Obituary

James Hopwood Jeans
1877–1946

In the death of Sir James Jeans on September 16, 1946, astronomy has lost its last remaining link with the great masters in Newtonian tradition of the 19th Century: Roche, Kelvin, Poincaré, Sir George Darwin and Liapounoff.

James Hopwood Jeans was born at Southport on September 11, 1877. His father, William Tullock Jeans who lived at Tulse Hill, London, was a parliamentary journalist. Jeans went to Merchant Taylors' School from 1890 to 1896. At first he took the classical side, but soon found that the mathematical side suited him better. While at school he also developed an interest in experimental chemistry and had a boy's ambition to be an engineer. He went to Cambridge as a scholar at Trinity College in 1896 and graduated as second Wrangler in 1900. In the following year he was elected both to an Isaac Newton studentship and to a fellowship at Trinity.

In 1905 he was appointed to a chair of applied mathematics at Princeton University (U. S. A.) which he occupied until 1909. In 1910 he returned to England as a Stokes Lecturer in mathematics at Cambridge University, but he soon gave up formal teaching for research. In 1917 he received the Adams Prize for a brilliant essay published as *Problems of cosmogony and stellar dynamics*. At this time he had already published his *The dynamical theory of gases* (1904), *Theoretical mechanics* (1906), *Electricity and magnetism* (1908), and *Report on radiation and the quantum theory* (1914).

He was elected a Fellow of the Royal Society in 1906, was awarded a Royal Medal in 1919, and served as secretary of the Society during 1919–29—a period of great expansion of the Society. He was knighted in 1928 and received the Order of Merit in 1939. Latterly, he had held a professorship of astronomy at the Royal Institution. He was president of the Royal Astronomical Society during 1925–27 and had been awarded its Gold Medal in 1922. From 1923 on he was a research associate of the Mount Wilson Observatory, and was the recipient of honorary doctorates from several universities at home and abroad.

One of Jeans's first scientific writings was a confirmation and rigorous establishment, on classical premises, of the law governing the distribution among the different wave lengths of the energy radiated by a black body which had been stated by Lord Rayleigh in 1900. The basic idea in Jeans's proof was the establishment of the equivalence of the electromagnetic radiation in an enclosure with a set of simple harmonic oscillators—an equivalence which forms the basis of all modern developments in the quantum theory of radiation.

His interest in the theory of radiation and the equipartition of energy between the different degrees of freedom of a classical system in thermal equilibrium led him to re-examine the foundations of statistical mechanics and gas theory; and in *The dynamical theory of gases* (1904) he developed the theory "upon as exact a mathematical basis" as possible. This book, which is much in the spirit of Boltzmann's *Vorlesungen über Gas Theorie*, found acceptance despite its severity, and its 1916, 1921, and 1925 editions were read by successive generations of physicists and mathematicians who looked to it "as an oracle, sometimes difficult to fathom as is the way with oracles" (S. Chapman).

His main love, however, was cosmogony, and it is probable that he will be remembered most for his *Problems of cosmogony and stellar dynamics*. In any event, there can be no doubt that his most massive contributions to science lay in this field.

It has long been known that a rotating incompressible mass under its own gravitation assumed for small angular velocities the form of a spheroid—the "flattened orange" —and that for increasing angular momentum, the ellipticity gradually increases. But when the equatorial diameter is 1.7 times the polar diameter, a new phenomenon begins: the equator ceases to be circular and bulges into an ellipse. At this state the configuration is ellipsoidal. Poincaré discovered that these ellipsoids, when there was no constraint compelling them to remain ellipsoids, developed a furrow around the long axis and became "pear-shaped figures"; but he left the stability of these configurations undiscussed. In 1902 Darwin convinced himself that they were stable, while Liapounoff, in a memoir published in 1905, announced the opposite result. The methods followed by Darwin and Liapounoff were very different, and a decision between their conflicting results was a matter of great cosmological importance. At this time it occurred to Jeans that it would be a valuable illustration of the behavior of a rotating liquid mass if the corresponding two-dimensional problem were fully worked out instead of the "heart-breaking actual problem of three dimensions." Accordingly, he considered a rotating cylinder constrained to remain in a cylindrical form. He showed that, for slow rotation, the cylinder is circular, corresponding to the flattened spheroid in the three-dimensional problem. This is succeeded by an elliptic cylinder and then by the analogue of the pear-shaped figure. The figures of equilibrium were traced much further along this last sequence—so far, indeed, as to show that a furrow was forming which "would deepen into a neck." This made it extremely probable that the pear-shaped figure would end in fission into two detached masses. Jeans, therefore, examined the stability of these pear-shaped cylinders. He was able to solve this problem completely, but, having successfully carried through all the difficult analysis, he was led by a numerical error in the final step to announce a result which was the opposite of that which the investigation had really demonstrated. It was not until 1916 that the mistake was discovered by Jeans himself and the pear-shaped cylinder found to be always unstable. This result would support Liapounoff's result as against Darwin's for the three-dimensional, pear-shaped solids. The latter problem was accordingly reinvestigated by Jeans in his Adams Prize essay, by an entirely new method. This enabled him to locate an error in Darwin's calculation and to confirm Liapounoff, thus resolving an enigma of years.

In his cosmological investigations, Jeans did not restrict himself to the incompressible liquid masses alone. The modifications caused by compressibility of the material were very fully considered. He studied a sufficient variety of models to straddle all reasonable possibilities. He showed that, in general, the results he had already obtained applied without significant modifications. A series of pseudo-spheroids branches off into a series of pseudo-ellipsoids, and from these in turn unstable pear-shaped figures branch away. The numerical constants are somewhat modified, but the general development is essentially the same. Jeans, however, added a new possibility to the former theory: the mass may separate in a new manner which he has called "equatorial break up." Owing to the compressibility of the material the protuberance of the equator takes a sharper form, and for sufficient compressibility and sufficient speed of rotation the figure, instead of being a spheroid, becomes lenticular. If this stage is reached, matter is thrown out in a continuous stream from the equator, where there is now a sharp angle.

> Accordingly we have at one extreme the incompressible liquid, which breaks up by elongating itself under excessive spin, the elongated figure becoming furrowed and so dividing into two parts. At the other extreme we have highly compressible matter such as the perfect gas, which never reaches sufficient elongation, but squirts out matter all around the equator and so avoids the impending catastrophe—like the prudent balloonist throwing out ballast to avoid the bump. In the intermediate cases it is a tussle between these two forces of separation as to which shall get into operation first and forestall the other; and according as the compressibility is above or below a critical value the disruption occurs in the second way or the first (Eddington).

In deriving astronomical consequences of these investigations, Jeans has been a bold speculator surveying the whole universe—the evolution of extragalactic nebulae, the formation of double stars by fission, and the origin of the solar system. Concerning the last, Jeans concluded that "it is probable, though by no means certain, that we must abandon the nebular hypothesis of Laplace." Instead, he pictured the formation of the solar system in the following terms:

> We conjecture that something like 300 million years ago our sun experienced an encounter of this kind, a larger star passing within a distance of about the sun's diameter from its surface. The effect of this, we have seen, would be the ejection of a stream of gas towards the passing star. At this epoch the sun is supposed to have been dark and cold, its density being so low that its radius was perhaps comparable with the present radius of Neptune's orbit. The ejected stream of matter, becoming still colder by radiation, may have condensed into liquid near its ends and perhaps partially also near its middle. Such a jet of matter would be longitudinally unstable, and would condense into detached nuclei which would ultimately form planets. The more liquid planets at the end of the chain would be those of smallest mass; the gaseous centre would form the larger planets Jupiter and Saturn. Owing to the orbital velocity which had been communicated to these planets by the attraction of the passing star, they would not fall back into the sun, but would describe elliptic orbits, passing fairly near to the sun's surface at their closest approach. As they passed relatively near to the sun, the same process as resulted in the formation of planets out of the sun may have resulted in the formation of satellites out of the planets.

If, indeed, the sun could not give birth to planets without calling in the aid of a neighbor, a conclusion follows which can only be described as sensational. For, it is obvious that to distort the sun beyond stable limits and cause ejection of the planet-building material, the approach of the passing star must have been a close one—so close, in fact, that planetary systems similar to ours must be of rare occurrence in Nature.

It is the usual fate of cosmological theories not to survive, but we should be grateful to Jeans for his bold speculations. As Eddington has said on the occasion of the award of the Gold Medal of the Royal Astronomical Society (1922):

> He might have retired among his mathematical models, where the materials behave as he ordains, and muddly old Nature cannot interfere. There is always an attraction to the mathematician in unimpeachable logical deduction, where the premises are explicitly assigned and the conclusion follows of a certainty. The problems of Nature are different; there we are given, say, half the premises and a quarter of the conclusions, not as fixed data but with varying degrees of probability. The binding chains, forged of rigorous logical reasoning, are needed here just as much as in the problems of pure mathematics; it is the anchorage at either end which is perilous. We are glad that Jeans has engaged on the bolder

adventure. When, for example, he had arrived at the instability of the pear-shaped figure, he proceeded at once to risk applying it to reconstruct our views of stellar evolution, instead of following the secure path, and, shall we say, generalising his result for a pear-shaped body of n-dimensions. But Jeans' contributions to cosmogony are not to be summed up in snappy sentences—that the solar system was formed by tidal disruption, that a spectroscopic binary cannot be formed until a comparatively high density is reached, that star-streaming must be in the transverse direction, and so forth. How these suggestions will stand twenty years hence, we cannot predict. As Jeans has said: "It has not been part of our task to arrive at a conclusion; the time for arriving at conclusions in cosmogony has not yet come." There are many who think that conclusions of this kind are a measure of the success of an investigator; but they make a great mistake. He is spinning the threads of a great synthesis; and it would be scarcely human, nor indeed scientific, not to cast curious glances at the pattern which is being formed, of which we can gain elusive glimpses. I will not predict how far the final fabric will be like that which we now seem to see through the eyes of our Medalist; but I will predict that in that fabric there are stout threads of his spinning which will not have to be unpicked.

His later volume, *Astronomy and cosmogony* (1928), was less successful. This can be largely attributed to the fact that he chose to take a stand in the growing problems of stellar constitution which was opposed to the natural line of development we owe to Eddington. This was unfortunate, but his critical attitude was not without value. On the positive side we should credit him as a pioneer in the difficult investigations of the stability of gaseous stars and for first drawing attention to the phenomenon of radiative viscosity.

No account of Jeans's life would be complete without mention of his popular books. Their phenomenal sales were equaled only by a few imaginative or religious works. His literary success might have been predicted from his treatises, the nonmathematical sections of which can be enjoyed even by the layman. As expositions of science, these popular books are unexcelled. But they also include his philosophical deductions from modern science, which were contentions. He emphasized the part played by mathematics in science and elevated the second law of thermodynamics into a position of supreme importance. And from the fact that the most important physical laws are statistical in character, he deduced the general indeterminism of Nature. He tended to a form of idealism approaching that of Bishop Berkeley, whom he admired. These opinions could be, and were, easily criticized. But as a contemporary has written, "It should not be forgotten how infinitely preferable they were to the barren scepticism into which so many men of science had sunk, and how great a part Jeans played in rescuing science from that morass."

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Boston Meeting Statistics

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The 113th meeting of the AAAS was held in Boston December 26–31, 1946. Ninety-nine years ago, September 24, 1847, the Association of American Geologists and Naturalists meeting in Boston passed a resolution transforming itself into the American Association for the Promotion of Science. A committee was formed to draft the Constitution and Rules of Order, and at the first meeting of the new society, held in Philadelphia the following year, the name was modified to the American Association for the Advancement of Science. In 1849 the Association held its second meeting in Cambridge, and since that date has met in Boston six times: in 1880, 1898, 1909, 1922, 1933, and 1946.

During the early period of its existence the growth of AAAS was reflected in the size of the meetings. In the last two decades, however, the size of the meetings has leveled off while the membership curve has steepened. At the Boston Meeting in 1933, 2,351 persons registered and 1,500 papers were read. In 1946, 2,736 registered and 1,332 papers were presented. The number of members in 1933 was 18,553, whereas in 1946 membership had increased to 31,000.

As the affiliated societies have grown in membership, several that originally met with AAAS have chosen to meet independently to avoid difficulties imposed by hotel limitations. Unfortunately, the advantage of meeting separately is offset to some degree by the disadvantage of isolation. One of the major aims of the Association is to facilitate cooperation among scientists. AAAS maintains an active interest in the major fields of science through its sections, and its annual meeting is now the only place where integrating programs can be developed.

The registration for the meeting at Boston by states and foreign countries was as follows: Africa, 1; Alabama, 7; Alaska, 1; Arizona, 1; Argentina, 1; Arkansas, 1; Belgium, 2; Bermuda, 3; Brazil, 4; California, 41; Canada, 66; China, 2; Colorado, 9; Connecticut, 110; Delaware, 7; Washington, D. C., 107; Ecuador, 1; England, 6; Florida, 14; France, 2; Georgia, 16; Greece, 1; Holland, 1; Hawaii, 2; Idaho, 0; Illinois, 102; India, 3; Indiana, 47; Iowa, 31; Italy, 1; Java, 2; Kansas, 9; Kentucky, 7; Louisiana, 16; Maine, 51; Maryland, 109; Massachusetts, 728; Michigan, 68; Minnesota, 44; Mississippi, 6; Missouri, 20; Montana, 4; Nebraska, 6; New Hampshire, 39; New Jersey, 108; New Mexico, 2; New York, 448; North Carolina, 22; North Dakota, 1; Ohio, 94; Oklahoma, 15; Oregon, 1; Palestine, 1; Pennsylvania, 131; Puerto Rico, 3; Rhode Island, 38; Siam, 1; South Carolina, 7; South Dakota, 3; Tennessee, 12; Texas, 28; Utah, 5; Venezuela, 5; Vermont, 21; Virginia, 34; Washington, 3; West Virginia, 7; Wisconsin, 40; and Wyoming, 11.