European Space Agency

Research and Scientific Support Department

Planetary Missions Division

Venus Express

Science Activity Plan for
Extended Mission
SAP-E-3, Part 1

VEX-SCIOPS-PL-030_1_1_part 1

Issue 1, Rev 1

January 25, 2010

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CHANGE RECORD SHEET

Date	Iss.	Rev.	pages	Description/Authority	CR No.
10 Jan 2010	1	0	All	first go	
25 Jan, 2010	1	1	All	1. Maps with orbital tracks added 2. Section 4 describing general strategy of joint VEX-Akatsuki observations added 3. Annexes updated	

Revisions are indicated by a vertical bar at the outside border.

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	ASPERA		
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1. INTRODUCTION

1.1 Introduction

Venus Express (VEX) is the first ESA mission to Venus. Its payload consists of seven scientific instruments: ASPERA, PFS, SPICAV/SOIR, VeRa and VIRTIS inherited from Mars Express (MEX) and Rosetta, and MAG and VMC, which are new instruments. The spacecraft was inserted in orbit on April 11, 2006 and since June 2006 performs routine science observations. The Nominal Mission ended on October 2, 2007. However the mission extension till the end of 2012 was approved. The VEX Science Operations Centre (VSOC) has the task to coordinate the scientific operations of the VEX mission.

1.2 Scope of the document

The Science Activity Plan (SAP) for the third Extended Mission of Venus Express (SAP-E-3) describes in a structured way the general strategy of scientific activities to be carried out in the third extended mission (September 2010 through January 2012, or MTPs #57-75). It follows the objectives set out in the Science Requirements Document (AD6), and is enhanced with specific information applicable to each phase of the mission, as provided by VSOC and the Science Working Team during the meetings and in written correspondence. It also includes the requests, per MTPs (Medium Term Planning cycle of 28 days), from each individual instrument team for the observations required to fulfil the different objectives for the respective phases. SAP-E-3 contains preliminary MTP timelines (sequences of science cases) agreed by the VEX Science Team. The timelines will be later used as starting point for detailed discussion of each MTP planning cycle. This document will for quite a period be a living document due to its iterative nature. In this respect the document can be considered as a combination of the long term plan and the medium term plan as outlined in the VSOC development plan. Once this document has been established and agreed, it will be used as an input for the detailed short-term plan.

This particular document covers part 1 of the 3-d extended mission (MTP #57-65). The second part (MTP 66-75) will be later addressed in a separate document.

1.3 General observation strategy for Extended Mission

The Venus Express Extended Mission has the following strategic objectives:

- Improve and complete spatial and temporal observational coverage;
- Study in detail the phenomena discovered in the Nominal Mission;
- Take advantage of the new operation modes (case#2 “pendulum”, spot pointing etc)
- Perform pericentre lowering down to the altitude that still allows usual operations without entering aerobraking mode (~170-270 km) and carry out atmospheric drag experiment;
- Carry out coordinated observations with the JAXA Akatsuki spacecraft expected to arrive at Venus in December 2010;
- Perform necessary studies and tests preparing the spacecraft for future aerobraking campaign.

1.4 Applicable Documents

1.4.1 Higher-level documents

AD2: Venus Express Mission Definition Report, ESA-SCI(2001)6, SCI(2001) October 2001

AD3: VEX-RSSD-PL-005_D_2_SAP_implementation_plan

AD4: VEX-RSSD-TN-001_1_b_VEX_Science_Cases

AD5: VEX-RSSD-SP-001_2_0_VSOC_Design_Specification_and_Requirements

AD6: VEX-RSSD-SP-002_1_1_VEX_Science_Requirements_Document

AD7: VEX-RSSD-LI-004_2_0_VEX_science_themes

AD8: VEX-T.ASTR.-TCN-00665_3/0_Science_Cases_Definition_and_Study_Assumptions

AD9: VEX-T.ASTR-TCN-00932_3/0_Synthesis_of_Science_Cases_Analysis, May 29, 2006.

AD10: VEX-T.ASTR-UM-01098_1/1_ Flight User Manual

AD11: VEX-RSSD-TN-0003_1/0_Thermal constraints and science planning

AD12:VEX-RSSD-TN-0006_1/1_Proposal for the post-FAR thermal analysis of the science cases

AD13: Venus Express science cases thermal analyses report, Draft, December 2005.

1.4.2 Documents on the same level

TBD

1.4.3 Lower-level documents

TBD

1.5 Reference Documents

TBD

1.6 Abbreviations

Note: A complete list of all experiment abbreviations and mission phases is given in RD1.

S/C	Spacecraft
CVP	Commissioning and Verification Phase
FoV	Field of View

1.7 Definitions

2. SCIENCE OPERATIONS PLANNING

2.1 Overview

Ten types of orbital science operations (called "science cases") were designed and studied early in the mission planning. They are now used as building blocks to design the Science Activity Plan. In order to check the experiment inputs and to merge them into a consolidated timeline, the VSOC uses a planning concept and two computer based planning tools: MAPPS and EPS. The concept and the tools are described below.

2.2 Science Cases

Science Cases are typical scientific orbital operations to be used as building blocks in the SAP development. The following ten science cases were designed in the early phase of mission planning (AD4, AD8).

Case #1: Pericentre observations (spacecraft sizing case)

Case #2: Off-pericentre observations

Case #3: Apocentre VIRTIS mosaic

Case #4: VeRa bistatic sounding

Case #5: SPICAV stellar occultation

Case #6: SPICAV solar occultation

Case #7: Limb observations

Case #8: VeRa radio occultation

Case #9: VeRa solar corona studies

Case #10: VeRa gravity anomaly studies

The Astrium study of the science cases (AD9) proved their feasibility with some constraints related to the thermal aspects and having seasonal implications.

2.3 SAP planning concept

In order to develop the Science Activity Plan a step-wise approach will be used. A detailed description of the steps are given in the SAP implementation plan (AD3). Current SAP (section 2.3.4) does not impose any limitations on number of cases as soon as the operational constraints (thermal, power, pointing etc) are not violated.

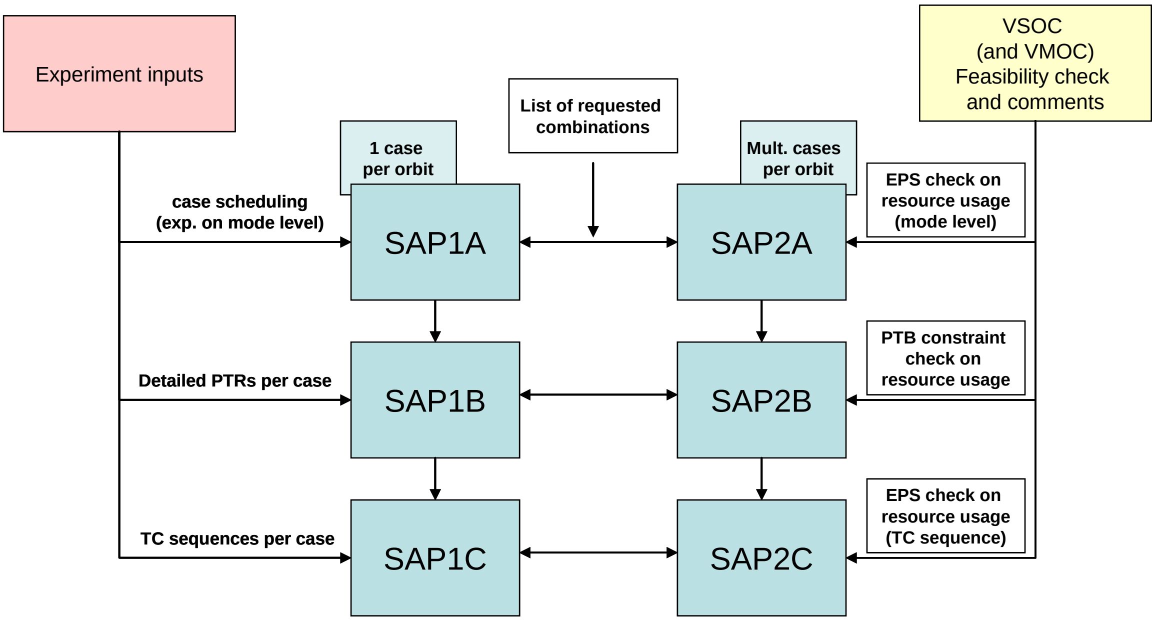


Figure 2.1 *SAP overview diagram*

2.4 MAPPS

MAPPS is a software package that will be used to analyze and plan the mapping of Venus. For Venus Express the EPS (see below) will be integrated within MAPPS. As a result MAPPS will also be able to make the necessary resource validation and conflict checking.

2.5 EPS

The Experiment Planning Software (EPS) is being used in the production of the Science Activity Plan. The particular functions of EPS used for this task are:

- Model and operate experiments on mode level (Experiment Description File, EDF)

- Consistency checks between the instrument timelines (ITL) on mode level
- Consistency check between the sequences and commands contained within the VMIB.
- Consistency checks between the instrument timelines (ITL) and the VMIB.
- ITL verification on mode level, EPS execution is prevented if ITL actions/transitions not consistent with mode.
- Modelling the resource allocation over the operational timeline.
- Output POR files for ingestion into VMOC MCS.

The use of EPS in planning is discussed in more detail in throughout this document. For more information on the capabilities of EPS refer to the user manual [AD xx].

2.6 Venus Express orbit and visibility of the ground stations

The Venus Express was inserted in a polar orbit with a period of 24 hours. The pericentre altitude is maintained between 165 km and 350 km. Pericentre lowering down to ~170km is used atmospheric drag experiment and allows plasma observations in this altitude range. This pericentre lowering does not require any changes in observations strategy or special spacecraft operations. The apocenter altitude is kept at about 66,000 km. In September 2009 the pericentre latitude reached the Northern pole. At the same moment gravitational perturbations that so far pushed the pericentre upwards change their sign and tend to decrease pericentre altitude. Thus the pericentre control maneuvers are needed to keep the spacecraft at safe distance from the atmosphere.

The Venus Express orbit is divided in three parts (figure 2.2): two of them allocated for observations and the third one for telecommunications with the ground station.

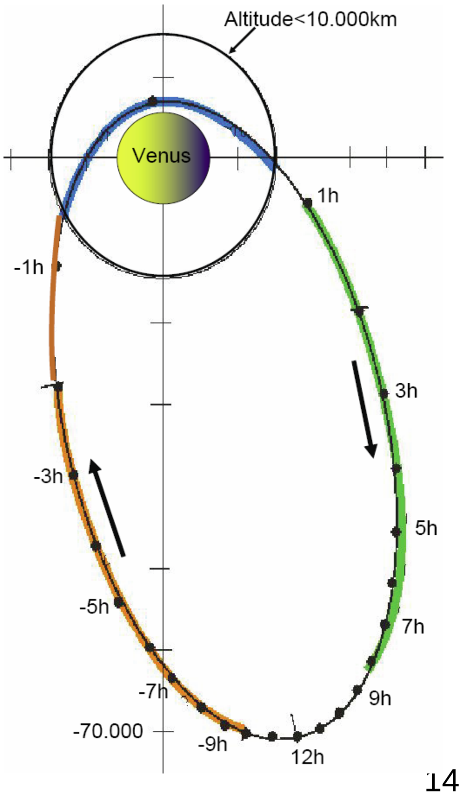


Figure 2.2 *The Venus Express orbit and orbital phases: blue - pericentre observations, brown off-pericentre*

observations in ascending branch, green – telecommunications with Cebreros.

Communication with Earth takes place in each orbit after the pericentre passage, i.e. in the descending part of the orbit. The orbit period is tuned such that the communication window always falls in daytime at the primary ground station Cebreros. Figure 2.3 shows visibility of the Cebreros station from the satellite. The lower of the upper two lines shows the end of telecommunication slot. Its duration does not exceed 10 hours even in case visibility of the planet is longer. The periods when the telecommunication phase ends early enough provide favorable conditions for the Case#3 apocentric mosaic since the observations can be carried out around pericentre. These periods are marked in figure 2.3.

Figure 2.3 *Visibility of the Cebreros ground station from the satellite.*

The ground station at New Norcia, Australia, will be visible around pericentre and will be used for the radio science experiments. The DSN support to the VeRa bi-static radar, solar corona, and some radio occultations as well as the support for the data downlink in the periods of low data rate is agreed between ESA and NASA.

3. THE SAP-E-3 PROPER

This section gives an overview of the Science Activity Plan for Extended Mission as a whole (chapter 3.1). It is followed by descriptions of payload activity during the period covering MTP#57-65 (September 2010 – April 2011). Depending on environmental conditions (occultation, illumination conditions etc.), the science will focus on different mission objectives.

3.1 Science Activity Plan overview

3.1.1 Coverage

The part 1 of the SAP-E-3 (SAP for the 3-d extension) will cover in detail the period from September 2010 till April 2011, or MTP range from #57 till #65.

3.1.2 Mission Objectives

The Venus Express mission aim is a global investigation of the Venus atmosphere, plasma environment and some important aspects of the surface. The detailed Science Objectives of the Venus Express mission are described in AD6.

3.1.3 Main principles of the SAP development

The SAP development was based on the following principles:

1. Complete and uniform coverage of the science themes;
2. Balance between distant and close-up views of the planet;
3. Balance between the observations of the Northern and Southern hemisphere;
4. Synergy between experiments in covering science objectives;
5. Use of multiple science cases in each orbit taking into account mission constraints (thermal, pointing, data volume etc);
6. Even distribution of pericentic science cases with priority given to the solar and Earth radio occultation experiments in specific seasons of the mission;

7. Maximum compliance with the current flight rules.

3.1.4 Extended Mission overview

Extended mission overview is given in the poster in Annex 1.

3.1.5 Instruments objectives and Request Summary

3.1.5.1 Introduction

In this section the individual objectives for each instrument are summarised and their over all operational requests are listed.

3.1.5.2 ASPERA

ASPERA shall be ON during the entire mission thus permanently collecting data. Strategically the ASPERA activity will consist of two parts: survey observations in the beginning of the mission and more specific, more detailed observations performed on selected part of orbit later in the mission. Data is collected at different rates depending on the selected mode.

3.1.5.3 MAG

MAG shall be ON during the entire mission and would permanently collect data. Data is collected at different rates depending on the selected mode.

3.1.5.4 PFS

PFS experiment has not been operational since the beginning of the mission despite of several attempts to unblock the scanning mechanism.

3.1.5.5 SPICAV

Environment dependent. The main goal of the SPICAV experiment is to sound the Venus atmosphere in solar and stellar occultation geometry with sufficient latitude and local time coverage. In these cases SPICAV will define the spacecraft pointing profile. SPICAV stellar occultation that require +Z axis pointing to a star at the limb will be combined with the observations of other +Z looking instruments. In case of stellar occultation observations of dark limb are preferable.

Environment independent. (1). Nadir observations by SPICAV will be performed together with other +Z looking experiments. (2). SPICAV will observe the Venus hydrogen corona. For this purpose in apocentre the s/c will perform a 90 degrees slew from nadir pointing and back.

3.1.5.6 VeRA

The VeRa experiment will perform 4 kinds of *"environment dependent"* observations.

(1) Earth occultation with as good as possible latitude and local time coverage of Venus. Attitude profile in this experiment is the most demanding for the spacecraft AOCS system. It will be provided by the VeRa PI for each radio-occultation individually and will define the pointing for the other experiments. It would be highly desirable to select the orientation of the spacecraft +Z axis during radio occultation so that the +Z looking instruments could simultaneously see the planet.

(2). Bi-static sounding of surface targets. These observations are abandoned since autumn 2007 due to power loss in the S-band.

(3). Solar Corona observations. These observations are abandoned since autumn 2007 due to power loss in the S-band.

(4). Gravity anomaly. This investigation consists of precise tracking of the spacecraft while it passes over global geological formations on Venus solid body.

The VeRa experiment is mainly performed using the ESA New Norcia station. Support from the DSN antennae for the VeRa experiments as well as for the data downlink is agreed between ESA and NASA.

3.1.5.7 VIRTIS

Environment independent. VIRTIS goal is to provide spectral mapping of Venus with moderate spectral resolution and high spectral resolution observations preferably imbedded in the spectral maps. Unfortunately In October 2008 VIRTIS lost its near IR channel due to the failure of cryo-cooler. However the instruments still has imaging capabilities in the UV, visible and near-IR on the day side and high-resolution spectroscopy 2-5 µm range. The off-pericentre and apocentre observations will be organized in special VIRTIS campaigns. They will consist of similar sessions performed on several (about 5) consecutive orbits and would allow continuous temporal coverage of atmospheric dynamical phenomena. In these periods VIRTIS will define VEX operations (e.g. pointing). VIRTIS specific pointing request concerns the apocentric observations in which the experiment will take twelve images organised in a raster of 3x3 images of the whole Venus disc. That would require 12 spacecraft re-pointings by an angle of < 5 deg. These mosaics campaign will be performed in specific seasons of the mission when the telecoms with Cebreros station end relatively early (figure 2.4)

Environment dependent. VIRTIS will provide spectral mapping of specific surface targets in order to search for traces of volcanic activity, provide thermal mapping of geologically interesting regions. This type of activity is possible on the night side only.

3.1.5.8 VMC

Environment independent. The task of VMC is to perform wide-angle imaging of Venus in 4 narrow spectral channels. VMC has no specific pointing requirements.

Environment dependent. VMC will provide imaging of specific surface targets in order to provide thermal maps of geologically interesting regions. This type of activity is possible when the spacecraft is in eclipse.

3.2 MTP #57

3.2.1 *MTP in brief*

MTP #57 covers the period from 22.08 till 18.09.2010 and orbits #1584-1611. This MTP includes eclipse season #15 that ends in orbit #1607 on 14.09.2010. Solar occultations occur after pericentre. Annex 4 gives the local time and latitude coverage in solar occultation experiment. The MTP is hot. The data rate is very low due to recent switch to HGA#2. After the end of quadrature period (orbit #1588) the CEB pass will be shared with Mars Express. That will result in reduction of the pass to 5 hours and further decrease the downlink. Local time at ascending node changes from 12h to 15h. Illumination conditions are similar to those in MTP #49. Night surface observations in eclipse will cover Thetis Regio of Aphrodite Terra and Llorona and Niobe Planitia. At egress from eclipses the Artemis corona can be imaged provided the spacecraft points slightly forward. Figures 3.1 and 3.2 show observations timeline and planet coverage by orbital tracks.

3.2.2 *Environmental conditions*

- Local Time at Ascending Node (LTAN): 12-15 h (similar to MTP#49)
- Eclipse season #15 till orbit #1607
- Surface targets in eclipse: Thetis Regio, Llorona and Niobe Planitia, Artemis corona
- Hot period
- Downlink is very low

3.2.3 *Specific observations and MTP#57 timeline*

Table 3.1 summarizes specific observation requests from the experiments.

Table 3.1 *Specific observation requests in MTP #57*

	Apocentre & ascending arc		**Pericentre pass**	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV/	Spicav-Spicam 2)		Polarization calibration 1)	Solar occs till #1607

SOIR				
VeRa				
VEXADE				
VIRTIS	Day latitude track		Orbits #1584 & 1598: VIR-H meridional [3] Phase function Day side spectroscopy	Orbits #1584 & 1598:VIR-H meridional [3] Night limb tracking Surface
VMC	Day side monitoring		Latitude tracking Phase function Day limb tracking	Surface Night limb tracking
ASPERA				
MAG				

Notes to the table:

1) SPICAV polarization calibration – observations of Venus close to equator in anti-solar direction. It can be combined with VMC phase function sequence or VIRTIS-H meridional cross- section.

2) Joint SPICAV-SPICAM observations of hydrogen distribution in solar corona. Perform in every 5-th orbit until orbit #1607. Can be embedded in case#2.

3) VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP with a step of 14 orbits.

The proposed observations timeline includes four types of orbits and their modifications:

- Type #1: cases 2-1-P-1 (VIR-H meridional cross section in orbits #1584 and 1598)
- Type #2: cases 2-1-P-6-1-6
    - 2-1-P-6-1 if egress occultation is replaced by case#1;
    - 2-1-P-6-6 when eclipse is shorter than 15 min.
- Type #3: cases 2-7-P-6-1-6
- Type #4: cases 2-1-P-7

In ascending arc the pendulum version of case #2 shall be used.

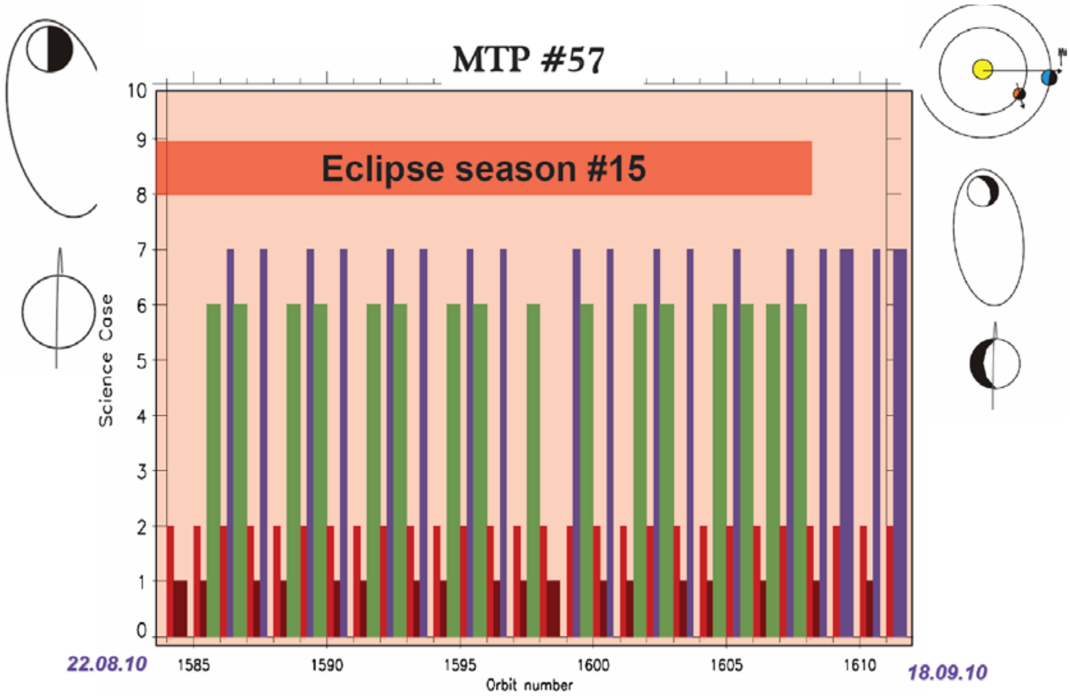


Figure 3.1 *MTP#57 timeline*

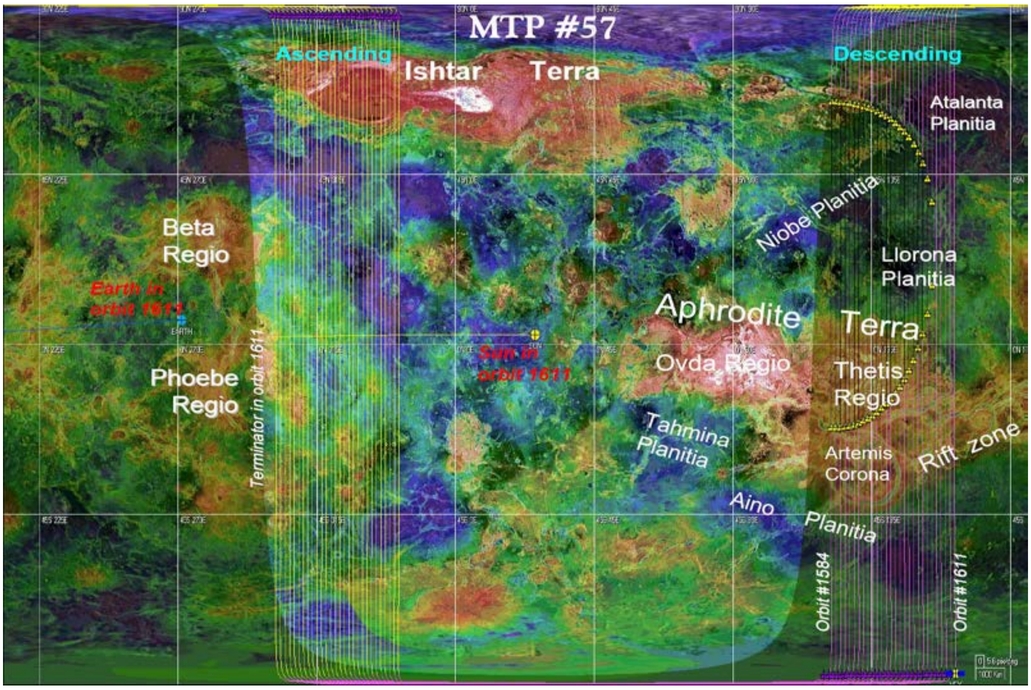


Figure 3.2 *Planet coverage by orbital tracks in MTP#57. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1611).*

3.3 MTP #58

3.3.1 MTP in brief

MTP #58 covers the period from 19.09 till 16.10.2010 and orbits #1612 -1639. This MTP includes neither Earth occultation nor eclipse season. The MTP is hot. The data rate is from moderate to high increasing to the end of MTP since Venus approaches inferior conjunction. Local time at ascending node changes from 15h to 18h. Illumination conditions are similar to those in MTP #50. Surface imaging will be possible either from apocentre by VIRTIS or by pointing the spacecraft to the night side at close approach (VMC). The last 3 orbits belong to the Drag Campaign #4. Figures 3.3 and 3.4 show observations timeline and planet coverage by orbital tracks.

3.3.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 15-18 h (similar to MTP#50)
- Hot season
- Downlink is moderate to high increasing by the end of MTP

3.3.3 Specific observations and MTP#58 timeline

Table 3.2 summarizes specific observation requests from the experiments.

Table 3.2 *Specific observation requests in MTP #58*

	Apocentre & ascending arc		Pericentre pass	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV				Stellar occs
VeRa				
VEXADE			Drag Campaign #4 (DSN) 3)	
VIRTIS	Day latitude track Full mosaic		VIR-H meridional 2) Day spectroscopy	VIR-H meridional 2) Night limb tracking
VMC	Day side monitoring Terminator orbit campaign 1)	Case #2 with off-set to day side	Latitude day tracking (evening) Day limb tracking Surface out of eclipse	Latitude day tracking (morning) Surface out of eclipse
ASPERA				
MAG				

Notes to the table:

1) Terminator orbit campaign: as long as possible imaging of the Southern polar region with minimized duration of CEB pass in several orbits around the terminator orbit (end of MTP#58). In each particular orbit the observations are performed from +3h till -3h.

2) VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP.

3) Drag Campaign #4 begins in orbits #1637-1639: Spacecraft tracking from -2h till +2 h. This part of campaign consists of 3 orbits with DSN tracking.

The proposed timeline consists of alternation of two types of orbits:

- Type #1: cases 2-1-P-1 (VIR-H meridional cross section in orbits #1612 and 1626)
- Type #2: cases 2-1-P-7
- Type #3: cases 2-1-P-5
- Type #4: cases 3-2-P (terminator orbit campaign including VIRTIS full mosaic in the last 3 orbits of the MTP). This period coincides with the drag campaign #4.

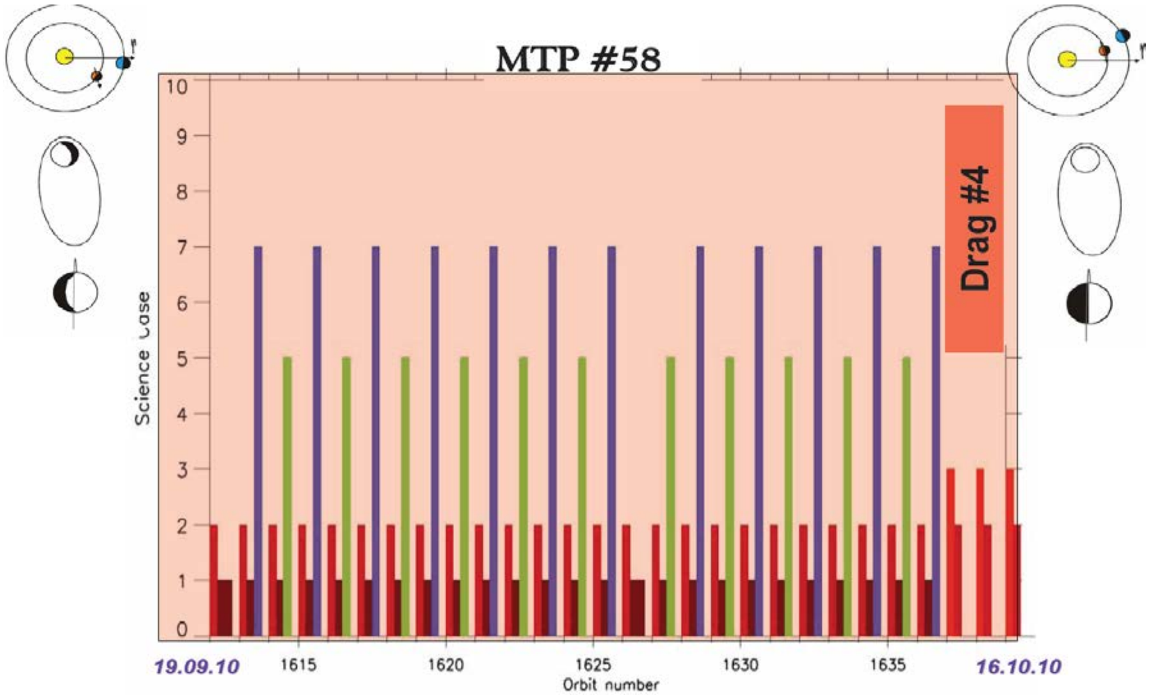


Figure 3.3 *MTP#58 timeline.*

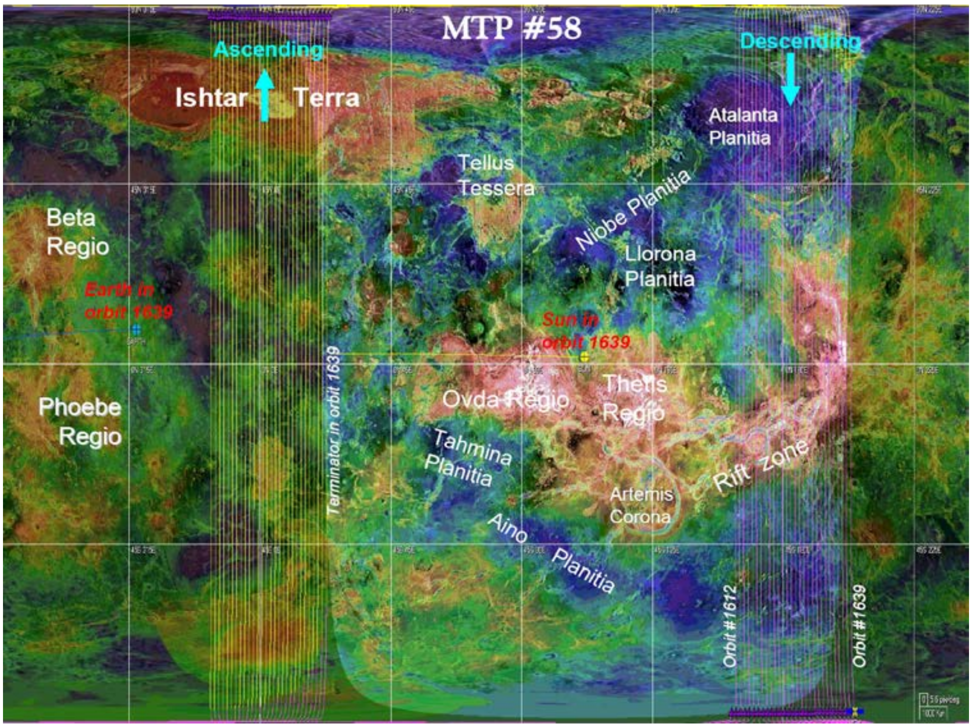


Figure 3.4 *Planet coverage by orbital tracks in MTP#58. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1639).*

3.4 MTP #59

3.4.1 MTP in brief

MTP #59 covers the period from 17.10 till 13.11.2010 and includes orbits #1640-1667. This MTP has neither Earth occultations nor eclipses. The MTP is cold. The data rate is very high since Venus is in inferior conjunction. Local time at ascending node changes from 18h to 21h. Illumination conditions are similar to those in MTP#51. Drag Campaign #4 is preliminary scheduled for the orbits #1648-1654 when pericentre altitude drops to ~165 km. In these orbits the pericenter arc (from -2h to +2h) will be devoted to the spacecraft tracking and no observations in pericentere will be allowed. Right after the drag campaign the pericentre altitude will be raised to 340 km. (So high pericentre altitude was selected in order to meet the Vera requirement of pericentre altitude >225 km in the next Earth occultation season without additional OCMs). Exact scheduling of the orbits devoted to spacecraft tracking will be done later. Figures 3.5 and 3.6 show observations timeline and planet coverage by orbital tracks.

3.4.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 18-21 h (similar to MTP #51)
- Cold season
- Downlink is very high
- Drag Campaign #4 in orbits #1648-1654 with pericentre altitude of 165 km (orbits for s/c tracking tbd)

3.4.3 Specific observations and MTP#59 timeline

Table 3.3 summarizes specific observation requests from the experiments.

Table 3.3 *Specific observation requests in MTP #59*

	Apocentre & ascending arc		**Pericentre pass**	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV	SOIR calibration 1)	Stellar occs		Aeronomic emissions 2)
VeRa				
VEXADE		Drag campaign #4 5)		
VIRTIS	Day side campaign Tracking along terminator 2 full mosaics Night side obs		VIR-H meridional 3)	VIR-H meridional 3) Night limb tracking
VMC	Case#2 Terminator orbit campaign 4)	Case #2 with off-set to day side	Latitude day tracking (evening) Surface out of eclipse	Day latitude tracking (morning) Day limb
ASPERA				
MAG				

Notes to the table:

[1)] SOIR calibration consisting of 2 miniscans, 1 alignment and 1 thermal performed in any part of orbit outside of eclipse.

[2)] Aeronomic day side emissions: Day limb in specific orientation with Sun on +X. Request shall be agreed by VSOC and VIRTIS.

[3)] VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP usually with a step of 14 orbits. However, in MTP#59 the second meridional cross-section is shifted to orbit #1655 due to Drag Campaign.

[4)] Terminator orbit campaign (case #3): as long as possible imaging of the Southern polar region with minimized duration of CEB pass in several orbits around the terminator orbit (beginning of MTP#59). In each particular orbit the observations are performed from +3h till -3h. Can be combined with VIRTIS tracking along terminator.

[5)] Drag Campaign #4 in orbits #1640-1648: Spacecraft tracking from -2h till +2 h. Campaign consist of 6 orbits with DSN tracking and 6 NNO orbits.

The proposed timeline consists of alternation of several types of orbits:

- Type #1: cases 2-1-P-1 (VIR-H meridional cross section in orbits #1640 and 1655)
- Type #2: cases 2-5-P-7 or 2-7-P-5
- Type #3: cases 2-5-P-1 or 2-7-P-1 (closer to the end of MTP when orbit progresses into the day side after pericentre)
- Type #4: cases 3-2-P (terminator orbit campaign including VIRTIS full mosaic in the first 9 orbits of the MTP). These orbits coincide with Drag campaign.

Note that case #3 in terminator orbit campaigns is different from the earlier defined case #3 as VIRTIS mosaic. In this case it looks more like extended case #2.

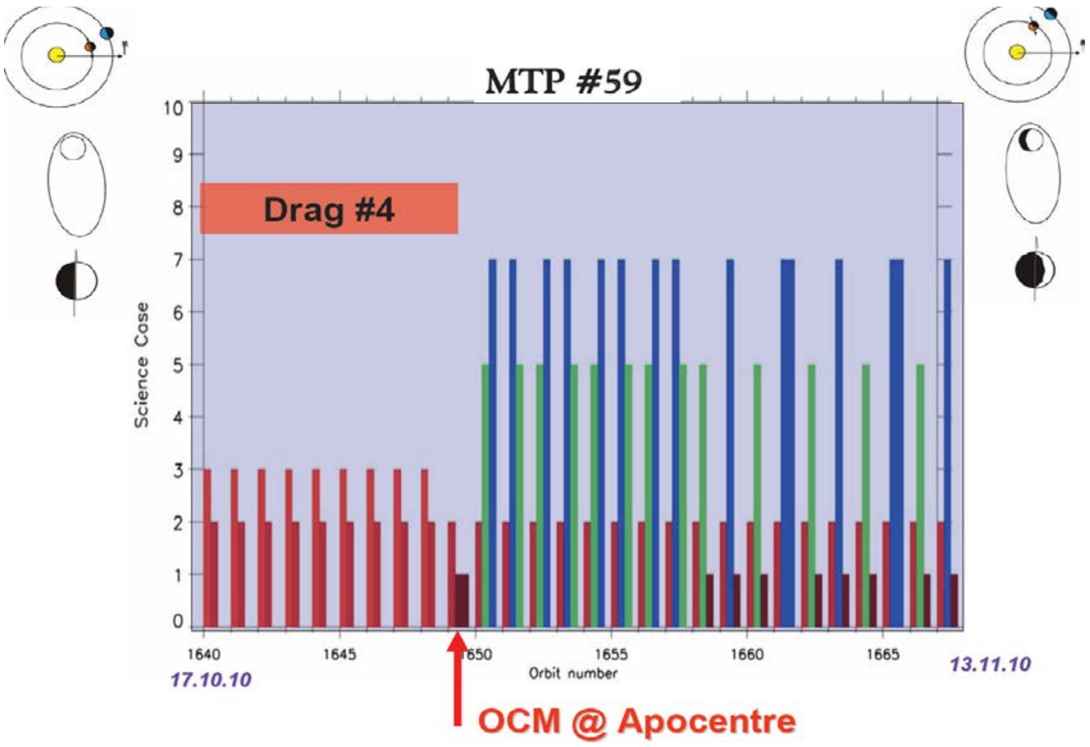


Figure 3.5 *MTP#59 timeline.*

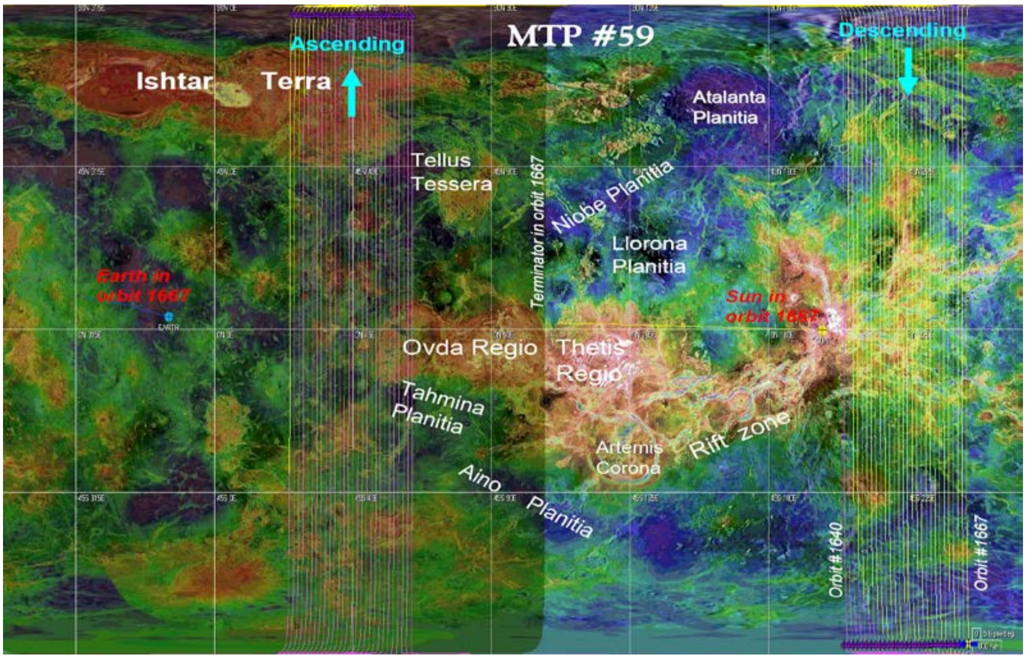


Figure 3.6 *Planet coverage by orbital tracks in MTP#59. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1667).*

3.5 MTP #60

3.5.1 MTP in brief

MTP #60 covers the period from 14.11 till 11.12.2010 and orbits #1668-1695. The MTP includes eclipse season #16 that starts in orbit 1671. Solar occultation occur before pericentre. Annex 4 gives the local time and latitude coverage in solar occultation experiment. The MTP has high to moderate data rate. Local time at ascending node changes from 21h to 24h. Illumination conditions are similar to those of MTP#52. Night surface observations in eclipse at ascending branch cover Ovda Regio of Aphrodite Terra, Tellus tessera and Niobe Planitia. Figures 3.7 and 3.8 show observations timeline and planet coverage by orbital tracks.

3.5.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 21-24 h (similar to MTP#52)
- Eclipse season #16 starts in orbit 1671
- Surface targets: Ovda Regio, Tellus tessera and Niobe Planitia.
- Cold period
- Downlink is high to moderate

3.5.3 Specific observations and MTP#60 timeline

Table 3.4 summarizes specific observation requests from the experiments.

Table 3.4 *Specific observation requests in MTP #60*

	Apocentre & ascending arc		**Pericentre pass**	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV/ SOIR	SOIR calibration [1)]	Stellar occs	Solar occs	Exospheric limb [3)]
VeRa				

VEXADE				
VIRTIS	Day latitude track		VIR-H meridional [2)] VIR-H limb scans [4)] VIR-M spectra VIR-M night limb (every 5-th orbit)	VIR-H meridional [2)] VIR-M day spectra VIR-M night limb (every 5-th orbit)
VMC	Days side monitoring		Surface in eclipse Limb in eclipse	Day latitude tracking till +2h (delayed CEB pass) Phase function Day limb
ASPERA				
MAG				

Notes to the table:

[1)] SOIR calibration consisting of 2 miniscans, 1 alignment and 1 thermal performed in any part of orbit outside of eclipse.

[2)] VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP: at the 1-st and 15-th orbits.

[3)] In-plane exospheric limb observations after pericenter, to be combined with ingress case 6 in every 4-5 orbit.

[4)] VIRTIS-H limb scans using 1). inertial pointing or 2). slow slew with star tracker data for aposteriori attitude reconstruction or 3). “limb track” mode for several attitudes in sequence.

The proposed timeline consists of alternation of several types of orbits:

- Type #1: cases 2-1-P-1 (VIR-H meridional cross section in orbits #1668 and 1682)
- Type #2: cases 2-6-6-P-1 or 2-6-6-P-7 (first 6 orbits of eclipse season when eclipses occur in low latitudes and eclipse is short)

  Type #3: cases 2-5-6-P-1 or 2-1-6-P-1 (when eclipse moves to high latitudes and its duration is >15 min)
- Type #4 (limb orbits): cases 2-6-7-P-7

Note that case #1 after Pericentre shall be extended till about +2h to allow extended day side observations. This causes delay of CEB pass.

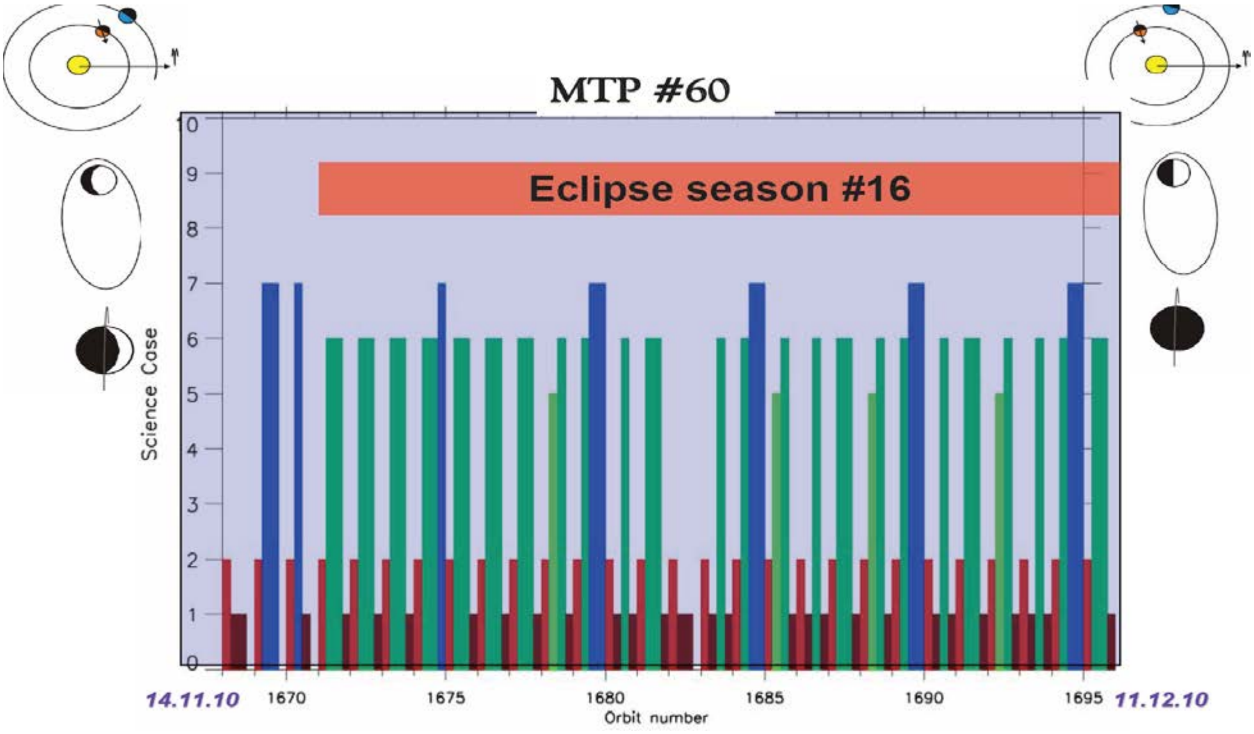


Figure 3.7 *MTP#60 timeline*

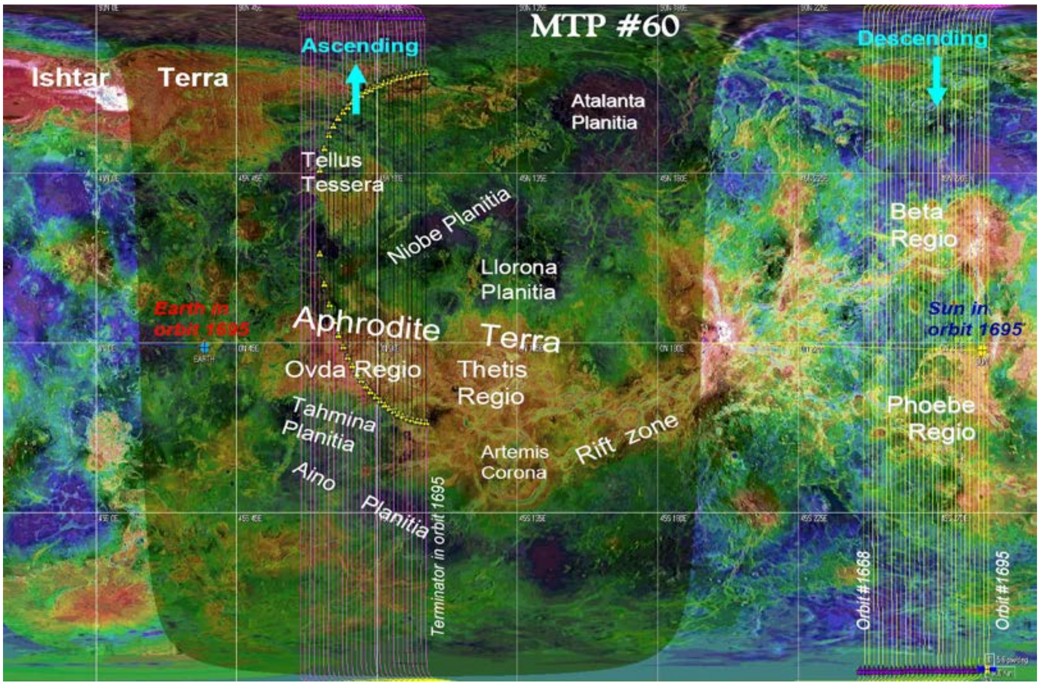


Figure 3.8 *Planet coverage by orbital tracks in MTP#60. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1695).*

3.6 MTP #61

3.6.1 MTP in brief

MTP #61 covers the period from 12.12.2010 till 8.01.2011 and orbits #1696-1723. The MTP contains eclipse season #16, so SPICAV/SOIR is given priority in pericentre observations. Annex 4 gives the local time and latitude coverage in solar occultation experiment. The MTP is cold and has low data rate. Local time at ascending node changes from 0h to 3h, so illumination conditions on the descending arc will be ideal to study the day side. It is preferred to extend observations till about +2:00 by delaying CEB pass. Illumination conditions are similar to those in MTP#45. Night surface observations in eclipse at ascending branch cover Thesis and Ovda Regio, Niobe and Llorona Planitia. Artemis Corona can be observed by pointing the s/c slightly backwards at ingress.

Downlink is very low since Venus is close to quadrature and VEX is still communicating with HGA-2. Quadrature period starts in orbit #1715, so after this orbit only cold observations are possible. This excludes solar occultations in this period. This also affects downlink rate since every second CEB pass will be skipped to allow cooling of VIRTIS. Figure 3.9 and 3.10 show observations timeline and surface coverage.

3.6.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 0-3 h. (similar to MTP#45)
- Cold season
- Eclipse season #16 (contd)
- Surface targets: Thesis and Ovda Regio, Niobe and Llorona Planitia, Artemis Corona
- Low data rate
- Quadrature starts in orbit 1715
- Arrival of the Akatsuki spacecraft

3.6.3 Specific observations and MTP#61 timeline

Table 3.5 summarizes specific observation requests from the experiments.

Table 3.5 *Specific observation requests in MTP #61*

	Apocentre & ascending arc		**Pericentre pass**	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV	SOIR calibration [1)]	Stellar occs	Solar occs NO emission mapping in nadir (every 2-d orbit)	Exospheric limb [3)]
VeRa				
VEXADE				

VIRTIS	Day latitude track		VIR-H meridional [2] VIR-H limb scans [4] VIR-M spectra	VIR-H meridional [2] VIR-M day spectra
VMC	Case#2 pendulum		Surface in eclipse Limb in eclipse	Day latitude tracking till +2h (delayed CEB pass) Phase function Day limb
ASPERA				
MAG				

Notes to the table:

[1] SOIR calibration consisting of 2 miniscans, 1 alignment and 1 thermal performed in any part of orbit outside of eclipse.

[2] VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP: at the 1-st and 15-th orbits.

[3] In-plane exospheric limb observations after pericenter, to be combined with ingress case 6 in every 4-5 orbit.

[4] VIRTIS-H limb scans using 1). inertial pointing or 2). slow slew with star tracker data for aposteriori attitude reconstruction or 3). “limb track” mode for several attitudes in sequence.

The proposed timeline consists of alternation of several types of orbits:

- Type #1: cases 2-1-P-1 (VIR-H meridional cross section in orbits #1696 and 1711)
- Type #2: cases 2-5-6-P-1 or 2-1-6-P-1
- Type #4 (limb orbits): cases 2-6-7-P-7

Type #5: cases 2-1-P-7 or 2-5-P-7 (in quadrature when hot observations are not allowed)

Note that, especially in the first part of the MTP, the case #1 after pericentre shall be extended till +2h that causes delay of CEB pass.

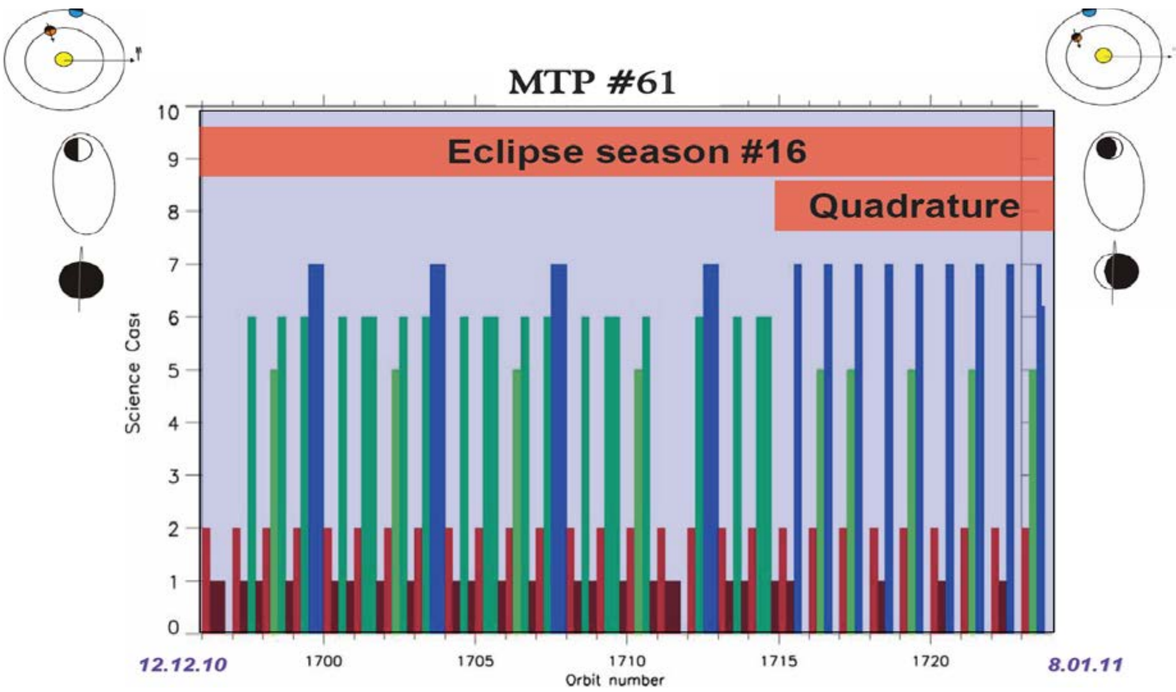


Figure 3.1 MTP#61 timeline

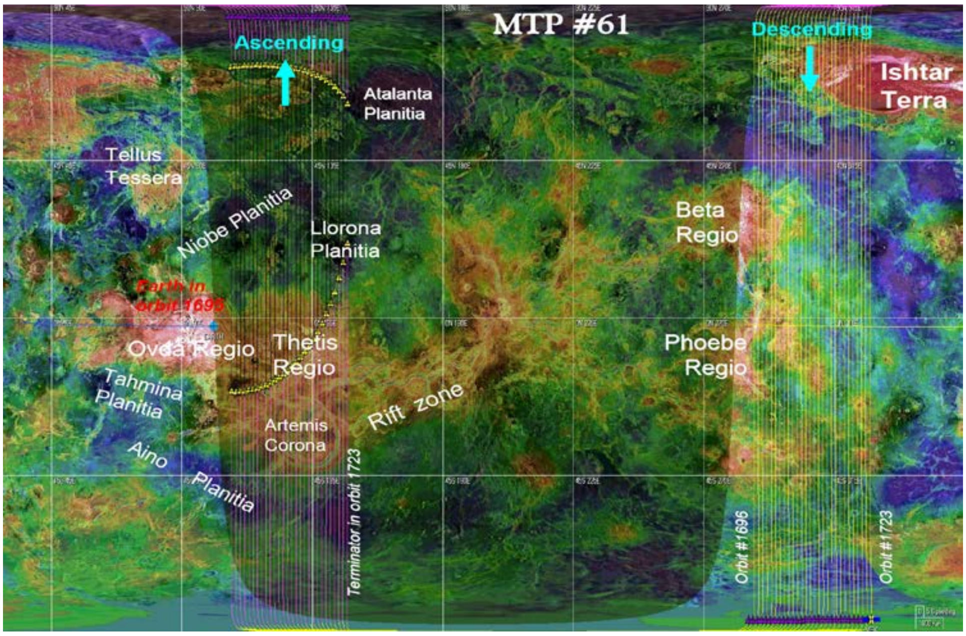


Figure 3.2 *Planet coverage by orbital tracks in MTP#61. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1723).*

3.6.4 Joint observations with Akatsuki

In the middle of MTP #61 (around December 15, 2010) the JAXA Akatsuki spacecraft is expected to arrive at Venus and be inserted in an equatorial orbit (Fig. 3.11). General strategy of joint Venus Express – Akatsuki observations is described in Section 4.

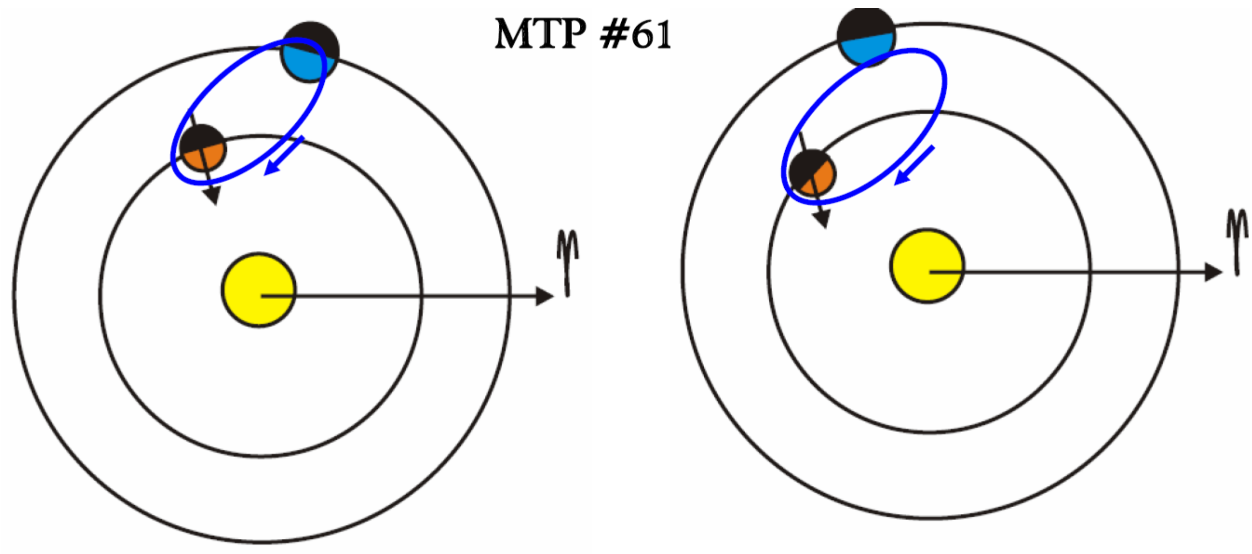


Figure 3.11 *Sketch of the relative positions of Earth, Venus, Sun, Venus Express (black arrow) and Akatsuki (blue ellipse) orbits in the beginning (left) and in the end (right) of MTP#61.*

Although it is expected that in this phase the highest priority for Akatsuki mission will be in orbit commissioning of the spacecraft and payload, some joint observations can be foreseen:

1). Simultaneous imaging and spectroscopy on the night side.

2). Day side imaging at different phase angles.

3). Sequential observations of cloud motions

More detailed timeline of the joint observations is currently under development.

3.7 MTP #62

3.7.1 MTP in brief

MTP #62 covers the period from 9.01 till 5.02.2011 and orbits #1724-1751. Eclipse season #16 ends in orbit 1726. Annex 4 gives the local time and latitude coverage in solar occultation experiment. Earth occultation season #10 begins in orbit 1729. The MTP is cold. Local time at ascending note changes from 3h to 6h that make this period similar to MTP #46. The data rate changes from very low to very high due to switch from HGA2 to HGA1 in orbit 1732. The MTP completely overlaps with quadrature that precludes hot observations. Thus no solar occultations will be performed. However, Earth occultations are possible during quadrature period. Figures 3.12 and 3.13 show observations timeline and planet coverage by orbital tracks. Local time and latitude coverage in the radio-occultation experiment in season #10 as well as the table with detailed scheduling are given in Annex 3.

3.7.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 3h-6h (similarity to MTP 46)
- Cold season
- Quadrature period till orbit 1750 → only cold observations are possible. However, slightly hot VeRa observations are allowed
- HGA2 → HGA2 switch in orbit 1732
- Data rate from very low to very high

3.7.3 Specific observations and MTP#62 timeline

Table 3.6 summarizes specific observation requests from the experiments.

Table 3.6 *Specific observation requests in MTP #62*

	Apocentre & ascending arc		Pericentre pass	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV	SOIR calibration [1]	Stellar occs	NO emission mapping in nadir (every 2-d orbit) SO_2 obs nadir at terminator in the end of MTP	SO_2 obs nadir at terminator in the end of MTP
VeRa				Case #8 according to VeRa Table
VEXADE				
VIRTIS	Day latitude track		VIR-H meridional [2] VIR-H limb scans [3] VIR-H co-located with VeRa ?	VIR-H meridional [2] VIR-M day spectra
VMC	Day side monitoring Terminator orbit campaign [4]		Morning sector	Day latitude tracking Evening sector
ASPERA				
MAG				

Notes to the table:

1) SOIR calibration consisting of 2 miniscans, 1 alignment and 1 thermal performed in any part of orbit outside of eclipse.

2) VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP: at the 1-st and 15-th orbits.

3) VIRTIS-H limb scans using 1). inertial pointing or 2). slow slew with star tracker data for aposteriori attitude reconstruction or 3). "limb track" mode for several attitudes in sequence.

4) Terminator orbit campaign: as long as possible imaging of the Southern polar region with minimized duration of CEB pass in several orbits around the terminator orbit. In each particular orbit the observations are performed from +3h till -3h. The observation is cold.

The main limitation in MTP #62 results from that it falls in the quadrature period when only cold observations (except for VeRa) are allowed. The proposed timeline consists of alternation of several types of orbits:

Before Earth occultation season starts in orbit #1729

- Type #1: cases 2-5-P-7 or 2-1-P-7 (case #7 after pericentre should be cold)

During the Earth occultation season

- Type #2: cases 2-5-P-8-8 or 2-7-P-8-8
- Type #3 (terminator orbits): cases 3-2-1-P-8-8 or 3-2-1-P-7

Note that case #3 in terminator orbit campaigns is different from the earlier defined case #3 as VIRTIS mosaic. Here it looks more like extended case #2.

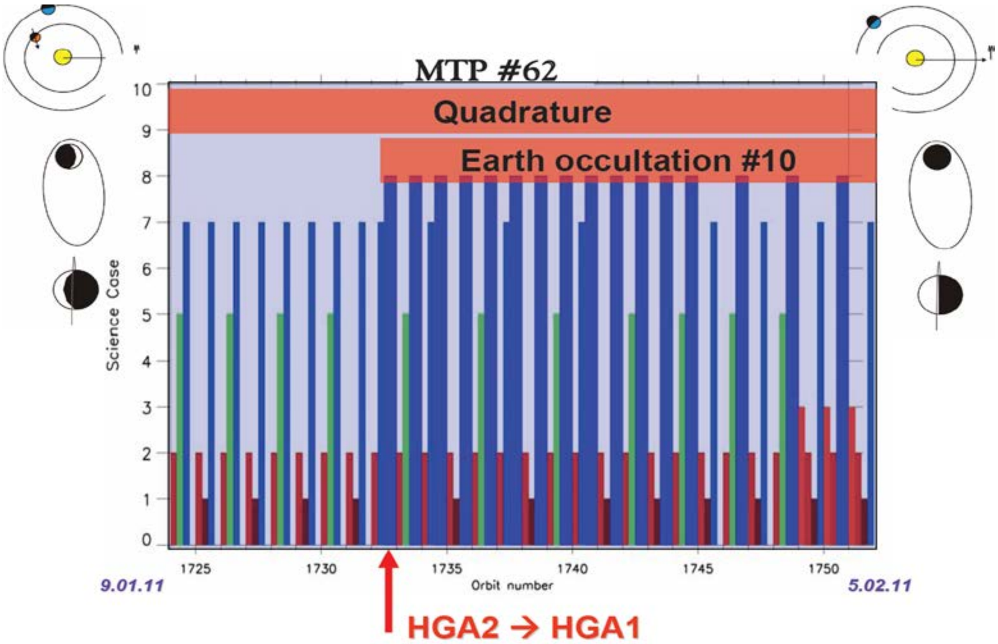


***Figure 3.32** MTP#62 timeline*

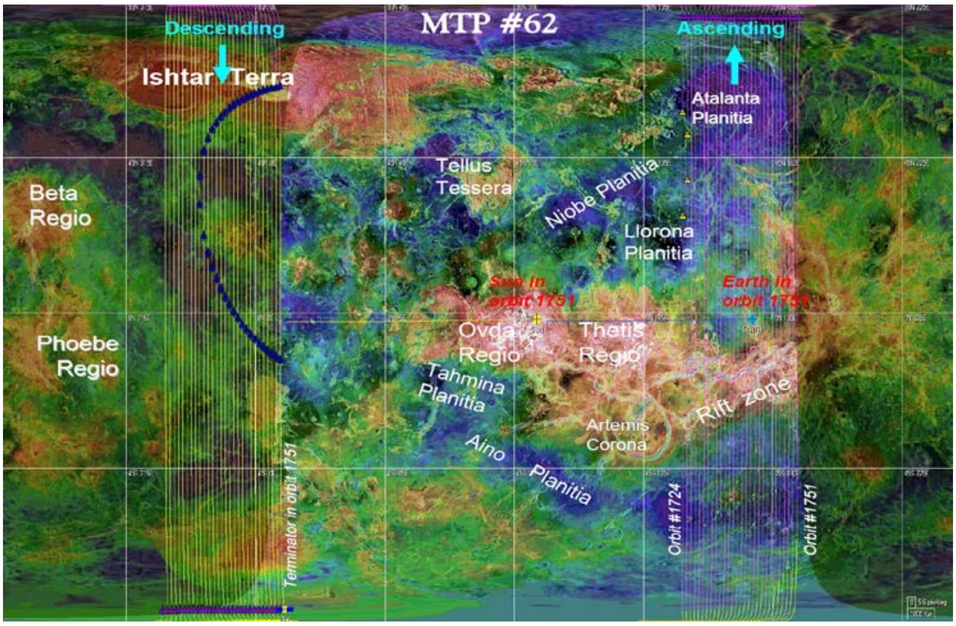


Figure 3.43 *Planet coverage by orbital tracks in MTP#62. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1751).*

3.7.4 Joint observations with Akatsuki

General strategy of joint Venus Express – Akatsuki observations is described in Section 4. Figure 3.14 shows the sketch of relative positions of VEX and Akatsuki orbits in this MTP.

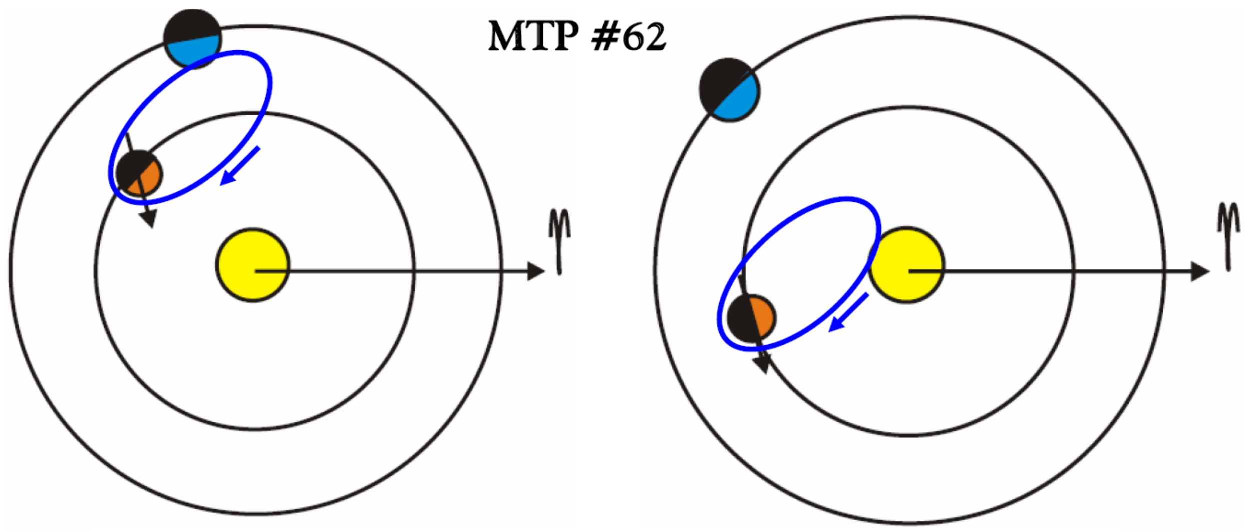


Figure 3.14 *Sketch of the relative positions of Earth, Venus, Sun, Venus Express (black arrow) and Akatsuki (blue ellipse) orbits in the beginning (left) and in the end (right) of MTP#62.*

The following joint VEX –Akatsuki observations will be possible in MTP #62.

1). Simultaneous imaging and spectroscopy on the night side.

2). Day side imaging at different phase angles.

3). Sequential observations of cloud motions

4). Simultaneous observations of cloud morphology: VEX polar regions, Akatsuki – tropics.

5). Co-located and probably simultaneous sounding of temperature structure by radio experiments. This will be the ONLY opportunity for joint observations in 2011.

More detailed timeline of the joint observations is currently under development.

3.8 MTP #63

3.8.1 MTP in brief

MTP #63 covers the period from 6.02 till 5.03.2011 and orbits #1752-1779. Earth occultation season #10 continues in this MTP. The MTP is hot and has high to moderate data rate. Local time at ascending note changes from 6h to 9h that makes it similar to MTP#47. Figures 3.15 and 3.16 show observations timeline and planet coverage by orbital tracks. Local time and latitude coverage in the radio-occultation experiment in season #10 as well as the table with detailed scheduling are given in Annex 3.

3.8.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 6 - 9 h (similarity to MTP #47)
- Hot MTP.
- Earth occultation season #10 continues.

- Downlink is moderate

3.8.3 Specific observations and MTP#63 timeline

Table 3.7 summarizes specific observation requests from the experiments.

Table 3.7 *Specific observation requests in MTP #63*

	Apocentre & ascending arc		Pericentre pass	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV	SOIR calibration [1)] SPICAV-SPICAM [5)]	Stellar occs	SO_2 obs in nadir at terminator in the beginning of MTP	
VeRa				Case #8 according to VeRa Table
VEXADE				
VIRTIS	Day latitude track Night obs		VIR-H meridional [2)] VIR-H limb scans [3)] VIR-H co-located with VeRa ?	VIR-H meridional [2)] VIR-M day spectra
VMC	Case#2 Terminator orbit campaign [4)]		Morning sector Day latitude tracking	Evening sector
ASPERA				
MAG				

Notes to the table:

1) SOIR calibration consisting of 2 miniscans, 1 alignment and 1 thermal performed in any part of orbit outside of eclipse.

2) VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP: at the 1-st and 15-th orbits.

3) VIRTIS-H limb scans using 1). inertial pointing or 2). slow slew with star tracker data for aposteriori attitude reconstruction or 3). “limb track” mode for several attitudes in sequence.

4) Terminator orbit campaign: as long as possible imaging of the Southern polar region with minimized duration of CEB pass in several orbits around the terminator orbit. In each particular orbit the observations are performed from +3h till -3h. The observation is cold.

5) Joint SPICAV-SPICAM observations of hydrogen distribution in solar corona. Perform in every 5-th orbit after orbit #1771. Can be embedded in case#2.

The proposed timeline consists of alternation of several types of orbits:

- Type #1: cases 2-1-P-8-8
- Type #2 (terminator orbits): cases 3-2-1-P-8-8 or 3-2-1-P-7 or 3-2-1-P-1
- Type#3: cases 2-7-P-5
- Type#4: cases 2-1-P-5

Note that case #3 in terminator orbit campaigns is different from the earlier defined case #3 as VIRTIS mosaic. In this case it looks more like extended case #2.

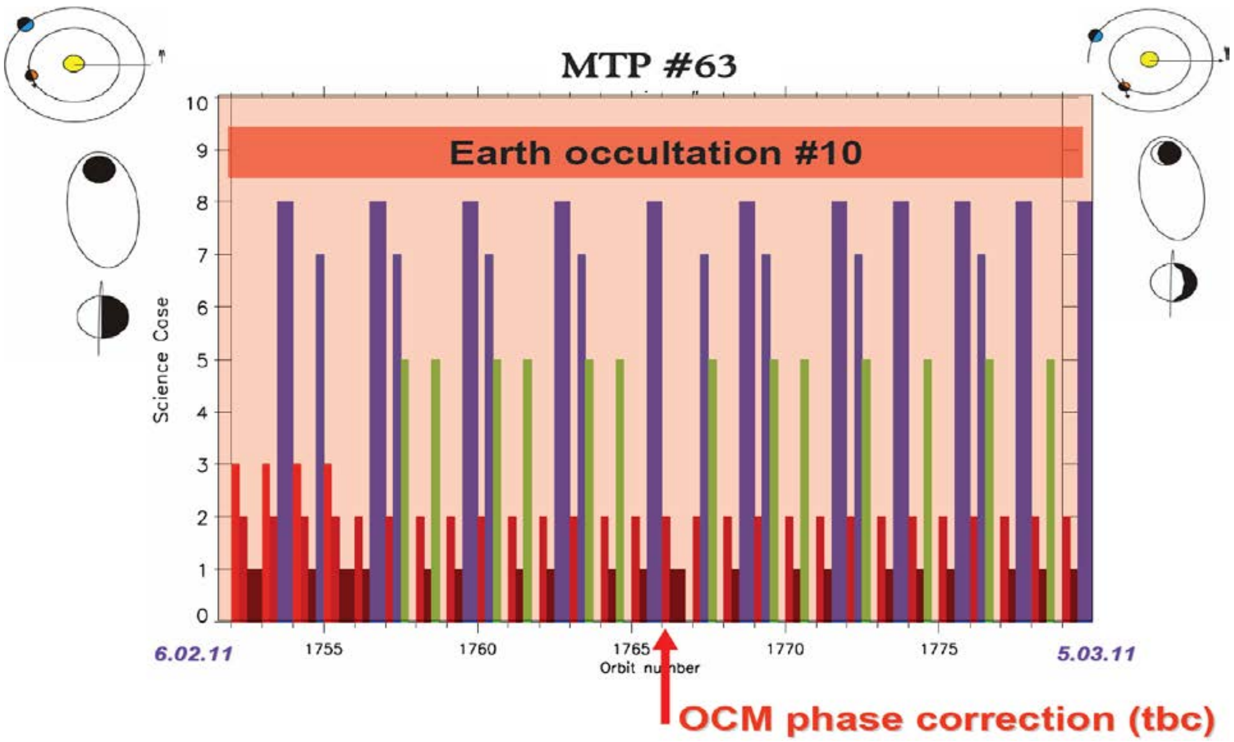


Figure 3.15 *MTP #63 timeline.*

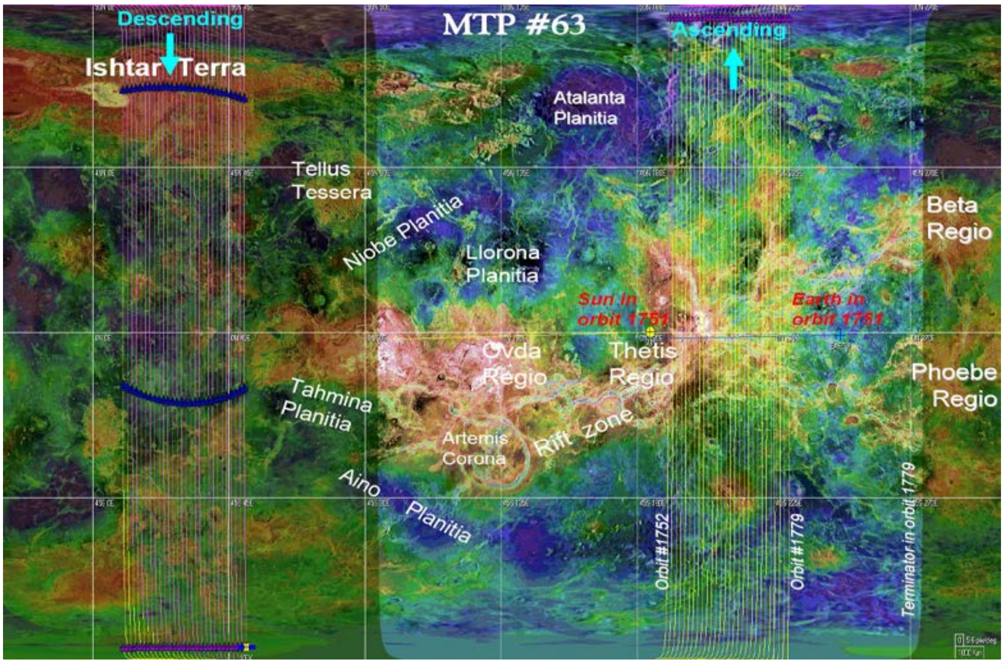


Figure 3.16 *Planet coverage by orbital tracks in MTP#63. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1779).*

3.8.4 Joint observations with Akatsuki

General strategy of joint Venus Express – Akatsuki observations is described in Section 4. Figure 3.17 shows the sketch of relative positions of VEX and Akatsuki orbits in this MTP.

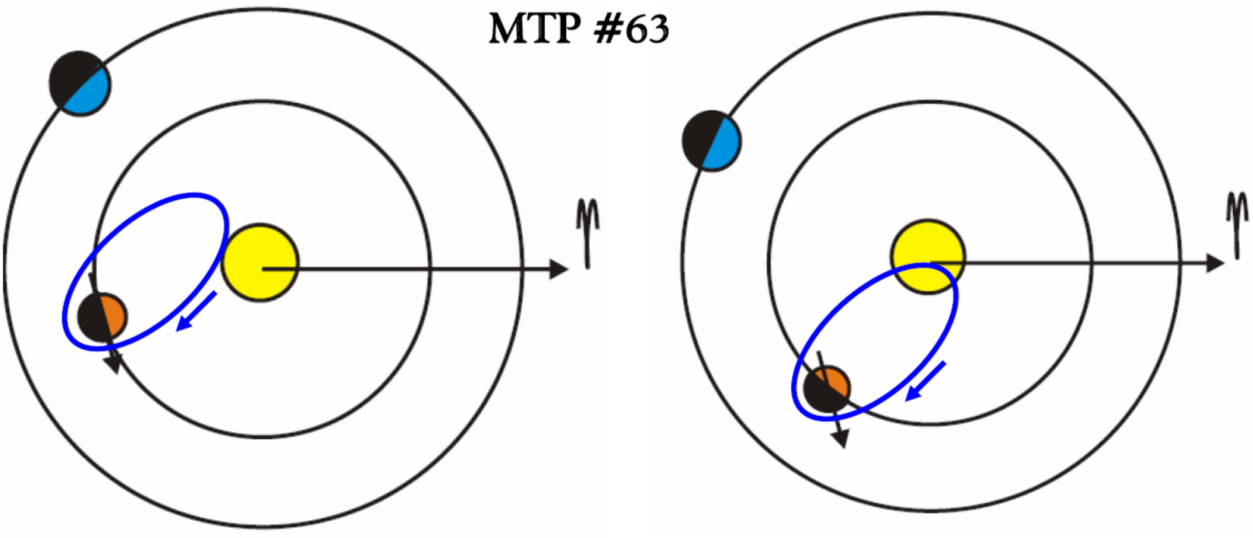


Figure 3.17 *Sketch of the relative positions of Earth, Venus, Sun, Venus Express (black arrow) and Akatsuki (blue ellipse) orbits in the beginning (left) and in the end (right) of MTP#63.*

The following joint VEX –Akatsuki observations will be possible in MTP #63.

1. Simultaneous observations of cloud morphology: VEX polar regions, Akatsuki – tropics.
2. Co-located and probably simultaneous sounding of temperature structure by radio experiments. This will be the ONLY opportunity for joint observations in 2011.
3. Day side imaging at different phase angles.
4. Sequential observations of cloud motions

More detailed timeline of the joint observations is currently under development.

3.9 MTP #64

3.9.1 MTP in brief

MTP #64 covers the period 6.03 - 2.04.2011 and orbits #1780-1807. The Earth occultation season #10 ends in orbit 1797. Eclipse season #17 starts in orbit 1785 with eclipses occurring after pericenter. Annex 4 gives the local time and latitude coverage in solar occultation experiment. The MTP is hot and moderate to low data rate. Local time at ascending note changes from 9h to 12h that makes it similar to MTP#48. Figures 3.18 and 3.19 show observations timeline and planet coverage by orbital tracks. Night surface observations in eclipse in descending branch cover Ovda Regio and Manatum Tessera, Tellus Tesera. Tahmina Planitia can be observed by pointing the s/c slightly forward at egress. Local time and latitude coverage in the radio-occultation experiment in season #10 as well as the table with detailed scheduling are given in Annex 3.

3.9.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 9-12 h (similarity to MTP #48)
- Earth occultations season #10 ends in orbit 1797
- Solar occultation season #17 starts in orbit 1785
- Surface targets: Ovda Regio, Manatum and Tellus Tessera, Tahmina PLanitia.
- Hot period
- Downlink from moderate to low

3.9.3 Specific observations and MTP#64 timeline

Table 3.8 summarizes specific observation requests from the experiments.

Table 3.8 *Specific observation requests in MTP #64*

	Apocentre & ascending arc		**Pericentre pass**	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV	SOIR calibration [1)] SPICAV-SPICAM [4)]	Stellar occs		Solar occs
VeRa				Case #8 according to VeRa Table
VEXADE				
VIRTIS	Day latitude track Night obs		VIR-H meridional [2)] VIR-H limb scans [3)] VIR-M day spectra	VIR-H meridional [2)]

			VIR-H co-located with VeRa ?	
VMC	Day side monitoring		Day latitude tracking	Surface obs
ASPERA				
MAG				

Notes:

1) SOIR calibration consisting of 2 miniscans, 1 alignment and 1 thermal performed in any part of orbit outside of eclipse.

2) VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP: at the 1-st and 15-th orbits.

3) VIRTIS-H limb scans using 1). inertial pointing or 2). slow slew with star tracker data for aposteriori attitude reconstruction or 3). “limb track” mode for several attitudes in sequence.

4) Joint SPICAV-SPICAM observations of hydrogen distribution in solar corona. Perform in every 5-th orbit. Can be embedded in case#2.

The proposed timeline consists of alternation of several types of orbits:

- Type #1: cases 2-1-P-8-8 or 2-5-P-8-8
- Type #2 : cases 2-5-P-6-6 or 2-1-P-6-6
- Type#3: cases 2-1-P-6-1 or 2-1-P-6-5 in which egress occultation is replaced by case #1 or #5

Note that in ascending branch the pendulum version of case#2 shall be used.

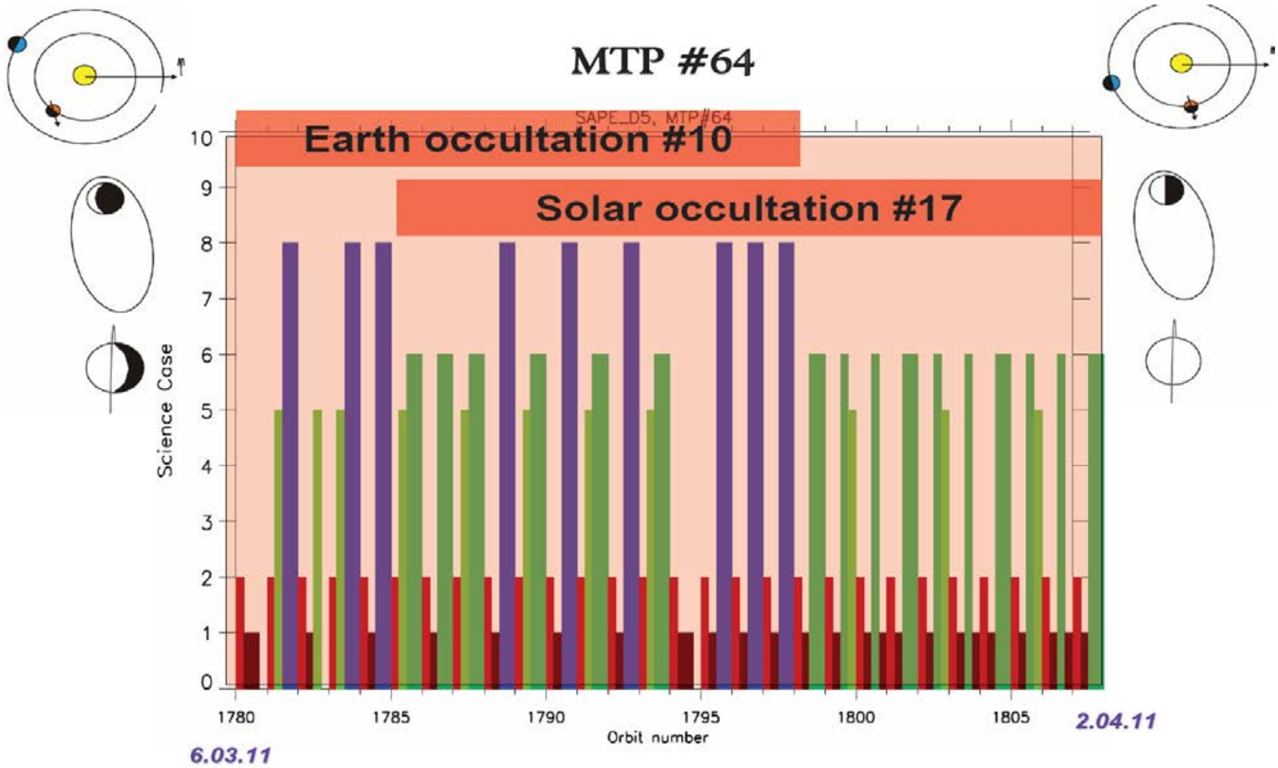


Figure 3.18 *MTP#64 timeline*

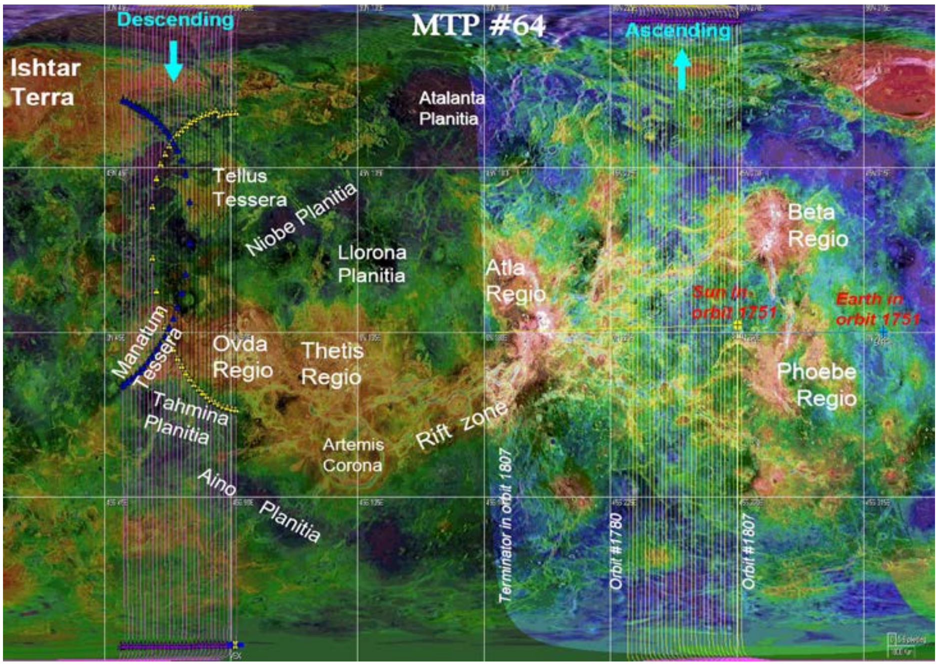


Figure 3.19 *Planet coverage by orbital tracks in MTP#64. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1807).*

3.9.4 Joint observations with Akatsuki

General strategy of joint Venus Express – Akatsuki observations is described in Section 4. Figure 3.20 shows the sketch of relative positions of VEX and Akatsuki orbits in this MTP.

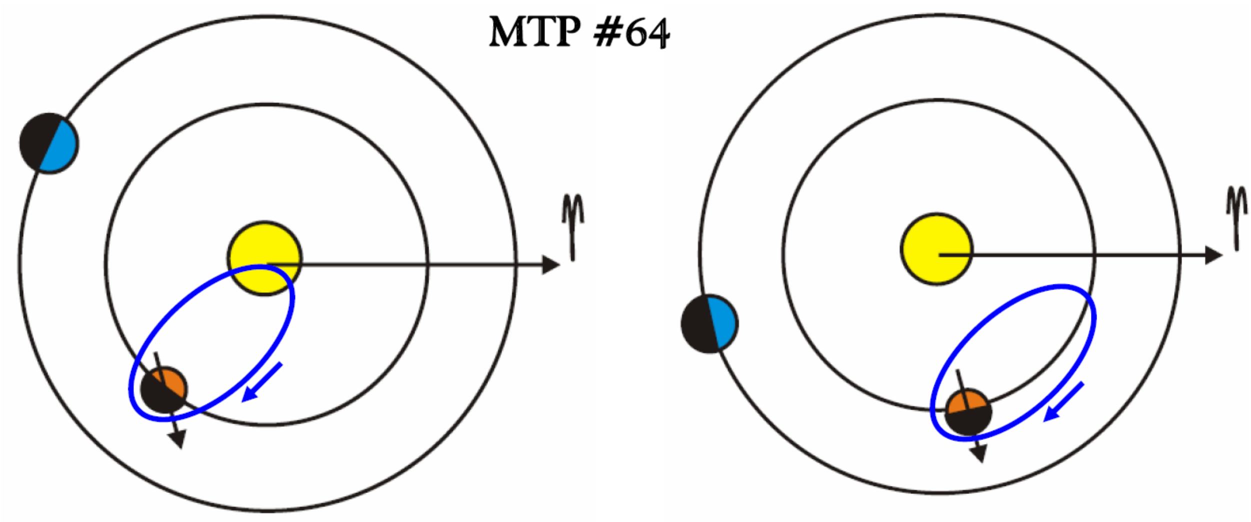


Figure 3.20 *Sketch of the relative positions of Earth, Venus, Sun, Venus Express (black arrow) and Akatsuki (blue ellipse) orbits in the beginning (left) and in the end (right) of MTP#64.*

The following joint VEX –Akatsuki observations will be possible in MTP #64.

1. Simultaneous observations of cloud morphology: VEX polar regions, Akatsuki – tropics.
2. Co-located and probably simultaneous sounding of temperature structure by radio experiments. This will be the ONLY opportunity for joint observations in 2011.
3. Day side imaging at different phase angles.
4. Sequential observations of cloud motions

More detailed timeline of the joint observations is currently under development.

3.10 MTP #65

3.10.1 MTP in brief

MTP #65 covers the period from 3.04 till 30.04.2011 and orbits #1808-1835. Eclipse season #17 continues till orbit 1830 (tbc) with solar occultation after pericentre. Annex 4 gives the local time and latitude coverage in solar occultation experiment. The MTP is hot and has low data rate. Local time at ascending node changes from 12h to 15h that makes the MTP similar to MTP#57. Night surface observations in eclipse in descending branch cover Ovda and Thesis Regio, Tellus Tesera and Niobe Planitia. Figures 3.21 and 3.22 show observations timeline and planet coverage by orbital tracks.

3.10.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 12-15 h (similarity to MTP #57)
- Solar occultation season #17 till orbit #1830 (tbc)
- Surface targets: Ovda and Thesis Regio, Tellus Tessera, Niobe Planitia
- Hot period
- Downlink is low

3.10.3 Specific observations and MTP#65 timeline

Table 3.9 summarizes specific observation requests from the experiments.

Table 3.9 *Specific observation requests in MTP #65*

	Apocentre & ascending arc		**Pericentre pass**	
Experiment	**< -3h**	**-3h….-1h**	**-1h…Per**	**Per… +1h**
SPICAV/ SOIR	Spicav-Spicam 2)		Polarization calibration 1)	Solar occs till #1830 (tbc)

VeRa				
VEXADE				
VIRTIS	Day latitude track Night surface		VIR-H meridional [3] Phase function	VIR-H meridional [3] Night limb tracking
VMC	Day side monitoring		Latitude tracking Phase function Day limb tracking	Surface Night limb tracking
ASPERA				
MAG				

Notes to the table:

[1] SPICAV polarization calibration – observations of Venus close to equator in anti-solar direction. It can be combined with VMC phase function sequence or VIRTIS-H meridional cross- section.

[2] Joint SPICAV-SPICAM observations of hydrogen distribution in solar corona in every 5-th orbit. Can be embedded in case#2.

[3] VIRTIS-H meridional cross-section: observations from -2h till +2h in local nadir or slightly off-nadir to cover all latitudes. Repeated twice per MTP.

The proposed timeline includes four types of orbits and their modifications:

- Type #1: cases 1-P-1 (VIR-H meridional cross section)
- Type #2: cases 2-1-P-6-1-6
    - 2-1-P-6-1 if egress occultation is replaced by case#1
    - 2-1-P-6-5 if egress occultation is replaced by stellar occ
    - 2-1-P-6-6 when eclipse is shorter than 15 min.
- Type #3: cases 2-1(5,7)-P-7(5) after the end of eclipse season

Note that in ascending branch the pendulum version of case#2 shall be used.

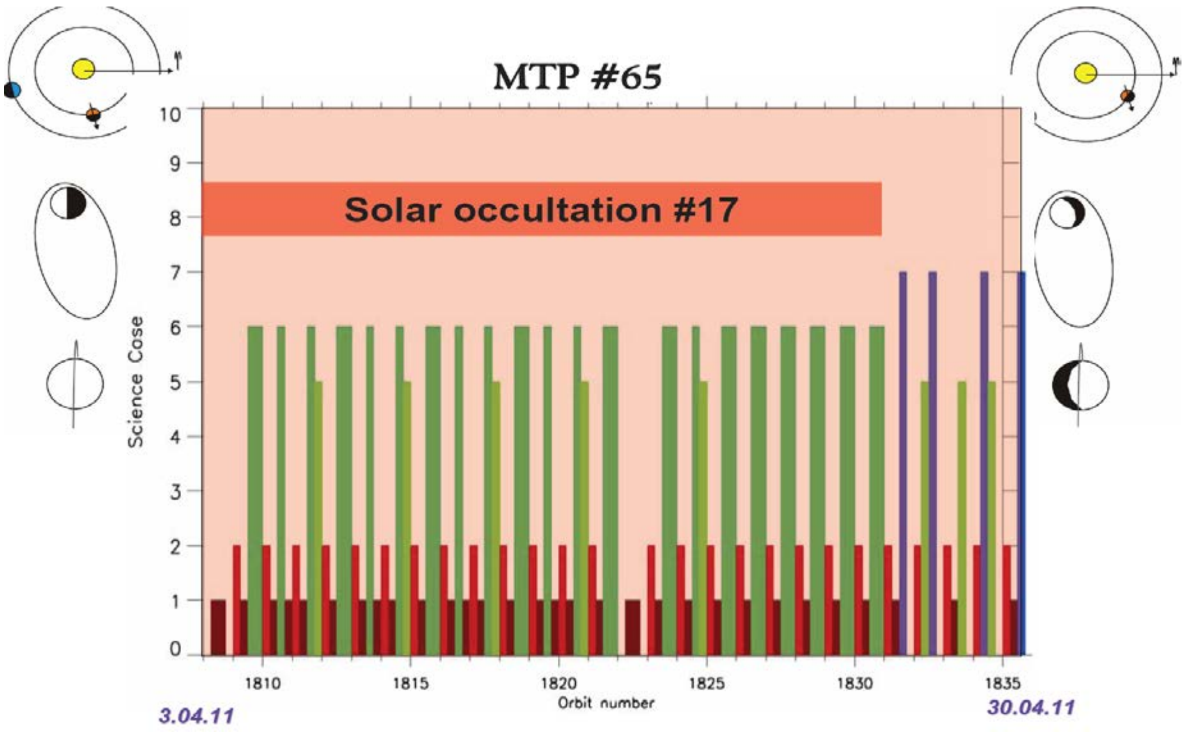


Figure 3.21 MTP#65 timeline

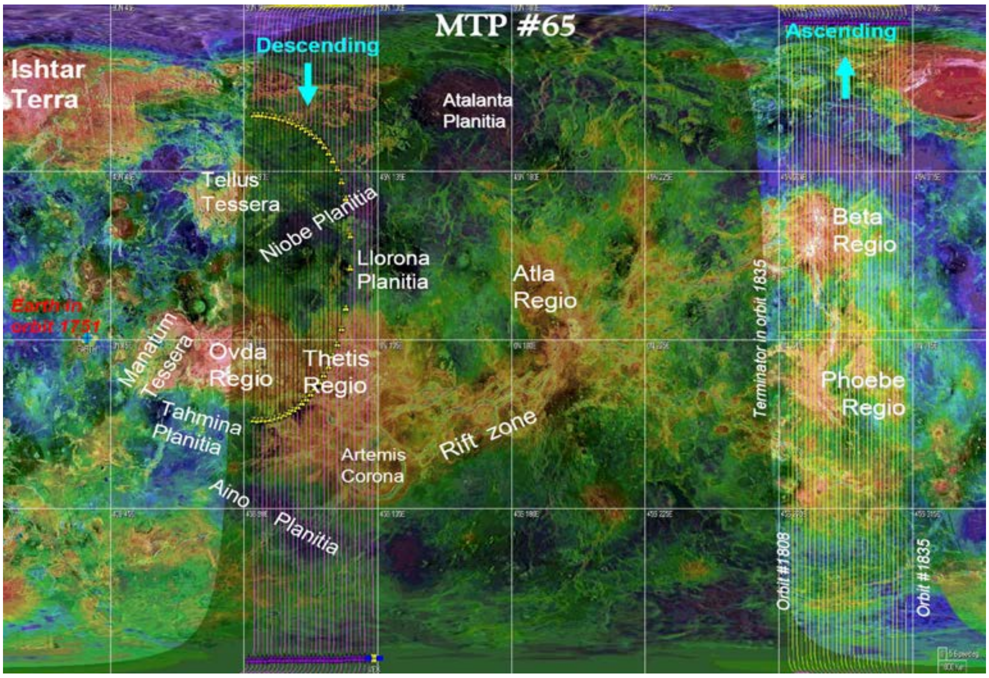


Figure 3.22 *Planet coverage by orbital tracks in MTP#65. Positions of terminator, Sun and Earth are shown for the last orbit of the MTP (#1835).*

3.10.4 Joint observations with Akatsuki

General strategy of joint Venus Express – Akatsuki observations is described in Section 4. Figure 3.23 shows the sketch of relative positions of VEX and Akatsuki orbits in this MTP.

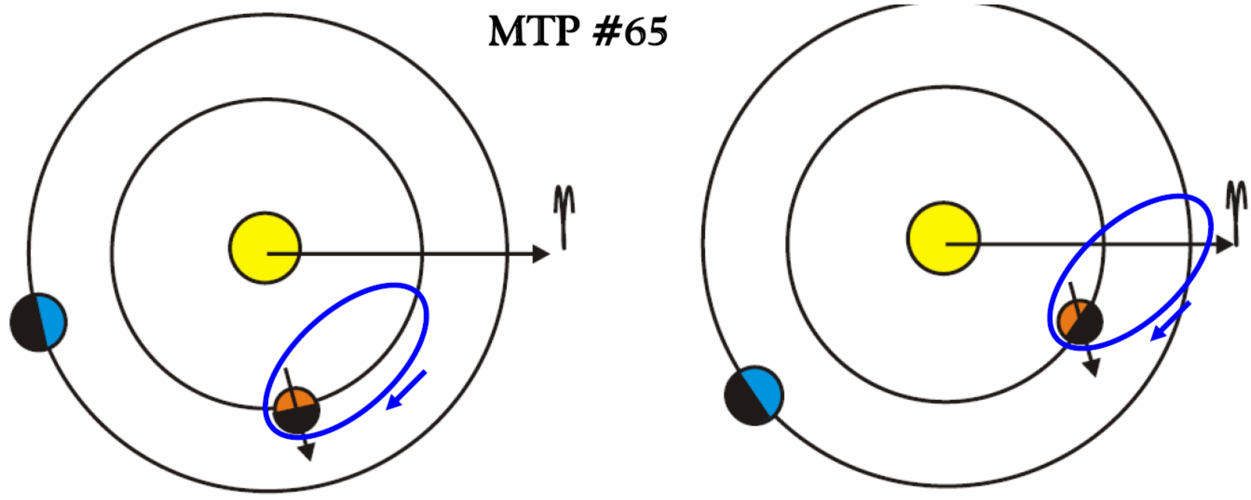


Figure 3.23 *Sketch of the relative positions of Earth, Venus, Sun, Venus Express (black arrow) and Akatsuki (blue ellipse) orbits in the beginning (left) and in the end (right) of MTP#65.*

The following joint VEX –Akatsuki observations will be possible in MTP #65.

1. Simultaneous observations of cloud morphology: VEX polar regions, Akatsuki – tropics.
2. Day side imaging at different phase angles.
3. Sequential observations of cloud motions

More detailed timeline of the joint observations is currently under development.

4. STRATEGY OF COORDINATED OBSERVATIONS WITH THE JAXA AKATSUKI MISSION

In the middle of December 2010 the Akatsuki spacecraft (JAXA, Japan) is expected to arrive at Venus that would create a unique chance to simultaneously study Venus by two orbital spacecraft. In January 2011 (VEX MTP 61-62) after several weeks of in orbit manoeuvring and commissioning Akatsuki will begin science observations. The JAXA spacecraft will deliver a set of remote sensing instruments: five cameras covering spectral range from UV to thermal IR and a radio-occultation experiment. The main goal of the JAXA mission is to study meteorology and cloud dynamics. Both the science objectives and the payload suite of Akatsuki make it very complementary to Venus Express. This section describes general strategy of joint Venus Express/Akatsuki observations. Detailed plan of joint observations will be elaborated in a dedicated document that is currently being developed by VSOC/ESA and the JAXA science operations team.

4.1 Venus Express and Akatsuki orbits

The Akatsuki spacecraft will be inserted in a quasi-equatorial orbit with 30 hours revolution period. This allows the spacecraft to co-rotate with the Venus middle cloud deck (~50 km), thus providing ideal conditions for tracking of cloud motions for about 20 hours. Table 4.1 compares orbital parameters of both spacecraft (Fig. 4.1).

Table 4.1 *Orbital parameters of the Venus Express and Akatsuki spacecraft*

	Venus Express	**Akatsuki**
Orbit type	Polar	Equatorial
Inclination	~90 deg	~8 deg
Pericentre latitude	~90 N	~0 deg
Pericentre distance, km	165-350	400 (tbc)
Apocentre distance, km	66,000	80,000

Period, h	24	30

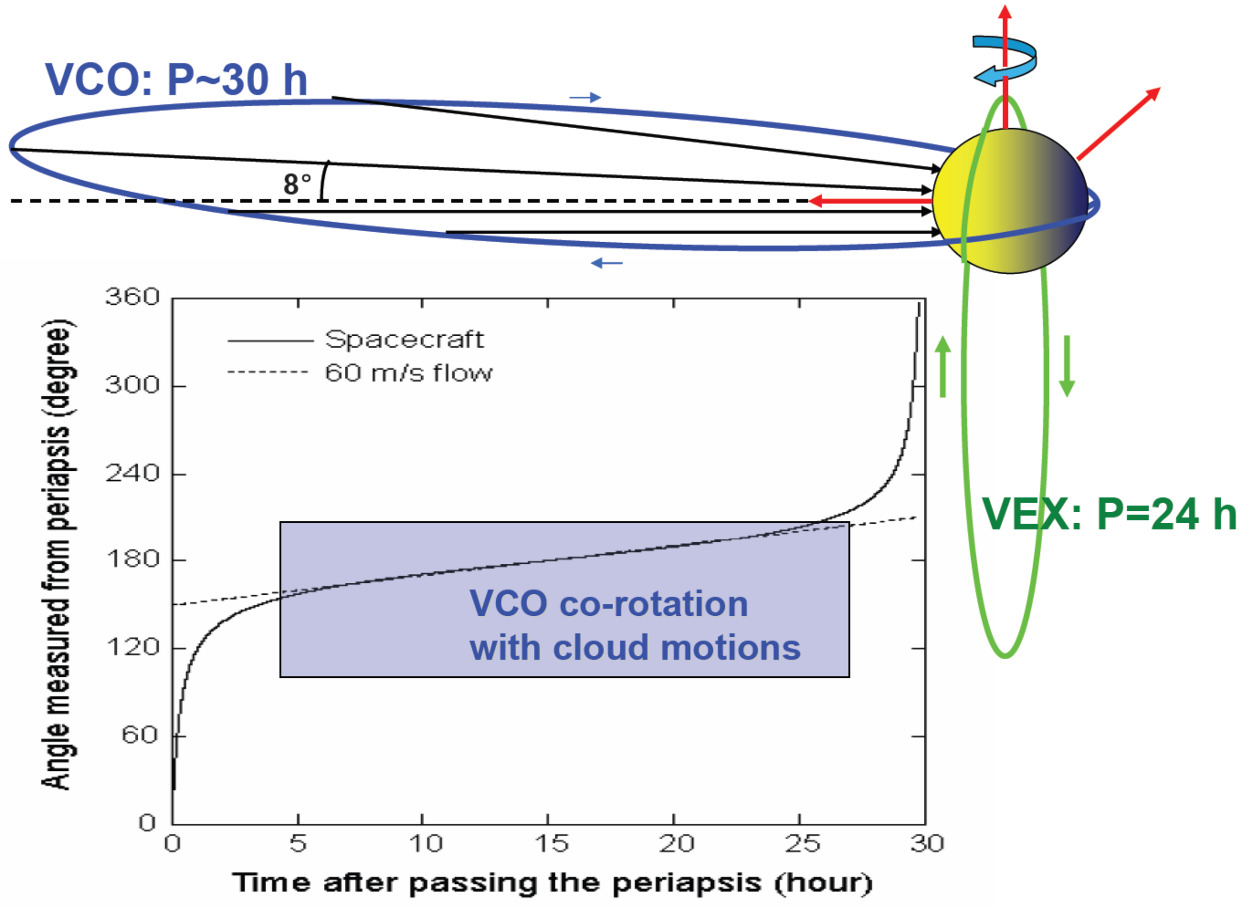


Figure 4.1 *Sketch of the relative positions of the Akatsuki (VCO) and VEX orbits. Inserted plot shows the orbital time range when VCO is in co-rotation with the main cloud deck superrotation.*

Akatsuki will be inserted in Venus orbit in the beginning of December 2010. The orbit parameters will slightly depend on concrete day of VOI. Figure 4.2 shows the sketch of Akatsuki orbit with respect to SUN, Earth, Venus and Venus Express orbit. Note that the major axis of the Akatsuki orbit is almost perpendicular to the VEX orbital plane. After VOI and orbit forming maneuvers the relative position of the VEX and Akatsuki orbits will remain fixed.

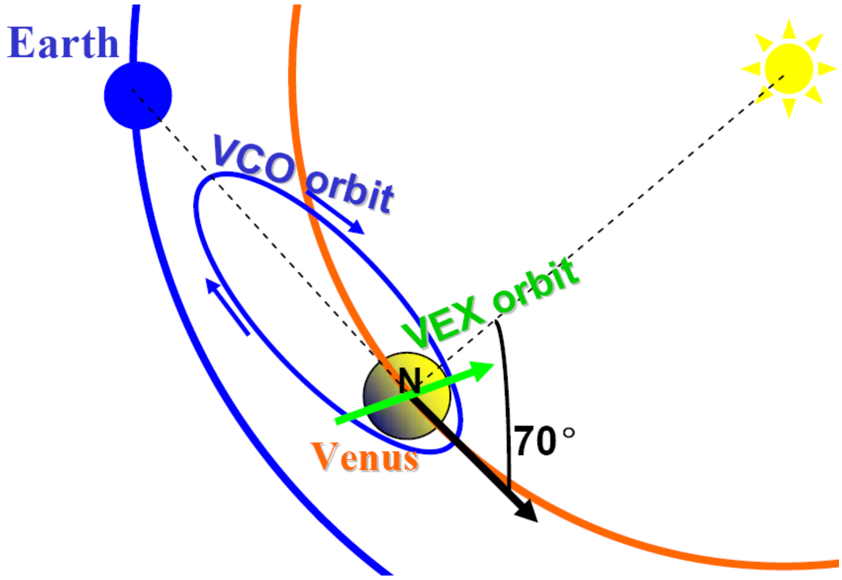


Figure 4.2 *Sketch of the position of the Akatsuki orbit (blue ellipse) relative to Earth, Venus, Sun and the Venus Express orbit (green arrow) for Akatsuki VOI on December 13, 2010.*

Figure 4.3 shows evolution of positions of Venus Express and Akatsuki spacecraft during one day in 4 hours step. Approximate locations of corresponding ground stations are marked in red (Cebreros) and yellow (Usuda) arcs.

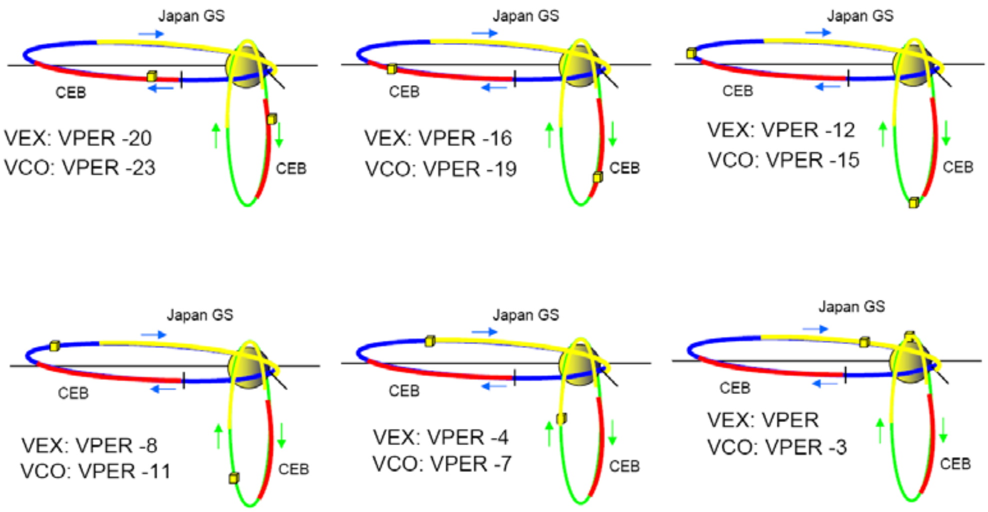


Figure 4.3 *Orbital positions of Venus Express and Akatsuki during one day. Red and yellow arcs show location of telecoms phases for VEX and Akatsuki.*

Figure 4.4 shows relative positions of two spacecraft and their ground stations during 6 days with a one day step. Since the ratio of orbital periods is 4:5 relative positions of spacecraft will have periodicity of 5 days.

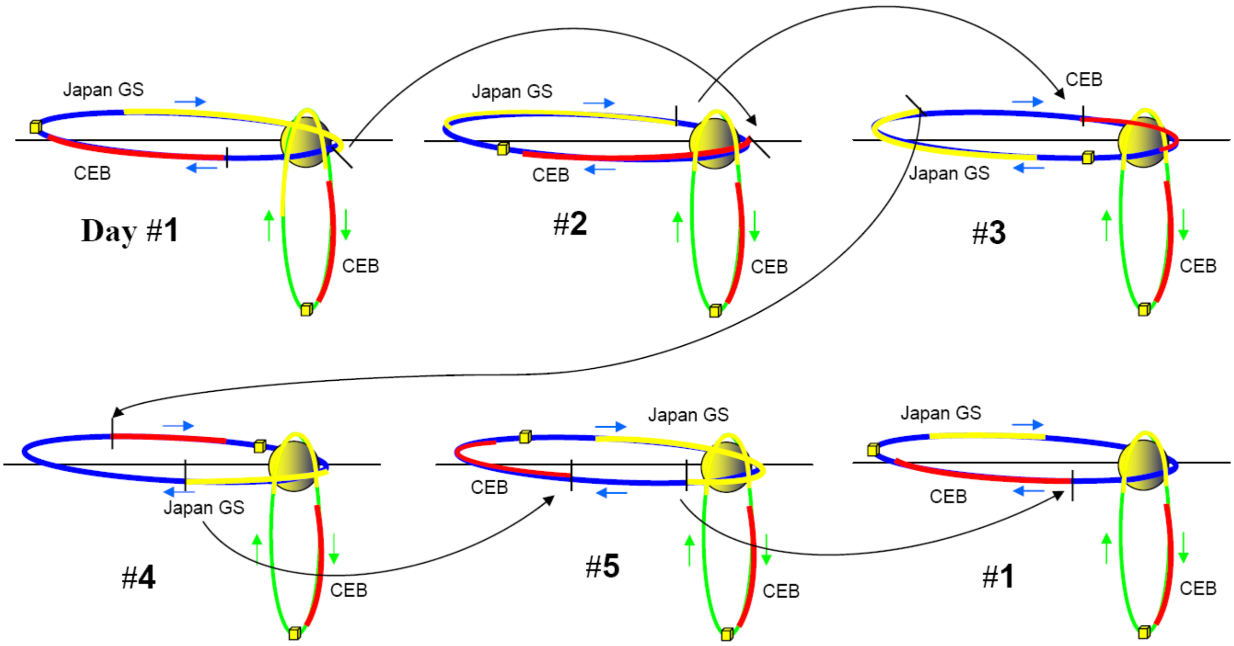


Figure 4.4 *Orbital positions of Venus Express and Akatsuki during six day. Red and yellow arcs show location of telecoms phases for VEX and Akatsuki.*

The above mentioned properties of the Venus Express and Akatsuki orbits have several implications on the strategy of joint observations.

1. Combination of polar and equatorial orbits provide favorable conditions for coordinated observations, especially in what concerns scattering phase function studies and latitudinal coverage. This also results in strong complimentarity in radio occultation sounding of low latitudes.

2. The 4:5 ratio of orbital periods results in repeating of observational geometry with a period of 5 days.
3. Downlink to two ground stations separated by 8 hours local time creates certain constrains in simultaneous observations that needs to be carefully taken into account in the planning.

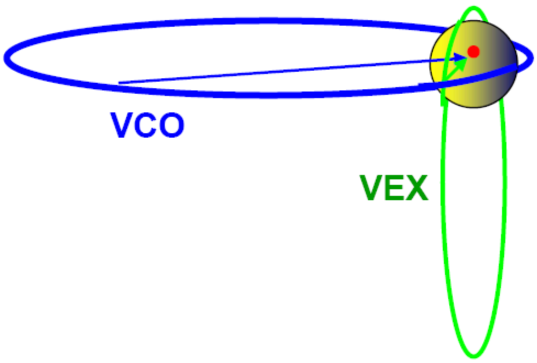
The following section describes major modes of coordinated observations.

4.2 Modes of joint observations

The equatorial orbit of Akatsuki and the polar one of Venus Express as well as their different orbital periods create unique geometry conditions for observing Venus from different angles and tracking cloud features for a long time. Both are very important for the study of cloud properties and atmospheric dynamics. Different orbit inclinations result in different geometries of Earth radio-occultation thus creating a background for complementary sounding of the atmospheric structure. This section provides typical modes of joint observations.

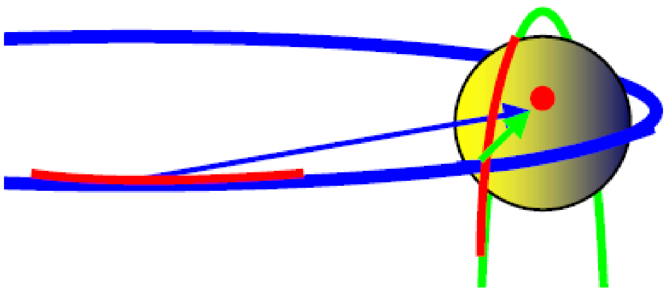
4.2.1 Simultaneous observations at different spatial resolution (day side)

These observations are possible when VCO is in the apocenter part of its orbit while VEX is close to the planet, thus resulting in about an order of magnitude difference in spatial resolution. In this case VCO will provide context imaging for Venus Express, which high resolution images can be imbedded in the global cloud patterns observed by VCO (see figure).



4.2.2 Simultaneous phase function observations (day side)

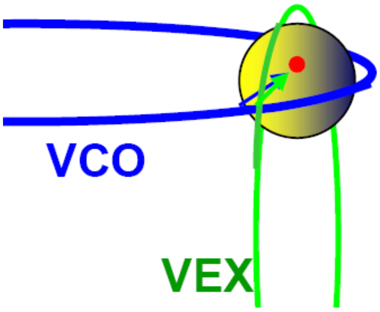
Observations of reflected solar light in the range of phase angles from 0°



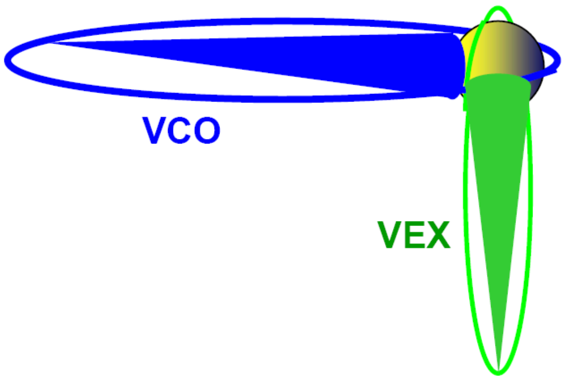
(backscattering) to ~90° are very informative about the microphysical and optical properties of aerosol particles at the cloud tops. Due to thermal constrains Venus Express cannot cover this range of phase angles in one orbit. Simultaneous imaging by Akatsuki will help to overcome this limitation. The figure shows that simultaneous observations by two spacecraft moving along red arcs in their orbits will cover the required range of phase angles.

4.2.3 *Cross-calibration of the optical instruments (day side)*

Cross check of the radiometric calibration of the Venus Express and Akatsuki optical instruments is an important task for joint observations. This task requires specific geometry when both spacecraft observe Venus simultaneously from the same direction that ensures similar illumination conditions (see figure).

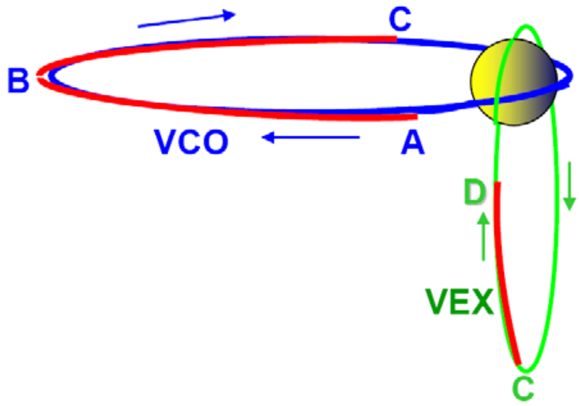


4.2.4 *Simultaneous observations of dynamics and cloud morphology at all latitudes (day side)*



The polar orbit of Venus Express is well suited for observations of cloud morphology and atmospheric dynamics in the middle to high latitudes of the Southern hemisphere. At close approach when VEX sees low latitudes fields of view of the imaging instruments are too narrow and the observations loose spatial coverage. Combination of VEX and Akatsuki observations from around apocentres of both orbits will allow to the planet from South pole to high Northern latitudes. These observations will give an instantaneous snapshot of cloud morphology and dynamics on the most of day side (see figure).

4.2.5 Continuous monitoring of cloud motions (day side)



Determination of the wind field from tracking of cloud features is one of the main goals of both missions. In this task keeping a cloud feature in the field of view and tracking its evolution for as long as possible is of great importance. Maximal duration of such observation is ~10 hours for Venus Express and ~20 hours for Akatsuki. Combination of both when, one spacecraft starts tracking of a certain feature and the second one takes over would result in extension of observation time to ~30 hours. The figure shows the sequence that starts with VCO observations for ~20 hours (red arc A-B-C), and when the feature disappears from the VCO field of view (point C) Venus Express takes over and continues observations for another 10 hours until point D.

4.2.6 Surface observations (night side)

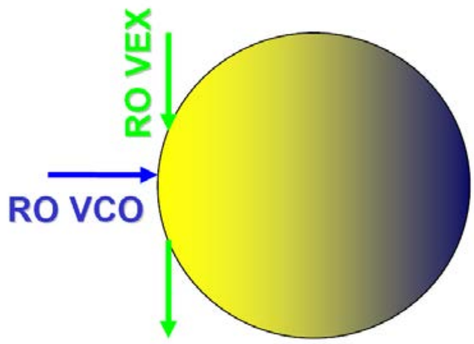
Surface imaging requires correction for variations of cloud opacity. Since the failure of the VIRTIS-M cooler in October 2008, this correction is not possible anymore. With arrival of Akatsuki spacecraft that carries near-IR cameras such correction will become possible again. Simultaneous observations by the JAXA spacecraft will help both VIRTIS and VMC to "de-cloud" the night images.

4.2.7 Observations of lightning (night side)

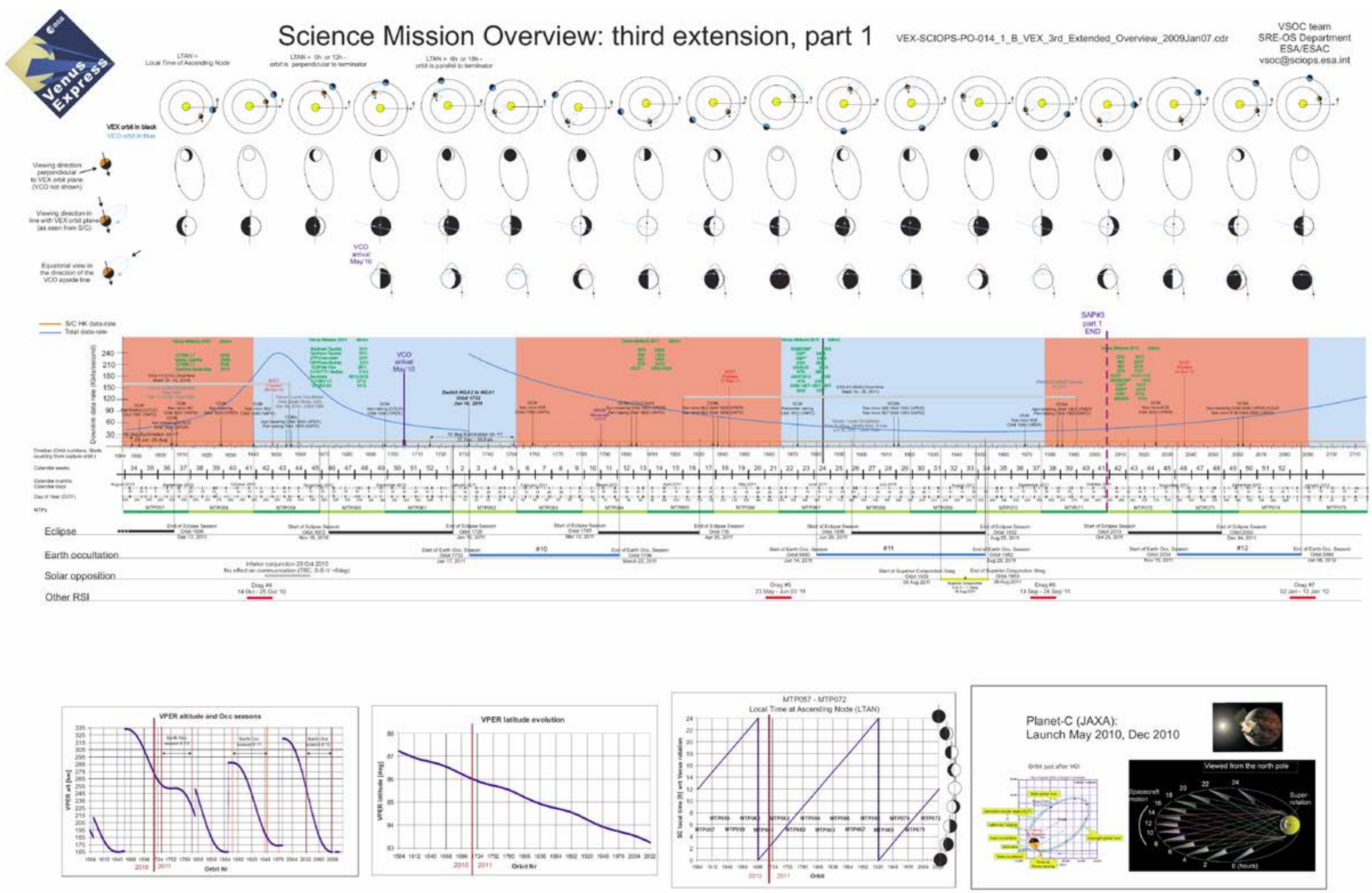
Lightning is regularly observed by Venus Express as whistler waves in the magnetometer records. MAG/VEX searches for lightning at closest approach to Venus in pericentre by switching to the high frequency (128 Hz) mode. However lightning has never been detected by the optical instruments of Venus Express probably because they are not suited for lightning detection. The Akatsuki spacecraft has the LAC camera which designed to detect lightning flashes. Simultaneous observations by both techniques can provide additional evidences for lightning. However, since LAC will observe lightning in tropics, MAG shall also switch to high frequency mode ~30 minutes before or after pericentre.

4.2.8 Coordinated radio-occultation experiments

The polar orbit of Venus Express provides almost complete latitude coverage in radio-occultation experiment. However low latitudes are sounded in grazing geometry that significantly decreases latitude resolution of the experiment. The Akatsuki radio-occultation will have close to nadir entrance of radio beam in the atmosphere that provides much better latitude resolution, thus giving important complement in sounding of Venus tropics. The figure compares geometry of VEX and Akatsuki radio-occultation experiment. Simultaneous and co-located occultation will help to compare both experiments.



5. ANNEX 1 – EXTENDED-3 MISSION OVERVIEW


Science Mission Overview: third extension, part 1
VEX-SCIOPS-PO-014_1_B_VEX_3rd_Extended_Overview_2009Jan07.cdr
VSOC team
SRE-OS Department
ESA/ESAC
vsoc@sciops.esa.int
Venus Express
VCO arrival May'10
SAP#3 part 1 END
Eclipse
Earth occultation
Solar opposition
Other RSI
VPER altitude and Occ seasons
VPER latitude evolution
MTP057 - MTP072
Local Time at Ascending Node (LTAN)
Planet-C (JAXA):
Launch May 2010, Dec 2010
Viewed from the north pole

6. ANNEX 2. LIST OF STARS FOR STELLAR OCCULTATION OBSERVATIONS

PTB	Star	RA	DEC	RelTimeSt	RelTimeE	Lat.in	Long.in	LSunIn	day/night	Lat.out	Long.out	LSunOut	day/night	OccDurIn	Dist.In	OTAngle	OccDurOu	Dist.Out	OTAngle	TotOccDu
0	Star02	14,18	60,72																	
1	Star05	24,43	-57,24	-00:15:24	0:06:39	-1,52615	76,51323	2,626595	day	22,72781	-62,6585	134,4168	night	20	6031,593	137,4298	20	2926,255	25,39706	1330
2	Star08	58,53	31,88																	
3	Star09	59,46	40,01																	
4	Star12	78,63	-8,2	-00:04:14	0:19:49	59,20332	84,87461	58,52108	day	-32,9264	-38,4585	112,0243	night	20	2281,488	14,9577	20	7500,586	50,42033	1450
5	Star14	81,28	6,35	-00:02:14	0:24:39	73,92013	79,05021	72,94643	day	-38,9943	-25,3373	100,4806	night	30	1671,059	4,914946	20	9115,084	55,89387	1620
6	Star16	83	-0,3	-00:03:14	0:22:59	67,03779	85,61797	66,31215	day	-41,4765	-32,4052	105,3624	night	30	1905,423	9,954681	10	8578,777	54,2923	1580
7	Star17	83,78	9,93	-00:01:44	0:26:49	77,29326	77,23876	76,31203	day	-44,0114	-21,5792	97,12293	night	40	1559,126	12,96677	20	9793,102	57,68868	1720
8	Star18	83,86	-5,91	-00:04:04	0:21:29	61,22688	88,54272	60,85109	day	-41,3905	-38,6019	109,8713	night	30	2113,063	14,1317	10	8095,281	52,76362	1540
9	Star19	84,05	-1,2	-00:03:24	0:22:59	66,05069	87,02989	65,4361	day	-43,0943	-33,8472	106,0254	night	30	1924,192	10,79526	10	8573,839	54,2463	1590
10	Star20	85,19	-1,94	-00:03:24	0:22:59	65,26197	87,71637	64,71658	day	-44,7144	-35,236	106,5763	night	20	2005,366	10,79526	10	8583,436	54,33569	1590
11	Star21	86,94	-9,67	-00:04:34	0:21:09	57,29751	91,5157	57,44477	day	-44,3804	-45,1392	113,335	night	20	2277,305	16,59827	20	7937,852	51,94641	1550
12	Star25	95,68	-17,96	-00:05:34	0:19:49	49,09939	98,23362	51,35743	day	-46,941	-63,5439	122,8486	night	20	2651,067	21,41675	10	7512,451	50,53084	1530
13	Star28	101,29	-16,72	-00:05:24	0:20:29	50,69713	101,6513	53,8204	day	-50,5652	-72,5089	124,2366	night	20	2547,36	20,62522	10	7748,924	51,4704	1560
14	Star29	104,66	-28,97	-00:07:04	0:17:19	38,80049	104,4555	45,23914	day	-38,7178	-79,7036	136,8199	night	20	3095,736	143,3061	10	6649,52	47,01372	1470
15	Star36	120,9	-40	-00:08:24	0:14:19	29,63647	113,6572	44,89034	day	-22,8603	-92,125	155,8545	night	10	3655,507	143,7496	10	5613,058	42,21509	1370
16	Star41	140,53	-55,01	-00:11:04	0:10:29	15,64025	121,4636	45,94201	day	-0,98847	-93,032	170,3865	night	10	4572,081	142,5674	20	4226,653	34,27959	1300
17	Star44	160,74	-64,39	-00:13:34	0:08:09	4,658614	125,9419	48,70821	day	13,13918	-91,2806	161,9285	night	10	5424,197	139,87	20	3401,374	28,78338	1310
18	Star46	182,09	-50,72	-00:11:54	0:06:29	20,99942	138,0424	62,45686	day	27,94993	-98,2228	150,7571	night	20	4807,523	141,7882	20	2865,369	24,92755	1110
19	Star48	186,65	-63,1	-00:14:54	0:06:19	2,881351	133,6256	56,32148	day	25,90673	-92,5787	151,4038	night	10	5897,068	138,1165	20	2814,149	24,54457	1280
20	Star49	186,65	-63,1	-00:14:54	0:06:19	2,881351	133,6256	56,32148	day	25,90673	-92,5787	151,4038	night	10	5897,068	138,1165	20	2814,149	24,54457	1280
21	Star53	191,93	-59,69	-00:14:44	0:05:49	6,217824	136,7763	59,55759	day	29,98369	-93,8861	147,9248	night	20	5827,177	138,3426	20	2654,043	23,31475	1240
22	Star55	201,3	-11,16																	
23	Star56	204,97	-53,47	-00:14:54	0:04:29	11,59861	143,4431	66,4495	day	40,67981	-94,6861	137,7106	night	20	5903,796	138,1165	30	2147,901	19,15139	1170
24	Star57	206,88	49,31																	
25	Star59	208,88	-47,29	-00:13:54	0:03:29	20,78805	147,4832	71,15649	day	48,10999	-96,6269	130,6286	night	20	5544,446	139,4451	30	1891,641	17,05003	1050
26	Star60	210,96	-60,37	-00:17:14	0:04:29	-1,55653	140,1299	62,88125	day	38,58507	-92,0297	139,2418	night	20	6686,812	134,8496	20	2237,505	19,98597	1310
27	Star62	218,88	-42,16	-00:14:14	0:01:49	25,96898	153,5111	74,414	day	58,79292	-96,78	120,1165	night	30	5651,26	138,9936	40	1543,116	14,07431	970
28	Star65	220,48	-47,39	-00:16:24	0:02:29	13,74902	151,1879	71,13378	day	54,01476	-93,7994	124,7265	night	20	6406,017	136,0191	40	1652,793	15,01162	1140
29	Star70	239,71	-26,11																	
30	Star71	240,08	-22,62																	
31	Star73	241,36	-19,81																	
32	Star74	245,3	-25,59																	
33	Star76	248,97	-28,22	-00:23:54	-00:06:44	17,83872	162,7077	82,40637	day	73,85444	-174,197	93,22955	term	60	8889,839	125,8604	110	2971,777	25,76973	1030
34	Star77	249,29	-10,57																	
35	Star84	263,4	-37,1	-00:36:04	-00:02:04	-33,6313	163,8089	85,16366	day	75,47152	-97,1408	103,4659	night	20	12628,92	113,5194	60	1601,644	14,59286	2040
36	Star86	265,62	-39,03	-00:36:24	-00:01:24	-39,3528	161,7472	84,04897	day	73,61713	-90,8344	105,1381	night	20	12718,15	113,2478	60	1434,464	13,10046	2100
37	Star89	283,82	-26,3	-00:53:44	-00:06:14	-79,3618	170,6336	91,09294	term	85,94663	-96,5174	92,99871	term	20	17419,86	102,3025	50	2807,568	24,52729	2850
38	Star91	306,41	-56,74	-00:29:14	0:02:09	-50,076	83,67022	51,35008	day	53,44445	-73,3506	120,3645	night	20	10586,77	119,8081	30	1562,408	14,22119	1890
	LSun	=	Local	(Zenith)																
		angle	>	90	->	dark	conditions													
		angle	=	90	->	terminator	conditions													
		angle	<	90	->	light	conditions													
		RA	of	Express	orbit	is	102	degrees												
		Stars	in	102	and	282	(102	+		180)	will	get		occulted	easily					
		Stars	in	192	(102	+	90)	and		12	(102	-		90)	will	not	get	occulted	easily	

7. ANNEX 3. VERA SYNOPTIC TABLE AND COVERAGE

Scheduling of the VeRa experiments in the Extended-3 Mission, part 1 (September 2010 – April 2011).

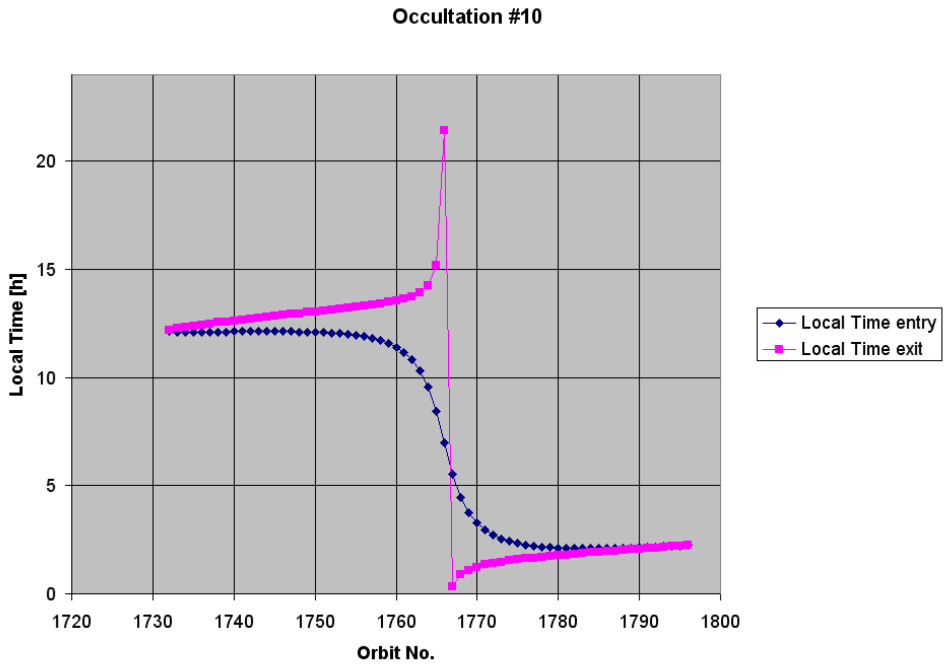
The VeRa Synoptic Table is taken from the document: VEX-SCIOPS-LI-500_30_VeRa_Synoptic_Table_2010Jan07_DT.xls

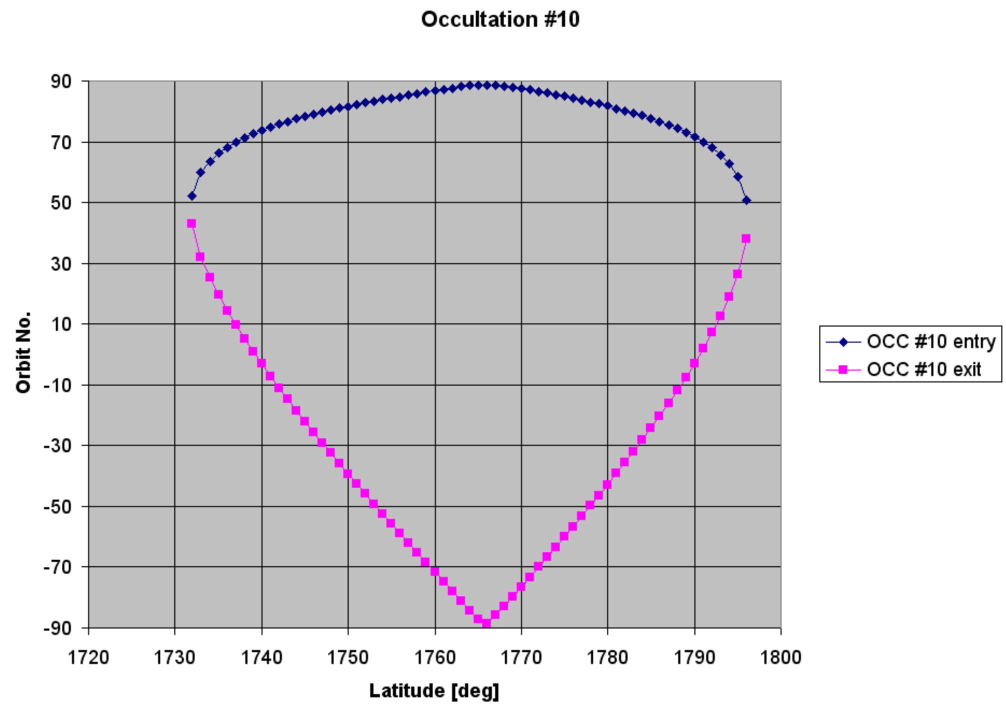
14.Oct.2010 - 25.Oct.2010	**1637-1648**	**287-298**	**Drag Campaign #4**	**0.3**		**DSN/ NNO**	**6 + 6**		Planning parameter for orbit selection: - altitude at pericenter shall be low, - angle between pericenter velocity vector direction and LOS direction shall be small, - distance SC - GS shall be small Execution Requirements: - 4hours centered on pericenter - minimum of 8 hours on the descending branch (realization is possible with a combination of NNO (at pericenter) and CEB during the normal telecom phase) The wheel off loading (WOL) shall be done during the Cebreros dump time such, that a minimum station availability time before and after the WOL is around 1h.
Part 1									**Combined observation Drag, Gravity**
14.10.2010	1637	287		0.3		**DSN**	1	requested	4hours around pericenter, HGA2
15.10.2010	1638	288				**DSN**	1	requested	4hours around pericenter, HGA2
16.10.2010	1639	289				**DSN**	1	requested	4hours around pericenter, HGA2
17.10.2010	1640	290				**DSN**	1	requested	4hours around pericenter, HGA2
18.10.2010	1641	291				**DSN**	1	requested	4hours around pericenter, HGA2
19.10.2010	1642	292				**DSN**	1	requested	4hours around pericenter, HGA2
Part 2									
20.10.2010	1643	293				NNO	1	requested	4hours around pericenter, HGA2
21.10.2010	1644	294				NNO	1	requested	4hours around pericenter, HGA2
22.10.2010	1645	295				NNO	1	requested	4hours around pericenter, HGA2
23.10.2010	1646	296				NNO	1	requested	4hours around pericenter, HGA2
24.10.2010	1647	297				NNO	1	requested	4hours around pericenter, HGA2
25.10.2010	1648	298		0.3		NNO	1	requested	4hours around pericenter, HGA2

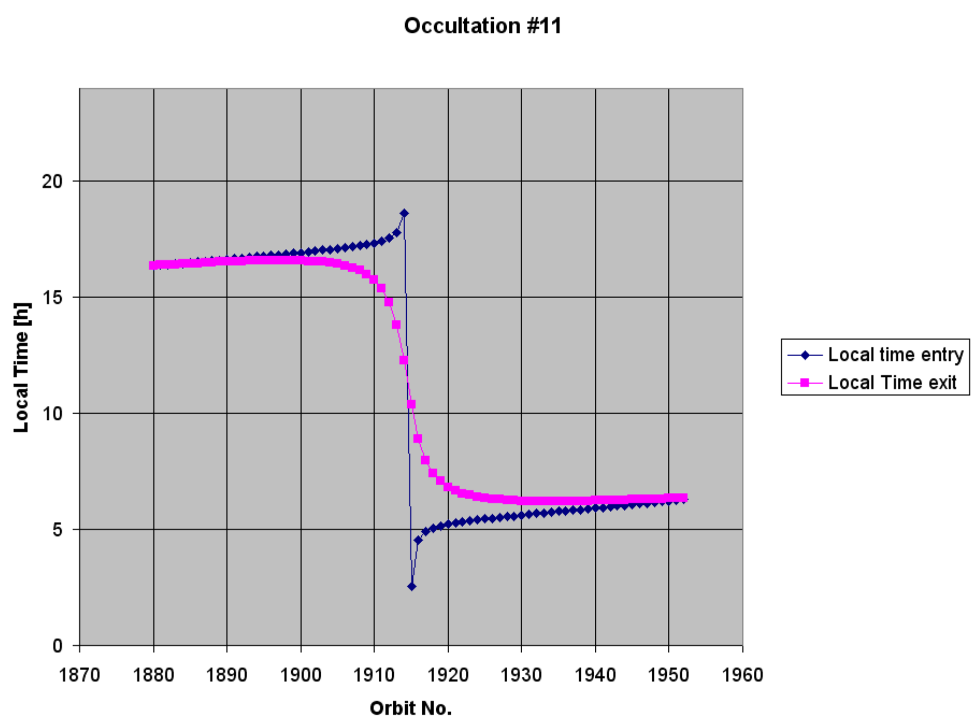
14. Jan. 2011- 23. Mar. 2011	**1729-1797**	**014-082**	**Earth Occultation #10**			**NNO**	**39**		**Planning Strategy Adapted to Lower Latitude Coverage** (on average over the OCC seasons in each season the request for 6 NNO passes can be replaced by a DSN request for the Canberra 35 m HEF or 70 m antenna to solve conflicts at NNO)
~~14.01.2011~~	~~1729~~	~~14~~				~~NNO~~	~~1~~	~~requested~~	~~HGA2~~
~~15.01.2011~~	~~1730~~	~~15~~				~~NNO~~	~~1~~	~~requested~~	~~HGA2~~
~~16.01.2011~~	~~1731~~	~~16~~				~~NNO~~	~~1~~	~~requested~~	~~HGA2~~
17.01.2011	1732	17				NNO	1	requested	HGA1
18.01.2011	1733	18				NNO	1	requested	HGA1
19.01.2011	1734	19				NNO	1	requested	HGA1
20.01.2011	1735	20				NNO	1	requested	HGA1
21.01.2011	1736	21				NNO	1	requested	HGA1
22.01.2011	1737	22				NNO	1	requested	HGA1
23.01.2011	1738	23				NNO	1	requested	HGA1
24.01.2011	1739	24				NNO	1	requested	HGA1
25.01.2011	1740	25				NNO	1	requested	HGA1
26.01.2011	1741	26				NNO	1	requested	HGA1
27.01.2011	1742	27				NNO	1	requested	HGA1
28.01.2011	1743	28				NNO	1	requested	HGA1
29.01.2011	1744	29				NNO	1	requested	HGA1
31.01.2011	1746	31				NNO	1	requested	HGA1
02.02.2011	1748	33				NNO	1	requested	HGA1
04.02.2011	1750	35				NNO	1	requested	HGA1
07.02.2011	1753	38				NNO	1	requested	HGA1
10.07.2011	1756	41				NNO	1	requested	HGA1
13.02.2011	1759	44				NNO	1	requested	HGA1
16.02.2011	1762	47				NNO	1	requested	HGA1
19.02.2011	1765	50				NNO	1	requested	HGA1
21.02.2011	1768	53				NNO	1	requested	HGA1
24.02.2011	1771	56				NNO	1	requested	HGA1
27.02.2011	1773	58				NNO	1	requested	HGA1
01.03.2011	1775	60				NNO	1	requested	HGA1
03.03.2011	1777	62				NNO	1	requested	HGA1
05.03.2011	1779	64				NNO	1	requested	HGA1
07.03.2011	1781	66				NNO	1	requested	HGA1
09.03.2011	1783	68				NNO	1	requested	HGA1
10.03.2011	1784	69				NNO	1	requested	HGA1
14.03.2011	1788	73				NNO	1	requested	HGA1
16.03.2011	1790	75				NNO	1	requested	HGA1
18.03.2011	1792	77				NNO	1	requested	HGA1
21.03.2011	1795	80				NNO	1	requested	HGA1
22.03.2011	1796	81				NNO	1	requested	HGA1
23.03.2011	1797	82				NNO	1	requested	HGA1
23. May 2011- 03. Jun. 2011	**1858-1869**	**143-154**	**Drag Campaign #5**	**1.5**		**DSN/ NNO**	**6 + 6**		
Part 1									
23.05.2011	1858	143		1.5		**DSN**	1	requested	4hours around pericenter, DSN 70 m

24.05.2011	1859	144				**DSN**	1	requested	4hours around pericenter, DSN 70 m
25.05.2011	1860	145				**DSN**	1	requested	4hours around pericenter, DSN 70 m
26.05.2011	1861	146				**DSN**	1	requested	4hours around pericenter, DSN 70 m
27.05.2011	1862	147				**DSN**	1	requested	4hours around pericenter, DSN 70 m
28.05.2011	1863	148				**DSN**	1	requested	4hours around pericenter, DSN 70 m
Part 2									
29.05.2011	1864	149				NNO	1	requested	4hours around pericenter
30.05.2011	1865	150				NNO	1	requested	4hours around pericenter
31.05.2011	1866	151				NNO	1	requested	4hours around pericenter
01.06.2011	1867	152				NNO	1	requested	4hours around pericenter
02.06.2011	1868	153				NNO	1	requested	4hours around pericenter
03.06.2011	1869	154		1.6		NNO	1	requested	4hours around pericenter
14. Jun. 2011- 25. Aug. 2011	**1880-1952**	**165-237**	**Earth Occultation #11**			**NNO**			**Planning Strategy Adapted to Lower Latitude Coverage**
									request of 6 (3 DSN) passes for ULP
									(3 DSN passes for half of the season because of overlap with SCO. Entering 10 deg. cone around Sun at 10.Jul.2010)
13. Sep. 2011- 24. Sep. 2011	**1971-1982**	**256-267**	**Drag Campaign #6**	**1.7**		**DSN/ NNO**	**6 + 6**		
Part 1									
13.09.2011	1971	256		1.70		**DSN**	1	requested	4hours around pericenter, DSN 70 m
14.09.2011	1972	257				**DSN**	1	requested	4hours around pericenter, DSN 70 m
15.09.2011	1973	258				**DSN**	1	requested	4hours around pericenter, DSN 70 m
16.09.2011	1974	259				**DSN**	1	requested	4hours around pericenter, DSN 70 m
17.09.2011	1975	260				**DSN**	1	requested	4hours around pericenter, DSN 70 m
18.09.2011	1976	261				**DSN**	1	requested	4hours around pericenter, DSN 70 m
Part 2									
19.09.2011	1977	262				NNO	1	requested	4hours around pericenter
20.09.2011	1978	263				NNO	1	requested	4hours around pericenter
21.09.2011	1979	264				NNO	1	requested	4hours around pericenter
22.09.2011	1980	265				NNO	1	requested	4hours around pericenter
23.09.2011	1981	266				NNO	1	requested	4hours around pericenter
24.09.2011	1982	267		1.68		NNO	1	requested	4hours around pericenter
15. Nov. 2011- 6. Jan. 2012	**2034-2086**	**319-006**	**Earth Occultation #12**			**NNO**			**Planning Strategy Adapted to Lower Latitude Coverage**
									request of 6 DSN passes for ULP
02. Jan. 2012 - 13. Jan.2012	**2082-2093**	**002-013**	**Drag Campaign #7**	**1.25**		**DSN/ NNO**	**6 + 6**		4hours around pericenter, DSN 70 m
Part 1									
02.01.2012	2082	002		1.28		**DSN**	1	requested	4hours around pericenter, DSN 70 m
03.01.2012	2083	003				**DSN**	1	requested	4hours around pericenter, DSN 70 m
04.01.2012	2084	004				**DSN**	1	requested	4hours around pericenter, DSN 70 m
05.01.2012	2085	005				**DSN**	1	requested	4hours around pericenter, DSN 70 m

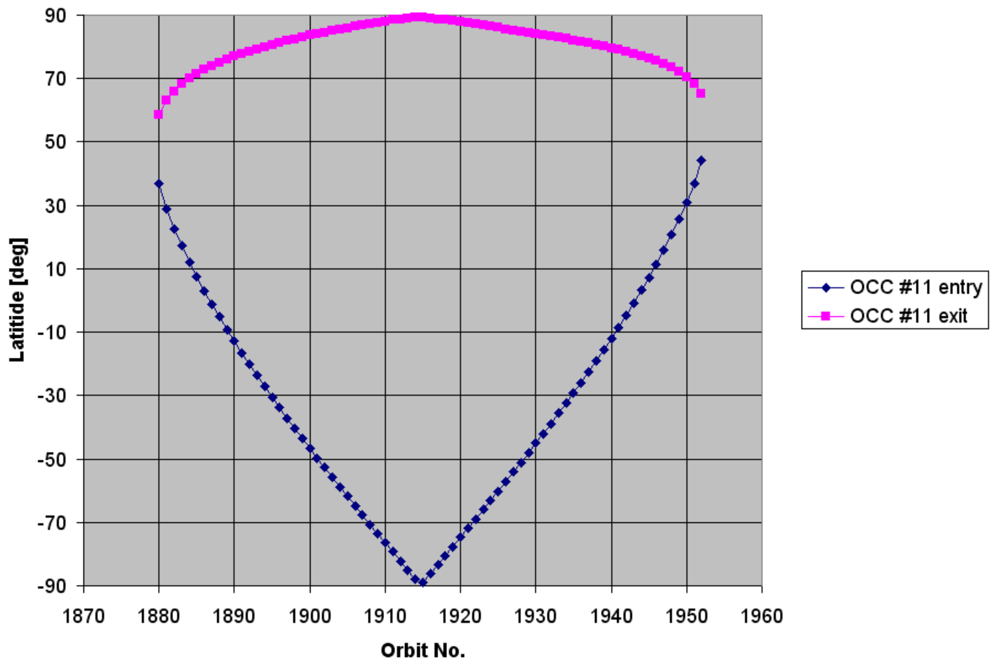
06.01.2012	2086	006				**DSN**	1	requested	4hours around pericenter, DSN 70 m
07.01.2012	2087	007				**DSN**	1	requested	4hours around pericenter, DSN 70 m
Part 2									
08.01.2012	2088	008				NNO	1	requested	4hours around pericenter
09.01.2012	2089	009				NNO	1	requested	4hours around pericenter
10.01.2012	2090	010				NNO	1	requested	4hours around pericenter
11.01.2012	2091	011				NNO	1	requested	4hours around pericenter
12.01.2012	2092	012				NNO	1	requested	4hours around pericenter
13.01.2012	2093	013		1.22		NNO	1	requested	4hours around pericenter
July 2012			**Drag Campaign #8 (Aerobraking)**			**DSN**	**6**		4hours around pericenter, DSN 70 m
November 2012			**Drag Campaign #9 (Aerobraking)**			**DSN**	**6**		4hours around pericenter, DSN 70 m


Occultation #10
Local Time [h]
0
5
10
15
20
1720
1730
1740
1750
1760
1770
1780
1790
1800
Orbit No.
Local Time entry
Local Time exit

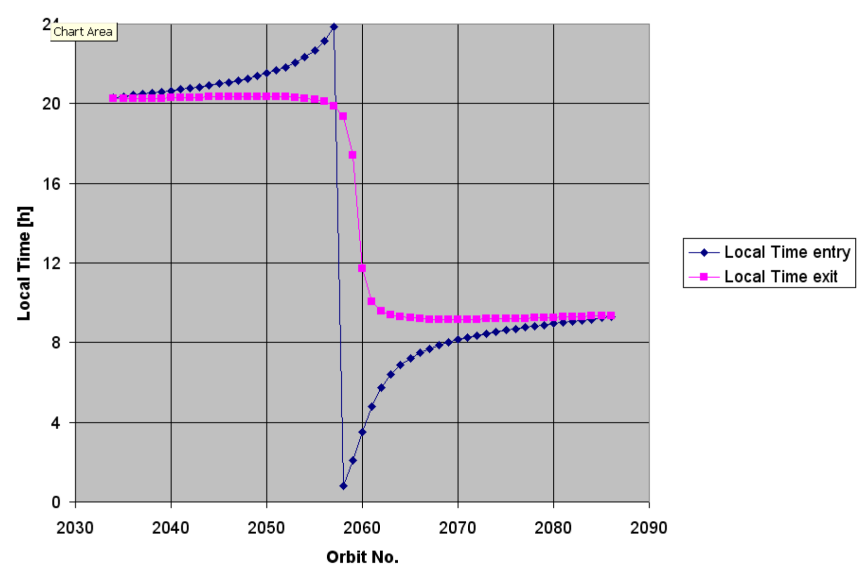

Occultation #10
90
70
50
30
10
-10
-30
-50
-70
-90
Orbit No.
1720
1730
1740
1750
1760
1770
1780
1790
1800
Latitude [deg]
OCC #10 entry
OCC #10 exit

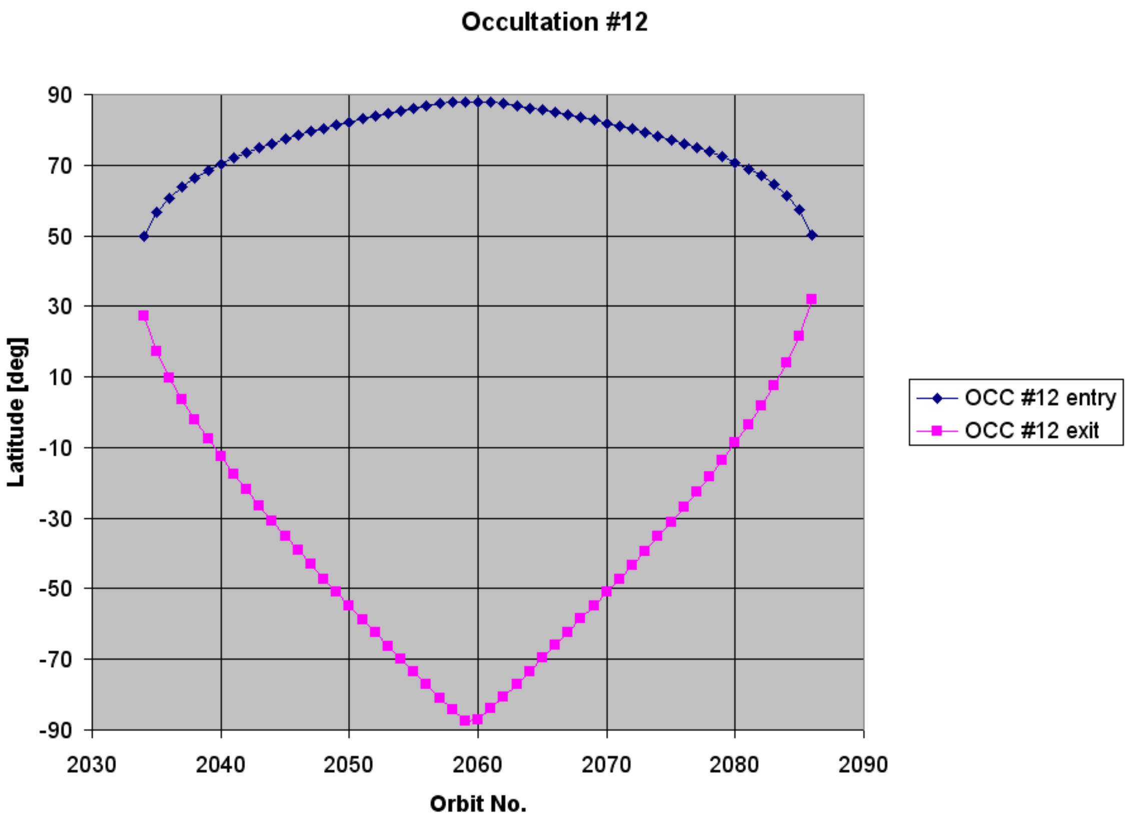

Occultation #11
20
15
10
5
0
Local Time [h]
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
Orbit No.
Local time entry
Local Time exit

Occultation #11



Occultation #12




Occultation #12
Latitude [deg]
90
70
50
30
10
-10
-30
-50
-70
-90
2030
2040
2050
2060
2070
2080
2090
Orbit No.
OCC #12 entry
OCC #12 exit

8. ANNEX 4. LATITUDE COVERAGE IN THE SOLAR OCCULTATION EXPERIMENT