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Non-standard models and the sociology of cosmology

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ABSTRACT

I review some theoretical ideas in cosmology different from the standard "Big Bang": the quasi-steady state model, the plasma cosmology model, non-cosmological redshifts, alternatives to non-baryonic dark matter and/or dark energy, and others. Cosmologists do not usually work within the framework of alternative cosmologies because they feel that these are not at present as competitive as the standard model. Certainly, they are not so developed, and they are not so developed because cosmologists do not work on them. It is a vicious circle. The fact that most cosmologists do not pay them any attention and only dedicate their research time to the standard model is to a great extent due to a sociological phenomenon (the "snowball effect" or "groupthink"). We might well wonder whether cosmology, our knowledge of the Universe as a whole, is a science like other fields of physics or a predominant ideology.

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1. Introduction

The present-day standard model of cosmology (the "Big Bang") gives us a representation of a cosmos whose dynamics is dominated by gravity (from general relativity), with a finite lifetime, large scales homogeneity, expansion and a hot initial state, together with other elements necessary to avoid certain inconsistencies with the observations (inflation, non-baryonic dark matter, dark energy, etc.). Although the Big Bang is the most commonly accepted theory, it is not the only possible representation of the Cosmos. In the last ~ 90 years—such is the brief history of the branch of science called cosmology—there have been plenty of other proposals. I describe them in Section 2 of this paper.

Cosmologists do not usually work within the framework of alternative cosmologies because they feel these are not at present as competitive as the standard model. Certainly, they are not so developed, and they are not so developed because cosmologists do not work on them. It is a vicious circle. The fact that most cosmologists do not pay them any attention and only dedicate their research time to the standard model is to a great extent due to a sociological phenomenon. In a second part of the paper, Sections 3 and 4, I will discuss the sociological aspects related to cosmology and the debate on the different theories.

2. Alternative models

Although the standard model ("Big Bang") is the most well known and commonly accepted theory of cosmology, it is not the only possible representation of the Cosmos, and it is not clear that it is the right one, not even in an approximate way (for a discussion of some of its problems see López-Corredoira, 2003, and see also below in Section 2.5). There were and there are many other alternative approaches to our understanding of the Universe as a whole. Among them, because of its historical importance and impact, the quasi-steady state model and plasma cosmology are significant examples. There are many other examples too. I will give a brief description of them in this section. I will not give a complete list of models, but this sample is large enough to give an idea of what theoretical approaches are being discussed in cosmology from heterodox standpoints: either from dissidence with respect to the standard model, or dissidence with respect to the dominant dissident theories.

2.1. Quasi-steady state cosmology

The theory (better call it a hypothesis) which is called nowadays the "quasi-steady state cosmology" (QSSC) was indeed first

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called the "steady state theory". Hoyle (1948), and independently Bondi and Gold (1948), proposed the hypothesis of the steady state in which, contrary to the Big Bang approach, there was no beginning of the Universe. The Universe is expanding, it is eternal and the homogeneous distribution of matter is being created at a rate of 10^{-24} baryon/cm^3/s, instead of the unique moment of creation in the Big Bang. The perfect cosmological principle of a Universe which is observed to be the same from anywhere and at any time is followed in this model, whereas the standard model only gives a cosmological principle in space but not in time. There is no evolution. The Universe remains always the same. Newly created matter forms new galaxies which substitute those that are swept away by the expansion.

Fred Hoyle (1915–2001) inadvertently baptised the rival theory: he dubbed the primaeval atom theory of Gamow and coworkers[1] the "Big Bang" in order to ridicule it. However, the name caught on. During the 1950s, both theories held their ground. While there were attempts to explain the abundances of the chemical elements with Gamow et al.'s theory, the Steady State Theory also provided plausible explanations. Burbidge, Burbidge, Fowler, and Hoyle (1957) explained the abundances of the light elements (helium, lithium, deuterium [an isotope of hydrogen] and others) in terms of stellar nucleosynthesis and collision with cosmic rays in the remote past of the Universe. The heaviest elements could also be explained in terms of stellar rather than primordial nucleosynthesis, and the defenders of Big Bang in the end also had to adopt the stellar nucleosynthesis of Burbidge et al. for the heavy elements.

Nonetheless, the steady state theory would lose competitiveness by the mid-sixties, because it could not explain certain observational facts. It could not explain why the galaxies were younger at higher redshift. It could not explain the excess of radio sources at large distances (Ryle & Clarke, 1961), nor the distribution of quasars. Most importantly, it did not explain the cosmic microwave background radiation (CMBR), discovered in 1965 by Penzias and Wilson.[2] This strongly favoured the Big Bang theory.

In 1993–1994, Hoyle, Burbidge, and Narlikar (1993, 1994)[3] published a modification of the model that was called the "quasi-steady state" theory. The main modification consisted in positing an oscillatory expansion apart from the exponential term:

$$a(t) \propto e^{t/P}[1+\eta \cos(2\pi\theta(t)/Q)].$$

$P \sim 10^{12}$ years, $\theta(t) \sim t$. The exponential factor had already been introduced in the first version of the Steady State model to keep $\dot{a}/a =$ constant and consequently maintain a constant density of matter by invoking the continuous creation of matter. The new term here is the sinusoidal oscillation. The creation of matter is confined to epochs with minimum $a(t)$ rather than being continuous. The parameter Q and η would be determined from Hubble's constant, the age of globular clusters and the maximum observed redshift in the galaxies. With this model, some of the problems that affected the original theory of 1948 were solved. This explained why there are younger galaxies at higher redshift, the problem of the radio sources, the distribution of quasars (with lower density for $z \gtrsim 2.5$), the formation of large-scale structure (Nayeri, Engineer, Narlikar, & Hoyle, 1999).

The CMBR and its blackbody spectrum would be explained as the effect of the thermalisation of the radiation emitted by the stars of the last cycle $P/3$ due to absorption and re-emission that produce needle-shaped particles ("whiskers") in the intergalactic medium. Due to the long distance travelled by the photons in the maxima of the oscillation and due to the thermalisation that occurs at each minimum, there is no accumulation of anisotropies from one cycle to another. Only the fluctuations of the last minimum survive, which gives fluctuations of temperature comparable to the observed $\Delta T/T \sim 5 \times 10^{-6}$. First, the carbon needles thermalise the visible light from the stars giving rise to far infrared photons at $z \sim 5$, keeping the isotropy of the radiation. Afterwards, iron needles dominated, degrading the infrared radiation to produce the observed microwave radiation (Wickramasinghe, 2006). The anisotropies of this radiation would be explained in terms of clusters of galaxies and other elements (Narlikar et al., 2003, 2007).

Concerning the origin of the redshift in the galaxies, the proposers of this model admit a component due to the expansion $a(t)$, like in the Big Bang, but furthermore they posit the existence of intrinsic redshifts. This allows the solution of problems such as the periodicity of redshift in quasars, and the possible existence of cases with anomalous redshifts (López-Corredoira, 2010). The total redshift would be the product of both factors, expansion and intrinsic:

$$(1+z) = (1+z_{\rm exp.})(1+z_{\rm int.})$$

The intrinsic redshift is explained by means of the variable mass hypothesis. Hoyle and Narlikar (1964) derived this hypothesis from a new gravitation theory based on Mach's principle with the solution that the Minkowski metric and the particle mass depend on time as $m \propto t^2$. This variable mass hypothesis is used by the authors of QSSC to explain cases of anomalous redshifts, but it is not part of the main body of the hypothesis QSSC, that is, it is optional; QSSC can be conceived without the variable mass hypothesis. The intrinsic redshift would be due to variation of the energy of the emitted photon when the masses of protons and electrons vary:

$$(1+z_{\rm int.}) = \frac{m_{\rm observer}}{m_{\rm source}} = \frac{t_0^2}{(t_0 - r/c)^2}.$$

In the case of quasars, anomalies in the redshift would be observed because the mass of their constituent particles grows proportionally to $(t-t_{quasar})^2$ instead of t^2 (Narlikar, 1977; Narlikar & Arp, 1993).

Summing up, they proposed a model which aimed to compete with the standard "Big Bang" theory but with a very different description of the Universe. According to the authors, QSSC is able to explain the existing cosmological observations, at least in an approximate way, and it can even explain some facts that the Big Bang model does not explain (such as the anomalies in the redshifts of quasars). It also contains predictions different from the standard model, though these are difficult to test. The predictions include (Narlikar, 2006): existence of faint galaxies ($m > 27$) with small blueshifts ($\Delta z < 0.1$), the existence of stars and galaxies older than 14 gigayears, an abundance of baryonic matter in ratios above those predicted by the Big Bang, and gravitational radiation derived from the creation of matter.

[1] George Gamow (1904–1968) and one of his students, Ralph Alpher, published a paper in 1948. Gamow, who had certain sense of humour, decided to put the reputed physicist Hans Bethe as second author, even though he had not participated in the development of the paper. Bethe was amused, so the result was a paper by Alpher, Bethe and Gamow (to rhyme with "alpha, beta and gamma"). Later, R. C. Herman joined the research team, but—according to Gamow—he refused stubbornly to change his name to "Delter".

[2] Indeed, the radiation had been discovered previously, but Penzias and Wilson, adviced by R. H. Dicke et al., interpreted it in cosmological terms (Dicke, Peebles, Roll, & Wilkinson, 1965). In the old Soviet Union, Shmaonov (1957) had made measurements at a frequency of 9 GHz of a background radiation that was isotropic and had an antenna temperature of 4 ± 3 K. There were also previous measurements by Japanese teams, and indirect measurements of the existence of radiation of ~ 2.3 K by MacKellar in 1941 with the spectral analyses showing excitation of rotational transition of cyan molecules (Novikov, 2001).

[3] See also Hoyle, Burbidge, & Narlikar (2000) or Narlikar, Burbidge, & Vishwakarma (2007) for a complete development of the theory and comparison with observational data.