

Fragmentation: from theory to numerical applications using FEM approaches

G. Anciaux

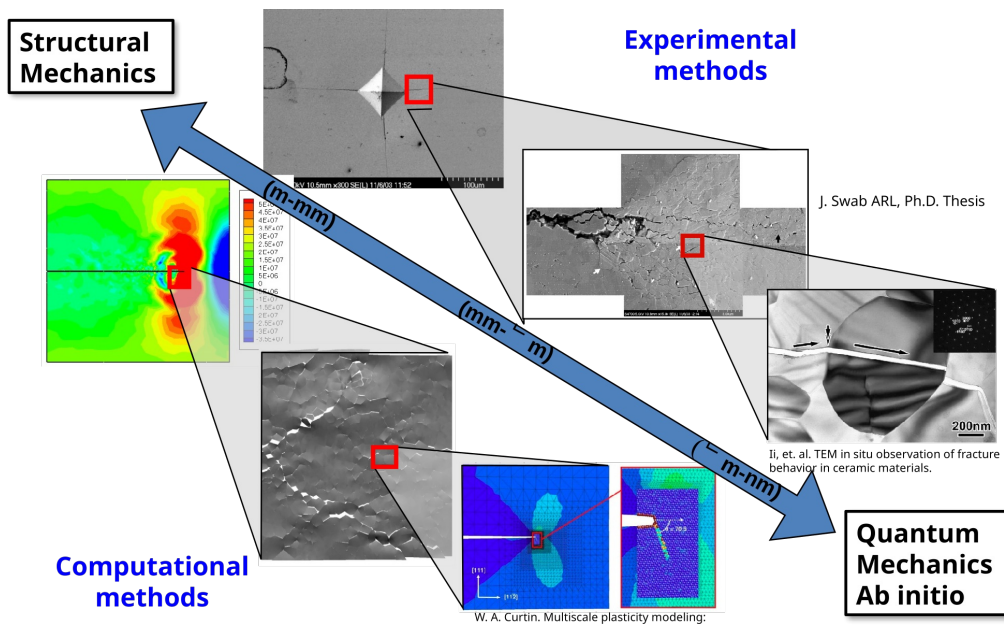
Civil Engineering, Materials Science, EPFL



What is fragmentation ?

Essentially, this is fracture ...
... with dynamical effects

Fracture: Multi-scale and Multi-Physics models



Dynamic fragmentation

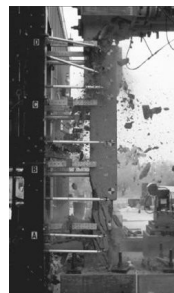
- Many cracks
- They propagate (at high speeds!)
- They coalesce
- Lots of mechanical waves

Complexity

analytical work intractable

Not well understood...

Costly...



UCSD simulates car bomb

blast of 1,100 pounds of TNT at
curbside

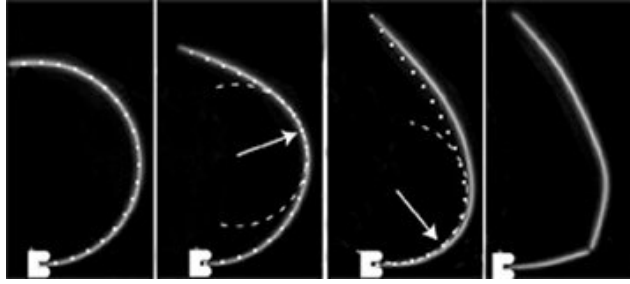
<https://jacobsschool.ucsd.edu/news/release/377>

Many applications

- Mining industry, road excavation, fuel fragmentation (1930's)
- 1940's: seminal contribution of Mott (bomb shells)
- Applications in
 - engineering (crash performance, impact)
 - medicine (kidney stone fragmentation)
 - Astrophysics (asteroid impact, big bang)
 - low-orbit launch debris

Fundamental physics problems

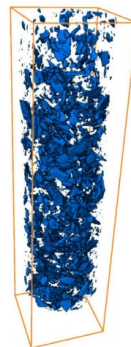
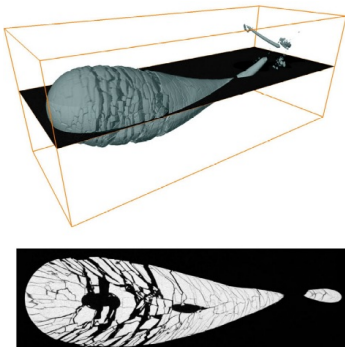
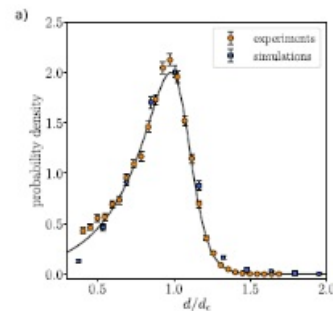
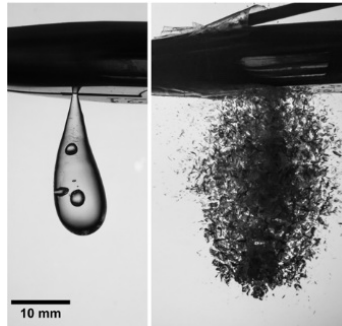
Why do pasta break in more than two pieces when bent?



B. Audoly, S. Neukirch. *Fragmentation of Rods by Cascading Cracks: Why Spaghetti Does Not Break in Half.* Physical Review Letters. 95(9),095505. (2005)

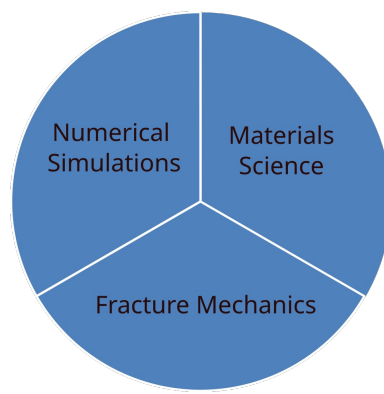
Challenging problems

Prince Ruperts' drops



S. Kooij, G. van Dalen, J.-F. Molinari, D. Bonn. *Explosive Fragmentation of Prince Rupert's Drops Leads to Well-Defined Fragment Sizes.* Nature Communications. 12(1),2521. (2021)

Multi-disciplinary efforts



Open science ?

LSMS ?

Open-source software @ lsms.epfl.ch

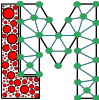
- Head: J.F. Molinari
- Team: <https://www.epfl.ch/labs/lsms/members/>

Numerical methods and open-source software (production of LSMS)

- Akantu 

- Cracklet 

- Tamaas 

- LibMultiscale 

Akantu – Swiss-Made Open-Source Finite-Element Library

General considerations on FE software

- Huge business: ex. Dassault Systèmes (3,5 billions €)
- Commercial software : Abaqus, Ansys, Comsol, ...
 - (+) Stable, robust, certified : great for industry
 - (-) Cost, “black box”, slow evolution
- Academic software : agile but confidential, tailored for specific pbs

Our philosophy:

- Knowledge creation and transmission for the greater good (tax payer money)
- Open-Source Software development

Akantu today

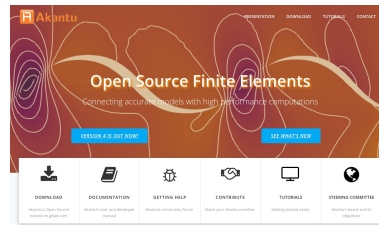
Some features of Akantu:

- statics
- dynamics
- contact detection
- extrinsic cohesive elements
- non-local continuum damage
- phase-field fracture
- *High Performace Computing* (HPC)

History

- 12 years of development
- C++ code with a python interface
- High performance parallel computing
- Hosted on GitLab (continuous integration and delivery with GitLab tools)
- Full documentation online

- Issues Review and Merge Requests
- Online tutorials on notebooks



<https://akantu.ch>



JTCAM specific features

- **Overlay Journal**
 - Always a preprint shared on Open Archives (even for refused papers)
 - Diamond Open Access
- **Team**
 - Technical board: creators of the journal + data/software editor
 - Scientific Board: invited
 - Editorial board: elected
 - Collegial decisions, no editor in chief
- **Open Review**
 - Valued Open Reviews and reviewers' work
- **Copy-editing**
 - Very high quality
 - Links to open data sets and software → Reproducible research!
 - Script to check the correctness of bibliographic entries

JTCAM
First Overlay Journal in Mechanics — <https://jtcam.episciences.org>
5 / 6

- Solid Mechanics
- Not well aware of Open Access good practices
- Wide spectrum: theoretical, applied, numerical, experimental
- Classical journals and publishers
 - IJP, JMPS, IJSS, CMAME, IJMM, TI, IJES, Wear, ActaMat (Elsevier)
 - IJNME, Adv Mat (Wiley)
 - Comp Mech, Meccanica (Springer)
 - PRS (Cambridge)
 - Mechanics of Adv Mat and Struct (Taylor & Francis)
- Alternate journals (Diamond Open Access)
 - CRAS (Mersenne)
 - Archives of Mechanics (since 1950)
 - Technische Mechanik
 - Mathematics and Mechanics of Complex Systems (half-diamond)
 - JACM
 - ACM

Open-science

Benefits:

- Reproducibility in science
- Transparency
- Efficiency
- Transfer of knowledge
- Sustainability
- Visibility
- Less cost (for society)
- Better Quality

Class Objectives

Open science

- Akantu
- Overlay journals (JTCAM)

Fundamentals

- Wave dynamics
- Fracture mechanics (mostly LEFM)
- Fragmentation theories

Numerical modeling with Finite Elements

- Dynamics
- Fracture
 - cohesive-element method
 - phase field models
- Dynamic fragmentation

Class content

<https://go.epfl.ch/anciaux-gdr-mecawave>

