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The relativistic inertial coordinate reference frames, synchronized the observed radio emission of pulsar

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Abstract. We obtain the es – as series of simultaneous and joint rotational motions of the planets. Copernicus (1473-1543 analytical coordinate-independent pulsar time scales, which are determined by the observed rotation parameters of pulsar. The scales extent into barycentric and any topocentric coordinate systems, providing simultaneity of the observed physical phenomena, including the periodic radiation of a pulsar as well, in any point of the three-dimensional space.

1. Introduction
For many centuries astronomers have studied the movement of the planets and the Sun, enjoyed the coordinate system associated with the Earth, which seems to be immovable and is considered then as the center of the world. Thus, the visible movements of the planets, Ptolemy (II century a new era) in this system is described in the form of epicyclic (II century a new era) has given its significantly different from the description of the Solar System, considered the same motion of the planets in the coordinate system associated with the Sun. Since that time, began the development of a common planetary theory, the contents of which were both analytical and numerical solutions of the tasks of the movement of celestial bodies with mathematical methods of celestia mechanics, based on the postulates of absolute time, absolute space, the laws of Newtonian mechanics and Newton's law of gravitation.
However, the difficulties that began in middle of the 19th century, led to the crisis of Newtonian physics in the early 20th century, when trying to explain the experimental data in the field of optics and electrodynamics of moving bodies. The crisis has stimulated the emergence of the theory of relativity, the special (SRT) by 1905 and general (GRT), formulated by Einstein in 1916 publication. Later relativistic celestial mechanics developed mainly on the principles of general relativity, expressed by the equations of the gravitational field, which in any reference frame are written the same way. Unlike the metric of SRT, in which the mathematical coordinates in a flat (no curvature) Euclidean space inertial systems are a Galilean, and have a physical meaning of time and the three spatial coordinates, in the Riemannian metric of GRT the properties of space and time in the form of event space metrics, are determined by the motion and distribution of mass, the movement and distribution of mass, in turn, are determined by the metric of field. Galilean coordinates in the GRT does not exist, and space of events under the influence of gravitating masses in different coordinate systems look as different. The mathematical relationship which are carried out in any space of events in the SRT, in space of events in the SRT are satisfied only within infinitesimal vicinities of the selected point defined by its coordinates. This means that the principle of equivalence flowing of all the physical processes that apply to any inertial system in the space of events in the SRT, in the space
of events in the GRT is valid only locally. Therefore, the solutions of the equations in the space of events in the GRT inevitably differ from each other in different coordinate systems, and, therefore, no GRT coordinates for finite (not infinitesimal) regions of space-time have no physical meaning and, in such a way, can not be compared with observational data [1]. In the special theory of relativity, as in Newtonian mechanics, this problem of comparison the observational and theoretical data does not exist, since the use of inertial coordinate systems from the beginning as a baseline, or go to him in the final stage of processing observational data obtained in RGR coordinates, automatically gives a solution to the equations of time-space directly in terms of the measured quantities.

The paper focuses on the interconnection of the metric of space-time relations in different coordinate reference systems, both dynamic and kinematic ones. A comparison of mathematical ephemeris time scales obtained in the form of a numerical solution of the movements of celestial bodies, and physical pulsar time scales expressed analytically as the intervals of the observed events of the periodic radio emission from galactic sources – pulsars, is done. Synchronize on the periodic emission of pulsar gives the inertial properties of the coordinate reference frames and, as a consequence, leads to metric compatibility and physical equivalence of the measuring and data processing in the relativistic positional astronomy, regardless of the initial choice of coordinate systems.

2. The hierarchy of the relativistic coordinate reference systems

In positional astronomy of space-time, it is important and takes into account the whole set of observational data obtained by different observers at different times. For further processing of this set essential theoretical results related both to the movement of celestial bodies (dynamic task), and the propagation of light (kinematic task). It is important that both of these tasks are solved at the same coordinates. Coordinate method in the relativistic celestial mechanics is implemented using four-dimensional coordinate system (CS) - three spatial coordinates and coordinate time scale. Although the framework of general relativity all the CS equivalent, to solve a specific problem, there are astronomical more preferred or less preferred CS. For example, if from the barycentric CS with the beginning of the spatial axes in the center of mass of the Solar System go to the relativistic geocentric CS with the beginning of the spatial axes in the center of mass of the Earth, where the main attracting body is the Earth, while the effect of all other heavenly bodies (Sun, Moon, planets) appears only in the form of tidal forces, so the contribution of the relativistic components is two orders of less [1].

Earth parameters, which are determined by the ratio \( V^2 / c^2 \) (non-spherical shape of the Earth, Earth's angular velocity, etc.), in the geocentric CS are closer to the measured values than in the barycentric CS. The fourth coordinate such relativistic systems is the scale of the corresponding coordinate time (barycentric, geocentric, topocentric time), which is an argument in relevant theories of motion or rotation of celestial bodies.

Practical implementation of the coordinate systems in astronomy attained by setting the coordinate values of the reference celestial objects. Thus, the coordinate system as a mathematical construct is transformed into meaningful astronomical reference frames (RF). The modern positional astronomy holds a permanent work to maintain the International Celestial Reference Frame (ICRF) and the International Terrestrial Reference Frame (ITRF). The ICRF is defined by the provisions of the quasars in the International Celestial Reference System (ICRS), which is a particular barycentric RF. The ITRF is defined by the provisions of ground reference stations in the International Terrestrial Reference System (ITRS), which is a rotating with the Earth geocentric RF. The relationship of these systems, on the one hand, is given theoretically by solutions relativistic equations of motion the celestial bodies and the Earth's rotation, and on the other hand, is determined from observations.

A special place in the hierarchy takes topocentric coordinate system, the beginning of which, unlike the geocentric system, can be selected at any observation point on Earth's surface, approximated as the geoid, which is associated with the system of astronomical coordinates, or ellipsoid, connects with the system of geodetic coordinates. On average, both approximations are almost identical, but in some areas of the surface differences can be substantial. Therefore geodetic methods on the surface built a network of local reference ellipsoids, which are tied to the topocentric coordinate reference system.
according to the average terrestrial ellipsoid. With the help of these coordinates is given by the mutual position of the observation points.

Thus, the topocentric system, the beginning of which, coinciding with the location of the observer in the phase center of the radio telescope, has the absolute physical significance as for the primary observational data based on direct measurements, as well as to check the consistency of reference coordinate systems on physical criteria in the framework of existing theories and models (ephemeris calculations and monitoring, conservation laws, etc.).

Reference coordinates systems are built so that they adhered to the principle of equivalence, mathematically it means that in such systems, all physical processes and phenomena occur equally and physical equations have the same form, that is, all reference systems should be equal, and observed them in the same conditions of physical phenomena and processes are indistinguishable. Such reference systems are inertial.

In contrast to the inertial coordinate Newtonian mechanics and SRT, the GRT coordinates for the finite (not infinitesimal) space of events have no physical meaning and cannot be directly compared with observational data. Therefore, the problem of comparing of the measured and calculated values becomes methodologically important and physically essential task of the modern relativistic astronomy.

The basis of the choice of coordinate methods for constructing theories of the motion of celestial bodies in GRT puts the mathematical approach, taking into account the convenience of the various coordinates for purely mathematical solving of dynamic task, adopted, for example, in the calculation of the coordinates in the equations of planetary ephemeris of the Solar System [2]. The subsequent transition from ephemeris coordinates to the coordinate-independent physically measured values is achieved by combination of solutions of the dynamic task (the motion of bodies) and the kinematic task (propagation of light) in the same coordinates [1]. To comply with the principle of equivalence is only important that both tasks have to be solved in the same coordinates.

3. Relativistic time scales

The fourth coordinate of a relative reference frame is a coordinate time scale, which is the mathematical argument in the appropriate theories of the motion or rotation of celestial bodies in the Solar System. In the article [3], the basic principles of constructing a self-consistent relativistic theory of time scales in the Solar System on the basis of the hierarchy of dynamical nonrotating reference systems of the General Theory of Relativity (GRT), is described. In accordance with this approach, the barycentric dynamic time (TDB) at a fixed point – the center of mass of the Solar System, and the terrestrial Earth's time (TT) are considered as the coordinate time of the barycentric (BRS) and geocentric (GRS) reference system, respectively.

The problem of physical realization of the fourth coordinate – time is caused by the fact that the variable of time in the equations of motion of General relativity theory is just a mathematical argument and is not an observable and directly measurable quantity that can be directly compared with the calculated values. The physical realization of TT is tied to the International Atomic Time (TAI), which is the result of averaging the readings of atomic clocks distributed over the Earth's surface and synchronized with TT. TAI transfer outside the Earth's surface can be performed within any three-dimensional hypersurface under the condition $TT = const$. The unit of measurement TT, defined by the TAI scale, is the same as the unit of measurement TDB and is equal to the second SI. The ephemeris Earth's time TT, which is the argument of the time of geocentric ephemerides, is reduced to the ephemeris scale of the TDB, which is the argument of heliocentric ephemeris, whose unit is also the SI second [2] of the TAI atomic time.

The relationship between TAI and TT in the form $TT = TAI + 32,184 \text{ s}$, refers to the geocentre, the point at which the averaged result of the readings of atomic clocks distributed over the real Earth's surface is localized. For a given unit of time, the scale TDB differs from the TT scale (TAI) only by relativistic nonlinear and periodic components resulting from the theories of the motion of the Earth, planets and the Moon. The proper time $\tau_0$ of the observer in any point on the Earth's surface coincides
with the coordinate time $\tau$ of the corresponding topocentric reference system (TRS), estimated at its beginning. The time $\tau_0$ is associated with the TT (TAI) relativistic transformation, including the GRS observer speed, its height above the geoid and the quadrupole tidal gravitational potential of the outer masses. This involves visualizing ideal clocks on the Earth's surface, the TAI of which extends within the hypersurface $TT = const$ and is synchronized with the TT.

It should be noted that this assumption does not explicitly take into account the coordinate topocentric time $\tau$, that is, the observer's proper time, depending on its location on the Earth's surface. For each observer, it is different, whereas ideal atomic clocks that reproduce the standard SI second-on-time cannot by themselves react to the relativism of topocentric coordinate time and, therefore, cannot perform the synchronization function of topocentric time scales in accordance with the principle of simultaneity of events observed in different coordinate systems.

Thus, the development of astronomical time scales is one of the most urgent problems of applied astronomy. This requires improving the quality of theoretical models, including mathematically accurate definitions and physically meaningful interpretations of all quantities involved in time measurements. Given that within the framework of GRT, no coordinates for any finite region of 4-dimensional time-space have no physical meaning and, therefore, cannot be directly compared with observational data, it is necessary to explicitly indicate the corresponding metric form that meets the requirements of direct comparison of measured and calculated values in the coordinate reference frames and formulate the conditions that must be met to construct this form.

The implementation of the principle of simultaneity of observed events, confirmed by the coordinate time scales, corresponds to the synchronise in the inertial systems and, consequently, to the physical equivalence of the observations in any of them.

4. **The principle of simultaneity in the coordinate systems**

In a non-inertial coordinate system, the interval $dt$ is expressed in terms of local physical quantities $dl$ and $d\tau$ as follows: $dl^2 = c^2 d\tau^2 - dl^2$. The physical time determines the course of the physical processes, but the quantity $d\tau$ in the non-inertial coordinate system has a local character, since it is not a complete differential. In this case, there is no single physical time, the lines of which would be orthogonal to the three-dimensional space of the variable $\tau$ [4-5]. Therefore, the concept of simultaneity of events in different points of space loses meaning in non-inertial systems, because synchronization of clocks in different spatial points with the help of physical quantities (light signal) cannot be carried out, since it depends on the signal propagation path. There does not exist a variable $l$, because $dl$ also has a local character. In the non-inertial systems, with necessarily there are the coordinate quantities, which in the space of events of the General relativity theory describe the phenomena with allowance for constraints due to the local nature of mathematical quantities, whether in barycentric or topocentric frames.

In the inertial system in Galilean coordinates, the value $dt$ coincides with the differential $d\tau$, therefore one can introduce a single time $t$ in Minkowski space. It will be physical time. The introduction of simultaneity for all points of a three-dimensional space is a consequence of the pseudo-Euclidean geometry of the four-dimensional space of events. The field at each point of the Minkowski space, according to the local characteristics of the $dl$ and $d\tau$, has a velocity equal to the electrodynamic constant: $dl / dt = c$. From this follows the axiom formulated by G.Minkovsky thus: “A substance located at any world point, always, with a proper definition of space and time can be considered as being at rest. The axiom expresses the idea that at every world point the algebraic sum of squares $c^2 dt^2 - dx^2 - dy^2 - dz^2$ is always positive or, in other words, that any velocity $V$ is less than $c$” (that is, with an appropriate choice of the reference frame in Minkowski space [4]).

It is necessary to distinguish coordinate values of physical quantities. The change in coordinate values leads only to a change in the relationship of the physical time with the coordinate values. The conditional agreement on simultaneity always corresponds to a definite choice of the coordinate
system in the inertial reference frame of the Minkowski space. In the inertial frame of reference, the physical values of time and distance do not depend on the choice of the agreement on simultaneity. Thus, the conditional agreement on simultaneity is nothing more than a definite choice of a coordinate system in the inertial reference frame of the Minkowski space. In this space, in the inertial system in Galilean coordinates there exists a single physical time $t$, the lines of which are orthogonal to the three-dimensional space; we can speak of a constant speed of light that is the same in all directions and coincides in magnitude with the electrodynamic constant $c$ [4].

5. Determination of the observer's proper time by the radio emission of a pulsar

The time in the coordinate reference system is determined by the local time scale. As a result of transition from one coordinate system to another, the time of the same event changes. Lorentz defined the coordinate transformations for inertial systems in such a way that the physical equations of the observable processes with respect to these transformations remained invariant. He found such relationship of coordinates and changed local time for which the condition of simultaneity in all systems under such coordinate transformations is satisfied on all points of space, and this modified local time is the observer's proper physical time. This time, being relativistic, reflects the position, the speed of the observer's movement and the time of light propagation into different points of space. For each observer it is different.

The ephemeris coordinates time $TCB$ and $TCG$, expressed by the arguments in the mathematical equations of the motion of the Sun and the rotating Earth, refers to the unobserved computed points of the barycenter and geocenter, respectively, which are inaccessible to direct measurements and comparison. Meanwhile, direct observation with the help of a radio telescope, taking into account the geographical location of the observation point, can be measured the observer's proper time $\tau$, which coincides with the coordinate time $\tau$ of the corresponding topocentric reference system (TRS) estimated at its beginning. This involves visualizing ideal clocks within the Earth's surface, the TAI readings of which are synchronized with the observer's proper time.

Using the equation of motion of celestial bodies of the planetary theory VSOP87, including the transformation of the BRS–GRS dynamic coordinate systems, including the coordinate time transformation $TCB$–$TCG$–$\tau$, one can determine the observer's own time, designated as the $\tau$–$TCG$ difference in dynamic coordinate systems. These measurements allow estimating the relativistic effects related to the reference systems and time scales. This approach, based on the difference measurements of the coordinate time, was applied in VLBI measurements of pulsar coordinates (Fomalont, 1984) [8], and later S. Kopeikin (1990) [9] within the framework of this problem, the difference between pulsar time at two different points observations of the pulsar with terrestrial radio telescopes. Reduction of the VLBI measurements of the pulsar coordinates to the form of the difference of the topocentric time $\tau_2 - \tau_1$ was performed by solving the dynamic task of General relativity in the pulsar reference system (PRS) for two points on the Earth's surface. To calculate the difference, the initial data necessary for such a task were taken, including the first and the second antenna coordinates in the GRS, the barycentric velocity of the Earth, velocity of the second radio telescope, Geopotential and Solar System's gravitational potential excluding the Earth, a relativistic correction for different time rates between observer clocks caused by distinct geographical positions of the radio telescopes.

It should be noted that in this task the time of propagation of an electromagnetic signal from a galactic source to the different points on Earth's surface is defined in a form of the solution of a dynamic equation of GRT, without involving of the Lorentz transformations.

Thus, the coordinate time measured from the observed pulsar pulse at the radio telescope at one point can be transformed into any other point with given local geodetic coordinates. By the difference $\tau_2 - \tau_1$ of the same pulse of pulsar radiation observed in two different topocentric points, the coordinated values of the coordinate time of these ground stations are found, having, as will be shown below, the physical meaning of the observer's proper time in these points.
6. **Synchronization of coordinate reference systems on the observed periodic pulsar radiation**

By observations of a pulsar on the radio telescope, the topocentric time $t_{TRS}$ of arrival of the radiation pulse in a point of the Earth's surface with the geodetic coordinates of the radio telescope, is measured. By solution of the dynamic task of motion of celestial bodies, the observed topocentric time $t_{TRS}$ is reduced to the ephemeris barycentric time $t_{BRS}$, taking into account the relativism of the observer's proper time on the radio telescope [9]. Figure 1a shows the difference $t_{TRS} - t_{BRS}$ from observations of the pulsar J1509 + 5531 on the phased array radio telescope BSA LPI (Pushchino). Here, the coordinate topocentric and barycentric pulsar time, which in both these non-inertial reference frames are defined as the solution of the dynamic task, refers only to two local points of space. The principle of simultaneity for them is not valid initially, in contrast to the inertial reference frames.

![Figure 1. The difference in the observed time (a) and the convergence of the pulsar time (b) of the pulsar J1509 + 5531.](image)

**Figure 1.** The difference in the observed time (a) and the convergence of the pulsar time (b) of the pulsar J1509 + 5531.

a) the difference of the topocentric and the barycentric time (non-inertial frame), b) the convergence of the pulsar time (inertial frame).

Meanwhile, the observed pulsed radio emission of a neutron star detects a strict periodicity of the pulses, which is generated due to the losses of the rotational energy of the star with a monotonous deceleration. The slowdown is shown in the gradual increase of the observed rotation period $P$, which is completely determined by its derivatives $\dot{P}$, $\ddot{P}$, and is detected in the measured intervals $PT_{obs}$ of the observed pulses, counted from some pre-selected pulse that fixes the initial observation epoch. It is shown [10] that for any initial epoch there exists the combination of numerical values of the rotation parameters $P_0$, $\dot{P}$, $\ddot{P}$, unique for each pulsar, such that the observed intervals $PT_{obs}$ represent the convergent power series which are expressed by the analytical function of the observed rotation parameters of pulsar.

The equation of the observed on the radio telescope intervals $PT_i$, written in the form of the convergent power series, is followed:

$$PT_i = (1 + \alpha_i) (P_i^0 N + \frac{1}{2} P_i^0 \dot{P} N^2 + \frac{1}{6} (P_i^0 \ddot{P} - 2 P_i^0 \dot{P}^2) N^3).$$  \hspace{1cm} (1)

Here are: $PT_i$ are the numerical values of the observed intervals coordinated with planetary ephemeris; $P_0$, $\dot{P}$, $\ddot{P}$ are the pulsar rotation parameters obtained by solving of the equation (1); $\alpha_i$ is divergence of the series of the $PT_i$. By the parametric approximation of the observed intervals $PT_i$, the consistency numerical values of the period $P_0$, for the initial epoch and its derivatives $\dot{P}$, $\ddot{P}$, are determined. The rotation period $P(t)$ within any duration of observations is calculated as follows:

$$P(t) = P_0 + \dot{P}_0 \cdot t + \frac{1}{2} \ddot{P} \cdot t^2.$$  \hspace{1cm} (2)

Equation (1) expresses the relationship between the observed intervals $PT_{obs}$ and the calculated intervals of periodic pulsar radiation in any coordinate reference system.
7. Extension of the synchronous pulsar time scales into Geo-cosmic coordinate systems

In order to obtain a physical pulsar time at any point with given geographic coordinates, it is sufficient to extend the topocentric PT scale obtained analytically from observations of a pulsar on a radio telescope from the observation point to this ground point. By analogy with the VLBI measurement of the difference $\tau_2 - \tau_1$ of the coordinate time in the pulsar reference system (PRS) for two spaced points on the Earth's surface, there were calculated the differences for three spaced points, one of which ($\tau_1$) coincides with the phase center of the BSA FIAN radio telescope (Pushchino), and the other two ones were determined by the flat coordinates of arbitrarily chosen points on the surface of the Earth, one in the north, and the other in the east direction of the radio telescope. For these two points, the coordinate time was calculated from the equations of motion of celestial bodies and the rotation of the Earth in the framework of the solution of the dynamic task of the GRT with subsequent approximation in the observed parameters of the rotation of the pulsar by solving the kinematic task within of the SRT.

This numerical experiment on the propagation of pulsar time scales into two points distant from the radio telescope, taken as a test case. It was carried out in 2015 with the active encouragement and kind assistance of the Laboratory of Ephemeris Astronomy of the IPA RAS (Prof. E. Pitjeva, Dr. D. Pavlov). For coordinate calculations, a specialized ERA software package, developed by the IPA RAS [11], was used.

The graphs in Figure 2 illustrates the results of a comparison of the physical coordinate time at the selected geodetic points calculated in inertial reference frames from the observed parameters of the rotation of the pulsar J1509+5531 in approximately three years of observations at the BSA FIAN (Pushchino). Barycentric TD (TDB) and topocentric TT coordinate pulsar time intervals are calculated from the observed parameters of rotation of the pulsar, consistent within any chosen extention, the same in any coordinate system for coinciding epochs of local coordinate time. The intervals are measured from the epoch of the initial observable event MJD 55960.1561 (TB) and MJD 55960.1542 (TT) they are obtained by the formula (2), which follows from equation (1). Solutions of equation (1) are fixed rotation parameters of pulsar, their values are shown under the graphs of the Figure 2. Both analytical scales TT and TB are expressed in the absolute calculus of intervals from the initial event with subnanosecond resolution. Graphs (b, c) show the differences of topocentric pulsar scales for three geodetic points, including two points distant from Pushchino, for which the TT scales were calculated with respect to the topocentric Pushchino pulsar scale for the same rotation parameters.
Figure 2. Comparison of physical coordinate time on the geodetic points.

a) Pushchino (1): 54°50'00"N; 37°37'00"E (BSA LPI); $P_0(\text{TRS}) = 0.739684538225754$ s (MJD 55960.1542); $P_0(\text{BRS}) = 0.739684538226603$ s (MJD 55960.1561); $\dot{P} = 4.99821 \cdot 10^{-15}$; $\ddot{P} = 9.821177 \cdot 10^{-29}$ s$^{-2}$;

b) North point (2): 62°57'36"N; 40°41'00"E; $P_0(\text{TT}) = 0.739684538225754$ s (MJD 55960.1542);

c) East point (3): 51°52'37"N; 128°20'47"E; $P_0(\text{TT}) = 0.739684538225754$ s (MJD 55960.1542).

Comparison of the coordinate time based on the pulsar scales, shows their parametric and numerical consistency. The condition for the convergence of analytic pulsar scales, expressed by a polynomial power series (1), is satisfied by a single combination of rotation parameters $P_0$, $\dot{P}$, $\ddot{P}$. It can be seen that TT and TB scales, which differ by hundreds of seconds due to the Earth's orbital motion, show significant differences between $P_0(\text{TT})$ and $P_0(\text{BT})$ in smaller decimal signs (in the Figure 2 it is allocated with a boldface type). However, at ground stations where the current coordinate differences of topocentric scales is only about 1 μs or less, the values of the $P_0(\text{TT})$ have no apparent differences at all geodetic points within the required subnanosecond accuracy of the approximation of intervals set by the quantity of decimal signs in a numerical format of the period. It indicates the parametrical and the numerical consistency of topocentric pulsar scales in any geodetic points, each of which corresponds to a single barycentric scale.

8. Conclusion

The relationship of spatial coordinates and time scales in different coordinate frames, both dynamic and kinematic, is considered. Metric compliance of mathematical ephemeris time scales in the chosen points of space and physical time scales obtained by the approximation of observed intervals of a periodic radio emission of pulsars in inertial systems with the coordinate beginning in the same points of space, is shown. Analytic coordinate–independent pulsar time scales extent unchanged to any topocentric coordinates system with a center given by three locally geodetic coordinates on the geoid. This proves that the periodic radiation from the galactic source of the pulsar determines the "true" physical time of any inertial system within the Solar system, which is determined by the form-invariant equations and localized in the form of time scales in any kinematic inertial system satisfying to coordinate transformations of Lorentz. In this case, all coordinate systems are equal. In each such system, there is a single physical time $t$, the lines of which are orthogonal to the three-dimensional space, and the time scale corresponds to the same conditions for observing the motion of celestial
bodies, in particular, the rotation of pulsars, and, consequently, the simultaneity for all points of the three-dimensional space.

The extension of the physical pulsar time scales into inertial coordinate systems confirms, firstly, the homogeneity of time, which means the same flowing of physical phenomena (under the same conditions) at different times of their observation and, as a consequence, the compliance of the law of conservation of energy. Secondly, it means the isotropy of space, that is the same properties of space at each point in all directions: the physical processes do not change when the coordinate axes rotate through the space to any angle and, as a consequence, the compliance of the law of conservation of the angular momentum (the pulsar as well).

Analytic pulsar scales TB and TT in barycentric and topocentric coordinate systems, synthesized on the radio telescope BSA FIAN in Pushchino from the observed rotation parameters of pulsar, reach of machine accuracy and subnanosecond resolution of the intervals, which are the same in any coordinate system for coinciding epochs of local coordinate time. The relative instability of pulsar scales, which are defined by the coherence periodic radio emission of pulsar, does not exceed $10^{-20} - 10^{-21}$ within the near 50-year long extension of the observations of pulsars.

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