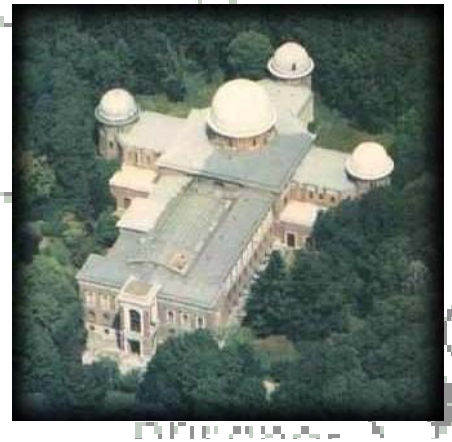
PLATO 2.0 Science Workshop

ESA-ESTEC, Noordwijk, on 29-31 July

What do we know about collisions in planetary systems?



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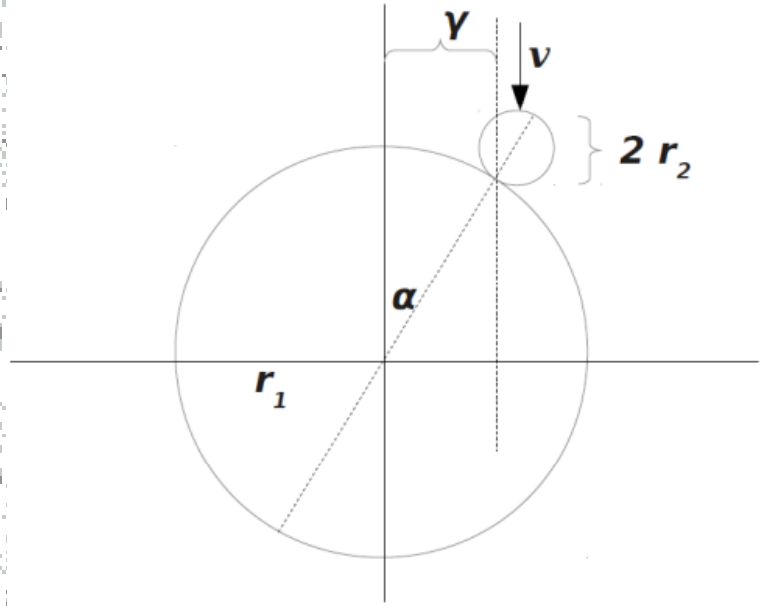
The different models of the 'planetesimals' for the mass range from a small asteroid to a body of ten times the Moon for the determination of collisions

name	mass $[M_{Sun}]$	Mass[kg]	radius [AU]	comments
Ce10	5×10^{-11}	2×10^{20}	$\sim 2.5 \times 10^{-6}$	$\sim M_{Ceres}/10$
Ce	5×10^{-10}	2×10^{21}	$\sim 5.5 \times 10^{-6}$	$\sim M_{Ceres}$
M10	3×10^{-9}	1.2×10^{22}	$\sim 1 \times 10^{-5}$	$\sim M_{Moon}/10$
M3	1×10^{-8}	4×10^{22}	$\sim 1.4 \times 10^{-5}$	$\sim M_{Moon}/3$
M	3×10^{-8}	1.2×10^{23}	$\sim 2.1 \times 10^{-5}$	$\sim M_{Moon}$
3M	1×10^{-7}	4×10^{23}	$\sim 3.3 \times 10^{-5}$	$\sim 3 \times M_{Moon}$
10M	3×10^{-7}	1.2×10^{24}	$\sim 1 \times 10^{-5}$	$\sim 10 \times M_{Moon}$

Collisions in the habitable zone (approx. 1 AU)



Extensive numerical integrations with Our Lie series code (automatic step-size) for several million years – 750 bodies in the seven models (Ceres/10 – 10 Moons)

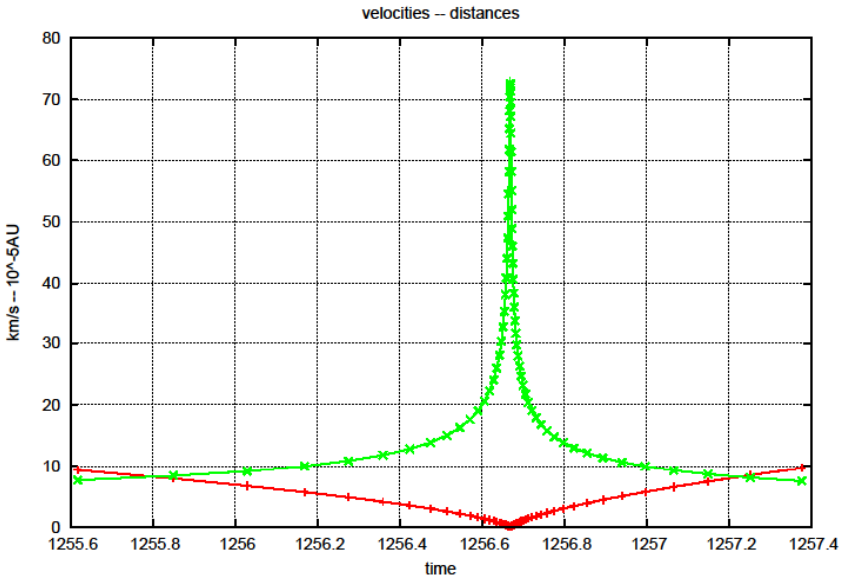
How many collisons occured?

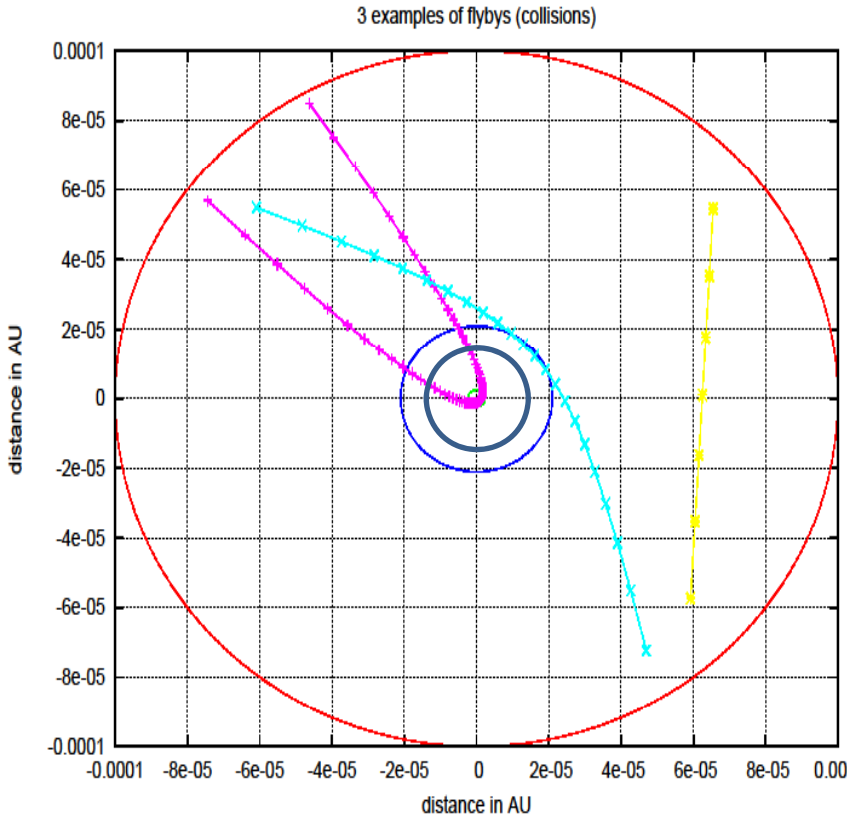
With what velocities?

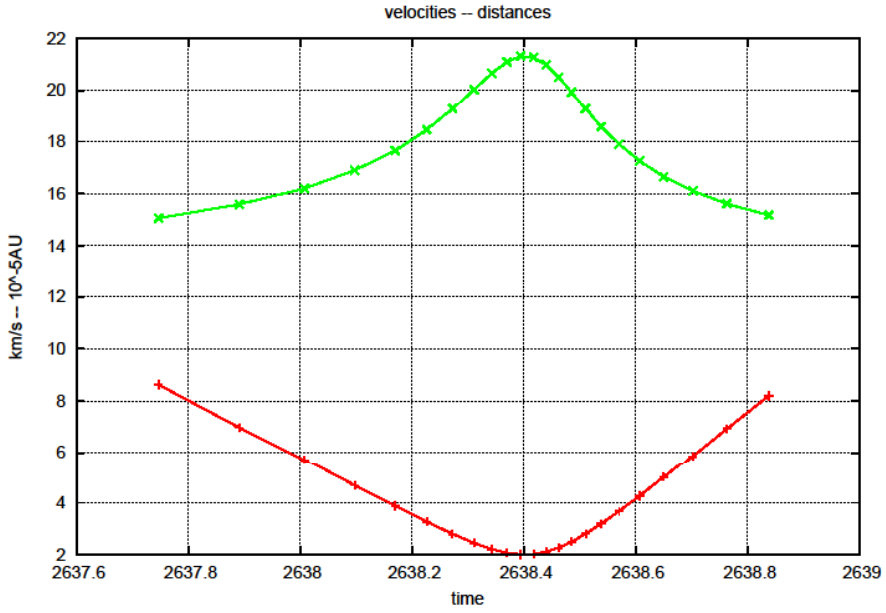
With what impact angle?

The growth of the planetesimals to protoplanets and finally planets is closely connected to the collision of the bodies in the early evolution of the planetary system (Leinhardt & Stewart, ApJ 745 (2012).

Such collisions with relatively low velocities may lead to the enrichment of water in the bodies, depending on the origin of the colliding bodies.

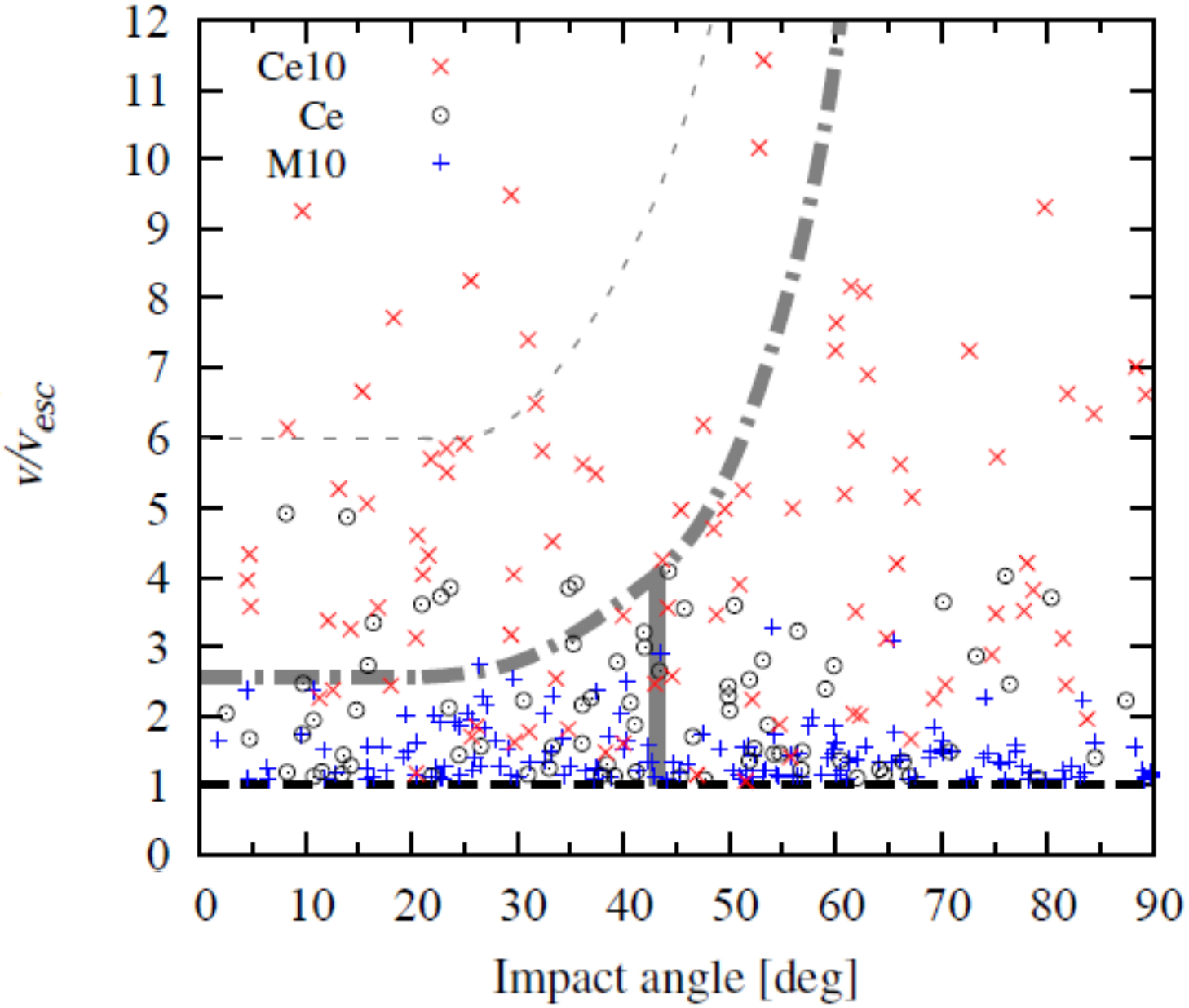

velocities -- distances
km/s -- 10^-5AU
time
80
70
60
50
40
30
20
10
0
1255.6
1255.8
1256
1256.2
1256.4
1256.6
1256.8
1257
1257.2
1257.4

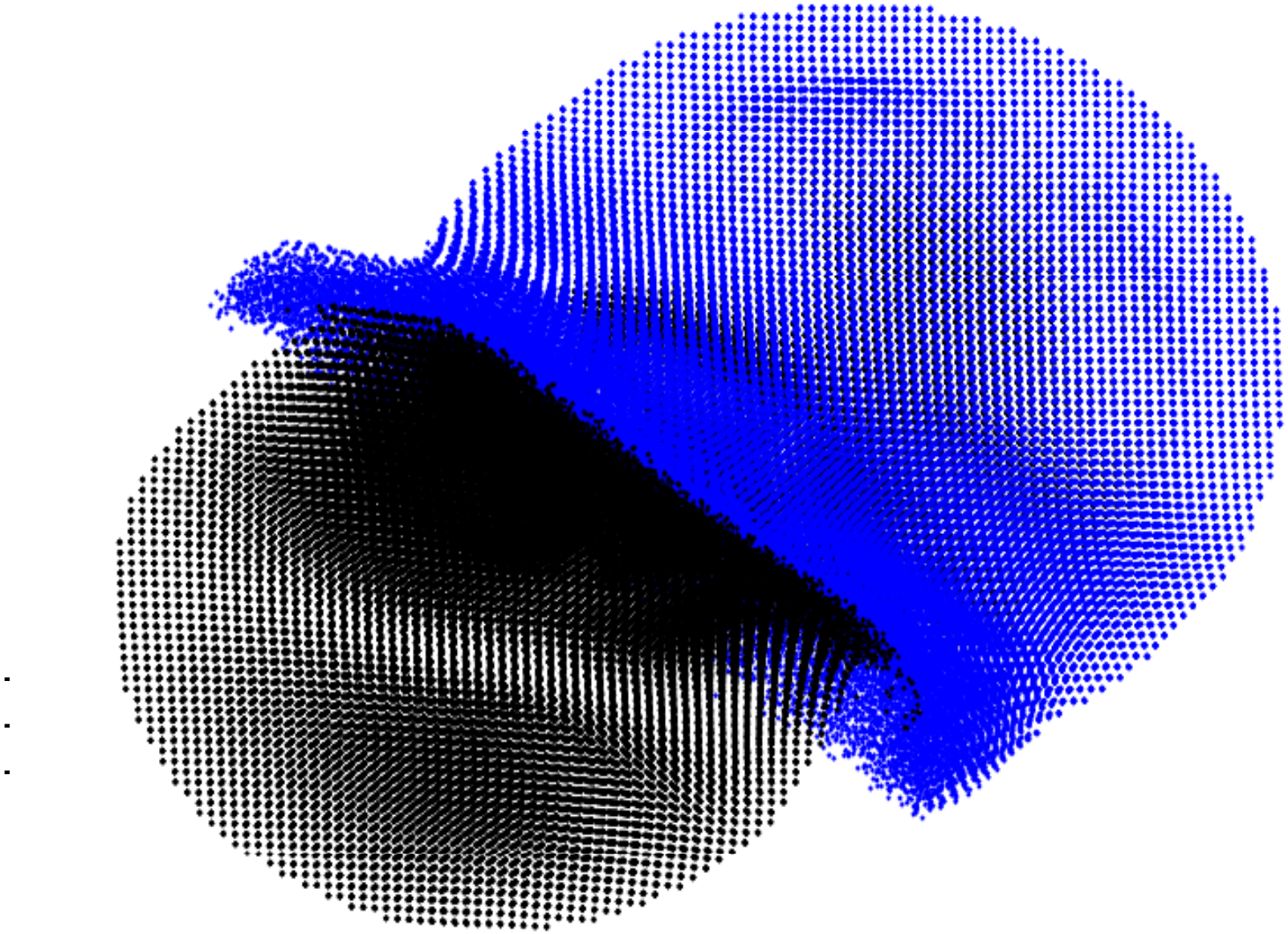

3 examples of flybys (collisions)
distance in AU
distance in AU
0.0001
8e-05
6e-05
4e-05
2e-05
0
-2e-05
-4e-05
-6e-05
-8e-05
-0.0001
-0.0001
-8e-05
-6e-05
-4e-05
-2e-05
0
2e-05
4e-05
6e-05
8e-05
0.00


velocities -- distances
km/s -- 10^-5AU
time
22
20
18
16
14
12
10
8
6
4
2
2637.6
2637.8
2638
2638.2
2638.4
2638.6
2638.8
2639

Maindl, T.I.,Dvorak, R. IAU symposium 299 (2013)

Stewart, S.T., Leinhardt, Z.M.,(2012), ApJ 751
Leinhardt, Z.M. ,Stewart, S.T.,(2012), Apj 745





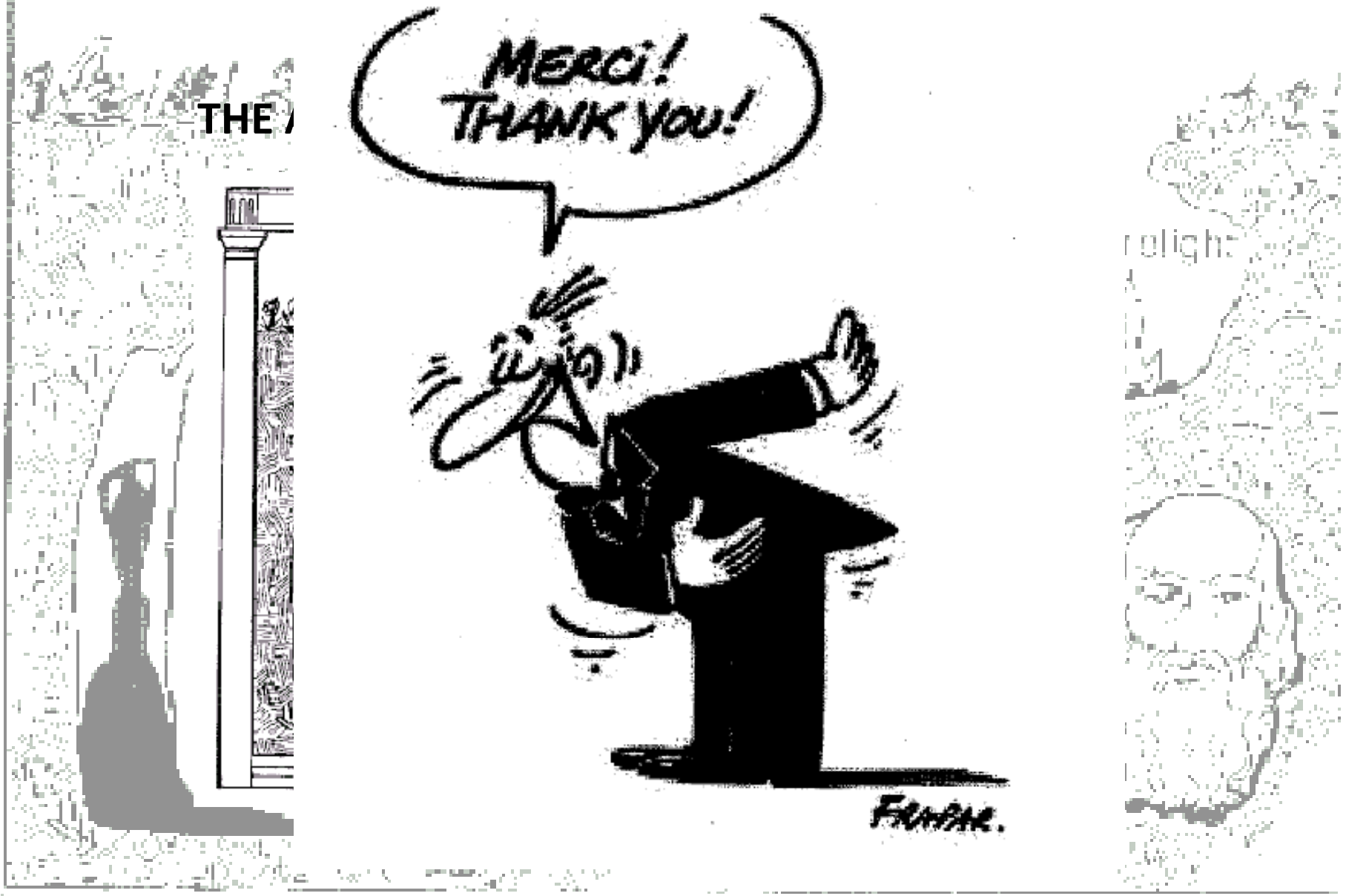
View of colliding planetesimals: Snapshot of a 300,000 particle SPH simulation of two basalt bodies of Ceres-mass 9 minutes after a 1 km/s impact at an angle of 30°. The right body is slightly bigger as it is covered with a 30 mass-percent ice shell.

Collision Simulations

- Objectives
  - Elasto-plastic solid state mechanics with brittle failure/fragmentation
  - Self-gravity
  - Track different materials (e.g., water/ice, basalt) and their distribution before, during, and after the impact
- Chosen method: smoothed particle hydrodynamics (SPH)
  - Lagrangian method
  - “Particles” of different material
  - Full elasto-plastic continuum mechanics including brittle failure
  - Tensorial correction (Speith 2007) for first-order consistency
  - New custom-developed code in cooperation with University of Tübingen

Summary and next steps

- N-body simulations results
  - Distribution of **velocities** and **impact parameters** in early planetary systems depending on
    - Planetesimal mass and impactor mass ratio
    - Perturbing bodies
- Ongoing/next steps: collision simulations
  - What happens to the bodies' water/ice content?
    - Different collision scenarios (hit and run, accretion, merging, erosion)
    - Different water distribution (shell, inclusions)
    - Can water be retained (internal energy-temperature)?


THE
MERCI!
THANK YOU!
FARFAR.