PROCEEDINGS OF

SRI LANKAN SKIES & SIR ARTHUR

A 2001 ODYSSEY:

"TEACHING THE UNIVERSE IN THE 21ST CENTURY"

An international planetarium and astronomy conference

hosted by the Sri Lanka Planetarium

Colombo, Sri Lanka

March 19-20, 2001
Proceedings of
SRI LANKAN SKIES & SIR ARTHUR:
A 2001 ODYSSEY:
“TEACHING THE UNIVERSE IN THE 21ST CENTURY”
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Text Preparation: Wade Kemp
Printing: Printing Services, Bowling Green State University

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Editor's Notes:

We thank the many authors whose cooperation made possible the preparation of these Proceedings. The keynote paper by Clarke is based on a transcript of the spoken paper edited by the author and editor to retain the conversational approach and spirit of the original presentation. The welcome session papers by Tissera, Gunawardana, and Wickremanayake are based on transcripts of the paper as read from text. All other papers are based on texts provided by the authors.

The ideas and opinions expressed by the authors are not necessarily those of the conference organizers, the International Planetarium Society, its officers or membership, or the editor.

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WELCOME ADDRESS

Mr. C. H. Tissera
Additional Secretary to the Minister of Science and Technology, Sri Lanka

Sir Arthur, Professor Arethanayaka, Prof. Tissa Vitharana, Prof. Dale Smith, Mr. Samaranayaka, distinguished delegates from the participating countries, special invitees, ladies and gentlemen. On behalf of the Ministry of Science and Technology, it is my privilege to extend a very warm welcome to every one of you to this inauguration ceremony of the International Planetarium and Astronomy Conference titled “Sri Lankan Skies and Sir Arthur: 2001: A Space Odyssey.”

It was indeed a privilege and a great source of inspiration for all of us to have had the consent of the Honorable Prime Minister to be the chief guest on this occasion. But just at this moment, a very important matter relating to the 2001 budget is being debated in Parliament, and the Honorable Prime Minister, as the head of the government group, has to be there. He regrets his inability to be present here, but he has sent his good wishes, and we will have the privilege and benefit of listening to his address delivered on his behalf.

Due to the same compelling reason the Honorable Minister of Science and Technology, Prof. Leslie Gunawardana, is also held up, and we hope that he will be able to make it somehow during the inauguration ceremony.

I know our Honorable Minister was very keen that this conference takes place and is successful. He took upon himself to take this matter to the Cabinet and get the concurrence of the government to hold this conference in Sri Lanka. I am sure he looks forward to the outcome of this conference and to our recommendations that might come up for the consideration of the government.

We are indeed very privileged that Sir Arthur is with us this afternoon as a special invitee. Sir Arthur, a distinguished guest resident of Sri Lanka, a visionary in space science, I am sure your presence here is really the icing on the cake. We are very glad that you consented to deliver the keynote address, and we are indeed looking forward to it.

I acknowledge the distinguished presence of Professor Dale Smith. I’m told that until a few weeks ago he was the President of the International Planetarium Society. He was very closely associated with us in the organization of this event, to make it a reality. Your presence at this inauguration and your participation at the conference is a great source of inspiration and encouragement for us, and we will no doubt be treated to a very informative address from you this afternoon.

We also have with us 33 visiting delegates from 11 countries participating in this conference. Your participation and your contribution during the technical sessions of this conference will enrich the proceedings both technically and intellectually. I wish to extend to all of you a very special welcome and I hope your visit to Sri Lanka and participating in this conference will be a great experience for you.

Conference organizers will have an unenviable task of limiting the local participation in this important conference, judging from responses we received. Given the circumstances, the conference organizers were constrained to invite only 25 of the eminent local scientists from the many others to grace this occasion. I welcome all of them and take this opportunity to place our deep regret that we were unable to make this list larger. Invited to this meeting also are about 100 representatives from relevant government sectors and private institutions. I thank them all for their presence this afternoon and extend them also a very warm welcome.

One of the objectives of the conference is to expose the Sri Lankan school children to an opportunity to meet eminent national and international astronomers of the present day. Invited to the inauguration therefore, though limited in number, are the staff and students from some selected schools. I welcome them all, and hope that this will give you an opportunity to meet your idols, shake their hands, and receive some useful information which otherwise would not have been possible for you.

Lastly, may I welcome to this inauguration session the staff of the Minister of Science and Technology and others who I was unable to mention by name due to time constraints and thank you for accepting our invitation and being present on this occasion.

Finally, on behalf of the Minister of Science and Technology, let me wish the conference all success and all the participants an enjoyable and a very fruitful experience. Thank you.
ADDRESS FROM IPS

Prof. Dale W. Smith
Past-president, International Planetarium Society
dsmith@newton.bgsu.edu

Mr. Secretary, Mr. Samaranayaka, Dr. Clarke, fellow planetarians, and skywatchers of the 21st century:

On behalf of the International Planetarium Society it is my great pleasure to welcome you to this special conference, Sri Lankan Skies and Sir Arthur: a 2001 odyssey.

We are gathered for what I believe is a historic occasion. We are meeting in the year 2001, at the dawn of a new millennium, in a resplendent land, in an island nation which in many ways mirrors our whole planet as an island afloat in a vast and wondrous universe.

In the century that just ended, we discovered just how vast and how old the Universe really is. We discovered that we share a common heritage in this cosmos: the atoms of our bodies were made in distant stars—we are starstuff. We put telescopes in orbit, we landed men on the Moon, and we sent spacecraft to all the major planets. In other words, we took the dreams of science fiction and made them real. Just before we went to the Moon, one of the century’s great visionaries looked ahead and gave us the year 2001 to live in our dreams and to inspire us as a spacefaring species.

And in the century that just ended, someone thought to bring the night inside: the planetarium was born. Today, more than 2000 of these domes populate our planet, about one for each star we can see in a dark night sky—a sky I hope we shall see this week in Habarane, in Kandy, and in Bandarawela, together with the teachers and school children of Sri Lanka.

It is appropriate that our meeting site is near the Equator, that one latitude from which we can see the entire sky, both north and south. For we know that this sky and its wealth of wonders is our common heritage, wherever we live, north or south, east or west. And we know that our planetariums are rooms in which we show and share and teach this universe.

We are gathered here, an international assembly of delegates hailing from eleven nations on five continents. We are women and men with a mission. We have taught the universe in the 20th century and we aim to teach it even better in the 21st. My friends, you represent the most creative and dedicated planetarium educators on this planet, and around us are the minds—both young and of any age—that we seek to teach and to touch. In this week together, we will share and explore ways to carry our mission, our odyssey, into the new century.

This is the first international planetarium conference in the new century, indeed of the new millennium. It is appropriate that this inaugural meeting is being held in Asia, the world’s most populous continent—and on the soil of a developing country that looks to the future with hope and promise—and in the adopted homeland of the man whose vision set our eyes on “2001” and whose brilliant gaze still peers forward.

I think that we shall see another vision this week as well, that of our host T. C. Samaranayaka, who I am privileged to call my colleague and friend. We shall see a glimpse of the work he has already done and his inspiring vision for the future.

The idea for this conference first reached my desk about three years ago in an email from “Sam.” Your assembled presence here is the first step now in bringing that dream to life. Not the last step, just the first. In the days ahead, we shall also discover a nation whose beauty lies in its landscape, its people, and its commitment to education. At the week’s end, we shall emerge enriched, inspired, and freshly ready to teach the universe to the world in the 21st century. Let’s have a great week—and future—together.
KEYNOTE ADDRESS

Sir Arthur C. Clarke, C.B.E.

Initial remarks

I am delighted to see so many people at this meeting. It does show a real interest in astronomy, and in particular in planetaria.

I think the planetarium is one of the most wonderful teaching and inspirational machines ever invented. Sadly it’s the only way that most people will ever see the skies, as smog, light pollution, and other disasters spread across the face of the planet. In fact, it would be interesting to do a survey to find out how many New Yorkers had ever seen the stars!

This is the golden age of astronomy in many ways. So much is happening now. I’m sometimes asked if I am sorry that the things we predicted in 2001 haven’t all happened. There’s no moon base. There’s no manned flights to Mars, Jupiter, or wherever. It’s hard to realize that when Stanley Kubrick and I started working on that movie in 1964, there were serious plans to put humans on Mars in the 1980s. That didn’t happen, but it will happen—one day. Maybe not for twenty years, but meanwhile I am by no means disappointed.

So much has happened that I never dreamed I would see in my lifetime: close-ups of all the major planets except Pluto; close-ups from the surface of Mars showing every pebble in that area around the Pathfinder. Incidentally, I was delighted to get the book Managing Martians from Dr. Donna Shirley who ran the Pathfinder program, thanking me for turning her on to Mars when she was a little girl. That makes me feel rather old, but at the same time, I am very flattered.

I’m leaving with you an interesting article that just came out today. It’s very much blurred in this part of the world. Whenever I’m asked for my views on astrology, I say, “I think it’s utter nonsense—but then, I’m a Sagittarius, and we’re very skeptical.”

Thank you.
Questions from Planetariums and Science Centers around the World
(Coordinated by Joanne Young, Audio Visual Imagineering)

(the questions appear in italics, followed by Sir Arthur's answer in plain text)

Will mankind ever colonize space?
(From a visitor to the Carl Zeiss Planetarium in Jena, Germany)

You can never predict the future. I'm always saying I don't attempt to predict it. I extrapolate, I map possible futures—many of which I hope won't happen. In fact, by mentioning them, I hope I can do something to stop the undesirable futures from happening. I'm always quoting my friend Ray Bradbury, "I don't try to describe the future, I try to prevent it!"

If our civilization does survive its infancy, and a glance at the morning papers does rather discourage one in that respect, we will certainly go on to set up scientific bases and I think ultimately self-sustaining colonies (although that's a politically incorrect word nowadays) on the major planets of this solar system and then build artificial structures in space. Those are just the beginning. I'm sure we will colonize space and then go on across the interstellar gulfs.

There's no reason I can set any limit to what we might do eventually. Although the universe is big, there is an awful lot of time. We may eventually explore this whole galaxy. It will take us a few million years to do it. By that time, we won't be recognizably human. In fact, there's a general feeling that after 2020, the computers will have taken over anyway. They are much better adapted for space than we are. So they may just take some of us along for the ride.

What do you think would be the strongest single reason for sending humans to other star systems?
(Ben Burress, Chabot Space & Science Center, Oakland, California, USA)

I can think of a number of humans I'd like to send to other star systems!

The urge to explore and discover is fundamental. If we hadn't had that from the beginning, we wouldn't be here now. We originated somewhere in the middle of Africa, or wherever it was, and if we had stayed there, we would have become extinct by now.

One of the best reasons for going into space is that we have too many eggs in one fragile basket called Earth. We've recently discovered that we live in a very dangerous neighborhood. This planet is continually bombarded by fragments of comets and asteroids. It has only just been realized that history has been changed many times by these cosmic impacts. In fact, if a rather large one hadn't hit the Earth 65 million years ago, we'd be a bunch of dinosaurs talking to each other—and they might have made a much better job of it too. This is going to happen again, so one of the reasons for going into space and finding out what is there is simply for our own protection. One of the last things Carl Sagan said was that any civilization that does not become a space-faring one dies.

As a young man you went to University to study physics, and had a strong interest in the British Interplanetary Society and the British Astronomical Association. Given your life over again, but starting in 2001, what would you, as a young man, be interested in studying, and what societies would you recommend to a student today?
(Martin Ratcliffe, Exploration Place, Wichita, Kansas, USA; President, IPS)

I was not a very young man when I went to university. I was in my mid-thirties, because I'd been to the Air Force and indeed the British Civil Service from which I "defected" to go into university.

You must follow what interests you. I was interested in space travel as a very young man. I read the first old pulp science fiction magazines, Astounding Stories, Wonder Stories. They triggered my imagination back in the 1930s and then I met my fellow crackpots in the British Interplanetary Society, going around telling everybody that one day, we would fly into space.

The newspapers all made fun of us. How can you go into space? How can a rocket take you there? There's nothing for the rocket to push against. Obviously a rocket can't work in a vacuum. That was the sort of criticism we used to have.

I remember another one: we discovered that the ionosphere (which we rely on to reflect our short waves around the world) is at a temperature of about a thousand degrees. So someone said that we are prisoners of fire, we can never escape from the Earth. They didn't realize the difference between heat and temperature. You would freeze to death rather rapidly in the ionosphere, even if the odd atom that hit you had a speed equivalent to a thousand degrees or so.

But I think we've won that battle in the long run.

With the coming of the space age in the 1960s and 1970s there was a great emphasis on science education. Science centers and planetariums were built in record numbers around the world and school systems spent record amounts
to improve science education. Yet in the year 2001, there appears to be less science literacy and more popular mythology than before our entering the space age. As a writer and futurist, can you tell us what you think science centers, planetariums, and school systems should do to reach that majority of Americans don’t believe in evolution and, in fact, appears to be less science literacy and more popular mythology than before our entering the space age. As a writer to improve science education.

Perhaps the first thing they should do is to pay teachers decent living wages. There’s no better investment than education. I hope people wake up to that.

I’m quite appalled by some of the things that are occasionally said by statesmen about scientific matters—global warming and lots of other things. Some of these issues are very complicated.

I’m appalled by the rise of superstition. I think the majority of Americans don’t believe in evolution and, in fact, the fight’s been going on. It’s absolutely incredible that people can be so stupid. This is a battle that we have to win and not give up on.

Has satellite communication been the revolution that you expected in educating the world and in particular the so-called “third world”?

Perhaps accidentally you touched on a subject of considerable interest to me. Nuclear fusion is always twenty years in the future. It’s been that way for the last thirty or forty years. I don’t think we’ll ever have it; I think we’ll find something much better. But, that’s a very controversial subject in which I have been personally involved.

I think we are on the verge of discovering totally new energy sources. Someone may be saying something weird like cold fusion, some may be tapping the energy of space. We now know that space is a sea of energy. In fact, the Nobel laureate Richard Feynman once said that the volume of space in a coffee cup contains enough energy to boil all the oceans of the world. If we can ever tap that, nuclear energy or anything else is just trivial in comparison. Although it’s a pretty terrifying thought, and this is not an original idea, I’ve often wondered how many supernovae are industrial accidents!

What is the greatest astronomical discovery in the 20th Century?

Oh! That’s a very good question. At the beginning of the twentieth century, we had no idea what the universe, the cosmos, was like. Or what anything was like. All of our ideas of astronomy have been revolutionized over and over again. In fact, most of the revolution has occurred in the last ten or twenty years as a result of the space age. So it’s really hard to pinpoint any one thing, but I would say perhaps learning the size and age of the universe. That’s a rather blanket description, but I can’t think of anything more important.

What year will we use fusion for energy?

Fiber optics also gets around one of the problems of the satellites in the geostationary orbit, the time lag of about a second and a half. This delay is rather annoying if you talk; you get mixed up because the echo comes back. With fiber optics you have no such delay problem, so the two complement each other perfectly—although I did say at one time that you could get around the geosynchronous satellite delay problem: Congress is very good at adding zeros to the budget, why don’t we add a couple of zeros to the velocity of light?

What is the greatest astronomical discovery in the 20th Century?

Minolta Planetarium Co., Osaka, Japan

The preceding text is based on an edited transcript.
ADDRESS BY GUEST OF HONOR

Hon. Prof. Leslie Gunawardana
Minister of Science and Technology

Read on his behalf by Prof. Tissa Wijarana
Advisor to the Minister of Science and Technology

Prefatory remarks

Sir Arthur Clarke, Professor Dale Smith, Professor Arethnayaka, Mr. Conrad Tissera, Mr. Samaranayaka, distinguished invitees from abroad, participants from Sri Lanka, distinguished invitees, ladies and gentlemen. I have been at many inauguration ceremonies but never one in which perhaps one of the most distinguished space visionaries has fielded questions, and I think we have created history here today. So I thank you very much, Sir Arthur, on behalf of the Minister for having enlivened the proceedings. I only hope no one asks me any questions!

The Honorable Minister was extremely keen on participating here today. Had it not been the critical day on which the vote on the budget is being taken, and the government has a very slender majority, he would have been present here. It gives me great pleasure to read his address on his behalf.

Minister’s Address

It is a great honor for me to be the guest of honor on the occasion of the International Planetarium and Astronomy Conference, which is being hosted by the Sri Lanka Planetarium, supported by the Ministry of Science and Technology.

We are all intrigued by and curious about the mystery and vastness of the universe. The selection of “Teaching the Universe in the 21st Century,” which is the theme of this conference, is most appropriate. As a teacher for over 40 children myself, I can appreciate the problems attached to conveying to the student and the public an understanding of a changing entity that involves the dimensions of both time and space.

The awareness of the extent and new discoveries regarding the constitution of the universe are rapidly increasing with the application of new technologies. Besides the use of larger, more powerful telescopes and infrared telescopes, the location of telescopes in orbit outside the Earth’s atmosphere, such as the Hubble Telescope, is making a great contribution to the new knowledge that is being continuously acquired. This requires a constant updating of the teaching material, but in addition, it is leading to changes in existing concepts, and also to the emergence of new concepts regarding the nature and origin of the universe. I am sure that through the present conference, the participants, as well as those entrusted in the field of astronomy, will be able to come abreast of this new knowledge and developments.

Before commenting any further on the conference itself, I would like to say something on the important teaching role of the Sri Lanka Planetarium, which is under the purview of my ministry. The Sri Lanka Planetarium, which came into existence in February 1965, has made headway in a noteworthy manner in the last decade. Thirty-year-old technology is now being replaced with modern technology. The quality of presentations at the planetarium has improved tremendously with the donations of audio-visual equipment by the government of Japan under the Cultural Grant-in-aid Program in 1996. One of the most useful items of equipment received under this program was the inflatable, mobile planetarium. The children and adults in the rural areas can now experience the wonders of the universe without coming all the way to Colombo. In addition to these facilities of the planetarium there are various astronomy projects which are conducted for the popularization of astronomy. Seminars and workshops are conducted for science and social science teachers from distant districts, and these teachers obtain knowledge of astronomy and space science. Activities of the planetarium for the popularization of astronomy and space science are boosted further with night sky observation camps, workshops, exhibitions, and seminars. The study of the planetary system is an important component of the syllabus for grades six, seven, and eight. It receives the attention of even the students in the primary classes. About twenty percent of the syllabus of science and social science is allocated to the study of astronomy. Visits to the planetarium are a noteworthy part of the school curriculum. The time taken by a teacher to cover the syllabus in astronomy is about twenty to twenty-five days of the school year. The planetarium and its shows are of vital importance from a purely educational point of view. This has been complemented by the facilities offered by the telescope located at the Arthur C. Clarke Institute of Modern Technology at Moratuwa.

With the recent inauguration of the Planet Internet the Sri Lanka Planetarium enters another year. Installation of these computers at the Internet Center was made possible through a generous donation from the National Development Bank. With this new facility, thousands of children from all parts of the country will be able to access the internet and
experience the wonders of the internet and see the latest discoveries in astronomy free of charge. In the last decade the Planetarium has made steady progress and I am happy to say that it is now one of the most popular destinations for educational tours in this country.

The conference objectives include the formulation and innovation of new and modern methods and approaches to education in astronomy, especially for the developing countries, and also to identify ways of furthering cooperation in this field among developing countries. It also includes the promotion of interest among the public, especially in the East where the traditional interest in astrology, which has been referred to already by Sir Arthur Clarke, has promoted an interest in astronomy, and this should be taken into account in trying to reach the public.

I am particularly happy to note the link between this conference and the name of Sir Arthur C. Clarke, who is a distinguished citizen of Sri Lanka. As a science fiction writer, he has stirred the imagination of the people, both young and old, about the mysteries and the wonders of the universe, the stars, and the planets. More significantly, he has played a crucial role as a visionary, one might say a prophet, who has anticipated many developments in space travel and establishment of satellites and other human interventions. His celebrated book *2001: A Space Odyssey* was made into a highly successful and popular film of epic proportions by Stanley Kubrick, for which he also shared an Oscar nomination. It is indeed opportune that he is here in person to star at this international planetarium conference in the year 2001.

As a historian, I am glad that organizers have decided to have night sky observations at locations close to archeological sites which bear testimony to Sri Lanka’s historical glory and heritage. Sir Arthur C. Clarke himself had been conscious of our heritage, and in his book *Fountains of Paradise* he makes reference to both Adam’s Peak, or as we call it, Sri Pada, and Sigiriya. With reference to the Sigiriya frescoes, Sir Arthur Clarke mentioned that “the attendant is clearly listening to the mysterious hinged box she’s holding in her right hand. It remains unidentified, the local archeologists refusing to take seriously my suggestion that it is an early Sinhalese transistor radio.” As often, Sir Arthur is noteworthy in giving expression to his impish sense of humor. In this book the point of take-off for space travel was Adam’s Peak, Sri Pada, a historic site in our country.

The contribution of all these fortuitous factors I’m sure will help to make a success of this important conference. I hope that the discussions will be fruitful and that the people of the world and of Sri Lanka and other developing countries will benefit from your deliberations. I want to make use of this opportunity to thank the organizers, especially Mr. Samaranayaka, for their efforts and last but not least, Sir Arthur C. Clarke for his distinguished patronage. I wish you all success and those from abroad a pleasant stay in Sri Lanka.

Thank you.
ADDRESS BY CHIEF GUEST

Hon. Ratnasiri Wickremesinghe
Prime Minister of Sri Lanka

Read on his behalf by Prof. N. R. Arethanayaka,
Secretary to the Minister of Science and Technology

Prefatory remarks

Sir Arthur C. Clarke, Chancellor of the University of Moratuwa, the only technological university in Sri Lanka, from its very inception in 1980. Professor Dale Smith, immediate past-president of the International Planetarium Society, we are very glad to have you here with us. Professor Tissa Vitharana, advisor to the Minister of Science and Technology, my colleague Conrad Tissera, additional secretary to the Ministry of Science and Technology, Mr. T. Samaranayaka, director of the Sri Lanka Planetarium.

We have been having an enjoyable afternoon, particularly listening to Sir Arthur C. Clarke. As was said by Arund, I have received a brief note from the honourable Prime Minister. Let me read his message.

Prime Minister’s Address

Sir Arthur C. Clarke, Professor Dale Smith, Mr. Arethanayaka, Mr. Samaranayaka, distinguished delegates from overseas, other invitees, ladies and gentlemen. I am happy to have been invited for the International Planetarium and Astronomy Conference, organized by the Sri Lanka Planetarium. Astronomy is a subject that has touched the lives of millions the world over, although it has evoked an interest of significance here only after the opening of the Sri Lanka Planetarium in the year 1965. The subject has induced the people of Sri Lanka still more with a scientific vision exhibited by Sir Arthur, who is a distinguished citizen of Sri Lanka. His highly imaginative writing and his creativity and incomparable imagination have been marveled by the people world over. Hence, it is quite apt that the conference has been titled “Sri Lankan Skies and Sir Arthur: a 2001 Odyssey.” The concept of the conference being to meet demands of the enthusiasm of the new generation, the need has now arisen for the development and expansion of the existing infrastructure and the propagation of the science, all the more because astronomy is now a subject of the school curriculum in Sri Lanka. In this context, this conference has been conceptualized and organized at a time quite right for the realization of a noble purpose.

The intention of the conference is far reaching. Among other things, it is to evaluate the accomplishments made so far on the subject of astronomy and formulate what are methods and approaches to its propagation. To understand the conditions the development of astronomy education in developing countries, create an environment for the astronomy educators from the world over to work in tandem with teachers and students of Sri Lanka and to explore what practical ways and means are available to promote the objectives of furthering astronomical education in developing countries—all notable aspirations. I wish this conference all success.
VOTE OF THANKS

Mr. T. C. Samaranayaka
Director, Sri Lanka Planetarium

Today is a day of much significance to Sri Lanka and those associated with the progress of Astronomy Education in the country as we are holding a planetarium conference of international recognition here in Sri Lanka for the first time, and we take pride in naming it the “Sri Lankan Skies and Sir Arthur: 2001: A Space Odyssey” in recognition of the distinguished space prophet, Sir Arthur C. Clarke, who is present here as a distinguished invitee and illuminated the conference with an absorbing and enlightening speech on Astronomy.

Today what you so far witnessed here was the inaugural meeting of the International Planetarium Conference. In the Conference proper to be followed hereafter, tomorrow at a different venue, namely the Sri Lanka Planetarium, you will participate in paper sessions and panel discussions. The following day, we will proceed to the dry zone areas of Habarana, then to the hill capital of Kandy, and to the cooler region of Bandarawela for Night sky observations.

This conference, I should say, is a dream come true for me, the fruition of something that was in the inner recesses of my mind, for since my assumption of duties at the Sri Lanka Planetarium, it was my earnest wish that the Planetarium Education in general and Astronomical knowledge in particular should be made a subject of fascination and interest to every one in the Country. On the premise that the Science of Astronomy is as old as mankind and its vistas being developed with tremendous explosion in Science and Technology, it should no longer be confined to a restricted group, but should be made available and accessible both to the rural and urban population of the country.

The benefit of the association of foreign countries with advanced knowledge of Astronomy was felt useful at this stage and with this in view Sri Lanka Planetarium obtained the membership of the International Planetarium Society based in the USA for Sri Lanka. With the auspices of this body I was able to attend more than one Astronomy conference abroad and the outcome was an idea blossoming in me to have an International Planetarium Conference in Sri Lanka as well. In pursuance of this I was able to persuade the President of the International Planetarium Society, Professor Dale Smith, who is present with us today to visit Sri Lanka for a feasible study as a preliminary to holding such a conference.

Although he had reservation at the outset because of prevailing ethnic disturbances in the Country, he did visit us in February 2000 for a first hand study and the Conference became a reality on his unrelenting commitment to put it through and for that act, this country’s thanks are due to him.

My special thanks are due to the Hon. Rathnasiri Wickramanayake, the Prime Minister of Sri Lanka, in spite of his tight schedule of work for finding time to be with us and treating us to an invigorating address.

My thanks are also due to the Hon. Minister of Science and Technology, Professor Leslie Gunawardana, for being present here and addressing the assembly.

To Sir Arthur C. Clarke we owe a special debt of gratitude for his presence and the illuminating and enlightening address he made, particularly in evaluating the concepts of his celebrated masterpiece “2001: A Space Odyssey” which I am sure was to the delight and edification of all present.

Let me on behalf of the Ministry of Science and Technology and the Sri Lanka Planetarium thank all the delegates representing the foreign countries who are here responding magnificently to our invitation to the Conference and being present in number.

Let me also thank the Secretary of the Ministry of Science and Technology Professor N. R Arethanayaka and the other officers who helped me to make this event a success.

I should thank the staff of the Planetarium for the assistance given to me to make this event a success.

My thanks are due to the members of all the Astronomical associations for the valuable contribution they made to organize this conference.

I must also thank the convention organizer ‘Ace Travels’ and Ceylon Cold Stores for helping us to make our dream come true.

Finally let me iterate that Sri Lanka Planetarium’s aims are high and forward-planning. Convinced that holding of conferences of this nature are a sine qua non for such achievement, it shall strive to organize more and more of them in the future where we shall meet again and again for the common purpose of furthering astronomy education the world over.

We are citizens of the world.
WELCOME TO PLANETARIUM

T. C. Samaranayaka
Director, Sri Lanka Planetarium
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It is with great pleasure that I welcome the delegates, members of the Astronomical Associations, the teachers and students here at the Sri Lanka Planetarium this second day of the International Conference. Those assembled here are now awaiting an enthralling show of planetarium presentations from the delegates, which I believe will be of absorbing interest to everyone present here.

Astronomy is a subject that has touched the lives of millions world over, although it has evoked an interest of significance here only after the opening of the Sri Lanka Planetarium in the year 1965. I have been in office as the Director of Sri Lanka Planetarium nearly 10 years and during this period I did my best to further the planetarium and astronomy education in this country.

Today I am going to make a special announcement and it will be news to many, especially to my foreign delegates. I am going to announce my retirement from Government service and relinquish my duties as the Director of the Sri Lanka Planetarium at the end of this International conference. I am very happy to see my retirement coincide with the International Conference.

Mind you!—this is only retiring from government service, but I will be there with the members of the Astronomical Associations, with my dear teachers, with my dear children, and with the members of all International Planetarium Societies to keep up the good work that I have been doing for the rest my life. I will be with all of you to promote, popularize, and propagate astronomy and promote the concept “we are the citizens of the world” world over. Please join hands with me.

As I am doing a later presentation regarding the activities of the Planetarium I do not wish to talk much here. I am sure that Mrs. April Whitt who is going to do the next presentation will keep you on your toes for the next half an hour or so. I thank all of you, especially the foreign delegates, members of the astronomical associations, teachers, my dear children for being here this morning. I must say that Sri Lanka Planetarium is honoured by your presence here today.
ACTIVITIES OF THE SRI LANKA PLANETARIUM

T. C. Samaranayaka
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I welcome the delegates here at the Sri Lanka Planetarium on this second day of the International Conference. Those assembled here are now awaiting an enthralling show of planetarium presentations from the delegates, which I believe, would be of absorbing interest to everyone present here.

The Sri Lanka Planetarium saw its beginning in the year 1965. The principal mechanism in the planetarium presentations is the universal projector, which you see installed at the center of the hall. This projector has now been in use for 31 years, and is still in peak performance. We are thankful to the care and skill of the technicians who handle it.

The services that the universal projector could be put to are limited and it did not take us much time to realize that improving the technology of the planetarium should be given top priority if it is to render a worthwhile service to the astronomy-loving young and old. The funds being scarce, efforts were made to canvas the Japanese government for help and I’m happy to say that our efforts bore fruit and we received the value of US$ 45,000 from the Japanese government for the use of the planetarium, supporting projectors, video projectors, a video camera, mobile planetarium, and the replacing of the entire sound system. With this supporting equipment we were able thereafter to improve vastly on the presentations of the Planetarium.

With the improvement effected, a sudden surge of enhanced interest in astronomy education was observed among the children and that enthused one to advise them on the desirability of forming themselves into an Interschool Astronomical Association. This was made a reality with these children forming what is described as Interschool Astronomical associations encompassing students from the majority of all the schools in the country and affiliated to the Sri Lanka Planetarium.

In continuity, the Interschool Astronomical Association membership on leaving their respective schools were made to form an association styled Amateur Astronomical Association. This was made a reality with these amateur astronomers comprising talented young boys and girls who would one day become acclaimed astronomers of the country.

With the introduction of astronomy in the school curriculum, the teachers were left puzzled as to how they could impact the children on this science in the absence of audiovisuals. One day they almost stormed the planetarium seeking my assistance. The doors of the planetarium were open and the teachers accessed the visuals, to their great relief and satisfaction.

In subsequent seminars held for the benefit of the teachers, the teachers themselves having exhibited the keenness to pursue their knowledge on this science, they were advised to form an association and thus saw the birth of the Teachers Astronomical Association where the present membership is well over 2000.

Other than planetarium presentations, the Sri Lanka Planetarium conducts a variety of activities for the benefit of these associations. We conduct night sky observation camps till the wee hours of the morning on any day of the week. These night sky observations are generally received with much enthusiasm and the viewers sometime exceed 500 at observation sites. This benefit is extended even to the schools situated in the remotest parts of the country. Seminars are usually conducted at the Planetarium as well as outstations.

Workshops are conducted exclusively at the Planetarium. Here the teachers and children are taught the fundamentals in making telescopes and visual aids. The planetarium telescope, which was once literally gathering dust, is now made accessible to every enthusiast. To inspire the creativity of the children the planetarium organized exhibitions where the children were given a free run to demonstrate their creative power in the creation of astronomy models. The first exhibition called ASTRO 2000 was held last year. The second called ASTRO 2001 was held in February 2001. It was encouraging to see the best models coming from children of remote schools. Today the prize winners at the ASTRO 2001 exhibition will receive their prizes and certificates during the lunch hour from the foreign delegates who are present here.

Not overlooking the youngest generation we formed a society for their membership called tiny stars, where these tiny tots between the ages of 3 and 5 belonging to all ethnic groups are taught the elements in astronomy in all three languages. Through this event we believe that we could promote ethnic harmony in Sri Lanka.

With the present urge from the astronomy education in the country and the wide program of activities of the planetarium it is apparent that a firm foundation has been made for the younger generation to be inspired and the subject popularized.

We believe that astronomy education would discipline a man in his temperament and behavior. A wide knowledge of the universe would certainly change a man’s pattern of thinking, leading him to realize the impermanence of life. Its transience brings about a change to be a useful citizen of a country free from the cravings of destruction.
Developed countries enjoy the luxury of astronomy education as a normal part of their educational curriculum due in large part to the availability of local planetariums.

Sri Lanka as a developing country is less fortunate. Although we have had a planetarium since 1965, we are filled to capacity and unable to satisfy the demand for astronomy education. Last year nearly 250,000 children, teachers and public visited the Planetarium. Large numbers had to turn away due to limited accommodation. In one occasion when I invited 500 teachers from a certain district to come for a seminar more than a thousand teachers attended. I could not drive them away. Most of them sat on the ground as seats were not available and continued to stay there for six hours.

Because of the lack of planetarium equipment there are scores of countries in the under developed world who are unable to teach the basics of astronomy. It is therefore critical that we develop the necessary infrastructures and resources to provide astronomy education for all nations.

To fill the void we must call upon the manufacturers of planetarium equipment in the advanced countries to partially fund the cost of the planetarium equipment in developing countries. As the demand for planetariums increases throughout the world, the financial benefits to the manufacturers of planetarium equipment will continue and thus all of us will benefit in the long run.

The teacher of astronomy has become literally the agent for the planetarium manufacturers. It is therefore time that manufacturers contribute their fair share towards the advancement of astronomy education in developing countries.

It is my belief that as our children study astronomy, they will begin to understand their place in the Universe. As a result of studying astronomy, they will appreciate the precious gift of humankind. Perhaps they will begin to see humanity as the family we are, and peace on our planet will become a byproduct of that understanding.

I propose that we form a pilot project in Sri Lanka with representatives from developed countries and other volunteers to propagate this noble gesture of expansion of astronomy education in developing countries. These projects are to be known as “Sir Arthur C. Clark Projects” in tribute to the space visionary, Sir Arthur.

Let us now have your comments on this subject.
Abstract: In teaching the universe in the 21st century, the current knowledge about the Solar System bodies is of greatest practical importance not only to the students of astronomy but also to the common people, who comprise the main audience of popularization programmes. In lunar and planetary geology, the circular craters, calderas and vast basins are some of the most fundamental topographical structures not only on the Moon but also on all terrestrial type planets and satellites, whose surfaces have been revealed by spacecraft cameras. Both high resolution visual studies and space mission results have led to discoveries of irrefutable evidences of endogenous volcanism on the Moon and in other bodies. Successively placed stratigraphical surface deposits show clear evidences of repeatedly extruded and ejected numerous craters. The overlying bright ray deposits on the lunar surface have been found to be of gas blown systems of fumarolic emissions of mineral condensates during the final phase of volcanism. Physical and chemical examinations of the lunar rocks and soil also point to internal origin, although a very small percentage of the material has been found to be of meteoritic origin.

The Moon is our nearest neighbour in space and it has been observed for hundreds of years. The craters and the vast basins on the lunar surface have been studied both telescopically as well as through spacecraft cameras. Both unmanned and manned explorations of the lunar surface and the physical and chemical examination of the lunar soil and rocks have given us a wealth of knowledge about the possible evolution of the topographic features, but still the process by which these craters and basins had formed, has been the subject of controversy. The same controversy has extended to the surface topographies of terrestrial type planets and satellites.

The two most important processes of crater formation that are debated are (1) exogenous impacts by space bodies, such as meteoroids, asteroids, and cometary debris, and (2) endogenous volcanism. The controversy continues mainly due to a number of misunderstandings and misinterpretations of the lunar and planetary geology and geophysics. But what are the evidences that lead to clearly defining the process involved and whether these have been understood?

The common impression an observer gets while looking at the Moon either through a telescope or in photographs is that the lunar surface is full of circular pits, large and small, made by some externally fallen objects on a soft plastic surface. This common impression is quite understandable because the observer is generally familiar with pits of such causes and forms in his terrestrial environment, and he is rarely aware of the endogenously caused geological and volcanological processes that build up structures of this nature. This impression also appeals to him as the craters look very small and flat with no direct understanding either on the enormity of the scale of their sizes or of the real spherically curved nature of the surface and also the craters and basins themselves.

Although the Moon is now a dead barren rocky globe without any atmosphere, it was indeed geophysically and geochemically active millions or billions of years ago, when the crust was forming and solidifying from a molten state. The heat flow experiment conducted on the lunar surface by astronauts and the extrapolation of the results showed that there is still a very hot core deep inside the Moon.

Volcanism

In considering past volcanism on the Moon and planets, it is not correct to compare the present-day volcanoes on Earth, which are actually the tiny remnants of the final dying phase of hot-core activity causing small eruptions and gas emissions from the molten interior, which has receded far down below the crust by gradual cooling during geological time. The great upheavals, the large circular subsidence structures and their boiling and bubbling floors, extrusions and ejections, extensive basaltic flows, and the towering
infernos of the Earth’s geological past are not known. They are only to be inferred from the strata of rock records and from the extinct and eroded calderas and craters in tectonic and volcanic regions. In this respect the surfaces of the Moon, planets and satellites help understanding each other and also the past history of the Earth itself as a part of comparative planetary geology.

With a view to understanding clearly the origin of the craters and their forms on the Moon, it is very important to study on-the-surface morphological evidences. There are numerous irrefutable evidences of widespread volcanism of all phases, such as effusive and explosive volcanism, glowing gas fountaining, etc., globally on the Moon.

**Lunar rays**

If the Moon is observed near or during full moon through any telescope, an observer can see bright ray-like deposits lying on the surface radiating in all directions from some of the prominent craters, such as Tycho, Copernicus, Kepler and many others, large and small. These ray-like surface deposits, which are known as lunar-rays, extend to considerable distances of several hundred km and even more than a thousand km over the surface. Impact theorists have explained that these are all ballistically thrown impact splashes of the excavated material (Shoemaker 2). This is a misunderstanding based on incorrect observational analyses. It has been found beyond doubt that they are all fumarolic (volcanic vents) emissions blown by gases.

After critical studies and mapping of the distribution of these ray deposits the speaker discovered that the rays are gas-blown deposits of mineral condensates released by hundreds of thousands of fumaroles, which liberated gases and mineral fumes (volatile). During the final dying phase of volcanism when the Moon had almost lost its atmosphere due to low gravity outgassing and releasing of fumes containing mineral vapours and condensates from the hot interior was a major process in the near-vacuum environment. This is known as incandescent gas fountaining in volcanology, as it also occurs on Earth. The lunar surface is full of these fumarolic vents, which have deposited their emissions around the vents exhibiting themselves as bright spots or haloes or blown in some directions as short ray elements. During this period of activity, some of the vents in larger caldera and crater centres have released enormous quantities of gases and volatiles, which had blown with force like storms in all directions along the surface, depositing not only their own condensates of minerals but also carried and deposited the materials of the surrounding vents, which were active and emitting then. As the vents were closely placed, their emissions made a sort of continuous ray-like deposit on the surface lying radially from the central larger crater source. The long rays are clearly found to be augmentation of small strips of ray deposits originating from thousands of individual vents at various distances giving more or less continuous streaky appearances on the surface. These evidences of final phase volcanism are irrefutable and have been confirmed by the findings of the renowned selenologist, Dr. Patrick Moore, and the writer’s investigations have been published in the Journal of the British Astronomical Association in 1962 (Devadas 3, Moore 4). Much later in 1965, after the arrival of the close-up photographs taken by the Lunar Ranger spacecraft, Gerard P. Kuiper of the Lunar & Planetary Laboratory, University of Arizona, had expressed identical findings on the nature of the lunar rays (5). Exactly similar fumaroles and their radially blown deposits have subsequently been found by the speaker on the surface of Mercury and on some of the satellites of Jupiter. Unfortunately this morphology has not been understood by the impact theorists.

Since the Earth has an oxygen-rich atmosphere, fumarolic emissions here are deposited in the form of burnt ashes, oxides and powders, but in an oxygen-free, near vacuum environment on the Moon, the emissions had settled down as fresh mineral condensates in crystalline form. The samples of lunar soil showed that they are in the form of fast cooled glassy spherules, teardrops and airborne powdery forms and fragments of fresh minerals ejected and blown by gas jets from the interior (Cadogen 6). Whittaker (7) also confirmed that from many lines of evidence the regolith is of volcanic origin. According to French (8), all specimens of lunar material brought by Apollo missions are igneusly formed by the cooling of molten lava.

If the craters had been formed by the impact of meteorites, considerable quantities of meteorite fragments should be lying on the lunar surface, whereas no such fragments has been found in the samples collected by the astronauts (9). Mineralogical and chemical examination of the samples showed less than one percent of meteoritic materials. Therefore the paucity of meteorite materials further disproves the impact process on a global scale as believed by impactors.

**Craters’ volcanic stratigraphical deposits**

As the lunar surface exhibits full of these fumaroles and vents situated on craters, their walls, floors, plains and all over the surface, they strengthened the speaker’s understandings that the craters in general are of volcanic origin and that further evidences of their past long-drawn activities must be observable on the surface. Therefore, the speaker undertook systematic critical studies of the surface particularly in and around craters, through powerful telescopes during very favourable angles of illumination in order to resolve the minute surface details, and also carried out comparative studies of the space mission results. These studies have revealed most remarkable and irrefutable evidences of past repeated igneous and volcanic activities in and around craters in numerous cases. There appear several layers of different textures of thin, low viscosity molten
eruptivity and depositions. Craters such as Copernicus, Tycho, Aristarchus, Kepler, Timmocharis, Lambert and numerous others have vast but thin sheets of magnetic flows mantling the surrounding regions and also submerging some of the earlier craters in many cases. Over and above these strata lie the subsequently formed hummocky, two or more ring-like or braided piles of ejected materials around the rims of craters forming the outer flanks (ramparts), which are fairly uniform in width and height in numerous cases, and the steppy down-slides inside wall slopes. Within the interstices of these inner slides there are numerous vents and their emissions. And again over these deposits lie the radially drawn ropy lava flows in ridge and through pattern extending to more than the crater diameters. These are observable during low and medium angles of illumination. Over and above all these extruded and ejected strata of deposits like the final phase of fumarolic emissions blown by gases forming the ray deposits as already explained. All these deposits of different textures during successive periods confirm beyond doubt the craters' endogenous long-drawn activities. No impact excavation can duplicate these repeated placements. Among these formations not even one impact excavated crater with its characteristic spattered or splashed morphology or ballistically thrown debris or molten clods has been observed. If large meteorites had fallen on the surface after the ray formation, the long ray deposits or the ray elements should form not even one impact excavated crater with its fumarolic emissions blown by gases forming the ray deposits as already explained. All these deposits of different textures during successive periods confirm beyond doubt the craters' endogenous long-drawn activities. No impact excavation can duplicate these repeated placements. Among these formations not even one impact excavated crater with its characteristic spattered or splashed morphology or ballistically thrown debris or molten clods has been observed. If large meteorites had fallen on the surface after the ray formation, the long ray deposits or the ray elements should have been obliterated extensively or disturbed at random by shattering or stirring the soil (gardening), whereas no such evidence has been found by the writer up to a fair resolution limit or in very large telescope photographs or even in the Ranger, Surveyor, Orbiter and Apollo mission photographs.

The lunar surface, however, shows evidence of considerable degradation and erosion by volcanic gases during millions of years of activity and all the old features with their extrusive and ejected deposits have been smoothened and modified by subsequent volcanic rejuvenation. Further, several meters thickness of mineral condensates, fragments and breccias (rock fragments in molten mix) released by vents have fallen over the surface forming the lunar soil, known as regolith, which blankets the fine surface texture.

There may be very small impact craterlets, but they are not of significant sizes at the resolvable limit.

Impact Process

The advocates of impact process by exogenous objects on the Moon (and planets) seem to have heavily relied upon an estimated estimate of planet crossing meteoroids, asteroids and comets, which could have impacted on these bodies, and also on terrestrial analogues, such as attributed impact explosion craters and astroblemes (assumed impact scars) around the world. One such example is the Arizona Crater in North America, which is 1.8 km. in diameter and is considered to be a meteoritic impact crater. They have compiled a list of assumed meteoritic craters around the world, but it has been found that many of them are of internal origin as they lie in major tectonic and volcanic regions (Smith 10). Further, many geologists and investigators after analyzing the field studies of such terrestrial craters have rebutted the attribution to impacts which relied on other doubtful attributions (McCall 11).

Criteria supposed to indicate meteoritic impact in terrestrial craters are the occurrence of shatter cones and high pressure silica polymorphs, etc., near craters indicating radiating explosive pressure. But geologists (McCall 11) have invalidated these as these are mere indicators of intense pressure experienced in volcanic explosions and have been found in structures of internal origin. Further, trace quantity of nickel-iron stated to be associated with meteorites found in and near craters on Earth is not a proof of impact, as nickel is commonly associated with iron geochemically and native nickel-iron of terrestrial origin has been found in several regions on Earth. Crater symmetry (circularity) advanced in support of impact is not also valid, as experiments conducted with hypervelocity projectiles by Ames Research Centre of NASA and the missile impact craters at White Sands Missile Range, New Mexico, clearly show that they apply only to miniature impact pits in sand and unconsolidated soil. Even slightly large impact pits and their ejecta on hard rocky targets deviate considerably from symmetry, and they do not make circular craters. The lunar and planetary craters completely differ from experimental impact craters (Keefe 12).

There are numerous other irrefutable evidences to confirm the endogenous origin of lunar and planetary craters which have been published elsewhere (13).

References


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Figure for "A New Planetarium For The 21st Century"
A NEW PLANETARIUM FOR THE 21ST CENTURY

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Abstract: We introduce a new planetarium and science center that will be built on the outskirts of Turin, Italy, and will be connected to an active astronomical research institute, the Turin Astronomical Observatory. The planetarium will use a new digital projection system that will allow it to introduce visitors not only to the night sky, but to travel through virtual space to and through astronomical objects at various scales. Being administered by an astronomical observatory, it will be a direct link between the public and research astronomers who will be able to immediately share new astronomical discoveries.

The advent of new digital projection technologies and powerful computers is opening new horizons for planetariums, transforming them into virtual reality theaters, from windows onto the Universe into vehicles for interstellar exploration. As a virtual reality theater, the planetarium becomes a powerful didactic tool for introducing the public not only to the night sky, but to astronomical objects of various scales.

Though developed by the largest planetariums, these innovations are being exploited in a new smaller planetarium that will be built as part of a center of astronomy and space science located on the outskirts of Turin, Italy, in the shadow of the telescopes of the Turin Astronomical Observatory. Being connected to a research institute, this center will be a direct link between the general public and ongoing research, allowing astronomers to immediately share new discoveries in their field.

This planetarium is a first example of how these new technologies can be exploited by small planetariums.

Purposes and Perspectives

The main goal of this project is to establish a link between scientists and the general public that communicates the basic astronomical concepts and the latest information on state of the art astrophysical research.

This ideal is reflected in the building itself, which offers to visitors an itinerary through which they can acquire astronomical conceptual tools to better understand the Universe.

The building will be composed of two parts: the planetarium itself with a dome that will host about 100 visitors, and an exhibition area on three levels. This area is intended for a permanent museum, temporary exhibitions on astronomical subjects, and for interactive workstations, where visitors can improve their astronomical knowledge. A bookstore, a video-library, and internet links to other research institutions will provide further sources of information.

Collaboration with other international educational centers and science museums (Chicago, Toulouse, etc.) will be cultivated to expand opportunities for enriching expositions and shows.

Projection System

We will acquire a Digistar II (Evans & Sutherland) projection system consisting of a special purpose computer graphics system that projects images onto the planetarium dome to simulate stars, planets, comets, nebulae and other standard planetarium objects. Since it is digital, however, it can be used to simulate special effects such as dynamic proper motions and travel through 3D space in real time.

Sponsors and Design

The Turin Astronomical Observatory starts the project of this new planetarium with financial supports of Assessorato Cultura Regione Piemonte, Fondazione CRT, Compagnia San Paolo, Comune di Pino Torinese e University of Turin.

The project has been funded and is expected to be completed in three years’ time.

BUILDING A DIGITAL GALAXY

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Abstract: Computers and digital projection technologies are initiating a renaissance of the modern planetarium, transforming it into a virtual reality theater that can transport the viewer to arbitrary points in space. One of the planetariums leading in these innovations is the Hayden Planetarium at the American Museum of Natural History in New York City. The construction of this new planetarium was accompanied by the construction of a digital representation of our Galaxy, the Milky Way. This effort, called the Digital Galaxy Project, produced a three-dimensional model of the Galaxy in the form of a digital database that can be utilized by a real-time rendering program. Such a program feeds digital projectors vistas of the stellar field, based on the virtual position of the viewer within the model and his/her direction of view. The complete model consists of data for a wide variety of astronomical objects; we describe here only the construction of the stellar database. Specifically we show how a statistical model of the Galactic stellar distribution, including colors and magnitudes, is used to fill volumes at arbitrary locations within the Galaxy, and how this statistical database is merged with a database of the observed stars around the Sun. While the content of the digital model is informed by current astronomical knowledge of our Galaxy, the architecture of the database is determined by the constraints of real-time computing.

The Digital Planetarium

The planetarium is now a nearly century-old teaching tool, wherein a visual representation of the sky is projected onto a dome. As such the traditional planetarium is a realization of the celestial sphere, or rather of a hemisphere of the celestial sphere that corresponds to the visible sky. This virtual sky, $S$, is determined by the virtual position of the viewer on the Earth (longitude and latitude) and the virtual (planetarium) time. These control variables essentially determine the local (virtual) zenith of the viewer that defines what part of the celestial sphere is visible. The time is also used for planet ephemerides. We can mathematically communicate these concepts with the equation $S(\text{long, lat, } t_v) = S(\hat{z}, t_v)$ where $t_v$ is virtual time and $\hat{z}$ is the vector representing the zenith direction.

The effectiveness of the traditional planetarium rests on the fact that interstellar distances are so much larger than the Earth or its orbit that our view of the stars is indeed equivalent to points of light on the inside of a dome; it is only by virtue of astronomical knowledge already in our heads that we “see” the stars in the sky filling an infinite volume. The essential constraint to the successful illusion produced by the traditional planetarium is that the viewer’s position remains within the Solar System.

Computers and digital projection technologies are beginning to provide an alternative to traditional planetarium projection systems, and have great potential in their...
flexibility. The digital planetarium allows the introduction of a fundamentally new control parameter, namely the virtual position of the viewer, $\mathbf{x}$, which like $\mathbf{z}$ can be changed in real time: The viewer moves within a virtual three-dimensional space. Now the virtual sky depends on three variables, that is $S(\mathbf{x}, \mathbf{z}, t)$ where $\mathbf{z}$ defines the viewing direction and the virtual time is retained only for planet ephemerides. The viewer is no longer constrained to remain within the confines of the Solar System.

This innovation transforms the dome of the planetarium into a virtual reality theater, in the full sense of the term. An ideal virtual reality environment is in part created by total sensory immersion. In the case of the digital planetarium a virtual reality environment is effectively achieved by satisfying two conditions: 1) total visual immersion and 2) distance perception via motion parallax. The first condition serves in lieu of total sensory immersion, as sight is normally the primary sense we use to perceive of our environment. This first condition is of course also met by the traditional planetarium, but the second is unique to the digital planetarium. An important, perhaps essential, ingredient for planetarium, but the second is unique to the digital planetarium. An important, perhaps essential, ingredient for sensory immersion. In the case of the digital planetarium a depth and can move within the perceived space. When the position of the viewer is changed in real time the digital planetarium achieves both these goals with motion parallax, a term from perceptual psychology that refers to the perception of depth achieved by motion of the observer; the moving observer perceives the distance of fixed objects by their apparent motion, which is inversely proportional to their distance.

A purist may object that the resulting view of moving through a stellar field with such a perceptible motion is not physically realistic, as the speed of the viewer would have to be significantly faster than the speed of light. A supraluminal speed is also required to travel to any other part of the Galaxy in the time span of a typical planetarium show. This objection is of course correct, as a real observer could not travel faster than light, and even an approach to the speed of light would highly distort the visual field due to relativistic effects. But such a voyage is a virtual one, and the viewer can be reminded of this. Instead, we preserve a rigorous faithfulness to reality by adopting a well-defined rule: The projected sky, $S(\mathbf{x}, \mathbf{z}, t)$ is at each moment in real time (each frame) that of a nonmoving observer, where motion is defined with respect to the static model.

The digital planetarium consists of several basic components. The first is a digital model of the space that we wish to present to the viewer. The model exists as a series of files of numerical data, containing such information as star positions, that must be interpretable by a rendering program which computes the visible sky, $S$, for a given set of control variables $(\mathbf{x}, \mathbf{z}, t)$. The control variables may be a pre-scripted path that specifies the control variables in a time sequence, or as feeds from input devices through which an operator may control motion and viewing direction. This latter option demands real time computing, whereas the first option can be used to calculate a sequence of prerendered frames that are stored for later viewing. Because it is often desirable to accompany planetarium shows with audio and possibly other effects, the control variables are fed to the rendering program from a show control program that synchronizes "events" from a suite of audiovisual systems. The model, rendering and show control programs exist and function within a computer system that feeds the output from the rendering program to the digital projection system, which may consist of one or more digital projectors.

At the beginning of 2000 the Hayden Planetarium at the American Museum of Natural History (AMNH) opened its new planetarium, a structure innovative in its architectural and technological aspects. In addition to a traditional planetarium projector is a digital projection system utilizing seven digital projectors. As construction of this planetarium proceeded a second construction project was underway within the confines of the museum; christened the Digital Galaxy Project, it created a three-dimensional digital model not only of the Solar System, but of the Milky Way and its environs. The digital model of the Galaxy describes the spatial distribution and visual aspect of numerous astronomical objects, incorporating actual observed data when available, and data generated from statistical models when otherwise not available. In what follows we describe only the construction of the stellar database.

Local Stellar Distribution

A basic priority of the construction of the digital model of the Galaxy at AMNH was scientific accuracy, that the visual realism in the dome coincide with actual reality. This priority dictated that the model be based on current astronomical knowledge of the structure of the Milky Way and specifically, with respect to the following discussion, of the physical characteristics of the stars inside the Galaxy. Consistent with this goal is the necessity that the model produce the same sky that we actually see from the Earth, necessitating that the model contain actual observed stars. However, a basic requirement that must be imposed on any observed data before it can be included in a three-dimensional model is that it contains distances. For stars these may be spectroscopic or parallactic distances. At AMNH a catalogue of stars fulfilling these requirements was compiled from the Hipparcos, the Gliese, and the Yale Bright Star Catalogues. However, the completeness of these catalogues reaches an apparent magnitude of about 7.5, only slightly dimmer than the magnitude limit of the dark-adapted human eye. This means that the visible sky as it would appear at any position in the Galaxy, $S(\mathbf{x}, \mathbf{z})$ is only precisely known at or very near the Sun's position. To travel away from the Sun a statistical model of the Galactic stellar distribution must be employed to populate other volumes in the Galaxy with stars. The statistical models are based on
studies of stellar catalogues and inferences made from observations of external galaxies similar to the Milky Way, but describe the spatial distribution and characteristics of stars with (probability) distribution functions.

The visible aspect of a star as a point source is determined by its brightness and color. These in turn are determined by the distance to the star and two intrinsic properties, the star's luminosity and surface temperature. The related quantities that astronomers use to describe these properties are absolute magnitude and the color index \((B-V)\). We must interpret these numbers to those used by digital projectors to represent the stars visually, namely an intensity and color. As a practical matter, the intensity with which to visualize a star is calculated by the rendering program that must take into account the star's distance from the observer at any moment in time, as well as any intervening dust clouds that may be present. In the case of color it is convenient to translate the color index \((B-V)\) to relative \(RGB\) intensities that can be used by projectors to represent color. Translating \((B-V)\) to effective surface temperature, and then using the Planck function as a simple approximation of stellar spectra, the relative intensity at three representative wavelengths are used for the relative \(RGB\) intensities, imposing the requirement that \(R + G + B = 1\). (This \(B\) is not to be confused with the broadband \(B\) magnitude used to calculate \((B-V)\). The resulting \(RGBs\) shown in Figure 1, which effectively demonstrates why we see blue stars and red stars, but not green stars; the \(G\) intensity does not dominate at any \((B-V)\) because of the breadth of the Planck function with respect to the color range of the human eye.

The model must thus contain the absolute magnitudes and color indices of the stars at various locations in the Galaxy. To produce a given number of stars within a limited volume with the correct distribution of these quantities we must first have a general description of this distribution. Therefore, before moving from the Sun's position, let us characterize the distribution of absolute magnitude \(M\) and \((B-V)\) of the stars in the Sun's neighborhood.

The absolute magnitudes and colors of stars are a consequence of the physics of stellar structure and evolution, and the resulting correlation is graphically represented in the well known Hertzsprung-Russell Diagram (HRD). A schematic version of the HRD is shown in Figure 2, showing the mean color at various absolute magnitudes for main sequence, giant branch and supergiant stars (vertical line at \(B-V = 0.85\), as adapted from the Institute of Advanced Studies Galactic (IASG) model (Casertano, Ratnatunga, and Bahcall, 1990, and references therein).

![Figure 2: Schematic version of Hertzsprung-Russell Diagram showing the mean colors along the main sequence (MS), the giant branch (GB), and for the supergiants (SG). The position of the Sun on the main sequence is shown for reference (☉). Stars can be placed into four groups according to their luminosity: the brightest, those that must be within at least 1 kpc to be visible, those that must be within 100 pc to be visible, and those so dim as to be very rarely visible.](image-url)

However, stars are not evenly distributed along any of the segments shown in our simple HRD, as there are relatively many more intrinsically faint stars than bright ones. The number density of stars with respect to absolute magnitude at the Sun's location is referred to as the luminosity function, which we designate as \(\Phi(M)\), and show graphically in Figure 3. From \(\Phi(M)\) we can estimate the number of stars of a given absolute magnitude that are visible to the human eye (would appear with an apparent magnitude less than 7), once we assume a spatial distribution. As a local approximation we can use a simple "slab" model (i.e. that the stellar density is proportional to \(\exp -lz/\hbar_n\), where

![Figure 1: The standard R (dotted line), G (solid line) and B (dashed) video colors of stars with respect to color index B-V.](image-url)
z and h are the distance from the Galactic plane and the vertical scale height). We then find that, though \( \Phi(M) \) peaks at \( M=12 \), only stars brighter than \( M=8 \) are likely to appear in the visible sky; while there are many stars fainter than \( M=8 \) they can only be seen when they are very close to us (within about 4 pc), while very luminous stars can be seen when they are far away. For instance, a star with an absolute magnitude \( M=1 \) will be seen by the human eye as a 6th magnitude star or brighter only if it is within 100 pc of the Sun, while a star with an absolute magnitude of -4 will be seen as a 6th magnitude star or brighter if it is within 1 kpc.

The lesser known Hess diagram specifies the number density of stars as a function of both absolute magnitude and color index, that is \( H(M,B-V) \). Stars do not precisely follow the curves shown in Figure 2, but at each absolute magnitude have a range of colors, especially in the case of the supergiants, which have color indices that range from the blue of the upper main sequence to the red of the giant branch. Graphically the Hess diagram adds another dimension to the HRD; turning Figure 2 180 degrees and showing the logarithmic number density as a vertical dimension, the Hess diagram appears as shown in Figure 4. The relationship between the Hess diagram and the luminosity function is simply an integration in color index:

\[
\Phi(M) = \int H(M,B-V) \, d(B-V)
\]

### Galactic stellar distribution

Having described the absolute magnitude and color distribution of stars in the Solar Neighborhood, we are now ready to consider other positions within the Galaxy. In general our problem is to create volumetrically complete stellar samples at any given position in the Galaxy, as we wish our observer to be able to move through interstellar space. However, at any given location we only need to know the stellar distribution near the observer. Given the large range of magnitudes it is convenient to “fill” different sizes of volumes for different magnitude ranges, populating only the volumes in the vicinity of the observer. Two predefined Galactic grids define cells with 200 pc and 1 kpc dimensions; stars with absolute magnitudes from 1 to 7 are placed within the 200 pc³ cells, while those with magnitudes between -4 and 1 are placed into the 1 kpc³ cells. As the stellar disk of the Galaxy has a radius of about 12.5 kpc, but is less than a kiloparsec thick, a grid of \( 125 \times 125 \times 7 \) small cells, with 7 levels in \( z \) (z-levels), is sufficient to enclose the Galaxy. Meanwhile the large cells are on a smaller grid with dimensions of \( 25 \times 25 \times 3 \). Stars brighter than \( M = -4 \) are rare enough and bright enough that it is convenient to generate a single list of these stars for the entire Galaxy. Below we describe the procedures for populating selected cells with stars, procedures emendable to real time execution, allowing an operator to move at will through the virtual space of the Galaxy, or to “pre-show” execution, for those volumes that fall within a minimum distance of a predefined flight path.

To determine the number of stars within a given cell we must know the stellar density at the cell’s position in the relevant magnitude range. If we were to assume that the luminosity function \( \Phi(M) \) described the relative frequency of absolute magnitudes throughout the Galaxy, then we could determine the total stellar density, \( v(x) \) at an arbitrary point \( x \) by specifying the relative stellar density \( n(x) \) and integrating:

\[
v(x) = \int n(x) \, \Phi(M) \, dM
\]
where the relative density at the Sun's position is by definition unity. For example, if we were to describe the Galaxy as a simple axisymmetric disk then we would specify that

\[ n = \exp \left( -\frac{(R-R_0)}{h_r} - \frac{|z|}{h_z} \right), \]

where \( R \) and \( z \) are radial and vertical cylindrical coordinates, with the Sun at a distance of \( R_0 \) from the Galactic center, and \( h_r \) and \( h_z \) being radial and vertical scale lengths. However, the Galaxy is not axisymmetric and the scale height is proportional to the age of the stellar population. In addition the distribution in the Galactic plane also varies with age, the youngest stars being found primarily in and near the spiral arms of the Galaxy. Not only must we adopt a more complex relative density, but we must differentiate between old and young stars, which occupy different parts of the HRD.

The above complications are treated by decomposing the Hess diagram into young and old components. For instance, the upper main sequence and supergiant stars are young stellar populations, while the giant branch is composed of old stars. Both young and old stars will be located on the lower main sequence, but the older stars will be far more numerous, so we can consider this part of the HRD as being old. Now we can effectively decompose the luminosity function into young and old stars by distinguishing between the main sequence (MS) and giant branch (GB) stars: \( \Phi = \Phi_{\text{MS}} + \Phi_{\text{GB}} \). (Supergiants are included in \( \Phi_{\text{MS}} \).) Likewise we must specify a relative density for these two populations that will allow us to assign them different spatial distributions. With such a decomposition our single integral above becomes two, each integral having the same form as that in Equation 1.

With respect to the spiral arms we have used a spiral geometry based on a mapping of HII regions, a prominent spiral arm tracer (Georgelin and Georgelin, 1976; Taylor and Cordes, 1993). Other aspects of the arms have been inferred from recent analysis of near- and far-infrared data (Drimmel and Spergel, 2001). For example, for old stars the arms are wider than those for the young stars, which are only found near their birthplaces. Also, while there are four spiral arms, two arms are stronger. Figure 5 shows the spiral arm dust density, based on far-infrared data, which is used to describe the distribution of the young stars. Since no HII data exists for the opposite side of the Galaxy, symmetry arguments have been used to infer the probable structure of the arms here, albeit with some necessary artistic license. While young stars are only in spiral arms, the old stars have both an axisymmetric and spiral component to their distribution. For the old stars the near-infrared (NIR) surface density is used to describe their surface density (see Figure 6).

**Faint stars (M>1)**

First we consider the intrinsically faint stars, in the absolute magnitude range \( 1 < M < 7 \), which must be placed into \((200\text{pc})^3\) cells. Formally the number of stars in a cell is

\[ N_{\text{cell}} = \int v(x; I < M < 7) \, dV, \]
the integration being over the volume of the cell, but a second integration over the faint star absolute magnitude range is in the expression for $v$ (Equation 1).

The youngest stars in this magnitude range (on average) are the more luminous stars on the MS, but even these are about 500 million years old, so that we can consider the faint stars as being dynamically old in the sense that most have completed at least several revolutions about the Galaxy. Therefore we adopt the same surface density profile for all these stars.

Because the size of these cells is small with respect to density variations in the plane of the Galaxy, we can assume that the stars are uniformly distributed in $(x, y)$ for any individual cell $i$, and use the coordinates of the center of cell, $(x, y)$, to calculate the number of stars in the cell. This reduces the volume integration to an integration in $z$ only (multiplied by an area).

Using the above assumptions, we arrive at a simple equation to calculate the number of stars in any cell $i$ at a given height $z$ above or below the plane of the Galaxy, corresponding to the $j$th $z$-level of cells:

$$N_{ij} = \sigma(x, y) N_{0j}$$

Here the function $\sigma$ describes the density variation in the surface density, taken to be equal to the NIR surface density, but renormalized to equal unity at the Sun’s position, while $N_{0j}$ is the number of stars in a cell at the Sun, but at a height $z$; we need only do our double integration once for each $z$-level to find $N_{0j}$!

Using these procedures we calculate the number of stars with absolute magnitude between 1 and 7 for every cell in the Galaxy. But this database only tells us how many stars there are in each cell. When we need to populate a cell with $N$ stars we must use Monte Carlo methods to generate a distribution of magnitudes, colors and $z$ positions consistent with our adopted Hess diagram and assumed vertical gradient. But since these distributions have been assumed to be the same for this faint absolute magnitude range, we need do this computationally complicated procedure only once for each $z$-level. That is, we populate a set of generic cells, one for each $z$-level, with many more stars than any one cell possesses. Then, as we travel through the Galaxy, cells in the immediate vicinity of the virtual traveler can be populated by simply drawing the appropriate number of stars from the appropriate generic cell.

**Luminous stars ($M < 1$)**

Stars with intrinsically high luminosities (-4 < $M$ < 1) are organized into 1 kpc$^3$ cells. For these stars we cannot use the same procedure of using generic cells as described above, first because in this absolute magnitude range the MS stars are much younger than the GB stars, and so have different distributions in the Galactic plane. This first problem could be overcome by creating two sets of generic cells, however our cells are also now too big for such a method, as the stellar surface density varies on scales smaller than a kiloparsec. Our procedure is then to generate all the stars in this magnitude range for the entire Galaxy, and then parse these into 1 kpc$^3$ cells according to their location.

The stellar surface density for each of our populations can be described by a simple formula analogous to Equation 2:

$$\Sigma_p(x, y) = \Sigma_{p}(x, y) + \Sigma_{p}$$

where $p$ (= MS or GB) indicates the stellar population. For $\sigma_{GB}$ we use the NIR surface density, while for $\sigma_{MS}$ we use the dust density associated with spiral arms. The total stellar surface density, $S = \Sigma_{MS} + \Sigma_{GB}$ is interpreted as a probability density to generate $(x, y)$ positions in the Galaxy. An example of a set of such positions is shown in Figure 7. Each of these positions are randomly assigned as being either a main sequence or giant branch star according to the relative fraction of these two components, i.e. $(\Sigma_{MS}(x, y)/\Sigma(x, y))$ and $(\Sigma_{GB}(x, y)/\Sigma(x, y))$. Then an absolute magnitude, color, and $z$ coordinate is assigned consistent with our adopted Hess diagram and vertical density profile. This statistical dataset is normalized to the observed dataset by requiring that the number of statistical stars with apparent magnitudes brighter than the completeness limit of our observed catalogue, $N(m < m)$, is equal to the actual number of luminous stars in our observed catalogue. The resulting data set of stars with absolute magnitudes -4 < $M$ < 1 is the parsed into 1 kpc$^3$ cells according to their location.

**Figure 7:** Twenty thousand positions for stars with absolute magnitudes -4 < $M$ < 1. The Sun’s position is indicated with $O$, and stars with $R < 5$ are not shown. Units are in kiloparsecs.
The most luminous stars, those with absolute magnitudes $M < -4$, are generated in the same manner as just described, the only difference being that the surface density has only a main sequence component, that is $\Sigma = \Sigma_{MS}$. Figure 8 shows the positions of about 5,000 such stars generated in this way.

![Figure 8. Positions for 5000 of the most luminous stars in the Galaxy, with absolute magnitudes $M < -4$. The Sun's position is shown with $\Theta$, and units are in kiloparsecs.](image)

**Putting it together**

In the previous section the reader may have noticed that no positions were shown for stars within $R < 5$ kpc of the center of the Galaxy. This is simply a self-imposed limit on the stellar database, as current limits on computer memory and cpu do not allow one to visualize the high stellar densities in the central regions of the Galaxy. We expect that these limits will be overcome in the future, but for the present a stellar bulge population is not included in the present form of the stellar database. In any case, the inclusion of such a stellar population can be treated in the same way as described above, after defining a $\Phi(M)$ and $n(\bar{x})$ for the Galactic bulge.

We have described the construction of the statistical part of the stellar data base which must be combined with the observed data set. With a position and absolute magnitude, we can calculate an apparent magnitude of a statistically generated star and ask ourselves whether such a "synthetic" star would appear in our observed database, that is, whether it is brighter than our completeness limit. If it is bright enough to be observed from the Sun then the star is removed from the statistical data set. The entire stellar dataset is then finally the simple merging of the observed and statistical datasets.

We have here described only one part of the Digital Galaxy. Other components to this model include a large database of important nonstellar objects such as planets, globular clusters, and various types of nebulae. Our presentation is also here limited in its presentation format, being constrained to two-dimensions. For a complete presentation of the Digital Galaxy the reader must go to the Hayden Planetarium in New York!

**Acknowledgments**

The first author would like to thank the Hayden Planetarium for the opportunity to work on with the Digital Galaxy Project. The four short months spent within the halls of AMNH were most fruitful and rewarding.

**References**


FIRE IN THE SKY

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Abstract: “Umlilo Esibhakabhakeni” (Fire in the Sky) is a new planetarium presentation in the Xhosa language (South African). It embodies particular concepts and situations, necessary for developing communities, especially those previously disadvantaged. The show is targeted at youngsters of 10-11 years old who have had little, if any, exposure to astronomy.

To the majority of the inhabitants of Southern Africa, the study of astronomy is far removed from everyday life and everyday priorities. Nevertheless efforts are being made to get parties of youngsters from previously disadvantaged backgrounds to visit the planetarium. However, putting a group of African youngsters in a planetarium may prove for them a completely foreign experience, one too easily associated with European-American technology and culture. There is a great need to make those youngsters feel much more comfortable in the planetarium setting, and to realise that what information is being put over is not some form of European propaganda, but is shared by all who live on the planet.

The first remedy is to have the presentation in their home language. Whilst South Africa officially recognises ten indigenous languages within its borders, we have the advantage that in Cape Town, almost all the African population originates from the Xhosa-speaking region. To western ears, Xhosa is a fascinating language that incorporates many click sounds. There are, however, as yet no members of the astronomical community—white or black—who can write a planetarium script directly in Xhosa. Consequently the script was drafted in English with subsequent translation into Xhosa. Much is a direct translation, but alternative words are sought where there are no direct Xhosa equivalents. The Xhosa version was then translated back to English to ensure that meanings had not been changed. The script will be recorded and the presentation of visuals will in the usual way be synchronised with the soundtrack.

Part of the reason why the soundtrack is recorded is to incorporate traditional music. Music is the rhythm of Africa. Song and chant often accompany daily chores and work. There can be no better way to reach out to African people than by putting out music with a beat. It is an immediate way of holding attention, and a very necessary element for the start and end of the planetarium show. In the present production, a number of traditional Xhosa pieces will be used.

Where possible, reference to Xhosa customs is brought in the script. Similarly it has to be correct for the Xhosa way of life. For instance in the English draft we had suggested that a man was cooking supper. This was removed as in Xhosa society only women do the cooking!

Given the very limited exposure to astronomical information, it is essential to find some common ground with everyday familiar objects. Five years ago, for our first Xhosa show, we used the idea of a soccer ball—something known to all African youngsters—as a starting point. We could then go on to explain that the Earth was like a ball, similarly the Moon, Sun, planets and stars. For the new show, we have chosen “fire” as the common theme. Rural and even many urban African people traditionally light fires in the evening for cooking and warmth. The new show is entitled “Umlilo Esibhakabhakeni (Fire in the Sky)”.

The show is aimed at youngsters of around 10 to 11 years old. For this reason, the script concerns two children of similar age who interact with their knowledgeable grandfather. The show starts with the children witnessing a red sunset and thinking there was a fire in the West. However, the grandfather explains that there is no fire, but that the Sun operates like a fire, generating heat and light, though not in the same way as a conventional fire, with wood as fuel. This brings in the concept of the Sun warming the Earth, and as with a camp fire, one should be neither too close to, nor too far from it, so as not to get too hot or too cold, the Earth being at an ideal distance from the Sun.

The Full Moon Rises. Xhosa people see in the maria patterns the image of a woman carrying firewood on her head. This leads to the question as to whether the Moon is on fire, and to the explanation that the Moon is not on fire, but that the Sun operates like a fire, generating heat and light, though not in the same way as a conventional fire, with wood as fuel. This brings in the concept of the Sun warming the Earth, and as with a camp fire, one should be neither too close to, nor too far from it, so as not to get too hot or too cold, the Earth being at an ideal distance from the Sun.
Finally, the stars are brought in with the knowledge that they are distant suns, analogous to many campfires in the country. Patterns that have Xhosa names, such as Orion’s Belt and the Pleiades, are pointed out. Isilimela (the Pleiades) are particularly noted because their annual cycle in the sky was used as a means of calendar keeping by Xhosa people. The heliacal rising of the Pleiades signified the start of a new year and a time when teenage boys were initiated into manhood. The number of years of manhood is still counted as so many “Isilimela”s. It is a familiar term, but few Xhosa people today know how it originates from the sky. It is a wonderful opportunity to introduce the new generation to the stars.
PLANETARIUM MAINTENANCE: PROTECTING YOUR INVESTMENT

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Abstract: The “electro-optical-mechanical” planetarium instrument has been the mainstay of planetarium theaters since their introduction in the 1920s. This basic design continues to dominate existing and new facilities and has particular maintenance needs. All too often, these needs are not adequately addressed, resulting in impaired operating parameters and shortened projector lifetimes. This paper will provide a strong rationale for ongoing service, provide various tips that will allow planetarium staff to perform limited maintenance procedures, and furnish criteria to identify and remedy projector problems.

There are a large number of 10 to 40 year old planetarium star projectors presently in service. In fact, the majority of all planetarium projectors in use at this very minute fall into that category. Some of those projectors have exceeded their useful operating lifetimes through deterioration and, as a result, perform at levels far below their original capabilities. Deteriorated conditions can have a direct impact on your ability as operators and educators to use the equipment in an effective and useful manner. Many planetarium projectors will reach their operating lifetime threshold within a few years, some sooner than others. Eventually, of course, every projector will reach that point.

To some extent a projector’s operating lifetime is determined by factors beyond the control of the owner. This may occur when a company goes out of business, when a particular model is no longer supported by a manufacturer, by a lack of availability of critical parts, by the lack of knowledgeable service personnel, or even vandalism or any number of other causes. In other cases, the operating lifetime can be affected by owner-induced factors such as misuse, abuse, lack of maintenance, improper maintenance, improper environmental conditions, economic hardship, etc.

Often it is difficult to determine the point at which a planetarium projector needs to be replaced. Refurbishment or corrective maintenance, perhaps extensive in nature, is sometimes a more practical option than projector replacement. Also, keep in mind that many state-of-the-art control systems and other enhanced operating features and upgraded components can be fitted to older projectors that are no longer in production.

Most importantly, almost all planetarium projectors can be maintained within acceptable performance and reliability standards for many years, usually measured in decades! The key word here is maintained. No matter how well your projector may be performing right now, ongoing preventive maintenance is a very important consideration and investment.

Each manufacturer has developed procedures to address the maintenance needs of their particular equipment. Read and familiarize yourself with the literature that should have been furnished with the projector. If this information is not at hand, contact the manufacturer or other qualified service providers. Another possibility is to contact other owners of similar models. Earlier editions of the IPS Planetarium Directory contain a listing of planetariums by the model and manufacturer, and are useful in identifying owners of identical equipment.

Some maintenance procedures require outside help or at least some technical know-how, but many procedures can be easily performed by non-technical staff. Each facility has its own unique mix of conditions so you will need to develop your own specific set of protocols and policies. At this point, rather than going into a lot of detail on the specifics of maintenance, I urge you to refer to my article in the March 1999 issue of the IPS journal, The Planetarian, entitled “Planetarium Maintenance: Protecting Your Investment”. That article provides a more comprehensive overview of planetarium maintenance including a basic checklist of criteria for recognizing projector problems, developing an operator’s manual, criteria for developing in-house maintenance procedures, and other miscellaneous considerations. (Editor’s note: A portion of this article is reprinted here, with permission, as Appendix A.)

In conclusion, the planetarium projector that is properly maintained is very likely to be one that continues to function...
effectively at a time when most other projectors of similar vintage are marginally operational or long since replaced. Whether you do it yourself, or contract with the manufacturer or other qualified source, PLEASE, see that your projector gets the attention it needs and deserves. When you consider that a new star projector can cost 10 times or more the price of your existing one, the amount you need to commit to regular maintenance can furnish ongoing dividends that can enhance the equipment’s longevity while providing reliable and accurate performance. You, your successors, your institution, and your audiences will enjoy these long-term benefits.

APPENDIX A: (reprinted from the Planetarian, March 1999)

The following is a rough guideline dealing with a variety of technically oriented situations that face planetarium theaters. This is not intended as an all inclusive compendium on these matters. Indeed, I hope that it fosters a continuing effort towards further clarifying the procedures and situations expressed.

Problems

Equipment-imposed problems and limitations:

Know your planetarium design parameters/limitations. Is the projector capable of doing what you expect?

Many “problems” are simply the projector being expected to do more than what is possible. For instance, the horizon cutoff height for the stars in most older Spitz projectors varies with the latitude setting of the projector. This results in stars being projected below the dome horizon when the operator changes latitude. This is a design limitation (that has been resolved with a newer design) that often is perceived as a “problem”.

Additional problems are often caused by adjustments being made to remedy situations that are caused by unrecognized factors or equipment limitations. If a particular planetary conjunction is off by time or position the “solution” is often found by the planetarium staff by turning an adjustment screw or loosening a mechanical coupling to reposition the image(s). The long term consequences of such “solutions” always results in increasingly out of adjustment conditions. While there may be a perfectly valid problem causing the incorrect planetary alignment, the correct solution isn’t always the most expedient one. It’s also possible that the planetarium is doing exactly what it is capable of doing and a particular planetary alignment cannot be presented any more accurately. Keep in mind as well that some tolerances will increase as the equipment ages.

Knowing these distinctions will give you a much more informed perspective to deal with or avoid actual problems.

Typical human-induced problems and concerns

poor/no training procedures
showoff “gee whiz/impress member of opposite sex” operators
I can fix anything type (staff, volunteer, friend)
unauthorized users/abusers (custodians/maintenance personnel, other staff, contractors performing other work, VIPs [museum director, board members, etc.], vandals)

What can you do?

If all else fails, read the directions! In the case of most planetarium projectors, it is essential that you familiarize yourself with the manufacturer’s literature that should have been furnished with the equipment.

Solutions

Develop your own facility’s protocols and policies.

See to it that there is a way to limit access by unauthorized or untrained users. If there are multiple operators, make certain that there is sufficient formal training for all concerned. You also must be assured that all of your operators are behaving within authorized guidelines. An operator’s manual should be developed that clearly defines all of the operating parameters that you deem necessary.

Areas that should be covered in facility operator’s manual:

locations of controls
operation of controls
allowed operator usage/disallowed operator usage
locations of necessary fuses/circuit breakers/spare lamps, etc.
procedures for reporting problems
procedures for fixing problems such as how to replace certain lamps

A basic checklist of criteria for recognizing projector problems may include such items as:

frayed wires—especially important near moving parts
does equipment shift due to loose hardware?
wires near gears/projector protrusions—is there adequate clearance?
has focus or brightness changed on any image? Spitz star (arc) lamp users please note—the condition of the star lamp degrades slowly with use. Look for “fuzzy” and dimming stars near the zenith. Replace the lamp when this becomes pronounced.
light leaks
  star projector
  auxiliary equipment
  external—under doors, around ducts, etc.
do all controls function normally?
are instrument readouts synchronized?
are instrument motions smooth?
unusual mechanical noises—identify location if possible
  louder than normal
  higher/lower pitch than normal
  clicking/intermittent noises
stains/discholoration from external or internal sources
  internal
    lubricant or other
  external
    drip from above
    overspray
    water in elevator pit
electronics
  odor
  scorched components

In-house maintenance procedures should be formulated and carried out based on a number of factors. Sometimes technical staff will be able to provide most of the maintenance. In other cases, one person may be the only one available for the entire planetarium operation. In these situations it is important to recognize what can and cannot be done as well as what must be done. Maintenance deficiencies must be provided for in other ways such as periodic service by outside sources. In either case, the frequency and extent of instrument maintenance will vary from facility to facility based on such differences as type of equipment, amount of usage, amount of dust accumulation, amount of abuse, etc. Some procedures will need to be performed more or less often than others. Your checklist should specify the frequency of specific maintenance procedures.

Such procedures should include:

- periodic visual inspection based on previous criteria list
- dusting
- starball
- mirrors
- lenses
- geartrains/other
- cleaning mirrors
- cleaning lenses
- cleaning other surfaces
- lubricating projector components
- periodic replacing/aligning lamps

Some maintenance procedures that may fall beyond the scope of in-house staff:
- cleaning slip rings/replacing brushes
- cleaning first surface mirrors
- cleaning internal projector optics
- lubrication of projector components
- recalibration of electronics
- precise alignment of star projector optical systems
- setting of all projection systems including annual motion

Miscellaneous considerations

- provide correct climate control
  - install light in elevator pit to help with humidity
  - maintain HVAC and/or humidity control
- provide adequate security
  - surveillance of theater at all times when in use
  - alarms when unoccupied
  - safeguards from unauthorized use
  - security codes
  - key switch breakers turned off

Finally, regardless of who performs the maintenance to your planetarium instrument, you should maintain a log of all problems and fixes. This will be especially helpful in identifying systems or components that are prone to failure and can significantly reduce analysis time and repair of certain future problems. It can also help in rectifying ongoing problems that can only be fixed by a process of elimination. Additionally, if you contract for outside maintenance, a long-term record of problems and repairs can be a valuable reference for improved service.
Abstract: The development of laptop computers, digital data projectors, and the proliferation of internet websites related to current astronomical research and observation have made it possible to use commercial presentation software in teaching highly visual lessons in astronomy.

Frame #1
Image:
Lunar Horizon, vertical at left of frame
Recorded voice:
"To see the Earth as it truly is, small and blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on that bright loveliness in the eternal cold, brothers who know now that they are truly brothers".
Image:
Earth lit from right, crawls into frame from behind lunar horizon
Text: Zooms out from Center
Teaching the Universe in the 21st Century
Text: Zooms out from center to replace previous text
Using the Power of PowerPoint

Frame #2
Recorded voice:
"Simple cut and paste techniques allow special effects"
Image:
Shuttle climbs up through picture and out of frame at the top

Frame #3
Text:
The PowerPoint software makes it easy to animate images:
Image:
space station
Image:
space shuttle rises into frame from bottom to dock with space station
PowerPoint can be used to pace the display of data.

The layer of atmosphere that covers the Earth is very thin.

If the Earth were the size of an apple, the atmosphere would be as thick as the skin of the apple.

Three more sentences appear, each at a touch of any key on the computer keyboard:

- The atmosphere is a radiation shield.
- The air protects us from meteors.
- Air is a blanket that keeps the Earth from getting too hot or too cold.

The software can be used to play narration recorded directly on the computer or specified tracks on a CD. Accesses third track on CD in computer CD player, Vivaldi’s “Four Seasons—Spring”.

Images:
- Whole Earth, centered over Sri Lanka.
- Overlay of larger Earth.
- Overlay of larger Earth.
- Overlay of larger Earth.
- Overlay of larger Earth.

This effect is a slow zoom in toward Earth. Part of same image, enlarged to show India and Sri Lanka.

Words appear:
- Today is the Vernal Equinox.

Venus is almost as large as the Earth.

...and beneath its thick sulfuric acid clouds.

Venus has continents!

...and beneath its thick sulfuric acid clouds.

Venus has continents!
Frame #8
Image:
Current image of sun
REF:
http://www.spaceweather.com
http://sohowww.nascom.nasa.gov
RUN:
MPG movie of Coronal Mass Ejection

Frame #9
AVI time-lapse movie of Sun in XRAY wavelengths
REF:
http://sohowww.nascom.nasa.gov

Frame #10
Text:
Animating words can help focus attention.
Text: Words drop from top, one at a time:
Plasma particles follow the Earth’s magnetic lines of
force down toward the north and south poles, hitting
the air so hard that they make the air molecules glow, creating
the aurora, or northern lights.
IMAGE: appears behind text
Aurora Borealis

Frame #11
Text:
It is easy to animate images, graphics, and text.
IMAGE:
Earth, sunlit from left side.
Moon, sunlit from same angle, moves into frame from
upper left.
Graphics:
Arrows zip in from left side to point to sunlit sides of
Earth and Moon
Text:
The Sun shines on one side of the Earth, making day and
night.
The Sun shines on one side of the moon, making phases.
Frame #12
Graphics:
   Big yellow circle
   Big black circle, moves in slowly from right to cover a third of the yellow circle.
Text:
   December 25, 2000
Appears:
   Partial Solar Eclipse!
   Virginia, United States

Frame #13
Image:
   Earth
Text:
   The Earth gets hit by meteors more often than the Moon
Image: Fades in over first image
   Moon
Appears on touch any key:
   but the Moon is covered with craters, and the Earth is not.
Zooms in from behind Moon image:
   WHY?

Frame #14
Text:
   Small pieces of rock and metal hit the Earth’s atmosphere and glow white-hot.
Image:
   Meteor – ZOOMS in from top left
Text:
   About 50 tons of meteor material fall on the Earth every day!
Text: flashes and disappears:
   ACCRETION

Frame #15
Text:
   A large meteor slammed into the desert of Arizona 55,000 years ago
AVI Movie of formation of Barringer Meteor Crater
Image:
   Aerial view of Barringer Meteor Crater
Text:
   The crater is still there today.
Text: flashes and disappears at edge of crater in image:
   ACCRETION
Frame #16
Image:
Earth
Text:
We fly past the Earth to our other next door neighbor, the Red Planet
Image:
Large image of Mars crawls into frame from right
Text: Pause three seconds, then zoom in from behind image of Mars
Mars!

Frame #17
Text:
Resizing images is easy, and allows accurate comparisons.
Images:
Small Earth in center of frame
Images, followed by text labels zoom in from left:
Jupiter
Saturn
Uranus
Neptune

Frame #18
Image:
Lunar Horizon
CD Access:
Vivaldi’s “Four Seasons – Spring”
AVI Movie:
Rotating Earth – crawls from behind lunar horizon
Text:
The Beginning – crawls into frame from bottom
ghastings@space.com - crawls from bottom
Sound Effect:
applause
Abstract: History indicates that the planetarium was developed for educating students. Slowly it was been developed to entertain the people for knowing about their universe. Presently Indian planetaria are successfully undertaking the work of removing superstitious belief. In every part of India, the planetarium is established to educate people through entertainment using audio-visual presentations. The survival of the planetarium is mainly dependent on the frequent visits of the people. This can be fulfilled by undertaking various programmes such as short term courses, organising various astronomical event camps, workshops on topics of interest, and hands-on experience in the planetarium. Some aspects of 21st century planetarium activity are to be enlightened with special reference to attracting more people to the planetarium.

The planetarium is an effective tool for imparting astronomical concepts to common man and younger generations. In olden days there were no clear thoughts and understanding of nature. People were afraid of astronomical events happening in those days. They coined stories; thus mythological stories were evolved. Through the planetarium, most of the events can be simulated and informed to the public for removing the fear. "Science without Society is lame." "Society without Science is blind." Astronomy is an observational science. The Planetarium can contribute more to Society than any other audio-visual entertainment.

History of the planetarium

The word “planetarium” today usually refers to an optical projection instrument that shows upon the inner surface of a hemispherical dome the stars, planets, sun, moon and, in most cases, additional astronomical effects. The term also refers to the room or building in which the projector is housed.

In earlier days to illustrate the stars and their patterns, the stars were painted in a hemispherical dome. The first static model of universe was fabricated by the Greeks. In the 3rd century B.C. Archimedes, the great scientist, constructed a globe with embedded Sun, the Moon, and planets. The entire system was rotated around the axis. Later small hand operated solar system models were developed.

In 1913 the astronomer Max Wolf, of Heidelberg Observatory, discussed with Oskar Von Miller, founder of the Deutsches Museum, the possibility of a display that would show the motions of the Sun, Moon, and planets within a dome of spherical curvature. In this device, light comes through holes in a darkened dome under which the audience sits. Miller proposed this project to the Zeiss works, but preliminary investigations were interrupted by World War I. It was proposed to construct a hemispherical dome with a white painted interior, and to place an optical projector in the center to show the stars, Sun, Moon, and planets together with their motions as observed from the Earth. The first planetarium projector was unveiled at the Carl Zeiss factory in August 1923.

This was moved to the Deutsches Museum in Munich and mounted temporarily in a 32-foot dome. It was permanently installed at the Deutsches Museum in May, 1925, where it was in use until World War II.

The Planetarium during the late twenties and early thirties—its “childhood years”—was viewed essentially as an educational tool, a marvelous teaching aid for the dissemination of astronomical knowledge.

The lecture was delivered in a classroom style and was limited to demonstrations of the sky from an earth-centered view. Emphasis was upon star identification, planets’ motions, aspects of the sky from different latitudes, and what might be called spherical astronomy. Those which did remain in operation were used in celestial navigation classes for service personnel, one of the many areas in which the planetarium excels as a teaching device.
During the fifties, the planetarium reached what might be termed its "adolescent years". It was beginning to feel its strength and potential. Jenoptik Jena, Gmbh in East Germany also resumed production after the war. In the United States, a custom-made projector was installed in San Francisco's A. F. Morrison Planetarium. In 1955, Goto Optical Mfg.Co., started research into the design and production of planetariums. Spitz Space Systems, Inc., U.S.A. and Minolta Corp, Japan also joined the planetarium business. The planetarium enterprise was growing. Planetarium administrators, technicians, and lecturers were sought.

The public's interest in astronomy and space was kindled. Adult education came into vogue. Also during this period, the educational planetarium came into being. Although large municipal and museum planetariums are educational in a broad sense, their main aim during this period was public presentations—general interest shows aimed primarily at adults.

With the development of optical and electronic systems, special effect projectors became the norm, not the exception. Stars, sun, moon and planets of the main projector were joined by panoramas, clouds, meteors, aurora, zoom effects, etc.

Up to 1950, the planetarium was mainly used for educating students and scholars. By use and development of audiovisual concepts, the planetarium became more entertainment along with educational content.

The planetarium for mankind

Planetaria are established nowadays in many places. Running and maintaining the planetarium in effective ways are undertaken. Nowadays most of the celestial events are simulated and illustrated. This paves the way to understand the universe and celestial events without much difficulty. In and around the planetarium an astronomical park may be created. This park may contain a solar village, which consists of a scaled-down model of our Solar members; the Universe and Milky Way galaxy in 3 dimensional form; different sundials indicating the accuracy of time with reference to our watch, etc. This will help the visitors to understand the physical concepts along with regular planetarium programme.

To obtain repeated visitors, the planetarium has to rethink its boundaries. The planetarium at Chennai was established on May 11, 1988. So far about 25 lakhs (25 hundred thousand) visitors visited. The visitor strength increases by introducing new planetarium programmes with reference to astronomical events. To attract the children and common man to the planetarium, the following events are organised:

* the planetarium is organising night sky observation,
* the special arrangements made during celestial events such as solar eclipses, lunar eclipses, blue moon, meteor shower, etc.,
* encouraging students and common man in identifying meteorites,
* conducting short term and week end courses.

Nowadays, advertisements in the media are very expensive. Through the above programmes, the planetarium activity can be made very popular. A periodical astronomy course for the varied nature of children and common man can be organised.

The planetarium movement in Tamilnadu is in high order. People are keen in knowing their universe and celestial events. The Government of Tamilnadu felt the need and necessity of the planetarium as an effective tool for removing superstitious beliefs and effective communication equipment for illustrating the universe.

The first milestone was achieved by establishing Anna Science Centre-Planetarium at Tiruchirappalli. Proposals are under active consideration for establishing a planetarium at Coimbatore. Apart from this, mobile planetarium shows are organised in schools and villages.

Conclusion

The survival of the planetarium is dependent upon the repeated visitors to the planetarium. This can only be achieved through vibrant planetarium programmes, special lectures, workshops, and astronomical observation programmes. In a specially constructed hemispherical dome, an astrodome can be constructed. The diurnal motion can given to indicate and identify the stars, their region during the daytime, if there is no sunlight. Normally common men are thinking, the stars appear only during night. Some telescopes can be mounted to identify faint stars. Initially, it can be in the diameter of 15-foot (5-meter) dome.

References:

The Astrophysics of the Solar System by K. D. Abhyankar

Manual on Planetarium by Goto Optical Mfg.CO., Japan

A Brief Introduction to Astronomy by Birla Planetarium, Kolcutta (Calcutta), India.
A MODEL KIT TO EXPLAIN THE APPARENT MOTIONS OF THE SUN, THE MOON, AND THE PLANETS

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Abstract: Using the model kit here presented one can give an explicit explanation about the apparent motion of the Sun, the Moon, and the planets. With the kit’s unique models of the zodiac, the planets and their orbits, it is possible to get a good understanding of various celestial phenomena: e.g. the phases of the Moon, the relation between the rotation and the revolution of the Moon. It’s also useful for studying the phases and the change of apparent diameter of Venus (an inferior planet) and of Mars (a superior planet), the planetary phenomena (conjunction, maximum elongation etc.), the direct and retrograde motions of Mars. Moreover it gives a clear image about the apparent motion of the Sun in the ecliptic, and the inclination of the Earth’s axis and the production of the seasons, etc. The models are so compact that it is possible for students to put them on their desks in class, and for each student the from-the-Earth viewpoint is secured for any object in question.

Introduction

In teaching the apparent motions and phenomena of the Sun, the Moon, and the planets, using models of the celestial bodies is effective. In using a model, it is important to secure the from-the-Earth viewpoint. Any apparent motion or phenomenon of a celestial body is observed from the Earth. In a class of 30 or 40, the students will usually observe a model in turn. It typically takes too much time for all of the students. The model kit presented here is so compact that it is possible for students to put it on their desks in class, and for each student the viewpoint is secured for any object in question.

This kit is suitable for teaching basic astronomy at the junior high schools and senior high schools in Japan. (Saito 1989,1991,1992a, 1992b, Nakayama 1989)

The contents of the kit and the exercises

The contents of the kit are as follows:

(1) The Moon and planet models (3 pieces, Fig.1). These models are small balls with stems and stands with one black hemisphere and one white hemisphere.

(2) The solar model (Fig.1). This model is the larger ball with stem and stand.

(3) The mini-Earth model (Fig.1) The model can rotate on its inclined axis and have a day and night divider, that is a plate to divide day and night.

(4) The figures of the stellar constellations of the zodiac. The figures are divided into four parts and connected to a ring shape (Fig.2).
(5) The orbit sheets (Fig. 3)
(a) The lunar orbit (the Earth and the Moon)
(b) The orbits of the Earth and the inferior planets (the Earth and the Inferior Planets)
(c) The orbit of the Earth and the superior planet Mars (the Earth and Mars)
(d) The solar system and the zodiac

(6) The longitude compass (Fig. 4). It is a unique compass for measuring the heliocentric longitude of a planet. The compass has two arrows, one at the end of each leg; one of the arrows is labeled as a planet, the other as the ver-
With this kit, the following observations of the solar system are possible.

1. The Earth and the Moon
   (a) The phase change (waxing and waning) of the Moon
   (b) The relation of the rotation and the revolution of the Moon

2. The Earth and the inferior planets
   (a) The phase change (waxing and waning) of Venus, and if necessary that of Mercury, as well.
   (b) The change of the apparent diameter of Venus.
   (c) The conjunctions and maximum elongations of Venus.

3. The Earth and Mars (a superior planet)
   (a) The apparent motion and the phase changes of Mars.

4. The Earth and the Sun
   (a) The revolution of the Earth and the apparent motion of the Sun
   (b) The zodiac and four seasons
   (c) The meaning of the equinoxes and solstices (the vernal and autumnal equinox, the summer and winter solstice)
   (d) The inclination of the Earth's axis and the annual changes of the length of day and night

Those models are put on their orbit sheet according to a theme, and looking at the planet or the lunar model from the Earth model, a student can then easily understand the relation of the phenomena of the Moon and planets.

The production of the models from the kit

The kit consists of several printed-paper sheets, seven styrene foam balls, and sticks, etc. (Fig. 5). Those materials are cut, jointed, and constructed to fit the models. Students can easily make those by hand within several hours.

The use of the models (Exercises)

In classes using the models, students observe the models and fill in forms on sheets that are prepared for every exercise subject.

Exercise No. 1. The phase change_waxing and waning_of the Moon.

One of the models, which has one black hemisphere, is put on the center of the lunar orbit sheet as the Earth, and the other one, as the Moon, on the lunar orbit. The white hemispheres of the models must be turned to the sunlight. And then one can observe the Moon model over the Earth model. The white part of the Moon model represents the part in direct sunlight, and the darkened side its shadow, or the night side of the Moon. Changing the position of the Moon model according to the Moon's age, students can see the Moon model just same as we see the waxing and waning of the Moon and they sketch them.
Exercise No.2. The relation of the periods of rotation and revolution of the Moon

Allows students to consider the reason why the Moon always shows the same surface to the Earth. Put a small mark on the small white model of the Moon. Move the Moon model in its orbit keeping mark of the Moon model facing to the Earth model. First describe the movement of the mark of the Moon model on an Exercise sheet as in Fig. 6, and then one can understand that the Moon rotates once during one revolution in a counterclockwise direction.

Fig. 6. The mark on the Moon model rotates once during one revolution.

Exercise No.3. The phase change (waxing and waning) of Venus (an inferior planet)

Just as in the Moon phase change, put the three models, a large white model of the Sun and two semi-darkened sphere models of Venus and the Earth, on their positions on the Earth and the Inferior Planets orbit sheet, respectively. The white side of the Earth and Venus models must face the solar model. Then one observes the Venus model over the Earth model. By changing the positions of the Venus and Earth models, one can observe the various phases of the waxing and waning of Venus as in Fig 7.

Fig. 7. Venus model before an inferior conjunction. Over the Earth model, the narrowed Venus can be seen on left-hand-side of the Sun.

Exercise No.4. The revolution of the Earth and the annual motion of the Sun

Put the solar model and the Earth model on the Earth and the Inferior Planets sheet, and also put on the zodiac ring. And then one can observe the projected position of the solar model with respect to the zodiac from the position of the Earth. The stellar constellations that lie on the Earth side can be seen in the night. It is possible to take up the meaning of the equinoxes.

Exercise No.5. The inclination of the Earth's axis and the four seasons

Attach the solar model and the mini-Earth model on the Earth and the Inferior Planets sheet. The axis of the mini-Earth model must be arranged to incline toward the summer solstice. The day and night divider of the mini-Earth model must be held perpendicular with respect to the sunlight on a line that combines the Sun model and the mini-Earth model (Fig.8). If one rotates the ball of the Earth model, the pass of the pre-marked point on the ball is divided into two parts by the day and night divider. The lengths of each part of the pass are proportional to the length of day and night respectively.
Fig. 8. The mini-Earth model (E) and the Sun model (S). Day and night divider (D) divides the pass of a point (P) into two portions following the rotation of the Earth model. N is the North Pole.

Exercise No. 6. The apparent motion and the phase change of Mars

One marks the positions of the Earth and Mars in the ecliptic longitudes on the orbit sheet of the Earth and the Mars. The positions must be selected monthly during about one year centered at the time of opposition of Mars. Put the Sun model and two planet models, as the Earth and Mars, on the suitable positions of the orbit sheet, respectively. And put the joint of the longitude compass on the Earth model, point the planet arrow of the compass toward the Mars model, and the other leg of the compass parallel to the line of the Sun to vernal equinox (Fig. 9 left). Then put the joint of the compass on the center of the zodiac ring (right). Reading the position on the ecliptic indicated by the planet arrow of the compass, it is the position of Mars at the time (Fig. 9 right). Pointing to Mars’ positions on the exercise sheet successively, one gets the apparent motion, direct and retrograde motions, of Mars. If one observes the Mars model from the Earth model the same as when observing the Moon or Venus phase change, one can confirm that Mars does show a little change of its phase.

Fig. 9. The measurement of the position of Mars on the ecliptic; an angle of the longitudinal compass coincides with a geocentric longitude of Mars (left), and then put the compass on the center of the zodiac ring (right).

Effects of the lessons using the models

(1) On the handcrafting of the kit

It is a very pleasant activity for students to make their own teaching materials. Some students who are weak at handicrafts were helped by other students or called on the teacher for help, so that classroom conversation became lively. Making their own teaching materials can help introduce them to their interest in astronomy.

(2) On the classes using the models

It is possible to clarify the phase changes of the Moon or Venus, and apparent motions of the Sun or planets in an ordinary classroom without darkening the room or using special light sources. From observations of the models the students can understand celestial phenomena in three dimensions. For example, the dividing line of day and night of the Moon phase is drawn exactly as an elliptical shape. In a pretest many students drew line as straight line, which did not reach pole to pole.

Those simple models can very closely reproduce the arrangement of the Sun, the Moon, the Earth, and the planets.

And students can observe the relations or the phenomena caused by those celestial bodies. They can learn the phenomena by intuition. Classes that make it easy for students to understand help their interest in astronomy grow.

The students’ impressions, which were written in the reports of my class, are in Table 1 below. About 90% of the students felt that the exercise was pleasurable, was easy to understand, or had affirmative impressions. A rate of 90-95% students also affirmatively received other exercises. But in the exercise of the apparent motion of Mars, 28% of students had expressed that it was difficult or incomprehensible. Because the inclinations of the planet’s orbits are ignored in this kit, it is difficult to understand that Mars goes
on a loop at its retrograde motion. The procedure to determine the apparent position of Mars in the zodiac is a somewhat complicated one that uses the longitude compass introduced to avoid a parallax.

Table 1. Students' impressions on the Exercise 1 (The phase change of the Moon)

<table>
<thead>
<tr>
<th>Impressions</th>
<th>Number of students</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Pleasure, interesting</td>
<td>21</td>
<td>26.6</td>
</tr>
<tr>
<td>B. Easy to understand</td>
<td>24</td>
<td>30.4</td>
</tr>
<tr>
<td>C. Felt understandable</td>
<td>5</td>
<td>6.1</td>
</tr>
<tr>
<td>D. Difficult (affirmative)</td>
<td>8</td>
<td>10.1</td>
</tr>
<tr>
<td>E. Difficult (negative)</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>F. Incomprehensible</td>
<td>5</td>
<td>6.3</td>
</tr>
<tr>
<td>G. Others (affirmative)</td>
<td>16</td>
<td>20.3</td>
</tr>
<tr>
<td>H. Others (negative)</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td>103.8*</td>
</tr>
</tbody>
</table>

(Note: The impressions were obtained by the reports of 79 students of our junior high school (Saito 1993). Some of the impressions were overlapping so that the total amount was over 100%.)

The kit is named “The Planets” and is sold by Kyoto Kagaku Co. Lit. and widely used at junior and senior high schools in Japan (Nakayama 1989).

The models are made from paper and styrene foam balls, which are not such strong materials, so it is necessary to handle the models carefully. Some students are weak at handicraft. It is necessary to select materials for the models that are stronger and easier to make, for example, a plastic model.

Acknowledgment

The author expresses an acknowledgment to D.Sc. Keishin Suzuki, professor emeritus of Tokyo Gakugei University, who permitted use the figures of the zodiac from his book, and gave him many useful suggestions to the kit.

References


Figure from “STARVID - New Technology For Learning About The Universe”
Abstract: STARVID is a multi-purpose projection system originally developed for learning about the Universe. It allows one to see the star-sky with correct gradation of stars and objects down to magnitude 6.5, the possibility of manually operating sky motion "as a planetarium", projection of actual planet positions, zooming in chosen objects (planets and non-sidereal objects), and some animations directly implemented (solar system, Jupiter and Galilean moons, meteor shower), as well as coordinate system projections. Depending on the system's version, it could be connected with an existing school video-projector or it can be provided with a special wide-screen high-resolution system. The most complicated versions can be connected with a school computer network and can directly cooperate with individual PC workstations. STARVID allows lecture preparation as well as running provided shows with various degrees of interactivity. It is possible to involve children with the lecture according to their age.

There exist many ways and facilities that are designed for learning about space. Among these are observatories, planetariums, museums, educational centers, TV, and I-net. It is quite important to get the basic knowledge about the Universe at school. Pedagogical skills and a certain enthusiasm will be always the most important thing, but technical possibilities are significant as well. There are only a few schools that have their own planetarium. In the majority of cases they rely on mobile portable planetariums or their students visit a "stone" planetarium once a year, if there is any nearby.

Planetarium devices are used all over the world, but they have different educational possibilities—from the most simple planetariums, which can display a quite stylized night sky, up to highly complex systems, which are equipped with fiber optics and a very complex control system and which are able to show everything almost in the same way as the real sky. On the other hand there exist various computer simulators, but their purpose is primarily not to show the real starry-sky.

Both advantages and disadvantages are known very well:

- Large planetariums are very expensive. A number of additional systems must be installed for production of high quality show (slide projection, video system).
- Small planetariums are cheaper, but technical possibilities are lower. It is difficult to install any additional systems, too.

- Large computer simulators capable of whole dome display are very expensive. The creation of new shows in such systems is very complicated, too.
- Simple computer simulators are designed for monitor output, and the scientific level is different. Usually they are not designed for classroom presentation.

In general, the quality of display and number of projection possibilities are proportional to the price of the device. If we want to use this technology in a classroom, we need to design a highly efficient low cost system. Only this system can be used directly in a classroom or in small observatories and educational centers.

What should the system be able to do?

- It must display a very realistic night sky. The possibility of schematic displaying of night sky is quite good.
- Of course, it must be easy to control.
- It must be able to display pictures, computer animation, and video.
- Easy implementation of new information.
- Possibility of presentation non-astronomical information is an advantage.

These demands are very difficult for the classical electromechanical planetarium, but easily realizable for a computer projection system. Computer catalogues of the sky are available in great number and the rest is only ingenious and user-friendly software.
What does user-friendly mean in our case? Is it a Windows computer screen? Maybe, it is a very frequent form. But I think it is not the most suitable for controlling in darkness. I would prefer a kind of simplified control console used by usual planetariums—turning knobs for motions, pushbuttons for other functions. Of course, when having a complicated and universal system we do not avoid “programming”—but it should be done before the lecture, just as the slides are normally put in the carousels before the lecture, not during it. It should be possible to prepare the lecture in an office.

Which kind of projectors are suitable? If we are thinking of a computer projection it is possible to use either CRT data projectors or projectors based on LCD or DLP. CRT projectors are advantageous because their black is really black—so it does not shine. On the contrary, the black of LCD is in fact dark gray; that means in absolute darkness this gray is strongly evident in the dark black environment. It is the reason why the LCD projectors are not used in planetarium domes. But in case the whole view is made by LCD projection, the whole background is equally gray, so that it will not make any difference. In addition, the contrast and light power of contemporary LCD projectors is so high that it is not necessary to have a complete blackout (darkness) during the projection. In this case the dark gray background does not matter.

Is it necessary to place the projection system in a dome? I think it is not. The wide observing angle is sufficient for a good result. It makes possible, for instance, to install the system right in a classroom. This solution removes difficulties with an inflatable dome or the high expenses for building a fixed dome.

All these aspects become a starting-point for new system, Starvid.

Starvid is a multi-purpose projection system originally developed for learning about the Universe. It allows one to see the star-sky with correct gradation of stars and objects down to magnitude 6.5, the possibility of manually operating sky motion “as a planetarium”, projection of actual planet positions, zooming in chosen objects (planets and non-sidereal objects), some animations directly implemented (solar system, Jupiter and Galilean moons, meteor shower) as well as coordinate system projections.

Depending on the system’s version, it could be connected with an existing school video-projector or it can be provided with a special wide-angle screen high-resolution system. It consists of up to three high-resolution LCD data projectors that collaborate on picture creation.

In basic mode the system works as an ordinary planetarium, except that it does not project to the whole dome but only to a part of it. It shows diurnal and annual motions, precession, and the sky in arbitrary latitude, and it can rotate in the azimuth axis. It shows Sun, Moon and planet positions correctly, of course, and the usual functions such as projection of various coordinate systems are implemented. Further, it is possible to zoom in a chosen sky part and to simulate observing with telescopes of different size. Depending on the data content, it is possible to zoom in some of non-sidereal objects in the sky fluidly up to the best pictures available. It is also possible to insert other pictures, animations, or video in whichever place and whenever.

It is possible to operate in three modes:

° fully manual control is suitable only for very simple lectures
° manual synchronization when the whole lecture was programmed in advance and the lecturer starts chosen individual sequences; when the sequence is not running, the fully manual control can be used as well
° fully automated mode when the whole lecture, including the sound track, runs automatically.

All these aspects allow one to prepare a very attractive lecture, as we know from large planetariums, together with a highly professional “live” presentation. Data used in one system are easily transportable, so the presentation prepared in Sri Lanka can be performed in Europe without any difficulties. Data transportation together with the worldwide spread of I-net gives the system a new dimension. It allows the school children from various schools in different places all over the world to cooperate on common projects. And the Universe provides so many topics that the number of projects is almost inexhaustible.

Starvid is able to simulate a large number of phenomena. It allows one to simulate various planetary systems and to study influence of small changes on whole system. The best way for people to learn is to use their own experience. Simulation of various processes in the Universe can help to better a understanding of life on Earth.
EYES ON THE SKY

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Abstract: A sampler of live, participatory school programs for many ages. Most of these emphasize a connection between the planetarium sky and the real sky and require only a star projector and simple supplies to run.

In this paper, I will describe some of the educational programs we carry out at the Bowling Green Planetarium, with emphasis on those that utilize the planetarium sky or require observation of the real sky. These programs need little equipment besides a star projector, so might be especially applicable to planetariums with limited equipment or which are located in dark-sky sites.

The facility

The BGSU Planetarium is a 12.2m horizontal dome in a university setting at a latitude of 40° north. It seats 118 students or visitors, has a Minolta II-B star projector, and was opened in 1984. The University is relatively large (17,000 students), but the city is relatively small (12,000 permanent residents).

The planetarium serves three primary audiences. University introductory astronomy classes meet in the planetarium on MWF during the academic year and daily in the summer. Public shows are run three evenings a week and some Saturdays from September through early May. Private groups (usually schools) can reserve programs during school year on Tuesday and Thursday and occasional other times.

A rooftop observatory is also connected with the planetarium. It houses an 0.5 m computer controlled telescope in the dome and several smaller portables can be set up on a open skydeck. The observatory is used for “stargazing” sessions by the general public (after planetarium shows) and by students in introductory astronomy classes (at scheduled times). The 0.5 m telescope is equipped with a CCD camera that is used for research training by physics/astronomy majors and graduate students.

A central tenet of my operating philosophy is that the real sky and its proxy, the planetarium sky, are at the core of why planetariums exist at all. Although our planetarium is a relatively well-equipped multimedia theater, we maintain a strong emphasis on the sky, both real and planetarium.

The sky in public programs

All our public shows begin with a live star talk, usually by me, but occasionally by one of my student workers. In the star talk, we show the constellations and planets of the current evening sky and sometimes include an astronomy module, which can range from telling myth to showing the progression of spectral types in Orion and the ring of bright stars around him.

The star talk is followed by a question and answer time before the planetarium show begins. The shows are multimedia programs, some created in-house, others purchased.

Our Friday and Sunday evening programs are followed by a real-sky observing session, weather permitting, in which we point out some constellations and look at one or more objects through the 0.5m telescope. The eyepiece assembly is constructed so we can readily switch between visual observing (for the public) and use of the CCD camera (for advanced students) without making an equipment change. These observing sessions last 30-45 minutes. Usually between one-quarter and one-half of the planetarium show audience stays for observing. People stay even on cold nights (SF, -ISC). Our limiting magnitude on a clear, moonless, haze-free night is about 4.5.

The printed program we pass out to audience members as they arrive for the planetarium show always contains a star chart that shows the current evening sky. So in many ways we encourage the public audiences to watch the sky.

The sky in school programs

Visiting school classes range in age from preschoolers through students from other area colleges. Teachers can choose from a roster of about 40 multimedia shows and about 15 live interactive shows. The live shows are always centered on the star projector and its sky. The multimedia shows include a question and answer time but do not include a star
talk except upon request. Here I will describe some of the live programs.

*Star Shapes (grades pre-school to K, ages 4-5)*

The goal of the program is to have the children learn you can see stars and star pictures (constellations) in the sky.

I do this program only for small groups (20 or fewer) and seat the children on the planetarium floor in a circle. I begin by introducing them to the round shape of the room and to the idea that we’ll pretend the ceiling is the sky.

Then using picture boards I tell a story of some children who watch the sky and find “star shapes” in it: the rectangle of Orion or the Bright Triangle (Vega, Deneb, and Altair). Next we pass out black construction paper (“pieces of the sky”), self-stick dots, and bright crayons, and the children make their own constellations. Then we introduce the idea that stars are made of something called “hydrogen” and are born in faraway clouds in outer space.

Finally, I bring up the starfield and show the constellation we learned about in the opening story. The last step is encouraging the children to watch the real sky with their parents (a convenient excuse for them to stay up late!).

So in a simple way, this activity introduces the idea of seeing constellations to very young minds. It takes about 35 minutes.

*Directions (grade 2, age 7)*

The goal of this program is to show that the source of directions lies in the sky.

After an introduction, four volunteers are sent to the cardinal points bearing large signs labeled N, S, E, and W.

Then I move the Sun across the sky for the dates December 21, March 21, and June 21 (all for our home latitude). Before each time, I call for guesses as to where the Sun will rise. Then we move the Sun, noting where it rises and sets and roughly how high it is in the south at noon. Volunteers with appropriate signs are sent to the azimuths of sunrise and sunset. During the June demonstration, I usually stop the Sun in early morning and ask whether it will reach the zenith at noon (at our latitude, it misses by 15°), and will usually bet a school lunch with those who say it will.

The students’ predictions tend to get a little better as the program progresses, but they are usually not too good. The students have not developed the formal reasoning needed to make good predictions, but they can readily see the concrete results.

The students learn that east and west are the general directions of sunrise and sunset, that the precise directions change with the seasons, and that south is the direction of the noontime sun.

Then we switch over to the night sky, see a few constellations, and demonstrate that the north star is stationary and marks the direction north.

The whole lesson takes about 35-45 minutes, shows a range of basic sky motions in a concrete way, and ties the directions to the sky.

*The Sun and Seasons (grades 3-6, ages 8-11)*

The goal of this program is to show the Sun’s diurnal motion in different seasons and at different latitudes.

It begins with demonstrations of the Sun’s diurnal path in December, March, and June, following the same steps and activities used in *Directions*, and done for our home latitude.

Then we stay with the June sun, but go to different latitudes, first north to Alaska and the North Pole, then south to the Equator and Australia. Volunteers with signs are sent to stand under the noon sun at each latitude.

Students learn the same points as in *Directions*, but also learn the Sun’s diurnal path changes as you travel north or south. In particular, they see the midnight sun in the arctic (usually a big surprise) and learn that the seasons in Australia are the opposite of those at home.

The lesson takes about 45-55 minutes. A similar program has been developed for the motions of the Moon, though it is necessarily more complex. A third related program samples stellar, solar, and lunar motions to show the roots of timekeeping in celestial motions.

*Sun in Earth’s Sky (grades 5 and up, ages 10 and up)*

The goal of this program is to examine in some detail how the Sun’s diurnal path varies with date and latitude. The program is run in the style of a science lab session.

First the students are given an explanation of the azimuth ring which will be used to measure solar rising and setting azimuths to the nearest degree. An altitude arm connecting the south point and the zenith is also explained and will be used to measure the Sun’s midday altitude to the nearest degree.

Then the students are given a worksheet that contains lines for each motion of the Sun that will be demonstrated. For each motion, the student must predict the rising and setting azimuth and the midday altitude and then record the observed values when the motion is demonstrated. Then
Predictions and observations are made for the next motion, and so on.

The first set of motions demonstrates the Sun’s diurnal path on the solstices and equinoxes at our home latitude. The predictions for the first motion (usually an equinox) are merely guesses, but the predictions rapidly improve, and the students concretely discover the seasonal patterns and symmetries.

The second set of motions demonstrates the Sun’s diurnal path for the summer solstice at a grid of latitudes, beginning at the home latitude and gradually moving north to the North Pole, and the gradually moving south to the South Pole. The first one or two lines of predictions are rather poor, but the students quickly discover the patterns both of diurnal altitude, where the changes with latitude are pronounced, and of rising and setting azimuth, where the changes with latitude are much more subtle, except at high latitudes. By the end, many students are attuned to changes of as little as a couple degrees in azimuth!

This program takes 60-75 minutes to complete if the entire grid of motions is demonstrated. Similar programs have been developed for the motions of the Moon and planets.

Kepler Second and Third Laws (grades 11 and up, ages 16 and up)

The goal of these programs is how these two heliocentric laws are derived from geocentric observations. Both are run in a science-lab mode. I have described both in detail elsewhere, so will recount them only briefly here.

Third Law: Students made methodical observations of the motions of the five naked-eye planets along the planetarium’s ecliptic and record dates of conjunctions. The dates of conjunction are used to determine the synodic period, which are combined with the change in ecliptic longitude of conjunction to calculate the sidereal period.

For the inferior planets, the maximum elongations are measured and used to calculate the orbital radius in AU. For the superior planets, the dates of quadrature are determined and used in a somewhat complex way to determine the orbital radius in AU (when a superior planet is at quadrature, the Earth is at maximum elongation, as seen from that planet). Students are given an extensive work packet explains the procedures in detail, provides space to record observations, and guides them through the calculations. This exercise is described more fully in the proceedings of the 1996 IPS conference in Osaka.

Second Law: Students make methodical observations of the positions of Mercury, Mars, and the Sun along the ecliptic on sets of carefully chosen dates. Knowing a planet’s position and the date, the geocentric ecliptic longitude can be converted to a heliocentric longitude, using a provided chart of the planet’s orbit and Earth’s orbit. In this way, a planet can be traced around its orbit. Chords connecting positions equally spaced in time give a dimensionless velocity for the planet. Mercury and Mars have sufficiently eccentric orbits that measurements made with a good star projector can show the variation of velocity around the orbit. As with the third law exercise, students are given an extensive work packet explains the procedures in detail, provides space to record observations, and guides them through the calculations. This exercise is described more fully in the proceedings of the 1998 IPS conference in London.

The sky in university astronomy classes

We typically teach four to six large introductory astronomy classes in the planetarium each semester. Most classes have about 115 students and meet three times a week in large-class format. The teaching load is shared among three or four instructors. We do not have graduate student assistants or “quiz sections.”

Our sky-related goal is to equip our students for a lifetime of enjoyable skywatching. We give students extensive exposure to the planetarium’s sky typically center about two to three of the semester’s fifteen weeks on the naked eye sky, its phenomena, and their explanations.

All the instructors use the star projector extensively to teach sky motions and cycles. We all teach some constellations but none of us places too strong an emphasis on them. The left column in Appendix A lists the complete set of phenomena we show using the star projector, though none of us shows all of them in any one course.

We also give our students exposure to the real sky by requiring them to attend a “stargazing session” at the Observatory. Our operating style here is shaped by the need to accommodate a large number of students (500 or more per semester), a relatively cloudy climate (two nights out of three are cloudy) with fairly cold winters, and our moderately urban location. The stargazing sessions are conducted by a team of undergraduate students. They are scheduled on four nights a week and each student is required to attend one session during the semester.

The typical session lasts about an hour. The student operators show several constellations and whatever planets are visible. Several portable telescopes are trained on the moon, planets, and deep sky objects. Finally, the workings of a reflecting telescope are explained and a visit is made to the half-meter telescope and one or two objects are shown through it.

We also offer an extensive set of optional observing projects for extra credit. These fall into two primary categories. “Basic” projects are ones students can do at the Observatory after a scheduled stargazing session. They
typically involve sketching the Moon or planets as seen through a telescope. “Advanced” projects are ones that students can do on their own at home. They range from simple projects like recording the direction of sunset once a week to intermediate ones such as photographing constellations to advanced ones that involve measuring the circumference of the Earth. These projects are listed in Appendix B.

I have also developed an honors-level naked-eye astronomy course that permits more extensive use of the star projector than is possible in a large class and involves more advanced exercises, explanations, and observing projects.

In all these ways, we introduce our various audiences—university students and public and school visitors—to the real sky both through direct observation and experience with the planetarium sky.

### Appendix A: Planetarium sky demonstrations and real sky observing projects

<table>
<thead>
<tr>
<th>demos in dome</th>
<th>real sky projects &amp; (dome exercises)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONSTELLATIONS</strong></td>
<td></td>
</tr>
<tr>
<td>current evening sky</td>
<td>attend stargaze Constellation album [Create your own constellations]</td>
</tr>
<tr>
<td>diurnal motion here</td>
<td>Changes in the sky North Star Measure latitude by star trails Circumference of the Earth</td>
</tr>
<tr>
<td>tilt of sky with latitude</td>
<td></td>
</tr>
<tr>
<td>diurnal motion at other latitudes Celestial Equator</td>
<td></td>
</tr>
<tr>
<td><strong>DIURNAL &amp; LATITUDE MOTION</strong></td>
<td></td>
</tr>
<tr>
<td>star colors</td>
<td>Star colors in Orion Variable star</td>
</tr>
<tr>
<td>OBABFGKM sequence</td>
<td></td>
</tr>
<tr>
<td>nebulae, clusters, &amp; galaxies visible examples of stellar evolution stages</td>
<td></td>
</tr>
<tr>
<td><strong>SKY FEATURES</strong></td>
<td></td>
</tr>
<tr>
<td>today’s path across sky</td>
<td>Setting Sun Midday altitude of the Sun [Sun in Earth’s Sky]</td>
</tr>
<tr>
<td>ecliptic and motion along ecliptic</td>
<td></td>
</tr>
<tr>
<td>compare ecliptic and celestial equator Sun’s annual motion relative to cel. eq. diurnal paths in different seasons diurnal paths at other latitudes solar vs. sidereal day</td>
<td></td>
</tr>
<tr>
<td><strong>SUN</strong></td>
<td></td>
</tr>
<tr>
<td>today’s path across sky</td>
<td>Setting Moon Moonmotion Length of the month Shape of the moon’s orbit Moonsketch [Moon in Earth’s Sky]</td>
</tr>
<tr>
<td>motion along ecliptic</td>
<td></td>
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<tr>
<td>(rise/set azimuths vs. phase and season) siderial vs. synodic month (regression of the nodes) eclipses: phase and node requirements</td>
<td></td>
</tr>
<tr>
<td><strong>MOON</strong></td>
<td></td>
</tr>
<tr>
<td>planets in today’s sky</td>
<td>Planetsketch Motion of a planet [Watching the Planets] [Kepler’s 3rd Law exercise (inf. &amp; sup.)] [Kepler’s 2nd Law exercise] [Make your own planetary system]</td>
</tr>
<tr>
<td>visibility when E/W of Sun</td>
<td></td>
</tr>
<tr>
<td>motion along ecliptic and relative to Sun inner: tied to Sun, synodic period, configurations outer: not tied to Sun, syn. pd., configurations retrograde motion</td>
<td></td>
</tr>
<tr>
<td><strong>PRECESSION</strong></td>
<td></td>
</tr>
<tr>
<td>precession circle change of pole star change of visible constellations</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B: Observing Projects

Basic observing projects

Moonsketch: Make a sketch of the moon, as seen through a telescope, and record the details of what you see.

Planetsketch: Make a sketch of the planets that are up, as seen through a telescope, and record the details of what you see.

North Star: Record the location of Polaris and some northern constellations in the sky at two times during the night and look for changes.

Orion: Record the colors of stars in the constellation Orion as a means of recognizing stars of different temperature. (Limited to winter months when Orion is up.)

Advanced observing projects

Setting Sun: Record the location and time of sunset (or sunrise) at least once a week throughout the semester to discover trends and changes.

Measurement of latitude by star trails: Make a half-hour photograph of the trails of rising or setting stars. Use the angle of the trails to the horizon to calculate your latitude. Camera required.

Changes in the sky: Attend two stargaze sessions at least two months apart and carefully record the changes in the sky between the two visits.

Star colors in Orion: Take a color photograph of the constellation Orion. Use the colors to rank the stars in order of temperature. Camera required.

Setting moon: Record the location and time of moonset and the moon’s phase every clear night for two weeks from new to full moon to discover trends and changes.

Moon motion: Record the location in the sky and phase of the moon nightly for two weeks from new to full moon to discover patterns.

Midday altitude of the Sun: Measure the length of a stick’s shadow at midday once a week all semester. Use these lengths to calculate the Sun’s altitude at midday and note weekly changes.

Constellation album: Photograph at least ten constellations, assemble the photos in an album, and identify each constellation its connect-the-dots figure. Camera required.

Motion of a planet: Select a planet visible in the night sky and carefully measure its position relative to nearby stars once a week all semester to chart its path through the starfield.

Variable star: Use binoculars to monitor how an assigned star varies in brightness. Record how much the brightness changes and how long one cycle of change takes. Binoculars required.

Length of the month: Record the moon’s phase and position in the starfield nightly for five weeks to measure the length of two kinds of month, sidereal and synodic.

Shape of the moon’s orbit: Photograph the moon nightly for a month. Measure the changes in its size and discover how its distance from the earth varies during the month. Camera and telephoto lens required.

Circumference of the Earth: Measure the altitude of the Sun or Polaris from two latitudes at least 150 miles apart. You must build the measuring device, measure the altitudes to an accuracy clearly better than 1%, and use their difference to calculate the Earth’s circumference.
WORKING TOGETHER IN IPS

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Abstract: The International Planetarium Society provides a variety of educational benefits to its members. IPS members can work together and share ideas and resources.

The scope of IPS

The International Planetarium Society is the largest global organization of planetarium professionals. IPS connects about 600 individual and institutional members in over 30 nations on 6 continents.

IPS also embraces 21 regional or national affiliate societies. These include seven associations in the United States, which has about half the world’s planetariums. Nine planetarium associations are found in Europe, including the British, Nordic, French, German, Italian, Russian, Ukrainian, Spanish, and European-Mediterranean affiliates. Further affiliates serve planetariums in Canada, Mexico, Japan, India, and Australasia. We are also taking steps to foster the formation of affiliates in other areas of the world, including central Europe, South America, China, and the Arabic countries.

IPS is led by a team of five elected officers, including the President, Past-President, President-Elect, Executive Secretary, and Treasurer. IPS is governed by a Council composed of the elected officers and representatives from each of the regional affiliates.

Though its conferences, publications, special services, and other activities, IPS provides many ways for planetarians to work together and to share ideas and resources. IPS is really just all of us working together, and the various channels described here find their value primarily through contributions made by individual members.

IPS Conferences

IPS conferences are held biennially in even numbered years. Recent conference sites include Cocoa Beach, Florida, USA (1994); Osaka, Japan (1996); London, England, UK (1998); and Montréal, Canada (2000). The 2002 conference will be held in Morelia, Mexico from July 14-18. Invitations for the 2004 conference have been received from planetariums in Melbourne, Australia; Valencia, Spain, and Oakland, California, USA.

IPS has been pleased to provide substantial support to the organization and promotion of this conference, Sri Lankan Skies and Sir Arthur. Many of the frontiers of the planetarium world lie in developing countries and our support of this conference is intended to underscore IPS’s commitment to this frontier.

IPS Publications

The principal IPS publication is the quarterly journal Planetarian edited by John Mosley. All IPS members receive the Planetarian as a benefit of membership. Each issue contains articles contributed by members and several feature columns contributed by associate editors. These columns include:

- Book Reviews
  reviews of books of interest to planetarians
- Computer Corner
  reviews of software
- Focus on Education
  educational materials and lesson plans
- Forum
  member responses to a quarterly discussion question
- Gibbous Gazette
  news and happenings of planetarians
- International News
  news from each regional affiliate of IPS
- Jane’s Corner
  a quarterly commentary
- Mobile News Network
  news of mobile planetariums
- Opening the Dome
  real sky observations & planetarium shows
- Planetechnia
  discussion of an aspect of planetarium equipment
The IPS slide service provides copies of selected images taken by the Hubble Space Telescope, space mission images from the Jet Propulsion Laboratory, and images from the European Southern Observatory. We expect that further sources will gradually be added.

The new IPS video service was inaugurated in 2000. Laserdisk 1 (still available) features 72 minutes of spacecraft animations and launch sequences from the European Space Agency. Laserdisk 2 features 60 minutes of Mars mission clips from JPL and will be available in May, 2001.

Web site

The IPS web site <www.ips-planetarium.org> is providing an increasing array of features to support planetarium operation and education. In addition basic information on the structure and organization of IPS, the web site contain also features:

- links to all planetarium web sites worldwide
- links to all vendors listed in the Resource Directory
- a roster of current planetarium job openings
- a “news and views” section containing press releases written by planetarians
- an on-line version of the IPS Directory (in members-only area)
- an email list of research astronomers willing to answer questions from IPS members (in preparation for the members-only area)
- update forms for both directories
- materials from the new Education Committee (see below)

Education Committee

A new IPS Education Committee was formed in 2000. This committee is developing the following resources:

- an on-line bank of lesson plans designed for use especially in school planetariums
- an on-line annotated list of astronomy education web sites
- a Focus on Education column for the Planetarian featuring lesson plans for use in planetariums
- an concise educational rationale for planetariums

Other services and opportunities

IPS offers several other opportunities for its member planetarians to share ideas and resources, including:

- the Eugenides script contest: a biennial competition awarding cash prizes to entrant submitting the best planetarium show scripts. Entries go into an IPS script bank available to members. Entries for the 2001-2002 cycle will be accepted until December 31, 2001. Complete information is listed in the March 2001 issue of the Planetarian.
• IPS News: a listserv distributing timely astronomical news releases and other IPS communications.
• the Star Partners Fund: a cash fund to provide IPS services to members in economically challenged countries. Funded by donations from IPS members.
• Planetarium Partnerships: an IPS-managed way to exchange material among planetariums and assist economically challenged facilities and to promote twinning efforts between individual planetariums
• several service documents, including a membership guide (in preparation), a packet for candidates for IPS office, and a revised conference planner to assist IPS conference hosts.

Conclusion

The goal of IPS is to help its members work together to become better planetarians. This article lists many of the ways IPS provides for its members to share ideas and resources. The success and value of any of these ways depends entirely on contributions made by individual members. This means each one of us. Please contribute!
INTEGRATION OF FORMAL AND NON-FORMAL EDUCATION UNDER THE PLANETARIUM

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Abstract: Since its inception in 1962, the M. P. Birla Planetarium at Calcutta has been carrying out programmes aimed at integrating formal and the non-formal education. Our experience in this kind of integration has been highly successful in the area of astronomy. The high content of science in the Indian system includes topics like colours of stars, seasons, and eclipses, even to students of class 3. Based on this background and the appetite Indian students have towards science and mathematics, the M. P. Birla Planetarium has been conducting an Evening Course in Astronomy for the last 35 years. From the experience gained the planetarium started the Post Graduate Diploma in Astronomy & Planetarium Sciences eight years back and two years back the M.Phil Degree Programme. Publication of a quarterly scientific journal and extensive press interaction have been towards reaching the final goal of a DEEMED UNIVERSITY.

The M. P. Birla Planetarium was set up in the year 1962 and formally inaugurated on 2nd July, 1963 by the late Prime Minister of India Pandit Jawaharlal Nehru. As we all know, the Planetarium as a sophisticated stereo-optical projection instrument and as an institution was at that time already forty years old. During those 40 years it was gradually becoming more and more of an entertaining institution only somewhat different from a cinema. When the first ideas of presenting the starry skies captured the attention of the founder-director of the Deutsches Museum Dr. Oscar von Miller and his associate Dr. Karl Bassler, they wanted the intricate knowledge of astronomy be taken to students in a spectacular and easy way to supplement the details of what they would learn from the rich astronomical collections in the exhibition hall of the museum. In view of this, the Planetarium demonstration lectures were handled with all the seriousness of a class room lecture but with the one difference that the lecturer had in front of him a very versatile astronomical instrument capable of presenting faithfully the naked eye view of the heavens, and in the later years presenting the same as from any place in the world of the northern and southern hemispheres. In the world’s largest and foremost planetaria like the ones in Chicago, Philadelphia, New York, and in the several cities of Europe as well as in Osaka and Tokyo, the lectures that were presented to the students and public explained the intricate astronomical points as well in a graphic and easily assimilated way. Gradually it was realized that with the high popularity of the spectacular shows, it was necessary to use the main sophisticated instrument more as a back-drop and the several innovative audio-visual effects took precedence.

In that existing background the Trustee of the M. P. Birla Planetarium was still keen that the educational impact should be kept intact. Accordingly the Planetarium organized and started a Free Evening Course in Astronomy lasting around eight months where 150 participants from different walks of life and in various age groups were admitted and divided into two batches, each one receiving one lecture per week. 18 topics were discussed covering the background in astronomy; the night sky through the seasons and the spotting of bright stars and constellations; the several systems of coordinates in the celestial sphere; the solar system in all its details; measurement of time through the centuries right up to quartz clock, ammonia clock, etc.; Kepler’s laws of planetary motion; and details about atmosphere, refraction, parallax, aberration, solar and lunar eclipses, precession and nutation, astronomical observatories, spectroscopy, physics of the sun and the stars, origin of the solar system, theories of origin of the Universe and related subjects. This course with some modifications has been given every year for all the past 35 years.

With the same approach of emphasis on education, astronomical exhibits in the gallery have been periodically rotated to cover current celestial events. The Planetarium also
carried out astronomical expeditions to solar eclipses whose path of totality was at various countries of the world at different times. The Planetarium has been conducting seminars on specific themes at the national level and also hosted the 7th International Planetarium Directors’ Congress in 1980. The M. P. Birla Planetarium through its director has been interacting and participating at the several international congresses of the IPDC as well as IPS.

As a further strengthening of the educational value of the institution of the Planetarium, we have been conducting during the last 8 years a ten-month course in Post-Graduate Diploma in Astronomy & Planetarium Sciences. We have been admitting up to a maximum of 10 students for this course. The candidates should have a background of Honours Degree level in physics, mathematics, geology, chemistry, or statistics. These candidates go through classroom lectures, as well as practicals and project work.

Two years back the Director of M. P. Birla Planetarium signed a memorandum of understanding with the Director of the Birla Institute of Technology & Science, Pilani (Rajasthan) for starting an M.Phil. Degree Programme in Astronomy & Planetarium Sciences. The Lectures for the students are given by a large faculty of external professors as well as in house staff. The first student has completed M. Phil Degree Programme and during this year in September we propose to start the course admitting 6 students. It is also proposed to gear up the research activities by taking 2/3 research fellows to work under specified guides for their doctoral theses.

Finally, it is hoped that not only this Planetarium but similar major big planetaria would move towards the goals of establishing astronomy departments affiliated to the Universities and in the long run to become deemed universities themselves.
Abstract: There are 16 public observatories and 5 planetaria that are permanently open to the public in Slovakia. These institutions offer different programs depending on their technical facility. This paper will show each observatory and planetarium with its main orientation in public education and also its scientific activities.

There is a network of 16 public observatories and 6 planetaria in Slovakia (in Nitra there is a detached place of work of the Slovak Central Observatory). Besides these there are also observatories that are wholly scientific, as in Stara Lesna and near Bratislava in Modra (the observatory of Komenky University in Bratislava).

The main role of the public observatories is to inform the wide public about the latest news on astronomy and related sciences. They also make it possible to provide public observations. Each observatory also participates in a scientific program according to its observing conditions and instrumental facility.

Observatories in eastern part of Slovakia are oriented to variable star observations. Observatories in Michalovce, Humenne, Presov and Svidnik participate in this program. They are well-equipped for this work and many of their staff specialize in variable stars. At present a new observation point is being finished in Humenné in co-operation with Odessa University; it will be a regional scientific and tutorial centre for observations on a high level.

The observatories in central part of Slovakia—Banska Bystrica, Ziar nad Hronom, Rimavská Sobota, Zilina, and Partizanske—are oriented to work on interplanetary matter. The staff of these observatories concentrates on the results of meteor shower expeditions all over Slovakia. During past years Slovakia became one of the most successfully organized countries in IMO. Another successful part of the observing program in the field of interplanetary matter is grazing occultations. We took in a number of such observations not only in Slovakia but also in Poland, with very good results.

The observatories on the west part of Slovakia—Hurbanovo and Hlohovec—are oriented to whole-disk studies of the Sun. The observatory in Hurbanovo provides research of the corona, quick changes on the photosphere, and Earth-Sun relations. This is complemented by research on sunspots using the non-linear systems in Hlohovec observatory, where photometric observation of variable stars by a 60cm-mirror telescope is also performed.

The University observatory in Modra (not accessible to the public) does very successful work in astrometry. Their program is oriented to asteroid detection. During the past few years, ten asteroids were found in this observatory.

There are six planetaria in Slovakia. Planetaria in Hurbanovo, Hlohovec, Ziar nad Hronom, and Presov are a part of observatories, and one planetarium in Kosice is part of a leisure centre and another is part of a Science Museum.

Projectors used in planetaria:

- Zeiss Jena ZKP2 in 10m domes: Hlohovec, Ziar nad Hronom, Presov and Kosice's Centre of leisure time.
- Zeiss Jena ZKP1 in 6m and 8m domes: Hurbanovo and Scientific Museum in Kosice.

An important part of the activities of the public observatories and planetaria are the organisation seminars for professional and amateur astronomers. The astronomers can present their work and discuss their research experience. Astronomical camps are organised mainly for young amateur astronomers, where young people can gain basic experience in observations and working–out the observing material.

A competition in astronomy is very popular among students. This competition is organised by Slovak Central Observatory in Hurbanovo and around 500 young people take part in this competition annually. The competition is organised in cooperation with all public observatories, so this way it is open for everybody in Slovakia. The main aim of competition is to let young people to present their knowledge of astronomy and motivate them for more work in this field.
PLANETARIA AND OBSERVATORIES IN SLOVAK REPUBLIC
The planetarium and its connection with practical observations as it works in the Slovak Central Observatory in Hurbanovo

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Abstract: The Slovak Central Observatory has many years of experience in the popularisation of astronomy. There is a qualification study in astronomy at the Observatory. The planetarium is used before students’ first practical observations. At first the beginning collaborator observers of the Observatory are introduced to a field of observations in the planetarium. It is good too for visitors to connect the program in planetarium with practical observation. Through the night the visitors to the observatory usually observe planets and some bright deep sky objects. During day they mainly observe the Sun’s surface. Experience shows that visitors remember the program much more when it is connected with observation. They can feel the direct touch of a real universe, not only a virtual space.

At first let me briefly introduce the Slovak Central Observatory in Hurbanovo. Nicolaus Konkoly Thege founded it in 1871 as a private observatory. Konkoly Thege was a skilled man in technique, and he liked natural science, especially astronomy. He had good contacts with active astronomers in Europe and thanks to them he built up a well-equipped astronomical observatory. From the beginning the observation program was oriented to the Sun and interplanetary matter. During next 20 years he managed to build up a geophysical and meteorological observatory on his site too. In the year 1899 the observatory became a state observatory. Through 130 years, many notable Slovak, Czech, and Hungarian astronomers worked in the observatory in Hurbanovo. A 60-cm refractor was installed in 1924 and was one of the biggest telescopes in Europe at that time. With this telescope the first photographic observation of Pluto was made in 1930. In 1969 the observatory in Hurbanovo became the Slovak Central Observatory as a methodical centre for the network of 15 other public observatories and 6 planetaria in Slovakia.

At the present the activities of the Slovak Central Observatory are divided into 4 parts.

1. The scientific department is oriented to observation of the Sun with its instrumental facility. It means the observation of surface of the Sun (over 300 observations a year), spectral analysis of the Sun’s surface, flare observation, and corona observation during a total eclipse of the Sun.

2. The editorial department issues the magazine Kozmos six times a year, the annual Astronomy Yearbook, an Astronomical Calendar, and textbooks on the topic of astronomy.

3. An optical and mechanical workroom is oriented to fabricate 120-mm mirror telescopes of Newtonian type and to repair astronomical instruments.

4. The planetarium is concerned with the popularisation of astronomy and astronomy education. This is the part of activities I will introduce to you here.

The planetarium in the Slovak Central Observatory was installed in 1983. A ZKPI projector (made in Zeiss Jena) was installed under a 6-m dome. From its beginning the activity in the planetarium was oriented to direct lectures for visitors. The programs are provided by skilled lecturers who have a lot of experience with astronomy and with communication in the popularisation of astronomy and collateral science. Our observatory is mainly oriented to educate young people between 10 and 18 years old. 70% of our visitors are between these age limits. Lectures under dome of the planetarium are adapted to the audience. The direct speech helps us to communicate with the people about topics they are interested in.

One of the most important connections between the planetarium and practical observation is in our scholarly activities. There is a qualification study in astronomy at the Slovak Central Observatory. This study is for people who have an interest in astronomy and would like to increase their knowledge in the field, but do not have an interest in university level knowledge. Our observatory gives students good conditions to study the whole width of astronomy. For this aim we use all astronomical instruments from the smallest telescope through the planetarium to our 60-cm coelostat for sun observation. It is very important for students to become familiar with constellations that are fundamental for a good
orientation to the sky.

The planetarium helps us to explain the basic laws of spherical mechanics and spherical astronomy. It is easy to explain the motion of heavenly bodies and the coordinate systems. After these lectures under dome of the planetarium, the students easily manage practical observation. They all go through basic observations made possible by our technical facility (variable stars, occultation, asteroids by CCD, sun observation...) and evaluate them. The orientation of this study is for amateur astronomers who want to know the secrets of the universe and mainly wish to observe the heavenly bodies not only for their pleasure but also for the basic scientific program suitable for amateurs with relatively simply techniques.

Another part of the activities of the Slovak Central Observatory is cooperation with so-called amateur astronomers who are interested in astronomy. At the present there are 15 young people who regularly provide observations under leadership of our workers and use the techniques of the Slovak Central Observatory. Their observations are oriented mainly to meteor showers, variable stars, and occultations. As you can see, it is necessary to have a good orientation to the sky to be successful in this part of astronomy. This team is regularly filled up with young people from 15 to 17 years of age. The first connection of these people with our observatory is a planetarium. Therefore we have prepared a program of basic introduction to the sky. They can obtain a basic knowledge of the orientation to the night sky (which means to be familiar with all constellations necessary for basic observations).

After successful handling of this part of practical astronomy, new members approach their first own observations of variable stars or occultations. It is really good to use the planetarium for this aim, because there is no restriction of bad weather such as cloudy skies, freezing, or bright moonlight. One of the most important parts of our contributors' work is to observe meteor showers. The first part of visual observations takes place in the lectures in the planetarium. Under the virtual sky, each person of a group of new observers has to become familiar with the observing field and reference stars. After this course, the new observing group could have some successful results from observations. It is good to compare their results. Usually we have two groups of observers of meteoric showers: one consists of experienced observers and the other of beginners not too far from each other, so the comparison is rather good. Our experience says that the new group of observers is almost as good as the skilled observers and their results are very usable in the final observations.

Our observatory has nearly 15 000 visitors yearly who visit mainly for the planetarium. 80% of our visitors are students of primary or secondary schools. For excursions we have built a screenplay that basically introduces the whole field of astronomy. As I maintained, we use a small 6-m planetarium. This is one of the main reasons why we prefer direct contact with our visitors. In this way we can utilise interaction between a lecturer and listeners. It is easy to adapt the lecture to the level of the age and knowledge of listeners. Our experience says that the quantity of information about the sky does not matter. There is a problem of understanding of basic notions. It is much more comfortable to explain the abstract problems of the evolution of the universe to older listeners than to the younger ones. But the basic structure of explanation about constellations and solar system is the same for everybody. Using the virtual sky, we can show to the people what they can observe by the naked eye on the real sky.

Sometimes it could seem that a small planetarium such as we use is an archaic instrument of explanation of the universe in comparison with some new projectors and multimedia computers. But we think that the main role of the planetarium is to inspire people for own observation that could be a step toward their understanding of science. Each lecturer under the dome of our planetarium tries to give the most information he can to the listeners. Unfortunately it is just a virtual sky, so they could believe it or not. This is why we started to provide public observations for most visitors.

The first look through the telescope is sometimes much more memorable than our explanation in the planetarium. During the day we show our visitors the surface of the Sun by projection with a 10-cm lance telescope. The visitors are often surprised that the Sun is not only a shining object, but it has a structure on the surface as it is presented on the pictures. At night the situation with public observations is better because a lecturer has a good scale of the object he can show. A lot of people realise just after the first observation that pictures from telescopes presented in magazines or in TV are not fantasy but that they have a real basis. The telescope is a real touch with science for people whereas a planetarium is often just a movie. Our experience says that our visitors remember one glance through the telescope much more than the whole program in our planetarium.

In conclusion I can recommend to everybody to use the telescope wherever the conditions for it are right. The connection between explanation in planetarium and practical observation helps people to understand the meaning of astronomy as a science and better retain the basic astronomical events.
PAPER PLATE EDUCATION:
ACTIVITY: COMMUNICATING WITH ISS

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Editor's note: This activity was presented as a live lesson during the conference to an audience of about 200 students in the Planetarium.

Abstract: Using simple paper plates, students will simulate the use of TDRSS satellites in communicating with the International Space Station. Included are web sites of more paper plate lesson plans, and background information about satellites and the ISS.

This paper plate activity is adapted from one developed by Star Station One™ folks at Bishop Museum in Hawai'i. It is listed on the web at the site: http://analyzer.depaul.edu/paperplate/

You’ll need twelve paper plates, six each of two colors, or six paper plates that are a different color on the front and back (the birthday party plates in the dollar store work just fine). I have used the "dessert size" and the "full size" plates; either one has been successful.

You’ll also need an image of the International Space Station (which can be downloaded from http://spaceflight.nasa.gov—hunt through the Shuttle mission information for the latest images).

Refresh your memory of communications satellites at the web site http://spaceflight.nasa.gov/shuttle/reference/shuttle/reference/shuttle/reforbits/e/comm/tdrss/. And this activity requires a fair amount of space—a clear floor area of six meters by six meters works well.

I begin with an image of the ISS, showing it to the students and explaining that the station is in orbit around Earth right now, that it looks like this, and that other modules will be added over the next few years. There is a crew onboard now. The station is visible in the night sky and looks like a very small dim star. (If you go to the heavens-above.com web site, you can find out when the ISS will be visible from your back yard.) Four years from now when all the components are assembled, it will be very large, nearly 100 meters across, and will look like a big bright star.

Communication in space is "line of sight" so when the ISS is not over Texas, communication with Houston is impossible. This is demonstrated first with the image of ISS. Facing the students, I move the picture of ISS around me (ISS orbits Earth), while describing the signal traveling straight out in front of me. A student volunteer then becomes the ISS and holds two different colored paper plates (or one bi-colored plate), while I hold the same. The student faces me from a meter or so away, and we practice "communicating", the student switching the plates to match the color I am showing with my plate(s).

The ISS student then "orbits" Earth, switching plate(s) to simulate communication, and when he or she is behind me I make sure the plate colors change. The other students in the group usually laugh or give hints.

When the volunteer ISS is back at the starting point, I ask if s/he could see the plates while s/he was behind me. Usually the student says no, and I repeat the "straight line signal" information. Then I ask students how engineers could overcome the problem, and lead them to the idea that we need four communications satellites, each 36,000 km out and spaced evenly around Earth, to relay information from the ground to the space station. Four students volunteer to become those TDRSS satellites. Each holds the plate(s) and stands facing me (Earth). One is about four meters out on my right, another the same distance on my left, the third faces me, and the last is behind me (all about four meters away from "Earth").

We practice changing plate colors with the TDRSS satellites and the ISS once more; then ISS orbits Earth and watches the satellites for information when out of sight of my plates. The other students watch and comment. I ask the satellites how they knew what color to show (information may be relayed through several satellites before reaching the ISS) and we discuss that. At the end I ask the students to applaud for the volunteers (which they usually do enthusiastically).

For the presentation in the Colombo Planetarium, I added a map showing the position of the International Space Station in the night sky on April 2, 2001. The chart was from the heavens-above.org web site. We set the planetarium to that date and sky position, and discussed where to look for the station as it passed over Colombo. Hopefully the students will be able to observe the ISS passage.
USING AMATEUR ASTRONOMERS AS VOLUNTEERS TO PROMOTE AN ASTRONOMY EDUCATION OUTREACH PROGRAM

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Abstract: This is a presentation showing the effectiveness of volunteer amateur astronomers, as used in the public outreach educational program at the Santa Barbara (California USA) Museum of Natural History. The program has been running for 16 years, and has reached thousands of people at public observations, school events, and during special astronomical phenomena. The program is implemented via the Museum’s astronomy club, “The Astronomical Unit”, which is jointly sponsored by the Museum and Santa Barbara City College. The paper discusses goals, how the club differs from “traditional” astronomy clubs, club organization, training and qualifications of volunteers, and lessons learned after 16 years of public presentations. The paper discusses the necessity of understanding the audience, and the importance of having a program that is both accessible and stimulating to people whose first exposure to astronomy may be through the view of the skies that we offer.

The Astronomical Unit club

I would like to introduce you a program that we have for presenting the night sky to the public using a group of dedicated amateur astronomers. I am an amateur astronomer myself, and have been part of this program since 1984.

The Santa Barbara Museum of Natural History was founded in 1925. It is an institution funded entirely by private donations. Santa Barbara is a coastal community in California—it shares with Colombo a western shoreline and we have the skies that come with a low elevation and coastal haze.

In 1984, Mr. Fred Marschak of Santa Barbara City College and the Museum formed a coalition to foster astronomy education in the community. The Astronomical Unit was established, as a club that would sponsor public outreaches for astronomical observations. The club currently has 250 members, including families, students, and single members, both men and women. The club is jointly sponsored by Santa Barbara City College and the Museum of Natural History.

The organizational goal is to educate people about astronomy by showing them the skies. The club officers’ duties are traditional in most cases; because of our special function they have duties that relate to the club’s outreach functions. The museum Director is Dr. Karl Hutterer. The club advisor is Mr. Steve Schmidt, who is an astronomy instructor at Santa Barbara City College. The current club president is Tony Galvan, and he, with the other officers coordinate our general activities. Our Outreach Coordinator, Edgar Del Campo, coordinates our public telescope observation activities. This is our club’s most important activity, and the reason for the club’s existence; to engage in astronomy outreach activities.

Outreach activities

So, what is an “Outreach Activity”? We do what we advertise as “Star Parties”. We set up telescopes at the museum, and almost any other place we can, and invite the public to have a look.

We have Star Parties:

- at public telescope observations on site at the Natural History Museum
- at Elderhostels–homes for the aged
- at schools—for Science Nights, for special gifted students programs etc. (Gifted Students are exceptionally bright students that attend special programs geared to students with higher IQs
- on National Astronomy Day we do solar observations (and radio observations using a small radio telescope one of our members has built) and sometimes observe Venus or Jupiter in the daytime!
- on special astronomical events such as eclipses, comets, occultations, etc.
What are the qualifications of the volunteers? Who do we have at these outreach activities?

We accommodate all sorts of skill levels. One of greatest the obstacles we have to overcome is the “fear level” of novice observers that might otherwise be interested in doing a live telescope show, but are intimidated by the possibility of being asked questions they cannot answer. The fact is that our experience has shown that a high level of scientific knowledge is not required or expected by the public. What is required is a basic knowledge of how the solar system works, what its relative scale is to the Milky Way galaxy, and understanding of very basic cosmology (lots of galaxies with huge areas of relatively empty space). The volunteers can explain concepts such as distance measurement by light years, colors of stars, and basic celestial mechanics. In fact, many of our volunteers have a great deal of knowledge from college level courses and self study.

We have recently reached a point where we have an almost overwhelming demand for our services. In the last year the astronomy program reached over 15,000 people. The Astronomical Unit participated in many events showing the skies to the public. About 5,000 pairs of eyes saw the skies through our telescopes last year, many seeing the wonders of the universe for the very first time.

Year 2000 Total Astronomy Program Attendance figures:

- Public: 5,641
- School: 5,769
- AU Meetings: 394
- Star Parties: 579
- Outreach: 3,071
- Totals: 15,454

How does a typical outreach observing session work? We arrive about an hour before the observing session is to start. We set up red marker lights, explanatory posters, information sheets, data cards for the observers, step stools for children, and a ticket table. Members either use their own equipment or one of the instruments owned by the museum.

We informally work out between us who will be observing which object, generally based on the skill of the observers, and the suitability of the instrument for a particular object. The goal is always to provide a variety of objects that are both interesting to the public as well as educational. For instance, the wide field telescopes or large binoculars will view the Pleiades, midsized Newtonians and Schmidt Cassegrains (SC) might look at bright gaseous nebulae and long focus refractors and SC’s at planets or the Moon.

It is worth saying here that while many experienced observers are quite bored with the Moon, a member of the public that has never seen the Moon through a telescope will be fascinated and astounded.

Also, it bears saying that in sixteen years of public outreach activities, we have never had any kind of problem with the public or with school groups, while on public streets downtown or at the museum.

What about equipment? What if a group has limited equipment and a limited budget? Remember that almost any telescope, of quality construction in capable hands will show far more than the naked eye. Small 60mm aperture telescopes of good quality with a decent eyepiece will show things that the public has never before. The “real” sky is an exciting thing to see after a planetarium show. Even binoculars on a steady mount are excellent for showing the sky.

How do we promote the club’s activities? We send announcements of our activities to newspapers, and the local television and radio stations. We make “cold” calls to schools; after a while, we no longer need to call, we get called!

What are we doing in the future? One of our projects is to address accessibility concerns to our public observations. The United States has public law that requires, among other things, that all public facilities provide equivalent access for the disabled to the facility. Advances in electronic imaging may offer an excellent solution, and provide an enhanced experience for all viewers, allowing many people to look through the best instrument at the same time.

We have made a proposal for a renovation of our own observatory to accomplish this goal. We recently had a demonstration of the new Santa Barbara Instrument Group STV camera. This device allows real time CCD video imaging of deep sky objects. It is nothing short of phenomenal to watch in real time the acquisition of a deep sky image on the screen. Large monitors could be placed for easy viewing, and the effect will be breathtaking.

As a footnote, we remind ourselves of the purpose of our institution. An observatory in an institution like ours is a public facility. Research projects may take place in the facility, but the facility should be designed to accommodate public education as a primary goal.

Lessons learned

Here are some lessons learned after 16 years of public outreach activities:

* Be prepared for a wide range of knowledge from your audience—some will be experienced observers, and some will not know the basics of the solar system. Be prepared to explain simple things such as the orbits of the planets around the Sun, or explain that stars are in fact distant suns.
We have a wide range of questions and responses from members of the public, such as young people who are quite expert, and adults who are very unfamiliar with the sky.

* Remember that it is more important to get people easily to the telescopes. While experienced observers will prefer to go to a dark sky observing site out in the hills, more people will come to a session if it easy to get to.

* Show enthusiasm! During the observing sessions, don’t complain or apologize about the sky quality to visitors; if the seeing is poor, the viewer may not know unless you tell him. Try to make it a positive experience. If they are experienced viewers, they will already know if the seeing is poor.

On a recent session on New Years Eve 2001 in downtown Santa Barbara, we had very poor seeing. We were in the middle of the city, and were plagued with city lights and coastal fog. Nevertheless, we persevered, and had a very successful night. What were the subjects? Jupiter and Saturn, which shown brightly though the haze, and were the only objects visible with the naked eye. The 300+ members of the public that approached our sidewalk observing site were thrilled with the view.

* Use low powers and eyepieces that are easy to look into with high eye relief (the distance one’s eye can be from the eyepiece to see an image). Those 4mm focal length high power eyepieces are great for our own sessions, but are next to impossible for inexperienced observers to use. There have been some improvements in technology lately, but this is still a good rule of thumb.

* Establish a small cadre of experienced observers that can encourage new volunteers.

* Encourage volunteers to not be afraid to participate. Reward participation: we have an annual awards dinner and give out “stars” for various categories.

* If you have a large amount of advance publicity, be prepared for any number of visitors.

* Be mobile—be able to travel to school sites or to public areas for special events.

* Remember the goal of the activity! To show the skies to people who have never before seen them, and to promote astronomy education in the twenty-first century.
ASTRONOMY TEACHING PACKAGE OF HONG KONG SPACE MUSEUM

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Abstract: In order to provide students with more hands-on and useful activities in learning astronomy, the Space Museum has developed an Astronomy Teaching Package for Primary Schools in Hong Kong. A number of innovative activities, including a Moon Finder, a Globe, a Planet Finder and a Space Exploration Board Game etc, were created. The first three activities, together with a Star Finder and a Sun Clock, are printed on paper and are inexpensive to reproduce while useful in observations. The Space Exploration Board Game is an educational simulation game that can be played by individual groups or by the whole class inside the classroom. All activities, along with suggested teaching instructions, questions and answers on astronomy, astronomy-related poems and songs, are packed inside an easy-carrying box. This paper provides details of how these activities were developed.

Education Programs of the Museum

The Hong Kong Space Museum, since its establishment in 1980, is dedicated to the promotion of astronomy and space science in Hong Kong. It has all along been an important astronomy education center for students, and a significant proportion of local schools have been bringing their students to attend various education programs developed by the Museum.

It has been noticed that students attending our programs always come in groups under the arrangement of teachers, especially for the primary students. Teachers and school principals are influential as usually it is they who decide whether to bring the students out or not. Therefore it is more effective to provide incentives for the teachers than for students.

Although the local science syllabus has always been encouraging teachers to bring their students to the Museum by explaining all the good things behind it, many teachers are reluctant to arrange the visits because of the following:

1. They have to take away the teaching sessions of other teachers. The visit will normally take half a day and so other classes and teachers will be affected;
2. They have to collect money from the students to cover some or all of the transportation and admission fee;
3. They have to get endorsement from the students’ parents for bringing the students out of schools for the activities, and/or
4. They have to bear all the other troublesome works such as arranging tickets and transportation.

Furthermore, some teachers may consider the programs offered by the Museum either uninteresting or too similar to the existing textbook or educational television programs.

As such, we have been making our programs more attractive and unique so to outweigh these deterring factors. Some of the typical ways are:
(1) The programs provide a view of the sky that cannot be recreated in class or television;
(2) The programs provide a fun learning experience to the students;
(3) The exhibits in the Museum provide a good collection of objects and interactive experience that are not available in schools.

However, for the past ten years, attendance for the school programs basically has reached a flat level. Teachers who have brought their students to the Museum before would continue so, but those who haven’t would never come. We see a need to enhance our education services so to provide even more incentives to the teachers.

The Astronomy Teaching Package

With the revision of the primary science syllabus in 1995, the Museum and the Education Department pulled resources together to create an Astronomy Teaching Package for Primary Schools. The Package was intended to cover all topics related to astronomy and space science for primary education in Hong Kong. The educational materials which have previously been developed were revised, and new materials were designed.

After five years of work and overcoming a number of obstacles, the Package was finally completed in early 2000. It was targeted at three different levels of primary education, including junior primary, middle primary and senior primary. The Package contains the following items:

1. A Teacher Handbook divided into 8 chapters, which consists of
   (a) 30 suggested teaching guides;
   (b) 180 questions and answers;
   (c) Sun Clock construction sheets;
   (d) Moon Finder construction sheets;
   (e) Rotating Star Map construction sheets;
   (f) Globe construction sheets;
   (g) Planet Finder construction sheets; and
   (h) Poems and songs.
2. A five-episode video named “Observing the Sun”;
3. A space exploration board game named “Space Race”;
4. A Solar System game card set; and
5. A set of three posters on Space Exploration, Lunar Exploration and Solar System.

A complimentary copy was given to each primary school, while the kits’ construction sheets were distributed to each student attending the school programs in the Museum. (The printing cost for the sheets had been kept to a minimum and was well covered by the admission charge for the programs at about US$2). The Package was soon well received by the teachers and even many secondary school teachers have requested it.

The Design

1. Rotating Star Map and Sun Clock

Our first effort could be traced back to 1986 when we had made two little paper kits on these two items. We borrowed the same idea this time but have repackaged them. Materials for constructing the Sun Clock and the Star Map were confined to one or two sheets of A4 paper so to minimize the printing cost. Cardboard paper was also used to provide the rigidity so that the final products could be used in observation for at least a few years.

2. The Moon Finder

When we went over the primary science textbooks in 1993, we discovered a strange exercise. The students were asked to observe the Moon for a month and draw all the phases on paper. We believed that no primary student could complete this exercise because:

1. the Moon is above the horizon only for half of the month;
2. the Moon is appearing with the Sun for half of the month;
3. the Moon appears in the first half of the evening for half of the month and appears in the later half of the evening for the rest of the period;
4. During the period when the Moon appears in the first half of the evening, it is in the eastern direction for half of the period and the western direction for the rest;
5. Good weather conditions also form a crucial prerequisite for successful observation.

Obviously those students who tried to complete this exercise could face a lot of frustrations. This is a typical example of a textbook writer who does not try out the whole exercise himself but just thinks that the results are straightforward. As such, something that can help the students to observe the Moon will enhance their sense of achievement. This is what we have in mind in developing the Moon Finder. This kit helps in the following ways:

1. The students will visualize the cyclic nature of the changes of phases of the Moon;
2. The students will know when and in what direction to look for the Moon;
3. The students will further find out that the Moon will sometimes appear in the sky with the Sun, and that they can find the Moon even in daytime.
In designing the Moon Finder, there are a number of further considerations:

(1) It is relatively easy for the Chinese people to find the lunar day of the month as the days usually appear in the Chinese Calendar. But for other ethnic groups, they would have the difficulties in identifying the lunar days;

(2) To facilitate other ethnic groups to use the Finder, we included a table showing the conversion between the common calendar date and the first day of lunar day for 10 years; and

(3) It will be better for the final product to be able to stand alone so that it can be used as a decoration, say on the desks. The angle of the Finder is also determined by the latitude of Hong Kong, which is 22.5 degrees north.

3. The Planet Finder

The Sun Clock, the Moon Finder, and the Star Map are more related to the junior primary syllabus. We have been trying to design some similar kits suitable for senior primary students. Many possibilities have been tried and it was not until early 1999 that we came up with the idea of a Planet Finder. In fact, an intermediate idea was turned into another product which we will discuss later. We found that the following issues are of interest:

(1) For an occasional star observer, is there any simple way for him to know what the bright objects in the sky of a certain day are? Stars can be identified using a star map, but how about planets?

(2) We may use a monthly star chart with the planet positions to identify the planets, or we can use a computer program to help us to find the solution. However, do we have other handy ways?

Our solution to this problem is our specially designed Planet Finder. It actually gives a bird’s eye view of the first six planets of our Solar System. The trick is to encode the relative heliocentric positional information of the planets so that we can know immediately the relative positions of the six planets on a certain day. Each planet will take up one disk that can rotate on top of the others. A window with dates will allow us to rotate the disk to a proper position. We can then do a simple transformation to convert the heliocentric positions into geocentric positions, and tell roughly where the planets are in the sky. Some problems were encountered during the design stage and we will discuss them here with our solutions:

(1) We selected only the disks for the five major planets together with that for the Earth. This would allow the students to find the positions of all planets that could be seen with the naked eye;

(2) If the paths of the selected planets were drawn to scale, the whole system would become too big to fit into a handy size with recognizable information. So we decided to follow the normal distance scale for Mercury to Mars, and a reduced distance scale for Jupiter and Saturn;

(3) The positions of the planets were calculated directly using the Ephemeris Generator program of NASA and were therefore free from propagating errors;

(4) We also gave a life span of ten years to the Planet Finder, i.e., it should be able to indicate the positions of the planets for ten years;

(5) In order to simplify the rotating mechanism, we decided to use relative positioning for the planets. For example, the information for Saturn was printed on the Jupiter disk, and this represented the relative position between Saturn and Jupiter in ten years;

(6) After some trials and errors, we found that we have to plot the position of the planets for only the 1st, 11th and 21st of each month;

(7) Within ten years, except for the relative positions of Saturn and Jupiter, all planets had made more than one turn. In order to allow the information to be displayed continuously without a break, the dates were calibrated along spirals;

(8) Even with the spirals, Mercury would have made too many turns in ten years to be presented clearly. Therefore, we represented the dates by numbers and included the data in a table for look-up.

Similar to the Moon Finder, we decided to make the whole Planet Finder standing on its own. We believed that this Planet Finder would help the students to understand why we had to change from a geocentric coordinate system to a heliocentric coordinate system for the study of planets.

4. The Globe

In Hong Kong, astronomy and space science appear only in the junior and senior primary curriculum, but not in the middle one. There is a curriculum on the Earth in mid primary, so we decided to develop a school program along it. Instead of producing a separate school show, we considered the Omnimax film *The Greatest Places* produced by Science Museum of Minnesota a suitable alternative. When identifying the type of construction kit, a globe is a natural solution.

We had tried a number of globe designs but most of them required a lot of cutting and gluing which we thought not easy to be handled by primary students. Furthermore, the globe so produced was not very smooth. We finally were able to locate a suitable design and modify it to be self-interlocking.
This globe is intended for primary students of approximately age ten. On one occasion we gave the paper kit to a five-year-old girl. With very few instructions she was able to make the globe. Judging from how she enjoyed it, we know that this design would be very successful.

Apart from studying Earth's rotation, seasons, and countries, we hoped to make the Globe useful as well for topics beyond the syllabus. The activities suggested from *The Greatest Places* about finding the place on the other side of the Earth underneath our feet gave us the inspiration. Other activities were also planned, such as estimating the time required to travel from one country to the other and identifying the countries that we might fly over. As people nowadays have more and more opportunity for international travel, they would find these kinds of activities brought along by the simple and inexpensive paper kit interesting.

5. The Solar System Card Game

As mentioned earlier, an idea that arose during the design of the Planet Finder became a separate activity, which was the Solar System Card Game. This activity was designed for the senior primary students. There are many objects in our Solar System. Except for the major ones, students are not expected to memorize all these information. However, some concepts are considered important and should be known by the students:

1. the major group of members of our Solar System;
2. the relationship between the various members;
3. the size of the various members;
4. the concept of distances; and
5. the concept of discovery history.

A set of playing cards showing pictures of the Solar System members, their sizes, discovery histories, and some orbital parameters quickly came to our mind. The next problem was how to make students to have fun with the cards rather than being bombarded by lots of numerical information. Our solution was to design a game of comparison. Students could use the cards to compare the various elements, and hopefully through this they could get a better idea of each member of our Solar System.

During the design of this game, we made a variation from normal card games that allowed single comparison only. The players would need to throw dice to determine what to compare, and even which categories were to be compared had to be determined during the game.

6. The Space Exploration Board Game

We once found a major mistake in an important consultation document on science. There was a statement mentioning that in order to minimize air friction, a spacecraft had to be designed into a streamline shape. To us the mistake is obvious, but for those with a good science but no space science knowledge can easily mix up spacecraft and rocket. We find it is necessary to help students to understand the differences.

With a similar thinking as in the Solar System game, the idea of having a set of cards on the history of space exploration came to our mind. Defining the scope of information for the cards was not difficult. The problem was what sort of game should we pursue to make playing of these cards fun. A comparison game similar to that of the Solar System Card Game was not possible, as there was not sufficient information for the comparison and many of cards, such as those about an astronaut and a spacecraft, could hardly be compared. A matching game, like matching the members of the family, had also been considered and again it was not fruitful.

Finally a simulation game came to our mind. We were talking about the various elements of space exploration and it was therefore educational for the players to follow the steps of scientists in conducting space exploration. More importantly the players should be exposed to the danger of losing rockets and spacecraft which meant losing their investment in the space race. After the game, the players should have a very good idea of the various processes of space exploration.

Once the idea was conceived, the rest of the work became relatively straightforward. The only difficulty was that we had to find some adults and young children to play the beta version of the game so to fine-tune the various parameters. Later on, a group of primary students was invited to try the game in the class under the supervision of their teacher, and the result was very encouraging.

When playing the beta version of the game, some people commented that the game instruction was too long. It seemed that people having such a feedback were those who had never played any simulation games before. In contrast, those who had had such an experience in general felt more comfortable.

Moreover, some felt that the concept of the game was quite confusing. Our observation was that this was due to an intrinsic fact of the game: the whole space exploration process was complicated. If the players did not have a good understanding of the various elements of the space exploration process, they needed to learn some before they could enjoy the game.
For the group of primary students doing the test, their teacher started the class by an introduction of the various elements of space exploration. As a result although the students knew very little about this topic before, they felt the game very enjoyable. Some students even asked whether the game was available for sale right after they had finished it. This result was definitely encouraging.

We had prepared the following to help the teachers to teach the topic:

(1) A large durable game sheet that can be held onto the white board by magnets;
(2) The checkers carried magnets on the back so that they could stick onto the white board as well;
(3) A video was produced to give the students an introduction to space exploration.

7. Video on Observing the Sun

This part of teaching began with a newspaper cutting about a real complaint from a man who observed a partial solar eclipse following a traditional method written by another newspaper. After observing the whole eclipse process, the man felt his eyes hurt. In order to explain the danger of solar observation, we produced a five-episode video. Each episode lasted for six to nine minutes and the story was about a detective trying to help a boy to find out the danger of solar observation. The five parts were:

(1) Who had done it? – the heat collected under a magnifying glass is great enough to burn the paper;
(2) When did it happen? – the effect of sunburn might not be noticeable immediately;
(3) The invisible killer – there was dangerous radiation that the eyes could not see;
(4) Catching the killer – made a pin-hole box or used projection method to observe the Sun; and
(5) Seeing the Sun again – more information about the Sun.

In observational astronomy, some of the most common but dangerous misconceptions involve solar observation, especially during the period of eclipses. Many traditional observation techniques are actually dangerous. The aim of the video is to ensure that the students can understand the danger of solar observation using sunburn as an example.

8. Suggested Teaching Guides

As most primary science teachers in Hong Kong did not have a proper training in astronomy, they require much guidance in teaching astronomy. In fact, it was reported that a number of teachers teach science in a way similar to that in teaching literature. They did not allow the students to ask questions and some even did not intend to explain the phenomena.

We considered these teaching guides able to help the teachers to develop more confidence in teaching. The Museum also runs workshops to help them in using the Teaching Package.

9. Questions and Answers

Having the chances of discussing with front line teachers and reading primary science textbooks, it is interesting to know that how easy a mistake on astronomy and space science can be made by teachers and textbook writers. As teachers in Hong Kong in general had no formal training in astronomy, it was therefore necessary to provide more background knowledge to them.

Some 180 questions were written. It is interesting to note that some of the questions seemed to be unimportant but they were actually being raised by teachers or they were answered wrongly in textbooks.

The answers to these questions adopted a three-tier approach. The first tier is a simple answer. The second tier provides more details. The third tier is for those people who want to know more about that topic.

10. Poems, Songs and Other Information

We wanted to demonstrate that astronomy is not just a science, but that it also exists in other disciplines. In our literature many poems were written with careful observation of the celestial phenomena. We therefore selected a series of poems for the appreciation by students.

The songs composed for the past Museum programs were also included.

A number of posters were designed. They include:

(1) Space exploration;
(2) Lunar exploration; and
(3) Solar System.
The Package also includes information on Web Pages related to astronomy and space exploration, and educational services available at the Hong Kong Space Museum.

**The Ways Ahead**

To attract more teachers to bring their students to the Museum, more incentives should be explored. The effectiveness of various activities should be further studied. New activities should be added if they are considered good.

One area that the Hong Kong Space Museum has been working on is the development of interactive school shows. One such school show has already been developed but its full potential, especially on the area of understanding how much the students have learnt, still needs to be studied. We expect that some time later when teachers bring their students to the Museum, our system should be able to analyze the learning pattern of each individual student, and give the analysis to the teacher plus the individual result to each student.

Some of the problems as discussed in the second section of this paper cannot be solved by this Teaching Package or the Museum. Some proposals have been made to the Education Department for a curriculum reform in Hong Kong. The formal education sector should recognize that museum education is an important part, not just a supplementary part, of the education system. Students should be encouraged to visit museums as far as possible. Reasonable resources should be allocated to schools for arranging students to make use of the museums. Schools should have at least half a day in each week without any specific lessons to arrange out-of-school activities such as museum visits or field trips. Suitable accounting procedures should be made available to simplify the workload of teachers in organizing such activities.