

A photograph of Pope Francis walking on a paved path outdoors. He is wearing his white papal vestments, including a zucchetto and a large white cape. He is smiling and looking towards a man walking beside him. The man is wearing a dark suit and glasses. In the background, other people in clerical attire are visible, along with a stone wall and trees under a clear blue sky.

The Vatican Observatory

Si Monumentum
Requiris,
Circumspice

Annual Report 2015



ANNUAL REPORT 2015

Vatican Observatory
V-00120 Vatican City State

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

vaticanobservatory.va

Vatican Observatory Publications



Vatican Observatory Staff

During the calendar year 2015, the following were permanent staff members of the Vatican Observatory, Pontifical Villas of Castel Gandolfo, Italy, and the Vatican Observatory Research Group (VORG), Tucson, Arizona, USA:

- GUY J. CONSOLMAGNO, S.J.,
Director
- PAUL R. MUELLER, S.J.,
Vice Director for Administration
- PAVEL GABOR, S.J.,
Vice Director for VORG
- JOSÉ G. FUNES, S.J.,
Director Emeritus
- JÓZEF M. MAJ, S.J.,
Vice Director Emeritus
- RICHARD P. BOYLE, S.J.
- DAVID A. BROWN, S.J.
- CHRISTOPHER J. CORBALLY, S.J.,
*President of the National Committee to the
International Astronomical Union*
- GABRIELE GIONTI, S.J.
- JEAN-BAPTISTE KIKWAYA, S.J.
- GIUSEPPE KOCH, S.J.,
Librarian
- ROBERT J. MACKE, S.J.,
Curator of the Vatican Meteorite Collection
- SABINO MAFFEO, S.J.,
- ALESSANDRO OMIZZOLO
- THOMAS R. WILLIAMS, S.J.,
Assistant to the Director and Vice Directors

Adjunct Scholars:

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

CREATOREM
E ADOREMUS

Cover: *Former director, Fr. José FUNES accompanies Pope Francis on a tour of the VO, Headquarters in Castel Gandolfo.*
Title: *“Si monumentum requiris, circumspice” - “If you seek his monument, look about you” - inscription from St. Paul’s Cathedral, London, UK.*

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

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FROM THE DIRECTOR

On September 29, 1935, Pope Pius XI dedicated our new quarters and telescopes in the Pope's summer palace in Castel Gandolfo. In celebration of 80 years since that dedication, the week of September 14-18 we held a symposium including a visit to the old telescope domes in the papal gardens, and the domes atop the Papal Palace (see page 35). The symposium finished on Friday with a private audience in Rome with Pope Francis.

When the Pope saw me at the audience, he smiled and said, "Ah! The New Director!" And that's when I finally believed it.

I had been informed that I would be appointed as the new director at the end of Father José FUNES' term of office. But with those words from His Holiness, it suddenly became real to me. I was going to step into Fr. Funes' shoes. It's an awesome responsibility... and a tough act to follow.

Along with my own appointment, Father Paul MUELLER, S.J. is also taking up new duties as the vice-director for administration in Castel Gandolfo. Father Paul GABOR, S.J. will continue in his role as vice-director of the Vatican Observatory Research Group in Tucson.

What are the tasks confronting us immediately? In fact, as you

can see from reading this annual report, the Observatory is in good shape, especially in Castel Gandolfo where a number of construction projects are nearing completion. But I believe that I will want to direct a lot of attention in the coming year to our work in Tucson.

That's not because the folks in Tucson haven't been doing their job, but rather because they've been doing it very well indeed. As a result of the upgrades and robotization of the VATT, we now have a telescope that is constantly being improved and ever more heavily subscribed, and therefore one that needs an ever more stable and secure source of annual funding. Thus I plan to spend the majority of the coming year in the US.

If we want to have stable funding for the VATT in Arizona, it has to come through the Vatican Observatory Foundation, a nonprofit corporation of the State of Arizona where our telescope is located. The Foundation in turn gets most of its funding from two sources: other foundations who fund educational projects, and personal donations that range from ten dollars, to tens of thousands of dollars.

In order to qualify for funding from educational foundations, we need to provide — and show we are providing — a variety of education and public outreach services. These are precisely the sorts

of programs that will also allow us to reach out to individual donors, especially smaller donors. To that end, we have developed a number of new initiatives in the US, from our new Faith and Astronomy Workshop, to a range of high school collaborations, to our Catholic Astronomer blog page.

But in fact this effort in education and public outreach is an essential part of the very mission we were first given by Pope Leo XIII when he founded the Observatory in 1891. At that time, he stated that his purpose was so that the world could clearly see that the Church supported good science.

Doing good science is, obviously, essential; otherwise we have nothing to show. But the "showing" is also essential. We've done that in an ad-hoc way for the past 20 years, at least. Our intention now is to organize a more systematic approach to our education and public outreach. The Foundation is the obvious vehicle for that effort. Thus, at least for the coming year, I will also be continuing as President of the Foundation.

But our work on outreach will not be confined to the US alone. One of the most exciting developments in Castel Gandolfo, begun by FUNES and MAJ, is the extensive work being done to adapt our historic telescope domes both in the Papal Gardens and on the Papal Palace as Visitor Centers. These

will be places where we can indeed show the world the essential role that the Vatican Observatory has played in the history of astronomy, and the work we are doing today.

The message of our outreach, and indeed of the Observatory itself, is that science is not a passive activity. The growth of our scientific knowledge of the universe does not occur automatically; rather, it is the result of the active choices of good and intelligent men and women who choose to dedicate their lives to scientific research. These choices are motivated by many things. But at its best, the goal of being a scientist is not money or fame, but a search for truth: which is to say, a search for God.

In fact, that connection between the abstract work of science and the real-life concerns of the scientists doing the work was a common

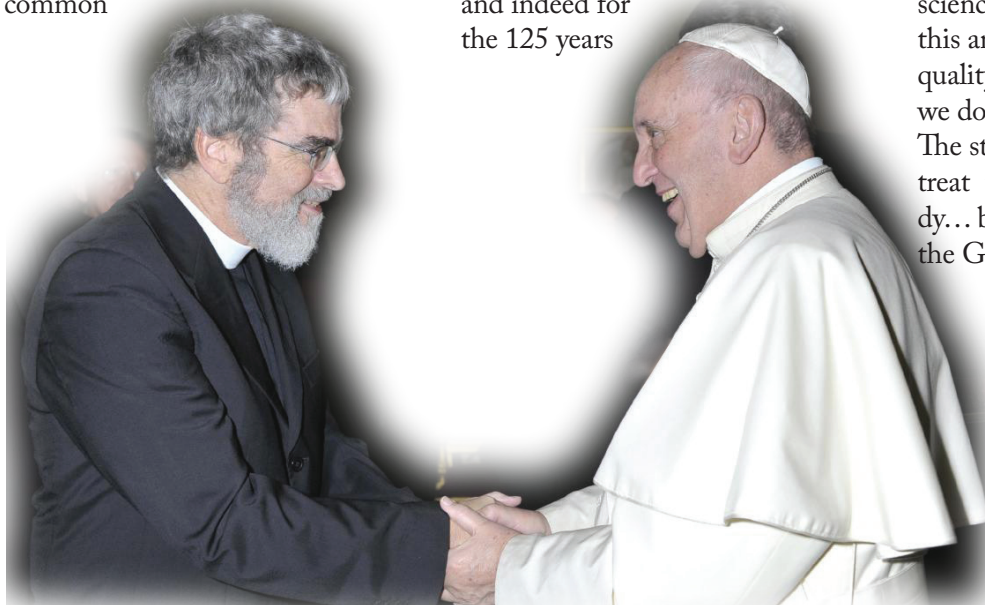
theme of our September seminar. We heard from theologians and philosophers about the way that scientific work shapes, and is shaped by, the scientists doing the work. We heard examples from the history of our observatory, about the people who chose to collect meteorites or catalog spectra. And we also heard from the scientists working now, where a common theme emerged that, for all the automation and data processing that can be done by machine today, in every project there is still a crucial role for the decisions and judgments of individual scientists.

And among the individuals whose choices have made our work possible, we recall first and foremost the Popes who first proposed and then supported our work for the 80 years we have been in Castel Gandolfo, the over 30 years when we've also been present in Arizona, and indeed for the 125 years

— as of April, 2016 — that the modern 'Specola Vaticana' (as the Vatican Observatory is known in Italy) has existed since it was founded by Pope Leo. The active involvements of the Popes in our work during all those years reminds us of the weight of history in the work we are doing, and the importance that the Papacy attaches to our work. Remember, this Observatory was the Pope's idea, not ours!

Meanwhile, I'm looking forward to working with the incredible staff and facilities that my predecessors have put together. I will be relying on them more than ever, especially when I am away from Castel Gandolfo. My task will mostly be to get out of their way and let them fly.

But beyond that, I hope that all the events we put on and all the science we do, as described in this annual report, reflects another quality that motivates everything we do in astronomy: a sense of joy. The stars are glorious, and it's a treat to be engaged in their study... because, their glory proclaims the Glory of their Creator.



Guy J. Consolmagno S.J.

*Guy J. Consolmagno, S.J.
Director*

RETROSPECTIVE: A MONUMENTAL TASK

Christopher Wren, the architect of St. Paul's Cathedral in London, is honored in that marvelous edifice by a plaque which reads, "*Si monumentum requiris, circumspice*" — "If you seek his monument, look about you." I am reminded of that motto when I contemplate what has been accomplished at the Vatican Observatory in the past ten years, during FUNES' directorship. You can find no better tribute to his care of the Vatican Observatory than if you simply visit us and look about you.

The most visible change is our new headquarters. Ten years ago, the Vatican Observatory was located in the Papal Summer Palace in Castel Gandolfo. While sharing quarters with His Holiness was an honor, and living in a palace sounds wonderful, in a practical sense those quarters left a lot to be desired. We were situated in a 400 year old building that was never designed for the Internet, much less with modern heating or cooling systems. Even the electrical outlets showed the history of Italy's ever-changing styles and standards. We were spread out over five floors; bits and pieces of the library were scattered into several rooms, and our laboratories were located at the opposite end of the building from our offices.

But most of all, the needs of both a modern observatory and those of a modern Papacy made it difficult for both to share the same quarters in the summer months. And so in 2006, just as FUNES began his first term of office, the decision was made to move from our home of 70 years to quarters within the gardens themselves, near the entrance to the regional city of Albano.

Our new quarters are housed in a building which dates back to 1631 – the same year that Galileo was finishing his book on the Two World Systems – when Princess Caterina Savelli of Albano built a convent for the Clarisse Sisters, also known as the "Poor Clares". In the early 20th century the southwestern end of the building, which now houses the Vatican Observatory, was given over to the Basilian sisters. With a diminished number of vocations, the Basilian sisters moved out of their part of the building around 2005. In 2007, work was begun to completely restructure their end of the building to match the needs of the astronomers of the Vatican Observatory. After two years of extensive work, the new Vatican Observatory headquarters was dedicated by Pope Benedict XVI on September 16, 2009. (The Clarisse sisters continue their prayer and work in the southeastern end of the building.)

The extensive renovation of the Basilian sisters' convent in the gardens was not trivial task. However, with the full support of the Vatican, the interior spaces were completely rebuilt. At the same time, the exterior has been transformed into a setting that has indeed become a "flower in the lapel" (the Italian equivalent of a "feather in the cap") of the Vatican. For example, in 2012, the Vatican Secretary of State chose our newly remodeled site to host their annual gathering of the diplomatic corps accredited to the Vatican. The ambassadors were given a tour of our offices and telescopes, leading up to a gala dinner in the Papal Gardens themselves.

Changes and developments over the past ten years have not only occurred in Castel Gandolfo. Perhaps the most visible part of the Vatican Observatory to the rest of the world is our Vatican Advanced Technology Telescope (VATT) on Mt Graham in Arizona. It was truly "advanced" when it first saw light in 1993; now, after more than 20 years of use, FUNES has initiated a program to keep the telescope "advanced" with a massive upgrade that will fully automate the telescope and integrate it into a network of telescopes in southern Arizona.

There are two complementary parts to this work. The first is to install new control systems for the telescope, with the goal of making it possible to operate it without physically being on the mountain. The second part is to integrate our telescope into a system with telescopes of similar size operated by the University of Arizona, so that these telescopes can work simultaneously to observe the same objects at the same time with a suite of different techniques.

Telescopes in our size range are ideal for observing unusual or short-lived phenomena that larger scopes, with their competitive scheduling, cannot respond to. For example, small and faint near-Earth asteroids are only visible when they pass near to the Earth. Other transient events such as bursting stars or distant supernovae likewise must be observed quickly, soon after their discovery. Thus any project to characterize such objects must take place before the object becomes too faint, or moves too far away to be seen.

Such an event's brightness and its spectral colors may both be changing rapidly with time. It would be ideal to be able to get both sorts of observations at the same time; but measuring these different aspects requires different instruments. The Arizona Robotic Telescope Network (ARTN), of which the VATT will be a charter



member, is designed to schedule and coordinate such simultaneous observations on different telescopes located on the mountain tops around Tucson. Developing the scheduling software and other techniques needed to make this practical is a major task of the project.

These projects are made possible by grants from the Papal Foundation, the William Randolph Hearst Foundation, and the Dan Murphy Foundation. The work is now well underway, with the goal of having the system complete in the next couple of years. In this way, the VATT is serving as a tool to improve the way that other telescopes in the future can be constructed and controlled. The VATT with its superb optics is once again becoming a model for how telescopes will function and be used for the next twenty years.

An observatory is more than buildings and instruments, however. The most essential part of the Vatican Observatory is our astronomers. And perhaps the most profound change to the Observatory over the past ten years has been the addition of a new cadre of young Jesuit astronomers. Our numbers have grown with the arrival of Father David BROWN, S.J., who models stellar interiors and evolution; GABOR, an expert on the instrumentation needed to detect extrasolar planets; Father

Gabriele GIONTI, S.J., an expert in cosmology and string theory; Father Jean-Baptiste KIKWAYA, S.J., who observes interplanetary dust entering Earth's atmosphere and asteroids passing nearby the Earth; Brother Robert MACKE, S.J., who has measured physical properties of meteorites in dozens of collections world-wide; and MUELLER, who continues to teach and publish on the history and philosophy of science while serving as the rector of our community.

These young men have transformed our work in both Castel Gandolfo and Tucson. And the impact of these new researchers goes beyond their own work. Each of them has brought with them a whole new cadre of colleagues and collaborators, who themselves are now a part of the Vatican Observatory family. The breadth of this outreach can be seen in the co-authors of our papers (see pages 43-48).

Along with the joys of greeting new members of staff, however, comes the far more difficult task of informing older, long-serving and beloved members of the community that their years of service to the Vatican Observatory are completed, and that the time has come for them to return to their provinces. Such partings are always necessary at some point, but never easy. Alongside those who have left us for reti-

rement are those who have been called from us to the Lord. Over the past ten years we have lost a number of figures whose presence made the Vatican Observatory what it was. We remember in particular: Father Andy WHITMAN, S.J., who died just this past January (see page 36); Father William STOEGER, S.J.; Father Juan CASANOVAS, S.J.; Brother Aloysio PUHL, S.J.; Father Emiel DE GRAEVE, S.J.; Father Gustav TERES, S.J.; Maria (Lilla) PIAZZA SCORDO; Bruna VERONI; and Romeo (Piero) PIERMETTEI. May they rest in peace with the Lord.

This is just a brief overview of some of the accomplishments of the Vatican Observatory during the time when FUNES has been director. It doesn't even begin to touch on his groundbreaking activities in connecting our work with the developing world, such as the International Network of Catholic Astronomical Institutions (INCAI), or the inter-religious dialogue with astronomers in the Islamic world... not to mention the ongoing Vatican Observatory Summer Schools, to which FUNES devoted so much of his time and attention in fostering and promoting.

FUNES would be the first to insist that all of these activities were collaborative projects, where he was well served by the other



Images of the VO telescopes in Castel Gandolfo and Tucson, AZ

members of the Vatican Observatory, especially his vice directors in Castel Gandolfo, Father Giuseppe KOCH, S.J. and MAJ, and in Tucson, Father Christopher CORBALLY, S.J. and GABOR. In addition, he would note that many of these accomplishments were begun during the tenure of his predecessor, Father George COYNE, S.J..

I find that thought to be quite heartening, since it reminds me that FUNES has left us an excellent legacy of projects and staff to build on as I take office. There are new Jesuits, currently in studies, who we hope will be joining us in the next five years; FUNES found and encouraged them, just as COYNE promoted many of the young men now working with us. Likewise, projects such as the ARTN that began under FUNES' watch will come to their full

potential only after he has returned to Argentina. I only hope that I can provide as much as he has to whomever my own successor may be.

The Vatican Observatory today is a monument to ten years of dedication and hard work from FUNES. It is our task to take full advantage of those efforts and to build on all the achievements he has left us. In this way we may continue to accomplish the mission first given to us from Pope Leo XIII and renewed in every subsequent Papacy over 125 years of our history: to show the world how the Church supports and encourages good science... so that we all may hear the heavens proclaiming the glory of God.

GJC



Pope Leo XIII

NEW INITIATIVES IN EDUCATION AND PUBLIC OUTREACH

The Vatican Observatory astronomers have a unique mission to better communicate that the Church, indeed faith, is not opposed to science, but embraces it as an important human endeavor to understand God's creation and marvel at how he reveals himself through science.

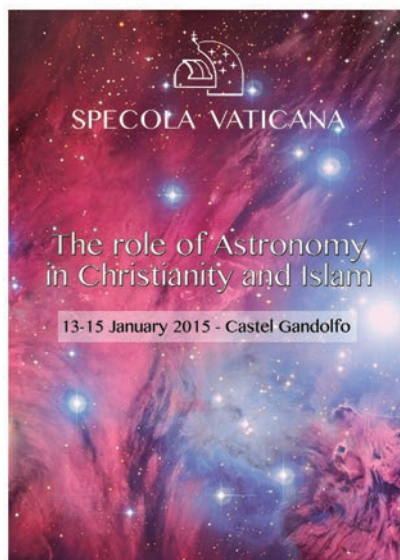
Education and Public Outreach are key factors to this, as Pope Francis himself noted when he spoke to VO staff in September, noting how he was particularly struck by the potential for furthering interfaith dialogue through exploring the relationship between science and faith.

Building bridges with Islam

In a major outreach project this year, the Vatican Observatory joined Iran's Embassy to the Holy See to sponsor a January 13-15 workshop to mark the International Year of Light. The week long seminar focused on studying "The Role of Astronomy in Christianity and Islam", and drew scientists, philosophers and academics from across the religious spectrum and indeed, many interested nonbelievers.

Light is extremely important in religion and culture, not just for science and technology. Light from the sun and its reflection on the moon are the foundation for telling time, creating calendars and establishing the rhythms that guide prayer, day and night.

Launching the initiative, FUNES noted that because it is the same moon, sun and stars for all people, space and astronomy are the perfect common ground for encounter and dialogue.



Farid Ghassemloou of the department of the history of science at the Islamic Encyclopedia Foundation said, "Today more than

ever, Islamic and Christian civilizations need a deep and complete understanding of one another." "We have a common past in the fields of science, mathematics, medicine and astronomy."

Both GIONTI and CHINNICI participated in the workshop together with FUNES, which brought Muslim, Catholic and other scholars together, looked at some of the ways Christianity and Islam studied the heavens in the fields of science and faith.

The seminar was widely covered in international press and it is hoped that it is just the beginning of a fruitful collaboration.

Faith and Astronomy

Along with the continuing work of individual members of the Vatican Observatory to give talks at schools and parishes, provide interviews with news media, and write articles for the popular press, a number of Jesuits this past year have taken part in new outreach initiatives organized by the Vatican Observatory Foundation.

The first Faith and Astronomy Workshop was held the week of



Participants at a January 13–15 workshop to mark the International Year of Light on “The Role of Astronomy in Christianity and Islam”, hosted by the Vatican Observatory and Iranian Embassy to the Holy See, on the rooftop of the Papal Palace in Castel Gandolfo (above)

FUNES accompanies participants at the workshop on a tour of the VO headquarters in Castel Gandolfo (below)

The flyer for the January 13–15 workshop (see previous page)

January 19–23 at the Redemptorist Renewal Center, outside Tucson. Organized by the Foundation and directed by CONSOLMAGNO, a group of 25 pastors, deacons, and religious

educators from parishes around North America gathered to learn about astronomy and how it can interact with our faith. Events included lectures on topics ranging from cosmology to light pollu-

tion; visits to the University of Arizona Mirror Lab, to the headquarters of the upcoming Osiris-Rex space mission, and to the Planetary Sciences Institute; and workshops on working with meteorites and on teaching astronomy to schoolchildren. Bishop Kicanas of Tucson celebrated the opening Mass, while CORBALLY and GABOR celebrated Masses during the week and helped out with evening telescope observing sessions.

The Foundation’s outreach to Catholic high schools in North America was expanded this year to include Loyola High School of Los Angeles, Mercy High School in Watertown, CT, St. Louis University High School and Bishop DuBourg High School in St. Louis, the University of Detroit Jesuit High School, and St. Ignatius College Prep of San Francisco. In some cases the interaction was a lecture in person by one of the Vatican astronomers, in other cases, the astronomers connected via internet video. One class, from Loyola Los Angeles, made a field trip to Tucson itself. Vatican astronomers who participated in this work included CONSOLMAGNO, GABOR, MACKE, and MUELLER.

Virtual Learning

In this connection, CONSOLMAGNO began teaching a distance-learning high school astronomy class organized by the Jesuit Virtual Learning Academy,

who organize such classes for full high school credit available to Jesuit and other Catholic schools across North America.

One notable high school project was an astrophotography opportunity offered to students of our long-standing partners at the Jesuit high schools of Los Angeles and San Francisco. BOYLE used time at the VATT to aim the telescope at coordinates provided by students in the astronomy classes at those schools. After doing the basic processing of the images (flat fielding, error correcting, etc.) he sent the resulting images of the objects found at those locations, taken in red, green, and blue filters, for the students to process and combine into full color images of notable astronomical objects.

Another new outreach initiative was the production of two series of twelve 25-minute lectures by CONSOLMAGNO, produced by the Catholic media company, Now You Know. The first series, “Galileo: Science, Faith, and the Catholic Church,” went on sale in the spring, while the second series, “Meaning: Exploring the Big Questions of the Cosmos with a Vatican Scientist”, was available in the fall. The lectures are available as DVDs with images and video, or as audio-only lectures.

The Catholic Astronomer

The most sustained new effort, organized by the Foundation and supported by the active participation of Vatican astronomers, is a blog site called The Catholic Astronomer (www.vofoundation.org/blog). Regular contributors include Vatican astronomers CONSOLMAGNO and GABOR along with a diocesan priest, Fr. James Kurzynski, who first suggested to us the idea of a Faith and Astronomy Workshop; Dr. Brenda Frye, an astronomer at Steward Observatory; and two NASA solar system ambassadors, Bill Higgins and Bob Trembley. Postings are updated on a daily basis. The topics range from the latest NASA news, to reflections on science and faith. Among the most popular posts have been Higgin’s descriptions of attending the Pluto flyby in July, and Fr. Kurzynski’s meditations on the papal encyclical *Laudato Si*. Readership has grown throughout the year, reaching more than 8000 visits during the month of September.

The Pope’s astronomers believe astronomy in particular can open people’s minds and hearts wider than before and bring them closer to God. CONSOLMAGNO has often summed it up by saying “science works with man-made theories about how the world works, while religion -- conversely -- starts with divine truth about the whys of the world”.



*CONSOLMAGNO speaking at Delaware Valley Amateur Astronomers, near Philadelphia (above)
GABOR speaking at the University Lecture Series in Ventura County, California (below)*

RESEARCH HIGHLIGHTS

Planetary Sciences

Centaurs

The Kuiper Belt, objects orbiting beyond Neptune, is thought to be the origin of short-period comets. Centaurs are small bodies, either asteroids or comets, whose orbits transition from the uninclined, circular Kuiper Belt Object (KBO) orbits to the highly elliptical comet orbits. Because they come closer to us than the KBO objects, Centaurs can be more easily studied. However, the exact nature of the relationship between Centaurs and KBOs is still an open question.

At the annual meeting of the American Astronomical Society Division for Planetary Sciences, Tegler (Northern Arizona University), Romanishin (University of Oklahoma) and CONSOLMAGNO presented new broad-band colors for 32 Centaurs objects, which they measured using the 4.3-meter Discovery Channel Telescope near Happy Jack, AZ and the 1.8-meter Vatican Advanced Technology Telescope on Mt. Graham. Combining these new colors with their previously reported colors, they now have optical broad-band colors for 58 Centaur objects. With these observations there is now a large enough data sample to allow reliable statistical analysis of trends seen in the data.

Previous work by these authors

had suggested that the centaurs could be split into two distinct groups: one with a gray color, and the other with a very red surface color. The original idea was that the gray objects would be covered in colorless ice, while the red ones might have had organic ices that had been turned dark and red by solar ultraviolet light; thus the gray objects would be much brighter than the red objects.

However, the exact opposite trend was suggested by the first sample of observations; red Centaurs have a higher median albedo than gray Centaurs. These new observations of a much larger sample of 58 Centaurs confirms that red Centaurs have a higher median albedo than gray Centaurs, at the 99.7% level. The gray objects are likely very dark, similar to what we see on the surfaces of comets.

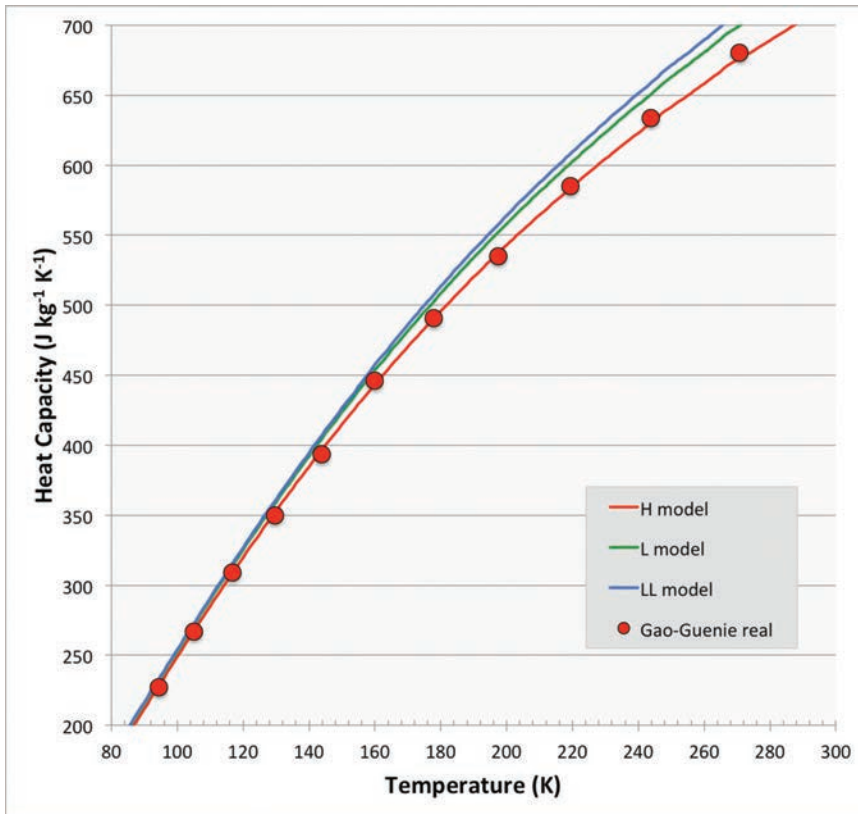
In addition, these new data show that red Centaurs have a lower median inclination angle than gray Centaurs, at the 99.5% confidence level. Because of their red colors and lower inclination angles, the authors suggest that red Centaurs originate in the cold classical Kuiper belt, among the objects whose orbits are essentially unperturbed and which their previous work had shown were also very red in color. Thus this work has found both a chemical and dynamical link between red Centaur Objects and the Cold Classical Kuiper Belt.

Meteorites and Moon rocks

MACKÉ continues his studies of meteorite physical properties, including density, porosity, and thermal properties. He is involved in several collaborations. With Walter Kiefer (Lunar and Planetary Institute), Tony Irving (University of Washington) and Dan Britt (University of Central Florida) he continues to study the density and porosity of lunar and martian materials to help interpret gravimetric data from orbiting spacecraft to better characterize the crust of the moon and Mars. This past year, with the addition of 3D laser scanning, they were able to add considerably to their database, including 16 more Apollo moon rocks measured at NASA Johnson Space Center in Houston, TX, and about 50 new lunar and martian meteorites covering a wide range of lithologies. At this point, the database is nearly complete and publications should soon be forthcoming.

Early results of this research were presented at the 46th Lunar and Planetary Science Conference and the Workshop on Early Solar System Bombardment.

With Cyril Opeil SJ (Boston College), Dan Britt (University of Central Florida) and CONSOLMAGNO, MACKÉ has also been working to characterize the heat capacities and thermal properties of ordinary chondrites from the Vatican meteorite



An early result of our studies of the thermal properties of ordinary chondrite meteorites. The solid lines represent theoretical heat capacities as a function of temperature, based on average composition of H, L, and LL ordinary chondrite falls. The red circles represent actual measured heat capacities of the H meteorite Gao-Guenie, based on work done by collaborator C. Opeil S.J. Note the good agreement with the theoretical curve for H chondrites

collection. In order to better understand the thermal behavior of asteroids undergoing heating and cooling, one must know their thermal inertia and thermal diffusivity, both of which are functions of density, porosity, and heat capacity. Through meteorite studies, there already exists a good database of density and porosity, but until recently not the equivalent database for heat capacities. Heat capacities are measured using the liquid nitrogen immersion technique pioneered at the Vatican

Observatory. As of now, there are more than 60 ordinary chondrites from the Vatican collection whose heat capacities have been measured. Cy Opeil at Boston College supplements these data with more detailed studies for select samples. His Quantum Design Physical Properties Measurement System (PPMS) can measure heat capacity and thermal conductivity as functions of temperature between 5K and 350 K. Where additional compositional data exists, the group finds good

agreement between theoretical models and measured heat capacities. The group also finds that the different ordinary chondrite types (H, L, LL) exhibit distinct ranges of heat capacities, and that thermal conductivities can vary with orientation of thermal flow, indicating that pore geometry and not merely porosity is important.

Early results of this research were presented at the 47th AAS Division for Planetary Sciences Meeting, the 2015 NASA Exploration Science Forum, and the 78th Meteoritical Society Meeting.

MACKE is also involved in collaborations with Melissa Strait (Alma College), George Flynn (SUNY Plattsburgh), and Dan Durda (Southwest Research Institute) to study the effect of high-energy disruption on meteorites using samples that have been disrupted at the NASA Ames Vertical Gun Range; and with Jon Friedrich (Fordham University) and Alex Ruzicka (Portland State University) to characterize the size and distribution of pore spaces within meteorites using a combination of x-ray microtomography and ideal-gas pycnometry.

Observing fast rotator NEOs

We study NEOs not only dynamically to address their impact hazard, but also physically to understand various properties important to constrain models of their potential hazard, and also to

know what they can tell us about the origin of the solar system and its ongoing processes. But this can only be efficiently done if they are observed with different instruments to cover as large a portion of the electromagnetic spectrum as possible.

Therefore setting up a network of telescopes to observe simultaneously Near-Earth Objects from different locations with different instruments in different bands will provide complementary properties that will help to understand them.

The project KIKWAYA is currently working on aims to take advantage of the two-meter-class telescopes around Tucson, in Arizona in USA to observe fast rotator NEOs ($H > 22$) synoptically at three different locations: VATT (Vatican Advanced Technology Telescope) at Mount Graham (longitude: -109.8719 , latitude: 32.7016 , elevation: 10469 feet), Bok 2.3 m at Kitt Peak (longitude: -111.6004 , latitude: 31.9629 , elevation: 6795 feet) and Kuiper 1.5-m at Mount Bigelow (longitude: -110.7345 , latitude: 32.4165 , elevation: 8235 feet). All three telescopes will aim simultaneously at the same object, each

with a different instrument. Since 2013, The VATT-4K, optical imager mounted on the VATT, is used for photometry. In the future we plan to utilize the BCSpec (Boller & Chivens Spectrograph) for visible spectroscopy on Bok 2.3 meter and a near-infrared instrument on Kuiper 1.5 meter.

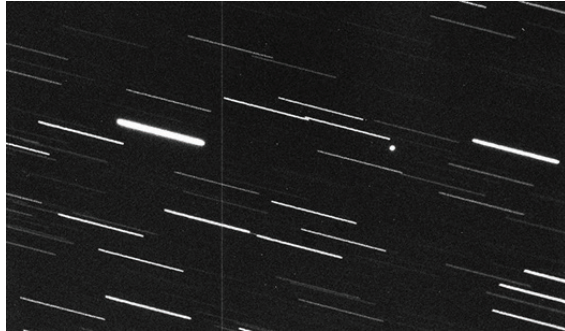
Iraf commands like ccdphot, digi-phot, apphot are used to perform photometry reduction. Radii of the sky annulus are fixed. Imexam is used to estimate the object radius for each frame and twice this value is inserted as the object aperture. 3 BVRI photometric standard stars are used each night at different magnitude and different air mass. For each standard star, total magnitude is given by catalog magnitude - instrumental magnitude. Linear fit of total magnitude versus air mass gives zero point (intercept) and slope

(extinction coefficient). Object magnitude on one frame is given by (zero point magnitude + Instrumental magnitude) - object air mass* extinction coefficient. Asteroid Lightcurve Analysis program by Petr Pravec is used to estimate the rotation of the object and also the color indexes B-V, V-R and I-R.

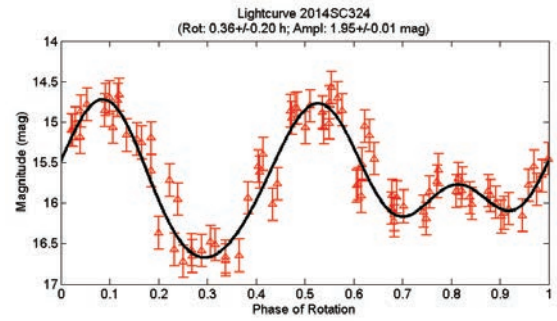
The results to date: 2009 SQ 4109, 2014 EC, 2014 FA44, 2014 KS40, 2014 SB145, 2014 AY28, 2011 PT, 2014 SC324, and 2014 WF201 showed clear spinning rates, but 2014 HM2 did not show any conclusive spinning rate. Using the classification based on the observation of asteroids by Zellner, Tholen, and Tedesco (1985), we found that thirteen objects are associated with different NEO groups. 2014 HM2, 2014 FA, 2014 SB145, 2015 LF21 fall among X-type aste-

	Name	Rotation Period	Amplitude	B-V	V-R	V-I	H	Type
		(h)	(mag)	(mag)	(mag)	(mag)		
1	2009SQ104	6.85+/-0.03	1.51+/-0.15	xx	xx	xx	21.0	
2	2014AY28	0.91+/-0.02	0.44+/-0.04	xx	xx	xx	21.8	
3	2014EC	0.54+/-0.04	0.47+/-0.16	xx	xx	xx	28.2	
4	2014FA44	3.45+/-0.05	0.95+/-0.06	0.624+/-0.015	0.462+/-0.013	xx	24.8	M
5	2014HM2	xx	xx	0.562+/-0.018	0.359+/-0.014	xx	21.9	M/C?
6	2014KS40	1.11+/-0.06	0.95+/-0.16	0.752+/-0.010	0.354+/-0.015	xx	21.9	C
7	2014SB145	0.77+/-0.01	0.21+/-0.05	0.676+/-0.014	0.437+/-0.018	xx	23.3	M
8	2011 PT	0.17+/-0.02	0.20+/-0.05	0.643+/-0.016	0.368+/-0.009	xx	23.9	C
9	2014SC324	0.36+/-0.20	1.95+/-0.01	0.752+/-0.019	0.526+/-0.013	xx	24.3	D
10	2014WF201	1.00+/-0.03	0.14+/-0.02	0.742+/-0.010	0.317+/-0.015	0.637+/-0.015	25.6	C
11	2015 FP	0.35+/-0.04	0.48+/-0.06	0.861+/-0.017	0.321+/-0.022	xx	25.2	C?
12	2015 FL35	4.30+/-0.09	1.27+/-0.08	0.595+/-0.012	0.031+/-0.012	0.319+/-0.018	24.3	
13	2015 FP35	xx	xx	0.667+/-0.013	0.327+/-0.015	0.654+/-0.020	24.3	C
14	2015 FF36	xx	xx	0.734+/-0.014	0.052+/-0.010	0.325+/-0.017	26.6	
15	2015 GE1	xx	xx	0.713+/-0.016	0.323+/-0.020	0.674+/-0.014	25.7	C
16	2015 GA1	xx	xx	0.728+/-0.011	0.012+/-0.013	0.121+/-0.022	26.6	
17	2015 LA2	0.21+/-0.02	0.41+/-0.05	0.7294+/-0.015	0.346+/-0.014	0.692+/-0.019	23.1	C
18	2015 LK	xx	xx	0.742+/-0.016	0.024+/-0.013	0.336+/-0.014	26	
19	2015 LG	0.71+/-0.05	0.34+/-0.03	0.731+/-0.018	0.412+/-0.015	0.662+/-0.017	24.5	C
20	2015 LF21	0.32+/-0.07	0.42+/-0.08	0.673+/-0.020	0.467+/-0.014	0.786+/-0.014	26	S

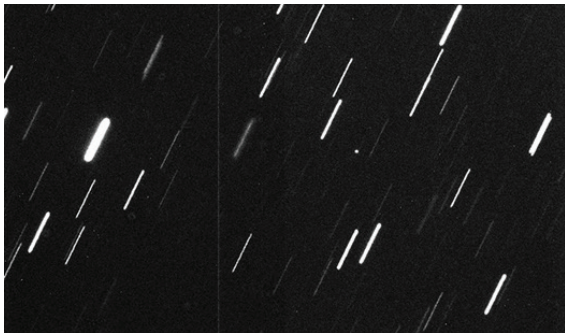
Table of 20 Neos observed since 2013



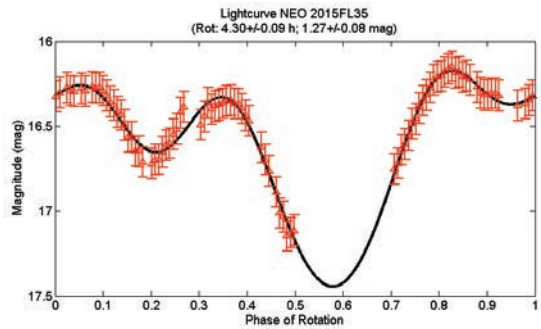
Neo 2014 SC324, the small dot amid the streaked images of stars, as observed on May 25th, 2014



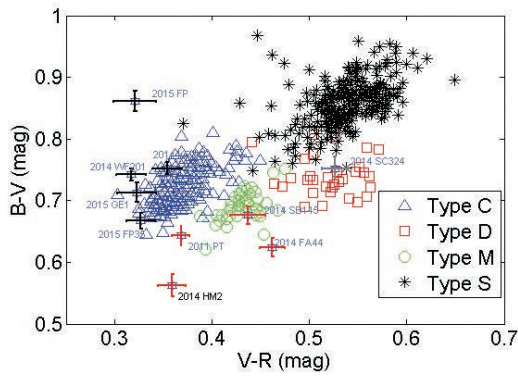
Lightcurve of Neo 2014 SC324



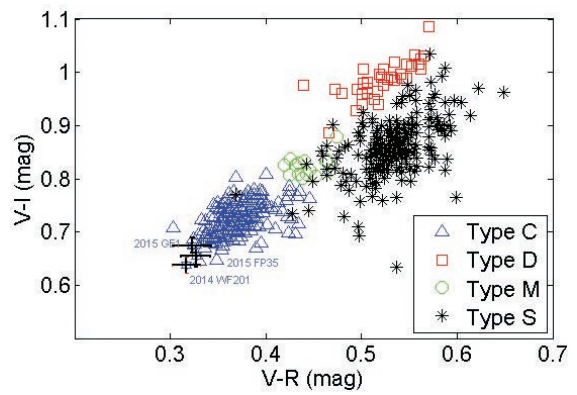
Neo 2015 FL35, the small dot amid the streaked images of stars, as observed on March 24th, 2015



Lightcurve of Neo 2015 FL35



Color of Neos from B-V and V-R color indexes



Color of Neos from V-I and V-R color indexes

roids; 2014 KS40, 2011 PT, 2015 FP, 2015 FP35, 2015 GE1, 2015 LA2, 2015 LG, and 2014 WF201 are likely to be C-type; and 2014 SC 324 is a D-type. 4 objects (2015 FL35, 2015 FF36, 2015 GA1, and 2015 LK) show the same color in R-filter or in V-filter (*see Table*).

Thus, out of over 13 NEOS for which KIKWAYA and collaborators were able to determine the color, 8 are associated with carbonaceous chondrites (type C). This number is in agreement with the observation of asteroids. 4 NEOS which are colorless give the evidence that new objects are constantly created in the main belt asteroid through collision process, or non-gravitational forces such as YORP, and Yarkovsky effect. Through YORP, one asteroid might start to rotate faster and faster until it breaks apart. Through Yarkovsky, one asteroid might shift from its original orbit and get into gravitational influence of other bodies that can bring it to separate in two pieces or more.

Stellar Astronomy

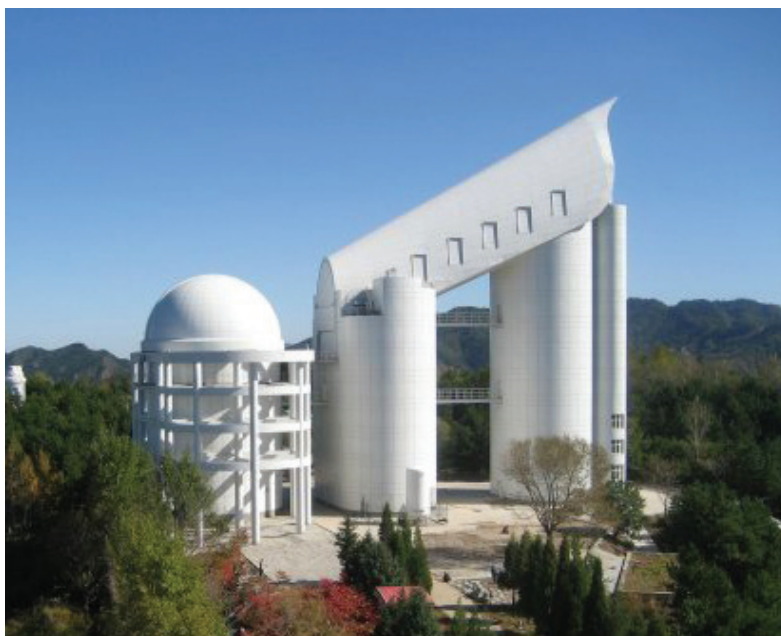
LAMOST observations in the Kepler field

Through their MKCLASS expert program, CORBALLY and Gray have been providing spectral classifications to feed into a database charting Kepler observations. The nearly continuous light curves

with micromagnitude precision provided by the space mission Kepler are revolutionizing our view of pulsating stars. They have revealed a vast sea of low-amplitude pulsation modes that were undetectable from Earth. The long time base of Kepler light curves allows for the accurate determination of the frequencies and amplitudes of pulsation modes needed for in-depth asteroseismic modeling. However, for an asteroseismic study to be successful, the first estimates of stellar parameters need to be known and they cannot be derived from the Kepler photometry itself. The Kepler Input Catalog provides values for the effective temperature, surface gravity, and metallicity,

but not always with sufficient accuracy. Moreover, information on the chemical composition and rotation rate is lacking. We are collecting low-resolution spectra for objects in the Kepler field of view with the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST, Xinglong observatory, China). All of the requested fields have now been observed at least once. Those observations have been described in a paper and provide a useful database for the whole astronomical community.

Gray and CORBALLY obtained automatically MK spectral



View of the Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST, also called the Guo Shou Jing Telescope) located at the Xinglong observatory (China). Picture taken by P. De Cat in December 2008

classifications for the 101,086 entries, so far, in the database for a total of 80,447 different targets. They are publishing a separate paper on these classifications.

P. De Cat, and 36 coauthors including C.J. CORBALLY and R. O. Gray (2015). LAMOST observations in the Kepler field. I. Database of low-resolution spectra, ApJS, 220, 19 (18pp)

<http://dx.doi.org/10.1088/00670049/220/1/19>

Lambda Bootis stars

CORBALLY and Gray are also continuing to explore Lambda Bootis stars in two separate collaborative projects. In the first they study the use of synthetic UV spectra to explore the physical basis for the classification of Lambda Boo-type stars. These are a group of late B to early F-type Population I dwarfs that show mild to extreme deficiencies of iron-peak elements (up to 2 dex), but their C, N, O, and S abundances are near solar. This intriguing stellar class has recently regained the spotlight because of the directly imaged planets around a confirmed Lambda Boo star, HR 8799, and a suggested Lambda Boo star Beta Pictoris. The discovery of a giant asteroid belt around Vega, another possible Lambda Boo star, also suggests hidden planets. The possible link between Lambda Boo stars and planet-bearing stars motivates

them to study Lambda Boo stars systematically. Since the peculiar nature of the prototype Lambda Bootis was first noticed in 1943, Lambda Boo candidates published in the literature have been selected using widely different criteria. The Lambda Boo label has been applied to almost any peculiar A-type stars that do not fit elsewhere. In order to determine the origin of Lambda Boo stars' unique abundance pattern and to better discriminate between theories explaining the Lambda Boo phenomenon, a consistent working definition of Lambda Boo stars is needed. CORBALLY, Gray and associates have re-evaluated all published Lambda Boo candidates and their available ultraviolet and visible spectra. Using observed and synthetic spectra, they explore the physical basis for the classification of Lambda Boo stars, and develop quantitative criteria that discriminate metal-poor stars from bona fide Lambda Boo stars. Based on these stricter Lambda Boo classification criteria, they conclude that neither Beta Pictoris nor Vega should be classified as Lambda Boo stars.

Kwang-Ping Cheng, James E. Neff, Dustin M. Johnson, Erik S. Tarbell, Christopher A. Romo, Arvind Prabhaker, Patricia A. Steele, Richard O. Gray, and Christopher J. Corbally, Utilizing Synthetic UV Spectra to Explore the Physical Basis for the Classification of Lambda Boo Stars, AJ submitted 2015

The literature on the Lambda Boo stars has grown to become somewhat heterogenous, as different authors have applied different criteria across the UV, optical and infrared regions to determine the membership status of Lambda Boo candidates. Together with a group of colleagues, CORBALLY and Gray aim to clear up the confusion by consulting the literature on 212 objects that have been considered as Lambda Boo candidates, and subsequently evaluating the evidence in favour of their admission to the Lambda Boo class. They obtained new spectra of ~90 of these candidates and classified them on the MK system to aid in the membership evaluations. The re-evaluation of the 212 objects resulted in 64 members and 103 non-members of the Lambda Boo class, with a further 45 stars for which membership status is unclear. CORBALLY, Gray and associates suggest observations for each of the stars in the latter category that will allow them to be confidently included or rejected from the class. Their reclassification facilitates homogenous analysis on group members, and represents the largest collection of confirmed Lambda Boo stars known.

Simon J. Murphy, Christopher J. Corbally, Richard O. Gray, Kwang-Ping Cheng, James E. Neff, Chris Koen, Charles A. Kuehn, Ian Newsome, Quinlin Riggs, An evaluation of the membership probability of

212 lambda Boo stars: I. A Catalogue, PASA, accepted 2015.

<http://arxiv.org/abs/1508.03633v2>

Horizontal Branch Stars

BROWN continues his research in the area of horizontal branch stars, which are older and more evolved stellar objects that the Sun will be one day become. Such older stars burn helium in their centers for about 10 million years in contrast to their younger progenitors, like the Sun, which burn hydrogen by about 10 billion years. How does a Sun-like star become one of these older horizontal branch (HB) stars, in this case a very hot horizontal branch star, known as an extreme horizontal branch star (EHB)? It is thought that low-mass stars (like the Sun) and intermediate-mass stars, after having expanded in size to become red giant stars, lose most of their outer envelopes just as they ignite helium in their centers, leaving a very thin hydrogen envelope which surrounds the burning helium core. However, the precise mechanism by which such extreme mass loss occurs remains undetermined. One explanation proposes that the outer envelopes of sdB/EHB progenitor stars are stripped off when two stars in a binary system (a double star system) interact. One star, having reached a certain stage in its evolution just before igniting its helium core, transfers

part of its mass to its companion. Another possibility is that a sdB/EHB progenitor, in this case, a single star, might lose most of its outer envelope due to a strong stellar wind. Then again, another single-star scenario suggests that a star might be enriched in

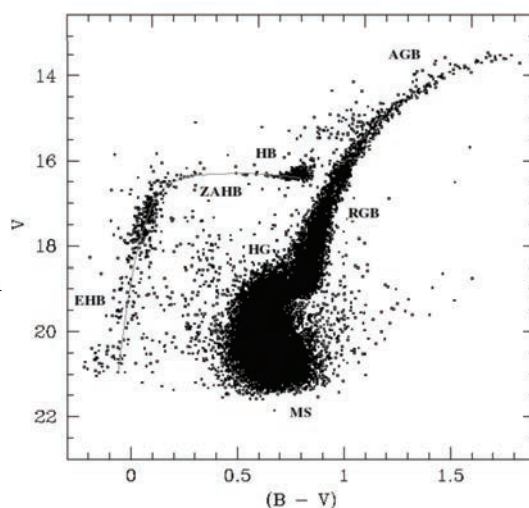


Figure B1: EHB/sdB stars are indicated in the CMD diagram of the globular cluster NGC 2808. Figure from Sosin et al (1997)

helium (after having formed from a cloud enriched by the ejecta of AGB stars from long ago), which might result in a very hot horizontal branch star.

This year, research continues with the ongoing use of the STAR95 computer program to simulate the evolution and production of EHB/sdB stars, including the incorporation of binary interactions. However, a new stellar evolution program, called MESA, is also gaining currency in research astronomy, and efforts are being

made to employ its impressive capabilities into BROWN's research. In particular, such a computer code includes the feature of stellar rotation (the rate at which a star spins about its axis) in its capabilities. As such, research this year is beginning to examine the effect

of stellar rotation in the production of sdB/EHB stars. Why? Observational studies of field stars and globular clusters over time have revealed a wide range of rotational velocities for HB stars, but there is a curious phenomenon observed --- such stars tend to group up into two different broad rotational velocities. In globular cluster horizontal branches, hot HB stars ($T_{\text{eff}} > 11000 \text{ K}$) tend to show lower rotational velocities ($v \sin i < 8-10 \text{ km s}^{-1}$) than cooler HB stars ($T_{\text{eff}} < 11000 \text{ K}$), whose rota-

tional velocities can approach $10 < v \sin i < 30-40 \text{ km s}^{-1}$, with most having more modest velocities of $v \sin i \sim 15-20 \text{ km s}^{-1}$ (Peterson 1983a, 1983b; Peterson 1985a, 1985b; Peterson et al 1995; Behr et al. 2000a, 2000b). This dichotomy in rotational velocities between hot and cool HB stars across the 11000 K transition point is also accompanied by a very big difference in chemical surface abundances for such stars. Moreover, the higher masses of cooler HB stars on the ZAHB, along with higher angular momenta, suggest

smaller amounts of mass lost from their progenitor RGB stars (e.g., stellar wind or binary processes) which might take away angular momentum. Greater clarity of the implied coupling between HBrotational velocities, the great variety of outer envelope masses of HB stars, and surface abundances across the $T_{\text{eff}} \sim 11000$ K transition could be obtained by studying the rotational properties and abundances of field sdB stars, corresponding to globular cluster EHB stars, in particular because most sdB stars are known to be slow rotators. Efforts are underway to do a binary population synthesis study, based on the sdB formation channels discussed by Han et al. (2002, 2003), in order to investigate the role of binary interactions in affecting the rotational rates of sdB stars and how this can contribute to the bimodality in rotational velocities in field BHB stars as in globular cluster BHB stars.

Asteroseismology

Asteroseismology is a technique by which pulsations in the luminosity of stars, analogous to earthquakes in the ground, are used to study the interiors of such objects. In turn, such investigations can yield much information about the physical properties of those stars, most especially their masses. The masses can then be used to

verify empirically the viability of theoretical predictions (including masses) by which such objects form. Continuing with observations of pulsating sdB stars conducted in 2014, BOYLE and BROWN conducted a 3-day observing run during January 14-16 2015 at VATT on Mt. Graham in order to study the pulsating sdB star PG 1047+003. This time they used the VATT 4K CCD camera. At the moment image data reduction continues to take place. It is hoped that the determina-

tion of the mass of such pulsating sdB/EHB stars will contribute to the determination of an empirical mass distribution of hot subdwarfs, something which could then give greater clarity about the formation channels of such objects, as seen in the Figure B2.

Stellar Observations

Vatican Observatory staff, particularly BOYLE and JANUSZ have been collaborating in the Vilnius photometry project of the open cluster in the M39, which began in the late 1990's. This year the team began publishing updated data from almost two decades of observations.

These include observing light of different colors (wave-lengths/frequencies) in eight intermediate-band filters of the Stromvil (Stromgren + Vilnius) system (each filter being sensitive to a particular range of wave-lengths of light), which were obtained during two separate periods of observation on the nights of 2007 November 2-8 (run "SQ") and 2008 October 28 - November 5 (run "SU"), using a 4K CCD camera on the 1.8m VATT telescope on Mt. Graham, Arizona.

M39 had been observed previously in seven filters of the Vilnius photometric system U,P,X,Y,Z,V and S, supplemented by the broad-band I filter, in December of 1999

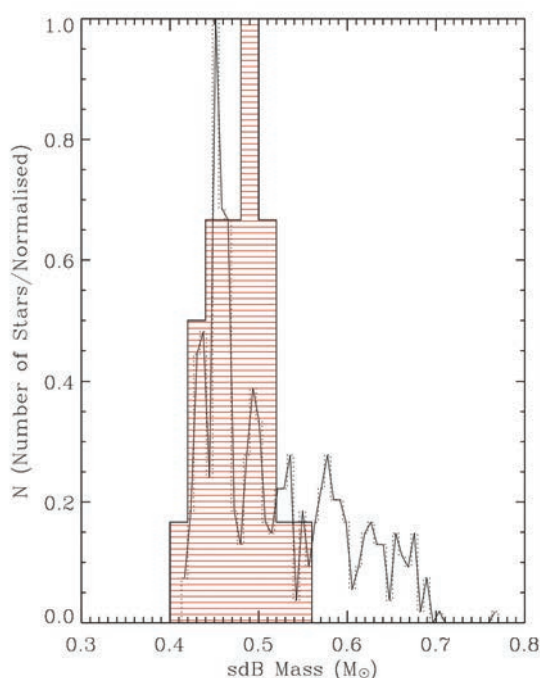
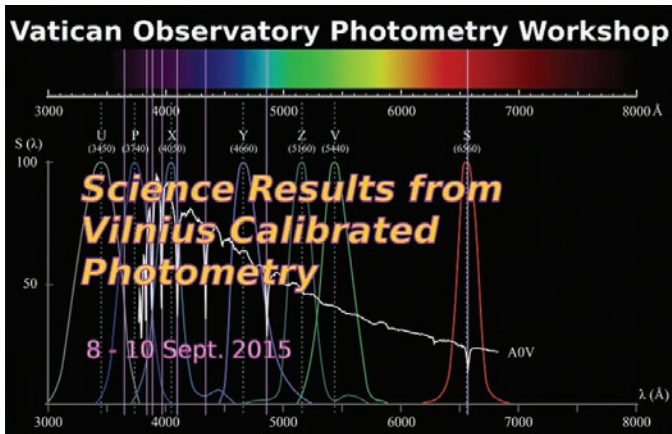


Figure B2: The black curve gives a theoretical approximation for the sdB mass distribution of a solar metallicity population consisting of a 5 Gyr subpopulation and a 13 Gyr subpopulation, taking into consideration an episode of recent star formation. The red histogram shows the observational mass distribution of sdB stars as a result of the asteroseismology of nine EC 14026 pulsators from Fontaine et al. (2006). The distributions are normalized here



with a 2Kx2K CCD camera on the 1m Ritchey telescope at the USNO Flagstaff Station (Arizona), which gives the 22' diameter field view of the sky. Repeated observations in the Vilnius filters were also done with the same telescope and a new 2Kx2K CCD camera in March of 2009 for which well-calibrated CCD data were obtained only for filters Y, Z, V, S because of the presence of cirrus clouds. Additional frames in the Vilnius filters U, Y, V were taken for the central part of the field (12'x12') in December of 2008 with a 4K CCD camera on the 1.8m Vatican Advanced Technology Telescope (VATT) on Mt. Graham (Arizona).

Stellar photometry in the Vilnius Photometric System requires one percent quality for deriving luminosity class and spectral type subclass. The team use such existing photometry of the open cluster M 67 to calibrate new CCD observations at the Vatican Advanced Technology Telescope (VATT)

37 #4, 2005). Recently BOYLE, JANUSZ and associates have developed a “tie-in” observational practice to apply the zero-point and color transformation of the M 67 observations to neighboring starfields of interest that have no existing photometry. Sky transparency must remain constant to better than one percent during a round of short exposures in a filter between the field having calibrated photometry and the new field having no photometry as if the new field was exposed simultaneously with the master field. Proof of success for this “tie-in” method is shown with the master field being M 67 and the “tie-in” field being the nearby extended “corona” area. The distinctive color-magnitude diagrams of the old open cluster M 67 reveal the sensitivity to having constant sky transparency during the round of short exposures on M 67 and its extended area. For the extended area has the same form in its color-magnitude diagram as

for correcting the flat-fielding zero-point and deriving the color-transformation in this intermediate-band, seven filter system (Boyle et al., BAAS

M 67. So variation in sky transparency shows displacement on the color-magnitude diagrams at the one percent quality. The team will attempt new analysis concerning evolution of this very old open cluster (2.56 Gyr, WEBDA, <http://www.univie.ac.at/webda/>) and the surrounding “coronal” extent with reference to previous work by Chupina and Vereshchagin (Astron. Astrophys, 334, 552, 1998).

Interstellar extinction

The interstellar extinction is investigated in a 1.5 deg² area in the direction of the open cluster M29 (NGC 6913) in Cygnus, centered at R.A. = 20^h 24^m, decl. = +38° 30'. The study conducted by BOYLE, JANUSZ and associates is based on photometric classification of 1110 stars in spectral and luminosity classes down to V = 19 mag using photometry in the Vilnius seven-color system published in Paper I (Milašius et al. 2013). Additionally, in the same area the extinction is investigated using 1147 red clump giants (RCGs), identified by combining selected two-color diagrams of the 2MASS and Spitzer surveys. The investigated area is divided into three parts with different obscuration and in these directions the extinction versus distance plots up to 5 kpc are presented. In the whole area a steep rise of the extinction is observed at a distance of ~800 pc; it should be related to dust clouds in the Great Cygnus

Rift obscuring the stars behind it by $A_V = 4.0\text{--}4.7$ mag. RCGs exhibit much larger extinction values, up to $A_{K_s} = 1.2\text{--}1.3$ mag in the more transparent areas and 1.45 mag in the northeastern part of the area and above it, where the dust cloud TGU H466 is located. These values of A_{K_s} correspond to $A_V = 10\text{--}12$ mag. The study does not exclude the possibility that the largest values of the extinction belong not to RCGs but to some contaminating intrinsically red AGB stars which penetrated through the applied RCG selection constraints. The extinction in the TGU H466 cloud probably originates in two cloud systems—the Great Cygnus Rift at 800 pc and the Cygnus X complex of dust and molecular clouds at 1.3–1.5 kpc.

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Straizys, V.; Maskoliunas, M.; Boyle, R. P.; Prada Moroni, P. G.; Tognelli, E.; Zdanavicius, K.; Zdanavicius, J.; Laugalys, V.; Kazlauskas, A. (2015). VizieR Online Data Catalog: NGC 7129 Vilnius photometry (Straizys+, 2014) VizieR On-line Data Catalog: J/MNRAS/438/1848

Straizys, V.; Vrba, F. J.; BOYLE, R. P.; Milasius, K.; Černis, K.; Zdanavicius, K.; Zdanavicius, J.; Kazlauskas, A.; Macijauskas, M.; JANUSZ, R. Interstellar Extinction in the Direction of the Open Cluster M29, (2015). The Astronomical Journal, Volume 149, Issue 5, article id. 161.

Galaxies

Jellyfish galaxy

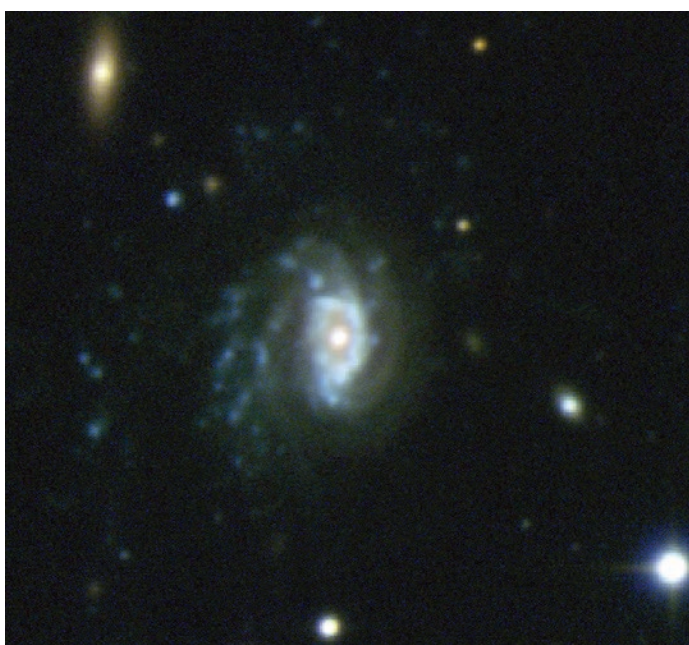
Together with a dedicated research group OMIZZOLO is working on the nearby clusters of galaxies, deepening their analysis

of an X-ray selected sample of 76 clusters. Following on from their publication of catalogs for galaxies in every cluster, the group has moved onto studying the properties of the galaxies and of the cluster, paying particular attention to the star formation rate, the interaction of the galaxies within the cluster, the surface photometry of the galaxies and the spectral properties and evolution of the galaxies in the clusters.

In the past year they have focused their research on a particular class of galaxies, the so called Jellyfish galaxies (fig. 1). An interesting phenomenon is occurring in these galaxies whereby they are losing part of their stars and gas. As part of the GASP project (Dissecting Gas Stripping Phenomena in galaxies with MUSE) OMIZZOLO and his team are able to use MUSE (Multi Unit Spectroscopic Explorer), at the European Southern Observatory in Chile, to further investigate these galaxies. A large amount of data is arriving and the team are currently elaborating it.

Galaxies that are being stripped of their gas can sometimes be recognized from their optical appearance. Extreme examples of stripped galaxies are the so-called “jellyfish galaxies”, that exhibit tentacles of debris material with a characteristic jellyfish morphology. OMIZZOLO and colleagues have conducted the first

systematic search for galaxies that are being stripped of their gas at low- z ($z=0.04-0.07$) in different environments, selecting galaxies with varying degrees of morphological evidence for stripping.



The Jellyfish Galaxy JO201 is located in the galaxy cluster Abell 85

They have visually inspected B and V-band images and identified 344 candidates in 71 galaxy clusters of the OMEGAWINGS+WINGS sample and 75 candidates in groups and lower mass structures in the PM2GC sample. They present the atlas of stripping candidates and a first analysis of their environment and their basic properties, such as morphologies, star formation rates and galaxy stellar masses. Candidates are found in all clusters and at all clu-

stercentric radii, and their number does not correlate with the cluster velocity dispersion σ or X-ray luminosity L_X . Interestingly, convincing cases of candidates are also found in groups and lower mass haloes ($10^{11}-10^{14} M_{\text{sun}}$),

although the physical mechanism at work needs to be securely identified. All the candidates are disk-like, have stellar masses ranging from $\log M/M_{\text{sun}} < 9$ to > 11.5 and the majority of them form stars at a rate that is on average a factor of 2 higher (2.5 sigma) com-

pared to non-stripped galaxies of similar mass. The few post-starburst and passive candidates have weak stripping evidence. OMIZZOLO and colleagues conclude that the stripping phenomenon is ubiquitous in clusters and could be present even in groups and low mass haloes. Further studies will reveal the physics of the gas stripping and clarify the mechanisms at work.

B.M. Poggianti, G. Fasano, A. Omizzolo, M. Gullieuszik, D. Bettoni, A. Moretti, A. Paccagnella, Y. L. Jaffe', B. Vulcani, J. Fritz, W. Couch, M. D'Onofrio Jellyfish galaxy candidates at low redshift The Astronomical Journal, in press.

WINGS galaxy clusters

The Wide-field Nearby Galaxy-cluster Survey (WINGS) is a wide-field multi-wavelength survey of X-ray selected clusters at $z = 0.04-0.07$. The original $34' \times 34'$ WINGS field-of-view has now been extended to cover a 1 sq.deg field with both photometry and spectroscopy. In this paper OMIZZOLO and colleagues present the Johnson B and V-band OmegaCAM/VST observations of 46 WINGS clusters, together with the data reduction, data quality and SExtractor photometric catalogs. With a median seeing of 1arcsec in both bands, their 25-minute exposures in each band typically reach the 50% completeness level at $V=23.1$ mag. The quality of the astrometric and photometric accuracy has been verified by comparison with the 2MASS as well as with SDSS astrometry, and SDSS and previous WINGS imaging. Star/galaxy separation and sky-subtraction procedures have been tested by comparing with previous WINGS data. The SExtractor photometric catalogues are publicly available at the CDS, and will be included in the next release of the WINGS databa-

se on the VO together with the OmegaCAM reduced images. These data form the basis for a large ongoing spectroscopic campaign with AAOmega/AAT and is being employed for a variety of studies.

M. Gullieuszik, B. Poggianti, G. Fasano, S. Zaggia, A. Paccagnella, A. Moretti, D. Bettoni, M. D'Onofrio, W.J. Couch, B. Vulcani, J. Fritz, A. OMIZZOLO, A. Baruffolo, P. Schipani, M. Capaccioli, J. Varela (2015). OmegaWINGS: OmegaCAM@VST observations of WINGS galaxy clusters, A&A, 581, A41

In a separate paper OMIZZOLO and team present the Morphology-Density and Morphology-Radius relations (T-Sigma and T-R, respectively) obtained from the WINGS database of galaxies in nearby clusters. Aiming to achieve the best statistics, they exploit the whole sample of galaxies brighter than $M_V = -19.5$ (5,504 objects), stacking up the 76 clusters of the WINGS survey altogether. Using this global cluster sample, we find that the T-Sigma relation holds only in the inner cluster regions ($R < 1/3 \times R_{200}$), while the T-R relation keeps almost unchanged over the whole range of local density. A couple of tests and two sets of numerical simulations support the robustness of these results against the effects of the limited cluster area coverage of the WINGS imaging. The above

mentioned results hold for all cluster masses (X-ray luminosity and velocity dispersion) and all galaxy stellar masses (M). The strength of the T-Sigma relation (where present) increases with increasing M, while this effect is not found for the T-R relation. Noticeably, the absence/presence of subclustering determines the presence/absence of the T-Sigma relation outside the inner cluster regions, leading us to the general conclusion that the link between morphology and local density is preserved just in dynamically evolved regions. They hypothesize that some mechanism of morphological broadening/redistribution operates in the intermediate/outer regions of substructured (non relaxed) clusters, producing a strong weakening of the T-Sigma relation.

G. Fasano, B.M. Poggianti, D. Bettoni, M. Donofrio, A. Dressler, B. Vulcani, A. Moretti, M. Gullieuszik, J. Fritz, A. Omizzolo, A. Cava, W.J. Couch, M. Ramella, A. Biviano. Morphological Fractions of Galaxies in WINGS Clusters: revisiting the Morphology-Density Paradigm MNRAS, in press.

Cosmology

Extended Theories of Gravity

In this last year GIONTI has worked on a major project studying extended theories of gravity, which are a direct derivation ultimately from String Theory.

Although these concepts look quite complicated, in reality they can be explained in a comprehensible way. Extended theories of gravity constitute an extension of Einstein's Theory of General Relativity. In fact, General Relativity continues to be a good theory which describes our universe on large scales. But recent observations have shown that, in order to explain the rotation curve (the orbital velocities of objects as a function of their distances from the galactic center) of galaxies, more matter is needed than can be accounted for by observed matter; this additional matter is called Dark Matter. Moreover, recent observations indicate that the expansion of the Universe is accelerating; this requires the introduction of some extra energy, called Dark Energy. Dark Matter and Dark Energy imply certain corrections to Einstein's General Relativity whereby gravity could be better described. One branch among these theories and extensions of General Relativity is called Extended Theories of Gravity.

Extended Theories of Gravity have been criticized as being "phenomenological" theories because they are seen as "ad hoc" explanations to problems; that is, these theories are different for different problems, and, therefore, they do not stem from a unique all-encompassing theory, which explains all cases. In particular, there are some doubts in the

scientific community that such theories can derive from a fundamental theory of gravity such as Quantum Gravity. Quantum Gravity seeks to describe how gravity behaves at the Planck length (the threshold below which the fabric of space-time becomes coarse and for which quantum mechanics has to be taken into account to describe gravity rather than classical theories, roughly at 1.6×10^{-35} m, or 100 millionth trillionth of a meter), close to the time of the Big-Bang; however, currently there has been no experimentally tested theory of Quantum Gravity, even though there are many theories surrounding it.

GIONTI and his collaborators have worked on showing that a class of non-phenomenological extended theories of gravity can exist, their being a low-energy limit of a theory (or better stated, a proposal for a theory...) of Quantum Gravity (in this particular case, String Theory). The starting point for such a class of theories is 'Bosonic String Theory', which is a theory of Quantum Gravity. It seeks to understand how the gravitational force is mediated via particles within the unified context of the other fundamental forces of nature. It can exhibit duality symmetry transformations, by which it can be described and related to very different theories which apply to very different regimes of nature.

This means that it is possible to derive a "Dual Theory" to the original Bosonic String Theory. "The new theory is mathematically not equivalent to the original theory, but solutions to its equations of motion are also solutions of its relative "Dual Theory".

At very small scales (the quantum level), it is necessary to require the condition that certain properties (symmetry) of Bosonic String Theory be preserved (the conformal invariance). This makes it possible to derive a set of equations that look like Einstein Equations. Thus one can say that the gravitational field is contained in Bosonic String Theory. This effective gravitational theory has duality symmetries as well, which means that it can connect two very different regimes in nature. Within the context of a FLRW cosmology (the homogeneous and isotropic model of our universe, known as the Standard Model of Cosmology), Gasperini and Veneziano proved that duality models exhibit Pre Big-Bang solutions, which means that aside from the solution for $t > 0$, there is a solution for $t < 0$. Therefore, if there is a Universe for $t > 0$, a universe for $t < 0$ could exist (Pre Big-Bang branch). GIONTI and associates are studying the class of extended theories of gravity which are a derivation of the gravitational low energy theory of gravity of bosonic string theory. In particular, they are now analy-

zing extended theories of gravity evaluated on a flat Friedmann, Lemaitre, Robertson, Walker metric (F.L.R.W.), which is the currently accepted model of the universe with matter in it. Imposing some Noether Symmetries and choosing particular cases, they arrive at extended theories of gravity evaluated on F.L.R.W. metric, which exhibit a duality symmetry transformations as the Gasperini-Veneziano model. This model can be explicitly solved, and exact cosmological solutions are found. In conclusion they have found a particular model in which the duality symmetry transformations are parity inversions (mirror reflection).

Capozziello, S., GIONTI, G., Vernieri, D. String duality transformation in $F(R)$ gravity from Noether symmetry approach. arXiv:1508.00441. Submitted to JCAP (Journal of Cosmology and Astroparticle Physics).

Capozziello, S., GIONTI, G., Vernieri, D. (2015). String Theory based $F(R)$ gravity with duality transformation. Proceeding of the conference "Fiat Lux", Rome, June 3-5. E. Fazio and R. Pascual, eds., Nova Science Publishers.

The origin of matter

This year HELLER and three colleagues reflected on the question of the origin of matter. As it is well known, the dark matter and dark energy problem is now

dominating the research in cosmology. This makes the question of the origin of mass-energy content of the universe more urgent than ever. There are two philosophies regarding this question: according to Mach's principle it is matter that generates geometry of space-time, and according to Wheeler's geometrodynamics some configurations of space-time geometry are to be interpreted as its material content. Neither of these philosophies has led to success. We have demonstrated that there exists a generalization of geometry that reconciles these two seemingly opposite standpoints. The geometry we constructed is a version of the so called noncommutative geometry. It is a mathematically elegant structure, and has a nice physical interpretation: in its construction the Lorentz symmetries, that are fundamental for relativistic physics, are incorporated. Basing on this geometry, we have deduced generalized Einstein equations with no matter sources and found its two exact solutions. It turns out that these equations contain additional terms (with respect to the standard vacuum Einstein equations) which are naturally interpreted as matter sources. In this way, matter is created out of pure geometry in agreement with Wheeler's philosophy. On the other hand, the creation of matter, being a global effect, also satisfies one of the strongest formulations of Mach's Principle.

Heller, M., Miller, T., Pysiak, L., Sasin, W., (2015). Geometry and General Relativity in the Groupoid Model with a Finite Structure Group, Canadian Journal of Physics 93(1), 2015, 43-54.

Interdisciplinary Studies

Human science

The Human Sentience Project (<http://thehumansentience-project.org>) of Margaret Boone Rappaport and CORBALLY this year saw the publication in Zygon of their model of Matrix Thinking, one derived from the theoretical concepts of Enhanced Working Memory, the human Socio-Cognitive Niche and Deep Social Mind, and placed in a context of the Social Brain Hypothesis. They used an invitation to address the Jung Club of Philadelphia to explore some of the origins of such "modern thinking" in Homo sapiens via evolutionary biology, cognitive archaeology, and analytic theory. The connections between Matrix Thinking, Jungian analysis, and religious experience were discussed during the lively afternoon seminar.

Cognitive archaeology again played a vital role in helping Rappaport and CORBALLY address a deceptively simple question from an astronomy student, "When did hominins first look up and see constellations?" Modern research on children's cognitive development pointed to a time

period in human evolution when hominins had likely developed the ability to see figures in groups of bright stars. Before that time, they probably couldn't do it, although earlier members of the genus Homo may have been able to locate and remember individual stars based on color, brightness, and position, much as done by the Polynesian ocean navigators. They postulate that having the complex skill of seeing constellations could significantly pre-date the generally accepted paintings of such in the Caves at Lascaux (at around 17,300 years ago), to 35-40,000 years before the present.

History of astronomy

The figure of the Jesuit astronomer Angelo Secchi (1818-1878) and his contribution to the development of astrophysics have been further studied by CHINNICI, on the base of the archival fund kept at the Gregorian University; his interactions with instrument-makers of his time, especially with Merz firm in Munich, have been explored. Moreover, on the occasion of the 80th anniversary of the Specola Vaticana in Castel Gandolfo, CHINNICI examined some lesser known aspects of the recent Vatican Observatory history, especially the role of Pius XI in deciding to move the headquarters to Villa Barberini.

Digitization of Vatican Observatory Archive

The painstaking task of keeping the Vatican Observatory Archives up-to-date both in real and digital terms is being studiously brought forward by MAFFEO and OMIZZOLO. All documentation pertaining to the Vatican Observatory from its foundation to date, and the operation of its original “Carte du Ciel” telescope have been completed. MAFFEO has also begun the scrupulous task of archiving documentation of past directors, from Cardinal Maffi (appointed by Pope Pius X), to Father George COYNE, S.J. under whose governance the VATT was founded in Arizona.

OMIZZOLO is continuing in the digitization of the VO archives, and is currently digitizing

plates produced by the Double Astrograph. This telescope is suitable for astrophotography but also for spectroscopy of all the objects in the field of view of the instrument (in a way similar to what happens with a Schmidt Telescope).

Finally, reflecting the Vatican Observatory’s new initiatives, MAFFEO has also begun an archive dedicated to Science and Faith containing all of the material and initiatives in this field produced by the Pope’s astronomers.



Maffeo in the VO archives, Castel Gandolfo, Italy

INSTRUMENTATION AND TECHNICAL SERVICES

Maintenance

Several corrective maintenance operations were performed. The secondary mirror quasi-hexapod's LVDTs were cleaned after the actuators ran into hard limits. The power cable to the cell fans was reconnected, having been ripped out. GRAY repaired the east deck, and the dome wheels. In order to eliminate obstruction in VATT's northerly light path, LBT's all-sky camera was moved and GRAY removed a fixed metal ladder, designed for easier access to the outside of the dome. A lightning strike took out the microwave tower causing extensive problems at MGIO but, fortunately, direct damage to VATT was limited to our fire alarm system which had to be replaced by UA (covered by insurance). Three windows had to be replaced in October because they had sagged allowing rainwater into the building.

Instrumentation and New Equipment

In collaboration with Elizabeth (Betsy) Green, University of Arizona, three Schott 8612 filters are now available for VATT's imager. Two filters were fitted in holders and tested. The third remains unmounted, as a spare. A 350 um longpass filter (ZUL0350) was acquired for VATT's spectrograph.

The flat-field screen was equipped with a new light source using 5 visible and 2 UV LED's plus an incandescent lamp. The source was mounted on top of VATT's secondary mirror assembly. It is run electronically by Arduino with an Ethernet link, so that the telescope operator can control the source with a GUI from any computer in VATT's network, adjusting intensities of each element individually.

GRAY built a new winching system which allows for safe handling of VATT's spectrograph by a single person during instrument changes.

The previously installed Apogee/Andor Aspen CG8050 guider camera for VATT's spectrograph had been advertised as having an rms noise level of 6 electrons.

During commissioning we found that the delivered camera had an rms noise of 13.9 electrons, and a dark current of 0.0082 electrons per pixel per second, allowing us to acquire objects of the 18th magnitude. Consequently, the camera was returned to its manufacturer this summer. The reconfigured camera has an rms noise of 8.9 electrons, and a dark current of 0.0010 electrons per pixel per second. Johnson installed a new guiding software package, viz., PHD version 2.0. The new setup allows to acquire objects of the 19th magnitude.

PEPSI

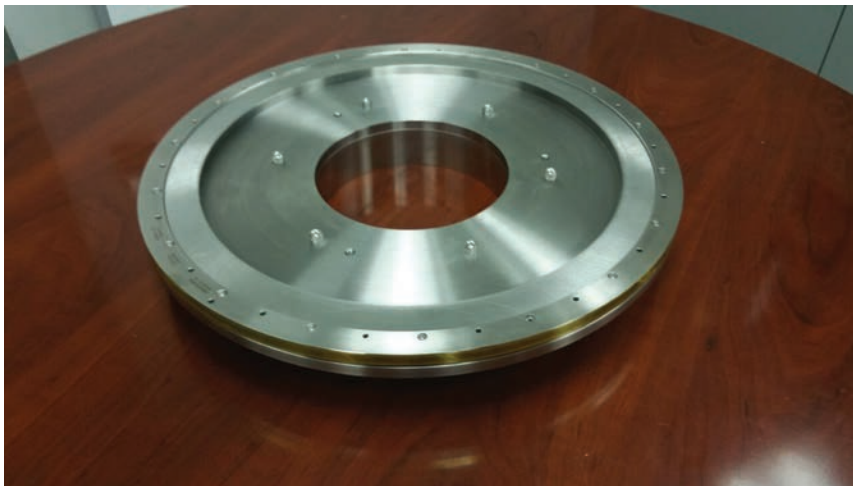
The commissioning of the Potsdam Echelle Polarimetric and Spectrographic Instrument (PEPSI) continues. The 500-m fiber link to VATT has been proved most useful in the process.



Winching system for safe instrument changes of VATT's spectrograph



New brake for VATT's azimuth axis



New encoder ring for VATT's elevation axis

PEPSI achieves unprecedented resolution in stellar spectra, reaching 270,000 with a signal-to-noise ratio of 3,000:1 on μ Leonis (3.9 mag). This is better than the National Solar Observatory's solar spectrum signal-to-noise ratio. With VATT and the current fibers, the resolution reaches 200,000.

A compelling science case for an automated VATT fiber-linked to PEPSI would be radial velocity measurements of exoplanetary systems. The potential of the setup for this program is being assessed, with observing runs in September and December 2015, and evaluation in 2016. PEPSI's commissioning will continue into 2017.

VATT Upgrades

VATT's major overhaul, started in 2014, reached several milestones this year. This major operation is part of a larger plan for developing a network of advanced telescopes in Arizona, the Arizona Robotic Telescope Network (ARTN). Steward Observatory linked the project with STELLARVIEW, the Global Astronomical Network for Space Situation Awareness. The project principal investigator is Benjamin Weiner and his co-PI is Michael Hart. The project manager is Victor Gasho. John Codona is a senior software engineer. They have joined forces with Steward Observatory's Mountain Operations team working on ARTN. Ben Weiner is compiling a list of possible science cases and the respective engineering requirements. Furthermore, a Statement of Work was signed with Petr Kubanek, the chief developer of the RTS2 software package.

Work progressed on the elevation and azimuth encoders. A set of encoders, which was specified and purchased from Renishaw in 2014, was supplemented with mechanical interfaces. At the same time, brakes were added to the azimuth axis, rectifying an oversight of the original setup. The blueprints were drawn up by FRANZ and the parts were machined at the Arizona Research Laboratories. VATT's elevation and azimuth

drive amplifiers were tested and tuned using a Next Generation telescope control system local control unit built for the Kuiper 61" telescope.

Much work was concentrated on the Kuiper 61" telescope. It was overhauled this summer and commissioning of the NGTCS with RTS2 started in September. Considering that 61" is a simpler telescope than VATT, this represents a major milestone for ARTN, allowing the team to develop the project in a logical progression.

VATT's overall automation architecture reached a milestone. DUFFEK produced a safety ladder-logic design based on his robotic topology, taking into account lessons learned from the Kuiper 61" commissioning. An internal design review was performed prior to the production of the mount control electronics by Steward Observatory's Engineering and Technical Services.

New arrivals for Meteorite Collection and Laboratory

The Vatican meteorite collection welcomed several new meteorites this past year, including the two largest meteorites currently in the collection. These two pieces are both samples of Campo del Cielo, an iron meteorite from Argentina, and weigh 24 kg and 14 kg. We also added to the collection a beautiful piece of the iron meteorite

Sikhote-Alin, several pieces of the iron meteorite Nantan, and the pallasites Seymchan and Brenham. Another benefactor, Todd Johnson of Illinois, donated a small piece of the Chelyabinsk meteorite which fell in Russia in 2013. It is a piece of the object that exploded over the city of Chelyabinsk, destroying windows throughout the region and causing many injuries, mostly from shards of glass.



All of the meteorites donated to the Vatican meteorite collection in 2015. The two largest are both pieces of the iron meteorite Campo del Cielo and are the heaviest meteorites currently in the Vatican collection

All of these meteorites were the result of the generosity of benefactors who donated them to us. The Vatican Observatory relies heavily on such generosity to grow the meteorite collection

and to acquire new scientifically important samples.

The Meteorite Laboratory also acquired a new NextEngine laser scanner for creating 3D computer models of meteorites, from which bulk volume and density can be calculated. This device replaces the glass bead technique (pioneered at the Vatican Observatory) for measuring bulk density. There is virtually no physical contact with the meteorite, enabling the study of very fragile specimens that could not have been immersed in glass beads. This new device also enables the study of very large specimens that would not fit in a bead container, and is precise enough to measure very small specimens. The device and its twins at NASA Johnson Space Center and the University of Central Florida have already been used to study dozens of Apollo moon rocks and scores of meteorites.

Maintenance of Zeiss Double Astrograph

Work also continued this year on the Zeiss Double Astrograph telescope on the roof of the Papal Summer Apostolic Palace. The primary mirror of the telescope was re-aluminised on 2014. This year, the entire electrical wiring of the telescope was replaced, along with the addition of a new circuit panel and repair of the telescope's clock drive. Finally, a video screen monitor was installed in the dome

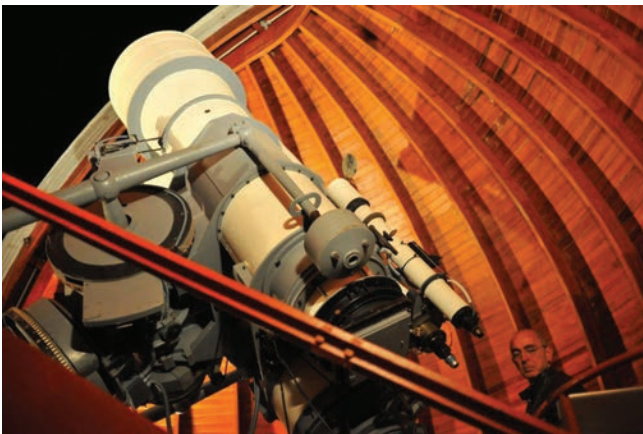


The new NextEngine laser scanner in the meteorite laboratory

in order to beam images taken by a video camera, which can be attached to the eye piece of the telescope. The same has been done in the dome of the Visuale telescope on the terrace of the papal palace. This allows for large groups of visitors to see a particular image made by the telescope when large numbers of people make it impractical to allow people onto the telescope platform.



Maintenance work on the Zeiss Double Astrograph, Castel Gandolfo



OBSERVATORY AND STAFF ACTIVITIES

Internal Symposium for 80th anniversary of VO

On September 29, 1935, Pope Pius XI officially inaugurated the new headquarters of the Specola Vaticana in the Papal Palace of Castel Gandolfo. With new telescopes, a new spectra laboratory, and a young staff of Jesuit scientists, this inauguration marked the beginning of an intense period of scientific achievements at the Vatican Observatory.

Eighty years later, the members of the current Vatican Observatory gathered around Pope Francis to celebrate this anniversary at the conclusion of an internal symposium that explored the scientific and cultural work that is being brought forward by the Observatory today.

The symposium gathered all of the staff from the Vatican Observatory's twin locations in Castel Gandolfo and in Tucson as well as the adjunct scholars to the Vatican Observatory headquarters. Stretching over four days from September 14-18, papers and presentations were given by various staff members on astronomy, cosmology, philosophy and theology.

Addressing participants at the end of the symposium in a special, private audience Pope Francis noted that "rather than a (scientific)

problem to be solved, the world is a joyful mystery to be contemplated with pleasure and praise".

The Pope had particular words of praise for the Vatican Observatory Summer Schools (VOSS), which over the 30 years have become a precious opportunity for young astronomers from across the world to dialogue and collaborate in the search of truth.

Pope Francis' interest was particularly struck by the emphasis given in the symposium to the importance of communicating the message that the Church and its pastors are embracing, encouraging and promoting authentic science.

He concluded his address by telling the participants that it was very important for them to share the gift of their scientific knowledge of the universe with other people, freely giving what they received for free. "I encourage you", he said, "to continue along this journey of exploring our universe".



Scientists and staff attend and Internal Symposium marking 80th anniversary of new Specola headquarters in Castel Gandolfo, Italy

Appointments

FUNES has returned to his home province in Argentina, where he takes up duties at the Jesuit university in Cordoba.

Following his six years of service as Vice Director for Administration in Castel Gandolfo, MAJ has begun a well-deserved sabbatical at Loyola Marymount University in Los Angeles.

Giuseppe KOCH, who had served as the rector of the Jesuit Community of the Vatican Observatory and assistant for administration in Castel Gandolfo in the 2000s, has returned to the Vatican Observatory as of November. He takes up duties as the Librarian and Curator of Rare Books.

CONSOLMAGNO was named chair of the Mars Task Group, a subcommittee of the IAU Working Group on Planetary System Nomenclature (on which he has served since 2008).

GIONTI was appointed associated member of the theoretical group division of the I.N.F.N. (Italian National Institute for Nuclear Physics) at the National Laboratories of Frascati. He works there in collaboration with Dr. Stefano Bellucci.

Four scientists who have close ties to the Vatican Observatory were named adjunct members of the Observatory in 2015. These include: Aldo Altamore, Professor of Physics at the University of Roma Tre, who has collaborated closely in the history of astronomy with MAFFEO; Michelle Francl-Donnay, Professor of Chemistry at Bryn Mawr University, Philadelphia PA, an expert in computational chemistry with applications to interstellar clouds, who is also a noted writer on Catholic spirituality; Fr. José Funes SJ, director emeritus of the Specola who will continue his research in galaxies at the University of Cordoba, Argentina; and Fr. Robert Janusz SJ, an expert in computational science and the philosophy of science who is a close collaborator of BOYLE in the automated reduction of astronomical data.

In memoriam

Father Andrew P. WHITMAN, S.J. was called to eternal life on January 7, 2015, in Lafayette, Louisiana. He was 88 years old, a Jesuit for 63 years and a priest for 51 years.

Andy was a part of the Vatican Observatory for many years. In 1982-83 he took a sabbatical year at the Vatican Observatory; in 1996 he joined the staff of the Vatican Observatory and was stationed at the Vatican Observatory Research Group at the University of Arizona as a research scientist and in 1998 he also took on duties of an administrator for the VORG. Andy's career in the field of mathematics (specializing in Lie Algebra) was a truly distinguished one, having taught at Loyola University in New Orleans, the University of Houston, and the Pontificia Universidade Católica of Rio de Janeiro, where he was a tenured Associate Professor before he joined the Specola. Even after joining us, he still maintained his work with a remote mission outpost up the Amazon River.

One of Andy's areas of passionate interest was the Clavius Group, which he co-founded in 1963. This group of lay and religious mathematicians meet each summer as a Faith Community who do mathematics, including research projects and seminars on current topics of interest to the group. His involvement with the

group reflected his lifelong dedication to linking mathematics and faith. In 2003, Andy wrote: "...if this does not seem too exaggerated, my mathematics that I do is a prayer. One faces naked and beautiful truth when he does mathematics. One cannot win in this game by banging the table, or claiming the wisdom of old age, or pretending. Either your logic works and can be acknowledged by others, or it does not. And when it does, say after a proof that carries through several pages, you are in the presence of the Divine."

In 2010, ill health required him to return to the South, eventually to the St. Alphonsus Rodriguez Pavilion in Grand Coteau. For as long as he could, he continued his work on a textbook in Lie Algebra. He was humbled and gratified in 2011, when he was awarded the Holy Cross Pro Ecclesia et Pontifice by Pope Benedict XVI in recognition of his service at the Vatican Observatory.

He was a man of many talents and enormous grace; we miss him.

Presentations, Academic Activities and Conference Participation

May 19 to 21, twenty three participants in the VISTA Variables of the Via Lactea Survey (VVS) held a workshop at the Specola headquarters in Castel Gandolfo. The VVS is an ESO public near-infrared variability survey that is sampling the galactic bulge and an adjacent section

of the Southern Galactic plane. Started in 2010, it uses the 4m VISTA telescope at ESO Paranal Observatory, in Chile, where it is scheduled to collect over 2000 hours of execution time. The main scientific aim of the VVV survey is to unveil the 3-D structure of the inner Milky Way; however, due to the large size of this survey, and the variety of interesting astrophysical objects found in the central Galactic regions, a dozen additional survey goals have also been defined by the team. The survey will complete its data taking in the next couple of years, thus the main goal of the Vatican VVV Workshop was to develop a strategy for a future coherent project that combines not only VISTA, but also includes other facilities that can enable spectroscopic follow-up of interesting targets. The VVV legacy and its extension will provide new targets and questions to address with the future giant telescope facilities located in Chile such as the European Extremely Large Telescope and the Giant Magellan Telescope.

BOYLE and JANUSZ organized the Photometry Workshop, on “Science Results from Vilnius Calibrated Photometry”, Castel Gandolfo, September 8-10. The previous workshop with the Vilnius group was held in Castel Gandolfo in 2004; since then the workshops (excluding observation runs) were organized in Lithuania and Poland.



Thanks to J.Koszteyn, an informative booklet was published as a simple introduction to the work of the Vatican Observatory photometric group.

BROWN attended the XXIX General Assembly of the International Astronomical Union, held in Honolulu, Hawaii in the USA during August 3-14.

CARUANA gave a lecture on ‘Nurturing the human face of science’, at the Gregorian University, Rome, March 4 * organized and introduced a symposium on ‘La libertà e i meccanismi del cervello’ [Freedom and the mechanisms of the brain], at the Gregorian University, Rome, April 20 * gave a series of three lectures on ‘Science and Cultural Transformation’ at the Australian National University, Canberra, Australia, August 14, 21 and September 4* gave a paper on ‘The Papal Encyclical Laudato Si: Some reflections on the philosophical and scientific background’ at the

Australian Catholic University, Canberra Campus, August 20 * gave a paper on ‘Contrasting Logics: the role of counter-evidence in science and religion’ at the Research School of Physics and Engineering, Australian National University, Canberra, September 2 * gave a paper on ‘Evolu-

tionary arguments and religion’ at the School of Historical and Philosophical Studies, University of Melbourne, August 25 and the same paper at the School of Philosophy and Historical Inquiry, University of Queensland, August 28* gave a paper on ‘Galileo and the Jesuits’ at the Institute for Advanced Studies in the Humanities, University of Queensland, August 27 * gave a paper on ‘The philosophy of expertise: the case of Vatican astronomers’ at the Vatican Observatory, September 17.

CHINNICI presented a paper titled “Practicing Faith and Science: a short history of the Vatican Observatory”, at the Internal Symposium for the 80th anniversary of the Vatican Observatory in Castel Gandolfo, September 14-18 * gave a paper on “On the Discovery of Ceres”, DAWN Science Team Meeting, Palermo, Hotel Borsa, September 14-18 * gave a paper on “The maker and

the scientist: the Merz-Secchi relationship”, Merz Telescopes in Italy Workshop, Palermo, May 26-27 * gave a paper on “An interesting case of Science-Faith connection: the astrophysicist Father Angelo Secchi SJ (1818-1878)”, The role of Astronomy in Christianity and Islam, Albano L. (RM), Vatican Observatory, January 13-15 * gave a paper in collaboration with A. Gasperini on “Analyzing Starlight e Polvere di Stelle: due iniziative di valorizzazione del patrimonio storico INAF”, LIX Congresso della Società Astronomica Italiana, Catania, Osservatorio Astrofisico, May 18-22 * gave a paper titled “Breve storia della Specola Vaticana dalle origini ad oggi”, Achille Ratti-Pio XI dalla Specola di Brera alla



Ileana CHINNICI at the VO Internal Symposium, Castel Gandolfo, Italy

Specola Vaticana, Desio (MB), Casa natale Pio XI, February 7.

CONSOLMAGNO gave the opening speech titled “What is Life?” at the annual University of Arizona School of Science Lecture Series, this year on the “Life in the Universe” January 26.

CORBALLY with Margaret Boone Rappaport led a seminar for The Philadelphia Jungian Professional Club on “The Origins of the Modern Mind: Finding Common Ground among Evolutionary Biology, Cognitive Archaeology, and Analytic Theory”, May 15 * while at North Fork, Virginia, worked with Margaret Boone Rappaport on Evolution Dialogues from June 25-July 25 * at the International Astronomical Union General Assembly XXIX in Honolulu, HI, gave a paper on “Variations In Young Solar Analogs Over The Last Eight Years” with co-authors Richard O. Gray, Jon M. Saken, and Michael Briley, August 3-14 * co-authored the papers “A Tale of Two Regions: Site Protection Experience and Updated Regulations in Arizona and the Canary Islands” given by Richard F. Green et al., and “Synergies Between Spectroscopic And Asteroseismic Surveys” by Jianning Fu et al * presented a paper with Margaret Boone Rappaport on “When Hominins First Looked Up and Saw Constellations” at INSAP IX, a Conference on the Inspiration of Astronomical Phenomena, Gresham College, London, August 23-28 * participated in the Internal Symposium for the 80th Anniversary of the Vatican Observatory in

Castel Gandolfo, and gave a paper “The Enigmatic λ Boötis Stars” Castel Gandolfo, September 14-18.

FUNES participated in the INSAP IX conference in London presenting a paper titled “A Cosmic End: from the Earth to the Universe” August 24-27. The INSAP Conferences are a series of international meetings, held every three years or so, that explore the effect on humanity and human culture of the astronomical phenomena * gave a paper on “Stellar Populations: The Vatican Meeting in 1957” at the Internal



Corbally after delivering his paper on the activity of young stars like the Sun at the IAU GA

Symposium to celebrate the 80th Anniversary of the Vatican Observatory in Castel Gandolfo.

GABOR taught a general education course in astronomy, PTYS/ASTR 170B, in the Spring 2015 semester at the UA * participated at the 29th General Assembly of the

International Astronomical Union in Honolulu HI * gave two talks at the Vatican Observatory internal symposium, one on Exoplanet Radial Velocity Program with VATT-PEPSI on September 14 and the other on the Leap Second Debate and the Lessons from Timekeeping History on September 17 * participated with JOHNSON and SWINDELL, in the Fourth Workshop on Robotic Autonomous Observatories AstroRob, in Malaga, Spain, September 28 – October 2 * participated in the 26th Annual General Meeting of the International Darksky Association in Phoenix, November 14-15.

GIONTI gave a talk on “String Theory based F(R) Theory with Duality Transformation” at “Cosmology and the Quantum” Conference, Rhodes, Greece, June 19 -25 * was member of the Scientific Committee and guest speaker at the UNESCO sponsored conference marking the International Year of Light “Fiat-Lux”. He gave a talk on A String Theory Based F(R)-Theory with Duality Transformations”, the conference was held in Rome, Regina Apostolarum, June 3-5 * representing the Vatican Observatory was a member of the Scientific Organizing Committee (S.O.C.) and of the Local Organizing Committee (L.O.C.) of the XIV edition of the Marcel Grossmann meeting (MGIV) held at La Sapienza University, Rome, July 12-18. This year, the meeting celebrated the

Golden Jubilee of Einstein’s submission of his paper on General Relativity in 1915. GIONTI gave a talk “Cosmology with Duality Transformations” in the parallel session “Quantum Cosmology”.

HELLER gave a lecture at the University of Silesia, Katowice, on the “Justification of the cosmic history” March 10 * gave a lecture on “The human actor: stage and drama” at Kraków, Tischner Sym-

Methodological Conference May 26-27 * gave a talk at the opening of the New Astronomical Observatory, “Travel to the beginning of the Universe” * gave a talk on “Creation of matter in a non-commutative universe” (with T. Miller), Castel Gandolfo, Symposium: Vatican Observatory’s 80th Anniversary, September 14-18.

JANUSZ gave a lecture on “The Photometry in the Vilnius Sy-



Fiat Lux Conference, for International Year of Light, Rome June 2015. Participants included two Nobel Laureates, Stefan Walter Hell and Ada Yonath, Google chief, Vint Cerf, the theoretical physicist Michael Berry

posium, April, 24 * gave a lecture on “How to justify the history of the Universe: From Big Bang to Gulag” Oxford, Ramsey Centre, May 7 * gave a lecture on “Theology and science: with nostalgia, without frustration” Science Festival, Kraków May,19 * gave a talk on “Hundred years of general relativity” at the 19th Cracow

stem at the Vatican Observatory” at the Astronomical Seminar of the Cracow Pedagogical University, April 21 * gave a similar lecture at the seminar of the Astronomical Observatory of the Jagiellonian University May 8 * gave a lecture on “The Vatican Telescope and the Colors of Stars” in UTW AIK, April 28.

KIKWAYA gave a paper and a poster presentation at the IAU general assembly in Hawaii, USA August 3-14 * attended the EPSC (European Planetary Science Congress) in Nantes, France from September 27 to October 2.

MACKE presented a talk on asteroid thermal inertias at the 47th American Astronomical Society Division for Planetary Sciences meeting in Washington, DC, USA, November 8-13 * presented a poster on 3-D laser scanning of Apollo moon rocks at the 46th Lunar and Planetary Science Conference at

Palermo Astronomical Observatory on the occasion of the arrival of the Dawn mission to the asteroid Ceres” in Palermo, Italy, April 16.

Educational and Public Outreach
CORBALLY, with Margaret Boone Rappaport, gave a talk on “Giant Molecular Clouds” at the inaugural meeting of the Skyline Astronomy Club, Tucson, on February 5 * with GABOR gave presentations for the Gila Valley Sci-Tech Day, Discovery Park, Safford, on February 28; they returned to Discovery Park on March 14, “Pi Day”, to contribute presentations and observing for

the Vineyard Catholic Conference, Diocese of Tucson, May 5-7; it was staffed with help from CONSOLMAGNO, KIKWAYA, and MUELLER * spoke on “Through Compact Telescopes to New Research Realms” at the Green Valley Amateur Radio Club on March 11; this became the basis for an expanded lecture on March 19 to the Manchester Astronomical Society, England, hosted by Anthony Cross, Past President of the MAS * on October 7, with Margaret Boone Rappaport, gave a discourse to the freshmen of Dominican University of California, San Rafael, California on “Human Evolution and Uniqueness: Dialogues toward an Accord between Science and Religion”; they followed this by a skit depicting early man’s culture and relation to the constellations* gave talks on December 1 about “The Christmas Star” to children and to adults at St. Odelia Parish, Tucson.

FUNES gave a presentation with the title “The beginning and the end of the universe: challenges to theology” at the Saint College Thomas in Moscow * presented the book “Esplorare l’universo, l’ultima delle periferie. Sfide della scienza alla teologia” published by Editrice Queriniana and the Vatican Observatory * gave a lecture on the end of the Universe in a series of public lectures organized by Susanna Tamaro in Orvieto * gave public lectures on the Cosmic End in the Colloquium Summer Series at NASA Ames



GABOR, CORBALLY, KIKWAYA and BROWN attend the IAU General Assembly in Hawaii

The Woodlands, TX, USA, March 16-20 * presented a talk entitled “What Can We Learn from Mete-

the Starparty * helped GABOR arrange a booth about the Vatican Observatory at the Co-Workers in

Research Center. The lectures were broadcast in English and Spanish * participated in the Sci Foo Camp organized by O'Reilly Media, Digital Science, Nature Publishing Group and Google at Googleplex * presented the photographic exhibition and its catalog: *Travelling Around The Vatican Observatory: Between science and faith* by Maria Rosati Buffetti, Rome.

GABOR gave a talk at the Faith & Astronomy Workshop in Tucson on January 21 * gave a two-part talk at Discovery Park in Safford AZ on September 20 and January 31 * welcomed at Steward Observatory a group of students from the Loyola High School of Los Angeles on March 13 * gave a talk in the University Series at St. Julie Billiart Hall in Newbury Park CA on March 2 * gave a talk in Frydek-Mistek, Czechia, on May 26 * as a part of the Proyecto Friends Chile, he was interviewed via Skype by two school groups simultaneously, one at the Colegio Alberto Hurtado de Villarrica, Chile, and the other at the Strašo Pindzur High School in Negotino, Macedonia on September 24 * gave two talks at the Observatory and Planetarium in Presov, Slovakia, on September 25 * gave several talks at UA's Newman Center * gave an astronomy-inspired eight-day retreat to Jesuits of the Czech and Slovak Provinces in Presov, Slovakia, September 21-29 * organized a booth at the

Co-Workers in the Vineyard diocesan conference at the Tucson Convention Center on March 6 and 7 * initiated a celebration of the International Year of Light on "Pi Day", with a star party, exhibits and talks at the East Arizona College Discovery Park Campus in Safford AZ, March 14.

GIONTI gave a talk "Da Padre Clavio al Big-Bang" at the Gregorian University for the students of the Roman High School "Il Virgilio" in January * gave a similar talk to the early classes of the Jesuit high school "Il Massimo" in March * gave a public talk to students of the Villa Nazeth college, in "Val Pusteria", Sud-Tirol, July 28 * gave a talk "Una breve storia dell'Universo da una prospettiva gesuitica" at the inauguration of the exhibit "Viaggio intorno alla Specola Vaticana", Rome, September 8.

KIKWAYA gave a lecture to the last year high school students of College Boboto in Kinshasa, Democratic Republic of Congo on the theme: "quel peut être le rapport entre l'astronomie et les autres sciences" * gave a lecture to the last year high school students of College Bonsomi in Kinshasa, Democratic Republic of Congo on the theme: "L'état actuel de l'astronomie dans le processus de la révolution scientifique."

OMIZZOLO gave public lectures on observational cosmology in

Milan, Novaro, Catanzaro, Padova, Pisa and Vicenza.

MACKE gave a talk on "The Vatican Observatory at the Crossroads of Faith and Science" MIT Tech Catholic Community, Cambridge, MA, November 2 * gave a talk on the Vatican Observatory to Bishop DuBourg High School (St. Louis, MO) "Big History" class via Skype, October 15.

News and Media Coverage

The publication late last year of the book by CONSOLMAGNO and MUELLER *Would You Baptize an Extraterrestrial?*, the publication of Pope Francis's encyclical on the environment, and the appointment of CONSOLMAGNO as the new director of the Specola has attracted significant press attention from around the world. Interviews were run in a number of magazines, ranging from the prestigious journal *Science* to the popular Italian gossip magazine *Chi*. CONSOLMAGNO was also interviewed for the BBC Radio program, the History of Natural History, along with programs for radio in Australia, Canada, and Romania. Magazines who ran articles about us included *Time*, *Arizona Highways*, *Ambassador*, and *The Christian Century*. Newspaper interviews ranged from *The Sunday Times* [London] to the [American] *Associated Press*.

CORBALLY and GABOR were interviewed by Matt Jaffe for a story about the Vatican Observatory that appeared in Arizona Highways, May 2015. They were also interviewed by Matthew Danzico for a BBC News Pop Up, February 3, on the Vatican Observatory: <http://www.bbc.co.uk/news/magazine-31051635>

CORBALLY was interviewed several times on the Drew Mariani Show, Relevant Radio, about the Christmas Star on December 22, about the discovery of Kepler-452b, about an earth-like planet in the habitable zone around a G2 star, 6 Gyr old, 1400 lyr distant, on July 28, and about the apparently streaming salty water on Mars, as well as the audience with Pope Francis to conclude the Vatican Observatory's 80th anniversary internal symposium on September 29. On August 11, during the International Astronomical Union General Assembly in Honolulu, HI, he gave an interview to Joan Lewis for Vatican Insider, EWTN radio:

<https://joansrome.wordpress.com/2015/09/04/>

<https://joansrome.wordpress.com/2015/09/11/>

GABOR gave an interview to BBC's Matthew Danzico which was broadcast online * to the Czech Catholic Weekly (Katolický týdeník) published on June

2 * to Dan Marries from KOLD News 13 television in Tucson which was broadcast prior to the Holy Father's USA visit * to Maciej Kautz of International Poznan, an English radio show, broadcast in September * to Radio Presov in Slovakia on September 25 * to Javier Yanes for BBVA's Open Mind published on October 5 * to the Slovak public television RTVS which was broadcast on November 8 * worked with Matt Jaffe (writer) and Bill Hatcher (photographer) who prepared a feature on VATT published in the May issue of the Arizona Highways Magazine * prepared a weekly radio blog, broadcast from January 2015 on Radio Lumen in Slovakia.

FUNES gave interviews to TV2000, Italy, Vatican Radio, and RAINEWS24, Italy.

PUBLICATIONS

Books

One of the outcomes of the Vatican Observatory general meeting in Loreto in 2012, was the decision to place the expertise of the Pope's Scientists at the service of priestly formation particularly in helping young priests better understand the relationship between science and theology today. Three years later, a book exploring this theme was published in Italy, edited by FUNES and OMIZZOLO. The book is titled *Esplorare l'universo, ultima delle periferie. Le sfide della scienza alla teologia*; (2015), Casa Editrice Queriniana, Brescia, Italy.

HELLER has also had a number of books published in the past year. These include:
Theology and Science, (2015), e-book, Copernicus Center Press, Kraków in Polish;
Morality of thinking, (2015), [new edition], Copernicus Center Press, Kraków 2015, in Polish;
Philosophy of Chance, (2015), [new pocket edition], CCPress, Kraków, in Polish;
The Meaning of Life and the Meaning of the Universe, (2015) [new pocket edition], CCPress, Kraków, in Polish;
God and Geometry, (2015), CCPress, Kraków in Polish.
HELLER, M., Pabjan T., *Creation and Beginning of the Universe* (2015), [new pocket edition], Copernicus Center Press, Kraków.



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VISITORS

Visitors to the VO headquarters in Castel Gandolfo

In February, a group of 27 priests from the Collegio Pio Brasiliano, Rome, and a group of seminarians from the Pontifical College of Regina Apostolorum for a faith-science talk. Rev. Fr. Abbe DeSaint from France.

In March, a CBS TV film crew to film partial eclipse on 20 March; Fr. Michael Fye, an amateur astronomer from the Diocese of Nashville and priests and seminarians of the Archdiocese of Washington, DC from the Pontifical NAC.

In April, Mr. Jordan Jones; a group of 21 students from the University of Washington; a visit by physics, chemistry, mathematics, and computer science students from the University of Dallas and a visit by a Dutch faith-science group, led by Cornelis Jonkman.

In May, a visit by Joel Dillaway, PhD candidate in theology/science studies at the University of Exeter; a visit by members of the Cambridge Muslim College and Center for Islamic Studies; a visit by Francesca D'Antona and Paolo Ventura, astronomers at INAF Monte Porzio Observatory (in Frascati) and visit by Ryan Zeigler, the curator of the Apollo moon rock collection at NASA Johnson Space Center and Cynthia Evans of NASA Johnson Space Center.

In June, a visit from members of Vatican City's Servizi Tecnici personel (+families).

In September, a visit from members of the Caritas branch of Albano Laziale.

In October, A visit from the Columbian Group 'Expedicion Side-reus Nuncius'; a visit by Christian Veillet, Xiaohui Fan, and Buell Jannuzi (Director of Steward Observatory) Group from Steward Observatory; visit by the Jesuit Conference of European Provincials.

A visit by the administration of the Gregorian University guided by the Rector Father François Dumourtier, S.J.,

Working visits to the VATT in Tucson

Richard Gray from Appalachian State University, NC.

Andy Rivkin from the Applied Physics Laboratory of Johns Hopkins University, MD.

Visits to other scientific institutions and universities

On September 5 GABOR visited the Bureau International des Poids et Mesures in Sevres, France, hosted by Felicitas Arias. On September 6 he visited the Institut d'Astrophysique Spatiale in Orsay, France, hosted by Alain Leger. On September 7 he visited the Observatory of Paris in Meu-

don, hosted by Sophie Jacquinod, as well as the Institut d'Astrophysique in Paris, hosted by Piero Benvenuti, General Secretary of the International Astronomical Union.



SPECOLA VATICANA

80th Anniversary of Specola Vaticana in Castel Gandolfo

Internal Symposium

14-18 September 2015 - Castel Gandolfo





