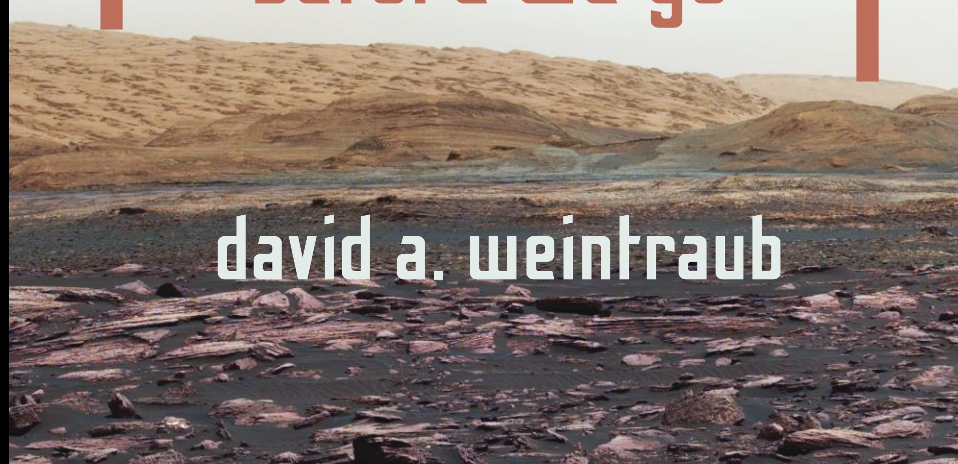
life on mars

what to know before we go



david a. weintraub

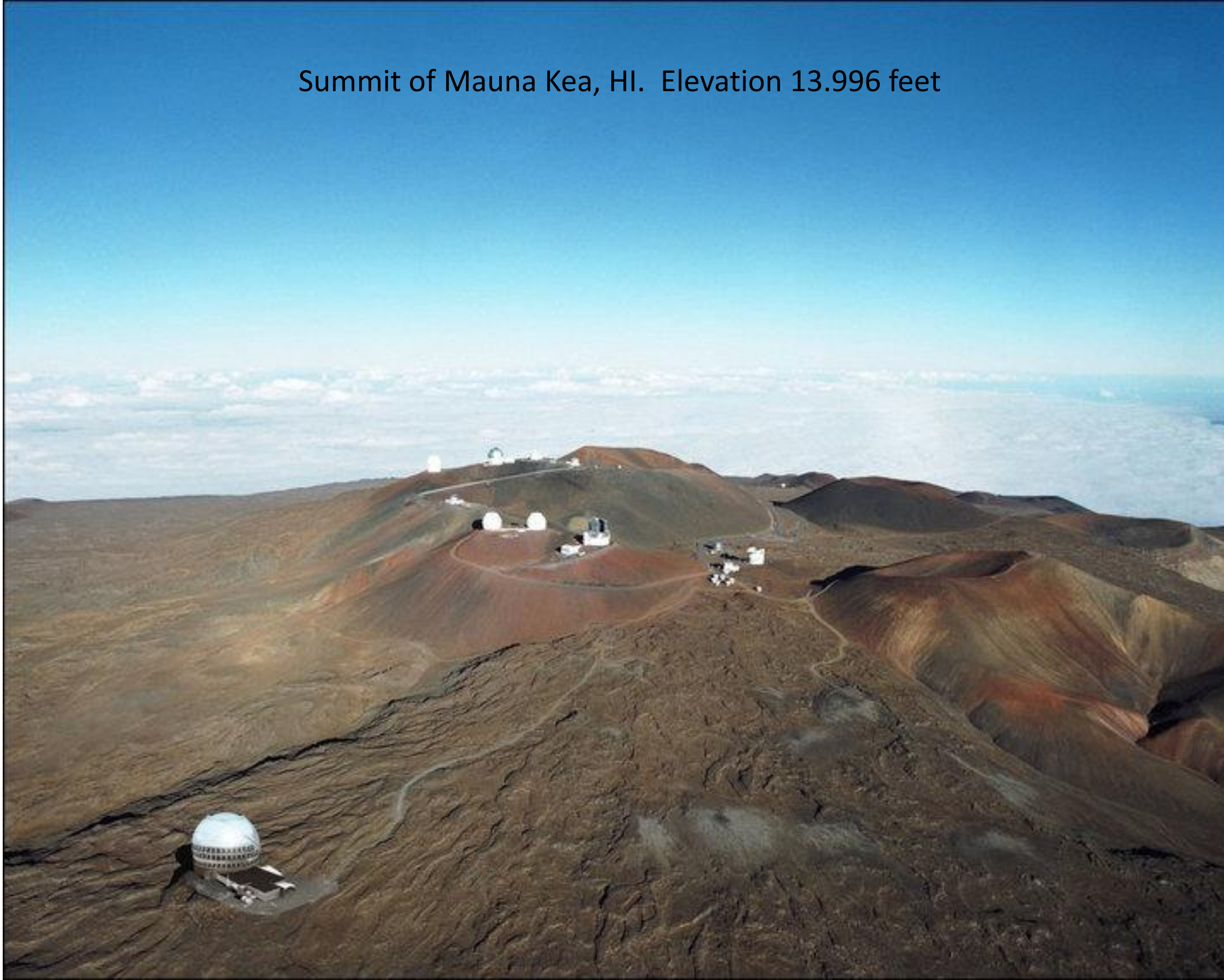
Rylie and Comet, age 8 weeks

Kepler, age 7

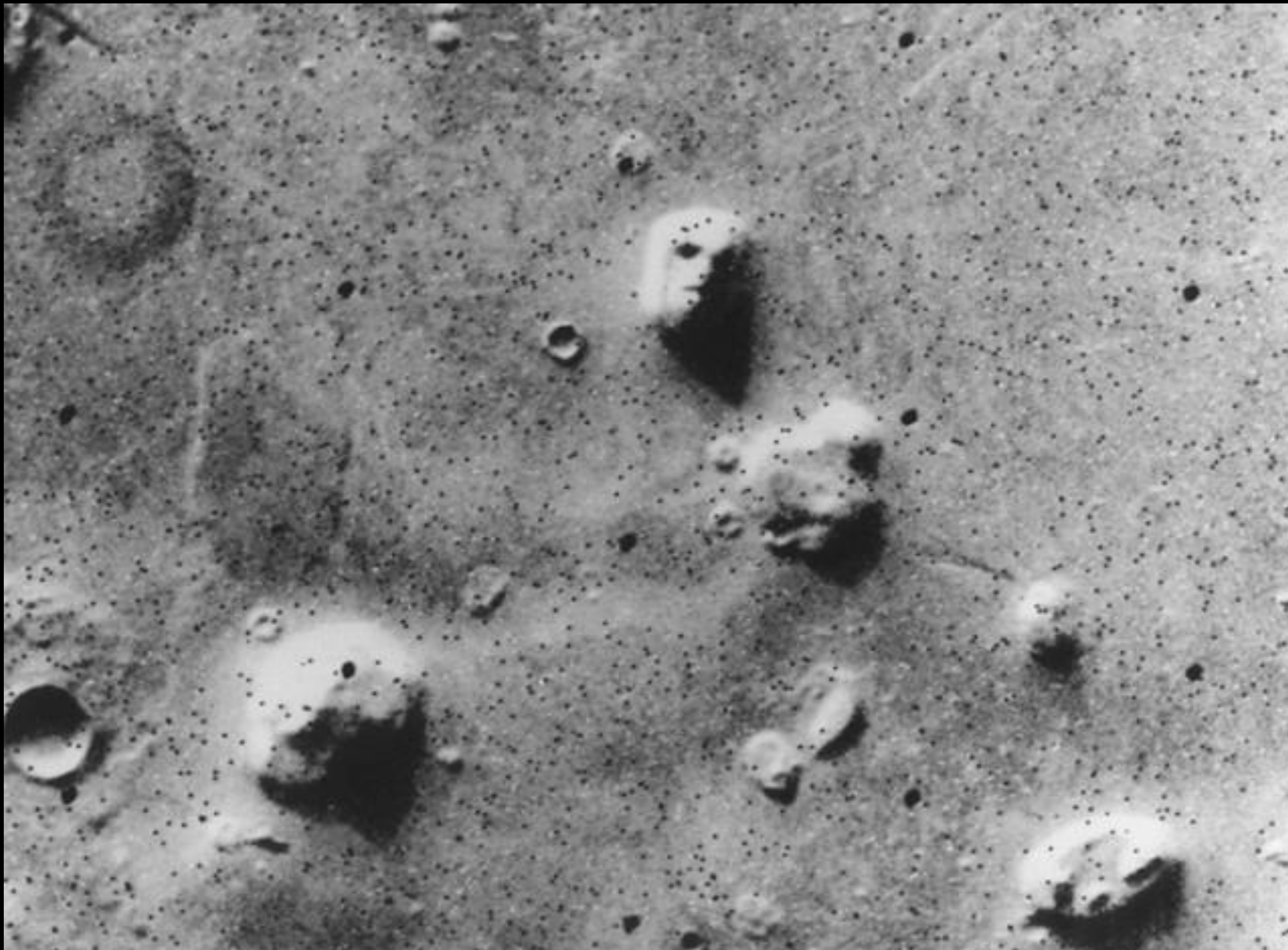
TMT = Thirty Meter Telescope (CalTech, UC, Canada)

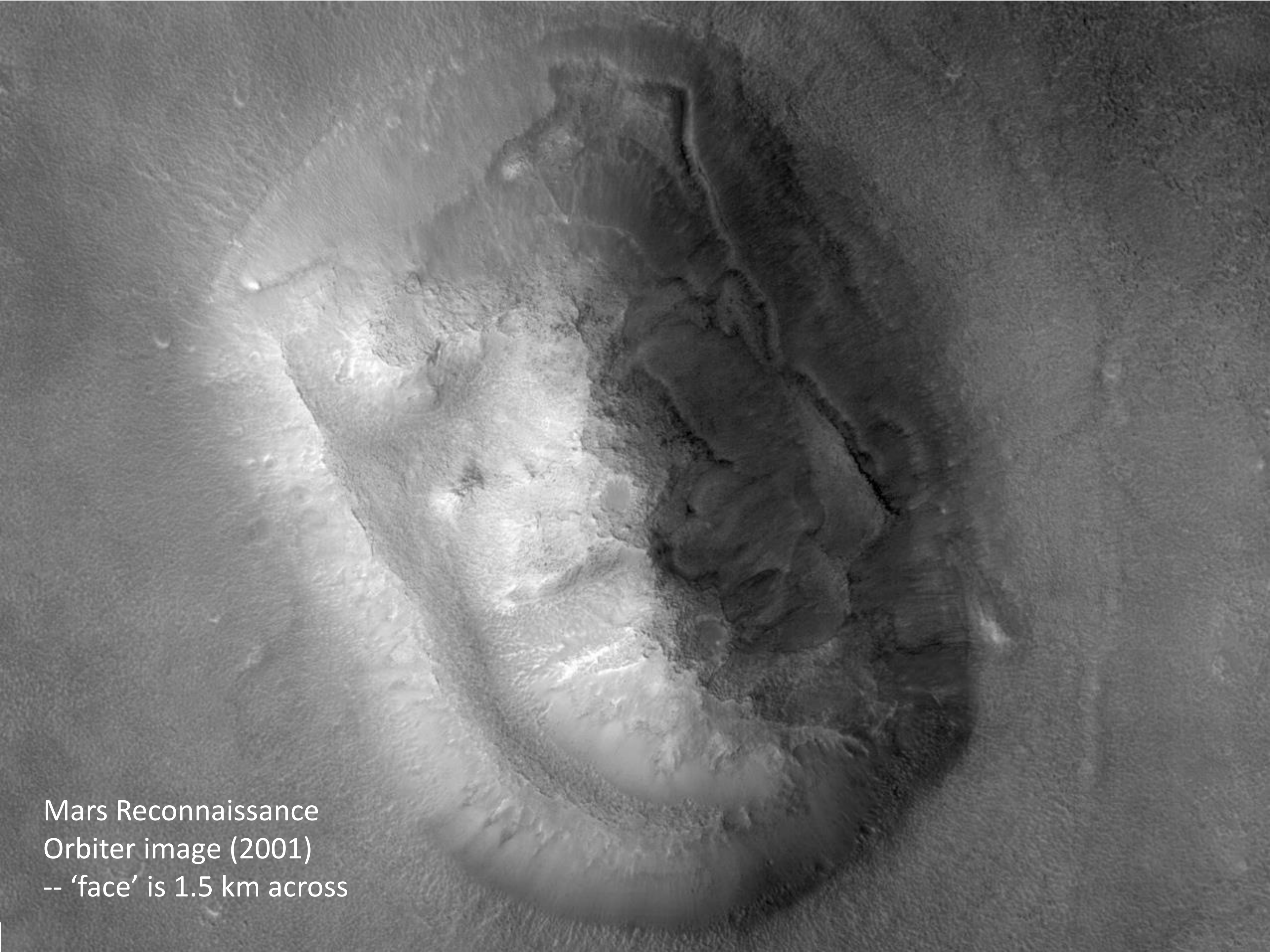
Construction Cost = $1.4B (telescope, only); Annual Operating cost $200M; NSF ASTR $250M/yr

Summit of Mauna Kea, HI. Elevation 13.996 feet



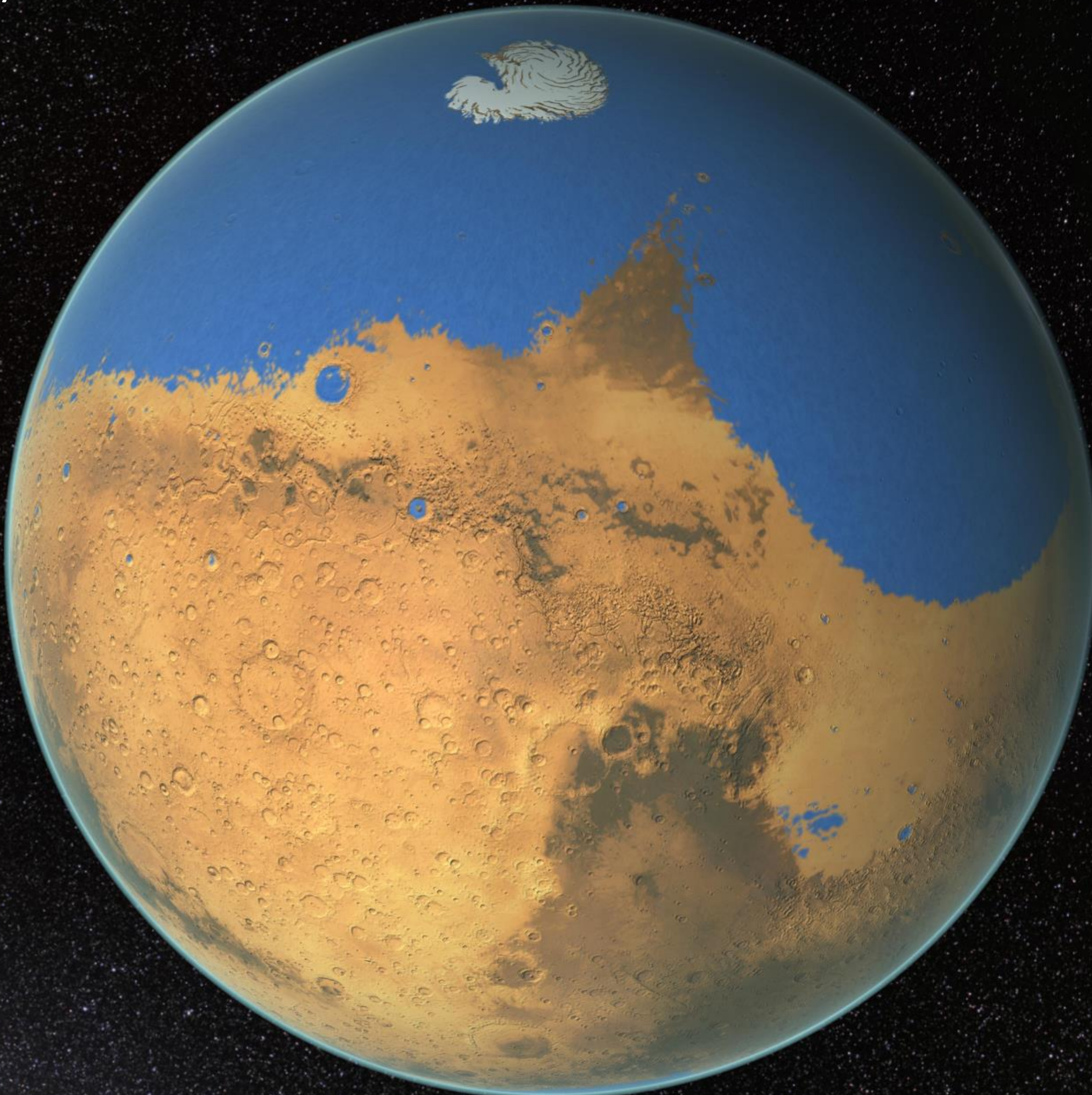
For Halloween: the Face on Mars!!! Viking Orbiter Image (1976) of Cydonia region





Mars Reconnaissance
Orbiter image (2001)
-- ‘face’ is 1.5 km across

Early Mars?



Recall: Evidence of water

A) shows that ancient mars had a Global Equivalent Layer (GEL) 1500-3000 feet of water **on the surface**.

B) suggests it may have lost as much as 85% of that water to space, leaving it with (today) a GEL of 200-400 feet (or more) – stored in ice caps and subsurface reservoirs

C) reveals that “The total amount of water **in the atmosphere** of Mars is at most a few cubic kilometers,” which would yield a global layer ~25 microns deep.

RED Mars --- in the 19th Century

London's Cornhill magazine, 1873

- Mars is "a charming planet . . . well fitted to be the abode of life."
- "the far greater lightness of the materials they would have to deal with in constructing roads, canals, bridges, or the like, we may very reasonably conclude that the progress of such labours must be very much more rapid, and their scale very much more important, than in the case of our own earth."

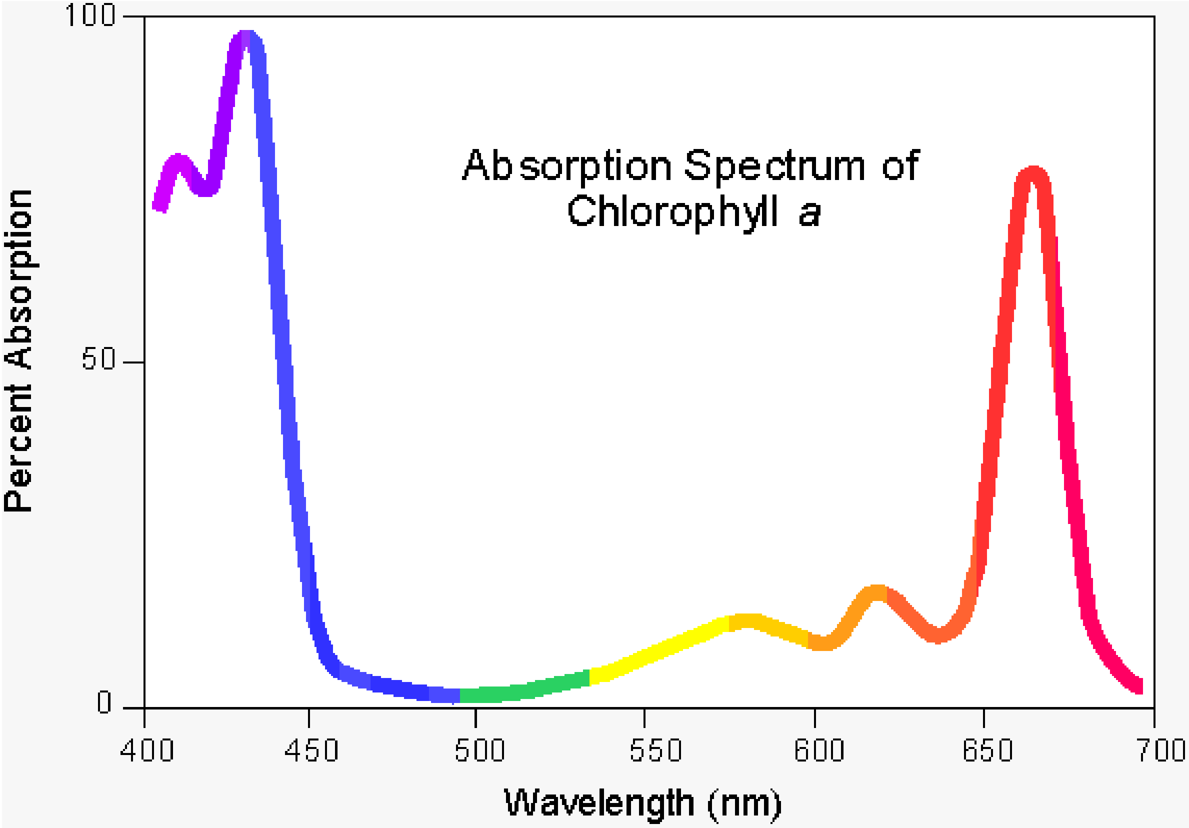
Camille Flammarion (1870s-1880s)

- "Since it is the surface which we see, not the planets [sic] interior, the red colour ought to be that of the Martian vegetation, since it is this species of vegetation which is produced there." The continents of Mars, he concluded, "seem to be covered with reddish vegetation."
- "There must be something on the lands, whether it be moss or even less." Mars has "species of vegetation which do not change [color with the seasons]," in the same way that on Earth "olive-trees and orange-trees are as green in winter as in summer."
- " this characteristic color [red] of Mars . . . is due to the color of the grass and other vegetation which must cover its plains. Can there be red meadows and red forests up there?"

The Search for Chlorophyll

Gavriil Adrianovich Tikhov, Pulkovo Observatory (outside Moscow)

- Began a search for evidence of green-colored patches, using ‘green’ filters



1909 – dark patches don’t look green!

1917-1920: continued work, despite WWI and Russian Revolution, but no luck

1941: relocated to Kazakhtstan’s Alma-Alta Observatory

- Argued: Lack of green not proof that life doesn’t exist
- Instead: Must be proof that life isn’t green, must grow without chlorophyll

- Invented ‘astrobotany’ to investigate different possible colors of life
  - Studied reflected light from plants that grow in “Mars-like” environments (i.e., cold-weather, high altitude)
  - Did find that some plants don’t look green

William Weber Coblentz, a physicist, National Bureau of Standards, 1920s

- Used IR filters to measure temperature of Mars
- Bright areas: 32 F (wrong!)
- Dark areas: 50-60 F (wrong!)

On Earth (he claimed):

  - Bright areas = hot deserts
  - (Reality: Earth's bright areas are polar caps)

On Mars (he concluded):

  - Bright areas = cold regions (the opposite)

"The observed high local temperatures of Mars [in the dark regions] can be explained best by the presence of vegetation which grows in the form of tussocks or thick tufts, such as pampas grasses, and the mosses and lichens that grow in the dry tundras of Siberia."
---- does high T trigger plant growth? Or does plant growth trigger high T?

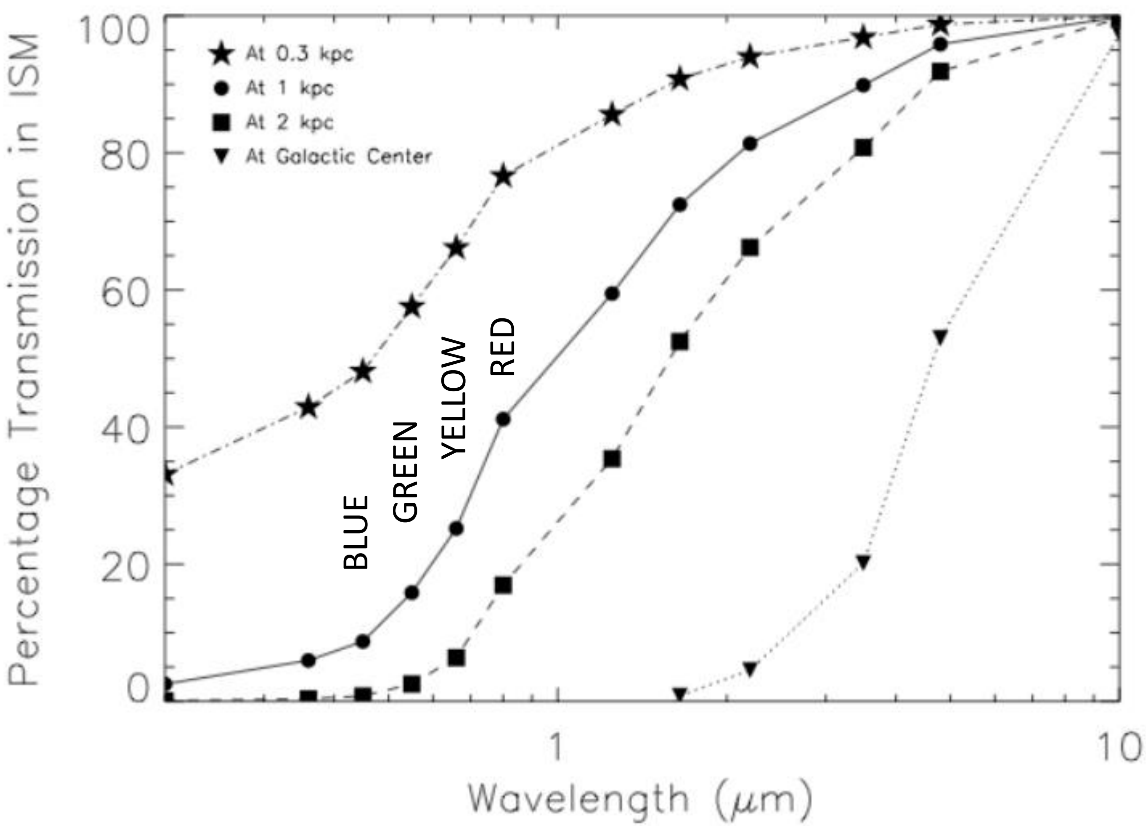
Henry Norris Russell, 1926

Mars has all the necessary conditions for life as we know it; in addition, the large green areas on Mars that change color with the Martian seasonal cycle makes it probable that vegetable life exists on Mars.

When did ‘red’ color of Mars become green?

Robert Trumpler

- Confirmed Einstein's theory of relativity (1924)
- Discovered interstellar dust (1930) which dims and 'reddens' the light of distant stars



1927:

identified a “close relationship between the network and the extended dark areas of Mars which are of a bluish-green tinge.” This relationship “suggests the hypothesis that both are made visible by vegetation and that the network-lines represent lanes of greatest fertility.”

When did ‘red’ color of Mars become bluish-green?

Is There Vegetation on Mars?

by

DR. PETER M. MILLMAN

David Dunlap Observatory, Richmond Hill, Ontario

THE planet Mars, of all the heavenly bodies we can observe, has a surface whose physical conditions most nearly duplicate those on the earth. Because of this fact, and because it is our next-door neighbor in the solar system and is thus very favorably placed for observation, Mars has always been a subject of great scientific and popular interest. Unfortunately, so much nonsense has been written about the planet in various branches of literary endeavor, that it is easy to forget that Mars is still an object of serious scientific in-

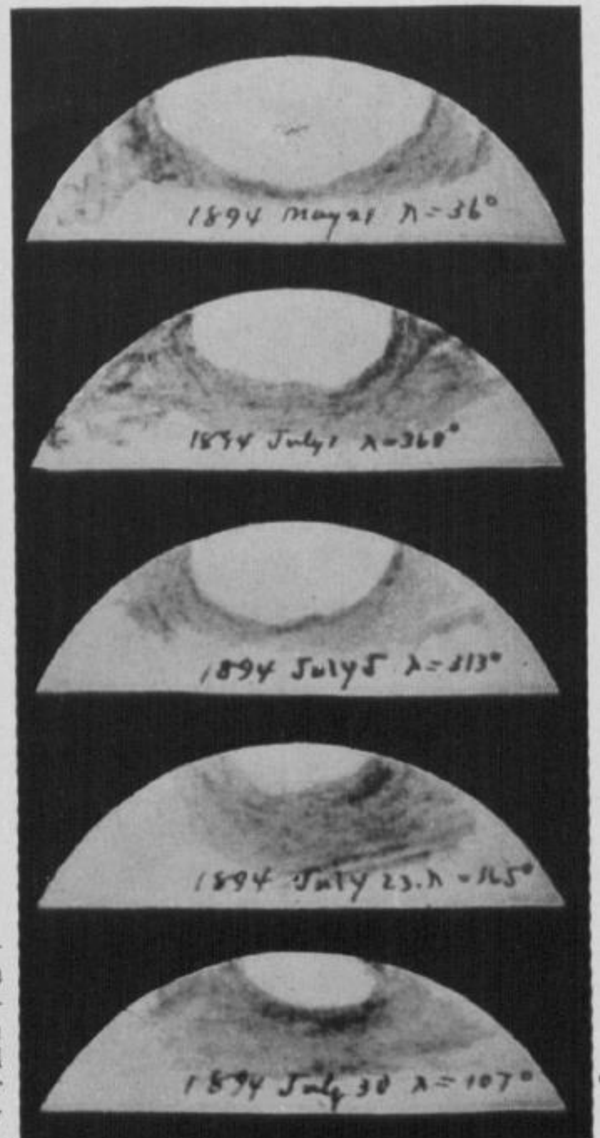


FIG. 1

The polar caps of Mars increase and decrease in size with the Martian seasons. Drawings of the south polar cap made by Barnard through the 36-inch Lick Observatory telescope

Millman:

- Canadian astronomer
- Expert on comets and meteors

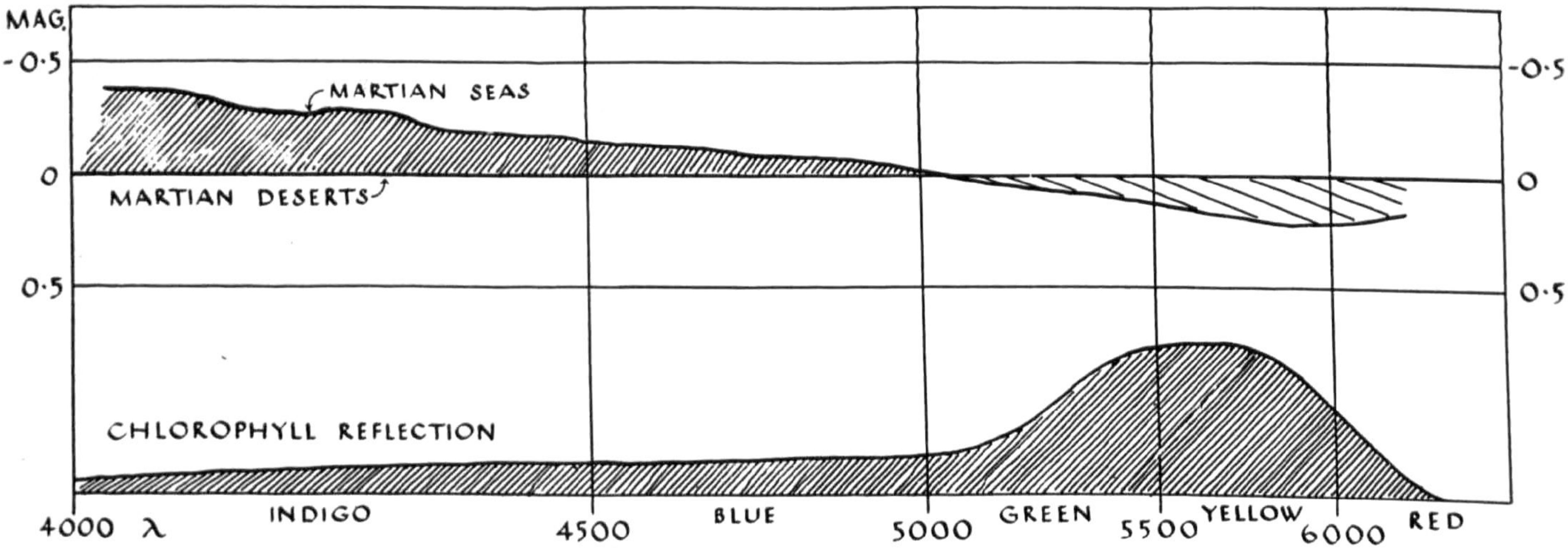
The Sky August, 1939

“So much nonsense has been written about the planet . . . that it is easy to forget that Mars is still an object of serious scientific investigation.”

But compelling reasons have led many astronomers to the hypothesis that Mars has vegetation.

This hypothesis should be tested

- Look for colors of reflected light, compare to that of chlorophyll
- Studied Syrtis Major and Mare Tyrrhenum: both dark, presumably both covered with vegetation
- Studied adjacent areas: bright, presumably not covered with vegetation



Plot of the intensity of reflected light from Mars (in units of stellar magnitudes) versus wavelength (in units of angstroms; 1 angstrom = one ten-billionth of a meter) or color of light. The upper part of the figure shows the intensity of reflected light from Martian seas (top line) and Martian deserts (bottom line). The seas are much brighter than the deserts in the colors indigo and blue, but are darker than the deserts in green and yellow. The bottom part of the figure shows the intensity of reflected light from chlorophyll, which is extremely reflective in the green and yellow and much less reflective at other colors**. Clearly, neither the Martian seas nor deserts reflect light in a way that would be similar to the spectral reflectance signature of chlorophyll.** Image from Millman, *The Sky*, 1939.

Although the dark colored seas “appear greenish in color to the eye,” the fact that they were “relatively strong in violet, blue, and blue-green light but weak in yellow, orange, and red . . . negates the existence of chlorophyll as an agent in producing that green color.”

Control test: Canadian leaves do, indeed, reflect green light (except in Autumn!)

results

“do not give any definitive evidence about the existence or non-existence of vegetation on the Martian surface. What they do seem to indicate is that the greenish color of the seas cannot be taken as a support for the vegetation hypothesis, since the green color does not seem to be like the green reflected from our terrestrial leaves.”

“Perhaps, after all, we are rather presumptuous to think that anything on Mars which might have some remote similarity to biologic life on the earth would develop under the same organic system as that found here.”

The Search for Lichens

Gerard P. Kuiper (triggered rebirth of planetary astronomy, post Percival Lowell)

- Discovered methane in atmosphere of Titan (biggest moon of Saturn)
- Discovered Miranda (5^{th} moon of Uranus)
- Discovered evidence for Kuiper Belt (environs of Pluto and beyond)
- 1948:obtained first color photograph of Mars
- Late 1940s: measured that Mars atmosphere full of CO_2, lacks O_2
- At McDonald Observatory in Texas, used a “new heat-light measuring instrument” to study Mars

Meet the humble lichen family

The lowly and primitive lichen is actually two different organisms, living together in a symbiotic relationship. Most of the lichen is composed of long cells of fungi, connected end-to-end to form long, tubular filaments. Unlike normal plant cells, many fungal cells contain multiple nuclei; also unlike normal plant cells, the cell walls of fungi are strong, as they receive structural support from the presence of chitin, a carbohydrate polymer molecule. The other living part of a lichen, which lives among the fungi cells, is photosynthetic, usually a type of algae known as green algae but sometimes an ancient form of bacteria called cyanobacteria (which are often called blue-green algae, although they are not plants).

Testing for Lichens

Kuiper designed an experiment using observations at wavelengths of 0.6, 0.8, 1.0, and 1.6 microns, in which he observed both the green areas of Mars and the surrounding, so-called desert regions.

Green plants reflect very well in green and also between 0.8 and 1.0 microns (near-IR) – should be darker at 0.6 and 1.6, brighter at 0.8 and 1.0 microns

- Looked for color contrasts on Mars with these filters
- Found no differences between filters
- Conclusion: Ruled out chlorophyll on Mars
- ruled out Earthlike “seed plants” as the dominant kind of vegetation that exists on Mars.
- “They could not be vegetation like trees or grass.”
- “not surprising, in view of the extreme rigors of the Martian climate, in particular the cold nights . . . Seed plants and ferns are both vascular plants containing a great deal of water. Such plants would undoubtedly freeze in the Martian climate.”

The reflectance spectra of lichens are just like what he had found for Mars; that is, lichens show the same (lack of) color contrast at 0.6, 0.8, 1.0, and 1.6 microns as does Mars.

"The spectrum of these lichens and that of the Martian regions are similar between 0.5 and 1.6 microns."

If all atmospheric water vapor were made available to the green areas [which cover, he estimated, one-third of Mars], they would receive a layer 0.02 mm [20 microns] thick. The height of the living parts of the 'vegetation' could hardly be more than ten times this amount, or 0.2 mm; presumably it is much less. *This estimate is compatible with a lichen cover*." [Italics in original]

Lichens "produce very little oxygen, and even the traces set free would gradually escape the planet." Therefore, the fact that observers had not detected oxygen in the Martian atmosphere is consistent with lichen life on Mars. "No contradiction with the spectroscopic tests would thus result."

"**They might be lowly lichens like those that grow on the dry rocks near McDonald Observatory. Lichens need no water in liquid form. Martian lichen-like plants might get enough water out of vapor from the ice caps, which evaporate without melting**."

The Search for Lichens

- Published in *Life* magazine

  "Newest photographs and studies disclose that life on planet is limited to simple vegetation."

  The "green patches are vegetation, but of the lowest order, lichens, which live by drawing moisture from the Air. … The lowly lichens represent life's last stand on the Red Planet."

  Big News? Yes, because Kuiper thinks he's proven that life on Mars is limited to rootless, stemless, leafless lichens, i.e., not LGM

- Reported in *Science-News Letter*

  "No trees, no flowers, not even ferns."

  "The only possible life forms would be mosses and lichens such as cling to lofty, frigid peaks hear on Earth."

  "There is no chance of the higher life forms such as the most primitive animals, much less anything like a man or a Wellsian monster."

  "Observations … are consistent with the existence of mosses and lichens in the green areas of the planet."

  "This new picture of Mars may be a forecast of things to come for the earth itself. Mars is a worn-out planet with conditions that probably will prevail on earth many millions of years hence when most of our atmosphere has been lost and mankind has long since disappeared."

As reported in *TIME* magazine, 1948 : “Mars is ‘just right’ for plants!”

“Last autumn he found that the atmosphere contains a small amount of carbon dioxide, which is necessary to plants (the basic living organisms). Without any carbon dioxide, plants’ chlorophyll, lichens, and algae cannot live, but too much would indicate that there are no plants on Mars to consume it.”

The climate of Mars resembles “earth at an elevation of 50,000 feet. . . . This probably would support lichen, since these plants act like sponges and suck up water vapor present in air. Rain is not necessary for their existence.”

The Search for Algae

Bill Sinton

Pioneered IR astronomy

Biggest problem with IR studies: thermal background
- heat/light from the telescope, **the detector/camera**, the sky, the clouds, the astronomers all swamp the faint IR light from Mars

Built an instrument that was cooled by liquid nitrogen down to almost 300 degrees below zero (–287 ˚F, or 96 K), a remarkably cold temperature for an astronomical detector system at that time.

Studied Mars at 3.4 microns

Why? 1948: chemists proved that **organic molecules** (because of the C-H bonds) are excellent absorbers and emitters at 3.46 microns

Hypothesis: should see drop in light around 3.4. microns

THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME 126 SEPTEMBER 1957 NUMBER 2

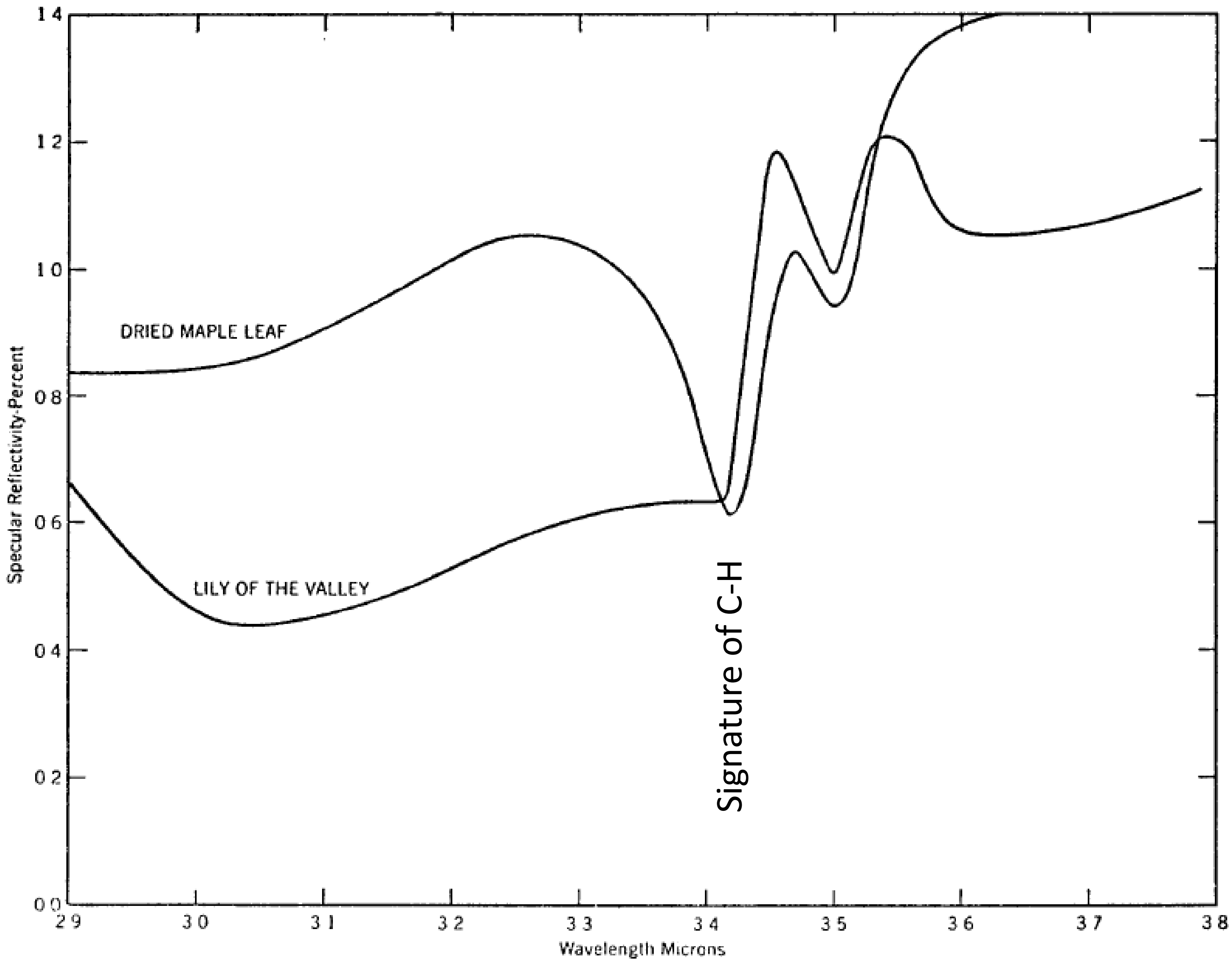
SPECTROSCOPIC EVIDENCE FOR VEGETATION ON MARS

WILLIAM M. SINTON
Smithsonian Astrophysical Observatory
Received May 6, 1957

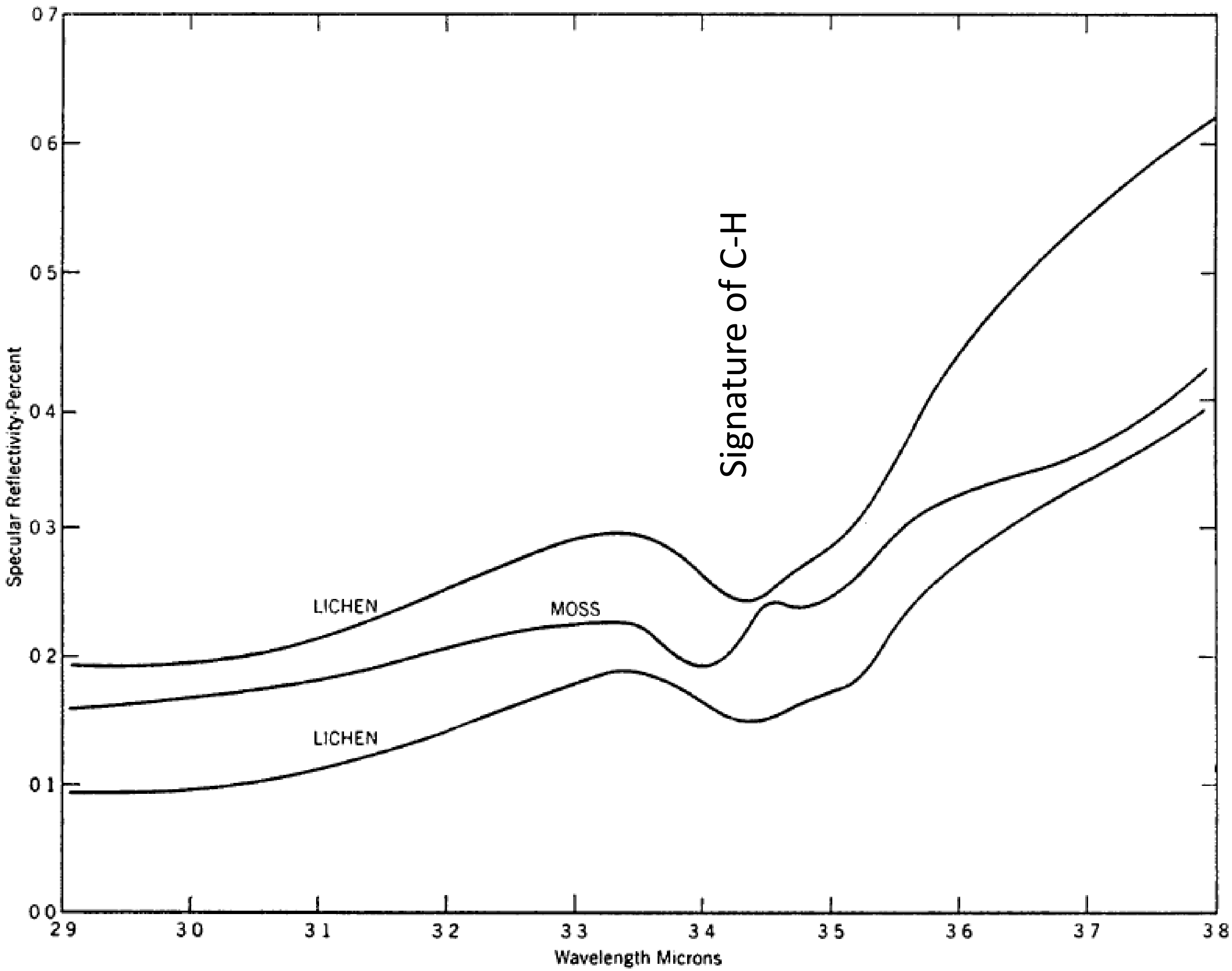
does not prove lichens exist but does prove “that organic molecules are present”

“the dip at the significant wave length is therefore additional evidence for vegetation. This evidence, together with the strong evidence given by the seasonal changes, makes it extremely likely that plant life exists on Mars. ”

1956 study results: Showed terrestrial biological materials (Lily of the Valley leaf, Maple leaf, two types of lichens, moss) show a drop in the intensity of reflected light near 3.4 microns.



1956 study results: Showed terrestrial biological materials (Lily of the Valley leaf, Maple leaf, two types of lichens, moss) show a drop in the intensity of reflected light near 3.4 microns.



For Mars: “a depression at the wave length of the organic band” at 3.46 microns.

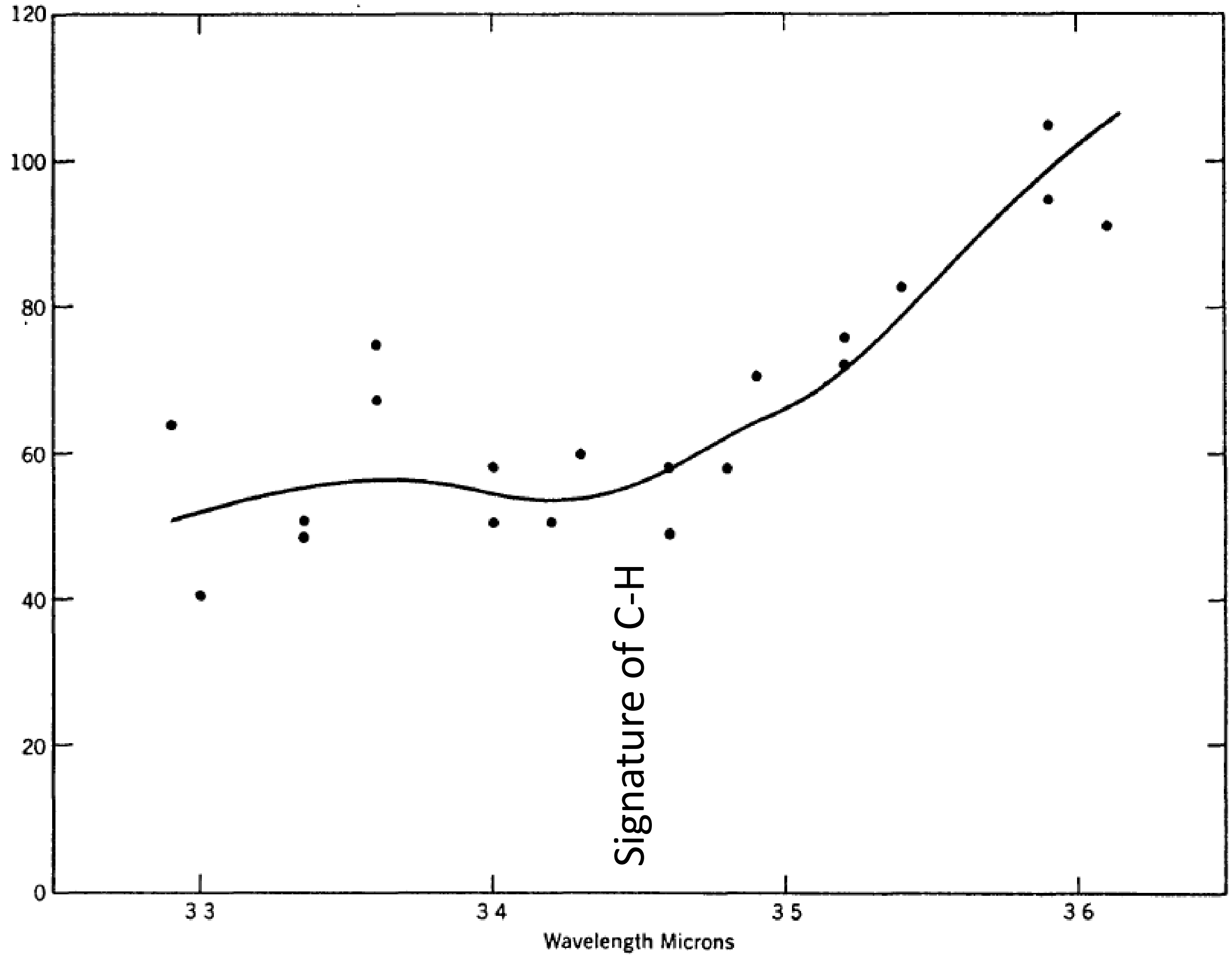


FIG. 3.—Observations of the spectrum of Mars obtained on four nights and after division by the solar spectrum (*solid curve* of Fig. 2).

This was enough evidence to get him time on the 200-inch Palomar Mountain telescope (instead of the 61-inch Harvard Observatory telescope)

November, 1959

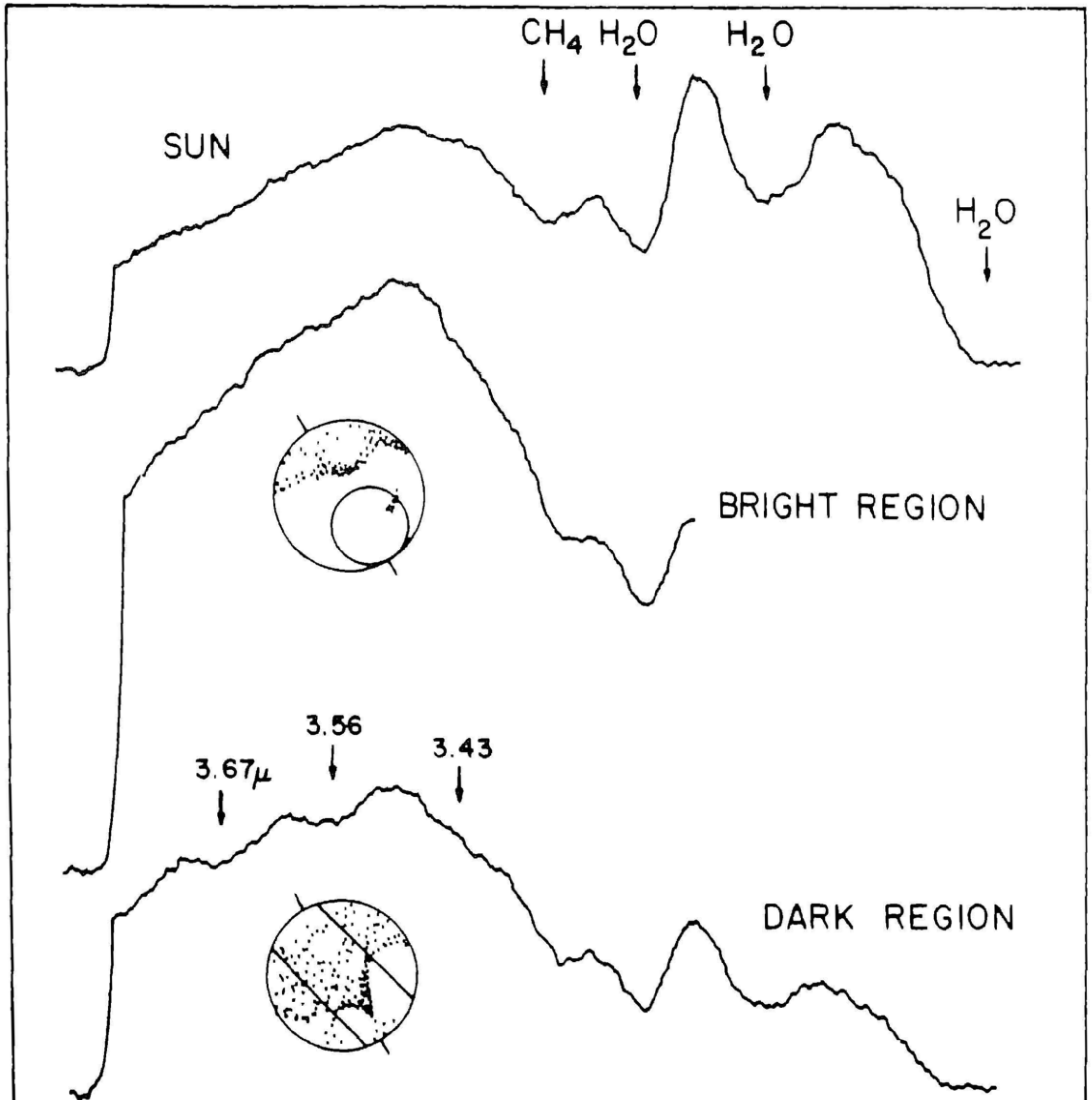
Further Evidence of Vegetation on Mars

The presence of large organic molecules is indicated by recent infrared-spectroscopic tests.

William M. Sinton

SCIENCE, VOL. 130

The Sinton Bands

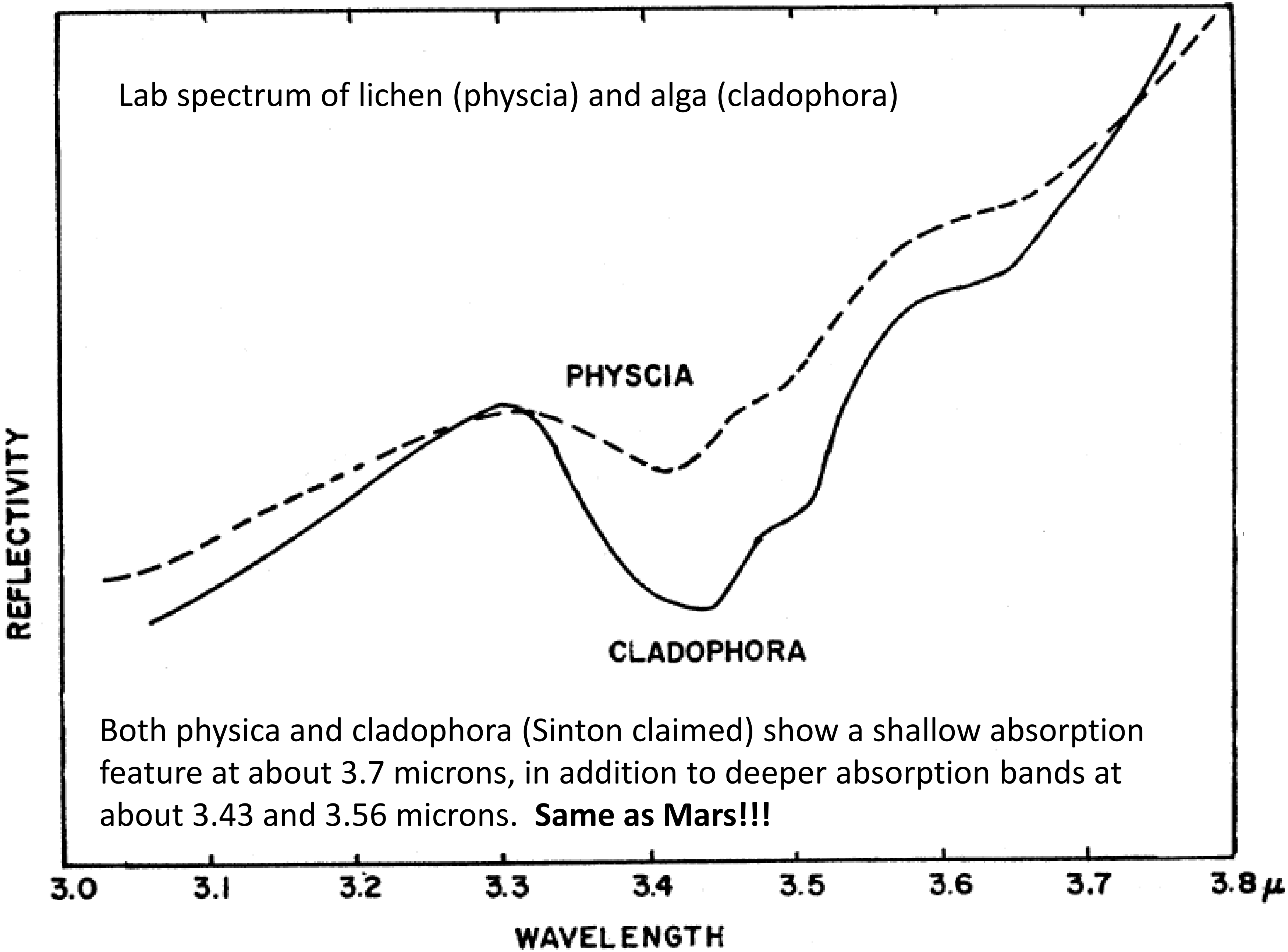


Long wavelength (about 4 microns) is to the left; short wavelength (about 3 microns) is to the right.

Top: spectrum of Sun, showing absorption signatures of methane and water (in Earth's atmosphere)

Middle: spectrum of Amazonis (desert region of Mars; location shown by circle).

Bottom: spectrum of region across Mars bounded by two lines, including Syrtis Major.



Lab spectrum of lichen (physcia) and alga (cladophora)

Both physica and cladophora (Sinton claimed) show a shallow absorption feature at about 3.7 microns, in addition to deeper absorption bands at about 3.43 and 3.56 microns. **Same as Mars!!!**

The “bands near 3.5 microns” are “most probably produced by organic molecules,” and these are “produced in localized regions in relatively short spans of time.”

“Growth of vegetation certainly seems to be the most logical explanation for the appearance of organic molecules.”

Sinton concluded that the similarity of the Martian spectrum to that of cladophora demonstrated that what was observed on Mars was “produced by carbohydrate molecules present in the plant … the evidence points not only to organic molecules but to carbohydrates as well.” **Alga, not lichens!!!**

Claimed as proof for the presence of life on Mars and also a clue about the need for Martian plants to have large food storage capacities.

Support for Sinton Bands

Norman Colthup, of Stamford Research Laboratories, in Connecticut

Band seen by Sinton at 3.43 microns was almost certainly due to a carbon-hydrogen bond in “carbohydrates and protein organic matter in plants which resembled terrestrial plants.”

The only likely source of the two spectral features at 3.56 and 3.67 microns must be molecules known as “organic aldehydes (but not formaldehyde),” because organic aldehydes “are among the few materials with a strong band near 3.67 microns” in addition to the band at 3.43 microns.

Aldehydes: chemical compounds that contain the elemental group CHO

Acetaldehyde is a very effective absorber at wavelengths very close to 3.58 and 3.68 microns, which, he argued, makes it a great match to the Martian spectral signatures

Identification of Aldehyde in Mars Vegetation Regions

In *Science*, 1961

Colthup identified the specific aldehyde, acetaldehyde (or ethanal, C_2H_40), as the most likely source of the Sinton bands and attributes the presence of this material on Mars to the near absence of oxygen on Mars, since this particular molecule preferentially forms in an oxygen-poor environment.

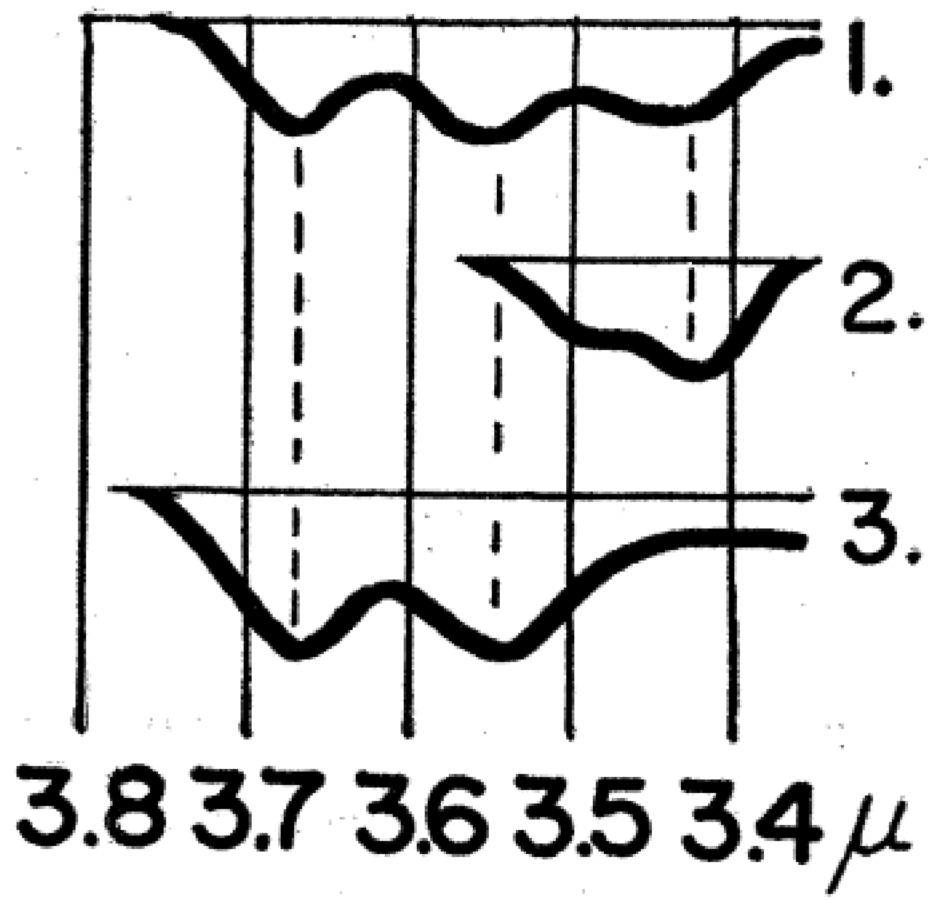


Fig. 1. (*1*) Infrared bands found in the Martian vegetation regions but not in the Martian deserts [adapted from *Science* **130**, 1234 (1959)]; (*2*) infrared bands in flour (terrestrial organic material); (*3*) infrared bands in acetaldehyde.

“If I may be permitted to speculate a bit, acetaldehyde may be an end product of certain anaerobic metabolic processes.”

This process is fermentation, in which carbohydrates are converted to acetaldehyde and finally to alcohol.

“This process yields much less energy for the organism than conventional oxidation . . . but certain organisms on Earth use fermentation as their source of energy when oxygen is not available, and perhaps this happens on Mars.”

Challenges to Sinton and the Sinton Bands

JAMES S. SHIRK
WILLIAM A. HASELTINE
GEORGE C. PIMENTEL
Department of Chemistry,
University of California, Berkeley

Sinton Bands: Evidence for Deuterated Water on Mars

Abstract. *The infrared absorption bands observed by Sinton at 2710, 2793, and 2898 cm^{-1}, in the spectrum of Mars, may be due to gaseous D_2O and HDO in the Martian atmosphere. The implication would be that the deuterium : hydrogen ratio exceeds that on Earth, presumably because of escape of the lighter gases from Mars, with accompanying gravitational fractionation of the hydrogen isotopes.*

Wrong … but almost right

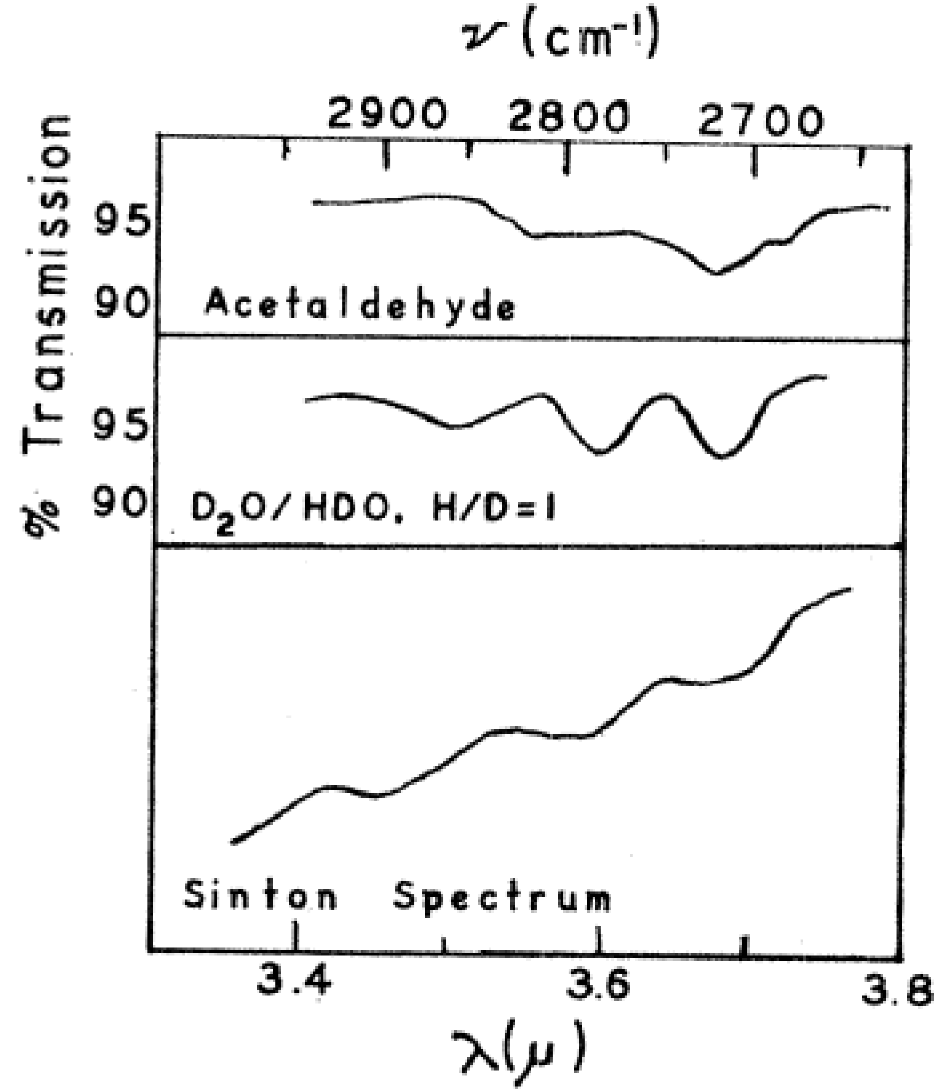


Fig. 3. Comparison of the Sinton, acetaldehyde, and D_2O : HDO spectra.

SCIENCE, VOL. 147

1965

Mars: The Origin of the 3.58- and 3.69-Micron Minima in the Infrared Spectra

D. G. Rea
B. T. O'Leary
Space Sciences Laboratory, University of California, Berkeley
W. M. Sinton
Lowell Observatory, Flagstaff, Arizona

Abstract. *The 3- to 4-micron spectra of Mars, recorded with the 200-inch telescope in 1958, were reexamined in order to ascertain whether the minima at 3.58 and 3.69 microns are due to telluric HDO molecules. Solar spectra obtained at Denver and water vapor abundances derived from radiosonde flights during the observing period were used. There seems to be a correlation between the intensities of the 3.58- and 3.69-micron features and the amount of telluric water vapor in the optical path. An important corollary is that there is no evidence for attributing these spectral features to Mars.*

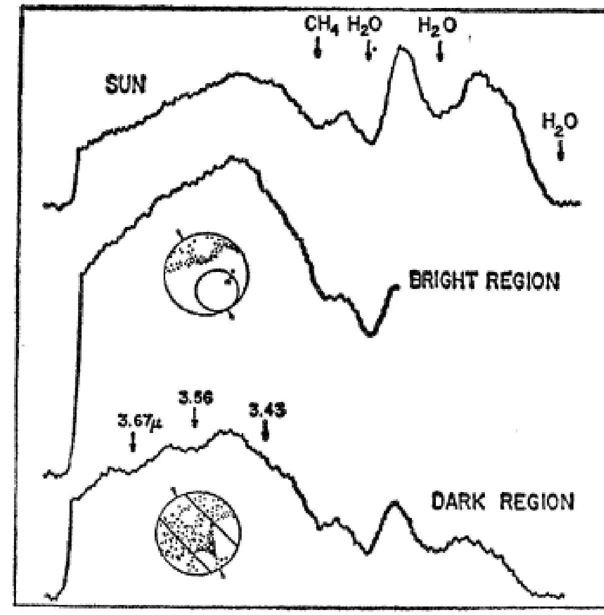


Fig. 1. Spectra of the Sun and Mars recorded at Mount Palomar in October 1958.

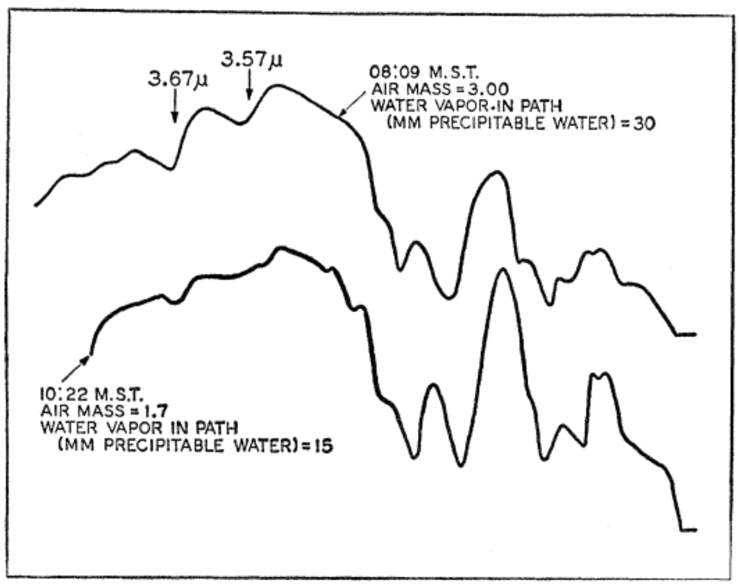


Fig. 2. Spectra of the Sun recorded at Denver on 21 October 1954. The spectral slit width at 3.67 μ was 0.014 μ (M.S.T., Mountain Standard Time).

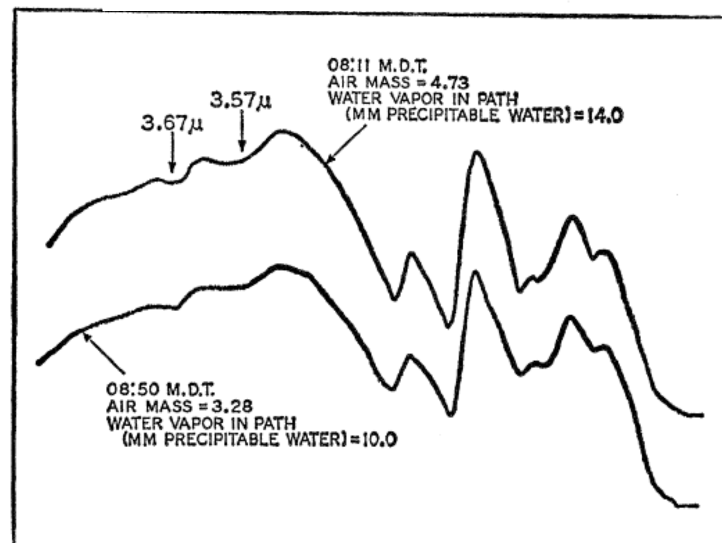


Fig. 3. Spectra of the Sun recorded at Denver on 12 May 1955. The spectral slit width at 3.67 μ was 0.03 μ (M.D.T., Mountain Daylight Time).

Windblown Dust on Mars

by

CARL SAGAN
JAMES B. POLLACK
Laboratory for Planetary Studies,
Cornell University,
Center for Radiophysics and Space Research,
Ithaca, New York 14850

The wave of darkening in the Martian springtime, which some say may have a biological explanation, can be explained in terms of windblown dust.

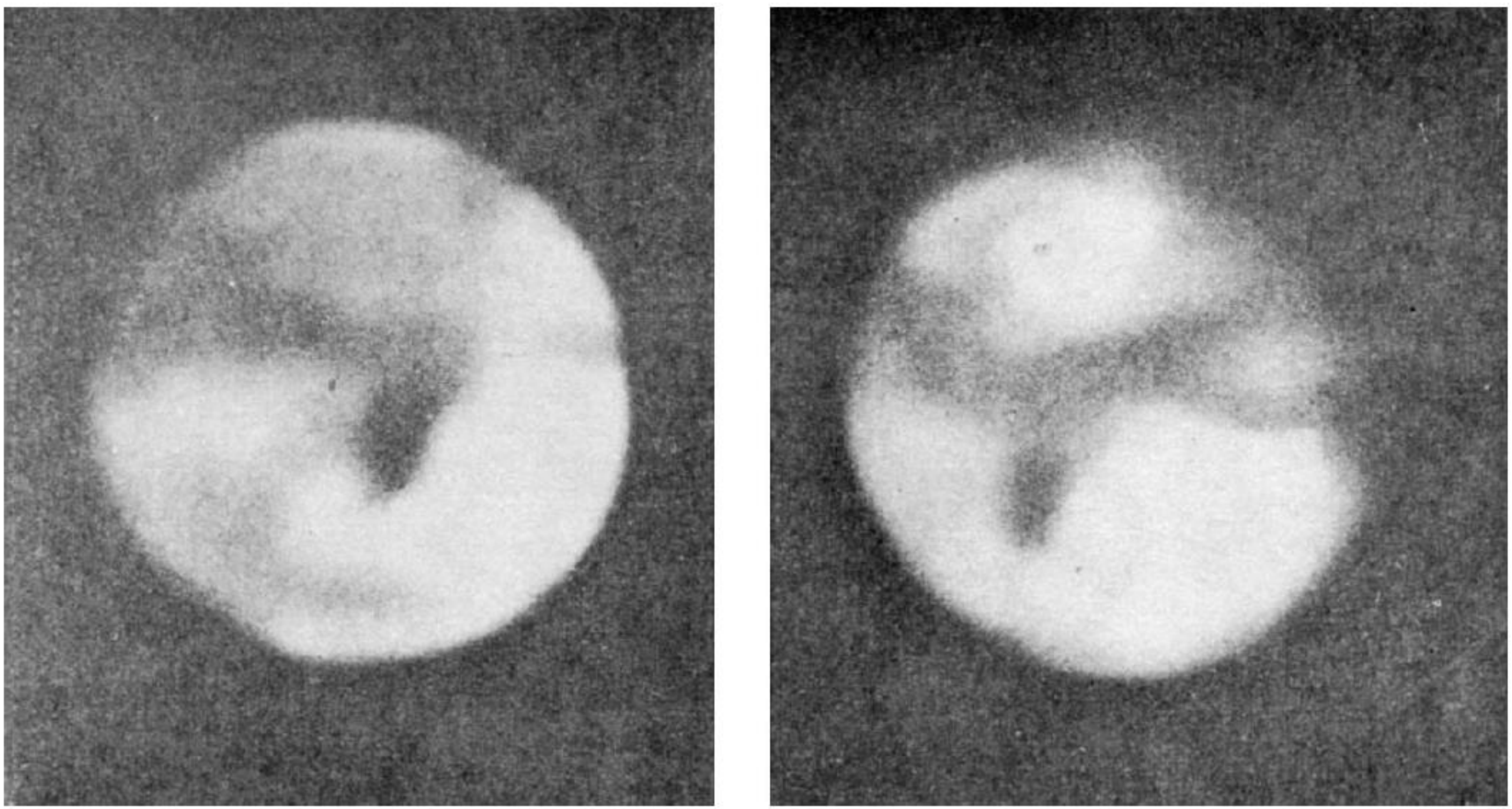


Fig. 2. Seasonal brightening of the Hellas–Eridania region. The photograph at left was taken on July 3, 1907 (Martian date, April 7); the photograph on the right was taken on October 4, 1909 (Martian date, July 1). After Slipher, 1961.

made radar maps of Mars, using Goldstone Deep Space Network antenna

70-m dish!

The dark areas of Mars were at higher elevations than the bright areas.

The dark regions that exhibit long-term changes in coloration have smaller slopes and elevations than the dark regions that do not undergo secular changes in color.
-- sand is easily blown on and off shallow-sloped regions at low elevation

They “hypothesize that the secular changes are due to the movement of sand and dust from the bright areas onto and off from adjacent dark areas of shallow slopes.”
-- areas of Mars brighten when the sand blows onto them

The so-called regenerative properties of the dark areas, that is, the ability of the dark areas to darken after lightening, “are due to winds scouring small deposited particles off the sloping highlands.”
-- dark areas, having turned light, then turn dark again when sand blows away

Restated:

Martian winds blow around Martian sand

Sand grains are highly reflective

Sand grains deposited in lowland ‘deserts’ (make ‘deserts’ look bright)

Wind blows sand onto shallow slopes, brightens them

Then wind blows sand off shallow slopes, creating ‘wave of darkening’

Darkening has been misunderstood as springtime regeneration of plant life

The success of their windblown dust models did finally put an end to the idea that the changing colors on Mars are caused by waves of greenery that roll across Mars as melting water from the polar caps ushers Martian springtime into bloom. No more trees; no more moss; no more lichens; no more algae. Just windblown sand.