Hypervelocity Impacts & Habitability

I. Observations
II. Simulations
III. Experiments

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Impacts in the Solar System: Disruptive

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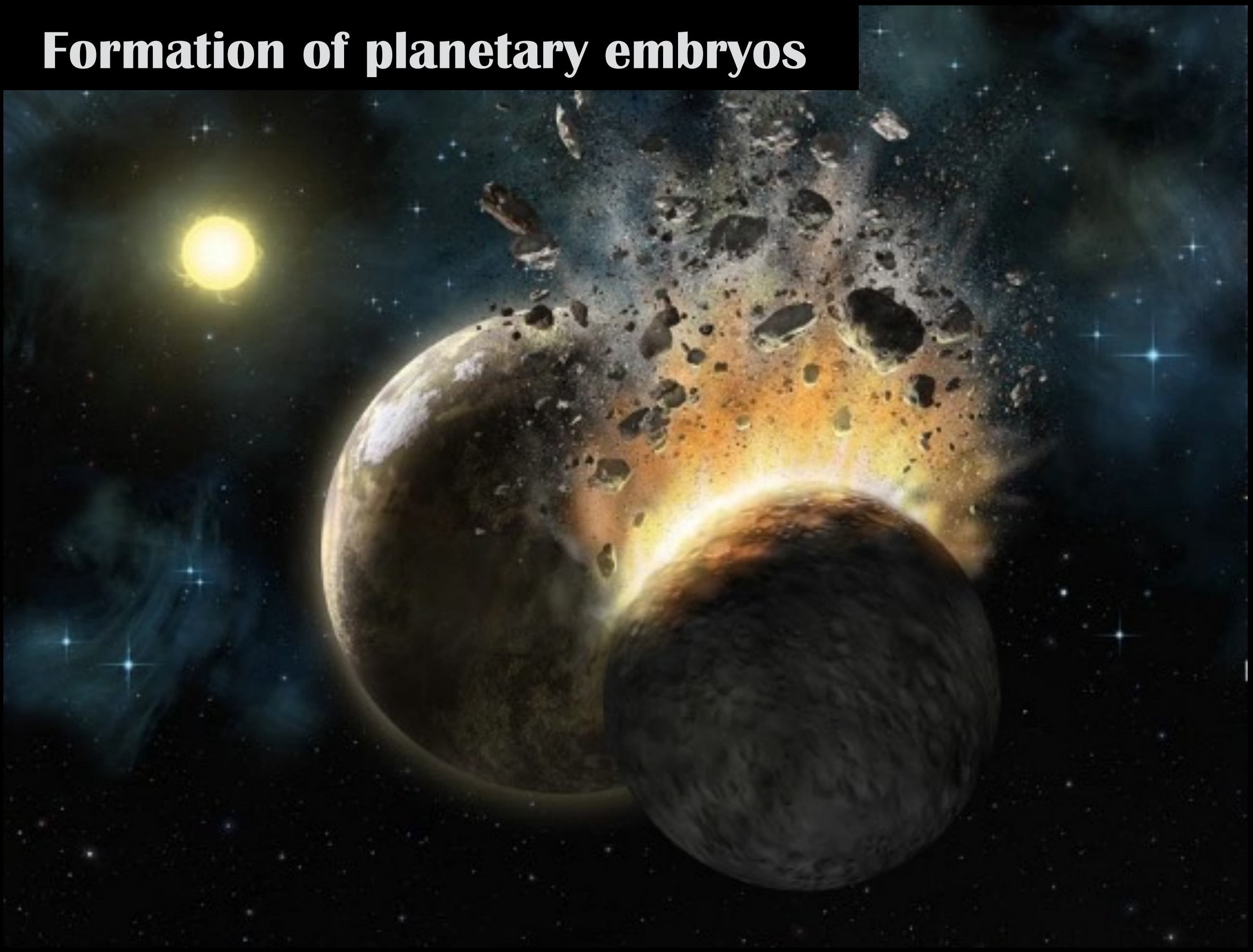
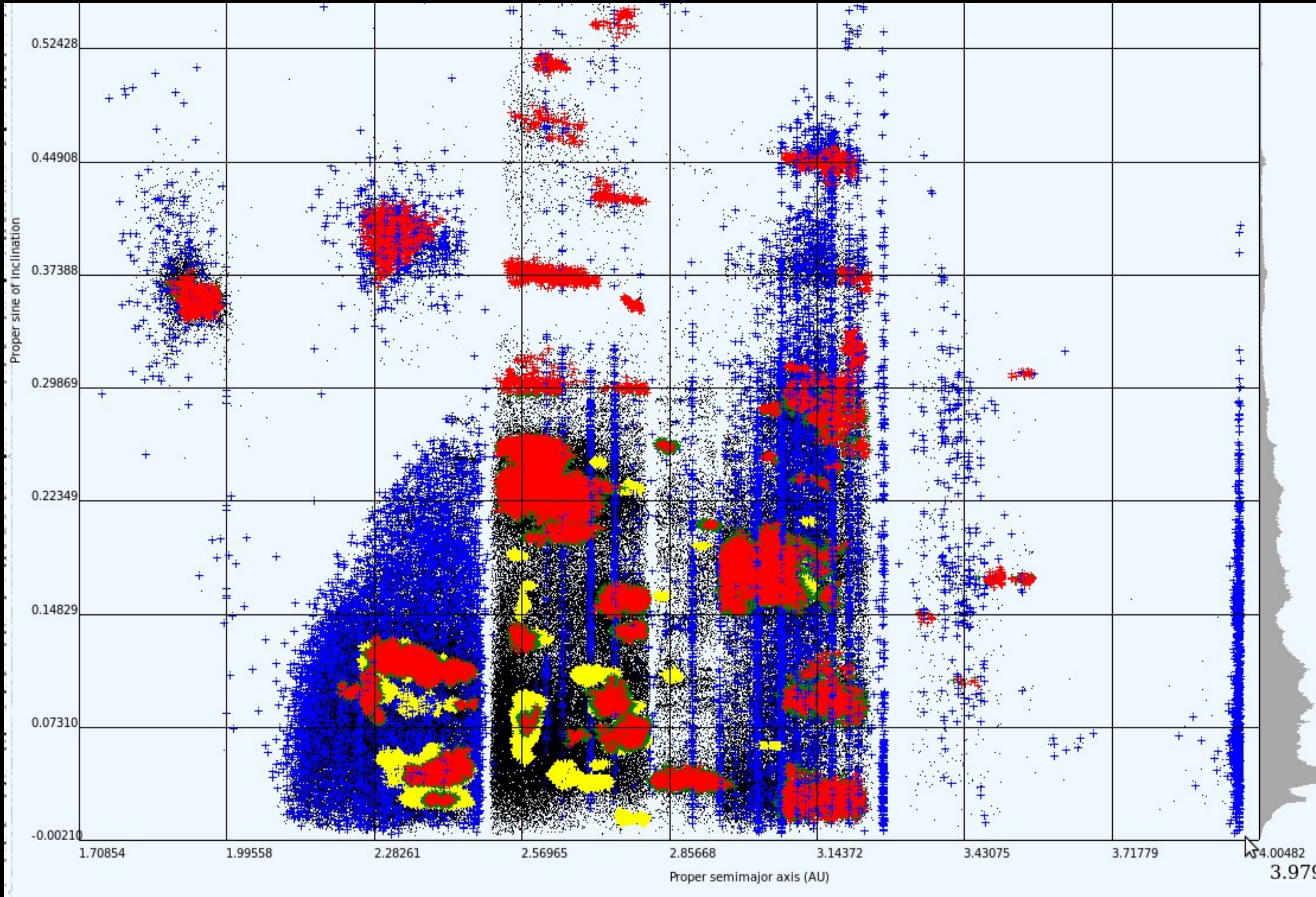
Formation of planetary embryos

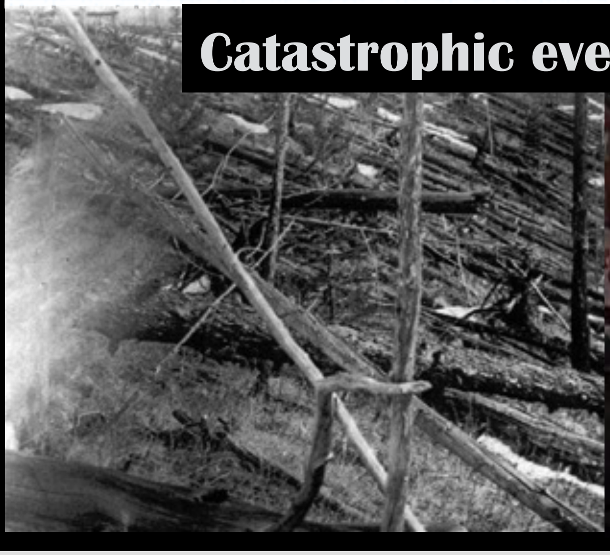


Broke the planetesimals creating the asteroid families (130, AstDys)



Cratering & regolith production Horz&Cintala 1997

Catastrophic events on Earth



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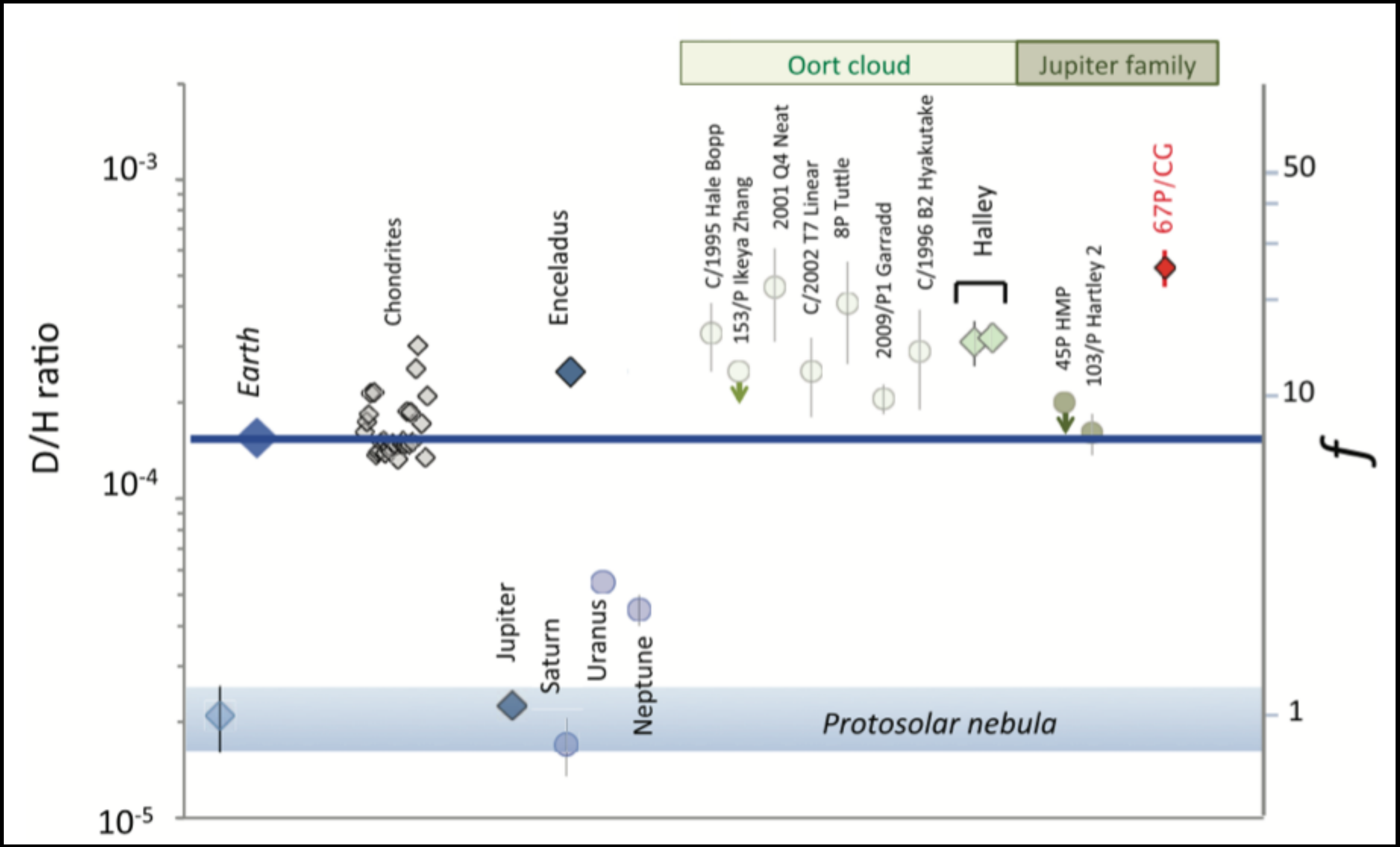
Impacts in the Solar System: Productive

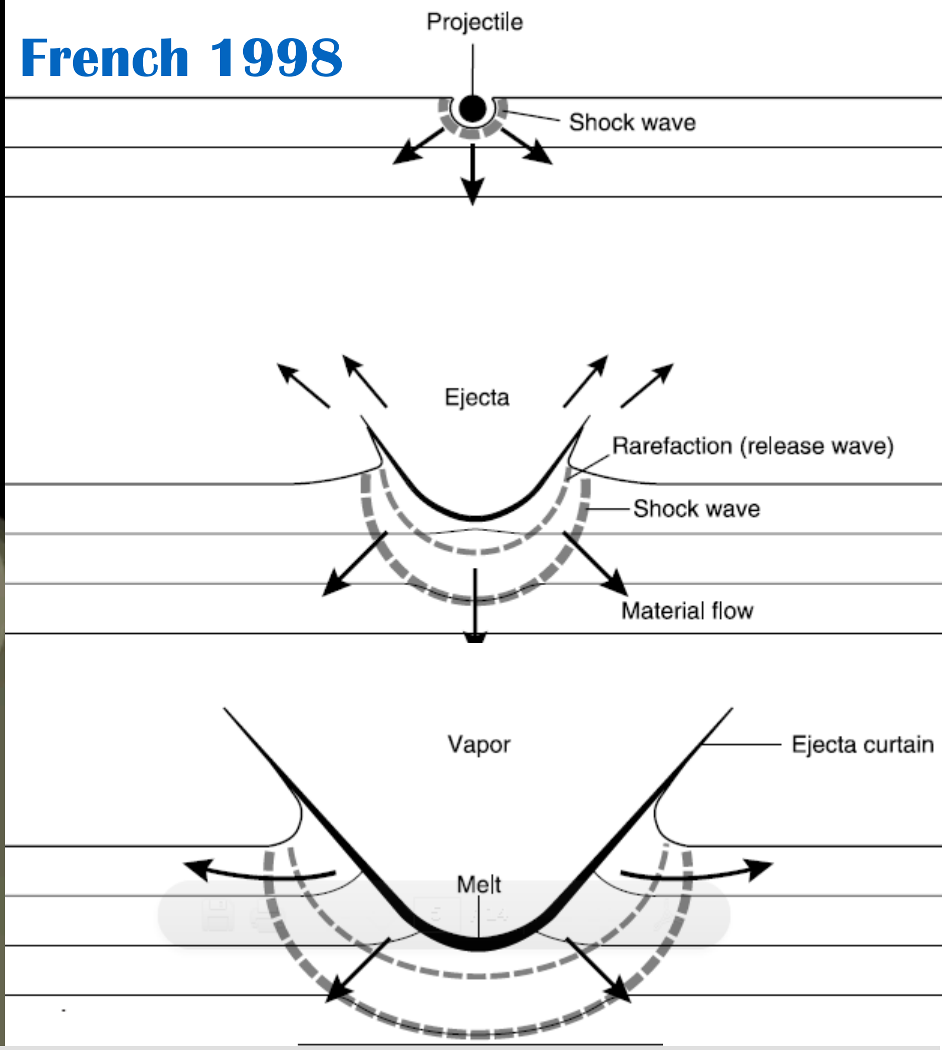
Water delivery on Earth



Altwegg+2015

Impact Event

Credits:
Stephen Schwartz
University of Arizona



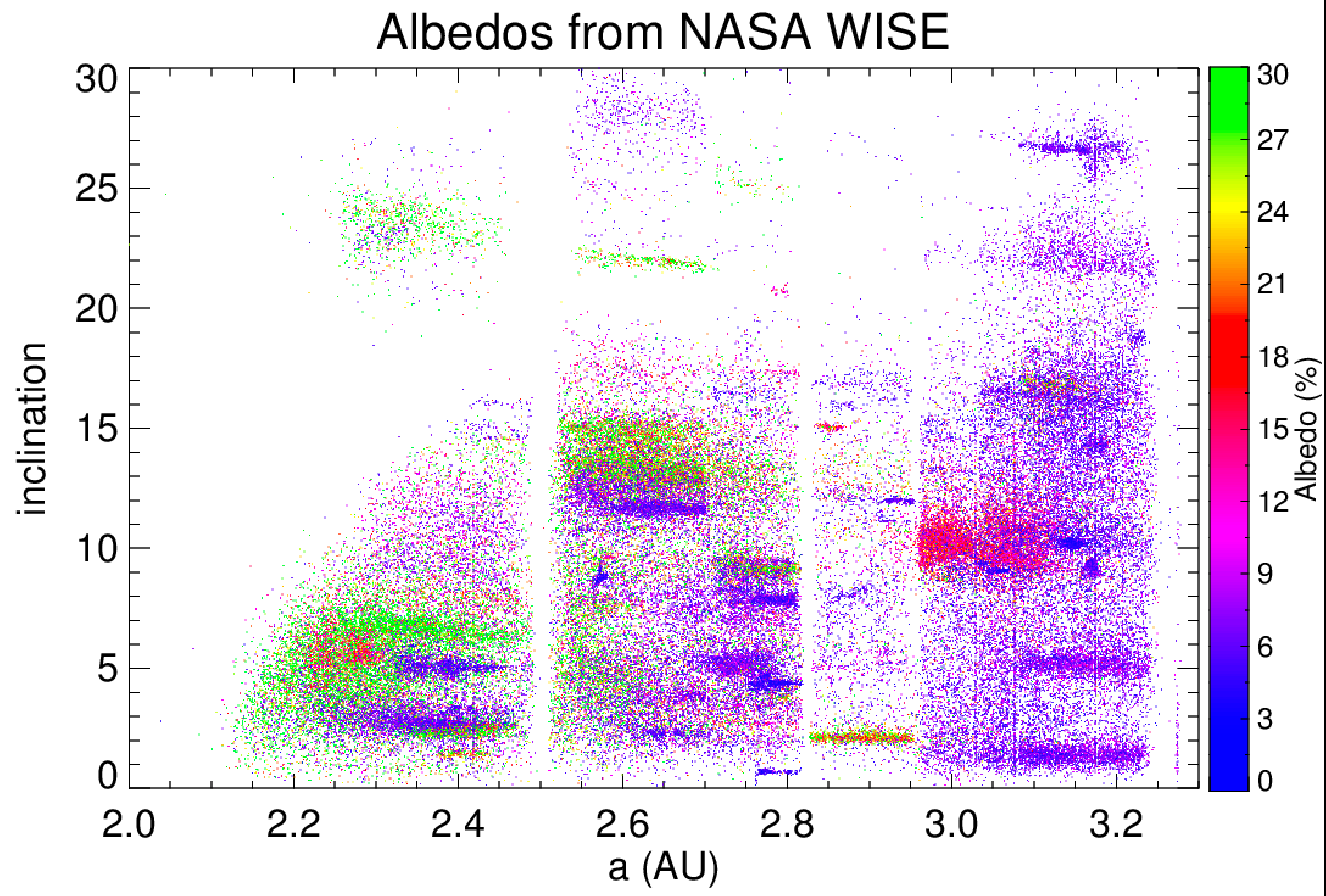
A ‘Canterbury tale’: 1st flash (?) 1178 AD

esa

First witnessing of an impact on another body?

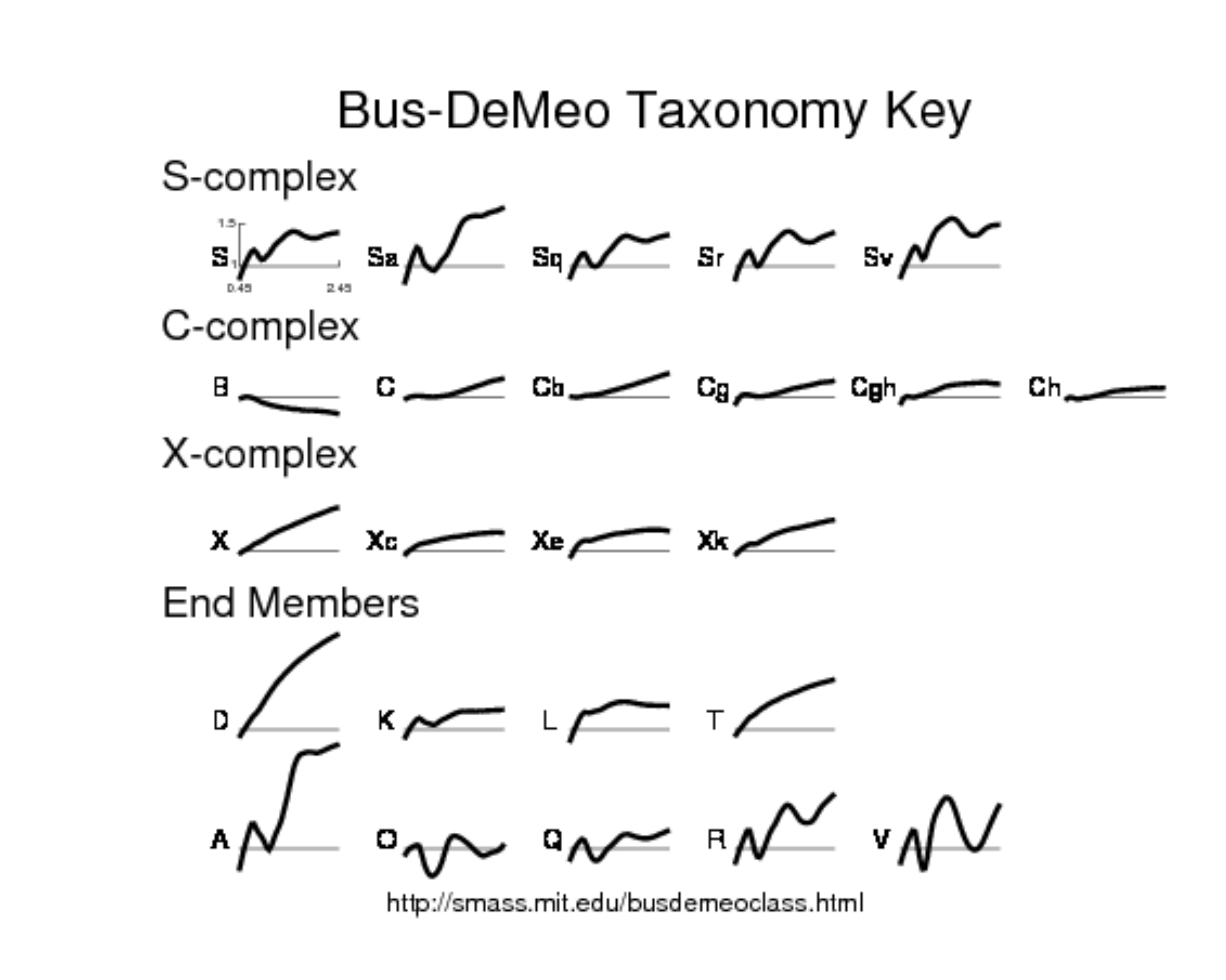
Impactors: Asteroids and Comets

Credits:
Marco Delbo'
Observatory of Nice

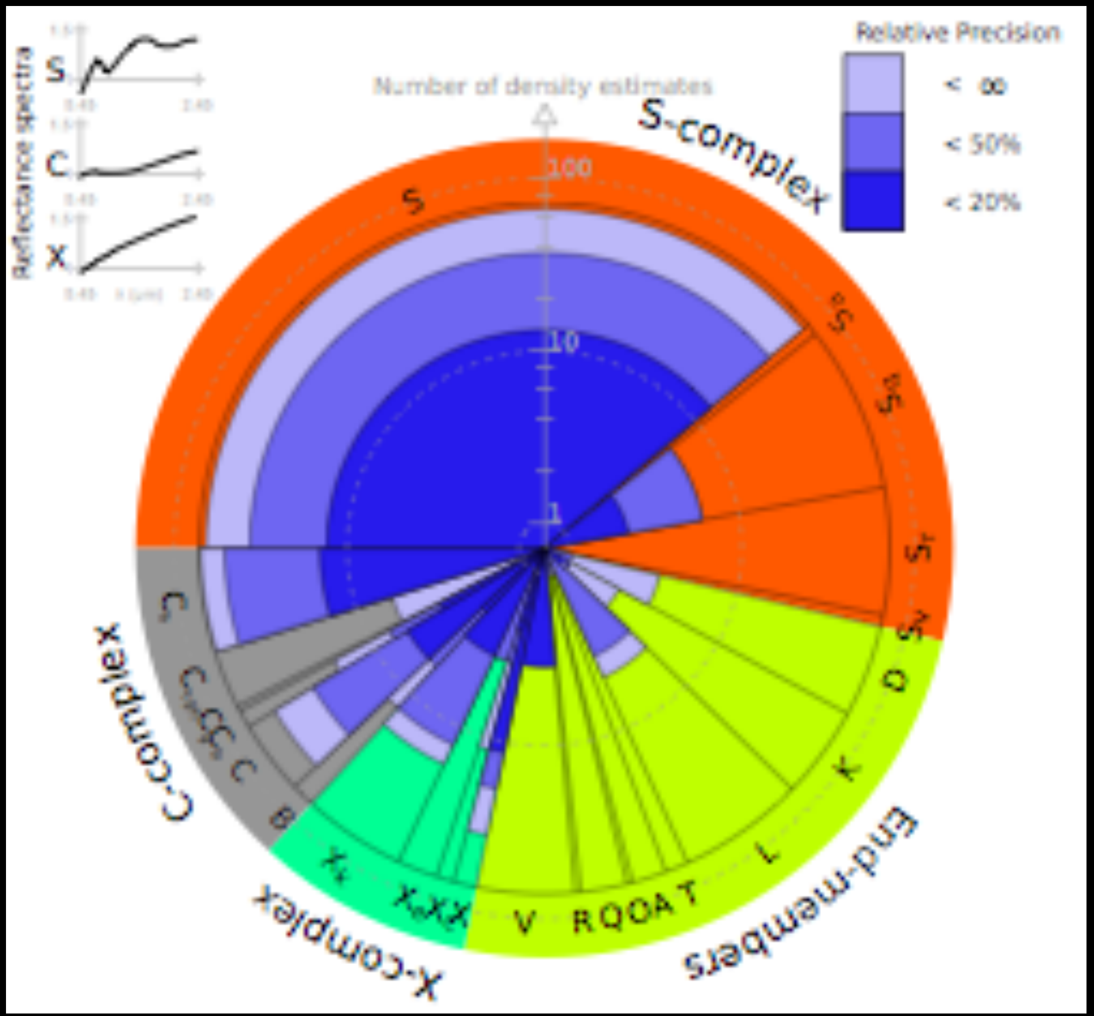


Impactors: Asteroids

See talk of Marco Delbo'
Wednesday Session 8

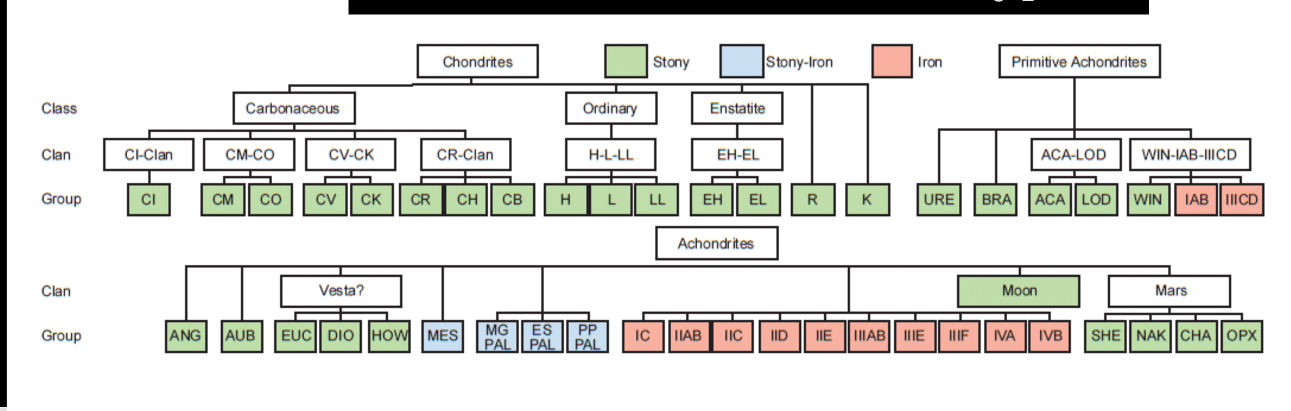


Different spectral types indicate different composition



Spectral variations with phase

Match with meteorite types



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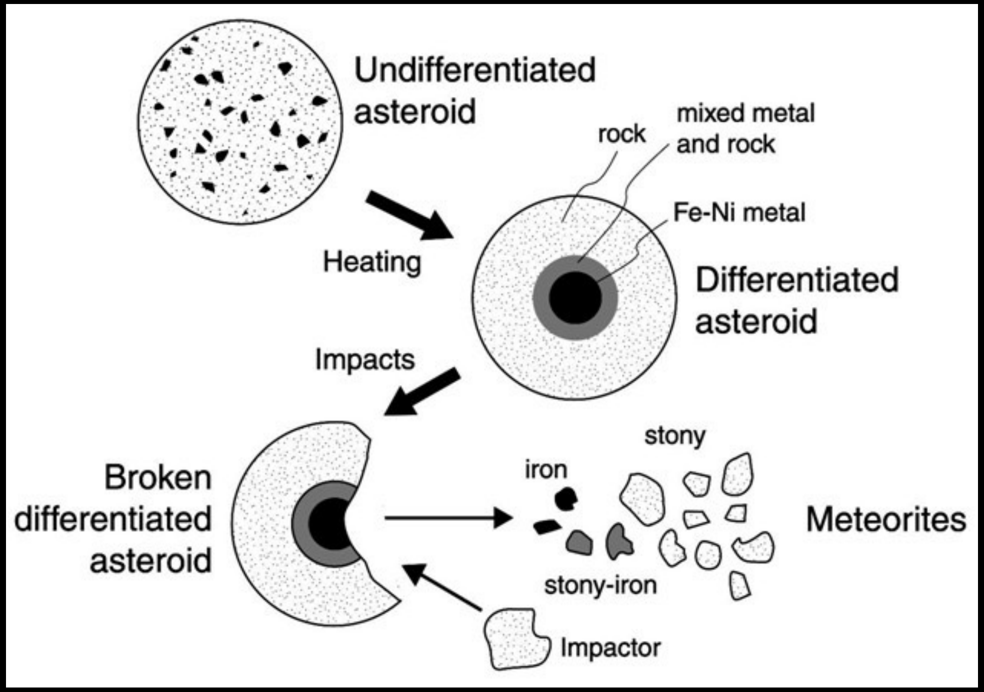
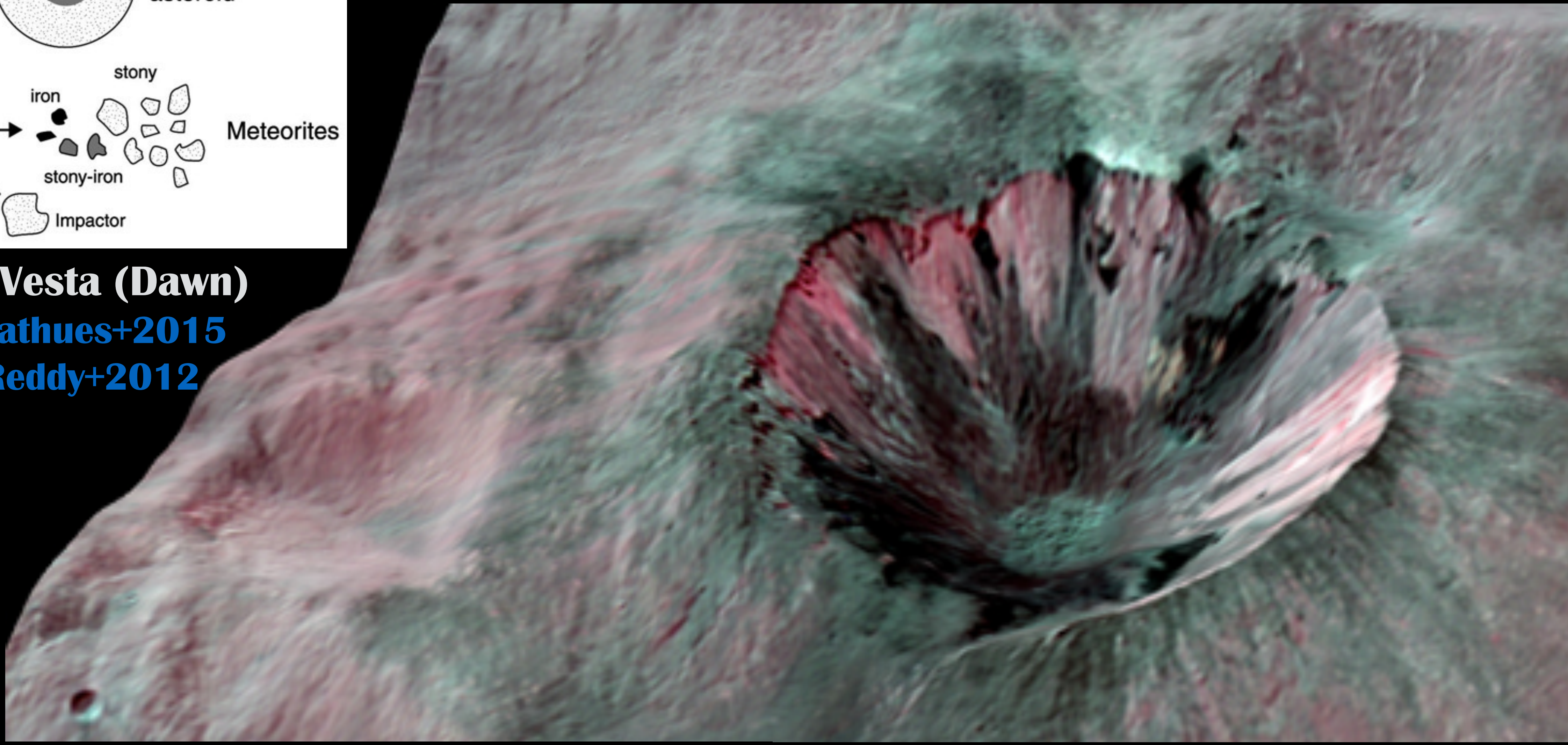
Asteroid Surfaces: Vesta



Vesta is a differentiated asteroid, the source of HED meteorites.

Dark material on Vesta (Dawn)

Palomba+2015, Nathues+2015
McCord+2012, Reddy+2012



There was a debate about the
origin of the dark regions (olivine).
1.~~endogenous~~
2.exogenous

The impacts related to this craters could not excavate so deep to reach the olivine mantle.

Turrini+2014,2016

Asteroid Surfaces: Vesta

Signatures of Hydration on Vesta (Dawn)
Prettyman+2012, De Sanctis+2012, Denevi +2012

Is the contamination effective?

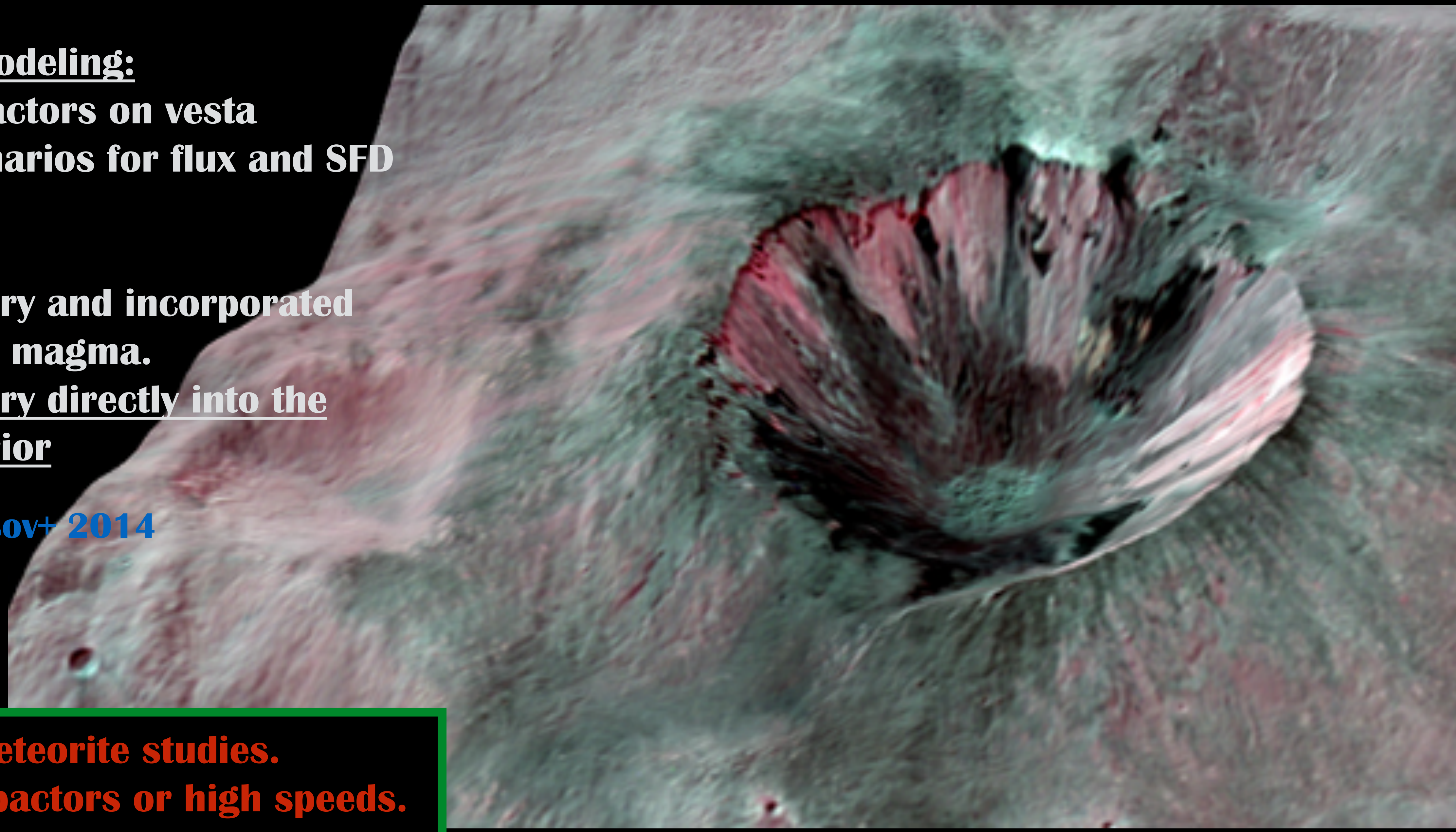
Some more modeling:

- 1-2 km impactors on vesta
- Several scenarios for flux and SFD

Possibilities:

- Water delivery and incorporated into eucritic magma.
- Water delivery directly into the molten interior

Turrini&Svetsov+ 2014

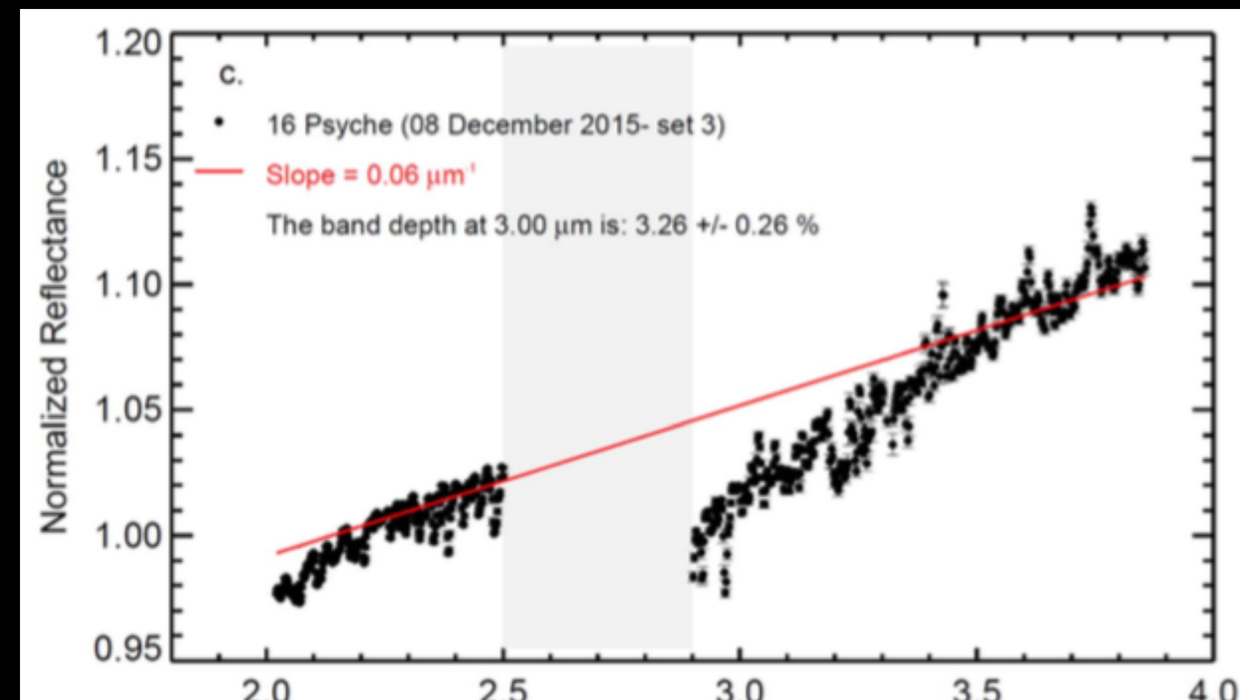


Supported by meteorite studies.
Need for big impactors or high speeds.
What is the influence of the T?

Asteroid Surfaces: Psyche

What we know:
- M-type (Xk-type, Bus-DeMeo)
- no sign of family around Davis+1999
- high radar albedo Shepard+2010
- Deff = 226 km Hanus+2017, Shepard+2017
- 3.5 < ρ < 4.5 g/cc Fienga+2014, Viswanathan+2017
- 3 µm band observed > hydration

Scenarios:
- stony/Fe with 0% macroporosity
- Fe/Ni with 55% macroporosity



Takir+ 2017

Elkins-Tanton+2016,2017

Asteroid Surfaces: Psyche

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Is the contamination effective?

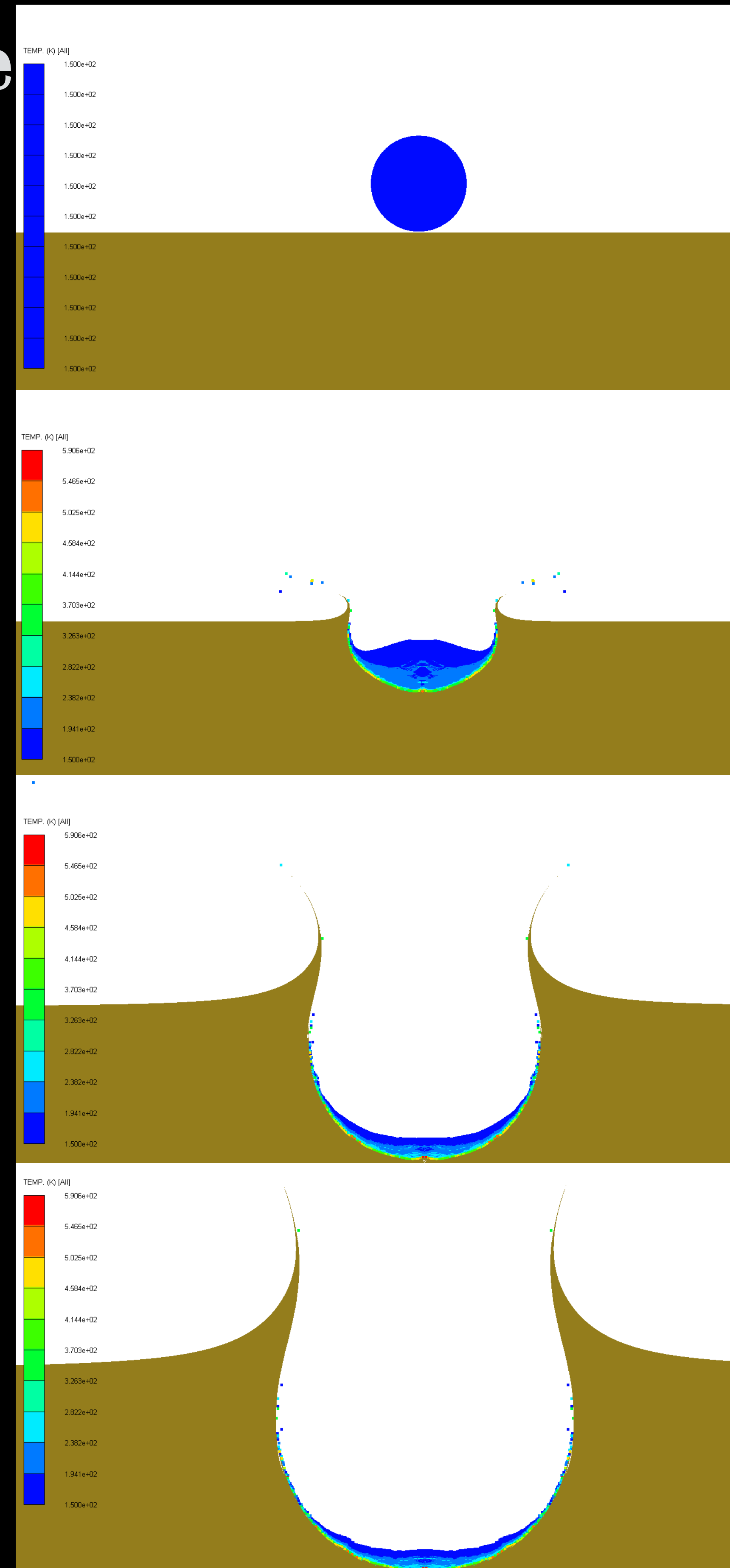
Assume Fe/Ni core of a differentiated asteroid.

Exogenous hydration.

Modeling indicates as source the nearby asteroid families (Themis & Hygiea).
Avdellidou+(revision)

Spectral signature matches with the hydration found in both families.

Takir+2012,2017



Hydrocode Simulations:

- stony/icy projectile
- Fe/Ni target

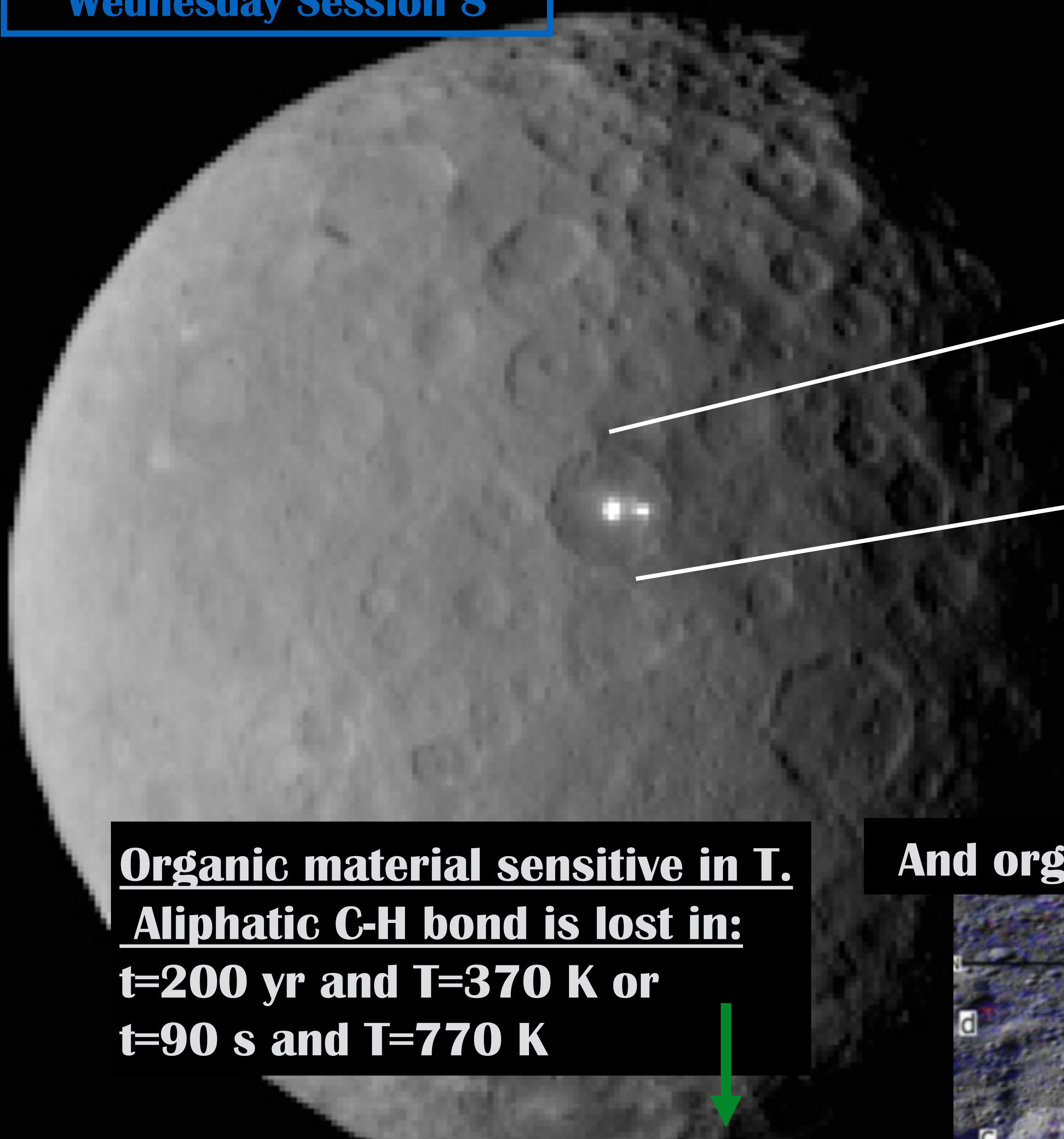
Yet the outcome depends on the T.

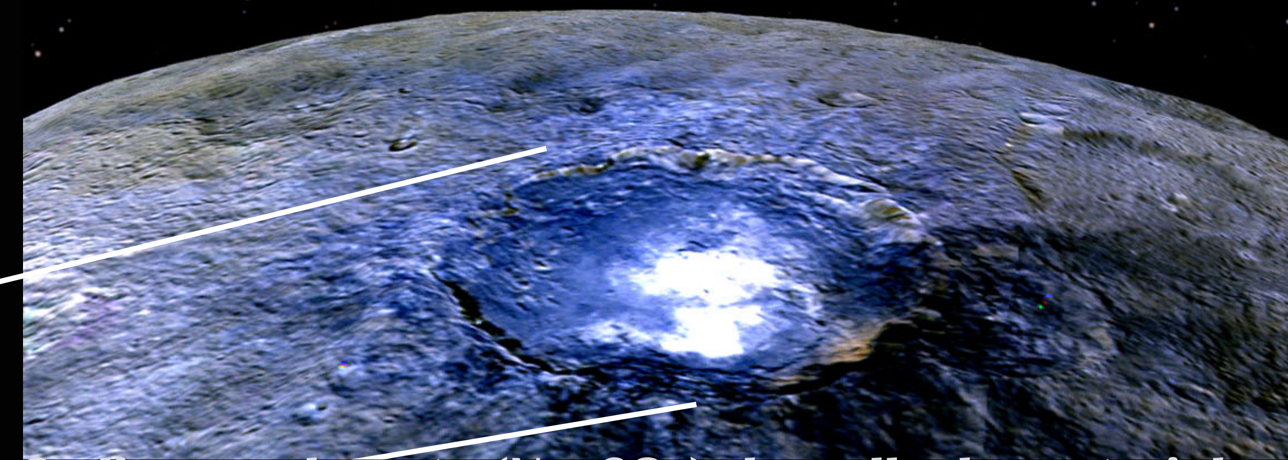
Credits:
Mark C. Price
University of Kent

Asteroid Surfaces: Ceres

See talk of M.C.De Sanctis
Wednesday Session 8

DAWN reveals the bright spots (Occator crater).
De Sanctis+2016





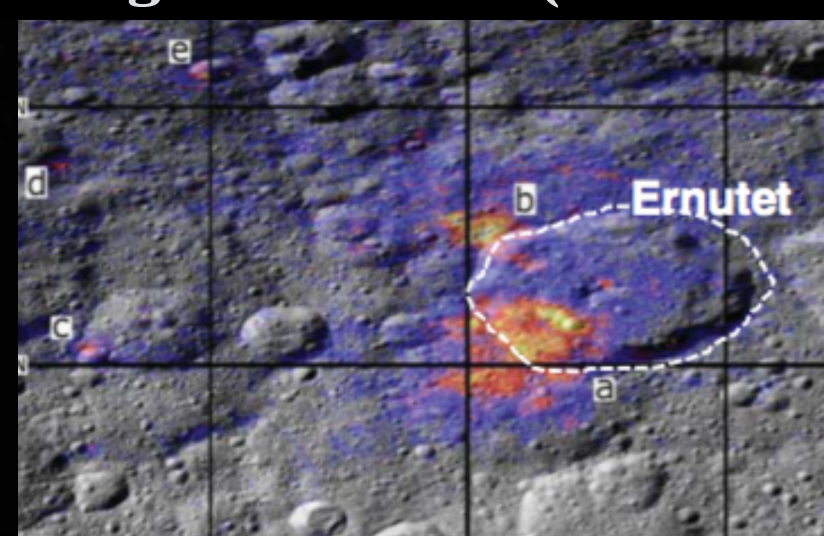
Sodium carbonate (Na_2CO_3), low-albedo material, illite or montmorillonite, small quantity of ammonium-bearing species

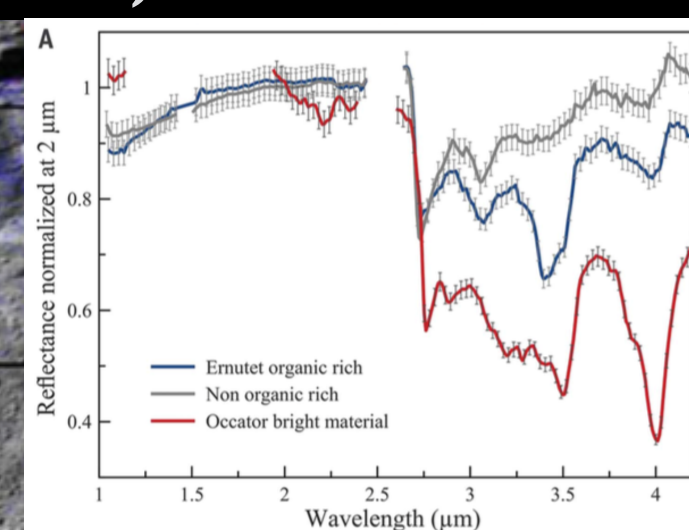
Was it revealed or formed due to the impact process?

Organic material sensitive in T.
Aliphatic C-H bond is lost in:
t=200 yr and T=370 K or
t=90 s and T=770 K

Energetic impacts are not good (e.g. cometary origin)!

And organic material (Ernutet crater)! De Sanctis+2017





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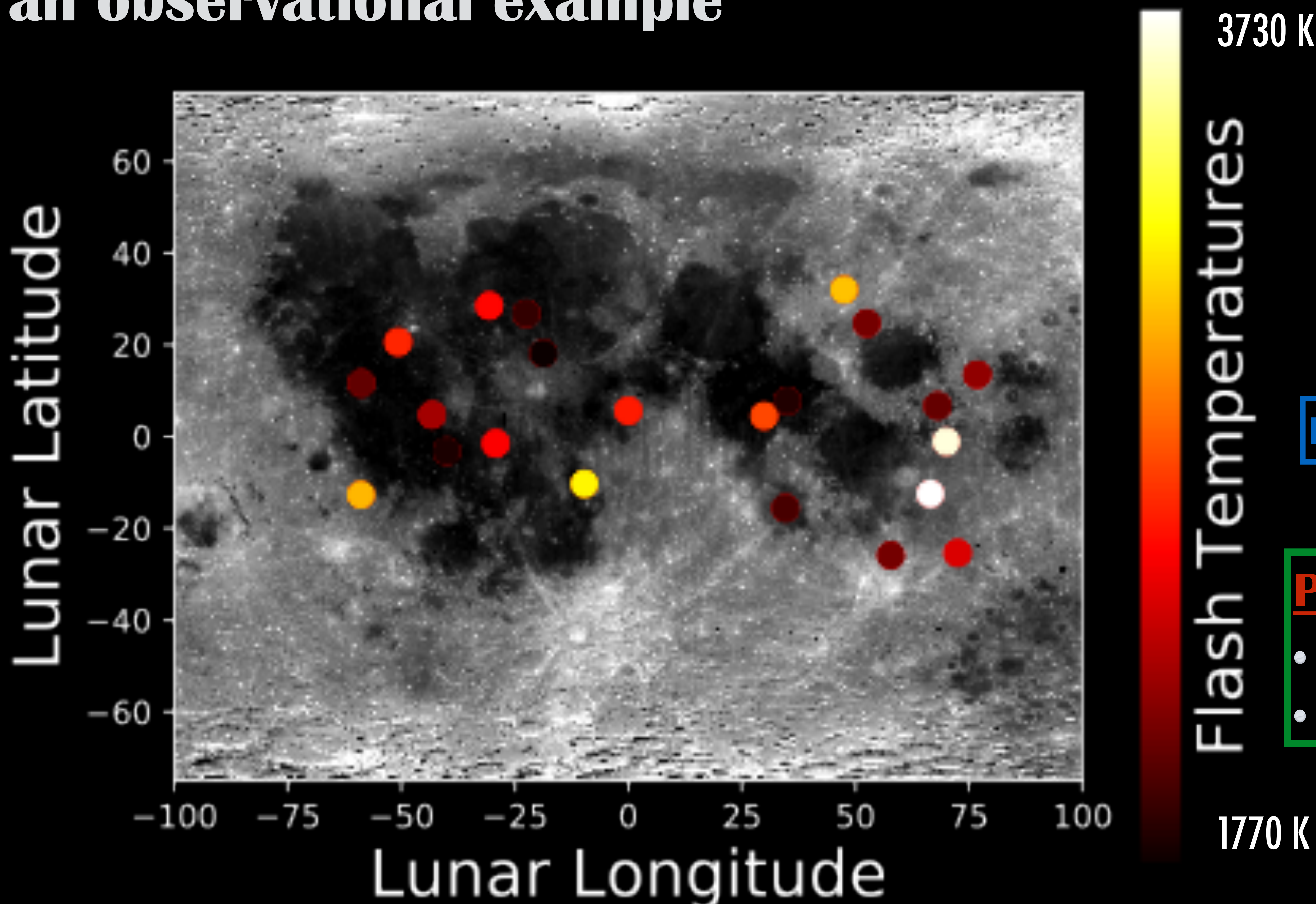
Impacts & Temperatures:
an observational example



Avdellidou+(in prep.)

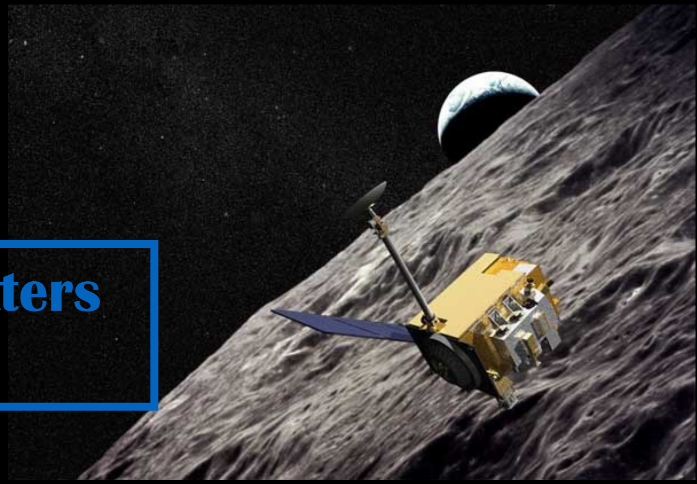
Lunar monitoring campaigns work towards the understanding of impact physics.

Data from NELIOTA project

Plume T is affected by:

- **target's material**
- **target's T**

Search for the craters using LRO data



Impacts & Temperatures:
an experimental example

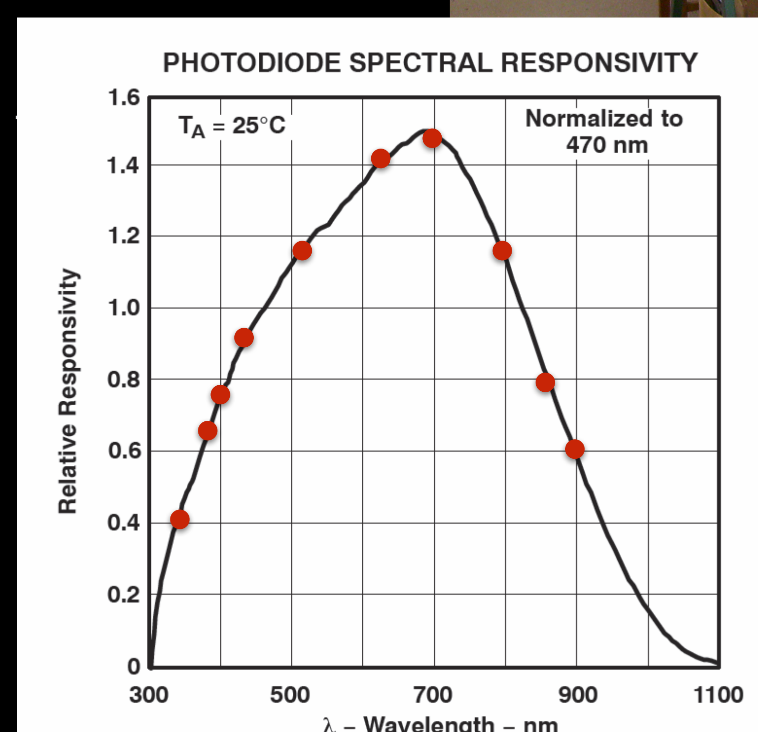
Small-scale work is needed to understand the observations.

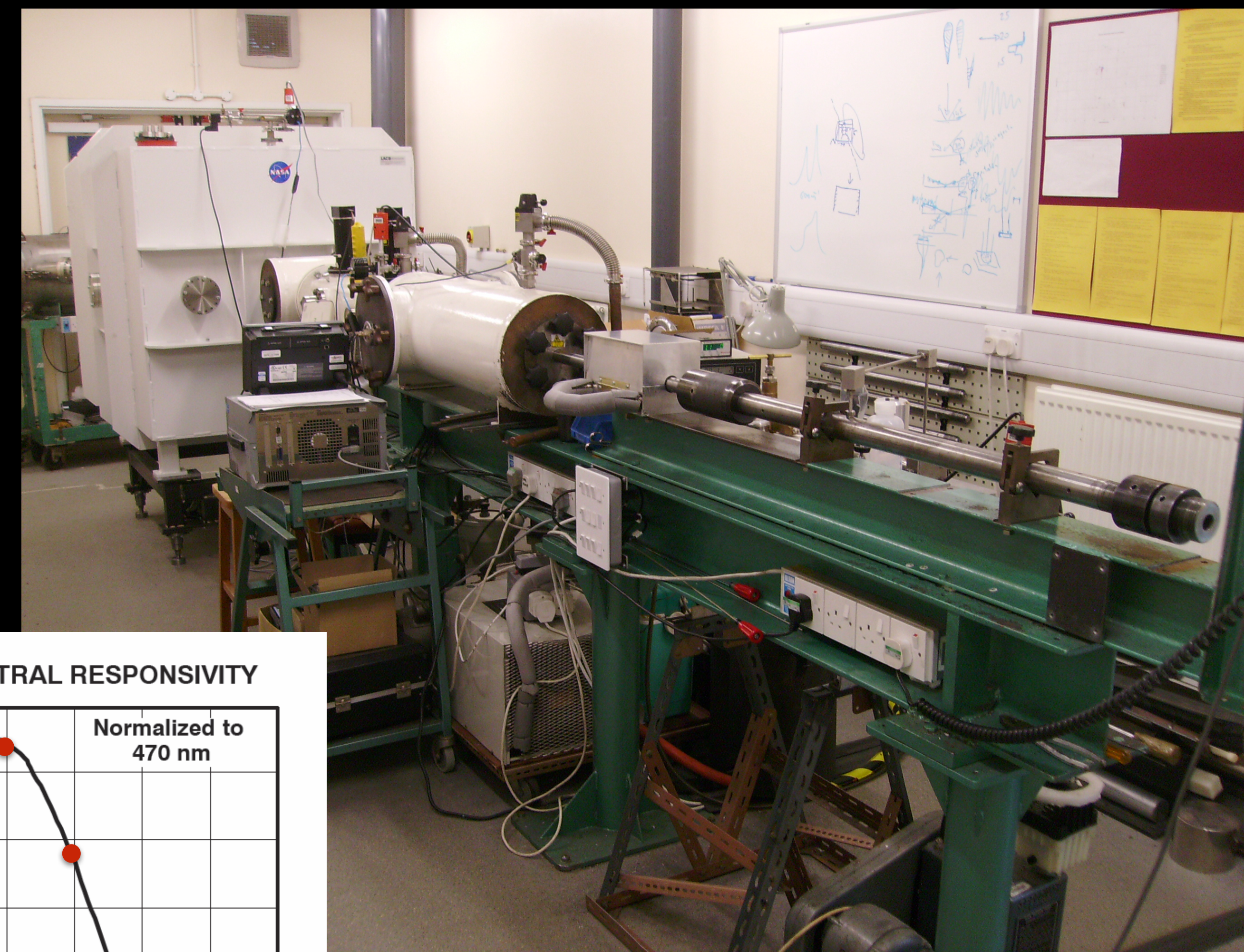
University of Kent

Campaign:
- lunar simulant (maria regolith)
- basalt, still impactor
- V representative of the belt
- photodetectors and spectrum of the ejecta

Expectations:
- T variability with impact properties (speed, materials)
- Towards the understanding of energy partitioning.
- Ejecta cooling phase

Avdellidou+(2016,2017)





Credits: Impact Lab, University of Kent

litho-Panspermia...

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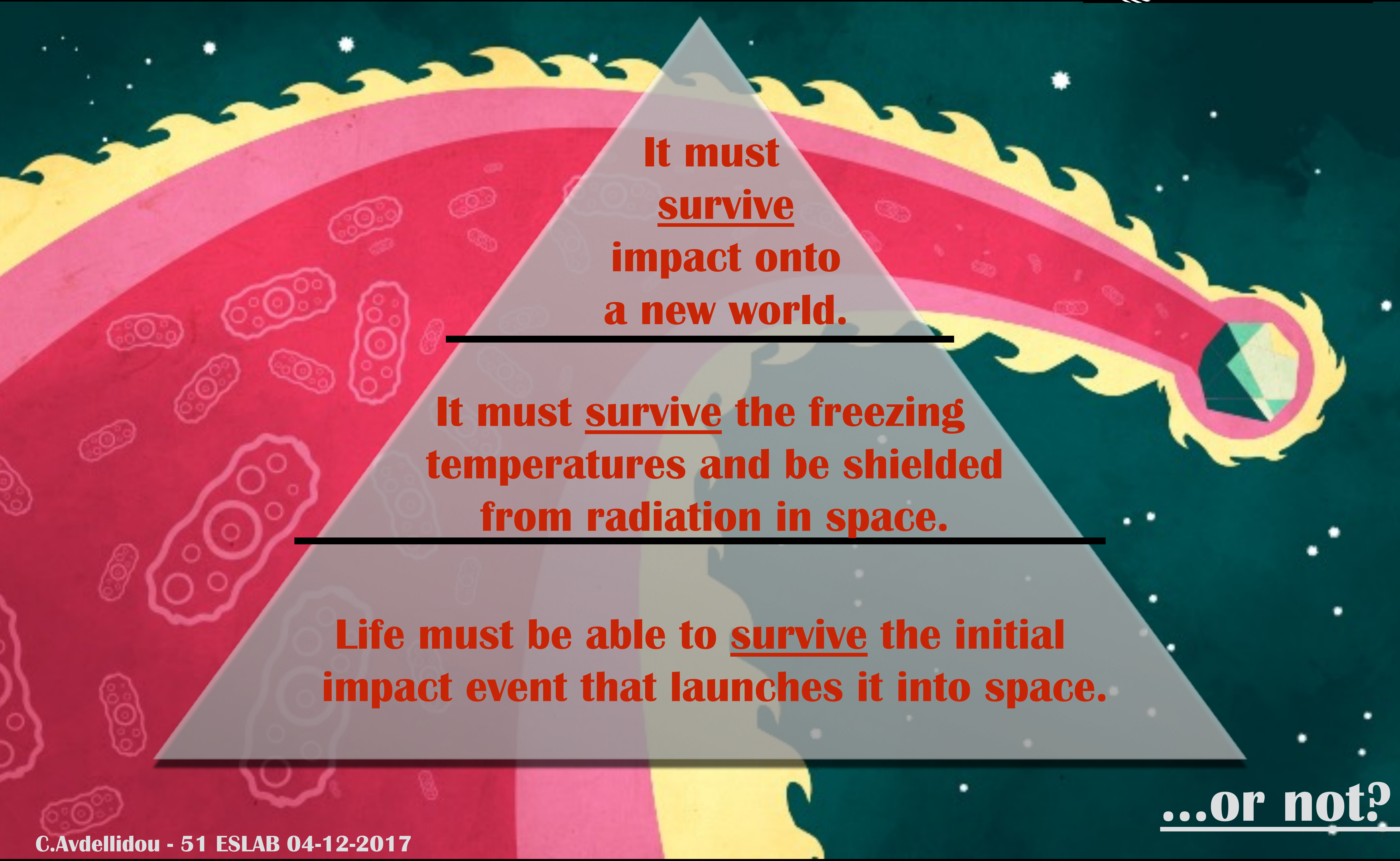

It must
survive
impact onto
a new world.

It must **survive** the freezing temperatures and be shielded from radiation in space.

Life must be able to **survive** the initial impact event that launches it into space.

...or not?

Survivability & Synthesis in Lab

Organics Burchel+2014
(anthracene, Quink, stearic acid)

- Targets: sand, water, ice
- V=2–4.2 km/s
- 45&90 deg angle
- Pmax= 16 GPa
- anthracene does not survive

Bacteria
(Rhodococcus erythropolis, Bacillis subtilis)
Burchel+(1999,2001,2004)

- Targets: agar, ice
- V=0.35–5.4 km/s
- Pmax= 78 GPa
- P= 10^{-4} – 10^{-7}

Yeast Price+2013

- V=1–7.4 km/s
- Pmax= 45 GPa
- P= 50%—0.1%

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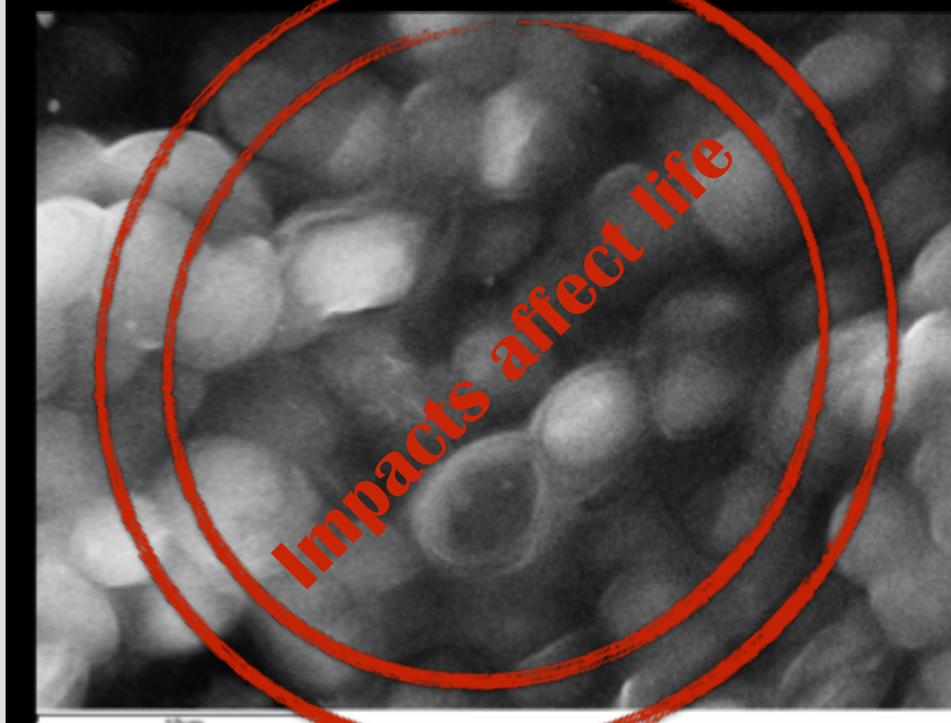
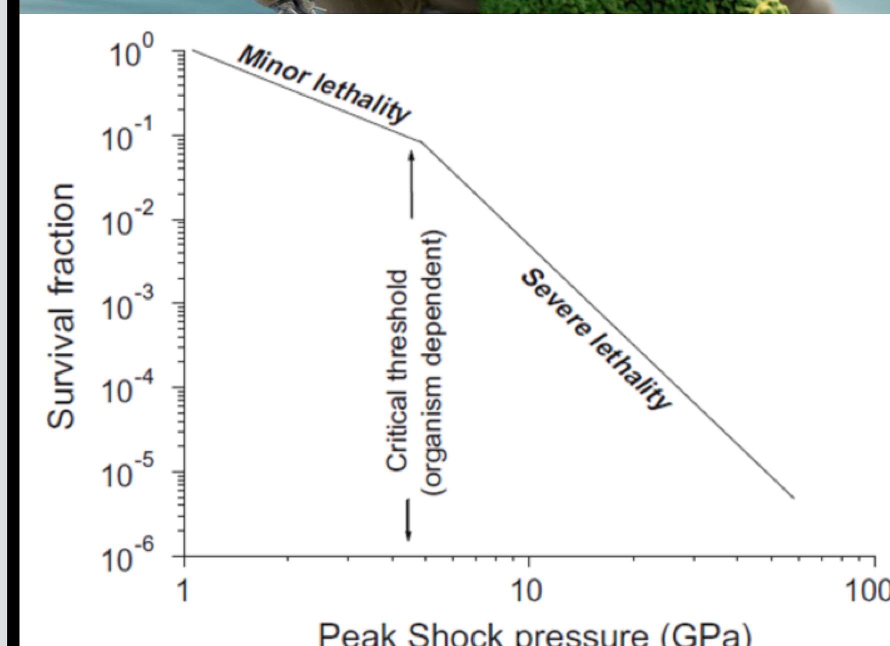
Nannochloropsis Phytoplancton Pasini+2014

- Target: water
- V= 1.3—6.3 km/c
- Pmax= 3—23 GPa
- Survival up to 4 km/s



Tardigrades Pasini+2014

- Target: water
- V= 0.3—5.5 km/c



Shock Synthesis Martins+2013

- still projectile on icy target (NH_4OH, CO_2 and CH_3OH)
- V=7 km/s
- Pmax= 50 GPa
- glycine, D- and L- alanine etc

Conclusions

Small bodies are essential in the concept: Impacts&Habitability.

Thorough examination of their physical properties is needed.
(e.g. carbonaceous, hydrated, water rich etc.)

Small bodies as carriers of life/organics.

Impacts destroy life/organics: temperature—pressure.

Impacts can create organics or generally a habitable environment.

Survivability at 10s of GPa. Planetary impacts need higher speeds.

As the ancient Greeks said:
There is nothing bad that does not bring something good!

Message