The Measurement of Apparent Size of Planets using the Interferometry Method

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Abstract

We demonstrate that the apparent size of Venus and Saturn can be measured using the interferometry method by masking a small telescope. This pedagogic project measured the apparent size of Saturn and Venus from data taken at Kirdkao Observatory in Thailand between 12-26 April 2009 and the Observatoire de Haute-Provence, France, respectively. Our analysis reveals that the baseline length at the resolve point of Saturn is 9 mm. and Venus is 10 mm, which correspond to Saturn angular size of 7.46×10^{-5} rad or 15.39", and the Venus angular size of 6.71×10^{-5} rad or 13.83", respectively.

Introduction

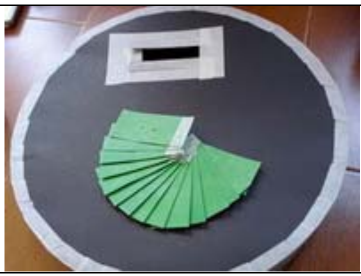
Interferometry is the technique of separating a beam of light into two and bringing them back together to produce an interference pattern. It can be used to measure wavelength, index of refraction, and astronomical distances. The interference pattern is demonstrated by Thomas Young's double-slit experiment in 19th century. The interferometry method has been used to measure the size of distant stars otherwise irresolvable by even a large telescope by using two or more telescopes separated by a large baseline distance to observe the interested star simultaneously and then combining lights from the telescopes to form interference patterns. For example, the two Keck Telescopes are separated by 85 meters and they can be used together interferometrically as a single telescope with the resolving power of an 85-meter telescope. However, such combination of two telescopes requires very precise wavefront corrections to form the interference pattern, usually achieved by adaptive optics, which is not possible for us to study by small telescopes.

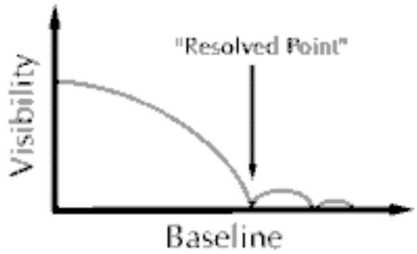
Therefore we experiment with a scaled-down project to demonstrate the interferometry method by masking a 16" telescope down to two small holes: each representing a tiny telescope that would not resolve even a large planet like Jupiter, Saturn, or Venus on its own. But when we study the interference pattern from the two "tiny telescopes" separated at different distances (the separation distance is called *baseline*), we can calculate the size of planets in the same way that sizes of distant stars are measured.

Procedure

We make several masks with two apertures on each. The size of apertures is 4 mm (each of them act as a 4-*mm* telescope, Fig. 1) and the separation between the aperture varies from 7 to 20 mm. We then mount this mask in front of a 16" telescope at the Kirdkao Observatory, Kanchanaburi, Thailand and take CCD image of Saturn at different aperture separations. Along with the raw CCD image, we also took dark frame, bias frame, and flat frame. The imaging was done in *MaxIm DL* software and the exposure time for each image is 60 seconds. We processed the images using the *Audela* software (*www.audela.org*) by first subtracting the dark frame from the raw image to reduce noises and also process the flat and bias frame using the equation $\frac{\text{Raw Image - Dark frame}}{\text{Flat frame - Bias frame}} \times 15000$

Visibility, *V*, is the measure of differences between the darkness and the brightness of fringes, which can be calculated by measuring the flux of the brightest and faintest part of the fringes, I_{max} and I_{min}, respectively and apply the equation $|V| = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$. We then plot the visibility as a function of the separation between apertures to estimate the "resolved point", shown in Fig. 2, which is the baseline that the planet is resolved. With the known baseline that can resolve the planet, we can then apply the equation $\theta = 1.22\frac{\lambda}{D}$ where *D* is the measured baseline and λ is the optical wavelength to calculate the apparent size of the planet, θ.

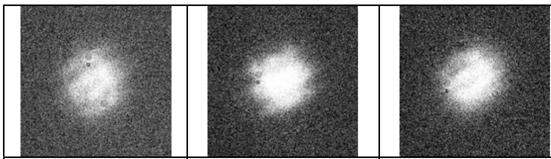




(Left) Fig. 1 The mask used to cover the front of 16” telescope to produce interference pattern with small apertures on it **(Right) Fig. 2** The method to determine resolved point from the plot of visibility as a function of baseline

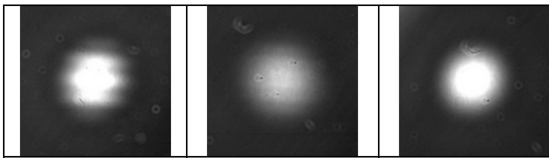
Analysis

The processed interference images at various baselines for Saturn and Venus are shown in Fig. 4 and 4, respectively. The fringe pattern can be seen clearly in these images.



7 mm	9 mm	11 mm

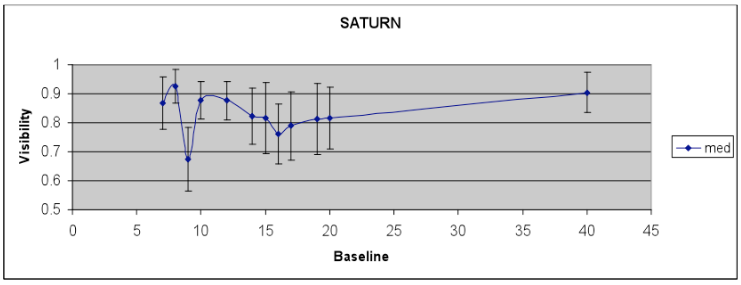
Fig. 3 Fringes from Saturn at various baseline (Kirdkao Observatory, Thailand)



8 mm	10 mm	13 mm

Fig. 4. Fringes from Venus at various baseline (Observatoire de Haute-Provence, France)

The plot of visibility as a function of baseline for Saturn and Venus are shown in Fig. 5, which are used to determine the resolved point.



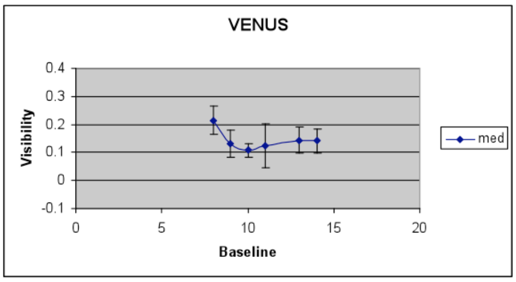


Fig. 5. Plots of the visibility as a function of baseline for Saturn (left) and Venus (right)

The Saturn and Venus has a resolved point at the baseline of 9 mm. and 10 mm, respectively. These correspond to angular size of 7.46×10^{-5} rad or 15.39” for Saturn and the angular size of 6.71×10^{-5} rad or 13.83” for Venus. We found that the interferometry method yields a slightly smaller apparent size than the direct measurement with the difference of about 20%.

Summary

We demonstrated that the interferometry method can be used to measure the apparent size of planets. Our study took images of Saturn at Kirdkao observatory between 12-26 April, 2009 and used interference pattern images of Venus from OHP observatory, France and found that baseline at the resolved point for Saturn is 9 mm. and its angular size is 7.46×10^{-5} rad or 15.39”. For Venus, the baseline is 10 mm, corresponding to the angular size of 6.71×10^{-5} rad or 13.83”. We thank Dr. Hervé Le Coroller of the OHP, France for his kind support on this project.