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VenSAR on EnVision: Taking earth observation radar to Venus

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ABSTRACT

Venus should be the most Earth-like of all our planetary neighbours: its size, bulk composition and distance from the Sun are very similar to those of Earth. How and why did it all go wrong for Venus? What lessons can be learned about the life story of terrestrial planets in general, in this era of discovery of Earth-like exoplanets? Were the radically different evolutionary paths of Earth and Venus driven solely by distance from the Sun, or do internal dynamics, geological activity, volcanic outgassing and weathering also play an important part? EnVision is a proposed ESA Medium class mission designed to take Earth Observation technology to Venus to measure its current rate of geological activity, determine its geological history, and the origin and maintenance of its hostile atmosphere, to understand how Venus and Earth could have evolved so differently. EnVision will carry three instruments: the Venus Emission Mapper (VEM); the Subsurface Radar Sounder (SRS); and VenSAR, a world-leading European phased array synthetic aperture radar that is the subject of this article. VenSAR will obtain images at a range of spatial resolutions from 30 m regional coverage to 1 m images of selected areas; an improvement of two orders of magnitude on Magellan images; measure topography at 15 m resolution vertical and 60 m spatially from stereo and InSAR data; detect cm-scale change through differential InSAR, to characterise volcanic and tectonic activity, and estimate rates of weathering and surface alteration; and characterise of surface mechanical properties and weathering through multi-polar radar data. These data will be directly comparable with Earth Observation radar data, giving geoscientists unique access to an Earth-sized planet that has evolved on a radically different path to our own, offering new insights on the Earth-sized exoplanets across the galaxy.

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1. Venus, our Prodigal Twin

Surprisingly little is known about our nearest planetary neighbour, not even the basic sequence and timing of events that formed its dominant surface features. NASA's 1989–1994 Magellan mission provided a global image of the surface at 100 – 200 m resolution, comparable in coverage and resolution to that of Mars after the Viking missions in the 1970s. Magellan revealed an enigma: a relatively young surface, rich in apparent geological activity, but with a crater distribution indistinguishable from random (Fig. 1). The initial conclusion was that a global catastrophe half a billion years ago had resurfaced the planet: Venus was solved. After Viking, Mars was similarly thought to be understood, with everything known that needs to be known. Two decades later, Pathfinder reignited public and scientific enthusiasm in Mars and since then newer and higher resolution data from MGS, MRO and Mars Express have revolutionised our understanding of current and past processes alike.

ESA's 2006–2014 Venus Express, the most successful mission to Venus in the last two decades, revealed a far more dynamic and active planet than expected, uncovering tantalising evidence for present day volcanic activity that demands further investigation (Svedhem et al., 2007). Nonetheless, the enigma remains: how can a geologically active surface be reconciled with the global stasis inferred from the apparently random impact crater distribution? The outstanding science goals are therefore to determine the level and nature of current geological activity and the sequence of geological events that generated its range of surface features; assess whether Venus once had oceans or was hospitable for life; and

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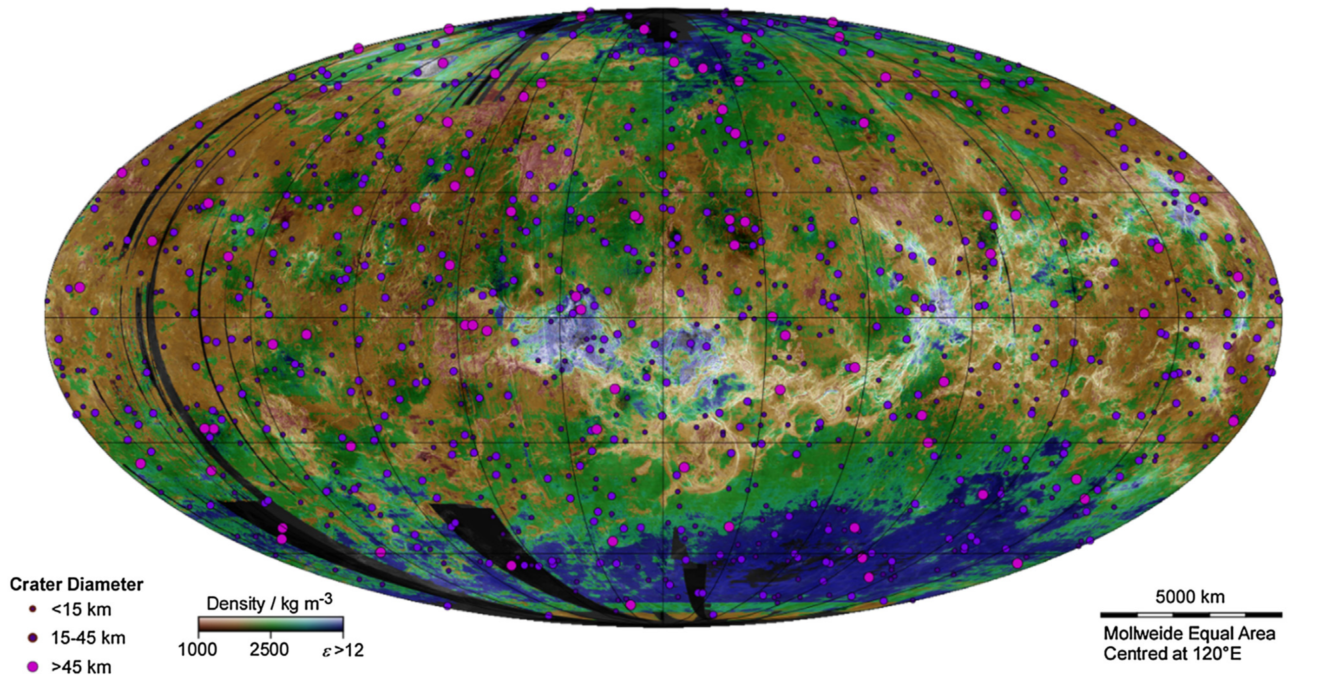

Fig. 1. Global Crater Distribution.(For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
That the spatial distribution of impact craters is indistinguishable from a random is a puzzle because no other features on Venus occur at random. Underlying colour map shows surface materials: pink – loose sediment; brown – sedimentary or weathered rock; green – volcanic rock; blue – low permittivity materials.

understand the organising geodynamic framework that controls the release of internal heat over the history of the planet. EnVision builds on Europe's experience and technology heritage in Earth Observation to take a comprehensive look at our nearest planetary neighbour in unprecedented detail.

1.1. Geology, but not as we know it

Observations from Magellan data imply a variety of age relationships and long-term activity (Chetty et al., 2010; DeShon et al., 2000), with at least some activity in the recent past (Ghail 2002a; Price et al., 1996; Smrekar et al., 2010a). There is a non-random distribution of topography (the highs particularly are semi-linear features) and an association between geological features and elevation, such that the uplands are consistently more deformed than the lowlands. The distribution of impact craters is not strictly random either (Campbell 1999; Hauck et al., 1998; Price et al., 1996), with recent observations about the degree of crater alteration (Herrick and Rumpf 2011) permitting a wider range of possible recent geological activity (Campbell 1999; Guest and Stofan 1999; Hansen and Young 2007; Johnson 2003; Stofan et al., 2005).

Steep slopes and landslides are very common on Venus, implying active uplift, but existing data provide no constraint on current rates of tectonic activity. The surface of Venus is not organised into large plates like Earth's oceans but it is partitioned into areas of low strain bounded by narrow margins of high strain, analogous to continental basins and microplates. Are these regions actively created and destroyed, like Earth's oceans, or simply mobilised locally? What is the significance of the global network of elevated rift systems (Fig. 2), similar in extent to mid-ocean ridges but very different in appearance? Unique to Venus are coronae, quasi-circular tectonic features, typically 100–500 km across, with a range of associated volcanic features. Are coronae the surface expression of plumes or magmatic intrusions? What role do they play in global tectonic and volcanic change?

Recent and perhaps ongoing volcanic activity has been inferred in both Venus Express (Marcq et al., 2013; Shalygin et al., 2014; Smrekar et al., 2010c) and Magellan (Bondarenko et al., 2010) data. Maintenance of the clouds requires a constant input of H2O and SO2 (Bullock and Grinspoon 1996) which equates to a magma effusion rate of only 0.5 $km^3\ a^{-1}$, assuming a saturated magma source.

However, only one significant volatile-rich pyroclastic flow deposit, Scathach Fluctus (Ghail and Wilson 2013), has been identified to date, and the morphology of most larger volcanoes is consistent with low volatile eruptions. The actual magmatic rate is likely far higher, ~10 $km^3\ a^{-1}$, about one third Earth's (Grimm and Hess 1997).

Constraining volcanic activity is critical to understanding when and how Venus was resurfaced, but it is also important to constrain the nature of that activity. Are there other large pyroclastic eruptions or is Scathach Fluctus unique? Are canali or other specific magmatic features confined to a past regime or still active today? Is there a correlation between mesospheric SO2 concentration and volcanic activity? Are crater floors effusively infilled and buried from below? Were the plains formed from a few massive outpourings in a short period of time or from many thousands of small flows over their entire history? Or were they formed, or modified, in an entirely different way?

1.2. Its hell down there

The slow moving dense lower atmosphere of Venus creates a sedimentary environment similar to the deep oceans on Earth, but at 735.3 K (Seiff et al., 1985). Dunes and other aeolian features are rarely large enough to be visible in Magellan images so new data to understand its modern sedimentary processes is key to distinguishing whether ancient deposits formed under similar conditions or under more benign water oceans. Surface images captured by Soviet Venera landers reveal a landscape more consistent with pyroclastic or sedimentary deposits, not the basaltic lava flows widely assumed to cover the plains. The bedrock recorded at the Venera 10, 13 and 14 sites consists of laminated or thinly bedded sheets with varying degrees of coarse sediment or regolith (Fig. 3).

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