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# Photometric flash-light observations of SL9 impact on Jupiter

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**Abstract.** The effect of SL9 impact on Jupiter has been assessed by observing flash-light effect on the nearest satellite of Jupiter, the Io, on 21 July, 1994. The observations in V filter of flash-light effect on Io suggest a considerable brightening of more than 2 magnitudes as compared to the normal brightness of Io. Three distinct peaks of brightening are visible in the light curve which indicate three collision events. The mass of the fragmented nuclei undergoing impact with Jovian surface is estimated to be slightly greater than $10^{13}$ kg.

*Key words* : SL9 - Jupiter - impact - V - observations

## 1. Introduction

Reappearance of the periodic comet Shoemaker-Levy 9 (1993e) was detected by Shoemaker *et al.* (cf. Marsden 1993). Subsequently, it was revealed that the comet consists of several pieces (Chapman 1993). The unusual appearance of SL9 and its close approach to Jupiter indicated the possibility of its split (Marsden 1993). It appeared as a dense linear bar. Scoti (1993) confirmed SL9 to be a moving object, in which atleast five discernible condensations were visible. Jewitt and Luu (1993) reported 17 nuclei in SL9 based on their observations through 2.2-m telescope. Gang *et al.* (1995) observed 13 fragments of SL9. Chapman (1993) reported that the periodic comet SL9 was expected to produce drastic phenomena on the Jovian surface due to huge energy deposit produced by the collision. Many researchers (Zahnle and Mac Low 1994; Takata *et al.* 1994) predicted the formation of large, hot plumes or fireballs up-welling from the Jovian atmosphere due to explosions. It was predicted because SL9 having tidally fragmented nuclei, the impact will occur several times over a few days (Hasegawa and Takata 1993) between 19 July 1994 and 22 July 1994. Some results seem to have appeared in ESO Proc. 52, 81-118, 1995, which are not available to us. Unfortunately, the predicted collision was expected to take place on the far-side of Jupiter, thus, it was impossible to see the collision events directly. However, since the impact energy was expected to be extremely large, the observers might be able to see the event as a reflected light from the Galilean satellites; if one of the satellite of Jupiter had a favourable position at the time of collision.

Because a huge number of researchers and astronomers employed big telescopes for the observations of SL9 impact on Jupiter and they, mostly, observed this event, mainly, in the near-infrared region, and also spectroscopically, thus, very little or negligible data of this event were expected to be available in the visible region. In this light, even meagre data available in the visible region was considered valuable.

The observations of impact of SL9 on Jupiter have been secured by us by observing the flash-light effect on the nearest satellite of Jupiter, Io, on 21 July 1994 through the 38-cm reflector of Uttar Pradesh State Observatory, Naini Tal employing a cooled (–20°C) 1P21 photomultiplier, V-filter, d.c. techniques and strip-chart recorder. During observations, we kept the light of Jupiter (or any other nearby object) completely out of the aperture to avoid any contamination and observed only the light of Io along with the background sky light separately. These observations are listed in table 1, and observed magnitudes are plotted in figure 1 against time (in UT). In order to assess the error in the observations we also secured pre-collision observations of Io on 12 July 1994, alongwith observations of $\eta$ Boo, and it was found that the maximum variation (at pre-collision state) in the Io's light was ± 0.15 mag., as shown on the top of figure 1. The differential magnitudes (Io-$\eta$ Boo) are given in table 2.

**Table 1.** Observed flash magnitudes of Io in V filter during SL9 impact on Jupiter on 21 July 1994.

| Time UT h m | Mag. | Time UT h m | Mag. |
|---|---|---|---|
| 15 13.4 | –1.594 | 15 25.0 | –1.761 |
| 15 13.6 | –2.148 | 15 26.5 | –1.594 |
| 15 13.7 | –2.943 | 15 26.8 | –1.708 |
| 15 14.6 | –2.845 | 15 27.1 | –1.993 |
| 15 15.9 | –2.303 | 15 27.3 | –2.184 |
| 15 19.0 | –2.636 | 15 27.7 | –2.954 |
| 15 22.0 | –3.900 | 15 28.6 | –3.114 |
| 15 22.4 | –3.949 | 15 29.0 | –3.253 |
| 15 22.9 | –3.848 | 15 29.6 | –3.578 |
| 15 23.3 | –3.371 | 15 30.7 | –3.693 |
| 15 23.4 | –2.850 | 15 30.9 | –3.763 |
| 15 24.8 | –1.950 | | |

**Table 2.** Observed differential magnitude (Io-$\eta$ Boo) of Io on 12 July 1994.

| Time UT h m | Mag. | Time UT h m | Mag. |
|---|---|---|---|
| 16 13.0 | 2.787 | 16 47.1 | 2.727 |
| 16 14.5 | 2.764 | 16 48.5 | 2.695 |
| 16 15.4 | 2.695 | 16 49.4 | 2.795 |
| 16 15.9 | 2.779 | 16 50.0 | 2.761 |
| 16 16.4 | 2.817 | 17 05.6 | 2.800 |
| 16 17.3 | 2.647 | 17 06.4 | 2.863 |
| 16 35.1 | 2.792 | 17 07.1 | 2.901 |
| 16 35.7 | 2.893 | 17 08.7 | 2.850 |
| 16 36.4 | 2.882 | 17 17.0 | 2.960 |
| 16 37.5 | 2.841 | 17 17.6 | 2.895 |
| 16 38.1 | 2.948 | 17 18.2 | 2.949 |
| 16 40.2 | 2.941 | | |

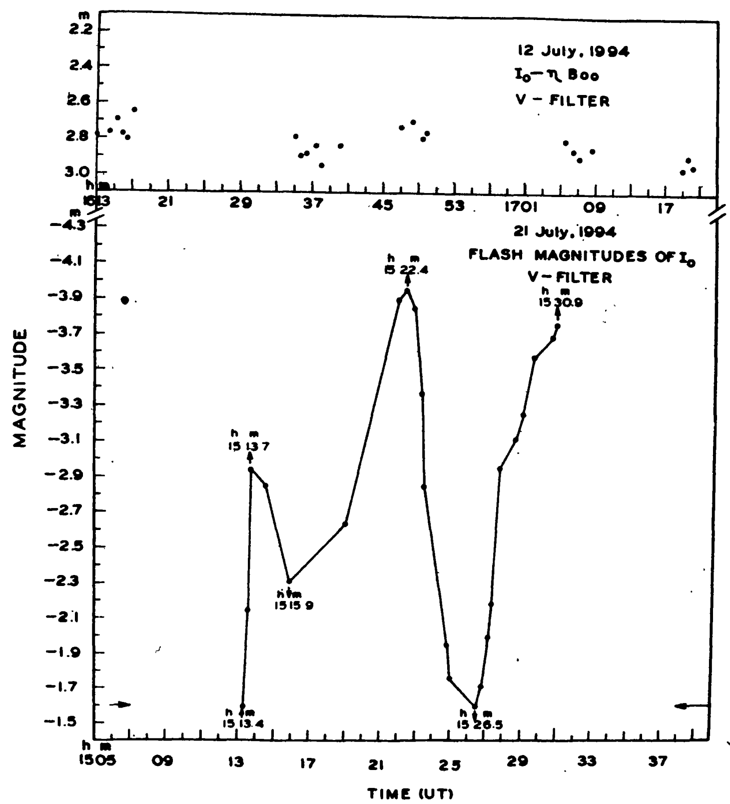


Figure 1.

## 2. Results

The V-light curve of flash light observations of the satellite Io show three distinct peaks at $15^h\ 13^m.7$ UT, $15^h\ 22^m.4$ UT and $15^h\ 30^m.9$ UT having magnitude variations (min. to max.) of 1.35 mag., 2.35 mag. and 2.16 mag. respectively in time intervals of 0.4, 6.5 and 4.4 minutes respectively. Last two impacts are prominently visible and indicate steep rise in the brightness (magnitude) level.

The timing of our rise and fading of brightness matched well with that of Shykula, Sekiguchi and Calar Alto observations. Sekiguchi (cf. Marsden 1994) obtained images of Jupiter with 0.75-m telescope during the impact and showed that a low-level brightening began around July 21.636, while our observations show the start of low level brightening around July 21.634. Likewise, Shykula (Marsden 1994) reported that it began to fade before a much more dramatic brightening began around July 21.640 while in our observations the corresponding time is July 21.636; also, he reported peak brightness occurred around July 21.645 while in our observations corresponding value is 21.641. Calar Alto results (cf. Marsden 1994) also showed that an impact-plume was found around July 21.645. Shykula (cf. Marsden 1994) observed in K-band, while we observed in V-filter. This small difference of time may be caused by wavelength dependence of the impact flash.

## 3. Discussion

Bo-chen *et al.* (1995) observed six impact events probably on 23 July 1994 (as nothing has been clearly mentioned) through 1.5-m telescope and secured CCD data in V-filter only. They exposed pre-collision images of Jupiter on 13 and 14 July 1994. They observed the flash light effect on Europa. Their flash V-light curve shows two distinct peaks having magnitude variations (min. to max.) of 0.5 mag. and 0.3 mag. respectively.

Hesegawa and Takata (1993) mentioned that a fragment impact will occur several times. Thus, these several impacts may be indicated by several peaks visible in the V-light curves.

Our V-observations on 21 July 1994 shows average brightening (due to impact flash) of nearly 2 mag., and maximum brightening of the three peaks vary from 1.4 mag. to 2.4 mag.

Hasegawa and Takata (1993) calculated the brightness variation for nuclei having different masses. Hasegawa and Takata (1993) pointed out that if the impact occurs at the visible side of Jupiter, we would be able to see its maximum brightness of the order of $-10$ magnitudes.

Our V-observations show that the largest brightening is of nearly 2.4 mag. By comparing this brightening with the figure 3 given by Hasegawa and Takata (1993), the assessed mass of the impact nuclei comes out to be nearly $10^{13}$ kg.

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