ESA's Science programme
Opportunities for Venus missions

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Picture: Lava on Etna, with Catania in the backgro

ESA's Science program

ESA Mandatory Science program, to which all member states contribute, includes:

- L-class missions
- M-class missions
- S-class missions
- Missions of opportunity

There is also an optional Mars Robotic Exploration Preparation (MREP) Programme:

- *Includes the ExoMars 2016 & 2018 missions*
- *Future mission options include Moon & Mars missions.*
- ***Optional** nature of the programme means that countries can vary at will the level of their contribution.*

L-class missions (~1000 MEuro)

- L-class missions have a cost cap of ~1000 MEuro
  - L1 (2022 launch): JUICE mission to Jupiter
    - Runners up were ATHENA (X-ray astronomy) and LISA (gravity wave detector)
  - L2 (2028 launch)
  - L3 (2033 launch)

- April 2013: Call for White Papers to define Science Themes for L2 and L3 missions

L2/L3 Science theme white papers

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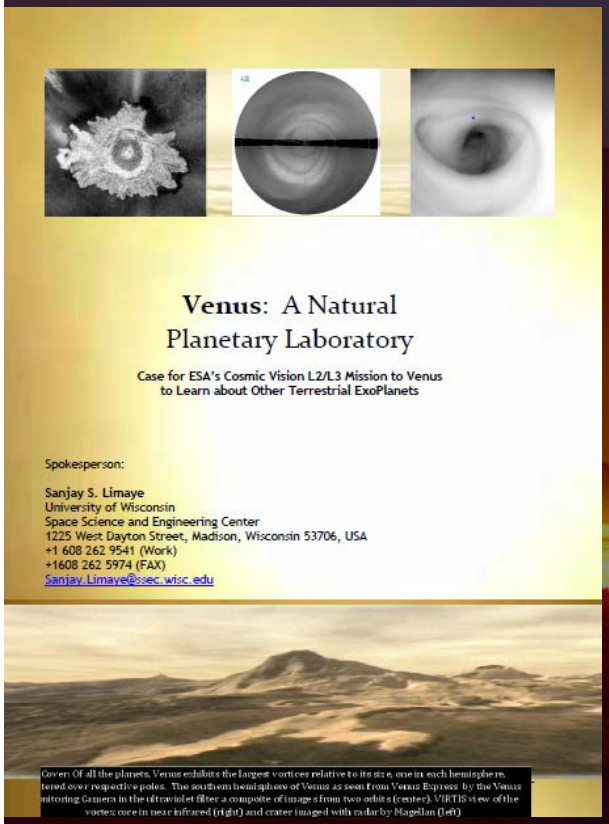
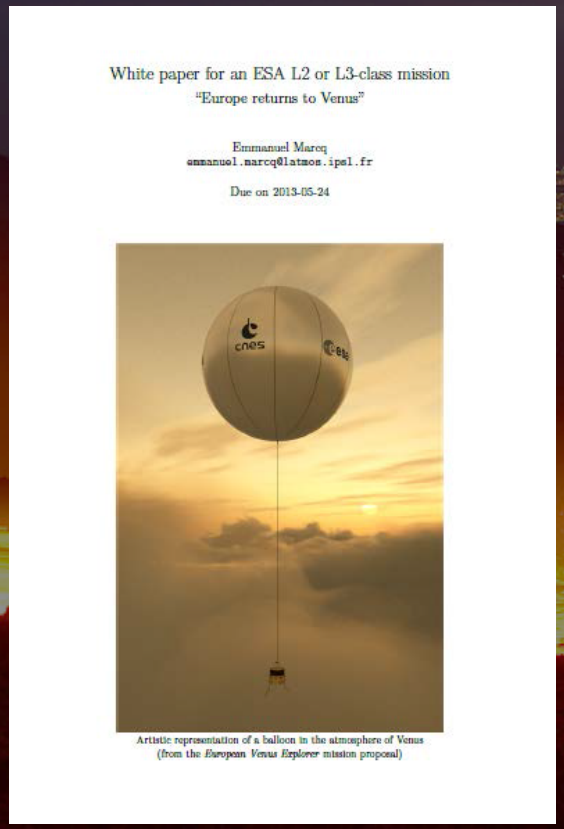
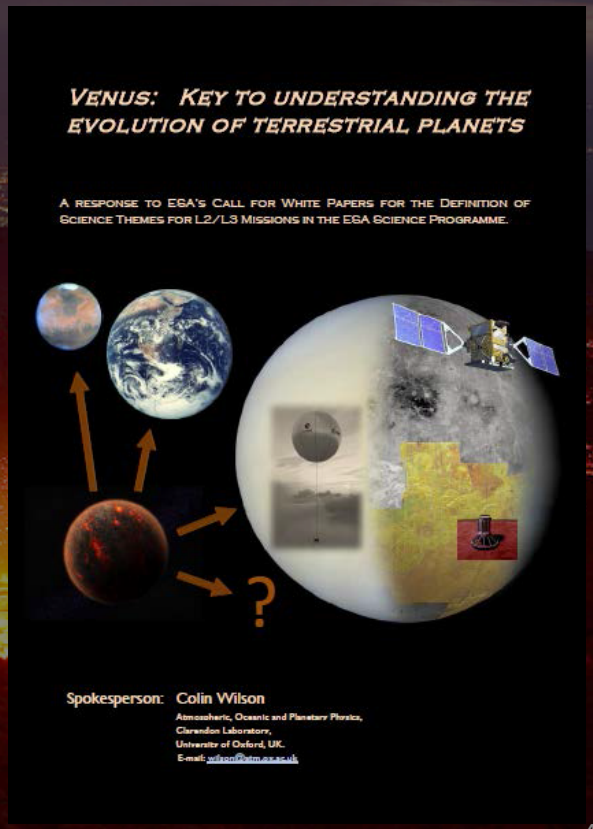
Three out of thirty white papers advocated Venus exploration:

Papers were led by Limaye, Marcq, Wilson. Presentation made in Paris Sep 2013.







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All three of us advocated Orbiter + In Situ element(s).

In particular, my paper suggested a focus on understanding the evolution of Venus, using:

- ***InSAR-equipped orbiter*** to study geological record of history
  - Orbiter also carried LIDAR, UV & IR spectrometers, cameras for atmospheric science
- ***In situ (balloon) measurements of noble gas isotopes*** to study pre-geological history
  - Balloon also carried chemistry & meteorology package to characterise cloud-level processes.

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And the winner is …

L-class missions (~1000 MEuro)

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  - L1 (2022 launch): JUICE mission to Jupiter
  - L2 (2028 launch): to address **"the hot and energetic universe"**
    - e.g. X-ray telescope (ATHENA)
  - L3 (2033 launch): to address **"the gravitational universe"**
    - e.g. space-based gravity wave interferometer (LISA)

(Note: LISA and ATHENA were the two runners-up in L1 competition)

- i.e. no L-class opportunities for Venus before 2035

M-class missions (~500 MEuro)

- M1 (2017 launch) is Solar Orbiter
- M2 (2020 launch) is EUCLID
  - Investigating dark energy / dark matter
- M3 (~2023 launch) downselection to be announced in Feb 2013
  - EChO Exoplanet Characterization Observatory
  - Marco Polo-R Asteroid Sample Return
  - PLATO Exoplanet transits & Astroseismology
  - STE-Quest tests of Einstein's equivalence principle
  - LOFT X-ray telescope
- M4 mission (~2026? launch)
  - Call for ideas anticipated ~Q2 2014 (TBC)
  - Proposals due ~Q4 2014 (TBC)

M-class mission proposals 2014

'EVE' (European Venus Explorer) Cloud-level superpressure balloon

- Proposed 2007, 2010 (Chassefière, Wilson et al. - doi:10.1007/s10686-011-9259-9)
- 2014 proposal will be broadly similar to 2010 proposal: 1 balloon at 55 km altitude.

<u>A balloon mission in the heart of the habitable layer</u>

- Helium superpressure balloon, 53-57 km float altitude.
- Benefit from benign climate: 10 – 50 °C, atmospheric densities like those found at 0 to 5 km altitude on Earth.
- Explore clouds of liquid water (albeit mixed with sulphuric acid).
- Use high winds of 200-250 km/h to circumnavigate the planet in 5-8 days.

M-class mission proposals 2014

'Envision' Venus Orbiter proposal

- See M3 Envision proposal by Ghail et al (described at doi:10.1007/s10686-011-9244-3)
- C-band InSAR based on ESA's Sentinel-1 radar (launching 2014)
- Atmospheric payload including LIDAR, spectrometers, cameras
- 2014 proposal likely to address same science as 2010 proposal, but with more optimised mission design and wider science team.

ESA Sentinel-1 Earth radar orbiter

ESA Venus radar orbiter

M-class mission proposals 2014

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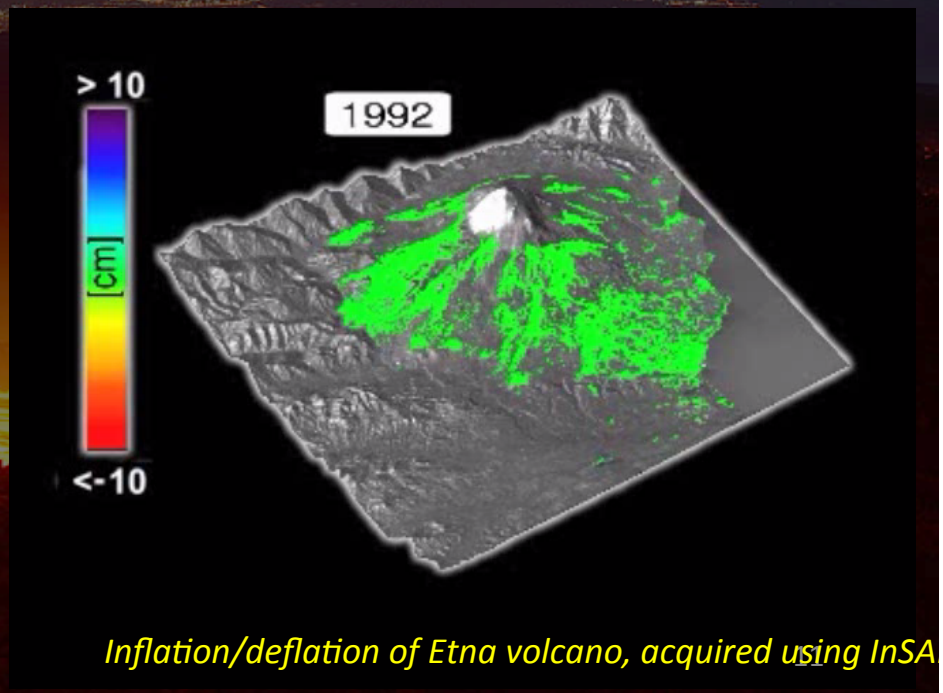


Inflation/deflation of Etna volcano, acquired using InSA

InSAR could allow measurement of surface changes down to cm scale

For Venus, this could provide the most direct possible evidence of active volcanism & tectonism

S-class missions (~50 MEuro)

- ESA contribution of €50m to mission led not by ESA but by another space agency.
- S1 (launch 2017) is CHEOPS
  - (CHaracterizing ExOPlanet Satellite using ultrahigh precision photometry of exoplanetary transits)
  - led by Swiss Space Office.
- No formal date set for S2 at present

Missions of Opportunity

- Finally in the Cosmic Vision stable of missions is one "mission of opportunity"

SPICA (Space Infrared Telescope for Cosmology and Astrophysics)

- Led by JAXA, launch planned for 2022
- ESA contributes the major instrument: 30-210 µm imaging spectrograph
- ESA's contribution is of the order of €200M

A potential ESA-CAS mission is being considered.

- 25-26 Feb 2014: 1st Workshop in China
- Q3 2014: 2nd Workshop in Europe
- ESA contribution is likely to be S-class, i.e. €50m contribution to a larger mission
- I plan to submit a paper on Venus exploration (abstracts due 16 Dec)

Missions of Opportunity

In principle, we could follow the MoO option for ESA participation in Russian-led Venus mission.

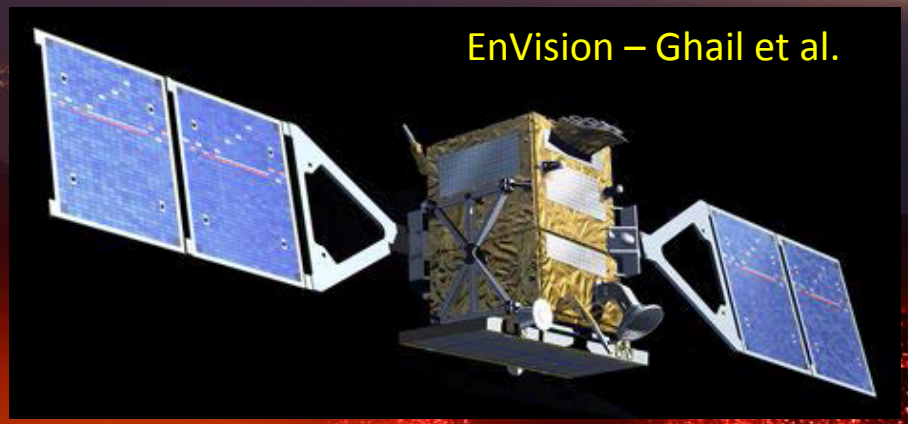
- For example, reuse of ExoMars TGO spacecraft (funded by ESA, built by European industry, launched by Russia) would give great science at Venus.
- Possibilities being investigated with Russian partners.
- Note that ESA's time horizon is long, e.g. typically launch dates 10+ years ahead. This generally precludes major ESA participation in NASA Discovery-class missions.

ExoMars TGO (2016, ESA/Russia)

In conclusion

- M-class mission proposals 2014: coming soon!

EVE – Wilson et al.



EnVision – Ghail et al.