Observational studies of gas in circumstellar disks around Young Stellar Objects

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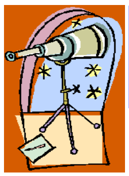


They are several fundamental questions concerning protoplanetary disks that await an **observational answer**

- ★ What is the disk density distribution as a function of the radius?
- ★ What are the dynamics of the disk?
- ★ What is the "real" dust to gas ratio?
- ★ Time scales. How fast does the disk disappear?
- ★ What is the mechanism of Giant Planet Formation? core accretion? gravitational instabilities?

Disks could be observationally studied using the GAS or the DUST

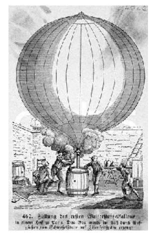
However, until now the effort has been focused mainly on the study of the dust

Dust causes the bulk of infrared radiation and strong spectroscopic features in the Infrared

Important discoveries have been done from dust BUT crucial information is still missing

- ☹ Dust does not provide kinematic information
  - *Spectrospic dust features are not sharp.*
- ☹ Dust not allows a direct measure of the disk mass
  - *Gas to dust ratio in a disk is expected to change with the disk evolution.*
  - *For estimating the disk's mass from dust observations models with high parameter uncertainties are required.*

Gas studies are essential to complement dust studies



WHY IS THE GAS SO INTERESTING ?

99% of the mass of the disk is GAS

- ☺ direct measure of the disk mass
- ☺ direct estimation of radial density distribution

Sharp lines

- ☺ kinematic information !

Giant Planets are gaseous

 connexion to exoplanets formation

What is required to study the gas?

Extremely High Spectral Resolution R~100000

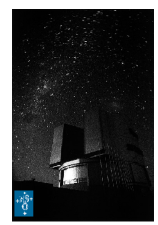
- ☺ resolve the weak features of the gas
- ☺ resolve disk's velocity profile

High Angular Resolution

- ☺ resolve the disk : 8 – 10 m class telescope

Large Aperture

- ☺ obtain the required sensitivity



This research is now possible thanks to the recent development of a new generation of high resolution spectrographs at ESO-VLT

What kind of stars we need ?

- Young stars

age < 10 My

- Nearby, big and bright enough

to be able to resolve the disk

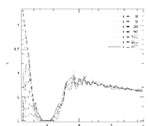
Herbig Ae/Be stars !!!

- Young *age < 10 My*
- Intermediate mass stars 2 – 10 $M_{\odot}$
  - *Bigger circumstellar disks*
- Fully radiative stars
  - *Brighter*
- Disks are "passive"
  - *Radiate mainly by star light reprocessing*

The GOAL

- Determine the disk's radial density distribution
- Obtain observational information on the gas dynamics
- Determine disk's life time
- *Gaps ?*
- *Spiral Waves?*
- *Resonances?*

This research would provide crucial observational constraints about giant planet formation scenarios



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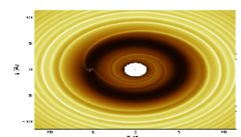

W. Kley. U. Tübingen

Method and Instrumentation

High Resolution Infrared Spectroscopy at ESO-VLT

☆ ISAAC ☆

VLT Infrared Spectrometer And Array Camera (in service since 1998)

- Wavelength range 1-5μm
- up to medium resolution Rs ~ 3000
- Pixel size 0.146 arcsec

☆ VISIR ☆

VLT Imager and Spectrometer for mid Infra Red (in service soon)

- Wavelength range 8-13 and 17-24 μm
- up to high resolution R=25000
- Pixel size 0.075, 0.127, 0.2 arcsec

☆ CRIRES ☆

High-Resolution IR Echelle Spectrometer (in service Oct 2004)

- Wavelength range 1-5 μm
- up to high resolution Rmax = 100.000
- Pixel size 0.1 arcsec
- Adaptive Optics