

Gas signatures of Herbig Ae/Be disks probed with Herschel SPIRE spectroscopy

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Abstract. Herbig Ae/Be objects, like their lower mass counterparts T Tauri stars, are seen to form a stable circumstellar disk which is initially gas-rich and could ultimately form a planetary system. We present *Herschel* SPIRE 460–1540 GHz spectra of five targets out of a sample of 13 young disk sources, showing line detections mainly due to warm CO gas.

Keywords. circumstellar matter, planetary systems: protoplanetary disks, ISM: molecules

1. Observations, processing, and line detections

In a 16-hour guaranteed time project (P.I. Göran Olofsson) using the SPIRE Fourier Transform Spectrometer (FTS), spectra in the 460–1540 GHz range were obtained of 13 protoplanetary disks around Herbig stars: AB Aur, HD 100546, HD 97048, HD 163296, T Tau, HD 142527, HD 144432, RY Tau, HD 104237, HD 36112, HD 169142, HD 100453 and TW Hya. The data were processed in HIPE 9, followed by subtraction of a median background signal obtained from the off-center detectors. All spectra show a smoothly rising dust continuum, while only the first five of the above list show detectable line signal. The disk emission lines, presented in Fig. 1, are unresolved both spatially (the SPIRE FTS beam is 42–17'') and spectrally ($R \sim 400$ –1300). Spectral lines are fitted using a dedicated Fourier Transform line fitter tool (available online at www.uleth.ca/phy/naylor/). Table 1 lists lines detected in at least one target besides T Tau.

2. Interpretation and analysis plans

First, it is evident from the observations that the continuum and CO lines toward T Tau originate in an extended protostellar envelope rather than in a much smaller disk. This is likely also the case for the cold H₂O vapor. Second, the N⁺ line toward HD 163296 is 10⁴–10⁵ times brighter than what is predicted by current (X-ray) irradiated disk models (e.g., Aresu *et al.* 2011), even when invoking X-ray luminosities much higher than appropriate for HD 163296. Since N⁺ is also detected in all off-center detectors up to 1' away from the star, we hypothesize that a single (external) source is responsible for ionizing nitrogen both in the disk/jet of HD 163296 and in the surrounding gaseous medium.

Finally, we plan to use the unique set of 4–3 to 13–12 lines of CO and ¹³CO ($E_{\text{up}}/k \sim 50$ –500 K) to characterize warm gas in the Herbig protoplanetary disks.

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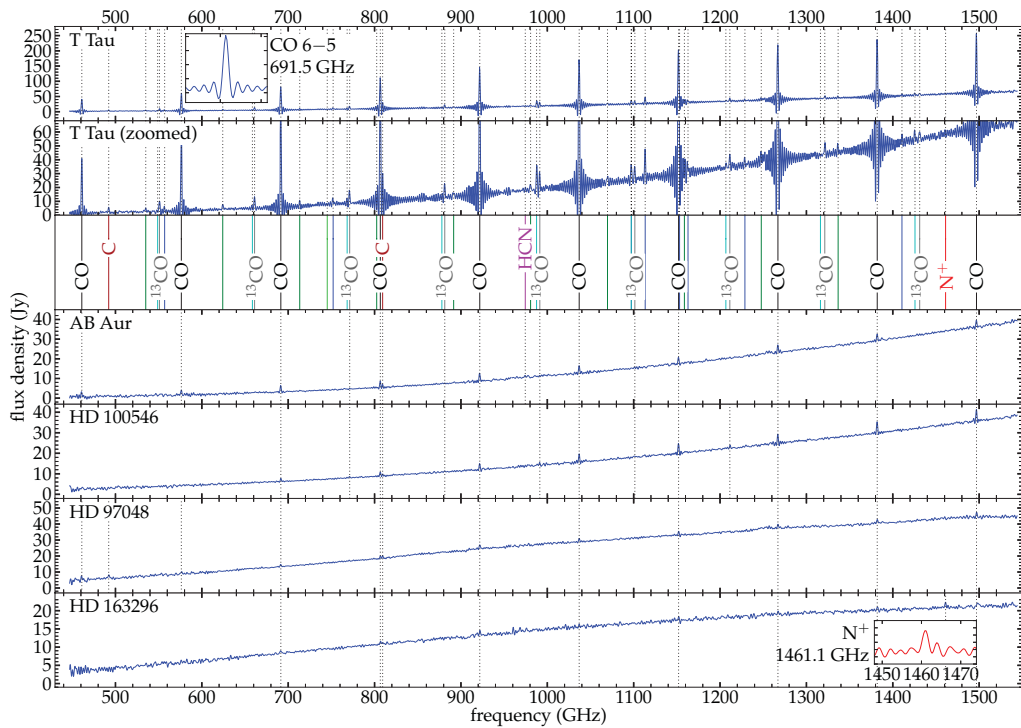


Figure 1. *Herschel* SPIRE-FTS spectra of T Tau (with the second panel zoomed in on the flux density axis to highlight weaker lines), AB Aur, HD 100546, HD 97048 and HD 163296. Detected gas lines are indicated by vertical dotted lines. The ringing of the sinc-shaped line profile typical of an FTS (see inset in top panel) is particularly noticeable near the ^{12}CO lines in T Tau.

Table 1. Spectral lines identified in the SPIRE spectra of at least one target besides T Tau.

line transition ⁽¹⁾	E_{up}/k (K)	frequency ⁽²⁾ (GHz)	line flux ⁽³⁾ ($10^{-18} \text{ W m}^{-2}$) [uncertainty]				
			T Tau	AB Aur	HD 100546	HD 97048	HD 163296
CO 4–3	55	461.0	448 [5]	35 [2]	-	37 [3]	-
$\text{C}^3\text{P}_1\text{--}^3\text{P}_0$	24	492.2	35 [5]	-	-	26 [3]	-
CO 5–4	83	576.3	599 [5]	25 [2]	-	13 [3]	-
CO 6–5	116	691.5	740 [5]	38 [2]	17 [2]	17 [3]	8 [2]
^{13}CO 7–6	148	771.2	100 [5]	6 [2]	7 [2]	-	-
CO 7–6	155	806.7	1141 [5]	38 [2]	22 [2]	17 [3]	10 [2]
$\text{C}^3\text{P}_2\text{--}^3\text{P}_1$	62	809.3	93 [5]	14 [2]	8 [2]	17 [3]	5 [2]
CO 8–7	199	921.8	1531 [5]	48 [2]	36 [2]	31 [3]	16 [2]
HCN 11–10	281	974.5	10 [4]	11 [2]	-	-	-
^{13}CO 9–8	238	991.3	75 [4]	5 [2]	14 [2]	-	-
CO 9–8	249	1036.9	1106 [4]	47 [2]	45 [2]	25 [3]	9 [2]
CO 10–9	304	1152.0	1202 [4]	39 [2]	53 [2]	29 [3]	12 [2]
^{13}CO 11–10	349	1211.3	50 [4]	-	14 [2]	-	-
CO 11–10	365	1267.0	1225 [4]	46 [2]	51 [2]	32 [3]	12 [2]
CO 12–11	431	1382.0	1224 [4]	38 [2]	59 [2]	24 [3]	10 [2]
$\text{N}^+ \text{}^3\text{P}_1\text{--}^3\text{P}_0$	70	1461.1	-	-	-	-	17 [2]
CO 13–12	503	1496.9	1262 [4]	44 [2]	62 [2]	41 [3]	11 [2]

Notes: ⁽¹⁾ In addition to the lines listed here, in T Tau we detect six H_2O lines and ~ 25 others identified as ^{13}CO , C^{18}O , HCO^+ , HCN and N_2H^+ . ⁽²⁾ Rest frequency from JPL, Pickett *et al.* (1998), except N^+ from SLAIM. ⁽³⁾ A ‘-’ indicates a non-detection. Uncertainties include only the formal fitting error.

References

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