CHARACTERISATION OF DISKS AROUND YSO'S WITH GENIE

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1. ABSTRACT

Recent interferometric observations show that the interfered near-IR size of the circumstellar material around Young Stellar Object (YSO) are larger than those expected from accretion disk models. There are currently different models that account for the excess IR emission of Young Stellar Objects (YSO). At the same time, the answers to many questions on the evolutionary status and the origin of the activity and variability depend critically on the relative importance of circumstellar distribution of material in disks or envelopes at different spatial scales. Operating at mid-infrared wavelengths, the Ground-based European Nulling Interferometer Experiment (GENIE) will be particularly sensitive to warm circumstellar dust and will thus provide the opportunity to characterize dust disks around YSO's. Observations with GENIE will enable us to investigate the properties of the circumstellar dust, which are responsible for the excess near-infrared fluxes. The nulling of the central star will bring out the disk in much more detail and hence put stronger constraints on these models.

2. INTRODUCTION

There is currently no fully accepted physical model to account for the excess near-IR emission of YSO [1] and to answer questions on evolutionary status and origin of activity and variability. Herbig Ae/Be (HAEBE) stars are young stellar objects of mass between 1.5 to 10 solar masses that show broad emission lines, rapid variability, and excess infrared and millimeter-wavelength emission. These properties are suggesting the presence of hot and cold circumstellar dust and gas [2]. While there is still some debate about the morphology of the circumstellar material, most observations strengthen the hypothesis that the dust and gas lie in a massive (about 0.01 solar masses) circumstellar disk [3][7]. Observationally the stars are spectral types B to F. Their pre-main sequence nature is well established, based on comparison of their localisation in the HR diagram with theoretical evolutionary tracks [4], their high rotational velocity [5] and association with dark clouds in which most HAEBE stars are found [6], though many are also found isolated.

The high stellar luminosity of HAEBE stars permits a number of alternative physical processes to reproduce the observations [1]. However, the limited number of HAEBE sources observed with near-IR interferometers and the sparse *u*-*v* coverage of these observations [1] make it difficult to draw unambiguous conclusions about the structure of the circumstellar material

Hillebrand et al [7] classified HAEBE stars in three different subgroups, according to their spectral energy distribution. They proposed an evolutionary sequence between the groups, where the originally complex gas and dust environment that results from the star formation process leads to the formation of an accretion disk that gradually disappears.

The proposed evolution sequence consists of 1) stars with flat or rising IR spectra, which require the presence of gas not confined to a flat disk (Group II) leading to 2) stars with IR spectral shape distribution of a star-disk system in which the disk both reprocesses star light and/or is self-luminous via active accretion onto the central star (Group I), to 3) stars with small IR excess above photospheric levels coming from the remnant disk or envelope (Group III). The scheme and the question of the geometrical distribution of the cool material responsible for the characteristic long-wavelength excess, remains controversial. Observations with GENIE using different baselines will enable us to investigate the properties of the circumstellar dust and verify the different models.

In this contribution we present GENIE simulations of simple dust disk models, using the results of a systematic study of HAEBE stars with long baseline stellar interferometry in the near-infrared at the Infrared Optical Telescope Array (IOTA) by Millan-Gabet et al [1][8] for the parameterisation. The model results are the base of the astronomical sources for the GENIE simulator.

From Millan-Gabet's sample, we took two of our target stars, HD150193 and HD163296, discussed here.

Proc. "Towards Other Earths: DARWIN/TPF and the Search for Extrasolar Terrestrial Planets", Heidelberg, Germany, 22-25 April 2003 (ESA SP-539, October 2003)

3. DISK MODEL

In order to interpret the visibility amplitude data different groups e.g. Millan-Gabet et al. [1] consider a two-component model consisting of the central star plus a component , which is the source of the near-IR excess. The star is approximated by a blackbody and entirely responsible for the short-wavelength (*VRI*) flux. The model we adopted for the component providing the IR excess is that of a circumstellar dust disk around the star.

In the disk model [9] dust properties are independent of vertical position. The properties of the dust grains at any place in the disk are the same as at the position in the ecliptic plane of the dust disk. This assumption is valid if the thickness of the disk is much smaller than its radius. For optically thin disks the model is even more restrictive than a simple model: no screening effect between dust grains is assumed. The observer therefore sees the emission from every single dust grain located within the field-of-view. The model does not take the scattered light into account.

The geometry of the disk is defined by the inner and outer radii (r_{in} and r_{out}), by the inner height h_{in} and by the flaring parameter *f*. The flaring parameter allows for a linear or exponential flaring of the disk. The vertical thickness of the disk is given by:

$$h(r_c) = h_{in}\left(r_c / r_{in}\right)^f \quad . (1)$$

The disks are modelled as blackbodies with an effective temperature *T*eff and radius *R,* heated by the central star. Also other models for the component [8] can be implemented in the GENIEsim simulation software and will restrict the possible explanations for the excess IR flux after the first nulling observations.

4. NULLING INTERFEROMETRY

GENIE works as a Nulling interferometer as a precursor for the DARWIN mission that will search for planets around other stars. Nulling Interferometry was originally proposed by Bracewell and McPhie [12]. The basic concept of nulling interferometry applied to planet search is to sample the incoming wavefront from the star and its planet with several telescopes that individually do not resolve the system. The beams are interfered while adding a phase shift into one arm or several arms of the interferometer array, to achieve destructive interference for a source on axis. Instead of the usual bright fringe, this places a dark fringe on the detector at the place where the bright star would be. The star can be centred on the deep central null while specific off-axis locations can be constructively interfered by adjusting the distances between the telescopes.

5. MODELLING DUST DISKS AROUND YOUNG STELLAR OBJECTS

Disks around pre-main sequence stars are modelled in the GENIEsim software as flared optically thick disks seen face on. The inner radius *rin* and outer radius *rout* as well as the temperature at the inner radius and the density and temperature power-laws coefficients can be specified. The inclination of the disks is set to be face on for now. The density and temperature power-laws are given by

$$\rho(r_c) = \rho_0 (r_c / r_{in})^{-\alpha} \qquad (1)$$

$$T(r_c) = T_{in} (r_c / r_{in})^{-\delta} \qquad (2)$$

where *rc* is the distance to the star projected on the ecliptic plane. We neglect the vertical dependence.

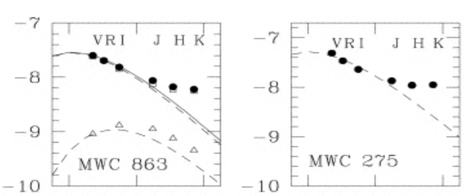


Fig. 1. Flux of HD150193 and HD163296 [1] reproduced with simulations of the flux generated by GENIEsim [9].

In these simulations the field-of-view corresponds to 172 milli-arcsec of GENIE, corresponding to 25.8AU at the distance of HD150193 and to 21AU at the distance of HD163296. The field-of-view thus does not contain the whole disk. The inner radius of the disk is much smaller than the FOV in the models used [1]. The majority of the flux from the disk should be found in the inner region.

Table 1. Properties of the star in the model [1]

Stellar properties			
Star name	**HD**	**Dist.**	**V mag**
MWC 275	163296	122 pc	6.8
Type	**Rstar**	**Teff**	**Lstar**
A1V	2.26 Rsun	9330 K	8.2 Lsun
Star name	**HD**	**Dist.**	**V mag**
MWC 863	150193	150 pc	8.8
Type	**Rstar**	**Teff**	**Lstar**
A1V	2.26 Rsun	10500 K	8.8 Lsun

Table 2.Properties of the disk in the model [1]

Disk properties				
Star name	**HD**	**Dist.**	**Rin**	**Rout**
MWC275	163296	122 pc	0.24 AU	300 AU
	Tin	**a**	**d**	**Ldisk / Lstar**
	2100 K	0	0.75	1.60E-01
Star name	**HD**	**Dist.**	**Rin**	**Rout**
MWC863	150193	150 pc	0.07 AU	300 AU
	Tin	**a**	**d**	**Ldisk / Lstar**
	2060 K	0	0.75	1.50E-01

Within this FOV the characteristics of a disk can be established. The simulations of GENIE observations shown in this article are performed with the GENIEsim software [11].

6. INFLUENCE OF DISK PARAMETERS ON THE NULLING RATIO

Using the above model, we have generated the image of the dust disk around HD150193 and HD163296 in the interferometric field-of-view of a VLT Unit Telescope. The flux of the disk within the field-of-view is of 1.1 Jy and 1.43 Jy in the N-band respectively. The nulling ratio is defined as the ratio of the total flux collected in destructive mode to the total flux in constructive mode (i.e. without p/2 phase shift). The contribution of the central star to the nulling ratio is negligible.

In Figs. 2-4, we have used different values of the inner radii *rin*, the density power-law exponents *a* and the temperature power-law exponent *d* for HD150193 and HD163296. The different model parameters influence the nulling ratio that will be observed with GENIE. The use of different baselines for the observations, simulated in Fig 2-4, will constrain the parameters for the stellar disks.

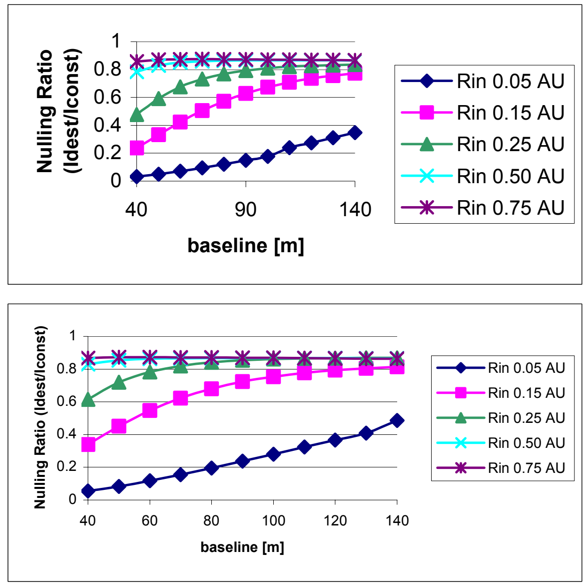


Fig. 2. The influence of the dust inner radius can be easily seen from observations: the nulling ratio is at maximum when a bright fringe transmits the large flux produced by the warm dust located at the inner cut-off *rin*.

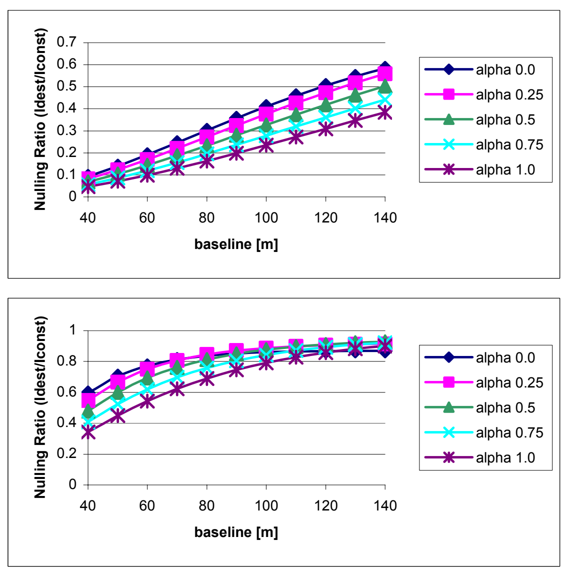
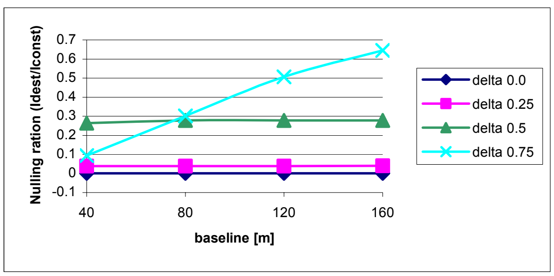


Fig. 3: The influence of the different density power-laws in the model will be difficult to extract from observations as the differences for the different values are small.

The inner radius has a large influence on the nulling ratio: the maxima of the curves correspond to the baselines at which a bright fringe is superimposed on the very inner dust (brightest part of the disk). On the other hand, the density power-law exponent has a smaller influence on the nulling ratio and the behaviour of the nulling ratio with increasing baselines is similar for all values of a. Retrieving this parameter from nulling measurements will be harder than retrieving the inner radius. The temperature power-law exponent d will be very hard to retrieve from measurements, but one has to view the results with caution as we model the disks only face on, because optical thick disks are not yet implemented in the GENIEsim simulator [9].

The simulations show the possibilities GENIEsim holds for characterizing the source of IR excess flux around YSO. Simulation results shown in Figs 2-4 (upper rows for HD150193 and bottom for HD163296) are for model disks seen face on optically thick disks with other inclinations are not yet implemented in the GENIEsim simulator.



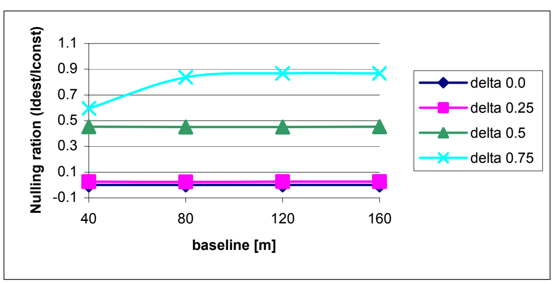


Fig. 4. The influence of different temperature power-law exponent d in the model will also be difficult to extract from observations, as the differences for the different values are small**.**

GENIE observations are proposed to be done in the infrared N band (8-13µm) with two VLT Unit Telescopes, with a typical baseline of 46m. Also other configurations are possible using other UT telescopes. The SNR after 1000s of observations is shown for different baselines including the noise sources taken into account by GENIEsim [9].

Table 3. Simulation of the SNR after 100s of integration using different baselines

SNR after 1000s			
Baseline	**UT2/UT4 89.4m**	**UT3/UT4 62.5m**	**UT2/UT3 46.6m**
MWC 275	1.01E+03	1.11E+03	1.15E+03
MWC 863	1.23E+02	1.96E+02	3.19E+02

7. CONCLUSION

Coronographic studies start to investigate the properties of the circumstellar dust around stars selecting very bright and nearby stars [10]. GENIE will be a next step to widen the sample of circumstellar disks and provide statistics on their properties, see also Absil et al [11].

The two stars selected for these simulations will be excellent targets for the first observations with GENIE. The simulations show the possibilities GENIEsim holds for characterizing the models and thus the source of IR excess flux around YSO. Simulations show that the influence of the dust inner radius can be easily seen from observations while the influence of other model parameters will be smaller and more difficult to detect.

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