

# Gas remnants in discs around T Tauri stars

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## Abstract

We are conducting an extensive single-dish survey of the gas content of T Tauri discs in Taurus. The spectra can be divided into 2 main classes: broad profiles associated with gas-rich discs of radius 100-500au, and narrow lines mostly from line-of-sight ambient gas. The presence of these large gas discs is compared with other T Tauri phenomena, such as the CTTS/WTTS transition, dust excesses and age.

## The Survey: What are the single-dish CO spectra tracing?

Sensitive single-dish J=3-2 <sup>12</sup>CO spectra have been obtained by the JCMT of ~60 of the more evolved T Tauri stars (>1Myr) in Taurus; many already have extensive optical, infrared and mm dust continuum data. The line profiles are used to derive basic information about the emitting region.

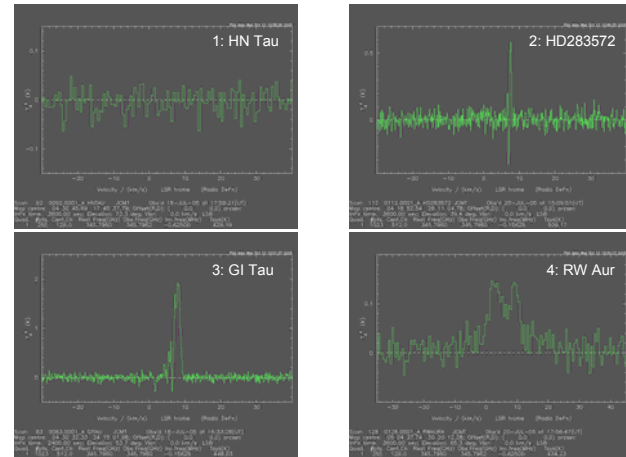
The spectra show a wide range of characteristics, from no line at all, through to broad double-peaked profiles. We have classified them into 4 types based on their spectra, as described below.

A positive CO detection is not guaranteed to be associated with the star: Extended gas near the star or along the line of sight will give +ve or -ve features. But in these cases the line profile is generally narrow (<1km/s). Broad lines (>2km/s) indicate gas associated with a potential well – either a disc, or an extended outflow driven by inner disc accretion. Our sensitivity limit implies we can detect discs of radius ~100-500au at typical inclinations of 40°. Face-on discs (inclination <10°) are difficult to detect.

**Discs or outflows?** Without interferometric mapping (eg with ALMA) we cannot be sure whether the class 3-4 (wide) profiles are from large discs or from outflows (driven by a compact accreting disc). But many of the class 4 spectra are characteristic of rotating discs (see lower right spectrum). *In either case, a broad line means that the star is likely still surrounded by a gaseous disc.*

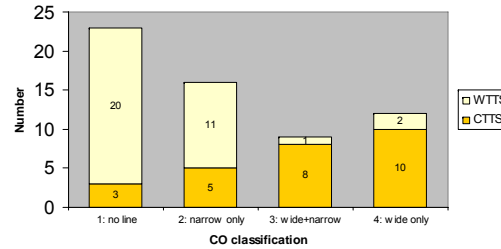
## Examples of the 4 classes of CO spectra, and (below) their interpretation.

(note: the velocity scales are the same)



Class	CO line profile characteristics	Likely location of gas	Interpretation
1	No emission	No gas in range 100<R<10000 au	No gas disc or remnant cloud
2	Narrow +ve/-ve features (< 1 km/s full width)	No gas in range 100<R<500 au	No gas disc. Possible ambient gas
3	Broad emission Narrow absorption features	Gas in range 100<R<500 au. Possible ambient gas.	Compact gas disc, or possibly outflow. Possible remnant cloud extended over ≥0.04pc.
4	Broad emission No narrow absorption features	Gas in range 100<R<500 au. No ambient gas.	Gas disc, or possibly outflow.

## CO line emission vs TTS type



## CO and TTS classification

The histogram illustrates the fraction of Classical vs. Weak-line TTS as a function of the CO line characteristics (from 1:no line to 4:broad CO profile).

Stars in the leftmost two bins have no large (~200au) gas disc. The rightmost two bins are stars with gas-rich discs.

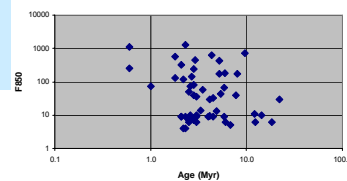
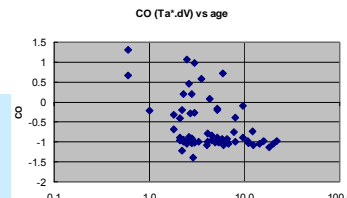
The high fraction of Classical TTS in the rightmost bins indicates a good correlation between the presence of large gas discs and the CTTS indicators. Approx. 70% of CTTS have large gas discs, as compared with only 9% of WTTS. This is similar to the fraction of TTS with dust discs.

## Evolution of gas in discs

Is there evidence of changes in the gas tracers as a function of age?

The mean ages of the stars depend on the CO line characteristic (right); TTS without gas discs are ~5-8Myr, compared with <4Myr for those with discs (note the sample so far has selected against the very youngest discs, <2Myr).

Class 1 : 8.1Myr  
Class 2 : 5.0Myr  
Class 3 : 4.3Myr  
Class 4 : 3.2Myr



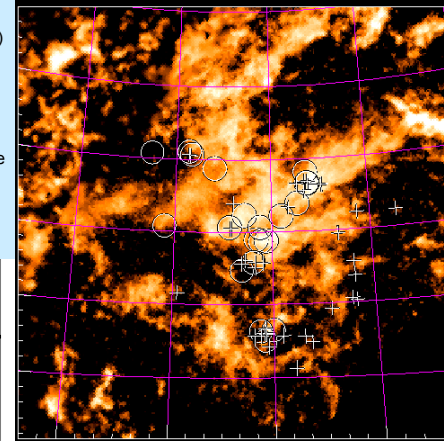
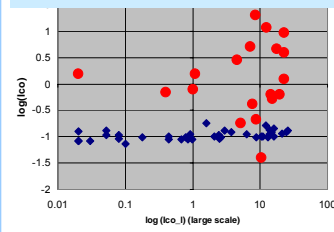
## Evolution of gas and dust

The comparison (right) of the CO intensity vs. stellar age and the dust continuum flux vs. stellar age shows no significant difference.

**This implies that the gas and dust removal timescales are similar – about 10Myr.**

## Discs and ambient gas

The large-scale CO map of Taurus (right) shows the location of the TTS with gas discs (circles) and without gas discs (crosses). The plot below shows the relation between CO intensity of the disc (~200au) and on the large scale (10<sup>4</sup>au). Gas discs (red) tend to be confined to the dense cloud cores, however, there are some odd isolated cases. Gas-free discs (blue), can be found throughout Taurus - even in the denser cores.

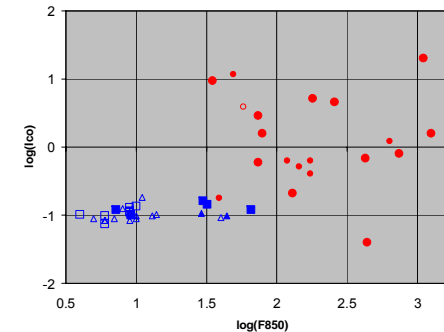


## Gas vs. dust content of discs

Comparison of the gas content (integrated CO) and dust content (850μm continuum flux; Andrews & Williams, 2005) of the discs is shown below.

This shows the discs have one of two conditions: those with an 850μm flux of >30mJy (equivalent to a total mass of >1M<sub>Jupiter</sub>), almost of which have detected CO, and those with lower flux, none of which has detected CO. Therefore:

- The disc mass needs to be ~1 M<sub>J</sub> before significant CO can exist
- There is no evidence for gas-rich/dust-poor discs



**Key:**  
Red: TTS with evidence of gas discs (CO class 3 or 4)  
Blue squares: TTS with narrow CO (class 2)  
Blue triangles: TTS with no CO (CO class 1)

Filled symbols are submm dust detections  
Open are continuum upper limits

Note: the only two stars with a submm flux>10mJy but without CO emission are both binaries.

## Conclusions

- Single-dish CO spectra are a simple and reliable tracer of CTTS
- Wide CO profiles imply extended gas, likely from a disc of ~200au
- The removal timescales of gas and dust from TTS discs are similar
- A minimum disc mass of ~1M<sub>J</sub> (as derived from dust) is required before CO is present in the discs
- There is no evidence for gas-rich/dust-poor discs