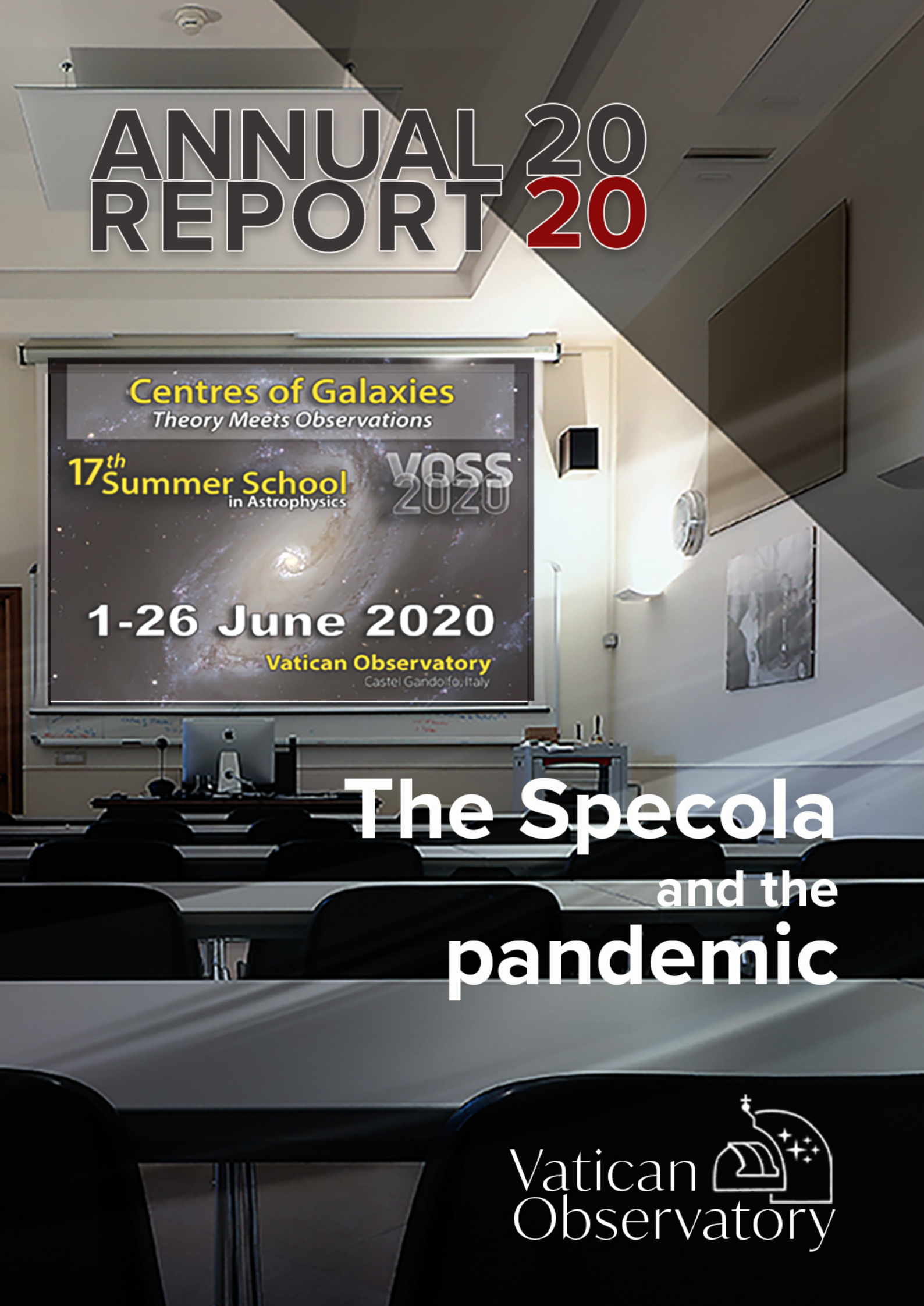
ANNUAL REPORT 2020



The Specola and the pandemic

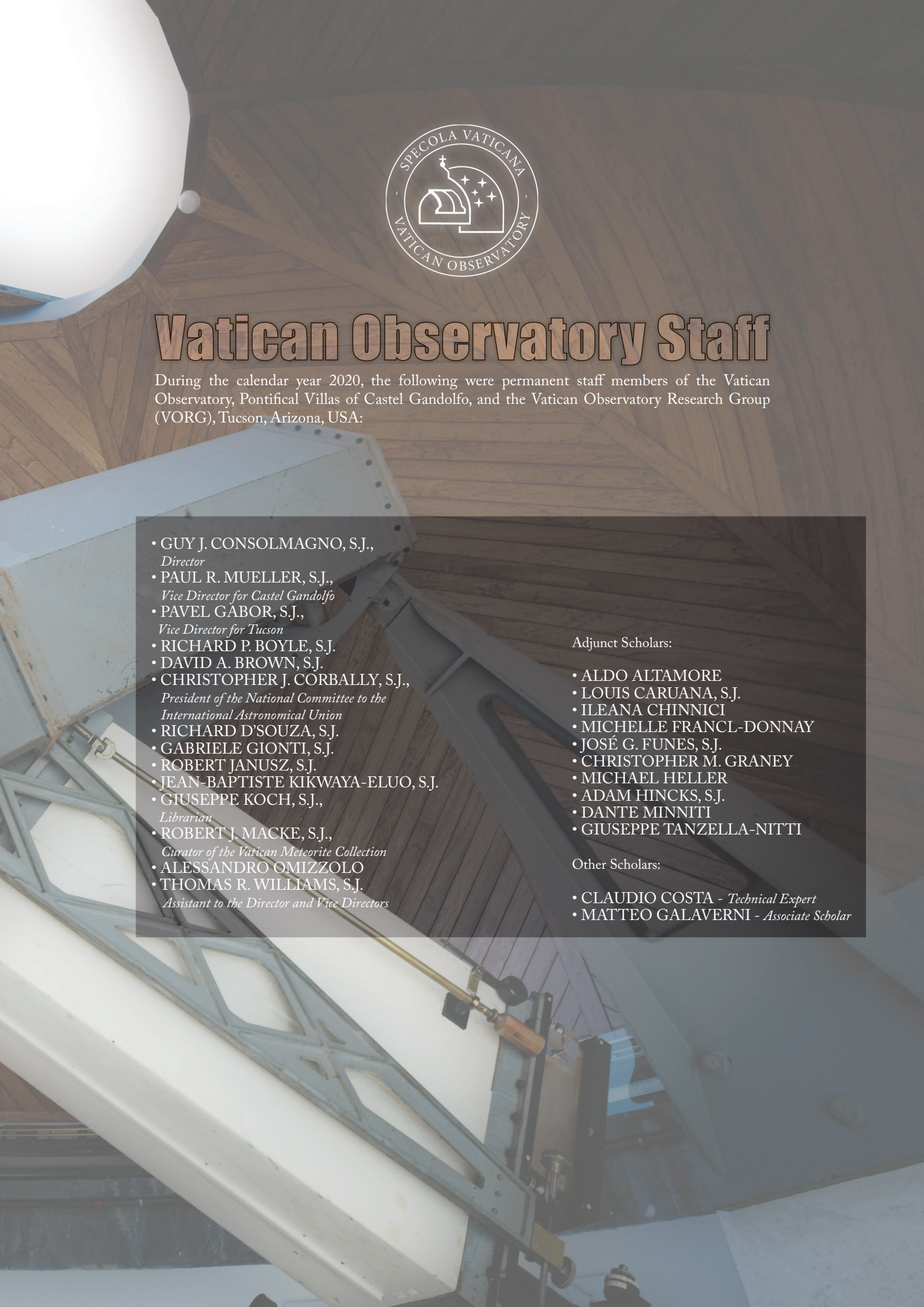
Vatican Observatory

ANNUAL REPORT 2020

Vatican Observatory
Castel Gandolfo
V-00120 Vatican City State

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

vaticanobservatory.va



Vatican Observatory Staff

During the calendar year 2020, the following were permanent staff members of the Vatican Observatory, Pontifical Villas of Castel Gandolfo, and the Vatican Observatory Research Group (VORG), Tucson, Arizona, USA:

- GUY J. CONSOLMAGNO, S.J., *Director*
- PAUL R. MUELLER, S.J., *Vice Director for Castel Gandolfo*
- PAVEL GÁBOR, S.J., *Vice Director for Tucson*
- RICHARD P. BOYLE, S.J.
- DAVID A. BROWN, S.J.
- CHRISTOPHER J. CORBALLY, S.J., *President of the National Committee to the International Astronomical Union*
- RICHARD D'SOUZA, S.J.
- GABRIELE GIONTI, S.J.
- ROBERT JANUSZ, S.J.
- JEAN-BAPTISTE KIKWAYA-ELUO, S.J.
- GIUSEPPE KOCH, S.J., *Librarian*
- ROBERT J. MACKE, S.J., *Curator of the Vatican Meteorite Collection*
- ALESSANDRO OMIZZOLO
- THOMAS R. WILLIAMS, S.J. *Assistant to the Director and Vice Directors*

Adjunct Scholars:

- ALDO ALTAMORE
- LOUIS CARUANA, S.J.
- ILEANA CHINNICI
- MICHELLE FRANCL-DONNAY
- JOSÉ G. FUNES, S.J.
- CHRISTOPHER M. GRANEY
- MICHAEL HELLER
- ADAM HINCKS, S.J.
- DANTE MINNITI
- GIUSEPPE TANZELLA-NITTI

Other Scholars:

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

COVER: *The Aula "Gabriele Buffetti" should have been filled with students of the 2020 Vatican Observatory Summer School this past June; instead, due to the COVID pandemic, it stood empty. Shot and Image collage by Antonio Coretti*

IN THESE PAGES: *Fr. James Kurzynski, a priest of the Diocese of La Crosse, Wisconsin and regular contributor to the Vatican Observatory Foundation's Sacred Space Astronomy site, took this image of Comet Neowise over the Chippewa River just north of Durand, Wisconsin, using a Fujifilm x-t2 at ISO 800 with a Fujinon 16mm f/1.4 lens and exposure of 25 seconds.*

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

In light of the COVID-19 pandemic, funding for printing the 2020 Annual Report of the Vatican Observatory has been provided by the Vatican Observatory Foundation.
The Annual Report is also available in PDF format at www.vaticanobservatory.va

Vatican Observatory Publications

Vatican Observatory
ANNUAL REPORT 2020

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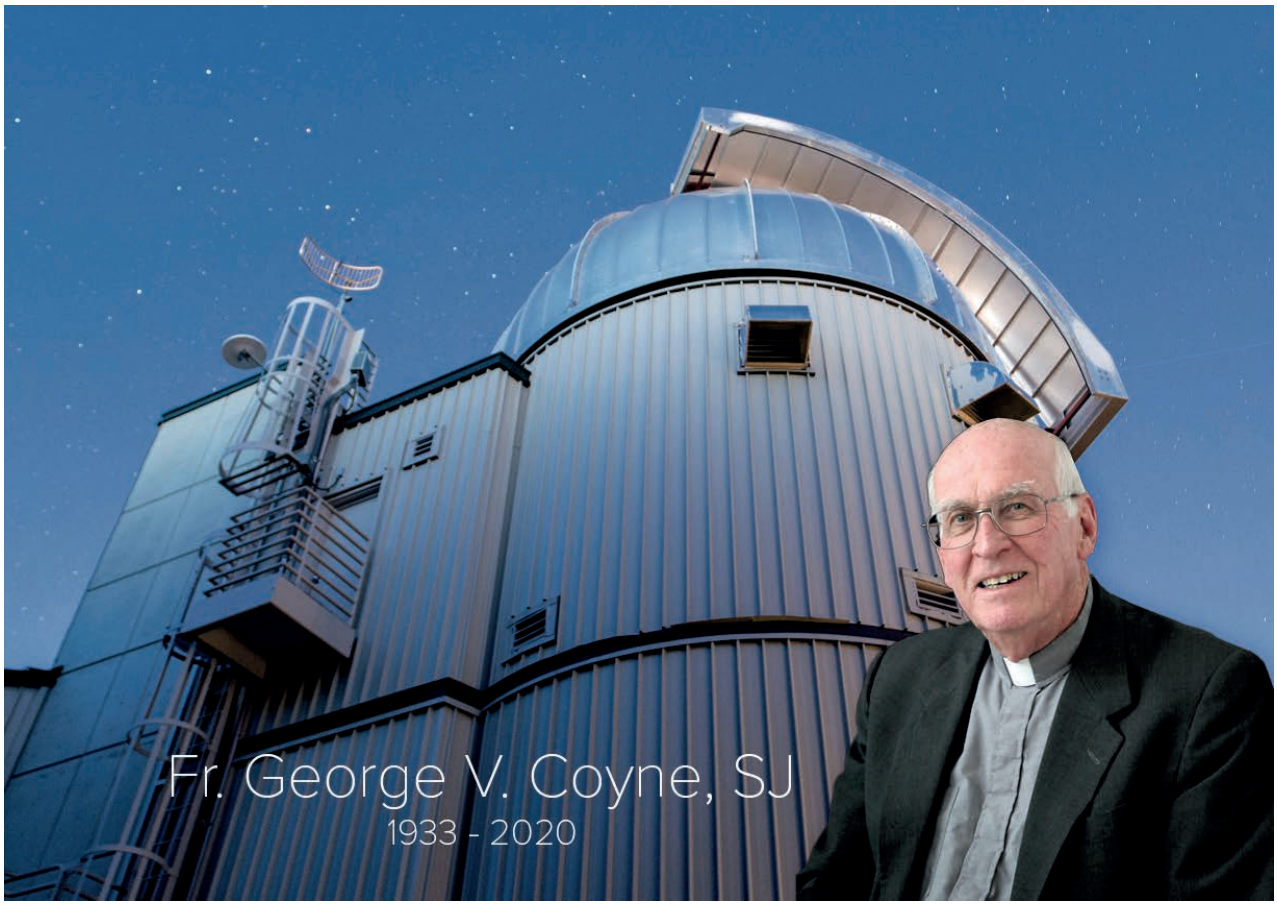
Chapter ONE

From the Director

A eulogy to Father George Coyne, SJ, priest, scientist, friend and mentor.



Fr. George V. Coyne SJ, director emeritus of the Vatican Observatory — and my role model in so many ways — died of cancer on Tuesday, February 11, in Syracuse, NY. He was 87 years old.

It's impossible to describe George. I could list all his scientific work, his writings on faith and science, his honors and degrees, but he was so much more than that.

Fr. Coyne was named director of the Vatican Observatory in 1978, at the age of 45, after the sudden death of his predecessor, Fr. Patrick Treanor. It is notable that he was one of the few appointments made by Pope John Paul I. He served until he was 73 years old, in 2006. With 28 years in office, his was the longest term of any Observatory director.

During his tenure Fr Coyne oversaw the modernization of the Observatory's role in the world of science. He welcomed onto its staff a number of young Jesuit astronomers from around the world; from Africa, Asia, and South America. And he established the rank of "adjunct scholar", providing access to our facilities for other religious scientists, including women.

Under his leadership the Vatican Observatory Research Group was established at the University of Arizona. In collaboration with the Steward Observatory, he oversaw

the construction of the Vatican Advanced Technology Telescope (the Alice P. Lennon Telescope and Thomas J. Bannan Astrophysics Facility), with the world's first spin-cast mirror, on Mt. Graham.

Fr. Coyne promoted the dialogue between science and theology at the highest level. In close collaboration with St. John Paul II, in the 1990s he organized a series of conferences on "God's Action in the Universe" at the Observatory's headquarters in Castel Gandolfo. A letter from St. John Paul to George Coyne on the occasion of the 300th anniversary of Newton's *Principia* was one of the most detailed modern statements of Catholic theology on the relation between science and faith.

And with the establishment in 1986 of the biennial Vatican Observatory Summer Schools in astronomy and astrophysics, Fr. Coyne advanced the education of a generation of young astronomers, especially from developing countries.

You can find a full biography at our web sites (*http://www.vaticanobservatory.va/content/specolavaticana/en/news/recent-news/remembering-father-coyne.html* and *https://www.vofoundation.org/fr-george-coyne/*). I just want to spend a moment here on some more personal reflections.

I first met George forty-five years ago, at the University of Arizona's Lunar and Planetary Laboratory (LPL) where he was an assistant professor and senior research fellow. At that time, he was living at the local parish, St. Peter and Paul's. I was a graduate student in the LPL then, not yet a Jesuit, but I got to see George regularly at daily Mass there.

The LPL was a wildly dysfunctional place in those days… lots of infighting among the faculty. One of the issues was a demand from the University that every professor's individual telescope (and support staff) needed to be combined into one common observatory. But no one trusted anyone else with their telescopes!

I was living in a house with four other grad students, each working for a different feuding professor. We would keep each other posted on what was going on in the department, what we had heard from our advisors. My contribution was to take the temperature of the fighting based on what George had preached that morning at Mass!

Finally, the other astronomers at the LPL all decided to have George become the director of the newly-formed Catalina Observatory, even though he was junior to the rest of them. He was the only one that they all trusted. And liked.

People liked George because he liked people. (I'll be honest, I knew some people who didn't like him; they were generally people who didn't like themselves, either.) He completely disarmed the Richard Dawkinses of the world who tried to debate him because they were not prepared for someone who wasn't mad at them, who didn't want to argue at them. He honestly wanted to learn from them and hear what they had to say. If he would argue — and he was not afraid to do so — it would be with, not against.

That trait was also a part of his Jesuit life. At his funeral in the LeMoyne College Chapel (where he had taken up a chair after his retirement from the Specola) we heard Matthew's Gospel (19, 13 - 29). It's the story of the rich young man who wants to know, "What good thing must I do to get eternal life?" He's taken aback by the answer Jesus tells him. It's not enough to follow the commandments, to just do what we're expected to do. Rather we have to be ready to give up all our other possessions, "all our liberty, our memory, our understanding, and our entire will, all you have and call your own."

Give up your understanding? Yes, indeed. That's what a scientist does; you have to be willing to give up being satisfied with the way you used to understand something, in order to understand it in a new and deeper way. And for the sake of their glorious obsession with science, many scientists — including those who live celibacy even if they haven't vowed it — like George have given up "houses or brothers or sisters or father or mother or wife or children or fields." How many Jesuit scholars have been willing to give up their fields? And for what? Only to receive "a hundred times as much and eternal life!"

In fact, that passage about the rich man in Matthew is introduced by the episode where people brought little children to Jesus. And when the disciples rebuked them, Jesus said, "Let the little children come to me."

George loved to do baptisms and weddings for the children of his scientist friends. (Funerals as well.) He was a pastor to astronomers. His Italian secretary, Rita

Callegari, married an American telescope engineer (George did the wedding) and when their little girls (George did the baptisms) would visit their mama at work, they would run into George's office with delighted cries of "paco, paco!" (They really were trying to say "capo, capo", the Italian for "boss," which is what Rita called him.) And George loved it. Those little girls, by the way, are both scientists themselves now.

George was a *capo*, a boss; and a pastor; and role model and friend to an entire generation of young astronomers on their way to their scientific careers. From him we learned astronomy… and the joy of learning… and the love of sharing what we'd learned with each other. Every two years another class would come to spend a month with us at our summer schools. I've gotten more than a hundred emails from alumni and other colleagues, from every corner of the globe.

Finally, I would like to recall three things that I remember George saying. First, his instruction to me when I first arrived at the Observatory was simply: "do good science." The science itself was the goal. And he gave all of us the space to make it happen.
But what made science itself a worthy goal? He once said, "yes, we must feed the hungry and cure the blind; but if that is all we do, then we will all be hungry and we will all be blind." Our goal in life can't be just to avoid hunger. Rather, we feed the hungry so that they may be able to encounter joy and truth, the markers of God's presence.

And George would say, in so many of his public talks, "in us, the universe has become self-aware." Indeed, as St. Paul reminds us, "creation waits in eager expectation for the children of God." Creation could not be revealed until we were ready to receive that revelation. We become the children of God when we become aware of God's creation and thus, in it, of God's presence. *When we become scientists.*

It is by being aware of the universe that we can become aware of the Creator. We, ourselves, creatures of that very same creator, become the consciousness of creation. And in that truth we find joy. That's where we find God.

That was George. And that is why we found God in him.

Br. Guy Consolmagno, SJ
Director, Vatican Observatory

Around 2000, George invited a number of young Jesuit scientists to come visit the Specola; today all of them are full time members! Shown here are: (back row, from left) Paul Gabor, Jean Baptiste Kikwaya Eluo, Richard D'Souza, Andy Whitman, Gabriele Gionti, José Funes, Sabino Maffeo, Richard Murphy (rector of the Jesuit community in Tucson); front row, Guy Consolmagno, George Coyne, Giuseppe Koch.

Chapter TWO

A Covid-19 Timeline

The COVID-19 pandemic changed the world in 2020. To fully appreciate how much and how fast these changes occurred and for posterity, our cover article is a timeline of how the Vatican Observatory and its scientists confronted work and community life in a global health emergency.

As this is being written, we are still in the midst of the worst spread of disease since the Spanish Flu of 1918-1919 (which killed 50 million people, more than World War I). And yet, just as much of the history of that disease has been forgotten, so too might the memory of this pandemic be lost in just a few years' time. Already too many of our memories of the details of what happened, and when, are a confused jumble.

The effects of this disease and the various lockdowns that occurred, in the US and Italy, were certainly the most notable story of the Specola for 2020. As reflected in our cover, the first and in many ways most significant change was the loss of the Vatican Observatory Summer School scheduled for June. But it also meant the almost complete cancellation of travel between Tucson and Rome; the elimination of trips to scientific meetings; the cancellation of all visits to our visitors' centre in Rome; a shutdown for several months of our telescope in Tucson; and of course, the challenges to the health and wellbeing of our astronomers, our staff, and their families.

What follows is a timeline of events assembled by the Specola vice directors, Paul Mueller in Rome and Paul Gabor in Arizona, based on emails and other documentary records, tracking the extraordinary year gone by.

FEBRUARY

23 **Rome**: Emergency measures are set in place for the areas of Lombardy and Veneto, the first to be affected by the contagion. BALZONI raises the question of whether the Vatican Observatory Summer School (VOSS) will be able to be held, or if it will need to be postponed.

25 **Rome**: Returning from Tucson, MUELLER arrives at Fumicino Leonardo Da Vinci airport where temperature checks are now required.

26 **Rome**: Second (and as it turns out final) in-person meeting of MUELLER's Pontifical Gregorian University (PUG) class, "The Philosophy of Biology."The next day, the PUG suspends in-person instruction and goes on-line for the rest of the semester.

27 The VOSS faculty and students are all sent the message:
"The appearance of the coronavirus in Italy has raised considerable uncertainty about air travel in and out of the country, and at the moment there is some confusion here about what the response will be from both the Italian government and other nations.We are monitoring the situation with the help of the Vatican Secretary of State.We hope and pray that in the next two weeks or so we might all have a clearer idea of the situation. Until then, however, it might be best for those of you who have not yet arranged for your airplane tickets to delay purchasing them until the situation is clearer.We will continue to follow developments and let you know when we can give you more specific advice."

28 **Rome**: The last in-person seminar at the Specola (with Simona Vegetti) and the last public tour of our visitors' centre (led by COSTA) are held. Further talks by outside speakers will only occur remotely, and all further tours of our domes and facilities will be cancelled.

MARCH

2 **Rome**: We inquire at the Vatican Secretary of State offices about the possibilities for holding the VOSS in June 2020, in light of COVID. The Secretary of State replies that as of this date, all Vatican meetings involving travel from outside of Rome have been put off until September or later.

3 **Rome**: MACIEJEWSKI, Chair of the VOSS faculty, communicates to Dean of the VOSS D'Souza that the VOSS faculty have indicated their availability to teach in the summer of 2021 if the school has to be delayed by a year.

5 **Rome**: The VOSS Faculty and students are informed that the 2020 VOSS is postponed to 2021. The message to the students reads:

"It remains to be seen how severe the CORVID-19 virus outbreak will be, and we can hope be that by June it will turn out to have been less worrisome than feared. In the meantime, however, travel to Italy has already been disrupted. Many universities around the world — including the University of Arizona, where I am at the moment — have already suspended student travel to Italy.We worry that students from some countries may not be able to get visas to come to Italy, or to return home from Italy to their home country.

Furthermore, all schools and universities in Italy have been closed for the next 10 days to prevent further spread of the virus and overloading the health system of the country.

We can hope for the best; but we must prepare for the situation as it is now, in order to give time for all of us to make other plans. Therefore, after considerable discussion among our staff, faculty, and representatives of the Vatican City State, we have come to the difficult decision that because of the disruption of travel to Italy due to the CORVID-19 virus, we will need to postpone the Vatican Observatory Summer School until next year.

At present our intention is to begin VOSS 2021 on the evening of Sunday, May 30, 2021, and conclude on Friday, June 25. The faculty have all agreed to participate next year as they planned for this year, and all of the students admitted to the 2020 school are welcome to come in 2021, even if you will have completed your studies or moved to a new situation in the meantime."

Accordingly, the insurance for the school, the audience with the Pope, hotel reservations, catering, and other room reservations are all cancelled. The Vatican City State Secretary General is informed of this decision.

6 **Rome**: BROWN returns to Rome from the USA. The Vatican City State puts out a document of norms for COVID safety.

8 **Rome**: Italy imposes special restrictions for the "orange areas" of Lombardy and the other 14 provinces most affected by the virus, with less severe limitations for the rest of Italy. The cathedral in Albano, San Pancrazio, announces that all Masses are cancelled until April 3.

9 **Rome**: OMIZZOLO is forced to cancel his planned stay at the Specola, since a "Red Zone" has been declared for Padua and the entire province, and no one is permitted to exit or enter.

A letter from Vatican Secretary of State outlines the Vatican's COVID response and norms. Among other things, for the rest of 2020 all events and programs are cancelled, no participation in or organization of congresses or conventions is allowed, no travel is allowed. A letter from the Vatican City State government repeats and reinforces these norms.

The Italian government extends to the whole of Italy the provisions for the "orange areas" of Lombardy and the other 14 provinces. We receive the first version (of many to follow) of the "auto-declaration form" which one must fill out and carry with you if you go outside during the lockdown, explaining the reason for your travel.

10 **Rome**: MUELLER puts out COVID norms for the Specola and community:

For your information, between now and 3 April:

- *Staff who have children under the age of 15 have the option of staying at home, at 50% pay.*
- *Staff who fear they may have been exposed to the virus, and who have a certificate from a doctor, can stay isolated at home.*
- *Staff who normally return after lunch and work until 18.00 two days per week have the option of instead working until 15.00 every day.*
- *According to norms issued by the Vatican, a Direction may close down, at the discretion of the Director. However according to the Personnel Office, that norm is intended to apply to entities such as the Museums, which deal extensively with the public and have been forced to close; it is not intended to apply to an entity such as the Specola, which does not deal regularly or extensively with the public.*

Regarding the life of the Specola and the community, between now and 3 April:

- *It is prohibited to receive external visitors in the Specola or in the community. If you need to meet with someone, please meet with them outside. This is not only for our sake, but for the sake of our staff — those who have small children are*

understandably concerned to minimize their risk of being exposed to the virus.

- *Some staff may stay home on some days, to be with their children. I have asked them to work out a schedule by which their absences from work will be staggered.*
- *Assunta will concentrate on keeping the common areas of Specola and community clean and disinfected; she will not be entering our private bedrooms to do cleaning. If you wish to have a change of towels or linens, let Assunta know.*
- *Gina will continue as cook, with increased attention to cleanliness and disinfection in the kitchen.*
- *We will continue to have community Mass as usual, observing the "security distance" and not sharing the chalice.*
- *If you will be moving about outside the house, carry your carta d'identità, [identity card] with proof of your residence at Castel Gandolfo. Also carry with you the filled-out "autodichiarazione" [declaration] of why you are circulating (i.e. the modulo from the Ministero dell'Interno).*
- *If any of you feels ill, with cough and fever, let me know, and remain isolated in your room.*
- *Let us use common sense, and let us be attentive to the norms issued by the government and by the Vatican.*

10 **Arizona**: University of Arizona announces its COVID19-related measures. This announcement occurs during the regular spring break of March 7 - 15, when most students are already off campus. Meanwhile, American Airlines announces the cancellation of all flights to Rome; CONSOLMAGNO remains in Tucson for the duration.

11 **Rome**: The government announces the list of shops and businesses that must remain closed.

11 **Arizona**: In the first COVID-related event of national importance within the USA, a player on the Utah Jazz team of the National Basketball Association (NBA) is tested positive for COVID-19 shortly prior to the tip-off of their game with Oklahoma City Thunder. The game is cancelled; and following the completion of the rest of that day's schedule, the NBA cancels all of its games until further notice. Many Americans date the beginning of the "COVID crisis" from this event.

Meanwhile, the University of Arizona announces that the start of classes after spring break will be delayed to Wednesday March 18; these classes would be held on-line whenever possible. The same announcement calls for faculty and staff to perform their job duties remotely, from home, effective Monday March 16.

15 **Arizona**: The University's Department of Astronomy announces that henceforth all classes will be online, and all Steward employees are instructed to work from home.

16 **Arizona**: MACKE, finishing his Tertianship in northern California where the outbreak of COVID-19 is becoming severe, asks to move to Tucson. He purchases an airplane ticket, planning to arrive in a few weeks' time.

17 **Arizona**: The Steward Observatory building is closed to the public. A proposed memorial for the late Fr. George Coyne, which was to be held at the University Newman Centre, is cancelled.

18 **Arizona**: Representatives of the Mount Graham International Observatory (MGIO) stakeholders meet to discuss pandemic measures. (Under normal circumstances, such meetings are conducted only once a year, to approve the MGIO budget.) The Submillimeter Telescope enters shutdown immediately; the Vatican Advanced Technology Telescope (VATT, including the Alice P. Lennon Telescope and Thomas J. Bannan Astrophysics Facility) on March 19; and the Large Binocular Telescope on March 21. There are no observers at the VATT at this time, which is near full Moon; the last observers had left on March 9, while VATT engineer JOHNSON was last at the VATT on March 10-11.

19 **Arizona**: GRAY shuts down the VATT. GABOR attempts to use the cameras and other equipment in his regular classroom at Steward to conduct a "live online" class from the empty classroom. All further classes are conducted from his home.

20 **Rome**: A special Lenten confession service at St. Peter's Basilica, at which Specola priests were to have participated, is cancelled.

25 **Arizona**: MACKE is informed that due to the worsening situation throughout the US west, it is best if he stays in lockdown in California.

30 **Rome**: The Specola requests an adjustment of its internet system, hosted by the Vatican, so that BALZONI and CORETTI and can log in to their computers directly from their homes.

APRIL

7 **Rome**: The Jesuit Community contributes to a special fund set up by the Diocese of Albano to help families hit hard by COVID.

9-12 **Rome** and **Arizona**: The Jesuit Communities at Castel Gandolfo and Tucson celebrate the Easter Triduum together at home.

12 **Arizona**: Vincent Trembley, the brother of Robert Trembley who is the IT specialist for the Vatican Observatory Foundation, dies of COVID-19.

26 **Rome**: The Italian government outlines a procedure, "Phase 2," for the gradual reopening of business in the country.

MAY

7 **Rome**: Fr. Delegate of the Jesuits in the Roman International Delegation (DIR) issues a letter on COVID. Italy sends norms to the Diocese of Albano for when and how to restart public Masses.

7-9 **Rome**: Fr. Delegate's canonical visit to Castel Gandolfo occurs on-line, not in person.

16 **Rome**: MUELLER writes to the Jesuit community members, saying that no one should expect to be able to take part in any international travel.

19-21 **Arizona**: Fr. Delegate's canonical visit to Tucson occurs on-line, not in person.

20 **Rome**: MACKE arrives directly from California to Rome, ending his extended Tertianship in the USA. He goes into 14-day quarantine in the visitors' apartment.

27 **Rome**: DIR Superiors meet on-line to discuss COVID procedures and policies for DIR communities.

28 **Arizona**: The VATT opens again with BOYLE as the VATT operator and observer (May 28 – June 9).

Note that under normal circumstances, given safety concerns on a site as remote as Mt Graham, the usual procedure calls for the presence on the mountaintop of sufficient trained personnel capable of dealing with emergencies, including medical evacuations. However, the pandemic dictates limiting our numbers on site to minimize contact. The COVID-19 protocols for Mt Graham established at this time are a compromise between these two opposing considerations; in practice this means that only one person can be staying at the VATT at any given time, provided that there is sufficient presence of qualified personnel in the other buildings at the summit. The protocols, which are still in force as of this writing, impose severe restrictions on our on-site activity. The list of observers approved for to run the facility solo is very limited, effectively comprising only 6 individuals. Only those projects which can be safely conducted by a single person with limited assistance, or by a team of astronomers who are already living within a "COVID bubble", are allowed.

31 **Rome**: A letter from Fr. Delegate about COVID says, in part:

To the extent that the health statistics in Rome and its environs (Lazio) continue to evolve favourably, we can begin to think of what comes next. What should that be? Given that all the Jesuits in Rome are living in relatively secure "bubbles", starting next weekend (June 6-7) we could receive our brothers from other Jesuit houses at our tables. If the epidemic continues to evolve favourably, from July 1 we could also receive non-Jesuits into our houses….

This should not mean that our hygienic measures are compromised; maintain distances even at table, don't shake hands, utilize disinfectants and masks, remain in your room if you are not feeling well, avoid public transport and stores as much as possible, stay away from bars and restaurants, do not participate in public events, etc. All these measures remain in force…

A good way to treat my proposal is to discuss it first with your house consultants, and perhaps more widely with your community, as a sort of spiritual exercise. In this way you can evaluate what people think. It is important to listen attentively and sense what the Spirit of God is saying on this delicate question…

May the Spirit of God inspire you and protect you on the Feast of Pentecost and in the days to come.

JUNE

3 **Rome**: Mueller writes a message to the Specola updating COVID norms for possible visitors to the

Specola:

Visitors to the Specola Headquarters (ground floor only): Upon entering the building, your visitor must sanitize their hands and wear a mask. Once you reach the privacy of your office, they can remove the mask, always observing a safe distance. The option to welcome visitors to the gardens is still available, and in some cases it may be preferable.

Visitors to the Community (on the upper floor):We follow the directions of Fr. Delegate. For the month of June, only Jesuits of Roman Houses can be welcomed. From July 1st, you can welcome other people. Before you invite someone to a community meal, you have to ask your superior's permission — that's to prevent us from having too many people at the table.

12 **Arizona**: This year's VATT observing campaign using PEPSI to observe TESS candidates begins. Unfortunately, wild-fire smoke and ash coming from the Bighorn Fire (consuming 120,000 acres in the Santa Catalina Mountains, to the west of Mt. Graham) keeps the dome closed for the next eight nights.

23 **Rome**: The Vatican City State Government Directors meet at Castel Gandolfo to discuss business including COVID related procedures.

JULY

1-24 **Rome**: Guests from the Jesuit Curia, Tom McClain and Charles Lasrado, stay with the community while working on a revision of the "Administration of Goods" guide mandated by the General Congregation.

13 **Arizona**: VATT enters the summer shutdown, which is a common practice in southern Arizona primarily due to the lightning risk during the monsoon season. It is also a time dedicated to various engineering projects, especially those incompatible with science operations.

30 **Rome**: Ignatius Day is celebrated with a meal for the Jesuits and the staff and their families. All are seated outside with only those who live together seated at the same table.

31 **Rome**: Ignatius Day Mass was celebrated at the Gesu with Fr. General; social distancing is maintained.

AUGUST

8 **Rome**: The situation in Italy has relaxed enough that several members of the Jesuit community, and several members of the staff and their families, feel able to travel away from their homes for vacation.

11-13 **Rome**: Fr. Delegate visits Castel Gandolfo for some rest and recreation.

17-21 **Rome**: Fr. Ed Fassett (minister of the Gesu community) stays with us at Castel Gandolfo for a short break, and does some cooking for us during the Ferragosto holiday.

18 **Rome**: A letter from Fr. Delegate discusses the arrival of Jesuits into Rome during the COVID crisis. While this is mostly concerned with students arriving to study in Rome, several parts also apply to members of the Specola. He writes:

Normally a 14-day period of isolation is required, which becomes mandatory if you return from a high-contagion country… Those who arrive by air can obtain a swab test directly at the airport in Fiumicino; that the easiest solution. If the swab test is not done immediately upon arrival at the airport, upon arriving home it is mandatory. First, put yourself in isolation; then contact your treating physician to request a test. The test must be carried out within 48 hours of arrival, in a licensed specialized health centre…

Those from outside Europe are required to be quarantined for 14 days and to perform a serological test, which does not replace the quarantine itself. Those arriving from non-European countries are required to report their arrival to the Lazio Regional Government.

24 **Arizona**: The University of Arizona starts the fall semester allowing some in-person classes again. All students arriving on campus are subjected to a SARS-CoV-2 antigen test. Personal Protection Equipment (face masks) and social distancing remain obligatory on campus. The Steward Observatory building remains closed to the public; the overwhelming majority of employees still work from home. Working on campus is currently allowed observing certain procedures: before coming on campus, the employee must complete the "Wildcat WellCheck" online wellness check, and download and install the COVID Watch bluetooth-based contact recording app or fill in the Steward Observatory online access log.

25 **Rome**: MUELLER, GIONTI, KOCH, and OMIZZOLO visit with MAFFEO for an hour at the Canisio in Rome. They are masked and meet in a downstairs parlour. This is the first time anyone in the community has been able to visit Sabino since January.

26 **Rome**: We learn that D'SOUZA's mother in Goa has a fever and has tested positive.

SEPTEMBER

7 **Rome**: With special permission of Father Delegate, D'SOUZA departs for Goa to care for his parents.

12-19 **Rome**: MUELLER and MACKE travel from Rome for a week's vacation.

13 **Rome**: Father Delegate sends a message reporting that the Orientale community is in quarantine following a positive COVID test there.

17 **Rome**: Father Delegate sends a message reporting a temporary stay-at-home order for the Jesuits at the Bellarmino, following a positive COVID test there.

24 **Rome**: Vatican City State directors meet at the Vatican Governatorato to further discuss response to the continuing COVID crisis.

OCTOBER

3 **Rome**: REGGIO reports that his wife Simona has tested positive for COVID. After Simona tests negative, their daughter Ilaria tests positive. As a result, Romano begins what will be three weeks of isolation at home.

9 **Arizona**: BROWN arrives at Tucson.

12 **Arizona**: Additional classes are allowed to be conducted in-person at the University of Arizona, but this does not affect any classes in Astronomy.

18 **Rome**: With a resurgence of the virus over the past few weeks, new restrictions are set up by the Italian government.

23 **Rome**: FAS (the Vatican health service) comes to Castel Gandolfo to give the flu vaccine to Specola Jesuits and staff.

27 **Rome**: The Vatican City State Directors of Works meet at the Governatorato to discuss how the crisis has affected the functioning of the government, and new steps for the workplace.

28 **Rome**: MUELLER puts out new policies at the Specola: Offices are reassigned so that no employees share an office. Masks are to be worn whenever one is outside of the office, even in the hallways. At coffee break, each person makes his/her own coffee.

NOVEMBER

3 **Rome**: New measures are announced in Italy to deal with the COVID-19 emergency, in force from November 6 to December 3, 2020. Once again, regions in the country are designated as yellow, orange, or red, corresponding to the different levels of infection in the regions, with specific regulations established for each level.

10 **Rome**: D'SOUZA returns from Goa. He goes into quarantine in the visitors' apartment.

27 After lengthy discussions with the VOSS faculty and the Specola Staff, the WITOLD and the rest of the faculty are informed that the 2020 VOSS, already postponed to 2021, is now cancelled. The next VOSS will not occur until 2023, with newly chosen faculty and students.

30 The 2020 VOSS students are informed that the school has been cancelled. Any of them who are still students by 2023 are invited to re-apply, should they wish, to the new school to be held at that time.

As of writing this (the end of November), the crisis continues with no easy solution in sight. Several promising vaccines have been announced, but the advice from health experts is not to expect them to be widely available until well into 2021. Meanwhile, we are all facing the likelihood of future waves of infection, while the fatigue of this crisis has worn all of us down.

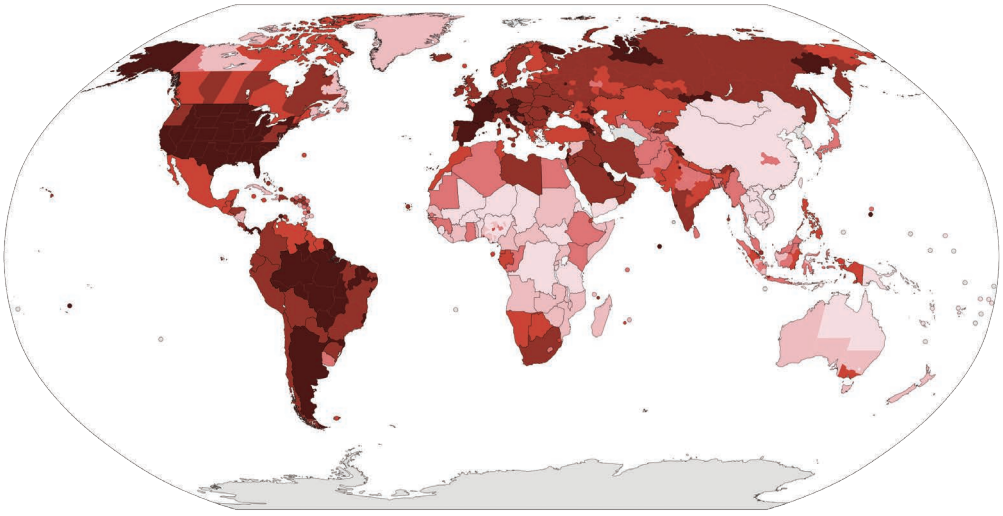
Everyone at the Specola has been affected, and all of us have had to alter the way that we work and the things we can expect to accomplish. The chapters that follow in this

Annual Report describe how each of us has dealt with the challenges this year. In some cases, the lockdowns and isolation have actually provided an opportunity to catch up reducing data and on writing papers. However, other activities, such as public tours, have had to be cancelled. We are all learning how to live and work on-line, and it is likely that even after the virus passes we will not be attending meetings and giving talks the way we used to before the pandemic. The one common lesson in all of our stories remains the need to be flexible and open to the challenges and opportunities of the moment.

We are Jesuits, members of the Society of Jesus, which has a long history of dealing with plagues and other crises. In every case, we succeed when we remember that if we are indeed doing the work of the Lord, then we need fear no evil, for God will be with us with His rod and staff to guide us.

Moths in the control room of the VATT after the two month shut-down

Break time at Specola: coffee and social distancing



Map of the COVID-19 verified number of infected per capita as of 29 November 2020 (source: World Health Organization)

Chapter THREE

The School that Never Was

Due to the ongoing covid pandemic, the Vatican Summer School on the "centres of galaxies" could not take place in June of 2020. In this article, we highlight some of the students selected for the summer school.

The Vatican Summer School on the "centres of galaxies" – originally scheduled for June of 2020 – will live on as the school that never was. The school, proposed by Witold Maciejewski (Liverpool), Peter Erwin (Munich), Isabel Pérez (Granada), Daniel Pfenniger (Genève) and Kanak Saha (India), was to focus to on studying the centers of galaxies and was to include the study of the complex interplay between stellar dynamics, hydrodynamics, star formation/feedback and supermassive black holes, using state-of-the-art simulations and 3D spectroscopy observations.

The preparations for the school were well underway, when the pandemic began in Italy in March of 2020. With international travel severely affected the world over, it was clear that the school could not take place in person that year. An attempt was made to postpone the school by a year to June of 2021, but the ongoing pandemic situation in Italy and the changing regulations of the authorities in response to the progress of the pandemic have made any planning for the school impossible. The 25 students chosen for the summer school were left deprived of a chance to benefit of the experience of living for a month at Castel Gandolfo and interacting with their instructor and peers. In these pages, we wish to highlight some of these students in the hope that they will be able to connect with the friends of the observatory and the vast community of the alumni of the Vatican Observatory Summer Schools.

Born in 1994 in Marau, a small city in the southernmost state of Brazil. The education until high school was conducted in the same city. Obtained a Physics undergraduate degree at Universidade Federal de Santa Maria (Brazil). She did her Masters of Physics and is currently enrolled in a PhD program at the same university. During the undergraduate and Masters she studied embedded stellar clusters in the Milky Way. Her main research interest in the PhD is the active galactic nuclei driven outflows and how they impact on the evolution of the host galaxy.

Marina BIANCHIN

marina.bianchin@acad.ufsm.br

Alexandra (Asya) was born and grew up in Milwaukee, Wisconsin, home to one of the world's largest dinosaur skulls. In May 2019 she graduated with a Bachelor of Science from the University of Wisconsin - Madison, with degrees in astronomy, mathematics, and physics. Three months later she moved to British Columbia, Canada, where she is currently finishing her Master of Science with supervisor Dr. Julio Navarro at the University of Victoria. Her research interests lie in the field of computational astronomy: probing the nature of dark matter and modelling the cosmological origin of galaxies using numerical methods. While her N-body simulations are running, she enjoys reading fantasy classics or learning how to play sea shanties on the concertina.

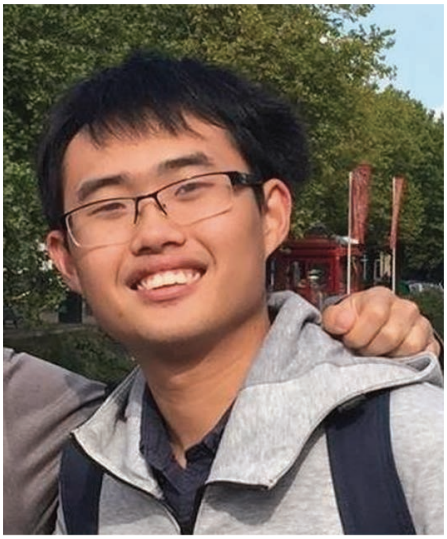
Alexandra BORUKHOVETSKAYA

asya@uvic.ca

I was born in Lipari (Sicily), in Italy. I did my Bachelor and Master's degree in Astronomy at the University of Padova, where I am also enrolled as a PhD student. My field of research is the structure and dynamics of barred galaxies. In particular, I am interested in the interplay between the dark matter and bar, I want to explore how the stellar dynamics evolve with time and in which way the dark matter can be responsible for these changes in the structure of the barred galaxy. In my free time, when I am at my Sicilian home, I enjoy boat trips and exploring my Eolian Islands.

Chiara BUTTITTA

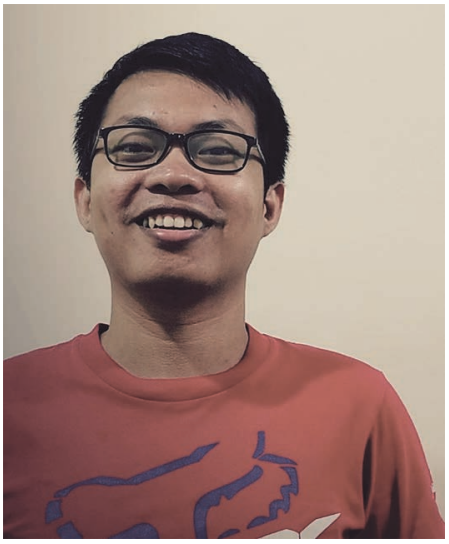
chiara.buttitta@phd.unipd.it



Born in Seremban, Malaysia in 1996. After spending most of his school years in Puchong, he obtained a scholarship to study Physics at the University of Edinburgh. During his undergraduate years, he worked on using the dynamics of the dwarf galaxy Eridanus II to put constraints of the properties in dark matter. He also spent a year on exchange at UC Berkeley and is currently pursuing a Physics PhD at the University of Chicago. At Chicago, he is working on using strong-lensed systems to obtain better estimates of cosmological parameters and is also trying to constrain mixed dark matter models with satellite galaxies. Other than astronomy, he also has an interest in biophysics and particle physics.

Tan CHIN YI

ywyh12345@gmail.com
chinyi@uchicago.edu



Born in Tanjungpinang, Indonesia in 1996. After finishing his initial schools in 2013, he continued to study Astronomy in Bandung Institute of Technology, Indonesia. He was awarded a scholarship to finish 4 years bachelor and a year master degree in the Department of Astronomy until 2018. His fields of research are dynamics and formation of star clusters, and stellar orbits. Since 2019, he has been teaching Astronomy for high school students and since 2020 he is responsible as a back-end developer in a digital company. He is now still active contributing in a collaborative research of binary star cluster formation in Bandung Institute of Technology (Indonesia) and Xi'an Jiaotong-Liverpool University (China). A PhD degree is his dreamful step in 2021.

Rendy DARMA

darmarendy@gmail.com

Born in 1994 in Welkom, South Africa. For high school she went to C & N Sekondêre Meisieskool Oranje in Bloemfontein. After graduating from Chemical Sciences at the North-West University, she completed her Honours (2018) and Masters (2020) in Astrophysical Sciences at NWU. She was one of 25 selected students for the Development in Africa of Radio Astronomy Big Data Africa School (2019). Previously, she organised a Women in Physics event at the Centre for Space Research. She is also the social media manager for The Cosmic Savannah podcast. The focus of her PhD (starting in 2021) is to unravel the nature and environs of fast radio bursts. Besides astronomy, she is an open water competitor and loves playing piano.

Sumari HATTINGH

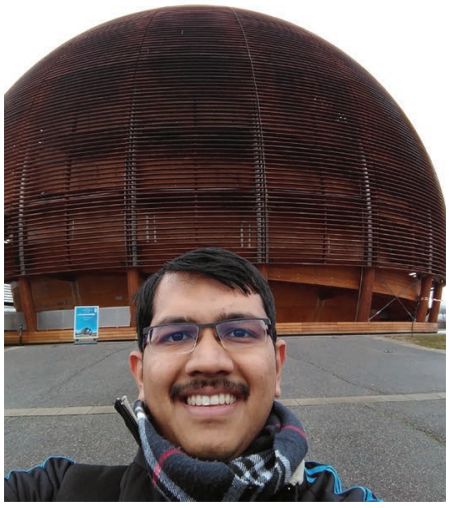
sumarihatt@gmail.com

Born in 1992 in Tultepec, Mexico. She studied Physics and Mathematics at the Instituto Politécnico Nacional (IPN) in Mexico City and graduated in 2018. She started her Master degree studies in Astrophysics at the Instituto de Astronomía, UNAM, in Mexico City. She graduated with honors in October 2020 with a thesis on Blazars, showing a great interest in observational astronomy in multi wavelengths. Since her childhood, her dream was to become an astronomer. She also enjoys painting and is a dog lover.

Jessica LUNA CERVANTES

jluna@astro.unam.mx

I developed an interest in astronomy during a summer camp in local planetarium in Bengaluru, India during my high school. With a strong passion to become an astronomer, I took up courses in basic science with physics and mathematics, and eventually completed Master's in science as a gold medallist with first rank. In the meantime, I got associated with amateur astronomy club, started my journey as amateur astronomer. I also got involved in science communication actively and have been a science communicator for outreach programs in science and astronomy. I'm currently pursuing a PhD on how accreting supermassive blackholes influence their host galaxies. My hobbies include origami, cooking, singing and playing mridangam (a South-Indian percussion instrument).



Sundar M N

sundar.mn@gmail.com

Born in 1992 in Santiago, Chile. In 2012 she began her undergraduate studies in Mathematics in Pontificia Universidad Católica de Chile and after two years she decided to change to the Astronomy program in the same university, a year before obtaining her graduate degree, she worked running stellars models and calculating pulsation modes of stars. Currently she is in her second year of the PhD. Her field of research is galactic dynamics with a special focus on globular clusters that belong to the Milky Way. In addition to Astronomy, she enjoys boulder climbing and trekking.

Alexandra MÉNDEZ

acmendez@uc.cl

Casmir Obasi is PhD candidate of Universidad Andres Bello Santiago Chile, working with Matias Gomez and Dante Minniti on low-luminosity bulge globular clusters using vista variables in the via lactea survey. He did his Bachelor degree and Masters in University of Nigeria Nsukka where he worked with A.E Chukwude and J. O. Urama on the "Design and installation of 2.4 m radio telescope" (2012) and "Search for the evidence of gravitational lens in globular clusters: the effect of pulsars as lens in globular clusters" (2016). He attended the 7th Byurakan International Summer School (2020), 39th International School for Young Astronomer (2017), and the West African Astronomy Summer School (2013). He enjoys volunteering for social work and teaching.

Casmir OBASI

casmiroluabuchukwuobasi@gmail.com

Born in 1989 in the northern city of Antofagasta, Chile. She obtained her undergraduate (in 2012) and master's degree (in 2014) in physics from Universidad Católica del Norte, where she studied long-range interactions of particles in complex systems. In 2018, she moved to Santiago de Chile to enter the Ph.D in Astrophysics program of Pontificia Universidad Católica de Chile, changing her area of research. She studied the Center of our Galaxy, trying to constrain the distance to different gas and dust clouds. Now she focuses her work on clusters in star forming regions that contain possible T Tauri stars. Besides enjoying physics and astronomy, she likes to read fantastic literature and train every day.

Camila ORDENES HUANCA

ccordenes@uc.cl

Nikita Parajuli is originally, from the land of Himalayan Nepal, she is the final years graduate student at Patan Multiple Campus, Tribhuvan University, Nepal. She is to complete her graduation in 2021. She is also the founder member of the National Science and Research Society(NSRS) and she works to promote science and research through her organization in Nepal. Her research interest lies in studying stars and star formation in different galaxies and their orientation. Besides astronomy and outreach, she enjoys spending time teaching children and traveling.

Nikita PARAJULI

nikiparnami1@gmail.com

Sophie was born 1997 and attended school near Berlin, Germany. She did her Bachelor studies at Freie Universität in Berlin, while writing her Bachelor thesis entitled "Characterisation of the galaxy NGC 7396 and its NaD feature" at the Leibniz Institute for Astrophysics Potsdam. Currently enrolled in the Master's programme at the University of Cologne, she continues focussing on astronomy and astrophysics. She enjoys theatre and sewing in her freetime.

Sophie PENGER

sophie.antonia_penger@yahoo.de

Kledsai is a Ph.D student at Chiangmai University. She was born in Kalasin, Thailand. She received a bachelor's degree in physics from Khonkaen University, and a master's degree in Astronomy from Chiangmai University. Besides astronomy, she enjoys playing with dogs and cats.

Kledsai POOPAKUN

kledsai_p@cmu.ac.th

Born in 1984 in San Rafael, Mendoza, Argentina. She moved to the city of La Plata to study Astronomy at the School of Astronomical and Geophysical Sciences of the UNLP, and graduated in 2016. She is currently doing her doctoral studies at the same University, with the support of a scholarship from the National Council of Scientific and Technical Research (CONICET). She is a member of the Research Group on Extragalactic Star Systems and their Cosmological Context and carries out her research tasks at the Astrophysical Institute of La Plata, Argentina. Her field of research is the study of the formation and evolution of early type galaxies in different environments through spectroscopic analysis and their photometric properties.

Maria Cecilia SCALIA

mcscalia@fcaglp.unlp.edu.ar

Born in 1995 in Arroio do Meio, Brazil. After completing high school in his hometown, he started his graduate studies in mechanical engineering at the Federal University of Rio Grande do Sul, in Porto Alegre, Brazil. After 3 semesters, however, he decided to pursue something less applied and more fulfilling, and thus changed his major to physics with astronomy. As an undergraduate student, he worked as a teacher assistant and participated in an undergraduate research project involving the evolution of compact galaxies. In 2020 he started a Master's program in the same university, studying galaxy evolution in the IllustrisTNG cosmological simulation. Personal hobbies include playing the piano, reading and studying foreign languages.

Felipe SCHMIDT LOHMANN

felipe.s.lohmann@gmail.com

Born in 1999 in Roskilde, Denmark. After graduating from the Danish Talent Center (ATU) and her local Danish high school in 2017, she received the 'Carlsen-Langes' scholarship for diligence and highest grade point average of the year. During her bachelor studies in physics at the University of Copenhagen, she contributed to the Apollo 11 50th anniversary exhibition by the Danish Astronautical Society and successfully participated in the Nordic Optical Telescope Summer School. She is now studying her Master's degree in astrophysics at the University of Copenhagen with a focus on the intersection between astronomy and machine learning. Besides her studies, she enjoys playing the piano and baking.

Simone VEJLGAARD NIELSEN

fgj787@alumni.ku.dk

Tadeja finished her bachelor's degree in physics in native Slovenia and received an international master's degree with honors within the Astromundus program from Innsbruck (Austria) and Rome (Italy). In her bachelor's studies, she was engaged in outreach and she prepared students for the International Olympiad in Astronomy and Astrophysics. During her master's degree, she carried out an internship at the European Southern Observatory (in Garching bei München), that later became her master's thesis and sparked her interest in understanding dark matter. Currently, she is doing her PhD within the Dynamics of Stellar Systems group in the Astrophysics Department at the University of Vienna, Austria. Her research is focused on observationally constraining the dark matter content of early-type galaxies.

Tadeja VERŠIČ

tadeja.versic@univie.ac.at

Chapter FOUR

A Year in Review

How greatly has Covid-19 impacted science and faith? In a most peculiar year to review, the Vatican Observatory astronomers consider creative solutions to their current reality and community life. New horizons in digital collaboration emerge, discoveries made in the study of historic data open up a spectrum of possibilities for future projects and academic productivity enjoys a new lease of life under lockdown restrictions, with prayers of gratitude and hope for a suffering world.

Father Richard BOYLE, SJ

Robert Janusz and I, along with Vilnius University collaborators have now collaborated with B-G Andersson and post-doc Archana Soam of Nasa-Ames in our Vilnius photometry from VATT and their polarimetry on the two reflection nebulae IC 59 and IC 63. This paper is in preparation.

Illuminated by the nearby hot blue star gamma Cassiopeia, B-G Andersson has likened these two dust reflection nebulae as a special physics laboratory where more detailed understanding can progress for polarimetry and total extinction mechanisms. The configuration is special for having the hot blue star only ~1.3 to 1.5 parsec nearby strongly shining on the dust clouds, and by the "radiative alignment torque" (RAT) mechanism causing polarization by the aligned dust particles on starbeams imbedded in the dust clouds. Such configurations are called "Bright Rim Clouds" (BRC).

To have other similar BRCs observed for comparative analysis of RAT, they have prepared the stellar polarimetry and have encouraged us to provide the total extinction, Av for the same stars. The research concerns star formation in the context of dust and magnetic fields.

So I have observed at VATT with the 7 Vilnius filters during Sept., Oct., Nov. and Dec. several BRCs for which Andersson and Soam already have the stellar polarimetry. We want to determine the polarization efficiency P/Av per star. This tells the effectiveness that the strong ultra-violet wind from the nearby hot blue star is having on dust in the BRC to polarize starbeams in the cloud.
But we can determine Av only if we can calibrate our CCD stellar images into the standard Vilnius photometric system. Twenty years ago this usually was done by having photoelectric standard stars accomplished by photoelectric photometry – done by a set of standard stars over the sky, precise work during most of a cloudless night. But this work has pretty much ended.

So we progress now with the use of a CCD panoramic camera by a tie-in method. How do it? The tie-in method is this: the new stellar field B of the CCD camera has no standards, so only a relative magnitude (brightness) scale is observed. But a nearby field A on the sky has a few or more standard stars. Both fields are observed with the same filter within a short time of a few minutes, between which the transparency of the sky is to remain constant within a few percent. It is to be as if A and B were in the same exposure.

But to have this stellar photometry be on the standard Vilnius Photometric System, the precise and accurate magnitude scale must be met. For only with such can we determine the spectral type and luminosity class of each star in the CCD panoramic pictures. How to do this? We call it "tie-in" to a star field nearby and already having at least a few standard stars. Call the field already having Vilnius photometry the "A" field, and the new nearby patch field "B". So observe A and B in rapid succession, during constant transparency, several times, with the same short exposure time of only several seconds, doing so "as if B were in the same snapshot as A, a crucial requirement.

Of course a change in transparency could happen by a passing cloud, but be evident by later analysis of the multiple exposures. Since the field A can be calibrated into the standard magnitude scale because it has some standards, also the new B field of stars gets accurately calibrated if sky transparency remained constant.

We go on to determine the total extinction Av per star after we classify each star by a comparison to a catalog of several thousand stars of all spectral types and absolute luminosity to find the closest match in a context freed of dust reddening. If this matching for most of the stars appears to be of not optimum quality, we can do some slight adjusting of the magnitude scale for optimizing.

So VATT is a very suitable and efficient telescope for progressive work about star formation nearby in our Galaxy.

Father David BROWN, SJ

The year 2020 began in a seemingly normal way for me. I had returned to the Vatican Observatory in Rome from having spent a semester at St. Louis University

in St. Louis, Missouri, as the 'Michael and Rita Mooney Visiting Professor in Catholic Studies'. January and February were filled with research with regard to the PEPSI collaboration between the Vatican Observatory and Potsdam Astrophysical Institute, a join effort to observe a subset of stars from NASA's TESS mission catalog in order to determine their detailed parameters, such as chemical composition.

I also prepared for an observing run at our VATT telescope in Tucson, this time as part of a collaboration between Fr. John Cunningham, SJ, professor of physics at Fordham University (New York City) and myself. The purpose of this particular collaboration is to determine the spectroscopic parameters of stars using our low-to-medium-resolution VATTSpec spectrograph, using a method which can allow us to determine more precise information than what our instrument would normally allow. Hence, on February 13, I travelled to Tucson in order to observe these stars at VATT. With the generous and expert guidance of Fr. Chris Corbally, John Cunningham and I had a successful observing run during Feb. 16-20.

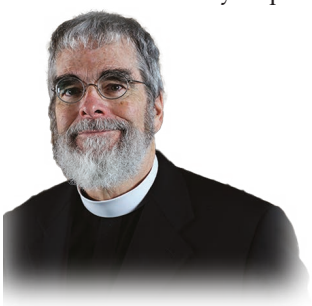
On February 21, I departed for San Antonio, Texas in order to officiate at a wedding. After a quick home visit to New Orleans (February 25 - March 5), I then departed for Italy, arriving in Rome on March 6. Four days later, the Italian government mandated very strict (stay indoors) lockdown and quarantine for the entire country on March 9. The next two months would be difficult as many people contracted the virus, with many dying. Even during this time, the research for us astronomers at the Specola in Castel Gandolfo/Rome continued along its normal indoor routine. Ironically, the time spent indoors because of the lockdown allowed me to get a lot of research done.

After the worst of the pandemic in Italy had passed by May, the country gradually reopened, and amazingly many aspects of 'normal' life returned, with some modifications. My research in spectroscopy continued throughout the summer. Given that my place of work/research and residence for the Vatican Observatory had shifted from Rome to Tucson before the pandemic, I was supposed to travel to Tucson, Arizona to begin my time there in April, but that did not happen because of the pandemic. It was further delayed in June, this time because of the pandemic raging in Arizona throughout the summer.

I was finally able to travel on October 8 to the Arizona branch of the Observatory to take up my post here. Since then, I have settled into life here in Tucson, and the work of research has assumed its normal routine. I had another observing run in mid-November with the assistance of Chris Corbally. After that, the remainder of the year was devoted to finishing my part of a journal article being submitted by the PEPSI collaboration.

Brother Guy CONSOLMAGNO, SJ

The coronavirus restrictions substantially changed the way I did my work this year. Gone are the many trips I used to take to give talks around the US, Europe, and even further afield. Normally I would rack up around 100,000 air miles a year; this year I flew barely 10,000 miles — one trip from Rome to Tucson in January, and a trip to Syracuse for George Coyne's funeral in February. Normally I would give as many as fifty talks in a year; this year, I gave exactly one



in-person presentation. (Elsewhere I list a sampling of the on-line and video talks that I've given instead.)

And of course, with the virus, both the Vatican Observatory Summer School and the Vatican Observatory Foundation's workshop for Catholic ministers and educators have been postponed.
Indeed, since March I have rarely left our Specola residence. Outside of my morning walks at sunrise (where I have met probably every neighborhood dog and its owner, also out for walks at that time, all of us keeping careful social distances) I have little need to leave the house; my office is in the residence, as is our chapel… the television room… and the kitchen.

On the other hand, ever since I became director it had become difficult to take time off for scientific conferences. But this year I attended the on-line version of the AAS Division for Planetary Sciences meeting, and presented a paper at the University of Arizona's Lunar and Planetary Laboratory Conference. This has not only given me a place to describe the work I have been doing with Britt, Macke, and Opeil, but it has also finally given me a chance to catch up on what's been happening in the study of asteroids and meteorites.

Living in Tucson has had another benefit, of keeping touch regularly (via Zoom) with the researchers in town who are active in the study of asteroids. Back when I was a graduate student at the University of Arizona, in 1975, Professor Tom Gehrels had started a weekly lunch on Mondays for everyone who was interested in asteroids. "Asteroid Lunch" is now 45 years old and still lives on, albeit remotely for the moment. Among the regular attendees are members of the OSIRIS-REx mission to asteroid Bennu (which was first proposed by my thesis advisor of 45 years ago, the late Mike Drake) and hearing first-hand how that mission has proceeded has been particularly exciting. The successful sampling of Bennu's surface in October was especially satisfying, and we are looking forward to actually seeing that sample close up when it arrives on Earth in 2023.

I have also been able to continue my research activities with Britt, Macke, and Opeil on meteorite thermal and physical properties, as Bob has also mentioned in his research report.

Our colleague at Boston College, Fr. Cy Opeil SJ, measures the properties of small meteorite samples over a temperature range from just above absolute zero, up to room temperature. When he measured a sample of the sort of meteorite type that we think represents the material on asteroid Bennu, CM chondrites, he found that as expected for most materials they slowly expand when they warm up from very low temperatures. But then, when they reach temperatures of about 75 degrees (Celsius) below freezing, they actually start to contract while they warm up! At about 50 degrees below freezing, this reverses itself again, and once more they expand upon heating. We think this is due to the unusual crystal structure of water-bearing clay minerals in this particular kind of meteorite.

But this means that such materials will be "flexing", getting bigger, then smaller, then bigger, as their temperatures pass through this range. And that's precisely the day-to-night temperature range that the surface of a near Earth asteroid like Bennu will go through while it spins, and as it orbits closer and then further from the Sun. As a result, one expects the rocks to become riddled with cracks, and even begin to flake apart. And, in fact, that is exactly what has been seen at the surface of Bennu.

While here in Tucson I have been able to devote much more attention to the necessary work of guiding the Vatican Observatory Foundation, which is the major source of our funding to support the VATT and our other research and outreach activities in the United States. Among other initiatives, this year we have received a grant from the Templeton Foundation to completely revamp our web presence, a major source of both outreach and fundraising. And with the generous support of the Jesuit Community, we have just signed an agreement with a local consulting group to develop an endowment drive aimed toward developing major donors for our work. I am especially reliant on the work of the Foundation staff here, especially Fr. Justin Whittington and Mr. Robert Trembley. The pandemic crisis hit particularly closely with Robert, as his brother died of the virus on Easter Sunday. We remember him in our prayers.

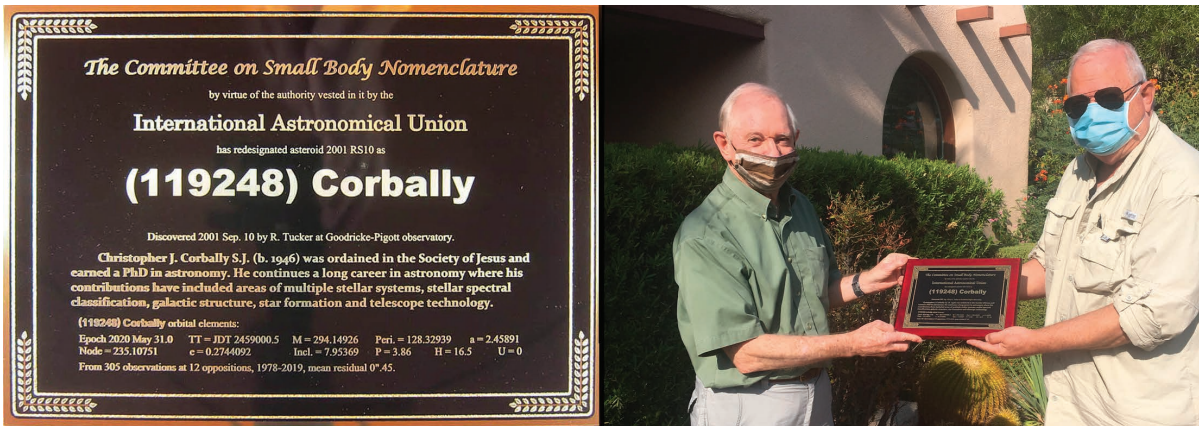
Being confined to our residence in Tucson means that I have had to rely completely on the vice director, Fr. Mueller, and our lay staff in Rome to carry on the day to day activities of the Specola there. I am grateful beyond words for all the extra work they have done as a result, especially during this most challenging year. The enthusiastic and understanding cooperation of the Specola's astronomers during this time has also made it

possible to not only endure this pandemic but in fact to carry out our scientific and other work at as high a level as ever. I am grateful to them and to everyone who has supported us with their prayers.

Father Christopher CORBALLY, SJ

Staying productive and safe during a pandemic has many creative solutions. Mine had the advantage of a bedroom which I had already divided into the back, sleeping part and the front, living and working part. I continue to miss going day-to-day to my office at Steward Observatory on the University of Arizona campus, the space there, and the interactions with the people. Still, the garden of our residence in Tucson and its back alley were good places for regular stretches and for the monitoring of our bird population, even when temperatures soared during a record-breaking summer.

Backed by the physical advantages, I remained productive thanks to fine collaborators, particularly Margaret Rappaport (Human Sentience Project) with whom I had co-authored the book "The Emergence of Religion in Human Evolution" as described in last year's Annual Report. We wrote on various topics. Naturally, reflections on the pandemic featured in three papers, one of which included the role of artificial intelligence to counteract future threats.



Asteroid (119248) Corbally plaque and its presentation to CORBALLY by Eric Crane on behalf of Roy Tucker (discoverer) and the Global Network of Astronomical Telescopes.

Such thinking led to a paper on whether AI robots could ever become electronic persons. The biological, cultural, and ethical challenges of spaceflight and colonization beyond the Earth also remained part of our research and writing papers. With a couple of Canadians who had newly minted doctorates, I enjoyed editing and preparing for publication a set of contributed chapters for a volume on the intersections of religion and cosmology. To supplement papers given at a weekend symposium that the two had organized in Montreal, we had recruited several excellent, additional authors. I also finished an extended review for a Book Symposium on "God's Providence and Randomness in Nature." The book in its entirety was hard going, but the review gave me a chance to gather my long-pursued thoughts on the reality of free will and the origin of human consciousness. Part of the attraction of writing about these was that both topics need the best of science and do not have easy answers.

Collaborations also featured in my specifically scientific output. One principally involved Simon Murphy (University of Sydney) and Richard Gray (Appalachian State University) in our completion of a survey to identify lambda Boötis-type (λ Boo) stars among southern hemisphere candidates. From observing spectra for 308 stars and classifying them on the MK system, we found or co-discovered 24 new λ Boo stars. Of the total 34 λ Boo stars in our sample, 21 at various main-sequence ages have infrared excesses, attributable to protoplanetary or debris discs. This confirms that not all λ Boo stars are young and helps our quest for understanding what makes these stars peculiar.

My collaboration with a China-Europe-USA consortium continued as we worked on spectra taken with the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST). The concentration this year was to prepare for publication the analysis of 21,000 stars which had been visited 60 times over the course of 5 years to determine variations in their parameters and radial velocities.

Another paper on LAMOST observations of stars in 15 "K2 Observing Campaigns" by the Kepler spacecraft was prepared by the consortium, as well as one giving an overview of the LAMOST-Kepler project.
Another enterprising collaboration, backed by the Global Network of Astronomical Telescopes (GNAT), is engaged in understanding a short-period photometrically variable object, with occasional highly energetic outbursts. This was discovered by GNAT from images taken at the Goodricke-Pigott Observatory (GPO) near Tucson and has been monitored since 2001. I facilitated obtaining further VATT spectroscopy of this object over six nights in February. This confirmed radial velocity variations of the object, which more securely looks like a binary system. A discovery paper, with data from nearly 20 years, is in preparation.
By kindness of Roy Tucker, an asteroid (119248) that he discovered at his GPO was named Corbally by the International Astronomical Union.

The pandemic, despite its restrictions, has not reduced productivity. As I heard one morning on PBS NewsHour, "Our humanity, which makes us vulnerable, will also overcome it".

Father Richard D'SOUZA, SJ

This academic year was spent in making the transition from a life as a postdoc at the University of Michigan, Ann Arbor, Michigan, USA to working independently at the Specola. A significant fraction of the time and effort was spent in picking up the Italian language and getting used to the way and rhythm of life at Albano Laziale, the small town outside the Specola's perimeter wall.

This year, I continued to make a lot of progress on our project (along with Prof. Eric Bell) to decipher the accretion history of a Milky Way-mass galaxy by studying its existing satellite galaxies. Along the way, we did a lot of unlearning, as we discovered new and exciting things. We are writing up these results and hope they will be published before long. This summer, I have also started collaborating on a new project with Khyati Malhan who is based at the University of Stockholm. We hope to understand how we can use our recently acquired knowledge of the accretion history of the Milky Way to constrain the type of dark matter halo we believe it sits in. Although the ongoing pandemic has given me more time to concentrate on projects, I am always surprised at how long they take to bring to completion, especially the last 20%.

Along with Alessandro Omizzolo, I have started backing up online all the historic plates we have digitized so far at the Specola. We have also started collaborating with the Leibniz Institute for Astrophysics at Potsdam as well as with INAF/INAPS at Rome to allow these digitized plates to made available to the public.
Although the Summer School (VOSS) originally scheduled for June of 2020 was postponed, I spent a significant fraction of my time as Dean of the school choosing and coordinating with the students and staff. In the beginning of March of this year even when the number of cases in Italy was not very high, we had to make the difficult call of postponing the school.

In retrospect this year two of my close collaborators were awarded research grants along with telescope time. I have actively contributed to the writing of both of these research grants. Prof Eric Bell received an NSF grant, and Adam Smercina got NASA Hubble time. I am excited about both of them and look forward to collaborating with them on exciting new projects in the coming years.

Finally, I had to travel to Goa, India amidst the current pandemic due to a family emergency. At the end of August, both my parents caught the Covid virus. While my father escaped with light symptoms, my mother was admitted into intensive care, and developed bilateral pneumonitis. I assisted them for two months. My mother has since recovered but is still dealing with a few long-term effects of the virus. I am grateful for all the help I received during this very difficult time.

Father Pavel GABOR, SJ

Is planning a waste of time? If 2020 is telling us anything, it might be to remember that there are many things beyond our control. But planning is not a bad thing, per se. In my case, most planned things did not work out, and yet, many unplanned things did. I was planning to attend a major

convention in Japan, my collaborators and I were planning to finish the VATT-PEPSI-TESS survey, I was supposed to give a keynote address at the celebration of the 300th anniversary of Maximilian Hell's birth, etc. The events were cancelled or postponed, and the observing was severely curtailed.

The unexpectedly productive aspect of 2020 has to do with the Vatican Observatory's contractual relationship with the University of Arizona.

Our collaboration dates back to 1980 when Fr. George Coyne and Peter Strittmatter agreed to establish the Vatican Observatory Research Group in Tucson, with the University providing office space, access to libraries and other infrastructure, foremost of which were the University's telescopes. Access to those was the main purpose of the agreement. All this in the expectation of collaborative research opportunities.
A flat annual financial contribution from VORG to UA was also set forward. These stipulations were made with a simple exchange of letters. Over the last few decades, however, business practices have evolved and an exchange of letters is no longer regarded as a sufficient legal basis for such a relationship involving transfer of funds.

In the late 1980s, an additional aspect of the VORG-UA collaboration arose in the form of the Vatican Advanced Technology Telescope (VATT, including the Alice P. Lennon Telescope and Thomas J. Bannan Astrophysics Facility). Its ownership, stakeholdership and other general provisions were covered by an Agreement of September 19, 1994. Unsurprisingly, a document of more than 25 years is not regarded as viable today. Today's good business practices dictate that such agreements must be renewed every 3-5 years.

Mark Buglewicz and I have been working on a new contractual foundation for the VORG-UA collaboration since 2014. The first agreement we obtained covered the services of Steward Observatory's Business Office. It entered in effect in January 2016. It was a modest starting point, establishing several footholds useful in drafting the following, more complicated agreements. This April, we have finally signed an Agreement on the VATT's operation and maintenance, superseding the 1994 document. It includes provisions regarding the Specola's stakeholdership in Mount Graham International Observatory, the University's care, custody and control of the VATT performed by Steward Observatory's Mountain Operations team, and the appropriate Annual Program Plans, containing budgeting tools. We are currently very close to signing a Task Order Contract which will circumscribe UA's execution of VATT's upgrade projects, and I am hopeful that it, too, will be signed soon. We have also made great progress on the last aspect of our relationship, viz., a document covering the matter of the 1980 foundational exchange of letters.

I know this does not sound very exciting but it has been bothering me for years and I am very excited that I see the light at the end of this particular tunnel beckoning ever brighter. It makes me optimistic looking forward to the coming months and the end of the pandemic.

Father Gabriele GIONTI, SJ

2019 ended with my annual trip to the University of Bologna for the Fields and Gravity (FLAG) group meeting of the Italian National Institute for Nuclear Physics (INFN). The traditional gathering was a delightful opportunity to meet friends and colleagues and to present on my research.

After Christmas, I went for my spiritual exercises to Acireale, close to Catania in Sicily, where I was welcomed by the Little Sisters of the Poor. This was my first time to do the exercises alone, without a guide, meditating on a line from Mark's Gospel proposed by Cardinal Martini.
I travelled on from there to the Astronomical Observatory of Catania where I was hosted by Alfio Bonanno. There I began to write a letter on the Hamiltonian inequivalence between Jordan and Einstein Frames discussing it with Alfio.

But as the year progressed, it grew clearer that the Covid-19 epidemic was spreading fast. Alfio and I debated whether it would be safe to go to Japan for a meeting organized by a Japanese friend of ours, Nabuyoshi Ohta, at the Yukawa Institute in Kyoto. This was when I discovered the "World Meter" website that tracked the number of Covid-19 infected people per day in China, Japan and South Korea. The first cases had started to appear in Italy too, but everything still appeared under control.
So I continued my research at home here in Castel Gandolfo as the situation slowly worsened. In early March,

I took my last Freccia-Rossa high speed train to Florence and then to Vicchio to help a Jesuit friend of mine, Fr. Secondo Bongiovanni SJ, to give a week-end retreat. It was my last train journey of 2020.

The rising number of cases and deaths for Covid-19 in Italy started to worry me. We went into strict lockdown and, in a sense, it was providential. In fact, a cousin of mine, who lives in Rocca di Papa, got Covid-19 and I could have caught it as well if I had not been forbidden to visit her… and I could have spread it to all community members in Castel Gandolfo!

In Spring, I worked on a "narrative" form of the letter I had been writing. I sent it out and got great feedback with comments and remarks. I sent the letter to Physical Review Letters (PRL) aiming for the "big hitter". A negative referee report questioned a key calculation (the algebra of the Poisson's brackets between Hamiltonian-Hamiltonian constraint) but she/he did not provide a good reason as to why. So I contested the referee report because, in my opinion, it was not real peer review and asked the editor to change the referee. The editor gave me a second chance to submit a revised manuscript.

Meanwhile, community life continued, attempting to cope with the severe Italian lockdown. There were a lot of activities, from more community prayers to the Passion and Easter liturgies together. And we started to cook together, from preparing the lunch and dinner for the festivities to making homemade pizza.

Toward the second half of May, I found a mistake in the calculations contained in my letter. It was in the variation of the metric tensor (covariant vs. contravariant) which affected the constraint algebra of the Hamiltonian-Hamiltonian constraint. Of course, it was difficult to accept, particularly after checked and re-checked the calculations so many times. It was crucial to confront my calculations with the calculations of another paper the first referee addressed. Sometimes this is the disadvantage of working alone. I pondered how I could modify my paper in order to convince PRL to accept it for publication. I still believe that the Hamiltonian inequivalence between the Jordan and Einstein frame held.

At this point I needed to take a break from my research, so as to come back to it refreshed and with clearer ideas. Therefore, I decided to work full time with Matteo on our joint project on Photon Helicity. We successfully derived a Lagrangian function for the Electromagnetic field manifestly duality invariant. This result was a boost for me, since I saw that it could be possible to use it in String Theory and improve earlier studies I had done on T-duality several years ago. We also applied this result to study helicity symmetry breaking at quantum level (anomaly), when photons pass through a curved space time. Unfortunately, we were unable to find anything of interest. Therefore, recently, on the advice of other colleagues, decided to publish the paper as is.

At the Specola we also organized a serious of seminars among ourselves. The original idea was to share our own field of research with other members of the Specola and to look for possible collaborations.

One of the 'in-house' seminars organised by scientists at the Specola during the Covid-19 lockdown.

After summer vacations in Anzio with Fr. Richard D'Souza, S.J. and alone on the Amalfi coast, I sent a second completely revised draft to PRL. A second referee said the manuscript was correct but not general enough for PRL and advised to send a longer and a more detailed version to Physical Review D (PRD). I followed this advice. In the meantime, I also attended two online conferences: one from Odense, Denmark and the other from Yukawa institute in Japan. In the last one I also gave a presentation on my last research.

At the beginning of October, the Nobel Prize in Physics was announced. It was a surprise that Sir Roger Penrose was awarded together with Reinhard Genzel and Andrea Ghez, for important contribution in the Singularity of Black Holes (Penrose) and the observation of super-Massive Black Hole at the center of Milky Way (Genzel and Ghez). Penrose has been an invited speaker at the Lemaitre

workshop at the Specola in 2017. Every participant who met him was fascinated by his charming personality, full of kindness, humility and wisdom. A real British gentleman who belongs to another era. Surly he can be considered one of the founding fathers of Modern Cosmology and Quantum Gravity. He is the typical person with whom you can talk with interest of every subject and of whom you never grow tired. He responded warmly to my congratulations and shared his fond memories of the time he spent with us at the Specola.

Nobel Laureate Sir Roger Penrose presenting at the Specola during the Lemaitre workshop in 2017.

Father Robert JANUSZ, SJ

It took time to set up my wonderful office in Castel Gandolfo. Some old pre-existing projects needed to be brought to a close, and new projects were soon going to start. And suddenly the pandemic arrived. It was a shock, especially in Italy, which remained alone in the European Union. Our community immediately made very good decisions which helped us all to stay healthy, pray for the sick and dying, and also try to work within the strict limits which would be replicated worldwide later on. All travel was canceled, resources limited and plans truncated. So we entered a period of great blessing, living like monks: Ora et labora.

With some delay, an excellent server arrived at Specola dedicated to numerical calculations. I had my account on a supercomputer in Kraków, however, the enormous repository of VATT scientific images, could not be used over the Internet due to a lack of capacity. Now the Dell PowerEdge R7235 server, with its 2 AMD processors (total 64 CPU cores; 256 GB RAM; RAID 10 TB + SSD scratch HDs; powered with Linux Centos 8) is smoothly working on our local area network (100 Mb). This has rendered our work so much more efficient than with the supercomputer; perhaps we can extend the network to 1 Gb, which would make graphics even more efficient; who knows if it will be possible, within our limits.

Of course, with the new equipment, new problems arrived. The first one, not directly related to it: the excellent IRAF system for astronomical calculations was abandoned by NOAO. "NOAO is transitioning IRAF to an end-of-support state and has taken NOAO's IRAF distribution offline pending final copyright and licensing review of the source code. Users interested in new IRAF installations during this review period may wish to consider the IRAF Community Distribution" (*http://ast.noao.edu/data/software* – access Nov 9, 2020).

Another problem was related to the workflow within our Photometry Group. We treated all telescope runs as separate logically and physically. There was one simple reason for this: there were several telescope data, and even on one telescope we used different CCD cameras to obtain images, different filters of different shapes, etc. So each run was a "stand alone" project with all databases fixed to a particular run. And finally, there were some promising methods and new approaches to apply: The AstroPy Project with parallel computing (ipyparallel) and fast file format HDF5 for our data.

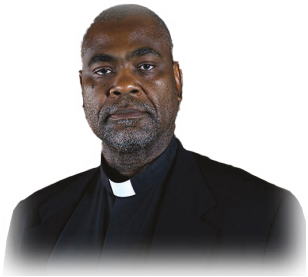
So I started slowly to apply the new problems and ideas to the huge repository of scientific data so as to not lose any of it, and to integrate it with the new perspectives. This work, of course, is not finished yet. However, we have now one SQL-database holding information on all relevant CCD photometry observations on the VATT and other telescopes and techniques. It contains records of 67015 images (the last two VATT runs are not included yet). Some of them are technical (zero-frames, flat-field-frames etc.) 37030 images are scientific, after excluding M67 calibration field we have 31004 images. 27036 images have already its photometry (PSF and Aperture) in the HDF5 format and I consider it as the 1st Data Release of all our reasonable observations. Other frames need an individual inspection of their quality. The software is also ready to dig into the photometry of our Vatican Observatory Photographic Plates Archive. Some prototype results are very promising, but the scanning process is not finished yet,

so it is better to wait for its end to have an overall vision. Our seminars are going pretty well over the Internet. I also did some work in philosophy and published some texts on spirituality. I guided only a few visits to our Observatory, because of lockdown.

If I have one wish emerging from this pandemic, it is that we gain a more hopeful outlook for humankind and correct our egoistic errors.

Father Jean-Baptiste KIKWAYA-ELUO, SJ

In March 2020, coming from Europe, I planned the semester around one major project that would consist in writing a review paper on physical characterization of Neos (Near Earth Objects) to show that the spectrophotometry, technique used from the beginning in 1970s to physically characterize asteroids could not totally be surpassed by the new technique of spectroscopy even if the later has some good advantages. The reason is simple: I observe the so-called fast rotator Neos whose absolute magnitude ranges around 23, have a size less than several hundred meters, are consequently faint (In V filter they are fainter than 19 magnitude), and could not then be seen by a spectrometer whose limiting magnitude in visible is around 16. For me, it was a good project that could cover the entire semester.



Unfortunately, on March 16, 2020, we were asked to go home and work from there until further notice that has never come. At home, I found myself with more time than what I usually spend in my office, so I had to find additional projects to cover it. Beside the project on writing the paper, I gave myself a project of writing a course for the students of the Jesuit University in Congo (ULC) on using Matlab as a tool to do mathematics (solve equations, differential equations, partial equations, find integrals and derivatives of all different functions, …).

I also involved myself in two other projects to study meteors and fireballs. As matter of fact, in December 2019, in Castel Gandolfo, I had obtained from the Vatican Observatory the permission to buy an all-sky camera for recording fireballs. This camera integrates an existing system of fireball cameras across Europe (France, Spain, Italy, Netherlands, Belgium, …) called Fripon run in France by a team of collaborators. The goal of this project is twofold: 1) work on fireball while still in the atmosphere to determine its trajectory (velocity, beginning and ending heights, …) and 2) for education purpose, to organize a search for meteorites with kids from high schools around the Specola (Castel Gandolfo) in the case a fireball lands some on the ground.

In Tucson, during the lockdown which is still going on somehow, I acquired three cameras to be installed at three locations (Kitt Peak, Mount Lemmon, and Mount Hopkins). There are already three cameras running at the same locations, as part of my collaboration with Asgard, Nasa all-sky cameras project in US. Asgard aims for meteors brighter than 3-magnitude. The new three cameras will observe faint meteors whose luminosity goes down to 7-8. So, while still working on Neos, and reading articles on new findings of in-situ missions, particularly Hayabusa-2 on asteroid Ryugu, and Osiris-Rex on asteroid Bennu, I am trying to open another front of research by studying physical characteristics of meteors, and particularly faint ones (speed, beginning heights, ending heights, bulk density, …).
I also took advantage of the lockdown to push forward a project I have had in mind since my own experience of studying science in Europe in 1994.

Seniors of "College Kubama", Father Eric Mashoko, Jesuit, Professor, and Father Jean-Baptiste Kikwaya, at the courtyard of "College Kubama", Jesuit High School in Kisantu, Democratic Republic of Congo.

The project consists in building a group of Jesuit scientists in the African conference, JCAM (Jesuit Conference of

Africa and Madagascar). The main goal for this group is to seriously engage in preparing young Jesuits destined by their provincials to study Science, a mission that usually comes after a long break from science due to their Jesuit formation (Novitiate, Philosophy, and Regency).

My personal reflection is based on what we are experiencing world-wide since last year: The Covid-19 pandemic. It does not want to go away. It would seem, as many say, that we need to learn to live with it. But I want to share some thoughts that cross my mind almost daily. The first thought is our resiliency in not giving in to the dictatorship of Covid-19. In fact, I see people who, maybe at the risk of their lives, keep society running and assure us that life continues as usual. I think about those who work in banks; they make sure that money is circulating, and some economic activity carries on. I think about those who, probably from home as they must work from home, maintain the communication systems (internet, social media applications, Zoom, Webinar, …). Without them, we would run into real trouble just to know how our love ones are coping with the isolation, with Covid-19 itself.

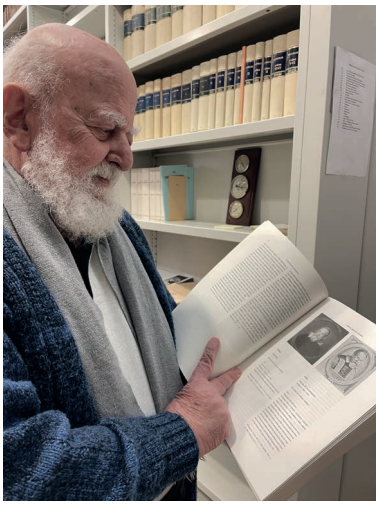
Bankers and people working for the communication network could be considered middle-class employees. But alongside them, there low-income employees who contribute to maintaining the society life. I think about food store, groceries, … These would not open without all these employees who supply them, those who sell, cleaners, … I hold our cook in Tucson, Ms. Margarita Garcia (Maggy) with great regard, I cannot help but admire her courage, dedication. I cannot thank her enough. She is really the one who keeps our house going. I think also about all these employees who collect the garbage every week in front of our houses. Without them, it would pile up, putting our own life in danger of other various diseases, microbes beside covid-19 itself. I think about medical personal, particularly nurses, who are on the front line in the fight against Covid-19. I pray for them; I knew some of them who unfortunately died from Covid-19.

However, I am frustrated about the way science is being conducted nowadays and how science is handling covid-19. Science has allowed itself to take on the traits of journalism: first to see, first to tell. Many scientists jump at the opportunity to reveal what little progress they make in understanding and approaching covid-19, only to be contradicted some hours later. People believe, and their frustration grows as they learn that what they had been told and built their hopes on has turned out to be irrelevant. People may want us to tell them that we know while we are still researching, but the right thing to do is resist hastily delivering research that is still in progress, and to keep quiet until it is complete, and has produced some solid results.

Father Giuseppe KOCH, SJ

In today's increasingly digital era, understanding how to work on enhancing the precious treasure of a library such the science and astronomy library at the Vatican Observatory in Castel Gandolfo is not an easy task. The library, after the demanding transfer from the Apostolic Palace to the new seat of the Specola, was deprived of attentive forward planning for some years. It was only in 2016 that it once again came under scrutiny when the decision was made to digitalize the catalog and properly archive the dwindling collection of paper journals. This decrease in the number of journals that arrive at the Specola is linked to their availability online, to their cost and also to the physical space that some of them require every single year.

The new Library Room located at the Specola houses collections of volumes that allow us to follow the development of the main astronomical themes, I would say up to the mid or late 1980s. The purchase of books has also been decreasing in connection with the opening of the Specola headquarters in Tucson, with the consequent possibility for Vatican astronomers to access services, including books, through our partnership with the facilities of the University of Arizona.



Father Koch in the library of the Specola, shows one of the volumes of the appendices of the Works of Galileo Galilei, recently purchased for our observatory.

Over the years books necessary for scientific work were purchased directly by individual scientists rather than for the common library. Currently, the arrival and purchase of new volumes is rather limited.

We must then consider the objective difficulty of allowing external scholars easy access to the library, due to its being in Vatican territory. This explains how the frequency of library users has also been decreasing to a few units per year. These are scholars engaged in research and publications relating to the great personalities of astronomy or to issues more closely related to the history of the Vatican Observatory and its historical operators. I would say that the library is slowly being used mainly by people interested in the history of astronomy.

In addition to the astronomy books - at the moment about 6500 are registered in the digital catalog, including about 500 books registered as 'antique' - the library room contains, at least four or five times as many volumes, collections of journals, some very old , and reports of scientific academies, as well as reports of the historic activities of many astronomical observatories around the world, and other large collections which for the moment are not registered and of which one would and should like to report and trace.

A good part of the historic material was transferred to the Specola from the Vatican Apostolic Library in 1909.
As I am more aware of the valuable assets of the library, I like to point out that there are shelves that contain the opera omnia of many first-class astronomers. Starting from the well-known National Edition of the Works of Galileo Galilei, edited by Favaro, and for which three volumes of appendices have recently been purchased.

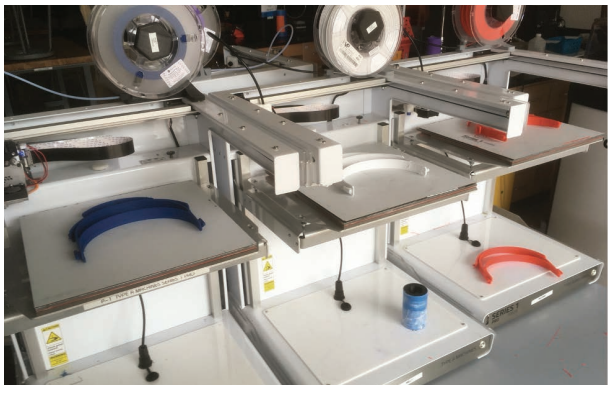
In the library room there are some cabinets which together with others, currently located in the small printer room, constitute an Archive of the Specola. Thanks to their contents, from the very beginning of the Observatory and then to the many documents of the time of the successive Directors, we try to respond to the most varied requests for information on the life and activity of the Fathers and Brothers, Jesuits and not, who have worked at the Specola and of astronomers who have been in correspondence with them. Sometimes these are requests relating to the compilation of degree theses or the search for articles or publications belonging to the Specola or in some way connected to its history.

Brother Robert MACKE, SJ

This year began in Portland Oregon, with the second half of my Tertianship program. (Tertianship is the last formal stage of Jesuit formation.) At the end of the first month, I went to San Jose, CA for what is called the "experiment." The plan was to stay there until mid-April, being a helpful presence on the campuses of Bellarmine Jesuit Preparatory School and Cristo Rey San Jose High School.

Br. Macke (left) with fellow Tertian Fr. DerekVo (right) during Jesuit Fr. General Arturo Sosa's (middle) visit to Santa Clara, CA in February.

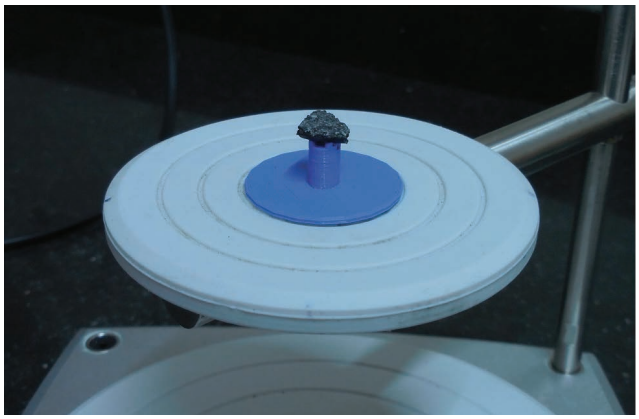
Then the pandemic struck, which closed both schools but prevented me from traveling elsewhere. I occupied some of my suddenly free time by helping with a project to produce personal protective equipment (PPE) for medical workers, using the 3D printers at the Bellarmine Prep maker lab.



3D printers in the Maker Lab at Bellarmine College Preparatory School, San Jose CA, creating PPE for medical personnel.

In early May, the opportunity arose to return to Rome. Back in my own office and laboratory, I was able to do a little research. Most of my work is done in collaboration with other researchers, and the current Covid crisis has limited their research capacity as well. One notable exception is a continuation of a collaboration from last year, with C.

Goodrich at the Lunar and Planetary Institute. Last year, I measured density and porosity of two tiny pieces of the meteorite Almahata Sitta, of a rare chondrite type that constitutes a small percentage of the recovered meteorite but we think may have been the dominant species in its parent asteroid 2008 TC3. These were the two smallest pieces for which I have ever measured porosity. This year Goodrich sent me a third specimen to study, only slightly larger than the previous two.



Almahata Sitta specimen AS202 on a special mount for 3d laser scanning.

Another collaboration that has proved fruitful this year has been work with Fr. Cy Opeil SJ at Boston College. We (along with Dan Britt and Br. Guy) have been measuring meteorite thermal properties, and this year we published a groundbreaking study of the thermal properties of CM2 carbonaceous chondrites, which have a surprising negative thermal expansion at around 235 K. In addition, my collaboration with George Flynn and others who study high velocity impacts, has resulted in several abstracts and publications this year from results of experiments performed last year.

I continue to write for the Sacred Space Astronomy blog. In addition to occasional stand-alone pieces, I write a weekly column entitled "Specola Guestbook." I enjoy digging through the guest book and learning about historical figures who have passed through our corridors. Several weeks this year were spent highlighting attendees at the first General Assembly of the International Astronomical Union in 1922, many of whom visited the Vatican Observatory and signed the book.

Father Paul MUELLER, SJ

For the last 5 years I have served as vice director of the Vatican Observatory at its Castel Gandolfo headquarters. Observatory Director Br. Consolmagno spends much of the year away from Castel Gandolfo, whether at the Observatory's Tucson location or on the road giving talks and participating in conferences. So for much of the year it falls to me to facilitate day-to-day life at Castel Gandolfo for the Observatory's Jesuit research staff and lay support staff. That means that I work closely with some very good and special people, every day. It also means that I end up interacting frequently with our colleagues in the Vatican. As a kid growing up in Cincinnati, I thought of the Vatican as a far-away place, mysterious and inaccessible. Now it's where I go to meet with co-workers from the departments of maintenance, personnel, legal and accounting – and it's a convenient place to park when I go into Rome. Life is full of unexpected twists!

For the last 11 years I have served as the religious superior of the Jesuit community associated with the Observatory. That makes it my responsibility to support, care for and at times challenge the other 15 Jesuits in the community, half of them based at Castel Gandolfo and the rest based at Tucson. I don't know of any other superior who is responsible for Jesuits at two residences separated by more than 9900 kilometers! Thank goodness I can depend on Fr. Chris Corbally S.J, who serves as vice superior at Tucson with great wisdom, generosity and grace.

Being vice director and superior takes up most of my time and energy. Whatever is left over goes into working in my area of expertise, history and philosophy of science. During the spring semester I taught a masters-level course at the Pontifical Gregorian University, "Philosophical Questions in Biology". I love teaching, but teaching in the Italian language remains a challenge for me. An added challenge this year was that two weeks into the term I suddenly had to move my class on-line, due to COVID-19.

It was very frustrating – I got to meet with my students only twice and then never got to see them again in person. I have new respect for those who are adept at teaching on-line; for me it was very difficult, isolating and discouraging. But we got through it as best we could.
In addition to teaching, during the past year I gave various retreats, workshops and interviews on science-faith themes, in the USA and in Italy. Also I guided many groups on didactic visits to the Observatory's historic telescopes at Castel Gandolfo.

The big story of this year was of course the COVID-19 pandemic. As vice director and as superior, I had great concern for the health and morale of the Observatory's Jesuit and lay staff, especially during the long hard days of Italy's strict lockdown in March-April. It was a bit of a challenge to come up with consistent and effective rules for COVID safety at Castel Gandolfo: The Vatican had one set of rules for the downstairs Observatory work-space, while our Jesuit bosses had a different set of rules for the upstairs Jesuit community! We muddled through, and everyone stayed healthy.

The Jesuits of the Observatory were quite fortunate during the lockdown to have access to the Papal Gardens, which are located right out our back door. We were able to go outside and stroll in the fresh air and sun, at a time when most Italians were cooped up in their homes. During the lockdown we Jesuits did a lot more than the normal amount of praying together. Usually we're all off saying mass elsewhere, for other groups, but during the lockdown we were consistently at home praying together. We prayed in gratitude and also in hope for a suffering world.

A personal disappointment for me during the lockdown was the cancellation of two Mueller family weddings at Castel Gandolfo. In March I was supposed to preside at the wedding of my nephew Ben at the Church of San Tommaso Villanova at Castel Gandolfo. For the first time ever, my whole family was going to be together with me here in Italy! But that didn't happen – Ben and Alexis ended up getting married in Florida instead. And then in June I was supposed to preside at the wedding of my brother-in-law's nephew Anthony at Castel Gandolfo. That wedding also got cancelled – or I should say delayed, since the couple is holding out for a future wedding at Castel Gandolfo, when COVID will permit!

Father Alessandro OMIZZOLO

I remember that my astronomy professor at the University of Padua told us when we started the course that the astronomer is a scientist who works for the future. The reason is simple: the time scale of astrophysical events goes well beyond the life time of a single person and for this reason the data collected in a life of research is often not sufficient to obtain a definitive picture of the phenomenon that is being studied. So we could say that when we our start work we do not know how it will end, because our lives are too short.

But this does not mean that the data collected has no value. On the contrary in some cases data whose origin is distant in time becomes decisive in gaining a greater understanding of a phenomenon. For example, the study of the variability of stars or quasars, and in general of all Active Galactic Nuclei (AGN), whose emission varies over time, requires a long database to obtain a satisfactory description and explanation of the phenomenon in spite of this variability. For these reasons there are no astronomical data that can be defined as "old" in the sense that it is no longer needed; if anything, it is "ancient" data and its value lies in its aging over time.
This is one of the reasons why for many years observatories all over the world, including the Vatican Observatory, have been preserving and making "ancient" data available to the international scientific community: data which is contained in the primary medium with which it was collected up to 35-40 years ago, that is, the photographic plates on which images of celestial fields and spectra of individual objects were imprinted.

The Vatican Observatory has been working to digitize its collection of plates for twenty years. So far this little treasure has been held at the Specola in the form of a collection of DVDs. But in the last few months a significant step has been taken to offer the scientific community access to such data. A collaboration has begun with the APPLAUSE project (**A**rchives of **P**hotographic **PL**ates for **A**stronomical **USE**), which is headed by a group German astronomical observatories (*www.plate-archive.org/applause*). Eventually they will host a complete copy of the Vatican Observatory plates: (photographic

plates of the Schmidt telescope, of the double astrograph and of the Carte du Ciel). Some of the material has already been delivered to the APPLAUSE project managers and should be online shortly.

Along with the high resolution images of the plates, scans of the envelopes containing each individual plate will be available as well. In fact, a large amount of information about where and when the plate was taken, only apparently secondary, was written by hand on the plate envelopes. This is very valuable if, as in some cases, a logbook of the observations was not kept.

A similar collaboration is also being studied with two Italian astronomical agencies, the Italian Space Agency (ASI) and National Institute of Astrophysics (INAF), with the dual purpose: having a secure backup of the plates, and also to encourage the use of such data by not only the Italian scientific community but also by education projects linked to high schools and university faculties.

It was during the recent scanning work, which intensified during the lockdown last spring, that some interesting plates were scanned proving how important it is not to lose these historic data. Two examples are significant. Novae are stars that in the last phases of their life are subject to explosive phenomena that make their brightness vary greatly with quite long scale times. After these explosive phases the brightness slowly decreases and returns to "normal" values. As it happens, in the archive of the Vatican Observatory a series of plates in the constellation of Delphinus were found dating back to 1967, when a nova star exploded. These data had never been published, and therefore this allowed us to add new data points to the trend of the variability curve of the nova.

Another example is provided by the systems for calibrating the magnitudes of celestial objects. For many years now, regions particularly rich in stars, some of varying brightness and others hopefully not variable have been identified in the sky. These regions are called Selected Areas and sequences of stars have been defined within them that serve as a reference to evaluate the magnitude of other objects (stars, AGN, quasars) that are found both in that region and in other distant regions. Over time the Vatican Observatory has contributed to the study of these standard stars; for example, we have found in the photographic archives a long series of plates made with the double astrograph aimed at the study of some of these selected areas, for example SA28 and SA54. Comparing recent magnitudes with those obtained 50 years ago can confirm the quality of the choice made or can reveal any variations in magnitude, those allowing us to exclude one or more stars from the defined photometric sequence.
We are also continuing our work on Jellyfish galaxies. We have already spoken about these galaxies with a very particular shape and the fact that in the vast majority of cases they can be found in groups and clusters of galaxies. The importance of their study lies in the fact that they can provide information on various topics: evolution of galaxies in the presence of strong gravitational fields (such as those present in galaxy clusters), or large amounts of dark matter. Another interesting aspect is the study of the star formation that occurs in the trails that these galaxies leave behind.

These are the topics that the GASP group addresses in the study of single jellyfish galaxies. The environment is extremely rich in questions and stimulates the construction of interpretative models of the physical phenomena observed there (chemical abundances of the elements present, effects of emissions and / or absorptions at various wavelengths on the physical phenomena in progress and in particular on star formation in contrails but also in blobs scattered in various regions of galaxies).

The quality of the data to be analyzed is crucial. We are lucky that the data used for this type of study comes mainly from a modern instrument used at ESO's Very Large Telescope (VLT), the Multi Unit Spectroscopic Explorer (MUSE). MUSE measures the intensity of light as a function of color or wavelength for each pixel of the image; the result is a set of three-dimensional data in which each pixel of the image contains a complete spectrum of the light from one location in the galaxy.

Large telescopes, both on the ground and from space (such as the Hubble Space Telescope, HST) have allowed us to find quasars even at great distances with a redshift (z) greater than 6, which means objects that date back to when the universe was less than a billion years old. The question that some are asking is, are there very bright quasars at great distances, very bright meaning having bright magnitudes ($i < 18$)? The answer requires large surveys in different areas of the sky in search of these objects. It also requires catalogs of possible candidates, starting from already existing catalogs of objects observed but not yet cataloged. The possible candidates are drawn from machine learning techniques applied to already existing photometric catalogs.

Once they have been identified, taking their spectra can determine whether they are quasars or other kinds of objects. This spectroscopic investigation is the subject of the QBRICS Bright Quasar Survey, which has so far studied a region of about 12,400 square degrees of the southern celestial hemisphere. The results are encouraging; but it is time to move on to study the northern hemisphere as well. The information collected in this way is useful for unraveling many cosmology questions and may form the basis of the observations to be made with the high resolution spectrograph that will be applied to the European telescope under construction, the Extremely Large Telescope, which will be operational in the southern hemisphere.

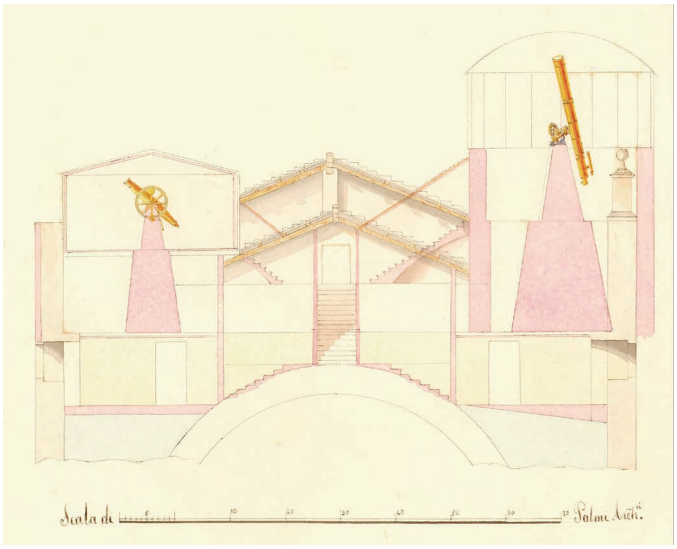
By good luck, in January 2020 it was possible to observe a sample of these candidates with ESO's NTT telescope in La Silla. However, a subsequent run of observations was not possible due to the generalized lockdown of ESO's telescopes. An observation run to be made in the northern hemisphere (presumably with the Bok telescope at the Steward Observatory in Arizona) also had to be cancelled.

ADJUNCT SCHOLARS

Aldo ALTAMORE

My work at the Vatican Observatory is mainly centered on the study of story of astronomy with particular regard to develop of astrophysics in roman area from its foundation in the mid of XIX century to the present time.

In this framework, as member of the National Committee promoted by Italian Ministry of Cultural Heritage, I was involved in the activities for the celebration of the second centenary of the birth of Jesuit astronomer Angelo Secchi (1818-1878), in 2018, which continued into 2019 and 2020.



The project of the Collegio Romano Observatory by the architect Angelo Vescovali (1826-1895). (Vatican Observatory Archive)

I am also involved in the working group for the restauration of Collegio Romano Observatory which is promoted by *Soprintendenza Speciale di Roma Archeologia Belle Arti e Paesaggio*.

A particular focus of my work is communicating science as part of the Vatican Observatory's projects in the field of outreach and education. I worked in the preparation of materials for an internet site for visitors to exhibitions

installed in the Cart du Ciel and Schmidt telescopes domes located in the gardens of Villa Barberini in Castel Gandolfo. Due to the pandemic a big part of this activity moved online.
Further tasks included management of the multicultural project "*Astronomy for Development*" which targets schools with a considerable presence of immigrant pupils.
In my everyday life, in addition to family commitments, I continue my work with my parish community of San Fulgenzio in Rome, as a lay minister of the Word and the Eucharist, and through my vocation as a youth catechist.

Father Louis CARUANA, SJ

The academic year 2019-2020 was my final year as Philosophy Dean at the Gregorian University. I had been thinking that, with my accumulated experience, the year would be smooth sailing. But the covid-19 pandemic changed all that. After February, the sailing was certainly not smooth. Now however I realize that, despite the confusion, the year was not completely unproductive. Before Christmas, I organized three research seminars dealing with philosophical or theological aspects of science. On November 6, Professor Josenir Dettoni, from the Federal University of Rondônia, Brazil, presented a paper on ecology and philosophy with special reference to the Amazon region.

On November 22, two professors from Charles University, Prague, D. Svoboda and P. Sousedik, were our invited speakers for a seminar on "Two Concepts of Science in Late Medieval and Early Modern Thought". On December 9, we were glad to welcome the renowned Galileo scholar William Shea who, together with Flavia Marcacci, Professor at the Lateran University, conducted a workshop on the important seventeenth century Jesuit astronomer Giovanni Battista Riccioli. These events involved primarily my research group that focuses on the scientific mentality and questions about God.

Towards Easter, I was happy to learn that the Gregorian University was offering me a sabbatical semester for research. I applied to Fordham University, the Jesuit university of New York, and they kindly accepted me as the holder of the St. Ignatius Loyola Chair in philosophy from August till December. I am now working away mainly on the emergence of the concept of environment, its historical development in science and philosophy.

At this stage, my work is revealing two main trends. One is evident in the work of some 19th century ecologists, a trend based on the idea that nature flourishes harmoniously towards a climax. The other is evident in the work of some Darwinism-inspired scholars, a trend based on the idea that life proceeds randomly through local struggle and competitiveness, without any overarching finality. This research, I hope, will enable a fuller appreciation of the encyclical Laudato Si'.

In October 2020, I was invited to report on this research in an online international workshop organized jointly by the Catholic University of Eichstätt-Ingolstadt, the Federation of German Scientists, and the Laudato Si' Observatory of the Gregorian University. I am glad that this encyclical is bringing various disciplines together, including science, philosophy, and theology.

One last thing to mention: a joint project between the Vatican Observatory and the Philosophy Faculty of the Gregorian University. The agreement consisted in organizing an annual lecture in the area of science and philosophical theology, to be delivered by a renowned scholar. Unfortunately, the covid-19 restrictions obliged us to postpone the first lecture. I am convinced however that, in the post-covid-19 world, this initiative will flourish and bear much fruit.

Ileana CHINNICI

This year opened with the celebrations for the centenary of the establishment of the Italian Astronomical Society, held in January, in Rome: I was invited to give a talk and had the opportunity to meet many colleagues. Who could imagine that I would no longer have this opportunity for the rest of this year.

From the end of February to the beginning of March I was again in Rome to participate in a meeting of the

National Committee for the Bicentenary of the Birth of Angelo Secchi (committee in charge for the third and last year) and to consult some documents at the Gregorian University. I got back to Palermo just in time: a few days later, the lockdown started - and our lives changed.

Smart working at home became the ordinary way to work – but I must recognize that it was very difficult to be concentrated on work, at the beginning. One's mind was captured by the news alerts arriving from everywhere that provoked anxiety and uncertainty. During the day I often thought of people working in hospitals, facing difficult situations. I felt helpless, but also compelled to dedicate myself to my chosen profession as they were to theirs

I managed to write some articles and contributions, but all my work in progress were ineluctably slowed down by the pandemic. The two publications on Angelo Secchi are still in press as well as other contributions in volumes. The participation in meetings via web platforms, however, has allowed to keep contact with the scientific and historians communities.

In summer I just participated in a retreat in Rome, trying to find time rearranging my personal and professional life, in the light of the new global situation. I wondered what the Holy Spirit was saying to me. Little by little, I have entered in a sort of normality, made of prevention and attention. I felt that I have to dedicate time to young people, who will have to build a new world, after the pandemic. They have right to be encouraged, formed, and prepared for this important task.

At the end of September, I received the unexpected news that the biography of Secchi was awarded the Osterbrock Book Prize 2021. What a surprise! I knew that John Hearnshaw and Jay Pasachoff intended to nominate the book, but I was also aware that the competition was hard. After the news, I received many, many messages of congratulations – too many, in my opinion! Then, I reflected that this extended amplification was probably due to the context of the pandemic that was getting closer once again – I felt happy to have offered to my friends and colleagues good news in such difficult times!

Michelle FRANCL-DONNAY

I am on sabbatical leave from teaching since the summer. As chair of my department, the abrupt shift to online teaching last spring in the face of the global pandemic was quite an adventure in the Chesterton sense: "An inconvenience is only an adventure wrongly considered; an adventure is an inconvenience rightly considered." My students were scattered over 12 times zones, some of them working from isolation, some of them working while they were ill. My colleagues were scrambling to figure out how to teach laboratory courses when students couldn't work in the physical spaces. It wasn't convenient, but colleagues and students alike were a courageous and adventurous lot and I'm very proud of their ability to persevere under these conditions.

Plans to travel during my sabbatical were put on hold. I have instead enjoyed the opportunity to give a couple of lectures via Zoom, including at Rockhurst University. I am principally enjoying the gift of several months of quiet time at home to write. I have continued my research work on the history and sociology of chemistry and on the structures of molecules with intriguing topology. I wrote several essays on the politics of science, including one advocating for a system of naming of scientific units that recognizes the diverse and international make-up of the scientific community and one on the potential effects of the pandemic on the work of women scientists and those with significant caretaking responsibilities. I'm diligently working on the manuscripts for two books, both of which I hope to complete by the end of the year. Two new books of reflections have appeared in the past year as well.

My younger son is following in his father's footsteps and has begun a doctoral program in mathematics at The Ohio State University. Meanwhile my oldest son, a historian, spent his lockdown time learning to code in Python to work on a project on Jesuit history.

Father José FUNES, SJ

This pandemic year in many ways has changed the life of billions of people. Also, in this year I have also been appointed superior of my Jesuit Community which is mostly formed by Jesuits working at the Jesuit University of the Universidad Católica de Córdoba. Our vocation as Jesuits leads us to travel a lot. We are not used to being locked down for long. We are not monks. Therefore, our community life has been quite a challenge. Our University also faced successfully the challenge to move classes to complete online mode in a couple of weeks.

In Argentina we start the academic year in middle March. After the first week of in-person classes we went to remote teaching. Since then we have been teaching in this way. We also have learned to collaborate in our research projects by using Zoom or Google Meet. My community is few blocks away from the Observatory of Córdoba. I used to see my collaborators face to face and attend in-person seminars. All of that has changed. There are many downsides in this situation, especially the suffering and the death of so many people. However, there are also many opportunities. For us, Argentines, it is very expensive, almost impossible to afford the participation in a scientific meeting abroad. With the new technologies I have been able to attend lectures and meetings in California from my home in Córdoba.

Though the difficulties I have mentioned, we have been able to make progress in our research project OTHER (Otros mundos, Tierra, Humanidad y Espacio Remoto which stands for Other worlds, Earth, Humanity and Remote Space) which is a laboratory of ideas that provides a multidisciplinary approach to the search for extraterrestrial intelligence. For more information, you can visit the website *https://blog.ucc.edu.ar/other/* in Spanish and *https://blog.ucc.edu.ar/other-en/* in English.

Father Matteo GALAVERNI

2020 was a very peculiar year. At the beginning of this year I renewed my affiliation with the Osservatorio di Astrofisica e Scienza dello Spazio, one of the institutes of the National Institute for Astrophysics (INAF) in Bologna. In February I had the opportunity to attend a conference on the Euclid mission, a new ESA mission to map the geometry of the universe and its cosmological composition.

At the beginning of March, everything suddenly changed. On the evening of Saturday March 7th I was visiting the Specola when watching the news, I realized that my city, Reggio Emilia, has been declared a "red zone" due to the increasing of COVID-19 cases. The following day I returned to the parish where I usually live, and remained there for four months. Almost all of the scheduled activities were cancelled (a Cosmology meeting in April, a conference with Guy Consolmagno and Alessandro Omizzolo in Fabriano, some scheduled interviews…).

I divided my time between helping in the parish house and my studies. It was not possible to visit the Institute in Bologna or the Specola in Castel Gandolfo, so I started working in my room. I began regular on-line meetings with Gabriele Gionti and the Cosmology group in Bologna. I tried to continue my research in theoretical cosmology, mainly focused on phenomenological implications of "new physics". Together with Gabriele Gionti we studied the implications of quantum anomalies on the propagation of photons in curved Space-Times (photon chiral anomaly). I also continued my research on cosmic birefringence (limits on rotation of Cosmic Microwave Background linear polarization) in collaboration with Fabio Finelli (INAF- Bologna).

Galaverni lecturing in Reggio Emilia Baptistery (the place where Angelo Secchi was baptized in 1818).

During the summer, the situation in Italy improved and I managed to visit the Specola again. In July Paul Mueller, Gabriele Gionti and myself visited my Bishop, Most. Rev. Massimo Camisasca, and discussed the possibility of increasing my time for research. There are good prospects for the future. I also helped in the organization of some outreach activities in Reggio Emilia.

Yet as I write the situation in Italy is getting worse again. I hope to be able to continue my work, at least from home… and I hope for an improvement in 2021.

Christopher M. GRANEY

Johannes Kepler, responding in 1610 to Galileo's just-published Starry Messenger, had a question about the nature of stars. He asked,

> *If they are suns having the same nature as our sun, why do not these suns collectively outdistance our sun in brilliance? Why do they all together transmit so dim a light…? When sunlight bursts into a sealed room through a hole made with a tiny pin point, it outshines the fixed stars at once. The difference is practically infinite.*

Kepler was arguing against Giordano Bruno's idea that stars were other suns, orbited by other Earths. Kepler felt that Galileo's telescopic observations of stars strengthened the case that our sun and its planets were extraordinary bodies.

Kepler's argument that basic observations opposed a universe of other suns has continued to be a focus of my research this year. Granted the understanding of stars that existed at the time, Kepler's argument seems robust, and so, unsurprisingly, this year I found another astronomer making such an argument, a century after Kepler: Jacques Cassini of the Paris Observatory, son of Giovanni Domenico Cassini.

I also studied how, between Kepler in the seventeenth century and J. Cassini in the eighteenth century, Jesuit astronomers such as Andreas Tacquet criticized Copernicans like Galileo for avoiding this aspect of the Copernican system. My friend and colleague Michael J. Crowe of the University of Notre Dame has shown that in the nineteenth century William Whewell argued that observations undermined the then-common assumption that most planets would be Earth-like (that is, inhabited), so I have this year become particularly interested in the seeming existence of a long-running "minority view" that held that science said that a Copernican universe was in fact not Bruno's largely homogeneous universe of many suns, solar systems, and Earths.

I find this possible "minority view" to be a fascinating topic of research for two reasons. First, it is history; it sheds light on what astronomers were thinking in the past, revealing robust scientific thought unknown to most people today. But the second reason is that people like Kepler, J. Cassini, and Whewell seem to have been prescient compared to their colleagues who assumed that the universe would be populated by suns and Earths. Today we are rapidly learning that stars, planets, and planetary systems are wildly diverse; most stars are not just like our sun, most planets not just like the Earth. Kepler, Cassini, and Whewell suggest that the broad acceptance, in the centuries following Copernicus, of Bruno's view of a homogenous universe was driven by something other than scientific evidence, and perhaps delayed astronomers in understanding the diversity of the universe.

Since the popular view of the universe remains Bruno's (as seen, for example, in the universe of the many "Marvel" superhero movies), this topic touches on popular culture and whether such a view is as informed by science as is commonly thought. Thus this topic has potential to be of broad interest, if this research continues to be productive. That is mighty cool!

Father Michael HELLER

Because of my health problems, my activities in this year considerably slowed down. The coronavirus pandemic further contributed to this – many lectures and conferences were canceled or moved online. I used the time of relative isolation to work on the book "Infinitely Many Universes". It was a period of intense study for me on the controversial issue of multiverse.

The modern story of the multiverse began with Leibniz. Although he treated "other worlds'" as mere possibilities, they played an important role in his logic. In a somewhat similar manner, the practice of cosmology presupposes considering an infinite number of universes. Einstein field equations are basic mathematical structure in cosmology, and each solution to these equations can be interpreted as a separate universe. Since the number of such solutions is infinite, we can truly speak of the "Einstein multiverse". Its status is not controversial. Moreover, cosmology itself could be regarded as a theory of "Einstein multiverse". Indeed, theoretical cosmology tries to penetrate as large areas of this multiverse as possible, whereas observational cosmology tries to narrow the field of its inquiry to those regions of the multiverse which best correspond to the results of observations. The solution space of Einstein equations, i.e. Einstein's multiverse, has a beautiful, albeit highly sophisticated, mathematical structure which is subject to careful mathematical investigations.
The multiverse idea as a collection of really existing "other universes", first appeared as an auxiliary concept in discussing the so-called anthropic principle, and then as a hypothesis that was supposed to solve some cosmological conundrums. Several chapters of the present book lead the reader through this labyrinth.

From the point of view of the philosophy of science the question should be asked: Could the explanatory power of multiverse ideology compensate for the relaxation of empirical control over so many directly unobservable entities? Is the appealing to a possibly infinite number of "other universes" in order to explain some problems in our world is a justified strategy? With no strict empirical control at our disposal it is logic that must take over.

In all multiverse versions classical logic is (tacitly) presupposed. And what if logic could change from one world to another in the multiverse? Such a possibility is suggested by category theory, quickly developing branch of mathematics. From this point of view, our present concepts of the multiverse seem hopelessly "not enough". In category theory, logic is not something "imposed from above", but it is rather a part of the game. Moreover, there are strong reasons to believe that all mathematics is but an infinite space of such "categorical universes".

One of the physicists once said that the whole of multiverse business is not physics but theology. And what would a theologian say about the idea of the multiverse? He might say, for example, that since God is infinity, He might be more interested in an infinite number of universes than in a single universe.

Father Adam HINCKS, SJ

This was a year of transition for me, as I finished my theology studies and embarked upon a new mission as an assistant professor at the University of Toronto.
In the first half of the year I completed a thesis for my Licentiate in Sacred Theology and Master in Theology. My topic was 'Natural Knowledge of Creation from Nothing' and I explored the question of whether the doctrine of creation *ex nihilo* can be understood on philosophical terms (like the existence of God, as affirmed by Vatican I) or whether it is only known through revelation (like God's Triune nature). I thought it was an important issue to sort out because often dialogue between science and faith presumes that the Christian notion of creation is something that can be treated of philosophically. I argued in my thesis that indeed it can be, but also showed how this philosophical understanding exists in the context of moral and religious commitments. This work was done at Regis College, the Jesuit faculty of theology at the University of Toronto; however, as I did not need to be on campus, I did my writing north of Toronto in Midland at the Martyrs' Shrine which commemorates St. Jean de Brébeuf and his companions. The Shrine has some important relics of the martyrs and is a very popular destination for pilgrims. Less well known to most pilgrims, but of interest to readers of this Annual Report, is that the Jesuit mission at Midland was the site of the first recorded use of a telescope in Canada. Fr. Francesco-Giuseppe Bressani, SJ, though not one of the eight missionaries who were martyred, was one of their companions at the mission and used a small telescope to observe the lunar eclipse of January 1646.

Returning to the present day, the plan was for me to help with the pastoral ministry at the Shrine while writing my thesis; with the coronavirus lockdowns in March, however, this plan came to an end, and I ended up using the time fruitfully towards my thesis in the Shrine's quiet, rural setting.

After completing my thesis, I transitioned to my current work at the University of Toronto, where I

am the inaugural holder of the Sutton Family Chair in Science, Christianity and Cultures. It means that I have an appointment in the Department of Astronomy & Astrophysics as well as at St. Michael's College, a Catholic institution within the University. One of my tasks will be teaching courses on faith and science, and currently I am developing a new course on cosmology and creation, which, if approved, will be jointly offered by the Department of Astronomy and St. Michael's College.

The new position has also meant a return to fully-engaged research in cosmology. I work on observations of the cosmic microwave background through my affiliation with the Atacama Cosmology Telescope (ACT), currently observing in Chile, as well as the Simons Observatory (SO), which is currently being built. With ACT and SO we address fundamental questions about the Universe, such as how it behaved soon after the big bang and how old it is. I have also joined the Hydrogen Intensity and Real-Time Analysis eXperiment (HIRAX), a new radio observatory that will be built in the Karoo region of South Africa. The full project—to be gradually built up over the coming years—will consist of 1024, 6 meter dishes operating as an interferometer in order to make a huge, 3D map of the Universe during the period when it began accelerating in its expansion. This will help us learn about dark energy. It will also be an excellent instrument for studying transient sources like pulsars and fast radio bursts. I have begun recruiting some local undergraduate and graduate students to work with me and contribute to the above projects. This new position is keeping me quite busy and there is lots to learn! But it is an exciting opportunity and I am doing my best to make the most of it. God has been very good to me. And hopefully, once the pandemic has been reined in, I will be able to visit the Specola in person again.

Dante MINNITI

2020 has been spent working on the ESO public survey VVVX (VISTA Variables in the Via Lactea Extended Survey). Among the many interesting new scientific results from this year, we have discovered a low luminosity globular cluster in the Milky Way disk. We also discovered the mysterious VVVWIT-01, that is a highly obscured classical nova or protostellar collision.

We found another low extinction window to probe the far side of the Milky Way bulge using the VVV Survey. We published a massive VVV infrared variability catalog (VIVA-I) containing hundreds of thousands of variable stars, and a qualitative classification of extraterrestrial civilizations. I also made a few interesting discoveries working with recent VOSS students: we found hypervelocity stars in the Galactic bulge using the VVV and Gaia Surveys, published a catalog of VVV Survey best and forsaken microlensing events, mapped the Galactic latitude dependence of microlensing, and discovered candidate events with sources in the far disk. We also used classical Cepheids to study the far side of the Milky Way's disk measuring the metallicity gradient, and discovered a super-Jovian planet in the Galactic plane using gravitational microlensing.

Father Giuseppe TANZELLA-NITTI

The year 2020 was characterized by the health emergency caused by the Covid-19 pandemic. This circumstance caused repercussions on everyone's work and therefore also on mine. Public opinion has also addressed important questions to theology, and therefore to the relationship between science and faith, which I am dealing with. Why does God allow this pandemic? How can it be useful to pray in these circumstances?

I tried to answer these questions in an article entitled "Science and Faith in the Coronavirus epoch" published on the website of the Interdisciplinary Encyclopedia of Religion and Science, inters.org. As a Catholic priest, I tried to encourage colleagues and acquaintances by proposing St. Paul's teaching to overcome evil with good, transforming evil into good (cf. Rom 12:21). The enormous development of online activities that we have seen grow in recent months, now able to reach thousands of people around the world, and whose functioning we had to learn, is a first example of this good.

As a premise, let me recall that my main field of study is now Fundamental Theology. Before committing myself to theology, I worked as an astronomer (1977-1987) in the field of extragalactic astronomy. My contribution as adjunct scholar to the Vatican Observatory scientific community concerns the history and philosophy of

science, theology and science dialogue, the philosophical dimensions of scientific research activity.

In January, before the pandemic broke out, I was invited to spend a couple of weeks at the Universidad de Los Andes, Santiago del Chile, to give lectures and offer advice to the newly established Center of Philosophy of Science active at that University, which is now interested in extending their interdisciplinary studies to theology. On this occasion I gave a keynote Lecture to all the Faculty members of the University entitled "Theology and Science: Reasons for a Fruitful Dialogue" (Teologia y Ciencia, razones para un diálogo fructifero).

I was also asked to give an evening public lecture on "The Origin of the Human Being between Biological Evolution and Theology of Creation" (El origen del ser humano: entre evolución biológica y teología de la creación).

I am also glad to announce that my volume "Scientific Perspectives in Fundamental Theology. Understanding Christian faith in the Age of Scientific Reason", partly supported by the Vatican Observatory Foundation, has been accepted by Claremont Press and will be published on Spring 2021.

Last but not least, I would like to mention the daily activity as Director of the Interdisciplinary Documentation Centre for Science and Faith in Rome, which offers its academic partnership to the Vatican Observatory. The Centre runs two important projects: The Interdisciplinary Encyclopedia of Religion and Science (inters.org), a registered philosophical journal (ISSN 2037-2329), and the Advanced School for Interdisciplinary Research (sisri.it), a program aimed to provide a philosophical-humanistic training for young scientists who wish to achieve a wider interdisciplinary expertise.

Fr. Tanzella-Nitti with authorities from the Universidad de Los Andes, Santiago del Chile.

Chapter FIVE

Instrumentation and Technical Services

Observing the stars while observing social distancing presented its own challenges to the "mechanics" of running the Vatican Observatory in 2020, with onsite restrictions in Rome and Tucson and even the brief shutdown of the VATT on Mount Graham.

Vatican Advanced Technology Telescope (VATT, including the Alice P. Lennon Telescope and Thomas J. Bannan Astrophysics Facility)

Personnel

Scott Swindell left Mountain Operations, and the VATT team on January 24, joining the MMT. Dan Avner, who had been a part of Mountain Operations in a different capacity, started with us on March 23 as a R&D software engineer.

Steward Observatory asked all faculty, staff and employees to perform job duties remotely, from home effective Monday March 16. Steward Observatory building was closed to the public starting on Tuesday March 17. These measures remained in place until the end of the year and beyond. Laboratory work was possible only when observing social distancing and using personal protective equipment (PPE), which in practice meant one person per room.

MGIO stakeholders convened a shutdown meeting on March 18, and agreed to shut the site down. We had no observers at the VATT at the critical time. Gary Gray conducted a shutdown of the VATT on March 19. We opened again with BOYLE as the VATT operator and observer (May 28 – June 9). Safety of our personnel and of visiting scholars is paramount. Under normal circumstances, safety on Mt Graham, which is a remote site, calls for a sufficient presence of trained personnel capable of dealing with emergencies, including medical evacuations. On the other hand, the pandemic dictates limiting our numbers on site in order to minimize contact. Our COVID-19 protocols for Mt Graham are a compromise between these two opposing considerations. The measures in place require that only one person can be staying at the VATT at any given time, provided that there is sufficient presence of qualified personnel in the other buildings at the summit.

VATT Upgrades

Several upgrade projects continued: network, commissioning of the Mount Control Unit and TCS-NG, commissioning of the guider box, and the automated collimation and collimation maintenance procedure. The primary mirror position monitoring system was installed by Michael Franz and Dan Avner. Gary Gray supervised the replacement of the remaining windows by Boulevard Glass, LLC, and an overhaul of the hydrostatic-bearing oil chillers by Advanced Air Systems, LLC.

High Performance Computing at the Specola

This year, the Specola initiated a small step in the direction of high-performance computing (HPC). It acquired a multi-processor Dell Poweredge Server to cater to the high-performance computing needs of the researchers based at Castel Gandolfo. The current configuration is also capable of analyzing large simulations as well as processing large datasets.

The new Dell server, hosted at the Specola in Castel Gandolfo.

Meteorite lab

The meteorite lab had a small budget for a meteorite purchase this year. (This purchase took place before the pandemic struck.) It was used to purchase one 25.3-gram specimen of the lunar meteorite NWA 11228, intended for the measure of heat capacity and other physical properties.

We also received three donations from generous donors. One is an 8.3-gram specimen of the CM2 carbonaceous chondrite Aguas Zarcas, which fell in Costa Rica in 2019. This specimen was donated by Dustin Dickens of Top Meteorite. Morten Bilet donated a 2.7-gram lunar feldspathic breccia, Lahmada 020. A friend at Portland State University in Oregon provided a 144-gram specimen of the ordinary chondrite NWA 869. This specimen is intended for didactic purposes and has already been used several times in classroom and public settings (before the pandemic made such gatherings impossible).
The growth of the meteorite collection is largely dependent on the generosity of donors.

Meteorites acquired in 2020. Top from left: NWA 11228 lunar feldspathic breccia, Lahmada 020 lunar feldspathic breccia, Aguas Zarcas CM2 carbonaceous chondrite. Below: NWA 869 L ordinary chondrite in a 3d-printed custom-designed demonstration case.

Chapter SIX

Education and Outreach

Globally, schools and universities moved on-line in 2020 meaning our work in education and outreach to future generations of astronomers largely embraced the new 'virtual reality'. Time saved in international travel was re-directed to digitally connecting to classrooms from the Philippines to Brazil. Yet despite the potential of e-learning and e-teaching, many of our scientists look forward to the restoration of 'in-person' conferences and seminars.

Education and Public Outreach

BROWN began the year by giving the "General Convocation" special address and lecture to students at Marymount International School, in Rome, Italy on occasion of NHS Induction. In October he gave lectures to two sections of Religious Studies S252 Theology Course on issues of faith and science at Loyola University, New Orleans, Los Angeles USA and took part in the "Vatican Observatory Foundation 6th Full Moon Meetup".

CONSOLMAGNO was only able to give one in-person popular talk before the pandemic hit; this was on January 25 to the Whipple Public Observatory, in Green Valley, Arizona, where the topic was the History of Planetary Sciences. He also traveled to Syracuse, NY, for the funeral of Fr. George Coyne, emeritus director of the Specola, where he presented a reflection on George's life.

Due to the pandemic a number of trips and talks had to be canceled. Others were converted to video format. As a result of the flexibility of online presentations, he was able to connect up with audiences from Japan and the Philippines, to Italy, Ireland, Japan, and the United Kingdom… all without leaving the Jesuit residence in Tucson.

Among the talks given remotely were "Faith, Science, and the Common Good" presented to the McCormick Theological Seminary of Chicago on February 13; "Astronomy, Religion, and the Art of Storytelling" to the Catholic Theological Union of Chicago on March 20; an informal presentation to a homeschooling group in New Hampshire on May 6; about "Astronomical Ideas that were Almost Correct" to the Cape Cod Astronomical Society on July 4; the "Light the World" event at the Catholic University of America, July 1; part of a panel discussion on "The Distant Future in Science Fiction" at the ReConvene online SF convention, August 15; a presentation about "Turn Left at Orion" with Dan Davis at the Detroit-area Astronomy at the Beach (online) event, September 26; an event in conjunction with the Living Laudato Si' organization in the Philippines, "FAITH and conSCIENCE for Our Common Home," October 3; "On Teaching the Relationship between Faith and Science," an online course for instructors at Holy Apostles College & Seminary, Cromwell CT, October 5; a presentation to the students of Westminster Abbey, London, "Does Science Need God?", October 14; a presentation to an astronomy class of the Columbus Catholic High School, Marshfield WI, November 3; the talk "Galileo to Laudato Si'" presented to the Cork, Ireland, Astronomy club on November 9; a presentation, "Discarded Worlds," to the Long Island Astronomy Club, November 15; and the talk, "The Heavens Proclaim", to the National Catholic Awareness Conference, Tokyo, Japan, on November 20.

Along with these interactive talks, he also provided pre-recorded videos on topics in faith and science for De La Salle College, Victoria, Australia; and a video on the possibility of finding life in icy moons for 100th Anniversary of the Great Galaxy Debate event featured on the popular Astronomical Photograph of the Day site.

In the spring of 2020, CONSOLMAGNO conducted his online regular class in high school astronomy for the Arrupe Virtual Learning Institute (AVLI). In addition, he produced an intensive four-week version of this class for adults, Astronomy for Mature Audiences, which was held

in October and November.

CORBALLY gave a talk on March 8 to the Saddlebrook Stargazers Astronomy Club on "A Revolution in Astronomy." On October 27 he joined the online meeting of the Spectroscopy Discussion Group, gave some background on the Vatican Observatory and its VATT, described recent spectral classification work on lambda Boötis stars, and discussed the contributions of small telescope scientists to variable star astrophysics.

FUNES continued to teach a class on Philosophy of Nature to grad students in Philosophy. He stayed at Santa Clara University for four weeks where he was invited by the Ignatian Center for Jesuit Education to give the 2019-2020 Bannan Memorial Lecture on Frontiers of Astrobiology. During the course of the year he also lectured at the Catholic Center, Boise State University, the Instituto Ciência e Fé da Pontifícia Universidade Católica do Paraná (PUCPR), Brazil and Universidad Católica de Córdoba, Colegio del Salvador (Buenos Aires) by Zoom on topics related to Astrobiology, Science and Faith.

In January, the Society of Ordained Scientists invited GABOR to give a talk at the RRC Tucson. In December he gave a public lecture to the Sonora Astronomical Society in Green Valley.

GIONTI together with R. Battiston, he gave an on-line panel presentation chaired by the astrophysicist and journalist Letizia Davoli titled "From the Space Station to the Deep Universe", at the meeting of Religious Publishing EURO 92 on September 25.

HINCKS was an invited speaker of the Astronomy and Space Exploration Society, Toronto, where he gave a presentation in August for their 'Star Talk' series, via Zoom, entitled 'How to Measure the Universe's Oldest Light and What it Tells Us'.

In January KIKWAYA held a conference on "Gravitational waves" at Jesuit High School College Boboto, Kinshasa in the Democratic Republic of Congo. He presented two further conferences, one in Congo on "The Place of Faith in Scientific Research" at Université Loyola au Congo (ULC), Saint Pierre Canisius, Department of Philosophy and on "Meteors, Meteorites, and Asteroids" at Jesuit High School College Kubama, Kisantu, Democratic Republic of Congo.

Due to COVID-19 OMIZZOLO's planned activities of outreach to the general public suffered a setback so, with the cancellation of all activities, except in the summer period when in collaboration with the diocese of Padua, he gave a talk to adult volunteers on Pope Francis's encyclical "Laudato sì".

MACKE offered online outreach during the year. In May he spoke to Bellarmine College Preparatory School, San Jose, California on "The Vatican Observatory: At the Crossroads of Faith and Science"; in October he spoke to MIT Tech Catholic Community in Cambridge Massachusetts on "Science and the Catholic Faith: Friends, Not Foes" and Bishop DuBourg High School Big History St. Louis, Missouri on "The Vatican Observatory".

Ahead of Italy's severe lockdown, TANZELLA-NITTI gave a lecture in Vatican City to the General Assembly of the Congregation for the Catholic Education, February 17-20, commenting Pope Francis' apostolic constitution Veritatis Gaudium Proemium, about the role of Catholic Universities and their dialogue with scientific culture. More than 50 Catholic Bishops attended the lecture, which was published on Osservatore Romano.

In July TANZELLA-NITTI was honored to be invited by Engineer Franco Malerba, the first Italian astronaut, to address the opening lecture of the "Genova Space Festival" on "Life in the Cosmos: A Theological Perspective". Other lectures and talks include: "Recent Developments in the Science and Theology Dialogue" for the Press Cultural Association, Aosta, February, "The Humanistic Dimensions of Scientific Research" III Gran Sasso Forum, Teramo, Italy and "The Metaphor of the Book of Nature: a Short Historical-Theological Journey" for the Accademia Urbana delle Arti, Rome, Italy in October.

News and Media

Interaction with the communications media, traditional and digital, is one of the fastest ways to catch popular imagination and by doing so introduce entire new generations to the fascinating binomial of faith and science.

Over the past 12 months BROWN was interviewed by the journalist Miguel Pérez-Pichel on behalf of Mundo Cristiano magazine April 2020 issue. CONSOLMAGNO participated in an interview with Austrian Radio/TV on December 9, 2019; and he participated in online interviews with France 24 television on February 28; with Aline Cox of

WGN television, Chicago, on March 11; and for the online magazine, Hour Detroit. He was a guest on a number of podcasts, including "Active Listening" and "Good Heavens". He was interviewed by Rev. Martin Fair, Moderator of the General Assembly of the Church of Scotland, for his regular series of videos, "A Fair Question", and appeared on "Event Horizon" with Ross Howard. Noted science videographer Brady Haran visited Castel Gandolfo in early January, from which three YouTube videos were produced: for the series Objectivity, "The Pope's Space Rocks"; for Deep Sky Videos, "The Pope's Telescopes"; and for Sixty Symbols, "The Pope's Astronomer."

Perhaps the most notable media event for CONSOLMAGNO was his appearance in the Werner Herzog/Clive Oppenheimer documentary *Fireball: Visitors from Darker Worlds*. The film, about meteorites and asteroids, is now available on the Apple + channel and it has received favorable reviews from a number of newspapers including *The Guardian* and *Variety*. The latter commented how "Oppenheimer…talks to a series of nerdishly possessed scientific luminaries, and to some quirkier mandarins as well, like Brother Guy Consolmagno, the Jesuit planetary scholar who presides over the Vatican observatory at the Pope's summer residence at Castel Gandalfo, Italy… To him, the science of it all is inextricable from the wonder."

CORBALLY was interviewed in June 2020 by Dennis Sadowski, Catholic New Service, and Luke Coppen, Catholic News Agency, on asteroid Corbally.
On December 21 he spoke with Drew Mariani on Relevant Radio about the Christmas Star and that night's conjunction of Jupiter with Saturn.

FRANCL-DONNAY was heard on September 29 episode of the NPR podcast, "Short Wave" and contributed to Loyola Press' 31 Days for Ignatius photo essay on "Experiencing God in the Ordinary".

The 2020 data release from the Atacama Cosmology Telescope, on which HINCKS collaborates, was picked up by major news outlets including BBC, CBC and Popular Mechanics. HINCKS was also featured the in the Catholic Register article 'St. Mike's reaches for the stars to fill Sutton Family Chair' and in the student-run The Mike article 'A Profile on Science and Theology'. HINCKS contributed an article entitled 'What Parish Are You At, Father?' for InsightOut, the blog of St. Michael's College, University of Toronto.

GABOR provided information to the East Arizona Courier covering the shutdown and reopening of the Mount Graham International Observatory (Jorge Encinas, "Scientists on Mt. Graham may be back in action soon," Aug 11), and gave a Christmas interview to Radio Kosice (Slovakia) covering the Jupiter-Saturn conjuction and the Star of Bethlehem.

GIONTI G. was interviewed by VaticanNews on the occasion of the launching of several missions of United States, China and the Emirates to Mars and by TV2000 in "Bel Tempo si Spera" in October on the anniversary of the miracle of our Lady of Fatima.
The Sacred Space Astronomy Blog has been a versatile window on the Vatican Observatory and over the past year MACKE has regularly updated it with the weekly column: "Specola Guestbook", the monthly "Religious Scientists" feature and other more time specific posts such as "Specola Adjunct Scholar Chinnici Wins Osterbrock Book Prize," "Asteroids Named for Jesuits: An Update," on the Corbally Asteroid and in May a post on being "In Isolation at the Vatican Observatory." He also looked at "Computer Models in the time of coronavirus." All of the posts are available online at *https://www.vofoundation.org/blog/*.

Presentations, Academic Activities and Conference Participation

Academic presentations would appear to have suffered most during the 2020 Coronavirus emergency with many seminar and conference organizers preferring to postpone in person meetings rather than move them online. This is reflected by the concentration of tour scientists' seminar attendance at the beginning of the year before lockdowns closed all travel and over the Northern summer months when restrictions were eased.

BOYLE was first author on a poster paper at the 235th Meeting of the American Astronomical Society, Honolulu, Hawaii in January. For his scientific work, CONSOLMAGNO presented a paper at the Lunar and Planetary Laboratory's internal conference on August 21 and attended the biennial Plenary Session of the Pontifical Academy of Sciences (PAS) on October 7-9, and the annual meeting of the American Astronomical Society Division for Planetary Sciences on October 26-30. In addition, he presented a memorial for George Coyne at the PAS closed session, October 28. He also attended the

on-line meeting of the SETI institute Science advisory board, held over two days, May 20 and 28; and an "all hands meeting" of the SETI Institute as a member of that board, on August 18.

CORBALLY participated in the Annual General Meeting of the International Dark-Sky Association, held online, D'SOUZA in the online meeting of the European Astronomical Society Annual Meeting in early summer. GABOR taught a tier II general education course on the history and philosophy astronomy, ASTR 320, in the Spring 2020 semester at the UA. He participated in the International Dark-Sky Association's Annual General Meeting & Conference, November 13-14 and in the EDEN collaboration workshop on December 14-17.

GIONTI presented on the "Inequivalence between Jordan and Einstein frames," at the FLAG meeting of the INFN at the Theoretical Physics Department of the University of Bologna in December 2019. He partecipated to the international conference "Quantum Gravity and Matter", at CP3 Origin, Odense, Denmark, 12-16 October 2020. On November 2020, he gave another on-line talk on "Canonical Analysis of Brans-Dicke Theory Addresses Hamiltonian Inequivalence between Jordan and Einstein Frames," at 10th Exact Renormalization Group 2020 (ERG2020), for the Yukawa Institute, Kyoto, Japan.

Through summer into autumn KIKWAYA – ELUO logged up 5 online conferences including the Lunar Surface Science workshop, Overview and Tools and Instruments, in May; the Lunar Surface Science workshop, Lunar Volatiles and Samples, in July; the Lunar Surface Science workshop, Dust and Regolith, in August; the Lunar Planetary Laboratory Conference, again in August and the South African Astronomy Observatory Virtual Symposium in October.

In November, CARUANA gave the St. Ignatius Loyola Chair Public Lecture at Fordham University New York, entitled "Exploring Conceptual Plasticity: Should We Attribute Legal Personality to Intelligent Machines?".

"Molecular Monsters: Designing molecules with Möbius topology" was the topic of presentation given by FRANCL-DONNAY at Wake Forest University in February. She was also invited to give the Rev. William Rossner, S.J., Lecture, at Rockhurst University, in October for which she presented on "Amid the Burning Layers of Grace: A Contemplative Approach to Science".

GALAVERNI attended the 3rd National Meeting of the Euclid Collaboration in February ant the Italian National Research Centre (CNR) in Bologna, Italy.

Zoom offered HINCKS the opportunity to attend the Simons Observatory Collaboration Meeting in July and the Atacama Cosmology Telescope Collaboration Meeting in August. MACKE attended the AAS Division for Planetary Science Conference virtual meeting in October.

TANZELLA-NITTI took part in the online International Conference "Are we alone in the Universe?" jointly organized by Italian National Institute for Astrophysics (INAF), the Italian Embassy in Kiev and the Karazin Kharkiv National University, on occasion of the 2020 Day of Italian Scientific Research. He gave an invited talk entitled "Plurality of Worlds and Christian Faith."

Appointments to committees and boards

In 2020 FRANCL-DONNAY was appointed to the board of the Institute for Religion and Science and appointed Chair of the Board of the Open Chemistry Collaborative in Diversity Equity (OXIDE). Having begun his faculty position at the University of Toronto in July this year, HINCKS was elected vice-president of the Toronto chapter of the Society of Catholic Scientists. GIONTI was appointed associate fellow of the National Laboratories of Frascati (LNF) of the Italian Institute for Nuclear Physics (INFN) for the year 2020.

Awards and distinctions

CORBALLY was honored with the naming by the International Astronomical Union through its discoverer, Roy Tucker, of asteroid (119248) Corbally. There are now six asteroids named for members of the Vatican Observatory, and it is the eleventh named for Jesuits.

Personnel news

This year GRANEY retired from Jefferson Community and Technical College in Louisville, Kentucky, having completed a thirty-year career there. While the idea of retirement had arisen on occasion in his and his wife Tina's minds, the impetus to action was, of course, COVID-19. We wish him a happy, healthy and active retirement.

In Memoriam

Fr. George Coyne, SJ (1933-2020), the director of the Vatican Observatory from 1978 to 2006, died on February 11, 2020. A full reflection on his life and his importance to the Observatory can be found in Chapter One, From the Director, pp 6-8.

Fr. Manuel Carreira Vérez, SJ (1931-2020) passed into eternal life on February 3 in Salamanca, Spain. He was 88 years old, a Jesuit for 71 years and a priest for 60 years. For many years, he was very active in the fields of theology, philosophy, and astronomy.

Manny, as he was familiarly known, was associated with the Vatican Observatory for many years. He was a member of the Vatican Observatory Foundation board during 1988-2002, and was appointed as an adjunct astronomer of the Vatican Observatory in 1994. His involvement in the life of the Specola Vaticana spanned the spectrum of activities, while he continued teaching and research at John Carroll University in Cleveland, Ohio and at the Pontifical University of Comillas in Madrid, Spain, not to mention his association with other institutions throughout Latin America. During his time at John Carroll University he developed a friendship with Fred Lennon, who would later be one of the principal benefactors of the VATT.

Manny was a frequent presence at the biennial Vatican Observatory Summer Schools. Every night he would open the domes of the telescopes (located on the roof of the apostolic palace) to show the young summer school budding astronomers how to use the telescopes and the instrumentation associated with them. This included passing along his knowledge and expertise in astrophotography; many of the best photographs in the Vatican Observatory archive were produced by him using those same telescopes. Another notable contribution by Manny to the dynamic of the summer schools was in his outreach to the summer school students from Latin America, for which his friendship was appreciated.

Manny's work in astrophysics covered a variety of fields and venues. His collaborative research with the Nobel Laureate Clyde Cowan, co-discoverer of the neutron, dealt with the cosmic rays. The bulk of his scientific work was done through teaching physics and astronomy at John Carroll University, for which he was awarded the Centennial Medal in 1987. His passionate involvement in issues of faith and science were also seen in his role as a professor in the natural and social sciences and in philosophy at the University of Comillas in Madrid, Spain, where he was one of the holders of the Chair in the Technical Sciences and Religion.

Beyond those institutional commitments, Manny also was a part of several collaborations that had associations with NASA, in particular helping to develop a system of control and detectors for NASA space probes. As an astronomer for the Vatican, he was a member of a collaborative endeavor using the Vatican telescopes to study the atmosphere of the Saturnian moon Titan, including the observation an occultation of the star 28 Sgr by Titan in 1989. Manny's passionate love for observational astronomy also included the development of various astronomical instruments, two of which have patents. All through this, Manny continued to direct people through the Spiritual Exercises of St. Ignatius Loyola and to give several conferences and talks on issues of faith and science.

In 2016, Manny retired to the place where his life in the Jesuits began, Colegio San Estanislao in Salamanca, Spain, this time at the retirement center, praying for the Church and for the Society of Jesus. His funeral mass was celebrated on February 5, 2020 in the chapel of the Jesuit community there; his burial followed. *Requiescat in Pace.*

Fr. Manuel Carreira Vérez, SJ (1931-2020)

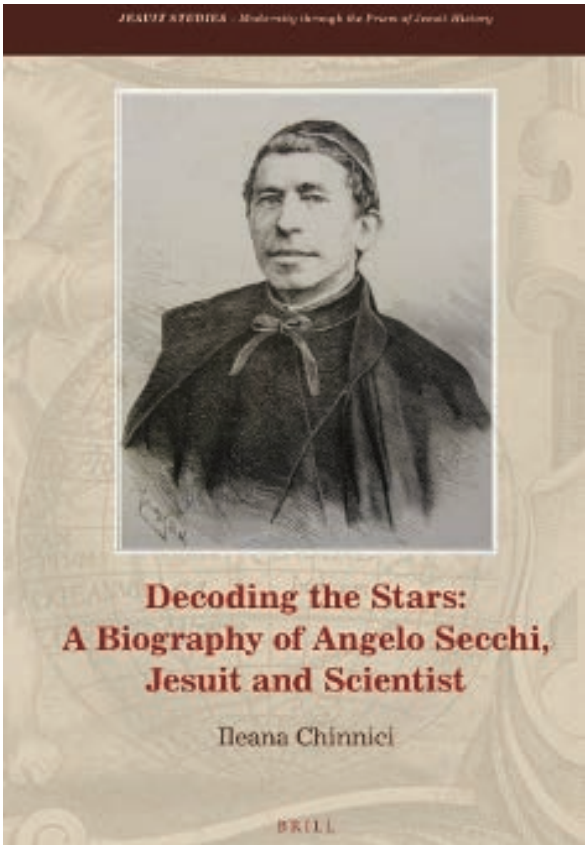
Chapter SEVEN

Publications

Through their academic publications Vatican Observatory staff and scholars share their ongoing work and research with the scientific community around the world.

Books

The Historical Astronomy Division of the American Astronomical Society chose to honor one of our adjunct scholars, Ileana Chinnici, with the Osterbrock Book Prize for her biography of Fr. Angelo Secchi SJ. The prize, named for the astronomer-historian Donald E. Osterbrock, is awarded every other year for a book "judged to advance the field of the history of astronomy or to bring history of astronomy to light."

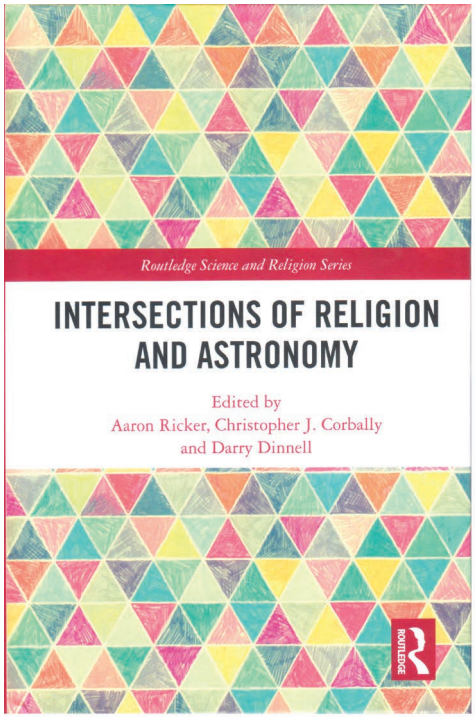


Her book, entitled *Decoding the Stars: A Biography of Angelo Secchi, Jesuit and Scientist* (2019, Brill, 367 pp.), is the first biography written in English about the Jesuit astrophysicist. There have been several academic works about Secchi written in Italian or other languages - several of which include contributions by Chinnici - but he remains relatively unknown in the English speaking world. [This is due in part to the influence of Normal Lockyer, the founder of the journal Nature and Secchi's main rival in the field of solar physics. He blocked any of Secchi's works from being published in English.]

In awarding the Osterbrock Prize to Chinnici, the Historical Astronomy Division recognized not only the value of Chinnici's research on the subject, but also the growing importance of Secchi himself to the history of astronomy. From their web page:

This is the first full-length biography of Italian astronomer Angelo Secchi (1818-1878) in English and will become the definitive work on this important figure in the history of astrophysics. Secchi became well known as part of the transition from classical positional astronomy to astrophysics. He was a pioneer of spectroscopy and its application to stellar classification and solar physics. At the 25th anniversary of Secchi's death, George Ellery Hale praised his contributions "to the present widespread interest in Astro-physical research." Chinnici's book covers not only the research that Secchi is remembered for, but also the broader environment in which he worked. Based on extensive research in Italian and Vatican archives, it is richly illustrated with many color and black-and-white photographs. [Source: AAS-HAD]

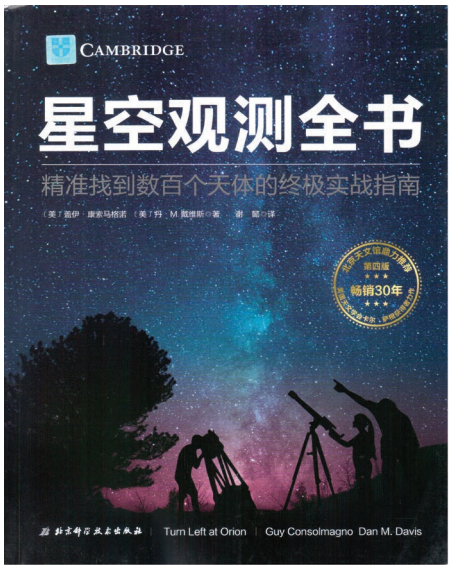
Intersections of Religion and Astronomy (2020), Routledge Science and Religion Series, London
Edited by Ricker, A., CORBALLY, C., Dinell, D.



This volume arose out of a weekend conference organized by graduate students at McGill University; Aaron Ricker, Christopher Corbally, and Darry Dinell realized how its scope could be broadened by an interdisciplinary team of international scholars, who would examine the way in which cultural ideas about "the heavens" shape religious ideas and are shaped by them in return.

Our approaches to cosmology have a profound effect on the way in which we each deal with religious questions and participate in the imaginative work of public and private world-building. Historical and contemporary case studies are included to demonstrate this lived reality in a variety of faith traditions and their interactions with the cosmos. This breadth of scope allows readers to get a unique overview of how religion, science and our view of space have, and will continue to, impact our worldviews and actions.

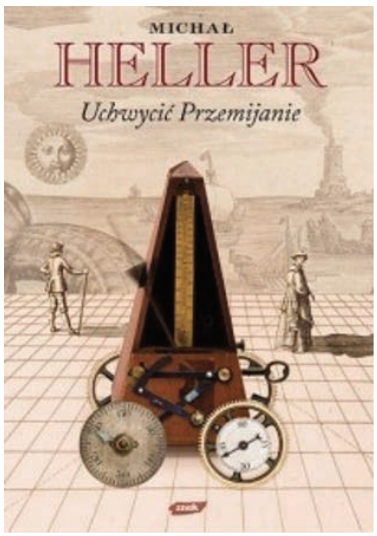
In 2019, a Chinese edition of the popular astronomy book Turn Left at Orion by CONSOLMAGNO and Dan M. Davis was published by Cambridge University Press. According to a Chinese colleague of Dr. Davis, the original title "Turn Left at Orion" must have given the translators some headaches trying to capture its whimsical nature, and so they used the more prosaic title, on the order of ""Starry Sky Observation." In fact, their title uses a term that is difficult to translate into English!



In the 2018 Annual Report we had noted German and Italian translations of Would You Baptize an Extraterrestrial? by CONSOLMAGNO, G. and MUELLER, P. through the good efforts of Fr. Michael HELLER and the Copernicus Center, it has also been published in a Polish edition.

Michael HELLER's *Uchwycić przemijanie* [To Capture the Passing Moment] was published in a third revised edition this year by Copernicus Center Press, Kraków, in Polish.

"Is physics able to analyze the flowing moment, movement and change by its own methods? Heller focuses not so much on the analysis of the most important concepts of science, but rather on the method by which they were developed, and which continues to be the most powerful driving force behind science."



Also this year saw the publication of HELLER's *Jednak chwila w dziejach Wszechświata. Lemaître i jego Kosmos*. [One Instant in the History of the Universe. Lemaître and His Cosmos], Copernicus Center Press, Kraków, in Polish.

Papers

BOYLE:

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Chapter EIGHT

Visitors

It is always a pleasure to welcome academics, scientists, students and our generous benefactors to our facilities in Castel Gandolfo and Tucson. However, the Covid-19 protocols issued by the various civil authorities that the Vatican Observatory must attend to, in order to ensure the safety of our staff, scholars and visitors means a greatly reduced hospitality this year, in the hope that next year will be a different, brighter story.

Visitors to the Specola in Rome for Scientific purposes included:

Fr. Secondo Bongiovanni S.J., from the Pontifical Faculty of Southern Italy San Luigi, Naples.

Paolo Ventura and Flavia Dell'Agli, L'Istituto Nazionale di Astrofisica (INAF) Monteporzio, Italy.

Visitors to the Specola in Tucson included:

John Cunningham, SJ from Fordham University, USA.
Alison Rose from Inigo Films.

Visits to other institutions for scientific purposes

GIONTI visited Catania Astronomical Observatory, hosted by Dr. Alfio Bonanno.

Visitors to the Specola for general purposes included:

Four friends led by Dr. Gianni D'Onofrio from Capua (CE). Architect and former Jesuit Robert Dolinar from Slovenia, who is working to build the Chapel for the EUM scholasticate of San Saba in Rome.

Simona Vegetti MPA, from Munich and John McKean from Kayptern, Groningen.

On December 30 the Observatory was privileged to receive a visit from Her Excellency the USA Ambassador to the Holy See Callista Gingrich and her husband Newt Gingrich, the former Speaker of the USA House of Representatives. Br. Bob Macke provided a detailed explanation of the Observatory's meteorite collection and of his own research, and Fr. Paul Mueller led a visit to the Observatory's telescopes and historic exhibit in the papal gardens.

The visit of the USA Ambassador to the Holy See at Specola Vaticana in Castel Gandolfo


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