



# Making an Impact

**The Vatican Observatory**  
**Annual Report 2016**





# ANNUAL REPORT 2016

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**Vatican Observatory Publications**



# Vatican Observatory Staff

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- PAVEL GÁBOR, S.J.,  
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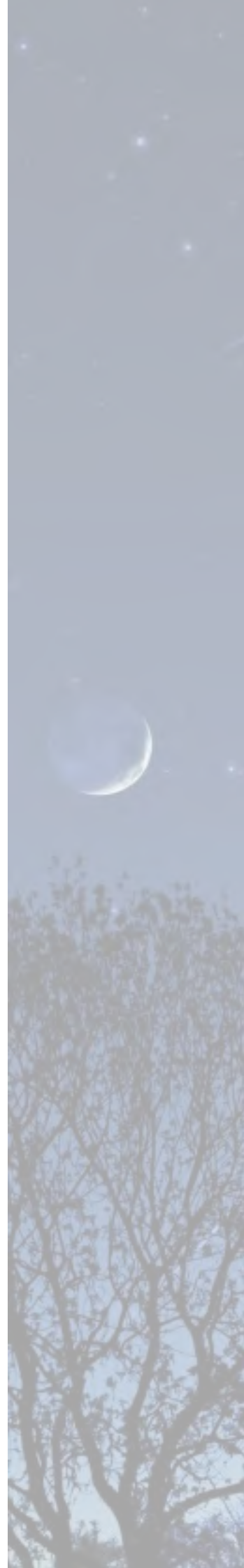
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- MICHELLE FRANCL-DONNAY
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Cover: *“The Fall of the Ensisheim Meteorite”* provided courtesy of the Vatican Library (MS Chigi G.II.36, folio 199v)

The Italian parish priest Sigismondo Tizio included a report and picture of the “immense portent” of the fall of a large stone meteorite near Ensisheim, Alsace, in his 1498 *History of Siena*. The Ensisheim Meteorite, which fell on 7 November 1492, is the oldest preserved fall of which appreciable remains are extant and available for research. (Paraphrased from Ingrid D. Rowland’s article “A Contemporary account of the Ensisheim Meteorite,” which appeared in the journal *Meteoritics* in 1990.)

Editor: Emer McCarthy

Design and layout: Antonio Coretti





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# MAKING AN IMPACT

## *From the Director*

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

When a fireball fell over Arizona last June and was imaged by a series of cameras that Father Jean Baptiste KIKWAYA, S.J. had set up around Tucson (see chapter 2), that was merely a literal example of how outer space impacts our world. In fact, the work of the Vatican Observatory touches the world in many ways. Perhaps the most visible impact we have is in the lives of the young students around the world whom we touch with our numerous outreach programs... school visits, online courses, even the chance for some classes to use our Vatican Advanced Technology Telescope (VATT). Members of our staff have spoken this year not only to numerous American and Italian school groups but also in schools from the Congo to Australia.

A special impact can be seen in the lives of the students who attend our biennial Vatican Observatory Summer Schools (VOSS). Of the 300 students who have attended our schools since 1986, the vast majority come from the developing world; and the vast majority have remained active research astronomers, helping feed the curiosity and ambitions of the next generation of young students in their home nations.

This year's summer school brought together two dozen students from 19 different nations for four weeks of intensive study on the topic of "Water in the Solar System and Beyond." Our international faculty, led by Meenakshi Wadhwa who directs the Center for Meteorite Studies at Arizona State University, also included Andrew Rivkin of John Hopkins University, Jennifer Grier of the Planetary Science Institute, long-time VOSS participant Christopher Impey of the University of Arizona, and Athena Coustenis, the director of research at the French National Center for Scientific Research. Brother Bob MACKÉ, S.J. served as dean of the school. Additional guest lecturers

included Seth Shostak of the SETI Institute and Bethany Ehlmann (VOSS 2005 alumna) of the Jet Propulsion Laboratory, speaking via Skype, and visits from Lynn Rothschild of NASA Ames Research Center, Diego Turrini of the Italian National Institute for Astrophysics, and retired astronaut Scott Parazynski.

The school included lectures and projects, a visit to the Galileo Museum and Galileo's villa in Florence, and a side trip to "study water" in the fountains of Tivoli. But the highlight of the school was an audience with His Holiness, Pope Francis. On that occasion he reminded the students, "Your presence as this summer school is also a sign that the desire to understand the universe, God's creation, and our own place in it, is shared by men and women of very diverse cultural and religious backgrounds. All of us dwell under the same sky. All of us are moved by the beauty revealed in the cosmos and reflected in the study of the heavenly bodies... I pray that you will be able to cultivate that interior joy and allow it to inspire your work. Share it with your friends, your families and your nations, as well as with the international community of scientists with whom you work."

The school also marked the inauguration of a new refectory building at the Specola Vaticana (the Vatican Observatory headquarter in Rome). The "Sala Clavius," named in honor of the 16th century Jesuit astronomer and mathematician Christopher Clavius, has a full kitchen and space to seat up to 50 guests. Beyond the summer school, it has already seen use for a number of other events, notably a gala dinner and reception for a meeting held at the Pontifical Academy of Sciences in December, honoring the work of Fr. Georges Lemaître, inventor of the "Big Bang" theory.



This building is only one of three new spaces, initiated by Father José FUNES S.J. and Father Jozef MAJ S.J. and completed this past year, which serve to greatly expand the impact of the Vatican Observatory's work.

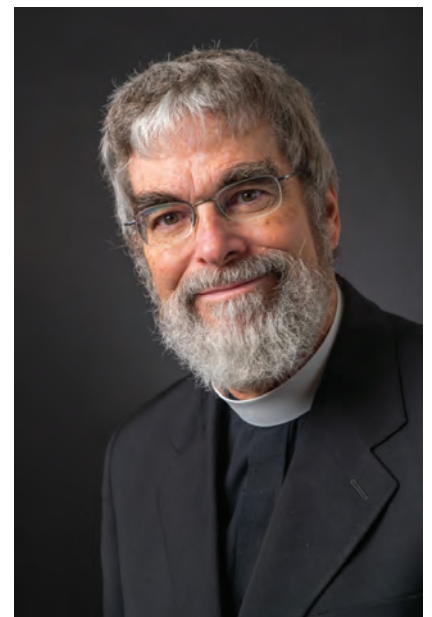
A small structure on the roof of the Papal Summer Palace between our two historic telescopes once housed offices and living quarters for Specola astronomers. It has now been converted into a meeting room where guided groups of visitors and students can learn about the history and current work of the observatory, before continuing on to visit our vintage telescopes themselves. This space fits into the new function of the Summer Papal Palace as a museum, many parts of which are now open to the public.

The final and most ambitious construction work has been the complete restoration of the Schmidt and Carte du Ciel telescope domes in the Papal Gardens near the Villa Barberini; support from this work came from both the Vatican and a generous donation from the Buffetti family. The final stage of this work was the complete refurbishing of the vintage 1891 Carte du Ciel telescope, bringing it back to working order, so that select groups of visitors can actually see how the sky might have looked to the first Vatican astronomers. We are now working with the Vatican Museums to set up this building with displays to show visitors both the history of the Vatican's support of astronomy, and a give them taste of our work today.

Carrying forth that work in astronomy, a young Jesuit scholar from Goa, Father – and now Dr. – Richard D'SOUZA, S.J. has arrived fresh from studies in Germany, and as of May, 1 became the newest full time member of the Vatican Observatory staff in the U.S. Just as the Observatory has had a big impact on his life, supporting his academic studies, so too his work now will impact how the human race (or at least that small number of us who are professional astronomers) understands the extended stellar populations of nearby galaxies... and wherever his work will lead him from there.

Exactly 125 years ago, in 1891, Pope Leo XIII founded the Specola Vaticana so that the world might see the Church supporting good science. Of course, doing good science is essential to that mission. In the pages that follow you can see the progress that each of us have made to that end. However, as the Pope reminded our students, science is not done by robots or computers (though we may use both in our work!) but by human beings, motivated by the desire to learn more of God's truth. In order to emphasize the human aspect of our work, this year we're trying a new format: rather than sorting the work by topic, I have asked each member of the Specola staff to give a short diary of all the different projects that occupied our year. In this way, I hope you can see not only what we've done and published, but where we hope to be going in the future. And you can see how our work fits into the larger picture of our lives... how it makes an impact on each of us.

And may God's blessings, expressed in His Glorious Creation, continue to impact each of you this coming year!



*Guy J. Consolmagno S.J.*

*Guy J. CONSOLMAGNO, S.J.  
Director*



# “A GREAT STONE FELL... ...accompanied by crashing thunder and lightning”

*This year's cover story*

*The cover of this year's annual report is taken from the chronicle of an Italian priest, Sigismondo Tizio, as an aside to his manuscript *Historia Senesium (History of Siena)* covering the years 1476–1505.*

*In it he writes, “At this point there has to be mention of the immense portent which was seen this year in Germany: for on the seventh day of November [1492], near the city of Ensisheim and the village of Bauenhem [Batterheim] above Basel, a great stone fell out of the sky, triangular in shape, charred, the color of a metallic ore, and accompanied by crashing thunder and lightning. When it had fallen to earth it split into several pieces, for it had traveled at an oblique angle; to the amazement of all, indeed it flattened the earth when it struck. A chunk of this rock was sent to Francesco Cardinal Piccolomini from Germany all the way to Rome, together with some verses skillfully composed by Sebastian Brant, of which a copy was made for me—including a picture.” (From I. D. Rowland, 1990, “A contemporary account of the Ensisheim meteorite, 1492,” in *Meteoritics*, vol 25, pp 19–22.)*

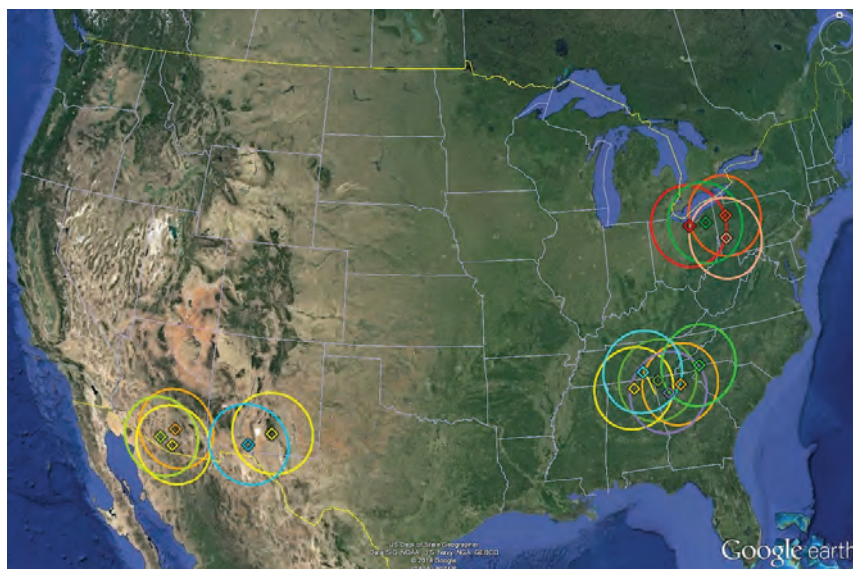
*The Ensisheim meteorite is the oldest observed “fall,” and these reports from the 15th century are remarkably accurate for their time. But what would happen if such an event were to occur today over a major astronomical center such as Tucson, Arizona? Rather than woodcuts, would we have videos? Rather than chronicles written ten years later, would we rely on instant tweets?*

On June 2, 2016 at 3:56 am (local time), a stunning flash crossed the night skies north of Tucson. Many residents were awakened by the sound of a loud bang. People immediately took to social media to report what they witnessed. “See something fall out of the sky? Everybody thought I was crazy this morning,” one

said. Another wrote: “Sky just lit up like an explosion. Several flashes, with a trail.” A third person added: “Heard the same thing. Whole house seemed to shake; huh? It is Arizona. We’re used to strange stuff, right?”

The event was recorded by the dash cams of several cars and some video cameras in the region. As expected, after sudden reactions of disbelief, people started to ask more profound questions: “What is it? Where did it come from? What is it made of...?” To bring these questions beyond the realm of idle curiosity, to answer them from a scientific point of view, requires more than just anecdotal evidence; it requires solid data. And getting this data was in fact possible thanks to a network of all-sky cameras that KIKWAYA S.J. of the Vatican Observatory helped to build in the region in 2014, with the collaboration of NASA Meteoroid Environment Office (MEO) based at the NASA Marshall Space Flight Center in Huntsville, Alabama.

NASA MEO began operations in 2004. Their goal is to observe meteors brighter than Venus and use the collected data to constrain models of the meteoroid



*All Sky Camera Network (credit: NASA-Asgard)*

environment; this could be useful in designing near-Earth artificial satellites for communication and navigation, or probes in space exploration missions. Two All-Sky Meteor Cameras were already in operation in Southern New Mexico in 2014, and Jean Baptiste's idea was to extend the network by adding three more cameras in southwest Arizona on the mountains surrounding the city of Tucson, as the weather is good and the sky mostly clear in Arizona. He also wanted to take advantage of the presence of an existing team of people in the area who work intensively with small cameras to observe meteors, and involve the collaboration of professionals who dedicate their life to studying planetary sciences, especially focusing on meteorites, asteroids, and comets, at PSI (Planetary Science Institute), NOAO (National Optical Astronomy Observatory), and LPL (Lunar Planetary Laboratory).

In 2014 he put together a team to work on the project. It includes Carl Hergenrother of LPL, who works presently on NASA's OSIRIS-REx mission (the sample-return mission now en route to asteroid Bennu); Tim Swindle, the director of LPL; Lori Allen, the director of NOAO; Grant Williams, the director of the MMT Observatory on Mt. Hopkins; and Vishnu Reddy of PSI. The three cameras of the all-sky network in southwest Arizona are placed at three different locations separated from each other about several dozens of kilometers, providing a perfect baseline between cameras to ensure the accuracy needed in computing the trajectory of the observed fireball. The three locations are: Mt Lemmon ( $32^{\circ}26'29.42''\text{N}$ ;  $110^{\circ}47'22.46''\text{W}$ ), Kitt Peak ( $31^{\circ}57'41.95''\text{N}$ ;  $111^{\circ}35'59.71''\text{W}$ ), and Mt Hopkins ( $31^{\circ}40'31.83''\text{N}$ ;  $110^{\circ}57'07.55''\text{W}$ ).

The three all-sky cameras that this team runs in the region did indeed record the fireball that occurred on June 2, 2016 around Tucson. In fact, it was seen as far as Phoenix and



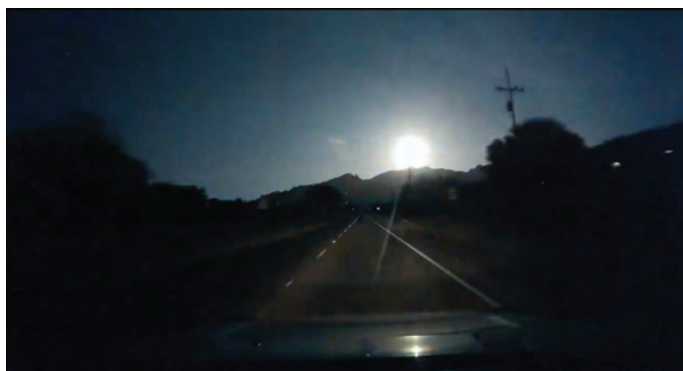
*Image of an all-sky camera*

Sedona areas. The event was so bright that it saturated the three cameras making it difficult to resolve its trajectory with high accuracy its.



*South-West Arizona all-sky camera network (credit: Jean-Baptiste Kikwaya)*





*Fireball on June 2nd, 2016 (North Tucson) (Credit: S.Paris from dashcam)*

While crossing the atmosphere, the fireball left trails in the sky that people could see in the early morning twilight. But beyond producing such traces in the sky, the big question remained: did it also produce meteorites?



*Fireball recorded by one of the MMT all-sky cameras (NASA-Asgard)*

The fireball occurred while Fr. Kikwaya was in Castel Gandolfo, taking part in the Vatican Observatory's biennial Summer School. However, the rest of his team, in Tucson, was able to swing into action. Using a Doppler radar he runs in the region, Vishnu Reddy was able to designate an area on the ground that might be a likely place to look for fragments of meteorites from the fireball. However, the area in question is part of an Indian reservation, and the fireball arrived during the local Indian hunting season, when the site was closed to the public. It was only after

several days that people could go and start searching for meteorites.

The team in charge of collecting and curating the meteorite samples was led by Dr. Laurence Garvie, who is curator of the meteorite collection in the Center for Meteorite Studies (CMS) at Arizona State University in Tempe. And, as it happened, the Director of the CMS, Dr. Meenakshi Wadhwa was in fact also in Castel Gandolfo, as the chair of this year's VOSS!

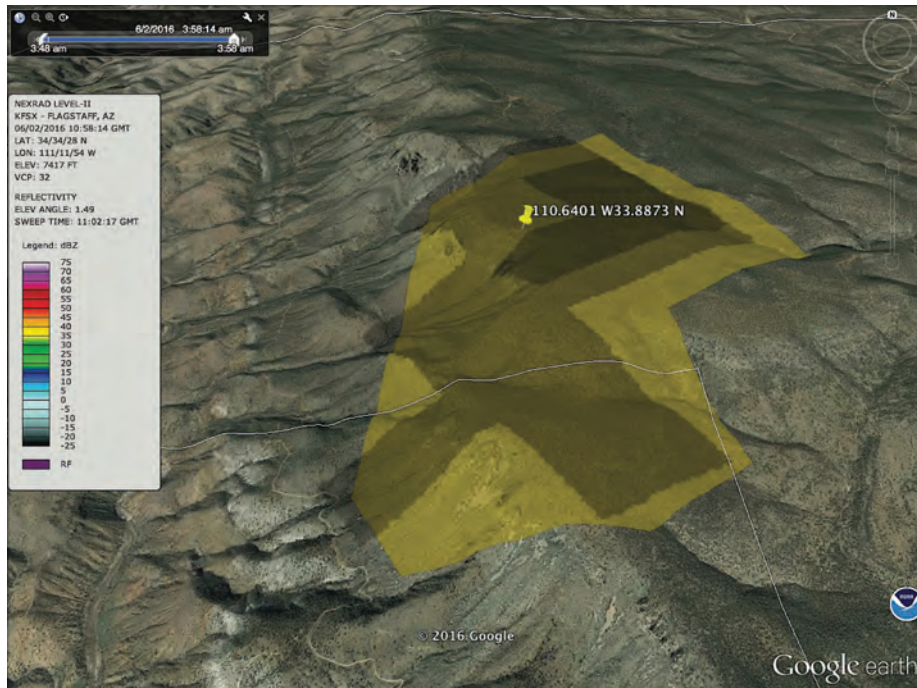
And meteorites were indeed found. About fifteen were recovered by the Arizona State University team. The meteorites are still the property of the White Mountain Apache Tribe (whose lands they fell on, and where they were recovered) but they are being curated by the Center for Meteorite Studies. After putting together all these different data – from the all sky camera network, from visual observations, from the doppler radar, and from collected meteorites – Jean Baptiste's team could then say something scientifically about the fireball.



*Trail left by Fireball on the sky. It is twisted and turned by the winds of the upper atmosphere (credit: David Adkins)*

The original asteroid that hit the top of the Earth's atmosphere was relatively small, with diameter around 1 to 2 meters (about 5 feet). Still, that's big enough that its mass would have been at least a few tons. The kinetic energy dissipated while entering the earth atmosphere was around half a kiloton. It came with a speed of 17.97 km/s (40,200 m/h, or 64,700 km/h).





*Region of possible meteorite drops centered at 110.6401 W 33.8873 N (credit: Vishnu Reddy)*

Eyewitnesses estimated its beginning height (when it started to produce light) was around 91.7 km (57 miles) above the National Forest east of the town of Payson, moving almost due south. Its ending height (where light production stopped) was at the altitude of 35.4 km (22 miles) above the same forest.

And the meteorites recovered from the fall? They are yet to be officially classified, but a believed to be L-type ordinary chondrites (similar, but somewhat more iron rich, than the Ensisheim meteorite). It is made of silicate minerals and tiny fragments of nickel-iron metal... traces from the origin of our solar system.



*Dr. Meenakshi Wadhwa with one of the recovered samples from the June 2 fall*

# A YEAR IN REVIEW

## *Staff activities*

*This year, instead of dividing up staff activities according to topic, we've invited each member of the staff and each adjunct scholar to provide a short report of their activities for the Specola over the previous year.*

### **Father Richard BOYLE, S.J.**



My year revolves around my work with the Vatican Advanced Technology Telescope, or VATT as it is more commonly termed. In 2016, my scientific work concentrated on galactic and stellar research and solar system asteroids.

Together with Father Robert JANUSZ and colleagues at Vilnius led by V. Straizys, we had three papers published on star-fields embedded in dark obscuring clouds local to the Sun. CCD observations in the seven-color intermediate-band Vilnius System are made on two telescopes: the wide-angle Maksutov at Moletai Observatory gives a larger areal coverage but to brighter star limit; the VATT probes fainter but in a smaller field-of-view. So observations from both telescopes complement the studies to cover a 1.5 degree square area but brighter limit from the Maksutov and smaller contained fields with fainter limit from the VATT.

This stellar research attends to questions of increased detail about the structure of the Galaxy, its spiral arms and star forming and evolving regions. Since it is known that the Galaxy rotates with a period of about 250 million years, the 4.5 billion year old Sun along with its local region of stars has made about 20 trips around the Galaxy.

My work on solar system asteroids continued through the year. Using VATT with Kazimieras Cernis of Vilnius University, we searched for and found many asteroids in the Solar System.

Their discovery of the faint asteroid beyond Neptune has now been assigned a number and name according to the policy of the Minor Planet Center. This publication now describes this TNO has an estimated diameter in the range of 302 to 425 km.

Perhaps most notably in 2016, an asteroid has now been observed, discovered and is now named "Richardboyle". Justas and Kazimieras Zdanavicius, using the Maksutov telescope at Moletai Observatory, sent their observations of March 26 and 27, 2003 to Kazimieras Cernis. He discovered an asteroid there and on April 8, 2003 he observed it at Mt. Lemmon to make the first astrometric data and send it to the Minor Planet Center. Since then a total of 89 astrometric observations from observatories throughout the world had given a well-determined orbit for this asteroid. Its perihelion distance is 2.79 AU, its orbit plane is highly inclined to the ecliptic by about 26 degrees, its orbit period 5 yr. 222 days outside the main asteroid belt, its estimated diameter 4 km. Kazimieras Cernis, as discoverer of this asteroid - now with its MPC number of (302849), with approval from the MPC has named it: asteroid "Richardboyle (302849)". It can be observed in October 2017 in the constellation Pisces. Orbital elements are:  $a=3.157$  au,  $e=0.115$ ,  $i=25.61$ ,  $P=5.61$  yr.

One of my duties includes drawing up the observers' schedule for VATT in the two semesters of the year, January to June and September to December. Observing requests from Vatican Observatory staff, the three universities of Arizona, and a few external parties were all satisfied, except for a certain technical interruption with the operation of the secondary mirror control. Also the PEPSI project of the LBT used VATT for 20 nights each semester to feed starbeams on VATT through a 500 meter fiber-optic to this powerful spectrograph located in the pier of LBT.



## Father David BROWN, S.J.

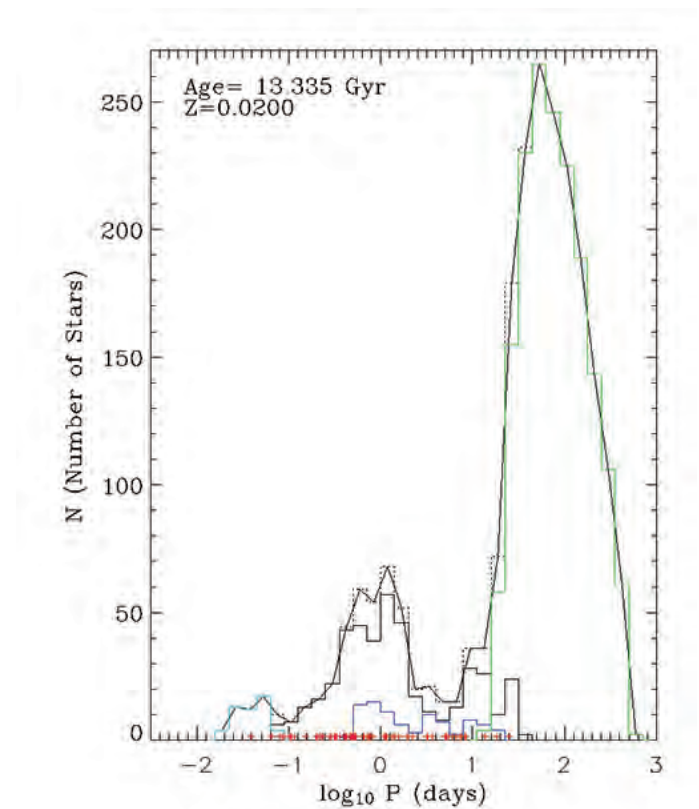


The main focus of my research continues to be in the astrophysical field of stellar evolution. In particular, I continue to examine hot subdwarf B stars, which are the products of the evolution of some low-mass stars similar to the Sun. They give a glimpse into a particular type of star that the Sun could become in

5 billion years. Unlike young stars, like the Sun, which generate and radiate energy from the fusion of hydrogen in their cores, such stars derive their energy from the fusion of helium He (a byproduct of the previous fusion of hydrogen H). These stars are hotter (30000K, 5 times that of the Sun), and their lifetimes are 1000 times briefer. The precise evolutionary mechanism(s) by which sdB stars form is not known, though there are a number of hypotheses. Among them is the idea that sdB stars form in binary systems (two stars revolving around one another) when the progenitor of the sdB star transfers most of its outer envelope to the companion star close to the point when it ignites its He-core. The result is a hot sdB star orbiting around a companion star, the orbital period depending on how the two stars interact.

My work with sdB stars is found, at the moment, in conducting computer simulations of how such stars develop within large populations of stars as time goes by. It's like taking a stellar census of a big sample of stars and seeing how many stars of each type develop. My research consists in adapting the numerical computer code and methods of Han et al. (2002, 2003) to account for a wider variety of stellar environments other than just the Milky Way Galaxy. Results are due to be published in a forthcoming paper in early 2017. Right now, the last modification being made in this aspect of my research deals with taking into account a certain subset of such sdB stars that have been observed to be in very long-period binary systems, which is very different from previous results obtained from by myself and Han et al. (2002, 2003) as seen in figure Hence, work is underway, building on theoretical simulations done by Chen

et al. (2013), to incorporate these features into the population synthesis code in order to provide more accurate simulations. This involves a modification of the work of Chen et al. (2013), and results should be published either in late December 2016 or early January 2017.



*Original simulations for the production of sdB stars indicated that a high number of them (indicated by the green histogram) in binary systems should have long periods in the range of 10 d to 600 d; however, recent findings indicate higher periods in the range of 400 d to 1000 d.*

Another research project in which I am currently engaged is in asteroseismology, in which the internal structure of a star can be probed by studying the oscillations (pulsations) of particular stars, thereby yielding different stellar properties such as mass. In particular, variations in the brightness of some sdB stars can yield their stellar masses, which provide a key empirical result in testing the theoretical simulations on how such stars are produced.

An ongoing internal collaboration between BOYLE and I has used the VATT in order to observe two pulsating stars, PG 0014 + 067 and PG 1047 +



003, during two previous observing runs. Such observations have been conducted to probe VATT's viability for asteroseismological studies.

Another research collaboration underway is my collaboration with Dr. Tony Lynas-Gray (University of Oxford) regarding the sdB star HW Virginis in an eclipsing binary system. Its orbital period has been observed to change over time, and it is suspected that either gravitational radiation, or magnetic braking and stellar wind losses, or a third body (a planet) could be the reason. A long time baseline is needed to examine how the orbital period of the sdB binary has changed over many years. It is thought that the Specola's plate vault (images obtained by the scopes in Rome over decades) might be useful in providing an observational history of HW Virginis.

Regarding computing research, I am also in the process of using a relatively new stellar evolution computer code, MESA, in order to model the evolution of stars, including sdB stars. Its advantage is in its ability to model binary systems more accurately and also in its capacity to do asteroseismology. I am also currently engaged in using N-Body codes in modeling the evolution of stars in globular clusters, investigating why it is that only 5% of sdBs in such clusters are observed to be in binaries whereas the proportion is much higher (2/3) in non-cluster environments. To this end, I am using Aarseth's NBODY6 n-body code.

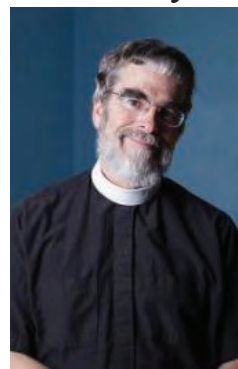
Other activities in 2016 for me included a brief research sabbatical at the University of Oxford during May 2016 during which I worked with two of his research collaborators, Dr. Philipp Podsiadlowski and Dr. Tony Lynas-Gray.

Additionally, in my capacity of curator of the telescopes at the Observatory in Rome, I worked with engineer Claudio Costa in order to fine-tune the Visuale telescope after the completion of its re-wiring in January. Still to be done are a better re-aligning of the finder scope and examination of defects in the clock drive of the telescope. As for the two newly-renovated Garden domes (housing the Carte du Ciel and Schmidt telescopes), attention

is now focused on restoration of the Carte du Ciel telescope to observing condition for educational purposes. Work by Claudio Costa in October and November 2016 has revolved around fixing one of the directions of movement of the telescope as well as installing a new motor to rotate it. Other areas of development were the drawing up of plans to buy a portable Schmidt-Cassegrain telescope to use in conjunction with the new visitor center on the 5th floor and terrace of the Papal Summer Palace. Likewise, a new CCD camera has been obtained for observational use for the palace telescopes.

Finally, 2016 finishes for me with a work-stay at the Specola in Tucson, AZ.

### ***Brother Guy CONSOLMAGNO, S.J.***



My scientific work in 2016 focused on three diverse areas: the physical properties of meteorites, the characterization of Trans-Neptunian Objects, and the origin of basaltic achondrite meteorites.

Since I have become director, most of my laboratory work on meteorites has been handed over to MACKE, though I still consult with him on possible directions for future research. One coda to this work on the topic of meteorite physical properties has been submitted as an invited review paper to the journal *Chemie der Erde*. George Flynn (SUNY Plattsburgh) is the principle author; other co-authors include Peter Brown (Western University, Ontario) and MACKE.

For many years I have collaborated with Stephen Tegler (Northern Arizona University) and William Romanishin (University of Oklahoma) on the systematic observation at the VATT (and other telescopes) of the colors of the large icy bodies that orbit beyond Neptune, the Trans-Neptunian Objects (TNOs), including the subclass of Centaurs which have comet-like orbits. After nearly twenty years of observing, we have extended this survey to 154 objects. We find that our entire sample of TNOs and

Centaurs can be split into two distinct color groups, one red and the other gray. Furthermore, from our survey, it appears red Centaurs have a broader color distribution than grey Centaurs, and these red objects orbit closer to the plane of the other planets than the grey ones. The review of this work, “Two Color Populations of Kuiper Belt and Centaur Objects and the Smaller Orbital Inclinations of Red Centaur Objects,” has been accepted for publication at the *Astronomical Journal*, and Tegler reported our results at the annual meeting of the American Astronomical Society Division for Planetary Sciences in October.

Finally, over the past three years I had been part of a team organized through the International Space Science Institute of Bern, Switzerland. This collaboration resulted in a new understanding of the evolution of asteroid Vesta and its relationship to the basaltic suite of “HED” (Howardite, Eucrite, Diogenite) meteorites. Our old model had assumed that asteroid Vesta was the intact parent body of these meteorites, which had formed from surface lava hiding a thick mantle of olivine-rich peridotite rock. However, our analysis of the structure of Vesta described by the NASA Dawn Mission had shown that Vesta could not contain such a peridotite mantle. So where did that material go?

Visiting with fellow ISSI team member Gregor Golabek at Bayreuth University in May, we joined with his colleague David Rubie for a possible solution. We noticed a large contrast in grain size and coherent strength between coarse-grained peridotite and fine-grained basalt; the large olivines can often break off in one’s hand, while the fine-grained basalt remains intact. Why does this happen? As the lavas crystallize, cool, and contract, one can expect micro-cracking along the boundaries between the crystals, but the amount of cracking depends strongly the size of the crystals. Crystals like olivine formed deep inside a parent body grow more slowly into larger grains, while basalts on the body’s surface freeze into tiny crystals. Thus, it seems reasonable to expect that if a molten and re-crystallized body such as produced the basaltic meteorites was completely disrupted, perhaps by collisions with other like-sized bodies, it would produce large cohesive fragments of

fine-grained basalt perhaps meters in size, whereas the mantle peridotite would be disrupted into millimeter-size crystals. The small crystals would be susceptible to non-gravitational forces such as gas drag in the disk, thus pulled into other accreting planets, while the crustal material would remain in the asteroid belt and eventually re-accrete into an asteroid like Vesta. This work was presented at the annual meeting of the Meteoritical Society in August.



*A terrestrial peridotite, from San Carlos, Arizona, demonstrates the large and friable grains of olivine (green) contrasted with the small-grained but coherent basalt rock (gray)*



Finally, I was elected to attend the General Congregation of the Jesuits, six weeks of intense prayer, discussion, and voting at the Jesuit Curia in Rome, from October 2 until November 12. The major outcome of this congregation was the election of Fr. Arturo Sosa, S.J., as our new Father General.



*Father Arturo Sosa, S.J.*



*For the first time, six brothers from around the world were also full members of the Jesuit General Congregation, participating in the election of a new Father General. Shown here are (from left to right) Br. James Edema S.J. (Uganda), Br. Eudson Ramos S.J. (Brazil), Br. Ian Cribb S.J. (Australia), Fr. Sosa S.J., Br. Thomas Vaz S.J. (India), Br. Stephen Power S.J. (United Kingdom) and Br. CONSOLMAGNO S.J.*

### ***Father Christopher CORBALLY, S.J.***



It's funny how things can suddenly come together. The outcome is going to take a few years, but I sense a little breakthrough in tracking down the elusive mechanism behind the Lambda Boötis-type stars. Their peculiarity lies in having a solar-like proportion of carbon, oxygen, nitrogen, and sulphur in their atmospheres, while elements such as iron, magnesium, aluminum, and other "iron-peak elements" can be between 10 and 100 times reduced in abundance compared with our Sun. Something odd is happening in the atmospheres of these stars, and they have been a puzzle since they were isolated as a small group of peculiar stars in an atlas of stellar spectra published in 1943.

One piece of the puzzle would be really good to have in place. Does their abundance peculiarity (normal in the volatile elements, weak in the refractory ones) extend throughout the stars' interior, or is it just a "skin disease?" A new way to tell is by asteroseismology. Just as seismology can give us the structure and content of the Earth's interior, we can do the same when we monitor the vibrations of stars, as shown by tiny changes to their light output.

The "coming together" started when Richard Gray (Appalachian State University) isolated from some 90,000 LAMOST spectra a list of 107 stars that were likely to be Lambda Boötis-type. These were up in an extended-hand-sized region of the Cygnus constellation which had been observed for such tiny light output changes by the Kepler Space Telescope.

Last May I obtained spectra with VAT7 for 34 of these candidates. Simon Murphy (Sydney Institute for Astronomy) and I determined that 15 were indeed Lambda Boötis stars. Eight of these "pulsated", of which four were hybrid  $\delta$  Sct/ $\gamma$  Dor-type pulsators. How exciting! These hybrid pulsators, when matched with theoretical models of stars, can allow us to probe both the outer atmosphere of the star and the deeper interior layers, giving us both physical parameters and abundances of the elements.



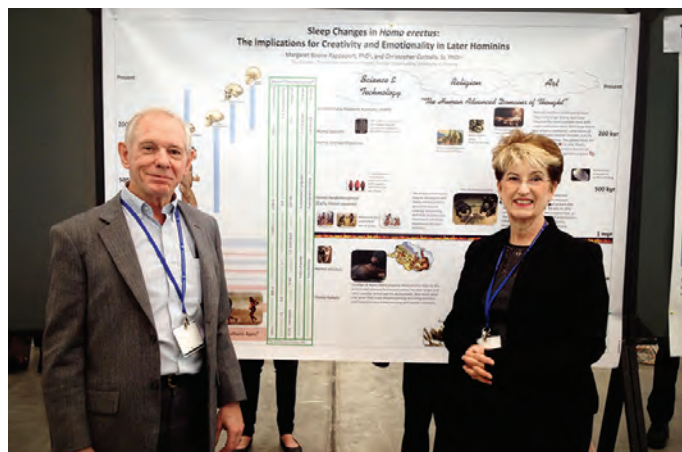
The next step happened in the idyllic Lake District of North East England. There the conference “Stars 2016” took place in mid-September. The conference was organized to honor Don Kurtz (University of Central Lancashire), a pioneer and expert in the hotter pulsating stars. I’d first met Don in Cape Town when I went there to observe in the 1980s. Don remains charming, a lively educator, and always ready to lead adventurous hiking trips.

During the conference, Simon, Richard, and I hung up our poster describing those pulsating Lambda Boötis stars, and it duly attracted the attention of Joanna Molenda-Żakowicz, a VOSS alumna now at Wrocław University. She volunteered to get the high-resolution spectra needed as input to the asteroseismology. Three asteroseismologists became interested in the project, along with a colleague from Joanna’s Astronomical Institute. So, we have a team, each with their complementary expertise and resources!

We are now looking for a large enough telescope and a research grant to make the next set of observations. Meanwhile, other data are being analyzed. Simon and a colleague have just incorporated the very first release of “Gaia distances” to refine the evolutionary status of Lambda Boötis stars. They conclude that, while “selective accretion” of material back onto the surface of these stars is the most promising mechanism for their peculiarity, there may well be more than one channel by which the accretion happens.

Watch this space. Hopefully, it will not take another 70 years to solve the Lambda Boötis enigma.

On the interdisciplinary front, it has been a remarkable year, one centered around the “Human Hearth and the Dawn of Morality.” It all started with a large poster that Margaret Boone Rappaport and I prepared for a meeting of the Society for Personality and Social Psychology in San Diego.



*Fr. CORBALLY with Margaret Boone Rappaport in front of their poster display at the 17th Annual Convention of the Society for Personality and Social Psychology in San Diego, January 30. An encounter at the poster led to an invitation to speak at Boston College.*

We realized that, in delving into the implications of sleep changes for creativity and emotionality for later hominins, we were in fact looking at the conditions under which morality arose in our ancestors, after they learned to control fire perhaps a million years ago. Adaptations included cognitive and neurological enhancements, and the control of fire led to an intense social environment where morality could flourish. Our model for the dawn of morality, something unique to humans, was set out in a paper now published in the December 2016 issue of *Zygon: Journal of Religion and Science*.

One thing leads to another. Since Rappaport and I were offering a paper at the ESSSAT meeting in Łódź, Poland, Father Michael HELLER kindly invited us to speak in Krakow to the Commission on the Philosophy of Natural Sciences of the Polish Academy of Arts and Sciences. Our topic was the same “origins of morality.” Afterward, we repaired to the De Revolutionibus coffee house and bookstore for an informal discussion of the same. The discussion in both venues was stimulating. You can find synopses of both our papers on the website of The Human Sentience Project (<http://thehumansentienceproject.org>).

There, you can also read about “our day” during the annual conference of the Institute on Religion in an Age of Science, held on Star Island, NH. We were

asked to reflect on the conference theme, “How Can We Know? Co-creating Knowledge in Perilous Times.” So, following on from our presentations in Poland, we dialogued about “The Biological Basis for Knowing Good.”

The year’s morality research had a final expression in mid-October through the kind invitation of the Director of the Jesuit Institute at Boston College, Father James F. Keenan, S.J. On the first day, we presented the talk we gave in Krakow, with some new points added. The next day was time for some fun at a luncheon workshop. We showed how simple theatre can stimulate discussion on moral issues, and followed with a short dialogue on science and religion. The workshop participants had strong backgrounds in ethics and theology, so the discussion proved very fruitful – and the luncheon very satisfying. It was a fine way to end a remarkable year.

### ***Father Richard D’SOUZA, S.J.***



My research over the last year has focused on studying how galaxies in our universe grow through accretion and mergers of smaller galaxies. To do this, I have been studying the outer light of galaxies, much beyond the typical visible radius of galaxies in our local universe.

Due to the low density of stars in the outer regions of galaxies, this region encodes information about the accretion history of galaxies through the presence of stellar structures like streams and shells which trace recent merger event of the galaxy. These outer regions of the galaxy have low surface brightness and are difficult to observe with conventional observational techniques.

Instead of taking long exposures of galaxies to study these outer regions, I use public images from the Sloan Digital Sky Survey (SDSS), which is a photometric all sky survey. to study the average outer light of galaxies. By stacking a large number of images of similar galaxies in the Universe from SDSS, I can study the average outer light of galaxies as a function of various galaxy properties. By

stacking (co-adding) a large number of such images (~5000), I am able to detect all that faint light in the outer part of the galaxy, which is generally not visible in a single image. In the recent past, I have show that the outer light increases as a function of the stellar mass of the galaxy as well as its shape. Through simulations, we know that this outer light is directly proportional to the amount of stellar material which has been accreted over the life time of the galaxy. The extra light we detect in the outer part of the galaxy from the deep image stacks is generally unaccounted for in a normal photometric all sky survey. This biases estimates of the total stellar material in the Universe measured through the galaxy stellar mass function (GSMF). The latter is a way of measuring the number of galaxies of various masses in the universe. By failing to measure the outer light of galaxies in normal photometric all sky-surveys, the estimates of the GSMF are generally biased especially at the very massive end. Using the extremely deep image stacks derived from the SDSS survey, I was able to derive corrections to the already-measured stellar mass of galaxies in the Universe, and thus provide a revised estimate of the GSMF. I was able to show that the previous estimates of the GSMF were indeed biased, especially at the massive end.



*After Fr. Richard D’SOUZA S.J. completed his doctoral work in astrophysics at the Max Planck Institute in Munich-Garching (shown here) in April, 2016, he joined the Specola staff full time.*

Part of my research time over the last year was invested in helping out with the next version of the SDSS survey, which is now measuring the properties of local galaxies through an integral field unit (IFU)

through the MaNGA (Mapping Nearby Galaxies at APO) survey. This allows us to get a spectral information at multiple spatial points of a galaxy. This provides a wealth of information including the kinematics and composition of the galaxy. I helped in improving the background subtraction of the pipeline of the MaNGA survey so that we could better study the spectra at the outer regions of the galaxy. Through a number of improvements in the pipeline, once the survey is completed in a few years time, we will be able to stack the outer light spectra of multiple galaxies so that we can study the properties of the stars at large galactocentric distances.

After graduating with a PhD from the Ludwig Maximilian University in April 2016, I joined the staff of the Vatican Observatory. From September 2016, I am on a collaborative visit to the University of Michigan where I work with Prof. Eric Bell to study further the accretion history of galaxies. Using various simulations and models, we are attempting to interpret the wealth of recent data on the outer stellar halo light of local galaxies (including the GHOSTS survey) in order to constrain their accretion histories!

In April 2016, I attended the IAU symposium on the “formation and evolution of galaxy outskirts”, and presented a talk on my research there. In November 2016, I was invited to give the 2016 Jesuit lecture at the University of Manitoba, entitled “God and the Galaxies: A perspective from the Vatican Observatory”, and dealt on the interface between science and religion.

### ***Father Pavel GABOR, S.J.***



2016 had two very distinct parts for me. In its first half, my primary preoccupations (apart from teaching my usual class on the history of astronomy at the University of Arizona) had to do with a new Papal document for the Vatican Observatory, a conference on timekeeping

held at Harvard, and a congress on astronomical and space instrumentation held in Edinburgh.

The core of the committee organizing the “Science of Time” symposium were the timekeeping experts who had already come together in Exton (2011) and Charlottesville (2013). The symposium in 2016 was held on June 5-9, 2016 at Harvard University in Cambridge, Massachusetts. Its scope was broader than that of the previous two meetings. Civil timekeeping has been always linked, at least in public perception, with Earth’s rotation or rather, with the diurnal motion of the sky. Today, however, timescales are in practice realized with atomic clocks. In other words, they do not have to have anything in common with astronomy. And yet, the accepted definition of civil time (UTC) adjusts the uniform timescale of the atomic clocks, so that a certain correspondence with the sky is maintained. This is the famous “leap-second” procedure. A proposal to discontinue this practice has been on the table since 1999, and the debate will not be decided at least until 2023.

I was a member of the Scientific Organizing Committee of the symposium, and took the lead editing the conference proceedings, which were submitted to Springer in November for publication in early 2017. I also presented a paper, addressing some of the unspoken presuppositions complicating drawing some lessons from the history of timekeeping and standardization. The position I took was that it would be presumptuous, counterproductive and deleterious to present the proposal as a definitive solution.

I was the lead author on one and co-author of another poster paper presented at the SPIE congress on astronomical and space instrumentation held on June 26 – July 1 in Edinburgh. Both papers present different aspects of VATT’s upgrades, its link with the PEPSI spectrograph, and its future integration within the Arizona Robotic Telescope Network. The first paper examines using robotic telescopes in education and public engagement (EPE). The advantages of such facilities for EPE are numerous, and increasing rapidly along with the growing number of robotic professional-grade telescopes. While experimentation was a positive force for



innovation in the early years, now it appears that co-ordination of efforts would prevent various teams from needlessly duplicating each other's work. The second paper provides an overview of the status of the VATT-PEPSI link, presents the fiber-link in detail from the technical point of view, demonstrates its performance from first observations, and outlines current applications.

I was also on the Scientific Organizing Committee of a conference entitled "The Clementinum and Jesuit Science" held in Prague on November 9-10. The Clementinum was built by the Society of Jesus as the main seat of their University in Prague. In 1622 the University of Prague, founded in 1348 by Emperor Charles IV, was entrusted to the Jesuits. After the suppression of the Society in 1773, the building became the National Library. It was the latter which organized the conference proudly commemorating the institution's Jesuit heritage. The occasion was the 400th anniversary of the Jesuit Academy's elevation to the rank of University (1616) and the 300th birthday of Joseph Stepling, S.J. (1716), the first director of the Observatory in the Clementinum.

The second part of my year was dominated by organizational concerns with the University of Arizona. A new Memorandum of Understanding was prepared and entered into force on November 1. This was the first such document since 1987, and the ease with which it was finalized, was due, no doubt, to the decades of mutually beneficial collaboration. We lost two important members of our team (see the chapter on Instrumentation and Technical Services), and had to rethink the team structure. The Director of Steward Observatory, Buell Jannuzi, his deputy Dennis Zaritsky, and others were supportive of the ongoing upgrades of VATT, and of the other telescopes destined to join VATT in the Arizona Robotic Telescope Network. It became clear, however, that a new approach to the project management was needed. In the meantime, VATT suffered a failure of the secondary mirror's support and positioning system. This 25-year old legacy system had to be refurbished and recommissioned. It took about two months. The affair was untimely not only because of the

staff shortage but primarily because replacing the system with a new one was (and still is) a part of the planned upgrades. Unfortunately, the new system takes about four months to deliver, and thus the old system needed to be repaired.

### ***Father Gabriele GIONTI, S.J.***



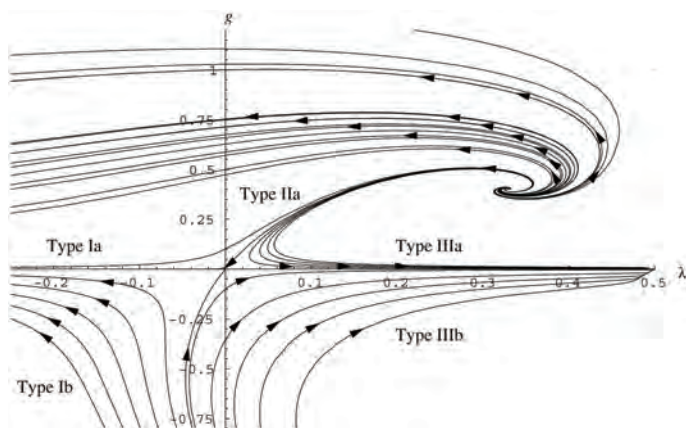
At the end of September 2015, I left the Specola to begin my Tertianship in Mexico. Tertianship is the last stage of formation in the Jesuit order and takes place, in general, three to five years after ordination. In discernment with my superiors, I chose a country in Latin America to gain a new experience of the Society of Jesus in a reality I was unfamiliar with. To date, my formation had taken in Italy and the United States. Now the time had come to embark on a new experience in my formation in the Society of Jesus.

My first month in Mexico, October 2015, I lived in the "Javier Limón community" in Mexico City and I worked as a visiting scientist with the Gravitation and Particle Physics group of the "Instituto de Ciencias Nucleares" (ICN) at UNAM (Universidad Nacional Autónoma de México) guest of Prof. Daniel Sudarsky. In the meantime, I tried to improve my Spanish taking private classes with a teacher at the University.

During this month I continued with a research project in sub-Planckian cosmology using results of Quantum Gravity in the approach known as Asymptotic Safety. It is well known that Quantum Gravity is the attempt to unify Quantum Mechanics with the gravitational field in a temporal interval of the Universe from  $t=0$  to  $t=10^{-43}$  sec. These are the first "moments of life" of our universe (the Big Bang) and it is not yet known what kind of physical laws regulated its evolution. In the recent past, I had also worked in cosmological applications of String Theory, which is a different approach to the theory of Quantum Gravity. Sub-Planckian cosmology is a window of time, in the Planck interval of time, in which it is assumed that the laws of gravitation

are still classical (not quantum) but modified by the quantum mechanical corrections (this approach is generally called effective theory). The Asymptotic Safety approach to Quantum Gravity is a field of research in which the main idea is that the coupling constants of the physical interactions, in our case the gravitational constant  $G$  and the cosmological constant  $\Lambda$ , are “bare” in the known laws of nature and change in interactions.

Therefore, they are allowed to run up to find a “non trivial” fixed point, around which the correct values of the coupling constant and the theory of Quantum Gravity is defined.



*An example of Renormalization Group Flow in Asymptotic Safety in the space of the two parameters  $g$ , the “rescaled” gravitational constant, and  $l$ , the “rescaled” cosmological constant, in Quantum Gravity.*

On November 1, 2015, I started my Tertianship program with eight other Jesuit fathers in Puente Grande a small town close to Guadalajara.

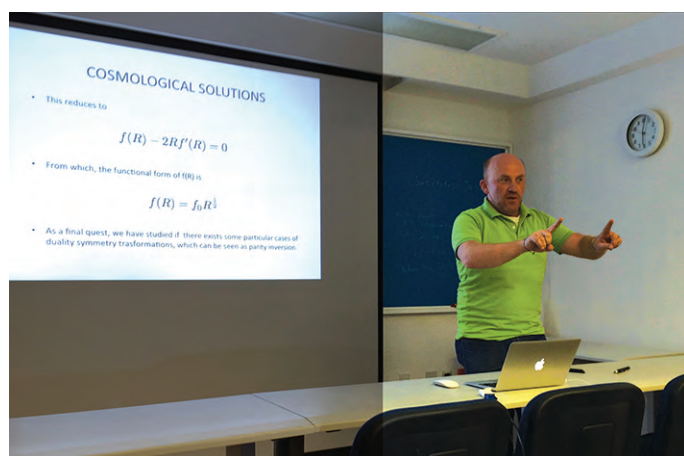
St. Ignatius termed Tertianship the “Schola Affectus”, the school of the heart, and it is meant to help Jesuits, both brothers and fathers, to rediscover their love for their vocation after many years of studies in the order. We spent one month in Puente Grande reading the life story of St. Ignatius and sharing our own life stories. We all had the opportunity to see just how God has guided us in our vocation with greater clarity. Then, during the month of December, I had a pastoral experience in Chiapas, in the Jesuit Mission of Bachajon in the dioceses of San Cristobal de Las Casas visiting the different communities of indigenous Mexican people

of Tzeltal ethnicity (they are descents of the Maya). I was struck by their poverty, living in huts in the forest and eating only the products they cultivate. Their Mass is quite long and mixes their ancestral rites with Catholic ones in their Tzeltal language; it was quite an astonishing experience!



*Mass in Tzeltal rite during the “Novena” for the feast of St. Francis Xavier at a Indigenous Tzeltal Village close to Bachajon, San Cristobal de Las Casas, Chiapas, Mexico*

During this time I gave two popular talks. One was to a science-theology group in Mexico City and one at the Ibero-Americana Jesuit University in the same city. In the meantime, I was asked to give two talks (one on Discrete Quantum Gravity and the other on aspects of Duality in Cosmology derived from String Theory) to the ICN relativity group, at UNAM.



*Seminar on “String Duality Transformation in  $F(R)$  Gravity FOM Noether Symmetry Approach”, Instituto de Ciencias Nucleares (ICN), UNAM, Mexico City, Mexico*



In January 2016, I returned to the Tertianship house in Puente Grande for a month of spiritual exercises. It was a profound experience of God, far more profound than the month of exercises I did in my novitiate. After that, I went to Honduras for a second month of pastoral experience. I worked as parish priest for the period of Lent and up to Easter, in a very poor village in the hills called “La Abisinia”, near the city of Tocoa. Once again, an experience of poverty and of love and gratitude from people who were beyond generous to me since they provided me with food and all of the basic necessities that I needed to stay with them.



*Student of the fourth year at the Jesuit High School “San José” at El Progreso, Yoro, Honduras*

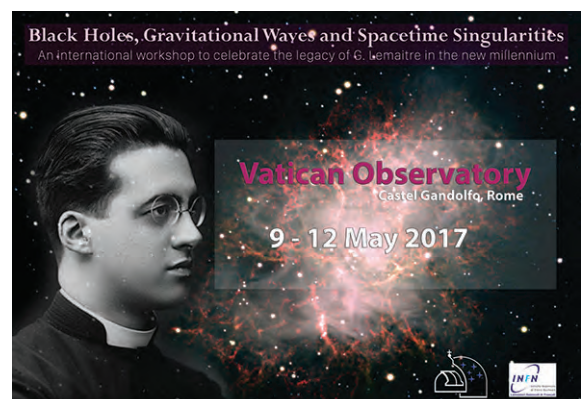
I finished my Tertianship on May 1, 2016, in Mexico City and I spent one week at ICN at UNAM with Prof. Sudarsky again. During my Tertianship I was able to find a publishing house, Springer, to publish the proceedings of the Specola’s 80th Anniversary Symposium and with two colleagues in dialog with the director CONSOLMAGNO we started the preparation for a workshop at the Vatican Observatory in Castel Gandolfo to celebrate the figure of Fr. George Lemaitre, cosmologist and priest, who was the inventor of the Big Bang.

Once back in Castel Gandolfo, on May 8, I began again to work on research of sub-planckian cosmology from the Asymptotic Safety perspective of Quantum Gravity. I also successfully applied to become an associate fellow of the National Laboratories of Frascati for 2016, where I was given an office space. At the same time, I had in mind

to write a proceeding paper for the XIV Marcel Grossman meeting in Rome in 2015 and my paper for the Specola 80th Anniversary Symposium (I was forbidden to work on them during Tertianship by the Tertian master).

I gave some help, not much, in the summer school and began to improve my knowledge of how to use the program of symbolic calculation, Maple, for the research on subplanckian cosmology. Together with my collaborator Alfio Bonanno, we discovered that the work done in October when I was at UNAM was not going anywhere. I spent three weeks at INAF in Catania where, together, we finally found that following some particular behavior, as function of time, of the gravitational constant  $G(t)$  and the cosmological constant  $\Lambda(t)$ . They helped in finding a solvable and interesting sub-Planckian cosmology from the perspective of Asymptotic Safety approach to Quantum Gravity. The results of this research will be published soon.

I presented this research at the XXII meeting of SIGRAV (Italian Society for General Relativity and Gravitational Physics) in Cefalù, Sicily, from September 12 to 18. I also wrote the two papers for the Specola proceedings and the Marcel Grossman meeting, but they were on my previous research of Duality Symmetries on the cosmological model derived from String Theory. I am finishing a paper on the nature of Time, comparing and contrasting theories from Philosophy and Physics, which, very probably will be published in *Civiltà Cattolica* in collaboration with Alfredo Sgroi. Most recently I participated in the Conference “The Nature of Our Biophilic Universe”: An interdisciplinary workshop in honor of Monseigneur George Lamaitre”.





### ***Father Jean-Baptiste KIKWAYA, S.J.***



From September 27, 2015 to October 2, 2015, I took part in the European Planetary Science Congress in Nantes in France, where I presented a paper on my current research on the physical characterization of Near Earth Objects (NEOs). A NEO is an asteroid or a comet whose orbit about the Sun brings it

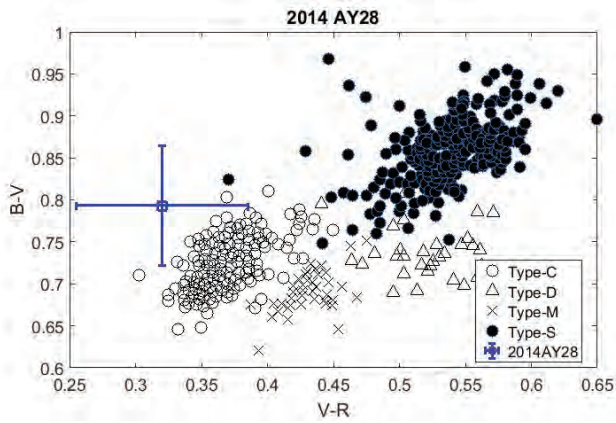
into proximity with Earth. Its closest approach to the Sun (parameter called perihelion) is about 1.3 AU, while the Earth evolves at 1 AU about the Sun (AU is a unit of distance called astronomical unit, and represents about 150 million kilometers). There are nearly 15000 NEOs discovered today by various programs, two in particular run by NASA: Catalina Sky Survey (CSK) in Arizona, and Pan-Starrs (Panoramic Survey Telescope & Rapid Response System) in Hawaii.

My work consists in studying the physical characterization of NEOs which have been they have been discovered either by Pan-Starrs or by Catalina Sky Survey. In fact, the dynamical properties of these bodies are not enough to tell us about how hazardous and disastrous they might really be; the physical and chemical properties need to be assessed before we can alarm people about the risk they may pose to Earth. I presented 10 NEOs I observed during the year 2015. All my observations are focused on very fast rotator NEOs with rotation varying from 12 minutes to 2 hours. These are very small NEOs with a diameter estimated from several dozen of meters to 1 kilometer. I don't only study the spin rate (rotation) of NEOs, but also their colors as an indication to the composition of their surface. This task is made possible when observing with a set of different filters. In my case, I use the very inexpensive set of broadband filters known as Johnson-cousins filters (BVRI). The differences in colors of an asteroid give me an idea about the composition of its surface. Asteroids are classified in different types, mainly types S-complex, C-Complex, X-complex, and D. S-type indicates that the asteroid is siliceous (or stony) object, C-type describes a very dark carbonaceous object. X-complex includes

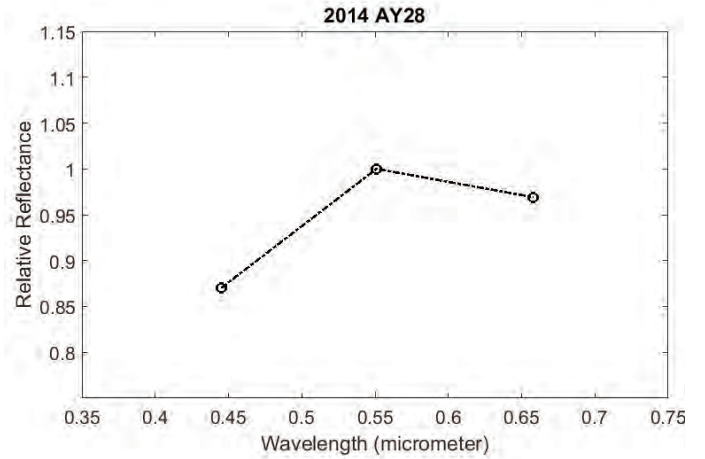
M-type, and describes metallic objects. All these different types give also an indication about the asteroid albedo, a very important parameter in the asteroid study. Albedo is the ratio between the amount of light received from the Sun by a surface of an asteroid and the amount of light it is able to reject or reflect.

Among the 10 asteroids I presented in Nantes, 5 were of C-type, 3 of S-type, but two did not show any clear color difference, particularly in V and R filters. I called them colorless. These two objects that I could not classify indicate that the study of identifying the type of an asteroid needs to be moved forward by adding new tools and techniques in the analysis. In fact, photometry what I use now is good as a first approach, but what really I need is to study asteroid spectroscopically. At VATT, beside VATT4k (instrument for photometry), there is a spectrograph (VATTSpec) whose big resolution works well for stars (stellar spectroscopy), but not for asteroid spectroscopy. I put together a team of 5 people (two from the Vatican Observatory), two from Steward Observatory and one from LPL (Lunar Planetary Laboratory) in order to work on the possibility of using VATTSpec with some modifications like inserting a very low resolution prism where light is collected in the instrument. This would allow us to start producing asteroid spectra. Combined with asteroid photometry, this new tool (asteroid spectroscopy) will help to make a complete study of asteroids. The project is still to be accomplished.

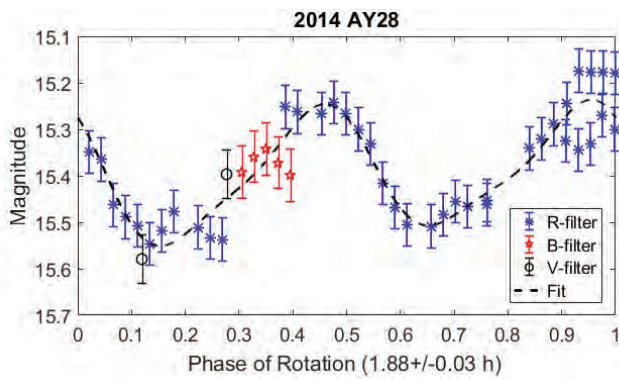
I attended DPS (Division Planetary Sciences) in Pasadena in October 2016. It was an opportunity for me to meet and talk with people who study asteroids. I had an opportunity to discuss with Mirel Birlan of IMCCE of Paris observatory. From this discussion, I found that I could compute the relative reflectance for each asteroid and produce its broad spectrum. I could then run the database of known asteroid spectra and find those that match within certain errors the broad spectrum.



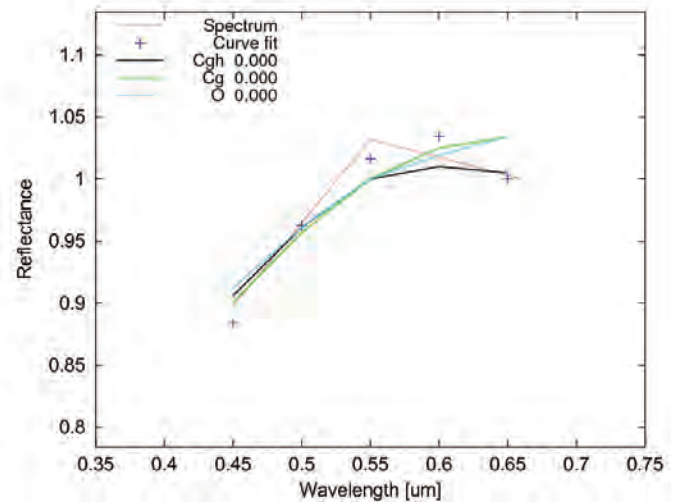
On the Plot  $B-V$  versus  $V-R$ , 2014 AY28 falls among C-type asteroids. (Zellner, B., Tholen, D.J., & Tedesco, E.F. 1985, *Icarus*, 61, 355)



Relative reflectance of 2014 AY28 normalized to V-filter.



Near Earth Object 2014 AY28. Its spin rate is  $1.88 \pm 0.03$  h



When compared with spectra in the database, 2014 AY28 matches Cgh-type, Cg-type and O-type. All these types belong to C-complex.

### ***Father Giuseppe KOCH, S.J.***



In recent years, little attention has been devoted to the Specola's Library, mainly due to the lack of a full time Librarian. Since my appointment, my focus has been on bringing greater consistency to the important task of archiving and cataloguing all of the materials at the Vatican Observatory as

well as its vast back catalogue. In fact, I have been pushing ahead with the compilation of the Digital Catalogue. More than 1000 books have been added in recent months, with thousands more still waiting to be catalogues. Then there is also the question of creating a special catalogue of 'antique manuscripts' which are of invaluable importance for historians and scholars of astronomy.

We have also resumed the binding of vintage journals, which was interrupted many years ago, with some 200 volumes waiting to be restored. We are also reflecting on the future purpose of the Library. For example, if we should open up its contents for external access and how we could achieve this. Another question regards the criteria for the purchase of additional volumes and for subscriptions to periodicals and journals.

The advent of the digital age is taking its toll on print media. For several years now, our access to major Astronomy publications has been strictly online. Therefore the use of the Specola library by scientists and staff must take into account their ability to easily access the University of Arizona library in Tucson.

### ***Brother Robert MACKE, S.J.***



I had a very eventful year. As part of my ongoing research on the physical properties of meteorites, particularly those of lunar and Martian origin, I came to the U.S. in January and spent several weeks studying the meteorites at the Marvin Killgore collection at the University of Arizona.

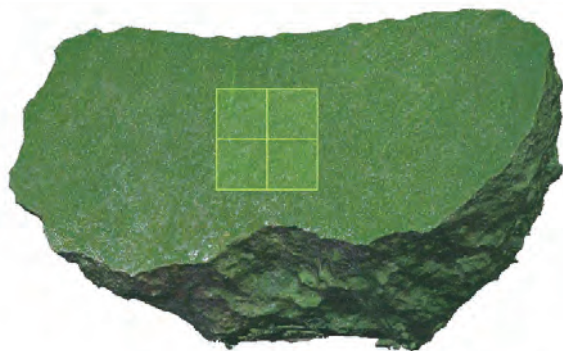


*Br. MACKE with his research equipment on-location at the meteorite collection of the Southwest Meteorite Laboratory (Marvin Killgore) at the University of Arizona.*

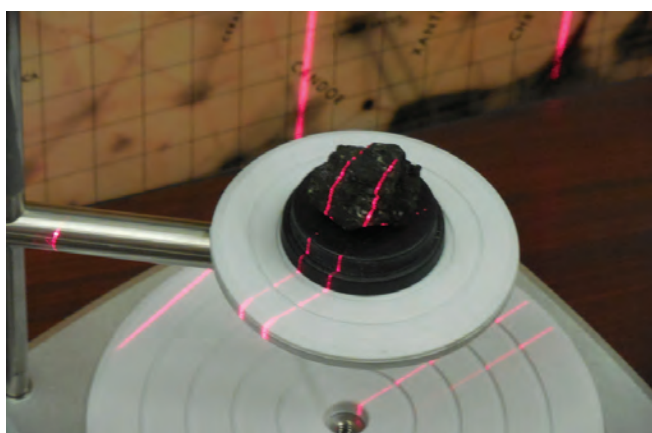
Among the notable specimens studied was the friable CI carbonaceous chondrite Ivuna, which became possible to study only after the acquisition of a laser scanner for bulk density measurements. It is only the second CI for which we have completed this measurement, after the Vatican specimen of Orgueil. The laser scanner also proved its worth by completing a scan of Killgore's very large 425 kg specimen of the pallasite Fukang. After the work on the Killgore collection, I visited the Institute of Meteoritics at the University of New Mexico in February, and then a private collection in San Antonio, Texas, to grow my study by 32 lunar and martian meteorites. At this point, the data gathering stage of the project is near completion. Collaborator Walter Kiefer (Lunar and Planetary Institute, Houston TX) has begun analyzing these data to better interpret gravity maps of the lunar and martian crust. We expect to begin publishing the results within the next year.



In 2016, I also became a member of the International Meteorite Collectors Association. The organization's board of directors honored me with a complimentary membership "in recognition of [my] accomplishments in our field."



*Laser-scanning the 425-kg specimen of the pallasite Fukang from the Southwest Meteorite Laboratory. Upper: scanning in progress. Lower: The computer model of the meteorite specimen produced from the scan data.*



*Laser scanning the extremely friable CI carbonaceous chondrite Ivuna from the Southwest Meteorite Laboratory, for bulk density measurement. This is only the second CI we have measured, after the Vatican specimen of Orgueil.*

I also served as dean of the 2016 Vatican Observatory Summer School, with the theme of "Water in the Solar System and Beyond." My duties over the month-long course were to coordinate between the faculty (all leaders in their field), the hard-working staff of the Specola, and the student body of promising young astronomers from around the world who came to learn. Because everybody did their own jobs extremely well, I actually had a fairly easy month.

Beginning in September, I started conducting video interviews of members of the Vatican Observatory for the purpose of sharing internally the work that we do. This "Inside the Specola" series of interviews provides our staff with a point of reference for understanding the work of their colleagues. Eventually, some of the footage may be edited into videos suitable for public viewing.

I am currently working on several papers with different collaborators. Most recently, together with Br. CONSOLMAGNO, we have been collaborating with George Flynn (SUNY-Plattsburg) and others on a review paper of meteorite physical properties. This serves not only as an update on earlier work by myself, CONSOLMAGNO, and others regarding density and porosity, but includes additional physical properties such as heat capacity, strength, and others. I am also working in collaboration with Jon Friedrich (Fordham University) and others on a new approach to understanding the conjunction between impact deformation, shock, and porosity on meteorites using my extensive database of meteorite porosities collected over several years, a fresh measurement of Saint-Severin, as well as new data from x-ray microtomography of the interior of meteorites.

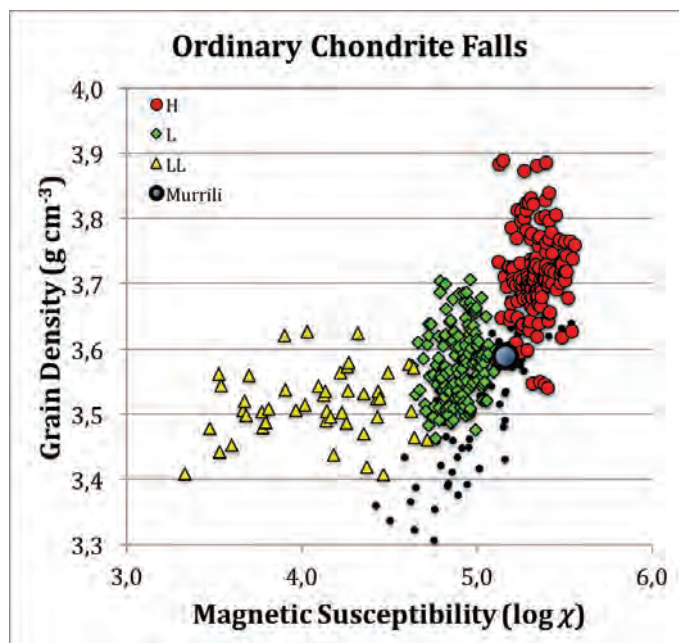
Again together with CONSOLMAGNO, I am compiling the data from heat capacity measurements on meteorites from the Vatican Collection. We measure heat capacities using the liquid nitrogen immersion technique pioneered by CONSOLMAGNO as well as high-precision measurements made using a Quantum-Design Physical Property Measurement System (PPMS) operated by collaborator Cyril Opeil S.J. (Boston College).

I continue to perform non-destructive and non-contaminating analyses for the benefit of other researchers who wish to complement their studies with porosity data. This past year, I performed density and porosity studies for specimens of the meteorites Murrili (provided by the Desert Fireball Network, Australia) and Kosiče (provided by Juraj Toth, Comenius University, Bratislava, Slovakia). I supplemented the Kosiče measurements with low-temperature heat capacity using liquid-nitrogen immersion.

Some results of much of this research were presented at the two conferences that I attended, including the 47th Lunar and Planetary Science Conference in March outside Houston, TX, and the 79th Annual Meeting of the Meteoritical Society in August, in Berlin, Germany. Between the two conferences, I was author or coauthor on six abstracts.



*The specimen that we studied of the meteorite Murrili. Notice the visible reddening of the interior due to terrestrial weathering of the embedded metallic iron.*



*Data from the relatively fresh specimen of the H5 meteorite Murrili, in comparison with other meteorite falls. Black dots represent weathered finds of H chondrites. Murrili exhibits trend in grain density and magnetic susceptibility consistent with moderate weathering caused by its month-long exposure to briny mud before retrieval in Australia.*

### **Father Sabino MAFFEO, S.J.**



As a historian, I manage the Vatican Observatory archives. This involves cataloguing and archiving all of the correspondence, newspaper articles, brochures, magazines and photos regarding the Specola from the founding of the Observatory to date. All of this information is divided

between fifty files.

The main file holds the Observatory Archive and it contains all documents, correspondence, official statements, newspaper and magazine articles and photos since its foundation. There is also a file especially dedicated to material and correspondence regarding the Carte du Ciel.

The remaining files contain various archive documents of interest. For example: Correspondence with the Holy See and others; minutes of



community meetings; documents regarding the construction projects of the Vatican Advanced Telescope in Tucson, with its difficulties to be overcome because of the opposition of a part of the local inhabitants, etc...

There is a press file containing all of the articles published in the *L'Osservatore Romano* regarding the Vatican Observatory and image file with stock photographs of the Observatory. One file of particular interest contains a series of letters to Father John Hagen S.J. (1847 – 1930), the first Jesuit Director of the Vatican Observatory, arranged in alphabetical order of authors.

Our archives also contain books and manuscripts penned by Cardinal Maffi as well as writings by Father Angelo Secchi S.J. (1818 -1878) gifted to us by the Observatory of Monte Porzio Catone. We possess four containers of books and articles on the Observatory at the Roman College, which was a precursor to the Vatican Observatory. These were generously donated by the Buffetti family who also gifted four containers of material on the Jesuits and Sciences to the Vatican Observatory.



*Fr. Sabino MAFFEO, S.J.*

### ***Father Paul MUELLER, S.J.***



Since 2010 I have served as religious superior of the Jesuit community of the Observatory, both at Castel Gandolfo and at Tucson – where I am assisted by vice-superior Fr. Chris CORBALLY. As superior I'm responsible for the physical and spiritual welfare of the Jesuits of the community: encouraging

them to good prayer, work, health, and recreation; seeing to their faithful observance of the religious vows of poverty, chastity, and obedience; and also seeing to it that there's food on the table. This year, in response to Pope Francis' concerns, our Jesuit community has become increasingly attentive to the plight of refugees. At Castel Gandolfo we offer pastoral and financial support to the lay association "Una Città Non Basta ONLUS", which supports the resettlement of refugees in zone near the Observatory headquarters. And at Tucson we offer similar support to the Kino Border Initiative, a Jesuit work based at Nogales, just south of Tucson, which operates in support of immigrants and refugees on the USA-Mexico border.

In addition to serving as superior of the Jesuit community, since September 2015 MUELLER served as Vice Director of the Observatory. During the past year Observatory Director Br. Guy CONSOLMAGNO was often away from Castel Gandolfo, sometimes working at Tucson and often on the road giving talks and seminars. Accordingly I found myself "minding the store" at Castel Gandolfo, for months at a time. This entailed doing a lot of administrative tasks, such as paying bills. And it meant coordinating the daily work of the Observatory's five fine lay employees at Castel Gandolfo. But it also entailed overseeing the completion of three half-done construction projects which Br. CONSOLMAGNO and I inherited from the Observatory's previous Director and Vice Director, Frs. Jose FUNES and Jozef MAJ. I'm a philosopher by training, and it's fair to say that overseeing construction projects (in Italian, with Vatican bureaucracy!) did not play to my strengths. But with good collaboration, and with a lot of help



from the Observatory's lay staff and other Vatican colleagues, all three projects were brought to completion on-time. A tip of the hat to Frs. FUNES and MAJ, who had the foresight and vision to initiate these projects, which will be of good service to the mission of the Observatory for many years to come.

In addition to my duties as superior of the Jesuit community and as Vice Director, I teach part-time at the Pontifical Gregorian University, offering masters-level courses in philosophy of science. In the fall-winter term 2015-16, I offered the course "The Concept of Force in Physics", and during the current fall-winter term 2016-17 I am teaching the course "Philosophical Questions in Physics". I love teaching! Prior to coming to the Vatican Observatory I was a professor of philosophy at Loyola University Chicago, and while there I was also academic supervisor of two programs of priestly formation. But teaching in the Italian language continues to pose a difficult challenge for me.

As Vice Director I represented the Observatory at various events, including the papal mass inaugurating the Church's Jubilee of Mercy on 8 December 2016, the 7 April 2016 Rectors' Dinner of the North American College, the Jubilee of Priests at Rome 1-3 June, the Celebration on 18 September of the 200th Anniversary of the establishment of the Vatican Gendarmeria, and the official opening to the public of the Apostolic Palace at Castel Gandolfo on 21 October.

Finally a word about Fr. Arturo Sosa S.J., the newly elected Superior General of the Society of Jesus. Over the past three years we at the Observatory have had frequent contact with Fr. Sosa, since we answered to him in his then-capacity as Fr. General's Delegate for the International Houses and Works of the Society of Jesus at Rome. Each year we hosted Fr. Sosa on his week-long official visitation at Tucson. A highlight for me of Fr. Sosa's time at Tucson was accompanying him on a half-day visit to the Kino Border Initiative at Nogales; the issue of immigration and refugees is dear to Fr. Sosa's heart. Another highlight was accompanying Fr. Sosa, along with Br. Bob Macke S.J., on a quick visit to the Grand Canyon. The visit

was in fact quicker than intended – we got snowed-out, and ended up leaving earlier than planned! But Fr. Sosa took it all in stride, and was in fact quite happy: it was his first time ever to see snow!



*Fr. MUELLER, S.J. (left in photo) with the new Superior General of the Society of Jesus, Fr. Arturo Sosa, S.J. at Grand Canyon.*

### ***Don Alessandro OMIZZOLO***



The study of galaxy clusters always offers new insight not only into the properties of the cluster but also about the life of the galaxies that populate the cluster itself. Thus it may happen that while analyzing the image of a cluster you see an unusual phenomena located in the sky!

In reality you usually need to dive into the sea to find jellyfishes but ... you can also find them in the sky and especially in the galaxies belonging to clusters of galaxies. You may well ask: Why? How is it possible?

The goal of my study is to find an answer and I am pursuing this goal together with my colleagues of the WINGS group, about twenty astrophysicists from all over the world. The work is done in Padua but the data comes from all over the world: Canary Islands, ESO telescope in Chile and Bok telescope at the Steward Observatory located on top of the Kitt Peak Mountain in the desert of Arizona.

But let us speak about galaxies. Inside a cluster of galaxies, as in the Solar System, life is very frenetic and sometimes also dangerous .for the galaxies. In fact nothing is steady but everything is moving inside, through and around the cluster: dark matter dominates the movement of the galaxies and is also the reservoir necessary to take control of what happens inside the cluster.

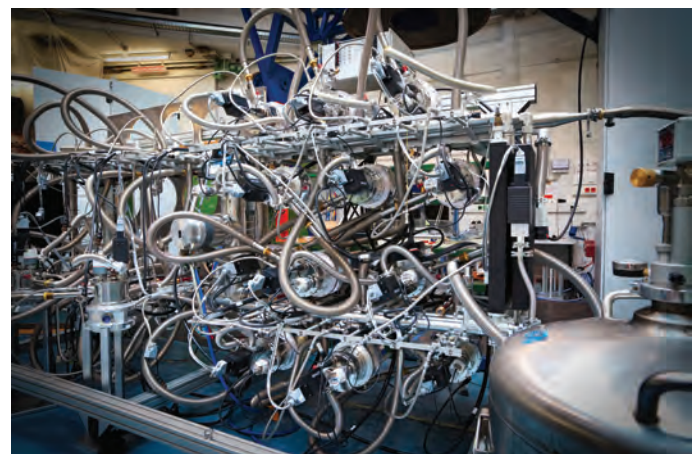
So during the motion of a galaxy in the cluster, it can happen that this galaxy begins to fall toward the center of the cluster where there is the Bright Central Galaxy (BCG) of the cluster, usually the largest and heaviest galaxy of the cluster. When a galaxy moves this way inside the cluster it can undergo some structural changes the most visible of which is its losing a notable amount of the gas and dust it carries with it. The pressure exerted by the intracluster matter on the inward falling galaxy has, observationally speaking, three main effects: a removal of gas without disturbing stellar component; a reduction of the content of atomic and molecular hydrogen; a variation of the star formation in the galaxy. The phenomenon is known among astrophysicists as “ram pressure stripping”.

The gas lost by the galaxy forms the stripes we can observe in these galaxies changing their appearance to that of a jellyfish galaxy. But there are more mechanisms producing this final effect on the morphology of a galaxy, mainly internal mechanisms such as galactic winds due to star formation or an AGN (a compact and very energetic nucleus of a galaxy).

The detailed study of this kind of galaxy is better done using particular instruments such as the MUSE (Multi Unit Spectroscopic Explorer). MUSE is an integral field spectrograph (IFS). An IFS allows you to observe the entirety of an astronomical object in one go, and for each pixel measures the intensity of the light as a function of its color, or wavelength. The resulting data is a 3D set where each pixel of the image has a full spectrum of light. MUSE splits the field of view into 24 individual image segments or channels which are each split further into 48 slices or “mini slits”, giving a total of 1152 mini slits. Each set of 48 mini slits is injected into a spectrograph, which

disperses the light into its constituent colors, and MUSE measures over 4000 of these colors! From this, the 3D image is created.

So we get a “cube” of images that is possible to scroll through to observe the galaxy at different wavelengths, in this way highlighting the different physical conditions (speed, temperature, star formation) in different regions of the same galaxy. In fig. 1 you can see a “wonderful” ESO image of the MUSE instrument with all the cables connecting the various components of MUSE.



*The MUSE instruments (courtesy of ESO)*

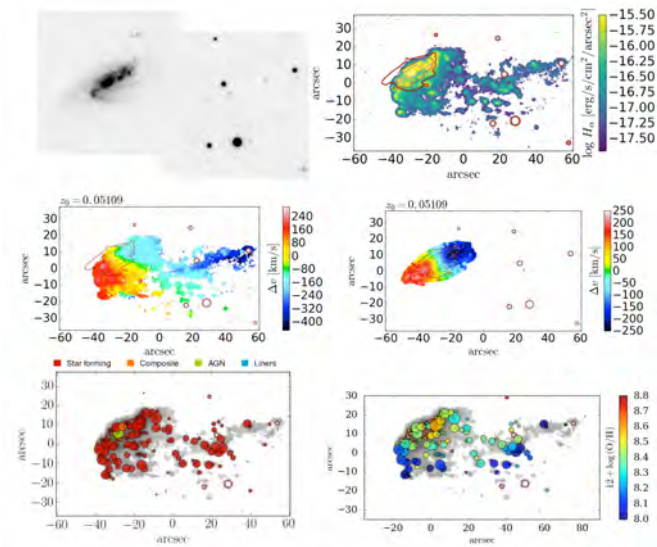
If we prepare an  $H\alpha$  map of a jellyfish galaxy we find tails (the stripes) of ionized gas up to 150kpc long; inside these tails luminous knots are observed where new stars are born. Studying such galaxies with MUSE has shown that the mechanism responsible for the removal of the gas from the body of the galaxy is not the gravitational interaction but the ram pressure that has removed the interstellar mass from the outer disk of the galaxy while the primary  $H\alpha$  tail is still being feed from the galaxy inner regions.

In the following figures two jellyfish galaxies are shown from our studies.

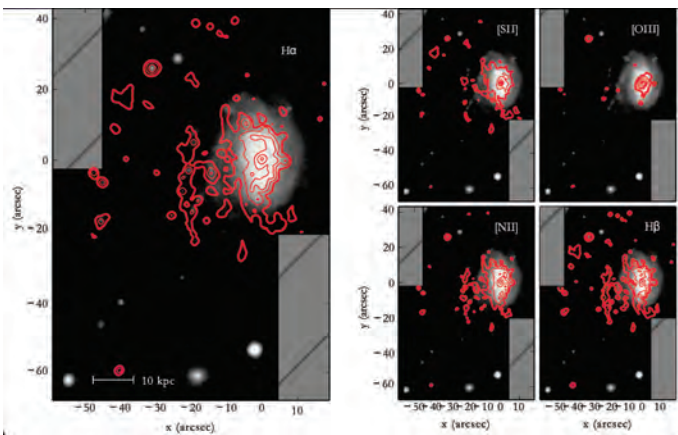
The above figures (top left and right), shows a Jellyfish galaxy from our sample, the galaxy JO206, as seen in a “normal image” and through the analytical eyes of MUSE. For example notice how the aspect of the galaxy changes observing it through the velocity of the gaseous component  $H\alpha$  and through the velocity of the stellar component of the galaxy (courtesy Poggianti et al. 2016 internal report).



In the figure on the bottom right, (Bellhouse private communication) another Jellyfish galaxy JO201 observed at various wavelengths corresponding to different chemical elements, in this case H $\alpha$ , Sulphur, Oxygen, Nitrogen, H $\beta$ . Again the morphology of the galaxy also varies in correspondence of the different chemical elements so we get information on the concentration of the different elements in different regions of the galaxy and also about their velocity and temperature.



*MUSE white image (top left), Halpha map (top right), Halpha velocity map (middle left), stellar velocity map (middle right), ionization source (bottom left) and gas metallicity (bottom right) of individual star-forming knots of JO206.*



*Jellyfish galaxy JO201 observed at various wavelengths corresponding to different chemical elements.*

2016 will be remembered for many things, but for astronomers all over the world it is the year of GAIA. Gaia is an ambitious mission to chart a three-dimensional map of our Galaxy, the Milky Way, in the process revealing the composition, formation and evolution of the Galaxy. Gaia will provide unprecedented positional and radial velocity measurements with the accuracies needed to produce a stereoscopic and kinematic census of about one billion stars in our Galaxy and throughout the Local Group. This amounts to about 1 per cent of the Galactic stellar population.

The spacecraft contains two telescopes, involving ten mirrors of different shapes and sizes to collect focus and direct light onto Gaia's camera. There, on the focal plane, are the mission's three science instruments: the astrometric instrument, the photometric instrument and the radial velocity spectrograph.

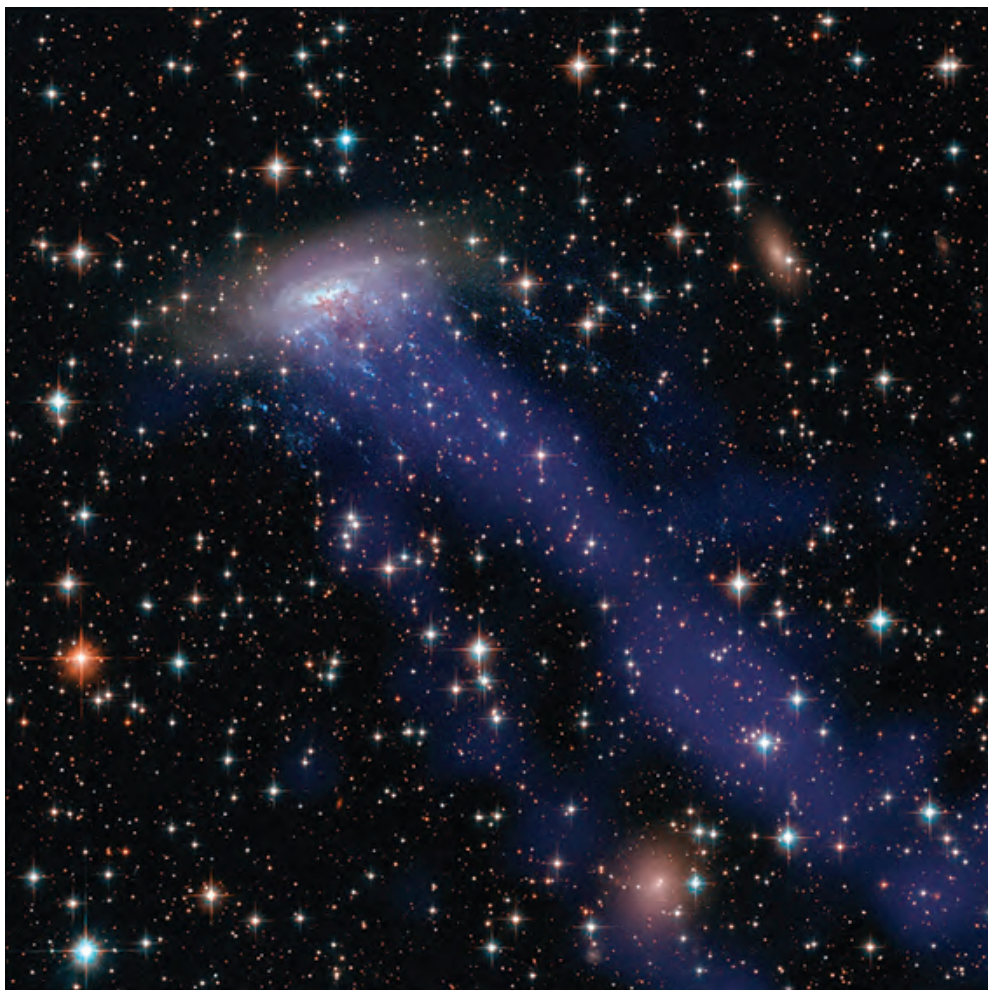
With a total of 106 CCD detectors and almost one billion pixels, Gaia's camera is the largest ever flown into space.

One thousand days after launch, on September 14, 2016, the mission released its first set of data, based on Gaia's first year of scanning the sky, from the start of scientific operations in July 2014 to September 2015.

The first Gaia data release contains a catalogue of 1 140 622 719 stars with precise measurements of their position on the sky and brightness. About one century ago a similar enterprise was done by the astronomical community and the result was the Carte du Ciel project whose outcomes were a photographic map of the entire sky and the publication of some catalogues reporting the positions and luminosities of the stars imaged by the various observatories participating in the project, including the Vatican Observatory. In the past 10 years we have digitized all the plates of the Vatican Zone of the Carte du Ciel. So now we are ready to compare this old data with the fresh ones coming from GAIA. We can gain a lot of information from this comparison of the position, the motion, the possible variability of the stars and we hope to do



this as soon as possible. The first thing to be done is to apply astrometry to the digitized images of the Carte du Ciel and get an electronical catalogue of the position of the stars to compare with those of GAIA. If a star is moving in the sky then we should notice the difference of its positions in the Carte du Ciel compared with GAIA: the astronomers call this difference proper motion!



*This image combines NASA/ESA Hubble Space Telescope observations with data from the Chandra X-ray Observatory. As well as the electric blue ram pressure stripping streaks seen emanating from ESO 137-001, a giant gas stream can be seen extending towards the bottom of the frame, only visible in the X-ray part of the spectrum.*

**Brother Thomas WILLIAMS, S.J.**



Most of my time in 2016 was occupied with keeping the books for the Vatican Observatory Foundation (VOF), the Vatican Observatory Research Group (VORG) at the University of Arizona's Steward Observatory, and the Jesuit Community of the Vatican Observatory in Tucson. I pay the bills, deposit

all VOF gifts and other income with Merrill Lynch, and take care of financial matters for the vice-director for VORG, Fr. Paul GABOR. This work is done in collaboration with Katie Steinke of the Foundation, Michelle Cournoyer (departmental secretary) and Laura Hammond (business manager) at Steward Observatory, and our accountants at Keegan Linscott & Kenon, in Tucson.

With my bad back and legs, my role as minister at the Tucson residence is somewhat limited but I do try to keep on top of repairs and problems, like leaks and mold. This past year saw a replacement of air conditioner units in 8 of our 12 bedrooms. This past year also saw the resealing of the buildings' roofs, which is done every 5 to 7 years. Those were the major repairs done in 2016; nothing major is planned other than ongoing and preventive maintenance.

This past year we welcomed a new addition to the community, Fr. Chrystoforus Bayu Risanto, S.J. ("Bayu") of the Indonesian province, who is living with us while pursuing his graduate studies in Meteorology at the University of Arizona. He is doing very well and is a great addition to the Community.

We have a steady stream of guests. We do look forward to some regular Jesuit guests, including Fr. Allen Deck S.J., Fr. Jim LaCasse S.J., and Fr. Felix Just S.J. One sad note is that both Felix's mother and father, who lived in Tucson, passed away this past year. Kurt Just, a professor at the University of Arizona in physics, had been a close collaborator in the field of cosmology with the late Fr. Bill Stoeger S.J. Kurt remained active until the

last months of his life, often visiting the community on his bicycle and chatting with the astronomers.



*Fr. KIKWAYA, Br. WILLIAMS, and guest scientist Dr Bill Romanishin of the University of Oklahoma celebrating in Tucson the 125th anniversary of Pope Leo XIII's Motu Proprio founding the Vatican Observatory on March 14, 1891*



*The Specola celebrated its 125th anniversary with a cake!*



## ADJUNCT SCHOLARS

### *Aldo ALTAMORE*



As an Adjunct Scholar, my historical research this year focused on rediscovering the personalities who populated the world of Roman astrophysics between the nineteenth century and the first half of the twentieth century, as well as the ancient instrumentation present at the Observatory and in the Rome area.

I also took part in internal discussions on communicating science to students and the wider public as part of the Vatican Observatory's future projects in the field of outreach and education. In collaboration with colleagues from the National Institute for Astrophysics, I helped in the organization of the Starlight Exhibition, dedicated to the birth of astrophysics in Italy, which was supervised by my colleague Ileana CHINNICI. The exhibition was held simultaneously at the Astronomical Observatories of Padua, Florence, Rome, Naples and Palermo; a virtual version is also available on the internet (see [www.starlight.inaf.it](http://www.starlight.inaf.it)). In particular, I edited the Rome section and I contributed to crafting the catalogue.

Over the same period of time, together with Fr. Sergio Cavicchia S.J., I organized an exhibition on Fr. Angelo Secchi S.J. It was held at the Massimiliano Massimo Institute in Rome, thanks to funding from the Italian Ministry of Education and Research.

The exhibition was enriched by a theatre play which I helped stage, titled "Sette Millimetri di Universo" [Seven Millimeters of Universe]. The play was produced by Padua's Zelda theatre company and held at the Massimo Institute auditorium in Rome. Altogether, about three hundred students and their families came to see the show which reflected on the scientific and human journey of those researchers who contributed to the rise of new science in Italy, known at that time, as the "New Astronomy".

As part of the same project, I organized two seminars concerning extrasolar planets and the Research of Intelligent Life in the Cosmos. The seminars were held in the aula magna of the Liceo Ennio Quirino Visconti in Rome, and were attended by students from Massimo and Visconti high schools.

In preparation for the bicentenary of Fr. Angelo Secchi S.J.'s birth, in 2018, I am coordinating the working group for the organization of events, consisting of researchers and experts from Rome, Palermo and Reggio Emilia.

At the Department of Mathematics and Physics of Roma Tre University, where I was on duty until my retirement, I continue to follow of issues regarding the Teaching and Communication of Physics and Astronomy. I also carry out advisory activities on these subjects, particularly regarding initial and in-service training for Physics and Natural Sciences teachers. I am involved in the Scientific Degrees Plan which aims to stimulate scientific vocations among high school students.

Further tasks include project management of the multicultural project "Astronomy for Development" addressed to schools with a considerable presence of immigrant students.

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

### *Father Louis CARUANA, S.J.*



This last year I have been busy as usual lecturing on topics in philosophy of science and nature but had to invest some extra energy in preparing a set of new lectures for graduate students on the philosophy of time. My main research output involved the organization of an international conference on Nature and



Naturalism held at the Gregorian University on April 18-19. During this conference, I presented my own research results in a paper entitled “Nature, science and critical explicitation” in which I explored in detail what happens when we have a clash between the scientific image and the everyday image of the world. Two other long-term projects came to fruition this last year. One dealt with astronomy. For about two and a half years, I had collaborated with a group of theologians, philosophers and astronomers on the topic of the beginning and end of the universe. The result of this collaboration was finally published as a book in May 2016. My contribution was not only the editing of this book but also an overview paper on current cosmological theories that describe the beginning and end of the universe and another paper on the universe’s directionality. The other long-term project involved the analysis of the scientific mentality’s role within the complex forces of secularization in the western world. This project, which drew inspiration from the philosophical work of Charles Taylor, had been going on for about three years in collaboration with a research student, Agnelo Pinheiro. In October 2016, he was successful in defending his doctoral thesis on this topic. This area of research resulted also in my publication “Nurturing the human face of science” in which I showed how the Church can be instrumental in securing the harmony between scientific rigor and human values. In March, I had the occasion of sharing and discussing some of my work at the philosophical institute, Istituto Bonó, in Santo Domingo, Dominican Republic. There I delivered a paper on some logical and semantic problems that arise when we talk about the nature of life. A similar occasion arose in November when I was invited to the Saint Thomas Institute in Moscow to deliver a paper on how some philosophical implications of quantum mechanics can be consistent with theological discourse. This was part of an ecumenical conference with contributions from various scholars, some Catholic and others Russian Orthodox.

## Ileana CHINNICI



This has been a quite complicated year for me, because of some unexpected events, the most striking of which was a bad fall in which I fractured my right wrist and the consequent operation to install a plate. Up to that point, I had been working on the *Starlight* exhibition, on the birth of

astrophysics in Italy in 19th century. I was the coordinator of this project, which connected five observatories (Palermo, Naples, Rome, Florence and Padua), each one hosting a section of the exhibition (more at: <http://starlight.inaf.it/?lang=en>). Fortunately, the accident occurred the day before the opening of the exhibition, so that everything was ready!

Apart from *Starlight*, there were other major projects this year. One of these works was the edition of a book on Merz telescopes in Italy which will be published by Springer hopefully next year. The book also includes an article on Merz telescopes at Rome Observatories in 19th century, which is co-authored by Father Sabino MAFFEO S.J.. The work which is most related to the Specola is the scientific biography of Father Angelo Secchi (1818-1878), a Jesuit who was a pioneer in astrophysics. I have spent almost two weeks at the Specola, to check some bibliographical references, and I hope to be able to come again in the next two months, to complete this work. Because of my accident and the consequent accumulation of work, the manuscript is not as advanced as I would have planned; fortunately, I have obtained a delay from the publisher, Brill, and I am now quite full-time working at this book. This was not the only reason for the delay: Secchi, in fact, is a very complex figure and many documents about his life and scientific activity are to be explored, especially those kept at Gregorian University Archives. It is a difficult but impassioned work, aimed at making him known to a wide public. Actually, the bicentenary of the birth of Secchi is approaching and the biography should be printed next year.

## **Michelle FRANCL-DONNAY**



My work on small organic molecules with interesting topologies continues, but has branched out to include rings comprised of organometallic compounds, in particular iron “sandwich” structures. As these structures are more easily synthesized, this shift opens the door to more practical

applications of these topologies. I had two scholarly essays in the history and philosophy of chemistry published this year in *Nature Chemistry*. The first considered the implications for chemists of the development of the thermometer, arguing it was instrumental in the shift from alchemy to the modern science. A second explored the role of fiction in sparking the imagination of scientists, and the price chemistry as a field might pay for the paucity of fiction exploring chemical problems. A third essay, also appearing in *Nature Chemistry*, explored the (virtually unknown to chemists) origins of water in the universe, sparked by this year’s topic for the Observatory’s Summer School. As part of the Field of Science blog network I continue to write informally about the history, philosophy and sociology of science, including two pieces on thermometry, one of which features the contributions of Jean Leurechon, S.J., and used materials from the Specola’s library.

I both wrote and spoke this year about the intersection of faith and science. I was invited to give this fall’s Ducharme Lecture at Mount St. Mary’s University. Taking a cue from St. John of the Cross, the talk titled *In the Thicket of this World: Doing Science as a Person of Faith* explored what a contemplative’s approach to doing science in the thicket of this world — where God’s glance “turns all things to beauty.” I wrote a number of pieces for Liturgical Press’ daily devotional, *Give Us This Day*, including a reflection on the apostles’ bursting nets and the vocation of the scientist. I contributed an essay to the Collegeville Institute’s *Bearings* Online magazine about a night of observing the planets through the Observatory’s Zeiss telescope. For Loyola Press’ *DotMagis* I wrote a half-dozen

pieces, including one for their annual festshrift for St. Ignatius of Loyola’s feast inspired by the Observatory’s meteorite collection (“Touching the Stars”), and one on finding God in my quantum mechanics course (“Imagine”).

I enjoyed a visit to the Specola in late May, particularly the opportunity to sit in on lectures with the students and faculty of the Observatory’s Summer School. I was on National Public Radio in the US twice last December, interviewed for *On the Media* by Bob Garfield, and in a piece on the history of chemistry sets for *Here and Now*. In the spring, I wrote a Lenten series for the Archdiocese of Philadelphia’s online paper, *CatholicPhilly*, and along with some occasional columns. An opinion piece I wrote considering what the general public should know about chemistry appeared in *Nature Chemistry* and gave a number of invited talks on public engagement with science, including at the national meetings of the AAAS and the American Chemical Society. I was honored to be given the Rosabeth Moss Kanter award by Bryn Mawr College for my contributions to social justice through my scholarship. And I just completed the draft of a book of Lenten reflections which will be published by Liturgical Press next fall.

## **Father José FUNES, S.J.**



After my 15 years at the Vatican Observatory, I started to work at the Universidad Católica de Córdoba, a Jesuit University, at the School of Philosophy and Humanities as professor and researcher. My sabbatical year has focused on establishing two lines of investigations. In the second semester, supported by

the Jesuit Community of the Vatican Observatory, I spent a few months in Berkeley, attending classes on Theology and Science, and holding meetings with scholars of the CTNS (Center for Theology and Natural Sciences), the University of California Berkeley, the Jesuit School of Theology of the University of Santa Clara, and the SETI Institute. In the first semester, I started two research groups on multidisciplinary studies based in Córdoba:

The first project, titled 'OTHER', focused on the question: Are we alone? This has triggered many scientific projects on the search for life in the universe, especially for extra-terrestrial intelligent (ETI) life.

Considering the growing number of discovered 'Earth-like' exoplanets located within the circumstellar habitable zone, the potential discovery of the existence of an ETI species elsewhere in the galaxy and then our potential 'first contact' might have a profound impact on our scientific, philosophical, and social comprehension of humanity.

The current scientific search for ETI poses questions that scientists could attempt to answer from a purely scientific point of view: What is life? How did life originate? What might the criteria that we adopt to identify what we might call an ET civilization be? However, such important questions require a thoughtful reflection from the perspectives of a variety of epistemological disciplines. The project OTHER (Otros mundos, Tierra, Humanidad, and Espacio Remoto) is a laboratory of ideas that deals with these and other similar questions.

Among other issues we propose to analyze the possibility and consequences, in different areas, of being the first and only technologically advanced civilization in the history of the universe.

The innovation of the project OTHER is the multidisciplinary approach in the Argentine community. Our goal is to provide new ideas that could offer new perspectives on the age-old question: Are we alone?

Our group presented a poster paper at a meeting of the Asociación Argentina de Astronomía. This project was awarded with a grant by the Ministerio de Ciencia, Tecnología e Innovación Productiva of Argentina. I am grateful to the New Paradigm Institute in Berkeley for the grant I received for this project.

Another project focused on the future of the Universe: philosophical and theological implications. Motivated by curiosity about the end of the universe, we consider the cosmic end at different scales. The question of the

end of the universe is one of the big questions which cut across human cultures: Where are we? Where did we come from? Where are we going?

The scientific method is not the only approach to address such questions, but it is certainly an important one.

We can think about the universe's past and future only from its present, and only from the data we have collected and interpreted. We have quite a good picture of the early universe, but are still unable to predict its future scientifically with any certainty. Our predictions depend on the different scales of time and space that we consider.

Eventually, in the very distant future, the universe will be shredded. It is moving toward a final state in which it will be cold and dark. Obviously, this long-term scenario would be hostile to the existence of life. This prospect poses many questions. If our location in the universe is crucial for life, will all life end with Earth? Or is life a common phenomenon in the universe? What will happen to life trillions and trillions of years from now, when the universe will fade? If there are other universes, will life survive in those places?

We plan to address these questions at different levels: social, philosophical, and religious.

The group presented a poster paper at a meeting of the Asociación Argentina de Astronomía. I have also given public lectures in schools, parishes in Argentina, and the Universidad Católica de Córdoba and in Berkeley. In Medellín, Colombia, I gave a public lecture that has been posted in You Tube ([https://www.youtube.com/watch?v=aainzR\\_gCgE](https://www.youtube.com/watch?v=aainzR_gCgE)). I also gave an inter-faith lecture at Cahuataqua Intitution, New York (<https://www.youtube.com/watch?v=VK-9WLHsd38>).

In December, I participated in a panel on Astrobiology at the University of California, Riverside.



### ***Father Robert JANUSZ, S.J.***



This year, with the help of Jolanta Koszteyn, I started a systematic elaboration of CCD photometry data collected at the Vatican Observatory. This involves very preliminary complete instrumental system results, for further detailed calibration and analysis. This is a massive undertaking but it

should provide (and partially it already does) accurate astrometry and approximate photometry of all sources as well. The basic problem is ordering the data in consistent “Fields of Views”, which allow a complete photometry analysis in the future. Doing this we must organize our precise, huge database and at some stage reconstruct an observation history to place the objects on the celestial sphere (usually we have only approximate RA/DEC indications). For example some observation runs only had a partial subset of filters, but we need seven of them to be able to make a full classification. In the ultraviolet range of the Vilnius Filters Set (U and P) we often needed to repeat “deep” observation due to the longer exposure time in different runs. In this case we create a “virtual run” i.e. a run which provides all photometric data which will enable full calibration and classification out of several real runs. Let us also say that the flat-field correction in the instrumental system is always applied by means of the known “calibrated object” (M67 or M29).

We would also like to expand our small photometric group to include others who share the same interest. We have tried this before in the past, but with little success. Besides this, we are continuing our work on particular fields with the full power of the Vilnius System to provide publishable data. We are still trying to develop the “tie-in” method i.e. to calibrate fields without standards, using the color transformation equations learned from a near-by object observed in the same (hopefully) photometric conditions.

We worked together with Richard BOYLE during our Castel Gandolfo Workshop on the data provided by VATT runs (coded as TY, TZ). This workshop was very productive; however the last run had significant Moon-light so in this condition not all data was useable.

During the Workshop we also finished our paper for the Jubilee Book describing the state of the photometric research at the Vatican Observatory. Currently we are working on a poster to be presented on LDN~183 star region and its interesting cloud.

### ***Dante MINNITI***



This year has been mostly spent working on the proposal for VVVX, which is the VVV Extended Survey. The VVV extension (VVVX) proposal was first drafted during the Vatican Observatory VVV Workshop on “A New Galactic Survey”, held at Castelgandolfo in May 2015, where twenty VVV science team

members got together. Now that the VVV survey completed its data taking, there are still open questions, and we had to plan the next steps ahead. The main goal of the Vatican VVV Workshop was to elaborate a proposal for the VVV Extension. We needed to consider the synergy with other survey telescopes and cameras (like VST, LSST, DECam, Gaia), and plan a legacy for the Astronomical Community of an extended and more complete survey of the inner galactic regions, which will be inaccessible for some of the other surveys. The VVVX will provide new targets and questions to address with additional dedicated spectroscopic survey instruments (Apogee-S, Winered, MOONS, 4MOST), as well as large facilities located in Chile like E-ELT and GMT, that are also scheduled, that can enable spectroscopic follow-up of interesting VVV targets.

After much discussion, we decided to map a total area of 1700 sqdeg, obtaining multicolor near-IR photometry, as well as about 25 epochs in the extended region. Also, the old VVV area will be reobserved for a few epochs in order to recover long term variability and to provide an extended baseline (~10 years) for proper motion measurements.

The VVVX proposal was successful (approved in 2016), with 200 nights awarded with the ESO VISTA telescope, and we are starting the first observations of the extended area. Even though VVVX will survey only cover about 4% of the sky, it will survey >50% of the Milky Way stars in the near-IR, because it is precisely

mapping the densest regions of our Galaxy: the bulge and southern plane. This means, for example, that we have a fair chance (~50%) of detecting a supernova in the Milky Way that explodes in the next few years.

With the VVV Survey we already obtained interesting scientific results, and with the extension VVVX there are many more to come. We are discovering our own galaxy, fostering international collaborations, promoting Astrophysics at every level, and securing resources for the future generations.

### **Giuseppe TANZELLA-NITTI**



During 2016 my academic activities as a lecturer of fundamental theology were largely devoted to activities and events related to the relationship between theology and science. Fundamental theology deals with the relations between faith and reason, and today the most common reference point for reason is scientific

reason. Before dealing with theology, I worked for several years as an astronomer in Bologna and then in Turin, in extragalactic astronomy. Last September 2015, I was appointed an Adjunct Scholar of the Vatican Observatory. In that same period I participated in the Vatican Observatory 80th Anniversary Symposium, presenting a report entitled “Some Reflections on the Influence and Role of Scientific Thought in the Context of the New Evangelization”. I have known my Vatican Observatory friends for many years and am pleased to be working with them now in this new official capacity.

I head the Interdisciplinary Resources for Religion and Science center in Rome which publishes two websites: [disf.org](http://disf.org) and [inters.org](http://inters.org). The Centre promotes RESHS (International School for Interdisciplinary Research, Advanced School for Interdisciplinary Research, [sisri.it](http://sisri.it)). The Advanced School has a permanent formation program on border issues between science, philosophy and theology, aimed at young researchers working in the world of scientific research who wish to enrich their scientific knowledge within a philosophical-theological framework. Information on the courses provided by these centers is available on the corresponding websites. In particular, on the anniversary of 50 years since the

death of George Lemaître (1894-1966), I proposed some online contributions on the Belgian cosmologist. Among the conferences organized by RESHS, the workshop “Space, Time, and representations of the world: cultural transformations of our reference systems 100 years after the General Relativity of Albert Einstein”, held in Rome on May 28-29, is of note.

During 2016 I took part in various events and conferences. Among those which relate to themes that are part of the mission of the Vatican Observatory, I would indicate the following: “The role of theology in the University: the modern era debate and today’s perspectives”; a lecture at the “Higher education in the history of the Church” Conference, Rome March 9 to 10; a seminar held at the philosophy faculty of the University of Urbino, May 13 “Scientific Culture and the New Evangelization: questions and opportunities”; “Knowing Humanistic and Scientific Knowledge: evidence of dialogue” conference at the University of Udine, September 27; “Physical Cosmology and Christian Theology of Creation”, lectures held September 7 to 10 at the Eranos Foundation, Locarno (CH); “The Question of God in Contemporary Society,” round table at the Association Francis Baron in Forlì, November 17; “Galileo Galilei and the Book of Nature, History and Implications of a Metaphor”, at the Religion and science: 400 years after Galileo conference, University of Chieti-Pescara and finally an invited paper on “Cosmos and Logos: Reflections on the Christological dimension of nature”, held at the Conference “A century in space-time. Physics, Philosophy and Theology in the era of New Applications”, at the Lateran University, Rome, November 24 to 25. I was also invited to the workshop “Georges Lemaître International Conference” organized by the Academia Belgica and the Belgian Embassy in Rome.

In 2016 there were some presentations of my Fundamental Theology in Scientific Context, a treatise in four volumes. The first two volumes were published in December 2015 (New City, Rome).

Finally, in April, National Geographic Channel, in the series “The Story of God,” broadcast a program that contains an interview with Morgan Freeman in which I respond to questions about the faith of the scientists, Creation and cosmology today.



# INSTRUMENTATION AND TECHNICAL SERVICES

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

## Personnel

The Mountain Operations team looking after VATT's operation and upgrades, has gone through momentous changes this year. First, in June, Kenneth DUFFEK announced his departure, effective on September 30. He became the Chief Engineer of the Monolithic Mirror Telescope, a 6.5-m on Mt. Hopkins. And on October 20, Bob Peterson died at his desk in his office at Steward Observer. Bob was Steward Observatory's Assistant Director for Operations, and in this capacity supervised the Mountain Operations team. Bob began working for Steward in 1984 and assumed responsibility for VATT in 2007.

The situation, although thrust upon us unexpectedly and in tragic circumstances, became an opportunity to rethink the team structure, the needs and the available assets. Buell Jannuzi, Director of Steward Observatory, Jeff Kingsley, Associate Director, and GABOR undertook this work, redrafting job descriptions to distinguish between operation and upgrades. Gary GRAY became the VATT's general maintenance supervisor, taking over some of the tasks previously carried out DUFFEK. Chris JOHNSON became VATT's acting Chief Engineer.



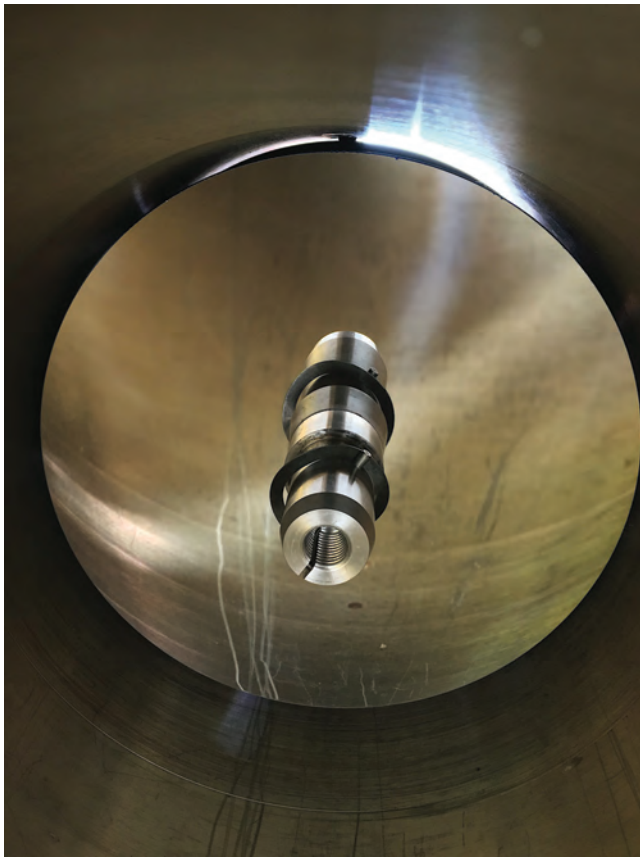
*Mr. Gary Gray*

## Maintenance

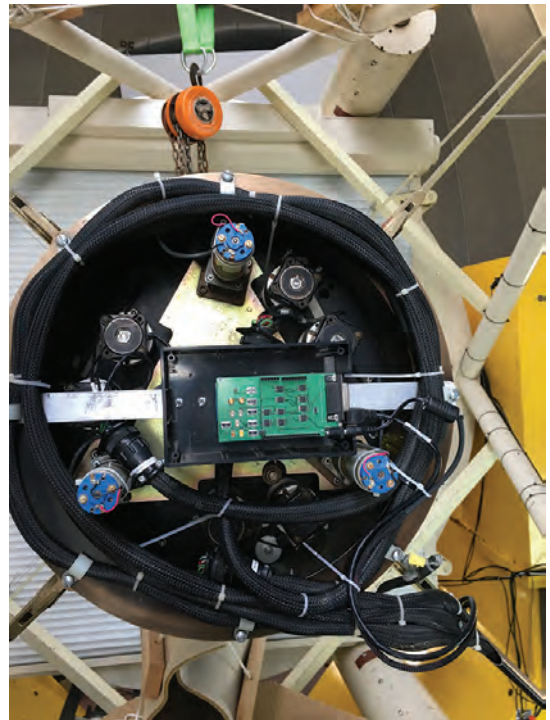
Several minor and one major corrective maintenance operations were performed. In September, the secondary mirror's support and positioning suffered a failure. The following corrective action was carried out by JOHNSON, Michael FRANZ, SWINDELL, GRAY and GABOR:

1. The secondary mirror was detached from the pseudo-hexapod (it was effectively glued to it with a cast-in-place RTV washer roughly 15 years ago).
  2. The micrometer heads were refurbished (the screws were replaced, the stems were cleaned, and lubrication suitable for operation down to -10C was applied) and reinstalled.
  3. The LVDTs were replaced with new ones.
  4. The wires were reconnected and back shells were installed (apparently for the first time in 25 years).
  5. The pseudo-hexapod was installed in the secondary mirror's baffle barrel.
  6. The mirror was re-attached to the pseudo-hexapod using a new silicon rubber washer of .015" (the steel washer was attached to the pseudo-hexapod with three screws). Several tools and methods had to be researched and developed for the process. The re-commissioning of the system was performed by BOYLE, JOHNSON, FRANZ, SWINDELL and GABOR on November 9-12:
1. The secondary's control through the GUI is responsive: motions up to 30 GUI units are reliable. Larger motions converge upon iteration.
  2. The telescope can be collimated reliably.

3. “Autocollimation” performs satisfactorily (some strange behavior was observed once in approximately 20 hours of commissioning on-sky time).
4. The secondary mirror does not vibrate, validating the two washers and the hub.
5. The secondary mirror’s mounting does not appear to have introduced optical errors (i.e., warped the mirror).



*Secondary mirror inside the baffle & support barrel. The mirror is ready for manipulation, enclosed in a protective cover and equipped with a handling rod.*



*Secondary mirror assembly (seen from the back) with dome flat-fielding LED system.*

## PEPSI

The commissioning of the Potsdam Echelle Polarimetric and Spectrographic Instrument (PEPSI) continues. The main milestone of 2016 are the very encouraging results on the system’s stability. It appears that the instrument is capable of radial velocity measurements down to 1 m/s. The Agreement between VO and AIP was extended through 2018.

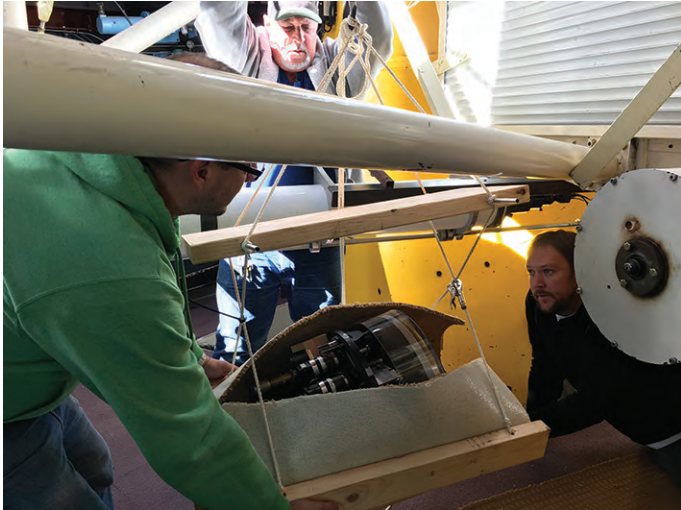
## VATT Upgrades

VATT’s major overhaul, started in 2014, reached several milestones this year. Work progressed on the elevation and azimuth encoders. At present, the elevation axis encoder ring is in place and the azimuth encoder ring with the break is ready to be installed. The cables leading from VATT axially down to the electronics racks were cut and connectorized by Steward Observatory’s Engineering and Technical Services (ETS) in preparation for the installation of the azimuth encoder ring.

The NGTCS Local Control Unit for VATT was completed by DUFFEK and the ETS, using a Controllino Mega Programmable Logic Controller, and implementing DUFFEK’s ladder logic design.



New servers (2 file servers HP ProLiant DL180 Gen9 and 4 servers HP ProLiant DL160 Gen9) and other IT equipment (Ethernet switches, uninterruptible power supplies, etc.) were procured.



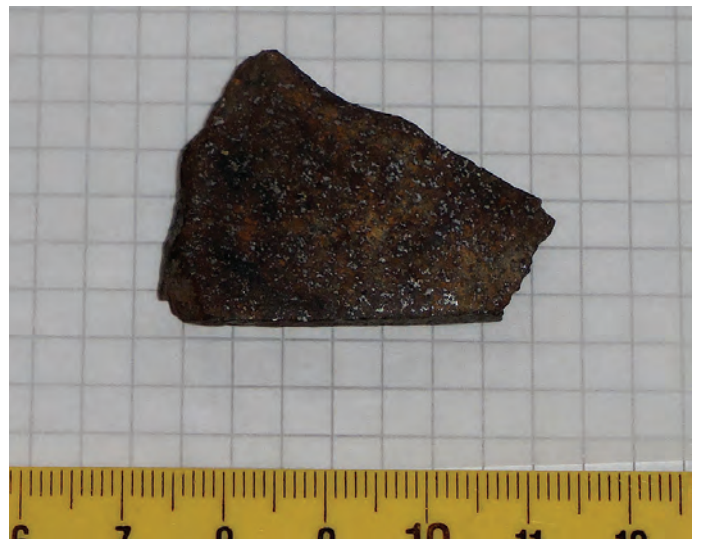
*Christopher Johnson (left), Gary Gray (center) and Scott Swindell (right) dismantling the secondary mirror assembly. (Photo Michael Franz)*



*Chelyabinsk*

## Meteorites

The Vatican meteorite collection grew by two meteorites this year. A benefactor in Arizona donated a 14-gm piece of the L chondrite NWA 869. More recently, a Norwegian benefactor donated a 16-gm piece of the LL chondrite Chelyabinsk. This meteorite originated from the fireball that exploded over the town of Chelyabinsk in Russia in 2013. The growth of the collection and the acquisition of new, scientifically interesting specimens is very much dependent on the generosity of our benefactors. A meteorite collector in Texas has expressed a desire that part of his collection goes to the Vatican Observatory if a generous benefactor is willing to purchase them. If interested, please contact the meteorite curator, Br. MACKÉ.



*NWA 869*

## A German clock master at the Specola

Thomas Rebényi, a clock master at the Deutsches Museum in Munich, visited the Vatican Observatory in August to oversee the continued restoration and maintenance of a number of the 19th century clocks which once controlled telescopes at the Vatican.

In total, there are nine Precision-Pendulum-Clocks (PPCs) at the Observatory. These were originally designed for precision timekeeping and to allow the precise determination of the right ascension of objects seen in a telescope. They include three clocks by Sigmund Riefler (1847-1912) and two made by Theodor Wagner (1805-1885), from Germany; and two clocks from Great Britain made by Edward Dent (1790-1853) and two by Charles Frodsham (1810-1871).

One can think of such objects historical documents. Since Rebényi began his work at the Specola in 2013 to restore and maintain these clocks, his goal has been to retain the traditional condition of the object, including all the traces of usage. This meant no polishing, and not making a new surface or any other irreversible changes. All the surfaces were cleaned of dust and old oil; but since it is problematic to remove fingerprints without grinding the surface, they often remain as traces of mistreatment or usage. Along with their maintenance, the two Frodsham clocks in the Aula Buffetti were affixed to the rear wall of the Aula, to prevent any jostling.

As Rebényi notes, “The very high quality of these PPCs indicates that the Specola Vaticana has historically used the highest quality equipment for science observations.”



*Thomas Rébenyi, Master watchmaker at the Deutsches Museum Watch Restoration Laboratory*



# EDUCATION AND OUTREACH

*Education and outreach initiatives by our staff and adjunct scholars are an essential part of the mission entrusted to the Vatican Observatory. This chapter gives an outline of some of the many events that they took part in throughout 2016*

Making an impact, a lasting one, means stepping up education and outreach to the general public. Throughout 2016, we continued to connect with students, fellow academics and all those interested in finding out more about what we do. We do this through conference participation, educational and academic activities and, in our increasingly connected world, engaging with the media.

## News and Media Coverage



*Pope Leo XIII*

*The mission we were given by Pope Leo XIII was to show the world how the church supports science. An essential part of our mission in “showing the world” is participating in press and media stories about the Observatory and its work.*

One of the most widely reported stories about the Specola Vaticana in 2016 concerned work that was actually done here more than 100 years ago.

For many years, our public talks about the history of the Vatican Observatory have often included a famous photograph of four Sisters of the Holy Child Mary who were part of the Specola’s role in the 19th century Carte du Ciel program to make a complete map and catalog of the starry skies.

But who were those Sisters? This past year, CONSOLMAGNO was asked directly if we know and remember them by name. He immediately put

this question to the Specola archivist, Fr. Sabino MAFFEO. Going through our records, MAFFEO quickly identified the sisters who did these essential measurements: Sister Emilia Ponzoni, Sister Regina Colombo, Sister Concetta Finardi and Sister Luigia Panceri. All born in the late 1800s in the northern Lombardy region near Milan.

The Specola was one of 18 national observatories cataloging data for the massive Carte du Ciel project, one of the first international projects in astronomy. The work at the Vatican was done under the direction of its founder Father Denza until his death in 1894; then the project languished until 1906 with the appointment of our first Jesuit director, Father John Hagen of Georgetown University. Noting that “lady computers” did such work at the Royal Observatory in Greenwich, he immediately thought of asking nuns to help.

A letter dated July 13, 1909, to the superior general of the Sisters of the Holy Child Mary, Mother Angela Ghezzi, asked for “two sisters with normal vision, patience and a predisposition for methodical and mechanical work.”

MAFFEO told Carol Glatz of the Catholic New Service that the sisters’ general council was not enthused “about wasting two nuns on a job that had nothing to do with charity.” However, Mother Ghezzi was “used to seeing God’s will in every request,” he said, and she let two sisters go to the observatory.

Work for the sisters began in 1910, but soon required a third and later a fourth nun to join the team. Two would sit in front of a microscope mounted on an inclined plane with a light shining under the plate-glass photograph of one section of the night sky. From 1910 to 1921, the nuns surveyed



the brightness and positions of 481,215 stars off of hundreds of glass plates.



*The Nuns at work at Vatican Observatory*

Their painstaking work did not go unnoticed at the time. Pope Benedict XV received them in a private audience in 1920 and gave them a gold chalice, MAFFEO said. Pope Pius XI also received the “measuring nuns” eight years later, awarding them a silver medal.

OMIZZOLO has scanned these plates by computer (the electronic kind); comparing the star positions recorded a century earlier with current satellite positions provides valuable information about star motions for millions of stars.

The story of the “Measuring Sisters” was distributed by the Catholic News Service (which is subscribed to by about 150 diocesan newspapers in the US) and picked up in a number of publications, from the *Irish Catholic* and *Corriere della Sera* to the *Atlantic* and the *Smithsonian*.

Also during the year CORBALLY was interviewed four times on the Drew Mariani Show, Relevant Radio, about the Christmas Star (December 23), about an ultracool dwarf star hosting earth-like planets (May 10), about a new form of light whose angular momentum is only half the Planck value (May 25), and about the discovery of the closest exoplanet Proxima Centauri b (August 29). He was interviewed twice by Mike Shaw on “4Tucson at 4”

KVOI radio, Tucson. On December 14, it was about the Christmas Star, and on June 3 he was joined by Todd Lauer (NOAO) to discuss the New Horizon probe’s sensational findings about Pluto.

CONSOLMAGNO was interviewed by the following press (including on-line): The *Catholic Sun* (Phoenix, Arizona); the *Catholic Register* (Toronto, Canada); MIT *Technology Review* (Cambridge, Massachusetts); Instituto Humanitas Unisinos online (São Leopoldo, Brazil); Life in the Day, Sunday *Times Magazine* (London); Toronto *Star* (Toronto, Canada); *Aurora* (Newcastle, Australia); Birmingham *Eccentric* (Birmingham, Michigan); *Ozy* (New York); *Der Spiegel* online (Hamburg, Germany); *Jesus* (Rome); *La Stampa* (Turin); *Perso* (Paris); *The Catholic Key* (Kansas City, Missouri); Melbourne *Catholic* (Melbourne, Australia); *The Southern Cross* (Adelaide, Australia); *Aleteia* (France); New Zealand *Catholic* (Auckland, New Zealand); Radboud University *Magazine* (Nijmegen, Netherlands).

Television and on-line videos: *Laudato TV* (Croatia); “Space and Exploration: Humans in a Vast Universe” *AAAS Dialogue on Science, Ethics, and Religion* (Washington DC); *Pane Quotidiano* (RAI 3, Italy); *Salt and Light* (Toronto, Canada); *TV-2000* (Rome); *EWTN* (Rome).

Radio and podcasts: The Bishop’s Hour (Phoenix, Arizona); STEM-talk Podcast (IHMC, Florida); Radio WJR (Detroit, Michigan); John Farrell/Forbes podcast (New York); BBC Radio 5 Live’s Up All Night (London); *On Being* (Minneapolis, Minnesota); “Religioni”, Deutschlandfunk / Radio Germany (Rome); ABC Radio (Adelaide, Australia).

GABOR was interviewed by Scott Douglas Jacobsen’s In-Sight Journal (English), by Interview Magazin (Czech and Slovak), Cesta (Slovak), ONET (Polish), and Nota Bene (Slovak). He also continued his weekly radio blog on Radio Lumen in Slovakia.

GIONTI was interviewed by Emanuele Fucecchi of *Jesus* magazine. His interview appeared as a page cartoon in two issues of *Jesus* magazine. He also participated in two different episodes of the popular science series “C’è Spazio”, directed by the journalist

Letizia Davoli, of TV2000: the two episodes were one on the “Mysteries of the Universe” and the second on Science-Theology.

KOCH gave an interview to the magazine Confronti Castellani: “Da Oltre 80 anni nei Castelli Romani: La Specola Vaticana”.

MINNITI gave interviews to Canal 13, Canal 13 Cable, TVN, La Red, CNN, Entrevista Radio Duna, Polo Ramirez, TV La Red (2016) Noticiero TVN 24 Horas (2016) - TV Program: “Hijos de las Estrellas” with Gonzalo Argandoña at Observatorio ESO Paranal, El Mercurio, La Tercera, La Nación, Diario Financiero, La Hora, Publimetro; Argentina: La Nación, Clarín, La Voz; Brazil: O Globo, Radio Cooperativa, Radio Duna, Radio UC, Radio Futuro, Radio El Conquistador, Radio Concierto.

## Educational Outreach



On May 29, 23 students representing 19 countries converged on Castel Gandolfo for the 15th Vatican Observatory Summer School (VOSS). These represented some of the best and brightest young astronomers and scientists, all at the end of their undergraduate or the early stages of graduate studies. The theme this year was “Water in the Solar System and Beyond”. In recent years, through space missions and improved telescopes, scientists have learned an incredible amount about water in many planetary bodies throughout the solar system, and the time was right for a VOSS on this theme. To convey this new learning, we gathered a top-

notch faculty. The chair, Meenakshi Wadhwa, is the director of the Center for Meteorite Studies at Arizona State University. She spoke about aqueous alteration in meteorites and the role of water in the formation of planetary bodies. Andrew Rivkin, one of the discoverers of subsurface water on the asteroid 51 Themis, spoke about asteroid spectroscopy. Jen Grier of the Planetary Science Institute supplemented information about asteroids and interpreting surface features of moons and planets. Athena Coustenis, the director of research at the French National Center for Scientific Research (CNRS), spoke about icy satellites in the outer solar system. Chris Impey of the University of Arizona discussed the role of water in cosmochemistry and astrobiology. These faculty were joined by our own CONSOLMAGNO and KIKWAYA, who filled in their own areas of expertise. MACKE served as dean.

The intense series of lectures were supplemented by a list of accomplished guest speakers, such as Seth Shostak of the SETI Institute, Lynn Rothschild of the NASA Ames Research Center, Bethany Ehlmann of the Jet Propulsion Laboratory, Diego Turrini of the Italian National Institute for Astrophysics, and retired astronaut Scott Parazynski M.D.

This school marked the inauguration of a new structure at the Specola Vaticana, slated for use as a refectory during VOSS and now available as a multifunction meeting space for the Specola. Sala Clavius, or “Clavius Base” as the students called it, could accommodate all of the students, faculty, and staff for lunch, and in the evenings it served as a social gathering place for the students. With an attached kitchen, students prepared a few “cultural dinners” featuring the food of their home countries.

The academic program was broken up by several outings, including Tivoli, Florence, and Ostia Antica. The highlight of the school was a visit to the Pontifical Academy of the Sciences, followed by an audience with Pope Francis. In addressing the VOSS group, Pope Francis encouraged the students to find joy in their research: “Scientific research ... can, and should be, a source of deep joy. I pray that

you will be able to cultivate that interior joy and allow it to inspire your work. Share it with your friends, your families and your nations, as well as with the international community of scientists with whom you work. May you always find joy in your research and share the fruit of your studies with humility and fraternity.”

*The Observatory's educational outreach is not just confined to VOSS. Our staff are committed on an individual level to integrating opportunities for education into their work commitments, wherever they may find themselves throughout the year.*

This year BOYLE made CCD observations at VATT on the request of two high school groups so they could form colored pictures of striking celestial objects.



*This image of the galaxy M82 was taken at the VATT for Andrey Aristov's astronomy class at Loyola High School, a Jesuit school in Los Angeles. Fr. Boyle provided images in red, green, and blue filters; Mr. Aristov's class then processed, combined, and balanced the images to make the color composite of the galaxy shown here.*

In 2016 BROWN gave a talk about the Vatican Observatory to juniors for the classes of Mr. Julio Minsal, S.J. at Jesuit High School in New Orleans, March 29 \* gave a talk about the Vatican Observatory to sophomores for the classes of Fr. Kevin Dyer, S.J. at Jesuit High School in New Orleans, March 29 \* gave a lecture “Catholicism and Science in the Modern Era: A New Rapprochement” as part of the Deitchman Family Lectures on Religion and Modernity at the College of the Holy Cross, Worcester, April 6 \* led a

Faculty seminar, “Jesuits and Astronomy”, at the College of the Holy Cross, Worcester, April 7 \* gave a lecture “The Untold History of the Relationship Between the Catholic Church and Modern Science” at the Fides et Ratio Conference at the Jesuit Ignatianum University in Krakow, Poland August 27 \* gave a lecture “God’s Universe: The Catholic Church & Science in a New Era” as sponsored by the Immaculate Conception Seminary School of the Theology and Department of Physics at Seton Hall University, August 29.

BROWN has also given a number of invited talks in 2016 at different universities, in the field of faith/science studies and issues: 1) “Catholicism and Science in the Modern Era: A New Rapprochement” College of the Holy Cross (Worcester, MA) on April 6; 2) “The Untold History of the Relationship Between the Catholic Church and Modern Science” at the Jesuit Ignatianum University in Krakow, Poland on August 27; 3) “God’s Universe: The Catholic Church & Science in a New Era” at Seton Hall University on August 29. I also led and guided a faculty seminar at the College of the Holy Cross on “Jesuits and Astronomy” on April 7 and also a talk to the Department of Physics at Holy Cross on the topic of sdB stars on April 7. Conferences attended included the ‘Fides et Ratio Conference’ at the Jesuit University Ignatianum in Krakow on July 27 and also the “The Physics of Fine Tuning” the University of Oxford (UK) on May 12.

In addition to scientific work of CONSOLMAGNO, education and public engagement efforts dominated his activities for the first four months of 2017. The second Faith and Astronomy Workshop was held at the Redemptorist Retreat Center in Tucson in January, bringing two dozen Catholic educators for a week of engagement with astronomy and astronomers, including a “back-stage” tour of the 4 meter telescope on Kitt Peak hosted by Kitt Peak director Lori Allen. Two weeks later at the same venue he participated in “Science in Seminaries,” organized by the Cardinal Suenens Center of John Carroll University. At that time, he accepted on behalf of the Observatory the Cardinal Suenens Center “Living Water” Award, a grant of \$10,000 to be donated in the name of the Vatican Observatory to a place where water is non-existent



or in acute supply; these funds were forwarded to the Jesuit Refugee Service to support a water project in Bambari, in the Central African Republic.

From February through April he gave more than two dozen talks in nearly a dozen locations from Ottawa, Canada to Merced, California. Among these events, he was the first non-Mormon to be invited to give the annual Summerhays Lecture on Science and Faith at Brigham Young University, Provo, Utah; and he served as the keynote speaker of the State University of New York at Geneseo's annual "Great Day" celebration.

Other outreach activities that occupied him for much of the year: In the spring, he taught an on-line astronomy class for the Jesuit Virtual Learning Academy. The Catholic Astronomer blog is now finishing its second year of operation with more than 300 subscribers, including support from nearly 125 Sacred Space donors. And he continued to produce monthly columns on science for the British Catholic magazine, *The Tablet*.

Perhaps the biggest outreach effort this year went into helping to prepare a new web site, *Faith and Science*, which should be "live" in early 2017. This site, which is in its final testing stage now, will provide Catholic educators and educated Catholics links to hundreds of articles, videos, and audio files on the topic of Faith and Science. Many of them have been produced by members of the Vatican Observatory, including a number of videos made especially for the site by Loyola Productions. This project is part of a long-term program of the Vatican Observatory Foundation funded in part by the Templeton Foundation to provide solid information about the relationship between science and our Catholic faith.

CORBALLY assisted with the Faith and Astronomy Workshop, January 11-15, in Tucson \* with Margaret Boone Rappaport performed a selection of dialogues on "Human Distinctiveness: Dialogues toward an Accord between Science and Religion" at the Newman Center, University of Arizona, Tucson, February 24 \* for both the Prescott Astronomy Club's 3rd Thursday talk on March 17, and for the Sun City Astronomy Club on December 15,

spoke on "The Role of Compact Telescopes in Astronomy" \* with GABOR, gave an afternoon seminar on Galactic Science for the Newly Ordained Mentoring Program of the Diocese of Tucson at Steward Observatory, August 24; it included a visit to the Mirror Lab \* gave talks on "The Star of Bethlehem" at St Thomas the Apostle parish, Tucson, December 7, and at Oracle State Park for the Oracle Piano Society and Oracle Dark Skies Committee, December 18.

GABOR recorded a talk for the Covington Latin School, Kentucky, at the beginning of February \* gave eight talks at the Redemptorist Renewal Center in Tucson to the participants of the sabbatical program on March 28 and 30, as well as October 24 and 25 \* with CORBALLY he hosted a group of the recently ordained led by Bishop Gerald Kicanas and Mgr Albert Schifano, August 24 \* gave a talk in Zilina, Slovakia, September 23, and in Tucson to the Tucson Catholic Physicians Guild on November 15, as well as a seven talks at the Newman Center in Tucson.

While in Mexico, GIONTI gave a popular seminar on the activity of the Vatican Observatory at Casa Loyola in Guadalajara and a second one, again, for a group of people that gather and discuss issues on Science and Theology in Mexico City \* back in Rome, he gave a seminar on popular cosmology for the association of young business men at the beginning of May \* participated at the American Academy in Rome to a panel discussion for the presentation of the book "La Specola Vaticana" of Maria Rosati Buffetti with prof. Simonetta Gentile, Physics department of Rome La Sapienza, with Dr. Franco Foresta Martin, science columnist at "Corriere della Sera", chaired by Dr. Marco Nese.

HELLER presented a paper at the Symposium of the European Society for the Study of Science and Theology, Referat "How to Justify the History of the Universe?" Lodz, Poland, April 26 – May 1 \* gave a public lecture on "Geometric Beauty of the Universe" at the Copernicus Festival, Krakow, May 22 \* presented a paper on "Science for Philosophy" at the 20th Cracow Methodological Conference, May 30 – 31 \* presented a paper "Synthetic Approach to the Singularity

Problem”, at the “Varying Constants and Fundamental Cosmology” Conference, Szczecin, September 12-17 \* gave a public lecture “How to Justify the History of the Universe at the Conference”, at the Conference “Varying Constants and Fundamental Cosmology”, Szczecin, September 12-17 \* gave a public lecture on “The Geometric Beauty of the Universe” at the Warsaw Science Festival, October 2 \* presented a paper on “The Cosmic Problem of Freedom” at the Fifth Congress of Christian Culture, October 13-16, Lublin \* gave a public lecture organized by the weekly Polityka magazine on “Is Chance Ruling the Universe?”, Warsaw, October 21.

JANUSZ was one of the directors of the “Science and Religion” project sponsored by the Ignatianum at the Copernicus Center Foundation in Krakow.

KIKWAYA held a question and answer session with high school students of Bonsomi College, in Kinshasa, Democratic Republic of Congo in January \* gave a talk to juniors and seniors of Cristo Rey School, San Miguel High School, in Tucson in February.

In December 2015, he made a trip to Kinshasa in Democratic Republic of Congo mainly to keep contacts with his Jesuit Province (Central Africa Province) and to visit his family. The Congolese Jesuits run several third level educational institutes. There are four main schools: Faculte Philosophique de Kimwenza where young Jesuits receive formation in philosophy; ISAV (Institut Supérieur d’Agro-Veterinaire) where students study agriculture and veterinary sciences; ESTAC (Enseignement Supérieur Technique en Afrique Centrale) which offers engineering and business courses. In this educational environment, he usually take two weeks of his visit time to teach one course. On this occasion he gave a statistics course to freshmen in engineering. Since October 2016, all four institutes have joined to form the Jesuit University, Université Loyola du Congo (ULC).

In June 2016, he participated in the summer school organized by the Vatican Observatory as one of the faculty. His course dealt with “Active Asteroids”, inspired by David Jewitt of the University of Hawaii, who gave a talk on the subject at Steward

Observatory. Active asteroids are asteroids in the main belt, but mostly in the outer belt that behave like comets, showing a tail behind the main body, indicating there that some asteroids might contain water, probably the same as the one we have here on Earth. he also conducted a student project on NEOs. He gave them 11 NEOs and asked them to determine for each of them the spin rate and the color. One was of a very high interest because peculiar and having V-R nearly zero. Its plot of relative reflectance (normalized to V) shows that the asteroid belongs to type-B that includes fresh asteroidal materials, probably recently excavated from an impact.

MACKE gave several presentations on the Vatican Observatory and the compatibility of faith and science to high school groups, both in person and remotely over Skype. These include Fr. Lopez High School in Daytona, FL, April 28-29, 2016 \* St. Scholastica Academy in Covington, LA, September 16, 2016 \* and Bishop DuBourg High School in St. Louis, MO, September 28, 2016. These were mostly in conjunction with Big History classes. Other public talks include: “The Vatican Observatory: At the Crossroads of Faith and Science” (Washington University Catholic Student Center, St. Louis, MO, September 15, 2016 \* “Meteorites and the Vatican Observatory” St. Louis Space Frontiers, St. Louis, MO, September 24, 2016.

MINNITI gave an invited public talk at the Academia Chilena de Ciencias on “Descubriendo la Via Lactea”, Santiago, November 2 \* gave an invited public talk on “Búsqueda de vida en el Universo” at the Planetario de Bogotá, Colombia, September 30 \* gave an invited public talk for the Asteroid Day “Colisiones Cósmicas”, Campus La Casona, Universidad Andres Bello, Santiago, June \* gave an invited talk on “Outreach with the VVV Survey: Lessons Learned”, Viña del Mar, Chile, May 26 \* gave an invited talk at the Workshop of Journalists on “Búsqueda de Vida en el Universo”, Univ. de Chile, Santiago, Chile, January.

During the past year MUELLER gave various public talks, some academic and others more pastoral in orientation. His presentation “Furnishing the Universe” was one of the several talks given at the September

2015 conference celebrating the transfer of the Vatican Observatory from Rome to Castel Gandolfo. In November 2015 he gave a lecture at the Pontifical Gregorian University, as part of a year-long program of the PUG concerned with the analysis and reception of Pope Francis' encyclical letter *Laudato sii*. His assigned task was to play "devil's advocate", critiquing the encyclical letter; his lecture will soon be published, along with the others in the series. On the Feast of the Epiphany, 6 January 2016, he appeared on a half-hour interview show on TV2000, the network of the Italian Bishops conference. The interview, conducted in Italian, was concerned with the work of the Vatican Observatory and with issues in science and religion. In April 2016, he was the featured speaker at a meeting of a New Jersey group of Amateur Astronomers. In May 2016 he gave a talk at Phoenix on the history and mission of the Vatican Observatory, and at Cincinnati he gave a "Theology on Tap" talk. In November 2016 he gave the talk "Jesuit Science: On the Threshold of Modernity" at the conference "The Clementinum and Jesuit Science", which was held at the National Library of the Czech Republic in Prague.

At Castel Gandolfo he guided numerous groups on visits to the Vatican Observatory, including the Dan Murphy Foundation, Loyola High School Los Angeles, Notre Dame University faculty and administrators, the Little Sisters of the Poor, Pontifical Atheneum of St. Anselm faculty and students, Georgetown University faculty and administrators, the Porticus Foundation, the Dutch Academy of Rome, British priests from the Nottingham Diocese, a Polish group gathered in connection with the Pontifical Council for Culture, and a group delegates from the Jesuits' 36th General Congregation.

## **Presentations, Academic Activities and Conference Participation**

BOYLE was first author on a poster paper at the 227th Meeting of the American Astronomical Society, Kissimmee, Florida, January 4-8.

BROWN attended the "The Physics of Fine Tuning", 3rd Workshop on Stars, Galaxies and the Multiverse, at Trinity College in the University of Oxford (UK), May 12 \* attended the *Fides et Ratio* Conference held at the Jesuit University Ignatianum in Krakow, Poland during July 26-27 \* gave a

scientific lecture on "Hot Subdwarf Stars and Stellar Evolution" to the Physics Department of the College of the Holy Cross, Worcester, USA, April 7.

CORBALLY with Margaret Boone Rappaport gave a poster display of "Sleep Changes in *Homo erectus*: The Implications for Creativity and Emotionality in Later Hominins" at the 17th Annual Convention of the Society for Personality and Social Psychology in San Diego, January 28-30 \* with Rappaport spoke on "The Human Hearth and the Dawn of Morality" to the Commission on the Philosophy of Natural Sciences of the Polish Academy of Arts and Sciences, April 25, in Krakow, Poland \* gave with Rappaport an "Update 2016: Our State of Knowledge of the Genomic Basis for Human Specialness, with Implications," during the conference of the European Society for the Study of Science and Theology, April 26 - May 1, in Łódź, Poland \* presented a talk at St. Augustine Cathedral, Tucson, on "Kino, The Scientist," during The Kino Symposium, celebrating the 50th anniversary of the discovery of Father Kino's grave, May 21 \* at the Institute on Religion in an Age of Science's annual conference on Star Island, NH, June 25 - July 2, conducted with Rappaport a daylong presentation and discussion on the topic of "Human Phenotypic Morality, and the Biological Bases for Knowing Good" \* from July 3-27, while at North Fork, Virginia, worked with Rappaport on Human Morality \* presented a poster paper on "Investigating Pulsating Lambda Boötis Stars" at the conference, "Stars 2016: Understanding the roles of rotation, pulsation and chemical peculiarities in the upper main sequence" held in the Lake District, UK, between September 11-16 \* through the Jesuit Institute, Boston College, MA, presented on October 17 a talk entitled "The Human Hearth and the Dawn of Morality" with Rappaport, and on October 18 gave a "Demonstration of New Modalities to Teach 'Science & Culture' through Theatre and 'Science & Religion' through the Short Dialogue" \* gave the Keynote address, "From Calendar to Cosmos", for the McGill-CREOR Graduate Conference Frontiers 2016 at McGill University, Montreal, November 12-13 \* spent November 15 with the Space Institute at the Department of Physics, McGill University, Montreal, and gave the Joint Astrophysics Colloquium on "The Enigmatic Lambda Boötis Stars" \* led a series of talks and discussions for



the Manchester Living Theology 2016 course entitled “Explorations on the Frontiers of Faith & Science”, November 25-27, Manchester, England.

GABOR taught a tier II general education course on the history and philosophy astronomy, ASTR 320, in the Spring 2016 semester at the UA \* was on the Scientific Organizing Committee of the Science of Time symposium held at Harvard University, June 6-9 \* also presented a paper and edited the conference Proceedings (Springer; in print) \* presented a poster paper at the SPIE meeting in Edinburgh, June 26 – July 1 \* was on the Scientific Organizing Committee of the Clementinum and the Jesuit Science symposium held in Prague, November 9-10 \* participated at the symposium honoring Michael Heller’s 80th birthday in Krakow, December 6-7.

GIONTI gave a talk: “Cosmologies of the Planck Era from Lorentzian Renormalization Group for Quantum Gravity” at the XXII SIGRAV (Italian Society for General Relativity and Gravitational Physics) in Cefalù, Sicily, September 12-18 \* took part in the conference “The Nature of Our Biophilic Universe”, Academia Belgica, Rome, December 1-2.

MACKE attended the 47th Lunar and Planetary Science Conference in the Woodlands, TX, where he presented two posters: “Ordinary Chondrite Heat Capacities Below 350 K” and “Density and Porosity Measurements of Lunar and Martian Materials.” He attended the 79th Meteoritical Society Meeting in Berlin, Germany, where he presented two posters: “Comprehensive Survey of Lunar and Martian Meteorite Physical Properties to Improve Interpretation of Spacecraft Gravity Data” and “Density, Porosity and Magnetic Susceptibility of the Murrili Meteorite Recovered by the Desert Fireball Network.” He was also coauthor on two other abstracts, one at each conference.

MINNITI organized the Aspen Center for Physics Working Group on The Milky Way Bulge-Halo Interface, Aspen, Colorado, September \* organized the Southern Astrophysics Network Workshop, held at UNAB, Santiago, Chile, November.

OMIZZOLO attended a conference on the life

cycle of galaxies in Venice, November 24-27 \* attended a conference on the Rosetta Mission in Padova, November 27-29.

## Awards and distinctions



*Fr. Michael Heller*

Adjunct scholar Fr. Michael HELLER received a variety of recognitions for his continued dedication to academic excellence and public outreach in his native Poland this year. These included: the “Crown of Laurels for Knowledge and Competence”, from the Regional Chamber of Commerce in Katowice; the Medal of Civic Wisdom, awarded by the Journal „Kraków”, a doctorate

Honoris Causa, from the Pontifical University of John Paul II, in Kraków.

## In Memoriam

A retired Jesuit priest who was once a member of the Specola staff and four lay collaborators who worked closely with the Vatican Observatory Research Group are among those whom we lost this past year.

Fr. Edmund Benedetti Kalitowski S.J. died on December 13 in Barcelona. Fr. Benedetti was born in London in 1920, entered the Society of Jesus in Turin, Italy, in 1935, and was ordained in Darjeeling, India, in 1950; he was 80 years a Jesuit, and 66 years a priest. Among other stops in his long and fascinating life he also worked extensively in South America. He trained as an engineer during the 1950s in London, and joined the Vatican Observatory in 1978 to work as an engineer on the telescopes, where he was famous for his enthusiastic pursuit of his hobby as an amateur radio “ham”. With the move of the telescopic staff to Arizona, he arrived in Tucson in 1988 and participated in the development of instruments for the VATT until 1992. Most notable was his work on the polarimeter VATTPol, which saw extensive use on telescopes both in Arizona and in Argentina. After completing his work at the Specola, he stayed on in Tucson as a parish priest in Wilcox, not far from the VATT location, and remained affiliated with

the Specola community. In 1998 he moved to Corpus Christi, Texas, where he continued his parish work well into his mid 80s. He retired to Spain (with trips to Brazil) in 2004.

Kurt Just, an emeritus physicist at the University of Arizona, died on June 19; he was 89. He had come to Tucson from Germany in 1961, where he served as Professor of Physics at the University of Arizona for over 40 years. In his later years he conducted an active research program in cosmology with the late Fr. Bill Stoeger, visiting with him often at Steward Observatory; with his unkempt white hair and German accent, he looked every bit the part of the brilliant scientist that in fact he was. A devout and active Catholic with a lively and enquiring mind, he was also a frequent visitor at our Lee Street house in Tucson; his son Felix, a Jesuit priest of the California province, would stay with us once his parents had moved to assisted living.



*Dan Blanco*

Dan Blanco, a telescope engineer on a number of telescopes in the Tucson area, died on September 19, following a diagnosis of late stage cancer; he was 63. Dan was a vital member of the initial team building VATT. He was borrowed from the MMT's staff as an "opto-mechanical engineer" with the very complementary skills of being an engineer in both mechanics and optics. The MMT

director, then Fred Chaffee, reckoned that if Dan took up the challenge of VATT's f/1 primary, he would learn valuable things to bring to the re-configuration of the MMT with a primary that was almost as "fast". On a lighter note, another of Dan's great contributions was the design of the VATT T-shirt! Dan was the son of Dr. Victor Blanco, the longtime collaborator of the Specola's Fr. Martin McCarthy S.J. studying M stars in the Magellanic Clouds and our Galaxy.

Bob Peterson, the director of Mountain Operations for the Mt. Graham International Observatory (site of the VATT) died suddenly



*Bob Peterson*

on October 20th, at the age of 67. He had worked at the University of Arizona's Steward Observatory since 1984, and at a time when larger telescopes were getting a lot of attention he was particularly dedicated to keeping the smaller telescopes, such as the VATT, running and productive. Bob's talent in developing and maintaining close personal working relationships led to outstanding relations with the Forrest Service, KPNO, and all the many communities inside and outside of the University who worked together to make our astronomy happen.

Dr. Vera Rubin died on Sunday, Christmas Day, in Princeton, N.J. She was 88. Vera was most famous as the discoverer of the unexpected differential rotation of stars in galaxies, now considered one of the first and strongest evidences for the existence of Dark Matter.

A graduate of Georgetown University, she also served on the faculty there where she became good friends of both Fr. Martin McCarthy and Fr. George Coyne, serving on Coyne's PhD committee. Thus when Martin and George proposed the idea of a Vatican Observatory Summer School, she (along with Dr. David Latham of Harvard) were their first choices to serve as faculty of the school.



*Fr. George Coyne S.J., Vera Rubin, David Latham, and Fr. Martin McCarthy S.J., at VOSS 1986*

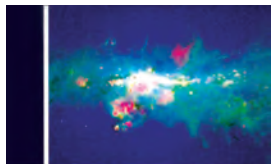
Vera's free giving of her unique talents had a lot to do with the success of the first VOSS, as well as setting a pattern for all the others. In 1996 Pope John Paul II appointed Vera to the Pontifical Academy of Sciences. On the occasion, Vera (an observant Jew) joked with Martin, "should you now call me, 'Your Eminence'?" Martin responded, "Only when you wear red, Vera!"

All of them will be missed, and are remembered in our prayers.

# PUBLICATIONS

This chapter lists the work of Vatican Observatory staff and adjunct scholars accepted for publication in 2016.

## Books



FUNES, J., OMIZZOLO, A. (2016). *Esplorare l'universo, ultima delle frontiere*, Specola Vaticana, Madrid. A Spanish edition of the book edited by the Specola Vaticana and published in Italy in 2015, was published in 2016 in Madrid. In the volume the authors, who are men of both science and of faith, reveal how scientific

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# VISITS

*Outreach to our fellow scientists, but also to the general public, includes visits to our facilities in Rome and Tucson.*



## ***Visitors to the Vatican Observatory headquarters***

Since the Pope's Summer Residence at Castel Gandolfo and its magnificent grounds were officially opened to the public as a museum, visitors to the Vatican Observatory have the added advantage of being able to take in a tour of the new museum at the Apostolic Palace and also the beauty of the historic gardens and farm that lie between our headquarters and the palace domes on top of the papal palace. (These tours are run by the Vatican Museums; the admission price supports the maintenance of those areas.) At the same time, those interested only in the Gardens or the Palace no longer need to ask the Specola astronomers for a tour... which is a welcome change for us!

This year we welcomed the following visitors and guests to the palace domes and Specola headquarters:

*For extended working stays, we were delighted to host:*

**Twenty four students and five faculty** participating in the Vatican Observatory Summer School. (Ambassadors to the Holy See from 11 nations represented by these students also came to visit at various times during the school.) In addition, NASA astronaut **Dr. Scott Parazynski** stayed for a week (with his wife, Dr. Wadhwa, the Chair of the school's faculty) and spoke to the students about his experiences in space.

**Jolanta Koszteyn**, of the Akademia Ignatianum, Cracow, Poland, who worked with Robert Janusz and Richard Boyle on the reduction of photometric observations.

**David Collins S.J.**, of Georgetown University, Washington DC, who pursued his studies in the history of science during the late medieval and early Renaissance periods.

*For day visits to the Specola, we welcomed more than 80 guests; among them were:*

Priests from the Diocese of Beauvais (France), led by Abbe Pierre Desaint.

The University of Dallas Alumni Group and President.

The Board of Directors of Georgetown University. Cardinal Stafford and Sisters of Mercy (of Alma, Michigan).

Dr. Lynn Rothschild of NASA Ames Research Center, California

Fr. Luke Sweeney and Fr. Kevin Basil, who work in the Vatican's Congregation of Bishops.

Thirty five staff members from the Swiss Embassy to Italy, including His Excellency Giancarlo Kessler (Swiss ambassador to Italy).



Dr. Peter Buseck, Regents Professor in the School of Earth and Space Exploration, Arizona State University, and his wife Cindy.

Dr. Andres Chianalino, attending the “Etica en el Gerenciamineto de la Salud” in the Vatican.

More than a dozen Jesuits who visited while attending the 36th General Congregation of the Society of Jesus in October.

Five seminarians from the Pontifical North American College, and eleven seminarians and instructors from the Pontifical Bede College, Rome.

A group of delegates from the European Space Agency (ESA) headquarter in Frascati (Rome) headed by Dr. Simon Jutz.

### *In Tucson we were delighted to welcome*

Fr. Jakubo Róg, University of Cardinal Wyszyński, Warsaw.

Prof. Klaus Strassmeier, Leibniz-Institut für Astrophysik Potsdam.

Dr. Hans Zinnecker, Sophia Science Center, NASA Ames.

### *A visit with Pope Francis*

“All of us dwell under the same sky”, Pope Francis told the faculty and students of our Summer School this year when they had the honor of visiting him in the Vatican. Specola staff gathered together with the young scientists in the Consistory Hall of the Apostolic Palace, a place heavy with history, to hear the Pope explain why our Church has always

had faith in the ability of science to bring us closer to our Creator. Here is a translation the full text of his speech (original in Italian) delivered on June 11, 2016.

*Dear friends,*

I am happy to welcome you, the professors and students of the summer course organized by the Jesuit Fathers of the Vatican Observatory. This impressive representation of persons from various countries and different cultures is a sign of how diversity can greatly enrich scientific research. I thank Father Paul Mueller, the Vice-Director of the Observatory, and the professors who generously accompany you young astronomers in the complex and exciting activity of studying the universe, the incomparable gift of the Creator. My gratitude goes also to those who through their generosity have contributed to make this international course possible.

Pope Leo XIII established the Vatican Observatory in 1891, exactly 125 years ago, not least to confirm the Church’s support for “true and solid science, whether human or divine” (Motu Proprio Ut Mysticam, 14 March 1891). Over the years, the Observatory has sought to fulfil its original purpose by employing new scientific instruments as well as



the tools of dialogue and cooperation with other centres of research.

Your presence at this summer school is also a sign that the desire to understand the universe, God's creation, and our own place in it, is shared by men and women of very diverse cultural and religious backgrounds. All of us dwell under the same sky. All of us are moved by the beauty revealed in the cosmos and reflected in the study of the heavenly bodies and substances. In this sense, we are united by the desire to discover the truth about how this marvellous universe operates; and in this, we draw ever closer to the Creator.

It is timely and providential that this fifteenth summer school is concerned with the study of water in the solar system and elsewhere. We all know how essential water is here on earth: for life, for us human beings and for our work. From the tiniest snowflake to the greatest waterfalls, from lakes and rivers to immense oceans, water fascinates us by its power and, at the same time, its simplicity. The great civilizations originated beside rivers, and in our day access to pure water continues to be an issue of justice for the human race, for rich and poor alike.

Dear brothers and sisters, scientific research demands great commitment, yet can sometimes prove lengthy and tiresome. At the same time, it can, and should be, a source of deep joy. I pray that you will be able to cultivate that interior joy and allow it to inspire your work. Share it with your friends, your families and your nations, as well as with the international community of scientists with whom you work. May you always find joy in your research and share the fruit of your studies with humility and fraternity.

With these prayerful good wishes, I cordially invoke the Lord's abundant blessings upon you and your work. And I ask you please to remember me in your prayers.











2016



15<sup>th</sup> Summer School  
in Astrophysics

Water  
*in the Solar System and Beyond*