First VLTI observations of Mira stars

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Abstract. We present first observations of Mira stars obtained at the Very Large Telescope Interferometer (VLTI) at 2 microns, equipped with the VINCI instrument, using different baselines with both the test siderostats and the 8.2m unit telescopes. These observations, collected in the course of the VLTI commissining program, have targeted so far about sixty cool giant stars. In this talk, we list and describe the measurements obtained for 14 Mira stars, many of them representing first-time determinations of the visibility. In particular, we devote special attention to a study of Mira itself, for which very accurate determinations of the visibility at several baseline lenghts and orientations could be obtained. We find that a two-component model is more consistent with the data than a single stellar disc. Further observations are needed for a better understanding of this source.

The VLTI will constitute an ideal instrument for such studies in the future. In particular it will permit detailed investigations of southern AGB stars, such as accurate measurements of surface structure parameters (diameters, diameter variations, asymmetries, center-to-limb variations, special features like hot spots) and of circumstellar envelopes.

Keywords: Techniques: interferometric – Stars: fundamental parameters – Stars: individual: Mira

1. Introduction

The ESO Very Large Telescope Interferometer (VLTI) is located on Cerro Paranal, in Chile. This facility consists of the four fixed 8.2m Unit Telescopes (UT), and of four 1.8m Auxiliary Telescopes (AT) which can be moved over an array of 30 stations. At present, small siderostats are being used routinely, mainly for commissioning purposes. Also, all UTs have been successfully combined and used during several runs. The ATs will become available starting from 2003. Two facility instruments will be available initially at the VLTI: MIDI and AMBER, operating in the thermal and near-IR respectively. MIDI has achieved first light in December 2002, while AMBER will follow shortly after in 2003. For the observations detailed in this paper, only the 40 cm siderostats were used.

The Mira star phenomenon is a fundamental stage of stellar evolution for stars of solar mass or slightly higher. Not only do Mira stars represent a critical check for evolutionary models, but they also shed light on important processes such as stellar pulsation, stellar chemical composition, and the dust enrichment of the Galaxy. With their extended, cool atmospheres, they have comparatively large angular diameters and substantial infrared fluxes. As such, they have been traditionally a key target for observations by high angular resolution techniques.

In this report, we illustrate first observations of Mira stars carried out at the VLTI, and present preliminary results on Omicron Ceti, i.e the star after which the whole Mira class is named.

2. Observations

A first sample of Mira stars observed with VLTI/VINCI is reported in Table I. In the table, the last column reports the number of entries present in the CHARM catalogue (Richichi and Percheron, 2002). It can be seen that apart from a couple of rather famous stars, most of the objects observed by the VLTI had been only scarcely studied before. In fact, for five stars the VLTI data represent the first observations ever. This highlights the fact that the VLTI is ideally positioned to expand significantly our knowledge in this field of research. The log of the observations is reported in Table II, in which the first and last date of observation are reported, along with the number of measurements and the baselines on which they were obtained. The actual projected baseline length and orientation of each observation was of course determined by the circumstances of the observation.

It can be seen that a total of 290 measurements were collected on 14 sources. Three different baselines were used, although in practice the 16 m baseline was used in most of the cases. The Mira phenomenon is characterized by significant pulsations, with periods which are typically of one year or longer. At this preliminary stage, our observations do not span a sufficient time span to characterize the pulsation characteristics of the sources.

3. Results

We concentrate on Omicron Ceti, i.e. Mira itself. A large number of observations were collected on this star using the 16 m baseline between October 2001 and January 2002. In this period, the phase of the source varied between 0.1 and 0.3. A first step was to convert the visibility measurements into equivalent angular diameters, using a simple model of a uniform circular disk. This is shown in Fig. 1.

Two conclusions can be drawn already, even if this approach is not formally correct since an asymmetric disc could not be uniformly illuminated. Firstly, the VLTI data are of remarkable accuracy and show

Table I. List of observed Mira stars

Name	V	K	Spec.	P(d)	CHARM
T Eri	9.3	2.6	M5/M6IIIe	252	0
R Leo	6.0	-3.0	M8IIIe	310	20
S Scl	6.2	0.4	M7IIIe	363	0
R Lep	8.1	0.1	CIIe	427	1
R Hya	6.4	-2.5	M7IIIe	389	1
U Her	8.5	-0.3	M7III	406	4
T Lep	9.9	0.3	M6evar	368	0
o Cet	3.0	-2.4	M7IIIe	332	27
UU For	9.8	1.1	M9	-	0
R Peg	8.1	0.3	M7e	378	2
U Ori	6.7	-0.5	M8III	368	7
R Cnc	7.1	-0.7	M7IIIe	362	1
X Hya	8.5	1.0	M7e	301	0
R Aqr	7.7	-1.2	M7IIIpevar	387	11

Table II. Summary of observations

Name	first	last	n	bas.
T Eri	03-Dec-01	03-Dec-01	5	102.5
R Leo	01-Apr-01	10-Feb-02	46	16+66
S Scl	21-Oct-01	14-Nov-01	23	16
R Lep	22-Oct-01	12-Jan-02	38	16
R Hya	01-Apr-01	01-Apr-01	3	16
U Her	01-Apr-01	01-Apr-01	1	16
T Lep	21-Oct-01	20-Jan-02	43	16
o Cet	22-Oct-01	20-Jan-02	55	16
UU For	24-Oct-01	24-Oct-01	1	16
R Peg	05-Nov-01	15-Nov-01	5	16
U Ori	05-Nov-01	22-Jan-02	18	16
R Cnc	05-Dec-01	08-Jan-02	32	16
X Hya	26-Jan-02	26-Jan-02	2	16
R Aqr	21-Oct-01	22-Jan-02	18	16

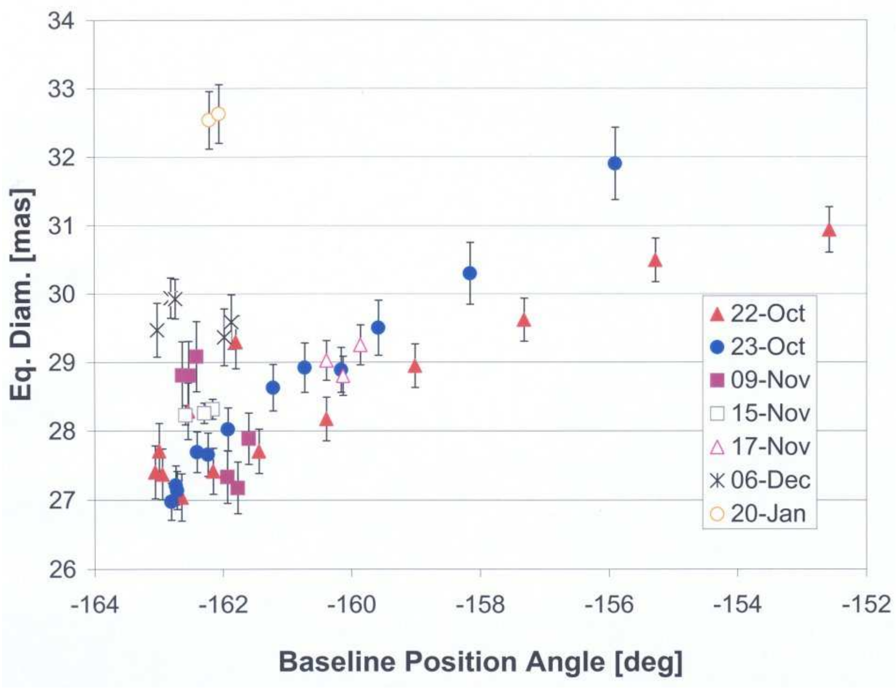

Figure 1. Measurements of Mira obtained using the VLTI on a 16 m baseline, coded by epoch. The visibility measurements have been converted, in a first approximation, to equivalent angular diameters.

consistency on a night-by-night basis. Secondly, they show a marked increase of the angular diameter with time. This is expected, since as the phase increases, the temperature drops and the diameter increases.

However, it can also be appreciated that the equivalent angular diameter seems to be a function of the position angle of the baseline. This is indicative of the fact that the assumption of a uniform disk is not adequate. Better models might be either an asymmetric disk, or a two (or more) component model for the stellar disk. This conclusion is highlighted very clearly in Fig. 2.

If one investigates further the hypothesis of a possible asymmetry of the stellar disc, a rather strong convex shape is found for the stellar limb. However, this explanation cannot be supported convincingly by the data, since the span in position angle is very limited. Furthermore, it is well known from observations at other wavelengths as well as in the near-IR, that Mira is surrounded by circumstellar emission (Quirrenbach et al., 1992; Tuthill et al., 1995). In order to test this possibility, we present in Fig. 3 a fit obtained with a simple-minded two-components model wihich assumes a circular disk of 30 milliarcseconds and a gaussian component about 7 times larger having 20these assumptions are

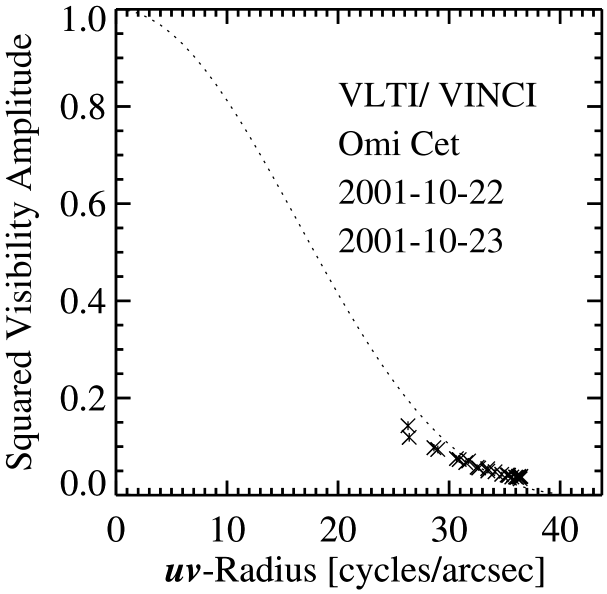

Figure 2. Global fit of the visibilities with a single uniform disk model, showing inconsistency of the model with the data.

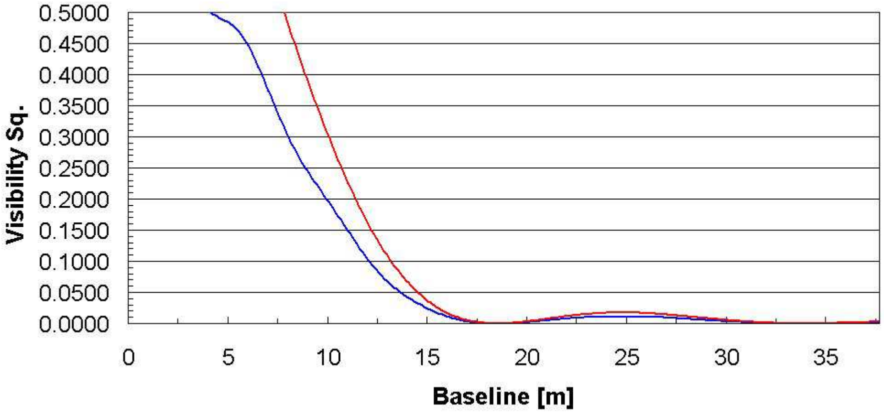

Figure 3. Comparison between the visibility plot of a model with a single uniform disk (top), and a model with two components (bottom). This latter is better suited to fit data such as those of Fig. 2.

totally ad hoc and will need to be quantified in a more detailed study, possibly taking into account also other baselines. However, one can see that the visibility curve of such a model is much more consistent with the observed data than that of a homogenous circular disc.

Acknowledgements

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References

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