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ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 15, Issue, 10, pp. 13165-13169, October, 2024

RESEARCH ARTICLE

INDETERMINACIES AT THE OBSERVATION

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ARTICLE INFO

Article History:
Received 22nd July, 2024
Received in revised form
14th August, 2024
Accepted 03rd September, 2024
Published online 30th October, 2024

Keywords:

Observer, time of life, distance, passive observation, active observation, micro-indeterminacy, macro-indeterminacy.

ABSTRACT

In the present work, the observation process, connecting the observer with the observed objects, is examined. Criteria limiting the possibility of observation and resulting indeterminacies are defined. Two fundamentally different ways of monitoring are shown - passive and active. Dependencies connecting the observer with the time of life of the objects and the distances between them are derived. A principle of macrouncertainty was formed, according to which the greater the average speed of the observed object, and the greater the distance to it, the greater the inaccuracy of the object's localization.

Citation: Nasko Elektronov. 2024. "Indeterminacies at the Observation", *Asian Journal of Science and Technology*, 15, (10), 13165-13169.

INTRODUCTION

By object we understand any material or field formation from the micro and macro world, having mass and or momentum. We assume that the space is homogeneous and isotropic. All objects are constantly moving and at any moment in time they are at a certain distance from each other. All objects are structured by other smaller objects and exist regardless of whether they are observed or not. Ideally, the observer describes the coordinates, momenta, and other physical quantities for an observable object without affecting it. In the exposition below, we will focus only on the main way of observation - observation with electromagnetic waves. We will not discuss aspects of Einstein's theory of relativity where uniformity of observation in different inertial frames is achieved by applying Lorentz transformations. The maximum speed for movement, observation, impact and interaction of objects is the speed of light in a vacuum[1]. The latter is an invariant and does not depend on the speed of movement of its source. The observer uses it for the fastest and most accurate observation in the entire electromagnetic spectrum, like the observers in the special theory of relativity. Observers continuously send and receive light signals[2]. Of course, the introduction of the observer should not be misunderstood as suggesting that some kind of subjective features should be introduced into the description of nature. Rather, the observer has only the function of registering processes in space and time, and it does not matter whether it is an apparatus or a human being[3].

Observering and time of life of objects: Observation, on the one hand, always requires the presence of an object or objects, and on the other, the presence of an observer. The observer, using a coordinate system, various measuring devices and a clock, describes the movement and state of objects. Every object is always at a finite instantaneous distance from the observer. If at time t_b the distance between the observer and the object is R, then the minimum time t_0 for radiation or particles from the object to travel this distance is

$$t_0 = \frac{R}{C} \qquad (1),$$

where C is the speed of light in a vacuum.

In the arrow of time, an object is structured (born) at time instant tb^{obj}, and destructed (dies, ceases to exist) at time instant td^{obj}.

The time interval

$$\Delta\theta = t_d^{obj} - t_b^{obj} \qquad (2)$$

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is (the time of existence) of the object[4].

The process of observing any object always begins with an initial moment of time t_b and ends at time t_e. Therefore, the required observation time interval is:

$\delta t = t_e - t_b$ (2a)

According to (1), the time required for light to travel the instantaneous distance R to the observer is R/C . Therefore, the total required observation time, considering (2) and (2a) is:

$\Delta t = \delta t + \frac{R}{C} \leq \Delta\theta$ (3),

Observing should always start after the object is created, i.e. when is fulfilled:

$t_b^{0bj} \leq t_b$ (4)

Also, the observation must have been completed while the object existed, i.e.

$t_e \leq t_d^{obj}$ (4a)

In this, observation is possible regardless of the distance R between the object and the observer or the length of the lifetime $\Delta\theta$.
Every object during its existence performs movements and undergoes changes due to internal reasons, interactions with other objects or the impact of other objects and forces on it. In real cases, the object is characterized by n number of quantities describing it, where n is an arbitrarily large integer.

Any observer-induced variation ∂k of an arbitrarily chosen observed quantity k of these n in number must obey the relation

$\partial k << k$ (5)

so as not to significantly affect the object.

Then the observed quantity k instead of its actual value will have a value

$k \pm \partial k \approx k$ (6)

The most important thing about observing an object is the non-influence of the observer on the aforementioned n number of magnitudes of the object.

For example, in the internationally accepted standardization for measuring Si, the number of observable physical quantities is n = 27 [5].
Relations (5) and (6) have meaning only when we observe an existing object at the time of observation, i.e. (4) and (4a) are fulfilled.
When the observation time interval Δt is before the creation of the object, i.e.

$\Delta t < t_b^{obj}$ (7),

then we cannot observe the object because according to (2) it does not yet exist.
When

$t_{op} > t_d^{obj}$ (8),

we only observe an impact from an object that no longer exists.

We can observe an impact from a non-existent object because once emitted particles or radiation generated by events in the object during its existence characterize it unambiguously enough and propagate through space regardless of any subsequent processes in it, its motion or its existence. There are basically two different ways of observing:

Passive and Active

Passive observation: In the passive way, we observe generated radiation or impact from an object reaching the observer during time t_0 , according to relation (1). The required observation time Δt is determined by relation (3). During this time, we determine the structure of the object and find the distance to it, as well as its speed of movement. We do not send signals to the object, nor do we return received signals from the object. Thus, we always satisfy conditions (5) and (6). Moreover, when conditions (4) and (4a) are met, we observe an existing object. When fulfilled. condition (7) we cannot observe the object. When condition (8) is met, we only observe an impact from a non-existent object. In passive observation, uncertainty arises in the sense that the observer does not know whether the observed object exists at the time of observation and condition (4) is met, or condition (8) is met and the object does not exist. This can only be understood in certain cases. Active monitoring is used for this purpose.

Examples of passive observation: Throughout our lives, we humans observe the environment and the movement in it of animals, terrestrial and celestial bodies thanks to their reflection of light from natural and artificial sources (Sun, stars, Moon, fire, lamps, etc.). In this case, and with the most precise monitoring, where we use devices created by us, we do not send signals to the monitored objects, i.e. we do not influence them.

Therefore, conditions (4), (4a), (5) and (6) are satisfied.

- Trigonometric method is used to determine distances up to 400 light years. The position of the same star on the celestial sphere over several months is observed. As a result of the Earth's orbital motion around the Sun, the angle at which we observe the star is different at different times of the year. By measuring this angle, called parallax, we can determine the distance from Earth to the star.
  Conditions (4), (4a), (5) and (6) are met.
- To determine greater distances, photometric and spectrometric methods are used to analyze images of objects. Areas with different brightness's and spectral color from the object are compared to a database of similar objects whose distances have been accurately measured using the parallax method. This is how stars and galaxies millions of light-years away are observed using powerful ground-based telescopes or space-based ones such as the Hubble telescope and the James Webb[6] telescope.

Conditions (5), (6) and (8) are met.

- SN 1054 is one of eight supernovae in the Milky Way.

It appeared on 04.07.1054.

She was seen during the day for 23 days, then only at night. The last observation was on April 6, 1056, after a total visibility period of 642 days. The remnant of SN 1054, which consists of debris ejected during the explosion, is known as the Cancer Nebula. It is located in the sky near the star Zeta Taurus (ζ Taurus). The radiation seen by the Chinese astronomers traveled 6500±1600 ly[7].

Conditions (5), (6) and (8) are met.

In natural radioactivity, for example in the α-decay of the nucleus of Uranium 238, it turns into Thorium 234 by emitting an α-particle. In this process, the mass number is decreased by 4 and the atomic number is decreased by 2.

$$^{238}_{92}\mathrm{U} \rightarrow \, ^{234}_{90}\mathrm{Th} + \, ^{4}_{2}\mathrm{He}^{2+}$$

Here the Uranium atom ceases to exist, turning into Thorium.
But the α-particle released from uranium radioactively affects the observer even though the Uranium atom no longer exists.
Conditions (5), (6) and (8)[8] are met.

Active observation: In the active mode of observation, we observe only existing objects, i.e. conditions (4) and (4a) are met. With it, we send an electromagnetic signal and analyze the transmitted or reflected signal from the object. We analyze the changes in the object as a result of the absorbed part of the radiation in it. We analyze the changes in the reflected signal, which, unlike the sent signal, is modulated by the measured values of the object. In active observation we are always contacting and interacting with the object. We must respect relations (5) and (6) in order not to influence the objects. Some interpretations of quantum mechanics place a central role on the observer of a quantum phenomenon[9,10]. The quantum mechanical observer is related to the issue of the observer effect, where a measurement necessarily requires an interaction with the physical object being measured, affecting its properties through the interaction. The term "observable" has acquired a technical meaning, denoting a Hermitian operator that represents a measurement[11]. Sending electromagnetic signals to objects and receiving the signals reflected from them is most often used to determine their position and their movement and state. If at time t_b the distance between the observer and the object is R, then the minimum round trip time of the signal at this distance and according to (1) is:

$$t_{0a} = 2\frac{R}{c} = 2t_0 \qquad (9),$$

Therefore, the total time required for active observation Δt_a, considering (2) and (2a) is:

$$\Delta t_a = \delta t + 2\frac{R}{c} \leq \Delta\theta \qquad (10),$$

Observation should always start after the object is created, i.e.
when condition (4) is met. Also, the observation must have been completed while the object existed, i.e. when condition (4a) is satisfied.
In this, observation is possible regardless of the distance R between the object and the observer or the length of the time of life Δθ.
When

$$\Delta t_a < t_b^{obj} \text{ и } \Delta t_a > t_d^{obj} \qquad (11),$$

we cannot actively observe an object with lime of life Δθ because it does not exist.

Examples of active monitoring: Radiography is a photographic method using ionizing radiation - X-rays, gamma rays or neutrons. Some of the radiation is absorbed when passing through the test object, depending on the density of the material and its thickness. The rays passing through the material blacken the silver bromide nuclei in the photographic film, the density of the blackening being inversely proportional to the density of the part photographed[12].

The radiation used is selected so that conditions (5) and (6) are met.

Radar and laser systems for determining the position and speed of movement use a directed beam of radio waves or a laser, according to (9). When radio waves or radiation reach the distant object, they are reflected from the object back to the source. Since it is known where the radiation is directed, the position of the detected object can be determined by measuring the time it takes for the signal to return. This is how the distance is determined, and by measuring the change in its frequency, depending on the Doppler effect, the speed of movement of the object can also be determined. The radiation used is selected so that conditions (5) and (6) are met.

Emerging Indeterminacies at the observation: In the microcosm, if (5) and (6) are violated, the Heisenberg uncertainty principle[13] comes into force. The smaller objects we want to observe, the more we are forced to increase the photon energy ΔE.

$$\Delta E.\Delta t \geq \frac{h}{4\pi} \qquad (12)$$

This principle states that the exact energy of a particle and the exact instant in time Δt at which the energy is possessed by the particle cannot be described with greater accuracy than $h/4\pi$ where h is Planck's constant. It is a fundamental equation in Quantum Mechanics. In other words, the simultaneous localization of the coordinates and momentum of a particle is not possible. In the macro world in any passive observation, in most cases the value of the energy of the photons does not matter, but an ambiguity arises as to whether the observed object exists or not. We passively observe billions of stars and galaxies millions of light years away. With precise photometric and spectrometric methods we can determine the distance to them (more precisely to the place where the radiation comes from). However, we have no way of knowing whether they exist at the time of observation. The only way to establish the existence of the object during observation is to use active observation by sending a signal according to condition (9) to the object. If the latter returns to the observer, then the object exists at the moment of reflection of the light signal. This is possible if subject to mandatory compliance with conditions (5) and (6)condition (11) is not met.

If we denote by t^{obj} the current moment in time at which an object exists, then the actual remaining lifetime of the object is:

$$\Delta\theta_{eff} = t_d^{obj} - t^{obj} \qquad (13)$$

In that $\Delta\theta_{eff} \leq \Delta\theta$.

Then the maximum instantaneous distance of interaction of the object with other objects and also the maximum distance for active observation is:

$$R^* = C\frac{\Delta\theta_{eff}}{2} \qquad (14)$$

For distances greater than R*, there is no way for the object to interact with other currently existing objects. The distance R* in relation (14) is the radius of a characteristic sphere. On the surface of this sphere and inside it (interaction zone) are all objects with which the object with lifetime $\Delta\theta_{eff}$ can currently interact. These objects can be actively monitored. This is shown in Fig.1. For an observer at the center of an object O, the interaction zone is actually the possible zone of active observation. For the same, the zone of impacting objects is a zone of passive observation. If n is the number of objects at distances $r \leq R^*$ and by $\Delta\theta_i$ we denote the life time of a randomly chosen object i, where i = 1, 2, …, n, then interaction with it is possible only when it is fulfilled

$$\Delta\theta_i \geq 2\frac{r}{c} \qquad (15)$$

Outside of this sphere, there are no objects to interact with. Outside of it is the zone of impacting objects on object O.

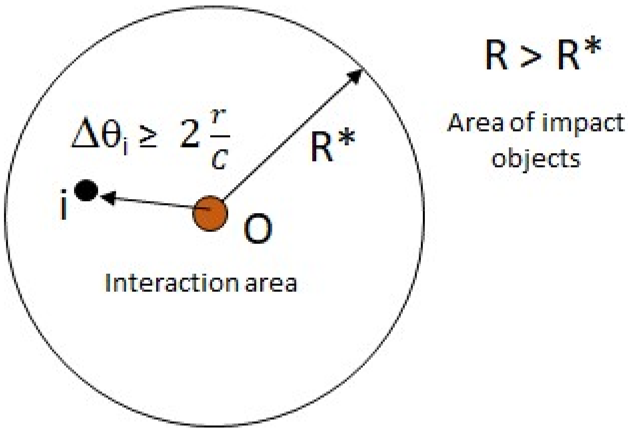

Fig. 1. Maximum instantaneous distance of interaction R* of object O with other objects and area of influence of other objects on object O

An example of impossible structuring of an object

Outside the nucleus, mesons appear in nature only as short-lived products of very high-energy collisions between particles made of quarks.
π - mesons are the most abundantly produced particles in proton-proton and proton-nucleus collisions at the Large Hadron Collider at CERN. The neutral π – meson (π°): m (π°) = 134.98 MeV /c^2, decays according to the scheme $\pi° \rightarrow \gamma + \gamma$ with a time of life
$\Delta\theta = \Delta\theta_{eff} = 8.4 \times 10^{-17}$ s[14]. This, according to (14), means that for one π° meson the maximum interaction distance is $R^* = 1.38\times10^{-8}$ m. Since by definition $r \leq R^*$, then $r \leq 1.38\times10^{-8}$ m and according to (15) $\Delta\theta_i \geq 4.60\times10^{-14}$ s.
Therefore, if object i is a neutral π°- meson time of life meson 8.4×10^{-17} s, then it could not interact with the central π°-meson. In other words, the two mesons cannot together form an object. Analogously, any object i with time of life $\Delta\theta_i < 4.60\times10^{-14}$ s cannot, together with the considered central meson, structure an object.

For existing objects under active observation, as the distance to the observed object increases, so the time for the photons to reach the object and return to the observer increases also. Since all objects move, then if the object has an average speed of movement ΔV relative to the observer, then for the required observation time $\Delta t_a$the object moves a distance:

$$\Delta R = \Delta V.\Delta t_a \quad (16)$$

The radius of the sphere ΔR is the larger as the average velocity of the object ΔV and the observation time Δt_a is larger. In this case, the direction of the velocity does not matter, and therefore we only consider the magnitude of the velocity vector.

Since the motion is perpetual, then $\Delta V > 0$ always. Also the distance $R > 0$ always. Otherwise, there is no way to observe an object.

The larger R is, the larger the required observation time Δt_a and therefore the larger ΔR. The simultaneous determination of the exact coordinates of the object at a given moment in time and the average speed of movement is impossible. The required observation time Δt_a is always equal to or greater than 2 R/C , according to (9). Therefore, since $R= C\Delta t_a$, taking into account (16) we get:

$$\frac{\Delta R}{R.\Delta V} \geq \frac{2}{C} \quad (17)$$

From (17) it follows that the more precisely we localize the coordinates of an object (i.e., we make ΔR smaller, the smaller $R.\Delta V$ should be. We can do the localization with no greater accuracy of 2/C = const, where C is the speed of light in vacuum[15]. The greater the average speed of the observed object, and the greater the distance to it, the greater the localization inaccuracy.

-For example, if we observe from a distance of 10 km, a car moving at a speed of 100 km/h, then according to (17) considering that $C = 2.9979 \times 10^8$ m/s, then
$\Delta R \geq 1.8531 \times 10^{-3}$ m, i.e. the localization inaccuracy is about 2 mm.
However, if we observe, for example, Sirius A (double star), which is located at a distance R = 8.60 ly (light years) and has an orbital velocity $\Delta V = - 5400$ m/s according to the NASA[16] and Symbad[17] catalogs, and 1 ly = 9.4607×10^{15} m, according to (17) the localization of the star cannot be more accurate than $\Delta R = 2.93 \times 10^{12}$ m.

CONCLUSION AND DISCUSION

Two fundamentally different ways of observing objects in the macro and micro world are defined. The possible uncertainties that arise in the passive or active mode of observation and which mode under which conditions can be used are shown. The greater the average speed of the observed object, and the greater the distance to it, the greater the inaccuracy of the object's localization. We can do the localization with no greater accuracy than 2/C = const, where C is the speed of light in vacuum. Examples from the micro and macro worlds clearly show the relationships between the observer, the times of existence of the objects and the momentary characteristic distances. Matter is structured by individual objects with limited lifetimes. The constituent objects and their interactions among themselves determine its properties. Only in the zone of interaction according to (15) and Fig,1 is it possible to structure objects and Newton's third law of dynamics is valid. Ceasing the existence of any object fundamentally changes the properties of matter. Both in the micro world and in the macro world, these changes generate redistributions of operating forces and movements.

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