The Jinn of the time machine: nontrivial self-consistent solutions

1992 Class. Quantum Grav. 9 2309

(http://iopscience.iop.org/0264-9381/9/10/014)

Class. Quantum Grav. 9 (1992) 2309–2321. Printed in the UK

The Jinn of the time machine: non-trivial self-consistent solutions

A Lossev†‡ and I D Novikov†§||

† NORDITA, Blegdamsvej 17, Copenhagen, Denmark
‡ ITEP, Moscow, Russia
§ University Observatory, Østervoldgade 3, Copenhagen, Denmark
|| Astro Space Centre of P N Lebedev Physical Institute, Academy of Sciences, Moscow, Russia

Received 31 July 1991, in final form 15 May 1992

Abstract. A new type of self-consistent evolution in the spacetime with a time machine is discussed. We propose the hypothesis of the possible existence of systems with closed world-lines (the Jinn¶ of the time machine). These systems are possible only if they can, by interacting with external objects, gain energy to regenerate their internal structure. The consequences of the hypothesis are discussed.

1. Introduction

1.1. Time machine

The spacetimes with closed time-like curves (CTCs) have been discussed for decades by many authors, including K Gödel, A Taub, R Kerr, S Hawking, C Misner, G Ellis, F de Felice and others.

New aspects of the problem, and especially the possibility of creating in principle a time machine (TM), allowing one to travel into the past, were discussed in [1–3].

In the case of the artificial creation of a time machine there is a Cauchy horizon dividing the region of the spacetime with CTCs from that without them [1, 4]. This Cauchy horizon seems to be stable against classical perturbations [1], but one cannot exclude the possibility that vacuum fluctuations of quantum fields could produce a divergent renormalized stress–energy at the Cauchy horizon, thereby preventing the creation of CTCs. The arguments in favour and against the possibility of the existence of CTCs are discussed in [5–7]. At the same time, our understanding of the fundamental structure of the vacuum and the effects of quantum fluctuations is so inadequate, that from existing quantum theory only we should definitely exclude the possibility of the very existence of the Universe (greater than the electroweak scale, due to renormalization of the cosmological constant), but experimentally it exists. There are other speculations about the possible ways by which the laws of physics might prevent an arbitrary advanced civilization from creating a TM (see [8]), but they are only speculations and the question is open. Thus, it is not clear now whether the

¶ Jinnee (singular) (also Genie (singular) and Genii (plural))—spirit of Arabian tales.

0264-9381/92/102309+13$04.50

laws of physics prevent the construction of a time machine, and to find out whether they do is likely to involve a long period of investigations. Accordingly, we will study consequences of an alternative possibility: that the creation of a time machine is possible.

In this paper we discuss the time machine, which is (after completion of its creation) a static wormhole. In this construction there are two spherical holes (mouths) A and B in a three-dimensional space, connected with each other by a short handle, and there are CTCs, which pass through the wormhole. The length l of the handle can be arbitrarily small and it does not depend on the distance $2r$ between the mouths A and B in the external space. We suppose that $l \ll r$ and that l is negligible, $l \approx 0$. In our model treatment the spacetime outside the mouths is a practically flat Minkowski spacetime. If somebody (or something) enters mouth B and moves through the short handle, he (or it) exits the mouth A practically immediately, according to his (or its) proper time, but with a shift into the past by a period T (we suppose that $T > 2r$), according to the time t of the reference frame in which mouths A and B are at rest. Travelling through the wormhole in the opposite direction (from A to B) would be to travel to the future (with a shift by a period T). This period T together with the length r (and l if it is not negligible) are the main parameters of the time machine.

In papers [2, 9, 10, 4] the principle of self-consistency (PSC) was declared and discussed. This principle states that the only solutions to the laws of physics that can occur locally in the real Universe are those which are globally self-consistent. The PSC by fiat forbids changing the past. All events happen only once, and cannot be changed.

1.2. Billiard ball problem

In the papers [11, 4] the self-consistent solutions to the so-called 'billiard ball problem' were discussed. The problem is the following: a solid perfectly elastic ball moves relative to the mouths of the wormhole. Its speed is assumed to be small compared with the speed of light, so it can be treated non-relativistically. The ball enters the wormhole through mouth B, appears from mouth A in the past and continuing its motion, it can encounter and collide with itself.

Naively, there is a 'paradox' in this problem (the so called 'Polchinski paradox' [12]). Namely the initial position and velocity of the ball are chosen in such a way that the ball moves along the trajectory α_1, enters mouth B, and exits from mouth A before it entered into B. The ball continues its motion along the trajectory α_2 (the trajectory α_2 is well defined if the trajectory α_1 is given [11]). The timing is just right for the ball to hit itself at the point Z, knocking its 'younger' self along trajectory α_3 and thereby preventing itself from reaching mouth B. Such an evolution is self-inconsistent and impossible. It is not a solution of the evolution equations.

There is the mistake in the previous discussion (the reason for the 'paradox'): when at the beginning of our discussion we continued the trajectory α_1 after point Z, we did not take into account the influence of the impact and considered the motion of this ball along the trajectory α_2 without taking into account this impact. This means that we did not take into account the influence of the future on the past. In paper [11] the authors demonstrated that for initial data which give self-inconsistent 'solutions' there are also self-consistent solutions. The initial data (initial position and velocity of the ball) are the same as in the previous case. The part of trajectory α_1 before the collision with the 'older' self coming from the future is the same. This 'older' ball moves along trajectory β_2 which is a little different from the one α_2 without the collision. The 'older' ball on β_2 strikes itself on α_1 gently, deflecting itself into a slightly altered trajectory β_1. This altered trajectory β_1 takes the ball into the mouth B at a slightly altered point compared to the point in the self-inconsistent case. The ball exits from the mouth A before it went into mouth B, and moves along the trajectory β_2 to the collision event. This solution is self-consistent.

1.3. Non-uniqueness of the self-consistent solution

Echeverria, Klinkhammer and Thorne ([11], see also [4]) showed that there is more than one self-consistent evolution in the case of a perfectly elastic billiard ball, and even an infinite number of them: the evolution in parts (*a*) and (*b*) of figure 1 are two self-consistent outcomes from the same initial data. In papers [13,7] the quantum mechanical interpretation of this multiplicity was made. We will not discuss this point here.

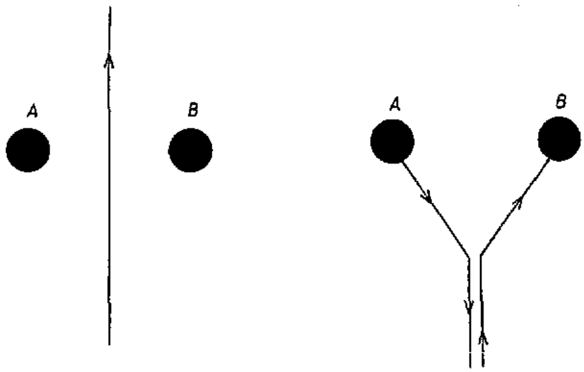

Figure 1. (*a*) A trivial self-consistent evolution for a billiard ball. (*b*) A non-trivial self-consistent evolution with the use of the time machine.

Here we describe a new approach to construction and interpretation of self-consistent solutions, which allows us to discuss the problem from another point of view.

1.4. Purpose of the paper

The purpose of this paper is to propose a qualitively new idea for constructing self-consistent solutions of equations of motion that can arise in presence of TM. These new solutions are based on the hypothesis of the existence of motion of subsystems (below we will call them the Jinn of the TM, or simply Jinn) along closed world lines. Note, that the proper time along such lines is finite and is equal (in the non-relativistic limit) to the characteristic time of the TM (if TM is used only once). Naively, such solutions are forbidden according to the irreversibility principle: the entropy of the system should increase with proper time, dissipation of energy (radiation of all kinds), material becoming older (decay of atoms, particles etc.). Really, this principle forbids motion along close world lines of *isolated subsystems*. But subsystems can get energy and decrease their entropy (i.e. gain information and self-organize) in interactions with external systems. In this case the existence of a Jinnee of the TM is possible and below we will consider examples of self-consistent processes with a Jinnee. We emphasize that conservation laws do not forbid the existence of a Jinnee [4].

It seems that along with the solutions described above there exist some other Jinnee-like solutions, in which not matter but purely information moves along closed world lines. We will call these solutions Jinn of the second kind and study effects that they produce in the external world.

2. Jinnee: definition, the simplest example

2.1. *Definition of the Jinnee*

Consider a TM like that described in the introduction, i.e. a wormhole in the space with two mouths A and B connected by an infinitely short corridor, and with the time shift into the past by a period T after passing the corridor from B to A.

We will define the Jinnee as follows.

By Jinnee we mean the following closed spacetime trajectory (satisfying classical equations of motion) of a Jinnee system: the Jinnee system in state α appears in the mouth A, then moves (during the time T) in the universe outside the mouths and finally comes to the mouth B in such a state β that after passing a corridor its state coincides with α.

Here by the state of a system we mean a point in the phase space of the system. Sometimes we shall use the term 'Jinnee system' instead of 'Jinnee'.

Comment 1. In more complicated cases the Jinnee system can use the TM many times before it closes its world line. But for the sake of simplicity we will consider here only 'one loop Jinnee solutions' (the system uses the TM only once).

Comment 2. From the point of view of classical (not quantum mechanical) physics it seems that there are no restrictions on the complexity of the Jinnee system.

Comment 3. It is obvious that in the process of motion between A and B the Jinnee system should interact with external systems in order to recreate its initial state, for example it should gain energy in order to compensate for dissipation of energy which is inevitable under realistic conditions. This dissipation may be internal, by radiation of all kinds, or perhaps kinetic due to some generalized friction. Moreover, in general, during the motion without external interactions the entropy of Jinnee systems (taking into account radiation) increases (systems becomes 'older'), and thus in interactions with external systems entropy of the Jinnee system should decrease, i.e. the Jinnee system should be able to self-organize itself in interaction with external systems.

Comment 4. From the previous comments it follows that the type of the Jinnee system is determined to some extent by available external systems (which from the point of view of Jinnee systems are sources of energy and raw materials for self-organization).

Comment 5. From the point of view of the external observer the conservation laws are satisfied in the following way: when a Jinnee of mass M_{Jinee} appears from the mouth A the mass of this mouth decreases by an amount M_{Jinee}. At the moment when a Jinnee enters the mouth B the mass of the latter one increases by the M_{Jinee}.

In order to make the idea of Jinnee solutions more transparent, we will discuss the simplest example, which reflects macroscopic physics only.

2.2. *A purely mechanical model*

Let us return to the example described above of a motion of a ball between two mouths. (Below we will refer to this ball as the external ball). Along with the set of possible solutions mentioned above there exists the following non-trivial possibility: the Jinnee ball appears from mouth A, hits the external ball and then disappears into mouth B, as shown in figure 2.

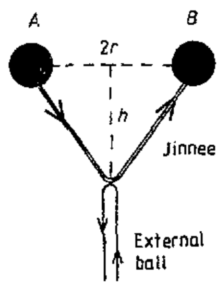

Figure 2. A self-consistent evolution with a Jinnee of the time machine

Let $2r$ be the distance between mouths, h be the distance between the place where the collision occurs and the line connecting the mouths, and let us neglect the radii of the mouths in comparison with these distances. Then the velocity of the Jinnee before and after collision should be equal to $V_{\text{Jinee}} = 2L/T$, where $L = (r^2 + h^2)^{1/2}$. Now let us suppose that the velocity and the mass of the external ball are equal to V and M respectively. If we suppose that the collision between balls is absolutely elastic, then from conservation of kinetic energy we get that the velocity of the external ball after collision should be equal to $-V$, and momentum is conserved in this collision if and only if the mass M_{Jinee} of the Jinnee ball is equal to:

$$M_{\text{Jinee}} = \frac{MV}{V_{\text{Jinee}} h/L} . \qquad (1)$$

Thus, for any parameters of the external ball (mass, velocity, distance from the TM) there exists a Jinnee ball that reflects the external ball from the TM.

The purely mechanical model does not reflect the very important property of the real world: irreversibility of the processes in a closed system. To simulate these effects we will study the simplest mechanical–thermodynamical model.

2.3. Mechanical–thermodynamical model

We will simulate irreversibility by demanding the following:

(1) The Jinnee balls have some temperature and thus they radiate, losing internal energy. The thermodynamic characteristics of the original ball are of no interest to us, as we shall see below. For simplicity we will characterize the Jinnee ball by a constant loss of internal energy per unit of time $\mathrm{d}E/\mathrm{d}t$.

(2) All collisions are not absolutely elastic, and we will characterize each pair of balls by a collision coefficient k,

$$k = \frac{E_{\rm fin}}{E_{\rm ini}} < 1 \tag{2}$$

where $E_{\rm fin}$ and $E_{\rm ini}$ are the total kinetic energy in the centre-of-mass system of coordinates after and before a collision. Moreover, let us suppose that the heat produced in a collision is given only to the Jinnee ball (only this part of heat is essential for our discussion).

We should consider parameters k, $\mathrm{d}E/\mathrm{d}t$ and also $M_{\rm Jinee}$ as parameters of the Jinnee ball, like $M_{\rm Jinee}$ in the mechanical example. These parameters will be determined from the possibility of the corresponding collision in a self-consistent solution. The mechanical example corresponds to $k = 1$, $\mathrm{d}E/\mathrm{d}t = 0$ with $M_{\rm Jinee}$ given by (1).

Let us determine these parameters. Suppose $\mathrm{d}E/\mathrm{d}t$ is fixed and is small. Then the loss of internal energy of the Jinnee is also fixed: $\delta E = (\mathrm{d}E/\mathrm{d}t)T$. We know that the Jinnee ball should have the same velocity after collision as before, thus the energy for the radiation of the Jinnee ball is taken exclusively from the kinetic energy of the external ball.

Thus, the velocity of the external ball after collision is lower than before it and is equal to: $V - \delta V$, where δV is determined from:

$$(MV^2/2) - [M(V - \delta V)^2/2] = \delta E. \tag{3}$$

Then, the mass $M_{\rm Jinee}$ is determined from the conservation of momenta and is equal to

$$M_{\rm Jinee} = \frac{M(2V - \delta V)}{2V_{\rm Jinee} h/L}. \tag{4}$$

Now that we know the velocities and masses of the colliding balls, so we can determine the coefficient k by calculating the kinetic energy in the centre of mass coordinate system from (2).

Thus, in the mechanical–thermodynamical model for all velocities, masses and distances of the external ball there exists a one-parameter family of Jinnee solutions—Jinnee balls that hit the external ball.

Note, that if in the process of collision the Jinnee acquires angular momentum (in the case of a non-zero coefficient of friction between the surfaces of the colliding balls), then we consider the Jinnee ball that appeared from the mouth A already rotating and in this case the Jinnee ball can get rid of additional angular momentum in many ways (asymmetric thermal radiation, gravitational radiation if the mass distribution of the Jinnee is not spherical, electromagnetic radiation if the Jinnee ball has non-zero dipole moment etc).

This model, together with models in the subsequent paragraphs, demonstrates that a Jinnee 'chooses' its parameters itself, matching them to the properties of the external system (or systems).

It is appropriate now to mention a solution of the mechanical model which at first sight looks like a Jinnee solution but which has no counterpart in the mechanical–thermodynamical model. (We did not discuss it above for methodological reasons). This solution corresponds to a ball that leaves the mouth A at the point A_1 and enters the mouth B at the point B_1 (see figure 3) without any collision with external balls. Its mass is arbitrary but its velocity is fixed and is equal to $2r/T$. It is obvious why this solution does not exist in the mechanical–thermodynamical model—without collisions with the external ball there is no way to obtain energy for the radiation.

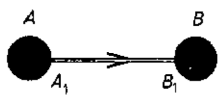

Figure 3. A Jinnee-type mechanical evolution without interaction with external bodies. This evolution could not be self-consistent (see text).

We will finish this section by mentioning the general case in this model. Suppose that the external ball is at the point P and is moving with velocity $\boldsymbol{v}$. Let us consider the ellipsoid with foci A and B that contains P. Then if the velocity of the external ball has a positive component in the direction normal to this ellipsoid at P (by positive we mean the normal direction inside the ellipsoid), there exists a Jinnee solution that reflects the external ball back from the TM. The motion in the shadow zone (the infinite cylinder that touches both of the mouths minus the part of this cylinder between mouths) will be discussed in a separate paper.

3. Jinn of the first and second kinds

3.1. The Jinnee of the first kind—matter makes a loop

In previous sections we discussed Jinnee solutions and Jinnee objects in mechanics and mechanics with thermodynamics. Now we will address the question of what a Jinnee in the real world can look like†.

Among macroscopic objects the only really good candidate to be a Jinnee that we have found is the black hole. It seems that black holes cannot become older in a way that cannot be reversed by giving them some energy. Really, they lose their energy and angular momentum by Hawking radiation and Zeldovich radiation for rotational energy (see [10]), and if their stretched horizon is moving, by classical gravitational radiation. By attracting matter and radiation and capturing it, a black hole can restore

† Since we cannot discuss all possible self-organizing systems, we restrict our analysis with the two simplest possibilities: electromagnetic waves and black holes. We recognize that our analysis is preliminary, and further investigation of the subject can change naive consideration presented below.

its energy, and if this attraction is not spherically symmetrical it will induce a motion of the stretched horizon and restore the angular momentum. The change of momentum can be achieved either by interaction with a gravitational field, or (if the black hole is charged) by interaction with an electric field†. Conditions allowing for the appearance of the Jinnee black hole (gravitational and electrical fields (for charged black holes), and the amounts of external matter and radiation near TM) should be separately studied, but here we would like to mention the following qualitative fact, that seems to be rather important. The loss of energy of the black hole due to Hawking radiation is proportional to the inverse square of its mass, but its ability to attract matter and energy grows with its mass, so the mass of the black hole is adjusted to the amount of energy at its disposal. Thus, if there is a trajectory (due to external field) for a black hole that starts at mouth A and ends in mouth B (and the time of this motion is T), and there is some amount of energy on this trajectory, it seems that we can always expect the appearance of Jinnee black holes, a large one for a small amount of energy and plenty of small ones for a large amount. That is why it seems that if you have a lot of energy a TM is a rather dangerous place: a lot of Jinnee black holes can appear and steal some or even all your energy. For such complex systems as human beings that can lead to terrible results.

Note that a classical electromagnetic wave in most situations cannot be considered as a Jinnee object, since in motion through the TM dissipation of its energy results in diminishing of amplitude, and it can normally get energy from the external object through reflection from a moving mirror, which results in an increase of the frequency.

3.2. The Jinnee of the second kind—information makes a loop.

Let us return to our failure to generate electromagnetic waves as Jinnee with the moving mirror. We recognized that we have to increase the amplitude of the signal—so let us use an amplifier! Namely, let us consider as an external object the following device, which consists of a receiver (directed to the mouth A), an amplifier of signals that come from the receiver, and a transmitter of these signals (directed to mouth B). Of course, this device is supplied by some source of energy, say, an electric cell. Then this system has a Jinnee-like solution: a signal with amplitude E comes out of the mouth A, some part of this signal reaches the receiver, then it is amplified and sent to mouth B by the transmitter. Again only part of this strong signal reaches mouth B, but our amplifier is strong enough to make the amplitude of that part equal to E. Since the coefficient of amplification depends on frequency, solutions always exists for an amplifier that is strong enough.

Note, that in this example no matter makes a closed loop: photons were born at the transmitter and die at the receiver. But their death generates them: dying at receiver, they give to the system information about themselves. Thus, in this case we may say that it is information about the signal that makes a loop. We will call such self-consistent solutions of the equations of motion Jinn of the second kind.

† Moreover, if we consider motion between A_1 and B_1, which is forbidden in the thermomechanical model, we will see that in that case we need not arrange for any strong interaction—it is enough to have some matter on this line, and then, it seems, that the mass of the Jinnee black hole will be automatically adjusted in such a way that the amount of energy would be equal to the amount of energy radiated. If the mass is very large, a lot of energy is captured in comparison with the radiated energy, but when the mass is very small, the energy radiated exceeds the energy captured, and thus there should be a balance somewhere in between. In all our discussions we did not consider the internal structure of a black hole.

The choice of this name is motivated by analogy with a perpetuum mobile of the second kind, that, strictly speaking, is not perpetuum mobile, but appears so from the 'common sense' point of view.

Similarly, the Jinnee object is an object that'nobody made' from the 'common sense' point of view. About Jinn of the second kind we formally know who made them (the transmitter in the example above) but due to the principle that 'reason contains information about consequence', 'common sense' refuses to recognize in the transmitter the reason for the signal.

3.3. The Jinnee of the second kind and clever spacecraft

In order to clarify the idea of a Jinnee of the second kind and to distinguish a closed loop that is made by information from a trajectory for matter, we will consider the following semirealistic example.

Suppose that a TM exists somewhere in the Universe, and this place can be reached by a photon spacecraft. Suppose that now or in the nearest future humanity will have enough raw materials, energy, computers etc. to make it without using men (e.g. by computer-controlled plants). Then people can act as follows: they can put all their resources in one place and agree not to interfere with what happens. Then (really, some time ago) an old spacecraft will appear from the mouth A. This spacecraft will keep in its computer memory the following:

(a) the design of itself;
(b) the direction from A to the Earth;
(c) the direction from the Earth to the mouth B;

and it will start its flight to the Earth. If the parameter T of the TM is less then R/c (R stands for the distance between the Earth and the TM) at the beginning of its flight the spacecraft uses the TM many times to obtain a large shift into the past. At the moment when people prepared everything for building a spacecraft, the very old spacecraft will land there, load its design into the computer memory of the computer controlled plants. These plants will build the new spacecraft from new materials, and according to its program this new craft will start its trip to the mouth B. When this craft reaches the mouth B it is already old.

(This is the end of the construction of this self-consistent solution).

In this example it is information (the design of the craft) that made the closed loop. What about the craft itself? It made a long trip, but not a closed loop, because it finishes its life on the Earth in the museum.

By the way, note that people, as a reward for their construction of the industrial society and their efforts in marshalling resources, will have

(a) the design for the very effective spacecraft;
(b) a very old, used spacecraft and
(c) information about the position of the mouths A and B.

3.4. The Jinnee as an inherent property of all self-consistent solutions

After examples of the Jinnee of the second kind one may think that these Jinn are very rare and to prepare conditions to make it possible for them to appear is a rather hard task. This is in some sense an illusion. Actually it is not so easy to prepare conditions to meet a significant† Jinnee of the second kind (and we discussed these

† By this term we mean a rather complicated system which could be really large. Subsequently we shall use the adjectives 'big' and 'small' in this sense.

examples in order to show outstanding representatives from a big family of Jinnee), but a small Jinnee of the second kind always appears in any self-consistent solution.

In the case of the 'billiard ball problem' the 'change of the naive trajectory' made a loop, in the case of Thorne's example, 'momentum to the right' made a loop, but these pieces of information were not recognized as something special—they were lost in the crowd of strictly moving matter and information. But, to tell the truth, it is cycling of information that really attracts our attention when we look at self-consistent solutions, because we never saw such cycling in ordinary life.

A rather 'big' Jinnee was already known in the so called 'bomb version' of the 'billiard ball problem' [14] in which balls were replaced by bombs, so that self-consistent solutions with soft collision became impossible. The self-consistent solution that was found is as follows: a bomb splinter appears from the mouth A, hits the bomb and, after explosion, one of the splinters reaches B, passes the corridor, and turns out to be the original splinter that produced all this mess. Note, that this solution *a posteriori* has nothing to do with the 'paradox', because the bomb can explode even it was quietly resting near the TM. Then this example is a version of the transmitter example. Here we come to the question: who really created this splinter? The answer is unambiguous: from one point of view, it is a bomb, and there is nothing interesting about it. From another point of view, it is the splinter itself, by hitting a bomb. Experience from normal life where the bomb is mostly responsible for splinters seems to be misleading. In the case of the transmitter, 'common sense' forces us to take the second point of view. (We are used to the idea that it is the radio station, not the receiver, that creates a broadcast).

The last thing that we want to say about the Jinnee of the second kind is the following: perhaps, it is not important to distinguish between Jinn of the first and the second kind. Really, human beings mostly are interested in non-trivially organized motion in nature, and pay less attention to whether it is motion of isolated subsystems or a complex collective effect, such as the motion of collective variables (coordinates of atoms seem to be appropriate variables in one case and not appropriate for the other; there are no preferable variables for the description of nature in all possible phases). When we look at the sea, we can see waves that exist for a rather long time, but it is a continuous process of cyclical motion of particles of water, each motion exists for a rather short time, and then it dies, giving energy to neighbours. Thus, it seems that there is no boundary, even no qualitative difference between self-reproducing motions and self-organizing systems. If we take this point of view, we can say that a Jinnee of the first kind is a loop made by a self-organizing system (with the help of external sources of energy). A Jinnee of the second kind is a loop made by a self-reproducing system, and there is no real difference between them.

3.5. The Jinnee of the second kind as 'Solving problems ltd' (with limited possibility and responsibility)

In the previous semi-realistic example we saw that any Jinnee of the second kind carries some knowledge about its internal structure and even can leave this knowledge in the possession of human beings. From the point of view of industrial society, it is important to get a spacecraft itself (in order to fly in it etc.). But from the point of view of the post-industrial society the only important thing is the knowledge of how to build such a spacecraft. In this subsection we shall discuss the idea of how to use a Jinnee of the second kind to get knowledge about something. We will call the corresponding hypothetical device 'Solving problems ltd', because (as we will see below) the ability and responsibility of such a device are limited.

In order to give an example, we will show how to solve the equation $F(n) = 0$ in natural numbers. Consider the receiver–amplifier–transmitter device from subsection 3.2. Let us make several modifications to it.

(a) Let us take the simplest computer with the following program in it: the input to this program is a number n (of impulses) and the output is 1 if $F(n) = 0$ and 0 if $F(n) \neq 0$.

(b) Let us put on the transmitter a switch which is connected with the computer and which turns ON if and only if the output of the computer is 1.

(c) Let the amplifier have two parallel outputs and let us connect the input port of the computer with the second port of the amplifier. (The first part is connected to the transmitter, and this connection introduces a time delay, t, delay of a signal, $t < T$.)

Near the TM such a device behaves as follows. If there exists a solution of the equation $F(n) = 0$ then there exists a Jinnee solution of the equation of motion of the full system, and the answer (the number of impulses) will appear from the mouth A. This signal will be amplified, and sent to both computer and transmitter. If the number is small enough for the program to finish its check with a delay time t in the first port, then the switch turns ON and this signal is transmitted to the mouth B.

But if either there is no solution to the equation under consideration or there is a solution but the number is too large for a program to finish in time t, then there are no Jinn of the second kind. Thus, if in our experience we do not meet Jinn of the second kind, it does not mean that there are no solutions. So we see that the 'Solving problems' device has limited possibilities, but they are much larger than in ordinary computers. Really, if it takes a time $\tau(n)$ to check whether the number of order n is a solution of the equation, then the 'Solving problems' device needs time $\tau(n)$ to find a solution while an ordinary computer needs time $n\tau(n)$ to do such a job because it needs to check first n natural numbers before it finds that the nth is a solution. Thus, the 'Solving problems' device is n times faster than an ordinary computer.

The most important thing in all versions of 'Solving problems' devices is a so called CHECKER that can decide whether the signal that comes to the receiver solves the desired problem. You can ask nature via the 'Solving problems' device about anything you wish, but you should be able to decide in a FINITE TIME whether or not you are satisfied with the answer. For example, when people write programs that do something, these programs are tested by special test programs. Let us consider the creation of an editor. If it is a man who writes an editor, then passing the test is enough to decide whether this editor contains mistakes or not. But if you use test programs as a CHECKER, it is highly probable that the 'Solving problems' device will give you not an editor but some other program that can only pass tests, but cannot do anything else. (Like a student, who knows the questions he will be asked in advance, can prepare answers without knowing the subject.)

Thus, the 'Solving problems' device is not responsible for giving misleading answers. The answer you get is only the answer that can pass CHECKER and nothing more so it is highly probable that the answer that you get in the 'Solving problems' device is an answer that just fools the checker. Only if the checker is absolutely reliable (as in the example with solving equations) can you be sure that the answer is correct.

That is why the 'Solving problems ltd' device has not only limited possibilities but also limited responsibility.

4. Concluding remarks

In conclusion we would like to make several remarks concerning different aspects of the Jinnee problem.

(1) If the Jinnee uses the TM very many times we must take into account the back reaction of the Jinnee on the TM. As was shown in [3], after the massive body enters the TM through the mouth B and leaves it through the mouth A, the mass of B increases and the mass of A decreases. Thus, if the massive system uses the TM many times, one needs to restore the TM (or the system can do that itself). Also if the Jinnee has an electric charge (for example positive), then after the completion of the external Jinnee motion there would be a negative charge at mouth A and a positive charge at mouth B.

(2) If one could show that there are initial data (for example, before the origin of the Cauchy horizon, i.e. before creation of the TM) for which there is no self-consistent evolution without a Jinnee, then the existence of self-consistent solutions with a Jinnee may be a way out. Also the Jinnee-type system can help in the solution of the 'paradox' (see [2, 8]): somebody after using a TM tries to kill his grandmother before his mother was born. The Jinnee could stay his hand at the moment of such an attempt.

(3) It could happen that, due to the Jinnee, the TM produces a restriction on the development of civilization. With increasing energy controlled by civilization, the probability of a Jinnee that steals this energy also increases. (Just remember what can happen with a bomb that is quietly placed near a TM).

(4) We would like to emphasize that even formally there is no strict boundary between Jinn of the first and the second kind. Really, we can consider the transmitter example with the coherent electromagnetic wave and a laser as an amplifier. The laser can amplify the wave without killing it. Thus, in this case only part of the matter (a coherent wave in this example) makes a loop. Depending on the configuration of the full system (including TM, laser, mirrors etc) this part can take all values between 0 and 1.

(5) In papers [4, 7, 13] it was emphasized that the multiplicity of the classical evolutions can be treated as a classical limit of the quantum mechanical approach to the problem. In this case each particular evolution is characterized by some probability that can be calculated according to the rules of quantum mechanics. It is also true for self-consistent solutions with a Jinnee. Moreover, the Jinnee itself can be a quantum system.

This approach (which uses a Feynman sum over all self-consistent trajectories) can result in strong suppression of probabilities of some self-consistent solutions. For example, it could happen that the probability of a process with a 'complex Jinnee' is practically zero in processes with 'simple' external objects, but such a Jinnee could arise in the presence of 'rather complicated' external objects; or another example: the probability of appearance of a Jinnee interacting with external objects far from TM could differ from the probability of appearance of a Jinnee interacting with the systems trying to enter TM.

Thus, whether solutions like a 'clever spacecraft' or 'solving problems ltd' are practically possible depends on a quantum-mechanical treatment of the problem. We will consider quantum mechanical aspects of the problem in a separate paper.

Acknowledgment

The authors are grateful to Chris Pethick and Eleonora Kotok for help.

References

[1] Morris M S, Thorne K S and Yurtsever U 1988 *Phys. Rev. Lett.* **61** 1446
[2] Novikov I D 1989 *Sov. Phys. – JETP* **68** 439
[3] Frolov V P and Novikov I D 1990 *Phys. Rev.* D **42** 1057
[4] Friedman J, Morris M S, Novikov I D, Echeverria F, Klinkhammer G, Thorne K S and Yurtsever U 1990 *Phys. Rev.* D **42** 1915
[5] Hawking S W 1991 *Preprint DAMPT R91 15*
[6] Frolov V P 1991 *Phys. Rev.* D **43** 3878
Yurtsever U 1990 *Class. Quantum Grav.* **7** L251; 1991 *Class. Quantum Grav.* **8** 1127; 1991 *Phys. Rev.* D **44** 403
Klinkhammer G 1991 *Phys. Rev.* D **43** 2542
Cutler C 1992 *Phys. Rev.* D **45** 487
Gott J R 1991 *Phys. Rev. Lett.* **66** 1126
Kim S-W 1991 *Preprint SNUTP 91-49*
Deser S, Jackiw R and 't Hooft G 1992 *Phys. Rev. Lett.* **68** 267
Carrol S M, Guth A H and Farhi E H 1992 *Phys. Rev. Lett.* **68** 263 (see also the erratum in *Phys. Rev. Lett.* **68** 3368)
't Hooft G 1992 *Class. Quantum Grav.* **9** 1335
[7] Kim S-W and Thorne K S 1991 *Phys. Rev.* D **43** 3929
[8] Thorne K S 1991 *Preprint Caltech GRP-251*
[9] Novikov I D 1983 *Evolution of the Universe* p 169 (Cambridge: Cambridge University Press)
Zel'dovich Ya B and Novikov I D 1975 *Stroenie i Evolutsia Vselennoi* p 679 (in Russian) (Nauka: Moscow)
[10] Novikov I D and Frolov V P 1989 *Physics of Black Holes* (Dordrecht: Kluwer)
[11] Echeverria F, Klinkhammer G and Thorne K S 1991 *Phys. Rev.* D **44** 1077
[12] Polchinski J, letter to K S Thorne, unpublished
[13] Friedman J L unpublished
[14] Novikov I D 1992 *Phys. Rev.* D **45** 1989