AMBER+FINITO+UT Science Demonstration Proposal

High S/N measurement of the molecular layers of a Mira star

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Abstract:
We propose to measure a high-precision, high-S/N visibility and closure-phase spectrum of a Mira star. Recently, we demonstrated, for the first time, that the VLTI/AMBER instrument is very well suited to measure the characteristics of molecular layers located close to the continuum-forming photosphere of Mira variables, and thereby to provide important constraints on the upper layers of dynamic model atmospheres. Here, we propose to obtain a visibility spectrum of a Mira star in medium resolution mode with very high S/N and much higher precision. Furthermore, it is expected that the molecular layers show asymmetric intensity distributions, and the obtained high-precision closure phases will be well suited to detect such asymmetries. These observations will be compared to available dynamic model atmospheres, and might also be very useful to provide constraints on new improved dynamic model atmospheres of Mira stars that are currently being developed and being tested by comparison to Keck visibility data.

Scientific Case:
Mira stars are low-mass, large-amplitude, long-period variable stars on the AGB, evolving toward the planetary nebula phase. The pulsating atmospheres of Mira stars can become very extended because of dynamic effects including shock fronts, so that they are very cool in their outer parts. Here, molecules can form, which for O-rich stars are most importantly H_2O, CO, TiO, and SiO (e.g., Tsuji et al. 1997, A&A, 320, L1; Tej et al. 2003, A&A, 401, 347).

Recently, we demonstrated, for the first time, that the VLTI/AMBER instrument is very well suited to measure the characteristics of these molecular layers located close to the continuum-forming photosphere of Mira variables (Wittkowski et al. 2008, A&A, 479, L21). We presented both a spectro-interferometric observation of the Mira star S Ori that covered the near-infrared J, H, and K bands simultaneously at a spectral resolution of 35 (low resolution mode) and a comparison to recent self-excited dynamic model atmospheres (M series, Ireland et al. 2004, MNRAS, 355, 444). S Ori shows significant variations in the visibility values as a function of spectral channel that can be understood as the effects from water vapor and CO layers lying above the continuum-forming photosphere. The measured values resemble and generally confirm the predictions by recent self-excited dynamic model atmospheres that include the effects from these molecular layers. Fig. 1 shows the uniform disk angular diameter as a function of wavelength compared to the prediction by a dynamic atmosphere model.

However, the observations so far were obtained at low spectral resolution and had rather large error bars. Here, we propose, for one Mira star, to obtain a high S/N and high-precision visibility spectrum of the full K-band in medium resolution mode. In addition, we would like to take a high-resolution visibility spectrum at $2.172\,\mu$m because this band will provide a high-precision estimate of the continuum layer near $2.2\,\mu$m and it covers as well the Brγ line. It has been measured that Mira stars may show Brγ emission at post-maximum visual phases (e.g., for χ Cyg by Wallace & Hinkle 1997, ApJS, 111, 445; for U Crt by Lancon & Wood 2000, A&AS, 146, 217), which most likely originates from the shock front.

Furthermore, it has been shown that many AGB stars including Mira stars, show (slightly) asymmetric intensity distributions, which most likely originate from the molecular layers (e.g. Weigelt et al. 1996, A&A, 316, L21; Ragland et al. 2008, ApJ, 679, 746). The high S/N and high-precision closure phases obtained here will be well suited to detect such asymmetric intensity profiles.

The observations will be compared to available complete self-excited dynamic model atmospheres of Mira stars (Ireland et al. 2004, MNRAS, 352, 318; 2004, MNRAS, 355, 444) that include the effects from molecular layers, as done in Wittkowski et al. (2008). These models include also predictions for the shock front position (described in, e.g., Gray, Wittkowski, Scholz, et al. 2008, submitted). Possibly, the observations can also already be compared to new improved dynamic model atmospheres (Ireland, Scholz, & Wood, submitted), that are currently being compared to Keck visibility spectra (Scholz, private communication).

This project will significantly improve our understanding of how the mass-loss process from AGB stars is related to the pulsating stellar atmosphere, which is currently poorly understood.

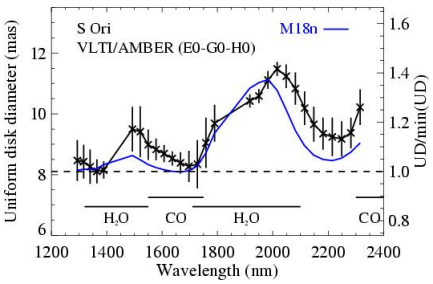

Fig. 1: Uniform disk angular diameter of S Ori as a function of wavelength compared to the prediction by a dynamic atmosphere model. From Wittkowski et al. (2008).

Calibration strategy:
An absolute calibration of the visibility shall be provided for a well calibrated high-precision visibility spectrum. The closure phase is of particular importance to detect possible asymmetries in the molecular layers of Mira stars.

Targets and number of visibility measurements

Target	**RA**	**DEC**	**V** mag	**H** mag	**K** mag	**Size** (mas)	**Vis.**	**Mode**	**# of** Vis.
V Scl ($\phi_{\rm vis} = 0.2$)	00 08 37	-39 13 05	8.7	3.3	2.9	2.2	0.9/0.8/0.6	MR 2.1	1
V Scl ($\phi_{\rm vis} = 0.2$)	00 08 37	-39 13 05	8.7	3.3	2.9	2.2	0.9/0.8/0.6	MR 2.3	1
V Scl ($\phi_{\rm vis} = 0.2$)	00 08 37	-39 13 05	8.7	3.3	2.9	2.2	0.9/0.8/0.6	HR 2.172	1 *OR*
RY Cet ($\phi_{\rm vis} = 0.1$)	02 16 00	-20 31 10	11	3.1	2.6	2.8	0.9/0.7/0.4	MR 2.1	1
RY Cet ($\phi_{\rm vis} = 0.1$)	02 16 00	-20 31 10	11	3.1	2.6	2.8	0.9/0.7/0.4	MR 2.3	1
RY Cet ($\phi_{\rm vis} = 0.1$)	02 16 00	-20 31 10	11	3.1	2.6	2.8	0.9/0.7/0.4	HR 2.172	1

We propose to observe one of the two targets (to be chosen depending on the conditions and the time of the observation). The priorities among the targets are (1.) RY Cet and (2.) V Scl. The priorities among the proposed modes are (1.) MR 2.3, (2.) MR 2.1, (3.) HR 2.172.

Time Justification:
We propose to observe one of the two provided stars. One star consists of three observations to cover the full K band in medium resolution (2 settings, namely MR 2.1 and MR 2.3) and one high spectral resolution band including a good continuum angular diameter near 2.2 μm and the Brγ line.

Mira stars are relatively bright, so that in principle this observation might also be feasible with the ATs. However, we aim at one very high precision and very high S/N visibility spectrum in the K-band, which can best be obtained with the UTs. This proposal may be considered a filler program in case that there is a gap at this time of the night. This program will quasi certainly provide important science without any risk of feasibility.