Down to Earth

Simulating asteroid and comet impacts with Earth, Moon and Mars

Paul Roche and Sophie Bartlett
(FT/Cardiff University)

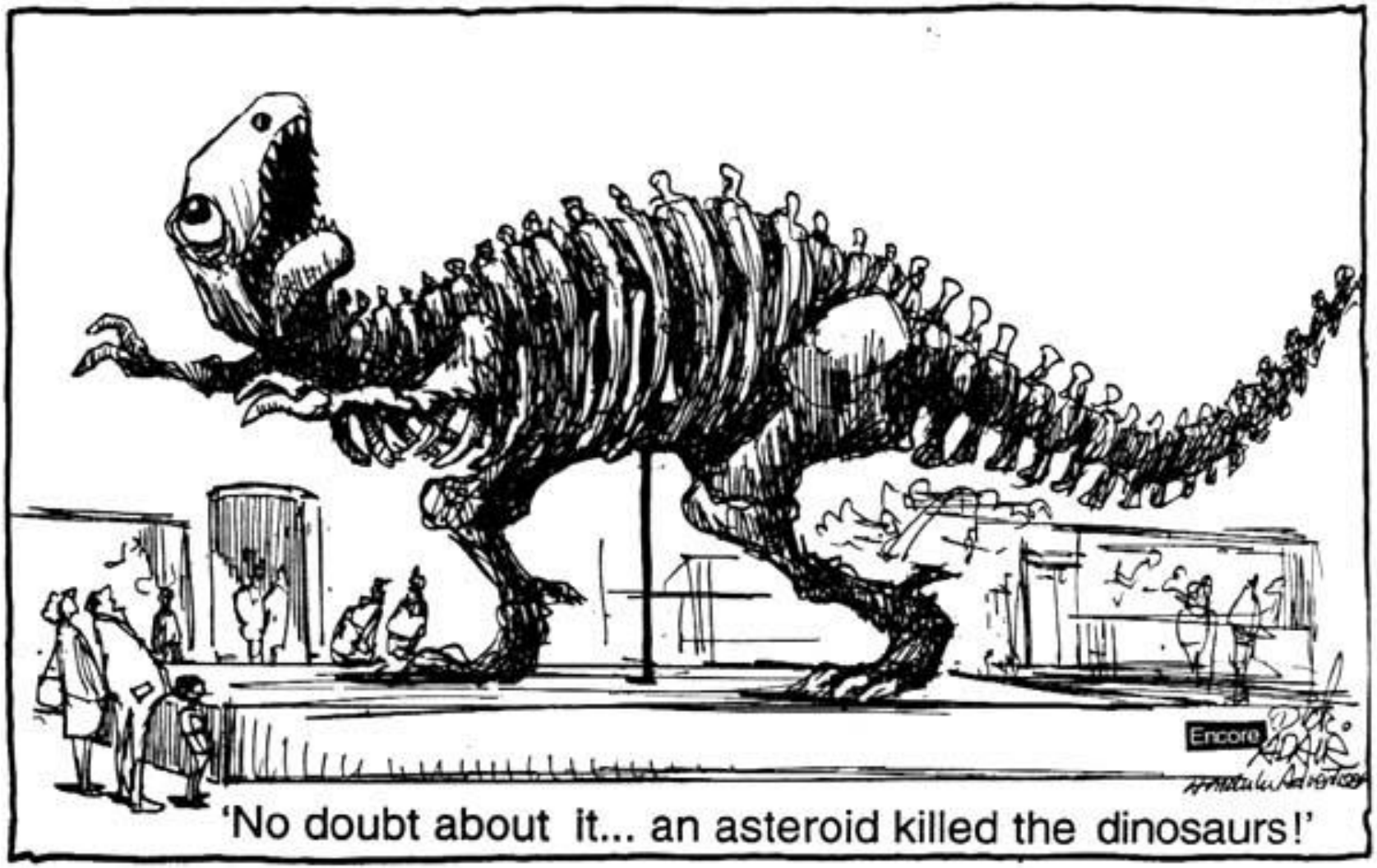
What is Down2Earth?

- An **inquiry-based science education (IBSE)** project based around asteroids, comets, meteorites and impacts
- **Multi-disciplinary** – physics, maths, chemistry, geology, biology etc.

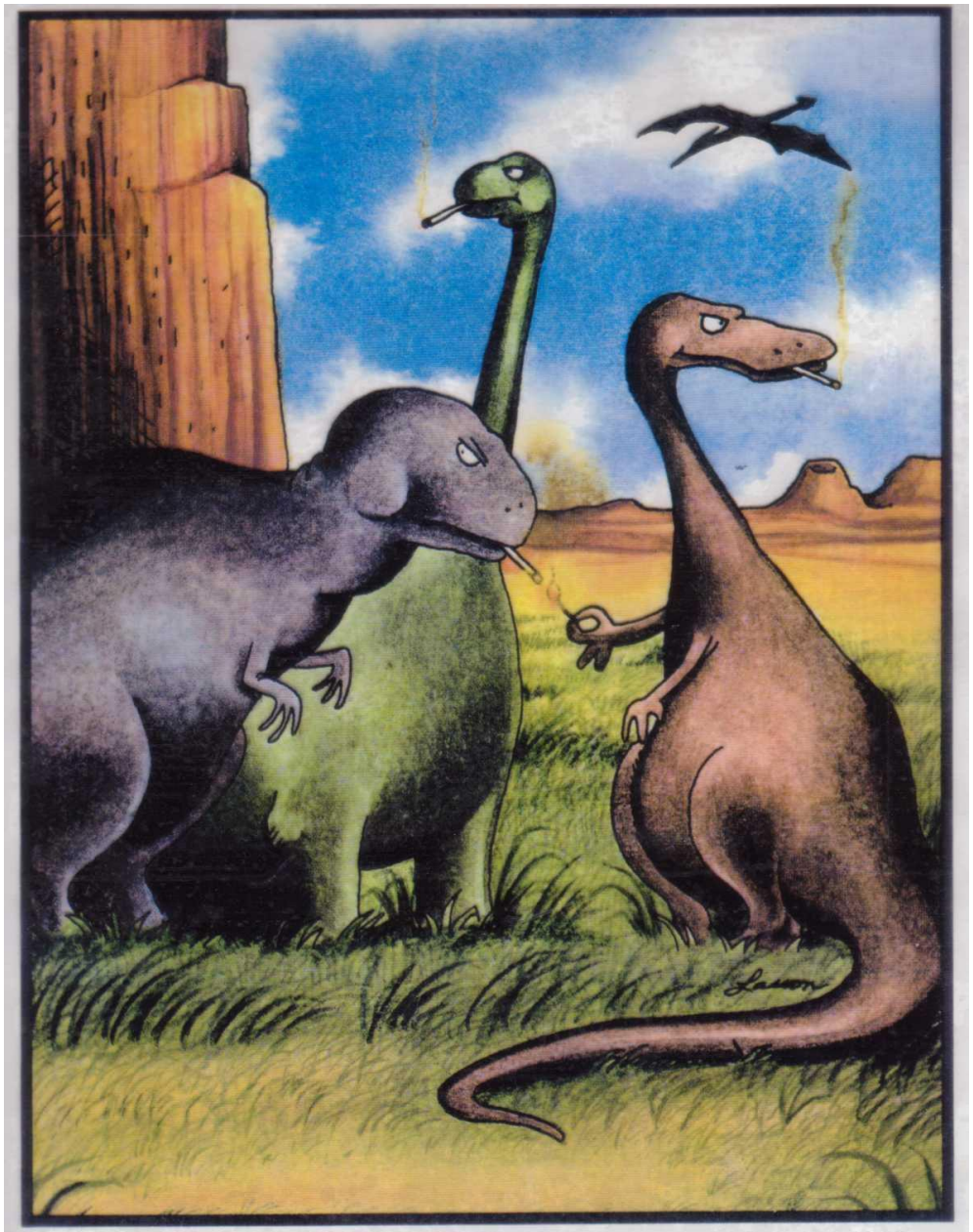
GO-LAB

Death, Destruction and Dinosaurs…

education.down2earth.eu

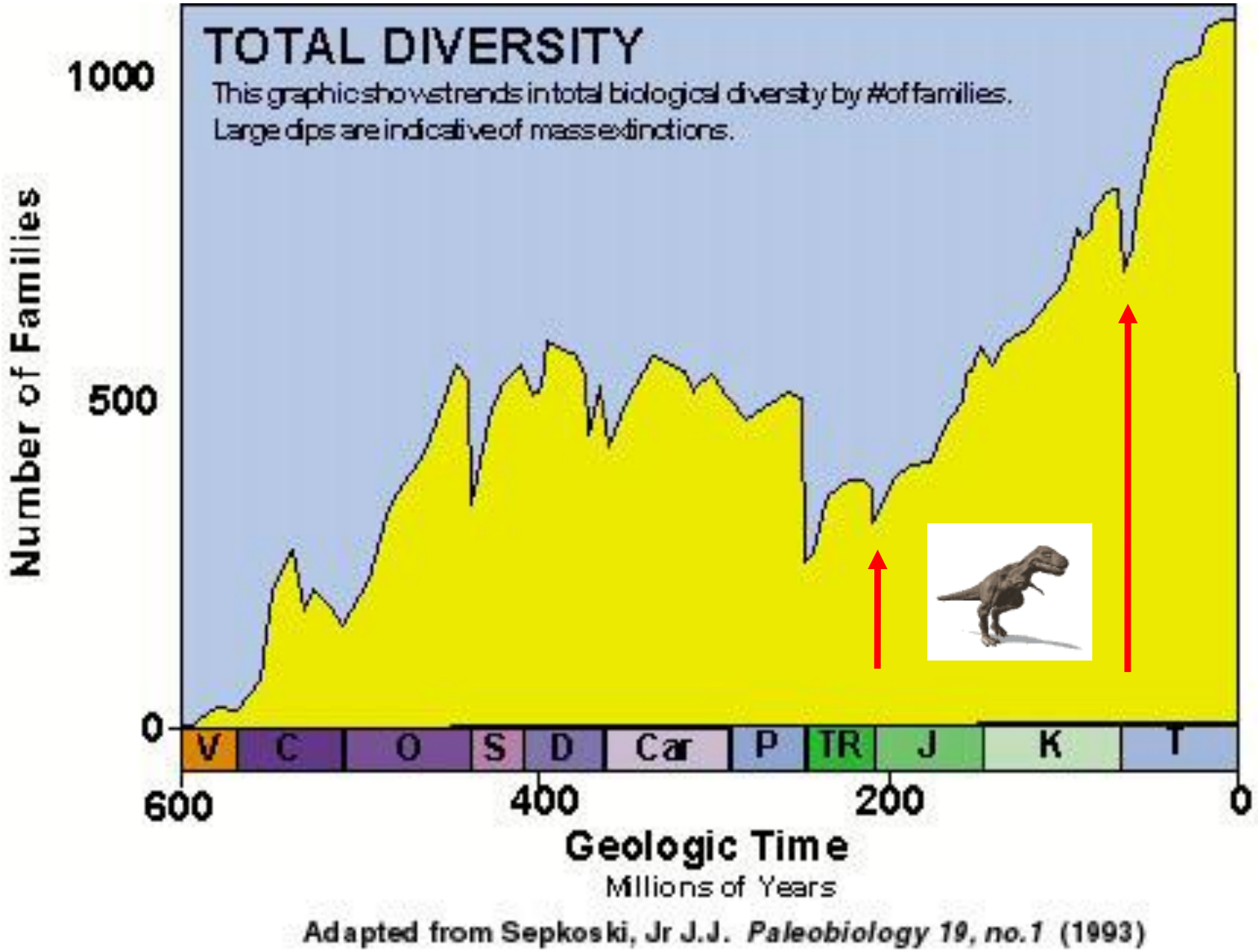


'No doubt about it... an asteroid killed the dinosaurs!'



The real reason dinosaurs became extinct.

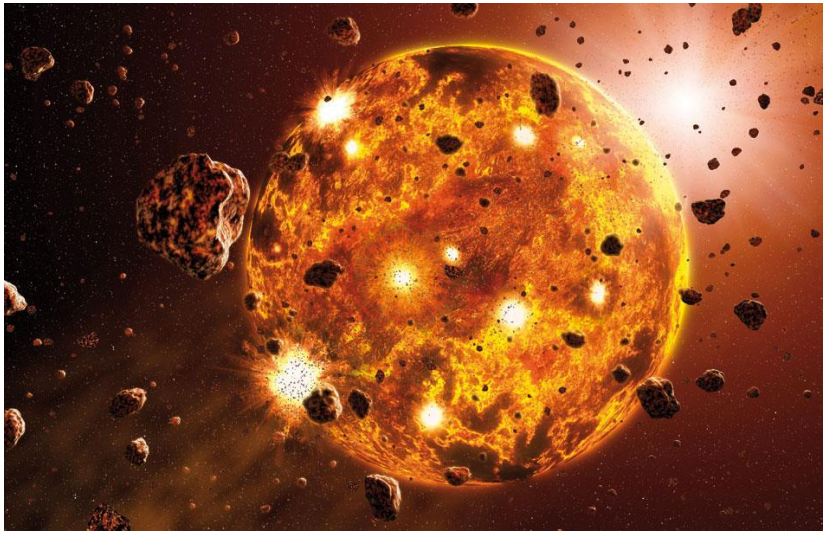
Mass Extinctions



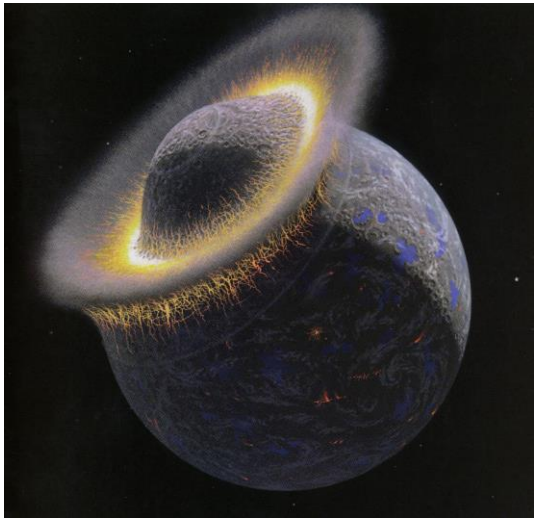
Adapted from Sepkoski, Jr J.J. *Paleobiology 19, no.1* (1993)

Why are impacts important?

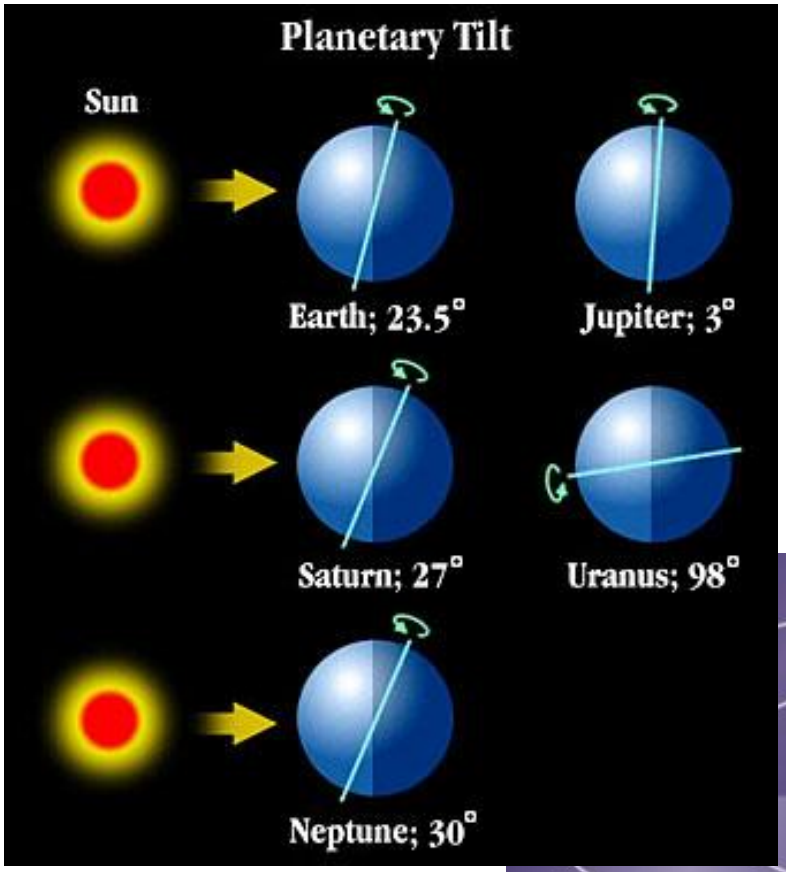
Planet formation

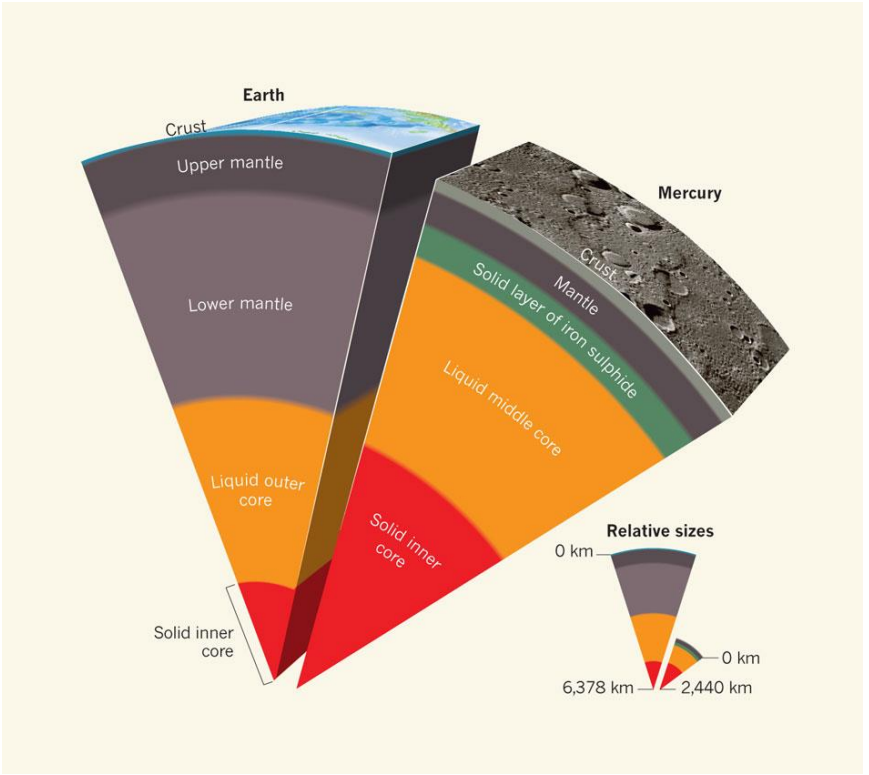


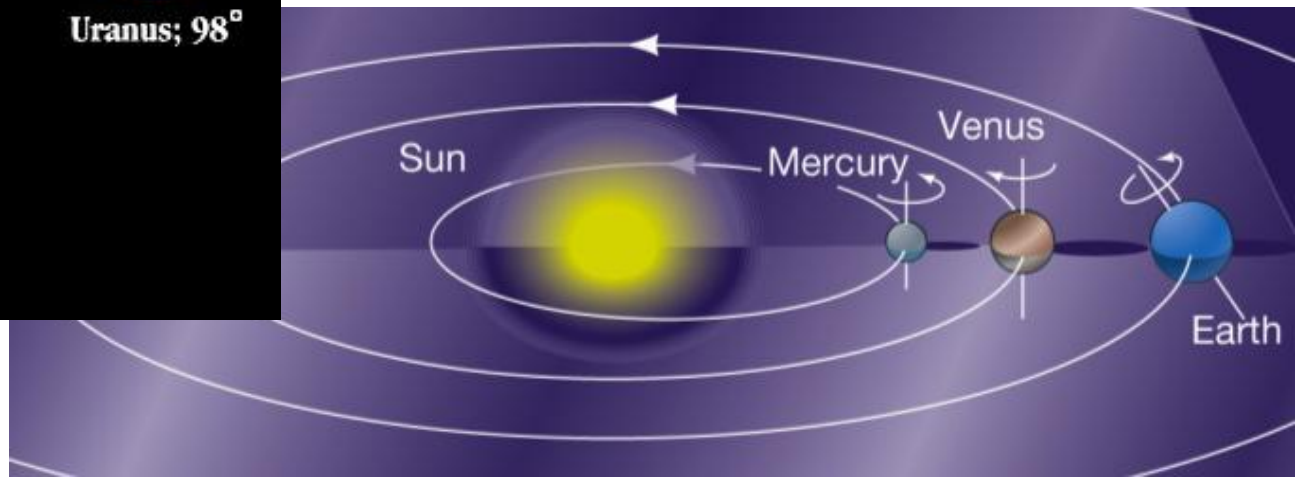
Moon formation



Unusual properties of planets







So what is Down2Earth?

- Several components – online and “in class”
- Schools and public
- **Multi-disciplinary** – mainly science, but can explore cultural and historical aspects

Meteorites in the classroom

Excellent “wow” factor!

UK: free loans to schools

4 different types of boxes containing meteorites, terrestrial rocks, dinosaur fossils & resources

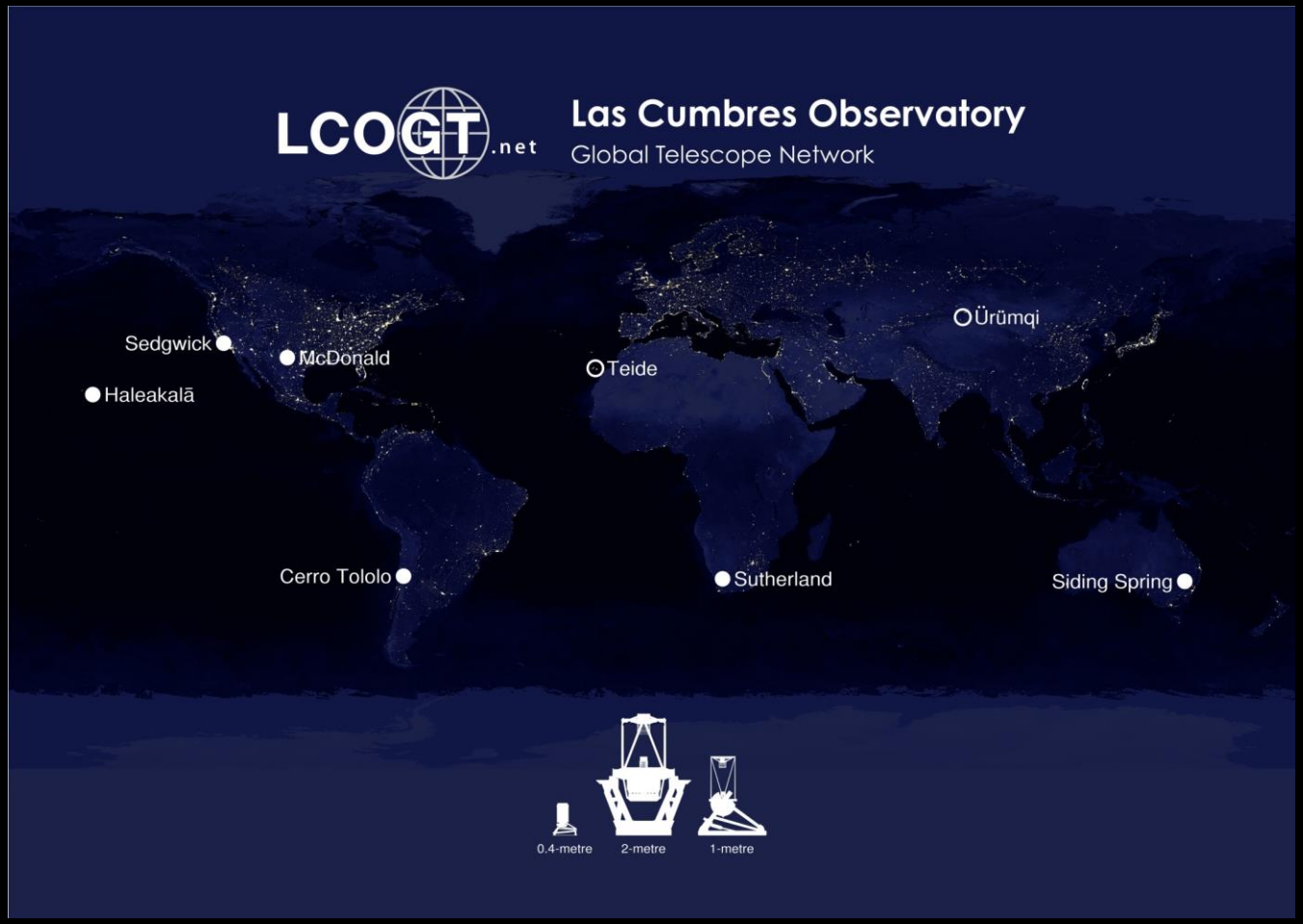
Cosmic comics

Comic strip cartoon about teenagers interested in astronomy and space

Asteroid hunting with the Faulkes Telescopes…

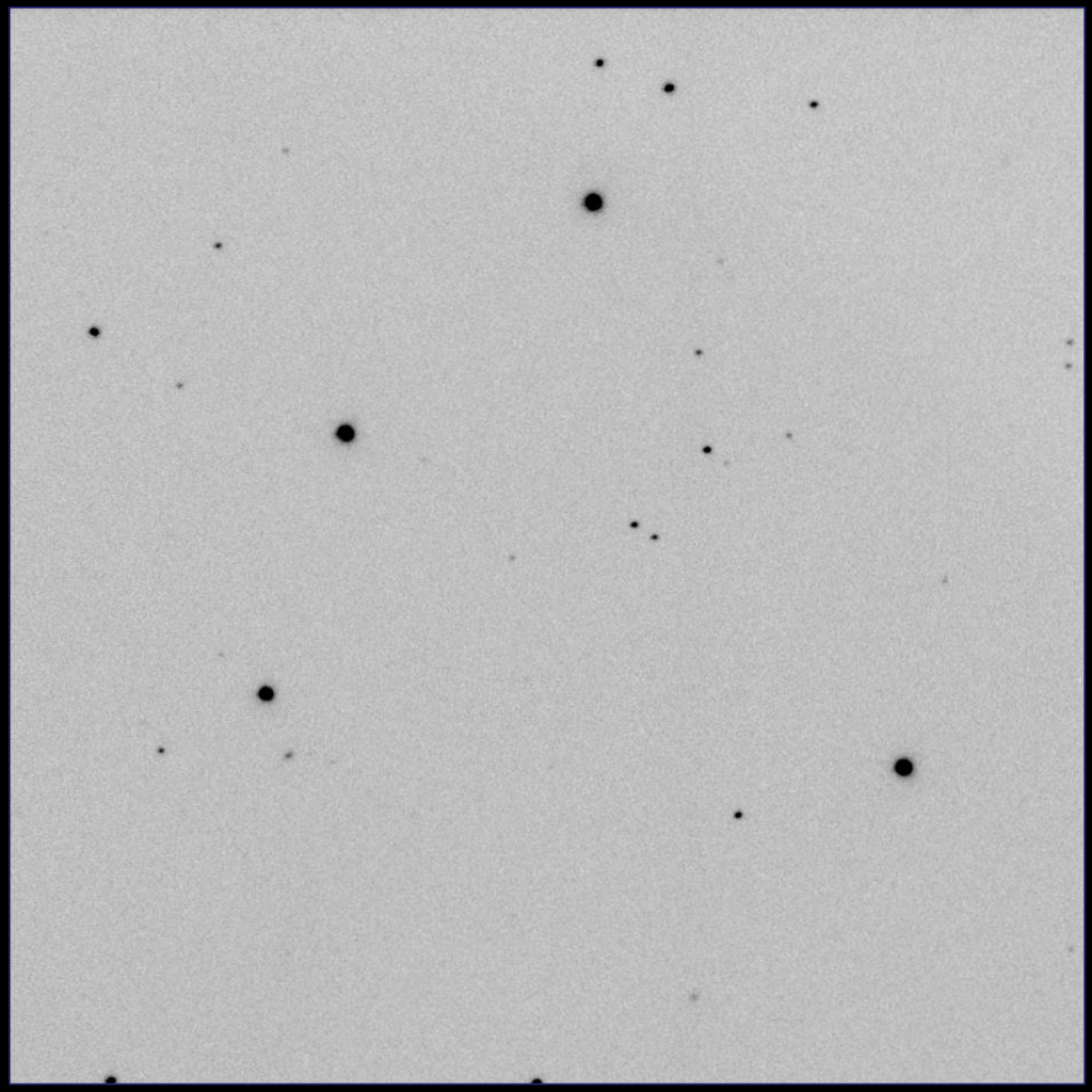
http://www.planet-science.com/categories/extras/cosmic-comics/

Observing asteroids and comets

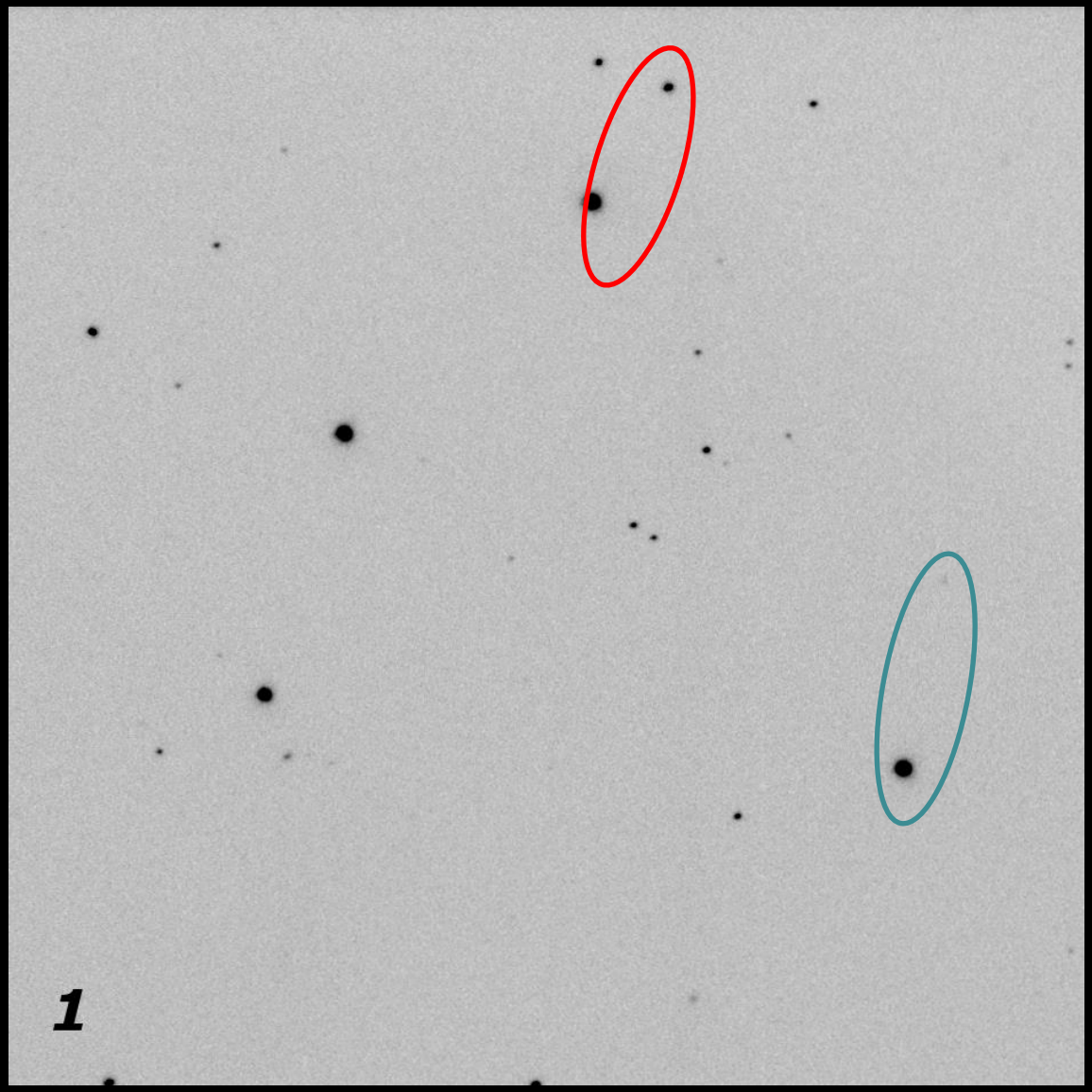


www.faulkes-telescope.com www.lco.global

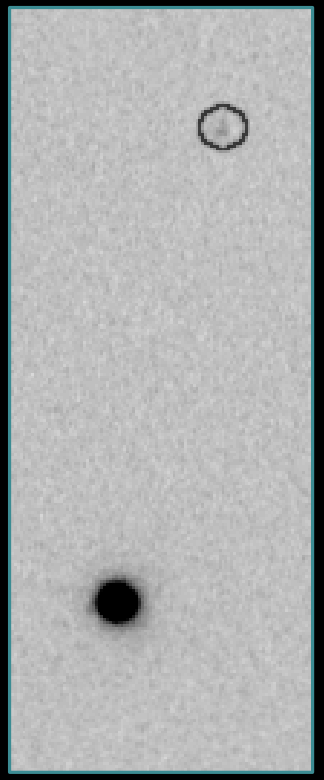
Can you spot the asteroid?



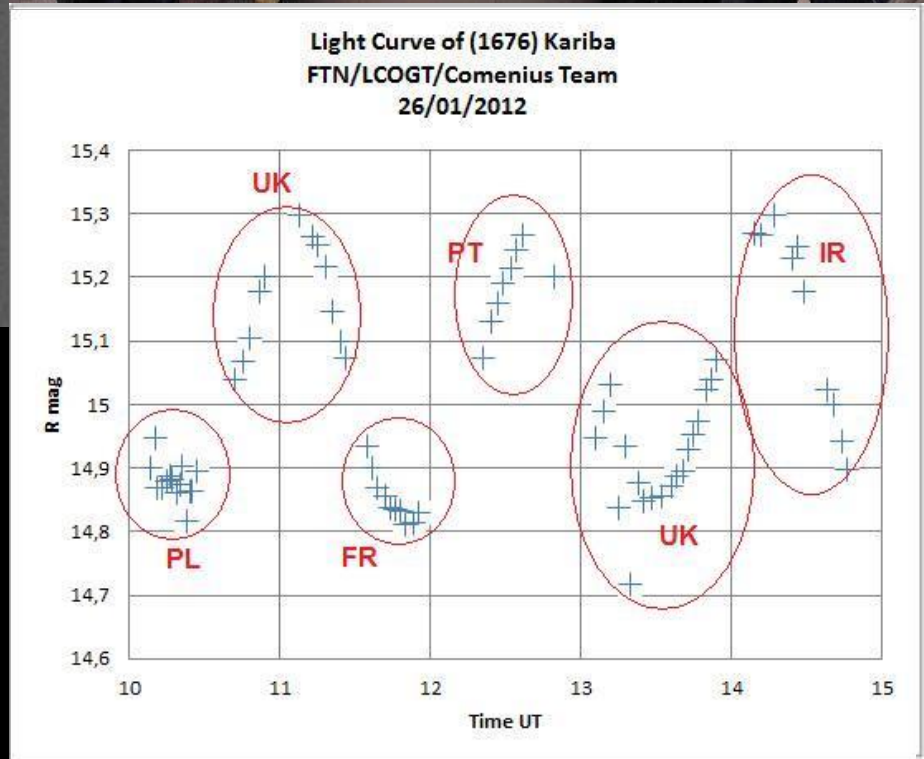
Use “false” colours

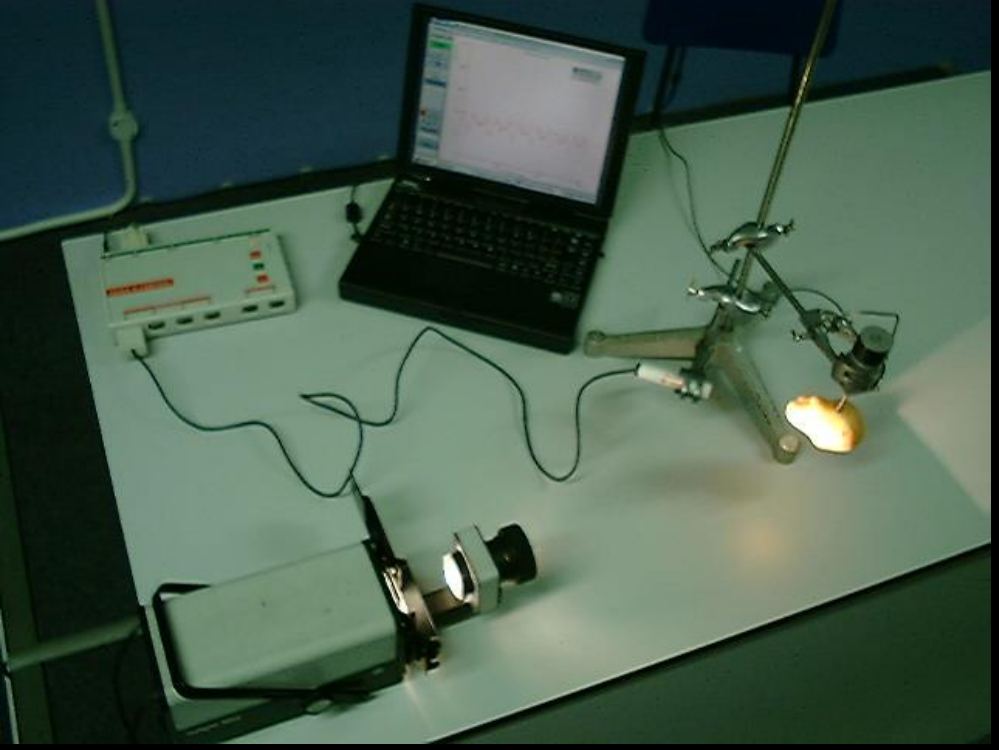


Several images at different times



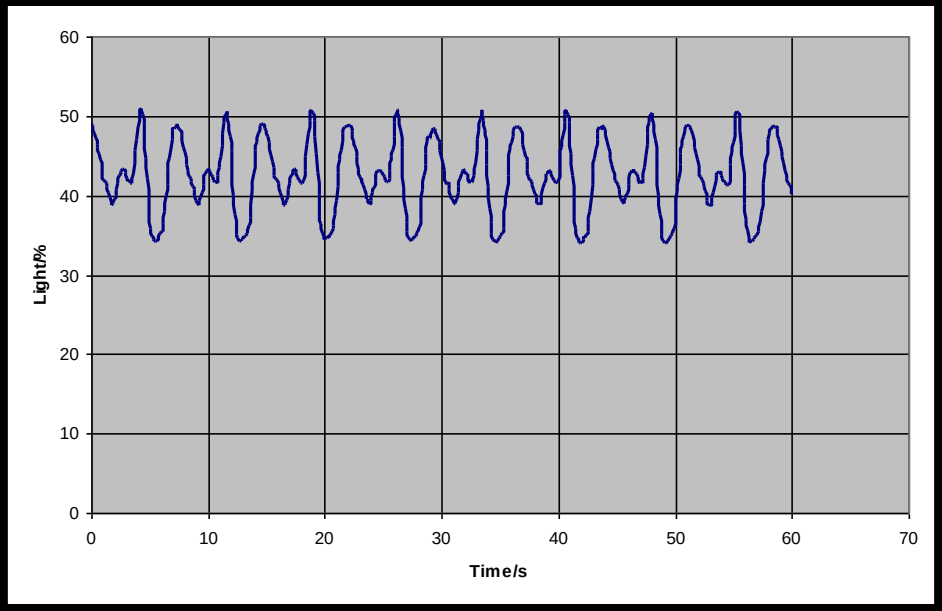
GTTP/EU-HOU teacher training 2010

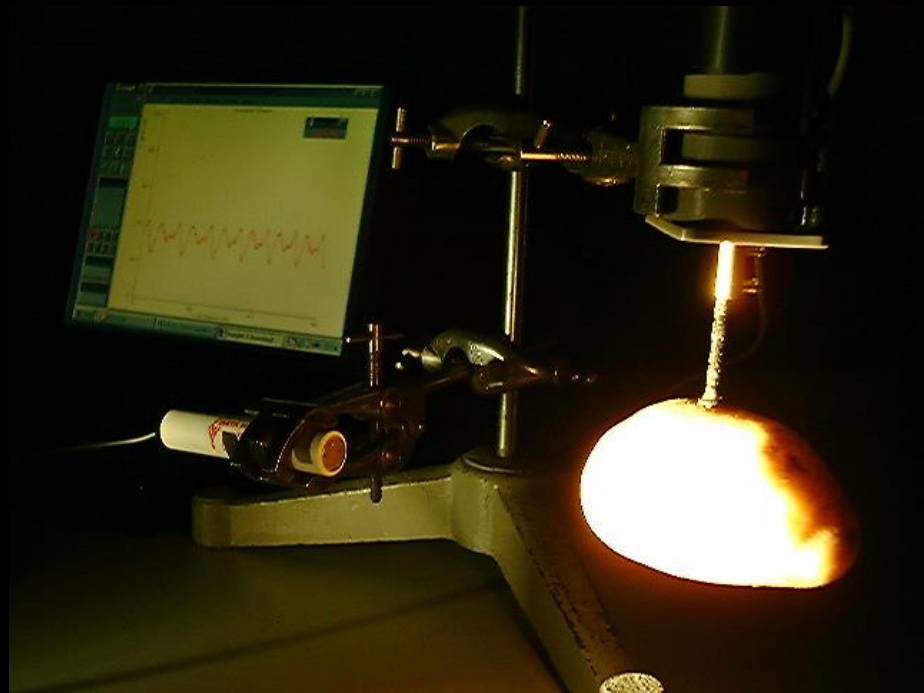




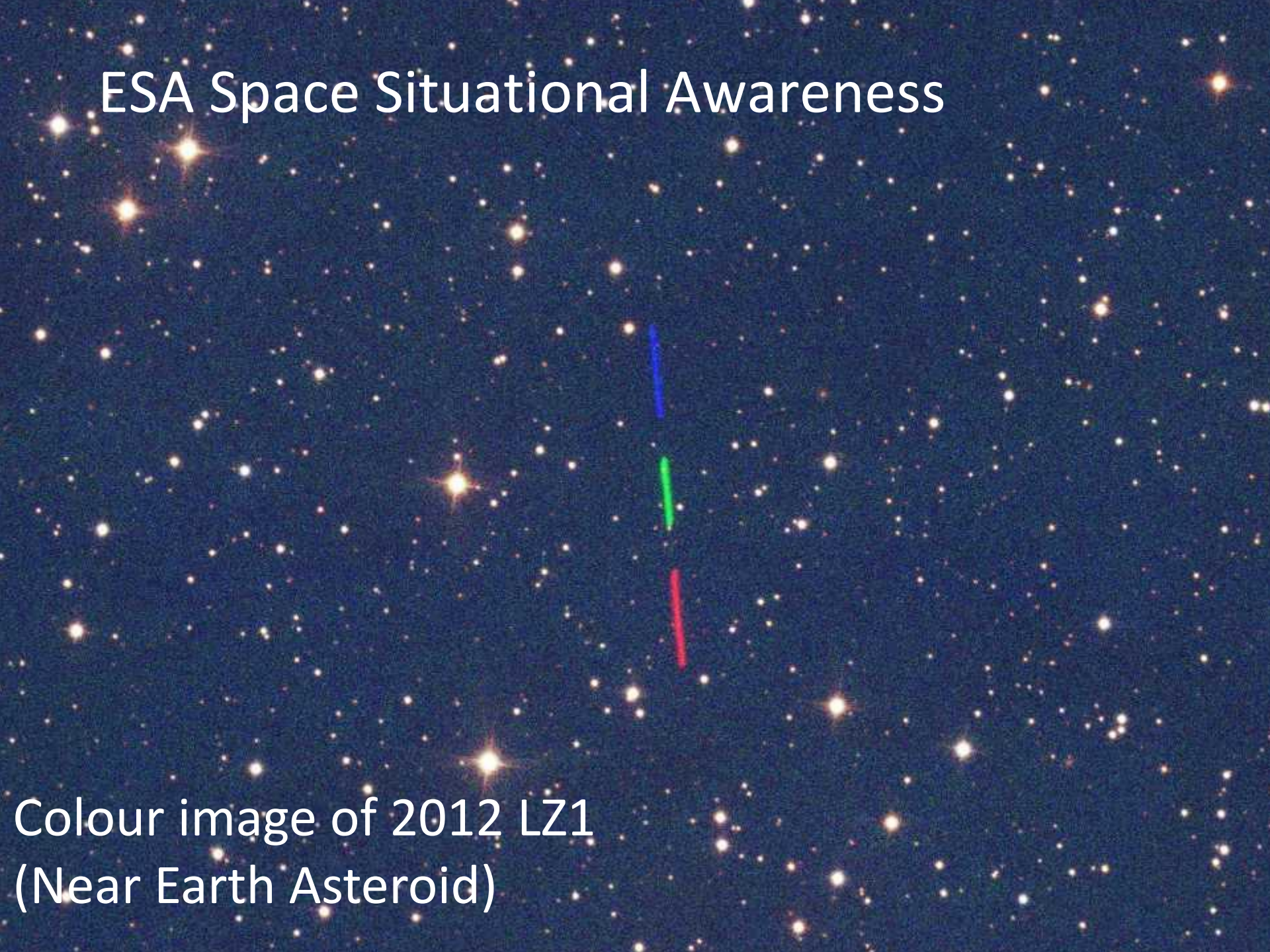
“The Rotato”

Classroom simulation of asteroid rotation





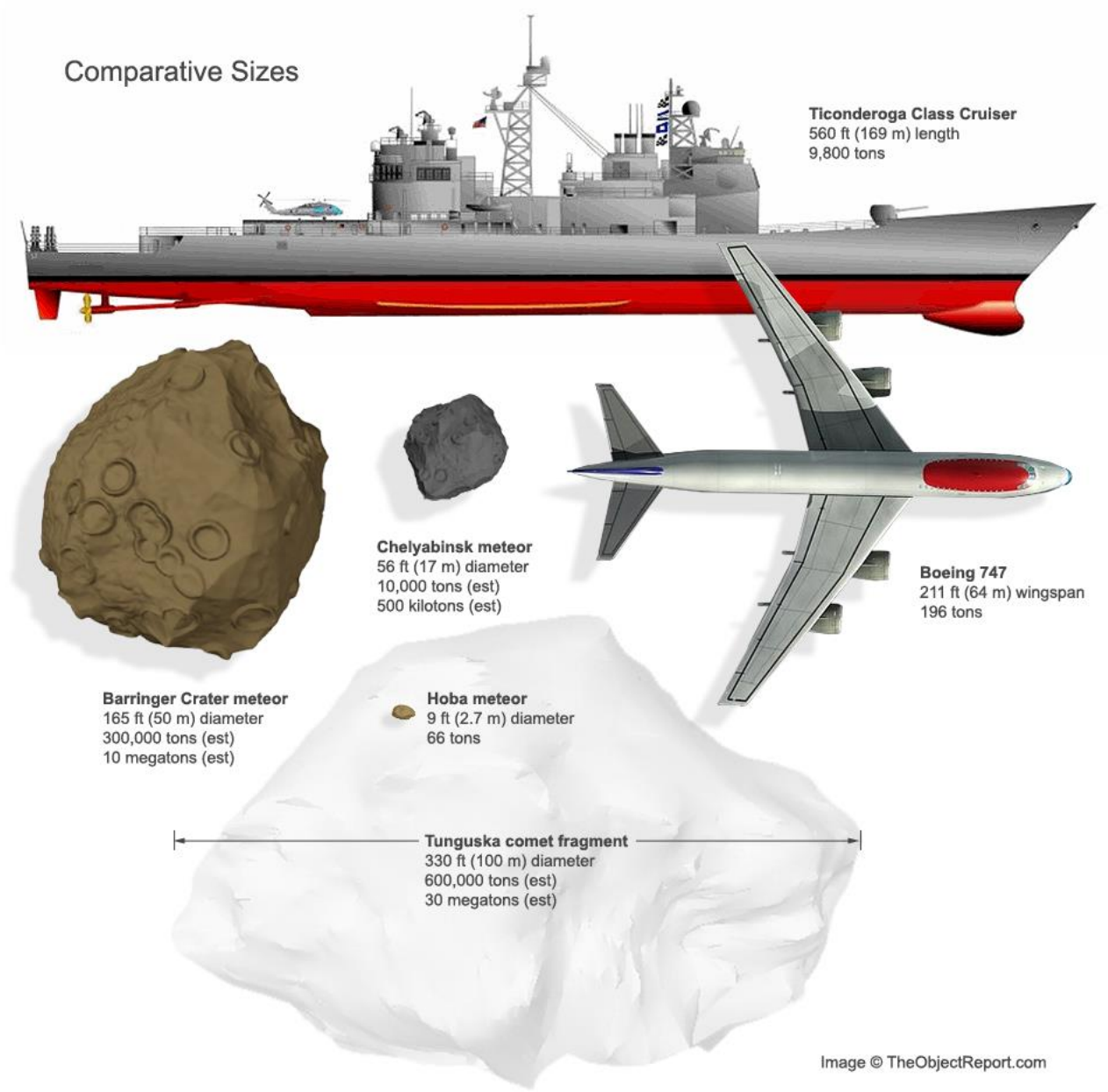
ESA Space Situational Awareness



Colour image of 2012 LZ1
(Near Earth Asteroid)

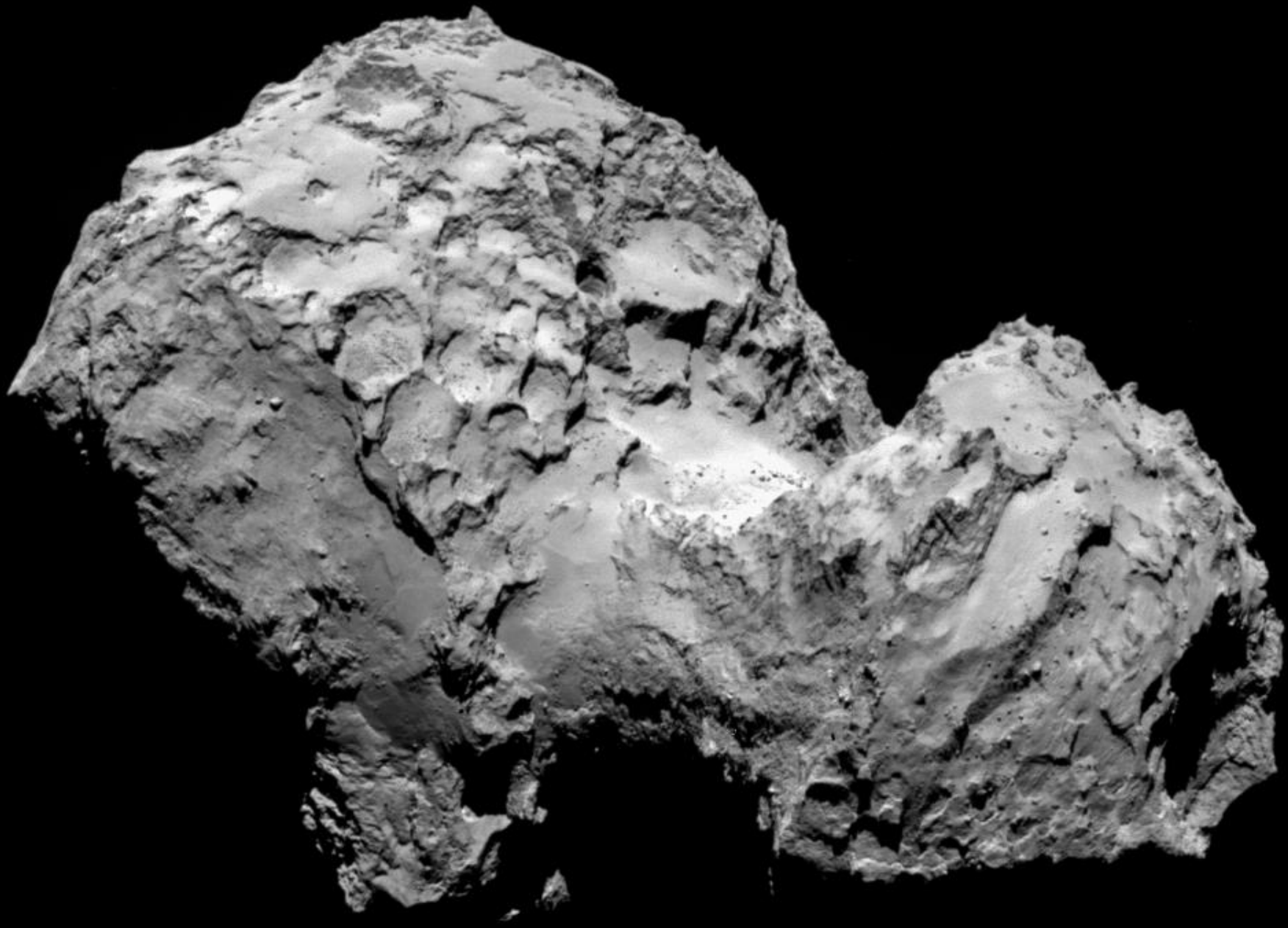
Chelyabinsk, 15/02/13

https://www.youtube.com/watch?v=tq02C_3FvFo

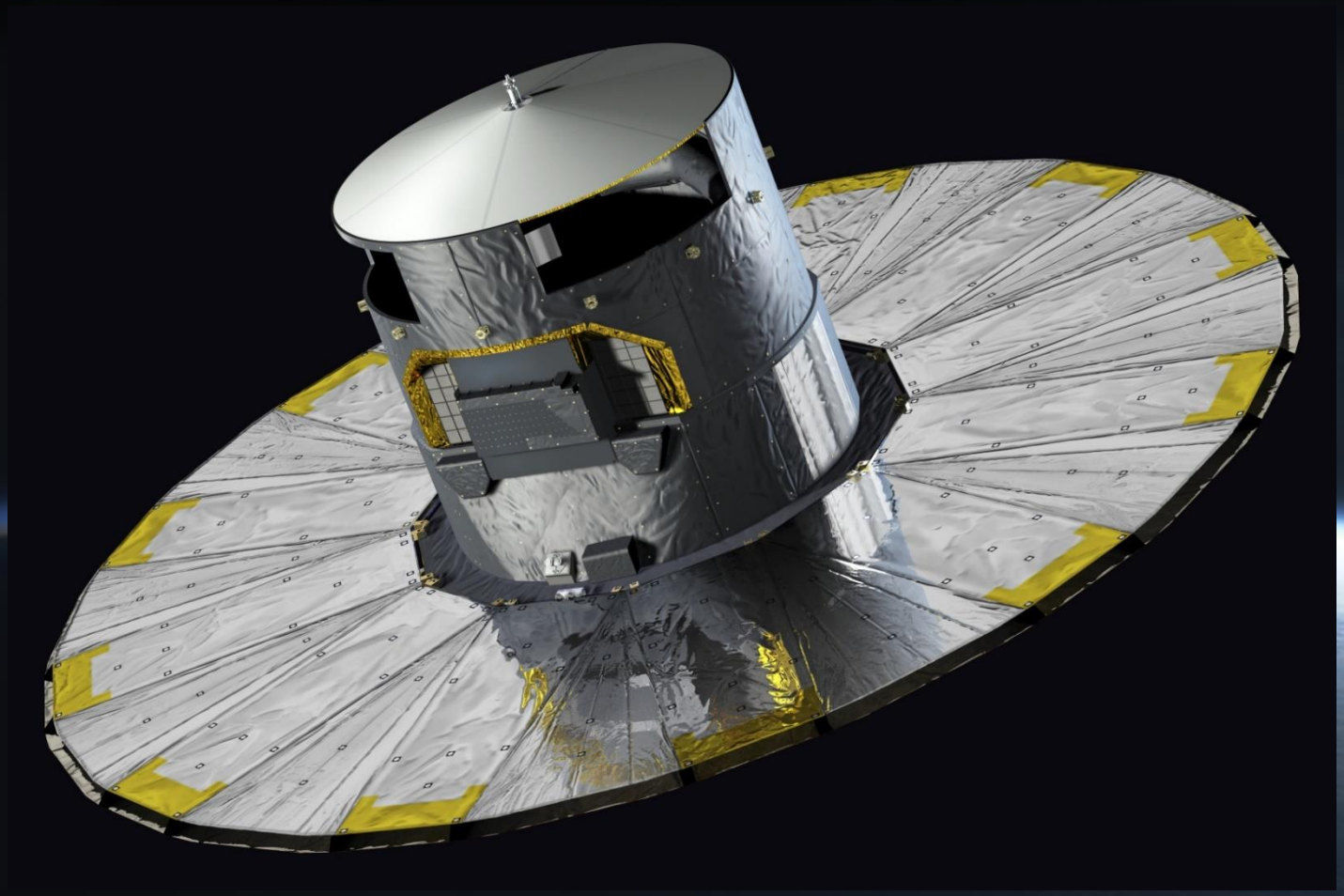

Comparative Sizes
Ticonderoga Class Cruiser
560 ft (169 m) length
9,800 tons
Chelyabinsk meteor
56 ft (17 m) diameter
10,000 tons (est)
500 kilotons (est)
Boeing 747
211 ft (64 m) wingspan
196 tons
Barringer Crater meteor
165 ft (50 m) diameter
300,000 tons (est)
10 megatons (est)
Hoba meteor
9 ft (2.7 m) diameter
66 tons
Tunguska comet fragment
330 ft (100 m) diameter
600,000 tons (est)
30 megatons (est)
Image © TheObjectReport.com

Links to ESA missions

Rosetta



Gaia



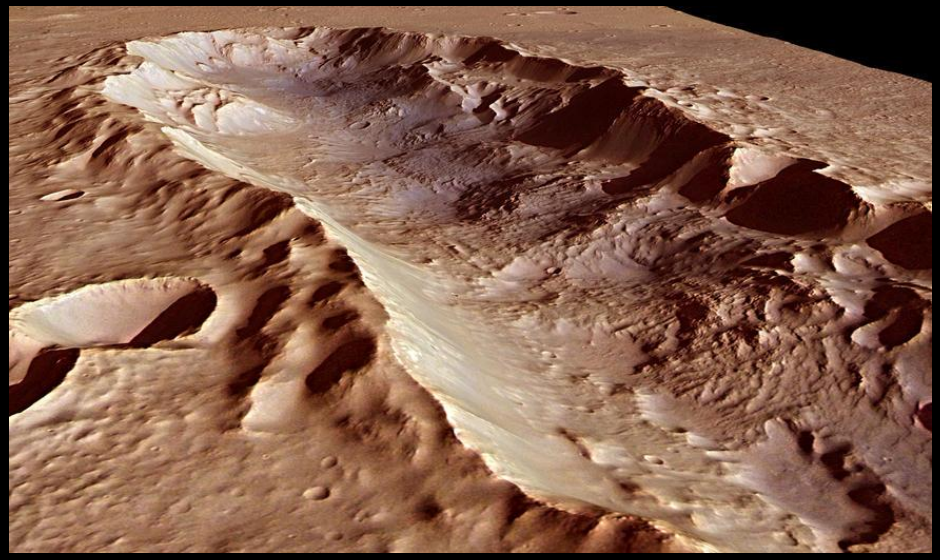
ExoMars

Craters

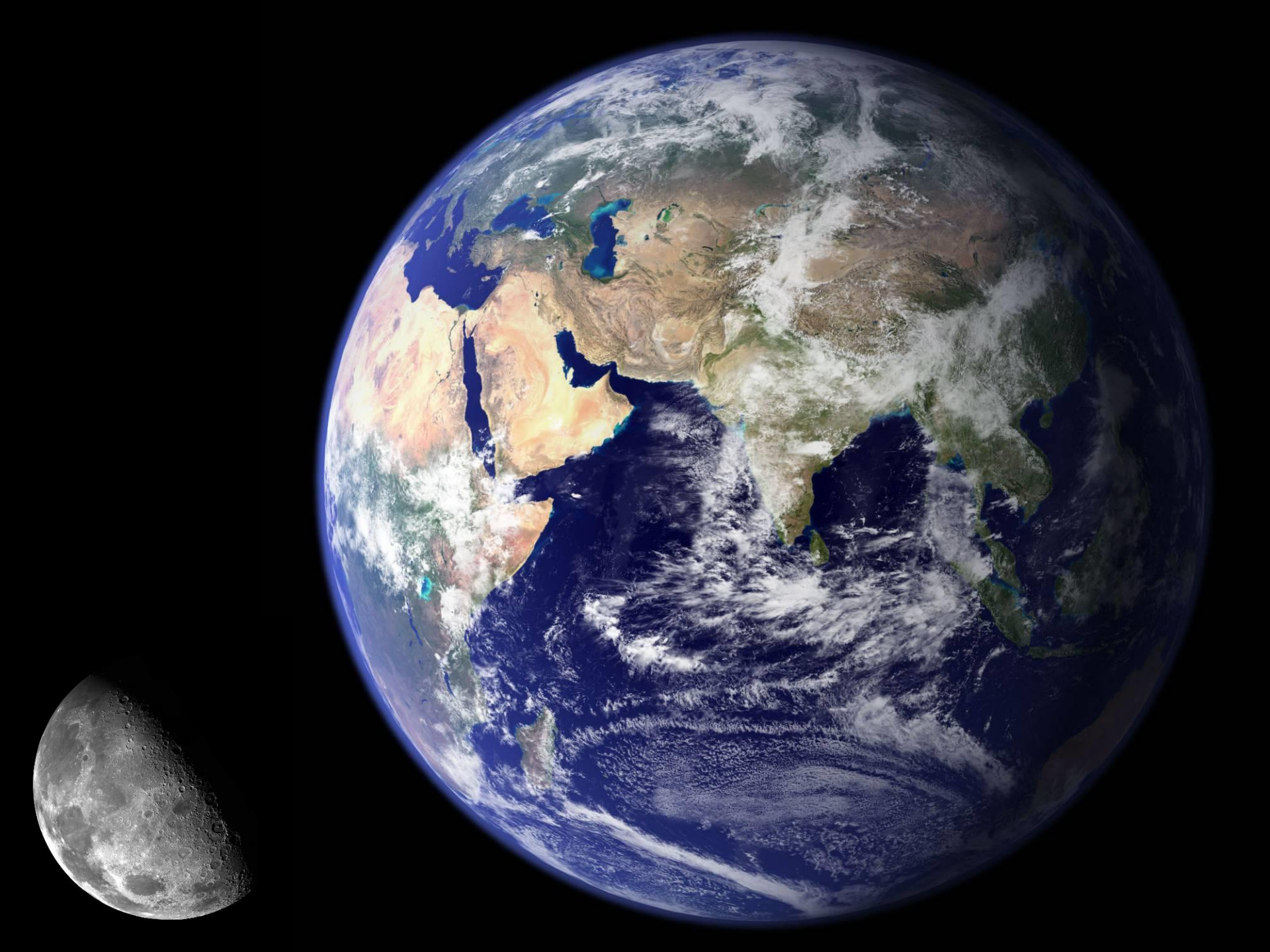
Mimas
(Saturn)

Callisto
(Jupiter)

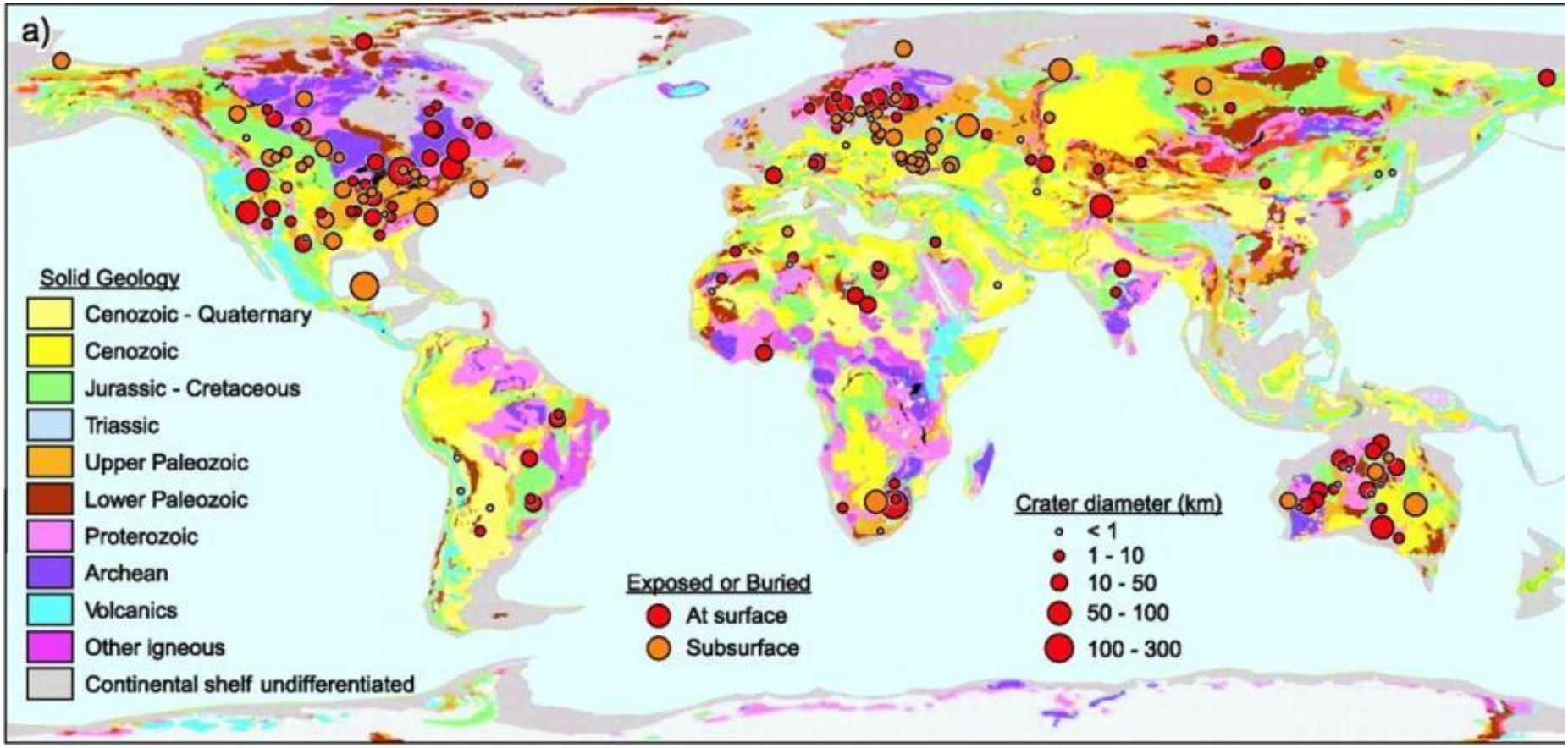
Craters are
everywhere!



Mars



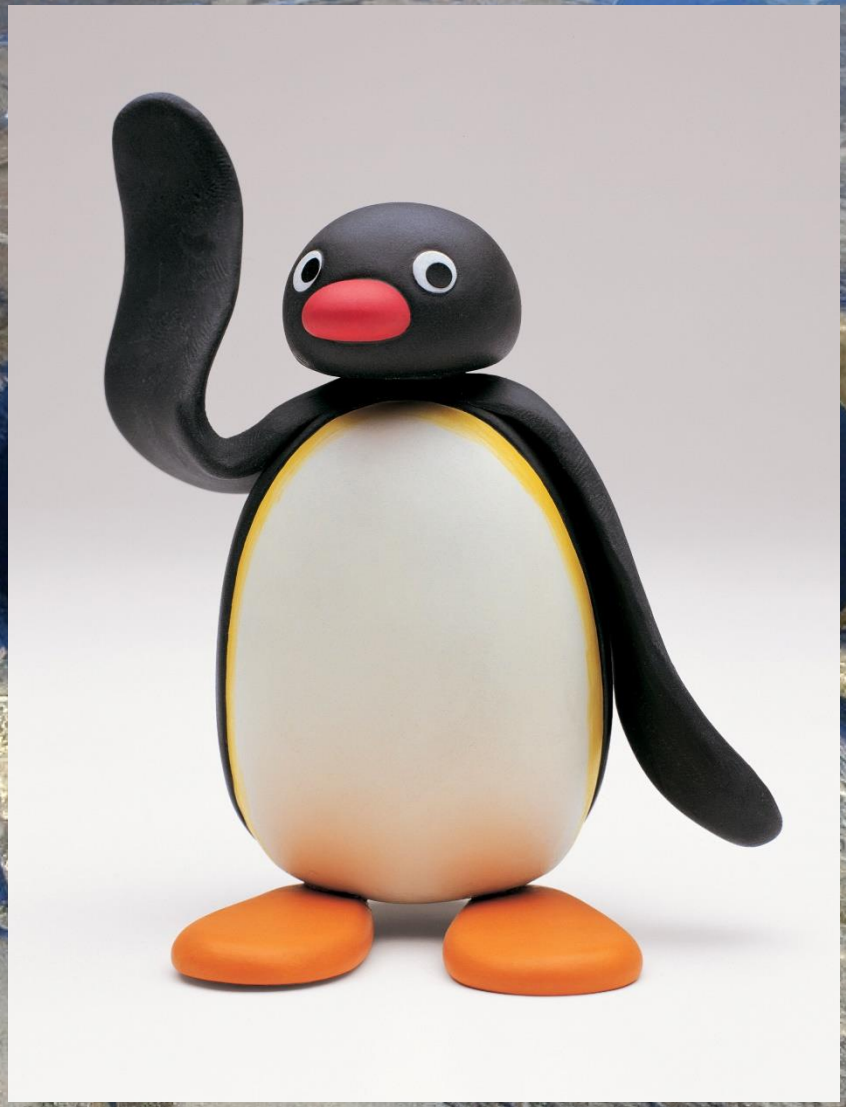
Craters on Earth



Meteor Crater

IR reveals **asymmetric** ejecta blanket at Meteor Crater

Pingualuit



Pingu

Manicouagan

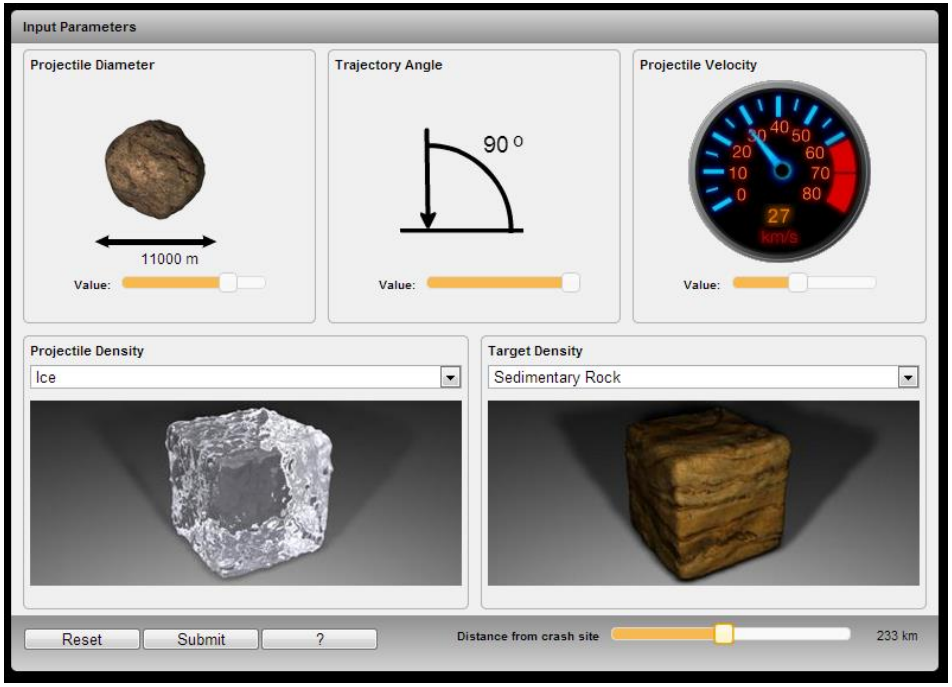
Simulating asteroid and comet impacts

The science of impacts

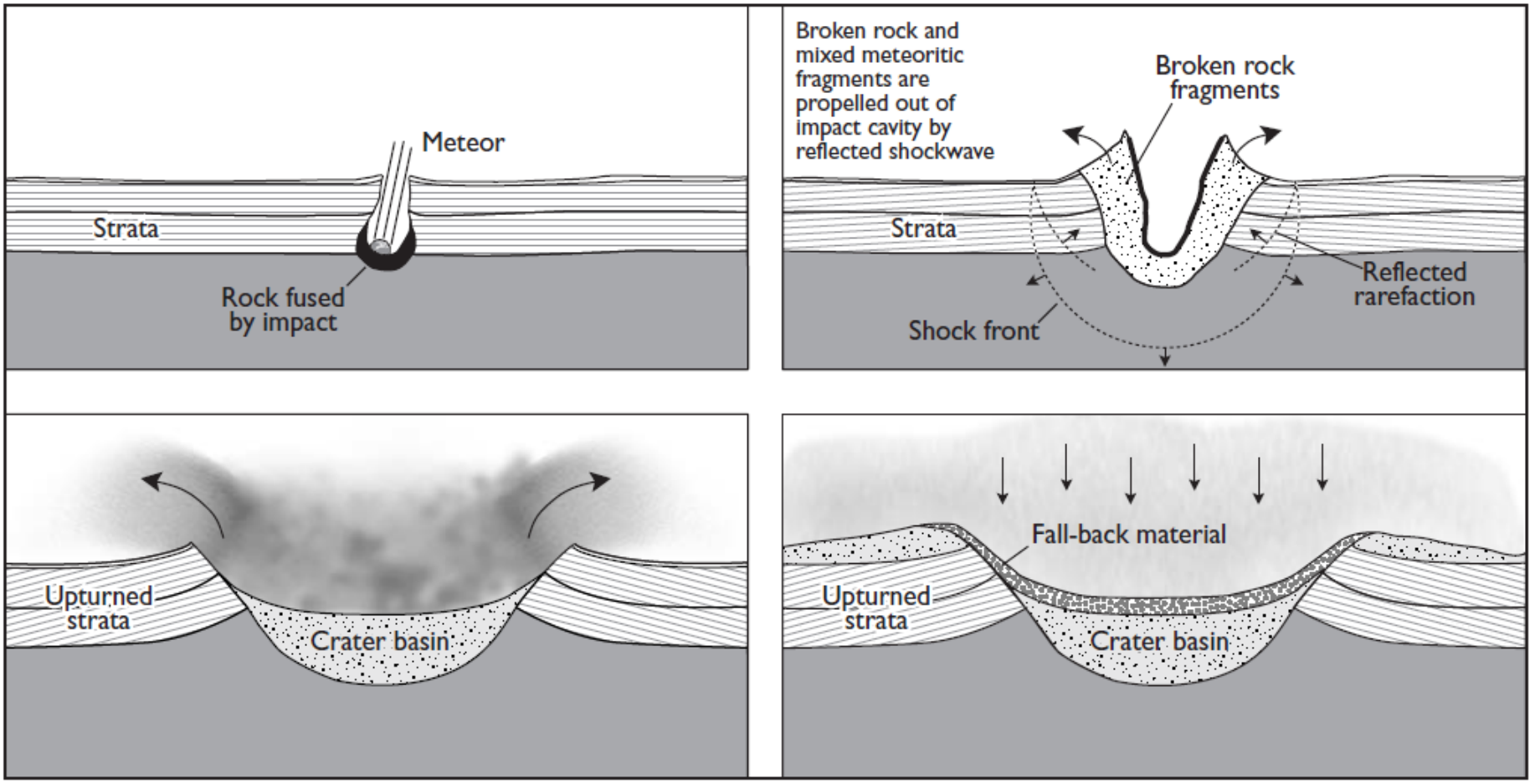
- Use impacts to teach STEM subjects
  - Kinetic energy, gravity, orbits
  - Impacts, crater formation
  - Mass extinctions, life (death!) on Earth
  - Planetary formation

The science of impacts

- Research code by Gareth Collins (Imperial) & Jay Melosh (U Arizona)
- Graphical user interface – student-friendly, multilingual
- Real physics

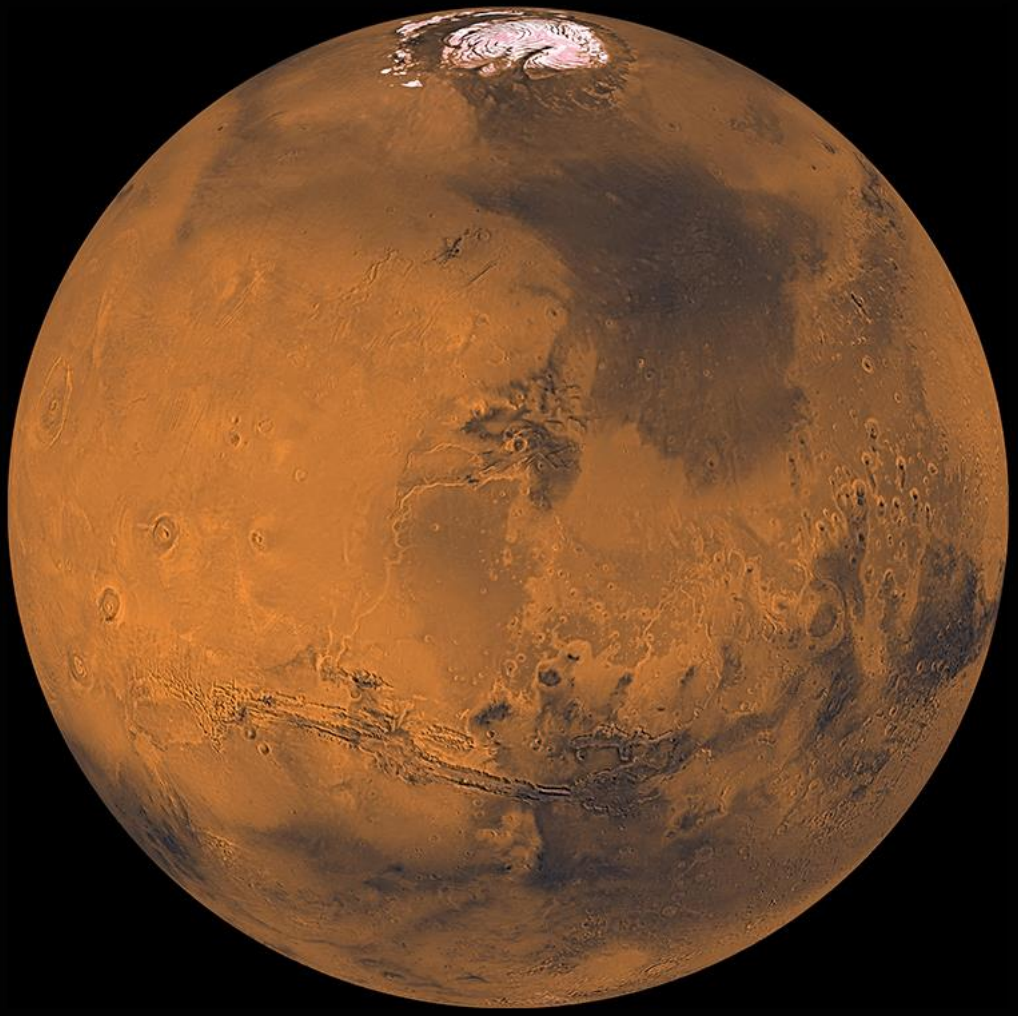


Crater formation



A lot of complex geology, geophysics etc.!

Impacts on Mars



- What are the key differences between Earth and Mars that could affect impacts?

(frequency of impacts, size of craters etc.)

Planetary mass (g)

Orbital velocity

Atmospheric conditions

Surface conditions

Proximity to asteroid belt

More but slower?

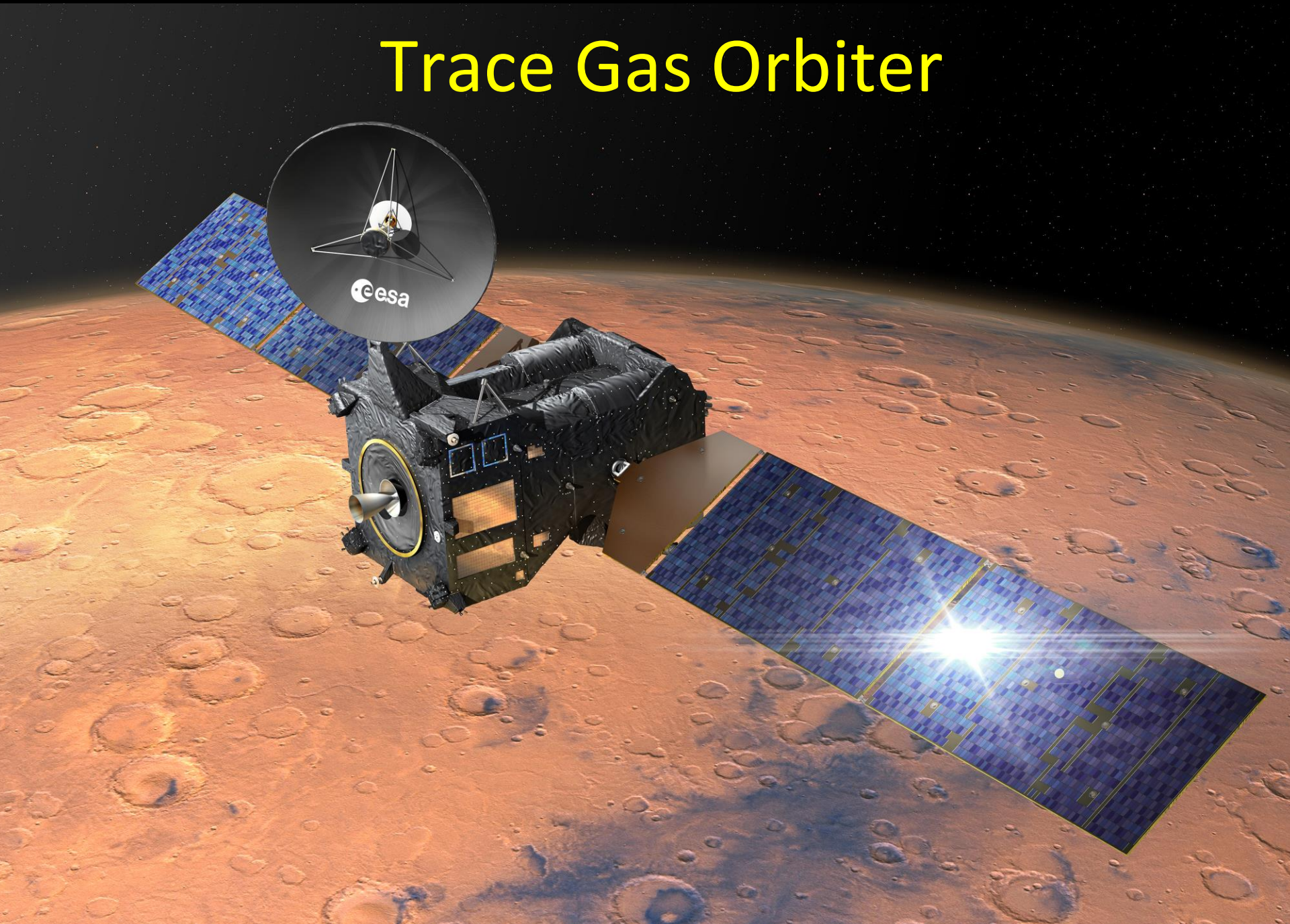
ESA at Mars

Today:
Schiaparelli lander
Trace Gas Orbiter

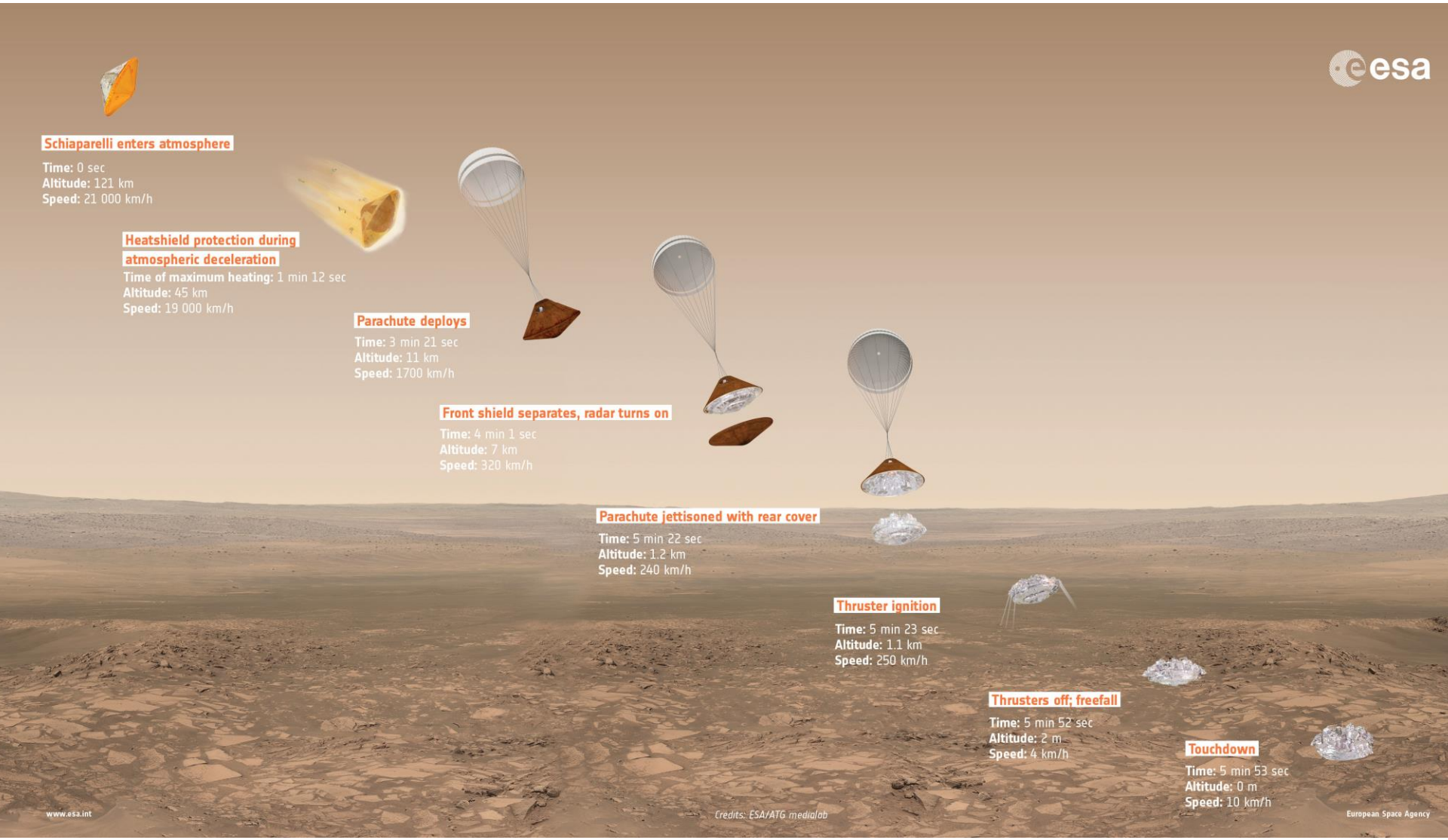
Launch 2020:
ExoMars rover

http://exploration.esa.int/mars/46048-programme-overview/

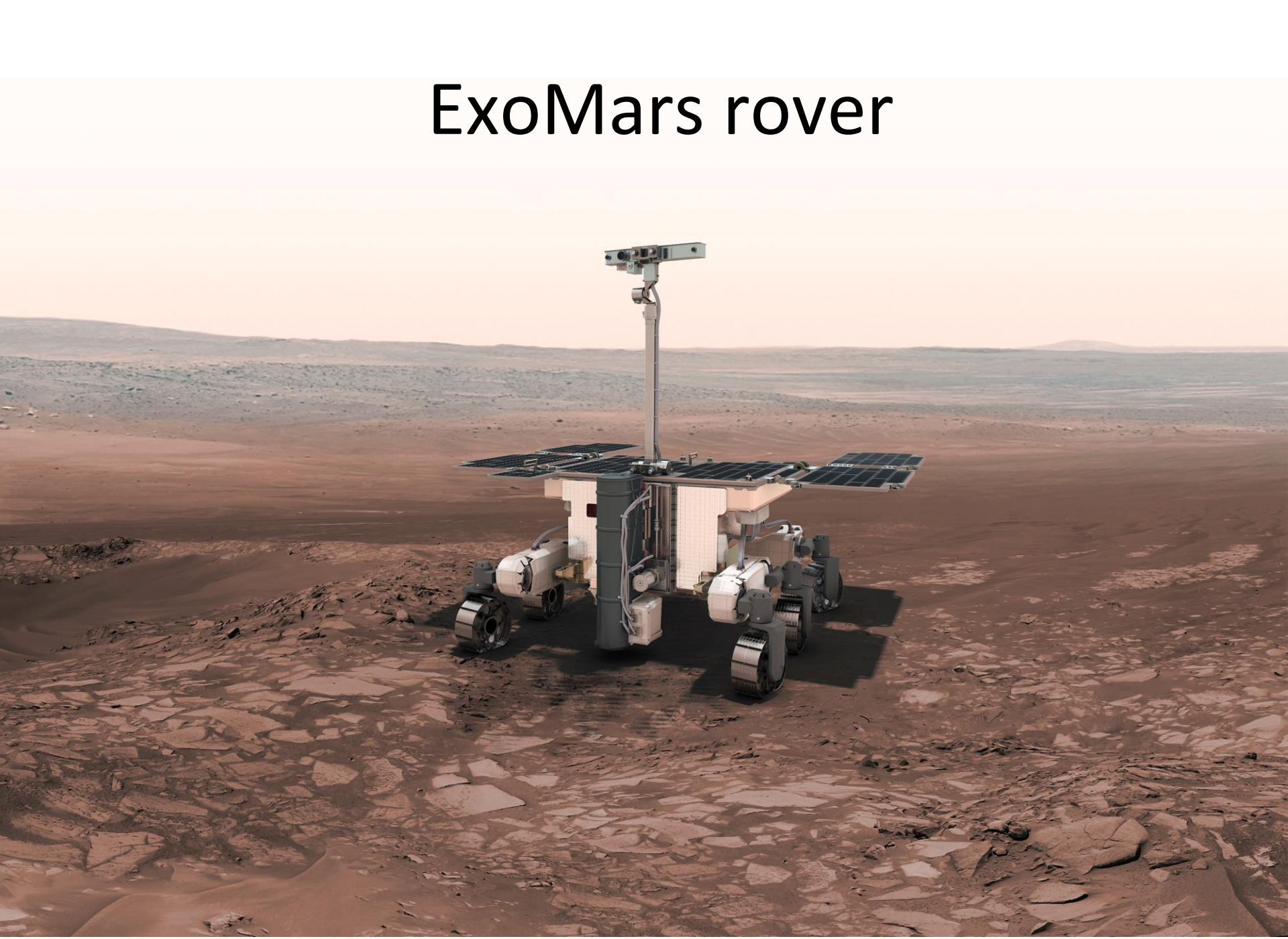
Trace Gas Orbiter



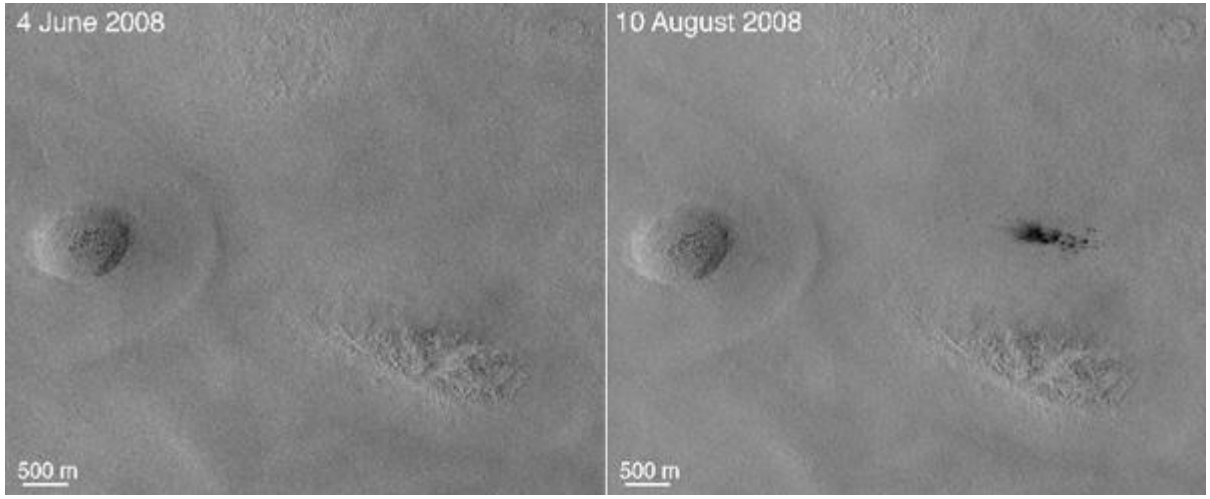
Schiaparelli lander

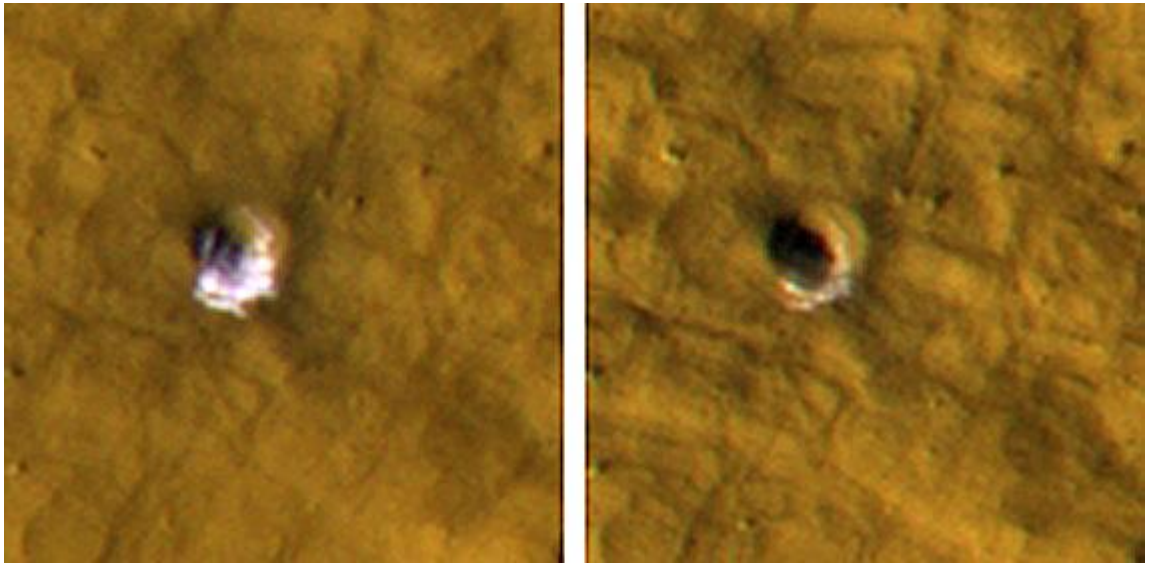


ExoMars rover

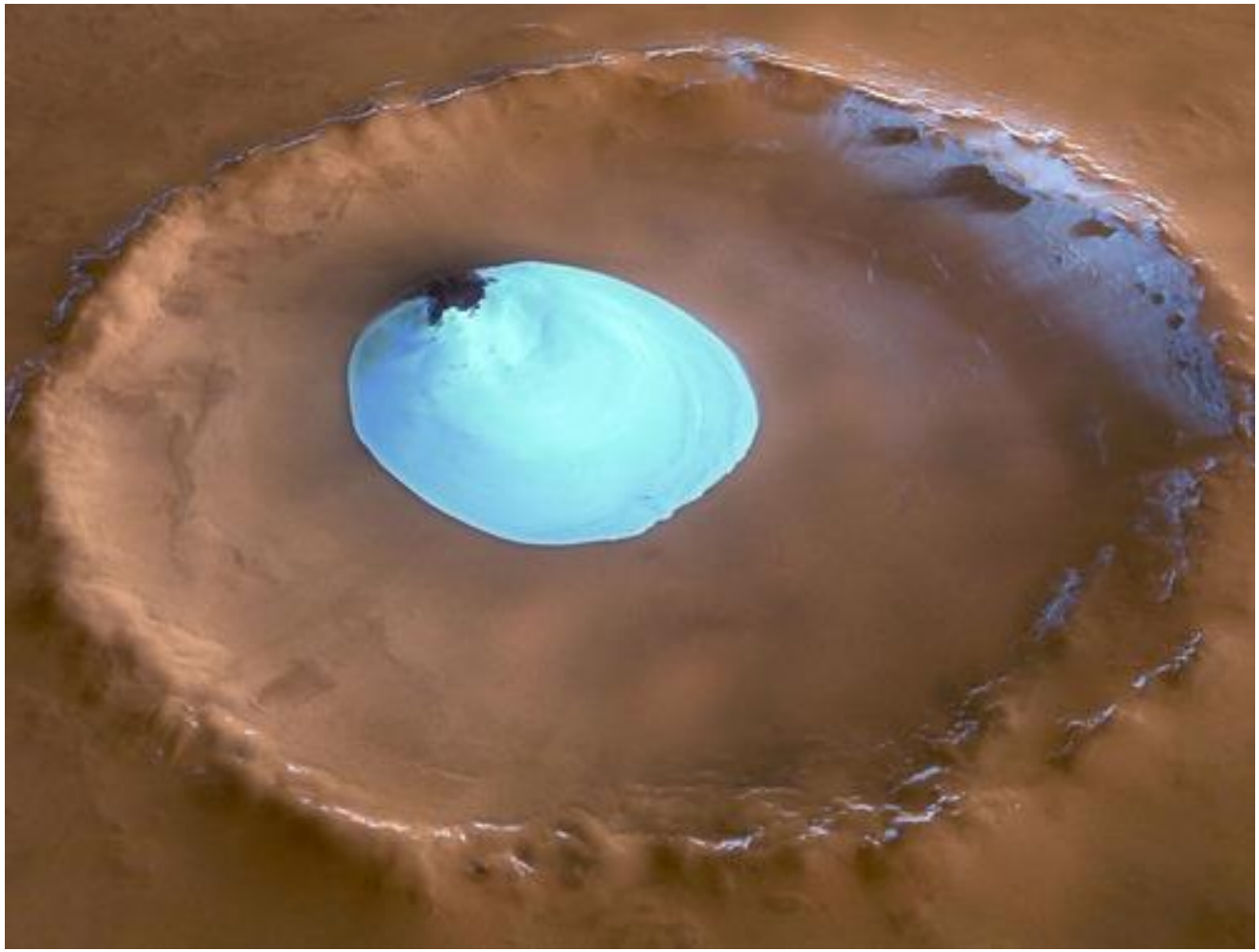


New craters

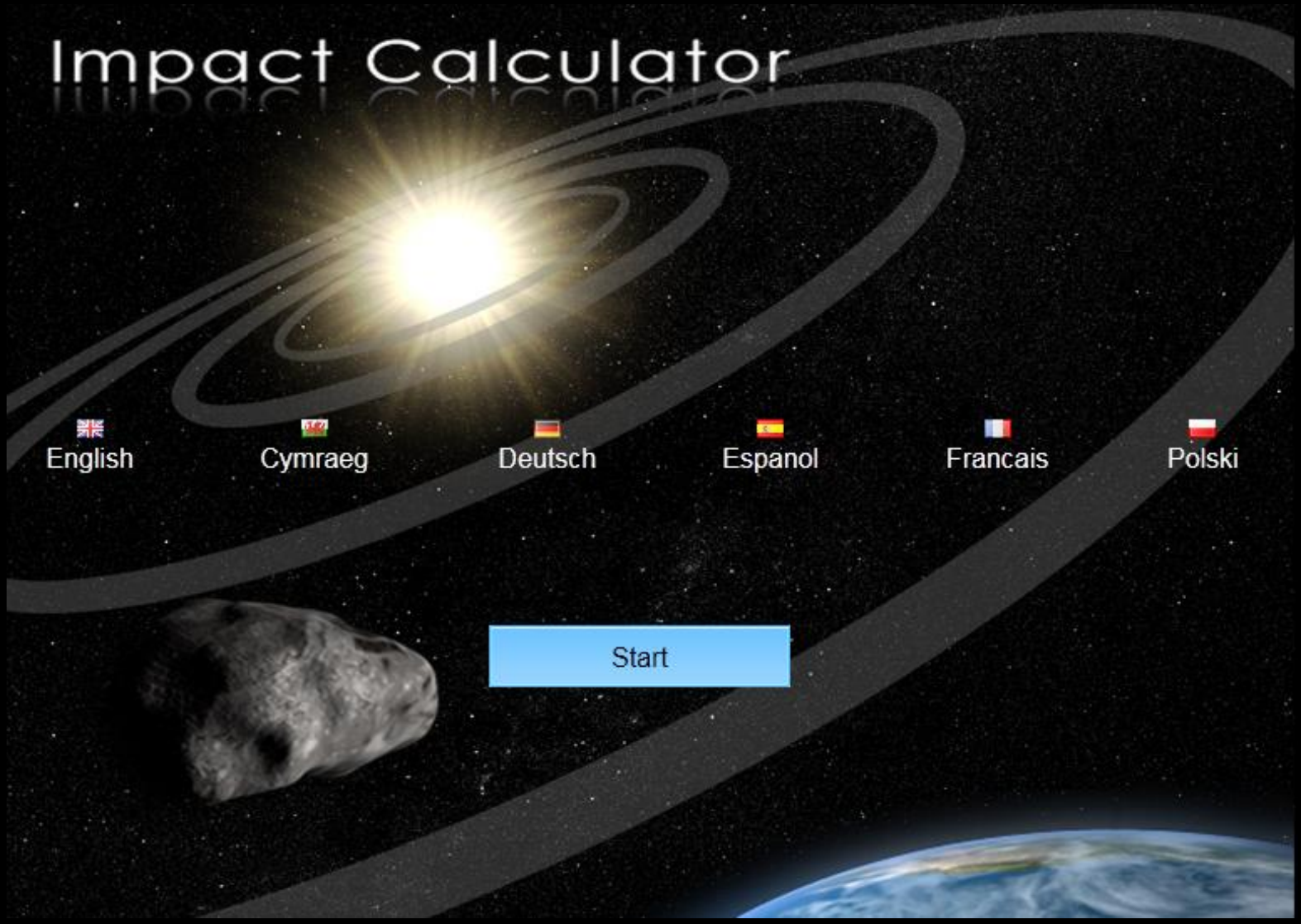




Martian craters



Splosh craters



http://education.down2earth.eu

Let’s blow things up…!

- Log on to the **Impact Calculator**
- Play with the simulator

Note: you will need IE 9, Chrome, Firefox, Opera or Safari as the website runs **html5**

http://education.down2earth.eu

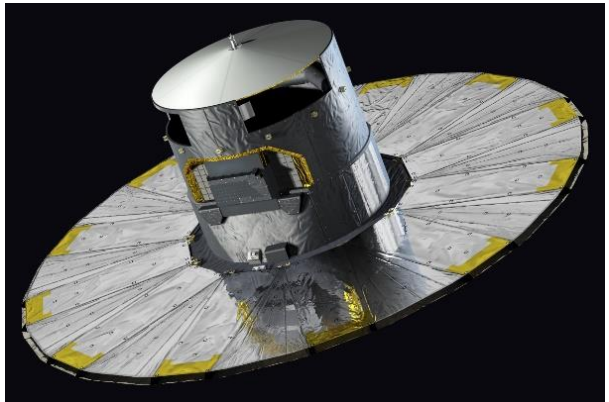
ESA Teacher Guides

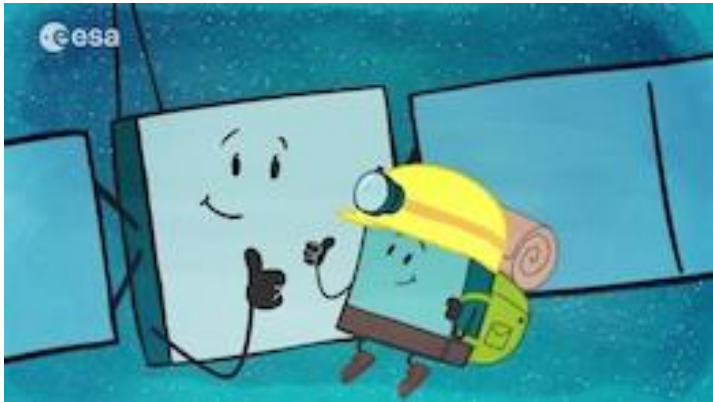
Teacher Guide	General Theme
TG1	Earth
TG2	History of Solar System and Role of Comets
TG3	Comparative Planetology

Currently with ESA scientists for review, available in 2017

Summary

- Online resources and simulators
- Teacher Guides and activities (with ESA)
- Links with ESA space missions (ExoMars, Gaia, Rosetta etc.)





education.down2earth.eu

www.faulkes-telescope.com

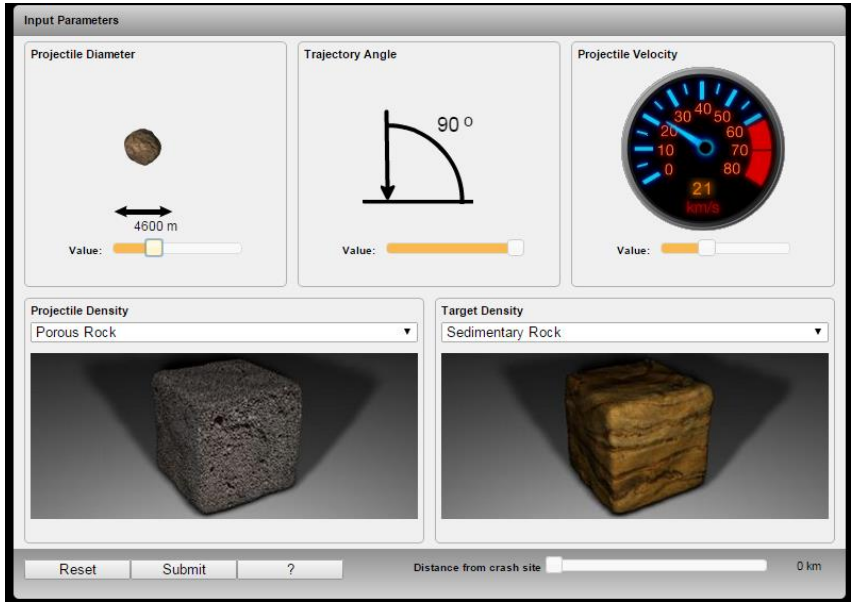
paul.roche@faulkes-telescope.com

TG1 and TG2

Down2Earth “Impact Calculator”

http://simulator.down2earth.eu/

Research Scenario



TG1 Earth

1/. Impacts from all Angles

2/. Preventing Deep Impact

3/. Wiping out the Dinosaurs…Again!

4/. Simulating Impact Craters

5/. Large-scale Impacts and the Chelyabinsk Meteorite

TG2 History of Solar System & Comets

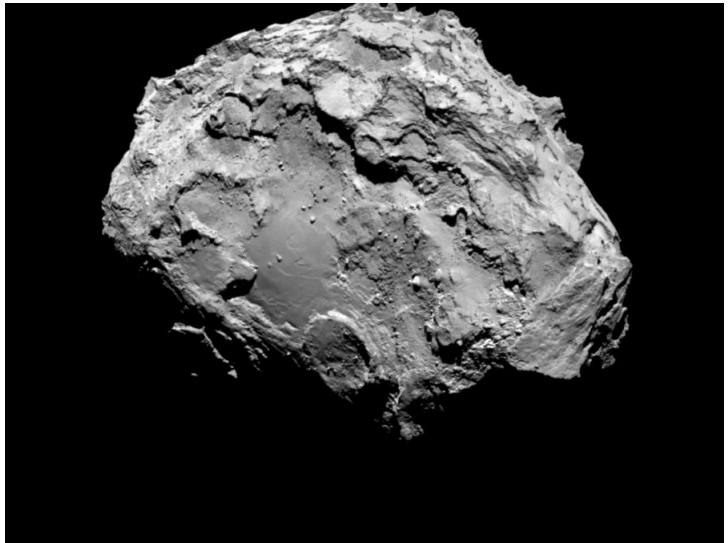
1/. Recreate a Crater

2/. Comet Collision vs. Atomic Annihilation

3/. Angles through the Atmosphere

4/. Quickening Comets

5/. Fabulous Flybys



TG3 Comparative Planetology

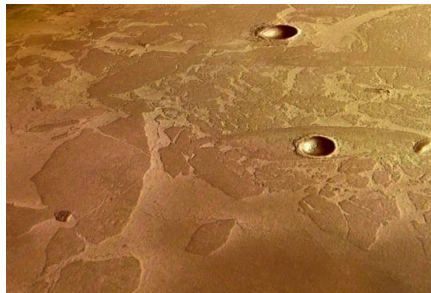
1/. Comparative Cratering in the Inner Solar System

2/. Cratering Density and Resurfacing on Mars

3/. Investigating the Atmosphere

4/. The Largest Craters in the Solar System

5/. Ejecta fields around Martian Craters



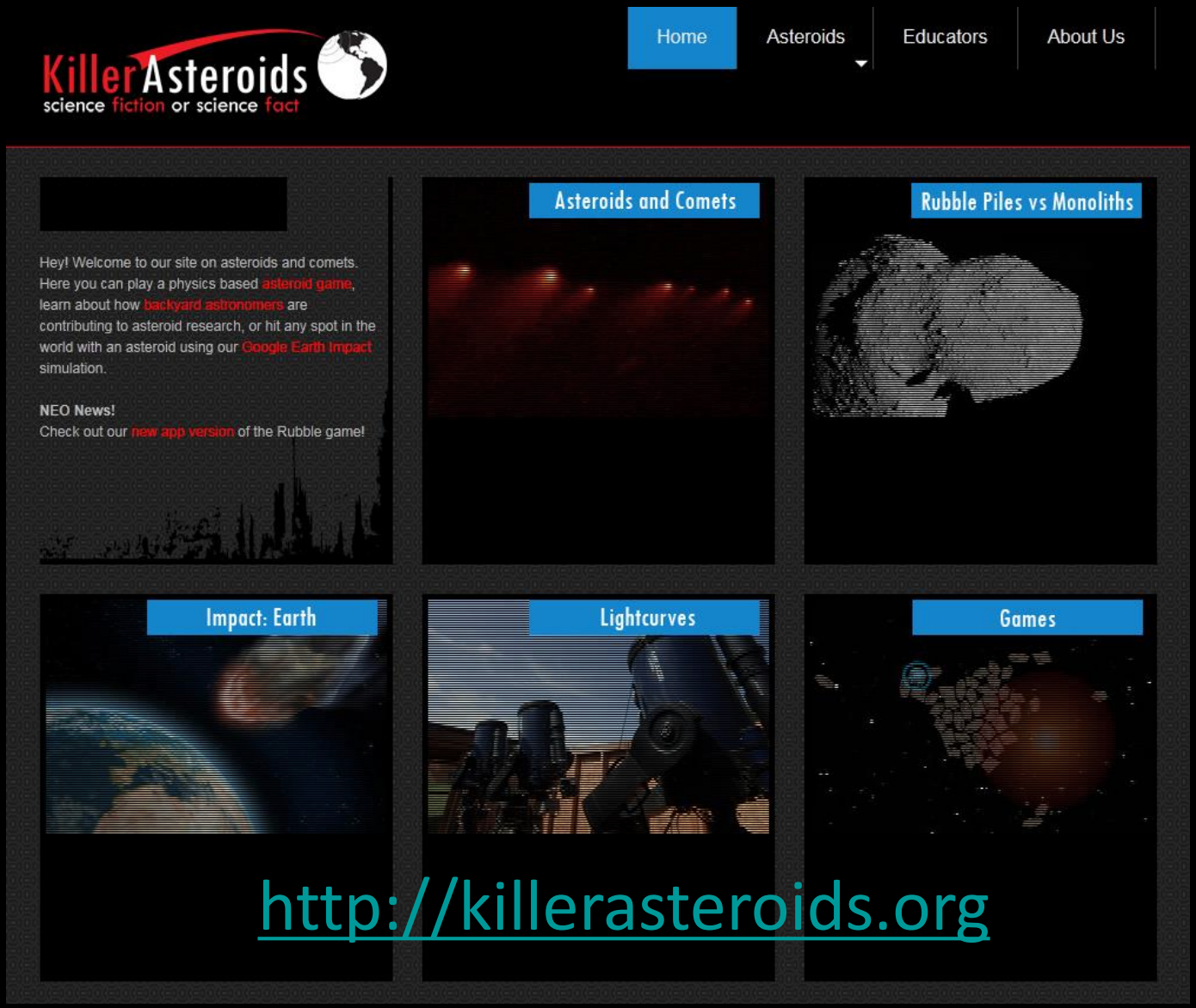
TG3 Comparative Planetology

- Using SalsaJ
  http://www.euhou.net/index.php/salsaj-software-mainmenu-9
- ESA images http://www.esa.int/spaceinimages/Images
- Moon and Mars impacts

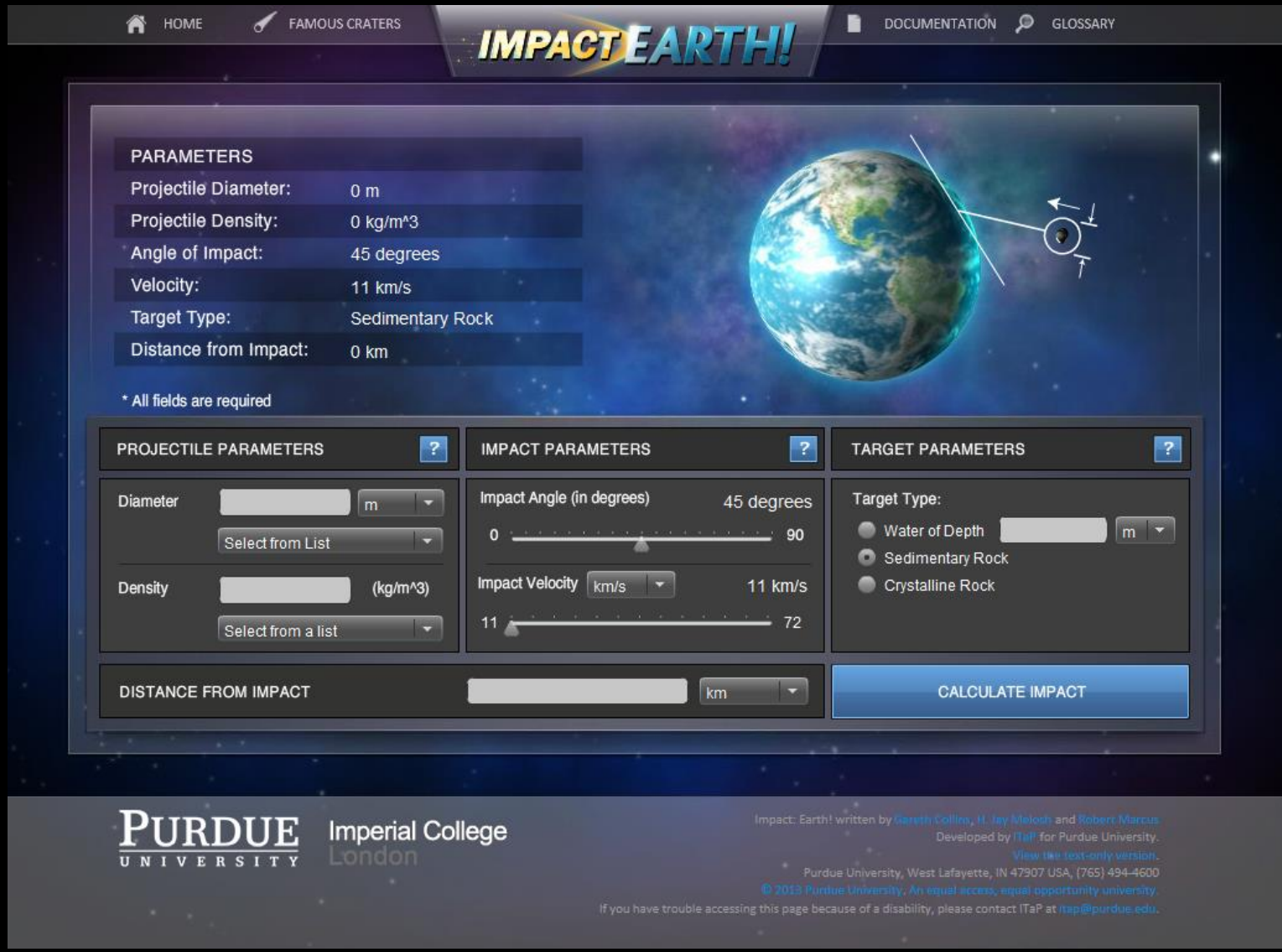
Other subject areas?

- Biology: Effects of impacts on life on Earth – mass extinctions, evolution
- Chemistry: Global climate change – massive effects on ocean and atmospheric chemistry
- Role of impacts, meteorites in history/culture?
- Even literature, art, music, poetry…

Other impact websites



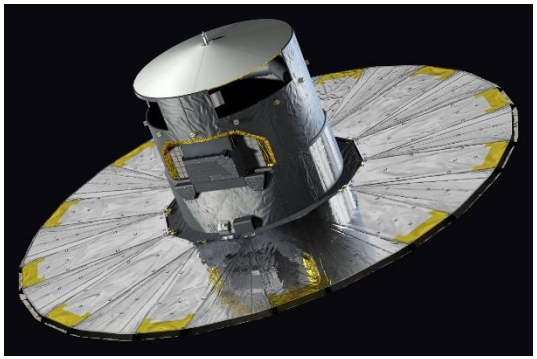
http://killerasteroids.org

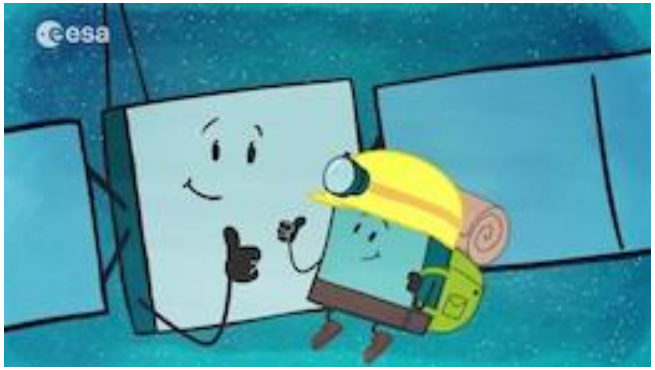


http://www.purdue.edu/impactearth

Summary

- Online resources and simulator(s)
- Teacher Guides in development
- Links with space missions (Gaia, Rosetta etc.)





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www.faulkes-telescope.com

paul.roche@faulkes-telescope.com

RUN IMPACT SIMULATOR

Down2 EARTH

BD2E BOOKLET

Welcome

Down2Earth is run by the Faulkes Telescope Project in partnership with the National Museum of Wales, supported by funding from the Science Technology Facilities Council (STFC).

The project encompasses a variety of resources for students and teachers, enabling them to learn more about the science of asteroids and comets (including their detection, orbits, deflection, effects of impacts, mass extinctions and the properties of meteorites).

Using the Impact Calculator, students can create a virtual impact on Earth by changing the size, speed and composition of an approaching asteroid or comet.

Hand specimens are available on loan to educational institutions in Wales, Scotland and Northern Ireland through our Meteorite Loan Box programme.

Useful links
Acknowledgements

RUN IMPACT SIMULATOR

Down2 EARTH

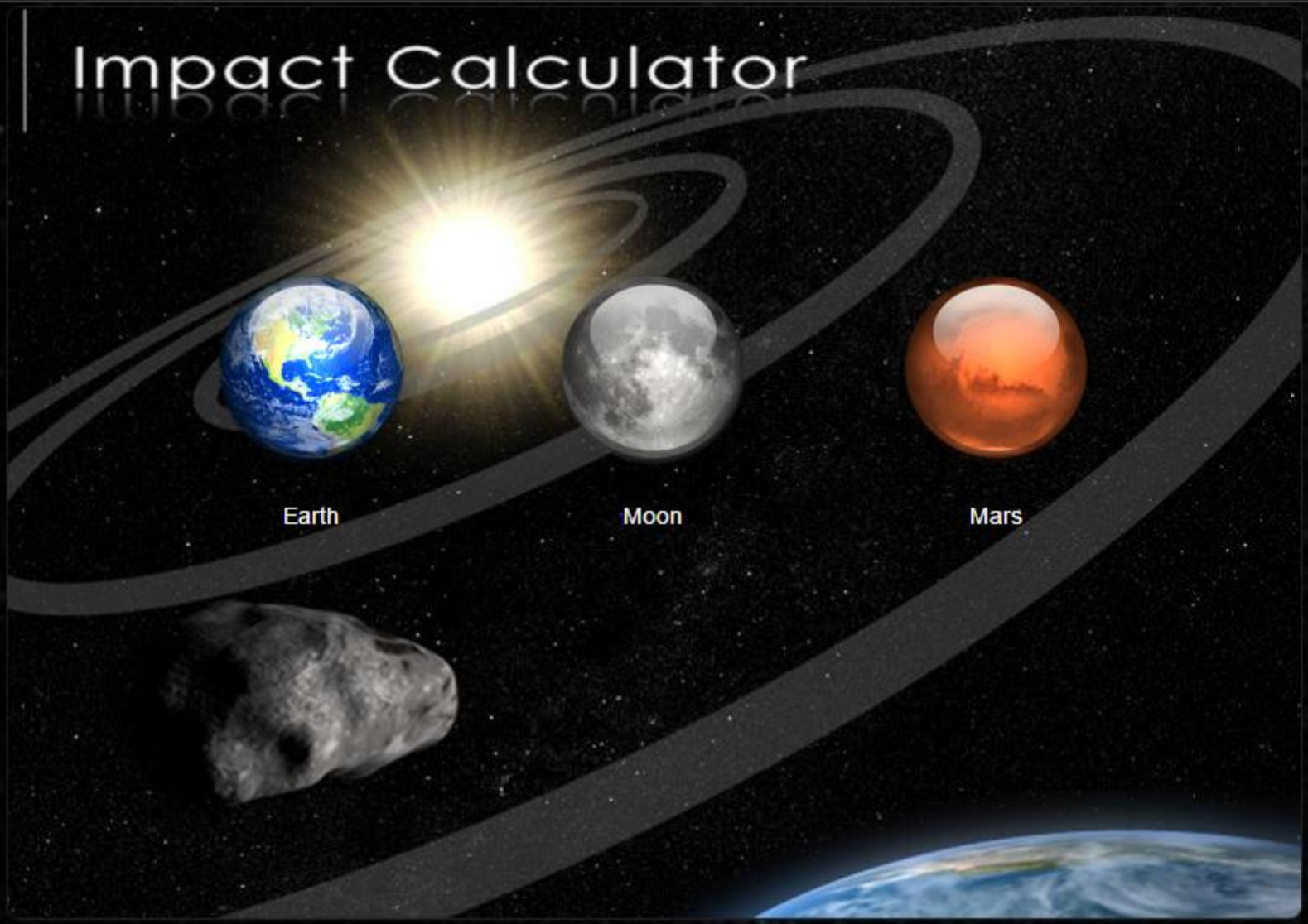
BD2E BOOKLET

Impact Calculator

Launch Impact Calculator

In February 2013 a meteorite only around 20m in diameter unexpectedly exploded over the Russian city of Chelyabinsk damaging buildings and injuring hundreds of people. Space agencies across the world are collaborating to develop the nuclear technology required to detect, track and eliminate potentially hazardous asteroids which pose a threat to our planet.

tor.down2earth.eu/planet.html?lang=en-US



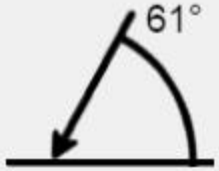
tor.down2earth.eu/input.html?lang=en&planet=Earth

ameters

Projectile diameter

7000 m

Trajectory angle



Projectile velocity

Projectile density

Porous rock

Target density

Sedimentary rock

Distance from crash site

230 km

Reset ?

Submit

tor.down2earth.eu/results.html?lang=en&dist=&planet=Earth&dist=230&diam=7000&traj=61&velo=32&pjd=2&tjd=s&wlv

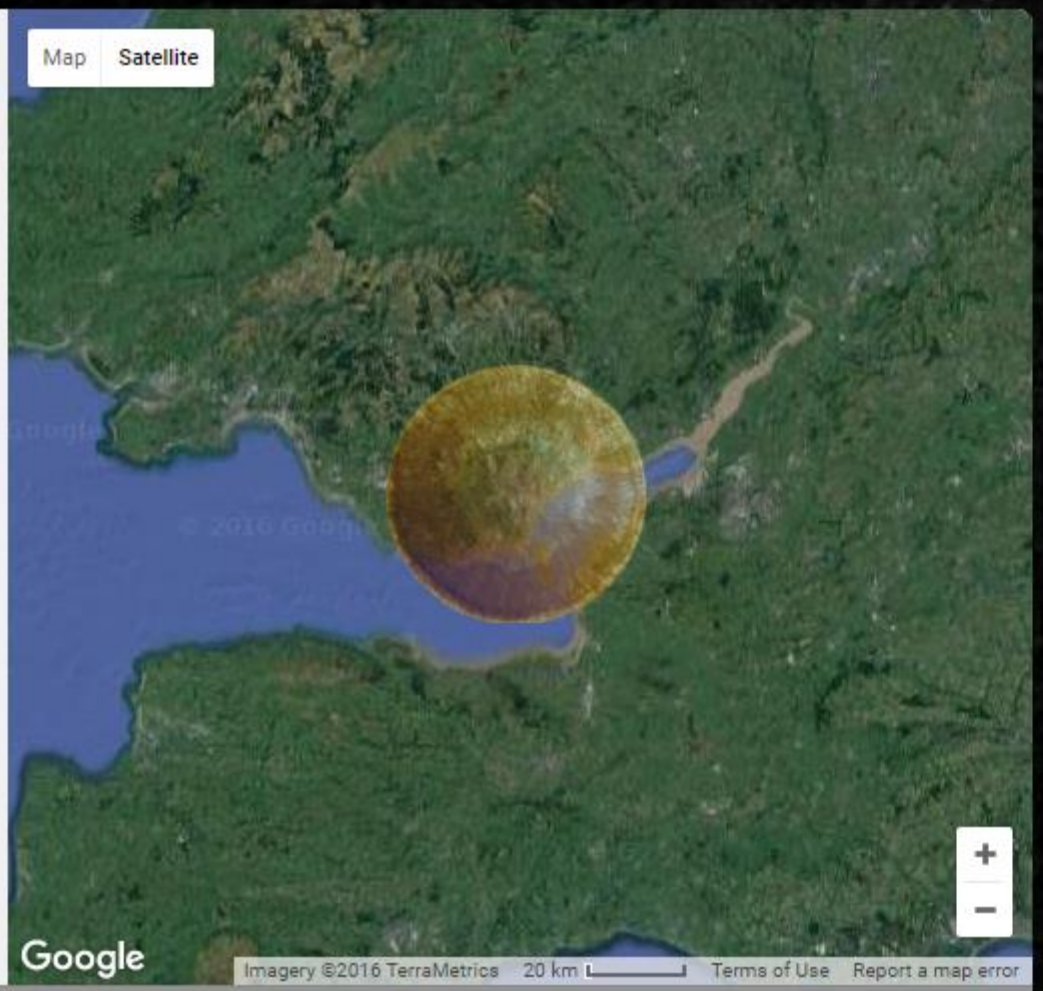
n Results › Crater size

Impact values

Parameter	Value
Crater depth	957 m
Crater width	49,359 m
Ejecta thickness	0.71 m
Break-up altitude	82,605 m
Wind velocity	940 m/s
Richter magnitude	10
Sound pulse amplitude	123 dB

Please select...

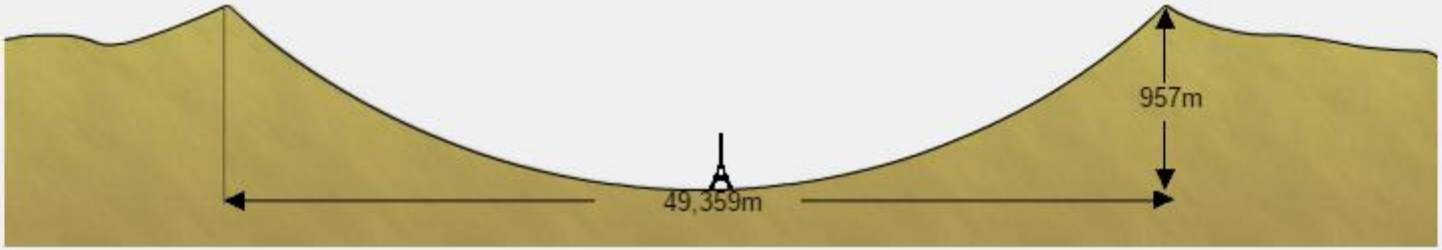
Click the map to place the crater...



Go back

Crater size | Crater depth | Data view

tor.down2earth.eu/results.html?lang=en&dist=&planet=Earth&dist=230&diam=7000&traj=61&velo=32&pjd=2&tjd=s&wlv



Select landmark: Eiffel Tower (324m)

Go back | Crater size | Crater depth | Data view

About your projectile

Parameter	Value
Mass	2.69 x 10^{14} kg
Projectile velocity	32 km/s
Trajectory angle	61°
Projectile density	1,500 kg/m^3
Target density	2,500 kg/m^3
Fireball radius	103.24 km

Damage at 230 km from crash site

Clothing ignites

Much of the body suffers third degree burns

Newspaper ignites

Plywood flames

Deciduous trees ignite

Impact energy

Parameter	Value
Kinetic energy	1.38 x 10^{23} J
Impact energy	1.38 x 10^{23} J
How frequent?	67,630,225 yrs

What happens to the impactor?

The projectile reaches the ground in a broken condition. The mass of the projectile strikes the surface at a velocity of 31.96 km/s

Is a fireball seen?

Parameter	Value
Radius	103.24 km
Peak thermal radiation at	3.23064 s
Irradiation duration	1.34 x 10^3 s
Exposure	1.18 x 10^9 J/m^2

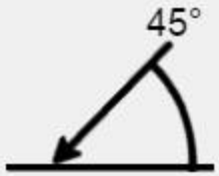
tor.down2earth.eu/input.html?lang=en&dist=230&diam=7000&traj=61&velo=32&pjd=2&planet=Mars

meters

Projectile diameter

4400 m

Trajectory angle



Projectile velocity

Projectile density

Porous rock

Target density

Igneous rock

Please select...

Igneous rock

Reset ?

Submit

tor.down2earth.eu/results.html?lang=en&diam=4400&traj=45&velo=30&pjd=2&tjd=i&planet=Mars

n Results › Crater size

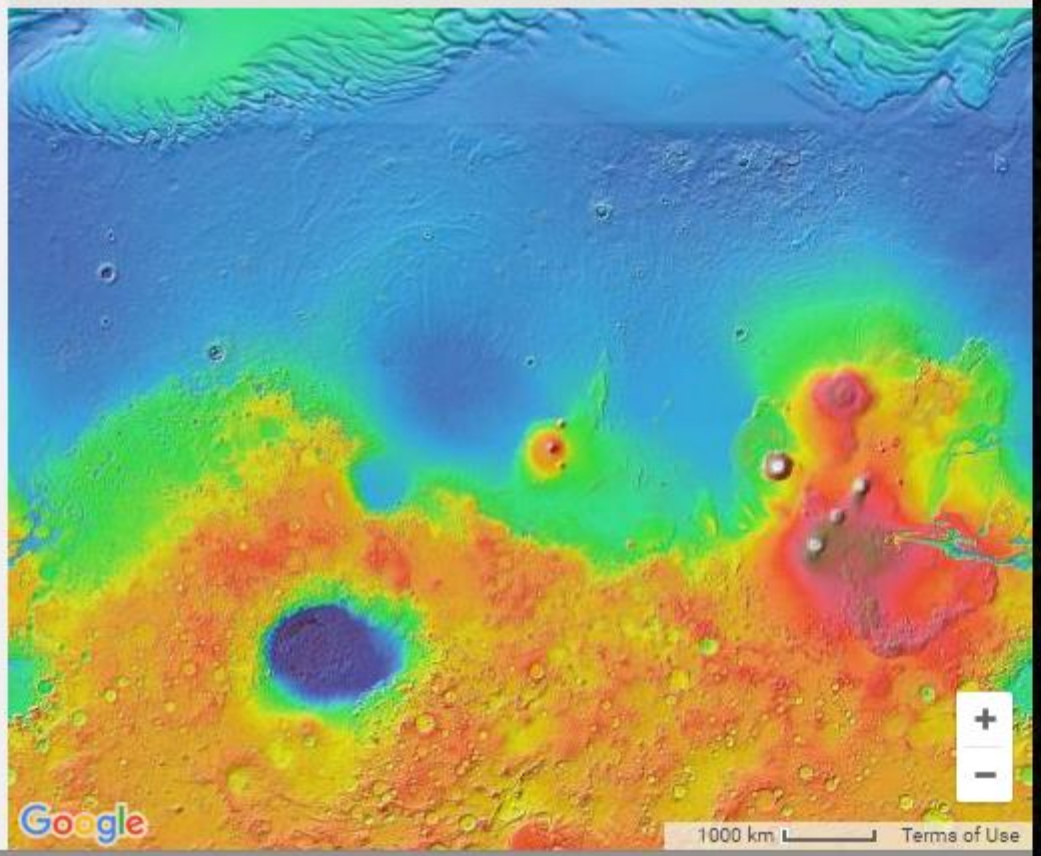
Impact values

Parameter	Value
Crater depth	624 m
Crater width	11,916 m
Ejecta thickness	0.00 m
Break-up altitude	26,335 m
Wind velocity	0 m/s
Richter magnitude	9
Sound pulse amplitude	0 dB

Please Select Crater:

Please select...

Click the map to place the crater...



Go back

Crater size | Crater depth | Data view

About your projectile

Parameter	Value
Mass	6.69 x 10^{13} kg
Projectile velocity	30 km/s
Trajectory angle	45°
Projectile density	1,500 kg/m^3
Target density	2,750 kg/m^3
Fireball radius	62.22 km

Impact energy

Parameter	Value
Kinetic energy	3.01 x 10^{22} J
Impact energy	3.01 x 10^{22} J
How frequent?	20,949,604 yrs

What happens to the impactor?

The projectile reaches the ground in a broken condition. The mass of the projectile strikes the surface at a velocity of 30.00 km/s

Is a fireball seen?

Parameter	Value
Radius	62.22 km
Peak thermal radiation at	2.07399 s
Irradiation duration	8.08 x 10^{2} s