Exploring terrestrial planet-forming zones in protoplanetary disks with CO line profiles

Jeanette Bast, K.M. Pontoppidan, E.F. van Dishoeck and the CRIRES team

Leiden Observatory, 2300-RA Leiden, NL and California Institute of Technology, CA 91125, U.S.A.

bast@strw.leidenuniv.nl

Abstract

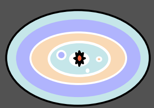
We present results from a large VLT program designed to provide information about the physical structure of the gas in the terrestrial planet-forming zones of protoplanetary disks. This inner gaseous region (radii less than 10 AU) can now be explored in unprecedented detail with the new high spectral resolution (R = 100 000) spectrometer CRIRES at the VLT. We clearly resolve the CO (4.7 μm) line profiles in our sample of more than 50 protoplanetary disks in different evolutionary phases and clouds. Surprisingly, 9 of these sources show single peaked line profiles where a Keplerian profile is expected. We here present a study of the single peaked CO lines and try to explain their origin. These results will be put in the context of the evolutionary phase of the disk, e.g. heavy accretor or not.

Introduction

Our sample of more than 50 young protoplanetary disks shows 9 sources with single-peaked line profiles, (Fig. 2 and 3). This is surprising since a Keplerian double peaked CO emission line profile is expected from the warm CO gas in the inner parts of the rotating disks, as shown below, and seen in most emission sources (e.g., VV Ser).

Basic Keplerian model

- Power law $T = T_0 \cdot (R / R_0)^{-\alpha}$
- T_0 = 3000 K
- R_0 = 0.10 AU
- LTE



•The model can explain double-peaked line profiles, however not the single peaked ones, unless the profile is narrow and the disk is seen face-on or if the emission is extended beyond 60-70 AU and the temperature is set to a constant value (Fig. 1). However lack of extended emission in our data limits their origin to the inner warm part of the disk (1-10 AU).

CRIRES at the VLT

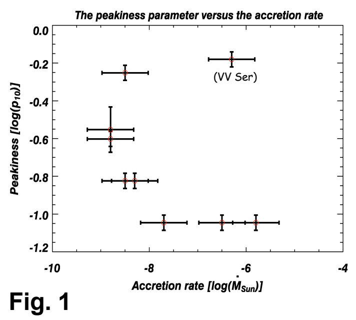


Fig. 1

Results

•To characterize the single-peaked profiles, a peakiness parameter is devised (see below).

• A negative correlation between the peakiness parameter and the accretion rate is shown. (correlation coefficient -0.75 without the Herbig star VV Ser)

• The broad base of the line may be explained by high accretion or outflowing material.

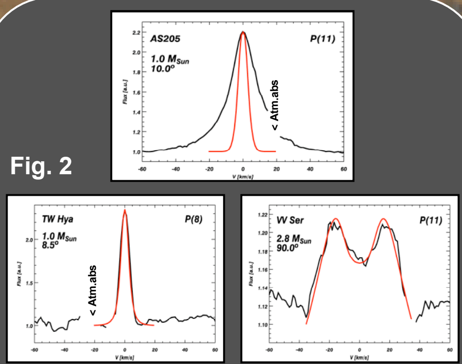


Fig. 2

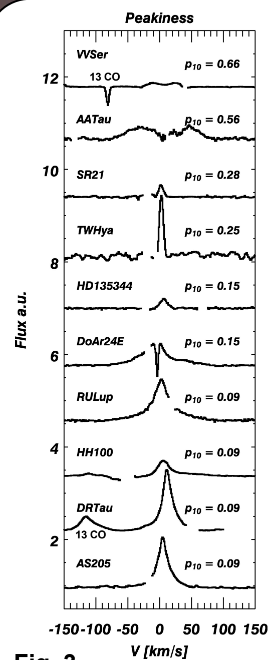


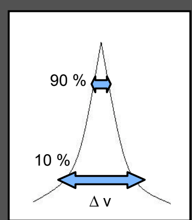
Fig. 3

Peakiness

A peakiness parameter has been constructed to measure how the width of the line at 90% of its height is changing with the line width at 10%.

$$p_{10} = \Delta v_{90} / \Delta v_{10}$$

The smaller the value the more peaky the line profile is.



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