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No "explosion" in Big Bang cosmology: teaching kids the truth of what cosmologists really know

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Abstract. Common wisdom says that cosmologists are smart: they have developed a theory that can explain the "origin of the universe". Every time an astro-related, heavily funded "big-science" project comes to the media, naturally the question arises: will science –through this or that experiment– explain the origin of the cosmos? Can this be done with the LHC, for example? Will this dream machine create other universes? Of course, the very words we employ in cosmology reinforce this misconception: so Big Bang must be associated with an "explosion", even if a "peculiar" one, as it took place nowhere (there was presumably no space before the beginning) and happened virtually in no time (supposedly, space-time was created on this peculiar –singular– event). Right, the issue sounds confusing. Let us imagine what kids may get out of all this.

We have recently presented a series of brief astronomy and cosmology books aimed at helping both kids and their teachers in these and other arcane subjects, all introduced with carefully chosen words and images that young children can understand. In particular, Volume Four deals with the Big Bang and emphasizes the notion of "evolution" as opposed to the –wrong– notion of "origin" behind the scientific model. We then explain some of the pillars of Big Bang cosmology: the expansion of space that drags away distant galaxies, as seen in the redshift of their emitted light; the build-up of light elements in a cooling bath of radiation, as explained by primordial nucleosynthesis; and the existence and main features of the ubiquitous cosmic microwave background radiation, where theory and observations agree to a highly satisfactory degree.

Of course, one cannot attempt to answer the "origins" question when it is well known that all theories so far break down close to this origin (if there was actually an origin). It is through observations, analyses, lively discussions and recognition of the basic limitations of current theories and ideas, that we are led to try and reconstruct the past and predict the future evolution of our universe. Just that. Sound science turns out to be much more attractive when we tell the truth of what we really know.

Keywords. Cosmology, Education and Culture, Books

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1. Introduction

The origin of the universe is one of those topics that has seeded most wrong scientific conceptions. Expressions like "the existence of a huge explosion" make us think –erroneously– that cosmic expansion began at a particular point in space, a sort of "primeval atom" inside of which the whole universe would have been concentrated initially. These wrong statements could lead us to ask: *where* was that primordial atom located? Which one in our big cosmos was the privileged point?

Figure 1. Bringing the heavens closer. A series of brief astronomy and cosmology books aimed at helping both kids and their teachers in these and other arcane subjects, all introduced with carefully chosen words and images that young children can understand (Gangui & Bilotti 2005, Gangui & Bilotti 2006, http://www.google.com/search?q="queres+saber"+gangui).

Modern science accepts the cosmological –or Copernican– principle: there exists no privileged place in the universe. Then, the "huge explosion" could not have occurred in just one particular point in space and *not* in the infinite other equivalent points of the universe. And what is still more disrupting, how could we claim that the "explosion" happened at a given point and at a given time, when it is precisely *at* the "explosion" that space-time would have been created?

The truth is that the Big Bang models do not explain the Big Bang! Got confused? The so-called model of the "huge explosion" does not pretend to explain what happens in this "huge explosion", nor how this "huge explosion" took place. Big Bang models *do* explain the existence of an expanding –evolving– universe which in the past was denser and hotter than is today. This leads to a whole series of theoretical predictions that have been verified by very different astrophysical observations.

Among these predictions, three are the main ones, and are usually referred to as "the pillars" of the Big Bang.

First, the Hubble's law for the expansion of the universe. As originally proposed by Edwin Hubble, the recessional velocity of far away galaxies is proportional to their distance from us (Fig. 2). Just to imagine the effect, consider a rubber band and place some ants along its length, separated at equal distances "d" from each other. Then, stretch the band and you'll see that each (non walking) ant recedes from its neighbors in the following way: with velocity "v" from the ant located at distance "d"; with velocity "2v" from the ant located at distance "2d"; and so on. Remark also that no single ant can claim to be "the center" of the expansion (of the rubber band universe). This is the cosmological principle, of course.

Hubble's law is valid for velocities that are much smaller than the speed of light. At higher velocities and distances, general relativistic models of modern cosmology slightly depart from this law, in a way that depends on the amount and kind of the matter-energy content of the universe, but the main essence of the expanding universe remains intact (Gangui 2005).

The second pillar of the Big Bang is the existence and properties of the so-called cosmic microwave background radiation. The very early universe was indeed very dense and hot, and under those physical conditions, matter and radiation were tightly coupled, sustaining continuous interactions. Bare positively-charged nucleons tried to capture free electrons to form neutral atoms, but more frequently than not, energetic corpuscles of light (photons) would destroy the result. However, in an expanding and cooling universe, a moment (actually, a temperature) arrived when photons could not destroy anymore the very first light atoms that formed. As a result, matter began getting structured and

Figure 2. Big Bang, pillar 1. The expansion of space drags away distant galaxies and we verify this expansion "indirectly" by detecting the shift in the frequency of light emitted by these sources: a blue shift (towards higher frequencies) when a source is approaching us (to the left of the picture); a shift to the red (to lower frequencies or higher wavelengths) when the source recedes from us (to the right of the picture). Although very distant galaxies need not have extremely large proper motions in space, the space containing them does stretch very fast, like a rubber band. As a result, the radiation we get from these sources gets redshifted when we detect it on the Earth.

photons "decoupled" from it, beginning their aimless journey "around" the universe, and making up a "relic" background of radiation.

This ubiquitous background fills the universe and is of course not coming from stars or other astrophysical sources (which did not exist at the time this radiation was "emitted"). Hence the name "cosmic". Its temperature was around a few thousand kelvin at the time of decoupling, which points to a peak in its spectrum corresponding to visible light, but the expansion of the universe made its wavelength stretch to the microwave band today. Recent discoveries and theoretical studies in the field of the cosmic microwave background radiation revolutionized cosmology and were awarded with the 2006 Nobel Prize in Physics.

The third fundamental pillar of the Big Bang is the explanation of how the light elements came to be. Theory predicts that this happened even earlier in the history of the universe than the decoupling of the cosmic background radiation. When the temperature of the universe was around a billion kelvin (i.e., the typical binding energy of a light nucleus) free protons and neutrons began joining together. In the process –known as Big Bang Nucleosynthesis– a few of the lightest nuclei saw the light: Deuterium and Tritium, Helium-3 and Helium-4, two isotopes of Lithium, and traces of Beryllium-7 and of a few other light nuclei (Fig. 3).

Of course, for this to happen, the universe ought to have had a hot and dense early phase in its evolution, something which not all contender cosmological models could supply. The Big Bang models do, and predict that about a quarter of the mass of the universe consists of Helium-4, a result which is in good agreement with current stellar observations. For the rest, the synthesis of the heavier elements we see around us today has to wait the formation of the first stars. It is in their cores –and, when they collapse

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Figure 3. Big Bang, pillar 3. Primordial light element formation when the temperature of the universe is around a billion kelvin. Under these physical conditions, photons are not energetic enough to prevent the first nuclei to form. Protons and neutrons merge to build up Deuterium and Helium-4 (as shown if the picture), and many other light elements.

in supernova events, in the shock waves thus generated– where the perfect conditions of density and temperature needed to generate many of the nuclei key to life are met.

2. Final remarks

These are just three of a whole series of theoretical predictions of the Big Bang models. Predictions that have been verified with ever increasing precision by very different astrophysical observations. This synergy between theory and observations is the main ingredient supporting our confidence in standard cosmology today (Gangui 2005).

To conclude, let us say once more that the Big Bang models do explain amazingly well the evolution of our universe, from very early times up to the present epoch; *not* its origin. Close to this "origin" the theoretical description of the universe through Einstein's general relativity breaks down. The theory becomes non-predictive and we are forced to search for another more adequate scientific description. Finding this new "big theory" remains as one of the main challenges for the XXIst century.

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