Venus – many opportunities for small satellites & probes

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Picture: Etna lava flow, with Catania in the background
A long time ago, three planets formed around a young star...

What would their futures hold?

“Precisely because it began so like Earth, yet evolved to be so different, Venus is the planet most likely to cast new light on the conditions that determine whether or not a planet evolves habitable environments.”

Buck Sharpton, LPI
Why Venus?

• Venus should be the most Earthlike planet we know.
  – Created at roughly the same time
  – Apparently similar bulk composition
  – Almost the same size & density
  – Today, similar solar energy input
    • (due to high reflectivity of Venus clouds).

• Early Venus was probably much like early Earth
  Hot dense atmosphere rich in CO$_2$ and water
  Similar initial inventory of volatiles and noble gas isotopes
  Did Venus ever harbor liquid water? Could life have evolved there?

• Venus also illustrates the probable fate of the Earth.
  In ~ 1 billion years, with a brighter sun, the insolation at Earth will be similar to that at
  Venus today.
  Will we be able to avoid the runaway greenhouse warming that is found at Venus?

Need to understand the ‘life story’ of terrestrial planets
Comparative planetology of terrestrial planets

- Compare Venus, Earth and Mars to deepen our understanding of fundamental geophysical processes.
Venus – good for cubesats?

- *Venus is the closest planet – typically 5 months cruise.*
- *Short Venus-Earth distance means high(er) datarates.*
- *Ample sunlight – lots of power.*
- *With several missions at Venus, a communications infrastructure could be formed (as at Mars)*
- *Many Venus gravity assists – frequent opportunities to be launched towards Venus.*
- *Venus: a good starter planet for your interplanetary adventures!*
Many environments, many vehicles

- **> 130 km: Exosphere**
  - Escape; solar wind interaction
  - Satellites / microsatellites

- **70 - 130 km: Mesosphere**
  - Escape; turbulence; cryosphere
  - Skimming probes; entry probes

- **48 – 70 km: Main Cloud layer**
  - Cloud processes; convection; greenhouse
  - Balloons / UAVs

- **0 – 48 km: Below the clouds**
  - Radiative balance; thermochemistry
  - Multiple miniprobes

- **Surface:**
  - Volcanism, tectonism; surface composition; seismology
  - Microlanders; high-temperature systems
(1) Ionosphere / Escape orbiter

• Goals:
  – What governs escape in weakly magnetised planets?

• Payload:
  – Neutral mass spec.
  – Magnetometer
  – Langmuir probe
  – Electron spectrometer

• Cubesat advantage:
  – Multi-point measurement

• Example: NSF DICE or UMich CADRE cubesats
(2) Atmospheric chemistry/dynamics orbiter

- **Goals:**
  - Map winds at different levels
  - Map sulphur dioxide

- **Payload:**
  - Generic UV-VIS-nIR imagers

- **Cubesat advantage:**
  - ?

- **Example: Akatsuki orbiter**

  Atmospheric levels targeted by Akatsuki orbiter’s imagers (Nakamura et al. 2007)
(3) Lightning hunting orbiter

• Goals:
  – Search for lightning!

• Payload:
  – UHF receiver
  – [ High-speed camera with event detection ]
  – [ Gamma-Ray detector ]

• Cubesat advantage:
  – Triangulation from multi-point UHF measurements

• Reference: Majid et al. (2013, 2015) Caltech study
(4) Volcano hunting orbiter

- **Goals:**
  - Map surface temperature at 1 µm wavelength on nightside

- **Payload:**
  - Near-infrared imager (0.8 – 1.7 µm) – 50 km resolution

- **Cubesat advantage:**
  - Cheaper…?
  - But may need onboard data reduction to reduce datarate

- **Reference:** VEM instrument, J. Helbert et al.

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Transient hot spots on the surface?  
Shalygin et al, 2014  
Embargoed until March 2014
(5) Earthquake hunting orbiter

• Goals:
  – Detect the signatures of seismic waves from the traces they leave in the lower thermosphere.

• Payload:
  – 4.3 µm (or 1.27 µm) imager in high equatorial orbit.
  – High datarate – intelligent onboard processing needed.

• Cubesat advantage:
  – High risk of non-detection
  – Orbit not of interest for most investigations

• Reference: KISS report (2015), David Mimoun et al.

↑ CO2 airglow at 4.3 µm at the South pole of Venus using VEx (Garcia et al., JGR 2009)

Airglow signature of tsunami on Earth →
(6) Skimming probe

- Goals:
  - Measure composition of atmosphere – without the hassle of ablative TPS!
  - *See next talk: Tony Freeman et al.*

- Reference: C. Sotin et al. “Cupid’s Arrow”

Reference: Russell Boyce et al., VAPR concept, icubesat 2015
(7) Small entry probes

• Goals:
  – Measure noble gas isotopic abundance
  – [and/or other chemistry]
  – Measure temperature, winds, etc.

• Payload:
  – Mass spectrometer / Tunable laser spectrometer
  – Meteorology (p, T, light, …)
  – Radio link for tracking

• Cubesat advantage
  – Multiple profiles

• Reference: Pioneer Venus multiprobe; Qarman cubesat entry probe

Pioneer Venus large (290 kg) and small (90 kg each) probes
(8) Balloon-deployed probes

- Goals:
  - Probe deep atmosphere

- Payload:
  - Meteorology (p, T, light, …)
  - Radio link for tracking
  - [imager; chemical payload]

- “Cubesat” advantage
  - Multiple profiles


Non-imaging: 100 g each
Imaging: 2 kg each
(9) Probe-deployed UAV

- **Goals:**
  - Explore horizontal variation at cloud level
  - [Measure UV absorber in situ]

- **Payload:**
  - Meteorology (p, T, light, …)
  - Radio link for tracking
  - [imager; chemical payload]

- **“Cubesat” advantage**
  - high-risk mission element

(10) Small high-temperature seismometry station

• Goals:
  – Short-term (<1 month) seismometry

• Payload:
  – Seismometer
  – High-Temperature SiC electronics
  – Primary battery (short lifetime)

• “Cubesat” advantage
  – high-risk mission element

A new view of Earth's sister:
Insights following seven years of observations with Venus Express
Dmitriy Titov
European Space Agency

Venus – a world of possibilities