OF MATHEMATICS, ASTEROIDS, AND BRAZIL NUTS

An investigation of the paper The Spherical Brazil Nut Effect and Its Significance to Asteroids, by Viranga Perera, Alan Jackson, Erik Asphaug, Ronald-Louis Ballouz, *Icarus* November 2016

presented by Ken Koester

Rubble Piles in Space

- Many asteroids likely rubble piles, weakly cohesive
  - Low bulk densities observed
  - Limited spin rates suggest low cohesion
- Impacts that do not disrupt will shake the pile
- Cumulative effects may differentiate bodies by size
- Some observations show boulders protruding from surface

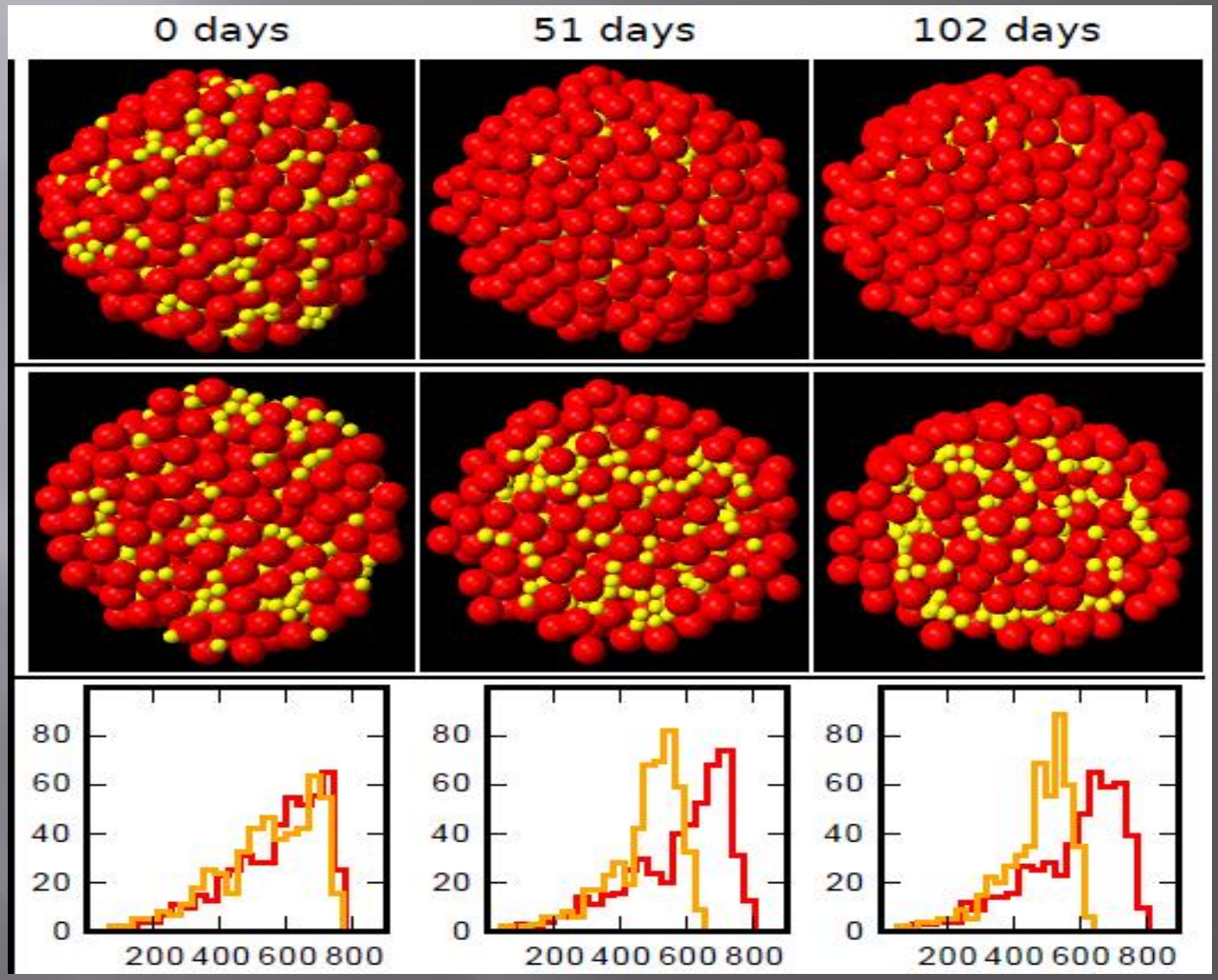
When All Else Fails, Simulate!

- 500 uniform spheres 80 m radius, 500 40 m radius, density 3 g/cm^3
- Settle into one aggregate mass ~800 m radius, 3.62X10^{12} kg, density 1.7 g/cm^3
- Each seismic event: each particle gets random velocity within run bounds
- Treat particle collisions as springs
- Let aggregate settle (~5 simulation hours)
- Repeat 515 times (102 simulation days)

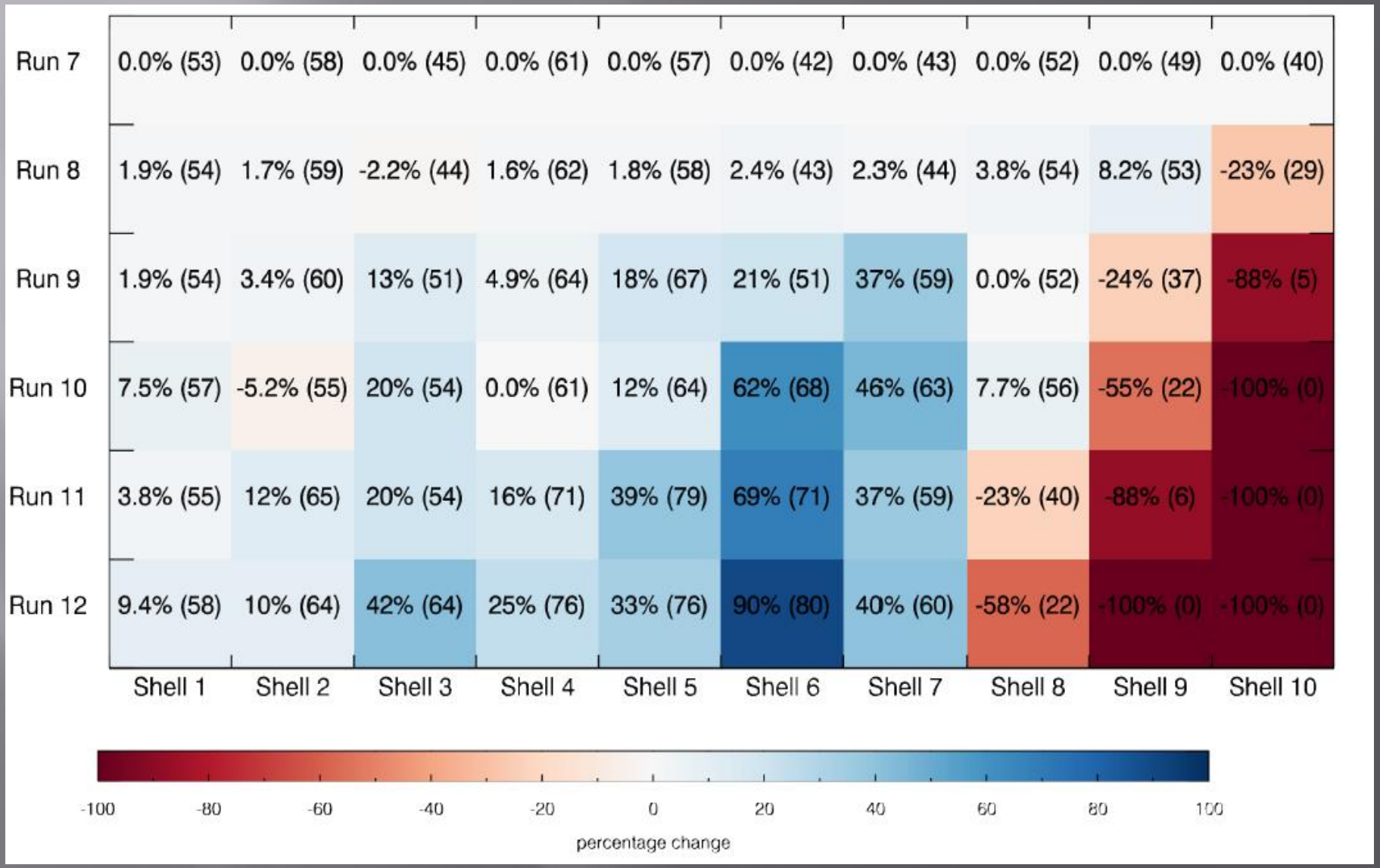
Results I (marbles)

Top

Cross-section



Results II (shell game)



Energize

- Max particle speeds for runs 8-12 (cm/s): 6.95,17.4, 20.9, 27.8, 34.7 (v_{esc} = 75 cm/s)
- Is there a reasonable impactor? Assume r = 40 m, inelastic collisions, no ejecta, then:

	Run 8	9	10	11	12
Avg v (cm/s)	3.47	8.66	10.4	13.9	17.3
Total E (J)	2.17E+09	1.36E+10	1.96E+10	3.48E+10	5.43E+10
Impactor v (m/s)	4.80	30.0	43.3	76.8	120.1

Home Brew

Run	Nut/MM	1st nut	1st layer	# on top at 150	# on bottom
1	18/100	20	70-80	6	1-2
2	18/100	20	70	8	1
3	18/100	10-20	60-70	6	1
4	16/100	5	40-50	8	1
5	8/100	50	80	6 (200)	1-2
6	6/100	5	40	4-5 (200)	1
7	5/100	30	100	4 (200)	1
8	4/100	40	120	3 (200)	1
9	22/44	4	30	8	5
10	22/100	12	110	9	6

Packing

- Can't do better than 0.74, single size; 0.8245, binary (de Laat, Filho, Vallentin, June 2012)
- Denser packs should be energetically favorable, but—

	800-600 m	600-400 m	400-200 m	200-0 m
Initial ratio l/s	250/225	185/190	70/75	10/13
Initial PF	0.5508	0.7032	0.7257	~0.74
Final ratio l/s	275/5	155/365	70/80	11/14
Final PF	0.4768	0.6758	0.7314	0.816

Packing It In

- Mechanism seems plausible:
  - sizes do get sorted
  - energy requirements feasible
- Simulation doesn't tell us if physics or math more important—but doesn't rule out physics
- "Experiments" suggest i.c. pretty influential