SPECIAL ISSUE
2003
WINTER SCHOOL

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IAC noticias

XV CANARY ISLANDS WINTER SCHOOL OF ASTROPHYSICS

Puerto de la Cruz, Tenerife

17-28 / XI / 2003

"Payload and Mission Definition in Space Sciences"

Poster advertising the XV Canary Islands Winter School of Astrophysics.

The IAC has organized its *XV Canary Islands Winter School of Astrophysics*, from the 17th to the 28th of November, at the Conference Centre in Puerto de la Cruz (Tenerife), with the support of the Canary Islands Government, the Spanish Ministry for Science and Technology, the European Solar Magnetometry Network (ESMN) and the European Space Agency (ESA), and with the collaboration of the Island Government of Tenerife and Puerto de la Cruz Town Council. This year's Winter School lectures are to be given by ten experts in space missions. There are 75 participants from 19 countries that are currently preparing, or have recently completed their doctoral thesis in a subject related to the theme of this School. The school will include visits to the Instituto de Astrofísica de Canarias in La Laguna and to the Teide Observatory (Tenerife).

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"Spacecraft and ground segment"
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Text, Format and Editing: *Carmen del Puerto, Bibiana Bonmatí y Karin Ranero*
English Text: *Karin Ranero*
Mailing List and Distribution: *Ana M. Quevedo*
Original Design: *Gotzon Cañada*
Poster Design: *Ramón Castro (SMM/IAC)*
Electronic Edition: *Inés Bonet*
Drawings: *Gotzon Cañada*
Group Photographs: *Miguel Briganti (SMM/IAC)*
Image Processing: *Gotzon Cañada*
Depósito Legal: *TF-335/87*
ISBN: *0213/893X*

DIRECTOR'S WELCOME

Prof. FRANCISCO SÁNCHEZ
(Director of the IAC)

Our knowledge of the Universe is based on information that, coming from outside our planet, we are capable of obtaining and interpreting. For this reason, astronomical observation will continue to be the key in the 21st century. Even though the Earth's atmosphere is a limitation, it is starting to be surmountable by going outside of it. Earth and Space are, therefore, complementary; they involve astrophysicists more in «space.» The Instituto de Astrofísica de Canarias (IAC) is an example of it, and it is logical that some of our *Canary Islands Winter School of Astrophysics*- like this one, the fifteenth- would be dedicated to the planning of space missions and their payloads.

On January of this year, the Commission of European Communities published a green book about European space politics. In it, the need to maintain a high transfer of knowledge and information between the different generations of scientists and engineers was emphasized, since these are long-term projects. In spite of the increase in the productivity of the space industry, a growing ageing of the population of Space experts has been noticed.

This edition of the *Canary Winter School of Astrophysics* will help the participants to deepen their knowledge in specific fields of space Astrophysics, creating a platform of communication between young scientists and experts in space techniques.

Moreover, just as in past years, the IAC does not want the relationship with the participants to end at the conclusion of this edition. For this reason, we encourage you to stay in touch with us through the email address *agg@ll.iac.es* . In addition, you will always find updated information at our web page: http://www.iac.es.

To conclude, I would like to thank the professors and the students for their participation, as well as the entities that, with their help and sponsorship have made the «Canary Islands Winter School of Astrophysics» possible for one more year.


Francisco Sánchez

OUR THANKS TO:

- The Island Government (Cabildo) of Tenerife
- Puerto de la Cruz Town Council
- The Canary Islands Government
- Spanish Ministry for Science and Technology
- ESMN
- ESA

What will you find in this Special Issue?

This special issue of *IAC Noticias* is dedicated to the XV Winter School and contains reports of interviews with some of the invited lecturers (pages 8-19), as in previous issues, as well as their individual answers to a set of common questions on various topics (pages 20-27). Further information on this and previous Winter Schools is also included.

SOME FIGURES:

N. Lecturers: 10
N. Students: 75
N. Countries: 19
N. Applications: 137

School of Space Astronomy

VALENTÍN MARTÍNEZ PILLET, ANTONIO APARICIO & FRANCISCO SÁNCHEZ)
(Organizers of the XV Canary Islands Winter School of Astrophysics)

Valentín Martínez Pillet

The Earth's atmosphere, which allows for the existence of life on our planet, and the day-night cycles, which regulate it, are the main limitations that astronomers encounter when studying the Universe. Our atmosphere distorts the luminous wave fronts of the objects that we study and, even worse, in some cases prevents these waves from reaching our ground-based telescopes because it absorbs them. Moreover, the duration of night (or day!) imposes limits on the amount of astronomical observing time, thus limiting the accuracy of our measurements. There is only one way to completely evade these harmful conditions for astronomical investigation: going to outer space.

Access to space, mainly via satellites, allowed, for the first time, the observation of the Universe in X-rays, UV or certain windows of the far IR. Our current idea of the Cosmos would be less complete had we not had access to these spectral windows. For a long time, space missions were fundamentally dedicated to the scrutiny of the Universe in these ranges, and to a certain extent, things remain the same. However, other missions like the Hubble Space Telescope (HST) or the Solar and Heliospheric Observatory (SOHO) have shown how valuable observing the Universe in the visible range is, as no atmospheric effects are present. Space allows for the continuous observation of astronomical objects (for example, from the Lagrangian points in the Sun-Moon-Earth System), and the achievement of a level of detail limited only by the quality of our instruments. Regarding the study of bodies in the Solar System (planets and interplanetary medium), the access to space allowed astronomy to go from being a merely observational science, to having an experimental component, allowing direct access to objects under study. We went from observing the Martian channels with a telescope to landing on Mars. The advantages are huge. However, difficulties also exist.

Space access is only possible with the use of extremely expensive launchers, and a percentage of success that is barely acceptable. When placing our instruments in space, we must consider their inaccessibility, and the impracticality of fixing or improving them. There is little or no margin for error. The environment in space, an almost perfect vacuum, is not necessarily harmful, but it entails different technology than the one used commonly on Earth. The great majority of materials that astronomical instruments in classic observatories are made of, experience losses (outgassing) that would contaminate the instruments when in a vacuum, requiring a careful selection of these materials. This vacuum does not allow the thermal control of the instruments to be carried out by convection, like Earth-based ones; thus, the heat dissipated by the instruments must be eliminated by radiating it to deep space.

Although we began by discussing effects that allow for the development of life on Earth, and that are no longer out in space, the converse also exists. Highly energetic radiation existent in space (like cosmic rays, solar protons, etc.), and that does not make it to Earth's surface, creates a very aggressive environment for the instruments, that must be considered during the design process. These conditions make space missions, and the apparatus used in them, significantly expensive. Equipment used in space could cost at least 10 times as much as an Earth-based instrument of similar function. How much more a 10 meter space telescope would cost than a 10 meter Earth-based telescope is mere speculation.

Our School will offer young researchers a complete vision of the space sciences, from the identification of its benefits to the grasp of its difficulties. Fundamentally, the School is scientific in nature. The starting point at all times will be establishing how scientific motivations define space missions and their instruments. However, this foundation must include the technical limitations imposed by outer space, and how its environment can have an impact on scientific reach.

Cosmic Vision 2020

The inherent difficulties of the accessibility of Space demand long-term strategies from the agencies in charge of their exploitation. In May of 2002 the European Space Agency launched the Cosmic Vision 2020 (CV2020) programme. This programme (a revision of the one existent until now, which appears in Figure 1) includes a series of missions with a launch expected before 2013. The XV Winter School focuses on the needs of future missions and useful payloads included in this programme. The ESA's scientific programme covers a great majority of the space sciences (only second to NASA's, sharing many common points with it). Using this programme as a starting point for the school we hope:

1.- To cover all aspects of astronomy as a space science.
2.- To offer a perspective of the future because the school will focus on the topics that the European and international community will put its effort on in the next few years.
3.- To provide a reference frame for the reach of a school as general as this one.

The ESA's scientific programme is divided into three sections: Astrophysics, the Solar System, and Fundamental Physics. The latter focuses on the detection of gravitational waves, a new window in the study of astrophysical objects that will not be dealt with directly in the school due to time restrictions.

To understand the proposed programme we must be familiar with the contents of the CV2020 programme. The following missions will be included in the Astrophysics section:

Group I: It includes the Herschel and Planck missions for the study of the infrared and microwave universe (Herschel), and the cosmic background radiation field (Planck). From a technical point of view, these two missions have been tied with Eddington mission, which focuses on the search for extrasolar planets, and stellar seismology. All these missions will be launched in the period from 2007 to 2008.

Group II: GAIA (cornerstone mission of ESA) is dedicated to astrometry (successor of Hipparcos) and galactic mapping. GAIA is expected to be launched in 2011.

Group III: JWST, the successor of the HST. This mission, headed by NASA, will have important European contributions, like the launch on an Arianne5, and the equipment for the mission. It will be launched in 2012.

In the Solar System section, we include two different groups of missions:

Group IV: A group of planetary exploration including the Mars Express mission, launched this year, that counts with the surface element Beagle-2, and the Venus Express mission, similar to the Mars mission but without a surface probe. Mars Express will reach the red planet this Christmas. Venus Express will be launched in 2005, making the most of its respective planetary window.

In this group, we must include the Rosetta mission, which should have been launched in January but, for one of the different difficulties related to space missions mentioned at the beginning, has been postponed and will be launched to a new destination at the start of 2004.

Group V: It will include Bepi-Colombo, cornestone mission which will head toward Mercury, and the Solar Orbiter that, as its name implies, will orbit the Sun with perihelion at Mercury and aphelion at Venus. The launches of these missions are expected between 2012-2013. The propulsion technology needed to arrive that close to the Sun (electric propulsion), in a little over a year, has recently been employed for the Smart-1 technical mission on its trip to the Moon.

Antonio Aparicio

All these clusters of missions, grouped by technical rather than scientific resemblances, present an ambitious atmosphere that will impact the advance of astrophysics in the near future in a similar way to how present missions have. Technological development will be necessary: low-consumption detectors, ultralight optics, and an efficient software to analyze and compress massive quantities of data. The success of the CV2020 programme depends, to a great extent, on the existence of a broad community of scientists and engineers

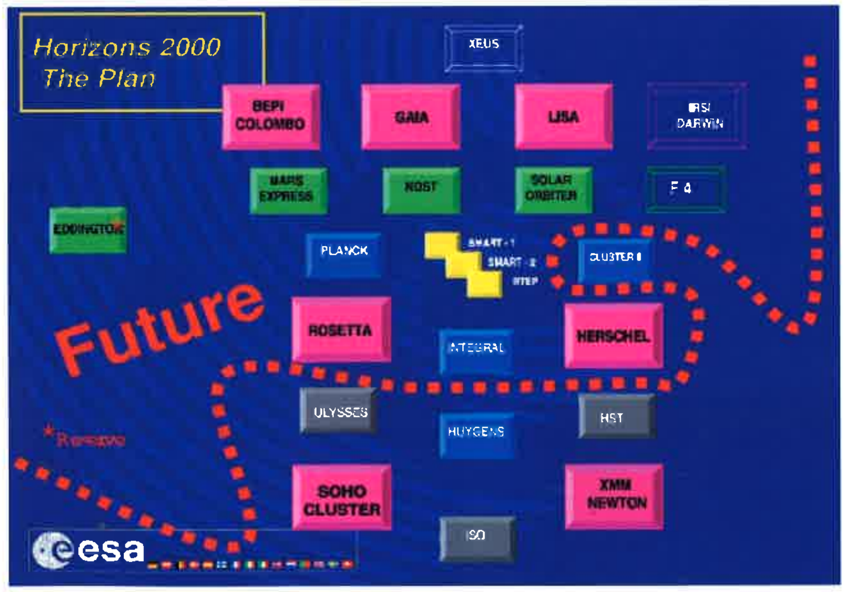


Figure 1. Diagram of the old scientific programme of the ESA Horizon 2000+ that has recently been restructured and broadened in Cosmic Vision 2020.

that, using their knowledge of the current in-flight missions, are capable of developing these technologies successfully. Our school is designed to be a contribution in the education of this community. We *have a* panel of first-class professors that have participated in missions as important as Ulysses, SOHO, Rosetta, Mars Express, Integral, HST, IUE, ISO and others. This heritage constitutes the most solid foundation of the future European space programme.

School Contents

The contents that will be presented are divided into three categories. In the first place, we have two contributions dedicated to the definition of the basic components of a space mission, starting with the launchers, their capacities, the possible orbits toward the different destinations. (Prof. Yves Langevin, IAS France), following with the programming aspects of missions (Dr. G. Schwehm, ESA, The Netherlands). These aspects include the needs for service modules (the satellite bus), operational matters (telemetry and its reception) and organizational aspects. The knowledge that our students will acquire in these lessons is what allows us to define which types of missions are possible and which ones are not. Tempting ideas like whether it is possible to send a probe outside of the Solar System, will be answered here. The specific themes include aspects as showy as the use of nuclear propulsion in space and how missions are planned in ESA and NASA.

Figure 2. Artistic impression of the NGST in one of its possible designs with a primary segmented mirror. Its launch is expected in 2012. ESA collaborates in this mission directed by NASA.

The second group is mainly focused on the useful loads of missions, that is, the instruments needed for each mission. The contributions were defined on the basis of a simple, but effective, division in spectral ranges. More specifically, the regions selected were the X and γ ray zones (Prof. X. Barcons, Instituto de Física de Cantabria), the UV region (Prof. R. Harrison, RAL, UK), the visible range (Dr. Michael Perryman and Dr. Thierry Appourchaux, ESA-ESTEC, The Netherlands) , and finally the near IR region up to the thermal and microwave region (Dr. McCaughrean, AIP, Germany).

Figure 3. Artistic impression of the Solar Orbiter close to the Sun, and inputting data.

Every one of these spectral ranges allows for the study of different physical processes, and has its own characteristics in terms of detectors, optical components, and image formation techniques and spectral analysis. The gamma and X ray regions of the spectrum are only accessible from space and constitute one of the traditional incentives when proposing new space missions. The main concepts of spatial resolution and optics, completely different than those used for longer wavelengths, will be presented in these lectures. The two missions used as reference will be XMM-Newton and Integral; however, we will not lose sight of subjects important for the near future, such as the focalization of gamma rays. Another spectral range used as reference for space missions is the UV region. These observations have been used to study the complex dynamics of the solar atmosphere, activity in cold and hot stars, and emission in active galactic nuclei. One of the missions to have most successfully used this part of the spectrum in imaging and spectroscopy has been the SOHO satellite; it represents one of the leading areas for Europe. The permanence of this success will depend on the Solar Orbiter mission, which will have great UV capabilities. However, successors to the role that the HST has with regard to this spectral region are also starting to be identified. All of this will be a part of the contents in this section of the school.

The following spectral region, the visible range, has had a more limited use in space, and is relatively new. The great possibilities of observation of this spectral region from Earth, without the risks and expenditures associated with space missions, have slowed down the process of making these types of observations from space. However, the benefits of space observation being commented are setting the use of this spectral range in space in motion, be it to see the hidden face of the Sun (Solar Orbiter) or to perform very accurate photometry/spectroscopy that allows for the detection of extrasolar planets (Eddington/GAIA). The adaptation of numerous instrumental techniques developed on Earth for this spectral range (spectroscopy, polarimetry, interferometry) to be used in space, with its limitations, will be another one of the attractive aspects of the lessons.

The last spectral range that we have chosen is the IR region. The ESA has created, and continues developing, important missions for this spectral range like ISO, Herschel and others. One of the technical oddities of observing these wavelengths is eliminating the thermal emissions produced by the telescopes in this region, and the need to cool them as much as possible to reduce the emissions. Cryogenics used for this purpose limit the lifetime of the missions. However, constant technological advances, are motivated by the need to study the omnipresent red shift of cosmological objects. In this field, the stellar mission, JWST (directed by NASA) will be emphasized during the lectures.

The last subject to be studied in the School is comprised of the direct measurements taken in our Solar system. These types of missions are key for the future use of potential available resources, and are part of the backbone of all space agencies; we refer to the in-place measurements of the interplanetary medium and the solid bodies of the solar system.

The interplanetary medium is mainly a plasma in constant interaction with the magnetic fields of the Sun and the different planets. This environment (where all satellites, space stations or manned exploration shuttles) can be described by complex processes of interaction between charged particles, magnetic and electric fields, static and oscillatory, that generate MHD shocks in the interplanetary medium or the aurora by means of the interaction with interplanetary ionospheres. We, therefore, talk about in-situ measurements, since our instruments are immersed at the location of study. Thus, the nature of this equipment is essentially different from that talked about in the rest of the course. The importance of this section is confirmed by the progress achieved by missions like the Voyagers in the past, or Cluster in the present.

We conclude with one of the main subjects in the space sciences: planetary exploration (including asteroids and comets). In a recent past, the study of planets was also accomplished by Earth-based observational institutions. Nowadays, these activities are minor if we compare them to the studies done from orbital satellites and planetary probes. The study of planets is accomplished by high resolution, direct-observation telescopes aboard satellites, spectroscopy in different spectral ranges, and radar techniques (similar to the ones used for teledetection of Earth's atmosphere). However, it also includes in-situ geology via surface probes and, in the case of the Moon, obtaining samples for its study on Earth. In the case of Mars, obtaining these samples represents the step preceding sending manned spacecraft to this planet. Planetary missions create a great *media* impact, motivated by the human desire to explore the unknown. The most recent cases have been the five missions sent to Mars, making the most of its relative proximity with Earth this past summer. The ESA launched the Mars Express mission. More missions are exploring our planets. Galileo has recently finished its study of Jupiter, and Cassini-Huygens is on its way to its destination: the moons of Saturn. Missions to Venus and Mercury will follow, and, without a doubt, so will more missions to Mars, until it is conquered. These types of missions have a clear connection with the rest of the subjects talked about in the School, since we use telescopes specialized in different spectral ranges to in-situ measurers. However, their specificity and importance need a special segment.

The Winter School will count with other enriching contributions, and will allow awareness of the current status of the CV2020 programme. Firstly, the XV Winter School will be inaugurated by Prof. A. Giménez (director of RSSD ESA/ESTEC) who will teach us the tricks of proposing a mission to the space agency and not losing strength in the process. Finally, Prof. José Miguel Rodríguez Espinosa (IAC-GTC, Spain) will present the Spanish Telescope GTC of 10.4 meters to discuss its complementarity with space missions.

From Space and from Earth

The Canary Islands are strongly associated in the astronomical world with the excellent Earth-based observatories located there. Just remember that the Spanish Telescope GTC is being constructed at the ORM (la Palma). However, our school has a theme in which the exceptional circumstances of the islands do not seem to have a major role (but remember the tracking station in Maspalomas and the discouraged ideas of shuttle launchers in our archipelago). Do Earth-based and Space-based astronomy compete? It is actually the exact opposite. Complementing is the norm, not the exception. Earth-based observatories will always be a perfect place to test ideas and technology that can be used in space (although at a more reduced scale). A perfect example of the ways they complement each other are the segmented mirrors, that were first used on Earth, then proposed for Space. A great majority of astrophysical research can be achieved from Earth, and only certain areas need platforms in space. Projects of telescopes based on Earth of 50 to 100 meters in diameter presently being studied, cannot be compared with projects in Space. Earth-based telescopes will continue developing real-time correction techniques of atmospheric effects like those based on adaptive optics. These developments will alleviate the noxious effects produced by the atmosphere in astronomical observations. Its complete elimination will, however, only be possible from space, creating a specific need for space missions. The assessing committees of agencies will determine what is sufficiently justified in the development of a new mission. With the Winter School we are attempting the next generation of mission proposers, evaluators, main equipment investigators and managers that can successfully achieve these missions.

Figure 4: Instruments for space must be strong and compact. Notice the exclusive use of refractive optics and spectral assortment wheels.

Course: "MEASUREMENT OF ELECTROMAGNETIC FIELDS AND PARTICLES IN SPACE"

Prof. André Balogh
The Blackett Laboratory, Imperial College
UNITED KINGDOM

A DANCE OF PARTICLES

André Balogh

Earth is shielded from solar radiation by the magnetosphere, whose magnetic field traps particles coming from the Sun. During periods of low solar activity, the solar winds that excite these particles in the upper atmosphere create aurorae. However, every eleven years, there is a stage of great solar activity. During this period, the solar wind becomes very energetic and can disrupt satellite communications and affect electric lines. The Cluster II mission, launched by ESA on July 2000, as a replacement of the previous failed mission, is composed of four satellites, named after different dance styles, which will observe the effects of the heightened solar activity in such periods. Studying this phenomena in the magnetosphere, the mission will help us to prepare for the effects of future solar eruptions.

What is the most interesting result obtained so far by the Cluster flotilla?

ESA's four spacecraft Cluster mission is fulfilling its promise to bring a new perspective and understanding on the underlying physical processes that control the structures and dynamics of the Earth's magnetosphere. Even though the magnetosphere has been well explored over the past forty years, Cluster is the first mission which aims at resolving the inherently three-dimensional space plasma processes, such as the interactions between particles and waves and the structure of magnetospheric boundaries, the bow shock and the magnetopause. No single discovery stands out from the results of Cluster, but there are many important results that relate to resolving the nature of plasma waves generated near the boundaries, the motion of the boundaries themselves and the three-dimensional structures associated with the sheet of plasma in the centre of the geomagnetic tail. None of these results could be obtained by either single- or double spacecraft missions. Overall, the exploitation of the Cluster observations proceeds steadily, constantly increasing the understanding of a wide range of phenomena first listed, but not resolved by previous missions. What is really expected of Cluster is that gradually a more complete, better understood picture of the magnetosphere will emerge, a full colour picture, compared to the black-and-white image that had been formed by the many single spacecraft observations.

"WHAT IS REALLY EXPECTED OF CLUSTER IS THAT GRADUALLY A MORE COMPLETE, BETTER UNDERSTOOD PICTURE OF THE MAGNETOSPHERE WILL EMERGE, A FULL COLOUR PICTURE, COMPARED TO THE BLACK-AND-WHITE IMAGE THAT HAD BEEN FORMED BY THE MANY SINGLE SPACECRAFT OBSERVATIONS."

What is space weather? Who should care about it? Does ESA care about space weather?

Conditions in the Earth's space environment are controlled by the interaction between the solar wind and the Earth's magnetic field. When solar conditions are steady, the magnetosphere provides an effective shield against small changes in the solar wind and its properties are generally predictable. But the Sun is rarely quiet. Particularly during the years around solar maximum activity, for several years every 11-year cycle, the Sun and its outer atmosphere, the solar corona, are filled with complex and unstable magnetic fields that lead to frequent, explosive ejections of large amounts of solar material. When such an event, called a Coronal Mass Ejection, hits the Earth's magnetosphere, sudden and large changes are seen in the space environment that can damage Earth-orbiting satellites, disrupt radio communications and introduce large surges in electricity power lines. Large magnetic storms (large amplitude disturbances) are generated in the Earth's magnetic field and displays of aurorae (northern light), normally seen only at high northern latitudes, can be admired at mid-latitudes as well.

We rely more and more on a whole range of satellites, particularly in geostationary orbit, and disruption of services can have wide-ranging economic and social consequences. There is nothing that we can do to prevent these space storms (just as we can't control the excesses of the weather), but precautions need to be taken, by building protective systems into vulnerable satellites to prevent costly damage. Space storms and highly energetic solar flares can also present a real danger to astronauts in orbit. I believe that ESA and NASA do care about space weather, by commissioning studies into the way they occur, the potential damage that they can cause and also into how their occurrence could be predicted. The objective of the International Living With a Star programme, undertaken jointly by NASA and ESA, is to build up a knowledge base and a better understanding of the complex ways in which the Sun affects the Earth, its environment and, ultimately, our quality of life.

Artist's impression of the CLUSTER satellites: Rumba, Salsa, Samba and Tango. © ESA

Would it be interesting to go to the bow shock region in the outer heliosphere? Can ESA go there?

The solar wind is contained within the heliosphere. At present, we can make estimates about how far the termination shock is, where the solar wind slows down to subsonic speeds. Beyond this termination shock, we expect that there is a heliopause, similar to the magnetopause near the Earth and, beyond this, we also expect (but this is not certain) that there is a bow shock formed by the interaction with the Local Interstellar Medium. NASA's Voyager spacecraft have been travelling to the outer reaches of the heliosphere since their launch in 1977, but haven't yet reached the termination shock which may be at least 100 AU from the Sun (a hundred times the distance between the Sun and the Earth). It would be interesting to cross these outer boundaries of the heliosphere for two reasons. One is that they are thought to control the access of galactic cosmic rays into the heliosphere, the other is that it would provide a test of the interpretation of our remote measurements of the interstellar medium. There have been proposals to build an interstellar probe, but it is unlikely to be implemented and launched in the next ten years, and then we will have to wait thirty years or more before it reaches the boundaries of the heliosphere. Although technically feasible, neither ESA nor NASA has plans at present to undertake such a mission.

ANDRÉ BALOGH was born in Hungary. He left his homeland in 1956 and continued his education in France and in Britain. He joined the Cosmic Ray Group in the Physics Department of Imperial College, London as a Fellow of the European Space Research Organisation (ESRO). From 1966, he was a member of the research staff that worked on energetic particle detectors for ESRO's early scientific satellites, ESRO 2 and HEOS 1, both launched in 1968. HEOS-1 was the first European satellite with an orbit that reached into interplanetary space. Since then, André Balogh has designed and led instruments on board several scientific space missions, the energetic particle telescope on ISEE-3/ICE (1978), the magnetometer and the energetic particle anisotropy telescope on the Ulysses mission, launched in 1990 and still returning observations from its high heliolatitude orbit around the Sun, and the magnetometer on ESA's four-spacecraft Cluster mission in the magnetosphere. He has also participated in several other magnetospheric and planetary missions, as well as in studies of future missions. In 1993, he proposed a Mercury Orbiter mission concept to ESA that has now become the Agency's BepiColombo planetary cornerstone mission. His scientific interests are the magnetic fields in the solar system, from the solar corona to planetary magnetospheres, and in resolving the puzzle of the origin of Mercury's internal magnetic field. He is Professor of Space Physics in the Physics Department of Imperial College London and is engaged in teaching undergraduate and graduate students.

Course: "PLANETARY OBSERVATIONS AND LANDERS"

Prof. Angioletta Coradini
CNR - IASF
ITALY

GRAZING THE PLANETS

Angioletta Coradini

For a long time, mankind thought that Mars harboured life, that the Moon was a very primitive object and Europa was only one of Jupiter's inhospitable moons. However, in the past 30 years, our views of the Solar System have changed thanks to continuous technological advances. Nowadays, we are aware that the Moon has been exposed to violent bombarding for millions of years, which have scarred its surface with impact craters, while Mars is a cold and arid planet with a hostile environment but a very interesting past, and Europa has an ocean, and it is covered in ice. These discoveries are the result of planetary missions and landings, like that of Mars Pathfinder, which, as its name indicates, «found its path» on July 4th 1997, coinciding purposely with the United States' Independence Day.

Rosetta is a mission coordinated by the European Space Agency (ESA), which is to be launched on February 26, 2004, with an Ariane 5, from the base of Kourou, in the French Guyana. This mission is named in honour of the famous trilingual Rosetta Stone, which was key in the deciphering of the Egyptian hieroglyphics, and the history of ancient Egypt. Until it was discovered, the Egyptian «images» were considered «scientifically unsolvable» enigmas, like our cosmic origin. The key could be in this mission. Its main objective is the study of the primitive bodies of our Solar System, in the attempt to get to know their origin and evolution, and deduce the history of the remaining objects orbiting the Sun. Rosetta will encounter comet 67P/Churyumov- Gerasimenko, orbiting it and making observations on its path toward the Sun. On its way, a trip lasting 10 years, the probe will fly by at least one asteroid.

Will your instrument on board Rosetta obtain the same science return from Churyumov-Gerasimenko as from Wirtanen, the comet that was to be observed before the mission was delayed?

Yes, in fact our experiment VIRTIS is a visual-IR imaging spectrometer, and has been built up in order to be able to work in very different conditions, from 1 AU up to more than 3 AU. Therefore the change in target does not affect the instrument performances.

Are ground-based telescopes of any use for the planetary sciences?

Yes, space missions can be considered as the «ground truth» of ground-based observations. In other words, the possibility of collecting data very close to the planet to be studied helps in understanding the main phenomena characterizing it. However, particularly if the mission consists of a «fly-by,» it gives us a view that is limited in time. So, missions to a planet are necessary in order to decipher the main phenomena responsible for its evolution, while ground-based observations are needed to follow the temporal evolution of such phenomena. The Rosetta mission is a good example: only one comet will be visited, and not for a long time. However, for the first time it will be possible to look directly at how, where, and in which conditions the activity starts. This will help in the interpretation of all the comet observations made by means of the new large telescopes, such as the VLT.

ESA is going to Mars, in 2005 to Venus and in 2012 to Mercury. Should ESA send a mission to the planets beyond Mars or concentrate on the inner Solar Systems?

I think that Europe is already able to send spacecraft beyond Mars. However the problem is cost and energy. At present, ESA has not developed, as far as I know, a RTG (nuclear battery system) that is necessary if a complex exploration, like Galileo and Cassini shall be performed. This is the main obstacle, that could probably be overcome with a serious and continuous investment.

Probably the best would be to participate in the outer Solar System exploration with reliable and resilient partners.

"EUROPE IS ALREADY ABLE TO SEND SPACECRAFT BEYOND MARS. HOWEVER THE PROBLEM IS COST AND ENERGY."

Artist's impression of the Rosetta mission, flying past Mars, at a distance of 200 km. © ESA

ANGIOLETTA CORADINI was born in Rovereto (Italy), on July 1st 1946. Since she began her scientific activity, she has been involved in many fields relating to the planetary sciences, such as lunar samples, the origin of planets and planetary satellites, the geology of interior planets, the thermal evolution of planets and satellites, the remote detection of volcanic regions in the IR, data processing and use of the information obtained by multispectral imaging, and the thermal evolution of comets. She obtained her Ph.D. in Physics at the University of Rome in 1970. She continued to complete her post-doctoral studies in the same university and at the Italian National Research Council. She was the Director of IFSI (Instituto de la Fisica dello Spazio Interplanetario), and throughout her career, besides having over 200 publications and three books, she has participated in various space exploration missions as co-Investigator and Principal Investigator. In these missions, we find Apollo and Luna, PHOBOS-2, Rosetta, and the Mars Surveyor Programme. Asteroid 4598 has been named Coradini, for her contribution to the development of the planetary sciences in Europe.

Course: "BASIC STEPS IN DESIGNING A SPACE MISION AND MAKING A PROPOSAL"

Prof. Álvaro Giménez
RSSD. ESA-ESTEC
THE NETHERLANDS

FROM THEORY TO REALITY...

Álvaro Giménez

When astrophysicists think of the possible missions that could be created for the investigation of Cosmic phenomena, their imagination wanders. Reality clashes with wishes. The design process and proposal of a project is complicated because technical and financial problems arise. Space missions have to go through many phases until they are proved to be physically and economically feasible.

What is the status of the ESA Science Programme today?

At this moment, we are living very interesting times, not to say exciting, in the Scientific Programme of ESA. In a period of months a series of very important missions for European space sciences are being put into orbit. Just one year ago, Integral, a high-energy observatory was launched into space. Last June was the time for Mars Express, the European mission to the red planet arriving in December and releasing Beagle-2, a probe to land on Christmas day. Finally in September Smart-1 was launched, a technology demonstration mission with the moon as the scientific goal. But the series continues, before the end of the year the first of the two Double Star satellites, that will explore the plasma in the magnetosphere, will be launched in cooperation with China and in February of next year the Rosetta mission will be finally launched, this time with comet Churyumov-Gerasimenko as its target. Moreover, the second satellite of the Double Star mission will be launched in June, and the Huygens probe will finally reach Saturn with the Cassini mission after a seven-year trip. In the meantime, other observatories like XMM-Newton, HST, SOHO and probes like Ulysses and Cluster still produce high quality science data.

Launch of Integral, of ESA, on October 17th 2002. © ESA

All these launches and missions in orbit, unprecedented in the programme, make us think of an «annus mirabilis» for science in ESA. However, other aspects have given a different view to this exceptional situation. The financial situation of the programme has been deteriorating during the past years and the last attempt to obtain an increase of the budget failed in Edinburgh at the end of 2001. Of course we had to revise the programme defining Cosmic Vision in 2002, with an ambitious series of scientific missions, basically maintaining the initial plans in spite of the budget restrictions.

This was only possible with certain conditions. Firstly, we had to decrease the flexibility of the programme and the capability to face serious, non-predictable issues. If needed, the new approved missions would be revised. In second place, we assumed the delivery of the payload with the required performances and schedule funded by national plans. Thirdly, project teams would be integrated to deal with more than one project, and hardware developments would be reused for cost minimization.

Unfortunately, three events during the first half of 2003 made the take off of the newly released Cosmic Vision programme difficult. In January, the launch of the Rosetta mission had to be delayed due to the risk generated by the accident of a new model of Ariane V in November of the previous year. Then, the Agency had to make a significant effort to ensure the delivery of the Herschel and Planck payloads despite lack of funding through national agencies. Finally, the situation of the European space industry demanded a re-scheduling of payments, which was incompatible with the necessary flexibility to deal with the previous effects.

The present situation is rather serious from the scientific point of view since decisions that ensure the programme's economic viability must be made, and it is not possible to achieve this without affecting the programme's scientific goals. In November we will have the answer but it will probably not be good, we can only expect the best of all possible, and bad, scenarios.

Who should build the payload for the Science missions?

Although in some cases the payload of the missions can be included in the activity developed by ESA, like in the case of Hipparcos and in GAIA, it should normally not be like this. The only problem is not the cost. Even if the budget of the scientific programme is increased in the necessary quantities to deal with the development of the payloads, ESA must work with methods based on industry and a workload distribution fitting the contributions of member states. This structure allows for the participation of everyone in the scientific programme and its mandatory character as required by its scientific goals. But industry cannot be involved with payloads with new technologies and hardly quantifiable scientific requirements. This can only be done in institutes whose financing follows national mechanisms of fund transfer and activity evaluation.

Industry is more prepared for recurrent developments or those that can be used in multiple applications. Institutes can develop instruments that have never flown, and possibly will not do it again in the same way. This is the challenge for scientists motivated to achieve a higher level of knowledge.

What must be assured is the adequate synchronization of ESA's activities and the involved countries to provide payloads. In the case of MIRI, for the JWST mission, in cooperation with NASA, ESA is attempting a new form of coordination with the idea of spreading it out to other cases like the Smart-2 payload, in fundamental physics, and Bepi Colombo, for the exploration of Mercury.

Does Spain need a space agency?

The organization of the management of space activities in every country depends on many aspects that are not directly transferable. In every case, we must evaluate global investment in space programmes, not only in science, and the most efficient methods of coordination before creating new structures with additional administrative costs.

ÁLVARO GIMÉNEZ CAÑETE, born on February 15th 1956 in Córdoba (Spain), obtained his Ph.D. in Physics in the specialty of Astrophysics at the University of Granada in 1981, after completing his pre-doctoral studies at the Universities of Manchester (United Kingdom) and Copenhagen (Denmark). He achieved a permanent position as Lecturer of Astrophysics at the Astrophysics Department in the Universidad Complutense de Madrid, where he participated in teaching and astrophysical research between 1982 and 1986. Later, he went on to the Consejo Superior de Investigaciones Científicas (CSIC) at the Instituto de Astrofísica de Andalucía, in Granada, where, after some years of being a Senior Scientist and a Researcher, he achieved the status of Research Professor, position he holds presently. Between 1991 and 1997, he worked at the Instituto Nacional de Técnica Aeroespacial (INTA) where he helped to create the Laboratory of Space Astrophysics and Fundamental Physics (LAEFF) and the Division of Space Sciences, which he initially directed until he became General Technical Vice-director of the Institute and, later, General Director. He is a founding member of the Center for Astrobiology (CSIC-INTA), associated with the NASA Astrobiology Institute, and presently directs the Department of Research and Scientific Support (RSSD) of ESA in Noordwik (Netherlands). His research has focused on stellar structure by means of observation and the analysis of eclipsing binary systems, especially from the viewpoint of their dynamic behaviour. In the field of space instrumentation, he has participated in various scientific programmes and he has been Principal Investigator of an instrument aboard the Integral mission of ESA. He has published several specialized books and over 300 scientific papers and contributions to meetings.

Course: "EUV AND UV IMAGING AND SPECTROSCOPY FROM SPACE"

Prof. Richard Harrison
Rutherford Appleton Laboratory
UNITED KINGDOM

THE ULTRAVIOLET UNIVERSE

Richard Harrison

Ultraviolet light is only a small portion of the entire electromagnetic spectrum. Much of this radiation gets blocked by our earth's atmosphere, so that it can only be observed and studied directly from Space. It is of great interest because the hottest and most active objects in the Cosmos emit large amounts of UV energy.

What are the prospects of UV spectroscopy in the space sciences?

For the moment, we have excellent spectroscopic capabilities in the EUV and UV for solar and astronomical research, and there are good signs for enhancing this in the coming few years. The long-term outlook is mixed, with the solar area covered pretty well, but with the emphasis in astronomy moving more towards the IR.

In the solar area, we have the on-going ESA/NASA Solar and Heliospheric Observatory (SOHO) which has a strong spectral and imaging capability in the EUV and UV. However, of the two spectrometers, the CDS and SUMER instruments, the SUMER instrument has a limited operational capability, restricting some of the longer wavelength observations. SOHO was launched in 1995 and is now in an extended phase of operations. Of the upcoming solar missions, neither NASA's STEREO nor NASA's Solar Dynamics Observatory (SDO), for launch in 2005 and 2007, respectively, will carry any spectroscopic capability. For SDO, in particular, this is very unfortunate because the mission is almost exclusively geared to high resolution imaging, including the UV/EUV, and the increase in scientific capability with a spectrometer on board would have been, in my opinion, very significant. The Japanese Solar-B mission, due for launch in 2006, will include an EUV spectrometer geared in particular to active solar conditions. There is also a spectrometer included in the strawman payload for the ESA Solar Orbiter, due for launch in 2012/13. Although these missions have very different goals, it is recognised that EUV/UV spectroscopy provides a basic 'tool box' for the detailed investigation of solar plasmas and, in most missions, it is included.

On the non-solar side, we have the NASA FUSE mission (Far-UV Spectroscopic Explorer), which was launched in 1999. Despite problems with gyros and reaction wheels, for pointing control and stability, FUSE is scientifically fully operational at this time, and we anticipate at least another year of operation. The Hubble Space Telescope (HST) provides a major UV spectroscopic astronomical capability. The Goddard High Resolution Spectrograph (GHRS) and the Faint Object Camera (FOS) were part of the original HST instruments payload, providing spectroscopic information in the 1050-3200 and 1150-8000 Angstrom bands, respectively. These were removed in the February 1997 servicing mission. GHRS was replaced by the STIS – the Space Telescope Imaging Spectrograph - which provides imaging and spectroscopy in the range 1150-10300 Angstrom. Continuing this UV spectroscopic capability on HST, the COS, Cosmic Origins Spectrograph, is to be installed in 2005. COS operates in the 1150-3000 Angstrom range and its order of magnitude sensitivity improvement over the previous instruments ensures a powerful UV spectroscopic capability to the end of mission. The next generation space telescope, which is regarded as the follow on from the HST, is the NASA James Webb Space Telescope. However, it operates in the 0.6 to 28 micron wavelength range of the infrared. Thus, the end of HST signals a closing of the UV observatory class capability.

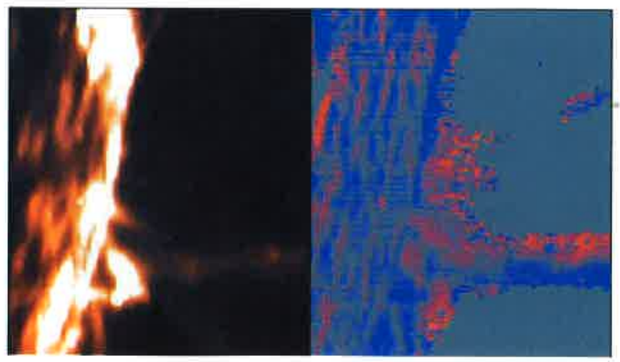
"EUV/UV SPECTROSCOPY PROVIDES A BASIC 'TOOL BOX' FOR THE DETAILED INVESTIGATION OF SOLAR PLASMAS AND, IN MOST MISSIONS, IT IS INCLUDED."

Solar Orbiter, being an encounter mission with the Sun, is a complex mission. Why not try something simpler?

I see Solar Orbiter as part of an international programme of solar physics research. We have the big all singing, all dancing solar 'flagship' observatory in the ESA/NASA SOHO spacecraft. SOHO is, of course stationed at the so-called L1 point, ahead of the Earth, looking at the Sun 24 hours a day with a wonderful complete set of instruments to study the solar interior, atmosphere and the heliosphere. We hope that SOHO will continue until at least 2007. The logical 'next steps' to study our star are (i) to get out of the Sun-Earth line - in order to view effectively Earth-directed solar ejecta, (ii) to have multiple vantage points - to study the Sun in 3-D (the only star for which we can do this!), (iii) to observe the Sun with ultra-high resolution - to study the fundamental processes of the atmosphere, (iv) to fly above the ecliptic plane - to study the polar regions, for which we have very limited information, and (v) to encounter the Sun - to study the Sun close-up and its direct influence on the inner heliosphere. In short, we have only ever seen the Sun from the vicinity of the Earth, yet we can study the Sun from all angles and encounter it, and we cannot do this for other stars! The twin NASA STEREO spacecraft (launch 2005) will provide the widely-spaced out of Sun-Earth line view; the NASA Solar Dynamics Observatory (launch 2007) and Japanese Solar-B (launch 2006) are the next generation high resolution solar observatories, from Earth orbit. The ESA Solar Orbiter (launch 2012/13) is the encounter mission, which also travels above the ecliptic plane. Thus, we have a remarkably complete programme of spacecraft providing a wonderful strategy for solar research.

Solar astronomers in the visible range almost always do spectropolarimetry today instead of just spectroscopy. In this way, they have access to magnetic field information. Will there in the future be orbiting UV spectropolarimeters to measure the coronal magnetic field directly?

In the presence of a magnetic field, the energy levels of an atom split according to the quantum number M. This is the so-called Zeeman effect. The degree of split is a function of the field strength, and the square of the wavelength. The bright coronal lines are emitted in the EUV, in particular by highly ionised iron lines, such as Fe X, Fe XI, through to Fe XVI. The Roman numerals indicate the degree of ionisation, Fe X and Fe XVI being ionised 9 and 15 times, respectively. This range of ionisation is emitted by plasmas in the range 1 to 2 million K. However, the bright lines are almost exclusively at wavelengths of under 300 Angstrom. A few are at longer wavelengths such as Fe XVI 360 Angstrom. In addition, the coronal magnetic field strengths are much weaker than those of the photosphere and chromosphere, probably by factors of 100 or more. Thus, the degree of splitting which would be expected in the corona would be a factor of 30,000 smaller for the coronal lines. We do not have the capability to measure this in the foreseeable future. Thus, we are restricted to attempts to calculate the coronal field, given the photospheric field measurements, or other novel means.



Double image of the solar limb, where we can observe a magnetic loop and a weak emission of a jet, in visible light (left), and UV (right), with SOHO's CDS EUV spectrometer. © ESA-NASA.

RICHARD A. HARRISON is a solar physicist whose research interests involve mass ejection processes, coronal structure and quiet Sun processes. Prof. Harrison obtained his Ph.D. in Solar Physics, at the Space Research Department, in 1983, at the University of Birmingham (United Kingdom). In 1985, he proceeded to go to the High Altitude Observatory, at Boulder (CO,USA) as a Long Term Visiting Scientist. Since 1986 he has been a solar physicist at the Space Science & Technology Department, at the Rutherford Appleton Department (United Kingdom). He has participated in many projects such as the NASA Solar Maximum Mission, and NASA's Transition Region and Coronal Explorer (TRACE). He is the Principal Investigator for the Heliospheric Imager Instrument on the NASA STEREO Mission, to be launched in 2005. He is a member of the Solar-B Extreme Ultraviolet Imaging Spectrometer (EIS) hardware/ science team, and of the proposing/study team for the ESA Solar Orbiter Mission. He has received many awards, such as the «NCAR (National Center for Atmospheric Research) Outstanding Publication Prize» in 1987, and the «European Geophysical Society Golden Badge Award» for Services to Solar-Terrestrial Sciences in 1997. Author of more than 140 full research papers in the referred literature and published conference proceedings, he has also participated in many publications, such as Annales Geophysicae, *the international journal of solar-terrestrial sciences. He has also been the general editor for the COSPAR (Committee on Space Research) information Bulletin. Since 1992, he has edited the annual COSPAR report on Space Research to the United Nations.*

Course: "DESIGN ISSUES FOR SPACE SCIENCE MISSIONS"

Prof. Yves Langevin
Université Paris-Sud
FRANCE

HIGH DESIGN

Yves Langevin

Space technology provides Earth-based activities with important applications. The scientific use of artificial satellites has revolutionized telecommunications, navigation, and the study of the Earth (meteorology, cartography and the environment). Science satellites and commercial communications satellites have followed specific trends dictated by the market, political environment, state of technology, and launch vehicle capabilities. Nowadays, the design process is one of the most evolved areas of research, and its improvements tend to decrease the duration of the development process, not only in its initial phases, but also in the building and testing of new spacecraft. The boost in performance and decrease in cost of modern day satellites will aid in insuring their continuous provision of services for the benefit of mankind.

What would be the most fascinating trip to make in the Solar System?

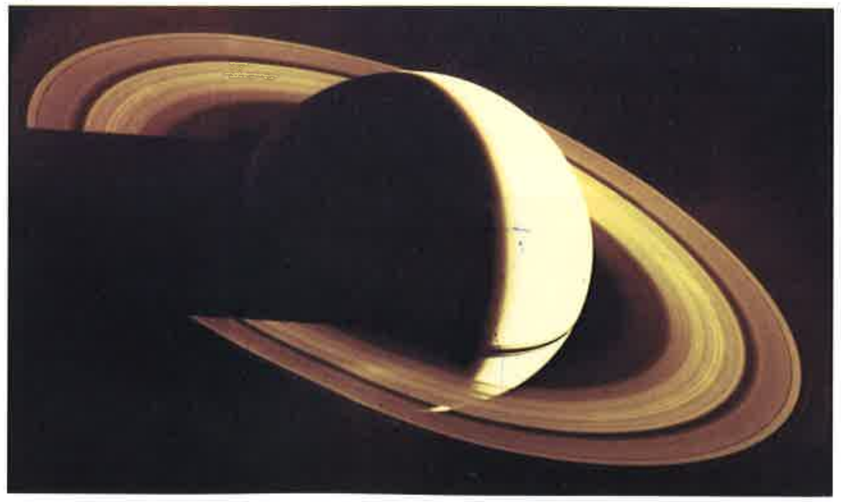
Quite a difficult question, with several answers, depending on whether you stick to the possible or you accept more science fiction. Among my favorites in the latter category:

- geological and internal structure investigations on the surface of Venus.

- detailed investigations of galilean satellites, including a probe in the possible ocean beneath the ice crust of Europa.

- Solar probe, a journey to a few solar radii for in-situ investigations, in an environment where one gets exposed to megawatts of solar energy

"NUCLEAR POWER ARE THE KEY TO MAJOR EXPLORATION PROGRAMMES OF THE FUTURE, SUCH AS MANNED MISSIONS TO MARS."



Photograph of Saturn by Voyager 2, when it was leaving towards Uranus. © NASA.

Which are the main difficulties involved in obtaining samples from Mars?

The problem is simply that Mars is already pretty big: one needs to provide 6 km/s for the return trip if one starts from the surface, more than half the velocity needed to leave the Earth (11.2 km/s). This requires either to send a launcher to the surface of Mars (not an easy task) or to send the samples into Mars Orbit, then to capture them and to send them back with a spacecraft that had been waiting in orbit. For a few kg of samples, a Mars Sample Mission needs to send at least 5 tons towards Mars. This already implied significant use of local resources so as to generate part of the fuel needed for lift-off from the surface of Mars.

Should space science missions in Europe (and elsewhere) use RTGs or any form of nuclear power?

Yes of course: the limitations of solar power (the only alternative) are severe. As an example, the lifetime of any Mars surface module which uses solar panels is limited by dust deposition (wipers are not very practical!). At Saturn, solar power is only 1/100 of what it is at the Earth (1.4 kW per m^2, hence 250 W/m^2 taking into account conversion efficiency). Cassini/Huygens, which will get there in August 2004, simply could not work at such a distance (10 AU) without RTG's. We have reached the limits of what can be done with chemical propulsion, which requires tons of propellant to get anywhere. More mass effective propulsion techniques, such as ion propulsion, require vast amounts of energy (hundreds of kW). A small nuclear power plant is again the only solution for any outer solar system missions. BepiColombo (a mission to Mercury) and Solar Orbiter can use solar panels, as they go quite close to the Sun, where solar power is abundant, but missions going out (to Mars, asteroids, comets, outer planets...) should use nuclear power if at all possible. Nuclear power (not only RTG's, but miniaturized power plants) are the key to major exploration programs of the future, such as manned missions to Mars. NASA has therefore launched a major development program, and Europe would be well advised not to lag too far behind on this issue, otherwise it will soon be marginalized.

The Moon, photographed by Apollo 17, the last manned mission to a planetary body. © NASA.

YVES LANGEVIN was born on July 25th, 1951. He has dedicated his research to the evolution of surfaces of solar system bodies and the study of extraterrestrial material. He completed his Ph.D. thesis work in 1978 in the «Centre de Spectroscopie Nucléaire et de Spéctrometrie de Masse» in Orsay (France). He has extended this research on to other atmosphereless bodies of the Solar System. From 1980 to 1990, he studied the structural defects in silicates caused by the effects of irradiation in lunar samples, which influenced the development of another PhD thesis and more than 25 refereed papers.
He participated in the creation of the «Institut d'Astrophysique Spatiale,» in Orsay, one of the leading laboratories in space experimentation in France. Between 1985 and 2003, he was involved in many experiments implemented on Solar system Exploration Missions, such as GIOTTO, VEGA, PHOBOS 89, Mars 96, Cassini/Huygens, ROSETTA, Mars Express, Smart 1, and Venus Express.
Today, he is very involved in BepiColombo, a new Solar System mission of the European Space Agency, to be launched in 2011/2012.
Yves Langevin has a very extensive career: he was a member and president of the Solar System working group of CNES from 1992 to 1997, and president of the division «Planetary and Solar System Science» of the European Geophysical Society since 2000. He has been the director of the French «Programme National de Planétologie» from 1991 to 1998, and a current member of the Solar System working group of ESA, of which he has been president from 2000 to 2003.

Course: "SPACE INFRARED ASTRONOMY"

Dr. Mark McCaughrean
Astrophysikalisches Institut Potsdam
GERMANY

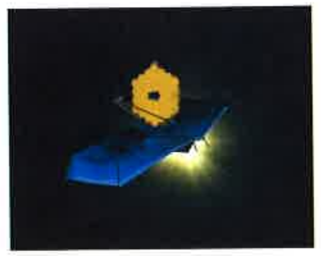
HEIRS TO THE HUBBLE

Mark McCaughrean

April 25th 1990 is a date to remember: NASA and ESA launch the Hubble Space Telescope (HST), a very costly instrument that, initially, had design flaws. However, in 1993 the COSTAR mission solved the telescope's chromatic aberration problem, and gave it the capacity to obtain results of true scientific quality. Until now, the HST has been a source of a great quantity of astronomical news. Now it is time to prepare its successor: the *James Webb Space Telescope* (JWST, previously NGST), next decade's space telescope.

What is the status of the JWST project? Is the size of the telescope decided?

As of summer 2003, the JWST has formally entered Phase B at NASA and is an officially approved project at ESA. After (many) years of work defining the observatory and its capabilities, detailed designs for the telescope, instruments, and spacecraft will now be drawn up by the three space agencies (NASA, ESA, and the CSA), the main industrial contractors (Northrop Grumman Space Technologies and Ball Aerospace), and the many universities, research institutions and companies involved. When these activities are complete and the project has passed its next series of major reviews, it should then proceed to Phase C/D, where everything is actually built. Finally, we're all looking forward to flying to Kourou to see the JWST launched on an Ariane 5 towards the Sun-Earth L2 point, 1.5 million kilometres away, where, chilled to 50K, it should start delivering exciting science. Launch is presently scheduled for the end of 2012, so we still have plenty of work to do.
The JWST primary mirror will be made up to 18 hexagonal segments, yielding a more or less hexagonal primary with a flat-to-flat span of 6.5 metres. Obviously, as the telescope is non-circular, that's not quite the same as saying it has a 6.5 metre diameter: in fact, the primary has the collecting area roughly equivalent to that of a 6 metre diameter circular mirror.
A decision was made a couple of years ago to reduce the mirror size from 8 to 6.5 metres. There were several key technical reasons for this, beyond the associated cost savings. The JWST primary mirror will be made from beryllium and there are very few companies who are able to machine this highly toxic material: reducing the mirror area by roughly a factor of two meant that the mirror can be made more quickly, getting us into space sooner rather than later. This also relieved pressure on the total mass budget, meaning that the mirror could be made quite a bit stiffer, so much so that it can now be fully tested on the ground under gravity. Anyone who remembers the problems with the HST primary mirror should feel more comfortable knowing this.
Finally, it's worth keeping in mind that decisions like this one are almost an inevitable outcome of the detailed study phases in a project, when wishes and desires meet hard technical and financial realities. The HST underwent a similar reduction in diameter from 3 to 2.4 metres, and the ESA Herschel far-infrared observatory due for launch in 2007 with a 3.5 metre mirror was originally approved with an 8 metre diameter primary. Ironically, the then NGST was first proposed to NASA with a 4 metre mirror; as the JWST has a 6.5 metre mirror, you could say we're actually ahead of the game for once.



Artist's image of NGST, now known as JWST. © NASA/ESA

Are 100 meter class telescopes a challenge for JWST?

As both the JWST and future large ground-based telescopes are designed for general-purpose infrared astronomy, there will be overlaps in capability and potential, yes, but I think it's really better to see them as complementary: both will have an important role to play in the coming decades.
One way to look at this is to think back to the mid-1990s, when the repaired HST and the first Keck were in simultaneous operation. Although the Keck has almost 20 times the light gathering power of the HST, the HST is free of the Earth's atmosphere, which means it suffers no atmospheric absorption, sees a lower background, and yields diffraction-limited images without undue trouble.
As a result, they in fact they proved quite complementary with, for example, the HST making very deep surveys such as the HDF and the Keck providing the spectroscopic follow-up. And even today, with ten or so 8—10 metre class ground-based telescopes in operation, the HST remains as much in demand as it ever was.
Thus, in a very broad sense, one might expect a space-based 6.5 metre telescope to remain competitive with and complementary to ground-based facilities with 20 times the collecting area, i.e. a 30 metre diameter telescope such as that planned by Caltech and collaborators. What about a 100 metre telescope however? Well, the JWST is much more than a larger HST: it is also a very cold telescope, making it extremely powerful at near- and mid-infrared wavelengths, and thus competitive with much larger ground-based telescopes. Also, keep in mind that no 100 metre class telescope is funded yet or has been assessed and studies to the same level of detail as the JWST: there are major challenges ahead of these telescopes in, for example, multiconjugate adaptive optics. As above, the history of telescope development from dreams to reality makes me somewhat sceptical that a 100 metre will come in the next generation.
But perhaps the best way to show the complementarity between the two (and the fact that astronomers like to hedge their bets) is to note that many people involved in the development of the JWST, myself included, are also working towards extremely large ground-based telescopes.

When will we detect an Earth-like planet near a star? Where in the galaxy do you think it will most probably be found?

The answer to the first question depends on whether you mean a planet with roughly the same mass as the Earth: if so, then the answer is 1991, when Alexander Wolszczan and collaborators discovered terrestrial-mass planets in orbit around the pulsar PSR B1257+12. More terrestrial-mass planets could be discovered tomorrow, if any of the microlensing surveys shows rapid intensity spikes characteristic of such a mass.
However, if you mean a potentially habitable planet, where we know that it has a terrestrial mass and lies in the right orbit around a star to sustain liquid water, the discovery probably won't come via the pulsar technique, as such planets are hardly likely to be habitable, or via the microlensing method, as these events do not as a rule repeat and thus we will not be able to determine the orbital parameters.
No, the first sign of such a planet is likely to come via the transit technique, where very small periodic dips in the intensity of a star can reveal a planet around it. This technique was spectacularly validated in the case of HD209458, a star previously known to have a planet around it via radial velocity variations. However, although the HD209458 transits are detectable from the ground, it is a massive gas giant: detecting an Earth-mass planet will require the precision only achievable from space. The HST could make such a discovery in principle, but in practice, you need to monitor the same field for years, in order to get orbits similar to that of the Earth.
Thus the first detection of a terrestrial exoplanet within the habitable zone is likely to come with a dedicated space transit mission such as NASA's Kepler or ESA's Eddington. Which also gives us the answer to the second question: it will lie along the line-of-sight through one of these space-based transit fields.

MARK MCCAUGHREAN was born on March 20th 1961 in Plymouth (United Kingdom). He obtained his Ph.D. in Astrophysics in 1987 at the University of Edinburgh. Later, he worked at the NASA Goddard Space Flight Center, as an NRC (National Research Counsil) Resident Associate. He continued as a NICMOS Project science data analyst. He moved to Heidelberg, becoming a Staff Research Astronomer at the Max-Planck-Institut für Astronomie. In 1996, he moved to Bonn, taking on the same position of Staff Research Astronomer, at the Max-Planck-Institut für Radioastronomie. In 1998 he went to Potsdam to work at the Institute of Astrophysics in the star formation group. Since August 2001 he has had a permanent position at this institute, and since April 2003, he has been a Professor at the University of Potsdam. Presently, his scientific interests focus on star and planet formation, in particular, young dense stellar clusters, circumstellar disks, jets and outflows from young stars. He is a member of the ESA Science Study Team of the JWST (Next Generation Space Telescope). He also works in many areas of ESA, like the Astronomy Working Group, where he is able to combine his interests in star and planet formation with infrared instrumentation.

Space science, like other scientific activities, is constantly being questioned by society, especially when a catastrophe occurs. In fact, many citizens wonder whether the conquer of Space has been worthwhile, in spite of the cost, in human lives (a couple of hundreds of deaths in about 50 years), economically (the millions of dollars destined for this field), and of a different nature (for example, the space debris generated). However, many conclude that the profits are obvious: society has benefited by acquiring knowledge and technology. «Maybe we do not realize it -said Luis Ruiz de Gopegui, ex director of NASA Programmes, in Spain-, but space technology is in almost everything. Nowadays, it would be very difficult to live without space technology. If all the satellites surrounding Earth were shut off, our civilization would be practically paralysed.»

THE CONQUER OF SPACE: a questioned success?

Bearing in mind the human and economic losses in accidents and other kinds of problems in space (Columbia, Rosetta, Ariane 5, etc.), how are such missions-both manned and unmanned-justified nowadays?

" THERE ARE MANY REASONS TO CONTINUE SPACE EXPLORATION AS A SCIENTIFIC ACTIVITY, BUT CLEARLY THE MISSION RISKS MUST BE MINIMISED TO ENSURE THAT THE OBJECTIVES CAN BE MET."

ANDRÉ BALOGH:
"Human tragedies in space, such as the Columbia disaster in February this year, always lead to the question: is it all worth it? And of course there is no clear answer to this question. Fortunately, there have been few such accidents, only the Challenger disaster in 1986 was of comparable magnitude. Human spaceflight remains a risky undertaking. As has been shown by the careful investigation carried out by the Columbia Accident Investigation Board, the launchers and vehicles, the Shuttle and the International Space Station, are technically very complex systems and it is probably impossible to eliminate all the potential failure mechanisms. All that can be done is to minimise the risks by careful and expensive safety procedures. But if we want to see the adventure of human spaceflight continue, we must accept the risks, while paying for the best safety that's technically possible.
The case of robotic, unmanned scientific spacecraft is rather different. Here we have to trade off the risks of failure against the costs of missions and their scientific objectives. The world would be a different place without the early scientific missions that prepared the way for the commercial exploitation of space that we now take for granted. Now, however, we are interested in the further exploration of space and the Solar System, and in the use of spaceborne astronomical telescopes for making observations of the universe that are impossible without going into space. There are many reasons to continue space exploration as a scientific activity, but clearly the mission risks must be minimised to ensure that the objectives can be met. The cost of space science is relatively high, but remains, at its present levels of funding, a relatively modest fraction of resources spent on research and development in general."

ANGIOLETTA CORADINI:
"The problem with human exploration is that a certain risk is surely present for the Astronauts. However, a honest risk assessment and a serious approach to the safety of the crew can help in accepting this risk. The recent accidents were also generated by an underevaluation of the risk in presence of an accident. This can increase the disaffection of the general public for the manned space exploration. As far as automatic space exploration is concerned, I guess and hope that it is perceived by the public as a way to extend to space our ability to enjoy the learning and studying of the Universe without colonizing it. The images collected during the space missions in the last twenty years were able to open new worlds to everybody."

ÁLVARO GIMÉNEZ:
"I think we can still do a lot of high-quality scientific research in Space, without the need for manned missions; but access to space is not merely justified by scientific research. There are two additional components of space activity of importance for our Society: exploration and applications. Exploration requires the inclusion of astronauts in space adventure and applications can certainly benefit from it in some cases, like the use of the Space Station.
Of course, we have to be conscious of the fact that any programme that includes astronauts to access space is necessarily more expensive than one that does not."

RICHARD HARRISON:
"There are so many answers to this question. Let me start from an astronomical viewpoint. We only have two windows into space from the surface of the Earth - the visible and the radio windows. The rest of the electromagnetic spectrum is lost to us because of absorption by the Earth's atmosphere. We are looking at the universe through a 'keyhole'. If we want to study the universe fully, we need to include observations in the UV, the X-ray and the gamma-ray regions, and for that we have to go into space. Much of the astronomical work may have little direct impact on the person in the street but it has always been mankind's desire to explore his surroundings and we want to explore our universe. There are practical benefits. For example, one major area of interest these days is the topic of 'space weather'. In effect, the giant plasma clouds thrown at us by the Sun, and the streams of energetic particles that can come from solar flares, are clearly of interest because of their detrimental impacts on industries concerned with navigation, communication, power distribution, satellite control etc... and we want to understand our local space environment as much as we want our terrestrial weather reports. There are also huge benefits from studying the Earth from space, from studies of our weather to disaster monitoring, from studies of atmospheric changes (such as the ozone layer and global warming) to prospecting. In addition, we are all increasingly using space for communications, navigation, weather forecasts etc. In effect, the economic demands are there for us to remain in space, the scientific demands and the fundamental human need to explore ensure that we will continue to expand into space, and the range of practical applications and spin-offs is growing all the time."

YVES LANGEVIN:
"One should clearly separate the issues. The Shuttle and Ariane programmes were funded so as to send men to low Earth orbit (Shuttle) or telecom relay satellites to the geostationary orbit (Ariane). Their development problems have impacted science missions, not the reverse! in particular, ROSETTA as a spacecraft was fully ready to go when its launch was postponed due to cold feet at Arianespace on the potentially disastrous impact on commercial markets of another failure following the ECA flop in November 2002.
It is clear that space missions are now required by the major science goals of Solar System Exploration as well as Astronomy. Do we need to improve our understanding of the Universe which surrounds us? My answer is of course an unqualified yes. The origin of the Universe, of the Solar System, of our planet and of life on our planet are questions which have fascinated mankind since the dawn of times. They are more critical than ever when one considers the planetwide scope of the problems facing us today, from global warming to ecological crises such as water resources (an issue which is likely to generate major conflicts before very long). In this respect, it is interesting to look at the two neighbour planets which went on the wrong track: Venus, with its runaway greenhouse effect, and Mars, which turned into a cold and very dry place after a few hundred million years of water rich episodes. The finite nature of our little oasis of life generates enormous interest in exobiology: was there life on Mars? if so, most likely life appeared everywhere in the Universe where water was present for even a «short» period (again, hundreds of million or years!). Are there planets around other Suns? if so, do they have atmospheres, and possibly spectral signatures of liquid water? Even if this sounds a bit like science fiction, I have no doubt that in the future of mankind there are only two tracks: one leads to a gradual collapse of our technological society, drowned in its own refuse, the other leads outwards, so as to establish our species in more than one place. When I present space missions to the general public, I have a distinct feeling that the Skinner box syndrome creates a psychological need of finding an outlet, even if it is distant in space and time."

MARK McCAUGHREAN:
"Before answering that, you have to separate human and economic losses right at the start: they are quite different things. The human losses are real but I personally feel it's wrong to label them as tragic, for example. Astronauts are generally extremely rational people who understand the risks associated with spaceflight and are willing to accept them in return for the excitement and opportunity of their job, much as generations of other explorers have in the past. As long as there are brave and skilled people willing to take such calculated risks, I see no reason why we as a society should be afraid to let them do so.
On the so-called economic losses in space, the key thing is to remember that rockets and satellites are not literally stuffed with Euros and sent into oblivion. Of course, they do cost lots of money, but that money is spent on the ground employing highly skilled engineers and scientists in government labs, universities, and commercial enterprises. Thus almost independent of any results, this money plays a part in fostering an informed, well-educated society which can also develop more fuel-efficient cars, disease-beating drugs, and the like, which are of direct benefit to the populace.
You could then argue that we should just build weather satellites, for example, rather than instruments for observing star formation and the Big Bang, but I personally believe that's short-sighted. In our increasingly mundane and profane modern society, I think it's important that we allocate time and resources beyond the purely pragmatic, to activities which can give us a broader sense of place, perspective, and inspiration. This might mean preserving wild places and wild animals, it might mean funding classical music and sports clubs, or it might mean building tools with which we can reveal the secrets of our universe. The cost-benefit ratio for such things is almost impossible to analyse in a hard-headed accounting way, but the value of realising just occasionally that we're more than mere cogs in a machine can be immeasurable."

"MUCH OF THE ASTRONOMICAL WORK MAY HAVE LITTLE DIRECT IMPACT ON THE PERSON IN THE STREET BUT IT HAS ALWAYS BEEN MANKIND'S DESIRE TO EXPLORE HIS SURROUNDINGS AND WE WANT TO EXPLORE OUR UNIVERSE."

"ASTRONAUTS ARE GENERALLY EXTREMELY RATIONAL PEOPLE WHO UNDERSTAND THE RISKS ASSOCIATED WITH SPACEFLIGHT AND ARE WILLING TO ACCEPT THEM IN RETURN FOR THE EXCITEMENT AND OPPORTUNITY OF THEIR JOB, MUCH AS GENERATIONS OF OTHER EXPLORERS HAVE IN THE PAST. AS LONG AS THERE ARE BRAVE AND SKILLED PEOPLE WILLING TO TAKE SUCH CALCULATED RISKS, I SEE NO REASON WHY WE AS A SOCIETY SHOULD BE AFRAID TO LET THEM DO SO."

In 1954, the United States of America and the Soviet Union put several launch programmes into practice for the International Year of Geophysics, which was to be celebrated beginning July 1957 and ending at the conclusion of 1958. On October 4th 1957, the Russians put the first artificial satellite-the *Sputnik 1*- in orbit, fulfilling the prophecies of science fiction. The Soviet news agency- *Tass*- made it public through the following press release: «As a result of the extensive and strenuous work of the Design and Research institutes, the first artificial satellite has been created. On October 4th 1957, in the Soviet Union, the Sputnik 1 has been launched successfully. According to the initial data, the launching rocket provided the satellite with the necessary orbital speed, about 8000 meters per second. At the moment, the satellite moves around the Earth in an elliptical trajectory, and its flight can be observed at sunrise and sunset by means of the simplest instruments... The satellite has a sphere with a diameter of 58 centimeters, and weighs 83.6 kilograms. Two transmitters that send continuous radio signals have been built aboard.»(*) Ever since that day, the Space Sciences have continued to develop, with more or less fortune, and always tied to political and economical situations.

AT THE MERCY OF CIRCUMSTANCES

Are the efforts made by nations involved in the space sciences sufficient? Why should these nations increase their space budgets?

ANDRÉ BALOGH:
"There will always be more good space science mission proposals than can be funded. Costs have increased, because in most disciplines we are at the third generation of scientific missions, requiring increasingly complex and refined payloads and platforms to meet ever more rigorous scientific objectives. If the funding available is not increased in line with the required complexity and sophistication, there will be fewer missions, and fewer high priority scientific objectives can be satisfied. NASA tried the «cheaper, faster, better» approach and it was found that cheaper and faster missions carried a greater risk of failure and could only satisfy relatively simple scientific objectives, so in the end these missions, on the whole, did not turn out to be «better», but, in fact, worse. There is always room for efficiency gains, but many simple recipes, such as the reusable platforms, did not deliver what they promised. A vigorous space science programme does need a stable budget as a first requirement, but genuine progress requires an increased budget. At this point, this becomes a political argument, as nations need to set their priorities over the much wider range of their responsibilities. However, the space budget is usually not a large fraction of any nation's budget, the only exception was at the time of the Apollo programme, when up to 4% of the budget of the United States was devoted to sending their astronauts to the Moon."

"A VIGOROUS SPACE SCIENCE PROGRAMME DOES NEED A STABLE BUDGET AS A FIRST REQUIREMENT, BUT GENUINE PROGRESS REQUIRES AN INCREASED BUDGET."

ANGIOLETTA CORADINI:
"Recently all the European nations, both as single countries and as ESA members are decreasing their investment in space. The USA is doing the opposite. This will bring Europe to a subaltern position with respect to the US. This will also drastically reduce the competitiveness of space industries, that are now producing a large amount of high-tech products. These high tech products are extremely important to allow a nation to be industrially competitive, thus attracting foreign investments."

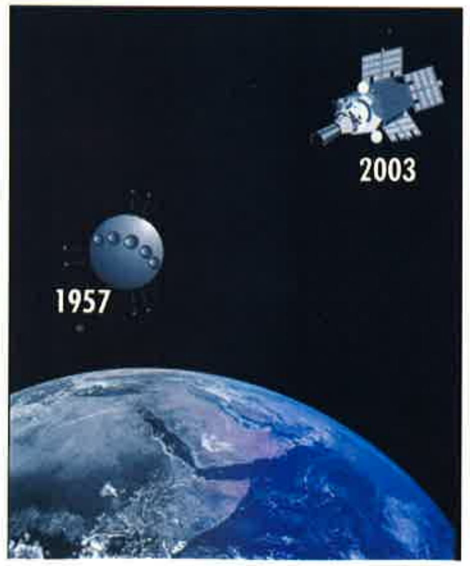
ÁLVARO GIMÉNEZ:
"Evidently not, but this is easy to say for those of us that are hooked on space research, and want to do more and get farther. I guess that if you ask someone about what their tax money goes to, and whether it should be dedicated to efforts in space activities, the situation could be different. However, I think that financing of the space sciences in Europe is not comparable with the one in the United States, with a similar gross product. Moreover, science allows for the assurance of industrial stability and the continuity of a launch rate at times when private initiative could go through difficulties."

RICHARD HARRISON:
"Here we are really talking about the money spent on basic space research - and this is not going to be paid for, in general, by anyone other than governments. In relative terms, the space budgets are always fairly poor. Space funding has to be a long term commitment and that flies in the face of political timescales, where rapid, high profile returns are required. Decade-long development programmes for major space missions do not fit with this. However, space does hold a profound interest to a large fraction of the population. Thus, individual governments do support space research, but usually at modest levels. There are many reasons why one might consider space research to be a key area for investment for the future - one has only to consider areas such as space weather and external impacts on the Earth-environment, and Earth observation from space to monitor ozone depletion and global warming. So, perhaps our problem is one of education, i.e. getting the right messages across to the politicians and the public. The current funding is not sufficient and a modest increase would make a significant difference."

YVES LANGEVIN:
"As outlined hereabove, there are important scientific and psychological reasons to increase these budgets. As far as Europe is concerned, there are other important reasons to do so:
- With our aging populations, we will never be able to compete with China or India on labor intensive activities. The only chance of preserving our standard of living is to maintain a technological advantage. This requires apparently non productive investments in cutting edge fields. With its long history of disastrous wars, Europe is not keen on investing massively in the military. Space technology is an alternative which is much better accepted and which provides the stringent constraints required to improve industrial capabilities.
- The European Union is nearly on a par with the US in terms of economic capabilities. If one considers high tech investments, the ratio is now of more than 1 to 4 in the military, and 1 to 5 in space technology. This is in part due to the present structure of space funding in Europe, through a multinational agency (the European Space Agency). As any budget increase has to get unanimous approval, it is no surprise that status quo is the most likely answer. The only solution to get such a technological drive is to involve directly the European Union. A single funding authority (similarly to NASA) would make possible a major increase driven mainly by technology, but beneficial to science."

MARK McCAUGHREAN:
"I wouldn't pick out the space sciences separately from the natural sciences in general here: we certainly should be spending more money on scientific research in Europe, a fact clearly recognised by the EU and other bodies, and space sciences should just be a part of that. For governments, it should be very much a matter of balancing pragmatic issues, such as supporting high-tech industrial development and thus creating skilled, well-paid (and thus well-taxed) jobs which go with it, against more philosophical ones, such as the need to inspire more of our children to enter the sciences. Many of today's scientists were inspired by achievements such as the Moon landings of the 1960s and 1970s, for example, or more recently, by the stunning images and scientific insights turned out by interplanetary probes and the HST.
We live in a time where our lives depend more and more on the technology that surrounds us, and yet an ever-decreasing fraction of the population actually understands this technology: this is a dangerous state of affairs. It's not that everyone should have a science degree perhaps, but it is important that those of us living in democratic, technologically-sophisticated societies should have a basic grasp of the scientific method, so that we can at least understand the background to such crucial and complex issues as global warming, genetically-modified foods, nuclear power, and human embryo research, and then make our decisions accordingly. Otherwise, political pressure groups and commercial interests will make these decisions for us, no doubt frequently to our detriment."

"SPACE FUNDING HAS TO BE A LONG TERM COMMITMENT AND THAT FLIES IN THE FACE OF POLITICAL TIMESCALES, WHERE RAPID, HIGH PROFILE RETURNS ARE REQUIRED."



"WE LIVE IN A TIME WHERE OUR LIVES DEPEND MORE AND MORE ON THE TECHNOLOGY THAT SURROUNDS US, AND YET AN EVER-DECREASING FRACTION OF THE POPULATION ACTUALLY UNDERSTANDS THIS TECHNOLOGY: THIS IS A DANGEROUS STATE OF AFFAIRS."

(*) M-H. *Enciclopedia Historia Gráfica del Siglo XX.* Ediciones Urbión. Madrid, 1982. Volume 6. Page. 238.

Never had «garbage» acquired as much importance as it has in the most recent years: recycling, selection, depuration…Many processes destined to reduce the amount of residue have emerged, due to Nature's incapacity to reabsorb many of them. On the other hand, many different campaigns have been created to raise people's awareness about this need. Space should not be any less and, nevertheless it is becoming an invisible wasteland for many, which could cause serious problems, beginning with the space missions themselves. Consequently, shouldn't we begin to have a "sustainable" space industry?

FOR A CLEAN ORBIT

With regard to the amount of space debris generated up to the present time, what steps are being taken in, for example, the design of future scientific missions in space?

ANDRÉ BALOGH:
"Many scientific space missions are launched into orbits that will remain relatively stable even after the spacecraft has ceased to function. It is difficult to devise a fail-safe way of disposing of such spacecraft. This is true of many other satellites, such as those in geostationary orbit from which used spacecraft can be displaced, but not otherwise destroyed, as that could prove even more dangerous by generating a large number of smaller fragments. Some of the orbits used by spacecraft are inherently unstable; these will generally burn up safely in the upper atmosphere, unless they are very large, but then they may constitute a hazard on re-entry, rather than in space. For the time being, there is no good solution to overcome the increasing amount of debris in space, but, at least for the near future, natural hazards, such as micrometeorites, probably constitute a greater danger than man-made objects. This does not mean that no effort should be made now to try and find appropriate solutions to reduce the amount of man-made debris in space.

"FOR THE TIME BEING, THERE IS NO GOOD SOLUTION TO OVERCOME THE INCREASING AMOUNT OF DEBRIS IN SPACE, BUT, AT LEAST FOR THE NEAR FUTURE, NATURAL HAZARDS, SUCH AS MICROMETEORITES, PROBABLY CONSTITUTE A GREATER DANGER THAN MAN-MADE OBJECTS."

ANGIOLETTA CORADINI:
"The problem shall be carefully analyzed: mitigation actions on newly developed satellites can be introduced, that will allow to send the satellite back down to the ground, when its scientific missions end."

ÁLVARO GIMÉNEZ:
"Space debris is a growing problem, with solutions. As always, debris controls increase the cost of missions but space ecology is fundamental. On the one hand, we have to ensure that it is not growing, and on the other, we must find solutions for accumulated garbage. Fortunately, future science missions will be placed in new orbits, in the so-called Lagrangian points that do not have this problem yet."

RICHARD HARRISON:
"Spacecraft and rocket upper stages often remain in space well after their scientific use. Break-up due to explosions, even collisions, result in smaller-scale debris. Debris mitigation procedures are being pursued but can increase the costs of missions. For example, components that could conceivably cause explosions should be passivated at the end of useful life, such as the burning of propellant, and deployment activities can be performed in a way that does not eject materials, e.g. bolt catchers for explosive bolts. Satellites and upper stages can take advantage of atmospheric drag to reenter quickly, and higher altitude spacecraft can use fuel to modify orbits for eventual deorbit through atmospheric drag. However, spacecraft with higher orbits than about 2000 km cannot be deorbited effectively, and it is recommended that they are placed in 'graveyard' or disposal orbits. For example, many geostationary spacecraft are already boosted into a higher disposal orbit at end of mission. One can imagine, in the distant future, a situation where there is active removal from orbit of satellites and upper stages. All of the activities of debris mitigation put a significant cost overhead on future missions but this is probably unavoidable. Much of the discussion of space debris related matters is coordinated through the Inter-Agency Space Debris Coordination (IADC) Committee, which is an international government forum for the worldwide coordination of activities related to the issue of man-made and natural debris in space. The main purpose of the Committee is to exchange information, facilitate cooperation, to review progress and identify mitigation options. The Committee members include, ESA, NASA and the national space agencies of Italy, the UK, France, China, Germany, India, Japan, Ukraine and Russia. In 2003, the IADC Committee presents Space Debris Mitigation Guidelines to the Scientific and Technical Subcommittee of the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS). This is a major step in the development of an internationally agree debris mitigation policy."

YVES LANGEVIN:
"Science missions in space do not go to Earth orbit, where the problem is most accute. Planetary missions land or orbit other planets, where the junk aspect is definitely marginal. Astronomy missions go to the Lagrangian points (L1 or L2), 2 million km away from the Earth. Furthermore, the launching rocket also goes out of the Earth influence. Therefore, there is no impact from these missions on the space debris issue."

"PLANETARY MISSIONS LAND OR ORBIT OTHER PLANETS, WHERE THE JUNK ASPECT IS DEFINITELY MARGINAL."

"SPACE DEBRIS IS A GROWING PROBLEM, WITH SOLUTIONS."

Scientists are often producers in search of the best setting for their movie. In the case of astronomy, there are two great sets: Earth and Space. The shots to be taken in each are a function of the requirements of the script. Space's main advantage is the absence of an atmosphere, which allows for a privileged vision of the Cosmos; however, its physical conditions do not allow for the sending of just any telescope. From Earth, on the contrary, it is possible to have telescopes that study the scheme of our universe at our disposal. In any case both are ideal sets for Astronomy, complementing each other, creating a film couple.

EARTH AND SPACE: movie sets

How will future space telescopes complement large ground-based telescopes and the very large telescopes now being planned?

"I GUESS THAT THE NEW GROUND BASED TELESCOPES IF THEY ARE BUILT IN SPECIAL PLACES, LIKE ANTARCTICA, BUT CHARACTERIZED BY LIMITED LIGHT POLLUTION AND BY AN EXCELLENT SEEING CAN BECOME COMPETITIVE WITH ORBITAL T1 TELESCOPES."

ANDRÉ BALOGH:
"Ground-based telescopes continue to improve in performance, both in terms of size and the way they are able to minimise atmospheric effects. This means that arguments for all astronomical space telescopes must be very carefully examined. However, there are astrophysically important wavelengths, such as gamma rays, X-rays, Extreme Ultraviolet (EUV) and infrared which can only be observed with a space-based telescope. Such telescopes will continue to fulfil an important role alongside the improved ground-based telescopes."

ANGIOLETTA CORADINI:
"I guess that the new ground based telescopes if they are built in special places, like Antarctica, but characterized by limited light pollution and by excellent seeing can become competitive with orbital T1 telescopes."

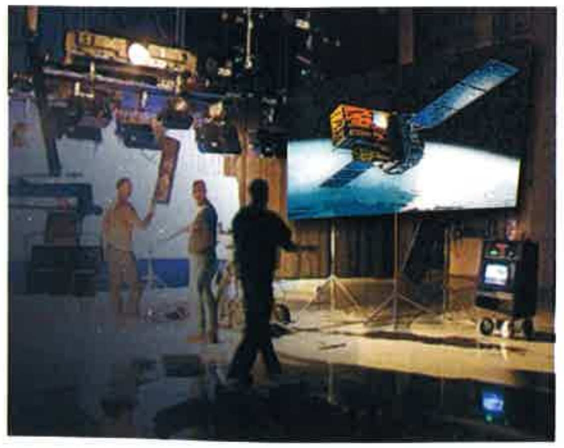
ÁLVARO GIMÉNEZ:
"Astrophysical space missions planned by ESA complement the efforts made in Earth-based observatories in a very careful way. With the existing limited budget, it would not be very wise to put in orbit space missions that do more or less the same that could be achieved with Earth-based telescopes, especially with ongoing large telescope projects. This is why space programmes are focused on regions of the electromagnetic spectrum inaccessible from Earth or measures that require global observation, of the whole sky, or continuous in time."

RICHARD HARRISON:
"The basic problem of only having two observing windows from the ground (visible and radio) demands that we maintain space observations to cover the UV, X-ray and gamma-ray ranges. Certainly, there is a need to combine such observations with ground-based observations from the next generation telescopes to provide the best coverage possible, and thus the best scientific interpretations possible. This means coordination of planning, observations and clear access to archives and software for joint analysis. With the Web and the so-called GRID technologies, such combinations and collaborations can be very productive. In particular the SOHO-spacecraft JOPs, Joint Observing Programmes, which often involve other spacecraft and ground-based observatories, have been a superb test-case for the planning, execution and exploitation of this kind of multi-disciplinary scheme. This is how I see things going in the future. In addition, one must not forget that with spacecraft we can observe without the problems of the day-night cycle and we can make observations from differing vantage points. Thus, there are many facets of space-based observations not open to the ground-based instruments and we can exploit these effectively, in collaborations between space and ground based instruments. To give an example, the NASA STEREO spacecraft will detect Earth-directed solar mass ejections by viewing the Earth-Sun line from both sides. Ground-based and other space-based instrumentation at or near the Earth, can be used to view the ejection site directly (from above) to study the physical processes of the eruption in detail, as well as to measure the effects at the Earth. I feel that we will all see a shift towards greater collaboration in mission and instrument operation to the benefit of science."

YVES LANGEVIN:
"I am not too much of a specialist in Astronomy, but it is clear that there is room for both until 2010-2015. After that, this question requires some thought. With the advent of adaptive optics, which correct for atmospheric turbulence, Earth-based telescopes have regained attractiveness. Their cost per m² is much lower than a space telescope. Among the large Earth based programmes which are already in exploitation or well advanced, one can mention the VLT (four 8 m class telescopes), ALMA (a large interferometer for submm wavelengths, programmed as a worldwide collaboration for a first light around 2010) and SKA (square kilometer array, for cm radio wavelengths, beyond 2010). Space observatories are mandatory for all wavelength ranges which are blocked by the Earth's atmosphere (mainly water vapor, but also CO_2): X-rays, UV, many regions in the IR, submm wavelengths... Furthermore, space observatories provide continuous coverage, which is not the case for Earth based telescopes (unless a network of at least 3 such telescopes can be used). Interferometry in space is considered as a very promising course.
The big issue is indeed whether very high spatial resolutions should be reached through 50 m to 100 m ground based telescopes or by interferometry in space. There are many associated questions, such as the maximum size beyond which adaptive optics does not work any more. ESO (the European Southern Observatory) has launched a study so as to define what is the best course for 2020 and beyond. As you can see, there is still some time to decide."

MARK McCAUGHREAN:
"If you mean 100 metre telescopes on the ground and optical/infrared space telescopes beyond the JWST, then that's perhaps a little too hypothetical: let's get the JWST built first! Nevertheless, it is interesting to note that no-one is yet talking about a general-purpose successor to the JWST, even though it's probably time to start doing so. Why? Because large space missions take a long time to realise. Assuming a launch date in 2011 and the goal lifetime of 10 years, the JWST will have finished its mission by 2021, i.e. 18 years from now. However, the first serious discussions of the then NGST took place in 1989, i.e. 22 years before a 2011 launch. Thus, all things being equal, we should be planning for its successor already.
However, looking that far into the future, it's not yet clear whether there will indeed be any further general-purpose optical/infrared space observatories such as the HST and JWST. It seems more likely at present that efforts will have concentrated on specific high-priority goals, where specialised techniques are necessary.
Prime examples of this are the Darwin and Terrestrial Planet Finder (TPF) projects of ESA and NASA, respectively, which are aimed at detecting and taking spectra of earth-like planets, searching for evidence of life. As a baseline, Darwin and TPF use a small flotilla of passively-cooled telescopes to create a long-baseline infrared interferometer, which is needed to yield the required spatial resolution and contrast to see an Earth-like planet close to its parent star. However, the field of view of such an observatory will be tiny, meaning that it will be essentially useless for, say, cosmology experiments.
That's not to say there won't be equivalent missions focusing on cosmology, but it may well be that the Big Questions to be answered in astronomy in the 2020-2030 timeframe will require a series of dedicated missions, rather than one, general-purpose observatory. Importantly, the same may well be true on the ground: there is already some degree of discussion as to whether a filled-aperture 100 metre diameter telescope is indeed the answer to all our desires. Star and planet formation studies may well be better off with a longer-baseline version of the VLTI, for example.
In any case, it'll be interesting to see what the new generation of astronomers will be making of these facilities: I'll be getting ready to retire in 2026."

"SPACE OBSERVATORIES ARE MANDATORY FOR ALL WAVELENGTH RANGES WHICH ARE BLOCKED BY THE EARTH ATMOSPHERE."



"WITH THE EXISTING LIMITED BUDGET, IT WOULD NOT BE VERY WISE TO PUT IN ORBIT SPACE MISSIONS THAT DO THE SAME MORE OR LESS THAT COULD BE ACHIEVED WITH EARTH-BASED TELESCOPES, ESPECIALLY WITH ONGOING LARGE TELESCOPE PROJECTS."

LECTURERS AT THE "CANARY ISLANDS WINTER SCHOOLS OF ASTROPHYSICS"

I. Solar Physics (1989)

- OSCAR VON DER LÜHE (Institute of Astronomy, Zürich, Switzerland)
- EGIDIO LANDI ((Institute of Astronomy, Florence, Italy)
- DOUGLAS O. GOUGH (Institute of Astronomy, Cambridge, United Kingdom)
- GÖRAM SCHARMER (Stockholm Observatory, Sweden)
- HUBERTUS WÖHL (Kiepenheuer Institute, Freiburg, Germany)
- PIERRE MEIN (Observatory of Meudon, France)

II. Physical and Observational Cosmology(1990)

- VALODIO N. LUKASH (Space Research Institute, Moscow, Russia)
- HUBERT REEVES (CEN Saclay, France)
- BERNARD E. PAGEL (NORDITA, Copenhagen, Denmark)
- ANTHONY N. LASENBY (Cavendish Laboratory, Cambridge, United Kingdom)
- JOSE LUIS SANZ (University of Cantabria, Spain)
- BERNARD JONES (University of Sussex, United Kingdom)
- JAAN EINASTO (Astrophysical Observatory, Tartu, Estonia)
- ANDREAS G. TAMMANN (University of Basle, Switzerland)

III. Star Formation in Stellar Systems(1991)

- PETER BODENHEIMER (Lick Observatory, California, USA)
- RICHARD B. LARSON (Yale University, USA)
- I. FELIX MIRABEL (CEN Saclay, France)
- DEIDRE HUNTER (Lowell Observatory, Arizona, USA)
- ROBERT KENNICUT (Steward Observatory, Arizona, USA)
- JORGE MELNICK (ESO, Chile)
- BRUCE ELMEGREEN (IBM, USA)
- JOSE FRANCO (UNAM, Mexico)

IV. Infrared Astronomy (1992)

- ROBERT D. JOSEPH (University of Hawaii, USA)
- CHARLES M. TELESCO (NASA-MSFC, Alabama, USA)
- ERIC E. BECKLIN (University of California, Los Angeles, USA)
- GERARD F. GILMORE (Institute of Astronomy, Cambridge, United Kingdom)
- FRANCESCO PALLA (Astrophysical Observatory, Arcetri, Italy)
- STUART R. POTTASCH (University of Groningen, The Netherlands)
- IAN S. McLEAN (University of California, Los Angeles, USA)
- THIJS DE GRAAUW (University of Groningen, The Netherlands)
- N. CHANDRA WICKRAMASINGHE (University of Wales, Cardiff, United Kingdom)

V. The Formation of Galaxies (1993)

- SIMON D. M. WHITE (Institute of Astronomy, Cambridge, United Kingdom)
- DONALD LYNDEN-BELL (Institute of Astronomy, Cambridge, United KIngdom)
- PAUL W. HODGE (University of Washington, USA)
- BERNARD E. J. PAGEL (NORDITA, Copenhagen, Denmark)
- TIM DE ZEEUW (University of Leiden, The Netherlands)
- FRANÇOISE COMBES (DEMIRM, Observatory of Meudon, France)
- JOSHUA E. BARNES (University of Hawaii, USA)
- MARTIN J. REES (Institute of Astronomy, Cambridge, United Kingdom)

VI. The Structure of the Sun (1994)

- JOHN N. BAHCALL (Institute for Advanced Study, Princeton, New Jersey, USA)
- TIMOTHY M. BROWN (High Altitude Observatory, NCAR, Boulder, Colorado, USA)
- JORGEN CHRISTENSEN-DALSGAARD (Institute of Physics and Astronomy, University of Århus, Denmark)
- DOUGLAS O. GOUGH (Institute of Astronomy, Cambridge, United Kingdom)
- JEFFREY R. KUHN (National Solar Observatory, Sacramento Peak, New Mexico, USA)
- JOHN W. LEIBACHER (National Solar Observatory, Tucson, Arizona, USA)
- EUGENE N. PARKER (Enrico Fermi Institute, University of Chicago, Illinois, USA)
- YUTAKA UCHIDA (University of Tokio, Japan)

VII. Instrumentation for Large Telescopes: a Course for Astronomers (1995)

- JACQUES M. BECKERS (National Solar Observatory, NSO-NOAO, USA)
- DAVID GRAY (University of Western Ontario, Canada)
- MICHAEL IRWIN (Royal Greenwich Observatory, Cambridge, United Kingdom)
- BARBARA JONES (Center for Astrophysics and Space Sciences, University of California San Diego, La Jolla, USA)
- IAN S. McLEAN (University of California, Los Angeles, USA)
- RICHARD PUETTER (Center for Astrophysics and Space Sciences, University of California, San Diego, La Jolla, USA)
- SPERELLO DI SEREGO ALIGHIERI (Arcetri Astrophysical Observatory, Florence, Italy)
- KEITH TAYLOR (Anglo-Australian Observatory, Epping Laboratory, Australia)

VIII. Stellar Astrophysics for the Local Group: a First Step to the Universe (1996)

- ROLF P. KUDRITZKI (University of Munich, Germany)
-CLAUS LEITHERER (Space Telescope Science Institute, Baltimore, USA)
- PHILIP MASSEY (Kitt Peak National Observatory, Tucson, USA)
- BARRY F. MADORE (Extragalactic Database Infrared Processing and Analysis Center (IPAC), NASA/JPL & Caltech, Pasadena, USA)
- GARY DA COSTA (University of Australia, Camberra, Australia)
- CESARE CHIOSI (University of Padua, Italy)
- MARIO L. MATEO (University of Michigan, USA)
- EVAN SKILLMAN (University of Minnesota, USA)

IX. Astrophysics with Large Databases in the Internet Age (1997)

- GEORGE K. MILEY (Leiden Observatory, Netherlands)
- HEINZ ANDERNACH (University of Guanajuato, Mexico)
- CHARLES TELESCO (University of Florida, USA)
- DEBORAH LEVINE (ESA, Villafranca del Castilo, Madrid, Spain)
- PIERO BENVENUTI (ST-SCF, Munich, Germany)
- DANIEL GOLOMBEK (Space Telescope Institute, Baltimore, USA)
- ANDREW C. FABIAN (Institute of Astronomy, Cambridge, United Kingdom)
- HERMANN BRUNNER (Institute of Astrophysics, Postdam, Germany)

X. Globular Clusters (1998)

- IVAN R. KING (University of California, USA)
- STEVEN R. MAJEWSKY (University of Virginia, USA)
- VITTORIO CASTELLANI (Astronomical Observatoryof Capodimonte, Italy)
- RAFFAELE GRATTON (Astronomical Observatory of Padova, Italy)
- REBECCA A. W. ELSON (Institute of Astronomy, Cambridge, United Kingdom)
- MICHAEL W. FEAST (Cape Town University)
- RAMÓN CANAL (University of Barcelona, Spain)
- WILLIAM E. HARRIS (Macmaster University, Canada)

XI. Galaxies at high Redshift" (1999)

- JILL BECHTOLD (University of Arizona, USA)
- GUSTAVO BRUZUAL (CIDA, Venezuela)
- MARK E. DICKINSON (Space Telescope Institute, Baltimore, USA)
- RICHARD S. ELLIS (California Institute of Technology, USA)
- ALBERTO FRANCESCHINI (University of Padova, Italy)
- KEN FREEMAN (Mount Stromlo Observatory, Australia)
- STEVE G. RAWLINGS (Oxford University ,United Kingdom)
- SIMON WHITE (Max-Planck Institute for Astrophysics, Germany)

XII. Spectropolarimetry in Astrophysics (2000)

- ROBERT R.J. ANTONUCCI (University of Santa Bárbara, USA)
- ROGER D. BLANDFORD (National Solar Obaservatory, USA)
- MOSHE ELITZUR (University of Kentucky, USA)
- ROGER H. HILDEBRAND (Enrico Fermi Institute, University of Chicago, USA)
- CHRISTOPH U. KELLER (National Solar Observatory, USA)
- EGIDIO LANDI DEGL'INNOCENTI (University of Florence, Italy)
- GAUTHIER MATHYS (European Southern Observatory, Chile)
- JAN OLAF STENFLO (Swiss Federal IInstitute of Technology, Switzerland)

XIII. Cosmochemistry: the melting pot of elements (2001)

-JOSÉ CERNICHARO (Structure of Matter Institute, CSIC, Spain)
-DONALD R.GARNETT (Steward Observatory, University of Arizona, USA)
-DAVID L. LAMBERT (University of Texas at Austin, USA)
-NORBERT LANGER (Utrecht University, The Netherlands)
-FRANCESCA MATTEUCCI (University of Trieste, Italy)
-MAX PETTINI (Institute of Astronomy, University of Cambridge, United Kingdom)
-GRAZYNA STASINSKA (Observatory of Paris-Meudon, France)
-GARY STEIGMAN (Ohio Sate University, USA)

XIV. Dark Matter and Dark Energy in the Universe (2002)

LAWRENCE M. KRAUSS (Case Western Reserve University, Ohio, USA)
PHILIP MAUSKOPF (University of Wales, Cardiff, United Kingdom)
JOHN PEACOCK (Royal Observatory of Edinburgh, United Kingdom)
BERNARD SADOULET (University of California, Berkeley, USA)
RENZO SANCISI (Bologna Astronomical Observatory, Italy)
BRIAN SCHMIDT (The Australian National University, Australia)
PETER SCHNEIDER (University of Bonn, Germany)
JOSEPH SILK (University of Oxford, United Kingdom)

OTHER EVENTS

Sunday 16th:
Registration and Welcoming cocktail.
Tuesday 18th:
Visit to the Instituto de Astrofísica in La Laguna. Public lecture by Prof. André Balogh: "Space Storms" at the Science Museum. Welcoming reception at the Instituto de Astrofísica.
Thursday 20th
Working visit to the Teide Observatory (Tenerife).
Tuesday 25th:
Visit to the Monje Winelodges
Thursday 27th:
Official closing dinner.

PUBLICATIONS

CANARY ISLANDS WINTER SCHOOLS OF ASTROPHYSICS

Cambridge University Press has published the following volumes on previous Winter Schools.

1. Solar Observations: Techniques and interpretation. *F. SÁNCHEZ, M. COLLADOS & M. VÁZQUEZ.*
2. Observational and Physical Cosmology. *F. SÁNCHEZ, M. COLLADOS & R. REBOLO.*
3. Star Formation in Stellar Systems. *G. TENORIO-TAGLE, M. PRIETO & F. SÁNCHEZ.*
4. Infrared Astronomy. *A. MAMPASO, M. PRIETO & F. SÁNCHEZ.*
5. The Formation and Evolution of Galaxies. *C. MUÑOZ-TUÑÓN & F. SÁNCHEZ.*
6. The Structure of the Sun. *T. ROCA-CORTÉS & F. SÁNCHEZ.*
7. Instrumentation for Large Telescopes. *J.M. RODRÍGUEZ-ESPINOSA, A. HERRERO & F. SÁNCHEZ.*
8. Stellar Astrophysics for the Local Group. *A. APARICIO, A. HERRERO & F. SÁNCHEZ*
9. Astrophysics with Large Data Bases. *M. KIDGER, I. PÉREZ-FOURNON & F. SÁNCHEZ*
10. Globular Clusters. *I. Pérez-Fournon, C. MARTÍNEZ ROGER & F. SÁNCHEZ.*
11. Galaxies at High Redshift. *I. Pérez-Fournon, M. BALCELLS, F. MORENO-INSERTIS & F. SÁNCHEZ.*
12. Astrophysical Spectropolarimetry. *J. TRUJILLO BUENO, F. MORENO-INSERTIS & F. SÁNCHEZ.*

XV CANARY ISLANDS WINTER SCHOOL OF ASTROPHYSICS

"PAYLOAD AND MISSION DEFINITION IN SPACE SCIENCES"

SNAPSHOTS



























PARTICIPANTS IN THE XV CANARY ISLANDS WINTER SCHOOL OF ASTROPHYSICS

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