V Reunión de Ciencias Planetarias y Exploración del Sistema Solar (CPESSV)

# DUST ON MARS FROM NAVCAM AND HAZCAM IMAGES ON MSL

**Hao Chen-Chen, Santiago Pérez-Hoyos, Agustín Sánchez-Lavega.**
Departamento de Física Aplicada I, ETS Ingeniería de Bilbao, UPV/EHU, Bilbao, Spain (hao.chen@ehu.eus)

Universidad del País Vasco Euskal Herriko Unibertsitatea | NAZIOARTEKO BIKAINTASUN CAMPUSA CAMPUS DE EXCELENCIA INTERNACIONAL | Grupo de Ciencias Planetarias

**Hao Chen Chen**
Madrid,
Jueves 8 de junio de 2017

# Index

- Introduction
- Dust on Mars: State-of-the-art
- MSL Engineering Cameras
- Image Data Sets and Processing
- Radiative Transfer Model
- Current Status Report

# Introduction

- Dust plays a critical role in the behaviour and evolution of the Martian atmosphere.

- For atmosphere modelling studies, the key properties that determine the radiative effects of dust are: particle size distribution, shape and complex refraction index.

- Alternative usage of Mars Science Laboratory ‘Curiosity’ (MSL) Engineering Cameras: retrieving Mars’ atmosphere dust properties.

- Dust properties can be constrained by evaluating the sky brightness as a function of the scattering angle retrieved from the image data.

- This is a progress report.

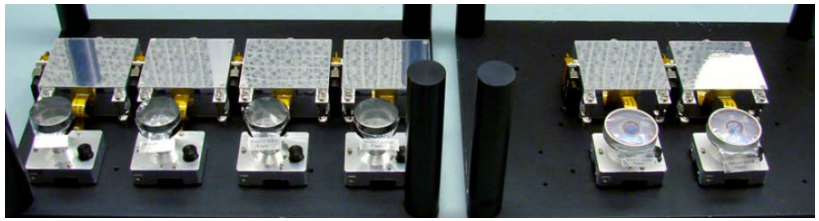
# Dust on Mars: State-of-the-art

- Dust optical properties: Complex refraction index. (*Wolff et al. 2009, 2010)*

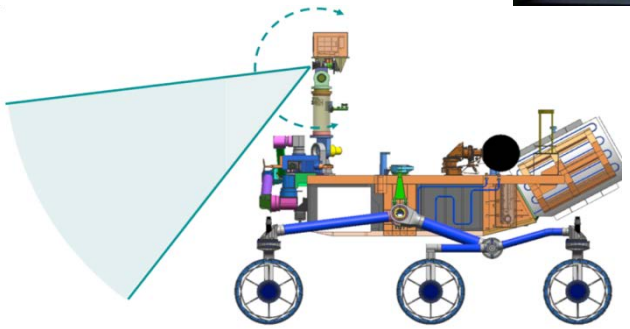
- Dust physical properties:
  - Size distribution (Mars Exploration Rover) *(Lemmon et al. 2015)*
  - Shape
  - Vertical distribution

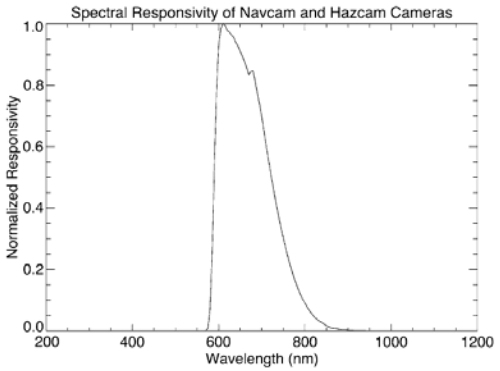
- Mars' ground observations with MSL:
  - Mastcam: Optical Depth record *(Lemmon et al. 2014)*
  - REMS UV: aerosol size and optical depth in UV (*Smith et al. 2016, Vicente-Retortillo et al. 2017)*
  - Navcam: line-of-sight optical depth inside Gale Crater (*Moores et al. 2016*)

# MSL Engineering Cameras



## Navcam






## Hazcam

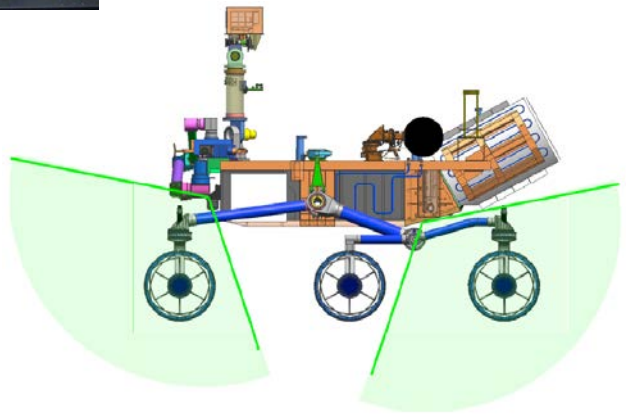


**Table 2.1.2 - Navcam Operational Characteristics**

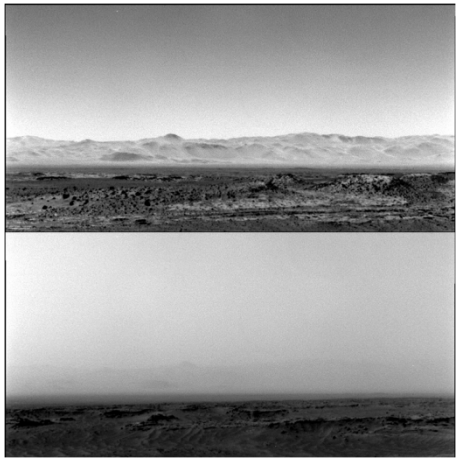
| Characteristic | Value |
|---|---|
| Field of View (FOV) | 45 x 45 deg |
| Baseline Stereo Separation | 42.4 cm |
| Angular Resolution | 0.82 mrad/pixel at center |
| Spectral Bandpass | 600 - 800 nm |
| Focal Length | 14.67 mm |
| f/number | 12 |
| Depth of Field | 0.5 m - infinity |
| Best Focus | 1.0 m |

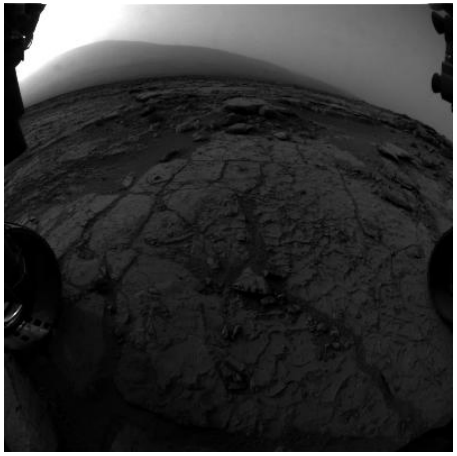
**Table 2.1.1 - Hazcam Operational Characteristics**

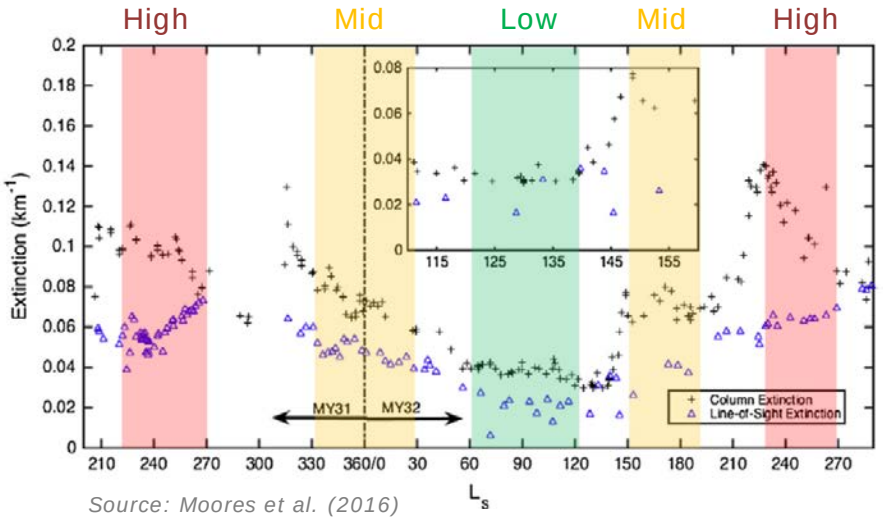
| Characteristic | Value |
|---|---|
| Field of View (FOV) | 124 x 124 deg |
| Baseline Stereo Separation | 16 cm for front, 10 cm for rear |
| Angular Resolution | 2.1 mrad/pixel at center |
| Spectral Bandpass | 600 - 800 nm |
| Focal Length | 5.58 mm |
| f/number | 15 |
| Depth of Field | 0.1 m - infinity |
| Best Focus | 0.5 m |

Source: - Maki *et al.* (2012), MSL Engineering Cameras, Space Sci Rev, 170:77-93
- JPL (2015): MSL Software Interface Specification (SIS) – Camera & LIBS EDR and RDR Data Products

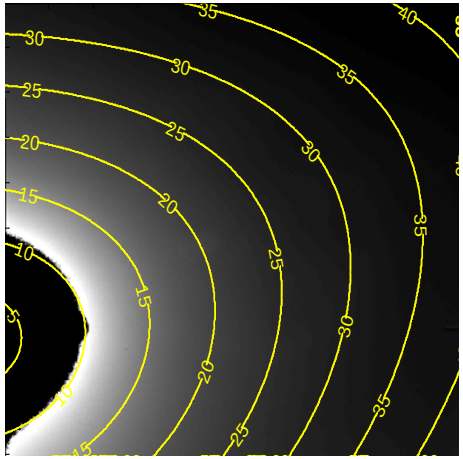
# Image Data Sets

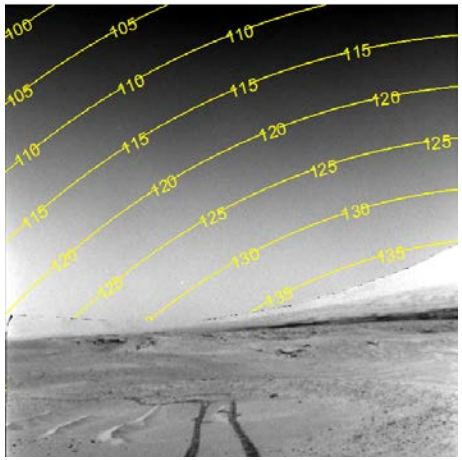


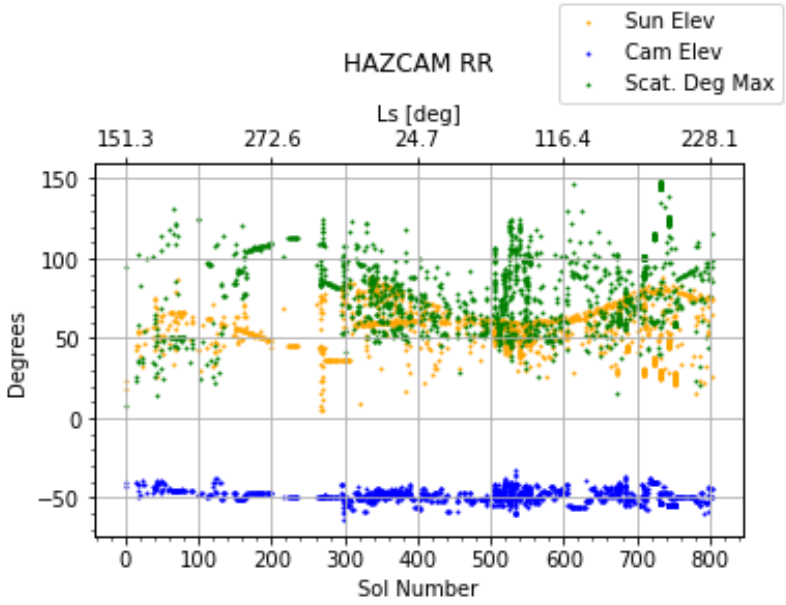




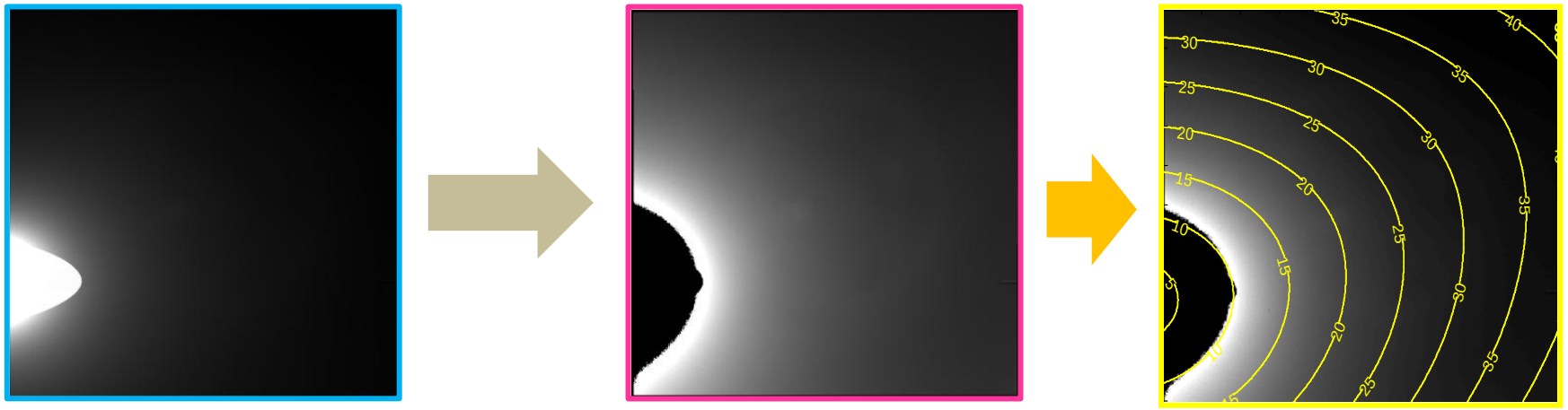

Source: Moores et al. (2016)







# Image Processing




## Navcam Calibration Pipeline

Raw Image **EDR**

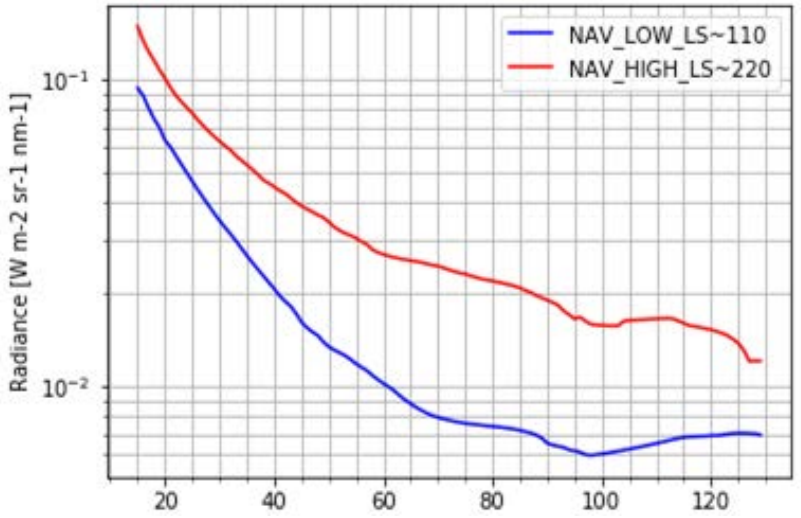
**Calibration Parameters:**
- Electronics Temperatture
- CCD temperature
- Exposure Time
- Camera flat field

**Operations:**
- Bias removal
- Dark current removal
- Shutter effect removal
- Flat-field Correction
- DN to Radiance conversion

Calibrated **RAD RDR**

*Source: Soderblom et al. (2008)*

MSL-NAVCAM Retrieved Radiance comparison



# Radiative Transfer model

- **Structure and Composition:** Plane-parallel atmosphere. Pressure, Temperature, density and species abundance from Mars Climate Database of LMD.

- **Gas opacity:** absorption for each gas calculated line-by-line from HITRAN 2012 database, correlated-k method.

- **Aerosol:** Retrieved Phase Functions using T-Matrix method for different particle shapes, Gamma size distribution function. Dust complex refraction index from Wolff *et al.* 2009.

- **Viewing geometry:** Sun elevation/azimuth, Instrument pointing elevation/azimuth, cameras FOV and scattering angle retrieval

- **RT solver:** Python implementaton of DISORT (PyDISORT, Adamkovics *et al.,* 2016)

# Current status

## Observations

Image Sets

Derived data

**Navcam**

- 360º Sky survey
- Sun images
- Line-of-sight extinction (optical depth) inside Gale Crater

**Navcam line-of-sight Optical Depth**

**Rad vs Scat. Angle**
- Near Sun
- 20º to 120º

**Hazcam**

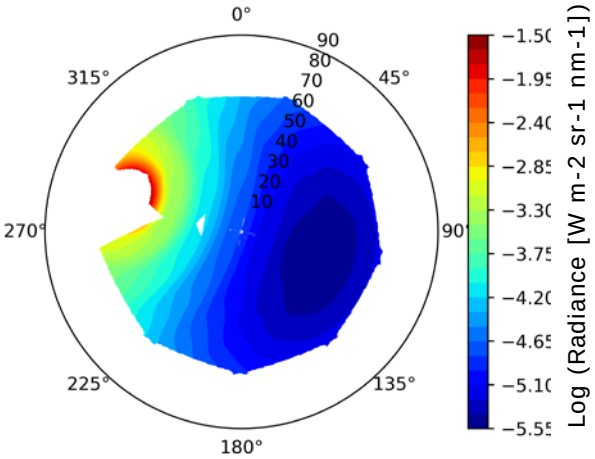
- Simultaneous Low and High scattering angle images

**Rad vs Scat. Angle**
- Near Sun
- At 145º

## Model

| | |
|---|---|
| Other MSL instruments | Multi-spectral Column Optical Depth |
| MCD | Atmosphere Structure and Composition |
| Dust | Complex Refraction Index |

DISORT Navcam Sol669 scenario simulation



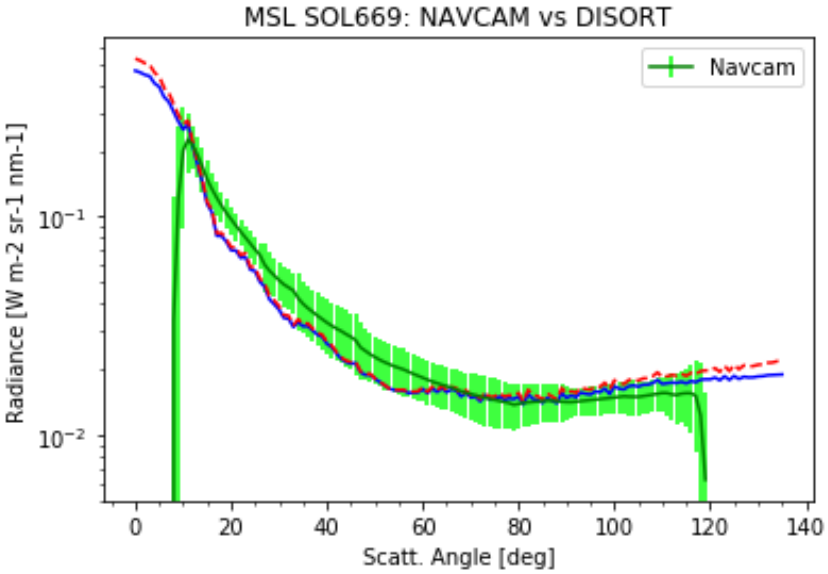

## Problem variables

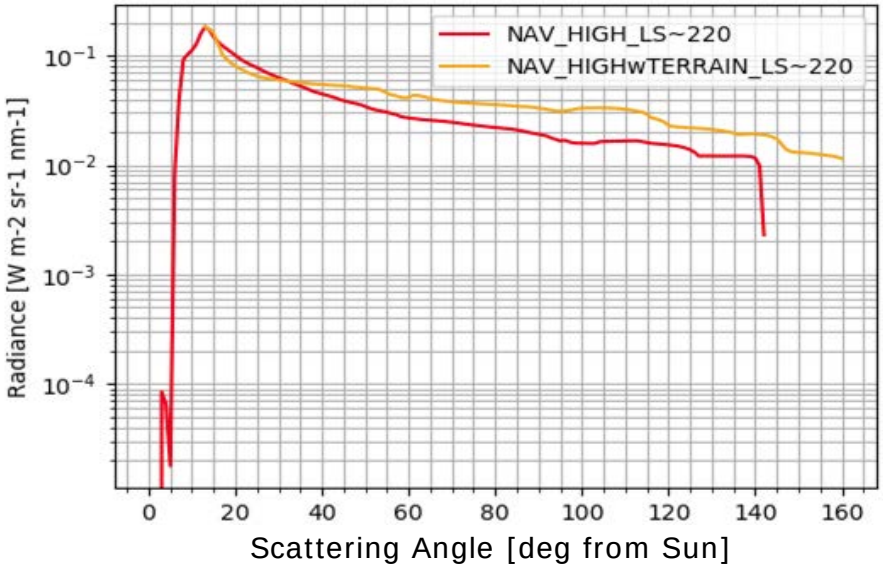
**Particle size (r_eff, v_eff)**

**Particle Shape**

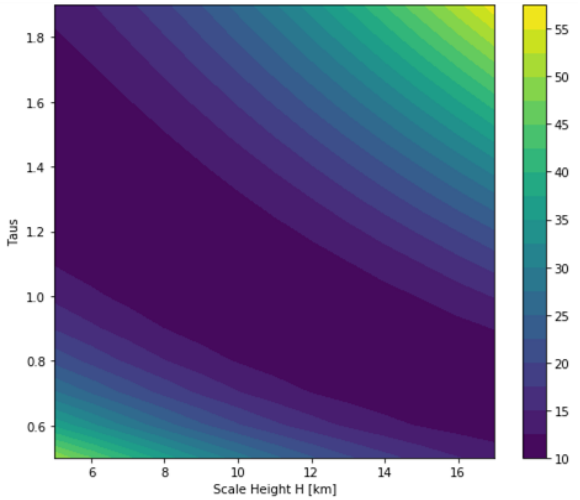
**Local aerosol vertical distribution**

# Current status

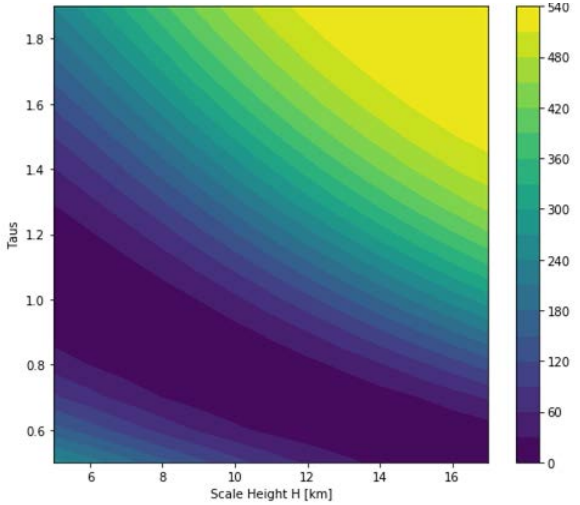



Model Chi-2 fit to Low Elevation Obs: Cam Elev ~15º deg




Model Chi-2 fit to High Elevation Obs: Cam Elev ~70º deg



# Muchas gracias por vuestra atención.

# ¿Preguntas?

# BACK-UP SLIDES