Advanced Concept for the Detection of Weather Hazards on Mars

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Introduction

• Study electric behavior of weather-related dust events
  – Dust devils and dust storms
    • Terrestrial
    • Martian
  – Field experiments
  – Laboratory simulations of dust devils
QuickTime™ and a Sorenson Video 3 decompressor are needed to see this picture.
Outline

• Research Goals
• Electric Theory of Dust Events
• Experiments
  – Lab Results
  – Field Results
• Plans for the Future
• Conclusions
Weather Hazards on Mars

• Dust events pose a significant hazard to future missions to Mars
  – High winds, high dust content could negatively affect manned missions
  – Electric activity could negatively affect robotic landers and manned missions
  – Electric fields can ionize the air and cause potentially hazardous chemical reactions
Research Goals

- To find an effective method for detecting weather hazards on Mars (dust events) at any time of the day or during periods of low visibility
  - To study microdischarges between colliding dust particles in the laboratory
  - To study microdischarges in terrestrial dust devils
  - To design an instrument to remotely fingerprint Martian dust events based on their microdischarges
Electric Theory of Dust Events
Microdischarges in Dust Events

• Asymmetric rubbing occurs between colliding particles
  – Causes a net transfer of electrons from larger to smaller particles
  – Smaller particles become negatively charged
  – Large particles become positively charged
• Microdischarges occur when the particles separate from each other, after a collision
Non-thermal Microwave Emissions

• Microdischarges produce non-thermal microwave radiation [Renno et al., 2004]
  – Non-thermal emissions can be used to remotely fingerprint dust events

• To distinguish thermal from non-thermal emissions we look at the probability distribution function of the amplitude of the emissions (pdf)
  – Gaussian: thermal
  – Non-gaussian: non-thermal
Bulk Electric Fields

• Charge separation occurs when small particles rise in updrafts
  – The larger particles stay near the ground
• Charge separation produces large electric fields in terrestrial dust devils and dust storms
  – Fields in excess of 10 kV/m on Earth [Renno et al., 2004]
Applications to Mars

• Martian dust events are significantly larger and dustier than terrestrial dust events.
  – There is evidence that microdischarges and large electric fields occur in these dust events [Renno et al., 2003, 2004]
  – Lower atmospheric pressure makes electric breakdown easier on Mars
  – Higher dust content and larger storms result in more collisions and therefore more microdischarges
Experiments
Laboratory Setup

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Particles of Interest

- Experiments with various materials
  - Representative of the Martian regolith
    - Silicon
    - Iron
    - Aluminum
    - Potassium
    - Magnesium
  - Particles of a range of sizes representing those likely to be found in Martian dust events

Martian Soil Composition
At Viking 1 Landing Site

[http://resources.yesican-science.ca]
Experimental Setup

• Materials classified by size:
  – Large particles (~1 mm diameter)
  – Small particles (~1 to 10 µm)
  – Mixed particles (half large particles, half small by volume)
Experimental Setup

• Used three materials:
  – Aluminum
  – Basalt
  – Hematite (Fe₂O₃)

• Experiments conducted at various pressures
  – Ranging from 0.1 to 1 Bar
Lab Experiments

• Lab experiments conducted using two different radiometers
  – First provides time series of emission amplitude
    • Look for peaks in the data to identify microdischarges
    • Sensitive to emission frequencies around 10 GHz
  – Second provides a probability distribution function (pdf) of electric field amplitude at small time intervals
    • Look for non-gaussian distribution to indicate the presence of non-thermal radiation
    • Sensitive to frequencies around 10 GHz
Sensor of Setup 1
Setup 1 Lab Results

- Observed microdischarges
- Only detected significant emissions in experiments with aluminum particles
- We might need to look at other frequencies or use more sensitive instruments to detect emissions from other particles
Equipment of Setup 2

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Setup 2 Lab Results

- Positive results with aluminum particles
  - Consistent with results from setup 1
- pdf significantly different from control (blackbody pdf)
- Did not detect emissions in experiments with basalt or hematite
- Did not detect emissions in experiments with only small particles
Kurtosis of the Emissions

- Kurtosis ~3 indicates gaussian distribution.

Large aluminum particles
0.29 Bar

Large aluminum particles
1 Bar
Field Experiments

• Searched for microdischarges in terrestrial dust devils
• Conducted in Summer 2005 near Eloy, AZ
• Used radiometer from setup 1
  – Recoded time series of the amplitude
Field Results

- Microwave Emissions from a dust devil on June 11th 2005 at 2:15pm and a corresponding image of it.

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More Field Results

12:02 p.m. MST on June 11, 2005

2:28 p.m. MST on June 9, 2005

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Plans for the Future

• Field Goals
  – Develop a more portable data collection system
  – Distinguish non-thermal from thermal emissions
  – Correlate emission amplitude with weather data at a fixed location

• Laboratory Goals
  – Conduct experiments with additional materials
  – Try different methods to detect emissions with hematite and basalt
  – Calculate pdf of non-thermal emissions by removing background noise

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Conclusions

• Have shown that emissions from colliding particles is non-thermal
• Identified a flight qualified instrument that can distinguish non-thermal from thermal emissions
• Additional lab experiments with different materials are necessary
• Additional field measurements using different data collection procedures are necessary
• Optimal frequencies must be identified
• Recommend an instrument to measure electric fields to be placed on Mars landers
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Questions?
Addressing Problems with Results

• Why didn’t we detect emissions with basalt and hematite?
  – Sampling rate may not be fast enough
  – May need to use a sensor with a different frequency

• In experiments with aluminum we detected changes in pdf for all but small particles
  – Small particles tend to coat the inside of the bell jar, which may interfere with detection of emissions
Why 10 GHz?

• Very sensitive
• Developed for satellite dishes
• Inexpensive
Effects of fan?

- No visible difference in pdf of electric field amplitude
- No change in kurtosis

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Charge Transfer by Asymmetric Rubbing

- Solid matter has more empty energy levels than electrons in high energy states.
- During asymmetric rubbing:
  - There is a net transfer of electrons to the smaller body because it slides more over the other.
  - The smaller body becomes negatively charged and the larger becomes positively charged.