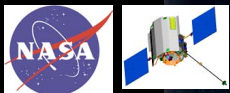
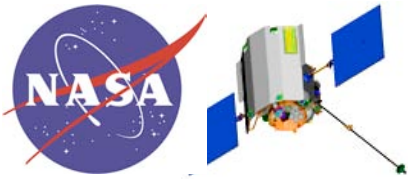


The MESSENGER Venus Flybys

Sean C. Solomon
Department of Terrestrial Magnetism
Carnegie Institution of Washington
Washington, D.C.

VEXAG Third Meeting
Crystal City, Virginia
11 January 2007





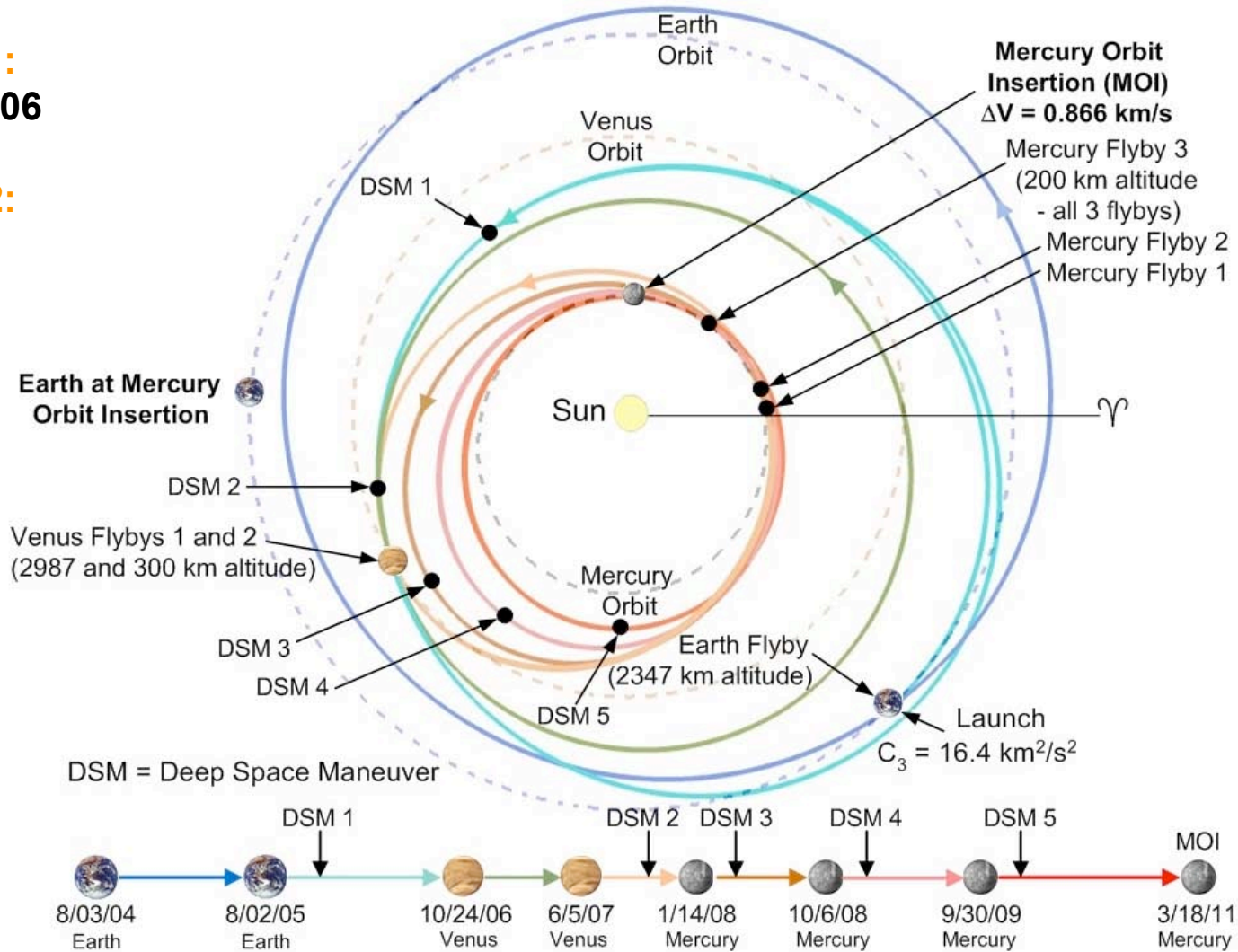
MESSENGER

MESSENGER Trajectory



Venus Flyby 1:
24 October 2006

Venus Flyby 2:
5 June 2007



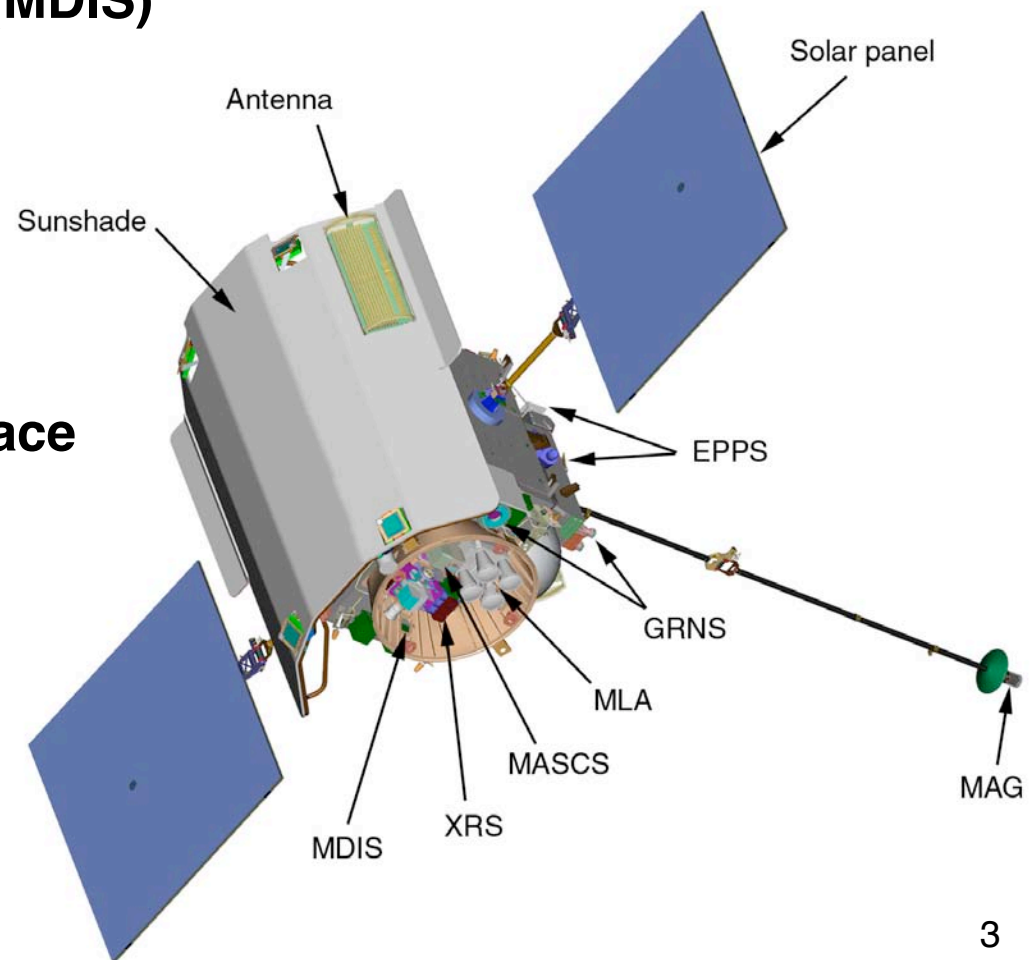


MESSENGER

Science Payload



- Mercury Dual Imaging System (MDIS)
- Gamma-Ray and Neutron Spectrometer (GRNS)
- X-Ray Spectrometer (XRS)
- Magnetometer (MAG)
- Mercury Laser Altimeter (MLA)
- Mercury Atmospheric and Surface Composition Spectrometer (MASCS)
- Energetic Particle and Plasma Spectrometer (EPPS)
- Radio Science (RS)



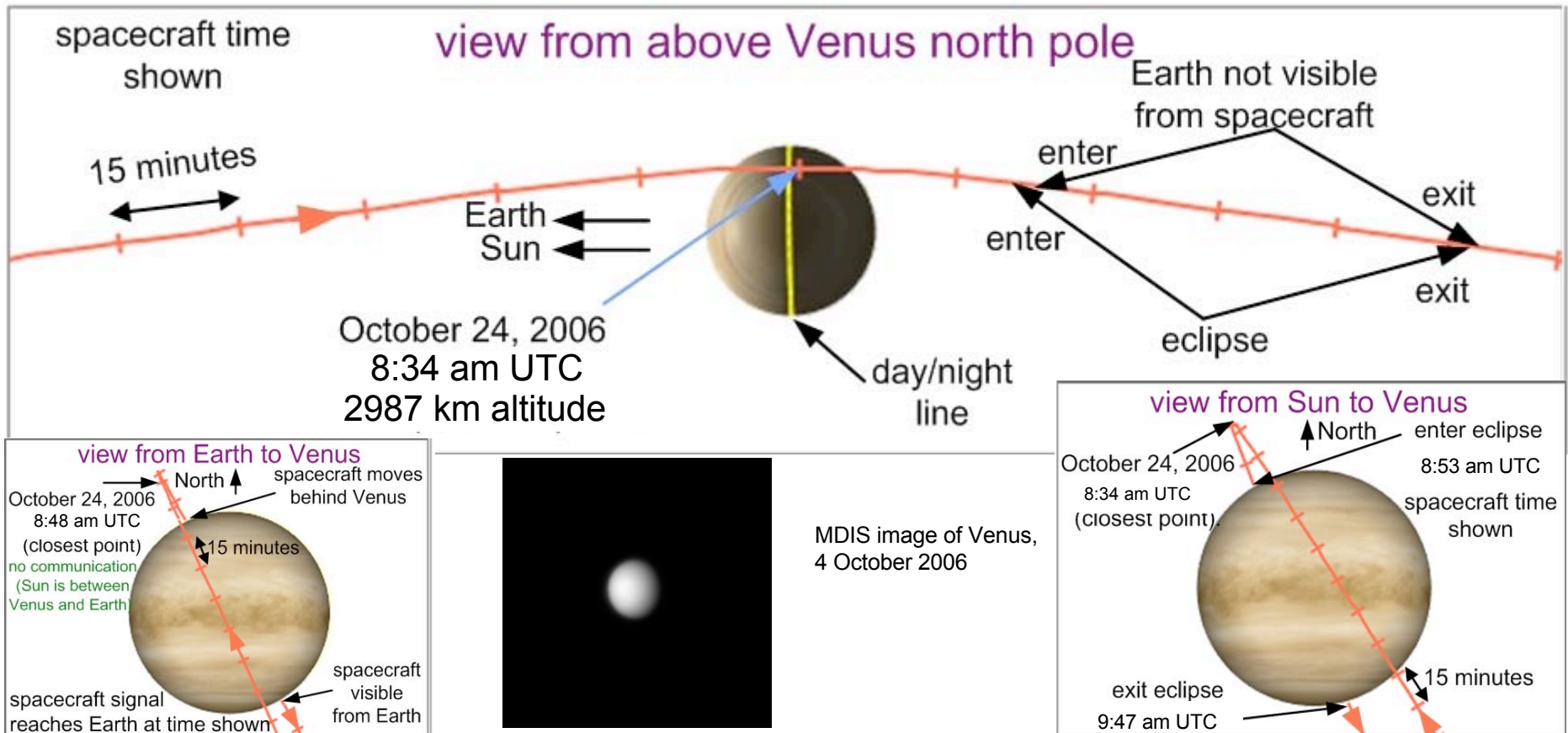


MESSENGER

Venus Flyby 1



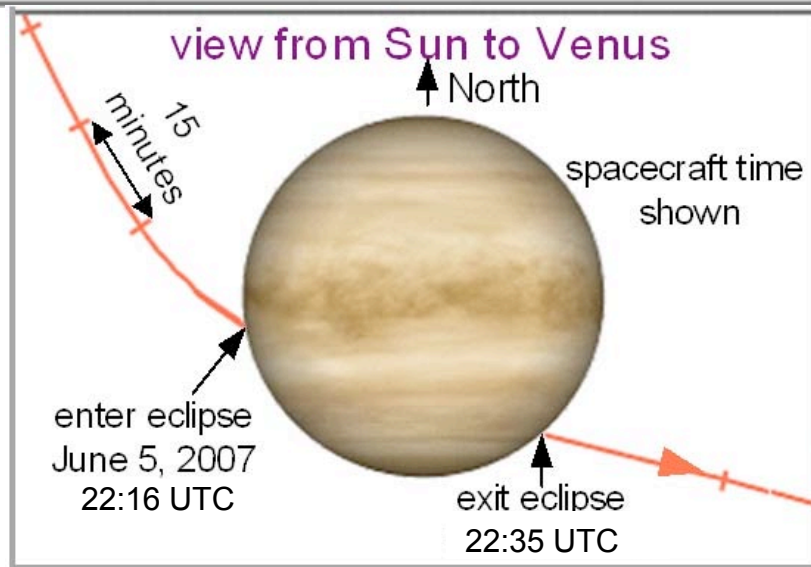
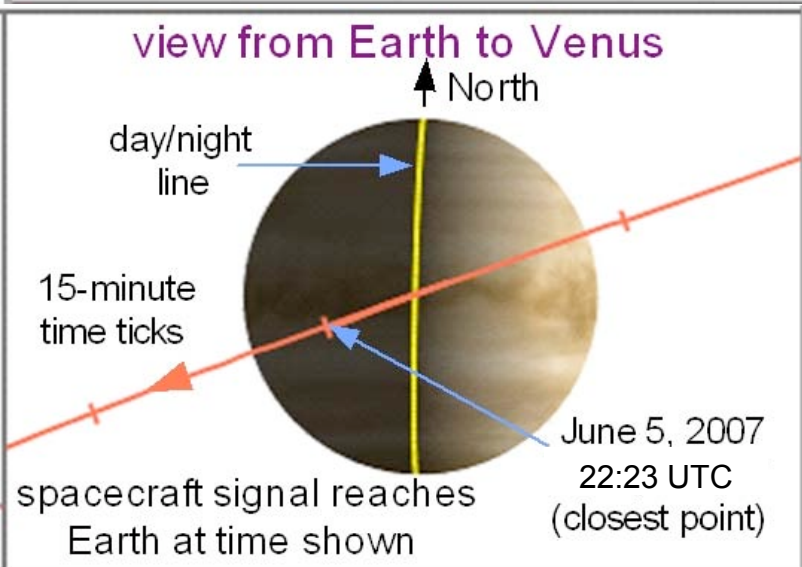
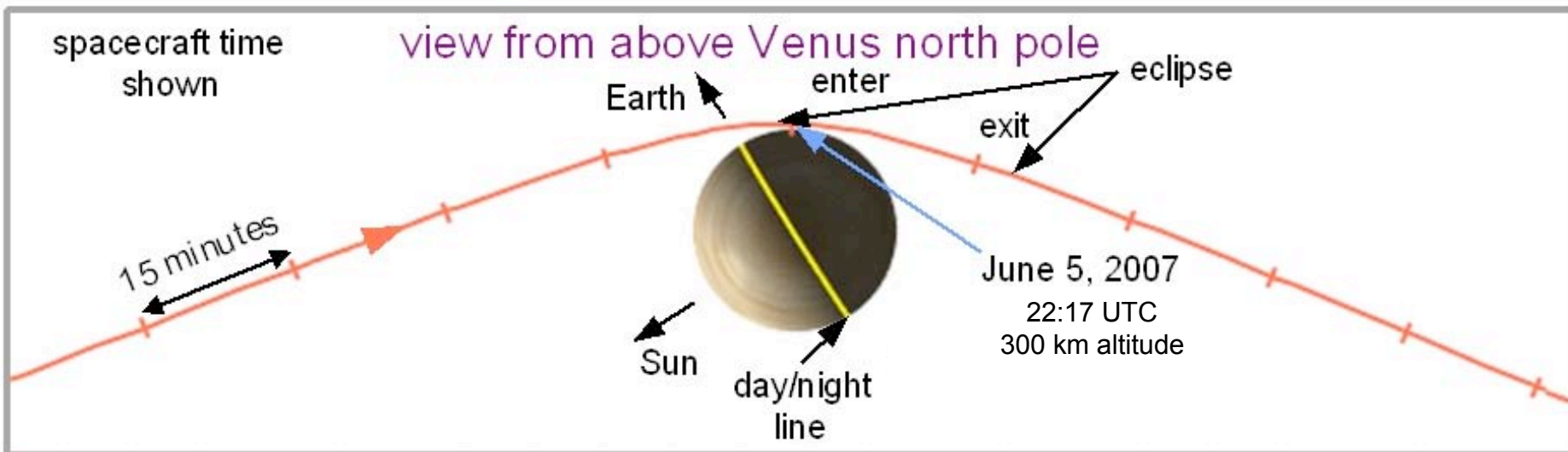
- Venus flyby 1 increased spacecraft's orbit inclination and reduced its orbital period
- No scientific observations were made, however, because Venus was at superior conjunction





MESSENGER

Venus Flyby 2



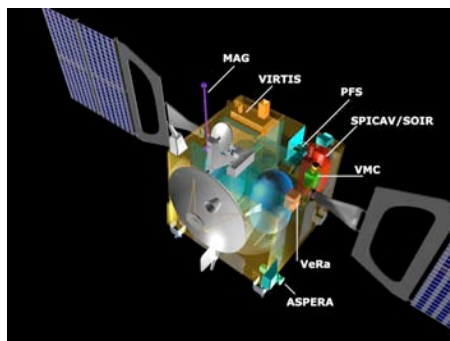
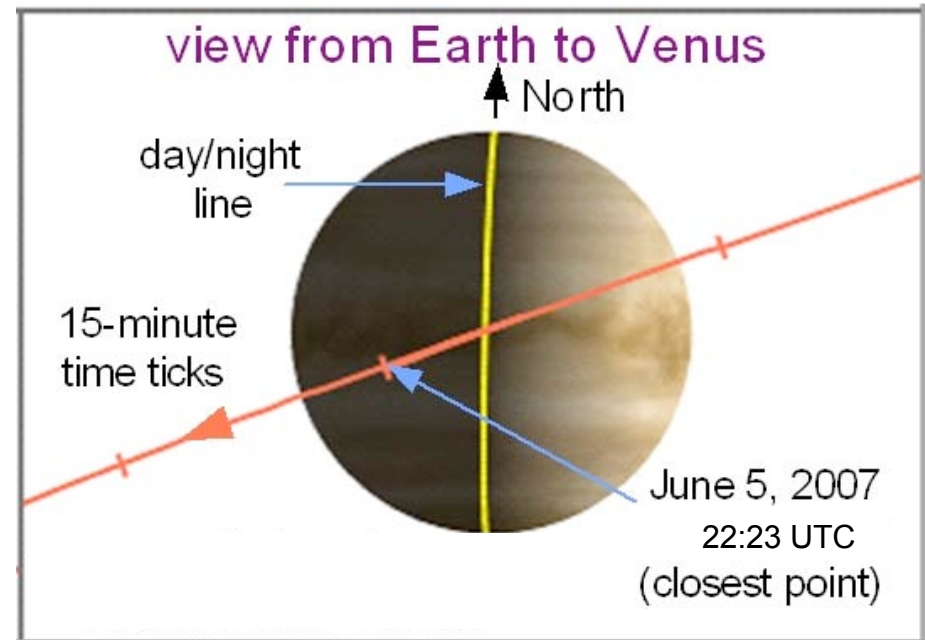


MESSENGER

Venus Flyby 2 Operations

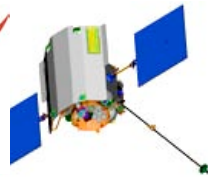


- Venus flyby 2 will occur while Venus Express will still be in operation.
- Venus flyby 2 operations will divide among instrument calibration, flyby practice, and opportunity science.
- All data will be deposited with PDS within 6 months of the flyby.



Venus Express

Credit: ESA



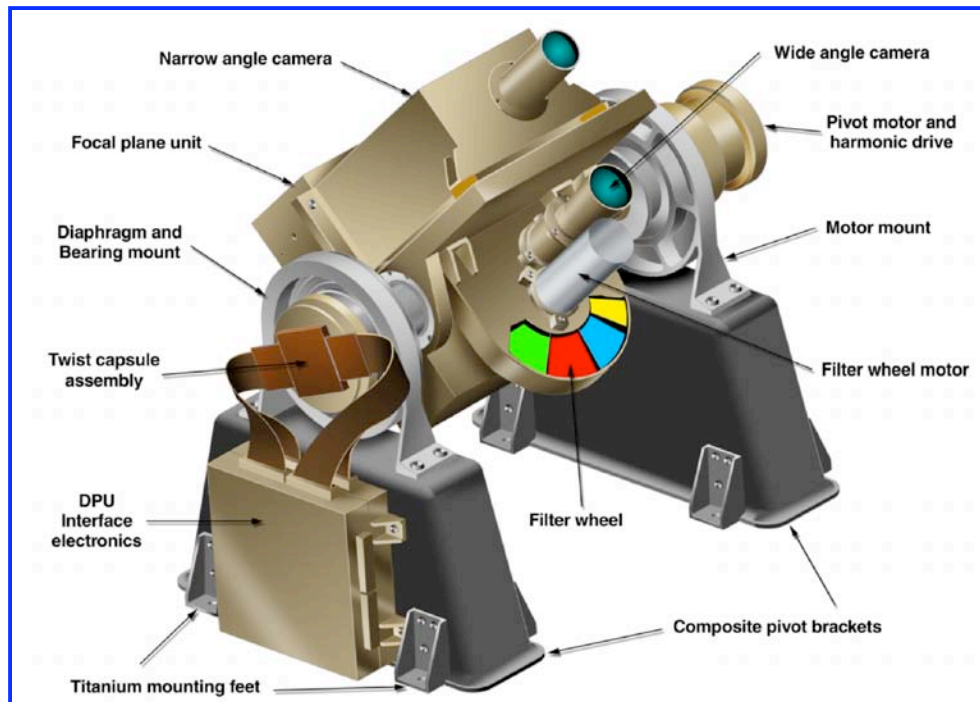
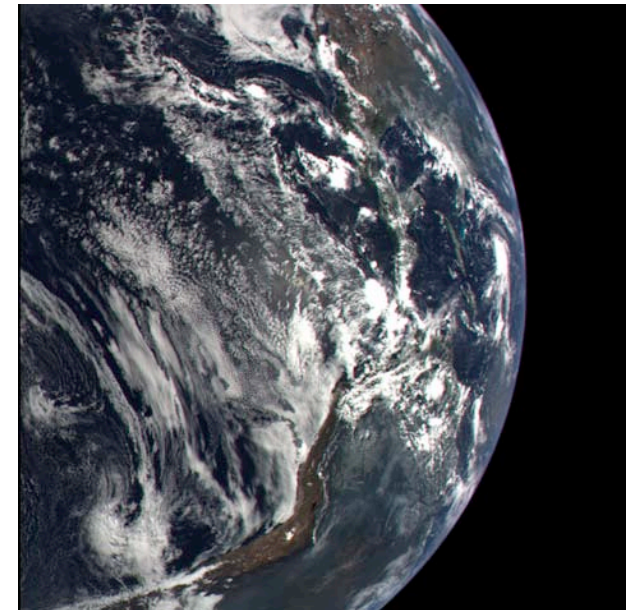
MESSENGER

Mercury Dual Imaging System

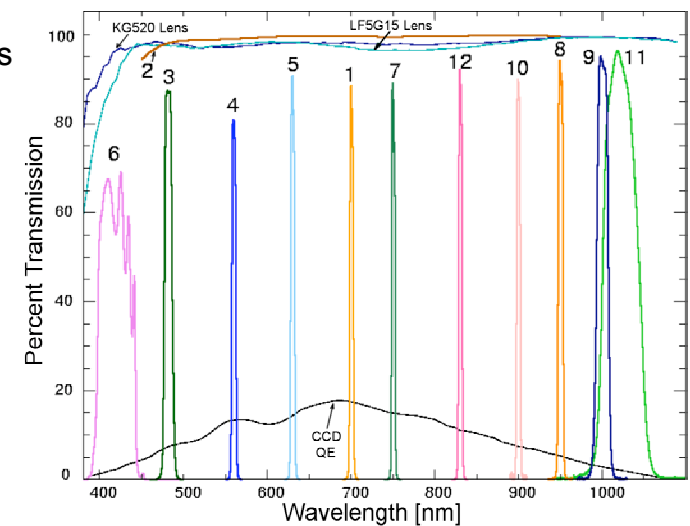


- Wide-angle and narrow-angle cameras (10.5° and 1.5° fields of view)
- 1024 x 1024 pixel CCDs
- 12-position filter wheel on WAC
- Auto exposure, 1 ms to 10 s range
- Pivot platform (140 μrad positioning)

MDIS WAC
image of Earth,
2 August 2005.



MDIS WAC
filter
passbands



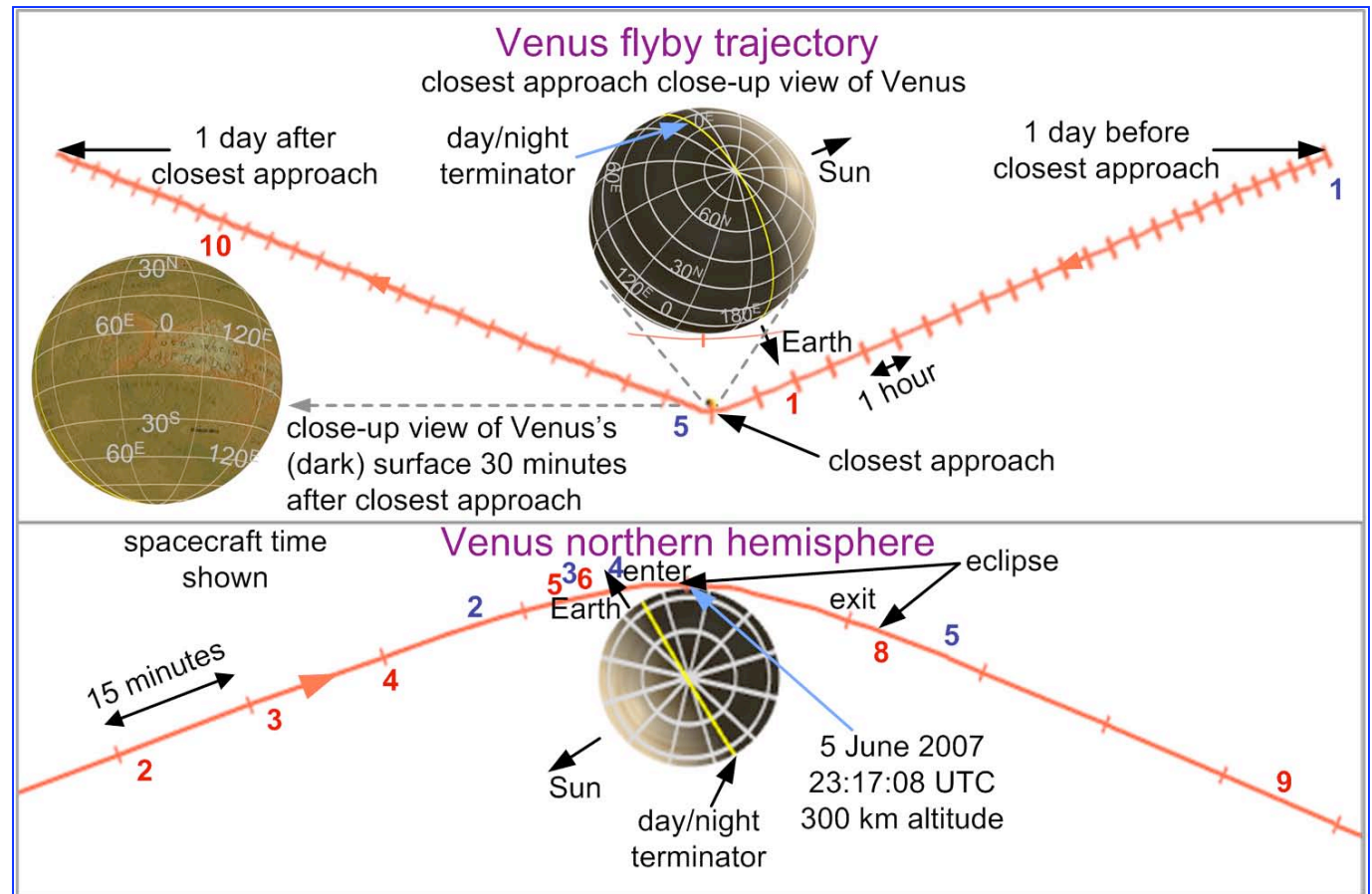


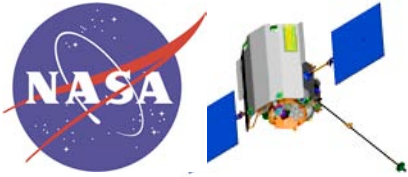
MESSENGER

Venus Flyby 2: MDIS



1. Approach color image centered on sunlit part of Venus
2. Flat-field measurement for calibration of CCD
3. Approach monochrome mosaic
4. Approach color mosaic
5. Color photometry, part 1
6. High-resolution monochrome mosaic
7. Color photometry, part 2
8. Departure monochrome mosaic
- 9-10. Departure movie
11. Departure optical navigation



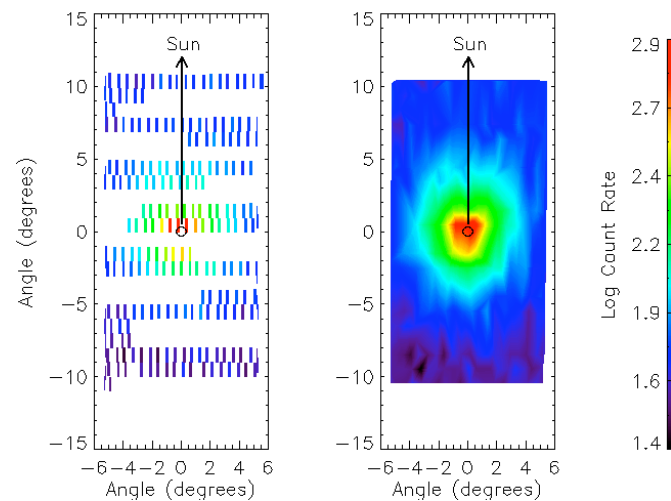


MESSENGER

MASCS



- Two sensors with a common telescope
- Ultraviolet and Visible Spectrometer (UVVS)
 - 115 - 600 nm
 - Moving grating spectrometer
 - Three photon-counting detectors
- Visible and Infrared Spectrograph (VIRS)
 - 0.3 - 1.45 μm
 - IR (InGaAs) 256-pixel line array
 - Visible (Si) 512-pixel line array



MASCS observed Earth's hydrogen corona following Earth flyby; shown are scans from 5 August 2005.

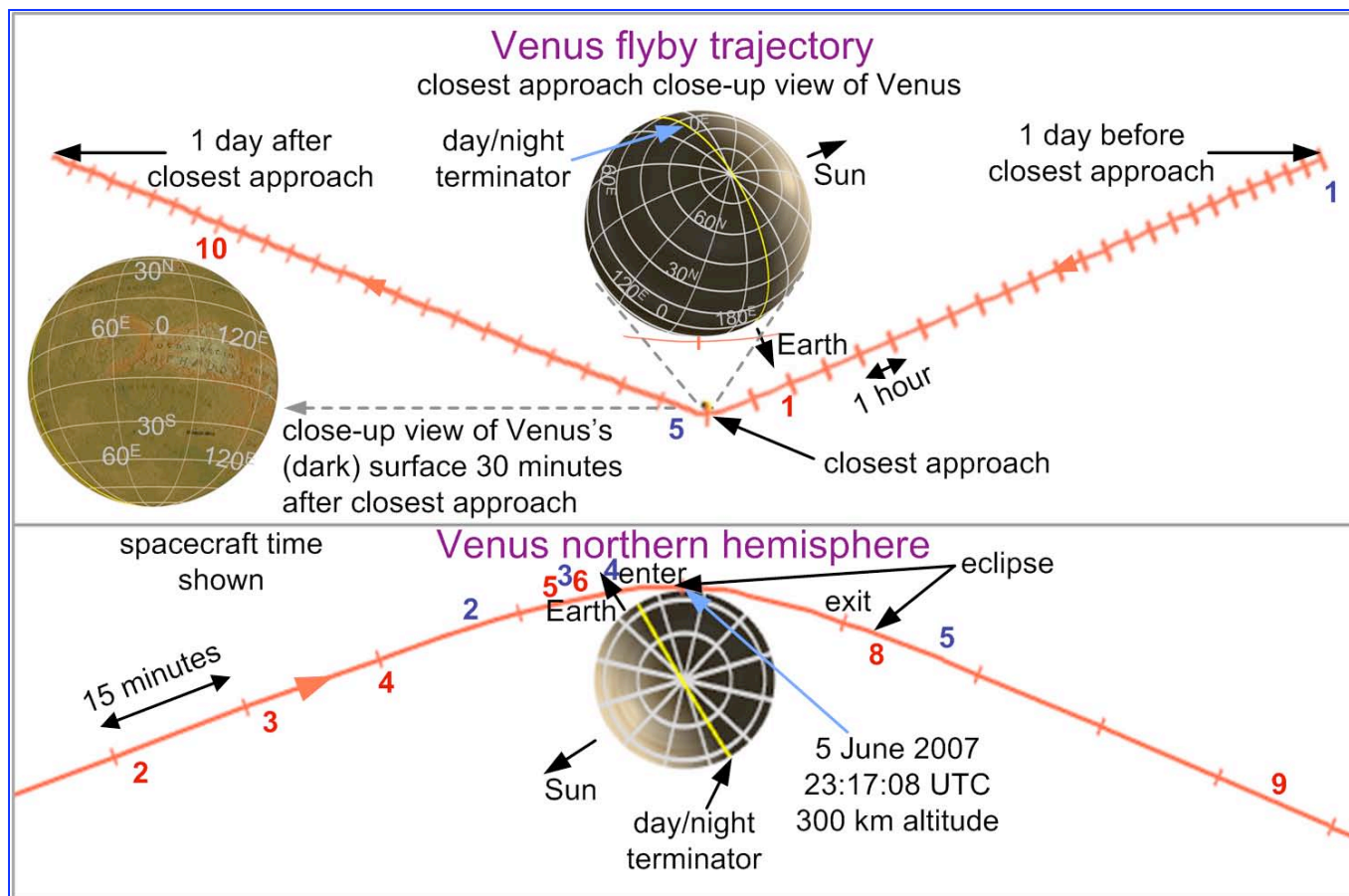


MESSENGER

Venus Flyby 2: MASCS



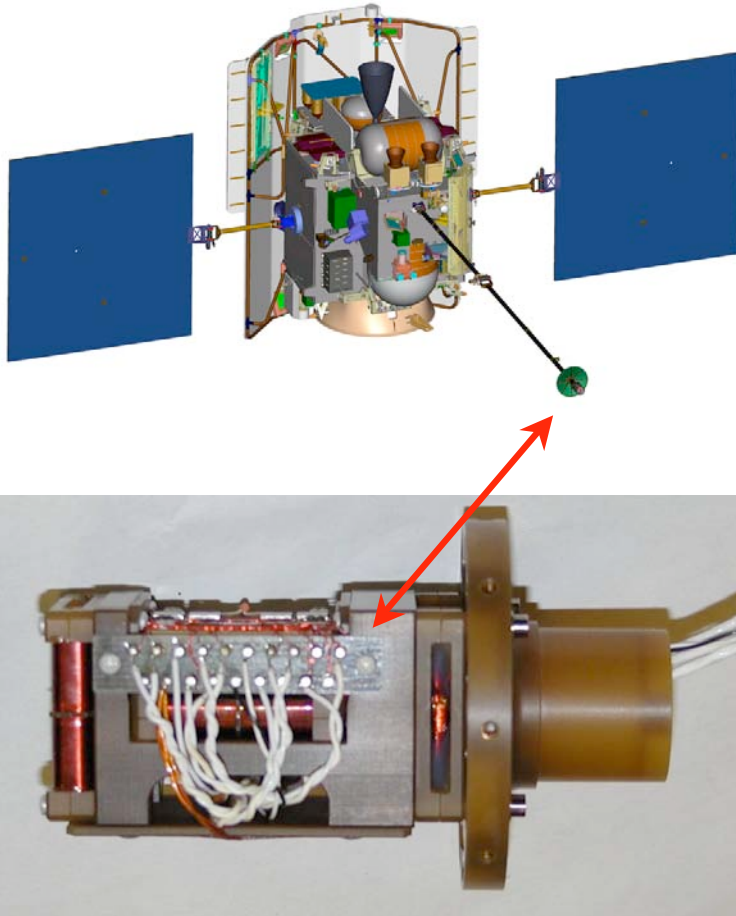
1. VIRS and UVVS observe Venus on approach
2. Atmospheric profile on flyby approach
3. Nadir observations of sunlit Venus atmosphere near closest approach
4. Nadir observations of dusk and night side Venus atmosphere, plus night limb after closest approach
5. UVVS Na and H scans of trailing Venus exosphere and corona after flyby





MESSENGER

Magnetometer



- **3-axis flux-gate sensor**
- **3.6-m carbon fiber boom**
 - Small sunshade protects sensor
- **Dual range: ± 2048 and ± 65536 nT**
- **16/17-bit quantization**
 - 0.047-nT resolution
- **Up to 20 samples per second**
 - 10 filtered rates from 10 to 0.01 s^{-1}
- **Extensive pre-flight spacecraft magnetic cleanliness program**



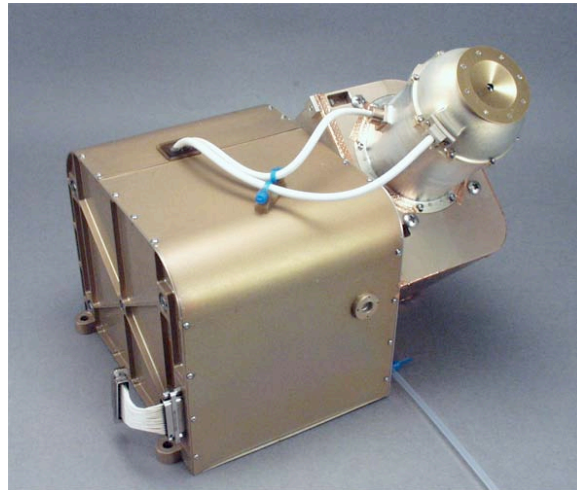
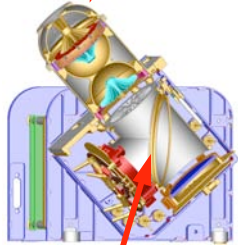
MESSENGER

EPPS



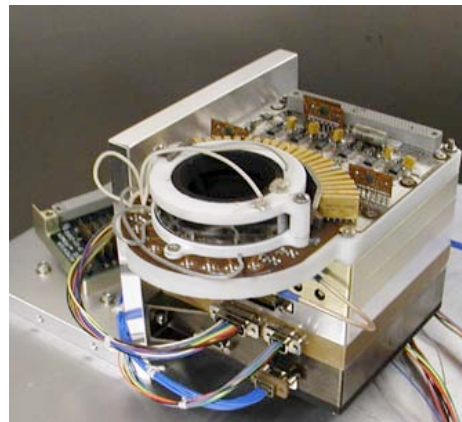
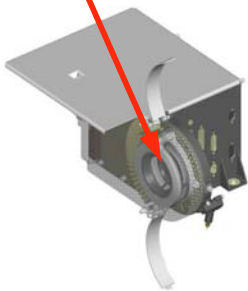
FIPS

Electrostatic analyzer



EPS

Time-of-flight spectrometer



- **Fast Imaging Plasma Spectrometer (FIPS)**
 - ~ 0 - 15 keV/q range
 - Innovative electrostatic analyzer
 - Hemispherical field of view
 - Scans full energy range in 60 s
 - Generates mass vs. E/q vs. angle spectrum
- **Energetic Particle Spectrometer (EPS)**
 - ~ 10 keV - 5 MeV ions
 - ~ 10 keV - 400 keV electrons
 - $12^\circ \times 160^\circ$ field of view
 - Energy spectra for H, He, O, Fe



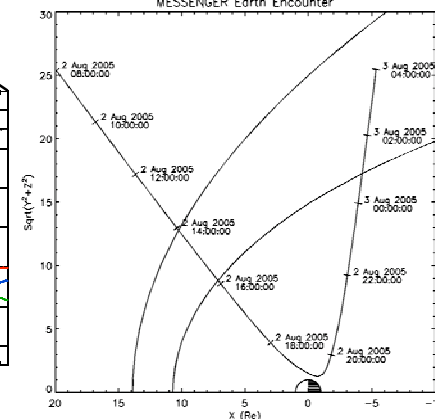
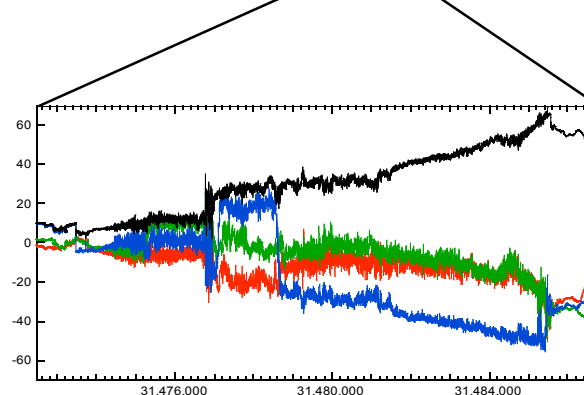
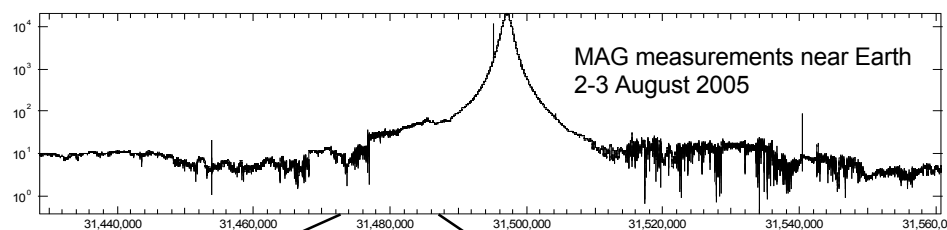
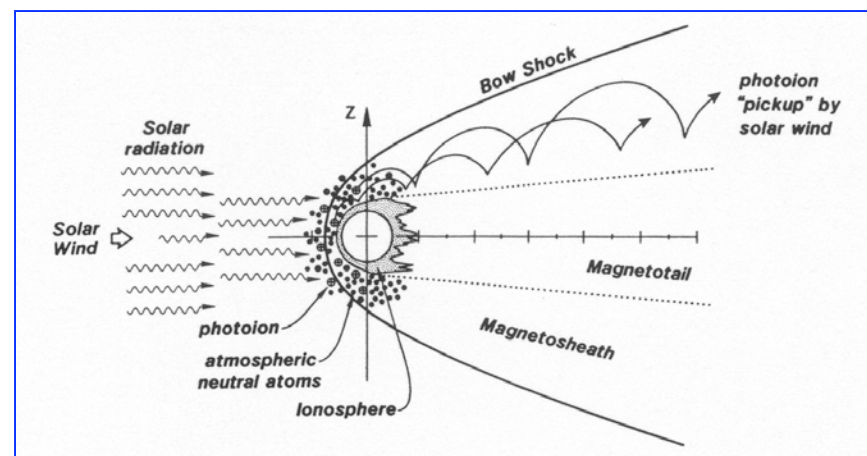
MESSENGER

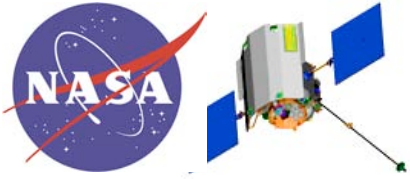
Venus Flyby 2: MAG and EPPS



- **Observe acceleration of energetic charged particles at Venus bow shock and elsewhere**
- **Measure interplanetary magnetic field (IMF) upstream of Venus**
- **Measure primary plasma boundaries:**
 - Bow shock and foreshock particle acceleration
 - Magnetic pile-up boundary
 - Ion pause
- **Measure near-tail region**

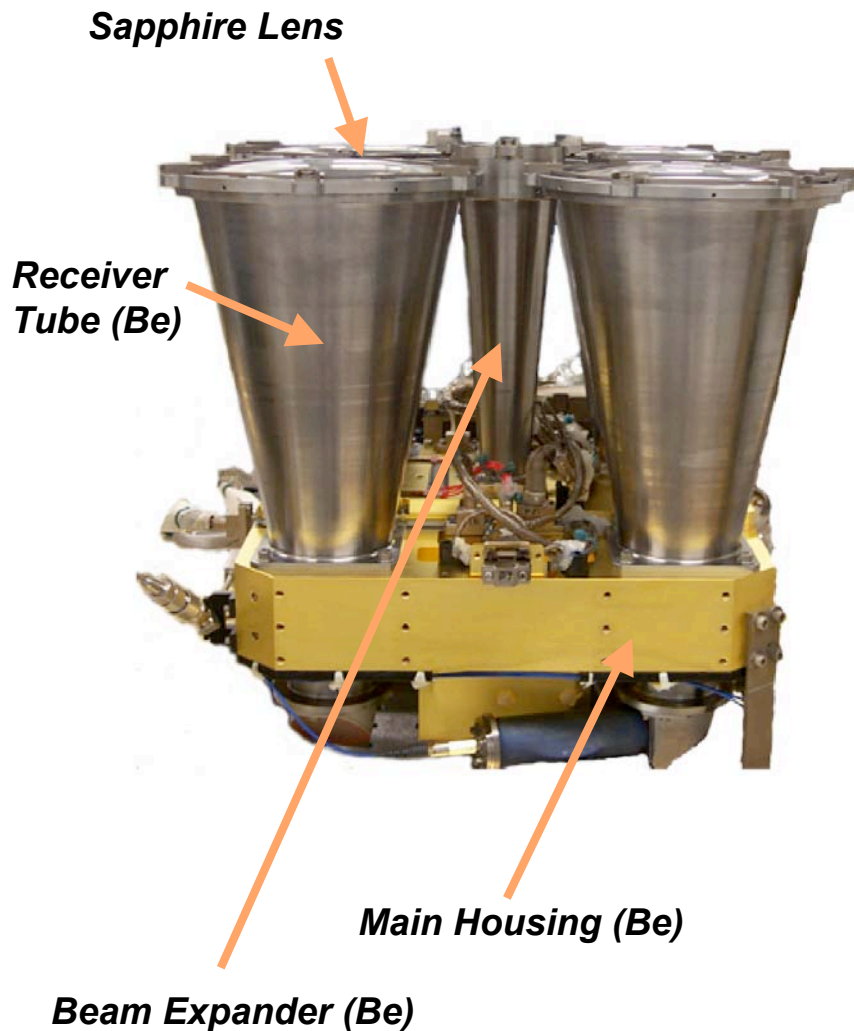
Solar wind-ionosphere interaction at Venus
[Luhmann, 1995]



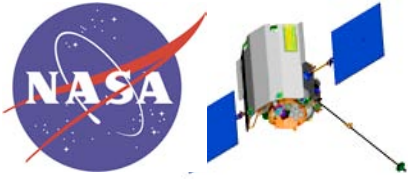


MESSENGER

Mercury Laser Altimeter



- 1000-km range
- 30-cm range resolution
- Cr:Nd:YAG laser
 - 1064-nm wavelength
 - Passive Q-switch
 - 8-Hz pulse rate
 - 7-ns pulse duration
- Avalanche photodiode detector
- Custom timing

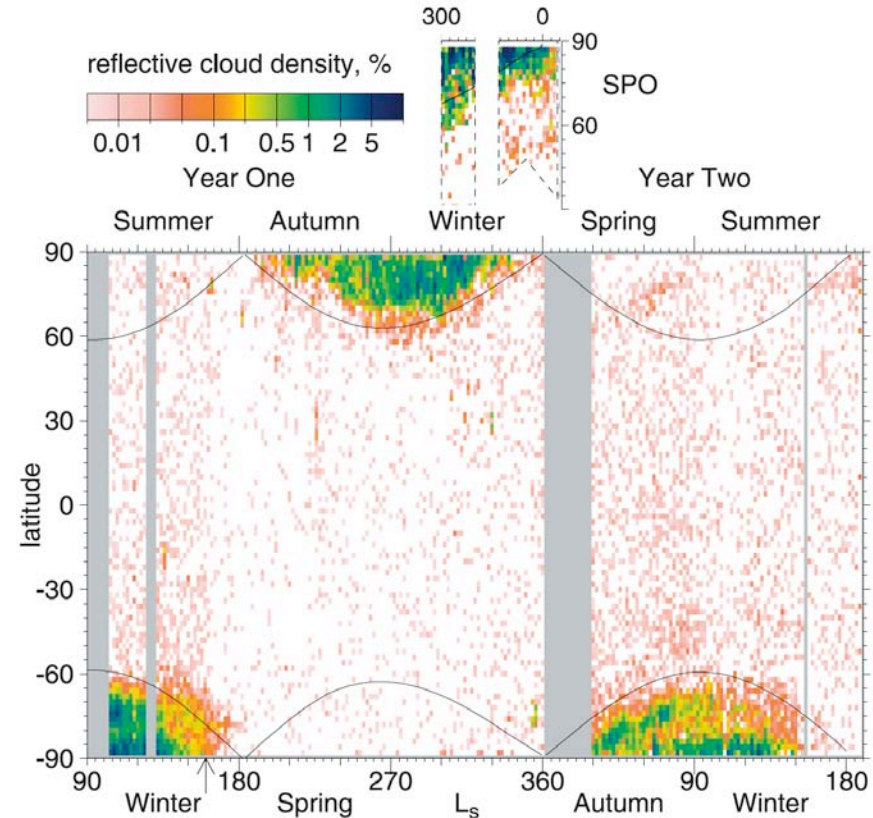


MESSENGER

Venus Flyby 2: MLA



- **Passive radiometry at 1064 nm**
- **Laser sounding to cloud decks**
- **Dusk terminator crossing at ~ 1000 km altitude**
- **Closest approach over night side**



Percentage of reflective clouds seen by MOLA at Mars versus solar longitude L_s [Neumann et al., 2003].

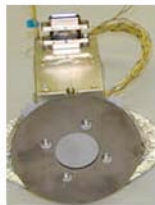


MESSENGER

X-Ray Spectrometer

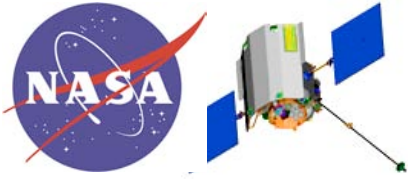


X-Ray Spectrometer Mercury Unit (XRS/MXU)



X-Ray Spectrometer
Solar Assembly
(XRS/SAX)

- **Solar-induced X-ray fluorescence**
 - Measures Mg, Al, Si, Ca, Ti, Fe
 - Energy range: 1 - 10 keV
- **Three gas proportional counters**
 - 12° field of view
 - Matched filters to separate Mg, Al, Si
 - Anticoincidence wires enhance SNR
 - Reject cosmic rays, solar flare ions, spacecraft background
- **Solar monitor**
 - Measures solar X-ray input
 - Be foils protect from direct Sun
 - Foils > 500° C; detector < 0° C

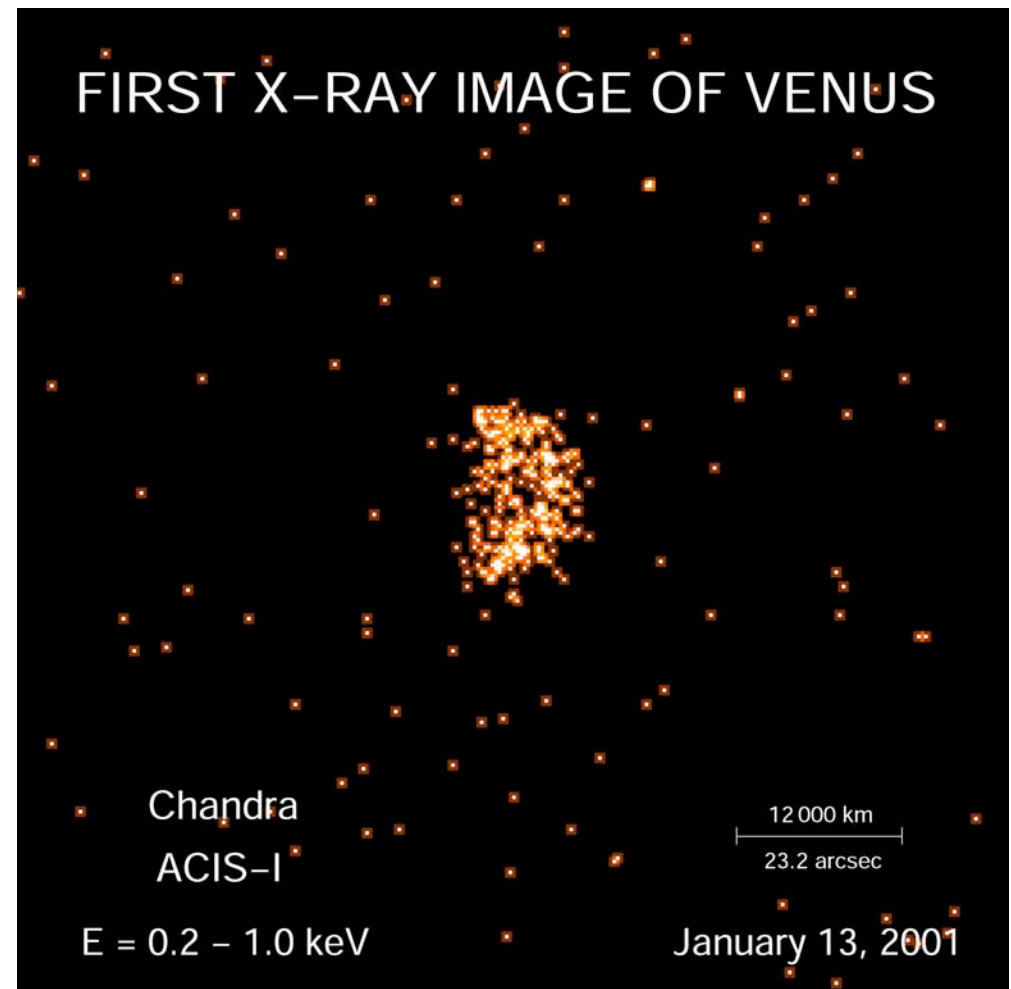


MESSENGER

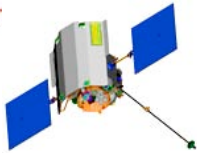
Venus Flyby 2: XRS



- Venus is visible in X-rays
- The Chandra X-ray Observatory detected fluorescent X-rays from O and C atoms between 120 and 140 km above the Venus surface
- Although the XRS energy range, 1 - 10 keV, is higher than that used to detect O and C, other species may be detectable
- Chandra will observe Venus at the time of the flyby



X-ray image of Venus taken by the Advanced CCD Imaging Spectrometer on Chandra on 13 January 2001.



MESSENGER

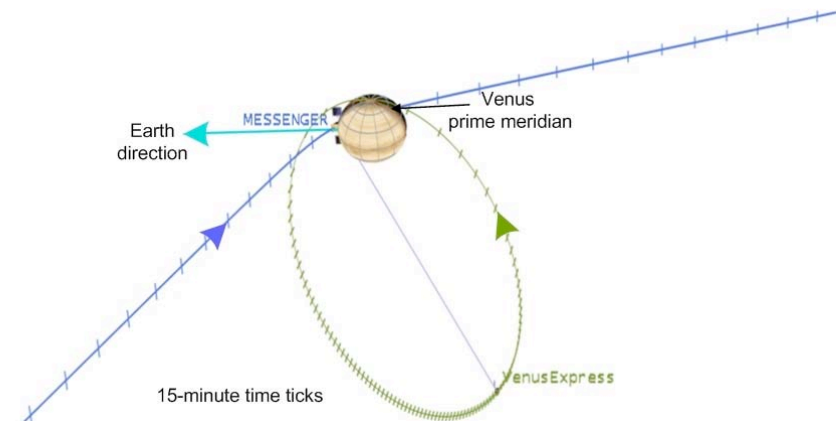
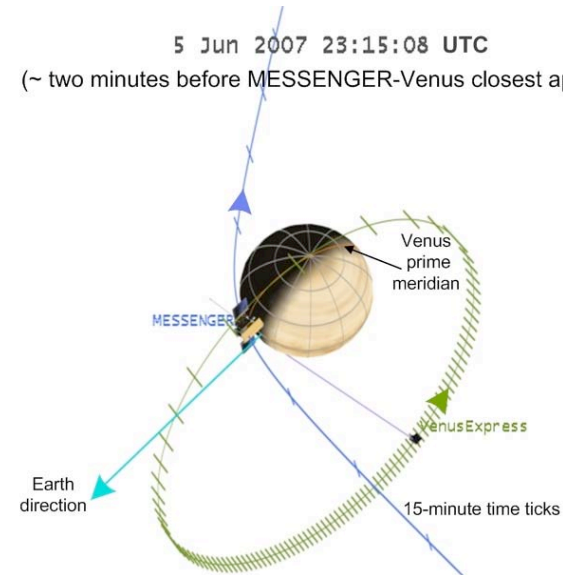
MESSENGER and Venus Express



Opportunity for coordinated two-point observations at Venus:

- Complementary viewing geometry of atmosphere and cloud properties
- Coordinated observations by MDIS, MASCS, and VIRTIS
- Complementary measurements of IMF penetration into ionosphere, plasma boundaries, and tail

5 Jun 2007 23:15:08 UTC
(~ two minutes before MESSENGER-Venus closest approach)



MESSENGER
Second Venus
Flyby