Two-stage destruction of the meteoroid

(On the mechanism of crushing meteoroid with end flash effect)

L. Egorova
Institute of mechanics,
Lomonosov Moscow State University,
Moscow, Russia

La Palma Island, Canary, Spain,
IMC2012, September 23

What is two stage model of fragmentation

- We assume two stage fragmentation for meteoroid.
- We consider that at first stage of fragmentation meteoroid divided to several rather big pieces.
- The second stage of fragmentation realized by sudden destruction of the body into the cloud of small particles and dust.

What can we find from the luminosity curve?

✓**Tool** - the physical theory of meteors

✓**Data** -visual data (light curve)

✓**The goal for the first stage**- to calculate the number of fragments

✓**The goal for the second stage**- to fit the time and the maximum value of lightening

Physical theory of meteors

$$\begin{cases} m\dfrac{dV}{dt} = \dfrac{1}{2}c_x \rho_g V^2 S \\ i^* \dfrac{dm}{dt} = \dfrac{1}{2}c_H \rho_g V^3 S \end{cases}$$

Meteoroid luminosity

$$I = -\tau \frac{V^2}{2}\frac{dm}{dt}$$

Time and pass length for each particle of the fragmented body

The particle is lightning while its velocity $>V_*$

$$L = \int_0^{t_*} V dt = \frac{r_0}{A} \ln\left(1 + \frac{V_0 - V_*}{V_*}\right), \quad A = \frac{3}{8} c_x \frac{\rho_g}{\rho_b}$$

$$t_* = \frac{8(V_0 - V_*)\rho_b}{3 c_x \rho_g V_0 V_*} R$$

First stage of fragmentation
(to several equal parts)

$$\frac{I_{fr}}{I_0} = \sqrt[3]{N} \qquad N = \left(\frac{I_{fr}}{I_0}\right)^3$$

$$\sigma_* = 0.365\rho_g V^2 = 0.365\rho_0 V^2 \exp\left(-\frac{H_*}{h}\right)$$

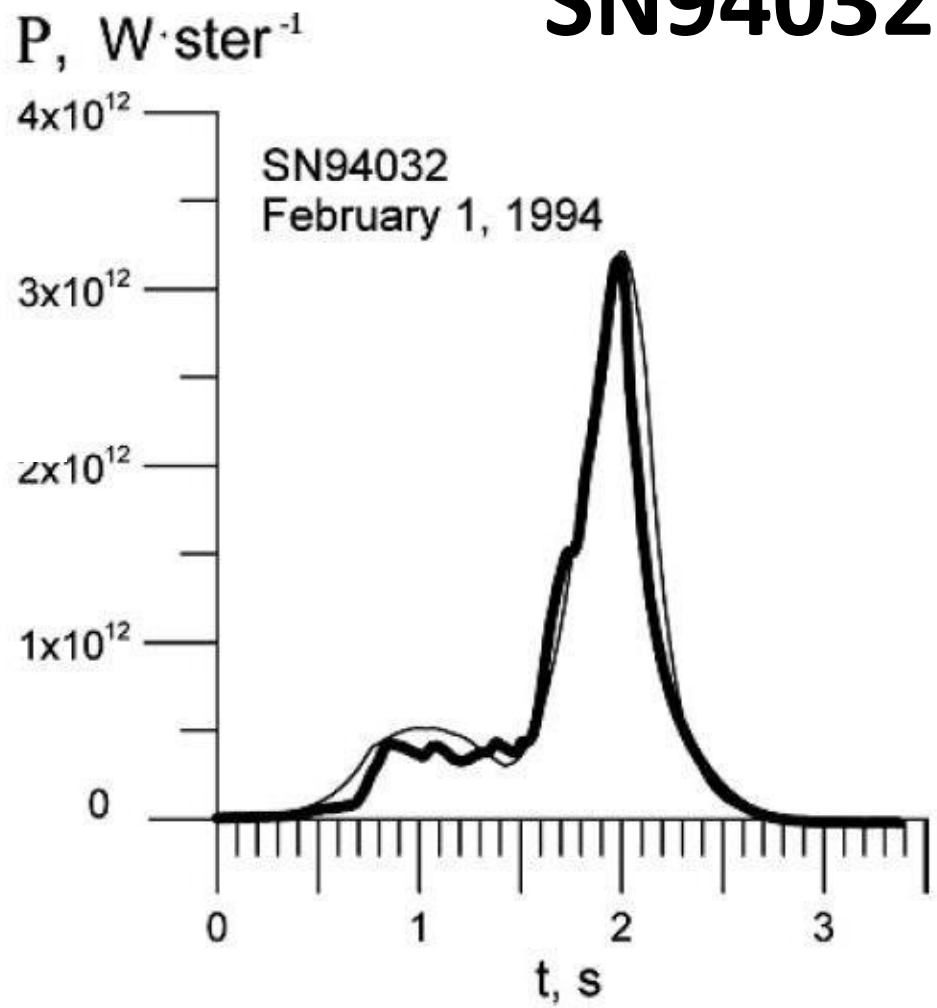
$$N^\alpha = \frac{\sigma_{**}}{\sigma_*} = \exp\left(\frac{\Delta H}{h}\right) \qquad \alpha = \frac{V\Delta t}{h \ln N}$$

Time and light intensity at the second (final) stage of fragmentation

$$I_{\Sigma}(t) = \int_{m_*}^{1} N_{m_0} \frac{d}{dm_0}\left(-\tau \frac{V^2}{2}\frac{dm}{dt}\right) dm_0$$

$$\Delta t = \frac{\left(\frac{3m_*}{4\pi\rho_b}\right)^{1/3} \bar{t}}{\frac{3c_x\rho_g}{8\rho_b} V_0}$$

SN94032 (data)

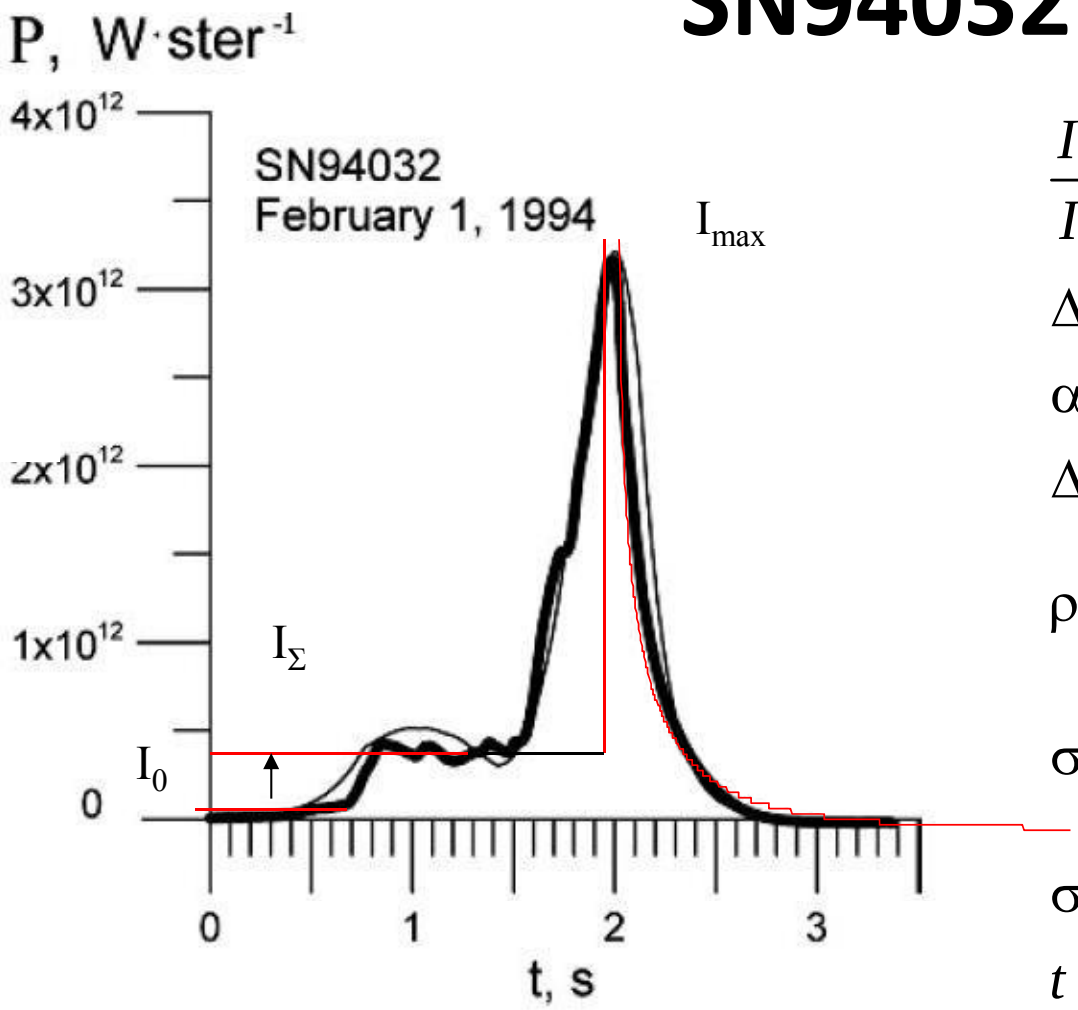


Light curve of one of the largest SN bolides—Marshall Island bolide (1 February 1994; SN94032) *from Nemtchinov et al. (1997)*

.

$M=4\cdot10^5$ kg
R=3.15 m
V=24 km/sec
H_1=34 km
H_2=21 km

SN94032



$$\frac{I_\Sigma}{I_0} \cong 20, \quad N \cong 8000$$

$$\Delta t = 0.7\,\text{sec}$$

$$\alpha = 0.278$$

$$\Delta H = 16.8\,km \quad \Delta H_{obs} = 13\,km$$

$$\rho_b = 3.055\,\frac{g}{m^3}$$

$$\sigma_* = 16.95 \cdot 10^5\,\frac{kg}{m \cdot \text{sec}^2} = 16.7 atm$$

$$\sigma_{**} = N^\alpha \sigma_* = 204.9 atm$$

$$t = 1.22\,\text{sec}$$

Conclusions

- The two stage fragmentation was considered and was verified by simple estimations.
- Number of fragments in the first stage of fragmentation was estimated by the change of light intensity.
- Using the statistical theory of the Weibull strength for fragmented particles was determined the path length and time before the second stage of fracture for particles.
- A model of sudden destruction used for the second stage. We estimated the time and maximum of luminosity.
- Estimations fitted the observations.

Thank you for attention

and to FASI
(state contract
02.740.11.00615)
for making possible
to take part in IMC2012