Pulsar: physical generalization of the galactic time-space

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Abstract. The article considers a complex of geometric representations of space-time, based on general dynamic theories of celestial mechanics in close connection with pulsar astrometry as the physical basis of coordinate-time transformations within the solar system and galactic space as a whole. The pulsar time scale is considered as a certain material system with continuous and stable motion, representing a certain measurable parameter – the rotation period *P*, which changes as a function of the independent time variable – its derivative. The physical pulsar scale is a sequence of measured daily increments of the initial radiation period within any duration. According to observations at the BSA radio telescope (Pushchino) of the pulsar B0950+08, the time scale was determined with an initial period of P_0=0.2530653211840410 s on the date MJD_0 = 58971 (02.05.2020; 21h.58m.07s). A measured daily increment △P = 1.4441·10E-11 s corresponds to the measured value of the derivative P = 1.6759949886E-16, which is determined by the observational timing data. Measured △P are defined in the 25th decimal place. Up to 14-15 digits, △ P there is a pulsar time scale with femtosecond resolution. From 15-16 to 25 digits △ P is presumably sequential fixation of discrete states of microparticles during quantum-mechanical interactions of matter and electromagnetic radiation of a pulsar. According to our hypothesis, the diversity of the material world and physical processes occurring in celestial and quantum mechanics are finite and it can be generalized. This implies the inseparable unity of physical laws in four-dimensional space of celestial and quantum mechanics, detectable on pulsar time scales under the same conditions.

1. Introduction

From a geometric point of view, the theory of space and time has historically developed in two directions: as a theory of homogeneous (Galilean) space and as a theory of inhomogeneous (Riemannian) space based on Einstein's theory of gravitation. The uniformity of Galilean space and time is determined by the group of transformations of the four-dimensional interval, the form of which is directly related to the form of the basic laws of physics, namely the law of motion of a free material point and the law of propagation of a light (electromagnetic) wave in free space.

The mathematical theory of gravitation, on the contrary, allows the uncertainty of the time-space metric and, as a consequence, the ambiguity of solutions. Fock [1,3], considering both theories as a whole, proved the existence of the necessary unambiguous solution of the equations of gravitation by imposing additional conditions compatible with them (1955). However, the law of transformation of physical quantities must be determined by the Lorentz transformation by the condition of preserving the form of general equations in the transition from one frame of reference to another. Fock proved that in an isolated mass system, similar to the solar system, there is a class of harmonic coordinate systems that are very close in their properties to the Galilean coordinates, also related to each other by the Lorentz transformation. In particular, the currently used time scales in modern ephemeris astronomy are defined in harmonic coordinates [9].

Historically, the possibility of establishing the basic physical laws of the motion of bodies in celestial mechanics arose much earlier, even at a time when observational astronomy had only direct visual methods. As Abalakin notes in his fundamental publication “O.V. Struve – G.V. Schiaparelli. Correspondence 1859-1904 (St. Petersburg, “NAUKA”, 2005)”, in the process of development of world astronomical science two directors of the Nikolaev Main Astronomical Observatory in Pulkovo and the Royal Astronomical Observatory of Brera in Milan - academicians O.V Struve (1819-1905) and G. V. Schiaparelli (1835-1910) united close attention to one of the remarkable classes of celestial objects - to binary and multiple star systems.

This attention and interest were combined in them with the art of observation and a deep scientific and theoretical approach, which allowed everyone to skillfully use their own series of observations of the position of stars to accurately derive the parameters of the orbits of the components of multiple stellar systems. Even earlier, Kepler (1571-1630) was the first to formulate the laws of motion of the planets of the solar system in the form of kinematic solutions of the equations of their elliptical orbits. The shape of the ellipse and the position of the planets in orbits directly follows from the physical laws of Newton. This unity of Kepler's kinematic laws and Newton's dynamical laws reveals their exhaustive completeness and sufficiency as applied to celestial mechanics as a whole.

The further development of celestial mechanics, on the general dynamic theories of which ephemeris astronomy is based, is associated with the practical establishment of space-time coordinate systems representing certain approximations to an ideal inertial reference frame. The requirements for the time scale in such a frame of reference were formulated by Abalakin [4] as follows. The time scale in ephemeris astronomy is considered as a certain material system with continuous and stable motion and representing a certain measurable parameter P, which changes with time as a function of the independent variable of time t.

It is precisely such a measurable parameter that satisfies these requirements is the period of rotation and, accordingly, the period of the electromagnetic radiation of a pulsar - a neutron star rotating with a gradual deceleration determined by the constant value of the derivative of the period. The values of the pulsar emission period measured from observations at the BSA radio telescope in Pushchino are used as the basis for the ephemeris coordinate pulsar time scales, which are uniquely related by the four-dimensional Lorentz transformation.

The paper considers the physical features and metric properties of the coordinate pulsar time scales according to the observational data on the timing of the pulsar B0850+08. The complete correspondence of physical pulsar and calculated ephemeris time scales of the solar system, satisfying the conditions of coordinate transformations and axiomatic transfer of coordinate time scales along a fixed origin within any duration, is shown.

By analogy with the solar second, canceled in 1967, a new definition of the pulsar second was given as a time interval consisting of a countable number of periods of radiation of the pulsar B0850+08 at a geodetic point with the coordinates of the BSA radio telescope for a specified date and time. The definition of the pulsar second equally applies both to the calculated ephemeris time and to the physical coordinate time in inertial systems, being a necessary condition for the simultaneity of physical processes occurring in any of them.

2. Parametric approximation of pulsar time scales

The monotonic deceleration of the rotation of the pulsar with a constant derivative of the period is fully consistent with the requirements of the time scale, which were formulated in ephemeris astronomy. The time scale is considered as any material system with continuous and stable motion and representing a certain measurable parameter P, changing as a function of the independent variable of time.

For an objective perception of time in space, the measurement of time in astronomy is based on the time scale, defined as outlined in [4]:

1) some material system with a continuous and stable movement and representing a certain measurable parameter P, changing with time;

2) a theory giving the values of this parameter P in a function of the independent variable t, called as time. The function $P = f(t)$ should be unambiguous and allow for the distinction between its particular values. Then the time it can be expressed in terms of the measured values of the determining parameter P in the form $t = \varphi(P)$. The scale, thus determined makes it possible to order events in the sense of "earlier" or "later" with respect to a certain time t_0, depending on whether there is $t_0 > t$ or $t_0 < t$, if it is the point in time at which the events occurred. Thus, when measuring time, it is necessary to strictly distinguish the point in time (or the epoch of the event) from the time interval (or time scale interval).

Pulsar time scales PT are defined as functions of the rotation period P and its derivatives $\dot{P}$, $\ddot{P}$ in the spatial coordinate reference systems adopted in the solar system: topocentric (TT) and barycentric (TB). Each of them is a digital series of intervals obtained by integrating the observed rotation period $P(t)$ determined for each date within the selected observation interval:

$$PT_{i,j} = \frac{1}{P_0^*}\int_{t_i}^{t_j} P(t)\,dt \,. \tag{1}$$

The period $P(t)$ within the observation interval is determined by the initial value P_0^* and derivatives $\dot{P}$, $\ddot{P}$:

$$P(t) = P_0^* + \left(\dot{P}\cdot t + \frac{1}{2}\ddot{P}\cdot t^2\right); \quad -\infty < t < +\infty \;. \tag{2}$$

Our studies [11] of the nature of the physical process of slowing down the rotation of pulsars based on the results of measuring the derivatives and the generalized braking index showed that its numerical values are in the range $n = -(0{,}9 \pm 0{,}2)$, that is, they are grouped near a negative unit with about near – 0,9 mean values.

So, the analytical model of pulsar time scales determines the unique consistent values P_0^*, $\dot{P}$, $\ddot{P}$, corresponding to the coherence of periodic radiation of pulsar, with the time of arrivals (ToAs) of the observed pulses only. Random variations of ToAs due to imprecise knowledge of physical variables and unmodelled noise of observations, have no significant impact on the modelled intervals of coherent periodic radiation of pulsar, which are identified with a machine accuracy and sub-nanosecond resolution by the consistent rotation parameters of the pulsar.

As a result of dividing the observed intervals, the random variations are not contained detectable rotation components. They can be analyzed additionally to identify with affecting factors, for example, the distortion of an atomic time scale of the radio telescope, for possible physical interpretation. It is assumed also, that the pulsar rotation parameters are independent of any physical factors, which are involved in a parametrical fitting [12].

Since both derivatives determine practically the same deceleration index for all pulsars, and the numerical value of the second derivatives (10^{-31}–10^{-23}) s^{-1} is many orders of magnitude less than the first ones (10^{-16}–10^{-13}) $s \cdot s^{-1}$, then in practical calculations of the pulsar scales in expression (2) we will take into account only the first derivative:

$$P(t) = P_0^* + \dot{P}\cdot t\,; \quad -\infty < t < +\infty\,. \tag{3}$$

Thus, we have two mutually agreed definitions of the time scale: a) traditional – for an integrated scale, in accordance with expression (1) – as a sequence of intervals of a certain duration, counted from a certain beginning within any duration, and b) – for a differential time scale, in accordance with the definition of Abalakin [4] for the ephemeris time scale.

The differential pulsar time scale is expressed as a sequence of measured daily increments ΔP_i of the initial period of the pulsar emission:

$$P_i = P_0^* \pm \Delta P_i \ ; \quad -\infty < i < +\infty . \tag{4}$$

Considering that all daily increments ΔP_i are the same and equal to ΔP, the value of the period P_k for any date can be calculated from the fixed difference *k* of the initial MJD_0 and the selected MJD_k dates for the observation epoch:

$$P_k = P_0^* \pm k \cdot \Delta P \ ; \quad -\infty < k < +\infty$$

$$k = MJD_0 - MJD_k . \tag{5}$$

Thus, we have determined the physical time scale, the requirements for which in ephemeris astronomy were formulated by Abalakin. The observed parameter *P* is the rotation period of the pulsar, which monotonically increases as a function of the independent variable of time.

3. Physical generalization of the proper time of an observer on a geoid

The coordinate time TCB in the BRS reference frame and the TCG coordinate time in the GRS reference frame refer to unobservable points of the barycenter and geocenter, respectively, and are expressed by arguments in the mathematical equations of the motion of the Sun and the rotating Earth [4]. Meanwhile, by direct observation with a radio telescope, taking into account the geographic location of the observation point, the observer's own time τ can be measured, which coincides with the coordinate time τ of the corresponding topocentric reference system (TRS), estimated at its origin on the geoid.

The relationship between TAI and TT in the form TT = TAI + 32,184 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 of the observer in any point on the Earth's surface coincides with the coordinate time τ of the corresponding topocentric reference system (TRS), estimated at its beginning. The time 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 τ, 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 can not 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 [13].

Fomalont (1984) [5], and later Kopejkin (1990) [6], by the VLBI method measured the difference τ–TCG, thereby determining the observer's own physical time in dynamic coordinate systems on the geoid. All values prescribed by general relativity with all the necessary accuracy provided by the theory of general relativity at a fixed point were taken as the initial ones for calculating the difference. As a result, a picosecond measurement accuracy is achieved, which is inherent in the observed object - a pulsar.

Now we will logically continue these measurements by successive movements of the second VLBI radio telescope point by point along any arbitrary closed geodetic line. The set of measured differences τ –TCG upon returning to the starting point, this difference will coincide with what it would have been at this point, as in the absence of movement of the radio telescope.

Thus, direct VLBI observation of pulsed radio emission from a neutron star, excluding the uncertainty of the gravity factor at fixed observation points, removes the uncertainty of the proper time τ during coordinate transformations at any point in space along a closed geodesic line. This confirms the uniformity of the pulsar time scales in the coordinate systems of the observer.

It is known [1], in the general case, that in a space of 4 dimensions, a group of transformations that leaves the expression for the square of the distance between infinitely close points unchanged can contain no more than 10 parameters. This coincides with the number of parameters in the Lorentz transformation for which the space is maximally homogeneous, like the Galileo space. In such a space (a) all points and moments of time are equal, which corresponds to 4 parameters: three initial coordinates and an initial moment of time; (b) all directions are equal, which corresponds to 3 parameters of rotation of the coordinate axes: three angles; and (c) all inertial systems with translational moving relative to each other are equal, which corresponds to 3 parameters: three components of the relative velocity.

Later, Logunov [2] clarified the signs of homogeneity by assuming an infinite set of inertial systems, in each of which space is orthogonal to time, as a result of which the rotation of the coordinate axes does not affect the coordinate time, which is the same at any point of the inertial coordinate system, coinciding with the time at its origin. It is in such a space-time that all physical processes take place, which under the same conditions in these systems are identical; that is why the laws of conservation of energy-momentum and angular momentum are fulfilled, and all natural standards in all inertial reference frames are the same. Therefore, 3 parameters of rotation of the coordinate axes are excluded from the group of transformations in inertial systems.

In addition, of the three components of the relative velocity, taking into account the remoteness of the source of electromagnetic radiation - the pulsar, only one remains - in the direction to the source along which the velocity is measured.

Thus, out of the possible 10 parameters of a 4-dimensional coordinate transformation, in a homogeneous Galilean space with electromagnetic radiation of a galactic source - a pulsar, only 5 physically significant measurable parameters remain: 3 initial coordinates of the radio telescope (Xo, Yo, Zo), the initial period Po of the coordinate time scale and the speed of the pulsar V towards the radio telescope.

Poincaré's physical theory of relativity, based on Lorentz transformations and extended to all inertial coordinate systems, unambiguously corresponds to the laws of motion of the planets of the Kepler-Newton-Galileo solar system and is fully consistent with homogeneous time-space.

All coordinate systems in which the listed homogeneity criteria are fulfilled are inertial. Physical processes occurring in these systems under the same conditions are identical. The same applies to the process of periodic radiation and propagation of the front of the electromagnetic wave of the pulsar.

This numerical experiment on the propagation of pulsar time scales into two points dist ant from the radio telescope, taken as a test case. For coordinate calculations, a specialized ERA software package, developed by the IPA RAS, was used. The estimated error of modern ephemeris time scales during coordinate transformations is on the order of 1 ns within a secular interval (Pitjeva, 2015) [7].

4. Physical pulsar time scales in the space of the solar system

We will consider pulsar scales as any material system with continuous and stable motion and representing a measurable parameter - the period of rotation P. The value of the period P is expressed as a function of the independent variable of time - the derivative of the period, which, in the process of a gradual deceleration of the pulsar's rotation, remains constant for an unlimited duration of the observations.

We took the daily data on the timing of the pulsar B0950+08 in the topocentric (TT) and barycentric (TB) coordinate systems from observations at the BSA radio telescope in Pushchino during 2020. Pulsar B0950+08 in a supernova remnant (age 1.7·107 years) in the vicinity of the Solar system (distance 0.26 kpc) can be attributed to older stars, the lifetime of which together with the Solar system is estimated to be approximately 4.6 ·109 years, as well as the Sun [10].

The parameters of the time scale of the pulsar B0950 + 08, which correspond to formula (5), are as follows:

$$P_0^* = 0{,}2530653211840410 \text{ s at } MJDo = 58971 \text{ (02.05.2020; 21h.58m.07s)}$$

$$\Delta P = 1{,}4441 \cdot 10^{-11}, \text{ s}$$

$$k = MJD_n - MJDo,$$

hence:

$$P_k = 0{,}2530653211840410 \pm k \cdot 1{,}4441 \cdot 10^{-11}; \quad -\infty < k < +\infty$$

or:

$$P_k = P_0^* \pm 1{,}4441 \cdot 10^{-11} \left(MJDn - MJDo \right).$$

According to the observational data on timing, the translational motion of the pulsar was detected and its velocity was measured in the topocentric (TT) and barycentric (TB) coordinate systems:

$V_{TT}=V_{TB}=0{,}05137\pm2\cdot10^{-5}$ m/s.

Since the speed of movement of the pulsar is constant and small, the movement itself was not detected either in observations with a radio telescope, or, even more so, in barycentric residual deviations, which led to a distortion of the derivative $\dot{P}$ = 2.2915E-16 indicated in the catalog. In fact, the true measured value of the derivative, corresponding to the observational timing data, is $\dot{P}$ = 1.6759949886E-16, or, in the format of the catalog for ephemeris calculations, $\dot{P}$ = 1.676E-16.

Thus, all five measurable parameters: coordinates (Xo, Yo, Zo) of the BSA radio telescope (Pushchino), the period of rotation of the Po pulsar at a fixed observation date, and the velocity V of the pulsar in the radial direction completely determine any coordinate-time transformations within the solar system.

In this case, according to the value of the period Po measured on a fixed date and the constant daily increment of the period, axiomatically, only by the difference between the specified and fixed dates, the value of the period is determined for any date in any coordinate system. Thus, in any inertial system, the beginning of the pulsar time scale is set on the selected date, which operates without change within any duration, both in the past and in the future.

Table 1 shows a fragment of the measurement data from daily observations on the BSA radio telescope (Pushchino) of the daily increments of the rotation period of the pulsar B0950+08 in the topocentric (TT) and barycentric (TB) coordinate systems.

The measured daily period increments △P show the absolute determinism of the pulsar rotation period with a resolution of up to 25 decimal places with a constant derivative of the period $\dot{P}$ = 1.676E-16. In this case, up to the 14-15th decimal place, corresponding to the femtosecond resolution of the pulsar time scale, the daily increments of the period are strictly constant within the entire observation interval. The remaining decimal places, from 14-15th to 25th, are expressed in a countable number of randomly repeating combinations of them. This testifies, according to our hypothesis, that here we are dealing with the quantum-mechanical interaction of a wave of electromagnetic radiation from a pulsar with a matter field, considered in the physics of nonequilibrium processes associated with the self-organization of dissipative structures [14]. The pulsar time scale thus detects these wave interactions and determines their sequence in time, thereby confirming that the pulsar time scales are the same for measuring any processes occurring in galactic space, at any time scale, including quantum mechanical ones.

According to de Broglie's hypothesis, a microparticle moving in regions whose sizes are comparable to the sizes of atoms has wave properties, and these properties cannot be neglected. In this case, the motion of a particle is associated with a change in the time of its mechanical states, and a continuous change of states corresponds to the motion of a particle along a certain trajectory.

Table 1. Measured daily increments of the rotation period of the pulsar B0950 + 0.

MJD	ΔP_TT, s	ΔP_TB, s	N
59108	0,00000000000014441**05945935800**	0,00000000000144161457087030	1
59109	0,0000000000001444111497050930	0,00000000000144178110432400	2
59110	0,0000000000001444111497050930	0,00000000000144178110432400	2
59111	0,0000000000001444111497050930	0,00000000000144178110432400	2
59112	0,0000000000001444111497050930	0,00000000000144183661547530	3
59113	0,00000000000014441**05945935800**	0,00000000000144183661547530	3
59114	0,0000000000001444111497050930	0,00000000000144183661547530	3
59115	0,0000000000001444111497050930	0,00000000000144189212662650	4
59116	0,00000000000014441**05945935800**	0,00000000000144189212662650	4
59117	0,0000000000001444111497050930	0,00000000000144194763777770	5
59118	0,0000000000001444111497050930	0,00000000000144189212662650	4
59119	0,0000000000001444111497050930	0,00000000000144216968238270	6
59120	0,00000000000014441**05945935800**	0,00000000000144189212662650	4
59121	0,0000000000001444111497050930	0,00000000000144200314892900	7
59122	0,0000000000001444111497050930	0,00000000000144211417123140	8
59123	0,0000000000001444111497050930	0,00000000000144183661547530	3
59124	0,0000000000001444111497050930	0,00000000000144205866008020	9
59125	0,0000000000001444111497050930	0,00000000000144211417123140	8
59126	0,0000000000001444111497050930	0,00000000000144211417123140	8
59127	0,00000000000014441**05945935800**	0,00000000000144216968238270	6
59128	0,0000000000001444111497050930	0,00000000000144205866008020	9
	Celestial Mechanics ↑ Quantum Mechanics	Celestial Mechanics ↑ Quantum Mechanics	

Since the Schrödinger equation is invariant under the Lorentz transformations based on Galileo's principle of relativity, this implies the existence of a number of operators of quantum and the existence of quantum mechanical invariants associated with Galileo transformations, similar to the transformations in celestial mechanics.

Thus, the front of a wave of electromagnetic radiation of a pulsar, in the process of interaction with particles with wave properties, on its scale records the change in time their mechanical state, and according to the observed sequence of alternating discrete states, their movement along a certain trajectory is recorded.

Note on the table that the uncertainty of the particle motion along the trajectory, observed when changing mechanical states on the TB scale, is approximately an order of magnitude greater (14th decimal place) than on the TT scale (15th decimal place). This is due to the uncertainty of the TB scale itself, introduced by its post-observational mathematical fit, while the TT scale is determined more strictly from direct physical measurements on a radio telescope. But on the other hand, on the TB scale, we have the opportunity to detect an order of magnitude more mechanical states of a particle than on the TT scale.

Such an unprecedented resonance stability of microparticles on the global effect of external fields is possible, apparently only on a large scale of space. As we are convinced, this is impossible, for example, in the local space of the measuring device of the atomic second. The practice here is that the maximum approximation of the measured second to the reference one, determined during the transition between two hyperfine levels of the ground state of the cesium 133 atom, is achieved only in a short, within a few hours, interval, but later, on a daily or more scale, these values diverge irreversibly.

5. Pulsar analogue of the ephemeris solar second

Ephemeris time, established back in the 19th century on the basis of the theory of planetary motions and their practical applications, refers to the form of classical dynamic time. The unit and the beginning of the ephemeris time T from 1960 to 1967 were determined by adopting a numerical expression for the geometric mean longitude L of the Sun, established by Newcomb [4]:

L=279°41^' 48^",04+129602768″,13 T+1″,089 T^2,

here time T is counted in Julian centuries, consisting of 36,525 days with a duration of 86400 s. The second was defined as 1/86400 of an average solar day, which corresponds to 1/31556 925.9747 part of a tropical year – as the interval during which all seasons change according to the movement of the Sun:

1s = 1/31556 925,9747 = 3,16888E-06 – by astronomical measurements

1s= 1/36525· 86400 = 3,16881E-06 – calculated value by ephemeris.

The relative discrepancy between the measured and calculated seconds is of the order of 10E-05 within a century. This, for comparison, is 3 orders of magnitude less than the estimated divergence of the orbital motions of the planets of the solar system from the resonant calculated Keplerian orbits due to small interactions of perturbations of planets orbiting the Sun and other factors of gravity.

By analogy with the definition of the solar second as a fraction of a tropical year we introduce a new definition of the unit of time the pulsar as the number of periods of the pulsar radiation at a fixed point in space at a given date and ephemeris time (epoch): a pulsar second is a time interval consisting of 3.951 548 933 378 950 periods of the radiation of the pulsar B0950+08 according to observations at the BSA radio telescope of the Pushchino Radio Astronomical Observatory with geodetic coordinates (Xo, Yo, Zo) and an initial value of the period P = 0.253 065 321 184 041 s, measured on the date 02.05.2020; time 16h 36m 25s GMT + 3.

Both definitions - solar and pulsar seconds, based on the motion of stars, have a certain functional continuity. Their fundamental difference is that the periodic radiation of a pulsar determines not only a unit of time - a second, but also highly stable time scales based on it in the entire physically significant, axiomatically transferred to any coordinate system of four-dimensional time-space of the solar system.

Like the previous definition of the second, canceled in 1967, it is also associated with kinematic characteristics, only now not the Sun, but the neutron star - the pulsar B0950+08.

Both definitions of solar and pulsar seconds are based on the kinematics of stars, the ephemerides of which are reliably established in long-term observations, and they have a certain functional continuity. The fundamental difference is that the periodic electromagnetic radiation of a pulsar determines not only a unit of time - a second, but also highly stable time scales based on it in the entire physically significant axiomatically transferred into any coordinate system of four-dimensional time-space of the solar system.

6. Conclusion

According to the observed electromagnetic periodic radiation of a galactic neutron star - a pulsar, the exhaustive completeness and sufficiency of Kepler's kinematic laws and Newton's dynamic laws as applied to celestial mechanics as a whole is manifested. All physical processes, according to A. Poincaré, take place in a homogeneous time-space in the Galilean coordinates of the inertial system. Physical states of the material world are generalized in 4-dimensional homogeneous time-space and are axiomatically transformed in inertial coordinate systems of celestial mechanics.

The study of the dynamics of celestial bodies and astronomical phenomena is directly related to the measurements of periodic pulsar radiation. For an objective perception of time in space, the measurement of time is based on the pulsar time scales PT, associated with a continuous and measurable rotation period P of galactic neutron stars, changing with time, so that pulsar time scales it can be expressed in the form PT = f (P).

Thus, in any inertial system - topocentric and barycentric, the beginning of the pulsar time scale is established on the selected date, acting without change within any duration, both in the past and in the future.

The front of a wave of electromagnetic radiation from a pulsar interacting with microparticles with wave properties, on its scale, records the change in their mechanical state in time, and according to the observed sequence of alternating discrete states, it detects their movement along a certain trajectory.

Hypothesis. The variety of the material world and its physical states in celestial and quantum mechanics is finite and can be generalized under the same conditions. This implies the inseparable unity of physical laws in four-dimensional space of celestial and quantum mechanics, detectable on pulsar time scales.

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