Granular Matter in Low and Zero Gravity

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Experiments in Weightlessness

drop tower

sounding rocket

International Space Station ISS

parabolic flight

Parabolic Flight:

- Reduced gravitational confinement
- Partial-g levels
- Soil tests
- Locomotion on soil

Drop Tower:

- High quality weightlessness
- Centrifuge for partial-g levels
- Fundamental granular interactions

Sounding Rocket:

- High quality weightlessness
- Long-time duration
- Fast turnover

Granular Matter in Low and Zero Gravity

(1) How can research in microgravity on the ISS and other platforms concerning granular matter be used to benefit exploration efforts?
(2) How can granular matter research enhance simulant materials and analog environments?
(3) What insights into their physical properties will allow processing and handling of granular matter on the Moon and other planetary surfaces?

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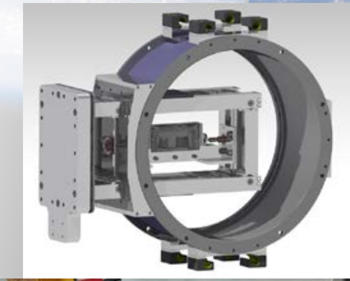
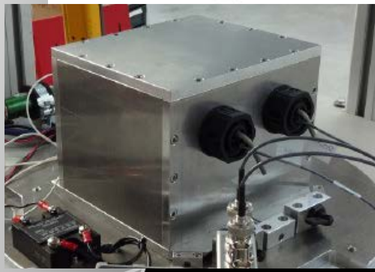
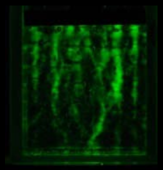
Fields of interest:
Structure formation in granular gases,
Dynamics and light scattering in granular fluids,
Stress and sound in granular packings







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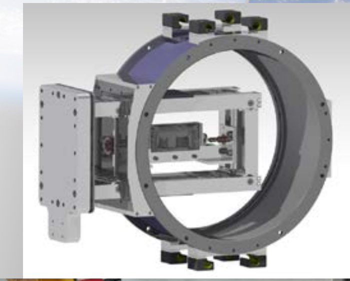

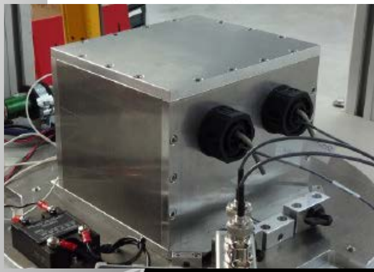

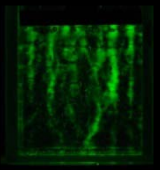

Granular Matter in Low and Zero Gravity

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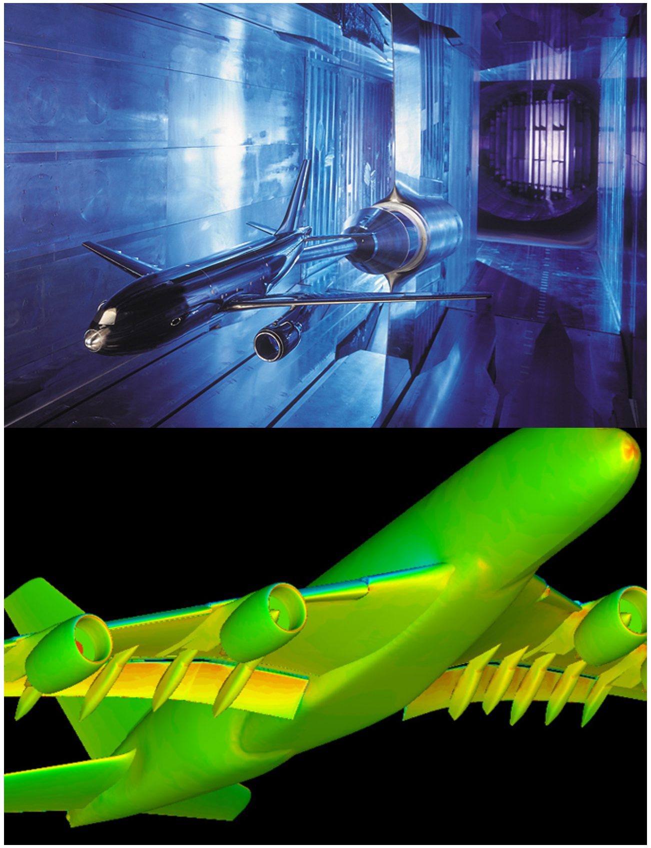
Liquids and Gases

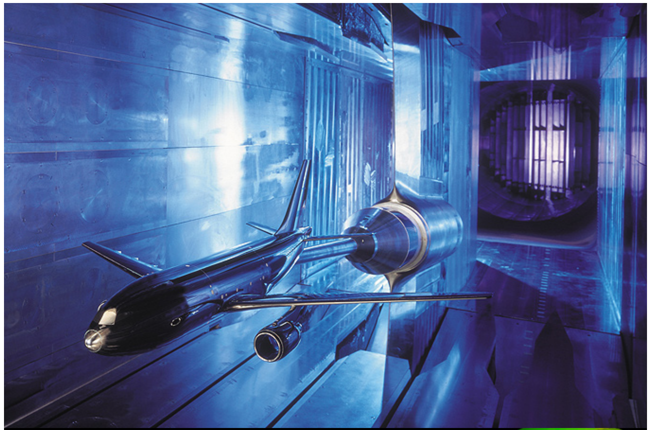


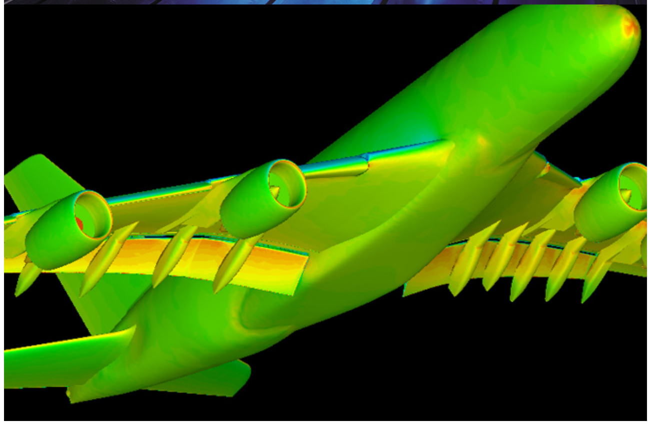
Windtunnel,

Computer Simulation,

predictable

Liquids and Gases ……………. and Granular Matter





Windtunnel,

Computer Simulation,

predictable

different and difficult

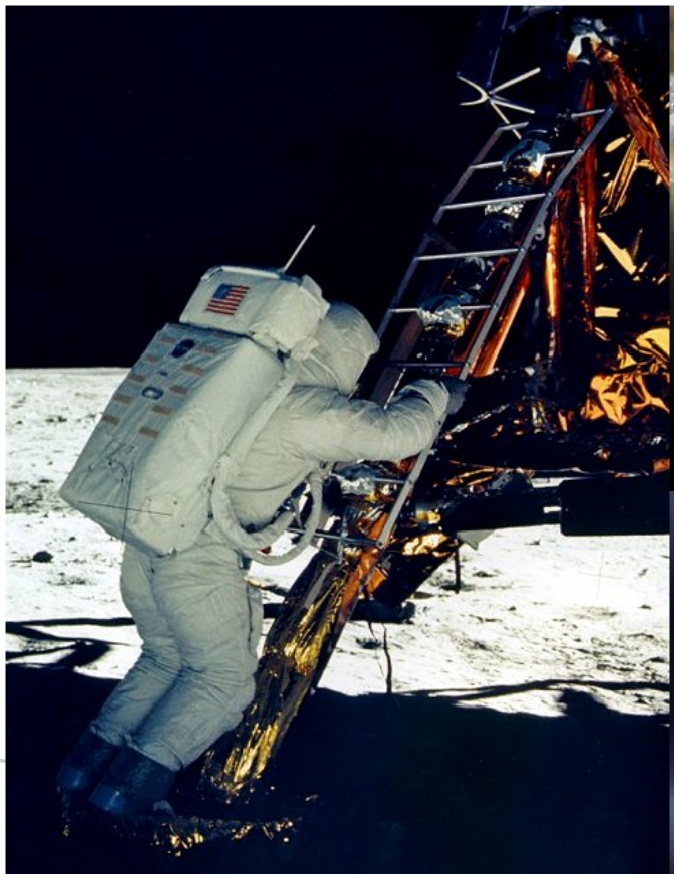
Granular Matter in Space

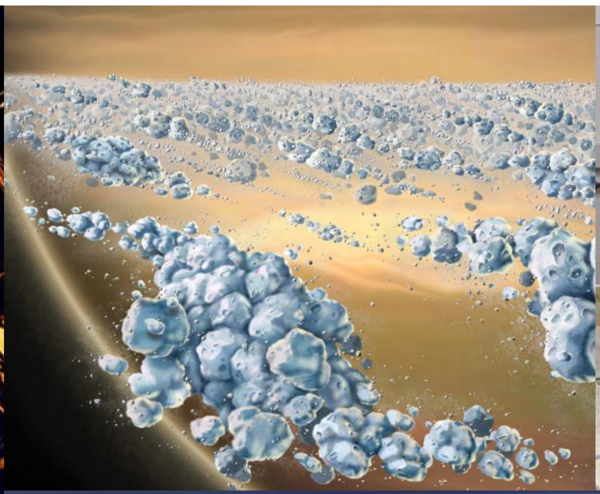
Fundamental problems: Saturn’s rings and planet formation

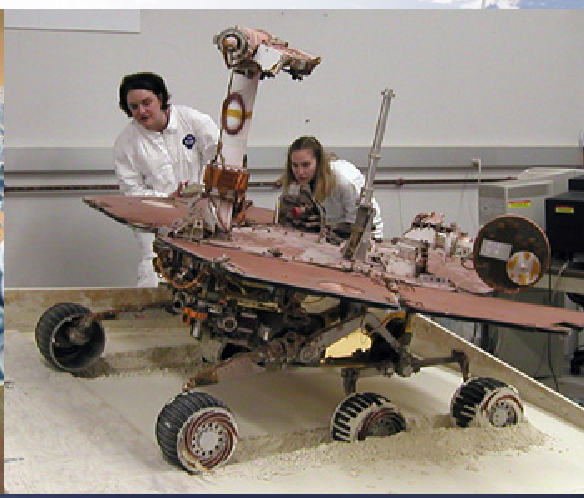
Practical problems: soil properties and process engineering

“trial and error” not possible in unknown environments

Goal: reliable predictions and on site measurements

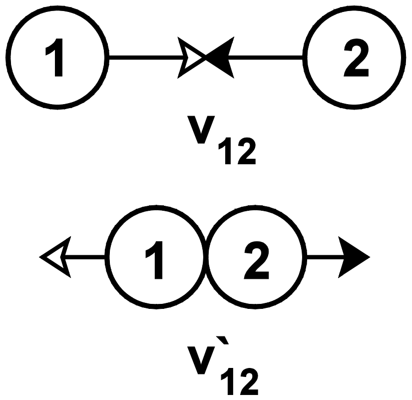






Why is Granular Matter difficult?

derivation of dynamics from
microscopic interactions



$$\hat{n} \cdot \boldsymbol{v}'_{12} = -\varepsilon \hat{n} \cdot \boldsymbol{v}_{12}$$

new for granular matter:
dissipation at collision
time reversal symmetry broken
out-of-equilibrium dynamics

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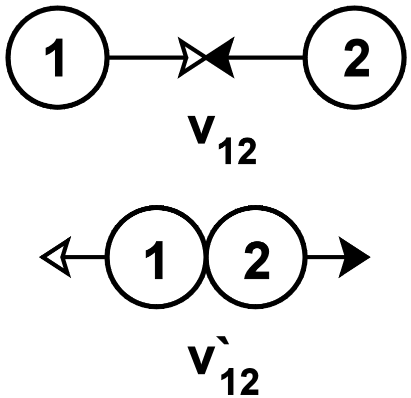

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new for granular matter:
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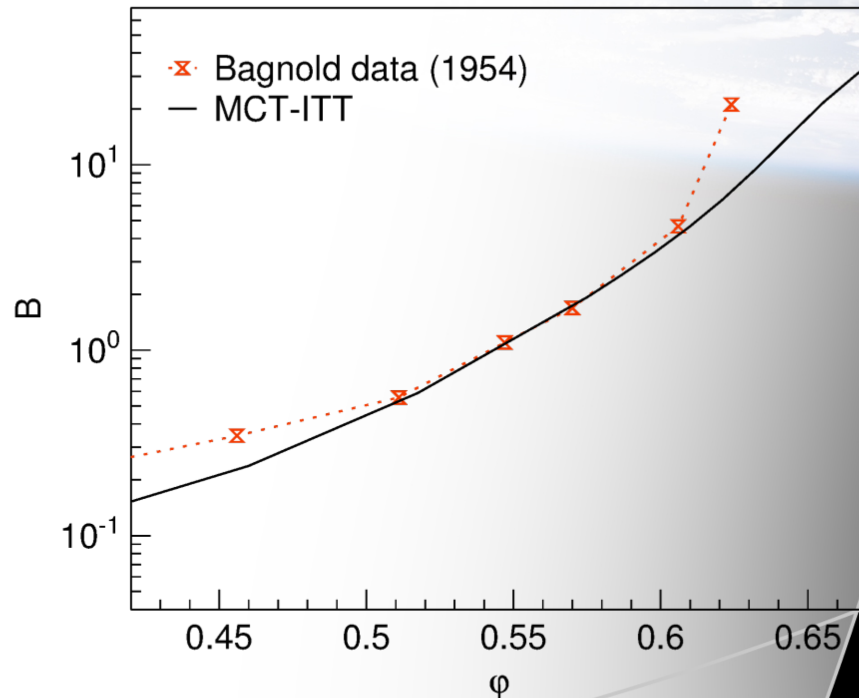
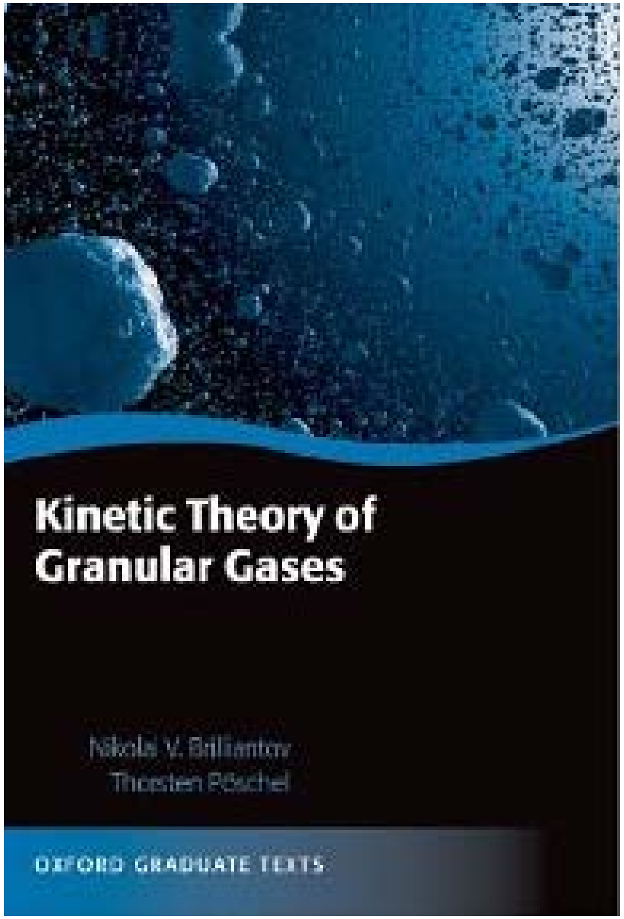
Novel laws of rheology (relation between shear stress and shear rate), e.g., Bagnold's law:

$$\sigma = B\,\dot{\gamma}^2$$



Granular Particles as Atoms of Granular Gases and Fluids



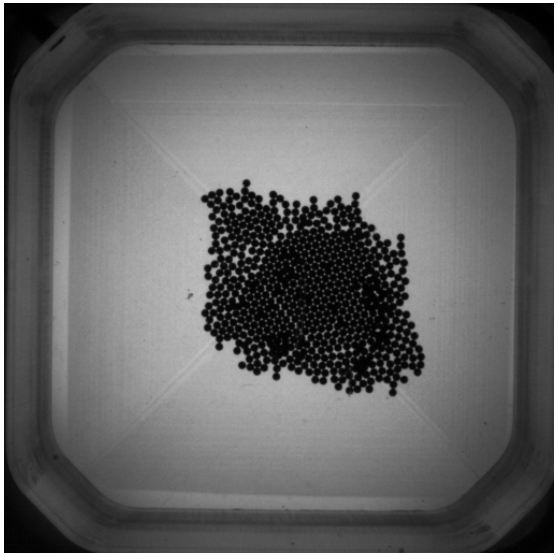
Tools from equilibrium physics applied to non-equilibrium situations.

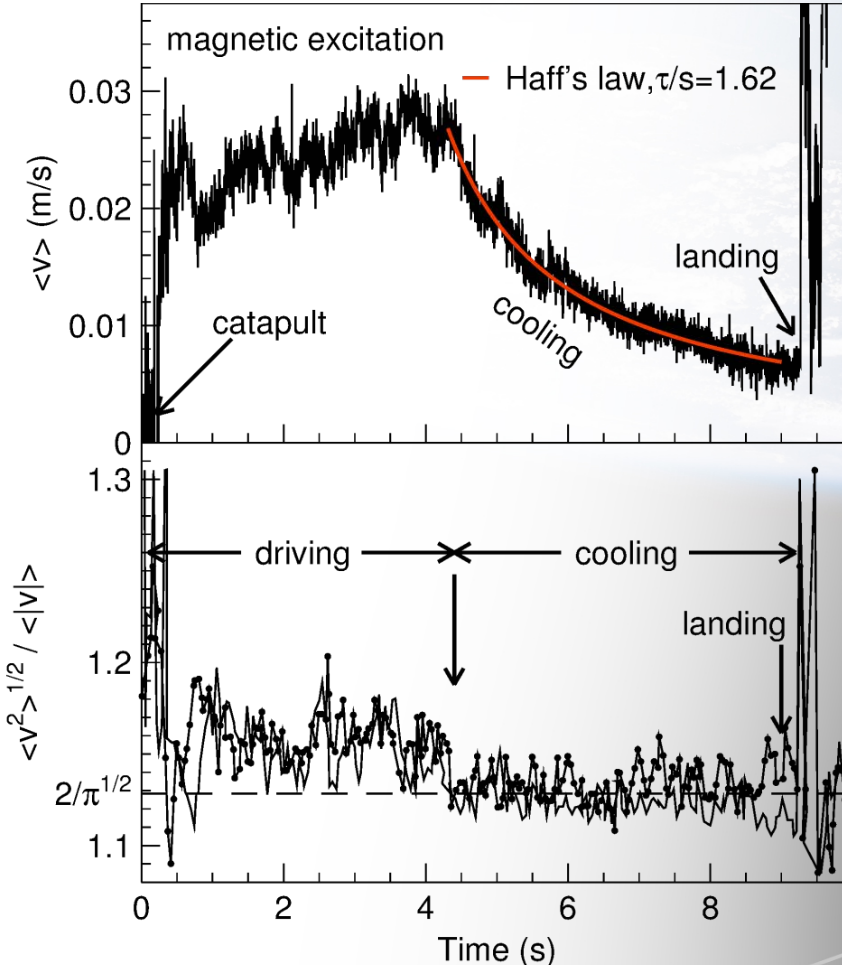
Derivation of continuum behavior from first principles.

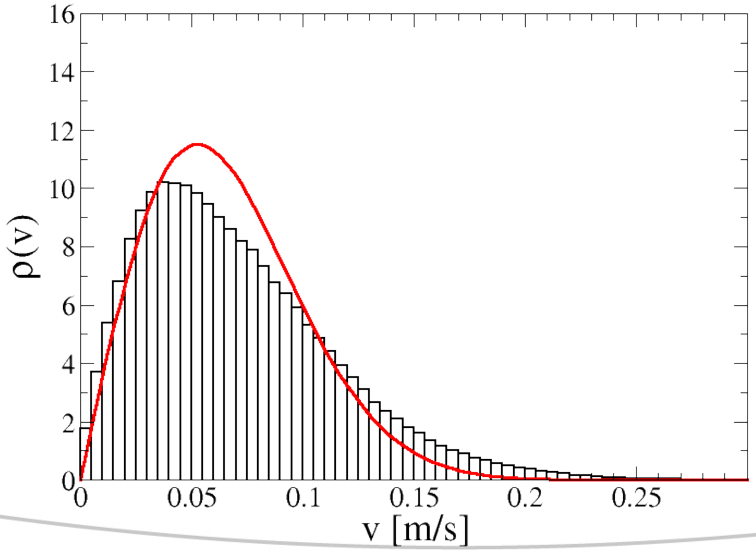
Tests of the theories in laboratory and microgravity.

Validated theory and simulation make granular matter predictable.

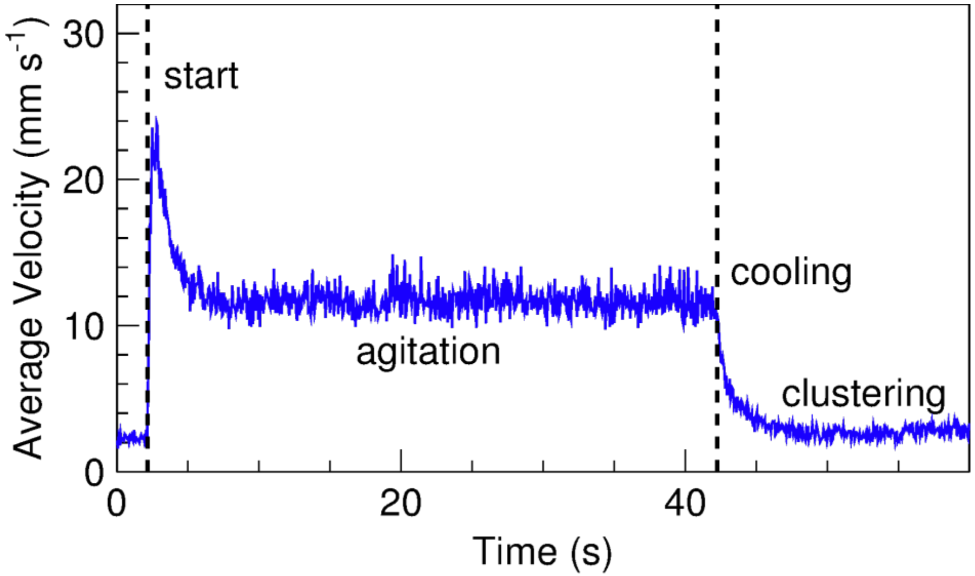
Granular Gases: Microgravity Experiments Testing Cooling

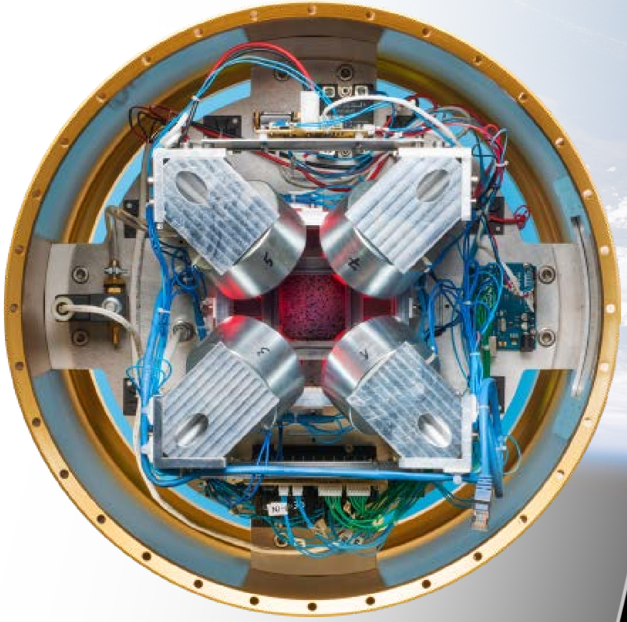






Granular Gases: Microgravity Experiments Testing Clustering





Results:

Fundamental properties of velocity distributions

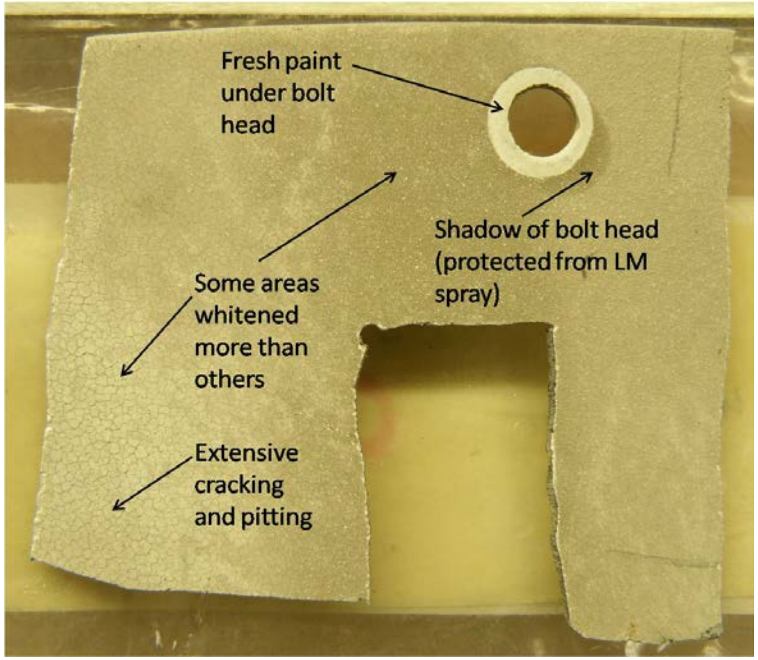
Cooling laws

Evolution of cluster formation

Granular Gases: Utilizing ISS

Granular Gases: Utilizing ISS

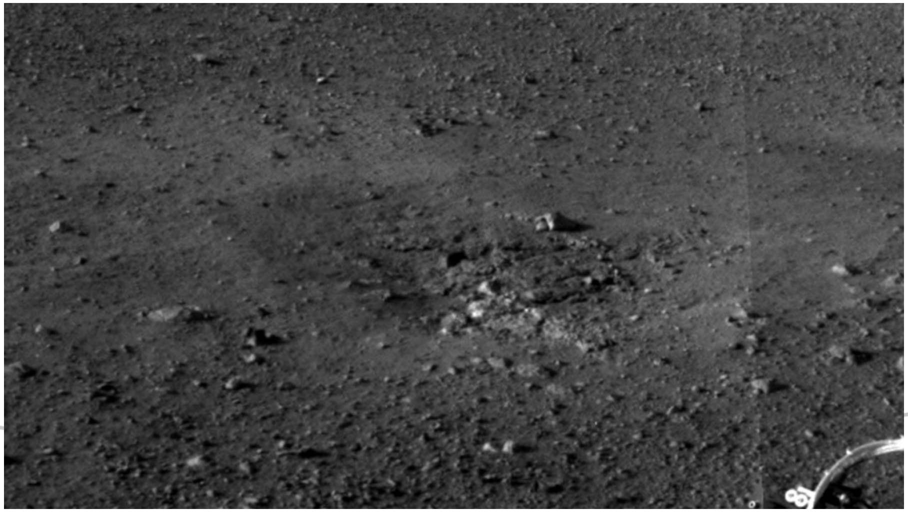
Granular Gases: Relevance for dust mitigation



Landing Apollo 12 destroyed protective coating of Surveyor III due to sandblasting with and clustering of granular dust.

Debris on top of Curiosity rover due to unresolved complexities of two phase flow.

Landing in dust cloud, Apollo 12 and 15.

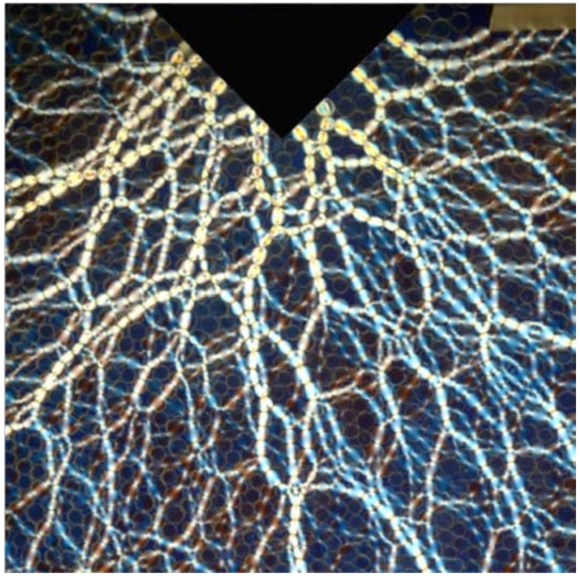


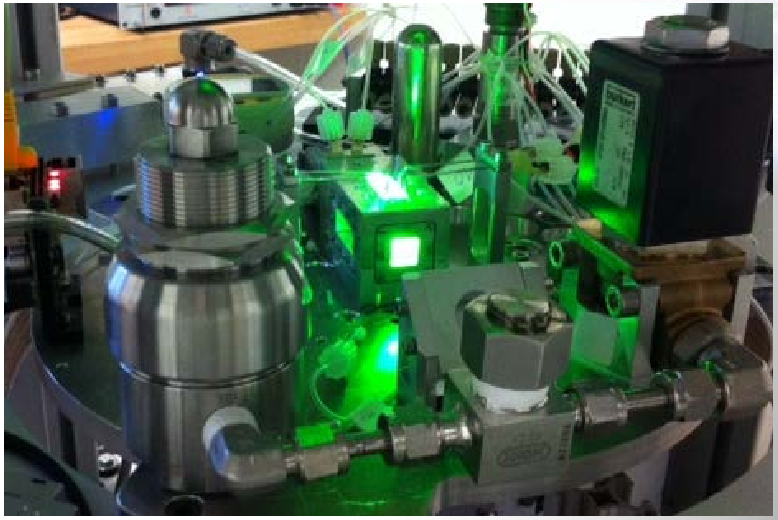
Granular Matter: Further Effects in Reduced Gravity

Sound transport: shock waves in low confining pressure

Packing properties: Stress distribution in soil, boundary condition

Light scattering: light transport without sedimentation





REGOLIGHT

SINTERING REGOLITH WITH SOLAR LIGHT

HORIZON 2020

RegoLight: 3D Printing on the Moon

- Printing building elements with solar radiation from regolith simulant
- 5 Partners: DLR, Space Applications, Comex, Bollinger, Liquifer
- Concurrent engineering: feeding physical properties into design process, feedback from design and structural engineering into sintering technique
- Mechanical properties of sintered soil: similar to concrete

Granular Matter in Low and Zero Gravity: Conclusions

Granular matter made more predictable by fundamental understanding.

Microgravity platforms help create such understanding.

ISS experiments allow for substantial progress in the field.

Progress beneficial for exploration techniques and engineering on ground.

Granular Gases: Utilizing ISS