Two-stage destruction of the meteoroid

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

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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

\[
\begin{align*}
    m \frac{dV}{dt} &= \frac{1}{2} c_x \rho_g V^2 S \\
    i^* \frac{dm}{dt} &= \frac{1}{2} c_H \rho_g V^3 S
\end{align*}
\]

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 $> V_*$

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

$$t_* = \frac{8(V_0 - V_*) \rho_b}{3c_x \rho_g V_0 V_*} R$$
First stage of fragmentation
(to several equal parts)

\[
\frac{I^{fr}}{I_0} = \sqrt[3]{N} \quad N = \left(\frac{I^{fr}}{I_0}\right)^3
\]

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

\[
N^\alpha = \frac{\sigma^{**}}{\sigma_*} = \exp\left(\frac{\Delta H}{h}\right) \quad \alpha = \frac{V \Delta t}{h \ln N}
\]
Time and light intensity at the second (final) stage of fragmentation

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

\[ \Delta t = \frac{\left( \frac{3m_*}{4\pi\rho_b} \right)^{1/3}}{\frac{3c_s\rho_g}{8\rho_b V_0}} \bar{t} \]
SN94032 (data)

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

\[ M = 4 \cdot 10^5 \text{ kg} \]
\[ R = 3.15 \text{ m} \]
\[ V = 24 \text{ km/sec} \]
\[ H_1 = 34 \text{ km} \]
\[ H_2 = 21 \text{ km} \]
SN94032

\[ \frac{I_\Sigma}{I_0} \approx 20, \quad N \approx 8000 \]

\[ \Delta t = 0.7 \text{ sec} \]

\[ \alpha = 0.278 \]

\[ \Delta H = 16.8 \text{ km} \quad \Delta H_{obs} = 13 \text{ km} \]

\[ \rho_b = 3.055 \frac{g}{m^3} \]

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

\[ \sigma_{**} = N^\alpha \sigma_* = 204.9 \text{ atm} \]

\[ t = 1.22 \text{ sec} \]

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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

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