

# Outflows from Young Stellar Objects

## MHD, Radiation & Chemistry

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# Outline

1 Introduction

2 Motivation

3 Methods : Numerical Simulations

4 Outflow Dynamics : Launching

5 Outflow dynamics : Propagation

6 Summary

# Star formation : What do we know

# Star formation : Feedback

Talk about winds and outflows

# Present challenges

# Outflow Evolutionary Picture

# Chemistry in outflows

# Molecular bullets and EHV emission

# Numerical code

# Launching and Propagation

# Radiation force

# Chemistry and Cooling

# MHD Acceleration

# Collimation and Radiation

# Force Parameters and its impact

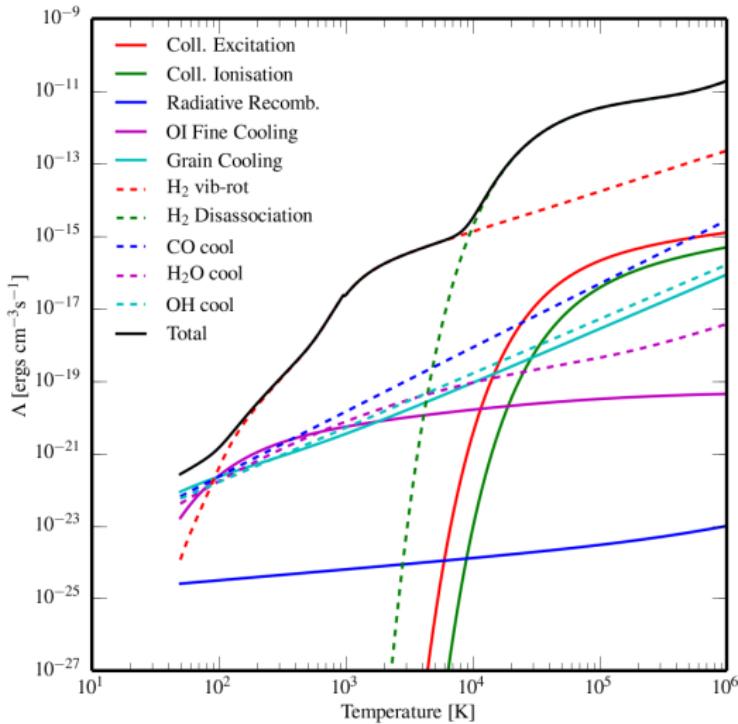
# Resistive effects

# A case of Orion Source I

# Cooling in Jets

Cooling is important

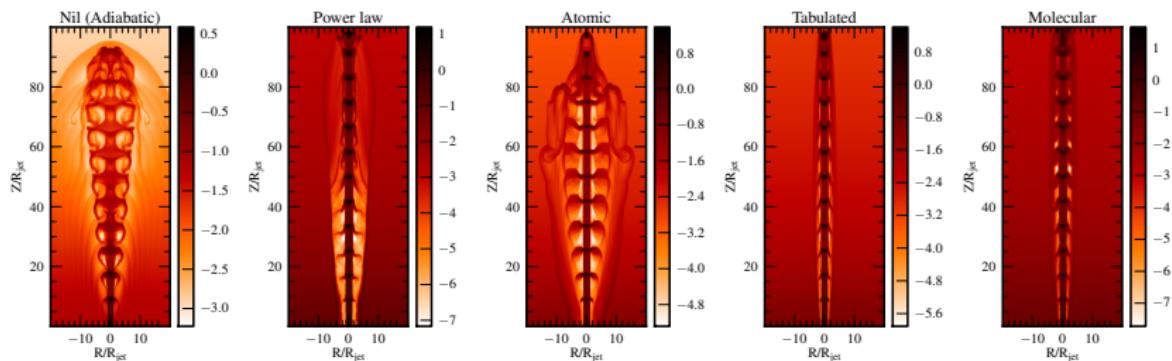
- $t_{\text{cool}} \sim n_0/\Lambda(T) < t_{\text{dyn}}$  (e.g, Blondin, 1990)
- Cooling rate for a molecular medium with  $n_0 = 10^5 \text{ cm}^{-3}$



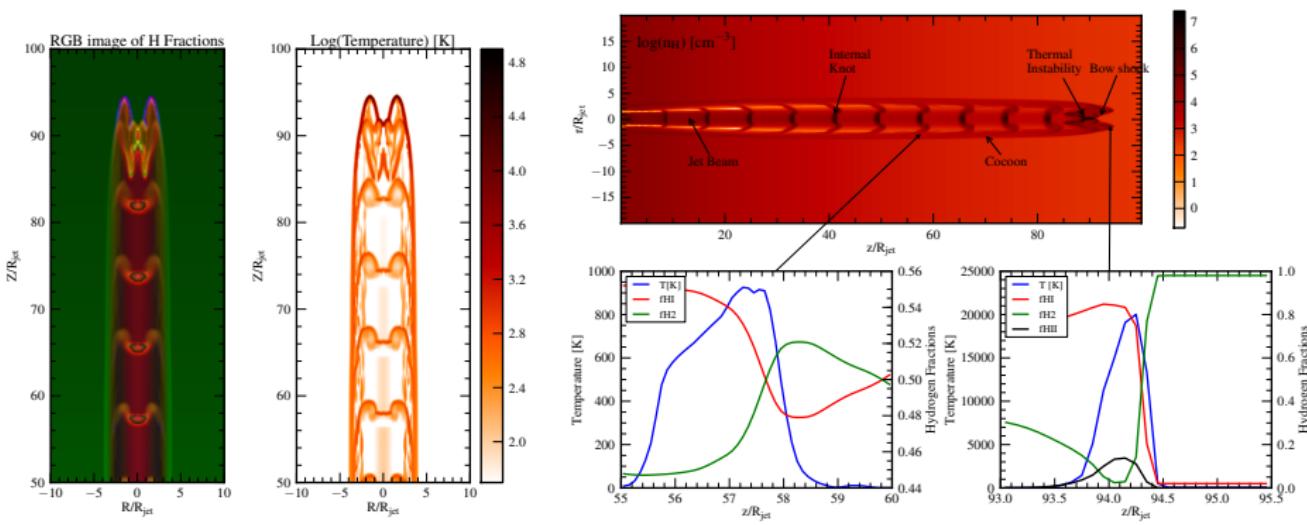
# Cooling in Jets

## Dynamical Effects

- Thinner jets with less pronounced cocoon
- Enhanced density in the internal knots with instable features.
- Thermal Instability in bow-shock of the jet.

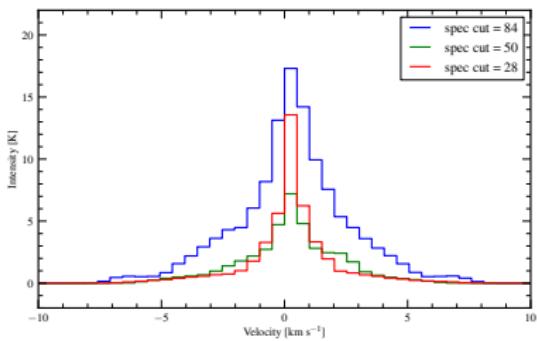
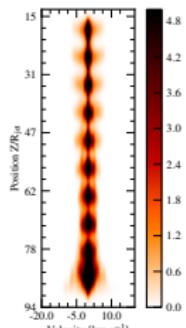
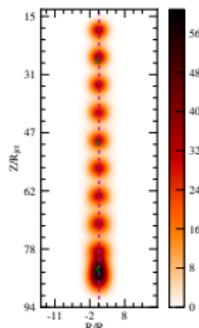


# Molecular Interplay

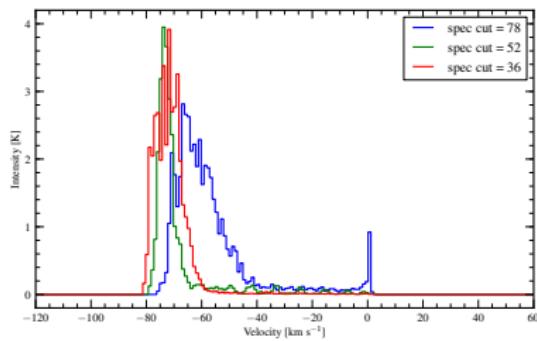
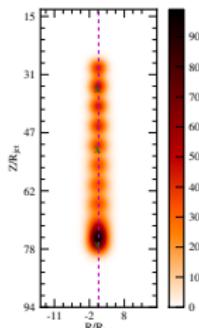


# SiO Abundance and Jet Velocity

# Spectra and PV diagrams : SiO (2-1)



$\phi = \pi/2$  (Plane of Sky)



$\phi = \pi/4$

# Multi-Line survey : Emission I

- Molecular Jet with  $\eta = 3.0$
- Line Intensities with Top Hat Profile.
- Jet is in plane of sky and convolved with a Gaussian beam of  $2.5''$

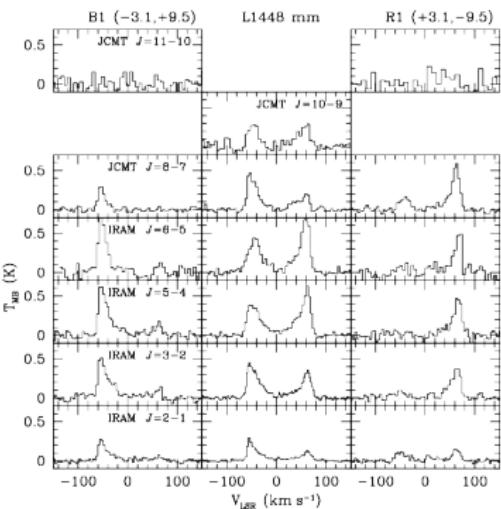
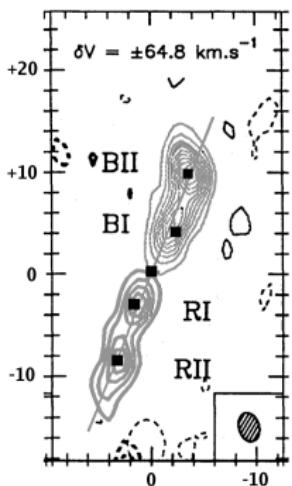
**J = 2->1**

**J = 5->4**

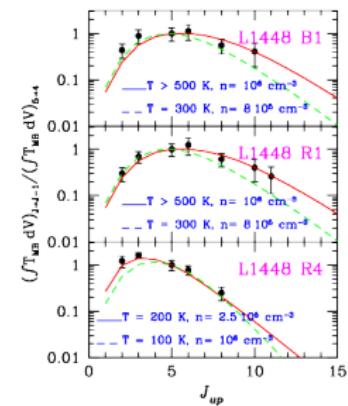
**J = 8->7**

# Multi-Line survey : Emission II

# Case of L1448 (Nisini 2007)



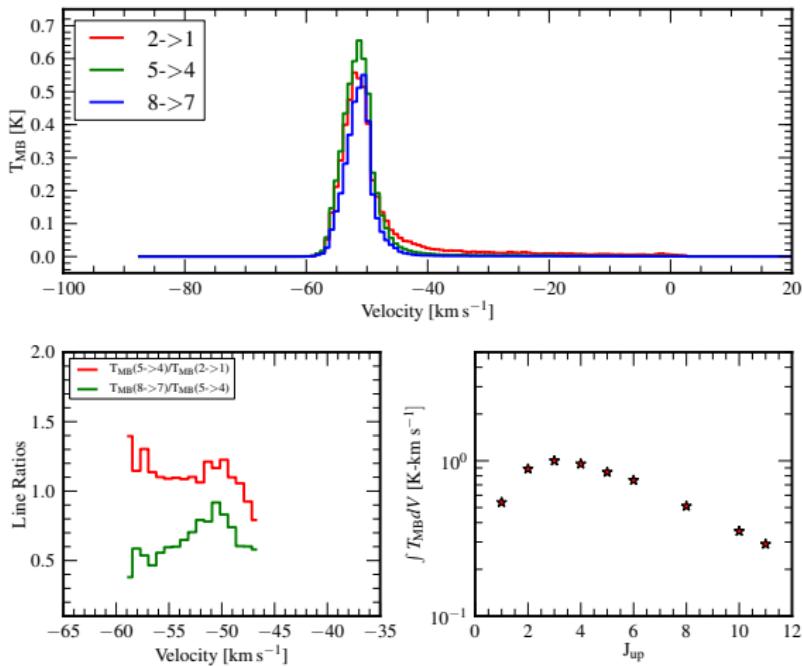
Spectral Features



Kinematic Study (LVG)

# Multi-line survey : Line Ratios

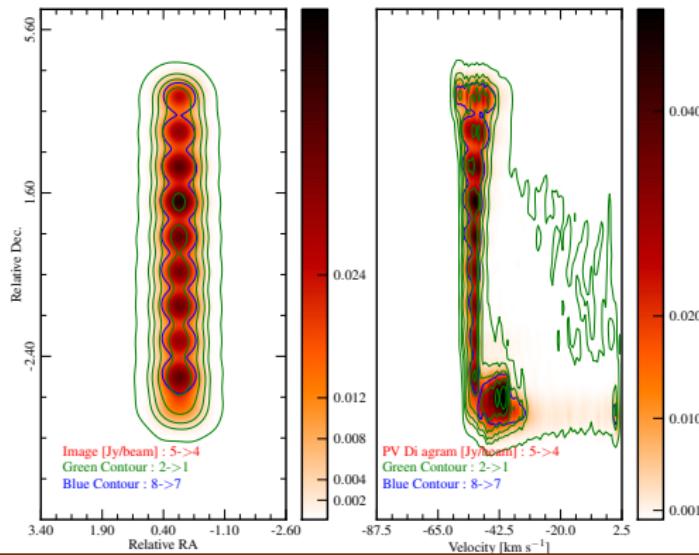
- EHV emission of 0.5 K.
- Line ratios close to Unity.
- Multi-line emission show a distinct fall at high  $J_{\text{up}}$ .



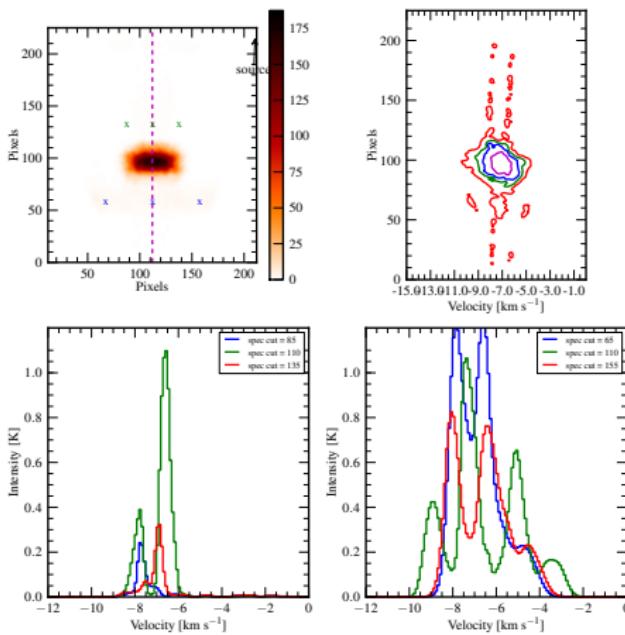
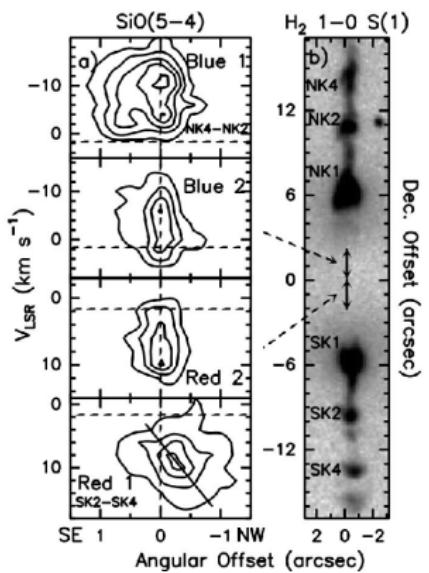
# Predictions for ALMA

ALMA Cycle 2

**Bands 3, 6, 7:** Assuming a source placed at 400 pc.(Orion - HH 212  
(Zinnecker,1998)



# Focussing on a single knot



# Rotation or Wiggles?

# Conclusions