The SOIR instrument and the 2012 Venus transit

Séverine Robert, Arnaud Mahieux
Valérie Wilquet, Ann Carine Vandaele, Rachel Drummond
Plan

- Introduction
- The SOIR instrument
- Method and results
- Why study Venus?
- The Venus transit
- Conclusions
Plan

- Introduction
- The SOIR instrument
- Method and results
- Why study Venus?
- The Venus transit
- Conclusions
Space observation of Venus started in the 60s (Venera)
- Last Venus dedicated satellite in 80s (Vega)

Measurements from the Venus Express spacecraft
- Orbiting since 2005, 1st European satellite to Venus

Venus Express’ goals are also to understand Venus atmosphere
- Composition
- Dynamics
- Evolution
- Comparative planetology
Venus compared to Earth

- At first sight, they look very similar
  - Almost identical mass and diameter
  - Venus is 25% closer to the Sun
  - Both located in the habitable zone of the Solar System

- Venus is very different to Earth
  - Very slow self rotation and opposite direction (-273 days)
  - No magnetic field, plate tectonics, natural satellite
  - Very warm and thick atmosphere (750 K and 92 atm at the surface)

- Where do these differences come from?
Atmospheric composition

- **Main compound:** carbon dioxide CO$_2$
  - 96.5%
  - Dayside carbon photochemistry
  - → Powerful greenhouse effect

- ** Entirely covered by cloud layer in super rotation (zonal @ 300 km/h)**
  - Made of H$_2$SO$_4$ droplets
  - SO$_2$, SO, OCS, H$_2$CO products

- **Low water concentration (~ 1 ppm)**
  - Variable
  - HDO/H$_2$O 140 x larger than on Earth

- **Halogens (~ 0.1 to 10 ppm)**
  - HCl, HF
  - Catalysts
Plan

- Introduction
- The SOIR instrument
- Method and results
- Why study Venus?
- The 2012 Venus transit
- Conclusions
Tool: the SOIR instrument

- **Solar Occultation in the InfraRed**
  - Belgian instrument
  - Observes using solar occultations
  - Near infrared (2.2 µm to 4.4 µm)
  - Combines echelle grating and Acousto Optical Tunable Filter (AOTF)
  - Best resolution ever obtained for instrument to other planet

- SOIR measures
  - Between 70 and 170 km
  - At Venus terminator
    - Dawn and dusk
  - At all latitudes
  - Species studied: CO₂, CO, H₂O/HDO, HCl, HF, SO₂, ...
Plan

- Introduction
- The SOIR instrument
- **Method and results**
- Why study Venus?
- The 2012 Venus transit
- Conclusions
Solar occultation – Measurement principle

Transmittance

Side view

To Sun

VEX

Atmosphere

Orbit 232 – Order 129

View from Venus Express
Solar occultation – Measurement principle

Transmittance

Side view

To Sun

VEX

Orbit 232 – Order 129

View from Venus Express

Atmosphere

IASB Seminar, 29/05/2012
Spectra recorded by SOIR
Spectral inversion
- Rodgers matrix approach
  - A priori atmospheric profiles + confidence
  - Uncertainties on the measurements
- Atmosphere hydrostatic equilibrium
  - To derive the kinetic temperature

Results
- Density vertical profiles
- Temperature vertical profiles
- Background vertical profiles (aerosols)

Unique information, never before obtained for Venus
Method

Transmittance vs. Wavenumber [cm⁻¹]

Temperature

Density
Inversion results

Orbit 687.1

Orbit 1557.1

CO₂ density [molec/cm²]

Temperature [K]
Results: CO$_2$ vertical profiles

VIRA model

Slope change

Cold layer

Density [mole/cm$^3$]  
Latitude [deg]

Local solar time [h]

Temperature [K]
Venus Atmosphere from SOIR data at the Terminator (VAST)

- From high altitude CO$_2$ density and temperature profiles
  - 170 km down to 70 km
  - 59 profiles selected

- Assuming
  - North – South hemisphere symmetry
  - Morning and evening symmetry

- Dividing in latitude regions
  - 0-30°, 30-60°, 60-70°, 70-80°, 80-90°
VAST CO$_2$ density

0° to 30° latitude

30° to 60° latitude

60° to 70° latitude

70° to 80° latitude

80° to 90° latitude

Altitude [km]

Partial density [molec/cm$^3$]

SOLR model
von Zahn 1980 (SMM1) - 5:00 AM, -40°
Kaing Model
VT03 Model
Zasova Model
Research goals in the BISA team and with external collaborators

- **VAST**
  - Understand and forecast the large observed variations
    - Time and latitude dependance
  - Define the sources and sinks of the major cycles (C and S)
    - Dynamics and chemistry
  - Collaborations with modellers
    - GCM
    - (photo)chemistry models

- Understand the observed isotopic variations (D/H)
- Characterize the aerosols of the upper haze
- CO$_2$ spectroscopy
  - New bands have been characterized
- Comparisons with groundbased groups

- Considering the good quality of the SOIR results, the NOMAD instrument will be launched to Mars in 2016 (ESA, Roscosmos)

http://venus.aeronomie.be
Conclusions on the science

- The instrument capabilities have now been proven

- Using the Asimat inversion algorithm, robust density and temperature profiles are obtained

- CO$_2$ density and temperature profiles have been computed
  - Unique results

- Venus Atmosphere from SOIR measurement at the Terminator
Plan

- Introduction
- The SOIR instrument
- Method and results
- Why study Venus?
- The 2012 Venus transit
- Conclusions
Why study Venus?

- Already in the past, studying Venus answered important questions about Earth
  - Sun – Earth distance calculation
  - Venus phases observations by Galileo during XVII\textsuperscript{th} century
    \rightarrow Heliocentrism

- Tomorrow’s discoveries?
Why study Venus?

- Study an environment different from ours in order to better understand the Earth climatology: **comparative planetology**
  - Venus and Earth had a similar composition
  - Why did the planets evolve so different?
  - Powerful greenhouse effect
  - Where did the Venus water go? Why?
  - Also comparisons Venus-Earth-Mars-Titan

- What shouldn’t we do on Earth to avoid such a scenario?

- From SOIR data: to understand the influence of CO$_2$ in the global greenhouse effect mechanisms
Why study Venus?

- Are there habitable regions on Venus?
  - Surface?
  - Above the cloud deck (60-65 km)
  - Atmospheric parameters variability
  - No magnetic field → solar wind
  - Dry planet

- Future missions
  - Atmospheric balloons
  - Surface landers

Venera 13 (1981)

Venera 14 (1981)
Plan

- Introduction
- The SOIR instrument
- Method and results
- Why study Venus?
- The Venus transit
- Conclusions
A transit takes place when the Sun, the Earth and Venus are all aligned.

Due to the inclination of the Venus orbit and the orbital period of the planets, transits occur rarely and following a « strange » pattern:
Historical facts

- 1631 & 1639: Kepler’s prediction & First observation
- 1761 & 1769: First international collaboration
- 1874 & 1882: Technical advances
- 2004 & 2012: The digital era
Kepler’s prediction & First observation

Kepler predicted the transit of 1631 but it wasn’t visible from Europe…

From Kepler's recently published Rudolphine Tables (1627), J. Horrocks, aged 22, worked out that a transit of Venus was due on November, 24, 1639, at 3 P.M. He prepared for the transit by directing the solar image on to a large sheet of paper in a darkened room.

J. Horrocks & W. Crabtree making the first observation of the 1639 Venus transit.
Historical facts

First international collaboration
More than 100 observations around the world

Lomonosov (1711-1765) predicted the existence of an atmosphere on Venus.

Captain J. Cook (1729-1779) sailed to Tahiti aboard the Endeavour to observe the 1769 Venus transit and to seek evidence for the Terra Australis Incognita.
Historical facts

- **Technical advances**
  - telescope construction
  - photography
  - clocks
  - determination of global position, particularly longitude
Historical facts

- **The digital era:** 8 June 2004

  ![Venus Express](image)

  Tanga et al., Icarus 218 (2012) 207-219
Venus as an exoplanet

- The transit method is used to detect and study exoplanets:
  - Photometric method gives access to the radius of the planet
  - Detection of the elements present in the planet’s atmosphere by studying the spectra of the light from the star passing through the upper atmosphere of the planet

- Test of the instrumentation used to study exoplanets
  - Physical characterization of the planet
  - Atmospheric composition
The 2012 Venus Transit

- **Worldwide observations: 5-6 June 2012**

**Phone App**

New technologies, like the *free* Transit of Venus phone app, will allow individuals to send their observations of the 2012 transit of Venus to a global experiment to measure the size of the solar system. Join this unique effort, spearheaded by the non-profit Astronomers Without Borders, as a supporter and a participant.

- Download *free* iTunes app.
- Download *free* Android app.

http://www.transitofvenus.org/

**Venus Twilight Experiment**

9 identical coronagraphs around the world (Svalbard, USA, Japan, India, Kazakhstan, Australia, Marquesas Is.) + one in Mongolia
The 2012 Venus Transit

- 5-6 June 2012

2012 Transit of Venus

Figure 3 - World Visibility of the Transit of Venus — 2012 June 06
The 2012 Venus Transit

In Belgium

Find a location with a clear view of the horizon in the ENE and/or join an astronomy club and benefit from their knowledge.

<table>
<thead>
<tr>
<th>Contact</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>First contact</td>
<td>00:03:57</td>
</tr>
<tr>
<td>Second contact</td>
<td>00:21:36</td>
</tr>
<tr>
<td>Mid-point of transit</td>
<td>03:29:59</td>
</tr>
<tr>
<td>Third contact</td>
<td>06:37:31</td>
</tr>
<tr>
<td>Fourth contact</td>
<td>06:55:02</td>
</tr>
<tr>
<td>Sunrise</td>
<td>05:38:22</td>
</tr>
</tbody>
</table>
Outreach

- Schools:
  - Institut Don Bosco
  - Uccle 1
- Publication: Ciel et Terre
- Poster presentation at EPSC
- Website:
Outreach

- Website:
  - Started 2 months before the event
  - 1 update each Friday
  - Text & images
  - Videos
  - Glossary
  - Astronomy clubs contacts
  - Links
  - Frequently Asked Questions
  - Facebook
  - Twitter

Conclusions

- There are still a lot of open questions about Venus

- A comparative study of the greenhouse effect origins would be instructive in the frame of the global warming problem

- The 2012 Venus transit is of interest for exoplanet research

- This event is a great opportunity for outreach and educational purposes
Thank you for your attention