The SS Theory, According to F.H.[1]

Although the age of the whole universe was thought in 1948 to be only about 2 billion years, whereas the age of the Earth was measured to be more than 3 billion years, the detail of this stark contradiction did not worry me unduly, because there was obviously room for adjustment in Hubble's determination of the age of the universe. It was rather than I felt uncomfortable with an age of the universe generally comparable to the age of the solar system. I came to wonder if there could be any form of cosmology, based in a broad sense on Einstein's general theory of relativity, with the time-axis open into the past, not closed at the definite moment of 'origin' of the universe, as it is in the Friedmann cosmologies.[2,3]

The sudden creation in Friedmann cosmologies of all the matter in the universe also worried me. Indeed, it seemed absurd to have all the matter created as if by magic, as is still done today, amazingly in most quarters without a blush of embarrassment. I therefore began to see if the creation of matter could be put into a rational mathematical scheme.

The standard method in physics for going about such a problem begins with a suitable new field that contributes in a clearly defined way to the so-called 'action'. There is then a standard mathematical process, known as the 'principle of least action' that leads to gravitational equations similar to those of Einstein, but with an extra term in the 'energy-momentum tensor', an extra term depending on the new field. I chose a scalar for my field, which became known subsequently as the *C*-field, and I constructed the contribution to the action from the derivatives of C, with the field taken to satisfy a coordinate-invariant wave-equation. This procedure fixed the situation uniquely within the framework of classical physics.

The consequences of these simple steps were startling. The solutions of the gravitational equations were quite unlike those obtained by Friedmann. The time-axis was indeed open into the past, as I had hoped it might be, and every solution of the equations tended asymptotically to a standard steady-state form, a form with the metric

$$ds^2 = dt^2 - \exp(2Ht)\,[dr^2 + r^2(d\theta^2 + \sin^2\theta\, d\phi^2)], \quad (1)$$

and with a constant mass density ρ_0 related to the Hubble constant H by

$$\rho_0 = \frac{3H^2}{4\pi G}, \quad (2)$$

where G is the constant of gravitation.

Unlike the Friedmann cosmologies, in which the Hubble 'constant' is a misnomer since it changes from one moment of time to another, H was now a genuine constant, the same at all times. It was determined explicitly by the coupling constant of the C-field as the field appeared in the mathematical formula for the 'action'.

Equations (1) and (2) gave an expanding universe and yet with a constant non-zero mass density ρ_0, from which it was evident that matter had to be created continuously. There were objections from critics that the conservation of energy was being violated, but this was not so, because it is an important property of the mathematical scheme I have just described that it automatically guarantees the conservation of energy and momentum. This criticism is discussed at greater length later in Part III.

It was a more relevant objection that the theory, being classical, said nothing about the kind of matter that was being created. It could be hydrogen atoms, or carbon atoms, or blocks of soap. To theoretical physicists this seemed a serious defect, they wanted to know the precise quantum details specifying the creation process. When I visited Zürich in the early 1950s, Wolfgang Pauli said:

> 'If matter could be created it would be very good, but you must tell me exactly how it happens.'

If I could have answered Pauli to his satisfaction everything would have seemed splendid. Yet an answer satisfactory in 1950 would have been quite unsatisfactory to theoretical physicists in 1980. The strength of a classical theory lies precisely in its ability to ride over such details. Without this strength we would still know very little about gravitation.

The SS Theory, According to Bondi and Gold[1]

Hermann Bondi and Tommy Gold began their work from what is known as the cosmological principle, which states that an observer at an arbitrary point of space cannot distinguish his particular position from any other by making large scale observations of the universe. Nor do the large scale features of the universe show any difference between one direction and another. These properties describe the homogeneity and isotropy of space. Yet in the Friedmann cosmologies such an observer can distinguish the moment of his existence, because the large scale features of the universe change with respect to time. Thus the Friedmann cosmologies are *not* homogeneous with respect to time.

What Bondi and Gold did was to postulate that the universe is homogeneous with respect to time as well as with respect to space. From this hypothesis they were able to deduce that the space-time metric must have the form (1), but they were not able to obtain the mass density (2). Thus the homogeneity postulate would have permitted the universe to be empty of all matter.

The two points of view I have described have the affinity of both giving (1), arriving at this metric from the front and the behind as it were. They differ, however, in a crucial respect, in the meaning to be attached to the word 'steady'. All I could say from my point of view was that the universe had to be approximately steady with respect to the characteristic time-scale H^{-1}. It was, on the other hand, in the very nature of the Bondi–Gold hypothesis that the universe had to be steady on a time-scale much shorter than this, say on a time-scale of $\frac{1}{100} \ H^{-1}$.

The Bondi–Gold point of view had drastic observational implications, since it permitted no property of the universe to change on a scale greater than $\sim \frac{1}{100} H^{-1}$, either with respect to time or space.* This was a far more disprovable position than my own, because much less distant observations than H^{-1} could be sufficient for establishing a disproof.

It was therefore at the Bondi–Gold form of the theory that observational astronomers elected to shoot, and it was in these terms that all the arguments of the 1950s and early 1960s were conducted.

Astronomers were pretty well uniformly hostile to the theory. Their hostility was, at any rate in part, due to a paper written by Bondi in the early 1950s, in which he gave a list of past mistakes by observers. His conclusion,

* Here, as in (1), the units of space and time measurements are taken to be such that the speed of light is unity, $c = 1$.

drawn from astronomical history, was that, in any face-off between observation and theory, it was theory that was more likely to come up with the puck.

The paper was submitted for publication to the Royal Astronomical Society. The Council of the Society was divided on whether the paper should be published, with a majority favouring rejection. I happened at that time to be a Council member, and I was therefore able to point out that Bondi's listing of observational errors were all taken from well-attested literature. 'Was a paper to be rejected because its statements were correct?' I asked. This argument was having a little success around the table, when the President of the Society, W.M. Smart, squirmed in the Chair, and exclaimed in an anguished voice: 'Then will somebody propose that this paper be rejected irrespective of its contents?'

Although the situation thus had its lighter moments, it was really quite badly one-sided. Besides being in a tiny minority of three, we then had no instruments for checking the statements of our opponents. Journals accepted papers from observers, giving them only the most cursory refereeing, whereas our own papers always had a stiff passage, to a point where one became quite worn out with explaining points of mathematics, physics, fact and logic to the obtuse minds who constitute the mysterious anonymous class of referees, doing their work, like owls, in the darkness of the night.

Although I was not really as deeply involved as Bondi and Gold, since it was not my form of the SS theory that was under direct attack, the observational claims were often so weak that I could not forebear speaking out against them. Weak they certainly were, as one can see from taking a look at them in a modern light. For brevity, I will confine myself to the two claimed disproofs that achieved the widest publicity in the 1950s and early 1960s, the redshift-magnitude relation for galaxies in clusters and the counts of radio sources.