Modelling of Stellar Atmospheres
IAU Symposium, Vol. xxx, xxxx
N. E. Piskunov, W. W. Weiss, D. F. Gray, eds.

Measurements of Mira stars with the VLTI

M. Wittkowski

European Southern Observatory, Casilla 19001, Santiago 19, Chile

A. Richichi, S. Correia, M. Schöller

European Southern Observatory, Karl-Schwarzschildt-Str. 2, D-85748 Garching bei München, Germany

Abstract. We present first observations of Mira stars obtained at the Very Large Telescope Interferometer (VLTI) equipped with the K-band commissioning instrument VINCI. Different baselines were employed using both the test siderostats and the 8.2m unit telescopes. These observations, collected in the course of the VLTI commissioning program, have targeted so far about 14 Mira stars among about 60 cool giant stars. Here, we concentrate on a study of Mira itself, for which visibility values at several baseline lengths and orientations could be obtained. Based on a very preliminary data analysis, these observations provide insights in the structure of the stellar atmosphere and its immediate surroundings, as well as in its temporal variation. The VLTI will constitute an ideal instrument for such studies in the future.

1. Introduction

The ESO Very Large Telescope Interferometer (VLTI) is located on Cerro Paranal, in northern Chile. This facility consists of four fixed 8.2 m Unit Telescopes (UT), and a number of 1.8 m Auxiliary Telescopes (AT) which can be relocated over an array of 30 stations (Glindemann et al. 2000).

All the AT stations, as well as the UTs, are connected by a network of underground light ducts. Central to the facility is the delay line tunnel, where the optical path difference is continually adjusted. Three delay lines are installed, and another three will be added in 2003 (Derie 2000). A number of relay mirrors feed the light from the telescopes into the tunnel, and from there to a central underground laboratory, where the beams from two or more chosen telescopes are brought together and coherently combined.

At present, small test telescopes (40 cm siderostats) are being used routinely, mainly for commissioning purposes. Also, some UT telescopes have been successfully used in several runs. Both the MIDI (operating in the mid-infrared, see Leinert et al. 2000) and the AMBER (operating in the near-infrared, see Petrov et al. 2000) instruments are in an advanced stage of construction, and are scheduled to begin operations between the end of 2002 and the beginning of 2003. The AT telescopes will be progressively added starting from 2003.

Star	Hipparcos Spec.
T Lep	M6e – M9e
R Peg	M6e – M9e
X Hya	Md
U Her	M6.5e – M9.5e
o Ceti	M5e – M9e
R CnC	M6e – M9e
S Scl	M7/8IIIe
R Aqr	M4pe
U Ori	M6e – M9.5e
R Leo	M6e – M9.5e
UU For	
T Eri	M5/M6IIIe

Table 1. Mira stars which have been observed during the VLTI/VINCI commissioning period until January 2002.

Two batches of VLTI commissioning data of scientific relevance have been publicly released in January and April 2002, and more are expected on a regular basis. Scientific proposals to be carried out on a shared-risk basis during commissioning are also accepted. A first call was issued for Period 70, offering 150 hours between October 2002 and April 2003.

More about the VLTI, its instrumentation, activities, and planning can be found at www.eso.org/projects/vlti.

Cool AGB stars have traditionally represented ideal targets for optical interferometers because of their relatively large photospheric sizes for any given brightness, and because of the ability to study their extended atmospheres exhibiting molecular species and the formation of dust. In the following we concentrate on VLTI measurements of Mira stars which were performed during the commissioning period, with an emphasis on Mira (*o* Ceti) itself.

2. Observations

We present in Table 1 a list of stars classified as Mira type stars in Simbad and observed with the VLTI and the near-infrared K-band instrument VINCI until January 2002. A detailed analysis is, for the most cases, in progress. For these measurements, the UT 1 – UT 3 baseline with a length of 102 m has been used, as well as the siderostat baselines E 0 – G 0 (16 m) and E 0 – G 1 (66 m).

2.1. Observations of *o* Ceti

Here, we concentrate on Mira (*o* Ceti) itself, the prototype of the class of stars with this name (see also Richichi et al. 2002a). A total of 36 observations were obtained with the VLTI from October 2001 to January 2002 in the course of commissioning activities. All these data are now publicly released. Most of the data were obtained on October 23 and 24 over time periods of about 5 hours each in order to probe the *o* Ceti visibility function on a range of *uv*-radii

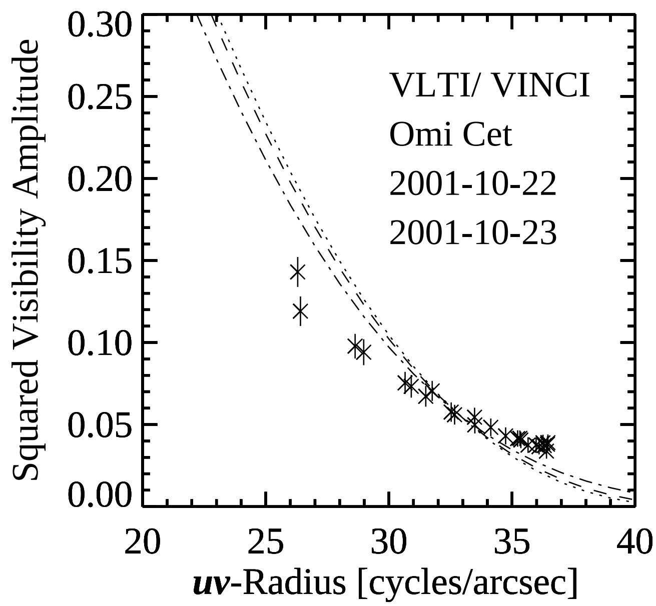

Figure 1. VLTI/ VINCI visibility curve of the prototype Mira star o Cet based on data obtained in the nights starting on October 22 and 23, 2001. Any single symmetric one-component model for the intensity distribution I of the form $I = \mu^{\alpha}$ can not fit the data. Shown are best fitting models of a uniform disk ($\alpha = 0$, dotted line), of a fully darkened disk ($\alpha = 1$, dashed line) and a Gaussian-like disk ($\alpha = 5$, dashed-dotted line).

and azimuth angles. Subsequent measurements in December and January were mainly intended to probe time variations.

Figure 1 shows as an example the o Ceti visibility curve for the nights starting on October 22 and 23, 2001. The figure shows that visibility values with can be obtained with high precision. The visibility curve cannot be explained by any single symmetric one-component model for the intensity distribution I of the form $I = \mu^{\alpha}$, which was shown to fit the center-to-limb intensity variation for many non-Mira as well as Mira type giants (Hofmann et al. 1998a,b).

This deviation from symmetric intensity profiles $I = \mu^{\alpha}$ might be explained by deviations from spherical symmetry as earlier reported by Quirrenbach et al. (1992) and Lopez et al. (1997), or by a more-component model for the atmospheric structure as discussed by Scholz 2001 (see also Richichi et al. 2002b).

The set of observations is planned to be expanded with new accurate results to measure the visibility function over a larger range of azimuth angles as well as uv-radii, and to monitor o Ceti's pulsation over at least one cycle. New observations are planned starting from September 2002, with different baseline lengths and orientations. More detailed modeling of o Ceti's atmosphere structure is planned as well.

Acknowledgments. This work has been made possible by the whole VLTI group at ESO. The used data are public data released from the Very Large Telescope Interferometer (VLTI).

References

Glindemann A., et al., 2000, Proc. SPIE 4006, 2

Derie F., 2000, SPIE 4006, 25

Hofmann K.-H., Scholz M., 1998a, A&A 335, 637

Hofmann K.-H., et al., 1998b, A&A 339, 846

Leinert C., et al., 2000, Proc. SPIE 4006, 43

Petrov R., et al., 2000, Proc. SPIE 4006, 68

Quirrenbach A., et al., 1992, A&A 259, L19

Richichi A., et al. 2002, in "Mass-losing Pulsating Stars and their Circumstellar Matter", Y. Nakada & M. Honma (eds.), in press

Richichi A., et al. 2002, Ap&SS, in preparation

Scholz M., 2001, MNRAS 321, 347

Lopez et al., 1997, ApJ 488, 807

Tuthill P., et al., 1995, MNRAS 277, 1541