Advances in Astrophysics, Vol. 3, No. 1, February 2018
https://dx.doi.org/10.22606/adap.2018.31002

Transport Processes in Physical Vacuum

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Abstract. The relationship is established between the Physical Vacuum (PV) description in the frame of non-local physics and PV boxes, clear air turbulence (CAT), the Shawyer EM-drive (PV-engines), and Special Theory of Relativity.

Keywords: Local physics and PV boxes, clear air turbulence (CAT), the Shawyer EM-drive (PV-engines), Special Theory of Relativity.

1 Introduction

In monographs [1 - 4] reveals the following effects of the principal significance:

1. The birth of the universe is convoying of appearance of the repulsion forces. In the existing terminology - we discover the “negative pressure” and “dark energy” in all cases. This fundamental result does not depend on the mechanism of external perturbations. In other words, the anti-gravity in the physical vacuum exists, if there is dissipation of energy or in the absence of dissipation at all.

2. Physical Vacuum (PV) is not a speculative object; it is a reality as “matter” and “fields”. In other words, the physical vacuum is "the third" physical reality along with matter and fields. In this case, it is natural to raise the question about the existence of the effect which is similar to the Hubble’s effect. As installed the appearance of this effect in the physical vacuum does not contradict the conclusions of non-local physics.

In this article we investigate in the frame of non-local physics the connection between from the first glance different effects like Physical Vacuum and PV boxes, clear air turbulence (CAT), the Shawyer EM-drive (PV-engines), Special Theory of Relativity.

2 The Burst of PV Volume as an Analogue of the Hubble Motion

The following progress in cosmology, in understanding the origin and evolution of the Universe, will be based on projects like Planck, NASA WMAP (Wilkinson Microwave Anisotropy Probe) space mission and the BICEP2 (Background Imaging of Cosmic Extragalactic Polarization 2) experiment. In this case we can speak about (now speculative) models like the burst in domains filled by PV. These models are analogue of the Hubble boxes which are observed in reality, [5, 6].

In the mentioned case it is reasonable to use the spherical coordinate system; [1 - 4]. Let us derive the transport PV equations in the non-stationary spherically symmetric case. In the usual hydrodynamic notations we have continuity equation:

$$\frac{\partial}{\partial t}\left\{\rho-\tau\left[\frac{\partial\rho}{\partial t}+\frac{\partial}{\partial \boldsymbol{r}}\cdot(\rho\boldsymbol{v}_0)\right]\right\}+\frac{\partial}{\partial \boldsymbol{r}}\cdot\left\{\rho\boldsymbol{v}-\tau\left[\frac{\partial}{\partial t}(\rho\boldsymbol{v}_0)+\frac{\partial}{\partial \boldsymbol{r}}\cdot(\rho\boldsymbol{v}_0\boldsymbol{v}_0)+\vec{I}\cdot\frac{\partial p}{\partial \boldsymbol{r}}-\boldsymbol{F}\right]\right\}=0 \quad (2.1)$$

which in the non-stationary spherically symmetric case is written as

$$\frac{\partial}{\partial t}\left\{\rho-\tau\left[\frac{\partial\rho}{\partial t}+\frac{1}{r^2}\frac{\partial\left(r^2\rho v_{0r}\right)}{\partial r}\right]\right\}+\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\left\{\rho v_{0r}-\tau\left[\frac{\partial}{\partial t}\left(\rho v_{0r}\right)+\frac{1}{r^2}\frac{\partial\left(r^2\rho v_{0r}^2\right)}{\partial r}-F_r\right]\right\}\right\}$$
$$-\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2\frac{\partial p}{\partial r}\right)=0 \quad (2.2)$$

where τ is a nonlocality parameter. The transfer to PV means the limit case $\rho \to 0$; as a result we have from (2.2)

$$\frac{\partial}{\partial r}\left\{r^2\tau\left[\frac{\partial p}{\partial r}-F_r\right]\right\}=0 \tag{2.3}$$

In the analogical 1D case in the Cartesian coordinate system we have

$$\frac{\partial}{\partial x}\left\{\tau\left[\frac{\partial p}{\partial x}-F\right]\right\}=0 \tag{2.4}$$

Equation (2.3) immediately can be integrated

$$r^2\tau\left[\frac{\partial p}{\partial r}-F_r\right]=C\ (t) \tag{2.5}$$

Momentum equation in the non-stationary spherically symmetric case is

$$\begin{gathered}\frac{\partial}{\partial t}\left\{\rho v_{0r}-\tau\left[\frac{\partial}{\partial t}\left(\rho v_{0r}\right)+\frac{1}{r^2}\frac{\partial\left(r^2\rho v_{0r}^2\right)}{\partial r}+\frac{\partial p}{\partial r}-F_r\right]\right\}\\ -\left[F_r-\tau g_r\left(\frac{\partial\rho}{\partial t}+\frac{1}{r^2}\frac{\partial\left(r^2\rho v_{0r}\right)}{\partial r}\right)\right]+\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\left\{\rho v_{0r}^2-\tau\left[\frac{\partial}{\partial t}\left(\rho v_{0r}^2\right)+\frac{1}{r^2}\frac{\partial\left(r^2\rho v_{0r}^3\right)}{\partial r}-2F_r v_{0r}\right]\right\}\right\}\\ +\frac{\partial p}{\partial r}-\frac{\partial}{\partial r}\left(\tau\frac{\partial p}{\partial t}\right)-2\frac{\partial}{\partial r}\left(\frac{\tau}{r^2}\frac{\partial\left(r^2 p v_{0r}\right)}{\partial r}\right)-\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2\frac{\partial\left(p v_{0r}\right)}{\partial r}\right)=0\end{gathered} \tag{2.6}$$

The transfer to PV means the limit case $\rho \to 0$

$$\begin{gathered}\frac{\partial p}{\partial r}-F_r-\frac{\partial}{\partial t}\left\{\tau\left[\frac{\partial p}{\partial r}-F_r\right]\right\}+\frac{2}{r^2}\frac{\partial}{\partial r}\left\{\tau r^2 F_r v_{0r}\right\}\\ -\frac{\partial}{\partial r}\left(\tau\frac{\partial p}{\partial t}\right)-2\frac{\partial}{\partial r}\left(\frac{\tau}{r^2}\frac{\partial\left(r^2 p v_{0r}\right)}{\partial r}\right)-\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2\frac{\partial\left(p v_{0r}\right)}{\partial r}\right)=0\end{gathered} \tag{2.7}$$

or using (2.3)

$$\begin{gathered}\frac{\partial p}{\partial r}-F_r-\frac{\partial}{\partial t}\left\{\tau\left[\frac{\partial p}{\partial r}-F_r\right]\right\}+\frac{2}{r^2}\frac{\partial}{\partial r}\left\{\tau r^2\left[F_r v_{0r}-\frac{\partial\left(p v_{0r}\right)}{\partial r}\right]\right\}\\ -\frac{\partial}{\partial r}\left(\tau\frac{\partial p}{\partial t}\right)-2\frac{\partial}{\partial r}\left(\frac{\tau}{r^2}\frac{\partial\left(r^2 p v_{0r}\right)}{\partial r}\right)+\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2\frac{\partial\left(p v_{0r}\right)}{\partial r}\right)=0\end{gathered} \tag{2.8}$$

or

$$\begin{gathered}\frac{\partial p}{\partial r}-F_r-\frac{\partial}{\partial t}\left\{\tau\left[\frac{\partial p}{\partial r}-F_r\right]\right\}+2\tau\left[F_r-\frac{\partial p}{\partial r}\right]\frac{\partial v_{0r}}{\partial r}-\frac{1}{r^2}\frac{\partial}{\partial r}\left\{\tau r^2 p\frac{\partial v_{0r}}{\partial r}\right\}\\ -\frac{\partial}{\partial r}\left(\tau\frac{\partial p}{\partial t}\right)-2\frac{\partial}{\partial r}\left(\frac{\tau}{r^2}\frac{\partial\left(r^2 p v_{0r}\right)}{\partial r}\right)+\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2 v_{0r}\frac{\partial p}{\partial r}\right)=0\end{gathered} \tag{2.9}$$

or

$$\begin{gathered}\frac{\partial p}{\partial r}-F_r-\frac{\partial}{\partial t}\left\{\tau\left[\frac{\partial p}{\partial r}-F_r\right]\right\}+2\tau\left[F_r-\frac{\partial p}{\partial r}\right]\frac{\partial v_{0r}}{\partial r}\\ -\frac{\partial}{\partial r}\left\{\tau\left[\frac{\partial p}{\partial t}+3p\frac{\partial v_{0r}}{\partial r}+v_{0r}\frac{\partial p}{\partial r}+\frac{4}{r}p v_{0r}\right]\right\}+\frac{2}{r}\tau\left[v_{0r}\frac{\partial p}{\partial r}-p\frac{\partial v_{0r}}{\partial r}\right]=0\end{gathered} \tag{2.10}$$

The corresponding momentum equation in the Cartesian 1D case is written as

$$\frac{\partial p}{\partial x}-F-\frac{\partial}{\partial t}\left\{\tau\left[\frac{\partial p}{\partial x}-F\right]\right\}-2\tau\left(\frac{\partial p}{\partial x}-F\right)\frac{\partial u}{\partial x}$$
$$-\frac{\partial}{\partial x}\left\{\tau\left[\frac{\partial p}{\partial t}+u\frac{\partial p}{\partial x}+3p\frac{\partial u}{\partial x}\right]\right\}=0 \tag{2.11}$$

Then we have the following dependent variables in this variant of nonlocal theory of PV description - pressure p, the force F_r acting in the radial direction on the unit of PV volume and the radial hydrodynamic velocity v_{0r}.

Consider now the energy equation

$$\frac{\partial}{\partial t}\left\{\frac{1}{2}\rho v_{0r}^2+\frac{3}{2}p-\tau\left[\frac{\partial}{\partial t}\left(\frac{1}{2}\rho v_{0r}^2+\frac{3}{2}p\right)+\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 v_{0r}\left(\frac{1}{2}\rho v_{0r}^2+\frac{5}{2}p\right)\right)-F_r v_{0r}\right]\right\}$$
$$+\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\left\{\left(\frac{1}{2}\rho v_{0r}^2+\frac{5}{2}p\right)v_{0r}-\tau\left[\frac{\partial}{\partial t}\left(\left(\frac{1}{2}\rho v_{0r}^2+\frac{5}{2}p\right)v_{0r}\right)+\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\left(\frac{1}{2}\rho v_{0r}^2+\frac{7}{2}p\right)v_{0r}^2\right)\right.\right.\right.$$
$$\left.\left.\left.-F_r v_{0r}^2-\left(\frac{1}{2}\rho v_{0r}^2+\frac{3}{2}p\right)g_r\right]\right\}\right\}-\left\{F_r v_{0r}-\tau\left[g_r\left(\frac{\partial}{\partial t}\left(\rho v_{or}\right)+\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\rho v_{0r}^2\right)+\frac{\partial p}{\partial r}-F_r\right)\right]\right\} \tag{2.12}$$
$$-\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2\frac{\partial}{\partial r}\left(\frac{1}{2}pv_{0r}^2+\frac{5}{2}\frac{p^2}{\rho}\right)\right)+\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\tau p g_r\right)=0$$

The transfer to the limit case $\rho\to 0$ leads to equation

$$\frac{\partial}{\partial t}\left\{3p-\tau\left[3\frac{\partial p}{\partial t}+5\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 v_{0r}p\right)-2F_r v_{0r}\right]\right\}$$
$$+\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\left\{5pv_{0r}-\tau\left[\frac{\partial}{\partial t}\left(5pv_{0r}\right)+7\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 pv_{0r}^2\right)-3F_r v_{0r}^2\right]\right\}\right\}-2\left\{F_r v_{0r}\right\} \tag{2.13}$$
$$-\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2\frac{\partial}{\partial r}\left(pv_{0r}^2+5\frac{p^2}{\rho}\right)\right)+\frac{2}{r^2}\frac{\partial}{\partial r}\left(r^2\tau p g_r\right)=0$$

or

$$\frac{\partial}{\partial t}\left\{3p-\tau\left[3\frac{\partial p}{\partial t}+5\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 v_{0r}p\right)-2F_r v_{0r}\right]\right\}$$
$$+\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\left\{5pv_{0r}-\tau\left[\frac{\partial}{\partial t}\left(5pv_{0r}\right)+7\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 pv_{0r}^2\right)-3F_r v_{0r}^2\right]\right\}\right\} \tag{2.14}$$
$$-2F_r v_{0r}-\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2\frac{\partial}{\partial r}\left(pv_{0r}^2\right)\right)+\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r-5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right]=0$$

with the external perturbation

$$A^{pert}=\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r-5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right] \tag{2.15}$$

Analogical value in the Cartesian case

$$A^{pert}=\frac{\partial}{\partial x}\left\{\tau\left(2\frac{p}{\rho}F-5\frac{\partial}{\partial x}\frac{p^2}{\rho}\right)\right\} \tag{2.16}$$

The following transformations of energy equation (2.14):

$$
\begin{aligned}
&3\frac{\partial p}{\partial t}-\frac{\partial}{\partial t}\left\{\tau\left[3\frac{\partial p}{\partial t}+5v_{0r}\frac{\partial p}{\partial r}+5p\frac{\partial v_{0r}}{\partial r}+\frac{10}{r}v_{0r}p-2F_r v_{0r}\right]\right\}\\
&+\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\left\{5pv_{0r}-\tau\left[\frac{\partial}{\partial t}\left(5pv_{0r}\right)+7\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2pv_{0r}^2\right)-3F_r v_{0r}^2\right]\right\}\right\}\\
&-2F_r v_{0r}-\frac{1}{r^2}\frac{\partial}{\partial r}\left(\tau r^2\frac{\partial}{\partial r}\left(pv_{0r}^2\right)\right)+\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r-5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right]=0
\end{aligned}
\tag{2.17}
$$

or using (2.3)

$$
\begin{aligned}
&3\frac{\partial p}{\partial t}-\frac{\partial}{\partial t}\left\{\tau\left[3\frac{\partial p}{\partial t}+3v_{0r}\frac{\partial p}{\partial r}+5p\frac{\partial v_{0r}}{\partial r}+2v_{0r}\left(\frac{\partial p}{\partial r}-F_r\right)+\frac{10}{r}v_{0r}p\right]\right\}\\
&-\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\tau\left[5\frac{\partial}{\partial t}\left(pv_{0r}\right)+8\frac{\partial}{\partial r}\left(pv_{0r}^2\right)+\frac{14}{r}pv_{0r}^2-3F_r v_{0r}^2\right]\right\}+5\frac{\partial}{\partial r}\left(pv_{0r}\right)+\frac{10}{r}pv_{0r}\\
&-2F_r v_{0r}+\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r-5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right]=0
\end{aligned}
\tag{2.18}
$$

or

$$
\begin{aligned}
&3\frac{\partial p}{\partial t}+5p\frac{\partial v_{0r}}{\partial r}+3v_{0r}\frac{\partial p}{\partial r}+2v_{0r}\left(\frac{\partial p}{\partial r}-F_r\right)+\frac{10}{r}pv_{0r}\\
&-\frac{\partial}{\partial t}\left\{\tau\left[3\frac{\partial p}{\partial t}+3v_{0r}\frac{\partial p}{\partial r}+5p\frac{\partial v_{0r}}{\partial r}+2v_{0r}\left(\frac{\partial p}{\partial r}-F_r\right)+\frac{10}{r}v_{0r}p\right]\right\}\\
&-\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\tau\left[5\frac{\partial}{\partial t}\left(pv_{0r}\right)+5v_{0r}\frac{\partial}{\partial r}\left(pv_{0r}\right)+11pv_{0r}\frac{\partial v_{0r}}{\partial r}+\frac{14}{r}pv_{0r}^2\right]\right\}\\
&-\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\tau v_{0r}^2\left[3\frac{\partial p}{\partial r}-3F_r\right]\right\}+\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r-5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right]=0
\end{aligned}
\tag{2.19}
$$

and finally

$$
\begin{aligned}
&3\frac{\partial p}{\partial t}+3v_{0r}\frac{\partial p}{\partial r}+5p\frac{\partial v_{0r}}{\partial r}+2v_{0r}\left(\frac{\partial p}{\partial r}-F_r\right)+\frac{10}{r}pv_{0r}\\
&-\frac{\partial}{\partial t}\left\{\tau\left[3\frac{\partial p}{\partial t}+3v_{0r}\frac{\partial p}{\partial r}+5p\frac{\partial v_{0r}}{\partial r}+2v_{0r}\left(\frac{\partial p}{\partial r}-F_r\right)+\frac{10}{r}v_{0r}p\right]\right\}\\
&-\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\tau\left[5\frac{\partial}{\partial t}\left(pv_{0r}\right)+5v_{0r}\frac{\partial}{\partial r}\left(pv_{0r}\right)+11pv_{0r}\frac{\partial v_{0r}}{\partial r}+\frac{14}{r}pv_{0r}^2\right]\right\}\\
&-6\tau\left[\frac{\partial p}{\partial r}-F_r\right]v_{0r}\frac{\partial v_{0r}}{\partial r}+\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r-5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right]=0
\end{aligned}
\tag{2.20}
$$

In the Cartesian 1D non-stationary case

$$
\begin{aligned}
&3\frac{\partial p}{\partial t}+3u\frac{\partial p}{\partial x}+5p\frac{\partial u}{\partial x}+2u\left(\frac{\partial p}{\partial x}-F\right)\\
&-\frac{\partial}{\partial t}\left\{\tau\left[3\frac{\partial p}{\partial t}+3u\frac{\partial p}{\partial x}+5p\frac{\partial u}{\partial x}+2u\left(\frac{\partial p}{\partial x}-F\right)\right]\right\}\\
&-\frac{\partial}{\partial x}\left\{\tau\left[5\frac{\partial}{\partial t}\left(pu\right)+5u\frac{\partial}{\partial x}\left(pu\right)+11up\frac{\partial u}{\partial x}\right]\right\}\\
&-6\tau\left(\frac{\partial p}{\partial x}-F\right)u\frac{\partial u}{\partial x}+A^{pert}=0
\end{aligned}
\tag{2.21}
$$

We write down the system of equations (2.3), (2.10) and (2.20) using the simplest solution (2.3).

$$\frac{\partial p}{\partial r} = F_r \tag{2.22}$$

$$2\tau\left[v_{0r}\frac{\partial p}{\partial r} - p\frac{\partial v_{0r}}{\partial r}\right] - r\frac{\partial}{\partial r}\left\{\tau\left[\frac{\partial p}{\partial t} + 3p\frac{\partial v_{0r}}{\partial r} + v_{0r}\frac{\partial p}{\partial r} + \frac{4}{r}pv_{0r}\right]\right\} = 0 \tag{2.23}$$

$$\begin{aligned} &3\frac{\partial p}{\partial t} + 3v_{0r}\frac{\partial p}{\partial r} + 5p\frac{\partial v_{0r}}{\partial r} + \frac{10}{r}pv_{0r} - \frac{\partial}{\partial t}\left\{\tau\left[3\frac{\partial p}{\partial t} + 3v_{0r}\frac{\partial p}{\partial r} + 5p\frac{\partial v_{0r}}{\partial r} + \frac{10}{r}v_{0r}p\right]\right\} \\ &-\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\tau\left[5\frac{\partial}{\partial t}\left(pv_{0r}\right) + 5v_{0r}\frac{\partial}{\partial r}\left(pv_{0r}\right) + 11pv_{0r}\frac{\partial v_{0r}}{\partial r} + \frac{14}{r}pv_{0r}^2\right]\right\} \\ &+\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r - 5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right] = 0 \end{aligned} \tag{2.24}$$

For the case (2.22) we find

$$A^{pert} = \frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r - 5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right] = -\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\frac{p}{\rho}\left(3\frac{\partial p}{\partial r} + 5p\frac{\partial}{\partial r}\ln\frac{p}{\rho}\right)\right] \approx -\frac{3}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\frac{p}{\rho}\frac{\partial p}{\partial r}\right] \tag{2.25}$$

Then the term $A^{pert} \approx -\frac{3}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\frac{p}{\rho}\frac{\partial p}{\partial r}\right]$ can be considered from the hydrodynamic point of view as external perturbation connected with appearance of particles like Higgs bosons.

Let us introduce an analogue the Hubble boxes which can be named as the PV box. Following this analogue we suppose:

A. The process of PV evolution is an implicit function of t.

B. Velocity v_{0r} is written as

$$v_{0r} = A\left(r\right)r \tag{2.26}$$

From Item A follows that time dependence exists in the form

$$\frac{\partial}{\partial t} = \frac{\partial}{\partial r}\frac{\partial r}{\partial t} = v_{0r}\frac{\partial}{\partial r} \tag{2.27}$$

Then we have from momentum equation (2.23)

$$2\tau\left[v_{0r}\frac{\partial p}{\partial r} - p\frac{\partial v_{0r}}{\partial r}\right] - r\frac{\partial}{\partial r}\left\{\tau\left[2v_{0r}\frac{\partial p}{\partial r} + 3p\frac{\partial v_{0r}}{\partial r} + \frac{4}{r}pv_{0r}\right]\right\} = 0 \tag{2.28}$$

and from energy equation (2.24)

$$\begin{aligned} &6v_{0r}\frac{\partial p}{\partial r} + 5p\frac{\partial v_{0r}}{\partial r} + \frac{10}{r}pv_{0r} - v_{0r}\frac{\partial}{\partial r}\left\{\tau\left[6v_{0r}\frac{\partial p}{\partial r} + 5p\frac{\partial v_{0r}}{\partial r} + \frac{10}{r}v_{0r}p\right]\right\} \\ &-\frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2\tau\left[10v_{0r}\frac{\partial}{\partial r}\left(pv_{0r}\right) + 11pv_{0r}\frac{\partial v_{0r}}{\partial r} + \frac{14}{r}pv_{0r}^2\right]\right\} \\ &+\frac{1}{r^2}\frac{\partial}{\partial r}\left[\tau r^2\left(2\frac{p}{\rho}F_r - 5\frac{\partial}{\partial r}\frac{p^2}{\rho}\right)\right] = 0 \end{aligned} \tag{2.29}$$

defining the PV evolution in the PV box. Write down these equations in the dimensionless forms using the scales

$$\left[x_0\right], \left[u_0\right], \left[p_0\right], \left[F\right] = \frac{p_0}{x_0}, \left[t_0\right] = \frac{x_0}{u_0}, \rho_0,\ x_0 = u_0 t_0, p_0 = \rho_0 u_0^2$$

and tilde for the dimensionless values.

Momentum equation

$$2\tilde{\tau}\left[\tilde{v}_{0r}\frac{\partial\tilde{p}}{\partial\tilde{r}}-\tilde{p}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}\right]-\tilde{r}\frac{\partial}{\partial\tilde{r}}\left\{\tilde{\tau}\left[2\tilde{v}_{0r}\frac{\partial\tilde{p}}{\partial\tilde{r}}+3\tilde{p}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}+\frac{4}{\tilde{r}}\tilde{p}\tilde{v}_{0r}\right]\right\}=0 \tag{2.30}$$

Energy equation

$$\begin{aligned}&6\tilde{v}_{0r}\frac{\partial\tilde{p}}{\partial\tilde{r}}+5\tilde{p}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}+\frac{10}{\tilde{r}}\tilde{p}\tilde{v}_{0r}-\tilde{v}_{0r}\frac{\partial}{\partial\tilde{r}}\left\{\tilde{\tau}\left[6\tilde{v}_{0r}\frac{\partial\tilde{p}}{\partial\tilde{r}}+5\tilde{p}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}+\frac{10}{\tilde{r}}\tilde{v}_{0r}\tilde{p}\right]\right\}\\&-\frac{1}{\tilde{r}^2}\frac{\partial}{\partial\tilde{r}}\left\{\tilde{r}^2\tilde{\tau}\left[10\tilde{v}_{0r}\frac{\partial}{\partial\tilde{r}}\left(\tilde{p}\tilde{v}_{0r}\right)+11\tilde{p}\tilde{v}_{0r}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}+\frac{14}{\tilde{r}}\tilde{p}\tilde{v}_{0r}^2\right]\right\}\\&+\frac{1}{\tilde{r}^2}\frac{\partial}{\partial\tilde{r}}\left[\tilde{\tau}\tilde{r}^2\left(2\frac{\tilde{p}}{\tilde{\rho}}\tilde{F}_r-5\frac{\partial}{\partial\tilde{r}}\frac{\tilde{p}^2}{\tilde{\rho}}\right)\right]=0\end{aligned} \tag{2.31}$$

Then we have the following system (SYSTEM PV) of the dimensionless equation defining the PV evolution in the PV box:

$$\frac{\partial\tilde{p}}{\partial\tilde{r}}=\tilde{F}_r \tag{2.32}$$

$$2\tilde{\tau}\left[\tilde{v}_{0r}\frac{\partial\tilde{p}}{\partial\tilde{r}}-\tilde{p}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}\right]-\tilde{r}\frac{\partial}{\partial\tilde{r}}\left\{\tilde{\tau}\left[2\tilde{v}_{0r}\frac{\partial\tilde{p}}{\partial\tilde{r}}+3\tilde{p}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}+\frac{4}{\tilde{r}}\tilde{p}\tilde{v}_{0r}\right]\right\}=0 \tag{2.33}$$

$$\begin{aligned}&6\tilde{v}_{0r}\frac{\partial\tilde{p}}{\partial\tilde{r}}+5\tilde{p}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}+\frac{10}{\tilde{r}}\tilde{p}\tilde{v}_{0r}-\tilde{v}_{0r}\frac{\partial}{\partial\tilde{r}}\left\{\tilde{\tau}\left[6\tilde{v}_{0r}\frac{\partial\tilde{p}}{\partial\tilde{r}}+5\tilde{p}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}+\frac{10}{\tilde{r}}\tilde{v}_{0r}\tilde{p}\right]\right\}\\&-\frac{1}{\tilde{r}^2}\frac{\partial}{\partial\tilde{r}}\left\{\tilde{r}^2\tilde{\tau}\left[10\tilde{v}_{0r}\frac{\partial}{\partial\tilde{r}}\left(\tilde{p}\tilde{v}_{0r}\right)+11\tilde{p}\tilde{v}_{0r}\frac{\partial\tilde{v}_{0r}}{\partial\tilde{r}}+\frac{14}{\tilde{r}}\tilde{p}\tilde{v}_{0r}^2\right]\right\}+\tilde{A}^{pert}\left(\tilde{r}\right)\end{aligned} \tag{2.34}$$

Three ordinary differential equations (2.32)-(2.34) define three dependent variables $\tilde{F}_r$, $\tilde{v}_{0r}$ and $\tilde{p}$. The energy equation includes in the last term the external perturbation. In principal, there are no difficulties to organize the mathematical modeling using this system of equations.

Is it possible to speak about existence of PV boxes and moreover about the practical interaction between known fields and physical vacuum? The last events (which can be discussed further) lead to the conclusion that we can't exclude this possibility.

It would be interesting to reveal the basic features which could be discovered. With this aim let us use the item B in the form $\tilde{v}_{0r}=\tilde{A}\left(\tilde{r}\right)\tilde{r}$. This relation should be introduced in the mentioned SYSTEM PV of equations; as a result we obtain the following dependent variables: $\tilde{F}_r\left(\tilde{r}\right)$, $\tilde{p}\left(\tilde{r}\right)$ and $\tilde{A}\left(\tilde{r}\right)$.

Let us consider the particular cases of relation (2.26) written as

$$\tilde{v}_{0r}=\tilde{A}\tilde{r}^n \tag{2.35}$$

where $\tilde{A}$ is const. If $n=1$ the space $v_{0r}\left(\tilde{r}\right)$ evolution is an analogue of the Hubble expansion, $n>1$ corresponds to the particular case known as "expansion with acceleration".

Substituting (2.35) in (2.33) we find

$$\tilde{r}^2\frac{\partial^2\tilde{p}}{\partial\tilde{r}^2}+\tilde{r}\left(1+\frac{5}{2}n\right)\frac{\partial\tilde{p}}{\partial\tilde{r}}+\tilde{p}\left[\frac{3}{2}n^2+\frac{3}{2}n-2\right]=0 \tag{2.36}$$

In this particular case we have the following chain of calculations: momentum equation becomes an independent equation; solution $\tilde{p}\left(\tilde{r}\right)$ of this equation defines the force $\tilde{F}_r\left(\tilde{r}\right)$ from equation (2.32) and $\tilde{A}^{pert}\left(\tilde{r}\right)$ from the energy equation (2.34).

Let us consider the particular case1) as an analog of "Hubble regime" $(n=1)$, we find

$$\tilde{r}^2\frac{\partial^2\tilde{p}}{\partial\tilde{r}^2}+\tilde{r}\frac{7}{2}\frac{\partial\tilde{p}}{\partial\tilde{r}}+\tilde{p}=0 \tag{2.37}$$

and

$$\tilde{p}\left(\tilde{r}\right) = \frac{C_1}{\sqrt{\tilde{r}}} + \frac{C_2}{\tilde{r}^2} \tag{2.38}$$

$$\frac{\partial \tilde{p}}{\partial \tilde{r}} = \frac{\partial}{\partial \tilde{r}}\left[\frac{C_1}{\sqrt{\tilde{r}}} + \frac{C_2}{\tilde{r}^2}\right] = -\frac{1}{2}C_1\tilde{r}^{-3/2} - 2C_2\tilde{r}^{-3} \tag{2.39}$$

Let $C_1 = C_2 = C > 0$ and it's as the force term (see 2.32)

$$\frac{1}{C}\frac{\partial \tilde{p}}{\partial \tilde{r}} = -\frac{1}{2}\tilde{r}^{-3/2} - 2\tilde{r}^{-3} \tag{2.40}$$

Fig. 2.1 reflects the results of calculations with the designations $\frac{1}{C}\frac{\partial \tilde{p}}{\partial \tilde{r}} \leftrightarrow y \leftrightarrow \mathrm{D(P)(x)/C}$, $x \leftrightarrow \tilde{r}$; $n = 1$.

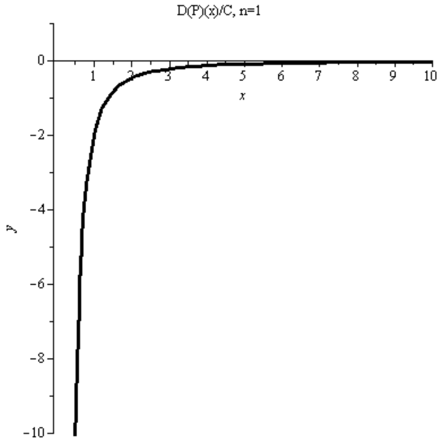

Figure 2.1. Dependence $\frac{1}{C}\frac{\partial \tilde{p}}{\partial \tilde{r}}$ on $\tilde{r}$ for $n = 1$.

Obviously in this case only the attraction forces act.
Consider the case 2) if $n = 2$ for which the following equation is valid:
2) For $(n = 2)$ we have Euler-Cauchy equation

$$\tilde{r}^2\frac{\partial^2 \tilde{p}}{\partial \tilde{r}^2} + 6\tilde{r}\frac{\partial \tilde{p}}{\partial \tilde{r}} + 7\tilde{p} = 0 \tag{2.41}$$

and

$$\tilde{p} = \frac{1}{\tilde{r}^{5/2}}\left[C_1\sin\left(\frac{\sqrt{3}}{2}\ln\tilde{r}\right) + C_2\cos\left(\frac{\sqrt{3}}{2}\ln\tilde{r}\right)\right] \tag{2.42}$$

Let $C_1 = C_2 = C > 0$

$$\frac{1}{C}\frac{\partial \tilde{p}}{\partial \tilde{r}} = \frac{1}{2\tilde{r}^{7/2}}\left[\left(\sqrt{3}-5\right)\cos\left(\frac{\sqrt{3}}{2}\ln\tilde{r}\right) - \left(\sqrt{3}+5\right)\sin\left(\frac{\sqrt{3}}{2}\ln\tilde{r}\right)\right] \tag{2.43}$$

Fig. 2.2 reflects the results of calculations if as before $\frac{1}{C}\frac{\partial \tilde{p}}{\partial \tilde{r}} \leftrightarrow y \leftrightarrow \mathrm{D(P)(x)/C}$, $x \leftrightarrow \tilde{r}$; $n = 2$.

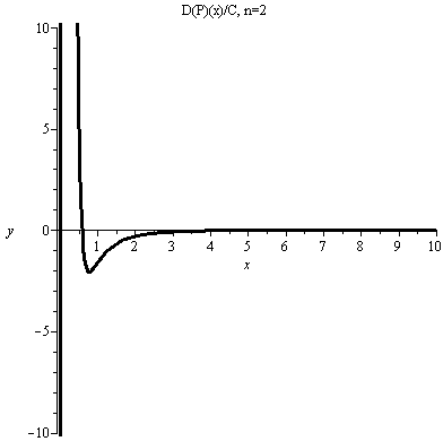

Figure 2.2. Dependence $\dfrac{1}{C}\dfrac{\partial\tilde{p}}{\partial\tilde{r}}$ on $\tilde{r}$ for $n = 2$.

In this case not only attractions forces act, but also the repulsive force in the close vicinity of the PV bubble. In the definite sense it reminds the behavior of the Van der Waals forces.
2) For $(n = 3)$ we have the following equation

$$\tilde{r}^2\frac{\partial^2\tilde{p}}{\partial\tilde{r}^2}+\frac{17}{2}\tilde{r}\frac{\partial\tilde{p}}{\partial\tilde{r}}+16\tilde{p}=0 \tag{2.44}$$

and solutions

$$\tilde{p}=\frac{1}{\tilde{r}^{15/4}}\left[C_1\sin\left(\frac{\sqrt{31}}{4}\ln\tilde{r}\right)+C_2\cos\left(\frac{\sqrt{31}}{4}\ln\tilde{r}\right)\right] \tag{2.45}$$

$$\frac{1}{C}\frac{\partial\tilde{p}}{\partial\tilde{r}}=\frac{1}{4\tilde{r}^{19/4}}\left[\left(\sqrt{31}-15\right)\cos\left(\frac{\sqrt{31}}{4}\ln\tilde{r}\right)-\left(\sqrt{31}+15\right)\sin\left(\frac{\sqrt{31}}{4}\ln\tilde{r}\right)\right] \tag{2.46}$$

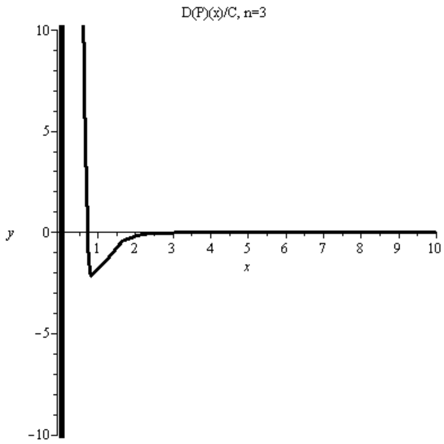

Figure. 2.3. Dependence $\dfrac{1}{C}\dfrac{\partial\tilde{p}}{\partial\tilde{r}}$ on $\tilde{r}$ for $n = 3$.

At large distances, the force curve experiences oscillations. Really

$$0=\frac{1}{C}\frac{\partial\tilde{p}}{\partial\tilde{r}}=\frac{1}{4\tilde{r}^{19/4}}\left[\left(\sqrt{31}-15\right)\cos\left(\frac{\sqrt{31}}{4}\ln\tilde{r}\right)-\left(\sqrt{31}+15\right)\sin\left(\frac{\sqrt{31}}{4}\ln\tilde{r}\right)\right] \tag{2.47}$$

This relation leads to the transcendent equation

$$\tan\left(\frac{\sqrt{31}}{4}\ln\tilde{r}\right) = \frac{\sqrt{31}-15}{\sqrt{31}+15} \tag{2.48}$$

with knots (m is integer number)

$$\tilde{r} = \exp\left\{\frac{8}{\sqrt{31}}\left[\pi m + \arctan\left(\frac{97+16\sqrt{128-15\sqrt{31}}}{128-15\sqrt{31}}\right)\right]\right\} \tag{2.49}$$

with the number line

For example for $m = 3$ we have

$$\tilde{r} = \exp\left\{\frac{8}{\sqrt{31}}\left[3\pi + \arctan\left(\frac{97+16\sqrt{128-15\sqrt{31}}}{128-15\sqrt{31}}\right)\right]\right\} \tag{2.50}$$

or in the general case

$$\tilde{r} = 7.0152\exp\left\{1.4368\pi m\right\} \tag{2.51}$$

Solutions (5.6.33), (5.6.34) for (2.37) in [4] are valid in vicinity of the transition point $\tilde{r} = 1$because of

$$\tilde{r}^2\frac{\partial^2\tilde{p}}{\partial\tilde{r}^2} + \tilde{r}\frac{7}{2}\frac{\partial\tilde{p}}{\partial\tilde{r}} + \tilde{p} = \tilde{r}^{1/4}\frac{5}{16}\left[C_1\exp\left(\frac{\sqrt{5}}{4}\tilde{r}\right) + C_2\exp\left(-\frac{\sqrt{5}}{4}\tilde{r}\right)\right]\left(1-\frac{1}{\tilde{r}^2}\right) \tag{2.52}$$

Now taking into account the obtained results, we can create the theory of Shawyer' engine.

3 To the Theory of PV-Engines

Let us discuss now from the position of the developed theory the situation with the so called "EM Drive". This (hypothetical) engine was invented by British scientist Roger Shawyer in 1999. The principal scheme of this EM Drive can be shown as follows (Fig. 3.1):

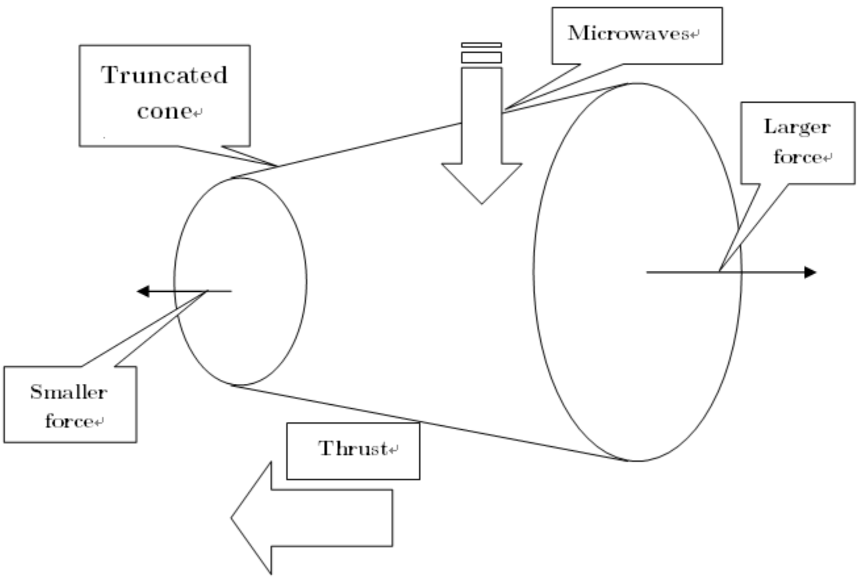

Figure. 3.1. Principal scheme of EM Drive.

Shawyer's testing was done on a torsion balance using air bearings [7, 8]. He observed rotation of the complete apparatus with all electronics and power supplies on-board. He discovered that the thrust (close to 5600 times) larger (Q-factor) than expected from pure classical radiation thrust. Q-factor can be defined by different way but in the general case Q ~ (maximum energy stored / power loss). Independent tests were carried out in China by Yang et al [9, 10] who tested the EMDrive on a force-feedback thrust stand and achieved up to 720 mN of thrust with 1000 W microwave power with even higher Q factors compared to Shawyer.

The typical parameters of following White's experiments [11 -13] are as follows. The RF resonance test article is a copper frustum with an inner diameter of 27.9 cm on the big end, an inner diameter of 15.9 cm on the small end, and an axial length of 22.9 cm. The vacuum test campaign consisted of a forward thrust phase and reverse thrust phase at less than 8×10^{-6} torr vacuum with power scans at 40, 60, and 80W. The test campaign included a null thrust test effort to identify any mundane sources of impulsive thrust; however, none were identified. Thrust data from forward, reverse, and null suggested that the system was consistently performing with a thrust-to-power ratio of 1.2 ± 0.1 mN/kW.

The test article contains a 5.4-cm-thick disk of polyethylene with an outer diameter of 15.6 cm that is mounted to the inside face of the smaller diameter end of the frustum. A 13.5-mm-diam loop antenna drives the system in the TM212 mode at 1937 MHz. Because there are no analytical solutions for the resonant modes of a truncated cone, the use of the term TM212 describes a mode with two nodes in the axial direction and four nodes in the azimuthal direction. A small whip antenna provides feedback to the phase-locked loop (PLL) system. The steady-state displacement from the calibration force is used to calibrate any force applied to the torsion pendulum by a device under pendulum.

The usual comment for the thrust appearance in this construction sounds as follows. The EM Drive uses electromagnetic waves as "fuel", creating thrust by bouncing microwave photons back and forth inside a cone-shaped closed metal cavity. In other words, electricity converts into microwaves within the cavity that push against the inside of the device, causing the thruster to accelerate in the opposite direction.

Obviously this explanation has no attitude to reality. The nozzle of this "jet engine" is closed by a round plate. It means that the formulated explanation leads to the contradiction with the Newton's Third Law, which states, "To each action there's an equal and opposite reaction," and many physicists say the EM Drive categorically violates that law. From the position of classical mechanics this corresponds to the attempt of Baron Münchhausen to pull itself out of the swamp by his own hair. In order for a thruster to gain momentum in a certain direction, it has to expel some kind of propellant or exhaust in the opposite direction. But the EM Drive knows nothing about the law of conservation of momentum, which Newton derived from his Third Law.

Since its invention, the EM drive was tested many times and reveals "anomalous thrust signals". Putting it mildly, we can say - if EM Drive indeed produces thrust we should find the corresponding explanation for this effect.

In this case I should define my position in connection with the mentioned problem:

1. Appearance of thrust in the systems like EM Drive does not contradict the conclusions following from nonlocal physics.
2. The emergence of the thrust is due to the interaction of radiation with physical vacuum.
3. It is impossible to provide an explanation of the effect using methods of local physics.
4. Then no reason to discuss other theoretical models originated by local physics.
5. We do not intend to go into details of the experiment organization including the possible experimental errors, because we are interested only in the correspondence between theoretical and experimental data in basic experiments.
6. Here we indicated only some main stages of the vast experimental researches.

Let us consider now the process of excitation of physical vacuum by radiation. It is known that the first experiments demonstrating the direct light pressure on a surface (including gases) were realized by P.N. Lebedev [14]. Then when light impinges on the surface of a liquid, part of the light is reflected (with the reflection coefficient χ) and the remaining fraction is transmitted. The new experiments show for the first time that the liquid surface bends inward, meaning that the light is pushing on the fluid in agreement with the Abraham momentum p_A of light. The corresponding equation for the photon momentum in a dielectric with refractive index n is:

$$p_A = \frac{h\nu}{nc} \tag{3.1}$$

where h is the Plank constant, ν is the frequency of the light and c is the speed of light in vacuum. Light pressure can be found by the formula

$$p_r = \frac{\Phi_r}{c}\left(\chi + 1\right) \tag{3.2}$$

where Φ_r is the density of radiation energy flux falling on a surface, for the mirror surface $\chi = 1$. For the state close to thermodynamic equilibrium we have

$$p_r = \frac{u}{3} \tag{3.3}$$

where u is the energy density.

As before we consider the limit case $\rho \to 0$ corresponding to transfer to Physical Vacuum in 1D case. For our aims is sufficient to use the plane model (for example this case correspond the spherical wave front of the large radius). Then for the flat case $r \to \infty$ we have the following system (SYSTEM PV) of the dimensionless equations defining the PV evolution (see also 2.32-2.34)

$$\frac{\partial \tilde{p}}{\partial \tilde{x}} = \tilde{F}_x \tag{3.4}$$

$$\frac{\partial}{\partial \tilde{x}}\left[\tilde{v}_{0x}\frac{\partial \tilde{p}}{\partial \tilde{x}} + \frac{3}{2}\tilde{p}\frac{\partial \tilde{v}_{0x}}{\partial \tilde{x}}\right] = 0 \tag{3.5}$$

$$\begin{gathered} 6\tilde{v}_{0x}\frac{\partial \tilde{p}}{\partial \tilde{x}} + 5\tilde{p}\frac{\partial \tilde{v}_{0x}}{\partial \tilde{x}} - \tilde{v}_{0r}\frac{\partial}{\partial \tilde{x}}\left\{\tilde{\tau}\left[6\tilde{v}_{0x}\frac{\partial \tilde{p}}{\partial \tilde{x}} + 5\tilde{p}\frac{\partial \tilde{v}_{0x}}{\partial \tilde{x}}\right]\right\} \\ -\frac{\partial}{\partial \tilde{x}}\left\{\tilde{\tau}\left[10\tilde{v}_{0x}\frac{\partial}{\partial \tilde{x}}\left(\tilde{p}\tilde{v}_{0x}\right) + 11\tilde{p}\tilde{v}_{0x}\frac{\partial \tilde{v}_{0r}}{\partial \tilde{x}}\right]\right\} + \frac{\partial}{\partial \tilde{r}}\left[\tilde{\tau}\left(2\frac{\tilde{p}}{\tilde{\rho}}\tilde{F}_x - 5\frac{\partial}{\partial \tilde{r}}\frac{\tilde{p}^2}{\tilde{\rho}}\right)\right] = 0 \end{gathered} \tag{3.6}$$

Therefore we can introduce in system of equations (3.4) - (3.6) an external dimensionless pressure $\tilde{A}^{ex}$. Generally speaking $\tilde{A}^{ex}$ is a function of coordinates and time and should be calculated independently with the help of the Maxwell equations.

As a result (if the mass perturbation can be omitted) we have the “system A”:

$$\frac{\partial \tilde{p}}{\partial \tilde{x}} = \tilde{F}_x \tag{3.7}$$

$$\frac{\partial}{\partial \tilde{x}}\left\{\tilde{v}_{0x}\frac{\partial \tilde{p}}{\partial \tilde{x}} + \frac{3}{2}\left(\tilde{p} + \tilde{A}^{ex}\right)\frac{\partial \tilde{v}_{0x}}{\partial \tilde{x}}\right\} = 0 \tag{3.8}$$

$$\begin{gathered} 6\tilde{v}_{0x}\frac{\partial \tilde{p}}{\partial \tilde{x}} + 5\left(\tilde{p} + \tilde{A}^{ex}\right)\frac{\partial \tilde{v}_{0x}}{\partial \tilde{x}} - \tilde{v}_{0x}\tilde{\tau}\frac{\partial}{\partial \tilde{x}}\left[6\tilde{v}_{0x}\frac{\partial \tilde{p}}{\partial \tilde{x}} + 5\left(\tilde{p} + \tilde{A}^{ex}\right)\frac{\partial \tilde{v}_{0x}}{\partial \tilde{x}}\right] \\ -\tilde{\tau}\frac{\partial}{\partial \tilde{x}}\left[10\tilde{v}_{0x}\frac{\partial}{\partial \tilde{x}}\left(\left(\tilde{p} + \tilde{A}^{ex}\right)\tilde{v}_{0x}\right) + 11\left(\tilde{p} + \tilde{A}^{ex}\right)\tilde{v}_{0x}\frac{\partial \tilde{v}_{0x}}{\partial \tilde{x}}\right] = 0 \end{gathered} \tag{3.9}$$

Now we are ready to display the results of the mathematical modeling realized with the help of Maple (the versions Maple 9 or more can be used). The system A of equations (3.7) – (3.9) has the great possibilities of mathematical modeling as result of changing of four Cauchy conditions and parameters $\tilde{\tau}$ and $\tilde{A}^{ex}$ describing the character features of physical system.

Maple program contains Maple’s notations – for example the expression $D\left(\tilde{v}_{0x}\right)\left(0\right) = 0$ means in the usual notations $\left(\partial \tilde{v}_{0x} / \partial \tilde{x}\right)\left(0\right) = 0$, independent variable t responds to $\tilde{x}$. The following Maple notations on figures are used: u- velocity $\tilde{v}_{0x}$, p - pressure $\tilde{p}$, and f - the self-consistent force $\tilde{F}$, A - $\tilde{A}^{ex}$. Explanations placed under all following figures. The results of the calculations are presented in figures 3.2 - 3.25. The information required is contained in the figures and in figure captions. We use for all calculations the Cauchy conditions

$$\tilde{v}_{0x}\left(0\right) = 1,\ \tilde{p}\left(0\right) = 1,\ D\left(\tilde{v}_{0x}\right)\left(0\right) = 1,\ D\left(\tilde{p}\right)\left(0\right) = 1 \to f(0) = 1$$

which of course can be changed; parameter $\tilde{A}$ varies widely. As a rule we use the following lines: $\tilde{v}_{0x}$ - solid line, $\tilde{p}$ - dashed line, $\tilde{F}$ - dotted line.

Remarks:

1. If $D(\tilde{v}_{0x})(0) = 0,\ D(\tilde{p})(0) = 0$ and $\tilde{A}^{ex} = const$, we have only trivial solutions $\tilde{v}_{0x} = const,\ \tilde{p} = const$. Conditions $D(\tilde{v}_{0x})(0) \neq 0,\ D(\tilde{p})(0) \neq 0$ deliver the appearance of non trivial solutions even if the mass perturbation $A^{pert} = 0$.
2. The figures 3.2 - 3.4 are constructed for the case when the external field is absent. The left boundary of the solution existence (lim1) is indicated.
3. The following figures 3.2 - 3.17 are constructed for conditions $\tilde{v}_{0x}(0) = 1,\ \tilde{p}(0) = 1,\ D(\tilde{v}_{0x})(0) = 1,\ D(\tilde{p})(0) = 1$ but for the parameter $\tilde{A}^{ex}$ changing in the interval $(10,\ 10^4)$. Captions like lim1 reflect the domain of the solution existence.

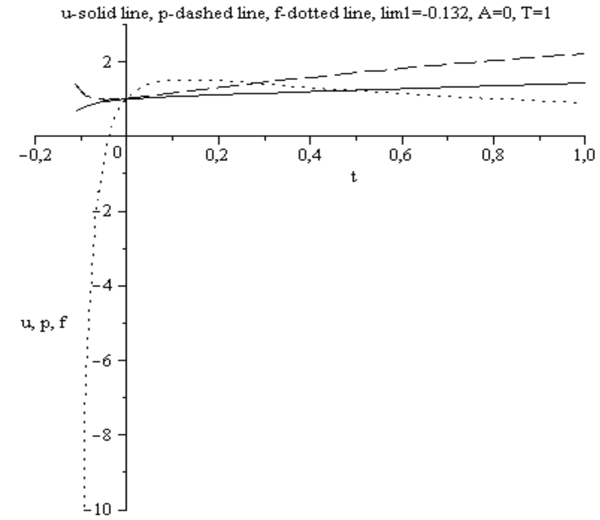

Figure 3.2. Evolution of $\tilde{v}_{0x}(\tilde{x}),\ \tilde{p}(\tilde{x}),\ \tilde{F}(\tilde{x});\ \tilde{A}^{ex} = 0,\ \tilde{\tau} = 1.$

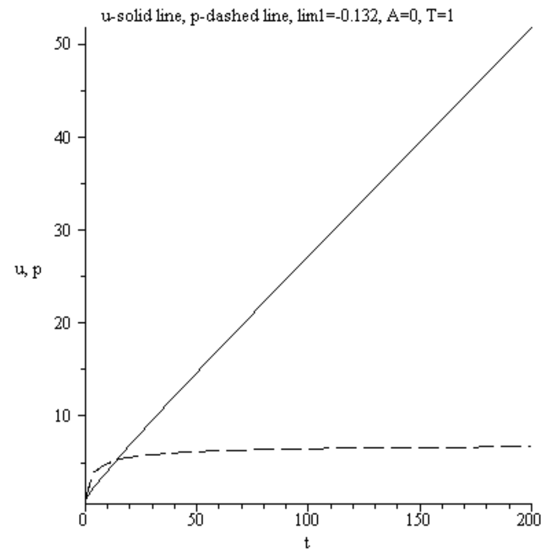

Figure. 3.3. Evolution of $\tilde{v}_{0x}(\tilde{x}),\ \tilde{p}(\tilde{x});\tilde{A}^{ex} = 0,\ \tilde{\tau} = 1.$

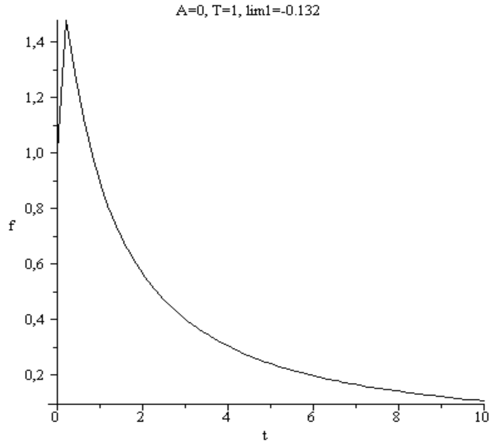

Figure 3.4. Evolution of $\tilde{F}\left(\tilde{x}\right); \tilde{A}^{ex} = 0$, $\tilde{\tau} = 1$.

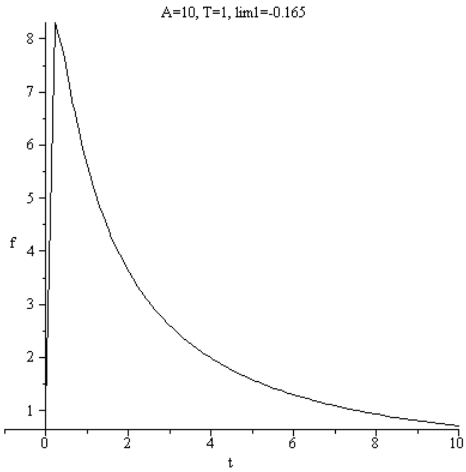

Figure 3.5. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = 10$, $\tilde{\tau} = 1$.

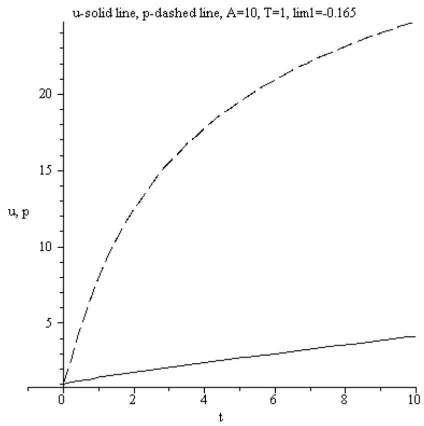

Figure. 3.6. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$, $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = 10$, $\tilde{\tau} = 1$.

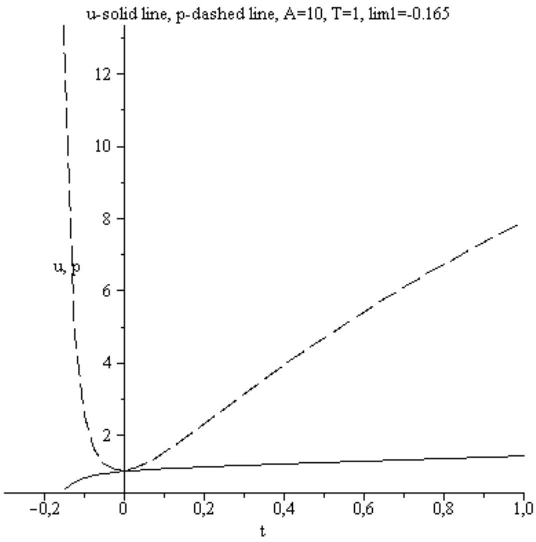

Figure 3.7. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$, $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=10$, $\tilde{\tau}=1$.

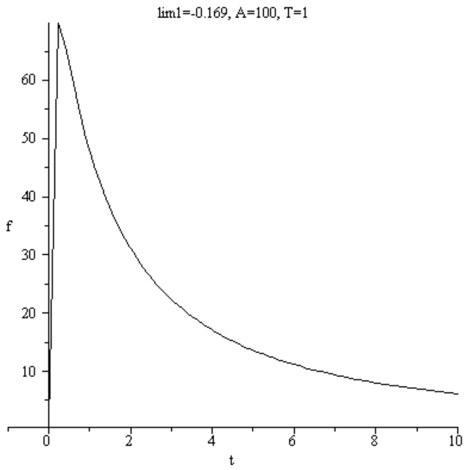

Figure 3.8. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=100$, $\tilde{\tau}=1$.

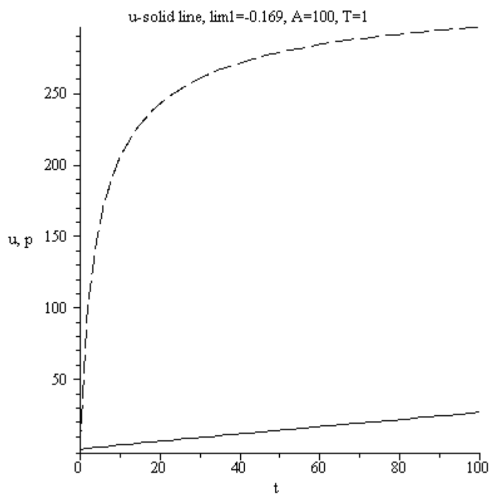

Figure 3.9. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$, $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=100$, $\tilde{\tau}=1$.

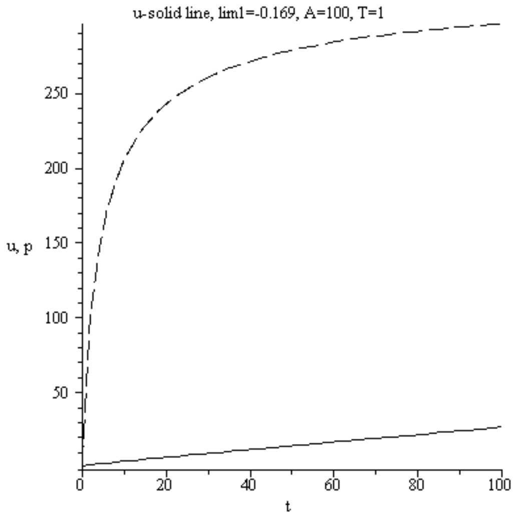

Figure 3.10. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$, $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=100$, $\tilde{\tau}=1$.

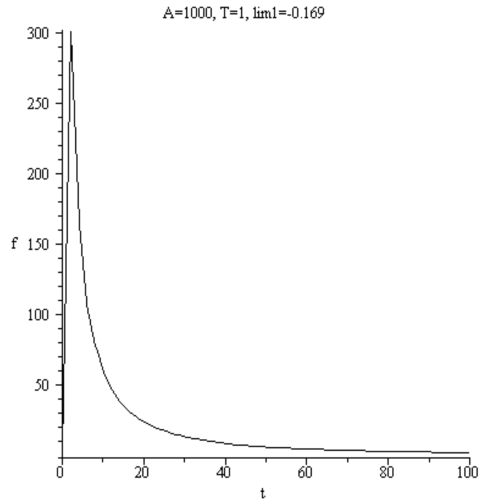

Figure 3.11. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=1000$, $\tilde{\tau}=1$.

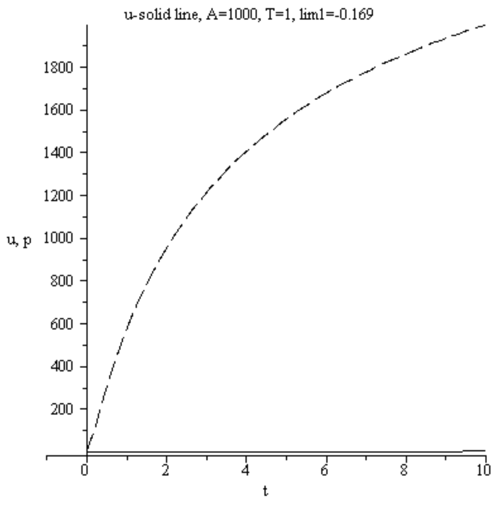

Figure 3.12. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$, $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=1000$, $\tilde{\tau}=1$.

Figures 3.13 - 3.15 reflect the calculations for the $\tilde{x}$ intervals (-0.5 - 2), (0 - 10), (0 - 100) correspondingly

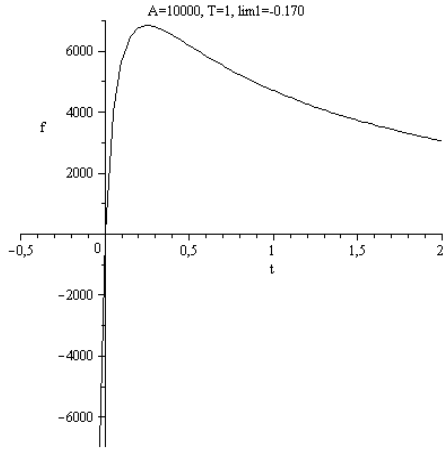

Figure 3.13. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = 10^4$, $\tilde{\tau} = 1$.

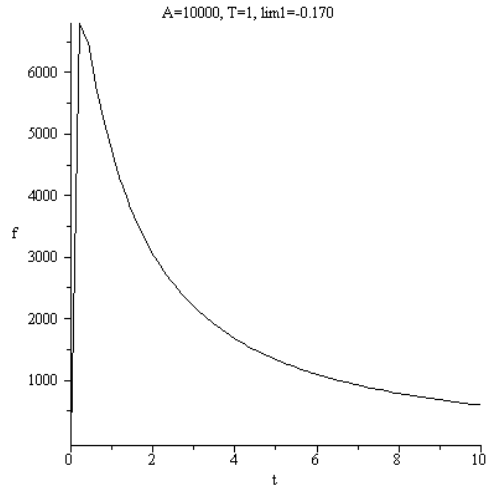

Figure 3.14. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = 10^4$, $\tilde{\tau} = 1$.

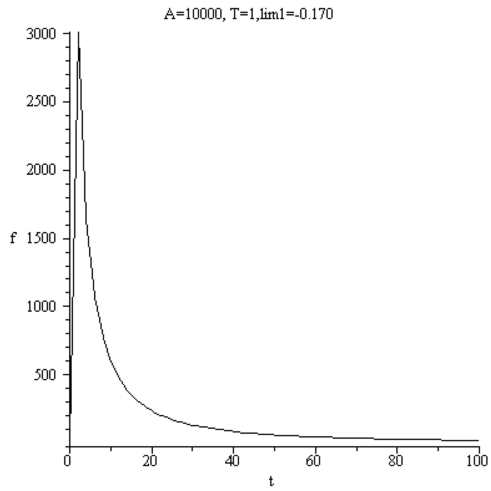

Figure 3.15. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = 10^4$, $\tilde{\tau} = 1$.

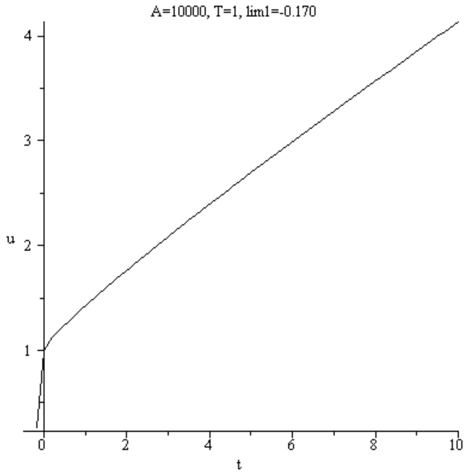

Figure 3.16. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = 10^4$, $\tilde{\tau} = 1$.

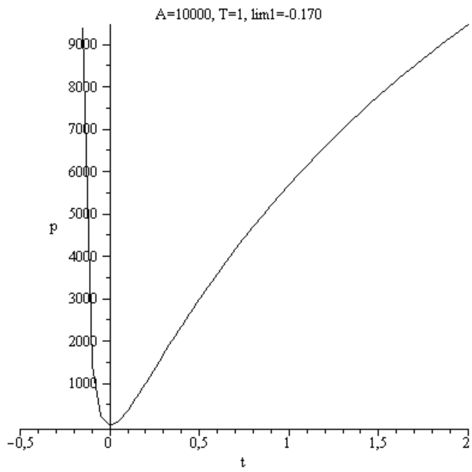

Figure 3.17. Evolution of $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = 10^4$, $\tilde{\tau} = 1$.

Important to notice that for all cases reflected in figures 3.2 - 3.17 we have the physical modes with a predominance of so called "anti-gravity"; but a narrow domain with usual gravitation is also presented.

The following figures 3.18 - 3.25 reflect the hypothetical situation when $\tilde{A} < 0$.

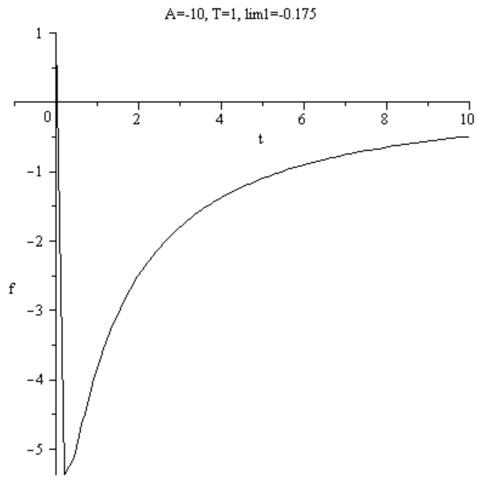

Figure. 3.18. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = -10$, $\tilde{\tau} = 1$.

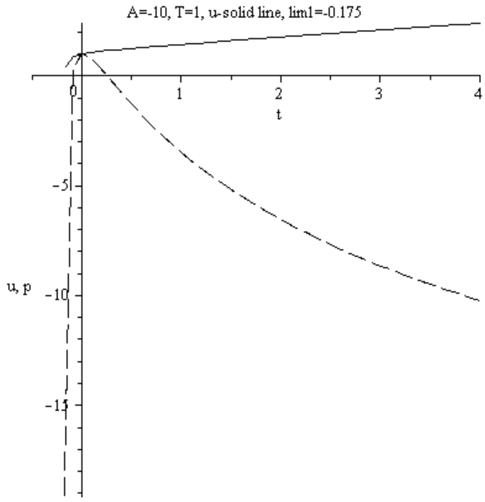

Figure 3.19. Evolution of $\tilde{u}\left(\tilde{x}\right)$, $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = -10$, $\tilde{\tau} = 1$.

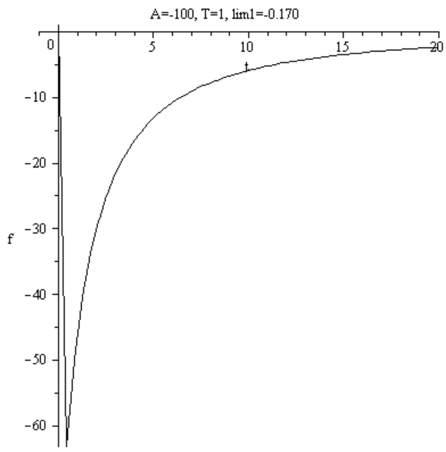

Figure 3.20. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = -100$, $\tilde{\tau} = 1$.

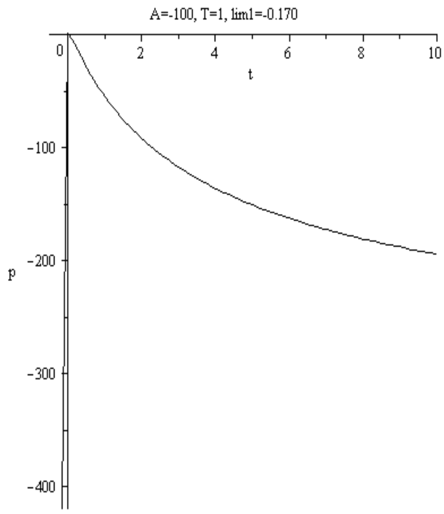

Figure 3.21. Evolution of $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = -100$, $\tilde{\tau} = 1$.

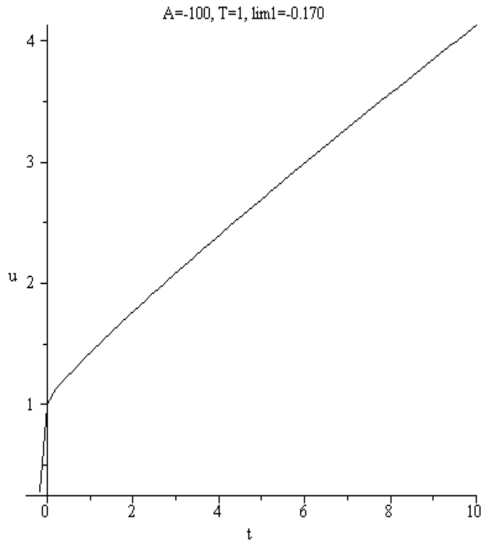

Figure 3.22. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=-100$, $\tilde{\tau}=1$.

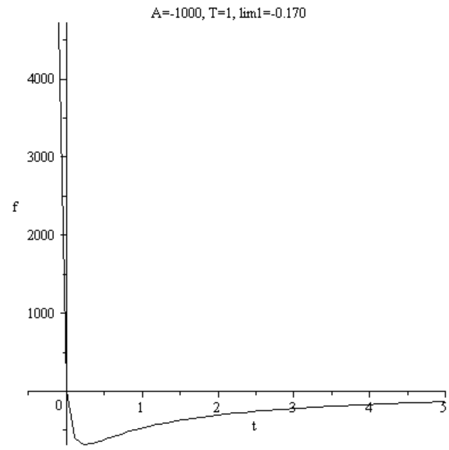

Figure 3.23. Evolution of $\tilde{F}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=-1000$, $\tilde{\tau}=1$.

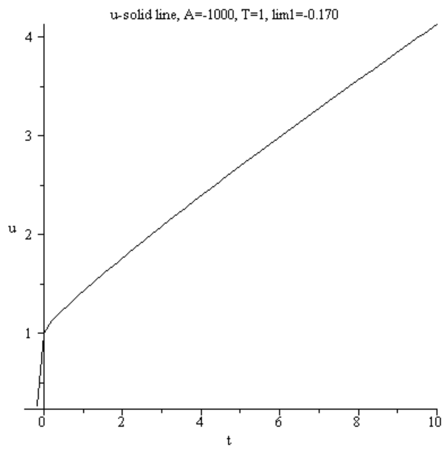

Figure 3.24. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$; $\tilde{A}^{ex}=-1000$, $\tilde{\tau}=1$.

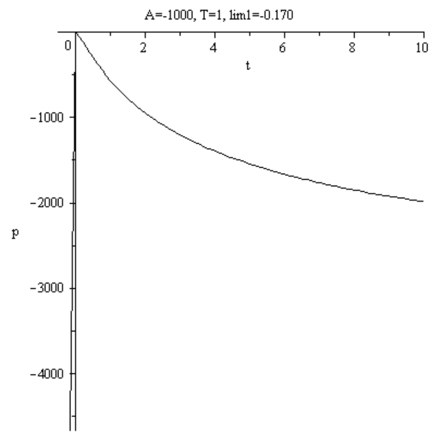

Figure 3.25. Evolution of $\tilde{p}\left(\tilde{x}\right)$; $\tilde{A}^{ex} = -1000$, $\tilde{\tau} = 1$.

The calculations presented on figures 3.22 - 3.25 give a general idea of the physical system filled by radiation and PV. But radiation occupies only a part of the considered system diminishing with the grows of the distance $\tilde{x}$ Let us reflect this fact introducing the approximation

$$\tilde{A}^{ex} = \frac{\tilde{B}}{1+\tilde{x}^n} \tag{3.10}$$

The following figures 3.26 - 3.29 show the result of modeling for approximation (3.10) for different $\tilde{B}$ and n.

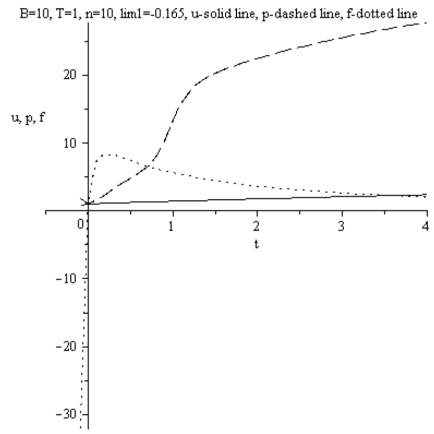

Figure 3.26. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$, $\tilde{p}\left(\tilde{x}\right)$, $\tilde{F}\left(\tilde{x}\right)$; $\tilde{B} = 10$, $n = 10$, $\tilde{\tau} = 1$.

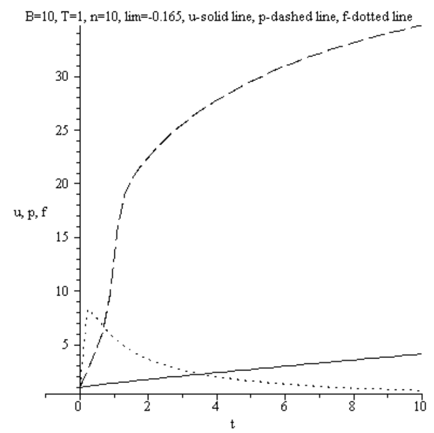

Figure 3.27. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right)$, $\tilde{p}\left(\tilde{x}\right)$, $\tilde{F}\left(\tilde{x}\right)$; $\tilde{B} = 10$, $n = 10$, $\tilde{\tau} = 1$.

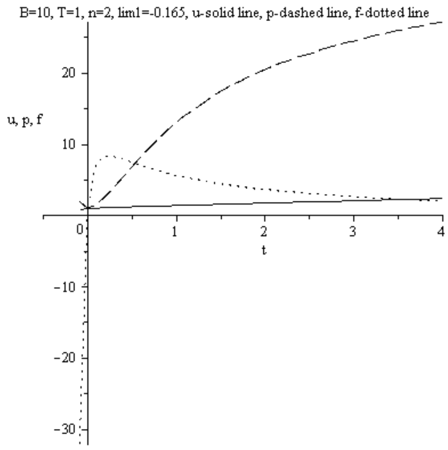

Figure 3.28. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right),\ \tilde{p}\left(\tilde{x}\right),\ \tilde{F}\left(\tilde{x}\right);\ \tilde{B}=10,\ n=2\,,\ \tilde{\tau}=1.$

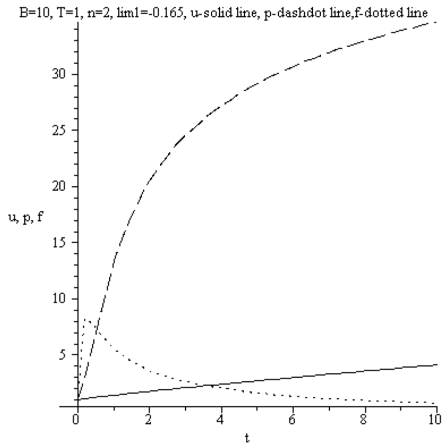

Figure 3.29. Evolution of $\tilde{v}_{0x}\left(\tilde{x}\right),\ \tilde{p}\left(\tilde{x}\right),\ \tilde{F}\left(\tilde{x}\right);\ \tilde{B}=10,\ n=2\,,\ \tilde{\tau}=1.$

Compare now the curves shown in the figures 3.2 - 3.6 and 3.26 - 3.29. As we see the general features of the $\tilde{v}_{0x}\left(\tilde{x}\right),\ \tilde{p}\left(\tilde{x}\right),\ \tilde{F}\left(\tilde{x}\right)$ evolution remain the same. The greatest changes correspond to the pressure of the physical vacuum. The greatest influence on the results of the calculations provides the initial Cauchy conditions.

The main result consists in the affirmation that the physical system "works" in regime of anti-gravitation. It is well-known that the Van der Waals equation of state leads to the force curves shown in Figure 3.30.

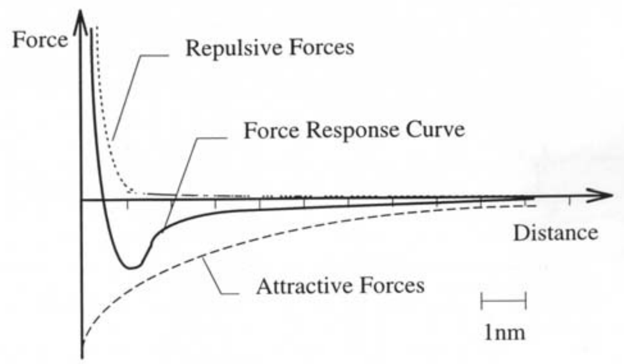

Figure 3.30. The typical van der Waals curves

Compare now the curves of Figures 3.30 and 3.26. We have the opposite behavior of curves - curves of attraction and repulsion are reversed. It is direct consequence of nonlocal physics. Interesting to notice, that we return to the Van der Waals curves as a result of diminishing of PV pressure by an artificial way (compare figures 3.30 and 3.23).

There are the experimental works (see for example [15]) confirming that at larger distances and between macroscopic condensed media the retardation effects can be revealed.

Although these long-range forces exist within all matter, only attractive interactions have so far been measured between material bodies [16 - 18]. In [18] is shown experimentally that, in accord with theoretical prediction [19 - 21], the sign of the force can be changed from attractive to repulsive by suitable choice of interacting materials immersed in a fluid. The mentioned theoretical predictions (as well as qualitative considerations in [22]) have phenomenological character and do not lead to transport PV equations in principal.

We often read phrases like “quantum fluctuations create intermolecular forces that pervade macroscopic bodies” without concrete calculations of quantum fluctuations in the quantum hydrodynamic equations in reality. Is it possible using this terminology to indicate explicit fluctuations in the nonlocal theory of PV? It is possible. Really, for example, let us return to 1D dimensional equations (2.4, 2.11, 2.21)

(continuity equation, 1D case)

$$\frac{\partial}{\partial x}\left\{\tau\left[\frac{\partial p}{\partial x}-F\right]\right\}=0 \tag{3.11}$$

(momentum equation, 1D case)

$$\begin{aligned}&\frac{\partial p}{\partial x}-F-\frac{\partial}{\partial t}\left\{\tau\left[\frac{\partial p}{\partial x}-F\right]\right\}-2\tau\left(\frac{\partial p}{\partial x}-F\right)\frac{\partial u}{\partial x}\\&-\frac{\partial}{\partial x}\left\{\tau\left[\frac{\partial p}{\partial t}+u\frac{\partial p}{\partial x}+3p\frac{\partial u}{\partial x}\right]\right\}=0\end{aligned} \tag{3.12}$$

(energy equation, 1D case)

$$\begin{aligned}&3\frac{\partial p}{\partial t}+3u\frac{\partial p}{\partial x}+5p\frac{\partial u}{\partial x}+2u\left(\frac{\partial p}{\partial x}-F\right)\\&-\frac{\partial}{\partial t}\left\{\tau\left[3\frac{\partial p}{\partial t}+3\,u\frac{\partial p}{\partial x}+5p\frac{\partial u}{\partial x}+2u\left(\frac{\partial p}{\partial x}-F\right)\right]\right\}\\&-\frac{\partial}{\partial x}\left\{\tau\left[5\frac{\partial}{\partial t}\left(pu\right)+5u\frac{\partial}{\partial x}\left(pu\right)+11up\frac{\partial u}{\partial x}\right]\right\}\\&-6\tau\left(\frac{\partial p}{\partial x}-F\right)u\frac{\partial u}{\partial x}+A^{pert}=0\\&A^{pert}=5\tau\left(F-\frac{\partial p}{\partial x}\right)\frac{\partial}{\partial x}\left[\frac{p}{\rho}\right]-5\frac{\partial}{\partial x}\left[\tau p\frac{\partial}{\partial x}\frac{p}{\rho}\right]\end{aligned} \tag{3.13}$$

For the case under consideration all terms proportional to τ should be considered as quantum fluctuations containing PV flashes and the mass perturbation A^{pert}.

Remind the basic conclusions following in particular from the results of mathematical modeling:

1. The calculations are realized in the vast diapason of parameter changing and Cauchy conditions.
2. In considered case (if the external pressure input is positive or equal to zero) the front of the physical vacuum waves convoy of appearance of the repulsion forces. In the existing bad terminology - we discover the “negative pressure” and “dark energy” in all cases. This fundamental result does not depend on the mechanism of external perturbations. In other words, the “anti-gravity” (better to say, the repulsion forces) in the physical vacuum exists, if there is dissipation of energy, supply of energy or in the absence of dissipation at all, (see figures 3.2 -3.17, 3.26 - 3.29).
3. If the external influence leads to diminishing the PV pressure we obtain the curves of the van der Waals type.

We have the following model EM thrust:

1. Electromagnetic waves create pressure acting on physical vacuum.
2. Appearing the PV flat waves create the repulsion forces. If the considered physical system creates PV boxes, it can lead firstly to the force of attraction and then repulsion demonstrating the effects like "anti-gravitation", characteristic for so called "dark energy". The point $\tilde{r} = \tilde{r}_{cr}$ exists where a mode of attraction is changed to repulsion mode. In this case a delay time should exist after the RF power is initiated.
3. The returning in the volume the repulsion mode is damping by the RF mode. As a result we obtain the outgoing flow of physical vacuum leading to the thrust effect. Practically we have no restrictions for the velocity for the outgoing vacuum flow.
4. This type of engine better to name as a Physical Vacuum Engine (PV Engine). If this effect exists, it is certainly a revolution in physics and technology.
5. In collider LHC $\sigma_{tot}\left(pp\right) = 10^{-25} cm^2$; taking into account the bunching effect $\sigma_{tot}^{bunch} \sim 10^{-21} cm^2$, [23].

This value is much less of the cross section of encountered particles which could lead to the dangerous anti-gravitation effect. But the mentioned particle collision can create -

a) Waves in the physical vacuum which correspond to the wake waves in colliders, [24].
b) Explosion of the PV bubbles in regime of Hadamard instabilities, [4].

Some general remarks:

1. The birth of the universe is convoying of appearance of the repulsion forces. In the existing terminology - we discover the "negative pressure" and "dark energy" in all cases. This fundamental result does not depend on the mechanism of external perturbations. In other words, the anti-gravity in the physical vacuum exists, if there is dissipation of energy or in the absence of dissipation at all.
2. Physical Vacuum is not a speculative object; it is a reality as "matter" and "fields". In other words, the physical vacuum is "the third" physical reality along with matter and fields. In this case, it is natural to raise the question about the existence of the effect which is similar to the Hubble's effect. As installed the appearance of this effect in the physical vacuum does not contradict the conclusions of non-local physics.
3. The birth of the PV boxes in Universe is convoying of appearance of the critical PV box dimension when a mode of attraction is changed to repulsion mode. In this case we can speak about models like the burst in domains filled by PV. These models are analogue of the Hubble boxes which are observed in reality. In principal the PV burst can be discovered in the collider experiments.
4. But in comparison with the Hubble expansion we need an evidence of the analogical PV expansion and the corresponding experimental data (from collider experiments for example). The excitation of the PV waves is the extremely important problem of the advanced technology.

4 The Theory of Physical Vacuum and Clear Air Turbulence (CAT)

Clear Air Turbulence (CAT) is defined as turbulence which is not associated with clouds and therefore cannot be detected visually or by conventional weather radar. The acronym CAT is now widely used throughout the world. Generally speaking CAT includes also two types of turbulence instabilities [25, 26]:

a) "Mechanical" turbulence which is connected with disruption to the smooth horizontal flow of air. Mechanical turbulence dominates the lowest few thousand feet of atmosphere.
b) Thermal turbulence caused by vertical currents of air in an unstable atmosphere.

Let us exclude the mentioned types of turbulence from consideration leaving the acronym CAT only for the last circus of the turbulent events. In this case CAT dominates (but not only) the upper troposphere and stratosphere, and evidence indicates that CAT is found at attitudes up to 100 km with the frequency maximum in the upper mesosphere [25], see Fig. 4.1.

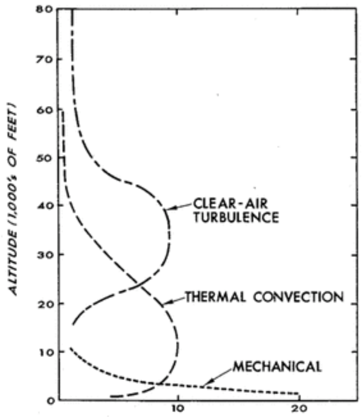

Figure 4.1. Relative frequency of turbulence [25, 26]

CAT can occur when there is a lack of evidence (like clouds or proximity to mountains) to alert pilots to the potential for turbulence on a plane. This means that a plane can hit a pocket of extreme turbulence without warning, catching passengers and crew members off guard.

This was the case when a recent Aeroflot flight (May 1st, 2017) from Moscow to Bangkok experienced severe turbulence with the plane hit an "air hole" without warning. Because there was nothing to prepare passengers, many were out of their seats and/or without seat belts at the time. According to CNN, 27 passengers were injured in the terrifying event, some reportedly with head injuries, fractures, and bruises.

Aeroflot said it was “impossible to predict” the clear air turbulence. “Therefore, the crew can’t warn passengers of the need to return to their seats,” the airline said. Clear sky turbulence isn't extremely common, but it can occur. CNN cited a flight operator as noting that about 750 cases of clear sky turbulence happen annually. The Federal Aviation Administration says 44 injuries were reported on commercial jets during turbulence last year.

The typical recommendation to the aircraft team consists *in reducing* the aircraft speed, as a result the risk reduces of structural damage and vibration reduces making instruments easier to read. Let us now investigate the Playback of Aeroflot flight SU270, (see Fig. 4.2) available in Internet.

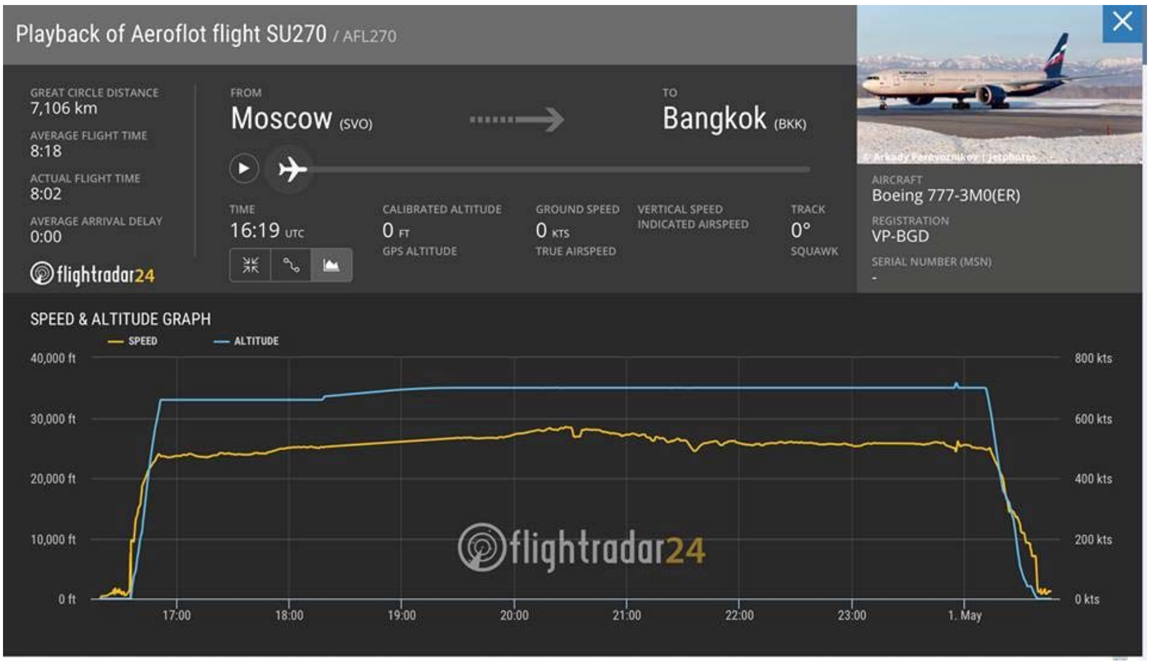

Figure 4.2. Playback of Aeroflot flight SU270 Moscow - Bangkok

Aeroflot said that clear air turbulence happened during the 777's flight 40 minutes before landing at Bangkok's airport. This event corresponds to the pike on the altitude graph which is visible on the right hand side of Fig. 3.2. The jump of altitude is more than 200 m convoying of reducing of the velocity flight. Obviously:

1. It is the beginning of the process when the crew had no possibility to interfere in the event.
2. The changing of the aerodynamic characteristic of flight is in contradiction with the usual forces balance acting on the aircraft.

Really, for any object immersed in a fluid we can define a flow direction along the motion. The spontaneous diminishing of the aircraft velocity leads to the loss of lift and to the instant diminishing of the flight altitude. But as follows from Playback of Aeroflot flight SU270 (Fig. 4.2) we see the growing up of the flight altitude instead of diminishing of the flight altitude. It would be strange to find a very narrow powerful vertical stream at this altitude invisible for radars. It is the facts of the fundamental significance; the following investigation should include the crew activity in the concrete situation and so on.

Let us consider now the possible force diagram in vicinity of PV bubble, see Fig. 4.3.

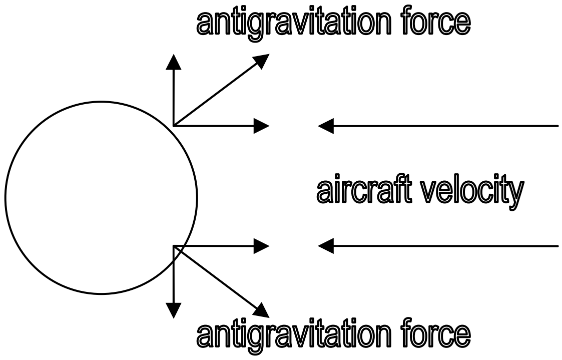

Figure 4.3. The possible positions of the anti-gravitation forces in the vicinity of PV bubble

As we see from Fig. 4.3 anti-gravitation forces in the vicinity of PV bubble lead to the instant diminishing of the aircraft velocity and the instant variation of the altitude flight including the possible jumping up of the altitude flight.

Remark:

A team of planetary scientists and physicists led by John Anderson (Pioneer 10 Principal Investigator for Celestial Mechanics) has identified a tiny unexplained acceleration towards the sun in the motion of the Pioneer 10, Pioneer 11, and Ulysses spacecraft. The mystery of the tiny acceleration towards the sun in the motion of the mentioned spacecrafts remains unexplained as of 2006 until now. The anomalous acceleration was identified after detailed analyses of radio data from the spacecraft.

This effect cannot be explained from position of local physics and have the same origin as anti-gravitational force in the constructed theory of PV-bubble.

5 Michelson - Morley Experiment and the Theory of Physical Vacuum

The Michelson–Morley experiment was performed by Albert A. Michelson and Edward W. Morley and published in November, 1887 [27]. They compared the speed of light in perpendicular directions, in an attempt to detect the relative motion of matter through the stationary aether. The result was negative, in that the expected difference between the speed of light in the direction of movement through the presumed aether, and the speed at right angles, was found not to exist. Michelson–Morley type experiments have been repeated many times with steadily increasing sensitivity. The result is considered as the evidence against the aether theory, and initiated a line of research that eventually led to special relativity, which rules out a stationary aether. The figure 5.1 shows the Michelson - Morley device. Calculate the time for which the light will pass the distance to the mirror in the horizontal direction. In one second light travels c meters, and the aether wind blows it in v meters back.

Therefore, the actual speed will be equal $(c-v)$. It means that light will reach the mirror over $t=\dfrac{L_{\Rightarrow}}{c-v}$.

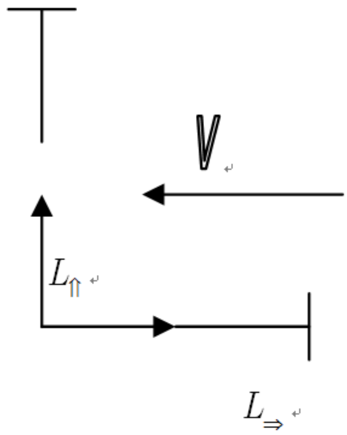

Figure 5.1. The principal scheme of Michelson - Morley experiment

Obviously the way back will take time $t=\dfrac{L_{\Rightarrow}}{c+v}$. Total time spent:

$$t_1=\frac{L_{\Rightarrow}}{c+v}+\frac{L_{\Rightarrow}}{c-v}=\frac{2L_{\Rightarrow}c}{c^2-v^2} \tag{5.1}$$

Calculate the elapsed time for moving in the vertical direction. In one second the aether wind will shift the light on the v meters to the left.

In other words the stationary observer should see the real velocity of the vertical movement as $u=c\ \cos\varphi=\sqrt{c^2-v^2}$. Then the real rate of convergence of the light with mirror (reflected on Fig. 5.1 as the upper mirror) is $u=\sqrt{c^2-v^2}$. Moving in the opposite direction leads to the symmetrical situation. Thus,

$$t_2=\frac{2L_{\Uparrow}}{\sqrt{c^2-v^2}} \tag{5.2}$$

The time difference is

$$t_1-t_2=\frac{2L_{\Rightarrow}c}{c^2-v^2}-\frac{2L_{\Uparrow}}{\sqrt{c^2-v^2}}=\frac{2c}{c^2-v^2}\left[L_{\Rightarrow}-L_{\Uparrow}\frac{\sqrt{c^2-v^2}}{c}\right]=\frac{2c}{c^2-v^2}\left[L_{\Rightarrow}-L_{\Uparrow}\sqrt{1-\frac{v^2}{c^2}}\right] \tag{5.3}$$

Some conclusions:

1. The mentioned above configuration known as Michelson-Morley experiment (1887) would have detected the earth's motion through the supposed luminiferios aether that most physicists at the time believed was the medium in which light waves propagated. From the first glance the null result of that experiment leads to the condition (see (5.3))

$$t_1-t_2=0 \tag{5.4}$$

2. But relation (5.3) is obtained for *closed* thermodynamic system without taking into account the direct influence of physical vacuum PV (or in old terminology) luminiferous aether.
3. In principal we consider the *open* thermodynamic system interacting with physical vacuum (PV). But the relation (5.1) - (5.3) obtained for classic dynamic system without taking into account the direct influence of PV on mentioned system.
4. Nevertheless we intend to construct simplified theory excluding the direct PV influence. This fact leads to kinematic relation

$$L_{\Rightarrow}=L_{\Uparrow}\sqrt{1-\frac{v^2}{c^2}} \tag{5.5}$$

Let us remind the corresponding consideration in the special relativistic theory. Deduce the equations of transformation from one inertial reference system to another. We use the standard inertial frames K and K' which are set up such that the x and x' axes coincide and the y and y' axes and z and z' axes are parallel. Let the system K' moves relative to the system along the x-axis with velocity υ. Then $y' = y$, $z' = z$. Seen from K, that K' moves in the positive x-direction with speed υ and, seen from K', that K moves in the negative x'-direction with speed υ (see Fig. 5.2). Furthermore, it is imagined that in each inertial frame there is an infinite set of recording clocks at rest in the frame and synchronized with each other. Clocks in both frames are set to zero when the origins O and O' coincide.

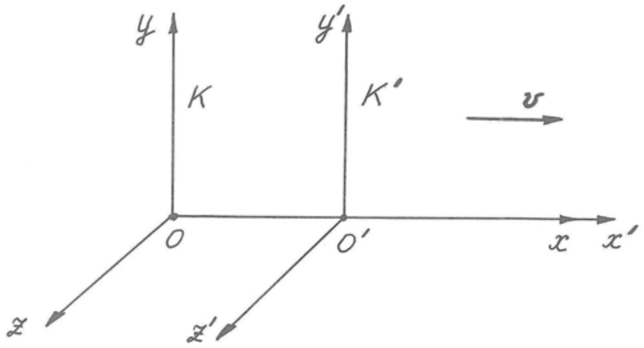

Figure 5.2. Inertial frames K and K'

Since space and time are homogeneous, the transformations sought are linear functions of the form

$$x = \gamma x' + \beta t' \tag{5.6}$$

$$x' = \hat{\gamma} x + \hat{\beta} t \tag{5.7}$$

where $\gamma, \hat{\gamma}, \beta, \hat{\beta}$ are constants. For the point O we have $x = 0$, $x' = -\upsilon t'$. Substituting these values into (5.6), we obtain $\beta = \gamma\upsilon$. Let us now consider a point O'. For this point $x' = 0$, $x = \upsilon t$. Substituting these values into (5.7), we obtain $\hat{\beta} = -\hat{\gamma}\upsilon$. Substituting β and $\hat{\beta}$ in (5.6), (5.7) and taking into account that $\gamma = \hat{\gamma}$ (because of the equality of the systems K and K′) we find

$$x = \gamma\left(x' + \upsilon t'\right) \tag{5.8}$$

$$x' = \gamma\left(x - \upsilon t\right) \tag{5.9}$$

The step of principal significance: to determine the coefficient γ. we use the principle of the constancy of the speed of light in both frames.

Let at the time moment $t = t' = 0$ from the point $O = O'$ in the direction of the axes x and x' sends a light signal that produces a flash of light on the screen. This screen is located at the point with x-coordinate in system K and x' coordinate in system K′. Then

$$x = ct,\ x' = ct' \tag{5.10}$$

Substituting (5.10) in (5.8), (5.9), we obtain

$$ct = \gamma\left(c + \upsilon\right)t' \tag{5.11}$$

$$ct' = \gamma\left(c - \upsilon\right)t \tag{5.12}$$

Multiplying respectively left and right parts (5.11) and (5.12), we have

$$c^2 = \gamma^2\left(c^2 - \upsilon^2\right) \tag{5.13}$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{5.14}$$

Substituting γ в (5.8), (5.9) we reach

$$x = \frac{x' + \upsilon t'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{5.15}$$

$$x' = \frac{x - \upsilon t}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{5.16}$$

Now we derive the transformation for time, expressing t from (5.15) and using (5.16):

$$t = \frac{1}{\upsilon}\left(x - x'\sqrt{1 - \frac{\upsilon^2}{c^2}}\right) = \frac{1}{\upsilon}\left(\frac{x' + \upsilon t'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} - \frac{x'\left(1 - \frac{\upsilon^2}{c^2}\right)}{\sqrt{1 - \frac{\upsilon^2}{c^2}}}\right) = \frac{t' + \frac{\upsilon}{c^2}x'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{5.17}$$

Thus, the formulae of transformations, called Lorentz transformations are of the form:

$$x = \frac{x' + \upsilon t'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}},\ y = y',\ z = z',\ t = \frac{t' + \frac{\upsilon}{c^2}x'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{5.18}$$

Reverse conversions can be obtained by replacing υ $(-\upsilon)$

$$x' = \frac{x - \upsilon t}{\sqrt{1 - \frac{\upsilon^2}{c^2}}},\ y' = y,\ z' = z,\ t' = \frac{t - \frac{\upsilon}{c^2}x}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{5.19}$$

We turn to the Minkowski coordinates

$$x^\alpha = \left(ct, x, y, z\right) = \left(x^0, x^1, x^{,2}, x^{,3}\right) \tag{5.20}$$

and designation of the upper index in the form like ",2" is done for the purpose to avoid misunderstandings with the exponent in the formula. Lorentz transformations (5.20) can be written as

$$x'^0 = \left(x^0 - \frac{\upsilon}{c}x^1\right)\gamma,\ x'^1 = \left(x^1 - \frac{\upsilon}{c}x^0\right)\gamma,\ x'^{,2} = x^{,2},\ x'^{,3} = x^{,3} \tag{5.21}$$

or, in matrix form,

$$X' = \begin{pmatrix} x'^0 \\ x'^1 \\ x'^{,2} \\ x'^{,3} \end{pmatrix} = \begin{pmatrix} \gamma & -\frac{\upsilon}{c}\gamma & 0 & 0 \\ -\frac{\upsilon}{c}\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x^0 \\ x^1 \\ x^{,2} \\ x^{,3} \end{pmatrix} = \ddot{\Gamma} X \tag{5.22}$$

The symbol « $\ddot{\Gamma}$ » emphasizes that « $\ddot{\Gamma}$ » is a matrix

$$\ddot{\Gamma} = \begin{pmatrix} \gamma & -\frac{\upsilon}{c}\gamma & 0 & 0 \\ -\frac{\upsilon}{c}\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{5.23}$$

Get some consequences of the Lorentz transformations.

Let in the system K lie the rod parallel to the axis x. Its length in this system is $l_0 = x_2 - x_1$ - a self - length of the rod. In accordance with (5.18) we have

$$x_1 = \frac{x_1' + \upsilon t'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}},\ x_2 = \frac{x_2' + \upsilon t'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{5.24}$$

where x_1' and x_2' - are the coordinates of the ends of the rod at the same time moment t'.

$$l_0 = x_2 - x_1 = \frac{x_2' - x_1'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} = \frac{l}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \tag{5.25}$$

or

$$l = l_0 \sqrt{1 - \frac{\upsilon^2}{c^2}} \tag{5.26}$$

Compare now the relations (5.5) and (5.26), we have the identical relations. This result is called as Lorentzian reduced size.

Since the transverse dimensions of the body in its motion do not change, then the body volume is reduced similarly

$$V = V_0 \sqrt{1 - \frac{\upsilon^2}{c^2}} \tag{5.27}$$

Interesting to notice, that Lorentz was aware in the aether existing and claimed in defense of his hypothesis that the size of the Michelson installation should be reduced in the direction of motion for the share $\sqrt{1 - \frac{v^2}{c^2}}$; indeed, in this case $t_1 = t_2$, (see (5.3)).

The origin of contradiction consists in situation when the open thermodynamic system is considered as a closed one. In other words the mirrors should not be considered as fixed objects.

6 Conclusion

1. The birth of the PV boxes in Universe is convoying of appearance of the critical PV box dimension when a mode of attraction is changed to repulsion mode. In this case we can speak about models like the burst in domains filled by PV. These models are analogue of the Hubble boxes which are observed in reality. In principal the PV burst can be discovered in the collider experiments.

2. But in comparison with the Hubble expansion we need an evidence of the analogical PV expansion and the corresponding experimental data (from collider experiments for example).

3. Existing of the PV boxes (bubbles) leads to effect of “clear air turbulence”.

4. Aether theories in physics propose the existence of a medium as a space-filling substance or field, thought to be necessary as a transmission medium for the propagation of electromagnetic or gravitational forces. The physical sense of aether theories should be reconsidered from position the theory of physical vacuum developed by me.

5. In the definite sense the Shawyer engine is analog of Michelson-Morley device but placed on torsion balance. Real existing of “anomalous thrust signals” in EM-engine leads to the contradiction with the special theory of relativity.

6. Special theory of relativity is kinematic theory which allows avoiding PV effects in the explicit form from consideration.

Acknowledge

I would like to thank Dr. Alex I. Fedoseyev for very useful discussions.

References

1. Alexeev B.V, “Generalized Boltzmann Physical Kinetics. Elsevier Amsterdam,” The Netherlands (2004) 368p.

2. Alexeev B.V., "Unified Non-local Theory of Transport Processes," Elsevier Amsterdam, The Netherlands (2015) 644p.
3. Alexeev B.V., "Unified Non-local Relativistic Theory of Transport Processes," Elsevier Amsterdam, The Netherlands (2016) 455p.
4. Alexeev B.V., "Nonlocal Astrophysics. Dark matter, Dark Energy," *Physical Vacuum*. Elsevier Amsterdam, The Netherlands (2017) 454p.
5. Chernin A.D., "Dark Energy and Universal Antigravitation," *Physics Uspekhi*, 2008. Vol. 178, No. 3. P. 267-300.
6. Lucas V. N., Rubakov V.A., "Dark Energy: Myths and Reality," *Physics Uspekhi*, 2008. Vol. 178, No. 3. C. 301-308.
7. R.J. Shawyer, "Microwave propulsion - progress in the EmDrive programme SPR Ltd UKIAC-08-C4.4.7," Glasgow, 2008.
8. Shawyer, Roger, "Second generation EmDrive propulsion applied to SSTO launcher and interstellar probe," *Acta Astronautica*, 116: 166-174, 2015.
9. Juan Yang, et al., "Prediction and Experimental Measurement of the Electromagnetic Thrust Generated by Microwave Thruster System," NWPU Xi'an China, Chinese Physical Society and IOP Publishing Ltd., 2013.
10. Yang, J., Liu, X.-C., Wang, Y.-G., Tang, M.-J., Luo, L.-T., Jin, Y.-Z. and Ning, Z.-X, "Thrust Measurement of an Independent Microwave Thruster Propulsion Device with Three-Wire Torsion Pendulum Thrust Measurement System," *Journal of Propulsion Technology* (in Chinese), 37 (2): 362-371, 2016.
11. D. Brady, et al., "Anomalous thrust production from an RF test device measured on a low thrust torsion pendulum," *NASA USA IAA Joint Propulsion Conference*, Cleveland, 2014.
12. H. White, P. March, W. Nehemiah, W. O'Neill, "Eagleworks Laboratories: Advanced Propulsion Physics Research," *NASA Technical Reports Server (NTRS) (Technical report)*, NASA. JSC-CN-25207, 2011.
13. H. White, P. March, J. Lawrence, J Vera, A. Sylvester, D. Brady and P. Bailey, "Thrust from a Closed Radio-Frequency Cavity in Vacuum," NASA Johnson Space Center, Houston, Texas 77058, *Journal of Propusion and Power*, Vol. 33, No. 4, p. 830-841, 2017.
14. Lebedew P., Untersuchungen über die Druckkräfte des Lichtes, "Annalen der Physik," 1901, fasc. 4, Bd 6, S. 433-458.
15. Munday, J.N., Capasso, F. and Parsegian, V.A., "Measured long-range repulsive Casimir-Lifshitz forces," *Nature,* 457(7226): 170-173, 2009.
16. Derjaguin, B. V., Abrikosova, I. I. and Lifshitz, E. M., "Direct measurement of molecular attraction between solids separated by a narrow gap," *Q. Rev. Chem. Soc.* 10, 295-329, 1956.
17. Van Blokland, P. H. G. M. and Overbeek, J. T. G. van der, "Waals forces between objects covered with a chrome layer," *J. Chem. Soc. Faraday Trans. I,* 74, 2637–2651, 1978.
18. Lamoreaux, S. K., "Demonstration of the Casimir force in the 0.6 to 6 μm range," *Phys. Rev. Lett.* 78, 5-8, 1997.
19. Casimir, H. B. G., "On the attraction between two perfectly conducting plates," *Proc. K. Ned. Akad. Wet*, 51, 793-795, 1948.
20. Casimir, H. B. G. and Polder, D., "The influence of retardation on the London-van der Waals forces," *Phys. Rev*. 73, 360–372, 1948.
21. Lifshitz, E. M., "The theory of molecular attractive forces between solids," *Sov. Phys. JETP* 2, 73-83 , 1956.
22. Harold White, Jerry Vera, Paul Bailey, Paul March, Tim Lawrence, Andre Sylvester and David Brady, "Dynamics of the Vacuum and Casimir Analogs to the Hydrogen Atom," *Journal of Modern Physics*, Vol.6 No.9, 2015, NASA Johnson Space Center, Houston, TX, USA.
23. Measurement of the total cross section from elastic scattering in pp collisions at ps = 7 TeV with the ATLAS detector," *Nuclear Physics B.*, European Organisation For Nuclear Research (CERN), CERN-PH-EP-2014-177.
24. Alexeev B.V., "To the nonlocal theory of waves in physical vacuum," *Advances in Astrophysics*, 2017.
25. Watkins C.D. and Browning K.A., "The detection of clear air turbulence by radar," *Physics in Technology*, Vol. 4, No. 1, 1973.
26. Saxton D., "The nature and causes of clear-air turbulence," *USAF, Air Weather Service Headquarters, Scott Afb, Ill. 3rd Annual Meeting Boston*, MA, U.S.A., 1966.
27. Michelson, Albert A.; Morley, Edward W. "On the Relative Motion of the Earth and the Luminiferous Ether," *American Journal of Science*. **34**: 333–345, 1887.

