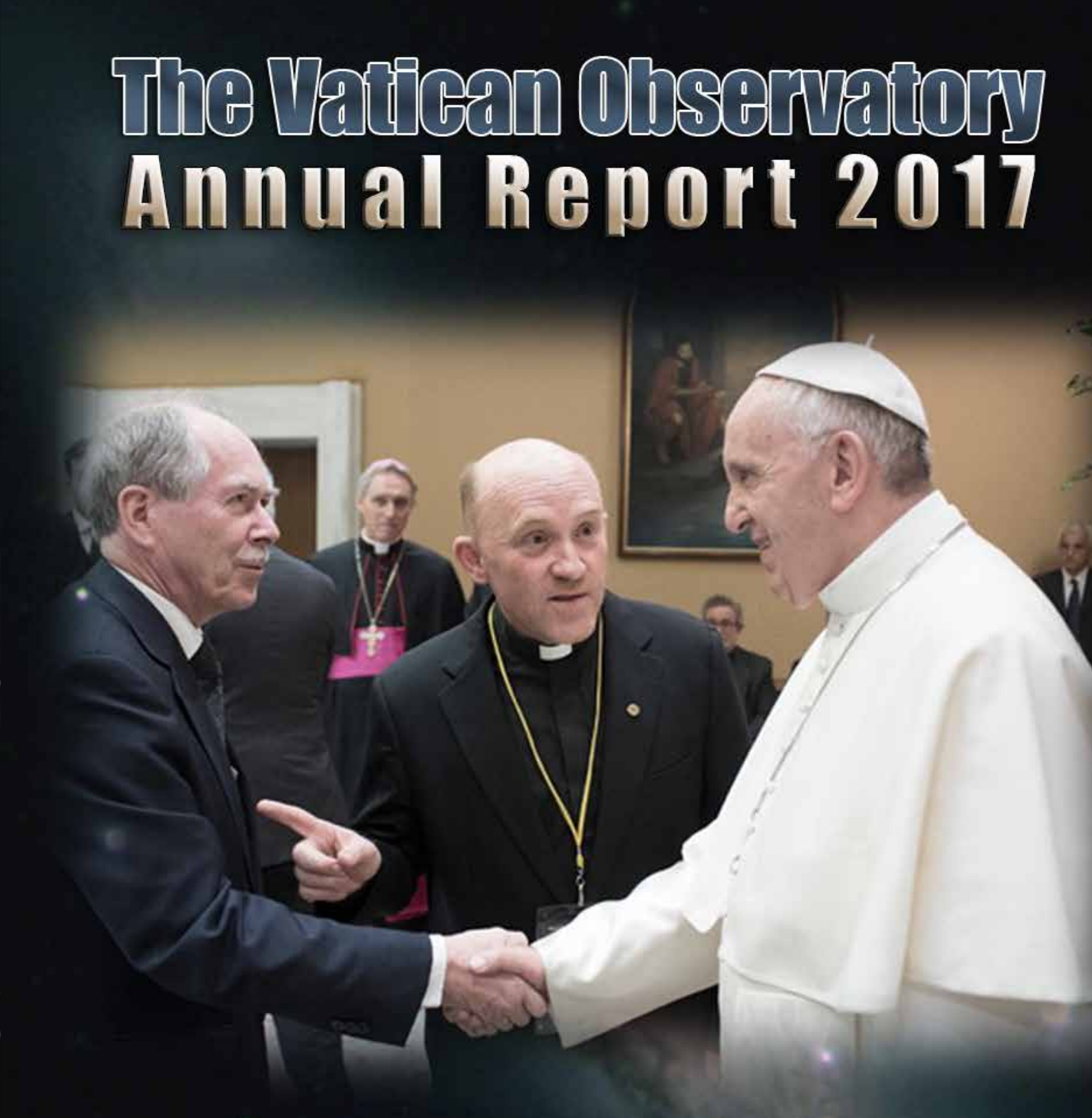
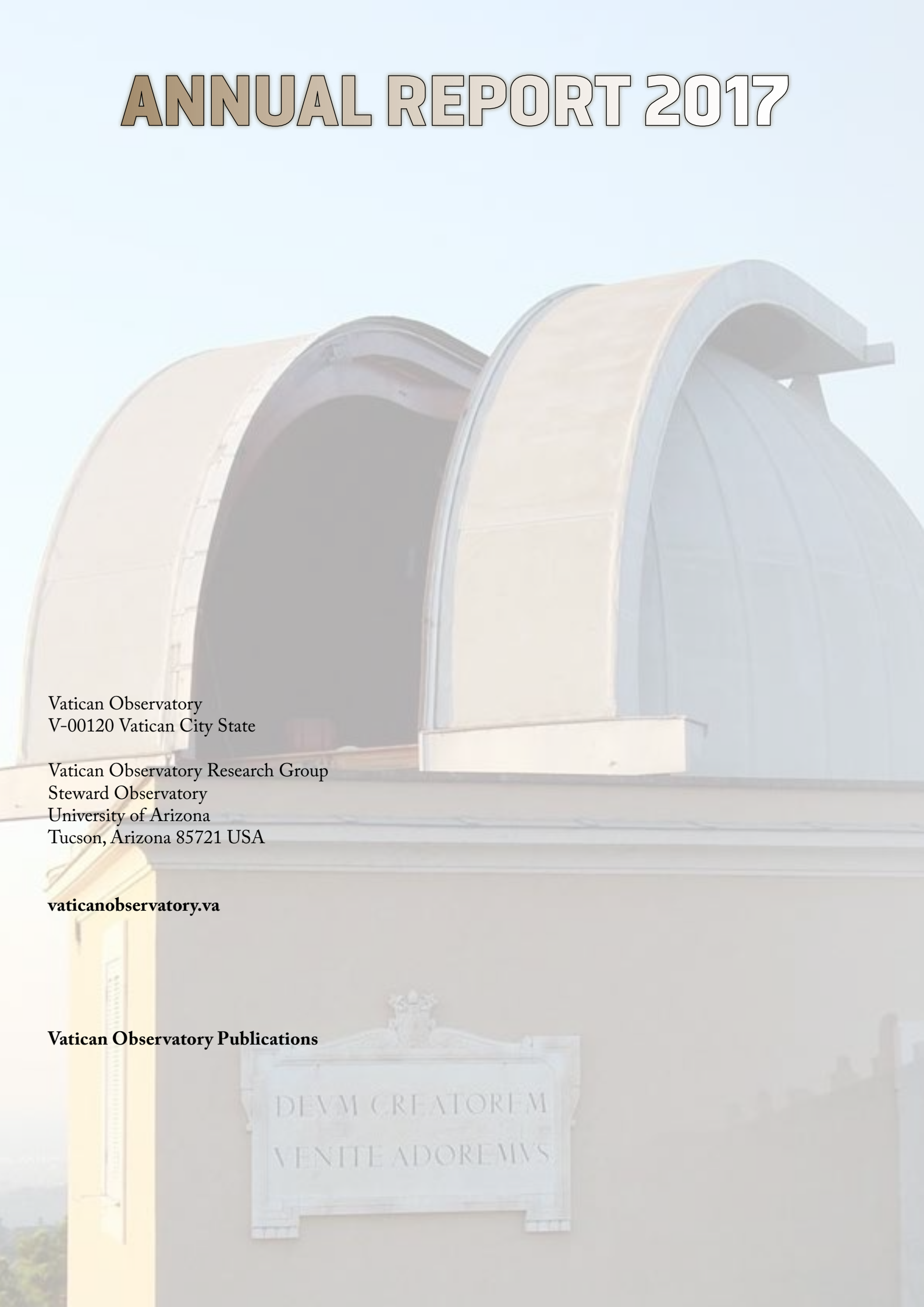
The Vatican Observatory
Annual Report 2017



a Singular Gathering

ANNUAL REPORT 2017



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Vatican Observatory Publications

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Cover: ***Fr. Gionti presents Nobel Laureate Gerald 't Hooft to Pope Francis. 't Hooft gave the opening address at the international workshop "Black Holes, Gravitational Waves and Spacetime Singularities", held at the Vatican Observatory headquarters in May 2017.***
Credit Photo: L'Osservatore Romano

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

Vatican Observatory
ANNUAL REPORT 2017

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From the Director

A letter from the Director of the Vatican Observatory to all our readers

It happened more than twenty years ago, when I was still new to the Specola. A friend from America had visited Europe with his family and his teen-age daughter had fallen in love with the stylish backpacks that Italian students used. Could I possibly help him get one for his daughter?

As a forty-something single male I had no idea what would make one backpack more stylish than another. Much less did I have a clue as to where one would buy such a thing. I spent a fruitless morning wandering around Albano, totally puzzled as to where to even start.

The next morning at our daily 10 am coffee I mentioned my plight, and Luigi Lori (who was on cappuccino duty that morning) volunteered to help. So together the two of us went back to Albano.

Through some radar that I didn't have, he found a likely shop. A few minutes chatting with the young woman behind the counter revealed that she had been a classmate of Rita Callegari, who was the Specola secretary. Another ten minutes of chat and the owner of the shop came out from the back; turns out, she was an old friend of Luigi's wife. Another chat ensued… and at the end of it all, through some magic that I don't even remember, we left the shop with a wonderful backpack. My friend's daughter was delighted.

What an introduction for an American like me to the best of Italian life! Life is not buying or selling; it is relationships between friends and family.

I thought of that episode this past spring, when we heard the sad news of Luigi's death.

Luigi Lori, long time member of the Specola staff, died on February 12. He first joined the Specola as a general caretaker in 1971, a position he filled until his retirement in 2007. But he was much more than that to us.

Luigi Lori

Luigi was born in Rome on November 7, 1939 and began his work at the Vatican Specola on December 16, 1971. Though he originally planned to retire in 2005, he continued to lend his work to the Specola to compensate for the premature death of his colleague at the Specola, Romeo ("Piero") Piermettei.

Despite being hired originally as a custodian, Luigi was in fact a skilled woodworker and wound up making much of the wooden furniture that furnished the premises of the Specola in the Papal Palace. Though he had retired by the time our move to the gardens in 2009, his artistry can still be seen in many places — for example, in the sacristy of the Specola chapel.

Indeed, a letter from Specola director Father Treanor S.J. in 1977, addressed to the Marquis Sacchetti, attests to Luigi's remarkable skills: "Mr. Lori, hired for cleaning work, represents an exceptional person of whom I have reported several times. In fact, while performing his custodial work with competence, he also manages to carry out many more difficult jobs, both in general maintenance and in construction (being also an excellent carpenter) and shows further

evidence of his ability and intelligence acting as an assistant in the Astronomical Library."

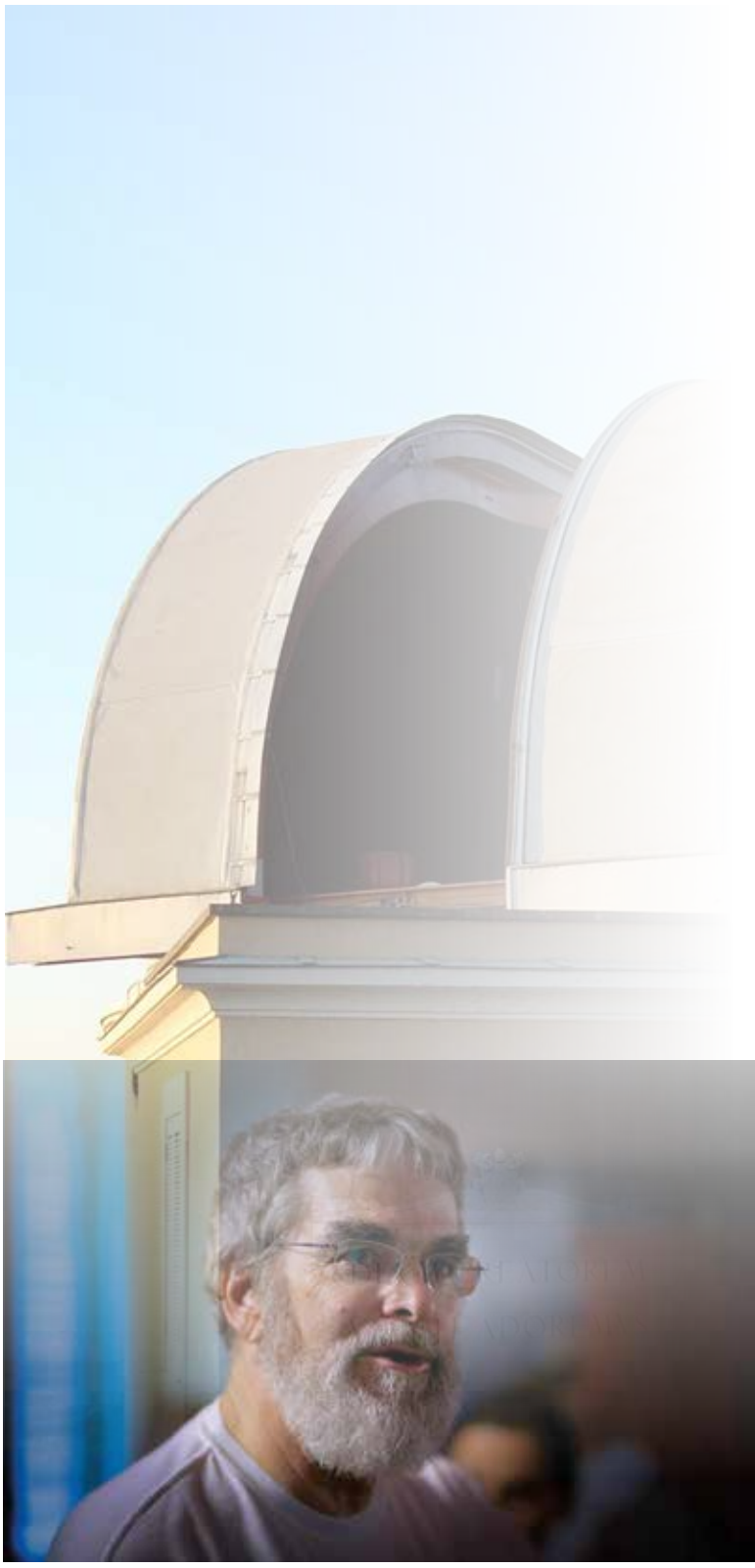
But beyond his remarkable craft, what made Luigi special to us was his warm, low-key personality. The personal touch he displayed over and over again, as illustrated in my little story, was simply who he was. The love he brought to everyone he worked with, multiplied itself over and over. He will be missed by us all.

Luigi in his workshop at the Papal Palace in Castel Gandolfo

Luigi's life reminds us all that the Specola is not a set of offices, books, and plates, but a collection of wonderful human beings. Astronomy is not the stars, it is the study of the stars… which is to say, it is the story of each person who dedicates countless hours to observing, pondering, and describing what they have seen and learned.

In this annual report, I am delighted to present to you the stories in astronomy and its related fields that each of us have contributed to over the past year. Whether it was a gathering of notable astronomers in May, or the defense of our telescope against forest fires in June; a quiet moment spent in solitude in September, or far-distant outreach events in November, each person here has a story to tell.

They are all a part of the greater Story of Creation, which we present as a way of glorifying its Creator. And as such, as with the life of Luigi Lori, they cannot help but be stories of love.



Guy J. CONSOLMAGNO, S.J.
Director

A "Singular" Workshop

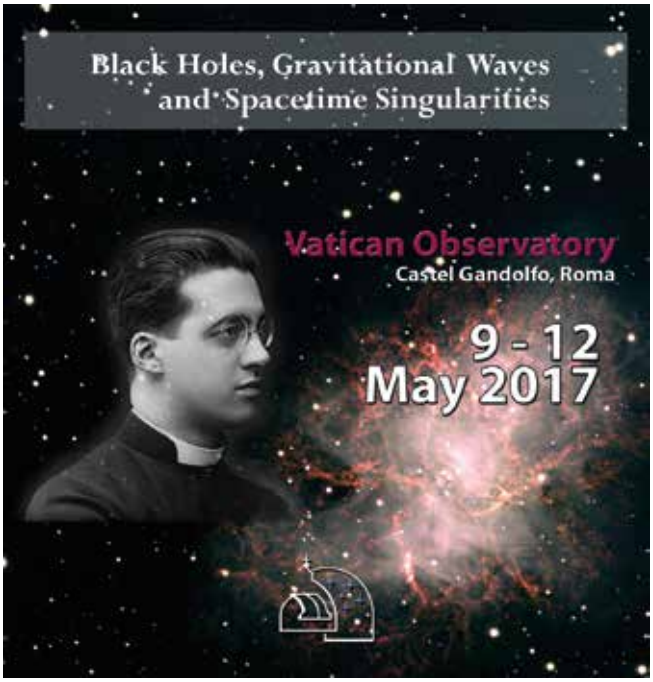
This year's cover story

What happens if an observer falls down into a Black Hole? What happened during the first moments of the Big Bang? What is the future of our Universe? These and other fundamental questions were debated at the Vatican Observatory in Castel Gandolfo from May 9th to May 12th during the workshop "Black Holes, Spacetime Singularities and Gravitational Waves" held in honor of the Belgian cosmologist and priest Mons. George Lemaître.

The cover photo of this year's annual report shows a picture of the 1999 Nobel Laureate Gerald 't Hooft shaking hands with Pope Francis. 't Hooft is a theoretical physicist working in particle physics who has made substantial contributions in quantum field theory, showing that gauge theories are renormalizable.

At the workshop, he highlighted that this hard task of unifying the physics of elementary particles with the gravitational physics, in order to explain the very first moment of our universe, is a fundamental aspect of Lemaître's legacy.

Lemaître can be considered a model for the members of the Specola, a living example of the true spirit of the mission of the Vatican Observatory. He was an outstanding scientist as well as devout priest. Not himself a Jesuit, he belonged to the priestly fraternity of the "Friends of Jesus" founded by Cardinal Mercier, bishop of Malines, who ordained Lemaître. At a time when the Church was under attack for being considered "obscurantist" and in denial of some scientific truths, Lemaître showed the world that a religious person can be at the same time a great scientist and a devout member of the Catholic Church.



The events of the workshop began on the morning of May 8 with a press conference at the Vatican press office. That afternoon, Cardinal Giuseppe Bertello, President of the Governatorato of the Vatican City State, welcomed the participants with an opening address at the workshop reception. On May 9, the first day of the meeting itself, the working session was opened by Mons. Tomasz Trafny, head of the department of theology and science of the Pontifical Council for Culture, on behalf of Card. Gianfranco Ravasi, president of the Council.

The conference program was designed in such as way to reflect the main topics in cosmology inherent to Lemaître's scientific legacy: Space-Time Singularities and Black Holes. Added to these was the "hot topic" of the Gravitational Waves, since their recent detection has opened a new window in the study of the universe. The goal of the workshop was to compare and contrast the cutting edge topics

of theoretical modern cosmology and astrophysics with these and other exciting new experimental and observational results.

Fr. Gionti beside a bust of Mons. Lemaître at the Pontifical Academy of Sciences

In order to set the scientific framework of the workshop, a number of renowned scientists were invited to present papers. These include the 1999 Nobel Laureate Gerald 't Hooft, the 1988 Wolf Prize winner Roger Penrose, the 2004 Templeton Prize winner George Ellis, the 2011 Balzan Prize winner Joe Silk, and the 2002 Dirac Medal winner Andrei Linde. All told, forty scientists attended from four continents: Europe, America, Asia and Africa. The scientific outcome of the presentations and the discussions over these days of hectic scientific activity may well have sowed the seeds for new lines of research in cosmology and astrophysics.
For example, a central topic was information loss inside a Black Hole. Some attempts at Quantum Gravity theories, a theory which aims to unify Quantum Mechanics and General Relativity, show that the central singularity of Quantum Black Holes (i.e. making the Black Holes "Quantum") disappear in a way that the information paradox can be overcome. Different approaches to Quantum Gravity theories were also discussed and compared.

One clear result of the discussions was that Inflation theory, which describes a tremendously rapid exponential expansion in the very first moments of the Universe and appears to be necessary to explain the uniform temperature of the Cosmic Microwave Background Radiation (CMB), is more a model than a satisfactory theory. The standard model of cosmology (ΛCDM) appears to be the most accurate theory one has in cosmology now to fit the observational data, but it needs two "exotic" ingredients: Dark Matter and Dark Energy. Dark Matter is an extra mass needed to explain the rotation curves of galaxies. Nobody is very clear about its nature; at the workshop, even its particle nature was questioned. Dark Energy is an extra, non-visible energy, introduced to explain the acceleration of the Universe. There are hypothesis about it but nothing has been detected yet. It appears clear that Gravitational Waves, predicted by Einstein's theory of General Relativity and recently detected, open a new window in the study of our Universe, which in turn opens a new era in modern astrophysics.

Black Holes are singularities. But the biggest singularity of all, of course, is the Big Bang. Indeed, all of these topics revolve around the Big Bang.

Today, even among the general public, everybody knows that the Universe in which we live was born in an "explosion" which happened 13.8 billion years ago called the Big Bang. Very few, on the other hand, know that the "father" of this idea was a young Belgian cosmologist and Catholic priest, Fr. George Lemaître.

By the early 1920's, it was understood that the measurement of the recession velocity of the galaxies (nebulae) showed an inexplicable movement of expansion, whose cause was completely unknown. Fr. Lemaître was the first one to explain, in 1927, that the recession of the galaxies was an effect of the expansion of the Universe and not the particular movement of the objects that had been observed. He obtained this result by solving the newly formulated equations of Einstein's General Relativity theory. This theory, published in 1916, predicts that the geometry of the distribution of the masses and energies in the Universe acts as a source of energy, which fixes the curvature of the geometry of Space-Time. Unfortunately, Lemaître published his work in French in a relatively obscure Belgian journal, so that his discovery (while brought to the attention of cosmologists by his mentor Arthur Eddington

in the early 1930s) remained relatively unknown to the general public for decades. Only recently has his scientific work gotten the popular attention that it has deserved since its publication.

Beyond merely explaining the observed expansion, however, Lemaître pushed his result even further. If the Universe was expanding, then going back in time there should have been a period in the earliest epoch in which the matter-energy of the Universe was contained within a tiny region, which represented the whole of space-time geometry. Quantum Mechanics was a new theory in physics that had been discovered in the same period; at that time it was quite successful in describing atomic physics. But Lemaître realized that at the beginning, if all the matter-energy of the Universe was contained in a tiny region of space of atomic size, then its laws of physics should also have been quantum mechanical.

He was thinking of the early universe as an atom, and thus he formulated his theory of the "Primeval Atom". He imagined that this Primeval Atom would have disintegrated, starting the expansion of the Universe. In this respect Lemaître was a visionary in cosmology, because even as he formulated the first theory of the beginning of the universe (the Big Bang) he foresaw the problem of singularities in cosmology. This would lead to the search for a unification of general relativity and quantum mechanics, Quantum Gravity, which remains an unfinished job to this day.

After three days dedicated to presentations and discussion, the participants were honored with a Papal audience on May 12, where Pope Francis spoke to all the participants before leaving for the centennial celebrations in Fatima. In his address, Pope Francis recalled the figure of Mons. George Lemaître, noting the careful division he followed between theology and science, and the wonder for Creation that the study of the universe generates in all human beings.

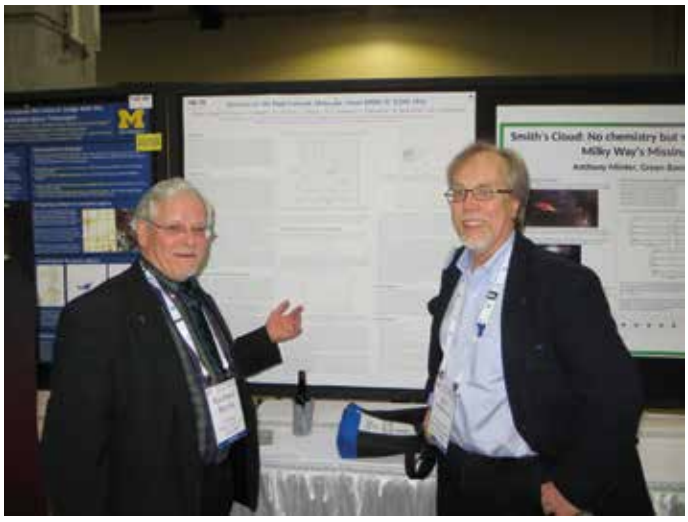
The theory of the Primeval Atom was a joy and a cross at same time for Lemaître. It was a source of incomprehension. The famous British astrophysicist Fred Hoyle was the one who renamed the theory "Big Bang", making fun of it since, he said, it seemed that the universe was born from an initial "bang". Einstein himself, as was the suspicion of many scientists, didn't like Lemaître's hypothesis because it was too close to the "fiat" of Genesis in Scripture. It was in this atmosphere of opposition that Lemaître developed his personal way of making a sharp separation between the two realms of faith and science. Although the young seminarian Lemaître thought that at the beginning of the Universe all energy was light and that the scripture carried a hidden meaning that could be used to extract scientific knowledge, his successive study of General Relativity dissolved this juvenile belief. Making shortcuts from theology to science and vice versa, he realized, could only be dangerous for both.

Participants at the workshop into the Papal Villas at Castel Gandolfo

2017 A Year in Review

Staff and adjunct scholars take us through 2017 at the Vatican Observatory, a year rich in activities for the Pope's astronomers.

Father Richard BOYLE, S.J.



Fr. Boyle with collaborator B-G Andersson of Sofia Science Center / USRA, Moffett Field, CA. at their poster at the 229th Meeting of the American Astronomical Society, January, 2017 in Grapevine, Texas.

What have I been up to this past year? Up to VATT (Vatican Advanced Technology Telescope), in Tucson, AZ many times to observe celestial objects near and far.
My main research is with the group of astronomers of Vilnius University, Lithuania, and with Father Robert JANUSZ, S.J. and Jolanta Koszteyn of the Jesuit University Ignatianum in Krakow, Poland. From star fields in nearby regions of our Galaxy observed at VATT with the set of seven colored filters of the Vilnius Photometric System, we determine just from precisely measured colors of stars their different spectral types and amount of any intervening interstellar dust. Such measurements turn the 2-dimensional stellar "wallpaper" into 3-dimensional structure of these nearby (less than 2 kilo parsec) parts of our Galaxy.
In January I presented at the *American Astronomical Society Meeting* in Grapevine, Texas a poster-paper on one of these regions, on the distance to the high latitude molecular cloud MBM 37 (LDN 183). Father Richard D'SOUZA, S.J. requested VATT observations on a few fields known to have micro-lensed images of distant galaxies. This pertains to the CASTLe Survey (CfA-Arizona Space Telescope Lens Survey) of all known galaxy-mass gravitational lens systems (see *https://www.cfa.harvard.edu/castles/*). With the VATT 4KCCD camera I observed five 300-sec. exposures in the r' Sloan filter two object fields "PG1115+080" and "J0924" in my Dec. 21 - 28, 2016 VATT run. And on March 5, 2017 with the camera GUFI I observed the two objects: "PG1115" for 42 min. in r' filter, and "J1433" for 55-min. in i' filter.

I also used the Galway Ultra-Fast Imager (GUFI) several times at VATT to observe Brown Dwarf stars in my collaboration with Ray Butler and his graduate student Salam Dulaimi. And Father David BROWN, S.J. joined me again in October at VATT for doing further observations of a few sub-dwarf hot B stars. From these observations we can learn more about these evolved stars from the cyclic quakes in their atmospheres that tell from the pressure and gravity waves emanating from below about conditions and composition in their cores.

A little closer to home but on external galaxies "NGC 3521" and on "M 51" the Whirlpool Galaxy I observed in the Vilnius filters for VOSS alumnus Rafael Eufrasio for research concerning star formation. Two high school classes can now use these galaxy pictures also for astrophotography.

And in my collaboration with Casimir Cernis in the search for new asteroids in the Solar System,

I observed several fields near the ecliptic plane. Since about 2009, we have discovered over a hundred asteroids by making five minute sequences of exposures with no filtering. Last September, I presented a poster at the at the *European Planetary Science Congress (EPSC2017)* in Riga, Latvia, prepared together with I. Wlodarczyk and K. Cernis on four interesting asteroids discovered at VATT. One special one is the trans-neptunian object, TNO. Under Minor Planet Center rules our discovery by VATT observation in 2012 and our follow-up observations has allowed us to name this TNO. We have called it "Praamzius" the goddess of creation in Lithuanian mythology. From its orbit its distance is about 43 astronomical units from the sun and its estimated size from an assumed albedo of 0.08, typical of TNOs, is similar to the state of New York. It is a lower border-line case of being a dwarf planet.

Father David BROWN, S.J.

Fr. Brown, inside the dome in Castel Gandolfo, Rome

The year 2017 has progressed very quickly, almost as if giving an example (metaphorically) of Einstein's relativistic view of time proceeding at different rates for different conditions. The year started with the acquisition and setup of new computer hardware, which is necessary for me to do my work, since most of my research is done front a theoretical standpoint. Much of this work involves running computer simulations of double stars (binary star systems) or of stars in large clusters (thousands or millions of stars), for which programming languages like Fortran, Python, C, and IDL are used. In addition to running computer simulations, there is the ongoing task of processing (reducing) the data collected from past observing runs with the VATT, done with a software package known as IRAF.

Research once again continues to center around 'middle-aged' stars known as horizontal branch (HB), stars similar to what the Sun will become in advanced stages of evolution. After having evolved from Red giant star progenitors, these helium-burning (nuclear fusion of helium at the center of a star) have surface temperatures that are 5-6 times hotter than the Sun. One aspect of researching these stars deals with how they form. Astrophysicists are still not sure about the precise mechanisms about how they evolve from Sun-like stars. That being said, it is suspected that they form in binary star (double stars) systems in which one star loses most of its outer layers (the stellar envelope) to the companion star. The result is a star that consists of a helium-burning core surrounded by a thin envelope of hydrogen. A journal article, dealing with these possible binary mechanisms of sdB star formation, is planned for submission for publication in early 2018. Its title is *Subdwarf B Stars from Binary Star Interactions at Different Metallicities: Population Synthesis Results.* Before the publication of that article, another article is also planned for submission for publication: *An Expansion of the Mass-Orbital Period Relation of sdBs from Stable Roche Lobe Overflow.* The article deals with one of the possible ways by which sdB stars may form, the results of which will be incorporated into research for the other article mentioned above.

Research on sdB stars continues from the observational side of astronomy as well. I collaborated on an observing run (October 8-14, 2017) at Mt. Graham in Tucson, AZ with BOYLE, using the VATT. Results from observations of

the sdB stars PG 0014+067, PG 1047+003, PG 0154+182, and PG 1419+081, taken with VATT, will also be processed and analyzed in during 2017-2018. These stars, which were observed using our 4k and GUFI cameras, are pulsating sdB stars; that is, these are stars whose luminosity changes periodically. The study of such pulsations (asteroseismology) can yield clues about the interior structures of such stars, from which astronomical quantities, such as stellar mass can be calculated. These results will be ready by the time that the Vatican Observatory Summer School (VOSS 2018) begins, the subject of which will be 'Stellar Variability in the Era of Large Surveys'.

Scientific aspects of my research also continued with the presentation of results at various conferences throughout the year. In late March (27-31), I attended a conference at the nearby INAF-OAR Astronomical Observatory in Monte Porzio. It had the theme '*AGB-Supernovae Mass Transition*'. I was a member of the local organizing committee, and, in that capacity, I was able to award the Vatican Observatory-sponsored junior prize to the young scientist who had the most impressive research credentials at the meeting. Then during July 3-7, I attended the conference 'The Impact of Binaries on Stellar Evolution' at ESO headquarters in Garching, Germany, just outside of Munich. After this meeting, I left directly for Krakow, Poland where I attended on another conference '*sdB08: The Eighth Meeting on Hot Subdwarfs and Related Objects*' during July 9-15, 2017. Several possible future collaborations were talked about with various members of the sdB star research community, involving the use of the VATT. I presented posters at the latter two conferences.

The year 2017 also involved continuing maintenance, upgrades, and improvements to the telescopes that are located at the Roman branch of the Vatican Observatory. This past May, the Observatory acquired a portable 11" (28 cm) Celestron CGEM computerized Schmidt-Cassegrain telescope (with a German Equatorial mount) to use with small groups at Observatory headquarters/offices in the Papal Villa, a nice complement to the telescopes at the papal summer palace. Moreover, we are in the process of obtaining a rolling tripod for the telescope to aide with ease of assembly and transport. But perhaps the biggest development with the telescopes deals with the full restoration of the Cart du Ciel telescope (1891), which was completed this year, an effort that was coordinated by Claudio Costa and friends. The aim is to use the telescope for night-time viewings in conjunction with visits organized by the Vatican Museums. This will be part of visits organized to the Garden Domes building (home to our Schmidt telescope and Carte du Ciel telescope) after its full renovation last year. Finally, the Double astrograph telescope and dome (on the roof of the summer pontifical palace in Castel Gandolfo) have also been a work in progress. During July 15-29, seminarian Thomas Rausch (Diocese of Sioux Falls) and I cleaned, reorganized, and catalogued all of the astronomical instruments in the storage room inside the Double Astrograph dome. Then on Thursday, September 28, a crew of seven people (Claudio Costa, Salvatore Lamina, Francesco Rossi, Romano Reggio, Antonio Coretti, Federico Balzoni, and BROWN) dismantled part of the Double Astrograph telescope in order to extract the secondary mirror. It was then sent to northern Italy in order to be re-aluminized. Since then, it is now back at Specola headquarters, awaiting installation.

The year 2017 also saw two interesting media moments for me. One was an interview with Carol Glatz from *Catholic News Service* about the recent discovery of exoplanets (planets outside of our own solar system) around the star TRAPPIST-1. Part of the interview appeared in the article 'Discovery of Earth-sized Planets Boosts Hope of Finding Alien Life' on *Catholic News Service*.' Then later in May 2017, the BBC interviewed several members of the Observatory, including me, with the aim of producing an episode for the BBC Four program 'The Sky at Night'. The episode was titled *Inside God's Observatory*, and I was asked to speak about the various aspects of the evolution of stars, including about stellar classification according to the spectra (each chemical element has a particular light 'fingerprint') of stars. In conclusion, I was also privileged enough to have witnessed the total eclipse of the Sun which was visible in a wide swathe of the USA on August 21, 2017. It observed it in the small town of St. Claire, just south of St. Louis. It was an unforgettable experience.

Brother Guy CONSOLMAGNO, S.J.
When I was named the director in 2015, I also became ex officio a member of the Pontifical Academy of Sciences, and as such took part in my first Plenary Meeting at the end of 2016. The theme of that meeting was "Science and Sustainability" and so I chose to focus on that aspect of my own work on asteroids and meteorites with a presentation titled, "Exploiting Solar System Resources: Opportunities and Issues".


Brother Consolmagno, inside visuale's dome, Castel Gandolfo, Rome

In the 1990s, the idea of mining asteroids for their resources was pushed from science fiction to science in large part due to the efforts of Dr. John Lewis, an emeritus professor at the University of Arizona who in fact directed my master's thesis at MIT, and one of his students (and a one-time scientific co-author of mine), the retired astronaut Tom Jones, is now active in one of the start-up ventures that have been organized to commercially exploit space resources.

However, though the benefits of exploiting asteroid resources are many, this work will also carry with it certain ethical issues, such as the disruption of many third-world economies which depend on the exportation of raw materials, and the replacement of many low-skill jobs with fewer jobs requiring higher skills. These issues can be met, but they need to be recognized early on.

This topic has come to the attention of the United Nations and the Vatican's Representative to the United Nations Office for Outer Space Affairs, Mons. Janusz Urbańczyk. The Specola will be working further with them on this topic in the coming year.

Meanwhile, my research into the origin of the basaltic achondrite meteorites and the "missing olivine" problem, described in last year's annual report, continues. This past fall, Don Davis and Stuart Weidenschilling (PSI) invited me to spend a morning with them at the headquarters of the Planetary Sciences Institute in Tucson, where we compared the problems of disrupting and dispersing the original parent body of those meteorites with their expectations from their research into collisions and accretion in the early solar system. From this meeting, plans are developing for a more broadly attended workshop day in early 2018. This looks to be the beginning of a beautiful collaboration.

Beyond the science, most of 2017 has seen me on the road fulfilling the other aspect of our charge from Pope Leo XIII: to "show the world" that the church supports science. I have been showing the world by giving talks and representing the Vatican Observatory in a number of venues. In fact, I have counted up more than 90 different presentations that I have given over this past year, along with more than two dozen press interviews. Some of these are detailed in the "presentations" and "media" sections later in this report.

One particular highlight of my public presentations was giving the banquet address at the first ever meeting of the Society of Catholic Scientists, which was held in Chicago in April. This society, organized this past year by Prof. Stephen Barr, has already attracted nearly 500 members.

The Vatican Observatory Foundation and the Vatican Observatory Research Group held our third Faith and Astronomy Workshop at the Redemptorist Retreat Center in Tucson from January 16-19. This brought together 25 Catholic educators and amateur astronomers for a week of exploring our universe, as well as learning how professional astronomers and collaborators of the Observatory actually do their science. As has been his custom, Tucson Bishop Kikanas opened the event with a Mass on Monday evening. Besides my own participation, CORBALLY and MACKE led a discussion of their research at the Observatory. Unfortunately, the planned visit to Kitt Peak National Observatory had to be cancelled due to snow on the mountaintop.

From March 19-15, it was my pleasure as President of the Vatican Observatory Foundation to accompany a group of a dozen VOF supporters on a pilgrimage to astronomical and historical sites in Italy. Along the events of that week were a visit to Secchi's observatory above the roof of St Ignatius Church in Rome (accompanied by Aldo ALTAMORE) and to the Tower of the Winds at the Vatican.

The group of VOF supporters, accompanied by Aldo Altamore

The group also got to visit religious sites in Assisi, the famous K-T Boundary site in Gubbio, Umbria (site where the first samples rich in extraterrestrial iridium were sampled, leading to the theory of an impact-related extinction of the dinosaurs) and a private tour of Galileo's home in Arcetri.

The year also found me back in the classroom for two weeks of special presentations. I was invited back to Notre Dame University in June to present a week of lectures at the annual Science and Religion seminar. Another course of lectures that I gave this year were ten hours of talks on the History of Planetary Sciences at the Scuola di Studi Superiori "Giacomo Leopardi" of the University of Macerata, Italy.

An unusual honor came to me twice this year, as I was invited to serve as the science guest of honor at two science fiction conventions: MiniCon in Minneapolis, Minnesota, in April and at the North American Science Fiction Convention in San Juan, Puerto Rico, in July. While in Puerto Rico I was able to give a scientific seminar at the Arecibo Observatory on my basaltic meteorite work, and speak to a group of avid high school astronomers at the San Antonio de Padua High School San Juan. who have built a beautiful observatory on the roof of their school. Thus when Hurricane Maria hit Puerto Rico three months later, I could feel a personal tie to my new friends there who are still (as of late 2017) recovering from its effects.

The most memorable event of this year for me, however, was my experience of the total eclipse of the sun on August 21 as the guest of the St. Peter and Paul's Parish of Hopkinsville, Kentucky. Along with talks to the school and a public event at the parish, and a number of media interviews, I also was honored by a personal visit from the honorable Matt Bevin, Governor of Kentucky.

Father Christopher CORBALLY, S.J.
What? A book on *Space Science and Astronomy Theatre*! "That's an unusual science-art combination," you'd say. And you would be right. I got into this thespian world thanks to my lead co-author Margaret Boone Rappaport, an indomitable colleague with a doctorate in cultural anthropology.

It all arose in response to our pondering what on earth to do for the Inspiration of Astronomical Phenomena (INSAP) conference 2013 at the Hayden Planetarium in New York City. Margaret and I wanted to put some new ideas across to a

mixed audience of scientists, artists, and writers. This complex of ideas flowed from our long careers in many disciplines, and centered around the underpinnings of human thinking in science, religion, and art. It was heady stuff! We had both been professors and given academic lectures: too abstract and boring for the INSAP group. So, what else could we do? One of us, and maybe both at once exclaimed, "Let's do a skit!" At that point, we both broke out in gales of laughter that subsided only when we realized we were both quite serious. So, I provided the astronomy, and Margaret provided her anthropology and gift for writing dialogue. In this unexpected way, our venture into using short, theatrical scripts and dialogues to educate about science, culture, and religion was born.

Over the next six months, we wrote more scripts and performed them in private homes, libraries, and at public gatherings to a variety of audiences. It was fun for everyone. Eventually we had twelve of them. We designed the scripts for students who may have given only light to moderate consideration of a science major and a science career, and other students who are captivated by space projects and astronomy but do not know how to articulate their interests with available career paths in the space agencies and astronomical research facilities.

Corbally presenting a poster paper with Margaret Boone Rappaport at the ASP Annual Meeting in St. Louis

We wrapped each script in a "package" that a teacher could use with a class: an explanation of the science and of the cultural background to a script; keywords for each student to explore before the script was performed and a few questions to answer; the script itself, lasting between 5 and 6 minutes; and some discussion questions after the script. We also added suggestions for simple props and costumes. There is always a point of tension in the script to keep interest, followed by some resolution, maybe with humor.

Do they work as a teaching tool and means to interest students in science? To find out we evaluated three script packages that we gave over the course of a morning to a graduating class of high school students. This research helped us develop best practices. We also tried out some of our scripts in several different college classes in astronomy.

In July, we presented the results of our evaluation at an International Astronomical Union Symposium on Education in Astronomy and Astrobiology in Utrecht, The Netherlands. Yes, the interest of those who self-identified as humanities students jumped up during the "scripts morning." Moreover, and surprisingly, the recollection of the women in humanities as to their past interest in science declined: i.e., the more they became involved in the scripts, the less they thought they had previously been interested in science careers. How gratifying this change of interest was to Margaret and me!

The effectiveness of "experiential learning" was confirmed by other talks during the Utrecht Symposium. Another tip we took from the meeting was to use social media to stir up interest in our theatre project. Once a social media chain gets started, one can reach out to the hundreds, the thousands, and even millions. So, when our book at last appeared in print through Archway Publishing during August, we set about learning Twitter. Do please retweet anything you enjoy from @AstronomyPlays! We have included lots of pictures. There, you'll also find the link to ordering a copy of the book.

Our other very significant project this year was writing, and having accepted for publication in *Zygon: Journal of Religion and Science*, three papers on the "Evolution of Religious Capacity in the Genus Homo." We best wait to describe the results of this extensive research after the papers have appeared in print, but you will find some pointers on the website of The Human Sentience Project (*http://TheHumanSentienceProject.org*).

Stellar Astronomy

In collaboration with several colleagues, I have continued to investigate the phenomenon of lambda Boötis-type stars, a puzzle for over 70 years. These are chemically peculiar stars on the upper main-sequence, 2 to 3 times the mass of the Sun but in its same stage of "core hydrogen-burning" evolution. They show near-solar abundances of carbon, nitrogen, oxygen, and sulphur in their atmospheres, but have up to 100-times deficiencies in the iron-peak elements, like iron, magnesium, and aluminum.

Thanks to the leadership of Joanna Molenda-Żakowicz (Uniwersytet Wrocławski), we have been acquiring high-resolution, high signal-to-noise spectroscopic observations for selected lambda Boötis-type stars, which have (from KEPLER) or will have (from TESS) high-accuracy satellite data on their variations in light output as they pulsate. So far this year we have excellent spectra from the 11-meter Southern African Large Telescope (SALT) for 54 stars and from the Astrophysical Research Consortium 3.5-meter telescope at Apache Point Observatory, NM, for four critical stars. All these high-quality data will be input into modeling the stars' composition via asteroseismology, so we can understand whether they are chemically peculiar only on the surface or throughout the whole star. How gratifying it is to be making good process, though there is still much work to be done!

Father Richard D'SOUZA, S.J.

Over the last year, as part of my postdoc here at the University of Michigan, Ann Arbor, I have continued my attempts to understand the diversity of galaxies found in the Universe. Galaxies come in all shapes and sizes – from the smallest known-dwarf galaxies containing 1000 stars to the largest known galaxies containing 10^{12} stars. Even at a fixed amount of stellar material – for example, at the mass of our galaxy, the Milky Way- there is an enormous amount of physical diversity ranging from star-forming disk like-galaxies to dead elliptical galaxies. While we have a few ideas, we cannot really quantitatively explain this physical diversity. It has been long believed that the merging of galaxies in the Universe is responsible for some of this physical diversity. We see dramatic examples of galaxies colliding and merging in the Universe. While mergers of two equally sized galaxies is considerably a rare occurrence today, a large galaxy like our own Milky Way have eaten-up ('accreted') a large number of smaller galaxies. Indeed, apart from forming their own stars, one of the other ways in which galaxies grow in the Universe is through accreting other smaller galaxies. While this idea has been firmly established, we have yet to understand what mergers actually do to galaxies: what are their physical consequences? While we can directly observe examples of galaxies merging, we actually cannot measure their consequences. On the other hand, while we can measure the diversity of galaxies in the Universe, till now we had no access to an observational measure of the merger history of a galaxy.

Father D'Souza

Technological advances in observing low-surface brightness regions around galaxies have revealed that there is a low-density halo of stars surrounding galaxies – technically called the 'stellar halo'. This low-surface brightness regions around galaxies are the tidal debris of smaller galaxies which have

been tidally disrupted by the main central galaxy. Hence, these low surface brightness regions encode information about the galaxies that have been accreted in the past. This is comparable to the analogy that the smaller galaxies often leave breadcrumbs as they are eaten by the host. By studying these breadcrumbs around the central galaxy, we can decipher what type of smaller galaxies were eaten.

As part of my PhD I developed techniques to observe the average properties of these stellar halos from large-scale surveys. Now, in my postdoc here at the University of Michigan, I am concentrating on developing theoretical tools to understand and interpret observations of the stellar halos of galaxies. In particular, I am trying to decode from the map of the stellar halo of a galaxy, what are the properties of the most significant and massive satellite to be accreted.

To develop these models, I am using large hydro-dynamical cosmological simulations. These simulations incorporate the effects of dark matter, stars as well as the effects of gas (which are ultimately converted to stars). Moreover, these simulations cover a large dynamical range from the smallest satellites to the largest types of galaxies by simulating a large volume (a cube) of the local universe. For instance, one of the sides of this cube will be larger than 10 times the distance from the Milky Way to Andromeda. Such a large volume contains a lot of Milky Way like galaxies. Each of these galaxies had a different accretion history. Hence, by simulating a large volume, these simulations also encode a diversity of accretion histories for Milky Way like galaxies. In our simulations, we know the accretion history of each of our galaxy – in terms of the mass and the timing of the merger of the satellite galaxy. By carefully comparing observations of stellar halos of nearby Milky-like galaxies with those found in our simulations, I am developing metrics which can help us decipher the properties of the most significant merger. This has resulted in a theoretical paper which will be appearing shortly in print.

Moreover, we have also tried to apply our metrics to decoding the most significant merger of our neighboring galaxy, Andromeda (M31). Our closest neighbor is the best observed of all the galaxies in the local Universe. Over the last decade, several teams have invested large amounts of observing time to study its huge stellar halo. M31 has a stellar halo which is nearly 10x more massive and at least 20 time more metal rich than our own Milky Way stellar halo. Using this rich data set in conjunction with our models, we have been able to tease out the properties of M31's most significant merger. We found that in order to reproduce the properties of M31's stellar halo, M31 must have merged with a smaller but massive galaxy (about 10^{10} stars, nearly 1/10 to 1/5th the size of M31) nearly 2 billion years ago. This galaxy would have been the third largest member of the Local Group after M31 and the Milky Way, and was considerably larger than the largest satellite galaxy of the Milky Way, the large Magellanic Cloud. Together with my mentor here in Ann Arbor, Eric Bell, we have written up these results and submitted them for review. Much of this work was done and written up in the two months I spent in Rome over the summer.

By studying the stellar halos of nearby Milky Way galaxies, we can finally begin to ask the question how mergers affect galaxies. In a paper published earlier this year, we found evidence that mergers are not solely responsible for the creation of central bulges in Milky Way like galaxies. We came to this conclusion by studying the stellar halos of 6 nearby Milky Way mass galaxies and comparing the estimated masses of their predicted significant mergers with the size of their central black holes and their central bulges. We did not find much of correlation, indication that there are possibly diverse ways in which galaxies grow their central bulges and that merging is not the sole cause of it.

Over the last year, I have also been engaged in a number of public outreach talks. In November of last year, I presented a talk on "God and the Galaxies: a Jesuit perspective from the Vatican Observatory" at St. Paul's College, University of Winnipeg, Manitoba. A number of science-faith talks were also given to the members of the local St. Mary's student

parish, the Catholic chaplaincy at the University of Michigan. Finally, I also spoke at the annual Vatican Observatory Foundation seminar held on 14th Oct in Ann Arbor about my academic work here at the Univeristy of Michigan.

Father Pavel GABOR, S.J.
For me, 2017 was a year of two VATT-related miracles. In March, the VATT 4k CCD Imager died. The fault was with its central component, the CCD chip itself. Without an imaging camera, many research programs on VATT were to come to a halt. I knew that replacing the imager meant having a new one built. To take advantage of Mount Graham's observing conditions (so called "seeing") and considering VATT's optical design, the appropriate chip is one with 15-micron pixels covering a square of 2.4 inches by 2.4 inches (6 cm by 6 cm). Unfortunately, such chips are not standard, which means that they have to be specially manufactured. Such an order takes more than a year to complete and costs $100,000. The prospects were bleak. Two weeks after the VATT 4k CCD chip failure, the first miracle of the year happened. Mike LESSER, head of Steward Observatory's Imaging Technology Laboratory, found an unused twin of the original chip. It sat in a box all these years, waiting for the right moment to come to our rescue.

The second miracle was no more dramatic and surprising for me but much more spectacular. It was the Frye Fire [See chapter four]. VATT survived the catastrophic conflagration without any damage.

Looking at the terms of VATT's the insurance policy I found that it would have fallen short if the fire had destroyed the telescope. I don't consider relying on miracles a sound strategy. The policy needs to reflect VATT's current replacement value. That means that we need an inventory for insurance purposes as well as a record of our assets. I found that Steward had experts on inventorying astronomical facilities, and I started the process with their help.

In January, I received an invitation to address a colloquium celebrating the 25th anniversary of the restoration of the University of Trnava, Slovakia. The original University was established in 1635 by Cardinal Peter Pazmany, S.J., and entrusted to the Society of Jesus. There was a significant astronomical observatory there in the 18th century run by (former) Jesuits after the suppression of the Order in 1773, and even after the University was moved to Budapest in 1777 (it later became the Lorand Eötvös Research University, Hungary's top science university boasting 5 Nobel laureate alumni). The 18th century library and astronomical equipment is preserved there.

The invitation prompted me to start looking into the Jesuit astronomers associated with Trnava. I found indications that they may have been among the proponents of the Catholic Enlightenment together with other Jesuit astronomers in Provinces

Father Gabor with Ryan Madrak, Ph.D., at the Benedictine College, Atchison, KS, August 21, 2017

of Austria and Bohemia, and possibly also of Silesia and Greater Poland. What was their position within the Society of Jesus? How much influence did they wield? How did they shape the educational institutions of their day? The topic will require more research. My paper merely frames and outlines my questions, and I submitted it for publication in the journal *Fons Tyrnaviensis*. I hope to continue this line of inquiry with collaborators from Trnava.

Another new research project I am very excited about is the VATT-PEPSI-TESS survey. The goal is to prepare spectroscopic deliverables on 311 brightest stars (V < 8.5 mag) to be observed in the vicinity of the North Ecliptic Pole (800 sq deg) by NASA's *Transiting Exoplanet Survey Satellite* (TESS) mission.

If, from our point of view, a planet passes in front of its host star the star appears to grow a little dimmer (this is a "transit"). TESS will try to detect exoplanets on the basis of this effect. What will we be able to tell about the detected exoplanets? Two key things: the exoplanet's period of revolution around its host star from the timing of the observations, and the exoplanet's geometrical size relative to the host star from the amount by which the host star grows dimmer. If the host star becomes less bright by 1%, i.e., 1/100, that means that the planet's disk obscures 1/100 of the host star's disk, i.e., that the planet's diameter is 1/10 of the diameter of the host star. But how large is the planet in absolute terms? What is its diameter in miles? That depends on our knowledge of the absolute diameter of the host star. Spectroscopy can tell us a lot about the composition of the star and about the conditions in its photosphere. Using these data, stellar astrophysics can tell us the diameter of the star. This simple example shows why it is vital to know as much as possible about the host star if we want to learn about its planets.

Thanks to the optical fiber link channeling light gathered by the VATT to the ultrahigh-resolution spectrograph PEPSI in the LBT building, we shall obtain two ultrahigh-resolution spectra (R=200,000) for of each star on our target list. Each exposure will take about 90 minutes (S/N of 100:1 in the red and 50:1 in the blue), amounting to 150 nights spread over three years. We shall observe for 50 consecutive nights from the last week in May to mid-July in 2018, 2019 and 2020, finishing the survey in time for the first TESS discoveries.

What makes this so interesting for me is that the spectra will be analyzed by a team of world-class experts. I hope to learn a lot. The survey deliverables are:
• Radial velocity: A single radial velocity per spectrum good to 2-3 m/s.
• Global stellar parameters: effective temperature, gravity, metallicity, microturbulence, v sin i, mass & age from a comparison with tracks and isochrones and a Gaia parallax.
• Chemical abundances of as many elements as possible. Most importantly α elements and CNO.
• An average line bisector and differential wavelength shift as a measure for convective blueshift.
• Activity: Hα & Hβ and CaII IRT line-core fluxes.

In the meantime, work continues on VATT's upgrades (see section on *instrumentation and technical services*). We have replaced the secondary-mirror support system with a new one. Over the years, we have lost much time maintaining the increasingly ornery old system, culminating in a major campaign in October and November 2016. In the end we found that the system worked adequately if its control electronics were kept at temperatures exceeding 80° F. Considering that these were in the same room as other crucial electronics (including the VATTEL server) and that electronics in general prefer a cooler environment, the situation was untenable.

We purchased a new support system (a hexapod from *Physik Instrumente*). Michael FRANZ designed a mechanical interface fixing the aluminum hexapod to the secondary mirror's steel baffle barrel. Scott SWINDELL wrote the new software. The new system was successfully commissioned at the beginning of November, making VATT more stable and reliable.

We have a new principal engineer, and I am optimistic that we shall commission the new encoders and drivers before the end of the season 2017/2018. This will make VATT's motion even more reliable, accurate, precise and smooth than it already is. It will mean less pointing overhead (the time a telescope needs to go from one object in the sky to the next) and better quality data (imperfections in how a telescope follows Earth's rotation lead to distorted images; when taking spectra, we want all of the light from the object to enter into the spectrograph; the imperfections in telescope's motion lead to fluctuations in how much light enters the spectrograph).

Father Gabriele GIONTI, S.J.

This year part of my work has been collecting papers for the conference *The 80th Anniversary symposium of the Vatican Observatory in Castel Gandolfo* together with Jean-Baptiste KIKWAYA ELUO, S.J. It has not been an easy task, because, although we set a sharp deadline for the submission of the speakers' conference papers, we had to change the final date of the proceedings conference book first draft submission three times. We really experienced what it means to "beg" since, with some of the participants, we had to be patient and wait until they submitted their paper. Jean-Baptiste and I decided, in order to have a good final product, to read all the papers submitted, check if there were same major corrections to inquire from the authors and choose referees for every single paper. Our goal was to have the best possible final book of proceedings. Of course this process was, in the end, quite long. In some cases we even had to mediate between the author(s) and the referee because there were serious disagreements, but, we believe, this contributed to a high quality final product.

Father Gionti

At the same time, as I described in the cover story for this year's report, I was also working on the preparation of the Lemaître workshop *Black Holes, Space-Time Singularities and Gravitational Waves*. We, with the substantial help of Antonio CORETTI, prepared the website for the meeting. The conference had an international organizing committee and a local organizing committee. I was the main reference person for the workshop, although I was greatly much helped by Alfio Bonanno and Fabio Scardigli. We were blessed to that renowned cosmologists (fifteen invited) accepted our invitation as guest speakers. The main issue at stake was how to recruit the remaining participants. There were diverging opinions on this that lent to no small amount of tension and stress, so we decided, in a communitarian way to invite prospective participants to apply for the meeting and the international organizing committee proceeded to select the best candidates. Therefore we set up an e-mail account to receive the applications and I took on the task of promoting the workshop in order to attract subscriptions. The result was quite good and it was a surprise for us that such renowned scientists enrolled as participants in the workshop. The practical organization of the workshop was also quite difficult for me, since It was my very first experience of the practical matters involved in organizing a conference from catering, flight tickets for the invited speakers to the time schedule of the talks. But I survived. The scientific level of the conference was very high. People experienced the familial atmosphere at the Specola, which encouraged deeper discussions and reflections on unsolved issues. During the conference we benefit the help of Daniela Recupero for coordinating the major practical asptects.
Media coverage went also extremely well, thanks to a press conference we did at the Vatican press office on the morning of May 8. To the joy of our participants they were received by the Pope in private audience on May 12.

This year I continued to work with my collaborator, Alfio Bonanno from the Astrophysical Observatory of Catania and his Ph.D. student, Alessia Platania, on Asymptotic Safety. Asymptotic Safety is an approach to Quantum Gravity in which the Gravitational Constant G and the Cosmological constant Λ are not anymore fixed, but they run, according to a flow determined by equations defined by the Renormalizzation Group, in order to find a non-Gaussian critical point and defining the theory at this point. We worked on different subjects related to the study of the ADM analysis of FLRW cosmologies improved through the renormalization group. At the beginning we studied FLRW cosmologies in a gravity theory in which we have considered the trace of the Ricci tensor and the square of the Ricci tensor. In

this cases the main problem was how to manage the boundary term. Thus we developed a constraint theory analysis of theories with higher order derivatives.
In a parallel way, in order to study the simplest case, we analyzed the theory with only the trace of the Ricci tensor in which we eliminated the boundary term by introducing a York term. Analyzing this simple model with a scaling relation of the constants G and Λ, we derive cosmological models that at the sub-Planckian regime exhibit bouncing universes and emergent universes as well. This result was reported in a letter, which was accepted to *Classical and Quantum Gravity*.
Since the end of May, after the Lemaître workshop, I have also been working on a project, with Alfio Bonanno and Father Matteo GALAVERNI, which aims to show that gravitational waves produced by coalescing objects could produce a breaking of the duality symmetry in electromagnetism so that the one could detect, in principle, a variation of the number of the right and left elicity photons coming from the coalescing objects.

Recently, with Andronikos Paliathanasis of the Universidad Austral de Chile, we tried to fix an issue in Duality Symmetry in alternative theories of Gravity, which I left open for years. It was quite nice to go back to study this problem. We have already a draft for a paper on this work, that we have posted on the electronic archives arXiv:1711.11106v1.

I continued my collaboration in philosophy and science with Dr. Alfredo Sgroi. This time we have completed and published a paper on the some aspects of the concept of time confronting and contrasting physical and philosophical theories in *La Civiltà Cattolica*. We explicitly wanted to inquire whether time exists or not. We confronted and contrasted existential philosophy on this issue with Husserl's position passing through St. Augustine's discussion on the nature of time. We arrived at the conclusion that the question of the existence of time is in itself quite problematic and there is not yet a definitive answer!

This year I also gave a serious of public talks on several subjects like the beginning of time in our Universe, the Lemaître theory of the Big-Bang, the problem of concordism in Theology and Science and the problem of time in science, theology and philosophy. I began with a lecture at the Gregorian University, a talk in the conference *The Discovery of the Gravitational Waves and its consequences for the Society* held in Pune, India, January 24-28 at the Pontifical School of Philosophy and Theology, organized by Fr. Job Kozhamthadam, S.J. I gave a series of talks in various parishes in Italy and a talk at the Festival of Science and Philosophy in Foligno (PG) invited by Prof. Roberto Battiston, director of A.S.I. (Italian Space Agency).

Father Jean-Baptiste KIKWAYA ELUO, S.J.

Father Kikwaya Eluo

There are three major ways to conduct research on asteroids: astrometry, photometry, and spectroscopy. But when it comes to study their physical characterization, which is my main project on asteroids, only the two last approaches (photometry and spectroscopy) help. Now, between the two, spectroscopy gives the direct results, and therefore is the most preferable. Yet, it has several shortcuts. Spectrographs are designed to observe only very bright asteroids with a limit in magnitude around 15 and 16. The size range of asteroids (NEOs) I observe corresponds to the absolute magnitude bigger than 22, meaning that their apparent magnitude are

not less than 18.5. The reason for me going only after these asteroids is simple. Beside their physical characterization, one can be able just in one run (4, 5 nights of observing) to determine their rotation spinning rate. Also, being small and NEOs, they eventually end up getting into the Earth atmosphere, producing fireballs, and meteorites, giving us then the opportunity to study them closely and even in our laboratories.

Since 2012, I study asteroids using photometry, or precisely what we call spectrophotometry, broadband spectroscopy, that consists in using a set of filters to cover one region of the electromagnetic spectrum. In my case, I concentrate on the visible part of this region that I cover with 4 broadband Johnson filters: B, V, R, and I. In 2015, I started to use not only the two-color plots to infer the color of asteroids, method used for decades since 1970 (Chapman, Ed Tedesco, David Tholen, Zellner, …), but also the optical reflectance of the asteroids that I compare through the least square method with the real observed asteroid spectra collected and made available in a database from 2001 (Bus, Binzel, DeMeo, …). The idea behind this effort remains to gain in accuracy in determining the physical characterization of NEOs. Another contribution in this effort could come from the study of the dynamics of the NEOs themselves. The question will be to establish whether the track one asteroid takes from the main belt to the reservoir of NEOs could be linked somehow to its color in particular, and to its physical characterization in general. This has been done before, but with a very small sample of data. The result was that asteroids with different colors were present in different families of NEOs (Apollos, Athens, Amors…) and were supplied in the reservoir of NEOs through different tracks going from seasonal secular motion μ6 to the mean motion resonances (3:2, and 5:2). Nevertheless it is worth trying again with a much bigger sample of NEOs. For this, I work in a very close collaboration with Mattia Galiazzo of the Institute of Astrophysics of the University of Vienna (he works on dynamics of the solar system) to address in a series of papers, the first to be published soon (Physical characterization and past orbital behavior of 11 NEOs fast rotators) whether dynamics can bring one more constrain in the understanding of the physical characterization of the asteroids. Is one particular NEO is what it is because of its origin, and also its evolution, the mechanism through what it arrived in the reservoir of NEOs?

The last thing I can mention about my research this year is the debate around the set of filters I used during the observation runs. My choice of broadband filters (B, V, R, and I) was justified by the fact that the fast NEOs I'm observing are faint, therefore the bandwidth of filters should be big enough to collect enough light in less than two minutes of exposure time. But when I compute the optical reflectance of these NEOs, they seem to cut off all interesting features we see in true observed asteroid spectra and that give us some ideas about the mineralogy of asteroids. There are three interesting absorption bands in the optical spectra: one around 0.6 micrometer representing Saponite (Cfr. Rivkin's article in Asteroid IV), one around 0.7 micrometer for Serpentine, and the famous 0.9 micrometer linked to the presence of olivine. Is there any way to see these features when still using spectrophotometry? My new idea is now to use ECAS filters (b, v, x, w, and p) instead of Johnson broad band filters. I do this work in collaboration with PSI (Planetary Science Institute) located in Tucson, and particularly with one of its members, Ed Tedesco. ECAS filters have very narrow bandwidths, and using them requires to increase the exposure time. Patience and work meticulously done are the keys to success for the project. I hope with this new set of filters to produce NEOs optical reflectances that will closely match the observed spectra, and therefore claim within an acceptable margin of errors the same physical characteristics.

Father Giuseppe KOCH, S.J.

Over the past year the Vatican Observatory library has gained 45 linear meters thanks to a new shelving system which includes a new display cabinet for recently published journals and magazines.

We are also pushing ahead with our painstaking compilation of the digital catalog: over the last few months about 800 books have been added. Several books have been relocated with greater attention to their specific themes. There is also a link to many vintage

magazines. We also plan to develop a special 'Antique Book Catalog', which is a valuable source for scholars and academics interested in the history of astronomy. Among those who have availed of the resources offered by our library this year, one scholar made a remarkable discovery: While consulting the 1674 volume *Cursus seu Mundus Mathematicus* by Jesuit Claude François Milliet Dechales (1621-78) [we have a second edition of 1690] Christopher M. Graney found that the phenomenon commonly known as Coriolis Effect had already been described by the Jesuit almost two hundred years before Coriolis himself. He published his finding in the July 2017 issue of *PhysicsToday* (pp. 12-13).

Father Koch before the new shelving system at the Specola Library.

Brother Robert MACKE, S.J.

This past year, I have continued my research with meteorite physical properties. These include density and porosity, as well as heat capacity. Two types of density are measured: bulk density (based on the entire volume enclosed by the outer surface) and grain density (based on the volume of just the solid component, omitting pore space). For the former, we use 3d laser scanning to produce a computer model of the outer surface of the meteorite, from which the volume and density is calculated. For the latter, we use ideal gas pycnometry, in which the pressure change as nitrogen or helium gas expands in volume is used to calculate the volume displaced by our meteorite. Porosity, or the percentage of pore space, is calculated from these measurements together. Heat capacity, or the energy per unit mass required to change the temperature by one degree C, is measured by a liquid nitrogen immersion technique developed by CONSOLMAGNO. *A summary of my past work as well as that of others was published this year in a review article in Chemie der Erde.*

The research that I do is part of several collaborations. The most notable is my collaboration with Walter Kiefer (Lunar and Planetary Institute), Dan Britt (University of Central Florida), and Anthony Irving (University of Washington) to measure densities and porosities of lunar and martian materials, including Apollo moon rocks, to better interpret gravimetric data from orbiting spacecraft, and ultimately to better characterize the crusts of the Moon and Mars. We have now completed the data gathering part of this study, this year measuring the last eight of over seventy total Apollo specimens at NASA Johnson Space Center in Houston. This year, due to difficulties in travel, Kiefer did the laboratory work and sent the raw laser scans and data to me here at the Observatory, where I processed them to produce final results. We are now in the process of analyzing a mountain of data accumulated over more than five years, and hope to see publications within the next year.

I am also collaborating with George Flynn (SUNY Plattsburg), Melissa Strait (Alma College), Dan Durda (NASA Ames) and others to study the behavior of high-energy impacts on porous meteorites, and the relationship of this behavior to porosity and other physical properties. They use the NASA Ames Vertical Gun Range to impact meteorites with aluminum slugs, and study the

Brother Macke

strength and recoil of these objects, determining the momentum multiplication factor β, which is the change in momentum of the target object divided by the momentum of the impactor. If there were no ejecta, momentum transfer would give a β-value of 1. The mean β-value for the ordinary chondrite NWA 869 is 2.7. The excess is due to ejecta thrown off during impact, which increases the recoil of the target. Because porosity is a vital physical property to incorporate into this study, I measure this property for both impacted and non-impacted specimens. The impacted specimens of NWA 869 are on average about 8% porous, not significantly different from other ordinary chondrites. It is too early to determine if there is any difference in porosity before impact versus after impact. *This research was presented at the 80th Annual Meteoritical Society meeting; the 48th Lunar and Planetary Science Conference; the 14th Hypervelocity Impact Symposium; and the 2017 meetings of Asteroids, Comets, Meteors; and the European Planetary Science Congress.*

I continue to collaborate with CONSOLMAGNO, Fr. Cyril Opeil (Boston College) and Dan Britt on the measurement of meteorite heat capacities (Cp) and other thermal properties at low temperatures (70-300 K). We are in the process of writing a paper describing our multifaceted approach to the heat capacities of ordinary chondrites, including whole-stone measurements performed by liquid nitrogen immersion, detailed study of Cp as a function of temperature for small flakes measured by a Quantum Design Physical Properties Measurement System at Boston College, and model heat capacities based on mineral compositions. We have found generalized parameters for the heat capacity curves for the three classes of ordinary chondrites (H, L, LL) over this temperature range. As a side project this year, I explored whether heat capacity by liquid nitrogen immersion for weathered ordinary chondrite finds might be used to determine degree of weathering in a quantifiable way, perhaps in conjunction with other physical properties such as grain density. This research was motivated by the fact that, in the weathering process, low-Cp iron metal is replaced by high-Cp oxidation products such as goethite and akaganeite. While ordinary chondrites do exhibit weathering-related trends, more work is needed before this approach might be used to actually quantify weathering. *This work was presented at the 48th Lunar and Planetary Science Conference.*
There are additional collaborations as well. With Jon Friedrich (Fordham University), Alex Ruzicka (Portland State University) and others, we study the relationship between meteorite porosity, shock, and internal structure of shocked meteorites. *This research has been published in Geochimica et Cosmochimica Acta.* With Gretchen Benedix and others from the Australian Desert Fireball Network (Curtin University), I have continued to help characterize meteorites collected by the Desert Fireball Network after observed fireball events. This year included the meteorite Dingle Dell, which was found in a very dry environment just six days after the fall. Its physical properties suggest that it ought to be classified as L/LL, rather than its initial classification as LL. *This research was presented at the 80th Annual Meteoritical Society Meeting.*

This past year I traveled to Bratislava, Slovakia to develop collaborations with Pavel Povinec and Juraj Toth (Comenius University), with the goal of assisting in their measurements of cosmic ray exposure ages of martian meteorites and to conduct a study of density variation with size of many fragments of the meteorite Kosice. While there, I also presented a colloquium on thermal properties of meteorites as asteroid analogs.

In other news, this year the International Astronomical Union bestowed on me the honor of naming an asteroid after me: 11266 Macke. According to IAU Minor Planet Circular 103977, this is for my contributions to planetary science including "studying the relationship between shock state and porosity in carbonaceous chondrites." This marks the fifth asteroid named after members of the Vatican Observatory. The others are: 14429 Coyne, 4597 Consolmagno, 23443 Kikwaya, and 302849 Boyle. In addition to scientific work, I continue to speak to high school and college groups when the occasion warrants, usually by telepresence from the comfort of my office in Castel Gandolfo. This past year I made presentations to the Mercy High School (Middletown, CT) astronomy club, the Bryn Mawr College (Bryn Mawr, PA) chemistry 252 class, and the Bishop DuBourg High School (St. Louis, MO) "Big History" class.

I have to continue my work making informational videos. In addition to a number of short interviews intended for private use within the Vatican Observatory, and a couple short clips that the National Jesuit Brothers Committee will incorporate into their productions, this year I have produced a short film introducing the Vatican Observatory for public audiences. This film was released on YouTube by the Vatican Observatory Foundation. In the future, more videos are planned. For this purpose, and to provide a good space for external film and news crews to perform interviews, we are planning to convert an underutilized space in a remote corner of our headquarters building into a video studio.

Father Sabino MAFFEO, S.J.

Father Maffeo

Early 2018 will see the second centenary of the birth of Father Angelo Secchi, S.J. Much of my work over the past year has been dedicated to preparations for events and celebrations to mark this anniversary. A conference organized together with Dr. CHINNICI will look at the life and work of Father Secchi based on the categories into which his writing has been divided: Biographical notes, his main scientific contributions; his personality as a scientist and a man of faith and his views on the relationship between science and faith.

Father Paul MUELLER, S.J.

Father Mueller

This was my second year as Vice Director of the Observatory, and it was notably calmer than the first. During my first year as Vice Director, I supervised several projects of restoration and construction which had been initiated by my predecessor Jozef Maj S.J.: the creation of a didactic lecture room adjacent to the telescopes atop the Apostolic Palace, the restoration and remodeling of the building housing the Carte du Ciel and Schmidt telescopes, and the construction of the new kitchen / dining room "Sala Clavius" adjacent to the Observatory's headquarters. But by late 2016, work on these projects had been completed. Consequently during 2017 I was free to turn my attention to other sorts projects for which my skills are better suited – I am a philosopher by training, not an engineer! Moreover during 2017 the Jesuit staff of the Observatory could begin to make good use of the newly completed spaces, at the service of the mission of the Observatory – which was a fine tribute to Fr. Maj's vision and planning.

In April I gave a public talk at the Stensen Institute in Florence addressing the topic *Pianeti extrasolari: alla ricerca dei gemelli della Terra*. This was one of a series of Stensen Institute conferences during the first half of 2017 addressing the general theme *Ricerca e esplorazione dell'universo: all'alba di una nuova era?* In September I presented a paper "The Scandal of Particularity" at the international interdisciplinary conference *Cosmological Evolution* hosted by the Ignatianum, in Krakow.

I continue to teach part-time at the Pontifical Gregorian University. During the first part of 2017 I concluded my course "Philosophical Questions in Physics", and during the second half of 2017 I have been at work preparing a new course to be offered in the first half of 2018, "Philosophical Questions in Biology". I also assisted with on-line interventions for courses offered at Clemson University and Loyola University Chicago.

I continue as a member of the editorial board of the *Philosophical Yearbook* of the Ignatianum, and this year I joined the editorial board of the new journal *Axioma Studies in Philosophy of Nature and in Philosophy and History of Science*. I serve as consultant to the Pontifical Council for Culture for projects concerning the dialogue of faith and science.

Throughout the year I hosted numerous groups for didactic visits to the Vatican Observatory at Castel Gandolfo, including groups from DePaul University, AstroBarcelona, the Lay Centre at Foyer Unitas, the Collegio Internazionale del Gesù, the North American College, the Fondazione Centessimus Annus Pro Pontifice, Lipsombe University, Loyola University Chicago, Boston College, and the Gregorian University Foundation. In addition I hosted visits to the Specola by ambassadors to the Holy See from Peru, the Republic of South Africa, and the Czech Republic. I also represented the Observatory in interviews given to Italian, French, American and Australian media outlets.

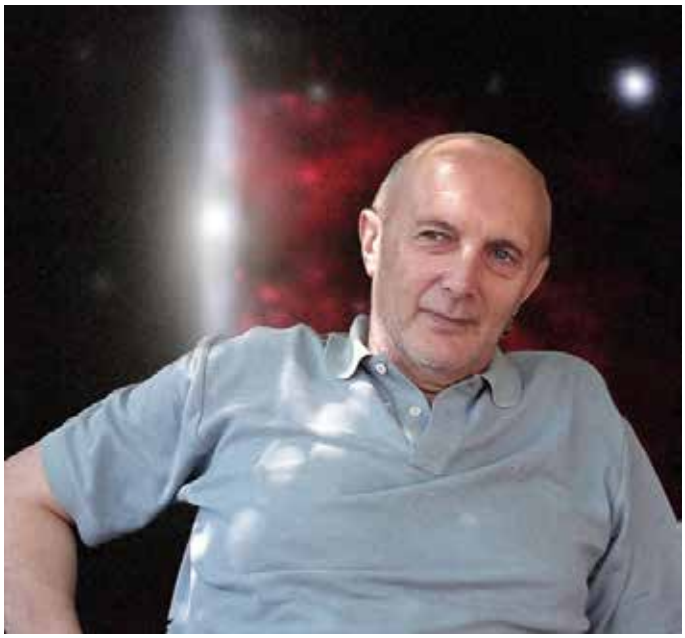
In February I preached the retreat "Guide Us To They Perfect Light" at Bellarmine Jesuit Retreat House in Barringon, IL. In March I gave a workshop on science-faith questions to the Novices of the Califorinia Province of the Society of Jesus. In September I assisted in directing week-long retreats for the third year seminarian of the North American College.

In October I gave the keynote address "From Miracles and Mysteries to Quarks and Quasars" at (re)Encounter, an event of the Archdiocese of Chicago attended by more than two thousand young adult Catholics. (re)Encounter intended to strengthen the faith of young adults, reminding them that they are not alone in their faith. The evening also featured a conversation about faith between actor Mark Wahlberg and Cardinal Blaise J. Cupich, Archbishop of Chicago. Also in October I preached a day of recollection for parents of students at St. Ignatius College Preparatory School in San Francisco.

As superior I am also responsible for the finances of the Jesuit community, and for the distribution of whatever surplus funds remain at the community's disposal at the end of the year. During this past year, the community gave from its surplus funds to support resettlement of immigrants in Italy, to support the Jesuits' Kino Border Initiative at Nogales, and to assist in equipping the Observatory's new kitchen in Sala Clavius. The remainder of the community's surplus funds were contributed to the "Fondo Opera", a reserved fund that the community is permitted to maintain to support the work of the Observatory. During 2017 the community's "Fondo Opera" was used to help support the ongoing studies at Tucson of a promising young astronomer from South America, who is an alumnus of a past session of the Vatican Observatory Summer School. The "Fondo Opera" was also used to fund installation of solar panels on the roof of the Jesuit community at Tucson. The installation of solar panels seems to us to be in accord with the orientation expressed by Pope Francis in his encyclical *Laudato si'*, and also it is expected that the cost of installation will be recovered within ten years via reduced electrical bills.

Father Alessandro OMIZZOLO
During 2017 I continued my work on scanning the historical plates of the Vatican Observatory archive, in particular the plates of the double astrograph telescope. The work consists not only of the digitization of the plates but also the storage on the fits images on hard disks and on double sided dvd (every 8.5GB dvd can host about 30 images).

The other part of my work consists in the study of the Jellyfish galaxies that me and my colleagues of the WINGS group found in the fields of our nearby galaxy clusters of the WINGS survey. In particular we are studying every Jellyfish galaxy candidate that we reported in the catalogue we published in 2016.



Father Omizzolo

The study is becoming more interesting, especially thanks to the use of the MUSE instrument. MUSE stands for Multi Unit Spectroscopic Explorer, an instrument realized by the ESO consortium, to work with the Very Large Telescope (VLT) in Chile. It is a panoramic integral-field spectrograph operating in the visible wavelength range. It combines a wide field of view with the improved spatial resolution provided by adaptive optics and covers a large simultaneous spectral range. MUSE couples the discovery potential of an imaging device to the measuring capabilities of a spectrograph, while taking advantage of the increased spatial resolution provided by adaptive optics. This makes it a unique and powerful tool for discovering objects that cannot be found in imaging surveys. (credit *https://www.eso.org/sci/facilities/develop/instruments/muse.html*).

In the two figures (fig. 1 and fig.2) you can see part of our jellyfish candidate observed with MUSE showing not only the color images of these galaxies but also the gas distribution inside these galaxies. In many cases the gas tails are clearly visible due to the stripping phenomena acting in these galaxies.

In order to complete this study of gas stripping phenomena we got observation time at VLT with MUSE with a long term program.

As part of this work we analyzed the connection between super-massive black holes and the stripping phenomena in our galaxies. When a supermassive black hole at the center of a galaxy accretes matter, it gives rise to a highly energetic phenomenon: an active galactic nucleus. Numerous physical processes have been proposed to account for the funneling of gas towards the galactic center to feed the active nucleus. There are also several physical processes that can remove gas from a galaxy, one of which is ram-pressure stripping by the hot gas that fills the space between galaxies in galaxy clusters. Here we report that six out of a sample of seven 'jellyfish' galaxies - galaxies with long 'tentacles' of material that extend for dozens of kiloparsecs beyond the galactic disks - host an active nucleus, and two of them also have galactic-scale ionization cones. The high incidence of nuclear activity among the most striking jellyfish galaxies may be due to ram pressure causing gas to flow towards the centre and triggering the activity, or to an enhancement of the stripping caused by energy injection from the active nucleus, or both. Our analysis of the galactic position and velocity relative to the cluster strongly supports the first hypothesis, and puts forward ram pressure as another possible mechanism for feeding the central supermassive black hole with gas.

Figures 3-5 show three examples of these Jellyfish galaxies (credit ESO and GASP collaboration).

The Venice meeting The galaxy life-cycle, October 24-28 (2016) was an important occasion to discuss also about the stripping phenomena in the Jellyfish galaxies. The full press release can be find here: *https://www.eso.org/public/news/eso1725/*.

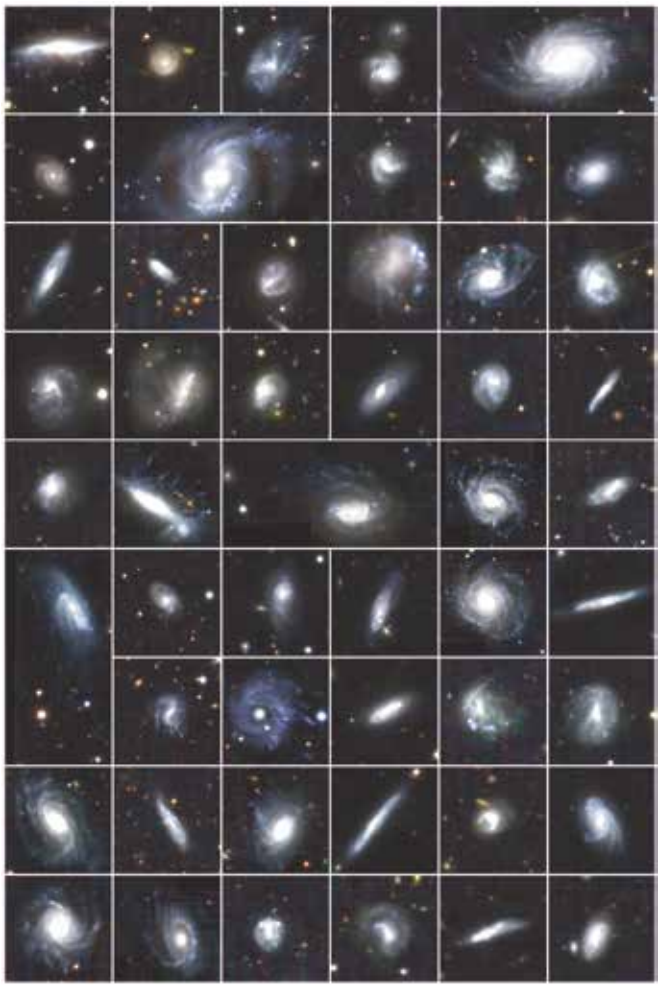


Fig. 1

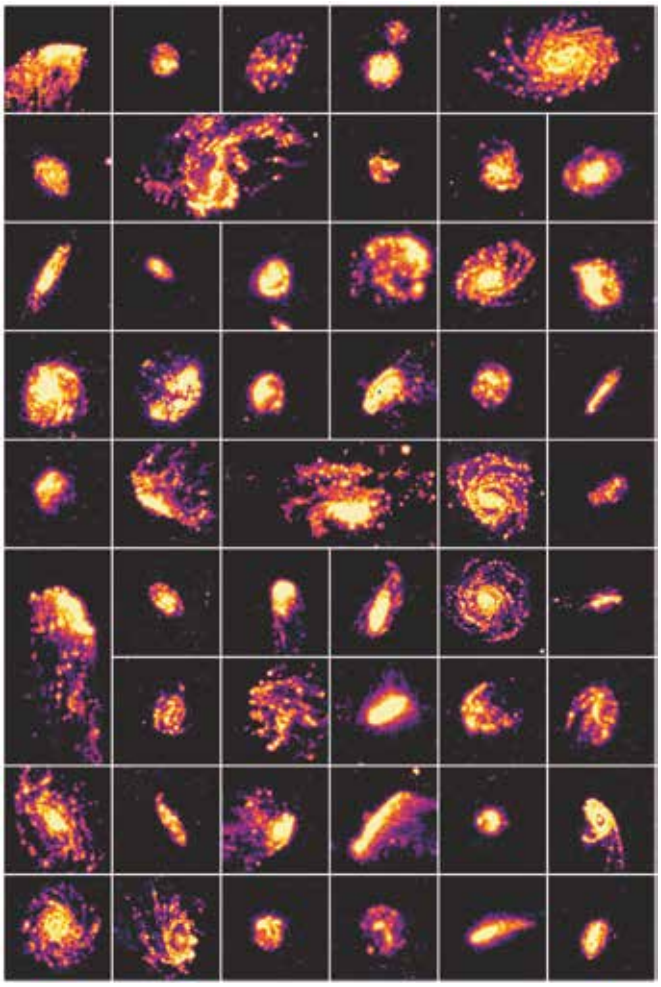


Fig. 2

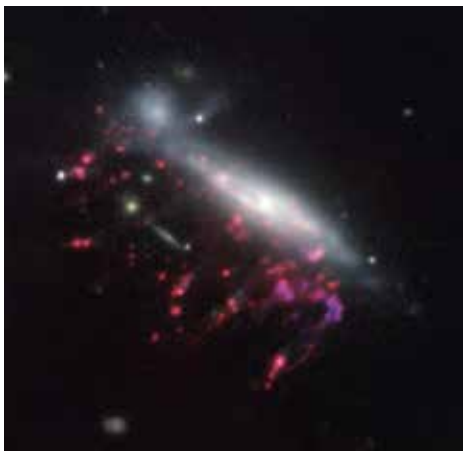


Fig. 3

Fig. 4

Fig. 5

ADJUNCT SCHOLARS

Aldo ALTAMORE

My work at the Vatican Observatory is centered on the study of the history of astrophysics in the greater Rome area from its foundation in the mid XIX century to the first half of the XX. This year I was involved in the preparation of the bicentenary of the birth of Jesuit astronomer Angelo Secchi (1818-1878), which will be marked in 2018. Secchi developed the first spectral classification of the stars which for the first time allowed scientists to evaluate the physical and chemical properties of stellar atmospheres. For this reason he is considered one the fathers of astrophysics.

I participated in the discussion and definition of events addressed to students and to wider public that will be held in 2018 in Rome, Palermo and Reggio Emilia, also with the participation of the Vatican Observatory.

In addition I collaborated with Katie Bannan Steinke, Development Director of Vatican Observatory Foundation, in the organization of a visit by group of benefactors of the Specola from United States. I guided the group on their tour of the historic Collegio Romano Observatory on the top of the St. Ignatius Church.

I took also part in the general internal discussions on communicating science as part of the Vatican Observatory's future projects in the field of outreach and education. At the Department of Mathematics and Physics of Roma Tre University, where I was taught until my retirement, I continue to follow the activities regarding the Teaching and Communication of Physics and Astronomy.

I was involved in initial and in-service training for Physics and Natural Sciences teachers. I contributed also in the projects which aims to stimulate scientific vocations among high school students.

Further tasks included management of the multicultural project "Astronomy for Development" which is aimed at 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 Fulgencio in Rome, as a lay minister of the Word and the Eucharist, and through my vocation as a youth catechist.

Ileana CHINNICI

This year has passed too fast for me! A huge amount of my working time has been devoted to end the scientific biography of Father Angelo Secchi (1818-1878), the famous Jesuit pioneer in astrophysics. It has really been a huge effort and I am eternally grateful to Br. Guy, who agreed to revise my poor English. The book will be published early in 2018, hopefully, in time for the bicentenary year of Secchi's birth. The preparation of the bicentenary has also been another major effort: in fact, the National Institute of Astrophysics (INAF) and the Accademia dei XL in Rome decided to establish a National Committee to organize some events in memory of Secchi and his remarkable

scientific contributions in many disciplines. I have been charged to redact and/or assemble the final document to be submitted to the Italian Ministry in order to have some financial support. The programme is very rich and extensive: many institutions - including the Specola, of course - are involved in several events and initiatives, mainly in Rome and in Reggio Emilia (the native town of Secchi) but also throughout Italy. I hope that this bicentenary will also prove to be a good opportunity to raise public awareness of the Jesuit contribution to science. In Palermo, I have been working – and still am – on the restoration and reopening of the Museum of the Astronomical Observatory, trying to reconcile the exigencies and ideas of all the actors of this endeavor – which is quite complicated! I am also working a new website for the Museum and other local projects to promote scientific heritage. In this context, I have collaborated with colleagues from the University of Palermo for a catalogue of instruments of acoustics, which are preserved in the University collections. Moreover, I have completed the time-consuming edition of the book on Merz telescopes, which has been published this year.

Beside work engagements, last summer I have spent three weeks in Senegal with a group of young people from many regions of Italy: we visited some villages and missions and participated in some camps with children. It was a precious experience which renewed and invigorated my faith and my sharing with disadvantaged people. It also allowed me to better know the current world of young people, so fragile and yet rich in potential and consequently see how urgent the next Synod of the Church on youth and discernment is.

Michelle FRANCL-DONNAY

My research group and I continue to explore the structures of molecules with unusual topologies, ranging from polyaromatic hydrocarbons with Möbius topologies to assessing the strain in trefoil knots built around organometallic centers. I published two scholarly essays on history and philosophy of science in Nature Chemistry, one on chemist Jeannette Piccard, who piloted a flight to the stratosphere in 1934 to investigate cosmic radiation. The second explored the expanding range of computational tools available to chemists and physicists, and the assumptions underlying our choice of particular methods and apparatus. I contributed an op-ed challenging the ways in which scientist's identities can obscure their scientific work to Nature Chemistry as well. As a historian of science, I consulted on a screenplay for a film loosely based on the life of African-American inventor Lewis Howard Latimer.

I continue to serve on the board of the OXIDE collaborative, a project to diversify chemistry faculty at research-intensive universities in the United States funded by the NSF and NIH. I was invited to participate in the Notre Dame led Virtuous Scientist project, supported by the the Templeton Foundation, which opened with a consultation between philosophers, educators and scientists at Notre Dame this spring. Work will continue to develop co-curricular materials that enable students to develop the intellectual virtues crucial to scientific research.

I was pleased to be invited to be one of the platform speakers at Philadelphia's March for Science last April, where the organizers specifically asked me to speak as a scientist who practices her faith. Along with Br. Guy Consolmagno and Prof. Dan Davis, I spoke at a daylong conference at St. Joseph's Seminary in New York about science as contemplative prayer. My writing around these issues this year included an essay on what contemplative Christians might have to offer to scientists, as well as the opening essay for Liturgical Press' Give Us This Day's April issue, "Overflowing with God's Glory," which was framed around chaos, creation and modern cosmology. I enjoyed the opportunity to visit with my colleagues at the Specola in July. As part of a day of science from around the world on Twitter, I chronicled a day at the Observatory, from morning coffee to the meteorite lab to the evening Mass (the only contributor from Vatican City State.)

My essay "We are never alone," written for the May 2016 issue of Give Us This Day earned 3rd place at the 2017 Catholic Press Association Awards, for best essay in a spirituality magazine. I completed a book of reflections for Lent, Not By Bread Alone, which appeared from Liturgical Press in November. I gave a half-dozen retreats, was a keynote speaker at the Lucian symposium at St. Edwards University in Austin, Texas, wrote a series of reflections for Advent in CatholicPhilly for the Philadelphia Archdiocese, wrote a review of Hope Jahren's Lab Girl, contributed to Loyola Press' DotMagis blog on Ignatian spirituality, began contributing to the Catholic Astronomer blog for the Vatican Observatory Foundation, had a piece reprinted in Sacred Space 2017, and wrote a Christmas reflection for Give Us This Day. I was interviewed on science and faith for NBC News, and was quoted in pieces in the Washington Post and on NPR around chemistry disasters.

Father José FUNES, S.J.

When I returned to Argentina at the end of 2015, I began to form two multidisciplinary research groups. The first project is supported by the Catholic University of Cordoba and the second was awarded with a small grant that the Argentine government offered to those scholars working abroad to support their return to the country. The first project regards 'Scientific eschatology and its anthropological and theological implications'. With respect to this project, the results were presented in two papers presented at meetings that will be published this year. These publications have been reviewed for publication by their editors. In those works, we presented an interdisciplinary group devoted to the discussion of topics that are common to science, philosophy and theology. In particular, we approach the study of the end of the cosmos and analyze the anthropological and theological implications of the scientific eschatology. From a scientific point of view, the end of the universe raises the challenge of making predictions from models that use observational evidence from alarge span of past times, but cannot be confirmed. Against this limitation, the complementary approach of the philosophy allows to build conceptual bridges between the scientific vision and the physical manifestation of the world, arising questions about the place of the human being in the cosmic eschatology. Also, we seek for the links between the natural and religious realisms, trying to stablish relations between the revelation of the image of God and their manifestation in the observable universe.

The second project, titled OTHER (Otros mundos, Tierra, Humanidad y Espacio Remoto wich 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. The search for intelligent life in the cosmos, with the fascination it arouses in public opinion, presents new challenges and new frontiers for science, philosophy and religion.

The Drake equation offers a very helpful educated guess, a rational set of lenses through which we can estimate the number of active, communicative extraterrestrial civilizations in the Milky Way galaxy. In this project we propose to develop and make explicit the last two social parameters of the Drake equation. This equation offers a platform from which to address some questions related to the search for intelligent extraterrestrial life in a multidisciplinary perspective. The different factors in the Drake equation can be grouped into three categories: astronomical, biological and social. Even though Drake's equation contains many parameters that are still unknown, it is very useful to describe the challenge of communicating with extraterrestrial civilizations.

The introduction of a "spiritual factor" allows us to orient the discussion by incorporating cultural and religious aspects that, studied in terms of the development of our own civilization or alternative situations, could cause different types of behaviors.

Although it does not emerge explicitly, the religious factor has played and still plays an important role in human cultural development because it can act

as a stimulus or as an obstacle to space exploration and technological advancement. It is not difficult to imagine that if there were an intelligent extraterrestrial species, the religious component would also be present in that civilization. Therefore, a "spiritual factor" should be considered as another parameter when considering the possibility of communicating with extraterrestrial civilizations.

We also take into account the possible impact of the potential discovery of an extraterrestrial civilization in the philosophical, social and religious conception of our own civilization. This approach requires a better calibration of questions about the nature of life, intelligence and spirituality, as well as about the possible scales and scope of civilizations.

In this line of research, I have published a chapter for an astro-theology book and the group presented the project at the Meeting of the Argentine Association of Astronomy of 2016.

From the project OTHER, we try to reach high-school teachers and students. We believe that researchers have an important social responsibility that consists of sharing their knowledge with the citizens of the country contributing to their education. The multidisciplinary dialogue should not be an activity that is limited to a few experts, but the high school should be the place where new generations are exercised in a dialogue that prepares them to address important and deeply human issues from a multidisciplinary approach. The theme of the search for other worlds can be an excellent forum.

With this objective I have initiated, together with teachers of the Jesuit High School, Sagrada Familia, in Cordoba, a monthly seminar in order to start next year a Science Club on the search of extraterrestrial life. We call this this initiative Educational OTHER.

Father Michael HELLER

In my present activities two things are worthwhile to be noticed: one is related to doing science, the other one to communicating scientific results and their philosophical significance to general public.
As far as the scientific part of the story is concerned, for couple of years I am fascinated with mathematical category theory. It has already conquered large areas of modern mathematics, and is persistently infiltrating various physical theories. I am especially interested in its applications to general relativity and cosmology. A few explanations seem to be in order.

Father Heller

Various categories turn out to have their own internal logic, and this logic need not be classical logic. For instance, internal logic of categories called topoi (or toposes) is the intuitionistic logic (this means that you are not permitted using the excluded middle law and the axiom of choice). And there are just topoi that are most often applied to physics. Changing logic from classical to intuitionistic has far-reaching consequences. For instance, in some topoi this enforces a substantial enriching of the real line: besides the usual real numbers there exist infinitesimals of various kinds. Mathematicians have elaborated the so-called Synthetic Differential Geometry (SDG) which generalizes the usual differential geometry to this new mathematical environment. The existence of infinitesimal enables one to gain an insight into "infinitely small" portions of space (or space-time) which so far were invisible for geometric methods.

This creates an exceptional opportunity for applications to general relativity and cosmology. An obvious target is the singularity problem in relativistic cosmology. And indeed, it turns out that "in the smallest" infinitesimals change the situation drastically. Preliminary results have been published in:

M. Heller, J. Król, Inifitesimal Structure of Singularities, Universe 2017, 3, 16; doi: 10.3390/universe3010016

A more detailed model will be presented at the conference in Warsaw, 16-17 November 2017, devoted to the mathematical, physical and philosophical aspect of category theory, in the paper "Beyond the Space-Time Boundary" (with Jerzy Król).

Philosophically the situation is also exciting since for the first time mathematics suggests that logic need not be given a priori, but it could depend on the context (on a category) in which it is used. I dealt with these aspects of category theory I two papers reported in the last year, namely

Category Free Category Theory and Its Philosophical Implications, Logic and Logical Philosophy, 25, 2016, 447-459, DOI: 10.12775/LLP.2016.015

Category Theory, Logic and Philosophy, Filozofia Nauki, t. XXIV 2, 2016, 5-15, in Polish.
Now, the other side of my activities. In my life I have written a handful of books popularizing science, philosophy and "science and religion". It turns out that there is a social need for such books since they sell well, and new editions of my older books are still wanted (in this year two such books were republished). I receive many requests for public lectures and various meetings of which only a fraction I am able to accept. This gives me an occasion to meet people who read my stuff. Conversations with them are for me a great reward for the work I have invested in writing these books and also an encouragement for not ceasing doing that.

Father Robert JANUSZ, S.J.
This year was very important for our Vilnius/Stromvil Photometry Group. We collected all relevant data observed at the Vatican Advanced Technology Telescope by Richard BOYLE since 1999. For each scientific image we did a plate solution for all light sources in three steps: (1) preparation of the DS9-regions with reference stars; (2) initial calibration with these regions; (3) accurate plate solution by means of *astrometry.net* software. The second step was done with the assistance of Jolanta Koszteyn. She also collected the BibTeX database of relevant publications of the Vilnius System and areas observed with it with links to the original papers.


Father Janusz in the new institute building in Vilnius

We also continue to reconstruct the previous data recorded on the DAT-Cassettes (4mm Data Tape DDS-60 Imation 3M, 72x53x10mm: MAXELL"HS-4/90s" 2GB, 90M/295FT). The old Kitt Pick first CCD observations in Vilnius System are also awaiting reconstruction (the huge type of magnetic tape is difficult to reconstruct now). BOYLE will do his very best. We hope to put the data on the real scientific repository that the Vatican Observatory is set to launch next year.

We also developed software to recalculate the photographic plates observed at the Schmidt Telescope in Castel Gandolfo (the second part of Vilnius filter set was provided by Filippo Smeriglio). Our results confirm the published results. However with the new computational techniques we will try to go even further than was possible in the 1980s.

Our Scientific Workshop was this year technically divided in two parts: One at the Specola in Castel Gandolfo, from July 22 to Aug 7 and one in Vilnius, Lithuania from Sep 11 to 20). The workshop explored various questions, for example: The tie-in observations - strategy and indications of success; the atmospheric extinction in tie-in equations; how

to "tune" the preliminary photometry for improved classification?; the Dark Clouds "LDN 183" and "LDN 483"; the Open Clusters "NGC 2236" and "King 7"; various programs for stellar classification (A. Kazlauskas, R. Janusz, K. Zdanavicius) and global precise astrometry of all known VATT/Flagstaff etc. data. Besides the main organizers (BOYLE and JANUSZ) the Castel Gandolfo workshop also welcomed Vytas Cepas, Justas Zdanavicius and Jolanta Koszteyn and the workshop in Lithuania - the rest of our Lithuanian Photometric Group.

We also continue to dig into the history of systematic photometry projects at the Specola. In a 1979 edition of *Specola Vaticana, Ricerche Astronomiche* [*vol. 9,Special No. 1979, Spectral Classification of the Future. Internal Astronomical Union Colloquium 47 commemorating the 100th anniversary of the death of Angelo Secchi, S. J.*, (eds.) M. F. McCarthy, S.J., A. G. D. Philip, G. V. Coyne S. J.], there is an article about the Vilnius System by V.Straizys, "Problems and Prospects of Multicolor Stallar Photometry" (p. 190-197) with a discussion (p. 198-202) in which (among others) Philip, Straizys, Nandy and Coyne participated. This is an objective record that G. Coyne and D. Philip - who worked with us a lot - heard of the Vilnius System directly from Straizys, at least as early as 1979. Dave Philip died on March 28, 2016.
With the new headquarters the Lithuanian Group Members now have a very comfortable working space. This is similar to the Specola move a few years ago. Despite some outstanding technical problems related to such big changes we hope to to lunch our scientific work on ever better paths.

Dante MINNITI
For most of 2017 I have been working on the ESO public survey VVVX (VISTA Variables in the Via Lactea Extended Survey). This VVV extension (VVVX) was approved last year, with 200 nights of telescope time allocated, to map a total area of 1700 sqdeg, obtaining multicolour and multi-epoch near-IR photometry. The VVVX is complementary with other survey telescopes and cameras (like for example VST, LSST, DECAM, Gaia). We are mapping the inner regions of the Milky Way, which are inaccessible for some of the other surveys. The VVVX will also provide new targets for dedicated spectroscopic survey instruments (Apogee-S, Winered, MOONS, 4MOST), as well as the giant telescopes being built in in Chile (E-ELT and GMT). Among the many interesting new scientific results, I have discovered several new globular cluster in the Galactic bulge. The high stellar density combined with the high and differential interstellar reddening are the two major problems for finding globular clusters located towards the bulge.
Using the deep near-IR photometry of the VVV Survey, we reported the discovery of 22 new candidate globular clusters in the Galactic bulge.

Dante Minniti

These objects, detected as high density regions in our maps of bulge red giants, are confirmed as globular cluster candidates by their colour-magnitude diagrams. The new globular clusters exhibit a variety of extinctions and distances. Our discoveries suggest that the census for Galactic globular clusters is still incomplete, and that many more globular clusters (particularly the low luminosity ones) await to be found in the central regions of the Milky Way. This work was carried out during my recent stay at the Vatican Observatory (June 2017).

Father Giuseppe TANZELLA-NITTI
I was appointed as Adjunct Scholar of the Vatican Observatory two years ago. This is the second time I can share with you some moments of my yearly activity. My main field of study and research is Fundamental Theology. This discipline includes the relation between faith and reason, and today we have to consider that reason is mainly understood as scientific reason. Precisely because of that, today I can take advantage from my previous activity as

astronomer (1977-1987), before becoming priest and move to theology, and try to foster the religion and science dialogue.

Father Tanzella-Nitti

My academic chair is at the Pontifical University of the Holy Cross, in Rome. Here I direct the Interdisciplinary Documentation Centre for Science and Faith (Italian acronym DISF), an Interdisciplinary Research Center that was set up in 2002. It is aimed to provide a philosophical-humanistic training for young scientists who wish to enrich their studies or professional activity with a wider interdisciplinary framework, exploring the philosophical foundations of the various disciplines. At the DISF Center operates the Advanced School for Interdisciplinary Research (ADSIR, Italian acronym SISRI), addressed to young researches aged no more than 35 years. The Center also 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 offers the *Interdisciplinary Encyclopedia of Religion and Science* (INTERS), a registered philosophical journal (ISSN 2037-2329). My present research deals with issues such as the natural knowledge of God the metaphor of the book of nature down through the centuries, the relation between the philosophical question on God and Judaeo-Christian Revelation, the humanistic dimensions of science, models of unity of knowledge, the role of the natural sciences in the work of theologians. I am now working at the book *Religion and Revelation*, that I hope to publish within 2018 as the III° volume of my 4-volume Treatise entitled *Fundamental Theology in a Scientific Context*.

From February 23 to 25, 2017, I participated in an international workshop on *The Metaphysical Dimensions of Nature* organized by the Pontifical University of the Holy Cross, where I teach Fundamental Theology. On March 10, the first two volumes of my work *Fundamental Theology in a Scientific Context* were presented at the Libreria San Paolo, Genova, during a round table with the Italian philosopher Roberto Timossi. *Scientific Progress and Human Progress* was the title of the lecture given at the Sala Consiliare di Loreto (Italy), a town known for the nice shrine built around the historical house of the Virgin Mary in Nazareth, which pious tradition holds was displaced to Italy during the Middle Ages. The talk *Life in the Cosmos. Some Theological Reflections* was presented at the Annual Meeting of the Centro Studi Astronomici, in Rome, on April, 8. I was also one of the invited speakers to the Conference *Economy and Ethics*, organized by the Department of Economics at the University of Catania, Italy, May 5-6. There I gave a lecture on Pope Francis' Encyclical *Laudato Si'*, offering some comments of the *Gospel of Creation*. I also took part in some sessions of the international conference *Black Holes, Gravitational Waves and Spacetime Singularities*, held at the Vatican Observatory, Castelgandolfo-Albano, on May 9-12, on the occasion of 50th anniversary of George Lemaître's death. Graduate students and teachers of the Lipscomb University, Nashville Tennessee, were received on May 21 at the Center of Interdisciplinary Research that I direct. They asked me to talk about *Science and Religion: Historical and Philosophical Perspectives*. A lively discussion followed the exposition, regarding the situation of this dialogue in US High Schools. During the meeting I had the opportunity to present the web site I edit on Religion and Science, inters.org, which is intended to provide documents and articles to school teachers of science, history and philosophy. The Plenary Assembly of the Pontifical Academy Thomas Aquinas, to which I belong as ordinary member, was dedicated to *Aquinas' Philosophy of Creation*: there I presented a talk on *The Contribution of Aquinas' Philosophy to the relation between Theology of Creation and the Natural Sciences*, on June 16. A special event was the lecture I gave on September 19 in Rovigo (Italy), *The Question on God and*

Scientific Research: more than 300 school teachers and students attended the talk, together with many priests and the Bishop of the Rovigo diocese. The many questions addressed by the public regarded the way in which science is often presented by the media as an obstacle to religion, instead of emphasizing, more properly, its openness to wonder and mystery. The organizing committee of the International Conference *Where are the Biological Sciences Going?* held in Rome on October 25-27, asked me to give a special session within their meeting and speak to a number of biologists and physicians on *God as Life*. Once more I realized how much theology can give to science, and also receive from it. Finally, on October 27, the Department of Philosophy of Religion of the University Tor Vergata, Rome, invited me to reply as *discussant* to a lecture on the philosophical dimensions of the Intelligent Design movement.

Father Matteo GALAVERNI

This year, in addition to my pastoral service in Reggio Emilia - Guastalla diocese, I had slightly more time to devote myself to study and research in theoretical Cosmology. My main fields of interests are: dark matter and dark energy, cosmic microwave background polarization, cosmological birefringence. I had the opportunity to visit the Specola in Castel Gandolfo a few times, to work with GIONTI and attend the workshop on "Gravitational Waves and Spacetime Singularities" organized to celebrate the figure of Mons. Georges Lemaitre. It was an unique opportunity to meet and talk with some of the more expert scientists in the field.

In Bologna I continued a research collaboration with Fabio Finelli at IASF-Bologna (one of the institutes of INAF, the Italian National Institute for Astrophysics, where I studied for my PhD).

Next year will be the bicentenary of the birth of Fr. Angelo Secchi (1818-1878) in Reggio Emilia and, since I live in Reggio, I am particularly interested in it. A working group, which includes among the others also Aldo ALTAMORE and Ileana CHINNICI, is planning several events. In particular a two day meeting on the history and science of Fr. Secchi is going to be hosted in Reggio next May.

Regarding outreach I was invited to give some popular talks to neighborhood high-school students and teachers. During the spring - summer term I was invited to teach a course on Science and Cosmology for the Bachelor of Theology at the local seminary (Studio Teologico Interdiocesano). The study of the influences of the main cosmological models on Philosophy and Theology is a very interesting topic in my opinion. I feel very grateful to GIONTI and OMIZZOLO: they came to Reggio and presented the Vatican Observatory and their research to the students in two very interesting seminars.

Father Galaverni

The Frye Fire

2017 was also a year of miracles as Fr. Pavel GABOR notes in his detailed report on the Fyre Fire which raged for almost a month and came to within mere feet of the Vatican Advanced Technology Telescope on Mount Graham.

On Sunday June 18 at 12:27 pm, Large Binocular Telescope's (LBT) Kevin NEWTON emailed this image from the LBT building with the caption, "VATT is in trouble."

"VATT is in trouble" at noon on June 18. Courtesy Kevin Newton

The photograph shows a red plume of fire in the direction where the VATT ought to be. When I saw it, I was very nervous but I knew that things could not be quite as bad as the picture suggested. Kevin's email came to me via the microwave communications tower standing 15ft from the VATT building. 'If the tower is OK,' I kept telling myself, 'then the VATT must be OK, too.'

The Frye Fire was started by lightning around 2:45pm on June 7 in a fire scar left by the 2004 Nuttal Complex Fire in the vicinity of Frye Canyon about 4 miles north-northeast of the LBT building. In the morning of June 10 its size was estimated as 50 acres. The risk to the astronomical facilities on Mt Graham was deemed 'low'. The only concern was that the fire was spreading in a southerly direction, i.e., towards us, and on June 10 the distance was estimated as 2.5 miles.

Eric Buckley, director of the Mt Graham International Observatory (MGIO) started sending us daily updates. As of the morning of June 11, the fire had grown to 300 acres. Eric's update on June 12 reported no significant changes but that evening there was a public meeting, and Eric wrote:

The fire is burning between 6300 and 9000 ft elevation. The fire has grown to over 580 acres and the Forest Service (FS) has significantly ramped up their efforts to prepare for the fire. They have employed over 160 people. They have re-built over 8 miles of fire breaks [...] The FS has a high level of confidence that the fire lines that have been re-established will hold this fire back. They will continue to hold off putting people at the front lines as long as the fire is in dangerous terrain. They made it very clear last night that all decisions are 'risk based' and they will not put their people's lives in danger if it is not absolutely necessary. They basically are being patient and letting the fire come to them. There was a lot of concern that this fire wasn't getting the 'attention' it deserved. The FS officials stressed that firefighting resources are distributed to the fires that have the most values at risk. At this point in time the Frye Fire is not posing enough risk to merit any more resources than it has right now.

The extent of the fire grew to 960 acres by the morning of June 15. Most of the growth was towards the north and west, i.e., away from the telescope site. By the morning of June 16, the fire doubled in size to 2,080 acres, and Eric wrote:

[The fire] ran south all the way up Frye Canyon towards High Peak then fell back in on itself [...] Fire fighters are continuing to prepare for attack on both the south ends of the fire (High Peak) [...] However, fire officials still have a high degree of confidence that they will be able to combat this blaze in an orderly and calculated fashion.

As a precaution, all observers and UA personnel left the telescope site that day, except for three LBT men (including Kevin Newton) and two MGIO men who remained at the summit to monitor the situation. In the morning of Saturday June 17, Eric reported:

The Frye Fire has grown to 6,305 acres. There are over 300 people assigned to this fire which is approximately 16% contained. Six helicopters have been assigned to this fire. [It] is being transitioned to a Type 2 Incident. This means that over the weekend a new fire management team will assemble and take over the firefighting efforts [...]. The fire has reached and surpassed certain trigger points that were set down from the original management team plan. Now that those lines have been reached and in some cases surpassed, new tactics are needed to combat this blaze.

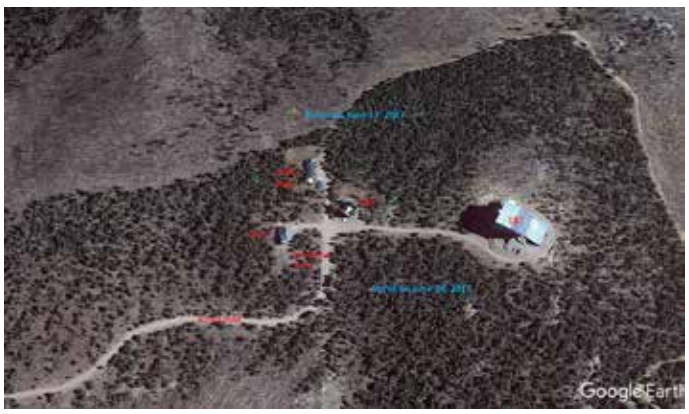
The fire has moved within ½ mile of the site. Some back fires were set yesterday evening [...] in an effort to suppress the southerly advance of the fire. Unfavorable winds put a halt to this effort, but more fires will be set today to resume this fight. Under FS command, MGIO crews will be running the sprinkler system around the site starting this morning [...]. To keep up with demand, MGIO crews will be running a water supply truck around the clock until it is no longer necessary.

On Saturday June 17 in the afternoon, the fire spread southward, burning a large tract of the forest untouched in 2004 reaching the north side of the telescope site, threatening the utility building. Christian Veillet, director of the LBT Observatory wrote:

[T]he firefighters and a ballet of helicopters succeeded in protecting the utility building which is currently not threatened anymore. The observatory was powered on again and the main subsystems restarted, restoring communications through the network as well as the rotation of the building & telescope to aid the spotters.

The battle for the Utility Building, Saturday July 17. Courtesy Steve Allanson

By Sunday June 18 the fire skirted around the LBT building on the eastern edge of the telescope site. The trees to the south of the site started burning, and the fire reached the access road.



Frye Fire damage to the vicinity of the telescopes on Mt Graham

That was the situation captured in Kevin's photograph. The three LBT men left the site, with Kevin leaving shortly after sharing his "VATT is in trouble" photograph. They left a webcam pointing southwest from the roof of the LBT.

The good people at the site informed me that the VATT appeared unharmed but I was still a little

uneasy. I knew that there had been a lot of heat and even more smoke. The heat could have damaged the dome. If the dome's roundness had been compromised, it would have lost its ability to rotate freely. If the smoke had deposited conductive soot on the electronic circuit boards and corrosive tar on the coated optical surfaces, it would have made us expend considerable resources on cleaning, testing, recoating and recommissioning. I feared that months of diligent work lay before us.

The only way to restore my peace of mind was to hasten to the VATT and assess the damage. But how? I made some preliminary arrangements to go to Mt Graham on Friday June 23 but I had to postpone the trip because there were fires by the roadside.

The first window of opportunity opened on Tuesday June 27, and we took advantage of it. On Sunday June 25, the coordination of the firefighters' efforts transitioned from a Type 2 Incident Management Team (IMT) to a Type 1 IMT. This meant that the fire was officially recognized as an emergency requiring the deployment of resources at the highest level. The transition was a sign that the fire was growing, and that was obviously a cause for concern. On the balance, however, although the surface area involved was objectively greater than before, the transition primarily marked an improvement because the Type 1 IMT could call upon even more resources than Type 2 IMT.

Regarding our little expedition, I was concerned that the transition might create an extra delay. MGIO director Eric Buckley had spoken with the Type 2 IMT about our trip last week. When would he manage to get through to the Type 1 IMT? It turned out that everything went smoothly and Eric conveyed the IMT's green light to me on Monday afternoon.

Previous week's planning had paid off because our small group was ready to go at short notice. VATT's acting principal engineer Chris Johnson and I went to the MGIO Base Camp from Tucson, arriving at 6:40 am on Tuesday. We were joined in short order by VATT's general maintenance manager Gary Gray who lives in Safford, and by Lou Hardin, adjuster for Travelers Insurance and a retired fire captain who came from Phoenix. We took two vehicles. The MGIO custodians drove in a third. We were all escorted by Sgt Wade Boltinghouse from the Mt Graham Unit of the University of Arizona Police Department who negotiated our passage through the checkpoints along the way.

We saw many firefighters having their morning briefings as we drove up the mountain after 7am. There were few smoldering fires along the road. At such an early hour there was no wind and the fires we saw were small. Some parts of the forest were burned completely, some were affected only partly and some were intact.

Once we reached the last switchback on the MGIO Access Road, we started to see the devastation caused by the conflagration on June 18. Looking right from our vehicles we saw that the forest in the area to the southeast of the road had been reduced to black stumps.

The view towards south-southeast from the foot of the microwave communication tower

When we reached the VATT's building, we first walked around it. It was covered with pinkish dots left by droplets of the fire-retardant slurry but there was no soot on the walls and no sign of heat damage (discoloration or deformation) anywhere, including the dome.

Let me note that the VATT has not received the fire retardant slurry directly. What we saw on the building was the result of droplets carried by the wind. The reason why there was no direct deployment of the retardant on our building provided by Eric Buckley in his report sent out on June 19 was quite terrifying:

The site was bombed directly with slurry and most of the perimeter as well. I believe the only side that did not receive slurry is the east side by the VATT ***as the fire was burning too intensely for the bombers to drop there at the time.***

The dome slit faced south during the fire, overlooking an area of intense heat (cfr. next photograph). Note the absence of any sign of damage except for the fine layer of fire retardant (pink).

The dome slit faced south (its default position during the shutdown procedure) during the fire. This meant that, during the fire, it was overlooking an area where the blaze was particularly fierce. But in spite of that an inspection from the ground identified no signs of damage.

The air on the mountain smelled of smoke, and by the time we entered the VATT building, we had become mostly immune to the smell. The interior of the building was noticeably more fragrant despite the fact the windows and balcony doors had been open for several days. To my great surprise, however, the walls bore no sign of dirt and discoloration.

The control room was in good order as all of the interior spaces but the equipment on the SW balcony off the control room is covered with the fire-retardant slurry. A similar description applies to the equipment on the roof. Fortunately, this particular fire-retardant mixture is water soluble and contains no adhesive admixtures.

View from the SW balcony off VATT's control room towards the south-southeast. An intense blaze devastated the trees as close as 50 ft from the foot of our building

We performed a cursory inspection of the integrated-circuit boards in the open rack in the VATTEL room finding no sign of smoke contamination. I was very relieved.

In the dome, the telescope was fixed in the maintenance position, and the wooden access platform was in its place on the struts, bearing witness to the state in which Gary GRAY left it prior to the evacuation on Friday July 16. Gary had done so in order to cover the secondary mirror with a tarp. I am very grateful to Gary for his quick thinking under stress. The only sign of fire inside the dome were a few hundred charred pine needles.

Charred pine needles in VATT's dome

VATT's primary mirror on June 27, 2017. It appears dusty but not more than usual at this time of the year

We opened the mirror cover of the primary mirror and inspected it. It appeared no dirtier than usual at this time of the year.

VATTspec remained mounted on the telescope during the fire. We dismounted its camera and inspected the interior surfaces of the spectrograph. There was no sign of contamination.

Driving down the mountain after 1pm we saw numerous spot fires along Arizona SR 366 with many fire crews tending them. Some were directly by the roadside. The flames were noticeably larger than in the morning, no doubt because there was some wind. Many trees have toppled over, and many more will do so in the future, creating additional hazards to traffic and accessibility, particularly dangerous when fast response or evacuation is required. I have to confess that I was relieved when we were safely down at the MGIO Base Camp.

Considering the fire on Saturday June 17, 2017, just 200 ft to the north of the utilities building (photographs below) and the extremely close proximity of the devastating fire on Sunday June 18, with the main blaze less than 50 ft from VATT and some spot fires within 25 ft, in conjunction with the conspicuous absence of damage, it is my considered opinion that the VATT had a miraculous escape, thanks to the valiant efforts of the firefighters who, especially on June 18, had to respond very fast, deploying considerable resources to protect our facility.

The Frye Fire destroyed 48,400 acres of forest, and was not contained until July 30. The monsoon rains in August caused landslides. By consequence, the summit was inaccessible for most of our scheduled summer shut-down period.

Instrumentation and Technical Services

This chapter offers an overview of the main activities of the team responsible for instrumentation and technical services at VATT and the Vatican Observatory headquarters in Castel Gandolfo.

During the Summer of 2017 work was hindered by the Frye Fire on Mt Graham which destroyed 48,400 acres of forest, and on June 18 came within 25 ft of VATT. The fire was not contained until July 30 [see previous chapter]. The monsoon rains in August caused landslides. By consequence, the summit was inaccessible for most of our scheduled summer shut-down period.

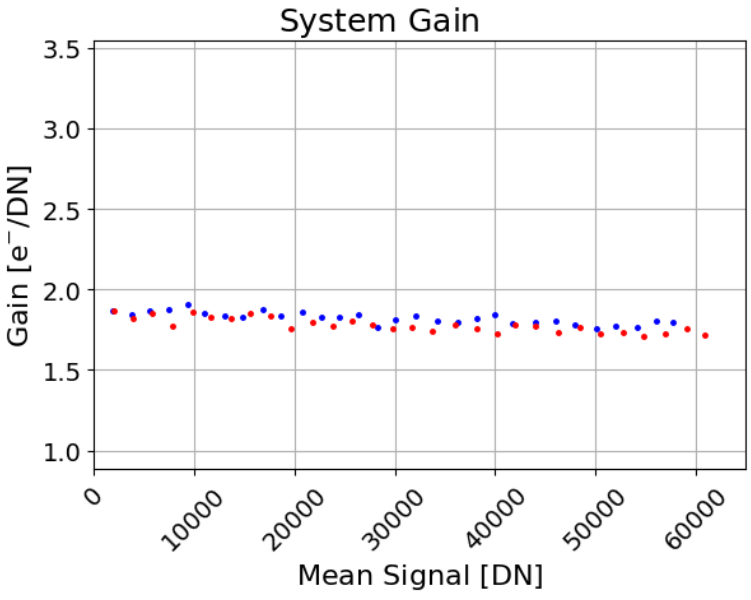
Personnel

The position of VATT's principal engineer was vacated on September 1, 2016. In addition to his many other duties, Chris JOHNSON became acting principal engineer for VATT. He acquitted himself admirably. Steward Observatory, with Vatican Observatory's understanding, intends to restructure the Mountain Operations group, in order to better support upgrades (including the Arizona Robotic Telescope Network, ARTN) while maintaining the current high level of commitment to operations. Meanwhile, the University of Arizona employed Taras GOLOTA as the new *Principal Engineer (Electrical) and Manager for the VATT* as of October 9, 2017. His primary mission is to finish VATT's robotic upgrade in the next few years. Once this is accomplished, his duties may include upgrades of other ARTN telescopes, provided the Mountain Operations group is restructured.

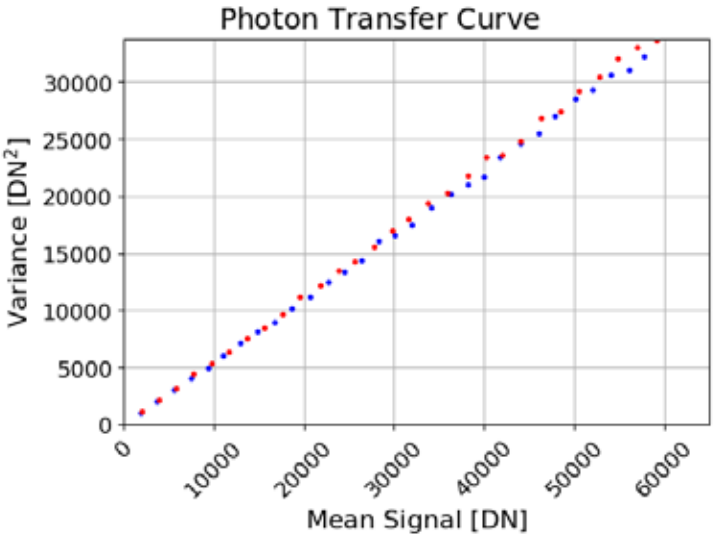
Maintenance

Several minor and one major corrective maintenance operations were performed. The CCD chip of VATT's 4k Imager was lost. Fortunately, Steward Observatory's *Imaging Technology Laboratory* (ITL; Mike LESSER) was in the position to replace it with an identical model and the repaired camera was commissioned on March 23–25 by BOYLE, reporting intermittent jumps in the noise level. The electronics were replaced and the software (AzCam) was updated during the extended summer shutdown by ITL. The refurbished 4k Imager was commissioned on October 16 – 18 with full success. The new characteristics are given in the table and two plots below.

CCD	STA0500A
Dimensions	4096×4096 pixels, 15x15 microns
Gain	1.8 e^-/DN
Full well capacity	ADC limited to 65k DN, i.e., ~117,000 e^- unbinned
Noise	~ 3.9 e^-
Date	October 8, 2017



VATT 4k CCD Imager gain. October 2017



VATT 4k CCD Imager photon transfer curve. October 2017

PEPSI

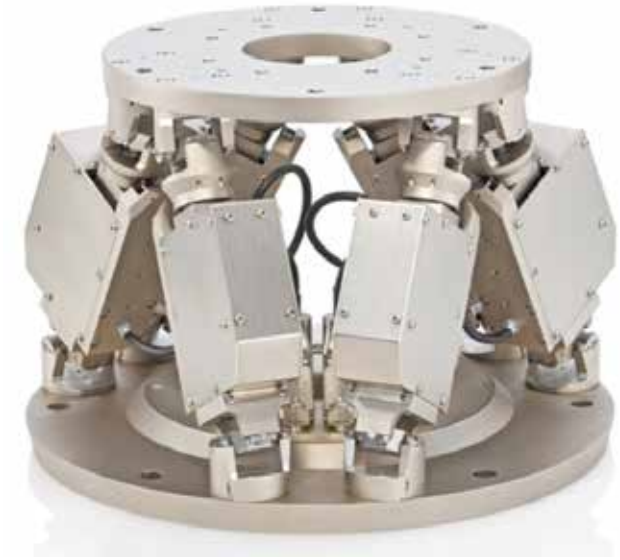
The commissioning of the *Potsdam Echelle Polarimetric* and Spectrographic Instrument (PEPSI) was completed, with the exception of the polarizers. A new Agreement between VO and *Astrophysics Institute Potsdam* (AIP) was executed through 2020.
It focuses on the VATT-PEPSI-TESS R=200,000 spectroscopic survey of 311 potential exoplanet host stars (V < 8.5 mag, cooler than F0) in the vicinity of the North Ecliptic Pole in preparation for NASA's *Transiting Exoplanet Space Satellite* (TESS) mission, entailing three 50-night runs, one each in 2018, 2019, and 2020, from the last week of May till mid-July.

VATT Upgrades

Work continued on VATT's robotization, started in 2014, installing the NGTCS Local Control Unit together with the new absolute encoders for the Altitude and Azimuth axes.
The Azimuth break was installed by Michael FRANZ. The commissioning of the new system began. The legacy system will remain online in parallel with the new one, and the latter's commissioning will not disrupt scheduled observing runs.

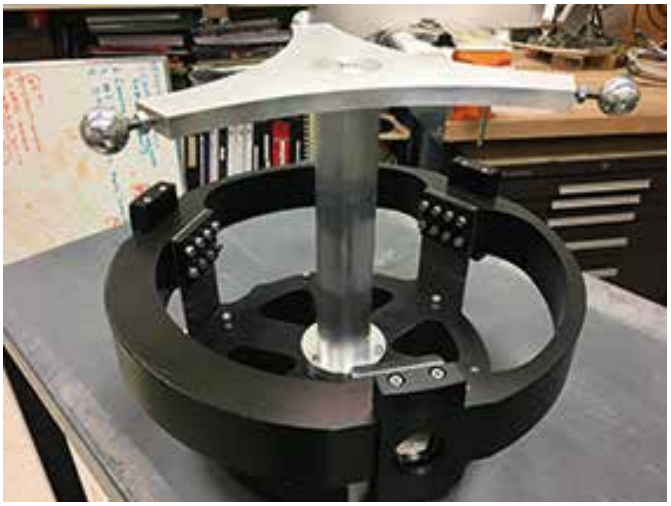
NGTCS Local Control Unit, including (clockwise from top left) the berth for the computer stack, four ELMO drive units, ladder logic relays, capacitors, fuses and power supply units, and the Arduino unit (Controllino Mega)

We have updated the support system for the secondary mirror (M2). We purchased a new hexapodal precision parallel-kinematic support system (H-824 from *Physik Instrumente*).



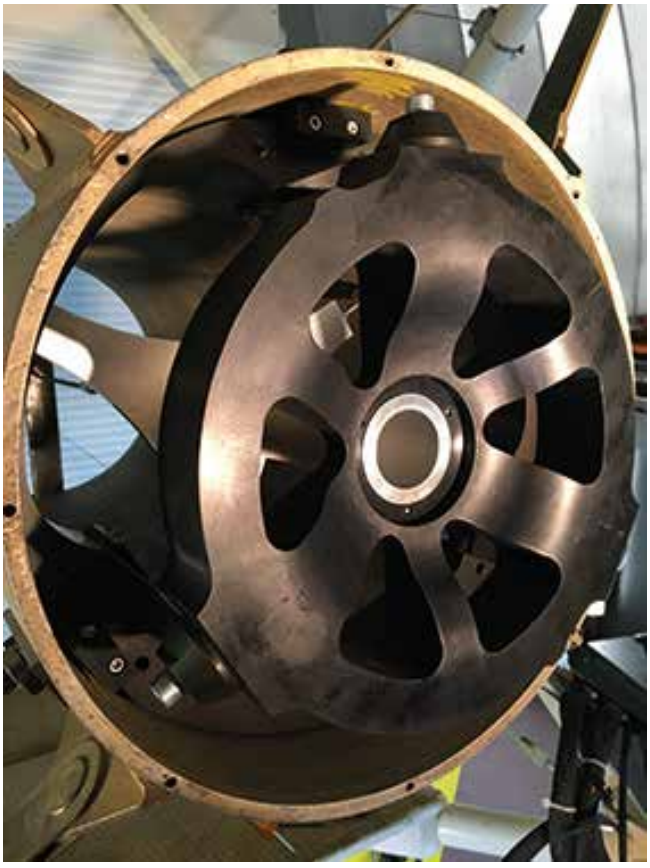
Hexapod H-824. Physik Instrumente

PI H-824 mounted inside the isogonic mechanical interface



Isogonic mechanical interface with handling implement

Isogonic mechanical interface with handling implement in M2's baffle barrel. View in the direction away from M1



Isogonic mechanical interface with handling implement in M2's baffle barrel. View in the direction towards M1

Michael FRANZ designed a mechanical interface fixing the aluminum hexapod to M2's steel baffle barrel, to compensate for the differential thermal expansion while maintaining parallelism and eliminating lateral motion (i.e., temperature changes produce displacement only along the main axis of symmetry). He also devised the protocol and designed a number of implements for safe and precise manipulation with the M2 and the hexapod. Scott SWINDELL wrote the new software, implementing the autocollimation function (compensating for thermal expansion of the struts supporting M2, and for their lateral sag when the telescope is inclined), and a temporary user interface (M2 control will ultimately be a part of the NGTCS user interface). The system was re-commissioned by BOYLE, GOLOTA, JOHNSON, FRANZ, and SWINDELL on October 30 – November 2.

From left GOLOTA, SWINDELL, JOHNSON

Meteorites

The Vatican meteorite collection grew by three specimens this year, all donated by a benefactor in Norway. The first is a 3.9-gram piece of the LL3.15 ordinary chondrite NWA 10598.

NWA 10598

Accompanying it was a 61.5-gram piece of an as-yet-unnamed ureilite. The third specimen is a 33.3-gram piece of the H5 ordinary chondrite Slovak (originally found in Arkansas in 1962). The growth of the collection and the acquisition of new, scientifically interesting specimens is very much dependent on the generosity of our benefactors.

Unnamed Ureilite

Slovak

Collaboration with Vatican Museums

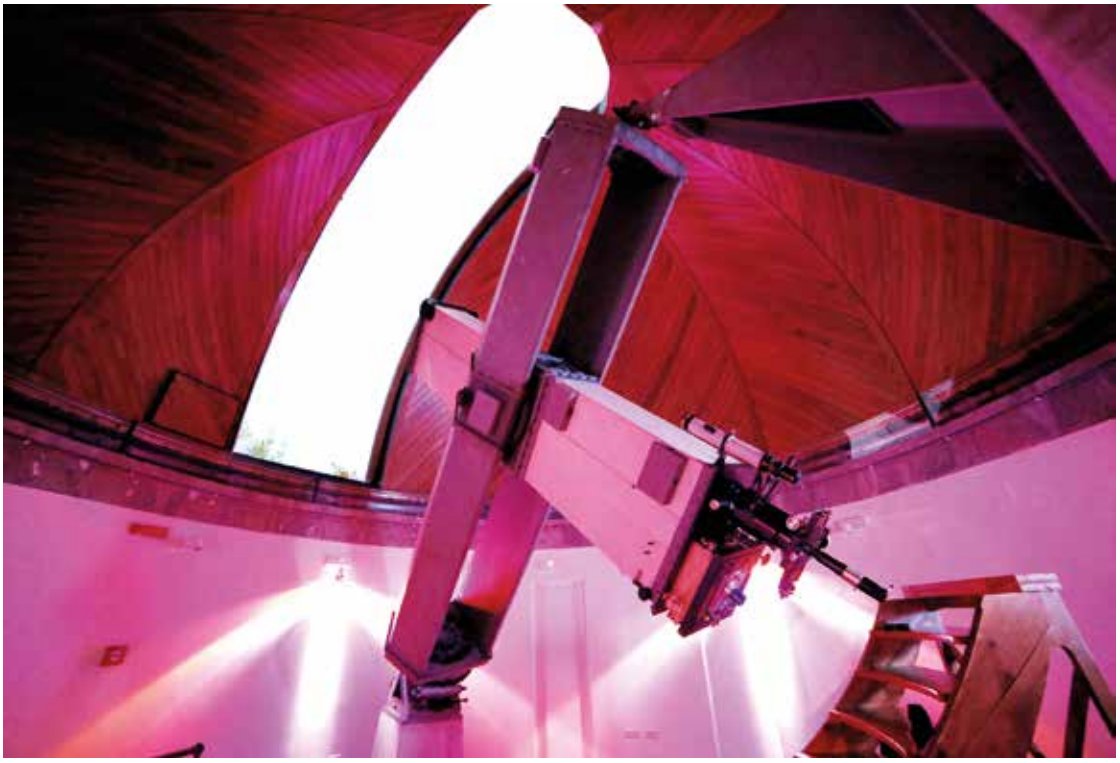
The Specola is collaborating with the Vatican Museums regarding the development and future use of the structure housing the historic Carte du Ciel and Schmidt telescopes. Over the course of the last several years the structure has been refurbished, with financial support from the Vatican and also from Roberto and Maria Buffetti. The plan is to initiate group sky-watching evenings in spring 2018, using the historical 1891 Carte du Ciel telescope, which was recently restored to operation through the dedicated work of Claudio Costa. The Specola is also developing an exhibit of historical scientific instruments and artifacts, to be housed in the same structure.

Garbage

Though located in the Papal Gardens, the Specola headquarters fronts onto Piazza Sabatini in the town of Albano Laziale. Early in 2017 Albano introduced a new procedure for the collection of refuse and recyclable materials, whereby each household was issued official containers for various categories of refuse and recyclable materials, to be put on the curb and collected on specified days each week. The minor problem was that the Specola, which is located in Vatican territory, does not qualify as a household in the town of Albano! So for a while the Specola had to deal with a bit of a stink regarding what to do with its refuse! Through the good efforts of Oswaldo Gianoli, the Director of the Papal Gardens, eventually the Specola was incorporated into the new system. But it is interesting that, for the Specola, something as mundane as the collection of refuse and recyclables must be governed by the 1929 Lateran Treaty!

Improvements

There were various helpful improvements at the Specola headquarters over the last year – some of them important in a building nearly 400 years old. Sound abatement panels were installed in Sala Clavius, in Aula Buffetti, and in the coffee room. Previously those spaces were characterized by distracting reverberations and echoes, but with the panels the sound quality is much improved. Additional shelving was


Carte du Ciel telescope restored and functioning

installed in the Specola library, providing space to exhibit recent journals and Specola publications. An improved water-proofing system was installed along the eastern external wall of the library, to lower the humidity and to protect the books. Similarly a dehumidification system was installed in the small chapel in the interior courtyard of the Specola.

Clocks

Thomas Rebenyi, master clockmaker of the Deutsches Museum in Munich, generously donated his time to spend a week at the Vatican Observatory last July doing repair and maintenance on the Observatories historical timepieces. First, he cleaned and restored the Dent Precision Pendulum Clock (PPC) N°1475.

Thomas Rebenyi at work

This clock, which dates from the 19th century, has a Graham lever escapement with inlaid pallets made from rubies. The pendulum of this clock compensates for linear expansion and contraction due to temperature variations by means of an enclosed cylinder of mercury. The expansion of the pendulum rod due to higher temperatures is compensated by the corresponding expansion of the mercury in the cylinder, so that the center of gravity of the pendulum remains in the same position. Thus changes in temperature do not result in variations or inaccuracies in time-keeping.

PPC PrecisionPendulumClock N°1475 from Dent, London, Clock Maker to the Queen

At the upper end of the pendulum rod there are special adjustment screws which are without function for Dent PPC N°1475, which has a Graham escapement. But those adjustment screws would be very helpful for the gravity escapement of Dent PPC N°1346. So it seems clear that somewhere along the way the pendulum of PPC N°1346 was moved to PPC N°1475.

At some point someone from the Observatory staff constructed and installed an adjustment unit on the pendulum currently in Dent PPC N°1346. The adjustment unit is attached to the pendulum rod by means of spring tension alone, so that there would be no need to damage the pendulum rod by the addition of holes or attachment screws.

Rebenyi's recommendation is that the pendulum currently in PPC N°1475 be restored to its original location in PPC N°1346. But the adjustment unit should be displayed next to or inside PPC N°1346, in order to document the history of the clocks, and also to illustrate the creative practical technical skill of the Vatican Observatory astronomers who devised the unit.

Financing the Specola

The Specola is collaborating with the Vatican accounting office, in an effort to update and rationalize how the Vatican provides financial support for VATT and other Specola facilities and operations. The goal is not so much to increase Vatican financial support for the Specola as to shift that support to regular/recurring expenses, so as to leave the Vatican Observatory Foundation free to seek financial support only for special projects and expenses.

Antenna

The Specola has been collaborating with the Vatican Secretariat for Communication to determine an appropriate site at Castel Gandolfo for a new antenna needed by Vatican Radio. All parties concerned are working together to ensure that the antenna will serve the needs of Vatican Radio without obstructing the good function of the Observatory's historic telescopes atop the Apostolic Palace.

Education And Outreach

This chapter gives an outline of some of the many events that Vatican Observatory Staff and Scholars took part in throughout 2017

Outreach to the wider public through education programs, media interaction and conference participation is a strong focus among staff and adjunct scholars and an essential part of the mission entrusted to the Vatican Observatory.

Without doubt the May workshop *Black Holes, Spacetime Singularities and Gravitational Waves* held in Castel Gandolfo in honor of George Lemaître was the stand out educational event for the Vatican Observatory in 2017. That said, throughout 2017 we continued to connect with fellow academics, future scientists and all those interested in finding out more about what we do. We do this through conference participation, educational and academic activities and, in our increasingly connected world, engaging with the media.

News and Media Coverage

The highlight of media attention for the Vatican Observatory came in May when the long-running BBC program *The Sky at Night* came to Rome to film an entire half-hour episode about the history and the work of the Vatican Observatory. Vatican astronomers David BROWN, Guy CONSOLMAGNO, Alessandro OMIZOLLO, and Gabriele GIONTI were all interviewed for the program while Ileana CHINNICI provided invaluable background information to the journalists. The program ran on the BBC in early June.

The Frye Fire and total solar eclipse also generated great media interest. GABOR was interviewed several times by Arizona Daily Star and by the Gila Valley Central regarding the Frye Fire in June and July.

Ahead of the August eclipse, CONSOLMAGNO held a press conference in Hopkinsville, KY, attended by dozens of reporters and television journalists. CORBALLY spoke about the total solar eclipse with guest host, Ed Morrissey on the Drew Mariani Show, Relevant Radio, while GABOR gave interviews with various media in Atchison, Kansas to coincide with the August 21 event.

In addition to the BBC program, CONSOLMAGNO participated in more than two dozen media interviews around the world, including interviews with the BBC Radio, Time Magazine, and Die Zeit.

BBC journalists visit the domes on the Papal Palace at Castel Gandolfo

CORBALLY gave a series of radio and print interviews over the course of the year about a variety of topics including the Cassini probe data on Saturn's rings; the hunt for Planet 9; on the end of the world from Nibiru and the Fatima prediction. He was also interviewed for an article appearing in *The Catholic Sentinel*, Portland OR, on Life Elsewhere and by the *The Sunday Times* on the lambda Boötis-type stars puzzle and on the Vatican Observatory.

GIONTI was interviewed on January 31 by Giacomo di Fruscolo for *Bel Tempo si Spera* of TV2000 and GIONTI was interviewed for the main Italian news program Dialogo, on TG1. He also took part in the press conference for the Lemaître workshop at the Vatican Press Office on May 8 and gave several interviews to many international televisions and newspapers. GIONTI was interviewed for the program *A Sua Immagine* broadcast on RAI1 on September 13.

As part of his media engagement initiative GABOR continues his weekly radio blog on Radio Lumen, Slovakia.

And finally the Agence d'Information d'Afrique Centrale ran a portrait on KIKWAYA ELUO titled *l'astronome Congolais du Vatican, or The Vatican's Congolese Astronomer.*

Education Outreach

Over the course of the year, CONSOLMAGNO has made 94 public presentations on the topics of science and the faith-science connection. These included invitations from Catholic High Schools in Puerto Rico, Florida, New York, Missouri, Colorado, and Washington; seminaries in New York and Florida; retreats and days of recollection in the United Kingdom, Rome, Maryland, Colorado, and California; presentations at science fiction conventions in Minneapolis, San Juan, Puerto Rico, and Helsinki, Finland; talks at universities in Ireland, Italy, New York, Missouri, Michigan, British Columbia and Alaska; at planetaria in Italy, New York and Michigan; at libraries and museums in Ireland, Italy, Austria, Missouri and Michigan; and many other venues such as grade schools, churches and observatories, as well. In January, CONSOLMAGNO prepared a twelve part video/audio series for Now You Know Media, An Introduction to the Universe. These lectures became available in September. This is the third such series on astronomical topics available from Now You Know Media.

CORBALLY continued his assistance with the Faith and Astronomy Workshop held in January in Tucson and his outreach to high school and university students. Together with Margaret Boone Rappaport and Stephen Rappaport, in February he gave a workshop on "Applied Astronomy and Consulting Roles: An Introduction" to graduate students and postdocs at Steward Observatory. In March he and M.B. Rappaport gave the keynote presentation and a workshop during the Institute Day of the McGrath Institute for Church life, University of Notre Dame, held at Mercy High School, Middletown CT. Also in March he joined a panel discussion for the University of California Riverside Science Lecture Series and gave a talk to UCR faculty and students on *Bridging Faith and Science at the Vatican Observatory*. In May he spoke to the 36th Annual Cornerstone Gala, Diocese of Tucson, on *Jesuits in Arizona* and in July he discussed the Vatican Observatory and sharing research with international organizations with Lowri Pritchard, of PolicyBristol for the University of Bristol, UK. In October, CORBALLY hosted an evening tour of MGIO and VATT for the Prescott Astronomy Club together with BOYLE.

Father Jim Kurzynski celebrating Mass on the last evening of FAW

Over the course of the year FUNES has lectured at the following universities and high-schools: Pontificia Universidad Javeriana, Colombia, IBERO Puebla, Mexico, Universidad Popular Autónoma del Estado de Puebla, Mexico, Universidad Católica Sedes Sapientia, Peru, Observatorio Astronómico de Córdoba, Universidad Católica de Córdoba, Instituto Oriente de Puebl, Mexico, Instituto Parroquial Monte Cristo, Argentina, Institutos Ntra. Sra. de la Medalla Milagrosa y San Francisco de Asís, Argentina.

In February GABOR gave a talk and took part in a panel in Phoenix with Deborah Haarsma, President of BioLogos, and Paul A. Scowen, School of Earth and Space Exploration, ASU, at an event entitled *God and the Cosmos*, hosted by the Arizona Center for Christian Studies at ASU's Marston Exploration Theater. He gave eight talks at the Redemptorist Renewal Center in Tucson to the participants of the sabbatical program in April and again in November. He gave talks in Kláštor pod Znievom, Slovakia, on July 30; at the *Researchers' Night* annual event in Košice, Slovakia, on September 29; in Olomouc, Czechia, on October 5; and in Paris, France, on October 14. He gave a lecture entitled, *Babylonians & the Leap Second. Precision measurements of Earth's rotation rate* at Benedictine College in Atchison, Kansas, on August 21, the day of the total solar eclipse. He gave a six-hour course for physics teachers in Velehrad, Czechia, on October 6, as a professional development program.

GALAVERNI gave a series of talks on Cosmology high schools students and teachers and a course on *Interactions between Cosmology, Philosophy and Theology* for the Bachelor of Theology program at the Studio Teologico Interdiocesano in Reggio Emilia.

GIONTI with the help of Alfio BONANNO and Fabio SCARDIGLI and Stefano BELLUCCI organized the International workshop *Black Holes, Spacetime Singularities and Gravitational Waves* held at the Vatican Observatory in Castel Gandolfo May 9-12, 2017. (see Cover Story of this year's annual report). He gave a seminar at the Gregorian University on the nature of time for the graduate philosophy class of Fr. Louis CARUANA, S.J. in January. Later in April he gave a seminar on "A History of Cosmology and the Question of God" at the San Martino di Venezze parish near Rovigo as part of a panel including Prof. Antonio Masiero and Fr. Secondo Bongiovanni, S.J. He also delivered a similar seminar for the festival of Science and Philosophy in Foligno, Italy in May. GIONTI gave a public lecture during the *Astri in Maremma* festival in Gavoranno, Italy. In October and November he delivered a series of talks in Italy on topics including the *Beginning and End of the Universe* and *Cosmology, the Big-Bang and God*, the latter as part of a panel with Roberto Battiston, president of the Italian Space Agency (ASI). He also participated in a panel chaired by Sergio Zavoli at the Italian Senate Library on November 28th.

In 2017 HELLER continued his series of public lectures exploring the relationship between faith and science. In February he spoke at Krakow's National Academy of Theatre Arts, in March, at the University of Gdansk's National Center for Quantum Informatics; in June, at Warsaw's Space Research Centre; at Krakow's John Paul II Hospital, and in Kielce also in June.

Delving into the digital world, MACKE presented an *Introduction to the Vatican Observatory* video clip for the Vatican Observatory Foundation channel. Through the wonders of modern technology he also gave presentations and held informal discussions on the Vatican Observatory to high school and college students in the United States via online streaming These include students from Bishop DuBourg High School, St. Louis; Bryn Mawr College Chem 252 Research Methodology class taught by FRANCL and the Mercy High School Astronomy Club and class, Middletown, Connecticut. MACKE also gave an invited talk to the Comenius University Dept of mathematics, physics, and informatics in Bratislava, Slovakia May 24, 2017.

Presentations, Academic Activities and Conference Participation

ALTAMORE contributed to the organization of the following meetings: * *XXII Scuola Estiva di Astronomia*. Società Astronomica Italiana, Stilo - Riace, July 24-29 * *Settimane Culturali 2017* - Ufficio Pastorale Universitaria Vicariato di Roma, May 4.
He attended *SETI INAF* meeting, Rome, October 24.

BROWN a was the local Organizing Committee Member for the *AGB-Supernovae Mass Transition* meeting; INAF-OAR; Monte Porzio-Catone; March 27-31, 2017 * presented the Specola Vaticana junior AGBSNe prize to the most impressive young scientist * presented 'An Expansion of the Mass-Orbital Period Relation of sdBs from Stable Roche Lobe Overflow' at *The Impact of Binaries on Stellar Evolution*; ESO; Garching, July 3-7, and again at *The Eigth Metting*

on Hot Subdwarfs and Related Objects; Predagogical University of Krakow Poland; Krakow, Poland; July 9-15. He also attended at the *International Workshop on Black Holes, Gravitational Waves and Spacetime Singularities*; Vatican Observatory; Vatican City State; May 9-12.
CORBALLY with Margaret Boone Rappaport gave a paper on "Evaluation research using astronomy theatre suggests good promise for young Spanish-origin women to choose science majors", at the *International Symposium on Astronomy and Astrobiology Education*, July 3 - 8, 2017, in Utrecht, NL * gave an invited paper with Richard Gray on "Science with the LAMOST-Kepler spectra based on an analysis with the MKCLASS Code" at the *2nd LAMOST–Kepler Workshop* titled "LAMOST in the era of large spectroscopic surveys", in Brussels, July 31 – August 3. They both were on the workshop's Scientific Organizing Committee * presented an invited talk on "Taking Science Seriously and Talking About God" at the *INCAI Symposium* at Benedictine College, Atchison KS, August 20 – 21, on the occasion of the total solar eclipse * with Rappaport gave a plenary address, "Intersection of Prehistoric Evolutionary Models for Moral and Religious Capacities", at the *2nd International Conference on the Evolution of Religion*, November 12 – 15 at Tamaya, Santa Ana Pueblo NM * presented a poster paper with Rappaport, "Proven Efficacy of New Experiential STEM Teaching Method", at the Astronomy Society of the Pacific's 129th Annual Meeting, "*Beyond the Eclipse: Engaging Diverse and Underserved Communities in Astronomy and STEM*", in St. Louis MO, December 5 – 8.

GABOR taught a tier II general education course on the history and philosophy astronomy, ASTR 320, in the Spring 2017 semester at the UA * participated in the workshop entitled *Building the Infrastructure for Time-Domain Alert Science in the LSST Era*, held on May 22-25 in Tucson, Arizona, and in the colloquium *La seconde atomique a 50 ans* commemorating the 50th anniversary of the atomic definition of the base unit of time, held at the Paris Observatory on September 13 * He co-authored a poster paper presented at the *2nd LBT User's Meeting* in Florence, Italy, on June 20–23, and co-presented a paper at the *5th Workshop on Robotic Autonomous Observatories (AstroRob)* in Mazagón (Huelva), Spain, on October 16–20 * gave an invited public talk at the *Astronomy and the Trnava University* colloquium in Trnava, Slovakia, on October 3.

GALAVERNI attended the workshop on *Gravitational Waves and Spacetime Singularities*, Vatican Observatory, May 9-12.

GIONTI gave a talk entitled "The Big-Bang Theory and the Question of God" at the International Conference "*The Discovery of Gravitational Waves and its Importance for the Society*", Pontifical Seminary in Pune, India, January 24-28 * participated in the workshop "*Quantum Space-Time and the Renormalization Group*", held at Lorentz, University of Leiden, Netherlands, Feb. 13-17 * participated in the workshop "*Black Holes, Spacetime Singularity and Gravitational Waves*" held at the Vatican Observatory, May 8-12 * gave a talk entitled "Analysis of Lorentzian Sub-Planckian Cosmology via Asymptotic Safety" at the International Workshop "*Testing Fundamental Physics Principles*", Corfú, Greece, September 22-28 * gave a talk entitled "Bouncing and Emergent Cosmologies from ADM RG Flows" at the Workshop of the Group "*Quantum Fields of Gravity, Cosmology and Black Holes*"(FLAG) of the National Institute for Nuclear Physics (INFN) in Como, Italy, December 14-15.

HELLER was invited to be a panelist for the Copernicus Festival, on the discussion "Emotions in Doing Science" in Krakow, March 31 * gave a public lecture entitled "Did It Start with a Bang?" at the *International Conference of Cariologists*, Krakow * delivered an invited paper on "The Logic of God" at the *Second World Congress on Logic and Religion*, Warsaw, Poland * delivered an invited paper on "The Philosophical Itinerary of Albert Einstein", at the *Congress of Polish Physicists*, Wrocław, September 14 * gave a public lecture entitled "Man and the Cosmic Drama" at the Wrocław University of Environmental and Life Studies, September 15 * participated in the *International Conference "What Exists in Physics"* at the Copernicus Center, Krakow, October 5-6.

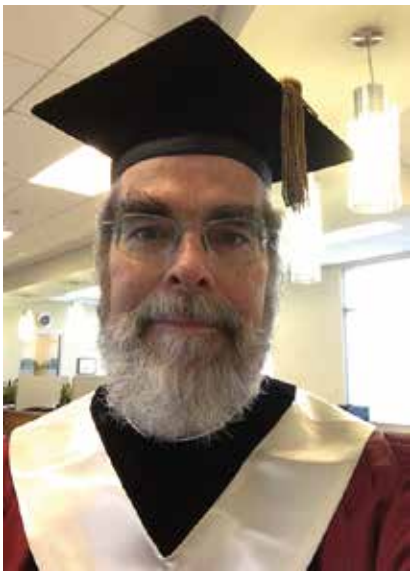
KIKWAYA ELUO participated in a conference entitled *Astronomie: que peuvent nous renseigner les asteroides sur le systeme solaire et sur nous-memes?* Alliance Francaise, Tucson, Arizona, USA.

MACKE presented "Quantifying Weathering in Ordinary Chondrite Finds Using Heat Capacity" at the 48th Lunar and Planetary Science Conference in Houston TX, March 24-27, and was coauthor on one other abstract * presented two posters at the 80th Meteoritical Society Meeting in Santa Fe, NM, July 23-28, and was coauthor on one other abstract.

Awards and distinctions

CONSOLMAGNO and MUELLER were both invited, and accepted, to serve as members of the Pontifical Council for Culture advisory board for science and religion.

On June 15, CONSOLMAGNO was awarded a Ph D Honoris Causa from Santa Clara University in recognition of his work promoting the unity of science and religion.



Br. Consolmagno at Santa Clara University

GIONTI was granted membership as associate fellow of the National Laboratories in Frascati of INFN (Italian National Institute for Nuclear Physics).
He was also awarded the Kielce –Sacroexpo Medal "Per Artem ad Deum", by Concilium de Cultura in Rome on June 12.

The IAU honored MACKE with an asteroid, 11266 Macke, named after him in recognition of contributions to planetary science including "studying the relationship
between shock state and porosity in carbonaceous chondrites" (IAU Minor Planet Circular 103977).

Personnel

The Specola has added a new category of Associate Scholars, scientists who are affiliated with the Specola while working on specific projects in collaboration with the Specola's permanent scientific staff or during a period when they would be separated from the Specola while pursuing studies or other work towards their further religious formation. These appointments are on an annual basis, at the discretion of the Director. Associates do not receive a salary from the Specola, but aspects of their research may receive Specola support. In their scientific publications they have the right to list "Specola Vaticana" as their affiliation.

The first two members of the Specola under this category are Adam HINCKS, SJ, and Fr. Matteo GALAVERNI. Dr. Hincks is a Jesuit scholastic from Canada with a doctorate in observational cosmology who is presently studying theology in Rome towards his ordination. Fr. Matteo Galaverni is a recently ordained priest of the diocese of Reggio Emilia with a doctorate in astrophysics. Both already have outstanding records in their astronomical careers but are not currently able to work with us full time.

In addition, we have long depended on the technical expertise of a number of local astronomers in maintaining our telescopes and helping out in our outreach programs. Most notable among these this past year has been the assistance of Claudio COSTA, a space systems consultant engineer and an expert amateur astronomer. Most recently he has overseen the renovation of the historic Carte du Ciel telescope. In point of fact, he has worked with us since his student days in the 1970s; he was the last person to use that telescope before it was abandoned in the early 1980s, and now has become the first to use it in its renovated state.

In memoriam

Luigi Lori, long time member of the Specola staff, died on February 12. He first joined the Specola as a general caretaker in 1971, a position he filled until his retirement in 2007. A tribute to Luigi can be found in

the Director's Letter.
Robert F. Garrison died on August 13 in Toronto, Canada, at the age of 81, so ending a 20-year fight against Parkinson's, which he had tackled with characteristic scientific interest and practical strategies. Bob joined the University of Toronto as faculty in the Astronomy Department in 1968, and served as Associate Director of the David Dunlap Observatory. In those capacities he directed the doctorate of CORBALLY, which led to his being invited to join the VOSS Faculty in 1990, an honor he always appreciated. As a superb stellar spectroscopist and devoted educator, Bob could think of no better way to start his year's sabbatical than a month of intensive teaching a keen set of international VOSS students, to whom he communicated what he put into practice, "One is responsible to oneself for what one learns." His colleagues and former students miss him for his deep humanity, devotion to science and teaching, and twinkling humor.

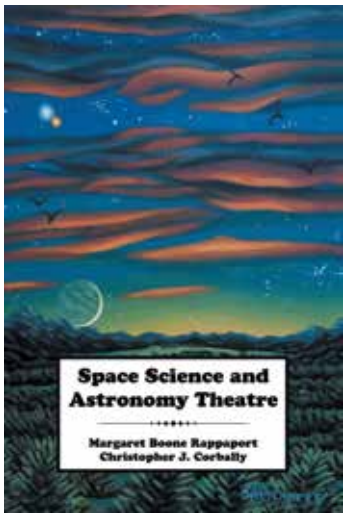
A. G. Davis Philip, 87, died peacefully at the Capital Living Nursing and Rehabilitation Center on March 28, 2016. Born in NYC on January 9, 1929, he received his BS in Physics from Union College; MS in Astronomy from New Mexico State University (where he served in the US army for two years); and his PhD in Astronomy from Case Institute of Technology. He is best known for his work on globular clusters, dense star clusters that orbit the Milky Way. He was a Visiting Fellow at Yale, a Visiting Astronomer at Moletai Observatory (Lithuania), Vatican Advanced Technology Telescope (Arizona), and the CASLEO Observatory (Argentina). He is survived by his wife of 51 years, Kristina; daughter, Elizabeth; grandsons, Ethan and Sullivan; brother, Peter Philip; nephews, William, Thomas, and Peter; and sister-in-law, Laima Drobavicius.

Three members of the Specola lost close family members this past year. John Corbally, the brother of CORBALLY, died on May 9, Anna Omizzolo, the mother of OMIZZOLO, died on October 29 and Patricia Claire (Duffy) Consolmagno, the mother of CONSOLMAGNO, died on December 27.
We remember them in our prayers.

Publications

This chapter lists the work of Vatican Observatory staff and adjunct scholars accepted for publication in 2017

Books



Space Science and Astronomy Theatre by Margaret Boone Rappaport (Author), Christopher Corbally (Author)
How can we communicate Space Science and Astronomy to children and teenagers in a anguage that is not only comprehensible but engaging? Turn it into theatre! This was the genesis of the book Space Science and Astronomy Theatre by CORBALLY and co-author Margaret Boone Rappaport.
In addition to astronomers and astronauts, this fun-filled book of theatrical scenes, also feature engineers, accountants, graphic artists, public relations practitioners, biologists, meteorologists, and others who play a critical role in space adventures. Scenarios will take you into the past and into the future and include:
- A cosmologist and a computer graphics artist are preparing a presentation for public television on theories about the distribution of galaxies in the universe, and the placement of voids where no galaxies are found.
- An astrobiologist and an engineer discover the first positive biosignature data from an exoplanet near Earth. The findings provide a big surprise.
- Two recent high school graduates explore a star factory (nebula) in the constellation Orion, and using a video arcade game, they make speculations about the future.
While the props and costumes needed for scripts are minimal, the scenes promote deep learning. It is essential reading for educators or parents who want to get their youngsters interested in the world of space science and astronomy.

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Visitors

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

Visitors to the 'Specola', Vatican Observatory headquarters

In December 2016, the Specola hosted 50 participants in a conference on Georges Lemaître sponsored by the Belgian Academy of Rome. The participants visited the Specola's historic telescopes and enjoyed dinner in the Specola's new dining room, the Sala Clavius. The dinner was prepared and served by the Specola's own crack cooking/cleaning team, Gina Savinetti and Assunta Rodia. In the same month Mons. Marcello Semeraro, Bishop of the Diocese of Albano, joined the Specola for lunch. A Group from DePaul University visited the Observatory telescopes at CG, hosted by MUELLER.

Also in December 2016, Roberto and Maria Buffetti, friends and generous benefactors, joined the Specola for lunch and for a visit to recently completed facilities. The Specola's Aula Buffetti is named in honor of their son Gabriele. We ask prayers for Roberto and Maria in light of the stroke which Maria suffered in summer 2017.

In February 2017, MUELLER hosted two groups of Astrophiles on visits to the Observatory telescopes, one from "AstroBarcelona" and another from Switzerland.

In March, BROWN gave a tour of the Palace domes to the Rome seminar German group (students of various German universities) led by Dr. Michael Korsey and a presentation in the 5th floor lecture room. He also gave a tour of the Observatory domes and offices to Dr. Zhanwen Han, former director of Yunnan Observatory (China) and research collaborator.

Also in March MUELLER hosted the Ambassador of the Republic of Peru to the Holy See, H.E. Mrs. Maria Elvira Velasquez Rivas-Plata. He celebrated Mass for a Vatican Observatory Foundation group at rooms of St. Ignatius at Rome and led the group on a tour of the telescopes and Observatory headquarters at Castel Gandolfo. He also welcomed a group of seminarians from the North American College on a visit of the telescopes.

In April, BROWN gave a tour of the palace domes to Drexel University students enrolled in the "History of Science and the Influence of Religion" course. MUELLER hosted a group of Jesuit scholastics from the International College of the Gesu on a visit of the Observatory Telescopes. They also joined the Jesuit community for lunch. Later that month MUELLER welcomed a group of Muslim students from the Lay Center in Rome.

In May the religious superiors and ministers of the various Jesuit communities comprising the Roman Delegation of the Society of Jesus were hosted for lunch and a visit to the Specola's historic telescopes. This was on the occasion of the patronal feast of the Specola, Our Lady of Good Counsel. The Roman Delegation is the administrative unit of the Society of Jesus which includes the Jesuit community of the Specola. The lunch was prepared and served Specola staff members Gina Savinetti and Assunta Rodia.

The Specola also hosted Nuno da Silva Gonçalves S.J., then recently installed as rector of the *Pontifical Gregorian University* (PUG). Fr. Gonçalves joined the Specola for lunch, and met with CONSOLMAGNO and MUELLER to discuss collaborative projects for the PUG and the Specola.

On May 20 over 100 participants in the annual international meeting of the *Fondazione Centessimus Annus Pro Pontifice* visited the Observatory telescopes, hosted by MUELLER and GIONTI. They also toured the Apostolic Palace and the Papal Gardens. Finally in May a group from Lipscombe University visited the Observatory telescopes, hosted by MUELLER.

In June, BROWN gave a tour of the palace domes to students from Montgomery Bell Academy (MBA; Nashville, TN, USA) High School. A group from Loyola University Chicago visited the Observatory telescopes, hosted by MUELLER. He also hosted a group from Boston College.

In July BROWN gave a tour of the palace domes to students of the University of Dallas program 'Rome and the Catholic Church'.

In August, the Jesuit community of the Specola hosted the employees of the Specola and their families for a cook-out on the occasion of the feast of St. Ignatius Loyola. MUELLER hosted the Ambassador of the Republic of South Africa to the Holy See, H.E. Mr. George Johannes, and the Ambassador of the Czech Republic to the Holy See, H.E. Mr. Pavel Vosalik.

On September 21, 2017 BROWN gave a tour of the Observatory to 50 emeritus members of ESA (European Space Agency)

In October, the Board of Directors of the Gregorian University Foundation visited Castel Gandolfo. Along with touring the Apostolic Palace and the Papal Gardens, they visited the Specola's historic telescopes and enjoyed dessert while visiting the Specola's headquarters.

GIONTI guided several groups to the domes of the Vatican Observatory, among them the major visits have been: 17 people, Lutheran Pastors, Psychotherapists, Musicians and Scientists from Sweden involved in a program of Ignatian Spirituality directed by Michelle Mope Andersson and Fr. Marc-Stephan Geese S.J.

Working Visits to the Vatican Observatory Headquarters
For extended working stays, we were delighted to host:
Christopher and Christina Graney, Jefferson Community College, Louisville, KY; Diana Pasulka, University of North Carolina, Wilmington NC; Timothy Taylor, NASA; David Collins S.J. and Fr. Matteo Galaverni, an astronomer associated with the Specola on a volunteer basis, is a priest of the Diocese of Reggio Emilia-Guastalla.

Br. Aaron (Ronnie) Nyadawa S.J. of the Zimbabwe Province of the Society of Jesus worked in a support/technical capacity at the Specola. This was so that he could be of help to the Specola, but also to provide him the opportunity to work side by side with fellow Jesuit Brothers MACKE and CONSOLMAGNO.

Dante MINNITI and Joyce Pullen were at the Specola during the whole month of June working on the VVVX survey and the organization of the next Vatican Observatory Summer School due to take place in 2018.

The following scientists also paid working visits to the Specola in Castel Gandolfo in 2017:
Mathew Chandrankunnel, CMI, Dharmaram Vidya Kshetram, Christ University, Bangalore, India; Piero Benvenuti, General Secretary, IAU; Maria Rosaria D'Antonio, Head of Administration, IAU Headquarters; emeritus scientists and engineers from the European Space Agency (ESA); a group of researchers from ESA in Frascati and Ray Butler, National University of Ireland, Galway.

In Tucson
In February the Tucson residence of the Specola hosted Gerald Kicanas, Bishop of Tucson, for dinner. Bishop Kicanas retired in October 2017. He has been a steadfast friend and supporter of the Specola; during a 2012 visit to Rome, he enjoyed lunch and a visit at the Specola headquarters.

Working Visits to other institutions
From July 29 to August 4, GABOR took part in the 34th Ebicycle, a 7-day, 350-mile cycling tour of observatories and astronomy sites, each year alternately in Bohemia, Moravia, and Slovakia. This was the 9th time he joined the group of 50 professional and amateur astronomers for the event. He visited observatories and planetaria in Žiar nad Hronom, Handlová, Partizánske, Hlohovec, and Hurbanovo (all in Slovakia).

Black Holes, Gravitational Waves and Spacetime Singularities

Vatican Observatory

Castel Gandolfo, Roma

9 - 12 May 2017

INFN Istituto Nazionale di Fisica Nucleare

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS