**31 август 2018г.**

**7.** Write the observational program for this night on a 40-cm telescope.
What stars would you observe this nigth? Write sequence of the observations.
Stars to observe:

| | | V (mag) | α | δ (1950) |
|---|---|---|---|---|
| 1 | **η Aql** | $3^m.5$ | $19^h\ 49^m.9$ | 0° 53′ |
| 2 | **β Per** | 2.1 | 3 04.9 | 40 46 |
| 3 | **χ Cyg** | 14.2 | 19 48.6 | 32 47 |
| 4 | **R Aqr** | 12.4 | 23 41.2 | -15 34 |
| 5 | **α Ori** | 1.3 | 5 52.4 | 7 24 |
| 6 | **RW Vir** | 6.7 | 12 04.7 | -6 29 |

Moon rise: 21:17:26, phase 0.77
Sideral time for $0^h$ $s_0$ = 0:31:04
You may use all observational time (since 20h till 5h 30 min).
Local time LT=UT+3
Coordinates of observatory $\lambda = 2^h16^m$ $\varphi = 44°43'$
Put your result into the table:

| Star | Interval of observation |
|---|---|
| | |

Stars that could not be included in the program:

Explanations and notes:

# 31 август 2018г.

6. **Motion of a planet.** Most of the time, planets move from west to east relative to the background stars. Occasionally, however, they change direction and temporarily undergo retrograde motion. After a few weeks, the direction is changed again. The apparent motion of a planet was observed in Hangzhou this year. Table 1 lists the values of the 24 hour angular displacement of the planet relative to the background stars (simplified as ADRS) on the day that the observation was made. Modified Julian Day (MJD = JD – 2400000.5) are used for the dates. Minus means the direction is from east to west.

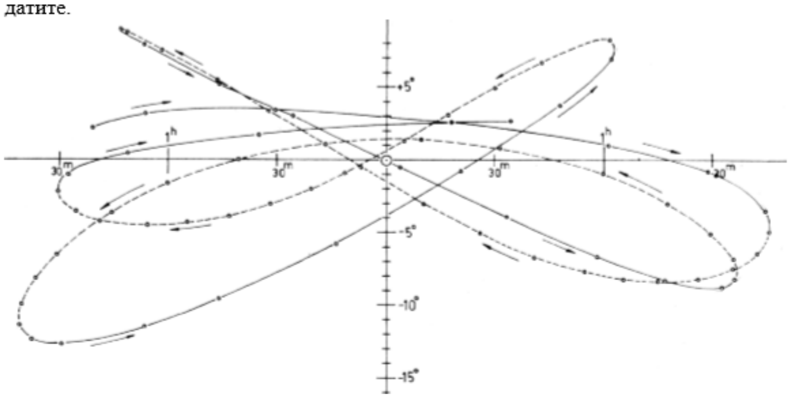
**6.1.** Find the date (MJD) when the planet is at stationary point (simplified as STP) and at opposition (simplified as OPP) graphically, respectively. Accurate to one day. Write your answer in table 2.

**6.2.** What's the value of 24 hour angular displacement of the planet per day when it is at opposition? Write your answer in table 2.

**6.3.** On the basis of the result of question 2, estimate the radius of the planet's orbit in astronomical units. Suppose the orbits of Earth and the planet are both circular and the planet is in ecliptic plane.

| Modified Julian Day | ADRS (degrees/day) |
|---|---|
| 54944 | 0.15 |
| 54965 | 0.1 |
| 54975 | 0.07 |
| 54989 | 0.03 |
| 55001 | -0.01 |
| 55014 | -0.05 |
| 55020 | -0.07 |
| 55032 | -0.1 |
| 55043 | -0.12 |
| 55055 | -0.13 |
| 55062 | -0.13 |
| 55074 | -0.12 |
| 55084 | -0.1 |
| 55092 | -0.08 |
| 55099 | -0.06 |
| 55109 | -0.03 |
| 55121 | 0.01 |
| 55133 | 0.05 |

На фигурата са изобразени положенията спрямо Слънцето на някаква планета, наблюдавани на земното небе през равни интервали от време. Началната точка на траекторията съответсва първи януари някоя година. По абцисната ос е нанесена разликата в ректасцензиите на Слънцето и планетата, а по ординатната ос – разликата в деклинациите. Да се определи коя е планетата. Определете датата на която планетата ще се отдалечи на максимално ъглово разстояние от Слънцето. Определете датата на която планетата преминава по диска на Слънцето. Оценете грешката при определяне на датите.




(D2) **Distance to the Moon**

Geocentric ephemerides of the Moon for September 2015 are given in the form of a table. Each reading was taken at 00:00 UT.

**31 август 2018г.**

| Date | R.A. (α) | | | Dec. (δ) | | | Angular Size (θ) | Phase (ϕ) | Elongation |
|---|---|---|---|---|---|---|---|---|---|
| | h | m | s | ° | ' | " | " | | Of Moon |
| Sep 01 | 0 | 36 | 46.02 | 3 | 6 | 16.8 | 1991.2 | 0.927 | 148.6° W |
| Sep 02 | 1 | 33 | 51.34 | 7 | 32 | 26.1 | 1974.0 | 0.852 | 134.7° W |
| Sep 03 | 2 | 30 | 45.03 | 11 | 25 | 31.1 | 1950.7 | 0.759 | 121.1° W |
| Sep 04 | 3 | 27 | 28.48 | 14 | 32 | 4.3 | 1923.9 | 0.655 | 107.9° W |
| Sep 05 | 4 | 23 | 52.28 | 16 | 43 | 18.2 | 1896.3 | 0.546 | 95.2° W |
| Sep 06 | 5 | 19 | 37.25 | 17 | 55 | 4.4 | 1869.8 | 0.438 | 82.8° W |
| Sep 07 | 6 | 14 | 19.23 | 18 | 7 | 26.6 | 1845.5 | 0.336 | 70.7° W |
| Sep 08 | 7 | 7 | 35.58 | 17 | 23 | 55.6 | 1824.3 | 0.243 | 59.0° W |
| Sep 09 | 7 | 59 | 11.04 | 15 | 50 | 33.0 | 1806.5 | 0.163 | 47.5° W |
| Sep 10 | 8 | 49 | 0.93 | 13 | 34 | 55.6 | 1792.0 | 0.097 | 36.2° W |
| Sep 11 | 9 | 37 | 11.42 | 10 | 45 | 27.7 | 1780.6 | 0.047 | 25.1° W |
| Sep 12 | 10 | 23 | 57.77 | 7 | 30 | 47.7 | 1772.2 | 0.015 | 14.1° W |
| Sep 13 | 11 | 9 | 41.86 | 3 | 59 | 28.8 | 1766.5 | 0.001 | 3.3° W |
| Sep 14 | 11 | 54 | 49.80 | 0 | 19 | 50.2 | 1763.7 | 0.005 | 7.8° E |
| Sep 15 | 12 | 39 | 50.01 | -3 | 20 | 3.7 | 1763.8 | 0.026 | 18.6° E |
| Sep 16 | 13 | 25 | 11.64 | -6 | 52 | 18.8 | 1767.0 | 0.065 | 29.5° E |
| Sep 17 | 14 | 11 | 23.13 | -10 | 9 | 4.4 | 1773.8 | 0.120 | 40.4° E |
| Sep 18 | 14 | 58 | 50.47 | -13 | 2 | 24.7 | 1784.6 | 0.189 | 51.4° E |
| Sep 19 | 15 | 47 | 54.94 | -15 | 24 | 14.6 | 1799.6 | 0.270 | 62.5° E |
| Sep 20 | 16 | 38 | 50.31 | -17 | 6 | 22.8 | 1819.1 | 0.363 | 73.9° E |
| Sep 21 | 17 | 31 | 40.04 | -18 | 0 | 52.3 | 1843.0 | 0.463 | 85.6° E |
| Sep 22 | 18 | 26 | 15.63 | -18 | 0 | 41.7 | 1870.6 | 0.567 | 97.6° E |
| Sep 23 | 19 | 22 | 17.51 | -17 | 0 | 50.6 | 1900.9 | 0.672 | 110.0° E |
| Sep 24 | 20 | 19 | 19.45 | -14 | 59 | 38.0 | 1931.9 | 0.772 | 122.8° E |
| Sep 25 | 21 | 16 | 55.43 | -11 | 59 | 59.6 | 1961.1 | 0.861 | 136.2° E |
| Sep 26 | 22 | 14 | 46.33 | -8 | 10 | 18.3 | 1985.5 | 0.933 | 150.0° E |
| Sep 27 | 23 | 12 | 43.63 | -3 | 44 | 28.7 | 2002.0 | 0.981 | 164.0° E |
| Sep 28 | 0 | 10 | 48.32 | 0 | 58 | 58.2 | 2008.3 | 1.000 | 178.3° E |
| Sep 29 | 1 | 9 | 5.89 | 5 | 38 | 54.3 | 2003.6 | 0.988 | 167.4° W |
| Sep 30 | 2 | 7 | 39.02 | 9 | 54 | 16.1 | 1988.4 | 0.947 | 153.2° W |

The composite graphic[1] below shows multiple snapshots of the Moon taken at different times during the total lunar eclipse, which occurred in this month. For each shot, the centre of frame was coinciding with the central north-south line of umbra.
For this problem, assume that the observer is at the centre of the Earth and angular size refers to angular diameter of the object / shadow.

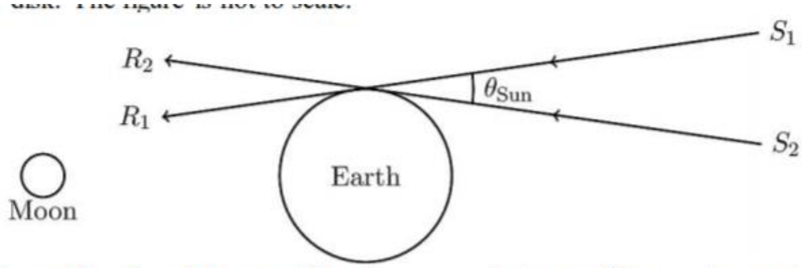

(D2.1) In September 2015, apogee of the lunar orbit is closest to New Moon / First Quarter / Full Moon / Third Quarter. Tick the correct answer in the Summary Answersheet. No justification for your answer is necessary. **[3]**

(D2.2) In September 2015, the ascending node of lunar orbit with respect to the ecliptic is closest to New Moon / First Quarter / Full Moon / Third Quarter. Tick the correct answer in the Summary Answersheet. No justification for your answer is necessary. **[4]**

(D2.3) Estimate the eccentricity, $e$, of the lunar orbit from the given data. **[4]**

(D2.4) Estimate the angular size of the umbra, $\theta_{\text{umbra}}$, in terms of the angular size of the Moon, $\theta_{\text{Moon}}$. Show your working on the image given on the backside of the Summary Answersheet. **[8]**

(D2.5) The angle subtended by the Sun at Earth on the day of the lunar eclipse is known to be $\theta_{\text{Sun}} = 1915.0''$. In the figure below, $S_1R_1$ and $S_2R_2$ are rays coming from diametrically opposite ends of the solar disk. The figure is not to scale. **[9]**




Calculate the angular size of the penumbra, $\theta_{\text{penumbra}}$, in terms of $\theta_{\text{Moon}}$. Assume the observer to be at the centre of the Earth.

(D2.6) Let $\theta_{\text{Earth}}$ be angular size of the Earth as seen from the centre of the Moon. Calculate the angular size of the Moon, $\theta_{\text{Moon}}$, as would be seen from the centre of the Earth on the eclipse day in terms of $\theta_{\text{Earth}}$. **[5]**

(D2.7) Estimate the radius of the Moon, $R_{\text{Moon}}$, in km from the results above. **[3]**

(D2.8) Estimate the shortest distance, $r_{\text{perigee}}$, and the farthest distance, $r_{\text{apogee}}$, to the Moon. **[4]**

(D2.9) Use appropriate data from September 10 to estimate the distance, $d_{\text{Sun}}$, to the Sun from the Earth. **[10]**