energy E and *momentum* $\vec{p}$, moving in direction $+x$.

As to the imaginary particle, the *imaginary particle wave function* will be denoted by Ψ_ψ and, by analogy with the expression of Ψ, will be expressed by:

$$\Psi_\psi = \Psi_{0\psi} e^{-(2\pi i/h)(E_\psi t - p_\psi x)}$$

Therefore, the *general expression* of the wave function for a *free* particle can be written in the following form

$$\Psi = \Psi_{0(real)} e^{-(2\pi i/h)(E_{(real)}t - p_{(real)}x)} +$$
$$+ \Psi_{0\psi} e^{-(2\pi i/h)(E_\psi t - p_\psi x)}$$

It is known that the *uncertainty principle* can also be written as a function of ΔE (uncertainty in the energy) and Δt (uncertainty in the time), i.e.,

$$\Delta E.\Delta t \geq \hbar$$

This expression shows that a variation of energy ΔE, during a time interval Δt, can only be detected if $\Delta t \geq \hbar/\Delta E$. Consequently, a variation of energy ΔE, during a time interval $\Delta t < \hbar/\Delta E$, cannot be experimentally detected. This is a limitation imposed by Nature and not by our equipments.

Thus, a *quantum* of energy $\Delta E = hf$ that varies during a time interval $\Delta t = 1/f = \lambda/c < \hbar/\Delta E$ (wave period) cannot be experimentally detected. This is an *imaginary* photon or a "*virtual*" photon.

Now, consider a particle with energy $M_g c^2$. The DeBroglie's gravitational and inertial wavelengths are respectively $\lambda_g = h/M_g c$ and $\lambda_i = h/M_i c$. In Quantum Mechanics, particles of matter and quanta of radiation are described by means of *wave packet* (DeBroglie's waves) with average wavelength λ_i.

Therefore, we can say that during a time interval $\Delta t = \lambda_i/c$, a *quantum* of energy $\Delta E = M_g c^2$ varies. According to the uncertainty principle, the particle will be detected if $\Delta t \geq \hbar/\Delta E$, i.e., if $\lambda_i/c \geq \hbar/M_g c^2$ or $\lambda_i \geq \lambda_g/2\pi$. This condition is usually satisfied when $M_g = M_i$. In this case, $\lambda_g = \lambda_i$ and obviously, $\lambda_i > \lambda_i/2\pi$. However, when M_g decreases λ_g increases and $\lambda_g/2\pi$ can become greater than λ_i, making the particle *non-detectable* or *imaginary*.

According to Eqs. (7) and (41) we can write M_g in the following form:

$$M_g = \left|\frac{m_g}{\sqrt{1 - V^2/c^2}}\right| = \left|\frac{\chi\ m_i}{\sqrt{1 - V^2/c^2}}\right| = |\chi| M_i$$

Where

$$\chi = \left\{1 - 2\left[\sqrt{1 + (\Delta p/m_{i0}c)^2} - 1\right]\right\}$$

Since the condition to make the particle *imaginary* is

$$\lambda_i < \frac{\lambda_g}{2\pi}$$

and

$$\frac{\lambda_g}{2\pi} = \frac{\hbar}{M_g c} = \frac{\hbar}{|\chi| M_i c} = \frac{\lambda_i}{2\pi|\chi|}$$

Then we get

$$|\chi| < \frac{1}{2\pi} = 0.159$$

This means that when

$$-0.159 < \chi < +0.159$$

The particle becomes *imaginary*. Under these circumstances, we can say that the particle made a transition to the *imaginary space-time*.

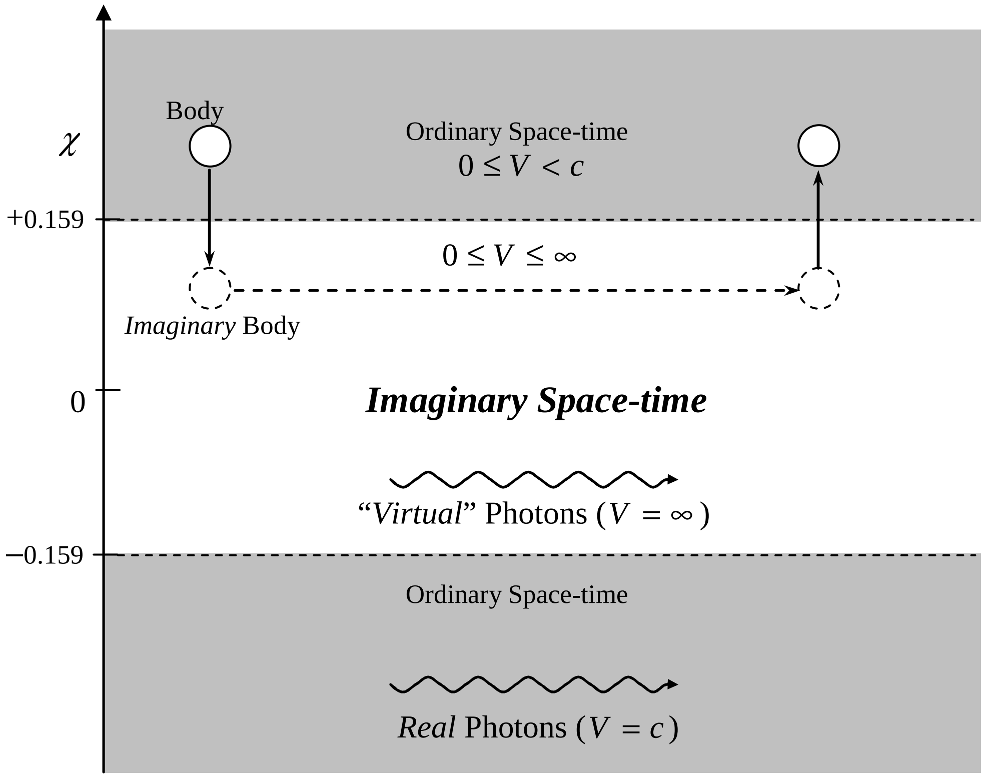

Fig. VII – *Travel in the imaginary space-time.* Similarly to the "*virtual*" photons, *imaginary* bodies can have *infinite speed* in the *imaginary space-time*.

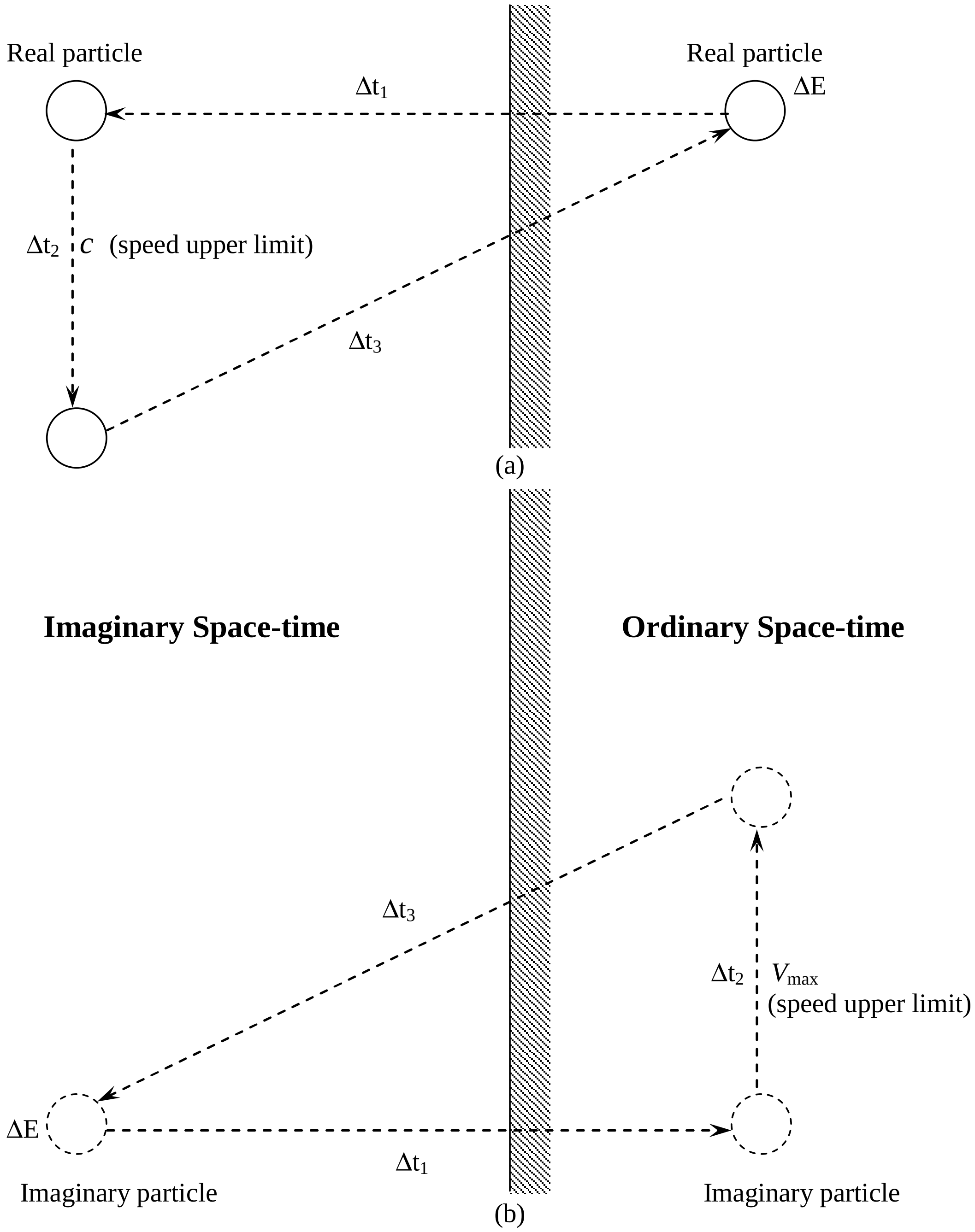

Fig. VIII – *"Virtual" Transitions* – (a) "Virtual" Transitions of a *real* particle to the *imaginary* space-time. The speed upper limit for *real* particle in the *imaginary* space-time is c.
(b) - "Virtual" Transitions of an *imaginary* particle to the *ordinary* space-time. The speed upper limit for *imaginary* particle in the *ordinary* space-time is $V_{max} \approx 10^{12} m.s^{-1}$

Note that to occur a "virtual" transition it is necessary that $\Delta t = \Delta t_1 + \Delta t_2 + \Delta t_3 < \hbar / \Delta E$
Thus, even at principle, it will be impossible to determine any variation of energy in the particle (*uncertainty principle*).

Note that, when a particle becomes imaginary, its gravitational and inertial masses also become imaginary. However, the factor $\chi = M_{g(imaginary)}/M_{i(imaginary)}$ remains *real* because

$$\chi = \frac{M_{g(imaginary)}}{M_{i(imaginary)}} = \frac{M_g i}{M_i i} = \frac{M_g}{M_i} = real$$

Thus, if the gravitational mass of the particle is reduced by means of the absorption of an amount of electromagnetic energy U, for example, we have

$$\chi = \frac{M_g}{M_i} = \left\{1 - 2\left[\sqrt{1+\left(U/m_{i0}c^2\right)^2} - 1\right]\right\}$$

This shows that the energy U of the electromagnetic field *remains acting on* the imaginary particle. In practice, this means that *electromagnetic fields act on imaginary particles*.

The gravity acceleration on a *imaginary* particle (due to the rest of the imaginary Universe) are given by

$$g'_j = \chi \, g_j \qquad j = 1,2,3,\ldots,n.$$

Where $\chi = M_{g(imaginary)}/M_{i(imaginary)}$ and $g_j = -Gm_{gj(imaginary)}/r_j^2$. Thus, the gravitational forces acting on the particle are given by

$$F_{gj} = M_{g(imaginary)} g'_j =$$
$$= M_{g(imaginary)}\left(-\chi G m_{gj(imaginary)}/r_j^2\right) =$$
$$= M_g i\left(-\chi G m_{gj} i/r_j^2\right) = +\chi G M_g m_{gj}/r_j^2 .$$

Note that these forces are *real*. Remind that, the Mach's principle says that the *inertial effects* upon a particle are consequence of the gravitational interaction of the particle with the rest of the Universe. Then we can conclude that the *inertial forces* upon an *imaginary* particle are also real.

Equation (7) shows that , in the case of imaginary particles, the relativistic mass is

$$M_{g(imaginary)} = \left|\frac{m_{g(imaginary)}}{\sqrt{1 - V^2/c^2}}\right| =$$
$$= \left|\frac{m_g i}{i\sqrt{V^2/c^2 - 1}}\right| = \left|\frac{m_g}{\sqrt{V^2/c^2 - 1}}\right|$$

This expression shows that *imaginary* particles can have velocities V greater than c in our ordinary space-time (Tachyons). The *quantization of velocity* (Eq. 36) shows that there is a speed upper limit $V_{max} > c$. As we have already calculated previously, $V_{max} \approx 10^{12} m.s^{-1}$, (Eq.102).

Note that this is the speed upper limit for *imaginary* particles *in our ordinary space-time* not in the *imaginary* space-time (Fig.7) because the *infinite* speed of the "virtual" *quanta* of the interactions shows that *imaginary* particles can have *infinite speed* in the *imaginary* space-time.

While the speed upper limit for imaginary particles in the ordinary space-time is $V_{max} \approx 10^{12} m.s^{-1}$, the speed upper limit for *real* particles in the *imaginary* space-time is c, because the relativistic expression of the mass shows that the velocity of *real* particles cannot be greater than c in *any space-time*. The uncertainty principle permits that particles make "*virtual*" transitions, during a time interval Δt, if $\Delta t < \hbar/\Delta E$. The "*virtual*" transition of *mesons* emitted from nucleons that does not change of mass, during a time interval $\Delta t < \hbar/m_\pi c^2$, is a well-known example of "*virtual*" transition of