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ACCURATE DIAMETER MEASUREMENT OF BETELGEUSE USING THE VLTI/AMBER INSTRUMENT

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The apparent size and greater luminosity of Red Super Giant stars (RSGs) make them ideal targets for astrometry experiments. Since the observation of Betelgeuse by Michelson & Pease (1921), several other works have been carried out improving the precision on the measurement of the diameter of the star (e.g., (Weiner et al. 2000; Young et al. 2000)). We present preliminary results of the observations of the super giant star Betelgeuse carried out with the AMBER (Astronomical MultiBEam Recombiner) instrument. AMBER is one of the first generation instruments of the VLTI able to combine the beams of two or three telescopes simultaneously, and brings spectral dispersion. The a priori knowledge of the angular size of Betelgeuse, gives us a well established reference to indirectly probe the stability of AMBER. Furthermore, we demonstrate the AMBER ability to measure low contrast visibilities under high flux conditions.

The observations of Betelgeuse were carried out on 2006 February 10 during the third commissioning run of the AMBER instrument. AT1-AT3 were used forming a projected baseline of B = 16 m. The instrument configuration was setup to work in medium resolution mode (R = 1500) covering the [2.099,2.198] μm spectral range. After the science target, Sirius (α CMa) was observed as a calibrator star to measure the instrumental coherence losses. Sirius is a spectroscopic binary with spectral type A1V, and with angular diameter of 5.936 ± 0.016 mas (Kervella et al. 2003); at the baseline of the interferometer Sirius is not resolved.

The data has been reduced using the improved P2VM algorithm (Chelli et al. 2009) and the Fourier method. The methods show compatible results with a relative difference between calibrated visibilities better than 1%. In Figure 1 (up) and (middle) we plot the average raw visibilities of Betelgeuse and Sirius as a function of wavelength, whereas the final calibrated visibility of Betelgeuse is shown in Figure 1 (lower). In Table 1, we summarize the global average visibility values and their corresponding errors.

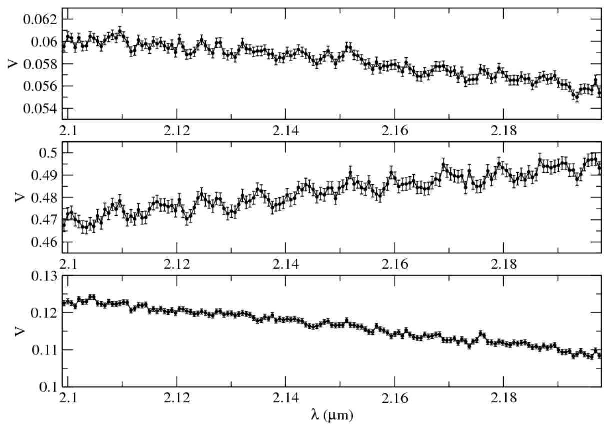

Fig. 1. Average raw visibilities as measured by AMBER on Betelgeuse (up) and Sirius (middle). Lower panel shows Betelgeuse calibrated visibilities.

TABLE 1

MEAN VALUES OF THE RAW VISIBILITIES OF BETELGEUSE AND SIRIUS, AND THE CALIBRATED VISIBILITY OF BETELGEUSE WITH ITS CORRESPONDING PRECISION

Object	Vis. Type	V	$\sigma(V)$	$\sigma(V)/V$
Betel.	Raw	0.0583	0.0004	0.7%
Sirius	Raw	0.4826	0.0028	0.6%
Betel.	Calib.	0.1164	0.0006	0.6%

The narrow bandwidth per spectral channel ($\triangle\lambda \sim 1.5$ nm) of the K band of AMBER at medium resolution authorizes to consider the observations to be monochromatic. Therefore, a simple uniform disk model can be used to retrieve the diameter of the star ($\theta_{\rm UD}$). Defining B as the projected baseline, the squared visibility model can be written as equation 1, where the quantity of interest is the diameter

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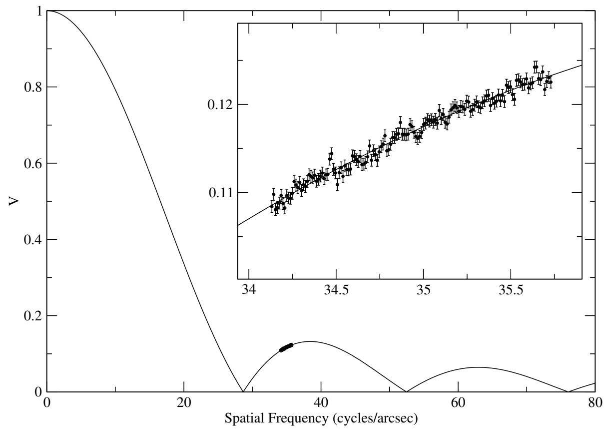

Fig. 2. Uniform disk fit of Betelgeuse visibilities.

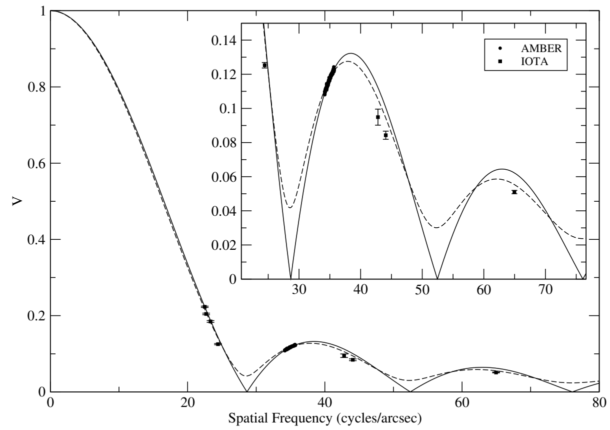

Fig. 3. Comparison between observations with AMBER and IOTA.

that minimizes in a least squared sense the expression in equation 2, where σ^2 is the variance on V_i^2

$$V_M^2 = \left[\frac{2J_1(\pi\theta_{UD}B/\lambda)}{\pi\theta_{UD}B/\lambda}\right]^2 , \tag{1}$$

$$\chi^2 = \sum_{i=1}^{N}\left[\frac{V_i^2 - V_M^2}{\sigma}\right]^2 . \tag{2}$$

The calibrated visibilities of Betelgeuse are plotted with the corresponding uniform disk model in Figure 2, and the diameter is found to be:

$$\theta_{UD} = 42.57 \pm 0.02 \text{ mas} \qquad \text{with} \qquad \chi^2 = 0.99 .$$

We verify the consistency of our result by comparing it with those previous published in the literature. The observations of Betelgeuse carried out by Perrin et al. (2004) with the IOTA interferometer are the most relevant to our study. They report a diameter of 43.33 ± 0.04 mas ($\chi^2 = 21.45$). In Figure 3 we plot the observations coming from AMBER and IOTA together with their corresponding uniform disk model (solid and dashed lines respectively).

The small difference in the estimated diameter between AMBER and IOTA data can be explained as follows: (1) IOTA is a wide band interferometer, whereas AMBER is monochromatic; (2) Betelgeuse is a semi-regular pulsating star. Thus, we can consider both results correct and consistent with each other.

This result demonstrates AMBER stability on the sky from a completely indirect way. Likewise, the results not only show the AMBER ability to measured low contrast visibilities, but also manifest AMBER capacity to produce reliable absolute visibilities with a precision of the order of 0.5% under high flux conditions.

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