FRAGMENTATION AND COMPRESSION DURING AGGREGATES GROWTH

Dominik Paszun
Carsten Dominik
University of Amsterdam
Objectives

- Provide collisional compression recipe
- Provide collisional fragmentation recipe
- Apply the recipes to a global disk model
Introduction

- N-body code
- Surface forces (Johnson et al. 1972)
- No external forces (gravity, electrostatic, magnetic)
Results

0.5 m/s

1 m/s

4 m/s
Results

1.5 m/s

offset

25 m/s

big aggregate
Results

Central collision

Offset collision

Grazing collision
Results

- Fragmentation
  \[ \rightarrow \]

- Grazing & missed collisions
  \[ \rightarrow \]

- Growth
  \[ \rightarrow \]

\[ V = 0.75 \text{ m/s} \]

Graph showing the relationship between mass and the parameter \( f(m)m^2 \) as a function of \( M/m_0 \).
Results

V = 0.5 m/s

Fragmentation

Grazing & missed collisions

Growth

\[
f(m) = \frac{m^2}{M_0^2}
\]
Results

V = 0.75 m/s

Grazing & missed collisions

Growth

Fragmentation

\[ f(m) \text{m}^2 \]

\[ \frac{M}{m_0} \]

September 20th 2007

5th Planet Formation Workshop
Results

Grazing & missed collisions

Growth

Fragmentation

V = 1.00 m/s

\[ f(m)m^2 \]

\[ \frac{M}{m_0} \]

September 20th 2007
5th Planet Formation Workshop
Results

- Fragmentation
- Grazing & missed collisions
- Growth

V = 2.00 m/s

Graph showing the relationship between $f(m) m^2$ and $M/m_0$, with markers indicating fragmentation and growth processes.
Results

V = 4.00 m/s

Grazing & missed collisions

Growth

Fragmentation

M/m_0

f(m)m^2
Results

Fragmentation

\[
\begin{align*}
\rightarrow & \\
\rightarrow & \\
& \rightarrow
\end{align*}
\]

Grazing & missed collisions

\[
\begin{align*}
\rightarrow & \\
& \rightarrow
\end{align*}
\]

Growth

\[
\begin{align*}
& \rightarrow \\
\rightarrow & \\
& \rightarrow
\end{align*}
\]

\[V = 6.00 \text{ m/s}\]

\[
\begin{align*}
f(m)^2 & \\
& M/m_0
\end{align*}
\]
Results

Fragmentation

Grazing & missed collisions

Growth

V = 8.00 m/s

\[ f(m) \cdot m^2 \]

\[ M/m_0 \]

September 20th 2007
5th Planet Formation Workshop
Scaling - fragmentation

Graph showing the relationship between $E_{\text{coll}}/(E_{\text{roll}}N_{\text{tot}})$ and the slope of fragmentation for different values of $D_f$. The graph compares $D_f = 2.0$ (red triangles) and $D_f = 2.5$ (blue squares).
Scaling - growth

\[ \frac{\langle m_{\text{growth}} \rangle}{N_{\text{tot}}} \]

\[ E_{\text{coll}} / (E_{\text{roll}} N_{\text{tot}}) \]

- Df=2.0
- Df=2.5
Results

compaction / decomposition

Slow collisions

Intermediate collisions

Faster collisions
Results

Compactness

\[ M/m_0 \]

FLUFFY
COMPACT

September 20th 2007
5th Planet Formation Workshop
Results

Compactness vs. $M/m_0$ for $V=0.1 \text{ m/s}$

- **Grazing**
- **Central**

- Compactness
- $M/m_0$
Results

Compactness vs. $M/m_0$ for $V=0.2 \text{ m/s}$

- **Grazing**
- **Central**
Results

$V=0.5 \text{ m/s}$

![Graph showing compactness vs. mass ratio]
Results

Compactness

\[ V = 0.75 \text{ m/s} \]

- \( \text{Grazing} \)
- \( \text{Central} \)

\[ \text{M/m} \]

\[ V = 0.75 \text{ m/s} \]
Results

V = 1.0 m/s

Compactness vs. M/m₀

Grazing

Central
Results

$V = 2.0 \text{ m/s}$

Compactness vs. $M/m_0$

- Grazing
- Central
Results

V = 4.0 m/s

Compactness vs. M/m₀

- **Grazing**
- **Central**
Results

Compactness vs. $M/m_0$ for $V=8.0 \text{ m/s}$

- **Grazing**
- **Central**

September 20th 2007

5th Planet Formation Workshop
Summary

- Compaction helps to dissipate energy
- Average fragment distribution consists of two components:
  - head-on collision output (fragmentation)
  - grazing and offset collision output (growth)
- **Simple collision recipe ready for small aggregates!**

- We still need to tune the recipe to include large mm-sized aggregates
- Implement the recipe to a global disk models