Deriving Time Dilation from Information Theory

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Abstract: On the following pages, I want to show, that time-dilation within a gravitational field cannot only be derived from Einstein's general theory of relativity, but also from an information-theory, that describes the information-content of a given mass within a given volume.

Information content of a given volume with a given mass

The maximum information capacity of a spherical volume is delimited by the information content of a hypothetic black hole with an event horizon that fits exactly into the referring spherical volume.
However, that does not define the actual information content of a volume with arbitrary mass inside.
Nonetheless, one gains a relatively simple solution, if the following is considered: *Systems exchange information by emitting and absorbing energy.*
In case a system absorbs energy or emits it, the wavelength of this energy is limited by the size of the system. You can best discern the border of a system with a black hole, because this is clearly delimited by its event horizon r_S .
If an area in space is defined with $\Delta x = r_S$, the Heisenberg uncertainty principle leads to

$$\Delta p \geq \frac{\hbar}{2 \cdot r_S}$$

With $p = \frac{E}{c}$ and $E = h \cdot f = 2 \cdot \pi \cdot \hbar \cdot \frac{c}{\lambda}$ we get the limitations for the wavelength of the energy that can be emitted or absorbed by a certain area in space:

$$\frac{2 \cdot \pi \cdot \hbar}{\lambda} \geq \frac{\hbar}{2 \cdot r_S} \text{ and thus } \lambda \leq 4 \cdot \pi \cdot r_S$$

This relation should be valid not only for black holes, but for all systems that can be characterized by a delimited volume.
Now I use Compton's Law to find a mass package that is equivalent to the energy package with the given wavelength:

$$\lambda_c = \frac{2 \cdot \pi \cdot \hbar}{m_q \cdot c}$$

The limitation of the wavelength λ_c means that a system with a given volume can only exchange information in packages with a mass not smaller than m_q .

$$\lambda_c = \frac{2 \cdot \pi \cdot \hbar}{m_q \cdot c} \leq 4 \cdot \pi \cdot r_S \text{ and thus } \frac{\hbar}{2 \cdot r_S \cdot c} \leq m_q$$

If we extract information out of a system, we extract energy, respectively mass.
If we extract all the information of the system, the system either vanishes or exchanges all its mass with a mass that is introduced into the system.
Thus we can define the information content of a system by counting the amount of the smallest packages that can carry information until the total amount of the mass of all packages is equivalent to the mass of the system.
Let's define the system volume by the radius r_S and let us express this by the mass $n \cdot m_p$ (n-multiple of Planck-mass) of a black hole that would have this radius:

$$r_S = \frac{2 \cdot G \cdot n \cdot m_p}{c^2}$$

So we get for the mass of the smallest information-package that can be exchanged by this volume:

$$m_q \geq \frac{c \cdot \hbar}{4 \cdot G \cdot n \cdot m_p} = \frac{m_p^2}{4 \cdot n \cdot m_p} = \frac{m_p}{4 \cdot n}$$

If such a spherical volume is not a black hole, but contains the mass:

$$m = o \cdot m_p$$

we get with

$$m = o \cdot m_p = 4 \cdot n \cdot o \cdot m_q$$

the amount of information packages that a given volume with a given mass has to exchange until it has exchanged all its information:

$$4 \cdot o \cdot n$$

We assume two hypothetic black holes, one with the given volume, the other with the given mass.

Information content of a hole with the same volume as the given volume: $I_V=4.n^2$

Information content of a black hole with the same mass as the given mass: $I_M=4.o^2$

Now we can give an exact value for the actual information content of a given volume with a given mass (or energy).

Then the actual information content of a given volume with a given mass is:

$$I_G = \sqrt{I_V \cdot I_M} = \sqrt{16 \cdot n^2 \cdot o^2} = 4 \cdot o \cdot n$$

Further conclusion:

If we measure the information in Qubits, we have to regard that the information packages representing those have a different mass, depending on the volume of the system that is exchanging this information.

Information and time dilation

With the method described in the preceding chapter the actual information content of a given volume with a given mass can be calculated by forming the geometric mean of the information content of two virtual black holes: one with the given volume and one with the given mass:

$$I_G = \sqrt{I_V \cdot I_M}$$

According to Seth Lloyd and Y. Jack Ng a black hole can be seen as a computer. The amount of bits in the storage of this computer is proportional to the squared computing speed of this computer:

$$I_S = t_p^2 \cdot b_S^2$$

I_S … information content of the black hole

$t_p = \sqrt{\frac{G\hbar}{c^5}}$ … Planck-time

b_S … computing speed of the black hole (in bits per second)

Thus, the maximum computing speed within a given volume (that is strictly separated from other systems) can be formulated:

$$b_S = \sqrt{\frac{I_S}{t_p^2}} = \frac{\sqrt{I_S}}{t_p}$$

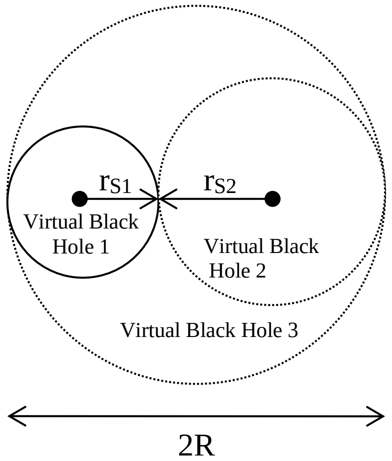
Let us assume, the amount of mass (or energy) within this volume is given.
The radius of this volume is R.
Then the information content of this volume would be:

$$I_G = \sqrt{I_V \cdot I_M} = \sqrt{I_V} \cdot \sqrt{I_M} = \sqrt{\frac{R^2}{l_p^2}} \cdot \sqrt{I_M} = R \cdot \frac{\sqrt{I_M}}{l_p}$$

Thus, the maximum computing speed within a given volume containing a well-known mass could also be given:

$$b_G = \frac{\sqrt{I_G}}{t_p} = \frac{\sqrt{R}}{t_p} \cdot \sqrt{\frac{\sqrt{I_M}}{l_p}}$$

Now let us introduce a second mass m_1 with the according Schwarzschild radius r_{S1} into the volume. Then there will be left only a volume with the radius r_{S2} for the other mass, that has already been in the volume before.



Thus, the computing speed of the mass that has been in the volume before would slow down:

$$b_{G2} = \frac{\sqrt{r_{S2}}}{t_p} \cdot \sqrt{\frac{\sqrt{I_M}}{l_p}}$$

We assume here that there is no interaction between the two masses that are now within the given volume.
Let us now look at the computation speed in relation to the speed the first mass was computing, before the second mass was introduced:

$$\frac{b_{G2}}{b_G} = \frac{\sqrt{r_{S2}}}{\sqrt{R}} = \frac{\sqrt{r_{S2}}}{\sqrt{r_{S1} + r_{S2}}}$$

This leads to the time dilation:

$$\frac{dt}{d\tau} = \frac{b_G}{b_{G2}} = \frac{\sqrt{r_{S1} + r_{S2}}}{\sqrt{r_{S2}}}$$

(Let us state here that a quantization of mass and radius also leads to a quantization of time.)
But let’s continue to bring the above equation into a known form.

$$dt = \frac{\sqrt{r_{S1} + r_{S2}}}{\sqrt{r_{S2}}} \cdot d\tau$$

With the Schwarzschild radius r_{S1} of m_1 :

$$r_{S1} = \frac{2 \cdot G \cdot m_1}{c^2}$$

$R = r_{S1} + r_{S2}$ is the distance of the two masses and so we get:

$$dt = \frac{\sqrt{r_{S1} + r_{S2}}}{\sqrt{r_{S2}}} \cdot d\tau = \sqrt{\frac{1}{\frac{r_{S2}}{r_{S1} + r_{S2}}}} \cdot d\tau = \frac{1}{\sqrt{\frac{r_{S2} + r_{S1} - r_{S1}}{r_{S1} + r_{S2}}}} \cdot d\tau = \frac{d\tau}{\sqrt{\frac{R - \frac{2 \cdot G \cdot m_1}{c^2}}{R}}} = \frac{d\tau}{\sqrt{1 - \frac{2 \cdot G \cdot m_1}{R \cdot c^2}}}$$

…this is the time dilation that follows from Einstein's theory.

All this doesn't lead to new results, but maybe it could help to re-formulate physics in the context of a new information theory.

I hope, that I could show that by using the "actual information content of delimited systems" as basic physical term, fundamental physical effects can be derived from a description of abstract systems that exchange information (in terms of Quantum-Logic). Volume (space), mass, time, etc. can be interpreted as a special form of coding the information physical systems exchange among each other.