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Personal computer based star changing device and occultation data-acquisition system

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This paper describes a personal computer interface card developed for occulation studies with our 1 m telescope at VBO Kavalur. The new feature of this system is the application of personal computer for the accurate positioning (Star Changing Function) and the data acquisition for occultation studies. The performance of the instrument is discussed with some examples.

1 Introduction

Occultation or eclipse observations require continuous monitoring of an object. The data-acquisition is terminated after a time interval depending on the duration of the event. The duration varies from a fraction of a second in case of lunar occultations to several minutes in case of planetary occultations.

Lunar occultations of clusters are of special interest. During cluster occultations the stars disappear behind the lunar limb in quick succession. The reapearance events also follow in the same manner. Soon after one event the telescope should be manoeuvred quickly to point towards the next candidate star. In such a situation two important instrumentation requirements arise. 1) The ability to move to a programme star precisely from a nearby guide-star, implemented by the Star Changing Device (SCD) and 2) fast acquisition of flux data in a cyclic buffer to record the Fresnel Zones of the occulted star.

The photon counting systems used earlier in occultation studies employed hardware approach which makes changes in operation difficult. Subsequently with the development of micro-processors the flexible software approach to the data-acquisition became possible[1]. The data were stored in cassette recorders due to the memory and file restrictions posed by the microprocessor approach[2,3]. Recently, the widespread availability of low cost IBM compatible personal computers has overcome the above difficulties[4,5]. The PC approach in addition provides for star changing function, cyclic buffer for data storage and display, thereby offering an integrated approach for pointing, data acquisition and display in occultation studies. In this paper we describe the hardware and software aspects of a PC based star changing device and occultation data acquisition system.

2 Hardware Description

A PC-XT (640 KB RAM, 20MB disk) has been used for the occultation observations. The interface electronics provides the following functions: 1) Star changing function; 2) pulse counter and data multiplexer; and 3) circular buffer and a digital to analog convertor.

2.1 Star Changing Function — Principle of Operation

During an emersion event, the program star is masked by the moon. Guiding is carried out on a nearby guide-star. The observer switches from a guide-star to the programed star a few seconds before the event using a star changing device (SCD).

A block diagram illustrating the principle of operation of the SCD is shown in the Fig. 1. The desired differential RA and DEC movements are stored in units of arcsecond. Depending on the displacement values, two speeds of motions are selected. The slow motion is covered in 10 arcmin/min

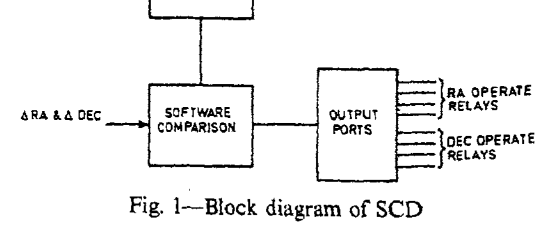

Fig. 1—Block diagram of SCD

and the fast motion corresponds to 3 deg/min. To avoid any overshoot, the fast motion is selected only for displacements greater than 1900 arcsec. For such displacements in order to meet the proper acceleration, deceleration requirements, the initial 100 arcsec and the final 200 arcsec motions select slow speed. The speed curves are shown in Fig. 2a and 2b. Using a software routine a match is sought between the desired displacement and the corresponding pulse counter values. The pulse counter is updated with the corresponding axis incremental encoder pulses with every tick representing one count per arcsec. The output port energises a relay for the corresponding axis movement, at the pre-selected speed. The incremental encoder interface and the relay selection are shown in Fig.3 and Fig.4 respectively.

2.2 Pulse counter interface and data multiplexer

The incoming star light is routed to the photo multiplier tube (PMT). The PMT is operated in pulse counting mode using a conventional pulse amplifier/discriminater circuitry. The counter interface card has been designed to accept either TTL or ECL inputs. A jumper option selects a ECL to TTL translator (IC10125) in the case of ECL inputs. The pulse counter comprises of six 4 bit synchronous binary counters cascaded to provide a 24-bit counting. The first stage of the counter uses a schottky version (82S91) to enable high frequency counting up to 100 MHz. The subsequent stages in the counter-chain use TTL ICs 74LS193. The counters can be reset to zero-count under program control and then gated for the desired integration time to count the PMT pulses. The resulting count values are transferred to the computer using a programmed data transfer technique. Since the input instruction can read a word (16 bit) at a time, a multiplexing arrangement is used to read the 24 bit counter values. The 'Word Select' bit selects either 'High Word' or 'Low Byte' to read at a time. The pulse counter interface arrangement is shown in Fig. 5.

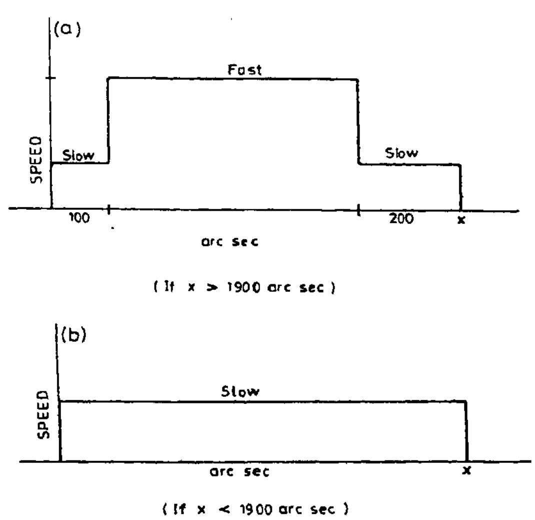

Fig. 2(a,b)—Speed curves of SCD

In order to achieve the SCD functions, the counters are arranged as two groups of 16 bit each. The differential RA and DEC values are matched with these counter values which obtain their inputs from their respective incremental encoders. The two multiplexing signals used in the SCD mode are SCD Select and RA/DEC Select. These multiplexer control signals are also shown in Fig.5. When SCD is selected, the low word represents the RA counter values and the high word represents the DEC counter values. Upto 64 stars can be programmed initially. The software menu prompts for entering the differential RA and DEC values. A skip facility is also provided to alter the course of motion, if so desired during observation.

2.3 Circular buffer and display

A 32 K byte buffer is used from the RAM space to store the PMT data. Data-acquisition is carried out on a command till the user terminates this process by pressing any key. The organisation of the data in the

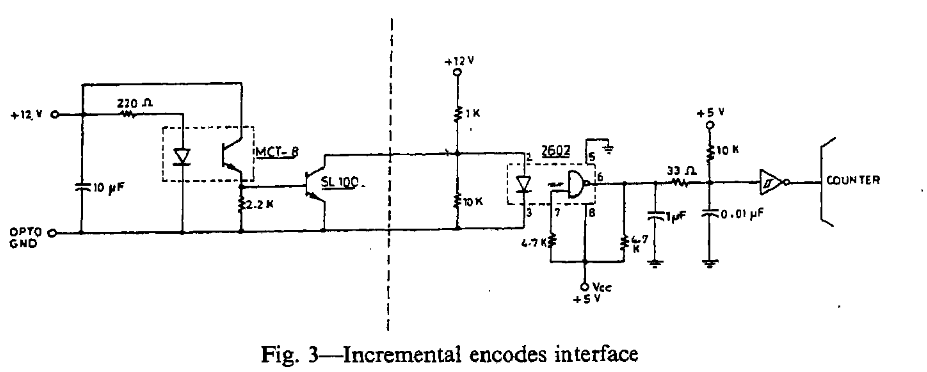

Fig. 3—Incremental encodes interface

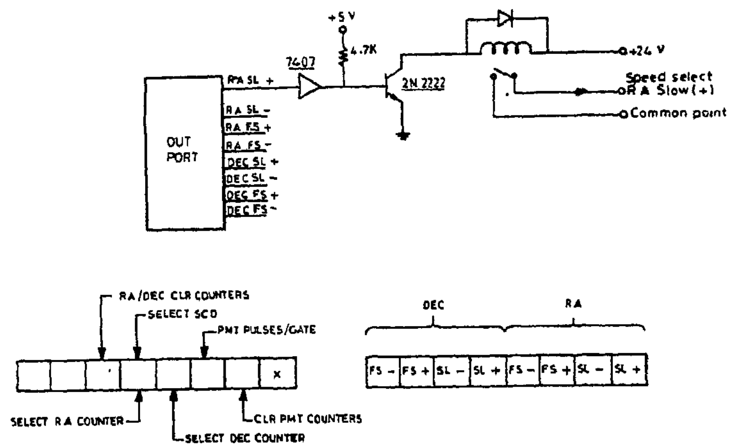

Fig. 4—Output port-relay selection

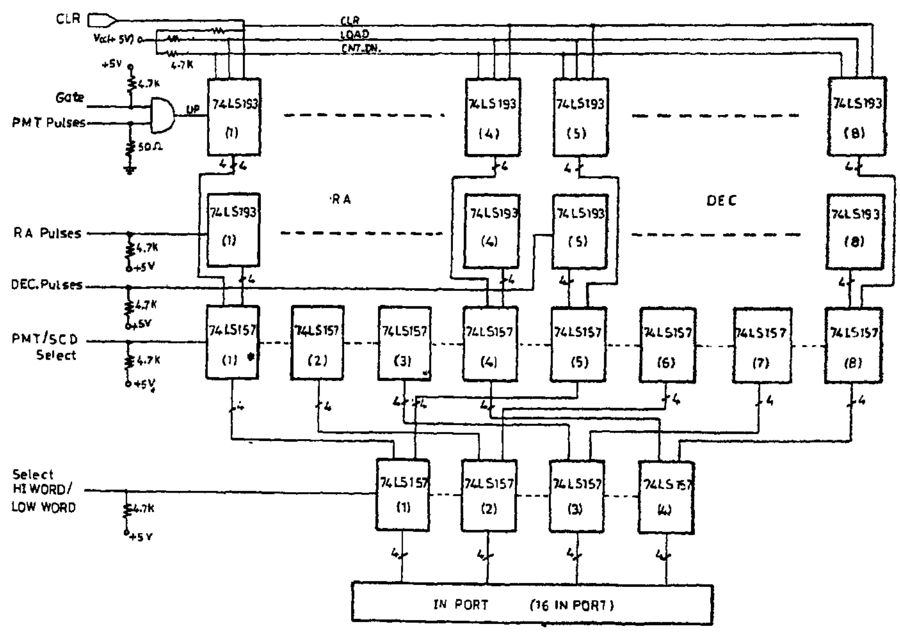

Fig. 5—Pulse counter interface arrangement

circular buffer and the arrangement of data is described under section 3.6. The circular buffer output is presented to a 16 bit Digital to Analog Converter in a cyclic fashion at a desired frequency so as to display the recorded occultation curves either on a CRT or a Strip Chart Recorder.

3 Software Description

The software for data acquisition is written in Turbo-Pascal. Being a structured language, the program is modular and provides easy modification if required. The program utilises the following procedures: 1) Set time; 2) get start-time of observation; 3) gate generation; 4) data acquisition; 5) get end-time of observation; 6) rearranging cyclic buffer data; and 7) data storage.

3.1 Set time

Syntax : SETTIME (var hour, min, sec : Integer)—This procedure sets the time maintained by DOS. This is done at the beginning of the program with reference to the standard time. This is accomplished by using DOS function call from Turbo-Pascal, using a procedure MsDos (Record).

2.2 Get start-time of observation

Syntax : GETTIME (var hour, min, sec : Integer)—When the data acquisition commences, this procedure gets the time from the DOS and stores in the fields Sthr, Stmin, Stsec of the record.

3.3 Gate generation

PC generates a gate pulse using the delay procedure the duration of which is specified by the user. It uses a standard procedure in Turbo-Pascal, and its syntax is:

DELAY(Var N)

where N is an integer and corresponds to the integration time in milliseconds the period for which the PMT pulses are counted.

3.4 Data acquisition

The two-dimensional array[1..16,1..1000] of integer (32K size) holds the values of the incoming data. Before commencing the integration, all counters are cleared and gate signal corresponding to the integration time is generated. At the end of the gate signal the pulse counter values are read into the data array. The data is continuously acquired and stored in the cyclic buffer array until the observation is terminated by pressing a key.

3.5 Get end-time of observation

This is similar to the procedure GETTIME. The values returned from the procedure are stored in the fields Ethr, Etmin, Etsec of the record.

3.6 Rearranging cyclic buffer

An important feature in the software is that a cyclic buffer of size 32 k is provided in the RAM space. The buffer is a two dimensional array[1..16,1..1000] of integer. The buffer is initialised before acquiring data. A loop passed flag is cleared at the beginning and is used to indicate whether the buffer is full. Initially a pointer is set to point to the beginning of the array. The acquired data is stored in the array as pointed to by the array pointer in the following way.

datavalues[1,1] ...... datavalues[1,1000]
datavalues[2,1] ...... datavalues[2,1000]
datavalues[16,1] ...... datavalues[16,1000].

Once the buffer is full the pointer is set to the beginning of the array and loop-passed flag is set. The program checks for the loop passed flag on termination of the observation. If the loop-passed flag is set, the data values are rearranged as shown in Fig.6 so that the data point which is recently acquired is stored at the end of the buffer. If the loop-passed flag is not set, the buffer remains unaltered.

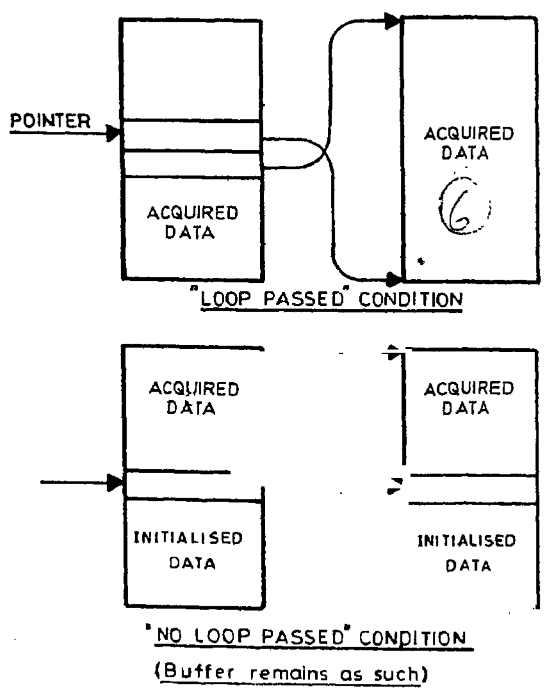

Fig. 6—Rearranging of buffer

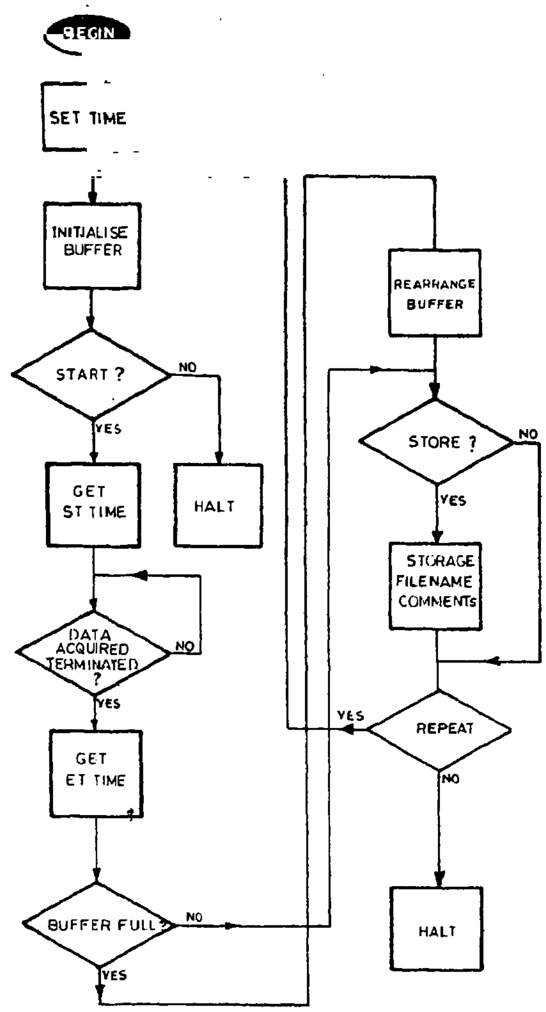

Fig. 7—Flow chart

3.7 Data storage

The data can be stored on to the disk under a file name specified by the user. Status of the file is identified, using function calls RESET and IORESULT. The function RESET(filevar) opens an existing file with a filename assighed to filevar using ASSIGN(filevar, filename) statement. The function IORESULT when called returns an integer value that represents the status of the last I/O operation performed. A zero value indicates the I/O operation is successful. The I/O directory should be off ({$I – }) while using these Procedures for finding the file status, so that the program will not be terminated even if it finds an I/O error (in case the file does not exist). If the file exists, the program waits for the user response to decide as to overwrite or create a new file. The file is organised as records with the following fields:

Comments	:	String [80]
Sthr	:	
Stmin	:	
Stsec	:	
Ethr	:	Integer;
Etmin	:	
Etsec	:	
IntTime	:	
Data	:	array[1..16,1..1000] of integer.

The total software flow chart is shown in Fig.7.

4 Performance of the Instrument

The present system is in regular use at the 102 cm telescope at VBO, for recording lunar occultations and mutal events of satellites of Jupiter.

Lunar occultations—Due to its orbit around the earth, the moon moves eastwards relative to the stars in the sky. Because of its large angular size the moon frequently occults the stars. Lunar occultations provide means to estimate angular sizes of celestial objects accurately.

Between new moon and full moon the eastern limb of the moon is dark. During this period the stars disappear at the dark eastern limb and reappear from behind the sunlit western limb. During an event the stellar light undergoes diffraction at the lunar limb. When the event is recorded at a time resolution of a few milliseconds, the light variation representing the

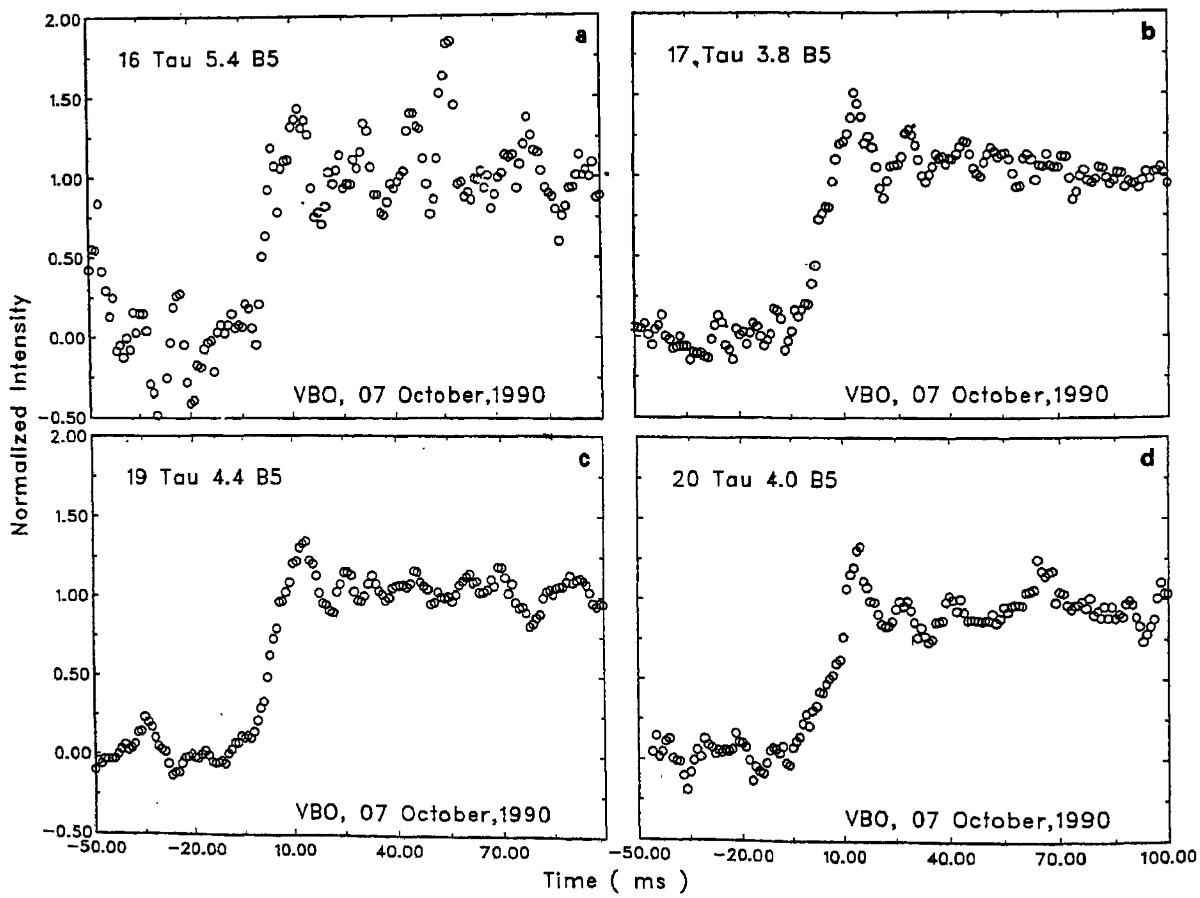

Fig. 8(a,b,c,d)—Lunal occultation of Pleiades cluster — normalized intensity versus time diffraction pattern can be registered. The diameter of the star can be estimated by fitting the observed light curve to a theoretical model. Binary stars disappear in steps. The composite light curve can be analyzed to estimate the angular separation and the intensity ratio of the stars in the binary system.

Between full moon and new moon the western limb is dark and the eastern limb is sunlit. The disappearance events at the eastern limb would be flooded due to light from the sunlit part of the moon. Except for very bright stars only the events at or from behind the dark limb yield light curves of good S/N. Recording an immersion event poses no problem as the star is followed till it disappears. For recording a reappearance (emersion) event the telescope should be pointed to a blind spot on the western limb from where the star will reappear. The size of the focal plane aperture which is normally between 10-30 arc-seconds is very much smaller than the angular size of the moon which is about half a degree. Precise manoeuvring of the telescope so that the star exactly reappears at the center of the diaphragm is therefore essential. Use of the star changing device described in this paper accomplishes this task elegantly.

During lunar occultation of clusters the stars during immersion at the dark edge disappear one by one in quick succession. Using the star changing device the telescope can be moved to the location of the next candidate star from the current position by preprogramming the required steps. During the reappearance of a cluster manual centering is quite difficult. The pointing accuracy provided by the SCD is essential to carry out observation.

Using our system the occultation of stars in the Pleiades cluster was recorded on Oct 7, 1990. All events were reappearance events. The sequence of occultation events is given in Table 1. The first star SAO 076113 which emerged at 17:14:45 UT was used as the starting target. Columns 5 and 6 give the shifts in the RA and DEC from one target to the next. All the stars in the table were attempted. Since the moon was 82% sunlit, only stars brighter than 5th magnitude

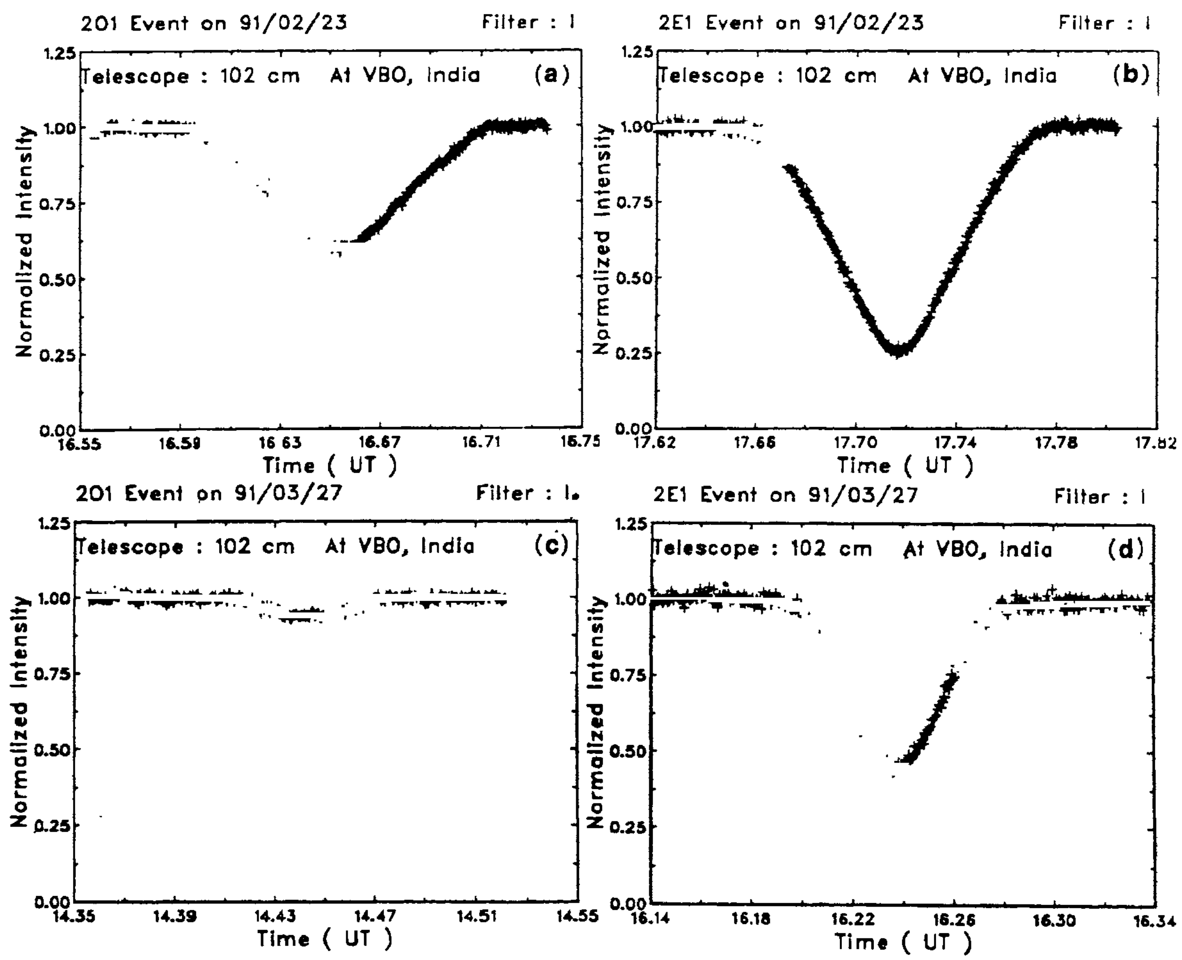

Fig. 9(a,b,c,d)—Light curves — normalized intensity versus time

Table 1—Lunar occultation of pleiades cluster on 07 Oct, 1990

Predicted Time (UT) HH:MM:SS	Star ID SAO	Magnitude	$\Delta\alpha$ (arc s)	$\Delta\delta$ (arc s)
17:14:45	076113	8.5 A2	0	0
17:22:08	076104	8.3 A5	−253	−657
17:30:08	076131	3.8 B5	+1039	−940
17:42:42	076119	8.5 A5	−403	+1013
17:48:13	076126	5.4 B5	+337	−379
17:52:57	076136	8.7 A0	+274	−93
18:06:16	076140	4.4 B5	+90	+733
18:14:35	076173	7.0 A0	+1122	−763
18:17:56	076155	4.0 B5	−565	+406
18:28:39	076159	5.8 B8	+72	+672
18:32:26	076164	6.5 B9	+126	−96
18:58:46	076183	6.7 B9	+847	−27

could be recorded with good signal to noise ratio. Occultation traces of 16 tau(SN 5), 17 tau(SN 3), 19 tau(SN 7) and 20 tau(SN 9) are shown in Fig.8(a,b,c,d).

Mutual events of Jupiter's satellites—Twice during a Jovian year 11.6 of earth years, the equatorial plane of Jupiter is seen edge on. During several months around the time of crossing, the four large satellites of Jupiter frequently occult(eclipse) each other whenever any two of them are aligned with the earth(sun).

The pulse counting system in occultation mode was used to record the recent mutual event series in 1991. Depending upon the duration of the event integration times used in each case were selected from 150ms to 1000ms. The light curves are shown in Fig.9.

Acknowledgement

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