M2 stage subject

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Venus as an exoplanet : modelling of Venus atmosphere by transit data

Science case – general context (http://venustex.oca.eu/)

Venus is one of the most intriguing bodies in the Solar System. It is almost the same size as the Earth and apparently has a similar bulk composition pointing toward a common origin – yet it has ended up with an extreme climate with surface pressure of 90 bar and surface temperatures of 740K. Venus' middle atmosphere (60-120 km, also known as the mesosphere) is a transition region between the lower atmosphere (from the surface to within the cloud layer near 60 km), where the circulation is primarily zonal retrograde, and the upper thermosphere (above 120 km), where the wind pattern is mostly driven by diurnal pressure contrasts, flowing from the sub-solar point to the anti-solar point (SSAS flow). Monitoring of thermal profiles and winds in the mesosphere has revealed important time variability, driven by processes largely unknown.
We are exploiting data collected during the June 2012 solar transit for investigating the dynamics and composition of the middle atmosphere of Venus by the June 2012 transit of Venus in front of the Sun, as seen by Earth-based observers. 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. Obtaining its transmission spectrum during its transit across the Sun will serve both as a comparison basis for transiting Earth-mass exoplanètes now being discovered, and a proof of feasibility that such observations can effectively probe the atmospheres of exoplanets in this mass range. In addition, transit observations of Venus can bring precious information about how the atmosphere of a non-habitable world – observed as an exoplanet – differ from that of a habitable planet, the Earth.

Our experiment

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 aureole, first seen in 17610 is the signature of the solar light passing through the mesosphere of Venus and can be explained by the refraction of solar rays. 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.

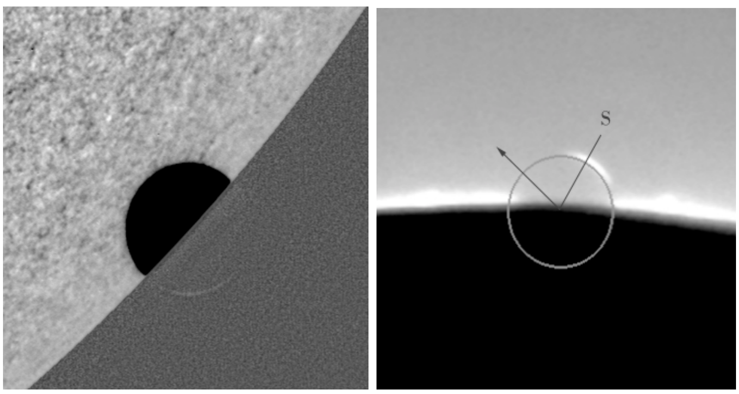

Fig. 1. – The direct refracted light of the sun during the transit observed with NASA's TRACE satellite (l.) and with an amateur coronagraph using a 9-cm refractor (r.) (Pasachoff, J.M., G. Schneider, and T. Widemann 2011, AJ, 141, 112 ; Tanga, Widemann et al., 2012 Icarus, 218, 1, 207; http://arxiv.org/abs/1112.3136).

It can be shown 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. For the first time, such a model was applied to data collected during the 2004 event (Tanga et al. 2012: Icarus, , 218, 1, 207; http://arxiv.org/abs/1112.3136). 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.

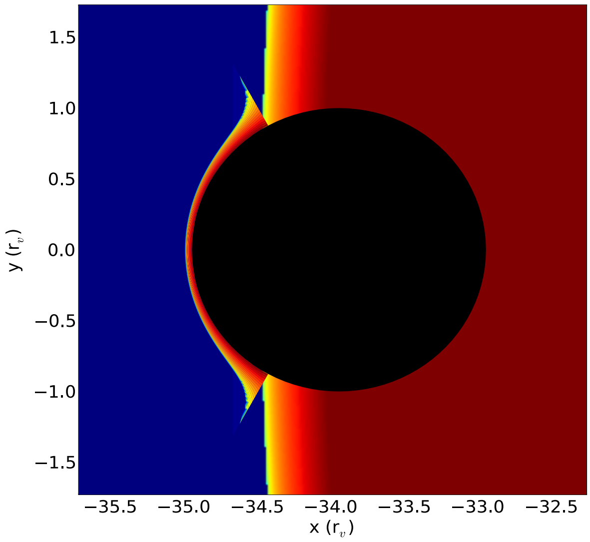

Fig. 2 Numerical model of the aureole. The light distribution inside the aureole is represented in false colors. The thickness of the aureole is amplified for better showing its structure.

The 2004 observations were the first ones in the technology era, allowing imaging and quantitative interpretation by a refraction model. 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.
The observations of the aureole in 2004, beyond confirming the presence of the aureole as it had been reported in historical records of similar events, were thus seminal in providing essential information about the details of the phenomenon. They also suggest that the variability of the aureola as seen over 3 centuries (5 transits) could be related to the variability recently discovered in the mesosphere of the planet. In 2012 a specific observing campaign was prepared, optimized for analyzing the signal of the aureole, at best 10-100 fainter than the solar photosphere nearby. From the obtained observations, we plan to extract a reliable multi-wavelength spectrum of the aureole, to constraint the role of Rayleigh or Mie scattering, etc. Recent models that we have developed (Ehrenreich et al. 2011: A&A, 537, L2) show that, depending upon the details of the scattering, the resulting signal could have a widely different wavelength dependency.

Aim of the stage

Analysis of the aureole data obtained in the frame of the VenusTEx campaign, and comparison with the numerical models. The student will get familiar with problems related to exoplanet characterization. The results will be of interest to the community around the Venus Express mission. Both these implications can open the possibility later on, of a PhD in this domain.

Collaborations :

Strong interactions with B. Sicardy, Th. Widemann (Obs. de Paris, Venus Express mission).