22. PROJECTIONS INTO THE FUTURE

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1. The Specialized and the Morphological Approach

Science owes much of its success to the *specialized approach*, which endeavours to isolate objects and phenomena and to study them under elimination of the disturbing influences of the surroundings and internal contaminations. Thus, for instance, physicists grow pure single crystals of various chemical elements and compounds and study their mechanical, thermal, electrical, magnetic and optical properties under strictly controlled conditions of pressure, temperature and other parameters.

The specialized approach, however, involves several dangers. In the first place, through the investigation of isolated objects and circumstances one cannot be quite sure to arrive at significant results of general validity. And secondly, the specialized approach may lead to scientifically worthless and even non-sensical results in cases where the environment and disturbing influences are in reality impossible to avoid. Under such circumstances the use of the morphological approach* is indispensable. Finally, scientists practicing exclusively the specialized approach may become narrow minded specialists who fail to maintain a balanced outlook on all aspects of life, a trend which has resulted in the ever widening and humanly disastrous gap between science and the general public.

To mention one specific example to demonstrate the necessity and the usefulness of the general morphological approach as a tool in the special field of astrophysics which we are discussing in the present symposium, let us consider the problem of the evolution of a single star. Theoreticians, working on the internal constitution of stars and their development in time, generally have considered them as isolated from all external influences for hundreds and even thousands of millions of years, although neither they, nor any observer could possibly point to specific stars for which this is really true. If any cosmic object had actually passed unscathed through the billions of years we would not have any criteria for detecting or discovering it.

On the other hand, there cannot be any doubt that most of the stars as we see them today have been subject to more or less severe external disturbing effects, such as collisions with interstellar gas and dust clouds, exposure to both electromagnetic and corpuscular radiation, close encounters and the physical interaction with other stars,

* This approach, which has been gradually developed, perfected and applied in many fields during the past four decades, essentially concerns itself with the visualization, the analysis and the constructive use of all of the structural interrelations among objects, phenomena and concepts which might enter a given problem or set of circumstances. For those who might wish to try their hand at this approach a number of references are listed in the appended bibliography. [1]

Luyten (ed.), White Dwarfs, 155–164.

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as components of binary and multiple systems, etc. As a result of such interactions stars may accrete matter and increase in mass, or they may be whittled down.

For instance, if one component of a binary star becomes a supernova and blows off most of its mass, its companion, if not completely blown out of existence, that is disrupted and evaporated, will be more or less severely whittled down and become a 'run-away star' [2]. Depending on how much it has been whittled down it will fly away as a more or less normal star or, in the extreme as a very much smaller and hotter object, which I have proposed to call a ,pygmy star' of a density comparable to that of normal stars. About typical pygmy stars of very high density we shall speak later on. Whittled down pygmy stars are no doubt being produced in great numbers in many of the compact galaxies as well as in the compact cores and nuclei of certain spiral and elliptical galaxies, in which normal stars are being whittled down over more or less long periods of time in the intense interstellar radiation fields due to the emission of the other stars of the system.

As to systematic projections into the future, the morphological approach has developed certain means of scientific and technological forecasting, the absolute validity of which cannot really be strictly proved, but which, in the recent past, that is during the past four decades have been remarkably successful. Among the predictions made in the 1930's, and which have been confirmed since are, the existence of neutron stars and their relation to supernova outbursts and the generation of cosmic rays, the occurrence of faint blue stars of many types in open clusters and especially in high galactic latitudes (Humason-Zwicky stars), of gnome, pygmy and dwarf galaxies and, most recently, of the huge family of compact galaxies. The conclusion reached more than thirty years ago that the luminosity function of normal galaxies must be of the type proportional to $10^{0.2(M-M_0)}$, rather than to $10^{-a(M-M)^2}$ currently accepted at that time has now found its remarkably accurate confirmation.

The long standing predictions of compact galaxies acting as gravitational lenses and of the occurrence of nuclear goblins still need verification through more decisive observations than are available to us today. Likewise, the anticipated existence of various types of pygmy stars needs to be confirmed more convincingly.

Most of the above mentioned predictions were made by what I have proposed to call the *morphological method of directed intuition* supplemented by the idea that cosmic objects and phenomena will be found to be subject to the following general aspects.

(1) Objects will be found to exist in large and interrelated families.

(2) Any cosmic object can be formed slowly or fast, as measured in terms of speed of the motions and of the velocities of sound present in the original systems. For instance, in many heads the myth has established itself that neutron stars can only be formed fast, a myth which has prevented many theoreticians to see and evaluate cosmic evolutionary events in their true light.

(3) If time is long enough, that is much longer than the transit times between the particles or light quanta in a given system, then the principles of the Boltzmann-Gibbs statistical mechanics regulate the formation of compact and dispersed cosmic matter [3].

(4) And finally, it may reasonably be conjectured that to all fundamental lengths which can be formed from the basic physical constants, there exists always some type of characteristic matter or body. Concentrating in this short study mainly on this conjecture we may, among others, expect to find the following types of matter and of bodies.

It must of course be emphasized that these bodies will seldom be found in nature in pure form, but will always be 'contaminated' to a greater or lesser degree by types of matter belonging to other categories.

2. On the Hierarchies of Distinct Bodies

As mentioned above, it has in the recent past proved fruitful to relate the occurrence of different states of matter and of distinct bodies among the elementary particles, the atoms and molecules, microscopic and macroscopic solid and liquid bodies, as well as of a series of cosmic objects to the various types of basic lengths which can be expressed in terms of the known physical constants. We shall consider for this purpose the masses and charges m_p, m_e and $\pm e$ of the proton and the electron, the velocity of light c, the Planck constant h and the universal gravitational constant G. The masses of other elementary particles such as the mesons and hyperons will be mentioned in passing, while we can give only a furtive glance to the as yet not definitely known masses of neutrinos and gravitons.

It should also be noted that the basic lengths used below may in some cases be expanded to other significant lengths when multiplied with certain powers of two important *dimensionless numbers* which can be formed from the physical constants in the following way, namely

$$\alpha = 2\pi e^2/hc = \tfrac{1}{137} \qquad \text{(Fine Structure Constant)}$$

and

$$R = e^2/Gm_e^2 = 4.2 \times 10^{+42} \qquad \text{(Cosmic Number)}$$

The selection of basic lengths which we propose to choose is as follows.

$d_B = h^2/4\pi^2 m_e e^2$ = BOHR'S LENGTH = 5.3×10^{-9} cm

As is well known, d_B is the characteristic length which essentially determines the sizes of free atoms and molecules. It is also important to remember that condensed matter in its usual macroscopic state, with a density of the order of unity (in terms of water at SPT) is generally electrically neutral in regions whose dimensions are of the order of d_B (in crystals the typical smallest electrically neutral components are the so-called elementary cells).

$d_S = d_B/\alpha = 137\, d_B = 7.3 \times 10^{-7}$ cm

d_S might be called the atomic phase communication length. Since it limits the distance to which motions in crystals for instance can be strictly kept in phase, due to the finiteness of the speed of light, it also is related to the dimensions of a secondary structure even in the most perfect real crystals, most of which show dislocations and mosaic structure when the specimens have sizes of the order of one micron [1]. In this connection the interesting question arises how long the so-called whiskers of certain single crystals may actually become and if they might be formed in interstellar space in lengths impossible or very difficult to achieve on the earth, and what role they might play in causing obscuration and polarisation of light from more distant objects.

3. Interference of the Exclusion Principle

Before proceeding to the discussion of lengths smaller than d_B we must mention the relation of the Fermi statistics to states of matter different from those known to us in our immediate surroundings. Such states were first suggested by R. H. Fowler in order to explain the existence of the white dwarf stars with average densities of the order of 10^6 g/cm^3 and greater. Idealizing the model of an electronically degenerate star, all of the electrons, each one with its own specific set of quantum numbers must be thought of as occupying all of the lowest possible energy states within a matrix of protons or other nucleons as compressed by their mutual gravitational forces. This model, which would have the appearance of one giant molecule at the absolute zero of temperature must of course be modified by endowing it with some heat content and with a non-degenerate atmosphere subject to an equation of state of a more or less conventional gas.

With a view to some of the states of stellar matter to be discussed further on, whose interatomic distances are governed by the Compton wavelength λ_{Ce} of electrons, we may discover that this state closely overlaps the electronically degenerate state of white dwarfs discussed above, which alone seems to have been considered by most astrophysicists during the past four decades. Not having followed developments in this field very closely I am not aware of whether or not the relation of the states of matter in degenerate stars governed respectively by the exclusion principle and by the Compton wavelength λ_{Ce} for electrons has been discussed by the theoreticians and, in which way it is relevant for our understanding of the constitution of under-luminous dwarf stars, white and red, as well as possibly of dense pygmy stars.

$\lambda_{Ce} = h/cm_e = 2.43 \times 10^{-10}$ cm = COMPTON WAVELENGTH FOR ELECTRONS

This wavelength corresponds to a frequency v for which $hv = m_e c^2$, that is equal to the energy of complete annihilation of the electron. Therefore we may picture a state of matter associated with this Compton wavelength, which in the first place consists of a network of protons or of nucleons locked together at interparticle distances of the order of λ_{Ce}, and with virtual or real pairs of positive and negative electrons emerging between them. The minimum density of a star of this type and consisting entirely of hydrogen would be of the order of 10^5 g/cm^3. It should be added that the possibility of pairs of positive and negative electrons appearing and disappearing will add a new aspect to the problem of the stability or instability of stars of this type and account for some of the oscillatory features.

$\lambda_{Cp} = h/cm_p = 1.32 \times 10^{-13}$ cm = COMPTON WAVELENGTH FOR PROTONS

This wavelength corresponds to a frequency ν, for which $h\nu = m_p c^2$, that is equal to the energy of the complete annihilation or irradiation of the proton. Therefore we may imagine a state of matter as being associated with this wavelength which, in the first place, consists of a network of protons, or of nucleons, locked together at interparticle distances λ_{Cp} by means of standing electromagnetic waves of this wavelength and, with virtual or real pairs of positive and negative protons, as well as with electrically neutral combinations of the lighter mesons and the positive and negative electrons emerging occasionally between the nucleons. The minimum density of a star of this type, and consisting entirely of hydrogen, is of the order of 8×10^{14} g/cm^3. This type of star, in addition to regular neutron stars, must therefore also be considered as a possible candidate for the compact remnants of certain supernovae and for pulsars.

Furthermore, since there are Compton wavelengths for all elementary particles, that is the heavier nucleons, as well as for the mesons and hyperons, both stable and unstable, we are actually confronted with the choice of a very great variety of possible degenerate stars, among which, as far as my own knowledge goes, no preference can immediately be given to one or the other type. These ideas, if confirmed, open up a distressingly large field for theoreticians and observers alike.

$d_{N1} = e^2/m_e c^2 = 2.8 \times 10^{-13}$ cm = FIRST NUCLEAR LENGTH

This length corresponds to the distance at which the positive electrical potential energy between two electrons is equal to the energy of annihilation of an electron, and also approximately equal to the energy of disintegration of a neutron into a proton and an electron. On the basis of arguments not to be repeated here, Baade and I in 1934 suggested the existence of neutron stars [4] and their probable relation to supernovae and cosmic rays. These hypotheses, which for more than thirty years found little or no credence among astronomers, seem now all of a sudden quite generally accepted, mainly as a consequence of the discovery of a pulsar as the stellar remnant of the supernova of 1054 AD which gave rise to the Crab nebula.

Here another thought must be inserted. It concerns the conjectured occurrence in the universe of degenerate dense bodies which are not of the thermodynamically stable (or strictly speaking pseudostable) type which we have discussed so far, but, which exist only temporarily because of local conditions of pressure, temperature, electric fields and so on and which are more or less highly explosive when released from these conditions. I wish to emphasize strongly that this idea promises to open up an enormous field of possibilities that is as yet unexplored but which will merit our serious attention if we are to understand the manifold as yet unexplained phenomena and events in the universe.

Here only one among these unstable compact bodies may be mentioned, namely the so-called *nuclear goblins**, some of whose characteristics I have discussed else-

* As designations of nuclear goblins in other languages I have suggested lutins nucléaires (Fr), Kernkobolde (G), folletti nucleari (I), duendes nucleares (Sp) and iadernie tshortiki (R).

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where [5]. Nuclear goblins are supposed to be made up of the same type of nuclear matter as neutron stars for instance. With typical sizes of the order of one meter diameter and masses of the order of 10^{21} g they would release, when exploding in regions of low pressure or in free space, each, an energy of the order of 10^{39} erg. Goblins might exist in normal stars, or especially in white dwarfs when surrounded by pressures of the order of 10^{19} atm. When travelling accidentally towards the surface of a star or, when being expelled into interstellar space, they would explode and either cause flares in their hosts or appear as flashes in interstellar space. Scanning through tens of thousands of films and plates during my surveys for supernovae, clusters of galaxies and compact galaxies I have off and on encountered stellar images corresponding to apparent photographic magnitudes of the order of $m_p = 12$ or fainter and which, on plates taken 15 min later had disappeared, being then fainter than $m_p = 21$. I suggest that all observers who are engaged in similar survey work watch for such short duration flashes and that theoreticians consider the possibility that nuclear goblins escaping from the interior of certain stars causes them to flare, since exploding goblins can satisfactorily account for the amounts of energy released in such flares.

$d_{N2} = e^2/m_p c^2 = 1.6 \times 10^{-16}$ cm = SECOND NUCLEAR LENGTH

In contradistinction to d_{N1} we do not yet know what role this second nuclear length plays in the theory of the elementary particles of matter and the various nuclei of the atoms in the periodic system. If any type of condensed matter, in elementary particles or in condensed cosmic bodies were associated with it, the expected characteristic density of these objects would be of the order of 4×10^{23} g/cm^3. Such densities would assure any corpuscle of tremendous 'surface loading' and of a degree of penetrating power such as it is exhibited by the neutrinos. Whether or not there is any connection between d_{N2} and the values of the rest masses and densities of neutrinos probably no one can say at the present time. Equally obscure, of course remains the possibility that the ultimately collapsed objects in the universe might consist essentially of neutrinos, that is bodies which might have to be identified with what some physicists and astronomers call *black holes*, but which I personally prefer to designate as OBJECTS HADES, since they clearly cannot be holes but must be objects.

$d_0 = (Gh/c^3)^{1/2} = 4.05 \times 10^{-33}$ cm = COSMIC MINILENGTH

All that can be said at the present time about the significance of d_0 is speculative in the extreme, since we need more basic observational data, about neutrinos and gravitons for instance, as well as more profound knowledge about the nature of gravitation and of its interrelation with the electromagnetic field (unified field theory). Some suggestions may nevertheless be made which might inspire others to produce the missing links. These suggestions are firstly concerned with the following entirely nebulous conjectures 1 and 2, as well as with the somewhat more concrete ideas 3, 4 and 5.

1. *Discretization of Space*. Since the curvature of space and gravitation are related according to the general theory of relativity, a quantisation of the gravitational field

might lead to the discretization of space, subdividing it in some way into cells with dimensions of the order of d_0. It is not known to me whether or not this conjecture has as yet been formulated in any more quantitative way so as to allow predictions which might be checked observationally.

2. *Zero-Point Energy of Space.* Closely associated with the above suggestion is the conjecture that, to the gravitational radiation travelling through cosmic space there might correspond a permanent set of essentially standing waves of all wavelengths down to a value of the order of d_0, all of them representing the zero point energy content of space, analogous to the zero point oscillations in crystals or in a closed radiation space. Once we know the energy associated with any specific type of gravitational radiation the average mass density of the mentioned zero point energy could be calculated. It would of course be highly significant if it turned out to be greater than can be tolerated in any of the currently acceptable models of the universe and that therefore other causes than an actual expansion would have to be found for the universal redshifts in the spectra of distant galaxies.

3. *Sizes of the Neutrinos.* If d_0 is assumed to be characteristic for the size of the neutrino, this conjecture could be checked against our approximate knowledge of the penetrating power of neutrinos, provided that we succeed experimentally in determining their rest mass and provided that their velocity, or velocities, can be measured.

4. *Characteristics of the Gravitons.* If, in analogy to the quanta of light, the gravitons have a rest mass equal to zero, then both, the coulomb forces between two electric point charges and the gravitational forces between two masses, respectively, decrease indefinitely with the distance r between them like $1/r^2$.

Since, however, among ten thousand clusters of galaxies surveyed, there exist no clusters of clusters of galaxies and, in addition, the velocity dispersion among neighboring clusters is only of the order of a few thousand kilometers per second instead of the expected ten thousands of kilometers per second, the simplest explanation of these facts is that at indicative distances of about $\Lambda = 20 \times 10^6$ parsecs from any given mass its gravitational field declines more rapidly than $1/r^2$. Taking Λ as the Yukawa length characteristic for the gravitational forces, it follows that the gravitons, as the exchange particles corresponding to these forces, have masses of the order [6]

$$m_G = h/c\Lambda = 5.65 \times 10^{-64}\ \text{g}.$$

About the same values for Λ and m_G can be derived independently from the hypothesis that the redshift in the spectra of distant galaxies is due to the gravitational drag of light [7], a coincidence which may be viewed as numerological in nature, as long as no additional confirmations are found.

Conjecturing in addition that the diameter of the gravitons might be of the order of d_0, they then would have to be assigned a mass density of the order of 2×10^{34} g/cm^3, which would be ample to explain their immense penetrating power, but which still would leave open the possibility of shielding any gravitational field to some degree by interposing some very dense objects, such as nucleons, neutron and hyperon stars, as well as of course objects 'Hades'.

5. *Object HADES – the Ultimate Collapsed Configuration.* We assume that matter, via white dwarfs, neutron stars and other degenerate highly condensed configurations may collapse only to the limit at which the energy lost on the way, divided by c^2 becomes equal to the initial 'dispersed' rest mass m_0 that is involved. We then have for the limiting final mass, both inertial and gravitational,

$$m_f = m_0 - \text{energy lost}/c^2 = 0$$

I propose the designation OBJECT HADES for such an ultimately collapsed configuration, because nothing can get away from it. In reality, when surrounded by other matter and radiation, m_f can never quite become equal to zero, and objects HADES will have some rudimentary 'thermal life' left in them which might correspond to a state of perhaps a few degrees Kelvin above absolute zero.

As to the internal composition and constitution, it may be conjectured among other possibilities, that object HADES is a cosmic ball of 'standing electromagnetic waves' which hold each other in place by their quantized masses $h\nu/c^2 = h/c\lambda$, where $\lambda_{\min}$ might be possibly of the order of the cosmic minilength d_0, and thus the maximum quantum in the zero point radiation complex would be $h\nu_0 = 5 \times 10^{16}$ erg.

At this perfectly enormous maximum energy of the light quanta, these may of course be expected to violate the superposition principle and the resulting interactions between them will endow object HADES with an inhomogeneous mixture of a multitude of neutral and of charged particles, such as gravitons, leptons and baryons. Just what the composition of this mixture, as well as its energy spectrum and that of the zero point electromagnetic radiation might be must obviously be left to a future analysis, which can be attempted successfully only after we have gained much more knowledge on the nature of the gravitons, the neutrinos, mesons and all of the other elementary particles as well as the physical laws which govern their interactions.

As to a possible observational search for objects HADES I have long ago suggested [8] the use of full size objective gratings mounted on large Schmidt telescopes and also inserted in the parallel beams between the components of zero correctors of large reflectors. What one may expect to see in the case of dead neutron stars and objects HADES is of course not their own light but light from surrounding sources bent around them towards the observer (see gravitational lens effects [9]).

4. Miscellaneous suggestions Concerning Extended Electric Charges and Fields

Magnetic fields in stars and galaxies have been considered ad infinitum in astrophysics, although little or nothing fundamental has been written about their origin. I hope to discuss some relevant ideas about this subject in another place.

The possible occurrence and the analysis of extended distributions of electric charges and fields, on the other hand seems to have been largely neglected, although they no doubt play an important role in some cases. For the reasons indicated in the following, more or less extended regions in both cold and very hot bodies may carry net charges which may materially influence the internal characteristics of these bodies and their interactions with other cosmic bodies.

In hot stars, for instance, large numbers of positive and negative electric charges may get separated as a consequence of the interplay of fluctuations in the heat content and the electrical potential energy. I think it can be shown that this separation of electrical charges, which occurs in all dimensions, starting from interatomic or interionic distances to the existence of net charges on almost any two hemispheres of a star may in some cases require significant alterations of the equations of state which so far have been overlooked or disregarded.

Net total electric charges can clearly be carried by solids, starting from interstellar dust particles up to meteors, asteroids, small planets and bodies of the size of planets and possibly greater.

The fundamental question immediately arises as to the sizes up to which conducting, respectively no-conducting insulating spheres can carry charges, such that the coulomb forces between them are greater or equal to their mutual gravitational attraction. Disregarding here insulating bodies, that is the possibility of having a net charge frozen in their interior, we consider only solid spheres carrying a uniformly distributed electric charge on their surface. Assuming that cold electron emission would set in if the sphere were charged up to 10^9 V, the corresponding critical size of the spheres, at an average density of 1 g/cm^3 would be about 1 km.

If therefore no interstellar plasma, compensating the net charge, is carried along by our 'planetoids' of 1 km diameter their electrical and gravitational interactions would be of the same order of magnitude.

Any tests of the general theory of relativity, using observations of the orbits of freely flying projectiles launched from the earth, or of planetoids like Hermes, Icarus, Halleria, Berna and Glarona, whose diameters range from 100 m to about 20 km, are therefore subject to severe objections. Even the interpretation of the perihelion motion of Mercury would seem to be in doubt if variable net charges are considered as well as line-up of electric forces differing in time and space from those due to gravitation.

As to continuing the search for as yet unknown types of cosmic objects, a discussion comes to my mind which, about thirty years ago I had with Professor C. G. Darwin. Driving him from Pasadena to the Palomar Observatory, just after having discovered a number of supernovae and the Humason-Zwicky stars, I suggested in my enthusiasm that probably one new cosmic object could be discovered every day for many years to come. Darwin responded in his typically British manner "Then, why don't you?".

Considering the number of supernovae, peculiar faint blue stars and possible pygmy stars, the pulsars and neutron stars, the gnome, pygmy and dwarf galaxies, the compact galaxies, the radio sources and quasars and the intergalactic matter discovered since, my estimate in 1939 was not too far off the mark.

If the generation following us is still of a mind of trying to discover one new cosmic object every day, Darwin's remark may accompany them on their way "Then, why don't you?".

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