Coordinated Sounding Rocket, HST, and SPICAV Observations of Venus in Nov. 2013

Fall AGU
P14A-08

John T. Clarke
Jean-Loup Bertaux
Carol J. Carveth
Jean-Yves Chaufray
Randy Gladstone
Nathan Darling

John T. Clarke
Center for Space Physics
Science Background - Isotopic Ratios

Assume Venus, the Earth, and Mars all started with the same amount of water and the same HDO / H₂O ratio.

Water near the surface will rise until the temp/pressure lead to condensation (clouds) - above that level the air is dry, and little water is photo-dissociated by solar UV light:

\[
H_2O + h\nu (UV) \rightarrow OH + H \quad \text{and same for HDO}
\]

H and D diffuse as H₂ to the top of the atmosphere, and can “boil off” into space if their thermal speed exceeds the escape speed.

H escapes faster than D due to mass difference, and D/H ratio increases as more water escapes.

Today:  Earth D/H ~ 1.6 \times 10^{-4}  \quad Mars \sim 9.3 \times 10^{-4}  \quad Venus \sim 0.05

Did Venus lose an ocean of water into space?
Measurements of deuterated water from Pioneer Venus and IR spectra both gave D/H ~ 0.05

Present escape depends on D/H atoms at the top of the atmosphere, look at UV H (and D) Ly α (reflected sunlight)

IUE UV spectra of Venus in early 1980’s resolved D and H Ly α lines (0.33 Ångstrom separation from mass difference) but did not detect D line, upper limit 1/6 of that expected (Bertaux and Clarke 1989)

**Complications:**

Rates of condensation are different for HDO and H₂O (well known from Earth atmosphere) - will act to remove more D than H in middle atmosphere, more H₂O subject to solar UV

Rates of photo-dissociation of HDO and H₂O are different - will also differentiate species mixed into upper atmosphere
Coordinated Rocket, HST, and SPICAV Observations of Venus in Fall 2013

A campaign has been organized for Oct/Dec 2013 to address:

- the loss of water into space

- the diffusion of hydrogen upward through the atmosphere

- the relative loss rates of D and H

One goal is to detect the D Lyman α line and derive the atomic D/H ratio (sounding rocket “VeSpR” and HST)

Another goal to measure the altitude profile of HDO and H₂O in the middle atmosphere (SPICAV on Venus Express).
look at Venus while HST in earth shadow
lines doppler shifted from LOS orbital motions

Observing geometry w/ long aperture ->

Aperture angle fixed, FOV limited
to disc of Venus

Model spectrum with VeSpR resolution

<- Simulated STIS echelle spectrum
with geocoronal, Venus, and IPH
emissions spectrally resolved
HST Observations of Venus on 24 Oct. 2013:

Quick look at HST data ->

Venus and geocoronal H Ly α emissions just resolved

D Ly α emission clearly detected with intensity profile across disc

Aperture Orientation on Venus:
The Venus Spectral Rocket Experiment (VeSpR)

Launched at WSMR on 26 Nov. 2013

Investigators:

John T. Clarke  Carol Carveth  Nathan Darling
    Boston U.

Jean-Loup Bertaux  LATMOS / BU

Jeff Hoffman  MIT
VeSpR:

Layout of the telescope and echelle spectrograph:

Launched on 26 Nov. 2013 from White Sands Missile Range, Venus was acquired as expected and both MCP detectors worked, quick look data indicate lower than expected count rate but a few thousand counts in the spectral channel

We will need to analyze the data in detail to learn more.
**SPICAV**: Venus’ middle atmosphere has been measured by the SOIR experiment on Venus Express. IR occultations provide altitude profiles of densities of $\text{H}_2\text{O}$ and HDO (Bertaux *et al.* 2007):

The decrease in HDO/$\text{H}_2\text{O}$ between 70-85 km is unexpected and unexplained:

HDO/$\text{H}_2\text{O}$ ratio is also higher than 0.05 for bulk atmosphere

May reflect differences in condensation and dissociation rates of $\text{H}_2\text{O}$ and HDO....

*SPICAV* observations set to begin 11 Dec. 2013 in post-eclipse season
Summary of Venus Campaign:

HST and VeSpR measure the D and H Ly $\alpha$ line emissions from the upper atmosphere, derive D/H ratio above the water.

HST has high angular resolution and can measure the profile across the disk, incl. limb brightening peak - gives altitude information about distribution of emission.

HST executed on 24 Oct., and VeSpR launched on 26 Nov.

HST data are high quality and clearly show the D emission, but do not extend off the planet disc for background measurement.

VeSpR has long aperture for better measurement of sky background.

SPICAV observations are constrained by s/c geometry, will begin in mid-Dec. and extend for several weeks.