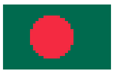
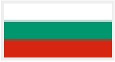
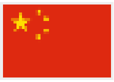
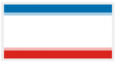
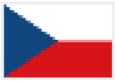
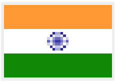
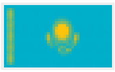
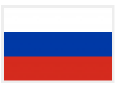

XVIII
INTERNATIONAL
ASTRONOMY
OLYMPIAD
6-14 September, 2013
Vilnius Lithuania
UMa
XVIII - IAO 2013
LITHUANIA
INTERNATIONAL ASTRONOMY
OLYMPIAD

Teams

1.  Armenia
2.  Bangladesh
3.  Bulgaria
4.  China
5.  Crimean Peninsula
6.  Czech Republic
7.  Estonia
8.  India
9.  Indonesia
10.  Italy
11.  Kazakhstan
12.  Lithuania
13.  Moscow land (Moscow Oblast)
14.  Romania
15.  Russia
16.  South Korea
17.  Sri Lanka
18.  Sweden
19.  Thailand
20.  Ukraine

Contestants, Group α

№	Name and Surname	Team
1.	Hrant Topchyan	Armenia
2.	Hayk Soghomonyan	Armenia
3.	Ara Mambreyan	Armenia
4.	Alif Marwabid	Bangladesh
5.	Teodor Aleksiev	Bulgaria
6.	Viktor Mirev	Bulgaria
7.	Dimitar Tomov	Bulgaria
8.	Huiyu Yang	China
9.	Zixuan Lin	China
10.	Shuoyu Xia	China
11.	Hana Lounova	Czech Republic
12.	Jan Preiss	Czech Republic
13.	Martin Orsag	Czech Republic
14.	Carel Kuusk	Estonia
15.	Kaarel Hanni	Estonia
16.	Jaanika Raik	Estonia
17.	Akbar Fachrezy	Indonesia
18.	Jorghy Sultan Bakhtari	Indonesia
19.	Bhavya Choudhary	India
20.	Charles Rajan	India
21.	Nagendra Reddy Kamana	India
22.	Marco Codato	Italy
23.	Marco Giunta	Italy
24.	Silvia Neri	Italy
25.	Seung Hyeon An	South Korea
26.	Myungheon Lee	South Korea
27.	Jae Yang	South Korea
28.	Anuar Azhenov	Kazakhstan
29.	Lyudmila Rvanova	Kazakhstan
30.	Kymbat Nurtayeva	Kazakhstan
31.	Titas Gabrielius Casas	Lithuania
32.	Antanas Valencius	Lithuania
33.	Emilis Kaziukenas	Lithuania
34.	Aleksei Shepelev	Moscow Land
35.	Andrei Catalin Raduc	Romania
36.	Malina Rosca	Romania
37.	Maria-Cristiana Dedu	Romania
38.	Sergey Zheltoukhov	Russia
39.	Ivan Uteshev	Russia
40.	Sunera Sevitha Somabandu	Sri Lanka
41.	Mansara Mihidul Aluthge	Sri Lanka
42.	Dilan Senuruk Wanniarachchi Kankanamge Don	Sri Lanka
43.	Natcha Chantachaiwat	Thailand
44.	Patchariya Patirongkavivat	Thailand
45.	Monchada Sukrong	Thailand
46.	Iurii Pekarskyi	Ukraine

Contestants, Group β

№	Name and Surname	Team
1.	Vardges Mambreyan	Armenia
2.	Siranush Babakhanova	Armenia
3.	Gevorg Martirosyan	Armenia
4.	Arsen Vasilyan	Armenia
5.	Chowdhury Zahirul Islam Arnob	Bangladesh
6.	Konstantin Karchev	Bulgaria
7.	Daniel Dakev	Bulgaria
8.	Aleksandar Atanasov	Bulgaria
9.	Keming Zhang	China
10.	Tianzeng Chen	China
11.	Roman Zvagelskyy	Crimea
12.	Mariya Makarova	Crimea
13.	Lucie Fortova	Czech Republic
14.	Lukas Supik	Czech Republic
15.	Silver Juvanen	Estonia
16.	Taavet Kalda	Estonia
17.	Kusuma Yani Pramanto	Indonesia
18.	Adhimukti Wibowo	Indonesia
19.	Edoardo Altamura	Italy
20.	Giovanni Barilla	Italy
21.	Francescopaolo Lopez	Italy
22.	Jun Ho Lee	South Korea
23.	Won Ki Lee	South Korea
24.	Gi Young Park	South Korea
25.	Bakhtiyar Dabylov	Kazakhstan
26.	Kirill Borodin	Kazakhstan
27.	Daulet Kurmantayev	Kazakhstan
28.	Justas Deveikis	Lithuania
29.	Vytautas Drazdauskas	Lithuania
30.	Evgenii Sheianov	Moscow Land
31.	Konstantin Vasilyev	Moscow Land
32.	Paul Andrei Draghis	Romania
33.	Denis Turcu	Romania
34.	Tudor Suciu	Romania
35.	Alexandru Calin	Romania
36.	Sebastian-Vlad Trifa	Romania
37.	Kirill Grishin	Russia
38.	Artem Mikhalev	Russia
39.	Pavel Usachev	Russia
40.	Torbjorn Lachlan Nilsson	Sweden
41.	Kateryna Barinova	Ukraine
42.	Yaroslav Ersteniuk	Ukraine
43.	Ivan Kokhanovskyy	Ukraine

Team Leaders and Observers

№	Name and Surname	Team
1.	Emilya Karapetyan	Armenia
2.	Marietta Gyulzadyan	Armenia
3.	Alexey Stoev	Bulgaria
4.	Eva Bozhurova	Bulgaria
5.	Li Jian	China
6.	Zhan Xiang	China
7.	Marina Kychyzhyyeva	Crimea
8.	Ganna Kostyk	Crimea
9.	Lenka Soumarova	Czechia
10.	Jan Kozusko	Czechia
11.	Hesti Retno Tri Wulandari	Indonesia
12.	Aprilia	Indonesia
13.	Abdul Kholik	Indonesia
14.	Yoto	Indonesia
15.	Saket Singh Kaurav	India
16.	Swapnil Sushil Jawkar	India
17.	Mayank Nalinkant Vahia	India
18.	Hyung Mok Lee	South Korea
19.	Yoojea Kim	South Korea
20.	Jong Hyeun Yun	South Korea
21.	Hyunsoo Kim	South Korea
22.	Amornrat Aungwerojwit	Thailand
23.	Wittaya Intho	Thailand
24.	Oradee Manakkong	Thailand
25.	Andrii Simon	Ukraine
26.	Oksana Vernydub	Ukraine
27.	Iryna Kostevska	Ukraine
28.	Gaetano Valentini	ITALY
29.	Giulia Iafrate	ITALY
30.	Ieva Sableviciute	Lithuania
31.	Andrius Zajanckauskas	Lithuania
32.	Sarat Chandana Jayaratne Kalu Pathirannahelage	Sri Lanka
33.	Nurzada Beissen	Kazakhstan
34.	Aizhan Mansurova	Kazakhstan
35.	Tiit Sepp	Estonia
36.	Tonis Eenmae	Estonia
37.	Rain Kipper	Estonia
38.	Boris Eskin	Russia
39.	Valery Nagnibeda	Russia
40.	Anders Roland Vasterberg	Sweden
41.	Anca Catalina Marian	Romania
42.	Grigoruta Oniciuc	Romania
43.	Morshed Ibna Rahman	Bangladesh
44.	Mikhail Kuznetsov	Moscow Land
45.	Dmitrij Chulkov	Moscow Land

Programme

Team leader & Observer

Sept. 6 (Fr)	Arrival of teams to Dubingiai centre. Registration	
	20:00~22:00	Welcome party
Sept. 7, (Sa)	07:30~09:00	Breakfast
	09:00~10:00	Meeting
	10:00~13:00	Excursion to Dubingiai mound
	13:00~14:00	Lunch
	15:00~17:00	Opening ceremony. Group photo session
	19:00~22:00	Welcome party. Presentation of teams
Sept. 8 (Su)	07:30~08:30	Breakfast
	10:30~14:00	Excursion to Vilnius. Shopping
	14:00~15:00	Lunch
	16:00~17:00	Lecture
	19:00~20:00	Dinner
	20:00~22:00	Open circle, games
Sept. 9 (Mo)	07:30~08:30	Breakfast
	09:00~14:00	Excursions to Astronomical observatory of Molėtai, etc.
	14:30~15:30	Lunch
	16:00~18:00	Practice session with the telescopes
	18:30~19:30	Dinner
	20:00~…	Meeting
Sept. 10 (Tu)	07:30~08:30	Breakfast
	09:00~19:00	Excursions to Rumšiškės / Vilnius
	19:00~20:00	Dinner
Sept. 11 (We)	07:30~08:30	Breakfast
	10:30~14:00	Excursion to Vilnius / Planetarium
	14:00~15:00	Lunch
	15:00~20:00	Excursion to Trakai
	20:00~21:00	Dinner
Sept. 12 (Th)	07:30~08:30	Breakfast
	09:00~19:00	Excursions to Vilnius / Rumšiškės
	19:00~20:00	Dinner
Sept. 13 (Fr)	07:30~08:30	Breakfast
	10:00~11:00	Lecture
	12:00~13:00	Lunch
	13:30	Departure to Vilnius
	16:00~18:00	Closing ceremony
	18:00	Departure back to Dubingiai
	20:00~24:00	Farewell party
	Departure of Teams	

Student

Sept. 6 (Fr)	Arrival of teams to Dubingiai centre. Registration	
	20:00~22:00	Welcome party
Sept. 7, (Sa)	07:30~09:00	Breakfast
	09:00~13:00	Excursion to Dubingiai mound
	13:00~14:00	Lunch
	15:00~17:00	Opening ceremony. Group photo session
	19:00~22:00	Welcome party. Presentation of teams
Sept. 8 (Su)	07:30~08:30	Breakfast
	09:00~09:30	Preparation for Theoretical Round
	09:30~14:00	Theoretical Round
	14:00~15:00	Lunch
	16:00~17:00	Lecture
	19:00~20:00	Dinner
	20:00~22:00	Open circle, games
orientatioS ept. 9 (Mo)	07:30~08:30	Breakfast
	09:00~14:00	Excursions to Astronomical observatory of Molėtai, etc.
	14:30~15:30	Lunch
	16:00~18:00	Practice session with the telescopes
	18:30~19:30	Dinner
	20:00~21:00	Drawing lots / Preparation for Observational Round
	21:30~…	Observational Round
Sept. 10 (Tu)	07:30~08:30	Breakfast
	09:00~19:00	Excursions to Rumšiškės / Vilnius
	19:00~20:00	Dinner
Sept. 11 (We)	07:30~08:30	Breakfast
	09:00~09:30	Preparation for Practical Round
	09:30~14:00	Practical Round
	14:00~15:00	Lunch
	15:00~20:00	Excursion to Trakai
	20:00~21:00	Dinner
Sept. 12 (Th)	07:30~08:30	Breakfast
	09:00~19:00	Excursions to Vilnius / Rumšiškės
	19:00~20:00	Dinner
Sept. 13 (Fr)	07:30~08:30	Breakfast
	10:00~11:00	Lecture
	12:00~13:00	Lunch
	13:30	Departure to Vilnius
	16:00~18:00	Closing ceremony
	18:00	Departure back to Dubingiai
	20:00~24:00	Farewell party
	Departure of Teams	

Jury

Sept. 6 (Fr)	Arrival of teams to Dubingiai centre. Registration	
	20:00~22:00	Welcome party
Sept. 7, (Sa)	07:30~09:00	Breakfast
	09:00~10:00	Meeting
	10:00~13:00	Excursion to Dubingiai mound
	13:00~14:00	Lunch
	15:00~17:00	Opening ceremony. Group photo session
	19:00~22:00	Welcome party. Presentation of teams
Sept. 8 (Su)	06:00~08:30	Translation of the Theoretical Round
	08:30~09:15	Preparation for the Theoretical Round
	10:00~10:30	Breakfast
	10:30~14:00	Excursion to Vilnius. Shopping
	14:00~15:00	Lunch
	15:30~18:30	Checking of the Theoretical Round
	19:00~20:00	Dinner
	20:00~22:00	Checking of the Theoretical Round
Sept. 9 (Mo)	07:30~08:30	Breakfast
	09:00~14:00	Checking of the Theoretical Round
	14:30~15:30	Lunch
	16:00~18:00	Checking of the Theoretical Round
	18:30~19:30	Dinner
	20:00~21:00	Translation of the Observational Round
	21:00~…	Checking of the Theoretical Round
Sept. 10 (Tu)	07:30~08:30	Breakfast
	09:00~13:00	Checking of the Theoretical Round
	13:00~14:00	Lunch
	14:30~19:00	Checking of the Theoretical Round
	19:00~20:00	Dinner
	20:00~22:30	Checking of the Theoretical Round
Sept. 11 (We)	06:00~08:30	Translation of the Practical Round
	08:30~09:15	Preparation for the Practical Round
	10:00~10:30	Breakfast
	10:30~14:00	Excursions to Vilnius / Planetarium
	14:00~15:00	Lunch
	15:00~20:00	Excursion to Trakai
	20:00~21:00	Dinner
Sept. 12 (Th)	07:30~08:30	Breakfast
	09:00~19:00	Excursions
	19:00~20:00	Dinner
	22:00~…	Final conference of Jury
Sept. 13 (Fr)	07:30~08:30	Breakfast
	10:00~11:00	Lecture
	12:00~13:00	Lunch
	13:30	Departure to Vilnius
	16:00~18:00	Closing ceremony
	18:00	Departure back to Dubingiai
	20:00~24:00	Farewell party
	Departure of Teams	

Rules and Regulations for a participant of the Olympiad

There is an obligation of team leaders to translate these rules and regulations to native language of participants in advance.
(Starting since 2004 this translation has to be done in written form as an obligatory part of application to the International Astronomy Olympiad.)

General information and recommendations:

— **The work must be carried out independently.**
— **Don't write the conditions of problem** in rough copy or clean copy.
— **Languages.** It is permitted to write solutions in one of three languages: native language or one of two official languages. Nevertheless numerical values must be written using standard symbols but not symbols of National alphabet.
— **Languages.** All additional information for participants to be done in both official languages of the Olympiad: in Russian and in English. It is helpful to know basis of one of these languages for correct understanding the additional information.
— **Questions to supervisors during of rounds.** Pay the especially attention to what a question you wish ask. Take into consideration that your question will be repeated for all participants as well as answer. A question of the type "Whether some effect must be taken into account?" means, very often, that you understood the idea of task; or mentioned effect is must essential part of the task.
— **Personal indication**. Before starting the work it is necessary to indicate the surname, name, patronymic, town, school, class and other individual data of participant at answer sheet. All there data are indicated on cover of the answer sheet only.
— **Rough copy.** If you haven't time to rewrite solution (or a part of solution) in your clean copy, please make a note "see rough copy" **in Russian or English by accurate printed characters**. But the index number of the task must be indicated in clean copy, and also a reference to rough copy. **Without such reference rough copy don't verified.** Considerations that you gave into account of rough copy are evaluated in such degree that they don't contradict to final solution in clean copy. In particular if solutions in clean copy and in rough copy are different, then clean copy is evaluated only.
— The **index numbers** of tasks must be distinguished clearly in rough copy as well as in final version. You **must separate** solution of one task from solution of another one **with intervals of 5 cm minimum**.
— If you have enough time, please try to **describe** clearly the physical or other **model** that you chose, and all **approximates**, **neglects**, etc. Don't omit description of thoughts that look as obvious. Take into consideration that written solution is evaluated only. Your thoughts that don't reflected in writing will not be evaluated even they are very right.
— When you give solution of **qualitative task**, you must give the ground for your solution. Brief answer such as "yes", "no", "don't changed" are not solution. Please think what quantitative criteria can be used for the ground of your thoughts.
— Pay attention to understand the **question** of the task. For example, if it is asked to find radius of a star then answer "a diameter of a tar is equal..." is not completely right.
— Pay attention to use symbols done in the task. For example, if it is written "Find distance **P** in perihelion" do not use $\mathbf{L_P}$ for this distance. Also do not use the same symbol for different value (do not use **P** also for power in the case above).
— The **sheet with the conditions of tasks** you can take with yourself *after* finishing of a round only, but if you made some geometrical sketches on the drawings in the task, then it will be better to return the sheet with task together with your clean copy (in this case you can't write any data about yourself on the sheet with task as well).

What is forbidden:

— To write anything (beginning solution) on the first white page of clean copy (having the stamp of the coordinating council). This page is intended for the work of a jury.
— To talk with other participants of Olympiad and ask questions.
— To use reference books, textbooks, any other books, tables, catalogue etc., if such items were not given to participant together with task.
— To bring to the round portable computers, mobile phones, navigation devices and other electronic means, and also calculators, which ones on exterior resemble mobile phones.
— To take calculations as well as write rough solutions and anything at all on own sheets that differ from given by organizers.
— To remove any page from the answer sheet copy-book.
— To use red colour pen or pencil anywhere in the solution.
— To write anything on the envelopes done with texts.
— To make changes in the work after time for solution is up.
— To ask teacher a question connected with used formulae, constant values, and also questions of type: "Is it necessary to take into consideration certain effect?"
— To make any superfluous noise (for example, from unwrap chocolate etc.)
— To finish the work and leave classroom earlier than 2 hours after beginning of a round expire.
— To come out classroom temporarily more than one participant simultaneously.

What is permitted:

— To write solutions of tasks in clean copy in arbitrary sequence.
— To use sliding rule, computational tables, engineering calculator with arithmetical, algebraical and trigonometrical functions (except calculators, which ones on exterior resemble mobile phones).
— To use penholder, pencil, ruler, protractor, compasses, squared paper, tracing-paper (if it is necessary).

What is recommended:

— To make all intermediate calculations, transformation symbol aspect, and substitute by number values in end only – it will diminish a probability of an error in final answer.
— To avoid use facts (numerical values, formulae, etc.) known to you, which may be not evident for jury members. Better to receive them from more evident values and formulae.
— To use in solutions only the numerals as sub-indexes: it will be better for jury to understanding the differences in the designations.
— To separate formulae and explanation texts with intervals (about 1 cm).
— If you introduce symbols for the designation of some quantity, you must explain clearly this quantity. For example: *"Let us **E** will be total energy of the celestial body..."* This way will make easier a mutual understanding between you and jury member that examines your work.

We wish you success !

Organizing committee, jury.

IAO 2001 Crimea, IAO 2002 SAO, IAO 2003 Stockholm, IAO 2004 Crimea, IAO 2005 Beijing, APAO 2005 Irkutsk, IAO 2006 Mumbai, APAO-2006 Vladivostok, IAO-2007 Crimea, APAO-2007 Xiamen, IAO-2008 Trieste, APAO 2008 Bishkek, APAO 2009 Damyang, IAO 2009 Hangzhou, IAO 2010 Crimea, APAO 2010 Papua, IAO 2011 Alma-Ata, APAO 2011 Aktobe, IAO 2012 Gwangju, APAO 2012 Cox's Bazar, IAO 2013 Vilnius.

Observational round
Rules and Regulations

Familiarization with a site of the round.

— The participants have to be familiarized in advance with the site of the round during the daytime in the case the round (part of the round) organized during the night.
— In the case the round have a task with a telescope (except for observations with the already adjusted and guided telescope) every participant has to be familiarized with that actual telescope, on which one the participant will work during the round.

Procedures before the round.

— At the planned time the team leaders (including **all** the jury members) and **all** the students have to arrive to the round (to the distribution auditorium or other common auditorium).
— For both team leaders and students: it is forbidden to come to the round (to the distribution auditorium) with any electronic device (calculators, mobile phones, computers, GPS-devices, players, photocameras, etc.) in any state of the device (on/off) if such items were not given or specially allowed (in written form) by organizers. Only watches are permitted.
— Organizers announce whether the round will be.
— In the case the round will be the team leaders-translators go to the translation room and cannot leave the room till the end of round (after the translation they continue to work in theoretical jury).
— During the translation and preparing the papers the procedure of defining the sequence of examination starts in the distribution auditorium. Every student takes a jetton with a Latin symbol (that means the examiner) and figure (that means the position in the queue to the examiner).
— A student cannot leave the auditorium (except for short hygienic procedures) till he or she goes to the examination.
— Team leaders (not translators) may leave the distribution auditorium at any time (but without permission to return back). After leaving the distribution auditorium the team leader must be in the “finish round auditorium” (if any) or at apartments till the end of the round.
— According to the sequence of examination every student will be called and leaded to the place of the observation by the helper of the examiner.
— In the case the round consist of a few parts (day and night parts, for example) the above-mentioned procedures should be organized separately for every part of the round.

Work of a student on the round.

— **The work must be carried out independently.**
— It is permitted to use your own pen, pencil and ruler (but not other instruments).
— **Languages.** Every examiner has a set of tasks written in all the languages on which the tasks have been translated. A participant may use any language to read the task.
— **Additional questions** to examiners during the round. It is proposed that there should be no questions during the observational round. All necessary data are written.
— **Rough copy.** Rough copy is not proposed at the Observational round.
— There may be in general **two types of tasks**:

1. To answer for some question in written form. In this case you have to work (write down answers, draw pictures, etc.) in the sheets of paper that given by the examiner. It is proposed that the answers should be done in numerical values, pictures or standard defined symbols of objects (like ♎, α UMa, M31, 5^m). The numerical values must be written using standard symbols but not symbols of National alphabet. **No any oral answer** will be taken into account.
2. To show something in the sky, adjust the telescope, etc. In this case you have to show answer for examiner (the necessary object, direction, adjusted telescope, etc.). Examiner put the necessary features of your showing to his/her table. **No any oral answer** will be taken into account as well.

— Take into account that the examiner, as usual, is not a jury member, he/she only register you answers. Jury checks only written documents: your written answers (including drawings, graphs, etc.) and tables of examiners.
— You have to finish every point of observational programme in a limited by the rules time. After the time finishing the examiner has to stop the work of participant.

What is forbidden:

— To indicate the surname, name, patronymic, town, school, class and other individual data of participant at the working sheet of paper. Only code should be written. The work must be anonymous. In the case of infringement a participant can be disqualified.
— To talk with other participants of Olympiad, and ask them.
— To talk with examiner, ask him/her a question connected with the matter of the round.
— To use reference books, textbooks, any other books, tables, catalogue etc., and also to use any electronic devices (except watch) if such items were not given to participant for the round by organizers.
— To make changes in the work after time for the task is up.

Procedures after the work.

— Student has not to keep with him/her any sheet of paper after finishing the work on the observational round.
— After finishing the work on the observational round the participant has to go to the “finish round auditorium” (if any) or to his/her apartments and stay there till the end of the round.

Round with artificial sky, demonstrations, etc.

— Special explanations to be done by the organizers in this case.

We wish you success !

APAO 2005 Irkutsk, IAO 2006 Bombay, APAO 2006 Vladivostok, IAO 2007 Crimea, APAO 2007 Xiamen, IAO 2008 Trieste, APAO 2008 Bishkek, APAO 2009 Damyang, IAO 2009 Hangzhou, IAO 2010 Crimea, APAO 2010 Papua, IAO 2011 Alma-Ata, APAO 2011 Aktobe, IAO 2012 Gwangju, APAO 2012 Cox’s Bazar, IAO 2013 Vilnius

Organizing committee, jury.

Сопроводительная инструкция Supplement Instructions

Rules and Regulations for a jury member of the Olympiad (theoretical round) and translators (all the rounds)

There is an obligation of ANRAO authorities to translate these rules and regulations from English to native language of team leaders. (Starting after the IAO-2004 this translation has to be done in written form as an obligatory part of application from an organization from a country to be national ANRAO or to continue to be national ANRAO.)

Initial originals of the instructions are written in Russian, originals of the instructions are written in English since 2003.

General information and recommendations

— **One of the team leaders from every team has to take part in work of jury of theoretical round.** Only one: neither more jury members nor none of them are possible. Jury member from the team should be the same for all periods of work of jury (maybe a few days, as usual it is the second part of the Day of Theoretical round, full next two days and final jury meeting in the late evening before the Day of Closing ceremony).

— It is necessary to inform organizers in advance who will be a jury member.

— Observers from non-participating states may be included into jury for theoretical round.

Requirements for jury member of theoretical round (i.e. requirements for one of team leaders)

— **Astronomy.** To be a specialist in astronomy or astronomy education, capable to solve problems of a level of the IAO and APAO, understand students' solutions (including ones using unusual ways) and a little higher.

— **Languages.** To know Latin and Cyrillic alphabets, English language and at least some 'key words' in Russian. Jury member have to know English in a level enough to understand solutions of students in English and to communicate with other jury members about these solutions.

Note (after IAO-2002): Not all jury members followed this requirements and did not understand even the main 'key words' in the students' copybooks like "Чистовик" (Clean copy) or "Черновик" (Rough copy or Draft copy) in Russian and so sometimes confused them. Or they miss "См. рис. в черновике" (See the picture in rough copy), etc.

— **Translation of solutions.** Jury members should ask to translate solutions from languages unknown to them (to English, Russian or other understandable for both people language).

Note (after IAO-2002): Some jury members did not ask to translate solutions from the unknown for them languages. Of course, sometimes translation from some languages not necessary since one may understand formulae and general way of solutions in such a languages as Portuguese, Swedish, Russian, Serbian, Italian, etc. Nevertheless it is evident that nobody non-native may understand such a way in (for example) Armenian, Chinese or Korean languages. So there were a few episodes during the Olympiad when an initial mark of evaluation (when the jury member decided that translation is not necessary) was 0 or 1 but later (after request from a native language jury member to listen for translation) it was changed up to 4 or 5. It means that some jury members overestimate their own linguistic possibilities.

— To be familiar with the rules and regulations for a participant of the Olympiad.

Translation of problems before rounds

— One of the team leaders from every team has to translate texts of the problems from Russian or English (written text on paper is provided by Organizing Committee) to native language of participants and prepare envelopes with the materials for every student of his team. Only one: neither more team leaders nor none of them are possible to make this procedure. Usually translation is done by the team leader – jury member, but it is not obligatory. The translations must be made only by handwritten way using blue or violet (but not black) pen, and not by pencil. And it is a duty of jury member to have blue or violet operable pen(s).

Note: The rule of handwritten way does not concern translations done by the organisers to other languages, for example, translation to Chinese at IAO-2005.

— Observers from non-participating states may be present at the translations.

— No discussion on the subject of the problems and on possibilities to include/exclude some information is possible during the translation. Nevertheless, misprints or grammar in the original texts should be corrected.

Note (after IAO-2002): Versions (dialects) of English and Russian languages may be different. Translation from official texts in English or Russian may be done to own version of English or Russian.

— In the translation should be:

- the **sequence** of the sentences – the same as in the original texts;
- the **units** (grams, for example) – the same as in the original texts;
- the **emphasizing** (like underlining) of words or parts of text – the same as in the original texts;
- **full** or **nothing** translation of the tables or supplement materials (e.g. it is forbidden to translate only word “Saturn” in the table when the names of other planets keep without translation);
- kept words in Latin (like “ζ Ursae Majoris”) as in the original texts.

— The time for translation is:

- for the theoretical and practical rounds – 2 hours 15 minutes;
- for the observational round – 45 minutes.

— Translation is started before rounds beginning:

- for the theoretical and practical rounds – at least 3 hours 15 minutes before;
- for the observational round – as usual 1 hour 30 minutes before.

— Translation should be finished by translators (final text written on the headed form of the round) not later than

- 60 minutes before the theoretical and practical rounds;
- 45 minutes before the observational round;

this time is necessary for technical jobs – copying of the texts, forming files for every participant, etc.

— It is **forbidden to have switched-on mobile telephones** and **mobile Internet** by translating team leaders (and observers) from the beginning of the translation till the round starting; any function of mobile phone cannot be used, calculator, for example.

— Any translator may arrive to the room of translations later than official time, but it is **forbidden to go out of the room of translations** earlier than the round starts.

— **Notebooks.** It is permitted to use own notebooks (**with internal power supply only**) as dictionaries. Connection to notebook of any external equipment except mouse is not permitted.

— It is an obligation of the translating team leader to form envelopes with all necessary texts and supplement materials for every participant of his or her team.

Checking of students’ solutions

— It is quite recommended **to solve problems yourself** to understand their level of difficulty and find other possible solutions.

— **Sketches for solutions.** Take into account that the sketch, as usual, shows one approach for solution. But it may be another or even a few others solutions of the problem. It is usual for the International Astronomy Olympiad that many problems have a few correct approaches to solution. It is one of the important difference of our Olympiad from many other International Science Olympiads.

— Every problem of theoretical round is to be checked and evaluated by **three jury members**: two of them check the solution through all papers of the students (of the group) and the third is the native jury member (team leader of the student). Translation of solution for two first jury members may be done by the third (native) one. There are only two checkings if the native jury member is simultaneously “through all of the students” jury member for this problem.

Evaluation criteria

— **Evaluation mark.** 100% of points for solution of 1 problem is **8 points**. The whole correct solution to be evaluated as 8 pt, 50% of solution as 4 pt, 75% as 6 pt, etc. Some **additional 1 or 2 points** (upto 9 or 10) may be done for solution with some extra conclusions or corrected additions **concerning to the matter of the problem** after consultation (**agreement**) of the Theoretical Round Jury Chairperson (as usual he/she is vice-chairperson of jury responsible for theoretical round). As a maximum jury member may evaluate not more than 1 student’s solution as 10 pt and not more than 2 student’s solutions as 9 pt. A desire of a jury member to mark as 9 pt a larger number of solutions means that he/she underestimated level of 100% of solution. If a few solutions marked as 8 pt, the jury member may choose the best of them and mark it as 9 pt (without consultation with the Theoretical Round Jury Chairperson).

— **Evaluation criteria.** In the evaluation of students’ solutions of theoretical problems the most attention should be done for understanding nature (physics, astronomy) of the effects but not for calculations. Some criteria may be done in the sketches for solutions. Otherwise the following gradation is recommended (roughly):

– Qualitative understanding of nature of effects of the problem – 1 pt.
– Necessary for solution formulae or (if formulae not necessary) necessary quantitative criteria of the nature of the effect – 2 pt.
(As usual it is not too easy to divide the above two criteria.)
– Algebraically (or logically) correct solving – 2 pt.
– Final calculations – 1-2 pt.
– Correct picture (if it is necessary due to requirements of the problem) – 1 pt.
– Final conclusion (if necessary) – 1 pt.

If solution is almost full, only arithmetical error has been done: total mark 6-7 pt. Nevertheless the "arithmetical error" should not lead to evidently incorrect answer. For example, an answer "mass of a star is 15 kg" or "stellar magnitude of an asteroid is -25^m" is an error much more serious rather than arithmetical one. Such an error should be "penalised" by 3-4 pt (or dividing all the points by factor 2).

— A correct solution with a correct answer has to be evaluated by full number of points regardless of the way of solution and regardless whether the student emphasized or not transitional (intermediate) steps.

— A participant cannot be "barred" (or disqualified) because of his knowledge, i.e. for using facts (numerical values, formulae, transitional steps of solution etc.) known to him, which may be not evident for jury members (the mass of asteroid Vesta, for example).

— **Evaluation of qualitative problems.** In the evaluation of qualitative students' explanation of ground for final answer is necessary. Brief answer such as "yes", "no", "doesn't change" is not a solution. Make attention for quantitative criteria of effects is the solutions.

— **Rough copy.** A jury member have to see also the rough copy of solution if it is mentioned in student's copybook "see rough copy" in **English or Russian**. Considerations that student gave into account in rough copy to be evaluated in such degree that they don't contradict to final solution in clean copy. In particular if solutions in clean copy and in rough copy are different, then clean copy should be evaluated only.

Preliminary native checking of solutions

— At first every jury member check their own students papers and emphasize by red pen the main parts of solutions (either positive and negative features, notes like "galaxy size" or translations of the main terms may be also done). Full translating is not necessary on this stage.

Note (after IAO-2006): This procedure recommended in order making easier jobs of "through all the papers" checking and evaluating.

"Through all papers" checking and evaluating of solutions

— After the previous procedure done, every member checks solutions of actual problem through all papers. As usual there are two problems for every jury member that he/she has to check and evaluate through all the papers. In this case one of the problems to be in group α and other one – in group β. The situations of the same pairs of jury members for different problems checking should be avoided as well.

— Before the evaluating the member has to check solutions of a few students to prepare a table of grading that concretised the recommendations for evaluating mentioned in the previous chapter. Points and its abbreviations should be written in English in this table. Do not hesitate to ask the Theoretical Round Jury Chairperson for recommendations, including situations with unusual solutions, and whether some solution is full or not. After that the jury member should fill the table-headers in the evaluating sheet of the problems and fill every column by figures. The last two columns as usual are: "equivalent correct parts of other ways of solution" and "extra conclusions or corrected additions".

— Two jury members who check and evaluate the same problem (as different members) have to do it independently.

— Evaluation marks should be written to the special table (to be done by jury secretary) but not to the student's paper.

Note: in the previous version of the rules this point existed in soft words – "jury members should do second and third checking without knowledge of other marks" – but many jury members did not follow it.

Native evaluating of solutions

— After two "through all of the students" checking done, evaluating sheets filled and given to the Theoretical Round Jury Chairperson (or jury secretary), jury members may work with their students' papers and make "native evaluation". Jury members must do their native evaluations without knowledge of other marks.

Note (after IAO-2005): This sequence is necessary to avoid political negotiations between jury members and “points markets”.

Recommendations

— To have own sheet of paper for own notes about every solution and preliminary marks.

— Do not hesitate to ask the Theoretical Round Jury Chairperson for recommendations in unusual and non-standard solutions. As usual the Theoretical Round Jury Chairperson is composer of the set of problems so may easily understand whether some conclusion in student’s solution is correct or not.

Final mark for the solution, procedures of its calculation

— If the native jury member is simultaneously “through all of the students” jury member for this problem, his/her mark is to be placed into the “native mark” column in minutes; the mark is also considered as “native” in the case of two jury members are working in-group and one of them is native.

— After three marks done they are typed into computer by the jury secretaries. Solutions with large differences between three (or two) marks may be rechecked by the Theoretical Round Jury Chairperson and/or members of an independent commission around him/her (using the written criteria of the jury members) and his/her/their marks are to be used instead. As a part of this job it is an obligation of the Theoretical Jury Chairperson (or commission) to look through all the papers where the marks 7-8 exist to be sure that the correct solutions with the correct answers are evaluated by mark 8 finally. In other cases the final mark for the solution as usual (*) calculated as average value of these three or two marks.

Note (after IAO-2005): An independent body of rechecking (the Theoretical Round Jury Chairperson who does not make regular checking and/or members of an independent commission around him/her) is necessary since in the previous system jury members were forced to be arbiters and advocates of their students simultaneously, there were stress situations.

— (*) First exception from the previous point. There is a procedure for stimulation correct checking solutions of native students. For every jury member calculation of the mean difference between his/her “native marks” and “non-native marks” (ones of other jury members for the same solution) is be done. All “native marks” of about 20% jury members whose differences are the largest will not be taken into account.

Note: The procedure cannot work without the distinct sequence of operations: first, – “non-native evaluations” and only then – “native evaluations”.

Note: the Theoretical Round Jury Chairperson informs individually each of these 20% jury members about this exception for his/her “native marks” and this information is hidden for others.

— (*) Second exception from the previous point. There is a procedure for stimulation correct checking “through all of the students” solutions and correct behaviour of jury member. For every jury member calculation of the mean module difference between his/her “non-native marks” and other marks (ones of other jury members for the same solution) should be done. Problems with the largest difference may be rechecked by the Theoretical Round Jury Chairman, in the case of large difference the marks of the jury member to be cancelled and the marks of the Theoretical Round Jury Chairman to be used instead.

Note: the Theoretical Round Jury Chairperson informs individually jury members about the situation mentioned above. Situations with the “points market”, pressure between jury members, tendentious evaluating and other negative features are considered as also very negative. In the case of repeating at one of the next Olympiads, the person cannot be a jury member later, it means that he/she may be other (non-jury) team leader or observer at the next Olympiads and this information is to be presented to the corresponding ANRAO.

Final Jury meeting. Voting

— At the conclusion of all the rounds, and once all the results are available, the jury members will meet and look at the overall performance of all the students without knowing their names or nationality (the so called "blind minutes"). In frames of the conventional rules they will then decide on the cut off level for the I Diploma, II Diploma, III Diploma (corresponding to the Gold, Silver and Bronze Medal Certificates) and Diploma of Participation or ratify the levels for the I, II, III Diploma in the case they were calculated automatically by defined mathematical procedures.

— More instructions to be done before the meeting in oral or (if the proposed procedure is not simple) written form.

— The decision of the Jury Board is final. Nobody can change the decision: neither Local Organizing Committee nor Olympic Coordinating Council nor Chairman of the Olympiad.

Theoretical round. Problems to solve

General note. Maybe not all problems have correct questions. Some questions (maybe the main question of the problem, maybe one of the subquestions) may make no real sense. In this case you have to write in your answer (in English or Russian): «**impossible situation – ситуация невозможна**». Of course, this answer has to be explained numerically or logically.

Data from the tables (Planetary data, stars, constants, etc.) may be used for solving every problem.

The answers «**Да-Yes**» or «**Нет-No**» have to be written in English or Russian.

1. **Star rise in Moletai.** An observer in Moletai recorded that a star culminated at 02:54 and set at 05:45 on September 8, 2013. Effects of irregularities of the horizon should not be taken into account.
   1.1. At what time will the star rise on September 9, 2013?
   1.2. In approximately which direction do you need to wait for the rising of the star? Choose one of the alternatives: N, NE, E, SE, S, SW, W, NW. Draw a picture with an explanation.

2. **Gliese 581 g.** This celestial body in the system of the star Gliese 581 is the most Earth-like planet found outside the Solar System, and the exoplanet with the greatest recognized potential for harboring albuminous based life.
   Estimate orbital period τ of Gliese 581 g. Consider the orbit to be circular.

3. **Observations from Gliese 581 g.**
   3.1. What is the apparent magnitude of our Sun and **3.2.** what is the approximate constellation in which our Sun will be seen when observed from the planet Gliese 581 g?

4. **XVIII century. Midday.** (Dubingiai is the nearest town to the accommodation place of XVIII IAO.).
   There were different systems of units of measurement in the history of science. This problem is to use historical (at present obsolete) units of measurement.
   4.1. Calculate the capacity of the solar energy that in the end of the XVIII century fell on the unit of area of the territory in the outskirts of Dubingiai at midday time:
   in winter, in spring, in autumn, and in summer.
   The answer must be given using only the «new» physical units, which were coming into operation in those days in this area: horse-powers per square verst.
   4.2. Estimate also the capacity of the solar energy incident on a local horse those times. The answer must also be expressed in physical units, which were coming into operation in those days. What can be surprising about the right answer?

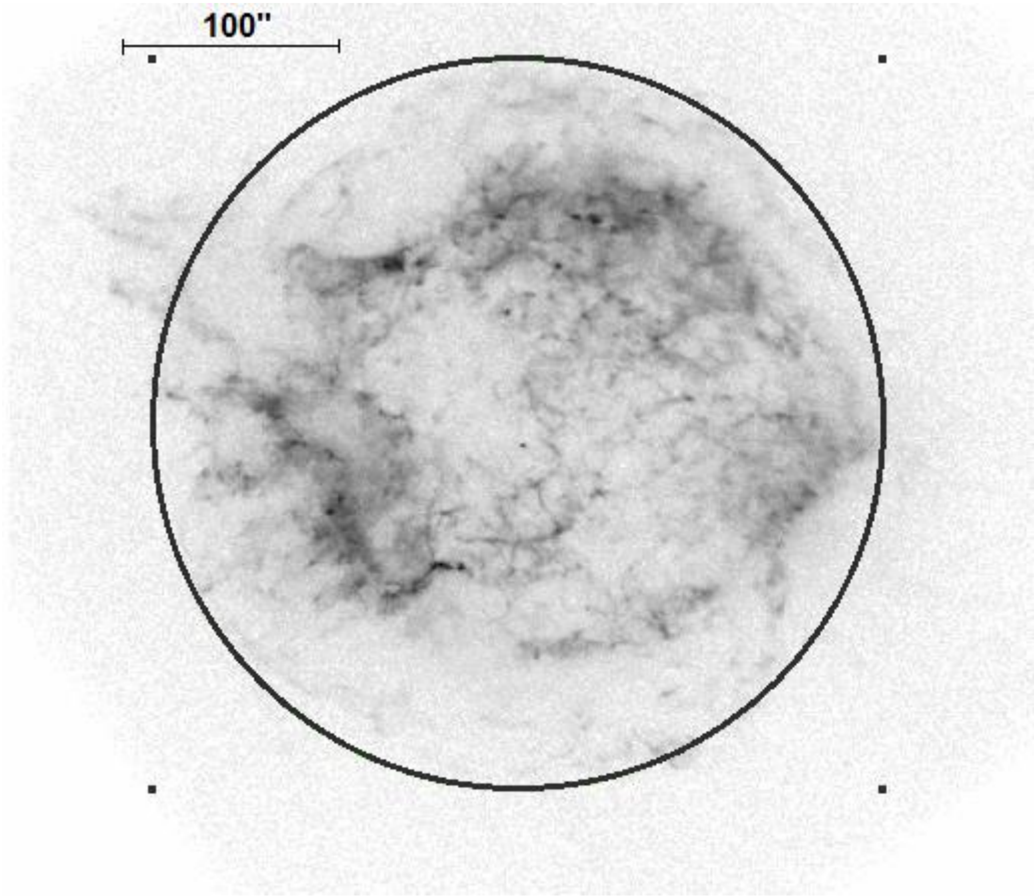
5. **XXI century. Midday.** As is known, the Republic of Lithuania (see map) uses zone with winter time UT+02 and summer time UT+03. Calculate and draw a conclusion about the following:
   5.1. Are there any places in Lithuania, where today (September 8, 2013) the Sun will be exactly in the south at a time when the watches of residents will show just 12:00? (**«да-yes»** or **«нет-no»**).
   5.2. And in general, on the other days of the year, are there such places? (**«да-yes»** or **«нет-no»**). If "yes", then calculate in what dates, if "no", then justify it by calculations.

6. **Supernova remnant.** An X-ray image of supernova remnant (SNR) Cas A located at a distance of d = 3400 pc was obtained using Chandra Space Observatory. The negative of this image is shown in Fig. SNR. The boundaries of the SNR region are marked by a circle. The scale of the image is shown in the upper left corner of the figure. A dot located close to the center of the circle is the neutron star – the remaining core of the collapsed star. The rectangular marks outside the circle are given for the reference when determining the center of the circle.
   Assume that the amount of energy released in the supernova explosion was about $E_{SN} \approx 10^{46}$ J, 1% of which drives the expansion of the remnant. The average density of the matter in the SNR is $\rho \approx 10^{-21}$ kg/m^3.
   6.1. Estimate the age of the SNR Cas A.
   6.2. Calculate the average velocity of the motion of the neutron star from the center of the SNR.

Round	Theo
Group	α β
язык language	Русский
язык language	English

Теоретический тур. Рисунок к задаче 6

Theoretical round. Picture for problem 6



S N R

Theoretical round. Problems to solve

General note. Maybe not all problems have correct questions. Some questions (maybe the main question of the problem, maybe one of the subquestions) may make no real sense. In this case you have to write in your answer (in English or Russian): «**impossible situation – ситуация невозможна**». Of course, this answer has to be explained numerically or logically.

Data from the tables (Planetary data, stars, constants, etc.) may be used for solving every problem.

The answers «**Да-Yes**» or «**Нет-No**» have to be written in English or Russian.

1. **RadioAstron.** The RadioAstron project is an international collaborative mission lead by Astro-Space Center of Russian Academy of Sciences. On July 18, 2011 a satellite, «Spektr-R», carrying a 10-m (in diameter) space radio-telescope was launched into an elliptical orbit around the Earth. Together with Earth-based radio-telescopes, «Spektr-R» works as interferometer. RadioAstron operates at the standard radio astronomical wavelengths of 1.19–1.63 cm (K-band), 6.2 cm (C-band), 18 cm (L-band), and 92 cm (P-band). Now «Spektr-R» is rotating in a very elongated orbit with a period τ = 8.3 days and a height of perigee h = 600 km from the Earth surface.
   1.1. Estimate the maximum resolving power (angular resolution in arcsec) of RadioAstron. Draw a schematic picture, explaining your choice of the situation when it may occur.
   1.2. Estimate the resolving power of RadioAstron if the target is observed in the direction of the major axis of «Spektr-R» orbit, and also draw a schematic picture.

2. **Gliese 581 g.** This celestial body in the system of the star Gliese 581 is the most Earth-like planet found outside the Solar System, and the exoplanet with the greatest recognized potential for harboring albuminous based life.
   2.1. Estimate orbital period τ of Gliese 581 g. Consider the orbit to be circular.
   2.2. Assume intelligent life resides on Gliese 581 g. The civilization uses radio-waves. Is it possible to determine the size (diameter) of the planet by observations on RadioAstron (**«да-yes»** or **«нет-no»**)? Justify the answer by calculations.

3. **Observations from Gliese 581 g.**
   3.1. What is the apparent magnitude of our Sun and **3.2.** what is the approximate constellation in which our Sun will be seen when observed from the planet Gliese 581 g?
   3.3. Estimate the angular diameter of the star Gliese 581 when observed from the planet Gliese 581 g.

4. XVIII century. Midday. (Dubingiai is the nearest town to the accommodation place of XVIII IAO.).

There were different systems of units of measurement in the history of science. This problem is to use historical (at present obsolete) units of measurement.

4.1. Calculate the capacity of the solar energy that in the end of the XVIII century fell on the unit of area of the territory in the outskirts of Dubingiai at midday time:

in winter, in spring, in autumn, and in summer.

The answer must be given using only the «new» physical units, which were coming into operation in those days in this area: horse-powers per square verst.

4.2. Estimate also the capacity of the solar energy incident on a local horse those times. The answer must also be expressed in physical units, which were coming into operation in those days. What can be surprising about the right answer?

5. XXI century. Midday. As is known, the Republic of Lithuania (see map) uses zone with winter time UT+02 and summer time UT+03. Calculate and draw a conclusion about the following:

5.1. Are there any places in Lithuania, where today (September 8, 2013) the Sun will be exactly in the south at a time when the watches of residents will show just 12:00? (**«да-yes»** or **«нет-no»**).

5.2. And in general, on the other days of the year, are there such places? (**«да-yes»** or **«нет-no»**). If "yes", then calculate in what dates, if "no", then justify it by calculations.

6. Supernova remnant. An X-ray image of supernova remnant (SNR) Cas A located at a distance of d = 3400 pc was obtained using Chandra Space Observatory. The negative of this image is shown in Fig. SNR. The boundaries of the SNR region are marked by a circle. The scale of the image is shown in the upper left corner of the figure. A dot located close to the center of the circle is the neutron star – the remaining core of the collapsed star. The rectangular marks outside the circle are given for the reference when determining the center of the circle.

Assume that the amount of energy released in the supernova explosion was about $E_{SN} \approx 10^{46}$ J, 1% of which drives the expansion of the remnant. The average density of the matter in the SNR is $\rho \approx 10^{-21}$ kg/m^3.

6.1. Estimate the age of the SNR Cas A.

6.2. Calculate the average velocity of the motion of the neutron star from the center of the SNR.

XVIII Международная астрономическая олимпиада
XVIII International Astronomy Olympiad
Литва, Вильнюс 6 – 14. IX. 2013 Vilnius, Lithuania

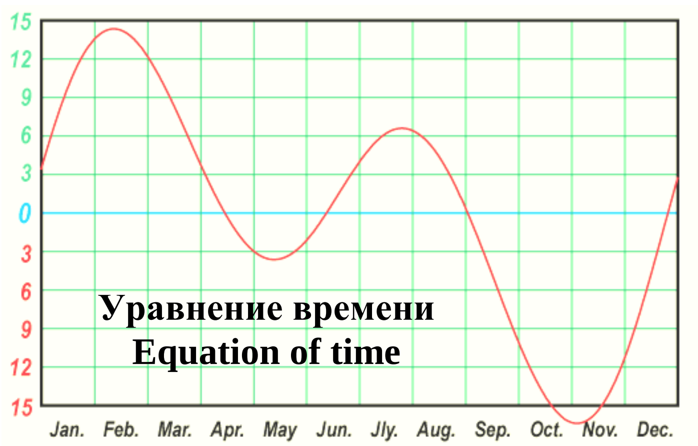
Элементы орбит. Физические характеристики некоторых планет, Луны и Солнца

Parameters of orbits. Physical characteristics of some planets, Moon and Sun

Небесное тело, планета / Body, planet	Среднее расстояние от центрального тела, в астр. ед. / Average distance to central body, in astr. units	Среднее расстояние от центрального тела, в млн. км / in 10^6 km	Сидерический (или аналогичный) период обращения, в тропич. годах / Sidereal period (or analogous), in tropical years	в средних сутках / in days	Наклон орбиты, i / Orbital inclination, i	Эксцентриситет, e / Eccentricity, e	Экваториальн. диаметр, км / Equat. diameter, km	Масса, 10^{24} кг / Mass, 10^{24} kg	Средняя плотность, г/см³ / Av. density, g/cm³	Ускор. своб. пад. у пов., м/с² / Grav. accelr. at surf., m/s²	Наклон оси / Axial tilt	Макс. блеск, вид. с Земли **) / Max. magn. From Earth **)	Альбедо / Albedo
Солнце Sun	$1{,}6\cdot10^{9}$	$2{,}5\cdot10^{11}$	$2{,}2\cdot10^{8}$	$8\cdot10^{10}$			1392000	1989000	1,409			$-26{,}74^m$	
Меркурий Mercury	0,387	57,9	0,241	87,969	7,00°	0,206	4 879	0,3302	5,43	3,70	0,01°		0,06
Венера Venus	0,723	108,2	0,615	224,7007	3,40	0,007	12 104	4,8690	5,24	8,87	177,36		0,78
Земля Earth	1,000	149,6	1,000	365,2564	0,00	0,017	12 756	5,9742	5,515	9,81	23,44		0,36
Луна Moon	0,00257	0,38440	0,0748	27,3217	5,15	0,055	3 475	0,0735	3,34	1,62	6,7	$-12{,}7^m$	0,07
Марс Mars	1,524	227,9	1,880	686,98	1,85	0,093	6 794	0,6419	3,94	3,71	25,19	$-2{,}0^m$	0,15
Юпитер Jupiter	5,204	778,6	11,862	4 332,59	1,30	0,048	142 984	1899,8	1,33	24,86	3,13	$-2{,}7^m$	0,66
Сатурн Saturn	9,584	1433,7	29,458	10 759,20	2,48	0,054	120 536	568,50	0,70	10,41	26,73	$0{,}7^m$	0,68

**) Для внешних планет и Луны – в среднем противостоянии.
**) For outer planets and Moon – in mean opposition.

Lietuva * Lithuania * Литва



Некоторые константы и формулы
Some constants and formulae

Скорость света в вакууме, c (м/с)	299 792 458	Speed of light in vacuum, c (m/s)
Гравитационная постоянная, G (Н·м²/кг²)	$6.674\cdot10^{-11}$	Constant of gravitation, G (N·m²/kg²)
Солнечная постоянная, A (Вт/м²)	1367	Solar constant, A (W/m²)
Параметр Хаббла, H_0 (км/с/МПк) — среднее значение / диапазон значений	71 50-100	mean value / diapason of values — Hubble parameter, H_0 (km/s/Mpc)
Постоянная Планка, h (Дж·с)	$6.626\cdot10^{-34}$	Plank constant, h (J·s)
Заряд электрона, e (Кл)	$1.602\cdot10^{-19}$	Charge of electron, e (C)
Масса электрона, m_e (кг)	$9.109\cdot10^{-31}$	Mass of electron, m_e (kg)
Соотношение масс протона и электрона	1836.15	Proton-to-electron ratio
Постоянная Фарадея, F (Кл/моль)	96 485	Faraday constant, F (C/mol)
Магнитная постоянная, μ_0 (Гн/м)	$1.257\cdot10^{-6}$	Magnetic constant, μ_0 (H/m)
Универсальная газовая постоянная, R (Дж/моль/К)	8.314	Universal gas constant, R (J/mol/K)
Постоянная Больцмана, k (Дж/К)	$1.381\cdot10^{-23}$	Boltzmann constant, k (J/K)
Постоянная Стефана-Больцмана, σ (Вт/м²/К⁴)	$5.670\cdot10^{-8}$	Stefan-Boltzmann constant, σ (W/m²/K⁴)
Константа смещения Вина, b (м·К)	0.002897	Wien's displacement constant, b (m·K)
Лабораторная длина волны H**α** (Å)	6562.81	Laboratory wavelength of H**α** (Å)
Длина тропического года, T (сут)	365.242199	Tropical year length, T (days)
Стандартная атмосфера (Па)	101 325	Standard atmosphere (Pa)
Ослабление видимого света земной атмосферой в зените (минимально)	19%, 0.23^m	Visible light extinction by the terrestrial atmosphere in zenith (minimum)
Показатель преломления воды при 20°C, n	1.334	Refractive index of water for 20°C, n
Момент инерции шара	$I = {}^2/_5\, MR^2$	Moment of inertia of a solid ball
Объём шара	$V = {}^4/_3\, \pi R^3$	Volume of a ball
Площадь сферы	$S = 4\pi R^2$	Area of sphere
π	3.14159265	π
e	2.71828183	e
Золотое сечение, φ	1.61803399	Golden ratio, φ

АСТРОНОМИЧЕСКОЕ ОБЩЕСТВО

EURO–ASIAN ASTRONOMICAL SOCIETY

Round | Theo
Group | α | β

XVIII Международная астрономическая олимпиада

XVIII International Astronomy Olympiad

Литва, Вильнюс 6 – 14. IX. 2013 Vilnius, Lithuania

язык / language: Русский

язык / language: English

Данные о некоторых звёздах

Data of some stars

			RA	DEC	*p*	**m**	S C	масса mass
Солнце	Sun	ʘ	0^h – 24^h	-23°26' +23°26'	8".794	vis $-26^m.74$ bol $-26^m.82$	G2	1 $\mathcal{M}_ʘ$
Проксима Центавра	Proxima Centauri	**V645** Cen, α Cen **C**	$14^h\ 29^m\ 43^s$	-62° 40' 46"	0".769	$11^m.05$	M5.5	0.123 $\mathcal{M}_ʘ$
Альфа Центавра	Alpha Centauri	α Cen **A** **B**	$14^h\ 39^m\ 37^s$ $14^h\ 39^m\ 35^s$	-60° 50' 02" -60° 50' 14"	0".747	$-0^m.01$ $1^m.34$	G2 K1	1.1 $\mathcal{M}_ʘ$ 0.9 $\mathcal{M}_ʘ$
Бета Центавра	Beta Centauri	β Cen	$14^h\ 03^m\ 49^s$	-60° 22' 23"	0".009	$0^m.61$	B1	21 $\mathcal{M}_ʘ$
Эпсилон Эридана	Epsilon Eridani	ε Eri	$03^h\ 32^m\ 56^s$	-09° 27' 30"	0".311	$3^m.74$	K2	0.82 $\mathcal{M}_ʘ$
Глизе 581	Gliese 581	HO Lib	$15^h\ 19^m\ 27^s$	-07° 43' 20"	0".16	vis $10^m.57$ bol $8^m.0$	M3V	0.31 $\mathcal{M}_ʘ$

Меры мощности

1 лошадиная сила (л.с.) = 735,49875 Вт

Units of power

1 horse-power (hp) = 735,49875 W

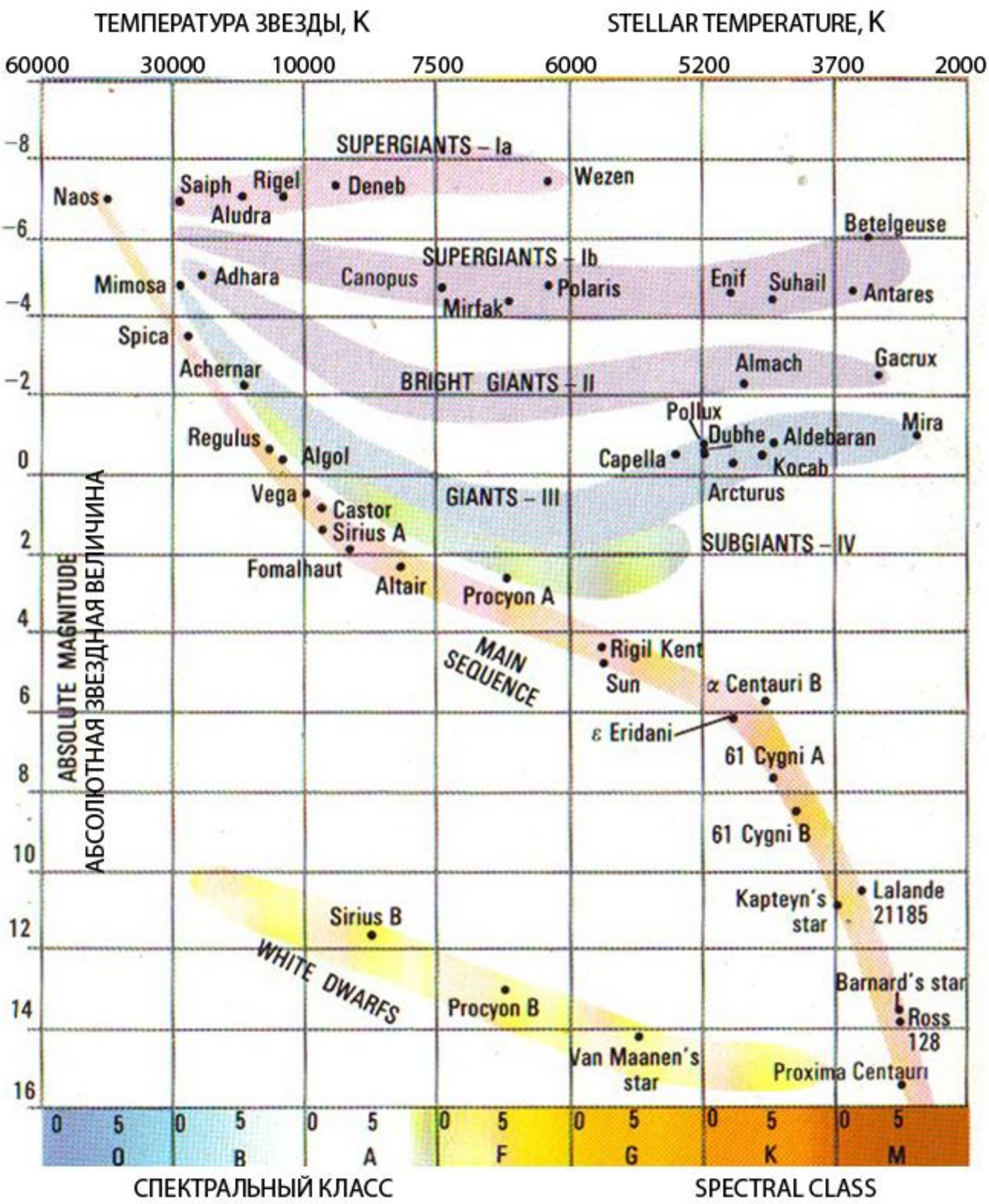
Местные меры длины конца XVIII века

1 аршин (арш) = 0,711187 м
1 пядь (пд) = 1/4 аршина
1 вершок (врш) = 1/4 пяди
1 сажень (сж) = 3 аршина
1 верста (врст) = 500 саженей

Local units of length in the end of XVIII century

1 arshin (arsh) = 0.711187 m
1 span (sp) = 1/4 arshin
1 vershok (vrsh) = 1/4 span
1 sajene (sj) = 3 arshin
1 verst (vrst) = 500 sajene

Диаграмма Герцшпрунга-Рассела / Hertzsprung-Russell diagram



Practical round. Problems to solve

7. Asteroid.

Analysis of observations of a near earth asteroid.

Astronomers of two observatories, which are located at a distance of 3172 km from each other, took CCD images of a certain region of the sky for the search of a near earth asteroid. Two images were obtained by Observatory 1 during the same night at 4^h53^m UT and at 7^h16^m UT. These images (negatives) are shown in Figs. 7.1 and 7.2, respectively. The next two images obtained on the same night were made at Observatory 1 .and Observatory 2 simultaneously. These images (negatives) are shown in Figs. 7.3 and 7.4. The scale of all the images is the same as shown in Fig. 7.1.

7.1. Identify and mark the asteroid in the given Figs.
7.2. Measure the angular displacement (in arcsec) of the asteroid as seen from Observatory 1 and calculate its angular velocity in arcsec/s.
7.3. Measure the parallax of the asteroid (in arcsec) and calculate its distance from the earth.
7.4. Calculate the tangential linear velocity (velocity perpendicular to the line of sight) of the asteroid.

Note: You are provided a transparency for measurements of angular displacements of the asteroid.

код	
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7. Asteroid. 7. Астероид.

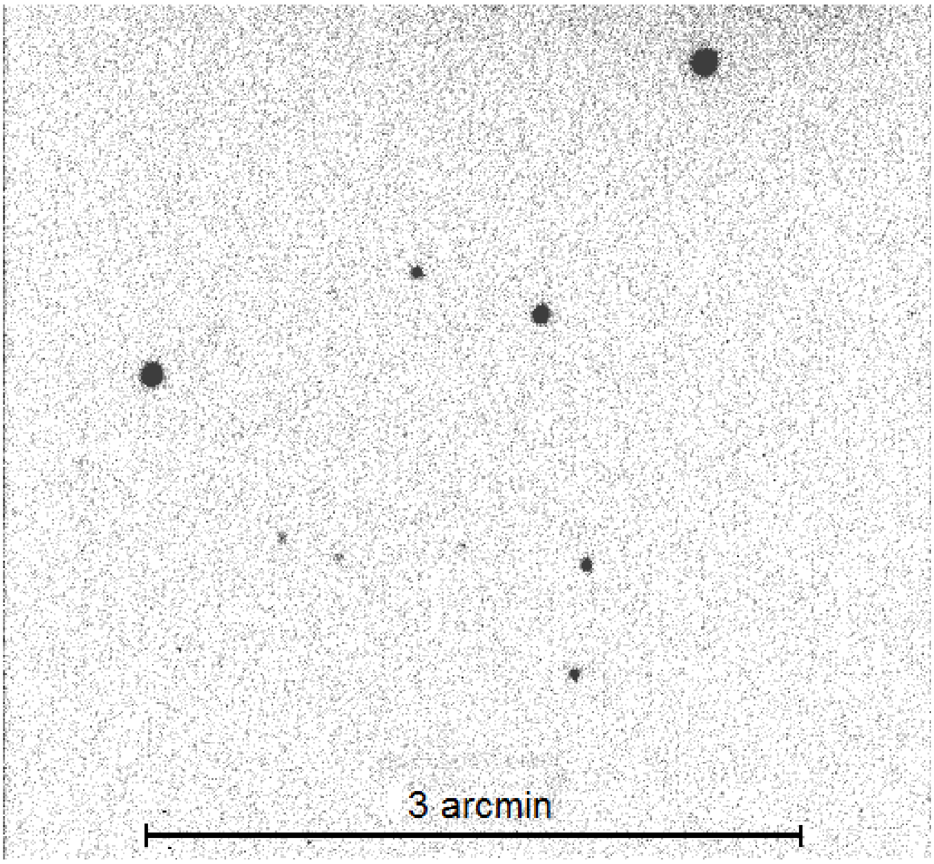

Fig. 7.1. 4:53 UT Рис. 7.1.

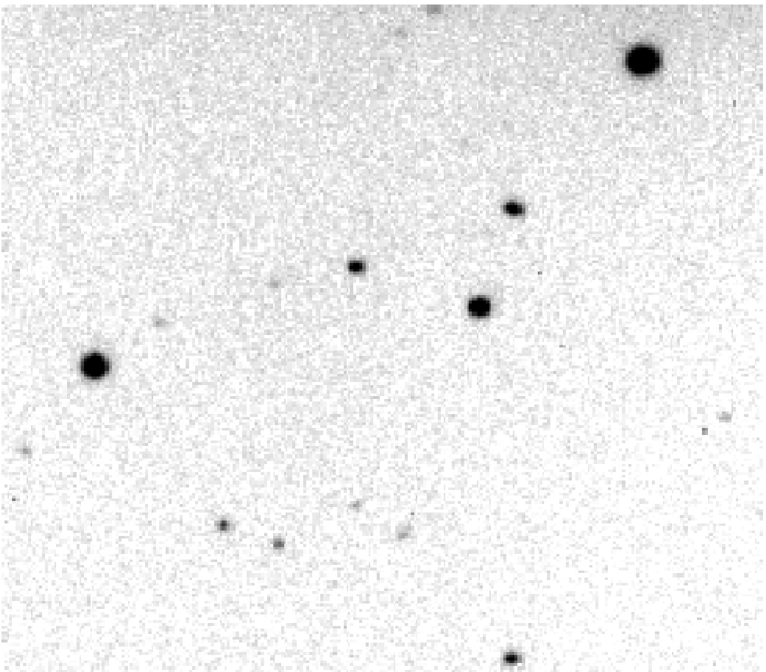

Fig. 7.2. 7:16 UT Рис. 7.2.

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7. Asteroid. **7. Астероид.**

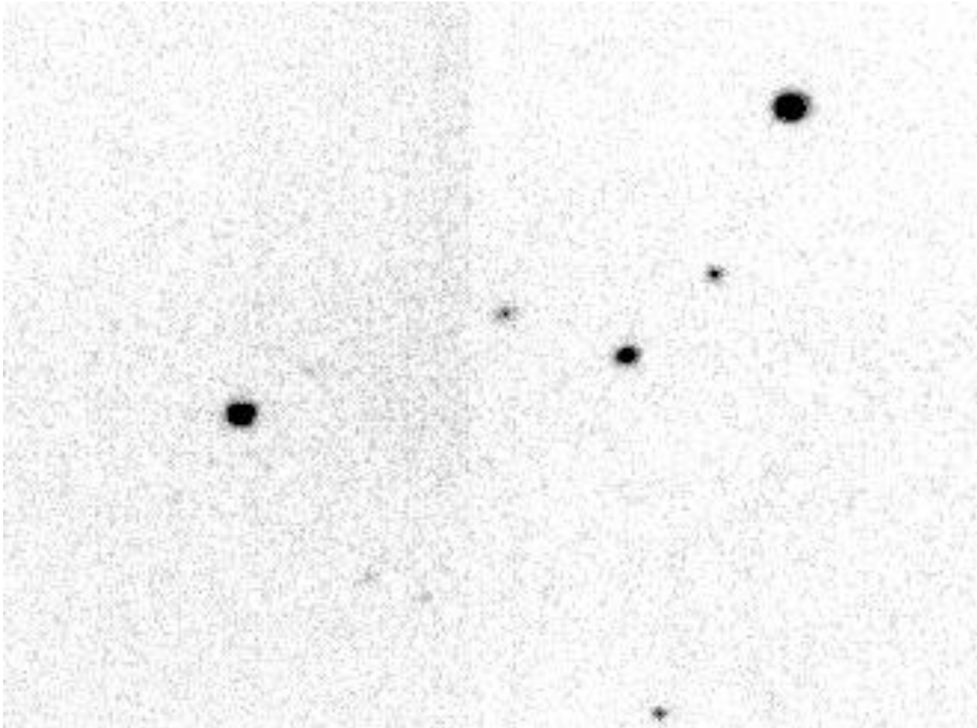


Fig. 7.3. Observatory 2 Рис. 7.3.

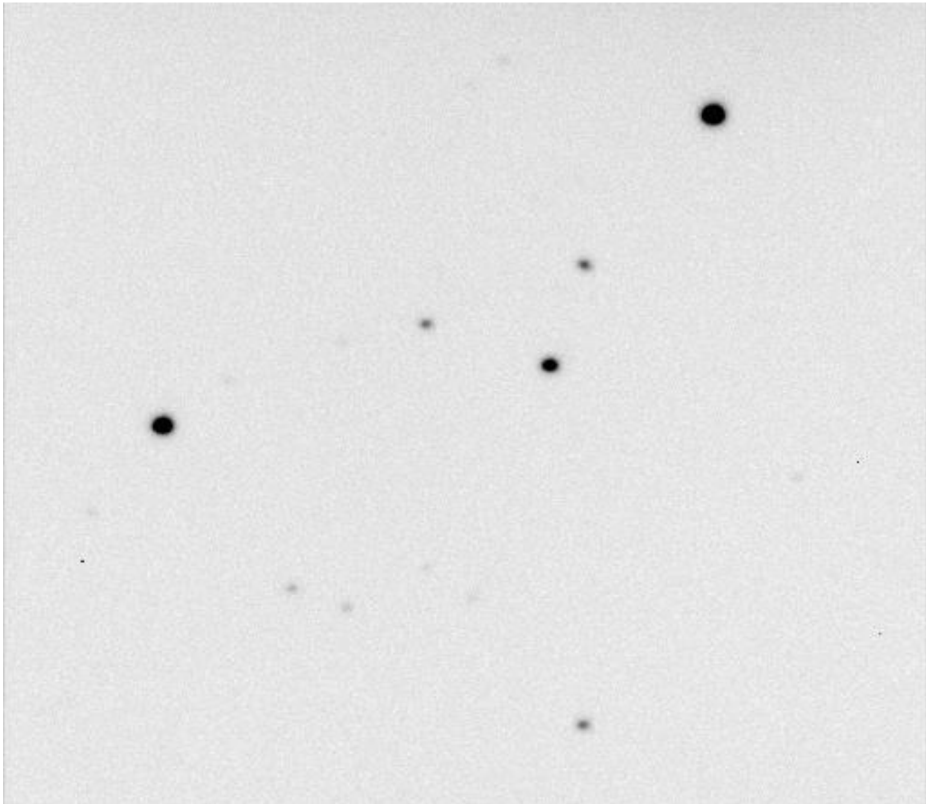


Fig. 7.3. Observatory 1 Рис. 7.3.

Practical round. Problems to solve

7. Distance to the galaxy NGC 4214

The usage of novae in outbursts as distance indicators is based on the correlation of their absolute magnitudes at maximum brightness with their rates of decline. The simplified relationship between the absolute magnitude at maximum of a nova and its rate of decline may be expressed through the linear expression:

$$M_{Vmax} = a + b\log t_2 \, , \qquad (1)$$

where a and b are constants to be determined using observational data of a certain number of galactic novae with spatially resolved shells, t_2 is the rate of decline, i.e. the time (expressed in days) that it takes the nova to drop by 2 magnitudes below its light maximum. t_2 should be evaluated from the graph of the light curve of a nova.

7.1. Using data of Table 1 determine the constants a and b in the expression (1). The results of the calculations should be written in Table 1a. A graph template (Fig. 1a) should be used for determination of constants a and b.

7.2. Using the obtained expression and photometric data of a nova, which erupted in the galaxy NGC 4214, calculate the distance to this galaxy. Photometric data of this nova are given in Table 2. A graph template (Fig. 2a) should be used for the plot of the light curve of the nova.

Data of Table 1:
1st column is the number of the nova;
2nd – the time of the maximum brightness of the nova, T_0, in Julian Days (JD);
3rd – the apparent magnitude of the nova at maximum brightness, m_{Vmax};
4th – the rate of decline, i.e. the time that it takes the nova to drop by 2 magnitudes below maximum, t_2, in days (d);
5th – the angular radius of the expanding shell of the nova, θ (in arcsec);
6th – the time of the measurement of the radius of the nova shell, T, in Julian Days (JD);
7th – the rate of expansion of the shell of the nova, v, in km/s;
8th – the interstellar extinction in the direction of the nova, A_V.

Data of Table 2:
1st column is the time of observation in Julian Days (JD);
2nd – the apparent magnitude of the nova.

Table 1. Data of the galactic novae for determination of the constants a and b;

Table 2. Observations of the nova in NGC 4214;

Table 1a. Results of calculations of the parameters of the galactic novae;

Fig. 1a. Graph template for determination of the constants in the expression (1);

Fig. 2a. Graph template for the plot of the light curve of the nova NGC 4214.

7. Distance to the galaxy NGC 4214.

7. Расстояние до галактики NGC 4214.

Table 1. **Таблица 1.**

No.	T_{max} (JD)	$m_{V max}$	t_2, (d)	θ (arcsec)	T (JD)	v (km/s)	A_V (mag)
1	2412083	4.5	45	9	2444798	600	1.3
2	2442655	1.9	2	1.5	2445707	1500	1.4
3	2427794	1.6	39	10	2444798	500	0.3
4	2438061	3.5	22	3.5	2445707	1100	0.6
5	2428340	2.0	5	11	2444798	1600	0.8
6	2430676	0.7	6	9	2450898	800	0.3

Table 2. **Таблица 2.**

Time (JD)	Apparent magnitude m_V
2455233.1	17.6
2455233.8	17.3
2455234.5	17.6
2455236.5	18.7
2455237.5	19.4
2455238.5	19.8

код	
code	

7. Distance to the galaxy NGC 4214.

7. Расстояние до галактики NGC 4214.

Table 1a. **Таблица 1a.**

No.	Δt (JD)	R (AU)	d (pc)	$M_{V\max}$	$\log t_2$
1					
2					
3					
4					
5					
6					

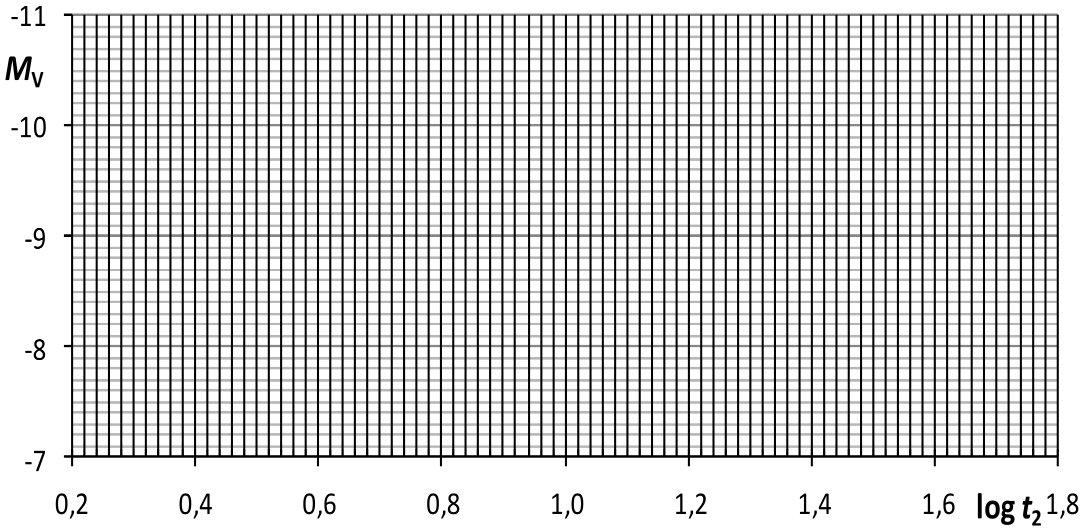


Fig. 1a.

Рис. 1a.

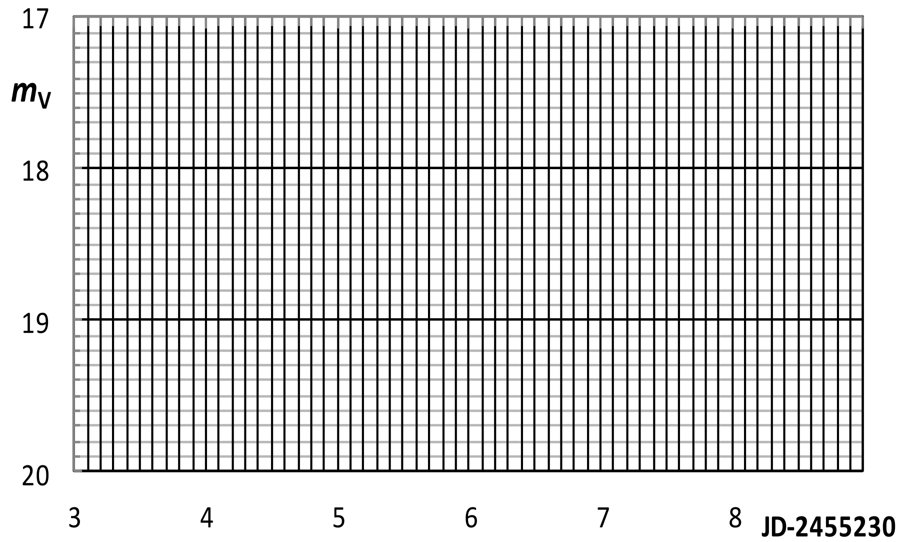


Fig. 2a.

Рис. 2a.

Practical round. Problems to solve

αβ-8. Jupiter. Analysis of observational data of Jupiter and its moons

Observational data of Jupiter and its moons are given on separate sheets.
Your answers (measured values, results of calculations, used formulas) must be written in corresponding tables.

A. See separate sheet.

B. Equatorial rotational period and radius

Two CCD images of Jupiter are shown in Figs. 2 and 3. The vertical lines in figures marks the position of the projection of Jupiter‘s rotation axis (we assume it is perpendicular to the line of sight). The rotation period can be obtained from horizontal shifts of stable atmospheric features located relatively close to the equator.

B.1. What time interval in seconds (**dt**) separate these images?
B.2. One feature useful for measurements is already marked “**1**”. Select and mark two additional features as “**2**” and “**3**” in both pictures.
B.3. Measure distances from the central vertical line to the marked features in both images ($\mathbf{x_1}$ and $\mathbf{x_2}$, respectively) and to the Jupiter limb at the feature’s latitude ($\mathbf{L_x}$).
B.4. Calculate the rotational angle (**ϕ**) for each feature.
B.5. Calculate the averaged value of rotational angle (**ϕ_avg**).
B.6. Calculate the rotational period ($\mathbf{P_{Je}}$), in hours.
B.7. Calculate Jupiter‘s equatorial radius ($\mathbf{R_{Je}}$), in km.

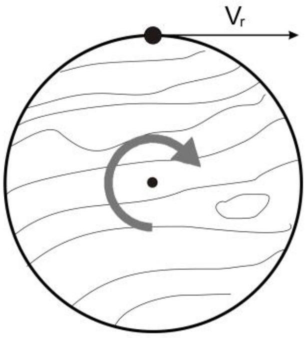
C. Mass and density

Figs. 4-6 display observations of three Jupiter moons obtained during five successive nights in September 2011. Abscissa in those figures is time of observation measured in hours from the beginning of the observing session. Ordinate is the angular distance (in angular minutes) of the moon from the center of Jupiter at the moment of observation. The equatorial radius of Jupiter in the angular seconds is also given for some moments.

C.1. Estimate the period of revolution of each Jupiter‘s moon ($\mathbf{P_m}$), in hours.
C.2. Estimate the semimajor axis of the orbit of each Jupiter‘s moon expressed in Jupiter‘s equatorial radii (**a_Je**) and convert it into meters (**a**).
C.3. Use your mesurements of each moon to calculate the mass of Jupiter ($\mathbf{M_J}$) independently.
C.4. Calculate the averaged value of Jupiter mass ($\mathbf{M_J}$**_avg**).
C.5. From Jupiter image estimate the ratio of Jupiter‘s polar and equatorial radii ($\mathbf{R_p/R_e}$).
C.6. Calculate the mean radius of Jupiter ($\mathbf{R_J}$**_avg**).
C.7. Calculate the density of Jupiter ($\mathbf{\rho_J}$).

8.

A.



V_r = 12.6 km/s

Practical round. Problems to solve

β-8. Jupiter.

A. Rotational velocity

Spectrum of Jupiter (Fig. 1) was obtained when the slit of a spectrograph was aligned along the planet's equator. Wavelengths (λ) of several recognized lines are shown. Due to Jupiter rotation the reflected Sunlight was affected by the Doppler effect. The spectral lines become inclined, because the spectrum of light reflected from the receding part of Jupiter is red-shifted, and of light reflected from the approaching part is blue-shifted. Non-inclined lines, which are visible in the spectrum, were formed in the Earth atmosphere.

A.1. Evaluate the mean scale of the given spectral interval (**N**), in nm per mm.
A.2. Measure the difference between the uppermost and the lowermost end of an inclined spectral line in mm (**dx**) and convert it into nm (**dλ**). Do this for 3 lines independently.
A.3. Calculate the equatorial rotational velocity of Jupiter (**v_r**) for each measured line and the final averaged value (**v_r_avg**).

Fig. 1

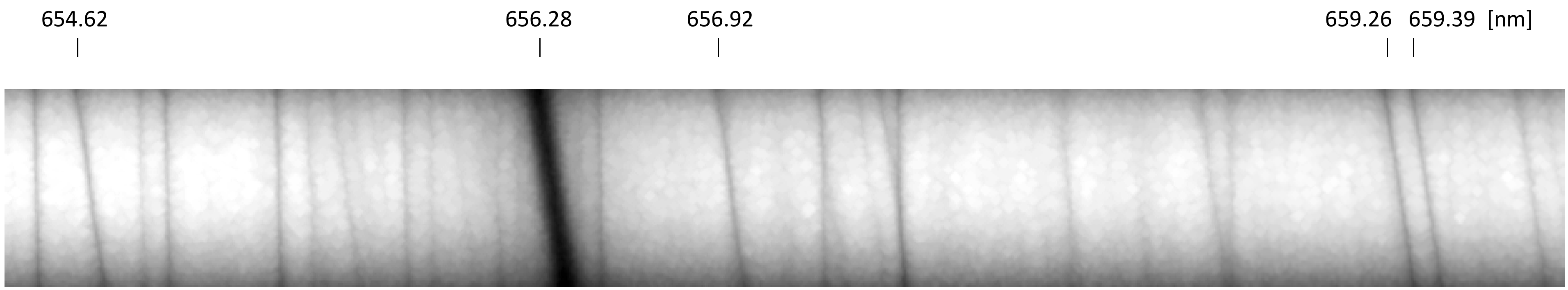
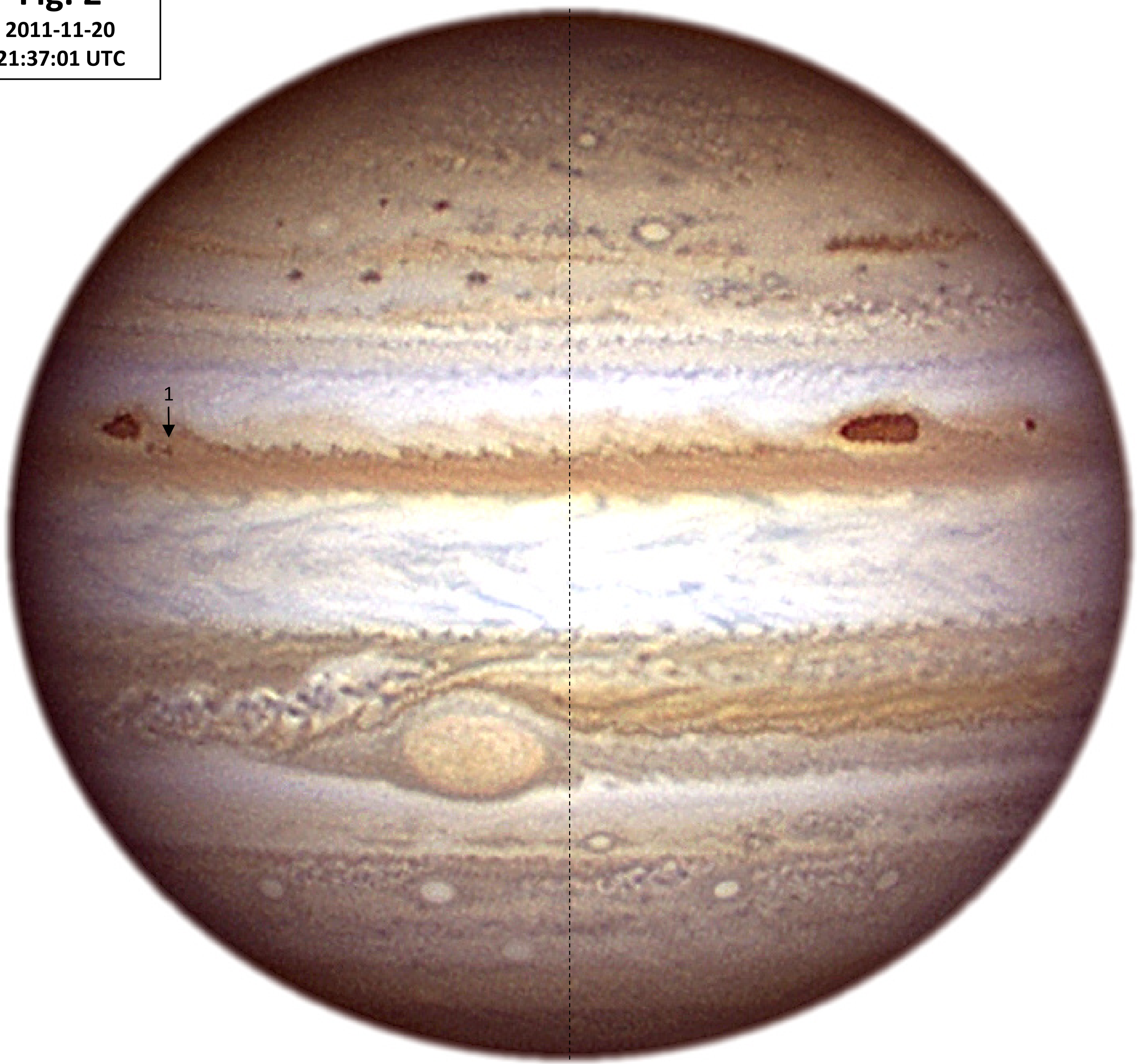


Fig. 2
2011-11-20
21:37:01 UTC



Round **Prac**

Group α β

код code

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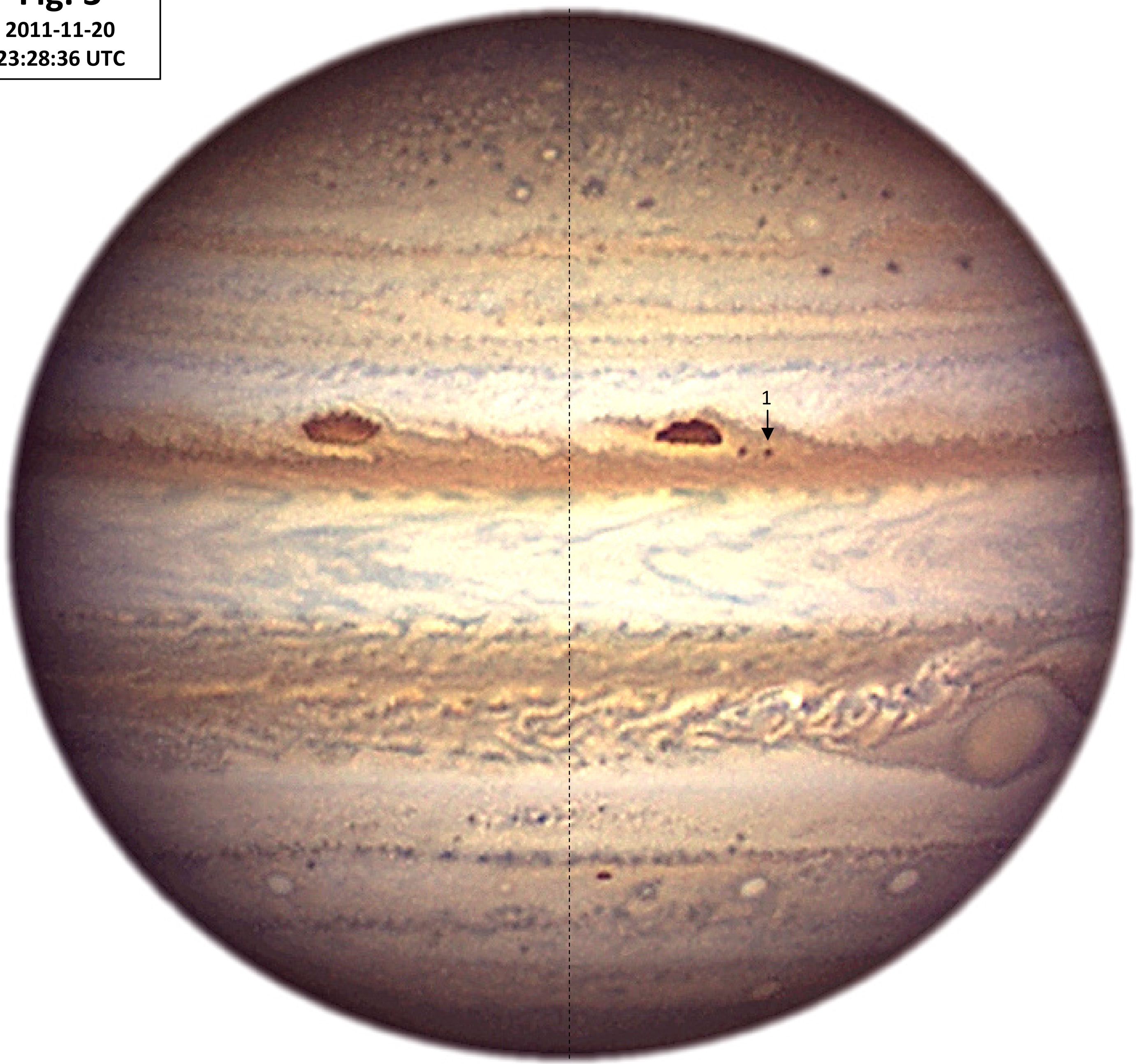
XVIII International Astronomy Olympiad

Литва, Вильнюс 6 – 14. IX. 2013 Vilnius, Lithuania

Fig. 3

2011-11-20

23:28:36 UTC



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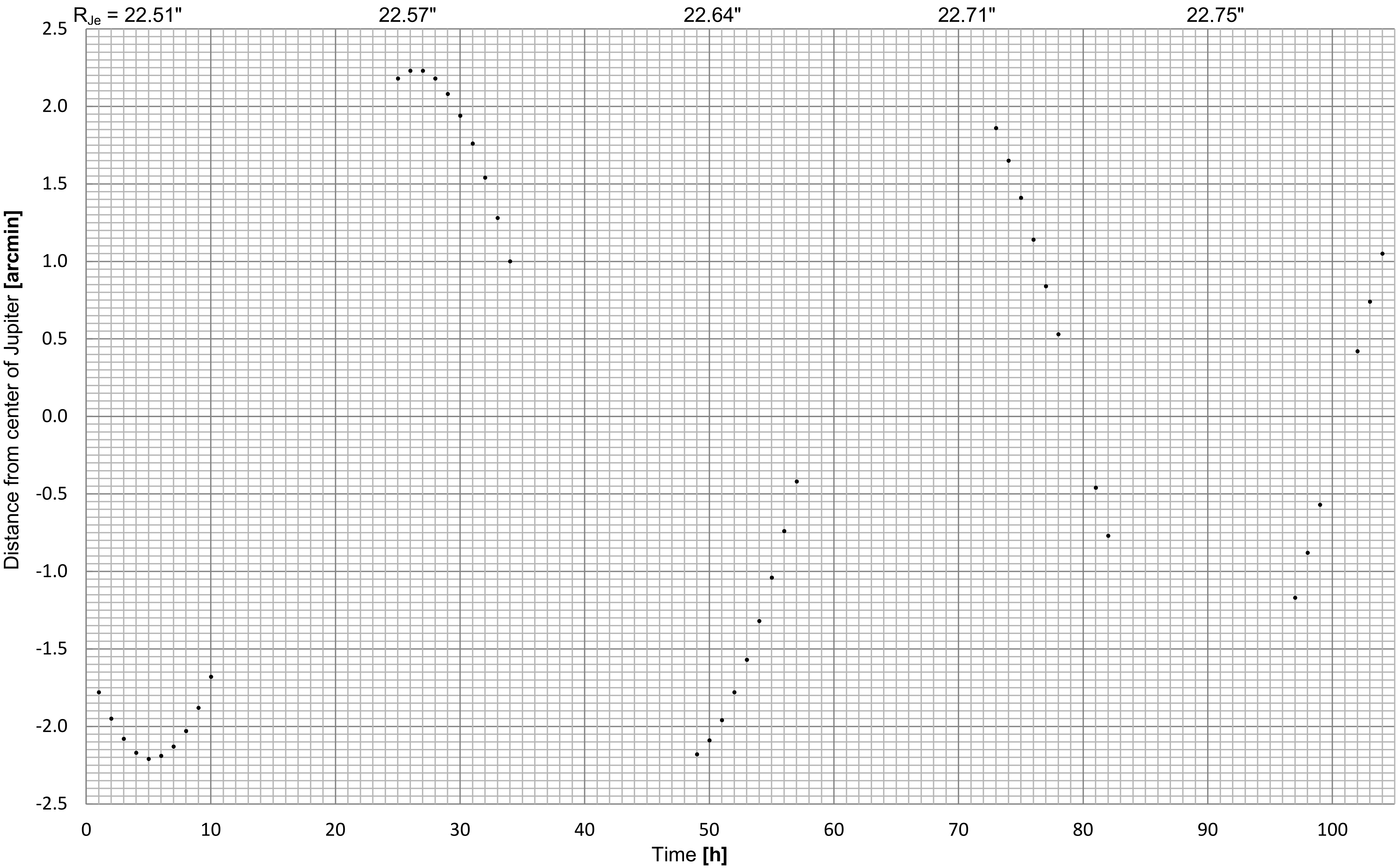
code

Fig. 4. Moon-1



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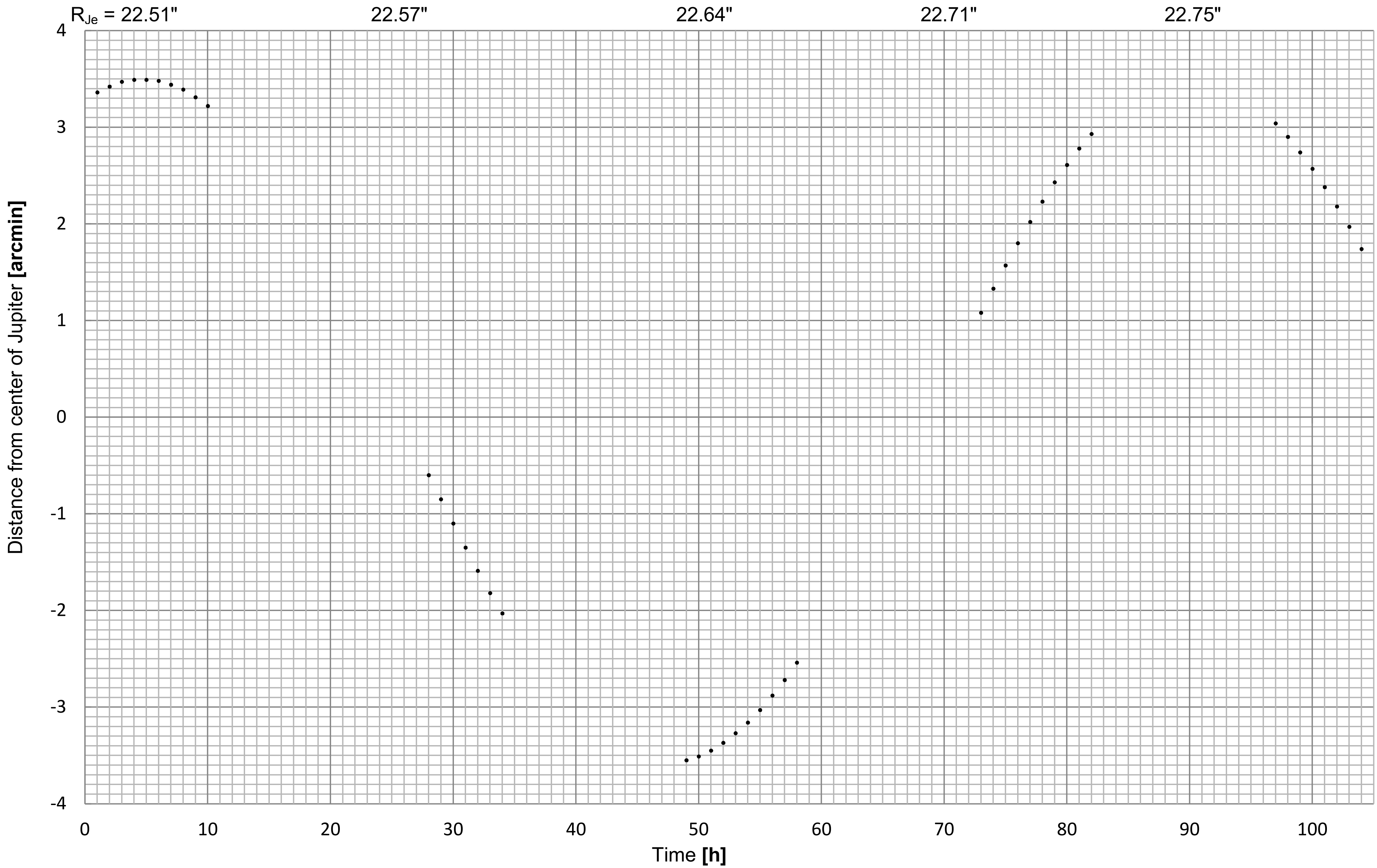
Group α β

код	
code	

Fig. 5. Moon-2



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Group	α β

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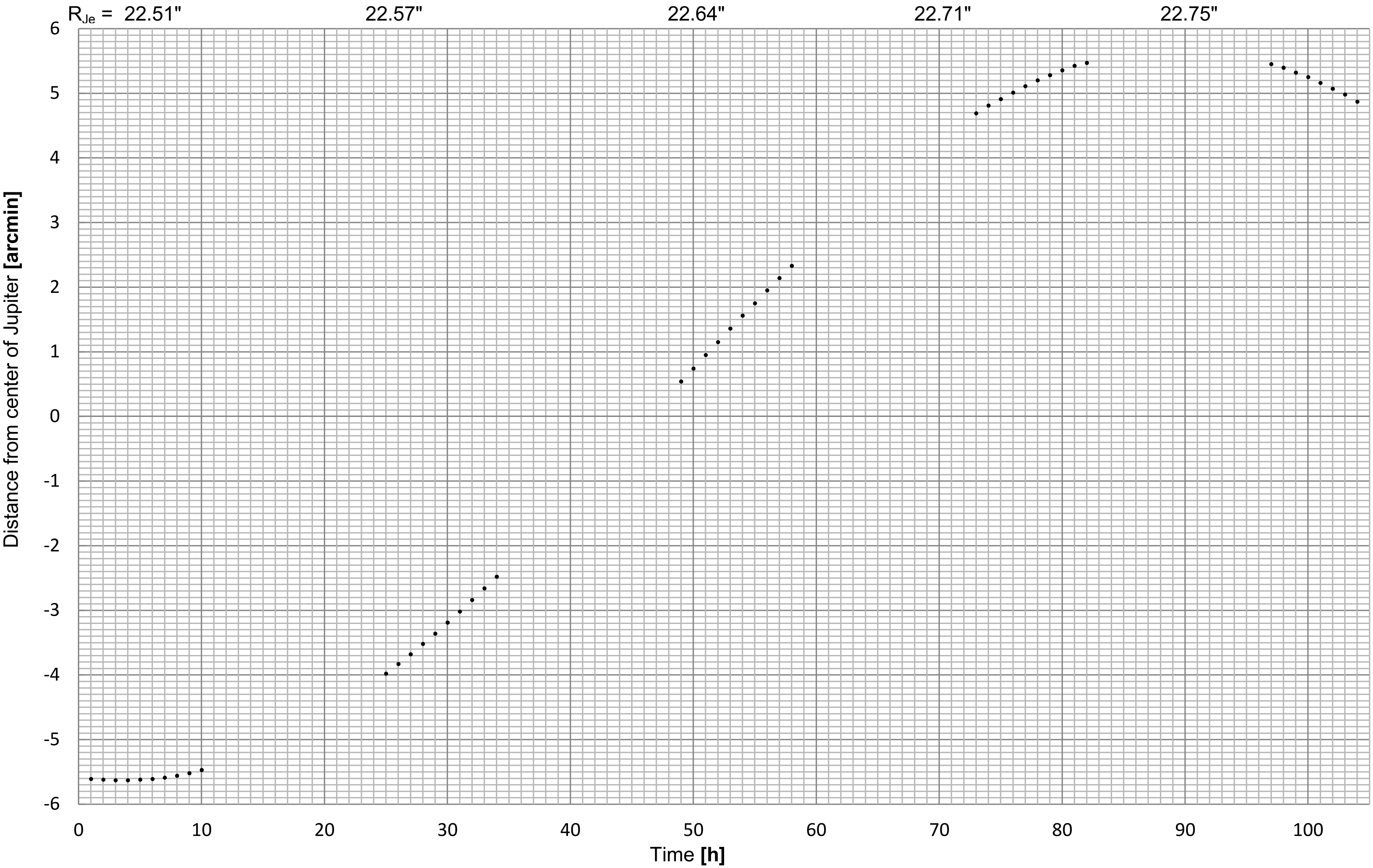
code	

Fig. 6. Moon-3



Code of participant код участника

Observational round. Questions.
Clear sky

Observations by the naked eye

9. Find the object corresponding to the following criteria:
- The object is the second brightest star in its constellation.
- The object is visible approximately 28 degrees from α UMi.
- The equatorial coordinates of the object are: **RA 11^{h}, dec +62°**.

Answer the questions: *Answers:*

a) What is the Bayer designation (e.g. β Ori) of the identified object?

b) Write the name of the constellation in Latin, which the object is visible in.

Answer:

10. What is the angular distance between Vega (α Lyr) and Albireo (β Cyg)?

Answers:

11. a) Find the horizontal coordinates of Thuban (α Dra).

b) Find the zenith distance of Alcor (near ζ Ursae Majoris).

Observations with telescope

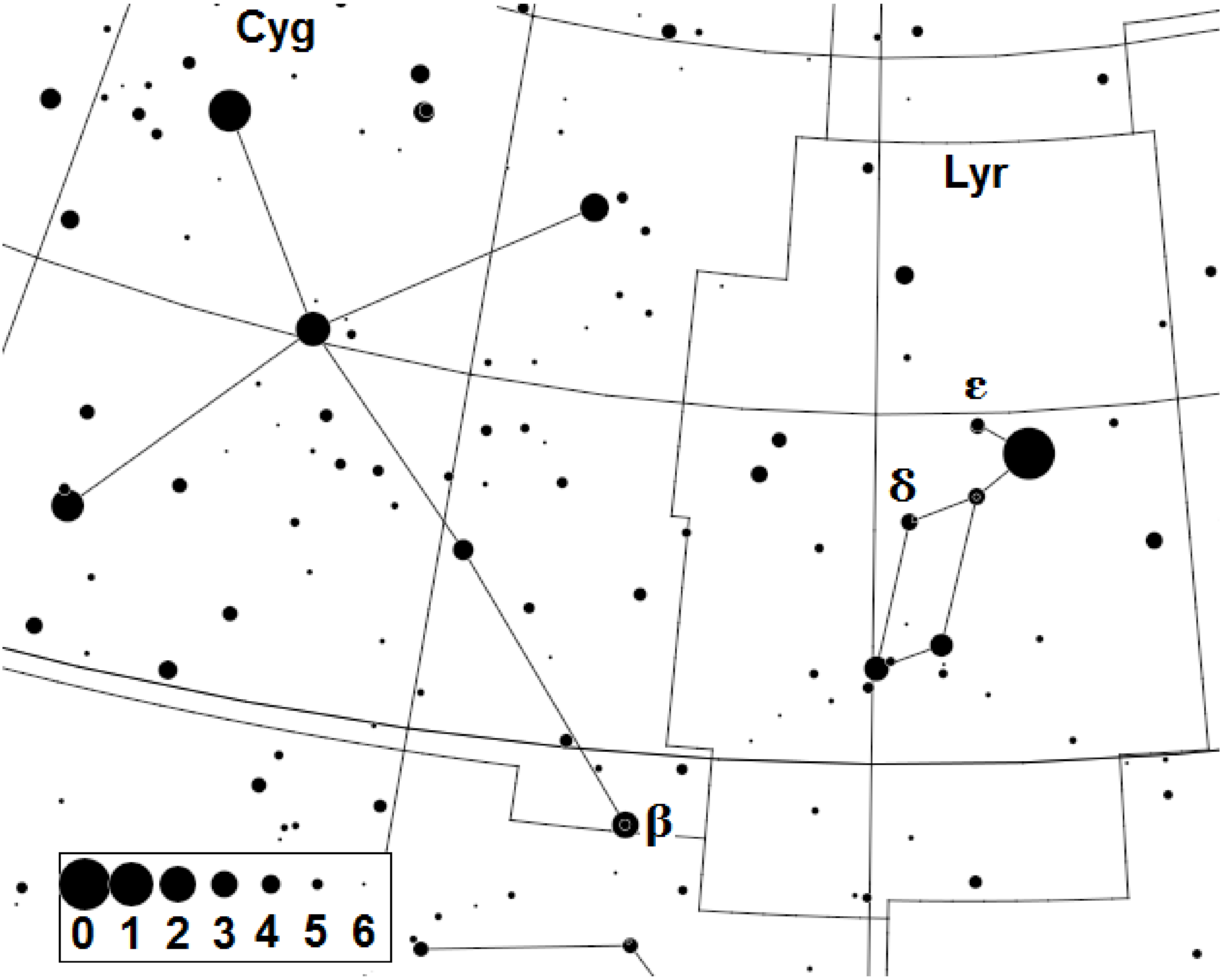
12. There are 3 binary stars on the given sky chart: β Cyg, δ Lyr, and ε Lyr.
For each of the binaries do the following:
Point the telescope to the binary. Compare the star field seen in telescope's field of view with three star charts given on a separate sheet. Write down the designations of the binary stars in each blank box under appropriate star chart. Mark North direction on every star chart.

*The maximum total time for all tasks is **20 minutes**.*

Round **Obs**
Group **α β**

Code of participant	код участника

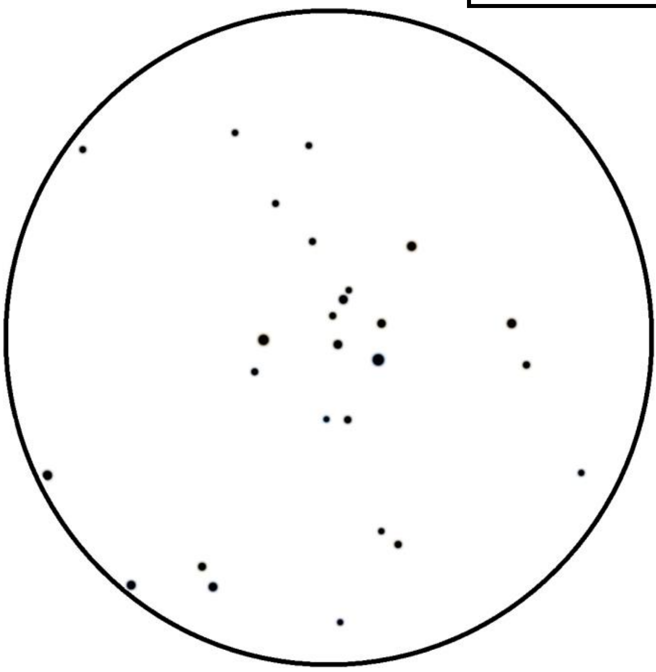
Наблюдательный тур. Чистое небо
Observational round. Clean sky

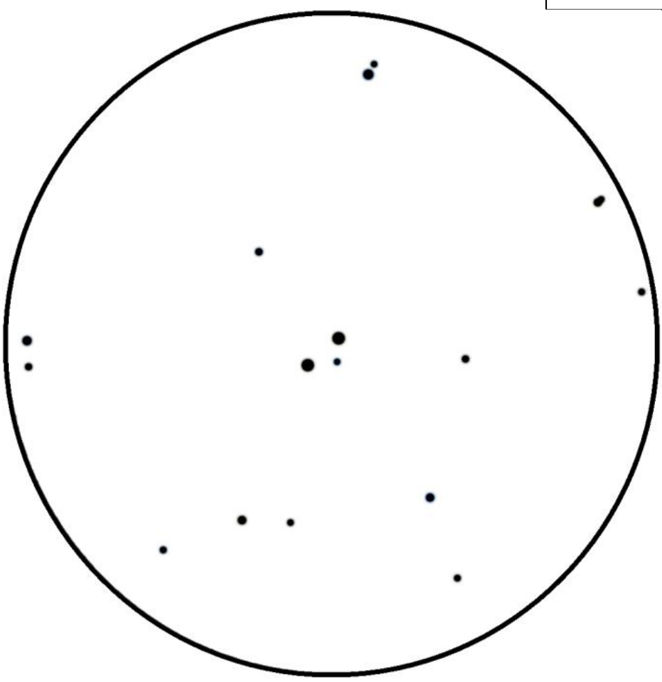


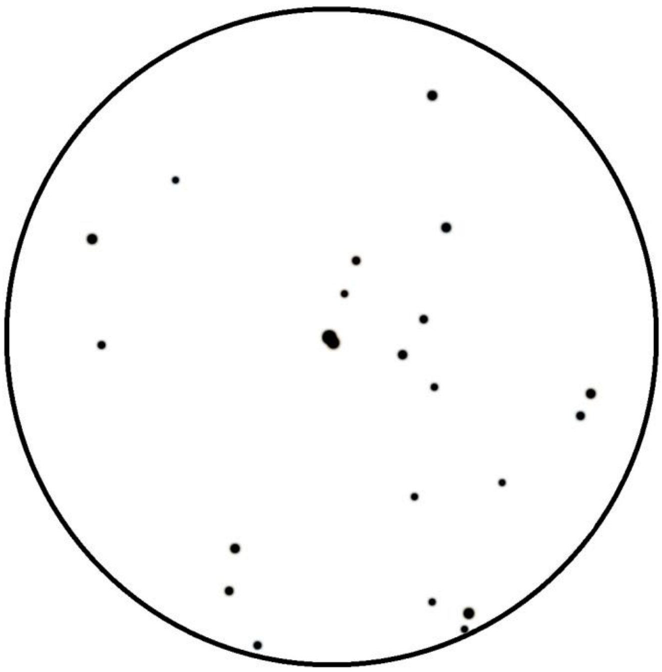
Round Obs
Group α β

Code of participant код участника

Вопросы наблюдательного тура. Чистое небо
Observational round. Clean sky







Theoretical round. Sketches for solutions

Note for jury and team leaders. The proposed sketches are not full; the team leaders have to give more detailed explanations for students. But the correct solutions in the students' papers (enough for 8 pts) may be shorter.

α-1. Star rise in Moletai.

1.1. The time elapsed from the rising of the star to culmination is equal to the time elapsed from culmination to set. Therefore, on September 8, this star rose at 02:54 – 02:51 = 0:03. The next time the star will rise after a sidereal day, equal to 23:56, that is, at 23:59 but still on September 8. On September 9 the star will rise after one more sidereal day, that is at 23:55.

1.2. Very roughly one can say that the star is above the horizon ¼ days, and under the horizon – ¾ days. The star culminates at south. Accordingly, it is above the horizon: ⅛ of rotation before the culmination and ⅛ of rotation after, that is, it rises approximately at south-east and sets approximately at south-west. At the picture that should be drawn by the participants, it can be seen even better. Answer: SE. (ЮВ in Russian).

β-1. RadioAstron.

The resolution of the instrument is determined by the working wavelength λ, and the base D. For telescopes the base is just the diameter of the front lens or mirrors, and for interferometers it is the distance between its elements, or rather, the projection of this distance on the plane perpendicular to the direction to the object under research.

$$\delta = \lambda / D.$$

Thus, the maximum resolution is achieved in the case of the minimum wavelength and the maximum base.

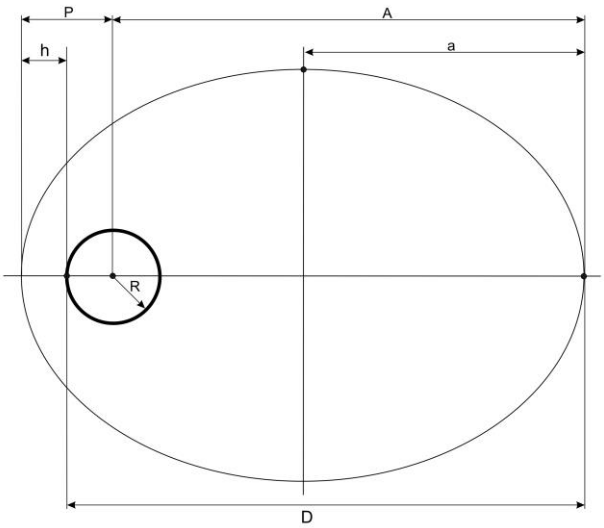
$$\delta_{min} = \lambda_{min} / D_{max}.$$

1.1. In our case it is achieved at the wavelength λ_{min} = 1.2 cm and the base of the Earth–"Spektr-R", in which "Spektr-R" is at apogee, and the ground-based telescope is at the opposite side of the globe; and while the observations are held in the directions perpendicular to the base of Earth–"Spektr-R", that is perpendicular to the major axis of the orbit:

$$D_{max} = A + R,$$

where A is the distance at apogee, and R is radius of the Earth. The apogee distance can be found as

$$A = 2a – (R+h),$$



where a is semi-major axis of the orbit, which, in turn, follows Kepler's third law. Comparing the motion of the satellite with the motion of the Moon we get:

$$a^3/a_☽^3 = \tau^2/T_☽^2, \quad a = a_☽\cdot(\tau/T_☽)^{2/3},$$

$$a = 384\,400 \text{ km} \times (8.3 \text{ days} / 27.32 \text{ days})^{2/3} = 173\,700 \text{ km}.$$

$$D_{max} = 2a – (R+h) + R = 2a – h,$$

$$D_{max} = 2 \times 173\,700 \text{ km} – 600 \text{ km} \approx 347\,000 \text{ km}.$$

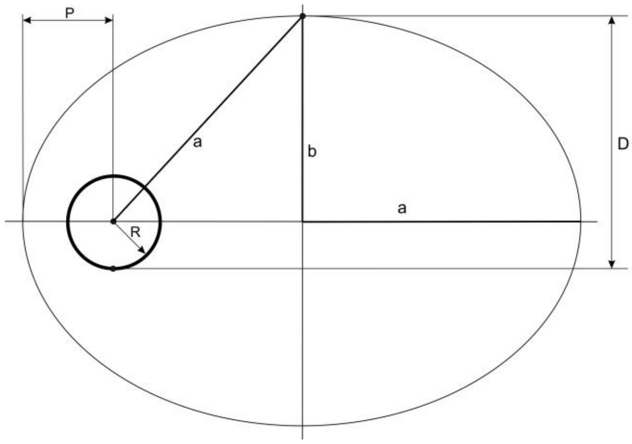
$$\delta_{min} = 1.2 \text{ cm} / 347\,000 \text{ km} \approx 3.5\cdot10^{-11} \text{ rad},$$

or in angular seconds:

$$\delta_{min} = 3.5\cdot10^{-11} \text{ rad} \times 206265''/\text{rad} \approx 7\cdot10^{-6}\,'' = 7 \text{ µas}.$$

1.2. In observations of objects located in the direction of the major axis of the orbit of "Spektr-R", the maximum base D will be equal to the sum of the semi-minor axis of the orbit and the radius of Earth:

$$D_{max} = b + R.$$



Semi-minor axis can be found from the geometric properties of the ellipse:

$$a^2 = b^2 + (a\text{-}P)^2, \quad b^2 = [a^2 - (a\text{-}P)^2]^{1/2},$$

$$b \approx 48\,900 \text{ km}.$$

$$D_{max} = 48\,900 \text{ km} + 6\,400 \text{ km} \approx 55\,300 \text{ km}.$$

$$\delta_{min} = \lambda_{min} / D_{max} = 1.2 \text{ cm} / 55\,300 \text{ km} \approx 2.2\cdot10^{-10} \text{ rad},$$

or in angular seconds:

$$\delta_{min} = 2.2\cdot10^{-11} \text{ rad} \times 206265''/\text{rad} \approx 4.5\cdot10^{-5}\,'' = 45 \text{ µas}.$$

αβ-2. Gliese 581 g.

2.1. It is obvious that there should be about the same conditions as on the Earth for the existence of albuminous based life on the planet.

(Following in the solution indexes $_G$ refer to the system Gliese 581, and indexes $_\Theta$ and $_E$ – to the Sun and Earth).

In the "data of some stars" table one can find the mass of the star Gliese 581, which is equal to $\mathcal{M}_G = 0.31\,\mathcal{M}_\Theta$, its parallax $\boldsymbol{p} = 0.16''$, and the apparent bolometric magnitude $m = 8^m.0$.

Knowing the parallax and the apparent bolometric magnitude of the star, one can find its absolute bolometric magnitude:

$$M = m + 5^m + 5^m \lg \boldsymbol{p} = 8^m.0 + 5^m + \text{-}3^m.98 \approx 9^m.0.$$

It is $9^m - 4^m.8 = 4^m.2$ greater than the absolute magnitude of the Sun. Thus, the radiation from Gliese 581 is $I_\Theta/I_G = 10^{4.2/2.5} \approx 48$ times less than that of the Sun.

Taking into account the Stefan-Boltzmann law, let us compare the temperature regimes on Earth (T_E) and on the planet Gliese 581 g (T_G).

It is known that the balance temperature T on the planet is defined by the balance of incoming and radiated energy. The radiated energy depends only on the surface area and the temperature (the dependence on the temperature is described by the Stefan-Boltzmann $E \sim T^4$, but is not necessary to know the exact relationship for the task). In absence of internal sources of energy (we make this assumption) the radiated energy is equal to the energy from the central luminary. Both the radiated and incoming energies are proportional to the surface area of the planet; hence the balance does not depend on the size of the planet.

The incoming energy is proportional to the radiation of the central star and inversely proportional to the distance to the star:

$$E_E \sim I_\Theta/R_E^2, \quad E_G \sim I_G/R_G^2$$

Thus, for the temperatures on Earth and Gliese 581 g to be equal, it is necessary that

$$E_E = E_G \quad \text{or} \quad R_G/R_E = (I_G/I_\Theta)^{1/2}.$$

According to the generalized Kepler's third law

$$\boldsymbol{\tau}^2\mathcal{M}/a^3 = \text{const}, \quad \text{that is} \quad \boldsymbol{\tau} \sim a^{3/2}/\mathcal{M}^{1/2},$$

or as the orbits are circular,

$$\boldsymbol{\tau} \sim R^{3/2}/\mathcal{M}^{1/2}, \quad \boldsymbol{\tau}_G / \boldsymbol{\tau}_E = (R_G/R_E)^{3/2}/(\mathcal{M}_G/\mathcal{M}_\Theta)^{1/2},$$

$$\boldsymbol{\tau}_G = \boldsymbol{\tau}_E(R_G/R_E)^{3/2}/(\mathcal{M}_G/\mathcal{M}_\Theta)^{1/2} = \boldsymbol{\tau}_E(I_G/I_\Theta)^{3/4}/(\mathcal{M}_G/\mathcal{M}_\Theta)^{1/2},$$

$$\boldsymbol{\tau}_G = 365 \text{ days} \times 48^{-3/4}/0.31^{1/2},$$

$$\boldsymbol{\tau}_G \approx 36 \text{ days}.$$

β-2.2. The size of the planet could be determined by recording the radio-sources from different points of the planet's surface (result of an activity of the civilization). In order to get at least some estimate of the size of the planet, one needs to get a "picture" of radio-sources distribution, and the angular size of the "picture" should exceed the angular resolution at least several times. It should be assumed that as the planet Gliese 581 g is similar to Earth, its diameter is comparable to the diameter of Earth D_E, at least in an order of the value. The angular size of a body with a diameter of Earth D_E in system of Gliese 581 is equal to

$$\alpha = \boldsymbol{p} \times D_E / R_E,$$

$$\alpha = 0{,}16'' \times 12{,}8 \text{ thous.km} / 149\,600 \text{ thous.km} \approx 14 \cdot 10^{-6}\,'' = 14\ \mu\text{as}.$$

As we see, this value is comparable with the best angular resolution of RadioAstron, and for the most of positions of the "Spektr-R" it is even less. In order to obtain any reasonable result an "image" have to be taken, that is the angular size of the object have to exceed the angular resolution at least several times. It is not possible to get a "picture", only a spot will appear as evidence of the extended radio-source. Thus only, it is clear that radio-sources are not at one point but at different locations. In the best case it will be able to determine the order of the diameter of the planet (which we had known earlier).

Answer: **«нет-no»**.

Note. The size of the planet Gliese 581 g, determined by other methods, is estimated as 1.4±0.2 of the size of Earth. The ratio of 1.4 does not introduce considerable amendments to the solution.

αβ-3. Observations from Gliese 581 g.

αβ-3.1. The magnitude of the Sun, visible from any remote location is

$$m_\Theta = m_0 + 5^m \log(206265) - 5^m \lg \boldsymbol{p}.$$

where m_0 is the apparent magnitude of the Sun visible from Earth, and $\boldsymbol{p}$ is the annual parallax of the location.

The magnitude of the Sun as seen from the system of Gliese 581 is

$$m_\Theta = -26^m.74 + 26^m.57 - 5^m \log 0.16 = -0^m.17 - -3^m.98 \approx 3^m.8.$$

(And it is not the only way of solution. The value can be found in many other ways, e.g., by formula $m_\Theta = M - 5^m + 5^m \lg \boldsymbol{p}$).

αβ-3.2. While observing from the planet Gliese 581 g, our Sun will be at a point opposite to where the system of Gliese 581 is seen from Earth. Because Gliese 581 is located in the zodiacal constellation of Libra, the sun will be approximately in the opposite zodiacal constellation, that is, in the **constellation of Aries**. (That solution is correct enough.)

Note: Using a sky-chart one can solve the problem more accurately. The point opposite to the location of the system Gliese 581 at the Earth's sky, has the coordinates $03^h 19^m 27^s$ and 07° 43' 20". This point is located in the constellation of Taurus (Tau), very close to the borders of the constellations of Cetus (Cet) and Aries (Ari). As the students were not provided by a sky-chart, and question was "what is the approximate constellation", the answer "approximately in the constellation, opposite to the constellation of Libra, that is in the constellation of Aries" is correct.

β-3.3. To keep the heat balance a Gliese 581 g should receive the same amount of energy per unit area as is received at Earth.

(As in the previous solution $_G$ indices refer to the system of Gliese 581, and indexes $_\Theta$ and $_E$ – to the Sun and the Earth).

From the given tables one may find that the spectral class of the star Gliese 581 is M3V. According to the Hertzsprung-Russell diagram the temperature of the star, corresponding to this spectral class, is about $T_G = 3300$ K. It is $T_\Theta/T_G = 5780/3300 \approx 1.75$ times less than the temperature of the Sun.

According to the Stefan-Boltzmann law the power emitted from the star is $P = \sigma \cdot S T^4$, and in just the same way we may discourse about the apparent angular area from which the radiation is coming.

Thus, since the apparent angular area of a star is proportional to the square of its apparent angular diameter $\boldsymbol{\alpha}$, the following equations should be correct:

$$\pi/4 \cdot \boldsymbol{\alpha}_G^2 T_G^4 = \pi/4 \cdot \boldsymbol{\alpha}_\Theta^2 T_\Theta^4 \quad \text{or} \quad \boldsymbol{\alpha}_G = \boldsymbol{\alpha}_\Theta (T_\Theta/T_G)^2,$$

$$\boldsymbol{\alpha}_G = 32' \cdot (1.75)^2 = 98'.$$

More than three times larger than the Sun!

αβ-4. XVIII century. Midday. Horse-powers per square verst is a power per unit of area, the quantity that dimension is similar to the solar constant. In physics, it is properly called the "power flux".

Let us calculate the solar constant in units, which were coming into operation in the end of the XVIII century.

I method – visual.

The energy-release of the Sun has not changed since the end of the XVIII century and in units of the horse-power is

$$L = 3.86\cdot10^{26}\text{ W} / (735.5\text{ W/hp}) = 5.25\cdot10^{23}\text{ horse-powers.}$$

The distance from the Sun to Earth has not changed since the end of the XVIII century as well, and in versts is

$$a = 1\text{ AU} = 1.496\cdot10^{11}\text{ m} / (3\cdot500\cdot0.7112\text{ m/vrst}) = 1.402\cdot10^{8}\text{ vrst.}$$

Thus, the solar constant in units of the end of the XVIII century is

$$A_{XIX} = L / 4\pi a^2 = 5.25\cdot10^{23}\text{ hp} / 4\pi(1{,}402\cdot10^{8}\text{ vrst})^2 = 2.12\cdot10^{6}\text{ hp / vrst}^2.$$

II method – formal.

$$A_{XIX} = A_0 \times k_{(hp/W)} / k^2_{(vrst/m)} = 1367\text{ W/m}^2 / (735.5\text{ W/hp}) \times (1066.78\text{ m/vrst})^2 = 2.12\cdot10^{6}\text{ hp / vrst}^2.$$

4.1. The outskirts of Dubingiai in the XVIII century were located on the same latitude as where they are located in the XXI century, that is, at about latitudes 54.7° – 55.2° (latitudes of Vilnius and Moletai respectively, may be found from the map). The value of 23.5°, the inclination of the equatorial plane of the ecliptic, also almost has not changed (strictly speaking, it had declined by about one arc minute). Thus, at the middays of the winter solstice in the XVIII century in the outskirts of the town Dubingiai the sun was at an altitude about

$$h_W = 90° – 55.0° – 23.5° = 11.5°,$$

at the middays of spring and autumn – at an altitude about

$$h_0 = 90° – 55.0° = 35.0°,$$

at the middays of the summer solstice – at an altitude about

$$h_S = 90° – 55.0° + 23.5° = 58.5°.$$

While the altitude of the Sun is h, the power flux to the unit of the territory is

$$W = A\cdot\sin h.$$

Thus, the target values are:

in winter – $W_W = A\cdot\sin h_W \approx 420\,000$ hp/vrst^2,

in spring and autumn – $W_0 = A\cdot\sin h_0 \approx 1\,220\,000$ hp/vrst^2,

in summer – $W_S = A\cdot\sin h_S \approx 1\,810\,000$ hp/vrst^2.

4.2. And what is the capacity of the solar energy incident at those times on a local horse? This value largely depends on the orientation of the horse relative to the Sun than the altitude of the sun above the horizon. Let us assume that the cross-sectional area of a horse perpendicular to the sun-rays is 1-3 arsh^2 (depending on the mentioned above orientation of the horse) and recalculate the value of the solar constant into horse-powers per square arshin.

Distance from the Sun

$$a = 1\text{ AU} = 1.496\cdot10^{11}\text{ m} / 0.7112\text{ m/arsh} = 2.103\cdot10^{14}\text{ arsh.}$$

The solar constant in these units equals to

$$A = L / 4\pi a^2 = 5.25\cdot10^{23}\text{ hp} / 4\pi(2.103\cdot10^{11}\text{ arsh})^2 = 0.94\text{ hp / arsh}^2.$$

Thus, a horse standing in the sun, receives about one to three horse-powers of solar radiation! Just this can be a surprise.

Answer: 1-3 hp.

Note. In solving the problem we emphasize very often that many of the physical parameters are not changed in the last two centuries: the solar constant, the distance from Earth to the Sun, the latitude of location, inclination of the ecliptic to the equatorial plane. Students who also record this constancy should be encouraged to add points.

αβ-5. XXI century. Midday.

5.1. Today (on September 8) the summer time is in operation, so the watches of citizens of Lithuania ahead the universal time by 3 hours. Local mean solar time coincide with this time on the meridian 45° of East longitude, located too far to the east (at the latitude of Lithuania it is in the Nizhny Novgorod region of Russia).

The adding of the equation of time (see figure) is in the range of -16 – +14 minutes, and this effect may replace the meridian not more than 4° in longitude. But even with this addition such areas are far beyond the borders of Lithuania.

Answer: **«нет-no»**.

5.2. To answer the second question of the problem you need to consider two periods: summer and winter time. For any of the day during summer time operation the situation is similar to that we discussed in sub-point 1.

The territory of Lithuania is approximately (we can measure it with an accuracy of a quarter degree) between 21°00' and 26°45' of East longitude. At the period when the winter time is in operation, the situation is queerer. Local mean solar time correspond to the meridian 30° East. Thus, in the winter time period mean local solar noon also does not occur before 12:00 of Lithuanian time anywhere in Lithuania.

However, there is a question about the upper culmination of the sun in the problem condition, as a rule it does not coincide with the mean solar culmination at 12:00 of mean solar time. The difference between the apparent (or true) solar time (T_A) and mean solar time (T_M) is defined by the equation of time,

$$T_M = T_A + \eta \ ,$$

where η is parameter of the equation of time, which is hereinafter referred to as simply "equation of time", as it is accepted by astronomers.

The meridian 30° East passes very close to the eastern border of Lithuania (about this meridian St.Petersburg, Nevel, Vitebsk, Orsha, Mogilev and Kiev are located), so one should pay attention to the equation of time. Winter time is in operation from the end of October to the end of March, and within this range the values of the equation of time may be both positive and negative.

Positive values of the equation of time move the apparent solar noon to later time (by the watches of inhabitants), and the negative to earlier time. Using the graph of the equation of time one can determine that the adding is minimal on November 3 and its value in a minimum is -16.4 minutes. The corresponding meridian (for the apparent culmination of the Sun at 12:00 Lithuanian time) is shifted by 4°06' West and by almost a degree enters the territory of Lithuania, till the longitude λ = 25°54'.

Thus, the apparent noon will occur at 12:00 of Lithuanian time somewhere at the territory of the country, if the values of the equation of time were below -3°45' in degrees, and so the values of η were below -15 minutes. And η is below -15 minutes from October 18 to November 17 (approximately, as we can find from the graph).

Answer: **«да-yes»**, October 18 – November 17 (part of this period when winter time is in operation).

Note. There is no universally accepted definition of the sign of the equation of time. This solution is written in accordance with the historically European definition of the sign of the equation of time (positive values of η in January-March, as it is displayed in the supplement page). However, in the British and American (and also translated from English) literature, the definition is inverse (negative values of η in January-March). The members of Jury must consider that solutions using both alternatives of definition are correct (of course, the answer does not depend on the choice of the alternative, turning "+" and "–" at the graph leads to turn the sign of η in the equation (1)).

αβ-6. Supernova remnant.

6.1. Assume that the SNR is a sphere with the linear radius R. Using a ruler we accurately measure the diameter of the circle and the scale length (e.g. in mm) in Fig. SNR (see the figure below, the initial figure was almost 2 times larger). From these measurements we get the radius of the circle ρ = 48.5 mm and 100" scale length l = 28.5 mm. With these data we can calculate the angular radius of the SNR

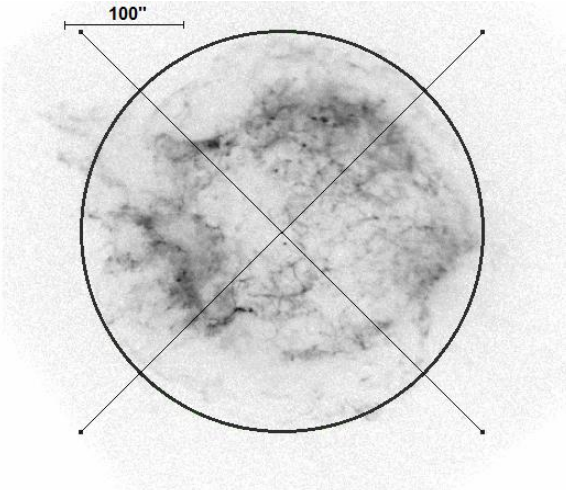
$$\theta = 100'' \rho / l,$$

$$\theta = 100'' \times 48.5 / 28.5 \approx 170''.$$

If the radius R of the SNR is measured in au, the distance d in pc, and its angular radius θ in arcsec, then

$$R = d \times \theta,$$

$$R = 170'' \times 3400 = 578000 \text{ AU} \approx 8.6 \cdot 10^{16} \text{ m}.$$



The mass of the SNR is confined within the sphere of the radius R.

$$M = \rho \cdot 4/3 \cdot \pi R^3,$$

$$M = 10^{-21} \cdot 4/3 \cdot 3{,}14 \cdot (8.5 \cdot 10^{16})^3 \approx 2.7 \cdot 10^{30} \text{ kg}.$$

The expansion speed of the SNR is calculated using the expression of the kinetic energy of the SNR

$$E_{kin} = ½\, Mv^2,$$

$$v = (2 \cdot E_{kin} / M)^{1/2} = (2 \cdot 0{,}01 \cdot E_{SN} / M)^{1/2},$$

$$v = (2 \cdot 0{,}01 \cdot 10^{46} \text{ J} / 2.7 \cdot 10^{30} \text{ kg})^{1/2} \approx 8.6 \cdot 10^6 \text{ m/s} \approx 10^7 \text{ m/s}.$$

As we see from the image, the darkest parts of it are distributed at distances about 60% of its radius. So we may propose that most mass of the SNR is distributed at these distances. Thus, by the above formulae we have found the average speed of matter at 0.6 R.

Assuming that the expansion velocity was constant we get the age of the SNR:

$$t = 0.6\, R / v,$$

$$t = 0.6 \times 8.6 \cdot 10^{16} \text{ m} / 8.6 \cdot 10^6 \text{ m/s} \approx 6 \cdot 10^9 \text{ s} \approx 190 \text{ yr} \approx 200 \text{ yr}.$$

Taking into account that most data in the problem conditions was done very roughly, with maximum 1 significant digit (and even with zero significant digits as only order of magnitude is done: the energy was about 10^{46} J, 1% of which drives the expansion; the average density is 10^{-21} kg/m^3), the answer should be expressed also with only one significant digit.

So the answer is: ~200 years.

6.2. Using a ruler we measure the distance of the neutron star from the center of circle in Fig. SNR. Say that we get $\sigma = 3$ mm. Then the angular distance δ of the neutron star from the center of the SNR is

$$\delta = 100''\ \sigma / l,$$

$$\delta = 100'' \times 3 / 28.5 \approx 10.5''.$$

The linear distance of the neutron star from the center of the SNR is

$$S_N = \sigma \times d,$$

$$S_N = 10.5 \times 3400 \approx 35700 \text{ AU} \approx 5.3 \cdot 10^{12} \text{ km}.$$

The velocity of the motion of the neutron star is

$$u = S_N / t,$$

$$u = 5.3 \cdot 10^{12} \text{ km} / 6 \cdot 10^9 \text{ s} \approx 900 \text{ km/s} \approx 10^3 \text{ km/s}.$$

Also taking into account that most data was done very roughly, the answer should be expressed also as an order of magnitude only or with only one significant digit.

The answer is: ~10^3 km/s.

Theoretical round. Basic criteria. For work of Jury

Note. The given sketches are not full; the team leaders have to give more detailed explanations to students. But the correct solutions in the students' papers (enough for 8 pts) may be shorter.

Note. Jury members should evaluate the student's solutions in essence, and not by looking on formal existence the mentioned sentences or formulae. The formal presence of the mentioned positions in the text is not necessary to give the respective points. Points should be done if the following steps de facto using these positions.

α-1. Star rise in Moletai.

1.1. Totally 5 pt, including:
Understanding approach that culmination is the middle point between star rise and star set – 1 pt.
Time of the first star rise on September 8 calculation, result 0:03 – 1 pt.
Using sidereal approach for the future calculations – 1 pt.
Issue that next sunrise will be still on September 8 – 1 pt.
On September 9 the star will rise after one more sidereal day, that is at 23:55 – 1 pt.

1.2. Totally 3 pt, including:
Argumentation about the star is above the horizon ¼ days, ⅛ of rotation before the culmination and ⅛ of rotation after – 1 pt.
Correct illustration – 1 pt.
Rises approximately at south-east, answer: SE – 1 pt.

β-1. RadioAstron.

1.common. Totally 1.5 pt, including:
General approach, formula $\delta = \lambda / D$ – 0.5 pt.
The base for interferometers it is the distance between its elements – 0.5 pt.
Understanding $\delta_{min} = \lambda_{min} / D_{max}$ – 0.5 pt.

1.1. Totally 3.5 pt, including:
Understanding λ_{min} = 1.19 cm – 0.5 pt.
The maximum base of the Earth–"Spektr-R", in which "Spektr-R" is at apogee, and the ground-based telescope is at the opposite side of the globe $D_{max} = A + R$ – 0.5 pt.
The directions perpendicular to the base of Earth–"Spektr-R" – perpendicular to the major axis – 0.5 pt.
The apogee distance can be found as $A = 2a – (R+h)$ – 0.5 pt.
Using Kepler's third law to find a, $a^3/a_☽^3 = \tau^2/T_☽^2$ – 0.5 pt.
Final calculations and correct result – 1 pt.

1.2. Totally 3 pt, including:
The maximum base $D_{max} = b + R$ – 1 pt.
Calculation semi-minor axis using the geometric properties of the ellipse – 1 pt.
Final calculations and correct result – 1 pt.

α-2. Gliese 581 g.

Conditions as on the Earth, the same temperature – 1 pt.
Correct taking the necessary data from the tables – 0.5 pt.
Finding (any way) that the radiation from Gliese 581 is about 48 times less than that of the Sun – 2.5 pt.
Dependence on R – 1 pt.
Correct using the generalized Kepler's third law, calculations – 2 pt.
Final calculations and correct result – 1 pt.

β-2. Gliese 581 g.

2.1. Totally 5.5 pt, including:
Conditions as on the Earth, the same temperature – 0.5 pt.
Correct taking the necessary data from the tables – 0.5 pt.
Finding (any way) that the radiation from Gliese 581 is about 48 times less than that of the Sun – 1.5 pt.
Dependance on R – 0.5 pt.
Correct using the generalized Kepler's third law, calculations – 1.5 pt.
Final calculations and correct result – 1 pt.
2.2. Totally 2.5 pt, including:
Issue that the order of the size of the planet is comparable to the size of Earth – 0.5 pt.
$\alpha = \boldsymbol{p} \times D_E / R_E$ – 0.5 pt.
Correct calculations, result about 14 μas – 0.5 pt.
Conclusion that the angular size of the object has to exceed the angular resolution at least several times, answer "no" – 1 pt.

α-3. Observations from Gliese 581 g.

3.1. Totally 5 pt, including:
Formulae for magnitude of the Sun (any way solution) – 3 pt.
Correct calculations – 2 pt.
3.2. Totally 3 pt, including:
Understanding that Gliese 581 is located in the zodiacal constellation of Libra – 1 pt.
Sun will be at opposite point – 1 pt.
Answer: constellation of Aries – 1 pt.

β-3. Observations from Gliese 581 g.

3.1. Totally 3.5 pt, including:
Formulae for magnitude of the Sun (any way solution) – 2 pt.
Correct calculations – 1.5 pt.
3.2. Totally 2 pt, including:
Understanding that Gliese 581 is located in the zodiacal constellation of Libra – 0.5 pt.
Sun will be at opposite point – 1 pt.
Answer: constellation of Aries – 0.5 pt.
3.3. Totally 2.5 pt, including:
Heat balance, the same amount of energy per unit area – 0.5 pt.
Finding spectral class and temperature (using HR diagram) – 0.5 pt.
Using Stefan-Boltzmann law – 0.5 pt.
Final formula – 0.5 pt.
Final calculations and result – 0.5 pt.

αβ-4. XVIII century. Midday.

4.common. Totally 2 pt, including:
Calculation of the solar constant in nesessary units, result $2.12 \cdot 10^6$ hp / vrst^2 or 0.94 hp / arsh^2 – 2 pt.

4.1. Totally 3 pt, including:
Latitudes the same as now (about 54.7° – 55.2°) – 1 pt.
Calculation of altitudes of midday Sun in winter, spring, autumn, summer – 1 pt.
$W = A \cdot \sin h$, correct final calculations – 1 pt.

4.2. Totally 3 pt, including:
Correct understanding on what the answer may depend – 0.5 pt.
Correct model of horse, including the picture – 0.5 pt.
The cross-sectional area of a horse perpendicular to the sun-rays is 1÷3 arsh^2 – 0.5 pt.
Correct calculations and result about 1-3 hp – 1 pt.
Common conclusion about surprise that horse standing in the sun, receives about one to three horse-powers of solar radiation – 0.5 pt.

αβ-5. XXI century. Midday.

5.1. Totally 3 pt, including:
Summer time, meridian 45°, far to the east, so not possible – 2 pt.
Mention that adding of the equation of time – correction not more than 4° in longitude – 1 pt.

5.2. Totally 5 pt, including:
For any day during summer time the situation is similar #5.1. – 1 pt.
Finding longitudes of Lithuania, meridian 30° is not too far – 1 pt.
Correct equation of time using – 1 pt.
Values of η were below -15 minutes – 1 pt.
Finding the period from October 18 to November 17 (approximately) – 1 pt.

αβ-6. Supernova remnant.

6.1. Totally 4 pt, including:
Correct measurements of distances – 0.5 pt.
Finding necessary distances and mass – 1.5 pt.
Energy, finding typical speeds – 1 pt.
Final the time, correct calculations – 1 pt.

6.2. Totally 2 pt, including:
Correct measurements of distance from the center – 0.5 pt.
Calculations and correct answer – 1.5 pt.

6.common. Totally 2 pt, including:
The most data in the problem conditions was done very roughly, with maximum 1 significant digit, so the answer should be expressed also with only one significant digit, follow this principle – 2pt.

Practical round. Problems to solve

7. Asteroid.

Analysis of observations of a near earth asteroid.

Astronomers of two observatories, which are located at a distance of 3172 km from each other, took CCD images of a certain region of the sky for the search of a near earth asteroid. Two images were obtained by Observatory 1 during the same night at 4^h53^m UT and at 7^h16^m UT. These images (negatives) are shown in Figs. 7.1 and 7.2, respectively. The next two images obtained on the same night were made at Observatory 1 .and Observatory 2 simultaneously. These images (negatives) are shown in Figs. 7.3 and 7.4. The scale of all the images is the same as shown in Fig. 7.1.

7.1. Identify and mark the asteroid in the given Figs.

7.2. Measure the angular displacement (in arcsec) of the asteroid as seen from Observatory 1 and calculate its angular velocity in arcsec/s.

7.3. Measure the parallax of the asteroid (in arcsec) and calculate its distance from the earth.

7.4. Calculate the tangential linear velocity (velocity perpendicular to the line of sight) of the asteroid.

Note: You are provided a transparency for measurements of angular displacements of the asteroid.

7. Asteroid. **7. Астероид.**

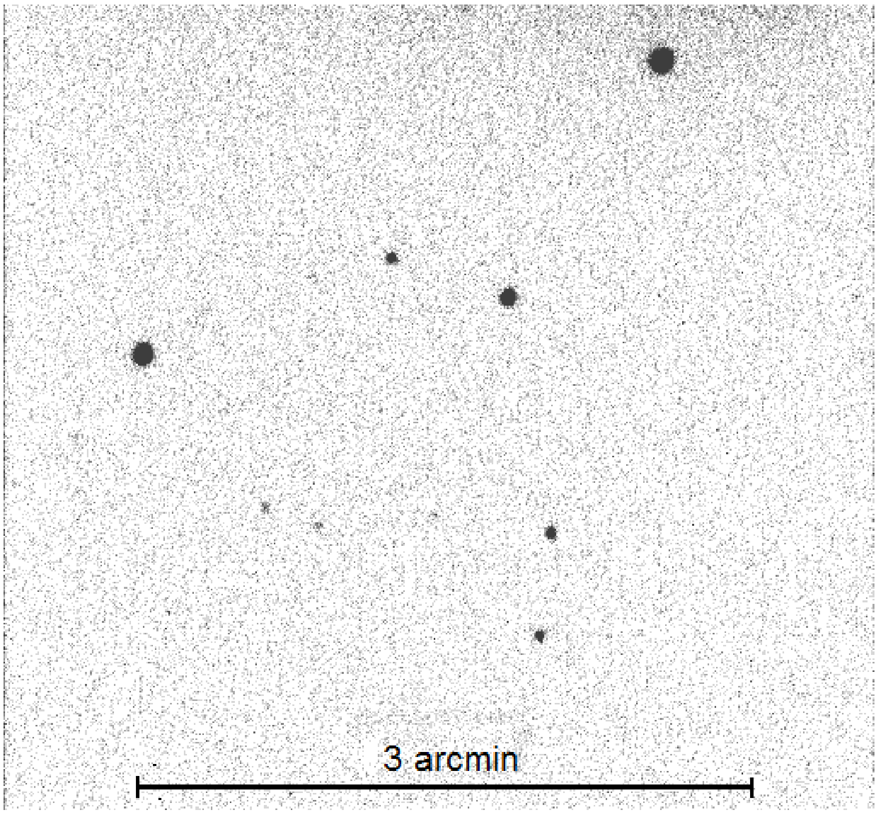


Fig. 7.1. ***4:53 UT*** ***Рис. 7.1.***

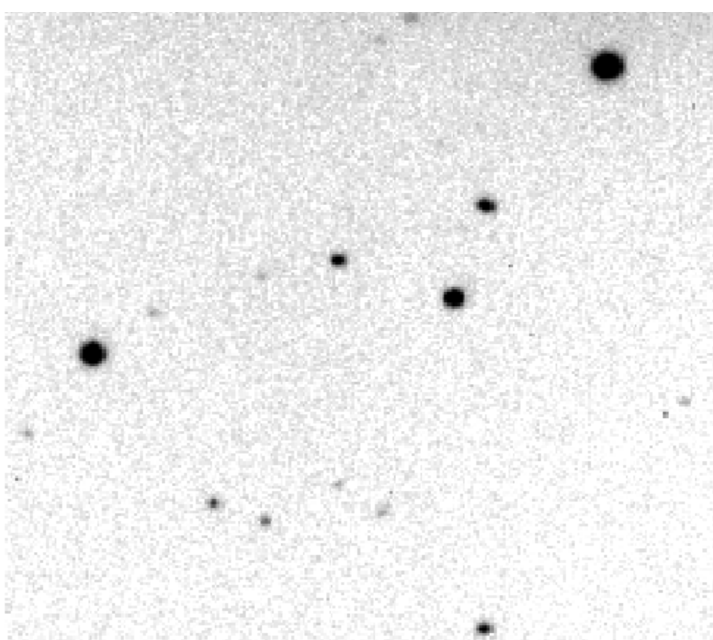


Fig. 7.2. ***7:16 UT*** ***Рис. 7.2.***

Round | Prac
Group | α

код	
code	

7. Asteroid. **7. Астероид.**

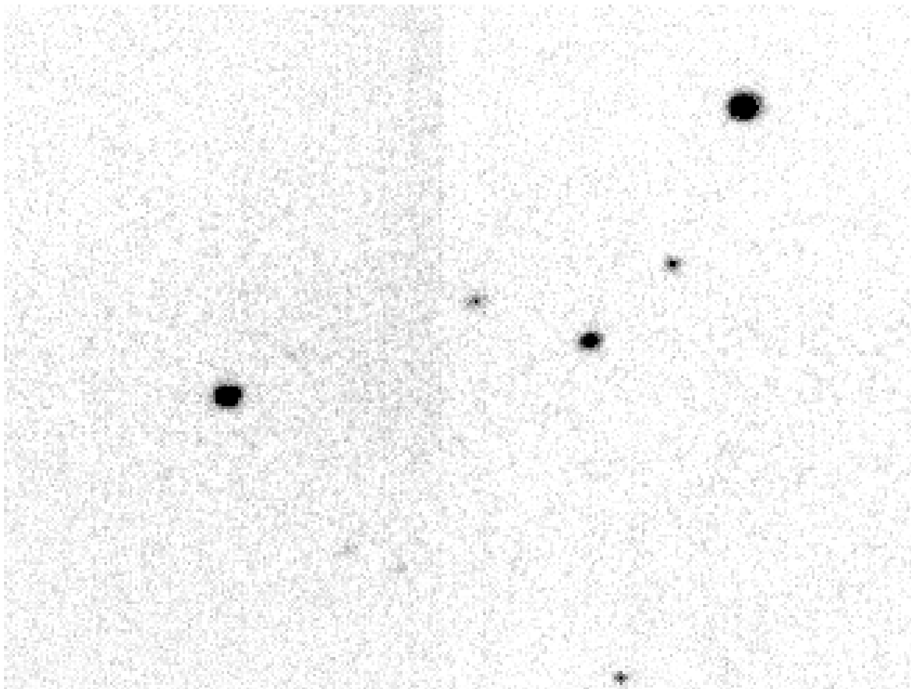


Fig. 7.3. Observatory 2 Рис. 7.3.

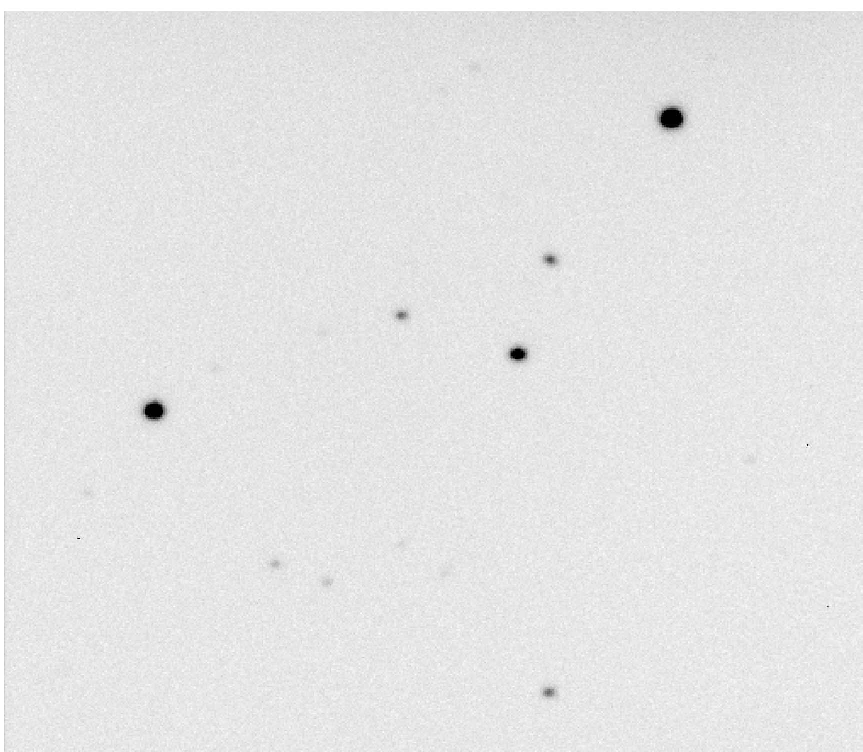


Fig. 7.4. Observatory 1 Рис. 7.4.

Solution

1) Comparison of Figs. 7.1 and 7.2 allow us to identify the asteroid and evaluate its angular displacement due to its motion. We put the transparency on Fig.7.1 and mark positions of several bright objects with a pencil. Then we put the transparency on Fig. 7.2 and move it until the markings of objects on the transparency will coincide with positions of corresponding objects in Fig. 7.2. We notice that one object changed its position considerably in Fig. 7.2. This is the asteroid.
2) We mark the position of the asteroid on the transparency. Then we measure the displacement of the asteroid on the transparency and get Δl =44 mm. Using the scale of Fig. 7.1 we calculate the angular displacement of the asteroid.

$\Delta\theta=180\times44/81=98$ arcsec

The time interval between images of Figs.7.1 and 7.2 is Δt =7h16m-4h53m=2h23m=8580 s.

The angular velocity of the asteroid $\mu= \Delta\theta/\Delta t=98/8580=0.011$ arcsec/s.

3) The parallax of the asteroid is evaluated by comparison of Figs. 7.3 and 7.4. These two images were taken from two different locations at the same time. We mark the positions of the asteroid overlaying the same transparency on Figs. 7.3 and 7.4. and measure the displacement of the asteroid on the same transparency, $\Delta b=7$ mm.

   Angular displacement of the asteroid is $\Delta\phi=180\times7/81=16$ arcsec. Then the parallax $p= \Delta\phi/2=8$ arcsec.

The distance of the asteroid is $d=B/(2\tan p)$, where B is the baseline, i.e. the distance between observatories. Then $d=206265\times B/(2\,p)$ since p is a small angle and measured in arcsec.

$d=206265\times3172/(2\times8)$ = 40900000 km = 0.27 au.

4) The tangential linear velocity of the asteroid is $v = d \tan \mu$ or $v=d\mu/206265$.

$v=40900000\times0.011/206265$ = 2 km/s.

Practical round. Problems to solve

αβ-8. Jupiter. Analysis of observational data of Jupiter and its moons

Observational data of Jupiter and its moons are given on separate sheets.
Your answers (measured values, results of calculations, used formulas) must be written in corresponding tables.

A. See separate sheet.

B. Equatorial rotational period and radius

Two CCD images of Jupiter are shown in Figs. 2 and 3. The vertical lines in figures marks the position of the projection of Jupiter's rotation axis (we assume it is perpendicular to the line of sight). The rotation period can be obtained from horizontal shifts of stable atmospheric features located relatively close to the equator.

B.1. What time interval in seconds (**dt**) separate these images?
B.2. One feature useful for measurements is already marked "**1**". Select and mark two additional features as "**2**" and "**3**" in both pictures.
B.3. Measure distances from the central vertical line to the marked features in both images ($\mathbf{x_1}$ and $\mathbf{x_2}$, respectively) and to the Jupiter limb at the feature's latitude ($\mathbf{L_x}$).
B.4. Calculate the rotational angle (**ϕ**) for each feature.
B.5. Calculate the averaged value of rotational angle (**ϕ_avg**).
B.6. Calculate the rotational period ($\mathbf{P_{Je}}$), in hours.
B.7. Calculate Jupiter's equatorial radius ($\mathbf{R_{Je}}$), in km.

C. Mass and density

Figs. 4-6 display observations of three Jupiter moons obtained during five successive nights in September 2011. Abscissa in those figures is time of observation measured in hours from the beginning of the observing session. Ordinate is the angular distance (in angular minutes) of the moon from the center of Jupiter at the moment of observation. The equatorial radius of Jupiter in the angular seconds is also given for some moments.

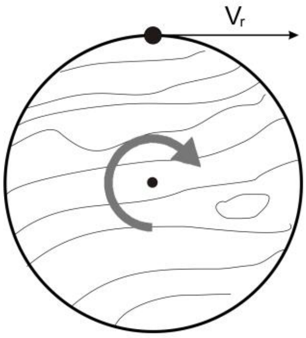
C.1. Estimate the period of revolution of each Jupiter's moon ($\mathbf{P_m}$), in hours.
C.2. Estimate the semimajor axis of the orbit of each Jupiter's moon expressed in Jupiter's equatorial radii (**a_Je**) and convert it into meters (**a**).
C.3. Use your mesurements of each moon to calculate the mass of Jupiter ($\mathbf{M_J}$) independently.
C.4. Calculate the averaged value of Jupiter mass ($\mathbf{M_J}$**_avg**).
C.5. From Jupiter image estimate the ratio of Jupiter's polar and equatorial radii ($\mathbf{R_p/R_e}$).
C.6. Calculate the mean radius of Jupiter ($\mathbf{R_J}$**_avg**).
C.7. Calculate the density of Jupiter ($\mathbf{\rho_J}$).

Round **Prac**

Group **α**

8.

A.



V_r = 12.6 km/s

Practical round. Problems to solve

β-8. Jupiter.

A. Rotational velocity

Spectrum of Jupiter (Fig. 1) was obtained when the slit of a spectrograph was aligned along the planet's equator. Wavelengths (**λ**) of several recognized lines are shown. Due to Jupiter rotation the reflected Sunlight was affected by the Doppler effect. The spectral lines become inclined, because the spectrum of light reflected from the receding part of Jupiter is red-shifted, and of light reflected from the approaching part is blue-shifted. Non-inclined lines, which are visible in the spectrum, were formed in the Earth atmosphere.

A.1. Evaluate the mean scale of the given spectral interval (**N**), in nm per mm.
A.2. Measure the difference between the uppermost and the lowermost end of an inclined spectral line in mm (**dx**) and convert it into nm (**dλ**). Do this for 3 lines independently.
A.3. Calculate the equatorial rotational velocity of Jupiter ($\mathbf{v_r}$) for each measured line and the final averaged value ($\mathbf{v_r\_avg}$).

8.

Table A

N [nm/mm] =	

λ [nm]	dx [mm]	$d\lambda$[nm]	v_r [km/s]
		v_r_avg [km/s] =	

FORMULAE

v_r [km/s] =

8.

Table B

dt[s] =	

Feature	**x_1 [mm]**	**x_2 [mm]**	**L_x [mm]**	**ϕ [°]**
1				
2				
3				
			ϕ_avg =	

P_{Je} [h] =	
R_{Je} [km] =	

FORMULAE

ϕ [°] =

P_{Je} [h] =

R_{Je} [km] =

8.

Table C

Moon	P_m [h]	a_Je	a [m]	M_J [kg]
1				
2				
3				
			M_J_avg [kg] =	

R_p/R_e =	
R_J_avg [km] =	
V [m^3] =	
ρ_J [kg/m^3] =	

FORMULAE

M_J [kg] =

R_J_avg [km] =

Fig. 1

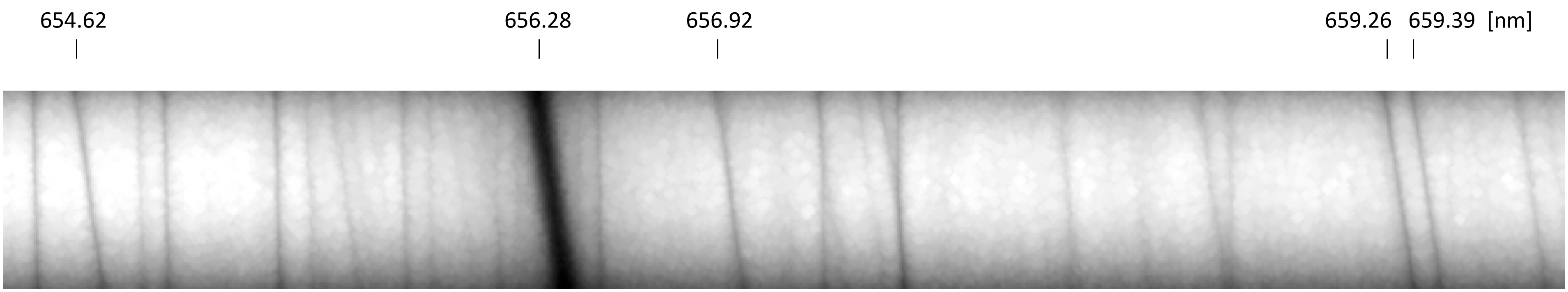


Fig. 2
2011-11-20
21:37:01 UTC

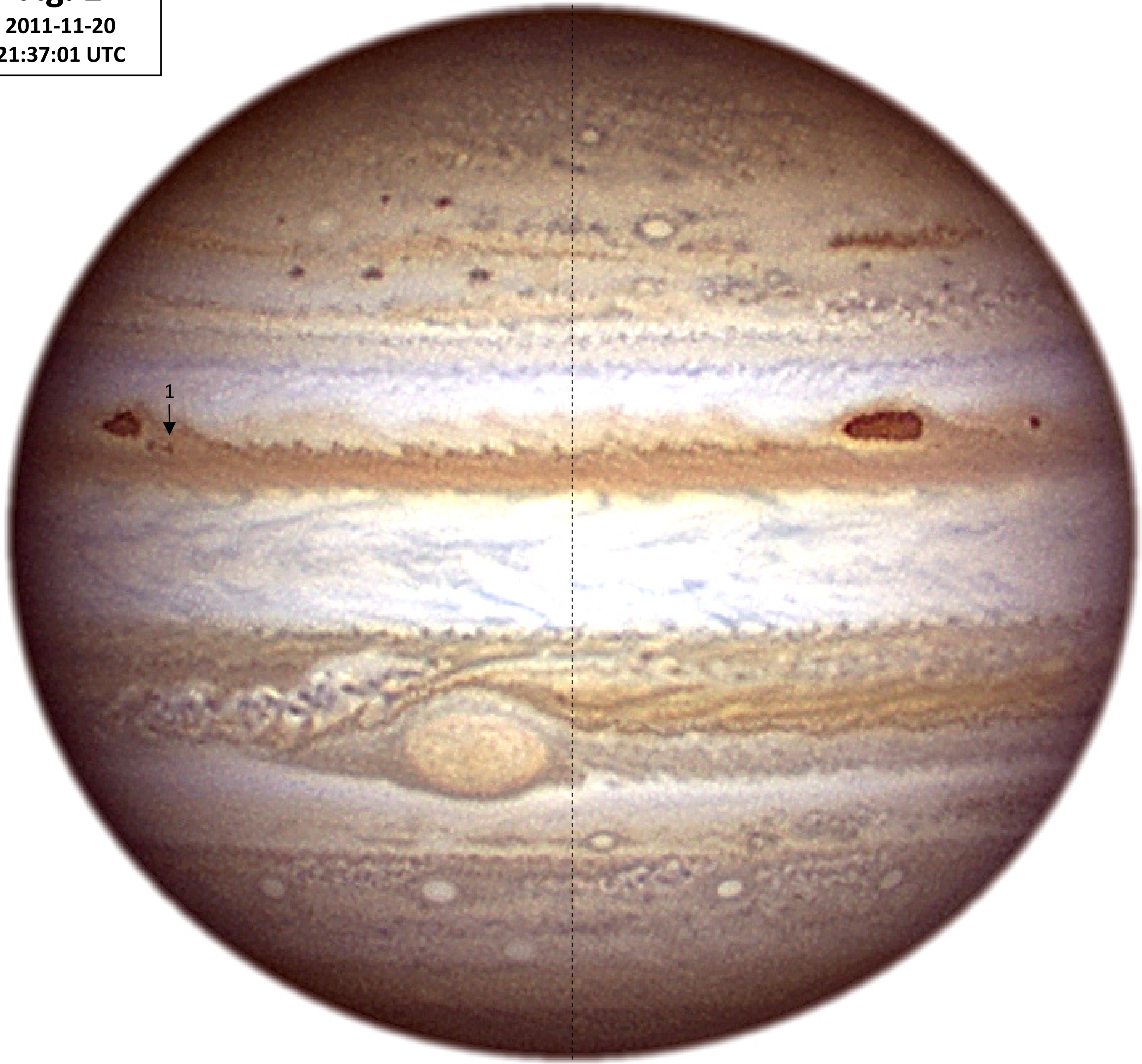


Fig. 3
2011-11-20
23:28:36 UTC

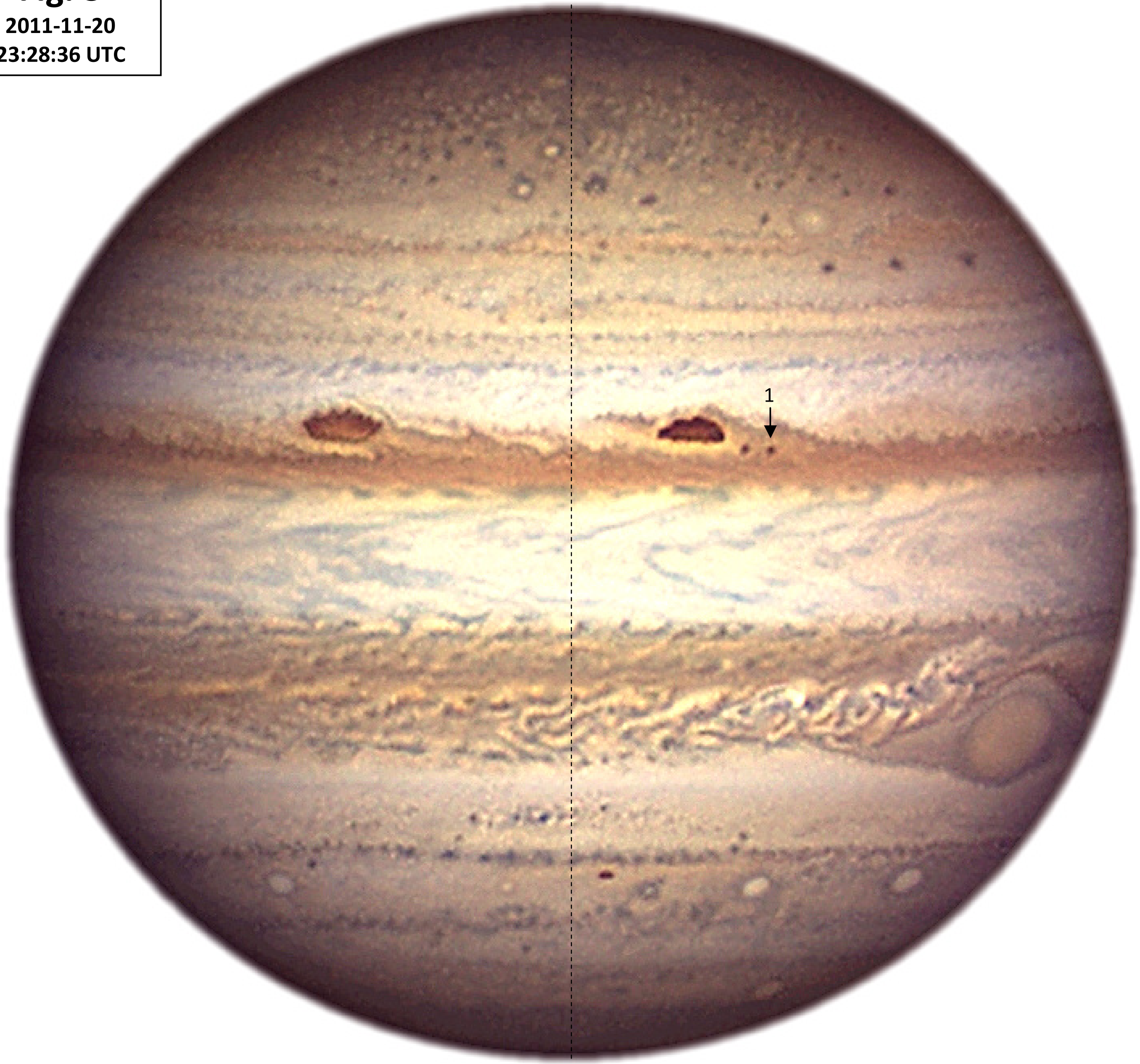


Fig. 4. Moon-1

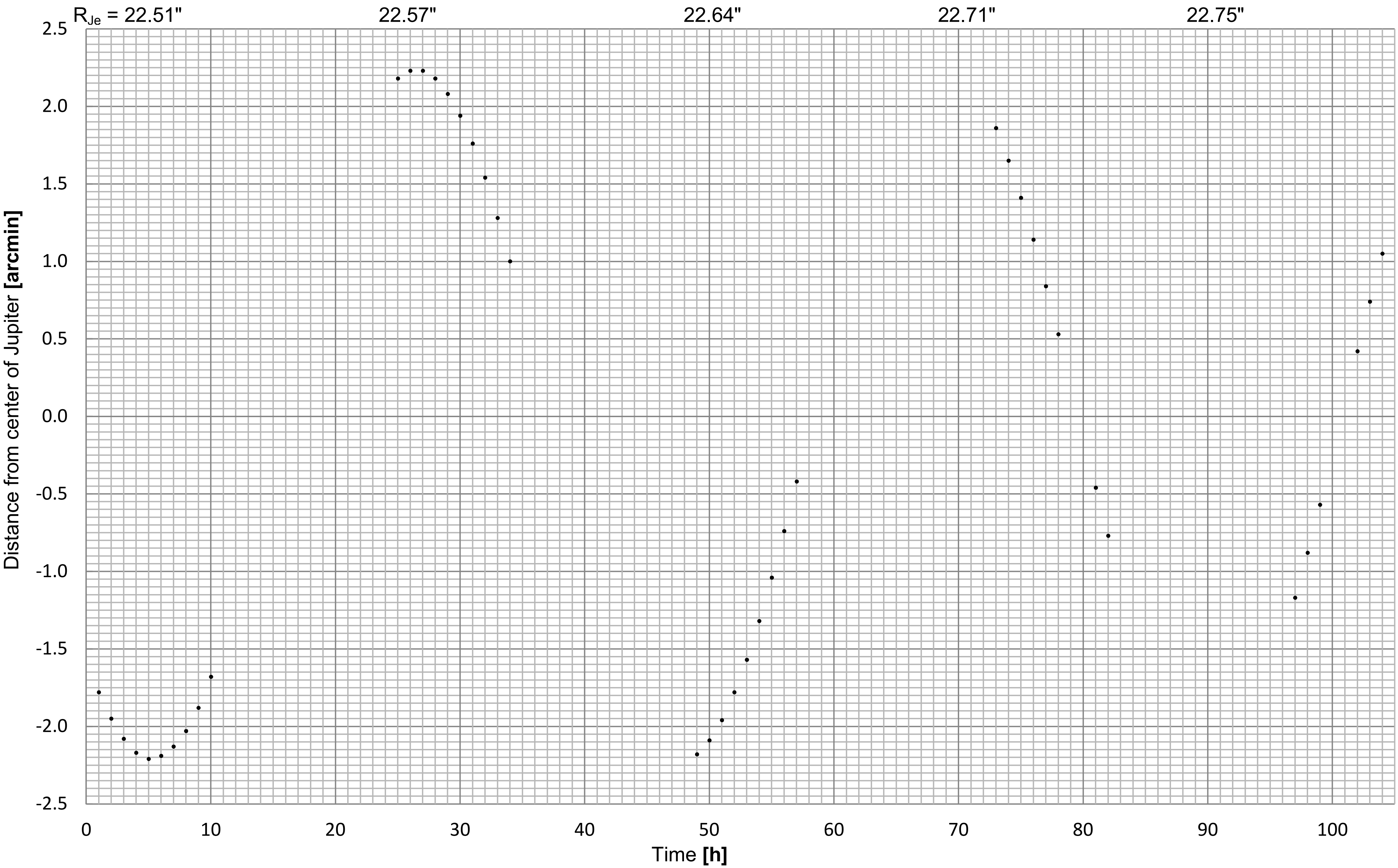
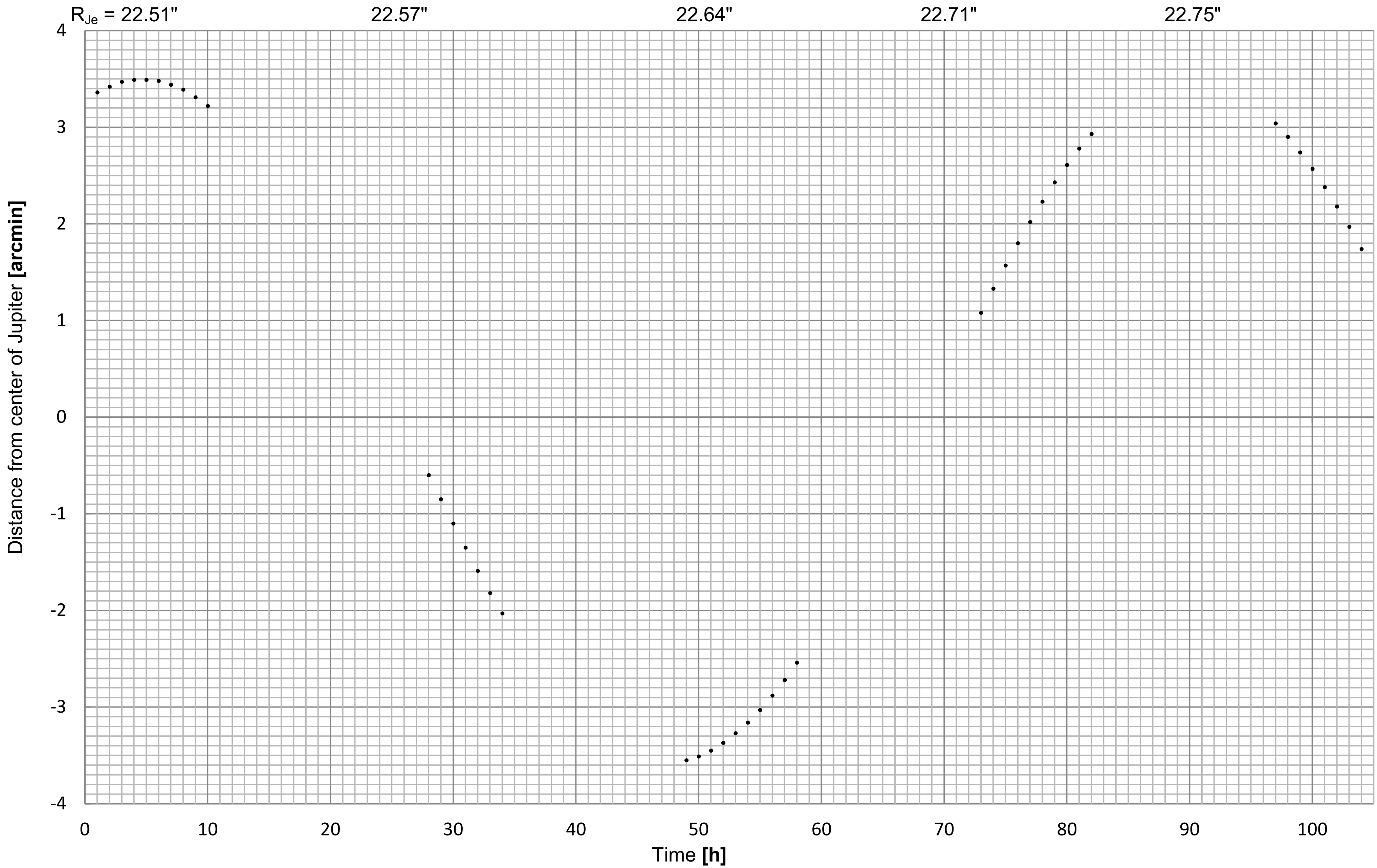

R_Je = 22.51"
22.57"
22.64"
22.71"
22.75"
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
Distance from center of Jupiter [arcmin]
0
10
20
30
40
50
60
70
80
90
100
Time [h]

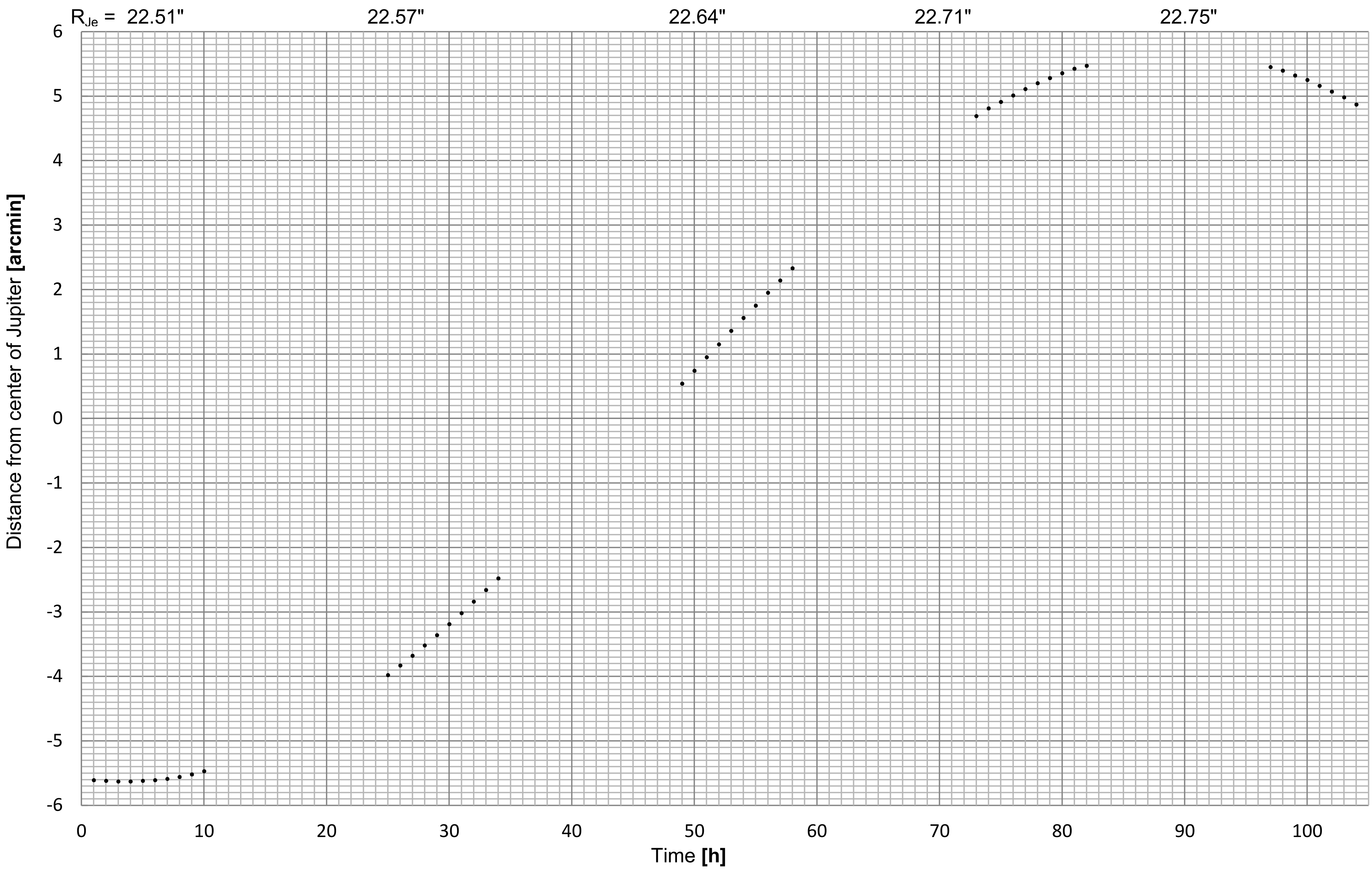
Fig. 5. Moon-2


R$_{Je}$ = 22.51"
22.57"
22.64"
22.71"
22.75"
Distance from center of Jupiter [arcmin]
4
3
2
1
0
-1
-2
-3
-4
0
10
20
30
40
50
60
70
80
90
100
Time [h]

Round	Prac	
Group	α	β

код	
code	

Fig. 6. Moon-3



Solution

Table A

N [nm/mm] =	(659.39-654.62)/215.5 ≈ **0.0221**

λ [nm]	dx [mm]	dλ[nm]	v_r [km/s]
654.62	~5	~0.1105	~12.65
656.92	~5	~0.1105	~12.61
659.26	~5	~0.1105	~12.56
		v_r_avg [km/s] =	**~12.6**

FORMULAE

Because of the Doppler effect the wavelength shift , dλ, observed at the edge of Jupiter's disk can be obtained through the following formula:

$$\mathbf{v_r = \frac{1}{4} \cdot \frac{d\lambda}{\lambda} \cdot c}$$

,where $c -$ speed of light in the vaccum.

Coefficient $\frac{1}{4}$ comes into effect due to the fact that:
-the sunlight, illuminating the planet, is reflected, therefore it was affected by Doppler effect twice,
- measurements are done at the edges of the disk and not relative to the non-shifted center, thus doubling the measured shift value.

Table B

dt[s] =	6695

Feature	**x_1 [mm]**	**x_2 [mm]**	**L_x [mm]**	**ϕ [°]**
1	66	33	92	66.86
*2**	*57*	*46*	*92.5*	*67.86*
*3**	*44*	*54*	*87*	*68.75*
			ϕ_avg =	**~ 67.8**

**only as example - acctual values depends on choosen feature and accuracy of measuremets*

P_{Je} [h] =	**~ 9.9**
R_{Je} [km] =	**~71470**

FORMULAE

$$\boldsymbol{\varphi = \arcsin\left(\frac{x_1}{L_x}\right) + \arcsin\left(\frac{x_2}{L_x}\right)}$$

$$\mathbf{P = \frac{360°}{3600\ s} \times \frac{dt}{\varphi}}$$

$$\mathbf{R_{Je} = \frac{v_r \cdot P_{Je}}{2\pi}}$$

Table C

Moon	P_m [h]	a_Je	a [m]	M_J [kg]
1	~ 43	~ 5.9	$\sim 4.22 \times 10^8$	$\sim 1.86 \times 10^{27}$
2	~ 85	~ 9.4	$\sim 6.70 \times 10^8$	$\sim 1.90 \times 10^{27}$
3	~ 172	~ 14.9	$\sim 10.65 \times 10^8$	$\sim 1.86 \times 10^{27}$
			M_J_avg [kg] =	**$\sim 1.87 \times 10^{27}$**

R_p/R_e =	174 mm / 186 mm ≈ **0.9355**
R_J_avg [m] =	**$\sim 69900 \times 10^3$**
V [m^3] =	**$\sim 1.43 \times 10^{24}$**
ρ_J [kg/m^3] =	**~ 1310**

FORMULAE

In case of a moon orbiting a much more massive planet, the mass of the central body (planet) can be obtained from Kepler`s Third Law:

$$\mathbf{M_J} = \frac{\mathbf{4\pi^2}}{\mathbf{G}} \cdot \frac{\mathbf{a^3}}{\mathbf{P^2}}$$

, where G – gravitational constant, a – semi-major axis of moon orbit in meters, P – period in seconds

The mean radius for a slightly oblate ellipsoid is:

$$\mathbf{R_J\_avr} = \sqrt[3]{\frac{R_p}{R_e} R_e R_e^2} = \mathbf{R_e} \times \sqrt[3]{\mathbf{R_p/R_e}}$$

Practical round. Problems to solve

7. Distance to the galaxy NGC 4214

The usage of novae in outbursts as distance indicators is based on the correlation of their absolute magnitudes at maximum brightness with their rates of decline. The simplified relationship between the absolute magnitude at maximum of a nova and its rate of decline may be expressed through the linear expression:

$$M_{Vmax} = a + b\log t_2\,, \tag{1}$$

where a and b are constants to be determined using observational data of a certain number of galactic novae with spatially resolved shells, t_2 is the rate of decline, i.e. the time (expressed in days) that it takes the nova to drop by 2 magnitudes below its light maximum. t_2 should be evaluated from the graph of the light curve of a nova.

7.1. Using data of Table 1 determine the constants a and b in the expression (1). The results of the calculations should be written in Table 1a. A graph template (Fig. 1a) should be used for determination of constants a and b.

7.2. Using the obtained expression and photometric data of a nova, which erupted in the galaxy NGC 4214, calculate the distance to this galaxy. Photometric data of this nova are given in Table 2. A graph template (Fig. 2a) should be used for the plot of the light curve of the nova.

Data of Table 1:
1st column is the number of the nova;
2nd – the time of the maximum brightness of the nova, T_0, in Julian Days (JD);
3rd – the apparent magnitude of the nova at maximum brightness, $m_{V\max}$;
4th – the rate of decline, i.e. the time that it takes the nova to drop by 2 magnitudes below maximum, t_2, in days (d);
5th – the angular radius of the expanding shell of the nova, θ (in arcsec);
6th – the time of the measurement of the radius of the nova shell, T, in Julian Days (JD);
7th – the rate of expansion of the shell of the nova, v, in km/s;
8th – the interstellar extinction in the direction of the nova, A_V.

Data of Table 2:
1st column is the time of observation in Julian Days (JD);
2nd – the apparent magnitude of the nova.

Table 1. Data of the galactic novae for determination of the constants a and b;

Table 2. Observations of the nova in NGC 4214;

Table 1a. Results of calculations of the parameters of the galactic novae;

Fig. 1a. Graph template for determination of the constants in the expression (1);

Fig. 2a. Graph template for the plot of the light curve of the nova NGC 4214.

Distance to the galaxy NGC 4214

Solution

7.1. Distances of the novae from Table 1 are calculated using their shell radii assuming that their rates of expansion are constant. Linear radius of the nova's shell:

$$R = v \times \Delta t \, ,$$

where v is the expansion rate of the nova's shell , and Δt is the time interval that elapsed from the nova's outburst up to time when the angular radius of nova's shell have been measured. Radii of the shells should be expressed in astronomical units (au). Since 1au=1.496 $\cdot 10^8$ km and 1day=24h $\cdot$3600s=86400s we get

$$R(\text{au}) = \frac{86400}{1.496 \cdot 10^8} v\Delta t = 5.775 \cdot 10^{-4} v\Delta t$$

Distance to a nova is calculated by the formula:

$$d = \frac{R}{\tan\theta}$$

Since θ is a small angle and is measured in arcsec, and R is expressed in au, we get the distance expressed in parsecs:

$$d = \frac{R}{\theta}$$

Then absolute magnitudes of the novae are calculated by the formula:

$$M_V = m_V - 5\log d + 5 - A_V$$

Table 1a. Results of calculations of the parameters of the galactic novae

No.	Δt (JD)	R (au)	d (pc)	$M_{V\max}$	log t_2
1	32715	11336	1260	-7.3	1.65
2	3052	2644	1763	-10.7	0.30
3	17004	4910	491	-7.2	1.59
4	7646	4857	1388	-7.8	1.34
5	16458	15207	1382	-9.5	0.70
6	20222	9343	1038	-9.7	0.78

Now we plot the graph $\log t_2 ; M_{V\max}$ and draw the straight line best fitted through the points (Fig. 1b).

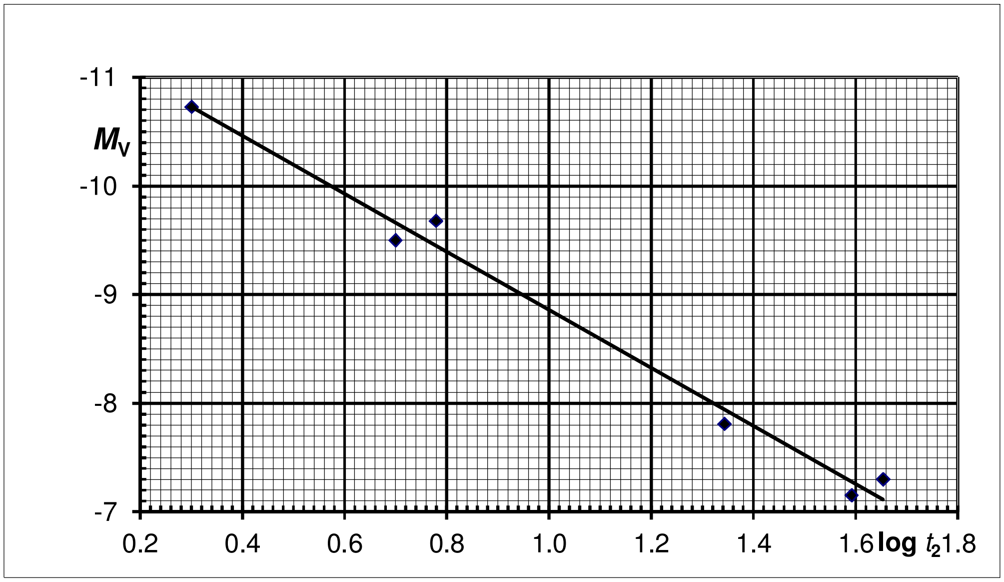


Fig. 1b. Graph for determination of the constants in the expression (1)

The equation of the line is

$$M_{V\,\max} = -11.53 + 2.67 \log t_2 \qquad \text{(1a)}$$

<u>7.2.</u> We use the data of Table 2 to plot the light curve of the nova in NGC4214 (Fig. 2).

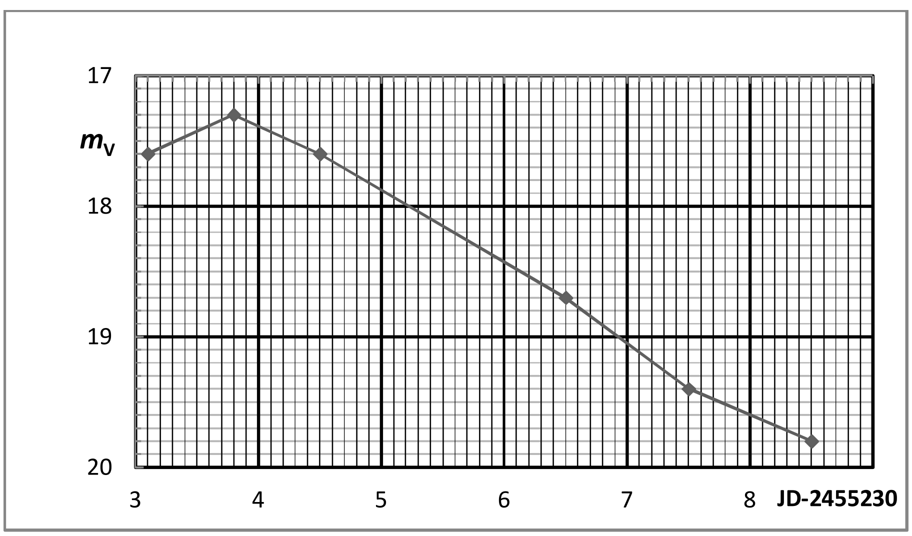


Fig. 2b. Light curve of the nova NGC 4214

From this graph we see that the nova reached its light maximum, m_V=17.3, at JD=2455233.8. Brightness of the nova dropped by 2 mag from its maximum at about JD=2455237.35. So we get the time $t_2 = 2455237.35 - 2455233.8 = 3.55$ days.

Using the relation (1a) we get the absolute magnitude of the nova NGC 4214 at its maximum

$$M_{V\,\max} = -11.53 + 2.67 \log 3.55 = -10.06$$

We assume that interstellar extinction in the direction of the nova (as well as NGC 4214) is negligible and calculate distance to the galaxy NGC 4214:

$$\log d = \frac{m_{V\,\max} - M_{V\,\max} + 5}{5}$$

$$\log d = \frac{17.3 + 10.06 + 5}{5} = 6.47$$

$$d \approx 3.0 \times 10^{6} \text{ pc}$$

***<u>Answer:</u>* Distance to the galaxy NGC 4214 is 3.0 Mpc.**

Round	Obs	
Group	α	β

язык / language	English

Code of participant	код участника

Observational round. Questions.
Clear sky

Observations by the naked eye

9. Find the object corresponding to the following criteria:
- The object is the second brightest star in its constellation.
- The object is visible approximately 28 degrees from α UMi.
- The equatorial coordinates of the object are: **RA 11^h, dec +62°**.

Answer the questions: *Answers:*

a) What is the Bayer designation (e.g. β Ori) of the identified object?	
b) Write the name of the constellation in Latin, which the object is visible in.	

Answer:

10. What is the angular distance between Vega (α Lyr) and Albireo (β Cyg)?	

Answers:

11. a) Find the horizontal coordinates of Thuban (α Dra).	
b) Find the zenith distance of Alcor (near ζ Ursae Majoris).	

Observations with telescope

12. There are 3 binary stars on the given sky chart: β Cyg, δ Lyr, and ε Lyr.
For each of the binaries do the following:
Point the telescope to the binary. Compare the star field seen in telescope's field of view with three star charts given on a separate sheet. Write down the designations of the binary stars in each blank box under appropriate star chart. Mark North direction on every star chart.

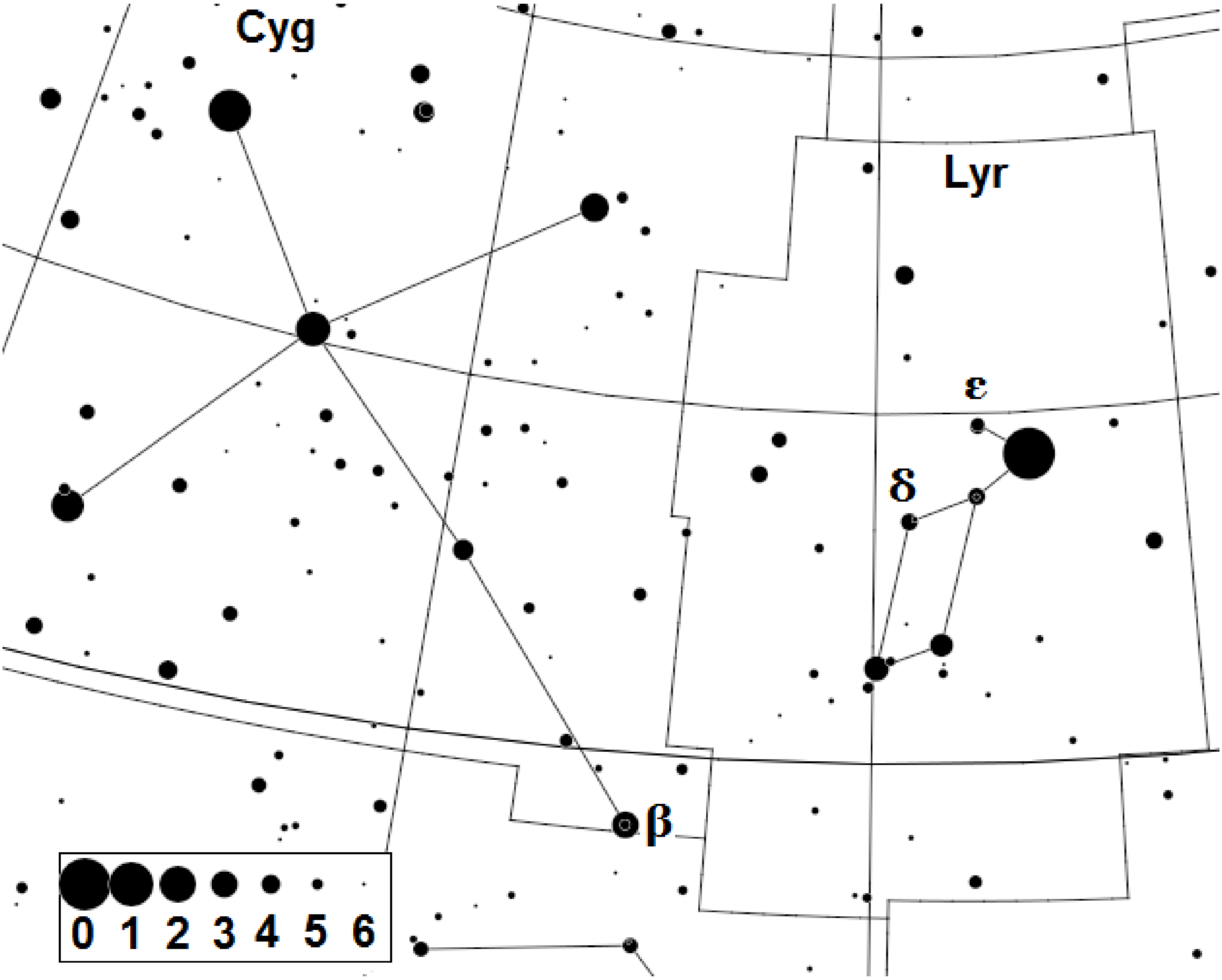
*The maximum total time for all tasks is **20 minutes**.*

Round **Obs**

Group **α** **β**

Code of participant код участника

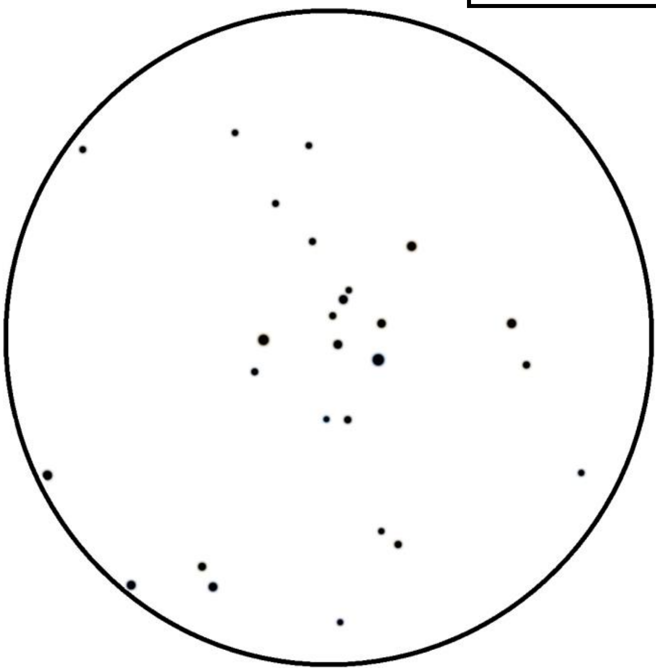
Наблюдательный тур. Чистое небо
Observational round. Clean sky

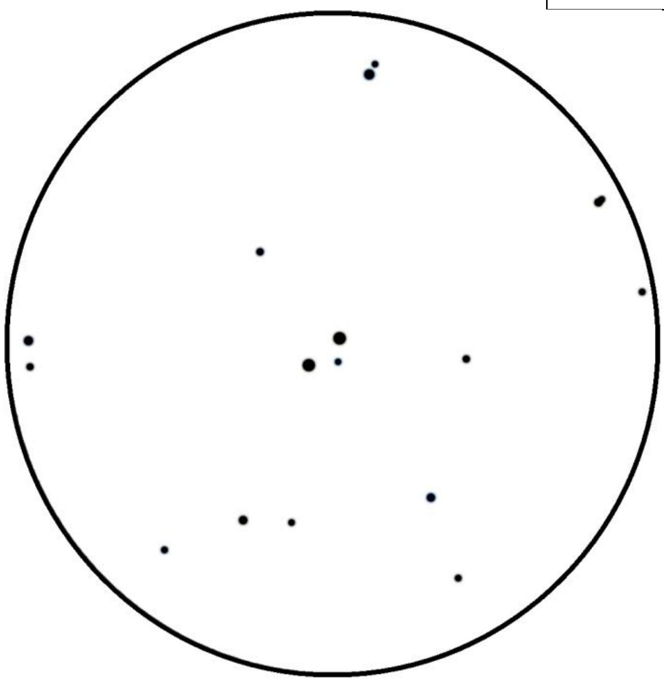


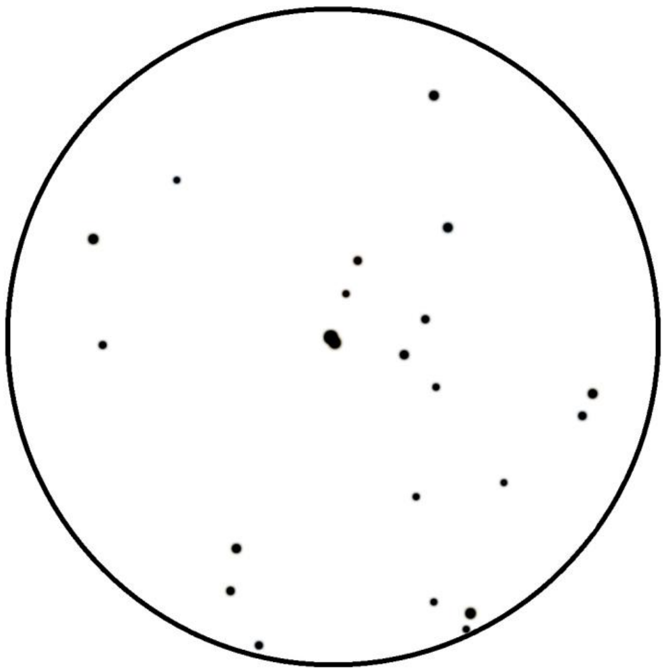
Round **Obs**
Group α β

Code of participant	код участника

Вопросы наблюдательного тура. Чистое небо
Observational round. Clean sky







Observational round answers

1. (9)

a) α UMa

b) Ursa Major

2. (10)

Correct answer between 14°-17°.

3. (11)

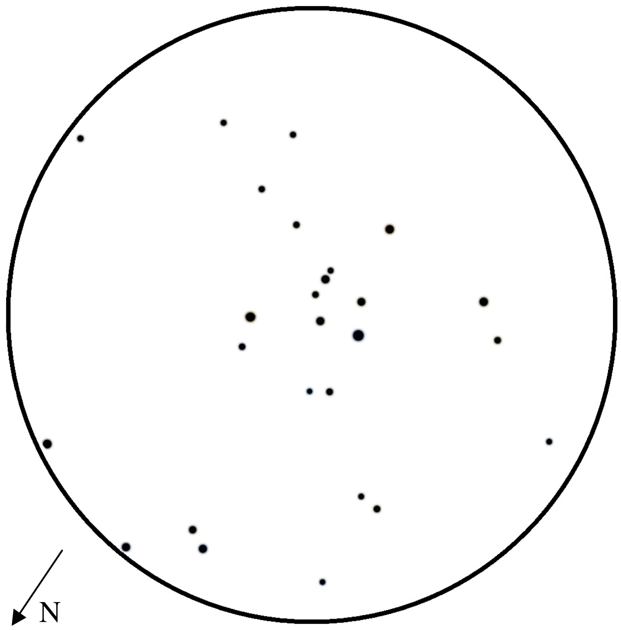
a)

I'st group (mid-round time 22:10)	**II'st group** (22:45)
Az.: 320°±5° (140°±5°) h: 47°±5°	Az.: 324°±5° (144°±5°) h: 44°±5°
III'st group (23:35)	**IV'st group** (00:10)
Az.: 328°±5° (148°±5°) h: 40°±5°	Az.: 332°±5° (152°±5°) h: 37°±5°

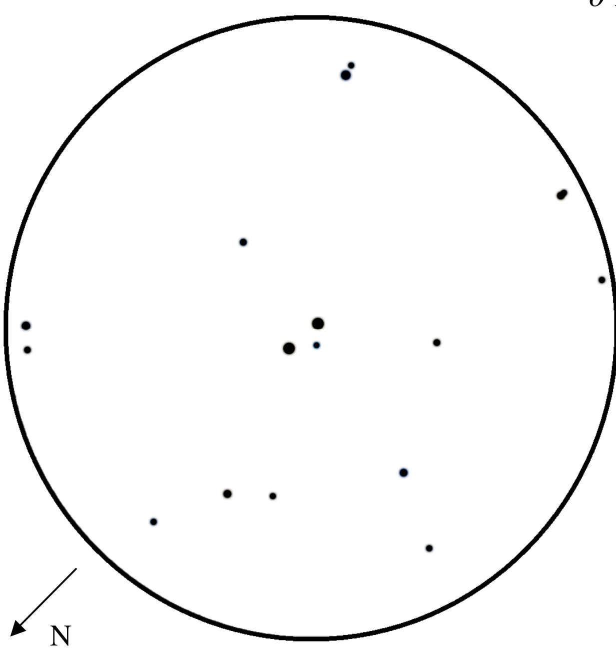
b)

I'st group (22:10)	**II'st group** (22:45)
53°±5°	56°±5°
III'st group (23:35)	**IV'st group** (00:10)
60°±5°	63°±5°

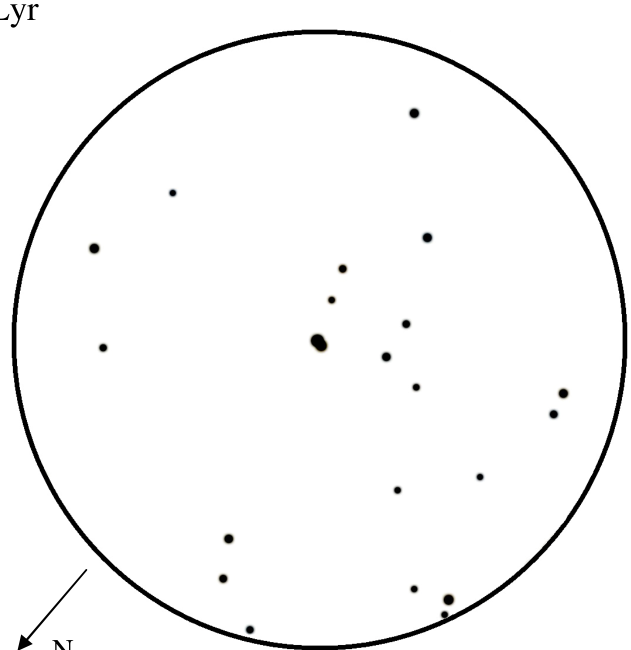
4. (12)



δ Lyr



ε Lyr



β Lyr