AMBER+FINITO+UT Science Demonstration Proposal

Probing the Brγ-emitting wind region around the massive hypergiant IRC+10420 with VLTI/AMBER in high-spectral resolution mode

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Abstract:

Mass loss is one of the most dominant processes during the evolution of massive stars resulting in a considerable strip-off of the outer stellar layers. As a consequence of the high mass loss with rates of up to several $10^{-4} M_{\odot}$/yr, circumstellar dust shells form around theses evolved massive stars and often these shells show features of non-spherical outflows. In addition, in some cases strong line emission from the hot circumstellar gas, for instance in the Brγ line, occurs. VLTI/AMBER with its high spatial and spectral resolution capability now offers, for the first time, a unique chance to probe the circumstellar gas and dust environment of massive evolved stars such as Wolf-Rayet stars, Luminous Blue Variables and hypergiants in great detail and with with high absolute and differential accuracy. Theses studies will help us to better understand the mass-loss evolution and dust-formation mechanism in evolved high-mass stars and, in particular, help to shed more light on the question where, when, and how asymmetrical structures in the innermost circumstellar gas and dust environment occur. Here, we propose VLTI/AMBER measurements of the famous yellow hypergiant star IRC+10420 in high spectral resolution mode to study the Brγ-emitting region of its stellar wind. With the high spectral resolution capability of AMBER, it will not only be possible to resolve the Brγ-emitting region, but also individual velocity components of the wind.

Scientific Case:

Throughout their entire evolution, high-mass stars expell a significant fraction of their initial star mass via strong stellar winds with mass-loss rates up to a few $10^{-4} M_{\odot}$/yr. The strong mass loss is so dominant in massive evolved stars that it determines their whole evolutionary path. In the late stages of massive star evolution, important information about the mass loss process is contained in the complicated circumstellar nebulae that are, for example, found around LBVs and Wolf-Rayet stars. The nebulae provide information about the mass-loss history and they allow us to identify phases where stellar wind properties such as the wind velocity and its geometry vary considerably. One explanation for the frequently observed asymmetries in these nebulae concerns the collision between a recent, fast wind with the slower wind from the previous mass losing phase. At least one of these winds has to be asymmetric to provide an overall asymmetric shape which could possibly attributed to mass loss anisotropies at the stellar surface (Maeder 2002, A&A 392, 575), but up to now it is still a matter of debate, in which evolutionary phase the transition from a spherical to an aspherical wind geometry really occurs and which physical mechanisms (such as binarity, stellar rotation, or magnetic fields) drive this evolution (e.g., Heger & Langer 1998, A&A 334, 210; Dwarkadas & Owocki 2002, ApJ 581, 1337).

IRC +10420 is a so-called yellow hypergiant star and one of the few stars that are known to evolve back from the Red Supergiant (RSG) phase towards the blue. This star underwent an rapid increase of its surface temperature of 2200 K during the last 3 decades, and its changed from F8 I_a^+ in the early 70's to mid-A today (Oudmaijer et al. 1996, MNRAS 280, 1062). The estimated distance of $\sim 3.5 \ldots 5$ kpc implies a luminosity typical for a star with an initial mass of around 40 $M_{\odot}$, which places it close to the Humphreys-Davidson limit in the Hertzsprung-Russell diagram. IRC +10420 exhibits a huge infrared excess resulting from an extended, warm circumstellar dust shell wich formed as the result of an extreme mass-losing episode during the Red Supergiant phase.

HST images show that IRC +10420 s optical reflection nebula is spherically symmetric at scales from 2 out to $\sim 8°$ (Humphreys et al. 1997, AJ 114, 2778), and also at longer wavelengths a spherical shape was found (e.g., J band measurements by Kastner & Weintraub 1995, ApJ 452, 833) On a scale of about 1° , a bipolar geometry is visible resulting from scattered light rather than thermal emission of hot dust, and at distance down to 0.3° HST reveals a complicated and non-uniform distribution of various jet- and arc-like features (Humphreys et al. 1997). The extended dust shell of IRC +10420 has been resolved, for the first time, at 2.12 μm by Blöcker et al. (1999, A&A 348, 805) using bispectrum speckle interferometry with the Russian SAO 6 m telescope. From a simultaneous 1-D modeling of the spectral energy distribution (SED) and visibilities, Blöcker et al. (1999) found that apart from its steady mass loss IRC10420 suffered from a temporal episode of very high mass loss roughly 100 years ago, resulting in two spherical shells with FWHM diameters of $\sim$ 70 and $\sim$ 300 mas. is surrounded by two separate spherical shells with FWHM diameters of 70 and 310 mas.

Very recently, de Wit et al. (2008, A&A 480, 149) published the first VLTI/AMBER observations of IRC +10420 obtained in medium spectral resolution mode and using the UT telescope configuration UT1-UT2-UT3 with projected baseline in the range from 40 m to 70 m. The spectral window was centered around the Brγ-emission line. Since the observations were carried out without the fringe tracker FINITO, the measurements had to be done with a short exposure time of only 50 ms. In the measurements of de Wit et al., the Brγ line-emitting region was resolved on all three baselines. From a Gaussian best fit model, a FWHM size of the Brγ emission region of 3.3 milli-arcsec was derived. Moreover, assuming that the hydrogen recombination line emission is optically thick, de Wit et al. indirectly concluded that the line emitting region is elongated. Unfortunately, the size of the continuum-emitting region could not be constrained by the observations, since it turned out that an absolute calibration of the data was not possible.

Here, we now propose to extend the previous VLTI/AMBER study of IRC +10420 by de Wit et al. (2008). By using AMBER with the UTs and FINITO, it will be possible to increase the exposure time considerably. This will allow us to go from medium to high spectral resolution mode and, thus, to detect substructures, i.e. individual velocity components in the Brγ line. In addition, with these new proposed observation an absolute calibration of the continuum-emitting region and an independent determination of the size and elongation of the line-emitting region will be possible.

Calibration strategy:

We would like to obtain both, high absolute calibration accuracy in the case of the continuum-emitting gas as well as high differential accuracy between within the Brγ line-emitting region of the stellar wind. To ensure a high accuracy of the measurements, we propose to obtain 2 calibrator measurements per target observation, i.e. an observing sequence calibrator - target - calibrator. The target is bright enough in the optical for Coudé guiding.

Targets and number of visibility measurements

Target	**RA**	**DEC**	**V** mag	**H** mag	**K** mag	**Size** (mas)	**Vis.**	**Mode**	**# of** Vis.
IRC+10420	19 26 48.1	+11 21 17	11.0	4.5	3.6	3.3	0.5/0.5/0.4	HR 2.17214	3

Time Justification:

We request 3 AMBER measurements to probe the Brγ-emitting wind region of IRC+10420. Three observations will ensure an optimal absolute accuracy of the data and, despite of the rather northern coordinates of the proposed object, a position angle coverage between 95° and 155° (assuming observations with a minimum elevation of 30°). Thus, with these observations at different hour angles it will also be possible to look for asymmetric structures in the line-emission region. If only less then 3 measurements can be accepted, this would also be acceptable in terms of the requested differential accuracy.