D'IKS à Mars, et au-delà,

le rôle essentiel de Michel

dans l'instrumentation infrarouge

Jean-Pierre Bibring
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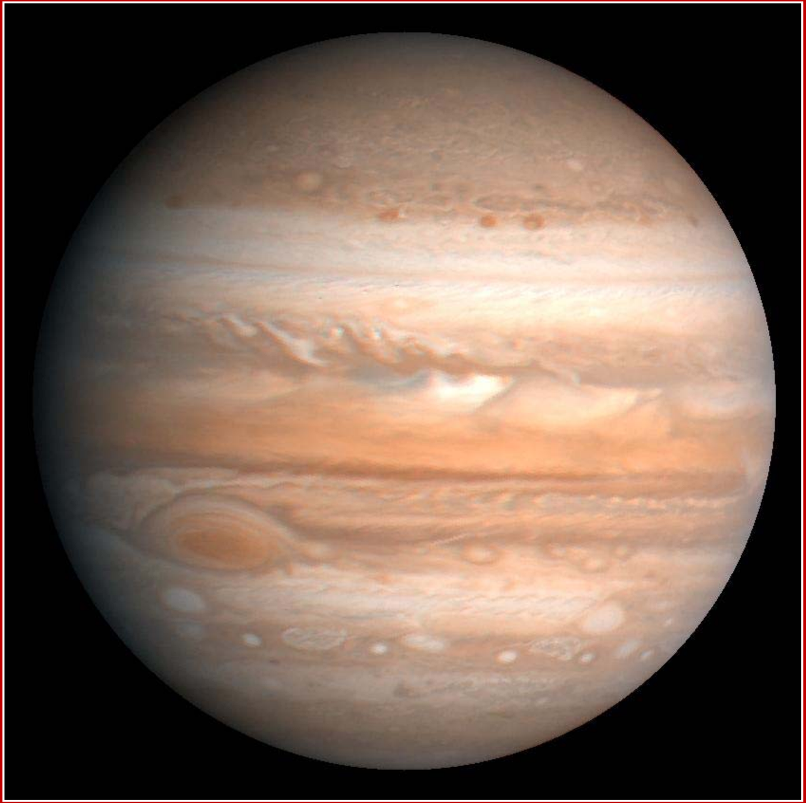
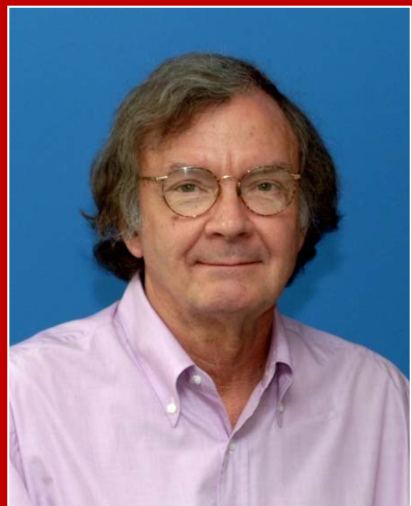
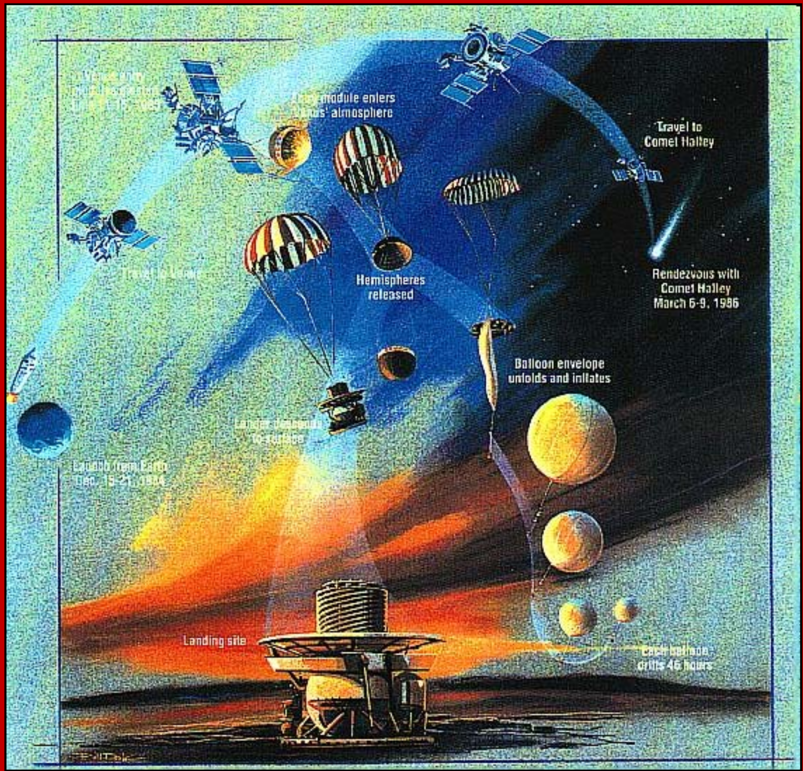
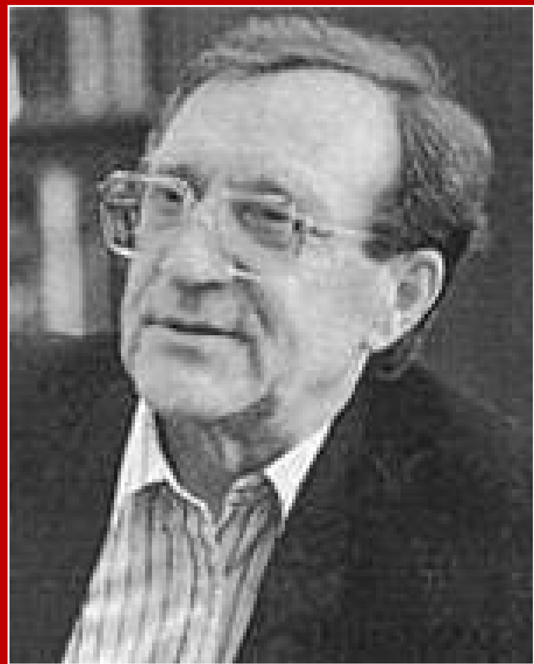


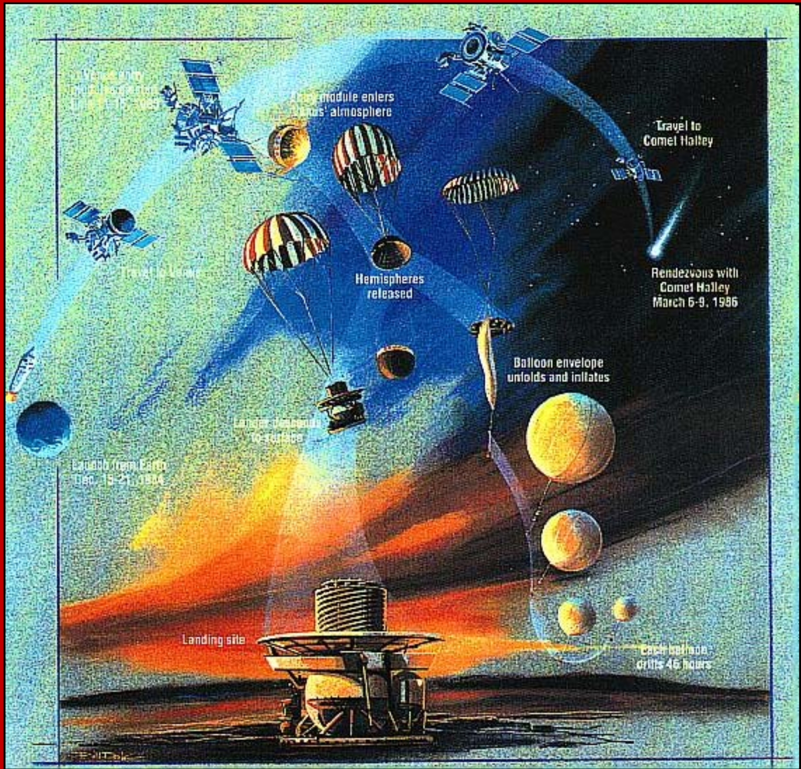





Travel to
Comet Halley
Hemispheres
released
Rendezvous with
Comet Halley
March 6-9, 1986
Balloon envelope
unfolds and inflates
Landing site



IKI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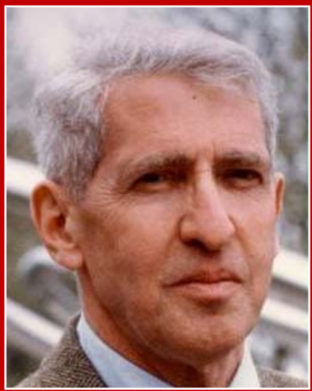
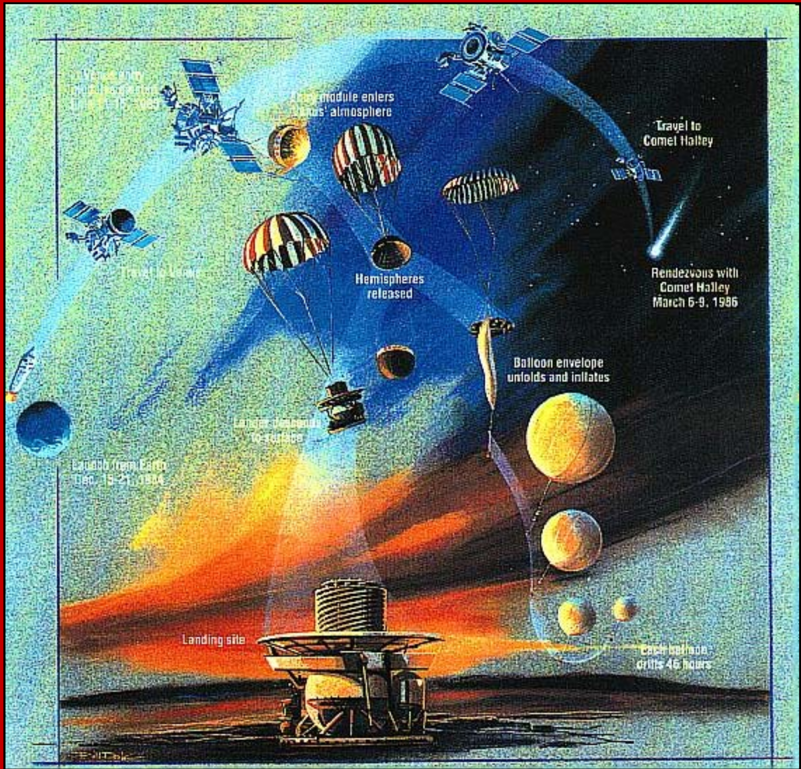
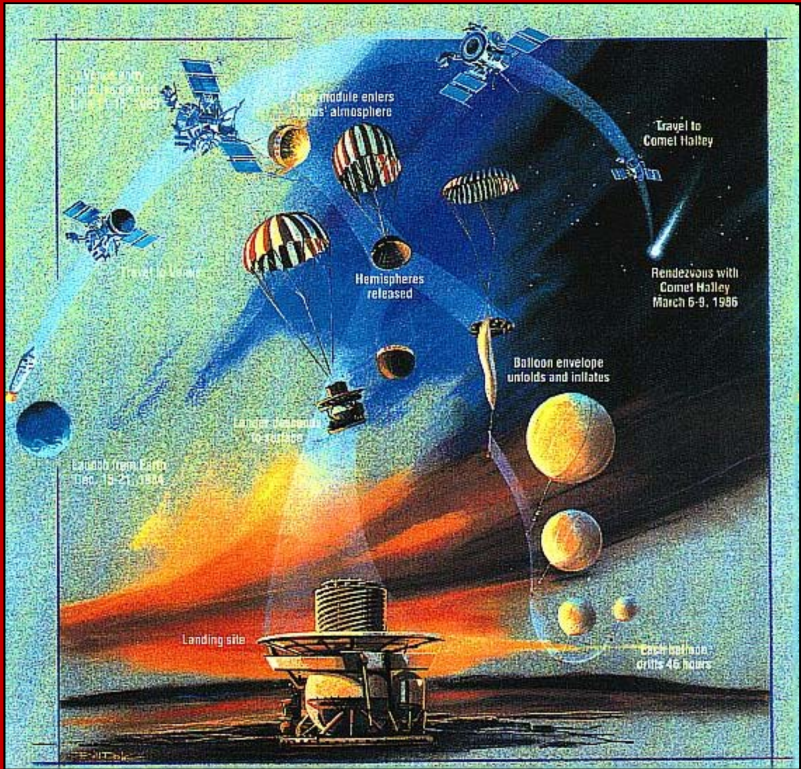




LPSP

Jean-François CRIFO
Jacques CHARRA
Alain SOUFFLOT
Guy GUYOT
Noel CORON
Jean-Michel LAMARRE
Serge CAZES
Jo LEVANTI
Richard GISPERT
Philippe SALVETAT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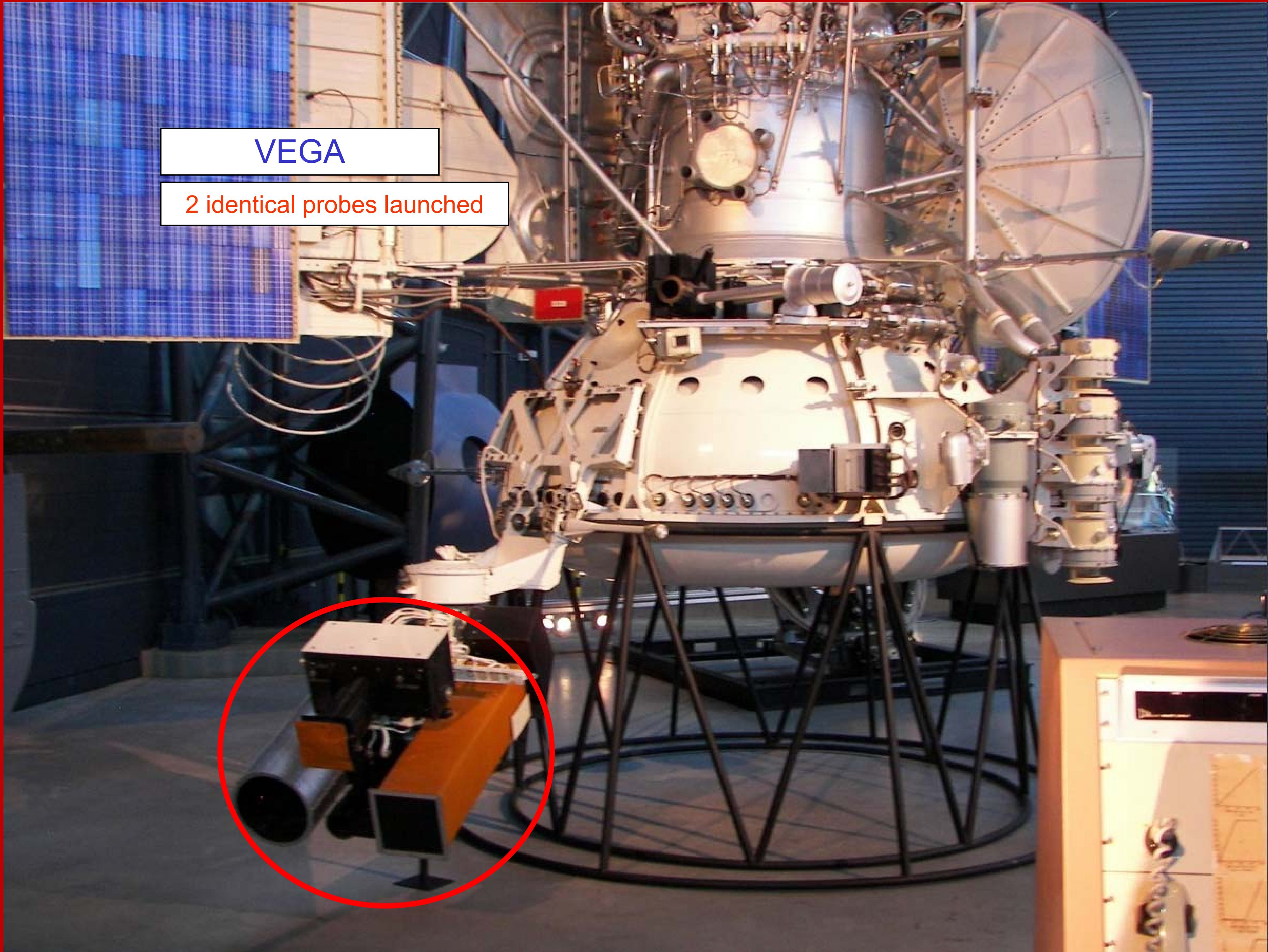
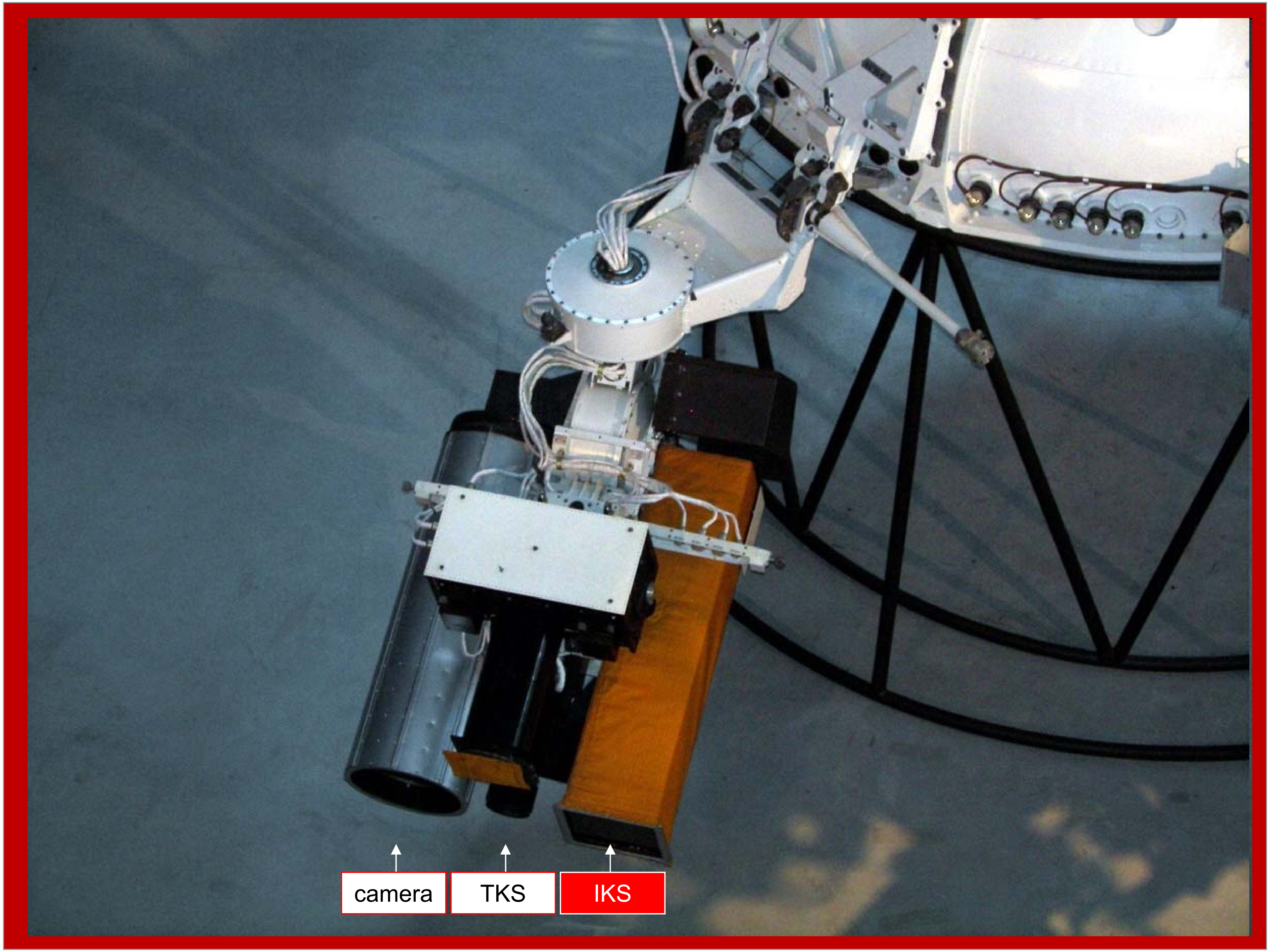
IKS


VEGA
2 identical probes launched


camera
TKS
IKS

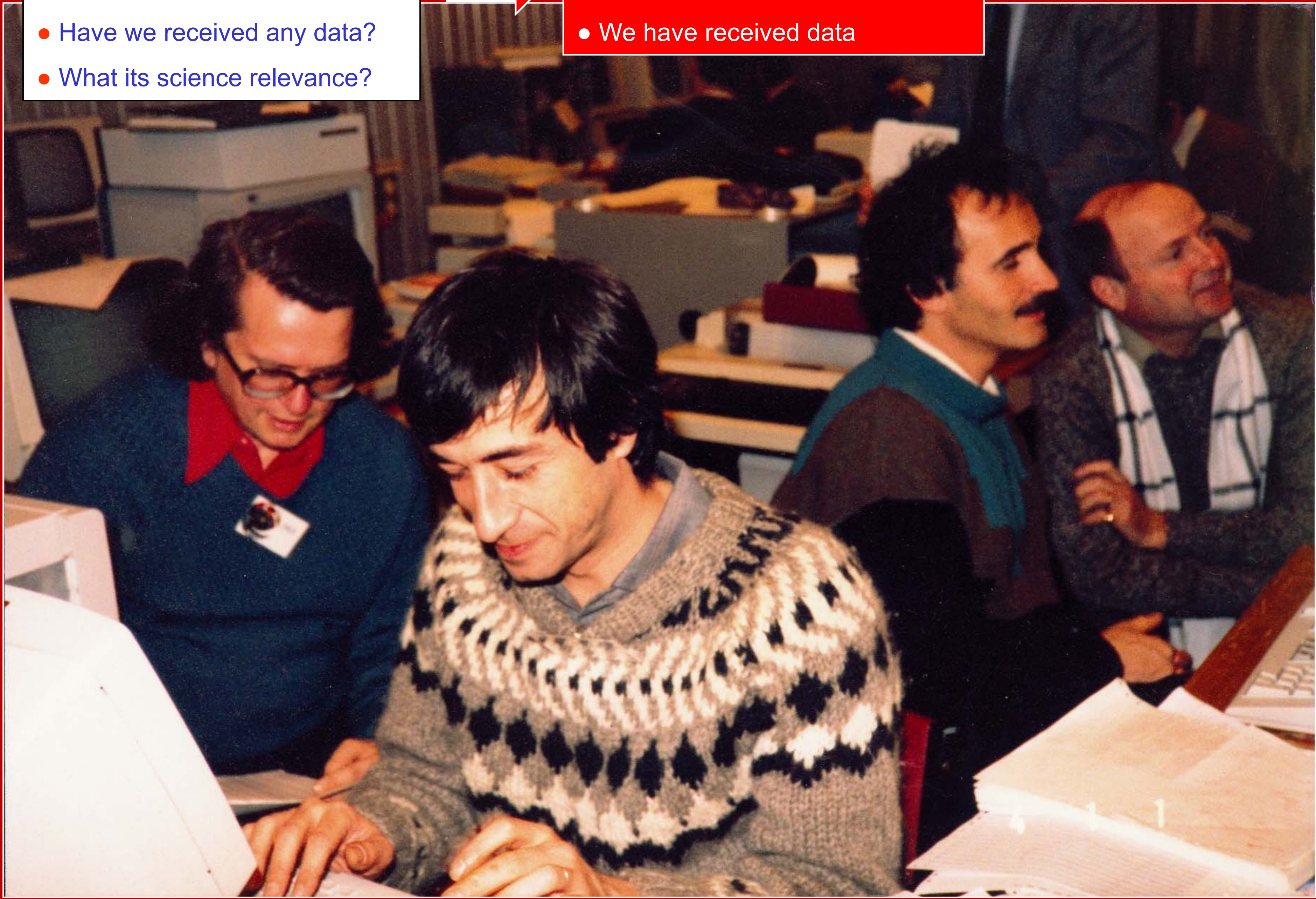
- Has the platform rotated?
- Did our instrument cool down?
- Have we received any data?
- What its science relevance?

March 6, 1986

- Has the platform rotated?
- Did IKS cool down?
- Have we received any data?
- What its science relevance?

- The platform had rotated
- IKS had cooled down
- We have received data

March 6, 1986

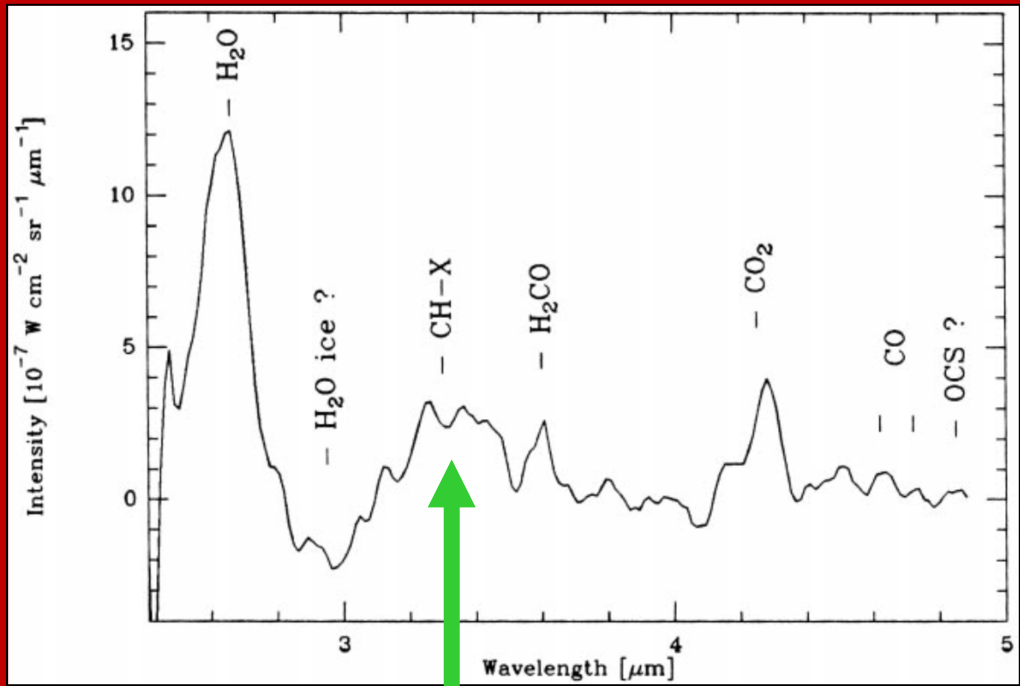


March 6, 1986

- The platform had rotated
- IKS had cooled down
- We have received data

March 6, 1986

- The platform had rotated
- IKS had cooled down
- We have received data



This spectrum exhibited for the first time the feature of a C-rich compound, lilely responsible for the very low albedo of the nucleus (prime discovery !), although formed essentially (?) of ices (H_2O, CO_2 primarily): these macro-molecules are considered having formed in the protosolar nebula. They might have played a major role in the synthesis of living species, through their feeding of the primitive planetary (terrestrial at least) ocean(s) via impacts.

The 2.5-12 μm spectrum of comet Halley from the IKS-VEGA experiment

Combes, M.; Moroz, V. I.; Crovisier, J.; Encrenaz, T.; Bibring, J. -P.; Grigoriev, A. V.; Sanko, N. F.; Coron, N.; Crifo, J. F.; Gispert, R.; Bockelée-Morvan, D.; Nikolsky, Yu. V.; Krasnopolsky, V. A.; Owen, T.; Emerich, C.; Lamarre, J. M.; Rocard, F.

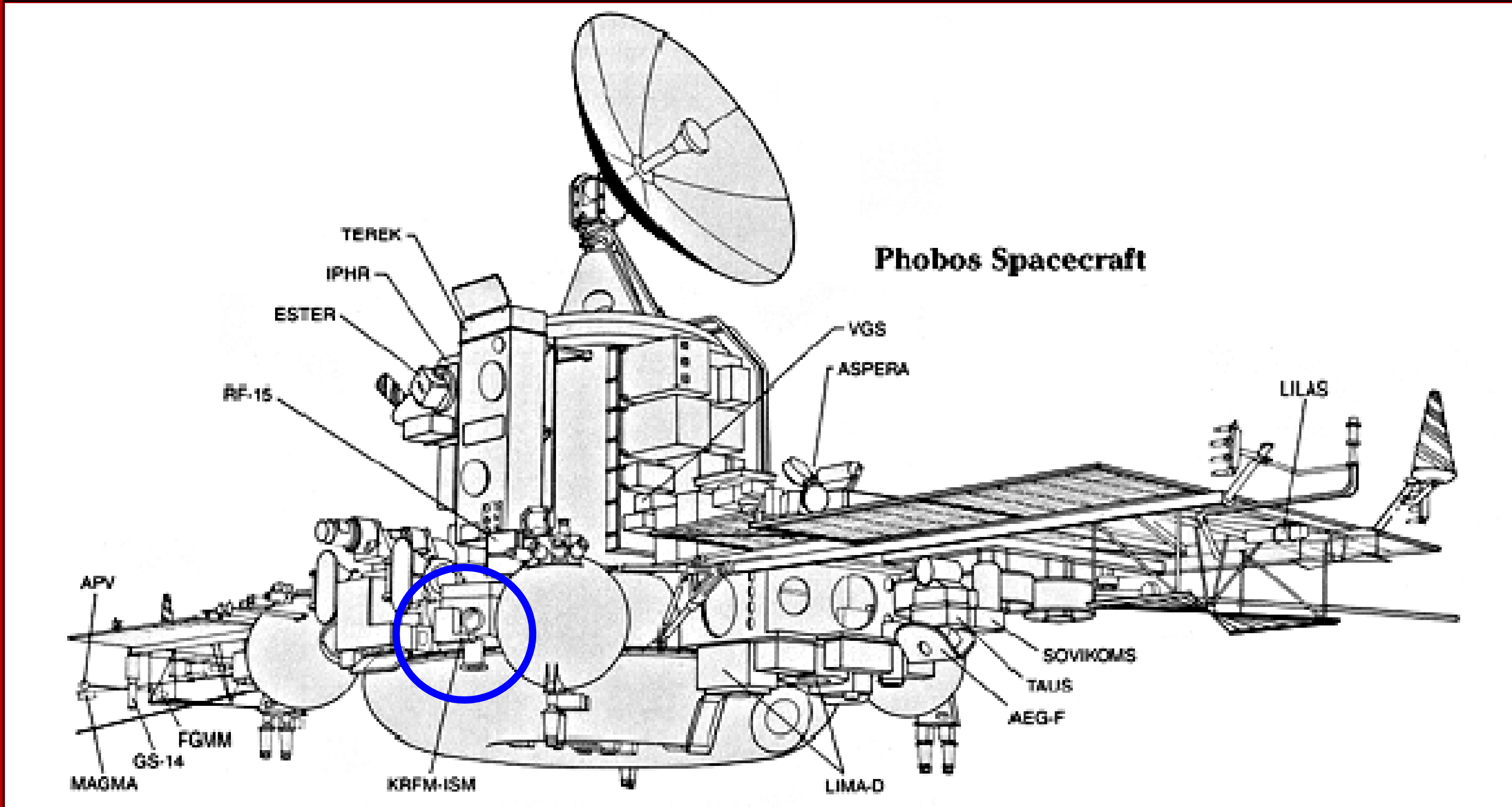
Abstract

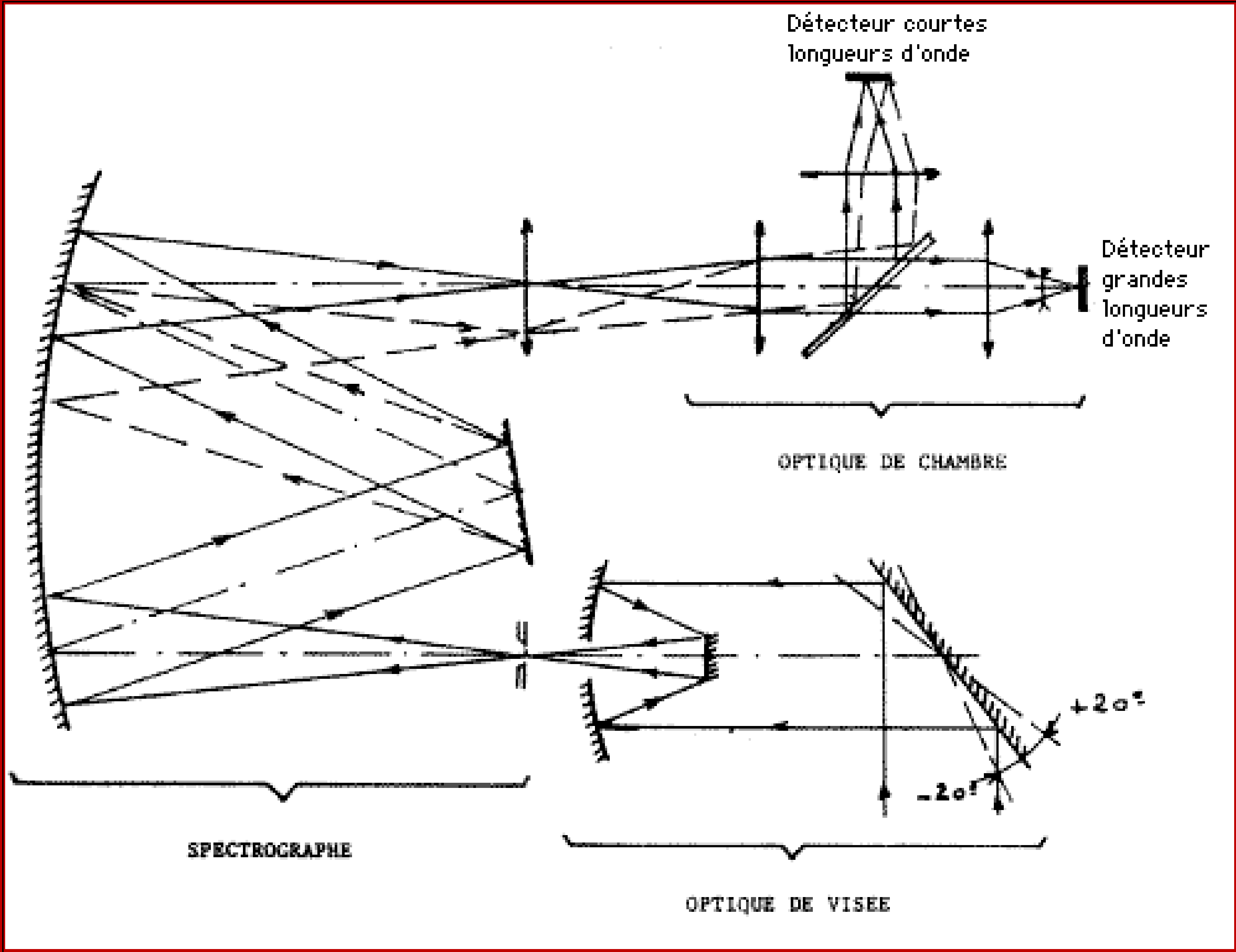
The infrared instrument IKS flown on board the VEGA space probes was designed for the detection of emission bands of parent molecules, and for a measurement of the size and temperature of the thermal emitting nuclear region. The instrument had three channels with cooled detectors: an "imaging channel" designed to modulate the signal of the nucleus and two spectroscopic channels operating at 2.5-5 and 6-12 μm, respectively, equipped with circular variable filters of resolving power ~ 50. This paper presents and discusses the results from the spectral channels.

Icarus, Volume 76, Issue 3, p. 404-436, December 1988

Rosetta

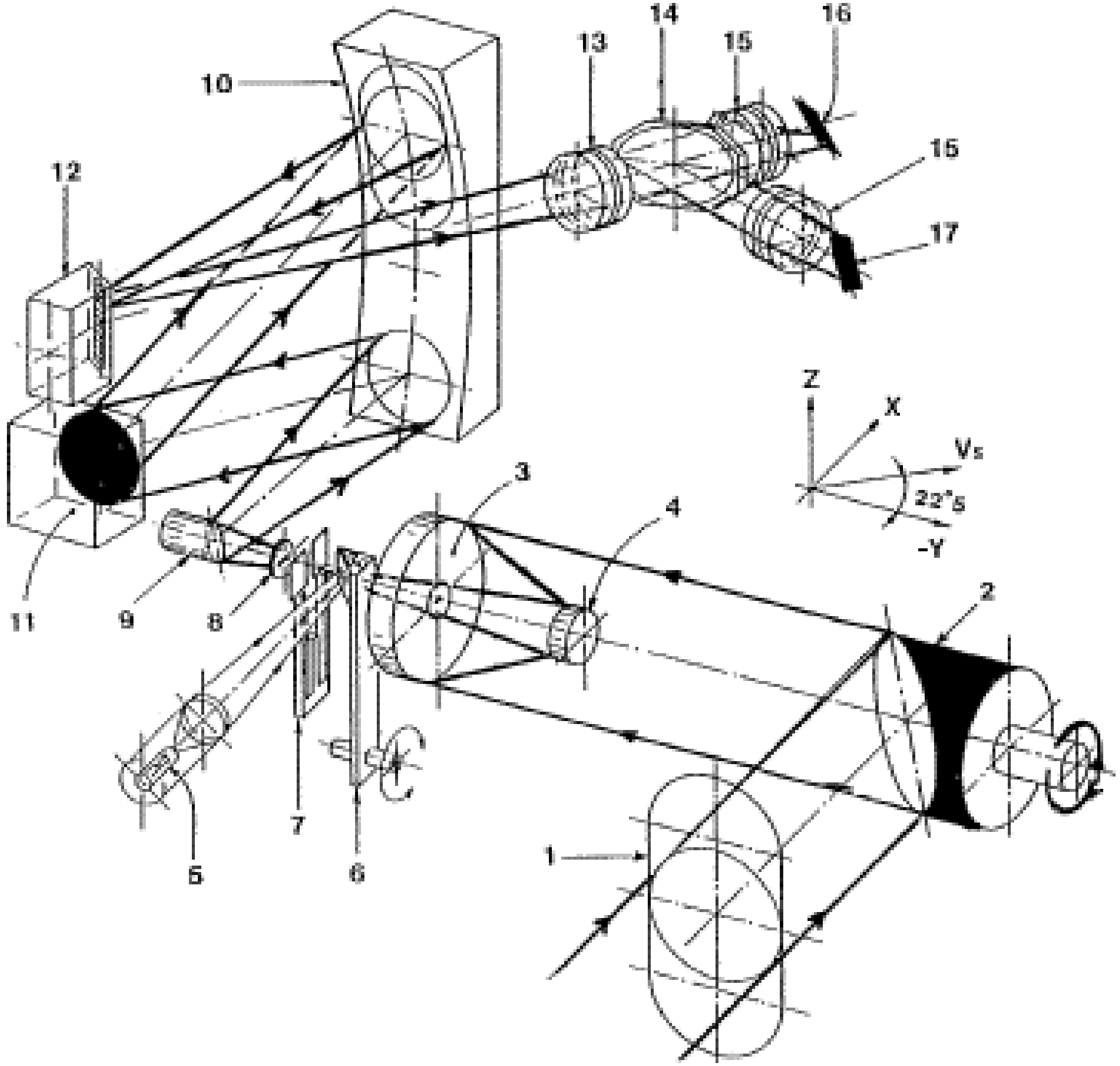
Décidées lors du lancement des VEGA en 1984, les missions Phobos 1 et 2 lancées en 1988, emportaient ISM, premier imageur hyperspectral proche infraouge planétaire, développé en coopération entre l'IAS et le DESPA





Michel, l'architecte optique

Schéma optique d'ISM



1 - Baffle d'entrée
2 - Miroir de balayage
3 - Miroir primaire
4 - Miroir secondaire
5 - Lampe d'étalonnage
6 - Miroir commutable
7 - Modulateur
8 - Fente d'entrée
9 - Miroir de renvoi
10 - Miroir parabolique
11 - Réseau
12 - Miroir de champ
13 - Lentille d'entrée
14 - Séparatrice
15 - Lentilles imageantes
16 - Détecteur 1,6 à 3,2 µm
17 - Détecteur 0,8 à 1,6 µm

1 - Entrance Baffle
2 - Scanning Mirror
3 - Primary Mirror
4 - Secondary Mirror
5 - Calibration Source
6 - Tilting Mirror
7 - Modulator
8 - Entrance Slit
9 - Folding Mirror
10 - Parabolic Mirror
11 - Grating
12 - Field Mirror
13 - Entrance lenses
14 - Beamsplitter
15 - Imaging lenses
16 - 1.6 to 3.2 µm detector
17 - 0.8 to 1.6 µm detector

Michel, l'architecte optique

Caractéristiques d'ISM

Spectrometer	Grating, first and second orders
Detectors	2 arrays of 64 PbS detectors in staggered rows -75°C operating temperature (passive cooling)
Electronics	0.125 to 1 s integration time 1, 2, 3 or 6 analogic gain

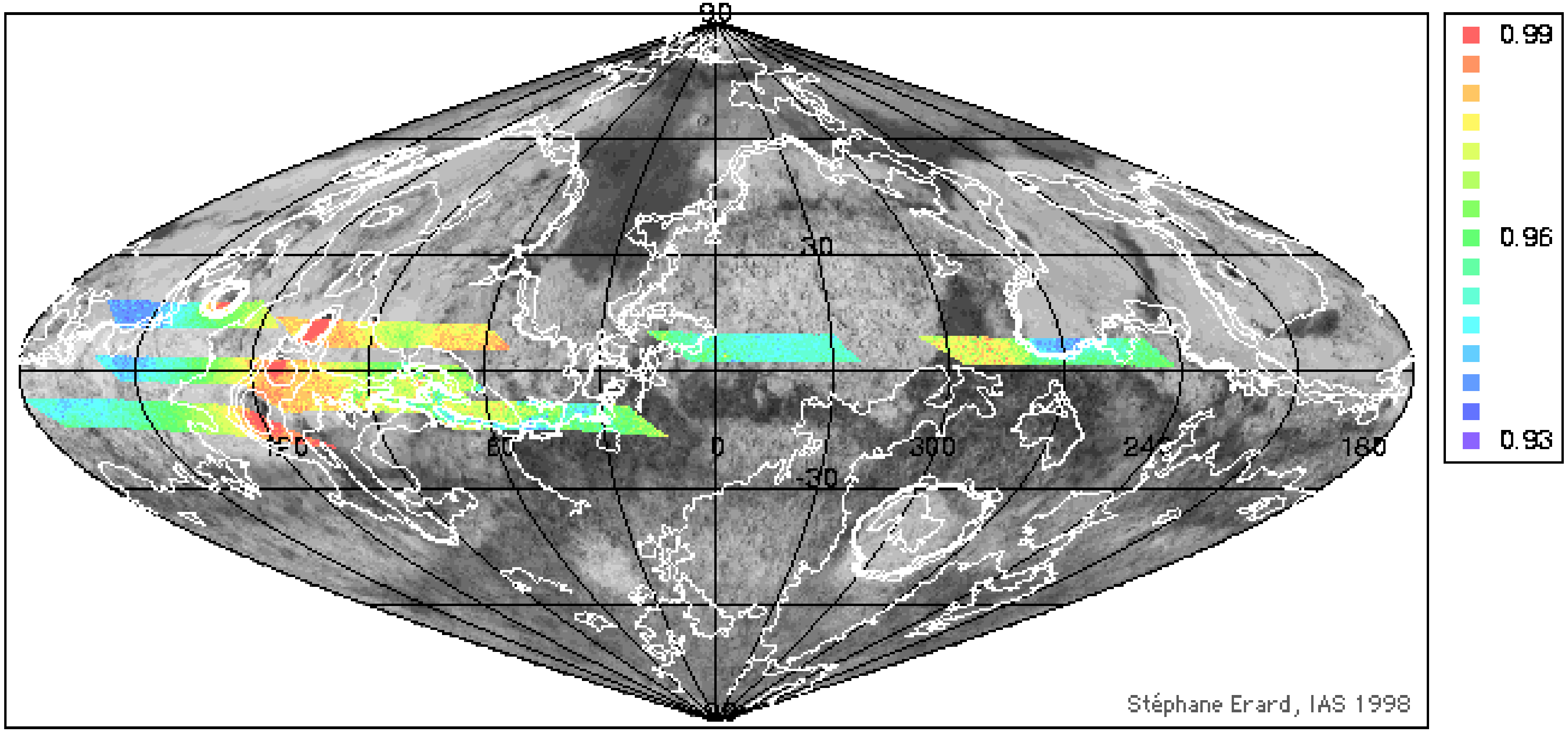
Optical path	**Short-wavelengths**	**Long-wavelengths**
Spectral range	0.76-1.51 μm (second grating order)	1.64-3.16 μm (first grating
Spectral sampling	12.5 nm	25 nm
Bandwidth	25 nm	50 nm

Subsystem	**ISM1** (optics and processing)	**ISM2** (electronics)
Size	274 x 271 x 212 mm	184 x 180 x 108 mm
Weight	~4 kg	~2.1 kg
Power consumption	14 W (1 W in stand-by mode)	

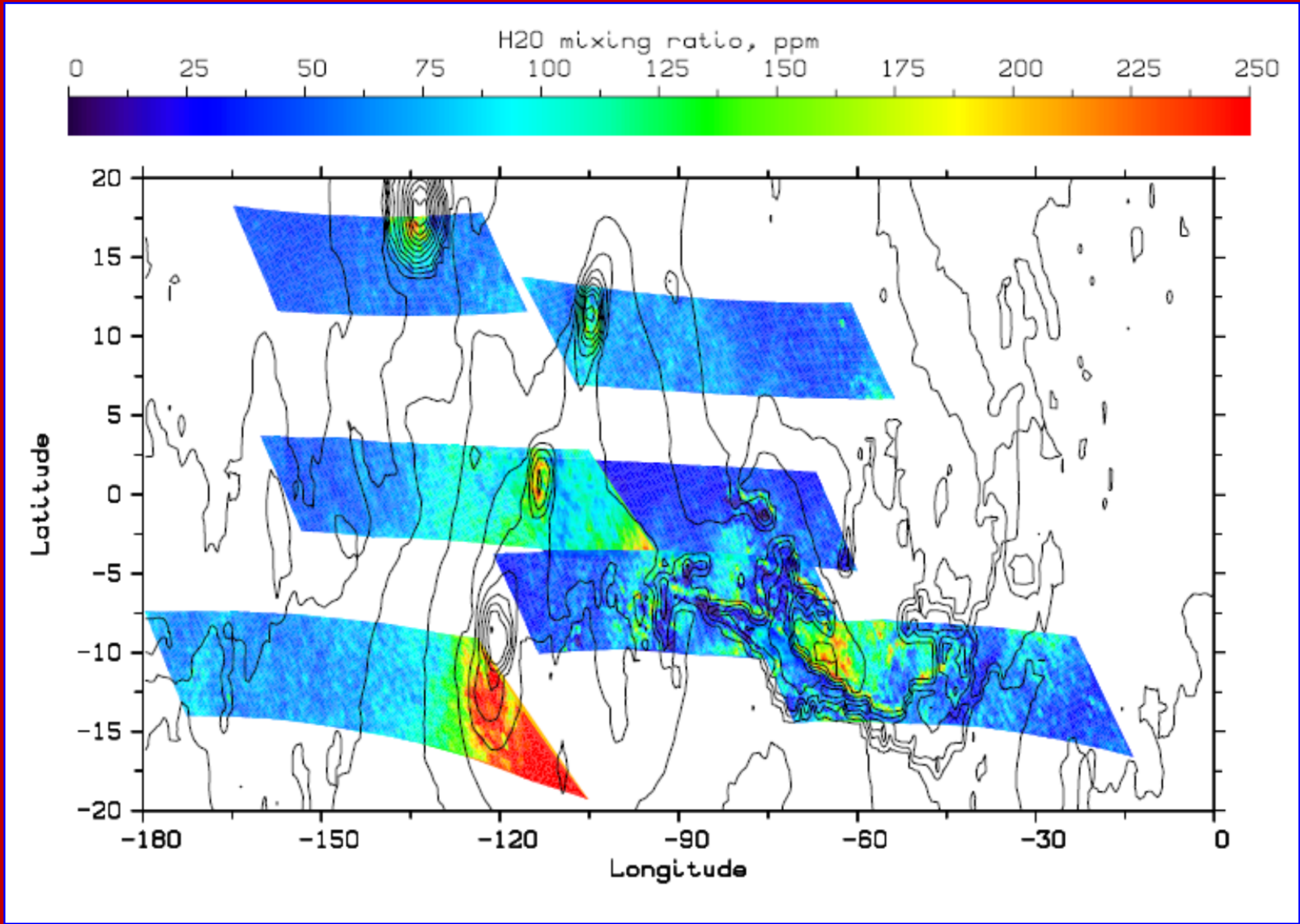
Michel, l'architecte optique

Avec ISM, 40 000 spectres de Mars ont été acquis, de 0.8 à 3.2 µm (contrainte pré-ITAR), couvrant 25% des terrains de latitude +/- 30°

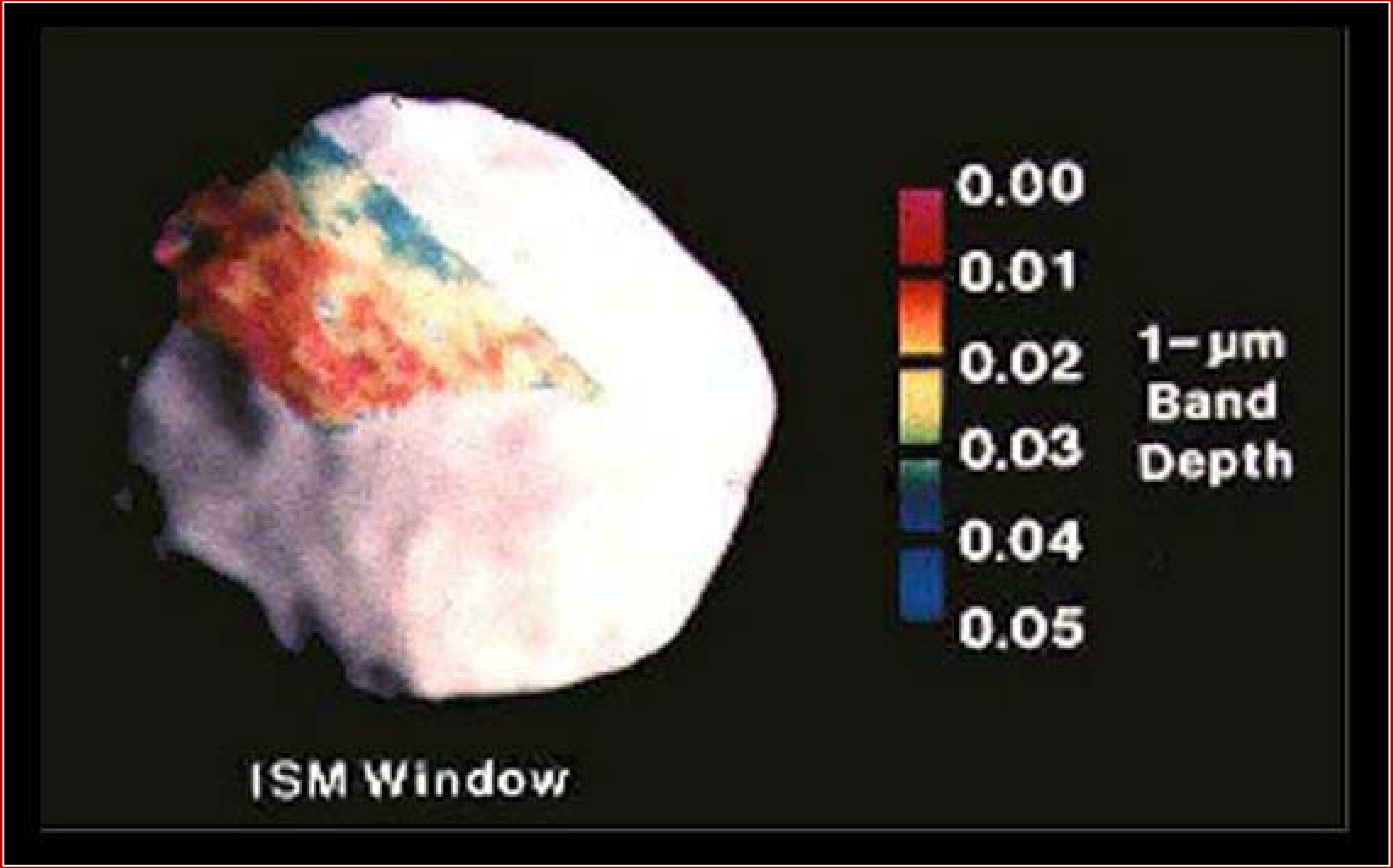
Altimétrie (bande du CO_2 à 1,44 µm) à partir des données ISM / Phobos



Distribution de l'eau atmosphérique à partir des données ISM / Phobos



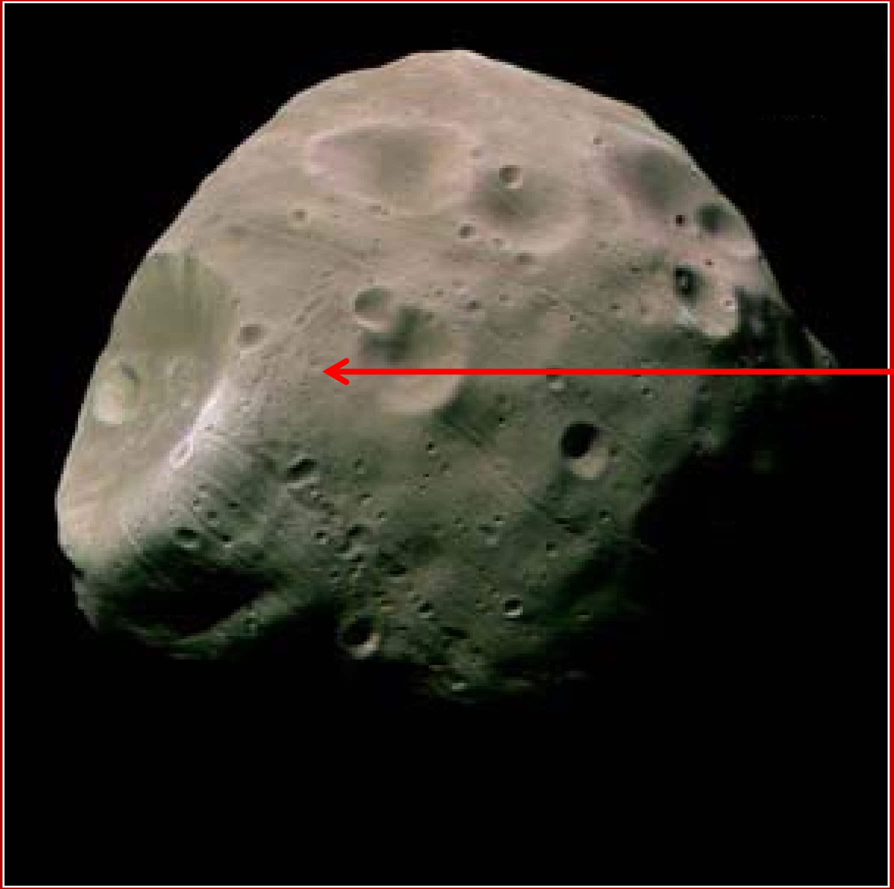
ISM a également réalisé les premières caractérisations de la composition de Phobos

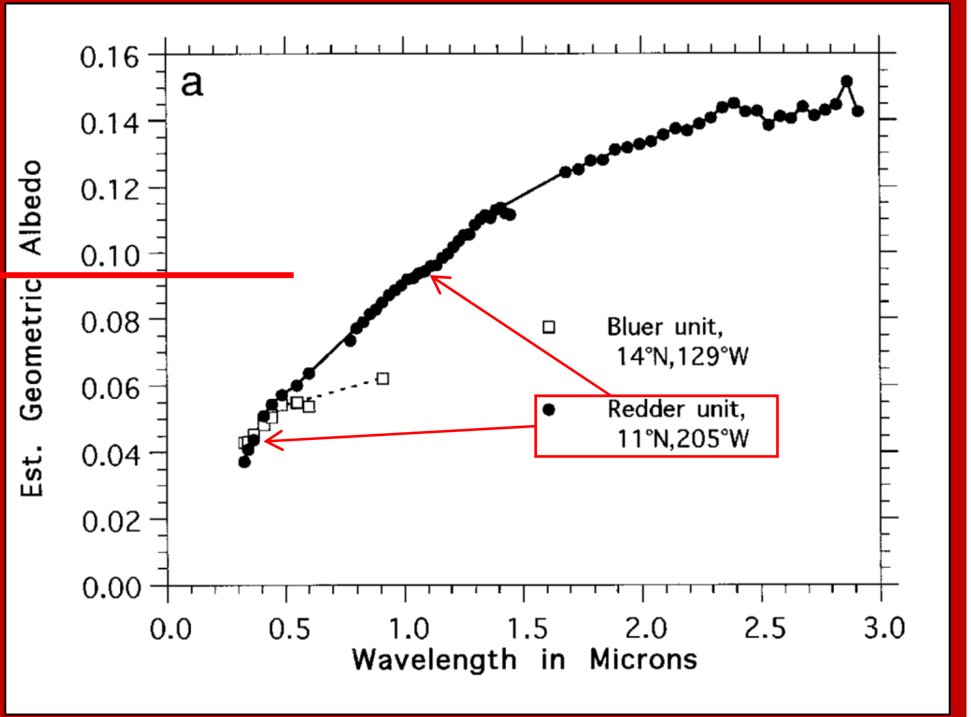


- très faible absorbtion mafique (@ 1.0 µm)
- pas d'hydratation 1.4, 1.9, 3 µm
- pas de signature C-rich

ISM a également réalisé les premières caractérisations de la composition de Phobos

Qui ont permis l'identification de deux types de terrains ("bleu" et "rouge")





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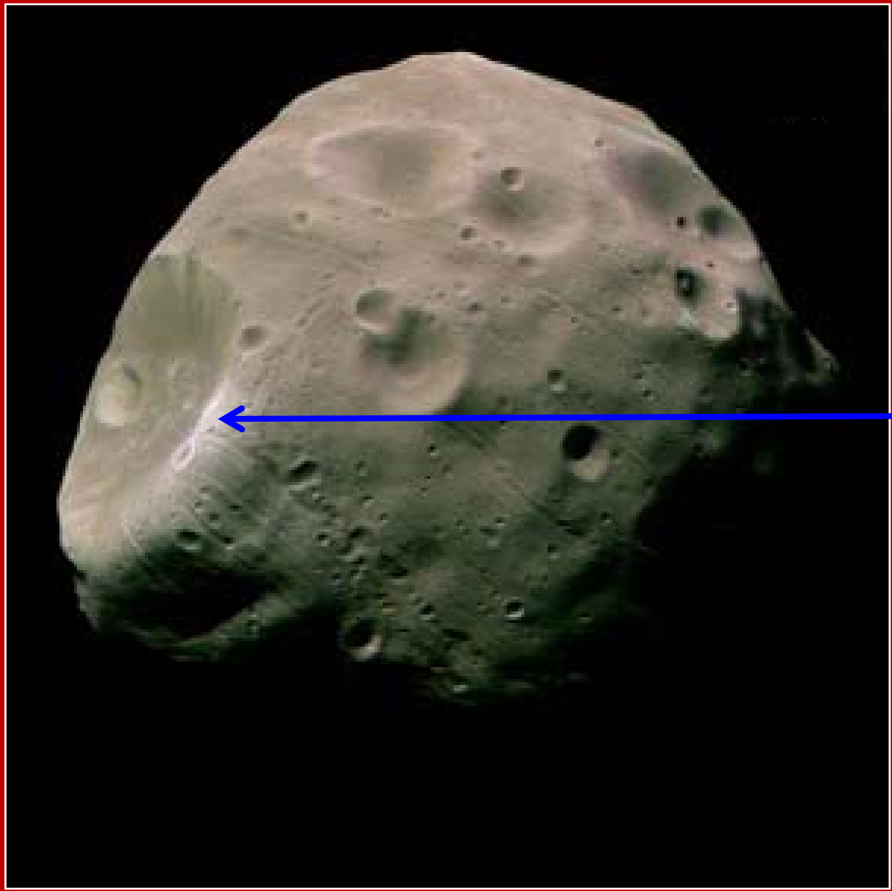
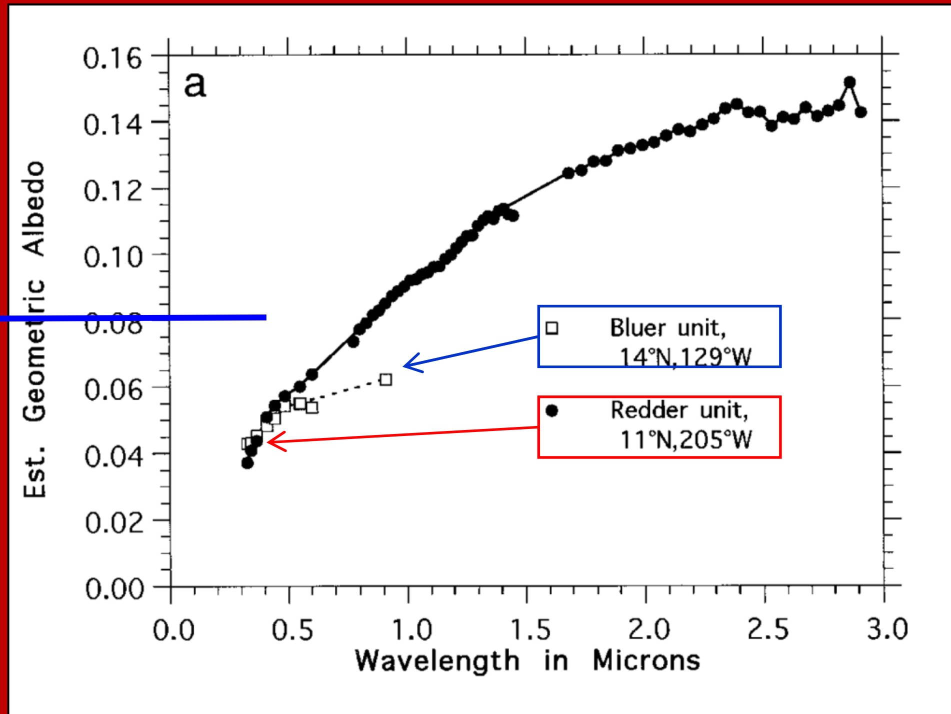
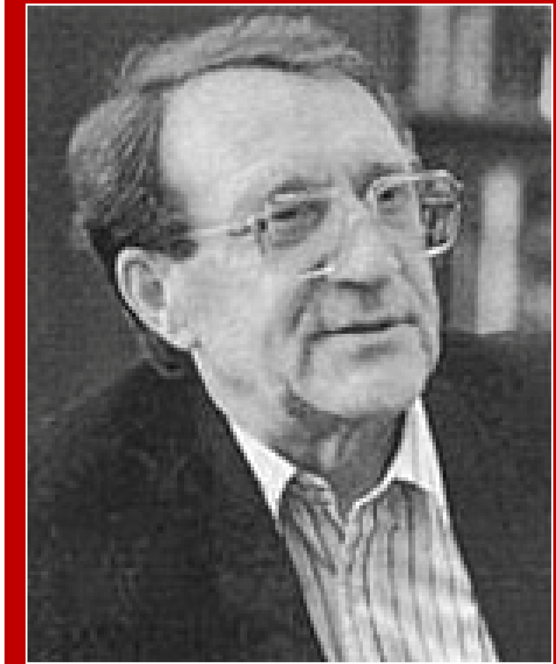
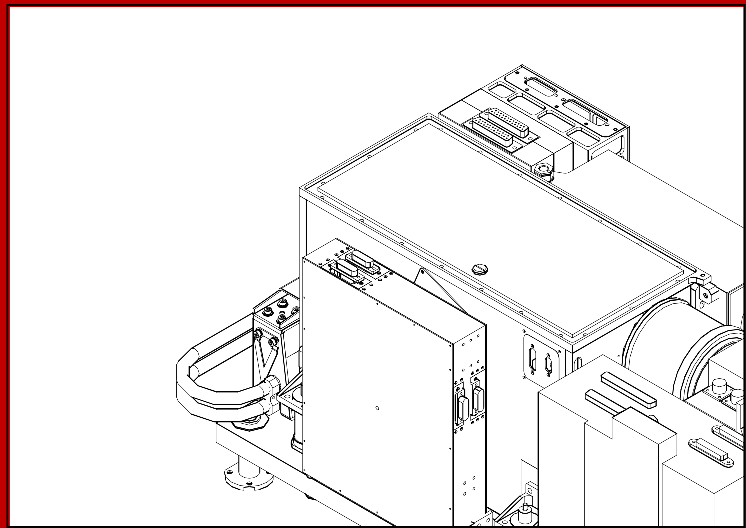




et selon la tradition soviétique, le jour du lancement des missions Phobos (juin 1988), la mission suivante a été décidée (Mars 92/94/96), avec (Perestroika et Glasnost) cette fois-ci…un vote sur la P/L, lors d'une session présidée par Vassili Moroz. C'est ainsi qu'OMEGA (ensuite sélectionné par le CNES) est né.





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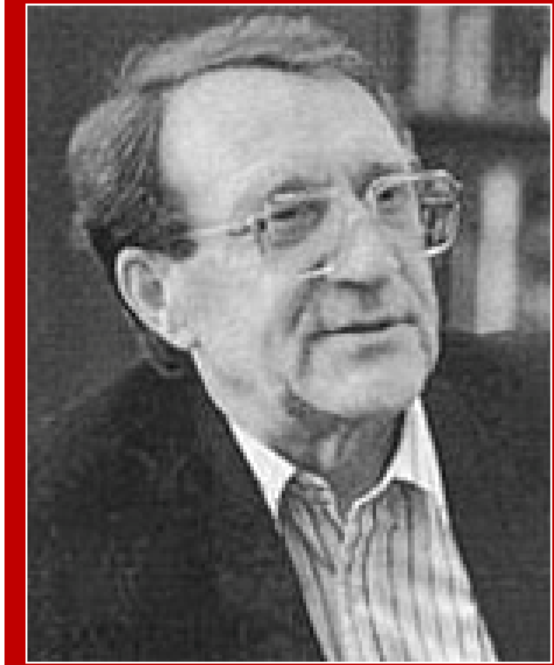
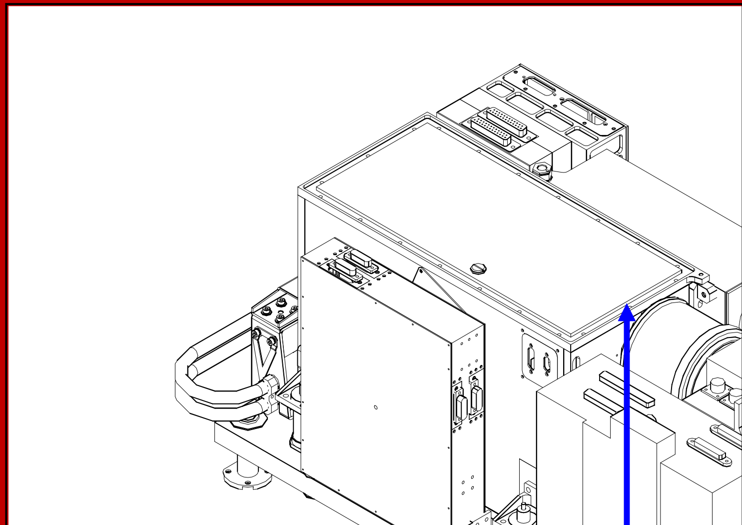
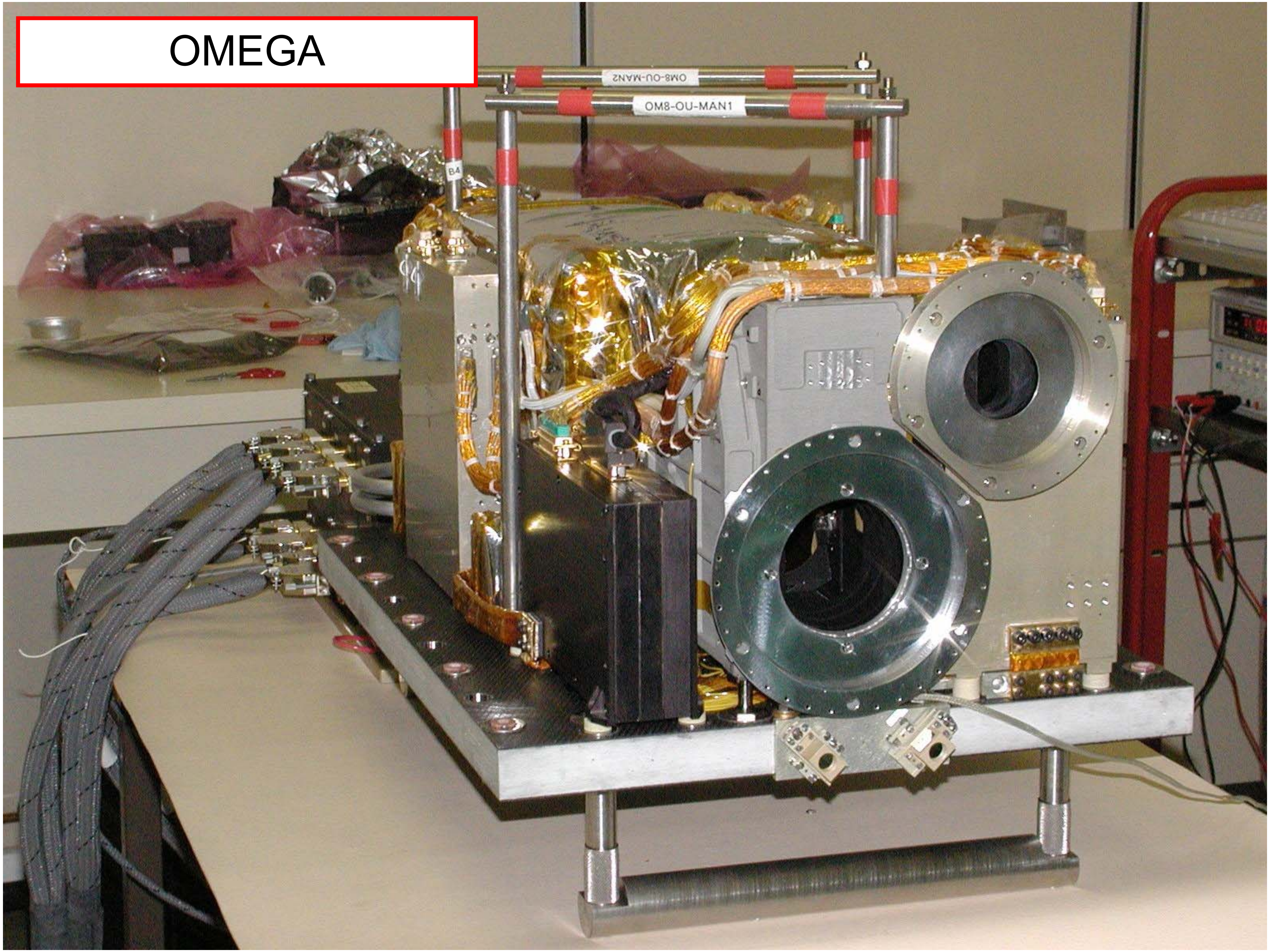




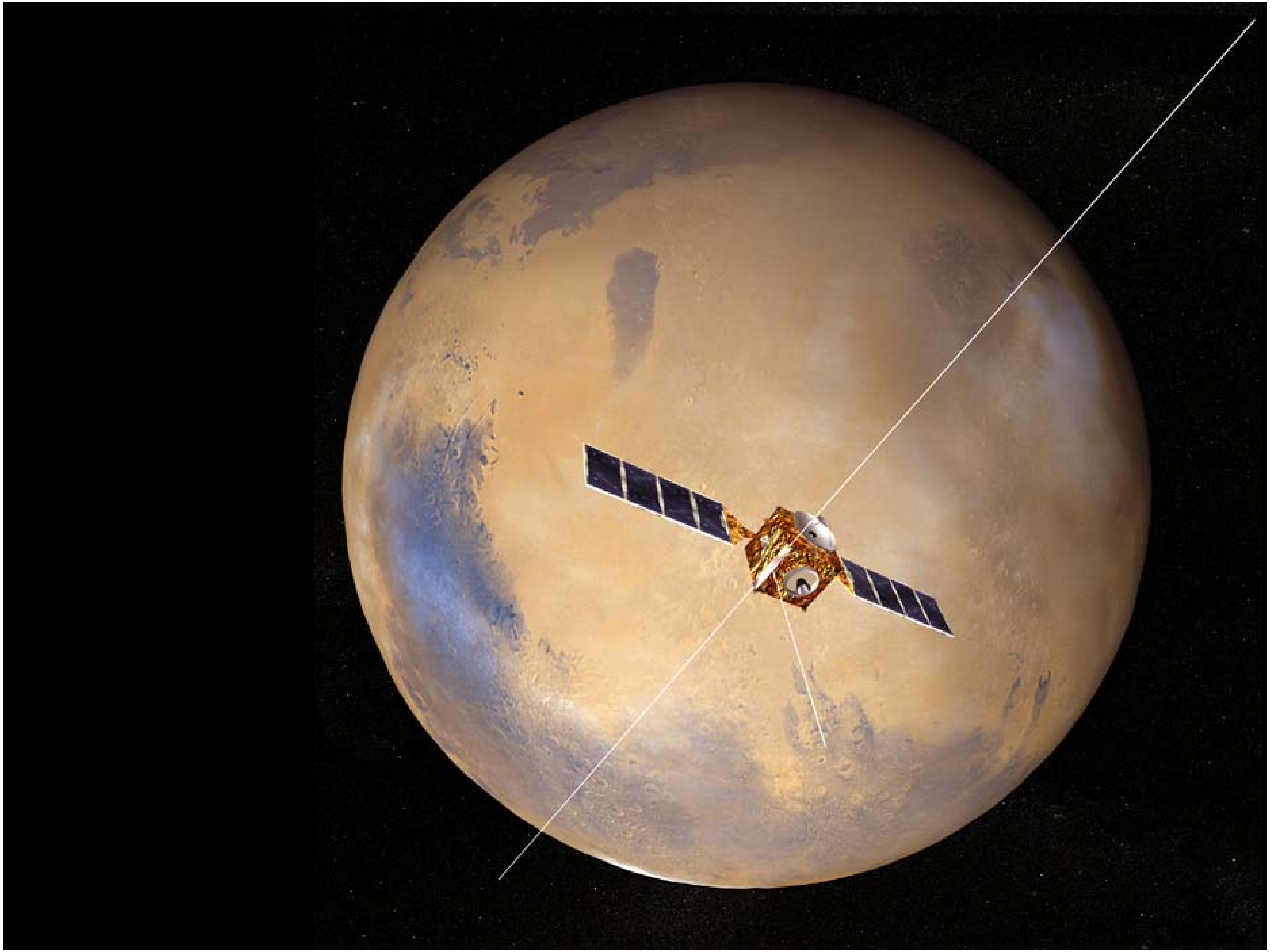
… avec la demande, évidemment acceptée (!), d'inviter un partenaire italien (V. Formisano), auquel nous avons proposé l'ajout d'un canal visible, co-aligné. C'est ainsi qu'est né le design dual utilisé par la suite par VIMS et tous les VIRTIS

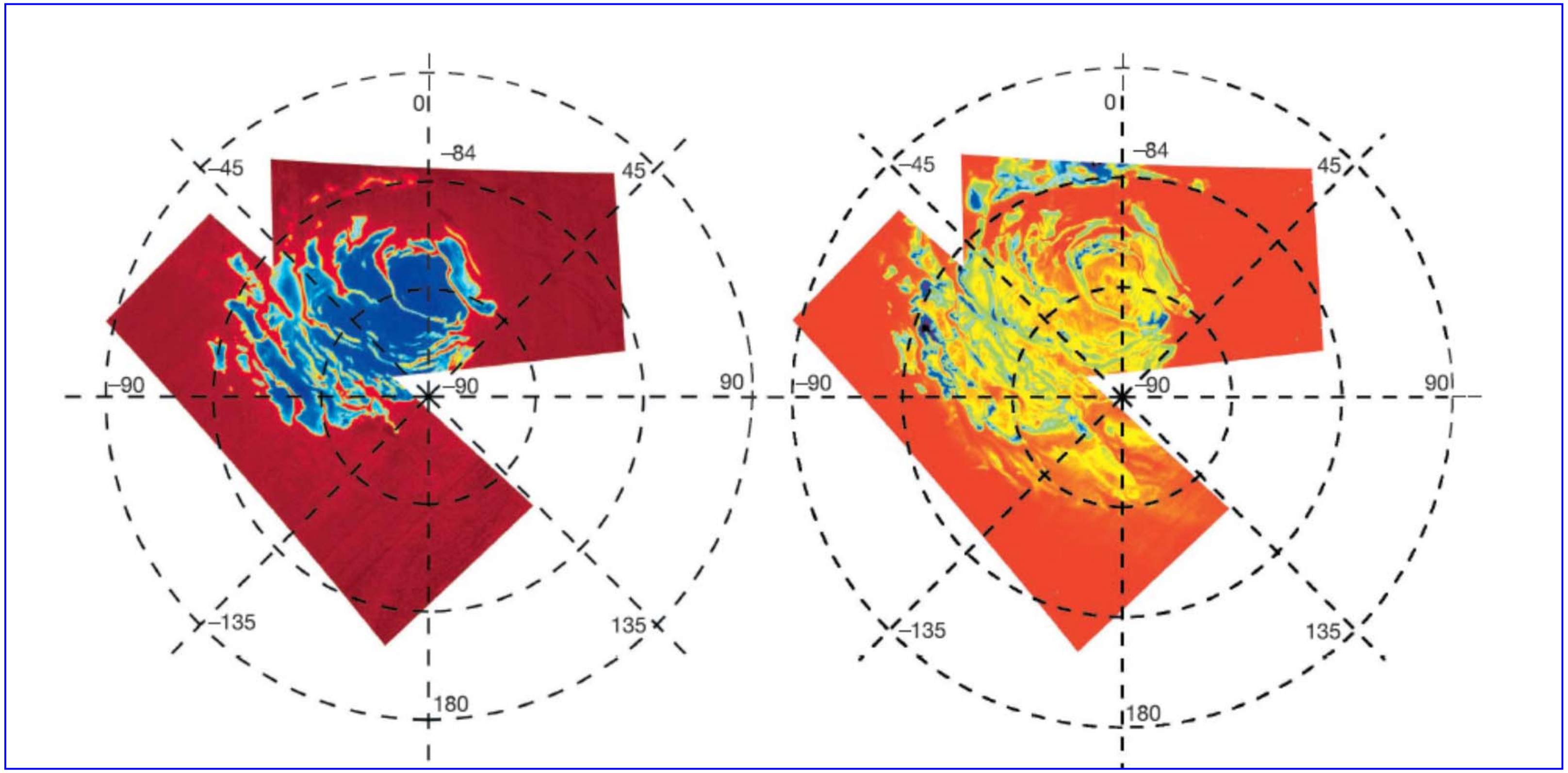

Mars 94
VESTA
CRAF
CASSINI

OMEGA



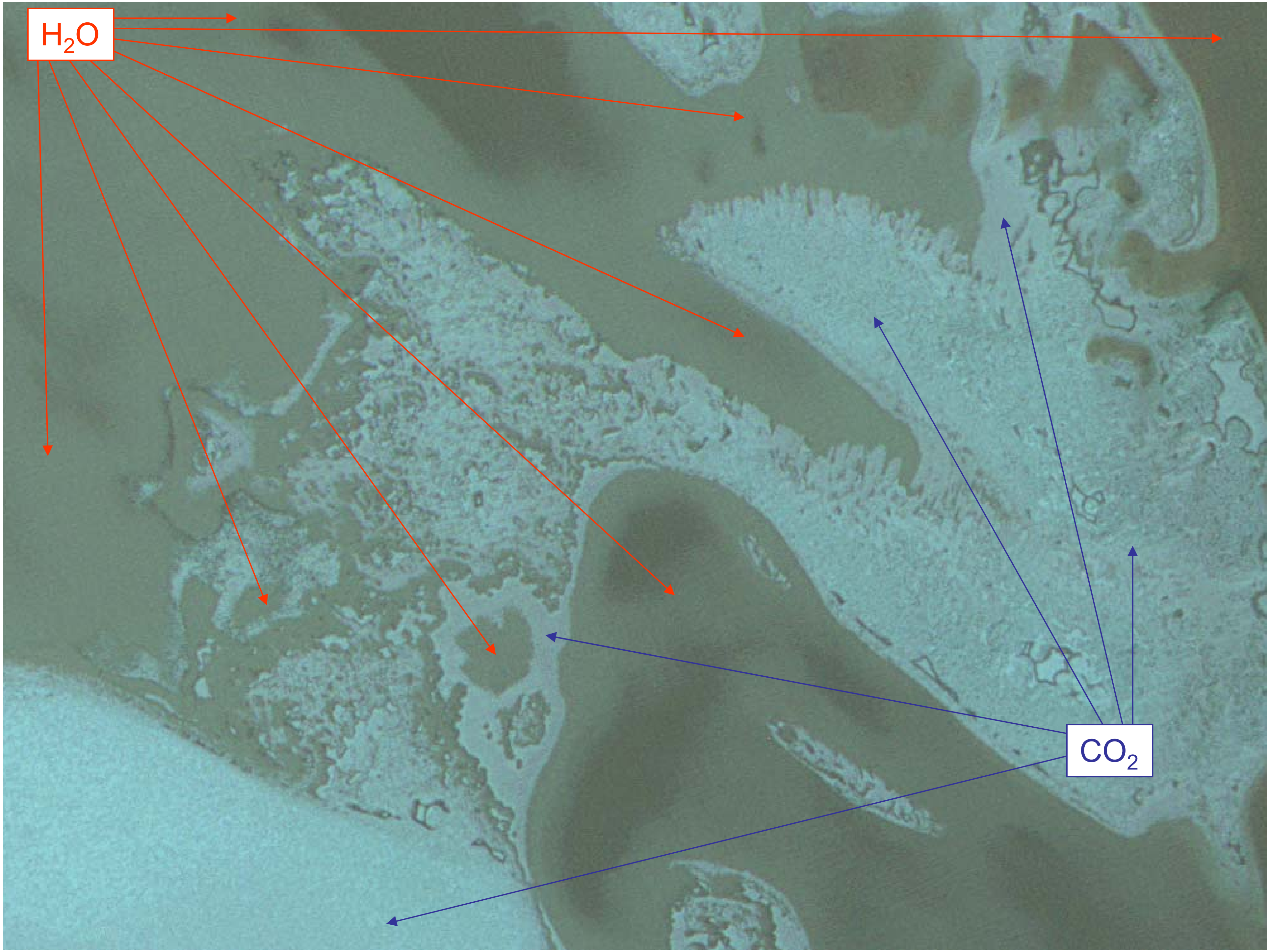

ЦПК



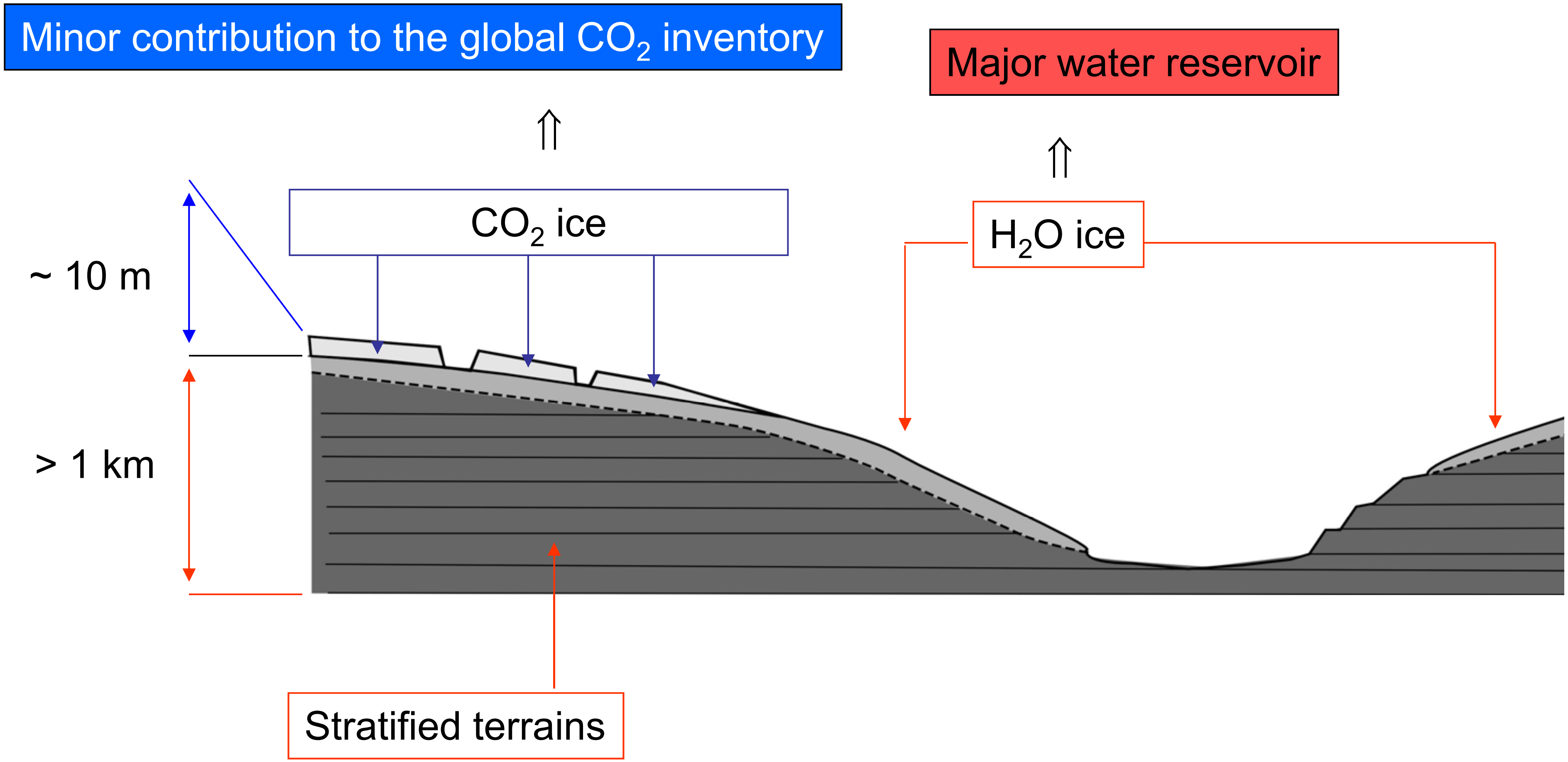


CO_2 ice

H_2O ice


H_2O
CO_2

Schematic of the perenial South polar cap



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The inventory of water and carbon dioxide reservoirs on Mars are important clues for understanding the geological, climatic and potentially exobiological evolution of the planet[1]. From the early mapping observation of the permanent ice caps on the martian poles[2,3], the northern cap was believed to be mainly composed of water ice, whereas the southern cap was thought to be constituted of carbon dioxide ice. However, recent missions (NASA missions Mars Global Surveyor and Odyssey) have revealed surface structures[4], altimetry profiles[5], underlying buried hydrogen[6], and temperatures of the south polar regions that are thermodynamically consistent with a mixture of surface water ice and carbon dioxide[7]. Here we present the first direct identification and mapping of both carbon dioxide and water ice in the martian high southern latitudes, at a resolution of 2 km, during the local summer, when the extent of the polar ice is at its minimum. We observe that this south polar cap contains perennial water ice in extended areas: as a small admixture to carbon dioxide in the bright regions; associated with dust, without carbon dioxide, at the edges of this bright cap; and, unexpectedly, in large areas tens of kilometres away from the bright cap.

The ESA/Mars Express Orbiter[8] was inserted into Mars orbit on 25 December 2003. The Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA) instrument[9], one of the seven investigating instruments on board, is an imaging spectrometer analysing the diffused solar light and the planetary thermal emission. On each resolved pixel, 1.2 mrad in the instantaneous field of view, OMEGA acquires a spectrum in 352 contiguous spectral channels from 0.35 to 5.1 μm, with a spectral sampling ranging from 7 nm (in the visible) to 13 nm (from 1.0 to 2.7 μm) and 20 nm (from 2.7 to 5.1 μm). A few initial observations were performed soon after Mars orbit insertion, in particular while the spacecraft was overflying the south polar areas. The altitude of observation ranged from ~1,500 km to ~2,000 km, providing an OMEGA surface sampling of ~2 km. OMEGA thus mapped a large fraction of the south polar regions, along four distinct orbits, from 18 January to 11 February 2004 (solar longitude, $L_\odot = 335°$ to 348°)—that is, about one month before the martian southern autumn equinox. At the time of the observations, the Sun's elevation was very low (<10°); however, given the very high performances of OMEGA, several tens of thousands of spectra were acquired with signal-to-noise ratios of >100 over almost the entire spectral domain. From the acquired spectra, it is possible to derive coupled maps of a variety of parameters and properties: in particular, the major icy constituents, CO_2 and H_2O, have several unambiguous diagnostic spectral signatures enabling the mapping of their respective distributions over the imaged areas (see below).

The OMEGA spectral images exhibit well-characterized high albedo perennial polar ice patterns. From their near-infrared spectrum, we can assert that these bright areas are those where CO_2 ice is highly concentrated (Fig. 1a).

A crucial finding is the identification of H_2O ice, with a varying concentration over a much larger area (Fig. 1b). H_2O ice is found in three distinct units, as follows.

Unit 1. On the bright cap. In this unit, water ice is mixed with large concentrations of CO_2 ice. This makes its spectral identification more difficult than in the two other units, as CO_2 ice exhibits spectral features in the same spectral domain. It requires a careful

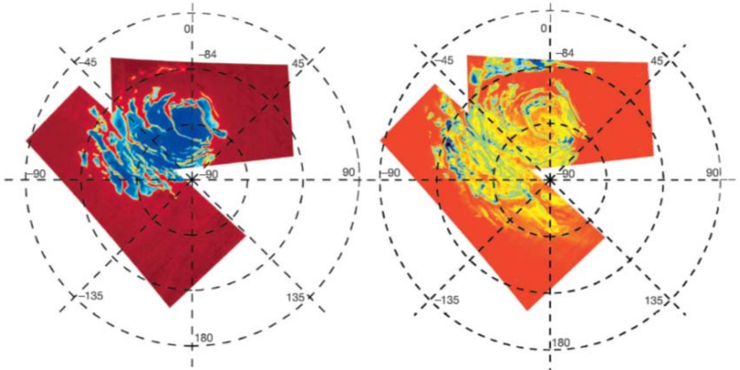

Figure 1 Global maps of CO_2 and H_2O ices at the south pole of Mars. Left, the CO_2-ice absorption feature is scaled from blue (deep) to brown (CO_2-ice-free areas); right, mapping of the H_2O ice, from blue (deep absorption) to red (ice-free). Comparison shows that the H_2O-ice areas extend far beyond the CO_2-rich bright cap, along its scarps up to isolated units tens of kilometres wide.

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April 8, 2004

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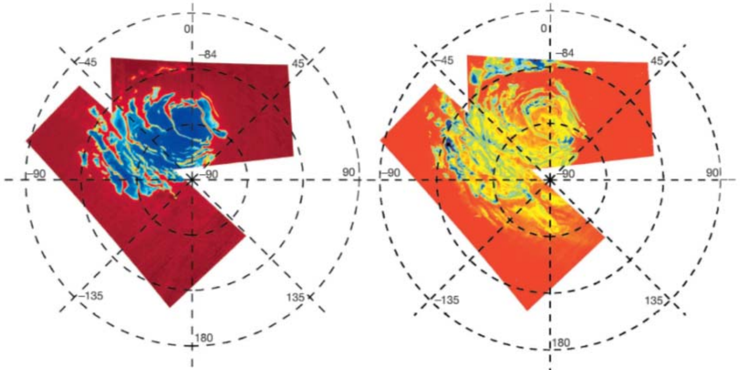

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* A list of all the members of the OMEGA team and their affiliations appears at the end of the paper

The inventory of water and carbon dioxide reservoirs on Mars are important clues for understanding the geological, climatic and potentially exobiological evolution of the planet[1]. From the early mapping observation of the permanent ice caps on the martian poles[2,3], the northern cap was believed to be mainly composed of water ice, whereas the southern cap was thought to be constituted of carbon dioxide ice. However, recent missions (NASA missions Mars Global Surveyor and Odyssey) have revealed surface structures[4], altimetry profiles[5], underlying buried hydrogen[6], and

Perennial water ice identified in the south polar cap of Mars

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temperatures of the south polar regions that are thermodynamically consistent with a mixture of surface water ice and carbon dioxide[7]. Here we present the first direct identification and mapping of both carbon dioxide and water ice in the martian high southern latitudes, at a resolution of 2 km, during the local summer, when the extent of the polar ice is at its minimum. We observe that this south polar cap contains perennial water ice in extended areas: as a small admixture to carbon dioxide in the bright regions; associated with dust, without carbon dioxide, at the edges of this bright cap; and, unexpectedly, in large areas tens of kilometres away from the bright cap.

The ESA/Mars Express Orbiter[8] was inserted into Mars orbit on 25 December 2003. The Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA) instrument[9], one of the seven investigating instruments on board, is an imaging spectrometer analysing the diffused solar light and the planetary thermal emission. On each resolved pixel, 1.2 mrad in the instantaneous field of view, OMEGA acquires a spectrum in 352 contiguous spectral channels from 0.35 to 5.1 μm, with a spectral sampling ranging from 7 nm (in the visible) to 13 nm (from 1.0 to 2.7 μm) and 20 nm (from 2.7 to 5.1 μm). A few initial observations were performed soon after Mars orbit insertion, in particular while the spacecraft was overflying the south polar areas. The altitude of observation ranged from ~1,500 km to ~2,000 km, providing an OMEGA surface sampling of ~2 km. OMEGA thus mapped a large fraction of the south polar regions, along four distinct orbits, from 18 January to 11 February 2004 (solar longitude, $L_{\odot} = 335°$ to $348°$)—that is, about one month before the martian southern autumn equinox. At the time of the observations, the Sun's elevation was very low (<10°); however, given the very high performances of OMEGA, several tens of thousands of spectra were acquired with signal-to-noise ratios of >100 over almost the entire spectral domain. From the acquired spectra, it is possible to derive coupled maps of a variety of parameters and properties: in particular, the major icy constituents, CO_2 and H_2O, have several unambiguous diagnostic spectral signatures enabling the mapping of their respective distributions over the imaged areas (see below).

The OMEGA spectral images exhibit well-characterized high albedo perennial polar ice patterns. From their near-infrared spectrum, we can assert that these bright areas are those where CO_2 ice is highly concentrated (Fig. 1a).

A crucial finding is the identification of H_2O ice, with a varying concentration over a much larger area (Fig. 1b). H_2O ice is found in three distinct units, as follows.

Unit 1. On the bright cap. In this unit, water ice is mixed with large concentrations of CO_2 ice. This makes its spectral identification more difficult than in the two other units, as CO_2 ice exhibits spectral features in the same spectral domain. It requires a careful

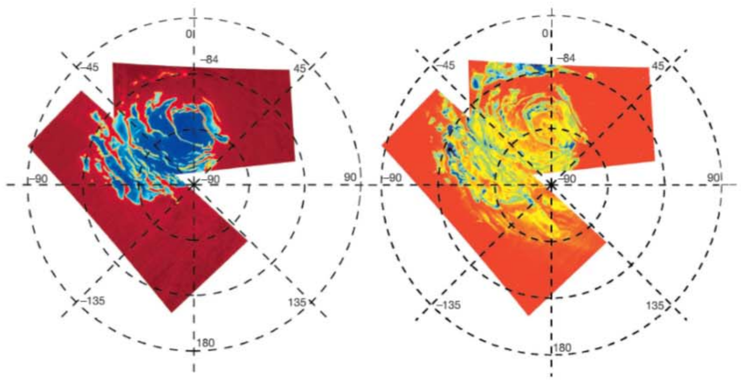

Figure 1 Global maps of CO_2 and H_2O ices at the south pole of Mars. Left, the CO_2-ice absorption feature is scaled from blue (deep) to brown (CO_2-ice-free areas); right, mapping of the H_2O ice, from blue (deep absorption) to red (ice-free). Comparison shows that the H_2O-ice areas extend far beyond the CO_2-rich bright cap, along its scarps up to isolated units tens of kilometres wide.

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OMEGA team meeting, IAS, Orsay, Mars 2004

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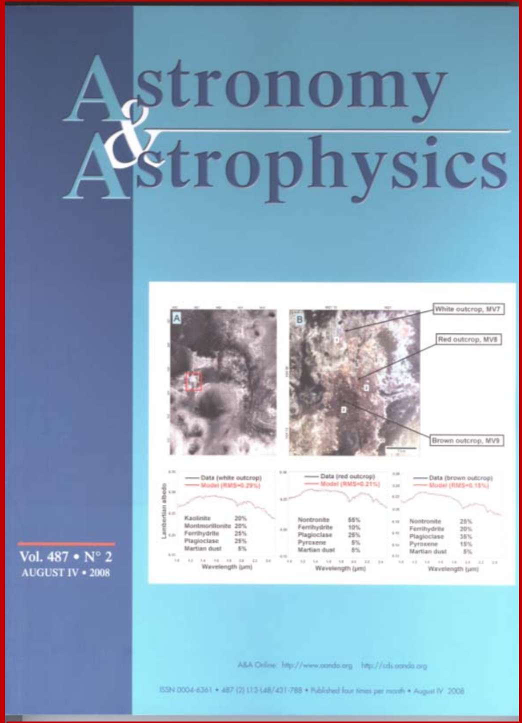
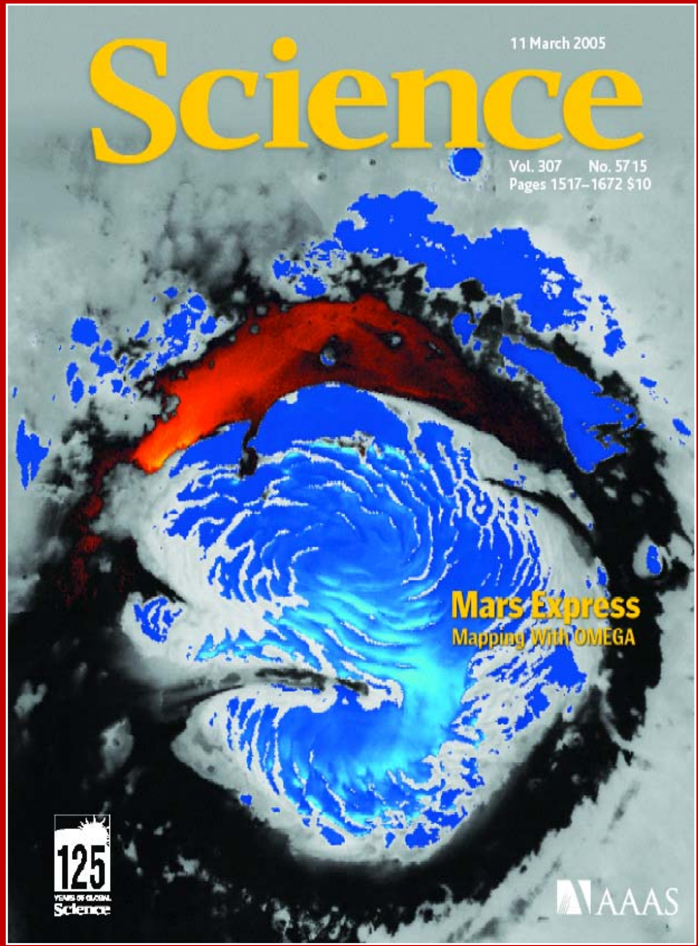
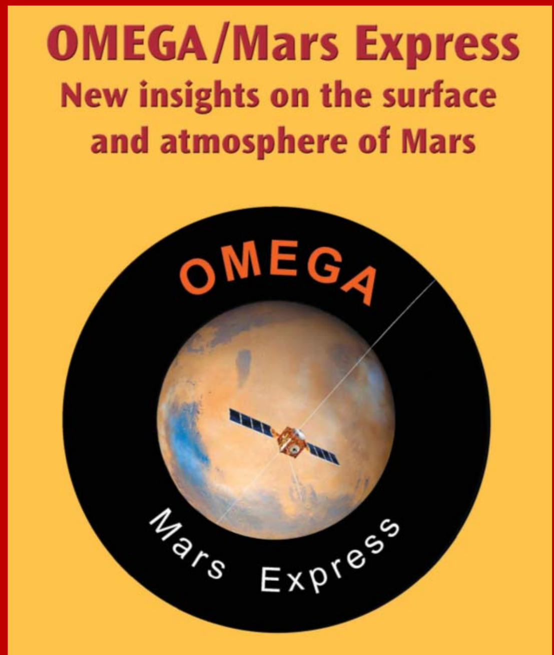
OMEGA team meeting, Venise, 2010







Go Phyllosian !


ExoMars, premier rover phyllosien
ESA / ExoMars 2020 ???

ESA / ExoMars 2020 ???

OMEGA

OMEGA/VIMS

ISM → OMEGA

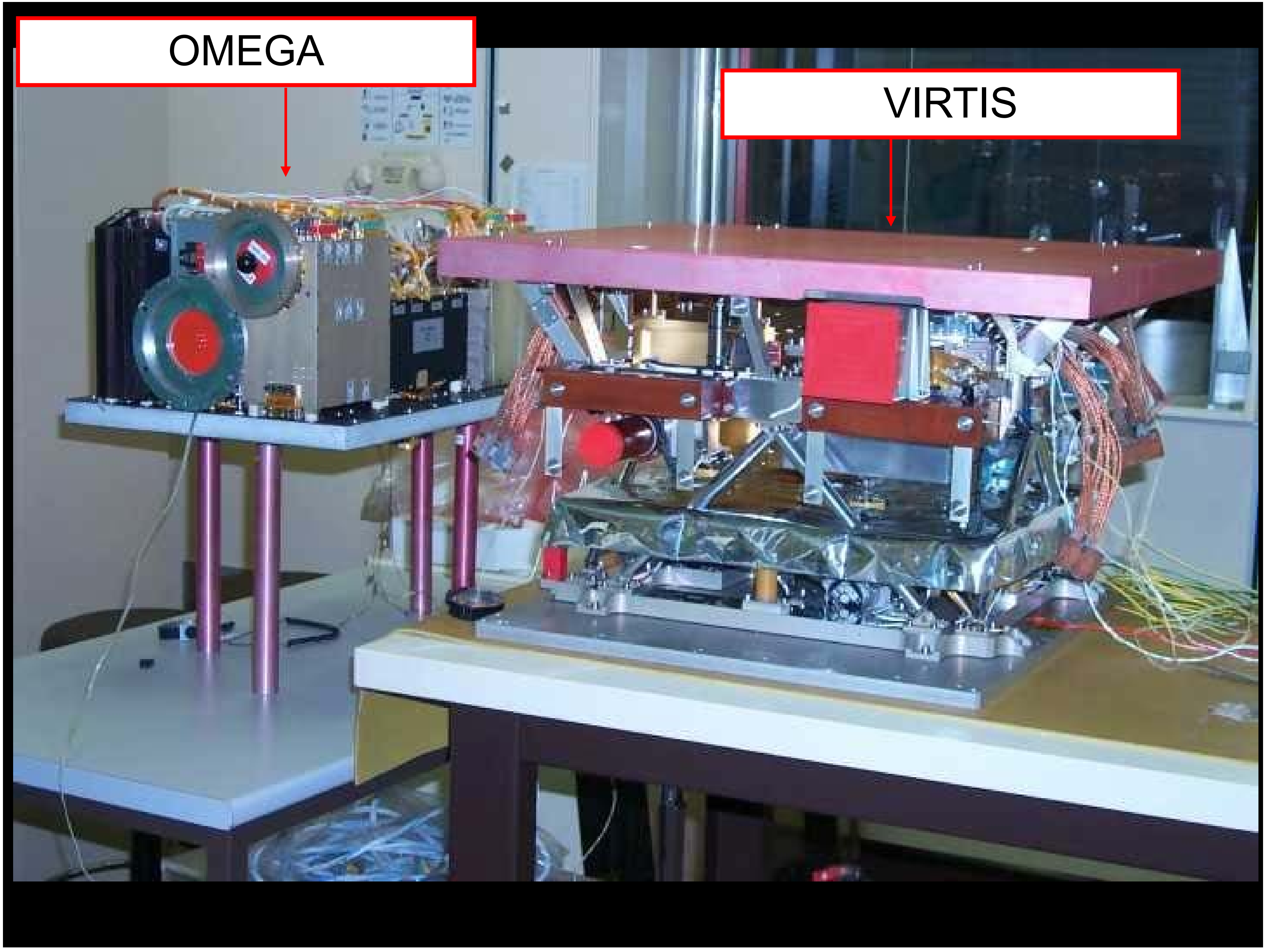
VIMS

VIRTIS-Rosetta

VIRTIS-Venus

VIRTIS-Dawn

1988 2004 2020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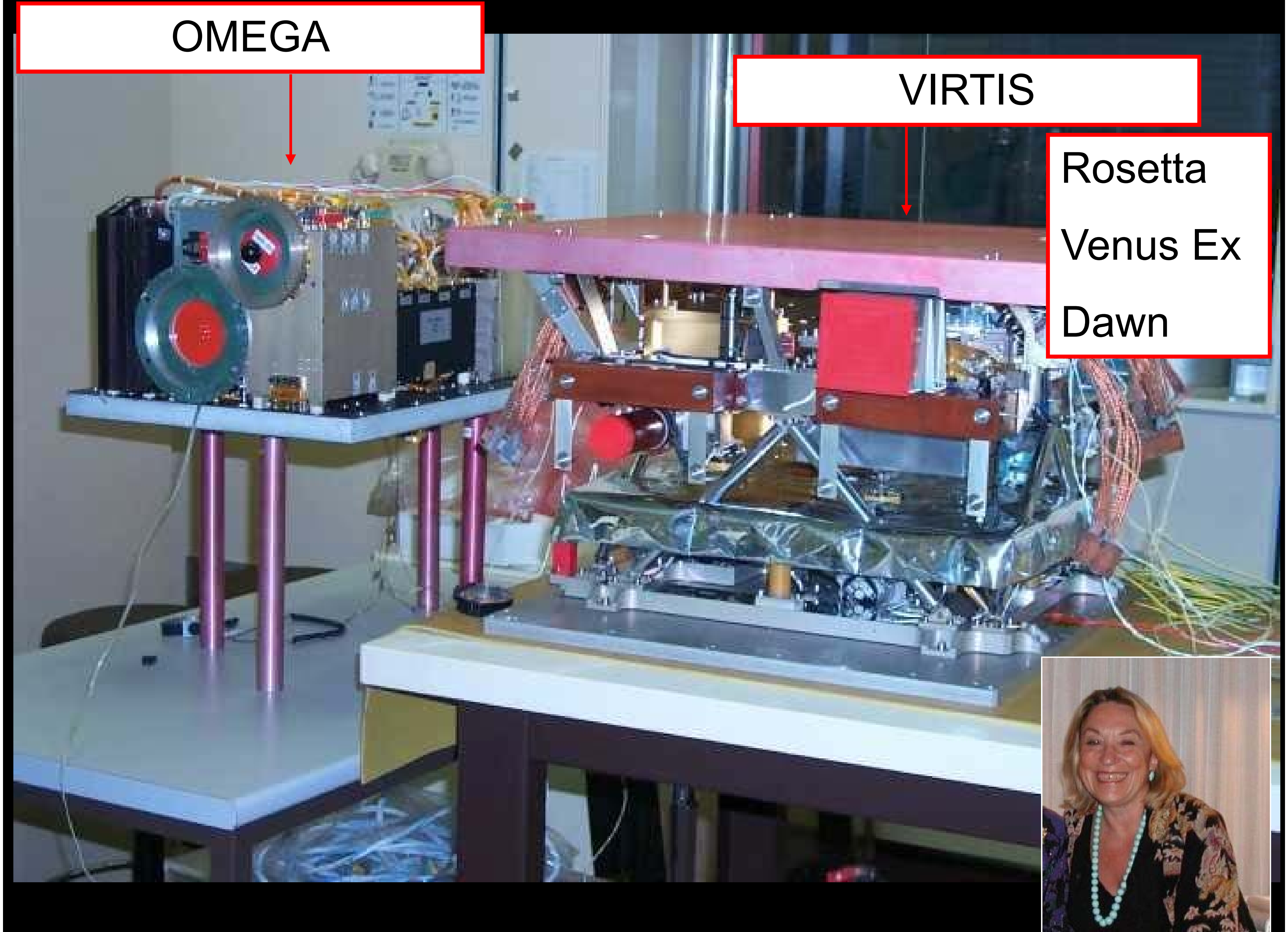
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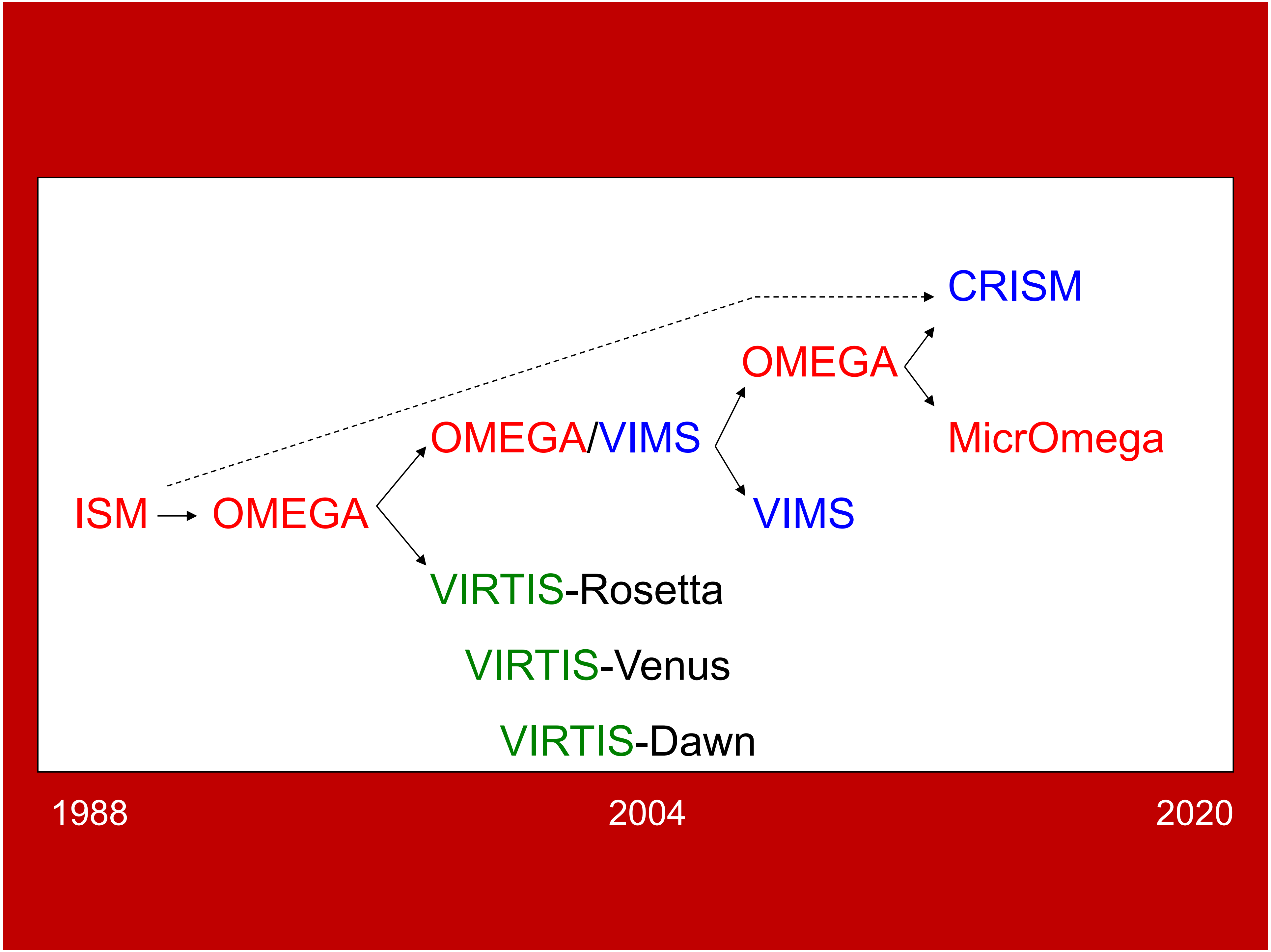
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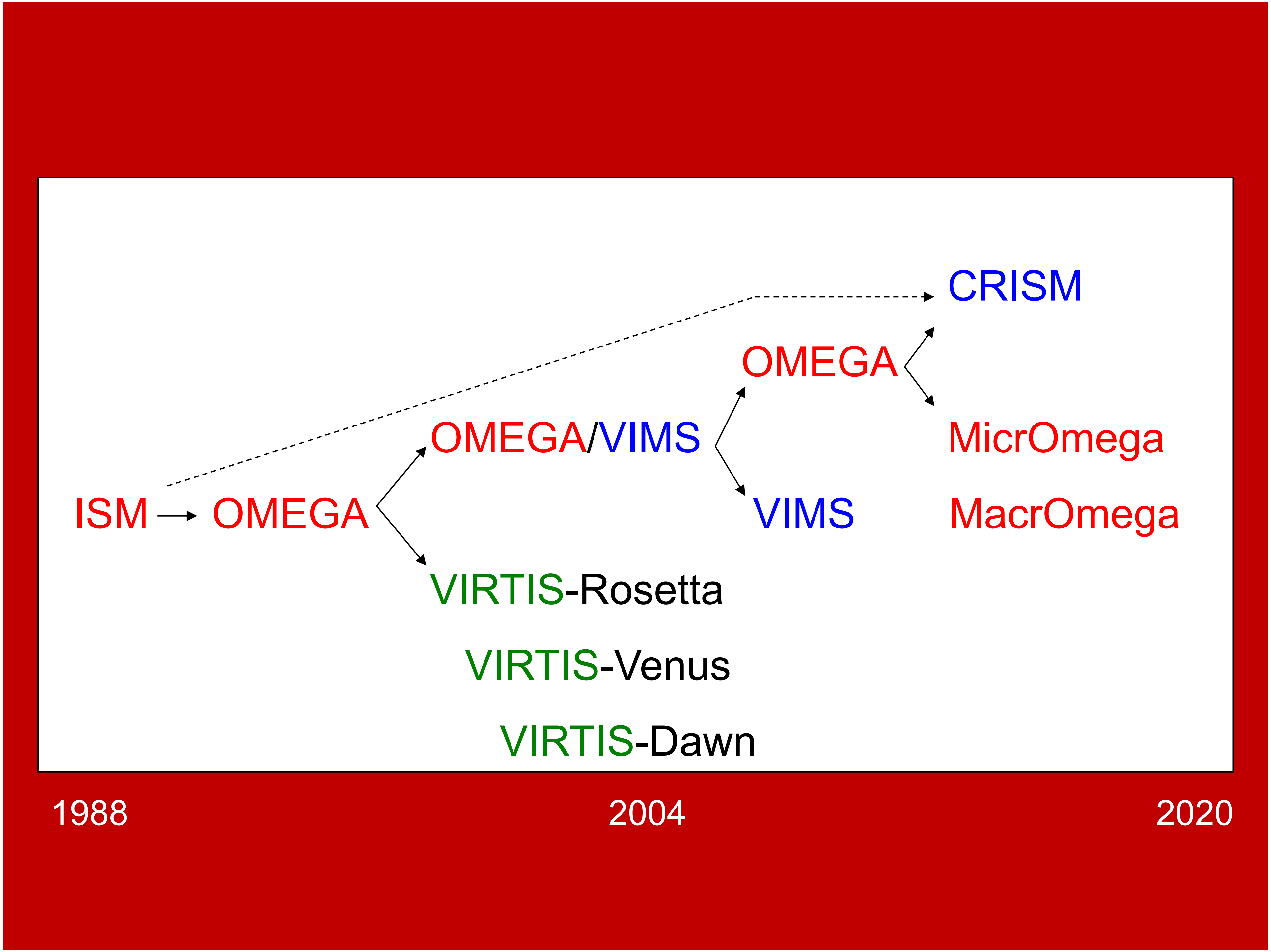
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1988
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BRAVO, Michel

et au nom de toutes les équipes qui, à l'IAS, ont eu le privilège de travailler avec toi, du plus profond de notre admiration,
et de toute notre amitié,

MERCI !

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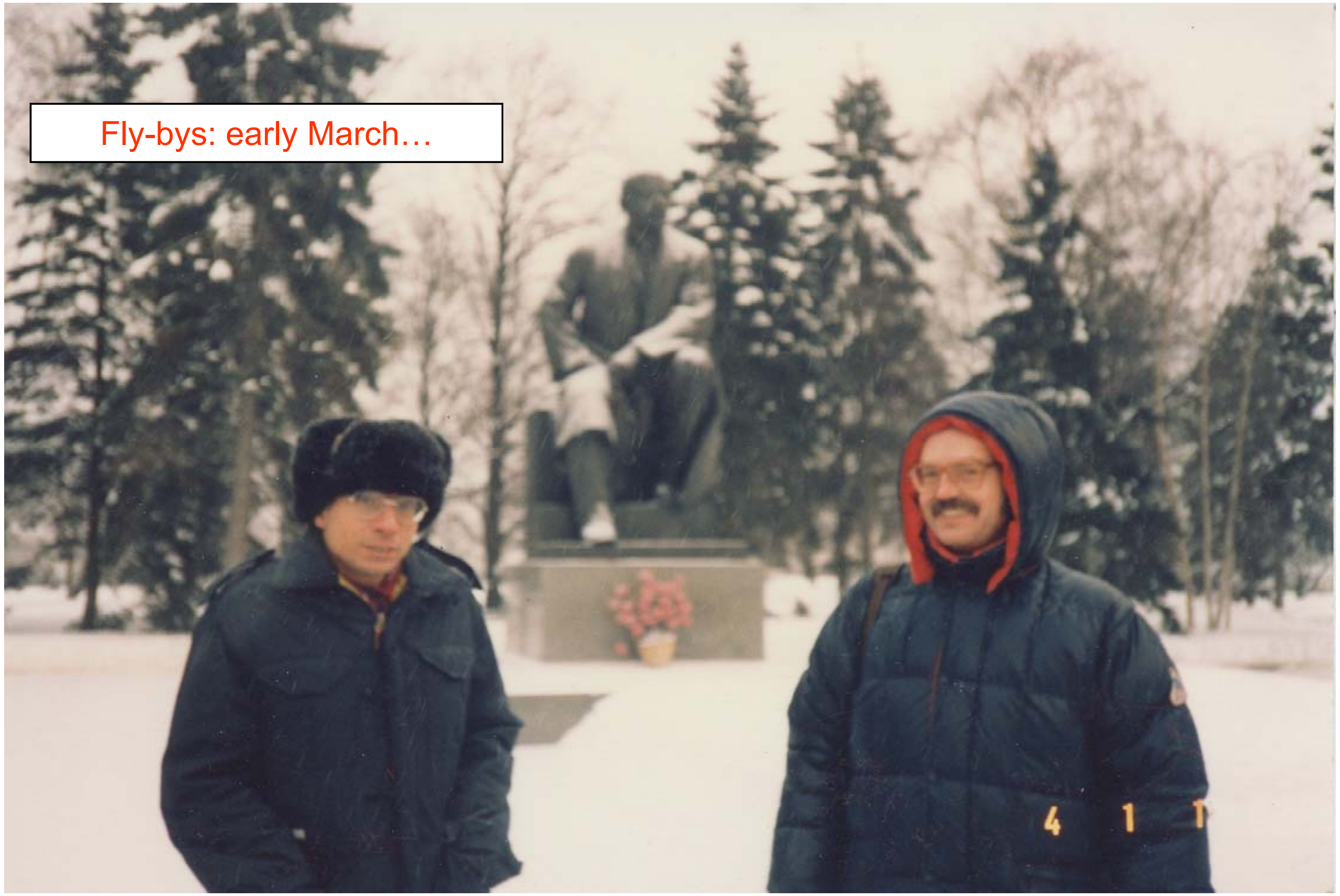

Fly-bys: early March…

Mars exploration: bridging our past and future

OMEGA, proposé (et sélectionné) en 1988
par l'IAS et le DESPA,
avec une coopération italienne et soviétique
pour la mission Mars 92