GLORIES ON VENUS: EXISTENCE CONDITIONS AND THE EFFECT OF SIZE AND SHAPE VARIATIONS

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We have studied in detail the question of the existence of glory with different parameters of scattering particles. We have found that prominent glory can exist at more wide range of size variations, than is believed to be before. Spherical sulphuric acid droplet having size R = 1.05 μm could produce glory even at size variation $\nu_{eff} \approx 0.34\mu m$ at wavelength 0.513 μm, as well as at 0.365 and 0.965 μm this variation is even wider. Moreover, we studied the influence of shape variation on glory formation. We found that nonspherical particles can produce glory too, and determine the range of appropriate nonsphericity of Venusian atmosphere particles.

Keywords: Venus clouds–Phase function–Light scattering.

1. INTRODUCTION

The atmosphere of Venus consists of a large part of spherical microparticles of highly concentrated sulfuric acid. Due to the spherical shape of the scatterers, in the atmosphere of Venus there is optical phenomenon known as a glory (see [1] and references therein).

A glory is an optical feature, consisting in the brightness of scattered light increasing at small phase angles (i.e. around of the observer's shadow). As usually believed that the existence of glory itself requires implies a rather narrow spherical particle size distribution. The measurements of the phase functions of light, scattered by Venusian clouds, were carried out by a number of spacecrafts, for example, by the Venus Monitoring Camera during the Venus Express mission. The observations were carried out at three wavelengths, equal to 0.365, 0.513, and 0.965 μm [2]. The glory patterns demonstrate noticeable maximums and mini-

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mums, but remain to be smooth, which points to the uniformity of the properties of the clouds on these wavelengths.

2. GLORIES PRODUCED BY MONODISPERSE SPHERES

We have studied the existence of glory with different parameters of scattering particles. For calculations we used the fundamental theory of electromagnetic scattering by a spherical particle, invented by Gustav Mie [3]. Glory can be characterized by relative values of maximum I_{max}/I_0 and minimum I_{min}/I_0, where I_0 is the intensity at zero phase angle, as well as position of glory minimum α_{min} and maximum αmax. Based on glories parameters of fig.1 from [2], we can formulate the conditions for well-marked glory appearance: $I_{max} > I0; I_{min} < I_{max}$; $0 < \alpha_{min} < \alpha_{max} < 50°$.

Fig.1 shows the area of distinct glories existence at sphere radius R =1.05 μm [2].

Three black points corresponds to parameters of observation [4]. So, we can conclude, that glory on Venus most likely does not exist at $\lambda > 1.4$ μm.

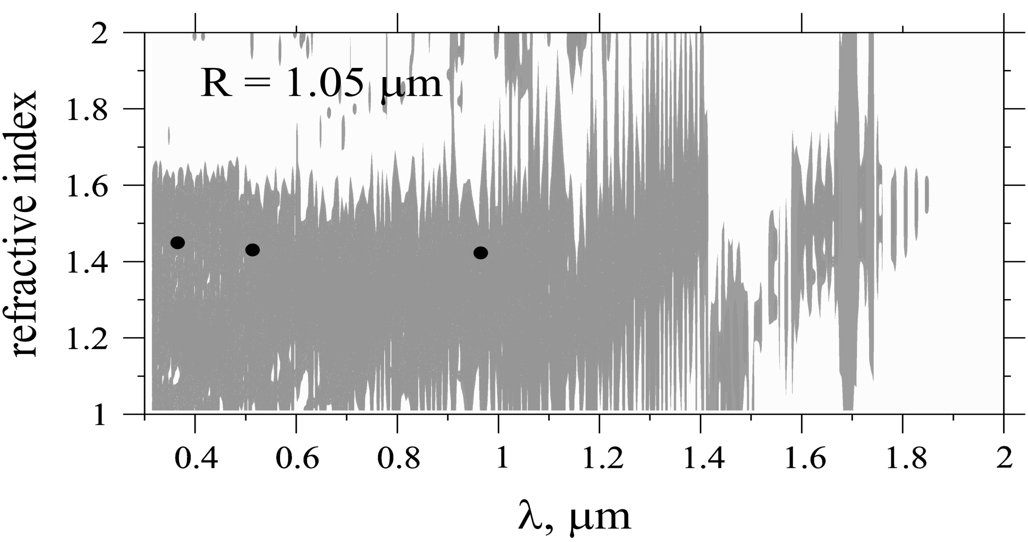

Fig. 1. Area of distinct glory existence for monodisperse spheres (zero size variation ν_{eff}), having size R = 1.05 μm at different wavelength and refractive indices.

3. EFFECT OF SIZE DISTRIBUTION

Monodisperse particle are rather rare in nature. Usually particles are distributed over sizes. Here we estimate an influence of size distribution, suggesting it has to be normal (Gaussian). Fig.2 shows the area of distinct glories existence at normal size distribution with variation $\nu_{eff} = 0.07$ μm. You can see, that glory are becomes smaller, but still exist. Fig.2 shows size variation dependence

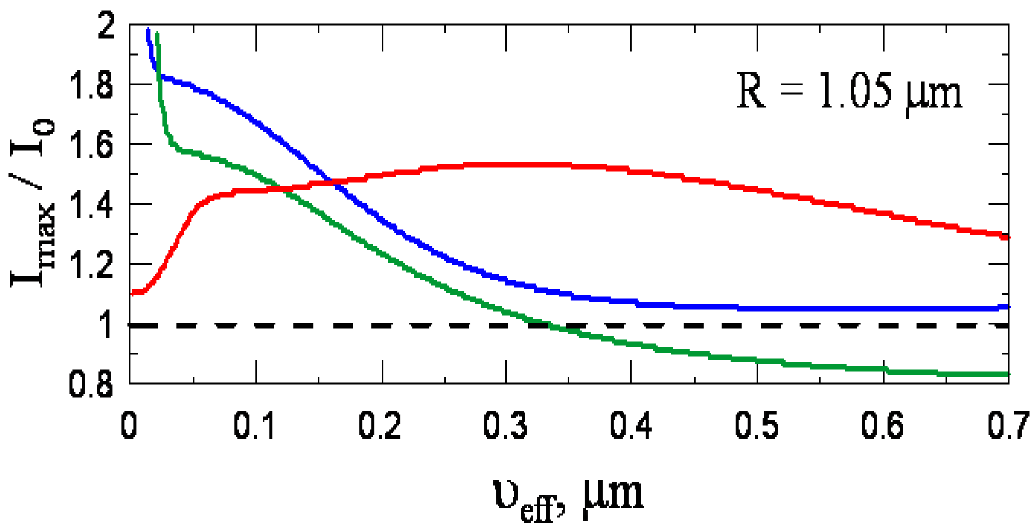

Fig. 2. Size variation dependence of glory parameters I_{max}/I_0 at 0.365 μ (blue curve), 0.513 μ (green curve), and 0.965 μ (red curve).

of main glory parameter I_{max}/I_0 at wavelengths 0.365 μm (blue curves), 0.513 μm (green curves), and 0.965 μm (red curves). Most important value I_{max}/I_0 tends to decreasing at large enough size variation, that easy explainable: as can be seen on Fig.1 in [2], glory is strongly dependent on the size of the scattering particle, and when averaged over the size, the glory is "eroded" and, therefore, becomes less distinct. Glory at a wavelength of 0.513 μm was the most sensitive to size variations. When value of I_{max}/I_0 becomes less than unity, and the glory becomes indistinct. Thus, $\nu_{eff} = 0.34$ μm is the maximum possible variation in the particle size of sulfuric acid on Venus.

4. EFFECT OF SHAPE VARIATION

According to popular belief, only spherical particles can produce glory. However, if the shape of the scattering particle deviates from the spherical glory, it cannot disappear instantly. To verify this, we investigated the scattering by spheroids. We calculated the changes in glory at different ratios of the axes of the spheroid a/b with the help of Sh-matrix method [4]. Fig.3 shows dependence of

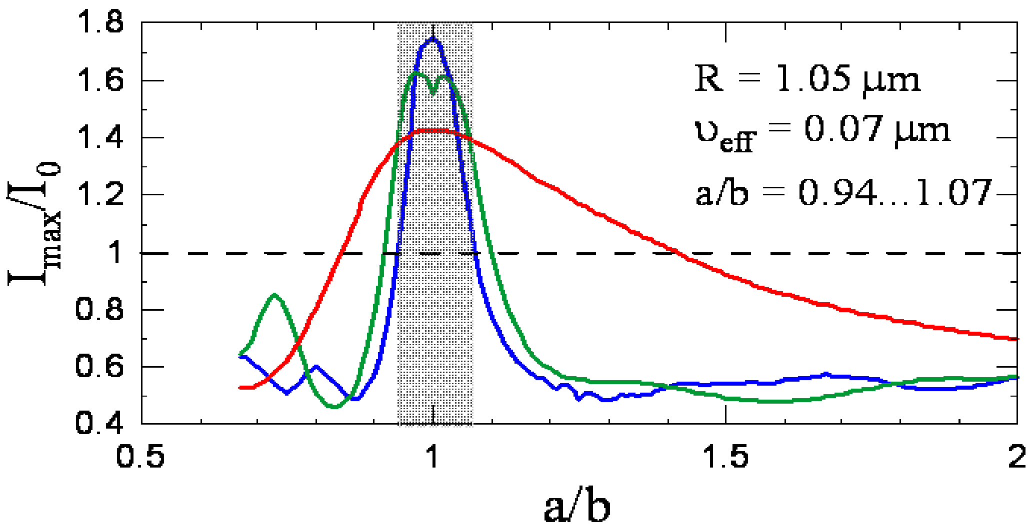

Fig. 3. Dependence of relative value of glory maximum I_{max}/I_0 over variations of shape of scattering particle at 0.365 μm (blue curve), 0.513 μm (green curve), and 0.965 μm (red curve).

relative value of glory maximum I_{max}/I_0 over changing shape of scattering particle. When a/b changed from 0.67 to 2, particle becomes consequently - prolate spheroid, sphere, oblate spheroid. As can be seen, variations of shape have strong influence on glory value. But there is some range of spheroid axes ratio, at which glory is still exist. Because of relative value of glory maximum should be more than 1, the glory cannot be lower than this value (dotted horizontal curve). Grey rectangle shows the area of maximum possible shapes variations. Therefore, ratio of two axes of scattering particles should be in the bounds of a/b = 0.94...1.07.

5. CONCLUSIONS

We investigated the effect of size and shape variations on the main parameters of glory on Venus. It has been established that with a sphere size 1.05 μm, glories can be produced mainly at wavelengths less than 1.4 μm and with refractive indices less than 1.6. Maximum possible variation of particles in size is 0.34 μm, and the maximum possible ratio of two axes of particles (non-sphericity parameter) varies from 0.94 to 1.07.

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