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The aureole of Venus: light refraction in the mesosphere during the solar transit of June 6, 2004

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Abstract

When the disk of Venus is in proximity of the solar limb, the atmosphere of the planet is revealed by a thin arc of light known as "aureole" or "Lomonosov's arc". The refraction of sunlight is responsible for this phenomena, which has shown a certain degree of variability from one transit to the other. The event of 2004 was the first one observed with modern electronic devices, so it was possible to derive a photometry of the arc. Our results indicate the presence of latitude-dependent signatures, as for example a bright polar spot. A simple refraction model reproducing the observations is capable of providing useful physical parameters concerning the mesosphere of the planet. A better focused observational campaign for the transit of 2012 is proposed to provide data of higher quality.

1. Introduction

Solar transits offer the opportunity to observe Venus at the highest phase angles. In particular, when the apparent distance between the disk of the planet and the solar limb is very small, interesting phenomena occurs. While Venus crosses the limb (at the beginning and end of the event) a luminescent arc outlines its disk, along the fraction of it that is seen projected against the dark background surrounding the Sun. This arc – or "aureole" – was first described by Mikhail V. Lomonosov (1711–1765) who observed the transit at St. Petersburg Observatory on May 26, 1761 [4]. Since its brightness appears comparable to that of the solar photosphere, it was ascribed to the refraction of light in the atmosphere of Venus.

During the subsequent transits the aureole was often described by several authors. From an overview of the different reports it appears rather clear that its aspect and evolution (extension, completeness, duration...) changed from one event to another although some properties repeat themselves, such as the presence of a persistent bright polar spot [3].

After the transit in June 2004 we had the opportunity to collect a number of CCD images from different observers, well documenting the aureole. This contribution illustrates the main results and the model employed for interpreting them, deriving useful constraints on the mesosphere of Venus.

2. The aspect of the aureole

The aureole of Venus was observed both at ingress and egress phases of the transit. It was also detected visually under good seeing conditions. With Venus less than $\sim 30\%$ outside the Solar disk, the aureole traced the entire Venus outline with varying brightness (the brightest portion closer to the Solar photosphere).

CCD observations (DOT telescope, La Palma; Tourelle Telescope, Pic du Midi; Themis Solar Telescope, Tenerife) offer further details, allowing us to measure the brightness of the aureole.

The results clearly show the general brightness variation along the arc as a function of time and polar angle. A bright segment around the South pole, poleward of $\sim 60\mathrm{deg}$, consistently shows up all along the duration of ingress and egress. It stands out as an isolated spot with the disk of Venus is more than $\sim 50\%$ outside the Sun.

3. The refraction model

Our simple model assumes that the refraction occurs in an atmospheric layer whose properties remain constant over the extension of a scale height H. Also, we consider the atmosphere to be transparent (no scattering, absorption) down to an altitude at which an opaque cloud layer is present, totally blocking any light transmission.

The flux received by an observer at a given geometry can easily be described by an equation similar to that employed in the case of occultations of stars by planetary atmospheres [1]. The brightness of a segment of the aureole will be given by the sum of

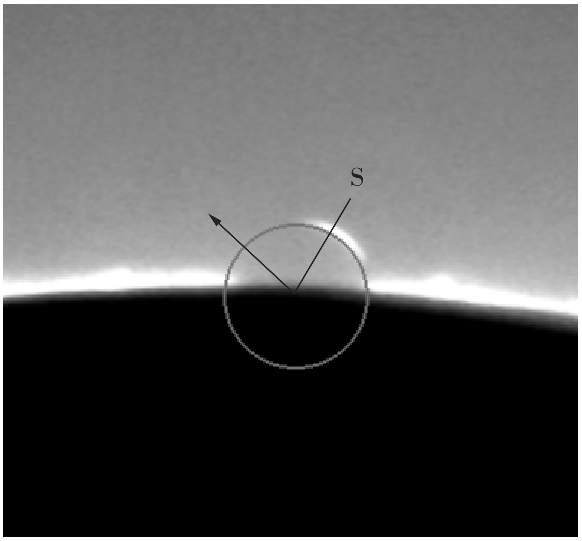

Figure 1: The appearance of the aureole – here reduced to a nearly pole-centered segment – in an image obtained during the transit egress through a coronograph (courtesy of A. and S. Rondi). The Sun is hidden behind the Lyot mask in the image bottom part. Venus is about half way out of the Solar disk, as indicated by the grey circle. Its motion relative to the Sun is indicated by the arrow. The South pole of the planet is also shown. The apparent width of the arc is due to Earth's turbulence.

the contributions of all the relevant photospheric elements. For each of these elements the refraction equation must be solved.

The resulting flux of the aureole depends only on two parameters: the scale height H and the altitude of the so-called "half occultation level" (corresponding to a 50% attenuation of the incoming flux) relative to the altitude of the opaque layer (Δr).

4. Results

The model fits the observed arc brightness and its variations in time for a very restricted range of parameters only. For equatorial latitudes around the equator, we find H=3.1$\pm$0.1 km and Δr=26$\pm$3 km. At the South pole, the brightness is higher all along the observed evolution. For the brightest portion the refracting layer appears more extended in altitude relative to the equator: H=4.8$\pm$0.1 km and Δr=38.5$\pm$3 km. By using the transmissivity data of [7] for fixing the altitude of the opaque cloud layer, we can determine the altitude of the half occultation level, resulting to be between 100 and 120 km.

No significant variation as a function of wavelengths has been found.

5. Conclusion

Measurements of the localized vertical profile for Venus atmosphere at 100 km and above are rather scarce in literature. Our findings are consistent with the presence of a transition to a banded, less convective flow around the polar latitudes. In this region a vast vortex exists, and the cloud layer is depressed by $\sim$10-12 km as determined by VIRTIS-M near-IR cloud top altimetry observations of ESA's Venus Express[2]. This value corresponds to the altitude difference that we derive for the half–occultation level, suggesting that refraction occurs at about constant altitude from the surface of Venus.

A full report on the observations and the model will soon appear in a specific, detailed paper [6]. A similar study using images from the TRACE satellite was described by [5] but without detailed quantitative measurements of the brightness of the aureole.

The forthcoming transit in 2012 will provide our last opportunity for obtaining accurate data on the Venus aureole.

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