Symmetry of STRUCTURE

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Abstracts

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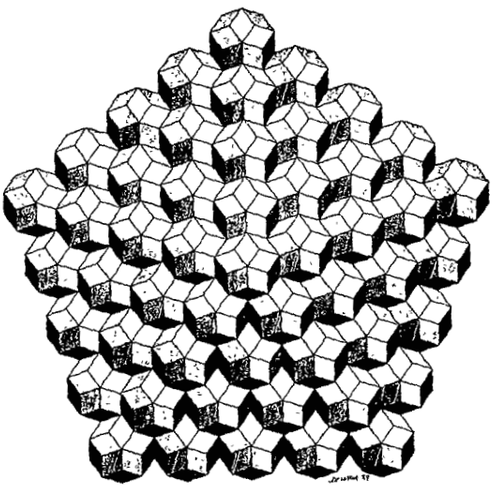

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DISCRETE SYMMETRIES IN COSMIC SCALES

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Summary: A lattice structure of discrete symmetries is demonstrated on the cosmic mass-size diagram.

While our world may appear confusing when studied at small details, it is simple and regular from a proper bird's-eye view. Indeed, the basic mass, length and time scales of phenomena seem to be arranged in a secret order manifested only when comparing orders of magnitude. Nowadays we are already able to recognize the *logical background* behind these regularities that can be expressed by simple *algebraic formulae* admitting in turn transparent *geometric interpretation* in terms of approximate *discrete symmetries*, as we shall see. Making use of this knowledge we may attempt to theoretically reproduce the design of Nature from elementary particles to the entire observable Universe in a simple and aesthetic way. The result is briefly explained in the present comment and summarized in the enclosed Figure where mass M vs. size R are displayed in logarithmic scales, with an origo corresponding to the proton (Lukács & Paál, 1981).

Each of the three basic physical phenomena of general competence, gravity, quantization and relativity, has one fundamental constant (Cavendish constant G, Planck constant ħ, and light velocity c, respectively). Note that c is also universal limitation for propagation of signals, so cannot be overrun by any velocity coming from other disciplines. Therefore one gets two lines

$$M = (c^2/G)R \quad \text{and} \quad M = (\hbar/c)R^{-1}$$

limiting the places of possible stable configurations on the diagram from the left. On the ascending line each mass defines a length (the Schwarzschild radius) below which irresistible gravitational collapse leads to black hole formation; on the descending line one finds to each mass a length (its Compton length), below which our naïve notions of space and time become obscure and even meaningless because of quantum uncertainty.

The objects of the real world are "well aware of the law", and apparently respect the above limitations. On the Figure the points representing astronomical objects lie close to the upper boundary, while microphysical ones are near the lower one, in the permitted region. Objects built up only from nucleons, atoms and (presumably) neutral leptons (e.g. neutrinos) are also roughly of nuclear, atomic (and "leptonic") density and therefore aligned

along equidensity lines (of slope +3, since $M \sim R^3$) attached to the respective objects. So matter can form stable equilibrium configurations only with masses and sizes corresponding to these lines. The natural laws and the building blocks determine the basic features of the structures.

The above "construction of the world" is surprisingly regular: the equidensity lines happen to be just equidistant. These lines reveal the intimate connection between the micro- and macrocosmos. The neutron star (n^*) is the "sign of the neutron in the sky"; the ordinary star and the quasar are those of the atom; while the protocluster (⊗), galaxy cluster now, is probably that of a neutral lepton (a kind of neutrino or other weakly interacting particle). So the astronomical macrocosmos is just the microcosmos "projected to the sky".

The central equidensity line is the most populated according to our knowledge. Here one finds the particles of cosmic dust, meteorites, biological and geological formations, moons, planets. In case of *stable* equilibrium the two extremes on this line are the atoms (purely electrically bound objects) and stars (purely gravitationally bound objects). Loosely speaking stars represent "gravitational atoms", while atoms mean "electric stars". Between these two extremities man represents *aurea mediocritas* - a "gravitationally limited electric being" - who is therefore larger than the H atom by just the same factor as smaller than the star. (Otherwise he would be broken in pieces if fallen down to the ground.) Calculating this geometric mean between star and atom directly from basic natural constants, one gets about 78 kg (!) just like our typical human mass indeed. Considering, therefore, orders of magnitude, one finds that the "measure of Nature" is "anthropocentric" both in mass and in size, but this fact has nothing to do with any kind of subjective wishful thinking.

Furthermore note on the Figure that the series *atom* (hydrogen), *bacterium* (simplest living), *man* (most evolved living), *mountain* (highest still stable) and *star* is also equidistant in a good approximation.

The above all-embracing order controls not only each individual, but also the "totality", i.e. the Universe as well. This can be made obvious by the Figure which shows that not only the above series of "ordinary" objects but also the series of extreme astrophysical objects (neutron star, minimal quasar, protocluster, observable Universe) is just equidistant. This implies that the series of equidistant equidensity lines can be extended to include the density line of the *Universe* (of $\sim 10^{-29}$ g/cm^3). The intersection point of this line with the black hole line of slope +1 correctly gives the mass and size of the entire observable Universe ($\sim 10^{80}$ proton mass and $\sim 10^{42}$ proton radius). It is worth mentioning that the point "Universe" equally well characterizes both the part of the totality observationally known at present and the part which can in principle become known via ideal observations, because signals from essentially more distant regions

have not yet reached us during the entire past of the Universe beginning from its "Big Bang birth" till now.

A further beautiful expession of the all-embracing regularity is that the geometric mean between the size of the *Universe* and that of the *atom* is just about the size of the *star*. The geometric mean between the size (or mass) of the *star* and that of the *atom* is the *man* while the geometric mean between the *man* and the *atom* is the *bacterium*.

As a consequence of the well known expansion of the Universe the position of the point U is time dependent, and, according to the suggestion of the Figure, it should move just along the limiting line of slope +1 (otherwise its present precise fitting to this line would be highly improbable). This is indeed true, so that the whole past history of the Universe can also be read off the diagram. Its evolution clearly ought to have started from the intersection point of the limiting lines (Lukács & Paál, 1988), corresponding to the so called Planck length and mass, given by the formulae

$$R_{Pl} = (\hbar G/c^3)^{1/2}; \qquad M_{Pl} = (\hbar c/G)^{1/2}.$$

These Planck data represent the only physical units defined uniquely by the laws of Nature themselves without any arbitrary convention. The ratio of Planck and proton masses is

$$M_{Pl}/M_P = (\hbar c/GM_P^2)^{1/2} = 1.3*10^{19},$$

a basic large dimensionless number of Nature. Its powers have important meaning in the structure and evolution of the cosmos. Integer steps by this ratio in the Figure give such series: Planck scale, presently exploding black hole scale, neutron star scale, Universe scale at the decoupling of the radiation, Universe scale at the time of final quantum evaporation of black holes of stellar mass. In the history of the Universe the corresponding time scales are: Big Bang, supersymmetry phase transition, quark confinement, decoupling from radiation, black hole evaporation.

Summing up we may say that in the structure and evolution of the cosmos one can find equidistant steps in mass, size and time on a logarithmic scale expressing orders of magnitude. Commensurable steps connect one important preferred formation or event to the other. This regularity can be compared to the discrete symmetries of crystallic lattices, although it is an essentially generalized "symmetry" connecting unequivalent (but equally important) objects or events. It is the logical interconnection what is common here, not the type of the objects.

All this is not merely a magic of numbers. Many of the found regularities are straightforward consequences of simple physical arguments, while others indeed "depend rather delicately on apparent *coincidences* among physical constants" which in turn prove to be prerequisites of our existence (Carr & Rees, 1979). A tiny distuning of initial data or strength of interaction or particle masses or asymmetries would be enough to completely destroy our comfortable Universe, which seems as a "suit tailored just to our human measure". We may therefore be surprised to find ourselves

in an "anthropomorphous" cosmos. The message of modern science appears to be that both the "anthropocentric" and the "anthropomorphous" characters are properties of Nature herself, so that these attributes begin to lose their purely pejorative meaning.

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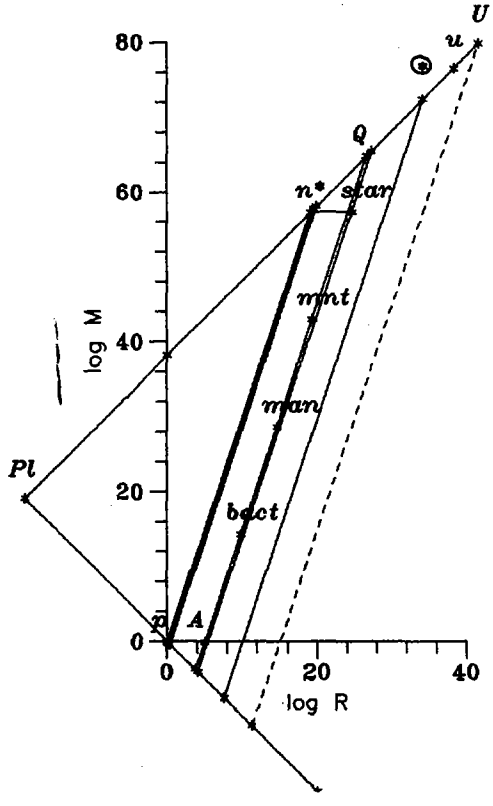

Cosmic mass-size diagram

p: proton, ν: neutrino, n*: neutron star, Q: quasar, ⊛ : protocluster, u: Universe at decoupling, U: Universe at present, Pl: Planck data, A: atom, mnt: mountain, bact: bacterium. Heavy line: nuclear density, double line: atomic density, single line: "leptonic density", dashed line: cosmologic density.