ULTRAVIOLET ABSORBER(S) ON VENUS – BACTERIA?

Physical, Chemical and Spectral Properties similar to some Micro-organisms?

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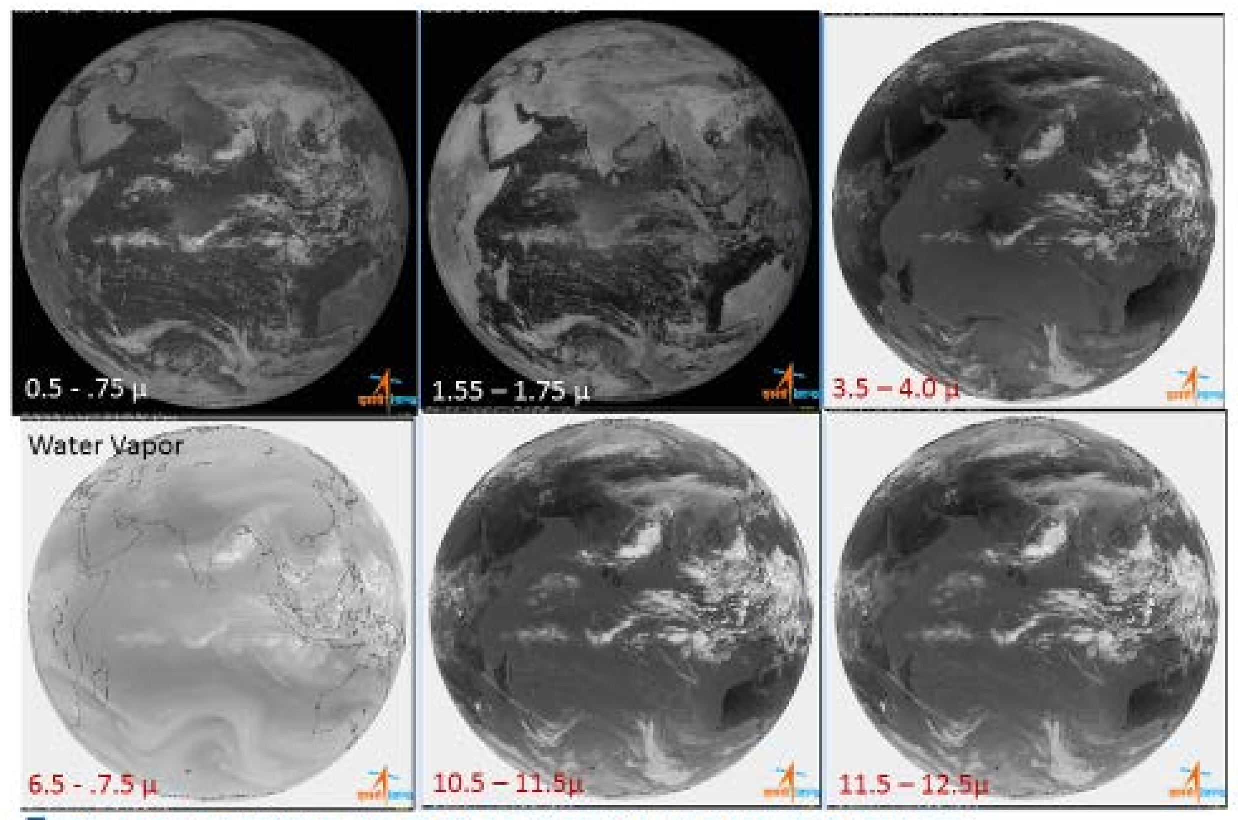


Most clouds can be recognized at all wavelengths

Hardest to see are the thin clouds in reflected solar light

EARTH AT DIFFERENT WAVELENGTHS FROM A WEATHER SATELLITE

What are the clouds of Venus made of?

- From ground based polarization data, Hansen and Hovenier concluded that clouds are 75% sulfuric acid droplets with equivalent radius of ~ 1.1 microns
- Venera probes showed that cloud layer is situated between ~ 48 to 64+ km
- Pioneer Venus Large Probe Cloud Particle Spectrometer (LCPS) showed that cloud particles are indeed sulfuric acid, with particles size close to the size inferred from polarization data and also has a small number of larger sized particles
- Pioneer Venus Cloud Photopolarimeter polarization data showed that a haze of sub-micron sized particles exists within and above the cloud layer to ~ 80 km
- Venus Express SPICAV observations suggests that the small particle haze extends to higher altitudes
- Venus Monitoring Camera images suggest that the haze abundance is asymmetrically distributed between morning and evening regions
- Contrasts are largest at uv wavelengths, but features can be seen in polarization even at 935 nm

Temperature range

A.s thiooxidans thrives at an optimum temperature of 28-30 °C.[2] At lower temperatures (18 °C and below) and at 37 °C or higher, sulfur oxidation and growth are significantly slower, while temperatures between 55 and 60 °C are sufficient to kill the organism.[2]

Metabolism

A. thiobacillus, a strictly aerobic species, fixes CO_2 from the atmosphere to meet its carbon requirements.[2] In addition, other essential nutrients are required in varying amounts.[2] A general lack of knowledge exists for acidophilic microorganisms in terms of the oxidation systems of reduced inorganic sulfur compounds (RISCs).[3]

Fazzini *et al.* (2013) presented the first experimentally validated stoichiometric model that was able to quantitatively assess the RISCs oxidation in *A. thiooxidans* (strain DSM 17318), the sulfur-oxidizing acidophilic chemolithotrophic archetype. By analyzing literature and by genomic analyses, a mix of formerly proposed models of RISCs oxidation were combined and evaluated experimentally, placing thiosulfate partial oxidation by the Sox system (SoxABXYZ), along with abiotic reactions, as the central steps of the sulfur oxidation model.[3] This model, paired with a detailed stoichiometry of the production of biomass, provides accurate predictions of bacterial growth.[3] This model, which has the potential to be used in biohydrometallurgical and environmental applications, constitutes an advanced instrument for optimizing the biomass production of *A. thiooxidans*.[3]

Tso lake in Ladakh, India (Altitude, ~ 5,100 m)

Shoreline of Tsokar showing deposits of salts

Bacterial colonies are abundant on the shoreline and lake bottom. Some of these appear to be sulfur reducing bacteria that react with iron, producing iron sulfate which has similar index of refraction as $FeCl_3$

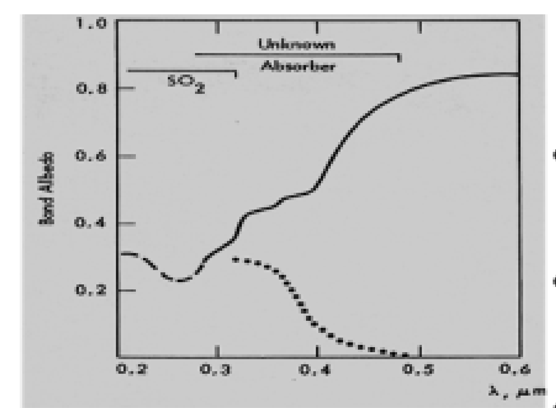
9/10/2016 Venus ultraviolet absorber - inforganic or organic? 18

When Venus atmoisphere with liquid water on the surface was warming up, such lakes could have existed and created salt deposits. Salt dust carrying life could have been lifted up wind gusts to the clouds

Venus clouds are different in many respects from those on Earth. From visible to thermal infrared wavelengths, the basic cloud patterns can be seen to be similar, unlike on Venus. Why?

Why isn't the uv absorber well mixed?

What are the sources and sinks?



So , What's the Problem?

- Sulfuric acid does not absorb at ultraviolet wavelengths.
- SO2 has been identified spectrally, but absorbs at the shorter than 300 nm
- So what is absorbing the ultraviolet radiation from the Sun in the Venus clouds?
- Sulfur present in too small quantities
- $FeCl_3$?
- Are there other possibilities that have not been considered?

Water could have existed on the surface of Venus for as long as two billion years (May et al., 2016)

Could life have evolved on Venus on the surface?

When the planet was warming up and losing its water, bacteria could have migrated to the clouds

Essential nutrients

Carbon

A. thiooxidans derives all of the energy needed to satisfy its carbon requirement from the fixation of CO_2.[2] An important distinction can be made between sulfur-oxidizing and nitrifying bacteria by their response to the introduction of carbon to the culture in the form of carbonates and bicarbonates.[2] Carbonates keep the medium alkaline, thus preventing growth of *A. thiooxidans* which grows best under acidic conditions, while bicarbonates have been shown to allow a healthy growth if kept in small concentrations.[2] Bicarbonate, however, is unnecessary because the CO_2 from the atmosphere appears to be sufficient to support growth of *A. thiooxidans*, and would actually have an injurious effect in that it would tend to make the medium less acidic.[2]

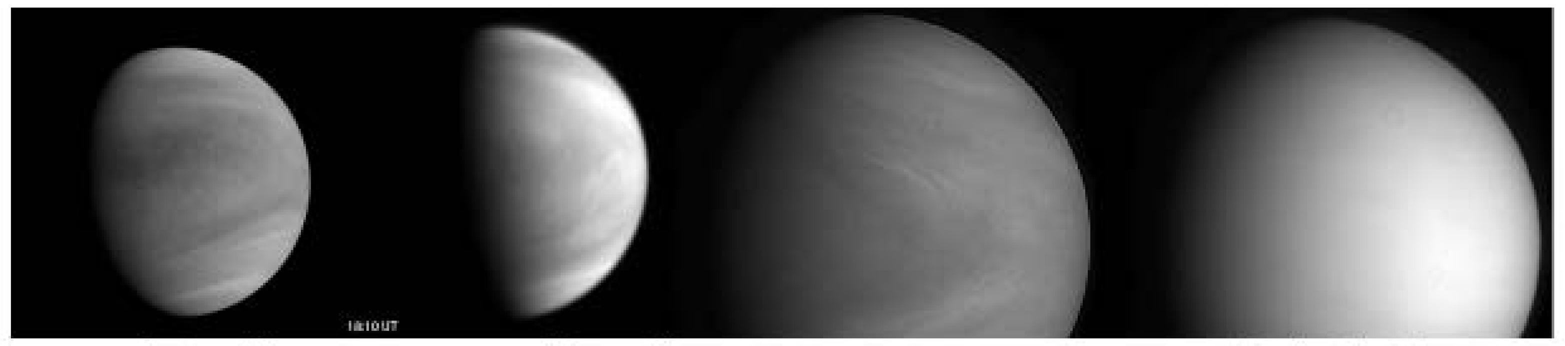
Nitrogen

A. thiooxidans requires only small amounts of nitrogen due to its small amount of growth, but the best sources are ammonimum salts of inorganic acids, especially sulfate, followed by the ammonium salts of organic acids, nitrates, asparagine, and amino acids.[2] If no nitrogen source is introduced into the medium, some growth is observed, with *A. thiooxidans* deriving the necessary nitrogen from either traces of atmospheric ammonia, distilled water, or the contamination of other salts.[2]

Oxygen

A. thiooxidans is obligately aerobic because it uses atmospheric oxygen for the oxidation of sulfur to sulfuric acid.[2]

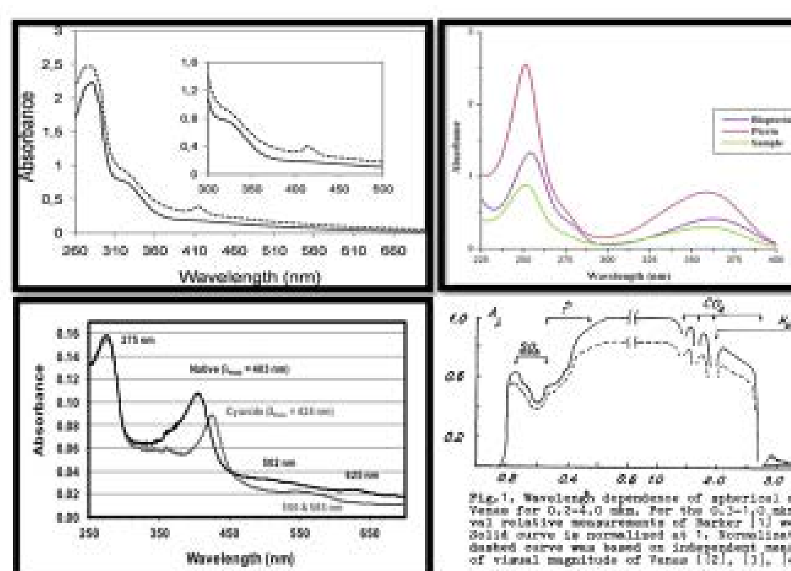
An ***autotroph***[a] *("self-feeding", from the Greek autos "self" and trophe "nourishing") or* ***producer****, is an organism that produces complex organic compounds (such as carbohydrates, fats, and proteins) from simple substances present in its surroundings, generally using energy from light (photosynthesis) or inorganic chemical reactions (chemosynthesis)*



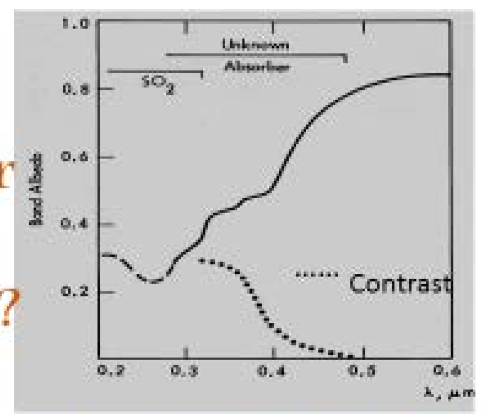
283 nm (Akatsuki) 365 nm (akatsuki) 410 nm white light (Galileo

Venus from ultraviolet to infrared - *cloud features are very different. Why?*

Clear (MESSENGER) 1.0 5 Micron (Akatsuki) 2. 1.74+2.26+2.32 μ (Akatsuki) 2.26 μ (Akatsuki) 10.0 – 14.0 μ



Could the uv absorber be Bacteria?



Absorption spectra for bacteria, macromolecules, and cofactors: (a) UV-Vis spectrum of Thibacillus Ferro-oxidans (Ossa et al. 2001), (b) UV spectrum of pteria cofactors (Durarajuet al. 2015), (c) UV-Vis spectrum of a Fe-heme catalase (Derecho et al. 2014) , (d) Venus albedo (Zasova et al., 1981)

- From D/H ratio measured from Pioneer Venus, Venera and Venus Express missions it is believed that Venus had reservoirs of liquid water on its surface at some time in its past
- Way et al. (2016) suggest that Venus could have harbored liquid water oceans for as much as 750 million years during its past.
- Bacteria could have evolved on Venus. Or, could be transported
- On Earth clouds harbor bacteria at altitudes as high as 41 km
- Physical, Chemical and Spectral properties of many species are similar to those of Venus cloud/haze particles
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How do we know we are not discovering bacteria?

The possibility of organic nature of ultraviolet absorber in the clouds of Venus cannot and should not be ruled out until we can obtain measurements to confirm their existence or absence. 4

Instruments and techniques are needed to discriminate between the two possibilities

In particular:

Microscopic images of cloud/haze particles to determine their actual physical shape and size

- Chemical properties of the haze and cloud particles
- Assessment of candidate bacteria in terms of their physical, chemical and spectral (uv-ir) properties
- Venera-D Enhanced mission and future NASA flagship mission have the potential to look for biogenic signature in the cloud layer from a capable mobile atmospheric platform at different altitudes and locations

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