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THE SCIENTIFIC BOOKS AND ASTRONOMICAL INVENTIONS OF THE JESUIT ASTRONOMER DR EMMANUEL CARREIRA

Carlos Viscasillas Vázquez
Institute of Theoretical Physics and Astronomy, Vilnius University, Sauletekio av. 3, 10257 Vilnius, Lithuania.
E-mail: carlos.viscasillas@ff.vu.lt

Ederlinda Viñuales Gavín
University of Zaragoza, Grupo de Mecánica Espacial, Edf. Matemáticas 3a Planta, 50009 Zaragoza, Spain.

Adriana De la Calle Viscasillas
Georgetown University, Walsh School of Foreign Service, ICC 3013, Washington, DC 20057, USA.

and

Ricardo Moreno Luquero
Network for Astronomy School Education (NASE), International Astronomical Union (IAU), Av. Padre Piquer 14, 28024 Madrid, Spain.

Abstract: Dr Emmanuel Carreira Vérez S.J. (1931–2020) was a Spanish Jesuit and astronomer best known for his popular science and philosophy works, his professional contributions to astronomy being more unknown despite their high scientific level. His doctoral supervisor and collaborator was the famous Clyde Cowan, co-discoverer of the neutrino. His biographical profile has been recently addressed, but a compilation, inventory, and critical analysis of his numerous popular scientific books and his astronomical inventions are still necessary. The aim of this paper is to compile and analyze them in the scientific context of his time. We found that his scientific output comprised just 5 refereed papers (including one in *Nature*), 15 books, and 2 inventions (one of them patented in the United States and Spain), besides contributions in other areas of knowledge. An excellent communicator, his life deserves to be documented as a part of the history of Jesuit astronomy.

Keywords: Biography, astronomy, telescopes, inventions, religion.

1 INTRODUCTION

This paper summarises the scientific work carried out by Dr Emmanuel Carreira Vérez, S.J. (Figure 1)[1] in the fields of astronomy and physics to make it better known, since at least in Spain (his country of birth), he is still largely unknown among professionals in these disciplines. Recently his biographical profile was explored by Pérez Garcia (2020), Consolmagno et al. (2020) and Viscasillas Vázquez (2020a; 2020b; 2020c; 2020d; 2020e) in short articles and obituaries; however, a compilation and inventory of his numerous scientific books is still necessary. For an overview of Carreira's life readers should consult Viscasillas Vázquez (2020d) and references therein.

Dr Carreira worked and collaborated with well-known scientists, including Clyde Cowan (1919–1974), the co-discoverer of the neutrino, with Frederick Reines in 1956.[2] Cowan supervised Carreira's doctoral thesis, which was defended in 1971. The dissertation was about cosmic rays, radiation that occurs in many astronomical objects and is of great interest to astrophysicists.

Figure 1: Dr Emanuel Carreira S.J. in 1972 (courtesy: CUA Archives Photographic Collection, Box 2, Folder 3).

An important factor in Dr Carreira's life was his friendship with the successful American industrialist and philanthropist Fred A. Lennon (1905–1998), who years later would help fund the 1.83-m Vatican Advanced Technology Telescope on Mount Graham, Arizona.

As an astronomer at the Vatican, in 1989 Dr Carreira participated in an international collaborative project to explore Titan's atmosphere during the occultation of the star 28 Sgr. The final results of this project were published in *Nature*.

Dr Carreira also was an inventor of astronomical instruments, one of which was patented and rated as one of the top ten products of 2001 by *Sky & Telescope* magazine.

A tireless scientific communicator, Carreira collaborated with numerous amateur astronomical associations, and was well known. He defended the compatibility of science and faith, fields that in his opinion were never opposed. He considered that they were two different ways of knowing reality, and that they complemented each other, since science could say nothing directly about theology, while faith could not respond to material questions.

We can assume that Carreira was inspired by well-known astronomer priests such as Angelo Secchi, S.J. (1818–1878), who established the first spectral classification of stars in the second half of the nineteenth century; George Lemaître (1894–1966), the 'Father of the Big Bang', who also dedicated many years of his life to the study of the cosmic rays; and the fellow-Galician priest, Ramón María Aller Ulloa (1878–1966), Director of the Astronomical Observatory at the University of Santiago de Compostela in the 1940s.

2 A BIOGRAPHICAL SKETCH: CARREIRA'S EARLY LIFE

Emmanuel M. Carreira was born on 31 May 1931 in Vilarrube, a locality on the Galician coast, in Valdoviño (A Coruña), Spain (for Spanish locations mentioned in the text see Figure 2). He was one of eight children born to Engracia Vérez Puentes (1901–1983), a school teacher and her husband Jenaro Carreira Penalonga (died 1978), an official who worked for the Vilalba (Lugo) City Council. Thanks to his mother, who was a woman of "… exceptional cultural breadth …", Carreira (2004) had the opportunity to read "… poetry, mineralogy, art history, travel narratives and even chivalric books." *(ibid.)*. From his parents he learned "… to value things well done and to feel the responsibility to take advantage of opportunities to develop any aptitude." (*ibid.*).

A knee injury when he was 9 years old, aggravated by an accident when he was 10, progressively limited his activities throughout his life. In addition, he survived the collapse of the Institute of Lugo building in which he was taking an exam at the age of 10, and the sinking of the ship on which he was travelling when going to the United States at the age of 26.

Emmanuel Carreira went to school at the Academy of Vilalba in Lugo (Spain) and completed the last three years of high school at the Apostle Santiago School in Teis, Vigo, Pontevedra (Spain). In Vilalba, he met the painting and drawing teacher Antonio Insua Bermúdez, who encouraged him to develop his artistic talent. He obtained a high school degree from the University of Santiago in 1948 with an 'Extraordinary Award' and a Bachelor's Degree in

Figure 2: Spanish localities mentioned in the text (map: Wayne Orchiston.

Classical Studies from the Higher Center of Saint Stanislaus College in Salamanca. He entered the Jesuit Order in 1948, and was ordained a priest in 1960. Fr Carreira, S.J. graduated Magna cum laude with a degree in Philosophy (1957) from the Pontifical University of Comillas (Santander) in Madrid and graduated Summa cum laude with a degree in Theology from Loyola University Chicago (1961) at the West Baden Springs seminary in Indiana. In 1966, he completed a semester of Philosophy at the Pontifical Gregorian University in Rome.

3 CARREIRA'S SCIENTIFIC CAREER AND PUBLICATIONS

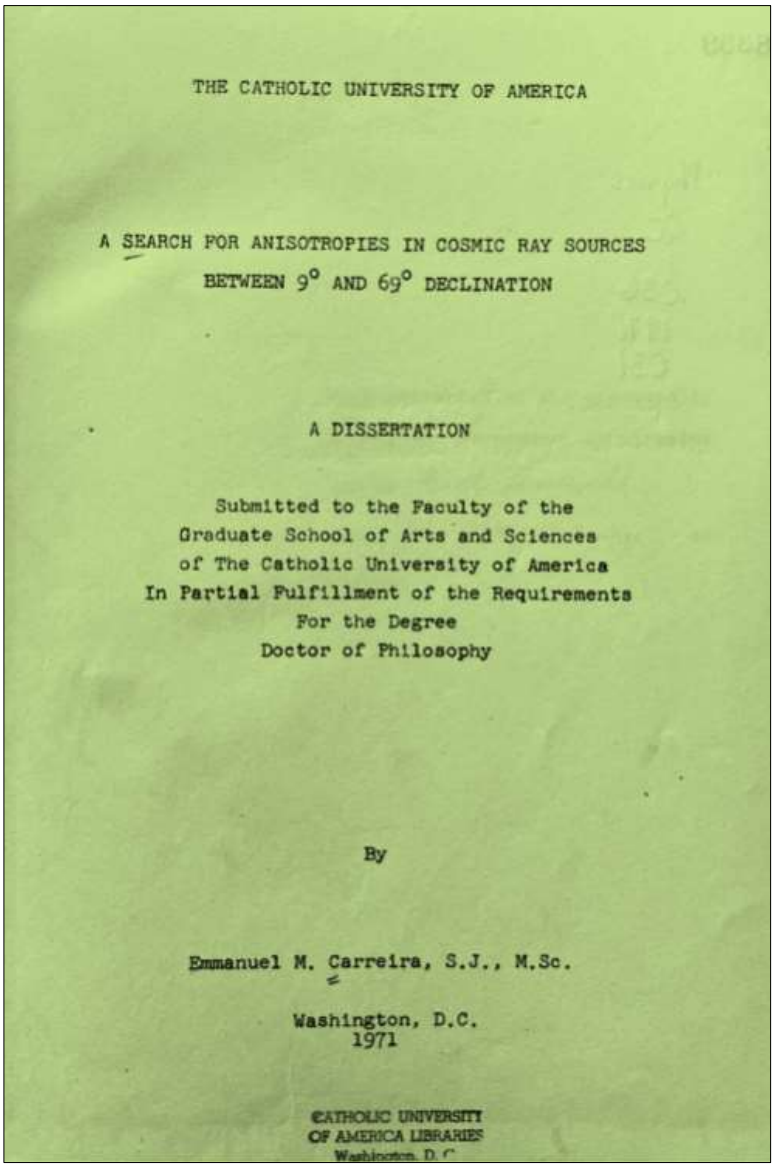
3.1 Carreira's Master of Science at John Carroll University and PhD at the Catholic University of America

In 1966, Carreira obtained a Master's degree in Physics from Carroll University (JCU) in Cleve-

land, USA[3] with a thesis on *Shadow Photography Studies of Laser-Induced Shock Waves in Liquids*, supervised by Dr Edward F. Carome (1927–2021).[4] Professor Carome was a physicist and researcher who received a PhD from Case Institute of Technology and worked for nearly five decades at John Carroll University. During Carreira's time in Cleveland we must highlight his friendship with the engineer and philanthropist Fred A. Lennon (1905–1998),[5] who years later would be the benefactor of the Vatican Advanced Technology Telescope.[6]

Carreira' first scientific publication reported on his Masters thesis, and was published in *Applied Physics Letters*. The title was "Photographic studies of laser-induced pressure impulses in liquids" (Carome, Carreira, and Prochaska, 1967), and as we can see the lead author was Carreira's thesis supervisor. In the paper, they used shadow photography techniques to study the effects produced in transparent liquids by the focused beam from a Q-spoiled ruby laser. They examined in detail the intense spherical acoustic transients generated in water and other pure liquids when dielectric breakdown occurs, finding that in solutions of benzanthracene in benzene, a linear region was strongly affected by the laser beam, and they also observed cylindrical acoustic disturbances. This paper continued to be cited during the fol lowing three decades.

Emmanuel Carreira received his doctorate in 1971 from the Catholic University of America (CUA). The title of the thesis was *A Search for Anisotropies in Cosmic Ray Sources Between Latitudes 9° and 69° Declination* (see Figure 3)



THE CATHOLIC UNIVERSITY OF AMERICA

A SEARCH FOR ANISOTROPIES IN COSMIC RAY SOURCES
BETWEEN 9° AND 69° DECLINATION

A DISSERTATION

Submitted to the Faculty of the
Graduate School of Arts and Sciences
of The Catholic University of America
In Partial Fulfillment of the Requirements
For the Degree
Doctor of Philosophy

By

Emmanuel M. Carreira, S.J., M.Sc.

Washington, D.C.
1971

CATHOLIC UNIVERSITY
OF AMERICA LIBRARIES
Washington, D.C.

Figure 3: False-color copy of the title page of Emmanuel M. Carreira's doctoral dissertation (courtesy: Catholic University of America University Libraries; photograph: Adriana De la Calle Viscasillas).

and was supervised by Clyde Cowan (1919–1974; Reines, 1974), a distinguished physicist and co-discoverer of the neutrino (Cowan et al., 1956). Carreira's doctoral thesis was a modest 123 pages, and was reviewed by Hall L. Crannell and Herbert M. Überall, both of whom at the time were Professors at the CUA (see Figure 4). The second reviewer, Dr Herbert Überall, was a well-known Austrian physicist who specialized in theoretical acoustics and nuclear physics.

To gather data for the PhD thesis, Carreira and Cowan made a survey of the distribution of cosmic rays,[7] registering more than 39,000 events using a spark chamber as a particle detector. Father Antonio Pérez García, S.J., recalls (pers. comm., 6 February, 2010) the

> … many hours that [Cowan and Carreira] spent in the depths of an abandoned mine, recording on their screens the rays that crossed the almost kilometer of land that separated them from the surface, which served to filter the particles that arrived from the distant space. (Our English translation from Spanish).

These observations allowed the determination of the incoming direction of muons, as well as drawing a map of the sky according to the number of relative tracks in each region. The results showed a direct relationship between the cosmic ray flux and the structure of the Galaxy in the solar neighborhood.

In the Acknowledgments section of his thesis, Carreira mentions several other scientists who helped him in some way. The first on his list was Dr Carol Crannell (1938–2009), the wife of his thesis reviewer. She was an astronomer who worked almost her entire life at the NASA Goddard Space Flight Center. Emmanuel Carreira (1971) thanks her

> … for providing a Monte Carlo model to which the response of our detector could be compared, and for her help in locating important reference works.

Professor Cowan and Dr Carreira presented a paper on their cosmic ray studies at the 12th International Conference on Cosmic Rays, which was held in Tasmania, Australia in August 1971, and a 1-page abstract was published in the *Proceedings* (Carreira and Cowan, 1971). They found three regions with especially high cosmic ray counts:

> … that near Cygnus (+45°, 21–23 hrs. R.A. and that near Perseus (+40°, 2 hrs. 30 mins. – 4 hrs. R.A.); while a third intense region appears near Orion (+15°, 6 – 7 hrs. R.A.). (*ibid.*).

Although Dr Careera is listed as the first author of this paper, Clyde Cowan probably attended the conference on behalf of both of them, which would explain why his name is underlined on the copy of the abstract provided to us by the University of Tasmania through ADS.

After obtaining his doctorate Dr Carreira taught Physics and Astronomy at the Catholic University of America from 1972 to 1975, but no publications by him are listed in ADS during this period. Professor Cowan's premature death in 1974 prevented them from continuing to work together on research.

In 1975 Dr Carreira began a Post-doctoral Fellowship at the Bohannon Science Center at John Carroll University. There he was able to collaborate with Professor Hall Crannell, one of his doctoral reviewers (Crannell's own PhD was from Stanford University, where his supervisor was the Nobel Laureate in Physics Robert Hofstadter). Carreira and Crannell published one joint research paper (Crannell, Maurer, and Carreira, 1977)—but this was in the field of nuclear instrumentation and methodology, not in astronomy. After the completion of his Fellowship, Dr Carreira continued teaching at John Carroll University up until his retirement, and was honored by the University several times. In 1987 he was awarded the prestigious Centennial Medal, and in 2002 the Distinguished Alum Award for "… professional achievement and for service to the Physics Department and John Carroll University."[8] It has been claimed on various web sites[9] that Dr Carreira and John Carroll University's Dr Klaus Fritsch carried out collaborative research under contract from NASA to develop a fiber optics control system for aeroplanes and space probes, but we were not able to confirm this (even though Professor Crannell was a known NASA collaborator).

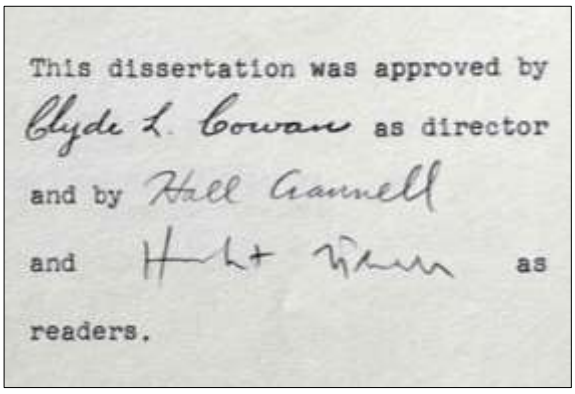


Figure 4: Signature of Clyde Cowan and the two reviewers, Hall Crannell and Herbert Überall approving Emmanuel Carreira's doctoral thesis, in 1971 (courtesy: Catholic University of America University Libraries; photograph: Adriana De la Calle Viscasillas).

Between 1971 and 2002, Dr Carreira also spent one semester each year teaching Philosophy of Nature and Sciences at the University of Comillas in Madrid. Thus, during his teaching career he was able to support the same three universities where he had been a student in earlier years.

Following his retirement in 2002 Dr Carreira continued to combine his scientific work with his religious activity, and his role as a scientific popularizer—for which he is best known (see Section 3.3, below).

3.2 The Vatican Observatory and the Occultation of 28 Sgr by Titan

In 1994, Dr Carreira was appointed an 'adjunct astronomer' at the Vatican Astronomical Observatory, although his collaboration there began much earlier: indeed, he was a member of the Board of Directors of the Vatican Observatory Foundation from 1988 to 2002.

As a member of the Vatican Observatory, he often participated in the Vatican Observatory Summer Schools. Director of the Observatory Dr Guy Consolmagno, S.J. (pers., comm., 14 May, 2020) mentioned that Dr Carreira

> … was a regular participant at our biennial summer schools. These schools are a four-week immersive experience where the students take classes in the morning from astronomers of international note on the specific topic of the school (which would vary from school to school); they would work on projects in the afternoon; and then in the evenings would either have more wide-ranging talks from visitors or use our historic telescopes. During these schools, Fr. Carreira was a friendly presence during the day (important especially for the students who came from Spanish-speaking countries; generally, about half of them would be from Central and South America). Importantly, he was available every night at the telescope on the roof of the Papal Palace, showing students how to use the instrument and often helping them with projects involving astrophotography.

Occasionally Dr Carreira also participated in Vatican Observatory astrophysics research projects, arguably the most important one being the 3 July 1989 occultation of the star 28 Sgr by Saturn's largest satellite, Titan. This event offered a unique opportunity to explore Titan's extensive nitrogen-rich atmosphere over an altitude range that was not investigated by the Voyager space probe. A large group of international researchers made photometric observations of the occultation from 15 different locations in the United Kingdom, Germany, France, Italy, Israel, Uzbekistan and the Vatican.

Both Dr Carreira and the astronomer Dr Francesco Rossi, participated in this project on behalf of the Vatican Observatory, observing from Castel Gandolfo. Dr Rossi (pers. comm., 18 May, 2020) recalls that they

> … received the instrumentation from the Tucson Observatory a few weeks before the event … [and therefore they] had time for testing and alignment of the instrumentation … [Thus] everything was ready except that on the day of the observation, bad weather was expected on the sky of Castel Gandolfo … [At the beginning of the occultation] the sky was covered with clouds and we had lost hope, it seemed then that all our work was lost … However … after a while, the sky opened and we started recording data, thus contributing to the success of the observation.

Successful observations of the transit are shown in Figure 5, which includes the Vatican chord. From the combined observations, the astronomers derived mesospheric temperatures and demonstrated inhomogeneities in Titan's atmosphere. Preliminary results were presented at a meeting of the American Astronomical that same year by nine of the collaborators (including Drs Carreira and Rossi), and summarized in the Society's *Bulletin* (Reitaema et al., 1989), and the results were reported by eight of these nine authors in *Nature* in June 1990 (Hubbard et al., 1990).

Research about Titan's atmosphere based on this occultation attracted further collaborators and continued for several more years, resulting in papers in *Icarus* with 22 authors (Hubbard et al., 1993a) and *Astronomy & Astrophysics* with a record 46 authors (Hubbard et al., 1993b). A final paper, this time with 24 authors, was also published in *Icarus* in 1999 (Sicardy et al., 1999), a decade after the occultation. As a co-author of all of these papers, Dr Carreira made good mileage out of this project, but it is telling that he did not co-author any other astrophysics papers. Instead, he increasingly devoted his time to popularizing science, mainly through his books. These are discussed below.

3.3 Dr Carreira's Books

Manuel Carreira wrote fifteen books between the years 1982 and 2020 (inclusive), that is while he was at John Carroll University and associated with the Vatican Observatory and the University of Comillas in Madrid. These academic affiliations

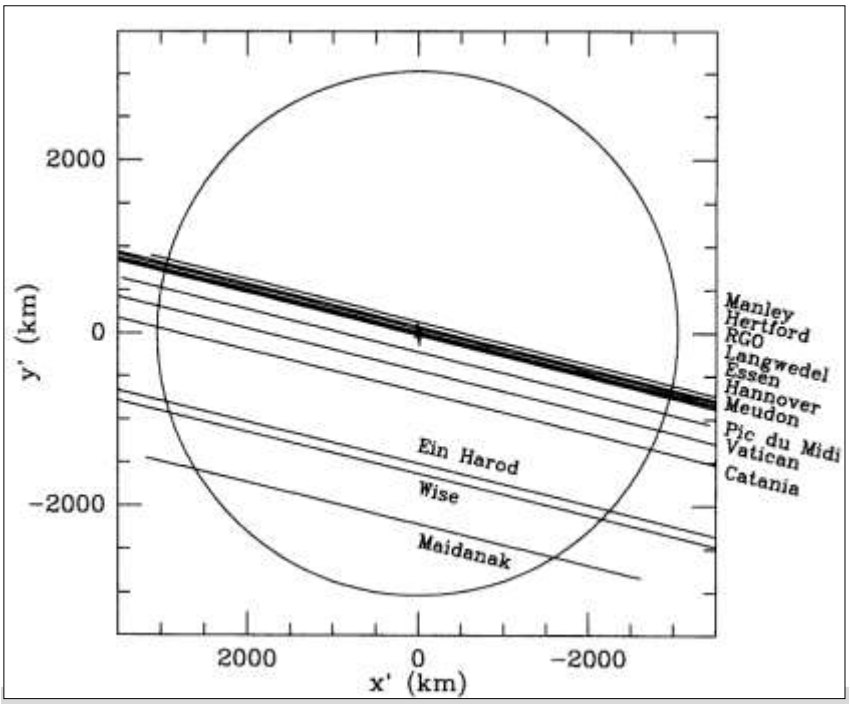


Figure 5: Chords for all stations where successful photometric observations were made of the occultation of 28 Sgr by Titan on 3 July 1989 (after Hubbard et al., 1993b: 543).

Table 1: Books authored by Dr Emmauel Carreira, listed in chronological order of first publication.

Author(s)	Year(s)	Title
Carreira	1982	*El Creyente Ante la Ciencia*
Carreira et al.	1983	*Fe Cristiana y Cultura Humana*
Carreira	1992	*La Mujer Vestida de Sol*
Carreira	1997, 2009	*El Hombre en el Cosmos*
Carreira	2001 (2 edit-lons)	*Metafísica de la Materia: Núcleos Temáticos de Filosofía de la Naturaleza, Materia no Viviente*
Carreira	2003	*Ciencia y fe ¿Relaciones de Complementariedad?: Algunas Cuestiones Cosmológicas*
Lobo and Carreira	2007	*Sagrada Familia. The Western Façade*
Carreira et al.	2008	*Planetas, Estrellas y Galaxias*
Carreira	2009, 2019	*El Hombre y el Universo: ¿Somos Fruto del Azar?*
Carreira and Gonzalo	2009, 2013	*En Torno al Darwinismo*
Carreira	2010	*El Origen y Evolución de la Vida*
Gonzalo and Carreira	2013	*Intelligible Design: A Realistic Approach to the Philosophy and History of Science*
Carreira and Gonzalo	2014, 2022	*Reason, Science & Revelation. Razón, Cencia y Revelación (Spanish Edition)*
Carreira and Gonzalo	2018	*Everything Coming Out of Nothing vs. A Finite, Open and Contingent Universe*
Carreira	2020	*El Origen del Universo*

are reflected in the themes pursued in these books, and the authors of the books. Dr Carreira was sole author of eight of these books (Carreira, 1982, 1992, 1997, 2001, 2003, 2009, 2010 and 2020), and co-author of the rest. Of the latter, he was lead author of six (Carreira et al., 1983, 2008; Carreira and Gonzalo, 2009, 2014, 2018, 2022) and the second author of two (Gonzalo and Carreira, 2013) and Lobo and Carreira, 2007). Note that Carreira (1997) was reprinted in 2009, Carreira (2009) in 2019, and Carreira and Gonzalo (2009) in 2013. Three of these books—all published towards the end of his writing career—were in English (Gonzalo and Carreira, 2013; and Carreira and Gonzalo, 2014, 2018); the remainder were in Spanish. All fifteen books are summarized here in Table 1, and further bibliographical details (including English translations of Spanish titles) are provided in the References section of this paper. Meanwhile, the cover of one of these books in shown in Figure 6.

As Table 1 indicates, most of the books were about popular science, with frequent mutual implications among astronomical, scientific and philosophical questions, such as the origin of the Universe, the origin of life, chance, purpose, etc.

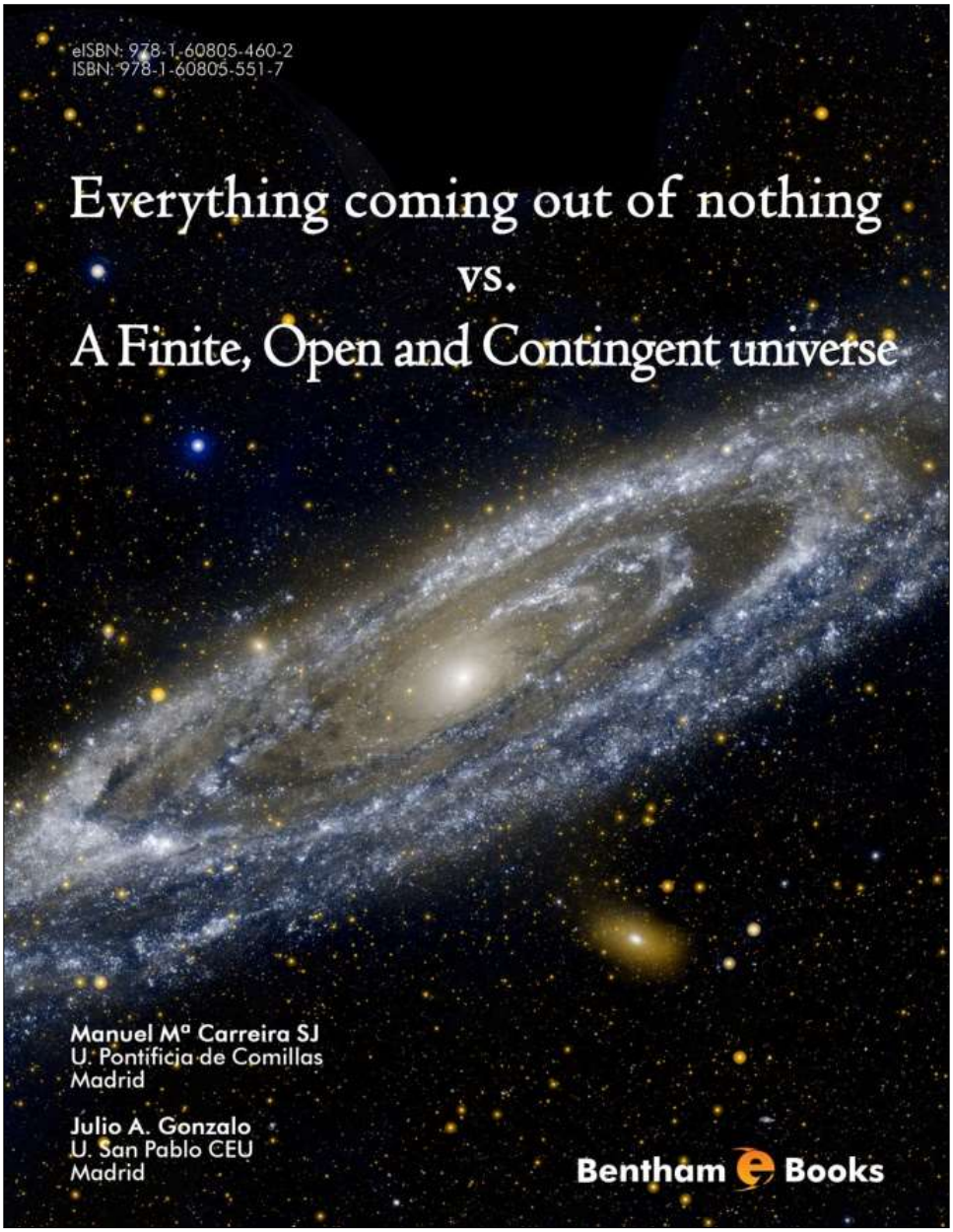


Figure 6: The cover of one of the last books written by Dr Carreira (photograph: Ricardo Moreno Luquero).

A theme present in most of his books is the complexity of reality, especially human reality, which means that full knowledge of it cannot be approached with reductionist models. The various facets of knowledge—science, philosophy and theology—complement one another and come together in a broad understanding of our lives and the Universe. For that reason, Dr Carreira insists that there is no relationship of opposition or conflict between science and theology.

In his books Dr Carreira presents the latest scientific research, but suggests that readers explore it from other points of view as well. For example, the evolution of the Universe forces us to deal with the philosophical concept of creation; its future underlines the need to explain its reason for the existence of Man, a unique structure in its materiality and its consciousness and intelligence.

It is not very common today to affirm, in the scientific field, the insufficiency of matter to explain all our rational activity. Nor is it frequent, in the theological field, to maintain the necessity of the matter of our bodies for true human survival. In both cases it is crucial to clarify the concept of matter that modern Physics uses. These lines give us an idea of the commitment that Dr Carreira had to science and at the same time to his strong religious beliefs. In his books he tries to seek a rational path that complements science and faith.

It is notable that six of the books listed in Table 1 were co-authored by 'J.A. Gonzalo'. A web search revealed that from 1978 to 2006 Julio A. Gonzalo González (b. 1936) was a Professor of Material Physics at the Universidad Autonoma in Madrid (UAM), and after 2006 he continued as a UAM research collaborator and as a Professor Emeritus at the Escuela Politécnica Superior-Universidad CEU San Pablo (http://www.cienciaycultura.org/jag_personal.htm).

One of books listed in Table 1 (Lobo and Carriera, 2007) differs markedly from all of the other books in that is it about the western façade of the Sagrada Familia temple in Barcelona, which includes 70 beautiful black and white photographs taken from street level and with natural lighting. These photographs show the sculptures with great expressiveness and in fine detail, highlighting Dr Carreira's passion for photography, and his natural ability in this area. Dr Guy Consolmagno, S.J., Director of the Vatican Observatory, specifically mentioned this (pers. comm., 14 May, 2020):

> Fr. Carreira was an excellent photographer, including a master in the darkroom; in those days we still had a full photographic darkroom including the ability to print color prints. He instructed generations of students in the techniques of using that equipment. To this day, the best photographs of the Moon that we have in our collection are those taken by him at the historic telescopes. He also took a number of remarkable close-up images of frescoes from a church in Spain, which hang today on the walls of our living quarters and chapel here in Tucson.

Finally, returning to books, we would like to point out that Dr Carreira's book, *Metafísica de la Materia: Núcleos Temáticos de Filosofía de la Naturaleza, Materia no Viviente* was for years a recommended textbook for Philosophy degrees at numerous universities around the world, and is still recommended today at the University of Comillas in Spain (even though this volume was first published back in 2001).

4 ASTRONOMICAL INVENTIONS

Dr Emmanuel Carreira was an inventor, and developed some astronomical instruments. Each of his inventions had the purpose of making existing instruments for observation more efficient and comfortable.

Thanks to the valuable profile that Debbie Hanson and Dan Hanson (2002) prepared for 'Cleveland Seniors' we know that Dr Carreira always liked machines and manipulating them. He started exploring and found an old brass telescope in an attic that had been made in France during the early nineteenth century. The lens was broken so the telescope was not functional, but it was certainly a start. He began searching out things that could be usable parts. Although he had never used the tools in a machine shop before this did not stop him, and he taught himself how to use an old lathe and other equipment. Thus, he acquired the skills necessary to tackle the tasks he had in mind: to renovate old instruments, to improve existing instruments in order to make their handling more comfortable, or to fabricate totally new instruments.

Below we present some features of his two best-known inventions: his 'Binocular support for astronomical observations' and his 'Drum Scope".

4.1 The 'Binocular Support for Astronomical Observations' (Sky Windows)

This invention consists of reflector supports for binoculars used for making astronomical observations (Figure 7). It is intended to avoid some of the problems that arise when making astronomical observations with binoculars, which, from the description that Dr Carreira himself makes of his invention, could be classified as follows:

a) great deal of discomfort occurs after a relatively short period of time because one must tilt one's head back in order to look upward;
b) if the binoculars are hand held, they tend to shake, slightly distorting the image; and
c) furthermore, the user has no means to control and check the direction in which the instrument is aimed.

Considering these drawbacks, the main feature of this invention is to provide a new and improved reflector binocular support particularly suitable for making astronomical observations. The device consists of a base with a pole on each side that supports a horizontal mirror the inclination of which can be can varied with respect to the base and the optical instrument to give the mirror the desired angle. There is a third central, higher mast, to which the binoculars are attached, which looks downwards, towards the mirror, forming a comfortable angle close to 30º with the vertical. The glass must first be cleaned to avoid double reflection of objects.

Other features and advantages of this invention become apparent when using it. The device can be placed on a table or can be attached to a conventional tripod. It has a compass inserted. The mirror makes the image look upside down, which does not matter when look-

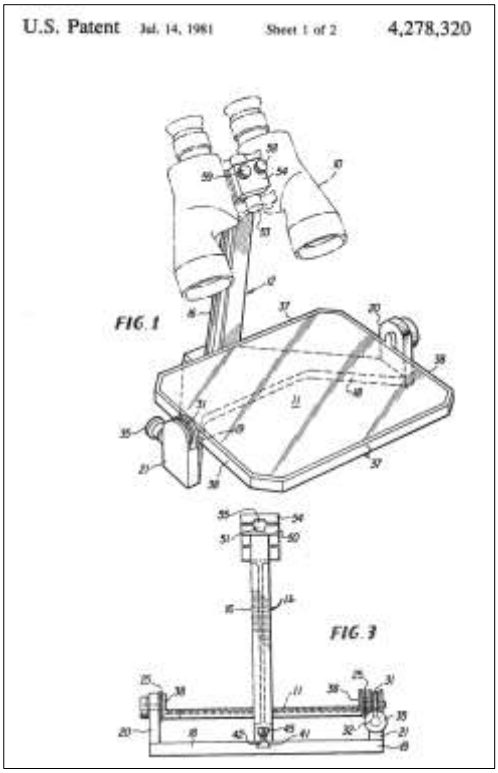


Figure 7 (Left): A drawing of the binocular stand, United States Patent US4278320A (U.S. Patent, 14 July 1981, 4,278,320). (Right): The cover of the December 1981 issue of *Sky & Telescope* where it is called a 'Sky Windows']

ing at the sky. In the Spanish patent, however, it is explained that binoculars can be replaced by binoculars with magnifying lenses and without prisms, which avoid the inverted image effect when reflected in the mirror and which, in turn, makes it useful for observing objects on land (animals, etc.). The device makes observation very comfortable and the image is totally stable, which allows the observation to be prolonged and to appreciate few details.

Carreira patented this invention in the USA in July 1981 (Patent: US4278320A1), and in Spain in April 2004 (Patent: ES1057166U2). Trico Machine Products of Bedford Heights, Ohio, bought the patent and sold the product for a few years under the trade name 'Sky Windows'.

It was very well received in reviews in astronomy magazines. For example, it was featured on the front cover of the December 2001 issue of *Sky & Telescope* (see Figure 7) where it was described as one of the best science and technology products of 2001. In the following issue of *Sky & Telescope* the well-known American amateur astronomer and member of the editorial staff Dennis di Cicco gave it a 'rave review'. It also received praise from other pundits, like Don Pensak in 'Cloudy Nights'. However, it proved commercially unprofitable, and production was discontinued after a few years. Today, original copies are highly valued on the second-hand market, and some hobbyists even make their own copies.

4.2 The 'Drum Scope'

Emmanuel Carreira's other well-known invention is the 'Drum Scope', which was very well received by amateur astronomers. With this device, Dr Carreira wanted to avoid telescopes with long tubes with lenses at the ends, and achieve a device that was stable and easy to use, assemble and transport. The light is captured by a lens and directed around a round drum until it reaches the eyepiece.

Dr Carreira explained the Drum Scope in an article titled "A refractor in the round", which was published in the October 2002 issue of *Sky & Telescope*. In this short paper, he describes the main characteristics of his invention and explains in detail the steps he followed to create his device: its design, advice, and construction and assembly details. The Drum Scope used three reflective surfaces, despite some opinions that these surfaces would produce a great dispersion

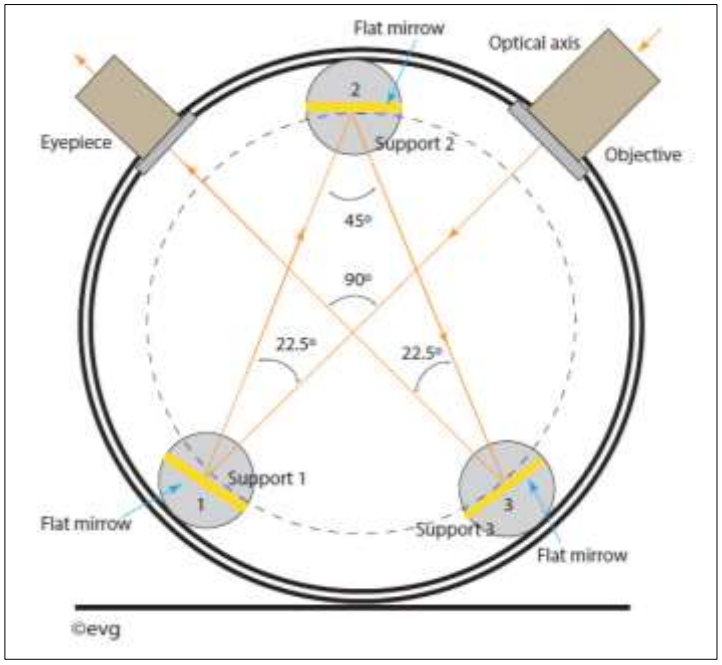


Figure 8: A schematic of Dr Carreira's 'Drum Scope' (diagram: Ederlinda Viñuales Gavín).

of light, but Dr Carreira considered that this was a small price to pay for the comfort and compactness of his invention. As the Figure 8 schematic diagram illustrates, he decided that the objective lens and the eyepiece form a right angle. In this system, the light that enters through the objective is reflected at an angle of 22.5° by a flat mirror located at 'Support 1'. This light reaches a second mirror, at 'Support 2' and is reflected at an angle of 45° to a third mirror (at 'Support 3", where it is finally reflected at an angle of 22.5° to the eyepiece.

The previous paragraph exposes 'the heart' of Dr Carreira's Drum Scope, and how it works. But the *Sky & Telescope* article was virtually a guide for anyone wanting to build their own Drum Scope. A version of this article subsequently was published in German in the January–February 2004 issue of *Astronomie Heute*, the German edition of *Sky & Telescope*. In this, Dr Carreira gave advice on what size of drum to choose, the relationship of the inner radius for mirrors and the focal length of the objective, etc. To point the telescope he used a right-angle 25-mm finder located near the focuser, and he added some additional elements to the instrument itself, such as a little drawer to store small items necessary for observation such as eyepieces, exterior metal handles for easy transport, a bubble level, a magnetic compass and a scale. Dr Carreira explained that "… these refinements allow me to aim the scope at a certain altitude and azimuth." Finally, he concluded that his Drum Scope has the performance of a larger telescope, but in a compact package.

5 DR CARREIRA: THE POPULARIZER

Dr Emmanuel Carreira was a great popularizer of science, not just through his books, but also the many lectures he gave in Spain, Germany, Ireland, the United States, and throughout Latin America. He also gave a series of free lectures at John Carroll University, where he covered topics such as the mysteries of the Universe, science and philosophy. His lectures were very popular, as he had a way of presenting difficult topics in a clear and logical way.

In 2009, Hogar de la Madre Television (in Spain) recorded the documentary series "From Science to God", with 13 chapters of 10 minutes each, in which Carreira presented his ideas on the relationship between science and faith in the same style.

5 DR CARREIRA: THE PAINTER, POET AND PHOTOGRAPHER

In addition to being a teacher and lecturer Dr Carreira was a painter, a poet and a photographer. As a person versed in a thousand subjects, Carreira even dared to write poetry. He began by translating verses from Spanish to English in sonnet form and later, from there, he began to write his own creations. Unfortunately, we have none of his work in this field that would allow us to assess his talent as a poet. Likewise, as a painter, none of his works has come down to us, or at least we do not know of them.

However, he is well known as a photographer, and many of his photographs have survived to the present day.

Figure 9: Dr Carreira's photographs of Cowned Herons featured on the cover of the Spring 1984 issue of the *John Carroll Quarterly*.

Figure 10: One of his photographs of the Moon taken with the historic Zeiss refractor at the Specola Castel Gandolpho (courtesy: Vatican Observatory).

Debbie Hanson and Dan Hanson (2002) reveal that in his photographs he pays the same attention to the photographed object, to the background, to the play of light and shadow, and to the composition itself. He shows all the splendor of the most humble objects through photography. As said before, Carreira's work reflects a strong attraction to light that plays on shadows, and he would take multiple pictures of the same object by changing viewing angles, lighting, perspective, color, etc. which allowed him to obtain a seemingly new object with a new intensity and meaning.

Father Gerald Sabo, S.J., Associate Professor of Slavic Languages and Literature at JCU, recalls (pers. comm, 11 May, 2020) that Dr Carreira

> … was also very much appreciated as a photographer … When I was Moderator of the Jesuit Honor Society, Alpha Sigma Nu, for the participants of the triennial convention held at John Carroll, he made a large photograph of the university's tower illuminated at night that framed was given as a gift to every participant of that convention. Because of his photography, he was a member of a local photography club/group. He had his own photo lab in the basement of Rodman Hall, the then Jesuit residence … Fr. Carreira also did the photographs for the 100 famous Jesuits of all time for display for many years in the university Campus Center ... I also remember that on various Friday Jesuit community evening get-togethers, he introduced "churros and chocolate" to the community.

Dr Carreira was also a regular contributor to the *Carroll Quarterly*, a magazine published by John Carroll University, where his photographs even featured on the front page (e.g. see Figure 9). They were photographs of diverse subjects and of great beauty.

Meanwhile, many of his astronomical photographs are kept in the Vatican Observatory (e.g. see Figure 10), and some of them have been published in books, promotional publications and even in an annual calendar.

In addition to the afore-mentioned book *Sagrada Familia: The Western Façade* (Lobo and Carreira, 2007) which included his photographs, Dr Carreira is known to have photographed the stained glass windows of the León Cathedral. Although some of his photographs were related to religion or to science, most were of ordinary objects but seen through his exceptional eyes. Finally, we should mention that he mentored the the prominent Jewish photographer Judith Wei-

denthal (1935–2017), who graduated from Cornell University with a degree in Art & Architecture and was associated with the Cleveland Institute of Art.

8 CONCLUDING REMARKS

The main aim of this paper is to inventory the books and inventions of Dr Emmanuel Carreira, S.J, and briefly explore his talents as an artist, a lecturer, a scientific communicator, and especially as a photographer. Although he was responsible for two astronomical inventions, the 'Sky Windows' and the 'Drum Scope', his major contribution was as a science popularizer. In 1999 he received a medal from the Government of Galicia that honors "… the people and institutions that have created exceptional works in the arts, culture, literature, science, or in any other field that is worthy of distinction." And as we have seen, in 2002 he received the James Carroll University Distinguished Alum Award. Given his life-long achievements, we believe that Dr Carreira's life deserves to be included in the annals of the history of astronomy and the history of science.

9 NOTES

1. In Spanish, the name of Emmanuel is often simplified to Manuel. In his books, Dr Carreira used both names. In the USA those who knew him well sometimes referred to him as 'Manny'.
2. For this discovery (the so-called Cowan–Reines Neutrino Experiment), Frederick Reines (1918–1998) received the Nobel Prize in Physics in 1995 on behalf of both, since Cowan had already passed away.
3. John Carroll University was founded in 1886 by the Society of Jesus. The first Catholic Jesuit University in the United States was Georgetown University, founded by Bishop John Carroll in 1789.
4. Professor Dr Edward Carome, who died in 2021, shared his testimony with us:

   > I knew Father Carreira, first as a student and then as a friend. He worked with me on his MS thesis research as a talented experimental physicist but I came to know him as a photography artist. His portraits and other works are beautiful and he not only took them but he personally developed and printed them in his laboratory dark room. He was kind enough to make a group of portraits of my children that for years have been on the wall in my home. After he completed his PhD work at Catholic University in Washington, DC, whenever there was an eclipse almost anywhere on the globe, on his way to or from it, he would stop by the John Carroll University campus to visit friends. He will be greatly missed.

5. Father Gerald Sabo, S.J., who died in 2020, gave us testimony of how

   > … a number of John Carroll benefactors were always in contact with Manny about astronomy; indeed, one of these was a benefactor for the Vatican telescope in Arizona ... I remembered that Manny flew a number of times on his private jet to Arizona during its construction and after its completion.

   Fr Chris Corbally, S.J. also shared with us that

   > Manny served as a Board Member of the Vatican Observatory Foundation for many of its early years, and he would travel to Tucson from Cleveland for the annual meeting in Mr. Fred Lennon's plane. Mr. Lennon was a major benefactor for what became the "Alice Lennon Telescope", a.k.a. the Vatican Advanced Technology Telescope, and was on the VOF Board until he died.

6. Lennon created the Fred A. Lennon Foundation in 1965 and after his death in 1998 the Fred A. Lennon Charitable Trust was created. This Foundation donated millions of dollars to hospitals, higher education and medical research, among other charities. He also supported the Vatican Advanced Technology Telescope at the Vatican Observatory in Tucson, Arizona, and so today the 1.8-meter telescope is named after his wife, Alice P. Lennon, in their honor. In this decision he was probably influenced by his friendship with Emmanuel Carreira, of whom, in fact, their trips together on Lennon's private jet to Arizona are known. In 1987, Fred Lennon was honored with an honorary doctorate from John Carroll University.
6. Victor Hess discovered cosmic rays in 1912, when he measured the variation in ionization in the atmosphere while he was ascending in a balloon up to 5300 m. Much later he received the Nobel Prize in Physics, in 1936. In the 1930s, Bruno Rossi and others verified that the cosmic ray intensity was greater towards the west, which showed that they were positively charged particles, and Pierre Auger discovered that cosmic rays interacted with particles in the upper layers of the atmosphere, forming cascades of high-energy elementary particles that could reach the Earth's surface. From then on, cosmic rays were of dual scientific interest: to identify the sources in the Uni-

verse that produced them, and to study the high-energy subatomic particles in them. The muon, pion, and positron were first observed in cosmic ray detectors.

7. Dr Carreira was even honored by University's rowing club which assigned the name 'Rev. Emmanuel Carreira' to one of its boats.
8. For example, see the following site: http://galegos.galiciadigital.com/en/manuel-maria-carreira-verez

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Carlos Viscasillas Vázquez was born in Vigo (Spain) in 1979. He is a researcher and member of the Astrospectroscopy and Exoplanets Group in the Institute of Theoretical Physics and Astronomy at Vilnius University. He has a PhD in astrophysics with a thesis on the chemical abundances of neutron-capture elements in the Milky Way.

He is co-investigator of the Gaia-ESO Survey (GES); MW-Gaia COST Action 'Revealing the Milky Way with Gaia'; the INAF Chemical Clocks (CheCs) project; as well as the future Wide-field spectroscopic telescope (WST). He was a trainee at the European Space Agency (ESA) with a project on mass loss and stellar wind of WR stars. He did his master's thesis on asteroseismology of OB stars. He has carried out scientific missions at the Arcetri Astrophysical Observatory, the Padova Astronomical Observatory and the Molétai Astronomical Observatory. At the Astroengineering Center (AIUC) in Chile, he participated in the first stages of the design and construction of the FIDEOS spectrograph.

Carlos has been a member of the SOC and LOC and participant in several international scientific conferences around the world, and is author of papers in well-recognized scientific journals.

Ederlinda Viñuales Gavín has a PhD in Mathematics from the University of Barcelona, and is a member of the SPACE Mechanics Group (GME) of the University of Zaragoza in Spain.

She has dedicated her work mainly to the training of high school teachers in Astronomy, mainly in Europe. She is the author of numerous articles published in various national and international magazines and more than a dozen books.

She is a member of the International Astronomical Union (IAU), and the European Astronomical Society (EAS), and currently is the President of the European Association for Astronomy Education (EAAE) and is Treasurer of the Network for Astronomy School Education (NASE). She is also a member of the Spanish Astronomical Society (SEA) and the Association for the Teaching of Astronomy (ApEA).

Adriana De la Calle Viscasillas (Pontevedra, 2004) is a first-year student in the Walsh School of Foreign Service at Georgetown University, majoring in International Politics and minoring in French.

During her secondary studies in Nicaragua, she competed in the Central America (CONTECA), Central America and the Caribbean (COTECC) and International (ITF) circuits with the National Tennis Team, including participation in the World Junior Tennis Competition and Junior Fed Cup. She also participated in and helped organize various international debate and Model United Nations conferences, including the North American Invitational Model United Nations (NAIMUN) in Washington, D.C. and the Debates Académicos de Líderes Estudiantiles

(DALE) in Managua, where she served as committee director and board member.

She is currently a staff member of the Georgetown International Relations Association, Inc., organizing staff of NAIMUN, and is a member of the Georgetown University Club Tennis Team.

Ricardo Moreno Luquero was born in Madrid in 1955. He is a Professor of Civil Engineering at the Colegio Retamar in Madrid (Spain).

He has focused his work on teacher training and astronomical popularization. He is a founding member of NASE (Network for Astronomy School Education), and is the Editor of *Nadir*, the magazine of the ApEA (Association for the Teaching of Astronomy).