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TO THE ISSUE OF THE OPEN SYSTEMS EVOLUTION: MASS DYNAMICS

Abstract. The article is presenting a part of our reports on an international gravitational conference (RUSGRAV-15, Kazan, 2014) where the main results of our regular observations of the weight (mass) dynamics of geological systems (mineral/mineral aggregates) are summed up: the experimental facts, visible examples of variation of weight (mass) and one fundamental feature of the temporal structures of open natural systems – average ranges of the weight (mass) magnitude over time intervals of different scales satisfy a definite power relation. Causes of necessity of using control of the corresponding system weight (mass) in modern long-term physical experiment are briefly discussed in conclusion.

Keywords: weight (mass) of open systems, annual weight (mass) dynamics, mineral, mineral aggregate, time series, temporal structure, unexplainable systematic effects, Hurst empirical law.

Introduction

The purpose of the present review is to attract attention to the appropriateness to control dynamics of the corresponding complex system in long experiments on gravitation and basically not only in gravitational ones – we mean all modern experiments in which open systems take part. As a matter of fact, according to the review of the results of gravitational experiments conducted by A. Cook [1], as well as in previous and modern experiments on gravitation ―unexplainable systematic effects‖ are usually observed [1, p. 754]. What can be the cause of the ―unexplainable systematic effects‖?

It is possible, in precision experiments, that are experiments on gravitation, the situation demands to be beyond our traditional representations. In particular, attention should be paid to the fact that the mass of an object is a characteristic of its inertial and gravitational properties, and they, according to the logic of things, do depend on the state of the object. I. S. Newton regarded the ―massive point‖ (i. e. a body that has no internal structure and is in one and the same state) and could assume that the mass of the body is determined only as ―quantity‖ of matter (see his definition of the mass in [2, p. 1]: *"quantitas materiale est mensura ejusdem orta ex illius densitate et magnitudine conjunctim"*[1]), because it stays in one and the same state, so that, due to its invariability, the mass is regarded as a constant value. In methodological notes [3] dedicated to the concept of mass L. B. Okun underlined that in case of the change of state (inner energy) of a complex system (i. e. the system that has an inner structure) its mass changes. That is why a long control of the weight (mass) of an open (i. e. specially unscreened) complex system with the simultaneous control of measurements conditions is of interest both from the point of view of evaluation of a possible change of its inner state and for finding out the origin of the mentioned systematic effects.

The given review sums up the main results of long-term observations of the natural dynamics of weight (mass) of the specimens of a representative geological collection compiled especially for the occasion.

Real examples of the mass variation

In this section we are given only the experimental facts, real, visible examples of variation of mass. These observations which were started in 1991 are considered in our monograph [4, Ch. 2] in detail. It makes sense to accent that the geological specimens with their of every

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[1] *The quantity of matter (mass) is a measure of the same established in proportion to density and volume of it* (A. N. Krylov's translation).

kind variety of the structure, form and content, genesis, porosity and permeability of a bounding surface were selected so that by means of a comparative analysis of their weight (mass) behaviour in time we can interpret physical cause of the phenomenon under study. That is why we put also in our observations various substances within the glass. (For instance, in order to evaluate influence of changes of relative humidity inside of the monitoring room, see Ch. 2 (p. 76–87, 90–92) in [4].) Time and place, order of the observations are defined according to the properties of that phenomenon which we are considering as a source of the mass variations. This phenomenon was considered in detail in our works [4–8].

In Figure 1 that reproduces Figure 2.2 from the monograph [4] we can clear see the three geological specimens' mass variation in spring of 1991: *A* – some garnet with admixtures (141 g; the variation range equals to 18 mg), *B* – the garnet from Dashkesan (aggregate of pure crystals, 137 g; its variation range is less than 2 mg), and *C* – certain aragonite (71 g; its variation range equals to 14 mg).

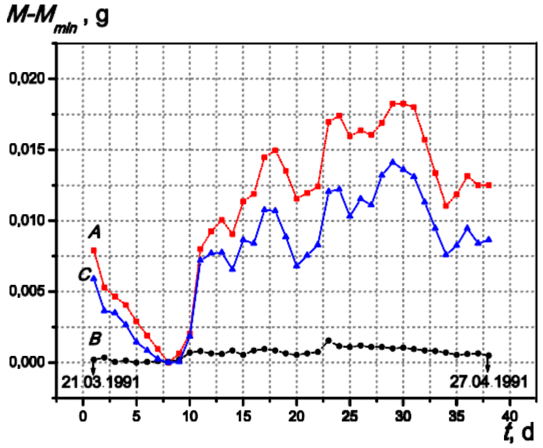


Figure 1. Mass *M* variation of the various specimens *A*, *B*, and *C*, M_{min} is the minimal value of *M* (measurement error is ±0.00075g for *A* and *B* and ±0.0005g for *C*)

In this first calendar observation under control were the masses of a small trial geological collection (13 specimens) and the observation conditions, too. Then, taking into account the results of the observation, a special representative geological collection (55 various specimens which related to various groups with the mass dynamics of definite type) was prepared.

In Figure 2 are given seven types of mass dynamics observed among the specimens of this collection. They were presented in Figures 2.6–2.10 in [4].

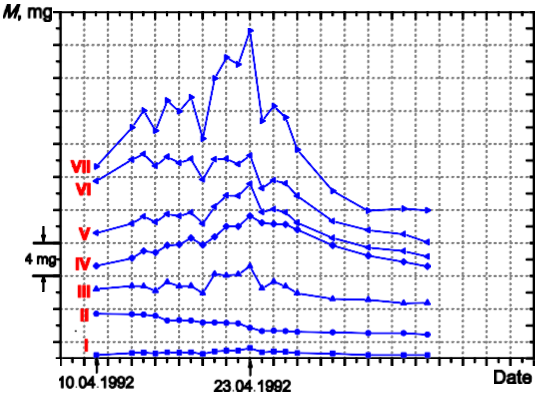


Figure 2. Seven types of mass dynamics observed in our geological collection (measurement error for all mass *M* is less than ±0.00025g)

As we can see, specimens with the mass dynamics of type I have in the given period of observations the mass variation of the order of 1 mg, while specimens with the mass dynamics of type VII have the mass variation of the order of 16 mg. However both variations have an identical rhythm – see Figure 3 where on the vertical axes are used different scales: one of them is 25 times as much.

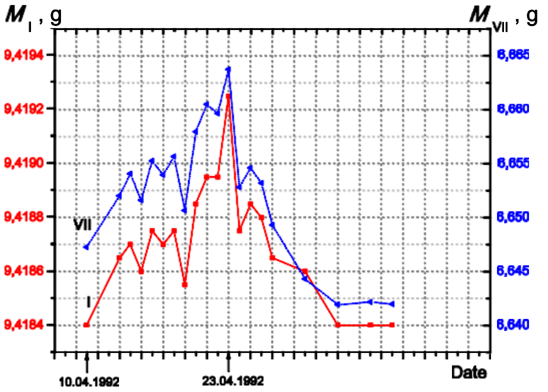


Figure 3. Data comparison of the first and seventh types (measurement error is ±0.00012g)

Observations hourly indicated that among the specimens, which belong, as a rule, to one type of the mass dynamics, one of them can react upon certain factor that other specimens of this type do not react upon – see Figure 4 which reproduces Figure 2.12 from [4]. The observations were carried out at Sayan Solar Observatory of Institute of Solar-Terrestrial Physics, Russian Academy of Sciences, Siberian Branch.

Annual dynamics of the mass of several geological specimens of various types (1994.07.02 – 1995.07.11) is discussed in section 2.3.3 in [4]. In Figures 5–7 reproducing ones from there we can find out its some attributes:

1. The rather different geological systems (the specimen *b* in Figure 5, specimens 1 and 2 in Figure 7) have identical specific annual dynamics of their mass *M* where well-known astronomical dates (autumnal equinox, winter solstice, vernal equinox, and summer solstice) showed themselves. Note, similar annual dynamics we observed during our special almost continuous monitoring (2010.11.19–2012.06.22 UT) when under control was some rolled pebble of paleozoic granite from recent river deposits of Tien Shan, 9 g – see Figure 8 that reproduces Figure 4.22 in [4].

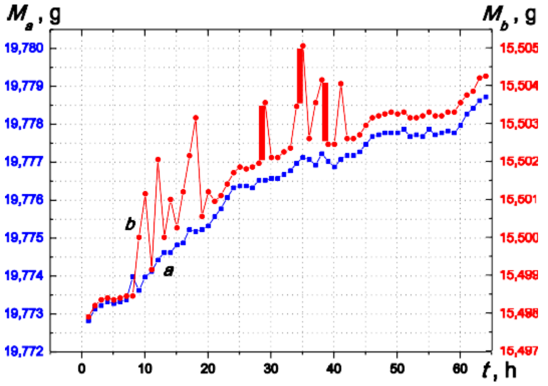


Figure 4. Mass dynamics of the two specimens *a* and *b* from the group VII; *a* – cubic crystal of pyrite, which was by magnetite replaced, *b* – green straticulate cryptomerous tuffite (measurement error is ±0.00012g)

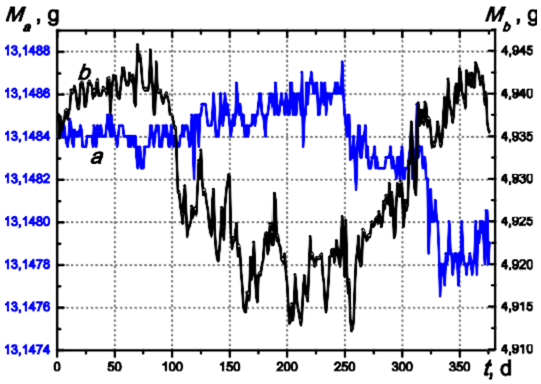


Figure 5. Annual mass dynamics of quartz crystal (*a*) and fine-crystalline aggregate of dolomite and mica (*b*) (measurement error is ±0.00012g)

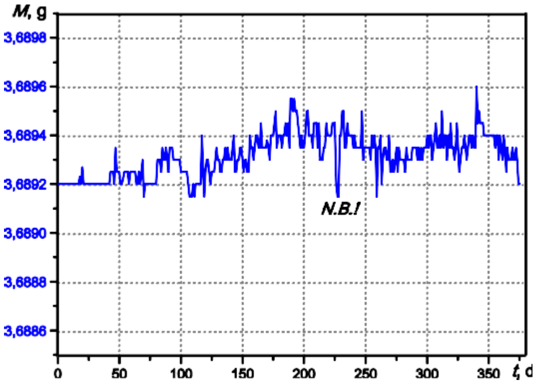


Figure 6. Annual mass dynamics of other quartz crystal (measurement error is ±0.00012g)

2. As we can see in our long-continued observations, transparent minerals can have contrary behaviour of their mass as compared with opaque ones – cf. dynamics of M_b (an opaque specimen) and M_a (transparent one, quartz crystal) in Figure 5.

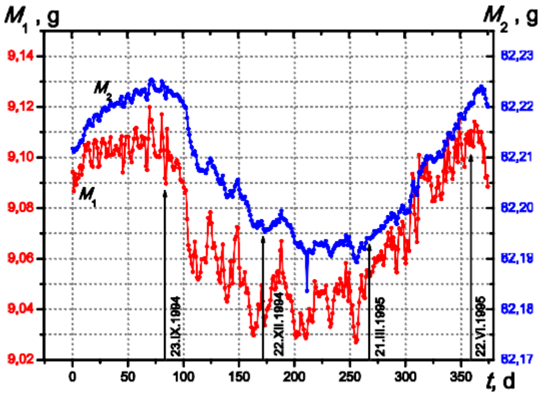


Figure 7. Annual mass dynamics of the two geological systems 1 and 2, 1 – siliceous argillite, stratified, with interbeds of cherty siltstone and 2 – mineral aggregate: combination of pirrhotite (predominates), chalcopyrite, and black shales (measurement error ±0.00012g for 1 and ±0.00025g for 2)

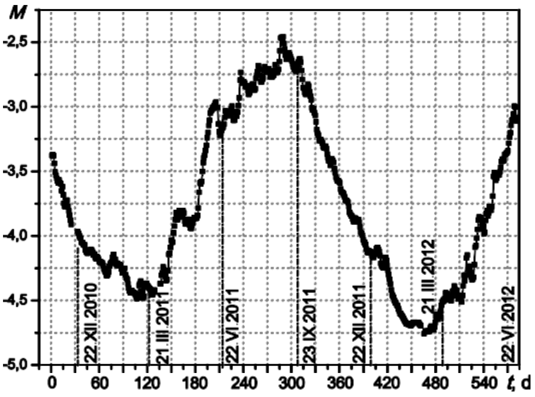


Figure 8. Annual dynamics of daily mean mass *M*; its change of 0.01 is adequate to the change of 0.05mg

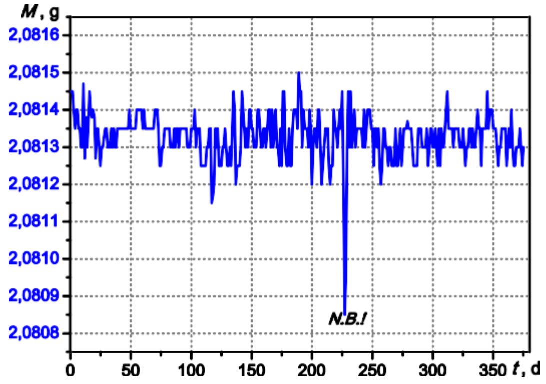
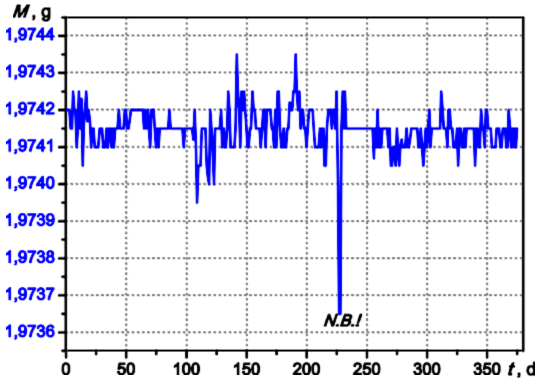


Figure 9. Annual mass dynamics of two identical medical ampoules with vitamin B12 (measurement error is ±0.00012g)

3. Two specimens with identical material composition but of different genesis can have rather different annual behaviour – cf. annual dynamics of M_a in Figure 5 and *M* in Figure 6.

In the observations during several hours every day manifested themselves some short-term fluctuations of the mass. So, for instance, in Figure 9 (it reproduces Figure 2.16 in [4]) is given the annual dynamics of the mass of two identical medical ampoules with cyanocobalamin ($C_{68}H_{88}CoN_{14}O_{14}P$) – vitamin B12. We can see there two visible identical fluctuations, they are indicated with mark *N.B.!* Such a fluctuation was observed in that day also in dynamics of the quartz crystal in Figure 6.



Another example, in Figure 10 (it reproduces Figure 2.13 in [4]) is given behaviour of the mass of several various specimens every hour during 2.5 days. We can see there two short-term fluctuations in dynamics of the mass of the two specimens *e* (orthoquartzite, aggregate of quartz crystals, very pure) – from the group of type I and *d* (fine-crystalline aggregate of dolomite and mica) – from the group of type VII. (The observations were carried out at Sayan Solar Observatory.)

Finally, in Figure 11 (it shows Figure 4.7 in [4]) are given measurements data of the *Dubna–Nauchny–Novosibirsk* geophysical monitoring [4, Ch. 3]: the geological specimen mass *M*, the relative humidity H_{in} and the temperature T_{in} in the monitoring room, the atmospheric pressure *P*. On the vertical axes are used monitoring's units: the mass change of 0.01 is adequate to the change of 0.05 mg, the temperature change of 0.01 corresponds to 0.44 , the relative humidity change of 0.01 – 0.32%, the atmospheric pressure change of 0.1 – 1mm Hg. As we can see, this fluctuation of the mass of the order of 0.25 mg was lasting in the course of eight minutes. (Note, that an information-measuring system, which realized this monitoring, measures and records data every 10 s.)

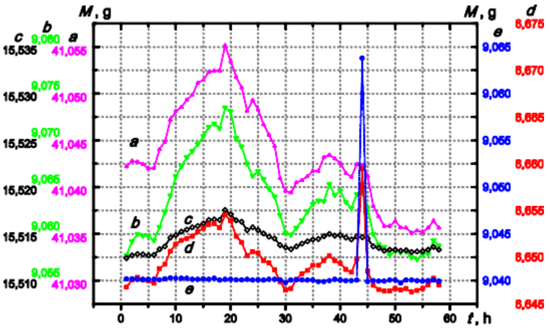


Figure 10. Mass dynamics of five specimens: *a*, *b*, *d* – from the group of type VII, *c* – of type VI, and *e* – of type I (measurement error is ±0.00025g for *a* and ±0.00012g for the others)

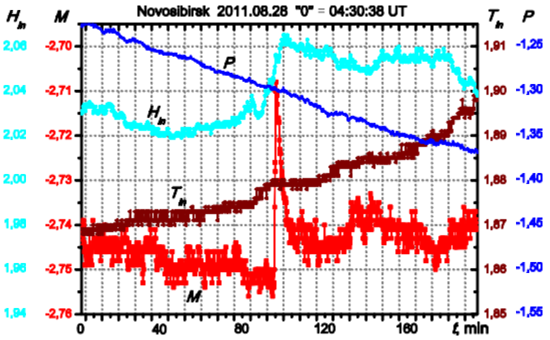


Figure 11. Fluctuation of the mass *M* of geological specimen from the group of type I under control (rolled pebble of paleozoic granite from recent river deposits of Tien Shan, 9g) and measurement conditions on August 28, 2011

Features of the mass dynamics

Consider time series describing the complex system state dynamics

$$A(t_0), A(t_1), A(t_2), A(t_3), ..., A(t_n), \tag{1}$$

where $A(t_i)$, $i = 0, 1, 2, 3, \dots, n$, is a value of the definite constitutive, key quantity *A* of the given system (for instance, its mass) at the moment t_i . We consider the structure of series (1) as the *temporal structure* of the given system and use for its description well-known mathematical characteristics. First of all, we are considering the series (1) when *A* is the mass *M* and examining behaviour of the average range $\overline{R_M}$ of the mass *M* magnitude over time intervals of different scales: τ and $m\tau$, where τ – minimal time interval (we deal with the case when $t_i = i\tau$, $i = 0, 1, 2, 3, \dots, n$), *m* is such integer for that the number *n* of minimal time intervals τ is equal to *mk* where *k* also integer. Experimental data analysis [4, 9] found out that a definite power relation takes place. It is described by the formula

$$\frac{\overline{R_M(m;\tau)}}{\overline{R_M(1;\tau)}} = m^{2-D_M}, \tag{2}$$

where $\overline{R_M(m;\tau)} = \frac{1}{k}\sum_{i=1}^{k} R_i(m;\tau)$,

$$R_i(m;\tau) = \max\{M(t),\ (i-1)m\tau \le t \le im\tau\} -$$
$$-\min\{M(t),\ (i-1)m\tau \le t \le im\tau\},$$

$$\overline{R_M(1;\tau)} = \frac{1}{n}\sum_{i=1}^{n} | M((i-1)\tau) - M(i\tau) |.$$

We suggested to consider quantity D_M as a characteristic of the time structure of a geological system because it turned out that this value corresponds to the material composition of the system and does not depend on the type of the mass dynamics. For instance, we see in Figures 5 and 6 that two different (variant genesis) quartz crystals have unlike annual dynamics, however values of D_M for them are identical: 1.54 ± 0.02 and 1.55 ± 0.02 (here τ = 1d, n = 375). For the kindred to them by substantial origin specimen (quartzite) D_M = 1.52 ± 0.02. For the specimen *b* in Figure 5 (fine-crystalline aggregate of dolomite and mica) D_M = 1.44 ± 0.02. This specimen (4.9 g) was picked out from one and the same crystalline rock together with the same two other specimens (18.1 g and 7.2 g), for them D_M is also equal to 1.44 ± 0.02.

In our works [9, 10] was shown that the power relation (2) is underlying of the well-known Hurst empirical law [11] for time series describing natural phenomena and processes $\frac{R_{X_A}(n\tau)}{S_A(n\tau)} \sim n^H$, H – the Hurst exponent.

Here $R_{X_A}(n\tau)/S_A(n\tau)$ is Hurst rescaled range, where

$$R_{X_A}(n\tau) = \max\{X_A(t),\ t = \tau, 2\tau, ..., n\tau\} -$$
$$-\min\{X_A(t),\ t = \tau, 2\tau, ..., n\tau\}$$

is the range of function

$$X_A(t) = \sum_{u=\tau}^{t}[A(u) - \overline{A}], \quad \overline{A} = \frac{1}{n}\sum_{t=\tau}^{n\tau} A(t),$$

used by Hurst, and S_A – the standard deviation of the quantity *A*:

$$S_A(n\tau) = \{\frac{1}{n}\sum_{t=\tau}^{n\tau}[A(t)-\overline{A}]^2\}^{\frac{1}{2}}.$$

Hurst rescaled range $R_{X_A}(n\tau)/S_A(n\tau)$, from the standpoint of the temporal structure of quantity A, is a number of constituents of that structure (see [10, p. 13–14]), of which size in time interval τn is defined by value of $S_A(n\tau)$, while $R_{X_A}(n\tau)$ characterizes size of the structure. That is why Hurst rescaled range can be used for a compact and data-intensive graphic representation of the temporal structure, see portraits of temporal structures in [4, p. 165].

In conclusion it makes sense here to pay attention to one Yu. G. Kosarev's result obtained in his investigations of ways for construction of cybernetic systems with the unlimited possibility for their development – they must be *harmonic systems*, whose main feature is the existence of corresponding power relations of their parameters [12, 13]. Generally speaking, the power relations are typical for spatial and temporal structures for natural systems, various phenomena and processes, see comprehensive experimental data in monograph [11].

Conclusion

On the whole, we have to state that when we deal with an open complex, organized system that can be in different internal states its integral characteristic – mass, which is an expression and a measure simultaneously of its inertial and gravitational properties – can (and must [3]) change. The complex system, which was not screened on purpose, stays actually in the world ocean of external irreversible processes that initiate it [5, 6]. That is why (under the corresponding conditions of observation) should be observed a certain dynamics of mass that is determined by a periodicity of external natural (cosmic) processes. It confirms the observed annual dynamics of mass of geological specimens.

Thus, in the modern precision experimental investigations planning where open complex, organized systems are involved, a possibility of variation of their internal state due to the world interconnection that is conditioning the space-time metric [5–8] should be taken into account. The observations results of the natural dynamics of minerals' and mineral aggregates' mass, given in this review, open an opportunity to study the origin of the –unexplainable systematic effects‖ in experiments on gravitation and also the origin of the well-known absence of the precise reproduction of results that are obtained in experiments where complex non-equilibrium systems or non-equilibrium processes are present by means of the synchronous control of the mass of the corresponding geological system.

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К ПРОБЛЕМАМ ЭВОЛЮЦИИ ОТКРЫТЫХ СИСТЕМ: ДИНАМИКА МАССЫ

Аннотация. Данная статья представляет собой часть нашего доклада на международной гравитационной конференции (RUSGRAV-15, Казань, 2014). Здесь суммированы главные результаты наших регулярных наблюдений динамики веса (массы) открытых геологических систем (минералы и минеральные агрегаты): экспериментальные факты, убедительные примеры вариации веса (массы) и одно фундаментальное свойство временных структур открытых естественных систем – средние размахи величины веса (массы) на временных интервалах разного масштаба удовлетворяют определенному степенному соотношению. В заключении кратко обсуждаются причины необходимости использования контроля веса (массы) соответствующей системы в современном долговременном эксперименте.

Ключевые слова: вес (масса) открытых систем, годовая динамика веса (массы), минерал, минеральный агрегат, временной ряд, временная структура, эмпирический закон Херста, необъяснимые систематические эффекты

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АШЫҚ ЖНЙЕЛЕР ЭВОЛЮЦИЯСЫНЫҢ МӘСЕЛЕЛЕРІ: МАССАСЫНЫҢ ДИНАМИКАСЫ

Аннотация. Бұл мақала біздің халықаралық гравитациялық конференциясындағы баяндамамыздың бір бөлігі болып табылады (RUSGRAV-15, Казань, 2014). Мұнда ашық геологиялық жүйелердің (минералдар және минералды агрегаттардың) динамикалық салмағына (массасына) үздіксіз бақылау жүргізудегі біздің негізгі нәтижелеріміздің жиынтығын ұсынады: эксперименталды фактілер, салмақтың (массаның) вариациясының көзжеткізілген мысалы және ашық табиғи жүйелердің уақытша құрылымының фундаменталды құрамы – әртүрлі масштабта белгілі дәрежедегі қатынасты қанағаттандыратын салмақтың (массаның) орташа шамасы болып табылады. Қорытындыда заманауи ұзақ мерзімді экспериментке сәйкес жүйелер үшін салмаққа (массаға) бақылау жүргізуді қолдану қажеттілігі туралы себептерге қысқаша талдау жүргізілді.

Кілт сөздер: ашық жүйелер салмағы (массасы), салмақтың (массаның) жылдық динамикасы, минерал, минералды агрегат, уақыт қатары, уақытша құрылым, Херсттің эмпирикалық заңы, түсіндірілмейтін систематикалық эффекттер.