ESAC: Centro Europeo de Astronomía Espacial

Introducción Grupo de Sistema Solar

Alejandro Cardesín Moinelo
Operaciones Científicas Mars Express, ExoMars 2016, JUICE

Alicante, Junio 2015

ESAC
Centro Europeo de Astronomía Espacial

Sede de la Agencia Espacial Europea en España desde 2006 en Villanueva de la Cañada, a 30km de Madrid

Centro de operaciones científicas para misiones de Astronomía y Sistema Solar.

Responsable de operaciones, procesado y archivos de datos

Incluye el centro de operaciones de SMOS y el Laboratorio de Astrofísica y Física Fundamental (CAB/INTA)

Cerca de 350 personas en total

(50~70 dedicadas a Sistema Solar)

Centros de Operaciones Científicas (SOC) en ESAC

Coordinación de actividades científicas de misiones y experimentos en vuelo

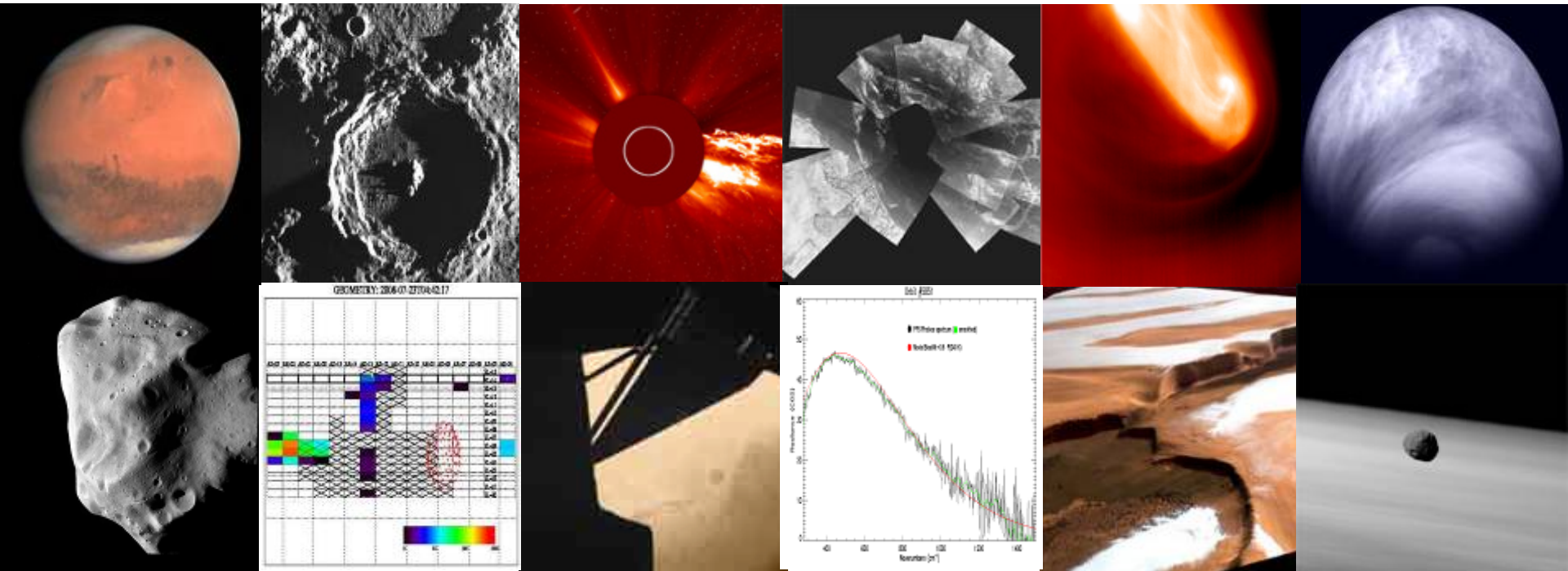
- UPLINK : Construcción y validación del plan de observaciones para comandar el satélite
- DOWNLINK : Generación y archivado de los datos científicos de cada instrumento

Archivos de Datos Científicos en ESAC

- El ***Planetary Science Archive (PSA)*** contiene los datos de misiones planetarias de la ESA: Giotto, Huygens, Mars Express, Venus Express, Rosetta y SMART-1. En el futuro también ExoMars, Bepi, JUICE, …

  http://www.sciops.esa.int/PSA

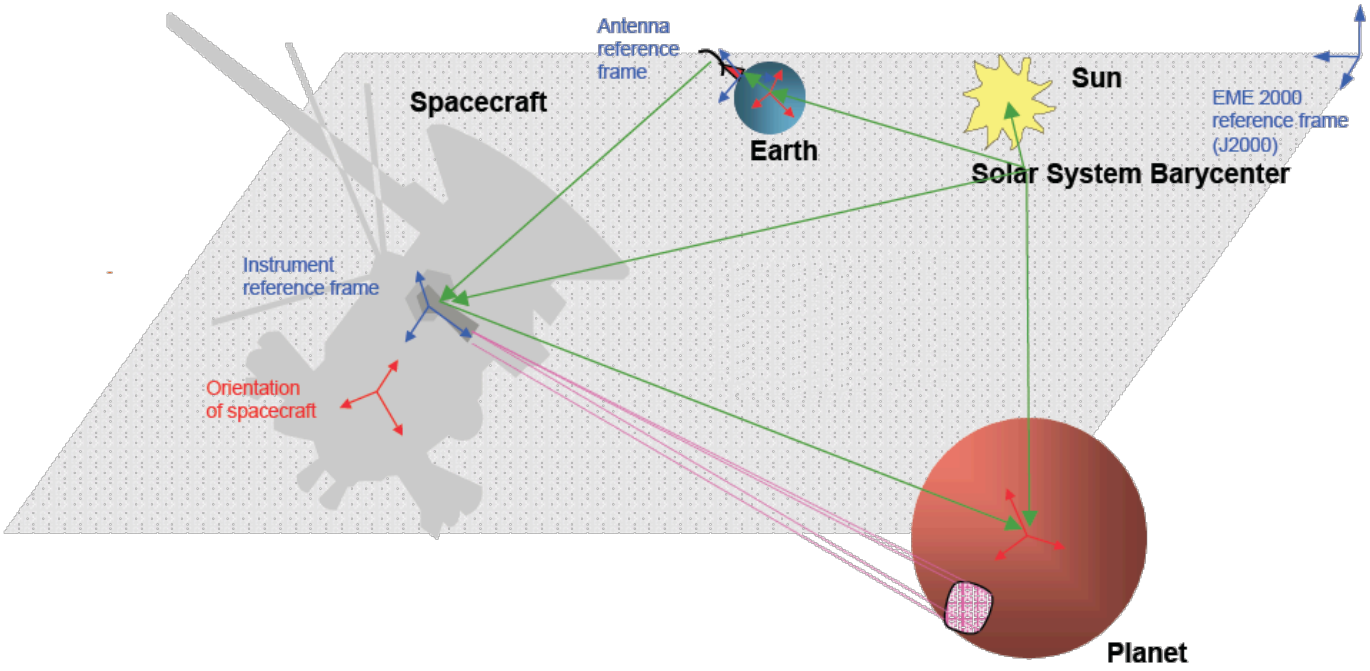
- El **ESA Science Data Center (ESDC)** incluye también los datos de SOHO, Solar Orbiter y todas las misiones de Astronomía y Astrofísica



Centro de Información Geométrica: SPICE en ESAC

ESAC Centro Europeo Responsable de SPICE :

- Sistema de información geométrica para misiones planetarias: ESA, NASA, JAXA…
- Información de objetos del sistema solar, efemérides, etc
- Librerías de cálculo de coordenadas, velocidades, ángulos, modelos 3D, …
- Soporte de misiones, organización de workshops y programas de formación



Investigación Científica en ESAC

- Las **tareas principales** en ESAC **son las operaciones** y el **procesado de datos**:

- La **investigación no es la tarea principal de ESAC**, sin embargo:
  - Hay posibilidad de dedicar tiempo a ciencia (*10-20% best effort basis*)
  - Acceso directo a los datos y contacto directo con los PIs

- Gran **interés por establecer contactos y colaboraciones**

Posibilidades de Colaboración Científica con ESAC

- **ESAC Faculty** proporciona soporte para actividades de investigación:
- **Fondos de Investigación** para proyectos internos o en colaboración

- **Convenios oficiales de colaboración en ESAC**:
  - Programas de estudiantes y jovenes:
    - Student Trainee (3~6 meses)
    - Young Graduate Trainee (1 año)
    - German/Portuguese/Spanish trainees (1~2 años)
  - Programa de post-doc :
    - Research Fellowship (2 años + 1)

Lightning on Venus

Searching for optical evidence with VIRTIS on Venus Express

Alejandro Cardesín Moinelo, *ESAC*
S. Abildgaard, *Aarhus University*
A. García Muñoz, *ESA-ESTEC*
G. Piccioni, *IAPS-Rome*
D. Grassi, *IAPS-Rome*

Encuentro de Ciencias Planetarias y Sistema Solar, Junio 2015, Alicante

Lightning in the Solar System

Lightning detected on Earth, Jupiter, Saturn, Uranus, Neptune

Practically, observed on most planetary atmospheres…

We should expect it to occur on Venus, right?

Previous searches for lightning on Venus

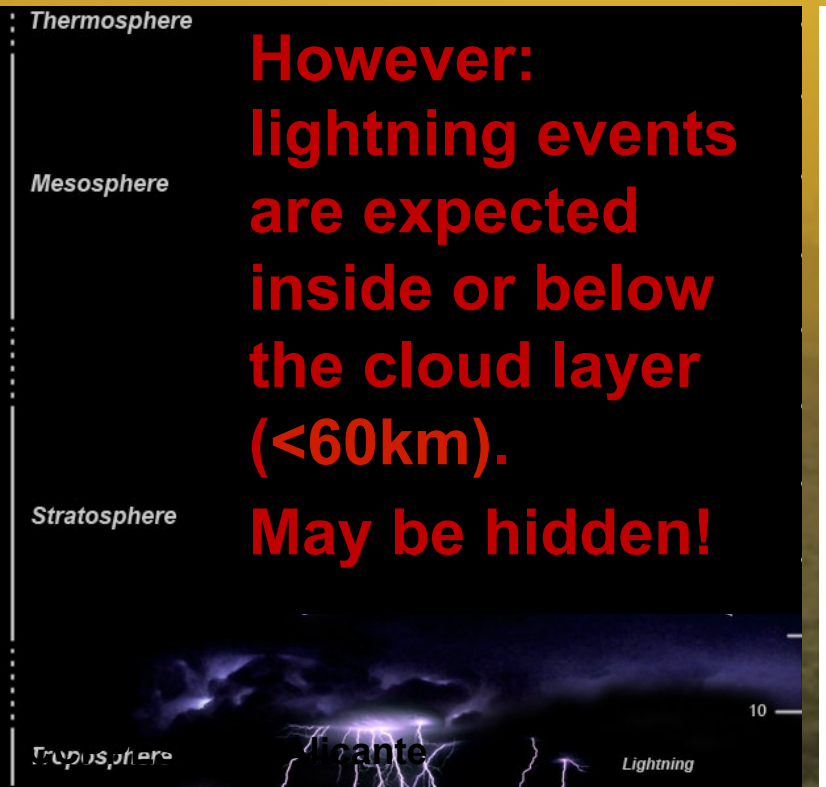
- **Electromagnetic evidence:**
  - Venera 11-14 landers — *Generated by the craft?*
  - Pioneer Venus Orbiter — *Generated by plasma perturbations?*
  - Galileo — *Too remote observation?*
  - Cassini flybys — *NO detection*
  - VEX magnetometer — *Clear evidence but still some controversy*

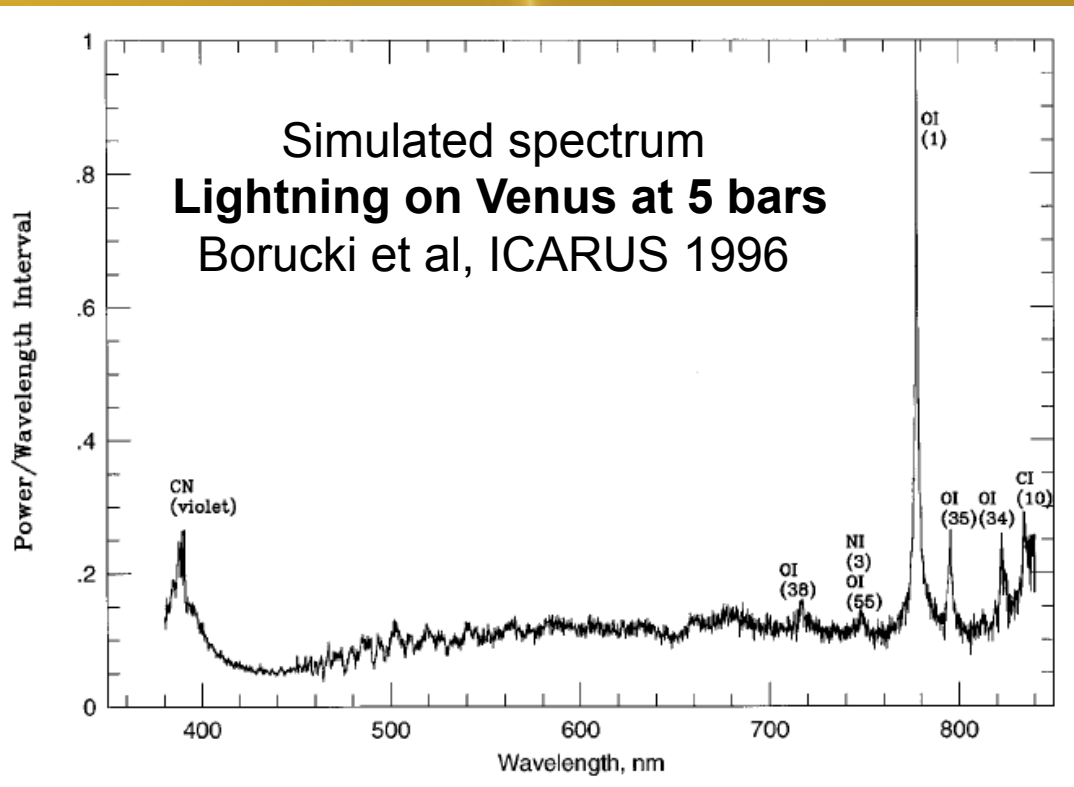
- **Optical evidence:**
  - Venera 9-10 — *noisy/random signal (inconclusive?)*
  - PVO Star Tracker — *NO detection*
  - Ground based observations: Hansell et al. 1995
  - Ground based observations: A. Garcia Muñoz at Calar Alto & La Palma 2011

The existence of lightning on Venus remains controversial!

Lightning on Venus
What can we expect?

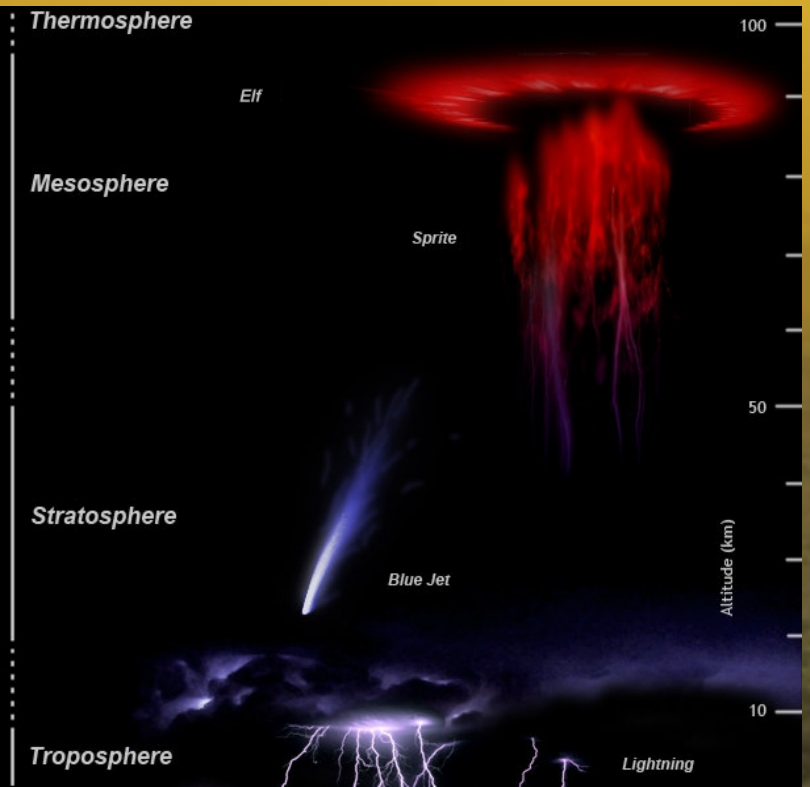
- **Lightnings on Earth have the strongest emission lines at 777.3nm and 844.6nm**, corresponding to atomic oxygen
- Laboratory measurements at higher pressures predict that the **dominant line at 777.3nm should be present on Venus**

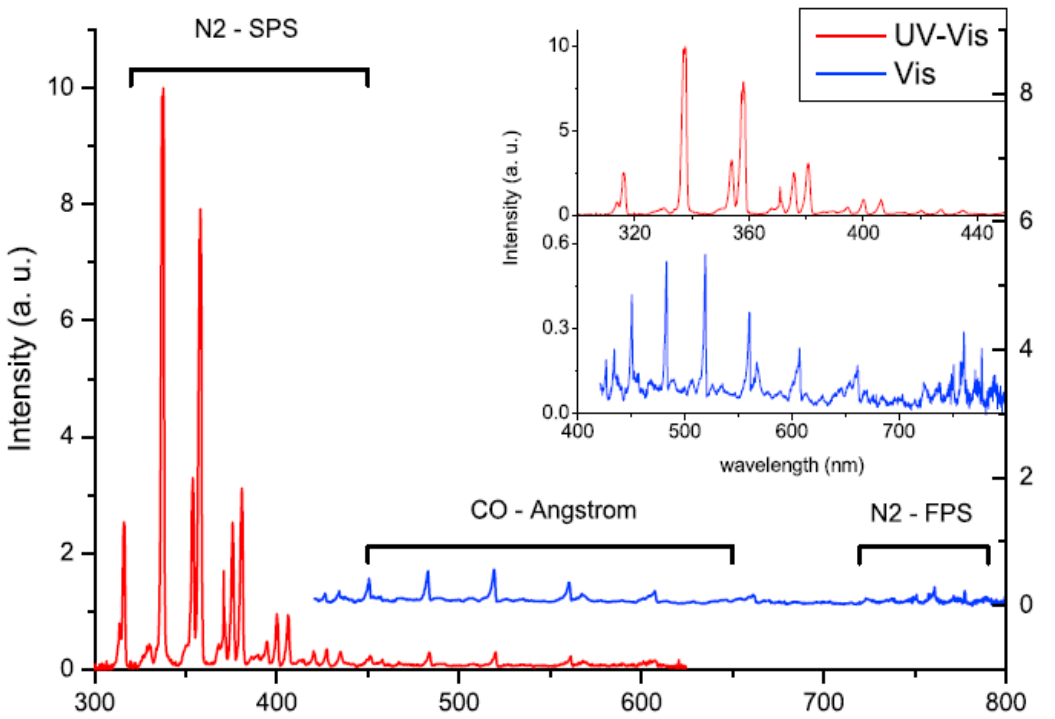




Lightning on Venus
What can we expect?

- **Transient Luminous Events** (TLEs): **Sprites, Halos, Elves**, are likely to appear **at higher altitudes** (50~90km)
- **Dominant emission around 280-420nm, peak at 337nm,** (2nd positive band of N_2) No presence of oxygen emissions

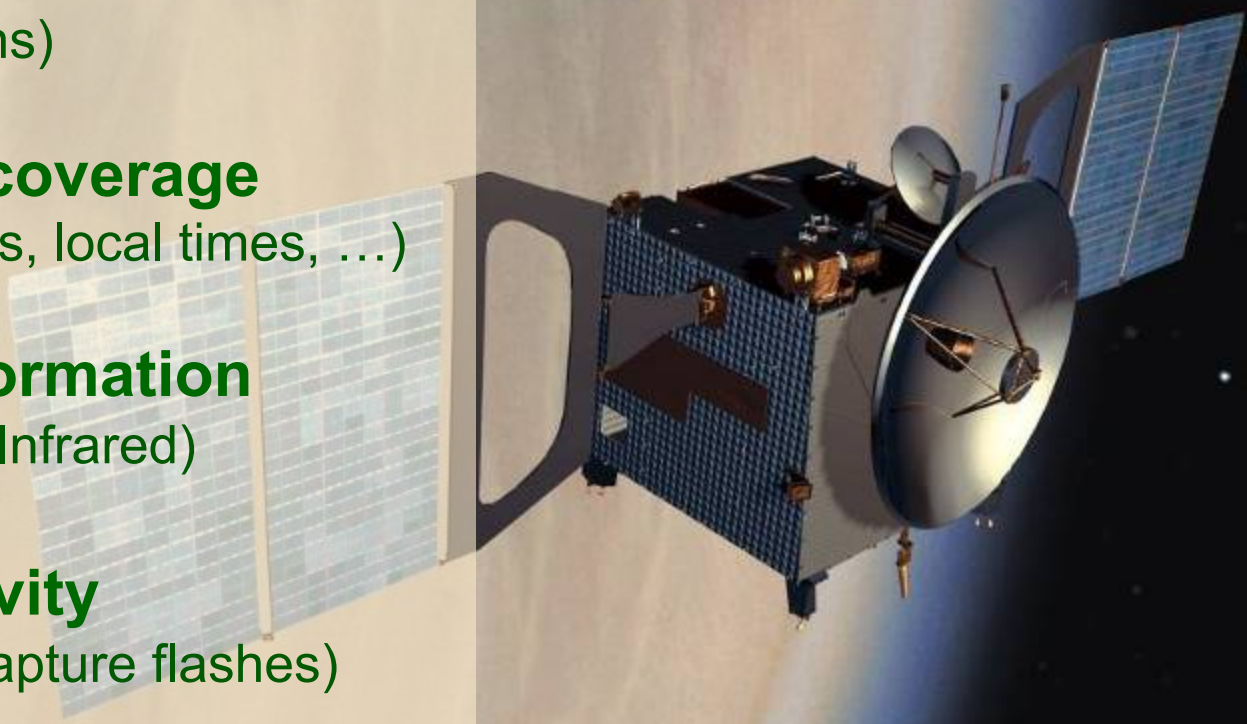




Dubrovin et al, JGR 2010

Venus Express Contribution

- **Huge data set**
  (7 years of observations)
- **Full atmosphere coverage**
  (all latitudes, longitudes, local times, …)
- **Multi-spectral information**
  (UV, Visible and Near Infrared)
- **”Enough” sensitivity**
  (theoretically able to capture flashes)
- **We can make the most comprehensive search so far!**



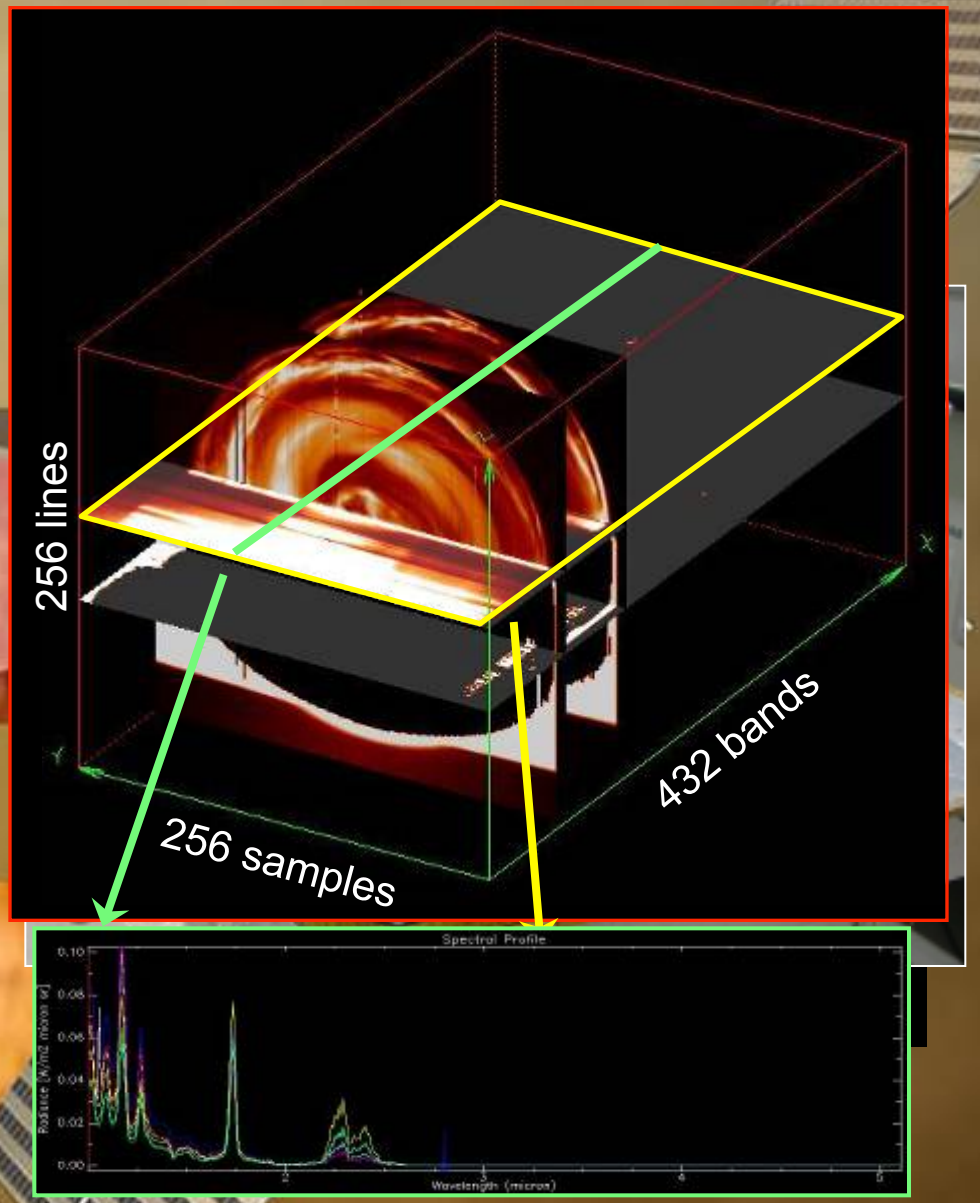
VIRTIS - Visible Infra-Red Thermal Imaging Spectrometer

- **VIRTIS-M: Mapping channel**
  - Visible 0.25-1μm
  - Infrared 1-5μm
  - 256 x 432 bands (δλ 1~10nm)

- **3-Dimensional data cubes**
  - 2 spatial dimensions (VIRTIS-M)
  - 1 spectral dimension

- **Scientific Objectives**
  - Global study of the atmosphere
  - Thermal mapping of the surface
  - Cloud Dynamics, Composition,...

Not designed for lightnings ☹

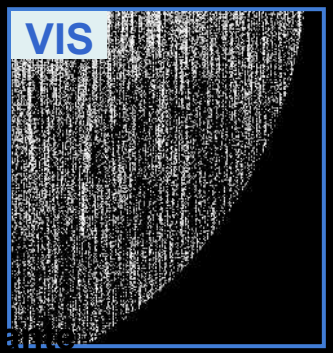


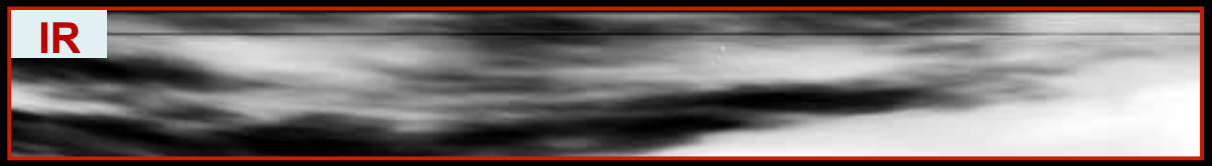
Lightning & Transient Events on VIRTIS data

- Frame/Line scanner: **not designed for lightning search.**
- Transient events cause **signal variation in a single frame/line**
- Effects can be filtered out by calibration, **need to analyze raw data**

- Both **Infrared and Visible data** with same geometry
- **Visible signal from nigthside atmosphere is almost negligible**

- We then use **Visible Nightside Long Exposure Nadir Images**





Analysis of the VIRTIS Archive Visible Images in the Nightside

Algorithm:

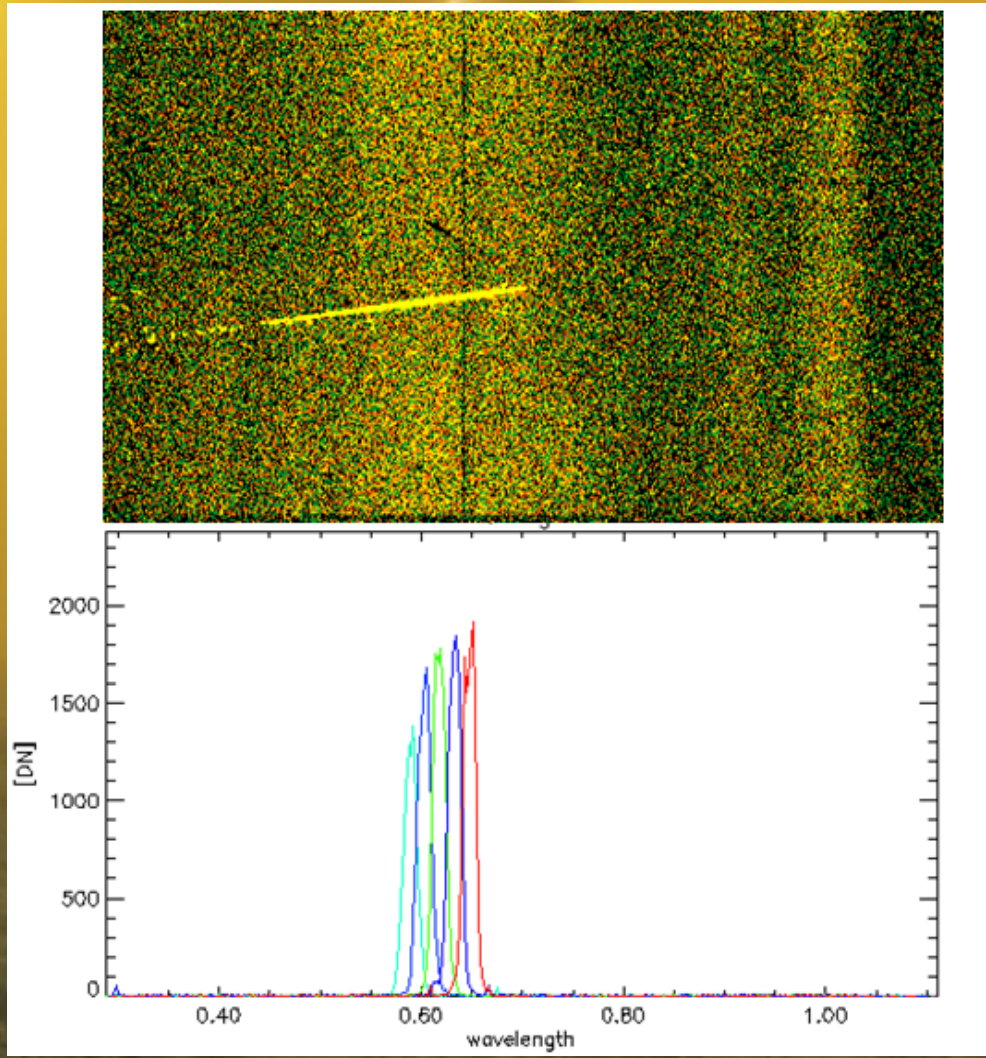
- Search for **spectral peaks in one single line/frame.**
- Nightside Raw Visible data
- No assumption on emission bands (all wavelengths are considered).

A lot of transient events are detected!

But we also detect other things.

How can we know if we have found lightning?

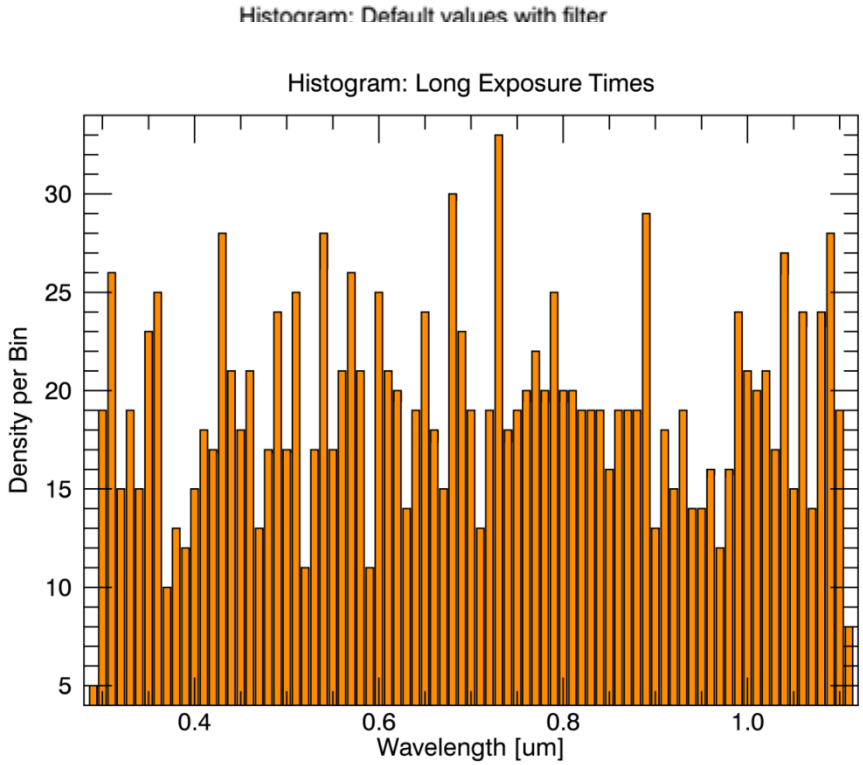
Statistical analysis needed!



Analysis of the VIRTIS Archive
Visible Images in the Nightside

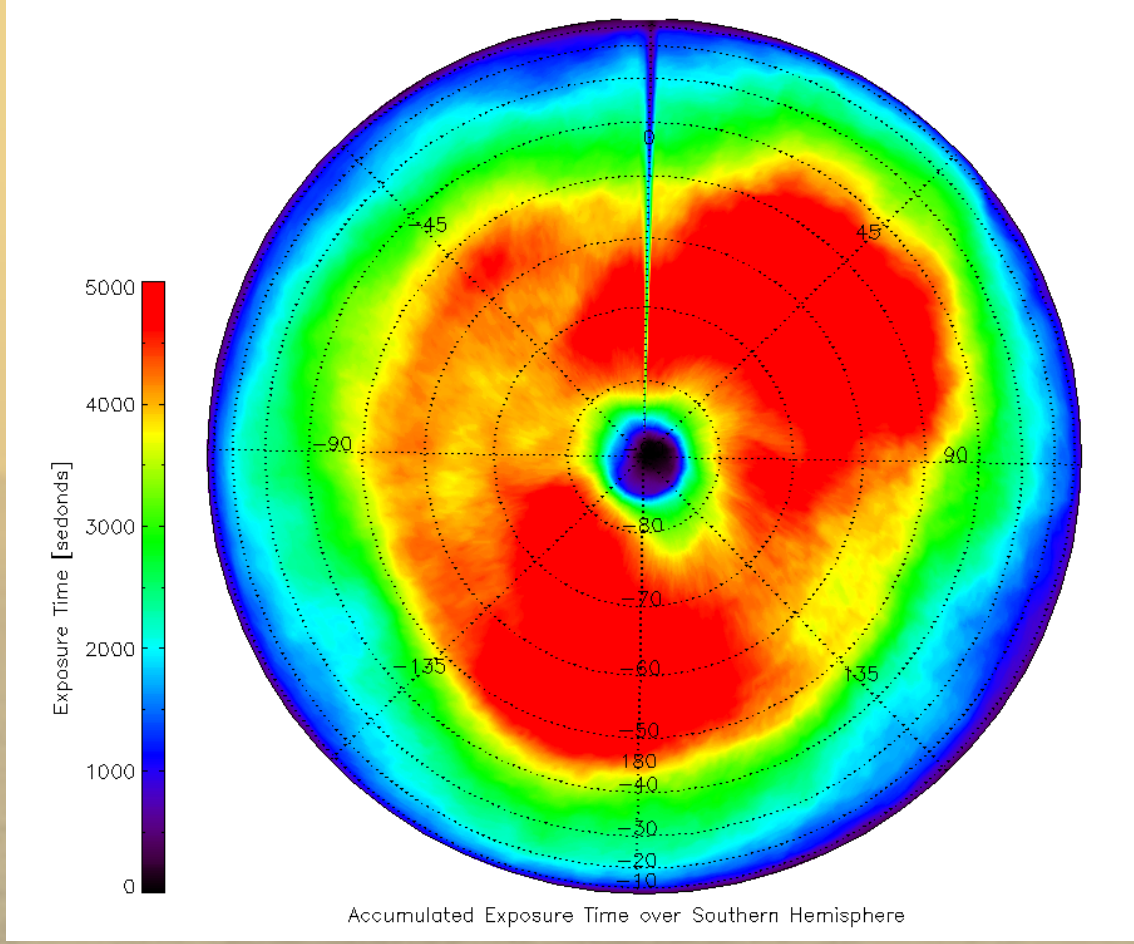
Search for a dominant peak wavelength:

- Various filters
- Various emission signal threshold
- Various emission band widths
- Only geographical poles
- Only very long exposures
- Only terminator
- Only limbs
- Only long nadirs
- Low distance images



Main Conclusion

No statistical evidence of lightning over several years of VIRTIS data



Implications

- **Lightning could be hidden under cloud layer**

  Contradicts optical observations of lightning on Venus

- **Lightning has too low energy to be detected by VIRTIS**

  Contradicts Venus Express Magnetometer observations that found the energy of the EM-signals to be close to terrestrial values

- **Lightning occurrence is rare**

  Also contradicts Venus Express Magnetometer result that predict lightning to be at least same rate as on Earth

- **Lightning happens only in dayside**

  But there is no theoretical prediction for this – However, this would be interesting!

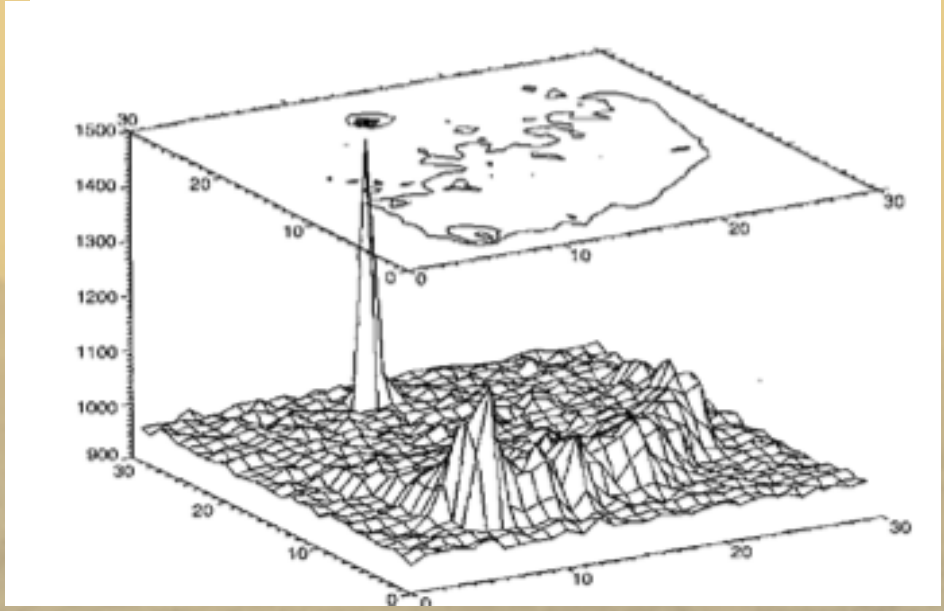
- **Or… no lightning on Venus?**

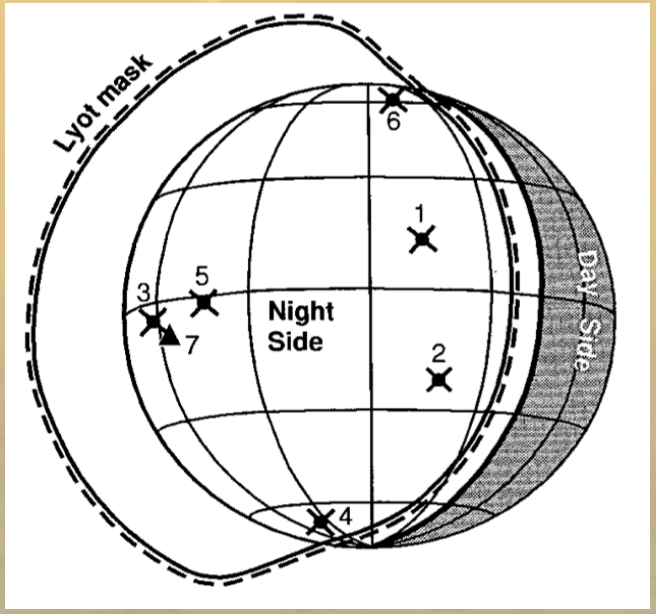
Hopefully the Akatsuki mission will bring more light to the subject.


THANKS
QUESTIONS?

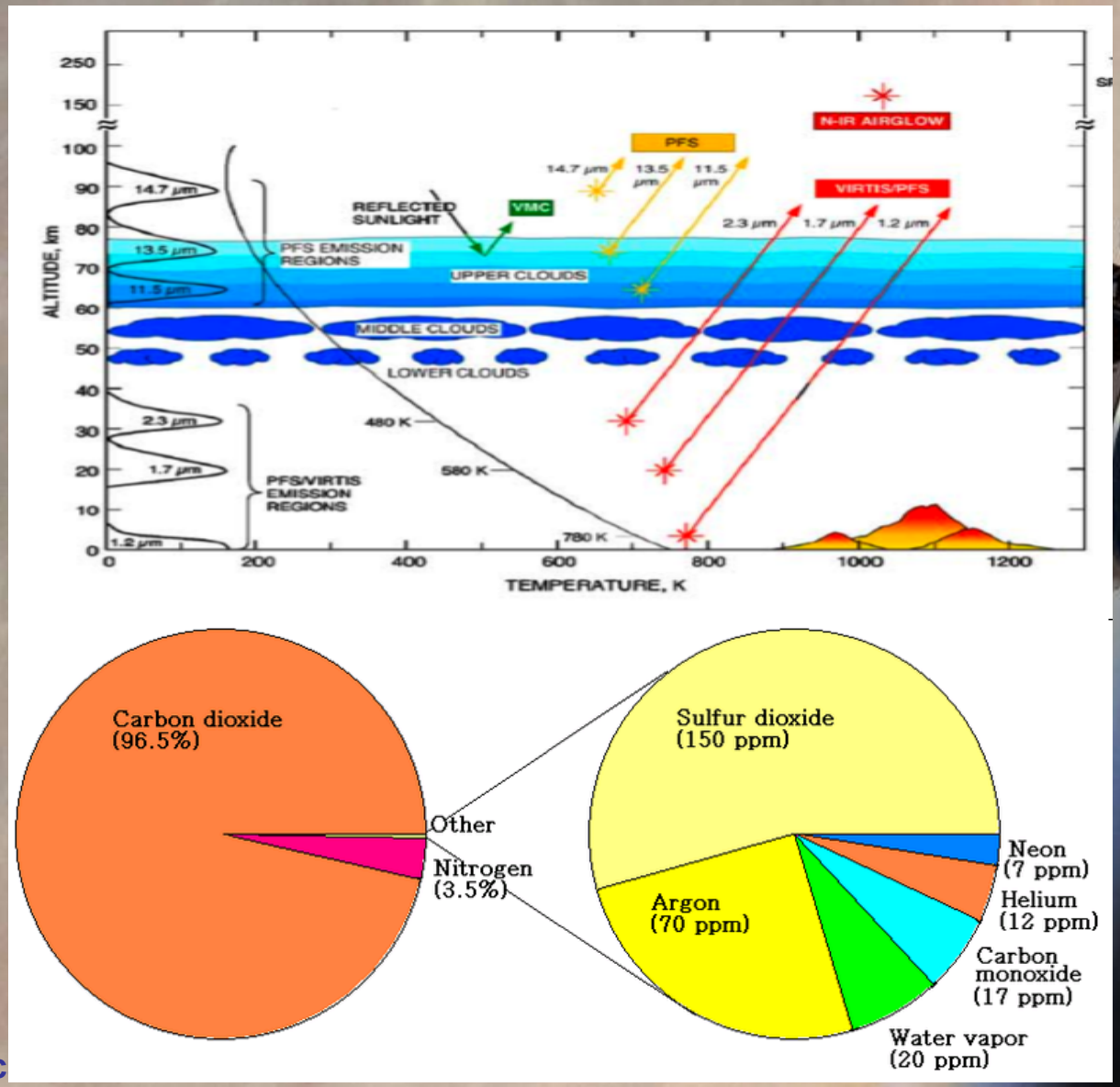
Lightning on Venus
Optical Evidence?

- Venera 9-10
- PVO Star Tracker broad band photometry
- Ground based observations: Hansell et al. 1995
- A. Garcia Muñoz at Calar Alto & La Palma



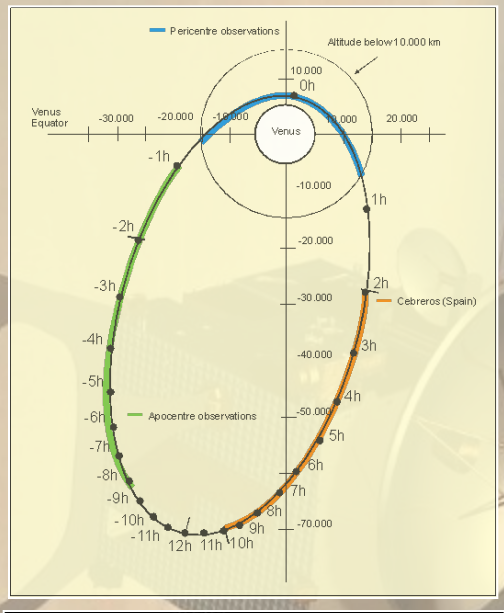


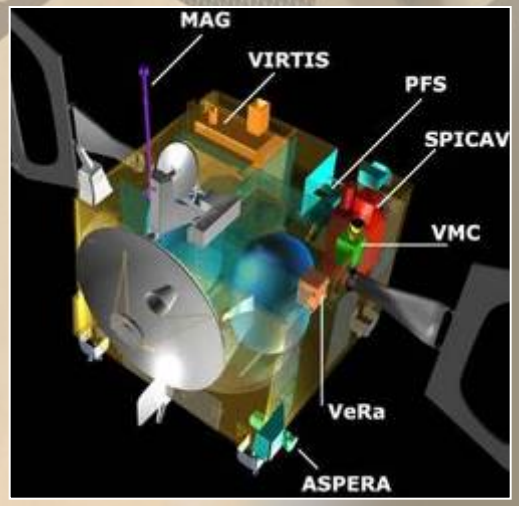
Venus Atmosphere



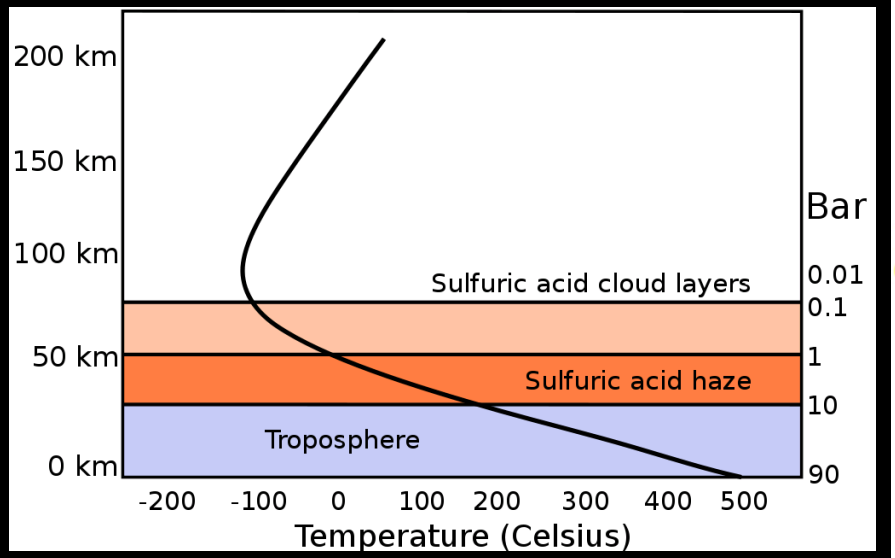
Venus Express

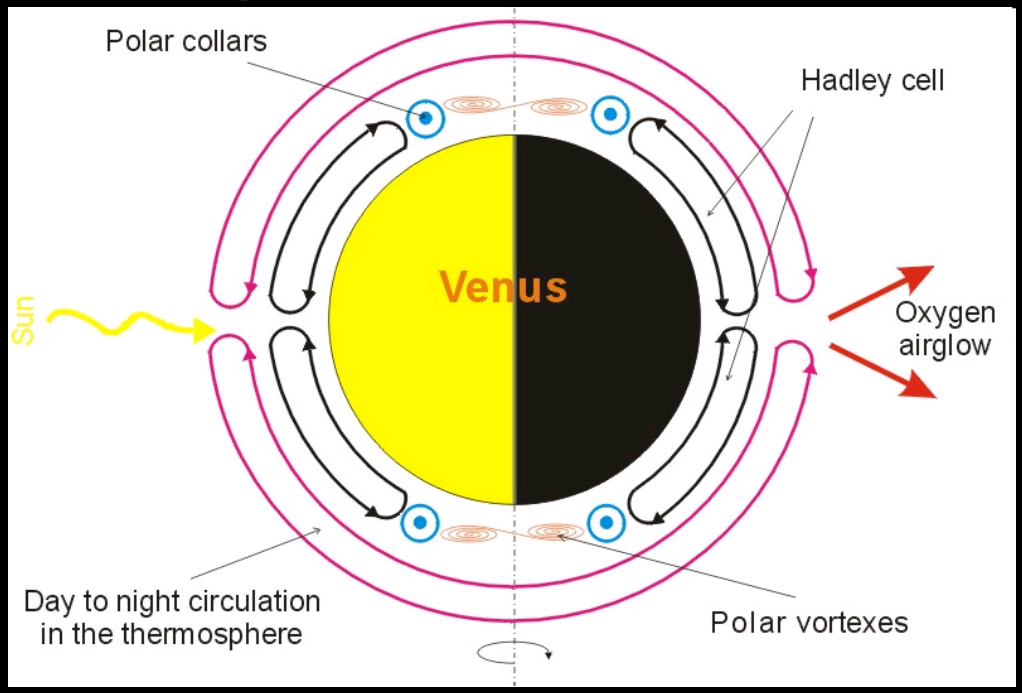
- Launch 09 November 2005 04:43 UTC
  - Venus Orbit Insertion 11th April 2006
- Polar elliptical orbit
  - Pericentre ~250 km
  - Apocentre ~66.000 km
  - Period ~24 hours
- Scientific Objectives
  - Atmosphere composition
  - Cloud morphology and structure
  - Atmosphere/surface interaction
  - Thermal mapping (and vulcanism)
- Instrumentation
  - VIRTIS (Imaging Spectrometer IR-VIS)
  - PFS (IR Spectrometer)
  - SPICAV (UV Spectrometer)
  - VMC (VIS-UV Camera)
  - ASPERA (Plasma science)
  - MAG (Magnetometer)

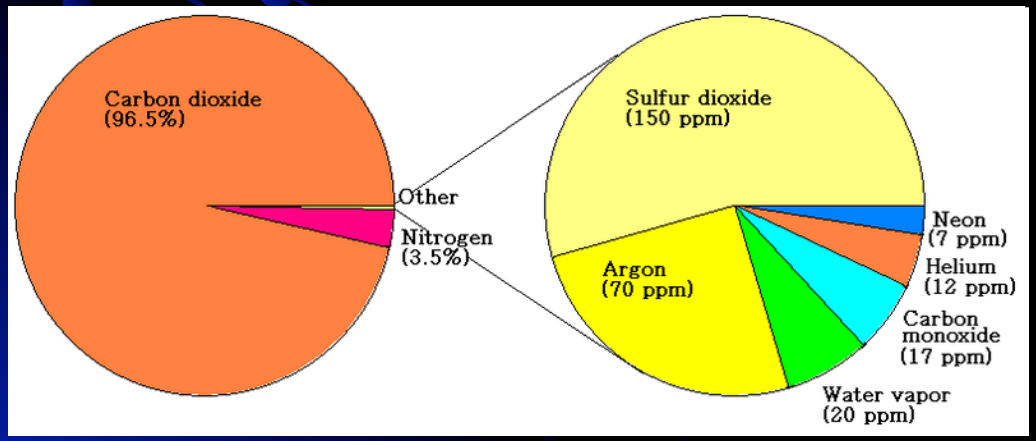


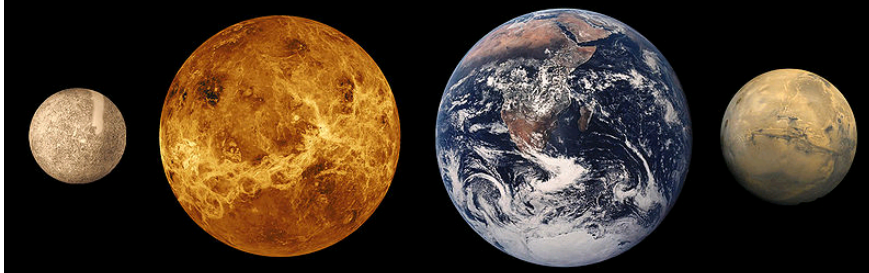


Venus Atmosphere









Data Calibration pipeline - Summary

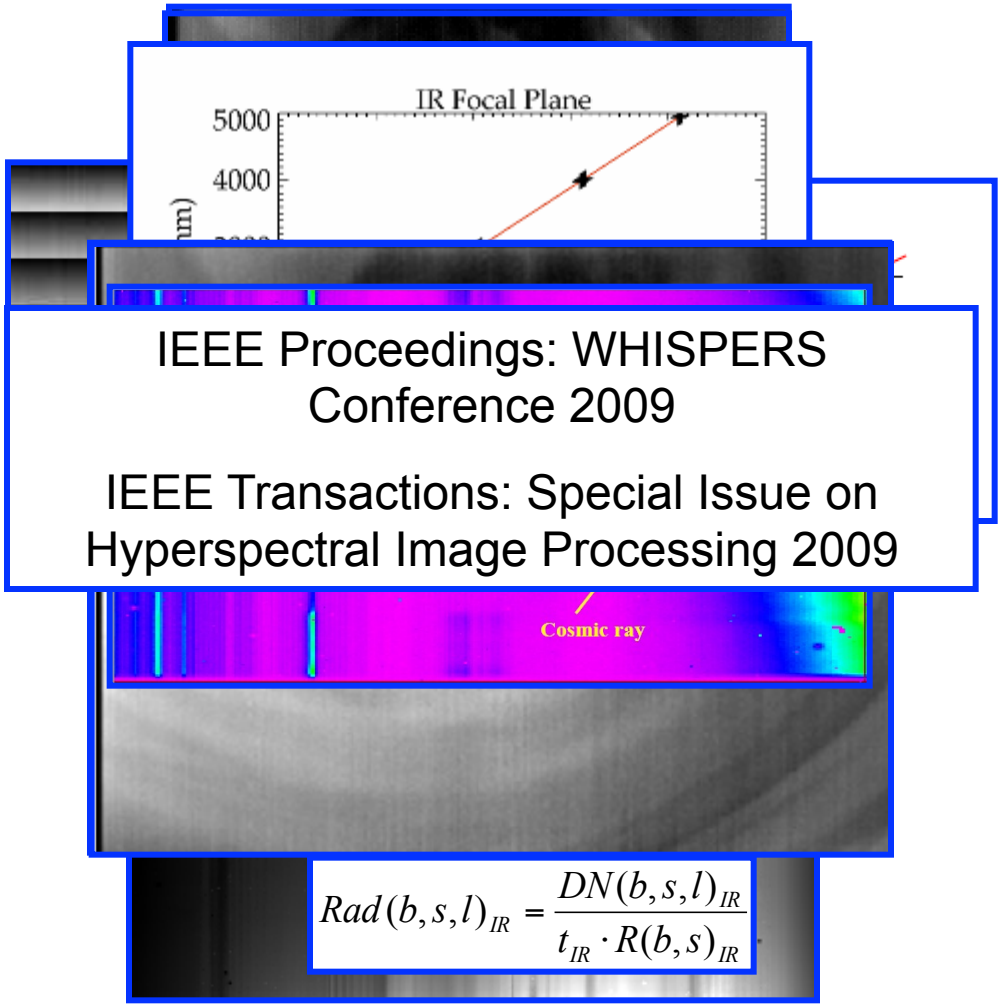
PDS RAW data cubes

VI0044_01.QUB

Calibration Pipeline

- **Initialization**
  - **- Dark Frame removal**
  - **- Bad/Saturated pixels**
- **Pre Processing**
  - **- Thermal correction**
  - **- Bad frame recovery**
- **Radio metric** / **Spectral**
  - **- Spectral Registration**
  - **- Radiometric Calibration**
- **Post Processing**
  - **- Despiking**
  - **- Destriping**

VI0044_01.CAL



IEEE Proceedings: WHISPERS Conference 2009

IEEE Transactions: Special Issue on Hyperspectral Image Processing 2009

VIRTIS details

	VIRTIS-M Visible	*VIRTIS-M Infrared*	*VIRTIS-H*
Spectral range (nm)	280 – 1100	1050 – 5130	1840 – 4990
Spectral resolution $\lambda/\Delta\lambda$	150 – 500	100 – 500	1300 – 3000
Spectral sampling (nm) [note 1]	1.89	9.47	0.6
Field of view (mrad x mrad)	64 (slit) x 64 (scan)		0.44 x 1.34
Max spatial resolution (µrad)	250 (slit) x 250 (scan)		–
Image size, full FOV high resolution (pixels)	256 x 256		–
noise equivalent spectral radiance (central band, $Wm^{-2}sr^{-1}\mu m^{-1}$)	1.4×10^{-2}	1.2×10^{-4}	1.2×10^{-4}
Telescope	Shafer Telescope	Shafer Telescope	off-axis parabolic mirror
Pupil diameter (mm)	47.5		32
Imaging F#	5.6	3.2	2.04
Etendue (m^2 sr)	4.6×10^{-11}	7.5×10^{-11}	0.8×10^{-9}
Slit dimension (mm)	0.038 x 9.53		0.029 x 0.089
Spectrometer	Offner Relay	Offner Relay	Echelle spectrometer
Detectors	Thomson TH7896 CCD	HgCdTe [note 2]	HgCdTe [note 2]
Sensitivity area format	508 x 1024	270 x 436	270 x 436
Pixel pitch (mm)	19	38	38
Operating temperature (K)	150 – 190	65 – 90	65 – 90
Spectral range (µm)	0.25 – 1.05	0.95 – 5.0	0.95 – 5.0
Mean dark current	< 1 e/s	< 2 fA @ 90K	< 2 fA @ 90K

Notes. 1: depends on selected mode of operation; the maximum value is shown. 2: VIRTIS-M and VIRTIS-H use identical IR detectors.