturbances can create his coordinate system. This reference system will be distorted in such a way that it is impossible to detect his velocity with respect to the ether as long as the clocks are also affected by this velocity in the same way as the period of the ether disturbances. This can be called *measurement relativity*, because it is due to the distortions in the measurement equipment due to the velocity with respect to the ether.

Experiments that would be able to detect the ether must incorporate interaction with matter as there are strong indications that Quantum Mechanics is not valid in special relativity theory but can be in correspondence with the Lorentz ether theory. The most important experiments that needs to be reproduced are first order experiments because of the expected magnitude of the effect.

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