Teaching of Astronomy in Asian-Pacific Region

Bulletin No. 15

The 1st Part of Special Issue on Special Workshop on Education in UNISPACE III

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Syuzo ISOBE
Syuzo Isobe
Chairman of Teaching of Astronomy
in the Asian-Pacific Region

Preface

Publication of this Bulletin was started in 1991 and the bulletin was published once or twice a year to be now No. 15. In October, 1992, we had the first meeting of Teaching of Astronomy in the Asian-Pacific region under the International Astronomical Union (IAU) and its proceedings were published as our Bulletin of No. 6 and No.7.

Activities of Teaching of Astronomy, IAU Commission 46, have grown much. To accelerate this movement, we hold a 2.5 day workshop by a chairmanship of Dr. Donat G. Wentzel (University of Maryland College Park) jointly supported by IAU and COSPAR (COmmission of SPAce Research) during the Third United Nation's Conference on Exploration and Peaceful Uses of Outer Space(UNISPACE III).

It was a successful meeting which created Recommendation to the whole UNISPACE III meeting represented by each national representative from UN member countries. Our recommendation has passed without much change and the final form of conclusion and proposals is shown in the following page.

These successful outputs were produced by many papers presented at the workshop. I, as the vice-president of the Commission 46 and the chairman of Teaching of Astronomy in the Asian-Pacific Region was asked to publish those papers in our Bulletin. We are much appreciated to take care it and will publish the bulletin No .15 and No. 16.

I hope this bulletin is useful for you and expect your further contribution to this Bulletin.

1999.10.1

Syuzo ISOBE
National Astronomical Observation

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THIRD UNITED NATIONS CONFERENCE ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE

Vienna
19-30 July 1999
Committee I
Agenda item 9
Benefits of basic space science and capacity-building

Technical Forum

Conclusions and proposals of the International Astronomical Union/Committee on Space Research/United Nations Special Workshop on Education in Astronomy and Basic Space Science

1. Having considered the draft report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) (A/CONF.184/3 and Corr.1 and 2), the International Astronomical Union/Committee on Space Research/United Nations Special Workshop on Education in Astronomy and Basic Space Science noted the following (paragraphs in parentheses refer to paragraphs in the draft report):

(a) Human resources with appropriate knowledge and skills are the critical factor in developing and using space science and technology (para. 184). Nevertheless, many countries still lack the educational capacity to build and deploy such skilled human resources. Thus, promoting scientific literacy is one of the great challenges for the future (paras. 190-192);

(b) Astronomy and the origin of humankind in the universe have fascinated humans through the ages and astronomy is still viewed favourably by a public that is otherwise becoming increasingly sceptical about science. Thus, astronomy and basic space science have a unique ability to make an education in the physical and applied sciences attractive to young people. Astronomy has also long been an important vehicle for effectively passing on a wide range of scientific knowledge and teaching the basic principles of scientific reasoning and for communicating the excitement of science to the public (paras. 191, 192 and 213);

(c) Education in astronomy and basic space science in many developing countries remains impeded by the lack of trained instructors, teaching materials and a clear vision of the role of astronomy and basic space science within the broader context of education in the physical and applied sciences (para. 325);

(d) Finally, many trained scientists remain unable to contribute effectively to the development of their countries because of scientific isolation and their lack of suitable employment and research tools (paras. 186, 206 and 325).

2. The Special Workshop made the following recommendations:

(a) All States should formulate national policies for education in basic space science. The International Astronomical Union (IAU), the Committee on Space Research (COSPAR) and other international organizations should help to collect and systematize information on experience with the build-up of education in astronomy and basic space science, at various levels of formal and informal education, in countries with differing conditions. That information could help interested States to assess their current situation and develop realistic national goals and expectations, as well as effective long-term educational strategies, adapted to local conditions. In implementing such strategies, it is recommended that a significant fraction (1-2 per cent) of the budgets of national space projects be devoted to education and public outreach activities (paras. 194, 229, 325 and 328);

(b) International organizations such as IAU and COSPAR should help to develop an inventory of teaching methods and materials that have proved effective in various countries at all levels of formal and informal education, up to and including the graduate level. The inventory should include methods and materials for the training and professional development of teachers, introducing multicultural and multidisciplinary elements as necessary. The materials should be disseminated to interested States and communities worldwide and adapted to local conditions as appropriate in collaboration with other partners (paras. 194, 196, 210, 211 and 229);

(c) Collaboration should be established between the regional centres for space science and technology affiliated with the United Nations and IAU, COSPAR and other scientific organizations to strengthen components of their curricula that involve astronomy and basic space science and thus increase the attraction and effectiveness of their programmes in basic, environmental and applied space sciences (paras. 199, 205, 206, 215, 217 and 231);

(d) All States should recognize that, for space scientists and engineers to serve effectively in the technical, economic and social development of their country, they need suitable employment and adequate research tools, as well as appropriate training. Developing partnerships with industry and increasing the public's appreciation of science should be considered important steps towards achieving those goals (paras. 197, 198, 226, 229, 328 and 337).

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WELCOME AND INTRODUCTION

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1. Introductory Remarks

On behalf of the IAU and COSPAR, I am pleased to welcome you all to this Workshop. I thank the United Nations Office of Outer Space Affairs for hosting us here and for co-sponsoring this joint event. I also extend my warmest thanks to Don Wentzel for doing the lion's share of organising this Workshop.

In a meeting of experts on education in astronomy and basic space science, it would make little sense for me to take up your time by praising the virtues of teaching these subjects or attempt to advise you how to do it: Your interest and experience in this subject are the very reason why we are here, and it is *your* experience, not mine, from which we will profit as a basis for our future activities. Therefore, let me just briefly recall why we hold this meeting here at the UN premises at the time of the UNISPACE III Conference and outline what I hope that we might accomplish.

2. Astronomy and Science Education

We all know that astronomical discoveries interest virtually everyone on the globe, especially young people, and inspire them to learn more. We also know that a vast number of skilled people will be needed worldwide for space activities planned for the near future, as you can hear right now at the main UNISPACE Conference elsewhere in this building. Most of these people will not be doing astronomical research: Astronomy itself is much better at interesting people than in providing paid jobs. But they can very well have been first interested by and even trained in astronomy and keep that perspective, although using their skills in other subjects. Or, to illustrate the philosophy with a quote from Dr. Margarita Metaxa (Greece), who at IAU Symposium 196 here last week described her high-school physics project on light pollution, "No, it doesn't make all the high-school kids go into a science education. But it teaches them to *think* like scientists!".

To help effectively, we need to better understand the sequence of events leading from excited elementary-school astronomy fans through high school, university, and the Ph.D. and postdoc stage. On the way, the perspective of the average student should gradually expand from pure astronomy to include a broad field of physical and space sciences and their applications. A clear overview of this process will help science educators to apply past experience and select and apply the most suitable of the many existing teaching materials and tools more effectively. But we also need to keep long-term national goals for education and the future of the students and young scientists sharply in focus.

3. Systematizing Experience and Forging New Partnerships

I especially hope that we can make progress on two specific topics this week:

First, I believe it would be useful to set up a kind of generalised "strawman" schedule for this process, based on experience from several countries. The idea is not to straightjacket everyone into one programme, but to help countries or groups wanting to use astronomy in the development of their science education programmes to better understand their particular initial situation and what options and expectations are practical and realistic in their particular circumstances. The schedule would list a number of useful main initiatives found to be suitable in certain typical situations (e.g. setting up a small telescope facility in a university department offering astronomy as part of the physics courses). It would list the measures that need to be taken together in order to make such an initiative successful (e.g. instrumentation, software, maintenance, and proper instruction in the small-telescope example), and also indicate what sort of results can be reasonably expected and on what timescale, so as to avoid unrealistic expectations and unnecessary frustration. And it should be supplemented by an inventory of specific teaching materials appropriate at each stage and found to be useful in similar settings elsewhere.

Second, I hope that we can find ways to establish a useful cooperation with the *Regional Educational Centres for Space Science and Technology*, affiliated with the United Nations. These have been or are being set up in several regions of the world under guidelines and with curricula and procedures defined by the UN, and they cover the whole spectrum from (almost) pure astronomy to the purely applied fields. These Centres offer an internationally recognized, independently funded infrastructure which we cannot realistically expect to duplicate for astronomy by itself, and they have an interesting structure for their courses which merits close study. I believe that it should be possible to set up an effective, even if perhaps initially informal, collaboration between these Centres and the IAU and COSPAR which could benefit both sides. On the one hand we, the professional non-governmental Unions, should be able to help enhance the attraction and quality of the courses offered by the Centres; on the other hand, the Centres could offer venues and direct links to the governments that could enhance the effectiveness of our own educational programmes in the future.

The *UN/ESA Workshops on Basic Space Science* include many of the cross-disciplinary and international aspects just mentioned, but in a mobile and temporary rather than stationary and permanent format. Based on my own limited personal experience (from the most recent *Workshop* in Jordan), these Workshops are very valuable as regional interest and contact promoting initiatives and thus play a complementary role to the systematic, longer-term programmes mentioned above. By working with the United Nations, we can better make governments aware of what we can offer to help making their science education programmes more effective. In this way, programmes may also become possible which are beyond our own limited current resources.

4. And afterwards...?

Giving young people an education in the science we love is gratifying, but I fear we are all only too familiar with the problems faced by bright young candidates looking in vain for a job in astronomy. It is important, therefore, to note that the intergovernmental agreements establishing the Regional Centres specify that the young scientists trained at the Centres must get a job and appropriate professional tools to do it - described in detail - after they return. Even from a purely pragmatic viewpoint, this is not philanthropy, but plain common sense: After all, the only good reason for a country to invest in the education of its bright young people is to put them to work using their skills for the benefit of the country. Yet, to get this simple message through to decision makers, it must be presented in clear terms at a venue where they will hear it. UNISPACE III is a unique such opportunity.

In the most rosy scenario for our future collaboration with the Centres, everybody will win: More people would get a science education and an interesting job (although not primarily in astronomy research), and their home countries will get more of the skilled human resources which everybody recognizes as one of the most crying needs for the future. After all, achieving more than the sum of the constituents is what collaboration is all about. For people hardened by long experience it may sound a bit Utopian, of course - but that has rarely deterred astronomers from doing what they found right!

As everybody here knows, educational programmes as outlined here take time to build up and become self-sustaining - decades rather than years. Recognising that fact from the outset makes it easier to deal with. But even long-term processes converge faster if they started early and with a recipe to keep them going in the right direction. It is my hope that the recommendations which will be formulated at this Workshop and transmitted via UNISPACE III and the United Nations system to the governments of the world may help to improve both the speed and the direction of this process.

The United Nations have so far organised UNISPACE conferences every 15-20 years or so; I trust that, by UNISPACE IV, some of the seeds we are sowing this week will have matured into healthy and thriving plants.

NATIONAL STRATEGIES FOR SCIENCE DEVELOPMENT

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1. INTRODUCTION

One of the background papers to UNISPACE III defines the objectives of education : to bring the individual to an understanding of the subject, so that he or she may form independent opinions, establish priorities and understand and discuss the methodology, the techniques used and their applications. The subjects of astronomy and basic space science are a particularly good vehicle for science education, in part because astronomy has deep cultural roots and receives attention, in part because these sciences stretch the imagination and their students have an extra advantage in absorbing the spirit of scientific inquiry and in forming independent opinions.

How can a country with very little science tradition, or perhaps no science tradition, introduce the spirit of scientific inquiry to its universities and government agencies?

I shall assume that there is some stimulus for a country to start science. Perhaps the country wants to begin space activities and it has learned from this workshop that space activities should include basic science. Perhaps the country has an environment conducive to science. For instance, Bolivia with its high mountains is natural for studies of cosmic rays. But I shall also assume that almost no one in the government knows what science is. I shall assume there is a university with a physics faculty who can teach a few standard physics courses up to what is locally called an M.Sc. in physics. I assume the government is willing to buy some basic technology like computers and email, but it only grudgingly provides some new human resources, such as new university faculty. Finally, I assume that the government of this developing country wants to minimize international help so as to create an indigenous scientific personnel. These are all very important conditions. Perhaps no individual country may fit all the conditions, but they are typical.

0) An insufficient strategy: Foreign-donated equipment. Historically, many a physicist in a developing country has thought: If only I had this equipment, then I could do some research. So he wrote a letter to a European scientist, asking for this equipment. That scientist told his university : Let us buy them this equipment and be done with the problem. That was probably wrong.

The physics community learned decades ago that the mere purchase of equipment usually does not lead to any successful science. Perhaps the equipment does not work because the university does not provide electricity and maintenance. Equally probably, the local scientist does not carry out the planned work because physics is a low-ranking science, and the local scientist is given other duties or moves away. The equipment soon sits idle and rusts.

The physics community has learned a lesson : donated equipment is probably useful only if it comes with donation of human resources. Continuous foreign support is needed both for the equipment and for the scientist.

In the case of astronomy and basic space sciences, we are now learning two very similar lessons.

A first lesson concerns computers donated to a developing country. The donated PCs are used intensively, but they are used almost only as typewriters. The donor of the computers probably expects some scientific computing, some data storage and data analysis. But these topics are new in the developing country. Real science is done with the computers only if the donor provides the needed education, a useful database, and is involved for the long term.

Our second lesson concerns the modest size telescopes that have been donated, mostly by Japan but also by other countries. These telescopes are intended both for education in science and for modest research. But local scientists may lack the experience of working effectively with telescopes, they lack the experience of assessing the quality of data, and they may not even know that they lack these experiences. Astronomers are learning now what the physicists learned decades ago, namely that long-term support is needed to make the telescopes reach their goals.

There is a modern version of let us buy them some equipment. It is : Let us get them a connection to the world wide web, so that they have access to data. But the data do not automatically become science. Pretty pictures on the web from the Hubble Space Telescope do not automatically become science. Again, what is needed to turn the web into science is a long term personal interaction with the local scientist.

2. STRATEGIES FOR INTRODUCING THE SPIRIT OF SCIENTIFIC INQUIRY

I want to discuss six national strategies that have been tried. You will see that they are ordered in terms of the established hierarchy, from lowly students to university faculty and up to exalted officials. I hope you will see that no one strategy is sufficient, but two or three together may work.

Strategy 1) Send students abroad for advanced study at a university with internationally accepted standards.

This must be an explicit strategy in the home country, because the young scientist, on returning home, must have waiting for him or her a scientifically useful position. It must be a position that makes use of the scientists insight and creativity. Of course, it is difficult to recognize this creativity in a home university that lacks any science tradition. Therefore, the home university must be prepared to accept advice, either by a national science advisor or from outside the country. This advice must be an explicit part of the strategy.

The goals for sending students abroad must be identified clearly. One goal is that the student learn the spirit of scientific inquiry. Frequently, at the home university, a student has been allowed to memorize all the equations in the physics text, even at an advanced level. Suddenly, in the new university, the student fails very badly, until he or she learns to think about the equations, and to use them in new situations together with actual data. In a good foreign university the student learns the spirit of scientific inquiry in the two years needed for an M.Sc. degree. A country wishing to start space activities is well served when such students return with an internationally recognized M.Sc.

A second goal of sending students abroad may be to acquire the experience of research. Then the returning scientist can formulate a useful science project and assure the quality of the resulting science. Usually, that means sending a student abroad to earn a Ph.D., and probably to stay for a two-year postdoctoral position. When the young scientist returns home, to a suitable job, he or she will also have the international scientific connections that can further benefit the local science.

It is risky for a university to reserve a good job for the several years. There is the chance of the young scientist staying abroad and becoming part of the brain drain, especially if a doctoral thesis depends on very specialized equipment. Ideally, the foreign thesis advisor should encourage the students scientific flexibility so that he or she can indeed return home. But in reality, most thesis advisors cannot advise usefully because they have insufficient knowledge of the students home country. A few large universities have organized their foreign faculty to provide this advice. Similarly, the IAU and COSPAR could organize a system of international advice to the academic advisors of foreign students.

How do you pay for study abroad? Students in the USA, Europe or Japan need more money per year than even a senior professor earns in most developing countries. It is politically very difficult for a government to invest more on its students than on its in-any-case underpaid professors, even if the money is available. Therefore, practically, the students must be supported by the host country.

Where should students go to study? If students are asked, most of them say: I can go study in the rich USA. But the chance for foreign M.Sc. students in the USA is decreasing, because the foreign students must be able to teach in English, the US students increasingly demand that they understand their foreign teachers and, therefore,large US universities increasingly require better spoken English of its foreign students who teach.

But foreign study need not be left to the students choice. The universities in developing countries must learn to seek out foreign opportunites for their outstanding students. Many potential host countries support foreign students as part of their foreign policy. For instance, some European countries feel responsible for their former colonies. The larger Latin-American countries, like Argentina, Brazil, and Mexico, provide fellowships for students from the smaller Latin-American countries. Japan seeks to aid not only SouthEast Asia but developing countries in all the continents. In the USA, there are groups of ex-patriates from many countries who sponsor a few fellowships for their own national students. These kinds of fellowships tend to be flexible so as to accommodate to the needs of the foreign student. The home universities must seek out these bilateral and ex-patriate connections, and then make the fellowships available to the most qualified students.

The strategy of sending students abroad has worked in several countries. Several astronomers, trained abroad with a broad outlook, have returned and even become science spokespersons in their countries. But we must recognize that this strategy requires many years to fruition. A young returning scientist can inspire colleagues of a similar age, but it takes many years for this scientist to influence the existing senior establishment. Ten years are the absolute minimum time for a scientist to acquire some influence, and at least ten more years are needed to see some success. Only few developing countries can maintain this one strategy consistently for that many years.

2) Visiting Scientist Program. This strategy is to invite a foreign scientist long enough to overcome the local inertia to change. In practice, a visit must be at least long enough to teach a full course at the university. As a prerequisite, each of the visiting scientists must be realistically informed, well ahead of time, of the academic level of the students. The visitor must be informed of available books and equipment, so that he or she can bring additional needed resources.

An ideal goal may be that several consecutive visitors together create a local M.Sc. program at an international academic level. To do this, each visitor must both teach the students and also prepare some local faculty to teach the same courses in the future. By teaching, I do not mean only lecturing about new subject matter, but actually to work with the students and faculty so that they learn the process and spirit of scientific inquiry.

A less ambitious goal may be just to give the local students a better rounded education, at a high enough academic level so that they later more easily can be sent abroad for further study. This was the goal of the IAU Visiting Lecturer Program. In practice, we found too few scientists willing to visit for even two months. They were to be paid only travel and local expenses, and, in Peru and Paraguay, had to speak in Spanish. Therefore, there were long time intervals between visitors, and no one student could benefit from a coherent set of courses. However, the program provided enough momentum so that other international help was provided subsequently, and the cumulative effect was useful.

3) Send university faculty or staff members abroad, for further study at an internationally ranked university. In principle that sounds very good : a young faculty member goes abroad, acts like a senior student, does some research with someone, learns how courses are taught, returns to modernize the curriculum and also continues an international scientific collaboration.

In reality, the privilege of going abroad is given only to senior faculty. A senior faculty member cannot be treated as a student and yet he or she is not qualified, in the host country, as a salaried scientific collaborator. Therefore, this strategy really works only if there already is an ongoing scientific collaboration.

The easiest way such collaborations can start is by sending students abroad. I think one function for the regional organizations in Latin America, Africa, or around the Mediterranean is to stimulate opportunities for real collaborations, and thereby for sending faculty and staff abroad.

4) Intense local workshops conducted by foreign scientist teachers. The workshops may be one to four weeks long, depending on the financial resources. Experience exists for this strategy because, in many countries, school teachers are trained in university workshops. For example, you have heard from Dr. Gerbaldi how it is done in France. However, some of the lessons learned from these teachers workshops are much harder to apply when a foreign scientist conducts a workshop in a developing country.

a) The workshops must have carefully specified goals. They must specify the methods to transmit, to the local faculty, both the spirit of scientific inquiry and some factual science. Lectures alone are not adequate. Discussion and practical work are absolutely necessary. But these are difficult for a foreigner, especially if there is a language barrier. A poorly chosen visitor may simply give lectures about not lecturing. The goals must carefully exclude such a visitor.

b) The participants must receive a lot of support even after one or two workshops. While they teach, they need scientific answers to questions quickly, preferably by email from an alert respondent. In fact, since the teachers are confused and cannot state their question precisely, they need scientific discussion during several e-mail exchanges. Now that most universities have e-mail, perhaps an international panel of patient educators might be identified for such a purpose.

But the new teachers in developing countries often need a much more important form of support, namely support to defend how and what they are teaching against a skeptical establishment. Traditionally, science departments in developing countries evaluate their students training in terms of the mathematical rigor of the courses. But we want to stretch the students imagination by orders of magnitude, we want to discuss with students which kind of physics is appropriate to explain new observations from Earth orbiting satellites, and we insist that theories based on observations require a judgment as to their validity. These aspects of science are perceived to lower the rigor of the courses and thus they threaten the departments prerogative to evaluate the students. Therefore, there is resistance to change. If the teachers do not receive longterm effective support, the results of the workshop simply diffuse away.

Fortunately, we can demonstrate that our science can be rigorous in at least two ways.

First, astronomy and the basic space sciences foster back-oftheenvelope calculations and a flexibility to use methods from a wide range of fields. When students have learned how to set up back-of-the-envelope calculations, then they understand the physics and its equations more rigorously than the students who memorize every factor of pi in the equations. When students habitually think about possible methods to solve a problem before they run to an equation or the computer, then later they are able to make wise decisions as they are needed in their country. It is perfectly possible to examine students quantitatively in this regard. We must demonstrate that this is a rigorous aspect of our science.

Second, astronomy and basic space science must deal very carefully with their observational data. Rigorous data analysis and error analysis are absolutely essential to the science. But data analysis does not exist in many physics departments, because they have no experiments that might need data analysis. Therefore, we must introduce the important role of data and careful data analysis as part of the more creative ways of teaching and learning.

5) Import a science spokesperson. A government may wish to create a National Science Council, and to import a science spokesperson as the head of the Council. The government will probably look for a reputable scientists in a culturally related country. It is difficult to find such a person, but it has been done. Alternatively, returning local scientists may develop into science spokespersons. Several astronomers have done that during the last few decades. Unfortunately, even with these spokespersons, it takes years for science to progress.

6) International workshops such as the UN/ESA workshops, and also a few of the IAU International Schools for Young Astronomers. These workshops

attract the attention of the national decision makers, the officials of government and university. When a workshop demonstrates the spirit of scientific inquiry, it validates in the officials mind the importance of basic science and the spirit of scientific inquiry. Therefore, the workshops not only make it easier to employ one of the other options I have listed, but they also help to reach the scientific goals more quickly.

I have listed for you six national strategies, all of which have been employed. I want to mention one additional strategy, in which I am involved. It needs no national policy and it needs very little international organization.

7) Infiltrate our science into existing university courses. We should encourage any professor to remove perhaps 10% to 20% from the regular, perhaps out-dated material of a course and to substitute some attractive topics from astronomy and basic space science including, of course, the methods of inquiry. For example, in a course on mechanics and orbits one can discuss the detection of super-massive black holes in distant galaxies. Later, in a course on radiation and Doppler shift, one can discuss the detection of planets around other stars. In each case, the accuracy of the data and the rigor of the data interpretation are essential aspects to get across to the student. This infiltration works not only in physics but also in chemistry, geology, meteorology, mathematics, etc. It can help create an interdisciplinary outlook at a university.

A minimum of new topics is of about 10% , because students need time to actually recognize that they should think differently. A maximum is about 20%, because that is small enough so that the professor can learn the subject and its manner of inquiry and also it is small enough so that it does not threaten the established curriculum.

I know that many professors would like to introduce astronomy and basic space science in this way. Needed from the international science community are suitable materials, materials that explicitly discuss how the students can be helped to think more broadly and creatively. Hans Haubold at the UN has begun this process by supporting my project Astrophysics for University Physics Courses. (see http://www.seas.columbia.edu:80/~ah297/unesa/astrophysics.) I suggest that an international workshop might prepare a more rounded supply of such materials.

I have now discussed seven possible strategies to introduce science and the spirit of scientific inquiry to a developing country. Any one strategy alone is not sufficient. But a combination of several does work. For instance, the donation of a small telescope may be combined with strategies one to four to provide the experience to run the telescope efficiently and usefully.

If a country truly has no scientific tradition, then it truly needs help from other countries, not only in terms of equipment but in terms of creating and recognizing scientific talent and identifying science appropriate to the country. And yet, these same developing countries want to control their own development, and they easily perceive outside help as a paternalistic imposition. In fact, the advice often is paternalistic. I think, for instance, of the large research group that asks a local scientist to collect or evaluate some results and send them back, without any real participation. That is not really a collaboration, and it does not benefit the developing country. A much better form of advice is given in a manner such that the developing countries can developed their goals by themselves, so that they know that they truly benefit. Good teachers can encourage this process. The supporting countries, and the international organizations, must become good teachers in that sense.

3. THE MEANING OF COOPERATION

Ultimately, enhancing science in developing countries requires cooperation among many parties. I want to conclude by citing two aspects of collaboration that need particular attention.

a) Collaboration within the developing country. In countries with few resources, many scientists reach their positions by acquiring resources for themselves. This culture works against collaboration. For instance, if you send a book to a professor, the book goes into a locked desk drawer. Neither students nor colleagues see the book. More importantly, if one university acquires some foreign support, it guards this opportunity jealously. It gives reasons why another university should not participate.

Foreign support under such restrictive conditions is inefficient. I think the foreign donor must require, as part of the support, explicit local procedures that open up the offered resources to all who should obtain them. And then the donor must verify that the procedures are followed. For instance, is the donated book really in a library accessible to the students? Once again, the donors personal and continuing attention is a requirement for a successful program.

b) Set goals but be patient. Finally, the supporting universities and organizations must learn to be patient. A fouryear agreement of cooperation may look excellent on paper but, in practice, unexpected developments and delays are inevitable. For example, needed permissions are delayed in government, or students lack an important subject because the appropriate professor was sick, or a university closes for a month because of political unrest, or the leader of the project is suddenly required for other duties, and so on. This means that a schedule of progress must be renegotiated every year. Nevertheless, it is important to set up a schedule of progress toward specified goals, to help everybody to know where they are in the process, how they are performing, and when advice is needed for adequate progress. Throughout these years, the personal and continuing attention paid by the foreign scientists is essential to help a developing country acquire astronomy, basic space science, and the spirit of scientific inquiry.

Education of Astronomy and Sciences
--- From Activities of Japan and Asian-Pacific Regions ---

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In 1978, the first Asian-Pacific regional meeting of IAU (International Astronomical Union) was held in New-Zealand, and astronomers from different countries attended the meeting (Table 1). This was a good occasion for astronomers from developing countries to get into international communication. Especially in 1981 Muller organized an educational meeting in Indonesia. At the fourth meeting in 1987 it was supported by the attendances that a new committee of teaching of astronomy in the Asian Pacific region should be set-up and that this author was chosen as a chairman of the committee.

Table 1. Years and places, when and where the Asian-Pacific Regional meeting was held.

1st Meeting	1978	New Zealand
2nd	1981	Indonesia
3rd	1984	Japan
4th	1987	China
5th	1990	Australia
6th	1993	India
7th	1996	Korea
8th	-	-

Since 1987, several activities started. At every regional meeting one or two session(s) for astronomical education has been hold, and those were good opportunities to exchange ideas of astronomical education and to understand what problems each country has. In 1992, we had a 3-day colloquium in Beijing and papers present there were published in the Bulletin shown below.

From 1990, the Bulletin of teaching of astronomy in the Asian-Pacific region started to be published semi-regularly and now number of publication is 14. 400 copies for each number of the Bulletin have been printed and 250 copies have been sent to registered people with free of charge. Although it has a name of the Asian-Pacific, people at all over the world contribute to and receive it. Unfortunately number of papers submitted goes down, and therefore, I request submission of papers to this Bulletin.

Several astronomical projects at different countries started with a support of Japanese government. Those are : 1) Indonesia set up a donated 45 cm photometric telescope, for observations of variable stars, 2) Thailand got the same telescope, 3) Sri Lanka opened Arthur C. Clarke Center for Modern Technology at a time when they got a donated 45 cm telescope, 4) Malaysia opened Science Museum at a time when they got a donated planetarium, and 5) Viet-Nahn also opened a planetarium. Addionally to these Egypt refabricated their 1.9 m telescope, Paraguay and Rumania will soon get planetariums. This kind of works should certainly link with the UN/ESA Workshop on Basic Space Science held once a year at different developing countries.

As shown here, each country which got a support from Japanese government is trying to develop astronomical programs, but has a difficulty to expand their activities further. Therefore, we should have a further good ideas.

Recently, there are some numbers of groups who are developing automatic and/or remote operation telescopes and inviting to use those telescopes. We have good international computer networks, and groups of countries which have good telescopes have now a possibility to use the remote operation telescopes in the other countries. However, there is one important difficulty, that is, only one group can use a telescope within a certain moment. Now, we are developing new telescopes (Isobe 1999) which have very wide field of 2-5 degree and obtain 80 K byte data per every exposure, to detect NEOs (Near-Earth-Objects). These systems will produce several 10 Gbyte data per night, which is too big data to be analyzed by a single group. We are intending to distribute a software to blink two images obtained on the same celestial field but at different times. We can distribute 1,000 sets of images per night. Then, many groups, scientific centers, amateur astronomers, school pupils, and public people have an opportunity to work on real science of astronomy.

I published an interesting diagram to show levels of people's interest in astronomy (Isobe 1990, here in table 2). We would be happy if all the people would be interested in astronomy at any levels. However, in practice, especially in developing countries, we should reach to people at the middle levels in the table 1 and bring them to have ability to teach astronomy to the other people at the lower levels. On this point our idea to distribute original image data containing undetected asteroids, comets, and variable stars and to make them detect those objects is the best one. We hope groups having a good telescopes will collaborate with us.

Table 2. Number of people depending on their degree of interests in astronomy.

Categories of People	Rough Number	Definition
A	10^2	produce useful observational data
B	10^3	observe frequently
C	10^4	observe several times per year
D	10^5	read astronomical magazines
E	10^6	read general science magazines
F	10^7	read scientific articles in newspapers
G	10^8	no interest in science

Another effective activity is to make people realize situations of light pollution. This activity is not only contribute to reduce light pollution but also to reduce energy loss and enhancement of CO_2. Figure 1 (Isobe and Hamamura 1998) shows night time light loss in Japan observed by DMSP (Defense Meteorological Satellite Program). We can estimate how much light energy each city lost at a certain time, and if people in a some city try to reduce light energy loss, we can easily detect how much efforts they did.

These two projects are not certainly confined within the Asian-Pacific region, but we will start our efforts within Japan, then, the Asian regions, and further to all over the world. By these works, we would like to have a common sense to evaluate astronomical output and also related environmental problem.

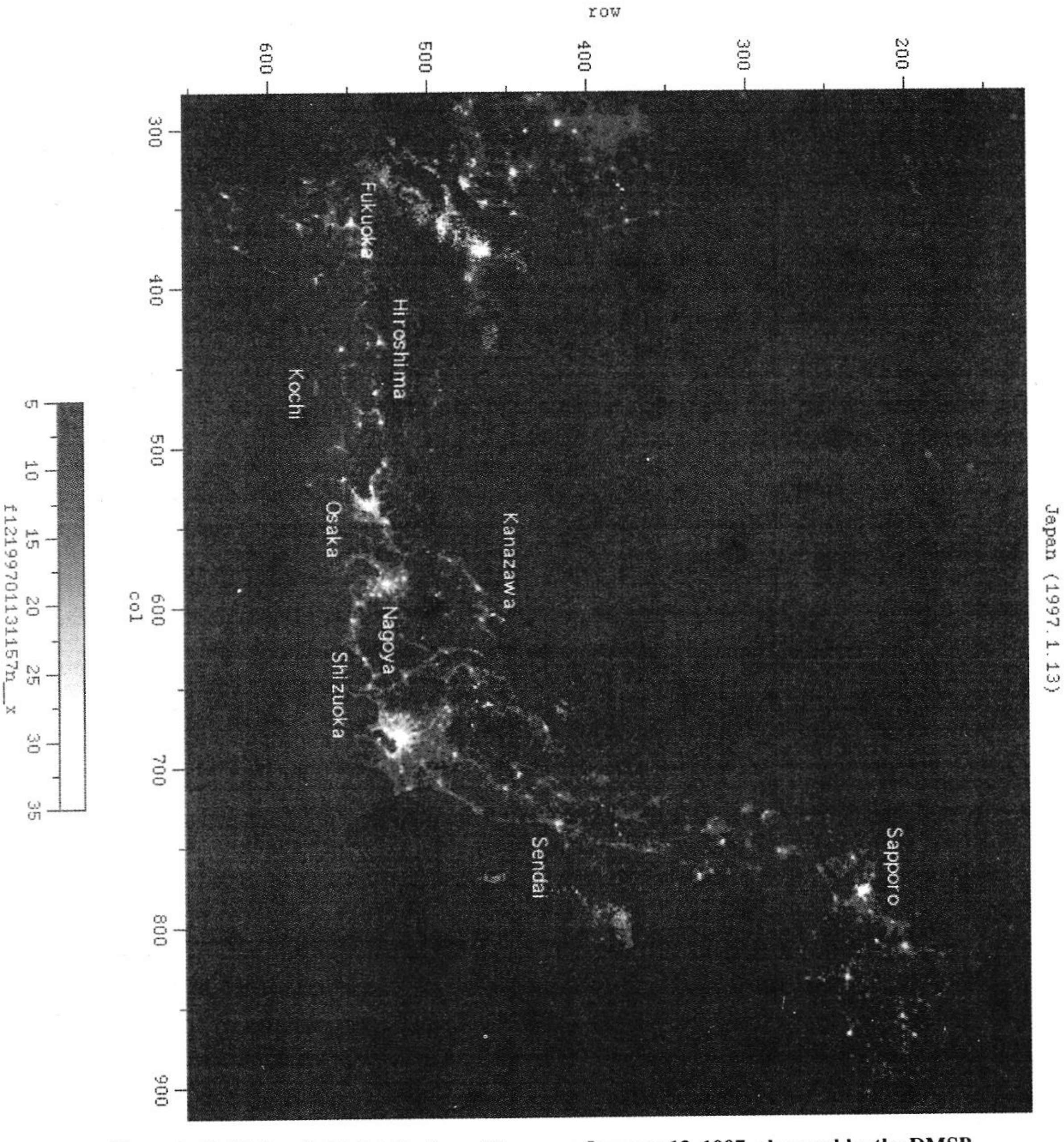

Figure 1. Night-time light distribution of Japan on January 13, 1997, observed by the DMSP.

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A Student Exercise in Astrophysics from Space: Interstellar Extinction from IUE Spectra of O Stars

(Submitted to the IAU-UN-COSPAR Special Educational Workshop on Capacity Building in Astronomy and Basic Space Science, 1999 July 20-23, Vienna, Austria)

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Introduction

The practical (Boyle, 1992) is one of the optional experiments on offer during a half-unit course in observational astronomy undertaken at the University of London Observatory. The course is held during the third year of the both the BSc and MSci (undergraduate) programmes in Astronomy and Astrophysics at UCL.

At the time of writing the practical, the IUE mission had been in operation for some 14 years. The mission's aims, methods and instrumentation are very well documented, allowing opportunities for easy and informative research by the student.

Aims

1. To give students an opportunity to work with digital spectroscopic data.
2. To introduce students to ultraviolet astronomy.
3. To familiarise students with the spectra of early-type stars, and to impress upon them that more of the interesting features of such stars appear in the ultraviolet region than in the visible spectral range.
4. To study some of the effects of the Interstellar Medium on the spectra of early-type stars, most notably interstellar reddening and the broad absorption feature at 220 nm.

Data

The student is supplied with digital IUE spectra taken from the catalogue of Heck *et al.* (1984). The spectra are of a set of 15 O-type stars, all dwarfs (luminosity class V). The spectra are already calibrated in wavelength and flux. Low- and high-resolution IUE spectra are employed. The spectral type, *V*-magnitude, *(B-V)* colour and approximate equatorial coordinates of each star are provided in the experiment script.

Procedure

The spectrum of each star in turn is displayed on a computer terminal. The student starts by locating the prominent resonance line due to C IV at 155.0 nm. In most of the stars this appears as a P-Cygni profile, indicative of a stellar wind. The strength of the emission component relative to the absorption trough is measured, allowing the student to comment on how the shape of the profile varies with spectral type.

Next, the broad absorption feature at 220 nm is located, and the correlation of the strength of this feature with extinction, *E(B-V),* is investigated. It is made clear to the students that there is as yet no universal consensus as to the origin of this prominent feature; most students are intrigued by this.

The student attempts to remove the effect of interstellar reddening from the spectrum of each star by dividing it by a 'standard galactic' extinction curve. A model spectrum is fitted to each dereddened spectrum, this procedure provides an estimate for the effective photospheric temperature of each star. Because the spectra are calibrated in absolute flux units, this procedure also yields an estimate of the distance to each star, since the stellar radius can be estimated from the spectral type. This in turn permits an estimate of the absorption measure, in magnitudes per kiloparsec. The student may then investigate the variation in absorption measure with galactic coordinates.

The Lyman-α feature that appears in the high-resolution IUE spectrum of each star is used to estimate the column density of atomic hydrogen along the line of sight to that star. The correlation of *E(B-V)* with hydrogen column density is then investigated.

Student reactions to the practical

The students in general react positively to this exercise and obtain pleasing results. They find the experience of manipulating and measuring digital spectra to be useful. Much is learned about the physical processes which affect the spectra of hot star, and about the effects of the interstellar medium on the spectra of distant stars. On the downside, weaker students are discouraged by the effort required to learn the techniques required to begin extracting meaningful results from the spectra. Most positively, some students have been encouraged by their work during this practical to embark upon doctoral studies involving IUE spectra.

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Science for the public in developing countries

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Introduction

Astronomy is a most appealing subject to young students and can be an excellent tool to convey scientific knowledge. Once students have understood the importance of science they might be more easily encouraged to continue their education in this field and technology. We could not imagine modern Astronomy without Space Science. Outreach programs that include Astronomy have proven to make people aware of the importance of research, to promote the interaction between industry and researchers, and have shown to be useful as and aid for education.

Outreach program's goal is to make non specialized general public aware of the way in which scientific discovery is achieved, its methodology and its findings. It should mention the importance of several scientific aspects for society and the differences from other fields of knowledge. Popularization of science tends to translate specialized language to a common one, and to render it accessible and attractive. Its long term goal is to help create a scientific culture among general population and to aid people in their personal development and help them appreciate science. A person dedicated to vulgarization must understand scientific concepts and be able to use the resources and the media.

For some colleges and universities popularization is one of their main goals because it is not enough to create and preserve culture it is also necessary to disseminate it. Due to this fact people dedicated to popularization must take this activity seriously. It is necessary for popularization to be as creative, diverse and as rigorous as other well established disciplines.

The need for education is a survival strategy of our species. Vulgarization is part of informal education so it can encourage people to pursue careers in science. If a nation wishes to undertake a new program it must take into account the following:

1- Popularization should be included in plans for developing science and technology.
2- Core messages about science and technology should be elaborated and socialized.
3- Software for distance activities should be distributed.
4- Intensive programs of popularization for teachers should be undertaken.
5- Programs for reaching the under served should be implemented.
6- Low-cost science equipment should be distributed.
7- Collections of "best practices" information should be available.

Why should we vulgarize science?

There are many reasons for conveying science in an accessible way to a large variety of people.

1- After school is concluded every person has to keep on learning on their own. Sometimes they have concrete needs and will take formal courses, but most of the time they use informal education to obtain the knowledge they are seeking.

2- People dedicated to industry need to be aware of advancement of science in order to incorporate it into their products, this is specially true in developing nations. There is great need to strengthen the links between research centers and industries.
3- It is necessary to vulgarize science at a high level amongst scientists so that researchers from different disciplines can improve their interdisciplinary activities.
4- Target groups such as housewives or teachers need particular outreach programs so they can make the most out of their every day chores.
5- In order to have governments and industries invest in science it is necessary for general population to be aware of its importance.
6- General population can benefit from popularization because it conveys to them the pleasure of understanding.

General considerations

Every outreach experience must provide meaningful answers, it must take into account the audience's needs and must try to answer their questions in a way that can be grasped providing the pleasure of understanding. So popularization is much more than a mere translation.

A person in charge of an outreach program should be able to adapt to their audience, understand science and must submit his/her work to rigorous assessment. He/she must also be able to stretch the audiences mind to the limit; this is more conveniently done during public lectures or workshops when he/she has direct contact with the audience. He/she must take advantage of particularly interesting situations: for instance eclipses, comets or meteor showers, in order to talk about science. The need to satisfy natural curiosity is a good moment to provide not only information but ways of understanding science. The important aspect of popularization is not only giving out information but helping people make sense of it.

Outreach programs should be diverse and meaningful, they should be carried out with great care. They can take advantage of the way in which human brain has developed. The most primitive centers are tact, smell and taste, later sight and even more recently hearing was developed, at the same time as higher intellectual skills appeared. An outreach program can take into account this fact by providing stimulation of each one of these cerebral parts: it can provide olfactory, physical, visual and acoustic activities, plus challenges, surprises and puzzles that apply to the higher elements of mind. Since our senses respond to contrasts it is important to provide a variety of activities to ensure good understanding.

When a vulgarization project provides explanations it must also present new challenges so that the receptor's mind continues to be stimulated. It is better to have an audience want more than to become tired or saturated. Less is more than too much.

Popularization programs must be run by specialists, that is to say people that are proficient in science and that are associated with other specialists in order to render a high quality product.

Amateur astronomers are a clue for outreach programs in developing nations. The Astronomical Society of the Pacific has included amateurs in its association, this provides them with a sense of belonging and makes them want to take their activity seriously. When they are involved in outreach programs they tend to be associated with professionals.

Science outreach programs must include technology, specially in the Third World. Most of the third world countries were colonies in the past. This historical situation impaired their development in many ways. In particular their technological achievements have been scarce since they were expected to provide raw materials to be processed by wealthier nations. In consequence general population did not develop the skills that are necessary for strong industries. In order to reverse this situation projects such as science centers should combine technical aspects in there exhibits, a good example are the new museums built in Japan.

It is wise to use popularization programs that have been created abroad, nevertheless one must bear in mind that every community is different and that concepts that make sense to one culture might not make any to another. Therefore one must try to balance adequately local and foreign information. In particular, in the case of science centers, building equipment locally has the advantage that is serves as a school for designers and that maintenance is straightforward. In the same sense a book written in the local dialect makes much more sense to the audience since language conveys culture.

Some of the materials that are created by people dedicated to popularization can later be used by teachers to help them with the understanding of science; outreach programs have benefited from items elaborated for education purposes. It is important to strengthen the links between formal and informal education.

Astronomy Popularization programs can include some of the following:

Books

It is important for countries to have astronomy books at all levels written in the local language. The examples must have to do with the local culture and present role models.

Magazines

Magazines on education are extremely important because they provide access to updated astronomical information.

Magazines that have proven useful are those dedicated to teachers. Specially those that invite them to share their pedagogical experiences. When a professor develops a new way of attacking a particular problem writing about it will encourage other professors to try similar methods.

It is important to have magazines on popular science for all age levels, including children. Good examples of astronomy magazines written in English are: *Astronomy, Mercury,* and *Sky and Telescope.* More should be edited in other languages.

Newspaper articles

Newspaper articles are convenient because they can be read in a relaxed environment. It is important to include sections for children. In my experience the latter are read by adults and elementary school teachers that feel more comfortable tackling with science that is written in a more informal manner.

Educational Television

I believe television has a great potential for outreach. In Latin America on the average every person spends 3 hours watching television every day. In order for such project to succeed three items are required:

1- Pupils must learn to watch television in a different way, not exclusively for entertainment or information.

2- Teachers that give the courses must get acquainted with the variety of options such a media has and to feel comfortable lecturing before a camera or a remote audience.

3- Teachers that use videos must learn how to get the maximum advantage out of them. For instance, to interrupt several times during the transmission and ask the students what they think about it. Discuss the video after it is concluded. Try to reproduce some of the hands-on activities, etc.

Radio programs and Hot Line

Radio is a very convenient way to popularize science. Some of the programs can be made rather inexpensively, for instance spots that can be transmitted via telephone, or talk shows that include participation by the public. The latter have the advantage of feedback, since they allow the conductor to sense the audience.

Hot lines are recorded messages on telephone, they are useful for outstanding phenomena such as the occurrence of bright naked eye observations when many people want information. In more developed nations a good web site can be an ideal substitute.

Museums

Science centers offer unique hands-on experiences. They are specially convenient for developing countries where few schools have laboratories. They should include a wide variety of activities if they are in small communities and provide materials for teachers so they can feel comfortable with the questions pupils will ask after a the visit. Science centers should take advantage of their exhibits to address topics concerning technology.

Planetariums

So much has been written on the use of planetaria that we will not comment on their great utility. It is my belief that portable planetaria are the convenient choice for popularization of astronomy in small communities due to their versatility and relatively low cost.

Plays

Plays on scientific topics appeal directly to sensual qualities which are very useful for developing pleasure in learning science for those who have had bad previous experiences with it. In my experience due to the difficulty of writing a "scientifically correct" script specially on such topics as cosmology it is good to have a narrator that gives the basic information. That way the actors can have certain liberties.

Software

More and more schools have access to teaching by computers so software in local languages must be developed in order to meet the needs of this demand. One must take advantage of the pupils interests in order to encourage them in broadening their knowledge by learning science. In the USA where statistics have been carried out comparing children that have access to computers and those who do not, it has been shown that having such equipment contributes substantially to children's better outcome at school.

One line items

The World Wide Web has proved to be a great information resource. One must bear in mind that understanding is not to have lots of information but of understanding.

In developing nations most of the population does not have access to the web. When it does it usually finds information that is in a foreign language and adequate to a different culture. This makes its understanding more difficult. Therefore it is very important to provide not only information but meaningful knowledge on the web in the language of the local people.

Public Lectures and Workshops

Both these activities are extremely popular. The disadvantage is that very few people have access to them.

Workshops are extremely useful because they promote several pedagogical qualities:

1- Students have hands-on activities, which have a very high retention coefficient.

2- They learn they can build things on their own.

3- They understand they are able to complete a task (a quality greatly needed in developing nations such as Mexico).

When an international committee interviewed graduate students in Mexico in order to find out why they had decided to do research most mentioned they had attended a public lecture or had read a book or magazine on astronomy.

Summer with a scientist

Programs such as *Spend a summer with a scientist* have been running in Mexico for several years. Statistics show that most students decide to continue their careers as scientists or at least are not negatively prejudiced against science once they complete their stay.

Olympiads

Olympiads on Astronomy do not exist in Mexico. The ones devoted to Mathematics, Chemistry and Physics have induced students to study science. Israel has held several with good success.

The disadvantage they have is that some of the students *feel* they already know enough and do not take school seriously for some time.

National Week for Science

Some nations carry out programs where during a week all outreach programs are enhanced and are included in a national programs. They not only include some of the items listed above but also science fairs at schools and visits to industries.

Scientific toys

The use of scientific toys is a great way to get youngsters involved in the joys of science. Unfortunately very few are available in developing nations. Hopefully with the increase of science centers and the proportional increase in their shops will encourage local industries to include scientific toys in their production.

Conclusion

Popularization of science can be a useful tool for formal education. One of the goals of developing countries is to provide a scientific culture for its population. The more ways science culture shall provide the more likely an educational project will succeed.

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ASTRONOMY AND TEACHER TRAINING IN FRENCH SCHOOLS

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The introduction of Astronomy to the French national curriculum was the result of a long term effort made jointly by professional astronomers and school teachers. The school teachers are the the main agent of the educational process not only at school but also they are very active in peri-scholar activities: they run club, educational projects. Therefore the emphasis has been put, on the school teacher training in astronomy since the beginning, in the seventies. The school teacher training is achieved using various methods from summer schools to distance learning courses. Such programmes comes with the development of pedagogical resources. In fact it is the way astronomy has been introduced to the French school curriculum.

I - WHY TEACH ASTRONOMY ?

We know on the one hand that pupils are not so easily interested in the study of sciences, and on the other hand they are curious about space and astronomy: how to connect those two facts in order to create a synergy ?

In the 1970's a discussion began in France about introducing physics to the curriculum, at the Junior High School (age 11 to 15), that is, earlier than at Senior High School (age 16 to 18) where physics was already taught.

The main ideas were:

- to avoid too much formalism, and formalism is a strong general characteristic of French science teaching
- to concentrate on experimentation and on the various representations of natural phenomena.

Obviously astronomy fits into this scheme perfectly well, but several arguments were developed against its introduction, which were mainly the hard competition between the various fields of Physics and the fact that the majority of school teachers had never studied astronomy.
Anyway, the push towards astronomy finally came from the pupils themselves:
in 1973, 10% of teaching time could be devoted to freely chosen topics by the pupils and astronomy was frequently one of them. A few professional astronomers decided to help teachers to introduce by going into the schools. This was done because personal relationships already existed between astronomers and teachers.

Through this experiment which lasted 4 years, the school teachers realized how astronomy could be a very good starting point for Physics teaching and because of this interest some French astronomers convinced the Ministry for Education to introduce the subject in schools. However, astronomy was not introduced as a new separate subject, but rather as part of another subject, mainly mathematics or physics.

The objective to be reached with the introduction of Astronomy in these fields was not to put this domain of research on the front line, but it was to widen the student's knowledge of science, giving him an idea of how to work scientifically from observations and known physical laws to get a new knowledge within another field of science.
This argument is still valid nowadays.

Astronomy is an interdisciplinary science.
This gives astronomy a double interest:

- to show the pupils that knowledge is not built upon separate fields as they may have the impression from their curriculum at school
- to show that knowledge, in general comes from interdisciplinary approaches.

Astronomy can inspire students to study sciences, can help to fight "math phobia", (see in the *Annexe 2* the testimony of a mathematic teachers) but it is efficient only if the science teachers have a sufficient specific knowledge in the field of astronomy so that they feel competent enough to teach this subject.

II - CREATION OF THE CLEA: COMITE DE LIAISON ENSEIGNANTS-ASTRONOMES

In 1976 a meeting took place between professional astronomers and French school teachers during the IAU General Assembly, held in France. This meeting was successful. It was attended by about 150 school teachers who expressed strongly their need for contact, information, and organization.
The training of school teachers and the role of astronomy in school programmes were the central points of this meeting.
The participants underlined the importance of organizing astronomy summer schools, publishing a newsletter, and circulating teaching material.

The first summer school took place in 1977, the first issue of the quarterly newsletter *Les Cahiers Clairaut* was published in 1978 and the non-profit organization CLEA *Comité de Liaison Enseignants-Astronomes* was born.
CLEA can be translated as Teachers-Astronomers Joint Committee.

It is important to underline that the push came from the teachers themselves, it was not given by the Ministry of Education: all the teachers adhering to the CLEA or participating in the summer schools are volunteers and it is through them that in a correlated manner on the one hand that the number of interested and trained teachers in astronomy began to increase and on the other hand little by little much more astronomy topics began to be introduced to the curriculum.

CLEA: Main Educational Objectives

CLEA's main educational objectives are the following:

- to give access to theoretical knowledge through practical activities
- to increase the mood of observing and experimentation
- to urge the various kind of teachers, working at various levels, on different subjects, to exchange their experiments and to hold a dialogue. This is particularly important to overcome the barriers between discipline and teaching orders
- to produce and circulate good quality educational material (textbooks, slides, video, scale models...) of low cost, user friendly, not too time consuming, and well tested from an educational point of view. The feedback comes from the network of CLEA members.

III - TEACHER TRAINING IN ASTRONOMY

A teacher can be trained in astronomy either during his or her curriculum at the university or during in-service training sessions.

III - 1 - Astronomy in the teacher university curriculum

Elementary school teachers seldom receive much training in science in general. Junior and senior high school teachers receive an initial training in mathematics, or physics-chemistry or biology, but with astronomy courses included in very few cases.
Besides the teaching of astronomy at university which is still only proposed in few universities, some astronomy courses are now included in the lectures given in some *Instituts Universitaires de Formation des Maîtres (IUFM)*, the training colleges, one for each educational district where the teachers to be are trained. (There are 28 educational districts in France)

So the main training of school teachers is during their professional life.

It is well known that one achieves better understanding of a subject by concentrated involvement. The solution adopted for training since the beginning, in 1977, was therefore to bring school teachers and astronomers, together, for usually 8 days.
So far, each year one or sometimes two, summer schools have been organized; 80 % of them were under the leadership of the CLEA.

III - 2 - Summer Schools

III - 2 - 1 - Objectives

The aims of the CLEA summer schools can be expressed on the one hand concerning the *content* and on the other hand concerning the *pedagogical methods*, both aspects being equally important.
The content varies from one year to next and covers a wide range of interests in the domain of astronomy astrophysics.
For example it is shown that the Universe is a unique laboratory considered as an extension of any terrestrial laboratory, which gives us a better understanding of the degree of approximation the physics laws deduced from experiences on Earth.
Concerning the methods, the goals for any participant are:

- to be able to develop their critical awareness, elaborating on what can be read in books
- to be willing to ask questions
- to be willing to explain their pedagogical experiences in a classroom
- to learn to use pedagogical tools such as: overhead projectors, models, planetarium, microcomputers, the web ...
- to be able to communicate with other teachers who attend the same summer school but who teach different subjects. This point is important: the school teachers who attend a summer school come from various backgrounds. Mixing school teachers with different backgrounds is enriching for everybody.

III - 2 - 2 - Pedagogical strategy

Three kind of activities are developed during these summer schools:
- lectures
- small workshops and practical classes
- tutorials.

The aims of the lectures are to give all the participants some basic facts related for example to modern astrophysics such as cosmology or it can be an epistemological reflection for example, the representation of the solar system during the 17th century.
The practical activities are organized into small workshops or practical classes of 10 people according to the subject: theoretical or more practical. Everyone can choose from all the activities proposed. Several workshops and classes run in parallel.
The overall aim of these activities is to illustrate an astrophysical concept that has been presented during the lectures.
During a summer school about 30 different small workshops are organized.

During a practical class, the participants make themselves a model or a small instrument that can be used during the following nights to make an observation. For the construction of these small instruments cardboard or wood is used, but every participant makes his own instrument and takes it home. Ready-made pieces are prepared so that everybody can participate even if he is not skilled at using materials and tools.

These activities are not designed for future work in the classroom. Participants must adapt them to the level of their pupils. We do not want to give packages of "ready-made" lessons.
During these summer schools there are informal sessions in which the participants discuss how to adapt the activities they have learned to their pupils.

Moreover tutorial sessions are organized at the demand of the participants themselves, to counterbalance the great variety among the background of the participants. The instructor for any of these activities can be a professional astronomer or a school teacher who has himself acquired sufficient knowledge in some astronomical field.
The methods used in a small workshop are direct and concise, but each instructor is free to choose any method he wishes to use. Because of the fact that there are many instructors in a summer school, the methods used can vary greatly. In any case a participant is absolutely free to choose any activity he likes.

We are aware that teachers even at the beginning of their training must be placed in a situation where very soon they have the capacity to do practical activities with their pupils.

Concerning the funds necessary for such a school, the CLEA succeed in obtaining financial support from the CNRS (Centre National de la Recherche Scientifique), the CNFA (Comité National Français d'Astronomie) and from the Ministry of Education. None of the lecturers received any fee.
The proceedings of these summer schools were published till the nineties, including the text of all lectures as well as that of the practical activities; then, they were only distributed to the participants, but last year we implemented it on the Web page of the CLEA having it available to everybody interested.

III - 2 - 3 - Feedback

How to evaluate what the participants had acquired during the school ?
We evaluate it throughout by informal reports or during the tutorial sessions in the evening as well as through questionnaires at the end of the summer school. We keep in touch with participants during the years that follow through the non-profit organization CLEA.

These summer schools have contributed to the training of school teachers from every region in France. It must be stressed that despite the fact that, in France, astronomers are concentrated in a limited number of observatories and institutes which are not linked with the universities - the method of school teacher-training by summer schools is powerful in the sense that it reaches school teachers far from astronomy centers.

Another success of these summer schools is that some of the teachers, after attending it - several times - can become tutors. Not only do they propose new experiments and test them with their colleagues, but they also organize local training sessions in astronomy during the school year, in their district.

These summer schools have been the backbone not only for the teacher training in astronomy but also for the introduction of astronomy in the curriculum and in parallel for the development of teaching material.

Consequently, these summer schools and CLEA activity in general have contributed to the creation all over France of a network of school teachers, trained in astronomy who are becoming *resource people* for this subject. So, in the CLEA Council there are 40 members who mainly represent the different French educational districts.

In *Annexe 1* Astronomy in the French school curriculum is described.

III - 3 - Other training sessions

Independently of the summer schools, presented above, there are training sessions which last about 3 days during the school year. They are offered by the professional observatories, as well as by the *Missions Académiques à la Formation des Personnels de l'Education Nationale (MAFPEN)* now part of the IUFM which exist in each educational district. These MAFPEN training sessions are often organized in collaboration with universities. The participants at such training sessions are school teachers who became instructors having being trained in summer schools. Many of them are CLEA members.

III - 4 - Distance Learning

The above methods of training the school teachers are done during a face-to-face session with the instructor. For various reasons, not all the teachers to-be-trained are able to participate in either a summer school or a training session. So, we developed a distance learning course.

This course was created in 1992 thanks to a collaboration between the CNED (*Centre National d'Enseignement à Distance*) and professional astronomers from the Université de Paris Sud XI.

III - 4 - 1 - Distance Learning Course in Astronomy-Astrophysics "Basic Training in Astronomy and Astrophysics"

This distance learning course rely upon the experience gained in the framework of the CLEA activities. This course called *Basic Training in Astronomy-Astrophysics* (*Formation de Base en Astronomie-Astrophysique*).
It is a post baccalaureat level course; it offers the opportunity to get an academic credit *diplôme d'université* at an undergraduate level.

It must be emphasized that this course is not written only for the training of the school teachers but it is widely open to everybody interested.
In France there are about 27 800 amateur astronomers practicing their hobby in more than 425 associations or clubs; there are also 100 scientific associations run by municipalities. In relation with their learning at school, the pupils come to visit these places where they can have informal astronomical activities under the guidance of amateur astronomers or staff members.
So astronomy is widely taught outside schools, in clubs or associations, and the amateur astronomers, the staff members feel the need of some training in astrophysics like the school teachers; usually they have a wide knowledge in the domain of practical observation, but they need to structure their knowledge as well as receive some kind of training on the basic astrophysical concepts.
This distance learning course was also designed for that purpose.

Which teaching material is provided ?

The teaching material provided consists of:

- a printed text (more than 500 pages) for the course
- black and white photographs (41)
- slides (60)
- video cassettes (3)
- micro flopydisks with dedicated programmes written specifically for this course.

As during the summer schools, but over a larger basis, one of the main objectives of this course is to demonstrate the reasoning methods used in science through astronomical examples. All along the various chapters the manner in which astronomical phenomena are interpreted in terms of physical laws are developed. This is what constitutes the foundation of astronomical knowledge. It is difficult to learn alone so various services have been developed in such a way that the students can test their progress.
The students study alone, in their own home and even if they have no television or no video cassette player and/or no personal computer, these media are not prerequisite for understanding. The students can study at their own pace and progress at their own rate but a guide with a calendar is provided.
In order to test their progression in understanding, all along the various chapters the readers is asked questions and the answers are given at the end of the chapter. Moreover 3 long homework assignments are offered and they are corrected individually by an astronomer.

But much more is offered to the students in order to help them in the learning process: twice a year, a full day meeting in a professional observatory is offered to the participants and two shows in a planetarium have been conceived for this correspondence course.

The role of a Tutor via Internet

More important is the direct link with a tutor which can be obtained at any time with the French e-mail system: the Minitel. This has been possible since 1993. 3 years later we got access to e-mail and Internet and now both systems are used.
The tutor is one of the professional astronomer who corrects the home work exercises; what is important is that the tutor is always the same person, so through the questions the tutor can understand the students'difficulties on certain points.
According to the opinions expressed by the participants, the variety of media and services used in this distance learning course fulfill their objectives due to the heterogeneity of the students, but also due to the variety of learning methods and approaches to the subject, characteristic, as we know, of each individual.

III - 4 - 2 - A Second Distance Learning Course: "The Age of the Universe"

Recent discoveries in astronomy are more and more frequently revealed in newspapers, on TV, ... Sometimes they are presented to the public by the media, with a provocative title: "the Universe is younger than the stars".
So, once more in relationship with the CNED, we took the decision to create in 1998 a second distance learning course whose content refers to the most recent discoveries in astrophysics.
The title of this course is *Astrophysics: deepening* with a sub-title: *The Age of the Universe.*
This topic is very suitable to show how progresses of this science are intimately connected to technological advances as well as to new developments in physics; it shows the iterative nature of the scientific reasoning. All along this second-year distance learning course, it is demonstrated how the astronomical phenomena which give access to the age of the stars - the stars being the bricks of the Universe - are interpreted using physical laws and making use of theoretical models, and how the given age "vary" according to the observations and/or theories available.
This course shows how "discoveries" arose, how knowledge is built upon various parameters which do not have the same weight and how, in such a context, it is difficult for the journalists to present these results. Some of the practical exercises in this course deal with analysis of articles recently published in newspapers in order to find the astrophysical background, not written in the article, but on which the discovery relies.

The teaching material provided for this second distance learning courses is similar to that of the previous one, as well as with a tutor via Internet.

Internet: supplementary activities

The participants to this distance learning courses are aware of the latest discoveries as revealed by the "hot news" offered to the public on T.V. or through the newspapers channels all along the year.

This give us the possibility to enlarge the feedback of this distance-learning course by offering an analysis of some of these "hot news" on Internet.
The CNED has set up pages on the Web where we analyze these publicized results. Such analysis is made in a way that the students are asked to answer questions in order to understand the processes of thought, how such new result has been obtained, all that using the knowledge acquired in their distance learning course.

These Web pages are intended to participate in the *training* process and not only to be *information* pages.

IV - TEACHING MATERIAL

Any school teacher training activity would be incomplete to some extend if not accompanied by pedagogical resources.

IV - 1 - Pedagogical resources

In addition to the textbooks, edited by private publishers, the Ministry of National Education runs the *Centre national de Documentation Pédagogique (CRDP)* which publish various booklets, slides and videos. Special mention is made of the bimonthly journal *Textes et Documents pour la Classe (TDC)* which is very popular and publishes a few scientific issues (recent ones are devoted to the Moon, to the Sun). We also mention the collection *Batiscience*, a series of videos including astronomical video cassettes.

The Planetarium are also good pedagogical tools. Their number in France is increasing; special mention should be made of the portable ones, easily interactive, which can be used in the school itself, by the school teacher.

IV - 2 - CLEA Pedagogical documents

The French-Astronomers-Teachers Joint Committee (CLEA) is in the forefront for developing and publishing examples of practical activities.
This is the natural extension of these teacher training sessions. Of course this does not supersede other teaching material mentioned in the previous section, but they have been developed in a different framework: that is, they were developed by the teachers themselves at the issue of these training sessions.

The CLEA Research Group for the Teaching of Astronomy has elaborated, experienced in the classroom and then published, at low cost, various materials:

- Activity Files
- Sets of slides
- Movable overhead transparencies

Due to CLEA collaboration with foreign groups with similar activities several of these items are available in English, some of them have been also translated into Spanish.

These activities do not rely directly upon the use of the Web, simply because we do not want to left aside any teacher who, in his or her school does not have an easy access to it.

IV - 2 - 1 - Activity Files

These Activity Files are written for teachers. They suggest activities related to a given topic and can be used directly with the students. Each of them suggests a possible approach to the topic they deal with. It may happen that several Activity Files deal with the same topic but the approach is then different, thus leaving it to the teacher to make his own choice.

They propose a strategy that emphasizes such objectives as:

- offering the pupils motivating activities that lead to discovery or creation
- basing these activities on astronomical observations, thus showing that astronomy is not a night activity only and that it can even be performed right from the middle of a big city
- assembling very simple instruments that can be later used by the students,
- guiding the students from observations or experimentations to interpretation with minimum mathematics
- using unsophisticated, cheap implements
- addressing every student, whether he is a science student or not
- teaching the students how to carry out bibliographical research or how to use database.

The following stages are particularly insisted upon: **observing, measuring and interpreting**.

The Files are presented according to a set pattern which starts from the objectives, describing the required implements, then the activities proper. They include practical practical tips and documents to be used by the students. They also propose exercises and an evaluation of the students'work that do not rely upon memorizing a set of facts or the ability to solve a mathematical problem. Some Activity Files also include bibliographical notes and further notes for the teachers.

These Activity Files are published as special issues of CLEA's Newsletters: Les Cahiers Clairaut and are oriented at different levels: Primary School, Junior School (lower Grade), Junior High School (Higher Grades) and Senior High School. Ease of use has been the key objective and each of them can easily be separated from the others.

Special mentions must be said concerning the activity files derived for the youngest. That children about 8-10 of age show keen curiosity for space and astronomy cannot be denied. It is important to come up to their expectation and keep on answering their demand always keeping their young age in mind. Most of their questions involve a *description* of the Universe, (the celestial bodies it contains, how large they are, how they move) rather than an *explanation* of the existence and formation of these bodies and the laws that govern their motions; at that age, "what is made of?" puzzles students more than "how does it work?". Astronomy is first and foremost based on observation In point of fact, children do not observe or do it badly. To teach them how to observe, how to question what they see and how to answer these problems is one of the goals of the teaching of Science.

In the *Annexe 2* a list of the content of these Activity files is given.

IV - 2 - 2 - Sets of Slides

They are meant as a teaching aid; their general philosophy follows the same guidelines as described above, for the Activity Files. Six sets (20 slides and booklet) are now available.
These sets of slides cannot by any means be a substitute for the observation of the real phenomenon: on the contrary they are a summary or an alternative solution.
Lets take an example: the analysis of the Sun rotation with the sun spots needs mapping the position on the Sun's disk everyday which may raise problems because of interferences with the class schedule, or the weather conditions.

In the *Annexe 2* is given a list of the content of these set of slides.

V - CONCLUSION

Astronomy is a magnificent tool to help develop the capacity to reason scientifically, but indeed to reach this goal teachers need to be trained.
We have shown how astronomy has been introduced in the French educational system; astronomy is not present as a separate topic but part of the science curriculum and it has been successfully introduced because school teachers are trained in astronomy.
Distance learning courses are created and summer schools organized, in parallel with the development of pedagogical material, at very low cost, to give the school teachers the means to respond effectively to their students' needs.
All that permit teachers to really exploit, for example, the typical outstanding images released by space agencies, that is to help their students, not to be just thrilled by these images but to incite them to use scientific reasoning to understand some of the background of such images.
We underline that this objective was achieved, with limited financial resources, by creating a network of extremely motivated teachers, the impetus being given by the non-profit association (*Comité de Liaison Enseignant-Astronomes CLEA*) Teachers-Astronomers Joint Committee.

The general objectives of this long standing effort, have for the first time, been explicitly taken into account by the Ministry of Education in the elaboration of the new physics/chemistry curriculum which will be implemented in September 2000 at the Senior High School (grade2).
Here are the first few objectives:

- to offer everyone, future scientists or not, a minimum scientific knowledge in order to have a basic understanding of the world, especially as we are at a time where we have to make important decisions regarding the environment
- to show that science differs from other fields of knowledge because it relies on scientific reasoning
- to give every high school student the opportunity to study science while trying to make science more popular among the pupils.

One of the subjects in this new curriculum is "The Universe: from the atom to the galaxies" and the emphasis is put on an experimental and deductive approach to instill the basic principles.

ADDRESSES

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ANNEXE 1

ASTRONOMY IN FRENCH SCHOOL CURRICULUM

In the primary cycle, for the pupils up to 11 years old, astronomy is present through the basic topics: light and shadow, day and night, etc...

1 - FRENCH SECONDARY SCHOOLS

There are two different main channels: the general one and the technological one. We shall only deal hereafter with the general one. The curriculum is national; the country is divided into 28 educational districts (*Académies*). Secondary education consists in two successive cycles:

• *Collège (Junior High School)* is compulsory: grades 6, 5, 4 and 3 correspond respectively to ages from 11 to 14.

• *Lycée (Senior High School)* grades 2, 1 and T correspond to ages from 15 to 17. At the end of the Lycee, students sit for an examination (and diploma) the *Baccalauréat*. Grade-1 students and those in the terminal year can choose between 3 options:
S, for Science; **L**, for Literature; **ES**, for Economy and Social Sciences, leading to 3 different branches of the Baccalaureat.

2 - ASTRONOMY IN THE PROGRAMMES

Astronomy fits quite well the general view that the teaching of experimental sciences must involve more experiments and/or observations.

Astronomy concerns 3 different fields:

- Life and Earth Sciences (**LES**)
- Physics and Chemistry (**PC**)
- and up to now, Mathematics

In the LES field, the main idea is that Earth, being one of the planets, should be considered as a global object compared with the others and that it depends strongly on the Sun. In the PC field, astronomical examples are chosen in order to illustrate physical laws.

2.1 - Collège

PC is taught in grades 4 and 3 (30 hours of Physics and 30 hours of Chemistry each year).
In grade 4 in physics the topics are: (1) Images and vision and (2) electricity. Astronomy appears in the first one including:
sources of lights, phases of the Moon; eclipses; sundials.
The possibility of introducing an optional workshop of physics, including some astronomy is under discussion, with experiments being made in a few places.

2.2 - Lycée

Grade 2:

Astronomy appears in LES under the topic: "Singularities of planet Earth":
Earth as compared to the other planets in the solar system: specifically of Earth, related to its mass and distance from the Sun. Constructing a scale model of the solar system.

In Physics, Astronomy fits quite well the spirit of the new curriculum, one of the main objective of which is that "the students should be aware of the major laws of nature and be able to understand what happens in the Universe in which they are living; in this regards, the teaching must be simultaneously of a high level but also simple and practical".
Astronomy appears in the chapter devoted to light (9 hours plus 6 hours of practical activities for the whole topic):
light; messenger of the heavenly bodies: planets, Sun, stars nebulae and galaxies; light year; measurement of the speed of light.
Time scales and velocity ranges quite different from the common experience are insisted upon, together with the historical aspect.
Astronomical examples are given to illustrate various topics:

topic	**example**
light sources and receivers	Sun, stars, planets, comets
linear propagation of the light	eclipses
velocity of light	light as messenger of heavenly bodies
light as a wave	spectrum of the Sun, of stars
the energy of light	power of solar radiation
gamma rays	the gamma ray image of our Galaxy

In chemistry, 3 topics are considered "chemistry in fields and in gardens; *the chemical elements on Earth and in the Universe*; oil and natural gas".

Grade 1 - S

Astronomy appears in LES in the section "Dynamics of external layers of Earth and the energy of solar radiation":
measurement of the solar constant; albedos.

Astronomy appears in Physics in the following sections:
"Motions": *Moon, planets and the Sun.*
"Energy balance": *energy of the Sun; life and death of a star.*

Moreover, the optional course of "Experimental Sciences", which is chosen by more than half of the students, includes a choice of different topics: 2 among 4 to be chosen in Physics, Astronomy appears in two of them.

"Observers and motion" (15 hours)

changing the reference frames and adding motions; examples: apparent and true motions in the solar system. Historical debate: from geocentrism to heliocentrism.
The Doppler-Fizeau effect; spectra of stars and galaxies: red shift. Expansion of the Universe.

"Radiation and colors" (15 hours)

continuum spectrum; black body radiation: temperature of the Sun. Line spectrum.

In LES, 3 topics must be chosen among 8, the most popular ones being all in the field of biology; however the one entitled :
"the Sun: its activity and its influence on Earth" also raises some interest.

Grade T-S

In LES: in the chapter "History and evolution of the Earth", mention is made of:
the big Bang: formation of chemical elements, of stars and planets.

Astronomy appears in Physics in the chapter on "Fields of interactions in the Universe":
the law of gravitation and the motion of planets and satellites; magnetic field of the Earth and of the Sun.
It also appears in the chapter on "visible and invisible light":
photons, line spectrum and energy levels; study of the spectrum of a star.

Moreover, the students can choose to develop one of the scientific courses (either mathematics, LES or PC) by choosing an "enseignement de spécialité" (30 hours). In Physics the following is proposed:
"optical formation of an image", with a mention of *Galileo telescope (history of the discovery and its consequences); refractors and reflectors.*

In **grade 1-L and T-L** the teaching in science is being modified: up to now the different astronomical topics (*calendar, the Copernican debate; star life and death*) have been fairly popular.

3 - NEW CURRICULUM FOR SENIOR HIGH SCHOOL LEVEL

Informations on this new curriculum starting September 2000, can be found on the Web page of the Physics Teachers Association *Union des Physiciens (UDP)*:
URL: www.cnam.fr/hebergement/udp/ then "Nouveaux Programmes"

ANNEXE 2

CLEA PEDAGOGICAL DOCUMENTS

1 - LES CAHIERS CLAIRAUT

4 issues every years since 1978 years (French only).

2 - ACTIVITY FILES

These are published as special issues of "Les Cahiers Clairaut".

Astronomy for the Elementary School
(French and English)
Contents: 1 - Shadows; 2 - Locating a Place on Earth; 3 - Daytime, Night and Seasons; 4 - Finding the Cardinal Directions; 5 - Solar Time, Civil Time and Time Zones; 6 - The Sun's daily Path; 7 - Sundials; 8 - Phases of the Moon; 9 - Making a model of the Solar System; 10 - Learning the Constellations; 11 - The Conquest of Space.

The Moon (Junior High School level
(French and English)
Contents: 1 - Phases of the Moon; 2 - Observing the Phases of the Moon; 3 - Observing the Motion of the Moon; 4 - Interpreting the Phases of the Moon; 5 - Interpreting the Motion of the Moon; 6 - Earth and Moon face to face; 7 - Studying the Phases and Motion of the Moon from an Almanac; 8 - The Moon in the Southern Hemisphere and at the North Pole; 9 - Eclipses; The Moon: Facts on Files; Glossary.

Astronomy: Time and Constellations (Senior High School)
(French and English)
Contents: 1 - In Search of Time ...;2 - ....Time Found; 3 - A perpetual Calendar; 4 - What a Star Map tells us; 5 - Constellations: a Trek across Space and Time; 6 - Constellations Observed from Deep space ...With a Pocket Calculator; 7 - The Astrolabe; 8 - Glossary: Fixing the Position of a Star.

Astronomy at the Junior High School
(French and English)
Contents: 1 - Measuring the Altitude of the Sun; 2 - Heliograph; 3 - Plotting a Curve (a skill-building file); 4 - Sundials; 5 - Making a Model of the Solar System; 6 - A Simplified Sky Chart; 7 - Refractors and Reflectors; 8 - Ocean Tides; 9 - Spectroscopy.

Astronomy: Light and Gravitation (Senior High School)
(French only)
Contents: 1- Ptolemy and Copernic; 2 - Aristotle and Galilee; 3 - Galilee and the Jupiter Satellites; 4 - The Moon and the Gravitation; 5 - Jupiter Moons and the Gravitation; 6 - Halley Comet; 7 - Phases of the Moon Calculator; 8 - Roëmer and the Light Speed; 9 - Galilee Refractor; 10 - Refractors and Reflectors; 11 - Spectroscopy.

The Spectrum of the Sun (Senior High School)
(French only)

Another one has been published (in French only) by a private publisher (BELIN): **Astrophysique: 18 fiches.**

3 - SLIDES SETS

Each set has 20 slides and a booklet with suggested practical activities.

Phases of the Moon
(French, English and Spanish)

Heavenly Bodies also Rise
(French, English and Spanish)

Learning the Constellations
(French only)

The Retrograde Motion of March
(French and English)

Sunspots and the Rotation of the Sun
(French, English and Spanish)

Comets
(French only)

4 - MOVABLE OVERHEAD TRANSPARENCIES

Earth-Moon System Simulation
(French and English)

Time Zones
(French and English)

5 - KIT

Kit for the Measurement of the Solar Constant
(French and English)

6 - EXAMPLES

We give here a short description of some of these pedagogical documents as well as references where more informations can be found.

Study of a spectrum of a star

The spectrum of Rigel was taken at the Observatoire du Pic du Midi, using the 60-cm telescope, by school teachers. A comparison spectrum was obtained from an Argon lamp. The students are first given information concerning the spectrum of Argon, then they are asked to identify the emission lines in the comparison spectrum and finally to calibrate their spectrum. Then they are asked to determine the wavelength

of different absorption lines in the spectrum of the star and to identify the chemical elements responsible for these lines.
A similar activity is proposed with a spectrum of the Sun, also taken by a school teacher, similarly calibrated with the spectrum of Argon, in which the brightest Fraunhofer lines can be identified.

Roëmer and the celerity of the light

The motion of the Galilean satellites of Jupiter were thoroughly investigated in the 17th century partly because it was felt that it might be a solution to the problem of longitudes. Instead, it revealed that light took finite time to travel between two points in space. A discussion of eclipses of Io over a long timespan will help students to gain an insight into the process that led Roëmer to the first estimate of the celerity of light. Emphasis is also laid on the History of Astronomy with a discussion of the paper that was published in the "Journal des Sçavans" in 1676 to announce Roëmer' s discovery.
This activity illustrates how enlighting can be the study of an historical text for the understanding of a scientific reasoning. The teaching of astronomy has much to gain going step by step, following the steps of the discoverers, which is a good way to simplify the problems.

The retrograde motion of Mars

Because observational data are not usually available to students, this motion has generally been presented too superficially, which does not motivate them.
Sometimes the analysis of this motion even requires students to operate the change of reference frame that accounts for the retrograde motion of Mars while they never heard of the phenomenon.
Because it is not possible to ask students to carry out observations at night for 6 months and more, the slide set is a substitute document that demonstrate the apparently erratic motion of Mars before trying to account for it.
The activities developed from these slides are, among other, the role of the position of the observer to explain these observations; it is a natural way to introduce the change of reference of frame without previous mathematical knowledge.

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In the following quoted papers more detailed descriptions are given of the pedagogical documents listed Annexe 2.

Training of school teachers at French astronomy summer universities

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IAU Colloquium 105: The Teaching of Astronomy, (Williamstown, USA, July 1988), page 297, Eds. J. Pasachoff and J.R. Percy, Cambridge Univ. Press.

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Astronomical Practical Activities in the new French Programmes

L. Bottinelli
Fifth International Conference on Teaching Astronomy, 1995, page 31, Institut de Ciències de l'Educació, Universitat Politècnica de Catalunya, Barcelone, Ed. R.M. Ros.

A multi-resource system for remote teaching in astronomy: its aims, its design, the point of view of the learners

M. Gerbaldi. A. Xerri
IAU Colloquium 162: New Trends in Astronomy Teaching, (London, UK, July 1996), page 60, Eds. L. Gouguenheim, D. McNally and J.R. Percy, Cambridge Univ. Press.

THE POINT OF VIEW OF A MATHEMATICS SCHOOL TEACHER (J. Sert)

As a Mathematics teacher, I have been teaching Astronomy to students in the last year of their curriculum and who have chosen the Literary option of the *Baccalaureat*. Until June 94, according to the official instructions for TA2 (students in the last year of their curriculum and taking the Literary *Baccalaureat*) stipulated that about one third of the curriculum could be chosen among several optional topics, Astronomy being one of them. The students were to go through an oral examination for the *Baccalaureat*,during which they could present a personal project related to this optional subject. The syllabus consisted mainly in the History of Astronomy up to Newton's gravitation law and the measurement of time (sundials and calendars).

As years passed and I gave lectures on these subjects, I could assess how important it was to teach Astronomy, and this in several ways:

First, Astronomy is a means of reconciling these students who had often be "negatively" oriented towards Literary studies because they were not good at mathematics, with scientific subjects. Their curiosity towards such topics emerges at once and bursts into numerous questions, especially if you are lucky enough to take them to an evening observing session. It increases when they are confronted with science, a field still fraught with uncertainties, but where knowledge progresses fast and it leads them to other fields that help them to get answers. You can then notice that students are more active and develop skills (such as searching for information, delivering a lecture...) and that they even accept using the mathematical tool which they have so far considered as artificial. As an examiner, I could see rich and thoroughly studies presented by students on topics they were particularly interested in (for instance the origin of the Universe, the possibilities of extraterrestrial life in the solar system...) as allowed by the particularly flexible syllabus.

Then, this brought them elements of a scientific culture which they had never approached before: the evolution of our ideas on the Universe through History, how and why this evolution occurred, what an experimental process consists in (the relationship between observation and the model), the difference between a model and a theory, how ideology or religion can influence the advancement of knowledge and stimulate their reflexion on Man and his place in his environment.

For that reason, throughout these years, because of the students' queries or hints, I have more particularly dwelt on some particular points, sometimes with the help of the Philosophy teacher. I developed Aristoteles' ideas; I made the students concretely study the equivalence between the Ptolemaic and the Copernican models. I emphasized the importance of observation in the process that led Kepler to his laws, the fundamental reflexion of Galileo on inertia. I opened the issue of the influence of the Copernican revolution in other fields than Astronomy. I tried to bring to light the qualitative leap that the theory of gravitation represented and at the same time I encouraged the students to apply their own research method, not only to books but also to their immediate environment: getting pictures from observatories, searching for calendars different from the Gregorian one, thus discovering that their grandmother, their neighbour or the grocer at the corner of the street may practice another religion (which is of great interest because it involves contact with other people and respecting them, and instructive in so far as beliefs may be an obstacle to exchanges, for example if you cannot obtain a calendar because any document that bear the name of God may not be thrown away, or because you don't pledge to burn the sheet of a block calendar after it has been used).

So I discovered that the great interest of Astronomy was that it could lead these non-scientific students towards processes that made them discover the surrounding world, in order to understand its physical reality and become aware of some of its human dimensions. Isn't that a promising start with respect to the education of the European citizens of the year 2000.

For that reason, I was sad to learn that Astronomy would no longer be included in the Mathematics syllabus nor indeed in any other syllabus of the Literary *Baccalauréat*, although it did provide an attractive and rich opportunity to science education and culture, approaching the issues of the present time. Mathematics, Physics and Biology teachers could join their efforts to give complementary courses included in a scientific curriculum, with the occasional help of Philosophy teachers. It would really be a pity to leave such gaps open in the culture of men and women who have to build the Europe of the 21st century.

Effective Learning and Teaching of Astronomy

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Abstract.
Much is known, from research in psychology and education, about effective learning and teaching of astronomy. Unfortunately, very little of this knowledge is actually used in teaching at the school and university level. The challenge, in both the developing and the developed countries, is to provide effective professional development for astronomy educators at all levels, from elementary school to university.

Based on material presented at the IAU-COSPAR-UN Workshop on Capacity Building in Astronomy and Basic Space Science, Vienna, Austria, July 1999.

1. Introduction

Astronomy and basic space science should be included in the science curriculum of the schools and universities as a way of increasing public awareness, understanding, and appreciation of astronomy, as well as for educating scientists, engineers, teachers, and other science and technology personnel. There are more than a dozen good reasons - scientific, educational, cultural - why astronomy is useful, and should be included in the school and university curriculum (Percy 1999), but there are also serious challenges to effective teaching and learning.

Keep in mind that any subject can be *taught*, but there is no assurance that it will be *learned.* Research shows that this is the case with astronomy (Baxter 1989, Nussbaum & Novak 1982, Sadler 1998). High school and undergraduate students, pre-service teachers (Woodruff et al. 1999), and the general public (including Harvard graduates (Schneps & Sadler 1988)) have deeply-rooted misconceptions about astronomical topics: day and night, seasons, moon phases, eclipses, gravity (including "weightlessness"), and light. These and other researchers (especially Ahlgren 1996, Sneider 1995) suggest several strategies for teaching more effectively. The following summary of what we know about effective learning and teaching of astronomy is culled from these and other sources, including my own experience.

- Students form new concepts by building on concepts which already exist in their minds. Students' minds are not blank sheets of paper on which we can write new information at will.

- Students have deeply-rooted misconceptions about basic astronomy topics. These misconceptions must be unlearned by the students, by having them confront these misconceptions with conflicting information which they themselves develop through observation or discussion.
- Many of these misconceptions are based on even deeper misconceptions such as about the behaviour of light and gravity.
- Students - especially younger students, and students without extensive experience with math and science - may have difficulty in visualizing three-dimensional concepts such as moon phases, and in moving from one frame of reference to another (in the case of moon phases, from the frame of reference of the observer on earth, to the frame of reference of an outside observer).
- Astronomical concepts must be introduced in logical order (according to "progress-of-understanding maps" (Ahlgren 1996)), and at an appropriate time in the students' cognitive development (Bishop 1996). Most students will have difficulty with three-dimensional concepts before the age of 12 years.
- Inquiry-based teaching, involving simple, hands-on activities, discussion of patterns, explanations, and predictions, are the most effective means of teaching. Hands-on activities alone are not sufficient to overcome misconceptions; a "minds-on" approach is ultimately necessary.
- Teaching more astronomy should give way to teaching it better. An overloaded curriculum increases students' confusion, and leads to more misconceptions.
- Expertise in astronomy does not guarantee expertise in teaching it. It is interesting to note that very few university professors have any training in teaching their subject - despite being looked upon as the highest authorities in their field. Professional development is essential at every level of the educational system.
- Every aspect of teaching, in every setting, at every level, should be subject to research, evaluation, and improvement. In most universities (including mine), instructors may have access to course evaluations, and to remediation, but this process is not part of their annual performance review, and department heads provide little or no feedback. In many research universities, teaching is seriously under-valued.
- Teachers at all levels overestimate what their students learn. In Sadler's (1998) research with high school students, teachers could accurately assess their students' knowledge at the beginning of a course, but they estimated that, by the end of the course, their students would have a level of knowledge equivalent to that of an undergraduate astronomy major; the actual knowledge gain was minimal.

These results suggest that teacher education (both pre-service and in-service) should be a key part of curriculum development and implementation. The content of the curriculum can and should be based on research and experience in the rest of the world.

It is also important to relate the curriculum to local language, culture and other needs. This is true on all parts of the world, and helps to meet another important challenge: reaching the underserved - women, minorities, and the economically-disadvantaged.

We recognize also that, in many countries, the education system favours rote memorization of lecture or textbook material. While this "classical" approach to teaching has some merit, it does not prepare students to develop new solutions, to new problems.

Another challenge is to maintain the sense of awe and excitement which astronomy can provide. The standard astronomy topics in the school science curriculum are day and night, seasons, moon phases, eclipses, and tides (even in land-locked countries!). I frequently visit grade 6 (age 11 years) classrooms, and I record the questions which students ask. They seldom ask about the topics listed above. They ask about the origin and fate of the universe, the lives of stars, the environments on the planets, and the possibility of extra-terrestrial life. No wonder many students are "turned off" by science!

2. Implications for the Astronomically-Developing Countries

In some ways, these results are "good news" for the astronomically-developing countries. The developed countries have failed to teach astronomy effectively. The problems - and solutions - are known; other countries can start "from scratch" and implement these solutions. Furthermore, experience suggests that "less is more" (Ahlgren 1996). Teachers would be better to master a small amount of basic material, and the methods for teaching it most effectively. High technology is not required; simple, inexpensive equipment is best. [This means "available materials"; what we in the industrialized countries consider "inexpensive" will be inaccessable in many countries.]

Resource material is still needed. Textbooks in the industrialized world are large, glossy, and expensive. I recommend simple, short, inexpensive, locally-produced books such as Mexican and South African astronomers and educators have developed. The basic content of these books (activities, diagrams, images) could be supplied by the IAU or the UN, using the best available material - and this is not always material from the industrialized countries. The text can supplied by local astronomers and teachers, who are familiar with the local language, culture, and needs.

3. Curriculum Suggestions

Much has been written about appropriate astronomy material for schools and universities; this is my own summary, for astronomically-developing areas:

- At age 10 to 12 years: observing and recording the sun, moon, and brighter planets and stars with the unaided eye (safely!); a balance between a few simple, explanatory activities (day and night, moon phases, eclipses, scale of the solar system) and a small amount of carefully-selected descriptive material about the sun, moon, planets, and stars; appropriate connection to local culture and needs.

- At age 13 to 15 years: continued observing, *measuring*, and recording of the night sky, where possible; a balance between a small number of activities and problems dealing with basic concepts such as gravity, energy, and light, and descriptive material dealing with planetary exploration, and the nature of the sun, stars, and galaxies; applications to technology (such as space technology) and society where possible.
- At age 16 to 18 years: as part of a course in physics, activities and problems dealing with how simple physical laws (inverse square of brightness, parallax, Kirchoff's laws, Doppler effect) can be used to determine the physical properties of the sun, stars, galaxies, and universe; and/or illustration of the laws of motion and gravitation through astronomical applications.
- At age 18 and above, in university: the topics above, as part of a physics course; and/or a stand-alone course in introductory astronomy. Can a single introductory course meet the needs of a variety of students? Perhaps not, but there may not be enough resources (and students) for more than one course. There could be a common lecture course, with separate small-group tutorials for science students, education students, and non-science students, and lots of opportunities for individual or small-group discussions and projects.

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Technology and Space Science in Schools – Benefits and Challenges

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I. Introduction and Collaborative Framework

This paper discusses how science education researchers, scientists, and educators have partnered to investigate the use of Internet technology to incorporate the latest NASA space science into the pre-college classroom. The potential of information technology for teaching and learning is presented through a research-based resource on *Sunspots*. Benefits and challenges are discussed.

Through a collaborative framework, NASA Office of Space Science is facilitating the participation of scientists in education and outreach. Programs such as the UC Berkeley Science Education Gateway – SEGway (http://cse.ssl.berkeley.edu/SEGway), and the NASA Office of Space Science Education and Public Outreach effort (http://www.hq.nasa.gov/office/oss/education), foster collaborations between space scientists and the pre-college education community through high-leverage partnerships with science museums and science centers around the United States. For example, SEGway is a collaboration involving the UC Berkeley Space Sciences Laboratory, four national science museums (Exploratorium, Lawrence Hall of Science, Smithsonian National Air and Space Museum, Science Museum of Virginia), and teachers from school districts in several states. SEGway is a national consortium of science centers, research institutions, school districts, teachers, and industry partners working together to bring the latest NASA space science and technology resources to the K-12 community and the general public. Resources are created by teams of teachers, science museum personnel, scientists, and technical staff, and are subsequently pilot tested in classrooms. SEGway, now in its sixth year, has extensive experience in adapting NASA space science research and information for the benefit of broad audiences using Web-based learning technologies.

In the SEGway model teams of teachers and personnel from science museums and research institutions leverage their unique skills to create inquiry-based lessons for the K-12 community using data from space missions such as the Hubble Space Telescope, Yohkoh satellite, etc. (Hawkins, Battle, and Wilson 1998; Battle and Hawkins 1996). Educators bring curricular and classroom expertise. Science museums provide a high profile outlet for public science education, technical and multi-media expertise, experience in the development of inquiry-based resources, and professional development opportunities for teachers. Scientists serve as role models and sources of scientific expertise, providing up-to-date research results, access to discoveries, and interpretive material. The collaborative framework accommodates new and experimental classroom resources in innovative ways.

The production cycle of a resource such as *Sunspots* involves authoring, testing in the classroom, evaluation, modification, and revision. *Sunspots* and other SEGway resources are made available through the museums' World Wide Web sites, and coordinated nationwide by the Center for Science Education at the University of California at Berkeley's Space Sciences Laboratory.

II. The Potential of Technology for Learning

The importance of the Internet is increasingly recognized in the educational community. Owston (1997) has argued that the Internet can improve learning in three ways: (a) by appealing to various learning styles and motivating students; (b) by offering convenient asynchronous communication capabilities; and (c) by fostering higher-order thinking skills. Computer tools enable electronic communication, scientific modeling, and scientific collaboration in and between classrooms.

The International Society for Technology in Education (http://cnets.iste.org) provides a comparison between traditional learning environments and those that foster critical thinking, inquiry and investigation, collaboration, and generally more authentic cognitive processes.

Traditional Learning Environments	New Learning Environments
Information delivery	Student-centered learning
Single sense stimulation	Multi-sensory stimulation
Single path progression	Multi-path progression
Single media	Multi-media
Isolated work	Collaborative work
Passive learning	Information exchange
Factual, literal thinking	Inquiry-based learning
Reactive response	Proactive, planned action
Isolated, artificial context	Authentic, real-world context

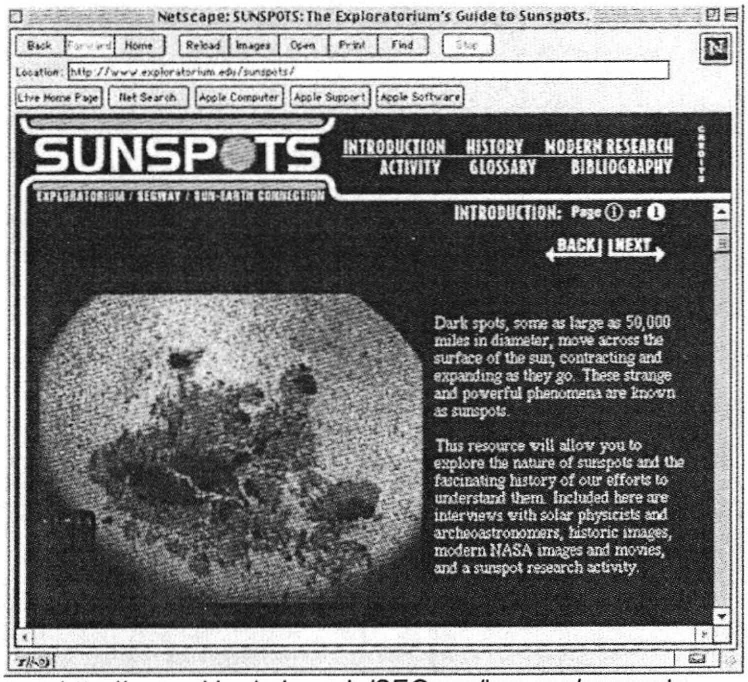
The Internet can promote an environment in which students can be expected to achieve the following outcomes:

- Communicate using a variety of media and formats
- Access and exchange information in a variety of ways
- Compile, organize, analyze, and synthesize data
- Draw conclusions and make generalizations
- Use information and appropriate tools to solve problems
- Access up-to-date content
- Become self-directed learners
- Collaborate and cooperate in team efforts
- Interact with scientists in effective ways

However, Roschelle and Pea (1999) point out that to achieve the full learning potential afforded by the World Wide Web, on-line resources need to be indexed and aligned with K-12 curricula, state frameworks, and national standards. The SEGway program, through its inquiry-based Internet resources, fosters more authentic learning environments and fully integrates the use of technology with the curriculum, frameworks, and standards.

III. Sunspots Resource

Sunspots was developed by a SEGway team with participants from the Exploratorium, UC Berkeley Space Sciences Laboratory, and teachers from several California schools. The resource allows students to explore the nature of sunspots and the fascinating history of solar physics in its effort to understand their nature. The resource includes interviews with solar physicists and archeo-astronomers, historic images, cutting-edge NASA images, movies, and research results, as well as a student-centered sunspot research activity.



http://cse.ssl.berkeley.edu/SEGway/lessons/sunspots

Sample Text and Image from Web Resource:
Dark spots, some as large as 50,000 miles in diameter, move across the surface of the Sun, contracting and expanding as they go. These strange and powerful phenomena are known as sunspots.

Learning objectives include:

- Students learn about the importance of solar observations in ancient cultures and how solar science changed with the advent of telescopes and satellites.
- Students know how to view the Sun safely using a simple projector, with or without a telescope.
- Students are able to discuss some of the main currents of modern solar research.
- Students can conduct and plot comparisons of X-ray active regions and sunspots, and investigate correlations.

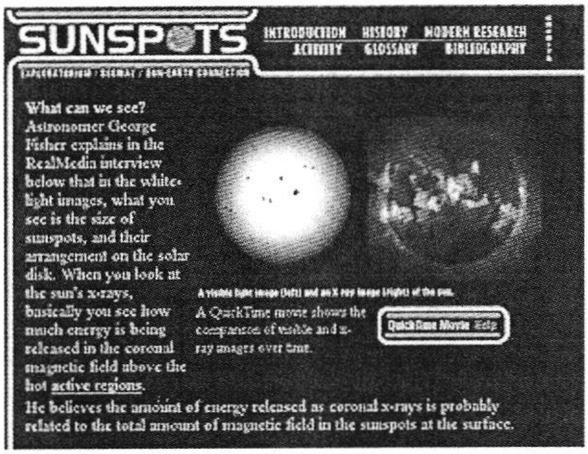
The resource contains several self-guided sections that serve as background material. A "HISTORY" section discusses the importance of the Sun to ancient cultures and their understanding of sunspots. The section also details how the development of telescopes and satellites changed our view and knowledge of sunspots. In addition, a simple method for observing sunspots safely is included.

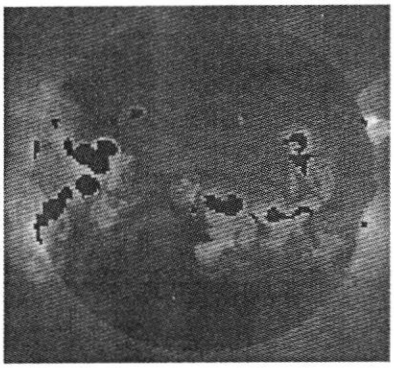
The "MODERN RESEARCH" section explains how the development of new technology has increased our knowledge of how the Sun works, what sunspots are, and how solar activity affects the Earth.

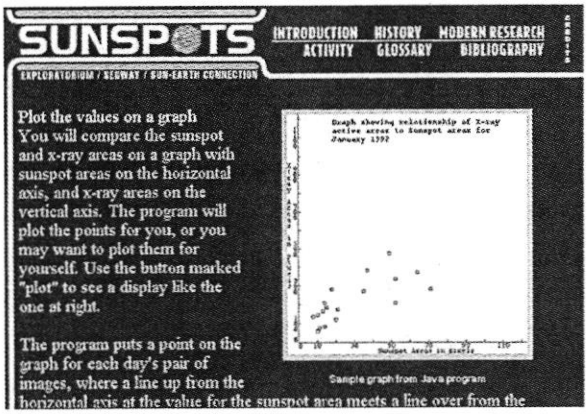
This site also provides students with the opportunity to do their own sunspot observations and measurements. Instruction for observations using simple projection equipment are included, as well as a computer interactive exercise. The "ACTIVITY" section contains these features. The interactive Java tool enables students to record the number of sunspots present in both visible light and x-ray images, compare measurements with peers, plot the data, and analyze possible correlations between solar x-ray activity and sunspots.

New vocabulary related to solar science is included in the "GLOSSARY" section.

Modern Research Section: NASA TRACE Satellite Image showing loops formed by magnetic field lines.

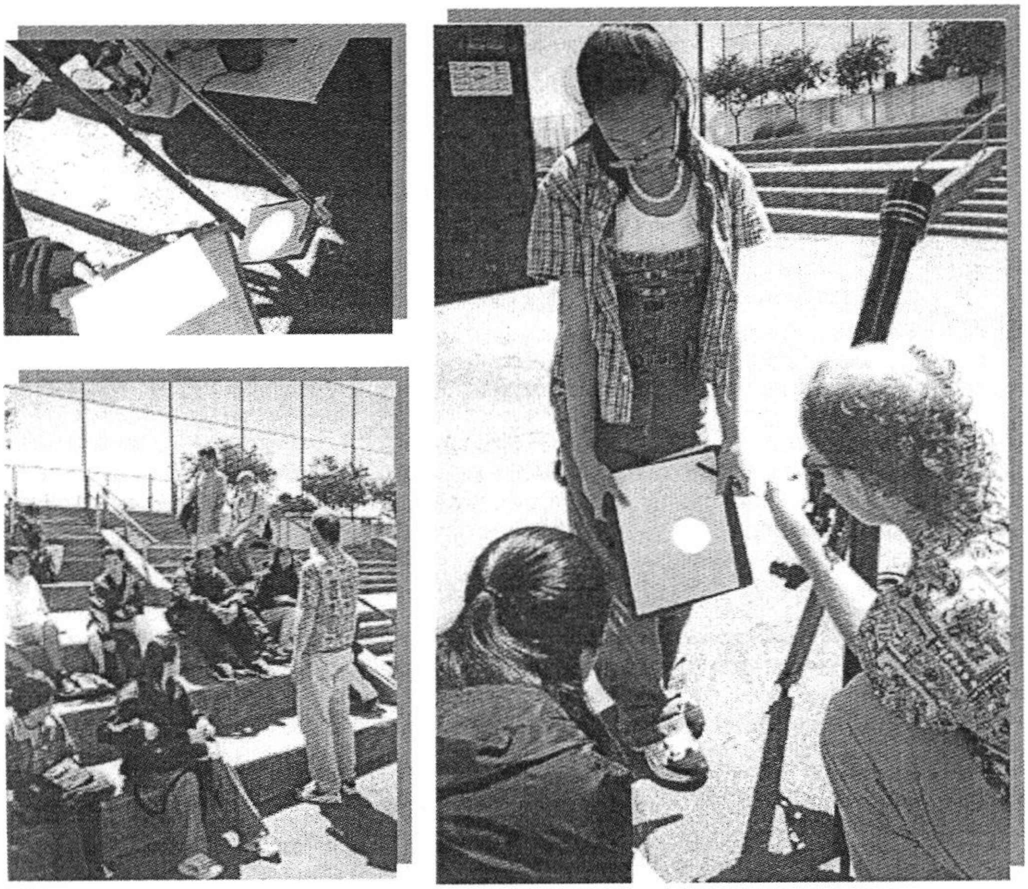






Students record and compare x-ray and white light images (upper left) using the computer mouse to 'paint' (in blue, above) the active solar regions and sunspots.

Students plot their results for several pairs of x-ray/white light images spanning several years, analyzing their results and investigating possible correlations.



Safe Sunspot Observing and Recording by 600 San Francisco Unified School District Students Participating in a Summer Enrichment Program

An important component of SEGway is the availability, for every resource, of a teacher's page containing information on grade level appropriateness; time requirements; needed materials and technical set-up; ties to curriculum frameworks and standards; student worksheets, pre-requisite skills and assessment tools; teaching tips; example student work, etc. – all essential information for teachers unfamiliar with the resource. This feature of SEGway has proven particularly popular with teachers, who have limited time and appreciate having all materials and information readily available.

IV. Benefits and Lessons Learned

Based on our classroom testing of resources and program evaluation results, we have found that the Internet can provide access to current space science data otherwise unavailable to students and educators who often rely of outdated instructional materials. The technology allows interactive analysis of NASA and other up-to-date research data, access to scientists and their discoveries, and the opportunity for participating in the inquiry process of science. Space science and computers seem to motivate students to become more self-directed learners, increasing their interest in science. However, technology is expensive, and should not be used as a substitute for access to materials that are best utilized in print form. Instead, the Internet needs to be used in effective ways that utilize its unique capabilities.

We have found several challenges in using technology in the classroom. Schools often have inadequate technology infrastructure and lack sufficient technical support. Teachers lack sufficient training on the use of technology, and are unfamiliar with strategies that allow the seamless integration of technology with the curriculum. In general, certain pre-conditions need to be in place for Internet technology to flourish in the pre-college classroom. These conditions include:

- Leadership support and policies that stimulate innovation
- Teachers skilled in using technology for learning
- Curriculum standards
- Curriculum resources that are inquiry-based and make appropriate use of the Internet
- Student-centered approaches to learning
- Assessment of effectiveness
- Access to, and support of, up-to-date technologies
- Technical and curriculum integration support

At times, these conditions are difficult to put in place in school systems, which respond slowly to new learning and teaching approaches. Science museums and science centers, on the other hand, often have the resources required to support engaging uses of Internet technology for teachers, students, and the general public. Students and teachers can take advantage of science center offerings through field trips, participation in special technology-rich events, and other informal science education activities. Science museums also provide professional development for teachers, and can stimulate educators' interest in using technology and science resources in the classroom. Access to science resources through technology at science museums and centers can fill the gap and provide a bridge for schools who are beginning to incorporate technology into their plans, facilities, and curriculum. These alternative approaches are of particular importance to developing countries, where technology infrastructure may only be available through the larger and better-equipped museums and centers.

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"Hands-On Astrophysics" - and Beyond

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Abstract.
Hands-On Astrophysics is a project which develops and integrates a wide range of science and math skills, through the measurement and analysis of variable stars. It can be used in a variety of settings, from junior high school to university. In this paper, we describe how it can be used in astronomically-developing countries or regions, as a stepping stone to more advanced astronomical activities, and as a model for using processes and databases developed by amateur astronomy as a way of doing useful science at low cost.

Based on material presented at the IAU-COSPAR-UN Workshop on Capacity Building in Basic Space Science, Vienna, Austria, July 1999.

1. Introduction

In any part of the world, *practical (or laboratory) activities* can be an important part of science education at the school and university level, especially when they include a strong element of inquiry and discussion. Carefully-chosen *research projects* can also be used; they are almost obligatory at the graduate level, highly desirable at the undergraduate level, and quite possible at the senior high school level - both because they contribute to effective learning of science processes and skills, and because they motivate students through the excitement of doing real science with real data. Research projects enable students to contribute to research; this is especially desirable in the developing countries, where the supply of research personnel is low.

How can students in developing countries do research? If specialized equipment is available and usable - in their supervisor's lab, for instance - there is less problem. Here, we suggest some solutions when little or no equipment is available. One solution is to make simple but useful measurements of the sky, using processes which have been developed and perfected by *amateur astronomers* and/or to use the data which amateur astronomers have obtained. We shall use the measurement of variable stars as an example. This may lead to the use of processes and data obtained by *professional astronomers*, as explained below.

2. Amateur Astronomers

An *amateur astronomer* is someone who loves astronomy, and cultivates it as a pastime or hobby. A more stringent definition might be that an amateur astronomer is someone who does astronomy with a high degree of skill, but not for pay (Williams 1988). Amateur astronomers make important contributions to astronomical research (Dunlop & Gerbaldi 1988) and education (Percy 1998a).

Astronomical research and education done by amateur astronomers is "democratic" in the sense that it enables anyone to do astronomy, whether they have formal credentials or institutional affiliations or not. It is "science for the masses". It is certainly true of variable star astronomy because, in the words of the song, "the stars belong to everyone". The Internet can also be a powerful tool for those who are "connected", since it provides access to large and sophisticated databases (such as the *Hipparcos* catalogue and epoch photometry) and instructions for analyzing and interpreting the data.

3. Variable Stars and the AAVSO

This topic was reviewed by us at the 1996 and 1999 UN/ESA Workshops on Basic Space Science, in Bonn, Germany (Percy 1998b) and Mafraq, Jordan (Mattei 1999), so only a brief account will be given here.

Variable stars are those which change in brightness. If measured sufficiently carefully, almost every star turns out to be variable. The variation may be due to geometrical processes, such as the eclipse of one star by a companion star, or the rotation of a spotted star, or it may be due to physical processes such as pulsation, eruption, or explosion. Variable stars provide astronomers with essential information about the properties, processes, nature, and evolution of the stars.

In many variable stars, the changes in brightness are large enough to be detected with the eye, using a small telescope, binoculars or (in the case of a few dozen bright variable stars) no optical aid at all. Amateur astronomers and students can make a useful contribution to astronomy by measuring these variable stars in a systematic way. The American Association of Variable Star Observers (AAVSO) was established in 1911. Its purpose is to co-ordinate variable star observations made largely by dedicated amateur astronomers, evaluate the accuracy of these observations, compile, process, and publish them, and make them available to researchers and educators. The AAVSO now receives over 350,000 measurements a year, from 550 observers worldwide. The measurements are entered in the AAVSO electronic database, which contains close to 10 million measurements of several thousand stars. The demand for these measurements, from researchers and educators, has increased by a factor of 25 in the last two decades - partly as a result of major collaborations in space astronomy. To contact the AAVSO, write to: AAVSO, 25 Birch Street, Cambridge MA 02138, USA; e-mail: aavso@aavso.org; web site: www.aavso.org.

4. Hands-On Astrophysics

It occurred to us, several years ago, that the measurement and analysis of variable stars could help students to develop fundamental science and math skills. Variable star measurement and analysis is inherently simple; it can be done by any high school student. The analysis and interpretation of the data involves a wide range of scientific and mathematical skills, some of which would be understood and appreciated by a junior high school student, and some of which would tax an expert in the field. We therefore developed *Hands-On Astrophysics*, with partial funding from the US National Science Foundation. Its purpose is to bring variable star observing and analysis into the classroom or lab. It includes 45 star charts, 31 35mm slides of five constellations, 14 prints of the Cygnus star field at seven different times, 600,000 measurements of several dozen stars, user-friendly computer programs to analyze them and to enter new observations into the database, an instructional video in three segments, and a comprehensive manual for teachers and students.

Hands-On Astrophysics is very flexible. It can be used in science, math, or computer classes, or for independent projects. It can be adapted to various levels, from junior high school to university. It can be used as a complete course of study, or in parts. It can be used by *any* individual, of *any* age, to learn the art and science of variable star astronomy. It is self-contained; no previous knowledge of astronomy, or variable stars, is assumed. It is open-ended, and can lead to sophisticated projects which are ideal for science fairs. It actively involves the students in the scientific process, and motivates them by enabling them to do real science, with real data. Students can observe variable stars in the real sky, and send their measurements to the AAVSO, thus contributing to astronomical research. *Hands-On Astrophysics* is available from the AAVSO (address above) and from the Astronomical Society of the Pacific (www.aspsky.org).

5. *Hands-On Astrophysics* and the School Science Curriculum

Variable stars are not a central topic in the high school science curriculum in North America (though they relate peripherally to several topics in the US National Science Education Standards (and the Canadian equivalent) dealing with the sun. stars, galaxies, and universe). It should be realized, however, that the science *content* in the curriculum is less important than the science *process* and *skills*. Variable star observing and analysis develops and integrates a wide range of science and math skills. In the grade 9 (age 14 years) science curriculum in the province of Ontario, Canada, for instance, the following skills expectations are listed:

- Plan ways to model and/or simulate an answer to the questions chosen, for instance ..... how astronomers are able to understand and compare the sizes and distances of objects ..... in the universe.
- Demonstrate the skills required to plan and conduct an inquiry into the ..... characteristics of visible celestial objects .....

- Select and integrate information from various sources, including electronic and print resources, community resources, and personally collected data .....

- Gather, organize, and record information using a format that is appropriate to the investigation (e.g. maintain a log of observations of changes in the night sky .....)

- Analyze qualitative and quantitative data .....

- Communicate scientific ideas, procedures, results, and conclusions using appropriate SI units, language, and formats

- Calculate and compare the ..... distances to objects ..... in the universe

- Predict the qualitative and quantitative characteristics of visible celestial objects .....

6. Applications to Astronomically-Developing Countries

6.1. A Prelude to Research

Variable star observing can be a prelude to more advanced astronomical activity. Wentzel (private communication), for instance, has found *Hands-On Astrophysics* very useful in workshops with physics teachers in Vietnam, as part of the IAU's "Teaching for Astronomical Development" program. Several developing countries have acquired (or are planning to acquire) small telescopes which will eventually be equipped with photoelectric photometers or CCD cameras. Is there a way to start doing real science, even before the telescope arrives and is operational? Yes! The solution is to begin doing serious visual measurements of variable stars, using binoculars or a very small telescope if available. The AAVSO, either through *Hands-On Astrophysics*, or by mail, by email, or by its web site, can provide assistance in setting up an observing program. The measurements, so obtained, can then be contributed to the AAVSO International Database, to be used by researchers and educators.

The next step is photoelectric or CCD photometry with the newly-acquired telescope. These measurements are more precise than visual measurements, but the general principles of analysis are the same. The AAVSO has both a photoelectric program, and a CCD photometry program. Other international collaborative photometry programs are listed in Percy (1998b), who pointed out the value of beginning research as part of an international collaboration.

6.2. A Stepping Stone to other Databases

Databases from space astronomy missions are increasingly available on CD-ROM and/or the internet, and they provide a practical way for astronomically-developing countries to begin research at very little cost - a PC with a CD-ROM drive and/or internet connection. One example is the *Hipparcos* catalogue of astrometry and epoch photometry (Turon 1997, Perryman 1999). AAVSO observers provided crucial support for this mission (Turon 1997). In turn, the mission has provided dozens of new variables to be studied by photoelectric or

CCD observers (Perryman 1999). It has also provided millions of photometric measurements of "unsolved" stars which require detailed analysis.

The *Hipparcos* mission has excellent research and education web pages (astro.estec.esa.nl/Hipparcos/hipparcos.html), with information on variable stars, interactive tutorials on variable star analysis, as well as data. Additional information on variable stars can be found on the AAVSO web site (www.aavso.org), and user-friendly software for analyzing them (the TS11.ZIP program for time-series analysis, and the WWZ11.ZIP program for wavelet analysis), can be downloaded from www.aavso.org/software.stm. *Period98*, a powerful period-analysis package, can be downloaded from the web site dsn.astro.univie.ac.at/period98 at the Institute of Astronomy, University of Vienna, along with an instruction manual.

The *Hipparcos* epoch photometry has two properties which can make it challenging to analyze. It is much broader-band than visual or photoelectric V photometry. *Hipparcos* photometry of stars with "simple" spectra can be transformed to the V system (Harmanec 1998), but *Hipparcos* photometry of red variables with strong TiO bands in the spectra is very difficult to transform or interpret. Also, the time distribution of the photometry is such that there may be several measurements over a few hours or days, then gaps of 20 to 30 days. These make analysis difficult for stars with periods in this range.

6.3. Hands-On Astrophysics as a Model

Hands-On Astrophysics makes use of techniques which have been refined by amateur astronomers over many years, and measurements which they have made for the benefit of research. There are other types of measurements and data which provide a low-cost introduction to real astronomical research.

Sunspot counting is an obvious example which can be done in the daytime with a small telescope. The AAVSO (www.aavso.org) has a well-established solar program, as does the Association of Lunar and Planetary Observers (ALPO: www.lpl.arizona.edu/alpo/); these organizations can provide guidance and coordination. Sunspot numbers, over decades or centuries, can be analyzed with the same software as for variable stars.

Timing of occultations of stars by the moon, planets, and asteroids is a useful scientific activity; among other things, it can provide estimates of the size and shape of asteroids. Since occultations occur along specific geographical paths, observers in the astronomically-developing countries can often provide otherwise-inaccessable measurements. A small telescope, a stopwatch, and access to a time signal, is necessary, along with predictions which can best be provided on the Internet. The International Occultation Timing Association (IOTA, www.anomalies.com/iotaweb/index.htm) coordinates this work.

Meteor observation has recently proven to be especially interesting because of the possible "storm" in the Leonid meteor shower. Meteor storms can occur within a very few hours in time, so it is essential to have observations from all longitudes. No telescope is required for these observations, and only approximate time signals are necessary. The American Meteor Society (www.amsmeteors.org) coordinates this work.

One of the advantages of these "amateur" techniques is that there may be a few local amateur astronomers who are familiar with the sky, with telescopes, and with basic observational techniques. These people can be a useful partners in the astronomy research process.

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Interdisciplinary Astronomy and Basic Space Sciences

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Abstract

Astronomy and the Space Sciences have much to contribute to education in the physical sciences, particularly at tertiary level. Two examples, the physics of stellar structure and evolution and information in signals are given of areas where astronomy and space science could give important input into science education.

It is noted that a course in "astronomy" and/or "space science" does not necessarily constitute interdisciplinary physical science education unless there is proper knowledge elsewhere of the nature and terminology of these subjects. However, it is essential to create widely based education - both in terms of breadth of topics and numbers of graduates - in the physical sciences in order to create a real basis for Public Understanding of Science.

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Interdisciplinary Astronomy and Basic Space Sciences

1. What is Interdisciplinarity?

Interdisciplinarity is one of those much overused words, attractive rhetorically, but otherwise nebulous in meaning. For the purpose of this paper I shall take "interdisciplinarity" to mean what astronomy and the space sciences can add to tertiary education in the physical sciences such as chemistry, geology, physics. There are two key areas where astronomy and the space sciences can introduce highly significant areas within the teaching of the physical sciences:

(1) the interaction of matter and radiation

(2) the nature of information in signals.

These two areas introduce topics which integrate across the whole of physical science bringing together diverse subjects which are of importance in many aspects of daily life.

In the nature of a short presentation, it is impossible to examine many other interesting areas such as astrobiology, except to express a hope that even students of physical science may be able to experience courses in such topics to further widen their outlook.

It should be stated while astronomy and the space sciences are excellent interdisciplinary subjects for the physical sciences, they are not unique since geophysics, meteorology, oceanography could fulfil similar, though not identical, educative purposes as I have argued elsewhere (1998, 1999).

2. Why introduce interdisciplinarity?

It may be argued that there is no need for interdisciplinarity in teaching physical science. In the first place interdisciplinarity is not new and is a concept which has not found favour in the last few decades because of lack of esteem from both teachers and taught vis-a-vis single subject degrees - teachers because of the pleasure of teaching their own subject and the taught because in today's job market there is safety in a "normal" degree pattern. Such single subject degrees in the physical sciences are now themselves in decline. This is utterly amazing in the context of the dazzling success of the physical sciences in this century, right from understanding the atomic nucleus to the origins of the Universe and the incorporation of the concepts of the physical sciences in all aspects of daily life from medicine to the supermarket checkout. One might legitimately ask why the physical sciences are not overwhelmed with students? Answers to this question dwell on putative perception of the physical sciences that usually avoid any criticism of the physical sciences themselves - e.g. the physical sciences are now so sophisticated they are out of touch with the rest of mankind, in the sense that, cutting edge physical science cannot relate in any way with young people at a stage when they make career choices. However, astronomy, geophysics, meteorology, oceanography are still highly apparent to us all and are areas which can impinge directly on everyday life, e.g. we all get wet in a shower of rain even if we have different interpretations of "beauty", "charm", "colour"!

But in point of fact interdisciplinarity goes very much deeper. Ziman's percipient remark "It is easy to argue ... for a multidisciplinary approach to every scientific and technological problem: it is not so easy to orchestrate the contributions from research specialists from very different scientific backgrounds" (1994) is clearly relevant. Specialists find cross-discipline communication is hard. We have neglected the obvious - that people with a multispecialist outlook could make such communication easier. I will concentrate on this aspect in this paper. The importance of a large number of graduates with experience of several areas of the physical sciences in the context of teaching at primary and secondary levels as well as formers and leaders of public opinion, cannot be neglected.

3. What is the value of astronomy and space sciences?

Astronomy and the space sciences force education in physical sciences away from the introspection of science for its own sake and towards science as a practical and useful tool. It may seem that this is an odd claim for two areas which are widely regarded as esoteric with, perhaps, little connection with the real world. Astronomy forces consideration of data, over which the investigator has no control. The space sciences have a similar discipline since a mission, once planned, may not function as designed and will certainly require operational decisions. Both subjects will produce data which may not be optimal - either because that is the only data available or the data has suffered degradation. These are useful disciplines to acquire. I shall confine myself to two aspects of astronomy and the space sciences which are of particular practical value educationally in the physical sciences - interaction of matter with radiation and information in signals.

3.1 Interaction of matter with radiation

The interaction of matter with radiation is an area of classical importance whether it be a diagnostic tool in medicine or evaluating the earliest history of the Universe. The understanding of atomic and molecular physics - a particular triumph of 20th century physics and chemistry - permits measurement of key parameters in many areas of science. Nowhere is this more obvious than in the science of astronomy and in the space sciences. One example will suffice from among many - the structure and evolution of stars.

The structure and evolution of a star is a result of a quasi-static balance between the force of gravity which attempts to hold a star together and gas pressure which tends to blow it apart. It could hardly be a simpler exercise in mechanics. Yet below that simple mechanical situation is an interplay of complex atomic and nuclear physics. Simple thermodynamical considerations show that a star must be highly compressed at its centre and at a very high temperature. Those temperatures are so high that reactions between atomic nuclei can take place - in particular the fusion of four atoms of hydrogen into one of helium. Everyone is very well aware that this is the basis for a thermonuclear explosion. But if a star is to be stable for many millions of years how does it control the explosive power of the release of its nuclear energy?

The answer is surprisingly simple - a star is a highly effective, sensitive, nuclear explosion control device and it is the pure atomic physics of the escape of radiation from time of the nuclear reaction - stellar opacity - that controls how much energy can reach the surface of the star which in turn controls how fast the nuclear reactions can proceed by altering the density and temperature at the centre of the star. A star is in delicate balance, producing just enough energy by nuclear reactions which can be transported through the bulk of the star to be eventually radiated into space. The immediate structure of the star, that is its internal distributions of density and temperature, is adjusted so that the atoms of the main mass of the star can just cope with the transfer of the radiation generated in the star's deep interior. Nuclear reactions change the balance of atomic species in a stellar interior in an irreversible way - it is therefore the physics of nuclear reaction which drives stellar evolution.

It may be surprising that it is the physics of the atom and nucleus that drives the large scale phenomenon of stellar structure and evolution. Yet that physics is immediately visible even to the naked eye through the simple observation that stars have different colours. No special apparatus is needed - anyone can make the observation. That simple observation leads in turn to structure and evolution of stars, to the best approximation to black bodies in the natural world, to quantum statistics and to thermodynamics. This is one example, among many, of how astronomy can integrate across many physics disciplines. However, these disciplines are approached by means of simple observation available to everyone.

3.2 Information in signals

Both astronomy and the space sciences rely heavily on remote sensing. Astronomy is a science limited by the fact that it must depend on information from extremely weak signals (on reception) emitted by astronomical objects. Until the era of the planetary probe, no astronomical object could be tested for "ground truth". This is important in two ways - the first is philosophical in the sense that astronomy is a physical science without a laboratory - astronomy can only use the signals it is sent and is capable of detecting. While this is important educationally as affecting the ethos of the discipline, what is more important in this context are the methods developed by the astronomical community to disentangle the essential astronomical signal from the noise imposed on an ever weakening signal by its passage through space, the Earth's atmosphere and the detector system. The concepts of noise and error are ever present in treatment of astronomical data and an essential part of astronomical education is to recognise the magnitude of errors of observation - whether random or systematic - that affect interpretation. This is a particularly useful skill to acquire when physical science moves out of the laboratory and into the field (e.g. in environmental applications, medicine, etc.)

There is an essential difference between carrying out scientific experiments in the laboratory and in the field. The laboratory allows for careful controls on experiments - temperature, humidity, cleanliness of equipment ... While one sticks to as close an approximation to laboratory conditions as can be obtained, working under field conditions imposes constraints. In both astronomy and the space sciences, there may be only one opportunity to get a certain piece of data. That data may not be of ideal quality but it maybe the only data available and the analysis must allow for its imperfections. It is very difficult to work under the constraint of knowing that one has a single opportunity to get an observation, it is much more reassuring to know that one can always try again tomorrow - as one can in the laboratory. These are good disciplines to acquire.

The space sciences are in a more fortunate situation than astronomy, in that they are not necessarily confined to signals serendipitously emitted from the objects studied - the space sciences can have a measure of control on the initial signal to be modified by the object under study, e.g. radar studies. Space sciences have an additional problem of handling extensive data streams. Signals received in space have to be transmitted back to Earth so raising additional issues of available bandwidth, data compression, etc. Again these are issues of significance in many practical applications.

Since astronomy and the space sciences are so dependent on maintaining signal quality in situations where few, if any, and certainly not all, parameters can be controlled by the experimenter, both these sciences force investigators to give special consideration to data quality and to devising methodologies which allow a verifiable signal from the object under investigation to be detected. It is then excellent training of scientific judgement to establish whether or not that signal contributes to understanding the physical situation under consideration.

4. Conclusion

I have given two examples of how the introduction of astronomy and the space sciences could enhance physical science education. However, it requires adroit handling and a proper basis within tertiary level education. The introduction of a course labelled "Astronomy" or "Space Science" will not produce interdisciplinarity in an otherwise single subject degree structure. There is no point in introducing such courses unless there is a proper basis and proper philosophical framework within which such courses operate. Clearly there have to be supporting knowledge orientated courses to ensure adequate background in concept and terminology. There has to be proper attention to practical work - the transition from the ethos of the laboratory to the ethos of the dome is not easy (one notes how many of one's colleagues express surprise that observational optical astronomy is done during the hours of darkness: administrators bridle at bending the established rules governing presence of undergraduates in university buildings). Care has also to be taken to ensure students do not miss the interdisciplinary message in their enthusiasm for a really exciting course.

To some extent interdisciplinary courses have to become the norm. They may be the only hope of reversing the flight from the specialisation structure of the physical sciences. Clearly a society with a substantial number of graduates educated as physical scientists will be essential if any impact is to be made on Public Understanding (as opposed to Awareness) of Science. The examples of today of science by media hype and hysteria are an all too alarming demonstration of what can happen when proper scientific education is not well disseminated through the population. It therefore seems to me that the old concept of a broadly educated scientist is well worth consideration for revival.

I have not attempted to set down model syllabi - there are no model syllabi. The basic sciences are there, in being and well considered. However, single subject degrees are failing to attract the students in the orders of magnitude to be expected for such glitteringly successful sciences. It is therefore important that each tertiary institution considers its priorities and makes use of those interdisciplinary subject areas of local relevance which could be used to enhance science education and understanding of the context of the world around us.

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UNIVERSITY AND WEALTH OF NATION

by

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Abstract

Science and technology are fundamental in enabling society to achieve social goals and fight ignorance and fear of famine, natural hazard and wars. While short-term science and technology activities are economically viable for the nation, devoting more attention to the long-term dimension of science and technology policy is critically important in today's rapidly changing, highly competitive, global economy and environment. Universities have key roles to play in the process of setting long-term science and technology goals. Not only universities have the manpower to carry out the task to do it but more importantly, it is the endeavour inherent to their noble duty.

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I INTRODUCTION

It is not an exageration by stating that civilizations are measured by their institutions of higher learning – and the maintenance of the climate of productivity of ethically acceptable new knowledge. Before going to the central theme it is perhaps necessary to say a few words about what science is, as opposed to other human knowledge. Briefly, science may be defined as a world picture, or it may be closer to the heart of the matter if it is said that science is the product of organized fantasy about the real world . Up to this point it must be hastily added that there are also many other branches in human knowledge that share the same characteristics with science. For example, experiment is thought to be peculiar to science.

Actually the alchemists of the middle ages did undertake experiments. What was missing in their experiments - and only later applied by Lavoisier and other giants of science in that period - are the hypothetical-deduction methods by which science evolved. Again, observations and logic were also thought to be peculiar to science. We learned, however, the astrologers did make observations and that theologians had logic. Logic is thus the most methodological component of all human inquiry. As such, one would not be able to discern science from other human thinking. But there are boundaries within which science can legitimately operate. The first one is that science denies two

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types of truth: truth by logic and truth by faith. On the other hand, science accommodates only one truth. The other is the constant test by internal logic of necessity and by external public record. These boundary conditions must always be observed as otherwise one would fall into the realm of magic.

From its cradle in the western civilization, science, as such, has been following the wave of western expansion since the 1600's to spread all over the world (Kumar, 1995). The propagation has been made possible by two principal methods. The first is due to survival of equilibrium state and the second, is caused by replication of structures. On its ways, as in other case of cultural propagation, science is not exempted from the general rule. Filtering processes must then have been operating at many countless cultural borders - whether it be called adaptation or adoption, reluctance or enthusiasm - manifesting itself in the different ways science progresses in the science-receiving nation. Such countries - to name a few examples Japan and India - seem to be ready to absorb science, while some other Asian countries seem to be less successful in adapting it. Is there any internal cause for it? Might it be that individuals and people equal in natural gifts are not dealt out equal fates by history?

II UTILITARIAN PRINCIPLES

A closer look at the growth of science at its origin indicates that there must have been a prerequisite for developing science. In the first place, in order to be able to accept change there must have been preparedness for ethical and cultural mutation. Some expounded the view of the cause of scientific revolution in the west as the realization of the hedonist-libertarian ethics - an ethic which provided the thinkers and philosophers of that time with the possibility to pursue their own interest and pleasure for the sake of uncovering the secret of nature (Bronowski and Mazlish, 1960). It then became more and more apparent, in later years, when science stroked many interfaces with other human interests and social structures, that other factors were necessary in order for science to evolve as it is today. One of the most demanding is the public and social needs that have entered in to scene of science - and external force that can not be ignored in the science-technological atmosphere. This is the situation that we in the developing countries have to deal with. Aspects of human thoughts which should be incorporated into the scheme of adaption of science is rapid changes of the world view. It is the vision not only how sciences themselves can and should advance but also return benefit to society. There are perspective which are embedded in the knowledge of specific, identifiable changes occurring in social dimensions and domains.

But the key to progress remain in the hands of the few, integrated, scientists or bodies of science communities. Some countries have shown that their success in developing science has been due to the vast amount of money. In reality, the progress of science was the result of intelligent use of large amount of funds, ingenuity of the scientific communities and the farsightedness of the policymaker on human resources. In the present model of technological society it is incomprehensible to see science exist independently without public support. It would therefore require a national policy which would serve as "foster parents" for science development, which should also emphasize the promise of science for the attainment of major public objectives. By stating this, it is not the intention of the present paper to stress the one-to-one correspondence between science and material return or productivity.

The founding of the tertiary-level of education in Indonesia and elsewhere showed that there were visions into the future, brewed by colonial administrations. But situation changed which showed that their existence helped to prepare the future of their environment in the sense that they accommodate three basic aspects of scientific endeavours. These are the development of:

a. the practical application of science
b. scientific knowledge and information
c. scientific attitude and approach to phenomena.

A good example can be cited was the foundation of the Bandung Technical High-School in Bandung, Indonesia in the year 1920. In the early days of its existence there were only few selected Indonesians who enjoyed the privilege of acquiring the western mode of education. Nevertheless, liberal teaching allowed the few practitioners to acquire the outside stimuli which, in turn, have brought them to a new worldview ranging from simple scientific-based engineering of water distribution, all the way to the concept of new nationalism. Another example was the contribution of natural scientists to the formation of colonial culture in Java (Hidayat, 1995; Doorn, 1995; Gonda, 1995)

III WIDER IMPACT

The impact of the development of Indonesian engineering in the 20's and creation of scientists in the late 40's is of enormous scope and interest and the spread of science as distinct from its impact, is a topic which must be explored. The subject of this paper is to present what university science has offered over the past 50 years. Time and space may be the limitation factors to include all aspect of it, but the intellectual aspect which grows together with scientific endeavour cannot be overlooked.

IV TERTIARY-LEVEL OF EDUCATION

Derived from the medieval Latin term universitas, the word university was at first not used exclusively. In the past the denotation was always *universitas magistrorum* or *scholarium* or *magistrorum et scholarium*. Toward the end of the medieval era the boundary between the terms *studium generale*-where learning and education were practised -- and universitas began to fade away. The term "universitas" was then to be used exclusively up to the present time. Universitas has become an institution a with dual role where two great human endeavours are developed. These are scientific knowledge and the teaching of higher learning programs. In the course of time research activities were flourishing gradually in western universities thereby creating a third function to those two already existed within the foundation of the university.

In the 20th century it has became a conventional wisdom that scientific and academic research are the primary ingredients of university function and crucial to the development of a nation's wealth. In the USA for example the single driving force which has generated the adagium and influenced political thinking after the 2nd world war was Vanevar Bush's book: "Science: the endless frontier" (Bush, 1945). In that book Bush wrote :... *"new products and processes are founded on new principles and conceptions which, in turn, are developed by research in the purest realms of science"*. This means that many technological innovations vital to competitiveness depend upon scientific discoveries that usually spring up from the research base in universities, government laboratories or some established industrial sectors. History has shown that there is a close connection between research and development with economic and social advancement. As such, it can be comprehended that scientific research is directly linked to the national economic growth. There is a problem, however, in that the process of globalization of technology poses difficult challenges for policymakers as well as those who are concerned with manpower development. Urgent and onforeseen environmental and social changes challenge scientists, as well as educators and policy makers which force them to sign new social contracts. One aspect of the contract which should not be overlooked is for us, as scientist and teacher, to devote our time to increase the intellectual and welfare capacity of the society, in return of their funding. For the developing countries the difficulty stems from the fact the developing nations not only have to compete with the industrial nations who started earlier in trade and in promoting advancement but lies in the area of teaching and learning. There is the problem in producing qualitatively able graduates who can cope with technological and scientific problems developed elsewhere. Science-related policy issues are made all the more difficult as the developing countries, due to lack in quantity and quality of scientific manpower, are ready to struggle to interpret their national interests. Who would decide whether the issues in the health and nutrition areas are more important than, for example, the nuclear driven power station. Nuclear power station forms an alternative means for powerful energy production because of the depletion of our natural resources. Although this is geologically apparent, some sectors in society may not be ready to accept the undertaking due to accidental technical error of nuclear reactors. At the same time, nobody doubts that the ethics of the 21st century should embrace an environment-friendly development. However one should first embark on real assessment and measurement of the parameters of the environment before any verdict about non-friendly industries can be passed. Developing countries, such as Indonesia, have occassionly become immobile against this process due to the fact development is usually attached to with a string which bound its freedom movement. In addition to this kind of situation we should be aware that much of the science and technology needed for our national growth is developed and, more often, managed by multinational enterprises whose markets, operations and sources of capitals are distributed throughout the globe. They have their own priority list which are sometimes counter productive to our national need. It is necessary at this point to remind the reader that national growth is not necessarily equivalent to economic growth in which the main interest is the accumulation of capital goods and financial.

V NATIONAL GROWTH

National growth is more than that in which the entire society is raised not only above the line of material poverty but structurally and culturally the society should find its place above the mere dividing line between traditional subsistence and the need for the food and housing. The process is far more difficult as it requires a persistent effort in order to create an intellectual atmosphere and to develop the attitude to search for betterment in a democratic way. This is in contrast to economic development where the main interest is the investment of capital that can flow around the world daily in search for the greatest return while the endogenous population is left in the state of intellectual paria in their own country.

Many countries were born with the wonderful philosophical outlook on education in which everybody shall have the right to obtain education. Many of the high expectation and hopes, based on that premise, have become realities. The number of educational institutions at primary, secondary and tertiary levels, have increased in number by more than one thousand times since before the war. Indonesia now harbours 76 state universities and more than 1200 private universities of various type and rank. More than 2 million young peoples participates in the process of acquiring knowledge in the tertiary level each year. In time these will form the working force, not necessarily the distinct, elite class in the future. Their usefulness to the national programs depends critically on how one looks and at how the university is run. It is projected that by 2020 the participation rate to the higher education effort would involve 50 % of the tertiary-education age group (19-22 yrs.). This means that around 3.5×10^6 people to be catered with high-level teaching and training for (Suhendro, 1998). In order to cope with this problem Indonesia has to produce 11,500 teaching staff each year. The impressive increase is shared by the birth and establishment of many scientific research laboratories in many specialized branch of sciences. The existence of institutes of higher learning must be viewed as the most important instrument for fostering science and technology, and which we must appreciate. However, the pride that we obtain from having built a great number of academies and institutes of higher learning is soon coupled with an uneasy feeling due to the fact that our active involvement in promoting science and applying it to our day-to-day affairs is still surprisingly limited. Gibbs (1995) pointed out that the scientific production statistics show "the lost of science" in the Third World. However looking into the detail one can argue that the data is biased toward publication in fields other than health, agriculture, nutrition, tropical diseases and ethnobiology. Many of the contributions in these field either appeared in non-English language or elsewhere. The contributions in these "traditional fields" may indeed exceed that of the science production in the so called "international science " like biochemistry, nuclear physics or microbiology of degenerative diseases where we in the Third World still have to work hard to attain our status on the international arena.

The satisfaction having produced professionals of higher learning in sciences sometimes obscured by disappointment, if no frustration, by realizing that many of our able, young and, presumably productive scientists are too soon leaving for non-academic jobs or engaged in non-professional activity. We realize that this is an unavoidable call of duty in view of the multifaceted and accelerated development in countries requiring experts and science managers. However, one should not neglect the scientific traditions in which student-teacher relationship is fostered. The "laboratory-benches", the seminar rooms, the studios should not be left unused - but filled with young and old, seniors and juniors staffs and students who exchange freely the results of their scientific work. There should be balanced distribution in number and equity of rewards between the academic and extramural scientists, if the country want to keep pace with development.

VI UNIVERSITY AT THE CENTER OF RESEARCH ACTIVITIES

In their paper Ginnot and Johnson (1996) noted that since the university as an institution is currently under attack from many quarters and since it already is undergoing considerable reform, why not consider a broadly restructured model of the university ? This is indeed an interesting challenge, but it can be imagined that the process would require much effort and quite a long-time in order to reach the state of equilibrium with no turmoil. Their view may certainly be applicable in some countries and valid for some advanced and already diversified universities but it would be too costly to be applied in the countries with large inertia and relatively few qualified staff members. Speaking of Indonesia, it can be said that it belongs in this latter category -- and for a university in this country the path that should be followed is to strengthen the basic premises of the university. While we can not ignore the fact that seats of higher learning in that country will still be limited in many years to come (Suhendro, 1997, 1998) the university should entertain the basic philosophy that it is a place to nurture one's capability for creative learning and research. It must be clearly stated that the mission of the university as an institution is to work toward the solution of regional as well as world-wide global problems for the country. Nevertheless, implanting intellectual curiosity rather than encouraging students to memorize facts should be the character of university teaching elsewhere.

There has been much discussion in recent years about the need for a new national science teaching policy (Hidayat, 1997). The arguments put forward were actually a simple reminders of our commitments to quality, rather than quantity alone. The increment in number of the participation in higher education is certainly very impressive, but we should not loose sight of the main goals, which is to produce qualified and dedicated manpower. Investing the future is building the country's educational institution. This kind of endeavour however requires vision as well as physical infrastructure planned consistently for multi-year to come. Many developing countries would certainly welcome extra financial resources in order to keep their young able, dedicated scientist to remain contributing to the body of knowledge. Some of them are unfortunately deprived of such means because of more immediate social problems (famine, etc.) to be solved. It is gratifying to learn that, albeit little late, the World Bank has started shifting some of the focus of its activities to supporting knowledge developments. Direct support for research, for university accreditation in developing countries are now seen as more of a priority.

VII THE ASIAN SCENERY

As has happened in many Asian countries, science and technology are, in a way, transplanted cultural entity. During the process of transplantation they have met certain entrenched attitudes, resulting from the past experiences that are inherent in our own "cultural" background. The problem is, therefore, how to nurture the newly transplanted species of academy within our domestic confines and improve the image of the university. The system should reflect the learning capacity of the nation where developing intelligence should come first, as it would then deny the natural heritage of the university system if it is solely used to produce bureaucratic attitudes. It would therefore be an honourable duty for the university system if it acted as an agent in which transmission of culture could flow freely and the creation of free thinking man can be ensured. Free in the sense that the graduates know his or her social contract, and is able to balance their responsibility against their rights. Higher Education should provide teaching, research, driven by his or her own curiosity, as well as group curiosity, and serving the community. These are the integral part within the university environment.

Research has many different forms and faces. Broadly speaking, research may be represented as striving toward two objectives: the first to improve our understanding of the nature of matter, energy and cultural phenomena. This is basic scientific research which has been cultivated since time immemorial. The second is to develop inputs to "tomorrow's" technology and engineering. Generally speaking, this second category is called applied research. Please note that within the adagium of "tomorrow" the sense of time embraces now, months, years and, not surprisingly, decades. Many aspect of pure sciences found their ways into application decades after they were formulated. Twenty years were needed to transform quantum mechanics into solid state physics whose application has now become part of our lives.

Universities should be endowed with facilities, manpower and not least, fund to be able to train the future researchers, whether for basic or for applied research. The main ingredient is to spark the attitude of questioning and inquiring. It will be naturally understood that research training for undergraduates and graduates degrees are not the same both in depth and in substance. The central element of the graduate education level is the doctoral dissertation, which is essentially an apprenticeship of "how to carry out research". This forms a rather unique part of graduate education, as opposed to undergraduate education. There should be an element of versatility in every graduate education that embodies real-problem solving methods. The training for problem-solving depends on many factors but personal capability and capacity is the foremost in this level. This is an important aspect of dissertation research as any specific knowledge gained. We should therefore welcome the initiative of many universities to allocate their fund and forces for dissertation research motivated by the production of able, skilled, future researchers rather than by the glamour attached to the degree. Foundation of good graduate schools are regarded not only as an endowment for the future but also form "play-grounds" where the professors and their apprentices play with the new "toys" using the same language of science. Here in this "play-ground" the frontiers of science are discussed, found and, occasionally, broken or pushed forward. While initial motivation for research would encourage experimentation and more systematic observations on things, the individual capacity still form the corner-stone of the future careers. The accumulation of people with a high piercing scientific curiosity is the asset of the nation that the country cannot afford to abandon.

VIII PRACTICAL APPLICATION

Examples of advancements in basic science that have changed everyday life are all around us. In supermarkets we can find the bar code reader and credit card scanner. Computers that interlink people separated by miles in space and several time-zones on earth are already found in offices in many remote areas. All of the familiar elements of daily life - undreamed off two decades ago - are actually applications of curiosity-driven basic research in solid state physics, optics, topology and abstract algebra. We should by now demystify the novel and science-fiction gadgets simply because these are the realization of scientific and technological inquiries. Many of them are the products of organized fantasies or scepticism - the trademark of science about which most people view science as an arcane activity.

Indeed, heavy task rests on our shoulder to enlighten the public but with a good and farfetched vision one should accept the fact that the university system is still the cradle for development of free thinking. The key ingredient in any real plan for balancing the national budget of developing countries must therefore be a sustained investment in fundamental and strategic applied research. This is true if we still intend to maintain our position in the cultural world of nations. Otherwise we are just members of countries which can only provide natural resources to a new type of expansionistic power. To sow the seeds for tomorrow's industry and technology is the way we pay the debt to our next generation. Therefore, in its simplicity and flexibility, Vanevar Bush's view would remain a model for future blue prints of our scientific commitments. It is gratifying to note that science and technology have found their place in the heart of developing countries and the execution of them in the day-to-day affairs will become more important because history will not give credit to promises. It only records the proven useful, results as the proof of our goodwill to show how science relate to society. At the same token this should be regarded as the way the university commitments meet standards of accountability.

IX OUR PUBLIC MANDATE

What does research means for us ? Why can we do without it. The answer may be lying outside ourselves as it is an important anthropological basis of knowledge in mind. With this we distance ourselves from our primate-cousins. Research and, interalia, good university teaching, have shown that our survival, if not said success, as a species is totally dependent on being able to discern realities of life, by understanding causes and effects of phenomena. But the results of research should be spread beyond the laboratory walls to reach the entrepreneurs and publics.

Electronic and printing media have become commodities which are highly valued by the learned layman, professionals as well as public at large. For the last group it can only be the source of science information. Here lie some problems as, science is more subjected to population and to governmental scrutiny than it was in the past. The public often sees seemingly contradictory stories in the media about results which came directly from within the laboratory walls, not knowing that part of the truth was actually the result of a limited, experimental, and a strictly controlled environment.

Not knowing how science operates, the public could easily blame scientists for lack of knowledge in their trade. Worse still, they will accuse science of fallacy, for not being able to offer "true" information. The obvious results from this ill-informed belief may be severe if the policymakers decide to suspend any action until scientists agree about what is happening. Examples abound. For example, the cure of certain disease with newly discovered medicine may be explained wrongly by a non-expert. Global or climatic changes, or even weather predictions, are viewed from many different angles employing different atmospheric models run on computers with various degree of sophistication and bulk of assumption. Fresh in memory was the El-Nino and La-Nina 1997-1998 which created so much misunderstanding.

All of these can produce different results. Scientists in the field will have the burden of eradicating the controversies not by explaining facts only, but better still, by providing the public with the working mechanism in science. One should realize that the seemingly controversial issues which bounce around actually are the logical mechanism in science which cannot escape from setting boundaries on the limit of knowledge.

Most of us here who work in scientific research establishments would have no difficulty in differentiating between risk and true uncertainty. The first is an event with a known probability and the second is an event with an unknown probability. Policy makers want to make unambiguous defensible, decisions which are often codified into law and regulations. Inherent in it they would appreciate more about knowing the risk, rather than a true scientific uncertainty. One of the tasks of scientists, in particular university scientists - who deal and teach students and young peoples - are to make these things understood.

Our commitment as scientific workers in developing countries can be severe as we also have clean up prejudice and, often, lack of common sense. To advocate against a scientific prejudice and to maintain scientifically acceptable propositions for the decision-makers would take much time and occasionally require courage so that he or she could not be blamed for running counter to policy makers. A tradition for open discussion on scientifically related matter which are usually based on knowledge or facts to be countered only by other arguments on the same reliable grounds, should become the way of life free from any coercion by power structure.

Universities in my view are still the best brewing pot for this kind of activity as the university life should be characterized by a collegial, structureless environment rather than by a power structure implanted by a decree. The only leadership that should flourish in the university confine is the intellectual wisdom, not ranks or degree only.

X CONCLUSION

The university system as part of the tertiary level of education has shown responsible for the improvement of scientific attainment. We learned that in order to be able to achieve that goal one should be able to balance the financial shortages and other financial problems in such a way that it should not fall into the trap of egalitarianism and mediocrity. This is to assert the fact that the university system must be able to maintain and preserve the value of equality and a high academic standard. From the university, which is regarded as the brewing pot for development, the academic scientists are later employed in Applied Research Institutions to perform their expected role in solving many of our endogenous problems. Science is not a separate entity, remote from the day-to-day affairs. It provides the basic of most of the requirements for living in the next century, covering the human, social and economic concern. Front-line scientific results have more often emanated from university laboratories than from anywhere else. Industrial research, significant as it is, is virtually focused on specific short-term problems and often borrows from the results of long-term university research programs. The accumulation of their experience is part of the wealth that should be channelled back into the university to be incorporated into the management in order to improve our teaching and research capability.

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Building an "Astronomical Community"

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Abstract.

Especially in astronomically-developing countries, it is important to build an "astronomical community" consisting of professional astronomers (if any); other scientists, engineers, and academics with an interest in astronomy; undergraduate and graduate students; educators of all kinds - schoolteachers and those who educate them, staff of museums and related institutions, and officials of ministries of science, education, and culture; amateur astronomers of all kinds, at all levels; and interested members of the general public. In this way, astronomers can develop broad-based support for the development of their science, and achieve the "critical mass" which is so important at all stages of development.

Based on material presented at the IAU-COSPAR-UN Workshop on Capacity Building in Astronomy and Basic Space Science, Vienna, Austria, July 1999.

1. Introduction

What is an astronomer? The term is often used to denote someone who is a *professional* astronomer, who has a university degree in astronomy, and who is paid for doing research or education in the subject. A broader definition would be that an astronomer is anyone who does astronomy - who studies the universe. This could include scientists and other academics in cognate disciplines, students at all levels, astronomy educators in all settings, amateur astronomers, and many members of the general public.

Graduate students are obviously involved in astronomical research and, at my university and others, they are enthusiastically active in teaching and public outreach. Undergraduate students are increasingly being exposed to research through project courses and summer research assistantships; they should be exposed to the joy of teaching and public outreach as well. Even high school students can be productively involved in astronomical research and education, through programs such as the University of Toronto Mentorship Program, which enables outstanding senior high school students to work on research and education projects at the university.

Astronomy has many interdisciplinary connections, so it tends to interest a wide variety of scientists and engineers, as well as historians and philosophers. There are also *amateur astronomers* who are interested in astronomy and do it voluntarily. They are often professionals in other fields, and bring a high level of skill, experience, and enthusiasm to the field. There are about 5000 professional astronomers in North America but, for every professional astronomer, there are 10 amateur astronomers (ranging from novices to highly-skilled "masters") and 40 people with sufficient interest in astronomy for them to subscribe to magazines such as *Astronomy* or *Sky & Telescope* (Gada, Stern, and Williams 1999; paper presented at the symposium on *Amateur-Professional Partnership in Astronomy*, Toronto, Canada) Other members of the general public may have a strong interest in astronomy, without identifying themselves as amateur astronomers.

Astronomy is also part of the school science curriculum in most countries, so there are teachers who teach the subject. Many of them consider themselves to be amateur astronomers, in the sense that they love the subject, follow recent developments, and observe the sky. There are other educators who work in museums of various kinds, including science centres and planetariums, and there are science journalists who play an important part in astronomy education. All these individuals - and more - are part of the "astronomical community".

2. "Astronomical Communities" in Larger Centres

In my city of Toronto, Canada, we have over 50 professional astronomers, and an equal number of graduate students and postdocs. Astronomical research can be done by individuals and small groups (though funding agencies always look favourably on projects which involve several universities or research institutes). The teaching of astronomy in the universities is also done quite independently, though we benefit from an "education discussion group" within the university, and education sessions at the meetings of our national astronomical societies.

Beyond the universities, however, we have found that *coalitions* and *partnerships* have been effective in promoting school and public education. These, of course, are essential to the health of astronomy, because they lead to public awareness, understanding, and appreciation of astronomy. For instance, partnerships between astronomers, museum and science centre staff, amateur astronomers (especially through the Royal Astronomical Society of Canada), teachers and teacher educators, the ministry of education, and publishers, have led to more and better astronomy in our provincial school science curriculum. This has been followed up by workshops for teachers at the elementary and secondary level - most recently 2-4 July 1999 - with the same coalition members as sponsors and presenters. Some of these same groups have collaborated to produce excellent public programs for International Astronomy Day, an annular eclipse of the sun, the appearance of bright comets, and a recent joint meeting of the Astronomical Society of the Pacific, the Royal Astronomical Society of Canada, and the American Association of Variable Star Observers. There was only one notable lack of success of this coalition - the closing of Toronto's McLaughlin Planetarium in 1995. Certainly any proposal for the reopening of this planetarium, or any other in the city, will require the broad-based support and partnership that a coalition can offer.

3. "Astronomical Communities" in Smaller Centres

There are many areas of the industrialized countries which are "astronomically developing" in some senses. For instance, research has shown that the vast majority of students, teachers, and the general public have deep-seated misconceptions about astronomical topics. This is true even for Harvard graduates (!) but it is even more true outside the larger cities. There, local schoolteachers have very little resources and support in the teaching of astronomy. Local newspapers may have information from news sources or the Internet, but they do not have local contacts that they can turn to for more explanation. Public education (if any) in astronomy, is very sparse. There may be one or two professional astronomers, but there are more often astronomy instructors in small local colleges, whose area of specialization is not astronomy.

There may, however, be other individuals in the community who have interest or expertise in astronomy - a physicist, chemist, or historian at the college, a teacher in the local high school who operates a small planetarium, a small group of amateur astronomers who have telescopes and know how to use them, and a few "armchair astronomers" among the general public. These individuals can meet occasionally, either informally or as a local astronomy club. Their telescopes can be made available to students or the general public through "star parties", or to schoolchildren through partnership programs such as the Astronomical Society of the Pacific's *Project ASTRO* (www.aspsky.org). The school planetarium can be made available to college classes, and some of the more interested college students can be trained to operate the planetarium - a first step, perhaps, to a career in education. The club can provide a regular column in the local newspaper, or even an occasional program on the local TV channel.

4. "Astronomical Communities" in the Developing Countries

The concept of the "astronomical community" is even more important in the astronomically-developing countries, because human and other resources are even more scarce and precious. There may be one astronomer ("the lone astronomer"). There may be a few undergraduate or graduate students. One or two of these may go on to become professional astronomers, but the majority are likely to go into other careers such as teaching, industry, or business. It is very important to keep these graduates within the "astronomical community". Their interest and education in astronomy cannot afford to be lost.

Undergraduate students should be encouraged to carry out independent projects, either of a research or educational nature. A project which involves photographing a lunar eclipse or some other celestial object or event may provide an image for the local media (hence publicity for the astronomy group) or for local schoolteachers. Students should also be encouraged to learn (and practice) how to give good oral and poster presentations, so that they can contribute to education and outreach, and develop useful skills for their future career. Posters describing their projects can become permanent displays in the astronomy group's headquarters or observatory.

There may also be a few local amateur astronomers. They are often affluent, influential people who can afford to purchase a telescope and build an observatory. Many of them have good connections with government and the media. Some of them become quite skilled in operating their telescopes, producing high-quality astro-images, and organizing events for the general public. Their instruments and skills can be very important for a local university group which wants to acquire a small telescope and observatory. It is also possible that a few of these amateur astronomers are doing useful science by observing variable stars, the sun or planets, or occultations of stars by the moon or other objects. Since these observations are scientifically useful, they represent one way in which students (and faculty) can be introduced to real astronomical research. Thus, the small observatory would be a community facility - not just the preserve of the academics.

Teachers are a key part of the astronomical community in every part of the world, since they educate the students who will be the scientists and educators of the future, and they promote public awareness, understanding, and appreciation of astronomy. Teachers are professionals; they can help university astronomers and students to be better educators, and they are often amateur astronomers. They can also work in partnership with astronomers, to organize and present workshops on astronomy for their fellow teachers.

Museums can be an effective way of disseminating astronomy and other sciences to tourists and the local public. One room (or part of one room) of the local museum could be the nucleus of a small, local, hands-on space and science centre. Eventually, a hands-on exhibit room should be part of the astronomical community observatory.

Finally - there are many members of the general public who are interested in astronomy. If they are in positions of influence, they can be very helpful in the development of astronomy. At the very least, they can provide strong grass-roots support.

How can you identify these people? One way is to hold an event such as a public lecture, a "star party", or an open meeting at which a new astronomical project will be discussed. This might be done in connection with a local scientific or educational meeting, or a "visiting meeting" such as a UN/ESA Workshop on Basic Space Science.

Astronomers are fortunate that our science appeals to such a wide cross-section of the community. This is the basis of much of the public support for our science. It benefits us, in many ways, to reach out to our "astronomical community" - wherever we may be.

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NAME AND DESIGNATION OF COMETS

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INTRODUCTION

The primitive men had no concern about the identification of an individual comet. They began to do so, when it was possible for them to mark a year as a unit of time in eternity. Accordingly, the ancient people used to identify a comet by its year of apparition. With gradual advent of more sophisticated observational facilities and techniques which were initiated by the discovery of telescope in 1609 by Galileo Galilei (1572–1642), comets have been discovered in ever increasing number every year. So, it become necessary to specifically identify a comet by naming it.

NAMING A COMET

The process of naming a comet originated in a way which rarely occured in later years. Edmund Halley (1656–1742) was a good friend of Isaac Newton (1642–1727). This friendship led to the publication of the epoch-making scientific treatise 'The Philosophiae Naturalis Principia Mathematica' or simply 'The Principia' by Newton in 1687. By application of the Theory of Gravitation Published in The Principia, Newton showed how the orbit of a comet could be computed. Following the same principle, Halley computed no fewer than a dozen of comet orbits, his attention was attracted to the similarity of the elements of four particular comet orbits of the years 1456, 1531, 1607 and 1682. From the observation of the above similarity, Halley concluded that these four apparitions must have been made by a single comet with a period of nearly 76 years. In his paper entitled "Astronomiae Cometicae Synopsis" published in 1705, in the Philosophical Transaction, a journal of the Royal Society, London, Halley made a historical prediction. He predicted that the comet of 1682 would make its return in 1758. The comet did return as predicted but sixteen years after Halley's death. The comet was recovered by a German amateur astronomer Johann Georg Palitzsch (1723–88) on 25 December, 1758. So in honour of his successful prediction which was the first of its kind in the history of cometary observation, made by Halley, this periodic comet was named after him as the Comet Halley or Halley's Comet.

Generally, a newly discovered comet has been named after its discoverer, since 1760. In the event, the number of discoverers is not more than three, the comet under consideration is named after its discoverers with their names in choronological order of their respective discovery moments. The glory of the first naming a comet after an individual discoverer, went to the French astronmer Charles Messier (1730–1817). On 26 January, 1760, he discovered a comet which was named after him as the Comet Messier.

If the number of discoverers is more than three, then the comet is not named after any discoverer. There are quite a goodnumber of comets which were not associated with the name of any paticular discoverers. But they were suddenly observed to make a startling apparition by a large number of observers at a time. These comets have been named as the Great Southern Comets, the Great January Comet and the like, signifying the nature, location and the time of apparition of the comets. In the history of cometary observation there were a unique discovery of comet which made a sudden apparition during the occurrence of the Total Solar Eclipse of 6 November, 1948. Hence, rightly it has been named as the Eclipse Comet 1948. There were instances when comets were observed during the Total Solar Eclipse ; but they were discovered before the occurrence of Eclipses. Such as example is the comet Hale–Bopp which was discovered on 22—23 July, 1995 and it was observed from Mongolia during the Total Solar Eclipse of 9 March, 1977. Like the Comet Halley, the Comet Encke which is the shortest periodic comet known so far having a period of 3.30 years, is the second one of its kind to be named after Johann F. Encke (1791–1865) who successfully predicted its return in 1822.

OLD DESIGNATION SYSTEM

Apart from naming a comet, it is also assigned a unique designation. The system of designating a comet was introduced by the Astronomische Nachrichten in 1846. According to this system of designating the comets, the year of perihelion passage of a comet was suffixed by an appropiate Roman numeral depending on the choronological order of its perihelion passage. In course of time, this process of assigning designation to a comet posed some inconveniences. In order to remove them, the same Astronomische Nachrichten, again in 1870, added a more meaningful stage in assigning designation to the newly discovered and recovered comets. Accordingly, at the first stage, immediately after its discovery, the year of discovery of a comet was suffixed by a small English letter implying the order of the comet in the serial of comets discovered in that year. At the second stage, the year of perihelion passage of the comet is determined and then it is suffixed by an appropiate Roman numeral indicating the order of its perihelion passage in that year. The International Astronomical Union (IAU) has been preparing the annual lists of newly discovered and recovered comets by disgnating the year/Roman numerals since 1939.

Example–1. While Prof. M. K. Vainu Bappu was in America as a student, he was the first person to discover a comet on 29 June, 1949. Incidentally, Bappu is the only Indian, so far, to discover a comet. The discovery was immediatly followed by his teacher Bart J. Bok and his fellow student G. Newkirk in succession. The comet discovered by these three astronomers was the third one to be discovered in that year. So at the first stage, it was designated as the Comet 1949c, Bappu-Bok-Newkirk. This comet was the fourth one to make perihelion passage in the year of discovery. So at the second stage, it was permanently designated as the Comet 1949IV, Bappu-Bok-Newkirk.

The discovery of a comet may be possible before or even after its perihelion passage and these two occassions may not occur in the same year. In addition to these, if the comet was found to have a periodic orbit with a period of less than 200 years and more so, when the apparition was not the first one, then its name was prefixed by the letter 'P/'.

Example–2. With the help of 200-inch Hale Telescope at Mount Palomar, two astronomers, David Jewitt and G. Edward Danielson discovered the ninth comet of the year on 16 October, 1982. The calculation for its orbital elements revealed that it was not a discovery of new comet but the 30th recorded recovery of periodic comet Halley. So at first it was designated as the comet 1982i P/Halley. Subsequently, this comet made its perihelion passage on 9 February, 1986 as the third one to do so in that year. Finally, it was designated as the Comet 1986 III P/Halley.

If an observer or a group of observers comprising upto a maximum number of three, happen to make multiple discoveries of comets, then the name of each comet was suffixed by a natural number indicating its order of discovery by the said discoverer or discoverers.

Example–3. In 23 March, 1993, three Americans comprising a couple, Carolyn and Eugene Shoemaker together with David Levy discovered the fifth comet of the year and it was the tenth one to make perihelion passage in 1994. This terio were so successful in their joint endevour that it was their ninth discovery of a comet. This comet, having a period of about 18 years, in the recent past suffered a split in its nucleus under the influence of differential gravitational force of the planet Jupiter, disintegrating into 19 component nuclei and finally, all of them crushed into the globe of Jupiter in July, 1994.

The Comet was primarily designated as 1993e Shoemaker-Levy 9 and permanently as the comet 1994X Shoemaker-Leavy 9.

PRESENT DESIGNATION SYSTEM

The commission 20 of the IAU considered the existing problems relating to comet designation and names. In a meeting held in August, 1994, the said 'commission' resolved to replace the present year/letter and year/Roman numeral system by a new one which came into effect since January, 1995. The new system is stated below :

a) Every discovery of comets should be immediately reported to,

The Central Bureau for Astronomical Telegrams,

IAU, Minor Planet Center,

Smithsonian Astrophysical Observatory,

60 Garden Street,

Cambridge, MA 02138, U. S. A.

which shall assign designation and name to it and announce its discovery. Having computed its orbit, the comet is first designated by the year of discovery announcement with an appropiate English capital letter indicating the particular halfmonth of discovery and then the letter is suffixed by a natural number implying the position of the discovery in that halfmonth. The English capital letter, A indicates the halfmonth of Jan. 1–15, B indicates Jan. 16–31, C indicates Feb. 1–15, ... Y indicates Dec. 16–31, I being omitted.

b) After determing the orbital elements of the comet under consideration, the year of discovery announcement is prefixed by

'P/' for a periodic comet having a period less than 200 years ;

'C/' for a comet having a period longer than 200 years or no period at all ;

'D/' for a periodic comet that no longer exists or is deemed to have disappeared ; and

'X/' for a comet for which a meaningful orbit cannot be computed.

c) The prefixed letter 'P/' or 'D/' is again preceded by a natural number indicating its historical order of discovery.

d) If a cometry nucleus suffers split and developes multiple nuclei, then each of these nuclei is identified by a capital letter succeeding the number after the halfmonth letter, in the order of its perihelion passage.

A few examples will help to understand clearly the present cometary designation and naming procedure.

Example–4. A comet was discovered on 22–23 July, 1995, independently first by Alan Hale and then by Thomas Bopp. The discovery was announced by the Central Bureau on 23 July, 1995, during the period of halfmonth July, 16–31 which is indicated by the letter O. As it was the first comet discovered in that halfmonth O and it was found to be non-periodic in nature, it has been named as the Comet C/1995 O_1 Hale-Bopp.

Example—5. The comet Halley, as stated in Example-2, has been designated as the comet 1P/1982 U_1 Halley. '1P/' has been designated as it was the first comet recognised as the periodic one and 1982 U_1 for it was the first comet recovered in the halfmonth Oct. 16–31, indicated by the letter U.

Exaple–6. Each of the 19 fragments of the comet Shoemaker-Levy 9, stated in Example–3, has been designated and named as follows : D/1993 $F_{2\text{-}A}$ Shoemaker-Levy 9 to D/1993 $F_{2\text{-}W}$ Shoemaker-Levy 9, omitting the letters I and J, as it was the second comet discovered in the halfmonth March 16–31 indicated by F. 'D/' is used for the comet crushed into the planet Jupiter and no longer exists.

Thus with this pracise knowledge about the old and present system of nomenclature of comets, it is possible for a reader to study the literatures on the comets without any hinderance regarding their identification.

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MARS

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Mars is a planet about which one has always thought if life exists. This is due to either its resemblance with the Earth or its appearance. The latest American spacecraft sent by NASA to Mars, Mars Pathfinder and Mars Global Survevoy, has made its fascination arise again.

We have remembered an article dated on 14 th July 1909, from a common reader's journal. It tells us about the opposition of planet Mars on 23 th September of the same year. The two illustrations of the article are eloquent enough and they show us the knowledge of that time.

We have used the article to work on the gravitation topic because at first sight their illustrations suggest us the questions related to the subject: why are the Mars's habitants tall and slim, while we look like tortoises?. Although the first reaction from the pupil was smiling when looking at those illustrations, we also obtained their attention to the topic immediately.

We propose an activity to make a more accurated analysis of it, with two objectives: to observe the evolution of knowledge towards Mars and its resemblances and differences with the Earth.

Scheme of the activity:

1. Brief observation of the article and opinion

It is interesting to collect the first opinion of the pupil about the article and perhaps to emphasise some characteristics of it.

2. Look at the information

We help the pupil a little in his/her search, we differentiate between two different periods, before and after the explorations on the planet..

First period: at the end of the 19^{th} century, during the oppositions of 1877 and 1879, Schiaparelli draw maps of Mars, which showed "channels" crossing the surface. Since then, the knowledge of the planet is continuously evolving.

We proposed two ways to deal with this early time: the first one is to draw our attention on those who have some knowledge about the planet: the observation of Mars planet, in the oppositions of years 1909, 1924, 1956... is bound to some names such as: Schiaparelli, Emmanuel Liais, Edward Barnard, Antoniani, Grevil Tikhov, Vesto Spliter, Bernard Lyot,...Gerard Kuiper... The pupils have to try to find information about them.

The second way, in order to avoid the possible difficulties generated to find information about the previous authors, we propose is a questionnaire. This can reflect now the information about Mars has evolved:

What were the channels supposed to be?

Do the bluish-green areas observed change with the seasons? Compared their spectra with those of some regions on Earth, what erroneous conclusions arised? What did they think they were?

What were the highest and lower values of temperature on the surface of Mars?

When were the two Moons of Mars discovered?

In this first period, had craters on Mars been seen?

2^{nd} period - From 1960, the explorations on Mars by USA and URSS enlarged a lot our knowledge about its surface and its atmosphere. We emphasise the information provided by the American , Mariner 4 (launched towards Mars in 1964) and Mariner 9 (1971), Viking 1 (1975) and Viking 2 (1975), Mars Pathfinger and Mars Global Survevoy (1996)... What is this information?

3. Study in depth of the article. Does it reflect the knowledge of the time?

It is important to compare this article to the knowledge on planet Mars of the time., in order to see to which extent it adjusted to reality.

4. Counteract/compare the present knowledge with those described in the article.

That is to say, observe the gap of science between these two periods. Here we can fall upon scientists of the area of the two different periods , in our case we pay attention to two Catalan scientists: J. Comas-Solà[1] and J. Orò-Florensa[2], in order to notice better the differences between the two times, know which is their view or their contribution to the knowledge of the planet and obviously know them.

5. Conclusions and personal opinion.

At the beginning of the century, one had detected an atmosphere in Mars, changes of colour in its surface and Polar Caps that increased or decreased with seasons. This was getting one to think about the existence of live on the planet. The pupil has to compare the physical facts and characteristics of Mars that we know nowadays with these of the Earth, and give his opinion.

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Como nos ven los habitantes de Marte Como podriamos verles - Alrrededor del mundo, Madrid, 14 julio 1909

[1] **Josep Comas-Sola** (1868-1937) Astronomer. We emphasise some of his large contributions: he discovered two comets, one variable star and eleven asteroids or small planets. He had researched work on Mars, Jupiter, Saturn and the double stars. He was the author of: a stereoscopic process that showed the proper motions of the stellar systems, and the first cinematographer study of the solar eclipses.

[2] **Joan Oró-Florensa**. Biochemist. He has contributed and managed some programmes of research work of the NASA (Apollo and Viking) , between others he has written: *The Viking Mission and the Question of live in Mars* (1979) and *Planetes comparats* (1980).

"Sun Rise Line" and "Sun Set Line"

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1. Introduction

It is quite unknown how much the time and the point of the sunrise changes in a year, although Japanese commonly know the sun rises in the east and changes its time and point in a year. Therefore, linking the points on a map where the sun rises at the same time, I drew a line and named it "Sun Rise Line." In the same way, the line linking the points of the sunset was named "Sun Set Line." In addition, I thought up the easy way of figuring

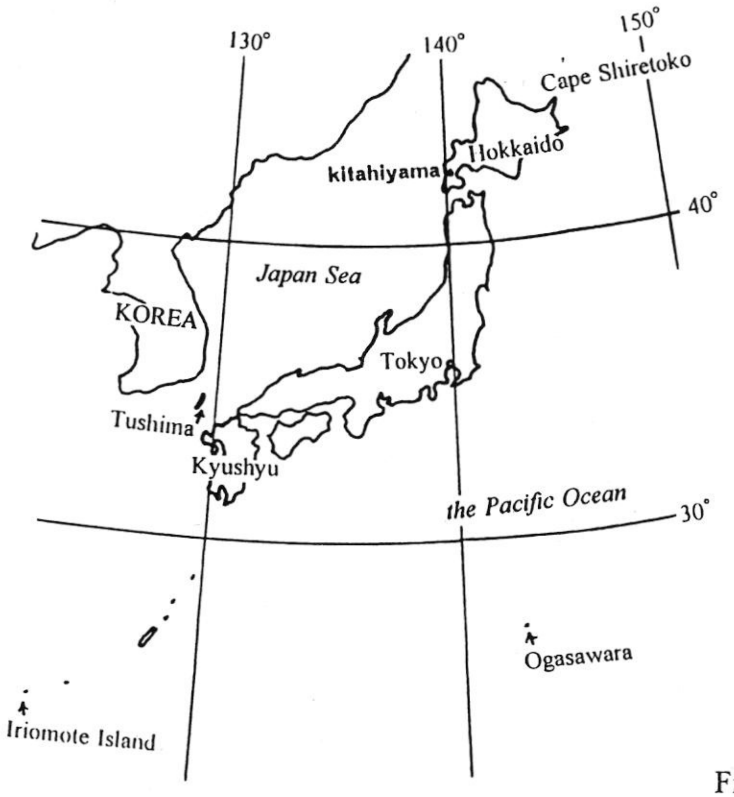

Fig.1 : Location map

the line. That gave us the fortunate opportunity to study the movement of the sun and the variations of the four seasons and to understand the nature in the world.

2. How does the sunrise and sunset change its point and time?

We know that the sun rises in the east and changes its point more or less, but not specifically. First, I examined the point of the sunrise and sunset at Kitahiyama, southwestern Hokkaido, Japan(Fig. 1) on the day of the summer solstice about 10 years ago with my students. Of course it is possible to find the answer by calculation, but I wanted to make my students realize that fact.

As a result, we found that the sun rises around the northeast and sets in the northwest on the day of the summer solstice. By researching the event we also found that the sun on the day of the winter solstice rises in the southeast and sets in the southwest. The point of sunrise and sunset at Kitahiyama(42.5 degrees north), theoretically, moves 33.6 degrees further north on the day of the summer solstice, and 31.8 degrees further south on the day of the winter solstice. Therefore the difference between the summer and winter solstice will be around 70 degrees(Fig.2).

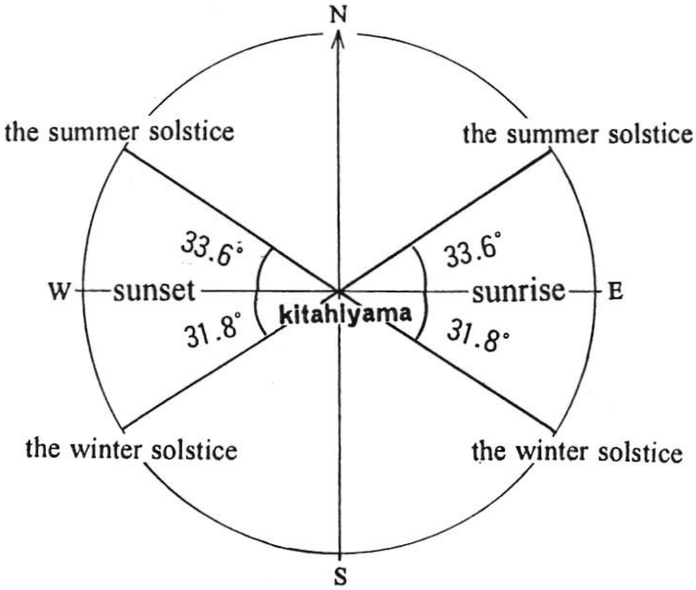

Fig.2 : A variation of the point of the sunrise and sunset during the year at Kitahiyama, southwestern Hokkaido, Japan.

As we live in Hokkaido, north island in Japan, we know that the sun rises around 4 o'clock in the morning of June while the sun of December rises at 7 o'clock in the morning, and the difference of the times will be no less than 3 hours. Some schools in Hokkaido have a different schedule between summer and winter, and that is an example of the impact of the summertime and wintertime, which is practiced in many other countries.

Comparing these two occurrences below, the different times of the sunset and sunrise between the summer and winter solstice is over 3 hours. However in Tokyo or Kobe, it is about 2 hours. On the other hand, it is only one and half hours in Naha or Ogasawara, which are both located in the south of Japan. Thus the difference between the times of the sunrise and sunset is getting smaller and smaller as we move to lower latitudes. Consequently , there is no difference on the equator.

On the contrary, the higher latitudes we move to, the greater the difference appears between the times of the sunrise and sunset. In the end, it will be 24 hours over 66.5 degrees latitude.

The sunrise and sunset change their times and points depending on mainly their place and latitudes in which they were located. I have talked about an issue of sunrise and sunset in a certain place. Now, how about the geographical differences of the time and the direction.

3. "Sun Rise Line" and "Sun Set Line"

a: What is the "Sun Rise Line" and the "Sun Set Line"?

The time and the point of a sunrise in a certain place changes day by day. In fact the data demonstrates that they also change in many different places. Therefore, on the same day, there must be many places where the sun rises at exactly the same time. On the surface of the earth, we can link such places with a certain line. I will call the line the "Sun Rise Line." In the same way, the line of places where the sun sets at exactly the same time will be called the "Sun Set Line." Actually these are specifically scaled down.

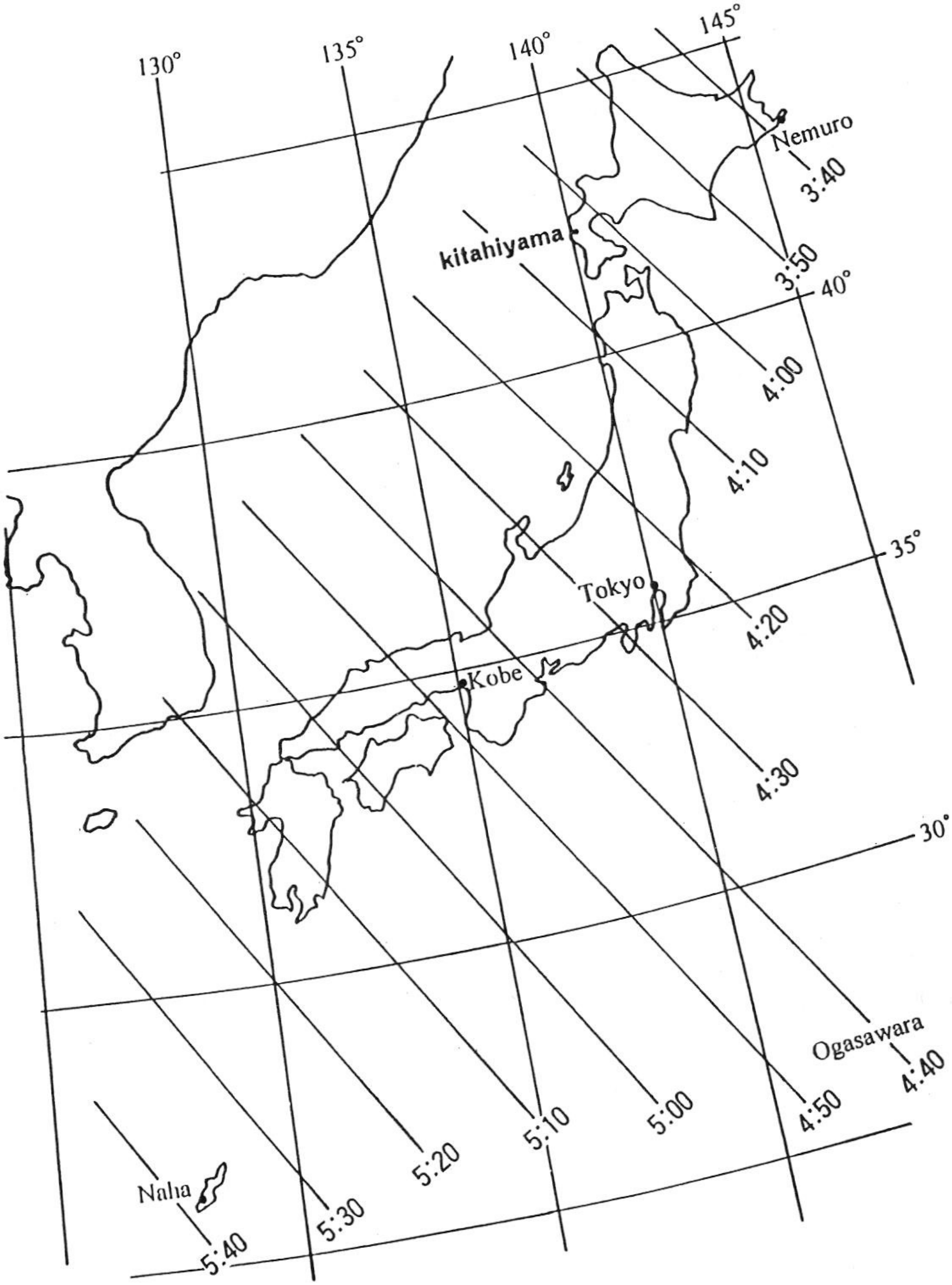

Fig.3 : Sun Rise Line (20. June. 1997)

b: How to draw the "Sun Rise Line"

In a chronological table of science in Japan, the time of a sunrise and sunset can be seen at 48 different places in Japan, including Naha in the southwest islands, Nemuro in Hokkaido in the very northeast, and even in Ogasawara, which is close to the southeast edge of Japan. Those times are divided by every 10 minutes. Those figures are for 37 certain days in a year. That is enough to be used as data. For example, take the 20th of June, which is very close to the day of the summer solstice, and plot the times at 48 different points. Use the collar, red, if it is between 6 o'clock and 7 o'clock, and blue between 7 and 8 o'clock, and so on. Then draw the "Sun Rise Line" linking the same time. Do it in 10 minutes intervals to avoid any inconsistencies. Each line will be a straight line in such a small region like Japan and approximately parallel with each other. On the map written with "azimuthal equidistant projection" like the figures above, the lines will be a little narrower with each other on the northern area, though that depends on which type of map will be used.

4. Annual changes of "Sun Rise Line" and "Sun Set Line"

On the 20th of June, the sun rises in Cape Shiretoko first in Japan at 3:36 a.m. and finally rises on the edge of the southwest, Iriomote Island at about 5: 55 a.m. The difference between the two places will be around two and half hours (Fig.3).

On the other hand, on the day of the winter solstice, the first sunrise appears in Ogasawara Islands at 6:10 a.m. and lastly in Tushima located between Korea and Kyushyu island at 7:20 a.m. The difference is one and half hours, which is smaller than it is on the 20th of June (Fig.4).

On the vernal and autumnal equinox days the sun comes up along the line of longitude (Fig.5 on 22nd of march). We can clearly see the movement of the Sun Rise Line, which naturally moves 2.5 degrees in 10 minutes(15 degrees in an hour). In these seasons, the sun rises in Kitahiyama at around the same time as in Tokyo.

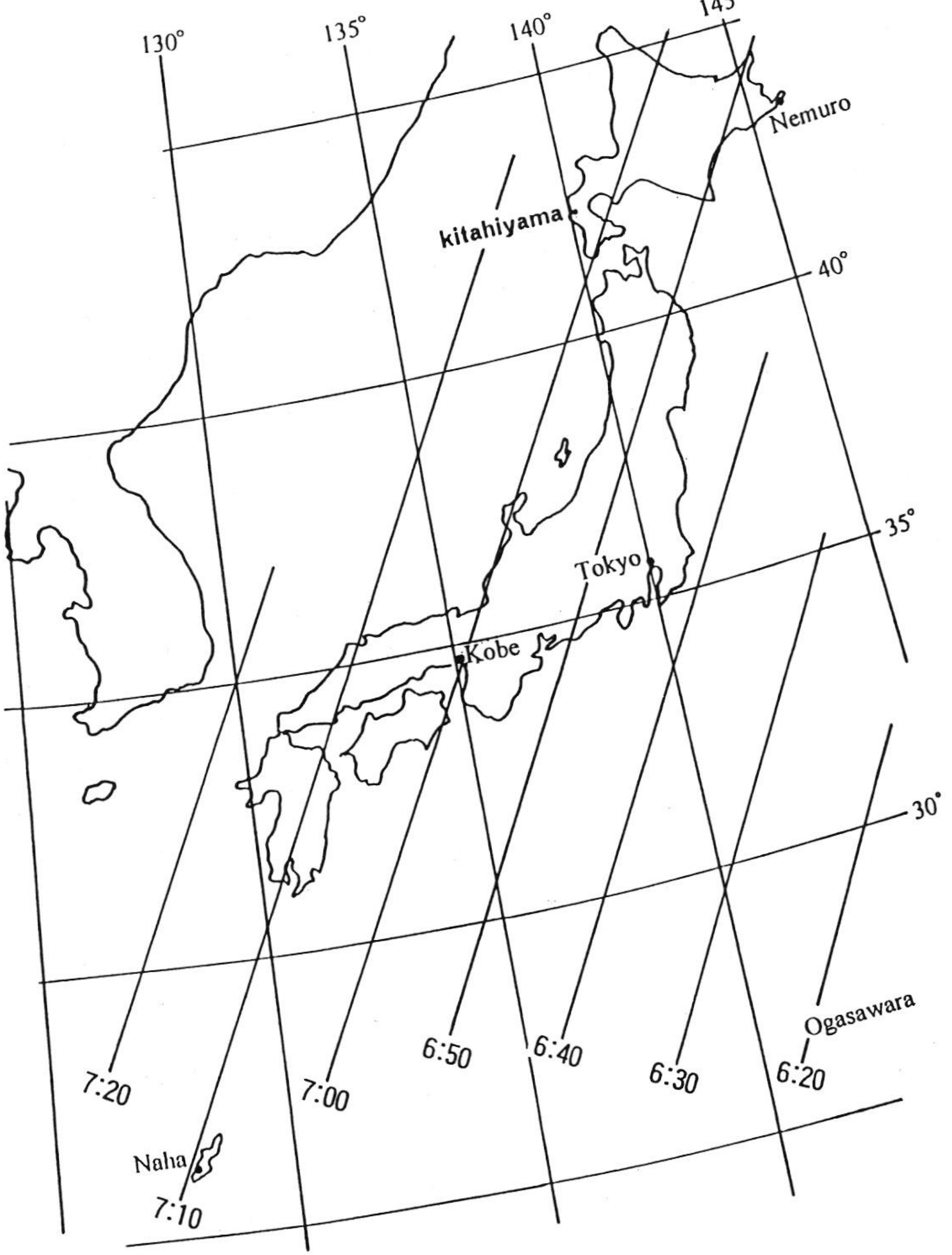

Fig.4 : Sun Rise Line (17. December. 1997)

Fig.5 : Sun Rise Line (22. March. 1997)

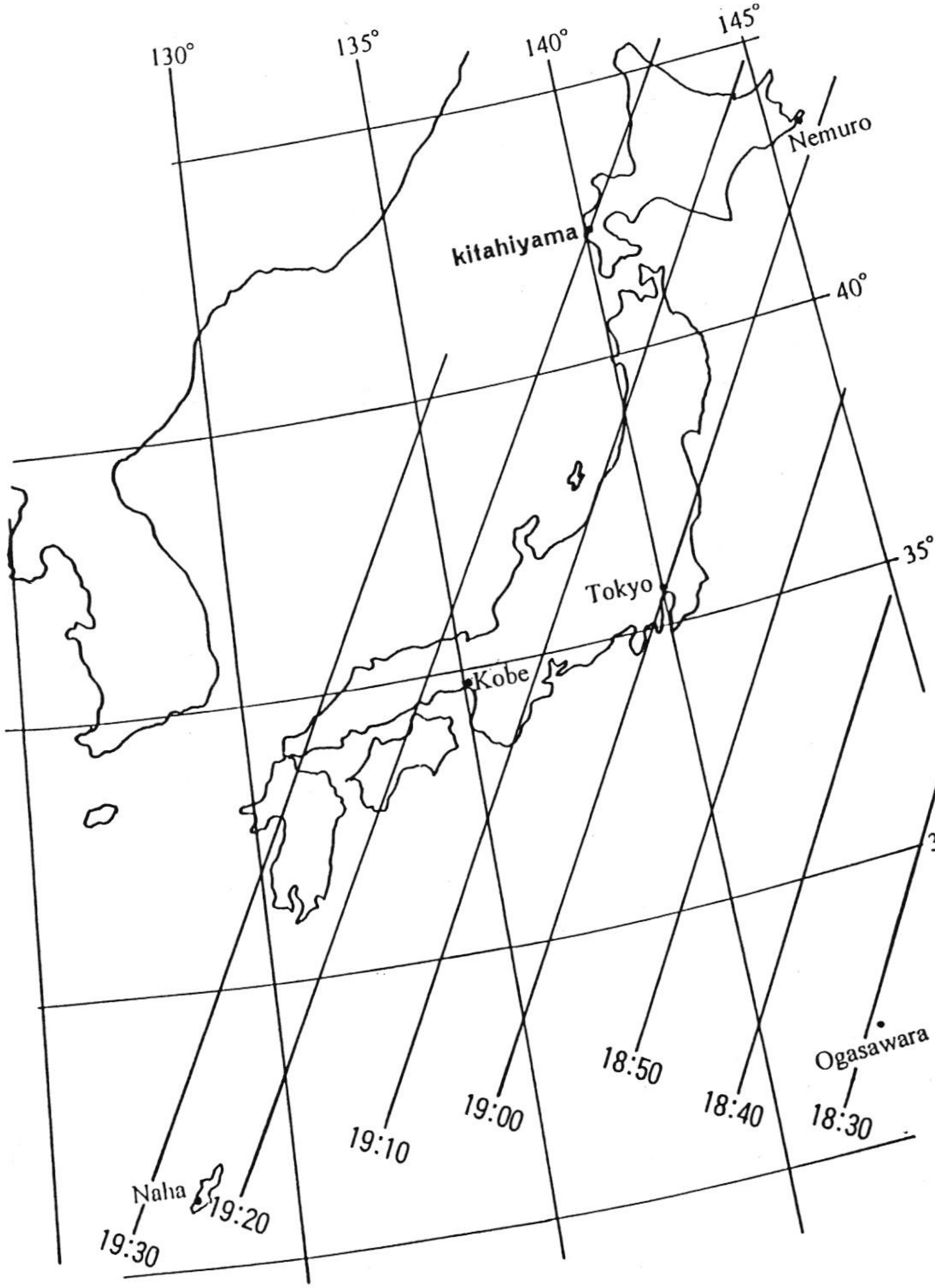

Fig.6 : Sun Set Line (20. June. 1997)

On New Year's Day, the sunrise begins in Ogasawara. The line on that day is almost the same as on the day of the winter solstice, and moves to north a bit. After the Sun Rise Line appears from SSW to NNE during January and February, it becomes closer to the south-north. It appears along the line of longitude on the vernal equinox day, and the sun rises in order from the east.

After April the line appears from SSE to NNW. And on the day of the summer solstice it becomes about southeast-northwest. Getting closer to south-north after July, it appears along the longitude on the autumnal equinox day again. It begins to move clockwise, and then, it is seen 30 degrees further east on the day of the winter solstice.

The Sun Set Line on 20th of June appears in the opposite direction of the Sun Rise Line on the same day (Fig.6). The Sun Rise Line on the day of the summer solstice resembles the Sun Set Line on the day of the winter solstice, and the Sun Set Line on the summer solstice resembles the Sun Rise Line in the winter solstice. Both Sun Rise and Sun Set lines on the vernal and autumnal equinox are seen along the longitude line.

5. "International Sun Rise Line"

a: What is the "International Sun Rise Line" ?

When the Sun rises in Hokkido, northeast Japan, the same Sun rises on the same time in *Primorskaya* (the Maritime Province of Siberia), New Zealand, and Alaska. Though the time the Sun rises in these countries is not always the same, we can draw the line linking the points of sunrise all over the world. The line linking the points of sunrise in Japan was named "Sun Rise Line"; therefore, this line linking the points of sunrise through many countries was named "International Sun Rise Line". For the same reason, The line of sunset was named "International Sun Set Line".

b: How to draw the "International Sun Rise Line"

Basically, we can draw International Sun Rise Line on the map as well as Japanese Sun Rise Line that I explained before. But we have to be regardful since there is the time difference among the countries all over the world. Thus, we need to add the information we need according to each local time, or use international standard time.

When we draw "International Sun Rise Line" in this way, We have to draw a line in every hour.

c: Usual changes of "International Sun Rise Line"

How will the figure look like when the Sun Rise Line and the Sun Set line expands worldwide? On the day of the summer solstice, the sun rises in Kitahiyama at around 4 o'clock, when it also rises in Khabarovsk and the Obi valley in the West Siberia, in the northwest, in addition to the Marshall islands and Fiji, in the southeast. According to their local time differences, it appears at 5:00 a.m. on the same day in Khabarovsk, and at 7:00 in Fiji.

On the other hand, the sun on the winter solstice day rises around 7:00 in Kitahiyama. At the same time, it appears in Petropavolovsk in Kamchatka peninsula and Fairbanks in Alaska in the northeast, and also in the Philippines and Indonesia in the southwest. At that time, it's local time is 11:00 a.m. on the same day in Petropavolovsk and 1:00 p.m. the day before in Fairbanks. It is difficult for us to understand that the sunrise can appear the day before, and even in the evening. We will see the sunrise vertically from the Sun Rise Line. Therefore, in Fairbanks, the sun rises in the SSE and sets in the SSW in a few hours.

On the vernal equinox day the sun comes up along the line of longitude (Fig. 9), and it is also the same on the autumnal equinox day.

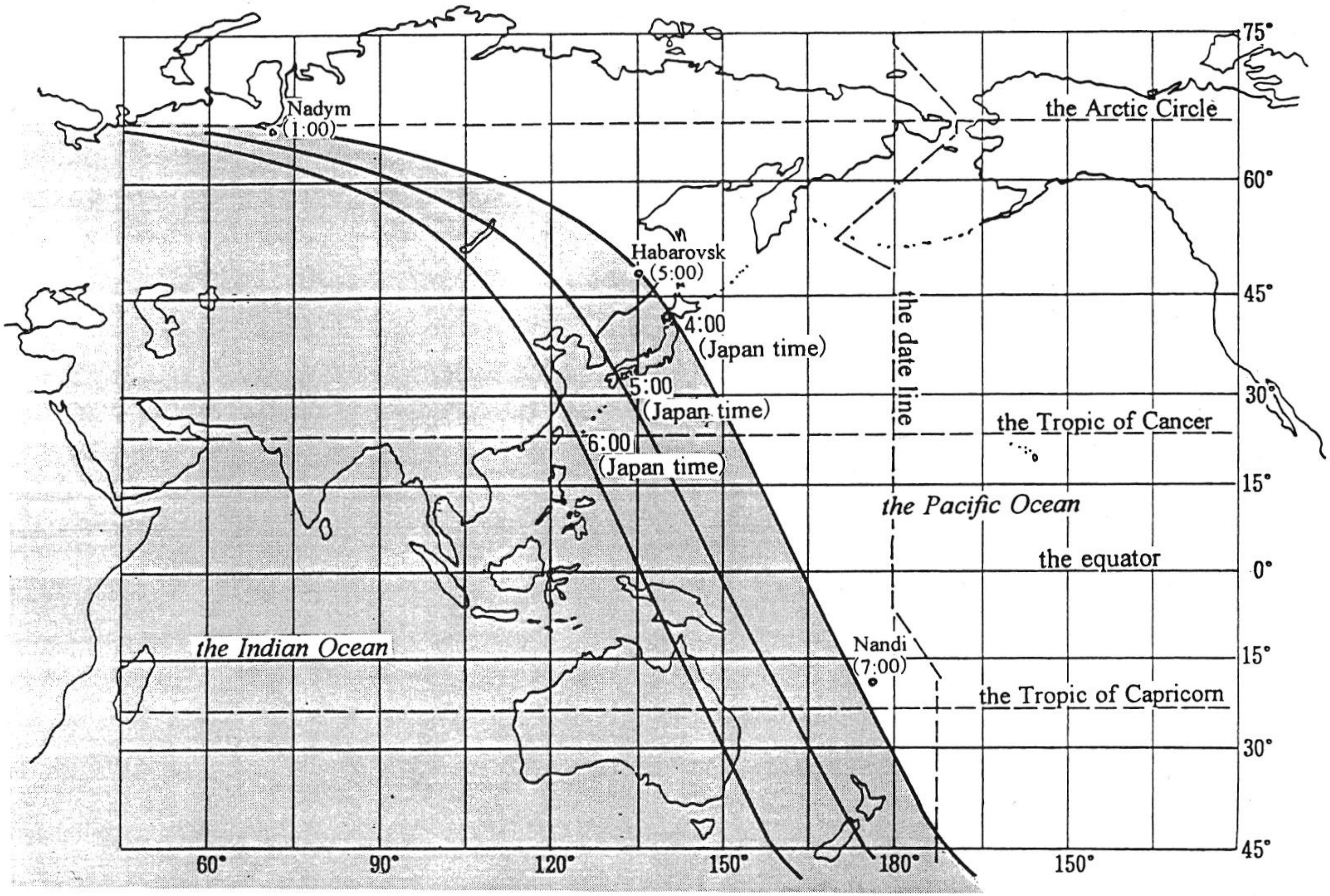

Fig.7 : International Sun Rise line (20. June. 1997)

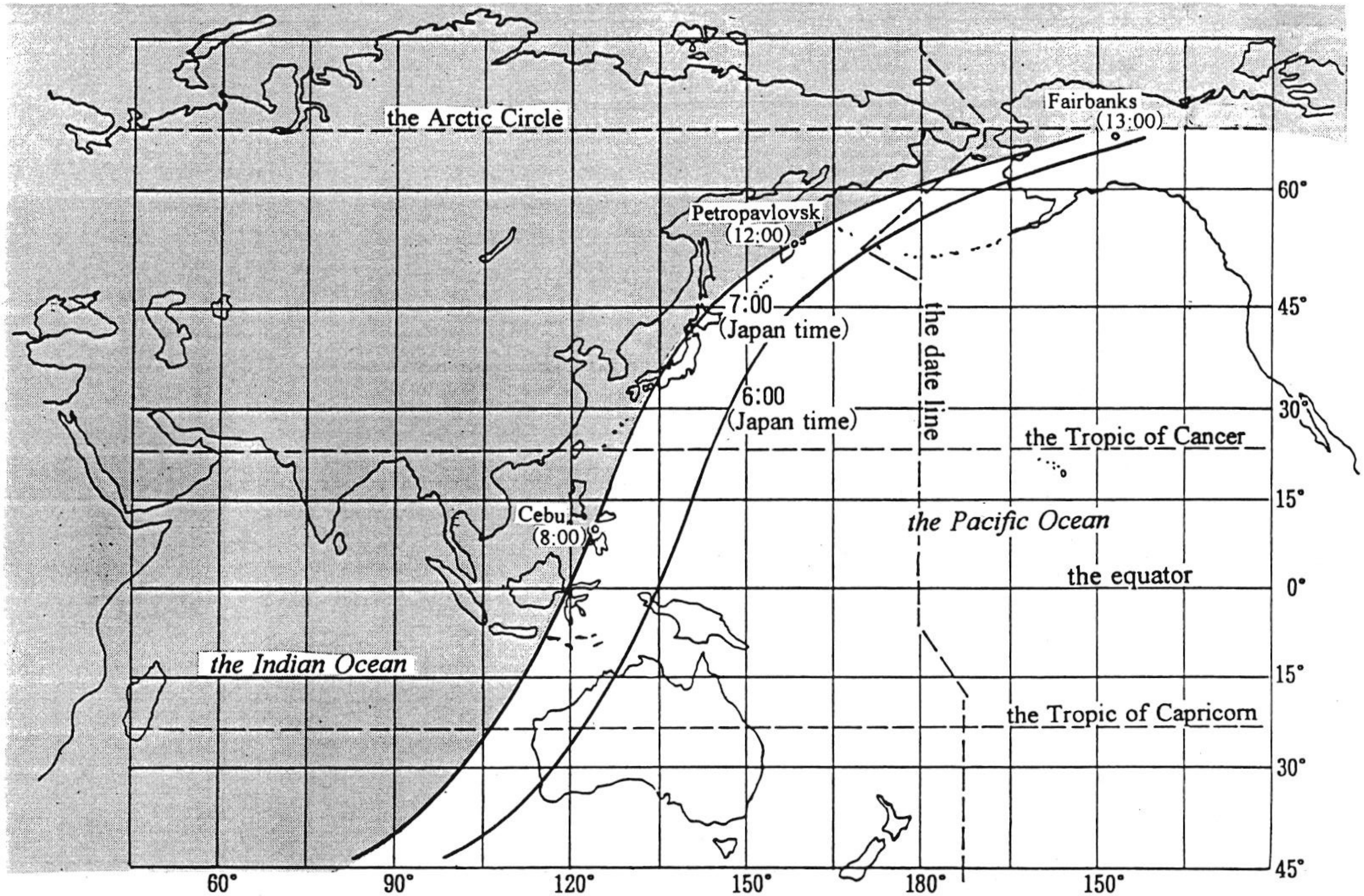

Fig.8 : International Sun Rise line (17. December. 1997)

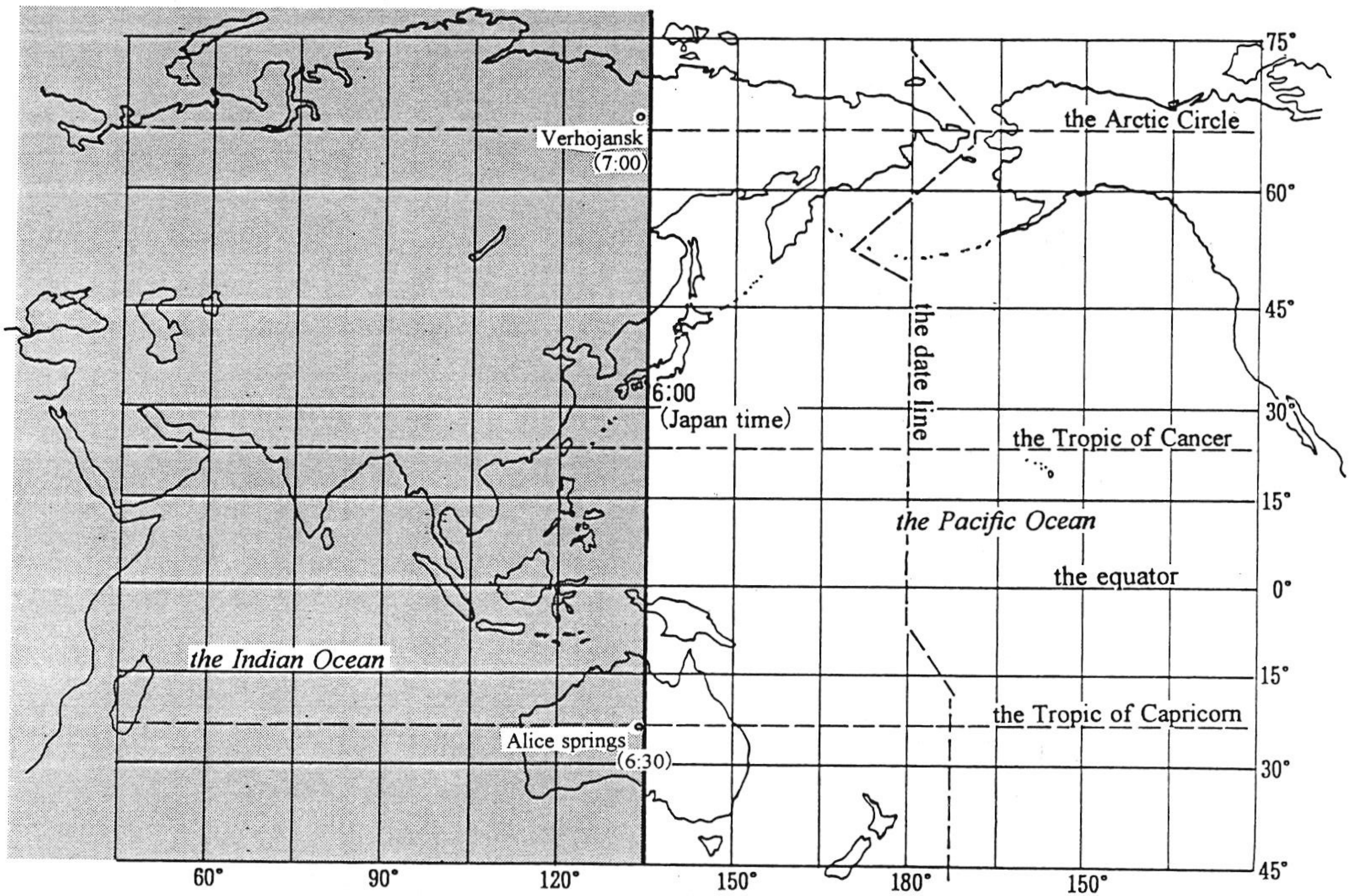

Fig.9 : International Sun Rise line (22. March. 1997)

6. The Sun in Arctic and Antarctic Circle
– as a conclusion –

The sun never sets on the day of summer solstice in the region which is further north from 66.5 degrees north latitude. Thus, in the Arctic Circle, both Sun Set Line and Sun Rise Line does not exist in this season, that is way we call this place the world of "the midnight Sun." On the other hand, the sun never rises in the Antarctic Circle, which has what we call "a polar night". Japanese believe that the sun rises in the east, but sun rises in the south in Alaska and rises in the north in Antarctic. The length in the day time changes extremely in a year, there is even a day when the sun doesn't appear at all, which we call a "Dark Period." A variety of nature all over the world can be seen more easily and reasonably by using the Sun Rise Line and the Sun Set Line which can be drawn very easily. We can draw the Lines more exactly if we use the data in the Korean peninsula, Australia, and Alaska. It also can be a good opportunity to understand our neighbors and the unknown world.

Acknowledgments

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