The Third Step: Part 2. Observations on Transit Day

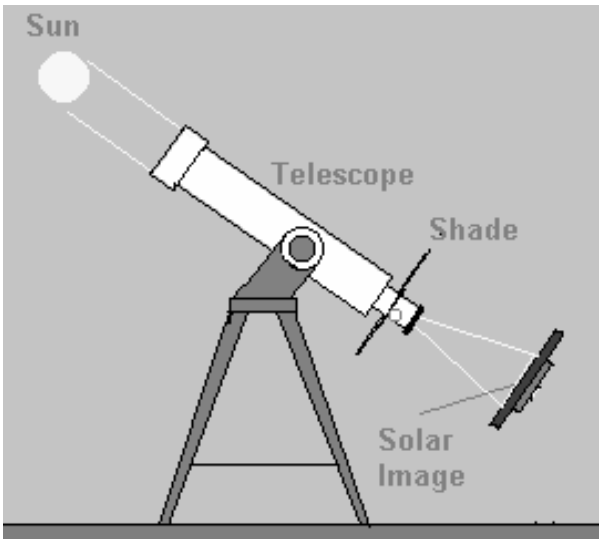
Nirupama Raghavan

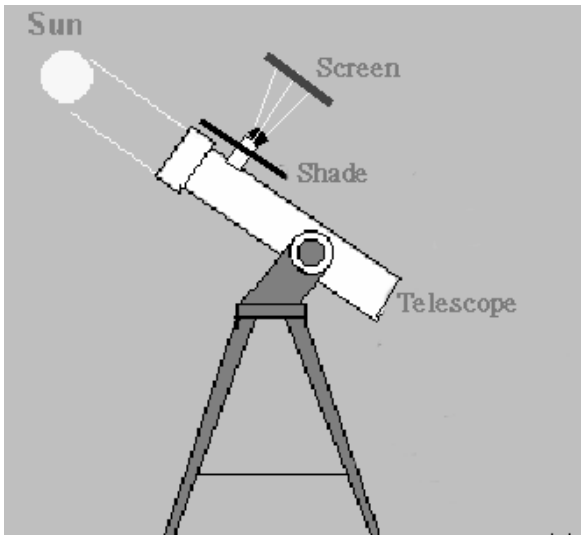
Introduction

This part is written for observers who are likely to have access to a telescope at least 60 mm diametre on an alt-azimuth tripod/mount and will use it in eye piece projection mode with out a drive. They will be noting the positions and the corresponding times manually, during the transit.

Preparing the Telescope

Be completely familiar with your telescope at least a week before the event. Notice how it moves in the two axes and how it is clamped in position. Most small telescopes have poor mounts and have some play of which you must be aware**. If your telescope has a finder, cover its objective firmly**. Fit the projection screen so that it is in a plane perpendicular to the optic axis of the eyepiece and the centre of the screen lies on this axis. An offset of the centre is not serious but the plane of the screen MUST be perpendicular to the optic axis. The figures below show the set up for a refractor and a Newtonian telescope.





Your telescope will get hot when pointed to the sun. Close the objective with a cover when you are not making an observation. A simple cover can be made out of cardboard to fit the telescope tube. The eyepiece that you use must preferably have a metal-holder, as a plastic-holder when used for a prolonged period is likely to melt! Assuming a field of view of 1.5 degrees the screen must be large enough to accommodate the entire field. If the image size is 10 cm, the screen must be 30 cm square.

Team Composition

Each team will consist of at least four members, A, B, C and D. Each member will have a task to perform. The major tasks are

1. Telescope Operation. Adjusting the telescope to keep the image on the screen.
2. Image observation. Visual monitoring of the solar image
3. Timer. Calling out the time continuously
4. Recorder. Recording the instant of contact

The success of the experiment depends on teamwork and each member performing the assigned task smoothly. The coordinators role is important in selecting the right member for the right task. If there are more than four per telescope, back up members can be selected and trained for any one of the four tasks. The change of team member can be made at a suitable time determined by the coordinator. IT IS IMPORTANT THAT EACH MEMBER HAS CLEAR INSTRUCTIONS ON HER/HIS ROLE.

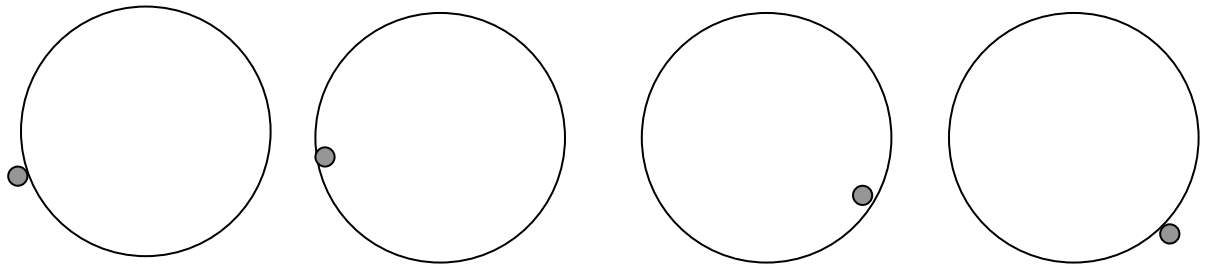
Setting up the Telescope

Remove the eyepiece. Point the telescope towards a part of the sky near the sun. **NEVER LOOK THROUGH THE TELESCOPE AT THE SUN.** Adjust the telescope by looking at the projection screen on which a white paper is fixed. The telescope is pointed at the sun when the sunlight falls on the screen. The telescope casts the smallest shadow at this position. Insert the eyepiece and focus the solar image on the screen. The image can be made smaller or bigger, by moving the screen closer or further from the eyepiece. Adjust it such that the image of the sun just fits the circle on the observational sheet given to you. Be sure to insert a shade as shown in the diagram so that the image of the sun on the screen is seen clearly.

Stages of Transit

There are four important stages associated with the transit of Venus.

1. The discs of the sun and Venus just touch each other externally as the transit begins. This is the first contact.



First Contact Second Contact Third Contact Fourth Contact

2. The discs of the sun and Venus just touch each other internally and Venus is fully in front of the sun. This is the second contact
3. This disc of Venus is on the disc of the sun
4. The disc of the sun and Venus just touch each other internally and Venus is just about to leave the disc of the sun. This is the third contact
5. The discs of the sun and Venus just touch each other externally and Venus is completely out of the sun. This is the fourth contact.

Stages 1 and 2 is described as the **ingress** phase while stages 4 and 5 together form the **egress** phase

The timings that are required for use in the Halley's method are the instant t_2 of the second contact and instant t_3 of the third contact. We have already seen in part 1 that the **black drop effect** makes it difficult to measure these times accurately. A procedure based on recommendations used in 1882 and subsequent understanding of the black drop effect through modelling will be described and may be adopted to minimise the uncertainty in timing the second and third contacts.

Each team must have four members A,B,C and D

1. Assign member A of the team to watch the projection screen from approximately 2 minutes before the theoretical time given for the first contact.
2. Assign member B to look at an accurate watch with a second hand and synchronised with the time signals.
3. B will be calling out each minute followed by the number of seconds elapsed. e.g. 55 -1,2,3,4 etc all the way to 59 and then 56 -1,2,3,4 etc.
4. Member C will have a sheet with the each second marked on a log sheet. C must continuously tick the times called out by member B.
5. Venus is initially not visible at all. It will just become visible as it enters the sun. At this instant, member A will say "now".
6. Member C should mark this second in the log sheet. This time t_1 the instant of first contact to the nearest half second
7. Member A should continue to watch the ingress of Venus
8. Assign Member D to adjust the telescope to keep the image on the screen. It should be adjusted so that **no movement of the telescope is needed during the several minutes bracketing the second contact.**

When half of the disc of Venus is on the solar disc steps 2 to 6 must be repeated for the second contact. Because of black drop effect the instant t_2 of the second contact will be difficult to judge. Venus will appear slowly in front of the solar disc. The black disc of

Fig: a

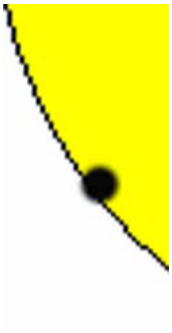


Fig: b

Fig: c

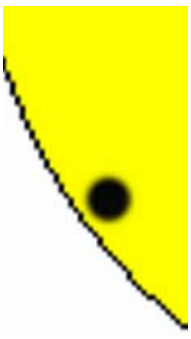


Fig: d

the planet will hide the solar edge or limb at the point of entry (Fig a above). At the stage shown by fig b this limb is still cut by the planet's disc. Fig c shows the critical instant, when the planet does NOT obscure the solar limb. But because of the turbulence in the earth's atmosphere, the non-uniform back illumination provided by the sun and the planets own atmosphere the appearance of the clear solar limb is difficult to judge. At fig d the solar limb is definitely clear. **So what should be taken as the time of second contact?** The instructions given to observers in1882 are reproduced below.

"Just before interior contact at ingress, the sun's limb and the sun will show two fine sharp horns of light, gradually approaching each other to meet around the dark body of the planet. The moment of contact is regarded as the time when the sharp points of the cusps begin to meet. But the ends of these cusps assume a certain haziness and their ill-defined outline will often be wavy and diffused by the effect of atmospheric tremors. The moment of interior contact at ingress is that at which light is about to glimmer all across the dark space between the cusps. Very generally there will be a period of several seconds during which the light will glimmer and disappear by turns. ***The middle of this period is that of true contact"****.*

At egress, all the phenomena described above will recur in reverse order. As the planet is approaching interior contact at egress, the band of light in front of it, as it fades away, very gradually grows fainter until it is almost lost in vision. The time of interior contact is marked by the moment at which light entirely ceases to glimmer across the dark space formed by the approach of the planet's limb to that of the sun. From the commencement of this darkening until its disappearance from view, there is a series of progressive changes, which may extend over a period of several seconds. ***Again, the middle of this period is that of true contact.***

However, the bright sunlight through the atmosphere of Venus, that appears on the planet's limb silhouetted against the dark sky during ingress and egress, should not be misapprehended for the glimmer across the dark space between the cusps. The distinction between the two is a matter of judgement which must be left to the observer."

Attention may also be fixed on the dark region between the bright cusps which connects the dark disk of Venus with the dark sky outside the sun, instead of the bright cusps. The aim is to record two times at second and third contact bracketing the actual instant. If t_{2a} and t_{2b} are the two times bracketing the actual instant of second contact t_2 then

$$t_2 = (t_{2a} + t_{2b})/2$$

Thus the visual observer will call "now" twice at second and third contacts and the recorder will note both these times.

The international effort also urges all observers to produce and submit valuable drawings and descriptions and not to confine themselves with the mere recording of the times of contact. So

additional team members may try to sketch what they actually see between the two times.

Typically there is a gap of 20 minutes between beginning of first contact and the end of second contact. So ten sketches of the Venus ingress phase can be made

Drift Scan and Position Marking

In a 10 cm image of the sun Venus will have a diameter of approximately 3mm.

1. Fit the sun in the circle of the observation sheet.
2. Mark Venus in it. Because the earth rotates the image of the sun will move on the screen. Mark Venus as the image moves across the screen. The direction of motion of the image is the east west line. This is called a drift scan. The *leading* limb is the west limb and the *following* limb the east.
3. Nudge the telescope towards the North. The north limb of the sun moves *away*. Draw the east west and the north south lines.
4. Orient the transparent observation sheet so that the 0^0 marking coincides with the north direction. Now the grid is aligned with N-S and E-W directions.
5. Mark the position of Venus on this new sheet as your partner notes the time. Enter time on the sheet.
6. Close the objective of the telescope with the cap.

Repeat steps 1 to 6 after every 15 minutes. If your telescope does not have a drive you must change the direction of the telescope tube and bring the image of the sun to the projection screen every time. This may have to be done every 5 minutes.

Position Angle on the Sun

The position of any feature on the sun can be specified by its position angle. This angle is measured from the north towards the east south and west. Thus a feature due east has PA $=90^0$. On the day of the transit Venus will appear at PA = 116^0 second contact is at 119^0. For third and fourth contact are at PA 213^0 and 216^0 respectively. Thus the first and second contacts will take place at the south-east quadrant and the third and fourth contact a in the south-west quadrant.

It is necessary to properly mark the North, South and East, West in projected telescope images for your own set up and use the appropriate observation sheets. The sample sheet given below must be modified accordingly.

Observation Sheet for Contact times sheet 1

10h

44		**45**		**46**		**47**		**48**		**49**		**50**		**51**		**52**		**53**	
01	✓	01		01		01		01		01		01		01		01		01	
02	✓	02		02		02		02		02		02		02		02		02	
03	✓	03		03		03		03		03		03		03		03		03	
04	✓	04		04		04		04		04		04		04		04		04	
05	✓	05		05		05		05		05		05		05		05		05	
06	✓	06		06		06		06		06		06		06		06		06	
07	✓	07		07		07		07		07		07		07		07		07	
08	✓	08		08		08		08		08		08		08		08		08	
09		09		09		09		09		09		09		09		09		09	
10		10		10		10		10		10		10		10		10		10	
11		11		11		11		11		11		11		11		11		11	
12		12		12		12		12		12		12		12		12		12	
13		13		13		13		13		13		13		13		13		13	
14		14		14		14		14		14		14		14		14		14	
15		15		15		15		15		15		15		15		15		15	
16		16		16		16		16		16		16		16		16		16	
17		17		17		17		17		17		17		17		17		17	
18		18		18		18		18		18		18		18		18		18	
19		19		19		19		19		19		19		19		19		19	
20		20		20		20		20		20		20		20		20		20	
21		21		21		21		21		21		21		21		21		21	
22		22		22		22		22		22		22		22		22		22	
23		23		23		23		23		23		23		23		23		23	
24		24		24		24		24		24		24		24		24		24	
25		25		25		25		25		25		25		25		25		25	
26		26		26		26		26		26		26		26		26		26	
27		27		27		27		27		27		27		27		27		27	
28		28		28		28		28		28		28		28		28		28	
29		29		29		29		29		29		29		29		29		29	
30		30		30		30		30		30		30		30		30		30	
31		31		31		31		31		31		31		31		31		31	
32		32		32		32		32		32		32		32		32		32	
33		33		33		33		33		33		33		33		33		33	
34		34		34		34		34		34		34		34		34		34	
35		35		35		35		35		35		35		35		35		35	
36		36		36		36		36		36		36		36		36		36	
37		37		37		37		37		37		37		37		37		37	
38		38		38		38		38		38		38		38		38		38	
39		39		39		39		39		39		39		39		39		39	
40		40		40		40		40		40		40		40		40		40	
41		41		41		41		41		41		41		41		41		41	
42		42		42		42		42		42		42		42		42		42	
43		43		43		43		43		43		43		43		43		43	
44		44		44		44		44		44		44		44		44		44	
45		45		45		45		45		45		45		45		45		45	
46		46		46		46		46		46		46		46		46		46	
47		47		47		47		47		47		47		47		47		47	
48		48		48		48		48		48		48		48		48		48	
49		49		49		49		49		49		49		49		49		49	
50		50		50		50		50		50		50		50		50		50	
51		51		51		51		51		51		51		51		51		51	
52		52		52		52		52		52		52		52		52		52	
53		53		53		53		53		53		53		53		53		53	
54		54		54		54		54		54		54		54		54		54	
55		55		55		55		55		55		55		55		55		55	
56		56		56		56		56		56		56		56		56		56	
57		57		57		57		57		57		57		57		57		57	
58		58		58		58		58		58		58		58		58		58	
59		59		59		59		59		59		59		59		59		59	

Observation Sheet for Chord Determination

The diameter of the inner circle is 10 cm. Fit the image within the inner circle