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Some Critiques of the Big Bang Cosmology

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Abstract. Still more shocking than the metaphysical assumption of some initial singularity, is the constant insistence upon the so-called cosmological principle of "homogeneity" and "isotropy" of the Universe. Observations do contradict this principle. And to me, the inhomogeneous, fractal at least on a certain scale range, of the distribution of matter is in itself an important cosmological fact, hitherto almost neglected. Moreover difficult-ties as to the applicability of the second principle of thermodynamics, observations of abnormal redshifts, etc., are casting large doubts not only upon the standard cosmological models, but even on the interpretation of the observed redshift as due solely to a universal expansion.

Key words. Cosmology—Big Bang.

1. The initial singularity

My own doubts concerning the Big Bang are very ancient. Already, in 1957, when Paul Couderc, Evry Schatzman and myself published "*L'Astronomie au jour le jour*" (Couderc *et al.* 1957), Paul Couderc was very much in favour of the Gamow's Universe, whenever I had my doubts, then expressed in a non-signed footnote to the chapter written by Couderc.

I had been rather shocked indeed, two years earlier, in Roma, by the equation: The "fiat lux" equals the "big bang" – implied by a long discourse, fiercely put in front of the IAU by the Pope Pius the XIIth (1951, 1952). So far, it was a question located in the realm of nonscientific disputes. But clearly, the metaphysical implications have been of a great weight to push some in the direction of the big bang, some others, like Einstein himself, definitely against... These non-scientific arguments are of course not valid. But we should be conscious of their huge impact.

Even admitting the reality of Hubble's expansion, it meant that it was taking place **now and here,** nothing more. Is an extrapolation of the present expansion to the past possible? Einstein's solutions (1917) of the GR equations introduce *a priori* a cosmological constant Λ, and the "cosmological principle" of homogeneity and isotropy (with no other justification, let us face it, than somewhat metaphysical: the stability, infinity and simplicity of the universe). But it contradicts the Hubble's law, if the latter is interpreted in terms of velocities. By equating Λ to zero, we readily obtain the Friedmann's solutions (1922, 1924); they fit the Hubble's law, and describe energy density as infinite. But, indeed, the cosmological principle is obviously wrong. No extrapolation of the Hubble's law should be excluded, so long as we have not reached definite solutions of the GR equations for a partly hierarchical universe, far from homogeneous.

The Hubble's findings had little influence upon our views of the Universe as a whole, until Gamow, Alpher & Herman had the idea that the "infinite" (or at least very large) density reached by the models of Friedmann and Lemaître, near time $t = 0$, could allow him to build the elements from nucleosynthesis. Their followers, immediately, and still more after the serendipitous discovery of the background 3°K radiation, so-called "cosmological" , did not hesitate to speak of a "time zero", of the "first minutes of the universe", etc., thus casting a large metaphysical shadow upon a theory otherwise reasonable.

2. Non-homogeneity of the Universe

But was it reasonable to accept the theoretical basis of Friedmann (1922, 1924) and Lemaître's equations, even that of Einstein (1917)? These equations, their solutions (that we call "standard cosmology)" were indeed stemming out from the Einstein's Equations of the GR. Not actually from the equations themselves, but also, from the use of the Robertson-Walker metrics, and from the cosmological principle. But the cosmological principle looked, to me and to others, as soon as in the sixties, quite untenable. Of course, the universe we see (Fig. 1) is not the whole Universe. At a much larger scale, it may be homogeneous…. So people say, to justify for the standard solutions. But, on a very large range of scales, it is certainly not the case. As well argumented by de Vaucouleurs (1970), the hierarchical structure of the Universe is clearly established (Fig. 2), on an extremely large scale of densities and sizes of structures.

This large departure from homogeneity appears indeed as a striking fact. To Alfvén (1981), it even appeared as the main argument against the big bang. To him, the cellular structure of the Universe was obvious and could not be understood in the standard theory.

Can we reconcile this perhaps local inhomogeneity with the large scale homogeneity that is claimed by the proponents of the standard model, on the basis that, at larger scale, the homogeneity and isotropy of the 3° radiation is clearly established? "Yes", was the almost unanimous reply - (provided, should we add, it is not of a relatively local origin).... Everyone recognised, by the way, the inhomogeneity at small scale, as an obvious observational fact. But the reply to the difficulty was simple: Weinberg (1971), in his book *Gravitation & Cosmology,* wrote: "Of course , the homogeneity of the universe has to be understood in the same sense as the homogeneity of a gas: It does not apply to the universe in detail, but only to a "smeared-out" universe averaged over cells of diameter 10^8 or 10^9 light-years, which are large enough to include many clusters of galaxies. Also it appears that the universe is spherically symmetric about us, so included in the Cosmological Principle is the assumption that the "smeared" universe is isotropic about every point "... At the opposite, Alfvén (1981) claims that: "Whereas the big bang cosmology is based on a four-dimensional, essentially homogeneous model, the new paradigm approach is based on an Euclidian model, reconcilable with Charlier-de Vaucouleurs model. General Relativity should introduce a correction, which only in rare cases is likely to exceed 10%.".... Without perhaps going as far, I feel we must agree with the first part of this last statement.

I feel therefore that this reply "Yes, the universe may be treated as homogeneous" is not satisfactory, even if the isotropic radiation at 3°K is cosmological in nature.

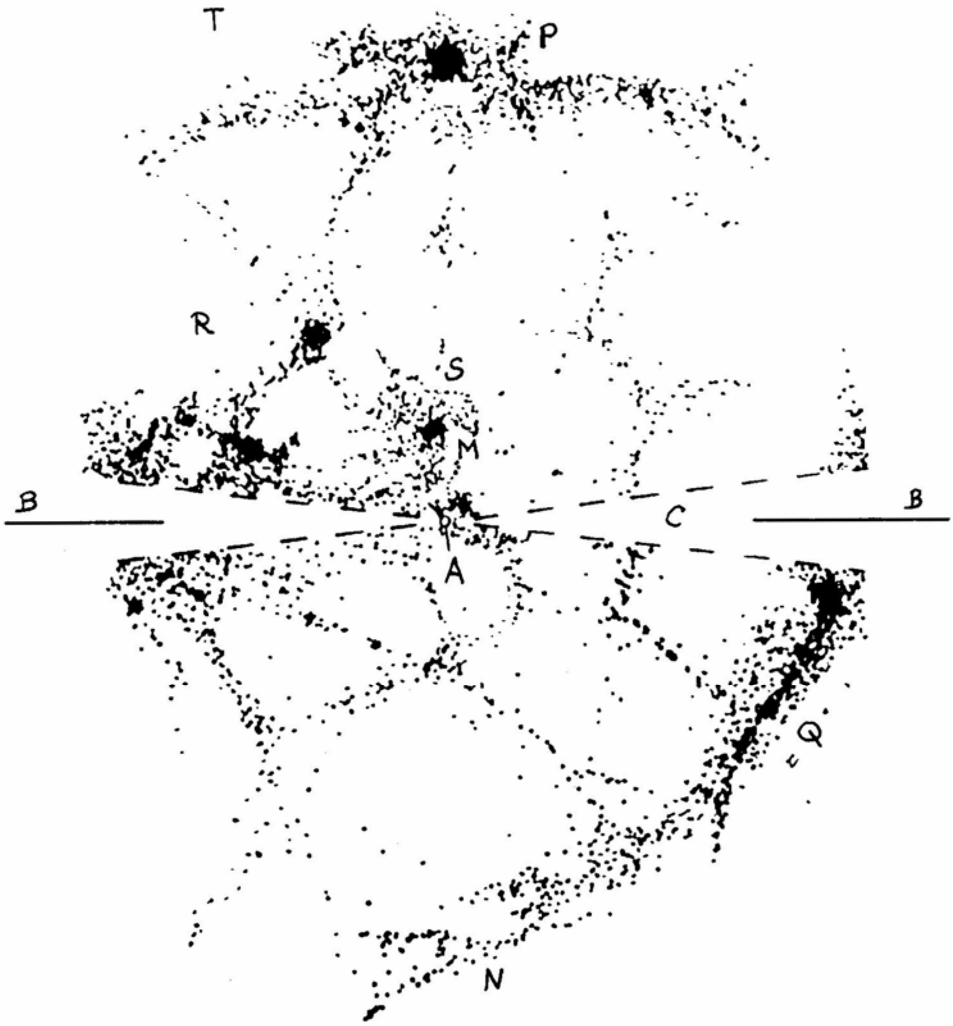

Figure 1. (Adapted from P. Léna, *Les Sciences du Ciel,* 1996, Flarnmarion éd., Paris, p. 574). Distribution of galaxies projected perpendicularly to the galactic plane. **A**: Our Galaxy; **B**: Plane of our Galaxy; **C**: Regions obscured by the Milky Way; **M**: Virgo cluster; **N**: Sculptor cluster; **P**: Coma supercluster; **Q**: Perseus-Pisces supercluster; R: Hydra-Centaumis supercluster; **S**:Virgo Supercluster; **T**: The whole spherical supercluster of galaxies.

We must indeed solve the GR equations, taking into account, at least between the scale of the neutron stars and that of the large scale (not yet observable) Universe, the existence of a hierarchy of structures. We know how to make $\rho =$ cst in the GR equations. But how to make $\rho = \rho(R)$, we do not know; one can only guess intuitively a few things: the equations written for a certain density show us that a wholly dense Universe has a "life-time" shorter than a wholly non-dense Universe; this implies that non-dense regions expand slower, and that H there must be smaller. It implies also that H_i, as measured using a given galaxy G_i, is an average $\langle H \rangle$ over the true, local H, which varies from point to point in the Universe – even from author to author.... This idea was developed without much echo (Pecker,

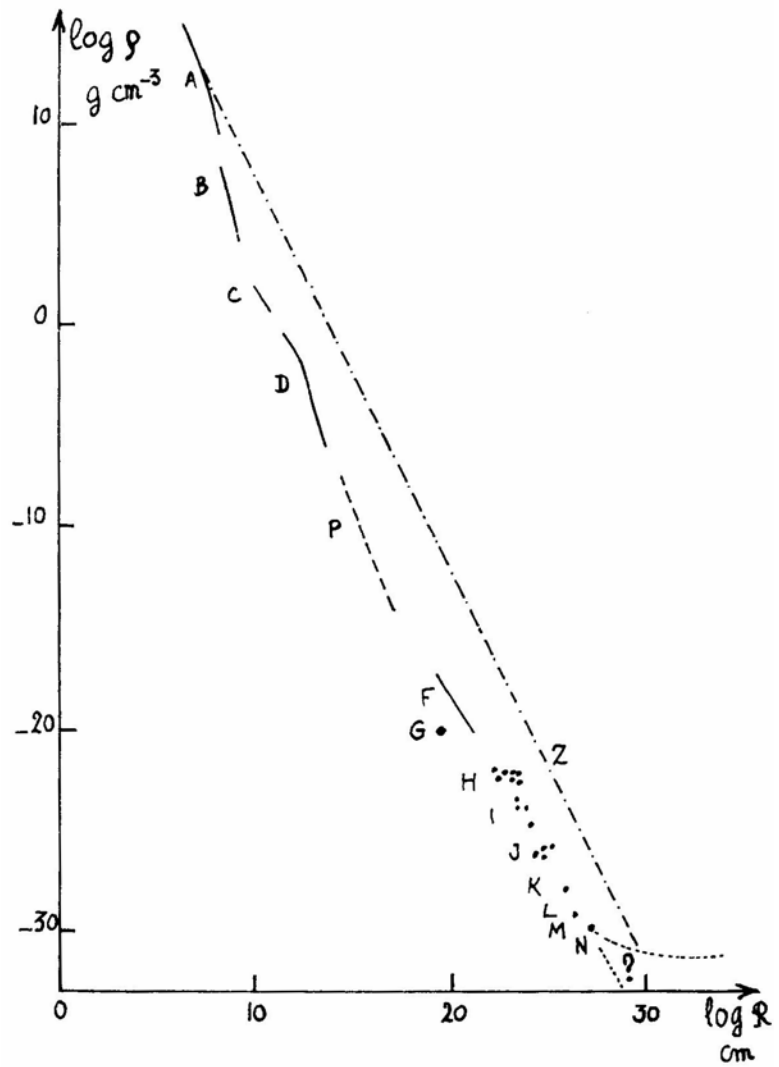

Figure 2. (Adapted from de Vaucouleurs, 1970). The hierarchical distribution of matter in the Universe. **A**: neutron stars; **B**: White dwarfs; **C**: Main sequence stars; **D**: Supergiants; **E**: Protostars; **F**: Compact galaxies; **G**: Globular clusters; **H**: Spiral galaxies; **I**: Compact groups of galaxies; **J**: Normal groups of galaxies; **K**: Large clusters; **L**: Local supercluster; **M**: Hubble-Mayall-Sandage "nearby region"; N: Lick counts; Z: Schwarzschild limit (above which collapse occurs). The hierarchy rules (at least) from log $\rho = 10^{10}$ to log $\rho = 10^{-30}$.

Vigier 1976). Let us admit in addition that a certain type of continuity physics must apply, and that the evolution cannot lead to inversions of the hierarchy, or in other terms that the $d(t)$ curves cannot cross each other, the d-curves representing the distance to us of any given region of the Universe as a function of time. If this is indeed the case, there is a limit (for these continuity reasons) that cannot be by-passed by the large structures, when they go through their minimum size (Fig. 3). Hence, only the smaller structures could endeavour a state of almost infinite density and temperature – stellar black holes? Black holes of higher mass are

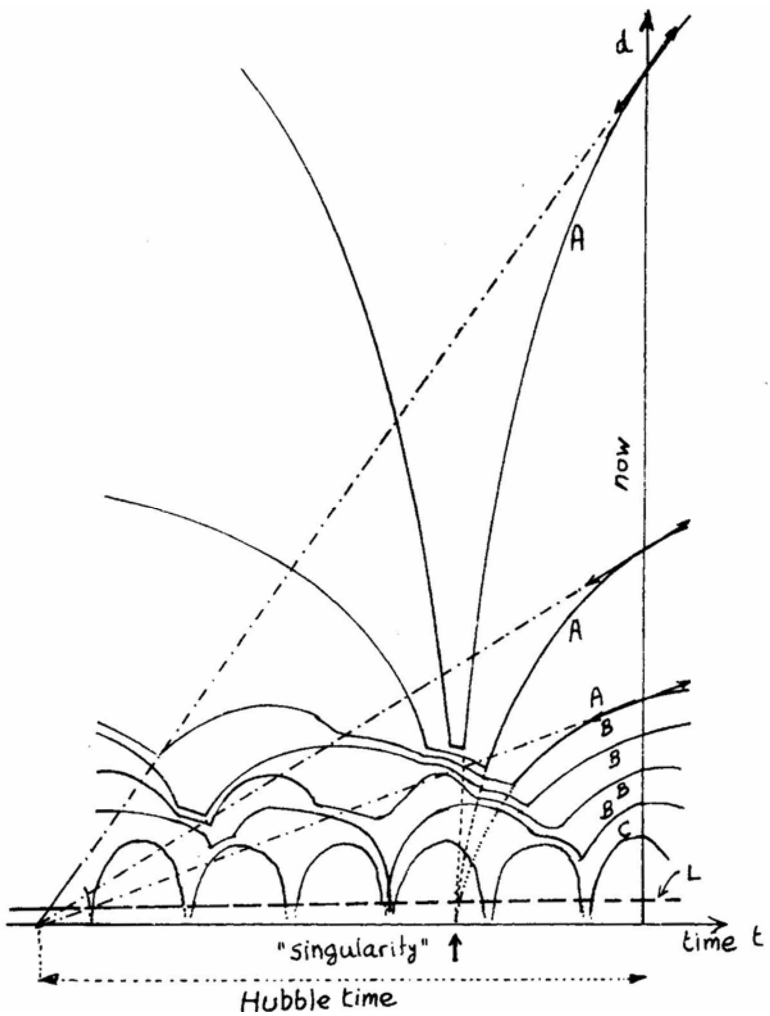

Figure 3. A possible solution of the GR equations in a partially hierarchical Universe. **A:** Friedmann's solution at a very large scale, in a homogeneous Universe. The dotted part of the curves corresponds to the part we reject, and ends at the classical singularity of standard models; **B:** Solution in the successive steps of the hierarchical distribution; **C:** Friedmann-type solution for the small scale objects (evolving into black holes, at a point such as P?); **L:** Limit of validity of classical GR physics.

there of course, much less numerous, but they do not reach an "infinite density" either.... This state of affair covers 40 orders of magnitudes in size, and forbids entirely the classical concept, where the singularity occurs everywhere at the same time. Even admitting that, at a *very* large scale, the universe is homogeneous, I do not see therefore how it could have been, or become, homogeneous at a small scale, and I see no other alternative than the one suggested by the Fig. 3 (see also Pecker 1988).

This is certainly not a "big bang" Universe! But I admit I may be quite wrong in my intuitions…. And I could refer to Souriau, to Nottale, to others..., and notably to

Narlikar, and Burbidge (this meeting) who propose quasi-steady state Universes, without singularity, based on different principles, but compatible with the GR.

3. The arbitrary choice of the "significant" facts

We shall use the word "old big bang" to designate the big bang admitting a singularity. Its proponents told us that three "cosmological facts" are well accounted for by the theory: the Hubble's linear law; the existence of a background radiation, isotropic of quasi-so, and the composition in light elements, H1, D2, He3, He4, Li7..., of the Universe. So simple! No other fact is indeed taken into account. Some add however the Olbers paradox as a fourth experimental argument. In front of them, some found that the non-homogeneity of the Universe is much more an obvious fact, on a very large scale interval, non accounted for by the old big bang.

We should note that the three "basic facts" of the classical Big Bang seem not so very well established: (**i**) Segal and Nicoll (1986 for example) have advanced many strong arguments in favour of a non-linear law between the redshifts and the distances, (**ii**) The background isotropic radiation may well be that of a local field of radiation, up to optical depth equal, say, to 1, in the millimetric radiation, not linked to the time where the matter and radiation decoupled from each other. We should mention it was predicted in 1954, not only by Gamow *et al.* but, with a better accuracy (!) by Finlay-Freundlich (1953, 1954) and Max Born (1954), on the basis of a tired-light mechanism. Let us not forget also that Eddington had also predicted a 3°K radiation, on the basis of the computation of the quantity of radiation produced by stars and its distribution in space. Several other authors found similar results. (**iii**) The helium or lithium abundances measured only in the rather near vicinity of our Galaxy may well be either very local, and/or strongly altered by migrations or diffusion phenomena. To quote just one of these, a forming galaxy, may, when rotating and flattened, accrete matter in the equatorial plane, but expel hydrogen from its poles, due to the radiation pressure of the Lyman hydrogen continuum, and to Lyα line, – whenever He II, or He I are trapped, because all the radiation that could expel them is used to ionise the hydrogen. A rough computation (Pecker 1972) has shown that this effect is far from negligible and may enrich strongly the galaxy in helium, (**iv**) As to the Olbers paradox, one knows that it can be understood in practically all cosmologies, be they static or not. The Charlier hierarchical construction was intended for that very purpose. Still more, the comparable gravitational paradox of Seeliger (1894, 1896) finds an easy solution in an hierarchical Universe, and is much more difficult to account for in "old big bang" theories.

The alternative cosmologies are perhaps not as "simple" as the big bang. For purely philosophical reasons, the tenants of the big bang, having in their hands the famous Occam's razor, were reluctant to accept that the Universe may be unnecessarily complex. To me, the argument of simplicity is a Pythagorician argument, which cannot convince.

I see no reason why the Universe should be "simple". I see no reason why it could be "homogeneous", even at a large scale, *a priori.* I see no reason why it should admit "singular" points, with "infinite" temperatures or/and densities.

Of course, many people were aware of these difficulties. In particular, in the reference frame of the old big bang, it was difficult to reconcile the isotropy of the background (so-called "cosmological") radiation , and the anisotropy and inhomogeneity of the observable universe. The "inflation theory" was invented for that very purpose. Therefore the "new big bang", which eliminates the "singularity", on the basis that the physics of the early instants is different from that of the GR equations, at very high densities, brings a reply. And obviously the new big bang has no more such an obvious metaphysical connotation as the old one.... Actually, without noticing it really, we have seen a soft, but essential, passage from the "old big bang" to the "new big bang".

Another much discussed argument came from the fact that the age of the stellar clusters (15 billion years, possibly more) seems to be larger than the "Hubble's age" ($t = 1/H$, – in proper units, i.e. around 10 billion years). The inflation does not give a reply to that fact; but the discussion on the value of H is still vivid, as we shall see these days. In any case, as I do not accept the standard cosmology, this argument does not seem to me very strong. After all, (except if we accept to use drastically the Occam's razor) why should we not use a cosmological constant Λ different from zero, and even varying from place to place (Narlikar *et al.* 1991) and from time to time? In any case, it was generally recognised ever since the eighties that the very early instants ($t < 10^{-43}$ s) of the Universe of the old big bang had no physical reality; that one should invent concepts such as the Grand Unification theory or even the Supersymmetry to describe them. I shall only note that this is rather artificial, linked only to the development of the group theory. The latter which, if it predicts correctly, so it seems, the number of quarks, and gluons, and the number of interactions, does not predict at all the distribution, very difficult to understand, of their masses – to quote only an example – showing thus the fact that these theories, that little experimental facts sustain, are still in the infancy. I wish them a bright future…. But I am not quite sure they are at all relevant when one speaks about the Universe.

The "new big bang" appears indeed similar to the "old big bang", but full of scars and repairs, complexifications and perhaps improvements; it is by no means "simple". But the shift to the "new big bang" implies nothing at all as to what happened really before the "early instants". One can admit that, such as proposed, I believe for the first time, by Narlikar (see for example Narlikar 1988), we had then to face a "quantum universe", the physics of which we know practically nothing... The "new big bang", similar in its observable consequences with the old one, has philosophically nothing to do with it…

The fact that we tend to reject the need for a "simple" explanation to observational facts, lead us to consider the debate about the "age of the universe" vs the value of the Hubble constant, or the debate about the so-called "missing mass", as completely irrelevant debates. For us, there is no reason why the present rate of measured expansion would reflect any age of the Universe, no reason why the average density of our Universe could even be defined, and if defined, why it should be close to the critical density of the Friedmann's models ….

4. The second principle of thermodynamics has to be verified

Who doubts the second principle of thermodynamics? The nucleosynthesis of helium from hydrogen seems to be an irreversible process, which orients, so to say, the arrow of time. Hubert Reeves has been using extensively, in his lectures, the argument that, as there is still some hydrogen in the Universe, it proves that the Universe had a finite duration, since the apparition of hydrogen in it, from more primordial particles, at least.

It seems to me that this question has received only very small attention. In the theory of oscillating universe, Tolman indicated clearly that the increase of entropy of the Universe would give to the maximum radius of curvature of successive phases of the universe an increasing size. Can we. apply the second principle to the Universe? No "closed box" can indeed be conceived, as soon as gravitation enters the picture! An important cosmological principle, rarely expressed, but always implied, is: "there is no wall against gravitation". But if we do consider the Universe as a whole, as defined as all what exists, then its entropy must increase. There are two ways to turn around that dilemma. One has been followed for example by Lukash & Novikov (1987), which assumes a multiplicity of mini-universes, ours being affected by expansion, and having no connection now with others. But at a time in the past, they may have been connected; or they may reconnect in the future. Another way to look at things, perhaps simpler, is to imagine that, locally, the arrow of time is well defined, but that some singularity in the space-time, or some domain avoided by the real Universe, may give place to a restoration of "neguentropy". Actually, these problems are far from easy. The appearance of life (i.e. neguentropy) on a planet, its eventual disappearance, may well occur without much gain of entropy as a final result. Who has established a proper balance of this process? I do not know the reply.

5. Abnormal redshifts

Even when assuming that the redshifts are measures of a recession velocity, and of such a quantity only, one thus finds difficulties both in the old or in the new big bang. They have been several times reviewed by the author (see Pecker 1977, 1988), notably on the basis of the use of the Hubble-Tolman tests (1935). These tests (La Violette 1986) seem to favour definitely the hypothesis of the "tired-light" mechanisms. One can however argue *ad infinitum* about the applicability of these tests.

I even see no reason why it should be expanding continuously (as assumed by the quasi steady-state Universe), or even now and here. When further reading the basic papers (from the late twenties to the early fifties), I noted that Hubble himself, even when the z-values where hardly 0.4 at the most, spoke about the "*apparent velocities*" of recession of the galaxies. That the redshifts discovered by Slipher could be interpreted in terms of recession velocities was of course a possibility; but, even to the eyes of Hubble, it was daring to tell it was the only possible one.

We do not know from physics whether other processes of redshifting light exist or not. Of course Compton effects are known, but they could not provoke such large redshifts. However a careful examination of observations leads us to believe that some redshifts cannot be accounted for by recession velocities. The existence of "abnormal" redshifts in the extragalactic Universe (see Arp, this colloquium) has been amply justified, in my eyes. Let us quote a few examples: (**i**) the limb effect of the solar spectrum, where an excess of redshift over the effect of the gravitational field was noted by the Oxford observers, Adam and others (1948, 1959), and by Roddier (1965); (**ii**) the strong redshifts observed in the light of objects eclipsed by the Sun, when the light crosses the vicinity of the Sun, effects that we have systematically studied in several papers; (**iii**) the extreme dispersion of redshifts in active galaxies and quasars of the same apparent magnitude, as often noticed, by the Burbidge's notably; (**iv**) the differences of redshift between galaxies of different morphologies, in the same groups, as shown by many observers, including us; (**v**) the large periodicities recognised several times (for example, in my group, by Depaquit *et al.* 1985) and carefully checked in the distribution of the redshifts of quasars; (**vi**) the smaller periodicities discovered by Tifft (1976, 1988) in some clusters of galaxies, later rediscovered by different analyses by Napier and Guthrie (1988), and by Arp (various references); (**vii**) of course, the so many cases of strange associations of objects at different redshifts, such as observed by Arp, Sulentic (1988) and others, in the extragalactic world….

One can always consider these observations as spurious…. Some have been often criticised, and sometimes on sound basis. But it should be done in the detail, for *each* of them. A *single observed undisputed fact* of the sort we just mentioned is underlining the *need for other mechanism*(*s*) *for redshift* than only the recession velocity….

What is then this other needed redshifting agent? If not the velocity, either some redshift at the time of emission of photons, as suggested by Arp, or some interaction of photons from the source with space or in other terms with other particles of the so-said empty space, which might be the Dirac's vacuum, and which is anyway crossed in all directions by gravitational waves, by neutrinos, etc..? I admit that several of the proposals made for that interaction are not adequately founded; but it is nevertheless clear to me that the Doppler effect, at those large velocities, has no reason to be the only redshifting agent. The very geometry of the space-time may have a redshifting effect upon the photons, as suggested by Segal and coworkers. Other suggestions were made, by Hoyle (1972), by Canute and coworkers (1978), by Jaakkola, by Arp, by Hoyle & Narlikar, etc. We cannot eliminate them without stronger arguments than those offered to us up to now.

Let us note in particular the discussion about the photon restmass m_γ To be subject to any "tiring" effect, it should have a non-negligible mass, that we know from experiment to be less than 10^{-54} g (probably still less)…. But assuming the mass of the photon to be strictly zero, is it not a much stronger assumption than to let his mass unknown? Only the group theory of elementary interactions and its developments tell us so…. But is it not an undue use of the Occam's razor, which tends to eliminate new "paradigms", to use the Kuhn-Alfvén terminology? Had we used in the past the Occam's razor, as some use it now (first to assume $\Lambda = 0$, then to assume $m_\gamma = 0$, although the second assumption is much more acceptable than the other!), we could as well have passed beside of the gravitation (G = 0?) or of the quantum physics ($h = 0$?)…. The Occam's razor may be a useful trick in fields where we are sure to deal with classical laws. In cosmology, we are sure of the reverse.

So far, the only argument that could be found against the steady-state Universes could perhaps come from the evidence of some galactic evolution between, say, $z = 5$ and $z = 0$. But the quasi-steady state Universe can account for that evolution, being, in some way, tangent to the big bang universes in that interval. The LST (Hubble telescope) seems to have shown the existence of such an evolution. To me, it is the strongest argument, *if confirmed*, in favour of the local expansion.

But, in any case, I feel that an open mind and good systematic observations without preconceived views, are still much better than the use of an old rusted razor, on the path of discovery and understanding.

6. Discussion

Patrick Dasgupta

Q: Although it is right that Universe is inhomogeneous on scales less than 100 Mpc, radio astronomers also have shown that the number of radio sources in a box of size 10^9 pc is constant within statistical fluctuation when the box is shifted around. This suggests that universe is homogeneous on scales of 1 Gpc.

A: I do not object to homogeneity at “some” scale. I just wanted to emphasize that, if hierarchy is there between two extreme scales (stellar vs supergalactic), it is enough to exclude a “singularity” universe.

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