Milli-arcsec spatial resolution tomography of two proto-planetary disks.

Evidence for a rich inner disk carbon chemistry?

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Introduction

We present spatially and spectrally resolved observations on the two Herbig stars **HD 97048** and **HD 100546**. Using a rich spectrum of fundamental Carbon Monoxide (CO) ro-vibrational emission lines, we probe the physical properties of the circumstellar gas and model its kinematics. Furthermore, by using milli arcsecond precision spectro-astrometry, we constrain the physical size of the emitting regions in the disks.

Comparing these results with already available data reveals interesting questions about the inner-disk chemistry.

Methods

High-spectral-resolution 4.6 - 5.1 μm spectra, taken with the CRIRES on the VLT (Figs 1,4) allow us to use the following techniques (see also Pontoppidan et al. 2008):

- **Emission line (modelling)**

  Modelling kinematics allows us to determine the inner, and to lesser extent the outer, radius of the emitting region.

- **Astrometry**

  [1] Spatial offset of the emission lines compared to the continuum (SPP) with milli arcsecond precision.
  [2] FWHM outside the emission lines translates directly to the size of the continuum emitting region.

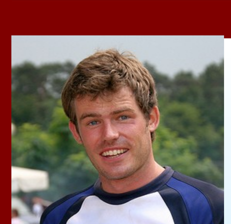
Conclusions

HD 97048 and HD 100546 Both lack detectable CO emission within 12 AU. This has been reported for more disks, e.g HD 141569, in which case this was explained by clearing of the inner disk (Brittain et al. 2007). HD 97048 and HD 100546 however, show abundant dust and gas well within these 12 AU. The absence of CO emission can therefore not be attributed to the paucity of matter in the inner disk. We suggest two possible explanations.

• The CO gas may be efficiently destroyed at radii smaller than 12 AU. A possible explanation is the higher temperature and density closer to the star, which may drive a rich chemistry in the disk, so that CO may be replaced by other species (e.g. Methane) as the dominant reservoir of carbon.

• Alternatively, radiative transfer effects could suppress the line emission from the innermost regions.

Solving this problem may offer us a first glimpse of the molecular chemistry of the inner disk. Furthermore, using CRIRES on nearby circumstellar disks allows for sub-AU resolution observations.



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HD 97048 (A0pshe, 2.5 Mʘ, i = 43°) Observations:

- 630 nm [OI] emission, tracing gas in the disk atmosphere, between 0.5 and 60 AU (Acke & van den Ancker, 2006, Fig. 3)
- The S(1) pure rotational line of H2 at 17.035 μm arising from the inner 35 AU of the disk (Martin-Zaidi et al. 2007)
- Hot dust in the SED (Fig. 2): Dust in innermost disk regions.
- Nano-diamond features from within 15 AU (Habart et al. 2004): Carbon chemistry?
- Fundamental CO emission outwards 12 AU (this work, Figs 1,3).

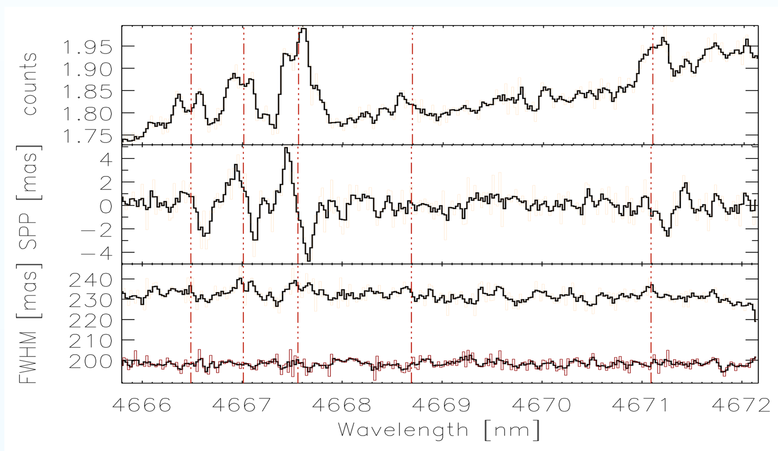

Figure 1. (top) *Part of the spectrum of HD 97048, showing with vertical dotted lines resp. the 12CO v(4-3) R23, v(3-2) R14, v(2-1) R06, v(5-4) R33 and 13CO v(1-0) R12 emission lines* . (middle) *The SPP (astrometric signal).* (bottom) *The FWHM of HD 97048 (black line) and the telluric standard HIP 052419.*

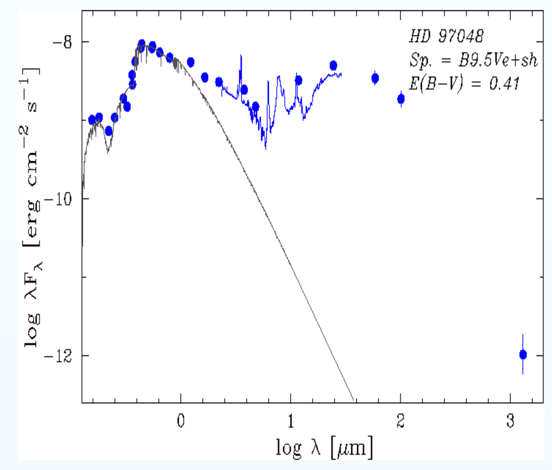

Figure 2. *The SED of HD 97048 showing photometric data points, the ISO-SWS spectrum and a reddened Kurucz model of the stellar atmosphere.*

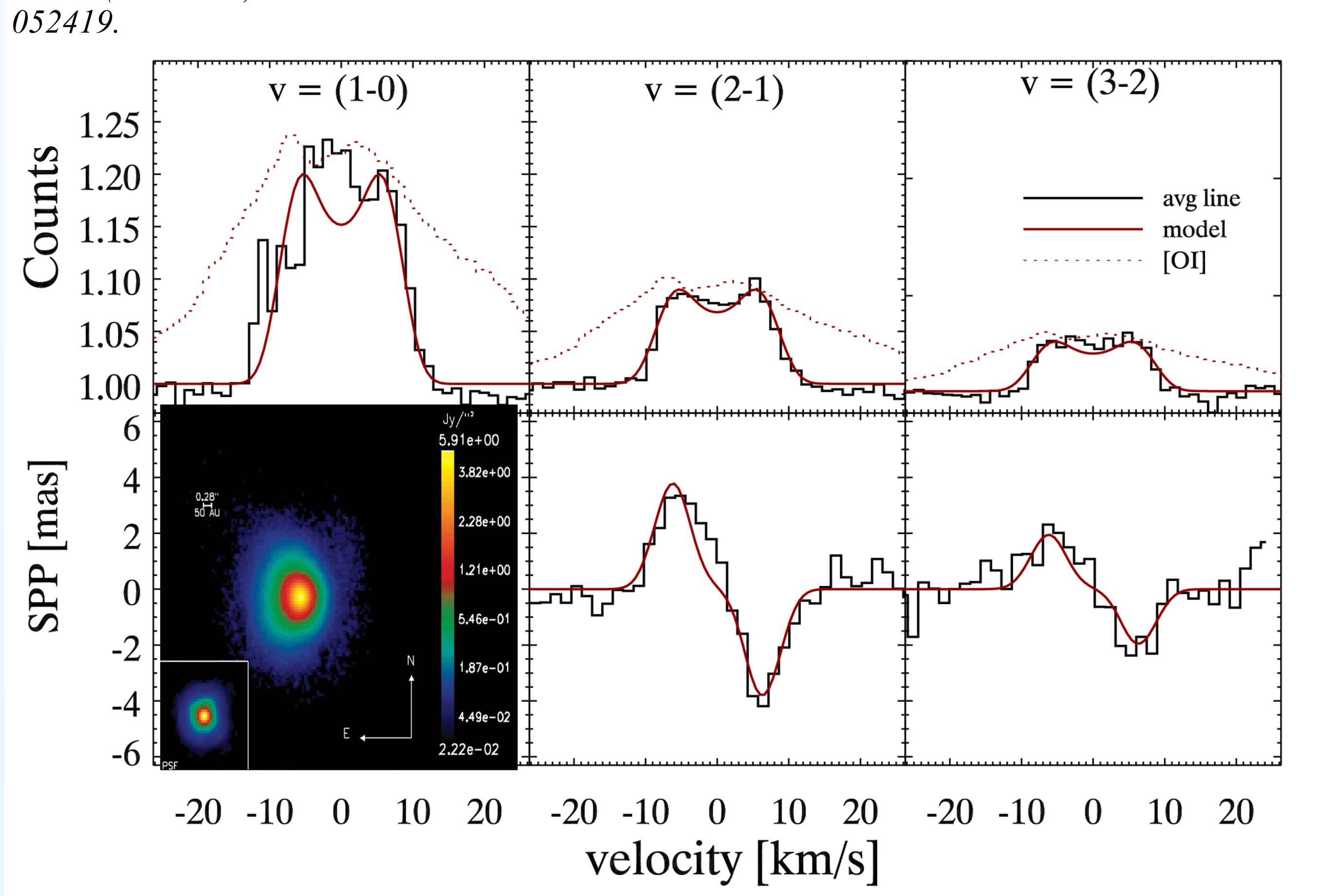

Figure 3. (top) *Average CO line profiles of the v = 1-0 to v = 3-2 vibrational transitions, with the [OI] line profile over plotted with red dots, and a kinematic fit with an inner and outer radius of 12 and 45 AU with the solid red line.* ***(bottom)*** *in panel 2 and 3 the average astrometric profiles of the v = 2-1 and v= 3-2 vibrational transitions. The red line is an over plotted model for the astrometric signal assuming the same parameter as used by the kinematic fit.* ***(bottom left)*** *VISIR false-color image of the emission from the PAH emission from the circumstellar material surrounding HD 97048 (Lagage et al. (2006) together with the PSF of the telluric standard observed before.)*

HD 100546 (B9Vne, 2.4 Mʘ, i = 42°) Observations:

- 630 nm [OI] emission, tracing gas in the disk atmosphere, between 0.5 and 60 AU (Acke & van den Ancker, 2006, Fig 6)
- A gap - or inner wall – at 10 AU from modelling the SED (Bouwman et al. 2003)
- PAH emission from within 12 AU (Geers et al. 2007)
- Fundamental CO emission outwards 15 AU (this work, Figs 4,6).

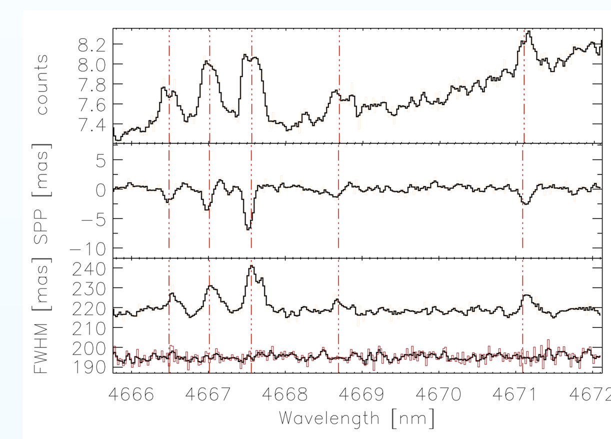

Figure 4. *Same as Fig.1 for HD 100546.*

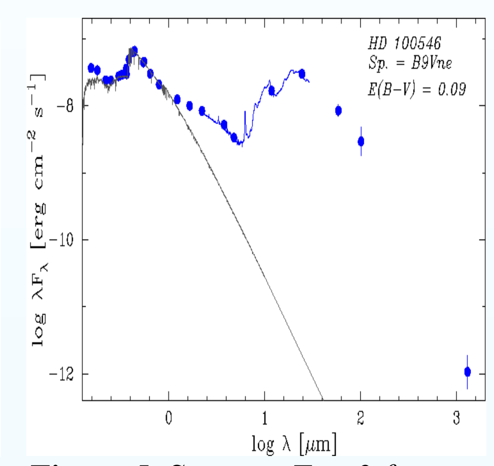

Figure 5. *Same as Fig. 2 for HD 100546*

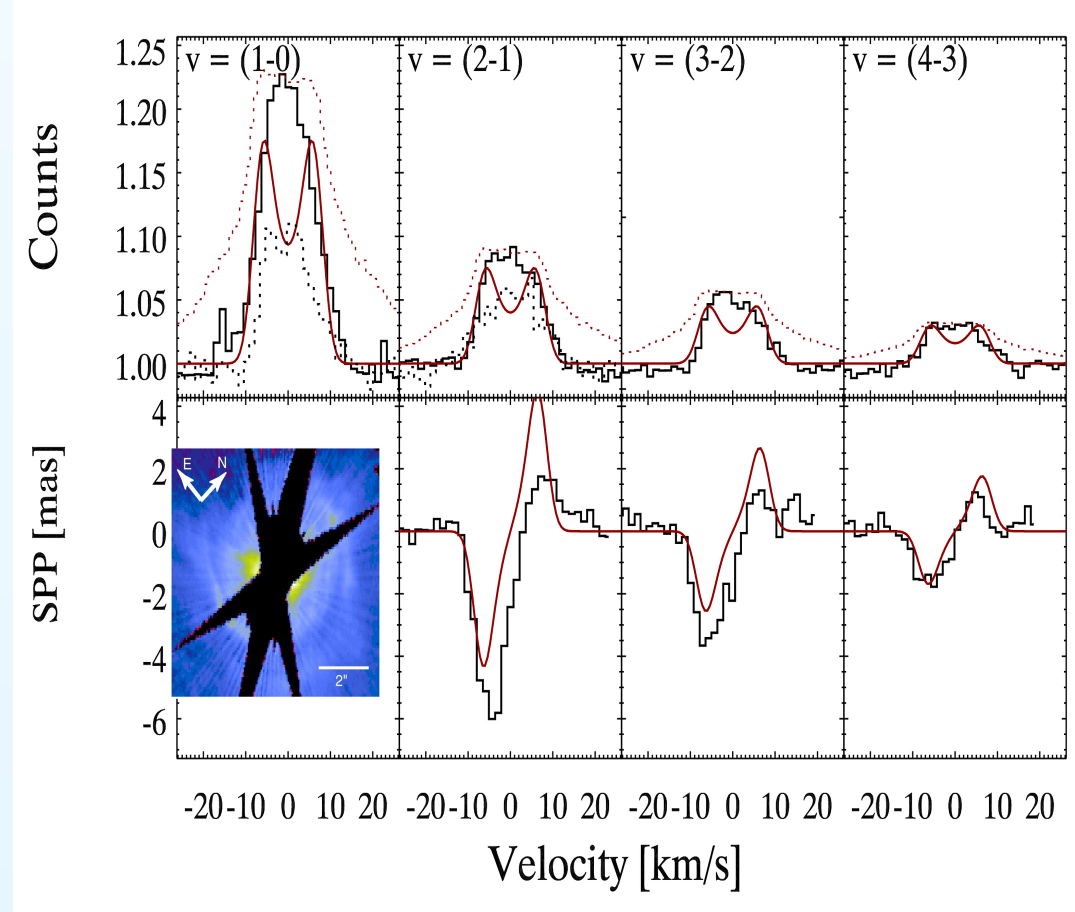

Figure 6. *Same as Fig. 3 for HD 100546. with the exception that the image at the* ***(bottom left)*** *is a false color deprojected image from STIS showing rich structure. (Grady et al. 2001).*

Gas and dust rich inner disks, but no CO detected < 12 AU

Table 1. Spatial information for the *averaged* vibrational transitions shown in Figs 3 and 6, and the radii used to model the kinematics.

HD 97048	cont.	v(2-1)	v(3-2)	v(4-3)	$R^{model}_{in,out}$
SPP [AU]	0	$18.2^{\pm0.9}$	$22.1^{\pm2.7}$	-	12
FWHM [AU][a]	$21.2^{\pm1.6}$	$\geq23.8^{\pm1.1}$	$\geq23.0^{\pm1.1}$	-	45
HD 100546					
SPP [AU]	0	$10.0^{\pm0.5}$	$8.7^{\pm0.5}$	$9^{\pm1.5}$	15
FWHM [AU]	$10.0^{\pm0.9}$	$\geq13.7^{\pm0.6}$	$\geq13.1^{\pm0.6}$	$\geq11.5^{\pm0.7}$	40

[a] Note that this FWHM is a function of continuum + line emission, but that the SPP has been corrected for the continuum dilution, and thus is a function of the line emission.

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