The Impact Effects Knowledge-Base:
Fast Prediction of the Consequences of NEO Collisions with Earth

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Prediction of Impact Effects

- small NEOs are difficult to discover
- emergency case: agencies require short prediction times for impact effects
- sophisticated numerical simulations of impacts and airbursts are time consuming

→ aim: Knowledge-Base for fast predictions
Aim:
› combine advantages
› accurate and fast predictions
› use both parametrisations and tabulated shock physics code results

Output:

Knowledge-Base

\[ v, \alpha, D, \text{type} \]

Input parameter evaluation (thresholds)

Parameterisation
› less accurate
› continuous range
› fast

Shock physics codes
› accurate
› discretised
› slow

Impact Effects
Knowledge-Base: Impact Effects

- shockwave in air causes overpressure $p$ and wind speed $u$ on the ground
- heated air and meteoroid vapour cause radiation $E_{rad}$
- sufficient large projectiles cause crater fields or single craters
Knowledge-Base: Approach

- multidimensional input space

\[ \vec{v}(v, \alpha) \approx 40 \text{ km/s} \]

\[ \approx 11 \text{ km/s} \]

\[ \approx 10 \text{ m} \]

\[ L \approx 200 \text{ m} \]
Knowledge-Base: Material Types

- material difficult to constrain by observation (magnitude, Albedo,...)
- distinguish between typical types of meteorites:
  - 2 types with iron composition (high/low strength)
  - 3 types with rocky composition (Chondritic, Carbonaceous, Chondritic, Basaltic)
Knowledge-Base: Approach

- multidimensional input space
- predict effects

\[ \vec{\nu}(v, \alpha) \]

\[ \sim 40 \text{km/s} \]

\[ \sim 11 \text{km/s} \]

\[ \sim 10 \text{m} \]

\[ \sim 200 \text{m} \]

\[ p, u, E, (x, y) \]
Parameterisations

- when accuracy is sufficient
- avoids interpolation
- fast

\[ \vec{v}(v, \alpha) \]

\[ \sim 11 \text{km/s} \]

\[ \sim 10 \text{m} \]

\[ L \sim 200 \text{m} \]

\[ p, u, E_r(x, y) \]
Atmospheric entry

› pancake model (Chyba et al. 1993) for rocky composition
Atmospheric entry

› pancake model (Chyba et al. 1993) for rocky composition

› separate fragment model (Artemieva and Shuvalov 1996, Bronikowska et al. 2017) for iron composition
Atmospheric entry

- determine energy release in atmosphere

**Type III (rock):**
- $\rho = 3400$
- $\Phi = 10\%$
- strong material

Inferred energy release curve, Chelyabinsk Popova et al. (2013)
determine effects for given energy release from fits to nuclear data (Collins et al. 2005 & 2017)

Overpressure & Wind Speed

- $r_{\text{max}}=4$, $C_D=0.5$
- Case I (point source)
- Case II (line source)

Popova et al. (2013) SOVA
Overpressure & Wind Speed

› PDC exercise:
  › $v \sim 19 \text{ km/s}$
  › $L \sim 100 \text{ m}$
  › $\alpha \sim 45^\circ$
  (USA, west)
  › assuming
    chondritic rock

› upon impact:
  › $v \sim 9 \text{ km/s}$, 1/3 of initial mass
Radiated energy determined from released energy by luminous efficiency (e.g. Nemtchinov et al. 1997)
Radiation & Cratering

- radiated energy determined from released energy by luminous efficiency (e.g. Nemtchinov et al. 1997)
- crater diameter according to scaling laws (e.g. Holsapple & Housen 2007) with parameters for different target material (e.g. Prieur et al. 2017)

Chelyabinsk, this study

Kamil crater: Tagesspiegel.de, 23.07.2010
Shock Physics Code

- SOVA
- chosen when parameterisations are not accurate enough
- results stored in database

Artemieva & Shuvalov 2019
100 m object, 30°
Shock Physics Code

› SOVA
› chosen when parameterisations are not accurate enough
› results stored in database
› require for interpolation between results in multidimensional input space
Conclusion

- fast predictions are derived by parameterisations:
  - atmospheric entry, overpressures on the ground,
    wind speeds, radiation, cratering
- Shock physics code results cover the range of the input space where parameterisations are not accurate enough
- accuracy needs to be tested against observed meteors
Thank you for your attention.