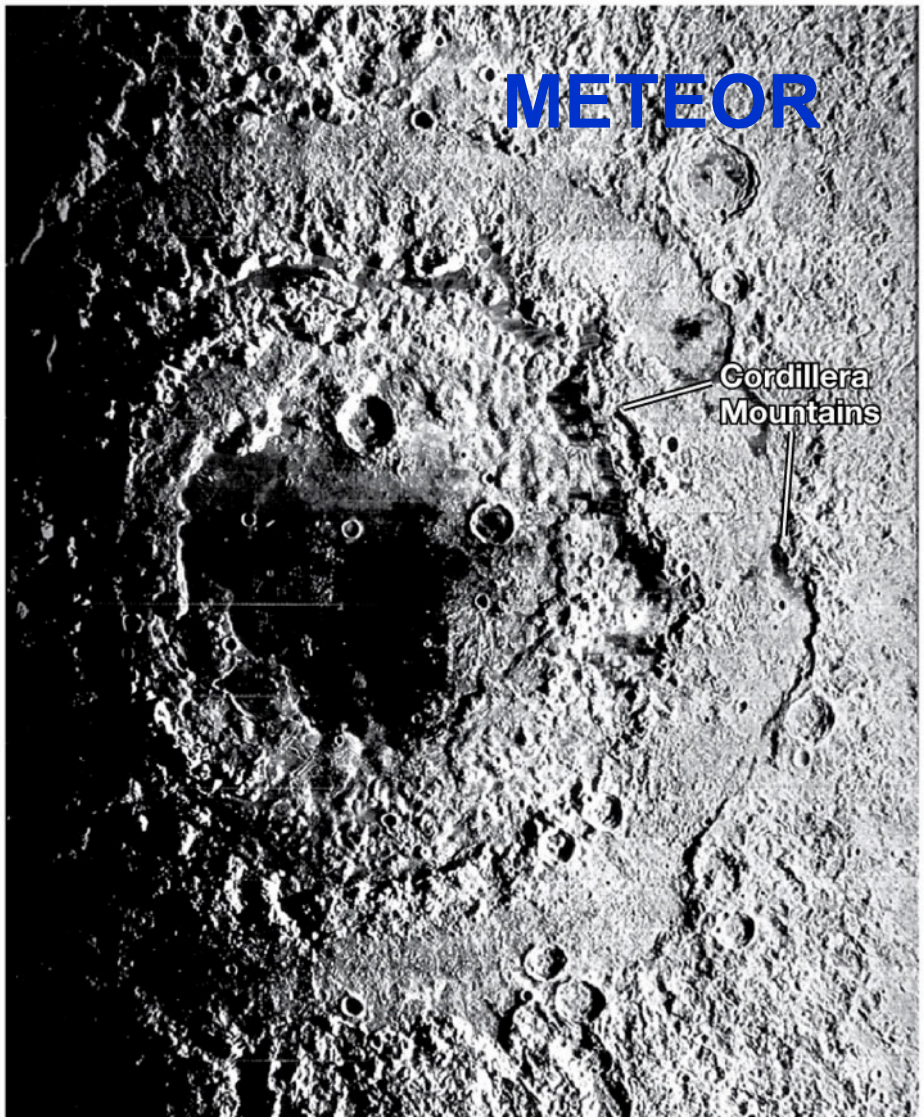
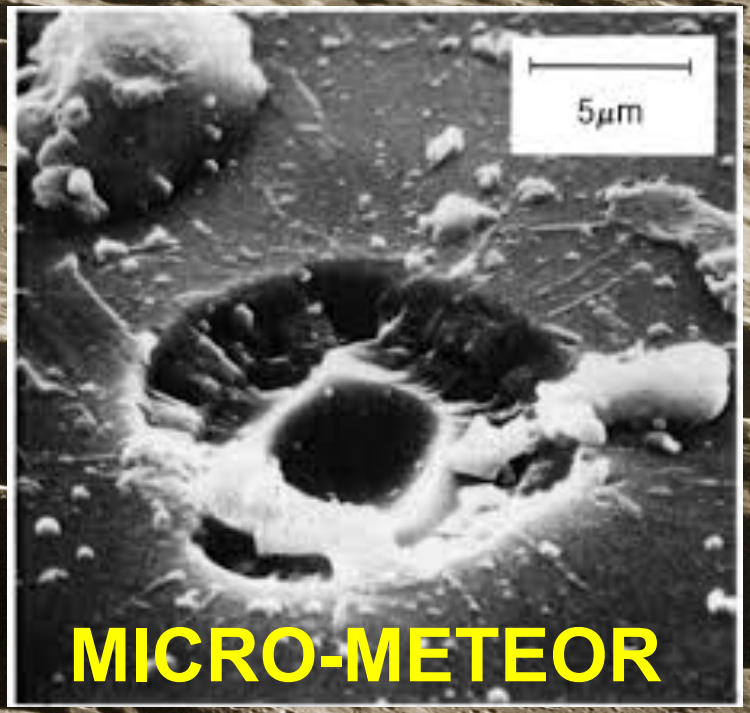
TODAY'S SESSIONS

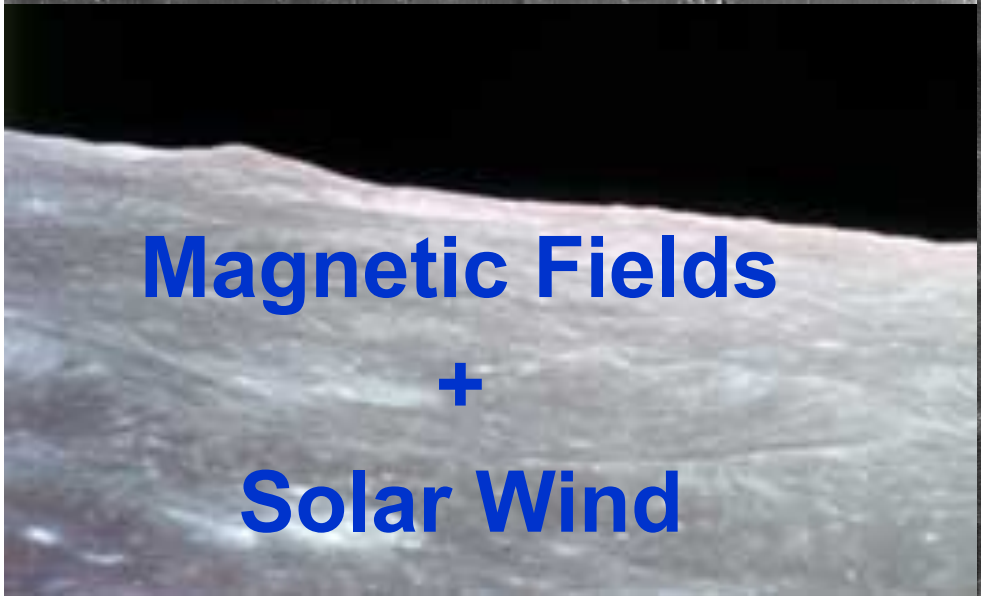
INTERACTIONS BETWEEN SPACE AND PLANETARY SURFACES





IMPACTS

LUNAR SWIRLS



Magnetic Fields

+

Solar Wind

INTERACTIONS BETWEEN SPACE AND PLANETARY SURFACES.

Amanda Hendrix: LRO/CRATER discoveries of the lunar radiation environment and lunar regolith alteration by radiation.

Anton Kulchitskiy: Regional Variations in UV Lunar Signatures. Solar wind access to lunar regolith DEM modeling.

Jan Deca: Electromagnetic PIC simulations of the solar wind interactions with lunar magnetic anomalies: Ion and electron dynamics.

Shahab Fatemi: (virtual) Plasma interactions with lunar magnetic anomales.

Andrew Poppe: Plasma modeling of solar wind interaction with Reiner Gamma and Airy magnetic anomalies.

Timothy Glotch: Diviner lunar radiometer observations of lunar swirls.

David Blewett: Nature and origin of lunar swirls.

PM ----------

Kathrine Burgess: EELS measurement of Fe oxidation state in space-weathered lunar soils.

Joshua Cahill: The Maturely, Immature Orientale Impact Basin.

Benjamin Greenhagen: Simulating lunar eclipse in the lab. Key to understanding the epiregolith.

Joshua Bandfield: Getting the temperature right-Accurately deter-mining thermophysical and spectral properties planetary surfaces.

Andrew Jordan: Possible dielectric breakdown weathering effects on the comminution of lunar regolith.

Leos Pohl: Asteroid material shielding potential against high energy particles.

SPACE WEATHERING PROCESSES: A MISSING FACTOR

Larry Taylor

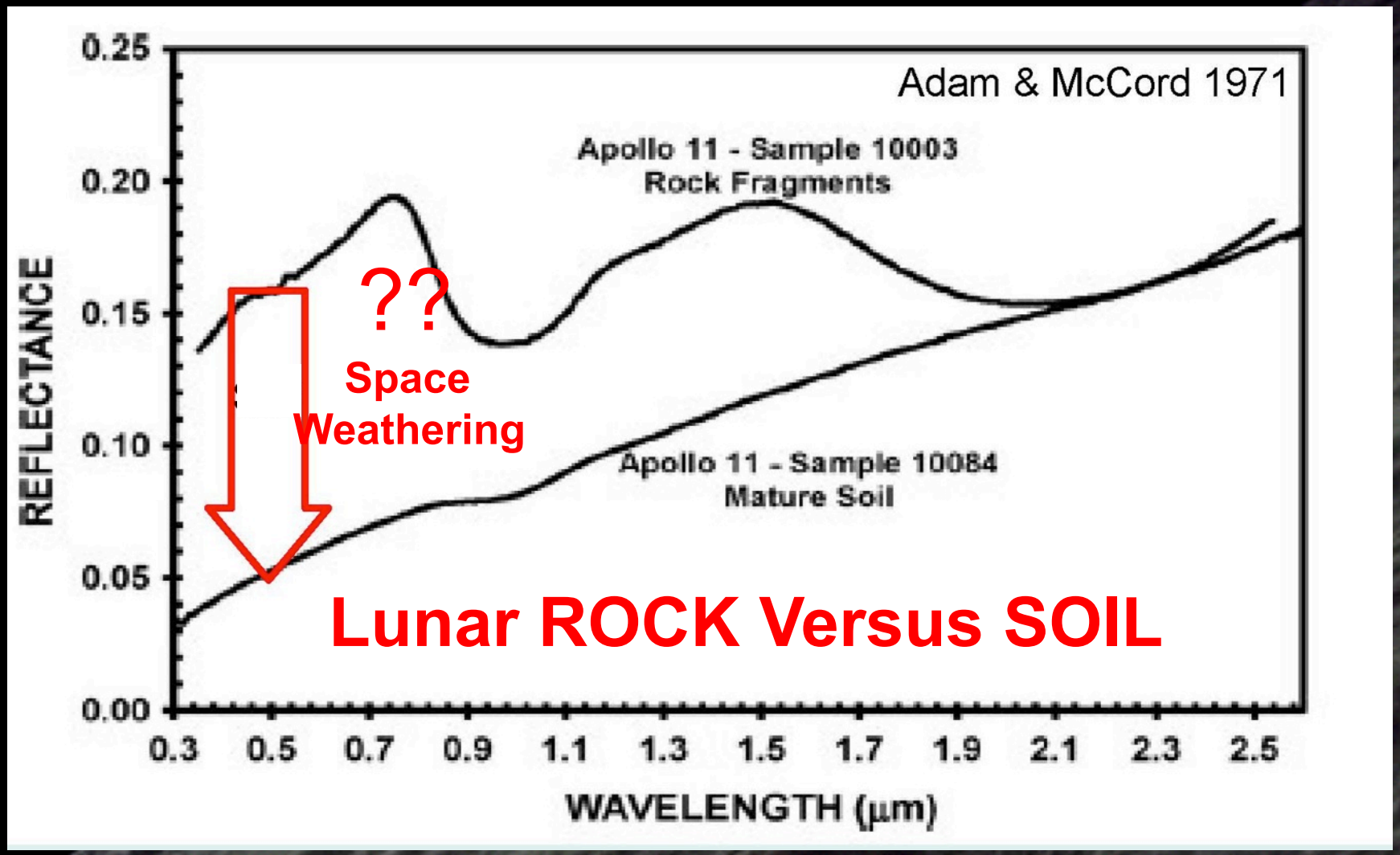
Planetary Geosciences Institute
University of Tennessee
Knoxville, TN, 37996
<lataylor@utk.edu>

OUR MOON

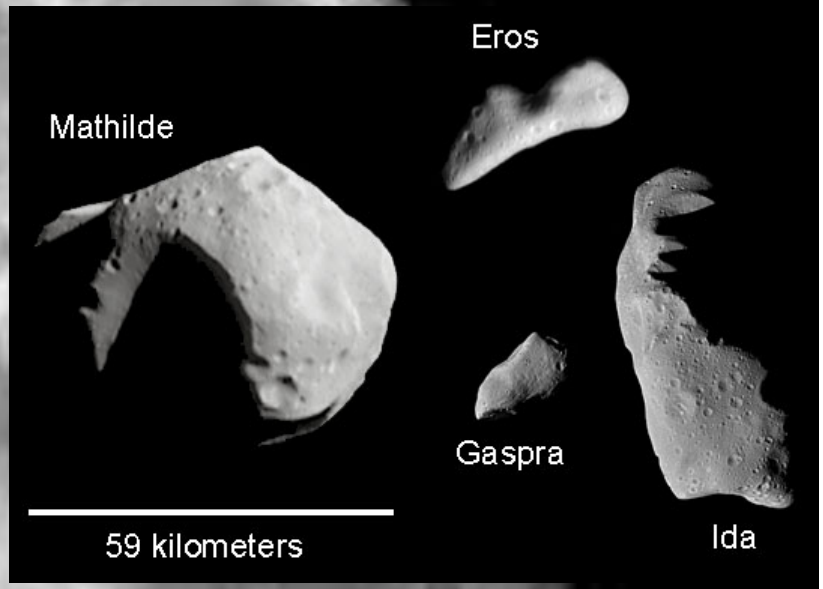
PROVIDES PARADIGMS for:

- PLANETARY EVOLUTION of the TERRESTRIAL PLANETS;
- SPACE WEATHERING on ALL AIRLESS BODIES

Space weathering includes all those physical and chemical factors that affect an airless body in space,

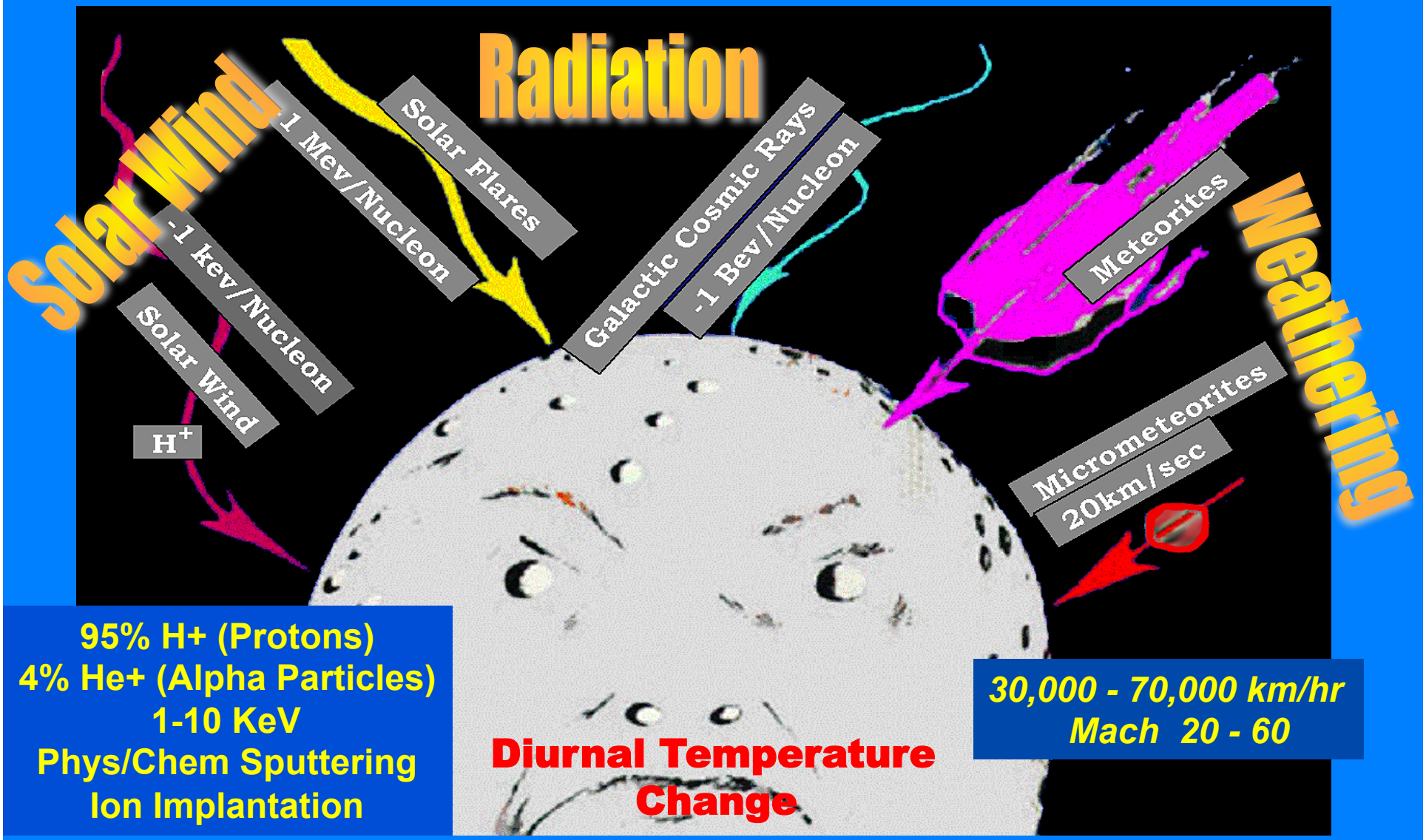


AGENTS OF SPACE WEATHERING



Micro-Meteorites
Solar-Wind Particles
Galactic/Cosmic/Solar Rays
Temperature (diurnal)
Gravity

Space Weathering on the Moon

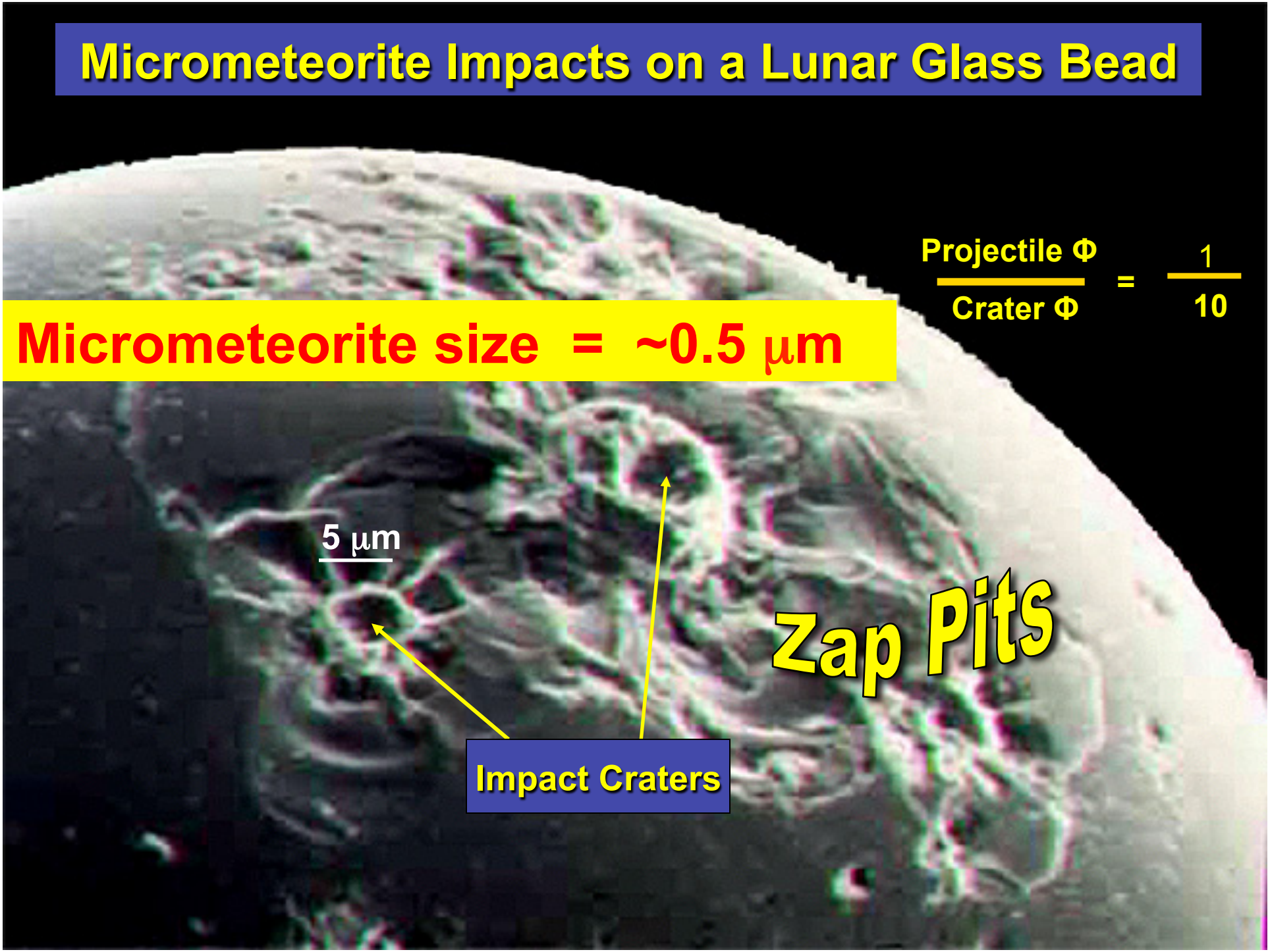


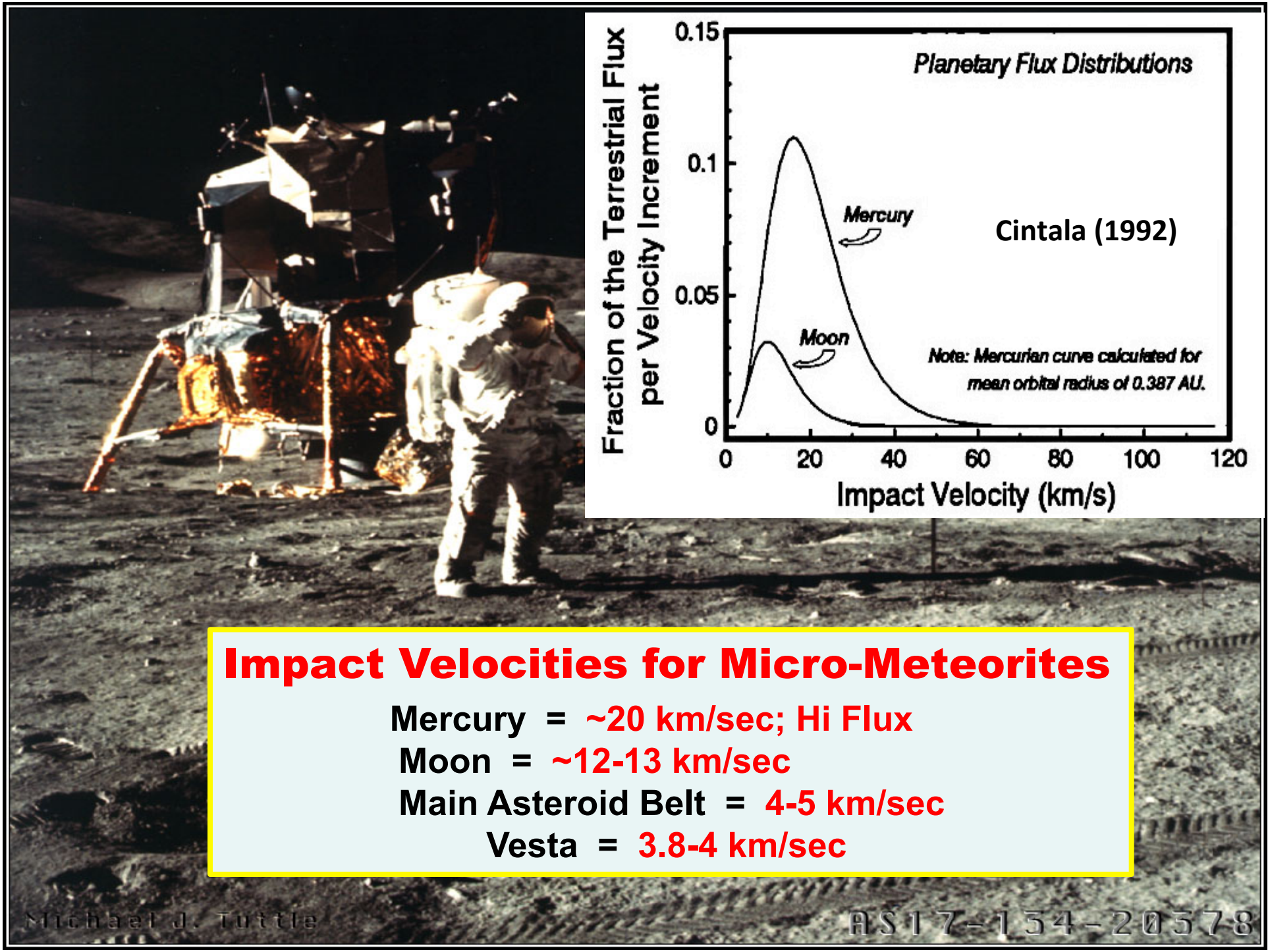
95% H+ (Protons)
4% He+ (Alpha Particles)
1-10 KeV
Phys/Chem Sputtering
Ion Implantation

Diurnal Temperature Change

30,000 - 70,000 km/hr
Mach 20 - 60

Micrometeorite Impacts on a Lunar Glass Bead





Cintala (1992)

Impact Velocities for Micro-Meteorites

Mercury = ~20 km/sec; Hi Flux

Moon = ~12-13 km/sec

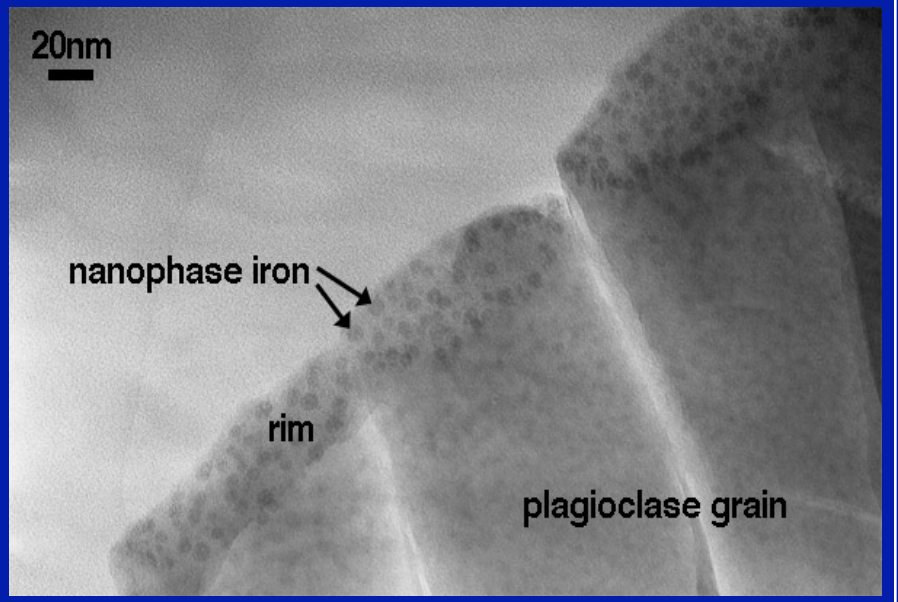
Main Asteroid Belt = 4-5 km/sec

Vesta = 3.8-4 km/sec

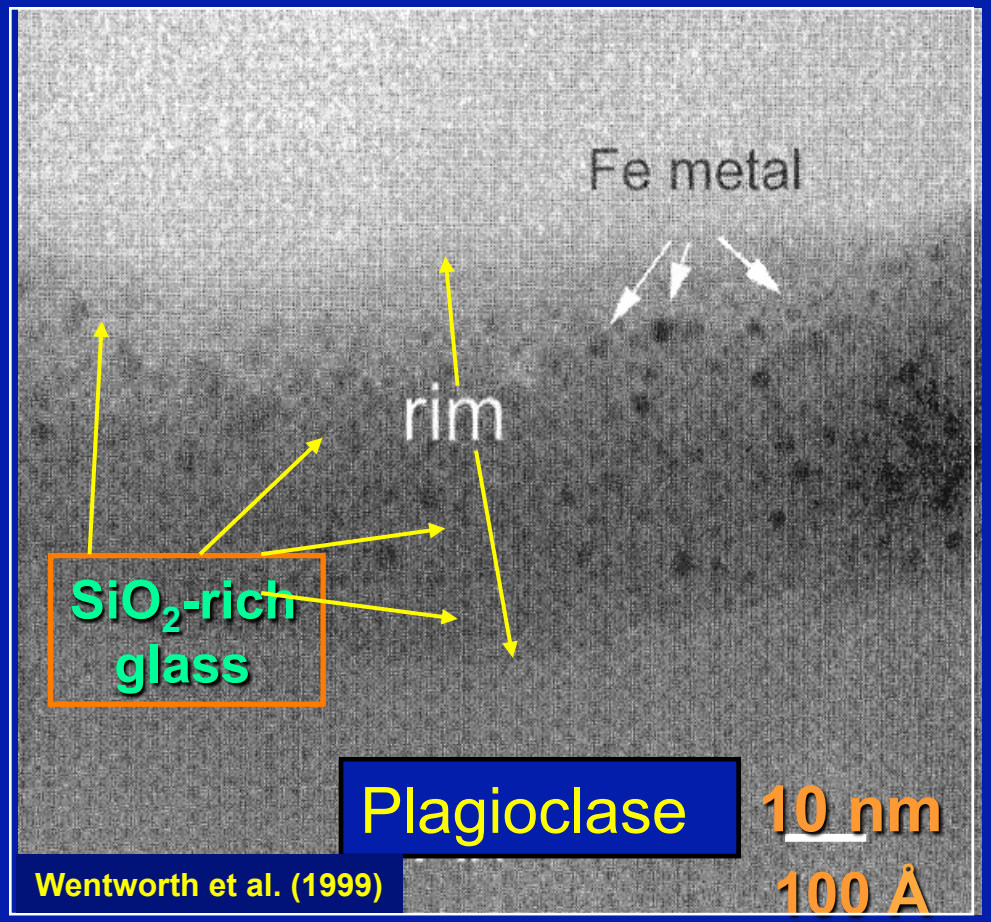
Vapor-Deposited Nanophase Fe° on Plagioclase

Keller & McKay (1993, 1997)

TEM: (all black spots = np-Fe)



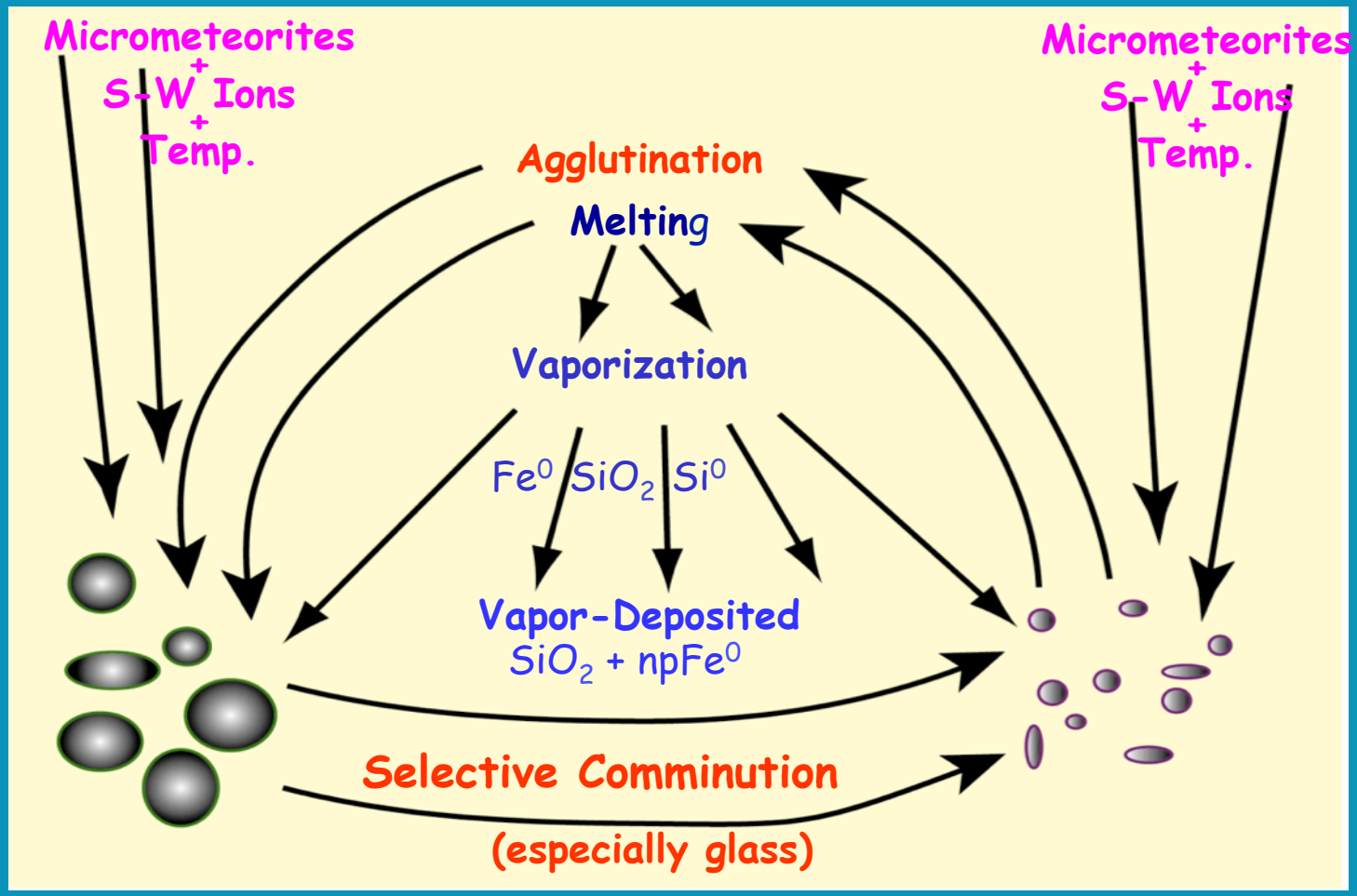
Courtesy of Sarah Noble



Wentworth et al. (1999)

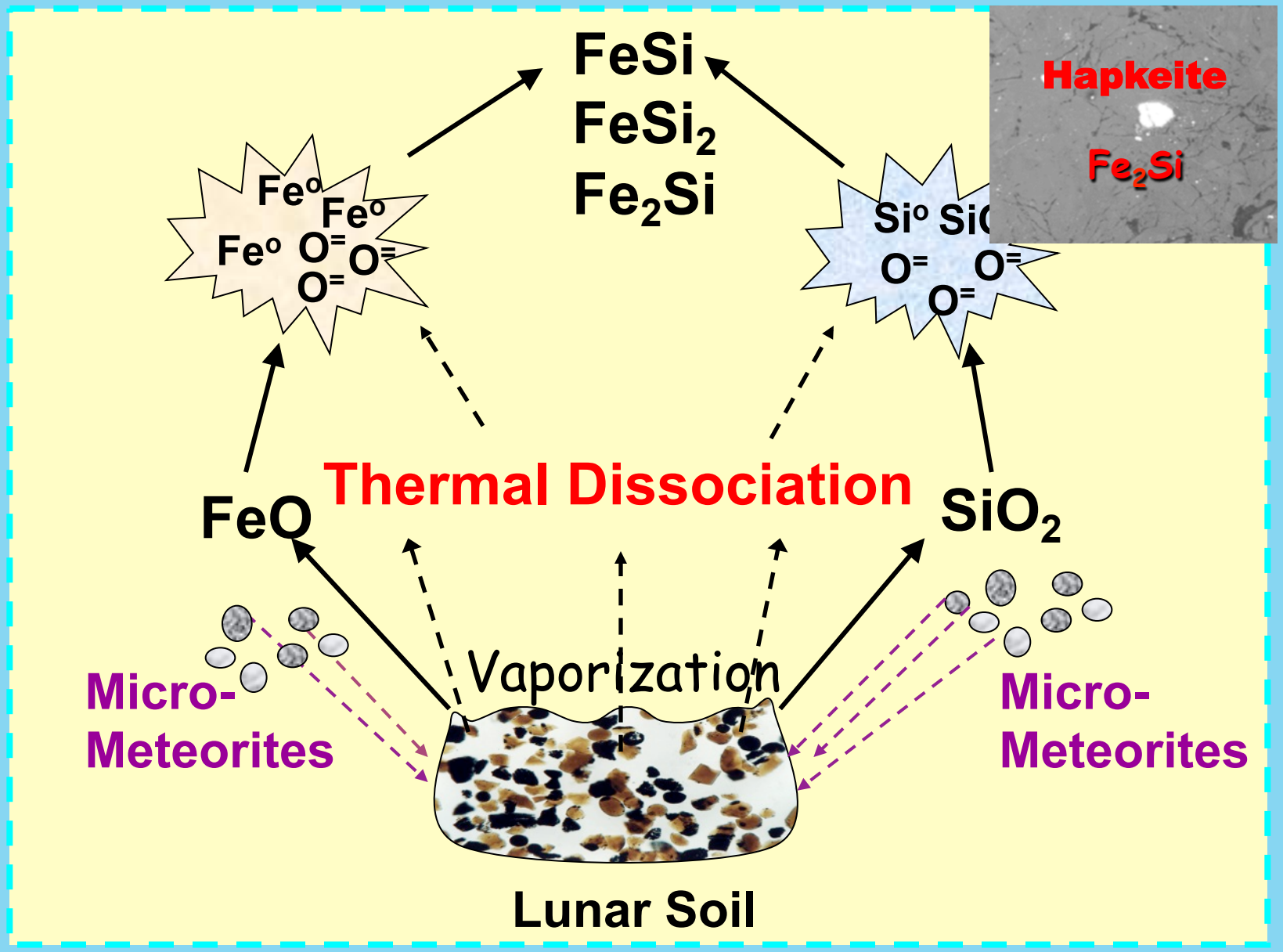
Airless-Body Regolith Cycle

Taylor (2000)

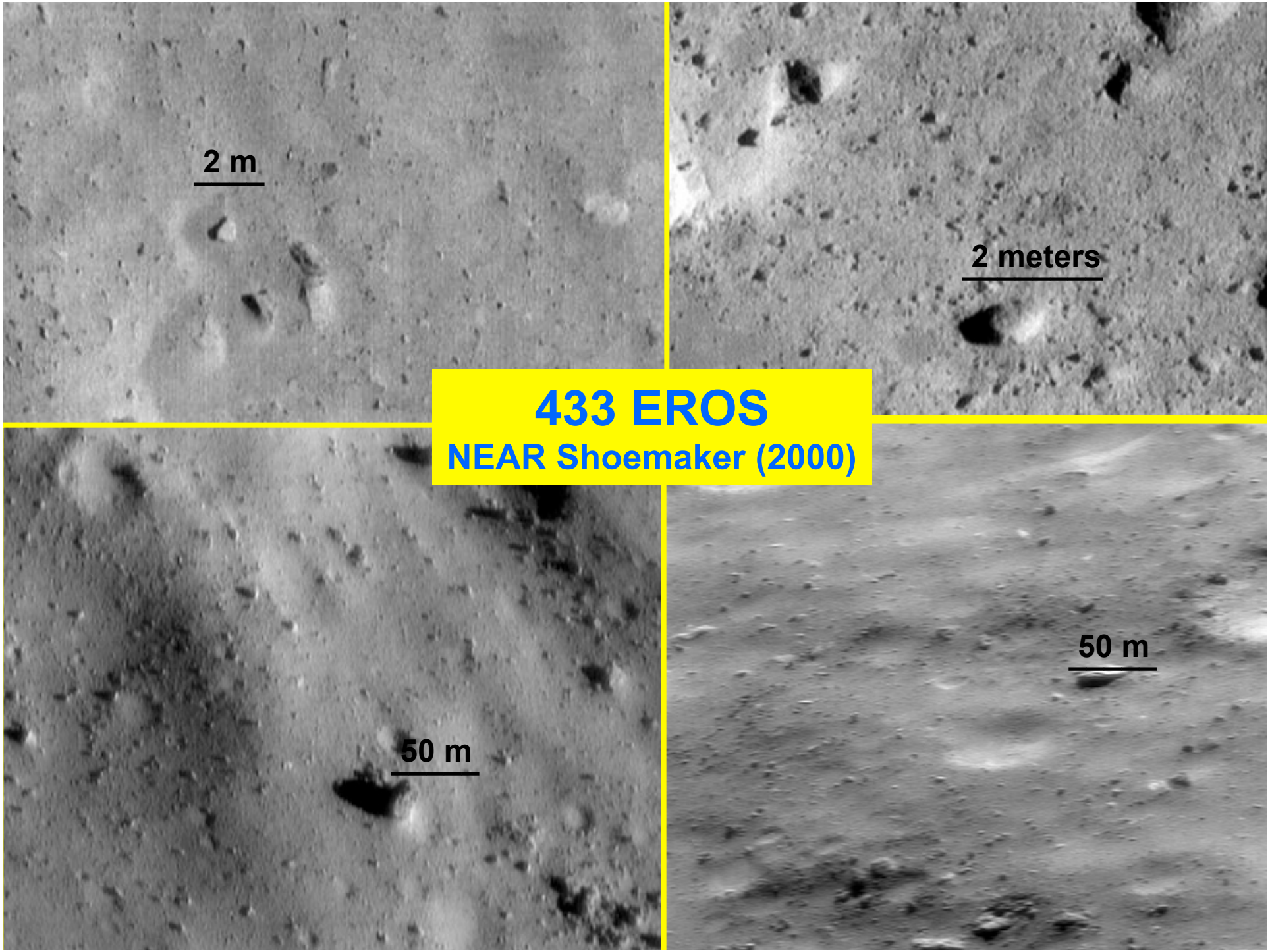


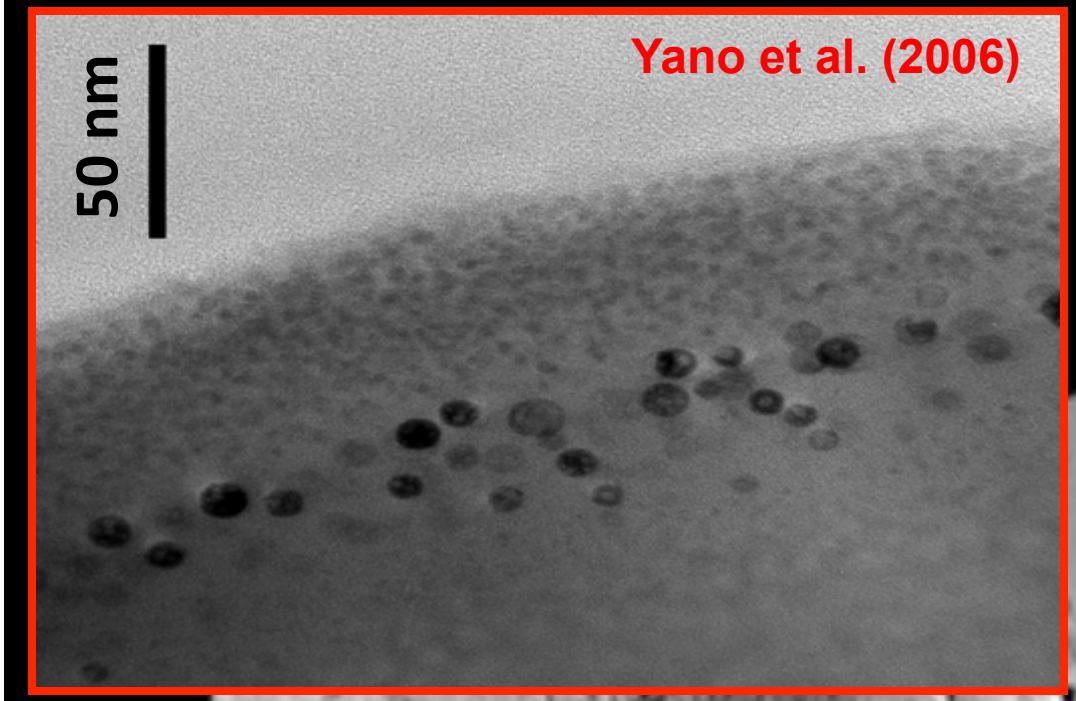
Course (100 μm) ⟵ Grain size ⟶ Fine (<10μm)

MATURITY

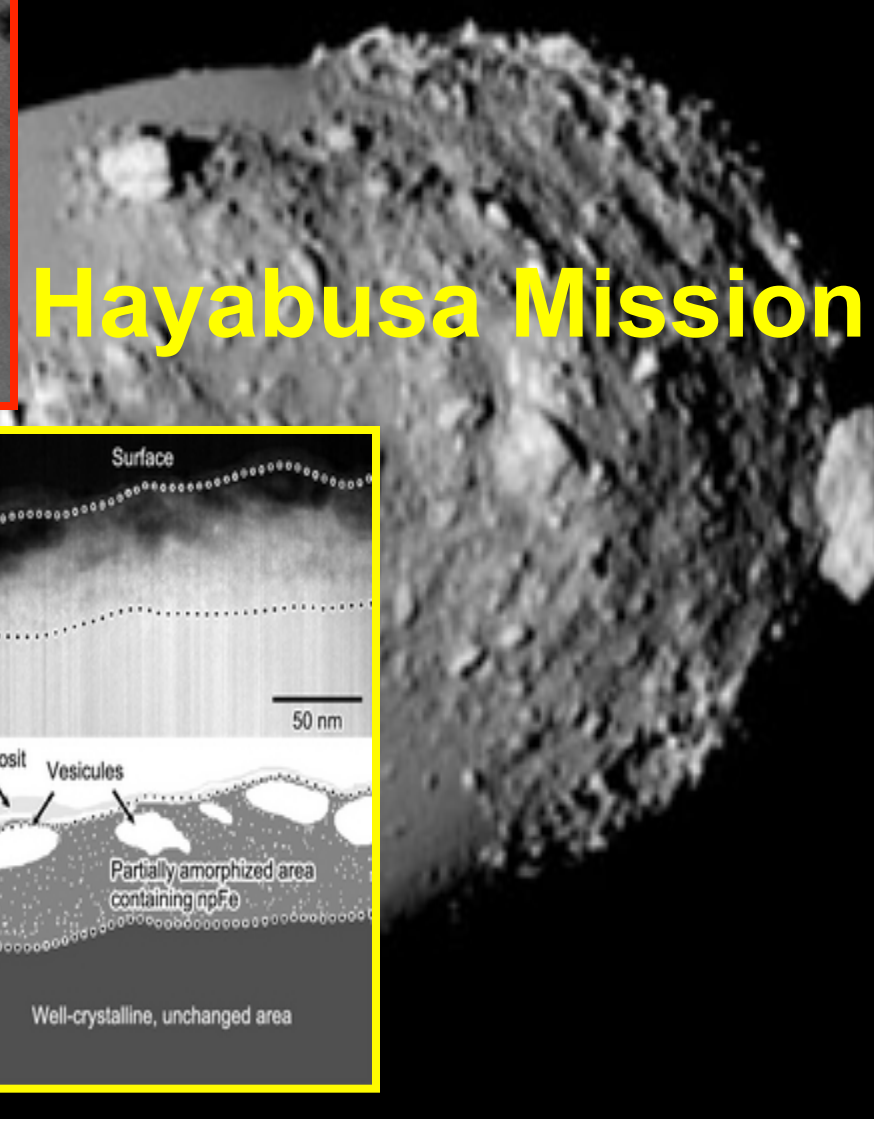


Anand and Taylor (2004)

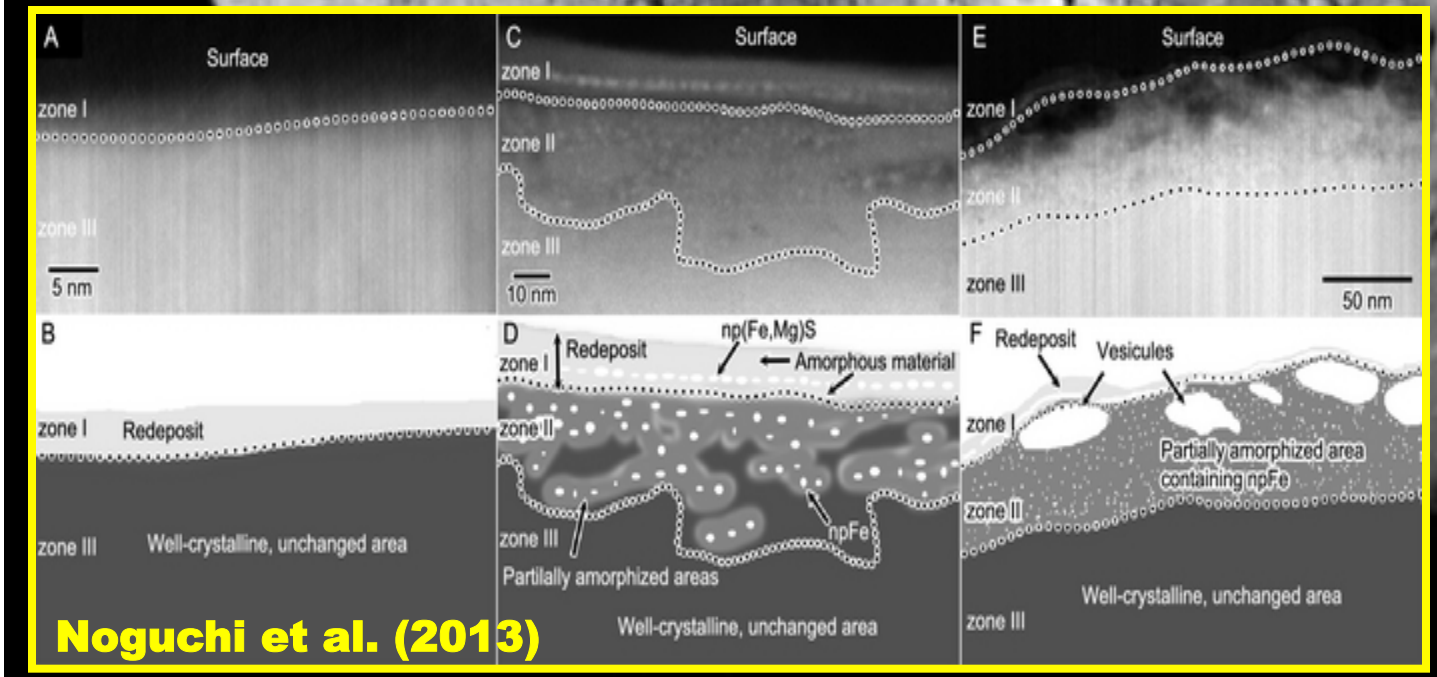

2 m
2 meters
433 EROS
NEAR Shoemaker (2000)
50 m
50 m



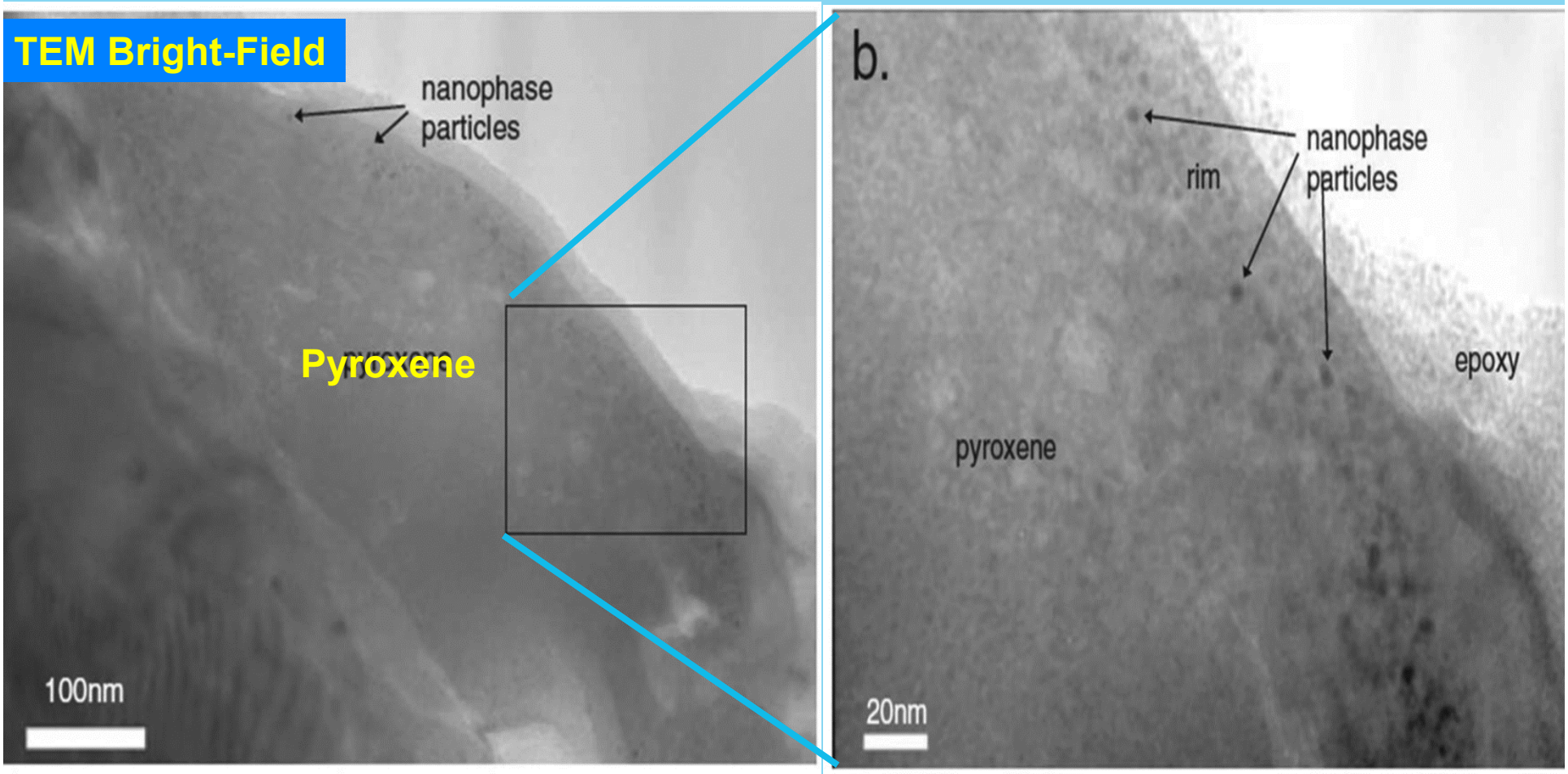
NEA Itokawa



Hayabusa Mission



Noguchi et al. (2013)

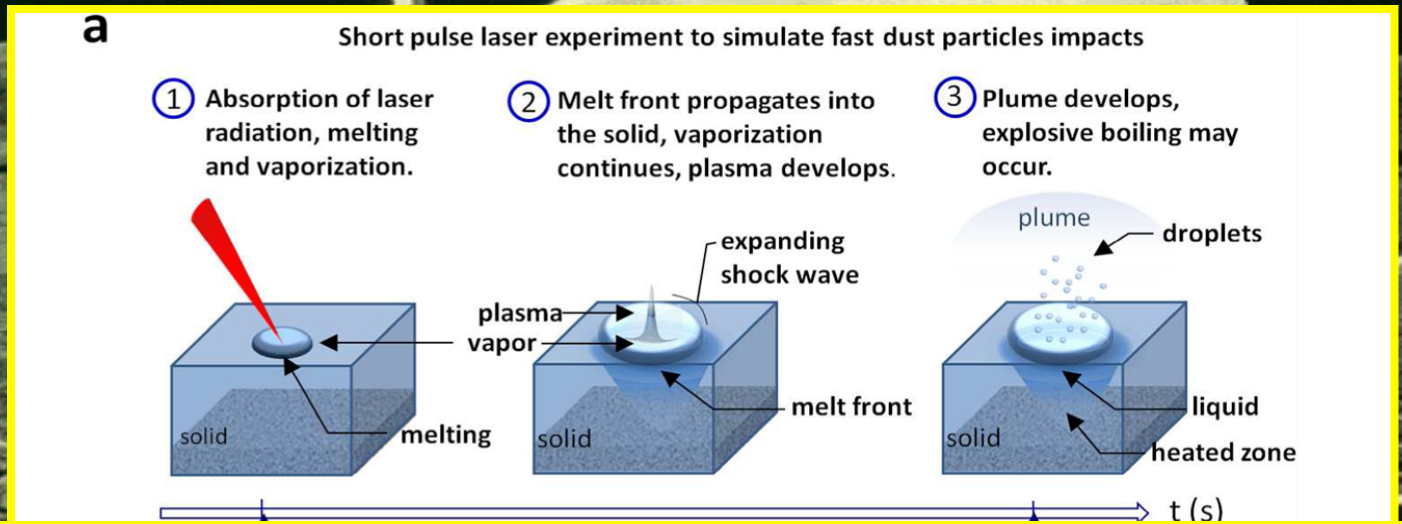


Kapoeta Meteorite

(Howardite)

Noble et al. (2010)

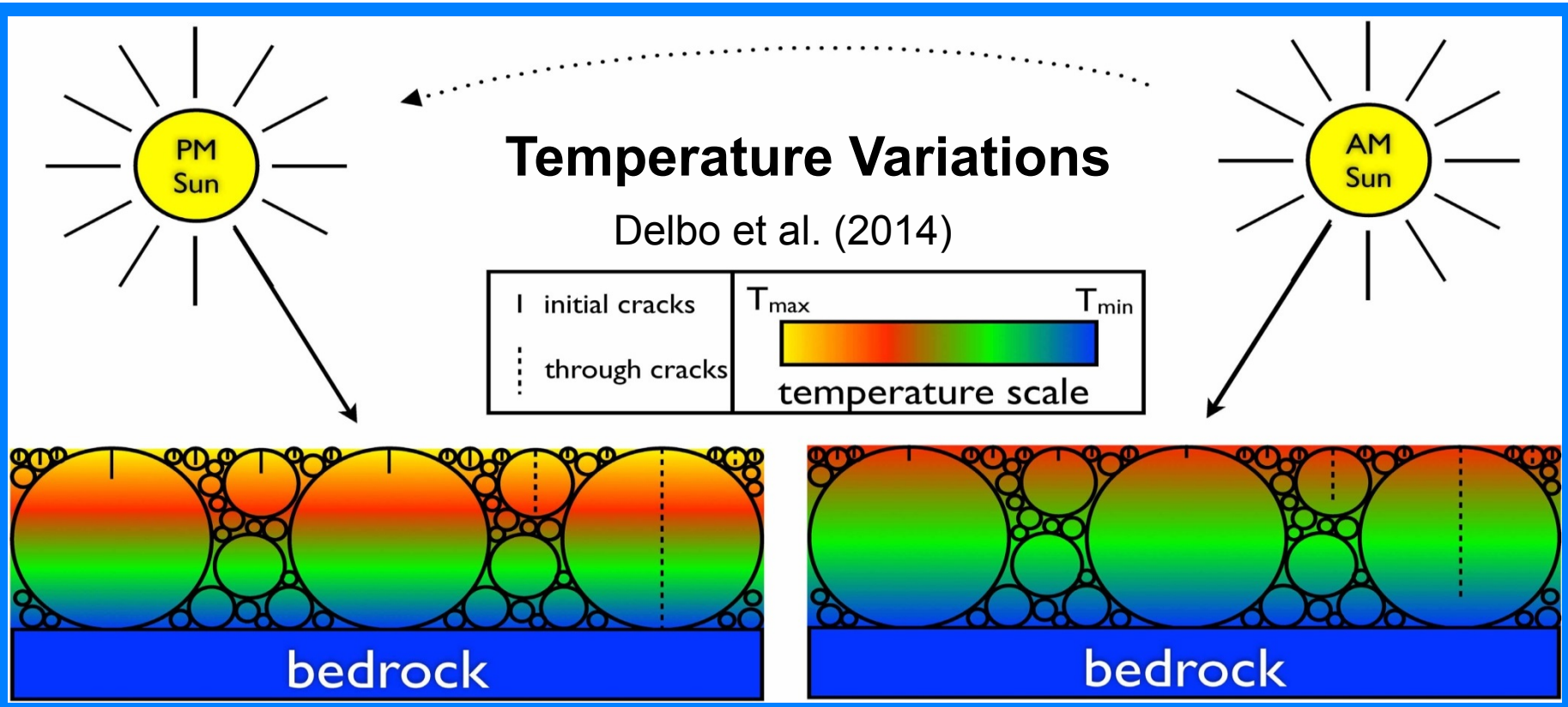
Short-Pulse Laser Experiments to Simulate Micro-Meteorite Impacts



Micrometeorite bombardment has been simulated in laser oblation experiments (Moroz et al. 1996, Yamada et al. 1999, Sasaki et al. 2001, 2002, Sasaki and Hiroi 2003, Brunetto et al. 2006)

Ion bombardment has been simulated in radiation experiments (Brunetto and Strazzulla 2005, Marchi et al. 2005, Strazzulla et al. 2005, Brunetto et al. 2006)

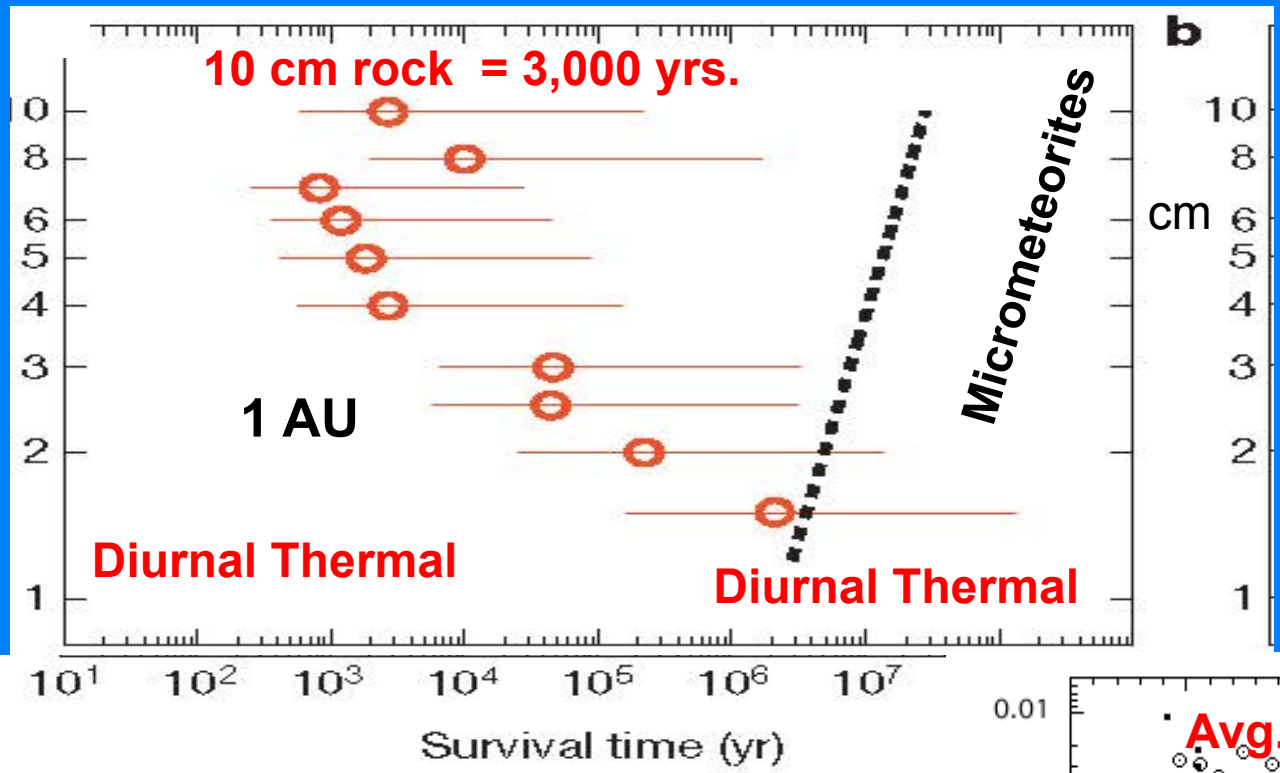
Np-Fe has been produced in these laboratory simulations, supporting the role of these particles in producing the effects attributed to space weathering. BUT *no duplication of vapor-deposited rims on lunar grains*.



Bennett et al. (2013) Space-weathering of Solar System bodies: A laboratory perspective. *Chem Rev., Spec. Issue Astrochemistry*, 9086-9150 (beaucoup refs.)

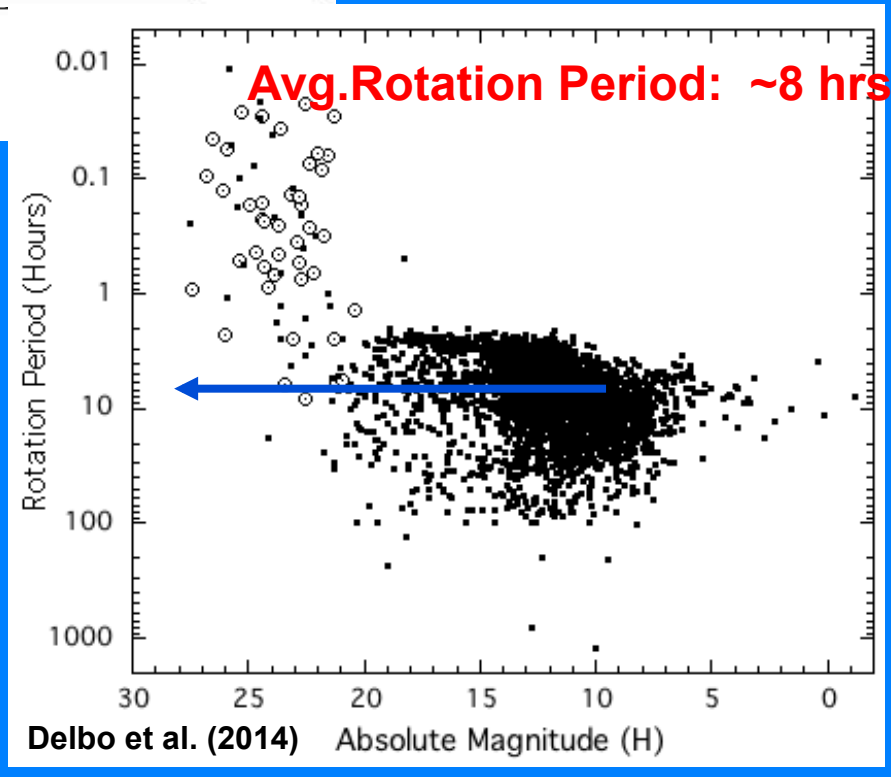
Delbo et al. (2014) Thermal fatigue as the origin of regolith on small asteroids. *Nature Res. Lett.* 508, 233-236.

Molaro et al. (2015) Grain-scale thermoelastic stresses and spatio-temporal temperature gradients on airless bodies, implications for rock breakdown. *Jour. Geophys Res.: Planet.*, 1-23.



Delbo et al. (2014)

Time Required to Break Down 90 % of Rocks on Asteroids



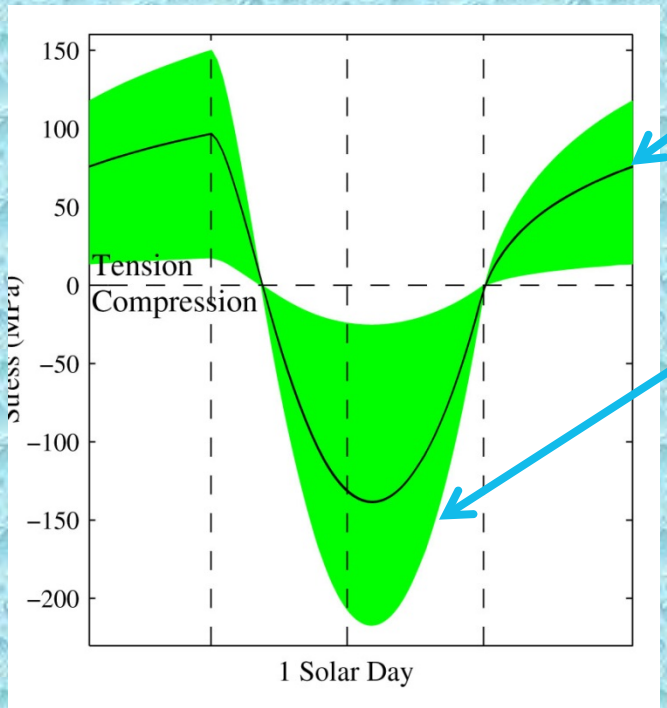
Delbo et al. (2014)

Thermal Cycling

Rock experiences thermal shock and stress!

Thermal-Mechanical Processes:
More efficient in weathering of asteroid surfaces than micro-meteorite impacts! ???

STRESS DEVELOPED



100 % Pyroxene

25 % Plagioclase
75 % Pyroxene

dT/dt

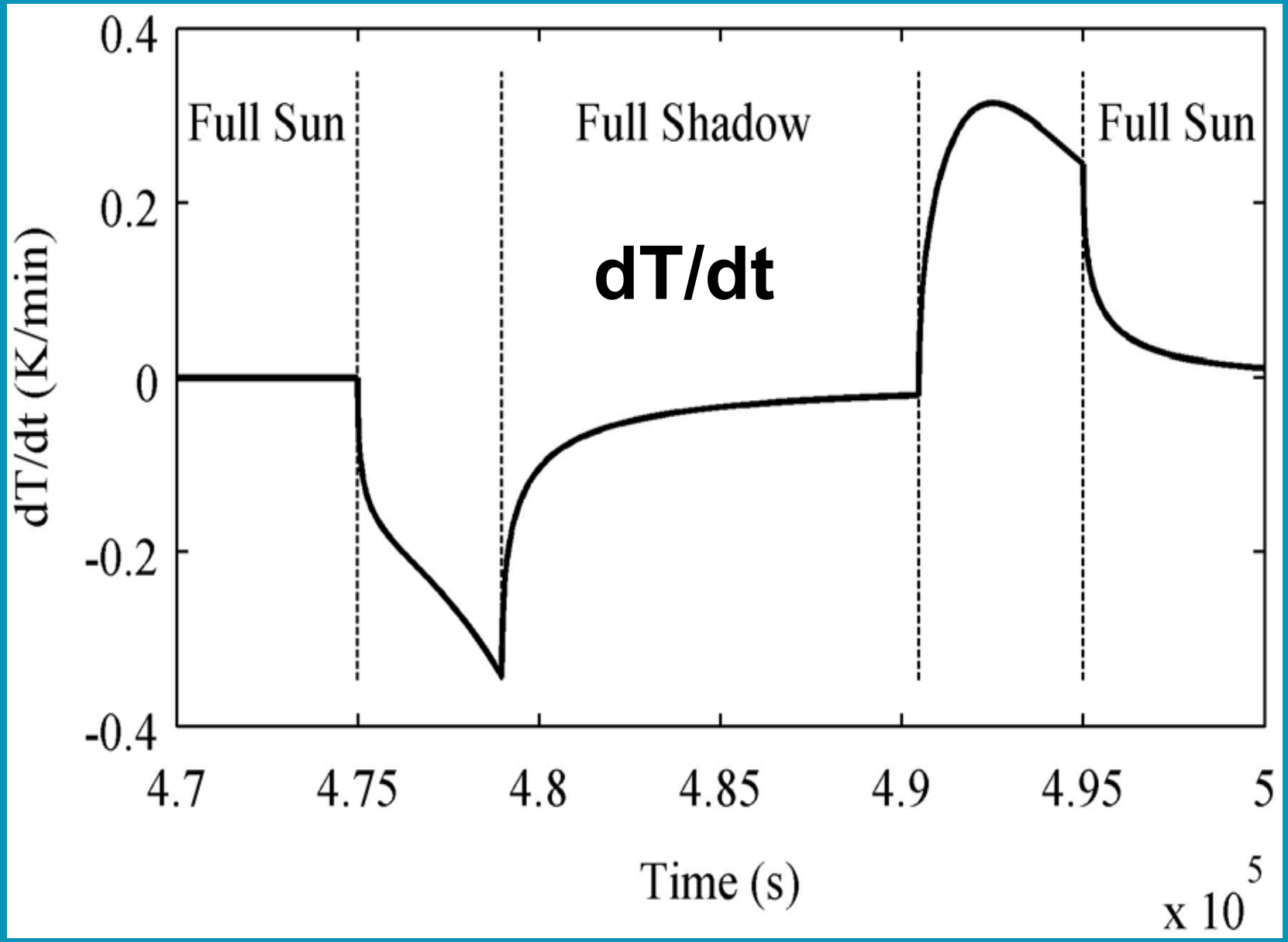
Hypothesis:

ASSUMPTION: Micrometeorite Impact + Low Gravity = Loss of Larger Grains.

Asteroid surfaces experience beaucoup thermal cycles (e.g., fast rotation)

Should have smaller-grained regolith

Molaro et al. (2015)



Molaro and Byrne (2012)

THERMAL-STRESS PROCESSES

PHYSICAL PROPERTIES

- Density
- Heat Capacity
- Thermal Conductivity
- Young's modulus
- Poisson's ratio
- Coefficient of Linear Expansion

Scale of observation of a process

≠

Scale of operation of that process

EROS

2 m

MET

MAJOR FACTORS FOR SPACE WEATHERING: MERCURY to ASTEROIDS

Understanding Space Weathering is the Key to Remote Sensing of Airless Bodies in our Solar System

MERCURY

0.4 AU

SW = Major++ 4xM

M-M = Major++ 30xM

T = Major ??

NP-Fe = Major ++ 4xM

Soil = Major++ + Agglut

MOON

1.0 AU

SW = Major

M-M = Major

T = Moderate

NP-Fe = lots

50 % glass

ASTEROIDS (Main Belt)

2-2.5 AU

SW = Minor

M-M = Minor

T = Major

NP-Fe = Minor

Soil = Eh! + Fine