VIII Международная астрономическая олимпиада
VIII International Astronomy Olympiad
VIII:e Internationella Astronomiolympiaden

Швеция, Стокгольм 2 – 8. 10. 2003 Stockholm, Sweden

Задачи практического тура **Practical round. Problems to solve**

язык / language	***English***

Groups A,B

7. Measuring the speed of light

Note: You must carefully account for every step in your calculations. Answers without motivation will not be accepted.

Imagine that the solar system in a distant future becomes inhabited by our descendants. On the asteroid *Saltis*, a small robotic mining establishment is supervised by Celesta Spacedigger, who also happens to be a dedicated amateur astronomer. Being bored by her job, Celesta spends the long nights of Saltis studying the stars and the planets, in particular the glorious planet Saturn. An old but reliable astronomical almanac helps her keeping track of celestial events like eclipses of the moon Titan by its planet Saturn. To her dismay, however, Celesta starts to note large deviations between her observed times of the eclipses of Titan and the tabulated ones. After years of careful observations (she has a long term assignment on Saltis) she begins to see a pattern; the deviations are largest when Saturn is close to opposition or conjunction (with the Sun, as seen from Saltis). She realises that this must be due to the finite speed of light, and a check in her almanac confirms that the tabulated timings are *heliocentric*, that is, as seen from the Sun, and not as seen from Saltis. Quite satisfied with her discovery, Celesta use her observations to calculate the speed of light.

In this problem you are asked to repeat Celesta's calculations by using her observations. The units of length and time that Celesta uses are a bit different from what you are used to. The unit of time is called *pinit*, and is defined such that there are 1000 pinit in one synodic rotation of Saltis. The length unit is called *seter* and is defined to be one billionth (10^{-9}) of the mean distance between the Sun and Saltis.

Table 1 *Eclipses of Titan by Saturn*

Tabulated[a] (pinit)	Celesta[b] (pinit)	Comment[c]
456.47	450.32	Opposition
18.50	12.28	Opposition
821.41	815.29	Opposition
444.70	450.85	Conjunction
615.43	621.52	Conjunction
791.94	798.02	Conjunction

[a] The tabulated values refer to when an observer located at the Sun would observe the beginning of the eclipse.

[b] Celesta observed timing of the beginning of the eclipses from Saltis. Her estimated accuracy in the timing is 0.03 pinit.

[c] The position of Saturn during an eclipse of Titan was never exactly in opposition or conjunction, but close to.

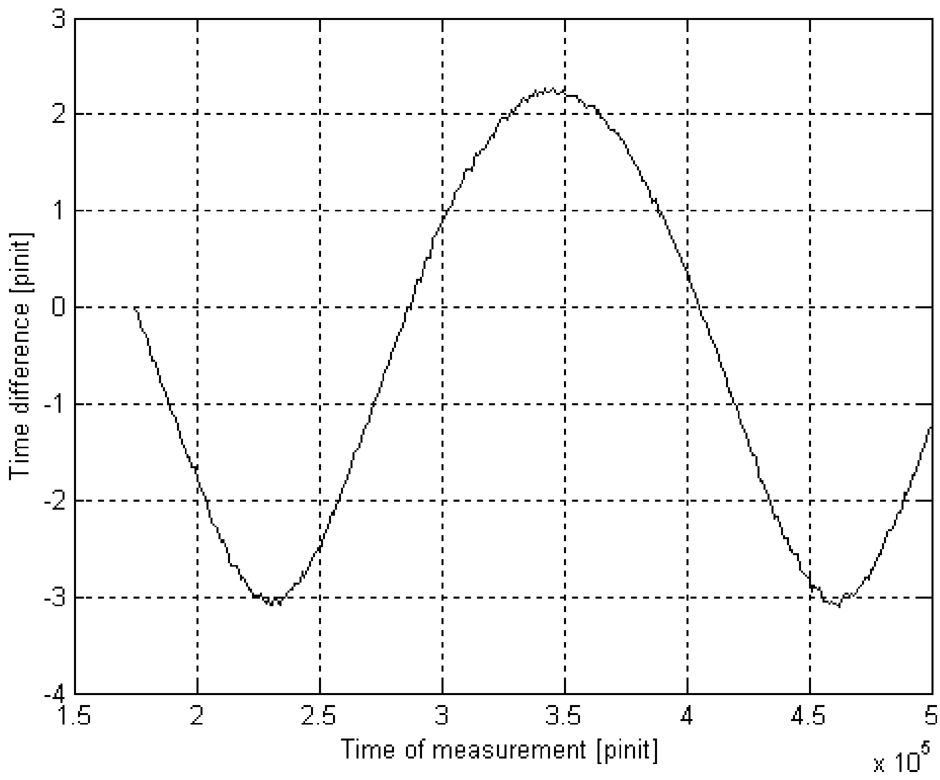

Figure 1 *Difference between Celesta's watch and the time signal received from Earth.*

7.1. Celesta observed eclipses of Titan when Saturn was close to opposition or conjunction during six occasions (Table 1). Analyse her data carefully and estimate the speed of light, in units of seter per pinit, and give the expected error of your estimate. (50%)

Celesta also enjoys listening to radio signals from Earth during her lonely days. With her re-discovery of the finite speed of light, Celesta gained enough confidence to try and measure the orbital radius of Earth (in seter). She synchronises her very accurate watch with a radio time signal from Earth, and then regularly follows how the time of her watch differs from the periodic time signal. Her measurements are presented in Fig. 1.

7.2. Use Celesta's data in Fig. 1 to estimate the radius of Earth's orbit in seter. (20%)

7.3. With 1 AU = $149.6 \cdot 10^6$ km and $c = 2.998 \cdot 10^8$ m/s, how many meter is a seter? How many seconds is a pinit? (10%)

7.4. Estimate the orbital period (in years) of Saltis from Fig. 1 and the answer to problem 3. (20%)

Attention: for group A there is the only problem Nr.7 on the Practical round for 3 hours; for group B there are the two problems: Nr.7 and Nr.8 for 4 hours.

Задачи практического тура **Practical round. Problems to solve**

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Group B

8. Estimating the mass of Saturn

Introduction

Ever since Galileo Galilei observed the ring of Saturn through a telescope for the first time, it has been regarded as one of the prime astronomical sights. The ring itself is not a rigid body, but consists of innumerable moonlets in Keplerian orbits around the planet, as shown spectroscopically almost simultaneously by Aristarkh A. Belopolsky and by James E. Keeler. The results of the latter were published in the very first issue of the Astrophysical Journal in 1895. In this problem, you are asked to repeat their argument using recent observations, and estimate the mass of Saturn.

Observational details

Saturn was observed by the Nordic Optical Telescope (NOT, a 2.5 m telescope on the Canary Island La Palma) 2002-02-25 at 23:25 Universal Time. A spectroscopic slit was placed over the planet as shown by Fig. 1. The retrieved spectrum (Fig. 2) shows the solar spectrum reflected on the planet. The straight vertical absorption lines are telluric, i.e. absorption lines arising when the light travels through the Earth's atmosphere, while the lines seen at inclination are the solar absorption lines reflected against the planet. The two strongest absorption lines seen in the spectrum are from the Na I (neutral sodium) D_2 and D_1 transitions, at rest wavelengths 589.00 nm and 589.59 nm respectively.

Problems

Note: You must carefully account for every step in your calculation. Answers without motivation will not be accepted.

8.1. The spectrum of Fig. 2 implies that the ring of Saturn cannot be a rigidly rotating body. Draw a figure that qualitatively shows what the spectrum would look like, if the ring was indeed rotating rigidly. (~20%)

8.2. The sidereal rotation period of Saturn is known to be 10.66 hours. Estimate the equatorial diameter of Saturn from the spectrum of Fig. 2. (~30%)

8.3. Estimate the mass of Saturn implied by the spectrum of Fig. 2. If you cannot remember the gravitational constant, you may use that 1 AU = 1.496×10^8 km and the mass of the Sun is $M_{Sun} = 1.99\times10^{30}$ kg. (~50%)

You may use the fact that the ring of Saturn is planar and parallel to the planet’s equator to calculate the inclination of the system relative to the line of sight.

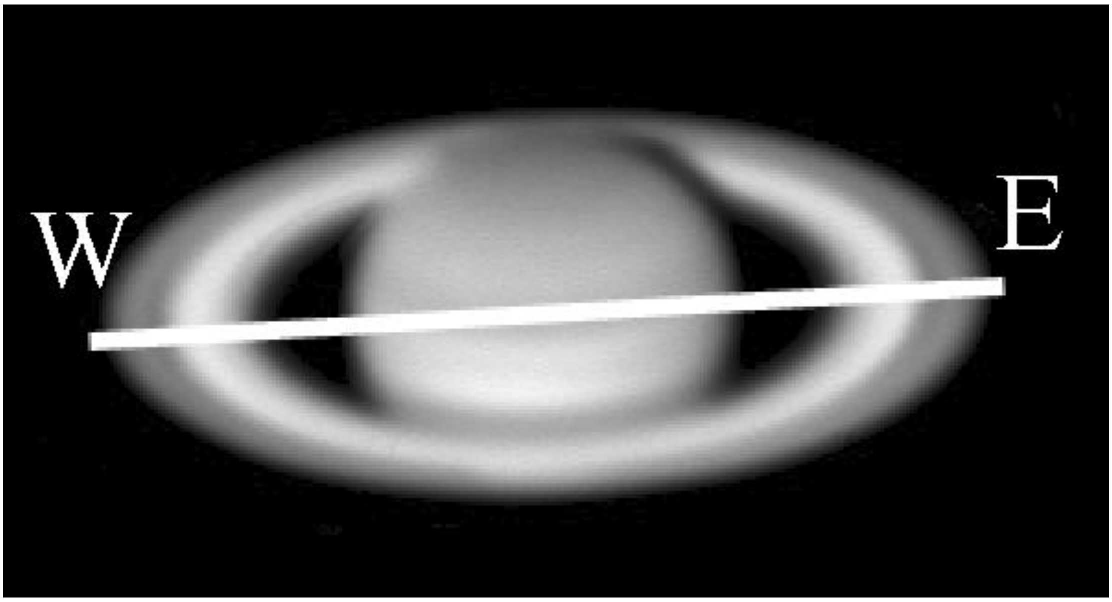

Figure 1

Position of the spectroscopic slit on Saturn. West and East are marked by W and E respectively.

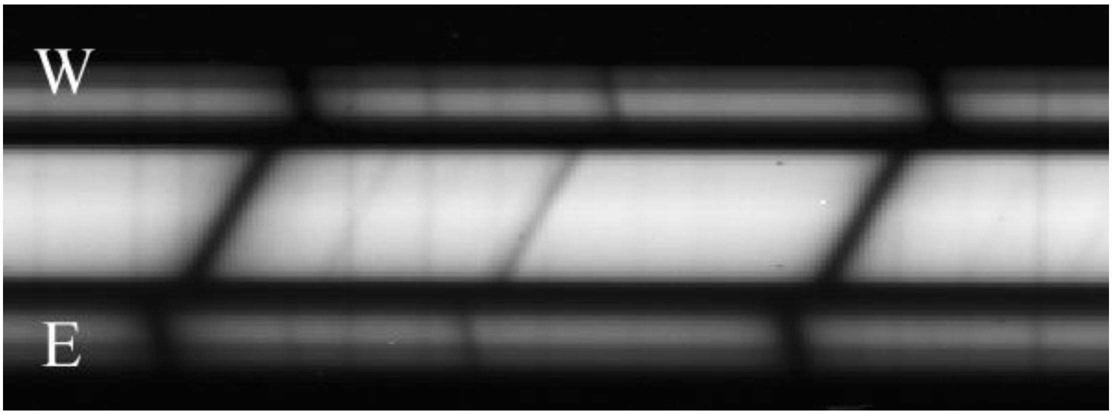

Figure 2

The solar spectrum reflected on Saturn. West is up, and wavelengths increasing to the right.