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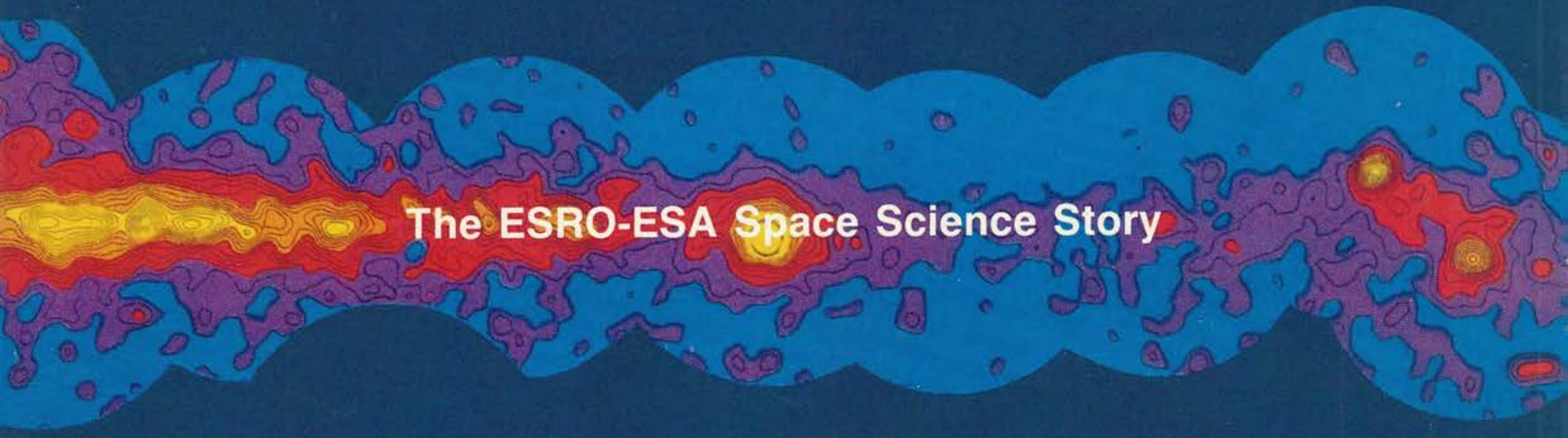
SOME PERSONAL REMINISCENCES -



The ESRO-ESA Space Science Story

Twenty-five years of European cooperation

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ESRO-ESA Space Science

The editor and authors wish to thank those institutes and individuals whose illustrations are used in this book. In some cases we regret that we have not been able to identify them and therefore have not been able to give due acknowledgement.

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ESRO-ESA Space Science ESA BR-66

SOME PERSONAL REMINISCENCES -

The ESRO-ESA Space Science Story

Twenty-five years of European cooperation

Dedicated to the late Dr. Ernst Trendelenburg who gave so much to ensure the success of the European Space Science venture

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ESRO-ESA Space Science

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ESRO-ESA Space Science - Chapter 1

Some personal thoughts on twenty-five years of European cooperation

Professor Johannes Geiss

Early Beginning and Evolution of the European Space Research Cooperation

The Founding Fathers of ESRO pictured at their decisive meeting in Meyrin, December 1960

In the early 1960s, a number of European scientists and other personalities met at Meyrin near the Lake of Geneva and initiated the forming of a European space research organization. Among these 'founding fathers' as we may well call them, pictured above, many a prominent scientist can be recognized. I wish to mention here one, the late Sir Harry Massey, standing in the foreground, who did so much to launch the European cooperation in space and to maintain it when adverse winds were encountered.

ESRO, the European Space Research Organization came into legal being in 1964; originally there were 10 member states. It was in a large part thanks to the scientific, technical and managerial experience gained by ESRO, and the confidence built by ESRO's successes in the mind of the public and in governmental circles, that the purely scientific organization could be enlarged, and merged with ELDO, the European Launcher Development Organization, into the European Space Agency (ESA). And today ESA's programme includes all important branches of space technology and science.

There has been much applause for ESRO and ESA at times of success, but also dissatisfaction has been voiced, and there have been times when the basic concept of European cooperation in space was in jeopardy. Today, looking back 25 years, it is clear that on balance this cooperation has been a success. Very prominently in this success stands the scientific programme, which is the subject of this article. Criticism notwithstanding, none of the original member states has left. On the contrary, four more countries, first Ireland, then more recently Austria, Norway, and Finland, have joined the organisation.

The founding fathers in the 1960s made two important and wise decisions. One was to create a truly international European organisation with a programme that was not merely the sum of national plans or wishes. A programme was created which the nations support in relation to their gross national product. Individual projects were defined and selected by groups of European scientists, and they were carried through by experimenter teams that were chosen strictly on a competitive basis among European proposers. Thus, any idea of national quotas or other forms of protection of real or imagined national interest were avoided from the beginning.

This principle of European-wide competition and selection corresponds to the reality of the scientific world. The scientific community is not structured according to national borders, but according to disciplines and fields of interest. There is fierce competition not among national groups or academies but among international groupings who want to fly an X-ray satellite or a UV satellite or to investigate a planet. The result of this competitive climate was that the scientific programme of ESRO and ESA gained worldwide recognition and became qualitatively the equal of the programmes of the large space powers which had started into space much earlier.

The second decision of the founding fathers was that ESRO would provide flight opportunities for the scientists in the member states but would not give funds to laboratories or finance the flight instruments provided by the scientists.

The ESRO logo with the flags of the ten member states

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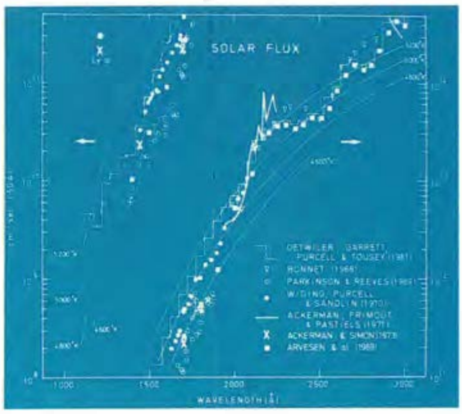
This forces the scientific group to compete not only for their place on the European spacecraft but also for national funding to build the experiment, to carry it out, to evaluate the data and to interpret them. Hard as it may be for the working space scientist, this funding system has assured that the new scientific activity — space science — gained acceptance in the European countries, in the scientific community at large, and by the national funding agencies. Furthermore, the system made the European scientists independent of ESA. They have the choice of flying with ESA, NASA or the Soviet space programme, or with their national programmes which exist in the large countries, and even in some of the smaller countries.

Because of their independence from ESA for funding and for flight opportunities, the European scientists are more than users of ESA's services. They are partners providing the scientific ideas, defining the goals of a mission, and contributing decisively to its successful completion. In this respect, the science programme of ESA is unique. There is no other programme where the commitment of outsiders from all over Europe is so strong and their competence and active cooperation is so essential.

The first programme to be established by ESRO was the sounding rocket programme. Using commercially available rockets, the organisation was helped by the experimental and operational experience that scientists had gained earlier in sounding rocket campaigns conducted in the Sahara, from the base Salto di Quirra on Sardinia, from the Northern bases at Kiruna in Sweden and Andoya in Norway, and in other such campaigns. Other scientific groups, though scientifically well prepared and motivated to engage themselves in the new possibilities that space offered, gained invaluable practical experience through this programme. Altogether, ESRO launched more than 180 rockets of various sizes before the programme was terminated in 1972. Sounding rocket research has continued since that time in national and multinational campaigns. The results demonstrate that this technique has not lost its significance.

The first ESRO satellite, ESRO-2, was successfully launched in 1968 by a Scout rocket provided as a gift by NASA, the National Aeronautics and Space Administration of the United States. Later launches were purchased for ESRO/ESA satellites from NASA. The first scientific mission of ESA to be launched by ESA's own rocket, Ariane, was GIOTTO, the spacecraft that visited Halley's comet. Even with the early small satellites of the ESRO and HEOS class, important results were gained which gave ESRO and the participating European scientists a respected place on the international market of scientific results.

Barium release over Kiruna, Sweden. Barium is a rather exceptional element in as much as both its atoms and its ions emit visible light. This allows dynamic processes in the upper atmosphere to be seen and to be studied. The ions (red) can freely move along magnetic field lines, but not readily across them. This leads to their elongated distribution. The atoms (blue) spread out isotropically, and they are carried away in the neutral wind. Comparison of successive pictures such as that shown above allow wind velocities and electric field strengths to be derived, and plasma instabilities to be studied.



The solar ultraviolet radiation is responsible for excitation, ionisation, and heating of atoms and molecules in the upper atmosphere. Thus a profound knowledge of averages and variations of the solar UV flux and spectrum forms the basis for understanding energetics and dynamics in the upper layers of our atmosphere. The diagram shows results (crosses and heavy line) of two rocket flights to an altitude of about 250 km from the Salto di Quirra range in Sardinia on 28 February 1972. For the purpose of studying time variations in the solar UV, results of earlier flights were included in this figure. (courtesy Institut d'Aéronomie Spatiale, Belgium)

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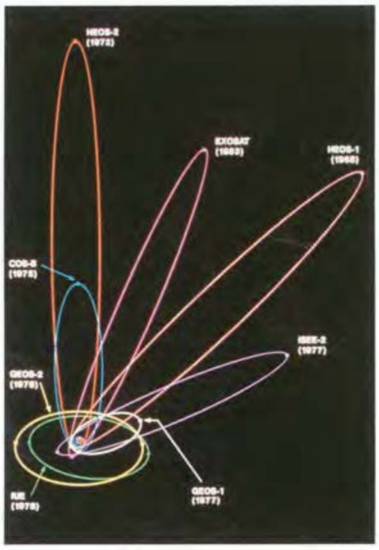
When ESRO started, other agencies had already flown many satellites, most of them in non-polar orbits. The ESRO/ESA satellites in low earth orbit (LEO) were all nearly polar. This reflects the determination of the European scientists to contribute relevant and original results from the beginning, and not simply to run after their Soviet and U.S. colleagues who had a head start of many years. Satellites in polar orbit not only allow the study of high latitude phenomena, but they also fly over all regions of the Earth every 12 hours, thus giving a global coverage of observations.

This was due to the work by ESRO project engineers and by industry, and also to the efforts made by the scientists cooperating in these novel European collaborative ventures. These scientists freely provided ideas that defined the direction of the mission, and they built experiments which were often of novel design yet, almost without exception, they were reliable. This was, of course, not a surprise, because by the 1960s the European scientific communities had regained an excellent reputation in a broad range of theoretical and experimental research, proof of which are the success of CERN and the discoveries by balloon flights of elementary particles produced in the stratosphere by cosmic rays.

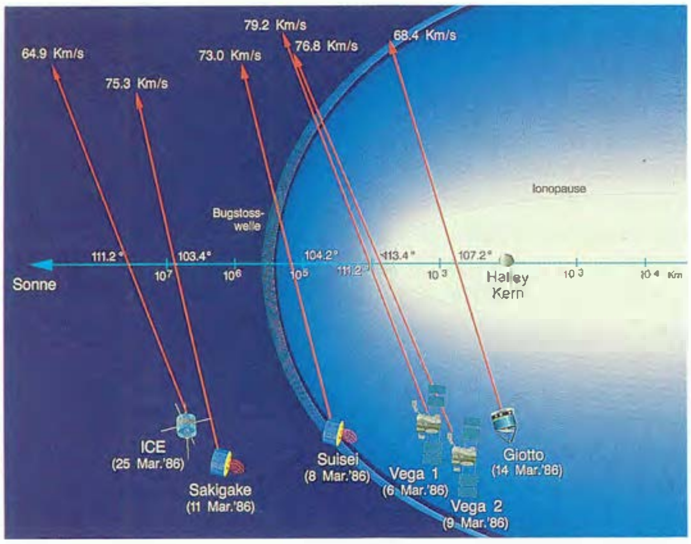
In the 1970s, satellites grew in complexity, size and cost. The excellent record of ESA and industry continued, the programme proceeded almost without flaw. The few setbacks encountered were met with remarkable technical and organisational competence. Without overstating the case, it may be said that each of ESA's missions in the seventies and eighties carried sophisticated and often novel scientific experiments which in their time provided the most advanced science in the particular field to which the mission was dedicated.

Before closing this introduction, it is important to remind the reader that parallel to ESA's programme, strong and scientifically significant national space projects were carried out. An account of their results is not the topic of this article. It must be stressed, however, that these programmes have provided many European groups with flight opportunities, though not in all countries. Thus, these national programmes helped to close the gaps between ESA opportunities which for any particular field are very long. ESA's low frequency of scientific missions reflects the organisation's science budget, which is low if considered as an effort on a continent scale; and which is small if one compares it to ESA's overall expenditure or to the space science efforts of the two large space powers.

The scarcity of flight opportunities has also been alleviated by the United States' and the Soviet Union's generous offer of flight opportunities to Western European experimenters. The experimenters could participate as equal partners in some of the most fascinating space endeavours, and this is wholeheartedly acknowledged here.



Over the years, ESRO/ESA has launched a set of high altitude satellites which have yielded impressive results. The orbits of the satellites devoted to solar terrestrial relation and magnetospheric studies (HEOS, GEOS, ISEE) cover most of the important regions in the Earth's environment: the approaching solar wind, the bow shock, the magnetosphere, the ring current, and the plasmasphere. In the case of astronomical satellites (COS-B, EXOSAT), the eccentric orbit allowed observations to be made away from any interference by the Earth, and at the same time, it allowed for long uninterrupted observation times, an important asset for the study of variable objects.



ESA's Giotto led an international fleet of spacecraft as the scientists of the world collaborated to obtain the most detailed data ever achieved on the composition and environment of a comet

It is not the intention of this article to provide a balanced or even complete overview of all scientific results obtained with ESA's spacecraft. Instead, I have chosen four major disciplines, named in the heading of the following sections, and I remark on their wider significance, and give a few examples of ESA's contribution to the advances in knowledge and insight in those fields.

Sun-Earth Relation and the Earth's Plasma Environment

Research in this field did not begin with the space age. The plasma surrounding the Earth and perturbations on the Sun have reverberations that have been observed and studied by scientists for a long time. The changes in the magnetic field of the Earth — the magnetic storms and substorms — were thought to be caused by a ring current far above the atmosphere, the strength of which was correctly inferred to be influenced by the Sun. Observers had earlier realised that the light of the aurorae borealis is caused by particles which obtained their energy at much higher altitude. It was recognised in the twenties that long distance radio communications depend on an ionised layer in the upper atmosphere. The ability of this ionosphere to reflect radio waves depends on the density of its electrons and ions; the density in turn, is affected by solar disturbances and magnetic storms.

Sounding rockets and satellites opened up the possibility to look and investigate directly the causes of these phenomena. The result is that we have obtained an understanding of the vast plasma regions surrounding us. We have been able to follow the causal chain which starts with the solar atmosphere; the source of the solar wind and extreme ultraviolet radiation. The latter heats and ionises the upper atmosphere of the Earth, whereas the solar wind pressure limits the influence of terrestrial magnetism to a volume that we call the magnetosphere.

The aurora borealis has been observed in Nordic countries with fascination and with fear throughout recorded history and probably even earlier. It belongs to the class of natural phenomena such as the solar eclipses or the yearly Nile inundations which inspired mankind's quest for understanding nature. As suspected by the founders of geomagnetic research and proved in the space age, the aurorae are the result of processes in the vast volume of the plasma environment of the Earth called magnetosphere. Particles, i.e. electrons and ions of both solar and terrestrial origin are accelerated in the magnetosphere and precipitate at high geomagnetic latitude. In colliding with atmospheric molecules and atoms they produce the light seen in the picture.

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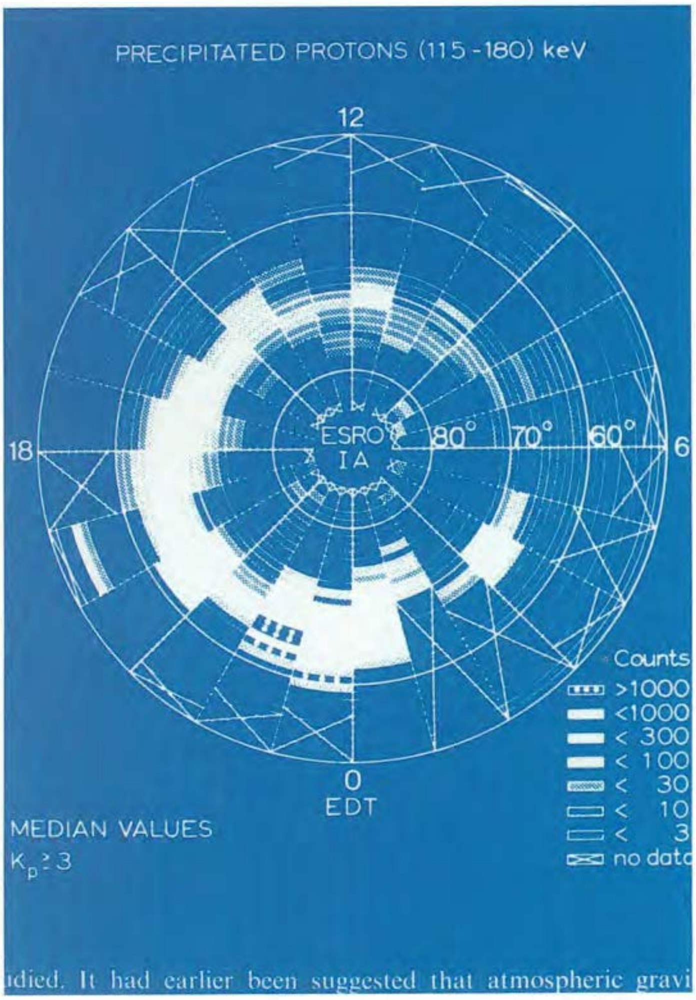
The weak magnetism carried by the solar wind is the ultimate cause of magnetic storms, because the connecting of solar and geomagnetic field lines lead to a piling up of magnetic energy in the geomagnetic tail which, when released, causes a chain of violent processes which are noticeable on Earth as magnetic perturbations.

All these events are governed by typical plasma processes. In the solar wind and most regions of the magnetosphere, the gas is fully ionised, giving rise to plasma phenomena which are totally different from phenomena that occur in a neutral gas. The collisionless bow shock in front of the Earth is an example that some aspects of plasma physics can be most ideally studied in space.

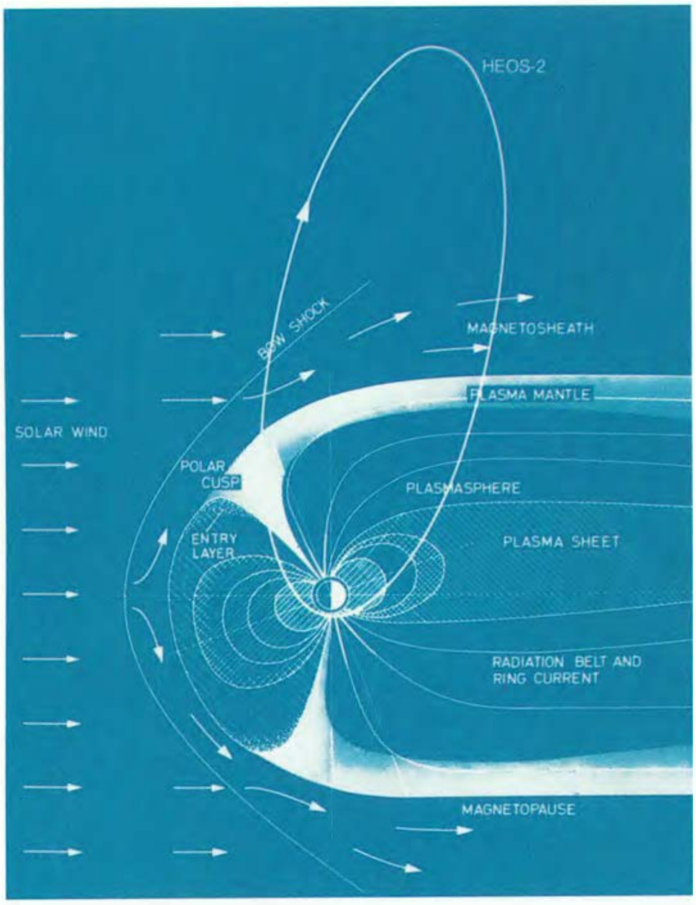
The plasma state is the normal state of matter in the Universe. No wonder then that what has been learned in the plasma environment surrounding the Earth finds many analogies and applications in astronomy. Magnetic structures beyond the solar system may be much larger, such as those in the galaxy, or much smaller, like the magnetospheres of neutron stars, but the laws of plasma physics are the same. Thus with proper rules of scaling, direct, near-Earth observations can help us in understanding the processes in those far-away objects.

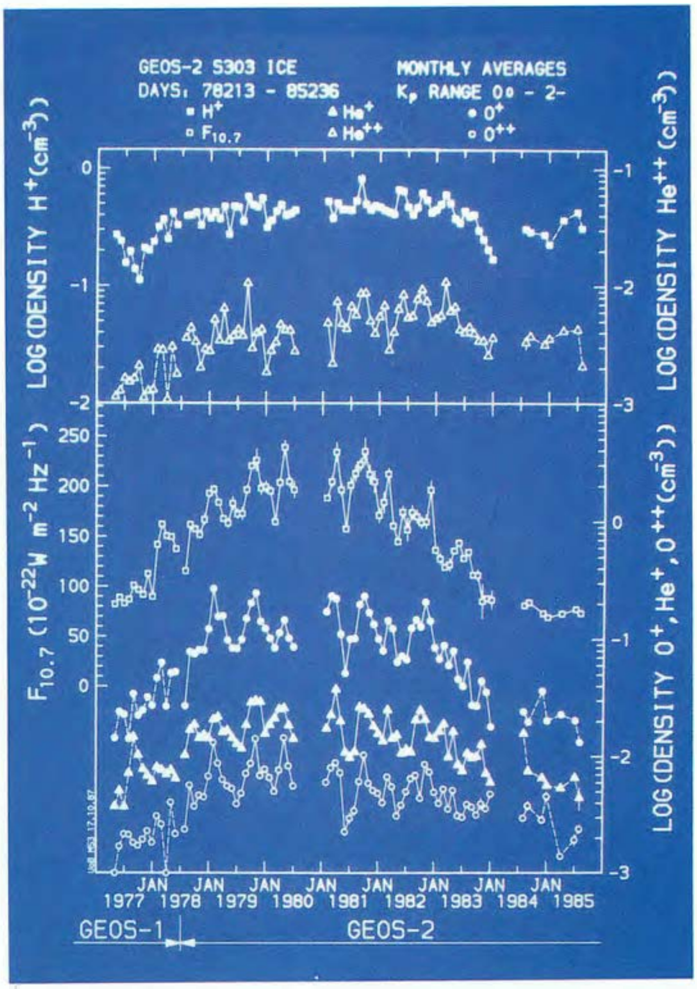
The contributions by ESRO, ESA and national European programmes in the fields covered in this section are manifold. Among the outstanding ESRO or ESA contributions, there are the global observations from ESRO-1A of the light emitted by the aurorae, revealing ringlike structures, the discovery by HEOS-2 of the plasma mantle and its role in supplying the magnetosphere with ions of solar wind origin, and the discovery by GEOS-1 and GEOS-2 of the strong response of the magnetospheric ion composition to changes in the solar extreme ultraviolet emission. Finally, the GEOS-2 satellite, because of its continuous data link allowed unprecedented plasma studies to be carried out.

GEOS-1 was the first scientific spacecraft to require a major orbital manoeuvre. This debut was to turn into a major challenge for ESOC (the European Space Operations Centre): the third stage of the Thor Delta launcher separated prematurely, and it was only by chance that the spacecraft achieved a stable orbit from which, however, the geostationary orbit could not be reached by the GEOS apogee motor. The choice was between a 12-hour and a 24-hour orbit, and the decision had to be taken quickly in view of the degrading effects of the radiation belts.



Observations of aurorae from the ground are local in nature and limited to darkness. The global view from space reveals ringlike zones — the auroral ovals around the poles. Their position changes with the level of geomagnetic activity. In situ measurements above the atmosphere allow directly to study the global distribution of precipitating particles, their nature and their energies. The figure shows the distribution of precipitating protons with energies of (115—180) keV at the time of moderate geomagnetic activity as measured by an experiment onboard ESRO-1A. Electrons tend to precipitate at higher latitudes than protons. The exact nature of the particle acceleration processes and their location in the magnetosphere is still the subject of investigation.





The HEOS-2 orbit was chosen for the investigation of the polar cusp regions. From the topology of magnetic fields in these regions where plasma of solar and terrestrial origin meet, it was suspected that solar wind ions could enter here into the magnetosphere. HEOS-2 proved this hypothesis to be right. However, the circumstances of entry were surprising. In the entry region, solar wind and particles of terrestrial origin mix. A flow — the plasma mantle — develops in which these particles are transported towards the geomagnetic tail from where they return and populate the plasmasheet.

The magnetosphere of the earth is filled with particles of solar and atmospheric origin. GEOS-1 and 2 allowed identification and monitoring a set of solar wind (H^+, He^{++}) and terrestrial (H^+, He^+, O^+, O^{++}) ions which gave rise to studies of the relative contributions of these two sources to the particle populations in the magnetosphere. At geostationary altitude, the absolute density of ions as well as their mixing ratio vary with local time and also with the level of geomagnetic and solar activity. The figure shows the influence of the solar extreme ultraviolet (EUV) intensity (represented by the 10.7 cm flux): The terrestrial ion densities increase with solar activity, and as a result display a remarkable 'solar cycle effect'. In particular, O^+ shows a close correlation with solar EUV. The reason is that EUV deposits its energy in the high atmosphere and causes heating and ionization. This interpretation is consistent with the absence of the clear correlation between the solar EUV and ions of solar wind origin.

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Ernst Trendelenburg, then the Director of ESA's Science Programme, thrived on this kind of emergency situation. Helped by the fast Concorde and not caring excessively for the advice of the experimenters, he made the decision to go for the 12-hour orbit, and this orbit was achieved by the operations team of ESOC in beautifully executed manoeuvres. Taken together, GEOS-1 in its elliptical orbit and GEOS-2 in its circular geostationary orbit have allowed European scientists to address a wide range of topics in magnetic physics.

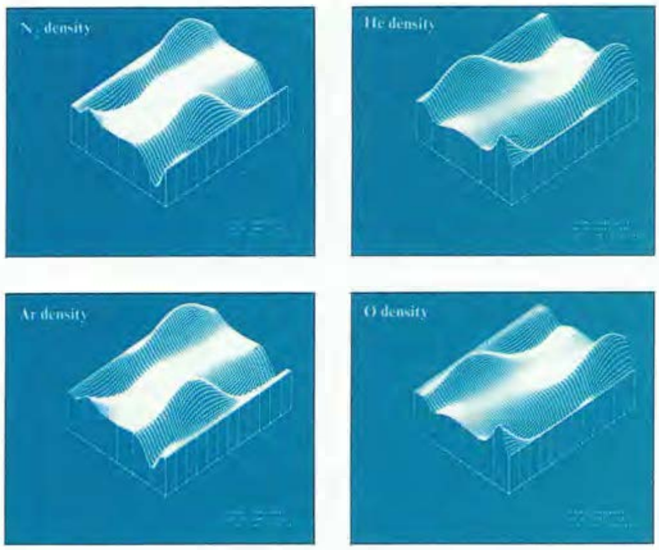
Distinction between variations in space and time is important but difficult in any rapidly shifting plasma environment. An important step was made by the NASA/ESA satellite-pair ISEE-1 and ISEE-2 which allowed, especially, processes at plasma boundaries and discontinuities to be studied.

The large space agencies, NASA, INTERKOSMOS, ESA and ISAS (the Institute of Space and Astronautical Sciences of Japan), have agreed to cooperate on a comprehensive solar-terrestrial science programme for the mid-1990s. ESA will make a substantial contribution to this undertaking: the CLUSTER mission consisting of four satellites will fly in tetrahedal formation and give perfect separation of variations in space and in time for a certain class of plasma processes. The solar observatory SOHO is a joint ESA/NASA programme. From its position near the L1 point more than a million kilometers away from the Earth in the solar direction, SOHO will provide continuous data which are expected to be relevant for all solar science: the interior of the Sun, its atmosphere, the solar wind and solar terrestrial relations.

Atmospheric Research

Space technology has not only enabled direct in-situ observations of the ionosphere and magnetosphere, but it has also revolutionised the research of the neutral atmosphere down to the lowest strata.

Even in the upper atmosphere, the density of neutral molecules and atoms is much higher than the density of ions until altitudes of several thousand kilometres are reached, where the ion density begins to surpass the neutral density. Thus, in the ionosphere the charged component may dominate electromagnetic and plasma phenomena, but regarding the mass and energy content, the neutral component is more important. Therefore, not only ions but also neutrals have to be investigated in order to monitor and to understand the processes going on in the upper levels of our atmosphere. The European satellite ESRO-4 made a lasting contribution to our knowledge of the composition of the upper atmosphere. Like most of the European near-Earth satellites, ESRO-4 had a polar orbit and thus, because of the Earth's rotation, the satellite could readily study the composition in the upper atmosphere around the whole globe as a function of time. The mass spectrometer data of ESRO-4 have provided invaluable data for constructing models of the densities and temperatures in the upper atmosphere and for studying the response of the upper atmosphere to the changing solar activity.



The mass spectrometer on ESRO-4 was the first instrument to provide a global coverage of the composition of atoms and molecules in the upper atmosphere at altitudes between 240 and 320 km. The figure shows the densities of four important species for quiet solar conditions as a function of longitude and latitude averaged over the seasons and over daily variations. The variations of the heavier species Ar and N_2 go in opposite direction to those of the lighter species O and He. A closer inspection of the profiles shows a relation to geomagnetic coordinates which points to the influence of ions on the distribution of neutral species at these altitudes. The ESRO-4 data provided an invaluable basis for developing models of the upper atmosphere which give temperature density and composition profiles as a function of local time of season and of solar activity. These models are important for many scientific studies and they are also used for predicting satellite lifetimes. (courtesy University of Bonn)

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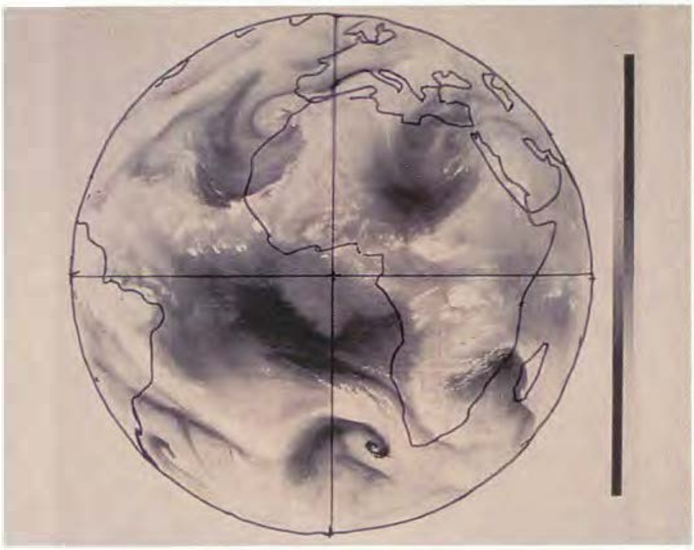
These data and the models built from them are not only of interest to atmospheric scientists; they also provide information needed for a variety of other areas in pure and applied science. For instance, they form the basis for interpreting the varying supply of atmospheric constituents to the magnetosphere, and they allow predictions to be made of the orbital decay of near-Earth satellites.

Concerning the middle atmosphere, intense research with sounding rockets continues. Europeans contribute significantly in this field which is of growing theoretical and practical importance, but the work progresses outside the ESA programme.

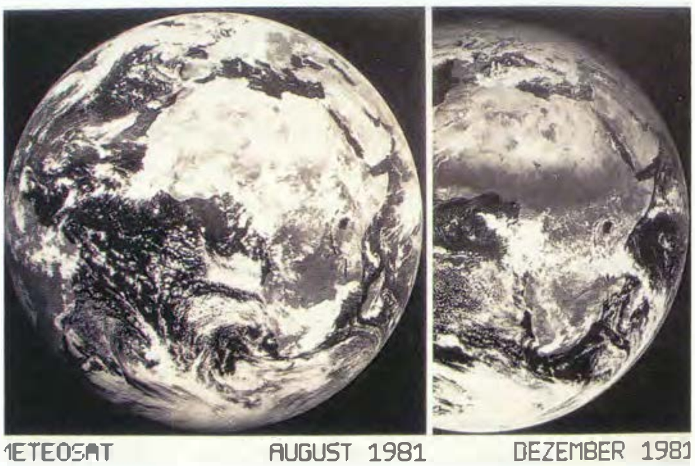
Deep down in the atmosphere, in situ measurements by satellites or sounding rockets become impossible. However, the atmosphere at lower levels can be studied by photography and remote sensing at many wavelengths, particularly in visible light, in the infrared, and at radio frequencies. The main advantage of photography and remote sensing from space over ground based observations is to be seen in the ease with which global data can be taken, and an overview of the whole Earth or a large part of it can be directly obtained. To exploit this capability, one needs remote sensing devices which give absolute data on temperatures, winds and partial densities of constituents, and all these parameters as a function of altitude. In the area of sensor development, much progress has been made during the last two decades but much still needs to be done.

In studies of our atmosphere, science and application cannot be easily differentiated, and they should not be. In meteorology and climatology, in studies of the exchange of constituents and energy between the atmosphere, the oceans and the biosphere, fundamental problems must still be resolved before many practical questions can be answered with confidence. On the other hand, questions posed by practitioners often stimulate basic research, and this is particularly true in the atmospheric sciences. Many examples of the close relationship between fundamental research and practical applications can be found in studies that use Meteosat data, which can, amongst many other things, be interpreted by climatologists looking into problems faced by developing countries. Water vapour data have to be available for the energetics and the motion of air masses to be described.

ESA continues with a vigorous programme of Earth observations and Earth sciences. The Meteosat series developed by ESA is continued and operated by Eumetsat. ESA itself intends to launch the satellite ERS-1 late in 1990. This satellite is devoted to studies of the atmosphere and the oceans.



The water vapour content in the atmosphere recorded by Meteosat. The invisible water vapour in the atmosphere is not only a potential source of precipitation, but it also carries an important content of latent heat. At low altitude, this latent energy content is usually much higher than for instance the energy of wind motions. The latent heat of water vapour is of dominant importance in meteorological phenomena as disparate as alpine Föhn winds or tropical storms.



The seasonal motion of the intertropical conversion zone causes a belt of clouds and rain to be displaced from the south during the winter (left picture) to the north during the summer (right picture). The summer rain in the Sahel zone, as well as in the source region of the blue Nile in Ethiopia, depends critically on the extent of this northward motion. Thus, the droughts in the Sahel zone and those in ancient Egypt have a common cause.

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These two fields are intimately connected because of the fast and important interchange of energy, momentum, water vapour and other constituents between the two. ERS-1 may be considered to be both a research and an application satellite. Hopefully scientists and those who apply the data will work closely together.

Galactic and Extragalactic Astronomy and Astrophysics

Astronomy is among the oldest branches of science. Modern thinking, world outlook, and the scientific method as we know it, were built to a great extent on observations and their interpretations of the world around us. It is remarkable that the momentous step from the geocentric to the heliocentric system, the realisation of the immense size of the Universe filled with countless stars and galaxies, and the recognition that we live in an expanding Universe all rested on observations made in a narrow range of the electromagnetic spectrum, the visible light.

For earthlings, visible light assumes special significance: the Sun radiates a large fraction of its energy as visible light. The atmosphere is highly transparent to this part of the spectrum, and our eyes — adapted through evolution — are sensitive to it.

Visible light does not have this singular importance in all corners of the Universe. Stars much more massive than the Sun emit most of their energy as ultraviolet radiation, and other more exotic objects in the sky emit large quantities of X- and gamma-rays. These parts of the electromagnetic spectrum became observable only with the advent of the space age, and a new and totally different look at the Universe could be taken. It was found that in addition to the countless well-behaved stars like the Sun there is a world of bizarre and often violent objects: Quasars, stars throwing off a large fraction of their mass, and stars exploding at the end of their lifetime, leaving behind a small remnant, which can be a neutron star with unimaginably high density or even a black hole.

To be sure, astronomers and astrophysicists have been correctly using the rather limited information carried by visible light and radio waves from these objects to recognize their existence and to infer something about their nature. However, observations from space covering the large range of electromagnetic radiation from the infrared to the most energetic gamma-rays enabled comprehensive studies of these objects to be carried out which defy our imagination.

Even earlier, cosmic ray studies from the ground and from balloons had revealed the existence in the galaxy of particle acceleration processes, and cosmic ray physicists had concluded that the conversion of energy into kinetic energy of the particles must be very efficient. The same was found for the energetic part of the electromagnetic spectrum which is emitted more readily and intensely from a variety of objects than had been suspected.

Early ESRO and ESA sounding rockets and satellites carried cosmic ray instruments and also detectors for non-visible electromagnetic radiation, and they made significant contributions to high energy astrophysics. The first ESA satellite largely dedicated to the study of ultraviolet astronomy was TD-1. The largest and most ambitious European project up to that time, TD-1 suffered a severe setback. Its two tape recorders ceased to function after a short time in space.

As in the case of the near-fatal launch of GEOS-1, the European Space Operations Centre (ESOC) was up to the occasion at this critical moment. Telemetry receiving stations all over the world were directed at this satellite with the generous help of other countries, and ESA itself installed some small stations in remote places. In the end, a high percentage of the data taken by TD-1 was recovered. Space agencies are judged in the public by their successes, but they should be equally measured by the way they react to setbacks, and in this instance, ESA reacted perfectly. To this day, TD-1 has provided the only total all-sky survey in the ultraviolet radiation, the catalogue of its ultraviolet observations contains 58,000 stars.

The two astronomical satellites to follow were COS-B and EXOSAT. Both scientifically and technically advanced satellites at the time of their launch, and they conquered first place for a while in their respective fields of gamma-ray and X-ray astronomy.

After TD-1, the European UV astronsmers could work with the data from the IUE, the International Ultraviolet Explorer. IUE is a joint project of NASA, the United Kingdom, and ESA. A UV telescope of high quality was available to European observers, and during the extremely long lifetime — 12 years so far — they have published numerous significant papers.

Even before Sputnik was launched, the potential of satellites for astronomical observations outside the visible part of the spectrum was well recognised and advertised. What was not foreseen was the importance that observations from satellites were to assume even in the visible wavelength range. In 1990, the Hubble Space Telescope was launched.

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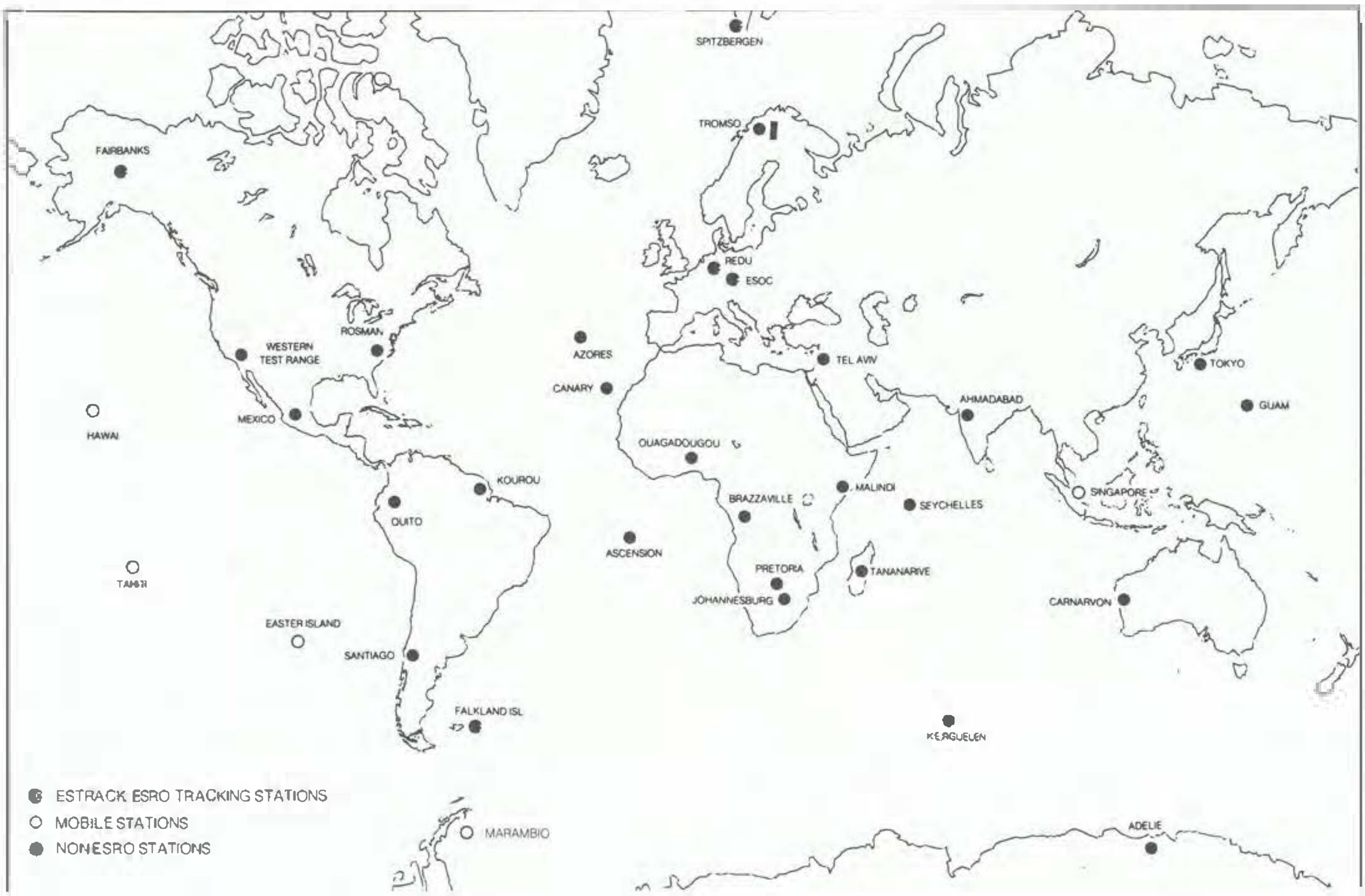

Following the failure of TD-1A's tape recorders, the setting up of additional ground stations in 1973 was an extensive and successful exercise which enabled ESRO's most complex and challenging spacecraft to fulfil its mission.

A NASA project with European participation, HST is expected to observe much fainter objects than is possible from the ground, and it will widen the horizon to which we can observe the Universe.

Even in astrometry, the most classical of classical astronomies, space is about to surpass ground-based observations. The ESA satellite HIPPARCOS, though in the wrong orbit due to a technical malfunction, is expected to advance the precision of measurements of distances and motions of stars by a decisive step, thus improving our measure of the absolute brightness of a large assortment of stars and of the absolute scale of the Universe.

Exploration of the Solar System

In the long run, the most far reaching consequences of the venture into space will come from the visit by unmanned and manned spacecraft to the Moon, the planets and other bodies in the solar system. The step from telescopic observation to direct measurements in the environment and the atmospheres of these bodies, experiments conducted on their surfaces, and the return of samples from them for laboratory analysis is revolutionising the solar system sciences. Close-up pictures and the other scientific results of research on the Moon, planets and comets have particularly fascinated the public, a fascination which has been amplified by the Apollo landings on the Moon and the similar exploration of other heavenly bodies.

Research with unmanned probes of a planet or some other body in the solar system is not just aimed at learning more about this particular body. It is the wider context that makes these missions scientifically so important: comparative investigation of a variety of bodies that have different orbits around the Sun and that have experienced different evolutionary paths allows us to reconstruct the formation process of the solar system which started with the collapse of a fragment of an interstellar cloud and continued with the development of a disk-shaped solar nebula from which the

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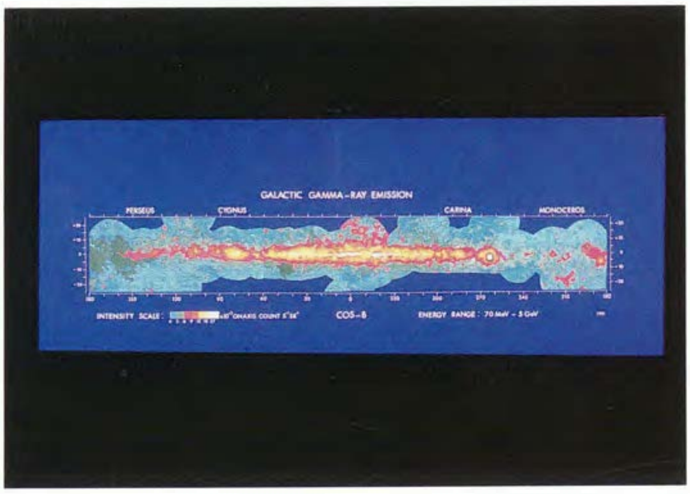
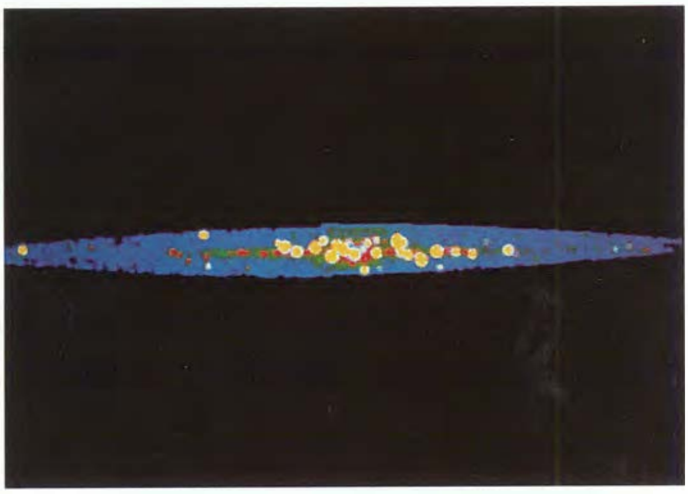
Some examples of the discoveries made by European scientists and guest observers from other countries using data from COS-B and EXOSAT

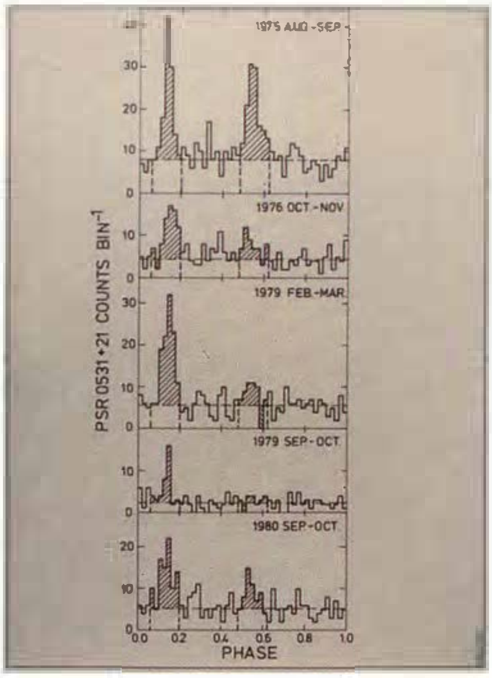


COS-B provided the first all-sky high energy gammy-ray survey of the galaxy. The intensity contours in this picture show a lense-shaped gamma-ray source region oriented along the galactic equator, the intensity being brightest towards the center. These gamma-rays are produced in interactions between galactic cosmic ray particles and the interstellar gas. Several bright spots of emission may also be seen. The brightest of which in this projection (at 26O° longitude) corresponds to the pulsar in the Vela supernova remnant. Towards the outer galaxy (near ~190° longitude) a pair of sources are seen. The lower one of the two is the Crab nebula.

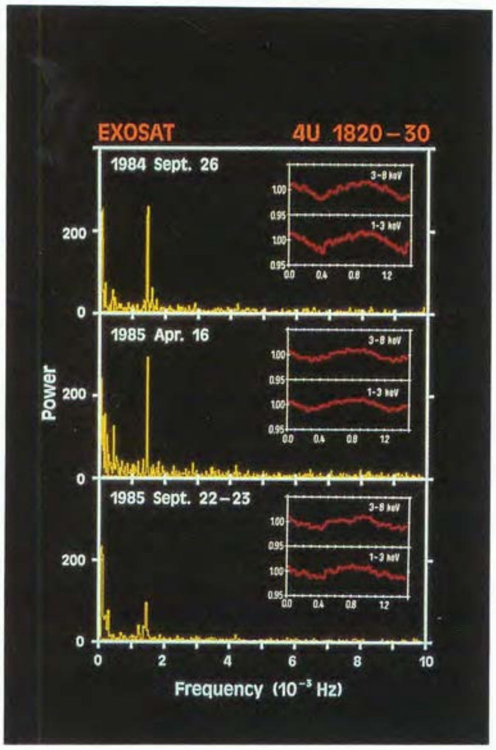


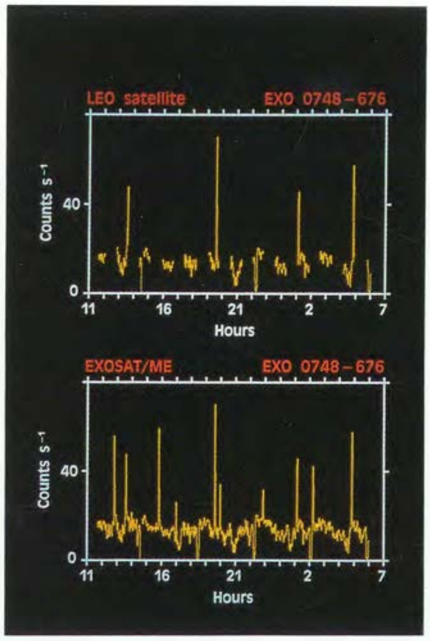
Our galaxy as seen in the light of soft X-rays (2—6 keV). One recognizes emission from numerous point sources within a lense shaped volume from which diffuse X-rays are emitted. This picture covers the galactic disc from −75° to +75° longitude. Although these two figures have different scales, their comparison still shows a significant difference between the gamma-rays and the X-rays of galactic origin: relative to the respective extended sources, the point sources are more significant for X-rays than they are for gamma-rays. The reason for this is that in the point sources, e.g. in the environment of neutron stars and other exotic objects, the energetics is such that X-ray emission is much more likely than gamma-ray emission. On the other hand, the collisions of cosmic ray particles with the extended galactic gas readily produce gamma-rays.

The Crab nebula as it is resolved at optical wave lengths: The angular extent of the optical nebula being 1/10°. The Crab nebula is the remnant of a supernova explosion that occurred in our galaxy relatively close (6000 light years) to the solar system and was observed by Chinese astronomers in 1054. The explosion followed a collapse of a highly developed massive star. The remainder of that star was left behind as an extremely dense object, a neutron star. The arrow in the optical image shows the position of the Crab pulsar (the rapidly rotating neutron star) whose gamma rays are recognised by the pattern of their times of arrival: the pattern reveals a fundamental period of 33 milliseconds which correspond to the rotation period of the neutron star.



The Crab pulsar light curve observed by COS-B as seen at several epochs during the COS-B mission. The main peak occurs every 33 ms, which is the rotation period of the pulsar. Comparison of the gamma-rays emitted at different epochs suggests that the shape of the light curve during a cycle varies with time.





The lower panel shows the X-ray light curve of the transient low-mass X-ray binary EXO-0748-676. This source was discovered by EXOSAT and shows a wide range of X-ray phenomena including X-ray bursts, irregular intensity dips and X-ray eclipses by the companion star. Due to EXOSAT's highly eccentric orbit, the temporal evolution of the X-ray emission could be followed continuously. To illustrate the advantages of EXOSAT's orbit, the upper panel shows the same light curve as it would have been observed by an earlier X-ray astronomy satellite in a low earth orbit (LEO). The frequent occultations of the source by the earth would have caused data gaps which would have made it impossible to study the temporal behaviour of the light curves in great detail.

XB 1820-30 is one of the variable X-ray sources observed by EXOSAT. It lies near the center of the globular cluster NGC 6624. The Fourier power spectra from three observations which led to the discovery by Exosat of a modulation of its X-ray flux with a period of 685 sec corresponding to a frequency of 1.46 mHz. The inserts give the averge folded light curves in two different energy bands for each observation. It is seen that the amplitude of the modulation is limited to only a few percent. The stability of the 685 sec period shows that it represents the orbital period of a binary system. A detailed analysis suggests that it consists of a helium white dwarf/neutron star. 685 sec is the shortest known period for a stellar binary.

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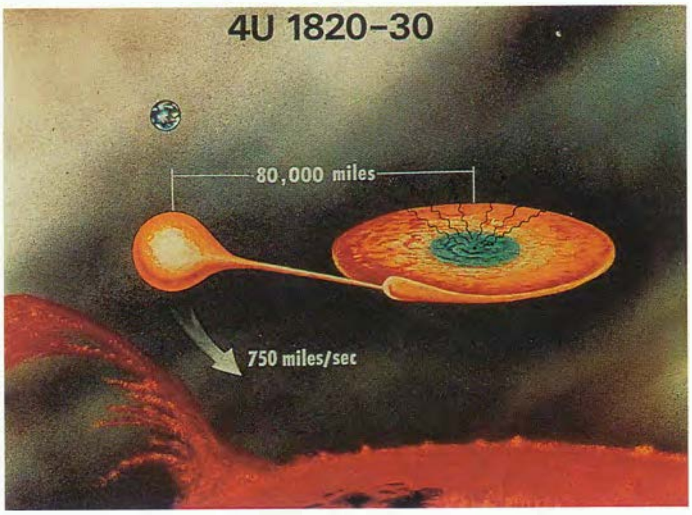
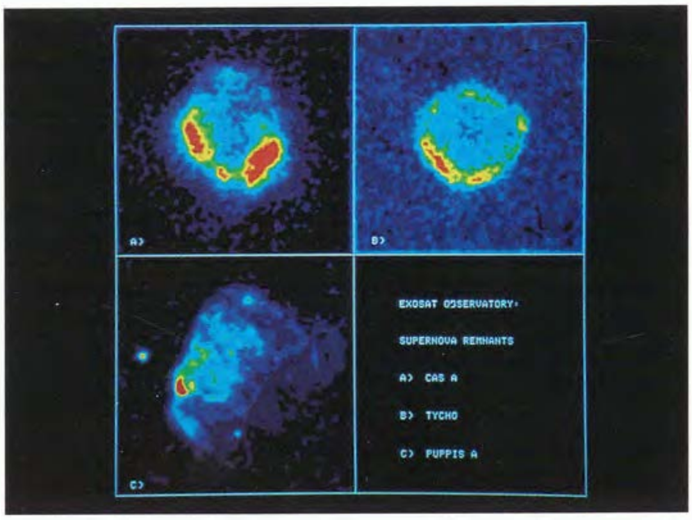


The structure and dimensions of the binary system XB 1820-30 can be inferred from the X-rays which it emits. The figure is an artist's impression of XB 1820-30. The Sun (bottom), Earth and Moon (top) are shown on the same scale. This peculiar binary system would easily fit between the Earth and the Mooon. Matter is pulled out of one of the partners, a helium white dwarf, by its companion, a neutron star which is heavier and much denser. The transfer of matter forms an accretion disc surrounding the neutron star.



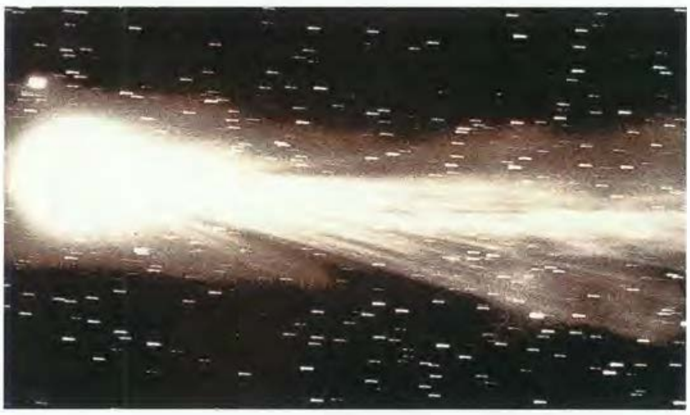
Smoothed low-energy X-ray images of the bright thermal supernova remnants Cas A, Tycho and Puppis A. X-ray emission is due to the interaction between the interstellar medium and stellar material ejected in the supernova event. The three remnants show a more or less pronounced shell structure.

M31, better known as the Andromeda nebula, photographed in visible light. Among the full sized galaxies, M31 is the nearest to our Milky Way. It can be seen in the constellation Andromeda by the naked eye as a diffuse spot.

EXOSAT X-ray images of a 17×17 arcmin region of M31, the nearby Andromeda spiral galaxy. The two arrows in the image point to sources which were not seen before. These are transient X-ray sources similar to those observed in our own galaxy. North is in the vertical direction and east is to the left.

Sun, the planets, and the smaller bodies formed. Comparative studies in the solar system also help us towards a better understanding of the Earth, the specific circumstances of its formation, the origin and history of its atmosphere and oceans, and its geological evolution. A better understanding of these problems will in turn give us a background for discussing rationally the momentous questions of the conditions that existed on Earth for life to evolve, and the frequency or the uniqueness of Earth-like planets in our galaxy and beyond which could bear life as we know it.

In many ways, deep space missions are technically the most demanding among unmanned space projects, and therefore, it was not surprising that the first visit of an ESA spacecraft to another body in the solar system occurred only in 1986 when Halley's comet returned to visit the inner part of the solar system. Every 76 years, when this most famous of comets returns, it finds the Earth in a new social, political, artistic, and scientific epoch. For instance, the punctual return in 1759 precisely predicted by Edmund Halley, was taken by scientists and laymen as the ultimate proof of the validity of Newton's laws, and the comet's first visit during our century in 1910 was marked by great publicity and by studies using the then latest scientific methods.

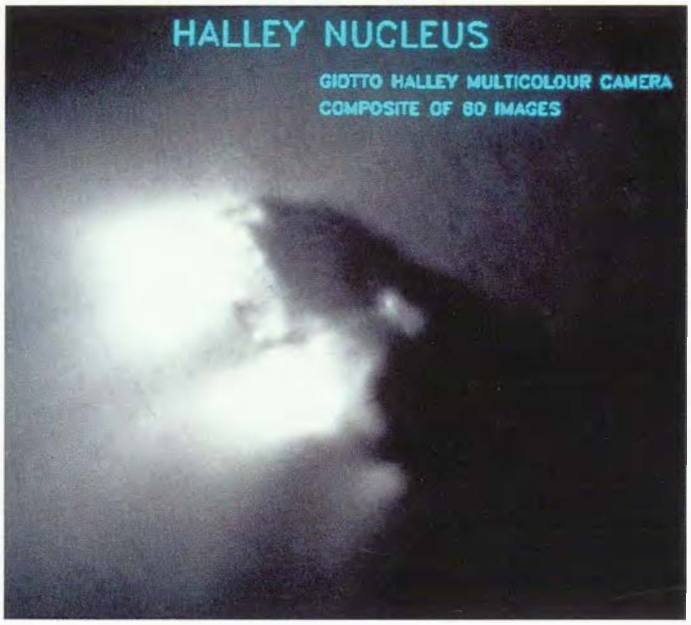


Halley's comet as photographed in 1910. This comet was particularly suited for the first attempt of a close encounter. From the observations during its last appearance in 1910, Halley's orbit could be predicted well enough to enable astronomers to re-discover the comet by their most powerful telescopes long before it develops a strong coma, thus enabling to measure the trajectory of the comet's nucleus with very high precision. A similar precision could also be obtained for comets with shorter periods. However, the stronger emission of gas and dust and the larger average distance from the sun suggest that Halley has better retained its original icy and dusty components than those short period comets.

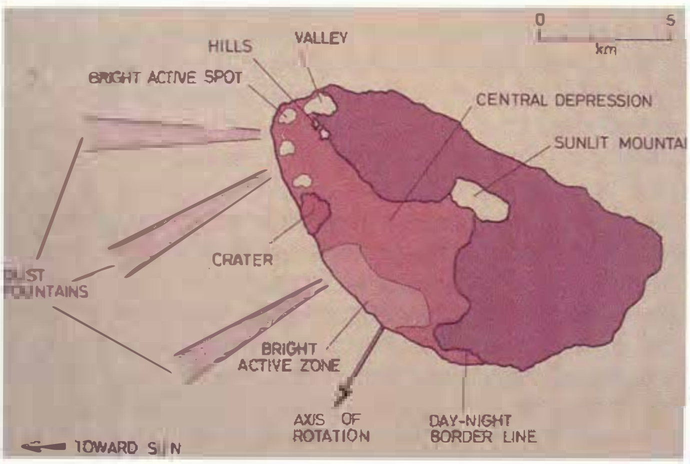
Towards the end of last century, spectral analysis opened up a new dimension for astronomy, the study of the chemical composition of celestial bodies. Shortly after 1900, prussic acid, the poisonous HCN, had been discovered in cometary spectra. When Halley's comet then approached for its apparition in 1910 and astronomers announced that the earth would pass through the comet's tail, a genuine media event broke out. Doomsday was forecast, but some, like the editors of 'La Vie Parisienne', took a fatalistic view and made the best of it.

GIOTTO, the European mission to Halley's comet was a resounding success on many counts. Launched by an Ariane-1 vehicle, GIOTTO was the first ESA spacecraft to leave the gravitational field of the Earth, and its special design allowed it to dive deep into the comet's coma, much deeper than the other spacecraft could. Equipped with superbly designed instruments including a special camera, it sent back pictures of the comet's nucleus and data which gave new insights into the physical processes that take place in the various layers of the comet's coma. Mass spectrometer data obtained close enough to the nucleus allowed the composition of the comet's ices and other relatively volatile components to be determined.

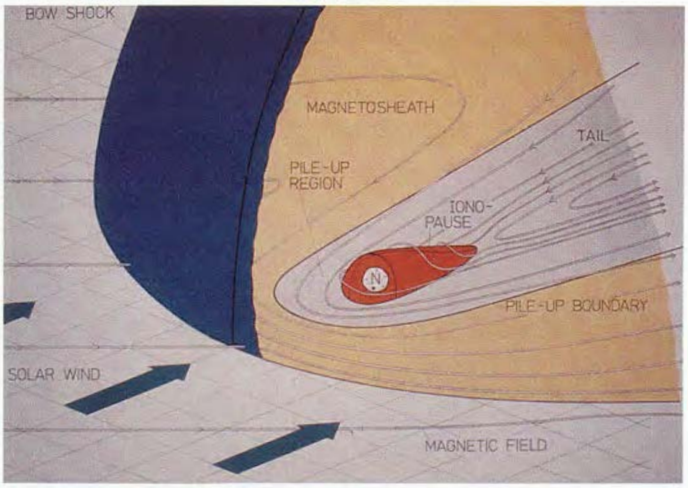
Although GIOTTO results can stand on their own, they were made even more valuable by an international coordination of all investigations of Halley's comet. For the first time, the four leading space agencies, Interkosmos, ESA, NASA, and ISAS (the Institute of Space and Astronautical Sciences of Japan) worked together in an Interagency Consultative Group and helped to coordinate all the scientific programmes concerned with Halley's comet, the observations from Earth orbit by IUE, and other satellites, and the ground-based observations which made use of the most advanced astronomical techniques. So much was learned by this concerted effort that without exaggeration we can speak of a new era in cometary research.



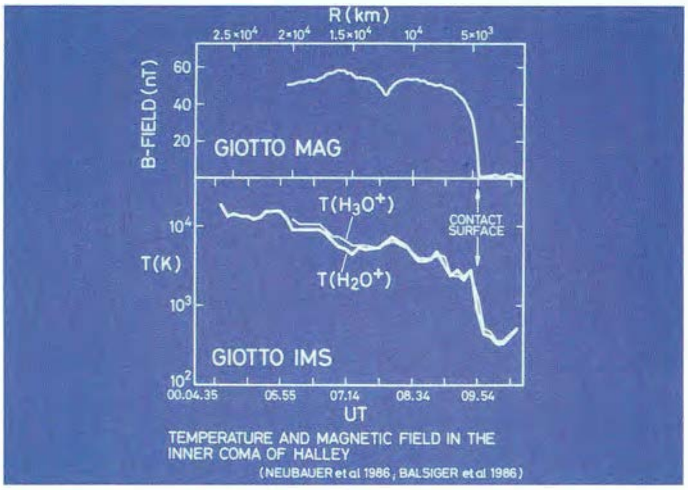
Picture of the nucleus of Halley's comet obtained from the Halley Multicolor Camera onboard GIOTTO. In spite of the high dust density surrounding the nucleus, its shape and several topographic details can be well discerned. Cometary observers and theorists were surprised by the elongated shape of the nucleus and the gas emission coming from a small fraction of the surface area.(courtesy MPAe, Lindau)



Shape, surface features, and topography of Halley's nucleus inferred from photographs. Comparisons of photographs from GIOTTO and VEGA allow the volume of the nucleus to be derived. This volume combined with estimates of the comet's mass gives a density for the nucleus which is much lower than the density of ice. Thus, the nucleus must be full of voids, the size scale of which, however, cannot be ascertained.



The interaction of the solar wind with the Earth and with a comet bears some resemblance. However, there is a fundamental difference in the nature of the obstacle that the solar wind faces. In the case of the Earth, it is the geomagnetic field produced by a dynamo in the core and solidly anchored inside our planet. In the case of the comet, it is the outflowing gas which through its ionised component gradually brakes the momentum of the oncoming solar wind. This process was understood in general terms two or three decades ago, but a quantitative prediction of the strength of the bow shock or of the position of the ionopause could not be made. The interpretation of data sent back by the space probes now leads us to a quantitative understanding of the plasma interaction processes which produce the complex structure of the cometary coma.



TEMPERATURE AND MAGNETIC FIELD IN THE INNER COMA OF HALLEY
(NEUBAUER et al 1986, BALSIGER et al 1986)

Halley March 1986

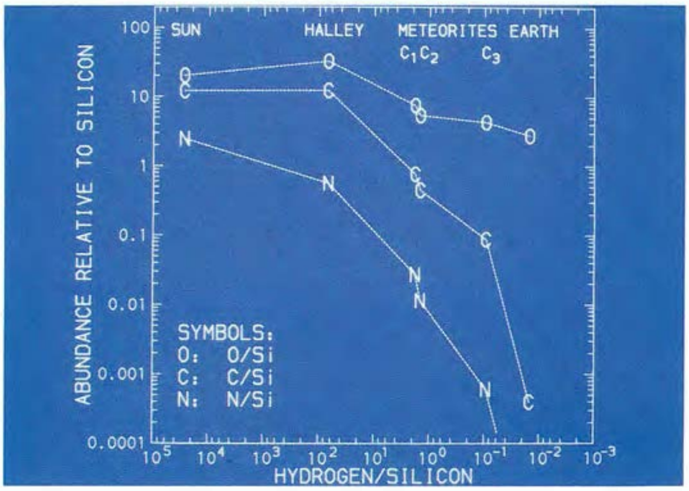
Parent Molecule Source Strengths
(Point Source + Extended Source $<10^4$ km)

(best estimates May 1988)

Species	Abundance	Species	Abundance
H_2O	100	NH_3	≤ 1.5
CH_4	2	HCN	0.1
CO_2	3		
CO }	15	N_2	<2
H_2CO }		NO	<0.5

ESA's GIOTTO was the only space probe to penetrate Halley's ionopause. The dramatic decrease of the magnetic field strength at 4600 km from the nucleus signals that solar wind fields and particles could not proceed beyond this point. The gas inside the ionopause is very cold and purely made up of the outstreaming cometary molecules, ions, and electrons.

This list of the most abundant primary molecules was estimated from a combination of methods: Mass spectrometric determinations of the neutral and ionized components in the coma, IR and UV data obtained by the Halley space probes spectral analyses from earth orbiting satellites and from the ground. At the time of GIOTTO's visit, the comet released 20 tons of gas per second. HCN is rare, but still more than a hundred thousand tons of it were spilled into the inner solar system by comet Halley's visit in 1986. The high abundance of carbon in oxidised form and the scarcity of nitrogen compounds came as a surprise.



In this diagram, the abundances of some key elements in the material (gas plus dust) released from Halley's nucleus are compared with the corresponding abundances in the sun, the earth, and the most primeval types of meteorites. The relatively volatile elements HCNO are related to the non-volatile silicon. This plot demonstrates that Halley's comet has retained much more volatile components than even the C1 meteorites. Relative to the unfractionated sun, oxygen and carbon are present with their full abundance. However, nitrogen is definitely depleted in the cometary material.

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Comets are of unique importance for investigating the origin of the solar system. Because they originated far from the centre of the solar system and spent most of their life far away from the Sun, and because they are small enough not to cause excessive internal heating, cometary material was expected to have remained at very low temperature from the time the comets were formed. This material is liberated when the comet is close to the Sun and thus is conveniently made available for direct or indirect analyses. The data from GIOTTO and the other spacecraft confirmed indeed that the material of Halley's nucleus is the most pristine ever investigated, as is evident from the content in volatile compounds, from the high abundances of oxygen, carbon, nitrogen, and hydrogen, and from the molecular forms in which these elements were found.

Concluding remarks

Starting into space late, Europe has been able to catch up and become qualitatively the equal of the large space nations. This development was initiated by ESRO and some Western European countries with their scientific programmes. The technical and organisational experience of ESRO and the successes of its scientific missions created confidence in Europe's ability to cooperate in space, thus laying the foundation for the formation of the European Space Agency in the early 1970s.

Europe, it seems, stands now on the threshold of a new era. The changes that we are witnessing will in due time also affect the space activities of the continent, hopefully leading to a close and harmonious cooperation between East and West. In the preceding decades, space scientists, like scientists in other fields in the two halves of Europe, have established contacts, entered direct cooperations, and formed personal friendships on which future cooperation of all countries of the continent could be built. With its inherent international nature, the flexibility of its programme and the experimental character of its missions science could once again lead the way to finding the right organizational form for this cooperation.

Today, ESA devotes to science only a modest part of its budget, although science still plays a central role as a motor for innovation and a force for cohesion. The science programme is uniquely anchored in the member countries through the direct cooperation of a large community of competent outsiders: the scientists coming from universities and research institutes of all regions in Western Europe. On balance, this cooperation has been spirited and successful. At least on the working level both sides are conscious of their interdependence. The scientists define the aim of a mission, provide scientific instruments, interpret the data, publish them and integrate them into the fabric of human knowledge. On the other hand, the scientists know that their success depends on the ingenuity, skill and perseverance of the engineers in the Agency and in industry. The scientists submit to the organisational and technical master plan of the project manager in order to do the science they want, very much as Charles Darwin had to accept the authority of Captain Fitzroy on the high seas, in order to make the voyage of H.M.S. Beagle the scientific success it became.

ESA depends on the support and goodwill of the governments of the member states and the delegates who represent these governments in the Council. However, to remain a truly Europe-wide organisation filled with life, ESA needs as well the direct cooperation and support of the European scientists. They represent the most active, competent and outspoken community that ESA works with. University scientists are best positioned and prepared to explain the deeper meaning of space activities to the younger generation and to the intellectual world which surrounds them, and they also hear critical voices from within the society. By doing so, the scientists have created a great deal of understanding and goodwill for space activities and for the need of international cooperation in this expensive, fascinating field.

The second half of this century marks our setting out to explore outer space. Nobody doubts that what was begun will continue in the next century, perhaps even with increased emphasis. Later generations may not remember one or other feat but will ask whether the venture into space that was begun in our time was to make a genuine contribution to human culture. Emphasis on science and an open dialogue between space agencies and with scientists and scholars should help to find the right course, so that later generations will not liken the venture into space to the tale of the Babylonian tower, but rather to the voyage of the Beagle.

Footnote
In this short account of the evolution and the achievements of the European space research cooperation, I could only include a small part of all the scientific results obtained. Accounting for all important findings and covering all fields was beyond the scope of this article, and in any case would have overtaxed my capacity. In publications of this kind, it is difficult to quote the sources of results or figures in a balanced way. Therefore the editor decided to do without quotations, and I ask my colleagues for their understanding. Over the years, scientists in ESA's member countries have benefitted from the cooperation with scientists and engineers in ESA and in European industry, and, on behalf of many of my colleagues, I should like to acknowledge this.

I am indebted to Clare Bingham and Graziella Troxler for their support in getting this article ready in time. Martin Huber's advice has been of great value to me, and I thank him as well as Arne Pedersen, Brian Taylor, and Peter Wenzel of the Space Science Department for their help and for critically reading the manuscript.

ESRO-ESA Space Science — Chapter 2

The EPONA instrument on the Giotto Mission — A personal reminiscence

Professor Susan M.P. McKenna-Lawlor

The wonderful adventure which culminated in the encounter of an instrument from Ireland with comet Halley began very unexpectedly, far from the Emerald Island itself, when I arrived in mid 1980 to present an invited talk at the STIP Meeting in Smolenicie, Czechslovakia. It had been very difficult to get there. Last minute visa problems and tortuous connections had raised between Smolenicie and myself a series of obstacles which might well have deterred a less determined traveller. But now, with my presentation over and a pleasant evening in a fairy tale like castle stretching ahead, I turned to get to know the Conference participant who was to dine at my right hand.

'I am Rudeger Reinhard, Project Scientist for the Giotto Mission' he told me and later remarked 'Ireland is now a full member of the European Space Agency, why is there no Irish experiment proposed to go to the Comet?'

There are moments in life for all of us which are of supreme significance. Moments when the inspiration provided by a startlingly important question can release the imagination to fly amid perspectives of previously undreamed of possibilities. There were many logical reasons to explain why no one had proposed an Irish experiment for the Comet. The special clean rooms, the environmental testing equipment, the particle accelerators, all of the special hardware that I personally knew from experience working with NASA would be required to construct an experiment that could go to and function in the cometary environment were, at that time, unavailable in Ireland. And yet, in the inspiration of the moment, I could look at my companion and say 'we have not so far proposed an experiment for Giotto from our country but — why not ?'

The very beginning is, they say, a very good place to start and so it was with this project. At the suggestion of Rudeger Reinhard I went to meet Professor Ian Axford, Director of the Max Planck Institute at Lindau, Germany, and together we discussed what the Irish experiment might be.

Since my background was in studying solar cosmic rays, it appeared very suitable, and timely, to propose an instrument that would at first monitor flare particles during the approximately eight month cruise phase and then investigate the behaviour of energetic cometary ions in the close environment of Halley.

As the discussions proceeded apace, it became clear to both of us that such an instrument from Ireland, with a lady P.I., would very soon be proposed to the Agency and Professor Axford said, 'You need a name for the experiment that will be representative of Ireland; what will you call it?'

My mind raced. 'It is 'I said' a device that measures energetic particles, the onset of energetic particles', and the letters EPONA (Energetic Particle Onset Admonitor) formed in my head, an acronym but also the name of the beautiful and mysterious EPONA, a Celtic Goddess associated with the commencement of the Solar Year. The experiment now had a name which would have a special resonance at home while linking our ancient culture with the new age of deep space exploration just then dawning in Europe.

Epona - the Celtic goddess

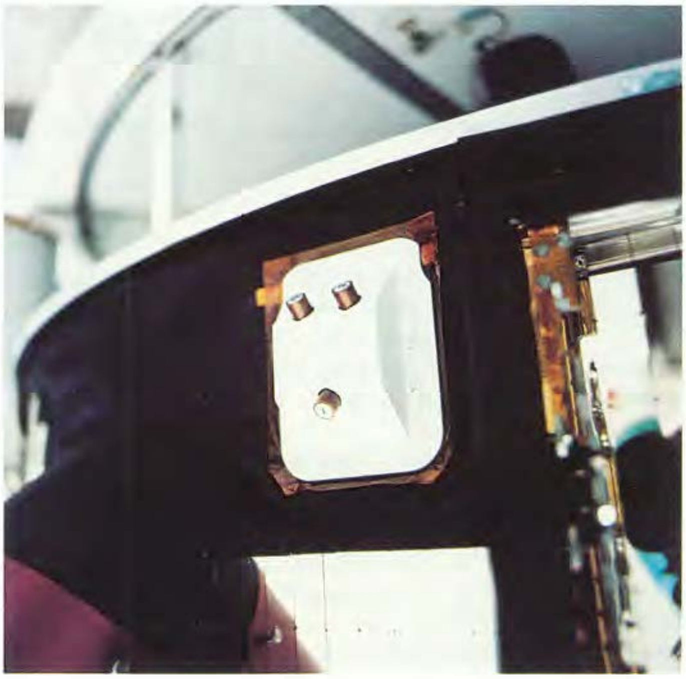
Professor Axford generously promised that, should the EPONA instrument be successfully selected for the mission, he would provide access to the Lindau specialist laboratories for my engineers until I could install at my own University the kind of in-house facilities required to build flight qualified instrumentation.

The next step was to gather together a team to formulate a proposal to the Agency and, if successful in the selection stage, to implement the experiment. Winning through to selection was not an easy task. Everyone in Europe it seemed wanted an instrument aboard the historic Giotto Mission and it was necessary to defend the EPONA Proposal like a thesis before specialist referees.

The instrument suggested was a lightweight single particle telescope (only 480 g were available for the device) and it was a joyous day for our group when it was finally selected as one of the ten experiments on the mission. Soon after this acceptance however, I became aware that a somewhat larger Giotto spacecraft would have to be built than had been originally foreseen, to accomodate extra hydrazine for necessary mid-course corrections. The possibility to increase significantly the mass allocation for EPONA and fly a sophisticated triple telescope on the mission thus began to suggest itself.

There were tough related negotiating sessions before this could be achieved since other experimenters who wanted to upgrade their designs were also in competition for the newly available resources. However, in the end, that triple telescope with its high spatial (8 sectors) and temporal (0.5 s) resolution made it through the second-step selection process.

The months that followed were filled with activity. Ireland owes a deep debt of gratitude to the personnel at the Lindau Institute who so generously gave of their time and expertise to advise those of our team directly engaged in instrument construction and testing. By the time the design of the Engineering Model had been fully developed and verified, up-to-date laboratories had been installed at Maynooth wherein electronics for the Flight Model could be built, and the media flocked to the College to photograph these facilities and to hear about EPONA.



Epona on the experimenters' platform - flight model of the Giotto spacecraft. The three telescopes are very clearly seen.

At last the time came for the launch campaign and I travelled to French Guiana to supervise the final tests before launch and sign the protocols that transferred the instrument, for the first time in five years, from my personal custody to that of the Agency. Experiment switch-on was to be on August 22, 1985 and it was a serious moment to sit in the big chair at ESOC, Darmstadt, while the command EPONA ON was uplinked to the spacecraft.

The instrument however answered very sweetly indeed. Interplanetary space was, on that day, particularly quiet, and it was clear that EPONA's performance equalled the very best we had observed in the laboratory.

As the period of encounter approached, the historic importance of what was about to happen became increasingly manifest to all. People gathered in droves around the tracking station to try somehow to get closer to what they perceived to be an event of great significance. I had not gone back to my hotel for two days, preferring to stay at the data monitor, and a red hat that I had placed on my head about 30 hours before, stayed forgotten in place.

As we flew within about 7.5 million km of Halley it was clear that the instrument had already detected cometary ions. Then, as we crossed the Bow Shock and flew close to the comet, a most dramatic signature indicated that we were recording ions of energies considerably greater than those attributable to the pick-up process acting alone. Remembering that I had promised TV presenter Patrick Moore to let him know if anything 'exciting' should happen within the experiment, I rushed into the BBC studios and showed on camera the wonderful record EPONA had sent us. All eyes apparently flew from the record to my red hat and, by morning, I was a celebrity since the viewing public had not at all expected to see a lady P.I., least of all one so attired.

Meanwhile, 'closest approach' was coming. A large screen in the laboratory showed a stream of updating pictures coming from the Halley Multicolour Camera and it was clear that we were flying into a most hazardous dust environment. Then, someone from the DIDSY Team yelled 'we have penetration' as a large dust grain hit the spacecraft and set it into nutation.

During this period, everytime the antenna pointed towards the Earth EPONA transmitted a burst of data and I knew that, if the instrument could but survive until the nutation dampers worked, we might well continue to receive 'outbound' records.

Explaining the exciting news to the ESA Council. Note that the hat has changed!

At this critical interval, when the spacecraft was at closest approach, the instrument was recording a most remarkable enhancement in particle fluxes, and I feared that each transmission that came might be the last and that we would miss the end of the event.

Sufficient data to provide the overall profile however came through and, after about 32 minutes, the telecommunications link with Earth was fully restored. EPONA then transmitted a steady stream of beautiful data, indicating, as time progressed, that the outbound energetic particle signatures were significantly different from those obtained inbound.

As the night wore on, with the help of a young engineer from my group, I continuously printed and pasted together the records coming in and an enormously long trace charting the complete flyby was formed. When morning came, there was a noise in the corridor and the Director General of the Agency Professor Lüst stopped at the door to see who was still burning lights in that part of the building. 'Come in, come in' I said, 'see what I have to show you, a complete Encounter with the Comet' He took one look and then called to Professor Bonnet to come in too to share the joy of the data-take.

Perhaps only scientists understand what such moments can mean when, through the medium of an instrument, we seek to ask of Nature a question and receive in return a majestic response, revealing things that are wonderful and new, with intimations of hidden depths about which we had previously not even guessed.

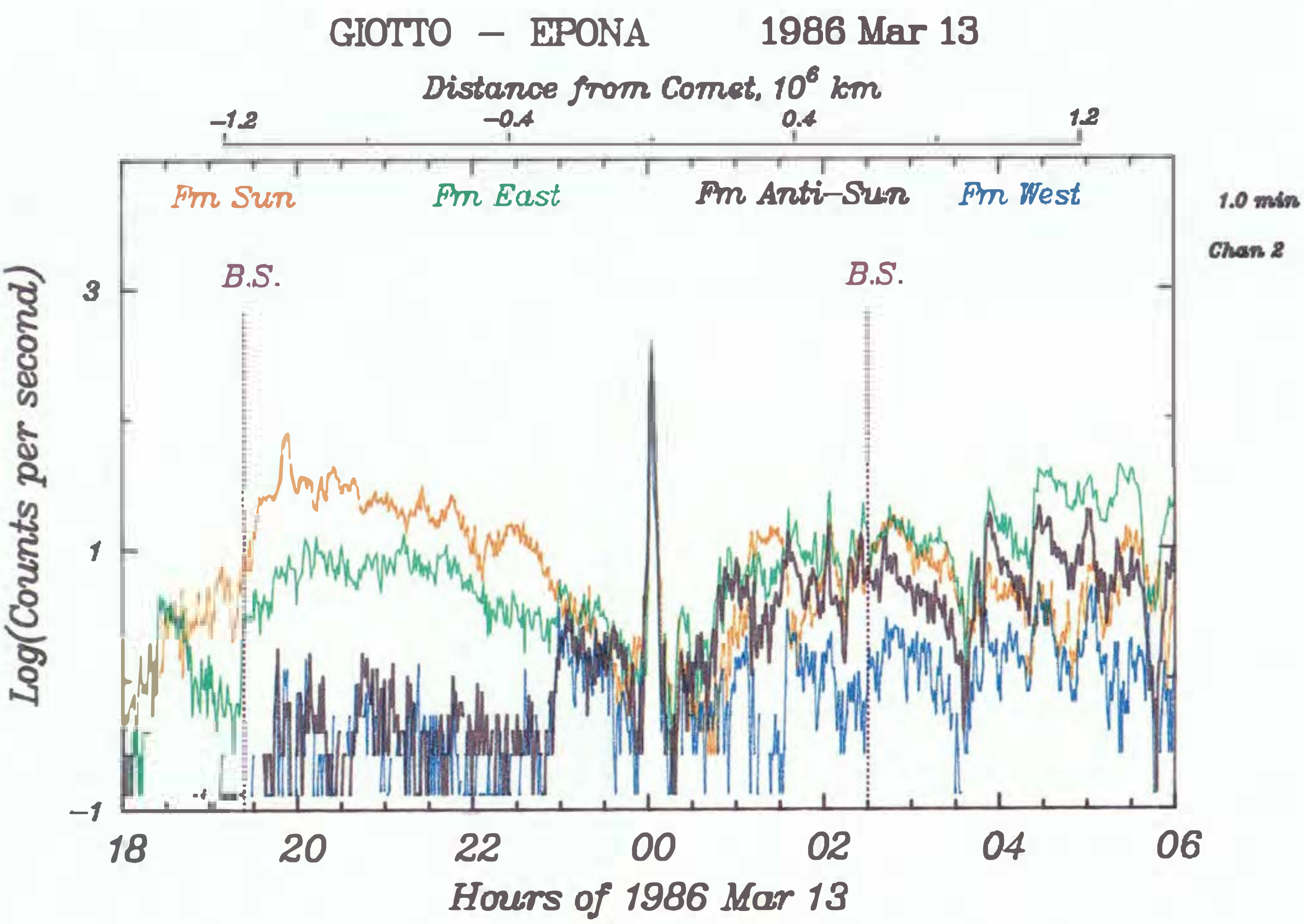
A major press conference was planned for the media that afternoon and each of the P.I.s was asked to present 'first results'. I brought along my big chart and instructed the projectionist to feed it through the projector when I gave the word. 'Gentlemen' I told the Press, when my turn came, I invite you to fly through the comet with me' and, as the chart moved along, I took them through all of the beautiful phenomena EPONA had recorded from the inbound bow shock to the latest piece of data that had been received.

The instrument continued to record spectacular traces until 3 a.m. on March 15 when the mission was deemed by the Agency to be complete and telemetry coverage was discontinued. At that time, only the magnetometer and EPONA were still transmitting data and, in the enormous control centre which had previously so buzzed with life, only four people, two representatives of MAG, my Chief Engineer and myself were still present. First the MAG screen went blank, then I heard a voice over the headphones say 'in one minute EPONA will be switched off'.

In the darkened laboratory tears rolled unbidden down my face as I waited for the data stream to disappear. It was as if a life were being terminated.

At the present time, all of us who have been privleged to take part in the remarkable Giotto Mission look to the possibility that the spacecraft may yet be commanded to encounter another comet. While it is not yet certain at this time if such an expedition will really be implemented, the spacecraft and its payload are scheduled to be thoroughly checked by the Agency to see if such a mission is achievable and we will, at that time, attempt to re-activate EPONA.

It is nice to think that perhaps our Celtic Goddess is presently but sleeping and will fly again through interplanetary space, gathering further beautiful data to provide to those on Earth insights into mysteries as old as time.



Part of the data received from EPONA during the encounter

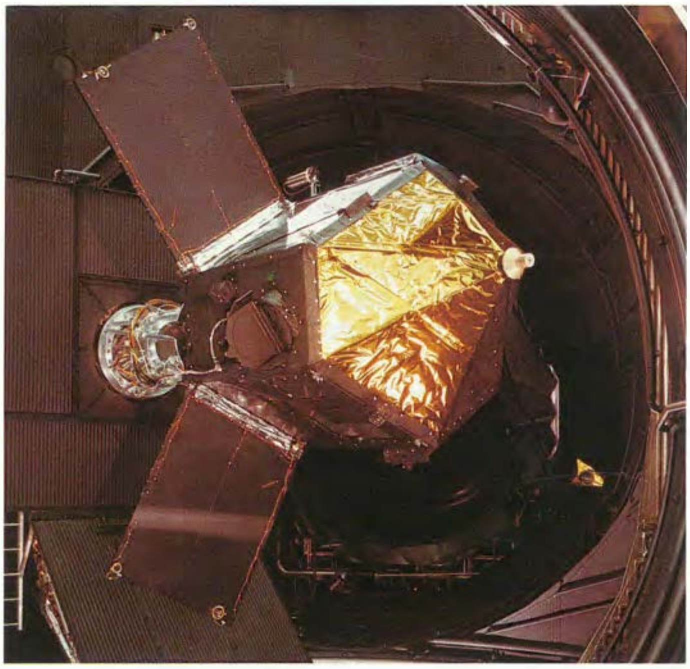
La naissance d'Hipparcos (Souvenirs d'un découvreur d'étoiles)

Professeur P. Lacroute

J'avais oeuvré en astrométrie, instrument méridien et astrométrie photographique. Après avoir recherché des améliorations possibles, j'étais arrivé à la conclusion qu'on ne ferait plus de progrès significatifs sans aller dans l'espace parce que c'était maintenant l'atmosphère qui était la principale source d'erreur.

Or, on commençait à aller dans l'espace pour utiliser les rayonnements arrêtés par l'atmosphère. On devait donc essayer de faire des mesures astrométriques dans l'espace sur les faisceaux lumineux non déformés par l'atmosphère. On verrait ce qu'on pourrait obtenir pratiquement, mais les perspectives étaient très séduisantes et j'étais fortement motivé.

Maquette à échelle réduite du mélangeur de faisceaux (source: REOSC, F)



Vue du satellite Hipparcos

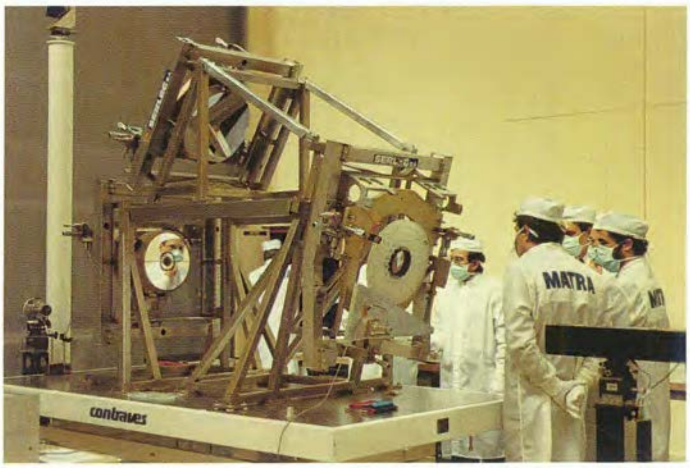
Depuis 1966 j'avais donc lancé à plusieurs reprises l'idée qu'il fallait aller dans l'espace pour effectuer des observations astrométriques. Après de nombreux tâtonnements et une longue réflexion, j'ai retenu quelques principes pour proposer des observations pratiques.

Le plus important me paraissait être d'établir un système de référence très riche en étoiles, très précis et très cohérent sur toute la sphère.

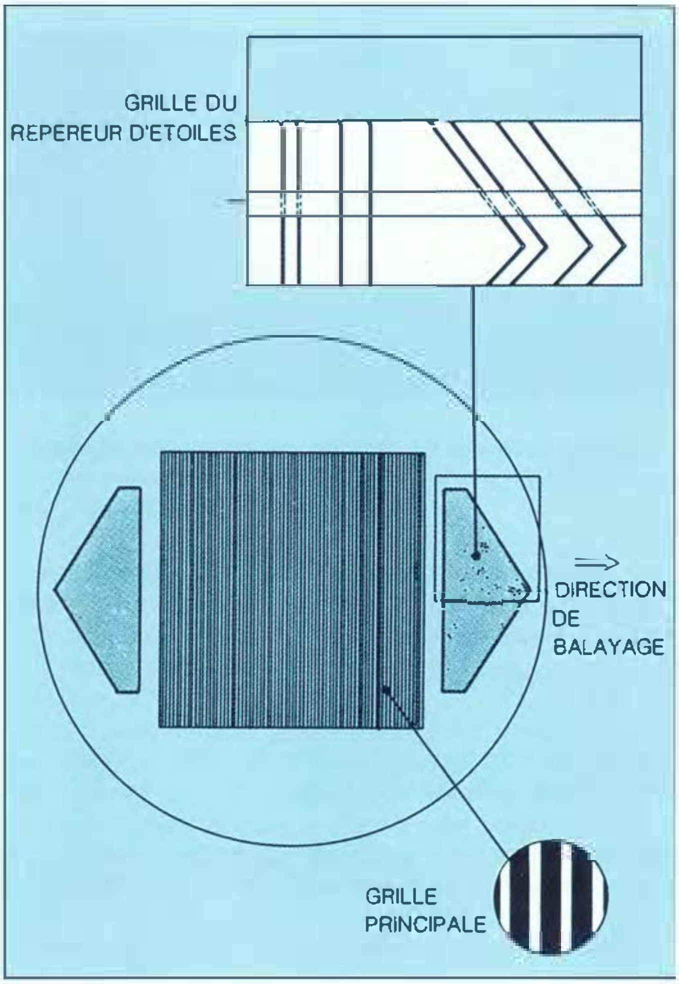
Dans l'espace, la réference à la terre n'est plus naturelle: c'est l'établissement de la sphère qui est l'essentiel. On peut établir la sphère par des mesures d'angles entre étoiles et ces angles sont des invariants sur des temps courts.

Dans le champ d'un télescope on ne peut mesurer sur les images que des angles assez faibles. Pour obtenir une sphère rigide on devait superposer dans le télescope deux champs stellaires faisant entre eux un angle constant. On mesurerait ainsi dans le champ des angles faibles et des angles voisins de l'angle de base.

L'expérience des mesures au sol montre la nécessité d'éviter les déformations instrumentales. A bord d'un satellite il n'y a pas de flexion. On réduit les phénomènes



Maquette optique de la charge utile durant les opérations d'alignement (source MATRA, F)



La surface focale, montrant les détails des grilles modulatrices primaires et du repéreur d'étoiles.

thermiques en utilisant exclusivement des optiques par réflexion et réalisées avec des matériaux non dilatables.

Pour obtenir sans manoeuvre beaucoup d'observations, on adoptera un satellite à balayage observant continument le passage des étoiles sur une grille dans le plan focal du télescope.

En 1973, on commençait à proposer des observations avec des résultats prometteurs. Mais je connaissais mal les techniques et les servitudes spatiales. C'est la prise en charge par l'ESA qui a permis d'aboutir au projet collectif d'Hipparcos, grâce au concours d'astronomes et d'ingénieurs au cours des études et de la réalisation.

Le travail en groupes a été passionnant. Des réalisations difficiles ont été réussies et des idées nouvelles ont permis d'améliorer les performances du projet. C'est ainsi que l'adoption d'un système sélecteur de champ, très mobile, a permis de limiter chaque mesure instantanée à porter sur une seule étoile. Au prix d'une gestion des observations en temps réel plus complexe, on améliore beaucoup la précision sur les étoiles brillantes et on peut atteindre des étoiles faibles.

La portée des résultats dépasse ainsi de beaucoup le système de référence précis, riche en étoiles et cohérent qui avait été prévu initialement. L'obtention de nombreuses parallaxes significatives, bien meilleures que celles actuellement connues, a une grande importance pour l'astrophysique.

ESRO-ESA Space Science — Chapter 4

Working with ESRO and ESA — A view from the UK

Professor Kenneth A. Pounds

My relationship with the European Space Science programme has had its ups and downs, but — like a good marriage — has never been boring. The earliest links were in solar physics: the Leicester Group enjoying six successful Skylark rocket flights over the period 1967-72 and the (eventual) launch of ESRO-II.

An early ESRO Skylark rocket launch from Sardinia

Association with this first-ever ESRO satellite provided an early experience of the vagaries of space research. The first launch attempt, on a Scout rocket from Vandenberg Pacific Missile Range in the summer of 1967, failed. This naturally was a great disappointment to those of us who had journeyed to California to witness 'Europe into space'.

ESRO-II — the second version — that was to lead ESRO into a series of very successful scientific satellites

However, those were the days when flight-spare science satellites could be afforded, and ESRO-II (version 2) was duly put in its correct 1500 km polar orbit 10 months later.

At that time, in the late 1960's, my interests were shifting from solar physics to X-ray astronomy and this brought my first involvement with ESRO science politics. The attempt to persuade the powerful COS Working Group to include an ambitious X-ray instrument in their gamma-ray payload failed, thus delaying Europe's entry into X-ray astronomy by some years.

That, for those who have ever pondered its absence, was the end of COS-A. However, my arguments had created a sufficient impression (on Beppo Occhialini, in particular, I heard much later) to lead rather quickly to a further mission opportunity, and this time it was dedicated to X-ray astronomy.

From the ensuing study, carried out in 1968-70, was born the HELOS mission, later renamed EXOSAT, wich was eventually launched in 1983.

EXOSAT — provider of much important data on X-ray phenomena over many years

Over the subsequent 20 years EXOSAT was to become much my most fruitful link with ESA (to date). Meanwhile, however, the cancellation of TD-2 was a further keen disappointment. Solar X-ray studies had by that time become quite sophisticated and we, at Leicester, had begun developing for TD-2 a 5-channel, high resolution crystal spectrometer which was ahead of anything else around. At the time of its cancellation, due to escalating costs (of course), we already had a working prototype, with a performance not to be approached until the launch, much later, by NASA, of Solar Max.

My role in EXOSAT began with the proposal to ESRO of a lunar occultation X-ray mission. This idea, first suggested to me by Connie Dilworth Occhialini, was put forward at a time when the identification of the 'enigmatic' cosmic X-ray sources was a prime objective, and against a background of approved US survey (UHURU) and imaging telescope (HEAO-2) missions.

Europe, it was agreed, needed to think of something different and the ability to locate hard X-ray sources precisely, beyond the reach of conventional X-ray telescopes, led to the selection of HELOS. (My memory, which might be faulty on this point, recalls my putting this proposal to a meeting of the LPAC chaired by Reimar Lüst, in Frascati, circa 1973).

After its selection, and fairly rapid evolution into the EXOSAT we now know, my own involvement continued with a part in the specification of the scientific payload, leading on to the development, at Leicester, of the prototype MEDA instrument. Then, after launch in May 1983, I was able to enjoy, with many colleagues, a share in the rich scientific returns of the EXOSAT mission.

Now, once more, I look forward to an extended connection with ESA through the XMM project. Viewed from the (island) perspective of an Englishman, I can identify a marked change in my (our) attitude to 'Europe' over the past 25 year association. This has followed, perhaps naturally, from a time when the UK was Europe's dominant space power to one where we now rely, increasingly, on the vision of our continental partners to keep space science alive in the UK.

My hope for the future is a situation somewhere in between, where the UK plays its full and proper part — no more and no less — in a healthy and competitive European space effort.

ESRO-ESA Space Science — Chapter 5

The Building of Horizon 2000 — some personal remininiscences

Professor Johan Bleeker

In reminiscing about the ESA science programme over the past decade, many events readily come to mind. However my most vivid recollection is certainly associated with the activities of the Survey Committee, which was set up by the Director of the scientific programme, Roger Bonnet, in the fall of 1983 with the aim of establishing a long term plan for European space science within ESA.

In my view, Roger's initiative was rather courageous: it had been tried before in 1978 by ESA's Science Advisory Committee, which happened to be chaired then by the same Roger Bonnet when he was still with the LPSP, but the recommendations had not really been picked up. Consequently another attempt could potentially backfire, since failure in this case to arrive at a compelling programme might be regarded as an intrinsic sign of weakness or disinterest on the part of the space science community.

Therefore, at the onset of the Survey Committee's work, two ground rules were firmly established. First of all, it should not become an academic masterpiece conceived by a couple of senior scientists in splendid isolation, but to the largest possible extent the user community should be involved in defining the content of the programme. Broad-based support from the users is a prerequisite for successful promotion and implementation of any programme. Secondly, the long term plan should be affordable within realistic and quantified budgetary limits and avoid an a priori stigma of yet another 'pie in the sky' proposal.

Sala Barbantini

Inevitably this required a fair degree of selectivity without impairing a proper, and hence delicate, balance between the various scientific disciplines involved.

After a preparatory period, during which various topical teams digested the massive response of the community to a call for mission concepts, and tried to formulate discipline-oriented recommendations, the Survey Committee met in Venice for three days to try and extract a general programme outline. Vittorio Manno, at that time science coordinator with ESA and unsurpassed in picking dazzling meeting locations in Italy, had arranged accomodation in a beautiful old, originally Benedictine convent on a small island in the Venetian lagoon just across from San Marco square: the isle San Giorgio Maggiore.

This site is not accessible to the public and can only be made available on special request for scientific or cultural events through the Fondazione Giorgio Cini. We met in the Sala Barbantini in the Centro di Cultura e Civiltà, a truly impressive and inspiring ambiance and it was up to us to make it work!

The presentations of the topical teams were of a very high calibre and comprehensively outlined a coherent approach for each of the science disciplines concerned, i.e. solar and heliospheric physics, space plasma physics, planetary science, space astronomy, relativity and gravitation. Obviously, integration of these elements into a global affordable programme was not going to be easy.

Previously I had discussed with several people, and notably with Vittorio Manno, how we should handle this. The best start seemed to be to try and define several levels of projects with respect to scientific timeliness and scale size. Vittorio originally tried to visualise this in terms of a number of concentric annuli representing different classes of projects, each class being then subdivided in a number of segments representing the various disciplines. The emerging geometrical picture gave a funnel-like impression which, according to Vittorio, strongly resembled Dante's Inferno and we contemplated whether such an 'infernal' approach could lead to a 'hell of a programme'.

The idea of trying to categorise the programme in various scale levels did strongly appeal to me. It offered the possibility to make more explicit the main thrusts in the programme, and allowed a timely identification of the required technological developments and logistics, while still maintaining a fair degree of flexibility for choices in the future which is mandatory for any rapidly evolving field.

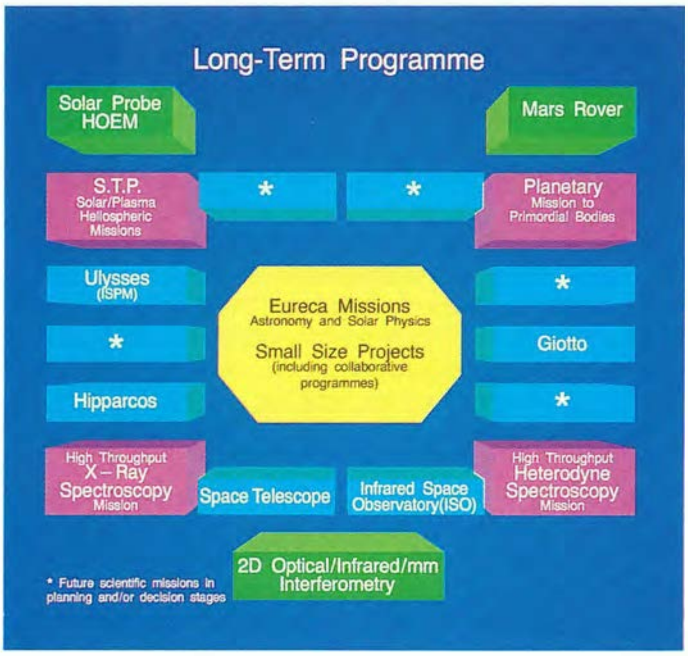
ESRO-ESA Space Science

Rather than the infernal picture, one could structure this in terms of building blocks of different types and identify the main thrusts as the cornerstones.

This concept was discussed extensively in Venice during the executive session of the Survey Committee and the members did indeed feel that such an approach might be fruitful. However to gain wide-spread support, the vast majority of the users should be able to identify themselves with the content of these cornerstone projects. The discussion on the number of cornerstones ESA could afford and on how specific we ought to be took quite some time.

I felt that we actually needed to be very specific on the content of the cornerstone projects in order to demonstrate that we were prepared to make choices and, also, for a timely assesment of the areas of technological development. In my view this part of the programme should not be regarded as a model programme but was for real.

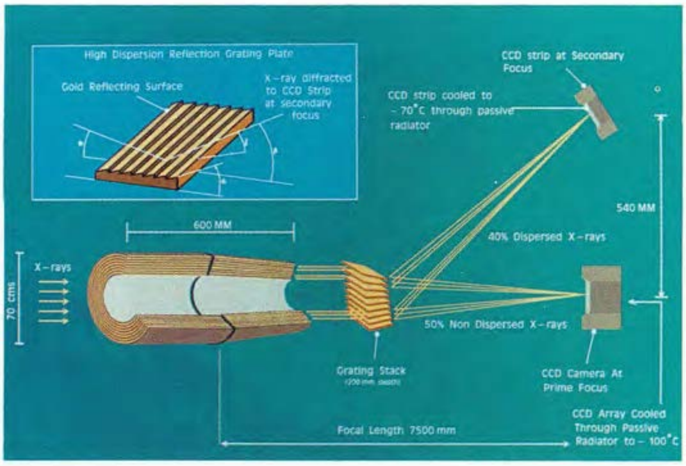
Several subgroups met until late in various Venetian trattoria's to discuss their willingness to settle for specific cornerstone aims. In the area of planetary and cometary science good old Johannes Geiss played a major catalytic role in deciding on the focus for these disciplines. Moreover there was a problem with solar and space plasma physics, for which people felt that both needed to be represented on the cornerstone level although this would clearly violate the budgetary guidelines or the level of flexibility.



It was Martin Huber, then chairman of the Solar System Working Group, who offered the solution: combination of two ongoing mission studies on a solar observatory (SOHO) and a multi-probe space plasma project (CLUSTER) into a tandem programme on Solar Terrestrial Physics could be rated on the cornerstone level.

Soho and Cluster — an artist's impression

The astronomy part was relatively easy and so we reached consensus on how the long term plan should be structured.



XMM - another of the Cornerstones

ESRO-ESA Space Science

To speak with St. George, on San Giorgio we succeeded in defeating the dragon of dissension which was continuously lurking in the background. Unfortunately I did not have the proper cartoon, however I did occasionally use another one (see picture) to emphasize that we should not accept defeat through lack of consensus.

Settling for less by keeping all options open should be regarded as a serious derailment and would certainly let off the precious 'steam'.

The overwhelming response of the science community and the fact that consensus was reached on a challenging but restricted programme is the best proof of the eagerness and the vitality of Europe in space science. The implementation of *Horizon 2000* is now well underway; successful completion is mandatory to give proper credit to what has already been achieved so far.

ESRO-ESA Space Science

Early Days in Service with ESRO

Dr. Edgar Page

He already had an exciting job in England, being largely responsible there for two experiments in preparation for the ESRO I spacecraft. And just months earlier he had taken on the responsibilities of a wife and a mortgage on a new house. Consequently, when in early 1965 the young Edgar Page was invited by the fairly young Hans Ortner to apply for a post with ESLAB, he was far from sure how to respond.

The idea of being in at the start of a European venture in space had enormous appeal and it has to be confessed that the salary increase was not without its attractions. I therefore set out to face, at ESRO headquarters in Paris, an interview board which included Ernst Adolf Trendelenburg, that colourful character who was to be my boss for 18 years.

Surprises, and perhaps even shocks, were not long in coming. The first was that the ESLAB, to which I thought I was being appointed, did not really exist. Various delegate bodies were still debating an arrangement which they hoped would provide a scientific liaison service but which would not produce scientific competition strong enough to deprive national institutes of their authority and their space flight opportunities. It proved necessary to maintain this delicate balance of being good, but not too good, throughout all my years with ESLAB — or Space Science Department as it was later called.

I have vivid recollections of an ESRO Director who, when told how successful we had been, said 'Page, what makes you think delegations want you to be successful ?' For someone young and keen, this aspect was hard to handle.

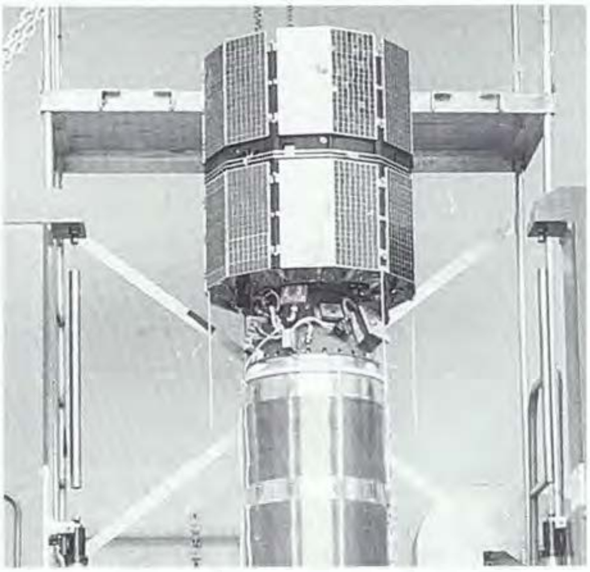
In the early days ESRO was advised by several scientific working groups. One of these was the COS group, another was the STAR group. The young Page was privileged to listen to an early COS group discussion where a menu of future ESRO projects was on the table. He heard a distinguished advisor reject one project on the grounds that 'The Americans already have plans to do that' and the same advisor later in the same meeting reject another candidate project because 'If it was any good the Americans would be doing it already.'

He (the young Page that is) was soon convinced that even eminent scientists were just as human and objective as stockbrokers, butchers and funeral directors.

On another occasion the STAR group chairman was bemoaning the fact that ESRO had selected no astronomy projects but had chosen from recommendations of the COS and ION groups. The young Page was foolish enough to venture the suggestion that the COS and ION groups had taken the more businesslike approach of considering what was financially and technically possible. He was forcefully told to speak only when spoken to and assured that no such mundane considerations would cramp the dreams of the STAR group.

Such were the shocks. Then we all tried to settle down to provide the liaison service that the European scientific 'community' required.

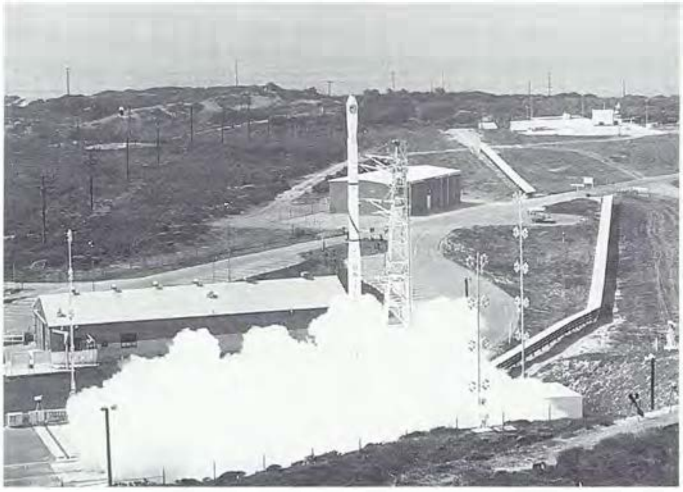
I found myself as Project Scientist for the cosmic ray spacecraft ESRO II, which, with true ESRO logic was ahead of ESRO I.



ESRO-II

The pressures on the scientists to meet the launch date were enormous and ESLAB had great difficulty in holding back the technical and industrial steamrollers sufficiently to allow a good science payload to be produced. I doubt if anyone who witnessed the launch will forget the occasion. We watched the trajectory plot board pen as it followed the first stage of rocket burn along the nominal trajectory, then the second stage, then the third stage — and the pen drifted away aimlessly. ESRO's first spacecraft was heading for the bed of the Pacific ocean.

The disaster helped unite the warring scientific and technical factions to the point where another ESRO II was prepared and launched about a year later with a set of scientific instruments in a much healthier condition.



ESRO-2: launch from Vandenberg Test Range, California

The associated launch campaigns at Vandenberg in California produced enough incident to fill a book — or at least a lurid Sunday newspaper. One dark night I was driving on a country road near Vandenberg and carrying as passengers Dr Lines, then Technical Director of ESRO, and Dr. Ortner, now a well known Austrian delegate, when we found ourselves not just stopped, but actually blockaded at a junction by California Highway Patrol cars whose occupants were directing automatic rifles at us. Apparently we had not seen a light warning us to stop and the police were convinced that only hardened criminals ignored such warnings. I took it all rather calmly at the time, but have shivered on occasions since at the realisation that one more misunderstood move could have had us all shot.

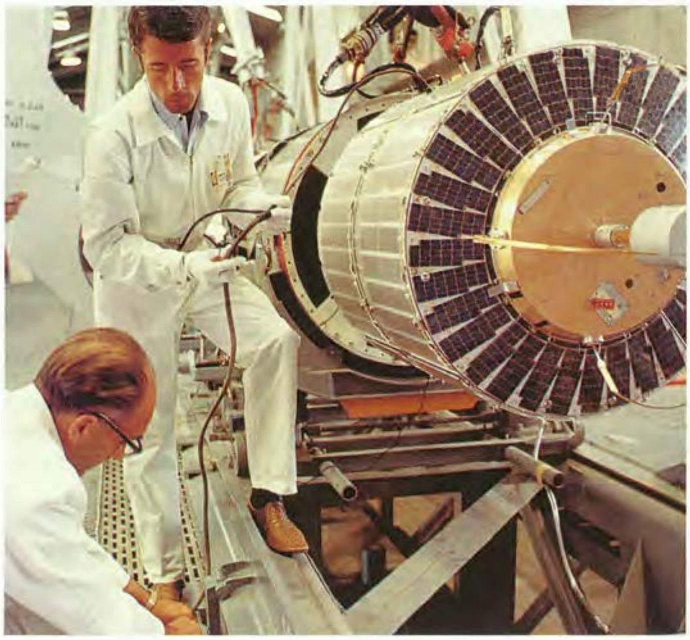
And there was the European visitor who developed a relationship with a Vandenberg lady only to discover later that she had a husband who was a local Highway Patrol man. The visitor moved to a distant motel and kept his head down!

The shifted campaign disrupted the personal plans of the Page family too. In fact it became necessary to deposit my very pregnant wife in England at very short notice. Since the arrangement was so hurried and ad hoc the medical people there were convinced that the poor girl was an unmarried mother telling the near-unbelievable story that her husband was launching a satellite in America. When the baby arrived she was only partly rescued by telegrams and flowers carrying the message 'Congratulations on the launch of ESRO III.'

Such was the enthusiasm of the young generation of ESRO people at the time that my not seeing our first child till he was 3 weeks old did not seem extraordinary. We had, we thought, adequate compensations.

About the same time we managed to get accepted ESLAB's first space experiment. Although it was only a ratemeter which we attached to somebody else's geiger counter on ESRO I, it provided a great sense of excitement and achievement at that stage. It opened up the possibility for us to do some research.

Throughout all the project service and research work we experienced the marvellous challenge of blending staff of all nationalities into a working system and we experienced too the great satisfaction of succeeding. In this we were helped by an ESLAB boss, who was not blessed with a great gift of diplomacy, but who was never observed by me to hire a staff member or take an important decision on the basis of nationality considerations. He frowned on private gatherings of any of his staff which involved one nationality only, and, when frequently on a Friday night we were 'commanded' to come and party at his home, we invariably encountered a truly multinational mix of fairly happy drunks.



ESRO-I which carried the first ESLAB experiment

There have of course been disappointments and sadnesses. But the privilege of helping to build a Space Science programme in Europe and through that to contribute to a Europe where people got along as friends has more than compensated for the difficulties.

ESRO-ESA Space Science — Chapter 7

Souvenirs of a certain period in ESA

Dr. Vittorio Manno

My first encounter with space was with 'comic rays'. At the end of my University curriculum I was preparing a thesis to get my title of Dottore in Fisica and was fully immersed in elementary particle physics which seemed to me then, and still does, to be the fascinating world of the unknown - difficult to comprehend and to measure, but nevertheless the world of true reality.

Then I came across a friend also preparing a thesis, but on 'cosmic rays'. However the way that was said coupled with the tiredness of one long night spent at the Frascati Synchrotron surveying our experiments, led to my mistaken understanding and a big laugh between the two of us.

The next encounter came a couple of years later as I was called for an interview at the (then) ESLAB in Noordwijkerhout in response to my application. There I was to meet the 'creme' of European space science in ESRO, the Trendelenburgs, Ortners and Pages.

The ESLAB buildings in Noordwijkerhout where so many ESRO scientists had their first 'encounters' with Ernst Trendelenburg

After having explained in detail my own work during the thesis, I was again confronted with the 'comic rays' as I was asked a question on the 'mirror' points in the magnetosphere. 'Mirrors? Mirrors in space? How did they manage to get there?' was my reply, which occasioned laughter in the room! The day was saved by my capability as a good horse rider! That admission, together with my candid ingenuousness about everything to do with space, convinced the interviewing board that I was the 'right stuff'. Admittedly, today I would stand zero chance at an interview on the basis of my above performance, but obviously the criteria were then different, the successes were still to come and Horizon 2000 was a couple of decades away.

But it was through such premises that I was given the formidable chance to witness and perhaps also to contribute to, the wonderful development of European Space Science over 22 years, until about a year ago when I joined the Italian Embassy in Vienna. The development was surely wonderful but the ride was certainly not as smooth as on one of those good horses I used to ride.

There were many obstacles in our path: confidence in, and from, the scientific community, confidence in and from the political authorities, financial constraints and limitations, unequal status with our international partners and difference of procedures.

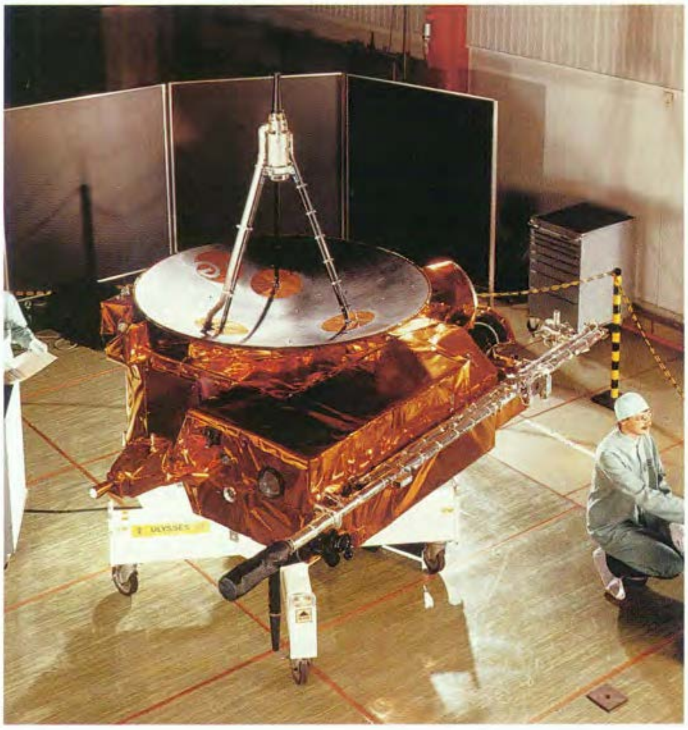
During the COS-B development we faced a sudden withdrawal of the British Institute involved in the development of the payload and a British attack on the validity of COS-B altogether. The day was saved by the Space Science Department taking up the telescope, and the political/scientific issue by a workshop, the chairmanship of which was intentionally given to that gentleman whom we knew as Sir Harrie Massey.

That problem had just been solved when the Italian participants threatened to quit unless their design of the electronics was preserved, which it was and which they developed beautifully. During the meeting of the famous COS-B Steering Committee, I, as its secretary, was sometimes instructed to write hard-worded notes to the Project Scientist who was ......myself, and to which I responded with more (but not much more) diplomatic wording! At the same Steering Committee meetings we witnessed J. Labeyrie entering with brio into the room, slipping and immediately disappearing under the table! Shortly afterwards B. Occhialini would, with equal brio, leave the room in protest. And (I intentionally mean and and not but) in the end COS-B was the resounding success that we all know.

ESRO-ESA Space Science

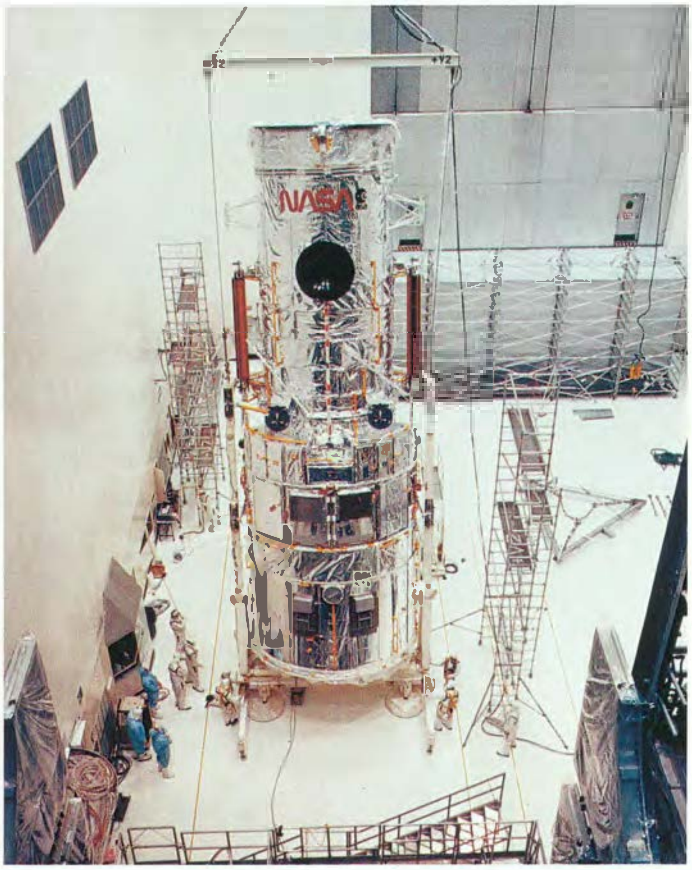
Then came the international crisis of ISPM/Ulysses. There Ernst Trendelenburg, (whom I knew as EAT) developed the right, and, needless to say, forceful strategy. But, by God's will, (accomplished through EAT's dog), he broke an arm and I was instructed to interpret his message to NASA. That cost ESA some 10 Concorde trips by the DG (E. Quistgaard) and me to the US (including an 'aller/retour' on the same day), meriting a front page article in the New York Times, which was not too friendly towards NASA.

I realised this, when, in the NASA elevator quite unaware of the article, I sensed some hostility from the NASA people around me. Perhaps that explains why, shortly afterwards at lunch, I got the soup, by accident, poured on my coat! Things were pretty tough and at a certain meeting the members of the ESA delegation folded their papers and solemnly left the room. I had hardly entered my room at the hotel when the telephone was ringing to propose compromising solutions etc. But we lost ! And now ISPM consists only of one spacecraft, Ulysses and when it will fly I am sure it will also be a resounding success, thanks to ESA and NASA.



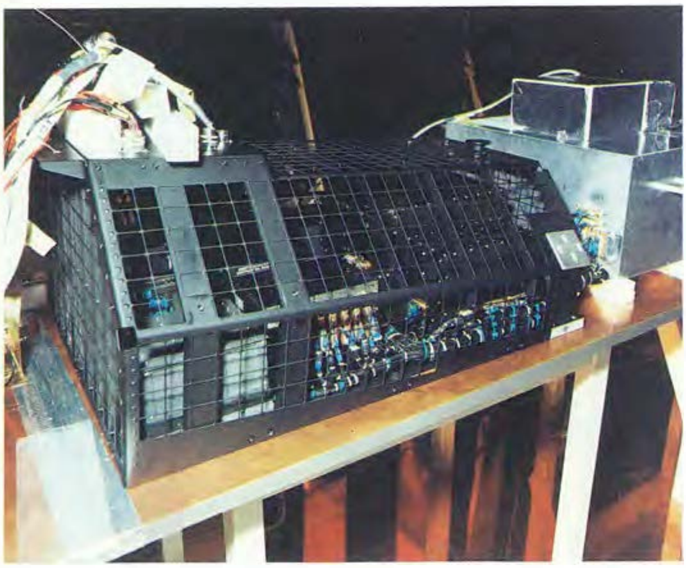
The Ulysses spacecraft due to begin its long journey in October 1990, which will take it via Jupiter to the poles of the Sun

On Space Telescope there were no such crises, but nevertheless quite some tough negotiations, which required careful give and take. Again it was all started by a comment of B. Occhialini who, in Frascati, addressed ESA vehemently about ESA doing nothing while NASA was embarking on such a big project. So we wanted to be part of that project, albeit on a modest but significant level. The building blocks of the participation were sound: the FOC (against quite some resistance from the US scientists), the solar array and a participation in the operations.



The Hubble Space Telescope being prepared for its successful launch. (courtesy NASA)

The question revolved on the return to European scientists: 10% or more. In Europe the debate was heated. Why should we invest in such a project to secure a return that Europe would in all probability get anyway? Franco Pacini countered that 'lots of girls are good looking, but we want to be sure we are recognised as good looking'.



The Faint Object Camera: perhaps not 'good looking' in Franco Pacini's sense, but hopefully it will take a good look back into time as a crucial part of the Hubble Space Telescope's observation programme

Finally EAT spoke: 'Let it be 15%' - and so it was! The agreement took uncountable meetings with the lovely Lady Nancy Roman knitting at the conference table. The final details were worked out between D. Macchetto, Nancy and myself at a little dinner at her house, (which did not make the first page of the New York Times!), but which we celebrated with ½ litre of wine, especially purchased by Nancy for these two 'wine drinking' Europeans!

An extraordinary experience was the periodic visits to Delegations which EAT and I made it a point of duty to do. In fact this turned out to be one of the most efficient tools for building up that reciprocal confidence which then gets eroded at the regular meetings of the SPC. Without exception these visits were successful and played a very great part in the success of the European Space programme.

EAT and I could have written pages about the different quality of reception that we received from our hosts. I remember the first visit we paid to the Spanish delegation and scientists. It eventually developed, against our best intentions, into a friendly but nevertheless tough skirmish between the scientists and their official representatives in ESA. EAT and I ended up quite rapidly in a car to the airport; but both of us with a delicious bottle of Porto. There were many further visits afterwards, and I can say that the success story which Spain became, and will become even more so in the future, is due to those two perfect Spanish gentlemen who then represented Spain in ESA and who both, to my deepest regret, are no longer with us.

Our financial limits were becoming intolerable and risked leading ESA's Space Science Programme to insignificance. The evolution of space science made it critical that we find ways to increase our budget, and to put on the table, squarely, what Europe wanted, would and could do. That was high in the minds of E. Quistgaard and E. Amaldi, the latter being a strong advocate of international cooperation. The idea was to develop a long term plan with clearly identified objectives and propose it to our masters.

The time became ripe when Roger Bonnet took the helm of the Directorate. The scepticism was widespread because of the limitations of our budget, no matter how convincing we would make the case. Roger Bonnet took over the Directorate with precisely this idea, and needless to say, he found himself in perfect communion with G.P. Haskell, H. Olthof, G. Whitcomb and myself. My crucial worry was: would the scientific community understand our effort and support it and would such an outstanding personality as Johan Bleeker be convinced and undertake it as the Chairman of SSAC ? Both reacted with extraordinary conviction and the Survey Committee chaired by Johan issued, after three days meditation in the town of San Marco, the unexpected: the Horizon 2000 programme.

It was based on the work of discipline teams, numbering more than one hundred scientists, all Europeans, who worked with fantastic devotion against all odds, with no personal prospects, no special remuneration, driven only by the conviction of working for the best interests of European Space scientists. It was a moment of grace, which was all accomplished in about nine months.

But miracles need help and there was B. Hultquist doggedly fighting for an STP, and J. Geiss marshalling a consensus on the planetary project. But still everything had to be put in a logical ensemble. Metternich prevailed and so it was that a few of us with Johan Bleeker went into a Venetian trattoria, and there, with the help of some Pinot Bianco to fight our exhaustion, the cornerstone concept and the whole architecture of Horizon 2000 was finally put in place.

I myself designed a 'gondola' type architecture and with the other participants, who had some equally adventurous ideas to frame the plan, we finally got to what is still today the basic construction of Horizon 2000.

Horizon 2000 was a success and still is today. It managed through its coherence and through the beautiful defence of it by L. van Hove, E. Quistgaard and R. Lüst, to rally the agreement of all the Ministers, including after an uphill battle, the British Minister. It was and still is a success because of the extraordinary coherence that Johan put into it, and by the intelligence of Roger who made it the paradigm itself of European Space activities. Even EAT was dubious of its success: we split a 100 DM note together, (a habit that he had to make bets, and which may be of some guidance to the present day discussions on the DM - Ostmark exchange rate !) and I got the other half back with his compliments !

As a conclusion, let me remark that Horizon 2000, which was for me the apex of my career at ESA, has broken new ground on all of the obstacles that I mentioned at the beginning. Only the financial problems remain, but these are due largely to events outside Horizon 2000. The history of the development of space science shows well that success does not come smoothly as a gift of God. It comes through dialectic, through argumentations, difficulties and tensions but it always comes when there is coherence in the approach and when there is a common goal which is clearly identified and accepted by all concerned.

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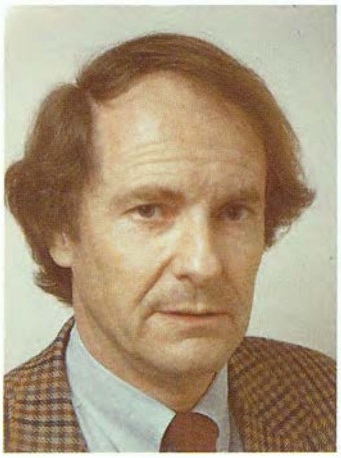
ESRO-ESA Space Science



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