Lightning on Venus: looking for their origin

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May, 2008

Studies of the atmosphere of Venus identified a problem of certain small gaseous components (NO, NH etc.) Their origin could involve electrical discharges.

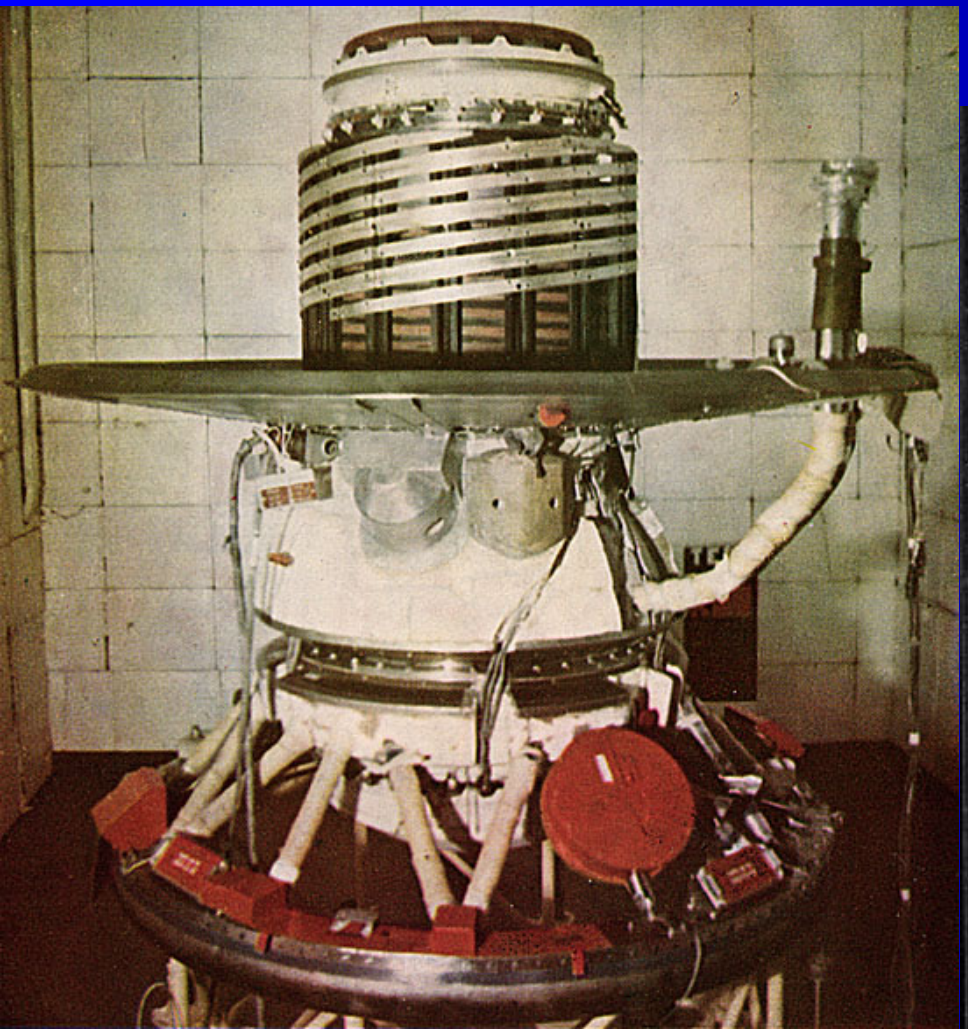
Measurements made by VENERA 11, 12, PIONEER-VENUS (1978-83) and subsequent missions indicated electrical activity of atmosphere of Venus.

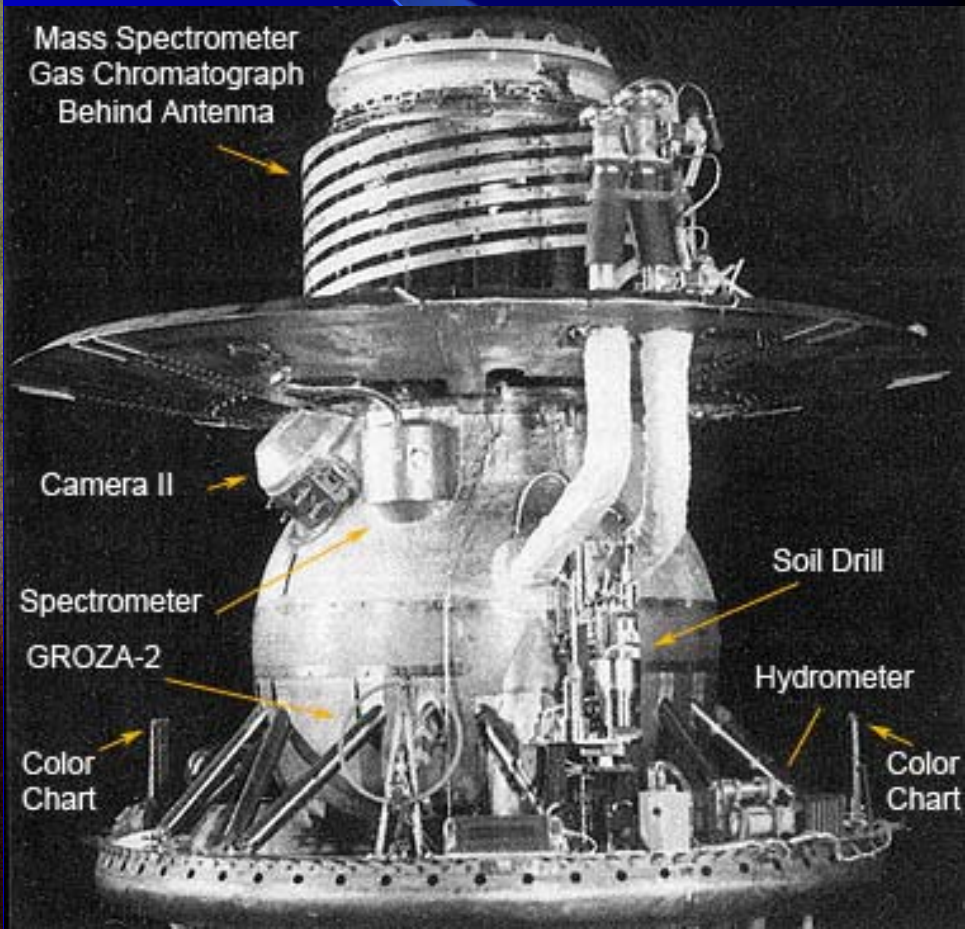
Just before the 1979 New Year I got a cable from F.Scarf: “ I congratulate you with the discovery of lightning on Venus 3 days earlier then we did it”.

Groza (Venera 11,12) & Groza-2 (Venera 13,14)

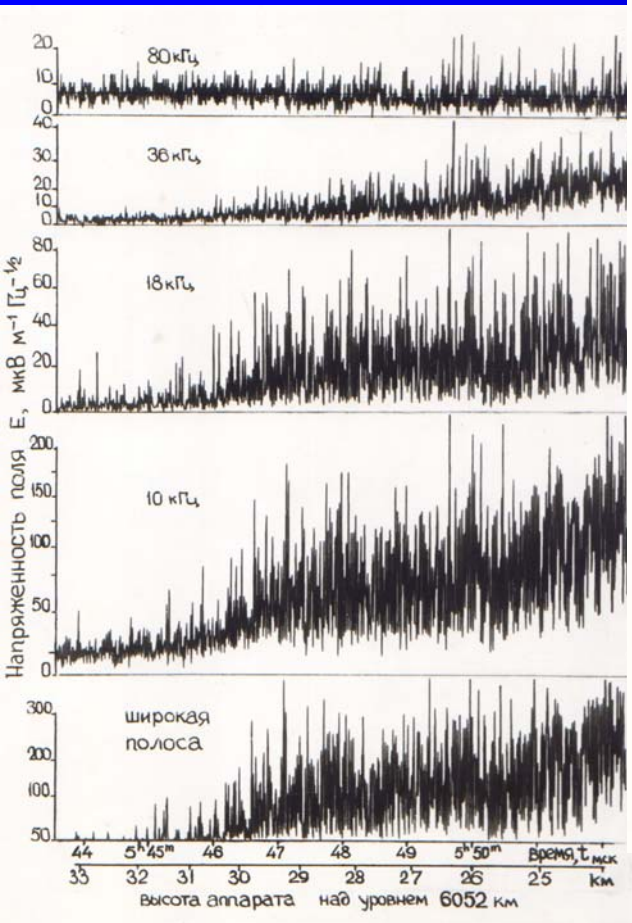
Groza = Thunderstorm

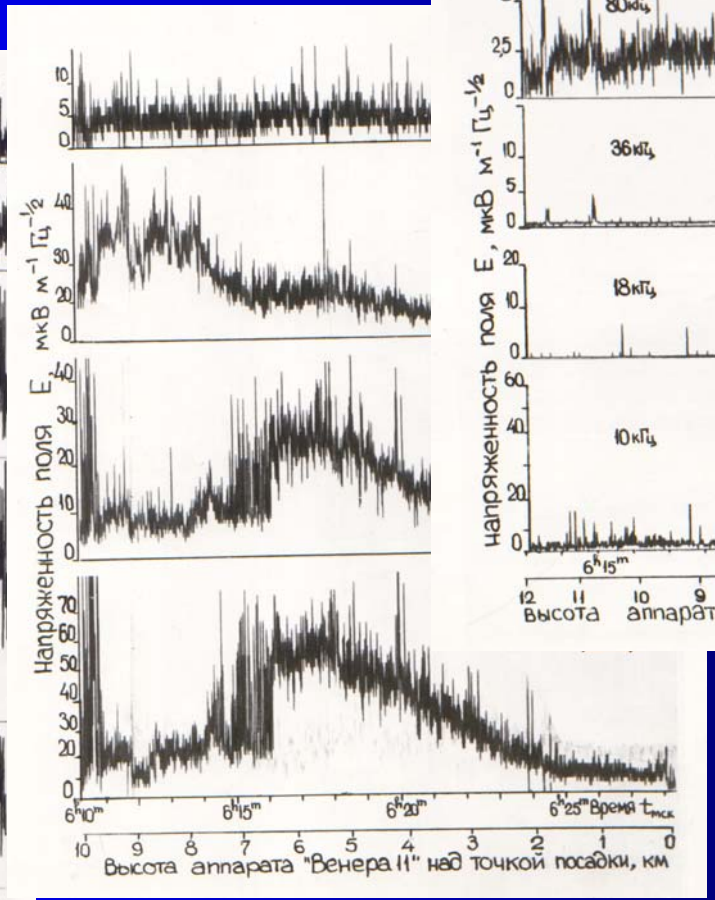
30th anniversary!

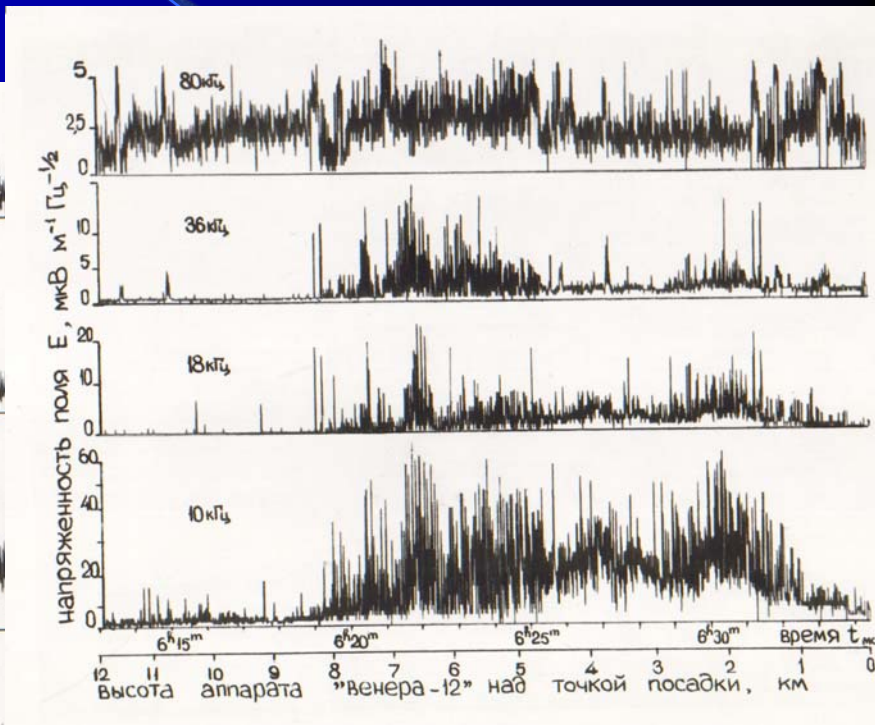




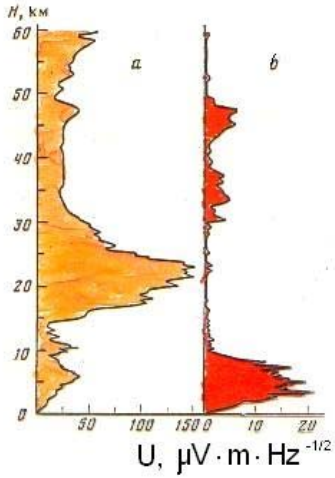
On 21 and 25 December 1978 the Groza instrument detected a large number of electromagnetic pulses







The measurements made on surface of the planet



GROZA measurements

* Field stength (max. values):

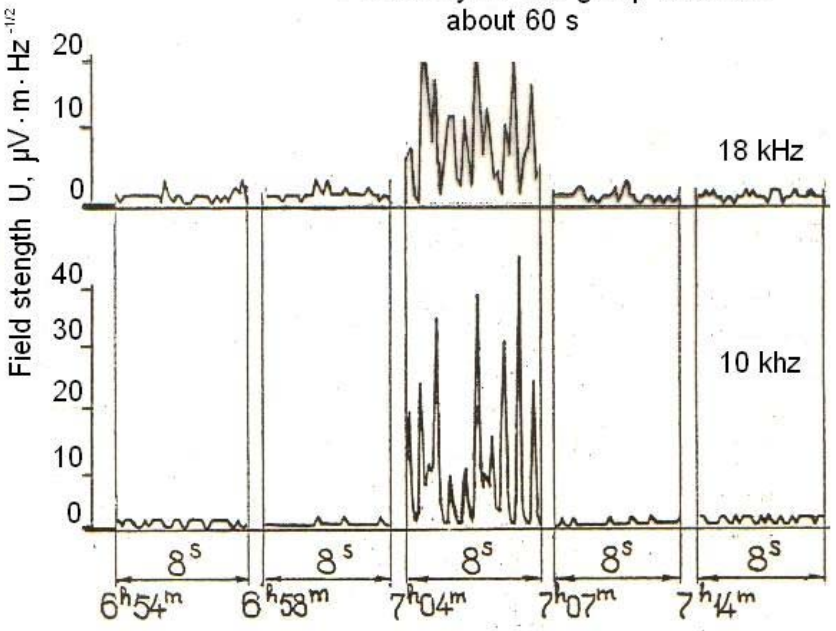
$280\ \mu V \cdot m \cdot Hz^{-1/2}$ for 10 kHz

$25\ \mu V \cdot m \cdot Hz^{-1/2}$ for 80 kHz

* Discharge rate: 30 - 35 s^{-1}

*Triboelectricity problem almost certainly excluded

* Periodicity for one group of bursts: about 60 s



Assumed:

Cloud-to-cloud discharge, the energy per discharge:

$2 \cdot 10^{9}$ J. Spectrum: $P = 0.33\ kW \cdot Hz^{-1/2}$ (10 kHz),

$P = 0.33 \cdot 10^{-2}\ kW\ Hz^{-1/2}$ (100 Hz)

A distant source was observed (for a close source energy 10^{6} J is too low for producing discharge)

Account for diffraction in Fresnel zone:

$$R_{d1} = [\lambda_n \rho_1 \rho_2 / (\rho_1 + \rho_2)]^{1/2}.$$

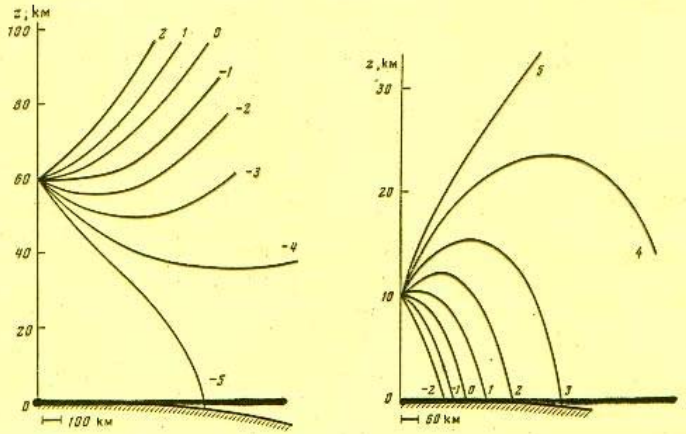
At 10 kHz R_{d1} = 86 km for $\rho_1 = \rho_2$ = 500 km.

The low altitude source: *Croft*, *Price* Radio refraction trape between 33 km and surface ICARUS, 1983, 53, 548

$$r_{\Lambda i} = \frac{m_i}{(dm_i/dz) \sin \bar{\delta}_i}, \qquad \bar{\delta}_i \text{ - zenith angle}$$

$$(R_{pl} + z_i)\, m_i \cdot \sin \bar{\delta}_i = \text{const}$$

Comparison with the experiment:



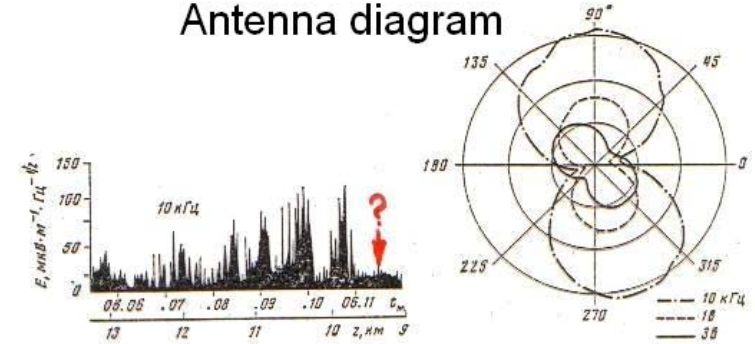
No Yes

Since the distance surface-to-inosphere is comparable to the wavelength, diffraction is of importance (*Brukhovetskii*, Kosmich. issled., 1983, 21, 758)

How the ionosphere produces no reflection at 10 to 80 kHz? A possible explanation is that electron-ion-neutral collisions occure at a level about 117 km.

The periodicity of groups of pulses pointed to a distant source producing electromagnetic noises.

Antenna diagram



* The distance, when calculated using the Austin formula:

$$R = \frac{300\sqrt{P}}{E}\sqrt{\frac{\Delta}{\sin\Delta}}\exp\left(-\frac{1.4\cdot10^{3}\,r}{\lambda^{0.6}}\right)$$

R = 1200 - 1900 km.

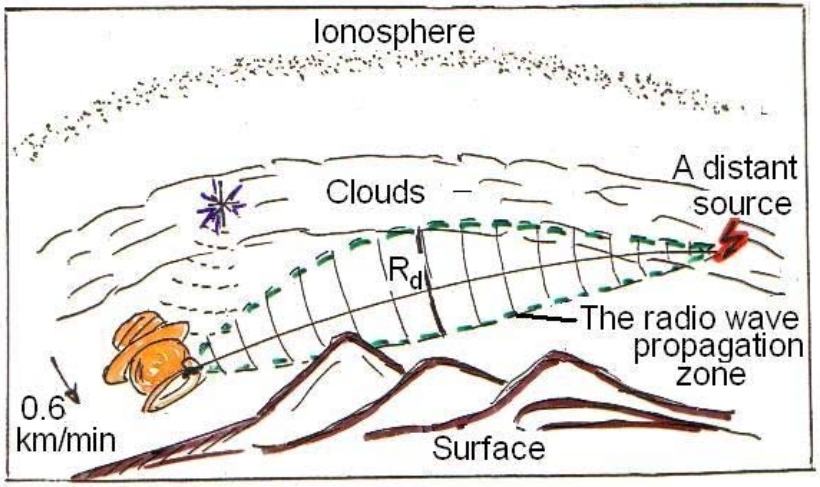
* The distance calculated based on geometry:

$R = (2R_{pl})^{1/2}(h^{1/2} + z^{1/2}) = 1200$ km.

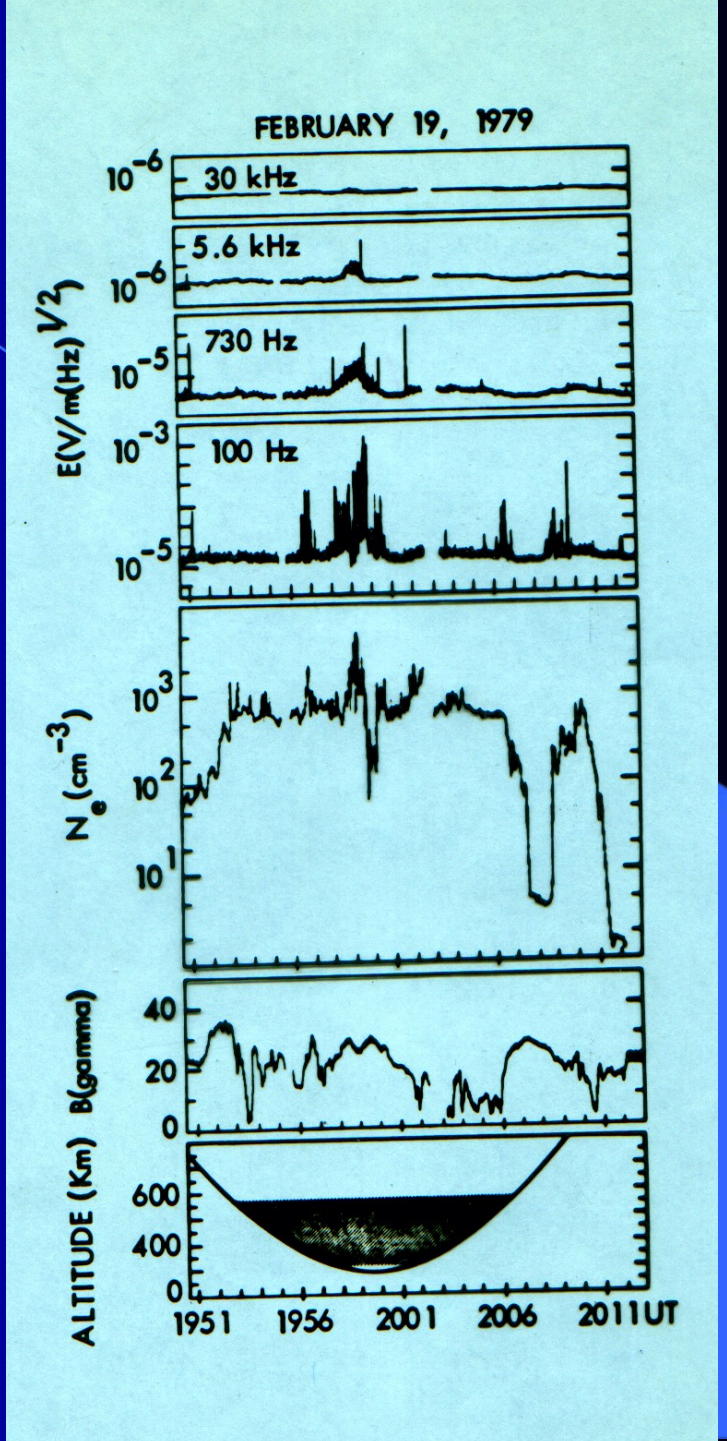
* The source size (calculated based on the signal periodicity prodoced by the sounder rotation):

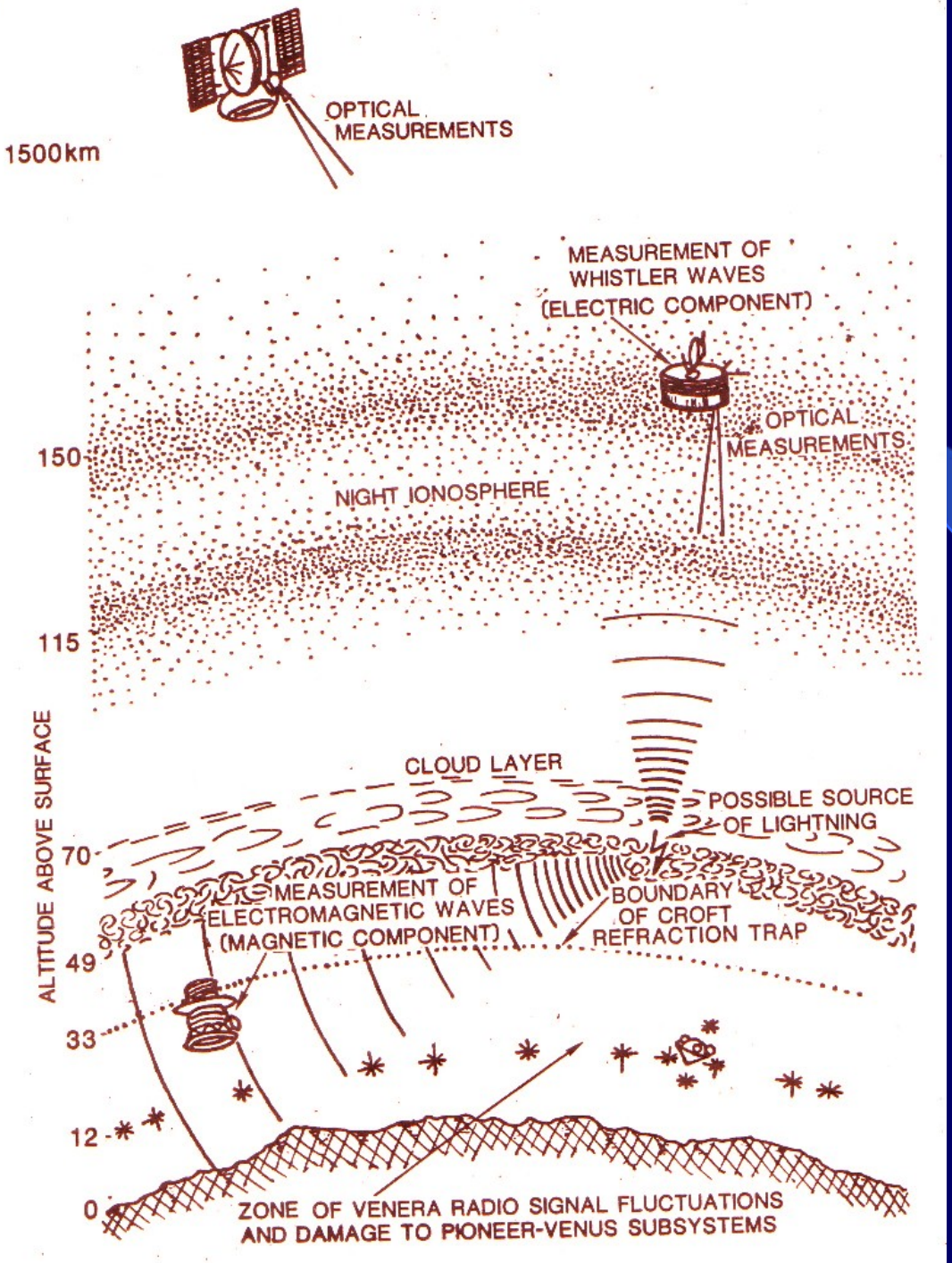
$E = E_f H \cos^2(\omega_x t + \theta)$:

$\alpha R =$ 100 - 120 km.

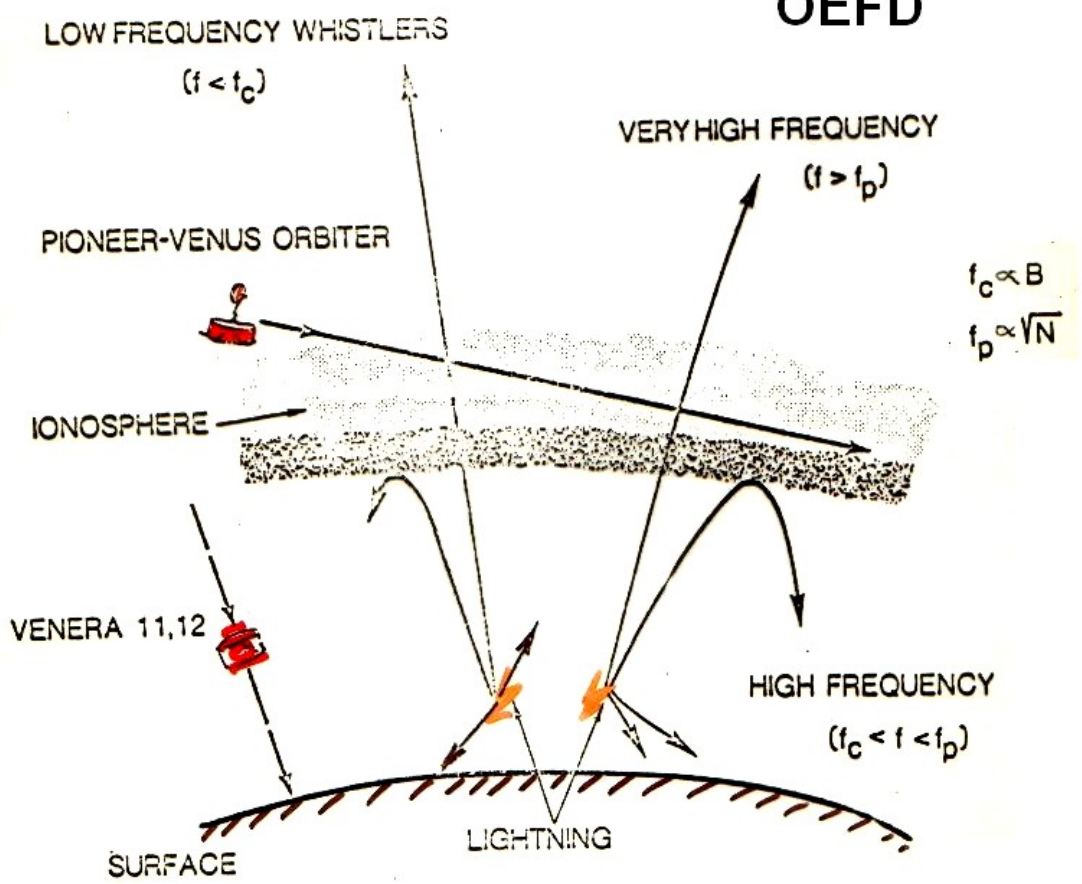


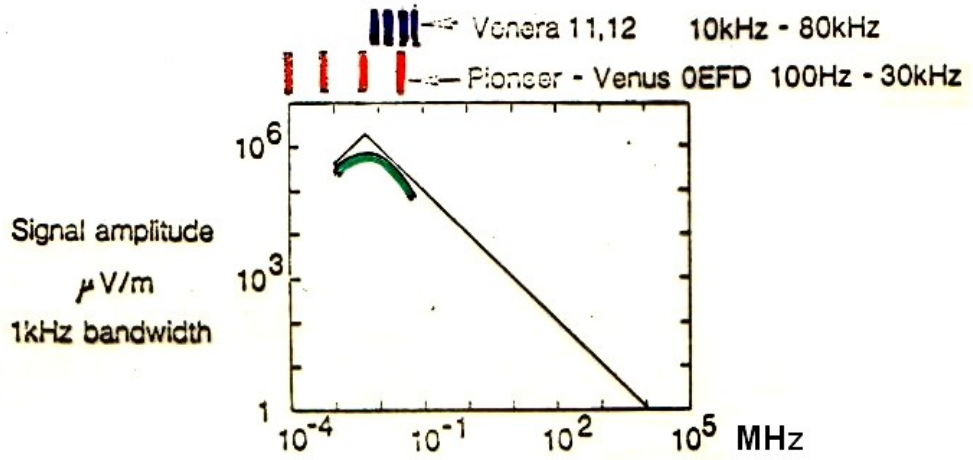
Simultaneously with the GROZA radio receiver the OEFD instrument on board of the PIONEER-VENUS registered electromagnetic pulses




1500km
OPTICAL MEASUREMENTS
MEASUREMENT OF WHISTLER WAVES (ELECTRIC COMPONENT)
OPTICAL MEASUREMENTS
150
NIGHT IONOSPHERE
115
CLOUD LAYER
POSSIBLE SOURCE OF LIGHTNING
ALTITUDE ABOVE SURFACE
70
MEASUREMENT OF ELECTROMAGNETIC WAVES (MAGNETIC COMPONENT)
BOUNDARY OF CROFT REFRACTION TRAP
49
33
12
0
ZONE OF VENERA RADIO SIGNAL FLUCTUATIONS AND DAMAGE TO PIONEER-VENUS SUBSYSTEMS

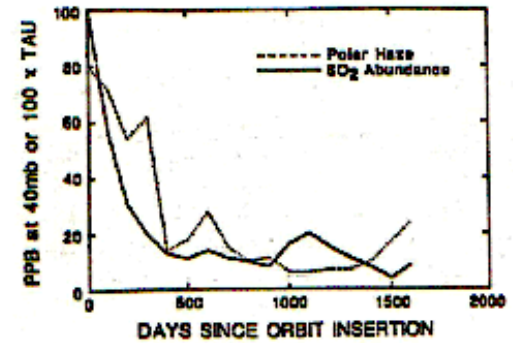
OEFD


LOW FREQUENCY WHISTLERS
(f < f_c)
VERY HIGH FREQUENCY
(f > f_p)
PIONEER-VENUS ORBITER
$f_c \propto B$
$f_p \propto \sqrt{N}$
IONOSPHERE
VENERA 11,12
HIGH FREQUENCY
(f_c < f < f_p)
LIGHTNING
SURFACE

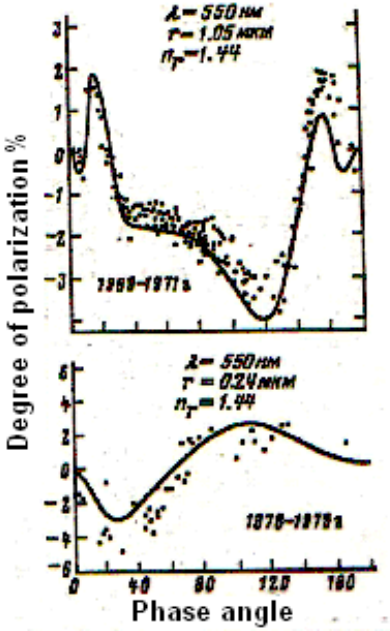

Venera 11,12 10kHz - 80kHz
Pioneer - Venus OEFD 100Hz - 30kHz
Signal amplitude
μV/m
1kHz bandwidth
10^6
10^3
1
10^{-4}
10^{-1}
10^2
10^5
MHz

Discharges inside Earth’ clouds are well visible from outside. A search for light flashes on the night side of Venus resulted in nothing.

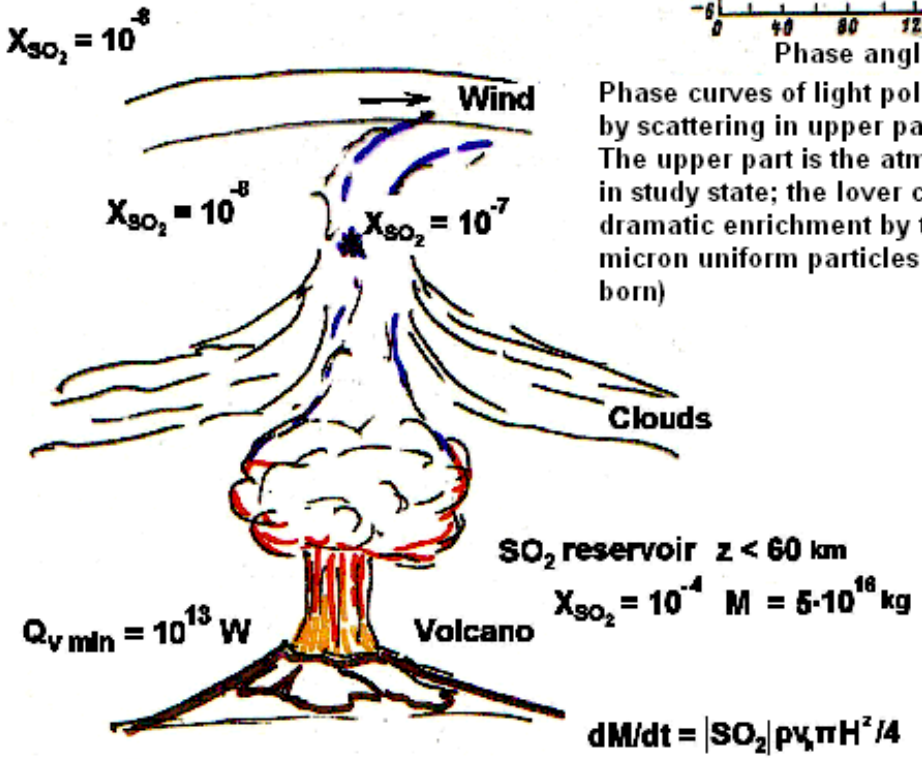
A quest for volcanism



Intercomparison of derived SO_2 (solid line, this work) and derived polar haze optical depth (dashed line) from PVO Cloud Photopolarimeter (L. D. Travis, personal communication, 1987).

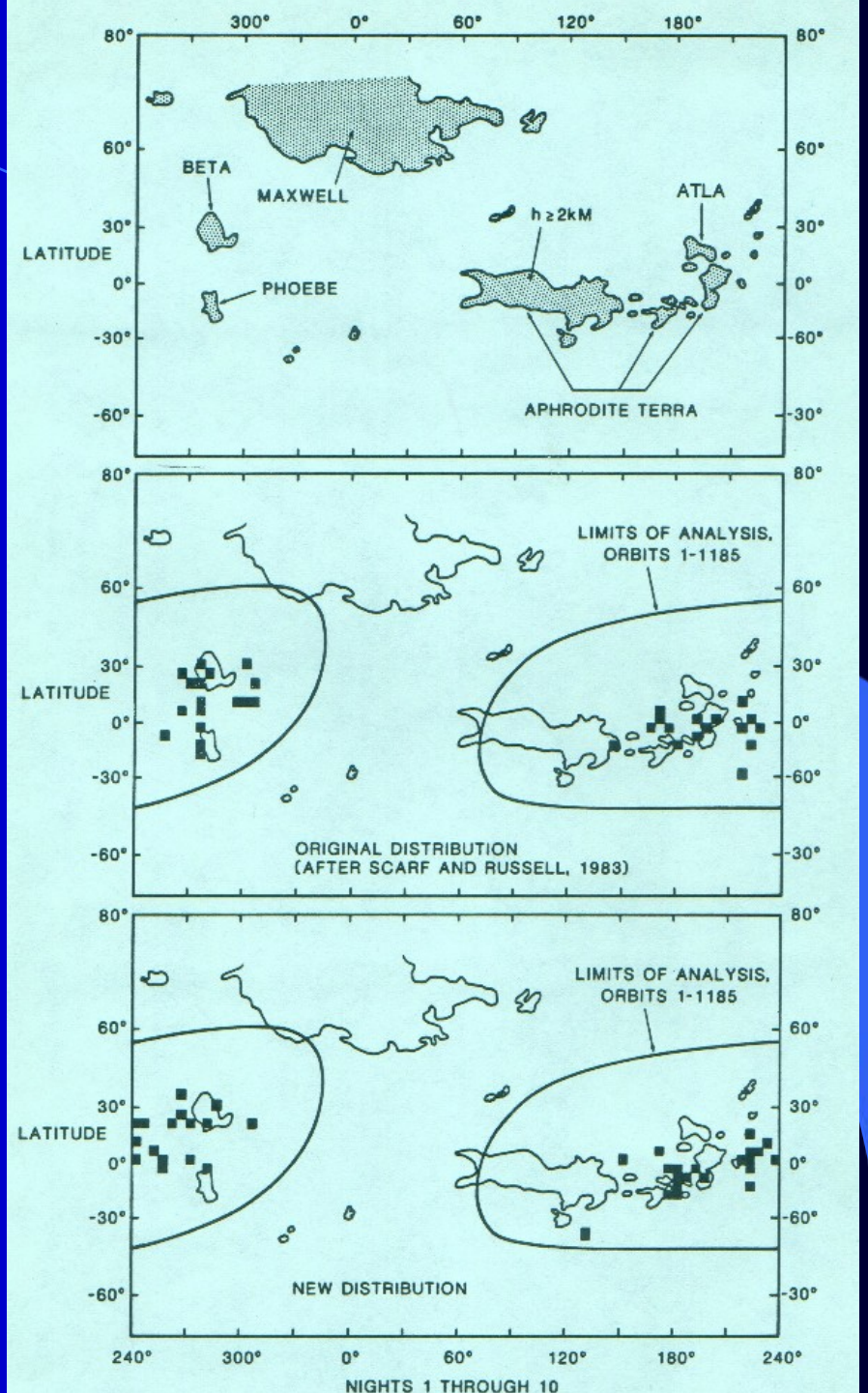


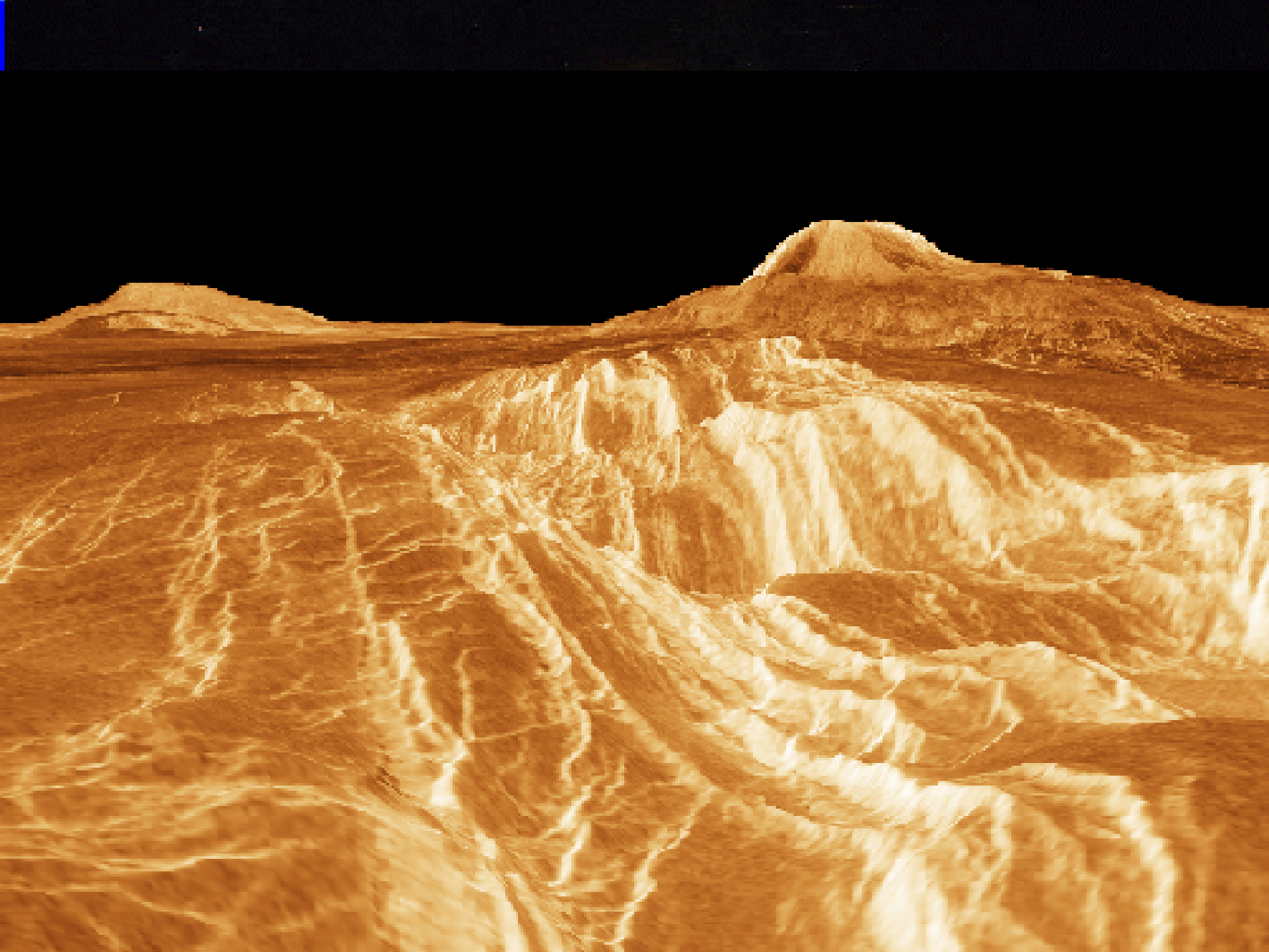
Phase curves of light polarization by scattering in upper part of clouds. The upper part is the atmosphere in study state; the lover curve is its dramatic enrichment by the sub-micron uniform particles (recently born)



Volcanism could be only indirect reason for arising SO_2 concentration

Are the impulses registered by the OEFD instrument connected to topography? (First attempt)





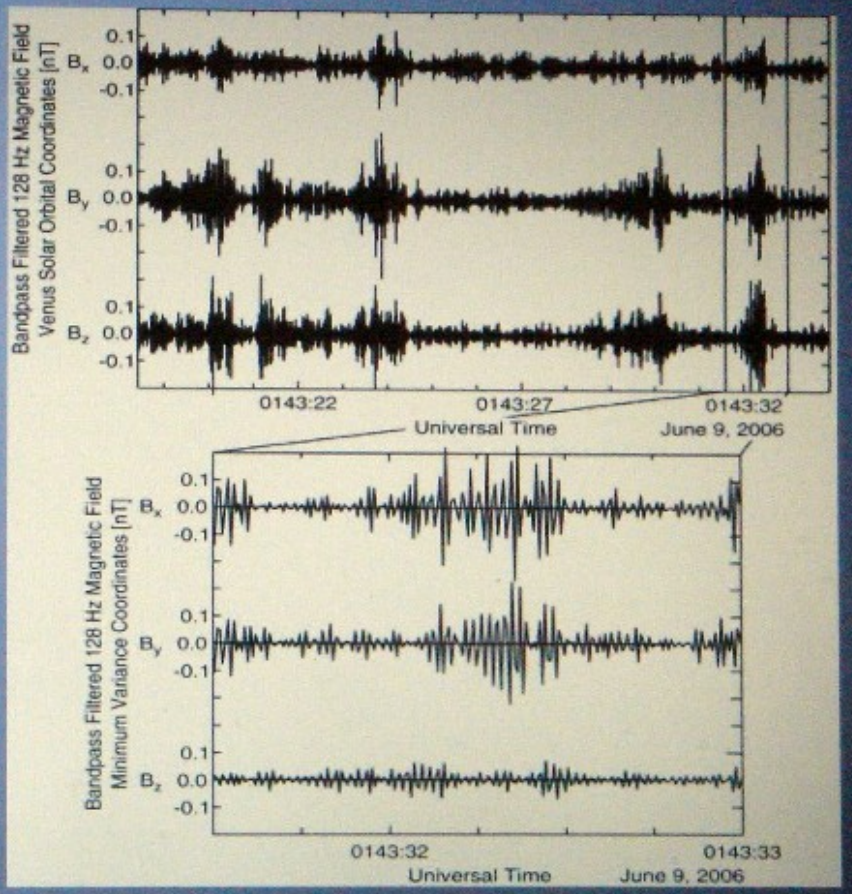
Electromagnetic pulses coming from the atmosphere of Venus were observed by instruments of GALILEO (Borucki et al., 1996).

Electromagnetic Waves in Venus Ionosphere Indicative of Lightning

Lightning produces a high temperature, high pressure pulse in a planetary atmosphere enabling chemical reactions that do not take place at standard temperatures and pressures. Nitric oxide, NO, is an example of such a product in the Earth's atmosphere. NO would be produced by lightning at Venus as well

Venus Express made resolving this controversy a major objective and transmits 2 minutes of magnetic field samples at 128 samples per second at each closest approach

About 15% of the passes contain signals like these that resemble in duration and spacing signals produced by terrestrial lightning discharges, confirming the presence of significant lightning activity in the Venus clouds, possibly similar in strength to that on Earth

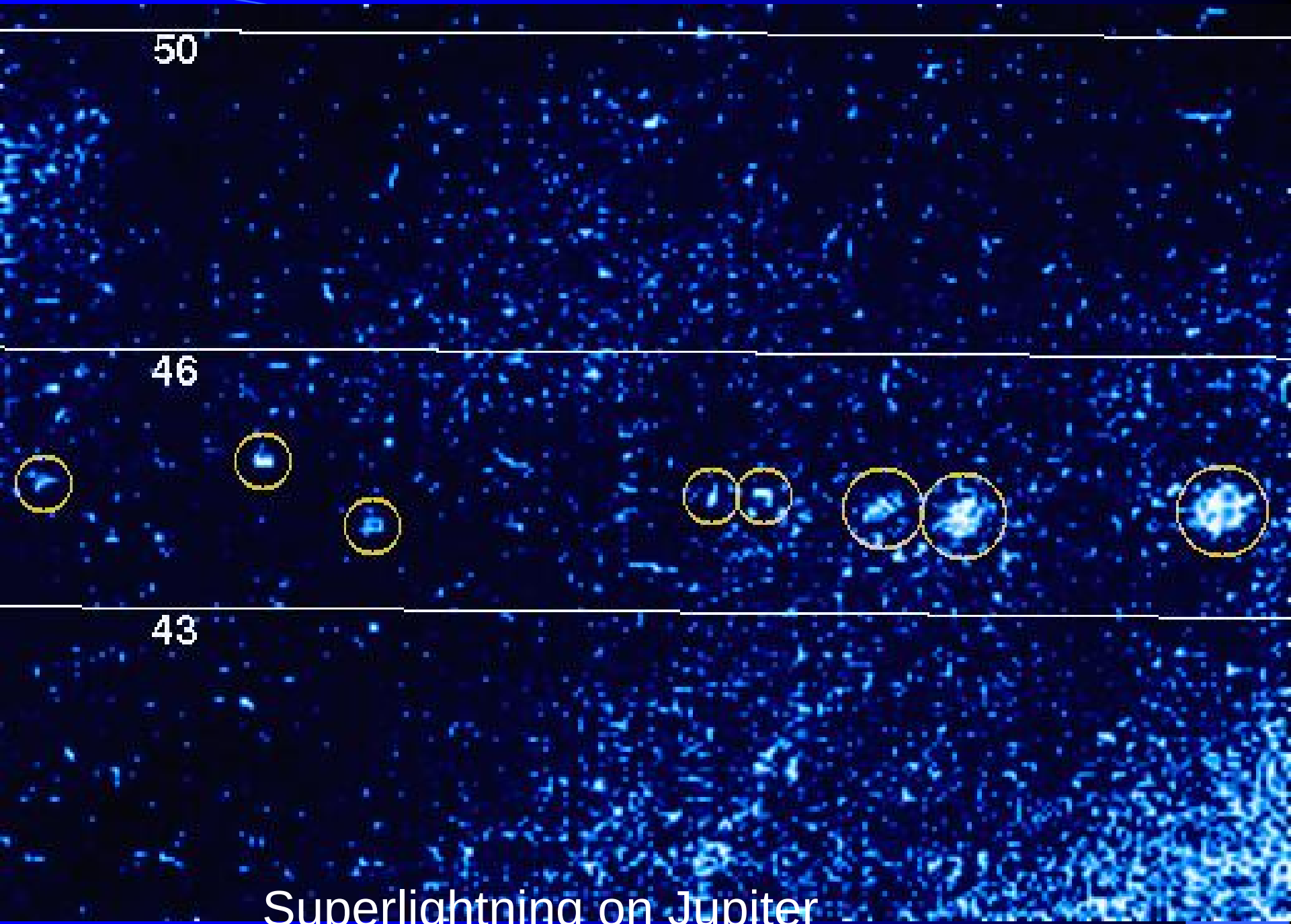


309 km altitude, 0516 LT, 85° latitude

C. Russell et al., 2007

Huge high-altitude lightnings

Taiwan researchers have discovered huge lightnings which rise as clusters from storm clouds to the upper layers of the atmosphere (up to 100 kms). As against usual lightnings, these sparkling streams are propagate in rarefied air, creating similarity of huge "trees" or " clusters " having height up to 80 kms.
The work has been carried out by Han Tsun Su from National University Chang Kun, and has allowed to observe five huge streams of the lightnings rising upwards from storm clouds above South China sea. Their duration was less than one second. It is very difficult to see these streams by the naked eye - probably for this reason researchers till now knew nothing about their existence. The scientist also has found out that four of these streams radiated radiowaves of extremely low frequency which could create handicaps for global systems of a radio communication.



Superlightning on Jupiter


The end