IR diagnostic of Class 0/I jets

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OUTLINE

- Introduction
- Kinematics of Class I jets
- Physical properties of Class I jets

  Electron density (n_e)

  Mass ejection flux ($\dot{M}_{jet}$)
- Work in progress

Low mass star formation

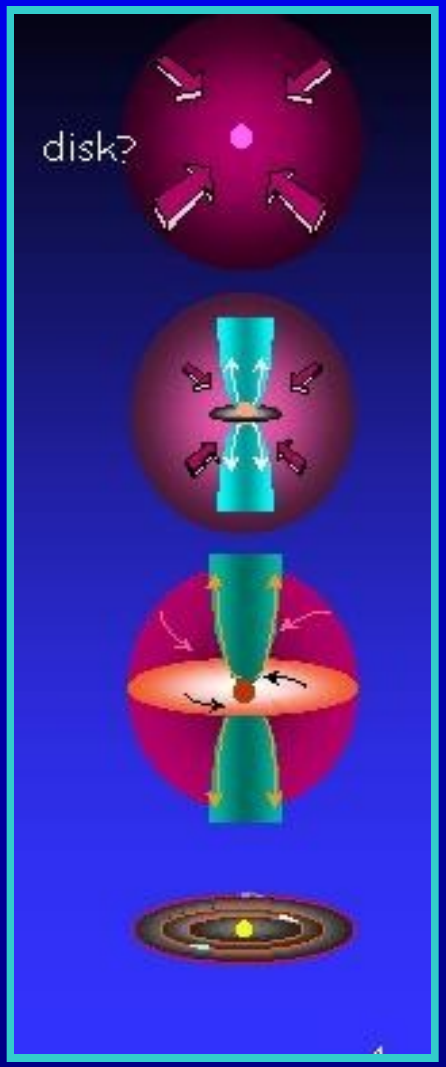
Time

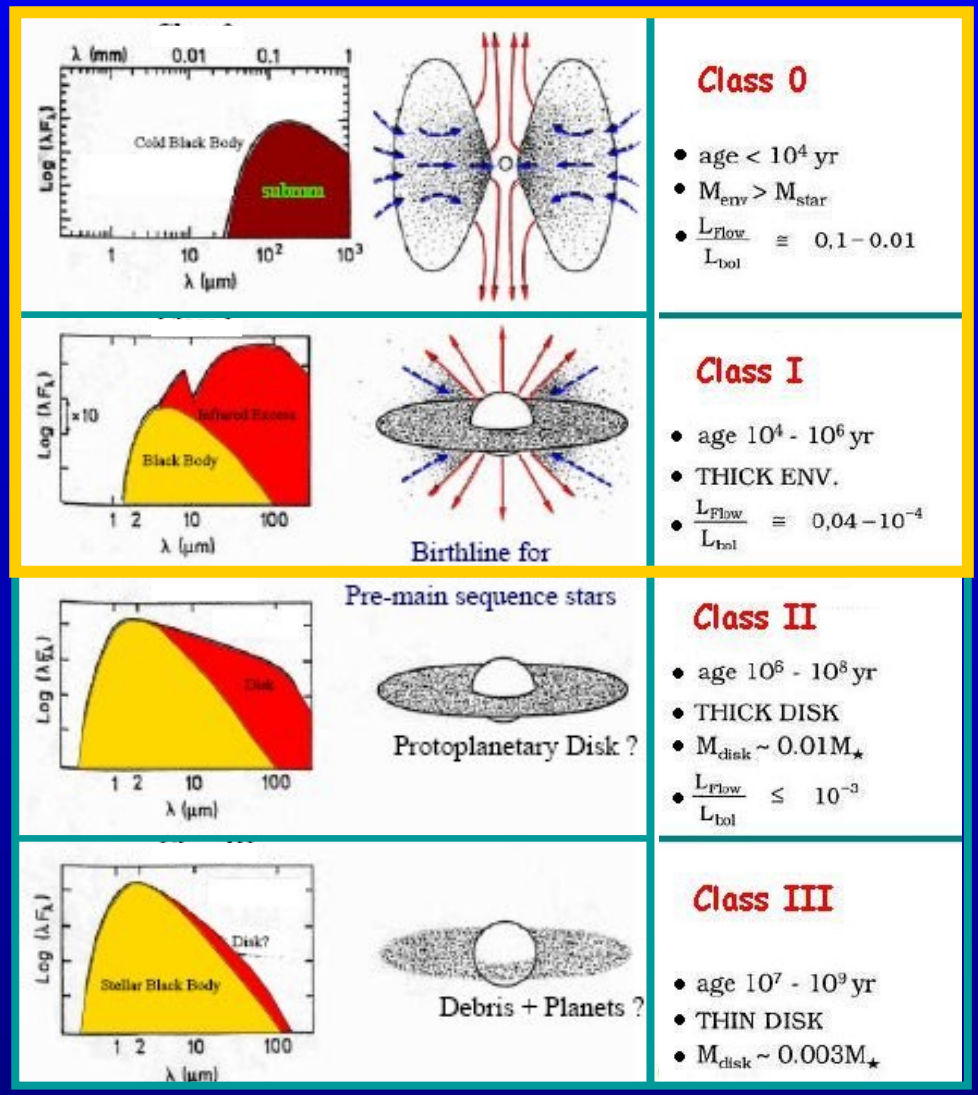
0 - 10^4 yr
pre-stellar core
→ collapse
→ main accretion

10^4 - 10^5 yr
protostar

10^6 - 10^7 yr
T Tauri star

10^8 yr
debris disk
→ ZAMS star





Jets from T-Tauri stars

First studies: optically visible

(class II sources)

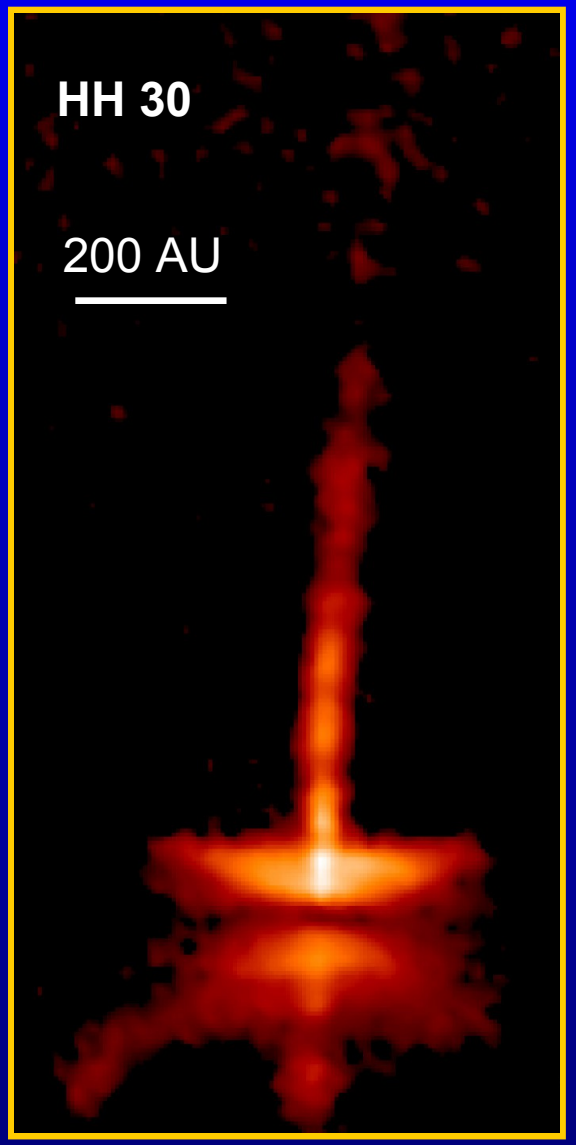
Distance ~ 140 pc

High spatial resolution

<u>Physical properties</u>:

$\dot{M}_{acc} \sim 10^{-8}\ M_o/yr$

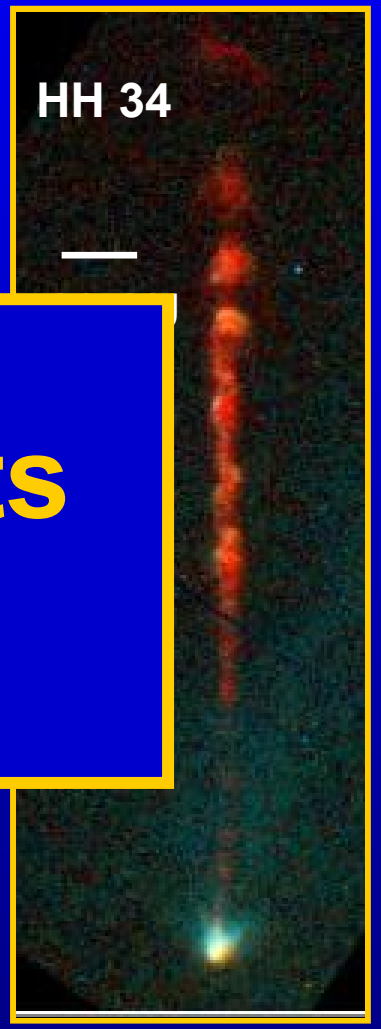
$\dot{M}_{jet} \sim 10^{-9}\ M_o/yr$



Jets from class I sources

Less evolved than T-Tauri jets

High A_V near the source



Do class I and T-Tauri jets form in the same way ?

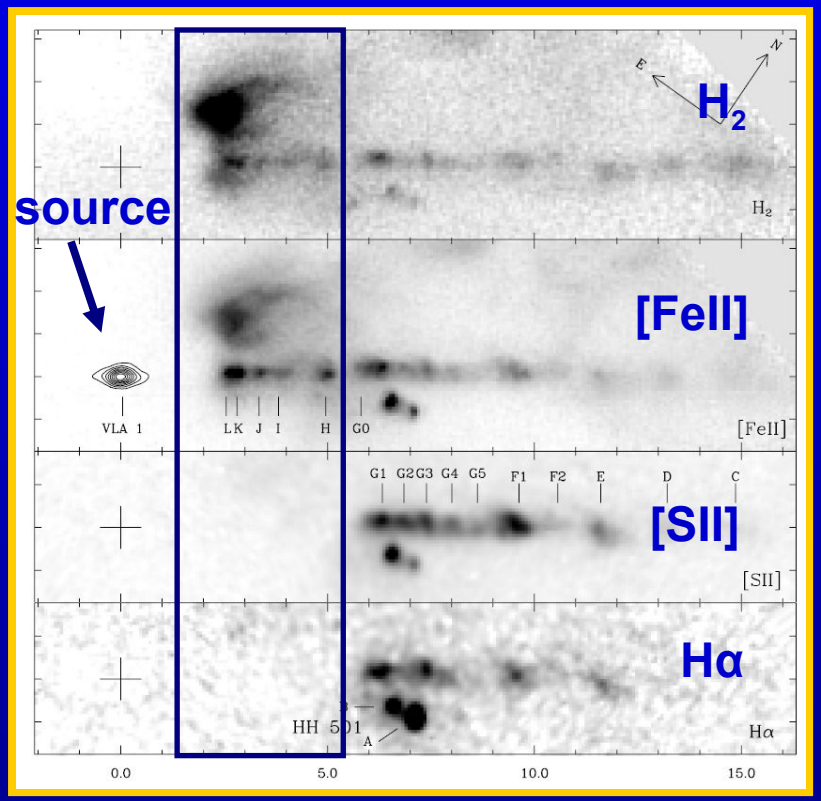
Physical properties:

$\dot{M}_{acc} \sim 10^{-7}\ M_\odot/yr$

$\dot{M}_{jet} \sim 10^{-8}\ M_\odot/yr$

Class I jets through NIR

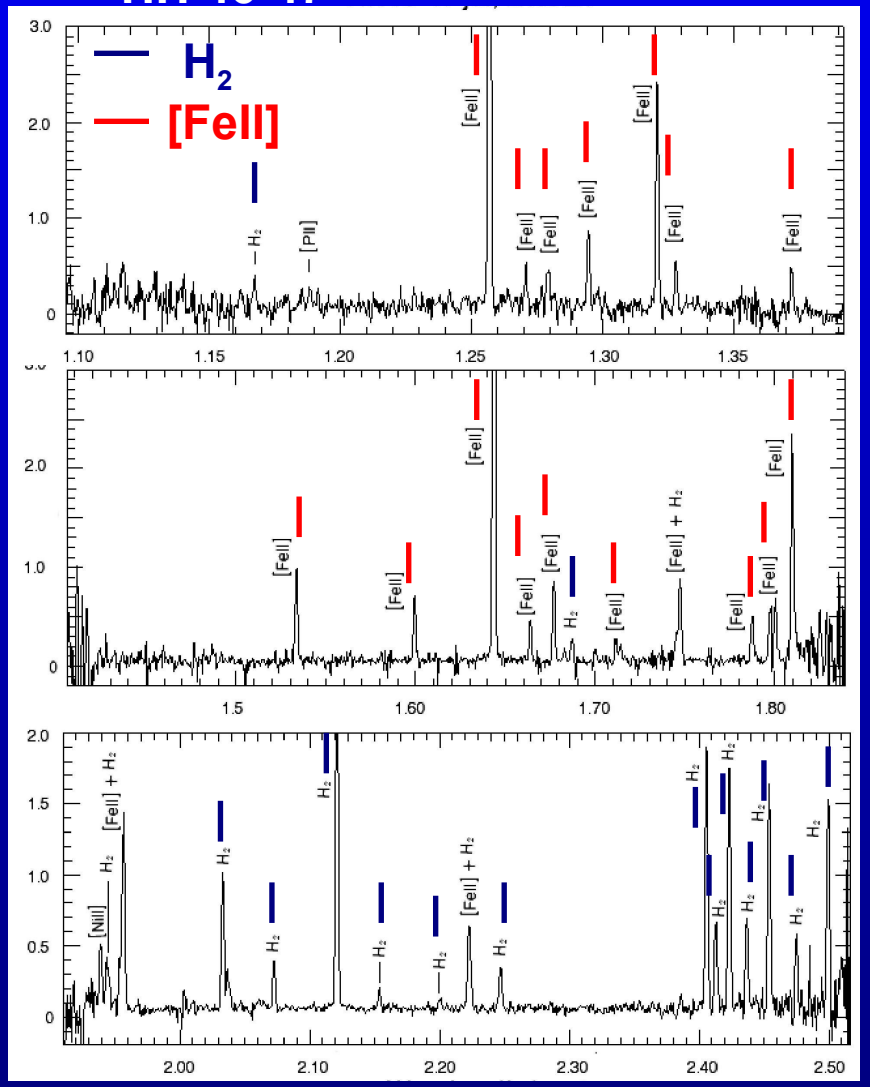
Embedded objects



$A_k \sim 0.1\ A_v$

HH 46-47

ISAAC



Trace gas at low excitation

Observations

NIR spectroscopy

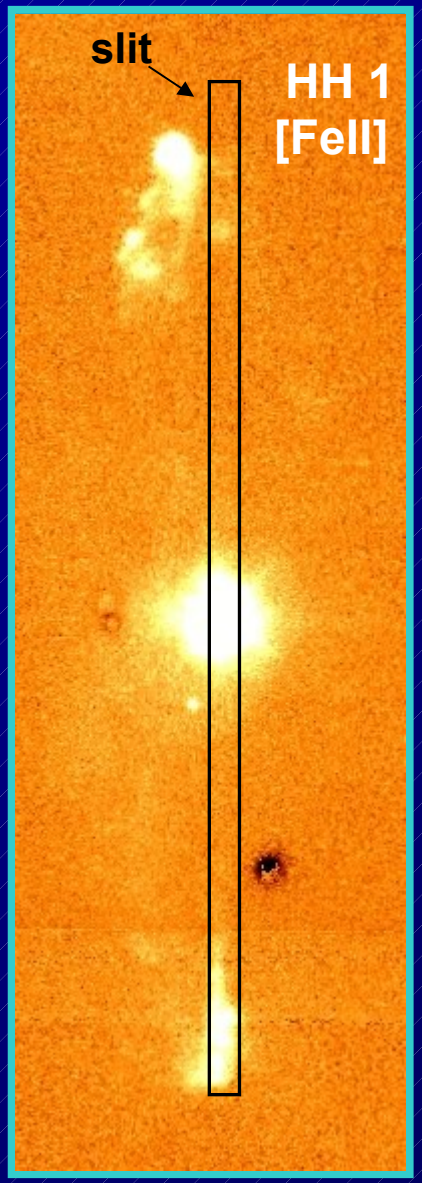
Instrument: ISAAC@VLT

Slit parallel to the jet axis

Medium resolution: H ~ 10000
K ~ 8900

Spatial resolution: 0.148”/pixel

Set of class 0/I jets: HH1, HH34, HH46-47, …



Kinematics

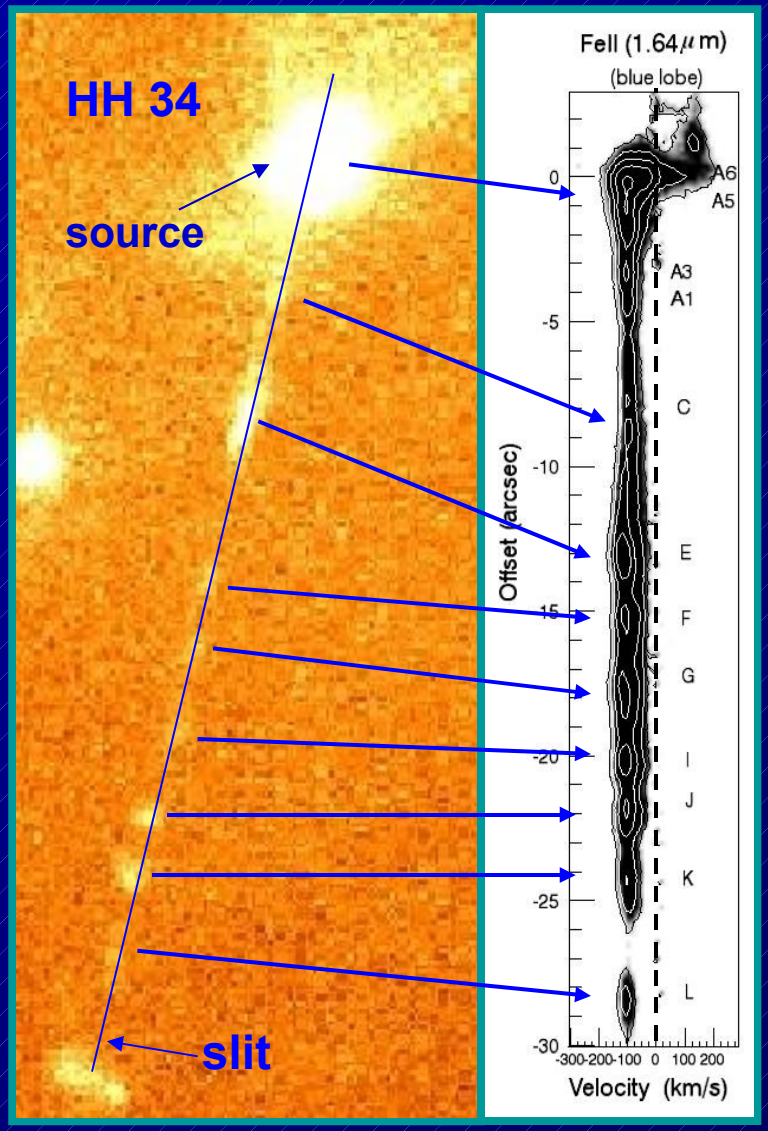
Kinematics

Position-Velocity Diagram (PVD)

Y-axis: distance from the source (arcsec)

X-axis: radial velocity with respect to the source (km/s)

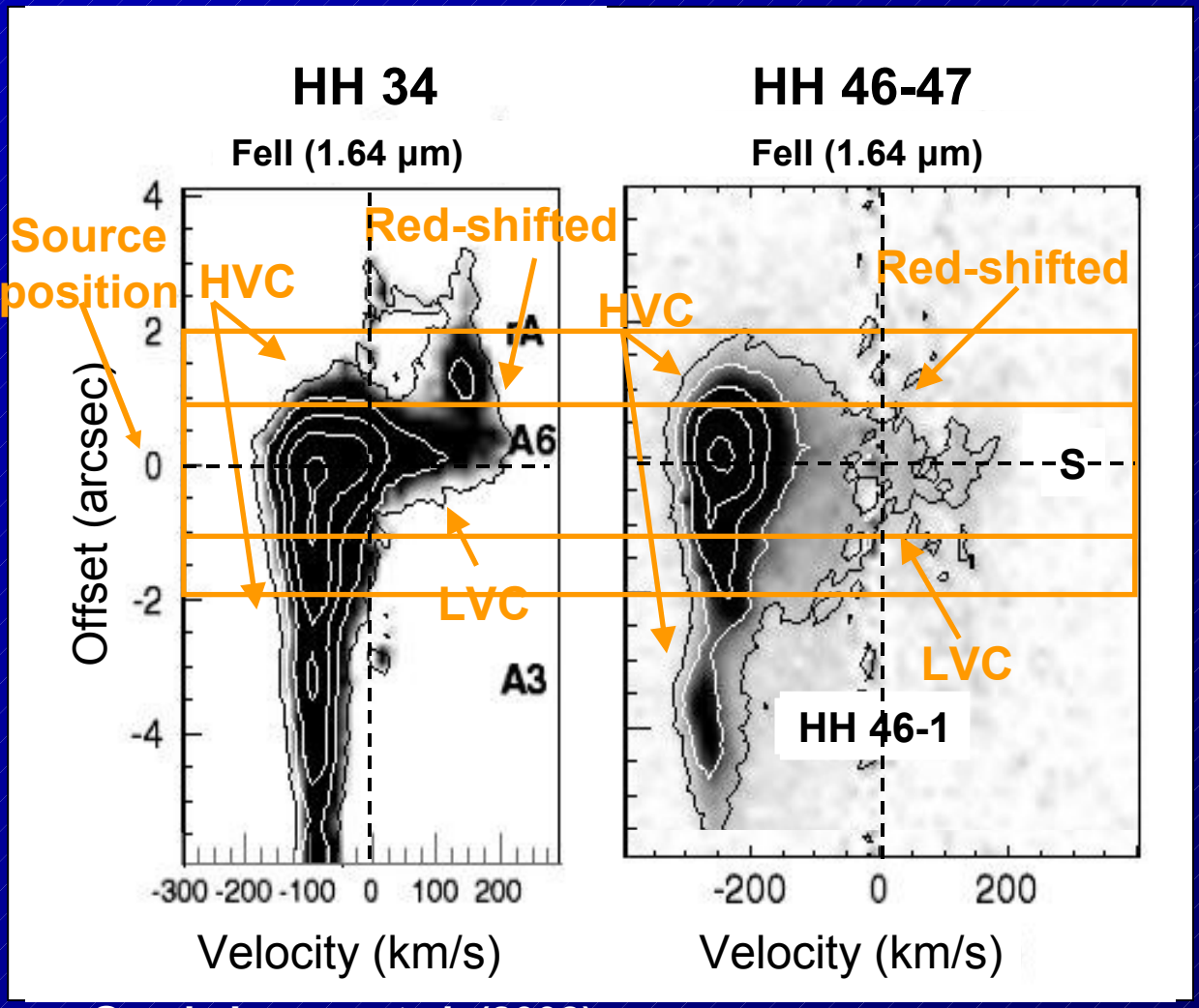
V. variation: along the axis



Kinematics

Atomic component: [FeII] emission

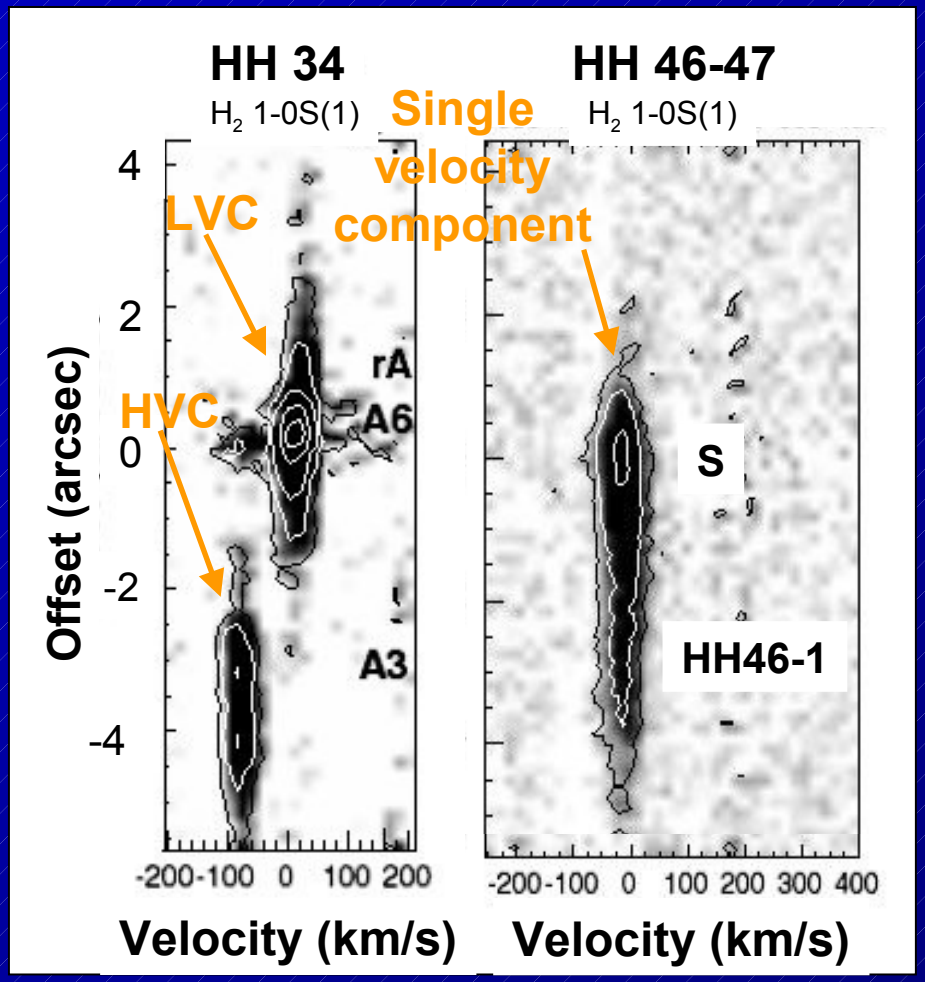
D=400 pc, 1” = 400 AU



Garcia Lopez, et al. (2008)

Kinematics

Molecular component: H_2 emission



Garcia Lopez et al. (2008)

- **HH34**

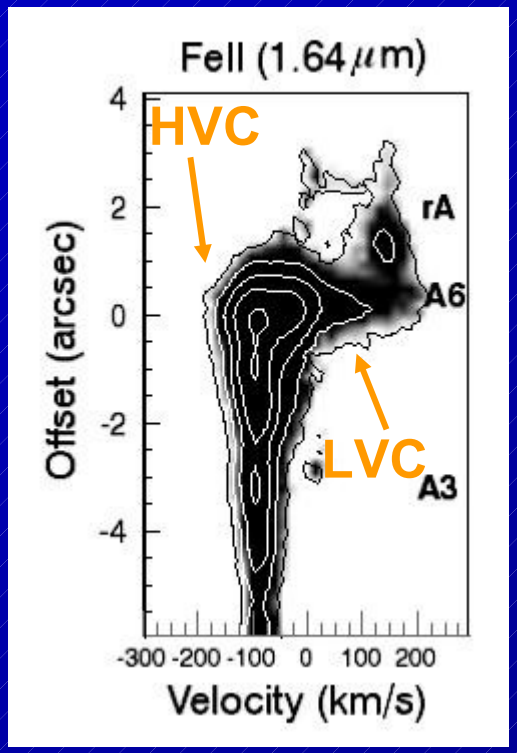
HVC + LVC

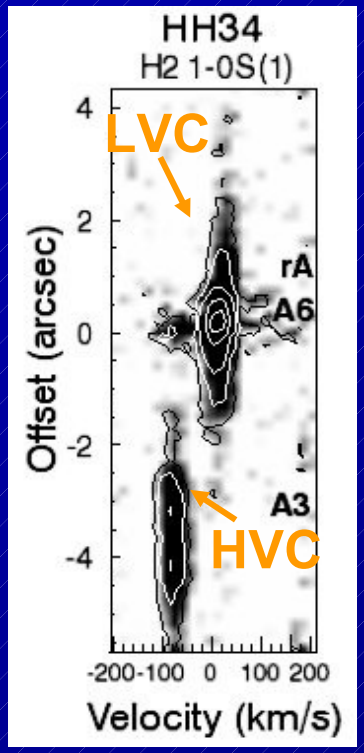
No emission in between

- **HH 46-47**

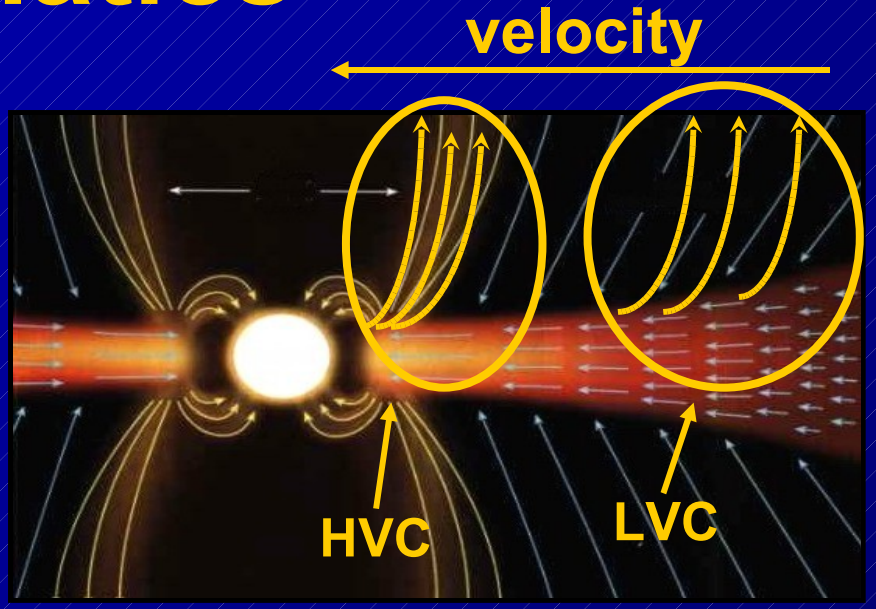
Single velocity component

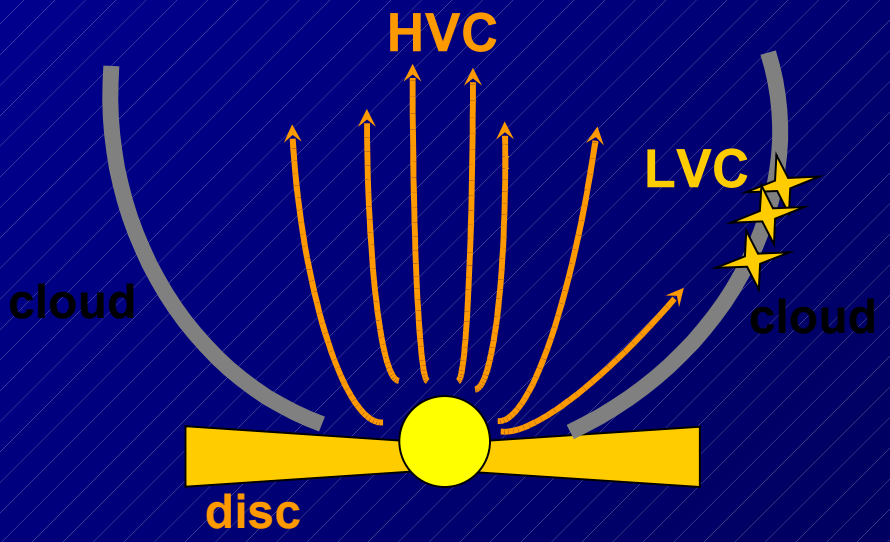
Kinematics





Garcia Lopez et al. (2008)



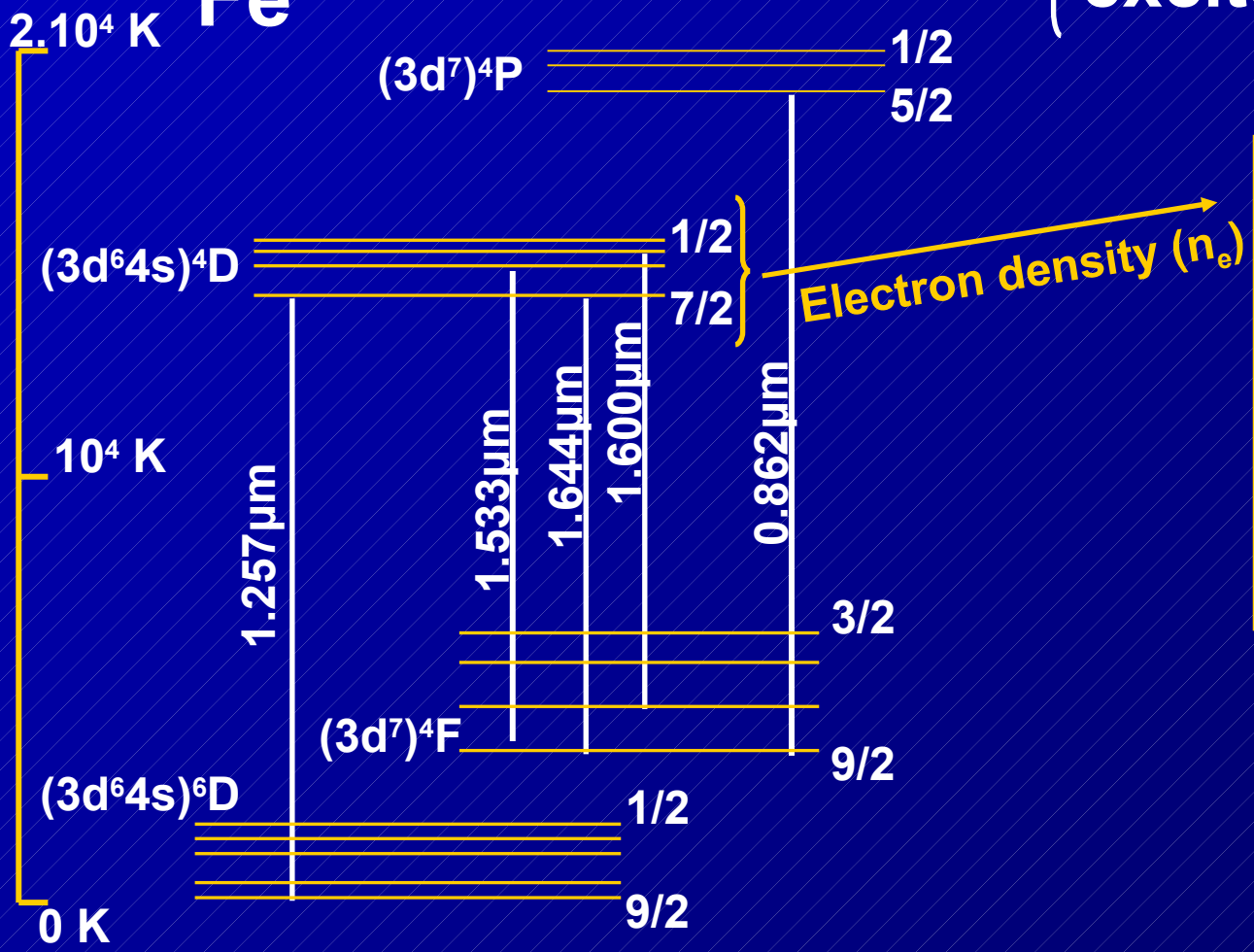


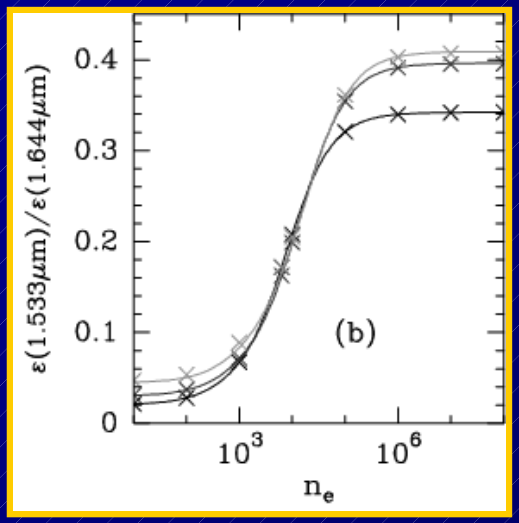
Physical properties

Diagnostic with IR lines

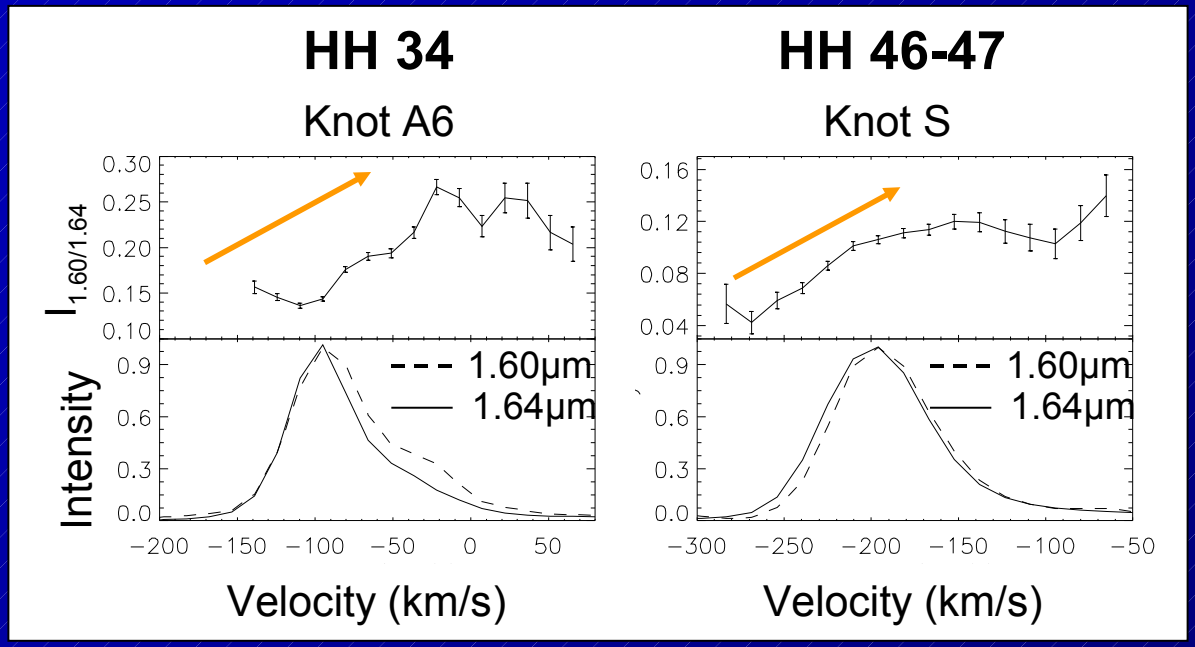
Basic assumption: lines { **optically thin** ; **excited by collisions**

Fe^+





Physical properties- n_e



Garcia Lopez et al. (2008)

Jet, knot	r_t (“)	n_e(HVC) (10^3cm^{-3})	n_e(LVC) (10^3cm^{-3})
HH34, A6	(-2.6,+0.9)	10.5	22.5
HH46-47, S	(-3.4,+2.8)	5.4	7.0

n_e(LVC) > n_e(HVC)

Physical properties- Mass flux ($\dot{M}_{jet}$)

From the [FeII] 1.64μm line luminosity:

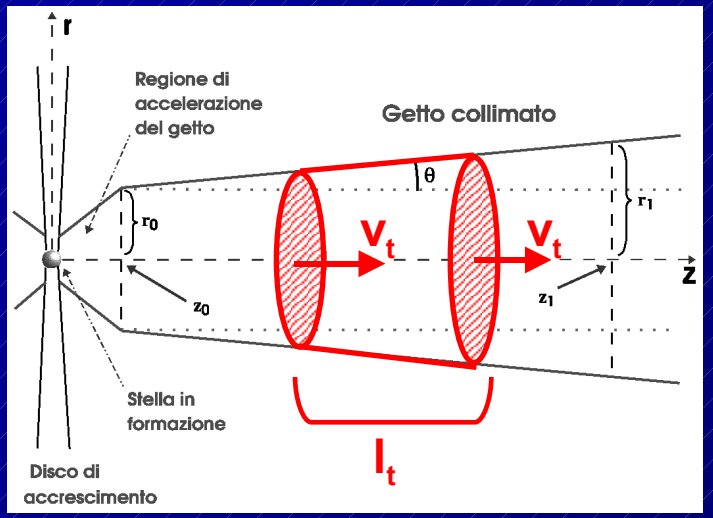
$$\dot{M} = \mu m_H \, x \, (n_H V) \, x \, v_t / l_t$$

m_H, proton mass μ=1.24, average atomic weight

n_H, total density

V, emitting volume

v_t, l_t, velocity and length of the knot, projected perpend. to the line of sight



$$n_H V = L([FeII]1.64\mu m) \, (h\nu \, A_i f_i \, (Fe^+/Fe) \, ([Fe]/H))^{-1}$$

Assumptions:

-$Fe^+/Fe = 1$

A_i, f_i, radiative rate and fractional pop. upper level

Fe^+/Fe, ionisation fraction

Lower limit

[Fe]/H, total abundance with respect to hydrogen

-$[Fe]/H = 2.8\ 10^{-5}$ (Asplund et al. 2005) ➡ No dust depletion

Physical properties- Mass flux ($\dot{M}_{jet}$)

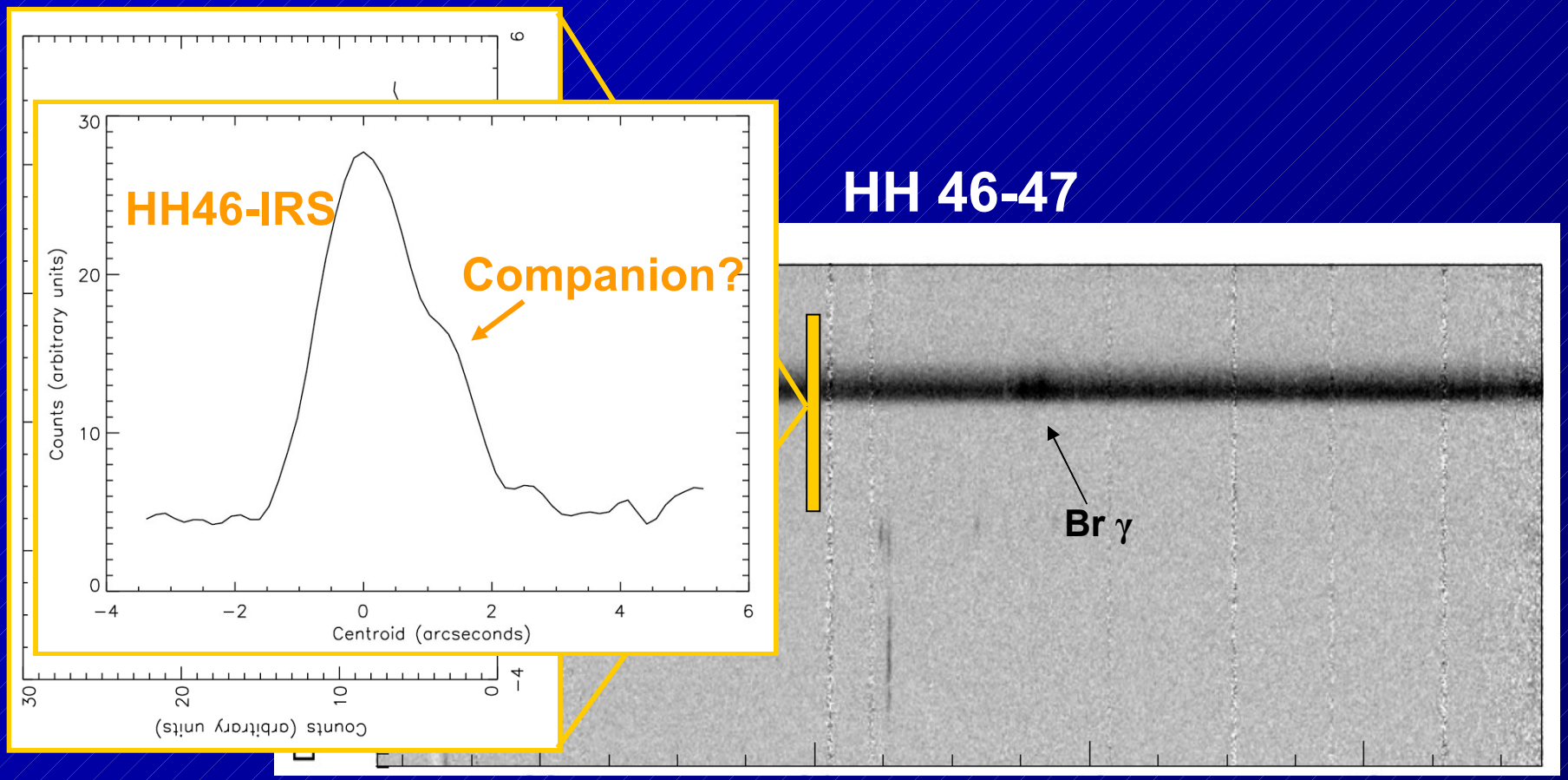
Jet, knot	r_t (“)	A_v (mag)	T_e (10^3 K)	$\dot{M}_{jet}$(HVC) (M_o/yr)	$\dot{M}_{jet}$(LVC) (M_o/yr)
HH34, A6	(-2.6,+0.9)	7.1	7.0	$5.2\ 10^{-8}$	$6.6\ 10^{-9}$
HH46-47, S	(-3.4,+2.8)	6.6	15.0	$2.6\ 10^{-8}$	$2.5\ 10^{-9}$

$$\dot{M}_{jet}(HVC) > \dot{M}_{jet}(LVC)$$

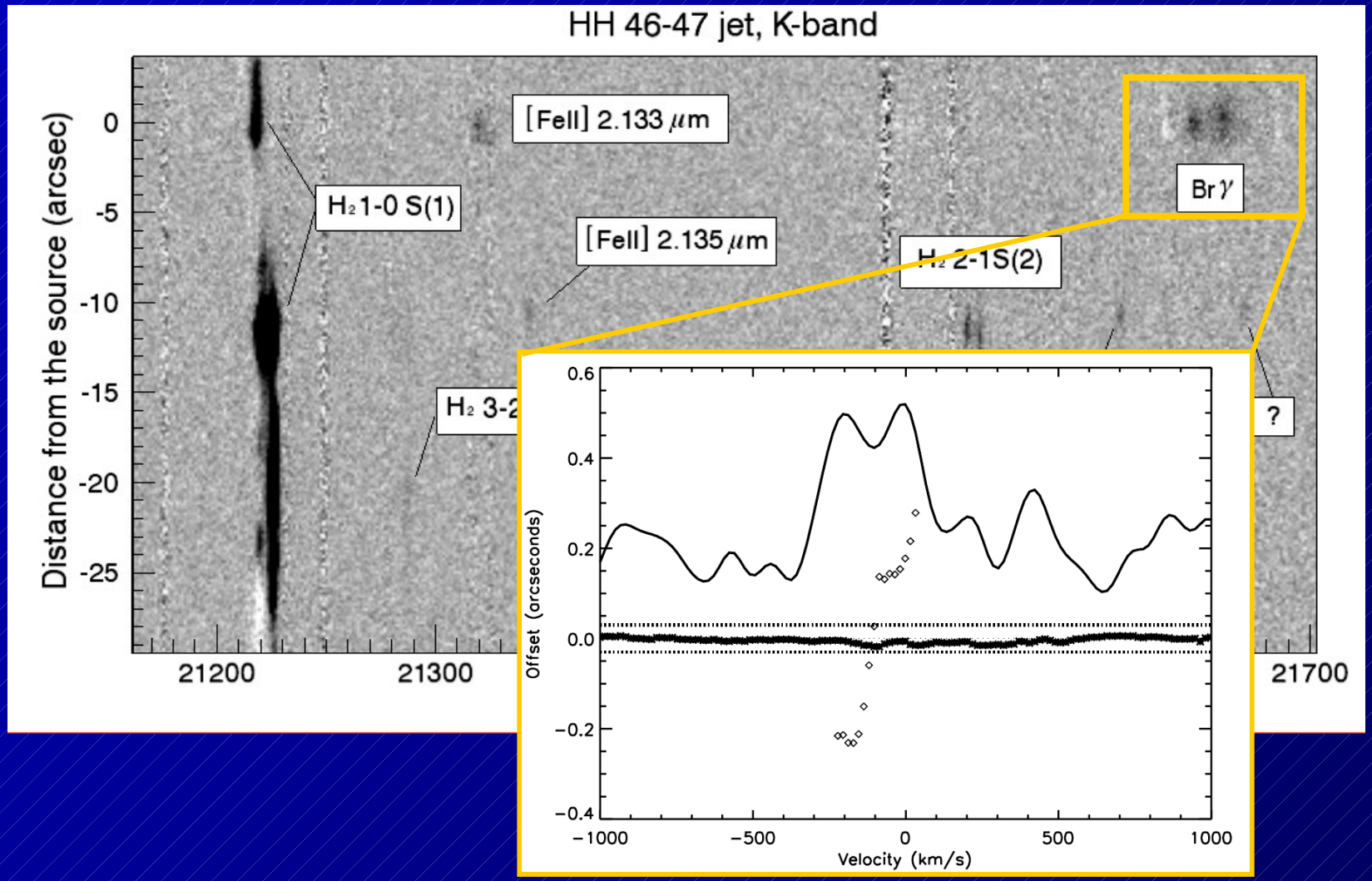
	$\dot{M}_{jet}/\dot{M}_{acc}$
HH 34	0.01
HH 46-47	0.1

($\dot{M}_{acc}$ from Antoniucci et al. 2008)

Work in progress: spectro-astrometry



Work in progress: spectro-astrometry



Conclusions

Kinematics

- FeII : HVC, LVC

- H_2 { HH34: HVC, LVC ; HH46-47: single v. component

- HH34, HH46-47 : LVC reaches redshift. velocities at 0”

Physical properties

HH34, HH46-47: $n_e(\mathrm{LVC}) > n_e(\mathrm{HVC})$

$\dot{M}_{jet}(\mathrm{HVC}) > \dot{M}_{jet}(\mathrm{LVC})$