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Editor's Note: Spherically Symmetrical Models in General Relativity.

by H. Bondi

Mon. Not. Roy. Astr. Soc. **107,** 410 (1947).

To anyone familiar with the later development of the subject, this paper reads like the book of Genesis: the origins of several contemporary research topics in non-orthodox cosmology can be traced back to this text. These are:

(i) In the very first paragraph of the paper the author says: "cosmological solutions suffer from the disadvantage that the spatial part of space-time is supposed to be homogeneous and isotropic. Therefore it is often difficult, owing to the lack of independent variables, to disentangle causes of various effects." Systematic pursuit of this idea led to the observational cosmology programme of G. F. R. Ellis and coworkers that has been flourishing for the last 20 years in South Africa (see e.g. Ref. 1).

(ii) Assumption (*iii*) in Section 2, expressed in modern language, excludes shell-crossings. The author was clearly aware of their possible existence (see also the third paragraph of Section 8). They have later become a subject in itself (see Ref. 2), also in connection with the cosmic censorship conjecture (see Ref. 3 — the historically earliest counterexample to the oldest formulation of this conjecture was a naked shell-crossing singularity).

(iii) The consideration about the sign of W in the second paragraph after eq. (31) is a precursor of the definition of a "neck" by Barnes [4]. This notion was then developed in an illuminating way by C. Hellaby [5].

(iv) The distinction between the velocity (Doppler) redshift and the graviational redshift, discussed in the paragraphs between eqs. (50) and

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(53), has been appreciated in the cosmological sector of the astronomical community only in recent years.

(v) The paragraphs after eq. (53) imply that, with parameters of the model chosen appropriately, light emanating from the center may be forced back inward by rapidly collapsing matter. Hence, the model discussed in the paper might be used to describe the process of forming a black hole. This process was more elaborately explained 23 years later by Barnes [4]. The very notion of a black hole is about 20 years younger than Bondi's paper.

(vi) The next-to-last paragraph of Section 8 is a precursor of studies of what is now called the shell-focusing singularity. Beginning with the paper by Eardley and Smarr [6], this investigation has been vigorously pursued by several authors in connection with the cosmic censorship conjecture; see a recent summary by Joshi [7]. The model discussed by Bondi provided a few counterexamples to various formulations of this conjecture.

(vii) The very last paragraph of Section 8 predicts that voids, once they appear, should persist in the model. Studies of voids on the basis of precisely this model have been undertaken by several authors. The apparently most mature study was summarized by Sato [8]; see also Ref. 9 for more references.

Apart from these points, in which H. Bondi anticipated future developments, the paper contains some well-researched contributions that still make illuminating reading today. These are:

(i) The interpretation of the function Y as the luminosity distance from the center of symmetry (Section 3; in newer papers this function is usually denoted R).

(ii) The distinction between the active gravitational mass, $\int M'W\,\mathrm{d}r$, and the sum of all rest-masses in the source, $M(r)$ (Section 4; Bondi's notation here is in conflict with that commonly used today — see Ref. 9).

(iii) The relation of the arbitrary functions in the model to physical initial conditions ($M(r)$ to the mass distribution and $W(r)$ to the velocity distribution, Section 4). For some reason, this identification has not sunk in with the public, and a few papers have been published much later in which the same conclusion has been meticulously rederived (see Ref. 9).

(iv) The relation between the sign of $(W - 1)$ and the curvature of the space t = const. (Section 5). In fact, the relation is opposite to Bondi's statement: the sign of spatial curvature coincides with the sign of $(1 - W)$, not $(W - 1)$, but this misreading had no consequences. As can be seen from the paper, it was clear to Bondi that this curvature need not be the same for the whole space. The sign of spatial curvature is a local property of a model. This sign is gobal in the Robertson-Walker

models as a consequence of the *assumed* symmetry of the latter, and this property is their peculiarity. This is indeed obvious if one thinks about the Universe as a curved manifold. However, this fact has not sunk in, in the astronomical community, until today.

(v) The conditions under which the model reduces to the Robertson-Walker models (Section 6).

Only one point needs to be corrected: the author attributed the solution of Einstein's equations that he discussed to Tolman, and this has probably led to the unfortunate misnomer "Tolman-Bondi model", commonly applied now to the underlying metric. In fact, the solution was found and first elaborately discussed by Lemaître [10].

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— *Andrzej Krasiński*

Brief biography

Hermann Bondi, born in Vienna 1 Nov. 1919, school in Vienna to Matura (June 1937). Studied Mathematics at Trinity College, Cambridge 1937-1940 (B. A. 1940). Fellow of Trinity College 1943-49 and 52-54 (M. A. 1944). Radar research for the Royal Navy 1942-45. Assistant lecturer in Mathematics 45-48, lecturer (1948-54) in Mathematics, University of Cambridge. Professor of Mathematics King's College, University of London 1954-67. Research Associate, Cornell University 1951, Harvard College Observatory 1953, Visiting Professor, Cornell University 1960.

Then career in the public service (mainly U. K.): Director General, European Space Research Organization 1967-71, Chief Scientific Advisor, Ministry of Defence 1971-77, Chief Scientist, Department of Energy 1977-80, Chairman and Chief Executive, Natural Environment Research Council 1980-84, then return to academic life: Master 1983-90, then Fellow of Churchill College, Cambridge.

Chief research interests: Accretion of gas & dust by stars (to mid-fifties), stellar structure (to mid-fifties), cosmology, gravitation and general relativity, occasional papers on other topics (water waves, meteorology, geophysics, ecology). Books: *Cosmology* (Cambridge University Press 1952, 1960), *The Universe at large* (1960), *Relativity and common sense* (1964, both by Anchor Books, Garden City, N. Y.), *Assumption and Myth in Physical Theory* (Cambridge UP 1967), *Science, Churchill and me* (autobiography) (Pergamon 1990).

About 10 honorary doctorates, honorary Fellowships of the Institutes of Electrical Engineering, Physics, Mathematics and its Applications, several Gold Medals.

Fellow of the Royal Astronomical Society since 1945 (secretary 1956-64), Fellow of the Royal Society since 1959, Knight Commander of the Order of Bath, 1973. Planetary Award, Einstein Medal, Award of the President of Austria 1997, Birla Prize for Humanism 1990, Raman Professor (afterwards Honorary Fellow), Indian Academy of Sciences, Bangalore, 1990; President, British Humanist Association since 1982.

— *Sir Hermann Bondi*

Editor's note. Sir Hermann was rather modest in listing his scientific achievements. He is best remembered for the following things:

(i) His book on cosmology was for a long time a standard textbook on the subject, and it was still recommended to students in the late 1960s.

(ii) Sir Hermann was a co-author (with T. Gold and F. Hoyle) of the steady-state model of the Universe. Although it was eventually disproven by the discovery of the microwave background radiation, it has provoked several important developments in astrophysics in the 1950s and 1960s.

(iii) The series of papers on gravitational radiation that Sir Hermann published with collaborators in late 1950s and early 1960s conclusively convinced the relativistic community that gravitational waves are not a coordinate effect and should be observable. Those papers are still canonical reading.

(iv) The paper from 1952 on spherically symmetric accretion continues to be a citation classic.

The book *Science, Churchill and me* is the most extended biography of Sir Hermann available on the market.

— *Ed.*