annual **REPORT 2022**

The Vatican Observatory

From Plates to Pixels

The **digitized archive** of the Specola Vaticana **telescopes**

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STAFF

During the calendar year 2022, the following were permanent staff members and associated scholars of the Vatican Observatory, Pontifical Villas of Castel Gandolfo, and the Vatican Observatory Research Group (VORG), Tucson, Arizona, USA:

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- PAUL MUELLER, S.J., *Vice Director for Administration (through July)*
- GABRIELE GIONTI, S.J., *Vice Director for Administration (from August)*
- PAVEL GABOR, S.J., *Vice Director for VORG*
- PAOLO BELTRAME, S.J.
- RICHARD P. BOYLE, S.J.
- DAVID A. BROWN, S.J.
- CHRISTOPHER J. CORBALLY, S.J., *President of the National Committee to the International Astronomical Union*
- RICHARD D'SOUZA, S.J.
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- ROBERT J. MACKE, S.J., *Curator of the Vatican Meteorite Collection*
- ALESSANDRO OMIZZOLO
- THOMAS R. WILLIAMS, S.J., *Assistant to the Director and Vice Directors*

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- GIUSEPPE TANZELLA-NITTI

Other Scholars:

- CLAUDIO COSTA, *Technical Expert*
- MATTEO GALAVERNI, *Associate Scholar*

Vatican Observatory
Castel Gandolfo
V-00120 Vatican City State

Vatican Observatory Research Group
Steward Observatory
University of Arizona
Tucson, Arizona 85721 USA

vaticanobservatory.va
vaticanobservatory.org

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CONTENTS

Cover: Fr. Alessandro Omizzolo has overseen the the work of turning astronomical photographs on glass plates taken at the Vatican Observatory from 1893-1986 into computer-readable digital images. After for than twenty years of effort, this task was finally completed in 2022.

Back cover: Negative image of the Milky Way in the constellation Cygnus, taken with the Double Astrograph telescope on July 10, 1948.

Pages 2-3: Star positions found on the Carte du Ciel photographs plates were measured by Sisters Emilia Ponzoni, Regina Colombo, Concetta Finardi and Luigia Panceri of the Sisters of the Child Mary.

Pages 4-5: Four different telescopes took astronomical photographs at the summer Papal Palace in Castel Gandolfo: left, the twin telescopes of the 1935 Double Astrograph; above, the 1891 Carte du Ciel telescope; bottom, the 1957 Schmidt astrocamera.

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p. 6 Karen Cox Photography; p. 8: Cathi Duncan, University of Arizona; pp. 9-10: Silver Orchard Creative; p. 60: M. Kapua, SURF

Editor: Christopher Graney
Design, layout and digital edition: Antonio Coretti

CHAPTER ONE

Letter from the Director

The right people, the right place, the right time

Astronomy is the study of stars and planets, yes? Well, not exactly. We spend at least half of our time writing up what we have discovered; going to meetings to share that with others; listening to what others have learned; reading the papers and books they have written. Perhaps it would be more correct to say that astronomy is the study of what people have said about stars and planets.

Astronomy doesn't happen without a community of people. And the community of the Specola Vaticana is no exception. Documenting what our community has done this past year is the whole point of this Annual Report. In fact, however, this year has seen a important changes in our community, both at the Specola itself and in the Vatican Observatory Foundation… on which we rely so much to be able to do the work we've been given.

A key player in our community and observatory for many years has been **Fr. Paul Mueller**. A philosopher and historian of science, he was assigned to be the superior of our Jesuit community in 2010, just as we had moved to our new quarters in the gardens near Albano Laziale. Leaving the papal palace, where the Specola had lived and worked for more than seventy years, was unsettling to say the least. He guided the community during those turbulent times; no small feat.

In 2015, when I was appointed director, our Jesuit superiors gave him the additional task of also serving as Vice Director of the Specola. From my point of view, he has had two important tasks in this role: to keep me sane, and to drive me crazy. The "crazy" part was essential; he had to remind me of all the tasks, duties, and opportunities that I didn't see — or didn't want to see. The "sane" part was his inexhaustible work in dealing with so many of those issues.

One vital issue that he kept closely in view was the state of our Foundation. Support from the Vatican Observatory Foundation is essential to the work of the Alice P. Lennon Telescope and Thomas J. Bannan Astrophysical Laboratory on Mt. Graham in southern Arizona. The Foundation is also a vehicle for us to reach out to the general public, especially in America where it is incorporated.

But for many years, and for many reasons, the money we have drawn from the Foundation has been a bit more than the money it has been raising. Not by a whole lot; it was easy to see each year's shortfall as minor, temporary, something that could be made up at the moment by nibbling at our endowment. But after too many years of nibbling, it was obvious that something had to change.

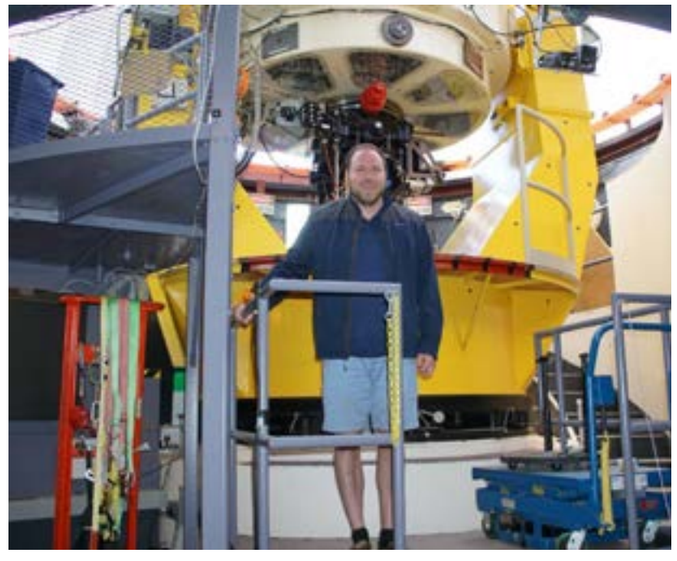
Paul pushed for that change, forcibly. Of course, this was in early 2020, just as Covid was hitting. We made two important moves that year. We hired a consulting company to show us a path forward. (In the process, they encouraged us that the situation was far from hopeless — something we needed to hear!) And then, just at the right time, we were able to bring a major donor, **Mickey Pohl**, onto the board. Finally, this past year we convinced Mickey to become the board chair.

Mickey is a retired lawyer and partner at the prestigious international firm of Jones Day… search his name on the internet for some fascinating stories about him, more than I could cover here! He's an active Catholic who has served on a number of charitable boards, and who loves learning new things — like astronomy. When he decided to take the Foundation under his wing, things started happening. Quickly.

One immediate outcome of these two events was recognizing the need, and finding the resources, to bring aboard a full time development director. Ideally, we would have liked to have had someone with plenty of experience in Catholic fundraising… but young enough that he would be eager to take on our challenge. (And affordable enough that we could hire him!) Even better would be someone with a knowledge of the Jesuits, our spirituality and our way of proceeding. But what are the odds we could ever find such a person?

Enter **Chris Kennedy**: a Fordham University graduate (class of 2012), well grounded in Jesuit spirituality, who'd worked for a large charity in New York City before looking for new heights to climb.

Chris came on board this spring. So far he's done a great job of keeping me sane by taking over all the tasks at the Foundation, from planning to day to day paperwork, that too often slipped out of my fingers. (I imagine it'll only be a matter of time before he takes up the mantle of driving me crazy when I need it!)



Chris Kennedy visited the VATT as part of his new duties with the Foundation..

Sister Raffaella Petrini FSE visited the University of Arizona in February and got a back-stage tour of the Mirror Lab.

Above, Astronomy Department chair Dr. Buell Januzzi explains the mirror polishing process to Sister Petrini and Katie Steinke.

Right, Br. Consolmagno, Dr. Januzzi, Sister Petrini, Ms. Steinke, Fr. Corbally, and Fr. Gabor pose before an 8.4 meter mirror being prepared for the Giant Magellan Telescope.

I should also mention the tremendous support he has gotten from **Katie Steinke**, who came out of retirement from her work on the board, and **Msgr. David Rubino**, an experienced fundraiser who's a personal friend of Mickey's. They agreed to help serve as mentors and institutional memory for Chris as he has come up to speed.

One last, but very important, piece of the puzzle was the arrival of **Sr. Raffaella Petrini**, a member of the Franciscan Sisters of the Eucharist, who was appointed Secretary-General of the Governorate of Vatican City State in November, 2021. As Secretary General, she has an ex-officio position on our Board of Trustees. But more than just keeping tabs on the emails we send to the board, she's taken an active role in promoting the work we do.

I had gotten to know one of her fellow sisters, Sr. Judith Zoebelein, who had set up the Vatican's internet office back in the 1990s. When I invited Sr. Judith and her community to visit the Specola headquarters in 2018, Sr. Raffaella came along. She was obviously impressed with what she saw.

In February of this year, she took the unusual step of making a visit to Tucson to meet us all. There she got to know Mickey (who had come for the annual board meeting) and the Jesuit community. She also spent several days meeting with high officials at the University of Arizona, where the Specola shares offices, telescopes, and other resources. This included a tour of the Mirror Lab, and lunch and private meetings with Dr. Buell Januzzi, chair of the Astronomy department, and top officials at the University. She also met the University president, Dr. Robert C. Robbins.

And so what has this dream team accomplished in their first few months? Well… we had a reception in October at the Nunciature of the Holy See in Washington DC where eighty friends of the Foundation, both scientists and supporters, got to meet and greet Sr. Raffaella, who flew in from Rome for the event. We offer our great thanks to the Nuncio, His Excellency Archbishop Christophe Pierre, for serving as our gracious host.

And then, just a few days later, the Thomas Lord Charitable Trust agreed to grant the Foundation $500,000 to help fund the complete automation of

Foundation chair Mickey Pohl (right) introduced Sister Petrini and Br. Consolmagno at the Papal Nunciature in Washington DC on October 8.

the Vatican Advanced Technology Telescope. (Watch this space in future years to learn about what this all will accomplish!) Mrs. Judy Alstadt, the chair of that board, also contributed a substantial sum from her own charitable fund… as did Mickey Pohl. The robotic system will be named "Don" in memory of Mrs. Alstadt's husband, Donald, who had been an inventor of note and who would have loved the technology now going into the telescope system that will bear his name.

With the work of all these great people, I do also want to note the departure of two long-standing supporters of our work. The first is the outgoing chair of the Foundation board, **Richard Friedrich**, who held things together during a very difficult time of transition. I thank him for all he did during his tenure; he has taken a well-earned retirement.

The other departure is, alas, the aforementioned Paul Mueller. In August, after twelve years as superior (twice the usual term of office), his Jesuit superiors missioned him to a new task as superior of the large community of Jesuit scholars at the Pontificium Institutum Biblicum, or "the Biblicum" for short. It will be a challenging post, but one which I am sure he will handle with aplomb. We already miss him here. Fortunately, he's just down the road, in Rome, and available to remind us where he's hidden the keys or whatnot.

It is taking two different people to fill Paul's roles. **Fr. Gabriele Gionti** has taken on the duties of vice Director, while **Fr. Richard D'Souza** is now superior of the Jesuit community. They are performing these tasks in addition to their very active scientific careers.

Br. Guy Consolmagno, S.J.
Director, Vatican Observatory

Other Personnel News:

Two notable milestones were achieved for members of the Specola family this year. On February 2, **Br. Robert Macke** took his final vows as a Jesuit Brother. And on December 2, **Dr. Maria Elena Monzani** was sworn in as a US citizen.

Along with the departure of Fr. Mueller, the Specola was the home for a few months of the Jesuit scholastic **Mr. Paolo Beltrame**. Paolo had already earned a doctorate in physics from the Karlsruhe Institute of Technology, Germany and had served as a senior research fellow at the University of Edinburgh and visiting research at University College of London before entering the British province of the Jesuit order in 2017.

A native of Rome, he visited the Specola many times during his Jesuit formation. Finally, upon completion of his theology studies in Paris, in August he joined the Specola in Tucson and began a research program with the cosmology group headed by Elisabeth Krause, working especially on weak lensing problems.

This period was a part of his Jesuit formation process called "regency", a time for testing one's vocation. In fact, Paolo had been praying about his vocation during his studies in Paris but he had, quite properly, delayed making any final decision during that period, which he had found quite stressful. His time in Tucson was in fact a period of consolation where he was able to discern more clearly where he felt he should be. It became clear to him that his questions about his vocation were not merely the result of the stress of studies, but an actual call from God to a different life.

On November 8, Paolo returned to Rome and officially informed Fr. Johan Verschueren SJ, Delegate to Father General for the international houses, that he wished to withdraw from the Society of Jesus. The withdrawal was completed at the end of November.

"It was a short experience," Paolo writes, "but an intense and very formative one. I would sincerely have loved to continue working in the cosmology group… maybe in another life."

Although we miss having him as a part of our community, we rejoice in his renewed clarity concerning his vocation and we hope to continue our close friendship and scientific collaboration as he moves onto the next chapter in his life.

Dr. Monzani with her congresswoman, Jackie Speier (left), at her naturalization ceremony in December.

CHAPTER TWO

From Plates to Pixels

Turning historic astronomical photographs into a digital archive

Photography and Astronomy

The photographic plate, a sheet of glass coated with a gelatin of photosensitive chemical (the "emulsion"), was invented in the mid 19th century. Such plates were soon recognized by astronomers around the world as an innovative tool for astronomical observations. If you could rely on photographs instead of the human eye, you could finally get an objective record of what was observed in the sky in a way that did not depend on the particular acuity of the observer (what was called the "personal equation"). Individual observations would not be biased by the expectations of the particular astronomer.

Furthermore, you could easily compare your observations with the measurements made by other astronomers. For example, when Angelo Secchi compared his photographs of the 1860 solar eclipse taken at Desierto de las Palmas in Spain with those of Warren de la Rue from some distance away, they saw that the shape of the solar corona was the same in both images. This proved that the corona was an actual feature of the Sun, not an artifact of Earth's atmosphere.

Furthermore, you could preserve these observations for study at a later date. What was probably not recognized so widely then was how important they would be, when that "later date" was more than a hundred years into the future!

By 1900, every serious observatory was equipped with a darkroom where these plates could be prepared and developed. The Vatican Observatory was no exception. It began to produce photographic plates from the very first years of its founding, especially with the 1891 Carte du Ciel Astro-camera. It continued to do so until the early 1980s, when the use of the photographic plate was abandoned in favor of electronic digital detectors.

The Vatican Photographs

The oldest photographic plate in Vatican Observatory collection was taken at the Carte du Ciel telescope on January 14, 1893; the identity of the astronomer is not known. The last photographic plate at the Vatican Observatory was taken on June 27, 1986, by Fr. Richard Boyle, using the Schmidt telescope. Between these two events, over a 93 year span, four Vatican telescopes produced nearly 10,000 photographic plates.

The oldest of these instruments is the Carte du Ciel telescope, which began to take plates from a location on the Vatican walls but which moved out of the city during World War II to a location in the Papal Summer gardens of Castel Gandolfo. Meanwhile, in 1935 three other telescopes were installed atop the Papal Summer Palace in Castel Gandolfo: a Zeiss refractor view of 40 cm aperture (which was not used primarily for photography) and two other telescopes on a common equatorial mount, the Zeiss double astrograph. Finally, in the 1950s a Schmidt telescope of 65/98 cm aperture was set up in the nearby gardens next to the 1942 installation of the Carte du Ciel.

The Carte du Ciel telescope was specifically designed to be a photographic instrument. This photographic equatorial telescope and its rotating eight-meter dome were constructed in Paris in the Gilon workshops. It consists of two lenses in a single tube; an eyepiece telescope with an aperture of 20 cm and a focal length of 360 cm, and the camera itself, whose lens has an aperture of 33 cm and a focal length of 343 cm. It takes a photographic plate of 13 x 13 cm covering a field of view of 2 degrees square. This telescope was set in place on the Leonine Tower in 1891, close to the present-day location of the Vatican heliport. The telescope was moved to the summer gardens of Castel Gandolfo in 1942; the final plates for this project were taken in 1953.

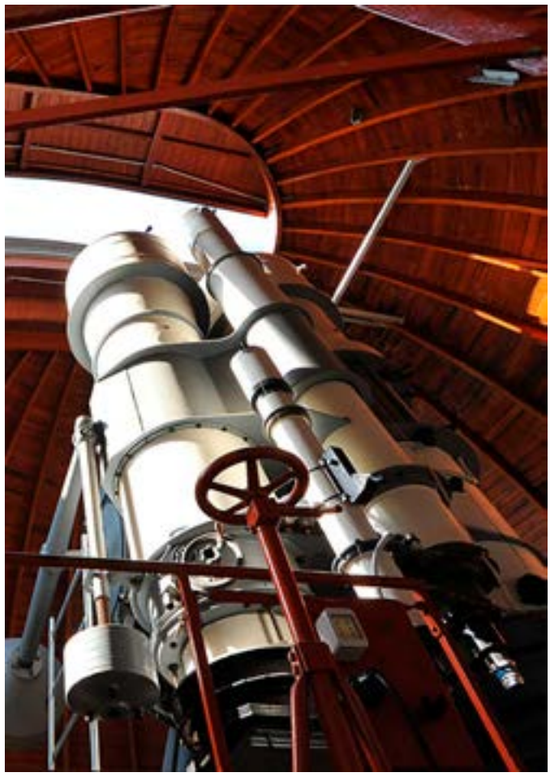
In total, 1688 plates were taken with this telescope: 540 plates for the map itself, and 1148 for the Astrographic Catalogue. These latter plates were measured by four human "calculators," Sisters Emilia Ponzoni, Regina Colombo, Concetta Finardi and Luigia Panceri of the order of the Sisters of the Child Mary. They determined the position and magnitude of each bright star, more than 500,000 in all, which were then published in several volumes of tables.

The two telescopes of the Z*eiss Double Astrograph* consist of a refractor with a 40 cm four-lens objective of 240 cm focal length and a reflecting telescope with a 60 cm parabolic mirror of 200 cm Newtonian focal length and an equivalent 8.2 m focal length at Cassegrain focus. The four-lens astrograph allowed 30x30 cm photographs with image correction to be taken; it was particularly suitable for photographic observations of variable stars and for the photographic determination of the positions of minor planets and comets. Both instruments plus two finders and a guide telescope were rigidly linked together and mounted on the same polar axis. A total of 4745 plates of various dimensions were exposed using the 40 cm refractor; the 60 cm reflector made a total of 1241 plates.

In 1949 a *Schmidt* telescope was ordered from the firm of Hargreaves and Thomson of London. Five years later work began on the construction of the Schmidt building, joined to the dome built in 1942 for the Carte du Ciel. The telescope was delivered in 1957; after several years for installation and testing, observational programs began in 1962. The instrument has a spherical mirror 98 cm in diameter, with a 65 cm aperture corrector plate mounted at the center of curvature of the primary near the tube opening. The focal length is 2.4 meters. The 20 x 20 cm photographic plate is placed at the focal plane, about half way down the tube. The usable field is about 5 x 5 square degrees, an area more than six times larger than that of the Carte du Ciel astrograph.

For spectroscopy it used a combination of three objective prisms at the tube opening; these prisms are among the most powerful in the world. The Schmidt telescope produced 794 plates of direct images; another 1326 plates of stellar spectra taken with a prism placed before the corrector plate; and 90 plates were obtained by applying a polarimeter to the telescope.

The Schmidt telescope replaced the Double Astrograph as the workhorse of the Observatory. It was used for about twenty years to study the evolution of star clusters by stellar spectroscopy and polarimetry. Unfortunately, by the early 1980s light pollution from the surrounding towns made the site unusable.



The photographic plates produced by these telescopes were kept in envelopes where the details of each exposure were recorded, and these in turn were kept in a series of wooden cabinets in a cool, dark location near the telescopes. With the construction of the Schmidt dome, the plates were kept for many years in the basement of that dome, and later in an out-of-the-way room in the Papal Palace near the darkroom. With the move of the Specola to its current location in the Papal Gardens in 2009, the plates were given their current climate-controlled location near the library and astronomers' offices.

Mining the Data

The historical value of all this material is great, and for that reason alone it would deserve to be preserved. But the scientific value of this material is perhaps even more important, because it constitutes a historical base of a century of data that can still provide useful information for contemporary astronomical research.

The Cart du Ciel Program

In 1887, astronomers in Paris organized the first photographically based atlas of the stars: the Carte du Ciel (Map of the Sky). The Carte du Ciel program enlisted national observatories from around the world to produce a photographic atlas of the entire sky. Eighteen observatories located in countries on all continents participated in the project.

The Paris agreements provided that all of the eighteen observatories participating in the Carte du Ciel project would obtain instruments that had the same characteristics, to assure uniform results. For this purpose the Vatican obtained the particular Carte du Ciel telescope made by Gilon in Paris described above. The inclusion of the Specola at this time was significant both for demonstrating the role of the Church in the world of science and in the recognition of the Holy See as a separate nation, equal to and independent of the other nations in the program… including Italy.

Each of the participating observatories was assigned a strip or zone of the sky, and two series of photographs were taken: a short exposure to catalog the stars down to 11th magnitude by their brightness and position, and a longer exposure to reach 14th magnitude. The map itself consisted of enlargements of these photographs. The Vatican Observatory was given its swath of sky between the parallels of +55 and +64 deg.

It required 1040 plates, each covering about two square degrees, to cover this area completely and with some overlap for both the Catalogue and the Map. In order to distinguish true stellar images from spurious ones, multiple exposures were taken on a single plate; three forty-minute exposures were taken with the plate moved between exposures to produce a small triangle of three images for each star.

Maurice Lœwy, director of the Paris Observatory and president of the permanent committee for the Carte du Ciel, said in 1891 that a prime motivation for this atlas was to establish the position of each star, so that one could determine at a later date whether it was still there, had moved, or had disappeared. This is in fact one of the great values of the atlas today, more than 130 years after the first plates were taken.

Top, the Milky Way in the constellation Cygnus; below, the star regions surrounding the constellation Orion

One example of how our plates have led to a deeper understanding of a scientific issue was the test of the "hibernation model" for the evolution of cataclysmic variables. It was assumed that binary stellar systems, where one star orbits another, can occasionally erupt into bright "novas" when material from one star is pulled onto the surface of the other. If that happens, the times between such events would represent the stars in "hibernation". This model could be tested because the transfer of such material from one star to the other as the star goes nova would make the orbital period of the pair grow dramatically after the nova event.

Can this be observed? If the nova occurred in a double-star pair of a particular type called an eclipsing binary, we can easily measure its orbital period; one simply measures how the long it takes for the brightness of the star pair to dip as one star goes behind the other. The trouble is that, while we can measure the star system's period after the nova, until it goes nova there would have been no reason to measure that pair's period.

The answer is to go to old photographic plates, measure the brightness of that star at many given times, and from that deduce what orbital period of the pair best fits the different brightnesses we see in the plates. Dr. Brad Schaefer, an expert in these variables and in the use of old photographic plates, tells what happened when he tried to make these measurements for one particular variable star:

"[I needed to find] a nova with deep eclipses… This was possible for QZ Aur, a poorly observed nova in 1964. But how to get archival plates of QZ Aur from before 1964 that shows at least several eclipses? …I made long searches at Harvard, and travelled to use the plate stacks at Sonneberg, Asiago, Jena, Bamberg, and the Maria Mitchell observatories. This covered nearly all the world's supply of old deep plates, and I found nothing.

Then I tried going to the Vatican plates. Among your cataloged plates, I found one old plate showing an eclipse, but that was not enough to get a period. So I kept trolling through a series of what were then uncatalogued plates, even looking on plates with QZ Aur far on the edge. And I found two more eclipses. This was great good luck. But it was enough to produce a solid pre-eruption orbital period and a measure of the change in the period.

To his surprise, the change in the period he observed was the opposite of what the theory predicted! And so the hibernation theory was refuted – the most commonly accepted theory of how cataclysmic variables behave. "There is still nothing to replace it, and the field is in disarray," according to Dr. Schaefer. "And this all came about because the Vatican plates stored a number of lucky plates showing very old QZ Aur eclipses."

Preserving the Data

To preserve these data and make them more widely available for researchers around the world, so that they would not have to travel themselves to so many different plate archives, in 2000 we decided to start a process of digitization of all of the Specola's astronomical photographic plates. George Coyne, then director of the observatory, entrusted this work to Alessandro Omizzolo; Richard D'Souza and Robert Janusz also contributed in processing and archiving these data.

First, we had to decide which type of scanner to use. After several tests, we opted for a high-level commercial scanner (Epson Expression 1640 XL, tested both at the Vatican Observatory and at the Department of Astronomy of the University of Padua) which offered many advantages. It provides a way for light to shine through the glass plates; it is large enough to scan large format plates (corresponding to the A3 format); and it has a resolution high enough to preserve image quality (maximum value 1600 x 3200 pixels). Then, once this scanner was set up, each of the 10,000 plates had to be scanned by hand, one by one.

And now, twenty-two years later, the scanning is complete.

Why did this effort take so long? The main reason is that the preparation phase of the scan for each plate required a considerable amount of time.

Before performing the actual scan, it was necessary to clean each plate from the traces of time, that is, from dust and other human interventions that made it little or not at all legible. But that was not the only preparatory work needed before a scan could be made.

It was important that the scanned data would provide an accurate ("linear") image of the plate. The density of the opaque chemical on a negative photographic plate varies from point to point on the plate according to the brightness the objects photographed. However, if the objects are too bright for the exposure time, they will show up on the plate as spots of "saturation"— the negative image of the star appears already as dark as the plate can show, and so any difference between the brightnesses of different bright stars is lost. This is an intrinsic characteristic of photographic plates (see the sidebar).

Thus particular care was taken in scanning these plates, especially for those plates from which one would want to extract photometric measurements of star brightnesses: for example the wide-field plates of the Schmidt telescope and in general the plates of the Double Astrograph.

This became an important factor in fixing the scanning parameters in order to obtain a digital image that was as faithful as possible to the original and as little saturated as possible. To do this, the saturation of the image was measured at various points on the plate and the values thus obtained were interpolated. The interpolated value became one of the scan parameters for that plate.

Another important element was to characterize each image with the data relating to the exposure of the plate. These include the telescope used, the day and time of the exposure, and the astronomical coordinates of the center of the plate. It is also important to record the quality of the sky during the exposure, and the exposure time used.

But in addition, it happened that over time Kodak produced plates with different sensitivities which, combined with appropriate filters, could provide magnitude and color values corresponding to the standards used: visual, photographic, bolometric magnitudes, UBV and UBVRI magnitudes. Thus it is also essential to record the type and characteristics of the plate itself and how it was processed, including development time and materials used for the development; any correcting plate (in the case of plates obtained with the Schmidt telescope); any filters used; any treatments of the plate before exposure (to increase its photometric capabilities and to make it more sensitive to certain wavelengths). All these data uniquely identifies each plate and so its digitized image as well.

All this information is usually found on the paper envelope that contains the plate. Thus a digital image has also been produced of each of the envelopes for all of the plates. But in addition, since the digital image is stored in a particular format known as FITS ("Flexible Image Transport System"), this information can be stored together with the image in a part of the file called the "header." That had to be added manually for each file.

Publishing the Data

After 22 years of work, the scanning of the plates and the envelopes that contain them is finally complete. It is now a question of making this heritage of history and science accessible to researchers from all over the world, including those involved in science education who can introduce the younger generation to the discovery and use of this precious material.

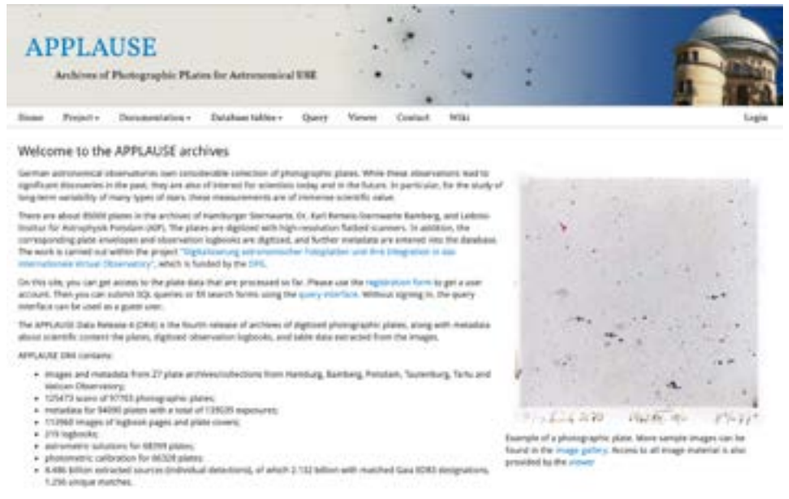
The images thus obtained have been stored on computer media of various kinds; and of course, over the time of this work, the media for storing large data files has also evolved. At first we used single- or double-sided DVDs. The choice was made because the size of each file is considerable (up to 300Mb) and therefore ordinary CDs, whose capacity did not exceed 700Mb, were not suitable for the operation. In addition to DVD storage, copies of each file were made on a hard disk drive that serves as a backup. Then, as cloud storage became available and economical, all of the images have also been written to a Dropbox server.

Finally, as other observatories around the world have also begun to preserve their precious record of glass plates, the *Applause* project is being developed in Germany (*https://www.plate-archive.org/cms/*) to bring all these plates into one searchable location. We have provided our plates to them to ensure that they will also be a part of this archive.

An abundance of storage/storage methods serves to avoid any data losses that can happen to a work that lasted 20 years. But the final issue is making these data easily accessible to the scientific community. Simply storing the data in "the cloud" is not sufficient if there is no way for a scientist to know what times and locations are available. That is the goal of the Applause project; unfortunately, Covid and funding issues have delayed its full implementation.

As a temporary measure, we are working to put online a simple database which could be downloaded from our website www.vaticanobservatory.va. It would list our plates including telescope, date, location, and other essential descriptors. An astronomer who might be looking to see what was in the sky at a particular place and time would then be able to search that file to see if we have such a location available; then they could write directly to us for our scan of that plate. Of course our staff is limited, so we hope that this service will not be abused!

That work is in progress. For the present, it is enough to celebrate the fact that the enormous work of digitizing the plates has been completed!



Eye, Film, and Electrons

Soon after the invention of photography, it became clear that the sensitivity of a photographic plate was different from that of the human eye. For one thing, the human eye can see different colors with a different intensity compared to the emulsions on the plates. Indeed, early plates might be sensitive only in red or the blue ends of the spectrum; "pan" films that could record all colors only became widely available in the 1920s.

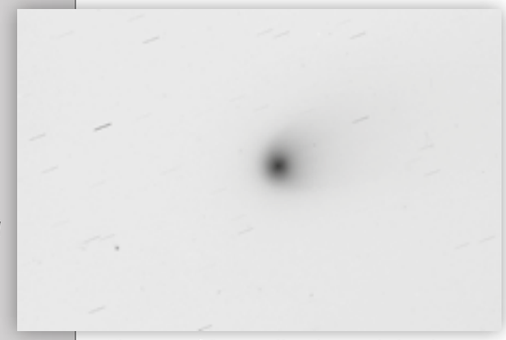
Furthermore, the sensitivity of the photographic plates depended on the choice of chemicals used in the emulsion and of any treatment they underwent before being exposed. For example, among the techniques used to increase the sensitivity of the plates might be to immerse them in a bath of pure nitrogen or oxygen gas. Likewise, different development chemicals and techniques could change the resolution and sensitivity of the photographic image. Thus, sifting through the records of the observations of any professional astronomical observatory, you will notice that alongside the coordinates of the object, the exposure time, the description of the conditions of the sky at the time of observation, and so forth, you will also find an indication of the type of plate and any filters used.

In addition, photographic plates were particularly vulnerable to a systematic error known as "reciprocity failure." It had been hoped that with objective photographic plates one could finally solve one of the most thorny problems of the previous research: to have a measurable record of the intrinsic brightness of one star compared to another. If the density of the chemicals on an exposed spot on a plate (which of course produces a "negative" image of the sky) lined up with the brightness of a star, one could simply measure the darkness of the spot, i.e. density of the dark chemical on the plate, with a special device called "densitometer" to measure accurately the star's brightness: the darker the spot, the brighter the star.

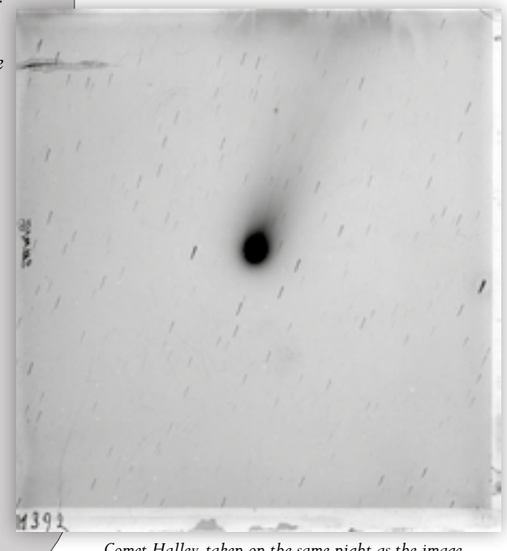
Unfortunately, this sort of reciprocal "linear" response was only valid for a narrow range of colors and a narrow range of brightnesses. This situation was greatly improved by using electronic chips to take the images. The response of a chip is linear over a much wider range of brightnesses ("dynamic range") although eventually they too can saturate. In addition, they are more sensitive to faint light, and the data that make up the image can be downloaded immediately into a computer for numerical analysis.

Since the development of the CCD and other electronic detectors in the 1980s, no scientific data have been obtained using photographic plates at Vatican Observatory. Meanwhile, thanks to light pollution around Rome, the usefulness of the site in Castel Ganfolo has been greatly reduced. Instead, the Observatory equipped itself with a telescope located on Mount Graham in Arizona, not far from Tucson: the Vatican Advanced Technology Telescope (VATT), consisting of the Alice P. Lennon telescope and Thomas J. Bannan astrophysical laboratory. No photographic camera and indeed no eyepiece was installed in this telescope; instead, it uses only electronic detectors.

This box of glass photographic plates from 1895 is now used to store the astronomical images taken at the Vatican with them at the end of the 19th century



This image of Comet Halley, photographed at the Specola, May 29, 1910, used a short exposure to bring out details of the coma around the comet nucleus



Comet Halley, taken on the same night as the image above but with a longer exposure time, brings out the comet's faint tail but the coma and nucleus are now "saturated" and detail there is lost

CHAPTER THREE

2022 A year in review

How does the VATT get scheduled? The committee is Paul Gabor (Chair), Jean-Baptiste Kikwaya and me. I receive each semester, from the Telescope Allocation Committee of the University of Arizona, those observing requests for the 25% of the time to be scheduled on the VATT that is reserved for the universities of Arizona (UA, ASU, NAU). I receive observing requests from the Vatican Observatory staff for the other 75%. Logistical considerations like instrument changeover and cleaning of the facility also must be scheduled. With feedback from observers I manage to please observers' requests almost all of the time.

I am pursuing observational research with the VATT in several areas: Vilnius stellar photometry with our 4KCCD camera on galactic star clusters; time series stellar photometry with the on-loan Galway Ultra-Fast Imager (GUFI); asteroid searching in collaboration with Kazimieras Černis of Vilnius; exoplanet discovery with Daniel Apai's EDEN project of Steward Observatory.

Katie Pighini, a USA citizen of Manassas, Virginia, and a graduate student of the National University of Ireland Galway group, arrived February 23 from NUI Galway, for a 13-night VATT observing run with me to use GUFI on a triple brown dwarf system. In my January VATT observing with our 4KCCD camera, I included test observations of that system. This was to prepare for our February VATT observing with the camera GUFI. We had a very successful run getting all the necessary observations (~9 GB of data). Katie, who returned to Galway March 13, is now processing the data by analyzing the light-curve of the three components of this gravitationally bound system.

And, good news, a paper by Dr. Salam Dulaimi with co-authors Aaron Golden, Ray Butler, and me has been accepted by *Monthly Notices of the Royal Astronomical Society* for publication. By our observations with GUFI at VATT the light-curve of a brown dwarf (the M9.5 dwarf BRI 0021-0214) has revealed information about this cool object: optical variability, rotation period and inclination angle.

In my November observing run, I observed with the seven Vilnius filters a new open star cluster by applying our tie-in method. This allows calibrating the new cluster into the standard Vilnius system from another star cluster nearby on the sky that is already calibrated. This method of tie-in has replaced the classical method of all-sky photoelectric stellar photometry. Every Monday at 10 a.m. Vilnius (1 a.m. Tucson) our Vilnius Photometry Group, including Robert Janusz (at 9 a.m. Rome), meets by video to discuss our progress in our research for Galactic structure.

Also I continue to search at VATT for asteroids in collaboration with Dr. Kazimieras Černis of Vilnius and Dr. Wlodarczyk of Poland. In November we may have discovered another Trans-Neptunian Object. Our confirmation of a TNO in January generated some media attention for the VATT and the Vatican Observatory.

The year 2022 actually began with the need to travel back to Rome, Italy on 17 January to Specola Vaticana headquarters in order to renew my residency for Italy. While there, my research, centered on the PEPSI collaboration and calculating the chemical profiles of stars, continued as in Tucson. With the necessary steps for renewing my residency having been completed, I returned to the USA.

I stopped at Fordham University in New York City during 25-29 March in order to meet with a research collaborator, Jesuit Fr. John Cunningham, about our common project with the Lennon-VATT telescope. I then continued on to VORG headquarters in Tucson, Arizona to continue my research there. During 3-11 May, I directed the novices of the Sisters of Mercy of Alma (Michigan) on their 8-day silent retreat in Alma. This was followed by another retreat, which I directed, at Cloisters-on-the-Platte retreat house in Gretna, Nebraska for a group of 80 men during 12-15 May.

Upon returning to Tucson, I went to Mt. Graham to do a two-week observation run at VATT during 17-27 May, as part of the 50-night set of observations required by the PEPSI collaboration for the past four years in May-June-July, of which this is the final year. Next, I travelled to New Orleans, Louisiana to help lead a week-long seminar/workshop for faculty and staff on faith and science at Loyola University, called the Loyola University New Orleans Faith and Science Seminar, organized by Dr. Chris Baglow of the Science and Religion Initiative of the McGrath Institute for Church Life of the University of Notre Dame. I then travelled to St. Louis, Missouri to attend the Jesuit priestly ordinations, and take part in the province congregation being held by the United States Central and Southern (UCS) province during 13-17 June. Then in July, while in the vicinity of Worcester, Massachusetts for a meeting of priests, I gave a talk at St. Mary Catholic Parish in Uxbridge, Massachusetts.

It was then time in August to travel to Vatican Observatory headquarters in Rome (Castel Gandolfo) to continue my research, travelling up to the Leibniz Institute of Astrophysics Potsdam (AIP) to confer with my PEPSI research collaborator (Martina Baratella) and with AIP director (of the overall project) Dr. Klaus Strassmeier during 17-20 October regarding the next phase of the PEPSI-AIP-VATT collaboration after the submission of the PEPSI pilot paper in October. While at our headquarters in Castel Gandolfo, I was able to help organize a star party given for the benefit of the citizens of the town of Albano Laziale, next to where the Specola is located.

Having collected my residency permit, I returned to USA on 27 October, again stopping at Fordham University during 3-7 November to confer once again with John Cunningham about progress with our common project with VATT. I then continued on to Tucson, in order to continue with the research of the Vatican Observatory as part of VORG in Arizona.

The major scientific project that I've been involved with this year has been the completion and publication of work with Bob Macke, Dan Britt, Cy Opeil, and Cy's student Chris Noyes on the low temperature thermal properties of iron meteorites.

This project had been started in the years "B.C." ("Before Covid", and at Boston College) when Chris, then an undergraduate at Boston College, was looking for a research project to help bolster his application to medical school. His advisor, Cy Opeil, suggested a series of measurements of iron meteorites. The project was

successful on that account; he's now a student at the Zucker School of Medicine at Hofstra University. But with the onset of Covid, the data lingered on Cy's hard drive for more than a year.

In the meantime, a mission to the iron rich asteroid 16 Psyche was approved by NASA and suddenly these data became of particular interest to both researchers and those planning the mission. (This mission is expected to launch in 2023.) As our collaborative team has several data sets which need to be completed, I volunteered to shepherd this work through to publication. That came to a successful conclusion with the acceptance of the paper by the journal *Meteoritics and Planetary Sciences* in July.

I also had the chance to present the results of this work at the annual Meteoritical Society Meeting ("MetSoc") in Glasgow in August, and the annual Division for Planetary Sciences meeting in London, Ontario, in October.

The August meeting was one that I had looked forward to for a while. As my friends know, I am a great fan of train travel and so I had arranged to go by train from Rome to Turin, where I could spend a couple of days with Claudio and Maria Casacci, great friends both of mine and of the Observatory. (They helped out in organizing the MetSoc meeting in Rome back in 2001, more than twenty years ago now!) From Turin, I took the train to Paris and then the Eurostar to London, meeting up with there with Dr. Sara Russell and her family; she and I had been part of the Antarctic Search for Meteorites program in 1996, and her daughter is my goddaughter. Next stop was a visit to St. Andrews, Scotland (via the Caledonian Sleeper) visiting friends there, before heading to Glasgow for the MetSoc.

And that's when I felt a little tired, checked my temperature, and found I had tested positive for Covid.

Fortunately, because I had been vaccinated, the symptoms were quite mild. The Jesuit community in Glasgow was wonderfully welcoming to me, providing me with meals and prayers — and a good internet connection. Meanwhile, the MetSoc meeting was being run both live and on-line; and so even though I was sitting in a room less than three miles from the meeting, I wound up participating only virtually.

I do look forward to getting to next year's meeting, live. That is when I will take on the office of vice president of the Meteoritical Society. My term as president will begin in 2025.

One final milestone was reached this year, as I passed my 70th birthday. How terribly strange it all feels. (And those of you in m-m-my generation will recognize the song lyric!)

It was a joy last summer to be back visiting the Specola, both its staff and location, after three years away. The pandemic had kept me mainly confined to Tucson, but its easing (though not disappearing, as a number of our personnel can confirm) together with the science meeting of the International Astronomical Union's General Assembly (IAU-GA) provided reasons for my return. The change in vice-director and superior, which are recorded elsewhere in this Annual Report, was another good reason since there is no substitute for in-person conversations.

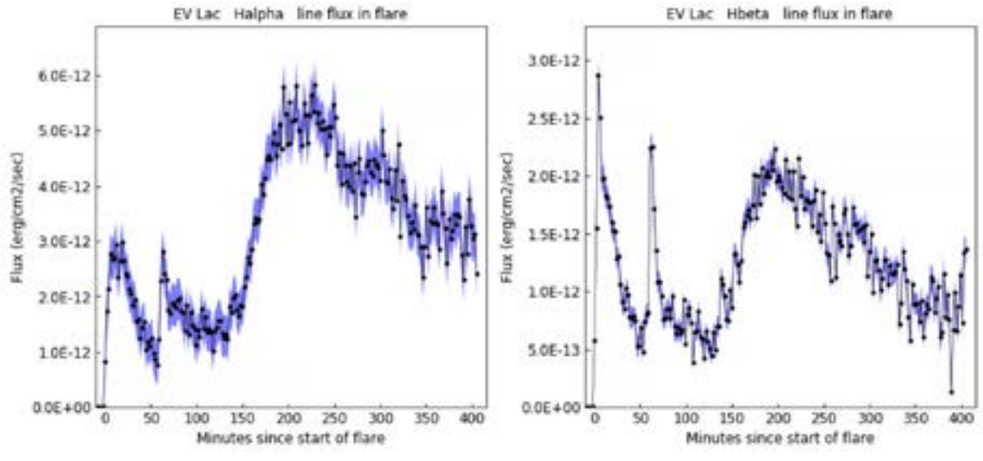
Now, the business meeting of the IAU-GA, which according to the bylaws needs to be held every three years, took place in August 2021. As President of the National Committee to the IAU, I duly participated in the sessions via video. However, the IAU Executive felt that the science sessions of the IAU-GA, postponed a year to August 2022, had to be held at least partly in-person. Besides, South Korea's astronomers had been preparing for the meeting over the last six and more years. Richard Boyle and I opted for virtual participation, he from Tucson which suited his nighttime schedule, and I from the Specola where the seven hours' time difference meant that I could attend the afternoon and evening sessions.

I heard some fascinating plenary talks, including one on machine learning for astronomical data, and anything on spectroscopy of stars featured by Division G (Stars) will always catch my attention. Since I am a member of the Working Group on Astronomy for Equity and Inclusion, I was glad to attend its talks and discussion. Still, I might most remember this IAU-GA for a first ever session on an overdue topic. The Working Group for Professional-Amateur Relations in Astronomy that ran this session had been going for just over a year. It was the brainchild of John Hearnshaw, emeritus professor at the University of Canterbury, New Zealand, who has over the years fostered the Vatican Observatory Summer School by recommending great students. Now at last the IAU was recognizing the significant contributions of dedicated and skilled amateurs to understanding our fascinating universe. They are far more than hobbyists with telescopes; they are true scientists.

Surely, I too have entered a bit late on the "pro-am" scene, but for the past couple of years I have enjoyed regularly learning from and contributing to the online meetings of the Spectroscopy Discussion Group. With the help of an astronomer at Arizona State University, James Jackman, their observations of flare stars are coordinated with the precise photometry of the *Transiting Exoplanet Survey Satellite* (*TESS*). Flare stars are perfect targets for amateurs since they can dedicate their telescopes to long hours of downloading one spectrum after another, waiting for the unpredictable flare, a rapid increase in brightness, to occur. Then, measurement of the energy output shown by various spectral features will go into online databases to help understand the phenomena. Recently, some in the group have spotted "peak-bump" events, when the minutes-long rapid rise and slow decline of the flare is followed by a bump-like increase in brightness lasting up to hours. Flares, as on the Sun, involve convective zones, magnetic fields, and atmospheric layers. What is happening in the star's atmosphere and on its surface regarding the dissipation of energy seen in the classic flare(s) and then a bump?

One of my recent observing contributions has been to a different pro-am project. Eric Crane, who I mentioned in last year's Annual Report as lead in carrying on the late Roy Tucker's work into the mystery system, MG1-688432, has interested several pro-am astronomers in monitoring its brightness fluctuations once it becomes observable in the first part of the year. Meanwhile, as a preliminary exercise in coordination, photometric observations of another peculiarly variable object have started. But a firmly non-variable reference star is needed in the same field, so I obtained a VATT spectrum of a proposed reference star and confirmed that it looked a perfectly normal, non-active K7V star. It will be quite suitable.

This has again been a productive year for interdisciplinary research and writing, particularly with Margaret Boone Rappaport (Human Sentience Project) as my principal collaborator. We were particularly challenged by an invitation from a guest editor to write a review article for a neuroscience journal's Special Issue "Beyond the Conductivity—The Impact of Neuroplasticity in Health and Disease". Well, we made the issue, and learned a good deal about current research into how neuroplasticity can help astronauts make decisions while on space missions.



A flare sequence in the hydrogen-alpha and hydrogen-beta features of EV Lacertae, showing two classic "Fast-Rise-Exponential-Decay" events followed by a slow "Bump" of significant energy output. The raw fluxes are from spectra by Forrest Sims, while the absolute energy emitted was calculated by David Boyd based on B-band photometry by Frank Parks, a truly cooperative result from the Spectroscopy Discussion Group. (With permission)

This year several projects which were long in the making finally came to fruition. One of these was an attempt to search for ultra-faint dwarf galaxies in the M81 group, the results of which were published early this year. Currently, the only ultra-faint dwarf galaxies that we know are found around the Milky Way and Andromeda galaxies. Accordingly, astronomers have tuned their models to reproduce these observations. Yet, the Milky Way may not be a typical galaxy, and there is a suspicion that its assembly history may have left a distinct imprint on its ultra-faint dwarf companion galaxies. Indeed, in an earlier work, we showed that the differences between the dwarf galaxies of the Milky Way and Andromeda could be explained by their very different merger histories. Discovering ultra-faint dwarf galaxy candidates outside the Local Group is essential to develop a global model of their formation while taking into account the merger histories of their hosts. The M81 group is the closest Milky-Way analogue outside the Local Group and a natural place to search for these extremely faint objects. Using our wide-field data of the M81 group from the *Hyper Suprime Camera* on the Subaru telescope, we were able to detect several ultra-faint dwarf galaxy candidates. While further follow-up observations are needed with the Hubble Space Telescope, this presents a great first step in understanding ultra-faint dwarf galaxies outside the Local Group.

Along these lines, undergraduate student Jiaming Pan from the University of Michigan led a project in which we were able to detect the globular clusters in the M81 group from the same ground-based wide-field Subaru data. This data set was used previously to study the stellar halo of M81, made up from past accreted dwarf galaxies. These advances will allow us to begin correlating various tracers of the assembly history of the M81 galaxy: its stellar halo, dwarf galaxies, and globular clusters.

Much closer to home, we published a paper studying how well we can recover the past orbits of the present-day dwarf galaxies of the Milky Way by backward numerical integration. The GAIA satellite has allowed us to understand the distances and the proper motions of Milky Way dwarf satellites to an amazing precision. Armed with these initial conditions and with reasonable assumptions of the potential of the Milky Way, it has become rather routine in the academic community to back-integrate the orbits of these dwarf galaxies. Yet little work was done to understand how well we can recover the original orbits, especially in the light of the fact that the potential of the Milky Way is currently changing with the accretion of the Large Magellanic Clouds. Our study aimed to fill this gap. We found that the uncertainties involved in recovering the orbits of the dwarf satellites are significant and are equivalent to back-integrating orbits with a 30% uncertainty in the mass of the potential of the Milky Way. This sets important limits on how well we as a community can reconstruct the orbits of the Milky Way dwarf galaxies, and the inferences we can draw about their origins from orbits alone.

This summer, I assumed additional responsibilities at the Specola, becoming the Superior of the Jesuit community both in Castel Gandolfo and Tucson.

This year was exceptional for me in two regards. First, since 2012 I always taught my history of astronomy and philosophy of science class only in the Spring semester. The Fall course was taught by other colleagues in the Department of Astronomy, lately by professor Christopher Impey. He asked me to switch semesters, and as a result, I taught my course twice this year, both in the Spring semester, and in the Fall semester. Second, I did not travel outside of the United States. These two anomalies were somewhat connected because my teaching obligations required my presence in Tucson by mid-August.

The classes were conducted in-person. This was a great relief, much preferable to the online teaching of the pandemic era. We took full advantage of the resources on campus in both semesters. Thanks to Prof. Thomas Fleming and the staff of the Flandrau Planetarium, we held a class session using the all-dome projection system of the planetarium, and thanks to Ms. Lisa Duncan of the University Library's Special Collections, we devoted one class session each semester to archival material and examined old prints, including the first editions of Copernicus, Galileo and Kepler.

I maintained the "flipped classroom" approach described in last year's annual report, adding two new elements. As a part of their preparation for the classroom session, each student, having watched the recorded presentation, composed a discussion-starter question and submitted it through the class's online platform. This stimulated the students' engagement with the material and made for livelier discussions in the classroom. Apart from the discussions, classroom time was devoted to nine small projects, working with various texts. The students worked in groups, identifying representative quotations, in answer to a roster of cues. Then they wrote short reports and submitted them individually.

This year marks an important milestone towards the robotization of the Alice P. Lennon Telescope and the Thomas J. Bannan Astrophysics Facility, known as the Vatican Advanced Technology Telescope (VATT). On behalf of the Vatican Observatory Foundation, I led the negotiations of a contract with ProjectSoft HK, and accompanied two of their lead engineers during their on-site technical inspection of the VATT (November 30 – December 4).

I have taken part in the third meeting of the Alliance of Historical Observatories. The first two took place in 2019 on Mt. Wilson, Palomar. After a pandemic hiatus, the meeting at Lowell Observatory in Flagstaff on November 4-5 recaptured the group's momentum and enthusiasm. The idea that resonated strongly at this meeting was that of awe. Astronomy has a great capacity for mediating life-changing awe at the grandeur of creation. And awe has a great capacity to kindle a passion for learning, as well as to make us grateful, humble, etc. Three years ago, at Palomar, it seemed that Yerkes Observatory was doomed. Since then they raised $17.2 million and hired a professional astronomer, Amanda Bauer. In spite of the Covid 19 slump and the raised cost of construction, Lowell completed the $4.7 million Giovale Open Deck Observatory, and is well on its way to build the $53.6 million Astronomy Discovery Center (they have raised $38.6 million already; they got the first donation in 2019; they raised a total of $70 million in the last three years, a substantial portion of which helped with the running costs). Speaking of money is often seen as an antidote to idealism, but in this case, money is a measure of the enthusiasm for astronomy which compels our souls to look up in awe (Plato's *Republic*, 529a).

Technical notes: Telescope operations throughout 2022 continued to follow the University of Arizona Covid19 guidelines in force since 2021B (Aug-Jan), namely, two observers/operators were allowed to work in the control room through the night.

As in the previous year, minor upgrade projects continued at the VATT: commissioning of the guider box, and the automated collimation and collimation maintenance procedure. Gary Gray continued to supervise the work on the hydrostatic-bearing oil chillers, switching to Trane Technologies. A new ZWO ASI 294MM guide camera was purchased.

The year 2022 was still a year marked by the "Covid Pandemic". Here at the Specola, in Castel Gandolfo, we continued to experience a lot of restrictions due to Covid.

The big paper Matteo Galaverni and I wrote on the Hamiltonian equivalence between Jordan and Einstein frames was accepted in *Physical Review D* at the beginning of March without any revision—Incredible! We advertised the paper by a press release through the Vatican press office. We phrased our press release with the help of Fr. Richard D'Souza, S.J. and Chris Graney who were very helpful in making it quite appealing. We mentioned, in the press release, that our result could

have consequences regarding some physical properties of our universe close to the Big-Bang (Carrollian Gravity behavior). We remarked that our result was still preliminary, and more studies were needed. The news had a great impact. Many newspapers, online journals and news agencies reported it in many languages.

At the end of this "social" year, I feel a bit like Einstein in the story of the cosmological constant. I have given several popular seminars in which I always tried to highlight that even very talented scientists can make mistakes because of their prejudices. Einstein was very much influenced by the cosmological theory of Kant-Laplace in which the Universe was static. When the homogeneous and isotropic Friedman-Lemaitre-Robertson and Walker (FLRW) solution of Einstein's equation was found, it predicted that the universe was expanding. Einstein said that the solution was mathematically correct but wrong from a physical point of view. He introduced the famous cosmological constant in his General Relativity equations to get a static solution, which means a non-expanding universe. When Hubble measured the redshift of the "nebulae" (as galaxies were then called), and then their recession, it was clear that the universe was expanding. Einstein admitted publicly that he made the worst mistake of his life.

I fear that this story applies to me in some sense. I had tried to prove that the Jordan and the Einstein frames are not equivalent, and I found several arguments in favor of this thesis. But, recently, the more results I got the more I discovered that, on the contrary, they seem to be equivalent. At the beginning it was clear to me that it was impossible, in the way in which it is written in the literature, that a solution of the equations of motion in the Jordan frame could be transformed into a solution of the equations of motion in the Einstein frame. But nowadays I have gotten several results, in collaboration with Matteo Galaverni, from which it is clear that if we reduce the number of variables in such a way to restrict ourselves to the truly "physical" degrees of freedom, the transformation from the Jordan to the Einstein frame maps solutions into solutions.

Does it mean that we, Matteo and I, have proved the equivalence of the two frames? Probably not. In fact, I agree with the comments of an anonymous referee to my first paper who said, "I think neither you nor I will be able to show either the equivalence or non-equivalence of the two frames in the near future…."

Last May I had a meeting with the delegate of the Father General of the Jesuits for the Roman international houses and he communicated to me that he had the intention to appoint me vice-director of the Vatican Observatory (Specola Vaticana) for Castel Gandolfo. It was a shock for me! I would never have thought I could be vice-director. I did not think I had the right skills to do it. His idea was that I can be both the vice-director and a researcher in cosmology. I was a bit afraid at the beginning, since I knew that the job of vice director would subtract time from my research activity. At the end I accepted the appointment in obedience.

This year was the first year after the pandemic that allowed us to be more open to the world, although it must be said, that did not happen immediately. I guided several groups coming to visit the Observatory. Regarding the community trips, the pilgrimage to the shrine of Montorella, visited by St. John Paul II, is worth mentioning, and my visit to Poland, where many refugees from Ukraine have found refuge from the horrors of war.

In photometry research, a challenge has been to get a better determination of the intrinsic photometry of images obtained on the VATT, related to systematic observation errors. These are not easy to detect. This can be demonstrated only by comparing VATT observations to those from other telescopes, such as GAIA. Since GAIA does not work in the Vilnius System we use, we are looking for methods to compare our results with an accuracy that would allow us to detect systematic errors, perhaps even using GAIA data or objects with known MK classification as standards to calibrate our observations. The usage of our software showed that it requires a change to a more traditional format, as HDF5 is not yet supported by our colleagues.

A more difficult problem is the synchronization of GAIA data with our observations, since this issue is not a purely technical one, but involves improving the way stars are classified in the Photometric Vilnius System. Due to the choice of filters, GAIA data are not spectrally as precise as observations by the VATT; GAIA errors in determining distances are significant for farther objects. Problematic is the extinction caused by the absorption of the "colors" of the spectrum by cosmic dust, which results in a reddening of the color of stars, better recognized by our observations; on the other hand, the distances determined by GAIA, especially of closer objects, are much more accurate than those that can be calculated by our photometric method. This problem of mutual matching needs more attention, which will help better calibrate the photometric system.

Kazimir Černis of Vilnius has begun a review of the archives of the late Professor Vytautas Straižys. His work is also bearing fruit for the Vatican Observatory, as he is sending us copies of documents relating to our extensive collaboration, including Prof. Smriglio from Italy. This enriches our archive devoted to photometry at the Vatican Observatory. The oldest document found in Vilnius dates back to 1975 (in it, Father Patrick Treanor, S.J., among others, thanks the Professor for the information about the establishment of the new observatory in Moletai).

In our team, we wondered how the Observatory's library catalog could be upgraded. This catalog has been in continuous operation for more than 10 years. For testing purposes, I created a Notebook in Python 3, which allows you to "play" with the structure of the catalog. Maybe one day we can turn it into a small "knowledge base"?

I have written several articles on philosophy and spirituality, some of which are in the process of publication.

Three years ago, an idea came to my mind to install cameras with large fields of view to observe meteors, called in scientific terms "meteoroids". There are small meteoroids and large meteoroids. We already have a system of three cameras to observe large meteoroids (fireballs) in collaboration with NASA (Marshall Space Flight Center). The reason for me to study small meteoroids is to bring knowledge of their physical proprieties to diverse areas of science.

The parent bodies of small meteoroids are either asteroids or comets; in terms of numbers, meteoroids are supplied more by comets than by asteroids. Therefore, what we know from small meteoroids tells us something about their parent bodies (comet or asteroid). Fortunately, it also helps us to build artificial satellites more robustly, as in space these are constantly impacted by small meteoroids. As a matter of fact, the James Webb Space Telescope launched in December 2021 to study the deep universe, was struck by a meteoroid just several months after it reached its destination. Its survival was owed to research on small meteoroids.

After three years without going back home to visit because of the Covid pandemic, the opportunity was given to me last summer to go to Kinshasa (Democratic Republic of Congo) for six weeks. At Castel Gandolfo, Guy Consolmagno was given a gift of a portable 70 mm telescope. I gently asked him for it, and I took it with me to Congo for astronomy outreach. I used it to show nearby objects to different people (kids from families I visited, students from the University of Kinshasa, our own scholastics at the Jesuit Philosophate in Kinshasa). I gave a talk on the moon to our scholastics after they observed it. The talk consisted of answering all the questions which their first contact with moon through the telescope raised: Why do we have bright and dark features? What are all these holes on the moon? I explained to them that all these holes on the surface of

the moon are craters, why they are there, and how they formed. In my explication, I also put a link between craters and the phenomenon of impact in the solar system, and how impact shaped the solar system, and continues to do so even today.

At the end of my stay in Congo-Kinshasa (DRC), I made a trip to Nairobi where I participated in a meeting gathering African Jesuit scientists. In 2016, I had an idea to create a forum where African Jesuit Scientists could meet, share their experiences as scientists, and engage themselves in helping young Jesuits missioned by their Provincials to do science and become scientists themselves. Starting as a forum, the group became a very well-organized group with a name AJiS (African Jesuits in Science) and with statutes and a charter. AJiS is committed not only to supporting the formation of the young Jesuits studying science, but also to educating Jesuits in different subjects where science is involved.

It's been quite a year for me. For starters, this past February I pronounced final vows as a Jesuit brother. Fr. General Arturo Sosa, S.J. received the vows at a Mass at the Gesù church in Rome (the Jesuit mother church). Several family members made the trip to Italy to celebrate with me.

I have also expanded my hobby of constructing models and dioramas into a full-blown YouTube channel, the *Macke MakerSpace*. There are currently more than 15 videos on the channel, with more planned for 2023. Among them are a five-part series covering the construction of a model of the Church of St. Ignatius in Rome, complete with Angelo Secchi's observatory on the roof. That model currently sits in the Vatican Observatory's visitor center at Castel Gandolfo.

Another video covers the making of a mascot called "Vatty" for the robotization of the VATT telescope, with the promise that I will make one special for anyone who makes a significant contribution to the robotization effort. The prototype went to Rich Friedrich in thanks for his service to the VOF board, and the first production model was given to Sr. Raffaella Petrini, the Vatican Secretary General. Model number 2 was made for Mrs. Judith Alstadt, in honor of her late husband Donald. (If you would like one, please contact the VOF development director, Christopher Kennedy.)

Sr. Petrini was one of the first recipients of Vatty, the mascot of the VATT.

On the scientific side, I continue to measure density and porosity of meteorite samples sent to the Specola by various scientists from Australia, the USA, and elsewhere. In addition, my work for the OSIRIS-REx space mission has really picked up. The OSIRIS-REx probe orbited the asteroid Bennu and collected some material from the surface, and it is currently on a return trajectory back to the Earth. The sample container will arrive in September 2023, and we are doing a lot of work in preparation for this arrival. I have been working on constructing an ideal-gas pycnometer that will be installed inside the glove box where the specimens will be stored. We had some engineering students at University of Arizona do much of the basic work, but I spent more than a month in Tucson this summer making it functional. Making a functioning pycnometer is relatively easy, but making something suitable for installation in a clean room glove box is turning out to be quite a challenge, and I will return to Tucson this winter to spend a few more months getting the device ready to go to NASA Johnson Space Center for installation.

Br. Macke and the pycnometer to be used in measuring samples from asteroid Bennu.

I have received a new mission from my Jesuit superiors. After 12 years at the Vatican Observatory, I took office on July 31 as the religious superior of the Jesuit community attached to the Pontifical Biblical Institute (PBI), located in central Rome. Now I have a special care for the 36 Jesuits of the PBI community, half of them faculty/staff members and half of them student-priests pursuing a licentiate or doctoral degree in biblical studies. I hope also to continue teaching philosophy part-time at the nearby Gregorian University.

The past months have been a bittersweet time of transition for me. On one hand I have been coming to know the PBI Jesuits, and I have been moved and humbled by their zealous dedication and holiness. On the other hand it is difficult to leave the Observatory! The Observatory has been a good and challenging setting for me to continue work in my own area of expertise, the history and philosophy of science. At the Observatory I helped to welcome and give tours to countless groups of visitors, almost always an occasion to meet interesting people and to have good conversations about science and faith. I feel a deep affection and care for the Jesuits of the Observatory, after 12 years of accompanying them as their religious superior. And I feel deep appreciation for and friendship with the Observatory's dedicated lay employees, after these past 7 years of working closely with them while serving as the Observatory's Vice Director. To all my friends at the Observatory and beyond, I do not say a final *addio* – I say *arrivederci, alla prossima!*

There are a couple of mementos which already serve as dear reminders of my time at the Observatory. First, my brother-in-law Mike Davis, husband to my younger sister Sue, was moved and inspired by his visit to the Observatory to paint a picture of the dome of the Double Astrograph, atop the Apostolic Palace. Mike's painting brings home to me the Observatory's evocative power as a unique meeting-place of science, faith, and beauty.

Also upon my departure from the Observatory its lay employees gave me the gift of a mosaic portraying the Apostolic Palace and its telescopes. For me this gift is so lovely and apt! Though a mosaic is piecemeal non-exact, it somehow highlights depths of beauty and reality which would remain hidden from us in a photo-realistic image. That's also true of scientific theories and models: they don't show us reality exactly as it is, but they reveal deep and beautiful realities which would otherwise remain hidden from us. For these gifts, and for my years at the Vatican Observatory, I give thanks to God.

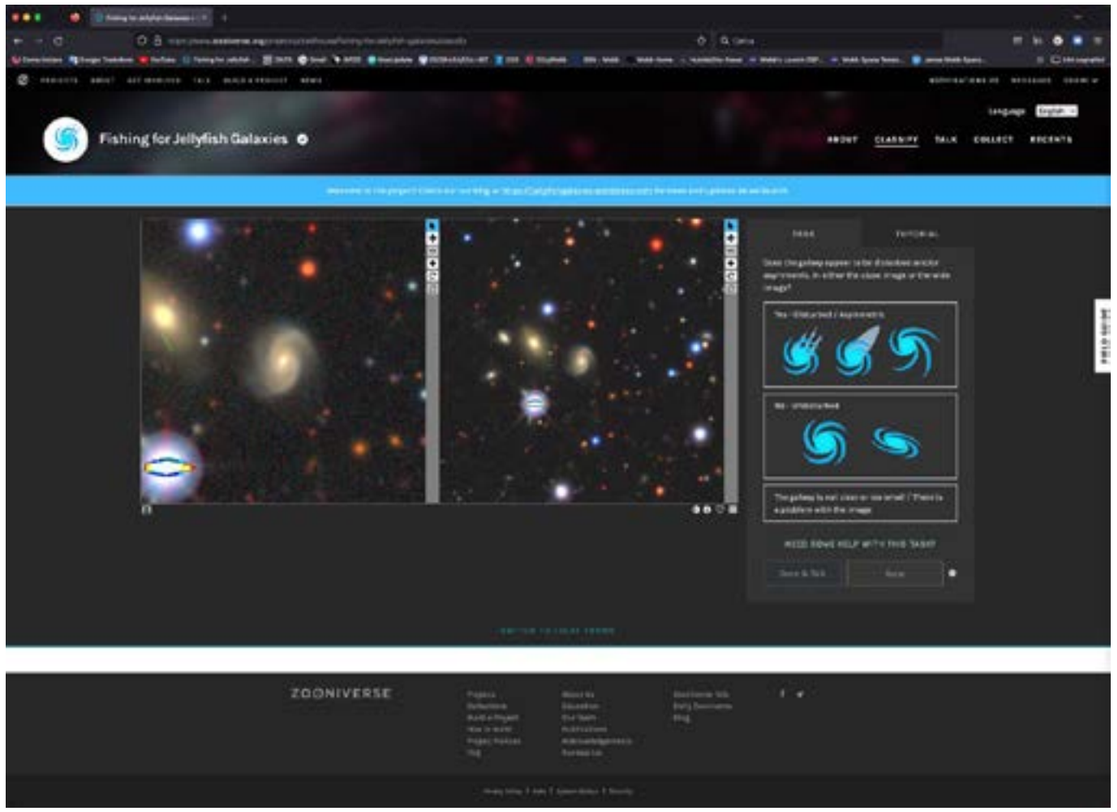
We are digitizing photographic plates from the Specola's archives. As part of this project, all the envelopes containing plates are being scanned. These contain important information necessary for scientific use of the images on the plates themselves (exposure time, type of plate, filters used, atmospheric conditions, etc.). All this is being recorded in order to make the information provided to the user wishing to use the images on the plates more complete. This work of scanning the envelopes is linked to the "Applause" project (Archives of Photographic Plates for Astronomical Use), which puts online the images of the main astronomical observatories of Germany and also of the Vatican Observatory. An extensive description of the Applause project can be found at the project website (*https://www.plate-archive.org/cms/*).

With the GASP research group (Gas Stripping Phenomena in galaxies), I am studying some galaxies interesting for the phenomenon of ram pressure stripping and, in particular, for the study of stellar formation and evolution both in the galactic disk and in the stripping trails. Collaboration with an Indian colleague, George Koshy, who has access to data from the UVIT (Ultra-Violet Imaging Telescope) satellite, has allowed us to add further information to the study of three "jellyfish" galaxies (galaxies in which stripped material trails from the galaxy, giving it an appearance reminiscent of a jellyfish). The outcome of this collaboration is an article that is being published in the journal *Monthly Notices of the Royal Astronomical Society*.

I have been involved in a public outreach activity that has been taking place for years in many dioceses in northern Italy: the Biblical Festival, during which experts from various disciplines are called to speak, each according to his or her specialization, on the theme chosen for that year. This year the festival took place in the city of

Treviso. Its theme was "Heavens and a new earth". On this occasion, during two public conferences, I presented the first images provided by the James Webb Space Telescope (JWST) and the first scientific deductions made from these images. A similar initiative was also undertaken by the diocese of Padua where, on two different evenings, I presented not only the images of JWST but also discussed the relationship between science and faith. In the province of Venice, in Santa Maria di Sala, there is an advanced amateur astronomy center (four telescopes, conference room, planetarium) which every year organizes astronomical conferences for members and for the general public. At this center I was asked to present on the history and scientific activity of the Vatican Observatory.

For some years now I have been following an online project whose aim is to catalog galaxies based on their visual examination. After cataloging Jellyfish galaxies in the last two years (Cosmological Jellyfish, Fishing for Jellyfish Galaxies and Galazy Zoo Jellyfish identification) during the pandemic, now the project aims to catalog older galaxies (Cosmic Dawn Galaxies). The image source is the Hyper Suprime-Camera (HSC) of the Subaru 8.2m telescope on Mauna Kea. The numbers are grand: we are talking about tens of thousands of galaxies. The project website is *https://www.zooniverse.org*.



"Zooniverse" is an online citizen-science project where ordinary people can contribute extraordinarily to the science of measuring and classifying astronomical objects. Among the projects has been one to indentify so-called "jellyfish" galaxies, key to the reserch work of Fr. Omizollo and his colleagues.

Adjunct Scholars

My work at the Vatican Observatory is centered on the study of the history of astronomy with particular regard to the development of astrophysics in the Roman area from its foundation in the middle of the nineteenth century to the present time. I also took part in the general internal discussions on communicating science as part of the Vatican Observatory's outreach and education projects.

In collaboration with Rome Astronomical Observatory, I started activities for the bicentenary of the birth of Lorenzo Respighi (1824-1889), director of Campidoglio Astronomical Observatory during the pontificate of Pius IX. Respighi invented the objective prism. This allows the simultaneous collection of thousands of spectra. The objective prism technique is currently employed in many observatories. The Specola historical collection of instruments includes some objective prisms which were used on the Vatican Schmidt Telescope.

In collaboration with Francesco Poppi, curator of the Museum of Rome Astronomical Observatory, I researched planetary and cometary observations made at Collegio Romano before the period of Fr. Angelo Secchi's directorship. This contribution will be published in a book edited by Ileana Chinnici.

In view of the Holy Year 2025, I participated in a working group promoted by Fr. Vincenzo D'Adamo, the Rector of St. Ignatius Church (the site of Fr. Secchi's famous observatory), to organize events aimed at students and the wider public.

In my everyday life, in addition to family commitments, I am an active member of my parish community of San Fulgenzio in Rome, as a lay minister of the Word and the Eucharist.

Have you noticed how the word "ecology" has become, within these last ten years or so, a household term? It has gained considerable importance also at the highest level of research, where ecology now represents a hub for crucial interdisciplinary work involving science, philosophy, theology, ethics, economics, and politics—a complex business. During this year, I continued working in this area, trying to further clarify the contribution that philosophy can make.

In June, I was especially glad to participate in an international conference entitled "Transitioning to integral ecology? Transdisciplinary approaches for the grounding and implementation of a holistic worldview", which was held at the Pontifical Gregorian University, Rome. My paper dealt with the natural and scientific foundations of so-called integral ecology.

Another highlight of the year was the European Jesuit Philosophers meeting, held in August at Innsbruck, Austria. This meeting was particularly rewarding, not just because of the beautiful scenery but also because we had not been able to meet for four years due to the pandemic. I presented some of my research on how militant atheists of these last decades, often called "New Atheists", seek to use science to justify their claims. I showed how, despite their captivating rhetoric, their reasoning is often biased or defective—and yet we can still find something to learn from them.

As regards my role in the Gregorian Faculty of Philosophy, it is always a great pleasure to see doctoral students working under my supervision successfully completing their projects. This year was especially significant in this regard because three such projects were completed, one on ethics and biological evolution, one on the inherent dynamism of nature, and one on the intellectual process to arrive at knowledge. Moreover, the research group I coordinate had a fruitful one-day

workshop in May at the Vatican Observatory on the effect of technology on human self-understanding. In view of a future joint publication, four members of the group explored this topic from different perspectives. Now, as I write these few lines, I am immersed in the preparation of lectures on the philosophical and scientific understanding of time, and in the preparation of a presentation for a workshop in Boston, during which I will explore how Ignatian spirituality has influenced, and still can influence, philosophy of science and nature. Jesuits have been involved in mathematics, science, philosophy, and theology for a very long time—about four hundred years, at least. There is a lot to explore and to learn from.

2022 has been a very busy year, full of work and travels. I very much liked being on the Academic Board of the "Observatory Networks" project, led by the Royal Greenwich Observatory, and discussing the themes of the four workshops held at Greenwich (one online and one in person), Edinburgh and Armagh Observatories. It was a beautiful opportunity to share ideas with other colleagues, meet many of them, and learn from their research work. It was a successful project and we are thinking about other possible topics. The Vatican Observatory also participated in the last workshop, with a video on the historical library featuring Fr. Giuseppe Koch, S.J. which was highly appreciated by all participants, both those in person and online.

I continue to serve as a member of the Organizing Committee in the IAU Commission C3 (History of Astronomy) and have exchanges with the other officers, preparing a letter of interest for a possible special session at the 2024 IAU General Assembly in Cape Town.

Moreover, after many years, at last I could attend the annual Scientific Instrument Commission (SIC) Symposium, held in Athens—a very inspiring conference, where all shared the joy of meeting again in person, after previous online meetings. I also announced there that Palermo Observatory is ready to organize the next SIC Symposium: the candidature has been accepted by the SIC General Assembly and the Symposium will be held in Palermo in September 2023. Of course, I have started the preparation work!

Unfortunately, I contracted Covid in Athens. This obligated me to stop working for two weeks. The recovery was not as prompt as I expected, with some long-Covid effects. However, thanks to God, nothing too serious—I only needed patience and time.

This year I concluded the work of some major publications (book chapters) and many papers. I have also collaborated in many dissemination projects regarding astronomical heritage (inside and outside of the Italian National Institute for Astrophysics). I will mention only the exhibition *Fotoscienza*, held in Pisa, where I have co-curated the section on astrophotography, and co-edited *Cosmic Pages*, the catalogue of star atlases in the Italian astronomical observatories. Unfortunately, my last works on Secchi are still in press, in spite of the manuscripts having been delivered last year! These publications have been quite troubled, as was Secchi's life!

Last but not least, I have been appointed advisor of a young researcher working on Italian astronomical heritage and co-advisor of a doctoral student with a preventive conservation project on the historical collections which are kept at Palermo Observatory.

Now, at the end of this year, I feel happy about these many works, but a bit … squeezed! And the next year may be even busier!

Perhaps the biggest sign of a return to pre-pandemic normalcy is that I was able to send students to an in-person conference. Four of my research students attended the American Chemical Society's national meeting in San Diego last March to present our work on metrics for the tightness of molecular knots. On other research fronts, I'm pleased to be part of a three-year multidisciplinary working group funded by the Templeton Foundation to explore the role of intellectual humility in science. We met in person at Notre Dame in August, and continue meeting virtually each month for stimulating conversations. I gave a talk at a conference organized by Prof. Deana Weibel, whom I first met at the Specola.

I was surprised and delighted to learn the book I published last year, *Prayer: Biblical Wisdom for Seeking God*, received an award from the Catholic Media Association, an honorable mention for books on prayer. I am midway through writing a new book on the chemistry of tea, tentatively titled *Steeped*, for the Royal Society of Chemistry Press. It's been a fascinating romp through the chemical literature and related trivia. For example, the botanical name for the tea plant is *Camellia sinesis*; the genus is named for 17th-century Jesuit botanist George Joseph Kamel, S.J.

I enjoyed two visits from Br. Guy Consolmagno, S.J. this summer, one of which overlapped with the long-delayed graduation ceremony for my younger son, Christopher, from University of Pennsylvania with his master's degree in math education. I'm also delighted to report that my older son, Michael, completed his master's degree at University College London in digital humanities.

The end of the year 2022 finds me getting ready to travel to the USA. I have received the International Fellows Initiative scholarship awarded by the Jesuit School of Theology of Santa Clara University in Berkeley. My plan is to study the concept of nature, considering the most recent scientific advancements and the future of humanity and its scientific, philosophical, and theological implications. I will spend the Spring 2023 semester in Berkeley.

The pandemic has profoundly challenged humanity. We need to revisit the future of *Homo sapiens* in cosmic perspective. The new challenges that contemporary science and technology pose should be considered from a multidisciplinary perspective. Within the framework of Big History studies, three thresholds can be considered: the origin of the universe, the origin of life and the origin of humanity. As we think on origins at these three levels, we consider with much more uncertainty the future of the universe, of life and of humanity. In my sabbatical semester I will focus on the future of humanity. My research proposal for the scholarship is a continuation of the work we carry on in our research team, Project OTHER (Otros mundos, Tierra, Humanidad, Espacio Remoto).

In that work, we seek to reflect on the challenges of Transhumanism based on the thought of Teilhard de Chardin. Teilhard's integration of geo-biological phenomena with philosophical and spiritual perspectives resulted in the concept of the "noosphere", a sphere of human thought and the next evolutionary stage of the biosphere.

Teilhard's notion may be key to interpreting the post-biological evolution of *Homo sapiens*. The concept of the noosphere can be applied to a kind of universal consciousness that humanity has laboriously achieved. The noosphere also encompasses scientific, cultural,

and religious thought. Artificial Intelligence is part of the noosphere today and is a successive step in the evolutionary process. While the post-biological process continues with its lights and shadows, the existential risks that threaten the existence of humanity are becoming more and more evident. We need to reflect from an interdisciplinary perspective on this issue with realism.

To study these topics, I have formed an interdisciplinary research group made up of relevant experts. Project OTHER (*https://blog.ucc.edu.ar/other/*) has made progress in studying both the epistemologies of complexity and other worlds, and the role of spirituality in the search for intelligent extraterrestrial life. In the first we consider the historical event that might best allow us to understand how a possible encounter with an extraterrestrial Other could take place, namely the discovery of America. We consider how scientific thinking would have to become more flexible in apprehending an extraterrestrial Other. Spirituality could be a hermeneutical framework from which to prepare for and understand a potential first contact with an extraterrestrial civilization.

In the second, we try to understand if spirituality plays a relevant role in the human desire to contact an extraterrestrial intelligence (ETI). To study the importance of spirituality, we have conducted an online survey among undergraduate students in the humanities, engineering, and natural sciences at the Catholic University of Córdoba, Santa Clara University, the Universidad Iberoamericana (Mexico City) and the Pontificia Universidad Javeriana (Bogotá). Our work will allow us to compare results from different cultural regions of the world. Our goal is to test the hypothesis that spirituality is a driving impulse in the search for and urge to communicate with ETI species. In addition, we will investigate if educational background influences the desire to contact an alien civilization.

During the last two years I mainly attended online events, but 2022 marked the restarting of in-person meetings. It was very enlightening to attend a conference on "The future of Cosmic Microwave Background physics" in Ferrara and the "41st International Conference on High Energy Physics 2022" in Bologna. Attending this kind of meeting is very important, not only to be updated in the latest developments in my fields of research, but also to meet other scientists (and friends). I hope new projects and collaborations can start in the upcoming years.

On April 15, a paper by Gabriele Gionti and myself appeared in the journal *Physical Review D*: "Jordan and Einstein Frames from the perspective of $\omega=-3/2$ Hamiltonian Brans-Dicke theory". Since the Brans-Dicke theory (an alternative form of gravity where the strength of gravity varies with space and time) is very difficult to describe mathematically, scientists often transform its complex equations into an alternative frame where they are much simpler to solve. We studied the mathematical properties of the transformation from the more complicated "Jordan" frame, to the simpler "Einstein" frame. Even though the topic is quite technical—and there are still a lot of things that we need to understand better—there was quite a lot of interest from the media. In the following weeks several journalists contacted the Specola and we gave numerous interviews (thanks to Chris Graney for his help in Public Relations).

In May we had the first Specola Cosmology Meeting. Paolo Beltrame, Gabriele Gionti, Adam Hincks, Maria Elena Monzani and I spent two days together in Castel Gandolfo. We discussed our science projects and our outreach activities.

The summer was quite busy with different public conferences on topics related to physics, astronomy, science and faith. For "European Researchers' Night" (the last Friday of September) we organized—in collaboration with Frascati Scienze—a star-gazing night in the main square of Albano Laziale. Many people were happy to look at Jupiter and Saturn through a small telescope operated by Claudio Costa.

In October, I attended the IRAFS22-International Symposium on "Science & Theology" at Pontifical Lateran University and presented a talk. Other scientific projects related to cosmic birefringence (limits on the rotation of Cosmic Microwave Background linear polarization) in collaboration with Fabio Finelli and Daniela Paoletti (INAF-OAS Bologna) are almost finished and we hope to publish our results soon.

God makes "two great lights" in the sky in Genesis 1:16 (the sun and the moon) and God makes the stars. Astronomical observations and calculations, however, show the stars to all be "greater" than the moon. This was understood even prior to St. Augustine. Nevertheless he, and later St. Thomas Aquinas, navigated with ease this contradiction between the results of science and the words of Scripture. Genesis speaks to the human experience of the night sky, they said; it gives no scientific description of the universe.

Yet, long after these two saints, Pope Leo XIII established the Vatican Observatory in part to address the then-popular idea that the Church opposed science and would reject scientific results that contradicted the words of Scripture. That idea remains popular today. All too recently, stories in major news outlets have described the Church as historically opposing scientific findings and as condemning the telescopic discovery of the moons of Jupiter. Many, especially younger people, leave the Church today, and often they cite "science" as a reason for doing so. Pope Leo might say that the need for the Vatican Observatory remains undiminished.

My colleagues on the Observatory staff who engage in pure astronomical research address that need by producing good science. My work as an astronomer, a historian of astronomy, and an educator addresses that need by helping to provide context for the work of my colleagues. Astronomy's history shows that their work is not an aberration; that the Church did not just recently embrace science; and, young people, that the stories you hear endlessly repeated about the Church opposing science are not correct, but merely accepted lore.

Therefore, while for many years I have been studying the history of early telescopic observations of stars, this year I was particularly pleased to discover the story of observations of the stars and Genesis, Augustine, Aquinas—and John Calvin, it so happens. The story seems to have been largely forgotten. I came across it while working with Br. Guy Consolmagno on a book (Br. Guy had made a reference to St. Augustine that I was looking to expand upon, and I promptly fell into Augustine talking about the sizes of stars).

The moon, stars, and Genesis are my favorite fun research highlight for 2022. That work has resulted in one publication so far. I expect more to come (hint—what Calvin has to say on this subject is really worth reading).

However, many other things have also happened this year. Most notable is that, for the first time since I joined the staff, I was able to visit the Observatory, both in Arizona and in Castel Gandolfo. I was named an Adjunct Scholar in August of 2019, but by March of 2020 the Covid pandemic arrived. I finally made it to Arizona in January, to help with Astronomy for Catholics in Ministry and

Education (ACME). In June I made it to Castel Gandolfo, where I worked on a book, met many people, ate a lot of sweets and did a lot of talking at the 10 o'clock hour each morning, and even observed with the historic Carte du Ciel telescope!

Therefore, this is my fourth Annual Report, but the first for which I can say, regarding the Observatory, "I have been there!"

One of my tasks as the Sutton Family Chair in Science, Christianity and Culture at the University of Toronto is to teach courses that span astronomy and religion. In 2022 I piloted a new course called "The Bible and the Big Bang". It was offered at the undergraduate level, cross-listed between the Department of Astronomy and Astrophysics and the Christianity and Culture Program at St. Michael's College. I made it truly interdisciplinary, as each week the students were required to master concepts in early Universe cosmology (without mathematics, however) and to engage with philosophical and theological ideas about creation within the Abrahamic traditions. We looked at topics like creation from nothing, whether the Universe has a temporal beginning, and cosmological fine tuning in the light of both these disciplines, and we examined to what degree they might be related to one another. The class went very well, with students coming from humanities, social science and science majors, all contributing different perspectives and getting stretched in new ways.

In the fall of 2021, I taught a more "traditional" but equally engaging course: Astronomy 101. This is one of the biggest classes at the University of Toronto, with an enrolment of about 1,500 students. We have to use one of the biggest halls on campus for the lectures! But with a faculty colleague co-teaching the course, a couple of talented administrators, and a sizeable army of graduate students running tutorials, answering emails and marking assignments, it was a well-organized process and it was fun to introduce astronomy to non-science majors.

Meanwhile, my research program continued. In 2022 I had three PhD students, a postdoctoral fellow and a few undergraduates working with me. We are doing analysis of cosmic microwave background (CMB) maps from the Atacama Cosmology Telescope in a couple of neat ways. First, with my students and collaborators I am using these maps to study how gas is distributed in the "cosmic web" of deep space. It turns out that of all the atoms in the Universe, fewer than 10% are actually in stars and galaxies, while around 25% are in long, filament-like structures between groups of galaxies. We are learning about this gas and the role it plays in how large structures get arranged in the Universe. Second, the CMB community has recently realized that you can do something quite exciting with our data: look at the "variable sky", i.e., look at objects that glow briefly, like supernovae, or that change their brightness significantly on short time scales, like the jets of material thrown out from supermassive black holes in centers of galaxies. We have been starting to explore this new domain of millimeter astronomy.

Additionally, I continued to work on the Simons Observatory, a next-generation CMB observatory: in 2022 construction began in earnest at our site in northern Chile and we are looking forward to "first light" in 2023. My group is contributing software that processes the data when it is first recorded by the cameras. I play a similar role with the upcoming Hydrogen Intensity and Real-time Analysis eXperiment (HIRAX) in South Africa.

A highlight of 2022 was my first visit to the Specola since I moved back to Canada from Italy in 2018. I spent three weeks there, meeting with other Vatican Observatory cosmologists (Paolo Beltrame, Gabriele Gionti, Matteo Galaverni and Maria Elena Monzani), and taking the opportunity to host some collaborators from the University of Rome "La Sapienza" at the Specola, as well as to give a colloquium to the Physics Department at "La Sapienza" and contribute to a conference on integral ecology at the Gregorian University. Right before my stay at the Specola, I was chaplain to a group of undergraduate students from the University of Toronto taking the "Gilson Seminar in Faith and Rome" course. We were based at the Villa Palazzola right across the lake from the Specola and I facilitated a visit by the students to the historic telescopes in the gardens, guided by Paul Mueller and accompanied by a lecture from me.

This year things went back to normal. I did research and teaching, and also continued working as Associate Editor for the European journal *Astronomy & Astrophysics*. Our proposal to create an Institute of Astrophysics at Universidad Andres Bello was approved, and I was appointed the Director of the Institute in July 2022. I remain as past-President advisor of the IAU Commission on "The Local Universe" until 2024.

Also, in August this year, the ranking released by Research.com placed me among the best scientists in Physics and Astronomy. I am listed as the top astronomer in my country with an "H index" of 82.

During the month of October 2022, I was delighted to visit the Specola Vaticana, (after two years away because of the pandemic) interacting with the staff, giving a talk, and working on a proposal for a Workshop at the Specola in 2023.

Regarding my research, I continued leading the ESO public survey VVVX (VISTA Variables in the Via Lactea Extended Survey), a 12-year long project to map the inner Milky Way (Via Lactea) in the near-infrared. Among the many interesting new scientific results from this year, we have characterized the large Ophiuchus galaxy cluster behind the bulge of the Milky Way, and also used the VVV Near-IR Galaxy Catalogue to find structures and new clusters in the Zone of Avoidance where the Milky Way makes it difficult to observe other galaxies. We also discovered and characterized new low-luminosity globular clusters located close to the galactic bulge and inner disk. We published the near-IR photometry for 99 low-mass stars in the Gaia EDR3 Catalogue of Nearby Stars, and now we have started a search for free floating planets in a nearby association. We discovered hundreds of long-period variable stars (including Mira-type variables) in the bulge and nuclear stellar disk of the Milky Way. We also released a massive VVVX variable star catalog, including the classification of periodic variables across the galactic bulge and disc.

2022 was my first full year as an Adjunct Scholar, and fittingly it started with a trip to Tucson, where I had the pleasure of participating in the ACME program. I enjoyed meeting the very energetic team of educators who attend these events, and spending time with other Observatory members. This was my first time visiting any of the Arizona telescope sites, and I was very impressed with the setup at Mount Lemmon. Having grown up in the Italian Alps, what I miss the most in California is the lack of seasons. In Tucson we were able to experience all four seasons in one day, as we travelled from the desert heat to the snow-capped mountains. That experience, together with the moonlight Mass at the retreat center, was one of the most memorable events in the entire year.

The biggest scientific event for 2022 was the long-awaited inaugural science run of the LUX-ZEPLIN (LZ) Dark Matter experiment, a noble liquid Time Projection Chamber located a mile underground in the former Homestake gold mine in South Dakota. This campaign was the culmination of a decade of effort and it was absolutely thrilling to finally turn on the detector, after prolonged delays caused by the pandemic. Our inaugural "Dark Matter Search" was executed over a 3-month period and was followed by a calibration phase.

We announced world-leading Dark Matter sensitivity results in July, barely five weeks after the conclusion of the data taking. This astonishingly fast turnaround was the outcome of a multi-year campaign of Mock Data Challenges, in which I led the international collaboration in a simulated "dress rehearsal" of the early science phase of the experiment. The expression "world-leading sensitivity" implies that, unfortunately, we did not discover the Dark Matter particle in this search. Indeed, we designed the campaign with the goal of validating the detector performance knowing that we would not have sufficient exposure for a discovery. We pivoted immediately to a longer data taking campaign, which will take us into 2027 and will accumulate 20 times more exposure, allowing us to probe interesting scenarios describing the nature of the Dark Matter particle.

The field of particle physics in the USA has been engaged in a Community Planning exercise, with the goal of charting the future trajectory of the field for the next decade and beyond. I participated very actively in this process by authoring or editing several whitepapers on a range of topics including large-scale computing, Machine Learning, accessibility in physics and, of course, Dark Matter. This exercise culminated in a Summer Study workshop that was held at the University of Washington Seattle in July. In combination with this meeting, I had the pleasure of spending two weeks in the Pacific Northwest, which is one of my favorite locations. In fact, I made a point of traveling to Seattle by car, because I wanted an opportunity to drive on the city's many wonderful bridges, and to visit the always stunning Crater Lake in Oregon. The entire field of particle physics was meeting in person for the first time in years, and we absolutely relished reconnecting and spending time with each others.

In 2021, I applied for the astronaut program of the European Space Agency. This was the first ever astronaut selection to include a "parastronaut" (or astronaut with a physical disability) category. This year I was invited to participate in the selections in Germany, over a period of six months, which allowed me to meet other candidates and some current and former career astronauts, while spending time at ESA's astronaut training center in Cologne. This was the culmination of a childhood dream which I never thought I would achieve due to my disability, and even though I was not ultimately selected for the Astronaut corps, it was a truly life-changing experience. Frequent trips to Germany also gave me the opportunity to spend time at the Specola in Rome, and to participate in the inaugural meeting of the Observatory's cosmology team in May. In turn, my time in Rome made it possible to visit different colleagues in Italy, and allowed me to refocus my enthusiasm for science.

In the Columbus laboratory training module, European Astronaut Center, Cologne

My work as an Adjunct Scholar of the Vatican Observatory deals with books, lectures, philosophical talks and the like, more than telescopes and spectrographs. Formerly appointed as an astronomer in Italy, at Bologna and Turin, I am now a theologian at the Pontifical University of the Holy Cross in Rome. In a sense, my work as Adjunct Scholar is part of the commitment of the Vatican Observatory to the interdisciplinary research on faith and science and to the evangelization of scientific culture.

This has been a good year indeed for my studies and research! Why? I finally succeeded in publishing the book *Scientific Perspectives in Fundamental Theology: Understanding Christian Faith in the Age of Scientific Reason* (Claremont Press, California). I thank the Vatican Observatory Foundation for generously sponsoring the English revision of this book. I also concluded a big, four-volume project entitled *Fundamental Theology in Scientific Context* (in Italian: *Teologia Fondamentale in contesto scientifico*, Città Nuova Roma), publishing the fourth and last volume *Faith, Tradition and Religions*.

What are the leading ideas of these books? Not only, of course, that there is a full compatibility between scientific knowledge and Christian Faith; but also, and most importantly, that science provides a relevant support to theologians to help them in doing a better theology. If new scientific perspectives may be, at times, a source of problems for philosophers and theologians, much more are they a source of positive insights!

Think for a moment on the wonderful opening of horizons provided by the recent James Webb telescope! On last July 13, the day after the distribution around the world of the first images of JWST, I wrote an article on the Interdisciplinary Encyclopedia of Science and Religion (inters.org) web site. I closed my piece with the following words:

> *Today, in the celebration of Holy Mass, I ideally placed on the altar, along with the bread and wine, "fruit of the earth and work of human hands", the extraordinary work that enables JWST to function and send us its wonderful results. Work of men and women who testify to the greatness of human intelligence, but also—I gladly add together with all believers in God—to the greatness of the Creator whose image we are.*

By the way, the inters.org web site I direct also supplies a good number of "Faith and Science Pages" the that Vatican Observatory Newsletter offers us monthly. Finally, I am happy to say that the web platform DISF Educational (*disf.org/edu*) of the Research Center on Religion and Science that I run in Rome, designed for teachers and students of high schools, now has about 50,000 monthly pages read. The web platform offers Didactical Paths, answers to Big Questions, Videos and other resources to help in addressing issues at the threshold of science, philosophy, history and religion.

CHAPTER FOUR

Eight Popes, One Remarkable Life

Happy 100th Birthday, Sabino!

On November 1 2022, longtime Specola member Fr. Sabino Maffeo, S.J. celebrated his 100th birthday. He had been a central figure of the Specola during the years Fr. George Coyne, S.J. was director, and beyond; he served at the Specola from 1985 to 2018, first as Superior and Vice-Director and later as assistant to the Director and as archivist/historian. His book *Nine Popes, One Mission* is still the best reference book on the history of the Vatican Observatory. He chose to retire five years ago — at age 95! — and now lives at the infirmary community of St. Peter Canisius in Rome.

On this occasion of his birthday, Father General of the Jesuits, Fr. Arturo Sosa SJ, celebrated a Mass in the community Chapel of St. Peter Canisius. At the Mass two of his nephews with their wives were present. Fr. Gabriele Gionti, S.J. delivered the homily. After Mass there was a lunch in the community of St. Peter Canisius.

Pope Francis wrote a letter to Fr Maffeo for his birthday and it was read at the end of the celebration.

Fr. Gionti's homily and Pope Francis's letter both give an excellent outline of not only what Fr. Maffeo did, but who he was. Here's a translation of what they presented:

HOMILY FOR THE 100TH BIRTHDAY OF FR. SABINO MAFFEO, S.J. 11 NOVEMBER 2022

I first met Fr. Sabino at the end of June, 2000, when I was a candidate to enter the Society of Jesus. Father Vincenzo Sibilio S.J., then regional assistant for southern Italy of the Italian Jesuit province, had arranged with Sabino, then superior of the community and vice-administrative director of the Vatican Observatory, for me to experience the Vatican Observatory in order to explore the possibility of working in field of science within the Society.

I remember Sabino asking me about what I had worked on in my doctoral thesis. I tried to explain it to him, quickly and in the most general way possible, but I realized that it was very technical and the result was that he almost fell asleep! However, he understood its importance at once, and arranged for me to talk to Fr. Michal Heller, an expert in quantum cosmology who was then spending some time at the Specola.

Sabino immediately struck me as a Jesuit who was very dynamic and "youthful" in the way he thought, despite the fact that he was already almost eighty years old at the time! He was not attached, as happens at times, to a style of religious life that makes it into something cumbersome and heavy. He was an example of a religious who really had something to say and teach to someone like me who was discerning his vocation.

He introduced me to the director, Fr. George Coyne, and during my formation he was always a point of contact between Fr. Coyne and me. As soon as he wrote the second edition of his monograph on the history of the Vatican Observatory, he sent a copy to all the houses of the Italian province. It was the first major work on the history of the Observatory, and I used it to write a paper on Jesuit spirituality during my second year of the novitiate. The book was translated into English by Fr. Coyne and is still the best reference about the Observatory.

I have always been struck by Sabino's humanity, which shone through the stories he told. Often we would meet together for breakfast or dinner at the Specola, and he would tell me anecdotes of his life in the Society. Once, in the Juniorate in Galloro, a number of juniors had collected chestnuts and roasted them; then they gathered together in someone's room to eat them. Suddenly they were surprised when the minister threw open the door to the room and discovered them. The minister then shut the door, and a minute later came back with a bottle of wine; he said, "roasted chestnuts should be eaten with wine!" And this was during the War.

From various testimonies that have come to me from my Jesuit brothers, a common picture of Sabino as a religious superior emerges: a man close to people, especially people in trouble. After I had returned to the Specola following my ordination, on some Sundays I would go out with him to visit friends who invited him for lunch, since at the age of 88 he no longer was comfortable driving. Among those we visited were the mother and aunt of a Jesuit, with whom Sabino had become friends. Later he told me that this Jesuit had been in danger of being dismissed from the Society, but Sabino had worked to keep him in, because he understood the man's human and religious qualities. Consequently, Sabino also became friends with his family, whom he continued to assist as he could.

And then there are all the many signs of affection that Sabino has received, and continues to receive, from his former students of the Massimiliano Massimo Institute in the EUR. Sabino taught physics and religion to many students when he was a professor and then rector of the Massimo. Several of them have become very famous. I personally know a professor of theoretical physics at the University of Rome Tor Vergata who says without hesitation that he went into physics because of how he was inspired by Sabino. They are all grateful to him for

the human gifts and affection they received from him, beyond the teaching they enjoyed.

Another characteristic is his great honesty. Once he told me that, as the principal of the school, he happened to have a student who was doing very badly. He called him in and asked him why it was going so badly for him. The student confessed that he did not like attending a Catholic school because he was not a believer, but his parents had forced him to come to the Massimo because it was a very good school. Sabino summoned his parents and convinced them that the boy should transfer to another school. The parents were amazed at Sabino's honesty; he had put the happiness of a student before the economic loss of a tuition.

Today's liturgy invites us to celebrate the Solemnity of All Saints and presents to us the Beatitudes from the Gospel according to Matthew. First there is a list of virtues that the Gospel proposes, which are characteristics proper to the Lord Jesus: meekness, poverty of spirit, being peacemakers, etc. Holiness for us is to have this "mindset", as it says in the hymn to the Philippians, to follow the Lord Jesus as required of us by the Spiritual Exercises.

However, the emphasis should be placed not in the first part of these Beatitudes in themselves, that is, in the fact of being poor in Spirit, meek, etc., but in the second part, that is, by having this mindset we can have God by our side… because God loves the poor in Spirit, the meek, the peacemakers, and remains close to them.

The second part of these Beatitudes comes next: the persecution. As was the case with the Lord Jesus, when we act evangelically we begin to disturb the world; and then the world will begin to persecute us. However, the Lord comforts us and tells us that we do not have to worry; He will always be at our side and will help us overcome these difficult situations. On the other hand, since Jesus himself defined himself as a "sign of contradiction" and this scandalized people, we too, if we set out on His way, we too can have no different fate.

There is, however, in my opinion a more practical way to holiness: that is to walk with those whom we call today "men and women of God". A decade ago a film with this name [in Italian *Uomini di Dio* or *Men of God*, released in English as *Of Gods and Men*] came out that told the story of some Cistercian monks in the 1990s who lived in Algeria and were killed by Islamic fundamentalists. The monks lived in communion and in total symbiosis with the Muslim inhabitants of a small village in the mountains of Algeria. They took care of them in all their various needs, including medical (one of the monks was a doctor). When Islamic fundamentalism began to harden, the civil authorities advised them to abandon their monastery and take to safety. The monks began a series of discernments among themselves, in which they discussed what to do. Some of them were afraid and wanted to leave, others were more determined to stay. During this long process everyone, in a transparent manner, expressed doubts, fears, and perplexities. With prayer and sharing, slowly, the doubts and fears vanished and everyone came to the decision to stay, to be close to "their people." The consequence was that they were kidnapped by the fundamentalists and killed.

In my opinion, this story represents a practical application of the holiness that flows from the Gospel Beatitudes. As men and women of God we are invited to be transparent and to manifest in full humility our fears, our limitations, our weaknesses, in the continuous tension to put ourselves at the service of the Gospel. If we persevere in the good intention of wanting to follow the Lord Jesus, the first thing we must honestly admit, if we make a careful examination of conscience, is that we are fearful, ambiguous, limited; that is, ultimately poor in spirit!

This humility, as I said, helps us to have God's love by our side. I believe that men and women of God must always be aware that their humanity, rich in both sins and virtues, if humbly accepted and offered to the Lord, can be completely transformed by Him. In fact, in our personal histories as Christians we can see that whenever we have made this offering to God, He has responded with a Love that draws us completely to His will. This is the grace that He always gives us, as a gift and never by dint of our own merit!

Surely this attitude shines forth in Sabino's life, from the way that he has lived and offered himself toward others: always kind and affectionate, never hiding his limitations, and always humble… always concerned for others, always entering into their confidence with an attitude of mercy towards the people he meets. Everyone talks about Fr. Maffeo with enthusiasm, with fond memories of a person who really loved them and towards whom they have always felt a deep emotional bond.

Indeed, men and women of God, redeemed sinners and increasingly confident in God, realize that this love which they have received through the grace of God can, in turn, be given to others. This makes those others feel truly loved for who they are; and in this way they can bind themselves deeply to the men and women of God.

This is the secret that we must always keep in mind. We must not close ourselves off in our selfishness and in the illusion that our happiness is realized in our own self-interest. This is a chimera, an idol, a worldly attitude that can slither its way into religious life. We are called to love people as we ourselves have experienced that the Lord has loved us. This is our witness to the Love of Jesus.

From left to the right, Fr. Federico Lombardi S.J., Fr. Sabino Maffeo, S.J., Fr. Manuel Morujao, S.J. (Superior of the Community of the Canisius), Fr. Arturo Sosa, S.J. (Fr. General of the Jesuit)

LETTER OF POPE FRANCIS TO FR. MAFFEO ON THE OCCASION OF HIS 100TH BIRTHDAY

From the Vatican, 20 October 2022

Dear Father Sabino,

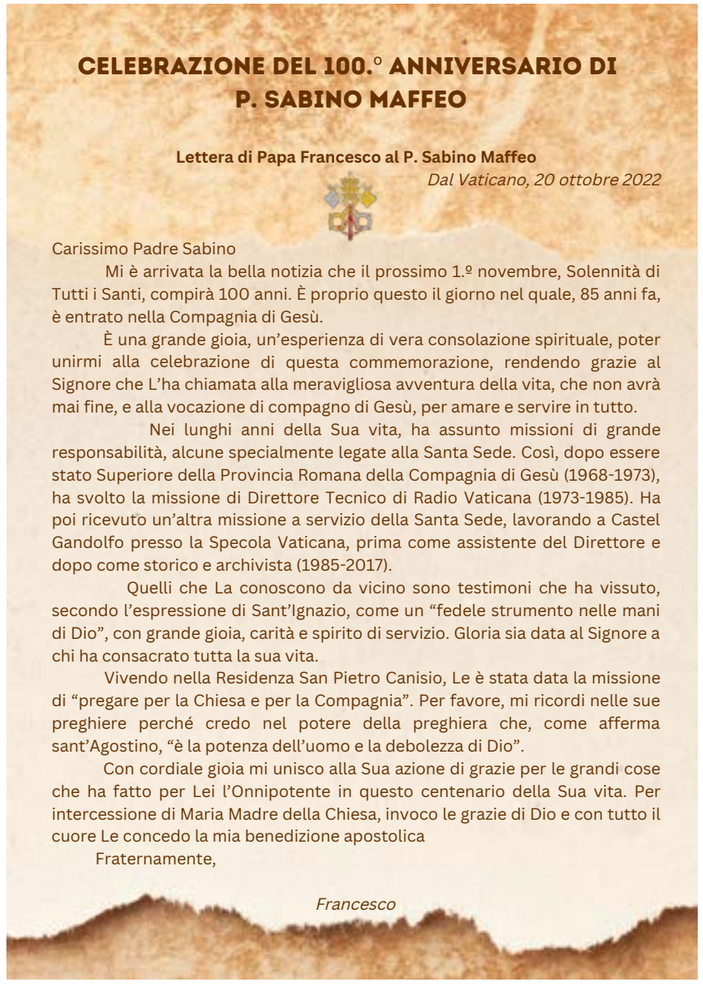
I have received the good news that on November 1, the Solemnity of All Saints, you will be 100 years old. This is also exactly the day on which, 85 years ago, you entered the Society of Jesus.

It is a great joy and an experience of true spiritual consolation to be able to unite the celebration of these commemorations, giving thanks to the Lord that He called you to the wonderful adventure of life, which will never end, and to a vocation as a companion of Jesus, to love and serve in everything.

In the long years of your life, you have assumed missions of great responsibility, some especially linked to the Holy See. Thus, after being Superior of the Roman Province of the Society of Jesus (1968-1973), you carried out the mission of Technical Director of Vatican Radio (1973-1985). You then received another mission at the service of the Holy See, working in Castel Gandolfo at the Vatican Observatory, first as assistant to the Director and then as historian and archivist (1985-2017).

Those who know you closely testify that you have lived, according to the expression of St. Ignatius, as a "faithful instrument in the hands of God", with great joy, charity and spirit of service. Glory be given to the Lord to whom your whole live has been consecrated.

Residing in the Residence of St. Peter Canisius, now you have been entrusted with the mission to "pray for the Church and for the Society". Please remember me in your prayers, because I believe in the power of prayer which, as St. Augustine puts it, "is the power of man and the weakness of God".



CELEBRAZIONE DEL 100.° ANNIVERSARIO DI P. SABINO MAFFEO

Lettera di Papa Francesco al P. Sabino Maffeo

Dal Vaticano, 20 ottobre 2022

Carissimo Padre Sabino

Mi è arrivata la bella notizia che il prossimo 1.º novembre, Solennità di Tutti i Santi, compirà 100 anni. È proprio questo il giorno nel quale, 85 anni fa, è entrato nella Compagnia di Gesù.

È una grande gioia, un'esperienza di vera consolazione spirituale, poter unirmi alla celebrazione di questa commemorazione, rendendo grazie al Signore che L'ha chiamata alla meravigliosa avventura della vita, che non avrà mai fine, e alla vocazione di compagno di Gesù, per amare e servire in tutto.

Nei lunghi anni della Sua vita, ha assunto missioni di grande responsabilità, alcune specialmente legate alla Santa Sede. Così, dopo essere stato Superiore della Provincia Romana della Compagnia di Gesù (1968-1973), ha svolto la missione di Direttore Tecnico di Radio Vaticana (1973-1985). Ha poi ricevuto un'altra missione a servizio della Santa Sede, lavorando a Castel Gandolfo presso la Specola Vaticana, prima come assistente del Direttore e dopo come storico e archivista (1985-2017).

Quelli che La conoscono da vicino sono testimoni che ha vissuto, secondo l'espressione di Sant'Ignazio, come un "fedele strumento nelle mani di Dio", con grande gioia, carità e spirito di servizio. Gloria sia data al Signore a chi ha consacrato tutta la sua vita.

Vivendo nella Residenza San Pietro Canisio, Le è stata data la missione di "pregare per la Chiesa e per la Compagnia". Per favore, mi ricordi nelle sue preghiere perché credo nel potere della preghiera che, come afferma sant'Agostino, "è la potenza dell'uomo e la debolezza di Dio".

Con cordiale gioia mi unisco alla Sua azione di grazie per le grandi cose che ha fatto per Lei l'Onnipotente in questo centenario della Sua vita. Per intercessione di Maria Madre della Chiesa, invoco le grazie di Dio e con tutto il cuore Le concedo la mia benedizione apostolica

Fraternamente,

Francesco

With cordial joy I join in your thanksgiving for the great things that the Almighty has done for you in this centenary of your life. Through the intercession of Mary, Mother of the Church, I invoke God's graces and with all my heart I grant my Apostolic Blessing.

Fraternally,

Francis

CHAPTER FIVE

Meetings and Outreach

SCIENTIFIC PRESENTATIONS and CONFERENCES

BOYLE

- First author on a poster paper at the 240th (online) Meeting of the American Astronomical Society, June 12-16.
- Participated in the XXXI (virtual) IAU General Assembly, August 2-11, in Busan, Korea.

CHINNICI

- "Observatory Networks" Workshop 2 (Greenwich).
- "Observatory Networks" Workshop 3 (Edinburgh).
- "Observatory Networks" Workshop 4 (Armagh).
- Closing event of the Commission for the Bicentenary of Secchi's Birth (Rome).
- SIC Symposium 2022 (Athens).

CONSOLMAGNO

- Annual Meeting of the Meteoritical Society, held in Glasgow, August 14-19; presented a paper.
- Northern Arizona University, gave a seminar "Physical and thermal properties of asteroid-analog meteorites", September 15.
- Annual Meeting of the Division for Planetary Sciences, American Astronomical Socity, held in London, Ontario, Canada, October 3-7; presented a paper.

CORBALLY

- Regular online meetings with the Spectroscopy Discussion Group; for an April 5 meeting of its subgroup on flare stars, described "Flickering in YSAs".
- With Margaret Boone Rappaport, on February 23, presented for the Heythrop Association an online lecture on "Cultural, Moral, and Religious Capacities: How important are these and in what order did they evolve?"
- Gave an online Lenten lecture for The University Series 2022 on "Faith Inspiring Science: An Interplay of Hiddenness".
- During August 2 to 11, participated online in the scientific meetings of the thirty-first General Assembly of the International Astronomical Union, held in Busan, South Korea.
- On December 7 during the webinar of the Institute on Religion in an Age of Science, gave the response to the topic "Nothing at the Cosmic Beginning?"

D'SOUZA

- Vegas Collaboration Meeting, 13-15 July, Pimonte, Italy.

GABOR

- Taught an advanced undergraduate course on the history and philosophy astronomy, ASTR 320, in the Spring 2022 semester, and then again in the Fall 2022 semester, at the University of Arizona.
- Participated in the International Dark-Sky Association's annual meeting, held online November 11-12.

GALAVERNI

- Yukawa International Seminar 2022a Gravity - The Next Generation, February 14-18 (online).
- Physics Opportunities at 100-500 MHz Haloscopes, February 17-18 (online).
- YOUNGST@RS - Feebly Interacting Sectors Impact on Cosmology & Astrophysics, March 1-4 (online).
- "Specola Cosmology group meeting" at the Vatican Observatory, Vatican City (Castel Gandolfo), May 16-17.
- From Planck to the Future of CMB, Ferrara, May 23-27.
- 23rd International Conference on General Relativity and Gravitation, Liyang, China, July 3-8 (online).
- International Conference on High Energy Physics 2022, Bologna, July 6-13.
- IRAFS-22, International Symposium on "Science & Theology", Pontifical Lateran University October 20-21.

GIONTI

- International Conference "SW-14-Hot Topics in Modern Cosmology", Cargese (Corsica), France, May 8-14.
- "Specola Cosmology group meeting" at the Vatican Observatory, Vatican City (Castel Gandolfo), May 16-17.
- "Eternity between Space and Time: form consciousness to cosmos", at the University of Padua, Padua, May 19-21.
- 23th International Conference on General Relativity and Gravitation, Lyiang, China, July 3-8 (online).
- "The Quantum and the Gravity", IV INFN-FLAG, Department of Physics University of Trento, October 7-8.
- IRAF-22, International Symposium on "Science & Theology", Pontifical Lateran University, October 20-21.
- "Quantum Gravity and Cosmology", INFN-QGSKY, Rome, CNR-Picone Institute, October 26-27.
- INFN-FLAG meeting. Department of Physics, Bologna University, December 20-21.

HELLER

- Panel discussion, Literary Festival of Olga Tokarczuk "Góry Literatury" (Mountains of Literature), Sarna Castle, Ścinawka Górna, Poland, 16 July.

HINCKS

- "Specola Cosmology group meeting" at the Vatican Observatory, Vatican City (Castel Gandolfo), May 16-17.
- Simons Observatory collaboration meeting, San Diego, USA, 11–15 July.
- SPIE Astronomical Telescopes + Instrumentation conference, Montréal, Canada, 18–22 July.
- Atacama Cosmology Telescope collaboration meeting, Princeton, USA, 20–21 October.

KIKWAYA ELUO

- Symposium of AJiS (African Jesuits in Science) in Nairobi held 31 August – 4 September 2022.
- Journees Scientifiques du Departerment de Physique (Universite de Kinshasa, Republic Democratic of Congo), held 12-14 August 2022.
- DPS 202 (Division Planetary Science) in London Ontario, Canada, held 2-7 October 2022; online.

MACKE

- International Astronomical Union Meeting August; online.
- OSIRIS-REx Sample Analysis Team Meeting #1 (Tucson AZ), February.
- OSIRIS-REx Sample Analysis Team Meeting #2 (Boulder CO; telepresence), August.

MONZANI

- "Specola Cosmology group meeting" at the Vatican Observatory, Vatican City (Castel Gandolfo), May 16-17.
- Dark Pollica Workshop, Pollica (SA), Italy, 6-10 June.
- Kavli Institute for Particle Astrophysics and Cosmology Retreat, Costanoa Lodge, Pescadero, California, 22-24 June.
- Snowmass Community Summer Study, University of Seattle, Seattle, Washington, 17-26 July.
- 50th SLAC Summer Institute, SLAC National Accelerator Laboratory, Menlo Park, California (online), 8-19 August.

TANZELLA-NITTI

- Invited as main lecturer to the XI Thomistic International Congress in Rome, September 19-24, to give a Lecture on "Thomism, Nature and Science". Here showed that Thomas Aquinas had a good knowledge of the sciences of his time, and suggested that much of his insights can be of advantage to us even today.
- Attended the yearly conference of the Italian Association of Pierre Teilhard de Chardin, November 12-13, and spoke on "The Religious Dimension of Scientific Activity".
- Attended the Space Festival at Busalla-Genova, organized by the first Italian astronaut Franco Malerba. There gave a lecture on "The Humanistic Dimensions of Scientific Research". During this event, the Advanced School for Interdisciplinary Research (sisri.it), which TANZELLA-NITTI directs, co-organized an International Award open to young researchers on the subject: Space Itineraries: Scientific, psychological and cultural aspects of human missions in extra-terrestrial Space. The prize was gained by a 27-year-old Italian engineer and technologist, Giovanni Garofalo.

VISITS to OTHER INSTITUTIONS

BROWN

- Visit to Fordham University in Bronx, NY (NYC) in order to confer with Fr. John Cunningham, S.J. on a mutual project using the VATT, 25-29 March.
- Travelled to the Leibniz Institute for Astrophysics Potsdam (AIP) in Potsdam, Germany in order to confer with German colleagues regarding the PEPSI-AIP-VATT collaboration, 17-20 October.
- Visit to Fordham University in Bronx, NY (NYC) in order to confer with Fr. John Cunningham, S.J. on a mutual project using the VATT, 3-7 November.

D'SOUZA

- Indian Institute of Astrophysics, Bangalore, India.

GABOR

- Had a series of online meetings with the Paolo Lazzarini (Vatican City State), Simona Morrone (Italian Ministry of Economic Development), Patrizia Tavella (International Bureau of Weights and Measures, BIPM) and Martin Milton (BIPM Director) on February 15, March 22, and May 6, to discuss Draft Resolution D, "On the use and future development of UTC" in preparation for the 27th meeting of the CGPM (General Conference on Weights and Measures) 2022. If adopted by CGPM, this draft will become a proposal to be submitted to the ITU World Radiocommunication Conference 2023 (WRC-23) Dubai, United Arab Emirates, 20 November to 15 December 2023.
- Participated in the third meeting of the Alliance of Historical Observatories (AHO) at Lowell Observatory, Flagstaff, on November 4-5. Visited the Lowell Discovery Telescope in March and the Naval Observatory Flagstaff Station in November, in both cases discussing telescope operations, upgrades, instrumentation, and potential contractors.

GALAVERNI

- Visit to Massimiliano Lattanzi and Marhgerita Lembo, Italian Institute for Nuclear Physics in Ferrara.

GIONTI

- Visited Prof. Martin Reuter at the Physics Department of the University of Mainz, Germany, June 20 to July 9.

MACKE

- University of Arizona Lunar and Planetary Laboratory to work on OSIRIS-REx pycnometer, June-July.

MONZANI

- Vatican Observatory Foundation Astronomy for Catholics in Ministry and Education (ACME), Redemptorist Renewal Center, Tucson, Arizona, 10-14 January.
- LUX-ZEPLIN Analysis Retreat, San Luis Obispo, California, 6-12 March.
- European Astronaut Center, Cologne, Germany, 18-21 May.
- University of Trento, Trento, Italy, 23-25 May.

AWARDS and GRANTS

FRANCL-DONNAY

- Honorable Mention, Books about Prayer, from the Catholic Media Association for *Prayer: Biblical Wisdom for Seeking God*.

GALAVERNI and GIONTI

- Awarded the prize "Fabula" at Bellizi (SA), Italy for "The new mathematical understanding of the first moment of the universe", September 2.

GRANEY

- Received the 2021 Nelson H. Minnich Prize from the *Catholic Historical Review* (Catholic University of America Press) for best *CHR* paper of 2021, "Galileo between Jesuits: the Fault is in the Stars", *CHR* 106, 191-225.

HELLER

- Received the Lubrański Prize, Academy of Lubrański, Poznań, May 26.
- Received the Szczepanik Prize, Tarnów, June 13.

MONZANI

- *DOE Cosmic Frontier, Facility Operations, LUX/ZEPLIN (LZ) Operations Support,* SLAC National Accelerator Laboratory, Menlo Park, California.
- *DOE Cosmic Frontier, Machine Learning and Artificial Intelligence Research, LUX/ZEPLIN (LZ),* SLAC National Accelerator Laboratory, Menlo Park, California.
- *DOE Mission Science allocation, LUX-ZEPLIN (2022*), the National Energy Research Scientific Computing Center, Berkeley, California.
- *Probabilistic Event Detection at the Cosmic Frontier,* Laboratory Directed Research and Development, SLAC National Accelerator Laboratory, Menlo Park, California.

Monzani with the Perlmutter Supercomputer, NERSC, Berkeley

COMMITTEES or BOARDS

CONSOLMAGNO

- Elected Vice President, Meteoritical Society (term starts 2023; term as president to start, 2025)

FRANCL-DONNAY

- Board, Institute for Religion and Science.
- Chair of the Board, Open Chemistry Collaborative in Diversity Equity (OXIDE).
- Chair, Parish Council of Our Mother of Good Counsel Parish Board, University of California, Irvine Graduate Alumni.

GIONTI

- Appointed associate fellow of the National Laboratories of Frascati (LNF) of the Italian Institute for Nuclear Physics (INFN) for the year 2022.

GRANEY

- Archdiocese of Louisville (Kentucky, USA) Faith and Science Dialogue Group.

HINCKS

- Board Member, Toronto chapter of the Society of Catholic Scientists.
- Literary Trustee, Estate of Bernard Lonergan.
- Local Organizing Committee, Astronomical Data Analysis Software and Systems (ADASS) XXXII conference (held 31 Oct. – 4 Nov. 2022).
- Committees in the Dept. of Astronomy & Astrophysics, University of Toronto: General Qualifier Exam Committee (until May 2022); Colloquium Committee (since Sept. 2022); Community Climate Committee (since Sept. 2022); Academic Appeals Committee.

PUBLIC PRESENTATIONS

BROWN

- Presentation given to physics and astronomy club students at Marymount International School in Rome, Italy, 16 March.
- Presentation given to parishioners at St. Mary Parish in Uxbridge, MA, 21 July.
- Reflections provided for service held at Dallas Jesuit College Prep in Dallas, TX, 23 November.
- Helped with the organization of a "star party" provided by the Specola Vaticana for the Commune of Albano Laziale, Italy at Piazza Pia, 30 September.

CONSOLMAGNO

- Organized and attended the Vatican Observatory Foundation's Astronomy for Catholics in Ministry and Education (ACME) workshop at the Redemptorist Renewal Center north of Tucson. Here, twenty Catholic educators and pastors spent a week immersed in the astronomical world around Tucson, including a visit to the University of Arizona's telescope mirror lab and a day visiting the telescopes on Mt. Bigelow and Mt. Lemmon, along with extended discussions on faith and the life of an astronomer. This was the relaunching of a biennial program that had been suspended due to Covid. January 10–14.
- Conducted monthly "Full Moon Meetups" for the Vatican Observatory Foundation, interviewing a dozen astronomers whose work is affiliated with the Vatican Observatory. Many of these events were recorded and became the basis of a podcast, which can be accessed at ***https://www.vaticanobservatory.org/podcast/***.
- Gave the annual Dehon Lecture at Sacred Heart Seminary in Wisconsin, on "Covid, Faith, and the Fallibility of Science", February 9.
- Participated in the Tucson Festival of Books, March 12.

Astronomy for Catholics in Ministry and Education (ACME) Workshop

The Vatican Observatory Foundation's Astronomy for Catholics in Ministry and Education (ACME) workshop was held at the Redemptorist Renewal Center north of Tucson in January. Here, twenty Catholic educators and pastors spent a week immersed in the astronomical world around Tucson along with extended discussions on faith and the life of an astronomer. Photos left: Kuiper 1.54 m telescope on Mt. Bigalow; Caris Mirror Lab, University of Arizona; Jared Males explaining Adaptive Optics. Right: Catalina Observatory; Meteorite lab; sunrise balloon over the Renewal Center; evening Mass with Fr. Kurzinski.

- Presented the commencement address to the graduates of St. Joseph's University in Philadelphia, where he received an honorary degree, May 21.
- Presented an address on the history of Jesuit scientists, "From Peru to Mars", at St. Ignatius Church in Manhattan, New York, May 23.
- Gave the Albert the Great address, "Science in a Fantasy Universe," at the annual meeting of the Society of Catholic Scientists in Chicago, June 2.
- Presented a public lecture, "Astronomy, God, and the Search for Elegance" at the "Frontiers of Quantum and Mesoscopic Thermodynamics" conference in Prague, August 4. While there he was also interviewed for Czech television.
- Spoke to two chapters of the Legatus organization, in Tucson and Phoenix, on Septembers 13 and 14.
- Presented "God's Mechanics: The Religious Life of Techies" at the Northern Arizona University Newman Center, September 15, and again at St. Michael's College of the University of Toronto, September 29.

- Participated in the presentation "Jesuits and Jedis" at the Sheen Center in Manhattan, September 27.
- Participated in a number of events at St. Cecilia's Parish in Boston, including a tour of the Harvard College Observatory with parish members and a public question and answer session (available at *https://youtu.be/PO6PzWee1PQ*), October 30 to November 1.
- Participated in the Mayo [Ireland] Dark Sky Festival, speaking on "Catholic Cosmologies", November 4–6. While in Ireland he also gave presentations at St. Peter's Seminary in Maynooth, and in Ballycotton and Cork.
- Participated in the Slovenia Book Fair in Ljublaja from November 22-23, including a presentation about his book, "Would You Baptize an Extraterrestrial?"

CORBALLY

- Assisted with the ACME workshop, and answered questions on Making Sense of the World from 40 Paulo Freire Freedom School students, hosted at the Diocese of Tucson Pastoral Center, January.
- Presented a morning based on the theme "Cosmic Expansion" to Sabbatical Groups at the Redemptorist Renewal Center, Tucson, April and November.
- Answered questions on Pro-Am Spectroscopy from Bert Pablo, Brian Kloppenborg, and Lauren Herrington, all from the AAVSO.
- Presented on "What was the Star of Bethlehem?", Astronomy Expert Speaker Series of the Astronomical League of the Philippines, December 17.

FRANCL-DONNAY

- "Simply unmoored: The rejection of complexity in quantum mechanical explanations of chemical phenomena", Fourth Annual Thomistic Philosophy and Natural Science Symposium: Complexity, Simplicity, and Emergence, July.
- "Folding up the questions", What is Life? Collegium, June.
- "Steeped: The chemistry of tea", Bryn Mawr College, May.
- "To boldly go where no woman has gone before", Roger That! Conference, March.
- "Making the desert bloom", St. Anastasia Parish, March.
- "Springs in the desert", Notre Dame Academy, March.

- "Commuting Operators: Moving Between the Humanities and Sciences", Pennswood Village Forum, February.
- "Hildegarde of Bingen", IHM Conference Center, January.

FUNES

- Continued to teach a class on Philosophy of Nature and gave lectures at the Catholic of Salta (Argentina) on topics related to Astrobiology, Science and Faith.
- Continued to publish opinion articles in *Diario Perfil*, Buenos Aires, Argentina.

GABOR

- Participated in the third Conference on Faith and Science (COFAS) held online February 11-12.

GALAVERNI

- "Faith and Science" at the Università Cattolica, Piacenza.
- "Guarda in cielo e conta le stelle – La notte silenziosa" with Sr. Irene Tranquillini at S. Maria Oliveto, Reggio Emilia.
- "Redshift evolution of cosmic birefringence in CMB anisotropies" at International Conference on High Energy Physics 2022 (Bologna).
- "Guarda la Stella, invoca Maria" – Passeggiata nello Spazio" at S. Ilario d'Enza.

- "Osserviamo più spesso le stelle – Viaggio ideale nell'universo" at Madonna di Pietravolta.
- "Passeggiata tra le stelle" at Vladimiro Spallanzani Istitute S. Antonino.
- "Padre nostro che sei nei cieli" - Montecorvino Lectures at Catanzaro (online).
- "Looking for Quantum Gravity imprints in the Universe" at Pontifical Lateran University IRAFS-22, International Symposium on "Science & Theology".

GIONTI

- INFN-FLAG" meeting. Department of Physics, Bologna University, December 20-21 2021.
- "A short and popular introduction to Quantum Gravity and Quantum Cosmology" for the series Science Talks, Loyola Institute for Peace and International Relations", Kochi, Kerala, India (online), February 18.
- "The history of the Vatican Observatory between Science and Theology", Pontifical University "Regina Apostolorum", March 22.
- "Jordan and Einstein frames from the perspective of Hamiltonian Brans-Dicke theory", at "Hot Topic in Modern Cosmology", Spontaneous Workshop XIV, Cargese (Corsica), France, (online), May 8.
- "The Jordan and Einstein frames debate" at the "Vatican Observatory Cosmology group meeting", Vatican Observatory (Specola Vaticana), May 16.
- "The Beginning of the universe and the question on God", at the "Vatican Observatory Cosmology group meeting", Vatican Observatory (Specola Vaticana), May 17.
- "Cosmology and the Catholic Church", at "Eternity between Space and Time: form consciousness to cosmos", University of Padua, May 19.
- "Einstein and Jordan Frame from the perspective of Hamiltonian Theory", 23rd General Relativity and

Gravitational Physics Conference, Beijing (China), Section D3 (online), July 6.

- "Inizio dell'universo o creazione" at S. Carlo da Sezze Church, Sezze Scalo (LT), August 25.
- "Il Big-Bang e la questione di Dio: una nuova prospettiva" at Frascati Scienza for the European Night of the Researchers, September 28.
- "Il cardinale Bellarmino e Galileo" for the students of the High School "Liceo Archita" at S. Bellarmine Church, Taranto, Italy, October 4.
- "The Jordan and Einstein frames debate", IV FLAG meeting "The Quantum and the Gravity", Physics Department, University of Trento, October 7.
- "A short introduction to Quantum Gravity" for the workshop "Science and Theology-a study program for future theologians-The Quantum Gravitational Challenge in Modern Cosmology", Pontifical Lateran University Rome, October 21.
- "Some aspects of the Jordan and Einstein frames debate", INFN-QGSKY meeting, Rome, CNR-Istituto Picone, October 27.
- Participated in on line panel on "Creazione divina e indagine umana" of "Nuovo SEFIR" and delivered the talk "Aspetti della cosmologia contemporanea e la questione di Dio", November 4.
- Il Big Bang e la questione di Dio: una nuova prospettiva" at the Open Space of the Mondadori Bookstore in Santa Maria Capua Vetere, (CE), Italy, November 27.

GRANEY

- "Thomas Aquinas and the Big Three of Faith and Science", St. Louis Bertrand Church, Louisville, Kentucky, USA, September 5, 12, 19.
- "Moon Over the Mount", Mt. St. Francis Retreat Center, Mt. St. Francis, Indiana, USA, March 12; October 1.

HINCKS

- Lecture for the Thomistic Institute at the Massachusetts Institute of Technology, Boston: "The Big Bang: Proof for Creation Ex Nihilo?", 10 April.
- Lunch Talk, Kavli Institute for Cosmological Physics, Chicago (presentation of journal article of same title; delivered remotely): "A high-resolution view of the filament of gas between Abell 399 and Abell 401 from the Atacama Cosmology Telescope and MUSTANG-2", 12 May.
- Colloquium [Seminario Generale], Dept. Physics, University of Rome "La Sapienza": "CMB Surveys from the Ground: Recent Achievements with ACT, Future Prospects with the Simons Observatory", 31 May.
- Invited talk, Conference on Transitioning to Integral Ecology? Transdisciplinary Approaches for the Grounding and Implementation of a Holistic Worldview, Pontifical Gregorian University, Rome: "Givens and Givenness: The Scientific Method and Integral Ecology", 8 June.
- Invited talk (delivered remotely by video), Green Bank Observatory Community, Green Bank Observatory, "Mapping the Gas in Intercluster Filaments with the Sunyaev-Zeldovich Effect", 8 June.
- Contributed talk, SPIE Astronomical Telescopes + Instrumentation, Montréal: "A graph database solution for tracking the deployment and layout of a large radio interferometer", 18 July.
- Colloquium, Department of Physics, Toronto Metropolitan University, Toronto: "The Cosmic Microwave Background: What It Tells Us and How We Observe It", 8 October.
- Presentation at St. Peter's Church, Toronto: "Knowledge, Belief and Faith", 8 November.

MACKE

- Presentation to Bishop DuBourg High School (St. Louis MO) Big History class (October).

MINNITI

- "A Small Telescope on the Moon" at the Annual SOCHIAS meeting, Copiapo, Chile, January.
- "The Galactic Extinction Horizon" at the Joint Observatories Kavli Science Forum, ESO Vitacura, Santiago, Chile, April.
- "Free Floating Planets" at the Vatican Observatory, Vatican City State, October.
- "Free Floating Planets" at the Osservatorio di Roma, Monteporcio, Italy, October.
- "Planetas Flotantes" at the Universidad de Los Andes, Bogota, Colombia, November (online).

MONZANI

- "A Sparkle in the Dark: The Outlandish Quest for Dark Matter", San Francisco Exploratorium, After Dark: Dark Matter, 28 April.
- "La Materia Oscura Illuminata: The Outlandish Quest for Dark Matter", Milano, Settimana dell'Astronomia, 5 May (online).
- "Direct Dark Matter Detection with the LUX-ZEPLIN Experiment", Physics Colloquium, University of Trento, 28 May.
- "Direct Dark Matter Detection with the LUX-ZEPLIN Experiment", Dark Pollica Workshop, Pollica (SA), 8 June.
- "Panel Discussion: Cosmic Opportunities for Fundamental Physics", Snowmass Community Summer Study, Seattle (WA), 21 July.
- "Computational Frontier: Small Experiments (Overview of White Paper)", Snowmass Community Summer Study, Seattle (WA), 23 July.
- "First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment", SLAC Colloquium, with T. Biesiadzinski and A. Fan, 1 August.
- "Dark Matter Direct Detection: 'Heavy' WIMPs", Menlo Park, 50th SLAC Summer Institute, 15 August (online).
- "Data-Intensive Searches for Dark Matter", Gear-Up for Science Data, Stanford University, 13 October.
- "Direct Dark Matter Detection with the LUX-ZEPLIN Experiment", Physics Colloquium, North Carolina A&T, 9 November (online).

TANZELLA-NITTI

- Gave a talk on "God's Revelation through Nature: Scientific and Theological Perspectives" for a Catholic Conscience webinar by the Canadian Chapter of the Society of Catholic Scientists, February 5.
- Offered to the Milan priestly seminar at Venegono a short course on "God's Two Books: The Heritage of a Metaphor", April 6-9.
- Gave a university course open to a wide public, "Lectures on Science and Theology: Historical and Epistemological Perspectives". The course was held at the Pontifical University of the Holy Cross, in Rome, March-May.
- Gave a lecture to the University of Milan-Bicocca on "The Galileo Galilei affair: historical and epistemological aspects of the confrontation between the Catholic Church and the sciences", October 11.

MEDIA EXPOSURE

BROWN

- Interview of David Brown by Emmanuel Van Lierde in Belgian Magazine *Tertio:* "Meerwaarde van Vaticaanse sterrenwacht", 18 May, Number 1162—*https://www.tertio.be/magazines/nummer-1162/meerwaarde-van-vaticaanse-sterrenwacht.*
- Interview of David Brown by Tanya Connor (after talk given at St. Mary, Uxbridge, MA) in the Worcester Diocesan newspaper, *Catholic Free Press*: "Universe Makes Sense Because it is Made by God, Astronomer Says", *The Catholic Free Press*, 29 July 2021, Vol. 71, No. 30—*https://digital.catholicfreepress.org/Catholic-Free-Press-07292022-e-Edition/1/.*

CONSOLMAGNO

- "Finding God in the Universe" *Christian Today* (United Kingdom), 3 January *https://www.christiantoday.com/article/finding.god.in.the.universe/137860.htm*
- "What are we searching for in space?" *L'Osservatore Romano* (Vatican), 21 January *https://www.osservatoreromano.va/it/news/2022-01/quo-016/cosa-cerca-l-uomo-nello-spazio.html*
- *Gazeta do Povo* (Brazil), 22 February. *https://www.gazetadopovo.com.br/vozes/tubo-de-ensaio/guy-consolmagno-ciencia-vacina-covid/*

- "Vatican Astronomer: Webb telescope images 'beyond a dream'" *Vatican News* (Vatican), 16 July, *https://www.vaticannews.va/en/world/news/2022-07/vatican-astronomer-webb-telescope-images-beyond-a-dream.html*

- "All my knowledge of the stars does not dim their beauty" *Ini* (India), October-December. *https://inimagazine.org/2022/01/06/all-my-knowledge-of-the-stars-does-not-dim-their-beauty/*

- "The beauty of great music" Irish Times, 14 November *https://www.irishtimes.com/culture/music/2022/11/12/the-beauty-of-great-music-a-vatican-astronomers-50-year-love-for-rory-gallagher/*

- "Wherever we go in the universe we will have the chance to meet God"; interview about the Artemis 1 uncrewed lunar mission for Società per l'Informazione Religiosa, (Italy), 17 November— *https://www.agensir.it/quotidiano/2022/11/17/artemis-1-consolmagno-specola-vaticana-ovunque-andremo-nelluniverso-avremo-la-possibilita-di-incontrare-dio/*

- "Anyone who needs scientific proof of the existence of God has a weak faith": the newspaper Druzina (Slovenia), November 22 *https://www.druzina.si/clanek/kdor-potrebuje-znanstven-dokaz-o-obstoju-boga-ima-sibko-vero*

CORBALLY

- For the 25th Anniversary of World Book Day on March 3, reflected via a British Jesuits website on a religious and non-religious book with the biggest personal impact on him.

- On April 1, was interviewed by Carmen Duarte, Arizona Daily Star, on the third class relic obtained from Father Kino's remains, which are in Magdalena, Sonora, Mexico.

- On May 26 discussed with Drew Mariani on Relevant Radio the mismatch between the cosmic expansion rate from HST and the CMB, and on July 15 they marveled together on JWST's first science images.

- On July 18, with Almudena Martínez-Bordiú, Aciprensa, outlined from his perspective how the Vatican lived the historic event of arrival of man on the Moon.

- Was interviewed by Madeline Shepley on October 6 for the podcast "Shine Bright Like the Firmament", a series that covers personal experiences of faith and astronomy.

GABOR

- Gave an interviews to the Slovak daily *Postoj* (Julia Kubicova), published on January 25, the Czech journal *Jezuite* (February), and to the international monthly *Le Messager du Saint Antoine* (Laurène de Beaulaincourt), published in #1407, July.

- With CONSOLMAGNO and KIKWAYA provided input for a *dossier* on space exploration and exploitation published in the *Revue Project*, #387, April-May.

GALAVERNI/GIONTI

- Matteo GALAVERNI and Gabriele GIONTI gave several interviews published in magazines, journals, and online news agencies in many languages. This was a consequence of the press release they submitted to the Vatican press office after their article was published in Physical Review D on March 2. For example, they were interviewed by Giovanbattista Brunori of the National Chanel RAI 2, in the news program "TG2 Costume e Società". The interview was broadcasted on June 21.

GRANEY

- Issued the following press releases for the Vatican Observatory: (1) February 9: VATT discovery of a Trans-Neptunian Object "2021 XD7" by BOYLE and others; (2) February 21: Galaxy mergers publication in *Astrophysical Journal* by D'SOUZA and others; (3) April 18: Gravity publication in *Physical Review D*, by GIONTI and GALAVERNI; (4) May 9: Awards received by CHINNICI (2021 American Astronomical Society Osterbrock Book Prize), GRANEY (2021 *Catholic Historical Review* Minnich Prize), CONSOLMAGNO (2022 Society of Catholic Scientists St. Albert the Great Award); (5) June 30: Vatican Observatory Summer School 2023.

- *The Western Kentucky Catholic* (print): March 3, "Faith and science: Allied in seeking the truth" (*https://westernkycatholic.com/2022/03/01/faith-science-allied-seeking-truth/*).

- EWTN News (television), February 25, on the discovery of TNO 2021 XD7 (*https://www.youtube.com/watch?v=G--yLXvJJ2w*)

- EWTN News (television), May 20, on awards for Vatican Observatory Astronomers (*https://www.youtube.com/watch?v=iN2BFXA9bJM*)

- EWTN News (television), August 5, on the 2023 Vatican Observatory Summer School (*https://www.youtube.com/watch?v=X1ohJIgcF0U*).

- EWTN Son Rise Morning Show (radio): June 3, on GIONTI and GALAVERNI's work on gravity.

- Archangel Radio: October 3, on history and Jupiter's moons (*https://youtu.be/4fTZiKzcKow?t=801*).

- American Astronomical Society, Sky & Telescope Series: October 17, on Jupiter's moons, with CONSOLMAGNO (*https://www.youtube.com/watch?v=pFnum-gEypg*).

HINCKS

- Interviewed for story in *Catholic Register* after the launch of the James Webb Space Telescope: "What we learn of the universe leads us to God". *https://www.catholicregister.org/item/33944-what-we-learn-of-the-universe-leads-us-to-god,* 20 January.

- Research featured in news story on University of Toronto's Faculty of Arts & Science website: "U of T astronomers are helping find the missing universe". *https://www.artsci.utoronto.ca/news/u-t-astronomers-are-helping-find-missing-universe,* 11 July.

- Interview on AMDG: A Jesuit Podcast: "God and the Big Bang with Astrophysicist Fr. Adam Hincks, S.J." *https://soundcloud.com/jesuitconference/god-and-the-big-bang-with-astrophysicist-fr-adam-hincks-sj,* 7 September.

- Interview on *Cosmos From Your Couch*, Dunlap Institute: "Sound Waves from the Early Universe". *https://www.youtube.com/watch?v=FDxqJoeW6SI,* 21 September.

KIKWAYA ELUO

- Benoit Hervieu-Leger, *La Vigie Cosmique du Vatican*, Revue Projet 387, avril-mai 2022.

- Le Telescope du Vatican, *Jour du Seigneur*, program of France 2, French Television, Published on May 4, 2022.

MACKE

- Interview for the "Man at Work" column of the UCS province magazine.

- YouTube channel "Macke MakerSpace" (*https://bit.ly/3vTUeVY*): Iron Man's Brass Rat; Observatory on a Church (5 part series); Vatty the Robot Telescope; Metal Earth Snowspeeder timelapses; Meteorite Display Maintenance; Grootsaber: A Space Wizard's Wand; Ideal-Gas Pycnometer for OSIRIS-Rex; Turning a Plastic Bin into an Airbrush Spray Booth; Maker Faire Rome 2022; Custom Box for a Meteorite.

MONZANI

- "Berkeley Lab Researchers record successful startup of dark matter detector at underground research facility", LBNL press release, 7 July (article quotes M.E. MONZANI).

- "Researchers mark successful startup of LUX-ZEPLIN dark matter detector at Sanford Underground Research Facility", SLAC press release, 7 July (article quotes M.E. MONZANI).

- "Dark matter hunt heats up with first result from world's biggest detector", *Science News*, 7 July.

- "The world's best dark matter detector whiffed on its first try", *Popular Science*, 8 July.

- "Underground Dark Matter Detector Begins Quest to Find the Unknown", CNET, 14 July.
- "This Badass Machine Could Hunt Down the Universe's Elusive Dark Matter for the First Time", *Popular Mechanics*, 29 July.
- "LUX-ZEPLIN Data-Management Needs Fuel Team Approach", *Berkeley Lab Computing Science News*, 10 August (article quotes M.E. MONZANI).
- "Researchers at SLAC use purified liquid xenon to search for mysterious dark matter particles", SLAC press release, 15 September (article mentions M.E. MONZANI).

Top: LUX-ZEPLIN scientists inspect the Xenon Detector for dust.
Bottom: The photosensor array for the LZ detector (photo credit: M. Kapust, SURF)

VISITORS HOSTED

BROWN

- Tour of VATT facility given to group of administrators and faculty of Discovery Park Institute, AZ, 23 May.
- Tour of VATT given to group of administrators from the University of Arizona, Tucson, 27 May.
- Tour given of palace and garden domes at Castel Gandolfo to first-year seminarians from the Pontifical North American College (NAC), 28 August.
- Tour given of palace and garden domes at Castel Gandolfo to Catholic clergy from the UK (as part of "Priest Conference at Palazzola" by the Mission Fraternity), 15 September.

CONSOLMAGNO

- Dr. Jack Wisdom, of the Massachusetts Institute of Technology, spent an extended sabbatical stay in Castel Gandolfo with his family, March 15 - May 12.
- Conducted a tour of the Vatican Observatory sites in Castel Gandolfo for a group of astronomers sponsored by Sky and Telescope magazine, May 3.

CORBALLY

Hosted in Tucson:

- Godehard Brüntrup, S.J. (Munich School of Philosophy).
- Hsin-I Chang (Hydrology and Atmospheric Science, University of Arizona).
- Katie Pighini (National University of Ireland, Galway).
- Katie Steinke (Vatican Observatory Foundation).
- Christof Wolf, S.J. (Munich School of Philosophy).

GIONTI

- With D'SOUZA, helped in the visit to the Vatican Observatory of the Patrons of Arts on May 5.
- Hosted the visit of a group of seminarians and fathers of the Legionary of Christ attending the Master in Science and Theology of the Pontifical University "Regina Apostolorum" in Rome.
- Hosted the visit of the Netherland Ambassadress to the Holy See and her husband accompanied by Fr. Johan Verschueren, Father Delegate of Father General Sosa to the international houses in Rome, on August 18.
- Hosted, at the end of August, the visit of all novices and fathers of the Salesian Noviciate in Genzano (RM).
- With D'SOUZA hosted on September 17 a group of journalists attending the master on scientific journalism at Santa Croce University in Rome.
- Hosted Fr. Francesco Citarda, S.J. and a group of four Indian Jesuits, who recently had finished their tertianship program, on May 26.

HINCKS

- Students from the University of Toronto's Gilson Seminar in Faith and Rome, 16 May 2022
- Colleagues from University of Rome, "La Sapienza" — Profs. Paolo De Bernardis, Silvia Masi & Elia Battistelli and the latter's graduate students, 7 June.

KIKWAYA-ELUO

- Hosted Juraj Toth, Stanislav Kaniansky, and others from Comenius University, Bratislava in Tucson and at the VATT for measurements of meteors.
- Satya Gontcho A Gontcho (Lawrence Berkeley National Laboratory, California).

MACKE

- Federico Tosi, Cristian Carli, Davide Grassi and meteorite-research colleagues from IAPS/INAF came to the Specola for a series of colloquium-style presentations.
- Juraj Toth (Comenius University, Bratislava) came to the Specola in November to measure physical properties of some meteorites from Slovakia.

CHAPTER SIX

Publications

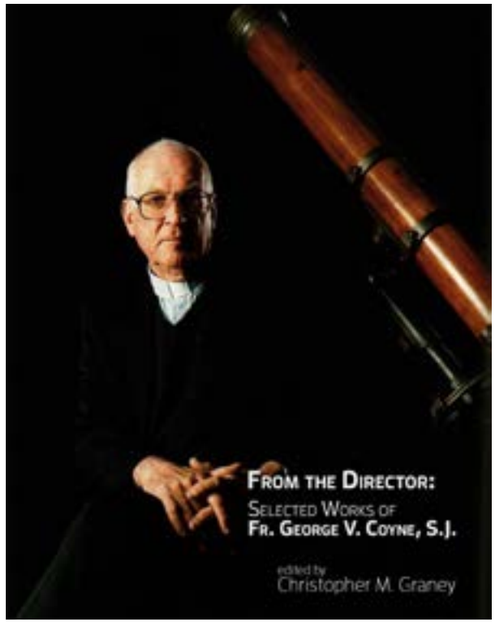
BOOKS

HELLER

Inspired by the Russian actions in the Ukraine, Heller published *The Question of a Clay Jar. Short Sermons on War and Peace*, CCPress, Cracow, 2022, in Polish.

GRANEY

GRANEY C. M., CORETTI A., eds. 2021. *From the Director: Selected Works of Fr. George Vincent Coyne, S.J.* Vatican Observatory Foundation.



TANZELLA-NITTI

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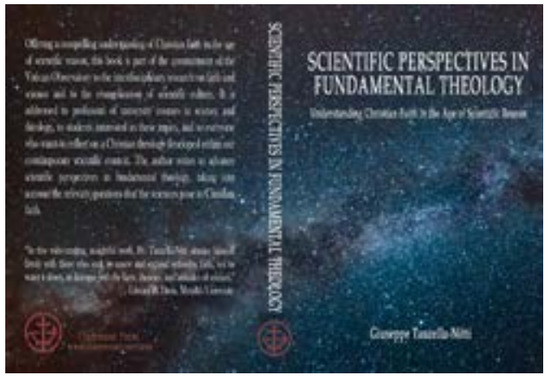

ARTICLES

BOYLE

Dulaimi S., Golden A., BOYLE R. P., Butler R. F. 2022. Optical Variability, Rotation Period and Inclination Angle of the M9.5 dwarf BRI 0021-0214. arXiv:2211.00809.

BOYLE R., JANUSZ R., Straizys V., Cernis K., Zdanavicius J., Raudeliunas S., Maskoliunas M., Kazlauskas A. 2022. Two Young Open Clusters in Cygnus. American Astronomical Society Meeting #240, id.201.03. Bulletin of the American Astronomical Society, 54:6. *https://baas.aas.org/pub/2022n6i201p03*

Straizys V. et. al. [10 co-authors including BOYLE R. P., JANUSZ R.]. 2022. VizieR Online Data Catalog: King 7 Vilnius photometry. II. Extinctions. *https://ui.adsabs.harvard.edu/abs/2022yCat..51620224S/abstract*

Wlodarczyk I., Cernis K., BOYLE R. P. 2022. Observational Data and Orbits of the Asteroids Discovered at the VATT Observatory in 2010-2012. *Bulgarian Astronomical Journal*, 37, 31.

CARUANA

CARUANA L. 2022. The Clash Between Scientific and Religious Worldviews: A Re-Evaluation. *Heythrop Journal* 63(1), 19-26.

CARUANA L. 2022. No Organism is an Island: The Philosophical Context Regarding Life and Environment. In *Foundations of Integral Ecology*, J. Azetsop, S.J. and P. Conversi, eds. Rome: G&B Press, 197-220.

CHINNICI

CHINNICI I., Gargano M. eds. 2022. *Cosmic Pages. Star Atlases in Italian Astronomical Observatories*, Arte'm.

CHINNICI I. 2022. Precursors to IAU: Paris Observatory and the Carte du Ciel Project. In *Astronomers as diplomats: when IAU builds bridges between nations*, T. Montmerle, D. Fauque, eds. Springer, 3-44.

Carotenuto M. R., Randazzo D., CHINNICI I., Genua G. 2022. Preventive Conservation Projects on LAM Materials at the INAF-Astronomical Observatory of Palermo 'G.S. Vaiana'. *Bulletin of the American Astronomical Society*, 54(2).

CHINNICI I., Coniglio M. 2022. Urania in Arcadia: l'Astronomia nelle pagine del «Giornale Arcadico». In *Scienza e Poesia Scientifica in Arcadia (1690-1870)* a cura di Elisabetta Appetecchi, Maurizio Campanelli, Alessandro Ottaviani e Pietro Petteruti Pellegrino, Collana "Il Bosco Parrasio" 9, 353-369.

CHINNICI I. 2022. Eclisse solare del 1883: una love story a Tahiti. *Giornale di Astronomia* 48, N. 4, 25-33.

CHINNICI I. 2022. Una lettera tra gli scaffali: William Herschel a Giuseppe Piazzi. *Giornale di Astronomia* 48, N. 3, 45-48.

Coniglio M., CHINNICI I. 2022. L'Osservatorio Astronomico di Palermo e l'Archivio Pascoli. *Giornale di Astronomia* 48, N. 3, 14-19.

Coniglio M., Randazzo D., CHINNICI I., Filippo Angelitti, astronomo dantista. *Giornale di Astronomia* 48, N. 2, 32-36.

CONSOLMAGNO

CONSOLMAGNO G. J. 2022. Covid, fede e fallibilità della scienza. *La Civiltà Cattolica,* 173, 15 January, 105-119; Covid, faith, and the fallibility of science. *La Civiltà Cattolica English Edition,* 6, no.2 art. 1, 0222: 10.32009/22072446.0222.2.

CONSOLMAGNO G. J. 2022. Following yonder stars. *The Tablet*, 276, January 8, 32.

CONSOLMAGNO G. J. 2022. Trust the science. *The Tablet*, 276, January 29, 12-14.

CONSOLMAGNO G. J. 2022. Pushing the boundaries. *The Tablet*, 276, February 5, 32.

CONSOLMAGNO G. J. 2022. All together now. *The Tablet*, 276, March 5, 32.

CONSOLMAGNO G. J. 2022. Being an astronomer brother. *Jivan*, March, 12-13.

CONSOLMAGNO G. J. 2022. The small world of space. *The Tablet*, 276, March 26, 30.

CONSOLMAGNO G. J. 2022. Creation in chaos. *The Tablet*, 276, May 7, 32.

CONSOLMAGNO G. J. 2022. Mysterious matters. *The Tablet*, 276, June 4, 32.

CONSOLMAGNO G. J. 2022. Space oddity. *The Tablet*, 276, July 2, 32.

CONSOLMAGNO G. J. 2022. Un'allettante sbirciata. *L'Osservatore Romano* 162, 160. 15 luglio, p. 6.

CONSOLMAGNO G. J. 2022. Heat waves. *The Tablet*, 276, August 6, 32.

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Fr. William Stoeger (1943-2014) was a longtime member of the Vatican Observatory who worked in the field of cosmology. He was a colleague and collaborator with observational astronomers, devising ways in which various aspects of cosmological theory could be tested by observations. This paper represents one final result of that collaboration.

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