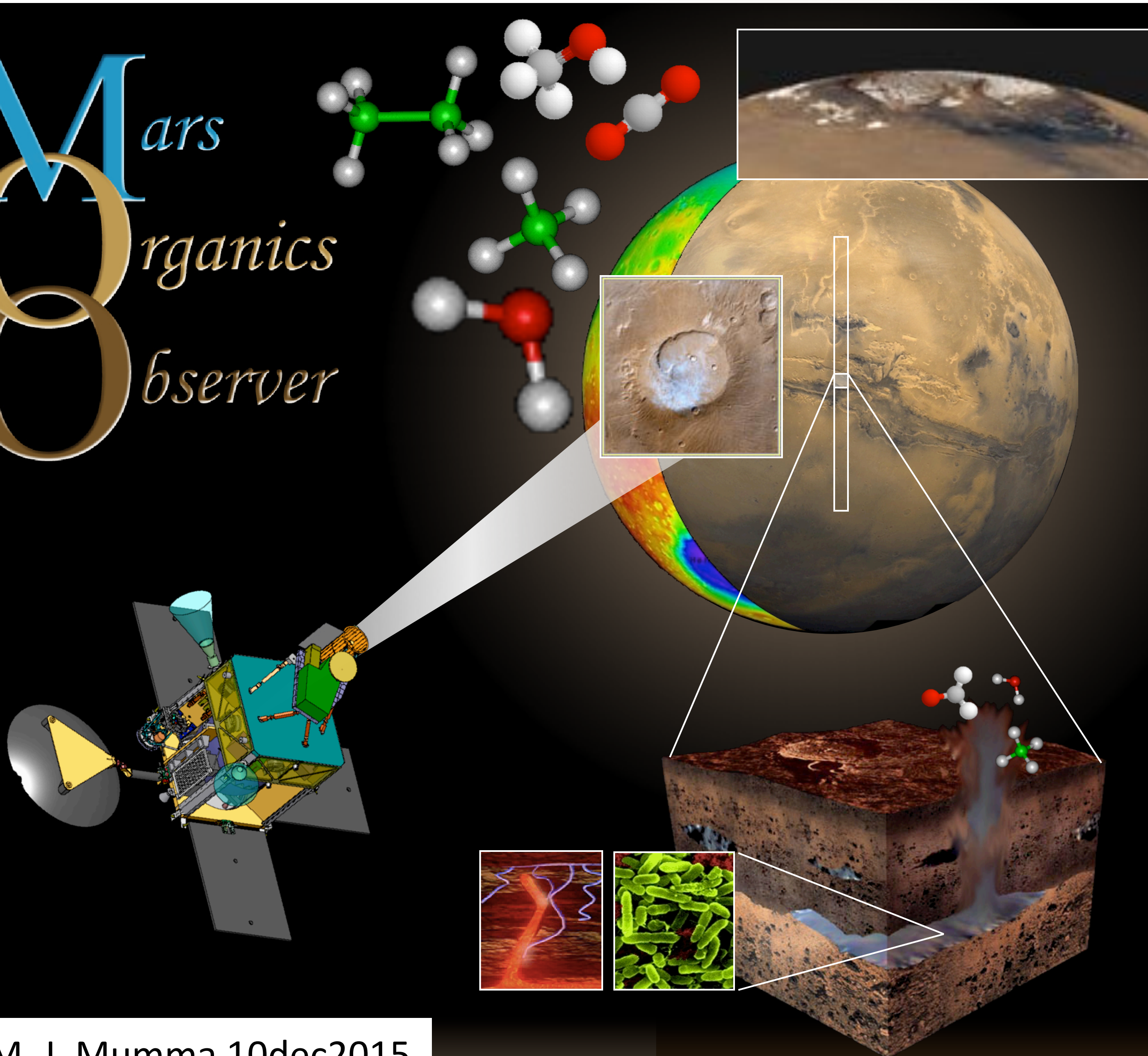
Mars Organics Observer



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Dr. Michael Mumma, Principal Investigator
NASA/Goddard Space Flight Center

in partnership with
Ball Aerospace and Technologies Corporation

The Science Driver: Active Release of Methane

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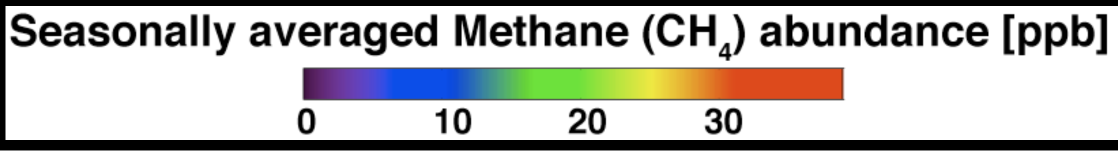
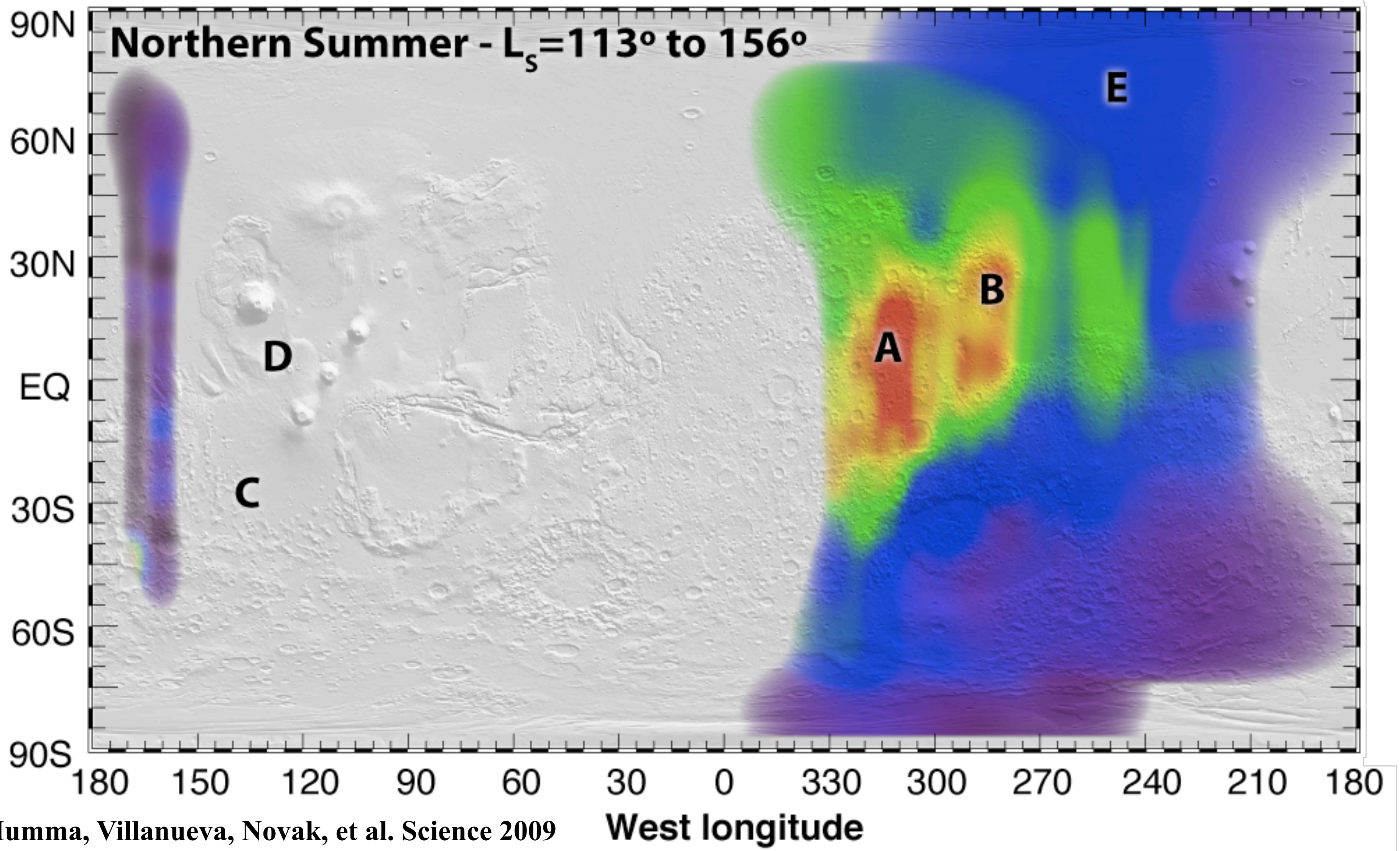


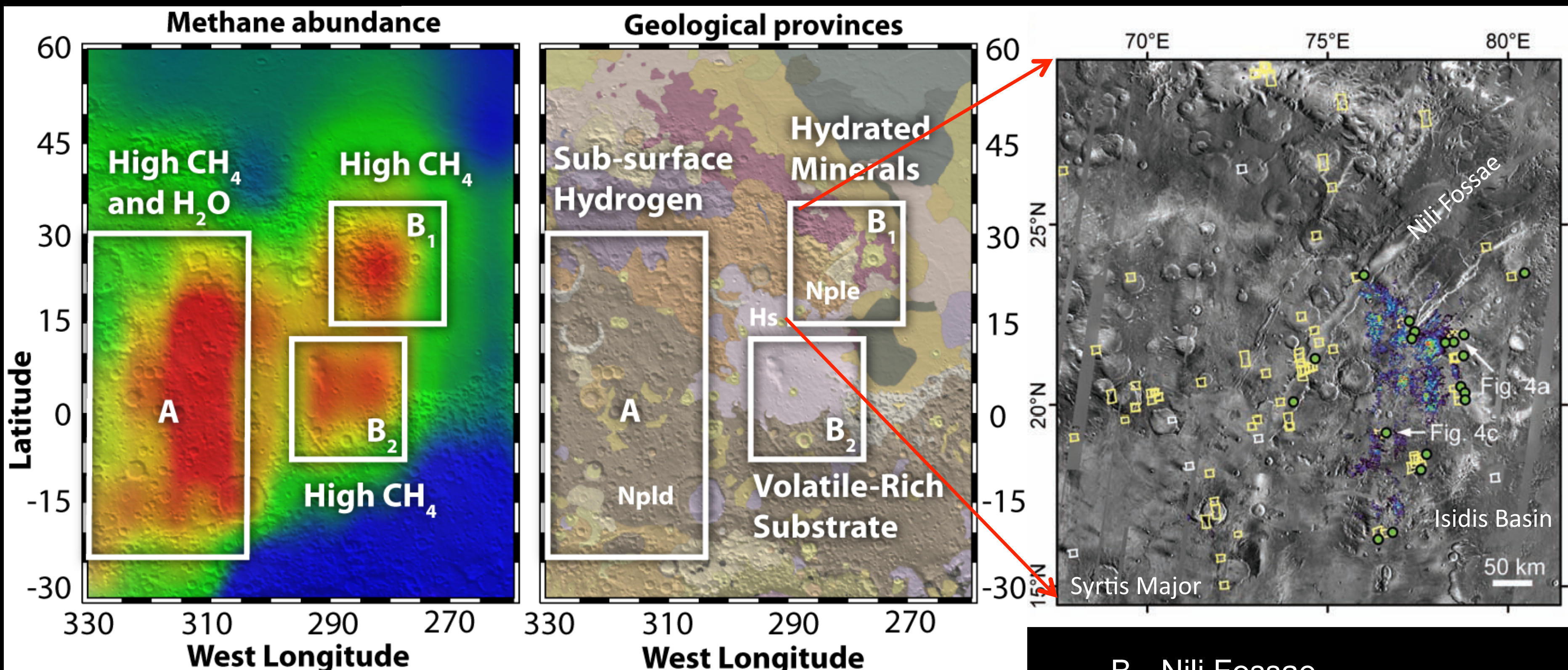


Mumma, Villanueva, Novak, et al. Science 2009

The Science Driver: Active Release of Methane

High resolution spatial maps reveal local methane plumes

A. Ancient Hydrated Terrain B$_1$. Nili Fossae B$_2$. Syrtis major volcano, S.E. Quadrant



B$_1$. Nili Fossae
Carbonates and Phyllosilicates
Ehlmann et al. Science 2008

Mumma, Villanueva, Novak, et al. Science 2009

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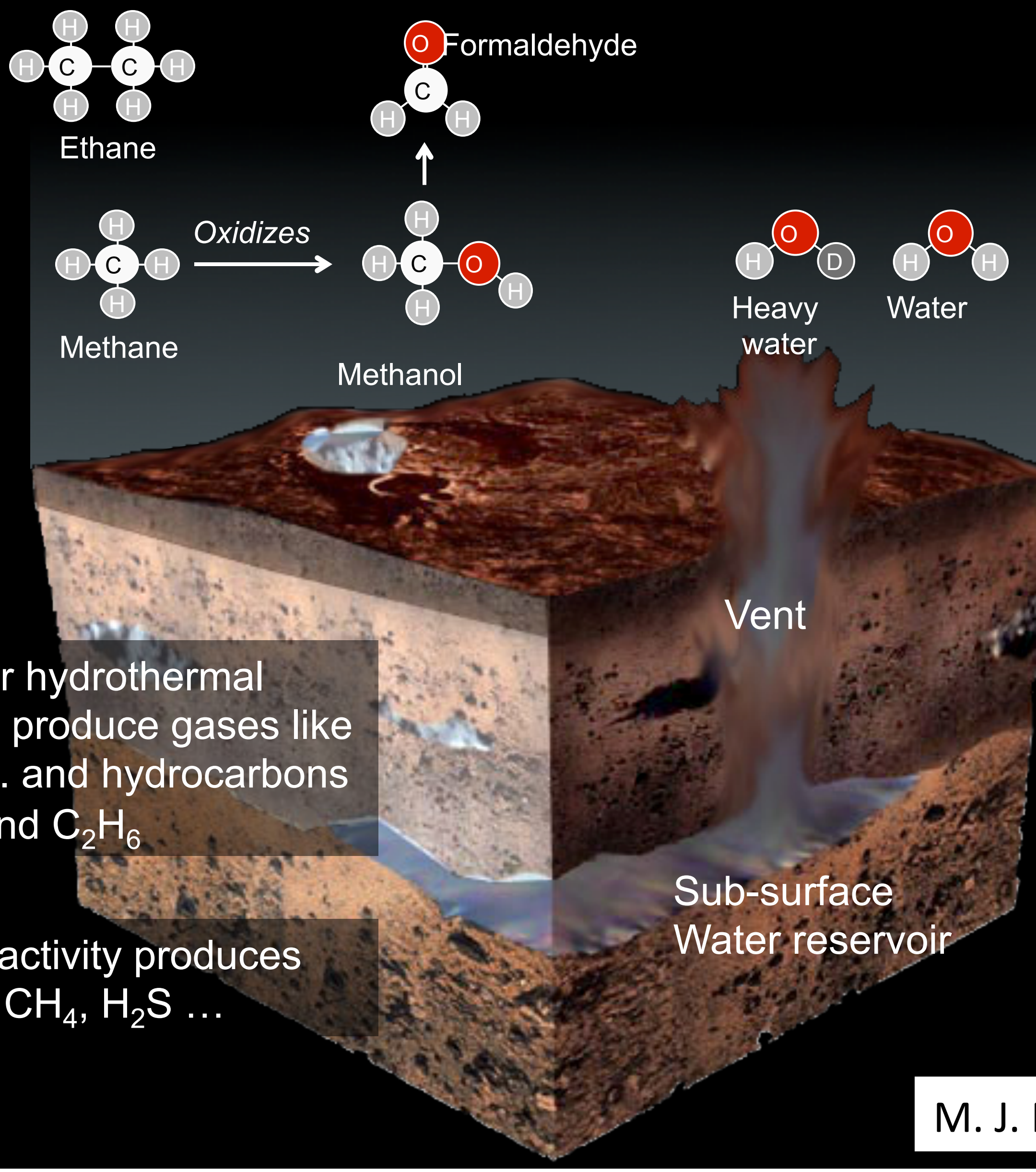
Mars Organic Observer: Science Objectives

The C_2H_6/CH_4 ratio is important for assessing the origin of the sensed gas.

CH_3OH and H_2CO are important for identifying the total production and also the sinks of CH_4

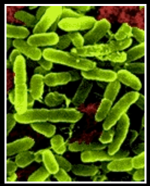


Atmosphere: $(HDO/H_2O)_{ER}$~ 5 because of preferential loss of the lighter isotope

The HDO/H_2O ratio reveals the loss of water from Mars and the age of the sensed gas.

Cryosphere: $(HDO/H_2O)_{ER} < 2$??? representative of a more primordial chemistry

Volcanic or hydrothermal processes produce gases like SO_2,CO_2,.. and hydrocarbons like CH_4 and C_2H_6



Biological activity produces gases like CH_4, H_2S …

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MOO: Science Objectives

- **Map organic source and sink regions**
  - Establish sources of methane, water, and related species
  - CH_4: 0.1 ppb (3-sigma), 100x100 km resolution, global coverage
    deeper integrations in selected regions (isotopes; super-resolution)
    12 x 12 km resolution on surface (sub-spacecraft region)
  - Evaluate sinks (surface, heterogeneous chemistry, etc.)
  - Measure dependence on surface temperature (season, time-of-day)
    Repeat at intervals of Mars month
- **Test factors affecting methane origin and destruction**
  - Age of water reservoir accessed: (D/H ratios in methane and water)
  - Destruction mechanisms (spatial distributions CH_4, CH_3OH, H_2CO)

  Biotic vs. abiotic production (homologous series: CH_4, C_2H_6, …)
- **Characterize the Climate and Geology of Mars**

  Study circulation patterns on Mars; the water cycle; HDO/H_2O, etc.
  Characterize Mars' present climate and climate processes.
  Characterize Mars' ancient climate.

  Test presence of active geothermal processes.
  Characterize the structure, dynamics, and history of the planet's interior.
- **Mission Duration: 3 Earth-years required, 5 years goal**
  - Two full Mars years goal
  - Provide long dwell-time over specific sites
  - Provide simultaneous images (local conditions, climatology)

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Other Issues: MOO & MSO-Lite

MSO vs. MOO? **or** **MSO <u>and</u> MOO**

Fact: Mars program is morphing towards a landed mission to an active vent of established biogenic potential. It is critical to accurately locate this vent.

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- **MSO**: Low Mars orbit
  - Science capability: Solar occultation high res IR spectrometer
    - Trace gas analysis, abundance & isotopic = **Very Good**
      - vertical profiles (Good, but sparse coverage)
    - Active vent properties (nature & location) = **Very Poor!**
  - Telecom capability, range (**few 100 km**), LOS time (**Short**)

- **MOO**: Mars-Sun L1
  - Science capability:
    - Trace gas analysis, abundance & isotopic = **Very Good**
    - Active vent properties (nature & location) = **Excellent**
      - vertical profiles (modest, but global coverage every day)
  - Telecom capability, range (**1.4E6 km**), LOS time (**Long – 12 hours every day**)

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MSO and MOO : The data polygon permits identifying all active vents, their seasonal behavior, annual repeats, and whether bio- or geo- active.

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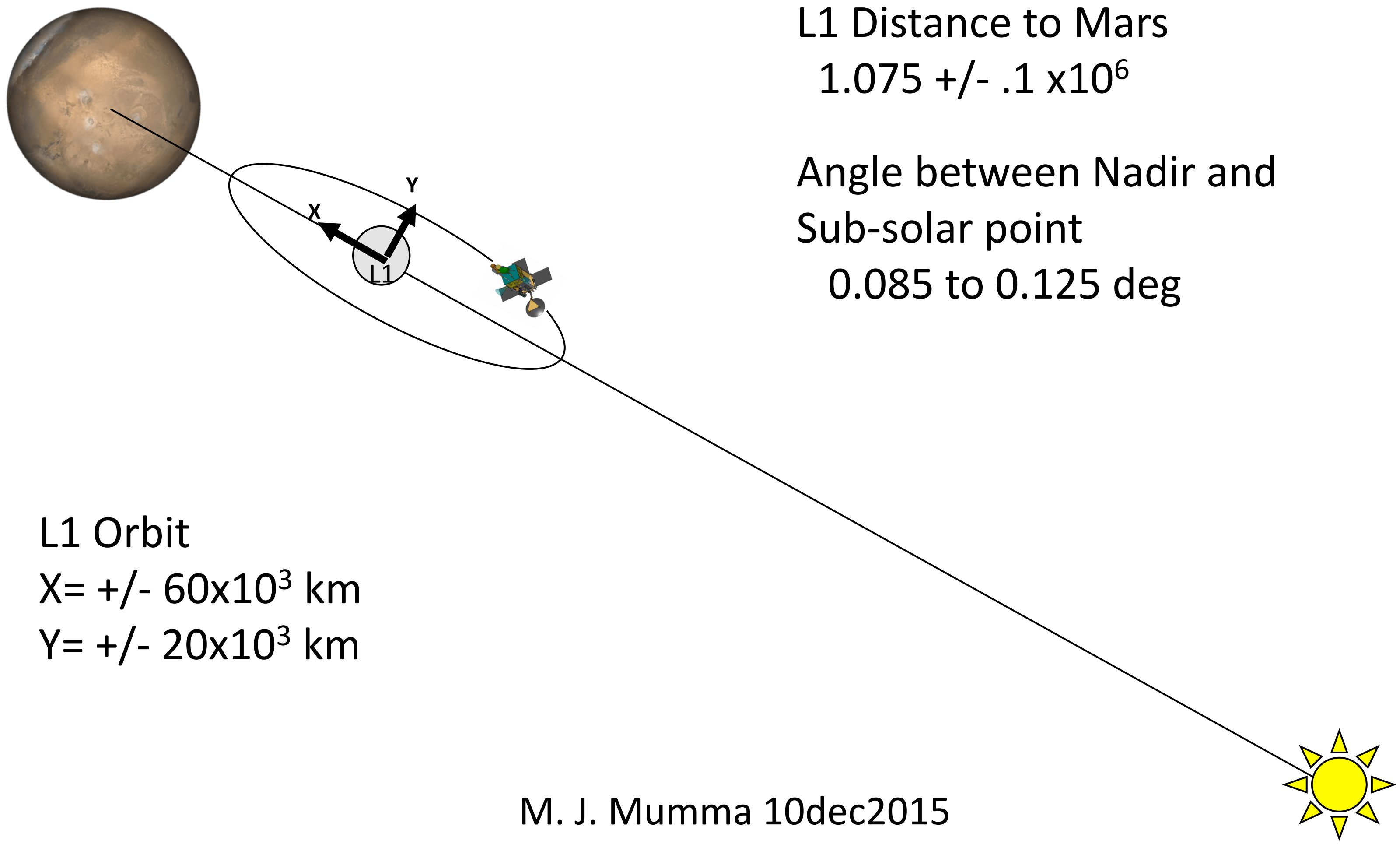
L1 Observatory - Orbit Concept

Looking Down on Mars Ecliptic and L1 Orbit Planes



L1 Distance to Mars
1.075 +/- .1 x10^6

Angle between Nadir and Sub-solar point
0.085 to 0.125 deg

L1 Orbit
X= +/- 60x10^3 km
Y= +/- 20x10^3 km

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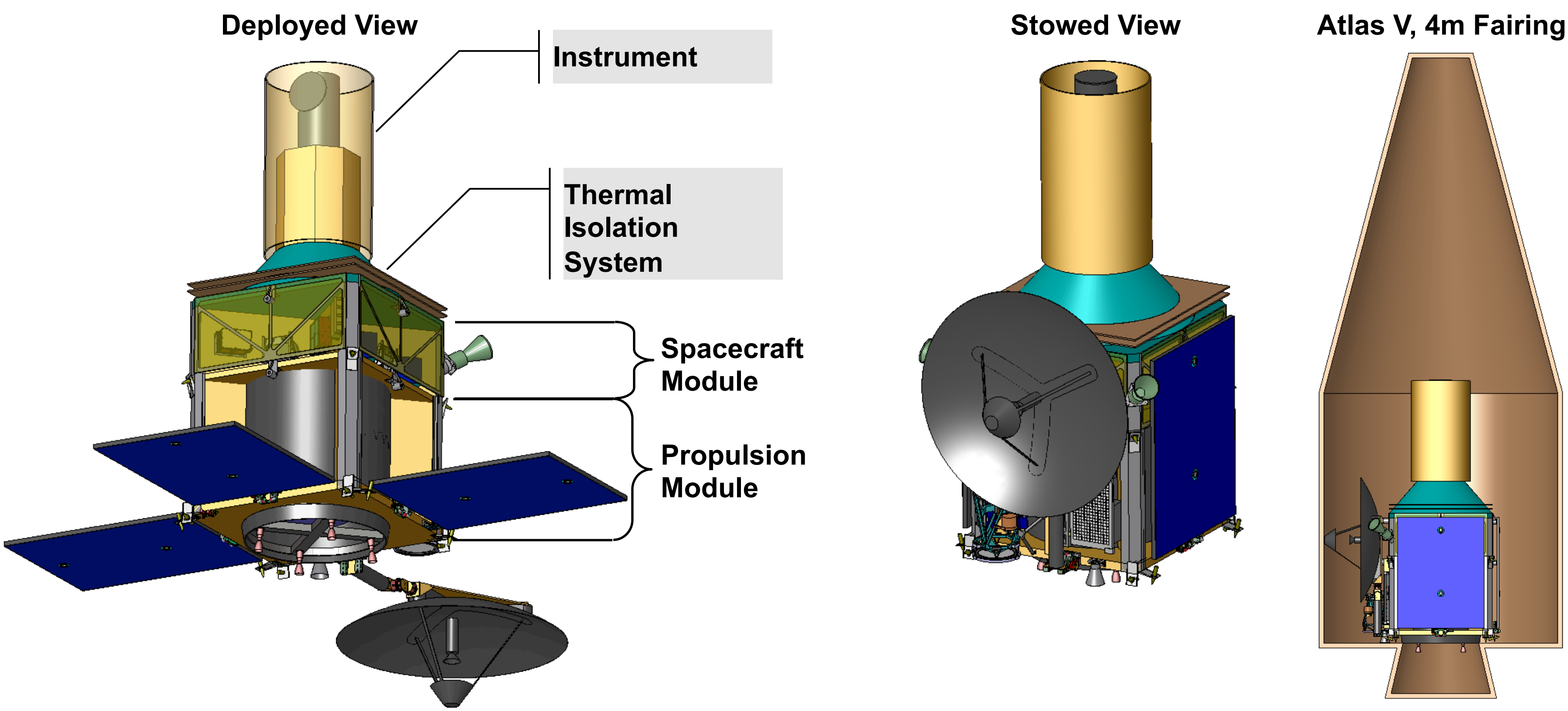
MOO Spacecraft Concept

- MOO spacecraft based on Deep Impact and Kepler Architecture
- Provide thermal isolation for instrument
- Stable and accurate pointing using camera in instrument



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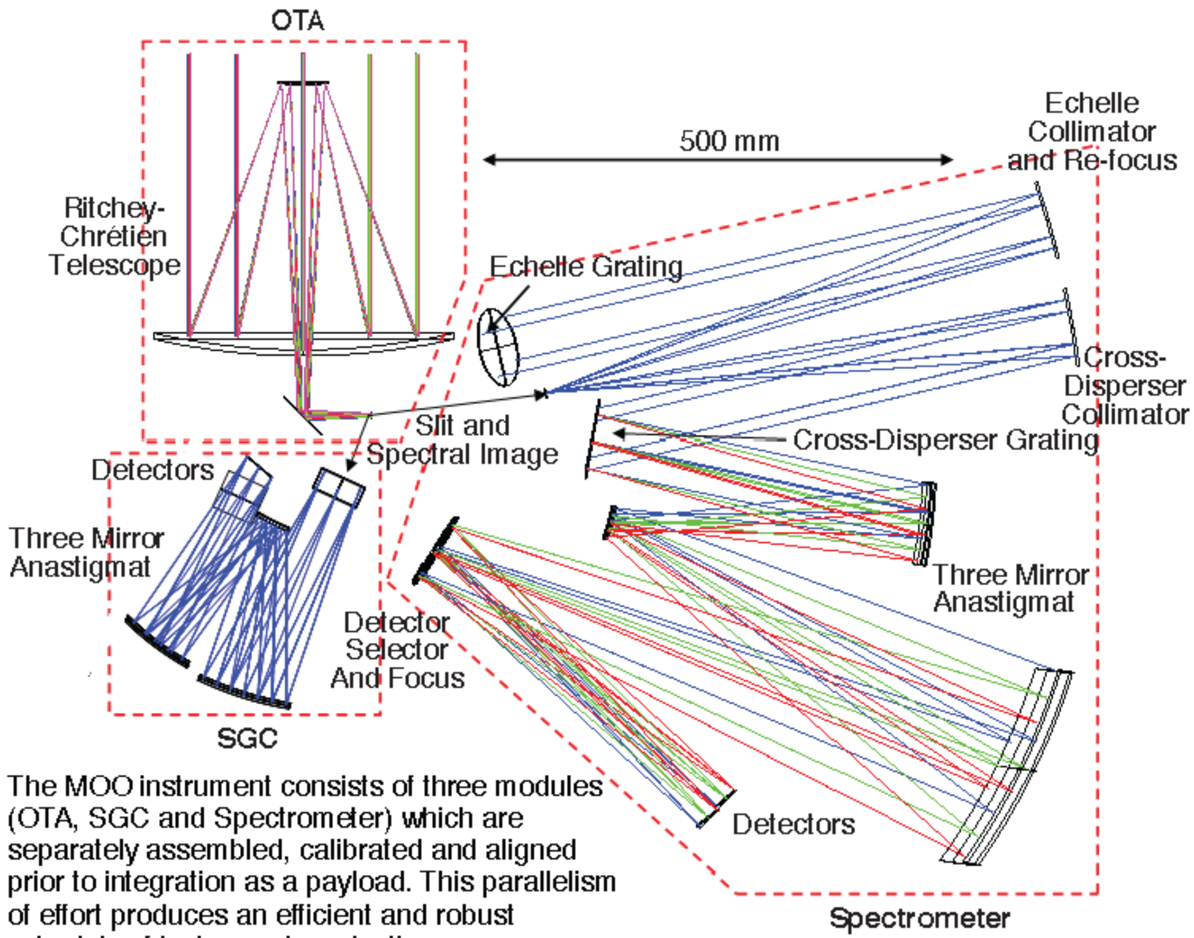
OTA – SGC – Spectrometer Ray-trace



The MOO instrument consists of three modules (OTA, SGC and Spectrometer) which are separately assembled, calibrated and aligned prior to integration as a payload. This parallelism of effort produces an efficient and robust schedule of instrument production.

Light collected by the OTA is directed onto the reflecting slit plate (0.8° x 0.8° field) which splits and redirects the field. Light transmitted through the slit (2 x 720 arcseconds) enters the spectrograph, is dispersed, relayed and recorded. Light surrounding the slit is reflected to the SGC allowing for accurate determination of slit location, for fine guiding and scientific imagery.

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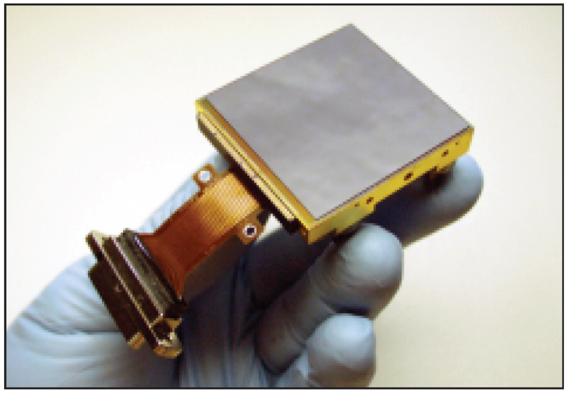
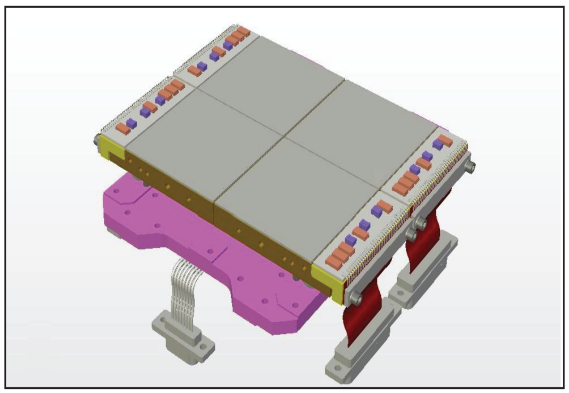
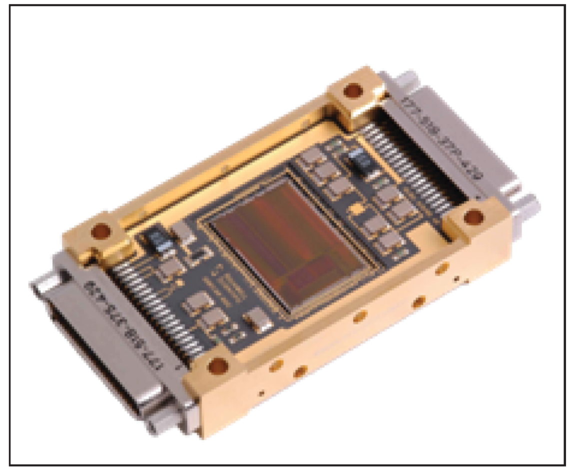
MOO – JWST Detectors & ASIC







A Hawaii 2RG format HgCdTe array of 2048^2 pixels (top, left). Four such arrays (butt-coupled) for MOO comprise primary (2K x 4K) and backup (2K x 4K) detector arrays, and one of the four SIDECAR ASICs (bottom, left). In 2006, arrays and ASICs were both TRL6. In 2015, both are TRL9.

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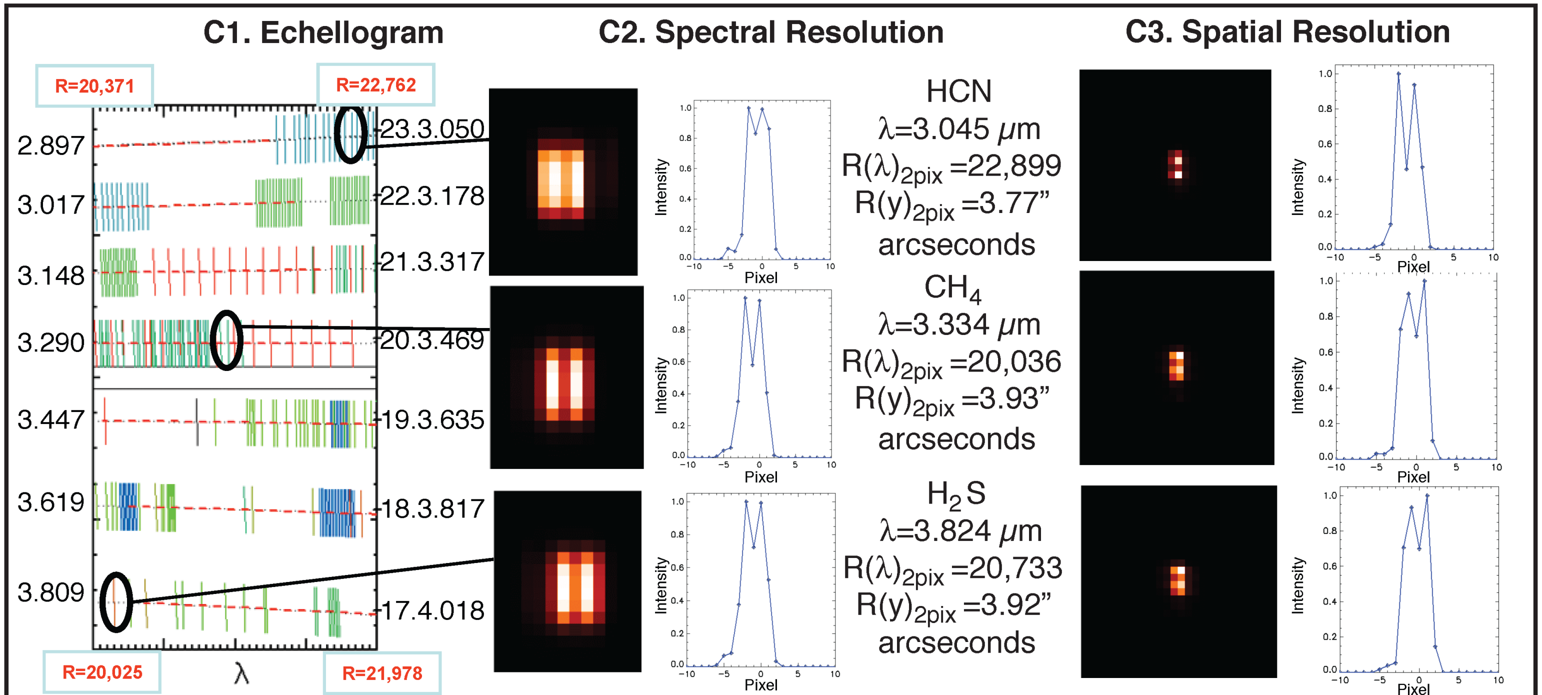
MOO – Echellogram Format



CO_2(628)	CH_3OH	HDO	OO
CO_2(626)	H_2CO	SH	HNO
CH_4	HCN	CH_3SH	SO_2
C_2H_6	H_2O	H_2S	N_2O
			H_2S

Panel C1 illustrates the echellogram format (orders 17-23) with selected key spectral lines across the 2K x 4K detector. The wavelengths at the ends of each order are specified. Spectral resolving power ranges from ~20,000-23,000 as noted at each corner of the field. Details of the spectral resolving power (panel C2) and spatial resolution (panel C3) are highlighted at three different points on the detector corresponding to key molecular absorption lines: HCN (3.045 μm), CH_4 (3.334 μm) and H_2S (3.824 μm). Panel C2 shows images of a pair of lines separated by two pixels (36 μm) and the corresponding line profiles. Panel C3 shows images and profiles of a pair of point sources along the slit, separated by two pixels (36 μm). In all cases the resolving power is ≥20,000 and the spatial resolution ≤4.0 arcseconds.

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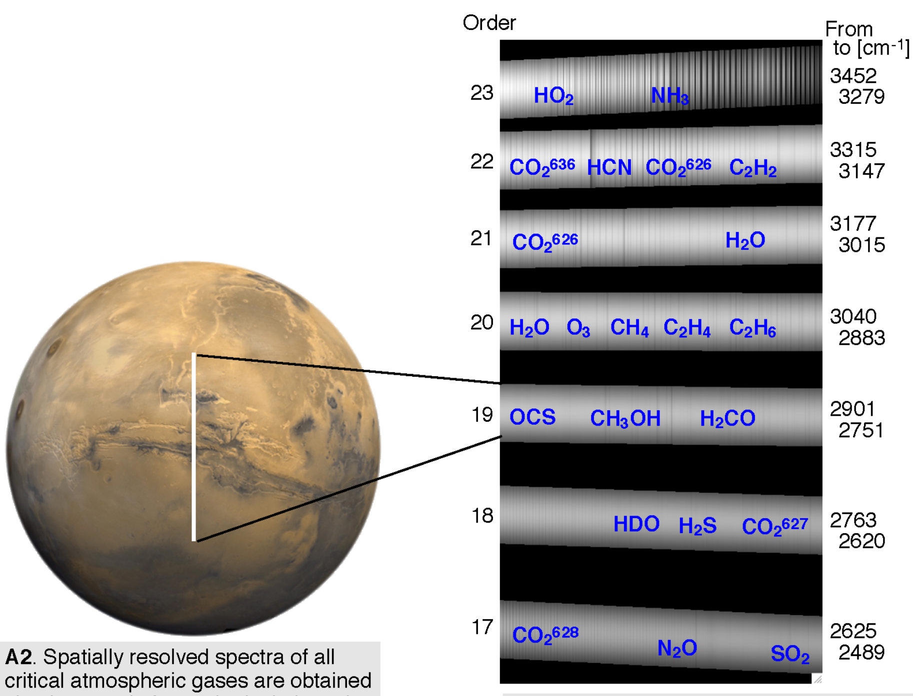
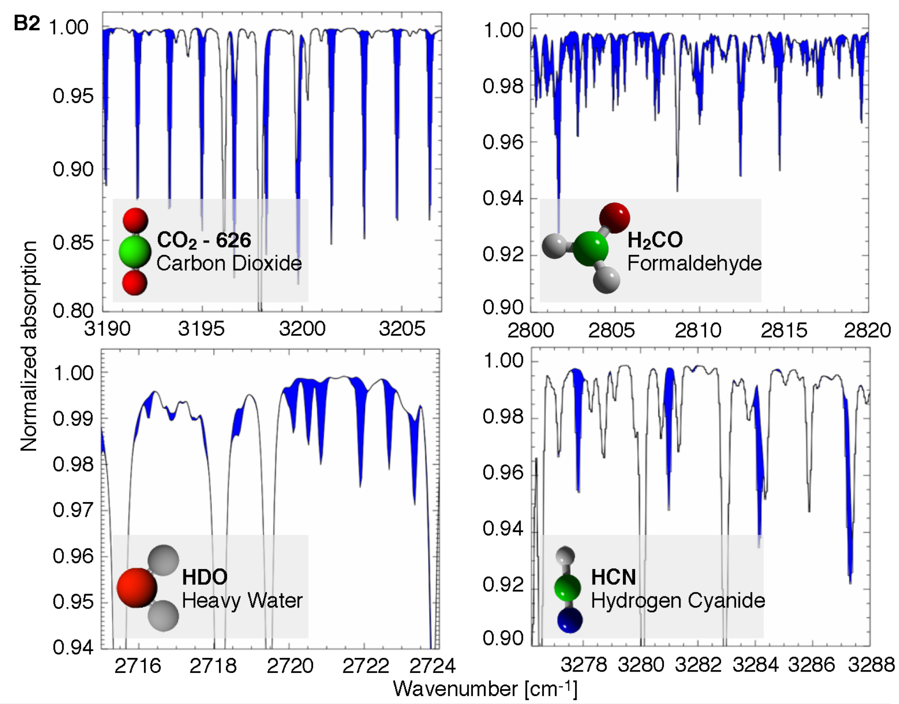
MOO – Simultaneous Detections



A2. Spatially resolved spectra of all critical atmospheric gases are obtained simultaneously for each pixel along the slit (12 km pixels at nadir). Each pixel along the slit maps into a spectrum on the 2Kx4K detector. In one Mars' day, 50% of the planet can be mapped.



Synthetic echellogram and selected spectral extracts for Mars, based on design parameters of the MOO spectrometer. **B1.** The echellogram samples the spectrum completely over the range 2.9 - 4.0 μm, in seven spectral orders. The spectrum was synthesized at a resolving power (l/dl=20,000) for Mars surface pressure of 7 mbars, standard temperature profile for mid-latitudes, and a two-way path at two air-masses. **B2**. Spectral extracts for carbon dioxide (CO_2, 626 isotope), formaldehyde (H_2CO, 50 ppb), heavy water (HDO, 10 ppb), hydrogen cyanide (HCN, 50 ppb).

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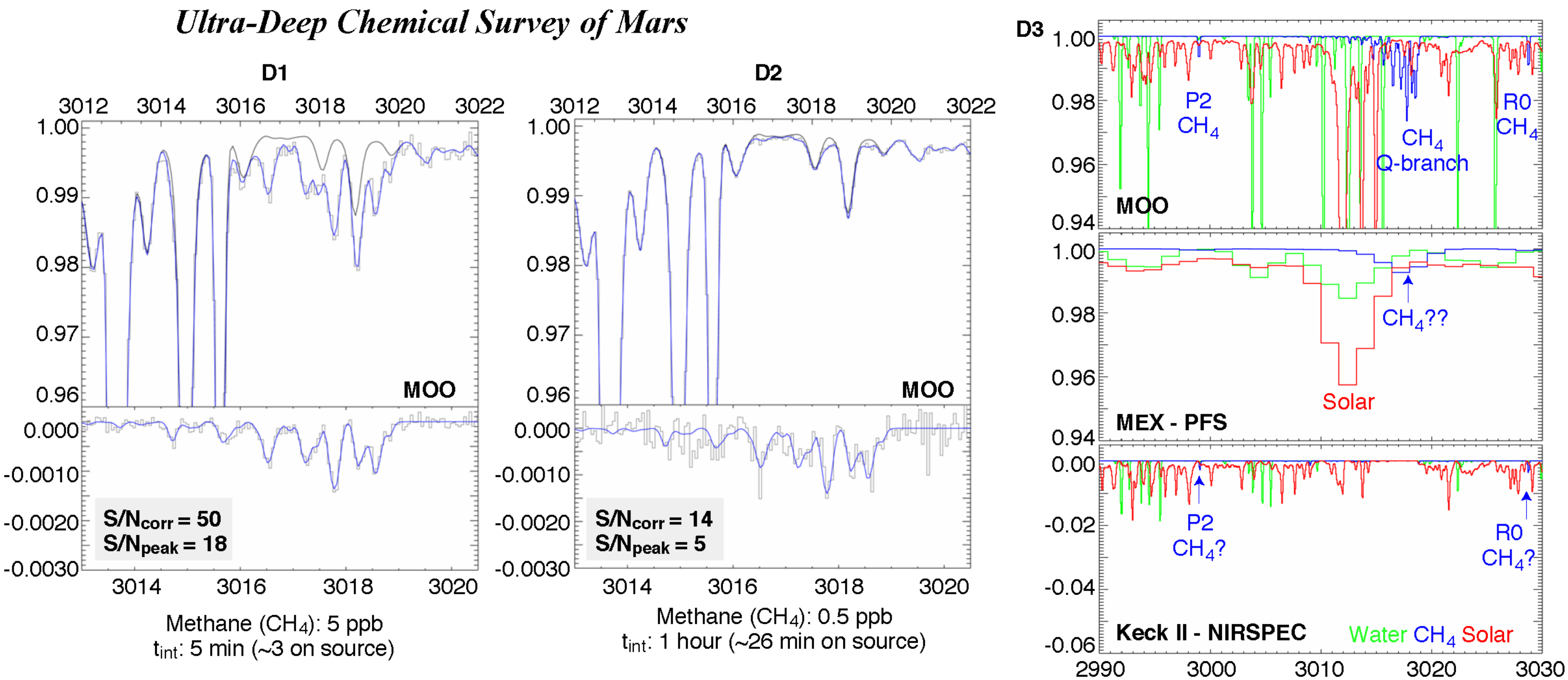
MOO – Sensitive Search for Methane



Sensitivity Estimates for Spectroscopic detection of Methane on Mars. **D1.** In the Rapid Planet survey, spectral lines in the Q-branch region are detected with high confidence in five minutes clock time, representing a 96 km x 96 km footprint (nadir) on Mars. **D2.** In the Deep Survey mode, 12 maps taken as in D1 are co-added, improving the S/N by 3.5. At 0.5 ppb, methane would be detected at the 14-sigma level (correlation mode). **D3.** The spectrum of sunlight reflected from Mars shows solar lines along with lines of H_2O and CH_4 in the Mars atmosphere. The spectrum is shown convolved to the resolving powers of 20,000 (MOO), 1500 (MEX-PFS), and 24,000 (Keck-NIRSPEC). The significant limitation of the PFS data is demonstrated, strongly putting into question their claimed detection of methane. All ground-based searches (e.g., Keck) are severely restricted by terrestrial extinction. With a resolving power of 20,000 MOO will separate these lines cleanly and will return clear detections of methane and other targeted species.

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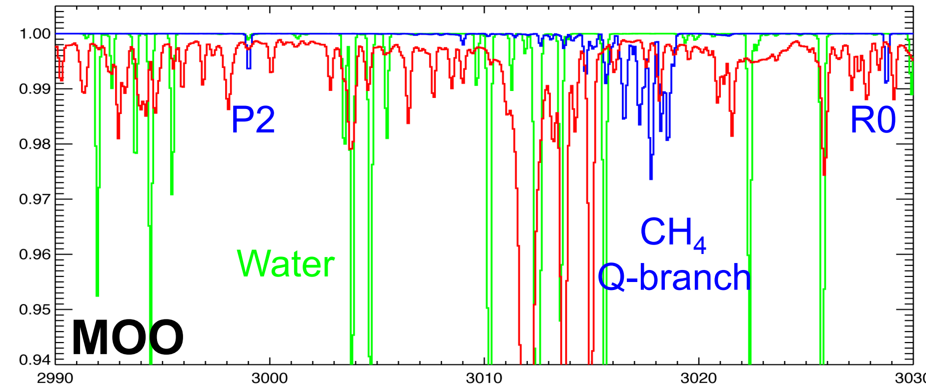
MOO 'Comparisons'

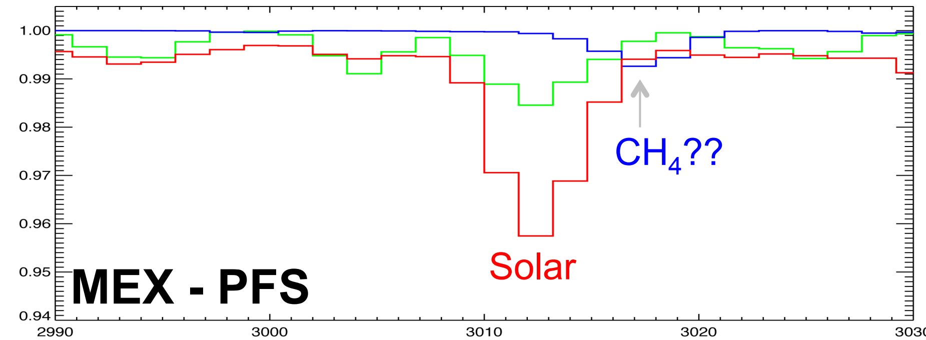
Mars Organic Observer
Cross-Dispersed Echelle Spectrometer
Minimum Resolving power: 20,000
Global coverage in 49 hours

National Aeronautics and Space Administration



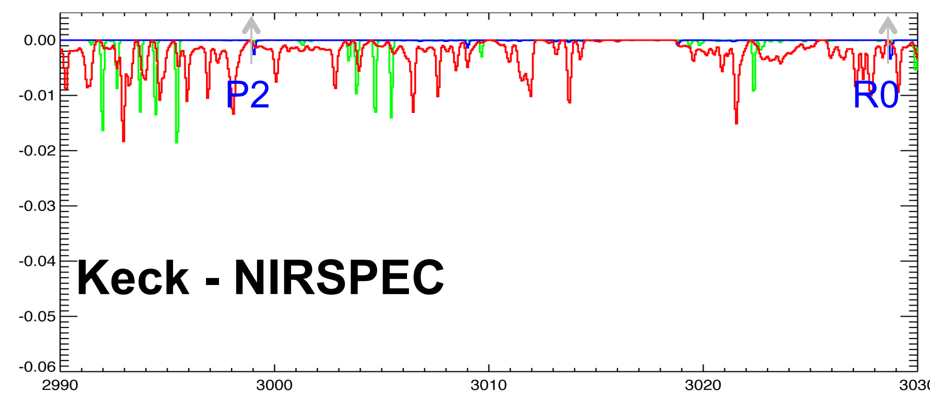
Mars Express Spacecraft
Planetary Fourier Spectrometer (PFS)
Maximum Resolving power: 1,500
Limited coverage because of orbit

European Space Agency



W.M. Keck Observatory
The world's largest infrared telescope
NIRSPEC Echelle Spectrometer
Maximum Resolving power: 25,000
Affected by atmospheric extinction

Caltech, UC and NASA



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MOO Mission Concept

- **Mission Life: 3 years required, 5 years goal**
- **Target Launch date: 2016**
- **Orbit: Mars L1 Lissajous 100,000 x 60,000 km**
- **Launch Vehicle Delta II 2925H (goal) Atlas V (if necessary)**
- **Observatory Best Estimate Requirements (includes allocated reserves)**
  - Dry Mass: ~640 kg
  - Power: ~511watts
  - Station keeping and momentum cold gas: 30 kg
  - Data collection rate, up to 6 Gbit/day (max)
  - Downlink rate: DSN compatible - Time of year dependent
  - Pointing knowledge (planet referenced): 0.35 arcsec
  - 30 cm telescope, < 120K optics, 70K focal plane
- **Operations Concept**
  - Telescope bore site always within 10 deg of the spacecraft to sun vector
  - Observing strategy set by Mission Science Center
  - Tactical execution by Mission Operations Center with engineering considerations
    - Sun avoidance
    - Momentum management
    - Power management
    - Ground contacts

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MOO Fact Sheet 1
Mars Scout 2006

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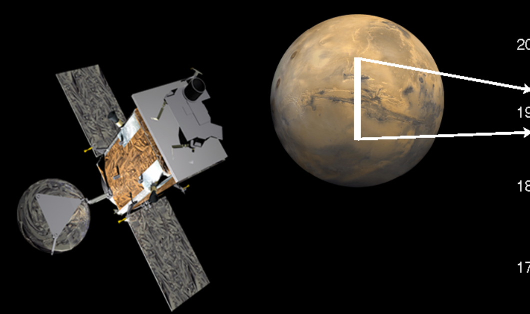
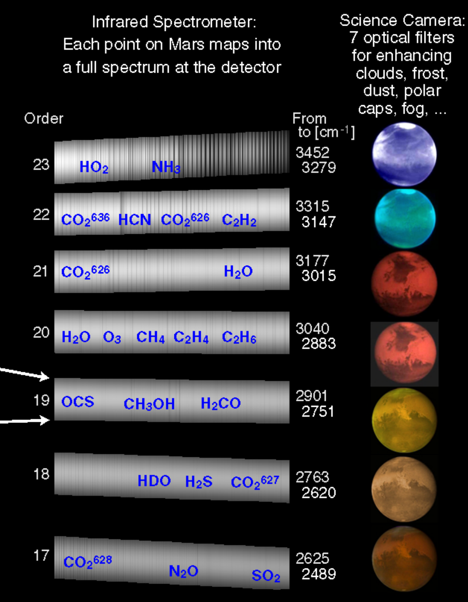
Mars Organics Observer

GSFC





Mission Overview

- Mission objective: Conduct a continuous spectroscopic and imaging survey of Mars over an extended period emphasizing the search for life and the climatology of Mars
- Mission duration: In-orbit 3+ Earth years
- Orbit: Mars L1 Lissajous
- Launch vehicle: Atlas 401 or equivalent
- Launch date: November 2011
- L1 arrival date: January 2013
- Low risk: No advanced technology development (all > TRL 6), low ΔV requirements for a Mars mission, no aerobraking, no landing

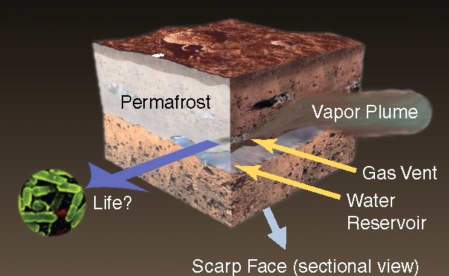
Mission Team

- PI is Dr. Michael Mumma, GSFC
- Science Team from GSFC, Cal. Tech., Indiana Univ., Iona Coll., ORAU, Princeton Univ., Sp. Sci. Inst., Univ. Toronto, Univ. Washington
- GSFC is responsible for overall mission management, system engineering, mission assurance, payload, observatory integration, mission operations, and science team management
- Ball Aerospace is responsible for the Spacecraft and Science and Guidance Camera

Science Objectives

MOO will:

- Address all 4 Mars Exploration Program's science themes
- Establish sources of methane, water, and related species
- Test biotic vs. abiotic production (homologous series: CH_4, C_2H_6, etc.)
- Study circulation patterns on Mars; the water cycle; HDO/H_2O, etc.
- Test presence of active geothermal processes
- Identify active vents as key targets for human exploration (in-depth biostudies; resources)



End