Modeling Spectro-astrometric Observations of CO in Circumstellar Disks

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Planet Formation

From atmosp.physics.utoronto.ca

From lpl.arizona.edu

From http://www-star.qmw.ac.uk/~masset/intertmr.html

From astro.psu.edu

NASA/ESA and A.
Observing
Wavelength ➔ Spatial

Acke & van den Ancker (2006)

Raw Data ➔ Spatial Pixels
Sky Line ➔ Spatial Pixels

Continuum ➔ Signal

Spectral Pixels
Spatial Pixels
Spectral Pixels
Spectro-astrometry

- If spatially extended, can find spatial and velocity information about extended object
- Used to observe BD companions, jets, binaries, etc.
- Can also be used for circumstellar disks

Pontoppidan et al. (2008)
Parameters

- Disk size
- Inclination - i
- Position angle - PA
- Distance
- Mass of star
- Disk flux
- Slit size
Disk Flux

\[ F(r) = \text{Flux from fluorescence model} \]

\[ F \approx \frac{1}{r} \]
Disk Velocity Field
Connecting to Flux
Connecting to SA Signal

Signal is taking “COM” of the flux from the disk for a specific velocity:

$$\frac{\sum F_i \times y}{\sum F_i}$$

This case is pretty boring
Velocity and Spectro-astrometry

![Graph showing velocity and spectro-astrometric data with axes labeled AU and Velocity (km/s).]
Example Data

van der Plas et al. (2009)

Brittain et al. (2009)
So Why is this important?

- Measure of velocity field independent of Keplerian assumption
- Can independently measure:
  - inclination
  - position angle
  - stellar mass
- Also...
Other Effects

Lin et al. (2006)
Evidence for Asymmetry?

Pontoppidan et al. (2008)

Brown et al. (2009)
Adding a Spiral Arm

- $F(s) = 10 \ F(ns)$
- $r = 7 \ \theta$
Flux Comparison

May not see this in flux signal!!
Spectro-astrometric Signal
Technique for Comparison
Spectro-astrometric Signal

Still observable with “non-optimal” PA
Summary

Spectro-astrometry is an extremely unique way to gain high spatial resolution from the disk, and find structures that cannot be probed with other techniques.