THE AMERICAN BRIDGE

2011 Annual Report

The VATICAN OBSERVATORY

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2011 ANNUAL REPORT

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Vatican Observatory Publications

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Cover: *Stained glass window in Boston College Library commemorating Vatican Observatory and Fr. Hagen, S.J.*
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1. From the Director

• *The Director, Fr. José Funes, S.J.*

The American Bridge

In 1906 Father Johann G. Hagen, S.J., director of the Georgetown College Observatory, was called to Rome to serve as the first Jesuit Director of the Vatican Observatory.

A few months ago Father Paul Mueller, S.J., our coordinator for Science, Philosophy and Theology Studies, caught our attention when he pointed out that one of the stained-glass windows in the library of Boston College commemorates the Vatican Observatory and Father Hagen. This is the image on the cover of this year's Annual Report.

When I saw the photograph of that window I decided that this year I wanted to highlight the activities that are developed in the United States by the Vatican Observatory staff and friends.

Fr. Hagen was the first connection between the Vatican Observatory and the United States, a connection which has grown not only in quality but also in quantity over the past two decades.

The history of the Vatican Observatory is quite similar to the history of other astronomical observatories. In its search for dark skies, in 1980 the Specola Vaticana set up a research group known as the Vatican Observatory Research Group (VORG) at the University of Arizona. This agreement with the Steward Observatory gave the Vatican astronomers access to many large telescopes in Southern Arizona. This fruitful collaboration blossomed with the dedication of the Vatican Advanced Technology Telescope in 1993. The construction of the telescope and the astrophysical facilities on Mount Graham was possible thanks to the support of donors and friends of the Vatican Observatory Foundation, especially the generosity of Mr. Fred A. Lennon and Mr. Thomas J. Bannan.

This period of important growth in the life of the Vatican Observatory took place under the directorship of Father George Coyne, S.J.. This year Fr. Coyne has been assigned by our Jesuit Superiors to LeMoyne College in Syracuse where he will teach astronomy and develop a lecture series on the dialogue between science and religion.

The entire staff of the Vatican Observatory is most grateful to Fr. Coyne for his inspired leadership. He has been on the staff for 42 years and director for 28 years. Fr. Coyne is a world-recognized leader in Astrophysics, earning the esteem of our colleagues and receiving many academic awards. With the encouragement of Blessed John Paul II, he has been a pioneer in promoting the dialogue between science and faith. We wish him well in the new mission that he has received.

First Remote Observing with the VATT from Tucson

Remote control of a telescope can mean that the observer-operator is not physically present at the telescope but can accomplish a full scientific observing run safely and efficiently from elsewhere. On March 30, Father Richard P. Boyle, S.J., observed in remote mode with the VATT for the first time from an office in Steward Observatory. This is an important milestone in the VATT's history and opens up a veritable treasure chest of new possibilities for VATT users. I would like to take this opportunity to congratulate the VATT team which is doing a really excellent job in running the telescope efficiently and keeping it in good shape for the new challenges ahead.

VOSS 2012

The Vatican Observatory is committed to offering educational opportunities for the next generation of astronomers. The Vatican Observatory Summer School (VOSS) is a concrete sign of that commitment. We are eagerly preparing for the upcoming VOSS12 on *The Formation and Evolution of Stellar Clusters: From Star Cluster Ecology to Tracers of Galaxy Evolution.* The school will be held for the second time in the new facilities of the Vatican Observatory in Castel Gandolfo. I am very grateful to Prof. Douglas Heggie (Chair, University of Edinburgh, United Kingdom), and to the faculty: Dr. Francesca D'Antona (Faculty VOSS01, INAF-Osservatorio Astronomico di Roma, Italy), Dr. Nate Bastian (VOSS03, Excellence Cluster Universe, Munich, Germany), and Dr. Mark Gieles (VOSS03, 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 accepting to serve as dean of the school. The school will explore the chemical and dynamical aspects of the formation and evolution of stellar clusters in the Milky Way and beyond.

International Network of Catholic Astronomical Institutions (INCAI)

The Vatican Observatory is committed to scientific astronomical research, education, and the promotion of scientific enterprise by being one of the founding members of the International Network of Catholic Astronomical Institutions (INCAI).

In 2008 the Catholic University of America, Washington DC, the Pontificia Universidad Católica, Santiago, Chile, and the Vatican Observatory signed a

memorandum of agreement to express their intent to cooperate in promoting education and research opportunities for faculty, staff, graduates, and students. Their goals also include the exploration of ways to work together in projects regarding Science and Faith and to organize workshops, conferences and schools on scientific topics relevant to the members of the network. Our group is also committed to promoting collaboration with other Catholic Institutions.
As a result of this collaboration the first INCAI workshop *Exploring the Nature of the Evolving Universe* was held at the Pontifical Catholic University of Rio de Janeiro from August 15-19.

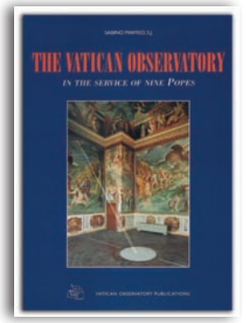
All the initiatives and activities we present in this Annual Report are made possible thanks to the support of the Governatorate of the Vatican City State, donors, friends and colleagues. To all of them goes our deepest gratitude.

José G. Funes, S.J.

José G. Funes, S.J.
Director

• Fr. José Funes, S.J., with former VOSS students participating in the INCAI workshop in Rio de Janeiro. From left to right: Roberto Saito (VOSS 2007), Verónica Motta (VOSS 1997), Carolina Chavero (VOSS 2007), Rafael Eufrasio (VOSS 2010)

2. The American Bridge



• Fr. Maffeo's book

In his book entitled *The Vatican Observatory – in the service of nine Popes*, Father Sabino Maffeo, S.J., speaks of the establishment of 'the American Bridge' as the beginning of a third historical period for the Vatican Observatory.

The year was 1980, and up to that point the Observatoy as an institute had been confined first to Vatican City and then later, to equally restricted premises at the Apostolic Palace in Castel Gandolfo.

However, the Vatican Observatory's growing collaboration on an international scale, coupled with a parallel realization of the need to establish another observing station, meant that its scientists began to look farther afield for darker skies. In the words of Fr. Maffeo, their journey was to take them westward.

• Boston College window

The Bridge to America - Fr. J.G. Hagen, S.J. (1847-1930)

The cover of this year's Annual Report gives us a clue as to why. It is a photo of a part of the Science window in Gargan Hall of the Bapst Building, one of the libraries at Boston College. There are 14 stained-glass windows in that library depicting all aspects of Jesuit education. They were designed and created by the American artist Earl Edward Sanborn (1890-1936), whose work also appears in the Washington National Cathedral. In the photo reproduced on the cover of this year's annual report, we clearly see the Vatican Observatory and Fr. Johann Georg Hagen, S.J.

Over the course of the 1900s, the universities, institutes and observatories of the United States had increasingly appealed to the Pope's astronomers. This 'American bridge' can be traced back to 1906, when at the age of 60, Fr. Hagen arrived in Rome from the Jesuit Georgetown College Observatory in Washington to take up the post of Director of the Vatican Observatory, the first Jesuit to hold the position.

A naturalized U.S. citizen, Fr. Hagen was widely respected in his field of observational astronomy, and counted among the most eminent American astronomers. He was also credited with having revolutionized the Georgetown facility, and a task no less daunting awaited him at the Vatican Observatory. At the time the Observatory had a photographic telescope – known as the *Carte du Ciel* – on the Leonine Tower. However, its other small telescopes along with the meteorology instruments and the Observatory offices were located on the

• *The Tower of the Winds, circa 1900*

lower floors of the Tower of the Winds, while the solar telescope (heliograph) was on the Pio VII museum building. Accessing the Carte du Ciel telescope from the offices in the Tower of the Winds was inconvenient, to say the least. So Fr. Hagen appealed to Pius X to be allowed to move the instruments and offices closer to the Carte du Ciel telescope. His appeal was successful and he was granted nothing less than the former summer residence (villa) of Leo XIII. In 1907 he was also granted permission to connect the same building via an iron bridge to the Leonine Tower and the *Carte du Ciel* telescope. Later, in 1910, a visual telescope was installed on the second oldest tower of the Leo XIII building, with which Fr. Hagen was able to continue his important research on variable stars and dark clouds. The iron bridge was funded by gifts from his American friends.

On the academic front, Fr. Hagen's first concern was to complete the Vatican's contribution to the Astrographic Catalogue, a project undertaken along with 17 other observatories around the world. He visited the various observatories which were already well along with the plate measurements and studied the best techniques and instruments to accomplish the task. The undertaking, which had begun in 1914, was finally completed in 1928: ten volumes printed with extreme care by the Vatican Publishing House, listing the brightness and positions in rectangular coordinates of 481,215 stars. Fr. Hagen also dramatically reduced meteorology research and reorganized the library by completing the series of astronomical publications and journals. He also transferred important collections of astronomical interest from the Vatican Library.

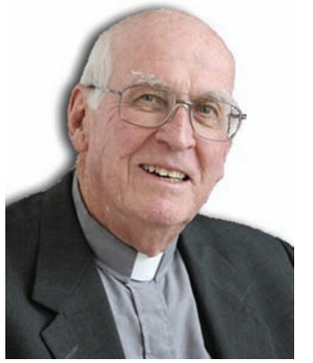
Fr. Hagen died on September 5, 1930; he was 83 years old. In the words of Fr. Maffeo, his was *"a successful life full of work to the good of science and the Church. Especially linked to his name will always be the reorganization of the Vatican Observatory"*.

The stained glass window bearing his image in Boston College is just one of the many tributes that have been made to this great priest and scientist.

Journey Westward - Fr. Coyne

Shortly after Fr. Hagen's death, the search for darker skies would see the Vatican Observatory relocated to Castel Gandolfo, home of the Papal Summer Residence high in the Alban hills. There the work of the Pope's scientists continued uninterrupted until 1980, when the need for better sky conditions became an imperative. One of the biggest questions facing Fr. Coyne, on his appointment as Observatory director in 1978 by Pope John Paul I, was where to go. There were various possibilities: But for the 45 year-old Baltimore native, the obvious choice was west and more precisely to accept an invitation to set up a branch of the Vatican Observatory in Tucson, Arizona. The Pope's astronomers could avail themselves of the large telescopes located there and collaborate with many other institutes such as the National Optical Astronomy Observatories, the Smithsonian Institute and the University of Arizona Observatories, which together make Tucson one of the most important astronomical centers in the world.

Fr. Coyne, a member of the Vatican Observatory since 1969, had already conducted research and held teaching positions in Tucson with the several astronomical institutes of the University of Arizona. He had developed very good working relations with colleagues at the University, and at the time of his appointment, he was Director and acting Director of two of the University's Institutes. Coupled with this, other members of the Vatican Observatory, particularly the younger members, were also involved with research in the Tucson area. These factors all pointed towards the establishment of some permanent collaborative relationship with a University capable of offering space and high quality instrumentation to the Pope's Astronomers. So, in 1980, Fr. Coyne set up a collaboration between the Vatican Observatory and the Steward Observatory of the University of Arizona in Tucson.



• *Fr. George Coyne, S.J.*

The agreement established between both parties stipulated that with the payment of an annual fee, the Vatican astronomers in Tucson (who now became known as the Vatican Observatory Research Group, VORG) would be given space and services at the University and access to the Steward Observatory. Fr. Coyne subsequently promoted the installation on Mount Graham of the Vatican's very own telescope, the Vatican Advanced Technology Telescope (VATT). The VATT's 1.8 m diameter mirror was the optical prototype for the new technology used for the gigantic Large Binocular Telescope, installed on the same site. To finance these endeavours, Fr. Coyne also established the Vatican Observatory Foundation, which aims to provide the means necessary for the construction and operation of the VATT.

The fact that there were now two locations, Castel Gandolfo and Tucson, marked a new beginning in the history of the Vatican Observatory and changed its way of doing research. And all of this was thanks to the vision Fr. Coyne and the generosity of the Observatory's many friends and benefactors in the US and beyond.

Full circle: From Tucson to Rome

As previously mentioned, Fr. Coyne will be leaving the Vatican Observatory at year's end, after 42 years of dedicated and energetic service (28 as Director) which brought the Vatican Observatory to new territory and new heights. In Tucson, he has passed the baton to a dedicated team of astronomers whose ongoing advances in research are highlighted in the following chapters of this report. However, one milestone reached this year deserves particular mention.

Since the very first design phases, remote observing has been one of the goals for VATT. This would allow the telescope to be operated by an off-site user. In 1995 when the telescope first began scientific operation, however, the hardware support and network infrastructure was simply not available to insure safe operation of the telescope, remotely.

Technology has improved significantly in the last 15 years, and the Vatican Observatory is proud to announce that the VATT has had its first fully-remote observing session.

In March 2011, Fr. Boyle, one of the astronomers at the Vatican Observatory, ran the telescope from his office in Tucson, 100 miles away from the telescope in our first-ever fully-remote observing session. While there is more work that needs to be done before this becomes routine (in particular, several safety systems are not yet accessible remotely), this is an important first step toward making the telescope available to off-site observers, for example, to someone in the offices in Castel Gandolfo. This will open up a whole new chapter in the history of the Vatican Observatory and its American connection.

• *Fr. Richard P. Boyle, S.J.*

• *The VATT (left) and Sub-Millimeter Telescope (right) on Mt. Graham. Photo by Alex Lovell-Troy*

3. Research Highlights

Planetary Sciences

This past year, Father Jean-Baptiste Kikwaya, S.J., successfully defended his PhD thesis, *The Bulk Density of Small Meteoroids*, at the University of Western Ontario. His analysis of the brightness and time of flight of meteors observed in Canada and the US allowed him to determine the densities of the grains of sand from comets and asteroids that produced those "shooting stars."

• *Fr. Jean-Baptiste Kikwaya, S.J.*

From this work, Fr. Kikwaya and his co-authors Peter Brown and Margaret Campbell have found evidence of large-scale radial mixing in the early solar nebula. They began with high resolution, multi-station video images of 92 meteors. By modeling the ablation of the meteoroid material, they could determine the combination of speed and density that best fit a meteor's observed brightness and deceleration. Typically, these meteoroids had a mass on the order of a milligram. The speed with which the meteoroid began its descent into the Earth's atmosphere can be related to the original orbit of the material; they found that 26% of their meteors had orbits indicating that they originally came from the asteroid belt, while 14% were in orbits similar to Jupiter-family comets, and the remaining 60% were in Halley-type comet or nearly-isotropic cometary orbits.

The overall bulk density distribution showed three distinct peaks. The lowest, at roughly 1 g cm^{-3} (similar to water), corresponded to the high inclination, long-period comet population, consistent with many other estimates of meteoroid cometary bulk density. A peak at higher densities (3 to 5 g cm^{-3}, similar to iron-rich rocky material) had orbits associated with the asteroidal meteoroid population. These densities are consistent with material made of a mixture of chondritic-rich bodies and some nearly pure iron particles, and they are also consistent with results found from spectroscopic bulk densities.

However, the final density peak near 3.1 g cm^{-3} is associated with Jupiter-family comets. This is a surprising result, as this material is believed to originate in the outer reaches of the solar system beyond Neptune called the Kuiper Belt. Whether such high bulk densities are due to evolutionary processes operating on the meteoroids or are indicative of primary materials from the parent bodies is unclear. Note that recently such dense refractory grains have been found among the samples returned from the Jupiter-family comet 81P/Wild 2 by the Stardust spacecraft. It may be that substantial amounts of higher density refractory material were transported outward from the inner solar system to the formation zone of the original Jupiter-family comet population while they were

being formed in the solar nebula from which the planets themselves were made, over four billion years ago.

Fr. Kikwaya presented his work at the annual European Planetary Science Conference, held in conjunction with the American Astronomical Society's Division for Planetary Sciences annual meeting, in Nantes, France, in October.

Meteoroids as small as those studied by Fr. Kikwaya will be completely consumed by the heat they generate as they pass through the Earth's atmosphere. Samples that are large enough to survive and reach the ground are meteorites, and 1200 such samples are held in the Vatican's meteorite collection. In 2004, a young Jesuit brother, Robert Macke, spent his summer at the Vatican Observatory working with Brother Guy J. Consolmagno, S.J., to measure the density and porosity of these meteorites. That was the beginning of a project that eventually led to a PhD for Macke at the University of Central Florida in 2010. That research is now being published in a series of papers with Br. Consolmagno and Daniel Britt (Macke's thesis advisor at UCF). Work published this past year has presented new data on the rare achondrite and carbonaceous chondrite classes.

Among the achondrites, they measured 174 stones from 106 meteorites. These included four meteorites from the Moon; 15 stones of the shergottite, nakhlite, and chassignite classes thought to represent samples from the surface of Mars; and 96 stones from the howardite, eucrite, and diogenite (HEDs) meteorites believed to come from the asteroid Vesta. (Notably, the NASA Dawn spacecraft went into orbit around as Vesta in August). In addition, a number of stones from rarer achondrite meteorite classes, such as ureilites, were also measured.

In the same way, 195 stones from 63 different carbonaceous chondrites were measured. Porosities were generally much higher for these meteorites than for the achondrites or the previously measured ordinary chondrites, averaging around 17%, with a range from 0 (for a number of meteorites) to 41% (for one stone of the CO Ornans). Notably, they found significant differences in porosity between the oxidized and reduced CV subgroups, with CV_o porosities averaging around 20% while the CV_r porosities were approximately 4%. Overall, porosities of carbonaceous chondrite falls trend with petrographic type, from type 1 (CI) near 35%, type 2 (CM, CR) averaging 23%, type 3 (CV, CO) 21%, to type 4 (CK and some CO) averaging 15%. There is also a significant decrease in porosity between meteorites of shock stage S1 (essentially unshocked) and those of S2 (the next-lowest value of shock), which indicates that slow impacts were able to significantly compress these samples. All these results show how meteorite porosity can be a useful tool to untangle the complex physical history of solar system material from the time when the planets first were forming.

• *Ornans meteorite, one of the carbonaceous chondrites measured by Macke et al. (Specola collection)*

The meteorite densities were presented in two papers in Meteoritics and Planetary Sciences (MAPS): the first in MAPS 46:311 (2011), and the second in MAPS 46:1842 (2011).

These meteorite density measurements have played an important role in improving our understanding of the remarkable asteroid 2008 TC_3. This near-Earth object had been discovered only a few days before it impacted the Earth in October, 2008. Meteorites recovered from the impact site at Almahata Sitta in northern Sudan showed a remarkable range in composition, but most of them were of the unusual ureilite class. Br. Consolmagno was a member of a team of scientists who measured the physical properties of these samples and then, using the 2008 TC_3 asteroid shape model and albedo, estimated the asteroid's initial mass.

The Almahata Sitta ureilites had an average bulk density of 3.1 g/cm^3. Based on the study of recovered meteorites and atmospheric entry observations, it was clear that asteroid 2008 TC_3 had been compositionally heterogeneous and of low mechanical strength, and most likely a rather loosely assembled pile of rubble rather than being a solid rock. Given a size based on the observed brightness of the asteroid, using the most realistic albedos (based on the meteorites) within a range of 0.09-0.2, and assuming the presence of significant macroporosity (thus lowering the asteroid's bulk density compared to that of the Almahata Sitta ureilites), they determined that the original mass of 2008 TC_3 was less than 20,000 kg. This was significantly lower than had previously been suggested.

• *Ureilite meteorite (Specola collection)*

The Almahata Sitta work was reported in T. Kohout, R. Kiuru, M. Montonen, P. Scheirich, D. Britt, R. Macke, and G. Consolmagno, Icarus 212:697 (2011).

Stellar Astronomy

Father Christopher Corbally, S.J., and collaborators have been carrying out a long-term project of measuring chromospheric activity and brightness variations in 31 young solar analogs (YSAs) using the Dark Sky Observatory (DSO – Appalachian State University) 32-inch telescope and the G/M spectrograph. These YSAs are solar-type stars with ages ranging from 0.3 - 1.5 Gyr. The goal of this project is to gain better understanding of the magnetic activity of Stars that are similar to the early Sun, and perhaps learn how that activity may have had an impact on the development of life on the Earth. This project will also yield insights into the space environments experienced by planets that are analogs to the Earth's situation in the early stages of its history. They are currently in their 5th year of obtaining chromospheric flux measurements, and are beginning to see signs of long-term activity cycles in a number of their stars. In addition, they have determined rotational periods for many of these stars. Short timescale increases in certain fluxes have been observed in a number of these stars; these events may be related to stellar flares. Photometry is being carried out with a

small telescope riding piggy-back on the 32-inch telescope at Appalachian State, but a robotic photometric telescope is currently being installed at DSO for this purpose.

Young stars can be found in regions of active star formation. One such region is located in the complex of dust and molecular clouds known as the Pelican Nebula and the dark cloud L935. A team of astronomers including Fr. Boyle, Father Robert Janusz, S.J., and Brother Jonathan J. Stott, S.J., and collaborators from Vilnius University (Lithuania) and the US Naval Observatory in Flagstaff have used CCD photometry in the Vilnius seven-colour system, obtained on the VATT and the 1 metre telescope of the US Naval Observatory Flagstaff Station, to classify stars down to seventeenth magnitude in a number of spectral and luminosity classes. Their measures of interstellar extinction values and distances to these stars were compared to data from various space-based observatories including the 2MASS, MegaCam, IPHAS and Spitzer surveys. From this work, the team was able to map out those stars in the foreground and background of the complex, compared to the stars within it. From this, the known and newly identified young stars in the area could be tabulated.

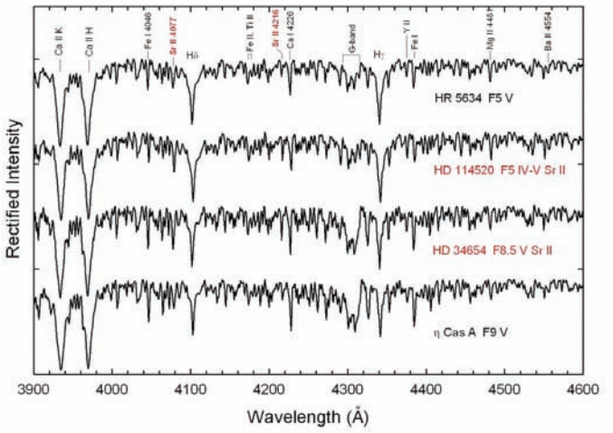
• *Pelican Nebula (VATT image)*

Young stars are generally found in open clusters of stars. Tombaugh 5 is a little investigated open cluster located in the northern skies near the Camelopardalis complex of dust clouds. This same team of collaborators has investigated an area centred on the cluster, determining the magnitudes and colour indices for 674 stars down to V = 17.7 magnitude in CCD images taken with the 1 metre telescope of the USNO Flagstaff Station in the seven-color Vilnius photometric system. These data allowed the team to calculate interstellar extinctions and distances, and to plot the colour-magnitude diagram, correcting each star individually for the reddening effects of the clouds of gas and dust between the star and our telescopes. This work can be used to identify which stars in the field of view are members of the cluster and to determine the cluster's age and distance.

The paper on young solar analogs by R. O. Gray, J. M. Saken, C. J. Corbally, M. F. Seeds, and S. S. Morrison will be presented in the Winter 2012 American Astronomical Society (AAS) meeting. The Pelican Nebula work by R. P. Boyle, R. Janusz, F. J. Vrba, V. Straizys, V. Laugalys, A. Kazlauskas, J. Stott, A. G. D. Philip was presented at the Winter 2011 AAS meeting; the Tombaugh 5 work by L. Vygandas, K. Zdanavicius, J. Zdanavicius, F. J. Vrba, V. Straizys, and R. P. Boyle was reported at the Summer 2011 AAS meeting.

Barium II (Ba) stars are chemically peculiar F-, G-, and K-type objects that show enhanced abundances of elements synthesized inside a star by the slow fusion of neutrons, known as the s-process. Since such s-process nucleosynthesis is unlikely to take place in stars prior to the advanced asymptotic giant branch (AGB) stage of their evolution, the prevailing hypothesis is that each Ba star was contaminated by an AGB companion which is now a white dwarf. Unless the initial mass ratio of such a binary was fairly close to unity, the receiving star is thus at least as likely to be a dwarf as a giant. So although most known Ba stars appear to be giants, the hypothesis requires that Ba dwarfs be comparably plentiful and moreover that they should all have white dwarf companions.

However, despite dedicated searches with the IUE satellite, no white dwarf companions have been directly detected to date among the classical Ba dwarfs, even though some 90% of those stars are spectroscopic binaries. Thus the contamination hypothesis is presently in some jeopardy. Recent work by Fr. Corbally and collaborators has analyzed recent deep, near-UV and far-UV



• *Classification spectra of two newly discovered Ba dwarfs, HD 114520 and HD 34654 compared with spectra of two MK standards at the top and bottom*

Galaxy Evolution Explorer (GALEX) exposures of four of the brightest of the class (HD 2454, 15360, 26367, and 221531), together with archived GALEX data for two newly recognized Ba dwarfs: HD 34654 and HD 114520 (which also prove to be spectroscopic binaries). The GALEX observations of the Ba dwarfs as a group show a significant far-UV excess compared to a control sample of normal F-type dwarfs. They suggest that this ensemble far-UV excess constitutes the first direct evidence that Ba dwarfs do indeed have white dwarf companions.

The Barium star work by Gray, R. O., McGahee, C. E., Griffin, R. E. M., and Corbally, C. J. , appeared in the Astronomical Journal, 141:160 (2011).

In the past decade, radio observations have detected both quiescent and time-variable radio emission from late-M and L ultracool dwarf stars. Four of these dwarfs have been found to produce periodic pulses associated with the dwarf's rotation. More recently, two of these radio pulsing dwarfs have also been shown to be periodically variable in broadband optical photometry, where the detected periods match the periods of the radio pulses. For one of these dwarfs in particular, it has been established that the mechanisms driving the optical and radio periodic variability may be linked, a consequence of a magnetically-driven auroral process. Fr. Boyle and collaborators from the National University of Ireland in Galway and the University of California, Berkeley, have undertaken a campaign to investigate the ubiquity of optical periodicity for known radio detected ultracool dwarfs, monitoring their brightnesses in many colours using the GUFI (Galway Ultra Fast Imager) instrument at VATT. Their observations have confirmed a periodic variability for five of these dwarfs, three of which were detected for the first time by this survey. These data provide an insight into the cause of this optical emission, its connection to the radio processes, and most importantly determine whether optical periodic signals are present only in radio pulsing dwarfs.

The ultracool dwarf star work was reported at the Summer 2011 AAS meeting by R. P. Boyle, L. K. Harding, G. Hallinan, R. F. Butler, and A. Golden.

Galactic and Extragalactic Astronomy

Prof. Dante Minniti and collaborators have made significant progress in the "VVV" survey – VISTA Variables in the Via Lactea – described in last year's annual report. (Via Lactea is, of course, the Latin for "Milky Way".) This is a 5-year long European Southern Observatory (ESO) Public Survey to map in five near-infrared filters the inner disc and bulge of the Milky Way using the VISTA 4m telescope at ESO's Paranal (Chile) Observatory.

• *Prof. Dante Minniti*

One of the aims of the VVV Survey is to measure accurately the physical parameters of the known globular clusters in the inner regions of the Milky Way and search for new ones that may be hidden in regions of large extinction. But many globular clusters may remain undetected towards the Galactic bulge.

Deep infrared photometry by the VVV team of a region surrounding the known globular cluster UKS 1 has revealed a new low-mass globular cluster candidate that the team has named VVV CL001. On the basis of near-infrared colour magnitude diagrams, they find that VVV CL001 is at least as metal-poor as UKS 1, although its distance remains uncertain. This finding confirms the previous projection that the central region of the Milky Way harbours more globular clusters. VVV CL001 and UKS 1 may well be a binary system of globular clusters, orbiting each other, but follow-up observations are needed to decide if they are located at the same distance and have similar radial velocities.

Another goal of the VVV survey is to map the edge of the Milky Way galaxy. A particular type of red giant star, which can be found clumped together in the standard stellar evolution diagrams, is called "clump giants" and these are particularly useful because they all have essentially the same intrinsic brightness regardless of differences in their ages or compositions. Because they are red, they are relatively easy to observe in the VVV survey. Using clump giants of the disc itself as standard candles, clump giants found with the VVV and other surveys away from the disc have been mapped; from this one can conclude that there is an edge of the stellar disc of the Milky Way at about 45,000 light years along various lines of sight across the Galaxy. This measurement takes into account the slight warp of the Milky Way disc, taking fields at different longitudes and above and below the plane. By mapping the edge of the stellar disc of the Milky Way, we can now test different models of galaxy formation and evolution, and establish our own place within the Galaxy.

• *Globular Cluster M3 (VATT image)*

Many galaxies show central bulges of stars whose properties may differ from stars further out in the disc. Our own Milky Way bulge is the nearest galactic bulge and thus the best laboratory for studies of stellar populations based on individual stellar abundances and motions. The observed properties point to a very complex nature that is hard to extrapolate from a few fields. One step is to use the VVV results to make reddening maps and trace the structure and composition gradients of the bulge. The VVV team has found that the reddening determination is sensitive to small-scale variations, which are clearly visible in their maps, allowing the X-shape morphology of the bulge to be traced. In addition, the remarkable agreement between the VVV results and those presented in the literature along the minor axis of the bulge suggests that this method can be extended to study the whole region covered by the survey.

Along with a central bulge, many disc galaxies also show a central "bar"; the Milky Way is one such galaxy. Using the results of the VVV, the team has been able to trace the inclination of the central bar of stars and to investigate structure within the inner regions of the bar. They detect a change in the orientation of the bar in the central regions, in agreement with results obtained at other latitudes by previous authors, which shows that this change in the bar orientation is real. This suggests that there is an inner structure distinct to the large-scale Galactic bar, with a different orientation angle. This inner structure could be a secondary, inner bar, with a semi-major axis of approximately 1500 light years, symmetric with respect to the Galactic plane.

The work by Minniti has been published in a series of papers in The Astrophysical Journal (AJ), The Astronomical Journal (AJ), and Astronomy and Astrophysics (A&A), including: Minniti, D. et al., A&A 527:A81 (2011); Minniti et al., ApJ 733: L43 (2011); Gonzalez et al., A&A 534:A3 (2011); Saito et al., AJ, 142:76 (2011); and Gonzalez et al., A&A 534:L14 (2011).

• *Galaxy cluster A397 (VATT image)*

In recent years Father Alessandro Omizzolo has been an active participant in the Wide-field Nearby Galaxy clusters Survey (WINGS), a project whose primary goal is to study the populations of galaxies in clusters in the local universe (within roughly one billion light years) and the influence of environment on their stellar populations. This survey has provided the astronomical community with a high quality set of photometric data for 77 nearby galaxy clusters, and spectroscopic data for 48 nearby galaxy clusters. This past year has seen the publication of a catalog containing the properties of galaxies observed by the WINGS SPEctroscopic (WINGS-SPE) survey, which were derived using a stellar populations synthesis modeling approach. Using a spectrophotometric model that reproduces the main features of observed spectra by summing the theoretical spectra of simple stellar populations of different ages, they derive the stellar masses, star formation histories, average age and dust attenuation of galaxies in their sample. Approximately 5300 spectra were analyzed with spectrophotometric techniques, and this allowed them to derive the star formation history, stellar masses and ages, and extinction for the WINGS spectroscopic sample.

The WINGS group has also published a morphological catalog of galaxies in nearby clusters of the WINGS survey. The catalog contains a total number of 39923 galaxies, for which they provide a computer-generated estimate of the morphological type to the V-band WINGS images. For approximately 3000 galaxies they also provide visual estimates of the morphological types. In addition to the galaxy morphology distribution (corrected for field contamination) in the WINGS clusters, they present the distributions of ellipticity, colour, and Sersic index (how the intensity of the galaxy's brightness varies from its centre to its edge) for different morphological types, as well as the morphological fractions as a function of their distance from the centre of their cluster.

Recent work with these data has included a study the colour-magnitude red sequence and blue fraction of 72 X-ray selected galaxy clusters, searching for correlations between the characteristics of the red sequence and the environment. They consider the slope and scatter of the red sequence, the number ratio of red luminous-to-faint galaxies, the blue fraction and the fractions of ellipticals, S0s and spirals that compose the red sequence. None of these quantities correlate with most of the ways in which clusters can be described, such as the cluster velocity dispersion, X-ray luminosity, number of cluster substructures, etc. Instead, the properties of the red sequence depend strongly on local galaxy density. Higher density regions have a lower red sequence scatter, a higher luminous-to-faint ratio, a lower blue fraction, and a lower spiral fraction on the red sequence. These results highlight the prominent effect of the local density in setting the epoch when galaxies become passive and join the red sequence, as opposed to the mass of the galaxy host structure.

This work has appeared in a series of papers by the WINGS collaboration including one published in A&A 526:A45 (2011), and two posted at the arXiv online archive, (arXiv:1109.2026) and (arXiv:1109.4011).

Astronomical Definitions and Techniques

Timekeeping has always followed the heavens for reasons of practicality and symbolism. But these two motivations, symbolism and practicality, can have conflicting implications for the concrete implementation of timekeeping mechanisms. Symbols need to be anchored in reality, and for timekeeping in recent years this has become a problem.

• *Riefler Clock, 1934 (Specola collection)*

For millennia the periodic movements of the Sun, Moon and the stars were the very image of predictability and stability. But eventually our timepieces became more regular than the rotation of the Earth. By the 18th century it was known that the Earth must be slowing down because of tidal forces, although this trend was first measured only in the 1930s. With the development of atomic clocks, we now know that Earth's slow-down is irregular, and that there are even times when the inertia of the Earth's core manages to speed the mantle up. Many other things also influence the rotation rate: with our precise measurements, we can see that even changing weather patterns have a discernible impact.

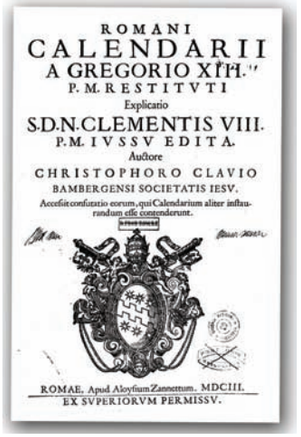
Of course, Earth's minutely erratic behavior is hardly noticeable in ordinary human life. But with the advent of the Global Positioning System (GPS), such details translate into hundreds of feet of navigational errors – unacceptable when landing an airplane, intercepting an enemy missile, or surveying a field.

An international body of astronomers, the International Earth Rotation and Reference System (IERS), monitors the exact position and motion of the Earth in space using very distant quasars as the reference frame. In order to keep civil timekeeping coupled with Earth's irregular rotation, once in a while a "leap second" is inserted into the uniformly flowing stream of atomic seconds. This tweak is done irregularly, according to a protocol agreed upon in 1972.

Many people feel that the protocol is unsatisfactory because it causes problems in many areas where the operating software sometimes breaks down due to a leap second event. Others feel that although the protocol is not perfect, it has been in place for 40 years, allowing plenty of time to debug the systems and insert leap seconds seamlessly. In January 2012, the international community is voting on a proposal to simply abolish the leap seconds, and disregard the Earth's rotation in civil timekeeping.

A meeting in Exton (outside Philadelphia, Pennsylvania) brought together experts from various fields who tried to asses the impact of such a change on their work. They included astronomers and representatives of the IERS, the International Astronomical Union, as well as GPS staff and US Air Force Strategic

Command. Among them was Father Pavel Gabor, S.J.
Fr. Gabor spoke on the underlying social mechanisms involved in timekeeping, drawing upon the historical evidence represented by the various calendric traditions. He discussed mainly the interplay of two factors: (1) the principle that civil timekeeping needs to be anchored in astronomical phenomena if its symbolism is to be maintained, and (2) the general trend to replace empirical timekeeping with calculated schemes. The 1972 protocol is empirical, and therefore it will be replaced by a regular, calculated scheme sooner or later.


ROMANI
CALENDARII
A GREGORIO XIII.
P. M. RESTITVTI
Explicatio
S.D.N. CLEMENTIS VIII.
P.M. IVSSV EDITA.
Auctore
CHRISTOPHORO CLAVIO
BAMBERGENSI SOCIETATIS IESV.
Accesit confutatio eorum, qui Calendarium aliter instaurandum esse contenderunt.
ROMAE, Apud Aloysium Zannettum. MDCIII.
EX SVPERIORVM PERMISSV.

• Title page, Fr. Christopher Clavius S.J.'s, explanation of the Gregorian Calendar, 1603 (Specola library collection)

Calculated timekeeping does not actually agree with the heavens at any given moment, but this does not seem to jeopardize the general perception of its astronomical conformity since it is rightly perceived as a way of preserving it on average. The current proposal, however, clearly wants to decouple civil time from Earth's rotation. Fr. Gabor argued that it would result in a direct and unprecedented breach with the principle of astronomical conformity. This conformity fulfills its social function even when it is not observed perfectly, because in the realm of symbolism what counts is the general perception, not the fact.

Fr. Gabor's paper appeared in Decoupling Civil Timekeeping from Earth Rotation*, eds. Rob Seaman, John Seago, Steve Allen. American Astronautical Society Science and Technology Series*, vol. 113, AAS 11-663.

Precise timekeeping has also provided the opportunity to compare the observations of the arrival of light waves seen by two distant telescopes and combine them, using a technique known as *interferometry*, into a high resolution image of objects in the distant sky.

The idea of "beams of light" focused by the eye's lens is how geometrical optics describes vision. With this simple model of how a lens works, optical astronomers can produce images and work with them; when optical astronomers want to know the size of a galaxy, they take a picture, measure the apparent size and multiply it by the scale of the image. Radio astronomers, on the other hand, cannot really obtain classical images in this way with their instruments. Radio waves and light waves obey the same physics, but the wavelengths are very different: radio's are more than a million times longer. This means that if a radio telescope were to have the same resolving power as your eye, it would have to have the diameter of at least a couple of miles! Instead, radio astronomers have developed methods that allow them to glean as much information about the incident electromagnetic field as possible. They do not take pictures of galaxies, but they can measure the sizes of distant objects using the technique of interferometry, which compares the arrival time of a signal at two widely separated telescopes to determine the angle of the wave's direction of motion compared to the line connecting the telescopes.

In order for this to give accurate results, the positions of the telescopes must be known to a high precision, and the relative timing of the signal arrival must be known to a very high precision. A number of techniques have been worked out to accomplish this. In particular, since the interpretation of the signal depends only on the relative difference of the arrival of the two waves, this information can be determined by observing how the two waves interfere (with the wave crests of one being added to the crests, or troughs, of the other): hence the name "interferometry".

This success has led to an interesting question: if you could use this method with optical telescopes, you could measure the sizes of bodies too small to image in a picture. The downside of interferometry is that the object needs to be relatively bright, and so the method was largely abandoned by optical astronomers, and only developed by their radioastronomical colleagues who have no alternative.

• Twin mirrors of the Large Binocular Telescope, located near the VATT on Mt. Graham

Nonetheless, with more sensitive optical receivers, interferometry is becoming more attractive also to optical astronomers. The twin Keck telescopes in Hawaii, the European Southern Observatory's Very Large Telescopes in Chile, and the Large Binocular Telescope (VATT's neighbor on Mt. Graham) were all built with this feature in mind. Currently, the Magdalena Ridge Observatory in New Mexico (operated from the New Mexico Tech campus in Socorro, NM) is building an optical interferometer with several 1.2-metre telescopes. This past year, the group organized an international workshop on optical interferometry primarily focused on possible applications of optical and infrared interferometry, listing scientific questions that only interferometers can resolve.

At this meeting, Fr. Gabor presented a new idea for infrared interferometry, suggesting that recently developed supercontinuum lasers might have a potential in this field. If it works, such optical interferometry would be useful in many fields of astronomy, from detecting exoplanets and finding planet-forming discs around stars, to determining the shapes and sizes of small Solar System bodies, to measuring the properties of stars and galaxies, especially in the study of Active Galactic Nuclei (AGN).

Fr. Gabor's contribution was published in Resolving the Future of Astronomy with Long-Baseline Interferometry, *ed. Michelle Creech-Eakman. ASP Conference Series.*

Cosmology

Understanding the origin and evolution of the universe means dealing with such extreme conditions that one cannot rely on a common-sense experience of how nature behaves. Instead we must use very speculative theories of physics, which

rely on advanced mathematical methods applied to theories of space and time such as Einstein's theory of General Relativity. A specific issue long confronting theorists in this field is how to relate General Relativity to Quantum Theory (this problem is known as Quantum Gravity): that is the physical laws which govern our Universe on extra-galactic scale with the physical laws that describe the sub-nuclear world.

Working in this field, Gabriele Gionti has been studying Regge Calculus applied to questions of Quantum Gravity. Following a suggestion by Rovelli (Université de la Méditerranée), one of the originators of the Spin Foam formalism of Loop Quantum Gravity (an attempt to connect quantum theory and gravity, involving a four dimensional evolution of spin networks defined on a three dimensional surface), Gionti has been looking for a connection between Regge Calculus, a discrete approach to Einstein General Relativity which is implemented naturally in a discrete theory of Quantum Gravity and in which he has a particular expertise, with the Spin Foam formalism of Loop Quantum Gravity. The issue at stake is that nobody has proved yet that Spin Foam formalism contains General Relativity in its classical limit, and there are also problems in implementing the coupling with fermionic matter. Gionti has shown that indeed the quantum (Local) Regge Calculus has a structure similar to the Spin Foam formalism. A further Barret-Crane quantization is implemented to show that in quantum (Local) Regge calculus an irreducible representation of the SU(2) group of General Relativity can be associated with each two-dimensional simplex, as in the Spin Foam formalism. However, intertwiners coefficients do not appear in quantum (local) Regge calculus.

• *Crab Nebula, supernova remnant (VATT image)*

In a similar vein, Michael Heller and his colleagues Pysiak and Sasin (Copernicus Centre for Interdisciplinary Studies, the Jagiellonian University and the John Paul II Pontifical University) have been exploring the Quantum Gravity aspects of noncommutative geometry. In a recent paper they have determined one of the sources of noncommutative geometry: they show that one must go beyond the traditional concept of geometry when some pathologies connected with the impossibility of distinguishing single points appear in the structure of space. The Hausdorff relation, topologically identifying points in a given space, is one of the elementary tools of modern mathematics. But if sufficiently subtle mathematical methods are used to analyze this relation, the conclusions may be far-reaching and illuminating. For example, a probabilistic description (in a generalized sense) naturally takes over when the concept of point looses its meaning; in this situation. counterparts of the position and momentum operators can be defined, and they satisfy a commutation relation which, in the suitable limiting case, reproduces the Heisenberg indeterminacy relation (which shows that one cannot completely and simultaneously define a body's position and momentum). This is neither an additional assumption or an effect of a quantization process, but simply the consequence of a purely geometric analysis.

One of the continuing challenges in cosmology, the description of our universe on large scale using Einstein's General Relativity, has been to determine the large-scale space-time metric from observations with a minimum of assumptions – without, in particular, having to assume ahead of time that the universe is almost Friedmann-Lemaître-Robertson-Walker (FLRW) (i. e. almost isotropic and spatially homogeneous). If this could be done, then one would have a way of actually demonstrating that our universe is FLRW, instead of presupposing it or being satisfied merely to show that our observations of the universe are consistent with the assumptions of FLRW. Showing how to do this within a more general spherically symmetric, inhomogeneous space-time framework would take us a long way towards fulfilling this goal.

• *Fr. Bill Stoeger S.J., at University of Arizona*

Recent work has shown that this can be done both in the traditional Lemaître-Tolman-Bondi (LTB) 3+1 coordinate framework and in the observational coordinate (OC) framework, in which the radial coordinate y is null (light-like) and is measured down the past light cone of the observer. This past year, Araújo (Departamento de Física-Matemática, Instituto de Física, Universidade Federal do Rio de Janeiro) and Stoeger have been carrying this work further, investigating the stability of solutions, and the use of data in the OC field equations, including their time-evolution – i. e. the solution of the field equations not restricted to our past light cone. As part of this work, they compare the LTB and OC approaches with respect to the singularity problem at the maximum of the angular-diameter distance, with respect to the stability of the one of the key (null Raychaudhuri) equations, and with respect to the use of data.

They also compare the two approaches with regard to determining the cosmological constant. This allows a more detailed account and assessment of the OC integration procedure, and enables a comparison of the relative advantages of the two equivalent solution frameworks. Both formulations and integration procedures should lead to the same results. However, as they show in this paper, the OC procedure possesses distinct advantages, particularly in the avoidance of coordinate singularities at the maximum of the angular-diameter distance, and in the stability of the solutions obtained. This particular feature is what allows us to do the best fitting of the data to smooth data functions and the possibility of constructing analytic solutions to the field equations. Smooth data functions enable them to include properties that the data must have within the model.

Gionti's paper will appear in the International Journal of Geometric Methods in Physics. The work by Heller and his coauthors was published in the Journal of Mathematical Physics, 52:0435061-7 (2011). The paper by Araújo and Stoeger appeared in the Journal of Cosmology and Astroparticle Physics 7:29 (2011).

• *Ceiling of New Mathematics Hall (c. 1760), Klemenitum University, Prague*

Philosophy and Science

Fr. Brown is one of four Jesuits based in Rome who in 2009 founded the New Jesuit Review, an online magazine designed to make Jesuit spirituality available and understandable to young Catholics. In an article published there this past year, Fr. Brown has discussed the reasons why the Catholic Church supports an institution such as the Vatican Observatory. He sees in its engagement with modern science an echo of the rapprochement between faith and reason expressed recently by Pope Benedict XVI but whose origins can be found in the Church Fathers, citing in particular the question first raised (and answered) by Tertullian in times of antiquity: "What has Athens to do with Jerusalem?" The "pursuit of truth" was crucial to the Church's capacity to engage Greco-Roman culture and philosophy as Christianity spread throughout the Roman Empire, a pursuit that continues to the present day. Fr. Brown also argues that the work of such an institution constitutes a kind of "cosmic liturgy;" experiencing the cosmos in all its splendor is a testament to the glory of God, the Creator, and parallels the experience of the liturgy of the Church, which orients a person toward God. The contemplation and sheer delight of truth, both of the natural world and of God, he concludes, is where science and faith respectively greatly resemble and complement one another.

Fr. Heller has been considering some of the deeper problems plaguing the present search for a "final theory" that would unify the various fields of physics. How can one find a mathematical structure rich enough to be suitably approximated by the mathematical structures of general relativity and quantum mechanics? How does one reconcile nonlocal phenomena of quantum mechanics with time honored causality and reality postulates? Does the measurement problem contain some hints concerning the future quantum gravity theory? He concludes that the "final theory" cannot avoid the problem of dynamics, and consequently the problem of time. What kind of time might this be, he asks, if this theory is supposed to be background-free – will the dynamics of the "final theory" be probabilistic?

The issue of Finality in Nature was the topic of two papers published this past year by Vatican Observatory members.

In March of 2009, Dr. Illeana Chinnici participated in a conference on Emergence, Directionality, and Finality at the Gregorian University. Her presentation at that time has now been published as a paper, "Emergence, Directionality and Finality in an Evolutionary Universe."
Dr. Chinnici argues that as we come to understand cosmic, chemical and biological evolution more deeply in light of the theology of creation, it becomes more and more evident that evolutionary biology, properly understood, is not only consonant with theology but also enriches it. In the course of cosmic history – and more recently in the history of our planet, the Earth – an amazing array of intricately interrelated, and interdependent, networks of systems have emerged at all levels, and then evolved into even more advanced systems and networks. Living organisms, and among them conscious, rational and freely choosing organisms, are the most notable of these. They exhibit capabilities and behaviours far beyond those of their basic components. This is the pervasive phenomenon of "emergence" – the emergence of life, of consciousness, of intelligence.

• *Astrolabe, 16th century (Specola collection)*

This suggests a directionality in the history of the universe, and in the history of the Earth and of life on it. Although a kind of directionality is certainly evident in, for instance, the expansion, cooling, differentiation and complexification of the universe, it is impossible on the basis of the natural sciences alone to either confirm or deny an overarching purpose (though philosophy and theology enable us to do so). However, within networks and systems themselves, it is clear from strictly scientific considerations that local, focused teleologies have emerged from the differentiated functionalities of their components. Within the bodies of mammals, for instance, the heart, the kidneys, the lungs, the brain all fulfill different essential functions which enable the mammal to continue living.

There is not only a directionality here, but also a definite finality. Each organ serves a definite "purpose" within the larger system. In evolution, differentiation of structures involves differentiation of functions or capabilities of the ways in which specific systems and structures relate to others. These become not only beneficial but also essential to the survival and successful operation of the larger, more complex systems or organisms. In fact, each component is selected precisely because of what it gives to the larger system. Natural selection is continually reinforcing and enhancing this choice – and modifying it in light of what leads to even more successful organisms.

Meanwhile, in an essay entitled "The Multiverse Debate," Fr. Gionti examines the assertion that the concept of a Multiverse has been introduced to water down the "design" and "purpose" that can be found in Nature. He notes that the concept of Multiverse actually derives from inflationary theory, which was introduced not for philosophical reasons but to explain the horizon problem in the analysis of the cosmic microwave background in observational cosmology. By contrast, he stresses that the Weak Anthropic Principle (i.e., the only universe that can be observed by intelligent beings is one compatible with the possible existence of such beings) was introduced to water down any possible concept of finality, which is present in the Strong

Anthropic Principle, which draws significance from the highly restrictive set of conditions necessary for the existence of intelligence that exist in our universe. A reconciliation between theologians and scientists, he argues, can only come about with a better understanding on both sides of the work that each is doing.

Fr. Heller's work appeared in the journal Foundations of Physics 41:905 (2011). Chinnici's paper appeared in the Analecta Gregoriana 312:479 (2011). Fr. Gionti's work appeared in the proceedings of the conference "Scienza, Fedi e Salute" held at the San Camillo-Forlanini Hospital, Rome.

• *Fr. Gabriele Gionti, S.J., at Matteo Ricci's Grave , in Beijing*

4. Instrumentation and Technical Services

Vatican Advanced Technology Telescope (VATT)

The technical work at the Vatican Advanced Technology Telescope continued in 2011 under Bob Peterson, Steward Observatory's assistant director of mountain operations, and Ken Duffek, the VATT manager. Fr. Corbally remains director for the VATT, while Fr. Boyle is the telescope scientist and scheduler. Dave Harvey, Chris Johnson, and Gary Gray comprise the rest of the VATT's regular engineering team. Michael Franz retired as mechanical engineer mid-year.

Telescope

The VATT engineering team met two major milestones this year. First light with the VATT Spectrograph was achieved and the first remote observing session from from our Tucson office was accomplished. The highlights of this work include:

• *VATT Spectrograph to the Vatican Telescope*

• Gray performed a modification to the handling fixture for the VATT Spectrograph (VATTSpec). After extensive experience gained on mounting and un-mounting this instrument to the Telescope, it was determined that the jack screws needed to be shortened to facilitate easy removal of the handling fixture from underneath the Telescope. This change has increased the efficiency of instrument changes.

• Duffek, Harvey, and Fr. Boyle obtained first light with VATTSpec, observing several M class stars and M42. Initial results look good.

• Duffek, Johnson, and Harvey, with Fr. Boyle, performed a remote observing session for the first time from the Tucson office. With Duffek and Harvey at the Telescope for safety, Fr. Boyle demonstrated that he was in control of the Telescope systems and instruments from Tucson. Further testing will be performed with other experienced VATT approved observers in the months to come.

• Johnson has been loading the software for VATTSpec and VATT 4K CCD on both control computers to increase our spares count on instrument computers.

• Fr. Corbally, Harvey, and Duffek have begun VATTSpec commissioning. Observations continue to provide data to determine instrument performance and efficiency.

• Harvey, Johnson, and Fr. Boyle have been instrumental in continued observer training and support during the observing season.

• *Microwave Tower at the VATT*

Microwave Tower Grounding

Since the repair of the microwave tower grounding system, MGIO and Duffek have implemented a yearly check of the ground impedance. The specification we need to meet is 25 ohms or less. Again, with another year of service (four in total) we are experiencing a total of 1 ohm which is only a .5 ohm increase since the fix. It is apparent the fix is working well.

Safety Program

Our safety program continues with great success. With Steward Observatory safety manager, Dale Web, and the assistant director of mountain operations Peterson, walk-throughs continue at six month intervals to identify any potential safety issues. Currently, this year, we had one issue arise in the area of emergency lighting in the dome stairwell. This problem has been rectified by Gray installing the additional lighting. No other issues have been identified. The engineering team will always continue to work towards a safer work environment.

Telescope & Building Maintenance

The Telescope primary mirror had its yearly hard wash by Gray. With this yearly maintenance it looks like we will get another great year of service.

This year Gray performed maintenance on our UPS systems. Gray re-wired the UPS system combining two independent UPS circuits into one. By accomplishing this task, a single UPS has been freed up from service and now will become a good working spare if a UPS failure should occur in the future. When Gray is not busy maintaining power systems and other projects as needed, he can be found performing routine building maintenance. This year a set of custom cabinets were fabricated in the instrument room. These cabinets house the GUFI instrument and VATT4K CCD, as well as the associated support equipment for all instruments.

Deck resurfacing was completed this year. With the snow and ice accumulation from last year's winter storms, the concrete on the east and south side decks took a real beating from shoveling snow and chipping ice. A new concrete sealer with traction grit was applied with traction grit in preparation for winter.

Engineering Projects

This year the VATT engineering staff, Harvey, Johnson and Duffek, have been laying out plans to upgrade the Guide Box control system. The current system has components that have been identified as obsolete. Although spares exist, a planned upgrade is needed to help alleviate performance issues. One such issue is the cable drape.

When the VATTSpec is in use the cable drape tends to get caught on the instrument housing and is at risk of damage during de-rotator moves. A temporary fix is currently, in place to allow VATTSpec commissioning. By converting to a smart motor controller system, the cable requirements change from a multi cable design to a single power and communication fiber. This new system will provide a weight savings as well as more robust control of the Guide Box axis.

Vatican Observatory Website

The Vatican Observatory website uses the content management system (CMS) Joomla. Its webmaster, Ayvur Peletier, harmonized the look of the Specola Vaticana section, the first to be converted to CMS, with the other sections. She continues to make major changes, while minor updates are made by Fr. Corbally, the overall website manager, and by the section managers. For the Specola Vaticana section, which includes the Vatican Observatory Summer School website, the managers are Fr. Omizzolo and Francesco Rossi, while Br. Stott managed the "Vatican Observatory Foundation" section. In the summer Juan Pablo Marrufo in worked under Br. Consolmagno and Peletier to translate the website into Spanish.

Library Catalogue

A problem emerged following the Vatican Observatory Headquarters' move from the Papal Palace to its new premises in the grounds of the Summer Residence in Castel Gandolfo. The computer-based library catalog, prepared under Father Juan Casanovas, S.J., with a simple but until now efficient software, had become corrupted and unusable. All that was available was the old card catalogue.

Fr. Robert Janusz, S.J., Adjunct Scholar, worked to solved this problem. Janusz's first step for the new catalog was to try to unblock the old ISIS database. To do this he had to make a piece-by-piece analysis of its contents. Thanks to documentation for UNESCO software he was able to "scan" the binary format of the catalog, remove corrupted records and save as much of the data as possible. As a result, he was able to assemble all of the records in humanly readable form.

• *Fr. Robert Janusz, S.J.*

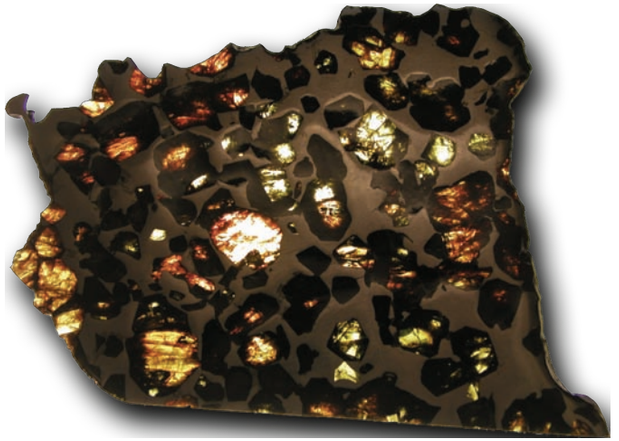
A quality medium-class server was bought and the Linux operating system was applied with an Open Source SQLite database engine and two Content Managers to do the work. This relatively inexpensive and stable solution worked well with the data recovered from the old system.

However a bigger problem soon emerged. The new system allowed for more in-depth searches of the database contents, revealing that in the past at least three different "formats" had been used to classify catalogue entries, subjects, authors etc. This unwelcome problem forced us to re-classify all of the library contents.

A new high quality catalogue system is now in place and will be constantly updated to ensure an optimum service. It will allow the Vatican Observatory library to link to other libraries, source texts etc., while also having an internal system specific to the Vatican Observatory and its staff.

Meteorites

Ten new meteorite samples were added to the Vatican collection in 2011. They include small (roughly 5 g each) samples, ideal for experimental work, of the ordinary chondrites Hassayampa (H4), NWA 2778 (H4), NWA 4293 (H6), and the carbonaceous chondrites NWA 1277 (CO3.6) and NWA 989 (CV3.2). These were the gifts of students and faculty from Ardingly College following their visit to the Specola and the meteorite laboratory in the spring. In addition, three pieces (including a 21 g slab) of the rare primitive achondrite NWA 6901 were supplied by an anonymous German dealer, along with a 145 g piece of the silicon-rich IAB iron NWA 5549 and a 206 g slice of the beautiful pallasite Esquel. A complete inventory of the meteorite collection was carried out in the summer of 2011. Of the 1059 pieces inventoried, only one sample, an ordinary chondrite, was not immediately accounted for.



• *New Vatican meteorite Esquel, a pallasite with translucent olivine crystals*

5. Observatory and Staff Activities

• *Fr. Albert J. DiUlio, S.J.*

Awards and Appointments

On January 1, 2012 Father Albert J. DiUlio, S.J., will become the next President of the Vatican Observatory Foundation. Fr. Coyne will be leaving the Vatican Observatory after 42 years.

A member of the Wisconsin Province of Jesuits, Fr. DiUlio entered the Society of Jesus in 1964 and was ordained in 1974. He holds a Masters in Finance and a Ph.D. in Education and Policy Analysis, both from Stanford University. He served as President of Marquette University in Milwaukee of Xavier University in Cincinnati. While serving on numerous boards and receiving many honors, Fr. DiUlio also spearheaded the development of the East African Catholic University of Ethiopia. His experience includes these positions and others in the Midwest and California. He most recently as the Secretary for Finance and Higher Education at the USA Jesuit Conference in Washington, D.C.

Fr. Coyne joined the Vatican Observatory as an astronomer in 1969 and was appointed Director by Pope John Paul I in 1978. As Director, he was a driving force in several new educational and research initiatives, including the Vatican Observatory Summer Schools and the Vatican Observatory Research Group in Tucson, Arizona. He retired as Director in August 2006, but remained as President of the Vatican Observatory Foundation

Fr. Coyne is moving to Le Moyne College in Syracuse, New York, where he will be teaching astronomy and developing a lecture series regarding the dialogue between science and religion.

Br. Stott has been assigned by his Jesuit Superiors to theological studies at the Jesuit School of Theology at Boston College. He will continue to collaborate with the Vatican Observatory.

• *Fr. Andrew Whitman, S.J., accepting his award from Fr. Funes*

On 26th January Fr. Andrew Whitman received the Holy Cross *Pro Ecclesia et Pontifice* in recognition of his laudable service at the Vatican Observatory. The award was conferred by Fr. José Funes, S.J., at St. Charles College, Grand Coteau, Louisiana, USA. The Holy Cross Pro Ecclesia et Pontifice is one of the highest honours awarded to clergy and religious for distinguished service to the Holy Father and the Catholic Church.

• *Fr. De Graeve with Pope Paul VI, c1975*

In Memoriam

We are saddened to report the death of Fr. Emiel De Graeve, from the South Belgian Province of the Jesuits. He served for 12 years at the Vatican Observatory in Castel Gandolfo, as the Superior of the community (1971-1980) and the Treasurer (1974-1983). He was a mathematician who collaborated with the Vatican astronomers.

We are also saddened by the death of two long-term friends and generous benefactors of Vatican Observatory Foundation, Mr. Thomas E. Golden, Jr. and Mr. Peter Mullen.

Staff Activities

Dr. Chinnici moved to London on October 31, 2011, to carry out a three-month research project on the 19th century spectroscope collection belonging to the Science Museum. These studies should provide additional information on the scientific exchanges between English and Italian spectroscopists in the second half of 19th century, especially between the astronomers of the Collegio Romano and Capitol Observatories.

In his capacity as Division IV president, Fr. Corbally was one of eight appointed to the International Astronomical Union Task Group on changes in Divisional Structure. This was mandated to draft suitable resolutions for the IAU General Assembly in Beijing, China, August 2012.

Br. Consolmagno continued serving as a member of the IAU Division III Organizing Committee, the IAU Working Group on Cartographic Coordinates and Rotational Elements, and the IAU Working Group on Planetary Surface Nomenclature, and as a member of the American Astronomical Society (AAS) Astronomy Education Board. This year he began a two-year term on the AAS Division for Planetary Sciences Prize Committee.

Adjunct Scholar Prof. Minniti spent the month of July in residence at the Vatican Observatory in Castel Gandolfo.

Staff presentations, Academic Activities and Conference Participation

Fr. Boyle presented a poster paper at the 217th meeting of the American Astronomical Society, Seattle, WA, January, 2-13 • presented a poster paper and co-authored another at the 218th meeting of the American Astronomical Society, Boston, MA, May, 22-26.

Fr. Brown attended the 218th Meeting of the American Astronomical Society in Boston, MA, May, 22-26.

Fr. Caruana presented a paper entitled: "Time as a Source of Identity: Some Christian Views" at the University Centre Saint-Ignatius, University of Antwerp, Belgium, February 22 • presented a paper entitled "Science, Religion, and Common Sense" at the International Conference in Philosophy of Religion: "Philosophy of Religion in the 21st Century", Krakow, Poland, June 27-29.

Fr. Carreira delivered papers at three congresses, in Mexico, Bogota and Spain, on the relationship between Science and Theology • held courses for teachers of religion in two dioceses in Spain, with over one hundred attending, on Science and Faith.

Dr. Chinnici gave an invited paper on the Italian Spectroscopists' Society (1871) at the Annual Meeting of the Società Astronomica Italiana (SAIT), Palermo, May 3 • gave an invited paper on the famous astrophysicist Fr. Angelo Secchi, S.J. (1818-1878) at the Séminaires d'histoire de l'astronomie, Paris, October 19.

Br. Consolmagno participated in five panels on science and science fiction at the Capricon Science Fiction Convention, Chicago, IL, February 11-13 • gave five presentations at the Catholic Network for Retreats and Spirituality, Alfreton, UK March 18-20 • gave three invited presentations at the National Jesuit Brothers' Conference on Science and Religion, St. Louis, MO, Br. Consolmagno and Br. Stott attended, June 19-22 • was the invited plenary speaker and gave five presentations at Living Theology, Liverpool, UK, July 24-29 • was co-author of two papers for The Meteoritical Society annual meeting, Greenwich, UK, August 8–12 • participated in three panels on recent advances in science and was interviewed for an hour about his life in science and religion at the World Science Fiction Convention, Reno, Nevada, August 17-21 • was the invited keynote speaker at the Leicester Diocese Clergy Conference, Alfreton, UK, September 20-22 • at the joint meeting, European Planetary Science Conference and the American Astronomical Society Division for Planetary Science, Br. Consolmagno delivered two papers and Fr. Kikwaya delivered one paper, Nantes, France, October 3-7.

• *Br. Guy Consolmagno at the Capricorn Science Fiction Convention, Chicago*

Fr. Corbally contributed a poster paper at the American Astronomical Society meeting #217, Seattle, WA, January 9-13 • participated in the Institute on Religion in an Age of Science, Annual Conference, Chautauqua, NY, June 18-24 • as IAU Division IV (Stars) president participated on March 22 in a telecom to discuss meeting proposals for 2012 • travelled to Prague, Czech Republic, for a May 24-26 session of the IAU Executive Committee during which the 2012 meetings were finalized and a reorganization of the Divisional Structure was discussed. At this he was invited to join an 8 member IAU Task Group preparing for the reorganization • presented a paper, "Lambda Boötis Stars or the Misfits", to the Star & Planet Formation Group, Steward Observatory, on April 25 • led a discussion on "Heroic Galileo?", December 5, at the St. Albert the Great Forum, Tucson, AZ • participated in the Council meetings of the Institute on Religion in an Age of Science, June 17 and 23, Chautauqua, NY.

Fr. Coyne gave a talk on "The Age of the Universe" at the Hughes Research Laboratory, Malibu, CA, January 27 • gave a paper on "Lemaître: Science and Religion" at the international meeting, "The Georges Lemaître Anniversary Conference," at Sidney Sussex College, Cambridge, UK, April 7-10 • participated in the conference announcing the award of the Templeton Prize to Sir Martin Rees, Lord of Ludlow at the Royal Institution of Great Britain, London on April 6 • delivered the annual Albertus Magnus Lecture on "Children of a Fertile Universe" at the Dominican University, River Forest, IL, November 17 • at the workshop on "Reason and Unreason in 21st Century Science," Christ's College, Cambridge, UK, December 11-13, gave a paper on "A Theology of Everything".

Fr. Funes presented a paper at the 217th meeting of the American Astronomical Society, 10-13 January, Seattle, WA • gave a review talk on "Galaxy Evolution in the Local Universe" at the INCAI workshop "Exploring the Nature of the Evolving Universe", held at the Pontifical Catholic University of Rio de Janeiro, August 15-19 • gave a main talk on "Church and Science in Dialogue" at the International Conference "The Person of Modern Age and the Church" held at the Pontifical Gregorian University, November 16-19 • gave seminars at the Facultad de Matemática, Astronomía y Física, Universidad Nacional de Córdoba, Argentina, and at the Department of Theoretical Physics and Astrophysics, University of Kiel, Germany.

• *Fr. Pavel Gabor, S.J.*

Fr. Gabor gave a paper at a conference on "Resolving the Future of Astronomy with Long-Baseline Interferometry" in Socorro, NM, on March 28-31 • attended the summer school "IMPRS Summer School, Characterizing Exoplanets: From Formation to Atmospheres" in Heidelberg, Germany, August 1-5 • gave a paper at the colloquium "Decoupling Civil Timekeeping from Earth Rotation" in Exton, PA, October 5-6.

Fr. Gionti gave an invited talk "Local Regge Calculus and Spin Foam Formalism" at the FunInGeo Conference, Ischia, Italy, in honor of Prof. Beppe Marmo, June 14-18 • gave a talk at the Specola Vaticana in Castel Gandolfo on June 22 • gave an invited talk: "Some Consideration on Discrete Quantum Gravity" at the Third Galileo-Xu Guangqi meeting in Beijing, China, October 11 to15.

Fr. Heller gave a paper: "Lemaître, the Big Bang and the Quantum Universe" at the The Georges Lemaître Anniversary Conference organised by the Faraday Institute and at Sidney Sussex College, Cambridge, UK, April 7-10 • gave a paper: "Cosmic Environment of Life" at the International Conference "What is Life? Theology, Science, and Philosophy", Kraków, Poland, June 24-28 • gave a paper: "What Does It Mean 'to Exist' in Physics? A Comment on the Leibnizian Question" at the Conference "Why Is There Anything?", Yale University, New Haven, CT, October 6-9.

Prof. Minniti organized the Aspen Center for Physics Summer Workshop on "The Milky Way Bulge", Aspen, CO, Aug-Sep • SOC Member for the Second VVV Science Workshop, Hertfordshire, UK, July • Member of the Observing Proposals Committee of the European Southern Observatory, as Chairman of Panel C3 on ISM, Star Formation and Planetary Systems, May and Nov • in 2011 Prof. Minniti was invited to give talks on: "The VVV Survey", at the 1st Binational SOCHIAS/AAA Annual Meeting, San Juan, Argentina, October 7 • on "The VVV Survey", at the Aspen Center for Physics Workshop on the Milky Way Bulge, September 7 • on "The VVV Survey Rocks", at the Workshop on Computational Astronomy, Cordoba, Argentina, August 9 • on "The VVV Survey of the Milky Way", at Hertfordshire Surveys Workshop, July 18 and 20 • seminar, "The VVV Survey: First Results", Vatican Observatory, Vatican City State, August 2 • seminar, "The VVV Survey: Current Status and First Results", European Southern Observatory, Santiago Chile, May • invited to give a talk on "The VVV Survey: Status and First Results", at the Workshop on Friends of Friends, Cordoba, Argentina, April • public talk "Planetas Extrasolares", Universidad Adolfo Ibañez, Santiago, June 15 • public talk "Mundos Cercanos y Lejanos", P. Universidad Católica, Santiago, October 4.

Fr. Omizzolo participated in the meeting "Star formation across space and time", Tucson, March 30 - April 4, presented a poster on work of WINGS group on the results of research into galaxy cluster and star formation • participated in the Italian National Workshop about LBT, Padova in October 26-27.

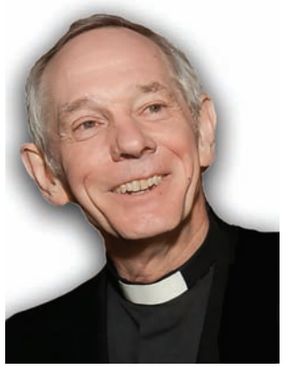
Fr. Stoeger attended the Catholic Theological Society of America Annual Convention, San Jose, CA, June 9-12, on the committee for planning and convening the Theology and Natural Sciences Topic Session • Templeton Foundation Workshop on Randomness, Calvin College, Grand Rapid, MI, August 23- 24 participated and gave a presentation, "Investigating the Meanings and Importance of Randomness in Reality and Its Compatibility with Divine Purposes and Action." • University of Dallas Ministry Conference, Dallas, TX, October 28- 29, gave a presentation, "How the Big Bang and Evolution Fits in with Divine Creation," and participated on a panel, ``Science and Belief." • Center for Theology and the Natural Sciences, Three Faiths Conference, Berkeley, CA, December 11, gave two talks: ``Our Understanding of the Universe Today," and "Connecting Christian Belief in Creation Big Bang Cosmology."

Br. Stott attended the XXII Canary Islands Winter School of Astrophysics, November 2010, on the topic of asteroseismology • served as a teaching assistant for Professor Don McCarthy at the University of Arizona, spring semester of 2011.

Educational and Public Outreach

Fr. Brown gave a series of talks to students at the Jesuit Colegio Virgen de Guadalupe in Badajoz, Spain, March • gave two talks at Colegio Santa Maria Assumpta, Badajoz, Spain, March • gave a talk at Santísima Trinidad Jesuit parish in Badajoz, Spain, February • gave a talk at Real Sociedad Económica Amigos del País in Badajoz, Spain, March 2011 • gave a public lecture to the Jesuit Community at Colegio Noviciado San Estanislao Kostka in Salamanca, Spain.

Br. Consolmagno spoke at nine universities and three high schools in the US and UK. Each school visit generally included a public lecture on science and religion, a technical seminar on planetary astronomy, and several classroom visits. Most notable of these talks was his presentation to an overflow crowd of more than 2500 attendees of the opening lecture of the annual University of Arizona College of Arts and Sciences Lecture Series, which this year centred on Cosmology (February 1); the Vivian J. Lamb Lecture on Science and Religion at Villanova University (November 9); and the Landegran Lecture on Science and Religion at the University of Dallas (December 3) • was an invited participant in a panel on Science, Culture, Religion, and Ethics, at the annual meeting of the Sigma Xi Science Honor Society in Raleigh, NC, November 12 • from April 7-14, the Vatican Observatory provided historic scientific materials for an exhibit at the American Academy in Rome celebrating the 400th anniversary of Galileo's demonstration of the telescope in Rome. As part of the festivities, Br. Consolmagno gave a presentation on the history of Galileo and the Vatican at the Academy.



• *Fr. Chrisopher Corbally, S.J.*

Fr. Corbally spoke about "Kino, the Astronomer" on January 29 at the Installation of Officers for Los Descendientes del Presidio de Tucson, and spoke to the Green Valley Forum on "Padre Kino: His life, journeys, and astronomy", February 9, both as part of the celebrations for the 300th anniversary of Kino's death • presented the topic of "Heroic Galileo and the Message in the Stars" in the Third-Thursday Star Talks series at Prescott Public Library, AZ, September 15 • spoke again to the Green Valley Forum on December 14 on "The Star of Bethlehem" • hosted visits to Mount Graham International Observatory for Scout Troop 818 (Scottsdale, AZ) on July 30 and for the Prescott Astronomy Club (an evening visit including observing at VATT, after a previous day tour of the Mirror Laboratory on UofA campus) on October 15.

Fr. Coyne gave a talk on "The Age of the Universe – And of Us Humans" at the Vatican Observatory Foundation Seminar on February 24 • on March 13 delivered a paper on "A Jesuit Scientist's Response to the Neo-Atheists" at the Sunday Morning Conversation with Jesuits, St. Ignatius Church, San Francisco, CA • spoke on March 21 to the Sun City Vistoso Havurah on "Science Meets Religion in Modern America" • spoke on March 22 at St. John's Seminary, Camarillo, CA on "The Dance of the Fertile Universe" • gave a lecture on March 24 on "The Universe in Evolution" to the University Series at St. Paschal Baylon Church, Thousand Oaks, CA • during Jesuit Heritage Week at St. Peter's College, Jersey City, NJ spoke on March 30 about "Jesuit Identity as Co-Creators in the Universe • on April 4 presented the keynote address to the Villanova University Theology Institute Annual Conference, Villanova, PA • gave a talk on the "Dance of the Fertile Universe" to the group, "The Salon," in Phoenix, AZ on April 19 • at the invitation of the Los Angeles Country Club spoke on June 1 about the history of the Vatican Observatory • on September 22 gave the Zahm Lecture at the University of Portland, Portland, OR • talked on October 13 to the California Club, Los Angeles on "At Home in the Universe" • on October 17 spoke to the St. Albert the Great Forum, Newman Center, Tucson, AZ on "Children of a Fertile Universe" • gave a breakfast talk on November 1 at the Jonathan Club, Los Angeles on evolution as a universal phenomena • at the Adler Planetarium on November 16 gave a talk on "Reaching for the Heavens: The Vatican Observatory."

Fr. Funes gave presentations and public lectures on Astronomy and Science-Faith Dialogue at the Marquette University High School, Milwaukee, WI; the Acción Social Católica, Zaragoza, Spain; St. Thomas More Catholic Newman Center, University of Arizona; Universidad Católica de Córdoba, Argentina; Cathedral of Reggio Emilia, Italy; Cefalù, Sicily; Studium Cattolico Veneziano, Venice, Italy; Merate, Italy • gave two lectures at the Festival of Books in Santo Domingo, Dominican Republic, as a member of the delegation of the Holy See.

Fr. Gabor Gabor gave three talks at Boston College, MA, April 26-28 • four talks in Slovakia (Kysucke Nove Mesto, Namestovo, Dolny Kubin, and Nove Mesto nad Vahom) July 9-14 • five talks in the Czech Republic (Praha, Pecky, Zabreh, Blatnice pod Svatym Antoninkem, Zelezny Brod) September 5-10 • a talk at the Sun City Vistoso Astronomy Club, AZ, November 17.

Fr. Gionti organized, jointly with the municipal administration of the town of Rocca di Papa, a series of public talks by the scientific staff of the Vatican Observatory at the city municipal hall. The amateur astronomer association "Tuscolana" provided some astronomical amateur observations in the municipal hall courtyard after the talks • Br. Consolmagno began the series on January 11 with "Meteorites: A Way to Touch the Heavens" • on January 21, Fr. Gionti talked about "One or Many Universes?" • on February 1, Fr. Maffeo delivered a talk on the "History of the Vatican Observatory" • on March 4, Fr. Omizzolo with "Creation and Cosmic Evolution: A Non-existent Clash" • on March 18, Fr. Janusz gave a talk on "Is there an Algorithm to Explain the Universe?" In his talk, Fr. Gionti discussed the possibility of the existence of many universes as an outcome from the Inflationary and String Theory • gave a series of public talks on Cosmology and the concept of God at the "Oratorio parrocchiale" di Borgomanero (Novara) on February 25 • gave a talk at the "Aula Magna" of

"San Camillo-Forlanini" Hospital in Rome at the meeting "Scienza, Fedi e salute", May 4 • at the Jesuit School of Philosophy "Aloisianum" in Padua to the scholastics during their last two hours of Natural Theology Class held by Fr. Secondo Bongiovanni, S.J. on May 18 • on May 31, he also gave an introductory talk on the Universe to the children of the elementary school of Rocca di Papa • took part in a panel with other scientists and one philosopher in Pisa on the topic of the Big Bang from scientific, philosophical and theological perspectives, September 24.

Fr. Maffeo gave a series of lectures on the history of the Vatican Observatory sponsored by the City of Rocca di Papa • participated in a conference on Science and Faith at the University of Regina Apostolorum, Legionaries of Christ.

Fr. Mueller gave a public talk at the VOF Seminar, Tucson AZ: "Misprints in the Book of Nature?" Feb 24 • public talk: St. Albert the Great Forum, March 7, Tucson, AZ: "Can I Take Your Word For It? Assessing Witness Reports, in Science and Religion".

• *Fr. Paul Mueller, S.J.*

Fr. Omizzolo gave a series of public talks about cosmology and also about science and faith • a public talk: "Science and Faith, a Non-existent Contrast" Università di Roma 3, Rome, Italy March 5 • a public talk about the relationship between science and faith: problems and possible solutions, Cologno Monzese, Italy, March 25 • gave a talk at the meeting "Lo spazio comune dell'uomo nel creato", organized by the GreenAccord Association, Pistoia, Italy, June 11 • a public talk on the topic of Cosmology and theology in cooperation with the Ministero dell'Università e della Ricerca scientifica (MIUR), September 11 • gave a paper on the History of the Vatican Observatory, for a book published by the MIUR in cooperation with the People's Republic of China; the paper was published in the Chinese language.

Fr. Stoeger gave a series of talks on Cosmology, Astronomy, Theology and Spirituality at the Redemptorist Renewal Center, Cortaro, AZ, May 16- 19; same Series presented there on November 7, 8 and 10 • invited public lecture at the St. Monica's Forum, St. Monica's Parish, Santa Monica, CA, May 21: "The Big Bang and Divine Creation – Enemies or Friends?" • invited presentations at the St. Albert the Great Forum on Theology and Science, Catholic Newman Center, The University of Arizona, May 2: "Pierre Teilhard de Chardin, Paleontologist and Priest: On Matter and Spirit." Chair and Convener of the St. Albert the Great Forum Board, Catholic Newman Center, University of Arizona.

News and Media Coverage

Fr. Brown gave a radio interview (broadcast nationwide in Spain) to the Radio Station of the Archdiocese of Mérida-Badajoz, the transcript of which appears in the the archdiocesan newspaper Iglesia en Camino, año xviii, no. 841, March 13, 2011.

Br. Consolmagno was interviewed more than a dozen times for media outlets in the US, the UK, France, and Australia. Among these were extensive interviews published in "The Vatican Past & Present", February 2011; a lengthy appearance on the National Geographic television special "Secret Access: The Vatican", aired worldwide in April; and a half-hour appearance on August 7 with Roger Phillips on BBC Radio Merseyside.

Fr. Corbally was interviewed for the Drew Mariani Show, Relevant Radio, on 20 December, about "The Christmas Star, Padre Kino, and the Lunar Eclipse at the Solstice" • was interviewed by Lorraine Rivera of News4/ NBC television at VATT and LBT on April 1 and featured in a two-part news story on May 10 & 11 • on April 5 was interviewed at VATT by Jonathan Taylor for a History Channel special "Proving God", produced by Cameo Wallace, Karga 7 Pictures, for A&E Television Networks • was featured with Br. Consolmagno in the Winter 2011 edition, Australian Catholics magazine, "Finding Answers in the Stars", by Fatima Measham http://www.australiancatholics.com.au/content/view/243/

Fr. Coyne gave an interview on February 10 to the Jesuit Virtual Learning Center on the interaction between science and religion • was interviewed on the Fred and Jeff Ronstadt Show on June 14 about the role of Tucson, Arizona and of the Vatican Observatory in astronomy • on August 10 was interviewed by Molly McCarthy of the Le Moyne College Alumni Magazine • on September 16 was special guest on the Michael Kell MBB2 Lyceum Show • interviewed by Archbishop Timothy Dolan of New York City on the "Seize the Day with Gus Lloyd Program."

Fr. Funes gave interviews to Radio Cope (Spain), El Heraldo de Aragón (Spain), France 2 (France), O Globo (Brazil), Cadena 3 (Argentina), La Voz del Interior (Argentina), Radio Maria (Argentina).

Fr. Gionti was an invited guest on "Spacelab", an Italian RAI News TV program, March 25. The topic of that particular episode was theology and science • interviews with Vatican Radio, L'Osservatore Romano and Tele Padre Pio TV.

Fr. Gabor gave a full-page interview to Zuzana Ulicianska published in SME (one of the main Slovak daily newspapers) on January 15 • Leslie Mullin, "Reverence for the Heavens", interview with Br. Consolmagno and Fr. Gabor, in Astrobiology Magazine, January 2011 • a 50-minute interview for the Czech national radio, broadcast in August.

Fr. Maffeo was interviewed by a private television of Sardinia • TV 5 Star: Russian NTV • a Japanese journalist.

Visits to scientific institutions and universities

From September 5-9, Br. Consolmagno visited Louisiana State University to work with Brad and Martha Schaefer on developing a laboratory technique for measuring the heat capacity of meteorites. While there he presented a seminar and a public talk. Br. Consolmagno paid short visits, with public lectures, to University of California Merced (February 8-10), Winona (Minnesota) State University (February 14-16), Michigan Technical University (February 17), Appalachian State University (February 28 - March 2), University of North Carolina at Charlotte (March 3-4), Ardingly College (September 16-19), Villanova University (November 8-10), University of Scranton (November 17-18), University of Central Florida (November 22), and University of Dallas (December 2-3).

Fr. Gabor gave an invited talk on Jesuit astronomy in China at the exhibit "Binding Friendship: Ricci, China, and Jesuit Cultural Learnings" at Boston College, MA, and visited Fr. Cyril Opeil's, S.J., low-temperatures laboratory, and Dr. Dominic Papineau's Precambrian Biogeochemistry and Exobiology Laboratory. He visited Prof. Klaus Strassmeier, Director of the Astrophysics Institute in Potsdam, Germany, June 22-23.

Fr. Gionti was invited to visit CERN from January 24-28, where he attended the CERN Winter School in Supergravity, Strings and Gauge Theory. February 26-27, Fr. Gionti participated, as a representative of Fr. Funes, in the board of directors meeting at the Icranet Centre in Pescara • was invited by the director, Prof. Hermann Nicolai, to the Max Planck Institute for Gravitational Physics in Potsdam, Germany, April 10-15 • gave a talk "A Review of Regge Calculus", April 15 • visited Dr. Franco Pezzella at the Physics Department of the University of Naples "Federico II", May 10 • Gave a talk at Berlin University, Phisycs Department, December 5.

Prof. Minniti was a visiting Professor at ESO Vitacura, Chile, March-June, and a visiting Fellow at the Departement of Astrophysical Sciences, Princeton University, August 2011-January 2012.

Fr. Stoeger visited the Dept. of Physics and Astronomy, University of Oregon, Eugene, OR from January 31- February 3. While there he gave a colloquium in the department, "Two Issues in Cosmology: Initiation of Inflation and Large-scale Spatial Homogeneity," and a public lecture, "The Big Bang and Divine Creation – Enemies or Friends?" • he also spoke at the Catholic Newman Center, University of Oregon: "Integrating Faith, Science and Work Today."

6. Publications

Books

The fourth edition of *Turn Left at Orion*, by Br. Consolmagno and Dan M. Davis (Stony Brook University) was released by Cambridge University Press in 2011. A complete re-write of a classic text for amateur astronomers, with more than 100,000 copies sold since it first came out in 1989, the new edition now includes directions and illustrations for Dobsonian-style telescopes as well as the traditional smaller scopes covered in the earlier edition. Nearly a hundred new objects have been included in this edition, including greatly expanded chapters on the Moon and objects visible from the southern hemisphere. The book's format has been expanded to accommodate the new material, and it now features a spiral binding to make it even easier to use at the telescope. Much of the observing for this book was done from the Specola itself with a Dobsonian telescope donated by Starizona of Tucson.

Heller: *Elements of Quantum Mechanics for Philosophers* ed.: R. Janusz, OBI – Kraków, Biblos – Tarnów, 2011 (in Polish). *Philosophy of Chance*, Copernicus Cener Press, Kraków 2011 (in Polish).
Heller edited the following books: *Infinity. New Research Frontiers*, ed.: M. Heller, W. H. Woodin, Cambridge University Press, Cambridge, 2011. Józef Życiński, *The World of Mathematics and of Its Material Shadows. Elements of Plato in the Foundations of Mathematics*, ed.: M. Heller, Copernicus Centre Press, Kraków, 2011 (in Polish).

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CONSOLMAGNO, G. J., (2011). E dal Gianicolo si videro i cieli. *L'Osservatore Romano* 151, April 15, 4.

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CONSOLMAGNO, G. J., (2011). Forbidden Transitions. *The Tablet*, 265, February 26, 36.

CONSOLMAGNO, G. J., (2011). A World in a Grain of Dust. *The Tablet*, 265, March 26, 36.

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7. Observatory Visitors

Visitors to the Vatican Observatory Headquarters in Castel Gandolfo

On November 11, H.E. Msgr. Giuseppe Bertello, President of the Governatorate of the Vatican City State, and H.E. Msgr. Giuseppe Sciacca, General Secretary, visited the Headquarters of the Vatican Observatory in Castel Gandolfo.

On November 9, a group of ambassadors to the Holy See visited the headquarters of the Vatican Observatory and the telescopes on the roof of the Papal Palace. The following ambassadors were part of the group: H.E. Tim Fischer (Australia), H.E. Lamia Aly Mekhemar (Egypt), H.E. Larry Yu-Yuan Wang (China, Taiwan), H.E. Georges El Khoury (Lebanon), H.E. Mercedes Arrastia Tuason (The Philipines), H.E. Ali Akbar Naseri (Iran), H.E. Thomas (Korea) Hong-Soon Han, Japan, H.E. Hidekazu Yamaguchi, Ms. Lusy Surjandari (Chargé of Indonesia), Mr. Armindo Pedro Simoes (Chargé of Timor Leste), Mr. Hasan Sekizkok (Counsellor of Turkey).

• Group of Ambassadors with Fr. Funes and Frs. Brown and Maj

On November 4, the Ambassador of Sweden to the Holy See, H.E. Ulla Gudmundson, also visited the Vatican Observatory. On October 5, Father Józef M. Maj, S.J., received H.E. Hanna Suchocka, Ambassador of the Republic of Poland to the Holy See and Prof. Adam Rotfeld, formerly Foreign Minister for the Republic of Poland, President of the Government Commission for relations between the Republic of Poland and the Russian Federation.

On October 3, Fr. Maj received H.E. Tim Fischer (Australia) and a group of Australian-New Zealand scientists, ministry officials for the Square Kilometre Array Project. Subsequently Fr. Brown led a tour in the headquarters and to the telescopes on the roof of the Papal Palace.

On August 27, Dr. Dominic Papineau, Boston College, visited Fr. Gabor, gave a seminar on "Searching for the Oldest Vestiges of Life on Earth", and visited the meteorite laboratory.

On July 8, Fr. Funes received the visit of H.E. Msgr. Mariano Crociata, the General Secretary of the Italian Bishops Conference, H.E. Msgr. Marcello Semeraro, bishop of Albano and the board of directors of the Italian newspaper, Avvenire.

• Fr. Adolfo Nicolás, S.J. at Specola Vaticana

On June 6, Fr. Adolfo Nicolás, S.J., Superior General of the Society of Jesus and his council visited the headquarters and the telescopes on the roof of the Papal Palace.

On May 28, a group of employees of the Governatorate of the Vatican City State and their families visited the Vatican Observatory.

On April 16, H.E. Miguel Diaz, US Ambassador to the Holy See, visited the Vatican Observatory.

On February 22, Fr. Maj received H.E. Hanna Suchocka, Ambassador of the Republic of Poland to the Holy See, and Mr. Henryk Litwin, Deputy Foreign Minister of the Republic of Poland, currently Ambassador in Ukraine.

On February 12, Fr. Maj received H.E. Msgr. Sergij from Solnechnogorsk, Head of the Administrative Secretariat of the Patriarchate of Moscow, accompanied by three other officials.

Fr. Maffeo accompanied about thirty groups, Italian and foreign, visiting the Zeiss telescopes within the Papal Palace of Castel Gandolfo.

Scientific and Academic visits to the Vatican Observatory headquarters in Castel Gandolfo

Juan Pablo Marrufo del Toro, a Jesuit scholastic of the Oregon province, worked with Br. Consolmagno during the summer on a number of projects updating the Vatican Observatory web site, public relations, and public outreach efforts.

Padraig Alton, an undergraduate in astrophysics at Cambridge University, spent three weeks working with Br. Consolmagno in the meteorite laboratory. He updated the meteorite catalogue and began a systematic study of the effect of weathering on meteorite mass.

On July 15, Franco Pezzella visited Fr. Gionti at the Vatican Observatory headquarters in Castel Gandolfo for research purposes.

In the spirit of cooperation with the University of Roma Tre, Fr. Omizzolo received numerous visitors at the headquarters in Castel Gandolfo, most notably Prof. Aldo Altamore.

Fr. Boyle received visits from Leon Harding, National University of Ireland, Galway, Ireland, and Vygandas Laugalys, Vilnius University, Lithuania.

Visitors to the Vatican Observatory Research Group and VATT

Duilia de Mello, of the Catholic University of America, Washington DC, was the guest of Fr. Funes.

Marcelo E. de Araújo, Universidade Federal do Rio de Janeiro, Brazil visited the Vatican Observatory Research Group, Tucson to do research with Fr. Stoeger February 3-15.

George F. R. Ellis, Department of Mathematics, University of Cape Town, Cape Town, South Africa visited the Vatican Observatory Research Group for discussions and research with Fr. Stoeger, February 16-21. He also gave a talk on top-down causality at the St. Albert the Great Forum.

Fr. Corbally received Aileen O'Donoghue, of St. Lawrence University, Canton NY, USA.

Back home in Rome

Concluding this year's annual report it seems only fitting to return to Rome, and again to that intricate bond between science and faith that is at the heart of the Vatican Observatory and the life of its scientists. More precisely, to the Church of San Tommaso da Villanova, in the village of Castel Gandolfo.

The Church lies a stone's throw from the main gates of the Papal Palace that has served as the site of Vatican Observatory telescopes since 1935. This bond between the Pope and his scientists, between Castel Gandolfo and the Vatican Observatory and between Science and Faith has now been 'cast in bronze' by the village community.

In recent extensive renovation work on the ancient Church, a set of bronze doors with a relief sculpture celebrating this relationship was installed on the north wall. The doors, created by the artist Battista Marello, were dedicated on August 15, the Feast of the Assumption, on the occasion of Pope Benedict XVI's visit to the church during his summer residence.
Fr. Brown, who celebrates early morning mass each Sunday for the Parish community, noticed the specific link to the Vatican Observatory. The left-hand door shows a woman representing the Church, under attack from below but surrounded by light, with the dome of the church as her crown, reaching toward the stars. The stars continue on the right-hand door, where Pope Benedict is portrayed watching over the Church. The fire of the Holy Spirit descends on him from the stars, while on his

vestments various equations from physics and geometry, and a depiction of a double helix are engraved. In his hands is a tablet inscribed Deus Caritas Est, his first encyclical. The artist's description specifically states that the stars depicted in the door are a reference to the 'Specola Vaticana', as it is known locally, which was founded by popes and has been located in Castel Gandolfo since 1935.

• Details of the Castel Gandolfo Church door, including a DNA double helix (upper left), Einstein's equation for mass and energy (upper right) and the Hubble equation descibing the expansion of the universe (bottom).