



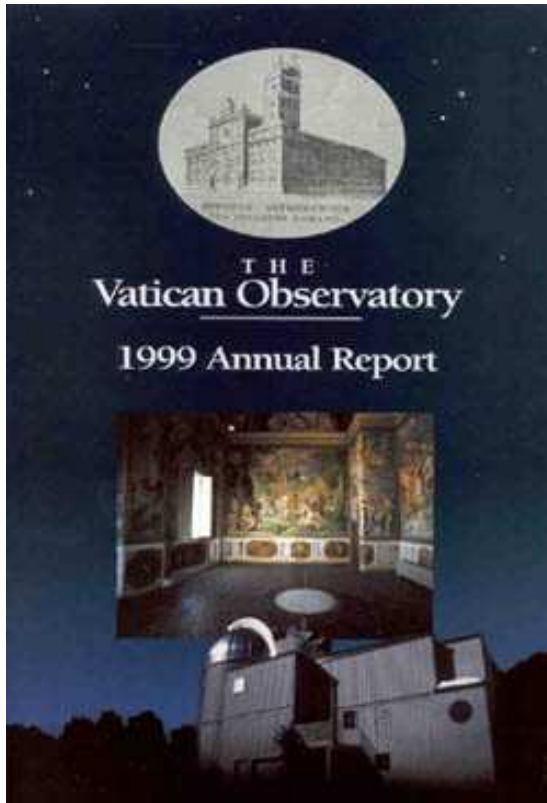
THE VATICAN OBSERVATORY  
1999 ANNUAL REPORT

Staff & Directors

From Director

Editor: Elizabeth J. Maggio

## Cover: Highlighting the History

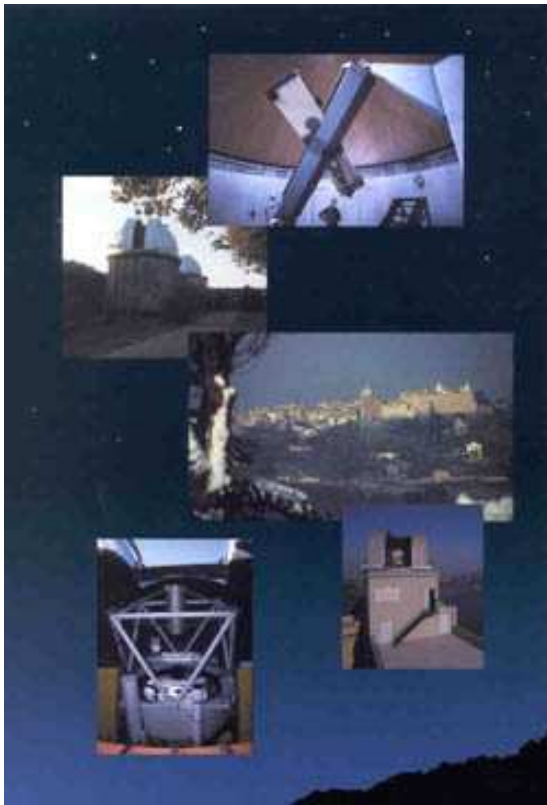


**Cover:**

Photo montage of highlights from the history of the Vatican Observatory.

**Front cover:**, top: Roman College; middle: Tower of the Winds; bottom: Vatican Advanced Technology Telescope (Alice P. Lennon Telescope in the dome at left; Thomas J. Bannan Astrophysics Facility at right).

**Back cover:** , from the top: Carte du Ciel telescope, Schmidt telescope, view across Lake Albano of the Vatican Observatory in Castel Gandolfo, double astrograph telescope, Alice P. Lennon Telescope.



Cover Artist: **Dave Fischer**



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Cover

Vatican Observatory  
Annual Report 1999



**Vatican Observatory**  
(Castel Gandolfo)  
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**Editor: Elizabeth J. Maggio**  
**Cover Artist: Dave Fischer**



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## From the Director

Cover

### From the Director

#### *Thanks for the Memories*

As we publish this last report of the 1990s we look back with gratitude to all that our colleagues and friends have helped us to accomplish so that the Church might be actively present in the world of science. We could not begin to name all who have been with us in our journey, but you are all in our hearts and in our thoughts. We have been pilgrims together in our journey to understand the universe and ourselves in it. Let us for a moment reflect upon our pilgrimage.

Our attempts to understand the universe have as much to say about ourselves as they do about the universe. In fact, in us the universe has become self-reflective. Today, as we scientists attempt to understand ourselves and the universe using the most advanced methods of physics and mathematics, we realize that we stand on the shoulders of giants of the past. The path to our present-day understanding has been a long one relative to a human lifetime but a very short one relative to the age of the universe itself. We are today's pilgrims: aware of what lies behind us and impatient to know what lies ahead.

We invite all of you to retrace with us some of the more significant and interesting episodes in the history of the Vatican Observatory. Items highlighted in bold refer to the images that appear in the photographic montage on the [front](#) and [back](#) cover of this year's Annual Report.

#### ● Beginnings

In its historical roots and traditions the Vatican Observatory is one of the oldest astronomical institutes in the world. The Observatory was foreshadowed by the call of Pope Gregory XIII to the Jesuit mathematicians and astronomers of the **Roman College** to study the scientific data required to reform the calendar. By the 1500s, a tiny error in the old Julian calendar, in use since the first century B.C., had become large enough that the calendar was about ten days out of phase with the seasons; this made it difficult to time holy days, especially Easter. The discrepancy was dramatically confirmed to the Pope in the Vatican's **Tower of the Winds**, which housed a meridian line used to measure the change in the sun's position and thus chart the change of seasons. The modern or Gregorian calendar was completed in 1582. From that time and with some degree of continuity, the Papacy manifested an interest in and support for astronomical research. In the nineteenth century, the famous Jesuit astronomer Father Angelo Secchi became the first scientist to classify stars according to their spectra. Inspired by the caliber of this work, Pope Leo XIII in 1891 formalized astronomy research with the establishment of the Vatican Observatory (Specola Vaticana). Three instruments, including the **Carte du Ciel telescope** used for an international program to map the whole sky, were located behind the dome of St. Peter's Basilica on the ancient Leonine wall. Several religious orders contributed personnel and directors to the Observatory, including Barnabites, Oratorians, and Augustinians, as well as Jesuits.



*Notable contributors to the founding of the Vatican Observatory. Center: astronomer Angelo Secchi, S.J., a founder of modern astrophysics. Left: Pope Gregory XIII, who called for the reform of the calendar in the 1500s. Right: Pope Leo XIII (in back), who formally established the Vatican Observatory in 1891, and Pope Pius XI (in front), who moved the Observatory to Castel Gandolfo in 1935. (Painting by I. Fantini)*

### ■ The Move to Castel Gandolfo

For a little more than four decades astronomical research — most importantly the sky-mapping project — was carried out in the shadow of St. Peter's, but soon urban growth of the Eternal City had brightened the night sky to such an extent that the fainter stars could no longer be studied. Thus it was that in the early 1930s Pope Pius XI provided a new location for the Observatory at the Papal Summer Residence at **Castel Gandolfo** in the Alban Hills, some 25 kilometers southeast of Rome. It is curious that in order to modernize, the Observatory was moving to a site whose recorded history predates the founding of Rome. The Observatory's new headquarters rises on land once inhabited by the Latins, the ancient race of people who founded Rome. These hills also attracted the rich and powerful from the Eternal City. One of them, Emperor Domitian (81–96 A.D.), had an extensive and luxurious villa where the Papal gardens are now located in Castel Gandolfo. It is amidst this antiquity that the modern observatory, entrusted to the Jesuits, took shape. Two new telescopes, a **double astrograph** and a visual refractor, were built on the roof of the Papal palace; an astrophysical laboratory for spectrochemical analysis was installed; and several important research programs on variable stars were begun. In 1941 the Carte du Ciel telescope, which had been left in Rome (the other two telescopes had been decommissioned), was moved to Castel Gandolfo and installed in the Papal gardens next to the palace. It was joined in 1957 by a new **Schmidt wide-angle telescope**, which was used to extend the Observatory's research interests to other topics, such as new techniques to classify stars according to their spectra. This is still an active program at the Observatory and recalls the early pioneering work of Angelo Secchi.

### ■ New Horizons

With the continuously increasing population of Rome, the night skies above the Observatory once again became too bright to do meaningful research, even in Castel Gandolfo. For this reason in 1981, for the first time in its history, the Observatory founded a second research center, the Vatican Observatory Research Group (VORG), in Tucson, Arizona. This area in the United States boasts one of the world's largest concentrations of modern centers for observational astronomy. The Observatory staff have offices at the University of Arizona's Steward Observatory, and they have access to all of the telescopes located in the Tucson area. In 1993 the Observatory, in collaboration with Steward Observatory, completed the construction of the **Vatican Advanced Technology Telescope (VATT)** on Mt. Graham, Arizona, which is considered the best astronomical site in the continental United States. The VATT, which consists of the **Alice P. Lennon Telescope** and the **Thomas J. Bannan Astrophysics Facility**, is the first optical-infrared telescope of the new Mount Graham International Observatory, which when completed will house some of the world's largest and most sophisticated instruments for studying the universe. The VATT uses a mirror made with new technology, pioneered at Steward Observatory, that makes it possible to create large, lightweight, stable mirrors in a rotating furnace.

With its two centers, the Vatican Observatory is expanding its work in many areas: Castel Gandolfo not only serves as administrative headquarters, but it is a center for meetings and summer schools, and its archives are used for research into the history of science. New scientific endeavors as well as long-term, continuing research programs that were the hallmark of research

at Castel Gandolfo are being carried out at the VATT. These include investigations of cosmological models, spectral classification of peculiar stars, the distribution of metal-rich and metal-poor stars, mass-exchanging binary stars, material in star-forming dark clouds, dust envelopes about young stars, and planetary dynamics.

For the members of the Vatican Observatory, science has undoubtedly been one of the principal factors in determining the direction of our pilgrimage through the universe. In attempting to unify our scientific knowledge with all that we know as human beings, we sense that we are being led to realities beyond understanding and that our passion to know is really a participation in Love. It is remarkable that our scientific investigations have brought us to this.

### *Vatican Observatory Summer School*

The Seventh Vatican Observatory Summer School (VOSS) in Observational Astronomy and Astrophysics was held at the Observatory in Castel Gandolfo from 13 June to 10 July. The topic, "Observations and Theoretical Understanding of Single Stars and Close Binary Systems," attracted twenty-four students from twenty countries.

*Felicitas Mokler, from Germany, observing prominences on the sun during the 1999 Vatican Observatory Summer School. Photo by VOSS student Jens Kube, Germany.*



The faculty included Richard O. Gray from Appalachian State University; Mercedes Richards from the University of Virginia; Rolf-Peter Kudritzki from the University of Munich; and the Vatican Observatory's Christopher Corbally, who also served as the School's Dean. On 30 June His Holiness John Paul II received faculty and students from the School in St. Peter's Square at the termination of the General Audience.

### *Research Highlights*

**GALACTIC DETECTIVES** Vatican Observatory astronomer José Funes, S.J. and colleagues from Italy and Germany have been poking around galaxies looking for tell-tale signs of pending and past cosmic disasters. They found pairs of galaxies that harbor clues of ongoing gravitational interaction with each other that could lead to close encounters, mergers, even collisions. At first glance, these galaxies appear to be peacefully coexisting. Then the astronomers took deep images of them with the Vatican Advanced Technology Telescope, used a special analytical technique that reveals faint structures, and found that tidal forces are stretching the gas in these galaxies into bridges and tails.





*The asymmetric shape of spiral galaxy NGC 772 is likely due to the gravitational tug of a nearby galaxy. Eventually the two may collide. Photo by E.M. Corsini and C. Scarlata (University of Padua); J.G. Funes and R. Boyle (Vatican Observatory)*

The team also found that some isolated galaxies probably once merged or collided with a small companion galaxy. The clue: the rotation of gas and stars in these galaxies is out of kilter. An important consequence of such interactions between galaxies is that new star formation is being triggered.

**RUBBLE PILES IN SPACE** "Space rocks" is a popular description for asteroids, but "rubble piles" may be more accurate, according to Vatican Observatory astronomer Guy Consolmagno, S.J. He and Dan Britt from the University of Tennessee found evidence that most large asteroids are not solid objects but unconsolidated piles of rock glued together by gravity with as much as 40% empty space. The scientists began examining asteroid data after completing an analysis of the density of meteorites, most of which come from asteroids, and discovering that meteorites are fairly porous. The new findings raise interesting questions about the origin of asteroids that the scientists hope to answer with further studies.

#### *Publications*

The Vatican Observatory is pleased to announce the publication of *The Vatican Observatory and the Arts: The Sculpture of John David Mooney at Castel Gandolfo*. This limited-edition monograph contains 162 color images that are the permanent record of the temporary sculptures created by Mooney during the Observatory's multidisciplinary conference "The Inspiration of Astronomical Phenomena" held in 1994 at Castel Gandolfo. The artist's work manifests the interrelationship between art and science.

The Vatican Observatory marked the passage into the year 2000 with its first official calendar—*Calendar 2000*. Its goal is to tell the story of the human need to record time and out of that need to understand the celestial bodies that mark the passage of time. The color calendar features astronomy-related photographs and dates marked with events and personalities important to astronomy and to the Vatican Observatory.

Information about purchasing these publications can be obtained by contacting the Vatican Observatory Research Group in Tucson or by linking to the Observatory's [web site](#).

#### *Personnel News*

As of 1 January 2000 José Gabriel Funes, S.J., who is finishing his doctorate in astronomy at the University of Padua, Italy, joins the staff of the Observatory. Under the direction of Francesco Bertola, Funes completed his thesis on the internal kinematics of galaxies. His research is described in this report.

As of October 1999 Louis Caruana, S.J., Assistant Lecturer in Philosophy of Science and Philosophy of Nature at the Pontifical Gregorian University in Rome, has been appointed an Adjunct Scholar of the Observatory.

At the end of its annual conference in August 1999, the Council of the [Institute on Religion in an Age of Science](#) (IRAS) elected Christopher Corbally, S.J. to be president for the year 2000. IRAS has been active in integrating scientific and religious knowledge since its establishment in 1954. In his new role, Corbally follows in the footsteps of Harlow Shapley, renowned professor of astronomy at Harvard University, who was one of the founders of IRAS and its first president.

In September Guy J. Consolmagno, S.J. was elected for a three-year term to the Committee of the [Division of Planetary Sciences](#) of the American Astronomical Society.

At Santiago de Compostela, Spain, Emmanuel M. Carreira, S.J., Adjunct Scholar, received an honorary medal given by the State Government of Galicia for his contribution to making the culture of Galicia known throughout the world.

#### *In Memoriam*

We were deeply saddened at the death on 3 September in New York of Maureen McCarthy. She and her husband, Eugene, have been fond friends of the Jesuits of the Vatican Observatory for many years. The McCarthy Family Foundation has made generous contributions to our work.

#### *Vatican Observatory Foundation Annual Meeting*

The annual meeting of the members and directors of the Vatican Observatory Foundation was held on 26 February 1999 in Tucson, Arizona. The following were elected to serve as members and directors for a three-year period: RICHARD P. BOYLE, S.J., EMMANUEL M. CARREIRA, S.J., CHARLES L. CURRIE, S.J., KAREN DALBY, SHEILA GRINELL, and BRENDAN D. THOMSON. During the two days preceding the annual meeting a seminar was conducted by members of the Observatory staff to present their research in a popular forum to friends of the Observatory and to members of the Board.

In 1999 the Vatican Observatory Foundation reached its goal of raising \$2 million dollars for its development campaign to support further technological advances at the Vatican Advanced Technology Telescope. By achieving its goal the Foundation was awarded a Science Initiative Grant of \$500,000 by The Kresge Foundation. This was a challenge grant and required the Foundation to raise the money by 1 December. The goal was reached in November. In addition to the many individuals who made generous donations to this campaign, we wish to thank the following corporations and foundations: Arline and Thomas J. Bannan Foundation, Los Angeles; Avery Foundation, Philadelphia; Cable Design Technologies, Inc., Pittsburgh; Community Counseling Service, Co., Inc., New York; Copernicus Society of America, Fort Washington, Pennsylvania; Crown Cork and Seal Company, Philadelphia; Homeland Foundation, New York; The Kresge Foundation, Troy, Michigan; Philip Morris Companies, New York; Dan Murphy Foundation, Los Angeles; F. J. O'Neil Charitable Corporation, Cleveland; and Warner Lambert Co., Morris Plains, New Jersey.

In May the Vatican Observatory Foundation hired NANCY KNOCHE of Phoenix, Arizona, as its Director of Development.

From 26 June to 3 July a group of friends of the visited the Vatican Observatory at Castel Gandolfo, the Vatican, and Rome. The trip was organized by KAREN DALBY and conducted by GEORGE COYNE. The group also shared in some of the activities of the Vatican Observatory Summer School.

***George V. Coyne, S.J., Director***





## Astronomical Research

Cover

### Theoretical Studies, Astrophysics, and Cosmology

In cosmology STOEGER and ARAÚJO (Universidade Federal do Rio de Janeiro and Universidade de Brasília) are continuing their work to correct and complete the integration of the generally perturbed field equations in observational coordinates. This provides the necessary foundation for finishing their analysis of cosmic microwave background anisotropies in those coordinates as well as enabling a precise characterization of the equivalence classes of cosmological models determined by the data.

STOEGER, HELMI (Sterrewacht Leiden, University of Leiden, The Netherlands), and TORRES (Universidad de La Plata, Argentina) have completed their linearized treatment of averaging in cosmology and are beginning to study how their procedure applies in situations involving stronger distortions of the Friedmann–Lemaître–Robertson–Walker background.

STOEGER has begun to review the general structure of the cosmological initial–value problem in cosmology with a view to seeing how the requirements for data specification may vary in different theories of gravity.

LISKA (Swedish Institute of Space Science, Sjörs), PACHOLCZYK (Steward Observatory, University of Arizona), and STOEGER have completed the first phase of their work on analyzing and modeling the X–ray variability of Seyfert galaxies and other active galactic nuclei (AGN). They are now beginning to study how to extract reliable energy spectrum information about the X–ray variable flux, and how to use that to constrain models of the underlying phenomena more stringently. STOEGER and PACHOLCZYK are beginning to explore other ways in which their ballistic black hole scenario may manifest itself, for instance, the possibility of its association with gamma–ray bursts.

STOEGER and JUST (Department of Physics, University of Arizona), along with JUST's graduate students, continue to pursue their research in fundamental quantum field theory. They are focusing on elaborating and solidifying the foundations of JUST's quantum induction program. STOEGER and JUST have also been concentrating on the gravitational physics aspects of the program, including issues

relating to the spin components of the gravitational field, the Einstein–Dirac energy tensor, the avoidance of ghosts, unitarity, and locality.

WHITMAN is studying the holonomy problem in modern differential geometry. This is essentially an investigation of possible irreducible geometries, one of which is the geometry that models the space–time of astronomy. In this way one can achieve a remarkable unification of the concept of possible geometric spaces, and this has ramifications throughout many models of our physical world. At the 37th Summer Meeting of the Clavius Group of Mathematicians, WHITMAN presented the primary background papers addressing the holonomy problem. In a series of six lectures presented he spoke of Marcel Berger's papers on the holonomy problem and noncompact symmetric spaces.

Using the software package *Mathematica*, WHITMAN finished the TeXing of his notes on a visual approach to the first–year calculus and has submitted them to two publishers for possible acceptance for publication.

HELLER, with SASIN (University of Warsaw), continues to explore noncommutative geometries with special application to our knowledge of classical singularities and to the unification of

quantum theory and general relativity. Interesting results have been obtained with respect to the emergence of time from classical singularities.

### **Extragalactic Research**

FUNES continues the study of the kinematics of stars and gas in the central region of disk galaxies. This work has been done as part of his doctoral dissertation with BERTOLA (University of Padua), his supervisor, and in collaboration with CORSINI (University of Padua), CAPPELLARI (University of Padua), PIZZELLA (University of Padua), VEGA BELTRAN (Instituto de Astrofísica de Canarias), and SARZI (University of Padua).

The researchers have studied the gas kinematics in the nuclear regions of a sample of 23 disk galaxies by obtaining high spatial resolution, long-slit spectra along their major axes in the H-alpha and O[III] 5007 spectral regions. The emission line spectra for 23 disk galaxies were obtained at the 3.6 m European Southern Observatory Telescope (La Silla, Chile), at the 2.5 m Isaac Newton Telescope (La Palma, Spain), and at the 4.5 m Multiple Mirror Telescope (Mt. Hopkins, Arizona, USA). In the circumnuclear regions, the gas kinematics has revealed a complex phenomenology. By comparing the gas velocity gradient and the velocity dispersion in the nuclear and outer regions, the researchers identified different types of bidimensional line shape in the position-velocity diagram. This kind of analysis allows one to identify galaxies that are characterized in their nucleus by the presence of a gaseous disk in Keplerian rotation. These objects are good candidates to harbor central massive black holes. For many of the galaxies in this sample, VBRI and H-alpha images were obtained at the Vatican Advanced Technology Telescope (VATT) on Mt. Graham in Arizona. In addition, a detailed study of the stellar and gaseous kinematics of Sa galaxies has shown an interesting phenomenon of bulge-disk orthogonal geometric and kinematical decoupling. This peculiarity suggests that the disk could be formed by accretion of material around the spheroidal component that we observe today. For the spheroidal components in S0 and Sa galaxies, R and I images were obtained also at the VATT for studying the intrinsic shape of bulges. The data have been reduced in Padua.

FUNES, in collaboration with RAFANELLI (University of Padua) and RICHTER (Astrophysikalisches Institut Potsdam), has started to investigate the relationship between gravitational interaction and galactic activity. The aim of this project is to identify signatures of interaction and/or merging in apparently isolated and morphologically undisturbed active galaxies. With this goal in mind, B, R, and H-alpha deep images of a spectroscopically selected sample of AGN were obtained at the VATT. The images were analyzed using an adaptive filtering technique designed to emphasize faint structures and knots and to reveal disturbed morphologies that can be interpreted as the effect of gravitational interaction. In addition, spectroscopic observations were carried out at the 1.52 m ESO telescope equipped with a slit spectrograph and at the Russian 6 m Special Astrophysical Observatory equipped with a Multi-Pupil-Fiber-Spectrograph. These observations show in some objects the presence of kinematical decoupling of gas and stars, a phenomenon interpreted as a signature of past interaction.

MOSS (Visiting Astronomer), working with WHITTLE (University of Virginia), has completed an objective-prism survey of H-alpha emission of an essentially complete magnitude-limited sample of galaxies of types Sa; he later conducted the same survey within 1.5 Abell radii of the centers of 8 low-redshift clusters (Abell 262, 347, 400, 426, 569, 779, 1367, and 1656). Some 320 galaxies were surveyed, of which 116 were detected in emission (39% of spirals; 75% of galaxies classified as peculiar). The emission survey distinguishes between "compact" and "diffuse" emissions, which are interpreted as circumnuclear starburst and normal disk emission, respectively. The circumnuclear emission is associated with a galactic bar or with a disturbed galaxy morphology, indicative of ongoing tidal interactions in the clusters (whether galaxy-galaxy, galaxy-group, or galaxy-cluster interactions).

It has been found that the frequency of tidally-induced starburst emission in spirals increases from regions of lower to higher galaxy surface density, and from clusters of lower to higher central galaxy space density. A similar trend is shown in the percentages of galaxies noted as disturbed

and in the percentages of those classified as peculiar. Indeed, the fraction of spirals that are undergoing tidal distortion and/or tidally induced star formation in the richest cluster surveyed (Coma) appears comparable to the (large) fraction of spirals showing these effects in intermediate-redshift clusters. A very high fraction (70%) of galaxies classified as peculiar are found to have compact emission, typical of circumnuclear starburst emission. Although they are unlike spirals with such emission, these galaxies show no tendency to have tidal companions. It is considered that the galaxies classified as peculiar are likely to be ongoing mergers and represent a later stage of close double, interacting systems, many examples of which are found in the clusters with tidally induced star formation.

The H-alpha survey work has generated interest and is considered important because of the insight it may give into the evolution of cluster disk galaxies. Recent observations with the Hubble Space Telescope have shown the remarkable changes in cluster galaxy populations between intermediate redshifts ( $z \sim 0.5$ ) and the present. At intermediate redshifts, a large fraction (up to 50%) of the cluster population are spirals, but these have been depleted by a factor of 2 by the present epoch and replaced with an S0 population. The discovery of enhanced tidally induced starburst emission in cluster spirals at low redshift suggests that tidal interactions may be the principal cause of this relatively recent morphological transformation of the cluster disk galaxy population. This picture accords well with the most recent theoretical modeling of clusters with a nonstatic potential undergoing collapse and infall, which predicts a high prevalence of galaxy tidal encounters.

MOSS and WHITTLE have also found that, for regions of comparable local galaxy surface density, the frequency of tidally induced starburst emission in spirals is greater in clusters of higher central galaxy space density. This implies that, for a given local density, morphological transformation of disk galaxies proceeds more rapidly in clusters of higher central galaxy density. This effect is considered to be due to subcluster merging and may provide an explanation for the anomalous lack of the correlation of galaxy type with surface density for irregular clusters at intermediate redshift.

MOSS, with ARAGON-SALAMANCA (University of Nottingham, UK) and BENNETT (Institute of Astronomy, Cambridge, UK), undertook U and B imaging of emission-line galaxies in several clusters, concentrating on Abell 1367 and Abell 1656, using the VATT2 CCD on the VATT. This observational program is designed to complement optical CCD H-alpha and continuum imaging that was previously obtained for these galaxies. The photometric and morphological information will be used together with detailed population synthesis models to help constrain timescales of star formation in the emission-line galaxies.

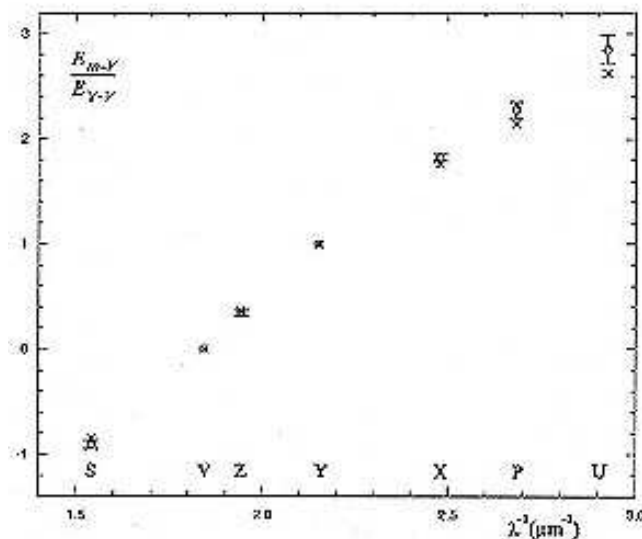
MOSS, KENNICUTT (Steward Observatory, University of Arizona), SAKAI (National Optical Astronomy Observatories, Tucson, Arizona), and WHITTLE (University of Virginia) have begun a deep survey of star formation in nearby galaxy clusters using the CCD Mosaic Imager on the 0.9 m telescope at Kitt Peak. The intent of the survey is to use the unique wide-field capability of the Mosaic Imager ( $8192 \times 8192$  pixels, giving a field  $\sim 1$  degree square on the 0.9 m telescope) to derive a complete inventory of H-alpha derived star formation rates for galaxies in the clusters. To date, some ten fields in four clusters have been surveyed. The data will be used, together with the results of the objective prism H-alpha survey of clusters by MOSS and WHITTLE, to directly test and calibrate the incompleteness of prism-based luminosity functions. The aim of this work is to better understand incompleteness effects in determinations of the local star formation rate density. The Mosaic CCD data will also be used to further extend studies of environmental influences on star formation and the evolution of disk galaxies.

OMIZZOLO, with the assistance of CORBALLY, continues a series of observations with the 2.3 m telescope of Steward Observatory on Kitt Peak for low-resolution spectra of X-ray sources in order to identify quasars and obtain their redshift. These observations are part of a program to determine the luminosity function of low-redshift quasars and to study the influence of quasar environment on quasar evolution. For the latter purpose, imaging of the same objects has also been done at the VATT. The first of a series of articles detailing the results obtained thus far has been submitted for publication. This research is being conducted with CRISTIANI (University of Padua). Plans are also underway for a series of observations with the Telescopio Nazionale Galileo (Canary Islands).

## The Galaxy and Galactic Objects

As part of a continuing search for peculiar A-type stars, including lambda Boötis stars, in open clusters of all ages, CORBALLY and GRAY (Appalachian State University, Boone, North Carolina) have obtained classification spectra of nearly 70 late B, A, and early F-type stars in 11 young and intermediate-age open clusters, including NGC 1039, 6633, 7039, 7063, 7092, 7209, 7243, IC 1396, IC 4665, IC 4756, and Stock 2. The spectra were obtained with a resolution of 3.6 Å on the Dark Sky Observatory 0.8 m telescope of Appalachian State University and were classified on the MK System. Numerous classical Ap and Am stars were found among the 70 stars examined, along with a few emission-line stars.

CORBALLY, STRAIZYS, and LAUGALYS (ITPA, Vilnius, Lithuania) have derived the interstellar reddening law for 15 heavily reddened stars in the area that includes the North America and Pelican Nebulae and the dark cloud between them. Their method is based on photometry of these stars in the Vilnius seven-color system and on CORBALLY's MK spectral types. The mean reddening law in this area is very similar to the law for a much wider area in Cygnus derived earlier by other authors. It differs from the normal law by exhibiting somewhat stronger extinction in the violet and the near-ultraviolet spectral region, i.e., it shows a smaller "knee" in the blue part of the spectrum. CORBALLY has continued to obtain spectra with the Steward Observatory's 2.3 m telescope for heavily reddened stars in the Camelopardalis and Nova V1500 Cygni regions and for a list of photometrically peculiar stars, all selected by STRAIZYS.



*Interstellar reddening law in the North America and Pelican nebulae area. The x's are for normal extinction law. Circles with error bars are for North America and Pelican area and show less "knee" in the blue part of the spectrum.*

Good photometric skies at the VATT in the spring enabled CORBALLY and GARRISON (David Dunlap Observatory, University of Toronto) to continue UBVRI observations of two calibration fields in the North Galactic Pole, where they are looking for G-dwarf star candidates. RUEGER (Diocese of Brooklyn) has been assisting in the processing of these observations.

ABT (National Optical Astronomical Observatories, Tucson, Arizona) and CORBALLY have finished their full report on the 285 candidate Trapezium systems that they have observed photometrically and spectroscopically in past years. They conclude that the maximum age of Trapezium systems, those groups of stars with relatively wide separations, is about 50 million years. They also find that Trapezium systems are large, with a median radius of 0.2 parsec and a maximum radius of 2.6 parsecs.

COYNE is working with THOMPSON (Steward Observatory, University of Arizona), Principal Investigator on the NICMOS instrument on the Hubble Space Telescope, in the analysis of polarimetric NICMOS data on bipolar nebulae and on disks around young stars. From the first set of data they expect to be able to establish the geometry of these nebulae; from the second set of data, they hope to obtain some indirect evidence of planet formation from the distribution of the

scattering material in the disks.

BOYLE and PHILIP (Union College and Institute for Space Observations, Schenectady, New York) continued their work on the VATT, making CCD observations in the Stromvil photometric system of open clusters and globular clusters. They attended a workshop on the Stromvil system held in Vilnius, Lithuania, in October.

JANUSZ (summer visitor from Krakow, Poland) was instructed by BOYLE on how to use IRAF software programs to process CCD observations from VATT. He is continuing to process the data in Krakow.

DASGUPTA and SMRIGLIO (University of Rome) continued their collaboration with BOYLE and STRAIZYS and KAZLAUSKAS (Vilnius Observatory, Lithuania) concerning CCD observations from VATT as well as from the 1.52 m telescope of the Astronomical Observatory of Bologna, Italy. They are paying particular attention to improving the photometric calibration of the CCD observations in order to extract stellar magnitudes as accurately as possible. Such photometry results in the classification of the stars.

## **Planetary Sciences**

### *Edgeworth–Kuiper Belt Object Analogs*

During the past two years, RETTIG (University of Notre Dame), TEGLER (Northern Arizona University), ROMANISHIN (University of Oklahoma), and CONSOLMAGNO have begun a program at the VATT to increase understanding of the Edgeworth–Kuiper Belt. This ring of small, frozen, distant objects orbiting beyond Neptune was predicted to exist more than forty years ago by Kuiper and Edgeworth, who believed it to be the source of short–period comets. But such objects were only first observed in 1995. Observations at the VATT, in collaboration with the University of Notre Dame, continued in 1999.

In 1998 TEGLER and ROMANISHIN reported that broadband colors of these faint objects are distributed into two groups: one set of objects appear to be neutrally colored, while another set are remarkably reddish, thought to indicate a surface rich in organic compounds. The ongoing VATT observations are designed to compare these colors with the colors of coma–free comets far from the Sun as well as with the colors of small irregular satellites of the outer planets. These satellites may have originally come from the Edgeworth–Kuiper Belt. Objects observed in 1999 included two newly discovered faint satellites of Uranus, Sycorax and Caliban; the coma–free comet P/Neujmin 1; the irregular moon Nereid orbiting Neptune; the irregular moon Phoebe orbiting Saturn; and all but one of the eight outer irregular moons of Jupiter.

Observing how the brightness of these objects varies with time yields information on both the spin rate (presumed to be the period of the fluctuation in brightness) and how asymmetric their shapes or colors are (as indicated by how much the brightness changes and if that brightness change is uniform over all colors.) Finally, the absolute measurement of the brightness itself can be translated (with appropriate assumptions about the object's intrinsic brightness, or albedo) into an estimate of the size of these objects.

A preliminary analysis of the data is already beginning to yield valuable results, which were reported at the annual American Astronomical Society's Division for Planetary Sciences meeting in October. Values for the irregular Uranian satellites Caliban (U1) and Sycorax (U2) are shown in the table below. There is excellent agreement between the colors from the 4 m telescope on Kitt Peak and the 1.8 m VATT for Sycorax; the V band photometry is in excellent agreement as well. Considering that the Kitt Peak telescope has 5 times the raw light–gathering power of the VATT, the fact that the two instruments give comparable results confirms both the superb location of the VATT and the remarkable quality of its optics.

### **Irregular Moons of Uranus**



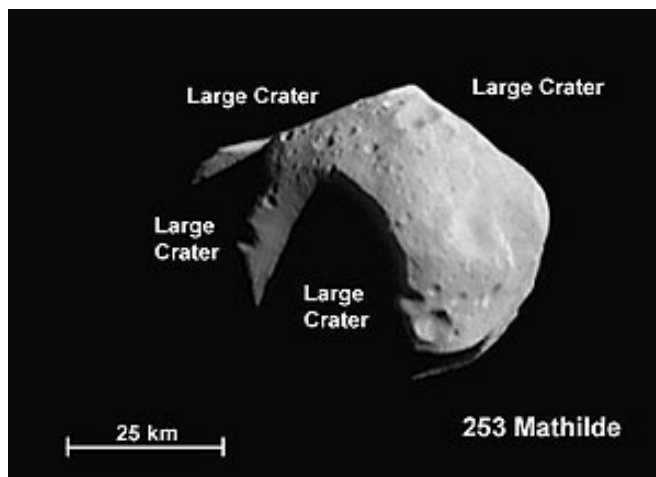
Object	UT Date	Telescope	B-V	V-R	V
Caliban	1998 Jun 19	KPNO 4-m	0.69	0.52	22.32
Sycorax	1998 June 18	KPNO 4-m	0.85	0.47	20.83
	1999 May 16	VATT	0.867	0.39	21.011
	1999 May 18	VATT	0.949	0.449	21.063
	1999 May 19	VATT	0.866	0.36	20.979

Taking an average of the colors for Sycorax yielded a B-V value of  $0.88 \pm 0.02$  and a V-R value of  $0.42 \pm 0.03$ . Interestingly, the B-V value compares well with the known B-V value of 0.867 for Pluto, and the combination of the two color indices is similar to the colors of the neutral class of Edgeworth-Kuiper Belt objects previously reported by TEGLER and ROMANISHIN. Based on the visual magnitudes and the known distance to the objects, and assuming an albedo of 0.04, a diameter of approximately 100 km was calculated for Caliban and approximately 190 km for Sycorax. Reduction of the other data continues.

### *Asteroid Structure*

Theoretical work on the rubble-pile nature of asteroids by CONSOLMAGNO and BRITT (University of Tennessee) was inspired by the meteorite density results obtained by these researchers and reported in previous annual reports.

A number of lines of evidence suggest that asteroids larger than a few hundred meters in diameter are not solid rocks but rather piles of rubble. Although recent radar observations of small, rapidly-spinning, near-Earth asteroids indicate that objects up to 100 m in diameter may be solid objects, none of the more than 500 larger objects observed so far have ever been observed to have spin rates so fast that they could not be held together by self-gravity alone. Images of asteroid Mathilde indicate that it has suffered extreme cratering events without having been destroyed, again an indication that it is not a rigid body but rather composed of fragments smaller than the resolution limit of the Mathilde imagery.



*Larger craters are visible on Mathilde, attesting to multiple large impacts that did not shatter the asteroid. This implies that it is not solid rock but a loose pile of rubble. Image taken by the NEAR spacecraft.*

Using asteroid and meteorite densities (including new data for asteroids Eros and Eugenia first reported in 1999), BRITT and CONSOLMAGNO have calculated that a typical asteroid may be as much as 40% empty space. This raises the questions: At what size scale do these spaces occur? And is there evidence in the imagery of asteroids (or the small Martian moons Phobos and Deimos, which are thought to be captured asteroids) consistent with this degree of macroporosity?

A careful analysis of Phobos and Deimos imagery indicates that boulders of several tens of meters can be seen on their surface, but otherwise the surface appears to be covered with material that is smaller than the several-meter resolution of even the best images—anything from boulders down to a fine powder. Hundred-meter pieces are not visible on the surface of these

asteroidal bodies. Indeed, a number of theoretical considerations suggest that the solid–rock components of asteroids may be at least partially sorted by size, with the larger pieces preferentially found in the center of the asteroids and smaller fragments more prevalent in the outer regions.

This rubble–pile model for asteroids has significance for understanding the current state of asteroidal bodies, including their response to continued impacts, and it also raises interesting questions about the origin of the asteroids themselves. Larger asteroids today are rubble piles, but were they ever solid rocks? Or is this porous structure characteristic of protoplanetary bodies even during the time of the accretion of the planets? Asteroid modeling to examine these questions continues.

### *Meteorite Formation*

The question of asteroid structure is related to a similar question concerning the meteorites that come from these asteroids: what processes lithified the meteorites?

Examination by CONSOLMAGNO, BLAND (British Museum of Natural History), and STRAIT (Alma College, Alma, Michigan) of the porosity of meteorite thin sections using a scanning electron microscope has shown that for many ordinary chondrites, the 10% porosity inferred for hand samples can be accounted for entirely by visible microcracks, a few microns wide but hundreds of microns in length, that run across grain boundaries. Such cracks must have been imposed after the formation of those boundaries and, hence, after the lithification of the rock itself. They are most probably due to impacts on the parent asteroid body. But this implies that the lithification process, in fact, completely closed the pore spaces between individual fragments of the meteorite. For terrestrial sandstones (the type of Earth rock whose physical structure best parallels the cumulate nature of meteorites), pressures of several hundred kilopascals are needed to effectively close out pore space. Such pressures are not found in any but the largest of the asteroids. Likewise, terrestrial sandstones are also lithified by the action of heat and water, which presumably are not present in the asteroids. Thus the mystery of what lithified the meteorites remains.

Brecciated meteorites, that is, meteorites that have been broken apart and relithified, presumably by impacts in the asteroid belt, may hold a key to the answer. A class of basaltic brecciated meteorites, known as Howardites, are now being studied by MOLIN (University of Padua) in consultation with CONSOLMAGNO. They are using samples from the Vatican meteorite collection to determine the peak temperatures experienced by pyroxenes in these meteorites at the boundaries between breccia fragments as a function of distance from the boundary. This should put limits both on the energy experienced during the lithification process and on the length of time over which that energy was deposited.

### **History and Philosophy of Science; Interdisciplinary Studies**

CORBALLY has studied the relationship between the "many worlds" concepts of Thomas Digges and of Giordano Bruno that came from each of their acquaintance with the Copernican system. The approach by Digges was mainly mathematical and experimental; that of Bruno was primarily philosophical. Yet, CORBALLY finds that the two approaches were complementary in providing the perspective of an infinite universe, a perspective that shaped the founding of modern astronomy.

COYNE and OMIZZOLO completed their book entitled *Wanderers in the Universe: Astronomy and the Meaning of Life*. OMIZZOLO gave a seminar in May on the themes of the book to the Department of Astronomy at the University of Padua, Italy.



## Instrumentation and Technical Services

Cover

### Instrumentation, Technical Services, and Meteorite Curation

CORBALLY continued to maintain the World Wide Web site of the Vatican Observatory (<http://clavius.as.arizona.edu/vo/>). For the first time, he posted the Annual Report (1998) on the site. He also changed the hit counter from a commercial one to a local SSI (server-side includes) counter, which shows that the average of 150 visits per day was sustained throughout the year as well as last year.

CROMWELL continued as project scientist for the Vatican Advanced Technology Telescope (VATT) and its instrumentation. In that capacity he provided scientific, technical, and managerial guidance in the activities reported below. NELSON, as on-site assistant staff scientist, and McKENNA, who was hired as senior engineer in December 1998, took the lead in many of the developments. The following personnel from the Steward Observatory Technical Division, directed by DERIGNE, made considerable contributions: WILSON, SCHALLER, BRAR, CORDOVA, DAVISON, LANUM, and HARVEY. The collaboration of Vatican Observatory scientists BOYLE and CORBALLY and of SWIFT and others of the Mt. Graham International Observatory staff, directed by RATJE, was indispensable. In December 1998 the Vatican Observatory Foundation was awarded a Science Initiative Grant by The Kresge Foundation (described in "From the Director") to improve the performance of the VATT. This award contributed significantly to the ongoing technical improvements being made to the telescope.

The VATT was regularly scheduled during the past year for astronomical observations. Long-exposure direct imaging was considerably improved as a result of the advances described below. Image quality was typically better than 1.5 arcsec fwhm, and under the best conditions it was on average 0.7 arcsec. Better performance and efficiency is expected when the following tasks are completed: dome thermal environment control, rebuilding the secondary mirror mechanical support hub, and refinement of auto focus and auto collimation systems.



*Michael Ned Franz of Steward Observatory adjusts the guider camera on the VATT, part of ongoing work to upgrade the telescope sponsored in part by The Kresge Foundation grant.*

Telescope positioning and setup at the beginning of the night have been simplified by the repair of an absolute encoder for the elevation axis and by the addition of calibration indexes to the azimuth and derotator axes. Guiding during long exposures was greatly improved with the addition of guide-star catalogs and auto guide-star finding software. New interface software has improved secondary mirror control: tip, tilt, and decenter and focus, which are all referenced to optical center zeros. Auto focus and auto collimation as a function of temperature and elevation have been implemented through empirical auto secondary-control algorithms. The secondary mirror control electronics were completely rebuilt; they now provide good stability, good noise

immunity, electronic fail-safe limit checking, and the elimination of earlier heat sources from motors in the secondary mirror volume. The offset guider positioning and mirror drives were sped up by a critical factor of 5-10 to increase the efficiency in moving from one guide star to another. WEST, using his wave front sensor, determined that the previous alignment of the optics had been set up on a local null, giving the wrong impression from earlier optical tests that the alignment was correct. When the optics were correctly aligned, the unsymmetrical off-axis astigmatism, previously experienced, vanished. Evidence now exists that a faulty mechanical secondary-mirror support is giving rise to some residual field-independent astigmatism. This will be eliminated with a new mechanical support hub.



## Observatory and Staff Activities

### Conferences

The Vatican Observatory was a cosponsor of the 31st annual meeting of the American Astronomical Society, Division for Planetary Sciences, 11–15 October in Padua, Italy. CONSOLMAGNO served as Chair of the Scientific Organizing Committee.

The second meeting on the Inspiration of Astronomical Phenomena was held 7–12 January in Malta under the sponsorship of the Observatory.

The Observatory, together with the Center for Theology and the Natural Sciences of Berkeley, California, continues to sponsor the series of conferences, "Scientific Perspectives on Divine Action." A pre-conference on "Quantum Mechanics and Quantum Field Theory" was held 24–27 September at Wye College, University of London, Wye, Kent, UK, in preparation for the meeting to be held at Castel Gandolfo in June 2000. STOEGER, HELLER, and COYNE participated in the pre-conference.

MOSS chaired the Sixth European Jesuit scientist meeting, which took place 8–12 September at Sankt Georgen Jesuit College in Frankfurt. There were approximately 40 participants—Jesuit priests and brothers who are scientists—from approximately a dozen countries. The participants included the Jesuit European Provincial Superior; both the Secretary for Education and the Secretary for the Social Apostolate for the Jesuit Order worldwide; the Coordinator for Jesuit scientists in India; and a delegate substituting for the Coordinator for Jesuit scientists in North America, who was unable to attend due to illness. The theme of the meeting was "Science and Culture." In addition, a special session was held to discuss the contribution that Jesuit scientists could make in the field of ecology, particularly in collaboration with the social apostolate. A planning process was begun for a joint European–Asian meeting of Jesuit scientists to be held in Madras, India, in January 2001, to be followed by the seventh European Jesuit Scientist meeting in Malaga, Spain, in September 2002.

The 37th Summer Meeting of the Clavius Group of Mathematicians was organized by WHITMAN and held at Holy Cross College, Worcester, Massachusetts, 6–30 July.

### Presentations and Academic Activities

**CASANOVAS** Participated at the meeting of the Spanish Jesuits in Science in Madrid, 5–8 May. Gave a seminar on the history of astronomy at Valencia, Spain, on 18 May. Lectured on early spectroscopy to the Agrupació Astronòmica de Sabadell, Spain. Gave a seminar on science and faith at Barbastro, Spain, on 22 July. Gave a paper on "The Contribution of the Vatican Observatory to the International Project, Carte du Ciel" at the Italian National Congress on the History of Astronomy at Cagliari, Italy, on 24–25 September.

**CONSOLMAGNO** Gave a seminar, "Meteorite Density and Asteroid Structure," to the Physics Department, University of Manitoba, Canada, on 22 January. On 23 February, gave a seminar, "Are Asteroids Fluffy?," to the Department of Geology and Space Sciences, UCLA, and consulted with RUBIN (UCLA). Presented a seminar, "Meteorite Densities and Asteroid Structure," to the Geology Department of Rutgers University, New Jersey, on 8 April; to the Physics Department of Lafayette College, Easton, Pennsylvania, on 9 April; and to the Geology Department of the College of Charleston, Charleston, South Carolina, on 14 April. On 21 June made a working visit to the British Museum of Natural History (BMNH) in London to meet with RUSSELL (BMNH) and

GRADY (BMNH) and to work on the BMNH microprobe. Presented the seminar, "Science as a Human Activity," at the Pontifical Gregorian University, Rome, Italy, on 19 October. Visited the Physics Department, University of Wyoming, Laramie, for a working visit with HOWELL (University of Wyoming). Consulted with STRAIT (Chemistry Department, Alma College, Alma, Michigan) on 22 November.



*Christopher Corbally (l.) chats with Dr. Leslie Kawamura (Univ. of Calgary) during the IRAS meeting on Star Island, New Hampshire. Corbally is the new IRAS president.*

**CORBALLY** Continued to serve on the Council of the Institute on Religion in an Age of Science (IRAS) and was appointed President for the 1999–2000 year. He attended council meetings in January in Boston, Massachusetts, and in July in Portsmouth, New Hampshire. Served on the Southern Arizona Light Pollution Advisory Council and attended meetings in the spring during which a revision to the outdoor lighting code for the Tucson area was prepared. Gave an invited talk 31 May on plurality of worlds at a session of the Historical Astronomy Division during the centennial meeting of the American Astronomical Society in Chicago. Served on the Stellar Parameters Panel of the National Science Foundation's Division of Astronomical Sciences and on 2–3 December, attended the meeting to review proposals.

**COYNE** Participated in the Council meeting of the International Center for Relativistic Astrophysics (ICRA) that was held at Stanford University, Palo Alto, California, on 20 February. He also participated on 24 November at the press conference for the opening of the new offices of the ICRA Network at Pescara, Italy. Gave the introductory lecture at the Vatican Observatory Foundation Seminar in Astrophysics on 25 February. On 18–19 March participated in a meeting entitled "The Future of Science Has Begun," sponsored by the Fondazione Carlo Erba in Milan, Italy, and gave a paper on "The Evolving Concept of Space, Matter and Materialism." On 15 April gave a seminar on "Proto–Planetary Disks about Young Stars" to the Physics Department, The College of New Jersey, Ewing. On 16 April lectured on "Galileo: The Myth and Attempts by the Church to Dispel Them" to the Department of History and Philosophy of Science, University of Pittsburgh. Participated on 23–24 April in the Advisory Council Meeting of the Centre for Studies in Religion and Society, University of Victoria, Canada, and gave a lecture on "The History of the Concept of Materialism." At the Pontifical Academy of Sciences, 12–14 November, participated in the meeting on "Science for Man and Man for Science" and gave a paper on "Modern Research in Astronomy"; participated at the meeting of the Council on 14 November.

**FUNES** Gave a guest lecture at the Seventh Vatican Observatory Summer School in Observational Astronomy and Astrophysics on "Kinematic Properties of the Gas in the Central Region of Galaxies."

**MOSS** Gave a talk on "Tidally–Induced Star Formation in Spirals in Low–Redshift Rich Clusters" at the Institute of Astronomy, Cambridge, UK, on 14 April and also at the National Optical Astronomy Observatories, Tucson, Arizona, on 30 April.

**STOEGER** During the spring semester 1999 at the Department of Astronomy, University of Arizona, Tucson, gave the final segment of the graduate course in cosmology on inflation, particle physics, and very early universe physics. Participated in teaching the course "Science and Theology" with LINDELL and HEWLETT in the Department of Molecular and Cellular Biology, University of Arizona, in both the spring and fall semesters 1999. 28 January–21 February worked at the Department of Applied Mathematics, University of Cape Town, South Africa; attended the conference "Relativistic Cosmology: A Symposium in Honour of George Ellis" 1–5 February; and

presented a paper, "The Exact Spherically Symmetric Solution of the Field Equations in Observational Coordinates with Cosmological Data Functions." During the same visit gave a seminar on "The Averaging Problem in Cosmology," in the Department of Applied Mathematics. 9–12 June participated at the Catholic Theological Society of America annual convention in Miami, Florida, and chaired the Theology and Natural Sciences parallel session. Participated in the Four–Corners American Physical Society Sectional meeting at the University of Arizona, Tucson, 1–2 October, and with JUST (Department of Physics, University of Arizona) gave a paper on "Restricted Test Functions and the Polarization of Photon and Graviton States." Continued to serve on the Boards of the Center for Theology and the Natural Sciences, Berkeley, California, and of the St. Albert the Great Forum at the Catholic Newman Center, the University of Arizona. Continued as the principal and managing editor of the series *Philosophy in Science*, published by Pachart Press, Tucson, Arizona.

Templeton Lectures: on 25 January, "The Laws of Nature and Divine Action," at Point Loma University, San Diego, California, where he also led a faculty discussion group; on 10 March, presentation on science and theology at Wheeling Jesuit University, Wheeling, West Virginia, where he also taught two classes; on 20 May, "Evolution as a Christian Theme: Cosmology," at Seattle University, Seattle, Washington. Continued his active participation in the "Eschatology and Science" project initiated by the Center of Theological Inquiry (CTI), Princeton, New Jersey. This work took him to the University of Heidelberg, Germany, where he took part in a discussion meeting, 24–28 March. Served as a resource person for the CTI Pastoral Theologian Program in Tucson, Arizona, 17–20 October and 25 October.

**TERES** On 7 August gave a talk to students and professors of the College Scolarum Piarum, Kecskemét, Hungary, on "Solar Activity Cycles and Solar–Terrestrial Relations." Participated on 11 August with Hungarian and Norwegian astronomers in observations of the total solar eclipse.

### **Public and Educational Outreach**

**CARREIRA** Lectured in Munich in June at a seminar on science and theology. During August and September spoke at the University of Monterrey and in Guadalajara, Mexico, on the "Origin and End of the Universe and the Origin of Life." Spoke at five state universities and four private universities in Lima and Chiclayo, Peru, during September. Gave a series of lectures at a symposium on "Faith and Reason" in Medellín, Colombia, sponsored by the Universidad Bolivariana and the Archdiocese of Medellín. Gave two papers, "Theological Implications of Modern Science" and "The Origin of Life and Evolution," in Cali, Colombia, at a congress on "Faith and Science" sponsored by the Pontifical Council for Culture.

**CONSOLMAGNO** 21–25 January presented a series of five talks to schools in Winnipeg, Manitoba, Canada. The highlight was the Annual Alumni Dinner speech, "Astronomy, God, and the Search for Elegance," at University of Manitoba. Other talks included presentations to schoolchildren, to amateur astronomers, a lunch time businessman's seminar, and an interview on a local radio show. On 11, 17, and 18 February presented three evening adult education sessions, the two–part "Seeing the Light, I and II" and "Astronomy and the Vatican," at the Adler Planetarium, Chicago. Presented "News from the Asteroid Belt" and participated on several other panels at the annual Capricorn Science Fiction Convention, Chicago, 12–14 February. On 16 February presented "Astronomy, God and the Search for Elegance," the featured evening presentation of the Science and Society seminar, Dickinson College, Carlyle, Pennsylvania. On 8 April presented "Life in Europa: A Historical Perspective" to the Friends of the Geology Museum, Rutgers University, New Jersey. Presented "Astronomy, God and the Search for Elegance," on 11 April to the Palisades Presbyterian Church, Palisades, New York. Described "The Adventures of a Vatican Astronomer" on 13 April at the Bishop England High School, Charleston, South Carolina. 26–30 April presented five talks at the Houston Museum of Science, featuring "Life on Mars?," "Judging the Evidence," and the Excellence in Science Education Awards luncheon speech, plus talks to museum staffers, volunteers, and a public planetarium presentation. On 3 May presented the keynote address, "God the Father of Creation: Reflections of a Vatican Scientist," at the annual convention of the Council of Catholic Women of the Diocese of Venice, Florida. On 22 November presented "God, Astronomy and the Search for Elegance" as part of the Craig–Thorn

Lecture Series at Alma College, Alma, Michigan.

**CORBALLY** At Marana High School, Arizona, on 2 February gave a presentation on astronomy as a career. 25 February, spoke on "The Birth and Death of Stars" at the Vatican Observatory seminar in astrophysics. 17 March, joined a small panel at St. Michael's and All Angels Episcopal Church, Tucson, for their Maturing in Faith talks, and treated the topic of "Relating Faith and Science Practically." As one of the invited presenters on 26 March at the Tucson Metropolitan Chamber of Commerce's breakfast meeting, *Good Morning Tucson*, spoke on how "To View the Stars."

**COYNE** Gave a talk on "A Roller Coaster Ride in the Evolving Universe" at the Arizona Science Center, Phoenix, on 3 February. Lectured on "Is there a God of the Cosmologists" at the Public Evening of Steward Observatory, University of Arizona, on 8 February. Gave a talk on "Our Place as Humans in an Evolving Universe" on 4 March to the SAGE Extended University Program, University of Arizona. Gave talks on "The Origins of Life in an Expanding Universe" on 16 March in Pisa, Italy, and on 17 March in Erba (Milan), Italy. Gave a seminar on science and faith on 15 March to the study group of van Beeck of the Pontifical Gregorian University, Rome. Gave a paper on "The Birth and Death of Stars" to the Sun City Astronomy Club, Tucson, Arizona, on 25 March. On 15 April gave a public lecture at The College of New Jersey, Ewing, on "Is There a God of the Cosmologists?" On 25 May gave a lecture on "Science and Faith" as part of the program, Science Week, at Mondovì, Italy, and on 26 May spoke on the same topic at the celebration of Alessandro Volta in the Cathedral of Como, Italy. Together with HELLER on 3 June made a presentation about the Russian edition of *Galileo: For Copernicanism and for the Church* by A. Fantoli at the National Library for Foreign Literature in Moscow. Presented a paper on "The Way a Scientist Thinks and Works" on 18 July to the seminar organized by the Italian Episcopal Conference at Frascati (Rome), Italy. Participated at the meeting of European Jesuits in Science, 8–12 September, in Frankfurt, Germany, and gave a paper on "The Vatican Observatory: Science–Faith and the Third World." On 15 October participated in a roundtable discussion on Galileo at the Berkeley Repertory Theater, Berkeley, California, sponsored by the Mathematical Sciences Research Institute at Berkeley. Took part in the Second Annual Catholic Leadership Conference in Philadelphia, Pennsylvania, 21–22 October. Spoke on "Reflections from a Religious Tradition on the Evolution of Life in the Universe" at the Reuben H. Fleet Science Center, San Diego, California, 27 October. Gave a talk on "The Universe is Expanding and so are We" at the Arizona Science Center, Phoenix, 4 November. On 8 November gave a talk at the Adler Planetarium, Chicago, on "The Sacred Cows of Science and Religion Meet." On 24 November and 14 December spoke to the Golden Age University of Ariccia (Rome), Italy, on "The Search for Extra–Solar Planets" On 9 December at Misano Adriatico, Italy, participated at a roundtable on "Chance and Finality in the Universe." At the Theological Center Pattaro, Venice, Italy, spoke on "The Origin of Life in the Universe." On 11 December participated at the meeting on "Science and Human Values" organized by the European Science Foundation in Strasbourg, France.

**FUNES** On 16 January spoke to the Amateur Astronomers of Urbana, Italy, on "Galaxies and Black Holes: Travel to the Limits of the Cosmos." on 10 August at the Colegio del Salvador, Buenos Aires, Argentina, gave a paper on "Galaxies and Black Holes." On 17 August to the Facultad de Filosofia, Universidad del Salvador, San Miguel, Argentina, gave a talk on "The Contemporary Image of the Universe."

**STOEGER** 17–20 August participated in the Franciscan Federation Conference "The Universe: Discovering the Heart of God," in Columbus, Ohio, and delivered one of the two keynote addresses, "God's Struggle to Create Through the Evolutionary Process." An image of spiral galaxy NGC 2903 taken at the VATT by BOYLE was used as the conference logo. Presented a talk on "Cosmology" at the Vatican Observatory Foundation Seminar, 24–25 February. 15–16 March taught two honors classes at Northern Arizona University, Flagstaff, on "Evolution and Religion." On 6 October gave a presentation at the University of Arizona Newman Center's St. Albert the Great Forum on "Cosmology and Eschatology." Gave two presentations on 5 and 12 December at the Community Christian Church, Green Valley, Arizona, on "How to Prepare for the New Millennium."

**WHITMAN** Attended the MathFest Meeting of the Mathematical Association of America 31 July–2



August. On 12 July gave a commentary to the Clavius Group on STOEGER'S article on "God and Time." Also gave a presentation on 20 October at the Saint Albert the Great Forum of the Newman Center at the University of Arizona on "What Does Mathematics Tell Us about God." At the annual board meeting of the Vatican Observatory Foundation gave a presentation on "Measuring the Shape of the Universe." Continued preparing the annual financial report for the Centro Social Presidente Kennedy of Campinas, São Paulo, Brazil.

### **News Media Coverage**

**CONSOLMAGNO** was featured in articles in the following newspapers: *Winnipeg Free Press*, Manitoba, 26 January; *The Lance*, Winnipeg, Manitoba, 27 January. *Manitoba Prairie Messenger*, 3 February. *The New Catholic Miscellany*, Charleston, South Carolina, "Vatican Astronomer Shows His Faith in Science," 22 April. *Houston Chronicle*, Texas, "Astronomer Looks at the Stars, Sees God," religion section, 8 May.

**CORBALLY** provided interviews to the following journalists: Gloria Thiele, *Catholic Heritage*; Alan Stahler, KVMR Radio, Northern California; Thomas Stauffer, *The Arizona Daily Star*, Tucson; Ana Magdalena Horta, *O Globo*, Brazil; Robin Ciriano, *Florida Today*, Florida; Daniel Hessel Teich, *Veja* magazine, Brazil; Don Gaughan, KVOA-TV, Tucson. Hosted visits to the VATT for the video teams of Kevin Barry, a producer for the Arts and Entertainment Channel, and of Chuck Condor, CNN, for a program shown during the Pope's visit to St. Louis in January. Hosted other visits to the VATT, including one by Tucson artist and photographer, Steven Meckler. Hosted a visit to the Vatican Observatory Summer School by Edwin Aguirre, associate editor, and Imelda Joson, image archivist, for *Sky and Telescope*.

**COYNE** provided interviews to the following journalists: Mervyn Marshall, London Film Academy; Michael Gregor, Tellux Film, TV Germany; Beate Ziegs and Rolf Hosfeld, TFC Transfer Film, Germany; Alison Rose, PTV Productions, Inc., Toronto, Canada; Donatella Mele, Vatican Radio; Alenka Lawrence, BBC World Service, London.

**TERES** worked at Castel Gandolfo 17–21 September with journalists of the Oasis Studio, Ltd. of Hungary on the production of two television programs: one on the history of the Vatican Observatory and the other on the star of Bethlehem.

### **International Meetings**

During 1999 representatives of the Vatican Observatory took part in the following international meetings:

5–9 January: Austin, Texas. 193rd Meeting of the American Astronomical Society. CHRISTOPHER CORBALLY, S.J. and RICHARD BOYLE, S.J. gave papers.

15–19 March: Houston, Texas. 30th Lunar and Planetary Science Conference. GUY CONSOLMAGNO, S.J. presented two papers.

18–19 March: Venice, Italy. Academia Nazionale dei Lincei, Structure and Dynamics of Galaxies. JOSÉ FUNES, S.J. gave a paper.

24–25 April: Tucson, Arizona. Eleventh Annual Meeting of the International Dark–Sky Association. CHRISTOPHER CORBALLY, S.J. participated.

5–8 May: Naples, Italy. Meeting of the Italian Astronomical Society. JUAN CASANOVAS, S.J. participated.

18–19 May: Padua, Italy. First Workshop of the Italian Network, Formation and Evolution of Galaxies. JOSÉ FUNES, S.J. gave a paper.

28–29 May: Como, Italy. Society for the History of Science. JUAN CASANOVAS, S.J. participated.

30 May–3 June: Chicago, Illinois. 194th Meeting of the American Astronomical Society. CHRISTOPHER CORBALLY, S.J. gave an invited paper.

9–13 July: Paris, France. 15th Meeting of the Institut d'Astrophysique de Paris, Galaxy Dynamics: From the Early Universe to the Present. JOSÉ FUNES, S.J. gave a paper.

12–16 July: Johannesburg, South Africa. Annual Meeting of the Meteoritical Society. GUY CONSOLMAGNO, S.J. presented two papers.

31 July–7 August: Star Island, New Hampshire. Annual Conference of the Institute on Religion in an Age of Science. CHRISTOPHER CORBALLY, S.J. participated and attended the IRAS Council meetings.

10–12 August: Castel Gandolfo, Italy. Science, Religion and History (seminar with the Holy Father). MICHAEL HELLER gave a paper.

6 September: Zakopane, Poland. Congress of Thermodynamics. MICHAEL HELLER gave a paper.

8–12 September: Frankfurt, Germany. Biennial meeting of European Jesuits in Science. GUY CONSOLMAGNO, S.J. and GEORGE COYNE, S.J. presented papers.

9–11 September: Durham, UK. Science and Religion Forum. MICHAEL HELLER gave a paper.

27–30 September: Cagliari, Italy. Symposium on the Motion of the Earth's Pole. JUAN CASANOVAS, S.J. participated.

5–8 October: Vilnius, Lithuania. Workshop on the Stromvil Photometric System. RICHARD P. BOYLE, S.J. served on the scientific organizing committee and gave a paper.

11–15 October: Padua, Italy. 31st Annual Meeting, Division for Planetary Sciences, American Astronomical Society. GUY CONSOLMAGNO, S.J. served as chair of the scientific organizing committee and coauthored a paper.

24–28 October: Denver, Colorado. Annual meeting, Geological Society of America. GUY CONSOLMAGNO, S.J. presented a paper.

16–18 November: Krakow, Poland. International Workshop on Noncommutative Geometry. MICHAEL HELLER gave a paper.

19–21 November: Warsaw, Poland. Man, Science and Faith: Congress to Commemorate 2000 years of Christianity. MICHAEL HELLER gave a paper.

22–28 November: Krakow, Poland. International seminar on Tunneling Effects and Other Fundamental Problems of Quantum Physics. MICHAEL HELLER gave a paper.



## Publications

Cover

### Publications

(The names of Vatican Observatory staff and visiting astronomers are noted in boldface.)

ARAÚJO, M. E. and **STOEGER**, W. R. "The Exact Spherically Symmetric Dust Solution of the Field Equations in Observational Coordinates with Cosmological Data Functions," 1999, *Phys. Rev. D.*, 60, 104020–1–104020–7

ARAÚJO, M. E., ARCURI, R. C., BEDRAN, M. L., de FREITAS, L. R., and **STOEGER**, W. R. "Integrating Einstein's Field Equations in Observational Coordinates with Cosmological Data Functions: The Friedmann–Lemaître–Robertson–Walker  $k=1$  Case," 1999, submitted for publication

BERTOLA, F., CORSINI, E. M., VEGA BELTRAN, J. C., PIZZELLA, A., SARZI, M., CAPPELLARI, M., and **FUNES**, J. G. "The Bulge–Disk Orthogonal Decoupling in Galaxies: NGC 4698," 1999, *ApJ*, 519, L17

BERTOLA, F., CORSINI, E. M., CAPPELLARI, M., SARZI, M., PIZZELLA, A., VEGA BELTRAN, J. C., and **FUNES**, J. G. "The Bulge–Disk Orthogonal Decoupling in Galaxies: NGC 4698 and NGC 4672," 1999, in *When and How do Bulges Form and Evolve?*, Proceedings of the STScI Mini–Workshop, Baltimore, Maryland, October 5–7, 1998, ed. C. M. Carollo, H. C. Ferguson, R. F. G. Wyse (Cambridge: Cambridge University Press), in press

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**CONSOLMAGNO**, G. J. "Midnight Sun," 1999, *Company*, 17, Spring, 27–30

\_\_\_\_\_. "The Ultimate Easter Egg Hunt," 1999, *Meteorite*, 5, 8–11

**CONSOLMAGNO**, G. J. and BRITT, D. T. "Turning Meteorites into Rock: Constraints on Asteroid Physical Evolution," 1999, *Lunar Planet Science*, XXX

\_\_\_\_\_. "The Internal Structure of Rubble–Pile Asteroids. Program and Abstracts," 1999, Geological Society of America Annual Meeting

**CONSOLMAGNO**, G. J., BLAND, P. A., and STRAIT, M. M. "Weathering and Porosity: A Preliminary SEM Study of Weathered Meteorites," 1999, *Lunar Planet Science*, XXX

\_\_\_\_\_. "A Preliminary SEM Study of Microcrack Porosity in Meteorites," 1999, *Meteorit. Planet. Sci.*, 33, A28–A29

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## Observatory Visitors

### Observatory Visitors

The Vatican Observatory in Castel Gandolfo, Italy, and the Vatican Observatory Research Group in Tucson, Arizona, hosted a number of visitors during 1999.

On 14 May members of the Pontifical Academy of Sciences paid a visit to the Vatican Observatory. On 10 June COYNE received Mr. Jürgen Oesterhelt, Ambassador of the Republic of Germany to the Holy See, and the embassy staff for a visit to the Observatory and the Papal Villas. In July COYNE hosted a visit by PETER LIKINS, president of the University of Arizona, Tucson, with a group of university alumni. In November MAFFEO hosted a working visit of the staff of the Vatican Radio to the Observatory. The Observatory hosted the meeting of the Associazione Tuscolana di Astronomia, 26–28 November, at Castel Gandolfo.

The following members of the diplomatic corps to the Holy See visited the Seventh Vatican Observatory Summer School: Mr. Marco César Meira Naslausky, Brazil; Mr. Bae Yang–Li, Korea; Mr. Marijan Sunjic, Croatia; Mr. Hermes Herrera Hernández, Cuba; Mr. Jürgen Oesterhelt, Germany; Mr. Nikolaos Kalantzianos, Greece; Mrs. Corinne C. Boggs, USA.

*The following individuals paid extended working visits to the Observatory:*

A. G. DAVIS PHILIP, Union College and Institute for Space Observations, Schenectady, New York, USA

ROBERT GARRISON, David Dunlap Observatory, University of Toronto, Ontario, Canada

RICHARD GRAY, Appalachian State University, North Carolina, USA

JOHN B. HEARNshaw, University of Canterbury, Christchurch, New Zealand

ROBERT JANUSZ, S.J., Krakow, Poland

*The following made occasional working visits to the Observatory:*

GIANANDREA BIANCHINI, University of Padua, Italy

CLAUDIO CASACCI, Alenia Spazio, Turin, Italy

AJOY K. DASGUPTA, Institute of Astronomy, University of Rome "La Sapienza," Italy, and South Glamorgan Education Department, Cardiff, UK

PHILIPPE EENENS, University of Guanajuato, Guanajuato, Mexico

CRAIG FOLTZ, Multiple Mirror Telescope Observatory, Tucson, Arizona, USA

WILLIAM MERLINE, Southwest Research Institute, Arizona, USA

JOHN DAVID MOONEY, John David Mooney Studios, Chicago, Illinois, USA

REMO RUFFINI, Institute of Physics, University of Rome "La Sapienza," Italy

WESLEY SALMON, University of Pittsburgh, Pittsburgh, Pennsylvania, USA



MICHAEL SHERWIN, O.P., University of Notre Dame, South Bend, Indiana, USA

FILIPPO SMRIGLIO, Institute of Astronomy, University of Rome "La Sapienza," Italy

MARK SYKES, University of Arizona, Tucson, Arizona, USA

XIANG-PING WU, Beijing Astronomical Observatory, China

*The following gave invited lectures at the Seventh Vatican Observatory Summer School:*

EDWIN AGUIRRE and IMELDA JOSON, *Sky and Telescope*, Cambridge, Massachusetts, USA

CARL ALLEN, NASA Johnson Space Flight Center, Houston, Texas, USA

PETER L. BIERMANN, Max Planck Institute for Radioastronomy, Bonn, Germany

HENRY M. BLAIR, Chemical Detection Technology, Inc., Tucson, Arizona, USA

JOSÉ G. FUNES, S.J., University of Padua, Italy

DONALD RICHARDS, University of Virginia, Charlottesville, Virginia, USA

THOMAS WILSON, Submillimeter Telescope Observatory, University of Arizona, Tucson, Arizona, USA

Among other professional guests of the Observatory during the year were: GIOVANNI BIGNAMI, Agenzia Spaziale Italiana, Rome, Italy; PEDRO CARTAYA, Belen Observatory, Miami, Florida, USA; ROBERTO COLELLA, Purdue University, West Lafayette, Indiana, USA; STEFANO LAGOMARSINO, Ente Nazionale Energia Ambiente, Rome, Italy; MARIO SCANDIGLI, University of Milan, Italy.

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