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Venus Twilight Experiment : Observation and analysis of the aureole during the 2012 transit

T. Widemann (1), P. Tanga (2), B. Sicardy (1), P. Machado (1,7), F. Braga-Ribas (1), C. Veillet (3), J. Pasachoff (4), F. Colas (5), F. Vachier (5), S. Bouley (5), L. Maquet (5), J. Berthier (5), T. Fukuhara (6), D. Luz (7)

(1) Paris Observatory, LESIA UMR 8109, 92190 Meudon, France (thomas.widemann@obspm.fr), (2) Laboratoire Lagrange, Observatoire de la Côte d'Azur, BP 4229, 06304 Nice Cedex 4, France, (3) Canada-France-Hawaii Telescope Corporation, Kamuela, Hawaii 96743, USA, (4) Williams College Hopkins Observatory, Williamstown, MA 01267-2565, USA, (5) Paris Observatory, IMCCE UMR 8028, 75014 Paris, France, (6) Graduate School of Science, Hokkaido University Kita 10-Nishi 8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan, (7) Centro de Astronomia e Astrofisica da Universidade de Lisboa, Observatorio Astronomico de Lisboa, 1349-018 Lisboa, Portugal

Abstract

On 5–6 June 2012, Venus will be transiting the Sun for the last time in this century. This unique opportunity, besides offering the opportunity of investigating the mesosphere of the planet, also provides a significant nearby analog of exoplanet transits. Several studies using the transmission spectroscopy technique have provided significant insights into the atmospheric composition, structure, and dynamics of hot giant exoplanets. In this context, Venus is our closest model for a telluric exoplanet.

1. Context

Besides confirming the historical descriptions, we performed the first photometric analysis of the aureole using various acquisition systems [1]. The spatially resolved data provide measurements of the aureole flux as a function of the planetocentric latitude along the limb. A new differential refraction model of solar disk through the upper atmosphere allows us to relate the variable photometry to the latitudinal dependency of scale-height with temperature in the South polar region, as well as the latitudinal variation of the cloud-top layer altitude. We compare our measurements to recent analysis of the Venus Express VIRTIS-M, VMC and SPICAV/SOIR thermal field and aerosol distribution.

2. Differential refraction of solar light

During Venus transits in front of the Sun, close to the ingress and egress phases, the fraction of Venus disk projected outside the solar photosphere appears outlined by a thin arc of light, called the "aureole". The rays that pass closer to the planet center are more deviated by refraction than those that pass further out. The image of a given solar surface element is flattened perpendicularly to Venus' limb by this differential deviation, while conserving the intensity of the rays, i.e. the brightness of the surface element per unit surface. This holds as long as the atmosphere is transparent, i.e. above absorbing clouds or aerosol layers.

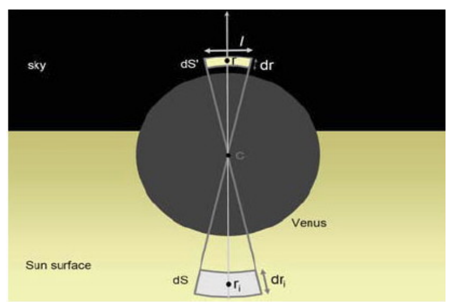

Figure 1: Venus (dark gray disk) observed from Earth, partly against the solar disk and partly against the sky. Each solar surface element dS as a refracted image dS′ of length l and width dr′, caused by Venus atmospheric refraction.

We have shown [1] that the deviation due to refraction and the luminosity of the aureole are related to the local density scale height and the altitude of the refraction layer. Since the aureole brightness is the quantity that can be measured during the transit, an appropriate model allows us to determine both parameters. Such a model was initially applied to data collected during the 2004 event.

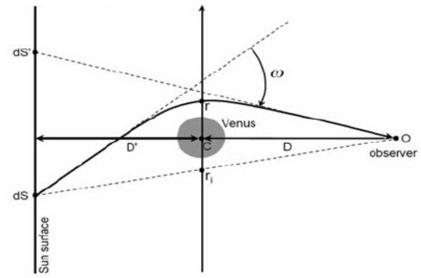

Figure 2: Geometry of the refraction of solar rays by Venus' atmosphere, sideview, All sizes and angles have been greatly increases for better viewing.

During its travel to Earth, the ray passes at a closest distance of r from the planet center. Furthermore, dS projects itself at a distance r_i from Venus' center C, as seen from O. The refraction angle ω is given by Baum and Code (1953): ω = −ν (r) 2πr/H, where ν is the gas refractivity, decreasing exponentially with r. The latter is related to the gas number density n by ν = K n, where K is the specific refractivity .It can be shown that surface element dS′ is radially shrunk with respect to dS by a factor Φ = 1/ [1 + D · (∂ω/∂r)], where D is the distance from Venus to Earth. Note that since the atmosphere is assumed to have a constant density scale height, ∂ω/∂r = −ω/H. We finally derive ω = −H · e−(r−r1/2) and therefore :

$$\frac{1}{k}\left(\frac{1}{\Phi}-1\right)+\log\left(\frac{1}{\Phi}-1\right)=\frac{r_{1/2}-r_i}{H}$$

This is the Baum and Code formula (apart for the correcting factor k, which is equal to unity in the original formula since D′ = +∞ for stellar occultations). Different surface elements of the solar photosphere, at different values of r_i will contribute the the total, integrate aureole flux. Since this is the quantity that can be measured during the transit, this model allows us to determine the scale height H and the half-occultation radius relative to slanted opacity τ ~1 ($\Delta r = r_{1/2} - r_{cut}$). In general, different portions of the arc can yield different values of these parameters, thus providing a useful insight of the physical property variations of the Venus atmosphere as a function of latitude.

Quantitatively, the altitude of the aureole's half–occultation level in the polar region (50% attenuation due to refraction) was found to occur at ~111.5 km, depending on latitude In general, different portions of the arc can yield different values of these parameters, thus providing a useful insight of the meridional variations of the Venus atmospheric structure.

3. The cytherograph

Identical coronagraphs have been built as an extension of an existing telescope tube, and each one, in principle, mounts a different 10-nm filter (B,V, R, I). The use of coronagraphs will enable us to obtain the best possible contrast between the faint features shown by the atmosphere of the planet and the bright background in the Sun's vicinity. Having at our disposal accurate flux measurements of the aureole will require substantial improvements in modeling. In particular we plan to complete the model by introducing a more realistic transition from a quasi-transparent atmosphere to the fully opaque region, by using the slanted absorption profiles deduced by the SOIR experiment on Venus Express [2] Also, the model – now monochromatic, should become fully chromatic by introducing the wavelength dependency of slanted haze opacity. First results of the 2012 campaign will be presented at the meeting.

1	Mees Solar Obs., Haleakala, HI, USA	B (450 nm)
2	Mobile station, Hokkaido, Japan	V (535 nm)
3	Moondara Obs., Mount Isa, QLD, Australia	I (760 nm)
4	Tien Shan Obs., Kazakhstan	B
5-6	Lowell Obs., AZ, USA	V
7	Taiohae, Nuku Hiva, Marquesas Is.	R (607 nm)
8	Mobile station, Svalbard Is., Norway	I
9	Udaipur Obs., India	R

Additional site, with its own coronagraph:
A Khurel Togoot Obs., Ulaanbaatar, Mongolia

Table 1 : sites, the observer(s) and the associated filters for each of them. All filters have a 10 nm FWHM. "R" and"V" correspond to SODISM filters on CNES/Picard orbiter.

References

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[2] Wilquet, V., R. Drummond, A. Mahieux, S. Robert, A.C. Vandaele, J.-L. Bertaux. 2012, Optical extinction due to aerosols in the upper haze of Venus: Four years of SOIR/VEX observations from 2006 to 2010., Icarus 217, 875-881, doi:10.1016/j.icarus.2011.11.002