Global dust storms and highly polarizing clouds on Mars

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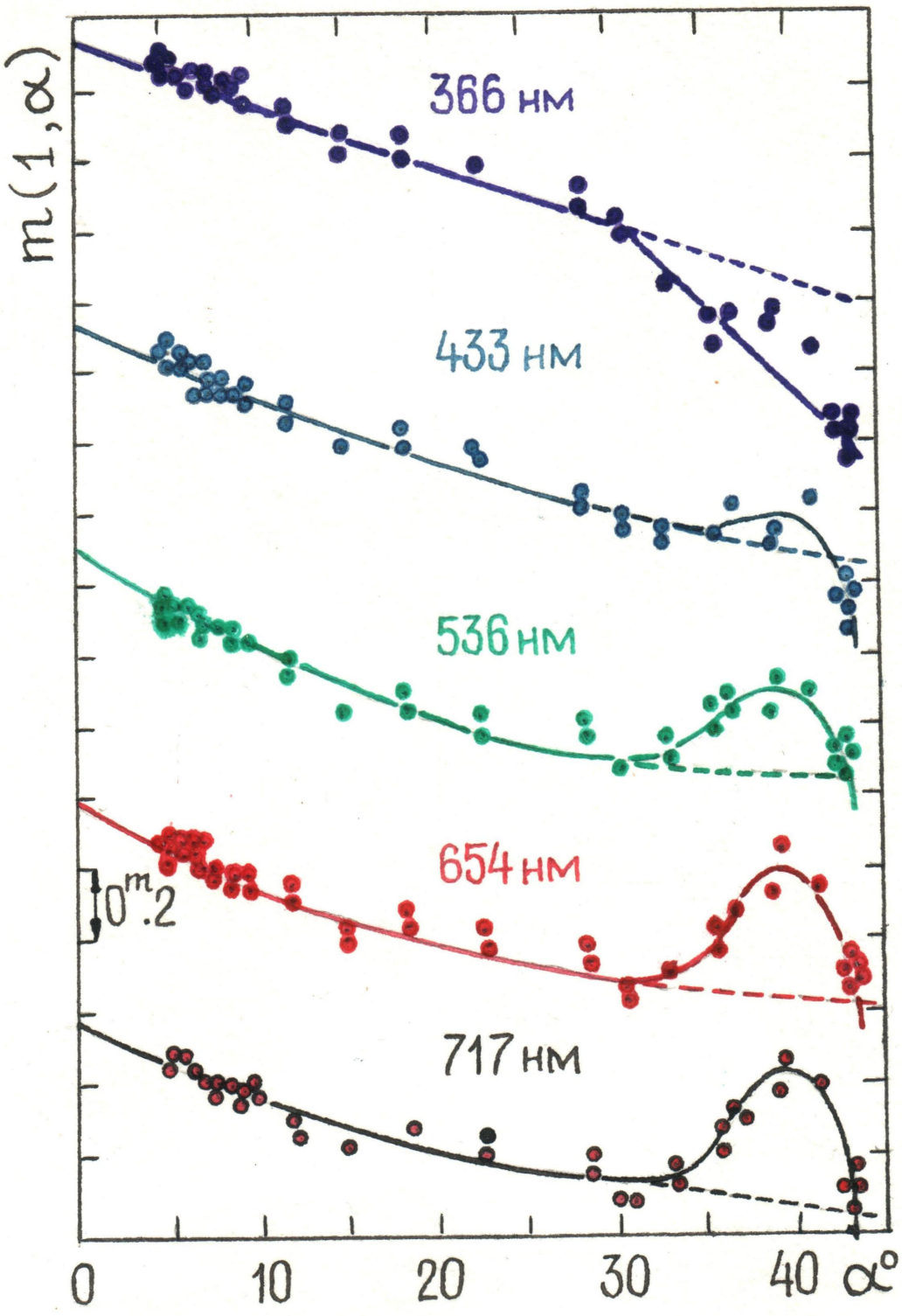
Nikolaj P. Barabashov
(1894 - 1971)

70-cm reflector of the Institute of Astrophysics of Tajikistan, located in 15 km from Dushanbe



Magnitude-phase dependences of Mars in 1971 great opposition

Phase angle α>33 deg (26 Sept. – 10 Dec.):

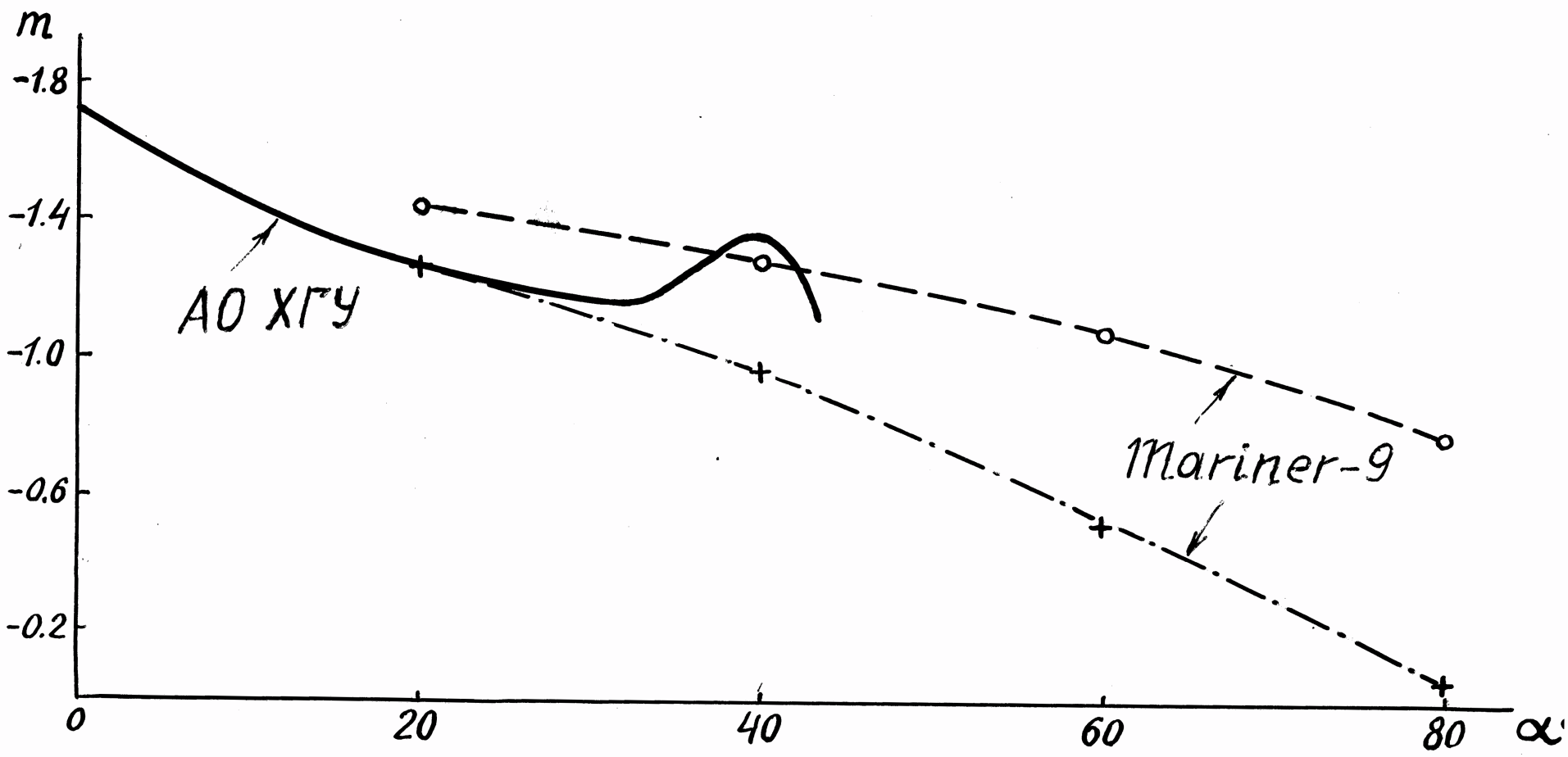
global dust storm

The maximum relative changes of disk-integrated brightness of Mars during its global dust storm in 1971

λ, *μm*	0.366	0.433	0.536	0.654	0.717
Δm, *mag*	+0.25	– 0.07	– 0. 21	– 0. 34	– 0. 35

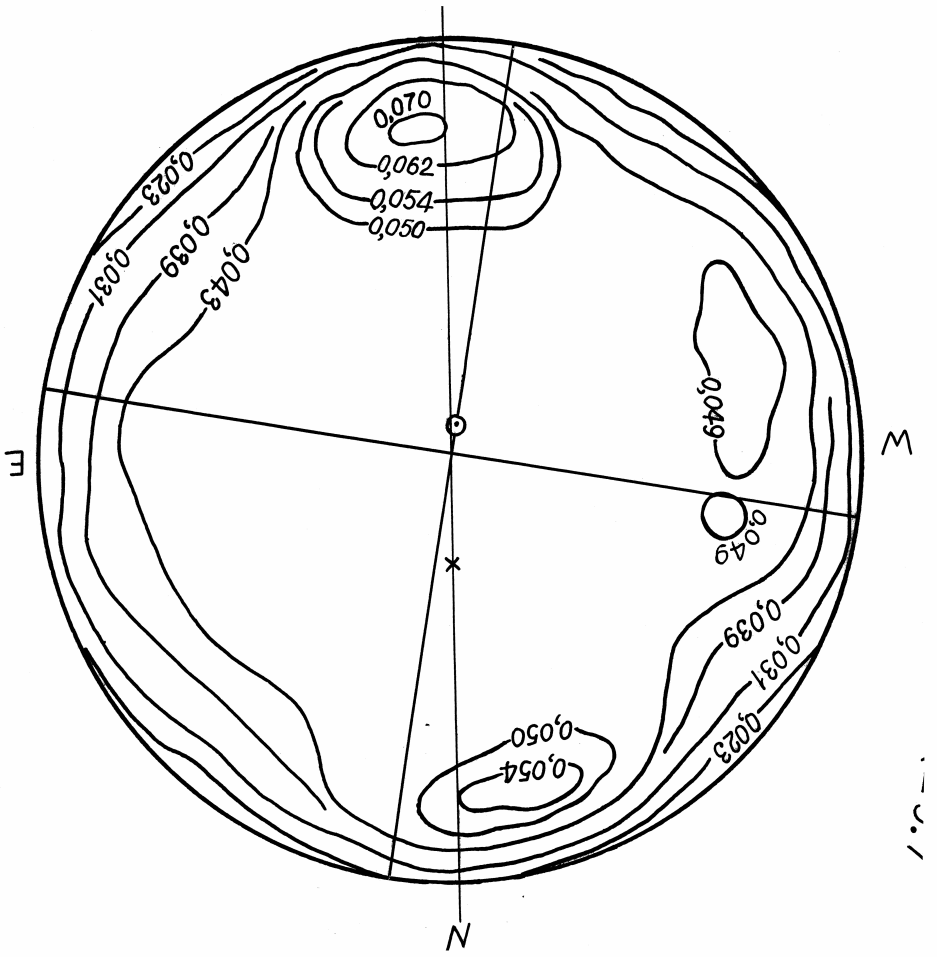
Color index of Mars (ΔUV- ΔR) = 0.60 mag (!)

Comparison with data of the USA mission Mariner-9 according to Thorpe (1973)

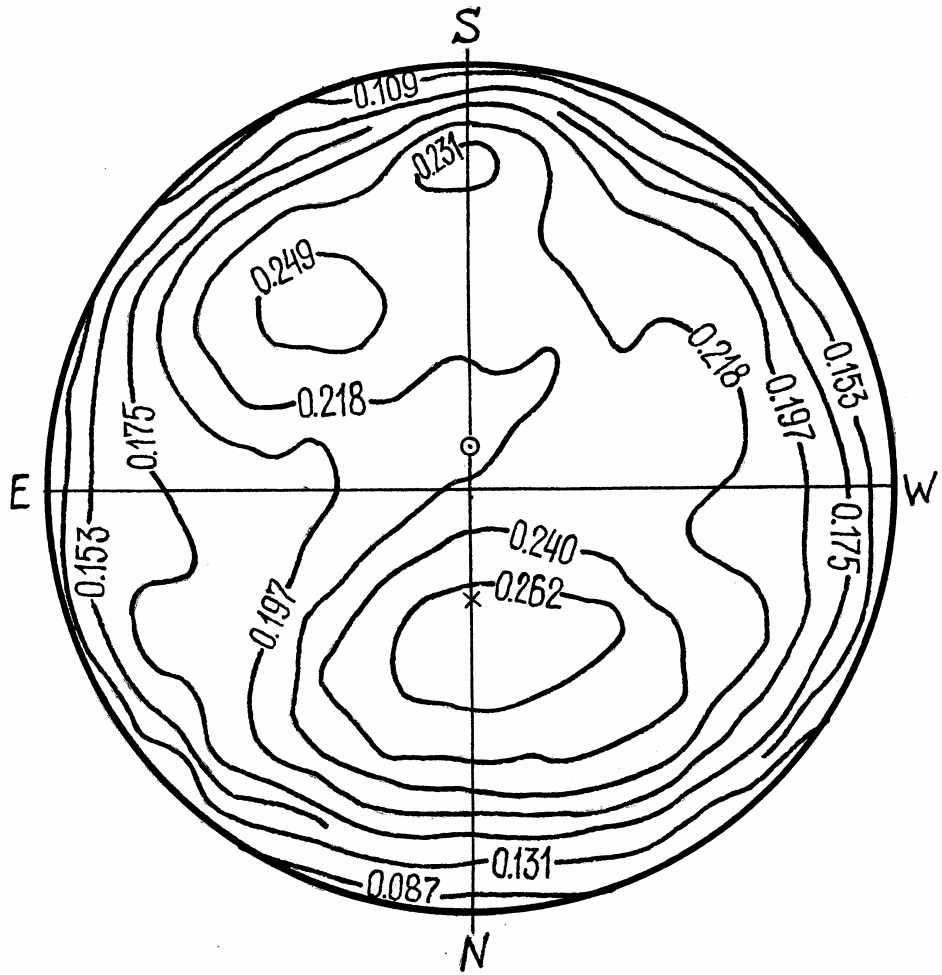


Brightness distribution on Martian disk for conditions of clear atmosphere

August 10/11, 366 nm, α=5.1 deg

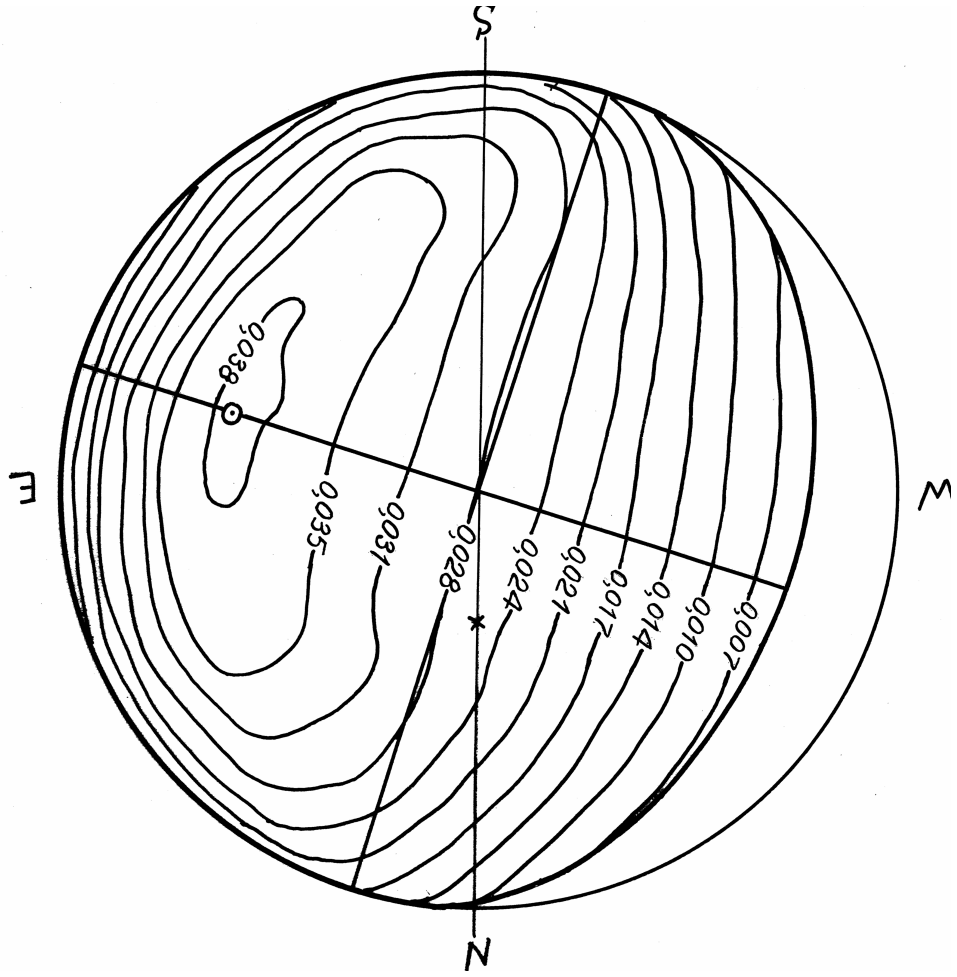


August 11/12, 625 nm, α=5.2 deg

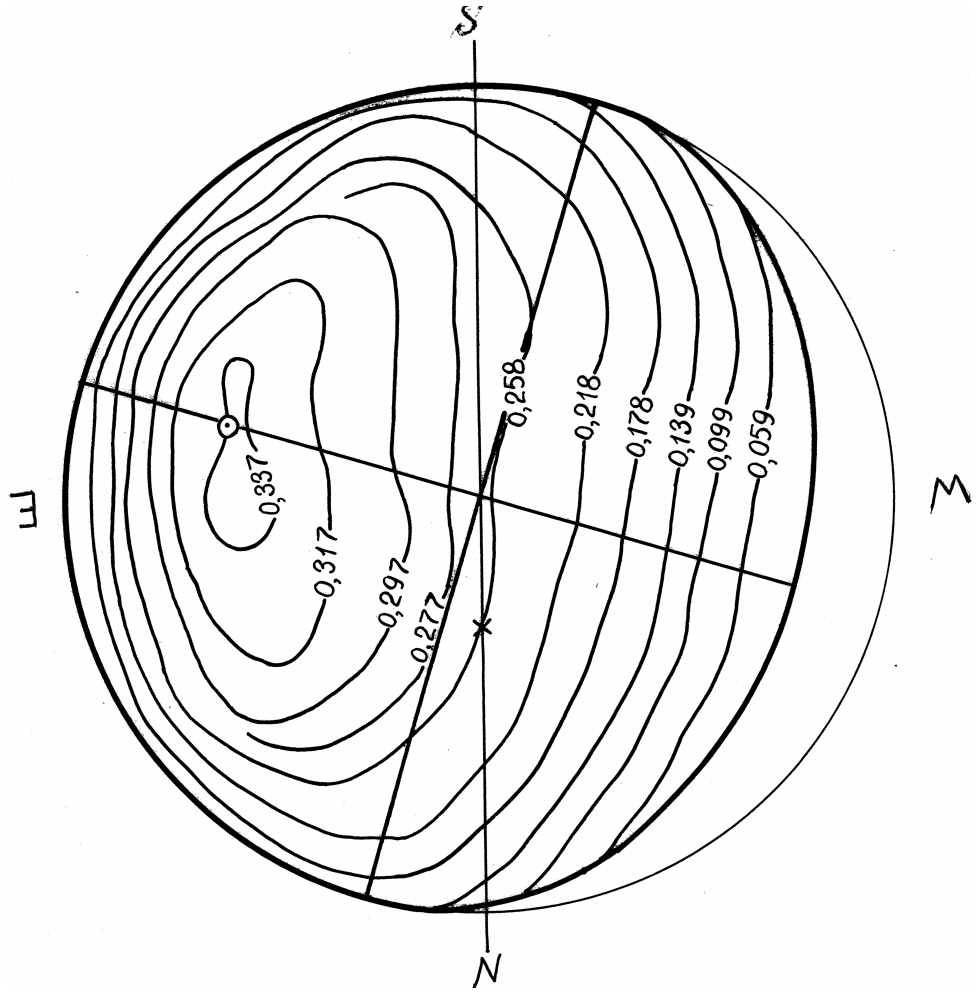


Brightness distribution on Martian disk at maximum stage of dust storm

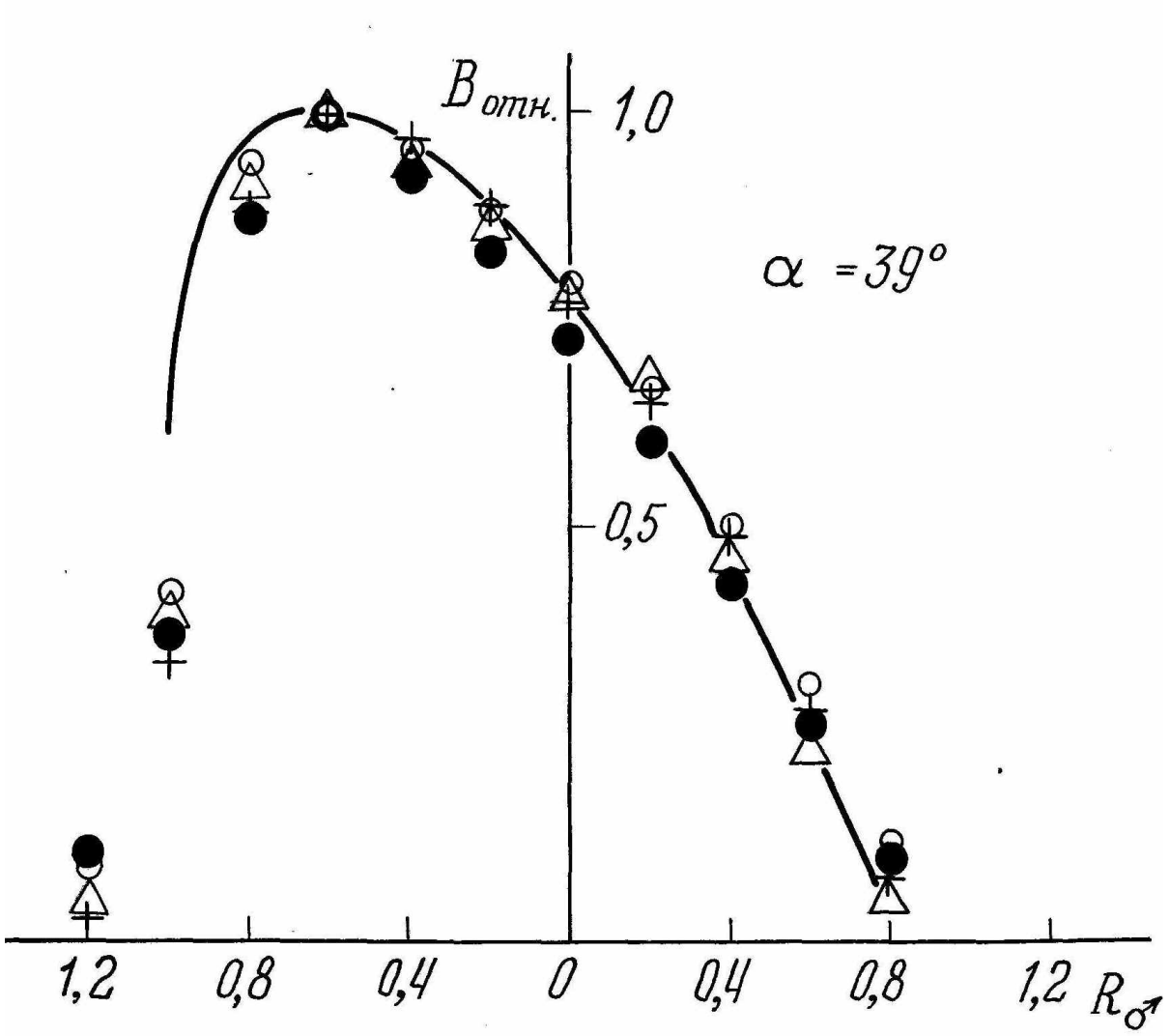
October 14/15, 366 nm, α=39.0 deg



October 14/15, 625 nm, α=39.0 deg



Brightness distribution along equator of intensity of Martian disk during dust storm 1971



14/15 October 1971

● 366 nm

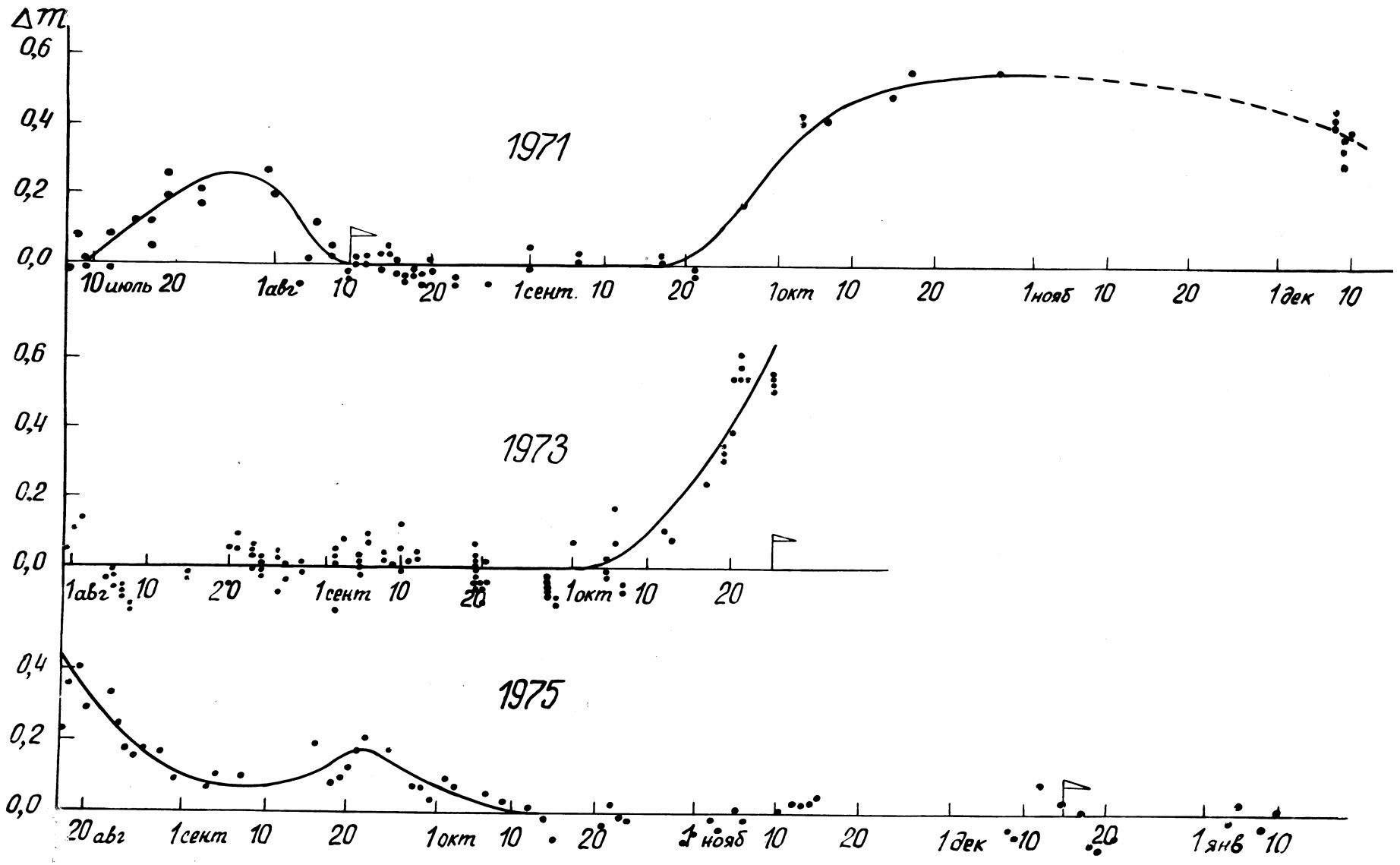
o 435 nm

\+ 548 nm

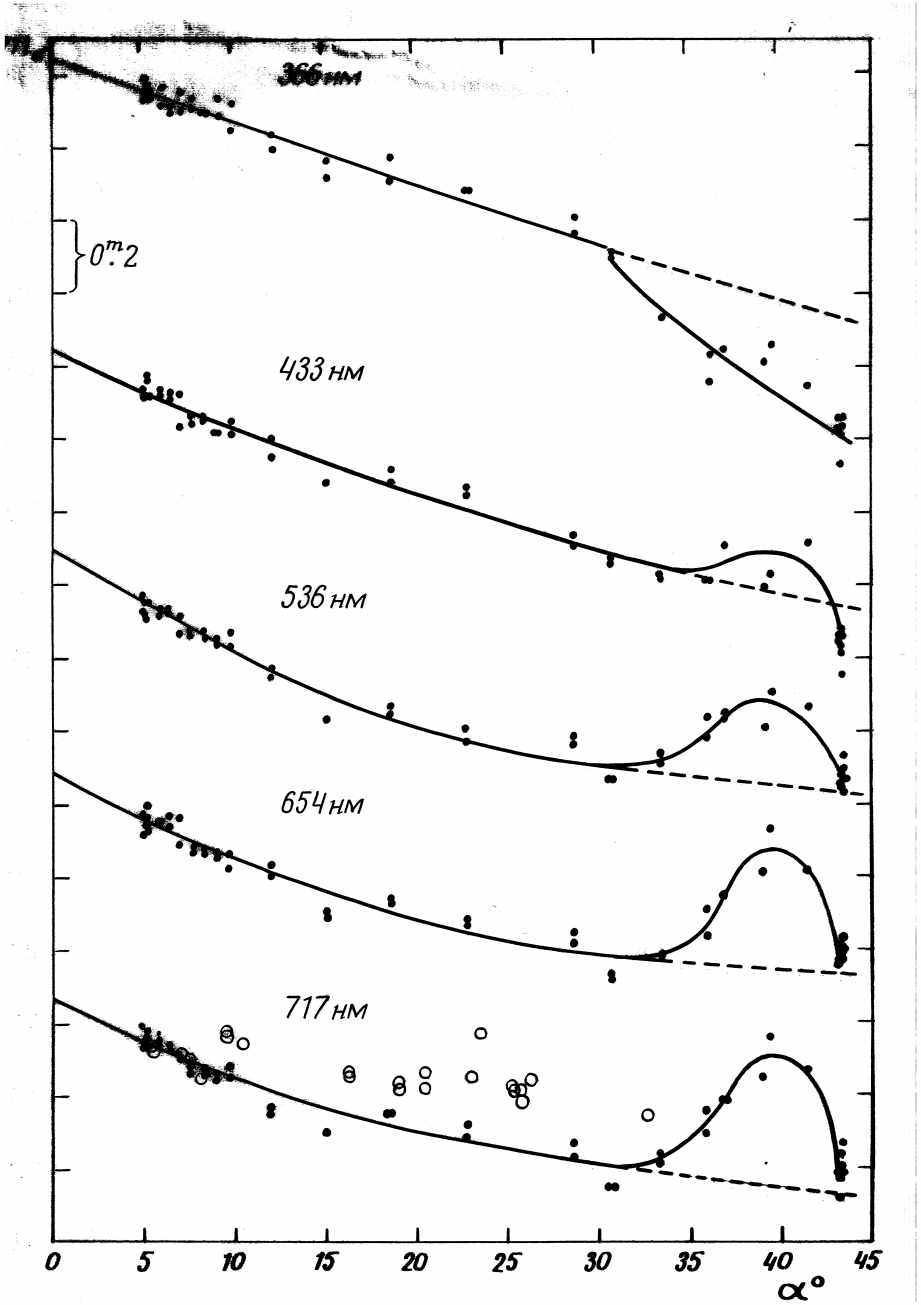
Δ 625 nm

——— Lambert law

Variable component of color index (UV-R) caused by dust storm



Magnitude-phase dependences of Mars in 1971 great opposition



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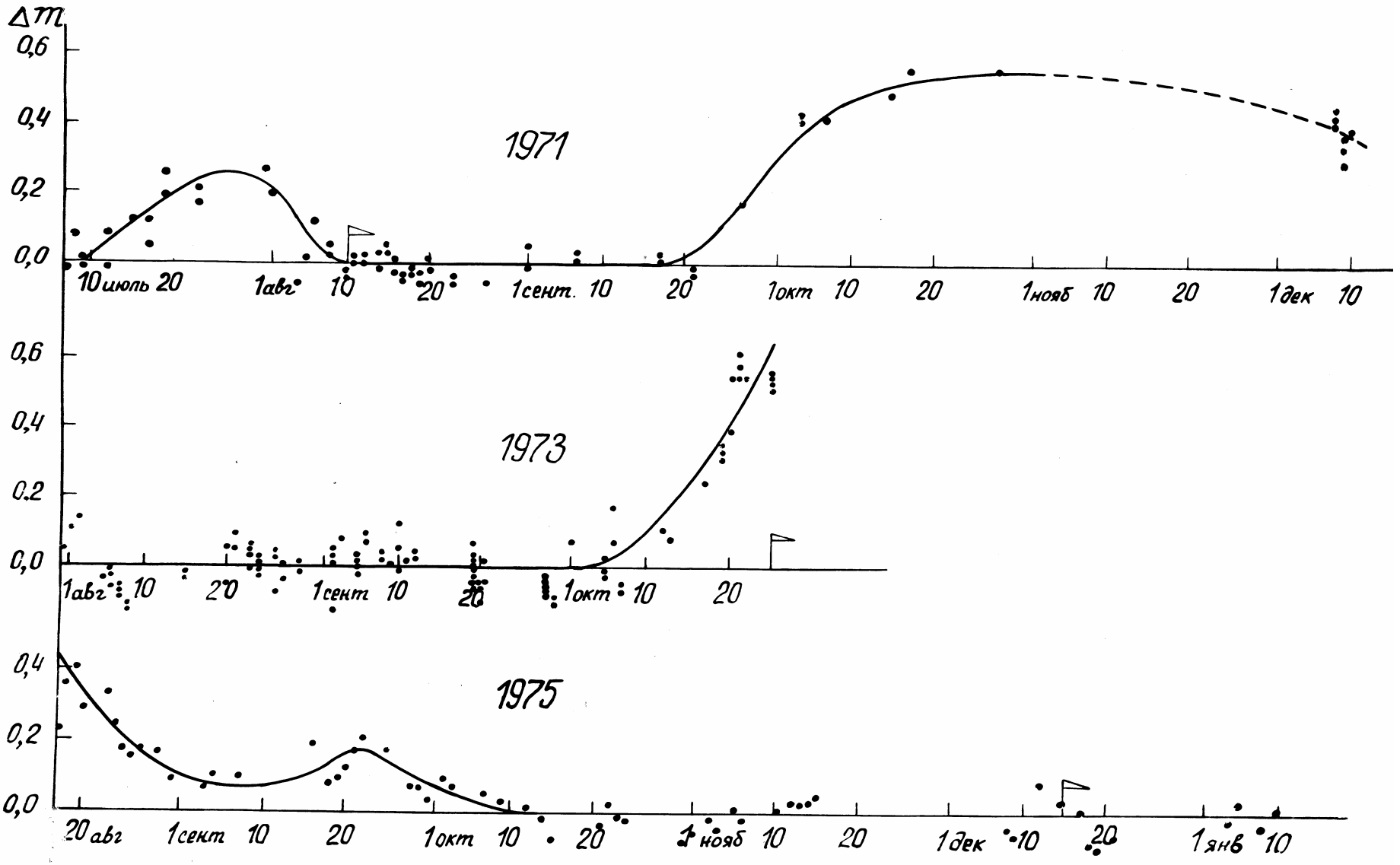


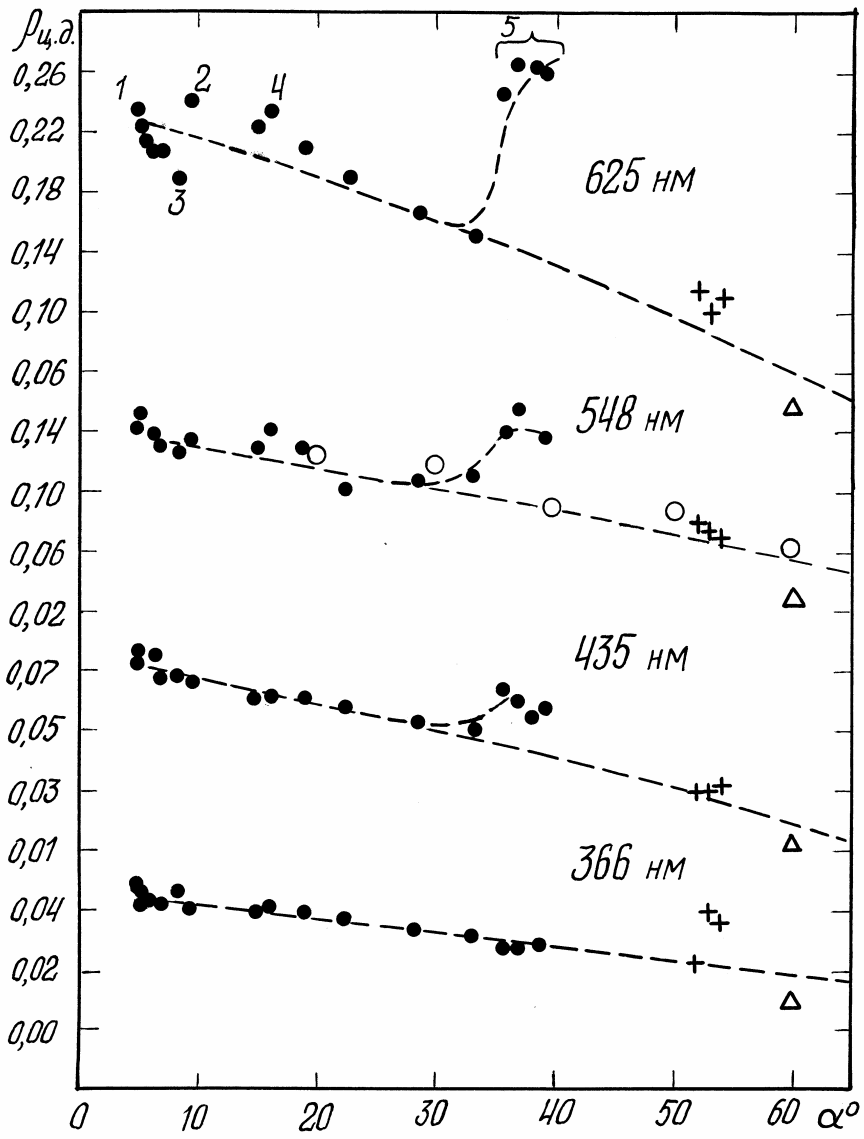
Observation data → physical parameters of dust storm

We used:

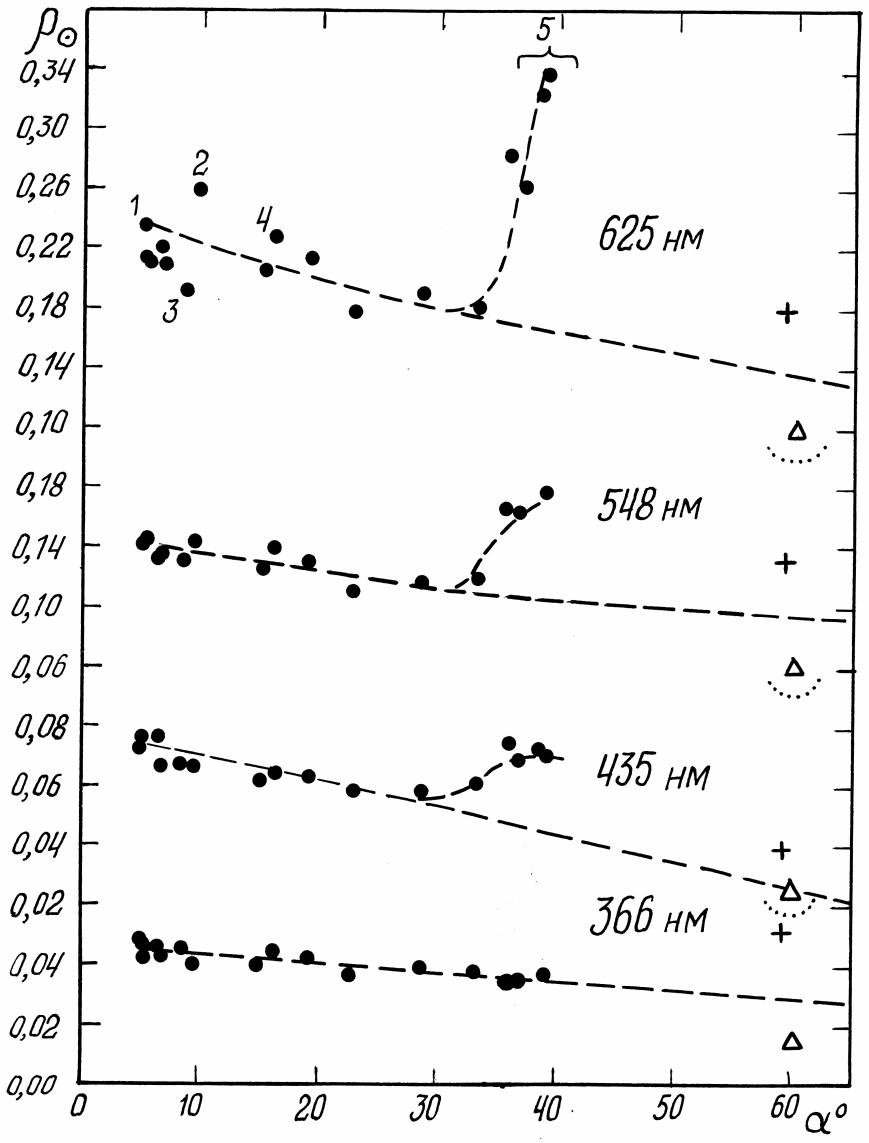
- measured absolute disk-integrated brightness of Mars in different spectral bands;
- absolute brightness of Mars' centre of disk and of sub-Solar point in different spectral bands;
- assumption about silicate nature of dust particles (according to Hanel et al. 1972 abundance of SiO_2 in particles of dust storm is 60±10%), refractive index $m=1.5-i(0.2\div0.3)10^{-3}$;
- the simplest nonspherical scattering indicatrix of particles $X(\gamma)=1+x_1\cos\gamma$

Absolute brightness of Mars in 1971

centre of disk



sub-Solar point



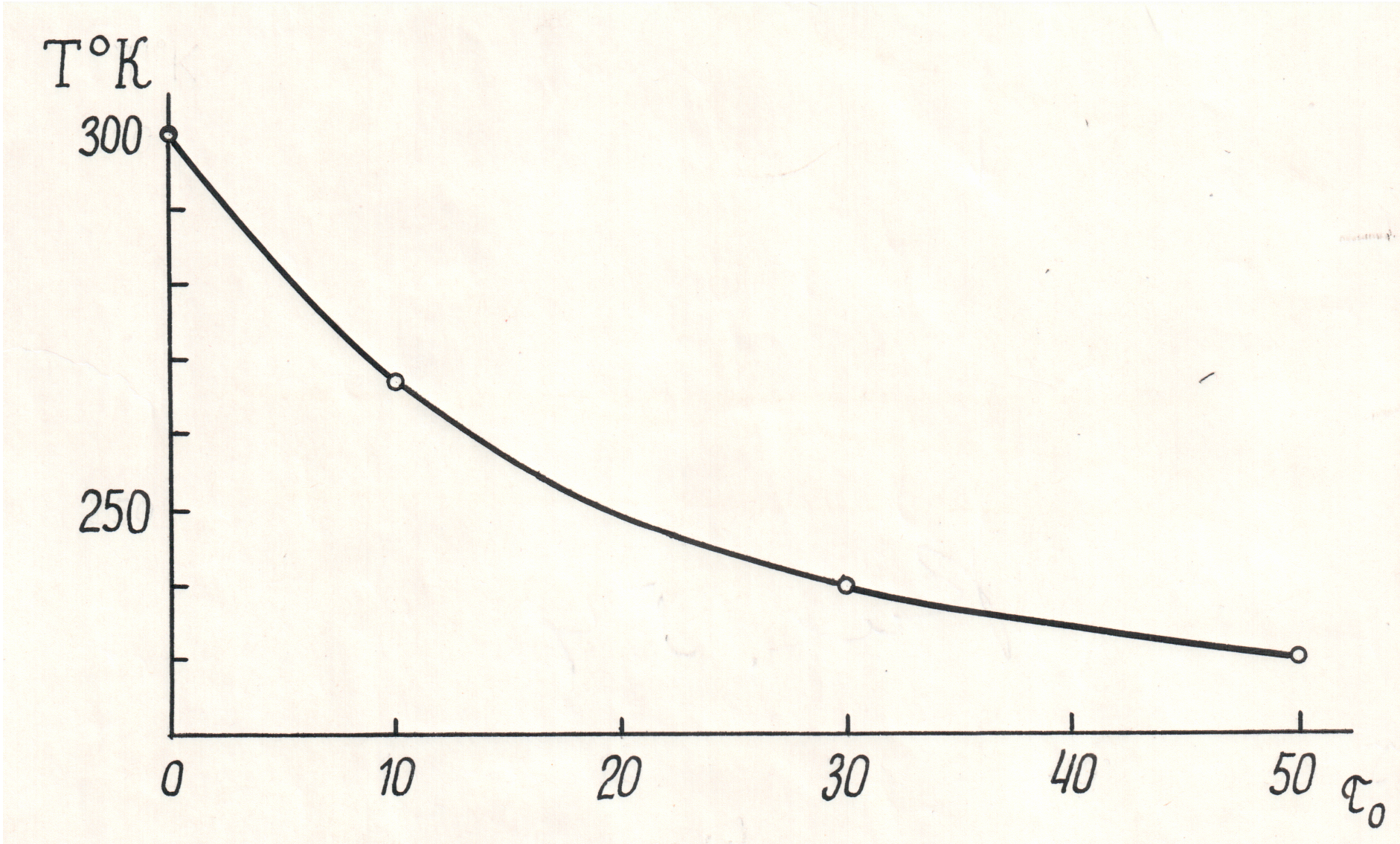
Two possibilities:

a) r_o~1 μm b) r_o~10 μm (Alexandrov & Lupishko, 1976):

- single-scattering albedo of dust particle ω=0.87÷0.99 for $\Delta\lambda$=0.366–0.625 μm;
- the mean radius of dust particles in maximum dust storm is r_o~10 μm;

  "Mars-3" data (Moroz et al, 1972): r_o~0.5–1 μm in December of 1971. In reality there is some size distribution of dust particles and its submicron part can be essential. However, the large particles contributed in the optical properties of dust atmosphere much more, what makes the small particles photometrically imperceptible.
- optical thickness of atmosphere in maximum of dust storm $\tau \sim 40$;
- $M_{(total)} \sim 10^{17}$ g (~10^{11} ton) at particle density $\rho = 3$ gcm^{-3};
- temperature pulldown of Martian surface due to "antigreenhouse effect" in sub-Solar point is $\Delta T = 60 \div 70$ deg, what is in well accordance with data (Liberman et al, 1972). According to "Mariner-9" and "Mars-3" data (Golitsyn, 1974) during period of storm decay "antigreenhouse effect" was equal to $\Delta T \sim 25$ deg, what corresponds to $\tau \sim 8$.

Calculated dependence of temperature in sub-Solar point of Mars on optical thickness of its atmosphere in maximum of dust storm



Obtained data allow us explain a peculiarities of Mars brightness during the dust storm:

- Single-scattering albedo ω of dust particles is found to be essentially higher than of particles of Mars surface, what have to increase the Martian brightness especially in visual-red spectrum, where ω tends to be equal to 1.

- At a new package of suspended in atmosphere surface particles the distances between them increase so great that mutual particle shading disappears. The absence of shadow increases the planet brightness too.

- In red spectrum it is necessary to take into account an additional brightening of Mars due to disappearance of low-albedo mare regions of Martian surface. It is easily to estimate that this brightening is about 0.1 mag.

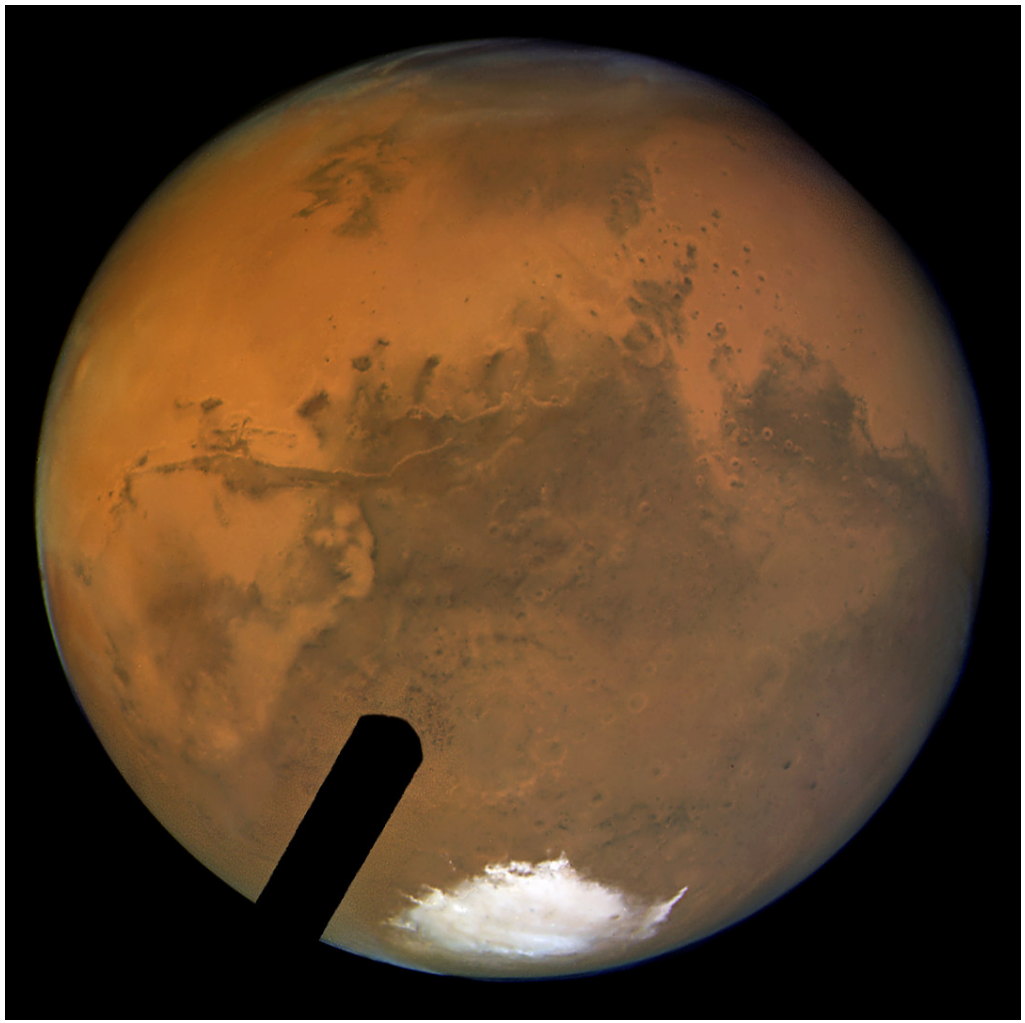
- In UV a) more essential light absorption as compare with red wavelength and b) more elongated scattering indicatrix of particles because wavelength parameter of particle $2\pi r/\lambda$ is about twice as large in red part of spectrum. Besides, there is no additional brightening due to masking mare regions. As a result, the brightness of dust atmosphere turned out to be smaller than brightness of the system ”surface plus usual clear atmosphere”.

Principal publications of this work

- Barabashov N.P., Lupishko D.F., Kiselev N.N. 1972. Observations of Mars in 1971. Astron. Circular, No. 687, p. 3-5.
- Alexandrov Yu.V., Lupishko D.F. 1976. Optical properties of the Martian atmosphere during the 1971 dust storm. Astron. Journal (Russian), v. 53, issue 1, p. 162-169 (in Russian).
- Lupishko D.F., Lupishko T.A. 1977. The possibility of Martian dust storm monitoring. Letters to Astron. Journal (Russian), v. 3, No. 11, p. 515-517 (in Russian).
- Alexandrov Yu.V., Lupishko D.F., Lupishko T.A. 1977. Absolute photometry of Mars in 1971, 1973, 1975. Kharkov, "Higher School", 126 p. (in Russian).

II. Imaging polarimetry of Mars in 2003 with the Hubble Space Telescope

(program HST-GO-9738 “Spectroscopy and Polarimetry of Mars at Closest Approach”)



- Earth-Mars distance

  0.372 AU

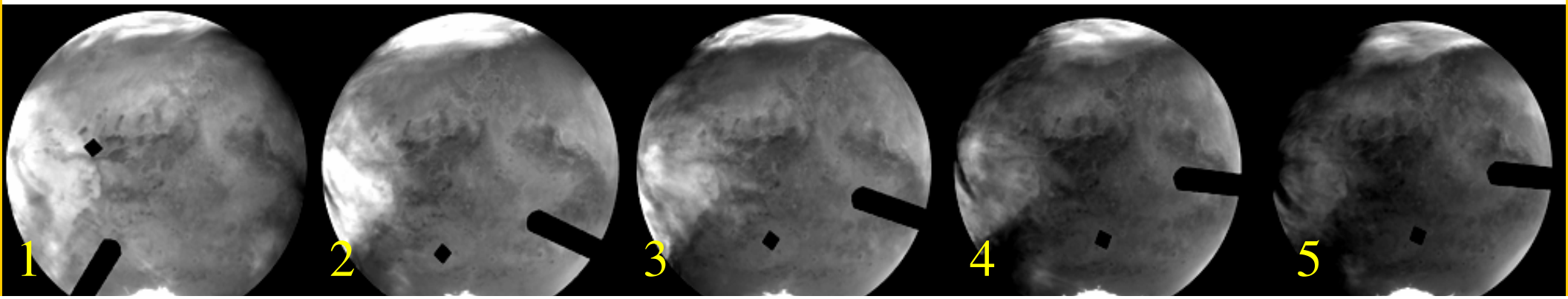
- Angular Mars’ diameter

  25.1"

HST observations of Mars Opposition 2003

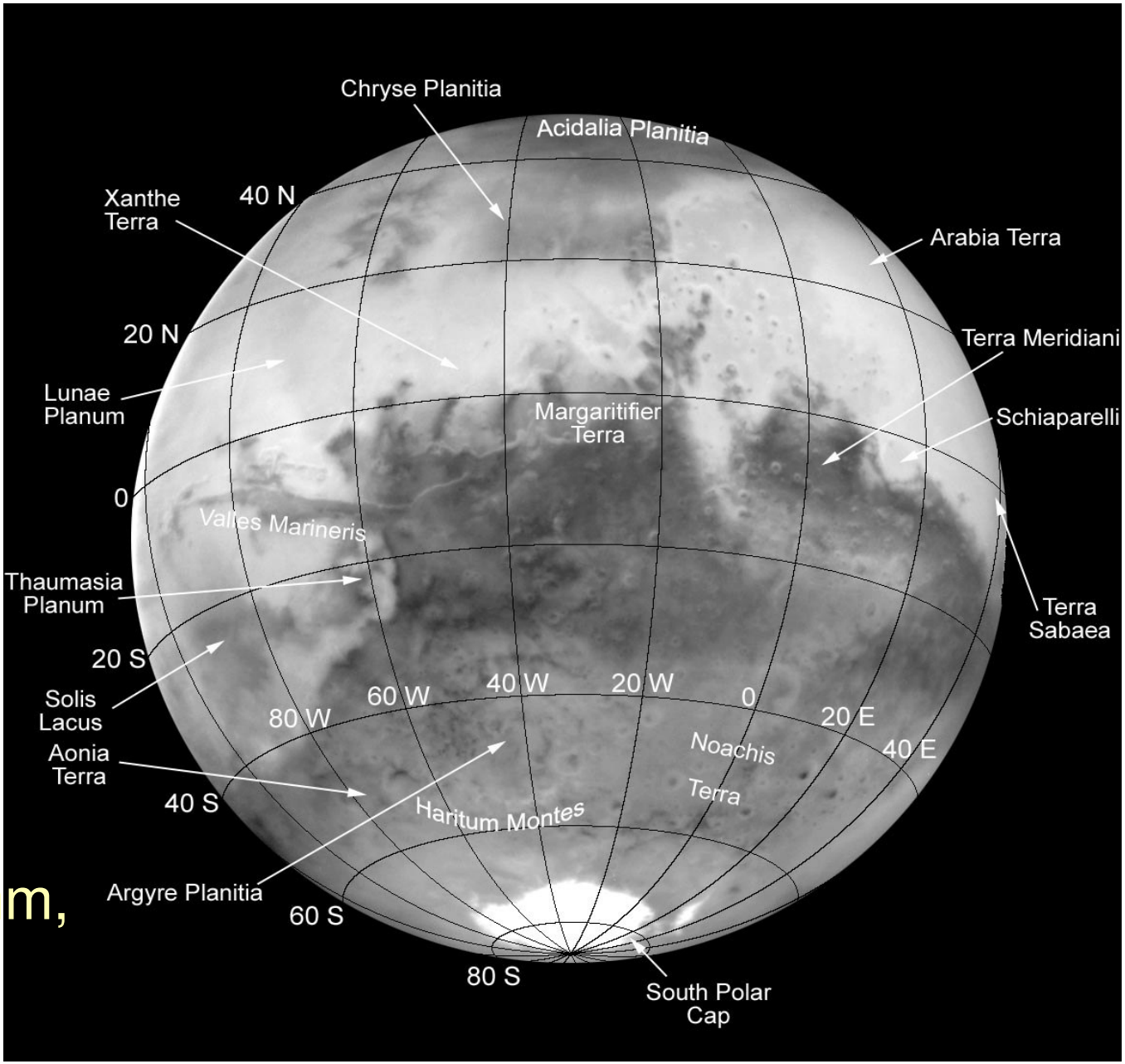
- **Camera**: HRC / ACS
- **Resolution** (disk center) ~ 7 km/pixel
- **Disk size** ~ 1000 pixels
- **Disk center**: 19°S ~30°E

	Date of 2003	α, deg	Spectral filters
1	Aug., 24	6.4	250 nm **UV I** 330 nm **UV II** 435 nm **Blue**
2	Sept., 05	8.2	
3	Sept., 07	9.7	
4	Sept., 12	13.6	
5	Sept., 15	15.9	



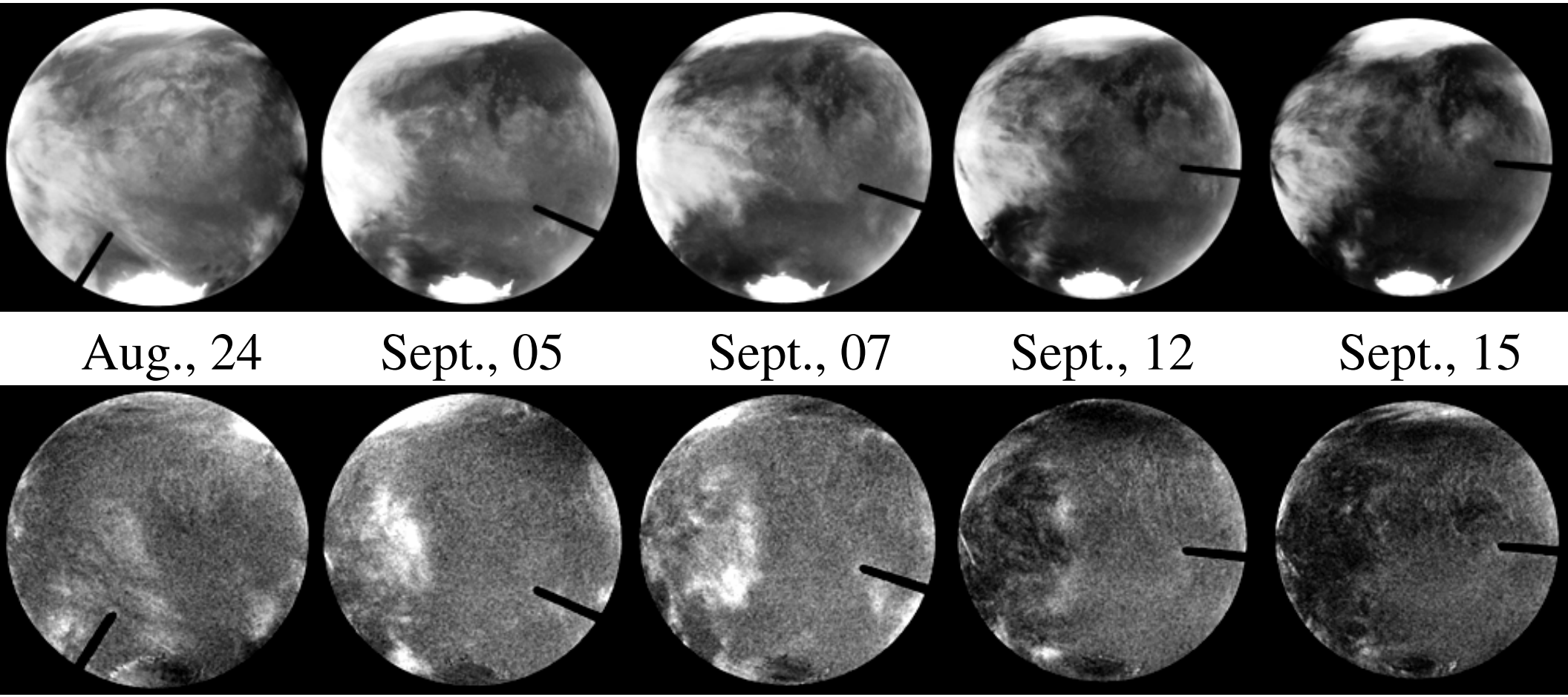
HST observations of Mars Opposition 2003

- Disk center: 19°S ~30°W



Filter 658 nm,
Date 5

Results: Polarization distribution (UV II)

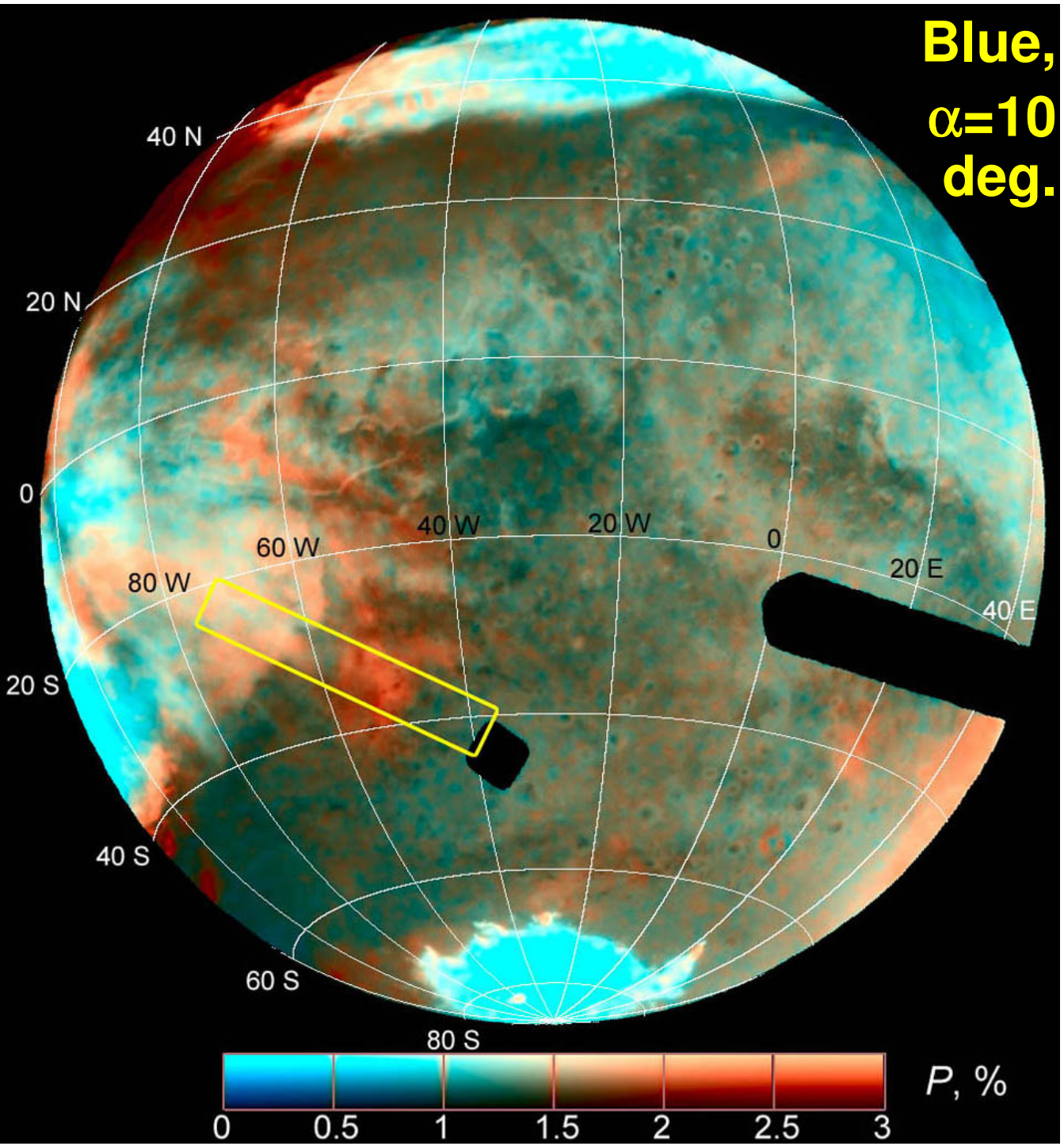


Aug., 24 Sept., 05 Sept., 07 Sept., 12 Sept., 15

High-polarization features:

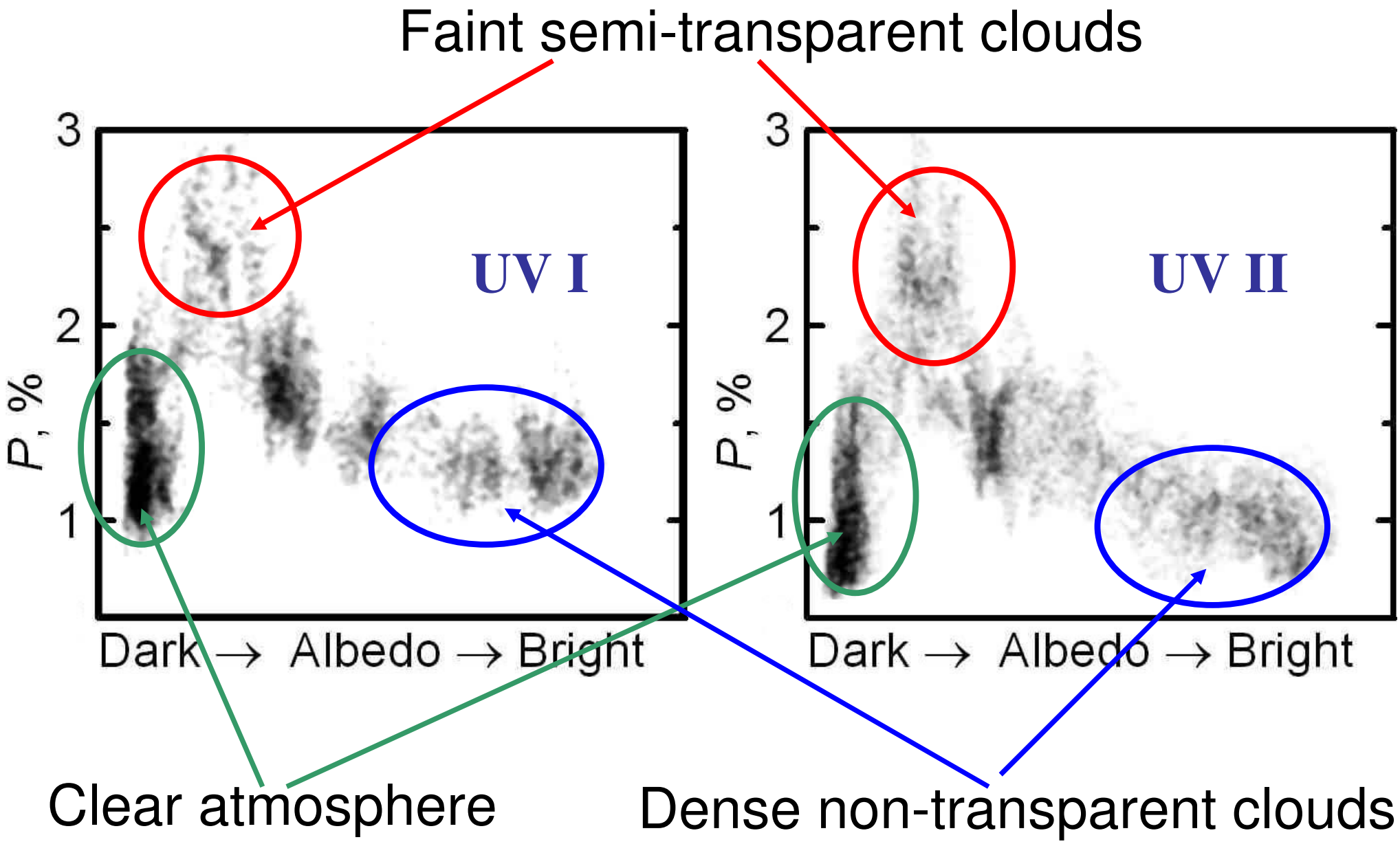
- best expressed on September, 5 and 7
- vary in size, polarization degree, and location

Transient polarization features: Sept. 7



Compare albedo & polarization profiles

Results: Polarization clouds in the UV, detailed view of correlation



Resume:

HST observations of Mars in UV in 2003 detected the new type of atmosphere clouds.

- **Optically thin clouds:**
  - √ made of highly polarizing scatterers
  - √ can be formed in very beginning of nucleation of H2O ice crystals on submicron dust (seeds)
  - √ located at 30-40 km above the surface
  - √ migrate with velocity of 40-80 m/s

- **MGS TES data confirm the higher ice opacity in the entire western part of disk that time**

Published in:

Shkuratov Yu., Kreslavsky M., Kaydash V., Videen G., Bell III J., Wolff M., Hubbard M., Noll K., Lubenow A. 2005. Hubble Space Telescope Imaging polarimetry of Mars during the 2003 opposition. Icarus. 176, p. 1–11.

Kaydash V.G., Kreslavsky M.A., Shkuratov Yu.G., Videen G., Bell III J.F., Wolff M. 2006. Measurements of winds on Mars with Hubble Space Telescope images in 2003 opposition. Icarus. 185, p. 97–101.

Mille grazie
per attenzione!

Dust storm over north polar cap of Mars

J-L. Dauvergne and F. Colas, Pic du Midi, 2 Febr. 2010