<u>"Measuring Mars"</u>

Introduction.

Understanding the motions of the planets is an intellectual challenge which has spanned the centuries. Plato (428-347 B.C.) thought that all motions in the Universe were perfectly circular whilst Eudoxus (408-356 B.C.) suggested that the Sun, Moon and planets moved on rotating spheres. Aristarchus (310-230 B.C.) developed a heliocentric model of the Universe (well before Copernicus) which failed to gain acceptance. However, astronomical motions were still thought to be circular. The notion of circular/spherical motions continued with Apollonius (265-190 B.C., who developed a geometric foundation for the epicycles), Hipparchus (190-120 B.C.) and Ptolemy (mid-second century A.D.).

The true story only started to appear through the work of Renaissance astronomers like Copernicus (1473-1543, who developed the heliocentric model in *De Revolutionibus Orbium Coelestium*), Tycho Brahe (1546-1601) and Johannes Kepler (1571-1630, realised that the planetary orbits are elliptical). Modern ideas were then forged by Galileo (1564-1642) and Newton (1642-1727).

Finally a satisfactory way to explain the retrograde motions of the superior planets appeared. We now know that these motions are a simple line of sight effect. Earth moves faster in its orbit than those planets and therefore passes them (in terms of angular distance about the Sun) at regular intervals. Before opposition, as it catches up with a superior planet, that planet's motion across the sky appears to slow down (and stops just before opposition). Its motion then appears to become retrograde as Earth overtakes it. A short while later it appears to stop again before recommencing in a prograde direction. These motions are well described by many sources, including those listed at the end of this article.

Measuring Mars.

Mars came to opposition on 28th August 2003. I belatedly realised that this gave me an opportunity to measure its retrograde motion for myself. On 24th August I hastily built a simple sight-tube (with cross-hairs) which could be mounted on a camera tripod. I placed a protractor on the altitude axis and used a sharpened matchstick for a pointer (placed perpendicular to the vertical axis of the tripod). I decided that I could determine azimuth using a compass. When I had finished building this my daughter asked why I was building "junk"; so this instrument was named the "junk-scope".

At 22:21 GMT on 25th August I took my first readings of the position (altitude and azimuth) of Mars. Subsequent measurements were taken whenever possible at sidereal day increments from then. The method used is simple :

1. Before any readings are taken the junk-scope is levelled horizontally and vertically using a small spirit level.
2. At the target time it is centred on Mars using its cross-hairs.
3. The altitude is read off the protractor. That angle and the time are noted.
4. The junk-scope is lowered to 0° altitude, taking care not to disturb its azimuth.
5. The junk-scope's azimuth is read off and recorded.

Steps 2 to 5 are repeated to allow 5 measurements to be taken as close to the sidereal date and time incremented from 22:21 on 25/8/03 as possible. If any reading is judged uncertain an extra reading may be taken. All readings are recorded. In this manner 104 measurements were made over 21 nights between 25th August and 26th October.

Figure 1 : The "Junk-scope"

Interpretation.

Figure 2 shows the apparent motion of Mars between 25th August and 26th October, as plotted against the background stars of Aquarius. The solid line is a plot of the actual data I have recorded.

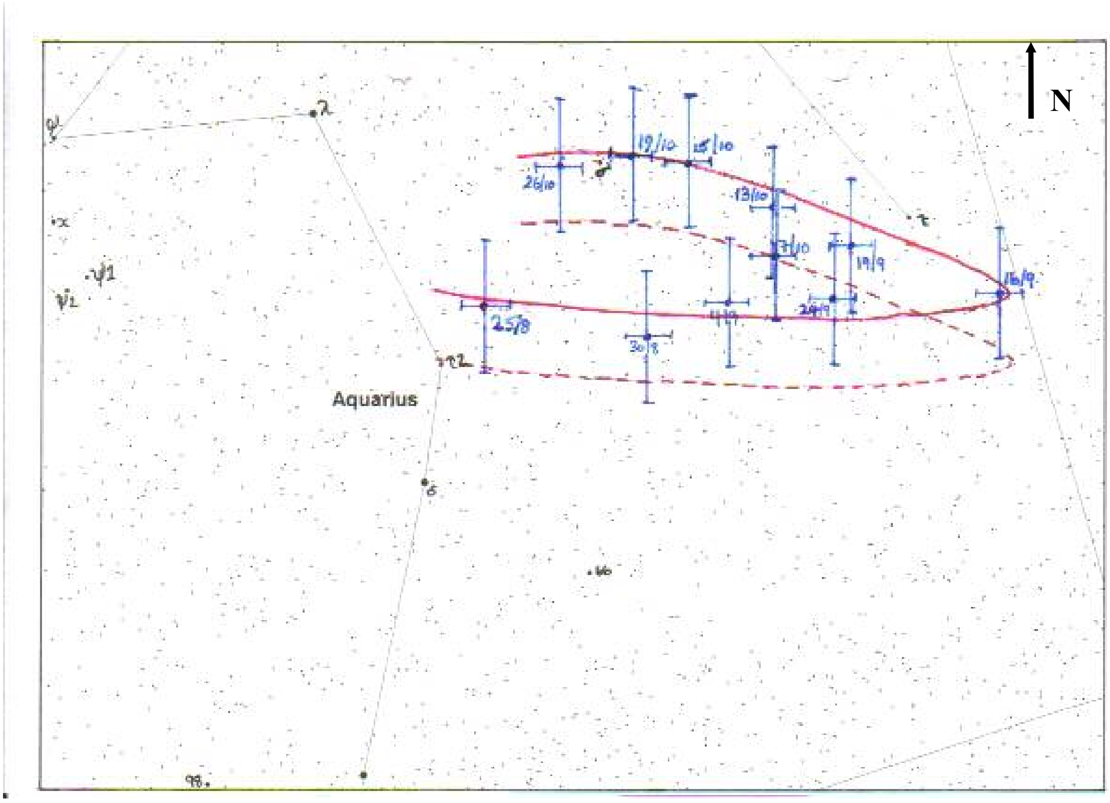

Figure 2 : Apparent motion of Mars, 25/8/03 to 26/10/03

A comparison of this data to the predicted positions of Mars in *Redshift 2* and *HNSky* showed that the altitude readings seem to be 1.5° greater than expected. This suggests a systematic error in the measurements, most probably arising from the pointer not being properly mounted perpendicular to the vertical axis of the tripod. A "corrected" plot of the data is represented by the dotted line in figure 2.

The curve does not pass within the error tolerance for 24th September so that point will be omitted from any subsequent analysis. The curve just fits the error tolerance on 7th October; that point should be treated with caution.

The shape of the curve is in accordance with published predictions (like Robert Ballantyne's website, for example) but at variance with many textbooks which show altitude decreasing immediately once prograde motion resumes. I would be interested in any comments on this discrepancy.

The westward track of Mar's motion to around 16th September represents part of the period of retrograde motion. Since then the planet resumed its prograde motion. Its apparent altitude increased rapidly between 16th September and 15th October, and may now be decreasing back to "normal" values.

During the period described by this part of the "retrograde loop" the average apparent speed of the planet in azimuth has varied, as show in table 1. Through Kepler's second law we know this is due to the line of sight effect.

Time period	**Number of days**	**Start azimuth / °**	**End azimuth / °**	**Change in azimuth / °**	**Average speed in azimuth / ° day $^{-1}$**
25/8 to 30/8	5	146	150	4	0.8
30/8 to 4/9	5	150	152	2	0.4
4/9 to 16/9	12	152	158	6	0.5
16/9 to 19/9	3	158	155	-3	1
19/9 to 7/10	18	155	153	-2	0.1
7/10 to 13/10	6	153	153	0	0
13/10 to 15/10	2	153	151	-2	1
15/10 to 19/10	4	151	150	-1	0.3
19/10 to 26/10	7	150	148	-2	0.3

Table 1 : Average speeds in azimuth

I find the apparent stationary moment around 7th to 13th October curious and would welcome comments on it.

Sources

Ballantyne, R. J. (2003) *Mars : The Great Opposition of 2003*, Internet : http://www.ballantyne.com/mars/MarsSummer2003.html

Price, F. W. (1994) *The Planet Observer's Handbook*, Cambridge, Cambridge University Press

Snow, T. P. & Brownsberger, K. R. (1997) *Universe - Origins and Evolution*, London, Wadsworth Publishing Company

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3rd November 2003