General Relativity and Gravitation, Vol. 32, No. 9, 2000

Editor's Note: A Newtonian Expanding Universe

By E. A. Milne (Oxford)
(Received 7 March 1934)
(*Quart. J. Math. Oxford* **5**, 64–72 (1934)).

Newtonian Universes and the Curvature of Space

By W. H. McCrea (London) and E. A. Milne (Oxford)
(Received 7 March 1934)
(*Quart. J. Math. Oxford* **5**, 73–80 (1934)).

The authors demonstrated that all the basic achievements of theoretical cosmology up to the 1930s could have been exactly deduced from Newtonian hydrodynamics in the 18th century or even earlier. The equations governing the motion of a homogeneous and isotropic cosmic medium in the Newtonian theory are exactly the same as in the Robertson–Walker models. Relativity theory would become significant at distances much larger than those within the field viewed by observers up to that time. The difference between the $k > 0$, $k = 0$ and $k < 0$ Robertson–Walker models has a very simple explanation in the Newtonian models: the matter moves with a velocity smaller than, equal to or greater than the escape velocity from its own gravitational field, respectively.

This is what the authors have proved. Had this all been done 200 years earlier, cosmology would have had a chance to become, already at that time, a natural science rather than part of philosophy and metaphysics. It is tempting to wonder: if the Milne–McCrea model was so simple, why had nobody even tried to find it earlier? The embarrassing idea that suggests itself most naturally is this: nobody asked the question how the Universe evolves because everybody was sure that he/she knew the answer—the Universe does not evolve at all, it is static.

This belief was so strong that it misled even Einstein. When he found out that a static model cannot be reconciled with his freshly invented general relativity, he preferred to modify his field equations (by including the cosmological constant) than to question the assumption of staticity.

The even more embarrassing idea that follows from this story is: Can we be sure that we are not allowing ourselves to be misled by another prejudice today? That we are not blind to a class of interesting problems just because we think we know the obvious answer to a question that has never been properly asked?

Ideas of this kind that the two papers seem to inspire even today are one good reason for reprinting them.

In the introduction to the first paper and in some other places Milne refers to the so-called kinematic relativity—a theory developed by himself as an alternative to relativistic cosmology. A complete exposition of kinematic relativity can be found in Ref. 1. This was an attempt to describe the Universe as a congruence of trajectories of free particles (with observers attached to them), expanding into empty flat space. Milne's insistence on operational definitions of all quantities used in the theory has led to a clarification of several notions also in Einstein's relativity. Among these is the method of measuring cosmological distances by registering the emission and reception times of light signals sent between observers. However, Milne was almost alone in pursuing his ideas, and his work mostly inspired criticism. Development of kinematic relativity stopped with Milne's death in 1950, and now his theory is considered merely a historical curiosity. The papers reprinted here are a singularly important offshoot of Milne's independent thinking.

Needless to say today, the ideas expressed in the first paragraph of the first paper also turned out to be wrong. Milne expected relativity to be equivalent to his "static space" with appropriately tuned motions. Instead, his kinematic relativity was later shown to be expressible in the language of Einstein's relativity and contained in the latter as one particular model. The Robertson-Walker type models look the same in relativity and in Newtonian gravity just because they are a rather trivial application of relativity in which many specifically relativistic effects (like gravitational waves) have been excluded by assumption.

The values of various cosmological parameters given by the authors are no longer valid. However, in the rapidly developing field of astrophysics any numbers considered as "current values" are short-lived. Therefore, we refer the readers to modern encyclopaediae for the current values of: 1. The maximal recession velocities measured (end of sec. 1 of the first paper—the cosmology of 1999 certainly cannot be based on Newtonian models); 2. The age of the Universe and the mean mass-density of the Universe (after eq. (8) in the first paper); 3. The radius of the region covered by observations (end of sec. 5 in the first paper).

In addition to the main result, the noteworthy parts of the second paper are

sec. 3, where the authors interpreted the cosmological term as a long-distance repulsive force, and sec. 6, where they showed that with $\lambda = 0$ the expansion in every Universe model is necessarily decelerated. Both these results seem fairly obvious today, but, apparently, they were novelties in 1934.

For a more detailed discussion of the Lemaître papers mentioned in sec. 6 of the second paper, the readers are referred to Ref. 2 below.

REFERENCES

1. Milne, E. A. (1948). *Kinematic Relativity* (Clarendon Press, Oxford).
2. Krasiński, A. (1997). *Inhomogeneous Cosmological Models* (Cambridge University Press).

—Andrzej Krasiński

SHORT BIOGRAPHIES

Edward Arthur Milne was born on 14th February 1896 in Hull, England.

He entered the Trinity College in Cambridge in 1914. In 1916 he joined the Anti Aircraft Experimental Section, where he worked on ballistics and sound-ranging. His duties included observations from an aircraft. For his war service he was awarded the Medal of the British Empire. His war experiences inspired his first published paper, on acoustics of sirens (1920).

He resumed his studies in Cambridge in 1919, and in 1920–24 was an Assistant Director of Solar Physics Observatory. In 1921–25 he was a lecturer in astrophysics at the Cambridge University, and from 1924 also a lecturer in mathematics. In 1925–28 he was a Professor of applied mathematics at the University of Manchester. From 1928 till the end of his life he was a Professor of mathematics at Oxford. In 1939–44 he took a leave of absence to work with the Ordnance Board, mainly on ballistics and armour piercing.

He died suddenly on 21st September 1950 in Dublin, where he was on a scientific visit. His early death was probably an after-effect of encephalitis that he suffered in 1923 during an epidemic.

For his scientific achievements, E. A. Milne received several honours that included, among other things, fellowship of the Royal Society (1926), Gold Medal of the RAS (1935) and the post of President of RAS (1943–45).

His best-known scientific contributions before 1932 were on radiative equilibrium and theory of stellar atmospheres. From 1932 till the end of his life he has kept developing his "kinematic relativity" theory, for which he is now best known (see Editor's note above).

More detailed biographies of E. A. Milne can be found in Refs. 1 and 2; Ref. 2 contains a complete list of Milne's publications.

A short biography of Sir William H. McCrea, dictated by himself to his daughter, appeared in *Gen. Rel. Grav.* **30,** 312 (1998) in the "Oldies" series. We are sorry to have to add the last piece of it: Sir William died on 25th April 1999 at the age of 95. Ref. 3 below is his extended obituary.

ACKNOWLEDGEMENTS

The Editor is grateful to G. Gale for bibliographical information.
The Editor is grateful to J. D. Barrow for information about Ref. 3.

REFERENCES

1. McCrea, W. H. (1969). *Mon. Not. Roy. Astr. Soc.* **111**, 160.
2. *Obituary Notices of Fellows of the Royal Astronomical Society* **7**, 421 (1950).
3. Barrow, J. D. and McNally, D. (1999). *Astronomy and Geophysics* **40** no. 6, 35.

By A. Krasiński, based on Ref. 1