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Universidad del País Vasco
Euskal Herriko Unibertsitatea

Grupo de Ciencias Planetarias

An extremely high altitude plume seen at Mars morning terminator

Agustín Sánchez-Lavega[1], A. García Muñoz[2], E. García-Melendo[1], S. Pérez-Hoyos[1], J. M. Gómez-Forrellad[3], C. Pellier[4], M. Delcroix[4], M. A. López-Valverde[5], F. González-Galindo[5], W. Jaeschke[6], D. Parker[6], J. Phillips[6], and D. Peach[7]

[1]Universidad del País Vasco UPV/EHU (Spain)
[2]ESA/ESTEC (Netherlands)
[3]Group Estudis Astronomics (Spain)
[4]Société Astronomique de France (France)
[5]Instituto de Astrofísica de Andalucía (Spain)
[6]Association of Lunar and Planetary Observers (USA)
[7]British Astronomical Association (UK)

This presentation is dedicated to the memory of Donald C. Parker (1939 - 22 Feb.2015), a friend, an exceptional planetary observer, coauthor of this research and regular contributor to the GCP research activities.

MARS HIGH PLUME → 'AN EXPLOSIVE COCKTAIL'

- Mars (First GCP paper on that subject)
- Amateur observations in the spacecraft era (3 rovers and 5 orbiters active)
- Published in NATURE (Editorial comment – promotion)

Article metrics for:

An extremely high-altitude plume seen at Mars' morning terminator

A. Sánchez-Lavega, A. García Muñoz, E. García-Melendo, S. Pérez-Hoyos, J. M. Gómez-Forrellad, C. Pellier, M. Delcroix, M. A. López-Valverde, F. González-Galindo, W. Jaeschke, D. Parker, J. Phillips & D. Peach

Nature **518**, 525–528 (26 February 2015) | doi:10.1038/nature14162

Last updated: 24 May 2015 4:59:12 EDT

Total citations

Data not available — Web of Science

Data not available — CrossRef

Data not available — Scopus

Online attention

723

Altmetric score (what's this?)

Tweeted by **196**

On 23 Facebook pages

Mentioned in **14** Google+ posts

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This Altmetric score means that the article is:

- in the 99 percentile (ranked 81st) of the 112,818 tracked articles of a similar age in all journals
- in the 96 percentile (ranked 27th) of the 823 tracked articles of a similar age in *Nature*

Page views 13,549

Article metrics for:

Deep winds beneath Saturn's upper clouds from a seasonal long-lived planetary-scale storm

A. Sánchez-Lavega, T. del Río-Gaztelurrutia, R. Hueso, J. M. Gómez-Forrellad, J. F. Sanz-Requena, J. Legarreta, E. García-Melendo, F. Colas, J. Lecacheux, L. N. Fletcher, D. Barrado-Navascués, D. Parker, the International Outer Planet Watch Team, T. Akutsu, T. Barry, J. Beltran, S. Buda, B. Combs, F. Carvalho, P. Casquinha, M. Delcroix, S. Ghomizadeh, C. Go, J. Hotershall, T. Ikemura + *et al.*

Nature **475**, 71–74 (07 July 2011) | doi:10.1038/nature10203

Last updated: 24 May 2015 5:7:55 EDT

Total citations

28 — Web of Science

30 — CrossRef

31 — Scopus

Online attention

46

Altmetric score (what's this?)

Tweeted by **7**

On 1 Facebook pages

Picked up by **2** news outlets

Blogged by **3**

This Altmetric score means that the article is:

- in the 88 percentile (ranked 46,052nd) of the 2,769,263 tracked articles of a

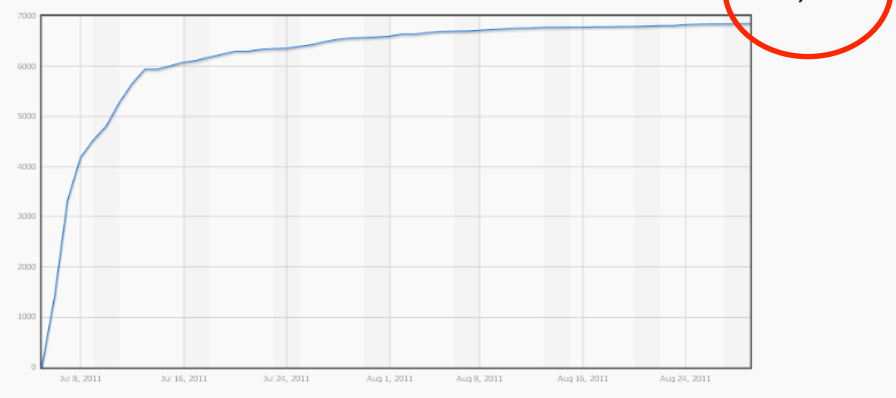
Article Download Statistics (Trial)

DOI: 10.1038/nature10203 CrossRef lists 2 articles citing this article Scopus lists 2 articles citing this article

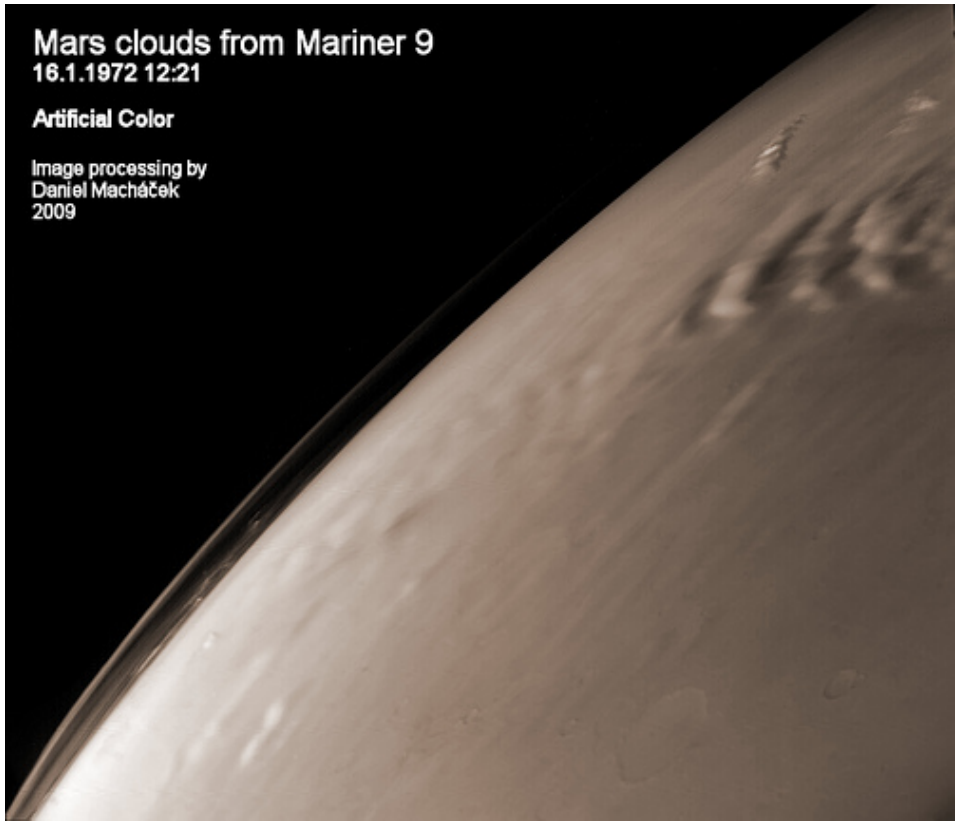
This article from 6th July 2011 to 29th August 2011 had 6848 downloads of its full text (PDF plus HTML views). Download to Excel

In Q2 2011 185 original research articles were published in *Nature*. During the first 28 days these articles were online, each one accumulated, on average (median), 10091 downloads of its full text (HTML plus PDF views). Fifty percent of the papers published had accumulated downloads in the range of 6671 to 15241 downloads.

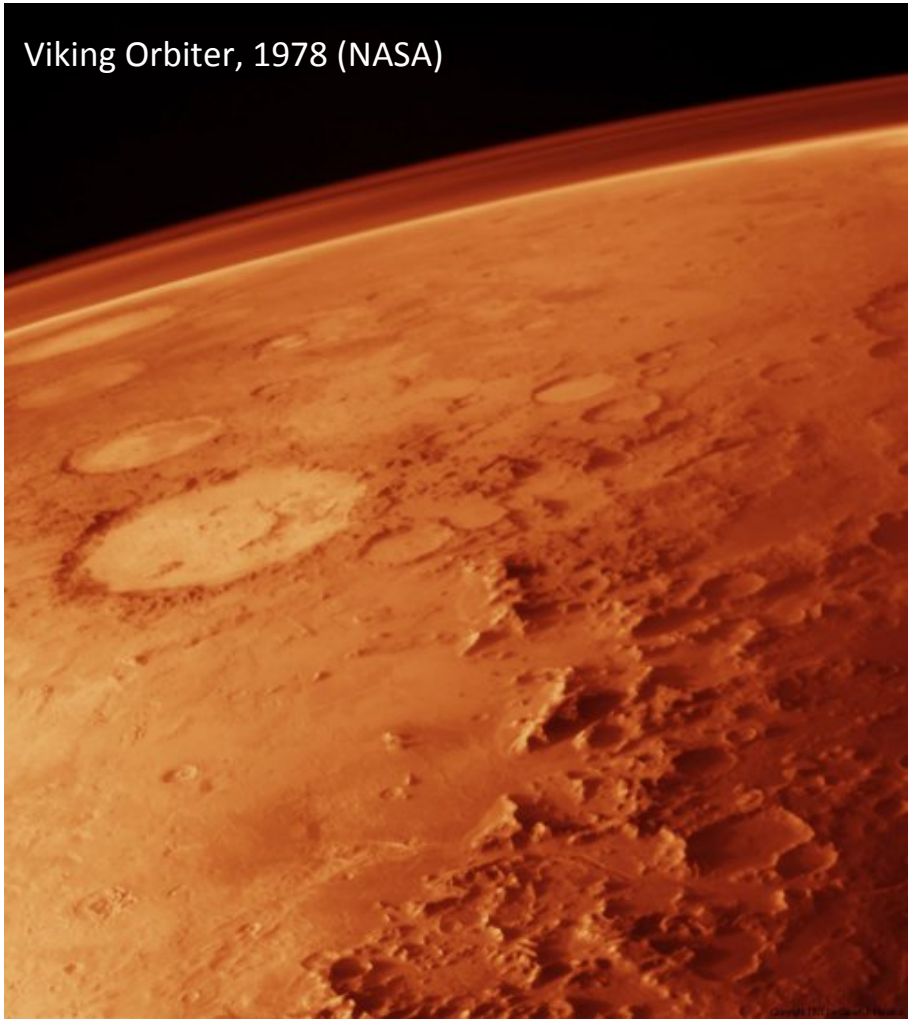
Views and downloads to date 6,900



Projected aerosols at Martian limb: Detached layers - I

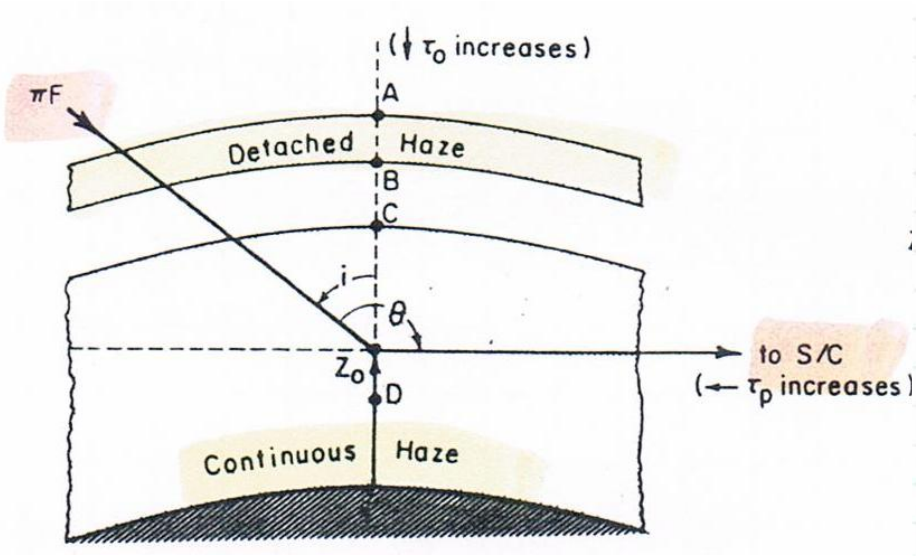


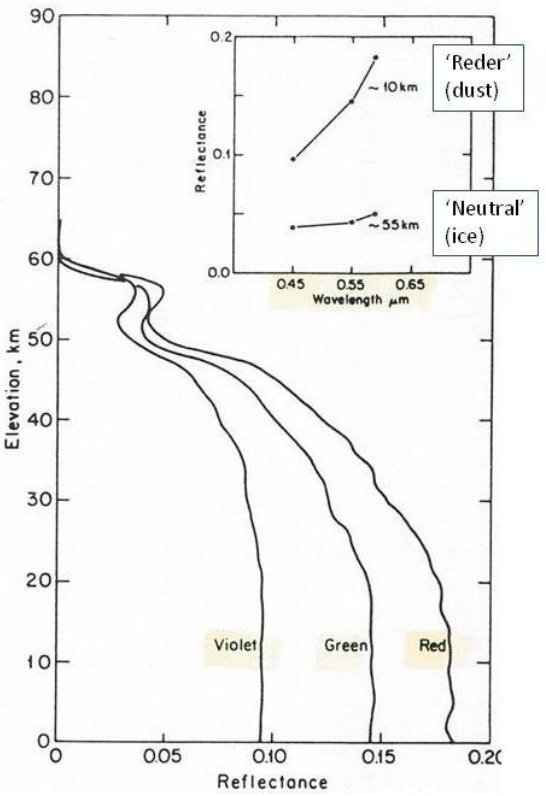
Z(max) ~ 40 – 60 km
Anderson and Leovy , J. Atmos. Sci. (1978)



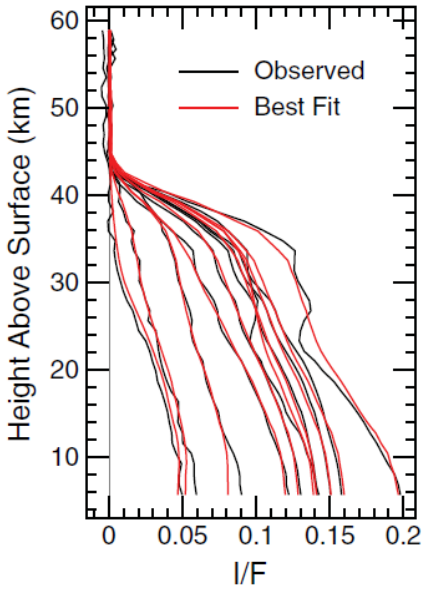
Z(max) ~ 60 km
Jaquin et al., Icarus (1986)

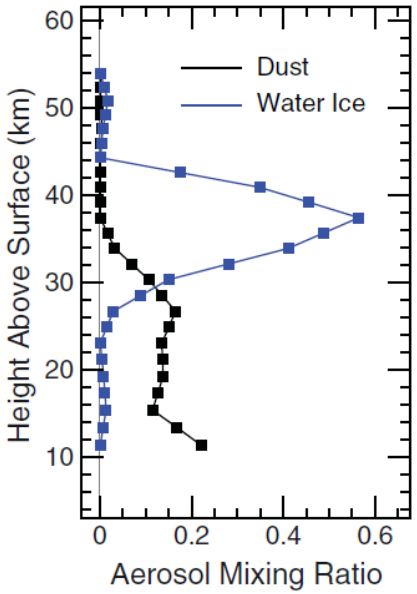
Projected aerosols at Martian limb: Detached layers - II





Jaquin et al., Icarus (1986)

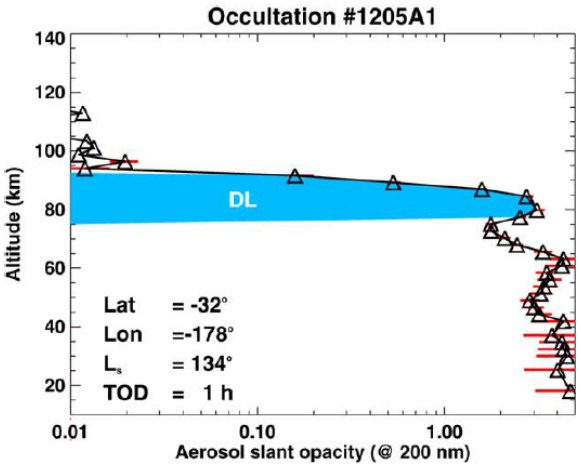




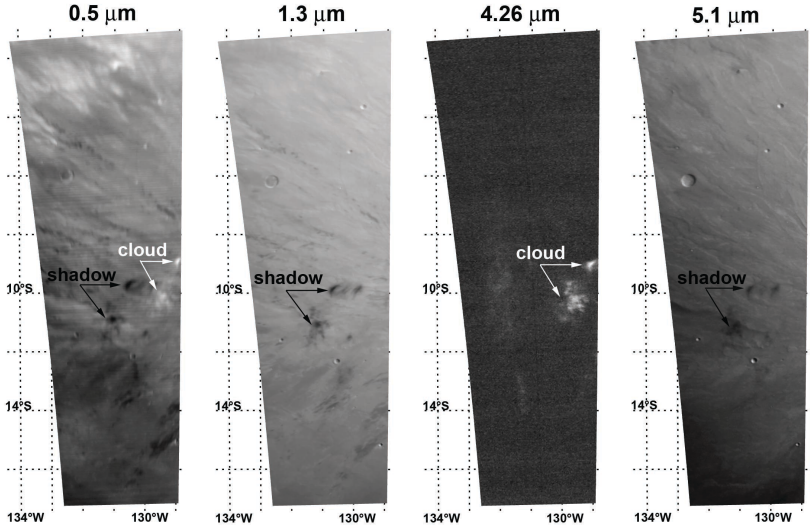
Smith et al., JGR (2013)

Continuous haze = dust (mixed water-ice)
Detached haze = H_2O-ice
Haze = Dust + H_2O-ice
Z(max) Dust ~ 50 km
Z(max) H_2O-ice ~ 60 km
Aerosols : r_{eff} = 0.5-3 μm → r_{eff} (z)
H_2O-ice hexagonal cristals

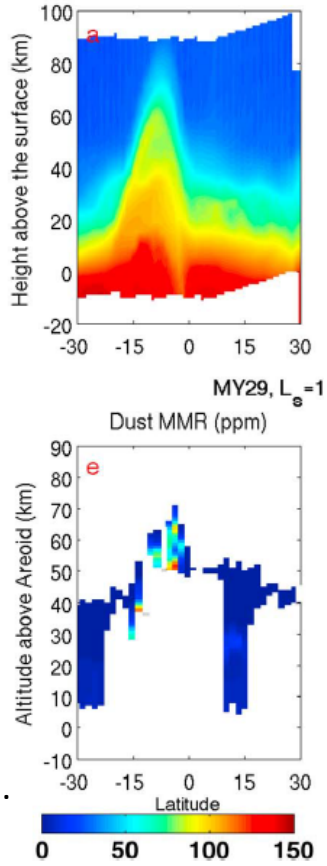
Clouds at High altitude



CO_2-ice clouds
Montmessin et al., Icarus (2006)



CO_2-ice clouds up to 100 km
Maattanen et al., Icarus (2010)



Dust
Heavens et al.
GRL (2015)

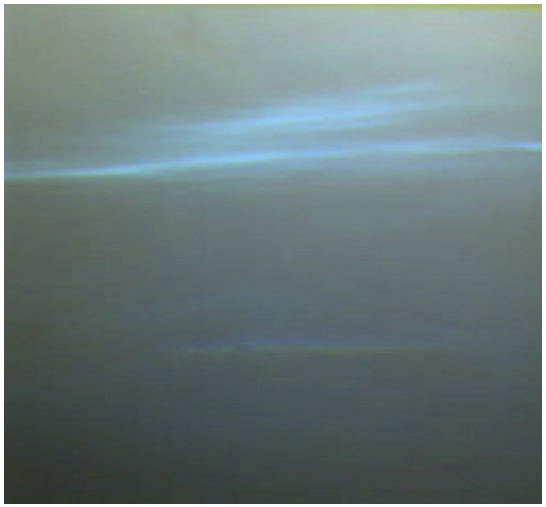
Imaging & Photopolarimeter at limb
Limb solar occultation (Phobos2)
Star occultation (SPICAM/MEX)
Limb spectra (CRISM/MRO)
Radiance scans (TES/MGS; MCS/MRO)
Imaging & shadows on disk (OMEGA-HRSC/MEX)
Thermal (THEMIS/MOdyssey)

High altitude ice-clouds:
H_2O-ice (Z (max) = 70 -90 km; r_{eff} = 0.2-0.3 μm
CO_2-ice clouds (Z = 90-100 km; r_{eff} = 0.1 μm)

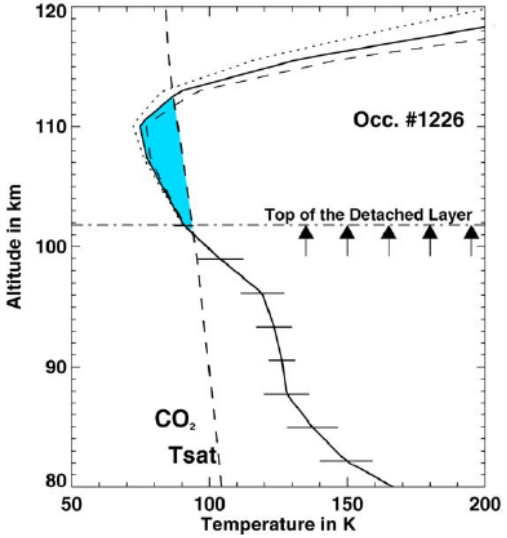
Extreme Detached Dust Layers (EDDL)
Z(top) ~ 80 km (over volcanos)

Origin of high altitude aerosols

H_2O-ice clouds. Phoenix.
Lat = 68.2°N
Z(land) = -4.1 km.
Whiteway et al., Science (2009)



CO_2-ice clouds .Pathfinder.
Lat = 19.1°N (Z > 70 km).
Smith et al., Science (1997)

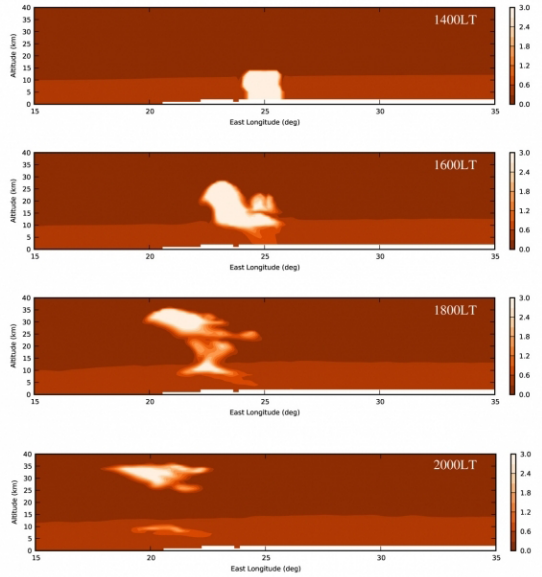


Montmessin et al., Icarus (2006)

*** Mainly in the Equatorial-Tropical band (~ 30°N-30°S)**
Topography and season. L (horizontal) ~ 100 – 1,000 km

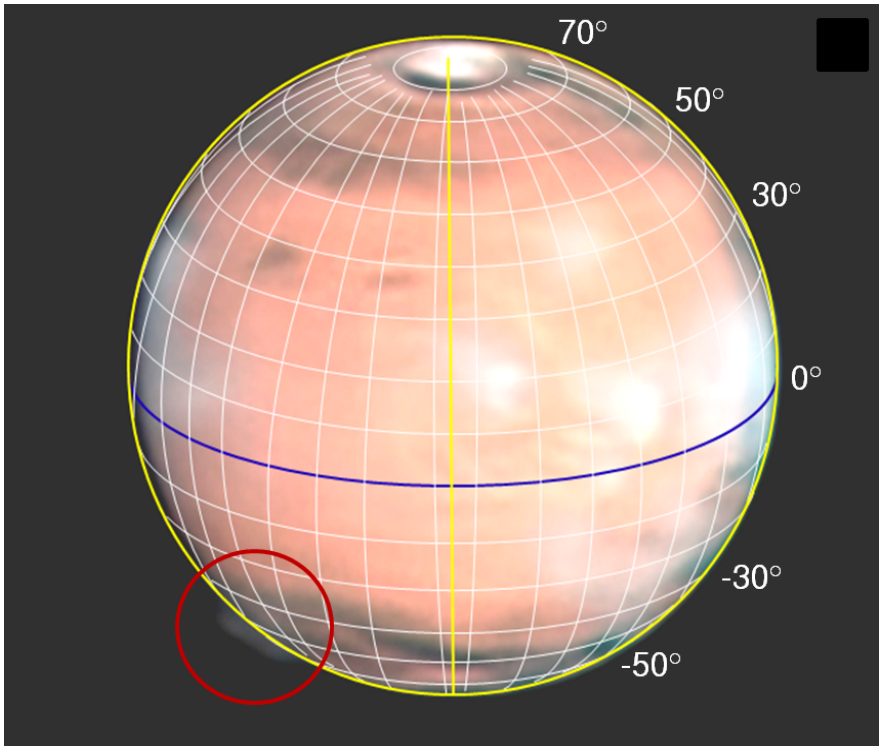
*** High altitude H_2O-ice & CO_2-ice clouds:**
Condensation on supercooled Cold air: Dynamics & transported by waves (tides, gravity)

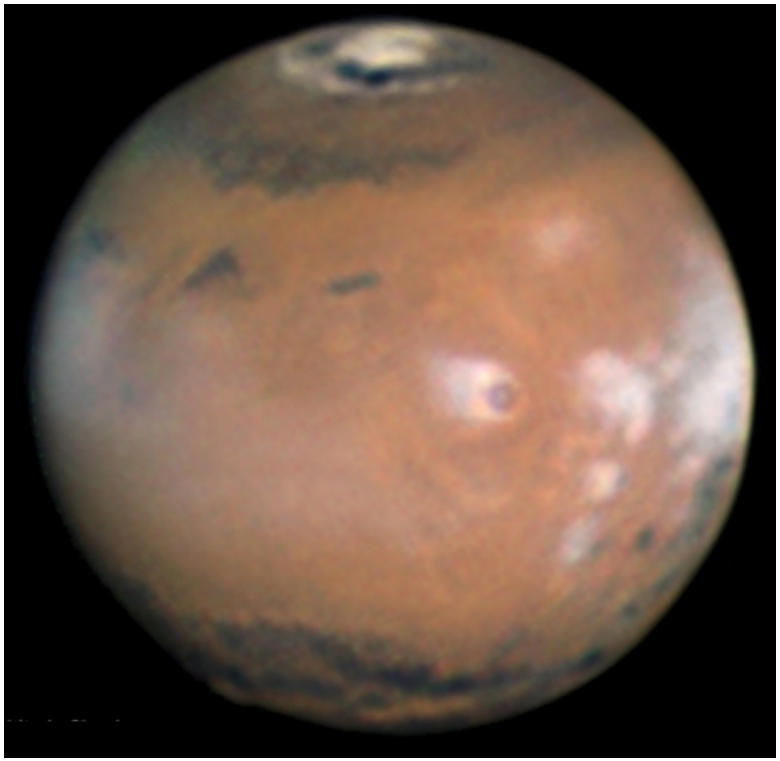
*** Detached Dust Layers (EDDL)**
Transport: updrafts over volcanos, 'rocket dust' convection, waves (tides, gravity), Hadley circulation; Dust storms)



Spiga et al., JGR (2013)

Plume (‘protrusion’): Observations in 2012
Two plume events: (1) 12 – 23 March ; (2) 6 – 16 April



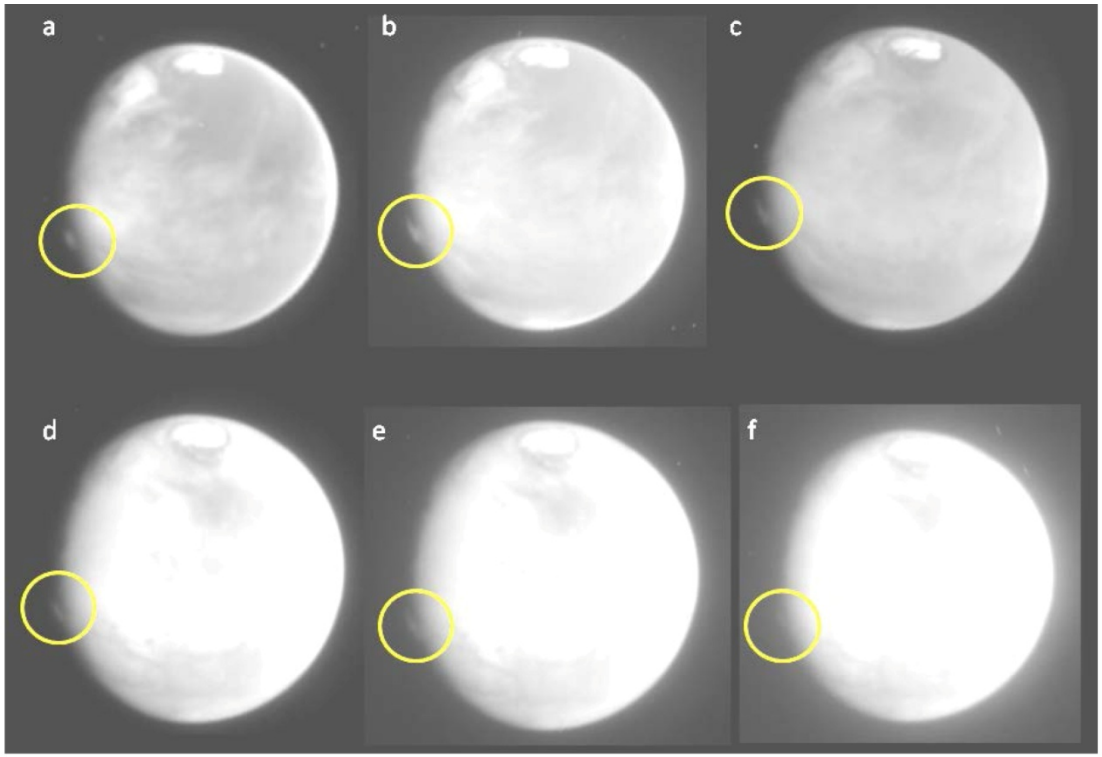


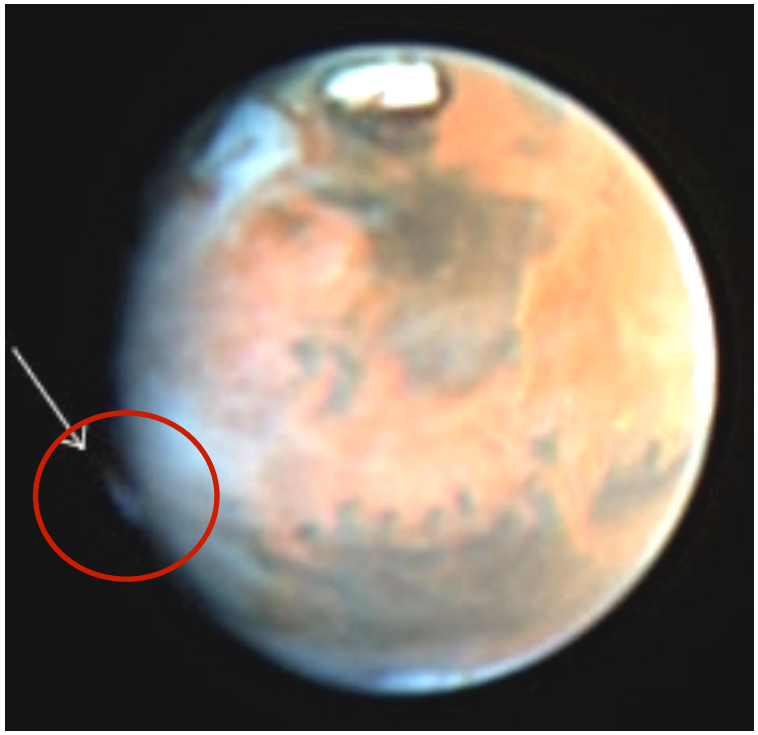
Observations:
* Telescope aperture = 20 - 40 cm
* “Lucky imaging” technique
* Plate scale ~ 0.045 arcsec/pixel
  (~pixel size = 25 km on Mars limb)
* Wavelength range ~ 450 – 650 nm, > 750 nm

Observing conditions:
Mars size = 13.8”
Illumination= 99.6% (phase angle α = 7.2°)
D_{Earth} = 22° (D_{Sun} = 25°) → North Pole vision

(a) 18 Independent observers; (b) Experienced observers; (c) 20 Different days; (d) Always same location and Mars local time; (e) Protrusion rotating → **Rule out “an artifact”**

Plume (‘protrusion): 17 May 1997
Hubble Space Telescope

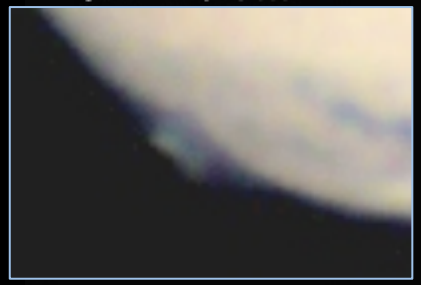


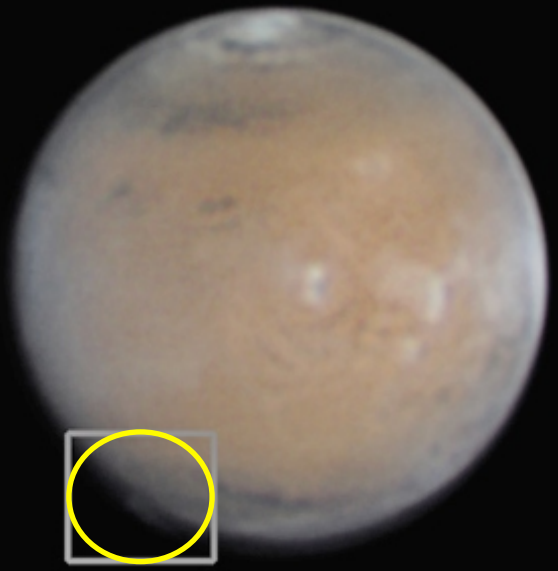


HST – Wide Field Planetary Camera
Wavelengths: (a) 257, (b) 409, (c) 502, (d) 589, (e) 673, (f) 1045 nm

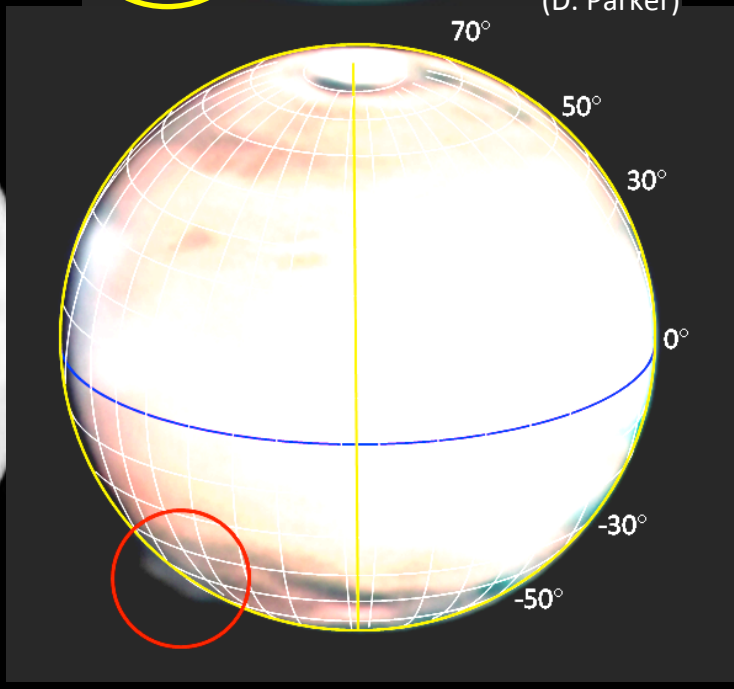
Plume (‘protrusion’): Observations in 2012

20 Mar 2012
(W. Jaeschke)





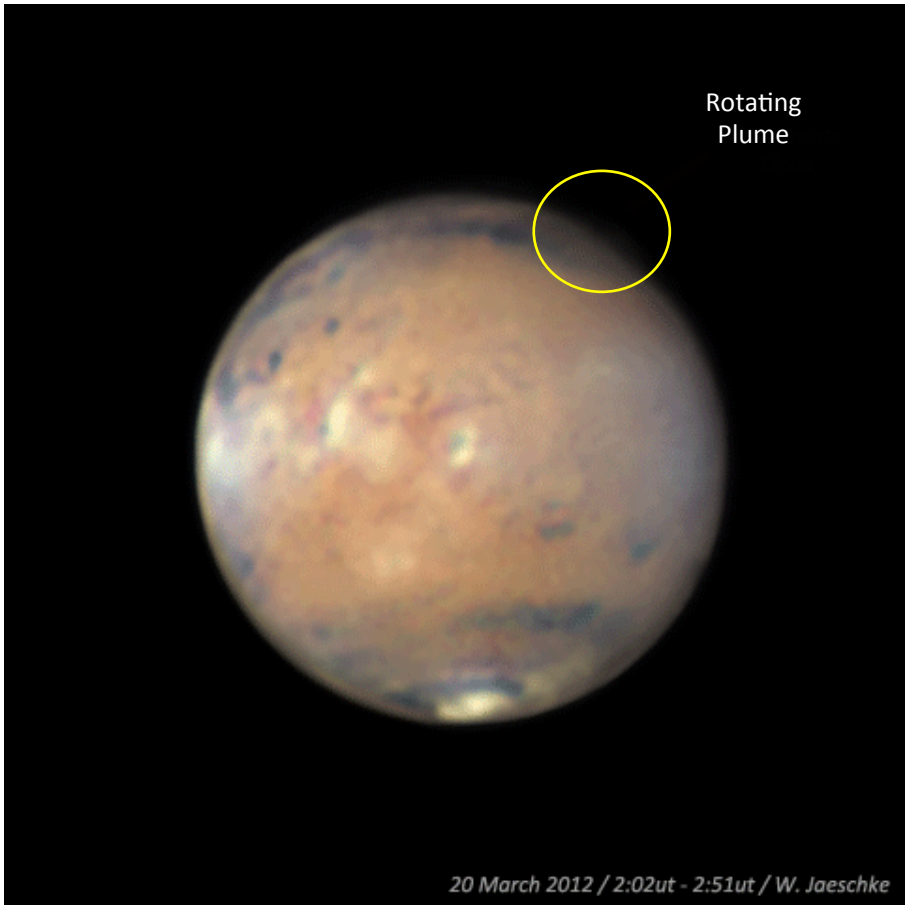
21 Mar 2012
(D. Parker)



21 Mar 2012
J. Phillips

13 April 2012
(D. Peach)

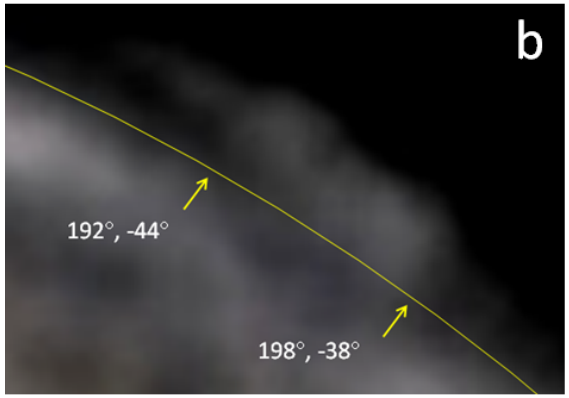
Plume rotating at morning terminator

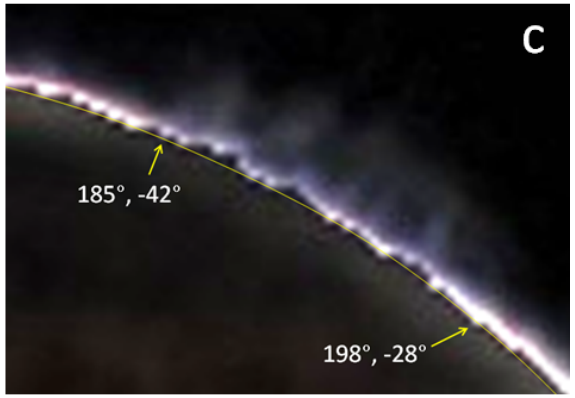


- Overall lifetime of each event ≥ 10 days
- Rapid changes with timescales < 12 hrs
- Plume not detected when reaching the evening limb
- Plume not detected when transiting on the CM.

Plume morphology: Rapid variability

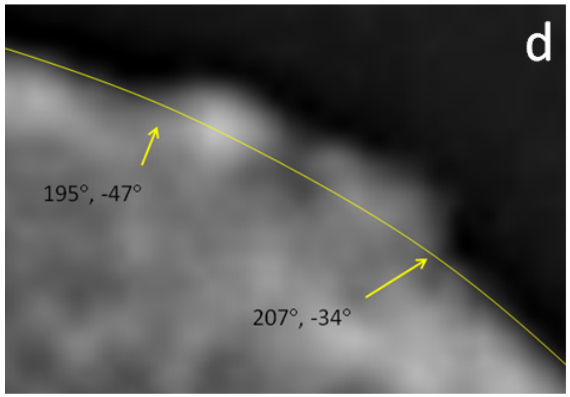
20 March
(02h 45min)

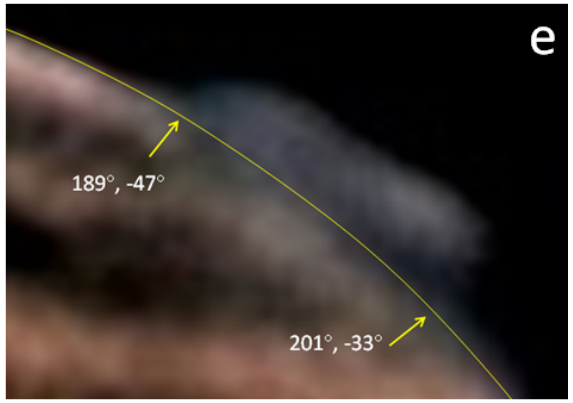




21 March
(02h 51min)

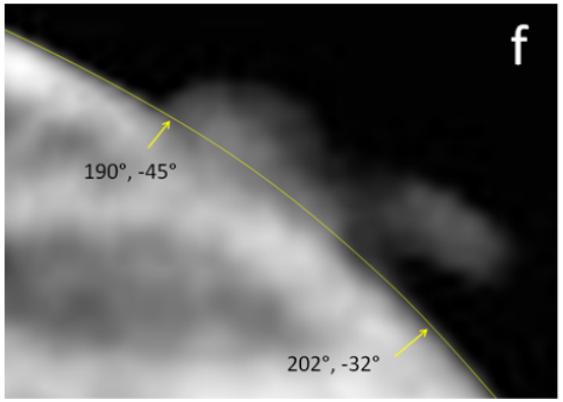
21 March
(03h 45min)

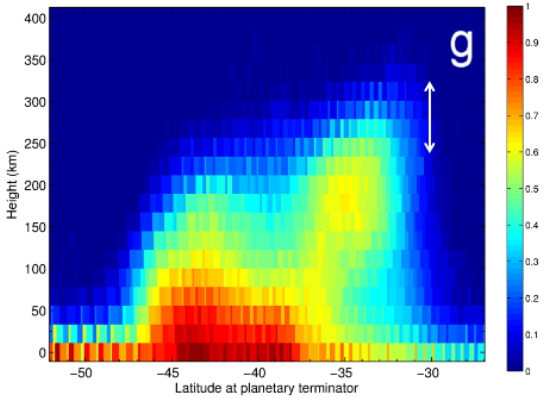




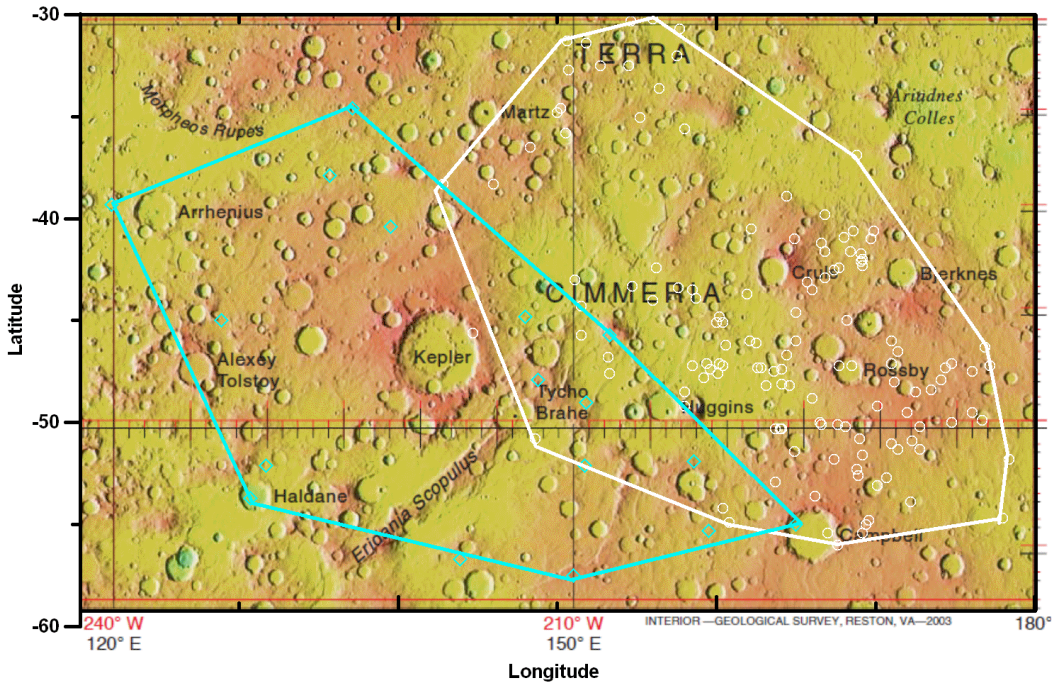
21 March
(03h 21min)

21 March
(03h 21min)

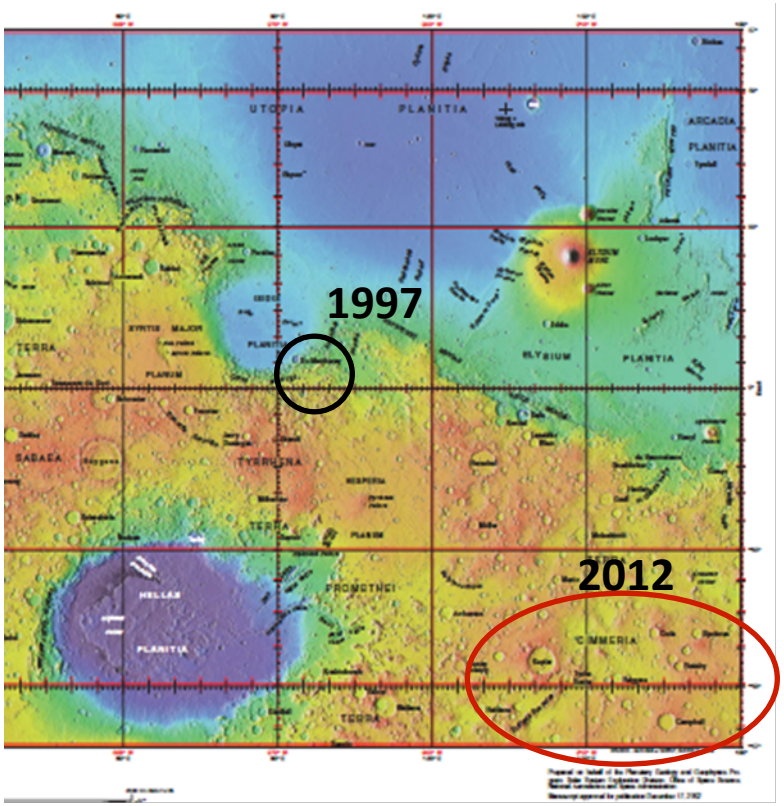




Areographical location of the 1997 & 2012 events



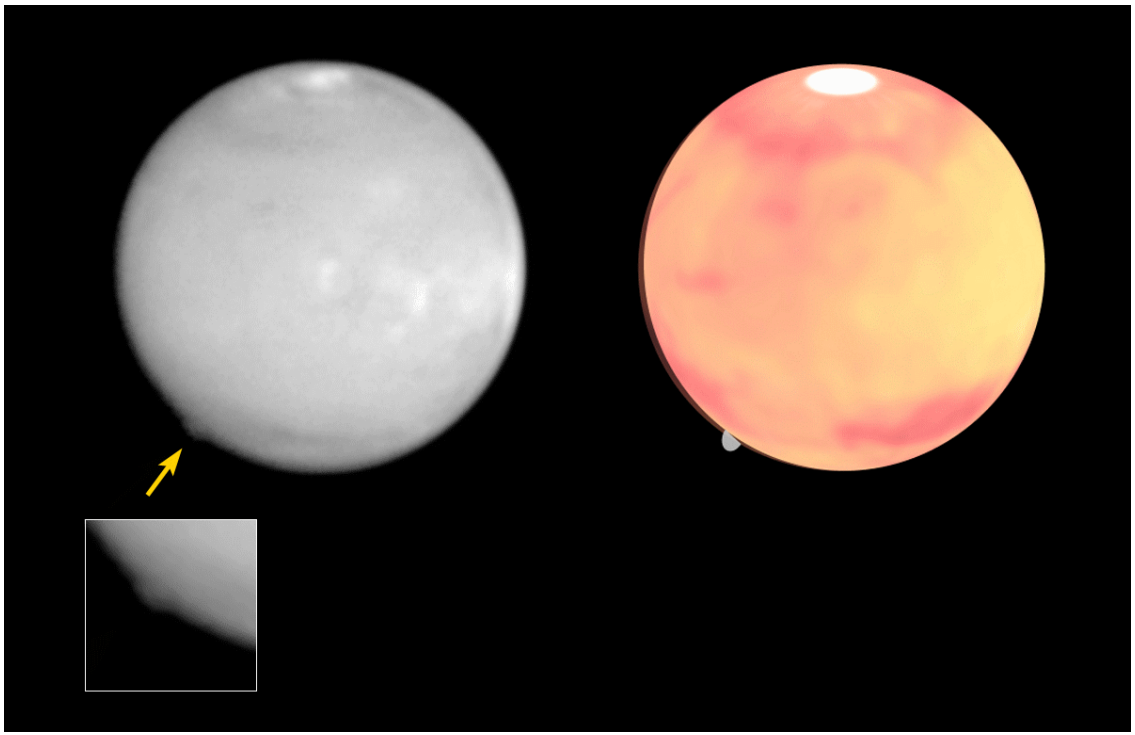
Horizontal scale ~ 1,000 km

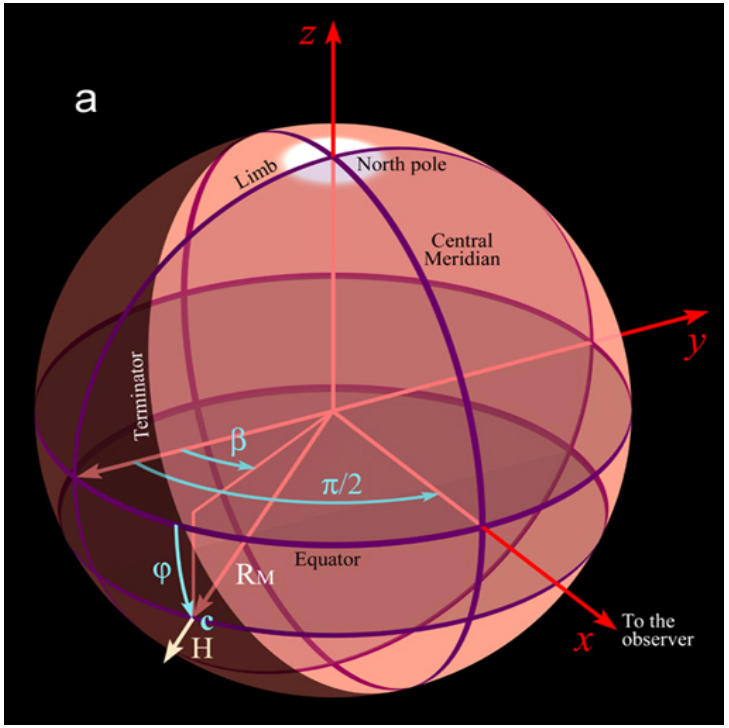


12 – 23 March 2012
Latitudes range: -35° → -54°
Longitude (West) range: 188°→ 225°
Heliocentric longitude: Ls = 82.5° - 90 °
Early winter (Southern Hemisphere)

17 May 1997
Latitudes range: -5°S → +5°N
Longitude (West) range: 93° → 103°
Heliocentric longitude: Ls = 119.5°
Summer (Northern Hemisphere)

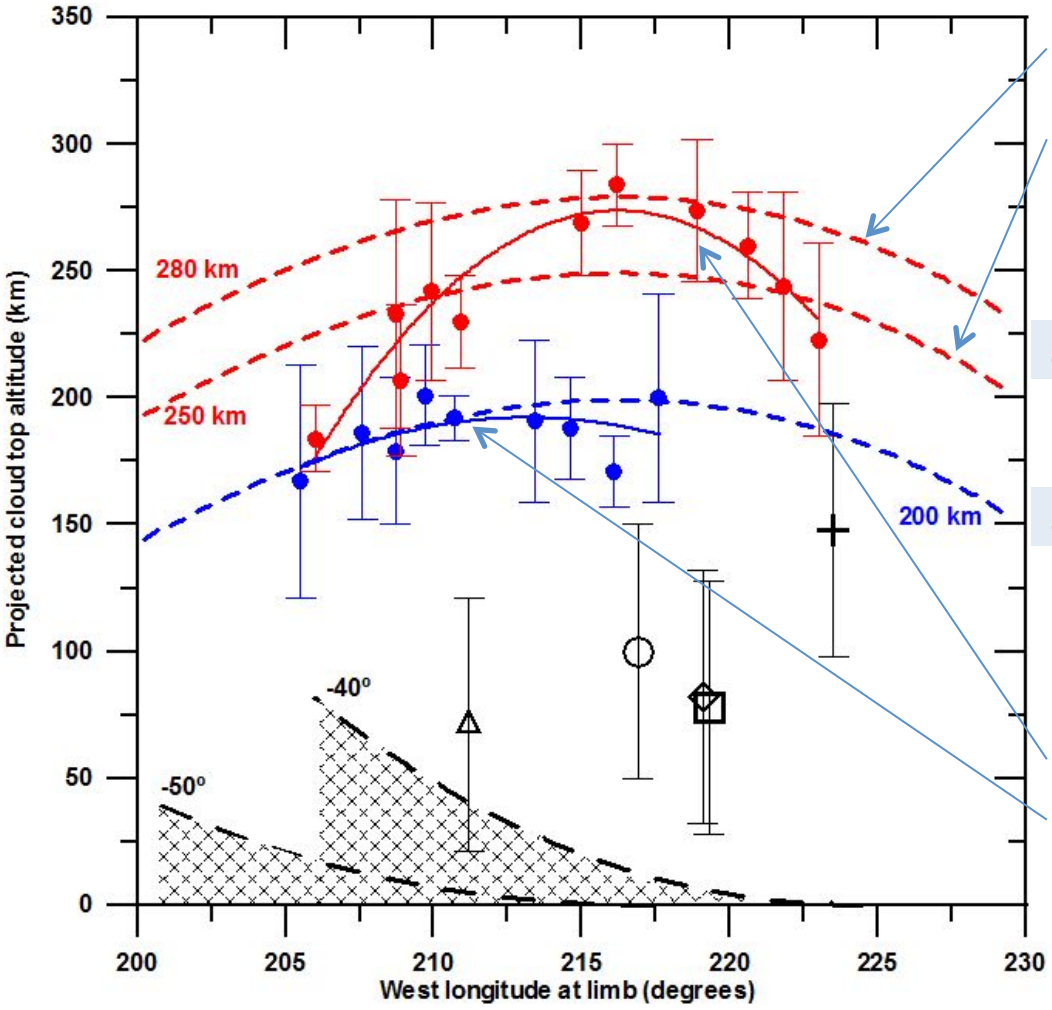
Plume's top altitude: Measurements in rotating frames

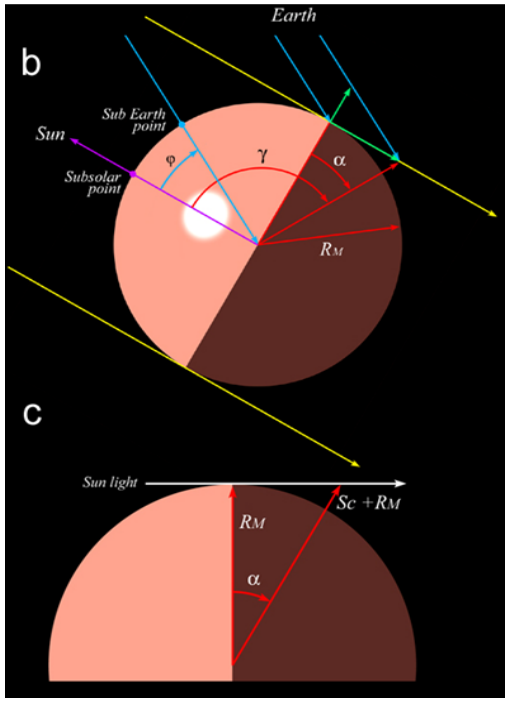




Rotating plume model → $$H = \frac{z'(\beta) + R_M}{\left\{\cos^2\varphi_c \cos^2\beta + \left(sin\varphi_c \cos D_E - \cos\varphi_c \, sin\beta \, sinD_E\right)^2\right\}^{1/2}} - R_M$$

Plume top altitude



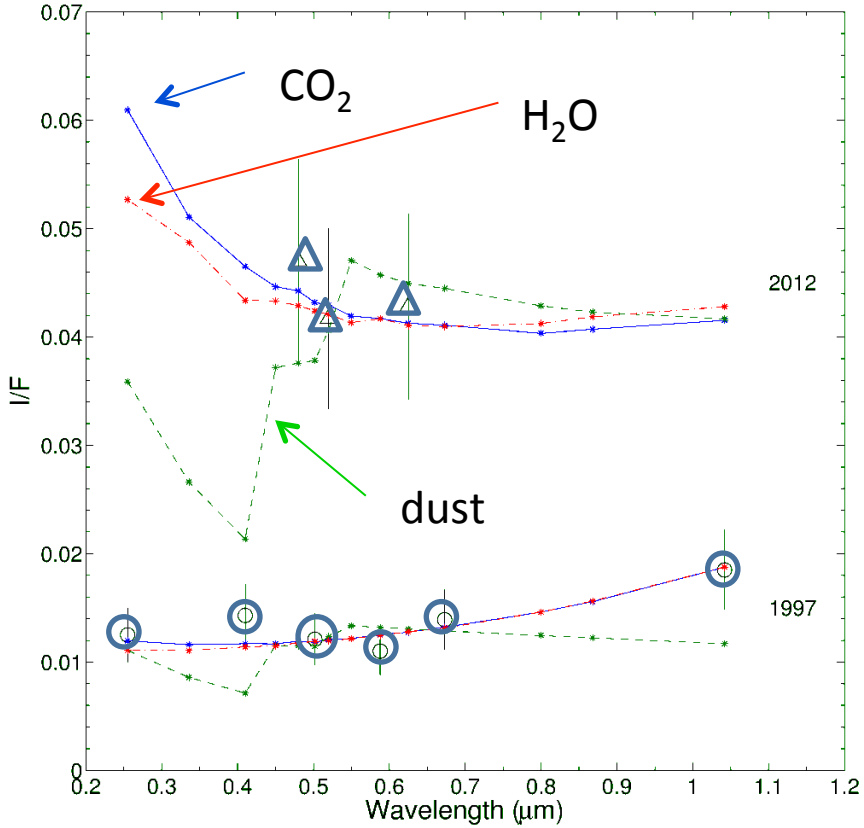


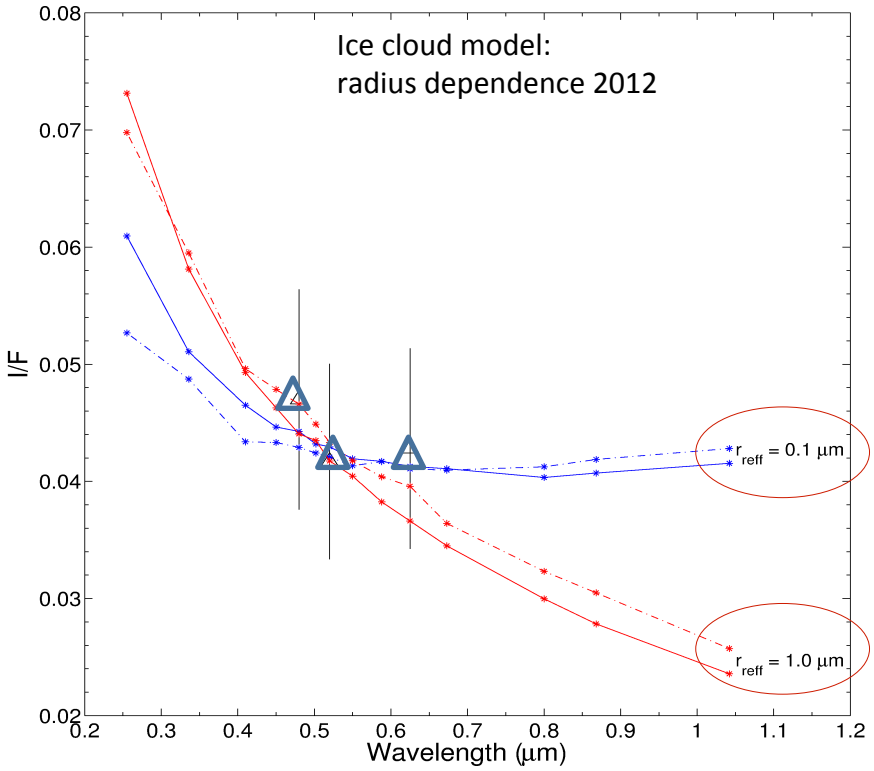
Maximum projected altitude from rotation:
20 March → h = 180 ± 50 km
21 March → h = 250 ± 50 km

HST plume altitude:
No rotation available
Altitude range:
H (min) = 50 km
(large horizontal feature illuminated by a grazing Sun)
H (max) = 480 km
(thin vertical feature under a 90° solar illumination)

Reflectivity & Cloud model hypothesis

Integrated area photometry in the plume





Radiative Transfer Model (Mie particles) : Monte Carlo multiple scattering for spherical geometry (*)

Best fits: CO_2 or H_2O ice particles

Effective radii = $0.1_{-0.04}^{+0.1}$ μm

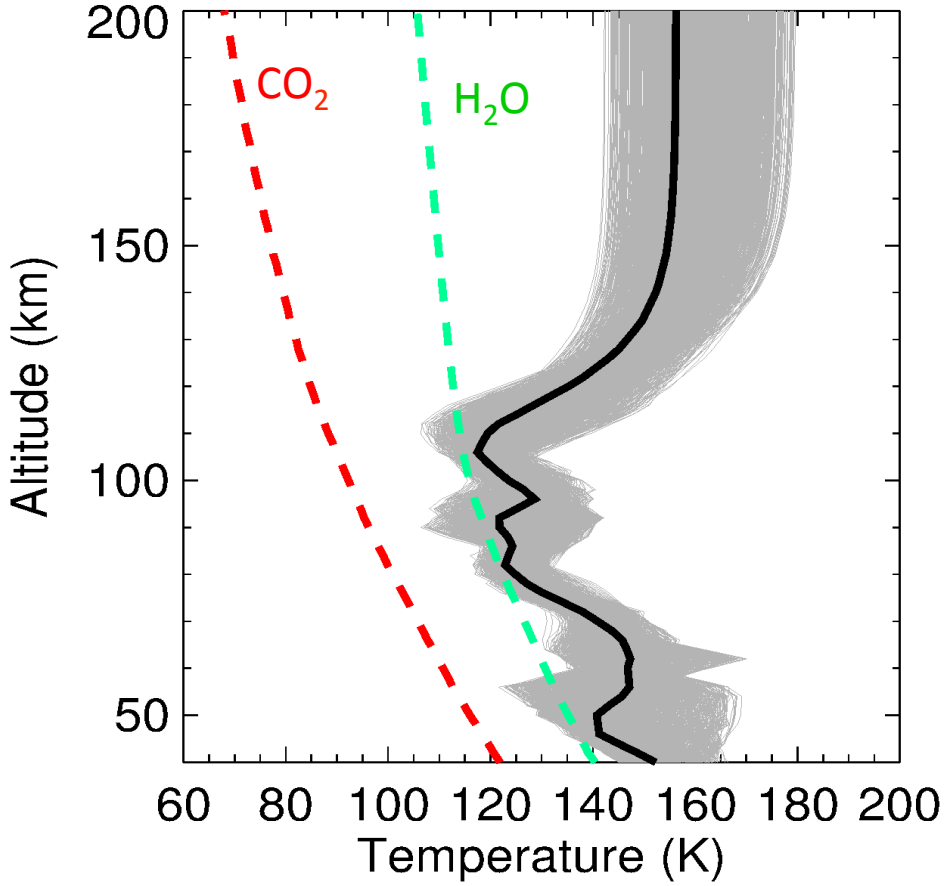
Effective variances = 0.1–2.0

Nadir optical depth $\tau_N > 0.5$

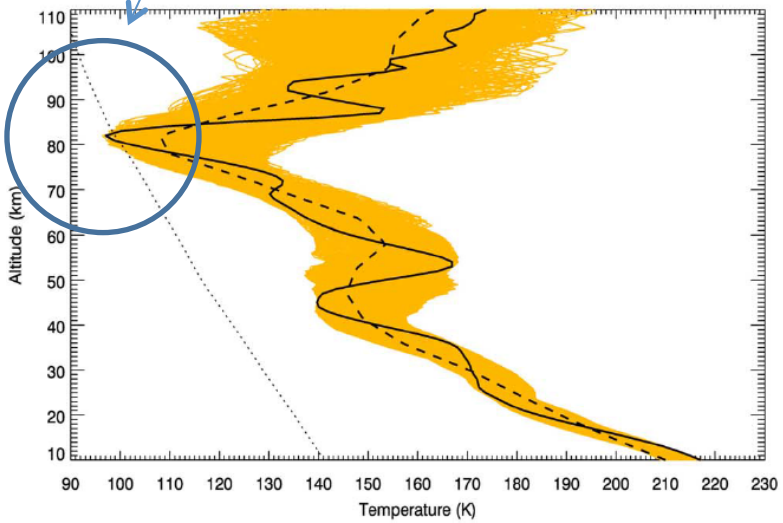
Number density = 0.01 particles cm^{-3}

(*) Garcia Muñoz & Mills, A.A. (2014)

Ice cloud hypothesis: H_2O & CO_2



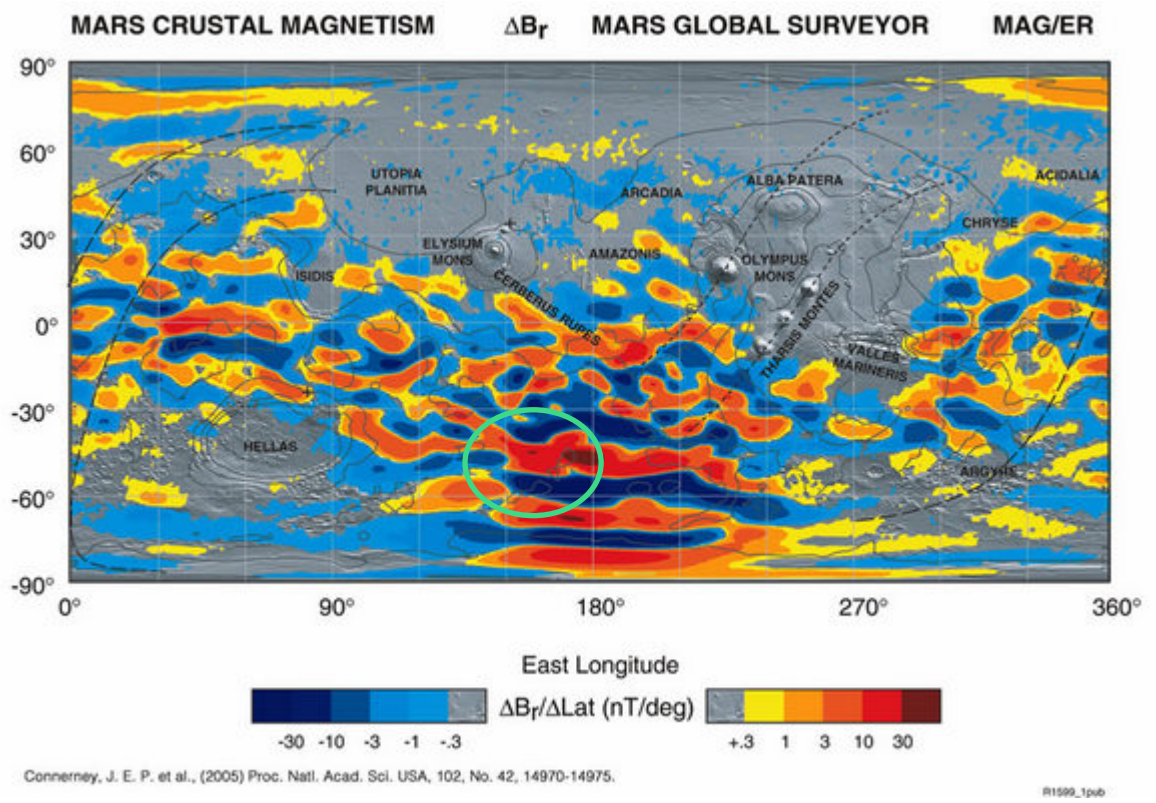
Dynamics ?
Gravity wave
vertical propagation → δT



Spiga et al., JGR (2013)

General Circulation Model → T(z), X(z) (Gonzalez-Galindo et al., JGR, 2011, 2013)
(1) H_2O –ice condensation
→ anomalously cold thermosphere temperatures (Temperature drop >50 K)
→ unusual increase in the H_2O mixing ratio from 10^{-4} to complete saturation above 140 km
(2) CO_2 -ice condensation →Temperature drop ~ 100 K above 125 km

A magnetic related event: Aurora?

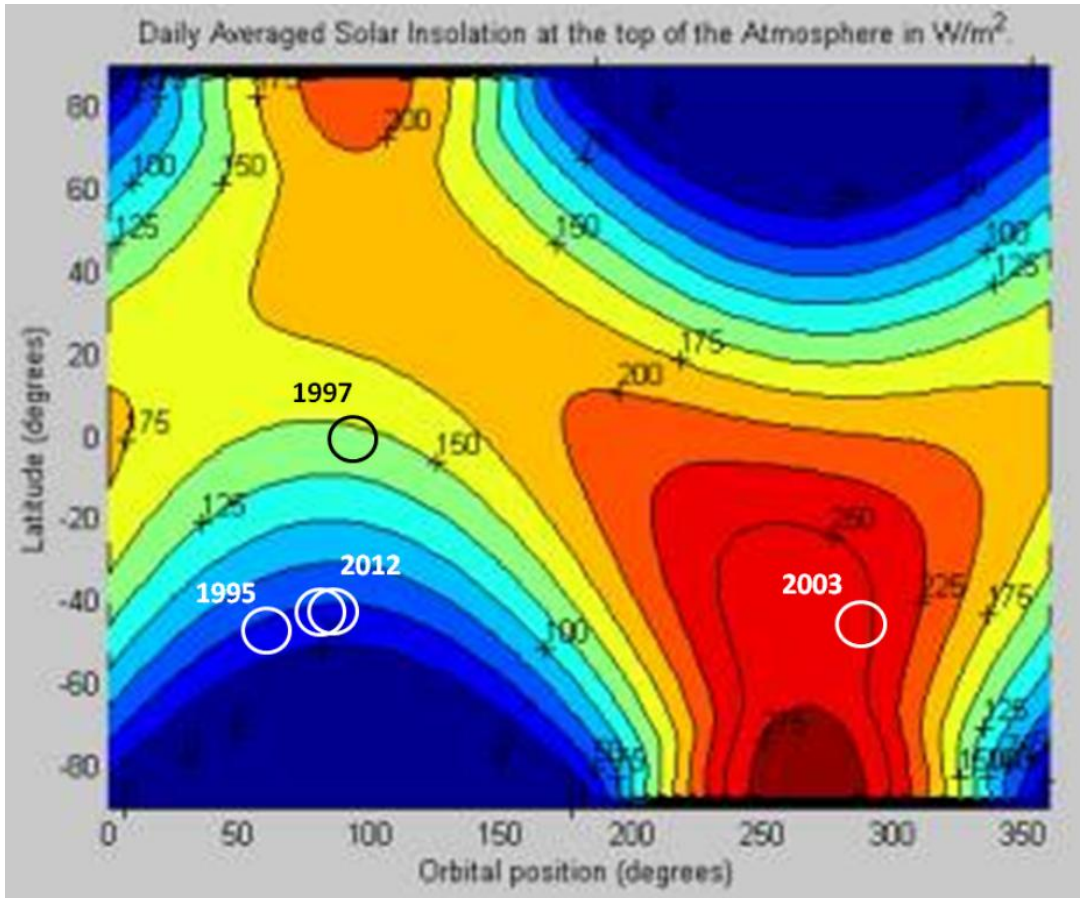


2012 Plume occurred over a large anomaly in the crustal magnetic field (175° East).

Reflectivity *I/F* (550 nm)= 0.04 → I_{Aurora} (limb) ~ 3,600 MR (>> 1-MR nadir emission terrestrial aurorae) >> Mars' UV aurora (CO Cameron bands) → I_{Aurora} (limb) ~ kiloRayleighs.

→ Exceptional influx of energetic particles over days.

Seasonal behavior: Events 1997 and 2012 (and in 1995, 2003)



Conclusions

- **Plumes in 2012:**
- Two events: 10-23 March, 6-16 April (lifetime ~ 10 days)
- Terra Cimmeria (Longitude: 190° - 220°W, Latitude: 45°S)
- Zonal and meridional lengths ~ 500 – 1,000 km → **NOT Detached Layer type**
- Maximum top altitude ~ 200 - 250 km (day to day variability)
- Only visible at morning terminator
- Ls = 82° - 90° (Early winter Southern H.)

- **Radiative Transfer Cloud model** → CO_2, H_2O ice (no dust)
- $r_{eff} = 0.1_{-0.04}^{+0.1}$ μm , $\nu_{eff} = 0.1–2.0$
- Nadir optical depth: $\tau_N > 0.5$ (N = 0.01 particles cm^{-3})
- Requires a large temperature drop or large vapor mixing ratio

- **Aurora** → Crustal magnetic field anomaly.
- Intensity ~ 3,600 MR (~ x1,000 Earth aurora)
- Requieres exceptional influx of energetic particles over days

→ **Defy current knowledge of Mars upper atmosphere**
→ **Need of continuous limb observations for similar events (particular survey of Terra Cimmeria)**

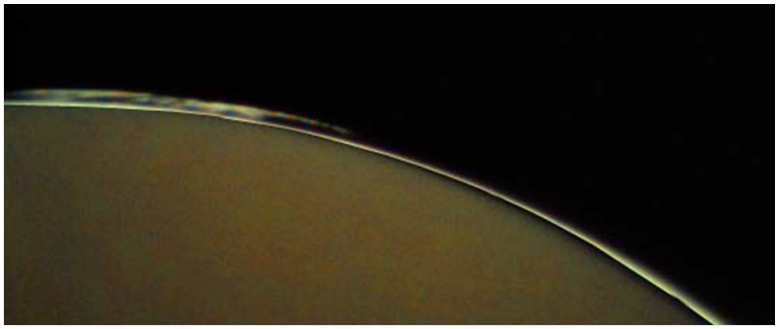
Future work in progress

(1) Understand the 2012 events and similar 'not layered' events

Explore models:

- Nature: Clouds? Emission? Both?
- Dynamical mechanisms?
- Seasonal?
- Recurrent? Periodic?
- Areographic dependence?
- Rule out: Internal (geology)? External (influx)?

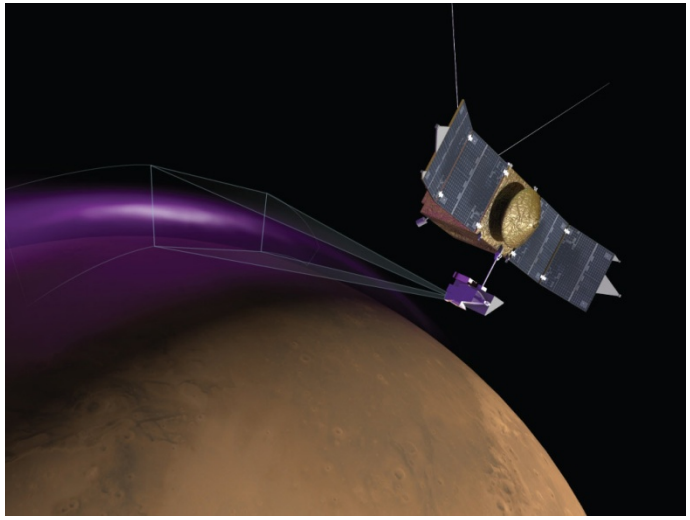
(2) Continuous limb observations



* VMC-MEX - 15 Dec.2009

Z(max) ~ 40 km - L ~ 1,000 km

* HST 1995-1997-1999



MAVEN -IUVS (LPSC, 2015)

Fine dust Z = 150-300 km

UV Aurora (30°-60°N

GRACIAS POR VUESTRA ATENCIÓN

eman ta zabal zazu

Universidad del País Vasco
Euskal Herriko Unibertsitatea

Ingeniaritza Goi Eskola Teknikoa
Escuela Técnica Superior de Ingeniería
Bilbao

Aula EspaZio Gela

Grupo de Ciencias Planetarias

Grupo Ciencias Planetarias UPV/EHU

2015

GCP MEMBERS (*)

- **UPV/EHU:**

1 CU
5 TU
1 PI

1 P. Adjunto
2 Postdoc (PIC)
2 Doctorandos

- **Un. MC-Valladolid**
- **JAXA (Japon)**
- **ESA**

3 Colab. Externos

- **Internactional Coll.**

USA, UK, France, etc.

(*) Unidad Asociada con el Instituto de Astrofísica de Andalucía-CSIC (2013-14)
Support by Euskampus-UPV/EHU & funded by Ikerbasque Foundation
up to 2014 (included). Closed in 2015.

Research

1. Planetary Atmospheres:
Venus, Mars, Jupiter, Saturn, (Titán), Uranus, Neptune, (exoplanetas)

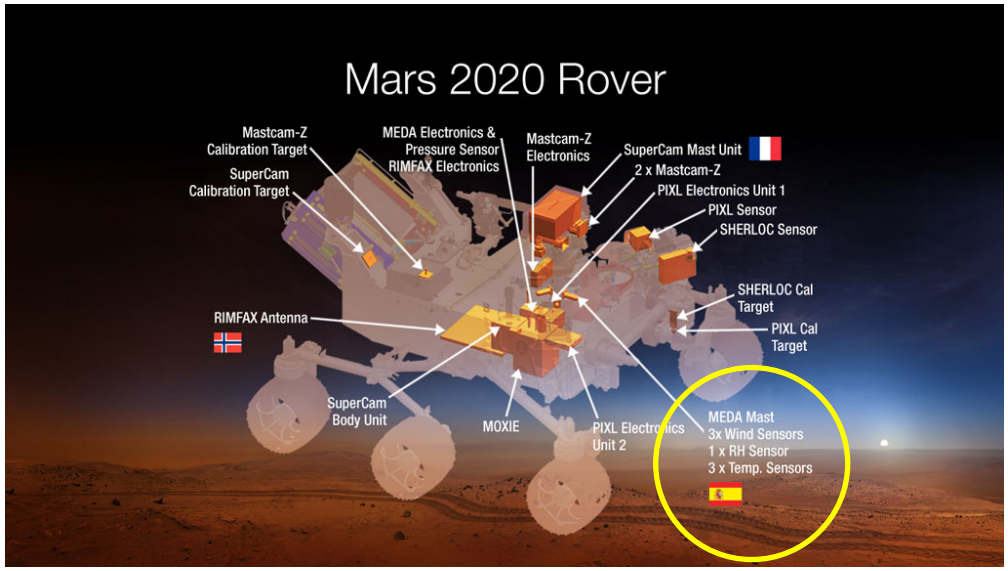
- General Circulation
- Dynamics and meteorology
- Radiative Transfer (clouds and aerosols)
- Impacts in Jupiter (Saturn)
- (Temperature structure)

2. Astronomical and Space instruments:
- PlanetCam (Vis-SWIR): two-channel lucky imaging astronomical camera
- MEDA for Mars 2020 (NASA)
- MAGIS and JANUS for JUICE (ESA) [launch ~ 2022]
- Software development for image analysis and instrument control

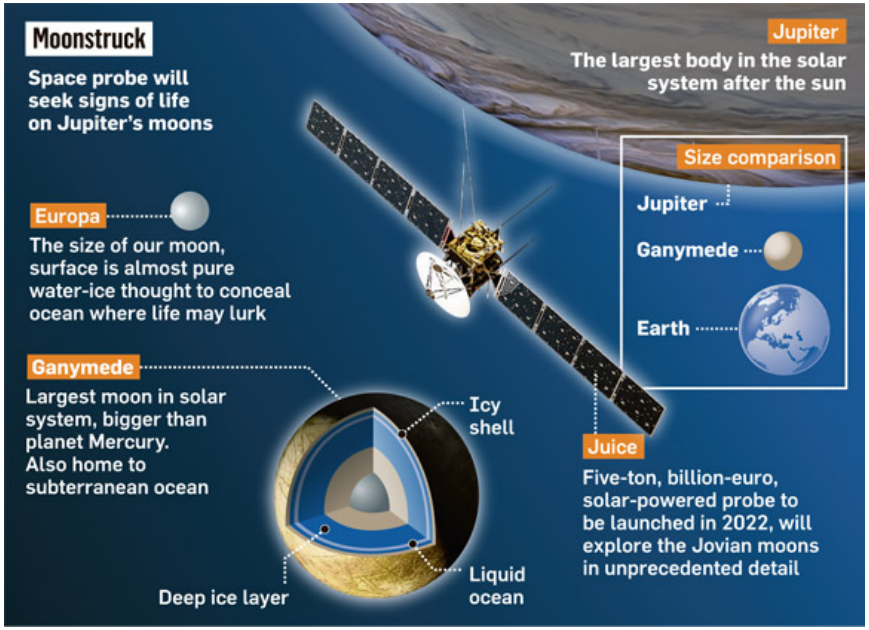
3. Data bases management:
- International Outer Planet Watch (IOPW) & Planetary Virtual Observatory (PVOL)
→ JUNO mission support (2016)

→ International collaborations (USA, France, UK, Japan, …)
Participation in proposals for ESA – AO

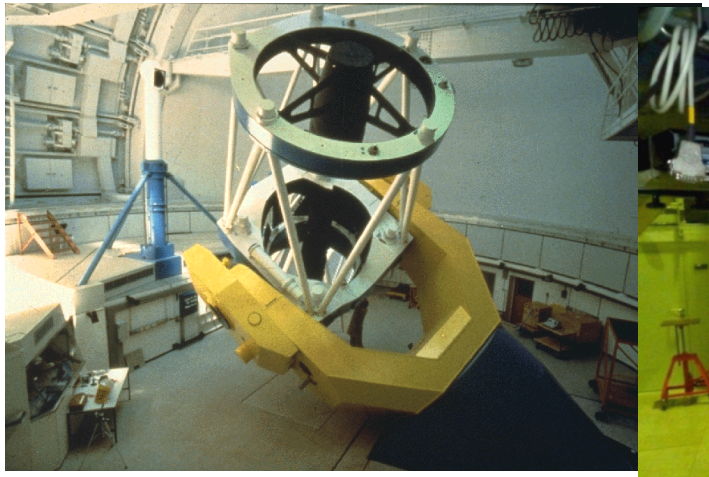
Instruments Project under development

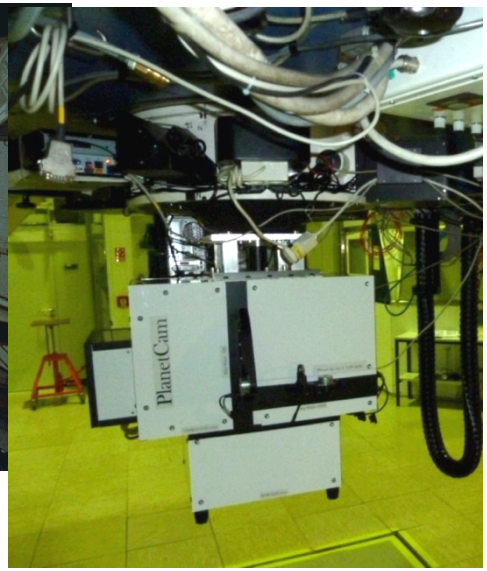


MEDA: Mars Environmental Dynamics Analyzer



JUICE: Magis & Janus





PlanetCam2 at Calar Alto Obs.

Meade 14” installation at Calar Alto Obs. (lucky imaging)

Postgraduate formation -Outreach

Aula y Master:
http://www.ehu.es/aula-espazio/
Master (UPV-EHU):
http://www.ehu.eus/es/web/cienciaytecnologiaespacial/aurkezpena

Aula EspaZio Gela

- Master in Space Science and Technology UPV/EHU (2009→, 6 editions)
- Doctorate program (included in Physics UPV/EHU)
- Industry collaboration (Master thesis) & Meetings - Workshops
- Support to students projects
- Outreach activities

Aula EspaZio Gela

Ingeniaritza Goi Eskola Teknikoa
Escuela Técnica Superior de Ingeniería
Bilbao

1. Headquarters:
Escuela Técnica Superior de Ingeniería
Computer facilities.
2. Aula EspaZio Gela (ETSI)
3. Astronomical Observatory (ETSI)

Support

1. **Project MINECO: AYA36666 (2013-15) + FPI.**

New application 2015

2. Grupos Consolidados G. Vasco IT765-13 (2013-2015 & 2016-2018)
Contracts

3. GCP en Unidad Formación e Investigación (UFI) UPV/EHU

~~**4. Unidad Asociada con IAA-CSIC (2013-14)**~~
~~**Ikerbasque support: 33.000 euros/year (*finished)**~~

5. Aula EspaZio Gela.
Pending new agreement 2015-16 to 2017-18.

6. Europlanet 2020 Research Infraestructure (H2020)
IP: Louise Thomas (Open University, UK)
Planetary archive


XII REUNIÓN CIENTÍFICA DE LA
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DE ASTRONOMÍA
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http://www.sea-astronomia.es/SEA2016
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