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Book review

STATISTICAL PHYSICS FOR COSMIC STRUCTURES
A. Gabrielli, F. Sylos Labini, M. Joyce and L. Pietronero
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That the cosmic matter is irregularly distributed is a matter of our everyday (better to say everynight) experience, from the prehistoric times up to modern ones (at least before the powerful telescopes have been put to use). And yet, the concept of a homogeneous universe is one of the principal assumptions of the modern cosmology. There are several reasons for the latter. First, it facilitates enormously mathematical handling of the theoretical modeling, including that based on Einstein's General Relativity. Second, observational evidence seems to favour this assumption, at least up to very recent evidence. And last, but not the least, homogeneity, or translational invariance of the matter distribution at large scale, satisfies the best our aesthetic feelings. But, as a quartets commissioner asked Beethoven, *Muss es so sein?* We are entitled to make the same inquiries regarding this central dogma of the Standard model. After all, cosmology is neither mathematics nor arts. As for the relevant empirical evidence, it changes from time to time, as we have witnessed it for the last century or so (the recent observation of the cosmic acceleration is the case in point). Besides, this evidence is strongly dependent on the ruling theoretical constructions, and we are thus brought back to square one.

Is the Universe really homogeneous at large scales and if not what kind of inhomogeneity one might expect? If the Cosmos is structured (as the very name implies) what kind of structure can it be? If there is some regularity in the eventual grand-scale structure, haw could we reveal it? These are the question raised in the book, written by the active researchers in the observational cosmology.

Whoever created the universe, she evidently did not consult Alphonso the Wise, and we may hardly expect to find a simple geometrical forms in eventual regularities concerning the overall is cosmic matter distribution. What makes the issue even more twisted is the fact that we can not have an eagle-eye look at the Cosmos we live in. Hence, one must by necessity resort to indirect evidence, with an extensive use of theoretical modeling and mathematical methodology. Concerning the latter, it is a traditional wisdom that one should expect the least favourable circumstances and face big difficulties in discerning any regularity at the cosmic scales. In other words, cosmologist must rely heavily on statistical method in revealing possible regularities in the content of the universe. And here we come to the crux of the matter.

It is rightly assumed that a theoretical method employed must be general enough as to meet any possible situation *in situ*. Modern cosmologists have been employing current statistical methods in detecting correlations in the matter distribution, which are expected to answer the question as to the possible regular cosmic inhomogeneity. Yet, there have been disagreements both in accepting the observational evidence and in interpreting the empirical data. The issue might be put in this way: If there is a large-scale cosmic structure, is every statistical tool available today effective for the purpose? The answer that the authors offer is definitely negative. Namely, one may envisage the overall cosmic structure that evades the standard statistical methods, as used in ordinary, laboratory situations. One of these structures is the so-called hierarchical cosmos, more precisely the fractal, scale-invariant universe. This cosmological model was on the market since the Antiquity, but has gained the support in modern observational and theoretical cosmology mainly in the second half of the last century, thanks in large extent to the authors of the book. The controversy *fractal or nonfractal* has been the subject of a number of research and review papers, but the book is the first rigorous and thorough exposition of the statistical methodology and evidence for the cosmic structuring.

The standard statistical methods rely heavily on a number of concepts that are taken for granted. The crucial assumption when the cosmic structure is concerned, is the concept of average matter density. This assumption, however, fails when dealing with structures like the fractal ones. The latter is not well defined in the fractal case, which yields an overall zero density, that is fractal cosmos is asymptotically empty. This amazing feature is not peculiar to the hierarchical structures only (one encounters it with de Sitter cosmos), but has far reaching consequences when the inhomogeneous structuring are considered. The first half of the monograph is dedicated to this issue, putting the whole matter into a wide methodological context. In particular, it demonstrates that the assumption of the (nonzero) average density leads to the homogeneous cosmos (empirical) conclusion, providing the *petitio principii* fallacy. A more general approach, that does not preclude other conclusions, is based on the conditional correlation function, which discards the concept of the local average density and thus provides a more general approach.

Self-similar geometrical structures appear non-analytic, but an advance in dealing with such objects has been made, in particular in devising so-called fractal operators, as generalization of ordinary calculus. I wished these advances have been mentioned in the book, and this is my main objection.

The second half of the book deals with applications of the general methodology, as scrutinized in the previous chapters, to the observational cosmology. The question tackled in this part are mainly these. Is the observed cosmos fractal and if it is, to which cosmic scales? What are the methods in obtaining relevant data, like the discerning three-dimensional structuring from the angular distribution surveys and red-shift data? Is the observed universe fractal or multifractal and if there is a transition from fractal to non-fractal (homogeneous) cosmos, what is the distance of this turnover? All relevant surveys are analyzed for that matter and the conclusion, already drawn in the relevant literature, is that up to 20 Mpc/h the cosmos appears fractal with the (fractal) dimension $D \approx 2$. In the last chapter authors show that if D ¡ 2 the net force on the galaxy coming from the (gravitational) interaction with the rest of the universe is finite. What is tantamount to solving the famous Seeliger-Neuman's paradox, known already in Newton's time, and resolved also within the FRW model.

The appendices provide some details of the calculations made, but some have independent values themselves, like that on cosmological models. The book provides an author-subject index and is richly illustrated by 119 figures. The style is clear and economic (perhaps too much) and the points, particular those subject to controversies, are fairly expounded. As for the prospective readership those engaged in observational cosmology will benefit the most, but theoreticians, in particular cosmologists, will find it useful too. Finally, I find it of a considerable epistemological value, in particular regarding the time honored issue of the biased observations and generally the correlation *empirical versus theoretical* evidence. Further empirical evidence on the real cosmic structure might well prove what Beethoven's commissioner found – that the price for the (homogeneous) simplicity was too high.

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