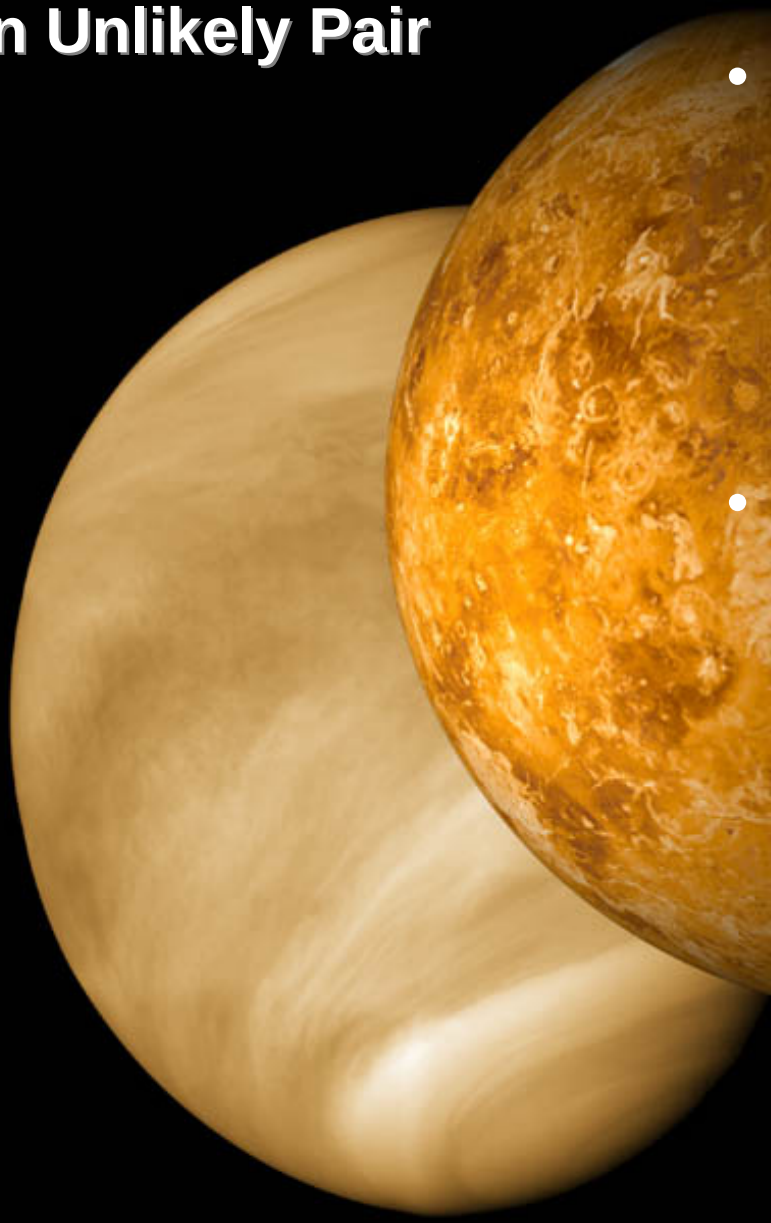
AOGS 1st Annual Meeting

A Renewed Focus on Venus Exploration

David Crisp (JPL) and the Venus Community Decadal Panel

Venus and Earth: An Unlikely Pair

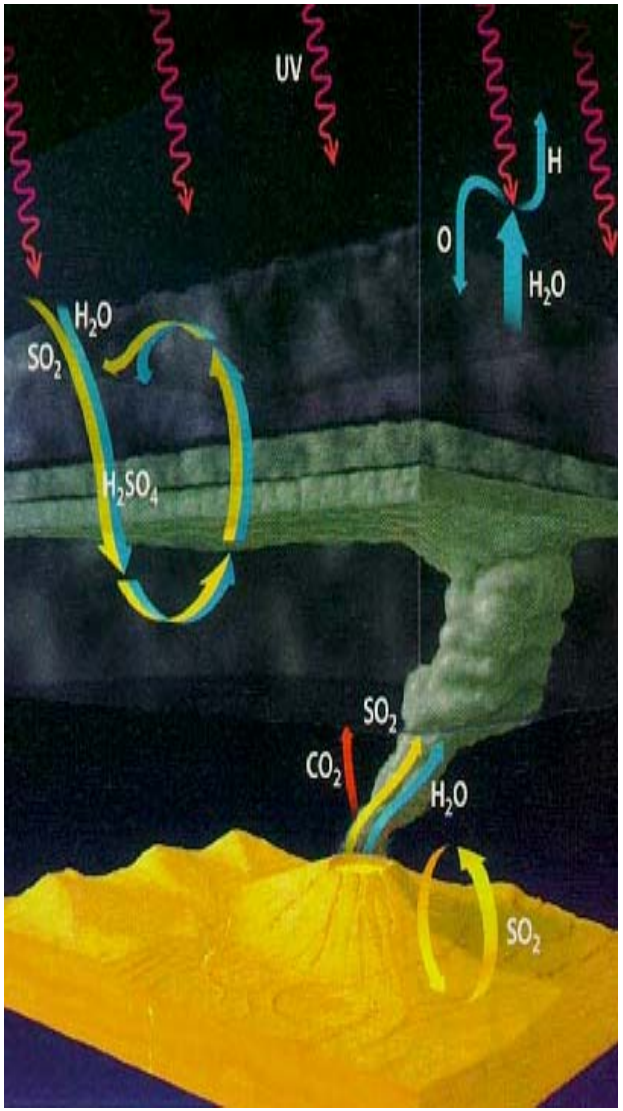


- Venus and Earth share a similar size, mass, and solar distance
  - Probably formed nearby in the solar nebula
  - Shared common initial inventories of refractory and volatile constituents
- Followed dramatically different evolutionary paths.
  - Earth evolved into the only known oasis for life
  - Venus developed an almost unimaginably hostile environment
    - Massive (90-bar) CO_2 atmosphere
    - Hellish (730 K) surface temperature
    - Global cloud deck composed of sulfuric acid (H_2SO_4) particles

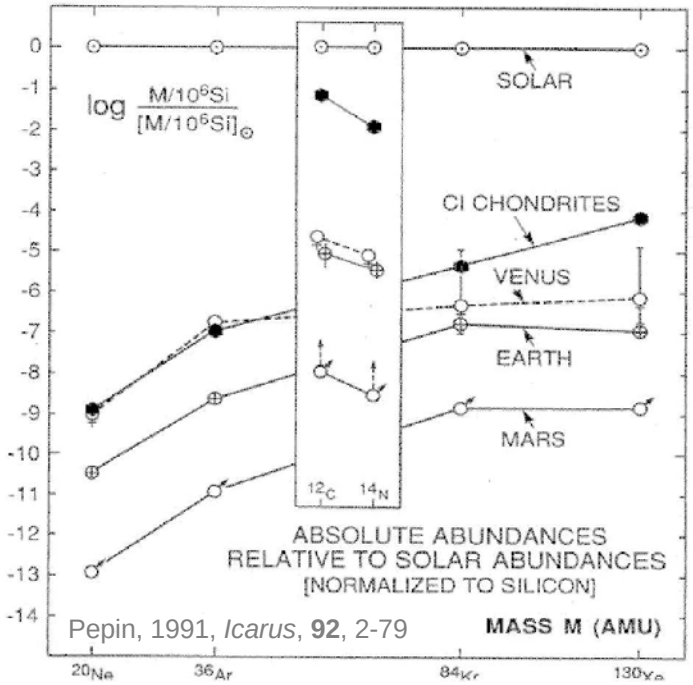
Venus with Visible and Radar Illumination

What led to the Divergent Evolution of Earth and Venus

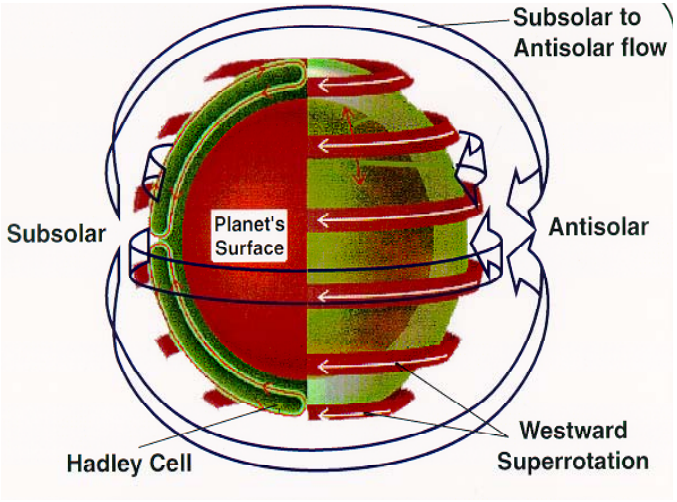
- Some differences can be attributed to their locations in the solar system,
  - Venus, at 0.7 AU, receives about twice as much solar radiation as Earth.
- The early Venus atmosphere may have experienced a runaway greenhouse
  - Available water evaporated, forming an optically-thick “steam” atmosphere
  - A large fraction of this early water-rich atmosphere may have been lost
    - photo-dissociation in the upper atmosphere
    - Subsequent escape of hydrogen to space
  - This left a devolatilized, oxidized crust and a massive, predominantly CO_2 atmosphere.
- The Earth may have lost much of its initial volatile inventory in the Moon forming impact



Unsolved Mysteries: The Atmosphere



Pepin, 1991, *Icarus*, **92**, 2-79



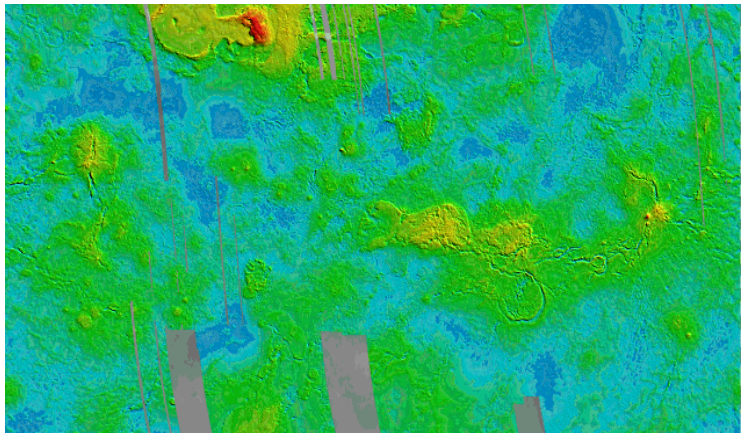
Venus has one of the most enigmatic atmospheres in the solar system

The volatile inventory of Venus is not as well characterized as those of Earth and Mars, but

- Relative abundances of noble gases in its atmosphere appear solar-like
- The atmospheres of Earth or Mars, seem strongly altered.

- **Contemporary Venus atmosphere**
  - Almost 100,000 times drier than Earth
  - D/H ratio is ~150 larger, suggesting the loss of a large fraction of the water inventory.
  - The specific processes and timing of this large loss of water are currently not known, frustrating efforts to understand the evolution of its surface and atmosphere.
  - The cloud-level atmosphere (~70 km) rotates with a period of 4 days, about 60 times faster than the planet's slowly-rotating surface.

Unsolved Mysteries: Surface and Interior



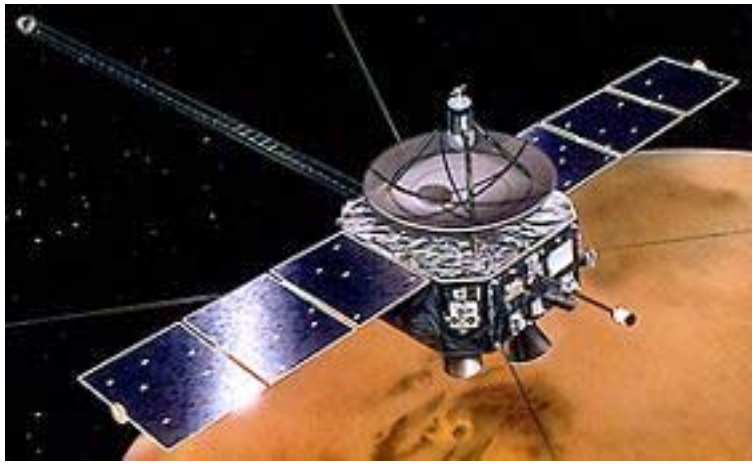
Global topography of Venus taken by Magellan

Radar observations reveal an intriguing surface.

- The cratering record indicates an average surface age of about 500-700 Ma
  - Similar to Earth's mean surface age, but
    - Only ~900 craters found
    - No evidence of plate tectonics
- The data support 2 geophysical explanations,
  - Catastrophic global resurfacing,
  - Local lithospheric thickness changes/volcanism.
- Do tesserae, volcanoes, plains and coronae have different local thermal histories.
  - What is their time/space relationship?
  - Is there evidence for any sequences or themes in the evolution of Venus' surface and interior?
- New measurements needed:
  - high spatial resolution imagery and altimetry,
  - in situ measurements of heat flow, seismicity, surface composition and age,
  - monitoring of possible current volcanic activity.

Upcoming Venus Missions

ESA Venus Express will be based on the ESA Mars Express mission



ISAS Venus Climate Orbiter (Planet C) will inherit characteristics of the Nozomi (Planet B) spacecraft

a. ESA Venus Express (VEX: 2005)

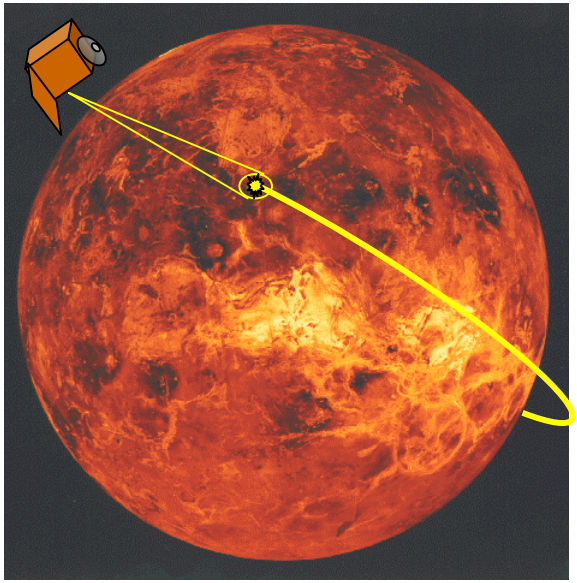
- Middle atmosphere temperature and trace gas composition
- Cloud level winds
- Cloud particle properties
- Lower atmosphere (bulk) cloud and trace gas composition

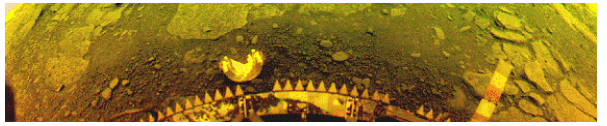
b. **JAXA Venus Climate Orbiter (Planet C: 2008)**

- Cloud-level wind fields
- Cloud particle size distributions
- Possible exospheric/space physics instrumentation

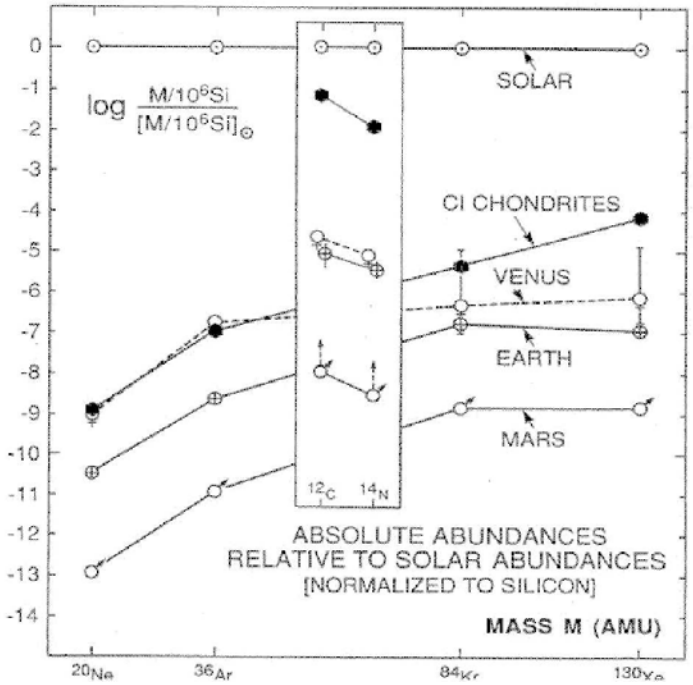
Conclusions of the Community Decadal Panel on Venus:

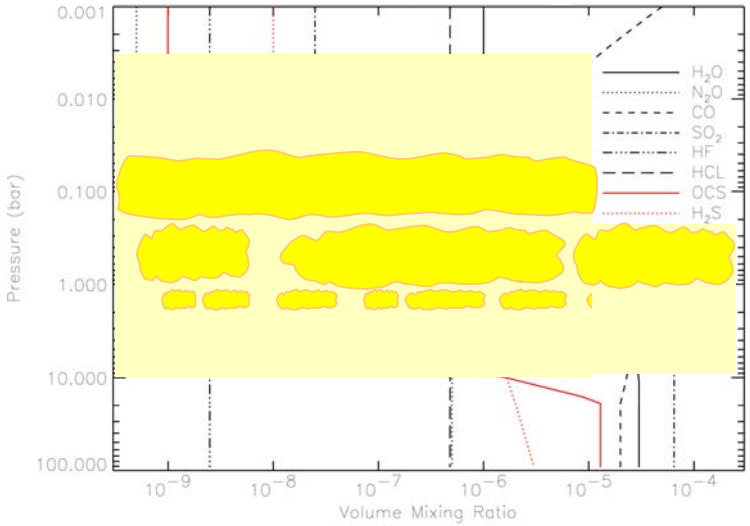
- It is not possible to address all of the questions with a single mission
- It should be possible to dramatically improve our understanding of our sister planet with a coordinated program of
  - small missions (Discovery Class)
  - medium missions ($650 M: New Frontiers)
  - large (~$1 B class) missions that is conducted by NASA and our international partners over the next 10 to 20 years.
- The NASA mission with the highest priority and greatest technological maturity is the Noble Gas/Trace gas explorer.
- The other missions have similar priorities, but
  - different levels of technological maturity
  - should fly as their critical technologies become available.





Noble Gas and Trace Gas Probe





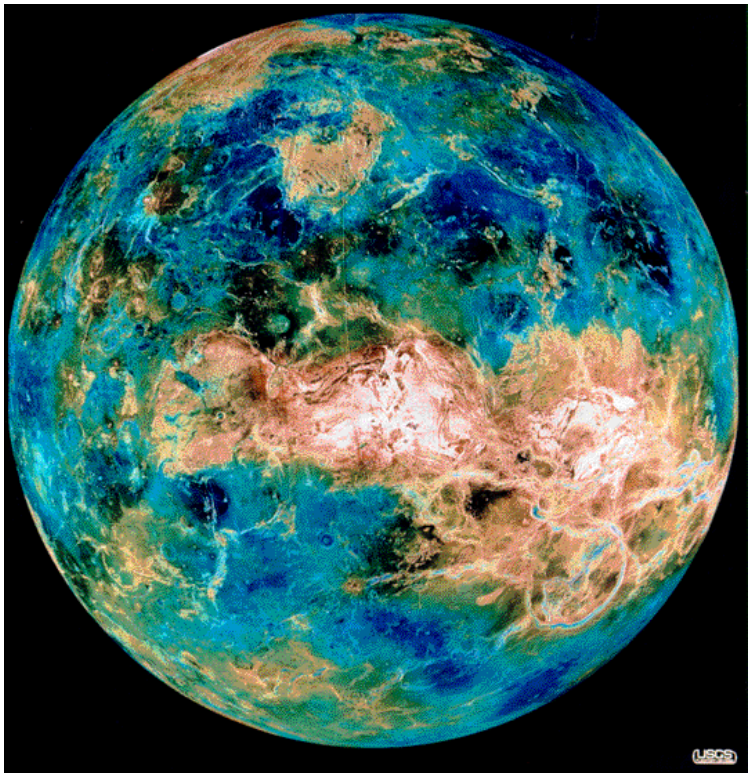
Objective: Complete the noble gas and trace gas inventories throughout the neutral atmosphere

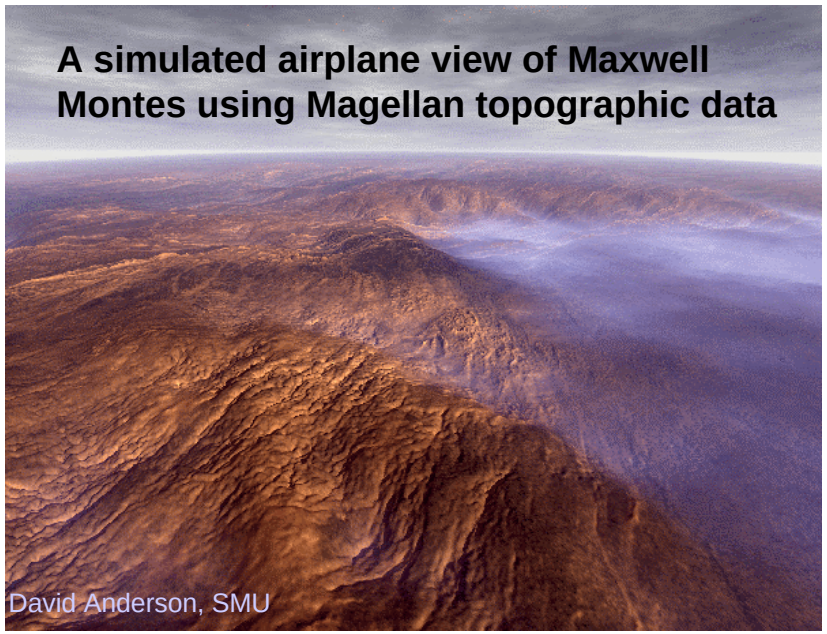
Approach: Single entry probe

1. State-of-the-art mass spectrometer, optimized for noble gas measurements
2. IR/UV spectrometers for high-precision trace gas profiling
3. Pressure/temperature sensors for altitude reference
4. Feed-forward technology: validation experiment for surface imaging and surface chemistry

Mission Class:

1. Small Mission (within the constraints of the Discovery program)
2. A single Medium Class mission combining these objectives with those of the Atmospheric Composition Orbiter would increase the science return.





Global Geological Process Mapping Orbiter

Objective: High Resolution Global Surface Imager/Altimeter

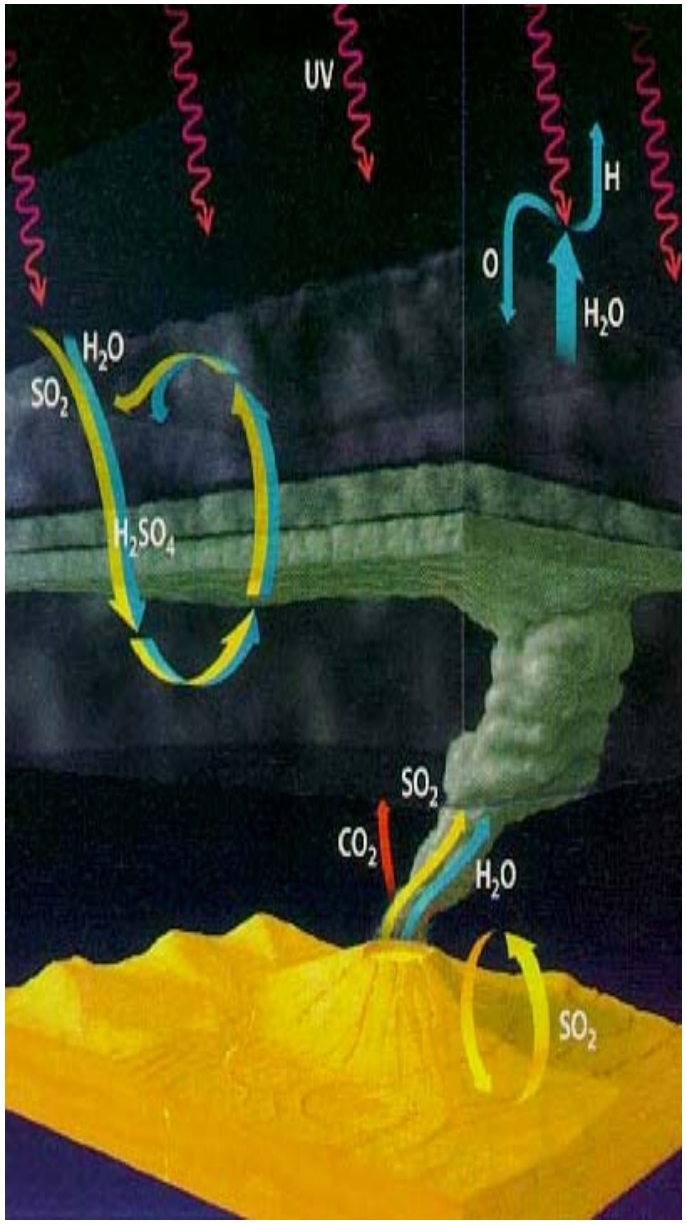
Approach: Polar Orbiter

1. C and/or X-band radar
   - Global stereo or interferometric coverage, possibly using a boom (e.g. SRTM)
   - imagery and topography with horizontal resolution ~30 m range
2. Instruments for identifying volcanic activity
   a. Near IR imaging spectrometer
   b. Nadir-looking multichannel microwave radiometer

a. Mission lifetime: 1-3 Venus years

Mission Class:

- Medium class mission (New Frontiers)
- Could be combined with the Surface and Interior Explorer, producing a Large Mission that with a greater science value

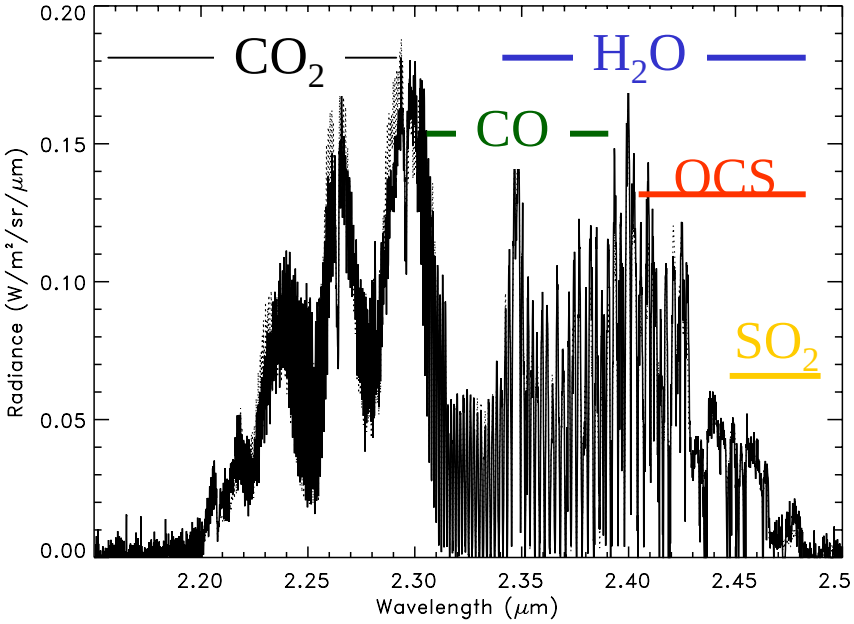


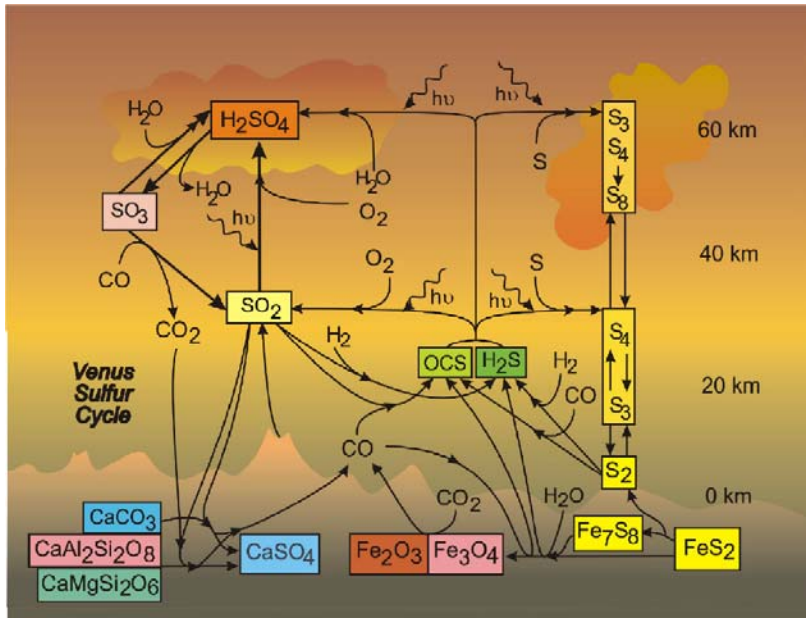
Atmospheric Composition Orbiter

Science Objectives:

1. High resolution near-IR imaging/spectrometer
   - Clouds, trace gases and dynamics
2. UV imaging for tracking cloud-top winds and characterizing the upper haze
3. Submillimeter heterodyne spectrometer for global measurements of middle atmosphere trace constituents and doppler winds
4. S and X-band radio science package
   - Sulfuric Acid Vapor profiles below clouds
   - Pressure/Temperature/Density (34 - 100km)
   - Thermal wind profiles in this altitude range
5. Thermospheric dynamics/mass loss

- Accelerometer for thermospheric scale height
- Neutral/ion mass spectrometer for in-situ exospheric mass loss measurements
- Fabry-Perot interferometer or baffled mass spectrometer for thermospheric dynamics





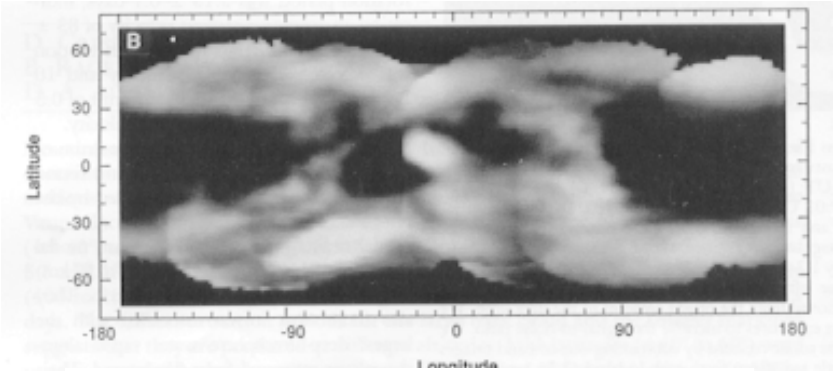
Atmospheric Composition Orbiter

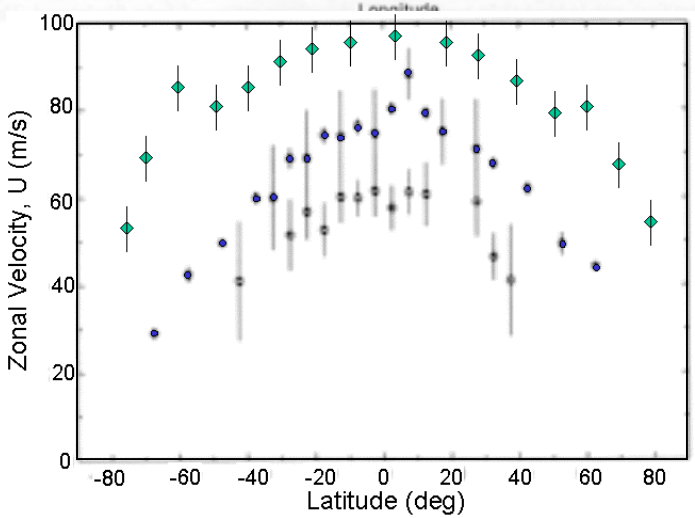
Approach:

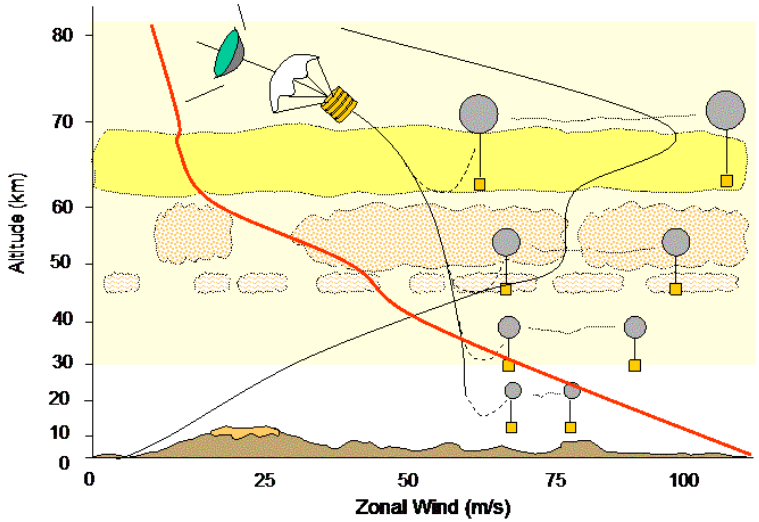
- Polar Orbiter with UV and NIR imaging spectrometers, submillimeter heterodyne spectrometer, neutral/ion mass spectrometers, interferometers, and accelerometers

Mission Class:

1. Small mission
2. A Medium Class mission that combines these objectives with those of the Noble Gas and Trace Gas Probe would yield a significantly greater science return per dollar







Atmospheric Dynamics Explorer

Objective: Acquire data needed to reveal the mechanisms controlling the superrotation

Approach:

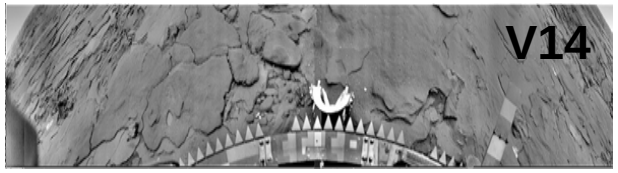
1. Network of 12 to 24 long-lived balloons

- Deployed between the surface and cloud tops at 3-4 latitudes (equatorial, mid, high)
- Time resolved measurements over one week to one month
- VLBI tracking, p, T, solar and thermal radiation

Orbiter

- Communications and balloon tracking
- UV and Near IR imaging spectrometers for tracking the upper, middle, and lower cloud decks and near surface static stability
- S- and/or X-band radio science package for retrievals of Pressure/Temperature/Density between 34 km and 100 km
- Signatures of gravity waves/thermal tides in temperature profiles

Mission Class: These objectives could be met by a Medium Class mission



Venera image of Venus surface

Surface and Interior Explorer

i. Objectives: Characterize the internal structure and surface composition

ii. Approach: Multiple long-lived (months) surface probes
   1.seismometers
   2. surface chemistry/mineralogy
   3. surface meteorology

iii. Significant technology development needed
   1. high temperature electronics and mechanical systems

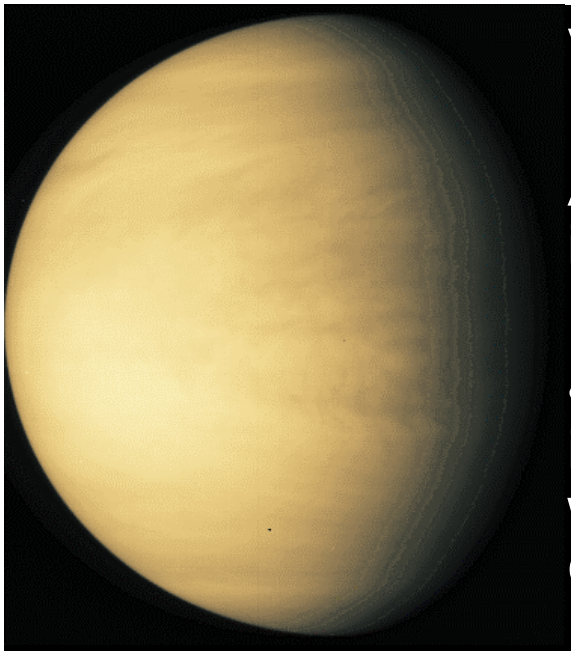
iv. Mission Class
   1. These objective would require a Large mission
   2. They could be combined with the Global Geological Process Mapping Orbiter to increase the science return per dollar

Sample Return

i. Capability needs, TBD

ii. Significant technology development needed

iii. Large mission



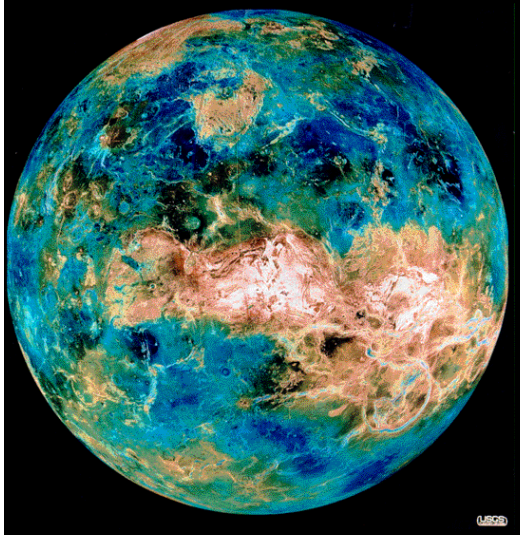
Venus: The Forgotten Planet

A reinvigorated Venus exploration program could improve our understanding of the origin, evolution, and habitability of terrestrial planets.

• A comprehensive inventory of the noble gases and isotopes of C, H, O and N in the Venus atmosphere would help us to understand our *past* by clarifying the conditions in the primordial solar nebula.

• A investigation of the processes controlling the current surface and atmospheric environment on Venus will provide a deeper understanding of the *present*

- greenhouse effects,
- atmospheric photochemistry, thermal chemistry,
- atmospheric dynamics,
- chemical weathering, and intraplate geology.



•A more comprehensive understanding of Venus could yield important clues about our *future* by providing

- atmospheric compositional stability and loss
- geophysical evolution of the Earth
  - •If plate tectonics evolves toward the stagnant-lid tectonics seen on Venus.

Why study Venus NOW?

Coordinated Venus and Mars programs are essential to the development of a comprehensive understanding of the origin and evolution of Earth-like terrestrial planets.

The present NASA Inner planets strategy, which focuses exclusively on Mars, will provide an incomplete, and possibly misleading description of processes that resulted in the current environments of Venus, Earth, and Mars.

Our lack of understanding of these processes could also cripple efforts to interpret observations of extrasolar terrestrial planets, which are expected to become available by the end of the decade.