Homi Bhabha Centre for Science Education

Tata Institute of Fundamental Research

8th Indian National Astronomy Olympiad

May 1 to 20, 2006

Lab Test II 18th May 2006, 9.00 pm to 12.00 pm

Seniors

1. Martian Retrograde Motion

Turkish astronomer Tunc Tezel takes series images of Mars from late July 2005 to February 2006, while Mars is in retrograde motion. On November 7th, the Red planet was at opposition, a date that occurred close to the center of this series when Mars was near its closest (0.482 AU) and brightest. The familiar Pleiades star cluster lies at the upper left.

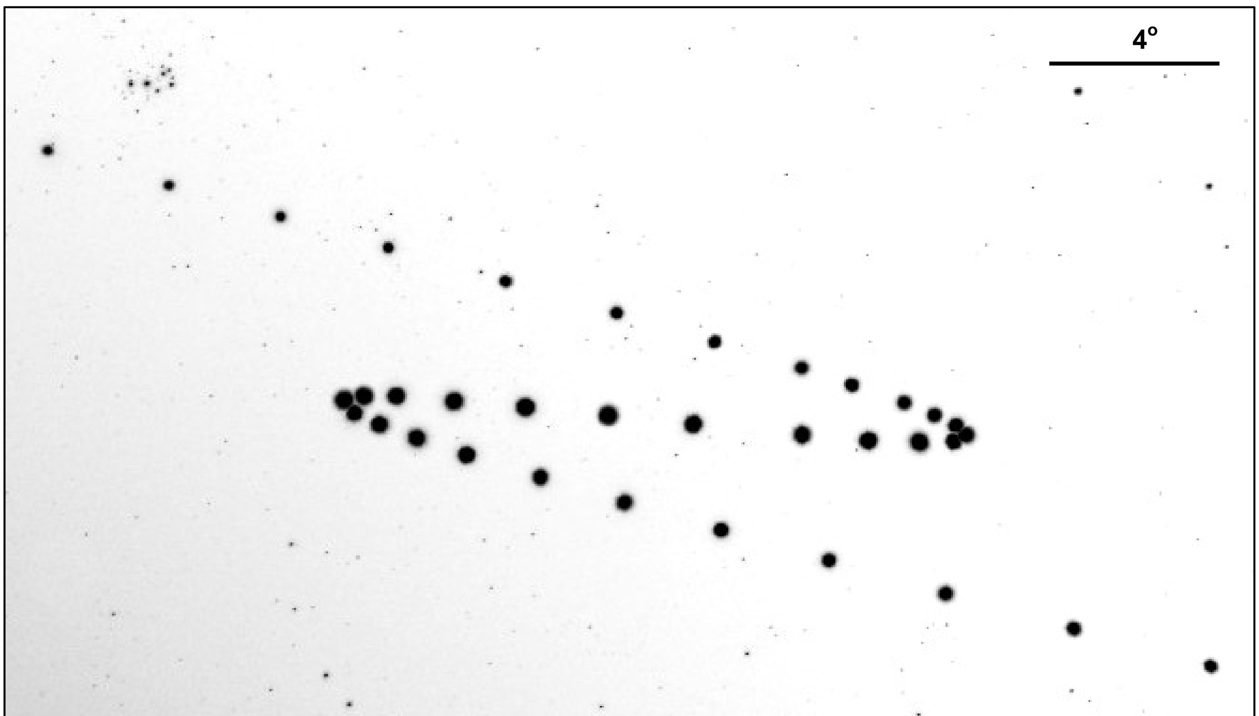

Fig.1

Around 2 years before Tunc took this picture, he had taken another series of pictures of a Martian Opposition. A digitally stacked composite of those pictures is shown in Fig. 2. This August 28, 2003 opposition was the great perihelic opposition of Mars, when Earth was farthest away from Sun and Mars was closest, making the distance between the two planets least. Incidentally, the picture also shows Uranus performing retrograde motion (a dotted line to the right of the image center).

a. Calculate how often you would see Mars in opposition.

Notice a striking difference in the two photographs - the shape of the retrograde loop. There is a rich variety in the form that the path of a planet has while it undergoes retrograde motion. Quite obviously, the difference has got to do with the shapes of the orbit of the two planets, their orientation and the timing of the opposition.

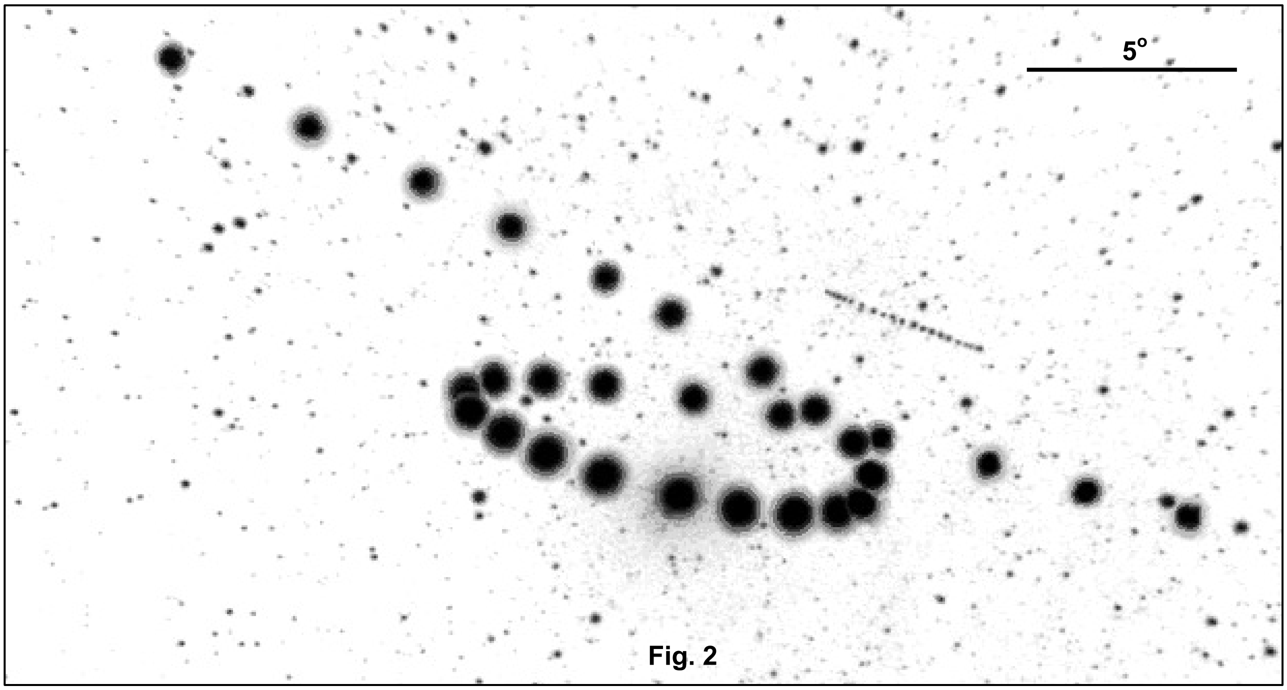

Fig. 2

b. Comment on the exact causes of these shapes. More specifically, describe the geometrical circumstances that cause the loop and the Z-shape.

In his paper titled "Using retrograde motion to understand and determine orbital parameters", Bruce G. Thompson of Ithaca College, New York describes the significance of retrograde motion in understanding the geometry of planetary orbits and its importance in determination of various orbital parameters. Two of his various observations are listed below:

- If the ecliptic latitude & longitude of Mars during two oppositions is similar, the shape of the retrograde loops around the two oppositions is also similar.
- The width (in ecliptic latitude) of the retrograde loop is not the same at all oppositions: some retrograde loops are narrower than others.

c. Explain these observations with regard to the orbital geometry of the two planets.
d. Demonstrate how you can use the above figures to determine the angle of inclination of the Martian orbit assuming that Mars was almost on the ecliptic at opposition.

Any elliptical orbit is defined by five parameters. Analysis of retrograde motions spread over years can yield quite accurate values of all five of those parameters, one of which (*i*) will be calculated as in d). The data for this kind of analysis can come from continuous naked-eye observation & plotting of planetary positions with respect to stars – the kind of observation typical of ancient astronomers like Tycho Brahe. This is the kind of analysis that astronomers of the pre-telescope times did to determine orbital parameters of planets and to convey the appreciation of this was the point of this lab exercise.

2. Magnitudes

The data presented in this table is the result of multicolor photometric observation of stars listed in the Bright Star Catalog. Observations were made on the 21′′, 28′′ and 60′′ telescopes of the Lunar and Planetary Laboratory of the Observatorio Astronomico Nacional, Mexico.

No.	V	B-V	U-B	T
1	6.29	1.1	1.02	4346
2	4.61	1.04	0.87	4486
3	4.28	0.96	0.71	4679
4	4.38	0.87	0.47	4922
5	6.33	0.74	0	5320
6	6.39	0.66	0	5600
7	4.23	0.58	0.02	5910
8	5.7	0.52	0	6166
9	5.93	0.44	-0.02	6544
10	5.69	0.35	0	7028
11	6.37	0.23	1	7799
12	6.19	0.14	0	8497
13	4.76	0.03	0.1	9541

The V, B-V, U-B magnitudes and the temperatures of these stars are given. It is known that the relation,

$$B\text{-}V = A + B/T$$

holds for $T < 10{,}000$K.

a. Use the data in this table to estimate the values of A and B.

The above equation can be derived theoretically from Planck's blackbody equation assuming that the B and the V filters are of equal bandwidth (assumed narrow) The B and V filters have central wavelengths at 450 nm and 550 nm respectively.
The Planck's equation is given by,

$$F_\lambda = \frac{2\pi hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$$

where F_λ is the flux at the wavelength λ per unit bandwidth.

b. Find the values of A_{th} and B_{th}. Comment of why there is a difference in theoretical and observed values of these constants.

c. The temperatures of these stars were also calculated spectroscopically using elemental abundances. These values were found to be slightly greater than the values listed in the table. Give reasons as to why this might be the case.

3. Would Hubble on Andromeda discover the same law?

	x(Mpc)	y(Mpc)	r(Mpc)	θ	v_r(km/s)
1	4.42	1.54	4.68	19.18	334
2	4.09	4.44	6.03	47.36	411
3	0.44	1.12	1.20	68.31	114
4	2.07	0.72	2.19	19.26	160
5	1.68	3.24	3.65	62.62	265
6	2.46	2.46	3.48	44.96	263
7	2.86	0.94	3.01	18.22	258
8	2.38	4.68	5.25	63.11	349
9	1.31	0.63	1.46	25.68	162
10	0.05	0.72	0.73	85.83	100
11	1.68	3.24	3.65	62.62	265
12	2.46	2.46	3.48	44.96	263

The position vectors and the radial velocities of various galaxies are given in the above table. It is well known that Hubble's Law is of the form $v=Hr$.

a. Use the data given to verify the law and find the value of the Hubble's constant.

Does the Hubble's Law give a preferential position to observer at the origin (earth in our case)? Or does apply in the same form from all points in the universe?

b. Shift you origin to Galaxy (5) and repeat part (a) for that galaxy?

c. Also, show that your finding of part (b) mathematically follows from the expression for Hubble's Law.