Annual Report 2018

When Galaxies Collide...

The Vatican Observatory

ANNUAL REPORT 2018

Vatican Observatory
Castel Gandolfo
V-00120 Vatican City State

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

vaticanobservatory.va

Vatican Observatory Publications

Vatican Observatory Staff

During the calendar year 2018, the following were permanent staff members of the Vatican Observatory, Pontifical Villas of Castel Gandolfo, and the Vatican Observatory Research Group (VORG), Tucson, Arizona, USA:

- GUY J. CONSOLMAGNO, S.J.,
  Director
- PAUL R. MUELLER, S.J.,
  Vice Director for Administration
- PAVEL GABOR, S.J.,
  Vice Director for VORG
- 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.
- GABRIELE GIONTI, S.J.
- JEAN-BAPTISTE KIKWAYA ELUO, S.J.
- GIUSEPPE KOCH, S.J.,
  Librarian
- 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

Adjunct Scholars:

- ALDO ALTAMORE
- LOUIS CARUANA, S.J.
- ILEANA CHINNICI
- MICHELLE FRANCL-DONNAY
- JOSÉ G. FUNES, S.J.
- ROBERT JANUSZ, S.J.
- MICHAEL HELLER
- DANTE MINNITI
- GIUSEPPE TANZELLA-NITTI

Other Scholars:

- CLAUDIO COSTA - *Technical Expert*
- MATTEO GALAVERNI - *Associate Scholar*
- ADAM HINCKS - *Associate Scholar*

Cover: ***Fr. Richard D'Souza S.J. and his colleagues have given us a new insight into the formation and evolution of galaxies with their studies of our neighbor galaxy, M31 in Andromeda (see chapter 2)***

Editor: ***Emer McCarthy***
Design and layout: ***Antonio Coretti***

Vatican Observatory
ANNUAL REPORT 2018

CONTENTS

Chapter ONE

From The Director

On June 28, 1818, a child was born to Giovanni and Luigia Secchi in the small town of Reggio Emilia, the heart of the Po valley in northern Italy. (The setting was later made famous in the Don Camillo books by Giovanni Guareschi.) Angelo Secchi, as he was baptized the next day, would come to be known as the Father of Astrophysics. And in many ways he was also, if not the father, then the grandfather of the Vatican Observatory.

Father Angelo Secchi, S.J.
(Photo by F.lli D'Alessandri)

This past year much of our activity here at the Vatican Observatory has been celebrating the bicentenary year of Father Secchi. This has included co-sponsoring and participating in four different Secchi conferences; the preparation of the first full biography of Secchi in English; and countless blog posts, videos, and interviews about the Jesuit priest who put telescopes on the roof of St. Ignatius Church in Rome… and fundamentally changed the way we do astronomy.

Secchi entered the Jesuit order at 15 years old, in 1833. Along with the usual studies in philosophy and theology he also studied physics, in preparation for a teaching career. But in 1848, the year after his ordination, the revolutions sweeping Europe and especially Italy resulted in the temporary occupation of Rome and the expulsion of the Jesuits of the Roman College, including Secchi.

He first went to Stonyhurst College in England (the alma mater of Fr. Chris Corbally) where he was introduced to astronomy; then he moved to Georgetown University (the alma mater of Fr. Richard Boyle) where he came in contact with some of the leading meteorologists in America. By 1850 he was back in Rome, the Italian army having been driven out by a French force supporting the Pope, and at that time he was named director of the Roman College's Astronomical Observatory. He was just 32 years old.

With his physics background, he approached astronomy in quite a different way from most of his contemporaries in the field. Instead of tracing the locations of stars and the orbits of planets, the typical work of astronomers at that time, he asked a new question: not, where are they, but what are they? Armed with the new science of spectroscopy, he went on to observe the spectra of thousands of stars and develop the first system of stellar classification.

Meanwhile, he also did outstanding work in meteorology (winning a gold medal at an exposition in Paris); terrestrial magnetism and solar physics (the NASA spacecraft instrument studying solar weather is called the Sun-Earth Connection Coronal and Heliospheric Investigation package – note the acronym); and even limnology (where the Secchi Disk, which he invented in 1865, is still a standard tool for measuring the clarity of lakes and oceans).

Even when the final fall of Rome in 1870 led to the confiscation of the Roman College, Secchi's international repute forced the anticlerical Italian government to allow him to continue his work there until his death in 1878. It even led the scientists of the International Meter Convention in Paris to choose to prefer his presence, from the Holy See, over that of the Italian delegation who had objected to the presence of a scientist representing a nation they no longer recognized.

The significance of this was not lost on the Papacy. There's no doubt that the political usefulness of having a national observatory was one of the inspirations behind the re-foundation of the Vatican Observatory by Pope Leo XIII just thirteen years after Secchi's death.

But of course Secchi's science has also been a foundation of our work… from the spectrochemical lab established at the Castel Gandolfo site in 1935, to the spectroscopy and spectrophotometry done at the VATT today as reported in this annual report; and indeed, including the study of planets as places that inspires my own work in planetary sciences. I'm also pleased to note that the upcoming Secchi biography, mentioned above, is by the Specola adjunct astronomer Dr. Ileana Chinnici; and that one of the Specola's associate astronomers, Father Matteo Galaverni, himself hails from Reggio Emilia!

The spectrochemical lab established at the Castel Gandolfo site in 1935

We all owe a great debt to Father Secchi. It has been our pleasure this year to celebrate his birth, his life, and his science… not the least because, as we hope is true of our own work, Secchi's life and work was inspired by the Jesuit motto, Ad Maiorem Dei Gloriam: for the greater glory of God.

Guy J. CONSOLMAGNO, S.J.
Director

Chapter TWO

In Search of the Milky Way's Long Lost Sibling

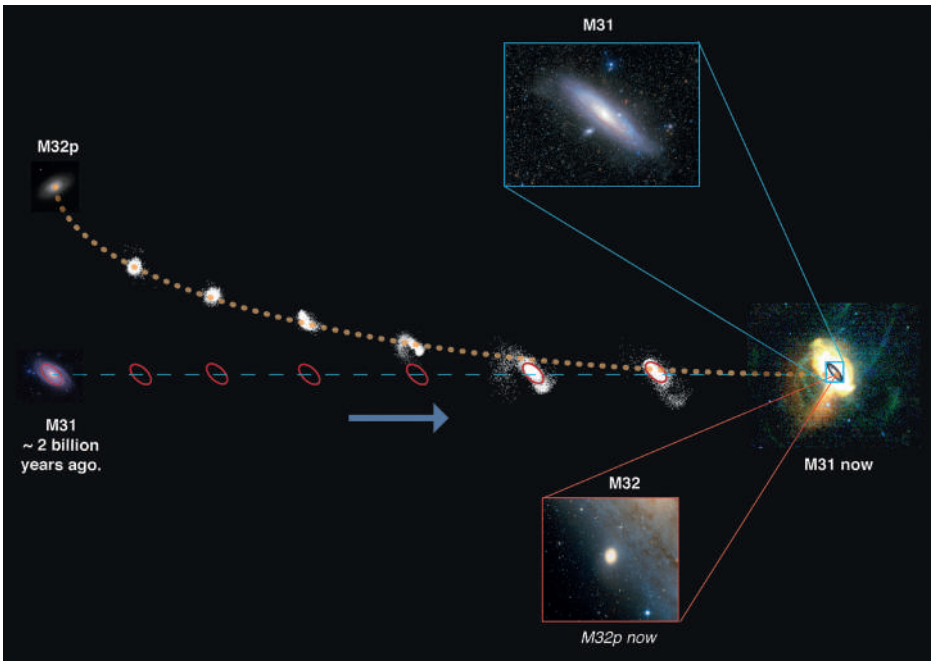
Vatican Astronomer Fr. Richard D'SOUZA, S.J. helped deduce that the Andromeda galaxy, our closest large galactic neighbor, shredded and cannibalized a massive galaxy two billion years ago. This disrupted galaxy was the third-largest member of the Local Group of galaxies, after the Milky Way and Andromeda galaxies. Even though it was mostly shredded, this massive galaxy left behind a rich trail of evidence: an almost invisible halo of stars larger than the Andromeda galaxy itself, an elusive stream of stars and a separate enigmatic compact galaxy, M32. This disrupted galaxy was a long-lost sibling of the Milky Way, and was nearly half its size in mass. This discovery will help astronomers understand how disk galaxies like the Milky Way evolve and survive large mergers. The finding was published in Nature Astronomy, and featured widely in the world press.

Earlier this year, my collaborator, Eric Bell and I, set for ourselves an interesting challenge. For a long time, we had been trying to explain the rich diversity in the properties of galaxies like the Milky Way in the Universe, a problem which continues to be one of the biggest unanswered questions in galactic astronomy. We were particularly interested in how a galaxy's past mergers affect its properties, including its star formation and morphology. Since the 70s, it has been postulated that not only does a galaxy grow through mergers, but that the largest of these mergers shapes its important properties. Yet, without access to a galaxy's merger history, it was impossible to empirically verify how mergers influence the properties of galaxies. The Andromeda galaxy (M31), our closest galactic neighbor, offered us the best opportunity to study its merger history because of its proximity. We realized that if we could not unravel the merger history of the Andromeda galaxy, then it would be much more difficult to decipher the merger histories of more distant galaxies. So, we focused our attention on the Andromeda galaxy.

Father Richard D'Souza and Eric Bell

The best tracer of a galaxy's merger history are stars found at large galactocentric distances, called its stellar halo. This outer low surface brightness region is made up of the debris of smaller satellite galaxies which are disrupted by tidal forces as they merge with the main galaxy. The positions, velocities and chemical composition of these outer halo stars encode the complex merger history of the galaxy. Because these outer halo stars are so difficult to observe, at first the only stellar halo we could study and build our intuition on was that of the Milky Way. It was only with the advent of charged-couple-device (CCD) imaging detectors on telescopes in the 80s, that the low surface brightness regions around neighboring galaxies became observationally accessible.

When the stellar halo of the Andromeda galaxy was eventually mapped out, it left everyone confused. To everyone's surprise, M31's stellar halo appeared very different from the Milky Way's stellar halo. Not only was it massive (20x), but it was also more metal-rich (10x). On the night sky, the stellar halo of the Andromeda galaxy is as large as the size of the Big Dipper and extends out to the Triangulum galaxy (M33). Moreover, in contrast to the Milky Way, some of the stars in Andromeda's stellar halo were considerably young, with a bulk of them having intermediate ages (4-8 Billion years). All this left astronomers bewildered about the stellar halo of the Andromeda galaxy and its merger history remained a mystery.

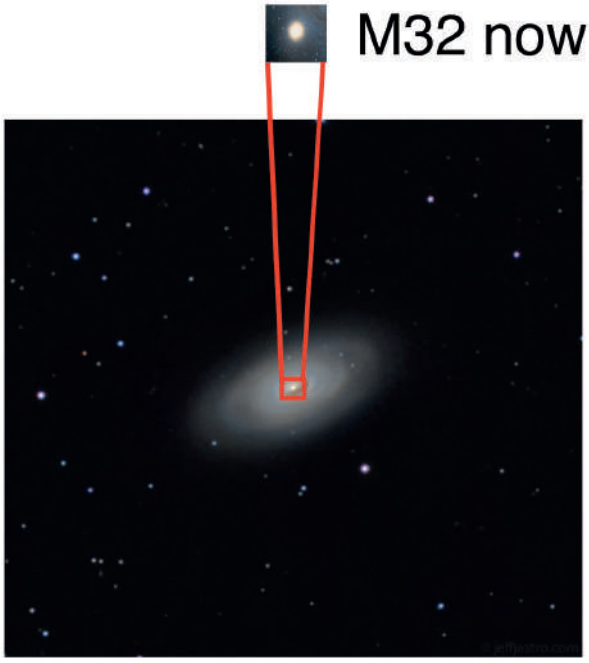


The process of shredding of the large galaxy M32p by the Andromeda galaxy which eventually resulted in M32 and a giant halo of stars. (Credit: D'SOUZA; M31, courtesy of Wei-Hao Wang; Stellar halo of M31: AAS/IOP)

In order to make some headway in interpreting the stellar halo of the Andromeda galaxy, we compared it to the stellar halos of nearby Milky Way-like galaxies. We found a large diversity in their stellar halos, with the Andromeda galaxy having the largest stellar halo, hinting at their different accretion histories. Moreover, the more massive stellar halos were metal-richer. Such a large range in the mass of the stellar halos of nearby Milky Way-size galaxies and a correlation with its stellar metallicity could only be explained by galaxy formation models where the bulk of the halo stars were contributed by a single large merger. This suggested that although the Andromeda galaxy merged with a number of smaller galaxies in the course of its life time, the majority of its halo stars came from the shredding of a single large metal-rich galaxy.

To confirm our intuitions, we turned to stellar halo models generated from a large publicly-available computer simulations of galaxies, which track their stars, gas and dark matter right from the beginning of the Universe to the present day. These large simulations contain thousands of Milky Way analogues, with a large diversity in their merger histories. By choosing galaxies in the simulations which were similar to the Andromeda galaxy in terms of its stellar mass, dark matter mass as well as its stellar halo mass, we were able to isolate simulated galaxies with merger histories similar to that of the Andromeda galaxy. This allowed us to statistically demonstrate that the only way the Andromeda galaxy could have built a large metal-rich stellar halo, was through a recent merger of a large metal-rich galaxy ($M^* \sim 2 \times 10^{10}\ M_\odot$). Moreover, the young stars in the halo of the Andromeda galaxy dates this merger to approximately 2 billion years ago. The merger history of the Andromeda galaxy was finally deciphered!

This large disrupted galaxy left behind a large trail of debris in terms of metal-rich stars as evidence. While most of the stripped material should have settled in the central parts of galaxy, the merger should also have left a large halo of stars surrounding the galaxy, and possibly a large stream. The Andromeda galaxy's giant metal-rich stellar stream is a likely candidate of possible debris from this large merger. Yet, the most metal-rich object of external origin near the Andromeda galaxy is the enigmatic compact elliptical galaxy, M32. It is one of the most compact galaxies known in the Universe and is only 100 parsecs across, and its origins have been a long-standing mystery. Owing to its very high metallicity, we suggest that the compact M32 is the surviving center of the large stripped galaxy.



A local analog of the M32p galaxy, cannibalized by the Andromeda galaxy nearly 2 billion years ago, compared to its present-day remnant, the compact elliptical galaxy, M32. The local analog of M32p is represented by the galaxy M64.
(Credit: Richard D'Souza; For the image of M64: NOAO/AURA/NSF)

The Andromeda galaxy (M31) offered us the best opportunity to study its merger history because of its proximity. The large galaxy is formally known as M31, while the smaller galaxy below and to the right, in this image, is M32, the presumed core of the galaxy that merged with M31 two billion years ago.
(Image taken by Claudio Costa from his home in Rome, 2018-12-10)

This disrupted galaxy (called M32p) was about half the size of the Milky Way, making it the third largest galaxy in the Local Group after the Andromeda and the Milky Way galaxies. Moreover, this disrupted galaxy was really the Milky Way's sibling: it was nearly half the mass of the Milky Way.

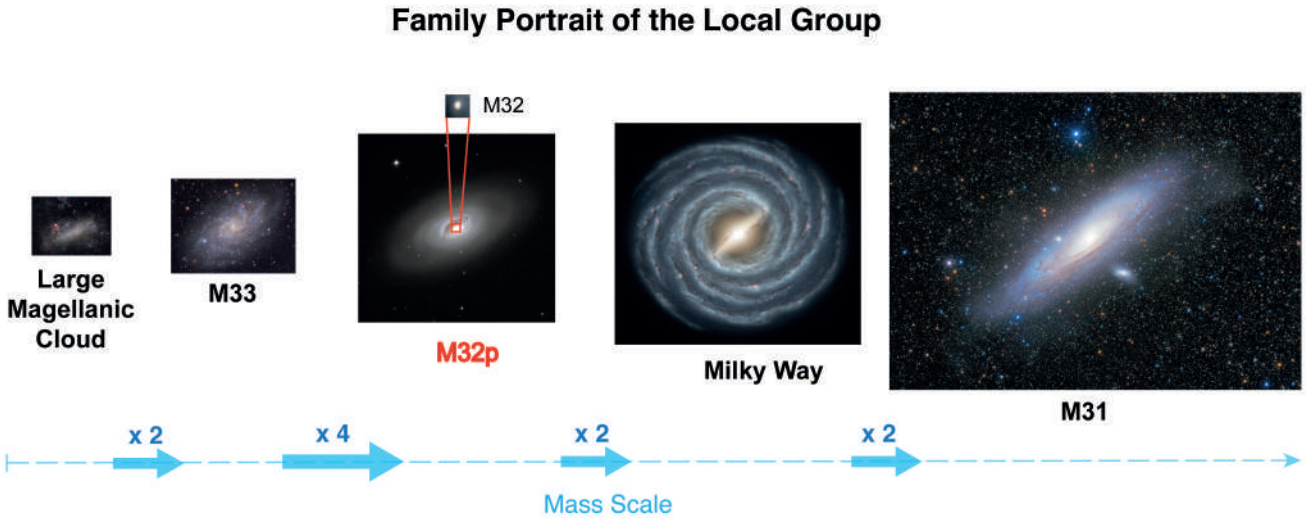
Details of the discovery were published in the September issue of *Nature Astronomy*, and featured on its cover page. Moreover, the findings were widely featured in the press around the world as well as in popular astronomy websites. The idea that the Milky Way galaxy once had a sibling that was 'cannibalized' by the Andromeda galaxy caught the attention of the media.

This inaugurates a new method in interpreting the stellar halos of nearby galaxies in terms of its most massive merger. Andromeda galaxy's stellar halo suggests that the galaxy had a much more active merger history than that of the Milky Way. The Andromeda galaxy accreted a galaxy 20x larger than what the Milky Way accreted in the course of its life time. With the aid of this method, it will now be possible to empirically measure the stellar mass of the most massive merger of a statistical significantly number of nearby Milky Way-like galaxies, enabling us to confirm theoretical merger rates as well as study how certain galaxy properties correlate with the mass of the most massive merger.

In the specific case of the Andromeda galaxy, we can directly measure the impact of its most massive merger. The timing of the merger may explain the global burst of star formation in the Andromeda galaxy ~2 billion years ago. Moreover, it comes as a total surprise that the disk of the Andromeda galaxy survived such a large recent merger. It was generally expected that the merger of two large disk galaxies would result in an elliptical galaxy. This did not happen in the case of the Andromeda galaxy. Instead, its disk got substantially heated up and thickened during the merger. The Andromeda galaxy's merger with M32p will go a long way in helping us understand the ubiquity of disk galaxies in the Universe and how they survive large mergers.

Nevertheless, our understanding of the 'Local Group' has also been completely revolutionized. No longer can we think of the Local Group in terms of its two largest members, the Andromeda and the Milky Way galaxies. Not

only has M32p usurped the position of the third largest member of the Local Group from the Triangulum galaxy, but it is comparable in size to the Milky Way. In trying to understand the history of the Local Group, future studies will have to consider how the M32p galaxy could have influenced the orbits of the Andromeda and the Milky Way galaxies.



A family portrait of our local neighborhood of galaxies, called the Local Group as it would have looked more than 2 Billion years ago. The missing galaxy, M32p would have been the third largest galaxy in the Local Group after the Andromeda and Milky Way galaxies. (Credit: Richard D'Souza; LMC, M33 and M31, courtesy of Wei-Hao Wang; Milky Way, NASA/JPL; M64, NOAO/AURA/NSF)

Chapter THREE

2018 A Year in Review

2018 has been a rich and productive year at the Vatican Observatory, from 'Seeking the Face of God' in scientific exploration to rediscovered astonishment in the evolution of Jellyfish galaxies. Over the following pages we retrace some of the highlights of the past twelve months for staff and scholars.

Father Richard BOYLE, S.J.

Father Richard Boyle

In January at the AAS Meeting at National Harbor, MD, I presented research from VATT observations on the Galactic cluster IC 4996. We elaborate improved details about Galactic structure in this area near the Great Rift in Cygnus by analysis of the Vilnius photometry combined with Asiago Observatory spectra of B-stars and stellar parallactic distances from the Gaia DR1 catalog.

In the Spring, I joined Project EDEN led by Dr. Daniel Apai of Steward Observatory. Quoting him, "Project EDEN's goal is to discover and explore the habitable planets closest to us." The major partners in Project EDEN are Steward Observatory of the University of Arizona, the Max Planck Institute for Astronomy, Heidelberg, the Vatican Observatory, and the NCU Institute for Astrophysics, Taiwan.

We did four initial observing runs on candidate dwarf stars in the spring and several more runs in the autumn on selected dwarf stars. Further description of this project can be found on the website: *project-eden.space/eden/*

With the LLCCD camera "GUFI" on loan from the National University of Ireland, Galway, Dr. Ray Butler and his graduate student Salam Dulaimi and I observed at VATT five brown dwarf stars in the broadband I-filter over many hours to obtain the light-curves. The processing and detailed analysis mainly by Dulaimi for his Ph. D. degree at NUI-Galway will further the knowledge about these cool stars that occupy the mass spectrum for low mass stars. Immediately following the observing run with GUFI in October, we welcomed two astronomers from Blackrock Castle Observatory, Cork, Ireland to come with a state of the art CMOS fast camera loaned from the Andor Company to test on celestial objects. This was the fastest way to test the new camera because it could be swapped in with GUFI out in the setup already proven for GUFI. Critical to have images to be in focus would be inserting this "Marana" camera precisely into the strictly located focal plane of VATT. It worked! We await now to see the efficiency of this new Marana CMOS camera compared to GUFI.

Father Robert JANUSZ, S.J. in this annual report gives detail about our collaboration on the large observational database we have from VATT in the Vilnius Photometric System on many stellar fields in the Milky Way. The database is now resident in the Dropbox space contracted by CONSOLMAGNO. Having our large observational database now securely stored on Dropbox assures its preservation and convenient access for our further collaboration.

By interacting with the requesting observers, I prepared the VATT observing schedule for the two semesters by accommodating all requested runs. In addition, I also trained several observers to become or continue as "Approved VATT Operators" for their safe and efficient use of the telescope.

Following my attendance at the IAU meeting in Vienna in August, during the first week of September I went on to the University of Edinburgh to take part in a conference of a hundred astronomers active in research on "The Wonders of Star Formation" which celebrated the still on-going work of Dr. Hans Zinnecker. For him, about ten others, and I this occasion meant a reunion of our first meeting during my two years of post-doctoral research while at Royal Observatory Edinburgh in 1984 - 1986.

Father David BROWN, S.J.

Father David Brown

The year 2018 has seen a continuation of several projects from the previous year. Work progresses on a series of three or four papers that will be published soon on various aspects of sdB/EHB stars. Present research has focused on how such hot stars (with surface temperatures of 4-5 times hotter than the surface of the Sun, having masses of about half that of the Sun, 0.5$M_\odot$) can form from a progenitor star, which has lost its outer envelope mass by interacting with a companion star in a binary system (a two-star system). The forthcoming papers will deal with the following: 1) the prevalence of such stars in long-period binary systems; 2) the formation mechanisms of such stars; and, 3) how these stars factor in the evolution of galaxies, namely how in very old elliptical galaxies they could be the origin of unexpected amounts of UV-radiation, the UV-upturn.

Research concerning the first paper occupied most of the first third of 2018. After a quick trip to the Tucson branch of the Vatican Observatory in May, a trip also punctuated by talks given in St. Louis, Lincoln, NE, and Dallas, TX, research back in Rome then started to move in the direction of looking at EHB stars in globular clusters (clusters of millions of stars), with an aim to presenting results at the General Assembly (GA) of the International Astronomical Union (IAU). In the midst of this, I also helped with some aspects of the month-long 2018 Vatican Observatory Summer School in astronomy (VOSS 2018) in June. This included giving a talk on pulsating sdB stars (stars that change their brightness periodically) and also helping to organize four nights of observation for the VOSS 2018 students at our Carte du Ciel telescope in the Papal Gardens, and, finally, joining a few NASA astronauts for dinner with other members of the Observatory one evening.

After finishing the yearly 8-day silent retreat mandated for all Jesuits in late July, I returned to Rome just in time to organize a night (July 27) of telescope observations for a group of forty people, the climax of which was observing the lunar eclipse that night.

As the summer progressed, research continued in preparation for attending the IAU meeting in August. It explored the production of EHB stars not only in binary star systems but also from single stars. In particular, single-star formation theories posit that multiple populations of stars in globular clusters could give rise to very hot EHB stars rather than binary star interactions, considering that not many EHB stars in GCs are found in binaries. Such stars could form from helium-enriched gases polluted by the ejecta of AGB stars from earlier generations of stars. The poster presented during the IAU (August 20-31) meeting was titled "To Be or Not to Be: EHB Stars and AGB Stars."

Once the IAU meeting in Vienna concluded, life in Rome returned to its usual routine, this time working on journal articles for publication. September was also a month in which I was interviewed by the Spanish Catholic newspaper, *Alfa y Omega*, about the work of the Jesuits at the Vatican Observatory. Finally, in late September, I departed for the USA in order to work for three months at the Arizona-branch of the Specola Vaticana, at our VORG offices at Steward Observatory. The purpose of the stay has been to partake of the numerous seminars and colloquia offered on a daily basis at Steward, to engage with the greater community of astronomers to be found there, and also to explore future collaborative endeavors in astrophysics research. To that end, I have become a member of VATT-PEPSI-TESS survey group that has as its goal to "provide precise spectroscopic parameters for potential planet-host candidates for TESS" (Blue Paper for VATT-PEPSI-TESS survey). As part of my time here, I was able to give a talk at the NOAO building on 'The Mystery of sdB Stars". On my way from Rome to Arizona, I also gave some talks at Rockhurst University, Rockhurst High School, Strake Jesuit College Prep; a talk was also given at Tampa Jesuit High School in November. I also continue to help with the Specola's Twitter account in Spanish.

Brother Guy CONSOLMAGNO, S.J.

Brother Guy Consolmagno

As I described in my opening letter, 2018 has been a year devoted to the memory of Father Secchi. Along with several conferences, book chapters, and other events in his honor (described elsewhere in this report), I also had a personal adventure this year not unrelated to Secchi's life and times.

Recall that one of Secchi's achievements was to participate in international conferences representing the Holy See as a nation state. Even today, the Vatican Observatory serves that role, for example in its participation in the International Astronomical Union. In 2018, the Specola was once again honored to serve the Holy See, this time representing it in the work of the United Nations Office of Outer Space Activities (UNOOSA).

In 2018, the UNOOSA celebrated the 50th anniversary of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space, following on the then newly signed Treaty on the Peaceful Uses of Outer Space. At the end of 2017 we were approached by the Vatican delegation to the UN office in Vienna, where the UNOOSA is headquartered, to provide a site for a workshop sponsored by the UNOOSA in preparation for their international meeting, UNISPACE+50, which was to be held in Vienna the following June.

We were delighted to oblige. And so on March 26-28, 30 experts from international organizations, governments and non-governmental organizations as well representatives of the private sector and research institutions, and leaders from the diplomatic arena, met in a workshop at the Specola headquarters in Castel Gandolfo.

To quote from the official UN report following the workshop, "the mandate of the Office for Outer Space Affairs is to bring the benefits of space to humankind and the Office is committed to ensuring that those benefits reach everyone, everywhere. The Holy See has a strong interest in matters related to the protection of the environment, and Pope Francis has repeatedly called for us to globally address the defining challenges of our time. Thus, a joint Office for Outer Space Affairs and Holy See seminar, 'Exploration and Development of Space Opportunities and Issues in the Context of the Sustainable Development Goals', provided a suitable framework for an exchange on how space science and technology can directly and indirectly escort the common global efforts to address climate change and the goals set in the Sustainable Development Goals."The meeting ended with a personal greeting to the attendees from Pope Francis at his Wednesday audience on March 28.

Following this meeting, the Vatican Secretary of State requested that I serve as the head of the Vatican delegation to the UNISPACE+50 meeting in Vienna. Thus, it was my honor to present the official Vatican position on the peaceful uses of outer space. There I delivered the message that "the potential for development through space technology is immense, and the best way to make use of this potential is through international cooperation."

My work as director of the Vatican Observatory (and president of the Vatican Observatory Foundation) has involved a lot of travel; indeed, too much travel. After years of being warned that I was overextending myself, my state of general exhaustion in late 2017 finally forced my doctor in Tucson to "ground" me for six weeks. Perhaps it had something to do with me turning 65 — the warranty had finally run out! I stayed in Tucson from December to mid-January, catching up on resting… and reading… and writing.

My first venture back on the road in January was a recording session for Now You Know Media with FRANCL for a program on the lives and discoveries of Catholic scientists, called *Seeking the Face of God*. This twelve-part audio recording was released in the summer. This is the fourth program that I have done for Now You Know Media.

Following this trip, I attempted to cut back on some of my travel, canceling several scheduled talks and doing more presentations via internet video. However, as outlined in Education and Public Outreach, I still did manage to visit the world from Austria to Australia, with many stops in the UK, Canada, and the US.

Among my other travels this year were to give the commencement address and receive an honorary doctorate from Fairfield University in Connecticut in

May. In September, I went to New York City to receive the Gaudium Award from the Breukelein Institute of the Pontifical Congregation of the Oratory of St. Philip Neri in Brooklyn, New York.

With all this travel, however, I was still able to continue my writing and even do a bit of science. Six books to be published in the upcoming year will have chapters that I have either authored or co-authored (with MUELLER), on topics ranging from Angelo Secchi and his connection to the Vatican Observatory, to a discussion of science and theism.

Though my active research has slowed down with the duties of director, I do keep abreast in the field by serving on advisory committees for several projects. These include the SETI Institute Scientific Advisory Board; the science advisory team of the Center for Lunar and Asteroid Surface Science (CLASS) node of the NASA Solar System Exploration Research Virtual Institute (SSERVI); the Conference Planning board of the Society for Catholic Scientists; and the editorial board of *Science, Religion, and Society: An Interdisciplinary Journal*.

One important activity in this line is my role on the IAU Working Group on Planetary System Nomenclature, which I serve on both as a regular member and as chair of the Mars Task Group. Over the past year, our Task Group considered proposals to name thirty craters and other features on the surface of Mars, as requested by scientists from around the world. In September, the full Working Group met in Flagstaff, Arizona, to discuss face to face a number of new procedural questions arising from current and upcoming spacecraft missions. One of the more delightful parts of that meeting was working with the Apollo 8 astronaut Bill Anders on the naming of craters visible in his famous image of "Earthrise", taken 50 years ago during the pioneering orbit of the Moon.

Other scientific visits during this year included tours of the exobiology laboratory at Georgia Tech, Atlanta; the Jet Propulsion Laboratory in Pasadena and its Mars Garden, where Mars rovers are tested; and the astronomy groups at the University of Melbourne, Australia; the University of Central Lancaster, England; and Imperial College London. While in Australia, I was also privileged to be shown the historic telescopes of the Sydney Observatory, overlooking Sydney Harbor, and of the Jesuits' Riverview College Observatory where Fr. Daniel O'Connell SJ had worked before becoming director of the Specola in 1952. My thanks to all who hosted me.

I also did get to do some science. This year has seen the publication of a paper that is the culmination of the work of the International Space Science Institute project led by TURRINI (INAF) on asteroid Vesta and its implications for our understanding of the dynamics of the early solar system. In addition, I have been able to continue my work with MACKE and OPEIL (Boston College) on meteorite heat capacity. Our focus this year has been to prepare for publication our data on the heat capacities of ordinary chondrites, with an eye on future work that will compare them with data for other meteorite types.

Father Christopher CORBALLY, S.J.

Father Chris Corbally next to Secchi's home in Reggio Emilia

This year I have had the pleasure of getting to know Father Angelo Secchi S.J., a lot better. True, he was born 200 years ago and is no longer alive, but bicentenary events for him have broadened my appreciation of his interests and achievements, and so made him much more vivid to me as a person. I found that Secchi is a person well worth celebrating today.

In September 2016, I was introduced to preparations for the 2018 bicentenary when I helped host a small meeting at the Specola of those interested. Our adjuncts, Aldo ALTAMORE, Ileana CHINNICI, and Matteo GALAVERNI, all became critically involved in the "National Committee for the bicentenary of the birth of Secchi" and in the resulting three successful meetings during 2018 as well as shorter celebratory events. From their accounts of this year, I expect you will learn more of the many details.

For a long time, I have respected Secchi's pioneering work in stellar spectroscopy and classification, which is my own expertise in astronomy, but a couple of web contributions that I was asked to make started me looking into his life and work more closely. For CHINNICI I wrote about his year at Georgetown University, just before he returned to Rome and assumed the directorship of the observatory at the Roman College. Then, the president of the Historical Astronomy Division of the American Astronomical Society remembered my earlier suggestion that Secchi must be commemorated in their June web page, the month of his birth in 1818, and he duly called on me to do it. Therefore, in May I attended the 2-day conference in his hometown, Reggio Emilia, with some background, even if my poor Italian made some of the talks difficult to follow. GALAVERNI's talk was easy to understand, but that was no surprise since I had helped him prepare the slides and he gave the talk in both our names. GALAVERNI was also a gracious host in Reggio to CONSOLMAGNO, who gave a talk, and to KOCH. We discovered just how good the gelato and pork can be in Reggio – lucky Secchi! I think the townspeople in turn discovered just how remarkable had been their local man. He was famous not just for his achievements in astronomy, but also in many branches of physics: meteorology, geomagnetism, oceanography, and geodesy. In addition, he wrote papers in archeology and paleontology as a result of his recreational walks around Rome. Only the shortness of his life – he died just before reaching 60 – prevented him from becoming an expert in earthquakes too.

I found an opportunity to insert Secchi into the two-week long General Assembly of the International Astronomical Union (IAU) in Vienna. The talk I offered to a symposium celebrating the IAU's centenary was about the IAU's contribution to stellar spectral classification. Such an account had, of course, to start with Secchi and the four principal classes into which he put the 4000 hand-drawn spectra that he had observed. I also pointed out how Secchi helped found astrophysics (what stars are made of and are like physically) rather than just where and how bright stars are in the sky.

Immediately following the IAU General Assembly, I participated in two complementary meetings on Secchi in Rome, organized through the Italian National Academy of the Sciences. These took place in the Biblioteca Casanatense, an historic library right opposite the former Roman College where Secchi taught and where he had his observatories on top of San Ignatio Church. Therefore, the location was most appropriate, and its warning that anyone taking a book out of the library would be *ipso facto* excommunicated, seemed respected. The "Legacy" conference selected a few of the modern science topics that can be traced back to Secchi's pioneering work. His breadth of research is quite amazing. The "History" workshop dealt more with what he was like as a man, a Jesuit, and a scientist, and how he interacted with the science and people of his time.

After all this wonderful input, it was time I too spread the word about Secchi. I had been impressed by his appreciation of science as a gift from God, and that it is a gift to be used in service. (It was remarkable that these last two thoughts were quoted during the Legacy conference by the head of a military department of meteorology.) My public talk in Prescott, sponsored by its astronomy club, made full use of an excellent video on Secchi produced by MACKE from interviews – thank you, Bob! The talk sparked a good half hour of questions before the library had to close for the day. More recently for a local vocations group, I compared Secchi with a missionary pioneer in the Southwest, Father Eusebio Kino, S.J. While a century and a half separated them, their love of science and finding its use in service were very similar. I also have a Secchi theme in mind for a talk at the Lowell Observatory in the new year. Now that I have got to know him better, thanks to experts, I cannot but spread his essential message about the harmony of science and faith.

My other research interests have also been fruitful this year. My interdisciplinary co-author, Margaret Rappaport, and I had a series of three papers on the "Evolution of Religious Capacity in the Genus Homo" appear in the March issue of *Zygon: Journal of Religion and Science*. We added two more papers in *Zygon's* September issue. These helped celebrate the work of Christopher Southgate, University of Exeter. Our papers studied the origins of ecotheology in his poetry and extensions of his pedagogy in science and theology. Our presentations at two conferences, one in Lyons, the other in Oxford, advanced our thinking on the origins of theological categories and of ethical systems, but we find that we are turning to consider the development of human sentience in response to the challenges of space travel and planetary colonization, particularly on Mars. More will follow, literally in the future.

I have not neglected those enigmatic lambda Boötis-type stars either. A late-May observing run at VATT, thankfully this time not curtailed by a severe forest fire, resulted in completing the spectra for a list of candidate lambda Boötis stars in a field of Cygnus. My spectral classifications show that we now have some 36 genuine lambda Boötis stars that, thanks to the high precision photometry of the Kepler space telescope (now retired) and to asteroseismology, can be used to investigate both the stars' surface and interior compositions. We take slow-step by slow-step, but progress is gratefully being made.

Father Richard D'SOUZA, S.J.

Father Richard D'Souza

The first half of 2018 was spent on finishing and revising our paper on the history of the Andromeda Galaxy entitled *"The Andromeda galaxy's most important merger about 2 billion years ago as M32's likely progenitor"*. The paper was published by *Nature Astronomy* and featured on their cover page in their September issue. The article was well received by the scientific community. It also got a lot of press coverage both in the newspapers, but also in the popular scientific publications. This is the first time that the merger history of a galaxy has been deciphered using its low surface brightness outer stellar halo. Moreover, the Andromeda galaxy's recent violent past came as a big surprise – and will force us to revise our understanding of how galaxies like the Andromeda and the Milky Way evolve over time.

A good part of the second half of the year was spent in writing observing proposals to observe the outer stellar halos of nearby Milky Way-mass galaxies in order to study their past merger histories.

This year, I have turned my attention to study the dwarf satellites galaxies around neighboring Milky Way-mass galaxies. In a hierarchical Universe, dwarf galaxies are constantly accreted by large central galaxies like the Milky Way. Those that are totally disrupted by tidal forces go on to build up the outer stellar halos of the central galaxy. In general, surviving dwarf galaxies are recently accreted, and can inform us about the recent merger history of the central host galaxy. Moreover, dwarf satellite galaxies are much easier to detect and observe in large surveys of the outer regions of the central host galaxy. Today, there is a lot of interest in studying dwarf galaxies. Not only are they the smallest galaxies in the Universe, but the discovery of smaller and smaller galaxies (~100-1000 stars only!) is forcing us to revise our understanding of how such galaxies form. Astronomers hope that by studying these small dwarf galaxies that are dominated by dark matter, they will get a better understanding of the nature of dark matter and the way it interacts. In addition to the uncertainties of how dwarf galaxies form, we are presently uncertain how we can use dwarf galaxies to study the recent accretion history of the host central galaxy. With the help of models, I am pioneering methods to study dwarf galaxies in conjunction with the stellar halo of the host galaxy to constrain its recent merger history.

I have also been helping a number of undergraduates with research projects at the University of Michigan along with my mentor Prof. Eric Bell.

I have also given a number of talks on the interaction of science and religion to a number of parishes and church groups in the Detroit area.

Father Pavel GABOR, S.J.

Father Pavel Gabor

Thinking back on 2018 a few years from now, I will probably recall it as the year when I got more involved in observing projects. In the fifty nights around the summer solstice, my collaborators and I performed the first of three campaigns of the VATT-PEPSI-TESS survey. I described its goals in last year's Annual Report. The observing campaign was a success, favored by good weather. We lost only 10 nights out of the 50.

Another very exciting project I am engaged in is the Exo-Earth Discovery and Exploration Network (EDEN).

It aims to examine all M stars within fifty lightyears and conclusively determine whether there are any Earth-sized planets in their habitable zones. The EDEN transit survey is a multinational collaboration, created by UA's Daniel Apai. BOYLE and I represent the Vatican Observatory that was the first to join forces with Daniel's team of students, committing considerable VATT time. Steward Observatory is dedicating observing time on the 90-inch Bok, the 61-inch Kuiper, and the 32-inch Schulman telescopes. Max Planck Institute for Astronomy in Heidelberg is contributing observing time on two Calar Alto telescopes, and the National Central University of Taiwan is committing astronomical resources in Lulin. EDEN has the capability of carrying out the most sensitive transit survey in the northern hemisphere.

Habitable zone Earth-sized planets around nearby M stars have been in the spotlight over the past decade for five reasons: (i) M stars, also known as red dwarfs, are the least massive main-sequence stars. Consequently, their habitable zones lie close to the star, and the geometric probability that a given habitable zone Earth-sized planet transits is about five times higher than in the case of a Sun-Earth analog. (ii) The proximity also means that the orbital periods are short (7–20 days), making it possible to probe each of these stars for habitable zone transiting exoplanets in about 20 times less time than it takes around Sun-like stars. (iii) Because M-dwarfs are relatively small compared to the size of Earth-sized planets, the typical transit depth is 1%, i.e., a hundred times deeper than around Sun-like stars. This makes planet detection and follow-up spectroscopy easier. (iv) Surprisingly, short-period small (broadly Earth-sized) planet occurrence rates were found to be about 3.5 greater around M stars than around Sun-like stars, further increasing the number of detectable habitable Earth-sized planets around M-dwarfs. (v) The James Webb Space Telescope will soon provide uniquely powerful capabilities for spectroscopic follow-up on transiting exoplanets. The EDEN Survey is uniquely positioned to discover potentially habitable planets that are ideal for such follow-up observations. EDEN, coordinating existing medium-sized telescopes, has the best sensitivity to M-star habitable-zone planets.

Work continues on VATT's upgrades. Admittedly, it is slower than I would like. If the VATT is to operate without human intervention, we need to "teach" it how to align the secondary mirror with the primary, i.e., how to collimate the optics, and how to maintain this collimation in spite of thermal effects (dilation of the struts holding the secondary mirror, differential expansion of the glass primary mirror and the steel mirror cell) due to temperature changes, and in spite of gravity-induced deformations due to changing orientation of the telescope assembly as it points at different elevations in the sky. I have started working with Dae Wook Kim from UA's College of Optical Sciences.

VATT has had an "autocollimation" system for a very long time. It is designed to compensate for strut sag and dilation. Despite the name, this legacy system only *maintains* collimation: a human operator is required to find the optimal alignment. The displacements of the primary mirror inside the mirror cell require an additional six sensors and FRANZ has designed and installed this system. KIKWAYA, Daniel Sablowski and I have taken test data in June, and Dae Wook with his collaborators, Heejoo Choi and Joel Bergson, proposed a collimation procedure that lends itself to automation. I am excited to see how it will perform in the coming months.

Father Gabriele GIONTI, S.J.

Father Gabriele Gionti

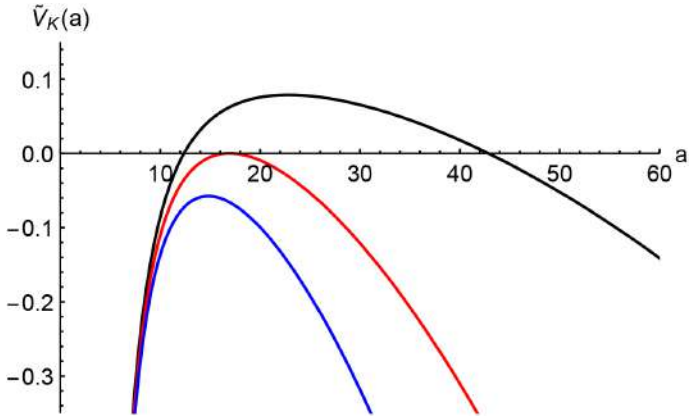
At the beginning of 2018, I certainly had a moment of "illumination". At the end of 2015, I had decided to change my field of research and move to studying the Asymptotic Safety approach to Quantum Gravity. This is an approach to Quantum Gravity that tries to find the Quantum Mechanical behavior of general relativity using the hypothesis that the infinities of the quantization of gravity can be resolved posing a cut-off on the value of the possible energies (infrared cut-off) and later sending this cut-off to infinity, hoping that the physical quantities do not diverge. In reality, it was not a change of field, since I did Asymptotic Safety in my Ph.D. project twenty years

ago, when I did research on Random Surfaces, Dynamical Triangulations and Regge Calculus. However, twenty year later I discovered that the community had developed new techniques that could be applied to my old problems that were difficult to solve then, but could be feasible now. Therefore, reviving the "hard and unsolved" problems of my Ph.D. thesis is an exciting research project for me to work on and I feel quite enthusiastic about it. I do not really know if I will succeed in it, but at least it looks worth a try.

The month of December 2017 was a bit busy. Invited by my friend Alfio Bonanno, INAF Catania, I took part in the annual meeting of the research group FLAG (Quantum Field of Gravity and Black Holes) of the I.N.F.N. (Italian National Institute for Nuclear Physics) in Como. Although I did not belong to the group, I was welcome to participate and delivered a talk, discussing my research with them. Once back from Como, I attended a meeting "On Weird Ideas" at the L.N.F. (Frascati National Laboratories).

Regarding my research, I continued to work on the problem of the Hamiltonian analysis of a version of Asymptotic Safety Gravity. Dirac's constraint analysis of this theory, that is the constraint functions one needs to introduce to make sense of the Hamiltonian theory, appeared quite difficult. One could study an ADM metric in *Gaussian Normal Coordinates* with reduced degrees of freedom, that is without "the shifts functions". In this case, the constraint problem is much simpler. If one considers the mini-super space case with a FLRW (Friedman-Lemaitre-Robertson-Walker) metric, the sub-Planckian analysis shows that Bouncing and Emergent Universes are solutions of the equations of motion. They are both universes without any mathematical singularity and the Emergent Universe solution shows a natural inflationary behavior. I presented part of these results at a short and informal meeting in February, at the Ludwing Maximilian University of Munich at the invitation of Prof. Georgi Dvali. The feedback I received was that more work is needed.

I made several work related trips to Catania on this topic with Alfio Bonanno and he was helpful in suggesting that I should also study the Brans-Dicke theory since it is quite similar to this modified version of Einstein Theory of Gravity through Asymptotic Safety.



The effective potential behaviour $\tilde{V}_K(a)$ as function of the scale factor of the Universe a in a quantum cosmological model of a FLRW mini-superspace model improved by Asymptotic Safety techniques. Black line represents Bouncing Universes condition, red line Emergent Universe condition, blue line singular universe

Toward the end of April, I organized a short meeting at the Specola with Alfio Bonanno, Alessandro Codello, and Matteo GALAVERNI. Together with Alfio and Alessandro, I worked on the idea of applying Renormalization technique ideas to Random Geometry. Matteo, Alfio and I continued to work on the estimate of the violation of electromagnetic duality caused by the passage of a gravitational wave that is originated by two merging objects with a gravitational anomaly. Matteo has worked on this project for all 2018 during his visits to the Specola and, occasionally, I have tried to help him.

In May, I spent fifteen days in Colombia, in Bogotà. Nelson Velandia, S.J., a Colombian Jesuit, was finishing his Ph.D. thesis in Cosmology and proposed me to be his external referee on his Ph.D. thesis defense at the Universidad Nacional de Bogotá. Nelson spent a semester in Tucson, more than four years ago, doing an internship with the late Fr. Bill Stoeger, S.J.. While in Bogotá, I gave several talks both on my research and science and theology at Universidad Javeriana and the Universidad Nacional de Bogotá. I talked a lot with physics scholars over there and we all agreed that it would be good to start a collaboration between Colombian research institutions and the Vatican Observatory. As a consequence of this project, Nelson will spend three months in spring 2019 at the Specola in Castel Gandolfo working on a project in classical cosmology with me, Donato Bini and his collaborators at CNR in Rome.

This summer was quite busy with a lot of travelling. Between mid-June and the end of September I went to

six conferences, including the IAU General Assembly in Vienna, giving talks on my research and collecting the comments of other researchers in my field and attending very inspiring seminars. It is a great grace to interact with other scientists, but it was also a pastoral opportunity. In fact, quite frequently, my discussions with colleagues shifted from science to the personal sphere, to science and theology and religion. I was impressed by the respect that the scientists show towards religious persons who are actively working in science. I also perceived a great respect among them for the Catholic Church.

From late September through to early November, I was based at the Specola in Castel Gandolfo to concentrate on my research. The feedback I had gained from attending conferences was important but now the time had come to sit down at my desk and do the calculations.

November saw me in Georgetown University, where I was invited by the Physics department for a visit and to give a seminar. My visit coincided with the Jesuit heritage month, a perfect opportunity to reflect on the scientific tradition of the Society of Jesus.

Father Jean-Baptiste KIKWAYA ELUO, S.J.

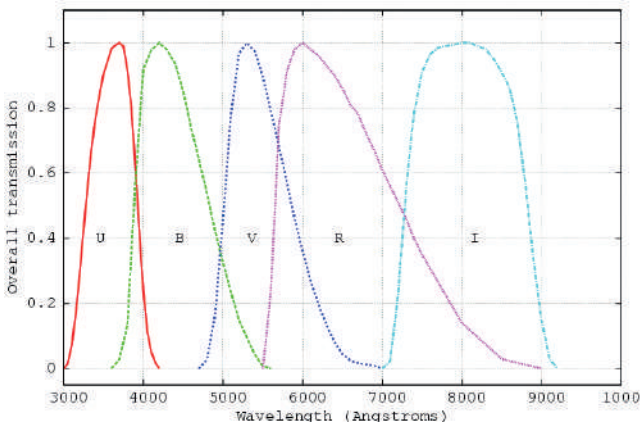
Father Jean-Baptiste Kikwaya Eluo

All this past year, I worked on asteroids, my main research. In addition, I worked on fireballs (meteoroids whose size varies between centimeters and meters) that the three all-sky cameras record around the city of Tucson. These cameras are set one on Kitt Peak, one on mount Lemmon, and one Mount Hopkins.

The goal remains to characterize physically those asteroids (and comets) that come close to the Earth. Being faint and therefore small, they become easily observable thanks to their proximity to the Earth as they make their close approach to us. The question in addressing the physical characterization of NEOs (near Earth objects) is strongly related to the technique employed. Two techniques are very well known: spectroscopy and spectrophotometry. If we wish to know the color of one particular NEO, this can be measured by spectroscopy, which spreads light over all its wavelengths and measures every fluctuation in its color. However, the amount of light at any given wavelength can be very faint, requiring a long time to collect these data.

The NEOs we observe are small and faint; the objects we are going after are fainter than 18th magnitude while the faintest object that class of spectrograph would see is limited to around 16th magnitude. Therefore our NEOs are not easily measured by any present asteroid spectrograph, particularly one that would be mounted on a 2-m size telescope like the VATT.

Spectrophotometry consists of observing a NEO using a set of filters to estimate its brightness in each of these filters and thus render a very broad relative reflectance. As the features we are looking for are also very broad, this should be sufficient to characterize the surface of the asteroid.

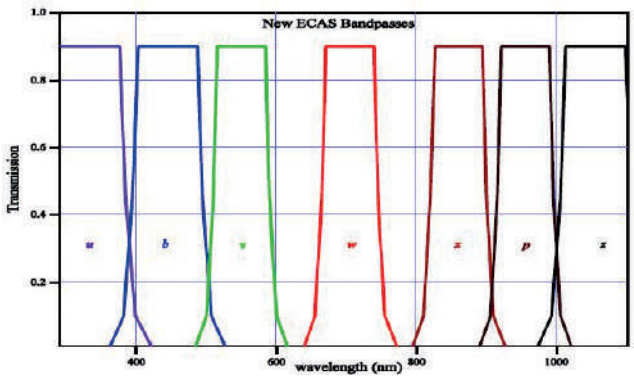


UBVRI Johnson-Cousins passband covering the visible region (300nm to 1000nm)

Using the spectrophotometry technique, we started our observations of NEOs with a set of well-known broadband Johnson-Cousins filters (BVRI) covering the visible part of the electromagnetic spectrum.

One of the most important features is the absorption band due to pyroxene and olivine located around 955 nanometers. However, as can be seen in the figure, the closest filter in the BVRI system, the I filter, is centered around 806 nanometers and does not reach the wavelengths of the feature we wish to study. Instead, we

intend to use a system of filters first introduced in the 1970s called ECAS (Eight-Color Asteroid Survey), but with only 5 filters from b (blue) to p.



ECAS passbands.We use b-v-w-x-z, u being not efficient, and z falls outside the sensitivity of our CCD limited at 1 micron (1000 nm)

Band	λ_{eff}	FWHM	Remarks
U	365	66	On the wing of a strong UV absorption in ferrous silicates
u	320	133	
B	445	94	Influenced by a strong UV absorption in ferrous silicates
b	430	110	
V	551	88	Reference λ for absolute photometry.
v	545	55	
R	658	138	Approximately at the peak of the continuum for S-class asteroid spectra
w	705	68	
I	806	149	Located on short λ shoulder of absorption bands due to pyroxene & olivine
x	860	80	
p	955	83	Near the center of an absorption band due to pyroxene
z	105 5	90	On long λ shoulder of pyroxene absorption band & near the center of an olivine band

Johnson-Cousins broad bands compared with the ECAS system passbands

As this is not a standard system, we need to tie the ECAS system to the traditional and well-known Johnson-Cousins system, as they react to the real sky over the VATT telescope at Mount Graham. In fact, we cannot start to use this set of filters to give some numbers that would infer the physical characterization of NEOs unless this first step is done properly and in a very robust way. We need to come up with what are called transformation coefficients, coefficients that would transform the ECAS system to Johnson-Cousins system.

For the past year we have been trying to accomplish this first task, but unfortunately either the weather or the telescope itself has not been cooperative. With luck at the end of this year (the months of November and December) we will accomplish this task and move on to using the system for the physical characterization of NEOs.

Still, from our work so far, we have come to realize that the p filter of the ECAS system requires a very long exposure of about 10 minutes for an object of 17th magnitude. We could use the broadband BVRI filters for NEOs fainter than 17 magnitude, knowing that the I filter can go as faint as 19th magnitude; but that would not solve our initial problem of being able to detect the absorption features due to pyroxene and olivine.

However, while the center of the I passband in the BVRI system lies at 806 nanometers, the one of the x passband in the ECAS system falls at 860 nanometers, which is closer to the center of the absorption bands we are interested in and which will record at least one wing of that absorption feature. Therefore, we have decided to use full ECAS system on objects brighter than 17th magnitude; when it comes to objects fainter than 17 magnitude, we will still use ECAS system, but without its p filter.

The system of three all-sky cameras has been running and recording cm-size meteoroids since 2014. Lori Allen, director of the NOAO and collaborator on the project, and I have been gathering data since then to work on determining their mass distribution. This work has been done for mm-size meteoroids on one end, and meter-size on the other end, but not on the range of the fireballs available now from our system. This work will tell us about the different grains in one particular meteor shower. Do we have more bigger grains than smaller grains in one particular meteor shower and why? Would smaller grains be a strong sign of collisional process going on in the meteor shower and a proof of its old age? Would the presence of bigger grains be interpreted as recent replenishing of the meteor shower by a recent passage of its parent comet?

I attended the IAU (International Astronomical Union) general assembly meeting in Vienna from August 20, 2018 to August 31, 2018. I attended almost all sessions, and talks, but the one I could relate to was given by Jiri Borovicka from Czech Republic. I worked for many years on meteors (mm-size meteoroids), and tried to determine their physical density as an indication to their origin (asteroids, comets, or Jupiter family comets). The work Jiri presented dealt with the physical strength of fireballs (cm-size to meter-size meteoroids). He tried to determine the strength of one particular fireball while crossing the Earth's atmosphere. Did it break (break of a meteoroid in

flight is shown by an increase of light along its light curve)? Where? Moreover, how many times?

It happens that some of these fireballs studied by Jiri also produced meteorites. Fortunately in this particular case, the mechanical strength these fireballs could also be calculated in the laboratory. It turns out that the estimated mechanical strength by modeling the light curve (Jiri method) is always different from the calculated ones in the laboratory. How is it possible? Who is right and who is wrong (light curve modelisation or calculation in the laboratory)?

Father Giuseppe KOCH, S.J.

Father Giuseppe Koch

The compilation of the digital catalog for the Vatican Observatory Library continues: the total number of recorded books now touches 5000. Many books have been re-categorized with greater attention to their reference themes. The binding of many vintage magazines continues. Soon, we will have to begin the cataloging of old books and journals. The second centenary of Fr. Angelo Secchi has seen several scholars consult the many documents related to him kept in our library, in particular, Dr. CHINNICI. Diverse sections of the archives have also been updated.

Brother Robert MACKE, S.J.

This has been a rather eventful year for me. A fair amount of it was spent organizing the first ever Workshop on the Curation of Meteorites and Extraterrestrial Materials and (prompted by preparations for the meeting) the reorganizing of the meteorite display here at Castel Gandolfo. Since more details are given elsewhere in this annual report, I will not dwell more on these two topics here.

In January, I attended the Tucson Gem and Mineral Show, during which I was the invited speaker for the annual dinner of the International Meteorite Collectors Association (IMCA). There, I gave a presentation on the scientific curation of meteorites in relation to private collections. Over the course of the year, I gave several other talks and presentations to school groups - mostly over Skype - including Holy Spirit Middle School (Appleton, WI), Loyola High School (Los Angeles CA), Saint Louis University High School (St. Louis, MO), St. Peter School (Huron, OH), and Bishop DuBourg High School (St. Louis, MO).

Brother Robert Macke

This year also saw an increase in my public media output. In honor of the 200th anniversary of the birth of Fr. Angelo Secchi S.J., I inaugurated a video series entitled "Religious Scientists of the Catholic Church" with a 16-minute video on Angelo Secchi that includes interviews with experts such as Dr. Ileana CHINNICI, Prof. Aldo ALTAMORE, Fr. Matteo GALAVERINI, and Br. Guy CONSOLMAGNO. I created two versions; one in English and one in Italian. I have already begun work on the next two installments in the series: Abbot Gregor Mendel OSA and Fr. Georges Lemaître. I also produced a promotional video for the Vatican Observatory Summer School using interviews with students and faculty from the 2018 VOSS. All three videos may be viewed on the Vatican Observatory Foundation YouTube channel. Beyond videos, I have also become a contributor to the Catholic Astronomer blog, and have published several short articles on the blog this year.

As for scientific work, studies of meteorite physical properties continue. In November of 2017, I traveled to Bratislava, Slovakia to study the density and porosity of a large number of intact stones recovered from the Košice meteorite fall in 2010. This year, my collaborator Juraj Toth brought several more specimens to the Vatican Observatory for further studies, to fill out the data set. We have found that there is a trend in the upper limit of porosity that varies by specimen size, with smaller pieces having greater porosity. This makes sense; more porous

portions of the incoming asteroid would be weaker than less porous ones, and so when it breaks up during the stress of atmospheric entry, the more porous regions would tend to break into smaller pieces. However, this is the first time that a systematic study has been conducted with sufficient precision to measure porosity in very small specimens. Plans are underway to expand this study to other large meteorite falls, starting with the collection of about 1000 pieces of Mocs at the Naturhistorisches Museum in Vienna. This research was presented at the 49th Lunar and Planetary Science Conference in Houston, TX. I am also still collaborating with George Flynn, Melissa Strait, Dan Durda, and their students on high-velocity impacts on meteorites. They measure the recoil parameter β using the NASA-Ames Vertical Gun Range. This parameter is dependent in part on the specimen porosity, which I measure in the laboratory here at Castel Gandolfo. This research was presented at the 49th Lunar and Planetary Science Conference in Houston, TX, and the 42nd COSPAR Scientific Assembly in Pasadena, CA.

One other noteworthy item: This year, I joined the science team for the Lucy space mission, organized by the Southwest Research Laboratory in San Antonio. TX. I will be assisting the interior and bulk properties team. The mission will visit six Trojan asteroids, which orbit at the same distance as Jupiter but 60 degrees ahead of and behind the planet, at the L4 and L5 Lagrange points. Some of these asteroids are thought to have been trapped in the Lagrange points since shortly after their formation, and may provide clues to the early history of the solar system. To my knowledge, I am the first Jesuit and the first member of the Vatican Observatory to serve on the science team of a space mission.

Father Paul MUELLER, S.J.

Father Paul Mueller

As administrative vice-director of the Observatory, this year I spearheaded development of a new exhibit concerning the history of the Vatican Observatory, located on the floor beneath the domes of the Carte du Ciel and Schmidt telescopes, in the Papal Gardens at Castel Gandolfo. I was grateful for the collaboration of Br. CONSOLMAGNO, Br. MACKE, Antonio CORETTI and Romano REGGIO in planning and setting up the exhibit, which includes antique instruments, meteorites, historical photos, displays concerning recent publications and activities of the Observatory, and a large video screen for showing presentations and archival film footage. A visit to the exhibit will be included in the program of evening sky-watching sessions with the Carte du Ciel telescope, to be conducted in collaboration with the Vatican Museums starting in summer of 2019. At present, the exhibit occupies only one of the two floors of space available beneath the telescopes. A decision as to how to make use of the remaining space will be made after seeing how visiting groups respond to the current exhibit.

I also oversaw the renovation of the Observatory's interior courtyard, which was carried out by Alessandro Reali and other workers of the Papal Gardens.

The courtyard at Specola, Vatican Headquarters

The courtyard has a more open plan, with ample space for strolling and sitting. It features two 2 x 2 meter ceramic installations: one depicting the Observatory's logo, and the other depicting the IHS sunburst from Pope Francis' insignia.

Father Alessandro OMIZZOLO

The universe offers so many astonishing things: from planets to stars to galaxies to clusters of galaxies! Moreover, each of these has unique peculiarities. Astrophysics is the study of the peculiarities of each class of object in the sky.

Father Alessandro Omizzolo

For some years I have been studying clusters of galaxies (which are clusters of hundreds and thousands of galaxies held together by gravity) and in particular those

closest to us. Cluster galaxies have unique peculiarities that we do not find in isolated or field galaxies. These peculiarities are linked to the fact that they are heavily affected by the forces in action in the cluster, forces related to the mass of the brilliant cluster galaxies, the presence of magnetic fields and high energy radiation (X rays for example) but also in the presence of the dark matter which alone seems capable of explaining the dynamics of the galaxies inside the cluster as well as the dynamics of the stars in the single galaxies.

Among all the peculiar galaxies, one class has aroused and continues to arouse the interest of the research group I have been collaborating with for the past few years, namely the Jellyfish galaxies. We already compiled and published a first catalog of these galaxies a few years ago relating to the Jellyfish galaxies present in the clusters of the WINGS sample. But we know that appetite comes with eating, so we have extended our research and study of these galaxies to other samples of galaxy clusters, and this time not to neighboring clusters but to those more distant.

The farther away you look, the faiter objects appear and consequently the more you feel limited by that thing above our heads called atmosphere, as vital as it may be for humans. This is why the Hubble Space Telescope is a unique opportunity to overcome the atmospheric barrier and provide quality images. Thanks to the Hubble Space Telescope, a group of astrophysicists has initiated a research project called RELICS (Reionization Lens Cluster Survey) with the intent of efficiently searching for brightly lensed high-redshift galaxies; these clusters are found at redshifts between 0.182 and 0.972 that correspond to distances between 2.4 and 10.7 billion light years. The sample thus obtained consists of 41 clusters of galaxies with high quality infrared images. Therefore, our group has started a systematic analysis of the images of these clusters in search of Jellyfish galaxies.

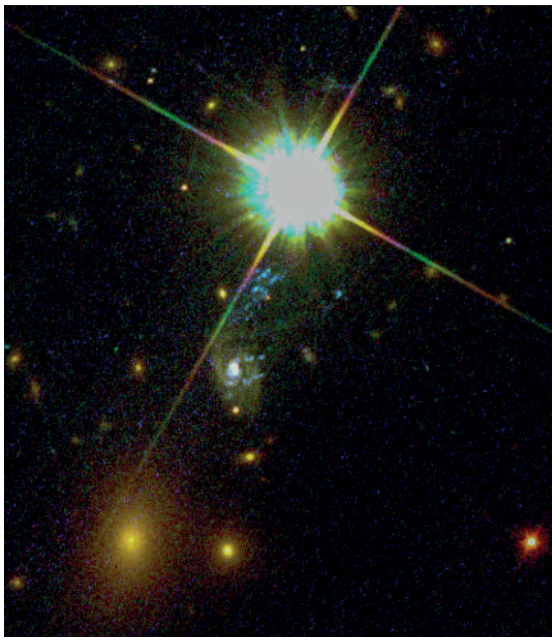
Analyzing the images, we became aware of the variety of shapes assumed by galaxies and the variety of physical phenomena that are occurring within the clusters, phenomena that form the shape of these galaxies and determine their history and evolution.

The most common of these phenomena to explain the formation of Jellyfish galaxies is the phenomenon of "ram pressure stripping" that happens when a galaxy that moves inside the cluster is affected by the action of a kind of wind due to the gas present in the mass and that can generate such a strong pressure on the galaxy to overcome the gravitational potential of the galaxy itself thus depriving it of the gas it contains. In this case, gas trails are formed that resemble those of a jellyfish. The gas "stolen" from the galaxy does not remain inert, but is full of activity including star formation, and it is this stellar formation taking place that produces these bright trails that the galaxies leave behind.

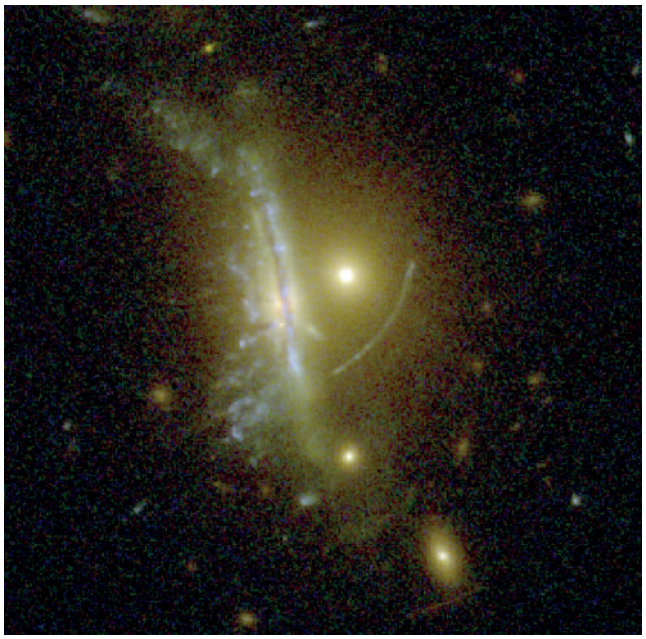
The best technique to study this type of object is spectroscopy and today the international scientific community has, thanks to the efforts of ESO (the European Southern Observatory), a spectrograph that delivers images of unprecedented quality which allow us to make a sort of tomography of the galaxy in question by obtaining images of the same galaxy at different wavelengths. Different wavelengths mean different physical processes and different chemical elements: the instrument is called MUSE (Multi Unit Spectroscopic Explorer) and is in operation at the ESL VLT (Very Large Telescope) in Chile.

ESL - VLT (Very Large Telescope), Chile (Credit: ESO)

Now that our first catalog is being enriched with new Jellyfish galaxies discovered in RELICS clusters, the next step will be to move to the detailed study of these new galaxies both to confirm the accuracy of the classification and to deepen our knowledge of the phenomena in progress. Another interesting question we hope to understand is if the phenomenon that generates Jellyfish is affected by the cosmological era at which these galaxies are observed or if it is independent of it.



ClusterWHL J24.3324-8.477



Cluster a1758. In this image with the Jellyfish galaxy, we also observe the effect of a galaxy (the bright one on the right) acting as a gravitational lens that generates the arc on the right This arc is the lensed image of another galaxy produced by the large elliptical galaxy in the centre of the image

ClusterWHL J24.3324-8.477

Three images of some of the more appealing Jellyfish Galaxies candidate found in the RELICS sample (NASA-ESO-HST)

In the cores of galaxy clusters there is a population of low-mass stellar systems such as dwarf early-type galaxies, ultra-compact dwarf galaxies (UCDs) and ultra-diffuse dwarf galaxies.

We got images for these clusters not only from the WINGS survey but also from the CFHT: these latter images are deeper than the WINGs ones. The aim of this research is to study the morphological and photometric properties of these galaxies which form about the 30% of the galaxies in the richer clusters and the 5-6% in the less rich ones.

Figure 1 (on the next page) is an example of faint galaxies candidate in the cluster MKW3s, while in figure 2 we see the process of modelling a galaxy to define its morphology *(top left: the original image of the galaxy; top right: the model for the galaxy; bottom left: the difference between the original and the model: in this case the modelling fitted very well to the original as the difference between the two is empty).*

I participated in the general assembly of International Astronomical Union held in August in Vienna and I presented a poster on a preliminary work of faint galaxy candidates in nearby WINGS clusters of galaxies.

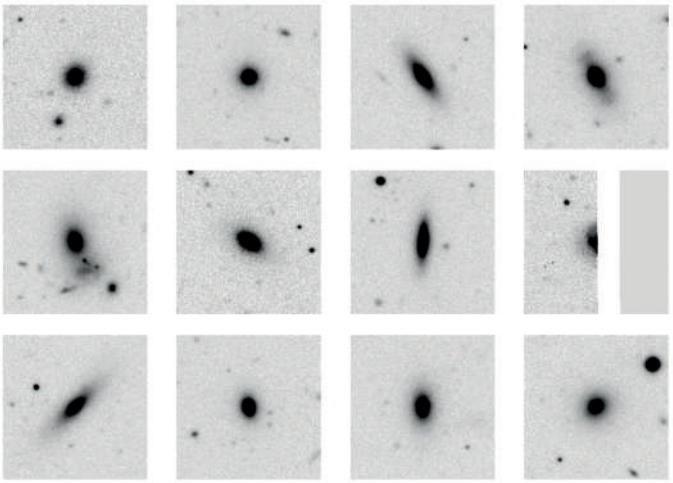


Fig. 1: The faint galaxy candidates in the cluster MKW3s

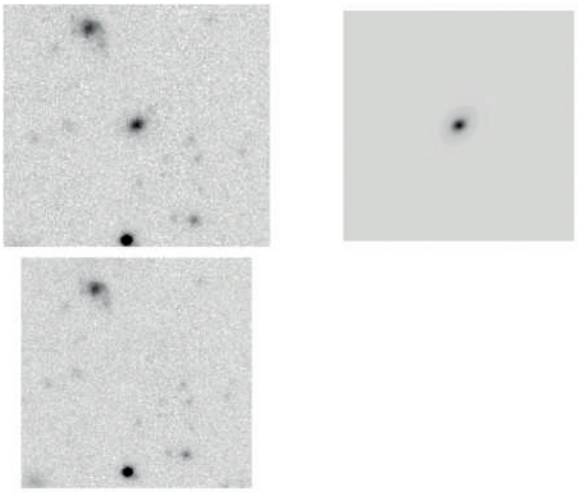


Fig. 2: A faint galaxy in the cluster Abell 85. Top left: the galaxy; top right: the model; bottom left: the difference between the two

With a colleague of the Osservatorio Astrofisico di Padova (Roberto Rampazzo), I applied and obtained observing time at the VATT to study a sample of isolated galaxies. We did remote observations from Tucson of 22 galaxies and we are now elaborating the data and preparing a first paper. We plan to observe 20 other galaxies which are observable only in the September-December period, during 2019.

The observing run was very good with a very clear sky (we lost only one night and we got nine very good nights) and that is why the image quality is very high. Figures 3A and 3B show preliminary images of one of the 22 galaxies observed (the galaxy and the field).

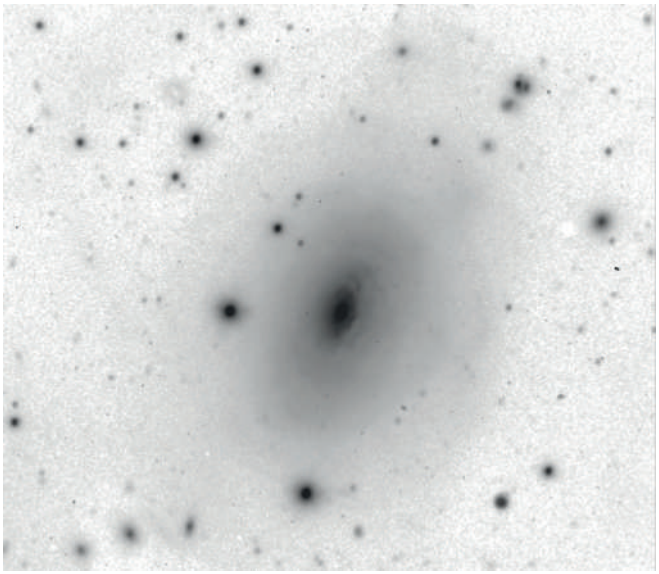


Fig. 3A: The galaxy KIG481

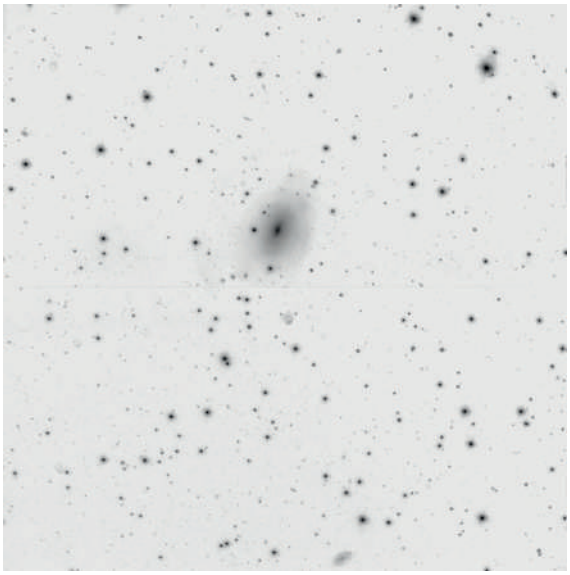


Fig. 3B: The field of the galaxy KIG481

Brother Thomas R. WILLIAMS, S.J.

Brother Thomas Williams

We have had a steady stream of guests; both friends of members of the Jesuit Community and collaborators of the Vatican Observatory have joined us in Tucson, Arizona over the past year.

In 2018, we carried out a major upgrade to the house with the installation of solar panels. The panels went live in December, 2017 for 2007 Lee Street and the following January for 2017 Lee Street.

The first few months saw adjustments on the bill taking into account what was called the "net metering one-time opt out fee" but the effect of the panels could be seen almost immediately. Keeping track of the electric bills has seen an almost 43% decrease in the charges over the past 9 months.

View of the newly installed cost-saving solar panels on the community house in Tucson, Arizona

Jesuit Community at 2017 Lee Street in Tucson, AZ. Note solar panels on the roofs of the various structures (Credit: Apple Maps)

ADJUNCT SCHOLARS

Aldo ALTAMORE

Aldo Altamore

My work at the Vatican Observatory is mainly centered on the study of its place in the history of astronomy, in particular astrophysics in the Roman period of the Specola, from its foundation in the mid 19th century to the present time.

In this framework, as a member of the National Committee promoted by Italian Ministry of Cultural Heritage, I was involved in the activities for the celebration of the second centenary of the birth of the Jesuit astronomer Angelo Secchi (1818-1878). Secchi proposed the first spectral classification of the stars which for the first time permitted one to evaluate physical and chemical properties of stellar atmospheres. For this reason he is considered one the fathers of astrophysics.

I participated in the organization of events for the wider public, such as school students, which were held in Rome, Palermo and Reggio Emilia, also with the support of the Vatican Observatory.

The interdisciplinary workshop on the history of science "Angelo Secchi: the scientist and his time" promoted by Accademia dei Quaranta and Italian National Institut of Astrophysics (INAF) stood out among the initiatives this year and was held in Rome at Biblioteca Casanatense on 6 September.

I collaborated in the project of the virtual exhibition "Tra cielo e Terra", giving my input on the section on scientific instruments used by Secchi at the Collegio Romano Observatory. *https://tracieloeterra.bicentenarioangelosecchi.it/gli-strumenti/*

Another area that I am collaborating in is ongoing efforts to boost communicating science as part of the Vatican Observatory's future projects in the field of outreach and education. At the Roma Tre University, where I formerly taught, I continued to follow the activities regarding the teaching and communication of Physics and Astronomy. I was involved formation sessions for physics and natural sciences teachers of diverse schools. I contributed also to projects which aimed to promote scientific vocations among high school students.

Further tasks included management of the multicultural project "Astronomy for Development" which is addressed to schools with a considerable presence of immigrant pupils. 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, and through my vocation as a youth catechist.

Father Louis CARUANA, S.J.

Father Louis Caruana

My lecturing at the Gregorian University during 2018 included the regular undergraduate course in the philosophy of science and a set of lectures for graduates on the philosophy of causality. These lectures explored in detail how the world is structured in terms of causes and their effects, an idea that constitutes the basic assumption behind the entire scientific enterprise. My ongoing research included completing two papers and having them published, one on philosophy of chemistry and the other on evolutionary explanations of religion.

In mid-December 2017, I had the opportunity of collaborating with the science and religion research group at the University of Comillas, Madrid, which is part of their *Catedra de Ciencia, Tecnología y Religión*. The workshop was on the notion of freedom, with contributions from neuroscientists, philosophers and theologians. In March, a three-year research project on the role of preconditions and possible bias within scientific knowledge came to a successful conclusion. The main researcher, James Kabata, a doctoral student working under my direction, defended his doctoral thesis successfully on March 5.

In April, I was invited to join an international team of scientists, philosophers, theologians and economists as a keynote speaker in a conference on ecological conversion in line with the Papal Encyclical *Laudato Si'*, held in Rome at the Gregorian University. My paper was on the intrinsic

value of nature considered from both a scientific and a philosophical viewpoint.

During Easter week, I was privileged to address a very interesting group of scientists and science-teachers in Malta during a workshop organized jointed by the Faculty of Theology of the University of Malta and the Faraday Institute of the University of Cambridge. My paper was on the causes behind the occasional clashes between the scientific and the religious worldviews. In July, the Pontifical Institute of Philosophy and Religion of Pune, India, invited me to address about three hundred undergraduate philosophy students. I took this opportunity to speak about our ecological responsibilities that are fast becoming apparent and urgent as science progresses. From Pune I travelled to Goa to deliver a paper at the Rachol Patriarchal Seminary. I explained my ongoing research on how our current scientific understanding of human nature can serve as a common platform for dialogue across cultures and religions. My hope is that this research would be publishable next year.

On September 11, I was a keynote speaker during the International Conference on Philosophy of Nature organized at Braga by the Faculty of Philosophy and Social Sciences of the Portuguese Catholic University. The general topic was "The Insides of Nature: causalities, causal processes, and conceptions of Nature" and my paper was on "The limits of causality". On September 24, the Diocese of Rome organized an evening of interdisciplinary discussions between high-ranking researchers in various fields, most of them scientists. I was responsible for chairing the debate at the end of a series of presentations. The atmosphere was cordial and full of hope for further events of this kind. As the new academic year started, I resumed my lecturing and administrative duties, together with the direction of my research group on the scientific mentality and questions about God.

Ileana CHINNICI

2018 began with a wonderful journey to the Holy Land, from January 2 to 7. For me, as an astronomer, it was significant to be there for the Feast of the Epiphany and I prepared for my pilgrimage as if I were guided by the star of the Magi. It is not easy to express the joy and the emotions of those days, I think they will rest secretly impressed in the depth of my heart.

Ileana Chinnici

This year was also the bicentenary of the birth of Angelo Secchi (1818-1878), the Jesuit pioneer of astrophysics and innovator in many other sciences, director of the Collegio Romano Observatory. I have finished writing his biography, which will be published at the beginning of next year, and I have discovered a man, a Jesuit and a scientist, who still has much to share with us today. A very modern figure emerged from the biographical research that I carried out and it has been a real joy to be able to boost awareness of him within the scientific community and among the public.

The National Committee, especially established by the Italian Ministry of Cultural Heritage, marked the bicentenary with many initiatives. I was part of the committee and charged with preparing two major events. The first was a workshop about Angelo Secchi and his time, held in the beautiful hall of the Biblioteca Casanatense, in Rome in September. This was a symbolic location, because the building is near the church of St. Ignatius – and Secchi's astronomical observatory was located on the roof of this church. The second was a virtual exhibition, "Tra cielo e terra/from heavens to earth)" *https://tracieloeterra.bicentenarioangelosecchi.it/?lang=en* It was prepared in collaboration with Mauro Gargano (INAF-Osservatorio di Capodimonte) and provides a "mosaic" of elements tracing the biographic and scientific profile of Secchi. It was a real pleasure to have been able to involve so many people who willingly contributed to this exhibition, and I hope they felt encouraged to continue and extend their research on Secchi.

I spent one week at the Specola in November revising the first proofs of the Secchi biography. It was a full-immersion, tiring and time-consuming work, and I am very grateful to the community and the staff for their help and support.

Though the Secchi bicentenary absorbed much time and energy, there are two other points that I would like to mention. First, I have been elected to the Organizing Committee of IAU Commission 3 (History of Astronomy) and I hope to make a useful contribution to its activities in the next triennium. Second, I have been encouraged by my female colleagues at Palermo Observatory to give talks on

Women in Science, a topic that I consider interesting in the current debates about gender equality.

Michelle FRANCL-DONNAY

Michelle Francl-Donnay

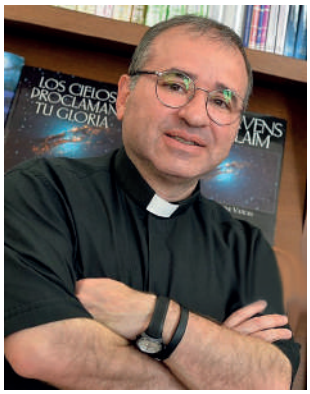
My research group has continued to explore the structures of topologically interesting structures of iron-carbon complexes, including some iron-carbon bowl shaped materials, which have the potential for host-guest chemistry, where organic complexes might nest in the carbon bowls supported on an iron-carbon base. I was pleased that two of my undergraduate research students presented their work at the national meeting of the American Chemical Society this past spring. We have recently expanded our exploration of molecular binding to include nanoputians, modular structures that resemble stick figures. At Bryn Mawr's commencement in May, I was honored with a named professorship at Bryn Mawr, and now hold the Frank B. Mallory Chair in chemistry as well as continuing to be the chairperson of the chemistry department at the college.

Br. Guy CONSOLMAGNO and I collaborated on a twelve-part audio series on the lives of Catholic scientists for Now You Know Media. We recorded the series, "Seeking the Face of God: The Lives and Discoveries of Catholic Scientists", on three very cold days in January and it was released this May. I continue to explore the philosophy and history of chemistry, producing two essays on the philosophy of chemistry — one inspired by the 200th anniversary of the publication of Frankenstein — and two historical essays this year.

I enjoyed a visit with my colleagues at the Specola in August, including chances to celebrate Ferragosto in Albano and to see the spectacular views from some of the highest points in the Castelli Romani. There were many delightful conversations to be had with other visitors, and a chance to visit with the Augustinians in Rome. While at the Specola, I worked on two essays and continued to work on a draft of a book of reflections for Lent, to be published late next year, as well as recording some material on Gregor Mendel for Br. Bob MACKE's video series.

I wrote for publications ranging from Catholic News Service to Liturgical Press' "Give Us This Day", blogged for the Catholic Astronomer and gave several days and evenings of retreat, as well as speaking at the Wagner Science Museum in Philadelphia on what the public should know about chemistry. My favorite talk of the year was at Siena College, titled "Making Molecular Monsters" and opened with a reading from Mary Shelley's "Frankenstein". In September, I was interviewed by Caspar Henderson for "Five Books" about the five books I would recommend someone read on chemistry. The list included "H_2O: A biography of water" by Philip Ball, a choice inspired by VOSS 2016.

Father José FUNES, S.J.



Father José Funes

In July, I was appointed researcher by the National Scientific and Technical Research Council of Argentina at the Universidad Católica de Córdoba. The appointment is related to the project OTHER that I am carrying out on the social and religious impact of a potential discovery of extraterrestrial intelligence (ETI).

OTHER (Otros mundos, Tierra, Humanidad y Espacio Remoto that stands for Other worlds, Earth, Humanity and Remote Space) is a laboratory of ideas that provides a multidisciplinary approach to the search of other inhabited worlds.

One of the challenges of the natural sciences to philosophical and religious thought is outlined by the question: are we alone in the universe? since it draws new frontiers in the fields of science, philosophy and religion. This question has motivated numerous scientific projects about the search for life in the universe, especially of ETI.

The attempt to communicate with a cosmic *alter ego* raises a series of questions about our very human condition:

Are we part of a more universal spiritual cosmic family? Could we establish an intersubjective relationship with other spiritual species? How could we relate to each other without being too focused on our earthling mentality?

The scientific search for extraterrestrial intelligence assumes that we live in a universe that is bio-friendly. We wonder if we live in a spiritual-friendly universe. We propose to include the search for spiritual intelligence in a new multidisciplinary approach. We consider different types of alien civilizations to include a spiritual factor according to the characteristics of those civilizations as described in a White Paper that FUNES presented at the Workshop "Detecting Extraterrestrial Technology: Signals and Artefacts", organized by the SETI Institute in Mountain View California (https://daiworkshop.seti.org/programagenda). This work was selected from 50 proposals by 75 authors and coauthors from 13 countries being the only one from Latin America.

In addition, we simulate the number of planets in our galaxy where there is an extraterrestrial communicating intelligence. To validate our purely mental experiment, we propose to apply this model to a particular human group. We propose to test the hypothesis that spirituality is a driving force in this search and in the ability to communicate with other intelligent alien species. In addition, we will try to determine (as a control variable) whether the educational background and the belief in the existence of ETI (Extra-Terrestrial Intelligence) are a determining element that could trigger or slow down our desire to contact an alien civilization.

The goal is to determine the role of spirituality in the search for an extraterrestrial intelligence. The methodological strategy combines primary quantitative instruments (surveys to university students in Córdoba) and properly qualitative (focus group with university faculty).

The search for ETI can somehow reveal aspects of our anthropological understanding. This search is connected to a broader relationship between science and spirituality. The multidisciplinary perspective of the project intends to study the impact of a possible discovery of ETI life in the social, philosophical and religious spheres.

I also presented the work developed at the SoCIA 2018: Social and Conceptual Issues in Astrobiology conference held in Reno, USA, in April. Finally, in 2018, I was appointed to the Advisory Council of the METI Institute (Messaging Extraterrestrial Intelligence, *http://meti.org/advisors*).

Father Michael HELLER

Father Michael Heller

Public lectures are an important ingredient of my present activities. Some of them attract great audiences. A good example is a lecture delivered during celebrations of the 10th anniversary of the foundation of the Copernicus Center, October 29.

As far as the scientific part of my activities is concerned, in this year I have continued my interest in the mathematical theory category. It has unexpected applications to various problems of physics and cosmology. Here is an example. The multiverse idea (claiming that a great, perhaps even an infinite, number of "parallel universes" exists) is now widely discussed. This idea, if taken seriously, certainly relaxes the postulate of the empirical control over theoretical constructs. From the point of view of the philosophy of science the question is: Could the explanatory power of multiverse ideology compensate for the relaxation of empirical control over so many directly unobservable entities? It is no surprise that appealing to a possibly infinite number of *"other universes"* in order to explain some regularities in our world would seem *"too much"* for a self-disciplined philosopher. With no strict empirical control at our disposal, logic must be our guide. Moreover, what if logic changes from one world to another in the multiverse? Exactly such a possibility is suggested by category theory (according to this theory, each sufficiently rich category has its own internal logic, and this logic "only exceptionally" is the classical logic). From this point of view, our present concepts of the multiverse are certainly *"not enough"*. My paper on this topic awaits publication. Some more technical papers are in preparation.

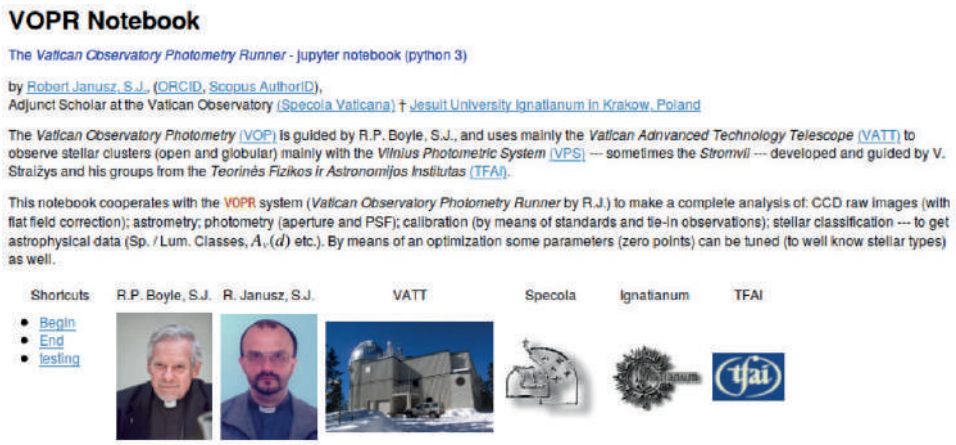
Father Robert JANUSZ, S.J.

I arrived at Castel Gandolfo with the lunar eclipse (27 July) and worked with Richard BOYLE on stellar clusters (until 18 August). It was a very intensive time when we tested the new implementation of the Vatican Observatory Photometry Runner (VOPR by R.J.), which is not finished yet. The initial cell of the Python-3 Notebook is shown below.

Father Robert Janusz

We also started to build a new and reliable repository for our data on the 2TB Dropbox cloud managed by Richard. In the beginning of November, all reliable scientific raw images for VATT photometry (as well as other data observed at CASLEO, Loiano, and Photographic Plates etc.) were uploaded to the Dropbox.

authors). For many sources, the ranking is done as Source Normalized Impact per Paper (SNIP). Scopus collects publications with the following variations: Vatican Observatory, Specola Vaticana, Vatican Observatory Research Group, Vatican Astronomical Observatory, Vatican Astron. Obs. – so it is important to use the correct name in publications in order to be recognized. So far, ca. 450 documents are located for 46 authors. Among the staff with assigned IDs are: Richard P. BOYLE 8969793700, David BROWN 56122062700, Guy CONSOLMAGNO6603022531, Christopher J. CORBALLY 6602876806, George V. Coyne 9437132100, Richard D'SOUZA 57200214140, José Gabriel FUNES 6701589520, Pavel GABOR 24832907100, Gabriele GIONTI 24782426000, Jean Baptiste KIKWAYA 26531317000, Robert J. MACKE 6603231414, and Alessandro OMIZZOLO 6508265938. The SciVal instrument connected to Scopus can be used to visualize the scientific activity of the Vatican Observatory.



VOPR Notebook

The *Vatican Observatory Photometry Runner* - jupyter notebook (python 3)

by Robert Janusz, S.J. (ORCID, Scopus AuthorID),
Adjunct Scholar at the Vatican Observatory (Specola Vaticana) † Jesuit University Ignatianum in Krakow, Poland

The *Vatican Observatory Photometry* (VOP) is guided by R.P. Boyle, S.J., and uses mainly the *Vatican Advanced Technology Telescope* (VATT) to observe stellar clusters (open and globular) mainly with the *Vilnius Photometric System* (VPS) --- sometimes the *Stromvil* --- developed and guided by V. Straižys and his groups from the *Teorinės Fizikos ir Astronomijos Institutas* (TFAI).

This notebook cooperates with the VOPR system (*Vatican Observatory Photometry Runner* by R.J.) to make a complete analysis of: CCD raw images (with flat field correction); astrometry; photometry (aperture and PSF); calibration (by means of standards and tie-in observations); stellar classification --- to get astrophysical data (Sp. / Lum. Classes, $A_v(d)$ etc.). By means of an optimization some parameters (zero points) can be tuned (to well know stellar types) as well.

Shortcuts
- Begin
- End
- Testing

R.P. Boyle, S.J. R. Janusz, S.J. VATT Specola Ignatianum TFAI

In addition, this year I participated in an excellent workshop in Vilnius and Moletai in September. With Vytas Straizys, Kazimieras Cernis, Algis Kazlauskas and other astronomers from the Vilnius Group we made progress towards a better understanding of our methods and goals. Several stellar areas were initialized and have promising conclusions for future.

In 2018, the Vatican Observatory received the Scopus Affiliation ID: 60073245. The Scopus (Elsevier) is a database that collects citations of scientific papers and books, similar to the Web of Science. Scopus is easy to integrate with the <Orcid.org> (a database to distinguish

Dante MINNITI

Dante Minniti

I have been mostly working on the ESO public survey VVVX (VISTA Variables in the Via Lactea Extended Survey). Among the many interesting new scientific results from this year, we have discovered new globular clusters in the Galactic bulge, discovered hundreds of microlensing events in the Galactic center, discovered windows of low extinction in the Galactic plane,

measured the bulge He abundance, traced the structure of the bulge, studied the bulge blue horizontal branch stars, and discovered a thousand RR Lyrae in the Galactic center. In addition, I organized the VOSS 2018, jointly with G. CONSOLMAGNO (Director), and A. OMIZZOLO (Dean).

Father Giuseppe TANZELLA-NITTI

Father Giuseppe Tanzella-Nitti

I was appointed as Adjunct Scholar of the Vatican Observatory three years ago. Formerly active as an astronomer at Bologna and Turin (1977-1987) before becoming a priest and moving to theology, today I hold the chair of Fundamental Theology at the Pontifical University of the Holy Cross in Rome. It is a task of mine, as well as a desire, to contribute to the philosophical and theological dimensions of the interdisciplinary work on faith and reason carried out at the Vatican Observatory.

In 2018, I served as director of the Interdisciplinary Documentation Centre for Science and Faith (Italian acronym DISF), which offers its academic partnership to the Vatican Observatory. The Centre runs two important websites: *disf.org*, established in 2003, which is the first Italian website dedicated to the relationship between scientific culture, philosophy and theology; and *inters.org*, established in 2006, which contains the "Interdisciplinary Encyclopedia of Religion and Science" (INTERS), a registered philosophical journal (ISSN 2037-2329). Moreover, the Advanced School for Interdisciplinary Research (ADSIR, Italian acronym SISRI) operates under the Centre. ADSIR is a teaching and research program aimed at providing a philosophical-humanistic training for young scientists who wish to enrich their studies or professional activity with a wider interdisciplinary framework. For the current year, these activities were supported also thanks to a donation received by the Templeton World Charity Foundation, which I acknowledge for its generous funding.

Last September I published the book *Religion and Revelation* (in Italian, "*Religione e Rivelazione*", 750 pp.); volume 3 of a four-volume treatise entitled "Fundamental Theology in Scientific Context". The first two volumes "Theology of Credibility" were published in 2015. An English translation of those chapters, which deal mainly with theology and scientific culture, is now in preparation under the title "Scientific Perspectives on Fundamental Theology. Understanding Christian Faith in the Age of Scientific Reason". The book will be co-sponsored by the Vatican Observatory Foundation and it will be part of the commitment of the Vatican Observatory to the evangelization of scientific culture.

As has already been noted, 2018 was the year of bicentenary of the birth of Fr. Angelo Secchi (1818-1878). I too was involved, like other colleagues of the Vatican Observatory, in giving talks and attending conferences dedicated to this great scientist and Jesuit priest. Namely, I was invited to give a lecture on Angelo Secchi at the LXII Meeting of the Italian Astronomical Society (SAIt), held in Teramo, May 2-5; at the II annual Meeting of the Centro Studi Astronomici (CSA), which took place at the Campidoglio, Roma, on April 28; and to the SEFIR Meeting, at the Lateran University in Rome, on October 26. Year 2018 was also the year in which the renowned scientist Stephen Hawking passed away; I published some reflections and obituaries, trying to clarify to the wide public why and in which way Hawking spoke of God.

I would also like to mention that I participated in the "2018 Expanded Reason Award", organized by the Joseph Ratzinger Foundation (Vatican) and the University Francisco de Vitoria (Madrid). About 300 people submitted teaching programs and research papers on the dialogue between theology and other sources of knowledge. The teaching program I submitted was ranked among the first 10 finalists.

A special event occurred on August 23, when I was invited to give a public lecture at the Rimini Meeting for Friendship among Peoples, entitled "From the Universe to Life: an inescapable result or a fortuitous singularity?" The Rimini Meeting is one of the most prestigious cultural events of the year in Italy: about 5.000 people attended the lecture, and it was broadcast live on various Italian TV channels.

Let me add, that next year 2019 we will celebrate 50 years since the landing of the first man on the moon. It will be a great opportunity for the Vatican Observatory and the DISF Centre which I direct, to reflect upon the meaning of scientific progress and how it should ever contribute to a true human progress.

OTHER SCHOLARS

Claudio COSTA

During most of 2018, I continued directing and coordinating the restoration of the historical Carte du Ciel telescope. One of my main activities included the development of an optical focus extractor for the collimator. It was designed to resemble as far as possible the original one used by the astronomers for taking glass plates, which had been lost. The new focus extractor has high quality apochromatic optics, no significant back focus and allows a 360° rotation of the diagonal prism to put eyepieces in a comfortable position for the observer whatever the position of the target object in the sky. This also required the restoration of the original brass plate holder. Unfortunately, it has not been possible to find the second plate holder that was in use when the last glass plates were taken with the telescope more than 30 years ago. As a result, we have had to construct another plate holder suitable to put a modern CCD camera at the focus of the telescope.

This year also saw slight changes to the system in place, including the ability to open and close the dome to allow for manual closure in case the motor fails, and the fine tuning of the drive sidereal rate of the telescope itself. The lather will mean it will be possible in the future to obtain long exposure CCD images. The focal end of the collimator will need reinforcing to safely hold the weight of the new focus extractor and eyepieces: this has already been designed and will be installed early in 2019. We have written a detailed checklist of instructions to be followed by the people operating the telescope. Finally, I conducted a series of training sessions with a small group of telescope operators on the correct usage of the telescope during public visits.

In addition, I helped to select a modern portable telescope that has been installed in the dome to allow groups of visitors to observe celestial objects from the terrace outside the dome while waiting for their turn to observe with the historical telescope.

During the year I also conducted several observing sessions with the Carte du Ciel telescope: during some of these the first ever CCD images of Jupiter and Mars were taken through the collimator. I also gave demonstrations of the telescope to several private visitors to the Specola (including the students of the 2018 Vatican Summer School) and many amateur astronomer groups: these visits were also trial runs to help us fine tune the best modalities for operators' activities during public visits to the Specola that are scheduled to begin during 2019.

Claudio Costa and Father Brown, inside the dome of the Carte du Ciel

Father Matteo GALAVERNI

This year we commemorated the 200th anniversary of the birth of Fr. Angelo Secchi S.J. (1818-1878) in Reggio Emilia, orgainizing a series of events in his hometown, where I also happen to live. All of these initiatives were in collaboration with National Committee for the celebrations of the bicentenary.

Br. Consolmagno and Fr. Galaverni during the two day meeting on Secchi in Reggio Emilia (11-13 May)

We started in early January with a public lecture given by Fr. Giuseppe KOCH at the local university titled "Father Angelo Secchi, a bright link of a long scientific and astronomical tradition of the Society of Jesus". In May, we offered a two-day meeting of both historical and scientific contributions related to the figure, the context and the works of Secchi. We were happy to host, among the other speakers, Br. Guy CONSOLMAGNO, Fr. Christopher CORBALLY, Aldo ALTAMORE and Ileana CHINNICI.

Ileana also returned in October for the inauguration of the exhibition "All the colors of stars: Father Angelo Secchi and the birth of astrophysics" in the City Museums of Reggio Emilia. I met several students, and with a group from the "Angelo Secchi" High School, with whom we organized a visit to the old Observatory in the Roman College on the roof over of the church of St. Ignatius. Finally, it was a pleasure to help Br. Robert MACKE in the realization of the first episode of the series "Religious Scientists of the Catholic Church" dedicated to Fr. Secchi.

On the scientific side, I continued my collaboration with Fr. Gabriele GIONTI studying the effects of gravitational waves produced by coalescing objects on photon propagation (the variation of the number of the right and left helicity photons). I also progressed in my collaboration with Fabio Finelli at OAS-Bologna (one of the institutes of INAF, the Italian National Institute for Astrophysics, where I studied for my PhD).

I am very grateful to have been in Castel Gandolfo during the Vatican Observatory Summer School, "Stellar Variability in the Era of Large Surveys" (4-29 June). VOSS is always a wonderful experience both on the scientific and human level. I also attended the International Astronomical Union and attend the 30th General Assembly. During the two weeks in Vienna, we were among more than three thousand astronomers from all over the world and were updated on the latest developments of research and outreach in astronomy.

Visit to the old site of Observatory of the Roman College over the roof of the church of St. Ignatius with Aldo Altamore and a group of students from the "Angelo Secchi" High School (Reggio Emilia)

Deacon Adam D. HINCKS, S.J.

Deacon Adam Hincks

I reached two milestones this year. First, on 3 April 2018 I was ordained to the deaconate at the Church of the Gesù in Rome. Then, a couple of months later, I finished my theology degree at the Gregorian University. With this chapter finished, I moved to Toronto to start a Licence in Sacred Theology at Regis College at the University of Toronto and to prepare for ordination to the priesthood in May 2019.

During my studies I have been able to continue my astrophysical research on a part-time basis and since 2017 I have been a proud associate member of the Specola. Back in Italy, I was affiliated with the University of Rome, "La Sapienza", where I was a guest researcher in the group of Paolo de Bernardis. Here in Toronto, I am a part-time guest at the Canadian Institute for Theoretical Astrophysics, where I try and spend about a day a week.

My area of research is "observational cosmology": that is, using telescopes to make observations that tell us about the history of the Universe and what it looks like on its largest scales. Right now I am focussing on two projects.

First, I am an associate member of the Simons Observatory (*https://simonsobservatory.org/*). This will be a multi-telescope facility in the high-altitude Atacama Desert of northern Chile for making sensitive measurements of the cosmic microwave background (CMB), the very first light emitted after the Big Bang. With this observatory we will improve our knowledge of some of the basic properties of the Universe (such as what it is made out of and how precisely it is expanding), discover thousands of previously unknown clusters of galaxies and determine the total mass of the three neutrino species, a fundamental parameter of particle physics that is currently still unknown. Moreover, we hope to detect the signature of the gravity waves produced by inflation, the hypothesised rapid expansion of Universe in the first second after the Big Bang. Altogether we are more than 150 members from dozens of institutions in several countries. I am contributing to the effort to develop software for controling and monitoring the telescope's instrumentation as well as for analysing our large datasets.

Second, with a small group of colleagues from La Sapienza and the Instituto de Astrofísica de Canarias I am looking at archival data from the Planck satellite, which observed the CMB from 2009 to 2013. Present in these data are many large clusters of galaxies. By doing a careful analysis several of the wavelengths observed by Planck we hope to use a relativistic effect to measure the temperature of the hot, intergalactic gas in these clusters.

Apart from pure research, I also enjoy engaging in popular outreach. I occasionally write for *America* magazine and this year I was pleased to publish an article on Angelo Secchi. In May, I helped host a group of undergraduate students from the University of Toronto's "Gilson Seminar in Faith and Ideas" who visited the Specola, and gave them a lecture entitled "Big Bang ex Nihilo?" Finally, in the fall, I gave two public talks in Toronto about the history and current mission of the Specola.

Chapter FOUR

Curation of Meteorites Workshop

In September, the Vatican Observatory hosted a workshop on the curation of meteorites and extraterrestrial samples at its site in Castel Gandolfo. This meeting brought together thirty curators and collections managers from around the world to discuss issues pertinent to the curation of these precious extraterrestrial specimens. The meeting was coordinated by Br. Robert Macke S.J., curator of the Vatican meteorite collection, and Ludovic Ferrière, curator of meteorites and geological samples at the Natural History Museum of Vienna.

The meeting was the culmination of several years' development. Curators had begun gathering informally at the annual Lunar and Planetary Science Conferences and the Meteoritical Society meetings, but these were generally limited to an hour or two over a meal. This was not ideal for making much progress on important issues, though it did help to bring curators together as a community. It was realized that it would be beneficial to have a workshop of several days in which to focus on topics relevant to curation of meteorites and extraterrestrial samples. At the same time, the Vatican Observatory had developed its physical plant to support workshops of this type, so it was an obvious choice for the location of the first meeting.

Thirty curators and collections managers attended the meeting. These included curators from major museum collections, such as the Natural History Museum of London, Muséum National d'Histoire Naturelle in Paris, the Natural History Museum of Vienna, the American Museum of Natural History in New York, and the Smithsonian; curators of extraterrestrial specimens from sample-return missions including the Apollo moon rocks and other astromaterials collections from NASA Johnson Space Center, and the Hayabusa sample-return collection from JAXA in Japan; university collections such as Harvard, Arizona State University, University of New Mexico; and several other institutions. Many of these institutions had been well-represented at the informal meetings during other conferences, but there were also several institutions that were new to the nascent curation community, including institutions in Prato, Italy; Florence, Italy; Budapest, Hungary; Casablanca, Morocco, and others. In addition, a few people could not attend in person but were able to present over Skype.

The meeting divided time between short presentations of each collection so we could each get to know about other collections, and more lengthy discussion of issues that were pertinent to the whole community. Other activities included a tour of the Pontifical villas, the new Specola visitor center and the Carte du Ciel and Schmidt telescopes; and a banquet held at the Vatican Observatory.

Topics that were discussed included best practices for curation, tracking laws of meteorite ownership and collection in different countries, allocation of specimens for research, acquisitions and evolution of collections, and record-keeping and sharing of information about collections. One result of the meeting was that the group will move forward on a recommendation for the Meteoritical Society, supported by the entire curation community, that researchers report in their publications the unique identifiers of the individual specimens they studied. Plans were also initiated to publish a journal article summarizing important results of the meeting.

By all accounts, the meeting was a smashing success, and the buzz among the group at the end of the week was anticipating when and where the group would hold the second meeting.

Ludovic Ferrière with Br. Robert Macke

Various moments during the meeting

Group photo from the Workshop on the Curation of Meteorites and Extraterrestrial Materials hosted at the Vatican Observatory Headquarters

Chapter FIVE

Instrumentation and Technical Services

This year has seen a number of upgrades to the telescopes and exhibits at the Vatican Observatory, both in Tucson and in Castel Gandolfo. Here's a report from our technical team.

Throughout 2018, Steward Observatory's efforts to restructure the Mountain Operations group continued, in order to better support projects (including the Arizona Robotic Telescope Network, ARTN) while maintaining the current high level of commitment to operations.

VATT Upgrades

Taras Golota

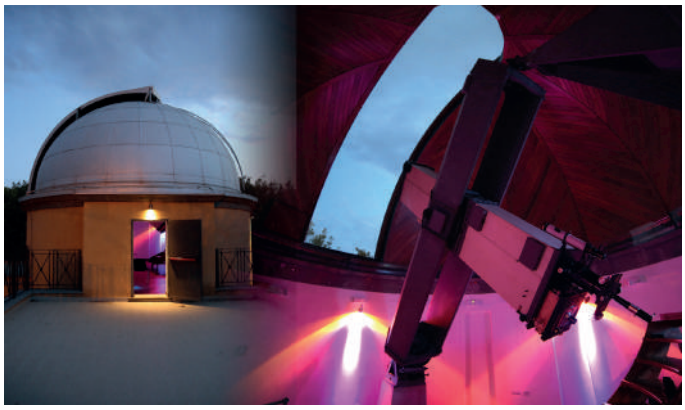
Several projects in the context of VATT's robotization were completed. GOLOTA worked with Sabino Electric on an upgrade of the electrical installation. A new power distribution panel was installed, and several aspects of the electrical system were modified to make them compliant with the safety code. GOLOTA designed, fabricated and commissioned a smart power supply unit for the telescope mount control system. In the context of safety system upgrades, new surveillance cameras were purchased and installed.

In order to automate VATT's collimation, GABOR enlisted the help of Dae Wook Kim and members of his team at UA's College of Optical Sciences. FRANZ installed six sensors (three linear encoders and three Linear Variable Differential Transformers or LVDTs, all by Solartron Metrology, UK) monitoring the position of the primary mirror in its cell. The performance of the new collimation system and procedure will be evaluated and completed in 2019.

Repairs at the Specola

This year has seen a number of repairs which needed to be made to the Roman Specola's Zeiss16-inch Visuale refracting telescope. Repairs to the wiring of the telescope are needed in order to ensure a proper functioning of its clock drive. In addition, repairs to the doors of the telescope dome will need to be conducted. As for the Zeiss 24-inch reflecting Double Astrograph telescope, also at the Roman branch of the Specola at Castel Gandolfo, the newly re-aluminized secondary mirror was re-installed in January 2018. A more fine-tuned collimation of the telescope is still needed.

With regard to the telescopes in the Papal Gardens in Castel Gandolfo, the Carte du Ciel refracting telescope continues to be upgraded after its restoration. A new mounted eyepiece/focuser was machine-made by Luciano Dal Sasso especially for the telescope. Preparations are well underway to host groups at the Carte du Ciel dome intermittently under the auspices of the Vatican Museums. To this end, a new small 8-inch Celestron Schmidt-Cassegrain reflecting telescope, with a computerized altitude-azimuth mounting, was acquired in order better to handle the flow of people during such group visits.



The Carte du Ciel Telescope in Castel Gandolfo

Likewise, one small addition has been made to the 11-inch Celestron Schmidt-Cassegrain reflecting telescope, which was acquired in 2017 for use at the Roman Specola headquarters in order to accommodate groups at night when the telescopes at the Papal Palace are not available. A new Geoptik rolling tripod was obtained and attached to the telescope in order to ease with the movement of the portable telescope, given that it takes much time to assemble. Finally, a small but optically superb Swarovski reflector, with a portable clock drive, was added to the collection of usable portable telescopes by Br. Guy Consolmagno. The telescope was the gift of Baxter Rice, and the Sky Adventurer drive was donated to the Specola by Kevin Legore of Sky-Watcher Inc.

Reorganization of the Meteorite Display

The meteorite display cabinet in the main entrance of the Specola Vaticana got a long-awaited makeover this year. Two things prompted this update. First, four meteorites from the display were moved into the new visitor center at the observatory domes in the Pontifical villas, creating a gap that needed filling. Second, the workshop on the curation of meteorites and extraterrestrial materials, held at the site of the Vatican Observatory in September, provided motivation to update the exhibit.

The new display at the Specola's Headquarter

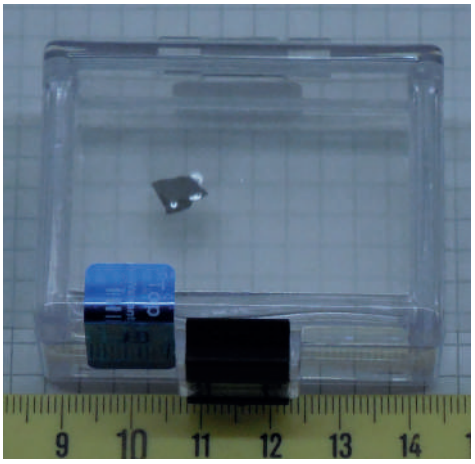
While much of the new exhibit traces its roots back to the previous display, the emphasis has certainly shifted, as have all of the labels. Labels now sport easily-readable white text on a blue background, and on the back wall of the cabinet are cards with more information about each portion of the exhibit.

Close-up of one section of the meteorite display. (Top) Some historically significant meteorites, including Ensisheim (fell 1492), L'Aigle (fell 1803), and Weston (fell 1807). (Bottom) Recent donations to the Vatican meteorite collection

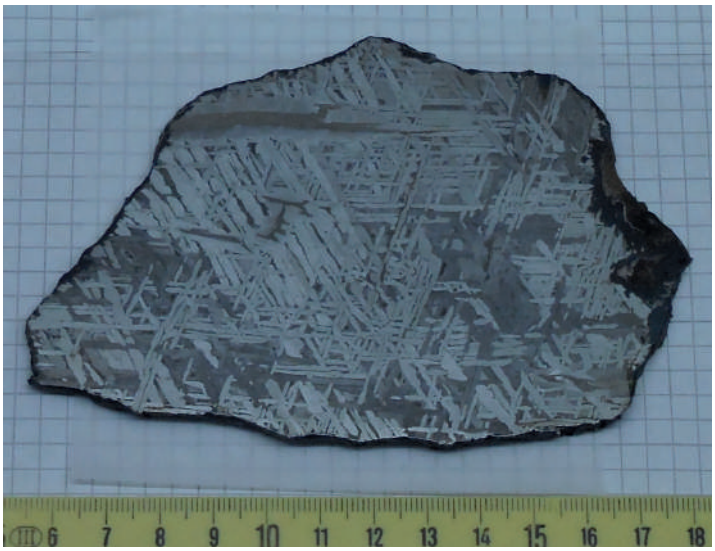
Lunar, martin, and HED meteorites are now located on the right side of the cabinet, alongside new metal models of the spacecraft that have visited those locations and allowed us to identify the sources of the meteorites. At the upper-left are historically significant or notable meteorite falls, including Ensisheim (1492), L'Aigle (1803), Weston (1807), Torino (1988), Peekskill (1992) and Chelyabinsk (2013). The lower portion of the cabinet has been slightly restructured to emphasize meteorite classification, with examples from all the major meteorite classes.

The display contains two new features. One is a small collection of artifacts from space missions, including a used shuttle tile and parachute cord, and a cutting from the "moon tree" outside the Lunar and Planetary Lab outside the University of Arizona. This tree grew from a seed that flew on the Apollo 14 mission to the moon. The other feature is a section highlighting recent meteorite donations.

Additions to Meteorite Collection



The Martian augite basalt NWA 8159. Donated by Dustin Dickens (Top Meteorite)



The iron meteorite Aletai, donated by Mendy Ouzillou (Skyfall Meteorites)

This year the Vatican meteorite collection received donations of two meteorites and a meteorite-related terrestrial rock. One of the meteorites we received was a beautifully etched 245-gram slice of Aletai, a type-IIIE iron meteorite from China. This specimen was donated by Mendy Ouzillou of Skyfall Meteorites. The second was a 0.17 gram piece of the Martian augite basalt NWA 8159. This type of meteorite is extremely rare and is an important addition to our collection. This specimen was donated by Dustin Dickens of Top Meteorite / Earth Space LLC.

Dustin also donated the meteorite-related terrestrial rock: a 2-kg piece of shatter cone from the Agoudal impact crater, a 70-million-year-old structure in Morocco. When there is a large impact, it deforms the rock underneath the impact site, creating branching striations that are known as a shatter cone.

The growth of the Vatican meteorite collection is dependent on the generosity of donors who either donate specimens from their own collections or wish to help us in acquiring new specimens. We are very grateful for their generosity, which is necessary for the continued usefulness of the collection as a valuable scientific resource of materials for study.

Shatter cone from the Agoudal impact crater, Morocco. Donated by Dustin Dickens (Top Meteorite)

PPC Restoration and Maintenance 2018

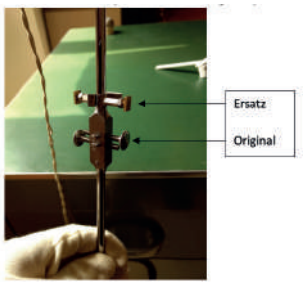
Thomas Rebeny

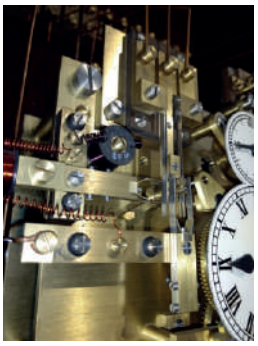
In July once again Thomas Rebenyi, a master technician of historical clocks and timepieces at the Deutsches Museum in Munich, contributed a week of his precious time and work to the Vatican Observatory. In addition to doing needed maintenance and repair on the Observatory's historic Precision Pendulum Clocks (PPC), Thomas also moved the PPC Dent N. 1346 from the Observatory headquarters to the dome of the restored Carte du Ciel telescope in the papal gardens at Castel Gandolfo.

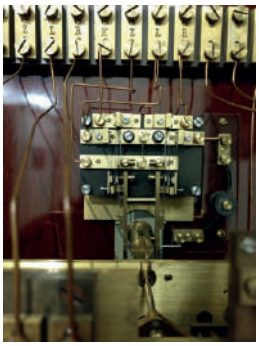
The photo below shows the Dent N. 1346 hanging on the wall in the dome of the Carte du Ciel telescope on the Vatican Walls early in the 20th century. Now the clock has been restored to its rightful place, next to the 1891 Carte du Ciel telescope.

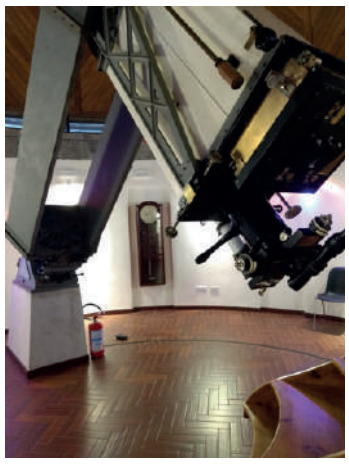
Hearing the gentle ticking of the clock, visitors to the Carte du Ciel telescope can feel themselves even more deeply immersed in the atmosphere of historic astronomy.

In the course of moving the Dent PPC, Thomas also restored the proper pendulum to it. While doing so he found a gear transition adjusting mechanism which had been built for that clock by the staff of the Observatory. The mechanism is not in use now, but Thomas left it on display in the clock cabinet, as a visible testimony to the technical ingenuity of the Observatory's staff.
Special problems were involved in maintenance of the Riefler N. 539 and the two Wagner "slave" clocks next to it. At the time when these clocks were constructed, their electrical lift mechanism was state of the art. But in the high-humidity environment of Rome the electrical contacts tend to corrode quickly, to the point that current does not flow reliably.









The Dent N. 1346 clock can be seen in the left photo on the wall next to technician Carlo Diadori, with Fr. Giuseppe Lais at the Carte du Ciel telescope. The clock now resides next to the restored telescope in the Castel Gandolfo visitor center

Chapter SIX

Education and Outreach

Sharing the Vatican Observatory's scientific endeavor through the universal language of astronomy with future academics and ordinary star gazers is the bedrock of our mission. The following pages trace the outreach of staff and scholars in matters of science and faith over the past twelve months.

Education and Public Outreach

BROWN continued his interaction with high school and university students in 2018. Through digital technology and personal visits he gave talks on 'Faith and Science' and was invited to give key note speeches at a range of institutions including: Rockhurst University; Dallas Jesuit College Prep; St. Louis University; the Newman Institute Catholic Chaplaincy of the University of Nebraska, Lincoln, New England; St. Gregory the Great Seminary, Lincoln, New England; Ville de Marie High School in Phoenix, Arizona; Rockhurst High School, Kansas City; Strake Jesuit College Prep, Houston, Texas; the University of Arizona, Steward Observatory and Tampa Jesuit High School, Tampa, Florida.

In April, CONSOLMAGNO spoke at Fordham and Cardinal Spellman High in New York; and at Georgia Tech, Emory University, Ignatius House Retreat Center, and St. Thomas More parish in Atlanta, Georgia. From mid-April until early May he was in Australia giving talks in the dioceses of Broken Bay and Melbourne. Later in May, he spoke in Malta. In July, he gave the British Province annual retreat at St. Bueno's, Wales, and the Barringer Public Lecturer for the annual Meteoritical Society meeting in Moscow.

August saw him travel to Saskatoon, Saskatchewan, Canada, as a keynoter of the Second Annual Conference on Science and Religion; and to serve on several panels of the World Science Fiction Convention in San José, California. In September, he spoke to the Great Lakes Star Party in Michigan; at Cal Tech and Holy Family Parish in Pasadena, California; and St. Meinrad Seminary in Indiana. October saw trips for talks at the Catholic education center Sodalitàs in Austria; and at the University of Central Lancashire, Rugby College, and Imperial College in the UK.

CONSOLMAGNO continued his monthly science column for the British Catholic magazine, *The Tablet*, and his weekly postings on "The Catholic Astronomer" blog based on these columns. He also continued to teach an on-line class in high school astronomy for the Jesuit Virtual Learning Academy.

In March, CORBALLY and MACKE spoke about the Vatican Observatory on related topics and their research, with senior students from Loyola High School of Los Angeles, who were visiting the VORG Offices at the University of Arizona with their honors astronomy teacher, Andrey Aristov. Also that month, together with Margaret Boone Rappaport, CORBALLY gave an Indie Author Tent Talk on "Space Science and Astronomy Theatre" at the 2018 Tucson Festival of Books. Other outreach included a public talk on "Angelo Secchi S.J., A Father of Astrophysics" both for a Third Thursday public talk sponsored by the Prescott Astronomy Club, Prescott AZ, on October 18, and for a meeting of the Padre Kino Vocations Ministry in Tucson, AZ, on November 9.

GABOR's educational outreach spanned Europe and the US in 2018. In February, he gave a series of talks on his research at INAF-Napoli, INAF-Bologna, INAF-Padua, the Scuola Normale Superiore Pisa and at the University di Roma, Tor Vergata. He was invited for the Astronomy colloquium talk at Michigan State University in April and taught a tier II general education course on the history and philosophy astronomy, ASTR 320, in the Spring 2018 semester at UA.

In public outreach, he gave a number of talks in Tucson: eight at the Redemptorist Renewal Center to the participants of the sabbatical program on April 2 and 4, as well as on November 19 and 21, one at the Newman Center on April 17, and one at the Academic Session of

the Raytheon Symposium on September 25. GABOR also gave several talks in the Czech Republic: in Dvakačovice on January 4, Pardubice on July 28, Litomyšl on July 31, Jihlava and Jindřichův Hradec on August 3, České Budějovice on August 4.

GIONTI delivered a seminar at the Observatory "Giandomenico Cassini" of Perinaldo (Imperia), Cassini's hometown. In June, he delivered a seminar on the studies of St. Aloysius Gonzaga, S.J. and the scientific tradition of the Society of Jesus at the Roman College in the fitting surroundings of Rome's St. Ignatius Church.

In Autumn GIONTI took part in the conference "Le Due Culture" held at Biogem, in Avellino, where he was involved in a panel discussion with Prof. Antonio Ereditato of Bern University, Switzerland. He also gave a seminar on "Jesuits and Science: the Scientific tradition of the Society of Jesus", at Georgetown University, Washington D.C., on occasion of the Jesuit Heritage Month.

KIKWAYA's educational outreach took him home to the Congo in August where he chaired discussions on "Science and faith exists only as conversation" and gave a talk to aspiring scientists and students of the Universite Loyola du Congo (ULC).

KIKWAYA with ULC students

Despite being the chief organizer of the first ever Workshop on Meteorite Curation, MACKE also found time to continue valuable public outreach through the Vatican Observatory Foundation blog, "The Catholic Astronomer", posting on subjects ranging from "Asteroids Named for Jesuits", to "Lemaître's Name to Hubble Law". He also continued production – under the aptly-named "Brother Bob Productions" – of popular and user-friendly YouTube videos for public consumption that are also valuable additions to any school science class. They can be found on the Vatican Observatory Foundation YouTube channel.

In September KOCH led a meeting on "Science and Faith" at the Specola with young people from Pordenone accompanied by their priests and catechists.

Science-faith issues were also the basis for a mini-workshop led by MUELLER with the contribution of CONSOLMAGNO for students from a high school located near the Vatican Observatory headquarters in Albano. The session was but one of a series of similar sessions that are being conducted by Observatory staff members with local high school students over the course of the current year, in response to a request from the Diocese of Albano.

MUELLER taught a masters-level course at the Pontifical Gregorian University during the spring semester, "Philosophical Questions in Biology". In addition, he delivered the annual Clavius Distinguished Lecture at Fordham University, "Comets, Craters and Calendars"; this title was stamped on glow-in-the-dark Frisbees distributed to all lecture attendees!

Back in Italy, MUELLER gave a lecture at the Church of San Biagio in Montepulciano, concerning the Vatican Observatory's historical work on the Foucault pendulum and other physical proofs of the Earth's motion; this was on the installation at San Biagio of a beautiful Foucault pendulum, in late March.

MUELLER also gave workshops concerning faith-science issues to two groups of employees of Loyola University Chicago. He gave workshops on faith-science and on history and philosophy of science to Jesuit novices studying at St. Paul, Minnesota, and at Culver City, California. Over the course of the year, MUELLER has also given spiritual retreats incorporating faith-science themes to seminarians in Rome and to large groups of lay people in Chicago and Omaha.

OMIZZOLO gave about ten public lectures on observational cosmology and on the relationships science-faith-theology throughout the year. In particular, in the framework of the Festival Biblico, he gave lectures at the Osservatorio Astrofisico of Padova and in the auditorium of Vicenza.

CHINNICI's outreach this year saw an emphasis on boosting public awareness, particularly in Italy, of the figure of Fr. Antonio Secchi. In Spring she was in Sicily, where she gave a public lecture on Secchi's years spent in Palermo for National Astronomy Week as well as a talk on "Journeying through the Cosmos" to high school students in Messina. In May she gave an invited talk at CNR Messina on "Disciples of Uranus: A brief history of female Astronomy," while Autumn saw her return to public lectures on Secchi's legacy in Reggio Emilia and Rome, including as part of the Masters in Science and Faith offered by the Pontifical Athenaeum Regina Apostolorum.

FRANCL-DONNAY's educational initiatives took place in high school, college and university locales on the East Coast of the US, with invited lectures on "Designing Twisted Cages: molecular hosts with Möbius topology" at Boston College; "Practically Impractical: What Contemplatives Might Teach Scientists" and "Impractically Practical: What Scientists Might Teach Contemplatives", the topics of her two invited lectures at the Cosmos and Creation Conference, Loyola University, Baltimore; and "Are Scientists Mystics?" at St. Bede's Circle, University of Pennsylvania. Public lectures included "The Good, The Bad, The Chemistry" at the Wagner Science Museum, Philadelphia and "Practical Notes: On developing a writing practice for working chemists" at the American Chemical Society National Meeting.

This year FUNES taught a class on philosophy of nature to graduate students and a seminar on science and religion for engineering students. Following FUNES' proposal, the Rector of the Universidad Católica de Córdoba has created a Chair on Science, Religion, and Education. Late August, FUNES organized the first workshop on science, religion and education for high school teachers about life in the universe. As a sign of the interest of the public on this topic, the national newspaper *La Nación*, the national Catholic magazine *Criterio*, and the local newspapers *La Voz Del Interior* published articles authored by FUNES. He also started a blog on science, religion, and education: *https://blog.ucc.edu.ar/cienciareligionyeducacion/*.

Participants of the First Workshop on Science, Religion and Education for high-school teachers in Argentina

FUNES also continued to collaborate with teachers of the Jesuit High School, Sagrada Familia, in Cordoba, Argentina. In 2017, he started a monthly seminar to prepare for a Science Club on the search of extraterrestrial life. The initiative is called *Educational OTHER*. For more information, you can visit the website in Spanish and English at *https://blog.ucc.edu.ar/other/*.

GALAVERNI together with CORBALLY marked the bicentenary of the the birth of Fr. Angelo Secchi S.J. with a public lecture on "Exploring the Universe: from Spectroscopy to Cosmic Microwave Background" in Reggio Emilia in May.

Over the course of the year, HELLER gave a number of public lectures as part of the Fourth Cosmological School public lecture series. These included talks on "Hawking's Physics and Philosophy", "Initial Conditions of the Universe", "Hyperfine Structure of the Initial Singularity", "Humans in the Universe", and "More Important than the Universe".

In 2018, HINCKS gave a public talk on "Jesuits & Astronomy" to Jesuit donors at Regis College; on "Why Does the Vatican Have an Astronomical Observatory?" at St. Peter's Parish, Toronto; on the "Big Bang ex Nihilo?" to participants of the "Gilson Seminar in Faith and Ideas" from St. Michael's College, University of Toronto visiting the Specola in Castel Gandolfo.

Presentations, Academic Activities and Conference Participation

BOYLE was first author on a poster paper at the 231st Meeting of the American Astronomical Society, Washington, DC, January 8-12 * participated in the 30th General Assembly of the International Astronomical Union, Vienna, Austria, August 20-31 * participated in "The Wonders of Star Formation" conference, Edinburgh, Scotland, September 3-7.

BROWN attended the General Assembly of the International Astronomical Union (IAU) in Vienna, Austria during August 20-31 * assisted with the 2018 Vatican Observatory Summer School in Astronomy.

CORBALLY with Margaret Boone Rappaport gave a paper on "Importance of the Activation and Deactivation of the Precuneus in Human Theological Thinking and Experience of Immanence and Transcendence", at the 17th conference of the European Society for the Study of Science and Theology, April 17-22, Lyon, France * GALAVERNI and CORBALLY gave an invited paper on "Exploration of the Universe: from Spectroscopy to Background Radiation", at the national conference on "Father Angelo Secchi: His person, works, and astrophysics", May 11-12, Reggio Emilia, Italy * CORBALLY presented a paper co-authored by Rappaport on "Ethical Systems Evolve Bio-culturally from Theological Thinking in the Genus Homo", at the conference on "Evolutionary Ethics: The Nuts and Bolts Approach", July 20-21, Oxford Brookes University, Oxford, UK * gave a poster presentation co-authored by Rappaport on "Quantitative and Qualitative Evaluation Methods to Assess New Experiential Teaching Techniques in Astronomy Theatre", at the Focus Meeting 15 on "Astronomy for Development" during the 30th General Assembly of the International Astronomical Union, August 20-31, Vienna, Austria * during the same IAU General Assembly, presented a paper on "The Spectral Classification of Stars over the last 200, 100, 75 years, and in the Future", for the symposium "Under One Sky – the IAU Centenary Symposium S349" * took part in the Welcome Address for the International Conference on "The Legacy of Angelo Secchi SJ 200 Years after his Birth", September 3-5, Rome, Italy * chaired a session of the Interdisciplinary Workshop in History of Science on "Angelo Secchi (1818-1878) SJ: The Scientist and His Time", September 6, Rome, Italy.

D'SOUZA presented a talk on "Stellar Halos across the cosmos" at the Max Planck Institute for Astronomy, Heidelberg, Germany, July 2-6 * attended the 30th General Assembly of the International Astronomical Union in Vienna from August 20-31.

GABOR gave invited talks at the 11th Epiphany Conference for Young Czech and Slovak Mathematicians and Physicists in Košice on January 5 and at the 23rd Conference of Slovak Physicists in Smolenice on September 5 * participated in the SPIE Astronomical Instrumentation and Telescopes in Austin, June 10-15, presenting a poster paper on the "Development of the Arizona Robotic Telescope Network" * participated in the 30th General Assembly of the International Astronomical Union, Vienna, Austria, August 20-31.

GIONTI gave the talk "Hamiltonian Analysis of Asymptotically Safe Quantum Gravity" at the meeting "Self-completion of cosmological and quantum field theories" at LMU University in Munich, Germany, February 12 -14 * gave a talk "La Natura Fisica della Luce" at the workshop "Dolce è la Luce", held at the Gregorian University, Rome, March 5-6 * participated and presented the poster "Hamiltonian Analysis of Asymptotic Safe Gravity" at 674 WE-Heraeus-Seminar on "Quantum space-time and the Renormalization Group", Bad-Honnef, Germany, June 12-18 * participated at the XV Marcel Grossman Conference in Rome, July 1-7 * gave a talk "Analysis of Lorentzian Sub-Planckian Cosmology via Asymptotic Safety" in the parallel session AT7 * organized with Dr. Costantino Sigismondi and Prof. Paolo De Bernardis the parallel session HR2 "Secchi and Astrophysics" and gave a presentation on "the Scientific Tradition of the Society of Jesus" * took part in the Conference "Exact Renormalization Group 2018" in Paris, July 9-13 and gave a talk on the "Hamiltonian Analysis of Asymptotically Safe Quantum Gravity" * gave a talk at the Asymptotic Safety online seminar (via Skype) * participated in the workshop "On the Safe Roads to Quantum Gravity and Matter", September 11-14 and gave a talk on "Wilson-like lattice gravity in the Palatini Formalism" * took part in DICE2018, September 17-2, Castiglioncello, Italy and gave a talk on "Bouncing and Emergent Universes from Hamiltonian Analysis of Asymptotically Safe Quantum Gravity" * gave a talk "Bouncing and Emergent Universes from Hamiltonian Analysis of Asymptotically Safe Quantum Gravity" at the Physics Department of Georgetown University on November 13.

KIKWAYA attended the 30th General Assembly of the International Astronomical Union, Vienna, Austria, August 20-31

KOCH participated in a Convention on Angelo Secchi in Reggio Emilia, Italy, May 11-12.

MACKE attended the 49th Lunar and Planetary Science Conference, Houston, TX, March 19-23 * the 30th General Assembly of the International Astronomical Union, Vienna, Austria, August 20-31* Workshop on the Curation of Meteorites and Extraterrestrial Samples, September 10-13, Castel Gandolfo, Italy (Organizer).

MUELLER represented the Vatican at the UNESCO International Expert Meeting on Astronomical Heritage and Sacred Places, held at Gran Canaria, Spain, May 23-24 * gave a presentation to the young scientists participating in the Vatican Observatory Summer School entitled "How to Annoy Philosophers and Historians" * lectured at the "International Conference on The Legacy of Angelo Secchi 200 Years after his Birth", held in Rome, September 3-5.

CHINNICI gave an invited talk titled "Padre Angelo Secchi: la figura e gli ambiti di ricerca. Una recente biografia", at the convention "Padre Angelo Secchi: la figura, le opere, l'astrofisica", Reggio Emilia, May 11-12 * "In memory of Angelo Secchi (1818-1878), Jesuit and scientist", Vatican Observatory Summer School 2018, June 26 * "Angelo Secchi: An Overview", 15th Marcel Grossmann International Meeting, La Sapienza University, Rome, July 1-7 * "Angelo Secchi: some recent biographic studies", International Workshop "Angelo Secchi (1818-1878): The Scientist and His Time", Rome, Biblioteca Casanatense, September 6 * "Angelo Secchi: A Multi-Disciplinary Scientist", International Meeting "The Legacy of Angelo Secchi S.J., 200 Years after His Birth", Rome, Biblioteca Casanatense, September 3-5 * "Angelo Secchi: recenti studi biografici, sui passi del gesuita scienziato", XXXVIII Convegno Nazionale della Società Italiana di Storici della Fisica e dell'Astronomia, Messina, Accademia dei Pericolanti-Reggio Calabria, Planetario Pitagora, October 3-6 * served on the National Committee for the Bicentenary of the Birth of Angelo Secchi * served on the Organizing Committee IAU Commission 3 (History of Astronomy) * SOC International meeting "The legacy of Angelo Secchi SJ 200 years after his birth" * SOC International workshop "Angelo Secchi (1818-1878): The Scientist and His Time" (chair).

FRANCL-DONNAY attended the American Chemical Society National Meeting in April * served on the Open Chemistry Collaborative in Diversity Equity (OXIDE), advisory board as well as the Institute for Religion and Science, advisory board.

GALAVERNI attended a cosmology meeting "UniVersum 2018", Bologna, April 11-13 * a meeting on "Padre Angelo Secchi. La figura, le opere, l'astrofisica", Reggio Emilia, May 11-12 * Vatican Observatory Summer School, "Stellar Variability in the Era of Large Surveys" June 4 - 29 * attended the XVth Marcel Grossmann Meeting, Rome, July 1-7 * 30th General Assemby of the International Astronomical Union, Vienna, August 20 – 31.

Vatican Observatory Group at IAU, Vienna

News and Media Coverage

BROWN was interviewed by Spanish newspaper *Alfa y Omega*: "Entre el cielo y el suelo" by María Martínez López in September, the article can be consulted at the following link: *http://www.alfayomega.es/163241/la-ciencia-te-lleva-a-un-punto-pero-las-preguntas-continuan*. *America Magazine*'s Fr. Sean Salai, also interviewed him for the December 2018 edition of the Jesuit magazine.

Among the many interviews given by CONSOLMAGNO over the year, perhaps the most notable was that published in the December 22, 2017, issue of the *New York Times*. The profile included a photograph at the Carte du Ciel telescope which ran on the front page of the *Times* that day.

D'SOUZA's research work on the Andromeda Galaxy was featured in a number of international press including CNN, The Guardian, the BBC, CNBC, Michigan Radio NPR, USA today, *The Times of India*, etc., as well as popular scientific press including Mashable, *The Smithsonian Magazine*, *Sky and Telescope*, *UniverseToday, Scify*, etc. He also

gave a number of interviews about how faith and science go together. These were published by *The Week, Scroll.in, FirstPost*, to mention but a few.

GABOR gave an interview to the Hungarian weekly *Heti Válasz* and he continued his weekly radio blog on Radio Lumen, Slovakia.

GIONTI was interviewed by the Italian TV program "Il Diario di Papa Francesco" in which he spoke about the Bethlehem Star and the Magi; by Vatican News on the total lunar eclipse in July; together with KOCH he was interviewed by Italy's RAI 2 TV channel and Spanish and Mexican televisions during a visit by journalists accredited to the the Holy See press office.

CARUANA was interviewed on the radio station of the University of Malta, "Campus FM", on the work of Pierre Teilhard de Chardin, S.J., the influential twentieth century Jesuit paleontologist and writer on science, evolution, religion, theology and spirituality. The interview was transcribed and published in Maltese as a chapter in a volume entitled *The voice in front of the mystery – profiles of twentieth century theologians*. The editor of the Belgian Christian weekly *Tertio* also interviewed him on March 1. He was interviewed on the notion of nature especially in relation to the Papal Encyclical *Laudato Si'*, and the article, in Flemish, appeared in the issue of April 18.

FRANCL-DONNAY gave an interview to *Five Books* on "The Best Chemistry Books".

HELLER was interviewed by l'*Eco di Bergamo*, and the Polish journal *Znak*.

HINCKS was one of four advance readers present who was available to speak with journalists at the press conference at the Holy See Press Office releasing the Apostolic Exhortation *Gaudate et Exsultate*, including an interview with Michael Swann, "Canadian Jesuit plays role in launch of Pope's exhortation" for *The Catholic Register*. He also gave an interview with *The Catholic Register* titled "Jesuit's passion is written in the stars" published in October 2018.

Personnel

At the end of 2017, having reached the grand age of 95 years old, Fr. Sabino MAFFEO announced that he would officially retire from the Specola. On April 3, 2018, he officially took up residence in the Italian province retirement community in Rome, located in the Infirmary of St. Peter Canisius.

For more than thirty-two years, Sabino was an institution at the Specola. He entered the Jesuits in 1937, at the age of 15, and he recalls once seeing Pope Pius XI with his novitiate class. After ordination in 1953 and earning a degree in physics (his thesis studied the propagation of neutrons in graphite), he taught physics at the Jesuit high school in Rome, the Istituto Massimiliano Massimo, from 1957 until 1968. He served as rector of the community there from 1962.

Father Sabino Maffeo

In 1968, he became Provincial of the Roman Province of the Jesuits, the last provincial of the province before it merged with the other Italian provinces in 1973. From 1973 until 1985, he served as Technical Director of Vatican Radio. After that, he was appointed to the Vatican Observatory, serving as rector of the community for twelve years and administrative assistant until 2003. After 2003, Sabino dedicated his efforts to serve as the historian and archivist of the Specola. He wrote our definitive history, *Specola Vaticana, Nove Papi Una Missione,* which first was published in 1991 and then greatly expanded in a second edition in 2001. Looking into the history of the first Jesuit director of the Specola, Father Johan Hagen, he wrote a book about Fr. Hagen and his spiritual direction of Saint Elizabeth Hesselblad, founder of the Bridgettine Sisters of Sweden and honored for her

work protecting Jews during the Second World War. He also edited a book of the letters of Fr. Angelo Secchi. Most recently, his searching of the Specola archives uncovered the names and stories of the four Sisters of the Child Mary who created the atlas of stars from the Vatican's Carte du Ciel plates (see the Annual Report for 2016).

In a culture where personal connections are everything, Sabino's presence at the Specola was a special gift. At the Jesuit high school, he wound up teaching many of the most outstanding scientists of that generation (and those he didn't teach were friends of those he did teach). His role as Roman provincial insured that he knew personally almost all of the Jesuits in Italy. And his time at the Vatican Radio meant that he knew the Vatican well, and was personally well known to nearly everyone else there.

These personal connections helped to integrate the Specola and its work with the larger world of physics and astronomy in Rome and the Vatican. To give but one example, at the Massimo he taught physics to Gabrielle Buffetti, the son of Ricardo and Maria Buffetti (founders of the Buffetti chain of stationery stores). After that young man's tragic death he stayed close to the Buffetti family; their support allowed us to restore the historic telescopes in Castel Gandolfo and the Jesuit quarters in our new headquarters. In memory of their gracious contribution, the classroom where our biennial summer schools are held is named the Aula Gabriele Buffetti.

This pastoral side was what has made Sabino truly special to all of us. Whether it was dealing with the needs of a dozen Jesuit scientists or speaking with the thousands of students and other visitors whom he showed around the Specola for many years, his gentle good humor and generous heart brought light and joy to everyone around him. We have been honored to have him live among us, and are delighted that he is now comfortably living in Rome — where he is still working and writing!

In memoriam

Two deceased members of the Specola staff were honored with memorial plaques this year. A citation and photograph of the late Mr. Luigi Lori, our beloved carpenter (see the Annual Report for 2017), now hangs in the Jesuit Community chapel next to the cabinets that he made for us. And the late Maria Piazza Scordo (see the Annual Report for 2010), known to all as Lilla, was for 32 years the community cook and so much more to us; her photo and plaque now graces the kitchen of the Sala Clavius dining area.

Over the past year, four members of the Specola staff have lost parents. The mother of Alessandro Omizzolo died on October 30, 2017. The mother of Paul Mueller died on January 8. The mother of Guy Consolmagno died on December 27, 2017, and his father passed on June 11. And the father of Paul Gabor died on November 2. *Eternal rest grant unto them, O Lord, and let perpetual light shine upon them. May they rest in peace.*

Awards and distinctions received in 2018

In May, CONSOLMAGNO was granted an honorary doctorate from Fairfield University, and in September he received the Gaudium Award from the Breukelein Institute of the Pontifical Congregation of the Oratory of St. Philip Neri in Brooklyn, New York.

FRANCL-DONNAY received the Frank B. Mallory Professorship in Chemistry. GIONTI was made associate fellow of the National Laboratories in Frascati of INFN (Italian National Institute for Nuclear Physics) for 2018.

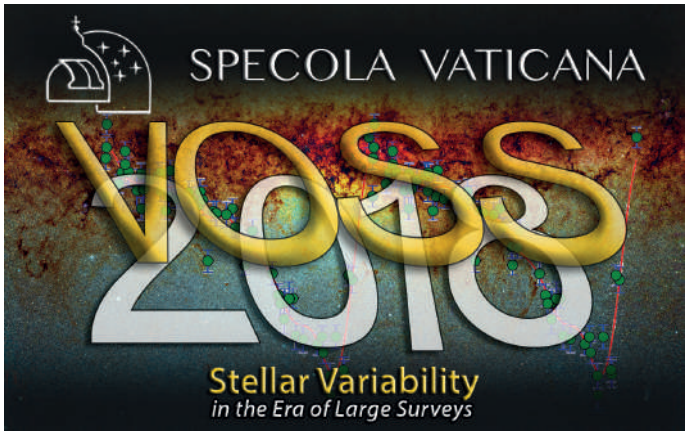
HELLER was the recipient of the Stefania Świątłowska Prize and the Tarnina Prize.

Chapter SEVEN

VOSS 2018

In 2018, the XVI[th] edition of the biennial Vatican Observatory Summer School (VOSS) was held at Castel Gandolfo, the highlight of a busy year for staff and scholars.

The XVI Vatican Observatory Summer School 2018 on "Stellar variability in the Era of Large Surveys"



The XVI biennial Vatican Observatory Summer School (VOSS) was a great success with 24 students from 18 countries mostly from developing countries (see the figure below) spending four weeks in Castel Gandolfo in intense studies on how to study variable stars in the era of large surveys, how to process data from tens of thousands of stars, and make scientific sense of the results.

The students and their countries

Main Themes

The topic of the school was "Stellar Variability in the Age of Large Surveys" which combined a classic of fundamental astronomical research (the theory of stellar pulsation and evolution: pulsation and evolutionary properties of radial variables) with a modern approach to the same phenomena through variable star searches in large databases: current statistics, sample biases, variability detection, period search techniques, variable star classification. For example, the ESA satellite GAIA has mapped the position of millions of stars in the Milky Way. This type of data that is now available in hitherto unthinkable quantities requires expertise to be used and applied to the various fields of study of modern astrophysics.

Alongside the systematic lessons on variability and on the use and processing of data from the large surveys, a large number of international "guest speakers" made important and very specific contributions that greatly enriched the more focused program.

Students also got to learn a little about the history of astronomy, with visits to Galileo's home and the Galileo Museum in Florence, as well as the Vatican Observatory's historic Papal Summer Gardens of Castel Gandolfo… including three nights observing with the newly restored 1891 Carte du Ciel Telescope!

Faculty

The VOSS2018 Faculty was chaired by Dante MINNITI, with Don Alessandro OMIZZOLO serving as Dean and Guy CONSOLMAGNO as Director. The main lecturers were G. Bono (Universita di Roma Tor Vergata, Italy) D. Casetti (Yale University, USA) M. Rejkuba (ESO, Germany) D. MINNITI (UNAB, Chile).

As well as Vatican Observatory speakers, the VOSS was grateful for the participation of the following distinguished external speakers: F. Comeron (ESO, Germany), A. Sarajedini (University of Florida, USA), R. Capuzzo Dolcetta (Universita di Roma Tor Vergata, Italy), E. Solano (ESA Villafranca, Spain), G. Fiorentino (Universita di Bologna, Italy), and N. Matsunaga (University of Tokyo, Japan). In addition, George Coyne, the fomer director of the Vatican Observatory, also toop par in a teleconference from the US.

We were also honored with a visit from the astronaut Claude Nicollier, astronaut of the Swiss Space Center, who played a decisive role in the repair of the Hubble space telescope immediately after launch; and retired NASA astronaut Nicole Stott who with Jay Honeycutt, former director of the Kennedy Space Center, spoke informally with the students one evening.

The faculty. From left to right: Giuseppe Bono, Dante Minniti, Enrique Solano (invited speaker), Dana Casetti, Marina Rejkuba

Faculty and some invited speakers in the gardens of the Papal residence in Castel Gandolfo. From left to right: Claude Nicollier, Dana Casetti, Alessandro Omizzolo, Marina Rejkuba, Dante Minniti, Fernando Comeron, Matteo Galaverni

The first days of the school gave space to individual students to present themselves, their origins, their country and their academic path. Morning lessons were followed by smaller group work by students, each group tasked with solving specific problems and the preparation of reports about their work. The last days of the school were dedicated to these group projects, which were evaluated by faculty members.

Our guest speakers dealt with specific astrophysical topics as well as issues related to the mission of the Vatican Observatory: we heard about the relationship between science, philosophy and theology and we discussed the history of science this year with a particular reference to the bicentenary of Fr. Angelo Secchi.

Faculty and students also enjoyed a day at the archaeological site of Pompei; a weekend in Florence with visits to Galilean sites of interest; and a trip to ancient Ostia — and the nearby beach!

The visit to Pompei

During the weekend in Florence. Here the visit to the Astronomical Observatory of Arcetri near Florence and where Galileo lived

Besides demonstrating their expertise in the astrophysical field, the students also showed off their talents in the kitchen: one evening they organized an ethnic dinner in which the students had prepared one or more typical dishes of his or her country of origin.

During the School an ethnic dinner was organised: every student prepared typical food from his country

One of the most striking features of the Vatican Observatory is to see how science can become a tool to promote respectful exchange between cultures. One can see students coming from countries in conflict who willingly work together, respecting and esteeming each other and cultivating sincere friendships. This once again underlines how the sincere desire for knowledge is one of the best ways to break down walls between different countries and cultures.

Twenty-four students from eighteen different countries means an extraordinary encounter of cultures and human experiences, of different attitudes and interests: between those who have climbed Everest, others who sing or play jazz music to those who act and dance. All of this contributed to making this summer school a special occasion, above all for the students who were the protagonists and who brought sincere friendships and the desire to live and work together with them. Also for the faculty and for all the staff of the Specola, the summer school experience remains one in which we willingly take part.

As always, a school works because so many people dedicate their time and energy and care. For this reason we cannot forget all those who with their daily commitment have made this wonderful adventure possible: not only the students, not only the faculty and the various speakers but also the technical and administrative staff of the Specola: Federico Balzoni, Antonio Coretti, Romano Reggio, Assunta Rodia and Gina Savinetti.

Faculty and students in the court of the Vatican Observatory

The final and crowning moment, however, was our private audience with the Holy Father, Pope Francis, during which he emphasized the potential of this teamwork and encouraged students to continue on this path of collaboration in diversity.

The Papal Audience in the Vatican during the School

The Holy Father's Address to VOSS2018

Dear Friends,
I offer a warm welcome to all of you, the professors and students of this summer course organized by the Vatican Observatory. Coming from many countries and cultures, you bring with you many different areas of expertise. You remind us that diversity can be united by a common goal of study, and that the success of that work depends on precisely this kind of diversity. By working together, from the variety of your backgrounds, you can help develop a common understanding of our universe.

Your topic this year concerns variable stars in the light of new, large astronomical surveys that are themselves the result of collaborative efforts by many nations and teams of scientists. As will become apparent in this course, only such teamwork can make sense of all these new data.

As our understanding of this vast universe gradually grows, so does our need to learn how to manage the flood of information we receive from so many different sources. Perhaps the way you yourselves manage such a torrent of data can offer hope to all those people in our world who feel overwhelmed by the information revolution of the internet and the social media!

Before all this information, and the vastness of our universe, we may be tempted to think of ourselves as small and insignificant. This fear is nothing new. More than two thousand years ago, the Psalmist could write: "When I see your heavens, the work of your hands, the moon and the stars which you arranged, what is man that you should keep him in mind, mortal man, that you care for him?" He then went on to say: "Yet you have made him little less than a god; with glory and honor you crowned him" (Ps 8:4-6). Both as scientists and as believers, it is always important to start by admitting there is much that we do not know. But it is equally important never to stop at a complacent agnosticism. Just as we should never think we know everything, we should never fear to try to learn more.

To know the universe, at least in part; to know what we know and what we don't know, and how we can go about learning more; this is the task of the scientist. There is another way of seeing things, that of metaphysics, which acknowledges the First Cause of everything, hidden from tools of measurement. Then there is still another way of seeing things, through the eyes of faith, which accepts God's self-disclosure. Harmonizing these different levels of knowledge leads us to understanding, and understanding — we hope — will make us open to wisdom.

The "glory and honour" of which the Psalmist speaks can also be understood in terms of the joy of intellectual work such as your own study of astronomy. It is through us, human beings, that this universe can become, so to speak, aware of itself and of its Maker. This is the gift, and the accompanying responsibility, given to us as thinking, rational creatures in this cosmos.

On the other hand, as human beings, we are more than thinking, rational beings. We are persons, with a sense of curiosity that drives us to know more; we are creatures, who work to learn and share what we have learned for the pure joy of doing so. And as people who love what we do, we can find in our love for this universe a foretaste of that divine Love which, in contemplating his creation, declared that it was good.

Dante famously wrote that it is love that moves the sun and the stars (cf. Paradiso, XXXIII, 145). May your work likewise be "moved" by love: love of truth; love of the universe itself; and love for one another as you work together amid your diversity.
With these prayerful sentiments, I cordially invoke the Lord's abundant blessings on you and upon your work.

Alumnae/Alumni of the Vatican Observatory Summer Schools: Save the Date!

The next "SuperVOSS" Reunion will occur

Tuesday 3 September - Saturday 7 September 2019 in Castel Gandolfo.

Stay tuned for more details, and spread the word!

Chapter EIGHT Publications

This chapter lists the work of Vatican Observatory staff and adjunct scholars accepted for publication in 2018

Books

CONSOLMAGNO, G. J. and Davis, D. M. (2018). *Turn Left at Orion: hundreds of night sky objects to see in a small telescope and how to find them*. Fifth edition. Cambridge: Cambridge University Press, 256 pp.

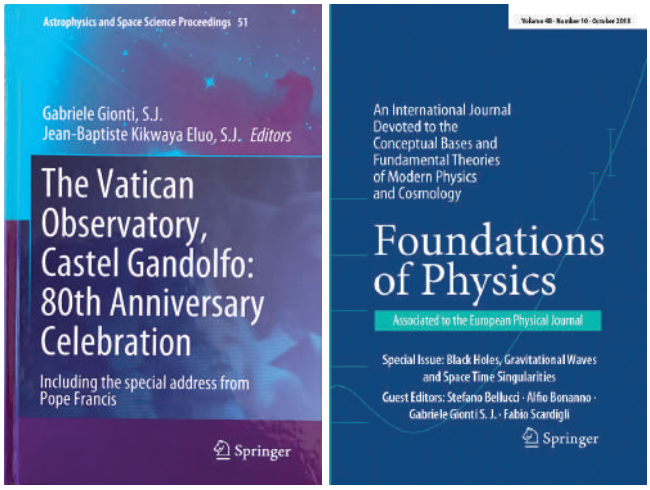
CONSOLMAGNO, G. J. and MUELLER, P. R. (2018). *Would You Baptize an Extraterrestrial? And other questions from the astronomer's in-box at the Vatican Observatory*. Revised paperback edition. New York: Image Books. 293 pp.

CONSOLMAGNO, G. J. and MUELLER, P. R. (2018). *Battezzeresti un extraterrestre?. . .e altre domande tra science e fede poste all'Osservatorio astronomico vaticano*. (Daniela Marina Ross, trans.) Milano: Rizzoli. 365 pp.

The book Would You Baptize an Extraterrestrial?, co-authored in 2014 by CONSOLMAGNO and MUELLER, came out this year in a new paperback edition in English, as well as in an Italian translation; the book has also been published in German

Bellucci, S., Bonanno, A., GIONTI, G., and Scardigli, F. (Guest Editors). (2018). *Black Holes, Gravitational Waves and Space-Time Singularities*. Special Issue of Foundation of Physics, 48:10, pp. 1131-1537

GIONTI, G. and KIKWAYA ELUO, J. B. (2018). *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration*. Astrophysics and Space Science Proceedings, Vol. 51. Cham, Switzerland: Springer. 265 pp.



Two volumes of proceedings papers for conferences held at the Vatican Observatory were published in 2018. GIONTI and KIKWAYA ELUO prepared and edited the proceedings of the 2015 celebration our move to Castel Gandolfo, The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Bellucci, Bonanno, GIONTI and Scardigli edited a volume titled Black Holes, Gravitational Waves and Space-Time Singularities which appeared as a special issue of the journal Foundation of Physics. This special issue collected the contributions of the participants to the Lemaitre Workshop held at the Specola, May 9-12, 2017. Both volumes were published by Springer

HELLER, (2018). Wszechświat jest tylko drogą. Kosmiczne rekolekcje [The Universe is only a Road], 2nd edition, CCPress, Kraków, [in Polish]

HELLER, (2018). Ważniejsze niż Wszechświat [More Important than the Universe], CCPress, Kraków, [in Polish]

Michael Heller had two books on the topic of the Universe published this year

TANZELLA-NITTI, G. (2018). *Teologia Fondamentale in contesto scientifico, vol. 3 Religione e Rivelazione*. Roma: Città Nuova. 735 pp.

Papers and Articles

Straižys, V., BOYLE, R. P., Zdanavičius, J., JANUSZ, R., CORBALLY, C. J., Munari, U., Andersson, B. -G., Zdanavičius, K., Kazlauskas, A., Maskoliūnas, M., Černis, K., Macijauskas, M. (2018). High-latitude dust clouds LDN 183 and LDN 169: distances and extinctions. *Astronomy & Astrophysics*, 611, A9

BOYLE, R. P., Straižys, V., Munari, U., Milasius, K., Černis, K., Zdanavičius, J., Kazlauskas, A., Maskoliūnas, M., JANUSZ, R., Zdanavičius, K. (2018). The open cluster IC 4996: new parameters. *American Astronomical Society Meeting Abstracts* 231, #344. 05. (Abstract)

BOYLE, R. P., JANUSZ, R. (2018). The Vilnius Photometric System - Studying Stars and Interstellar Matter at the Vatican Observatory. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit*. pp. 89-110

BROWN, D. (2018) EHB Stars and AGB Stars. IAU General Assembly, Meeting #29, id. 2255803 (Abstract) Montenegro, K., MINNITI, D., Alonso-Garcia, J., Hempel, M., Saito, R. K., Beers, T. C. and BROWN, D. (2018). VVV Survey of Blue Horizontal-Branch Stars in the Bulge-Halo Transition Region of the Milky Way. *Astrophysical Journal*, in press (arXiv:1810. 00316)

CONSOLMAGNO, G. J. (2017). How Do Faith and Reason Work Together? Pamphlet, Our Sunday Visitor Press

CONSOLMAGNO, G. J. (2017). First scout. *The Tablet*, 271, December 2, 32

CONSOLMAGNO, G. J. (2018). A conversation with the universe. *Human Development*, 38, 6-11

CONSOLMAGNO, G. J. (2018). Showing the world: how Vatican astronomers interact with the popular press. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration*. *Op. cit*., pp. 177-184

CONSOLMAGNO, G. J. (2018). Sognando i marziani. *L'Osservatore Romano* 158, 4 August, p. 4

CONSOLMAGNO, G. J. (2018). Heavens above. *The Tablet*, 272, January 4, 32

CONSOLMAGNO, G. J. (2018). Belts and braces. *The Tablet*, 272, February 3, 32

CONSOLMAGNO, G. J. (2018). Space oddity. *The Tablet*, 272, March 3, 32

CONSOLMAGNO, G. J. (2018). An extraordinary, ordinary man. *The Tablet*, 272, March 31, 38

CONSOLMAGNO, G. J. (2018). Patrolling the final frontier. *The Tablet*, 272, April 28, 28

CONSOLMAGNO, G. J. (2018). Father of the future. *The Tablet*, 272, May 26, 32

CONSOLMAGNO, G. J. (2018). Father's day. *The Tablet*, 272, June 23, 30

CONSOLMAGNO, G. J. (2018). Mars approaches. *The Tablet*, 272, July 28, 32

CONSOLMAGNO, G. J. (2018). Sun seeker. *The Tablet*, 272, August 25, 40

CONSOLMAGNO, G. J. (2018). Relics from space. *The Tablet*, 272, September 22, 32

CONSOLMAGNO, G. J. (2018). What's in a name? *The Tablet*, 272, October 27, 32

CONSOLMAGNO, G. J. (2018). Ancient geeks. *The Tablet*, 272, November 24, 30

CONSOLMAGNO, G., FRANCL-DONNAY, M. M. (2018). Seeking the Face of God, *NowYou Know Media* (audio presentation)

Turrini, D., Svetsov, V., CONSOLMAGNO, G. J., Sirono, S., Jutzi, M. (2018). The late accretion and erosion of Vesta's crust recorded by eucrites and diogenites as an astrochemical window into the formation of Jupiter and the early evolution of the Solar System. *Icarus* 311, 224-241

Allen, L. E., Walker, C. E., Hall, J. C., Larson, S., Williams, G., Falco, E., Hinz, J., Fortin, P., Brocious, D., CORBALLY, C., GABOR, P., Veillet, C., Shankland, P., Jannuzi, B., Cotera, A., and Luginbuhl, C. (2018). Protecting dark skies as a state-wide resource. *American Astronomical Society Meeting Abstracts* 231, 142. 08

CORBALLY, C. J. (2018). The enigmatic Lambda Boötis stars. *In The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit.*, pp. 43-61

CORBALLY, C. J. (2018). The bicentenary of the birth of Angelo Secchi, SJ. AAS, Historical Astronomy Division, June 2018. *https://aas.org/posts/news/2018/06/month-astronomical-history*

CORBALLY, C. J. (2018). Review of *Astrophysics and Creation: Perceiving the Universe through Science and Participation by Arnold Benz. ESSSAT News & Reviews* 28-2: 39-41

CORBALLY, C. J., Gray, R. O., Karmo, T. (2018). Spectroscopy of stars, *Observer's Handbook* 2019 (James S. Edgar, ed.) Toronto, Canada: Royal Astron. Soc. Canada. p. 284

CORBALLY, C. J. and Rappaport, M. S. B. (2018). Teaching science and religion in the 21st century: the many pedagogical roles of Christopher Southgate. Festschrift for Christopher Southgate, ed. Bethany Sollereder. *Zygon, Journal of Religion and Science* 53(3): 897-908

Karmo, T., CORBALLY, C. J., and Gray, R. O. (2018). The brightest stars, *Observer's Handbook* 2019, (James S. Edgar, ed.) Toronto, Canada: Royal Astron. Soc. Canada. pp. 275-283

Molenda-żakowicz, J., Gray, R. O., CORBALLY, C. J., Murphy, S. J., Chojnowski, D., Hasselquist, S., Niemczura, E., Paunzen, E., and Koen, C. (2018). Spectroscopic investigation of selected λ Boo - type stars. *PTA Proceedings* 7, 201-3

Rappaport, M. S. B. and CORBALLY, C. J. (2018). Update: our state of knowledge of the genomic basis for human specialness, with implications. *Studies in Science and Theology* 16: 37-56

Rappaport, M. S. B. and CORBALLY, C. J. (2018). Evolution of religious capacity in the genus homo: origins and building blocks. *Zygon; Journal of Religion and Science* 53(1): 123-158

Rappaport, M. S. B. and CORBALLY, C. J. (2018). Evolution of religious capacity in the genus homo: cognitive time sequence. *Zygon; Journal of Religion and Science* 53(1): 159-197

Rappaport, M. S. B. and CORBALLY, C. J. (2018). Evolution of religious capacity in the genus homo: trait complexity in action through compassion. *Zygon; Journal of Religion and Science* 53(1): 198-239

Rappaport, M. S. B. and CORBALLY, C. J. (2018). Tracing the origins of 21st century ecotheology: the poetry of Christopher Southgate. Festschrift for Christopher Southgate, ed. Bethany Sollereder. *Zygon; Journal of Religion and Science* 53(3): 866-875

Zong, W., Fu, J-N., De Cat, P., Shi, J., Luo, A., Zhang, H., Frasca, A., CORBALLY, C. J., Molenda- Żakowicz, J., Catanzaro, G., Gray, R. O., Wang, J., Pan, Y., Ren, A., Zhang, R., Jin, M., Wu, Y., Dong, S., Xie, J-W., Zhang, W., and Hou, Y. (2018). LAMOST observations in the Kepler Field. II.

Database of the low-resolution spectra from the five-year regular survey. *Astrophysical Journal Suppl.*, 238, 30-39

D'SOUZA, R. and Bell, E. F. (2018). The masses and metallicities of stellar haloes reflect galactic merger histories, *Monthly Notices of the Royal Astronomical Society*, 474, 5300

D'SOUZA, R. and Bell, E. F. (2018). The Andromeda galaxy's most important merger about 2 billion years ago as M32's likely progenitor, *Nature Astronomy*, 2, 737

Smercina, A. ; Bell, E. F., Price, P. A., D'SOUZA, R., Slater, C. T., Bailin, J., Monachesi, A., and Nidever, D. (2018). *A Lonely Giant: The Sparse Satellite Population of M94 Challenges Galaxy Formation*, 863, 152

Wang, J., Zheng, Z., D'SOUZA, R., Mo, H., Józsa, G., Li, C., Kamphuis, P., Catinella, B., Shao, Li, Lagos, C. del P., Du, M., and Pan, Z. (2018). The prevalence of type III disc breaks in H I-rich and low-spin galaxies. *Monthly Notices of the Royal Astronomical Society*, 479, 4292

GABOR, P. (2017). Jesuit Astronomers and the Enlightenment. *Fons Tyrnaviensis VII*. Trnava: Historical Institute of the University of Trnava. pp. 134-144

GABOR, P. (2018). The Leap Second Debate and the Lessons from Timekeeping History. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit.*, pp. 203-217

Weiner, B. T., Sand, D., GABOR, P., Johnson, C., Swindell, S., Kubánek, P., Gasho, V., Golota, T., Jannuzi, B., Milne, P., Smith, N., and Zaritsky, D. (2018). Development of the Arizona Robotic Telescope Network. Proc. SPIE 10704, *Observatory Operations: Strategies, Processes, and Systems VII*, 107042H

GIONTI, G. (2018). Hamiltonian analysis of asymptotically safe gravity. *Proceedings of Science Corfu 2017* (POSCORFU2017) 192 arXiv:1805. 02318

Bellucci, S., Bonanno, A., GIONTI, G., and Scardigli, F. (2018). Black holes, gravitational waves and space-time singularities – editorial. In *Black Holes, Gravitational Waves and Space-Time Singularities, Op. cit*. pp. 1131-1133
GIONTI, G. (2018). Interview in *Scienza ed Umanesimo una Alleanza? Atti del convegno tenuto alla Biblioteca Giovanni Spadolini del Senato della Repubblica il 27 e 28 Novembre*. pp. 340-348

KIKWAYA ELUO, J. B. (2018). Near Earth Objects and their physical characterization. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit*. pp. 27-42

Flynn, G., Durda, D., Strait, M., and MACKE, R. (2018). Momentum enhancement from hypervelocity crater ejecta of anhydrous and hydrous porous targets. *42nd COSPAR Scientific Assembly*, Abstract #21772

Flynn, G. J., Durda, D. D., Molesky, M. J., May, B. A., Cogram, S. N., Strait, M. M., and MACKE, R. (2018). Recoil from crater ejecta in hypervelocity impact of hydrous and porous targets. *Lunar and Planetary Science Conference XLIX*. Abstract #1167

MACKE, R. J., Kohout, T., and Toth, J. (2018). Scale dependence in porosity for intact stones of Košice. *Lunar and Planetary Science Conference XLIX*. Abstract #1279

Povinec, P. P., Beier, R., Ferrière, L., Kováčik, A., Koeberl, C., MACKE, R., Masarik, J., Porubčan, V., Sýkora, I., and Tóth, J. (2018). Radioactivity of chondrites and meteorites from Mars and the Moon: Measurements and Monte Carlo simulations. *18th Radiochemical Conference*

Flynn, G. J., Durda, D. D., Patmore, E. B., Jack, S. J., Molesky, M. J., May, B. A., Congram, S. N., Strait, M. M., and MACKE, R. (2018). Hypervelocity cratering and disruption of the Northwest Africa 869 ordinary chondrite meteorite: implications for crater production, catastrophic disruption, momentum transfer and dust production on asteroids. *Planetary and Space Science*, 164, 91-105

Poggianti, B. M., Moretti, A., Gullieuszik, M., Fritz, J., Jaffé, Y., Bettoni, D., Fasano, G., Bellhouse, C., Hau, G., Vulcani, B., Biviano, A., OMIZZOLO, A., Paccagnella, A., D'Onofrio, M., Cava, A., Sheen, Y. -K., Couch, W., and Owers, M. E. (2017). GASP. I. Gas stripping phenomena in galaxies with MUSE. *Astrophysical Journal*, 844, 48
Poggianti, B. M., Moretti, A., Gullieuszik, M., Fritz, J., Jaffé, Y., Radovich, M., Tonnesen, S., Fritz, J., Bettoni, D., Vulcani, B., Fasano, G., Bellhouse, C., Hau, G., and OMIZZOLO, A. (2018) Ram-pressure feeding of supermassive black holes. *Nature*, 548, 304P

OMIZZOLO, A. (2018). Clusters of galaxies and some Jellyfishes in the sky. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration, Op. cit*. pp. 111-122

ALTAMORE A., Brenni P., and Faccini M. (2018). Gli Strumenti. In Tra Cielo e Terra - *Mostra virtuale in occasione del Bicentenario della nascita di Angelo Secchi. https://tracieloeterra.bicentenarioangelosecchi.it/gli-strumenti/*

CARUANA, L. (2018). Nature, science, and critical explicitation: does conceptual structure reflect how things are? *International Philosophical Quarterly* 58, 93-105

CARUANA, L. (2018). The philosophy of expertise: the case of Vatican astronomers. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit*. pp. 245-252

CARUANA, L. (2018). Mechanistic trends in chemistry. *Substantia* Vol. 2, No. 1: 29-40

CHINNICI, I. (2018). Astronomy and correlated sciences in the Arabic Sicily. *The European Physical Journal Plus*, 133, 330

CHINNICI, I. (2018). Practicing science and faith: a short history of the Vatican Observatory. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit*. pp. 219-231

CHINNICI, I. (2018). La fisica solare in Italia nel XIX secolo. *Quaderni di Storia della Fisica* 20

CHINNICI, I. (2018). Ricordando Angelo Secchi: cronaca della spedizione in Spagna per l'eclisse del 1860. *Giornale di Astronomia* 44 23-26

FRANCL-DONNAY, M. M. (2017). Pondering. *Give Us This Day*, December

FRANCL-DONNAY, M. M. (2017). Show Me the Door. *Ignatian Volunteer Corps*, December

FRANCL-DONNAY, M. M. (2018). Making Molecular Monsters. *Nature Chemistry*, 10, 1-2

FRANCL-DONNAY, M. M. (2018). Awash in the Joy of Conversion. *Liguorian*, March 16-19

FRANCL-DONNAY, M. M. (2018). Atomic Women. *Nature Chemistry*, 10, 373-375

FRANCL-DONNAY, M. M. (2018). Reach for Mercy. *Give Us This Day*, April

FRANCL-DONNAY, M. M. (2018). Talking to Pauling's Ghost. *Nature Chemistry*, 10, 688-689

FRANCL-DONNAY, M. M. (2018). Church has long history of supporting science. *Chicago Catholic* and other outlets, 5 July

FRANCL-DONNAY, M. M. (2018). Eat My Words. *Give Us This Day*, August

FRANCL-DONNAY, M. M. (2018). It's Alive. *Nature Chemistry*, 10, 993-994

FUNES, J. G., Lares, M., Martiarena, M., Asla Florio, L. and Bernardello, G. (2018). The Spiritual

FUNES, J. G. (2018). The road map to other Earths: lessons learned and challenges ahead. In *Astrotheology, Science & Theology Meet Extraterrestrial Life* (Ted Peters, ed., with Martinez Hewlett, Joshua Moritz, and Robert John Russell.) Eugene, Oregon: Cascade Books

FUNES, J.G., Lares, M., Martiarena, M. Asla, Florio, L., and Bernardello, G. (2018) The Spiritual Quest in the SETI Research. White Paper presented at the Workshop, "Detecting Extraterrestrial Technology: Signals and Artefacts", organized by the SETI Institute

FUNES, J. G. (2018). El hallazgo de moléculas orgánicas en Marte dispara el interés por la astrobiología. *Diario Perfil*

FUNES, J. G. (2018). De grietas y puentes: ciencia, religión y educación. *La Voz del Interior*

FUNES, J. G. (2018). La madre de todas las grietas. Ciencia, Religión y Educación. *La Nación*

FUNES, J. G. (2018). De grietas y puentes: ciencia, religión y educación. *Criterio*, November, p. 19

GALAVERNI, M. (2017). Testing new physics with polarized light: cosmological birefringence. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit*. 165-174

Miller, T. and HELLER, M. (2018). Creation of matter in a noncommutative universe. In *The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit*. pp. 149-163

HELLER, M. (2018). How may we justify the history of the universe? In *Issues in Science and Theology: Are We Special?*, (Fuller M., Evers D., Runnehov A., Saether K-W., ed.) Springer. pp. 223-233

HINCKS A. D. (2018). What does physical cosmology say about creation from nothing? In *Creation ex nihilo: Origins, Development, Contemporary Challenges*, (Gary A. Anderson & Markus Bockmuehl, ed.) Notre Dame: University of Notre Dame Press, 2018

HINCKS A. D. (2018). Angelo Secchi, the Jesuit father of astrophysics. America: *The Jesuit Review of Faith and Culture*, 219 (3)

Coulton, W. R., Aiola, S., Battaglia, N., Calabrese, E., Choi, S. K., Devlin, M. J., Gallardo, P. A., Colin, Hill J., HINCKS, A. D., Hubmayr J., Hughes, J. P., Kosowsky, A., Thibaut, L., Madhavacheril, M. S., Maurin, L., Naess, S., Nati, F., Niemack, M. D., Page, L. A., Partridge, B., Sherwin, B. D., Spergel, D. N., Staggs, S. T., Van Engelen, A., and Wollack, E. J. (2018). Non-Gaussianity of secondary anisotropies from ACTPol and Planck. J. *Cosmology Astropart*. Phys. 9:022, 2018

Hilton, M., Hasselfield, M., Sifón, C., Battaglia, N., Aiola, S., Bharadwaj, V., Bond, J. R., Choi, S. K., Crichton, D., Datta, R., Devlin, M. J., Dunkley, J., Dünner, R., Gallardo, P. A., Gralla, M., HINCKS, A. D., Shuay-Pwu, P. Ho, Hubmayr, J., Huffenberger, K. M., Hughes, J. P., Koopman, B. J., Kosowsky, A., Thibaut L., Madhavacheril, M. S., Marriage, T. A., Maurin, L., McMahon, J., Hironao, M., Moodley, K., Naess, S., Nati, F., Newburgh, L., Niemack, M. D., Oguri, M., Page, L. A., Partridge, B., Schmitt, B. L., Sievers, J., Spergel, D. N., Staggs, S. T., Trac, H., van Engelen, A., Vavagiakis, E. M., and Wollack, E. J. (2018). The Atacama Cosmology Telescope: The two-season ACTPol Sunyaev-Zel'dovich Effect selected cluster catalog. *Astrophysical Journal Suppl.*, 235, 20

Sazowski, G., Schultheis, M., Hasselquist, S., Cunha, K., Sobeck, J., Johnson, J. A. ; Rojas-Arriagada, A., Majewski, S. R. ; Andrews, B. H., Jonsson, H., Beers, T. C., Chojnowski, S. D., Finchaboy, P. M., MINNITI, D., Nidever, D. L., and Nitschelm, C. (2018). APOGEE DR14/DR15 abundances in the inner Milky Way. *Astrophysical Journal*, in press (arXiv:1811. 01097)

Navarro Molina, C., Borissova, J., Catelan, M., Lucas, P. W., Medina, N., Contreras-Peña, C., Kurtev, R., and MINNITI, D. (2018). Long-term stellar variability in the galactic centre region. *Monthly Notices of the Royal Astronomical Society*, in press (arXiv:1811. 01897)

Banerjee, D. P. K., Hsiao, E.Y., Diamond, T., Galbany, L., Morrell, N., MINNITI, D., Kuncarayakti, H., Mattila, S., and Harmanen, J. (2018). Unravelling the infrared transient VVV-WIT-06: the case for an origin in a classical nova. *Astrophysical Journal*, in press (arXiv:1809. 06801)

Saito, R. K., MINNITI, D., Ivanov, V., Catelan, M., Gran, F., Baptista, R., Angeloni, R., and Caceres, C. (2018). VVV- WIT-07: another Tabby's star or a Mamajek's object? *Monthly Notices of the Royal Astronomical Society*, in press

Borissova, J., Ivanov, V. D., Lucas, P. W., Kurtev, R., MINNITI, D., Froebrich, M., Hempel, M., Medina, N., Chene, A. -N., Ramirez Alegria, S., and Kuhn, M. (2018). New galactic star clusters discovered in the disk area of the VVVX survey. *Monthly Notices of the Royal Astronomical Society*, 481, 3902B

Alonso-Garcia, J., Saito, R. K., Hempel, M., MINNITI, D., Pullen, J. B., Catelan, M., Contreras Ramos, R., Cross, N. G. J., Gonzalez, O. A., Lucas, P. W, Palma, T., Valenti, E., and Zoccali, M. (2018). Milky Way demographics with the VVV Survey IV. PSF photometry from almost one billion stars in the Galactic bulge and adjacent southern disk. *Astronomy & Astrophysics*, in press (arXiv:1808. 06139)

MINNITI, D., Schlafly, E., Palma, T., Claria, J. J., Hempel, M., Alonso-Garcia, J., Bica, E., Bonatto, C., Braga, V., Clementini, G., Garofalo, A., Gomez, M., Ivanov, V., Lucas, P., Pullen, J., Saito, R., and Smith, L. (2018). Confirmation of a new metal-poor globular cluster in the galactic bulge. *Astrophysical Journal*, 866, 12M

Braga, V. F., Bhardwaj, A., Contreras Ramos, R., MINNITI, D., Bono, G., De Grijs, R., Minniti J. H., and Rejkuba, M. (2018). Structure and kinematics of type II Cepheids in the galactic bulge based on near-infrared VVV data. *Astronomy &Astrophysics*, in press (arXiv:1808. 10838)

Tang, B., Fernandez-Trincado, J. G., Zamora, O., Souto, D., Cohen, R. E., Dell Agli, F., Garcia-Hernandez, D. A., Masseron, T., Schiavon, R. P., Meszaros, S. Z., Cunha, K., Hasselquist, S., Shetrone, M., Schiappacase-Ulloa, J., Geisler, D., Schleicher, D. R. G., Villanova, S., Mennickent, R. E., MINNITI, D., Alonso-Garcia, J., Manchado, A., Beers, T., Sobeck, C. J., Zasowski, G., Schultheis, M., Majewski, S. R., Rojas- Arriagada, A., Almeida, A., Santana, F., Oelkers, R. J., Longa-Peña, P., Carrera, R., Burgasser, A. J., Lane, R. R., Roman-Lopes, A., Ivans, I. I., and Hearty, F. R. (2018). The metal-poor non-Sagittarius globular cluster NGC 5053: Orbit and Mg, Al, and Si Abundances. *Astrophysical Journal*, in press (arXiv:1801. 08265)

Navarro, M. G., MINNITI, D., and Contreras Ramos, R. (2018). VVV Survey microlensing: the galactic longitude dependence. *Astrophysical Journal Letters*, 865, L5N

Gonzalez, O. A., MINNITI, D., Valenti, E., Alonso-Garcia, J., Debattista, V. P., Zoccali, M., Rejkuba, M., Dias, B., Surot, F., Hempel, M., and Saito, R. K. (2018). The structure behind the Galactic bar traced by red clump stars in the VVV survey. *Monthly Notices of the Royal Astronomical Society*, 481L, 130G (arXiv:1809. 03792)

Medina, N., Borissova, J., Bayo, A., Kurtev, R., Navar- ro-Molina, C., Kuhn, M. Kumar, N., Lucas, P. W., Catelan, M., MINNITI, D., and Smith, L. C. (2018). An automated tool to detect variable sources in the VISTA variables in the Via Lactea Survey. The VVV Variables (V^4) Catalog of Tiles D001 and D002. *The Astronomical Journal*, 864, 11M (arXiv:1806. 04061)

Abolfathi, B., Aguado, D. S., Aguilar, G., Allende Prieto, C., Almeida, A., Ananna, T. T., Anders, F., Anderson, S. F., Andrews, B. H., Anguiano, B. et al. (The SDDS Collaboration) (2018). The fourteenth data release of the Sloan Digital Sky Survey: first spectroscopic data from the extended baryon oscillation spectroscopic survey and from the second phase of the Apache Point Observatory galactic evolution experiment. *Astrophysical Journal Suppl.*, 235, 42A

Contreras Ramos, R., MINNITI, D., Gran, F., Zoccali, M., Alonso-Garcia, J., Huijse, P., Navarro, M. G., Rojas-Arriagada, A., and Valenti, E. (2018). The VVV Survey RR Lyrae population in the galactic center region. *Astrophysical Journal*, 863, 79C (arXiv:1807. 04303)

Skinner, J., Covey, K. R., Bender, C. F., Rivera, N., De Lee, Na., Souto, D., Chojnowski, D., Troup, N., Badenes, C., Bizyaev, D., Blake, Cullen H., Burgasser, A., Cañas, C., Carlberg, J., Gómez Maqueo C., Yilen, D., Rohit, F., Scott W., Fernández-Trincado, J. G., García-Hernández, D. A., Hearty, F., Kounkel, M., Longa-Peñe, P., Mahadevan, S., Majewski, S. R., MINNITI, D., Nidever, D., Oravetz, A., Pan, K., Stassun, K., Terrien, R., and Zamora, O. (2018). Forty-four new and known M-dwarf multiples in the SDSS-III/APOGEE M-dwarf ancillary science sample. *Astronomical Journal*, 156, 45S

Renzini, A., Gennaro, M., Zoccali, M., Brown, T. M., Anderson, J., MINNITI, D., and Valenti, E. (2018). The WFC3 galactic bulge treasury program: relative ages of bulge stars of high and low metallicity. *Astrophysical Journal*, 863, 16R

Contreras Ramos, R., MINNITI, D., Fernandez Trincado, J., Alonso-Garcia, J., Catelan, M., Gran, F., Hagdu, G., Hanke, M., Hempel, M., Moreno-Diaz, E., Perez-Villegas, A., Rojas- Arriagada, A., and Zoccali, M. (2018). The orbit of the new Milky Way globular cluster FSR1716 = VVV-GC05. *Astrophysical Journal*, 863, 78C

Bica, E., MINNITI, D., Bonatto, C., and Hempel, M. (2018). A new globular cluster in the area of VVVX. Publications of the *Astronomical Society of Australia*, 35, 25B

Fernandez-Trincado, J. G., Zamora, O., Garcia-Hernandez, D., Schiavon, A., Geisler, R. P., Shetrone, D. M., Johnson, J. A., Alves-Brito, A., Cunha, K., Hasselquist, S., Robin, A. C., Moreno, E., Perez Villegas, A., Pichardo, B., Meszaros, Sz., Schultheis, M., Anders, F., Zasowski, G., Tang, B., Villanova, S., Hayes, C., Majewski, S. R., Garcia Perez, A. E., Meza, A., Valenzuela, O., Lane, R. R., Beers, T., Nitschelm, C. C., MINNITI, D., Carrera, R. et al. (2018). The Mg-Al anticorrelation sequence in the Milky Way field discovered by APOGEE. *Astrophysical Journal Letters*, in press

Fernandez-Trincado, J. Zamora, O. Garcia-Hernandez, D. Schiavon, A., Geisler, R. P., Shetrone, D. M., Johnson, A. J., Alves-Brito, A. Cunha, K., Souto, D., Hasselquist, S., Robin, A. C., Moreno, E., Perez-Villegas, A., Pichardo, B., Meszaros, Sz., Schultheis, M., Anders, F., Zasowski, G., Tang, B., Villanova, S., Hayes, C., Majewski, S. R., Garca Perez, A. E., Meza, A., Valenzuela, O., Lane, R. R., Beers, T. Nitschelm, C. C., and MINNITI, D. (2018). Abundance variations found by the APOGEE survey: metal poor field giant stars with globular cluster like abundance patterns. *Astrophysical Journal*, in press

Fernandez-Trincado, J., Zamora, O., Garcia-Hernandez, D., Schiavon, A., Geisler, R. P., Shetrone, D. M. Johnson, A. J., Alves-Brito, A., Cunha, K., Souto, D., Hasselquist, S., Robin, A. C., Moreno, E., Perez-Villegas, A., Pichardo, B., Meszaros, Sz., Schultheis, M., Anders, F., Zasowski, G., Tang, B., Villanova, S., Hayes, C., Majewski, S. R., Garca Perez, A. E., Meza, A., Valenzuela, O., Lane, R. R., Beers, T., Nitschelm, C. C., and MINNITI, D. (2018). Abundance variations found by the APOGEE survey: metal poor field giant stars with globular cluster like abundance patterns. *Astrophysical Journal*, in press

Valenti, E., Zoccali, M. A., Mucciarelli, Gonzalez, O., Surot Madrid, A. F., MINNITI, D., Rejkuba, M., Pasquini, L., Fiorentino, G., Bono, G. R., Rich, M., and Soto, M. (2018). The central velocity dispersion of the Milky Way bulge. *Astronomy & Astrophysics*, 616A, 83V (arXiv:1805. 00275)

MINNITI, D., Saito, R. K., Gonzalez, O. A., Alonso Garcia, J., Barba, R., Irwin, M., Lucas, P. W., Majaess, D., Rejkuba, M., Valenti, E., and Zoccali, M. (2018). A new near-IR window of low extinction in the Galactic plane. *Astronomy & Astrophysics*, 616A, 26M (arXiv:1804. 07785)

Majaess, D., Dekany, I., Hagdu, G., MINNITI, D., Turner, D., and Gieren, W. (2018). Establishing the galactic centre distance using VVV bulge RR Lyrae variables. *Astrophysics & Space Science*, 363, 127M (arXiv:1805. 04119)

MINNITI, D. (2018). Mapping the Milky Way in the near-IR: the future of the VVV survey. *In The Vatican Observatory, Castel Gandolfo: 80th Anniversary Celebration. Op. cit*. pp. 63-72
Schiappacase-Ulloa, J., Tang, B., Fernandez-Trincado, J. G., Zamora, O., Geisler, D., Finchaboy, P., Schultheis, M., Dell Agli, F., Villanova, S., Maseron, T., Meszaros, S., Souto, D., Hasselquist, S., Shetrone, M., Cunha, K., Smith, V., Garcia- Hernandez, D. A., Vieira, K., Robin, A. C., MINNITI, D., Sazowski, G., Anguiano, B., Majewski, S. R., Moreno, E., Perez-Villegas, A., Lane, R. R., Evans, I. I., Pan, K., Nitschelm, C., Santana, F. A., Carrera, R. et al. (2018). A chemical and kinematical analysis of the intermediate age open cluster IC 166 from APOGEE and Gaia DR2. *Astronomical Journal*, 156, 94S

Clarkson, W. Calamida, A., Sahu, K., Brown, T. M., Gennaro, M., Avila, R., Valenti, J. A., Debattista, V. P., Rich, R., MINNITI, D., Zoccali, M., and Aufdemberge, E. R. (2018). Chemically-dissected rotation curves of the galactic bulge from main sequence proper motions. *Astrophysical Journal*, 858, 46C (arXiv:1804. 01103)

D'Orazi, V., Magurno, D., Bono, G., Matsunaga, N., Braga, V. F., Elgueta, S. S., Fukue, K., Hamano, S., Inno, Kobayashi, L. N., Kondo, S., Monelli, M., Nonino, M., Przybilla, P. N., Sameshima, H., Saviane, I., Taniguchi, D., Thevenin, F., Urbaneja-Perez, M., Watase, A. Arai, A., Bergemann, M., Buonanno, R., Dall'Ora, R., Silva, R., Fabrizio, M., Ferraro, I., Fiorentino, G., Francois, P., Gilmozzi, R., Iannicola, G., Y. Ikeda, Y., Jian, M., Kawakita, H., Kudritzki, R. -P., Lemasle, B., Marengo, M., Marinoni, S., Martinez- Vasquez, C., MINNITI, D., Neeley, J., Otsubo, S., Prieto, J. L., Proxauf, B., Romaniello, M., Sanna, C., Sneden, K., Takenaka, K., Tsujimoto, K., Valenti, E., Yasui, C., Yoshikawa, T., and Zoccali, M. (2018). On the chemical abundances of Miras in clusters: V1 in the metal-rich globular NGC 5927. *Astrophysical Journal Letters*, 855, L9 (arXiv:1802. 07314)

Souto, D., Cunha, K., Smith, V. V, Allende Prieto, C., Garcia-Hernandez, D. A., Pinsonneault, M., Holzer, P., Finchaboy, P., Holzman, J., Johnson, J. A., Jonsson, H., Majewski, S. R., Shetrone, M. J., Sobeck, G., Stringfellow, G., Teske, J., Zamora, O., Sazowski, G., Carrera, R., Stassun, K., Fernandez-Trincado, J. G., Villanova, S., MINNITI, D., and Santana, F. (2018). Chemical abundances of main-sequence, turn-off, subgiant and red giant stars from APOGEE spectra I: signatures of diffusion in the open cluster M67. *Astrophysical Journal*, 857, 14S (arXiv:1804. 04461)
Roman-Lopes, A. C., Roman-Zuñiga, M., Tapia, D., Chojnowski, Y., Gomez, M., Chew, D., Garcia- Hernandez, A., Borissova, J., MINNITI, D., Kovey, K. R., Longa-Peña, P., Fernandez-Trincado, J. G., Zamora, O., and Nitschelm,

C. (2018). Massive stars in the SDSS / APOGEE survey. I. OB Stars. *Astrophysical Journal*, 855, 68 (arXiv:1802. 01724)

Braga, V. F., Stetson, P. B., Bono, G., Dall'Ora, M., Ferraro, I., Fiorentino, G., Iannicola, G., Marconi, M., Marengo, M., Monson, A. J., Neeley, J., Persson, S. E., Beaton, R. L., Buonanno, R., Calamida, A., Castellani, M., Di Carlo, E., Fabrizio, M., Freedman, W. L., Inno, L., Madore, B. F., Magurno, D., Marchetti, E., Marinoni, S., Marrese, P., Matsunaga, N., MINNITI, D. Monelli, M., Nonino, M., Piersimoni, A. M., Pietrinferni, A., Prada-Moroni, P., Pulone, L., Stellingwerf, R., Tognelli, E., Walker, A. R., Valenti, E., and Zoccali, M. (2018). On the RR Lyrae stars in globulars: V. the complete near-infrared (JHKs) census of Omega Centauri RR Lyrae variables. *Astronomical Journal*, 155, 13 (arXiv:1802. 03578)

Abolfathi, B., Aguirre, V. S., Almeida, A. et al. (327 coauthors including D. MINNITI) (2018). The fourteenth data release of the SLOAN Digital Sky Survey: first spectroscopic data from the extended baryon oscillation sky survey and from the second phase of the Apache Point Observatory galactic evolution experiment. *Astrophysical Journal Supplements*, 235, 42A (arXiv:1707. 09322)

Hasselquist, S., Shetrone, M., Smith, V., McWilliam, A., Majewski, S. R., Holtzman, J., Beers, T., Cunha, K., Sobeck, J., Nidever, D., Frinchaboy, P., Tang, B., Garcia-Hernandez, D. A., Fernandez-Trincado, J. G., MINNITI, D., Placco, V. M., Allende Prieto, C., Ivans, I., and Roman, A. (2018). APOGEE chemical abundances of the Sagittarius Dwarf Galaxy. *Astrophysical Journal Suppl.*, 235, 42 (arXiv:1707. 03456)

Marconi, M. and MINNITI, D. (2018). Gauging the helium abundance of the galactic bulge RR Lyrae stars. *Astrophysical Journal*, 853, L20 (arXiv:1801. 05883)

Ness, M., Hogg, D. W., Rix, H-W., Casey, A. R., Holtzman, J., Fouesneau, M., Sazowski, G. Geisler, D., Shetrone, M., MINNITI, D., Finchaboy, P., and Roman-Lopes, A. (2018). Galactic doppelgangers: the chemical similarity of field stars and stars with a common birth origin. *Astrophysical Journal*, 853, 198 (arXiv:1701. 07829)

Hayes, R. C., Majewski, S. R., Shetrone, M., Fernandez-Alvar, E., Allende Prieto, C., Schuster, W. J., Shetrone, M., Carigi L., Cunha, K., Smith, V., J. Sobeck, Almeida, A. Beers, T. C., Carrera, R. Fernandez-Trincado, J. G. Geisler, D. Garcia-Hernandez, D. A. Lane, R. R., S. Lucatello, A. M. Matthews, MINNITI, D., Nitschelm, C., Tang, B., Tissera, P. B., and Zamora, O. (2018). Disentangling the galactic halo with Apogee: I. Chemical and kinematical investigation of distinct metal-poor populations. *Astrophysical Journal*, 852, 49 (arXiv:1711. 05781)

Smith, L. C., Lucas, P. W., Kurtev, R., Smart, R., MINNITI, D., Borissova, J., Jones, H. R. A., Zhang, Z. H., Marocco, F., Contreras Pena, C., Gromadzki, M., Kuhn, M. A., Drew, J., Pinfield, and D. J., Bedin, L. R. (2018). VIRAC: The VVV Infrared Astrometric Catalogue. *Monthly Notices of the Royal Astronomical Society*, 474, 1826 (arXiv:1710. 08919)

Baravalle, L., Alonso, M. V., Nilo Castellon, J. L., Beamin, J. C., and MINNITI, D. (2018). Searching for extragalactic sources in the VISTA Variables in the Via Lactea survey. *Astronomical Journal*, 155, 46 (arXiv:1712. 00041)

Tissera, P. B, Machado, R. G., Carollo, D., MINNITI, D., Beers, T., Zoccali, M., and Meza, A. (2018). The central spheroids of Milky Way mass-sized galaxies. *Monthly Notices of the Royal Astronomical Society*, 473, 1656 (arXiv:1709. 06605)

TANZELLA-NITTI, G. (2018). Alle porte del mistero (Stephen Hawking's obituary), «Il Regno - Attualità», n. 8 pp. 204-205

Chapter NINE

Visitors

There is great interest in the life and work of the Vatican Observatory. Outreach to our fellow scientists, but also to the public, includes visits to our facilities in Rome and Tucson

Working visits to Vatican Observatory Headquarters in Castel Gandolfo, Italy:

- Ferdinando Fava, Professor of Cultural Anthropology at the University of Padua, Italy
- Alfio Bonanno, INAF, Astrophysic Observatory of Catania, Italy
- Alessandro Codello Ph.D, Physicist
- Christof Wetterich, Professor of Theoretical Physics at the University of Heidelberg, German
- Thomas Kupfer, post-doc at Cal Tech University, USA
- PhD student Lia Sartori, of ETH Zurich, Switzerland
- Nathan Cunningham, Physicist at Nebraska Wesleyan University, USA
- Federico Tosi of INAF - IAPS, Institute for Space Astrophysics and Planetology, Italy
- Michele Cicoli, Department of Physics and Astronomy, Bologna University, Italy
- Juraj Tóth, Comenius University, Bratislava, Slovakia.
- Ludovic Ferrière, Natural History Museum of Vienna, Austria

Working visits to the VATT, Tucson, AZ, USA:

- Timothy Hamilton, Shawnee State University, USA
- Rae Stanley, Marshall University, USA
- Roberto Rampazzo, INAF, Padua, Italy
- Daniel Sablowski, AIP, Potsdam, Germany
- Ray Butler and Salam Dulaimi, National University of Ireland, Galway, Ireland
- Alan Giltinan and Niall Smith, Blackrock Castle Observatory, Cork, Ireland

Working Visits to other institutions:

BROWN paid a working visit to VORG/Steward Observatory offices in May, October and December as well as periodic visits to Monte Porzio INAF Observatory in the Castelli Romani region.

From July 28 to August 5, GABOR took part in the 35th Ebicycle, a 7-day, 350-mile cycling tour of observatories and astronomy sites, held each year alternately in Bohemia, Moravia, and Slovakia. This was the 10th time he joined the group of 50 professional and amateur astronomers for the event. He visited observatories and planetaria in Pardubice, Litomyšl, Jihlava, and České Budějovice (all in the Czech Republic).

Group tours of Vatican Observatory Headquarters in Castel Gandolfo, Italy:

- Students from the Scotts College, Rome, Italy
- Students from the University of Nebraska Newman Institute, USA
- Students from Belmont University, USA
- NASA astronauts
- Students from the Montgomery Bell Academy, USA
- Altars servers from St. Peter's Basilica, Rome, Italy
- Students participating in the 'Rome and the Catholic Church' program, organized by the University of Dallas in Irving, Texas, USA
- A group of amateur astronomers from the Netherlands
- Students from the Galileo-Galilei High School (Liceo Scientifico), Trieste, Italy
- The Vatican Foundation "PATRONS"
- Students from the Blaise Pascal High Schools (Liceo Scientifico and Liceo Classico), Pomezia, Italy
- Journalists accredited to the Holy See Press Office, Rome, Italy