VISIR OBSERVATION OF H_2 EMISSION FROM THE CIRCUMSTELLAR DISK AROUND THE HERBIG Ae STAR HD97048.

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In the past twenty years, both planets and disks have begun to be observed around nearby stars. Some young stars with disks, e.g. the pre-main sequence solar-type star (T Tauri star) GM Aur (Rice et al. 2003), are also suspected of harboring young planets. It is now well established that planets around T Tauri stars form in massive, gaseous and dusty protoplanetary disks that survive for several million years around the stars (Greaves 2005). The situation is less clear for the more massive Herbig Ae/Be stars (HAeBes). A particular interesting object to study the circumstellar material around a pre-main sequence intermediate mass star is HD97048.

HD97048 is a nearby relatively isolated Herbig A0/B9 star located in the Chameleon cloud at a distance of 180 pc (van den Ancker et al. 1998). Its age has been estimated from evolutionary tracks to be of the order of 3 million years (kindly computed for us by L. Testi and A. Palacios). The *VISIR* (*VLT Imager and Spectrometer for the mid-InfraRed*) imaging observation of this star conducted in 2005 June 17 and 19, has revealed a large extended emission from PAHs (Polycyclic Aromatic Hydrocarbons) at the surface of a flared disk (Lagage et al. 2006, see Fig. 1) . The flaring index has been measured to be 1.26±0.05, in good agreement with hydrostatic flared disk models (Lagage et al. 2006). This flaring geometry implies that a large amount of gas should be present to support the flaring structure. It is thus important to try and get information on the gaseous component of the disk around HD97048.

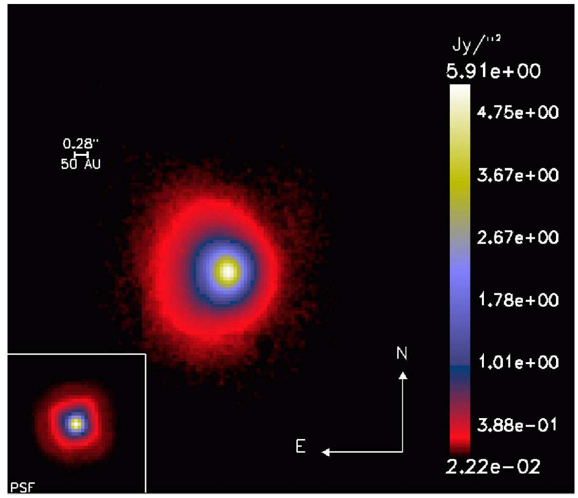

Figure 1: *VISIR* false-color image of the emission from the CS material surrounding the Herbig star HD97048, after a deep exposure of 36 min. A filter centered at 8.6 μm (PAH1 filter) and with a full width half maximum of 0.42 μm was used. The emission is widely extended with a east/west asymmetry , as compared with the point spread function (inset) obtained from the observation of the pointlike reference star HD102964. From the image it has been possible to infer that the disk was flaring, which implies that a lot a gas should be present to support this geometry (Lagage et al. 2006).

1 Observation and data reduction

In order to get information on the gas content of the disk around HD97048, we have performed high resolution spectroscopic observations with *VISIR*. Indeed, the spectral ranges covered by *VISIR* at high resolution offer access to the most intense pure rotational lines of molecular hydrogen (H_2): S(1) ($v = 0-0, J = 3-1$) at 17.0348 μm, S(2) ($v = 0-0, J = 4-2$) at 12.2786 μm, S(3) ($v = 0-0, J = 5-3$) at 9.6649 μm, and S(4) ($v = 0-0, J = 6-4$) at 8.0250 μm, except the S(0) ($v = 0-0, J = 2-0$) transition near 28 μm which is not observable from ground due to the Earth's atmospheric absorption. The detection of these H_2 emission features at IR wavelengths, produced in the surface layers of the disks/envelopes surrounding the stars, provides constraints on the dynamics of the gas and gives access to the mass of warm gas.

HD97048 was observed with the high spectral resolution long-slit mode of *VISIR* during 1800s in 2006 June 22; the central wavelength of the observation was set to 17.035 μm. We used the 0.75" slit, providing a spectral resolution about 10 000, i.e. Δv=30 km s^{-1}. The weather conditions were very good and stable during the observations; the optical seeing was less than 0.66" and the airmass (<1.8) was close to the minimum airmass accessible when observing this object from the Paranal ESO observatory. Standard "chopping and nodding" mid-infrared observational technique was used to suppress the background dominating at these wavelengths. Secondary mirror chopping was performed in the North-South direction and with an amplitude of 8" at a frequency of 0.025 Hz. Nodding technique, necessary to compensate for chopping residuals, was applied using a telescope offset of 8" in the South direction, every 3 minutes. The pixel scale is 0.127"/pixel resulting in a total field of view along the slit of 32.5". The elementary frames are coadded in real-time to obtain chopping corrected data; then the different nodding positions are combined to form the final image. *VISIR* detector is affected by stripes randomly triggered by some abnormal high-gain pixels. A dedicated destriping method has been developped (Pantin 2007, in prep.) to suppress them.

In order to correct the spectrum from the Earth's atmospheric absorption and obtain the absolute flux calibration, we observed the CERES asteroid and the standard star HD89388 (see www.eso.org/VISIR/catalogue) just before and after observing HD97048. HD89388 and CERES were observed at nearly the same airmass and seeing as the object. We have divided the spectrum of HD97048 by that of CERES (which have a much better signal-to-noise ratio than that of the standard star) to correct from the telluric absorption, and used the standard star observation and modelled spectrum (Cohen et al. 1999) to obtain the absolute flux calibration. The wavelength calibration is done by fitting the observed sky background features with a model of the Paranal's atmosphere emission.

2 Results

As shown in Fig. 2, we have detected the H_2 pure rotational line S(1) near 17.03 μm. In the flux-calibrated science spectrum, the standard deviation (σ) of the continuum flux was calculated in regions less influenced by telluric absorption, and close to the feature of interest. We deduced a 6σ detection in amplitude for the line. The line is not resolved as we can fit it with a Gaussian with a full width at half maximum equal to a spectral resolution element of 30 km s^{-1} (see Fig. 2). From our fit, we derived an integrated flux in the line of 2.4×10^{-17} W m^{-2} or 2.4×10^{-14} ergs s^{-1} cm^{-2}.

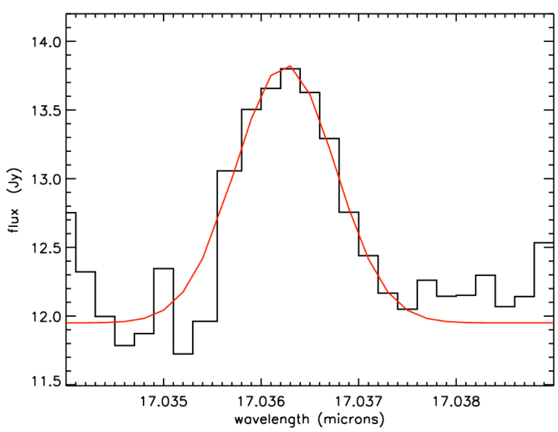

Figure 2: S(1) H_2 emission line from HD97048 circumstellar disk, observed with the high spectral resolution mode of the VLT/VISIR instrument. The black line corresponds to the observed spectrum corrected from the telluric absorption. The red line is the fit of a gaussian with FWHM equal to the spectral resolution element.

From the wavelength position of the Gaussian peak, we can estimate the radial velocity of H_2 to be about $+4\pm2$ km s^{-1} in the star's rest frame. We thus considered that the radial velocity of the H_2 is similar to that of the star, implying that the emitting gas is bound to the star. The H_2 line is not resolved spatially. Given the *VISIR* spatial resolution of about 0.427" at 17.03 μm, and the star distance (180 pc from the sun), we can assess that the emitting H_2 is located within the 35 inner AU of the disk, and we calculated the corresponding upper limits to the masses of warm gas as a function of the assumed gas temperature (Table 1). For this purpose, we assumed that the medium we observe is homogeneous, optically thin, that the H_2 is in Local Thermodynamical Equilibrium , and that the radiation is isotropic. For the details of calculations see Van Dishoeck (1992), Thi et al. (2001), and Takahashi & Uehara (2001).

Table 1: Upper limits to the mass of warm H_2 as a function of the temperature. Masses are given in M_{Jup} ($\sim 10^{-3}$ $M_\odot$).

T	M(H_2)
150 K	7.37×10^{-1}
300 K	4.51×10^{-2}
1000 K	1.33×10^{-2}

3 Conclusion

Our high resolution spectroscopic observation at 17.03 μm of HD97048 has revealed the presence of warm gas in the inner region of the disk. It is the first time that the S(1) pure rotational line is clearly detected (6σ detection) from the disk of a Herbig Ae star. Masses of the warm gas in the range of 10^{-2} to nearly 1 M_{Jup} have been derived, depending on the adopted temperature. However, infrared observations only probe the warm gas of the surface of the disk and we can expect that a large amount of cold gas is also present as supposed from the flaring geometry of the disk (Lagage et al. 2006).

Observations of the other pure rotational lines of H_2 will be performed with *VISIR*, in order to better characterize the physical conditions of the gas in the inner disk. Especially, the detection of these lines would help to better constrain the temperature of the warm gas. In addition, observations of cold gas such as CO observations would be necessary to precisely estimate the total mass of gas. Such observations would provide constraints for the giant planets formation time-scale in the inner region of the disk.

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