AMBER+FINITO+UT Science Demonstration Proposal

A unique view of the gas+dust inner environment of the Herbig Be star HD50138

Investigators	Institute	EMAIL
E. Tatulli	Laboratoire Astrophysique de Grenoble, F	etatulli@obs.ujf-grenoble.fr
A. Isella	Caltech, USA	isella@astro.caltech.edu
M. Benisty	Osservatorio Astrofisico di Arcetri,I	benisty@arcetri.astro.it
F. Massi	Osservatorio Astrofisico di Arcetri, I	fmassi@arcetri.astro.it
A. Natta	Osservatorio Astrofisico di Arcetri, I	natta@arcetri.astro.it
L. Testi	ESO	ltesti@eso.org

Abstract: This analysis is a pilot study to probe the close gas+dust environment of Herbig stars using the unique combination of high spatial and high spectral resolution provided by AMBER+FINITO+UT. Our goals are to measure the characteristic scale sizes of the emitting dust and gas, to investigate the physical processes responsible for such emission (accretion, outflow, winds) and, for the first time, to obtain kinematic constraints on this emission, that will allow to spatially discriminate the velocity contributions along the line. To do so, we propose to dedicate one observation in the HR-K mode, around the Brγ line to spatially and spectrally resolve the K-band emission of the HerbigBe star HD50138.

Scientific Case: The innermost regions (R $\ll$ 1 AU) of circumstellar disks around pre-main sequence stars are the sites of complex processes that have a strong influence on the stellar and disk evolution, as well as on planetary formation. Theoretical models developed to explain the stellar activity during the pre-main sequence phase predict that the matter accreting through the disk is deflected along the magnetic field lines (of stellar and/or disk origin), giving rise to columns of ionized gas accreting onto the star, to jets and winds (Pudritz et al. 2007, Shu et al. 1994). These processes control the angular momentum transfer from the disk to the star, and vice versa, influencing both the time scale of the disk dispersal and the properties of the central star itself (Shu et al. 1994).

The hot gas in accretion or ejection emits in hydrogen recombination lines, such as the Brγ (at 2.165 μm), within few stellar radii from the central star, and for this reason, it is commonly used to measure the mass accretion rate (Muzerolle et al. 2004). In the case of low mass pre-main sequence stars (M< 1.5 $M_\odot$), the magnetospheric accretion model successfully explains most of the observed properties, but its validity in the case of higher mass objects, the Herbig AeBe stars (HAeBe), has been questioned by recent spectrally dispersed interferometric observations of the circumstellar emission. In fact, in most objects studied so far, the Brγ emission line arises at a stellocentric distance larger than 0.3 AU, which is larger than the few stellar radii ($\sim$0.05-0.1 AU) predicted by the magnetospheric accretion model (Kraus et al. 2008). For example, in the case of the HBe star MWC 297 (Malbet et al. 2007), the visibility in the Brγ line were well reproduced using an extended stellar wind up to several AU from the central star, while for the HAe stars HD 104237 (Tatulli et al. 2007; see Fig. 1) and MWC 480 (Eisner et al. 2007b) the Brγ line is more likely emitted by the base of a wind (or a jet) starting from the inner disk surface at about 0.3 AU from the central star.

Therefore, the environment of HAeBes is quite complex and the emission in the inner AUs is composed at least by three distinct components (see Fig. 2): (A) the dust thermal emission from the disk inner rim, which dominates the continuum flux in the K-band (Millan-Gabet et al. 2007; Isella & Natta 2005), (B) an optically thick emission arising from a gaseous inner disk of a few thousand K hot that dominates the continuum flux in the H-band and contributes to the K-band flux (Tannirkulam et al. 2008); (C) hot gas emitting in the Brγ line emission, coming from an outflow (stellar/disk wind) and/or from the accreting columns.

However, because of insufficient spectral resolution, the first published studies about such environment could not constrain the exact mechanism responsible for the gas emission (stellar wind, X-wind, disk wind) and/or the type of connection to the disk.

Only AMBER/VLTI/FINITO in its HR-K mode can disentangle from the different possible mechanisms by providing spatial constraints of the different velocities components within the line. To achieve this goal, we propose such observations on the Herbig star HD50138. It is of spectral type B9 and was shown to have a gaseous and dusty disk (Grady et al. 1994; Carpenter et al. 2004). Pogodin et al. 1997 also analyses the hydrogen and sodium lines using a stellar wind and discuss the variability of the HeI line with the presence of both outflow and accretion. The star displays a strong Brγ emission line as shown in Fig. 3, and is bright enough (in K and H) with respect to the AMBER+FINITO requirements. This star thus appears suited for this pilot study, allowing to optimize the observations and demonstrate the feasibility and the potential of such analysis.

Therefore, with the proposed observations, we will (1) investigate the presence of hot gas inside the dust evaporation radius by spatially resolving the Brγ line emission and the dust continuum. By measuring the scale size of the gas and dust emission (with the relative levels of their visibilities), we will test the magnetospheric accretion and gas outflow models. Then, thanks to the high spectral resolution of R=12000 provided by AMBER, we will (2) determine for the first time kinematics informations of its gaseous region, disentangling between contributions from the accreting gas and/or from the outflowing jet unveiling its own nature (e.g. stellar wind, X-wind, disk wind).

Calibrated visibilities, and closure phases measured in the continuum will be analyzed with our disk model (Isella and Natta, 2005) which has been already successfully applied to near-IR interferometric observations of HAe/Be stars (Isella et al. 2006, 2008; Tatulli et al. 2007; see Fig. 1). A first analysis of Brγ line observations will be performed with simple geometrical models, as discussed in Tatulli et al. (2007, see Fig. 1). Then, more detailed investigations of the physical processes responsible for the line emission will be performed using wind models (Malbet et al. 2007), accretion models (Muzerolle et al. 2004), and an inner gaseous disk emission model we are now developing.

Calibration strategy: The AMBER data will be reduced using the standard AMBER data reduction software (Tatulli et al. 2007b). For the Brγ region, we will be interested in spectrally dispersed visibilities (i.e. characteristic size), closure phase (i.e. asymmetry) and differential phases (i.e. displacement of the photocenter) all along the line. Note that, since we are specifically requesting for HR-K mode, such observations can not be done without FINITO.

Targets and number of visibility measurements

Target	**RA**	**DEC**	**V** mag	**H** mag	**K** mag	**Size** (mas)	**Vis.**	**Mode**	**# of** Vis.
HD 50138	06 51 33.398	-06 57 59.44	6.6	5.1	4.1	6.0	0.65/0.4/0.3	HR 2.172	3

Time Justification: Given the orientations and the lengths of the three baselines, one single observations, consisting of 3 dispersed visibilities, one closure phases and 3 differential phases, will be enough to constrain the geometry of the dust and the gas emission, as well as recovering kinematics constraints of the gaseous region. Hence, according to "ESO Call for proposals - P82" for which a calibrated point with AMBER needs 70 minutes, we require a total time of 70 minutes to complete the observations of the proposed source

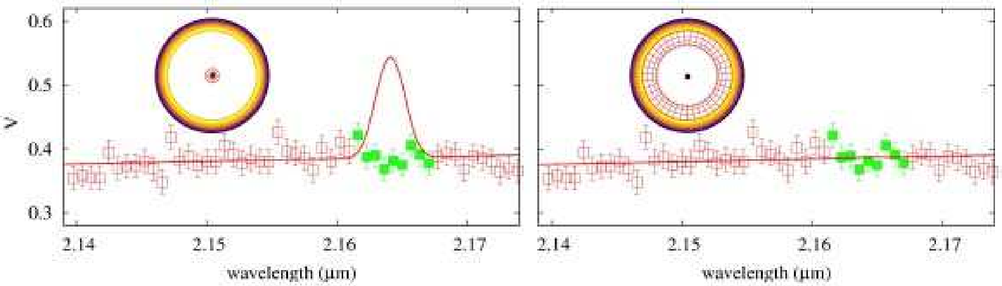

Figure 1: (adapted from Tatulli et al. 2007) Comparison between the observed visibilities of HD 104237 (empty square are the measurement in the continuum while the full squares correspond to the Brγ) and two different models for the gas emission (sketched in the same panels). In both cases the continuum emission is the sum of the stellar photosphere (represented with the central black dot) and the dusty disk inner rim, which is located at the dust evaporation distance Rrim = 0.45 AU and which appears as the bright color (gray) scale ring. In the left panel, the Brγ line is emitted by a very compact region (R<0.07 AU, represented with the grid surface) as predicted by the magnetospheric accretion model. As a consequence consequence, the visibility in the line should increase (being the emission less resolved) as shown by the solid line. This model is not in agreement with the observations. The right panel shows the model in agreement with the observations. The emission is confined close to the inner rim, between $\sim$0.2 AU and $\sim$0.5 AU.

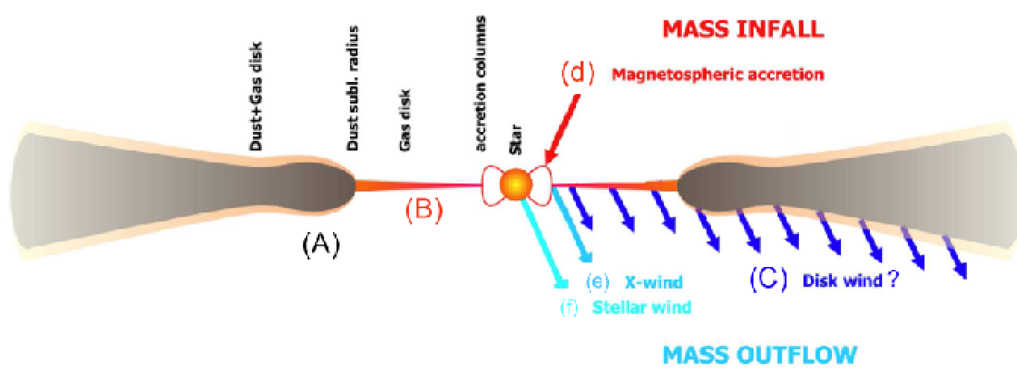

Figure 2: Vertical section of the structure of the inner region (R<1 AU) of pre-main sequence star circumstellar disks (adapted from Kraus et al. 2008) as derived from the existing near infrared interferometric observations of HAe/Be stars. Different component can be identified: (A) the dusty disk inner rim located at the dust sublimation radius which dominates the K-band continuum disk emission as predicted by Isella and Natta (2005); (B) a gaseous disk inside the dust sublimation radius which, as shown in Isella et al. (2008), dominates the H-band continuum disk emission; (C) the Brγ line which arises from disk regions more extended than the gas accretion columns (d) as predicted by the magnetospheric accretion model. The origin of the Brγ emission in HAe star is still under debate.

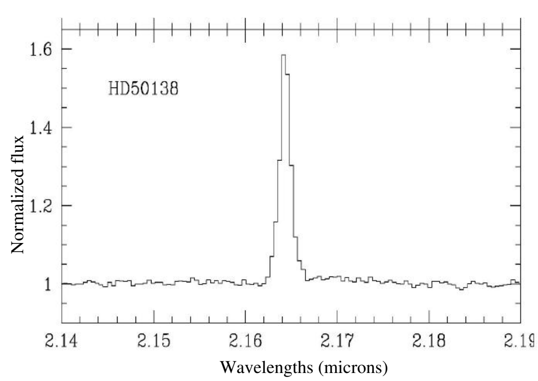

Figure 3: K-band spectra of the proposed target HD50138 recently observed with the TNG (Telescopio Nazionale Galileo, R=2500). We can see that this star displays a strong Brγ emission of $\sim$ 50% of the continuum.