1ST INTERNATIONAL OLYMPIAD IN ASTRONOMY AND ASTROPHYSICS

Aniket Sule[1,#], Willie S. M. Yong[2], Radu Zapotinschi[3], Grzegorz Stachowski[4]

[1]Homi Bhabha Centre for Science Education, (TIFR), V. N. Purav, Marg, Mankhurd, Mumbai, 400088, India.
[2] Apartment Block 551, AMK Avenue 10, No 14 - 2224 S(560551) SINGAPORE
[3] Astronomy and Mechanics Department, University of Cluj-Napoca, Kogalniceanu 1, Romania.
[4] Mt. Suhora Astronomical Observatory, Krakow Pedagogical University, ul. Podchorazych 2, 30-084 Krakow, Poland

Abstract:

We report on the 1st International Olympiad in Astronomy and Astrophysics (IOAA) held in Chiang Mai, Thailand from November 30th to December 9th, 2007. We discuss the philosophy behind the initiative, the need for such activities and the execution of the first IOAA in Thailand. To give readers the flavor of the Olympiad, we discuss a challenging problem posed to the students during the Olympiad and compare responses to the same, as given by the students of the Indian, Singaporean, Romanian and Polish teams.

1. Introduction:

Olympiad movements for various subjects are not a new concept anymore. The idea was first introduced through the International Mathematics Olympiad and the International Physics Olympiad. Over the course of time, Olympiads for other subjects like Chemistry, Biology, Earth Sciences and Informatics were also introduced. Typically, the students participating in these Olympiads are pre-university students. There are also Olympiads like the International Junior Science Olympiad, which cater to students of a relatively younger age. The philosophy behind all these competitions is the same. These Olympiads serve as a platform where students come together, not just to compete, but to interact with students from other countries and build bridges of friendship spanning nations and continents. Many of these Olympiads were started by erstwhile Soviet bloc Countries and the movement has survived and matured through the hay days of the cold war era. More than 50 countries, with representation from each continent, participate in each of these Olympiads. Thus, by and large, one can say the Olympiads have succeeded in their primary motive.

Romania and Poland have been at the forefront of the Olympiad movement from the early years. Romaniawas host to the first ever International Mathematics Olympiad in 1959 and its teams have always done well in all the science Olympiads. Singapore has been participating in various science Olympiads for more than two decades and it successfully hosted the International Physics Olympiad in 2006. Poland has run a national Astronomy Olympiad annually since 1957, and is a regular participant in the International Physics Olympiads. Comparatively, India started participating in the Olympiads very late. However, it has already hosted International Olympiads in Mathematics (1996), Chemistry

#Corresponding Author: anikets@hbcse.tifr.res.in

(2001), Astronomy (2006) and will be hosting the International Biology Olympiad in July 2008.

Astronomy is the most ancient of all the sciences. Twentieth century astronomers made unprecedented advances in our knowledge of the universe. An average young student is fascinated more by astronomy than any other science. Yet, on the Olympiad front, the astronomy situation was very glum. It took a while for the astronomy community to start an international Olympiad devoted to astronomy. In 1996, Euro-Asian Astronomical Society, based in Russia, introduced the International Astronomy Olympiad (IAO). Over the course of time, few more countries joined this Olympiad. However, unlike other Olympiads, this one was not able to attract a wide spectrum of countries. There were tentative attempts to invite those countries which have a strong base of professional as well as amateur astronomers; but they were not very successful for various reasons.

The need for a truly international Olympiad for astronomical sciences was apparent to IAO participating nations as well as others. Hence, on the initiative of Thailand, representatives from Thailand, Indonesia, Hong Kong, Iran and Poland met in Thailand a couple of years back and started working on the idea of the "International Olympiad in Astronomy and Astrophysics" (IOAA). Thailand offered to host the first IOAA with Indonesia and Iran offering to be subsequent hosts. Year 2007 also coincided with the 80th birth anniversary of the King of Thailand and Thailand decided to host IOAA in such a way that it blended nicely with the festive mood in the country.

2. First IOAA at Chiang Mai.

Chiang Mai (19^{o} N, 92^{o} W) was chosen as the host city of the 1st IOAA. Chiang Mai is an old city in the northern part of Thailand, which once served as the capital of northern Siam (as Thailand was known then). It has a large university with an active faculty of science and hosts a royal observatory on the hills surrounding the city. The dates of IOAA were announced one year early on a specially commissioned website (www.ioaa.info) as November 30th to December 9th, 2007. Invitations were sent through the Thai ministry of education to its counterparts in the various countries. In all twenty-one countries from three different continents participated in the 1st IOAA. The IOAA rules clearly restricted each team to a maximum of five pre-university students, accompanied by one or two team leaders. The team leaders could be either professional astronomers or astronomy educators. IOAA introduced a system of official team rankings. This feature is unique to IOAA and to be eligible for a place in the ranking table, a minimum of three students were required to participate. Most countries sent a full contingent of five students; few like India only sent three and there were four countries with only two students each.

2.1 Schedule

The opening ceremony took place on 1st December at the Chiang Mai University with an Olympic style parade of the teams. The students and the team leaders were informed that all the students would be isolated from the team leaders from the end of the opening ceremony until the end of the last examination. To nullify chances of any unfair practices, students were told to deposit their mobiles phones and laptops with either their team leaders or their student guides. Student guides is a concept common to all Olympiads where each team is allotted a local student as their guide and the point of contact in the absence of the team leaders. However, no restrictions were put on the team leaders.

Opening Ceremony of 1st IOAA (Photo Courtesy: Official IOAA photographs)

The schedule for IOAA had the right blend of academic and fun elements. Excursions to local attractions such as the night safari, golden pagoda, highest mountain in Thailand, royal horticulture garden and elephant training camp were arranged for the students as well as team leaders. The students were taken to the "Study Centre for Sufficient Economy" to showcase Thailand's economic initiatives. After all the rounds of examinations, on the evening of the 5th of December, the students and leaders joined organizers and other citizens of Chiang Mai for birthday celebrations of the King of Thailand.

The closing ceremony was held on 8th December in the presence of the Thai minister of education. All students were awarded a certificate of participation. Better performing students were rewarded with Gold, Silver and Bronze medals and honourable mentions. Special prizes were awarded to some students for exceptional performances. A closing dinner in traditional Lanna (Northern Thai people) style was arranged for all the participants in the campus of the Chiang Mai University.

2.2 The competition

The competition consisted of 2 rounds: theoretical and experimental. For convenience, the experimental component was subdivided into two parts, with one examination testing knowledge of the night sky and the other examination focusing on data analysis skills.

International Jury Meeting (Photo Courtesy: Official IOAA photographs)

The first round was the sky observation round. Students were provided with a thin, hollow PVC tube mounted on a polar mount as a pointing device and a 7x50 binocular for observing deep sky objects. Questions ranged from pointing the tube to the approximate position of the vernal equinox to drawing the shape of the Andromeda galaxy as seen through the binocular.

The second round was the data analysis round. Three questions were posed to the students. One involved identifying the Galilean moons of Jupiter by observing a computer simulation, the second asked the phase of the moon on Einstein's date of birth (14^{th} March 1879) using pictures of a few moon phases captured in June 2006. The third problem was, arguably, the best problem posed in the Olympiad. We will discuss this problem at length in the next section.

The theoretical round was the last one. It had fifteen short and three long questions covering the entire spectrum of astronomical concepts from positional astronomy and Kepler's laws to interacting binaries and gravitational lensing. In accordance with the statues, the problems were designed in such a way that a standard solution to any problem would not involve calculus.

The total duration of the theoretical round was five hours and that of the data analysis round was three hours. Every student was given a time of 40 minutes for the observation round.

2.3 Team leader duties during the Olympiad

After the opening ceremony, the team leaders gathered for the first international board meeting. The statutes of the IOAA, as devised in the conception meeting of the IOAA, were ratified by the international board. The only point of discussion was the system of team rankings. As per the proposed system, the three best scores from the theoretical round were to be added to the three best scores from the experimental round for each team. The total of these scores were to be compared to decide the ranking of the teams. Some countries felt that in this particular form, the system can be exploited by sending a team of specialists (students who are good in only theory or only experiments), resulting in a high rank for the country but relatively lower medal tally. A formal proposal to revise the rules in this regard was put forward by team leaders from India and will be discussed at the next IOAA.

Questions for the competition were shown to the international jury comprising all the team leaders on the nights prior to each round. The questions and their solutions were discussed at length in these meetings to make the questions as precise and as competitive as possible. Open and thorough discussions of all problems allowed all team leaders – experienced professionals in Astronomy education – to make an important contribution in setting the level of this competition as well as indicating the expectations for future editions. It was generally agreed that at this level, one should not aim to merely test students' knowledge, but rather the way they are capable of using their knowledge in a creative way. It was deemed desirable to put students in situations as close as possible to those they will encounter in the future as professional astronomers. After the English version of each question was approved by the jury, leaders from non-English speaking countries translated the question paper to their native languages.

The system also led to a few interesting experiences. At the time of the translation of the observation round, the jury agreed to the questions and they were duly translated. Late in the night when only a few leaders were left in the room, two of us (RZ and AS) realized that one question, which asked students to point to the "brightest star in the great square lying in the constellation of Pegasus", was ambiguous. The ambiguity arose because, as per the IAU convention, the brightest of the four corner stars of the great square is technically part of the Andromeda constellation. At that point all team leaders were called back for discussion from their hotel rooms and the wording of the question was changed to remove the ambiguity. A similar situation also arose while discussing the theoretical round problems.

Students taking the Data Analysis test (Photo Courtesy: Official IOAA photographs)

The approved statutes of the IOAA stated that the standard solution to any problem should not involve calculus. On the other hand, all the proposed long problems in the theoretical round, including (as we saw later) the spare/reserve problem used differentiation in their solutions. The way out of this dilemma was ingeniously found by Willie Yong. He suggested that all differential operators $\mathrm{d}f/\mathrm{d}x$ should be replaced by small difference approximations ($\delta f/\delta x$) and the students should be given the binomial expansion for the related functions approximated for small increments. In fact, in a way that meant reinventing calculus. We had however the pleasant surprise to see that some of our students had done exactly that! Problems were solved almost perfectly, without using calculus at all – only in later discussions it became apparent to the students that what they had done was in fact differentiation. Most of the team leaders agreed that in future statutes should be changed such that the use of basic calculus would be allowed.

The third task for the team leaders was to grade their own team's papers. Most of the questions were designed in such a way that student's answers were readable to local juries from Thailand, i.e. primarily answers involved numerical values and equations, which are generally written using the Greco-Roman character set and Arabic numerals. However, there is always a possibility of the local jury not understanding the solution presented by the student because of language problems or some non standard method used by the student. To avoid such problems, team leaders were presented a photocopy of their own team's answer sheets. While the local juries graded the original answer sheets, team leaders graded using the photocopies. Team leaders then compared their grading with that of the local jury and final marks for each student were agreed upon.

On the 7th of December team leaders met for the second international board meeting. The results for the IOAA were presented to the board and were duly ratified. The board elected Prof. Boonrucksar Soonthorntum of Thailand as the president and Dr. Chatief Kunjaya of Indonesia as the secretary of the IOAA international committee, in recognition of their efforts to bring the IOAA to reality. Many participating countries showed enthusiasm to host an IOAA in the future and a list of probable future hosts was drawn up. As per the schedule, the 2nd IOAA will take place in Bandung, Indonesia, in August 2008 and the 3rd IOAA will be hosted by Iran in 2009. As the host of IAU's general assembly in 2009, Brazil showed a lot of interest in hosting the IOAA at the same time in Brazil with the possibility of linking it with the IAU general assembly programmes. However, the board decided in favour of Iran to honour a prior commitment made to Iran, by the initiators of IOAA, in the pre-IOAA meetings.

3. Data Analysis Round: Question Number 3

As mentioned before, the third question was the best question posed in the competition. We discuss the problem and its solution at length here (see Box 1).

The question was followed by a table of data which ran six A4 size pages in small font. It specified R.A. and Dec. for four unknown objects A, B, C and D for each day from Jan. 1 to Dec. 31 for some unknown year. A few lines of the data are shown below as a sample (see Table 1).

Question:

A set of data containing the apparent positions of 4 Solar System objects over a period of 1 calendar year is given in Table 1. Show your method of data analysis carefully and answer the following questions.

(a) Put the letters A, B, C and D beside the appropriate objects on the answer sheet. **(2 pts)**

(b) During the period of observation, which object could be observed for the longest duration at night time? **(1 pt)**

(c) What was the date corresponding to the situation in (b)? **(1 pt)**

(d) Assuming the orbits are coplanar (lie on the same plane) and circular, indicate the positions of the four objects and the Earth on the date in (c), in the orbit diagram provided in your answer sheet. The answer (sheet) must show one of the objects as the Sun at the centre of the Solar System. Other objects including the Earth must be specified together with the correct values of elongation on that date. **(4 pts)**

Location of observer: Latitude : N 18° 47' 00.0"
Longitude : E 98° 59' 00.0"

Box 1. Question 3.

Date	Object A						Object B						Object C						Object D					
	R.A.			Dec.			R.A.			Dec.			R.A.			Dec.			R.A.			Dec.		
	h	m	s	°	'	"	h	m	s	°	'	"	h	m	s	°	'	"	h	m	s	°	'	"
Mar 20	23	56	13	- 0	24	44	8	44	22	+19	0	41	21	32	45	-14	47	50	18	41	50	-23	27	38
21	23	59	51	- 0	1	1	8	44	10	+19	1	22	21	37	30	-14	28	4	18	44	35	-23	26	3
22	0	3	30	+0	22	40	8	44	0	+19	2	0	21	42	14	-14	7	53	18	47	20	-23	24	19
23	0	7	9	+0	46	21	8	43	50	+19	2	35	21	46	58	-13	47	18	18	50	4	-23	22	26
24	0	10	47	+1	10	0	8	43	41	+19	3	7	21	51	40	-13	26	20	18	52	49	-23	20	23
25	0	14	26	+1	33	38	8	43	33	+19	3	36	21	56	22	-13	4	58	18	55	33	-23	18	10
26	0	18	4	+1	57	13	8	43	25	+19	4	2	22	1	3	-12	43	15	18	58	17	-23	15	49
27	0	21	42	+2	20	47	8	43	18	+19	4	25	22	5	44	-12	21	9	19	1	1	-23	13	18
28	0	25	21	+2	44	17	8	43	12	+19	4	45	22	10	24	- 11	58	43	19	3	44	-23	10	38
29	0	28	59	+3	7	44	8	43	7	+19	5	2	22	15	3	- 11	35	56	19	6	27	-23	7	49

Table 1. Note: In the actual question, accuracy level of the data was 0.01s and 0.01". It is truncated in the table above.

3.1 The solution

Clearly, in a three hour competition nobody expects students to plot all 365 data points on any kind of graph to spot the pattern. The student should always remember not to get intimidated by such a huge amount of data. Only a small fraction of data from the table is actually used in the solution. The trick of the question is to understand what part of the data is relevant and what is irrelevant.

One should first start with the assumption that all four solar system bodies in the problem are drawn from the so called "seven luminaries" i.e. the Sun, the Moon and five planets

visible to the naked eye. This assumption is not part of the solution but it helps in reducing the number of possibilities to a manageable number. If one cannot identify any of the objects with one of the seven bodies, other solar system bodies can always be included at a later stage, without compromising any analysis up to that step.
Now, a glance on the table above is enough to say that the Sun is a very good candidate to be object A. It is the only object out of the four which is at vernal equinox on 21st March. The hypothesis is confirmed by the fact that it is changing its position in R.A. by roughly 3.5 to 4 minutes, i.e. 52 to 60 arc minutes close to the vernal equinox, i.e. 1^o per day.

Now, on the 21st March object B is about 130^o away and object D is about 80^o away from the Sun. Clearly, neither of them is an inner planet. However, object C is about 35^o away. If object C's position is scanned for the entire year, it becomes apparent that maximum elongation of object C from the sun is roughly 47^o. This matches perfectly with Venus.

To identify object B and D, one should try to find the period of motion for those objects. It is important to note that change in position of an outer planet in any small time interval has two contributing factors, namely, the heliocentric motion of the planet and the heliocentric motion of the earth. To eliminate the contribution due to the motion of the earth, one must measure position of the outer planet at two distinct times from the same heliocentric longitude. Translated in to simple language, it means, one needs to note the position of B and D with a time interval of 1 year. Any other interval may yield an incorrect answer. In the data given, one can choose positions of object B and object D on 1st January and 31st December as they are spaced by one year. Object B changes in R.A. by roughly 2 hours in one year, which translates into heliocentric period of 12 years. Clearly, object B is Jupiter. Object D is much faster than object B, moving by more than 9 hours in R.A. in one year. Object D is most likely Mars.

The second part asks which object can be observed for the longest duration at night time by the unaided eye. It cannot be either the sun or Venus. From the data it becomes clear that Jupiter is in opposition to the sun in February and Mars is in opposition in August. As the observer is at 19^o N, duration of nights in February is longer than the duration in August. So the answer to this part is Jupiter. From the data, the exact date of opposition (i.e. 12 hours difference in R.A. of the sun and that of Jupiter) turns out to be the 3rd of February.

To know the positions of all the planets, we need to find ecliptic longitudes for each of them. It is said that all objects are assumed to be co-planar; hence ecliptic latitude for each of them is zero. In such case, ecliptic longitude is given by,

$$Cos\lambda = Cos\alpha \cdot Cos\delta$$

Where λ is the ecliptic longitude; α is the R.A. and δ is the declination. Following table shows R.A., Dec. and ecliptic longitudes for all objects.

Object	α	δ	λ	Elongation
Sun	21h 04m 47.25s	– 16° 42' 23.36"	– 45.88°	---
Venus	17h 52m 30.35s	– 20° 47' 31.23"	– 91.77°	46°
Mars	16h 37m 14.36s	– 21° 43' 06.44"	– 109.35°	63°
Jupiter	09h 02m 57.94s	+17° 44' 05.28"	133.01°	179°

Note: sign of λ is chosen in accordance to the value of α.

Hence, in heliocentric representation, the Earth should be placed at 314°, Jupiter in opposition with respect to the earth, Venus with 46° elongation further away from vernal equinox and Mars with 63° elongation in the same direction.

3.2 Student Responses

We analyse a few of the better student responses (8 in all) to this question.

Identification

While most students simply identified object A as the sun by spotting its coordinates on equinoxes and solstices, one student calculated the monthly shift in R.A. for object A, zero declination on the equinox days and overall sinusoidal pattern of yearly movement.

Some students followed the model solution mentioned above to identify Jupiter. A second student calculated the time interval of retrograde motion for object B and converted it to the orbital period of the planet as $T_P \approx Cos^{-3}\left(\pi T_{retro}\right)$. This particular relation had actually been derived in the answer sheet. Using the relation, the orbital period of B turned out to be 10 years. Thus, Jupiter was correctly identified. Some other students calculated angular separation between the Sun and the object for various dates and correctly concluded it to be an outer planet, moving much more slowly than Mars. However, inexplicably, four students out of eight assumed that the data tabulated was that of year 2007. They noted conjunction of object B and the sun in August (i.e. in the constellation of Leo) and with their *a priori* knowledge of the fact that Saturn was in Leo in August 2007, concluded that object B is Saturn.

All students noted correctly the fact that maximum angular separation between the sun and object C is about 47° and concluded it to be Venus. One student simply noted that object D is an outer planet (in context of earth) moving faster than Jupiter and hence it was identified as Mars. Another student noted the period of object D was less than 2 years.

Longest seen object and the date.

Two students noted the fact that, for an object to be visible for the longest duration, it should be in opposition with respect to the sun during the winter months. However, the date for this event was calculated wrongly in haste (February 1st and 2nd, instead of February 3rd).

Angle of elongation

Only one student reached this stage of the problem. He used the ecliptic to equatorial transformation equation, exploiting the fact that all objects were assumed to be coplanar. Thus,

$$Sin\lambda = \frac{Sin\delta}{Sin(23^{\circ}26')}$$

However, he made mistakes in identifying correct quadrants of the angles and hence could not get ecliptic longitudes correctly.

In short, all eight students fell well short of acceptable solution.

4. Impact of Astronomy Olympiad

The teams bagged a significant number of medals in the IOAA. The medal tally for the four teams was as follows:

Team	Participants	Gold	Silver	Bronze	Honourable Mention
India	3	3	--	--	--
Poland	5	2	3	--	--
Romania	5	1	2	--	2
Singapore	4	--	1	1	2

However, the medals are only a small part of the story. We, as astronomy educators, are more interested in the long term influence of these competitions on the career choices of the students.

For a first time participating country like Singapore, participation in IOAA has given the students confidence and motivation to perform even better next time around. The team participated in IOAA 2007 simply due to the enthusiasm of the four students and the support from the team leader. The team hopes for support by the Ministry of Education and the academic community in Singapore for future participations. Romania and India have been participating in IAO for the last few years and both countries have seen a constant increase in the number of participants in the entry level National Olympiad as well as the level of knowledge of students qualified in international competitions. For Poland, where the national Olympiad already enjoys a high profile, participation in the IOAA is the next logical step, and has attracted much interest from students, teachers and the general public. In all these countries, we are very happy to see students engaged in very demanding intellectual activities – such as studying topics in physics / astronomy / astrophysics years before their curricular schedule – motivated only by their passion to understand astronomy and to compete well in this Olympiad, without any of the restrictions specific to compulsory school subjects. In the case of past Indian participants, we already see the Astronomy Olympiad movement bearing fruits as more than half of the students have decided to make a career in Physics / Mathematics research with two specifically taking up PhD positions in Astronomy. This fact is an excellent advocate for a generalized study of astronomy in high schools.

5. Summary

We have discussed most aspects of the 1st IOAA. Competition, such as IOAA serving the greater purpose of generating enthusiasm amongst students for astronomical sciences. Such competitions will go a long way to improving ties between astronomical communities from different countries. We hope to see many more countries in the future IOAAs.

Acknowledgements
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For more information please refer to:

1. www.ioaa.info
2. www.ioaa2.itb.ac.id
3. “The International Physics Olympiad”, R. Edge & A. Eisenkraft, The Physics Teacher, May 1986, 265 - 269.