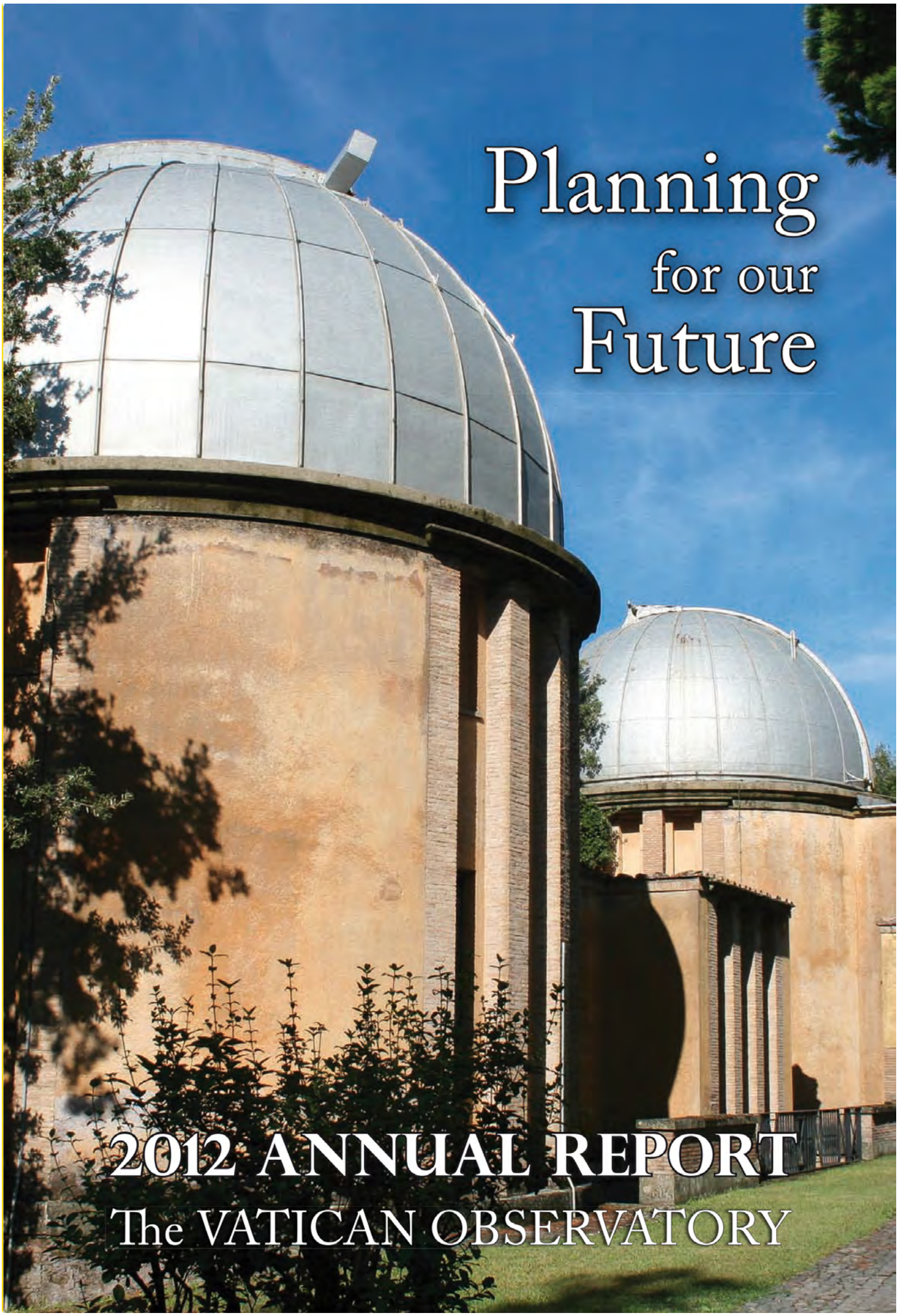
Planning
for our
Future
2012 ANNUAL REPORT
The VATICAN OBSERVATORY

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Vatican Observatory Publications

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Cover: *For decades, the site of the Schmidt (left) and Carte du Ciel photographic telescopes in the Papal Gardens have been home to a number of remarkable events in the history of the Specola. They housed war refugees in 1944, and the Vatican Observatory's first computer in 1966. In February of 1969, Apollo 8 astronaut Frank Borman visited this site, and later that summer from the Schmidt dome Pope Paul VI greeted the first men on the Moon. Light pollution forced the telescopes to close down in the early 1980s; but in the near future the Specola hopes to convert these domes into a museum.*

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1. From the Director

Planning for our future

On January 2, 2012, Pope Benedict XVI confirmed me as director of the Vatican Observatory for another 5-year term. I am very grateful to the Holy Father for such an honor and also grateful for the support we have received from the authorities of the Governatorate of Vatican City State, our Jesuit superiors and the friends of the Vatican Observatory Foundation during these years.

I am grateful to the Lord for all we have accomplished in the last five years, especially for the renewal of the staff. Today there are sixteen people on staff; five of them have arrived in the last four years with prospects for another four candidates over the next five years. I see this as a sign of the vitality of this work of the Catholic Church, which is crucial in witnessing the complementarity of science and faith.

The Headquarters

In the last three years our facilities have been completed and beautified. I am very grateful to Father Józef M. Maj, S.J., Vice Director for Administration, for his dedication in making this possible. Many visitors have praised the work done.

The number of visitors continues to increase. Among them, in May we were very pleased to welcome the Diplomatic Corps accredited to the Holy See. The diplomats had the opportunity to meet the Vatican astronomers and appreciate the meteorite collection, the antique telescopes and books. After visiting the telescopes on the roof of the Pontifical Palace, the visit ended with a reception offered by the Secretary of State, Cardinal Tarcisio Bertone.

•*Mons. Fortunatus Nwachukwu, head of the Protocol Office of the Secretary of State, and Fr. Funes during the visit of Diplomatic Corps accreditated to the Holy See*

Due to the increasing number of visitors and our revaluation of the Observatory's heritage, we aim to restore the domes in the Pontifical Gardens of Castel Gandolfo. The first phase of the project has already been completed and hopefully we will start work on the second phase soon.

The domes house two telescopes, the Carte du Ciel (1891) and the Schmidt (1957), which were advanced technology telescopes in their day. The domes are ideally situated to be utilized as a museum to showcase the Holy See's commitment in contributing to the progress of scientific knowledge.

The projected Visitor Center will offer the younger generations a different perspective from the one they get from main stream media. More than words ever can, the historical testimony of the Vatican astronomers tells us that science and faith can complement each other.

Our facilities in Castel Gandolfo also house the meteorite laboratory. The Observatory has an important collection of 1100 samples of more then 500 different falls. We would like to improve the laboratory with new furniture, instruments and the addition of new pieces to the collection.

In June we hosted the 13th Summer School on *The Formation and Evolution of Stellar Clusters: from Star Cluster Ecology to Tracers of Galaxy Evolution*. It was another successful and joyful experience thanks to the great dedication of the faculty and the generous participation of the students. I am very grateful to the faculty, Prof. Douglas Heggie (Chair, University of Edinburgh, United Kingdom), Dr. Francesca D'Antona (INAF-Osservatorio Astronomico di Roma, Italy), Dr. Nate Bastian (Excellence Cluster Universe, Munich, Germany) and Dr. Mark Gieles (University of Cambridge, United Kingdom) for organizing an excellent academic program. I am also grateful to Father David Brown, S.J., from our staff, for serving as dean of the school.

The beginning of my new term was an appropriate time to call a "retreat" of the Observatory staff to examine the ways we might better fulfill our mission and focus our efforts in that direction. From July 3- 6, we met in the beautiful city of Loreto in central Italy. In our discussions we considered how our scientific expertise and religious background can contribute to the dialogue between science and faith, an important frontier in the New Evangelization.

In this meeting we also focused on our scientific priorities and especially on research with the Vatican Advanced Technology Telescope (VATT).

Science with VATT

VATT has a potential that has yet to be fully exploited. With the remote-observing and the available instruments (CCD Camera, GUFI CCD Camera, and VATT Spectrograph), there are many exciting projects that can be carried out:

• Observation of Near Earth Objects and Trans-Neptunian Objects in order to put limits on their physical properties,
• Examining globular clusters in order to determine how many of the extreme horizontal branch stars are in binary systems,
• Doing follow-ups to large surveys like Pan-STARRS, Kepler, etc..,
• The identification of multiple stellar populations in globular clusters,
• Observation of active galaxies in their central regions using the VATT Spectrograph,
• Direct imaging of nearby galaxies using broad-band, narrow band, and SLOAN filters to study stellar populations,
• VATT can be used in combination with large telescopes and space-telescopes for multi-wavelength surveys.

In a difficult international context for investment in astrophysical research, VATT offers every opportunity for success. VATT is located in the darkest site of the continental US. There we are partners of the Mount Graham International Observatory which includes the Large Binocular Telescope, one of the largest telescopes in the world. Also, our good relations and collaboration with the Steward Observatory (University of Arizona), one of the leading research centers in the world, allows us to upgrade VATT according to the new scientific challenges.

There are many other challenges ahead. We know and are thankful that we can count on the support of many friends and colleagues.

José G. Funes, S.J.

José G. Funes, S.J.
Director

•Fr. Funes at St. Ignatius College Prep in Chicago

2. VOSS 2012

The 13th Vatican Observatory Summer School (VOSS) in Observational Astronomy and Astrophysics was held at the Vatican Observatory in Castel Gandolfo, June 3 – 29, 2012, on *The Formation and Evolution of Stellar Clusters: from Star Cluster Ecology to Tracers of Galaxy Evolution*.

In 1985, the late Fr. Martin McCarthy S.J., an astronomer at the Observatory, recognized that there was too little contact between the astronomers at the Observatory and younger researchers. His solution was to open the observatory to students for a month-long intensive program on some aspect of astrophysics. The first school occurred in 1986, and they have been held roughly every two years since then. The goal of the schools is to give young astronomers an in-depth exploration of some particularly important aspect of modern astrophysics.

The twenty five students for this year's school were selected from 150 applicants. The main criterion for selection was that they show promise of a successful professional career in research astronomy. In fact, of the 337 students who have graduated from these schools since they were founded in 1986, about 85% are still active in research.

•*VOSS2012 Students in the Gabriele Buffetti Aula*

Of particular interest is that the majority of the students have always come from less-developed nations. This year's school included students from 22 different nations, coming from Eastern Europe, Latin America, Africa, and Southeast Asia as well as Western Europe and North America. Thanks to the generous support of a number of donors and the Governatorate, the Observatory is able to support the participation of students from developing countries, paying 75% of their travel and lodging costs.

The faculty of this year's school, under the direction of Prof. Douglas Heggie of the University of Edinburgh, included two alumni of previous summer schools: Dr. Nate Bastian of the Excellence Cluster (a consortium of universities associated with the European Southern Observatory in Munich), and Mark Gieles of the University of Cambridge. Rounding out the faculty was Dr. Francesca D'Antona of the Italian National Institute for Astrophysics (INAF) and the Astronomical Observatory of Rome, who has also been a instructor at previous Vatican Observatory summer schools.

•*June 6: VOSS Students observe the Venus transit from the roof of the Papal Palace*

Topics included stellar structure and evolutionary phases, planet formation, stellar populations, stellar dynamics, dynamics of binary formation and evolution in dense stellar systems, basic principles of dynamical 2-body relaxation, Monte Carlo methods, direct N-body methods, globular cluster populations, generating simple stellar populations and simulation of star clusters by computer modeling, different ways of age dating clusters, theory of cluster formation, formation and evolution of Young Massive Clusters.

Transit of Venus Enchants Vatican Observatory Summer Students

Traditional activities of the Vatican Observatory Summer School include lectures and team projects centered on the theme of the school, informal gatherings around pizza in the evening, and a weekend in Florence and Pisa. Students this year were also privileged to observe a rare transit of Venus across the face of the Sun on the morning of June 6 from the telescopes on the roof of the Papal Palace.

The students were up before dawn, waiting for sunrise over the Alban Hills. For an hour they followed the shadow of Venus, using small telescopes and binoculars equipped with solar filters. In addition, the Vatican Observatory's Coronado Solar Telescope, attached to the large Visual refractor telescope on the Papal Palace roof, was connected to a new CCD imaging camera and computer network, recently provided to the Observatory from the Governatorate, to provide the students with a close-up view of Venus' passage. (This telescope uses special filters to observe the Sun in a particular wavelength of light radiated by hydrogen atoms, providing striking views of sunspots and solar prominences.)

Venus transits are remarkably rare events; they occur in pairs, eight years apart, followed by more than a century before the next pair occur. This year's transit was

paired with a previous transit, in 2004, which had also been observed from the Papal Palace. The next transit will not take place until the year 2117.

"Seeing the transit was especially exciting to me because I had read so much of the history about transits," said Nora Lützgendorf, a student from Germany. "It was amazing to think that we are seeing the very same thing that they saw."

"This will be my last chance to see a transit," said Giannina Dalle Mese Zavala, a student from Mexico. "It was a special thrill to be able to see it from the Pope's palace." Zara Randriamanakoto, from Madagascar, agreed with her. "We were lucky to just be in the right place at the right time."

Zara came to the school from her studies at the University of Cape Town, South Africa. "I knew I wanted to come to this school when I saw who the faculty was. These are the scientists whose work I reference all the time. It is exciting to actually meet them and have them give me advice on my work."

"The school is a wonderful opportunity to meet students from all over the world, especially those who are interested in the same things I am," added Nahathai Tanakul, from Thailand.

Alumni of past Vatican Observatory Summer Schools have gone on to remarkable careers at prominent universities around the world. But many of them have also been instrumental in developing astronomical observatories in their own nations.

•VOSS students also visited astronomical sites in Florence and Pisa

•Dr. Francesca D'Antona directs a team project in modelling cluster evolution

3. Meteorite Laboratory

The Vatican Observatory Meteorite Collection

The Vatican Observatory Meteorite collection is one of the major meteorite collections in the world, with over 1100 samples of more than 500 different falls, representing nearly 150 kg of extraterrestrial material.

•The Marquis de Mauroy and his wife, original donors of the meteorite collection

The Vatican Meteorite Laboratory

The meteorite collection at the Vatican exists today thanks to Adrien-Charles, Marquis de Mauroy (1848-1927), a French nobleman and distinguished agronomist and gentleman-scientist who was a life member of the Société Française de Minéralogie. His collection of minerals was famous throughout Europe, and his meteorite collection was said to have been the second largest private collection in the world. A great friend of the Church, the Marquis hoped to found a Museum of Natural History at the Vatican. In 1907, a subset of the de Mauroy meteorite collection was donated by the Marquis; another 50 meteorite samples were added in 1912. Following his death, his widow Marie Caroline Eugénie donated the bulk of his meteorite collection to the Vatican: a thousand pieces sampling more than 400 different meteorite falls.

In the years following the Mauroy bequest, the collection has grown slowly by gifts and trades. One important addition occurred in 1912 when John Ball, acting director of the Geological Survey in Egypt, donated a 154g piece of the newly fallen meteorite Nakhla – now identified as a basalt from planet Mars. More recently, the discoverers of a number of important falls have donated samples to the Vatican collection.

•The collection is stored in wooden cases made for the Specola by Luigi Lori

The collection was maintained by a number of Jesuits over the years, most notably by Fr. Ernst W. Salpeter, S.J., who conducted significant correspondence with the meteoriticists of his day and made chemical studies of the meteorites in the Vatican Observatory's Spectrochemical Lab during the 1950s. But a separate meteorite lab was only set up in the mid-1990s with the arrival of Br. Guy Consolmagno, S.J., who had studied meteoritics at MIT and the University of Arizona before entering the Jesuits.

The challenge facing Br. Consolmagno at that time was simple: what sort of scientifically important work could be done with this collection, which had small bits from virtually every meteorite class, but only a minimal amount of equipment?

In the years following the Moon landings, the chemical study of extraterrestrial samples had advanced at a remarkable rate, coinciding with the development of highly precise (but very expensive) devices such as scanning electron microscopes/microprobes and mass spectrometers. These instruments allowed ever finer measurements of chemical and isotopic compositions to be made at ever higher resolution on ever tinier samples. By contrast, the measurement of the physical properties of these samples had not been pursued with the same vigor. But properties such as density and porosity are important values to understand the physical state and evolution of a number of bodies in the solar system. Knowing them can lead to a deeper insight into the structure of the early-forming solar system itself.

The challenge in measuring the density (mass divided by volume) of an irregular object like a rock is to determine its volume in a way that gives an accurate answer without altering or contaminating the sample. The standard technique in geology is to immerse the sample in water, but water would likely cause serious problems for samples like meteorites which rust easily, even in the humid air of Rome. What fluid could be used instead of water?

Helium gas is one such fluid. Note, however, that this gas completely penetrates all the cracks and pores of the sample; it provides a volume of just the grains of rock itself. To measure a volume including those cracks and pores, which represent the rock's porosity, one needs a fluid that merely surrounds the outside of the rock without penetrating it.

The idea came to Br. Consolmagno during a cappuccino break while pouring sugar into his coffee: a fine powder could imitate a fluid. Soon he and his colleague Dan Britt devised a system to measure rock volumes using tiny glass beads, like those used in optics shops to polish lenses. The first measurements of meteorite bulk densities using glass beads instead of water were reported by Consolmagno and Britt in 1998. Since then, the combination of glass bead and gas pycnometry methods has become the standard method to measure meteorite densities and porosities.

These measurements were then combined with other measures of meteorite physical properties. In 2001 the French geophysicist Pierre Rochette, of the French National Center for Scientific Research in Aix-en-Provence, arrived with a device to measure a meteorite's magnetic susceptibility – the degree to which it interacts with a small magnetic field. This measure is directly related to the iron content of the meteorite. More recently, Consolmagno has been devising a way to measure the thermal properties, such as heat capacity, of a meteorite.

The Vatican collection, with so many samples of different meteorite types, is ideal for such survey measurements. In this way the scientists have been able to learn how different physical properties are associated with each meteorite type.

The key to all these measurements is that, first; they measure a characteristic of the entire sample, not just a small spot. In this way one can be sure that the measurement is not representing only an unusual grain that by bad chance was taken to represent the entire meteorite. In fact, many meteorites are inhomogeneous "breccias" of many different rock types, so it is especially important to get whole-rock data on such samples.

Just as importantly, these measurements are completely non-contaminating and non-destructive. The meteorite does not have to be sliced or crushed; the rock remains intact, and can be used again for other sorts of measurements.

And finally, these measurements are quick and inexpensive. The techniques devised in the Vatican's meteorite lab can be, and have been, replicated in labs large and small around the world. As an example, in 2009 the young Jesuit brother Robert Macke, S.J., defended his doctoral thesis which used these techniques (refined and perfected by him) to measure more than a thousand meteorite samples in collections around the world.

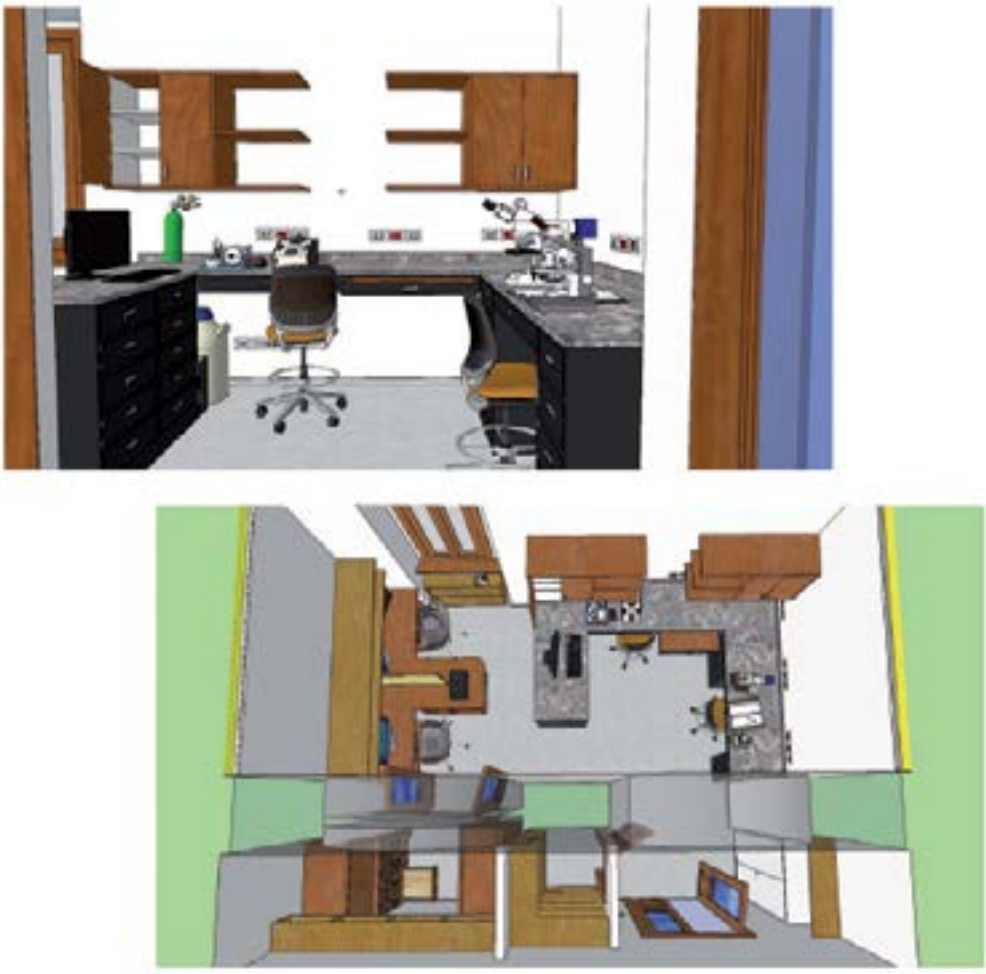
When the new Vatican Observatory quarters were built in the Papal Gardens, special care was taken to organize one of the rooms specifically to serve as a meteorite lab, with space for the collection within the lab and electrical outlets

•*Pope Benedict XVI visited the Meteorite Laboratory in 2009*

designed to sit above lab benches. At the present time, the equipment in the lab includes a Quantum Dynamics Ultrapycnometer and along with a glass-bead set-up for measuring densities and porosities, and a ZH Instruments SM-30 Magnetic Susceptibility Meter, on long-term loan from the University of Central Florida. In addition the lab boasts two Meiji Techno microscopes, one with crossed-polarized filters for observing mineral thin sections, the other a binocular microscope to look closely at whole rocks. A new laboratory set up for measuring heat capacity includes a working Dewar and storage Dewar for liquid nitrogen, while our Mettler electronic scale is connected to a Dell computer

to allow the automatic read-out of data. The lab also has a vacuum pump and chamber, used to draw adsorbed water off the surface of meteorites, a cabinet for chemicals used to clean and prepare samples, and the usual collection of small tools and instruments.

But the development of the laboratory itself continues. Br. Macke, who has worked closely with the Vatican Observatory since 2004, has developed a plan for upgrading the laboratory layout. Work will be begin in early 2013 to install meter-high lab benches with impervious surfaces (and plenty of storage space below them), and to close off the meteorite storage area for improved climate control and security. As the next generation of meteorite scientists, represented by Br. Macke, arrives at the Vatican Observatory we hope to have a space that can carry this work well into the 21st century.



•Plans by Br. Robert Macke envision a meteorite lab with workbenches, extended storage area, and room for two scientists to work together

4. Research Highlights

Cosmology

It is well understood that the presence of Dark Matter and Dark Energy in the Universe may require a modification of the description of gravitational force at long distance, presently best described by Einstein's Theory of General Relativity. To overcome this issue, many people have suggested the use of so-called "Extended" theories of gravity - theories of Gravity which are modified versions to Einstein's theory. But to date there have not been any clear justification for the use of these theories. One possible way to get such "extended" theories of gravity is to approach them from the point of view of quantum physics. Fr. Gabriele Gionti, S.J., is exploring the possibility that String Theory could be a way to get to a theory of quantum gravity.

String Theory suggests that that the fundamental objects at the Big Bang were one-dimensional objects called Strings. Strings need to exist in extra dimensions, but since our world is only four-dimensional (space plus time) we need to assume that the other dimensions are very small and undetectable. One trick is to wind these extra dimensions around circles; the technical term is to "compactify" them. Compactification around a circle ultimately ends up in a compactification around a "generalized Torus"; such closed Strings have a special symmetry when they are compactified which is called Toroidal-duality, abbreviated as T-Duality. If we push this symmetry even further, one can calculate from quantum theory the gravitational effective field given by a String Theory that is manifestly T-Duality invariant. The result should be some particular extended theory of gravity which could explain Dark Matter and Dark Energy.

Preliminary results of this work by Fr. Gionti and his collaborator Franco Pezzella were presented in a talk entitled "T-Duality in String Theory and its implication for extended theories of the gravitational field" given at the meeting of the Italian Society of General Relativity and Gravitational Physics held in October at the Astronomical Observatory of Capodimonte in Naples.

• High energy particle detector (photo by Consolmagno at Fermilab, Chicago)

As it is well known, our Universe is expanding: the distances among the galaxies are increasing and it has even been shown that this expansion is accelerating. If one goes back in time, the distances among galaxies must have been smaller and smaller until we reach a minimal distance, called Planck length, 1.6×10^{-35} m. Below this distance, according to the laws of quantum physics, the entire Universe should behave as a global system described by a wave function like that for the Hydrogen atom. Since the equations to determine this wave function are quite complicated, it has been proposed to calculate the wave function through a method of discretization, which exploits the same principle of finite element

methods used to solve many problems in engineering by dividing complex continuous system into tiny but discrete parts.

One standard technique for describing a continuous system by discrete parts is called Regge Calculus, introduced by Tullio Regge in 1961; a similar discretization, called Spin Foam, was introduced more recently by other people in a different context. Both provide a way to describe the space-time universe in discrete parts. Spin Foam has looked more appealing to many in the field because it can be connected to quantum theory: its related continuum theory implies that two-dimensional surfaces in the Universe (space-time) have their areas quantized, in the sense that these areas may only have discrete values like the energy of the Hydrogen atom. However, it is not clear that the Spin Foam technique converges to General Relativity, the physical theory that describes the gravitational force on cosmic scales. By contrast, Regge Calculus does converge to General Relativity when one uses a particular mathematical technique (converges in measure) to extrapolate the discrete structure toward the continuous limit.

Fr. Gionti's work has been to compare the two theories, hoping that Spin Foam could be shown as a particular case of Regge Calculus, so that its convergence to General Relativity would thus be demonstrated. His work has shown that there does not appear to be any clear connection between the two theories; Spin Foam looks to be a completely different theory than Regge Calculus. Indeed, he has even shown that not only is there no easy way to relate Spin Foam to General Relativity, but that in fact some Spin Foam assumptions and positions seem to be completely different than standard definitions in Quantum Gravity as well. Thus this technique may not be a particularly fruitful way of describing the physics of the earliest moments of the Big Bang.

Portions of this work have been published by Gionti in the International Journal of Geometrical Methods in Modern Physics, Volume 9, paper 1260013, and the International Journal of Modern Physics Conference Series (2012); and in a paper in press in the Proceedings of the 3rd Galileo-XuGuangqi Meeting (GX3), edited by Remo Ruffini (2012).

Fr. William Stoeger, S.J., and his collaborators Alvaro Iribarrem, Amanda Lopes and Marcello Ribeiro at the Federal University of Rio de Janeiro, are continuing their detailed study comparing the distribution of galaxies observed by modern surveys with that predicted by cosmological theory.

Their data comes from the FORS Deep Field galaxy survey, which provides a large data set of galaxies out to redshifts z = 5.0 in the blue bands and z = 3.0 in the red ones (i.e. roughly ten to eleven billion light years away). This significantly extends earlier work the group did on this subject. The cosmological theory they are using to compare against the distribution of galaxies observed in this survey

is a standard flat Friedmann-Lemaître-Robertson-Walker (FLRW) cosmology with a non-zero cosmological constant, that is, including a term to describe the effect of Dark Energy.

The primary focus of this work has been to compare the theoretical galaxy number counts for a given redshift (i.e. distance from us in space, and thus in time) against what the survey actually sees. Even in earlier results, it has been clear that the data significantly deviates from the theory. The present work substantiates this conclusion.

There are several reasons why this may be the case. The fact is that we really do not know how the mass per galaxy (including Dark Matter) varies with redshift for any of the different types of galaxies, independent of the cosmology. Nor do we know how many galaxies of various types we are missing in our counting, particularly the faint ones; or how galaxy luminosities and number densities vary with redshift.

• A portion of the Hubble Space Telescope Ultra Deep Field, which shows galaxies at distance up to 13 billion light years away (NASA image)

This last contribution is usually included as a rough estimate in the luminosity function results given in the survey. However, that estimate is made presupposing that one knows the cosmology in detail (e. g. the exact amount of matter, visible and dark; the exact amount of Dark Energy; and whether the space-time is spatially homogeneous and isotropic on the largest scales.) The luminosity functions always presuppose a given cosmology in order to determine the operative volumes.

But in fact it is fairly easy to extract number counts from the luminosity function data that are independent of any assumption about a cosmology. Once that is done, one can compare that "purified" data with any cosmological model you want. This is the focus of ongoing work by Fr. Stoeger and his colleagues.

Some of the models that they are interested in are spatially inhomogeneous – that is, unlike the standard FLRW models, they are lumpy on very large scales when one looks at a slice of space-time for a given constant time. (In FLRW models these slices are homogeneous, or smooth, with constant densities.) These other cosmologies might fit the data just as well as, or better than, the FLRW model they have been considering here. It is crucial to determine which of these potential best-fit models is the one that most accurately represents our universe, once all the data are in. This will be the focus of the group's future research.

A secondary focus of this research is to look at how the results vary as a function of the type of cosmological distance they use. (There are several different distances one can define in cosmology. These lead to different volumes within which one counts the galaxies.) Even though there is a definite preferred distance that is to be used, the results for other distances shed considerable light on the quality of the data, and on some characteristics of the cosmology that is assumed. These

results can also show what looks like a power-law behavior in the observational inhomogeneity of the galaxy number counts as one goes to higher redshifts, which may be significant.

It is important to note that observing an inhomogeneity in the distribution of galaxies does not actually mean that there really is a spatial inhomogeneity. Even in a spatially homogeneous (e. g. FLRW) universe, there can be – and usually is – observational inhomogeneity. This is simply because our observations with increasing redshift down our past light cone sample all the constant-time spatial slices between ourselves and the farthest galaxies we observe. In a spatially homogeneous (smooth) universe, the homogeneity is only on constant-time spatial surfaces – not along our past light-cone down which we actually observe the galaxies in ever more distant regions, and therefore at a succession of ever earlier times.

This work was reported in Astronomy and Astrophysics 539, A112, 2012.

Galaxies

Galaxies are an important focus of astronomical research for a number of reasons, reflected in the research done at the Vatican Observatory. These large, bright collections of billions of stars apparently originated from the growth of small irregularities in the initial Big Bang and thus their very existence gives us clues as to the events at the very beginning of the universe. Because they are so large, they can be observed even at great distances from us. But the light we observe today reflects the state of those galaxies when that light left them; and since their light travels to us at a finite speed, the greater their distance from us in space, the farther back in the past we also see. Thus comparing distant galaxies to nearby ones allows us to observe how the galaxies themselves have evolved over time. And finally, since the galaxies themselves are the home of stars and planets, observing the details of star populations and formation regions in other galaxies allows us to understand better how stars and planets may have formed in our own galaxy.

About 80% of all nearby galaxies come in clusters; the remaining 20% are called "field galaxies". In this past year Fr. Alessandro Omizzolo has continued his ongoing research into nearby galaxy clusters as a member of the international group named WINGS (the Wide-field Nearby Galaxy cluster Survey). The goal of this group is to study the populations of galaxies in clusters within one billion light years of us – which, in astronomical terms, is "nearby" – to compare them against those galaxies that are more distant from us in space, and thus in time.

It is difficult, of course, to observe much more than the shapes of the most distant galaxies, as they appear as nothing more than faint smudges of light in our telescopes. However, even from their shapes one can derive interesting conclusions about those galaxies. Superdense galaxies are a particularly useful

subset of the galaxy population to observe for this purpose, since they are among the easiest to observe at great distance. But to understand those distant galaxies, one must first understand similar galaxies that are closer to us and thus more amenable to observation. Therefore, recent work from the WINGS project has been an analysis of nearby superdense galaxies and the relationship seen in them between their masses and their sizes, comparing field galaxies against cluster galaxies.

They began by searching for relatively nearby field galaxies that are massive and compact (superdense galaxies, or SDGs) in the Padova-Millennium Galaxy and Group Catalogue; this catalog is a spectroscopically complete sample, representative of the local Universe general field population. In this population, they found that compact galaxies with radii and mass densities comparable to more distant massive and passive galaxies represent 4.4% of all galaxies with stellar masses above 3 x 10^{10} solar masses (i. e., galaxies with more than about 30 billion stars). Most of them are spiral galaxies of type S0 (70%) or elliptical galaxies (23%). Most are red and have intermediate-to-old stellar populations; the average age of the stars in these galaxies, weighted by the stars' brightness, is 5.4 billion years, but if you average by the mass of the stars one arrives at an average age of 9.2 billion years.

• *Galaxy clusters: Top, Abell 2256; Bottom, Abell 119 (images by Omizzolo at Isaac Newton Telescope, La Palma, Canary Islands)*

Comparing these with the WINGS sample of cluster galaxies at similar distances, they found that the fraction of superdense galaxies in the field galaxies is three times smaller than that of those in clusters, and cluster SDGs are on average 4 billion years older than field SDGs. This confirms the existence of a universal trend that galaxies with older luminosity-weighted ages, for a given galaxy mass, have smaller radii. On top of the well-known dependence of stellar age on galaxy mass, the luminosity-weighted age of galaxies depends on galaxy compactness at fixed mass, and, for a fixed mass and radius, on the environment in which it is found.

This effect needs to be taken into account to make sure that one does not overestimate the evolution of galaxy sizes from the more distant to those nearby. These results, and theoretical simulations, suggest that a significant fraction of the more distant massive compact galaxies have evolved into compact galaxies in galaxy clusters today. When stellar age and environmental effects are taken into account, the average amount of size evolution of individual galaxies between distant and nearby ones is mild, a factor of about 1.6.

This work has been accepted for publication at the Astrophysical Journal, and is available online at 2012arXiv1211.1005P.

Within a typical spiral galaxy, one can observe lanes of dust which obscure the visible light but glow in infrared light. Stars are formed from clouds of gas and dust; and once star formation in such a region has begun, the ultraviolet light

from the newly formed stars should ionize that gas, producing regions rich in both dust and ionized gas. Such bands are poorly studied in elliptical galaxies, however; indeed, under the traditional classification of galaxies pioneered by Edwin Hubble, it was assumed that such regions would not exist in ellipticals.

But both dust and ionized gas have been found in elliptical and S0 galaxies. Since it has normally been thought that elliptical galaxies are the mature result of galaxy merger and unlikely to host star formation regions, where did their dust and ionized gas come from? Are these potential regions of star formation? The first step in answering these questions is to examine if the locations of the dust regions and ionized gas regions in these galaxies are related.

Fr. Funes, and colleagues Ido Finkelman and Noah Brosch from Tel Aviv University and Sudhanshu Barway, Alexei Kniazev, and Petri Väisänen from the South African Astronomical Observatory, observed more than twenty such galaxies with the 1.8 meter Vatican Advanced Technology Telescope (VATT), the 1.9 meter telescope of the South African Astronomical Observatory, and the 1 meter Wise Observatory in the Negev desert of Israel, to look for an association between dust and ionized gas in elliptical and S0-type spiral galaxies with dust lanes. Their data, together with results from previous studies of E/S0 galaxies, demonstrate the close relationship between these two components.

• NGC 5128, elliptical galaxy with dust band (image by Funes at Cerro Toloto Observatory, Chile)

They showed that focusing on dust obscured regions as tracers of the ISM, and on their properties, serves as independent evidence for the external origin of the dust and ionized gas. It appears that these regions actually originated outside of those galaxies. The dusty gas may be evidence of an accretion or merger of other smaller galaxies into these galaxies. This challenges the traditional view that elliptical galaxies are simple objects, and adds a new wrinkle to the classical Hubble classification of galaxies. This relationship between ionized gas and dust in these galaxies may throw light on our current understanding of the nature and origin of the interstellar medium (ISM), and in particular in the context of the interplay between the different multi-temperature components.

In further work, Finkelman, Funes and Brosch observed 16 candidate polar-ring galaxies (PRGs) identified by the Galaxy Zoo project. (Galaxy Zoo, at http://www.galaxyzoo.org, is a project that encourages members of the general public to help classify thousands of galaxies and identify those of particular interest. To date more than sixty million classifications have been made by hundreds of thousands of on-line volunteers. Their identifications of PRGs among these galaxies was instrumental to the work described here).

PRGs are one of the more remarkable objects of the large family of non-barred ring galaxies. They are generally composed of an S0-like galaxy encircled by a

ring of stars oriented in a nearly polar orbit, highly inclined from the plane of the galaxy itself. The two sets of stars orbit the same center of mass, but they otherwise can remain separate for billions of years. These galaxies apparently result from a main disk galaxy capturing stars from another galaxy that passed nearby; as such, they are ideal laboratories to gain insight into galaxy formation processes.

• *Composite of the ring galaxy NGC 660, North at top and East to left, VATT exposures. (Image Boyle and Laugalys)*

Deep images of five of the candidate galaxies were available in the SDSS Stripe82 data base; Funes and his colleagues observed the others with the VATT. They produced a basic morphological and environmental analysis of the galaxies and compared their properties with other types of early-type galaxies. Although previous studies had argued that the environment of PRGs was similar to that of normal galaxies, their analysis revealed that PRGs are actually more common in regions that have a lower density of galaxies. Since the luminous polar ring extends well beyond the main body of the galaxy, it could be that such a ring would be more likely to be disrupted and dispersed if there were other nearby galaxies.

Follow-up photometric and spectroscopic observations will allow a kinematic confirmation of the nature of these systems and a more detailed analysis of their stellar populations. In particular, they hope to confirm that the host galaxies and the rings really represent two distinct stellar populations, with different ages or metallicities.

The work concerning the dust and gas association in galaxies was reported in the Monthly Notices of the Royal Astronomical Society, Volume 422, Issue 2, pp. 1384-1393; that on the polar ring galaxies was published in the Monthly Notices of the Royal Astronomical Society, Volume 422, Issue 3, pp. 2386-2398.

Stellar Astronomy

Classifying stars by their spectral colors goes back to the 19th century work of Fr. Angelo Secchi, S.J., who observed starlight through a prism with his telescope on the roof of St. Ignatius Church in Rome. By the early 20th century a scheme of classification had been worked out that sorted stars into the familiar stellar types O, B, A, F, G, K, and M, based on their color and brightness.

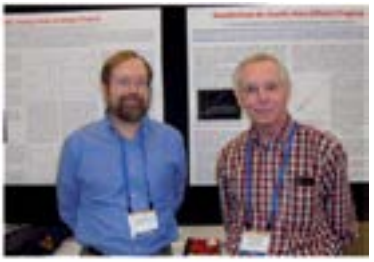
But not all stars fit easily into this scheme. One example is Lambda Boötes, a fourth-magnitude A type star visible not far from the handle of the Big Dipper, which shows an unusually low abundance of metal in its spectrum. It is the class type of a rare population of stars, now called λ Boo type stars. Stars classified as λ Boo have late-B to early-F spectral types, and exhibit (often substantially) low abundances of Fe and related elements, even while the lighter elements such as C, N, O may have more nearly solar abundances. Since less than 2% of objects within the relevant spectral-type domain appear to be λ Boo stars, their existence must be the result of some rather special conditions.

The λ Boo class of chemically-peculiar stars has puzzled a number of researchers, challenging spectroscopists to produce a model which is plausible, comprehensive and predictive. One suggestion has been that this group of stars may not in fact be real, but that each case might be explained as an unrecognized close binary, two stars with very different spectra in a close orbit about each other whose light would blend together and thus appear as one spectrally-odd star in our telescopes.

In a recent paper, Fr. Chris Corbally S.J. and his collaborators Elizabeth Griffin of the Dominion Astrophysical Observatory in Vancouver and Richard Gray of Appalachian State University tested that claim by monitoring 10 stars listed in the literature as possible λ Boo stars but said to be "likely candidates" to be composite-spectrum binaries. They used high-dispersion spectroscopy to look for the sort of line-profile changes that should be detectable if each object were really a pair of similar stars in an SB2 system. Among the ten stars observed were four that were definitely classified as λ Boo types, one listed as possible, and one where the classification was considered marginal. In addition to these ten stars, they also monitored two other stars: HR 7903, said to be a binary (but is more like an Ap star), and λ Boo itself.

They derived the physical properties of these twelve stars by photometric and spectroscopic synthesis, and measured their radial velocities. Three of the sample showed small line-profile variations, but not of the sort that can be attributed to the presence of a companion star; they are the suspected Ap star HR 7903, HR 6878 (which exhibits spectrum peculiarities very similar to those of HR 7903 but has not previously been classified as Bp or Ap), and λ Aql, whose rapid spectrum variations resemble those observed in spotted or CP stars. Most importantly, none of the stars shows any evidence to suggest that it could be a composite-spectrum binary.

This is a classic example of a "null" result that is nonetheless important. After some 8 years of patient observing, it is now clear that λ Boo stars cannot be explained away in a simple manner as just composite-spectrum binaries. The λ Boo problem, first identified around 1940, is real and so far remains unsolved.



• Richard Gray and Fr. Corbally at annual AAS meeting, Jannuary 2012

The work showing that the composite-spectrum binary hypothesis does not explain the λ Bootis stars, by R.E.M. Griffin, R.O. Gray, and C.J. Corbally, was published in Astronomy and Astrophysics, 547, A8, pp. 1-14, 2012.

NASA's Kepler mission is a space telescope with a highly precise photometric camera aimed at a rich field of stars in the Milky Way, studying each star for the faint changes in the brightness, such as that which might indicate the presence of a planet crossing between that star and us. Though it is best known for its

mission to detect exoplanets, in fact this uninterrupted time-series of high-precision photometry of thousands of stars of every pulsational type and flavor is also a precious resource for studying other phenomena that produce small variations in the light from stars. One such phenomenon is the faint flickering of starlight that results from the oscillation of the star itself. The study of such oscillations is astroseismology; like the more familiar study of seismology on Earth, astroseismic studies can reveal a wealth of detail about the interior of stars.

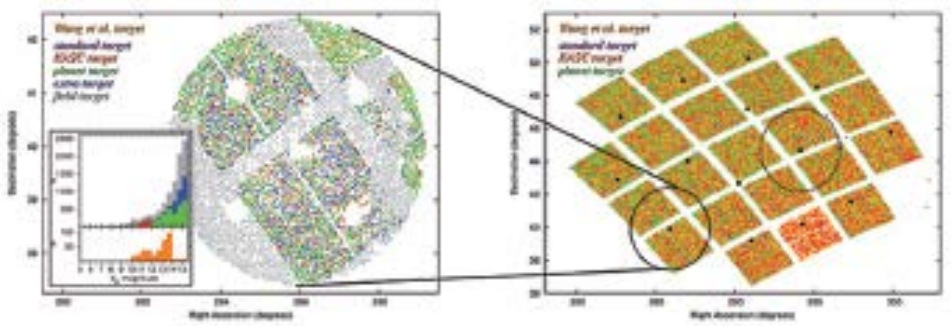
However, the Kepler data do not provide physical parameter information for the stars being observed, such as the effective temperature, surface gravity, metallicity, and projected rotational velocity. This information is key for solving many astrophysical problems. In order to be able to use the Kepler data best, one needs additional ground-based data for these stars.

This has led to an ambitious international project involving researchers from Belgium, China, Italy, Poland, USA, and the Vatican. The astronomers have been organized into three teams. The new LAMOST telescope, a 4 meter telescope located at the Xinglong Observatory, China, is being used to deliver spectra of stars in the Kepler field which are pulsating and so astrophysically interesting. Fourteen fields of stars, fully covering the field-of-view of the Kepler mission, were selected to be observed during the test phase of LAMOST (the Large Sky Area Multi-Object Fiber Spectroscopic Telescope). This telescope has a circular field-of-view of diameter 5 degrees equipped with 4000 optical fibers. The target list consisted of roughly 250 "standard targets" (MK secondary standard stars), with about 7,000 "KASC targets" (targets of the Kepler Asteroseismic Science Consortium) and some 150,000 "planet targets" (targets from the planet search group). Meanwhile, the other teams in Europe and the US gathered supplementary data and provided software to analyze the results.

As a complement and check to the physical parameters of these stars which are being obtained by other teams, Richard Gray and Fr. Corbally are obtaining the stars' spectral classifications. Since there are far too many thousands of "targets" to do this in the traditional "by eye" method, they have developed an automatic classification code, MKCLASS, that surpasses in accuracy and scope any previous auto-classification method. As a check on the classifications of the spectra delivered by the LAMOST fibers, Fr. Corbally has very recently obtained a dozen ground-based spectra with VATTSpec.

Eight of these show close agreement with the automated classifications, while the further four may do so once the star-to-fiber identifications are clarified.

The LAMOST observations in the Kepler field by De Cat, P., Fu, J.N., Yang, X., Frasca, A., Molenda- Żakowiczakowicz, J., Gray, R.O., and Corbally, C.J. were presented at the Fifth Kepler Astroseismology Workshop (KASC5), Hungary, June 2012.

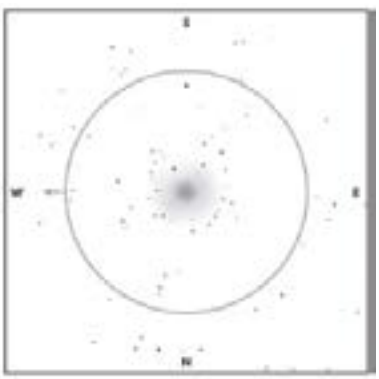


• The objects observed by LAMOST, marked in red (right) were selected from the field of stars (left) obserbed by Kepler space telescope

Fr. Brown, and his colleagues Philip Podsialowski of Oxford and Zhanwen Han of Yunnan Observatory, China, are continuing their work modeling the evolution of subdwarf B Stars of different metallicities undergoing binary interactions.

While most stars shine from the fusion of hydrogen nuclei, hot subdwarf stars of the types sdB, sdO, and sdOB are thought to shine by fusing helium nuclei in their cores. It is believed that these stars form from progenitor stars that have lost most of their outer envelopes of hydrogen, leaving only the helium core behind, but the precise mechanism by which such loss occurred remains unclear. Some modelers have suggested mechanisms in the evolution of a single star, while others look at binary star formation scenarios; so far, it has not been possible to choose between these plausible explanations.

However, one argument in favor of the idea that the stripping comes from the interaction of a star via a binary partner is the observation that a large fraction of hot subdwarf stars in the Galactic field are found in binary systems. Indeed, most of them are short-period binary systems with periods of less than 100 days, suggesting that the star pairs are quite close together, consistent with the idea that one of them may have stripped material from the other. By contrast, in globular clusters such as NGC 6752 only a small fraction of sdB/EHB (extreme horizontal branch) stars are found in short-period binaries.



•The globular cluster NGC 6752 in Pavo, studied by Brown, in a beautiful object in a small telescope (sketch from Consolmagno and Davis, Turn Left at Orion)

Hot subdwarf stars are also thought to be the likely source of the ultraviolet upturn (UVX) in giant elliptical galaxies and early-type spiral bulges. Once again, both single-star and binary-star hypotheses have tried to account for this phenomenon: binary models involve some sort of mass transfer mechanisms, while single-star models appeal to mechanisms which depend on the star's chemical abundance. Seeking to provide a consistent and natural physical explanation for the origin of these hot stars, it was once again proposed that hot subdwarf stars in the Galactic field are the products of binary interactions. When one applies a binary evolution model to the modeling the ultraviolet upturn, it is possible to reproduce most of its properties in systems where it is observed. In their current work, Fr. Brown and his collaborators are working now to expand this binary model. That model originally assumed that the

metal fraction of the stars was originally two percent, but these stars are observed in many chemically diverse environments. Brown's new models now include the effects of different metallicities, ranging from 0.01% up to 5%, in the production of hot subdwarf stars. To date, this population synthesis study has found that varying the original metallicity of a population does not strongly affect the overall formation of hot subdwarf stars in a population, though important second-order effects may be noted.

• *David Brown at the IAU General Assembly in Beijing (photo by Corbally)*

This work, an outgrowth of Fr. Brown's doctoral thesis, will be the first of a series of papers to be submitted for publication over the coming year. It will be presented at the winter meeting of the American Astronomical Society.

For twenty years, Fr. Richard Boyle, S.J., and his collaborators have been refining the use of a system of specially chosen filters, the Vilnius seven filter intermediate-band photometric system, to classify stars in stellar clusters. This work not only involves observing the clusters with this filter set but also testing this system with more traditional observations to confirm that it provides consistent classification.

Using the Vilnius system on three moderate size telescopes, the 1.8 meter VATT, the US Naval Observatory 1 meter telescope in Flagstaff, Arizona, and the Moletai Observatory Maksutov telescope in Lithuania, Fr. Boyle and his coauthors have determined stellar populations in various nearby regions (within 32,000 light years) both above and in the dusty plane of the Milky Way. For stellar classification they have a reference catalog of 13,000 stars representing all classes of the H-R diagram. Precise Vilnius photometry as well as spectral types and luminosity class have been independently determined for these stars.

Newly observed stars receive photometric classification from the closest matching stars of the reference catalog. The Vilnius Photometric System was designed for photometric classification, even in dust-reddened fields; but for determining a star's spectral type and luminosity class to a fine sub-class the photometry must be of 1 to 2% quality. They accomplish this photometric precision for all stars across a CCD exposure field by calibration based on observing the open cluster M67 also in the observing run; all the stars of M67 are now standards with one percent photometric quality, so they serve very effectively to correct the new object fields from systematic error.

They are determining stellar populations, distances, reddening and total extinction Av, and metallicities in some cases, for open clusters, field stars, and

some nebulous regions. For example, they have made observations in the North America Nebula, Pelican Nebula, Horsehead Nebula, and reflection nebula in Auriga. And in some cases they can recognize that named apparent clusters are in fact simply asterisms - chance collections of stars visible in the same line of sight to us but in fact lying at widely differing distances and thus not actually clustered together.

One example of the results of this work can be seen in their observations of the emission nebula Sh2-231 and its relation to the dust cloud TGU 1192 (LDN 1525) by Boyle and his collaborators Fr. Robert Janusz, S.J., from Cracow, and Vytautas Straizys and Vygandas Laugalys from the Vilnius Observatory in Lithuania. The HII region Sh2-231 is thought to belong to the Auriga OB1 association, together with other emission nebulae, Sh2-232, Sh2-233 and Sh2-235, which all can be found near each other, within 1 square degree of the sky. The area is surrounded by a giant molecular cloud G173.7+02.7, which is also known as the dust cloud LDN 1525 (or TGU 1192). Distances estimated from the exciting stars of the HII regions are not well known; they are estimated to lie between 3200 and 7500 light years. Most authors consider that all these HII regions are related to the association Aur OB1: the mean distance of its stars is 4200 light years. In an earlier paper, Boyle and his collaborators argued the Sh2-231 nebula might not be related to the association; more probably this nebula is in the Perseus arm seen semi-transparently through the dust cloud TGU 1192.

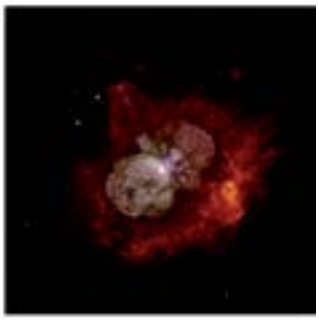
To study this region further, they observed a 12′ by 12′ area in this region with the VATT using the seven filter Vilnius photometric system. From their observations they were able to determine spectral and luminosity classes, interstellar reddenings, extinctions and distances for the field stars down to a visual magnitude of 17 mag. From these observations they calculated the distance to the dust cloud and its relation to the nebula Sh2-231. IPHAS and MegaCam photometry provided spectral types for fainter stars. Both Vilnius and IPHAS photometric data are in agreement that the dust cloud in the direction of Sh2-231 begins at a distance of about 4200 light years, and so it is undoubtedly related to the Aur OB1 association. However, the star ALS 8476 is calculated to be at a distance of 7500 light years, too far to be related to the Aur OB1 star-forming region. Consequently, if this star is the exciting source of Sh2-231, they conclude that the nebula belongs to the Perseus arm.

• *Open cluster top, NGC 609; bottom, M67 (image by Stott at VATT)*

In a similar manner, Fr. Boyle and collaborators Algirdas Kazlauskas and Julius Sperauskas from Vilnius observed the star field Dol–Dzim 5 using the Vilnius photometry system and radial-velocity measurements of the brightest stars in the region. The long-term radial-velocity monitoring revealed that one of the stars, BD + 38d2777, is a spectroscopic binary star with a period of 541 days, calculated from 16 Coravel-type radial-velocity measurements. Furthermore,

the analysis of the available astrometric, photometric and spectroscopic data has shown that it is unlikely that Dol–Dzim 5 is actually an associated open cluster of stars. Rather, the stars are unrelated to each other and merely appear by chance to be in the same line of sight as seen from Earth.

A description of the Vilnius technique was presented in an invited talk given by Fr. Boyle at the European Week of Astronomy and Space Science in Symposium 6, July 2-4, 2012 at the Pontifical Lateran University, Rome, Italy. The scientific results described here were presented at the 219th Meeting of the American Astronomical Society at Austin, TX January 8-12, 2012, and in the journal New Astronomy, volume 19, pp. 34-41, 2012.



• *Eta Carinae nebula (NASA Hubble Telescope image)*

Eta Carinae is one of the most massive binary stars in the Milky Way. It became the second-brightest star in our sky during its mid-nineteenth-century "Great Eruption", but then faded from view (with only naked-eye estimates of brightness). Its eruption is unique in that for ten years it exceeded the Eddington luminosity limit, where the pressure of the light emitted by the eruption was stronger than the star's force of gravity. Because it is only 7500 light years away, spatially resolved studies of the nebula have constrained the ejected mass and velocity, indicating that during its nineteenth-century eruption Eta Carinae ejected more than ten solar masses in an event that released ten per cent of the energy of a typical core-collapse supernova, without destroying the star.

But how can one observe, today, an event that occurred nearly two hundred years ago? It is possible because the light from that eruption traveled away from the event in all directions, including into the gaseous nebula surrounding the star; and so we can see light now that has traveled some hundred light years away from the star, and then has been reflected back by that nebula to reach our telescopes today. This signal of that light is called a "light echo."

In February, Dante Minniti was part of a team organized by the Space Telescope Science Institute in Baltimore who reported observations of a region of gas and dust near Eta Carinae. These consisted of images and spectra taken over several years using the Cerro Tololo Inter-American Telescope in Chile that revealed light echoes from the 1838-1858 Great Eruption. Spectra of these light echoes show only absorption lines, which are blue-shifted by 210 km/s, which is in good agreement with the predicted expansion speeds of the cloud from the eruption. The light-echo spectra correlate best with those of G2-to-G5 supergiants, which have effective temperatures of around 5,000 kelvin. In contrast to the class of extragalactic outbursts assumed to be analogs of the Great Eruption of Eta Carinae, the effective temperature of its outburst is significantly lower than that allowed by standard models of opaque stellar winds, which predicted that the temperature ought to have been close to 7,000 kelvin. This indicates that other physical mechanisms, such as an energetic blast wave, may have triggered and

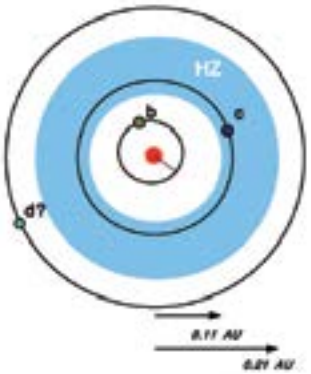
influenced the eruption.

This work was reported in Nature, volume 482, issue 7385, pp. 375-8, 2012.

Exoplanets

Dante Minniti was a member of a team of astronomers from Europe, the US, Chile, and Australia who have discovered a planetary system around a nearby M dwarf star with at least one super-Earth planet in its habitable zone. This star, GJ 667C, is a triple-star system located 22 light years from Earth; it can be found in the sky near the curving tail of the constellation Scorpius.

The data used in this discovery were collected by HARPS, the High Accuracy Radial Velocity Planetary Search, a Swiss-led project that monitors the Doppler shift of stellar spectra to find the very tiny shifts that might indicate that the star is being tugged by the gravity of an orbiting planet. The HARPS team had already searched for and found one planet orbiting very close to this star, with a 7.2 day period; after they had finished their analysis, they then put their data into an archive accessible to any other group of astronomers. When the team that Minniti was part of re-analyzed 4 years of HARPS spectra, they found two new members of the planetary system, among them a terrestrial planet a few times larger than Earth orbiting in a region where liquid water ought to be stable on the planet's surface. They also report a hint of a possible third planet, a gas giant, in the data they analyzed.



• *Diagram of GJ667 planetary system; "habitable zone" shaded blue*

The key to this discovery was a new data analysis technique to find radial velocity (RV) measurements that derives the Doppler measurement and other instrumental effects using a least-squares approach, rather than the technique previously used by the HARPS team.

To make these discoveries, the team made 143 analyses of the HARPS data with their new technique and then added 41 additional new radial velocity measurements from the Magellan/PFS and Keck/HIRES spectrometers. With these data, they found three additional signals beyond the previously reported 7.2-day candidate planet, with periods of 28 days, 75 days, and a secular trend consistent with the presence of a gas giant (with a period of approximately 10 years).

The 28-day signal implies a planet candidate with a minimum mass of 4.5 Earth masses orbiting well within the region around the star at which an Earth-like planet could sustain liquid water on its surface. Still, the ultimate ability of this planet to support water depends on properties that are unknown, such as how much light the surface of the planet actually absorbs from its star, its atmospheric composition, and the dynamics of its interior.

The signal indicating a planet with a 75-day orbit is less certain, being significantly affected by aliasing interactions among a potential 91-day signal and the likely

rotation period of the star at 105 days detected in two activity indices.

The star GJ 667C is the common proper motion companion to the GJ 667AB binary. One surprise is that this particular star is metal poor compared to the Sun. Previous work had suggested that metal-rich stars were more likely to be the hosts of planetary systems, and there had been some speculation that multiple star systems might be unlikely to form planetary systems because of the interfering gravitational pull of the other stars in such systems. However, the presence here of a super-Earth in the habitable zone of a metal poor M dwarf in a triple star system supports the evidence that such worlds should be ubiquitous in the Galaxy.

This work was published in The Astrophysical Journal Letters, Volume 751, article id. L16 2012.

To date, most exoplanets have been detected by their effects on dimming the light of their host star during a transit, or shifting the spectra of that star by its reflex motion as the planet orbits the star. Only a few planets have actually been imaged directly, since they are so much smaller and dimmer than their host stars while being so close to them.

One promising technique to image planets directly is to combine the light from two telescopes in such a way that the light from the star is canceled while that from the planet is enhanced. This technique is called "nulling interferometry." While in theory it should be possible to detect planets in this way, the technical details so far have been insurmountable. Not the least of the problems is the necessity of having a telescope with two mirrors in a fixed position. But one such telescope ideally suited for this work is the Large Binocular Telescope (LBT) at the Mount Graham International Observatory. Fr. Paul Gabor, S.J., is taking part in the team effort led by Dr. Philip Hinz of the University of Arizona's Steward Observatory to bring this "nulling interferometry" to the LBT.

The Large Binocular Telescope, along with the Submillimeter Telescope, is the VATT's neighbor on Mt Graham. It has two light gathering mirrors, each 8.4 meters in diameter, on a common mount. The structure was a major engineering challenge. There are several other telescopes, such as the twin Keck telescopes on Mouna Kea, and the four VLT telescopes of the European Southern Observatory in Chile which can be used in interferometric mode (see Annual Report 2011, pp. 22-23) without placing giant mirrors on a common mount. But the reason why the LBT chose this ambitious design was precisely so that it could be used not only for ordinary constructive interferometry, but also for nulling interferometry.

As explained in last year's Research Highlights, the purpose of constructive interferometry is to measure the sizes of various objects in the sky. Nulling interferometry, on the other hand, is a way of enhancing the visibility of objects such as planets, debris disks, or protostellar/protoplanetary disks in orbit around

•*Diagram of Large Binocular Telescope's twin 8.4 m mirrors*

stars which are much brighter. A nulling interferometer can make the star appear much dimmer, allowing astronomers to study the light coming from the star's immediate vicinity. In order to do that, the instrument has to be extremely stable.

Recall that, when seen from space in the visible light, the Earth is 10 billion times fainter than the Sun. If an alien on a planet orbiting a nearby star wanted to see the Earth orbiting the Sun in visible light, that alien would have to make sure that the optical field captured by each of the two telescopes is identical to within at least one part in 10 billion, so that he/she/it could use destructive interference to eliminate sunlight, and see only earthlight. This need for such extreme precision is why nulling interferometers are exceedingly difficult to build and to operate. What is more, looking through our own atmosphere to a distant star makes the undertaking even more challenging, because our atmosphere makes the star "twinkle" in slightly different ways between the two telescopes.

However, the LBT was designed with such observations in mind. The two mirrors are on a common mount; though this approach initially created a great engineering challenge, it was necessary to make nulling interferometry possible. Furthermore, both of the telescopes are now able to compensate for the "twinkling" effect: adaptive optics systems operate on both telescope mirrors. What remains to be commissioned is the nuller itself: an optical setup with small mirrors that can move with atomic precision (0.2 billionths of a meter) in order to combine the two optical fields and eliminate about all but 1/100,000 of the starlight.

Fr. Gabor's expertise in interferometry began with his thesis work at the Institute of Space Astrophysics in Paris where he worked on an interferometer to be flown in space on a mission dedicated to searching for planets. Here on Earth those same talents can be used with the twin mirrors of the LBT. Thus his work on this team is to participate in the alignment of the nuller optics, and to contribute in other technical ways to the work of the team. The Nuller is scheduled to be commissioned in 2013.

Planetary Sciences

On January 5, 2012, Fr. Boyle and Casimir Cernis (from Vilnius University) first noted a slowly moving object in the field of view of a star cluster that they were observing at the VATT. Boyle returned to image this same field in late January, and with these new images Cernis and his colleague Vygandas Laugalys, also of Vilnius University, made the precise measurements of the body's location relative to the fixed stars in the images which allowed them to determine that they had discovered a Trans-Neptunian Object: a large proto-comet orbiting

•Newly discovered trans-Neptunian object 2012 BX85 (top); three main belt asteroids are also shown (image by Boyle at VATT)

our Sun beyond the orbit of Neptune. Once this observation was accepted by the Minor Planet Center it was given the provisional name "2012 BX85."

According to their calculations, the brightness of this body suggests that it has a size somewhere between 200 and 470 km. (Depending on the brightness of its surface, it may be bright and small or dark and large.) It orbits the sun once every 284 years, at an average distance of 43 AU, that is, 43 times the distance from the Earth to the Sun. Compared to other TNOs its orbit is relatively close to the plane of the other planets in the solar system and only slightly eccentric; such objects are considered part of the "cold classical disk" of TNOs.

Only three TNO objects were discovered in all of 2011; this one marked the first TNO discovery of 2012.

The discovery of this object was reported in the Minor Planet Bulletin M.P.E.C. 2012-B100, issued 2012 Jan. 30, 15:54 UT

This discovery presaged a very fruitful year at the VATT. Even though asteroid discovery is not the prime goal of this team's observing, with so many hours at the telescope it was inevitable that they would come across many faint objects moving through their field of view. As it happened, in 2012 they discovered about 70 new main belt asteroids; a "Centaur" (a proto-comet orbiting among the giant planets) designated 2012 DS85; a particularly distant object, 2012 VU85, with a period of 922 years which may be a Scattered Disk Object from the Kuiper belt or perhaps a comet; and, at the other extreme, a new Near Earth asteroid of the Amor type (orbiting just outside Earth's orbit) designated 2012 XH16, which has a diameter of only about 150 meters - about half again as large as a football field.

Meteorite heat capacity (also known as specific heat) is an essential parameter in modeling many aspects of the evolution of asteroids, the parent bodies of meteorites. Understanding how asteroid interiors (or indeed the interior of any primitive body, such as comets or icy moons, which are thought to have a significant component of meteorite-like material) will heat up or cool down requires knowing how much energy is gained or lost for every degree of temperature change.
Furthermore, some of the most important non-gravitational forces that change the way small bodies alter their spin or change their orbits around the Sun, the Yarkovsky and YORP effects, depend on how their surfaces collect, hold, and re-emit the heat of incident sunlight. And in fact, models for the brightness of meteors and the response of planetary surfaces to impact cratering depend, along with other factors, on the heat capacity of material involved. Beyond these

uses, however, heat capacity is itself an independent measure of the meteorite's composition that could provide a non-destructive way of indicating the bulk composition of a whole meteorite.

Br. Consolmagno, along with colleagues Dan Britt at the University of Central Florida and Brad Schaefer and Martha Schaefer at Louisiana State University, are developing a new, non-destructive procedure for measuring the heat capacity of minerals and rocks that can be applied to measure this quantity in meteorites. An insulated dewar of liquid nitrogen is placed on a balance and its evaporation rate is measured over time. A small sample (to date, the range covered is 5 to 30 g) is dropped into the dewar and the amount of nitrogen evaporated by the heat input from the sample is determined. By measuring how much nitrogen is needed to cool the sample from room temperature down to liquid nitrogen temperature (77 K), one can calculate the average heat capacity of the sample over this range of temperature.

The procedure is still being refined; measurements on laboratory-grown quartz standards have allowed the researchers to calibrate the system and correct for the typical systematic error. The spread among the averages of samples of the same meteorite type is less than 3%, but the variation from run to run can be as much at 10%. The quartz standards and achondrite values are about 7% lower than literature values for quartz and pyroxenes.

The more traditional ways of measuring heat capacities for geological samples usually only work at room temperature or higher, but there is a procedure using a Quantum Design Physical Properties Measurement (QDPPM) System which does cover the cold temperatures found in the asteroid belt. Unfortunately it only measures small samples, and it is expensive both in terms of sample consumption, and time (as well as being an expensive instrument itself.) So far, our results are consistent with the one QDPPM heat capacity measurement that has been published.

In addition to these standards, however, to date Br. Consolmagno has made more than 220 runs on 27 meteorites, including both ordinary and carbonaceous chondrites, achondrites, and metal rich meteorites, along with the quartz standards. Furthermore, the Louisiana State collaborators have access to a QDPPM and so it is possible that a limited number of meteorites can be measured there with the results compared against the new liquid nitrogen technique.
Of the results so far for meteorites, significant differences have been found in the average heat capacity among different meteorite types. Iron and mesosiderite samples have the lowest heat capacity values, but metal content alone is clearly not the only factor in a meteorite's heat capacity since the metal rich CR and aubrite classes have in fact the highest heat capacity values measured. Ordinary chondrite types H and L are essentially indistinguishable from each other and from quartz, though the two finds measured to date have a slightly higher value

•Dewars in the meteorite lab used to measure meteorite heat capacity (photo by Consolmagno)

than the falls. Our measured CVs are similar to the ordinary chondrites, while COs are slightly higher.

This work was reported at the annual meeting of the Meteoritical Society, held in Cairns, Australia in August.

In 2011, NASA put a pair of spacecraft in orbit around the Moon which today is producing a map of the gravity field of unprecedented accuracy. The GRAIL mission, which was completed in December 2012, has provided very tight constraints on how large and dense the Moon's core is, the thickness of its crust, and the location of denser basaltic features. However, accurate lunar rock densities are necessary for constructing gravity models of the Moon's crust and lithosphere. Most Apollo-era density measurements have errors of 2-5% or more and few include porosity measurements.

•*Consolmagno holding a piece of the basalt 12051, collected on the Moon by Apollo 12 astronautus (photo by Macke)*

Br. Consolmagno and Br. Robert J. Macke, S.J., at Boston College, are members of a team who have reported new density and porosity measurements for Apollo samples and lunar meteorites to fill this need. They used the bead method for measuring bulk densities pioneered in the Vatican meteorite lab, along with helium pycnometry, to measure six Apollo samples and seven lunar meteorites to an unprecedented precision. Typical grain density uncertainties were only 0.3-0.9% with porosity uncertainties of 1-3%.

Basalt grain densities are a strong function of composition, varying at least from 3.27 g/cm^3 (high aluminum basalt) to 3.46 g/cm^3 (high titanium basalt). (By comparison, water has a standard density of 1 g/cm^3.) In contrast to these relatively high densities, the feldspathic highland crust has a bulk density of 2.2-2.6 g/cm^3 and a porosity of 10-20%. Impact basin ejecta has a bulk density of 2.35-2.6 g/cm^3 and a porosity of about 20%.

These densities are significantly lower than what had previously been assumed for the crust of the Moon. Applying them to the new results of the GRAIL mission for the gravity field structure of the Moon has led to a significant change in the way we understand the composition of the bulk Moon. This, in turn, may lead to a significant change in our understanding of how the Moon itself formed.
This work was published in the Geophysical Research Letters, Volume 39, Issue 7, CiteID L07201.

History and philosophy

After some delays in obtaining appropriate permissions, the correspondence between Fr. Angelo Secchi S.J. (1818-1878) and Pietro Tacchini (1838-1905),

edited by Ileana Chinnici and Antonella Gasperini (INAF-Osservatorio Astrofisico di Arcetri), is now at a very advanced stage and it is expected to be ready by the end of 2012. A preliminary presentation of this work has been given in Florence, and at the Pontifical Ateneum "Regina Apostolorum" in Rome. Of particular interest in these letters are Secchi's positions concerning the religious, philosophical and scientific controversies of his time.

Meanwhile, Dr. Chinnici is still working on scientific exchanges between English and Italian spectroscopists in the second half of 19th century. After her stay at the Science Museum in London, where she collected many interesting materials on this subject, a paper is now in preparation.

•*Spectra of stars observed in the mid 19th century by Fr. Secchi (from his book, Le Stelle, 1877)*

•*Fr. Teilhand de Chardin, S.J.*

Fr. Paul Mueller, S.J., is contributing to the collaborative research project "Taking off from Teilhard," which is being sponsored by the Woodstock Theological Center, an independent theological institute located at Georgetown University in Washington, D.C. This project aims to focus critically on key ideas from Fr. Teilhard de Chardin, S. J., one of the seminal thinkers of the 20th century on the role of science and theology, and to develop those ideas in new ways for the 21st century. Fr. Mueller's contribution pertains to Teilhard and science.

Fr. Mueller has also been immersing himself in the work of the noted 18th century Jesuit scientist and philosopher Fr. Roger Boscovich, S.J. He presented a paper, "Boscovich and the Jesuit Scientific Style," at a symposium held at the Gregorian University in December, 2011, in honor of 300th anniversary of the birth of Boscovich. And he continues his ongoing inquiry into possible methodological connections or "cross-talk" between the new science of the early 17th century and contemporary biblical philology.

• *Fr. Roger Boskovich, S.J.*

One of the first philosophers to reflect on the concepts of Space and Time, following the developments of the new physics born out of the researches of Galileo and Newton, was Immanuel Kant. Since his early works, he combined

his thinking on cosmological questions with his enquiries on the nature of Space from a philosophical point of view.

Fr. Gionti and Alfredo Sgroi of the University of Catania have examined how Kant slowly departed from Leibnitz's position, which considered Space as a simple relation among objects, to arrive to his own original idea that Space is "an *a priori* form of the human external sensibility of the knowing subject". In his Critique of the Pure Reason Kant dealt with the crucial issue about the extension of the known Universe. Kant arrived to the conclusion that the *a priori* form of Space cannot be applied to an entity, like the Universe, that transcends any limit of human exterior sensibility. On the other hand, he also worked not to fall into Hume's skepticism (that one cannot be sure at all of reality).

•*Immanuel Kant*

The authors note that many researchers believe Kant's theory is outdated because it is based on Newtonian physics, which has been surpassed by Einstein's theory of Relativity. However, they conclude that in fact Kant's theory of Space is still valuable and can be easily used also in Relativistic Theories. This confirms that Kant's philosophy can be interpreted as a metaphysics of scientific concepts, which was probably the main intent of his philosophy. This work was published under the title "Spazio e Cosmologia nel Pensiero di Kant" in La Civiltà Cattolica. 2, 353-366, 2012.

Finally, after some delays in obtaining permission, the edition of the correspondence between the renowned astrophysicists Fr. Angelo Secchi S.J. (1818-1878) and Pietro Tacchini (1838-1905), is now at a very advanced stage.A preliminary presentation of this work was given this year in Florence by the two curators, Ileana Chinnici and Antonella Gasperini (INAF-Osservatorio Astrofisico di Arcetri).

5. Instrumentation and Technical Services

VATT Team Changes

The year 2012 brought about changes in the Vatican Advanced Technology Telescope (VATT) team.

• *David Harvey (1958-2012) was an essential part of the VATT team for many years (photo by Frank Gacon of Steward Observatory)*

Our talented and dedicated software engineer, David Allen Harvey (1958-2012), passed away in September after 30 years of distinguished service to astronomy. He greatly helped the Vatican Observatory with VATT, beginning in 1991 during its construction phase. He developed the VATT's Telescope Control System (TCS), the software that makes the direct drive motors access and track objects across the sky, and he designed its accompanying GUI to relay the observer's commands. As he did for other Steward Observatory telescopes, Harvey maintained the VATT's pointing map. When in 2007 the management of VATT was transferred directly to Steward's Mountain Operations, Harvey formally became a member of its engineering team with responsibilities for software, instrumentation, and observer support. Many VATT users have been grateful for his expertise in solving all manner of problems. The Vatican Observatory has also benefited from his artistic and technically innovative photographs. We have lost a true "friend of the telescope", but we are glad to help keep his memory alive by supporting a new gallery of his photographs in Steward Observatory.

Three further team changes occurred in 2012. Scott Swindell was hired on September 1 as a new software engineer. He has a degree in physics, programming experience, and great motivation for working in the field of astronomy. This is his first position, after graduating from college and spending three years in the Peace Corps in Kenya and South Africa. His first project was to focus on the Next Generation Telescope Control System, Dave Harvey's brainchild. Together with Chris Johnson, they continued NG TCS development aiming to implement it soon on VATT as well as on other telescopes operated by Steward Observatory.

The team was joined also as of September 1 by Michael Franz who came on board as a telescope operator facilitating remote observing runs. Michael knows VATT intimately because he contributed to its mechanical design and construction over a period of 9 years. His duties therefore include assistance with documentation, instrument changes, and mechanical issues. During his first months on the team in his new capacity Michael became a fully certified observer, a prerequisite for his main role which concerns VATT's remote observing capability. He can now train and certify new observers himself.

Last but not least, on September 15, 2012, Fr. Gabor joined the VATT team in

his new capacity of Vice Director for VORG, succeeding Fr. Corbally's excellent record of service since the very beginning of VATT. Fr. Corbally remains on the team as the Principal Investigator of the VATT Spectrograph, together with Fr. Boyle, telescope scientist and scheduler, Bob Peterson, Steward Observatory's head of mountain operations, Ken Duffek, VATT manager and principal engineer, Chris Johnson, software engineer, and Gary Gray, site manager.

•*At the telescope with VATTSpec are Ken Duffek (left) and Gary Gray (right)*

Telescope & Infrastructure

Maintenance had to be performed on one of the incremental encoders. Duffek replaced a light source and calibrated the encoder.

As a service to the general astronomical community in southern Arizona and worldwide, at the initiative of Fr. Corbally and the International Dark-Sky Association (IDA), Duffek and Gray installed the Night Sky Brightness Meter which is a photometer collecting information about the levels of light pollution on Mt Graham, and submitting it to IDA headquarters. The NSBM project was started by Dan McKenna, with the support of the Vatican Observatory, while he was VATT telescope manager.

A new flats screen was installed in the dome by Franz and Gray for the convenience of observers, facilitating the calibration procedures of VATT's imagers VATT4k and GUFI.

Duffek completed an upgrade of the VATTSpec and VATT4k computers. Before the upgrade there was a single computer controlling the VATTSpec and VATT4k cameras. Although the lack of a back-up has never caused telescope down-time, it was nonetheless a liability which needed to be eliminated.

•*A new screen in the VATT dome allows a target for flat-field images to calibrate a telescope cameras*

VATT Spectrograph

During commissioning of VATTSpec Corbally, Duffek, and Harvey discovered a small shift in the grating tilt, perpendicular to dispersion, as the telescope elevation changed. After considerable effort by Mario Rascon, Steward Observatory Machine Shop, and Duffek the shift was halved so that performance became acceptable. Scientific observations with VATTSpec started in May and both observations and commissioning continued through the end of the year, thus gaining experience for optimum settings.

Remote Observing & Beyond

Remote observing brings certain benefits (increasing on-sky time and subscription rate, and thereby the scientific productivity of the telescope) but they are probably not sufficient to justify remote observing as a goal in itself. Its true benefits arrive with automation/robotization:

- optimal use of shutter time (time sharing),
- allowing (indirect) access to scientists, students and amateurs from around the world,
- facilitating synoptic observations,
- allowing survey-type observations,
- facilitating observing programs spread out over time (e.g., 10 minutes on a target once every month).

Simply put, remote observation with robotization provides more kinds of science programs, plus education and public outreach (EPO) benefits. In addition, robotics means reducing the annual bill for operation and maintenance, and therefore a more effective use of the talents of our engineering staff (e.g., development of new instruments).

Preliminary studies commenced in 2012 to explore possible scenarios of VATT's mid to long term future (automation and/or robotization of the telescope, overhaul of the optical layout, and future instrumentation). Co-ordination and collaboration with Steward Observatory's new Director, Buell Jannuzi, and Assistant Director, Dennis Zaritsky, emerged as a priority in the process in which VATT is considered in the context of the broader set of telescopes operated by the University of Arizona and other partners.

Two teams were invited to inspect VATT with view of its automation/robotization. The team of Professor Klaus Strassmeier, Director of the Observatory in Potsdam, Germany, prepared a study after a visit in November, and a team from ProjectSoft collated information during their visit in December with view of submitting a proposal in 2013.

An important prerequisite for this work concerned VATT's documentation. Duffek and Franz organized the archived material and prepared it for consultation by the visiting teams.

Preparatory work has begun on a scheduler, i.e., a software system the purpose of which is creating a sequence of targets distributed during the night and/or during the month or even the year, according to object visibility, distance from the moon, time sensitivity of the observation, priority of the scientific project, etc. Such a tool is required for queue observing where a human or robotic operator and/or service observer performs scheduled observations, collecting science

•Ken Duffek (left) with Zdenek Bardon (center) and Tomas Turek (right), the CEO and Technical Director of ProjectSoft

data for the astronomers. An additional requirement for the scheduler will be the upcoming installation of a laser guide star facility on the Large Binocular Telescope. The scheduler will help co-ordinate observations, prevent targeting conflicts, and generally contribute to a harmonious co-existence of the telescopes on Mt Graham.

Vatican Observatory Website

Ayvur Peletier, the administrator of the domain vaticanobservatory.org, performed an audit of the website content, analyzing what number of hits various sections receive, identifying content bloated sections, etc.

In December, the Vatican Observatory began a presence on Twitter with the account @VaticanObserv. Accounts in other languages include Italian (@SpecolaVaticana), Spanish (@ObserVaticano), French (@ObsDuVatican) and Polish (@WatykanskieObsA).

Meteorites

Olivine grains from three pallasite meteorites, Brenham, Finmarken, and Ilimaes, have been loaned to Dr. Elisa Wheeler of the Institut Laue-Langevin, Grenoble, France for neutron spectroscopy. These samples may be among the first meteorite to be measured in this way.

The carbonaceous chondrites Grosnaja and Vigarano and the basaltic meteorites Juvinas, Dhofar 018, Dhofar 081, and Shalka were loaned to the Institute for Space Physics (IFSI) in Tor Vergata for measurements of visual and infrared spectra for comparison with the surface of Ceres and Vesta by the Dawn mission using instruments developed at IFSI.

Three remarkable meteorites have been added to the Vatican Observatory collection in 2012. A Shergotty class meteorite, believed to originate from Mars, was seen to fall near the town of Tissint, Morocco, 2011; two pieces summing nearly 50 grams of this rare piece were donated to the Vatican Observatory by an anonymous collector. In April, 2012, a fireball visible across northern California dropped pieces of a rare volatile-rich carbonaceous chondrite near Sutter's Mill, the location of the famous California gold rush of 1849. Half a gram of this rare meteorite type (valued at more than its weight in gold!) was provided to the Vatican Observatory by Greg Hupe. And finally, a fragment and a thin section of the carbonaceous meteorite Murchison was donated to the Vatican Observatory collection by Dr. James Shorten, a meteorite collector in Tucson. This meteorite is famous for providing the first unambiguous evidence of complex organic material known to come from outside Earth.

•*A sample of the Murchison meteorite donated by James Shorten*

6. Observatory and Staff Activities

•Fr. Pavel Gabor, S.J., new VORG vice-director

Awards and Appointments

On August 22, Cardinal Giuseppe Bertello, President of the Pontifical Commission for Vatican City State, approved the appointment of Fr. Gabor as Vice Director for the Vatican Observatory Research Group (VORG) in Tucson. Starting on September 15, Fr. Gabor replaces Fr. Corbally in that position. On behalf of the Vatican Observatory staff we are most grateful to Fr. Corbally who has served in this position since 1984 as Administrator and since 1993 as Vice Director. He has played a crucial role in building and running the VATT.
Fr. Corbally continues to be on our staff in Tucson. We wish Fr. Gabor well in his service as VORG Vice Director.

In August this year, the XXVIII International Astronomical Union General Assembly in Beijing, China, admitted Fr. Brown, Fr. Gabor and Fr. Kikwaya to IAU membership.

Dante Minniti was named Academician at the National Academy of Sciences in Argentina, November 2012.

Also this year Fr. Corbally completed his 3-year term as IAU Division IV (Stars) President at the end of the IAU General Assembly.

On February 24, Fr. Coyne, emeritus director of the Vatican Observatory and emeritus president of the Vatican Observatory Foundation received the Holy Cross Pro Ecclesia et Pontifice in recognition for his outstanding service to the observatory. Fr. Funes conferred the award on Fr. Coyne at the Foundation's Annual Awards Dinner in Los Angeles. The Cross is one of the highest honors bestowed on clergy and religious and is awarded for distinguished service to the Holy Father and the Catholic Church.

•Luigi Lori is inducted into the Sylvestrine Order by Cardinal Bertello

On April 3, Cardinal Giuseppe Bertello, who is also President of the Governatorate of Vatican City State, conferred the Pontifical Order of Pope Saint Sylvester on Mr. Luigi Lori in recognition of his devoted service to the Observatory for 31 years.

On April 17, Cardinal Giuseppe Bertello presented Mr. Roberto and Mrs. Maria Buffetti the Grand Cross of the Order of Pope Saint Sylvester in the degree of Knight Commander and Dame Commander in recognition for their generous gifts to the Vatican Observatory. The ceremony was followed by a lunch in the community with the Buffettis and Cardinal Bertello.

•*From left: Fr. Maffeo, Cardinal Bertello, Roberto and Maria Buffetti, Fr. Funes, Fr. Maj*

•*Br. Aloysio Puhl (circled) with Pope Pius XII and the members of the observatory staff at the Schmidt telescope in 1958*

In Memoriam

This year we were saddened by the death of Brother Aloysio Puhl S.J. Br. Aloysio served at the Vatican Observatory in Castel Gandolfo for 30 years (1954-1984) giving technical support to the Vatican astronomers.

On occasion, the Holy Father would turn up unannounced and ask Br. Puhl to see the stars through the Observatory's large telescope located on the rooftop of the Pontifical palace.

After 30 years of service at the Pope's astronomical Observatory, Br. Puhl revealed the following to a Jesuit confrere: "Those were years of grace. Immerging oneself in this immense, marvelous universe, man can only sense how small, how infinitely tiny he is. This endless universe is quite simply awe-inspiring and fascinating, and its very contemplation brings man to his knees before God, the Creator".

Pisa Exhibit

On March 9, the exhibition "*Storie Dall'Altro Mondo*" (Stories from Another World) opened in Pisa, Italy. Co-sponsored by the Vatican Observatory, this show presented a collection of astronomical photos, meteorite samples (including pieces of rock from the Moon and Mars), modern artifacts, historical instruments and books, and interactive educational experiences. Besides the Vatican Observatory, the other collaborators for this exhibit included the Italian National Institute of Nuclear Physics, the Department of Physics at the University of Pisa, and the Archdiocese of Pisa.

•The exibit "Storie dall'Altro Mondo (Stories from Another World) in Pisa ran from March 9 to June 30

This exhibition also celebrated the life of Cardinal Pietro Maffi, a scientist and historian of science who served as Archbishop of Pisa in the early 20th century. Cardinal Maffi also served as president of the Vatican Observatory during its formative years. He was responsible for bringing Fr. Johann Hagen, S.J. from Georgetown University to be its director, the first Jesuit to hold that post.

The Cardinal's letters and writings on matters both religious and scientific were on display. In addition, among the books on display was one on astronomy and geography that Cardinal Maffi received from friends in China which may be the work of the famous Jesuit missionary Matteo Ricci.

The theme of the exhibition was "the universe within and without us." When the Vatican Observatory's role in this exhibition was first announced, Fr. Funes underscored the connection between the universal and the particular. "The history of the universe could not be told without our 'small' human stories," he said. "Cardinal Maffi lived a dual existence: the world of the Church and that of science... in his search for a deeper meaning to human existence."

Staff presentations, Academic Activities and Conference Participation

BOYLE presented a poster paper at the 219th meeting of the American Astronomical Society, Austin, TX. January 8-12 • gave an invited talk entitled "Stellar Populations and Intermediate-band Photometric Systems" at the Pontifical Lateran University, Rome, Italy. This talk was within Symposium 6 from July 2-4: "Stellar Populations 55 Years after the Vatican Conference" during the European Week of Astronomy and Space Science 2012.

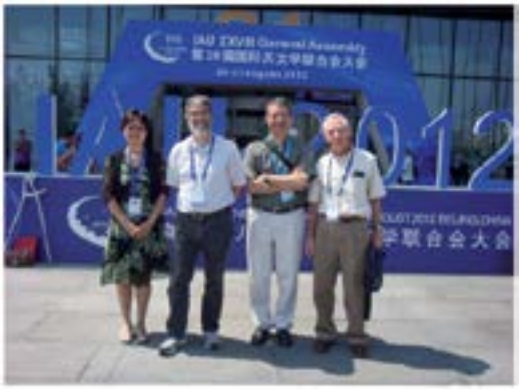
BROWN gave a seminar at VOSS on "Binary Population Synthesis and Binary Stars" • attended the 28th General Assembly of the International Astronomical Union in Beijing, China, August 20-31 • attended the European Week of Astronomy and Space Science at the Pontifical Lateran University, Rome, July 2.

•Fr. Brown presented the Globular Cluster Prize, sponsored by the Observatory, to Nikolay Kacharov and Anna Fabiola Marino at the Globular Clusters Conference held in Frascati in December

CARUANA continued to lecture on topics related to the scientific mentality and its relation to religious belief and unbelief at Heythrop College, University of London • presented a paper on June 13, 2012 entitled "Life, Science, and Meaning: some logical considerations" • invited speaker for the lecture series on "Can Science define Life?" organized by the Chair in Science, Technology and Religion, at the Universidad Pontificia Comillas, Madrid, Spain.

CHINNICI gave a conference on Fr. Secchi's life and scientific activity, May 29, Rome • gave a talk on Fr. Secchi's spectral studies June 12, Albano • gave an invited paper on "Astronomy and Worldviews" during conference Man and Universe – East, West, South, Kraków, June 22-23 • gave a conference on Fr. Secchi's life and scientific activity, Palermo, October 12 • gave a conference on Fr. Secchi's case in Faith-Science dialogue, Rome, November 6 • gave a conference on the scientific cooperation between Secchi and Tacchini, seen through their correspondence, Florence, November 22 • gave a conference on Fr. Secchi's life and scientific activity, Reggio Emilia, November 23.

CONSOLMAGNO completed his term on the Prize Committee of the American Astronomical Society Division for Planetary Sciences • continues on the International Astronomical Union Working Group on Planetary System Nomenclature and the Working Group on Cartographic Coordinates and Rotational Elements • served on the Scientific Organizing Committee and presented a poster at the triennial conference on Asteroids, Comets, and Meteors held on 15-20 May in Niigata, Japan • presented a paper at the annual Meteoritical Society meeting held 13-18 August in Cairns, Australia • participated in the General Assembly of the International Astronomical Union, 20-31 August, in Beijing, China • presented a poster at the annual meeting of the American Astronomical Society Division for Planetary Sciences, held 15 - 19 October in Reno, Nevada • presented an invited paper in December on the physical properties of dark meteorites at a workshop in Paris for the ESA Marco Polo space mission.



•*Yping Wang (VOSS93) joined Br. Consolmagno, Fr. Brown, and Fr. Corbally at the IAU General Assembly in Beijing*

CORBALLY was first author of one poster paper and co-author of a further two papers at the American Astronomical Society meeting #219, Austin, TX, January 8-12 • served on the SOC of the International Network of Catholic Astronomical Institute's Workshop Exploring the Nature of the Evolving Universe II, at Catholic University of America, Washington, DC, July 16 – 20, where he also presented a paper on stellar spectral classification • participated in the Annual Conference and Council meeting of the Institute on Religion in an Age of Science, July 28 – August 3, Silver Bay, NY. • for the IAU: as Division IV (Stars) president participated on April 4 in a telecom to discuss meeting proposals for 2013, and

at the IAU XXVIII General Assembly in Beijing, China, August 19-31, 2012, participated in the IAU Executive Meeting #91, attended business meetings of the various Commissions and Working Groups under Division IV, co-chaired a joint meeting of Division IV and V; as chair of the National Committee for the Vatican City State voted during the two sessions of the General Assembly; as a member of the Astronomy and Planetary and Space Sciences group in Arizona, gave a paper at the Special Session 17 of the General Assembly on Light Pollution • on November 9 gave a colloquium at Valparaiso University, IN, on "λ Boötis Stars" to its Department of Physics & Astronomy, and on the previous day gave a public lecture on the topic of Galileo • paid a working visit to Appalachian State University, Boone, NC, over December 9-11.

FUNES gave the Nieuwland Lecture at the University of Notre Dame on Science and Faith, South Bend, IL • gave a lecture at the Catholic University of America, Washington, DC • gave a talk at the meeting organized by the Institut für Astronomie and the University of Vienna on Extraterrestrial Life in Vienna May 21-22 • gave the introduction to the Symposium on Stellar Populations 55 years after the Vatican Conference at European Week of Astronomy and Space Science 2012, Rome, July 2-4 • gave a poster paper on the Vatican Observatory Summer Schools in the 28th International Astronomical Union General Assembly, Beijing, August 20-31 • gave a paper on Complexity and Analogy on the Search of Extraterrestrial Life at the Plenary Session of the Pontifical Academy of Sciences, Vatican City, November 5-7 • invited by the Embassy of the Republic of China (Taiwan) to the Holy See, Fr. Funes visited the National Science Council, Central Weather Bureau, the Fu Jen Catholic

• Fr. Funes with a group of faculty and students at the Institute of Astronomy, National Central University, Taiwan

University, Institute of Astronomy & Astrophysics, Academia and Sinica and Institute of Astronomy, National Taiwan University in Taipei, National Tsing Hua University, Hsinchu, Institute of Astronomy, National Central University, Chung-li • invited by the Embassy of the Islamic Republic of Iran to the Holy See, Fr. Funes gave a lecture at the Teheran University and at Teacher Training University in Teheran on the Astronomical research of the Vatican Observatory and visited the Kaajeh Nasir-od-Din historical observatory monument and Maraghe Observatory in Maraghe and the Astronomical Research Center in Qom.

GABOR visited the Astronomical Institute of the Academy of Sciences of the Czech Republic in Ondrejov on August 12. He consulted with the engineering and scientific staff, drawing upon their experience with the Czech Two Meter telescope automated by ProjectSoft HK in 2007 • gave a seminar on Exoplanet Space Missions at the Steward Observatory and Lunar and Planetary Laboratory astrobiology and exoplanetology journal club on February.

GIONTI was invited by the theoretical division of C.E.R.N. to attend the 2012 Winter School in Gauge Theory, Supergravity, Superstrings from February 6 - 10 • with GABOR, was asked to organize the meeting of the Vatican Observatory Scientific Staff, which was held in Loreto (AN)-Italy at the House of the Clergy near the Loreto Basilica, July 3-7 • attended the annual meeting on String Theory, STRINGS 2012, July 23-28, Ludwig-Maximilians-Universität (LMU) Munich, Germany • attended the XXXI European Symposium on Occultation Projects (ESOP) in Pescara, Italy, August 24 – 27, giving a talk on "Fr. Christopher Clavius, S.J. Jesuit and Scientist and his legacy at the Roman College" • attended the 97th meeting of the Italian Physics Association (Societá Italiana di Fisica) from Monday, September 17 – 21, at the University of Naples "Fredrick II", gave a talk, "Some considerations on Discrete Quantum Gravity" in the Astroparticle and Cosmology section • attended the XX meeting of the Italian Society of General Relativity and Gravitational Physics, October 21 – 26, at the Astronomical Observatory of Capodimonte in Naples. At this meeting, one of his collaborators, Prof. Franco Pezzella, gave a talk on their common project on T-Duality in String Theory and its implications for extended theories of the gravitational field.

HELLER Polish Mission by UN, talk: The Road through the Universe; Man in the Universe April 18, Geneva • CERN, Cosmology of Lemaitre, April 20, Geneva, • International Conference "The Causal Universe", talk: Bottom-up Causality in a New Setting, May 17-18, Kraków • gave a talk at the Congress of the Christian Culture, Catholic University of Lublin, on: Science and Religion – the Current State of the Dialogue, September 27-30 • CERN Conference: Big Bang and Religion Debate, talk: The language of a dialogue: what it is about? October 15-17 Nyon, Switzerland •Plenary Session of the Pontifical Academy of Science "Complexity and Analogy in Science", talk: Analogy, Identity,

Equivalence, November 5-7, Rome • Milano Cultural Center, Aula Magna of the "Sacro Cuore University", public lecture: The Universe as a Mind of God November 12 • public lecture: Creation of the Universe Bergamo, November 13.

JANUSZ attended international conference on science, philosophy and theology "Man and Universe -- East, West, South", June, 22-23, by The Jesuit University Ignatianum and The Copernicus Center for Interdisciplinary Studies in Kraków, Poland, presented paper on the medieval approach to science and creation -- "Medieval 'Magnetic' Cosmology" • organized a workshop on behalf of the Vatican Observatory and the Jesuit University Ignatianum, Kraków, September 10-13, on photometry of the "StromVil" Group.

MAFFEO participated in a conference marking the 40th anniversary of the death of Fr. Christopher Clavius, S.J. at the National Library in Rome. Maffeo presented two little known documents by Fr. Clavius on the importance of teaching mathematics at the Pontifical Roman College • presented lecture on importance of relationship between science and faith at adult spiritual retreat.

MUELLER gave a talk at the "Simposio Scientifico Internazionale: Padre Ruđer Josip Bošković, cultore della verità", on "Bošković e lo stile scientifico dei Gesuiti," 10 December 2011. The Symposium was sponsored jointly by the Pontifical Gregorian University, the Ministry of Foreign Affairs and European Integration of the Republic of Croatia, and the Philosophy Faculty of the Society of Jesus at Zagreb.

OMIZZOLO participated in public conferences at the University of Roma 3, at the Bergamo Science festival and at the Universita' della Magna Grecia in Catanzaro • gave a short talk at the "Notte dei ricercatori" organised by University of Padua and by the Istututo Nazionale di Astrofisica (INAF) in Padua, September 28.

STOEGER gave an invited lecture "Cosmology, Evolution, Causality and Creation: The Limits, Compatibility and Cooperation of Scientific and Philosophical Methodologies" at the Templeton Foundation Conference on "The Causal Universe," Kraków, Poland, May 16-18 on cosmology and philosophy • Catholic Theological Society of America Annual Convention, St. Louis, MO, June 7-10 – on the convening committee for the Theology and Natural Sciences Topic Session for 2011-2013 • gave an invited talk, "Two Issues in Cosmology: Initiation of Inflation and Large-Scale Spatial Homogeneity at conference on "Exploring the Dark Universe: Frontiers of Cosmology and Astrophysics in the 21st Century," in memory and in appreciation of Professor Fang Li Zhi, October 7-8, Westward Look Resort, Tucson, Arizona."

•Fr. Corbally, and Catholic University of America's President John Garvey, Dr. Duilia de Mello, and Dean Lawrence R. Poos, Dean of the School of Arts and Science, at the opening of the INCAI Evolving Universe workshop (photo courtesy of Duilia de Mello)

Educational and Public Outreach

BROWN served as Dean for the 2012 Vatican Observatory Summer School (VOSS). This included planning and organization of the school and conferring with its professors, June 3-29 • a seminar on *Faith & Science* was provided for the Roman chaplaincy of the University of St. Thomas (Minneapolis-St. Paul, MN), April 18 • a seminar on *Faith & Science* was given to engineering students from various American universities on May 28 at the Vatican Observatory headquarters • a seminar on *Faith & Science* was given to the English Seminarians at Villa Palazzolo at Rocca di Papa on July 8.

CHINNICI led an evening conference on a historical subject for VOSS participants. "Back to early astrophysics: Fr. Secchi's spectral studies" followed by a small but appreciated exhibition of Secchi's books from the Vatican Observatory Library.

•Br. Consolmagno's presentation in British Columbia in February coincided with celebrations for the 400th anniversary of the arrival of Jesuits in Canada

CONSOLMAGNO gave 47 public presentations on science and science/religion issues in the United States and Canada during the year 2012. Among the most notable of these presentations was the 12th annual Kennedy Lecture. "The Heavens Proclaim," at St. Peter Catholic Church in Charlotte, North Carolina, on January 28; the annual Nash Lecture, "The New Physics and the Old Metaphysics" at Campion College of the University of Regina, Saskatchewan, on February 2; and the Herzfeld Lecture, "The Matter of Meteorites, and Why It Matters," at Catholic University on April 12. He also spoke as a Visiting Scholar on Catholic Thought at Benedictine University, Chicago, in February, and gave keynote addresses to the Archdiocese of Denver annual conference, "Doers of the Word," and the annual lecture series on science and religion at the Siena Center of Dominican University, Chicago. In addition, over the US Labor Day weekend in early September, he sat on eight panels discussing popular science, astronomy, and the role of religion in fiction at the annual World Science Fiction Convention in Chicago, Chicon 7. Along with talks in North America, he also spoke at the "Infinitamente" Science Festival in Verona, Italy, in March and at the University of Freiburg, Switzerland, in April.

CORBALLY at the Arizona State Parks "Star Night" at Kartchner Caverns, AZ, on March 17, gave a talk on "The Vatican Observatory: From the Calendar to the Cosmos" • was the keynote speaker on May 5 at The 5th Annual St. Peregrine Shrine Charity Golf Tournament & Dinner and presented "The Vatican and

Astronomy" • presented the topic of "Astronomy in China" in the Third-Thursday Star Talks series at Prescott Public Library, Arizona, on September 20 • was hosted at St. Lawrence University, Canton, NY, October 14-17, where he visited the Adirondack Public Observatory (under construction), gave the 2012 Niles Lecture on Science and Religion entitled "Heroic Galileo and the Message in the Stars", and contributed to several classroom sessions • gave evening talks on December 7 and 8 at the Primland Resort, VA, on "Astronomy in China" and "The Star of Bethlehem", and repeated the latter talk at the Sun City Vistoso Astronomy Club, AZ, on December 20 • hosted visits to the Mirror Laboratory on University of Arizona campus and to the VATT. One of the latter on April 11 included the Belen Jesuit Observatory group with Fr. Pedro Cartaya, S.J. and five docents from the Mirror Laboratory.

FUNES gave presentations and public lectures on Astronomy, the Vatican Observatory, and Science and Faith Dialogue at the "Inigo" Cultural Center at the Novosibirsk Diocesan Center, the M'ARS Contemporary Art Center and Institute of St. Thomas in Moscow; at the annual seminar of the Vatican Observatory Foundation in Los Angeles (CA); at Saint Ignatius High School, Chicago; at Observatory of Naples.

GABOR taught a 3-unit undergraduate course at the University of Arizona on the History and Philosophy of Astronomical Thought (ASTR320) in the Spring Semester 2012. He gave a talk to the Tucson Paulist Associates at the parish of St Cyril of Alexandria on the Vatican Observatory and exoplanet direct imaging on Oct 6.

GIONTI participated in writing several posters on Fr. Christopher Clavius, S.J., life and legacy, which are now displayed at the Gesù Church in Rome • gave a talk on "Cosmology and the Question of God" at the high school-Liceo Scientifico- in Genzano (Rome) • chaired the meeting "Knowledge and Wisdom in Engineering" held at the University of Rome "La Sapienza" Engineering Chapel in 'S. Pietro in Vincoli', Rome.

MAFFEO took part in organizing VOSS, in particular in promoting fundraising for students and institutions in developing countries.

OMIZZOLO spent the large part of 2012 heavily involved in the Pisa Exhibition and connected events. About 21500 people visited the exhibition and young people were the majority. Concerts and conferences accompanied the exhibition on a monthly basis.

STOEGER gave workshops on Cosmology, Theology and Spirituality at the Redemptorist Renewal Center, Cortaro, AZ, March 26-29 and October 22-25 • A number of other cosmology, and science and theology talks, retreat and workshops, including those in Tucson, Anthem, AZ, Santa Cruz, CA,

Albuquerque, NM • was chair and convener of the St. Albert Science, Faith and Spirituality Sessions at the Newman Center, University of Arizona, including a presentation, "A Creating God and Big Bang Cosmology: Are They in Conflict?" • visiting lecturer on several occasions in University of Arizona Courses • Chair of the Board of the Center for Theology and the Natural Science, Berkeley, CA, and Trustee of the University of San Francisco.

News and Media Coverage

BOYLE and CORBALLY welcomed the German ZDF TV staff to visit them at VATT in January. A resulting video in German was broadcast on the ZDF TV Sonntags program on Jan. 29. This is now archived on the website: www.zdf.de

BROWN gave an interview regarding the Vatican Observatory and *Faith & Science* done for the Jesuit Conference of the American Jesuit Assistancy, April 16.

CONSOLMAGNO participated in a five radio interviews, ranging from a local Catholic radio station in Kentucky and a college station in Chicago, to Radio Veritas in South Africa and an appearance on the Public Radio International program "To the Best of Our Knowledge"; he also appeared in a Catholic News Service video. Interviews by CONSOLMAGNO appeared in newspapers in the US and Brazil following the announcement of the possible discovery of the Higgs Boson by CERN; in addition, an op-ed piece by him on that topic appeared in the Washington Post science and religion blog page. Perhaps the most unusual interview this past year asked CONSOLMAGNO for his advice as a frequent traveler in the syndicated newspaper column "Go away with..." written by Jae-Ha Kim.

CORBALLY on July 2 joined Paul Davies & Seth Shostak on the Colin McEnroe Show on WNPR, Connecticut Public Radio, for interviews on the search for extraterrestrial life • was a special guest on August 9 for "The Bishop's Hour," hosted by Michael Dixon and broadcast on 1310 AM Radio in Phoenix, AZ, and by internet • was interviewed on October 11 for the "White Dove of the Desert", an independent documentary on San Xavier del Bac, Its Art & History, by Joel Ailer for Sky Media Company.

FUNES on February 2 participated in a press conference at the Holy See Press Office to present the Exhibit in Pisa • gave interviews to the Vatican Radio, Radio-5 (National Radio of Spain), Clarín (Newspaper, Buenos Aires), Arizona Daily Star and Estrella de Tucson (Tucson).

GABOR gave an interview to Tarsicius, a Czech monthly, published in the Dec 2011 issue, pp. 4-5, under the title Pilgrimage through Infinite Space.

GIONTI was interviewed by a representative of the USA Jesuit conference for a web-based project, April 16 • was interviewed on the announcement of CERN regarding the discovery of the Higgs boson by the Vatican Radio on July 5 • by

the News Agency "Rome Reports" July 18 • O Universo como manifestação de um Deus criador benevolente. Interview by Márcia Rosane Junges. Revísta do Instituto Humanitas Unisinos • took part in panel discussion for presentation of Fr. Heller's book "Tensione Creativa", Ferrara, November 28 • participated in conference "Visione del Cosmo", Cremona, November 29.

MUELLER was interviewed by a representative of the USA Jesuit conference for a web-based project, April 16 • was interviewed by a representative of Vatican Radio, August 19 • was interviewed by the Ignatian News Network, October 10.

7. Publications

Books

The book *Angelo Secchi. L'avventura scientifica del Collegio Romano*, edited by Aldo Altamore (Università di Roma Tre) and Fr. Maffeo was published in May 2012; it contains two contributions by Ileana Chinnici and Fr. Maffeo on Fr. Secchi's life and activity and on his relationship with the other astronomers of that time. A book presentation was held in Rome in May and in Palermo in October, and in Reggio Emilia in November, each featuring a presentation about Secchi by Ileana Chinnici.

Frontiers of Astrobiology, edited by Chris Impey, Jonathan Lunine and José Funes, was released by Cambridge University Press in November 2012. The volume is the result of a "Study Week" in Astrobiology organized by the Pontifical Academy of Sciences. The Study Week explored issues related to one of the most profound questions humans can ask in science: Is there life beyond Earth? The editors have paired authors of differing disciplines or viewpoints and asked them to write their chapters in a seamless, collaborative style. By common assent, the authors have written chapters for a much broader audience than would normally read a volume of conference proceedings.

Fr. Heller has been busy in 2012 with the publication of the following books: *The Universe as a Road*, Znak, Kraków, 2012 (in Polish); *La scienza e Dio*, ed. Gulio Brotti, La Scuola, Brescia, 2012; *Tensione Creativa. Saggi sulla scienza & sulla religione*, Akousmata – Orizzonti dell'Ascolto, Ferrara, 2012, transl. Marina Alfano and Rosolino Buccheri; *Filozofia przypadku* [Philosophy of Chance, paperback], Copernicus Center Press, Kraków, 2012 (in Polish). Philosophy of Chance, Copernicus Center Press, Kraków 2012, transl. R. Śmietana.

Vistas de la Galaxia by astronomers Dante Minniti, Joyce Pullen and Ignacio Toledo, tells the story of an ambitious astronomical project and the people involved in the amazing discoveries of a three-year trip through the Universe using ESO's 4.1-metre Visible and Infrared Survey Telescope for Astronomy (VISTA), the world's largest survey telescope. The book describes a series of discoveries made with VISTA in recent years. These include more than 100 new star clusters (eso1128, eso1141), novae and over 300 new distant galaxies, among many others.

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8. Observatory Visitors

Visitors to the Vatican Observatory Headquarters in Castel Gandolfo

On April 17, Cardinal Giuseppe Bertello President of the Governorate of Vatican City State, visited the Headquarters of the Vatican Observatory in Castel Gandolfo to present Mr. Roberto and Mrs. Maria Buffetti the Grand Cross of the Order of Pope Saint Sylvester.

On June 27, Cardinal Bertello met the faculty and students of VOSS 2012.

On May 10, the diplomatic corps accredited to the Holy See visited the Headquarters and the domes on the roof of the Pontifical Palace. The visit ended with a reception offered by the Secretary of State, Cardinal Tarcisio Bertone.

•The visit of the Diplomatic Corps to the Vatican in May included a tour the Double Astrograph Dome on the roof of the Papal Palace

During the VOSS 2012, we welcomed the following diplomats:

Mr. José Carlo Diaz, Minister Counselor of Argentina to the Holy See; Mr. Silvio Garcia Meneses, Minister Counselor of Brazil to the Holy See; H.E. Mrs. Anne Leahy, Ambassador of Canada to the Holy See; H.E. Mr. Fernando Zegers Santa Cruz, Ambassador of Chile to the Holy See; H.E. Mr. Larry Yu-yuan Wang, Ambassador of the Republic of China (Taiwan) to the Holy See; H.E. Mr. Fernando F. Sánchez Campos, Ambassador of Costa Rica to the Holy See; Her Royal Highness Princess Khétévane Bagration de Moukhrani, Ambassador of Georgia to the Holy See; H.E. Mr. Marcus Nigel Baker, Ambassador of Great Britain to the Holy See; Mr. Iván Eduardo Cáceres Andino, Minister Counselor of Honduras to the Holy See; H.E. Mr. Bahar Budiarman, Ambassador of Indonesia to

the Holy See; H.E. Mr. Francesco Maria Greco, Ambassador of Italy to the Holy See; H.E. Mr. Héctor Federico Ling Altamirano, Ambassador of Mexico to the Holy See; H.E. Mr. Joseph Weterings, Ambassador of Netherlands to the Holy See; H.E. Mr. César Castillo Ramírez, Ambassador of Peru to the Holy See; H.E. Mr. Jozef Draveckỳ, Ambassador of Slovakia to the Holy See; Mrs. Kesinee Rojdenduang, Minister Counselor and Mrs. Apha Thirakaroonwongse, First Secretary of Thailandia to the Holy See; Mr. Héctor José Perez Romero, Minister Counselor of Venezuela to the Holy See.

We also accompanied the following visitors on tours of the Vatican Observatory headquarters in the past year:
In January, 5 Jesuits from the Jesuit Curia and two visiting priests from America;
In February, Fr. Gerald McGlone S.J. and 5 associates;
In April, Kaitlyn McCarthy of the USA Jesuit Conference, June Scobee Rogers and husband Don, a group of Jesuit Provincial Superiors from Africa;
In May, a group of engineering students from Duquesne University (Pittsburgh, PA), the Most Rev. Paul Hendricks, auxiliary bishop of the Diocese of Southwark, UK, Michael Hilbert S.J. and a group of 4 benefactors, Fr. Larry Ober S.J. and 4 associates, 6 faculty members from various USA universities;
In June, a group from VOF and a group from Loyola University Chicago;
In July, members of the Swiss Guard;
In August the Galileo Circle of Benefactors of the University of Arizona, USA, led by Dr. Chris Impey, a group of benefactors and Australian philosopher Philip Matthews;
In September, a group of friends and benefactors; in October, American Seminarians and families, Jesuit faculty member from John Carroll University, USA and 4 associates of Fr. Stephen Planning S.J.
In October, the Most Rev. Roger Foys, bishop of the Diocese of Covington, KY, USA; American Seminarians and families, Jesuit faculty members from John Carroll University, USA and 4 associates of Fr. Stephen Planning S.J., H. E. Mons. Gerald F. Kicanas, Bishop of Tucson, and H.E. Mons. William C. Skurla, Archbishop of Pittsburgh;
In November, a group of employees of the Internet office of the Governatorate of the Vatican City State visited the VO;
Seminarians and priests accompanied by a bishop from the Slovenian College in Rome;
Jo Walton, award winning science fiction author.

•Fr. Brown (left) and Br. Hollywood and Fr. Mueller (right) were hosts to Bishop Skurla (second left) and Bishop Kikanas (center) at the Papal Palace in October

The following paid working visits to the VO in Castel Gandolfo

Dr. Fernando Comeron, European Southern Observatory Headquarters, Garching.
Prof. Alejandro Clocchiatti, Pontificia Universidad de Chile, Santiago.
Prof. Christopher Impey, University of Arizona, Tucson.

Visitors to the Vatican Observatory Research Group and VATT in Tucson, Arizona

Fr. Corbally hosted visits to the Mirror Laboratory on University of Arizona campus and to the VATT. One of the latter on April 11 included the Belen Jesuit Observatory group with Fr. Pedro Cartaya, S.J. and five docents from the Mirror Laboratory.

Marcelo E. de Araujo, Universidade Federal do Rio de Janeiro, Brazil, January 27 to February 7, to work with Fr. Stoeger on their theoretical cosmology research projects.

Bill Mathews, S. J., Milltown Ecumenical Institute, Dublin, Ireland, March 28-April 9, to consult with Fr. Stoeger on philosophical issues in theology and science, and philosophy of mind.

Nelson Velandia Heredia, S. J., Pontificia Universidad Javeriana and Universidad Nacional de Colombia, Bogota, Colombia, August 18 to December 1, during this period he worked with Fr. Stoeger on his Ph.D research in gravitational physics.

VATT hosted working visits from Aileen O'Donoghue and Jeff Miller, St. Lawrence University, Canton NY, USA Frank Younger, DAO, Victoria BC, Canada.

VO staff working visits to other institutions

Fr. Boyle along with Dr. Vygandas Laugalys visited Caltech in Pasadena, CA, to confer with Dr. John Stauffer, organizer of a survey concerning the variability of Young Stellar Objects. There they also discussed joint work with Dr. Luisa Rebull about dark clouds in the Milky Way.

•Dr. Aileen O'Donoghue and Fr. Corbally at the VATT

They also spoke with Leon Harding there from the National University of Ireland, Galway, who was finishing his dissertation using VATT observations on Brown Dwarf objects. Boyle and Laugalys also visited B. G. Anderson at NASA-Ames to discuss joint work concerning VATT observations on reflection nebulae. Also they did an observing run in collaboration with Dr. Fred Vrba at the U. S. Naval Observatory, Flagstaff, with the 1-meter R-C telescope.

Fr. Boyle and Fr. Janusz organized a four day workshop for September 10-13 at the Ignatium University in Cracow, Poland. They participated in it with seven collaborators come from Vilnius to discuss their joint work on stellar photometry in the StromVil Photometric System.

Fr. Gionti visited the Department of Physics of the University of Naples "Fredrick II" from Monday, May 27- June 2, for collaboration with the local String Theory Group on a research project on T-Duality in String Theory and its consequences on "extended" theories of Gravitation. Fr. Gionti took part, as proxy of Fr. Funes, at the 8th Steering Committee meeting of I.C.R.A.net (International Center for Relativistic Astrophysics) in Pescara on February 2012 (and another extraordinary Steering Committee meeting in Rome, on October 15, at the University of Rome "La Sapienza" in occasion of the signature for a project of collaboration between ICRAnet and the Brazilian "CAPES". This project included the development of an ICRAnet site in Brazil and the institution of several Ph.D. and Postdoc positions financed by the Brazilian "CAPES".