ASTROPHYSICAL LETTERS
& COMMUNICATIONS

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6 October 1988

Dr. Alex Saharian
President, Polytron Corporation
2445 DeCamp Avenue
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Dear Dr. Saharian,

Enclosed is a copy of your paper entitled "On the Origin of the Universe" which you sent for review for Astrophysical Letters and Communications. I am sorry to inform you that the paper has been rejected for publication. Enclosed please find the original manuscript, along with the Referee's comments.

Sincerely,

Giovanni G. Fazio
Regional Editor

Enclosures

Gordon and Breach Science Publishers
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REFEREE REPORT

Author:	Alex Saharian
Title:	"On the Origin of the Universe"
Journal:	Astrophysical Letters and Communications
Manuscript Number:	#052
Date:	October 3, 1988

The author of this article is clearly a careful and perceptive thinker, and I would like to encourage him to continue to think critically about theories in cosmology. In my opinion, however, the present article is inappropriate for publication in *Astrophysical Letters and Communications*. The article is concerned mainly with questions that the author has raised concerning a popular-level article published in *National Geographic* in 1983. These questions show that the author is an astute and clever reader. The questions, with appropriate answers, would probably make an interesting and informative "Letter to the Editor" in *National Geographic*, although I fear that the editors there might be reluctant to publish a letter commenting on a 5-year-old article. In all cases, however, I feel that the questions raised by the author are motivated primarily by the oversimplifications inherent in a popular-level article. I feel that all of these questions already have answers which are well-known and accepted by essentially all workers in the field of cosmology. I therefore see no point in publishing this article in a technical journal.

The author's central thesis begins on page 2, where the author states that PKS 2000-330 "theoretically constitutes the outer limit of space expansion produced by the big bang 16 billion years ago." Since nothing travels faster than light, the author reasons, a 16 billion-year-old universe must have a radius of at most 16 billion light-years. Since we can see quasars nearly that far away in all directions, the author continues, we must clearly be near the center of the universe.

In the detailed mathematical theory of the big bang, however, there is <u>no upper limit</u> to the radius of the universe. This theory is described in the context of general relativity, rather than special relativity, and in this theory the notion that "nothing travels faster than light" has to be carefully qualified. It is still true that nothing travels faster than light in the sense that if any material object has a race with a light beam, the light beam will always win. It is more complicated, however, to ask how fast the distance to an object like PKS 2000-330 can change with time. In general relativity, the gravitational field is described as a distortion of space and time— in this theory space can bend, twist, and stretch. In the standard big bang theory, space is described as uniformly expanding. The distance to PKS 2000-330 can in principle change because PKS 2000-330 is moving through space, and the speed of this motion is indeed limited by the principle that PKS 2000-330 must lose any race with a light beam. The distance can also change, however, simply because the space between us and PKS 2000-330 is stretching. General relativity contains no limit on the stretching of space, so there is no limit on how fast the distance between us and PKS 2000-330 can change with time.

In the standard big bang model the velocities of distant galaxies are due entirely to the stretching of space.

[It is true, however, that the standard big bang model gives rise to what is called the "horizon"— an upper limit to the radius of the visible universe. The light from galaxies beyond this horizon radius has not yet had time to reach us, so they cannot be seen. The value of the horizon radius depends on the details of the evolution of the universe's expansion, but it typically lies between $2ct$ and $3ct$, where c is the speed of light and t is the age of the universe. The horizon grows as the universe evolves, so it is not an edge to the universe— it represents instead only an upper limit to what we can see at the present time. In this model there is no such thing as an edge to the universe. In the popular literature the horizon is sometimes confused with an edge, and it appears that the author has been misled by this confusion.]

There are several other minor points raised by the author which are inconsistent with the understanding of cosmology as it exists in the technical literature. For example, on pages 2 and 3 the author asks whether scientists would change their estimate of the age of the universe if a quasar were discovered at a distance of 20 billion years. The author seems unaware that we have no way of directly measuring the distance to a quasar. We measure instead only the red shift. The age of the universe is estimated primarily from the expansion rate of the universe, which is measured by observing objects much nearer than the quasars. (There are also consistency checks based on understanding the evolution of various systems within the universe.) Once the age has been estimated, one can use it and the red shift of a distant quasar to calculate the distance to the quasar. The result of this calculation, however, is always consistent with the age that was used in the calculation.

On page 5 and in other places, the author shows that he is unaware of the complexities of the addition of relativistic velocities. The author concludes that if PKS 2000-330 is moving away from the earth at 90% of the speed of light, then an object moving at more than 10% of the speed of light away from the earth in the opposite direction would be invisible to observers on PKS 2000-330, since the relative velocity would exceed the speed of light. This rule of adding velocities is of course correct in Newtonian physics, but any textbook on special relativity discusses the correction. For the addition of velocities along a line, as in this example, the correct formula in special relativity is:

$$v_{\text{total}} = \frac{v_1 + v_2}{1 + (v_1 v_2 / c^2)} \, .$$

Note that v_{total} can never exceed the speed of light, regardless of the values of v_1 or v_2. In general relativity things are more complicated, since the answer depends on the gravitational field as well.

In describing the possible frequency reduction of signals from distant galaxies, the author begins one discussion with "in the case of visible light", and then begins the next paragraph with "in the case of an electromagnetic wave." Is the author unaware that visible light is an example of an electromagnetic wave? Perhaps the author just didn't notice the misleading impression that these sentences presented. The author discusses

the possible gravitational effect on the frequency of photons, but seems unaware that this effect is already contained in the theory of general relativity, and is already incorporated into the standard big bang theory. The effect of charged particles on electromagnetic waves is also well-understood, but is found to have no signficant influence on the red shifting of light from distant galaxies.

I would recommend that if the author would like to explore the mysteries of cosmology, he should go beyond the popular literature. In particular, I would recommend Steven Weinberg's **The First Three Minutes** (although still at a semi-popular level), Joseph Silk's **The Big Bang**, and Edward Harrison's **Cosmology**. At a still more technical level, the author might read Steven Weinberg's **Gravitation and Cosmology**.