

A panoramic view of the Oxford skyline at sunset, with numerous church spires and domes visible against a warm, orange-hued sky. In the foreground, there is a green lawn with some trees and a few people walking.

VIRTIS-H

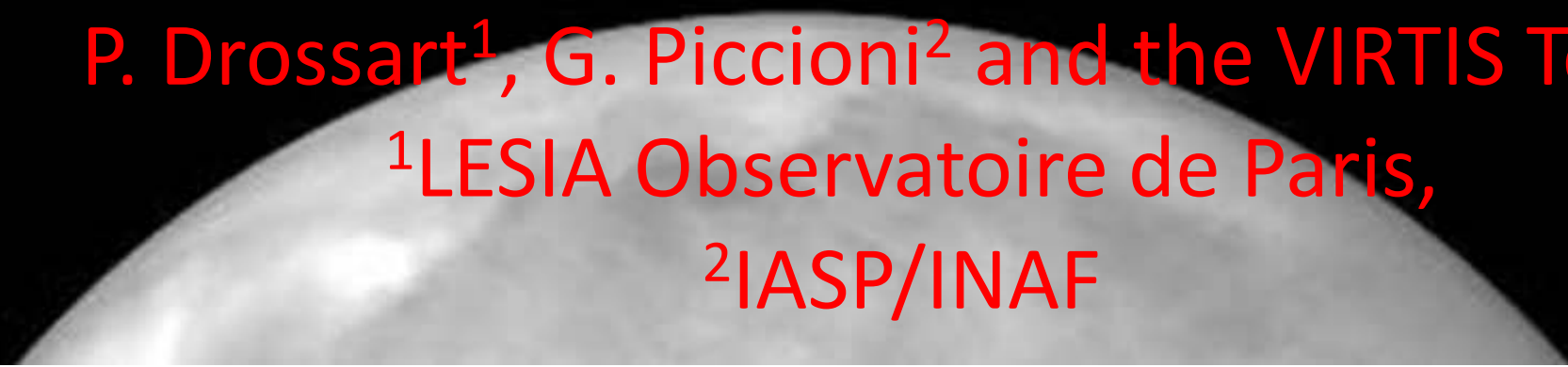
International Venus Conference 2016

Oxford, UK, 4-8 April 2016

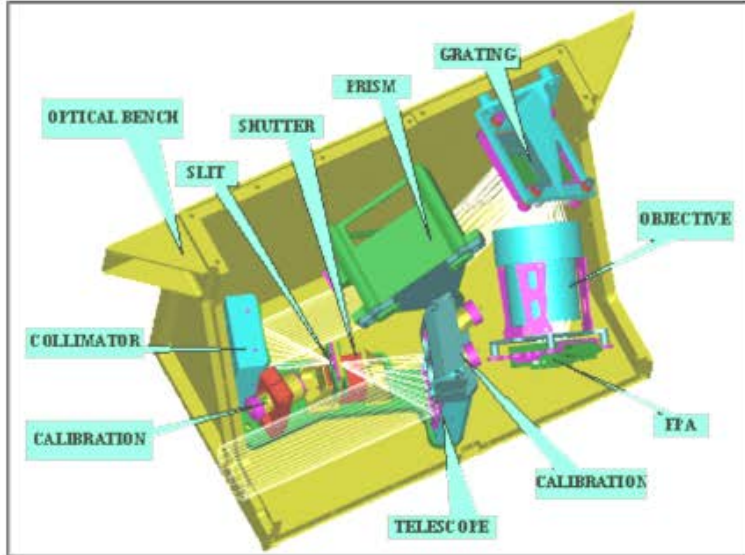
P. Drossart¹, G. Piccioni² and the VIRTIS Team

¹LESIA Observatoire de Paris,

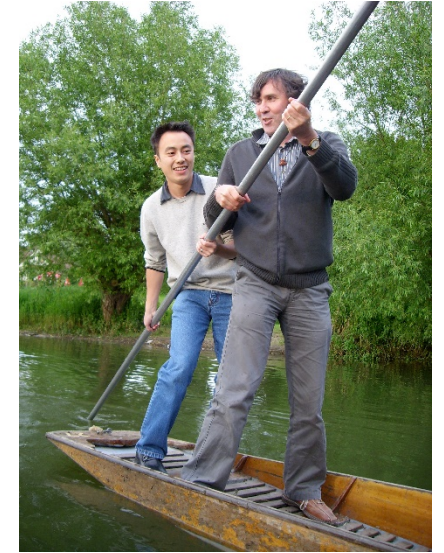
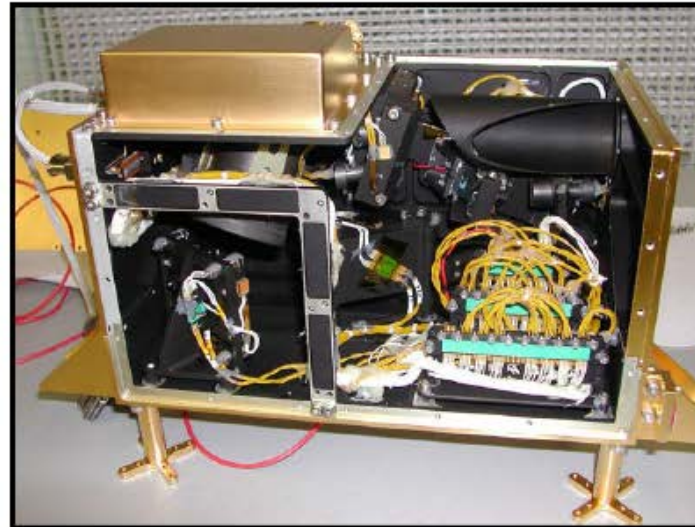
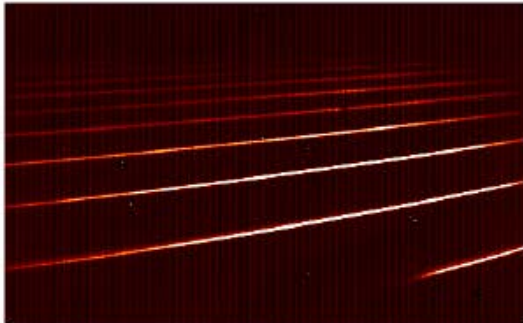
²IASP/INAF

A large, detailed image of the planet Venus, showing its characteristic yellowish-orange surface and swirling cloud patterns, positioned in the bottom half of the slide.

VIRTIS-H Channel characteristics (VIRTIS Rosetta twin)



Virtis-H Channel

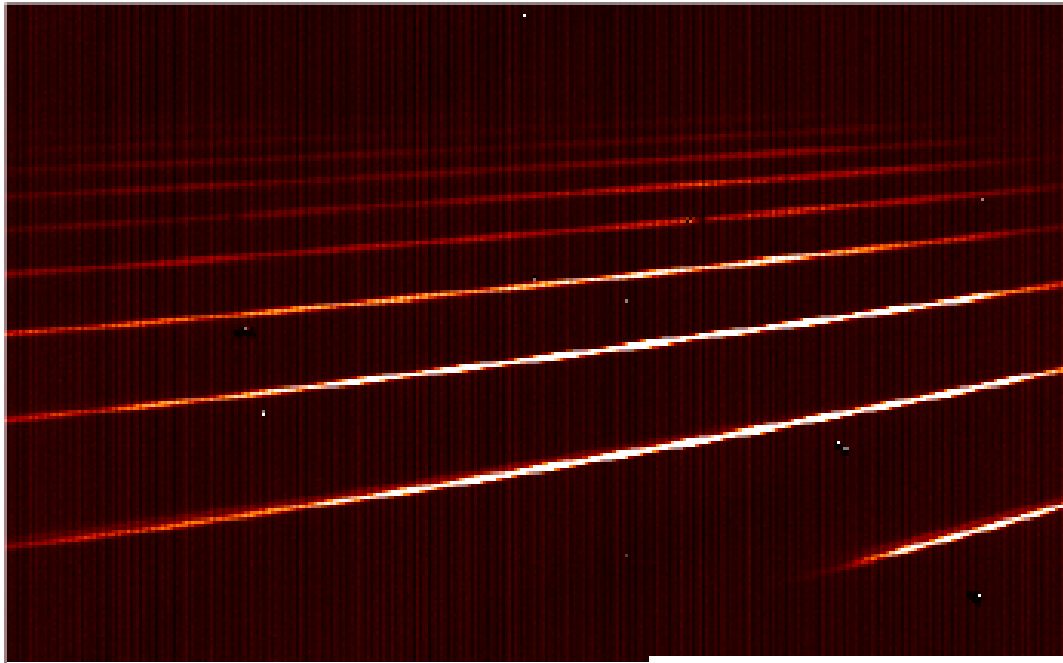


VIRTIS team :

- **Rome**
- **Paris**
- **Berlin**
- **Granada**
- **Bilbao**
- **Warsaw**
-
- **Oxford**

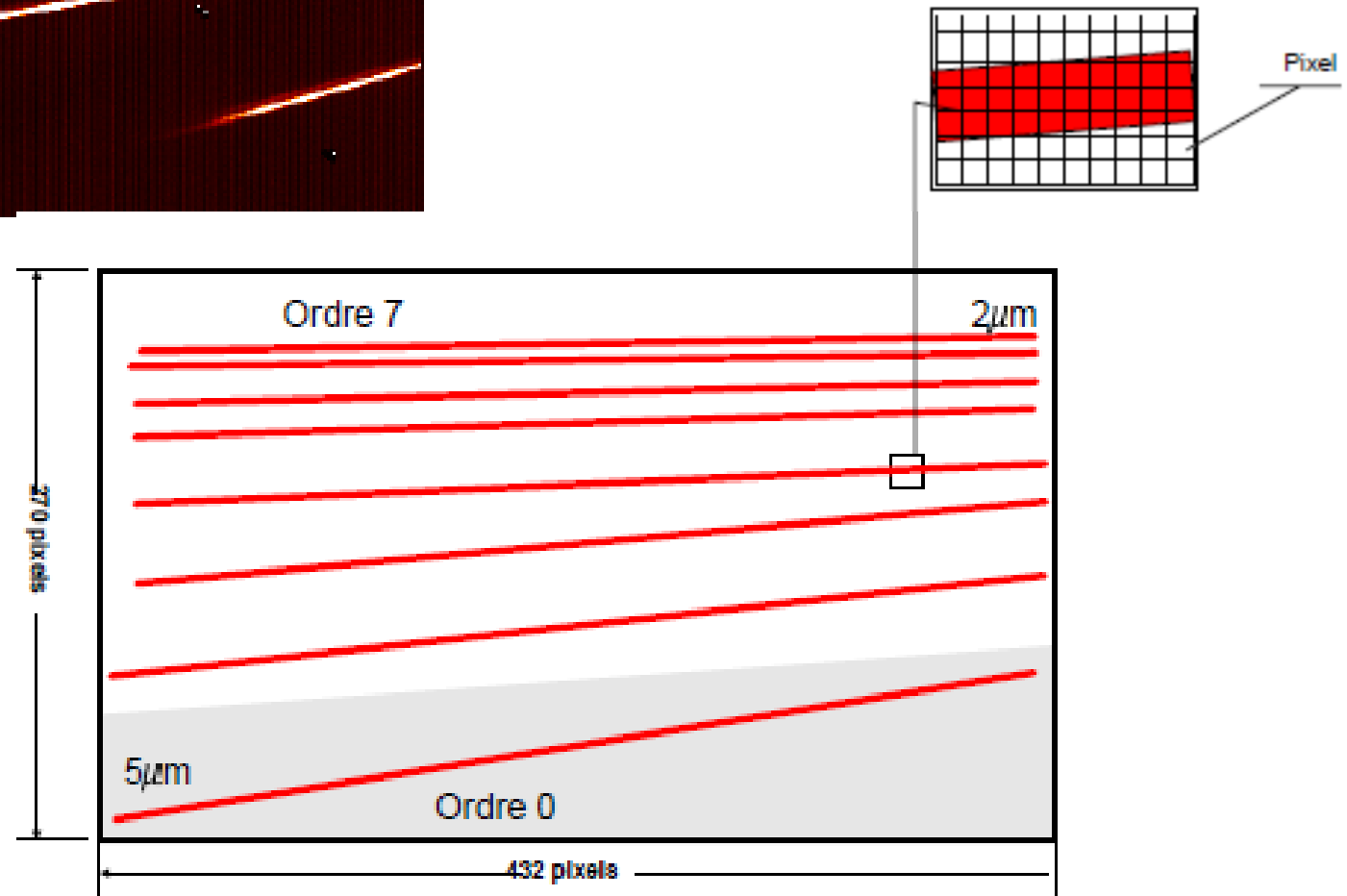
VIRTIS technical specifications

Parameter	VIRTIS-M		VIRTIS-H
	Visible	Infrared	Infrared
Spectral range [μm]	0.27-1.1	1.05-5.19	1.83-4.98
Spectral sampling [nm]	1.9	9.8	0.6
FOV [mrad^2]	64x64		0.58x1.75 per 3 pixels
Pupil diameter [mm]	47.5		32
F#	5.6	3.2	2.04
Etendue [$\text{m}^2.\text{sr}$]	$3.6.10^{-11}$	$7.5.10^{-11}$	$0.8.10^{-9}$
Slit dimension	$38\mu\text{m} \times 9.53\text{mm}$		$29 \times 89\mu\text{m}$
Detector format [px]	512x1024	270x438	270x438
Pixel pitch [μm]	19	38	38
Saturation charge [Me]	>0.4	>2	>2

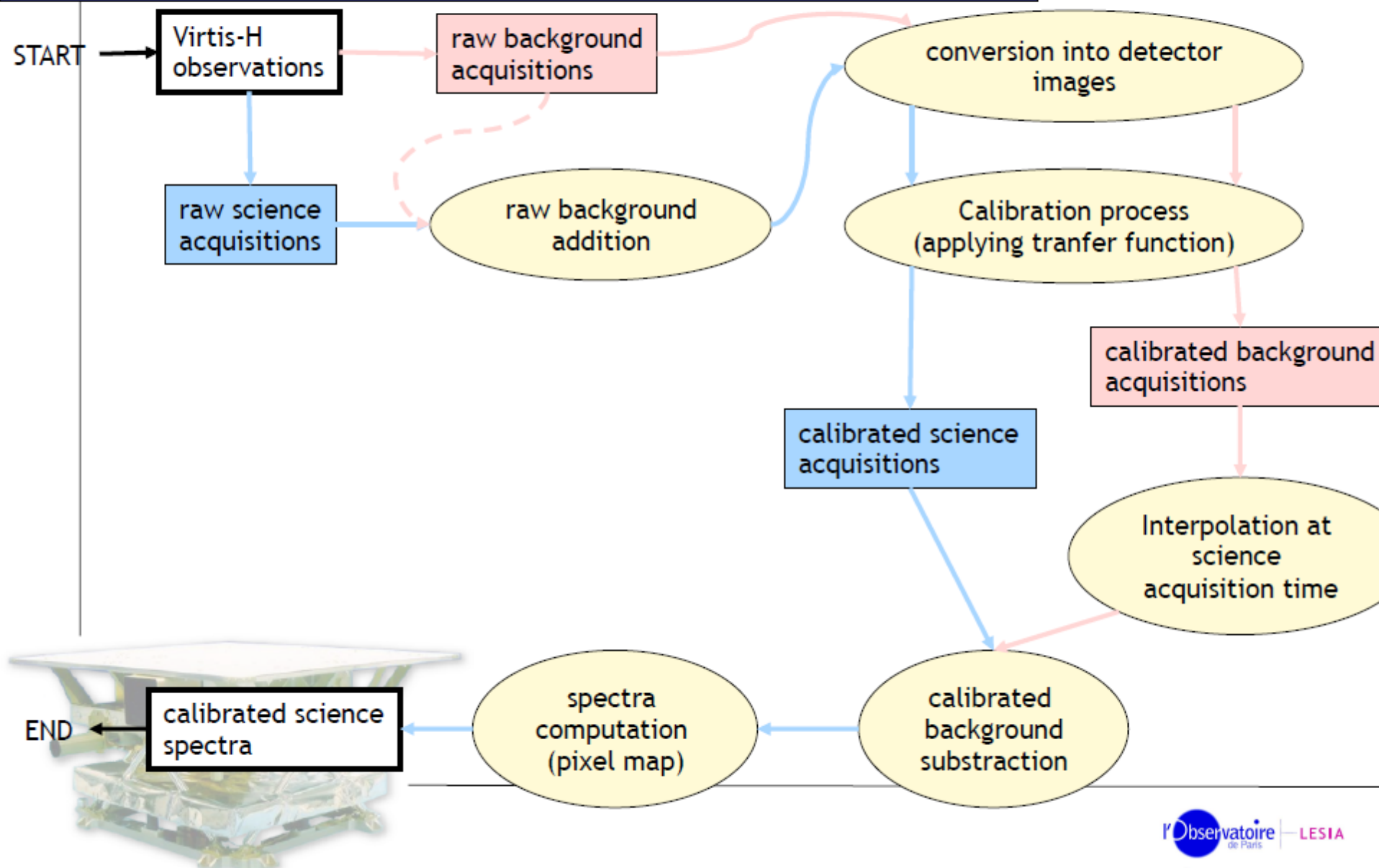


VIRTIS H matrix

Blocking filter



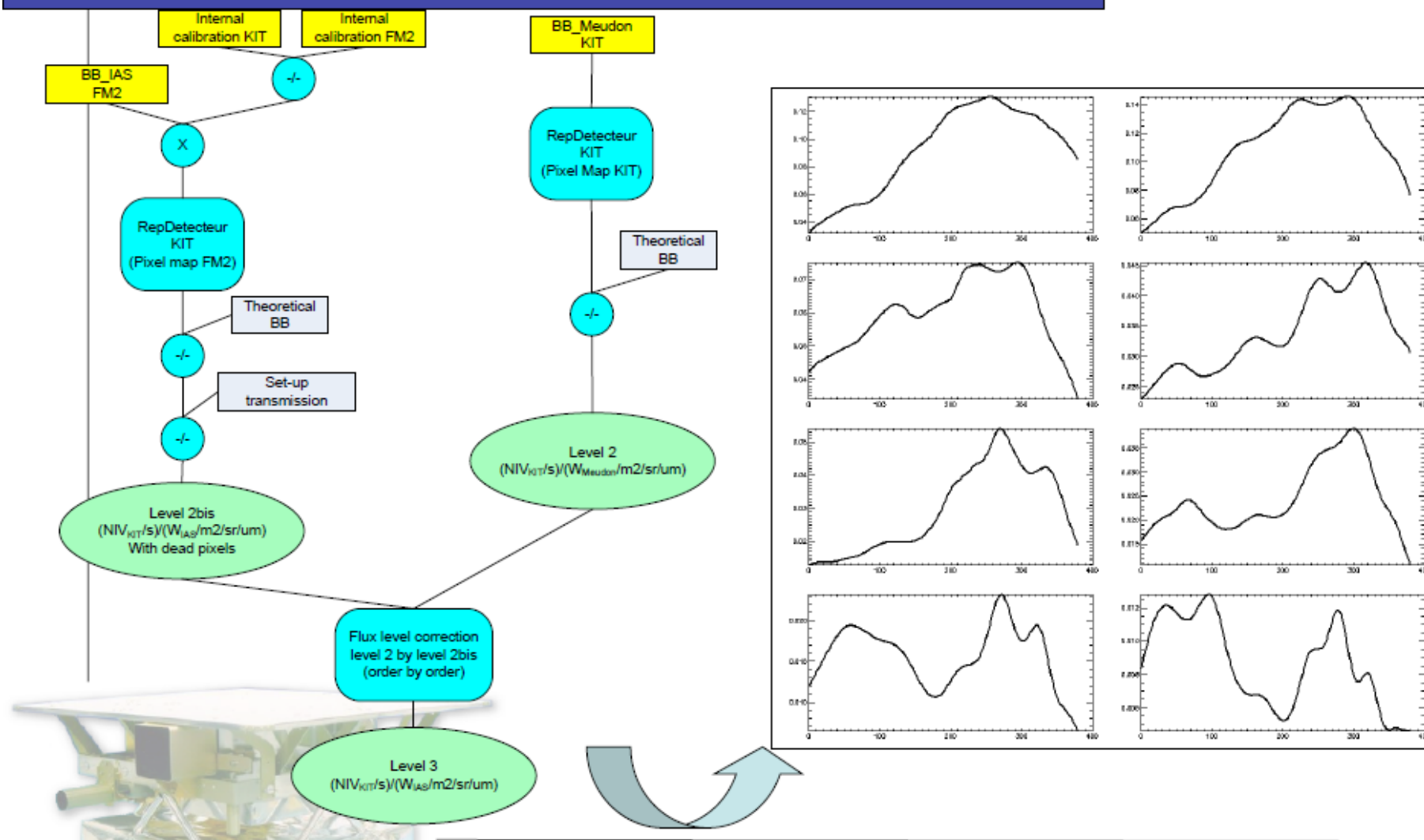
Virtis-H calibration : basic scheme



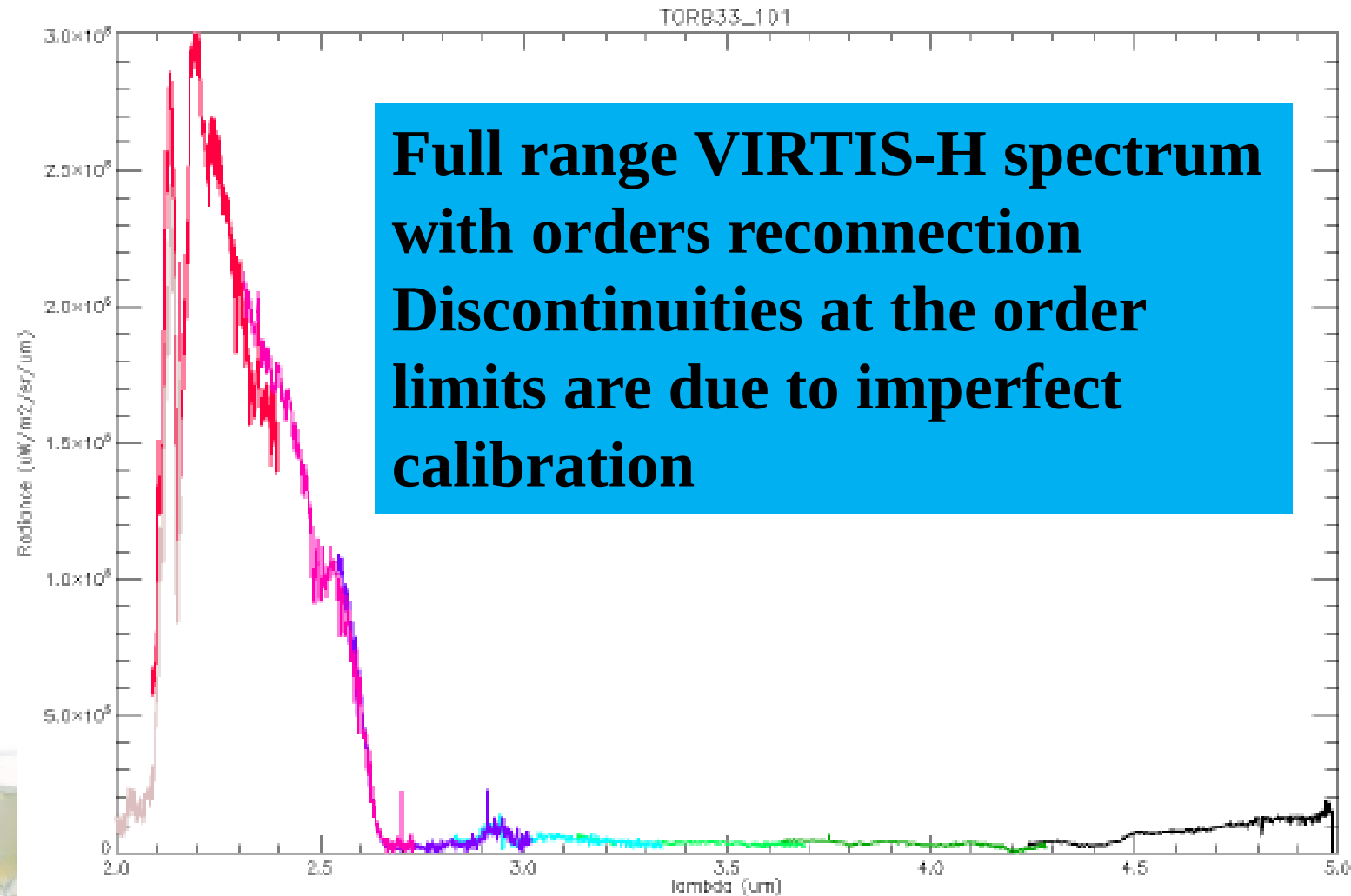
Computing transfer function (2/2)

FM2 : old detector

KIT : new detector



Transfer function : results



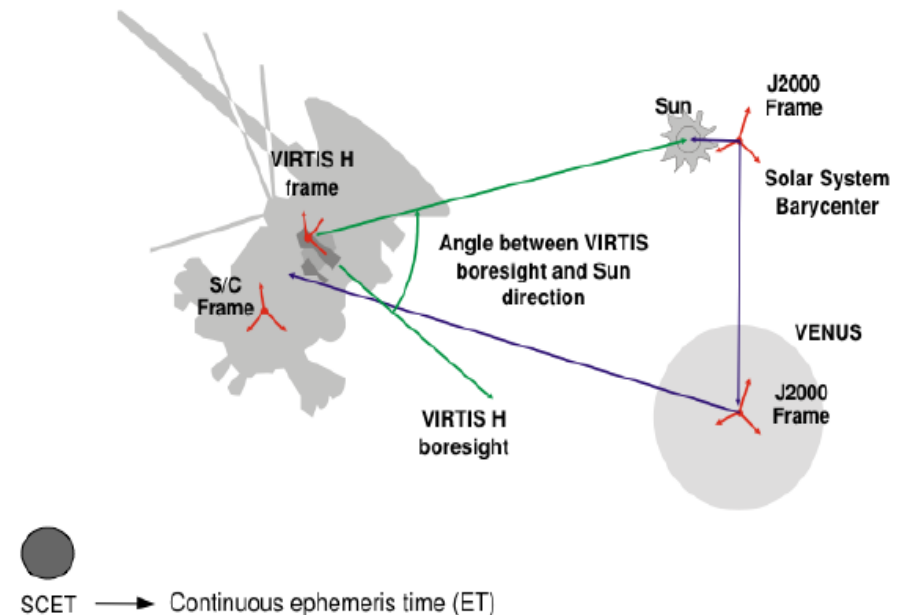
Geometric calibration (-M and -H)

Main points

- Geometric files have to be generated several times, as navigation Spice kernels are updated by ESA
 - 1st time : when the raw data file is generated by the EGSE, using predicted orbital parameters
 - 2nd time : about three weeks later, when the final (reconstructed) orbital parameters and time correlation files become available.
 - The first generation of geometry files have extension “PRE”, whereas the final version have extension “GEO”. Only the .GEO files, which are the final versions, are included in the archive.
- One geometric file associated to each data file
 - geometric files are relevant to one focal plane only (separated files for H, M-vis, M-IR)
 - when processing a data file, only the corresponding geometry file needs to be loaded

Tools used to compute geometry

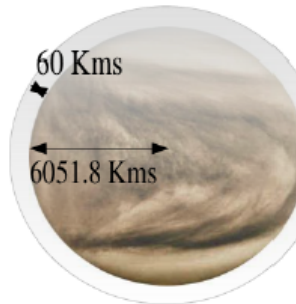
- SPICE IDL routines (ICY Library)
 - SPICE deals with observation geometry and time



Geometric parameters

Main points

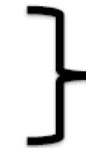
- Two projection surfaces are used to allow for simple interpolation of the footprint at various altitudes in the atmosphere :
 - 1st projection surface : a sphere with 6051.8 km radius : Venus reference surface used in SPICE kernels, (IAU 2000 standard)
 - 2nd projection surface : a cloud layer at 60km above the reference ellipsoid (This particular altitude is selected to match approximately the upper cloud layer on the day side).



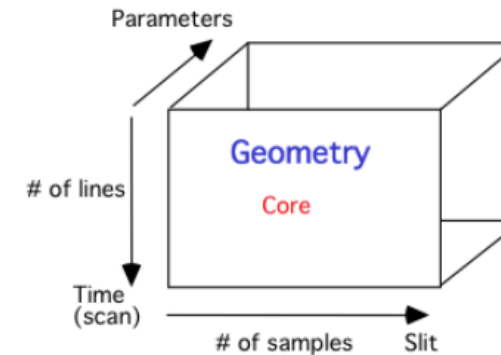
Geometric cubes size

- One Geometric cube per science data cube
- Same X/Y spectrum reference as science data cube

33 parameters for M
41 parameters for H



computed at
mid-exposure



Order of the computed parameters

Plane #	Parameter description	
1-4	Longitudes of 4 pixel footprint corner points	Geometrical projection on surface ellipsoid
5-8	Latitudes of 4 pixel footprint corner points	
9-10	Longitude & latitude of pixel footprint center on surface ellipsoid	
11-13	Incidence, emergence & phase at footprint center, relative to Venus center direction	
14	Surface elevation (footprint corners average)	
15	Slant distance (line of sight from spacecraft to surface ellipsoid at pixel center)	
16	Local time at footprint center	
17-20	Longitudes of 4 corner points on cloud layer	Geometrical projection on cloud layer (60 km)
21-24	Latitudes of 4 corner points on cloud layer	
25-26	Longitude & latitude of pixel center on cloud layer	
27-29	Incidence, emergence & phase, relative to local normal of cloud layer	
30	Surface elevation at the vertical of cloud layer intercept	
31-32	Right ascension and declination of pointing direction.	

Science results (summary)

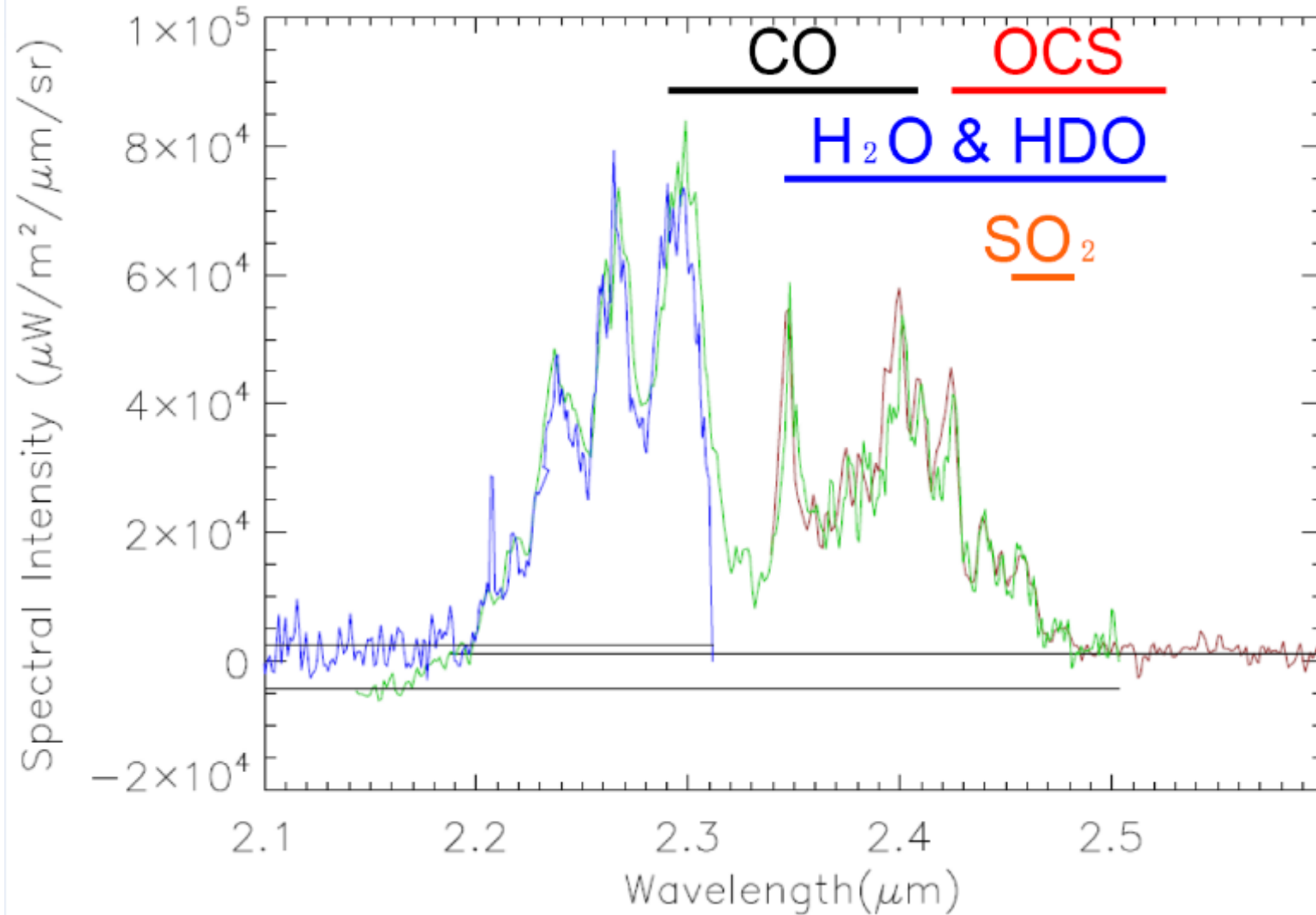
VIRTIS-H Main purpose related to spectral resolution (1500) : minor constituent detection, rotation/vibration bands resolved

The spectral domain (2-5 micron) is not ideally suited for Venus (Rosetta choice!) – but : combination M and H observations provide a unique capability to study Venus atmospheric science.

- Night side : 2.3 micron atmospheric sounding (OCS, CO, H₂O, SO₂ @ 30 km altitude
- Thermal profiles from CO₂ 4.3 micron inversion
- Day side : fluorescent emission at 4.3 micron (nadir and limb)
- Cloud IR absorptions

Cf Drossart et al PSS 2007 (pre-launch science specifications)

Lower atmosphere : VIRTIS-H observations from the night side



E. Marcq et al., JGR 2008

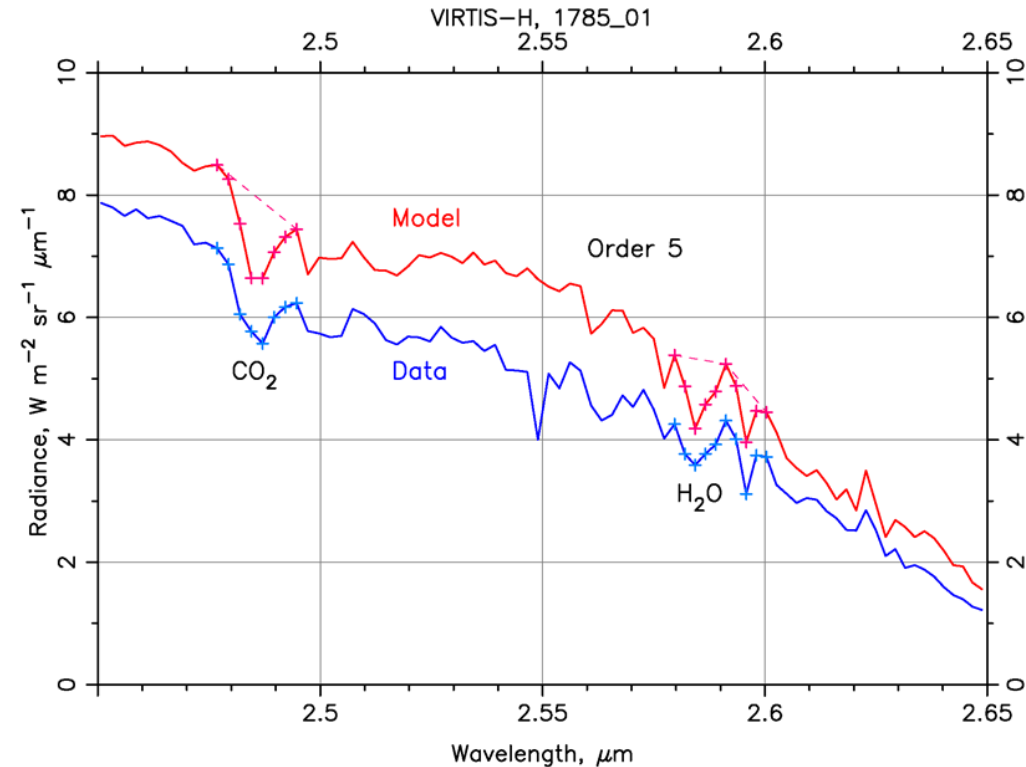
VIRTIS Observations from the night side : retrievals

Unit : ppmv	0°-20°		60°
CO (36 km)	24±3	<	31±3
OCS (33 km)	4±1	≥	2.5±1
H ₂ O (35 km)	31±2	=	31±2
SO ₂ (35 km)	130±50	=	130±50

E. Marcq et al., JGR 2008

H₂O & cloud variations

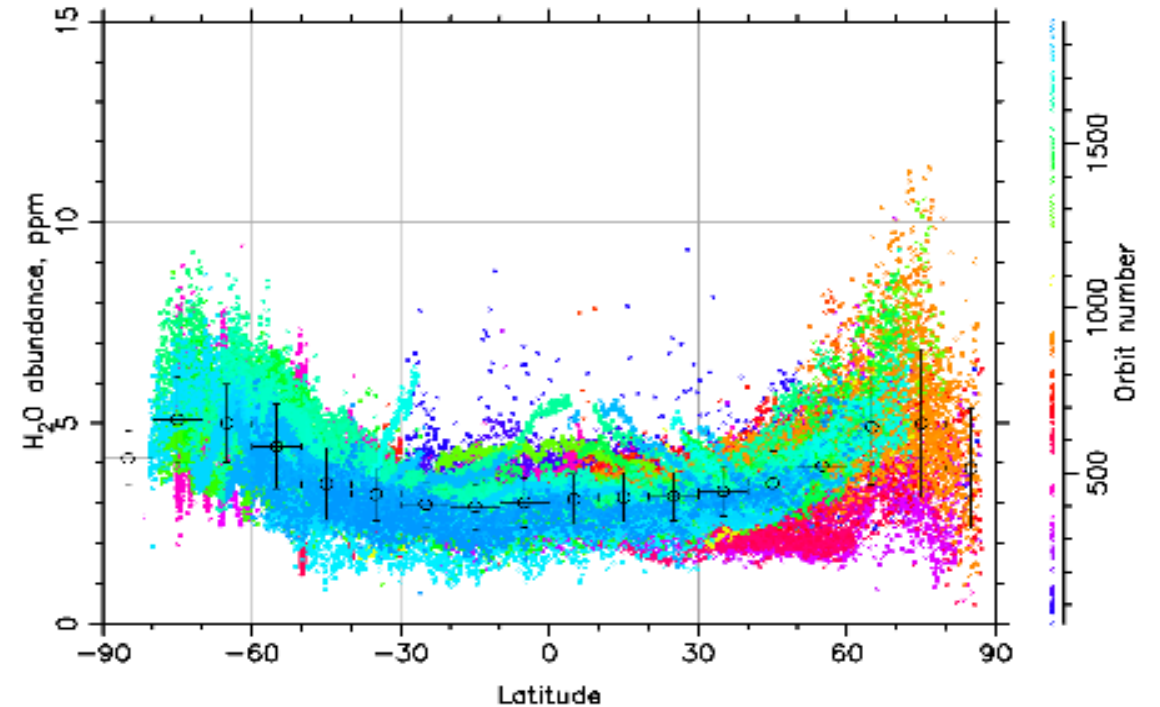
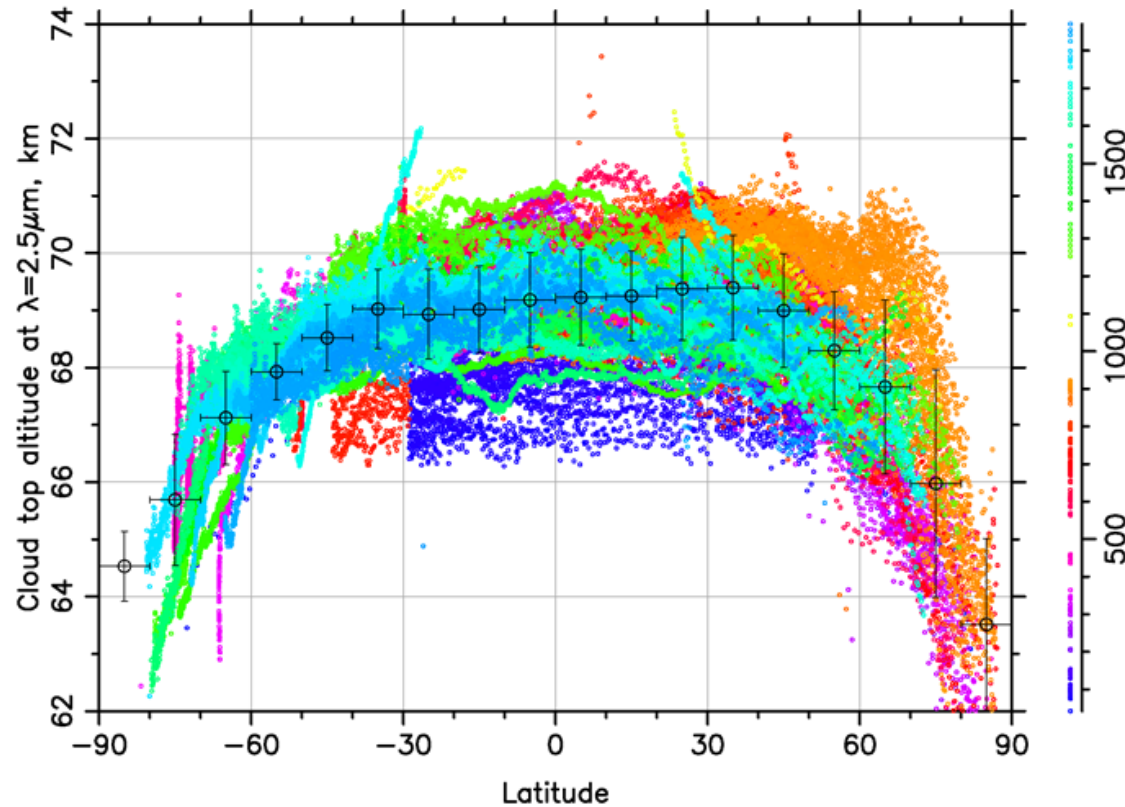
Cottini et al., PSS 2015



. VIRTIS-H day-side part of the spectrum including absorption bands of CO₂ and H₂O between 2.48 and 2.60 μm that are used to determine the cloud top altitude and water vapor abundance near this level in the measured (blue) and calculated (red) spectra, orbit 1785, order of diffraction 5.

H₂O variations with latitude above cloud top

Cloud tops altitude retrievals (upper panel)
used to measure the water vapor content
(lower panel) as a function of latitude for all
VIRTIS-H observations, acquired

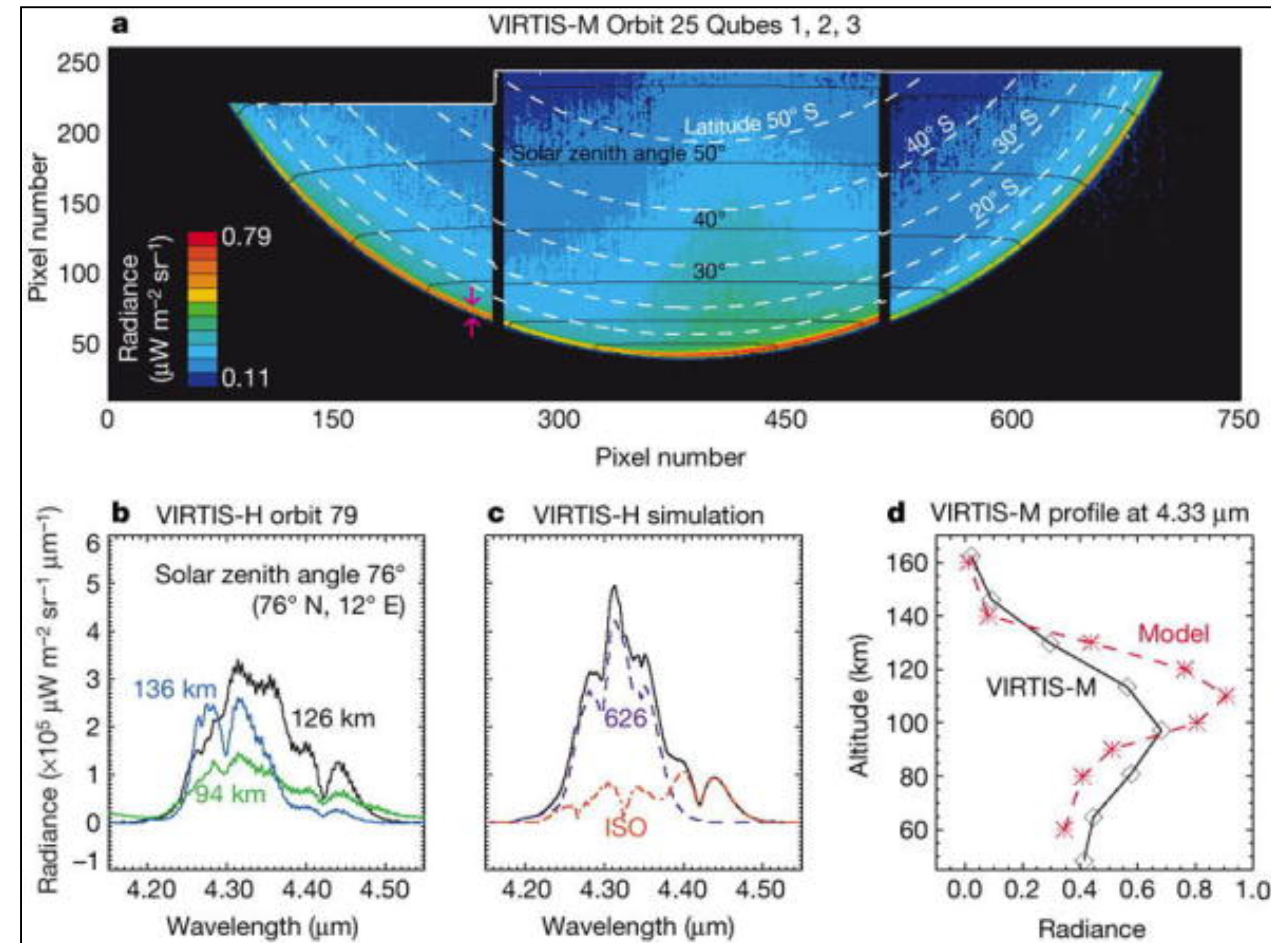


Fluorescence of CO₂ at limb

- Drossart et al, Nature 2007

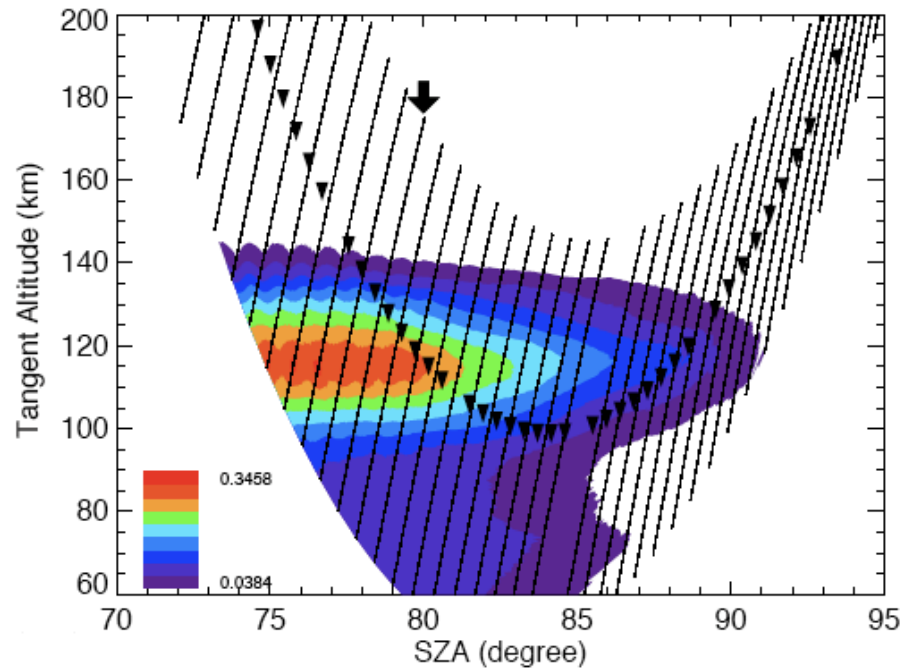
Combination of M and H observations :
Map of CO₂ fluorescence (top) at 4.3 μm .
Limb profiles and H-spectra at different altitudes (bottom curves)

This map is one of the first observations of
CO₂ fluorescence in VIRTIS data

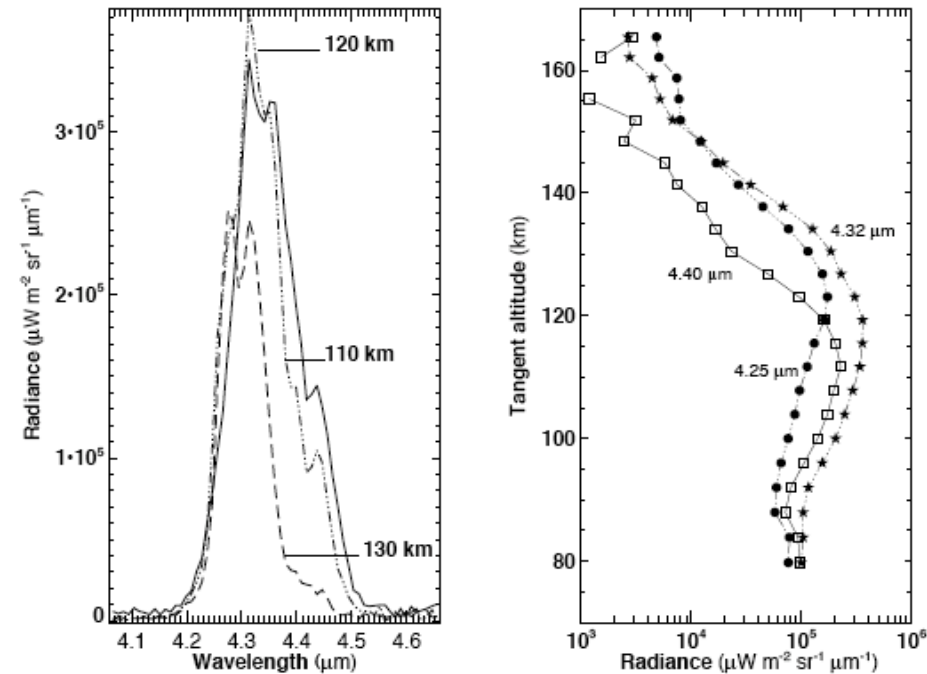


CO₂ 4.3- μ m non-LTE measurements

VIRTIS-M maps



VIRTIS-M spectra & profiles

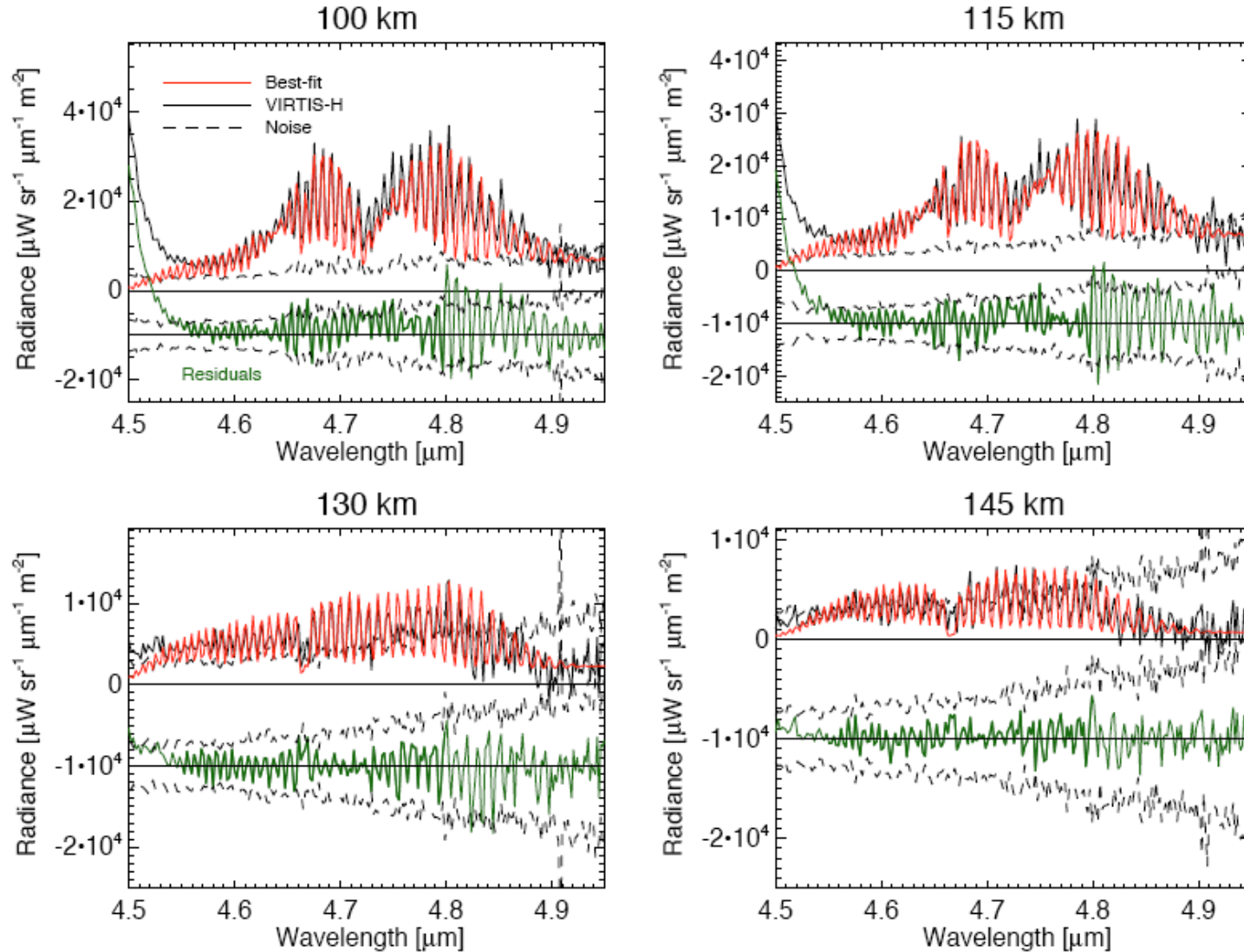


Gilli et al. JGR, 2009

- CO₂ emission peak around 110-120 km
- Higher emission at lower SZA

- good S/N up to 160 km
- Change in the overall shape of the band with altitude
- The altitude peak is maximum at the centre of the band (4.32 μ m)

CO fluorescence of Venus (limb observations, VIRTIS-H)



- Noise level increases with the wavelengths
- S/N above 140 km is very low
- Background correction included in the retrieval
- Most cases the residuals are within the noise level

Outstanding science for the future (!)

Some science investigations are still expected to extend present science results, in particular with joint H/M data analysis in particular for :

- completion of thermal maps (night side –H+M),
- fluorescence inversion (CO₂, CO, day side –H+M)
- Potential vorticity retrieval through thermal and dynamics simultaneous retrieval (in progress: cf Itziar Garate – Lopez work)
-

Data processing – (April 2006 – December 2014)

Data archive organization

- Data are gathered by dataset
- Then per month (called MTP)
- Then per orbit : MTP021/VIR0589
- And by data type : RAW, CALIBRATED and GEOMETRY

Dataset	Start date	MTP	Orbit	Name
Nominal	4 June 2006	002	44	VENUS EXPRESS VENUS VIRTIS 2/3 V3.0
Extension 1	3 October 2007	019	530	VENUS EXPRESS VENUS VIRTIS 2/3 EXT1 V2.
Extension 2	31 May 2009	041	1136	VENUS EXPRESS VENUS VIRTIS 2/3 EXT2 V2.
Extension 3	22 August 2010	057	1584	VENUS EXPRESS VENUS VIRTIS 2/3 EXT3 V2.
Extension 4	6 January 2013	088	2452	VENUS EXPRESS VENUS VIRTIS 2/3 EXT4 V1.

File naming convention

- H raw data :
 - VHxxxx_yy.QUB
 - VSxxxx_yy.QUB
 - VTxxxx_yy.QUB
- H calibrated data :
 - VTxxxx_yy.CAL
- H geometry :
 - VHxxxx_yy.GEO
 - VTxxxx_yy.GEO
- M raw data :
 - VIxxxx_yy.QUB
 - VVxxxx_yy.QUB
- M calibrated data :
 - VIxxxx_yy.CAL
 - VVxxxx_yy.CAL
- M geometry :
 - VIxxxx_yy.GEO
 - VVxxxx_yy.GEO

xxxx : orbit number
yy : file number

How to access to VIRTIS data – PSA database

Virtis-M-IR : 1713h 43m 15.952s - last observations MTP033, orbit 921 (10/27/2008)

Virtis-H : 4849h 00m 24.22s. Last observation MTP 067, orbit 1888 (06/21/2011)

Virtis-M-Vis : 7195h 40m 56.957s. – last observation MTP110, Orbit 3098, 10/06/2014

- **Data delivery in June 2013**

- **Nominal** *MTP 2 - orbit 44 → MTP 19 - orbit 530*
- **Extension 1** *MTP 19 → MTP 41 - orbit 1136*
- **Extension 2** *MTP 41 → MTP 57 - orbit 1584*
- **Extension 3** *MTP 57 → MTP 87*

- **Delivery in February 2015**

- **Extension 3** *MTP 57 → MTP 87 – orbit 2451*
 - *Missing data in the CK kernels for the orbit 2066 (MTP 74)
→ no geometry computed for this orbit*
- **Extension 4** *MTP 88 → MTP 110 – orbit 3098*

All the documentation is complete

- **Future delivery considered with refined Mvis calibration**

Documentation & References

Technical documentation available on PSA

<ftp://psa.esac.esa.int/pub/mirror/VENUS-EXPRESS/VIRTIS> or <http://rssd.esa.int/>

- EAICD ,
- Geometric Documentation,
- Software data handling documentation,
- Calibration documentation,
- instrument doc and manual
- PSA tutorials (manuals, exercise, etc)

A link to access to VIRTIS data with some catalog functionalities in addition to PSA

<http://voparis-europlanet.obspm.fr/othertool.shtml>

Science References :

- Planetary Space Science special issue 2007
- Nature special section 2007
- ESA SP 1295: VIRTIS (Piccioni et al., 2007) : <http://sci.esa.int/venus-express/41537-virtis-the-visible-and-infrared-thermal-imaging-spectrometer>
- J. Geophys. Res. Special issue 2008
- Icarus special issue 2012
- Planetary Space Science special issue (in press)
- Drossart & Montmessin, Astronomy & Astrophys. Review, 2015

Venus Express legacy

**“I will imagine you
Venus tonight and
pray, pray, pray to
your star like a
Heathen.”**

— [John Keats](#)

July 25th 1819



Bright Star

Bright star, would I were stedfast as thou art--
Not in lone splendour hung aloft the night
And watching, with eternal lids apart,
Like nature's patient, sleepless Eremite,
The moving waters at their priestlike task
Of pure ablution round earth's human shores,
Or gazing on the new soft-fallen mask
Of snow upon the mountains and the moors--
No--yet still stedfast, still unchangeable,
Pillow'd upon my fair love's ripening breast,
To feel for ever its soft fall and swell,
Awake for ever in a sweet unrest,
Still, still to hear her tender-taken breath,
And so live ever--or else swoon to death.

John Keats