

RADIATIVE SIGNALS FROM IMPACT OF SHOEMAKER-LEVY ON JUPITER;

Thomas J. Ahrens , *Glenn S. Orton , Toshiko Takata and John D. O'Keefe, Lindhurst Laboratory of Experimental Geophysics, Seismological Laboratory, California Institute of Technology, Pasadena, CA 91125; *Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109

Background. We used the temperature and internal energy fields calculated by Takata et al [1] in the plume to calculate the greybody thermal radiation emitted versus wavelength, to predict what might be observed by several spectral sensors operating from different platforms when fragments of Comet Shoemaker-Levy-9 (SL-9) impact Jupiter in July 1994 [1-5].

A SPH code was used by Takata et al [6] to calculate the full three-dimensional flow and thermodynamic fields in the comet fragment and the atmosphere of Jupiter. We determined the fragment penetration depth, energy partitioning between the atmosphere and the impactor, and energy density deposited per unit length over the trajectory.

Once the impactor had disintegrated and stopped, and the strong atmospheric shock decayed, the flow is driven by buoyancy effects. We then used our SPH code to calculate the flow and thermodynamic fields---pressure, article velocity, temperature and internal energy distributions in the plume.

The calculations for 2 and 10 km cometary fragment yielding maximum deposition of depths of ~175 and ~525 km, respectively (1 bar = 0 km depth). We also calculated that 0.7 and 0.6 of the initial kinetic energy of the 10- and 2-km diameter bolides, respectively, are deposited as internal energy in Jupiter's atmosphere.

Radiative Signatures. The radiation upon entry from the heated atmosphere and vaporized cometary media within the temporary conical cavity will be multiply Rayleigh scattered by the H₂ and He of Jupiter's atmosphere, and obscured by the several Jovian cloud decks. Moreover, as pointed out by Field and Ferrara [7], the radiant flux may also be reflected from one or more Galilean satellites depending upon their position during impact. The observed color temperature during entry of a cometary fragment into Jupiter's atmosphere will be in excess of 10⁴ K. The details of the spectrum will depend on the degree of ionization which occurs in the bolide material and in Jupiter's atmosphere [8,9]. In any case, the ~10⁴ K temperature seen in the impact flash during bolide entry will occur (because of radiative cooling) for only a minute or so.

Because the optical radiation from the (~10sec) entry of a SL-9 fragment into Jupiter will emit radiation anisotropically , we chose to model only the radiation from the second SPH calculation describing the plume. Moreover, the entry flash may be partially obscured in many directions by the asymmetry of the entry hole, opacity of ionized gas, and the NH₃, NH₄SH, and H₂O cloud layers.

Starting with plume calculations of 2-and 10-km SL-9 fragments, we have considered each particle as a greybody radiator disc and calculated the total normal radiative power as a function of wavelength at a series of times (e.g. Figure 1). Since we are not accounting for the absorption of CH₄ or Rayleigh scattering from H₂, the present calculations are an upperbound to the actual radiating power. However, most of the hot materials, shown in Figure 2 a,b, are at, or above, the elevations such that there will be minimal absorption effects of clouds. We observe that in the case of the 2 km comet nucleus fragment impact (Figure 2b) that its particle velocity is such that it should achieve an altitude of 3000 km within several minutes.

Predictions. In July 1994, the Galileo spacecraft will be in a good position (1.6 AU away from Jupiter) to observe with the Solid State Imaging Experiment [10] the plumes from Shoemaker-Levy-9 fragment collisions directly. The flux emitted by the plume associated with a 2-km diameter fragment is some 30% of the solar visible flux reflected by Jupiter. It is comparable to both Jupiter's reflected solar flux near 1 micron and an order of magnitude or more higher than Jupiter's near-infrared reflected flux, and Jupiter's average 5- and 7.8-micron thermal emission. Using our 2-and 10-km results, we infer that the plume from impact of a 2-km diameter fragment yields a radiant

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power equivalent to 3% of Jupiter's total flux and some 10% of Jupiter's average thermal emission at 5 and 7.8 microns. Thus, observations by Galileo instruments are technically feasible for a large number of the fragments if they are as dense as we have assumed.

Direct earth-based observations of the impact-induced plume may be possible as it rises above Jupiter's horizon as seen from the earth (prior to dawn at the impact point). However, observation of the inner Galilean satellites brightnesses as a function of time may detect a reflection of the plume illumination superimposed on the solar illumination. The plume generated by a 1-km diameter fragment would increase Io's visible flux by some 10% in the visible and by 1% or less in the near infrared. The plume generated by the 0.5-km fragment illuminates Io only 0.01-0.03% more than the sun between the visible and near infrared. However, at wavelengths of 5 microns and longer, the 0.5 km fragment induced plume illuminates Io some 1-3% more than the sun. Clearly, the most favorable spectral band indirect detection of impact-induced plumes in the near or middle infrared.

For SL-9 fragments with diameters <1 km, impact-induced plume brightnesses are expected to be decreased by plume and atmospheric opacity effects [9]. In these cases, the wavelength of peak spectral power is likely to be diagnostic of fragment size. Our present study indicated the wavelength of maximum plume intensity, λ_m , and fragment diameter, d , are related by the Wein's law type relation: $\lambda_m d^3 \approx 5 \times 10^{11} \text{ cm}^4$.

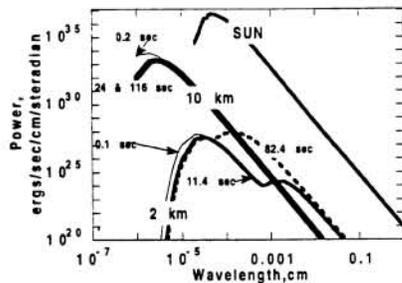


Fig. 1 Calculated spectra from Shoemaker-Levy-9 impact-induced plumes for 2 and 10 km diameter fragments. The peak power from the 2 km fragments radiates at the approximately same power level as the total Jupiter disk. The total power from the sun, considered as a point source is shown, for comparison.

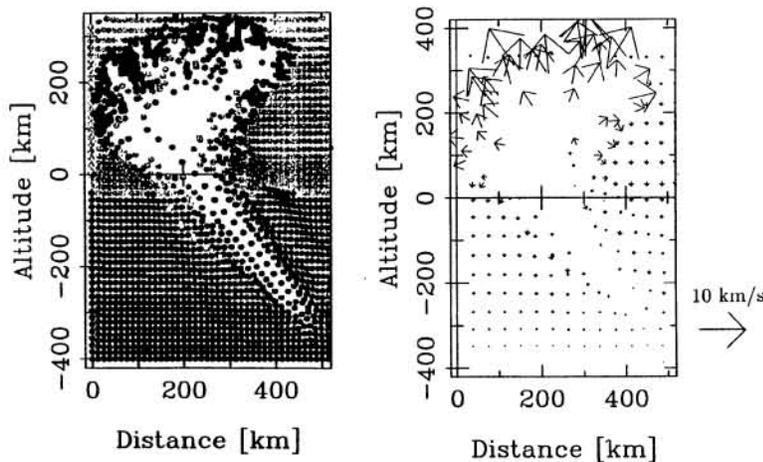


Fig. 2 (a) Impact plume (75 secs.) configuration for 2 km fragment impacting at 40° from zenith. (b) Particle velocity field for plume at same time.

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