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# De Sitter Projective Relativity

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*The authors dedicate this modest work to the memory of distinguished professors Luigi Fantappié and Giuseppe Arcidiacono*

Luigi Fantappié; Viterbo (Italy) 1901–1956

Giuseppe Arcidiacono; Acireale (Italy) 1927–Rome 1998

Prof. Giuseppe Arcidiacono and Ignazio Licata (left) converse during a break in a scientific meeting (1991)

# Foreword

Half a century ago, the proper name “de Sitter” was known only, or almost so, to a small bunch of theoreticians working in cosmology—which was far from being such a fashionable and active subject as it is now. De Sitter had in fact discovered a few decades before a particular solution of the Einstein’s equations in general relativity, describing an expanding universe, unfortunately empty of matter and thus appearing to lack a deep physical interest. However in the 60’s, as the group-theoretical foundations of Einsteinian “special” relativity were becoming common knowledge in mathematical physics, the attention was drawn to the symmetry properties of the de Sitter universe, expressed through a specific group structure generalizing the Poincaré group which underlies the fabric of the Minkowski space-time.

It is revealing that, while, up to that period, the name de Sitter appeared essentially in the expression “de Sitter universe”, new syntagms such as “de Sitter space” and “de Sitter group” quickly spread thereafter. These mathematical objects were then studied in their own right and shown to possess some very elegant properties, which made them an interesting playing ground for quite a number of works dealing for instance with the problems of quantization in a curved space-time as well as, of course, with cosmological considerations, especially when the cosmological constant came back into favour.

Nevertheless, as pointed out by Dyson in 1972 and recalled in the introduction of this book below, a serious examination of what Dyson called “de Sitter relativity”, expressing the chronogeometry associated with the intrinsic structure of the de Sitter space-time, was still lacking. Or so it seemed. For, indeed, as revealed by the authors of the present book, an abundant and thorough work on the subject had been done in the 50’s by the Italian mathematician L. Fantappiè followed by his colleague G. Arcidiacono. Unfortunately, their papers were mainly written in Italian and published in mathematical journals, which accounts for the fact that they were largely ignored, another reason probably being that they did not refer explicitly, at least in their titles, to de Sitter.

Beyond the case in point, there is here a rather general lesson to be drawn. Out the immediate reach of main line research and escaping the linguistic domination of basic English in hard sciences, there certainly lie quite a number of interesting and promising studies in many domains, buried in high quality but low readership journals in various languages, sometimes going back to an almost forgotten past. The present electronic information systems are quite unadapted to tracing back such works of value. One can only wish that brave young princes of science will try to discover and awaken these sleeping beauties.

Coming back to the specific theme of this book, one must be grateful to the authors for this timely review which has the double merit of giving due regard to the work of unjustly forgotten precursors while at the same time offering a thorough perspective on modern developments.

At this very day, the interesting figure of Willem de Sitter and the wide scope of his scientific work remains largely ignored. It is thus worthwhile to devote a few lines to the man.

Willem de Sitter (1872–1934) was a Dutch astronomer with a brilliant career. While he had a mostly mathematical training, he was at the beginning interested in celestial mechanics. He did some observational work at the Cape Observatory in South Africa, where he went in 1897–1899, in order to, according to his own words, "complete my astronomical education—or rather begin it, for up to that time I had never made a speciality of astronomy and intended to become a mathematician". His doctorate and most of his early publications in the first decade of the twentieth century were dedicated to a thorough analysis of the motions of the planet Jupiter and its satellites. In 1908, he took up the chair of astronomy at the University of Leiden, and in 1919, was appointed Director of the Leiden Observatory in addition to his professorship. At that time, he had started to work on the then very recent theory of general relativity, which he was certainly one of the first to understand in depth. He wrote an early non-technical presentation of general relativity still worth reading ("Space, Time, and Gravitation", *The Observatory*, n° 505, 1916, 412–419, to be found online at http://articles.adsabs.harvard.edu/), and went on to publish a number of significant papers on its astronomical consequences. De Sitter, unlike Einstein, stressed and maintained that general relativity actually implied the expansion of the universe. In 1932 Einstein and de Sitter published a joint paper in which they proposed a simple solution of the field equations of general relativity for an expanding universe. They argued in this paper that there might be large amounts of invisible matter. This was the first hint of the now well-known but still mysterious 'dark matter'. Although de Sitter is best known for this work on relativity, he made many other contributions of great significance. He kept his interest in Jupiter's satellites throughout his life, using data on eclipses of the satellites dating back to 1668 in order to produce definitive results on the orbital elements and masses of the four Galilean satellites, on which he was still working when he died in 1934. Another study which de Sitter undertook was to refine the data for the fundamental constants of astronomy, associated with precession, nutation, solar parallax, lunar parallax and the mass of the moon. At the time of his death, de Sitter had almost completed a new updating of these constants.

De Sitter was much appreciated and admired, as shown by the following extract of one of his obituaries :

> In [de Sitter's] work we see the creative mathematician at his best. He is not a cold, dispassionate juggler of Greek letters, a balancer of equations, but rather an artist in whom wild flights of the imagination are restrained by the formalism of a symbolic language and the evidence of observation. Only the musician can fully grasp what it must have meant to de Sitter to see the cosmos shaping itself in new ways in his formulas. Like musical notes, strange symbols, standing for forces and masses that were divined rather than known, arranged themselves into a coherent message. And when the message came to be read a totally new universe was revealed. Here we have something of the direct personal experience of the outer world, of the significance of nature's wonders, that comes only to a Beethoven or a Milton. The expanding universe of de Sitter must be regarded as something more than an inexorable conclusion drawn from the strictest kind of logic with which the human mind is familiar. It is poetry of a new sort - the scientist's way of writing an epic.

October 2016

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# Preface

The idea of this little book was born many years ago when, just graduated, Leonardo Chiatti and I frequented Giuseppe Arcidiacono.

Furthermore, Leonardo lives and works in Viterbo, Fantappiè birthplace. I remember our long bus tour through Rome while talking about Einstein and de Sitter. The first time I met Arcidiacono is set in my memory indelibly. I was doing military service in L'Aquila, and after a long exchange of mails I made an appointment with the Professor at his home in Rome. As soon as he opened the door—avoiding any formality!—asked me what I thought about Lorentz Symmetry! And we went on in this way for about 4 hrs, then he opened the old box of Sicilian pastries where he usually put the mails by Freeman Dyson, Jean Marc Levy Leblond, Feza Gursey, Erasmo Recami and some other names the reader will meet in the pages of this book. The Euclidean line of attack to Quantum Cosmology by Hartle and Hawking stimulated Leonardo and me to recover the Group Approach. We realized that a long work of revision had to be done before the "quantum jump" ahead. In fact, most of the papers were in Italian and followed a classical approach. We, finally, completed this work in 2009, too late to be seen by Arcidiacono.

Later, a young and brilliant mathematician, Elmo Benedetto, joined us. We all decided to give the reader an agile and unitary vision of de Sitter projective approach, an extremely fecund one in particle physics and cosmology.

This is a little book, but with big debts: first of all to two great masters: G. Arcidiacono and L. Fantappié. And then to a formidable group of colleagues and friends: Eliano Pessa, Erasmo Recami, Giuseppe Vitiello, Jean Marc Levy Leblond, Basil Hiley, Jose Geraldo Pereira, Reuben Aldrovandi, Ugo Moschella and PCW Davies.