Venus: Mysteries of the forgotten planet
**Structure of the Atmosphere**

**Thermosphere:** very cold and highly variable

**Very high surface temperature**

**No day/night and equator/pole contrasts**

**Greenhouse effect**

**Atmospheric composition**

- **Main gases:**
  - $CO_2$ (96.5%), $N_2$ (3.5%)

- $SO_2$, COS, $H_2S$ – sulfur cycle

- CO – photodissociation

- $H_2O$ – greenhouse agent
Chemical Cycles

- **Photochemistry**
  - $HO_x$, $Cl_x$, $SO_x$, $O_x$

- **Thermochemistry**
  - $COS$, $CO$, $H_2SO_4$,
  - $SO_3$

- **Surface-atmosphere interactions**

Cloud Layer

- **Visibility** $> 300$ m
- **Total opacity** 20–40
- **Particles**: 1–10 μm, 100–1000 cm$^{-3}$
- **Composition**:
  - $H_2SO_4 + ?$ ($S_{\alpha}$, $AlCl$, $H_3PO_4$, ...)

Aerosol extinction, km$^{-1}$

UV, NIR
Atmospheric Dynamics

- Troposphere and mesosphere
- Zonal superrotation (>100 m/s)
- Poleward winds v ~ 10 m/s
- Cyclostrophic balance
- Thermosphere (>120 km):
  - Solar – antisolar circulation

Wave phenomena

- Planetary waves: “Y” feature
- Wave trains
- Convective cells
- Polar dipole
  - 250 K
  - 220 K
Venus atmosphere in motion

Pioneer Venus Orbiter
Cloud Photopolarimeter
Spring 1982 Images
6 Feb 1982 – 8 May 1982

Goal – to reach the surface!

Venera-13
Venera-14
Venera-14
Venus unveiled…

Venus Surface

- Main landforms
  - Lowlands
  - Tesserae
  - Volcanoes
  - Impact craters
- Global resurfacing ~500 My ago
- Very slow weathering
- No plate tectonics

Ishtar Terra
Aphrodite Terra
Magellan
Peeping through the cloud curtain

Composia spectrum of Venus

Non-magnetic planet
Direct interaction of the solar wind with the atmosphere
Complex structure of the ionosphere
Atom and ion escape
Summary of the first phase of Venus exploration
/1962 – 1990/

- Flotilla of more than 20 spacecraft visited the planet
- Fly-bys, orbiters, descent probes, balloons
- Ground-based observations

- Basic understanding of the conditions on the planet
- Complete mapping of the surface
- Power of remote sensing tools
- Great number of unsolved fundamental problems

Mysteries of Venus

- Composition and chemistry of the lower atmosphere
- Physics and chemistry of the cloud layer
- Nature and mechanism of the general circulation
- Details of greenhouse effect
- Evolution of the atmosphere and the surface
- Plasma environment and its interaction with the solar wind
Uniqueness of Venus

- Natural laboratory to study thermochemistry and surface-atmosphere interactions
- Atmospheric dynamics on a slowly rotating planet
- Radiative transfer at extreme conditions
- Surface is one of the youngest in the Solar System
- Plasma around non-magnetic planet

Key Question
Venus Express mission goal

Global investigation of the Venus’ atmosphere, plasma environment, and some important aspects of geology and surface physics from orbit
Venus Express payload

- **PFS** (V. Formisano) - high resolution IR Fourier spectrometer
- **SPICAV / SOIR** (J.-L. Bertaux, O. Korblev, P. Simon) - UV & IR spectrometer for solar/stellar occultations and nadir observations
- **VIRTIS** (P. Drossart, G. Piccioni) - UV-vis-near IR imaging and high resolution spectrometer
- **VMC** (W.J. Markiewicz) - Venus Monitoring Camera
- **VeRa** (B. Häusler, M. Pätzold) - radio science experiment
- **ASPERA** (S. Barabash) - Analyzer of Space Plasmas and Energetic Atoms
- **MAG** (T. Zhang) - Magnetometer

Temperature structure:
**SPICAV, PFS, VIRTIS, VeRa**

- **Thermosphere and Ionosphere**
  - Solar & stellar occultation by SPICAV/SOIR (80-150 km)
  - Radio occultation by VeRa (140-600 km)
- **Mesosphere**
  - PFS and VIRTIS (60-100 km)
  - VeRa (40-100 km)
- **Lower troposphere (0 - 8 km)**
  - PFS, VIRTIS, and VMC
Lower atmosphere composition: VIRTIS, PFS, SPICAV, VMC

Venus night side by NIMS/ Galileo

Venus night side PFS and VIRTIS

Composition of the upper atmosphere: SPICAV / SOIR

Star occultation geometry

SPICAV UV occultation spectra

SOIR IR occultation spectra
Cloud layer: VIRTIS, PFS, SPICAV, VMC

- Optical properties
- Microphysical parameters
- Vertical structure
- Aerosol composition
- Cloud layer formation
- Atmospheric dynamics

Aerosol extinction, km$^{-1}$

Vertical structure

Cloud layer: VIRTIS, PFS, SPICAV, VMC

Atmospheric Dynamics

- VIRTIS spectral mapping
- VMC global imaging
- PFS thermal wind field
- Time varying 3-D picture

Airglow at 130 km

Surface

70 km
50 km
Plasma and escape processes: ASPERA, MAG, SPICAV, VeRa

ASPERA and Magnetometer
- Global plasma and neutral gas distribution and velocities
- Magnetic field measurements
- Solar wind - atmosphere interaction
- Study of escape processes

SPICAV/ SOIR
- Neutral atmosphere up to ~ 180 km

VeRa
- Ionosphere up to ~ 600 km

Surface studies: VeRa, VIRTIS, PFS, SPICAV, VMC
- VeRa bistatic sounding
- Thermal imaging of the surface
- Correlation with earlier radar investigations
- Search for volcanic activity
- Gravity anomalies

Magellan radar map

Venera-13 panorama
Spectral characteristics of the payload

Fields of view of the instruments at 20,000 km
Coverage of the science themes

- Structure
- Composition
- Dynamics
- Clouds
- Plasma & escape
- Surface

Venus Express Orbit and Science Operations

- Pericentre obs
- Off-Pericentre and apocentre obs
- Limb obs
- Solar and stellar occultation
- Earth occultation
- Bi-static and solar corona sounding
Mission scenario

- Launch: Oct-Nov 2005 by Sojuz-Fregat from Baykonur (Kazakhstan)
- Arrival to Venus: April 2006
- Polar orbit
  - Pericentre latitude 80N
  - Pericentre altitude 250 km
  - Apocentre altitude ~65,000 km
  - Period ~ 24h
- Mission duration 4 Venus sidereal days
- Complete latitude and local time coverage

The spacecraft

- Solar panels: smaller and different composition
- Smaller dish of the main antenna
- Second antenna
- Modified thermal design
Venus Express integration at Alenia Spazio, Turin