Understanding the origin of outflows and their feedback on cores: the case of IRAS 04166+2706

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OBSERVATIONS OF CO IN L1551: EVIDENCE FOR STELLAR WIND DRIVEN SHOCKS

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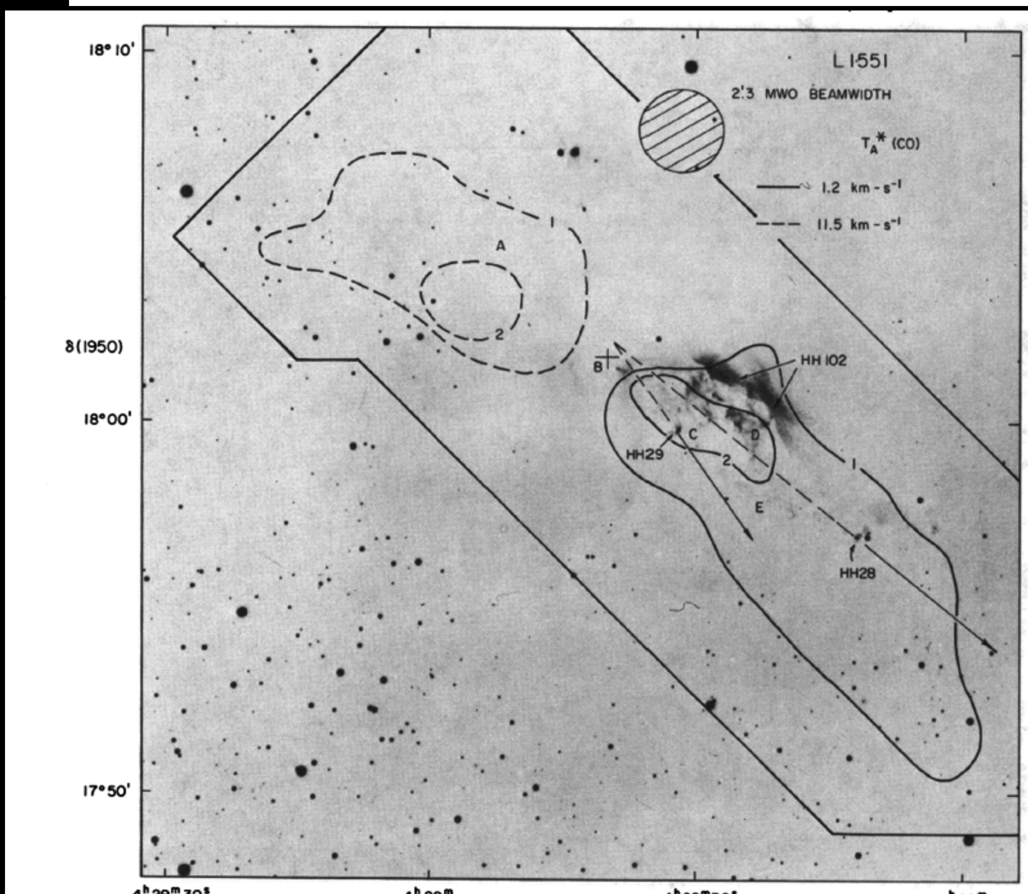
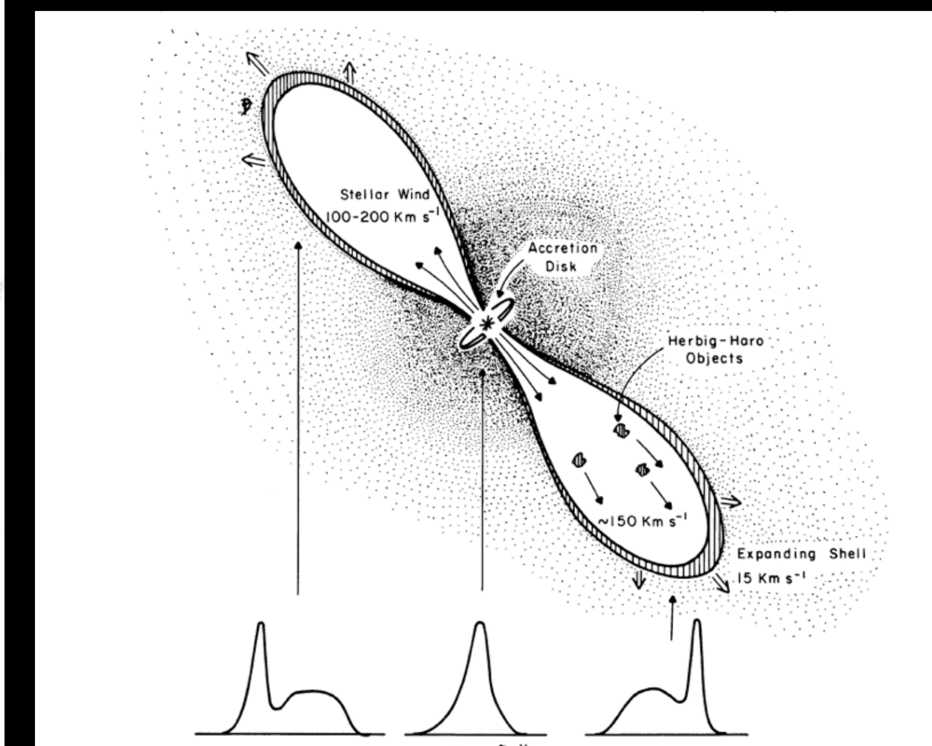
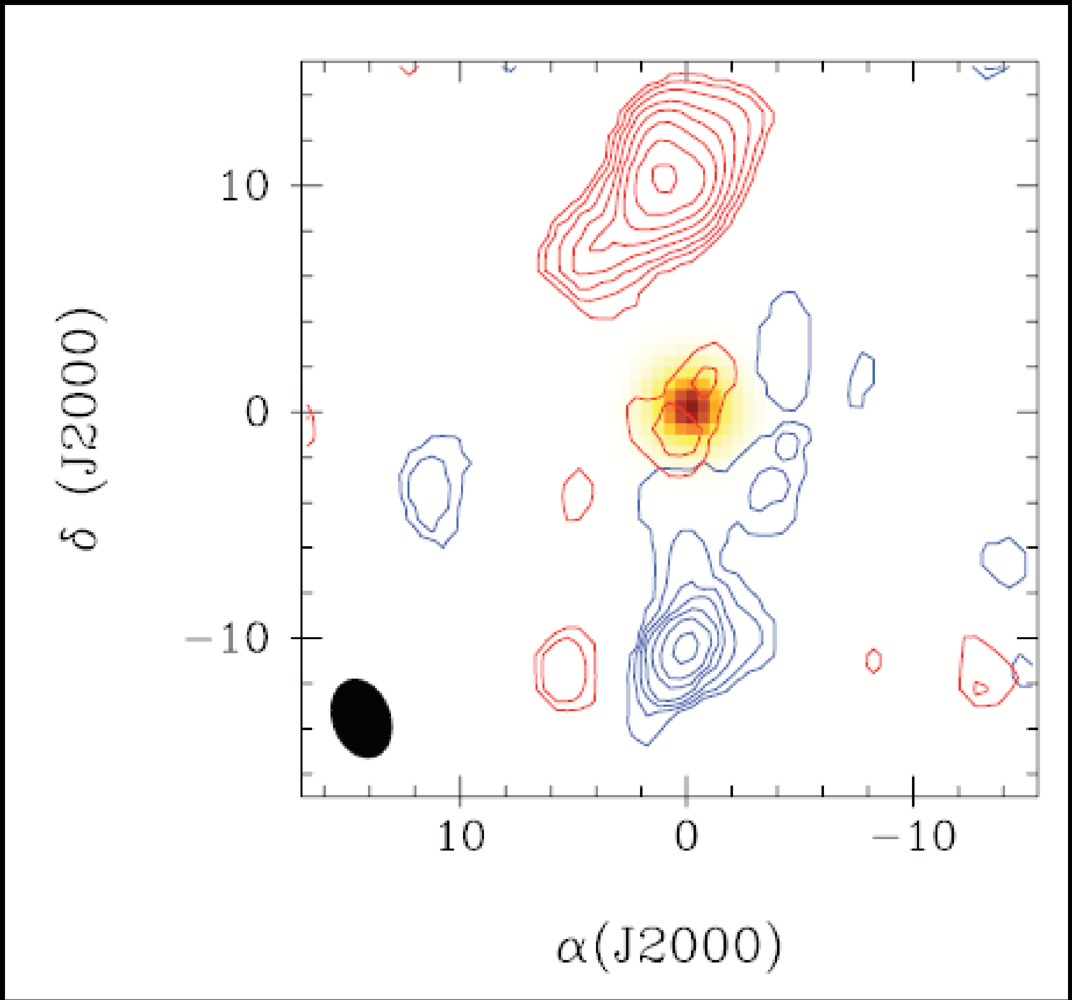
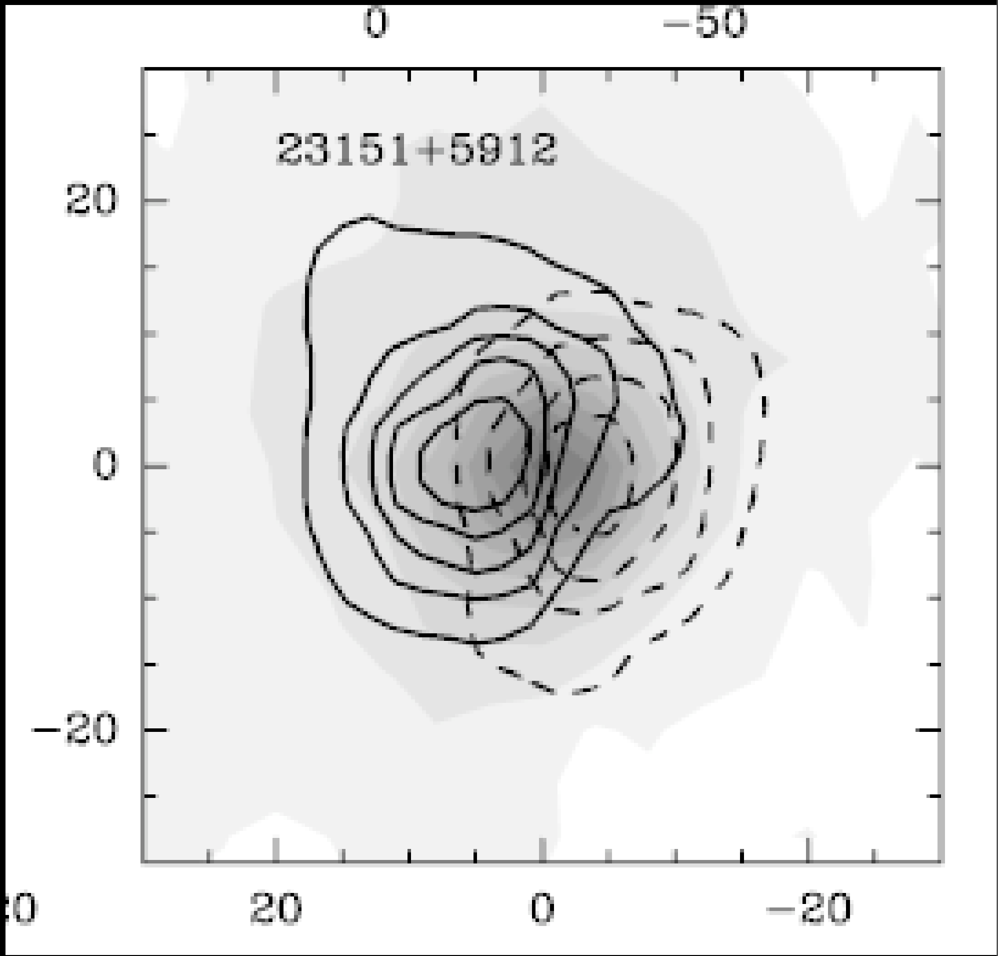




Characteristic element of star formation process



ISO-Oph 120: BD (60 M_J)
Phan-Bao et al. (2008)

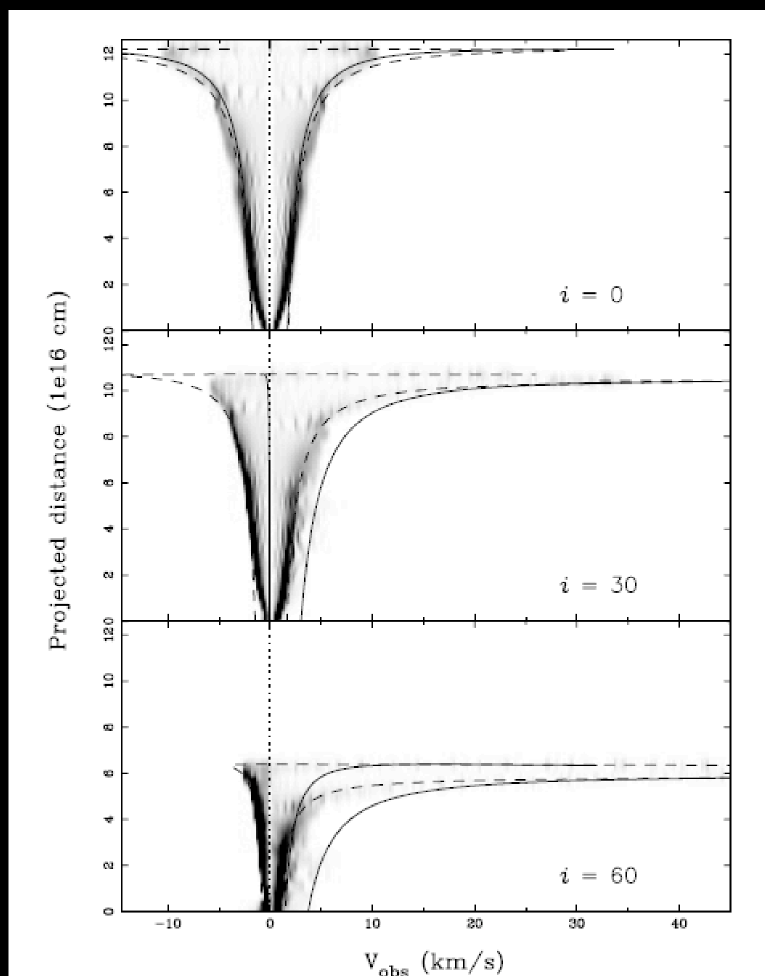


IRAS 23151: L = 10^5 $L_\odot$
Beuther et al. (2002)

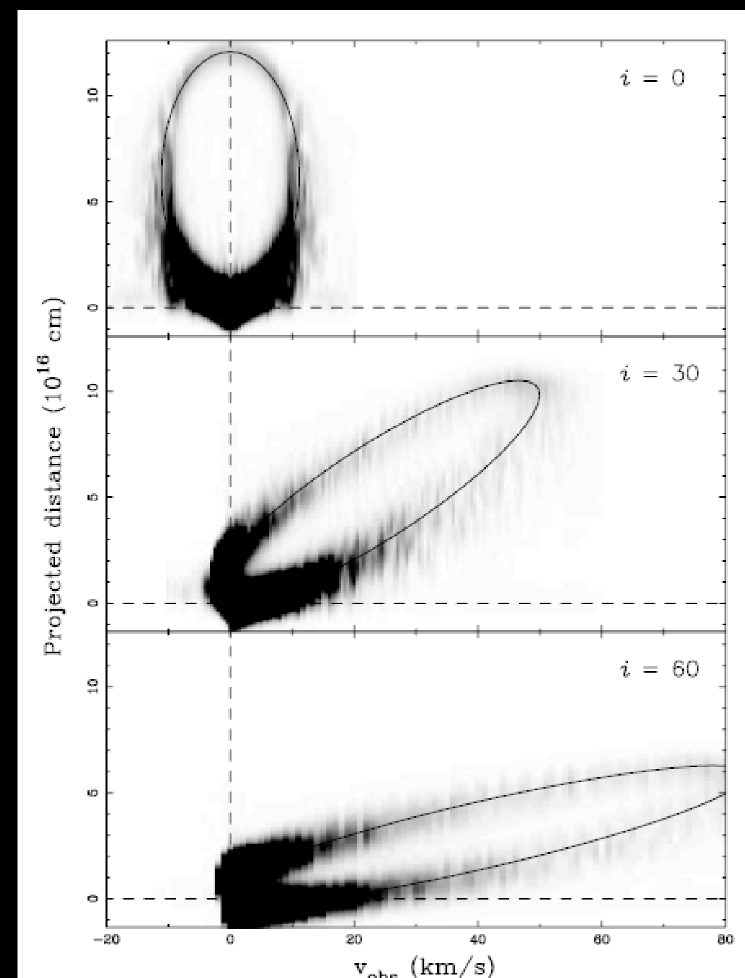
A number of pending issues

- **Launch** mechanism
  - disk wind vs X-wind
- wind **geometry**
  - jet-like vs wide-angle

PV diagrams for jets



PV diagrams for shells

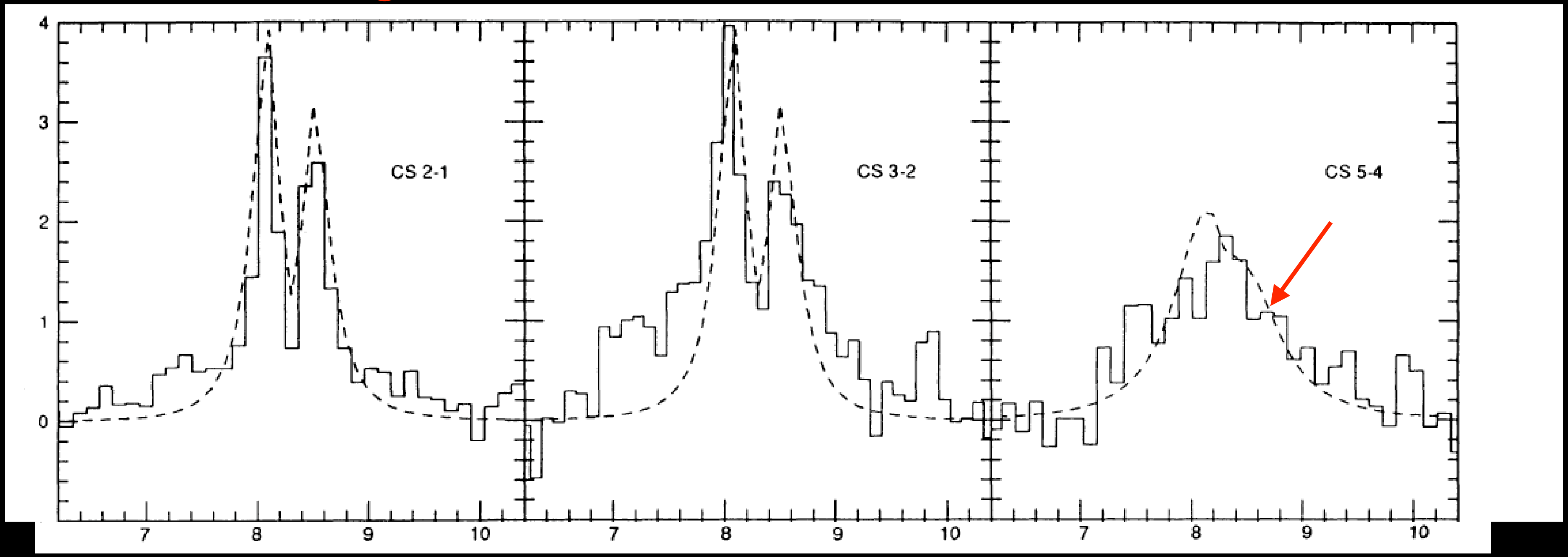


Lee et al. (2001)

Impact on core studies

- Disentangling infall and outflow
  - infall sonic/subsonic - outflow supersonic

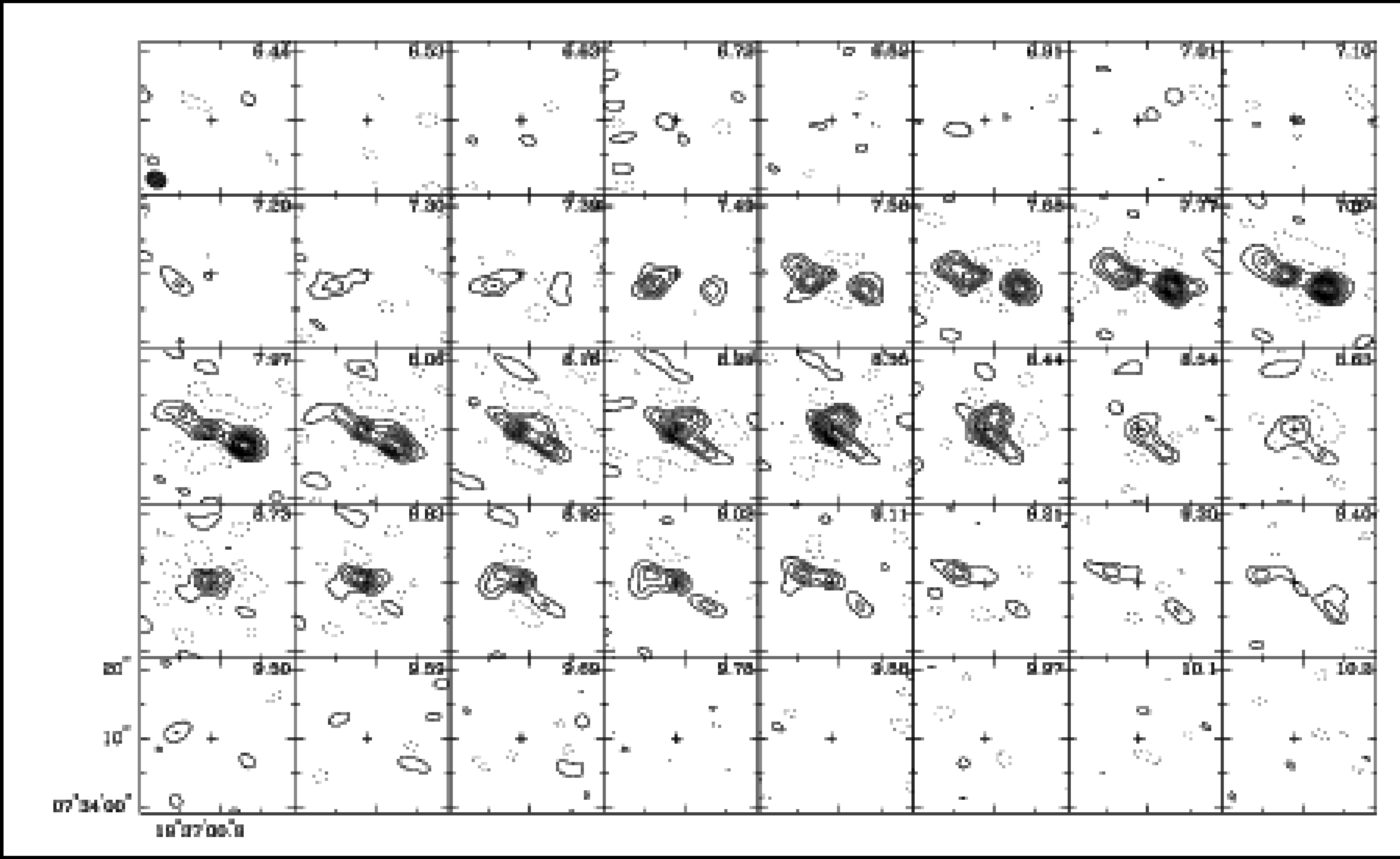
B335 - single dish data



Zhou et al. (1993)

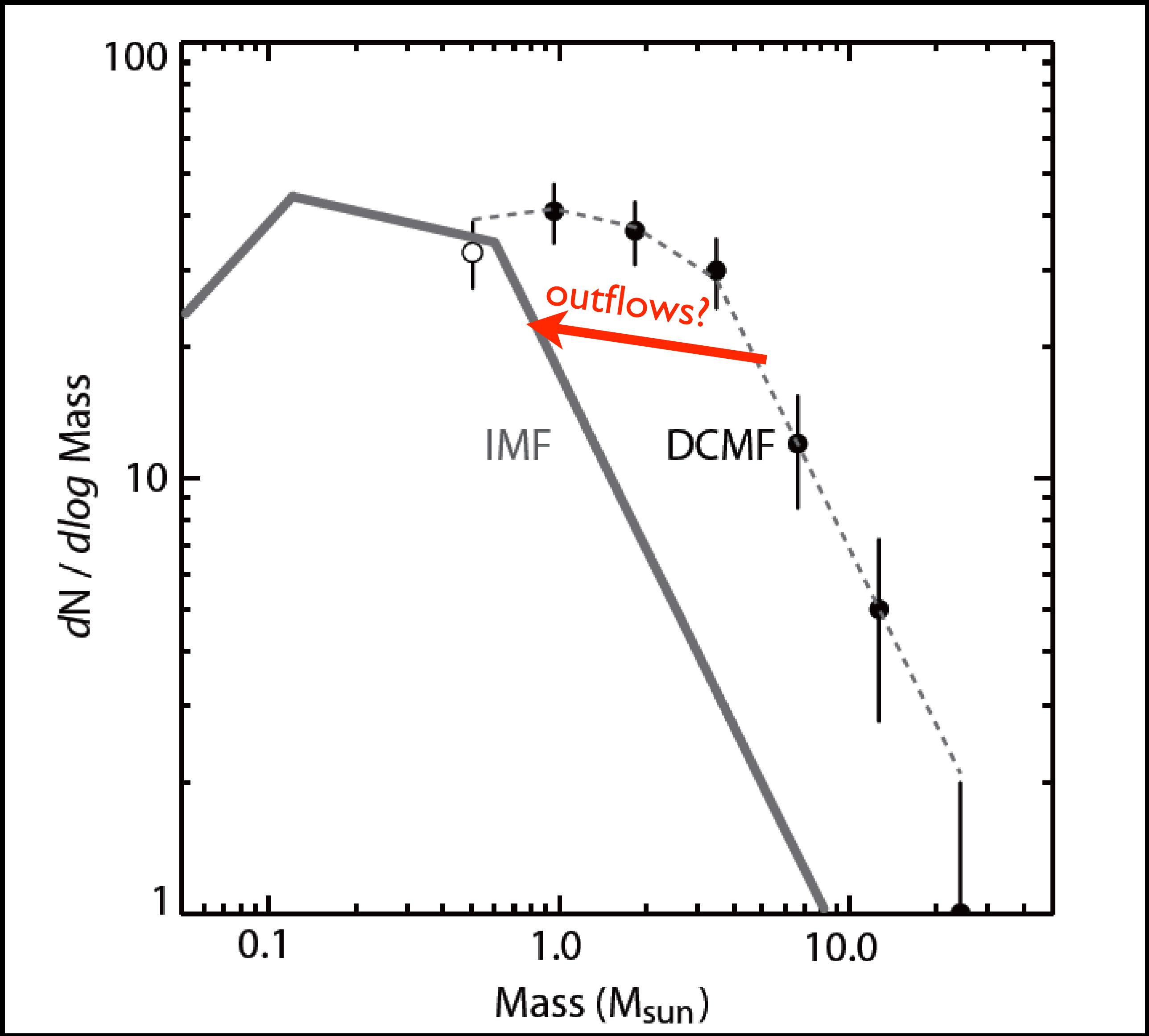
Infall wing becomes outflow shell

B335 - interferometer data CS(5-4)



Wilner et al. (2000)

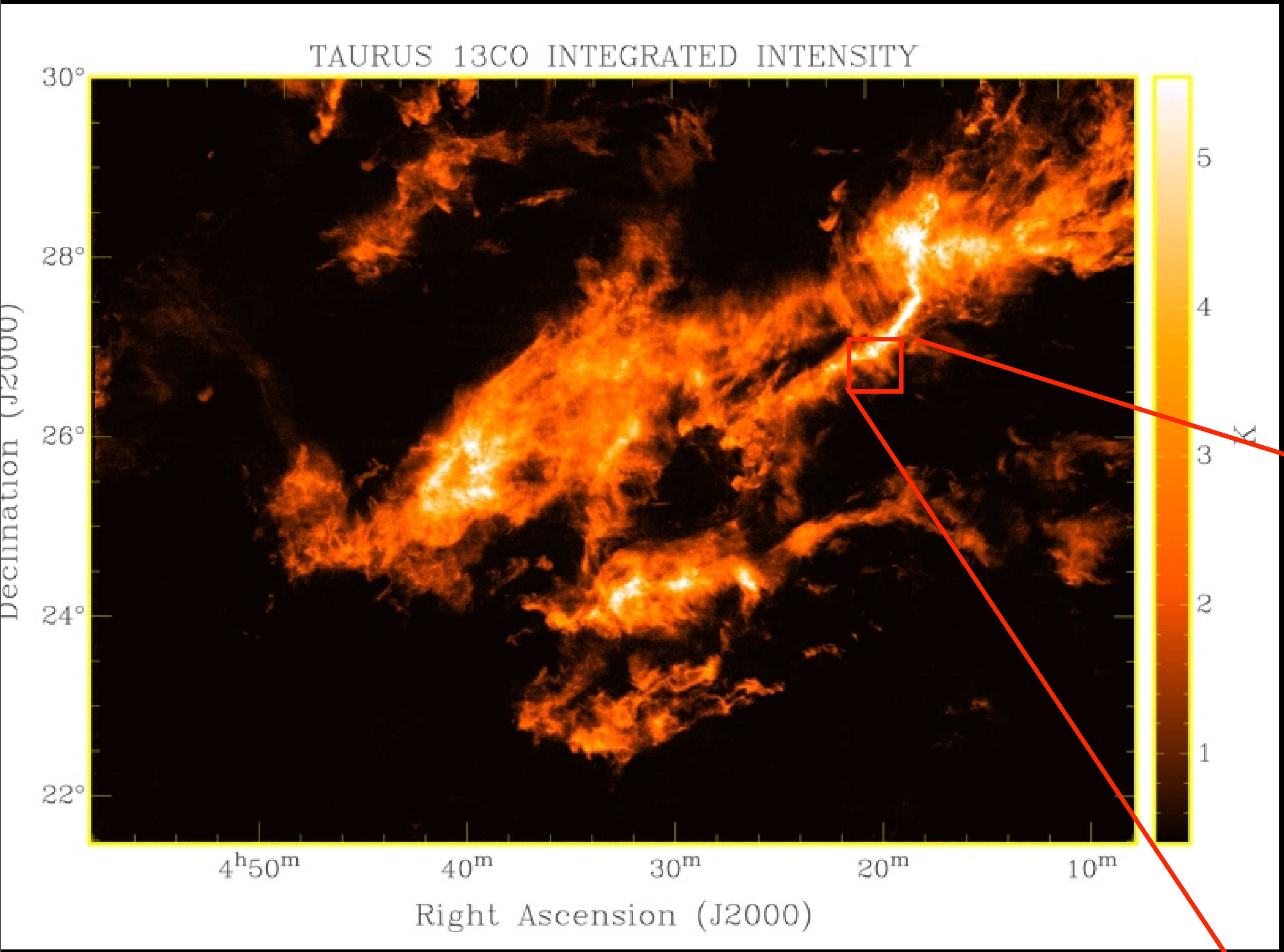
Feedback effects



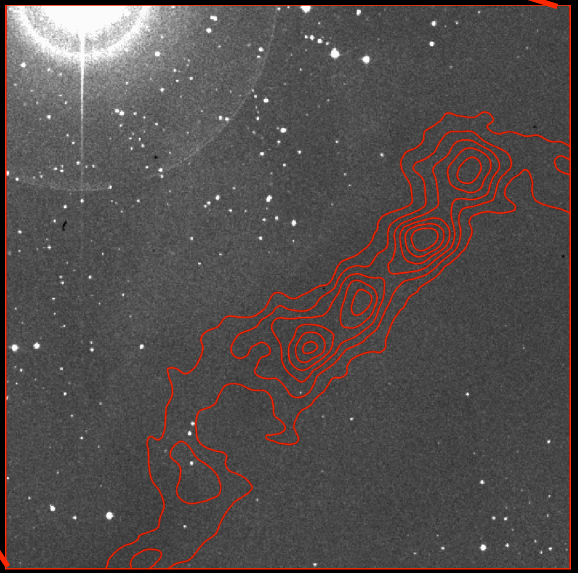
Alves et al. (2007)

- Simple feedback prescription still needed for modeling IMF origin (e.g., Phil Myers talk tomorrow)
- How much turbulence injection?

IRAS 04166+2706



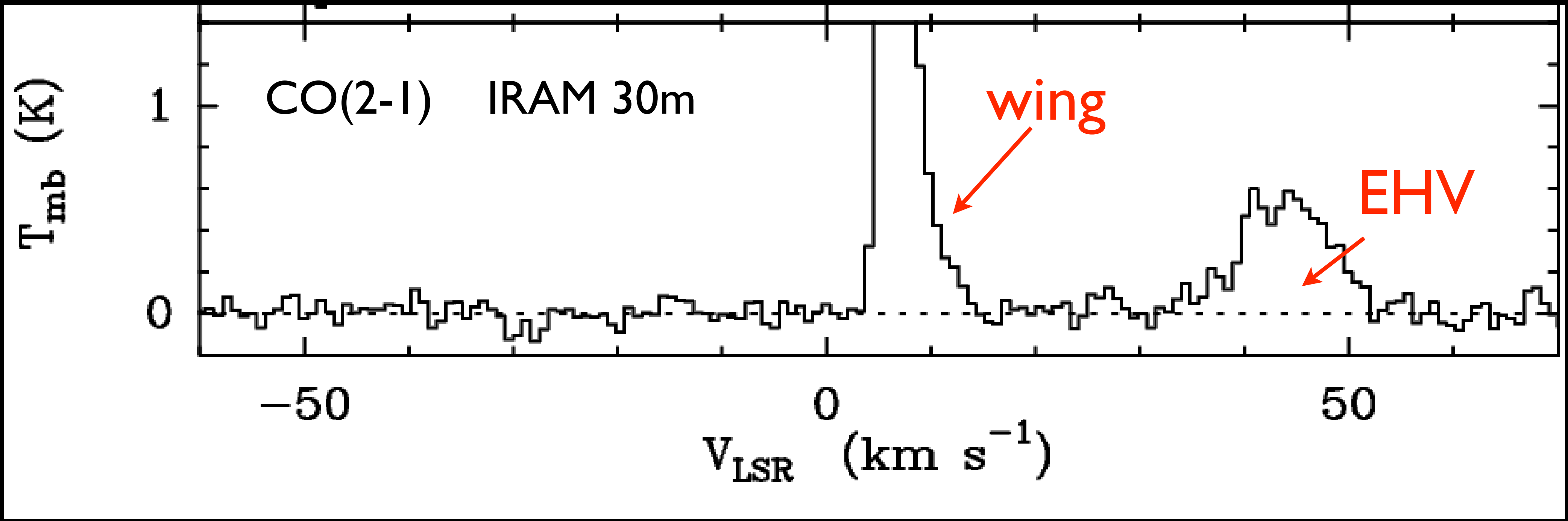
- Taurus
- Class 0/I
- 0.4 $L_{\odot}$



Goldsmith et al. (2007)

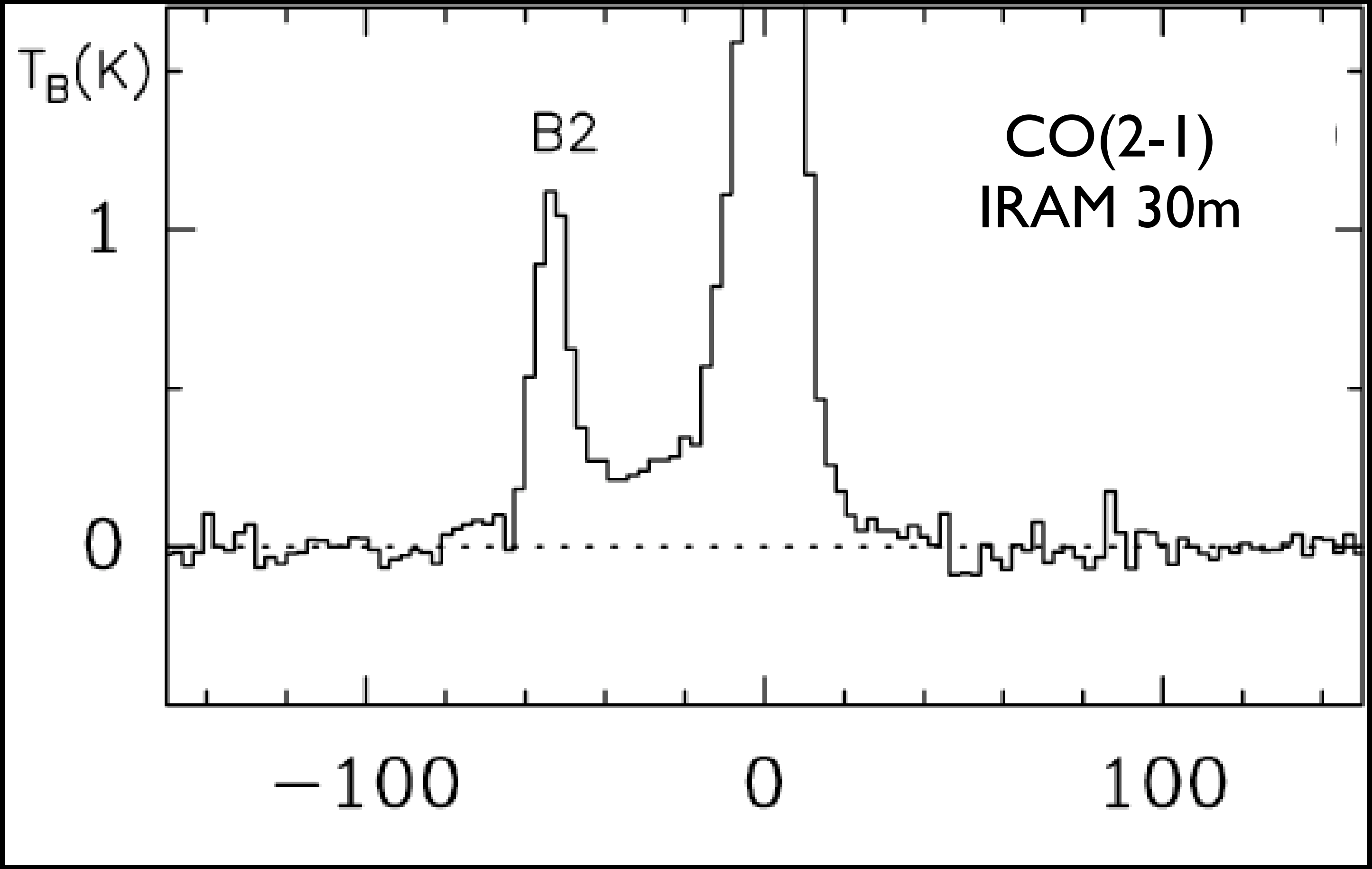
I04166 outflow

- Prominent Extremely High Velocity component



Tafalla et al. (2004)

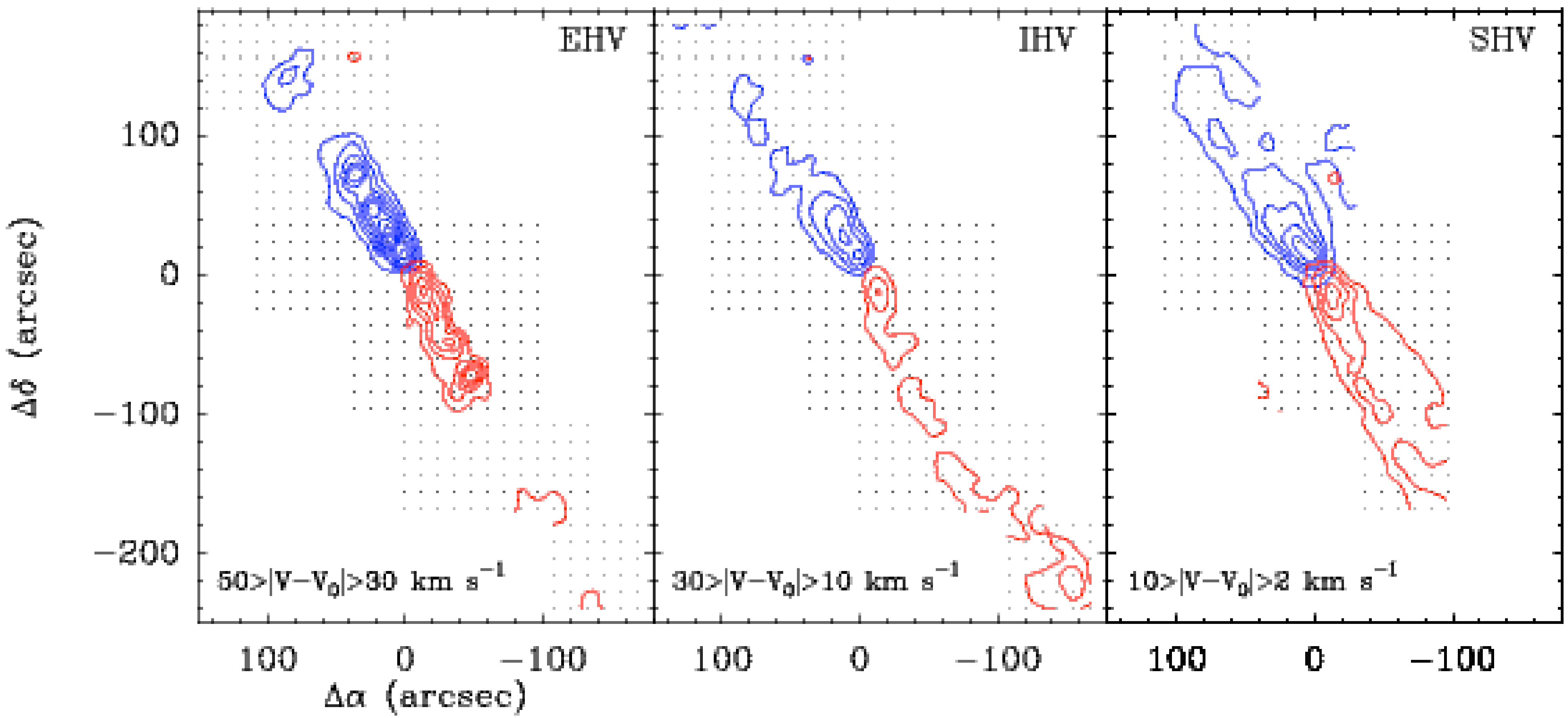
L1448 EHV gas



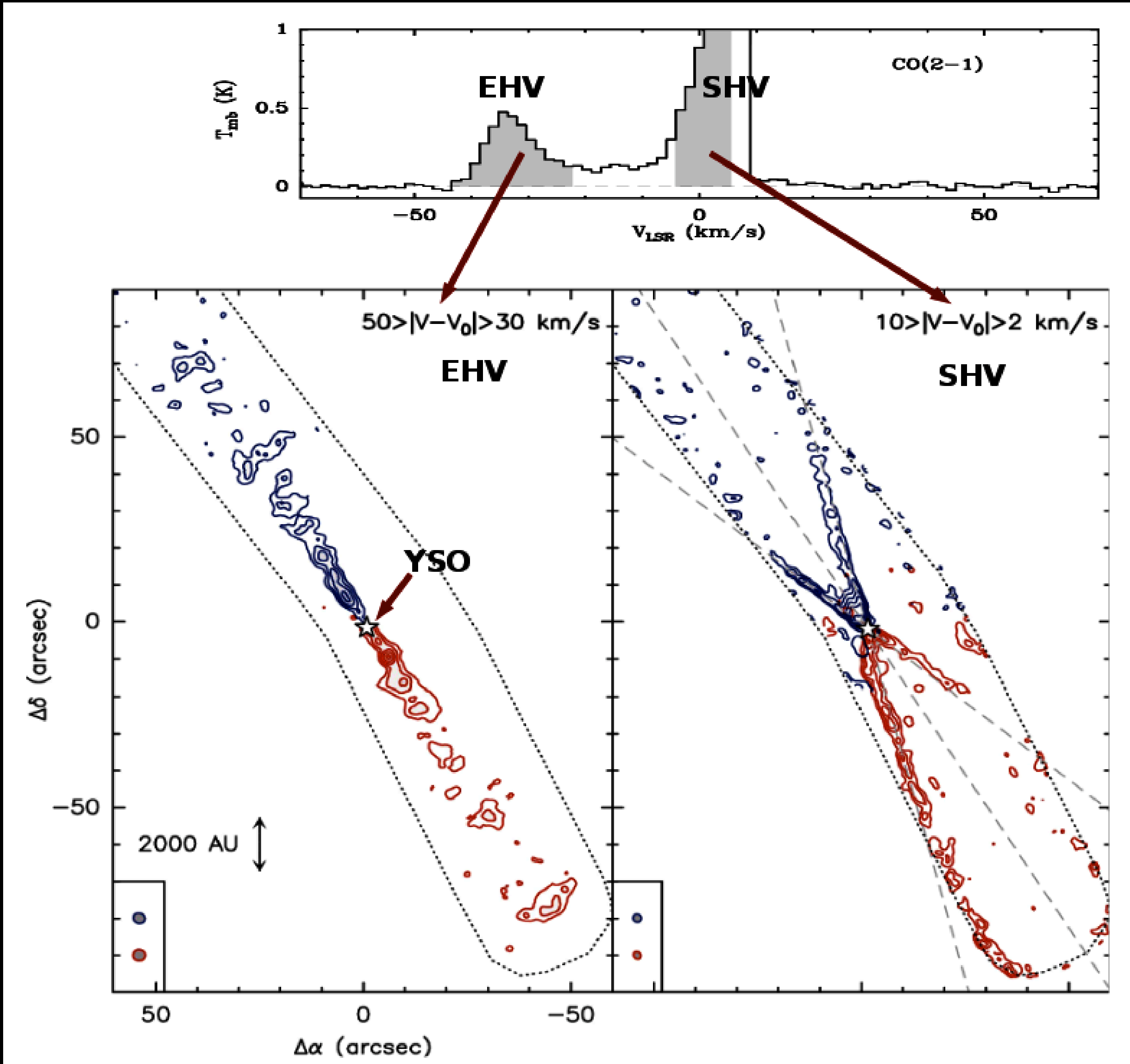
Bachiller et al. (1990)

I04166 outflow

CO(2-1) IRAM 30m



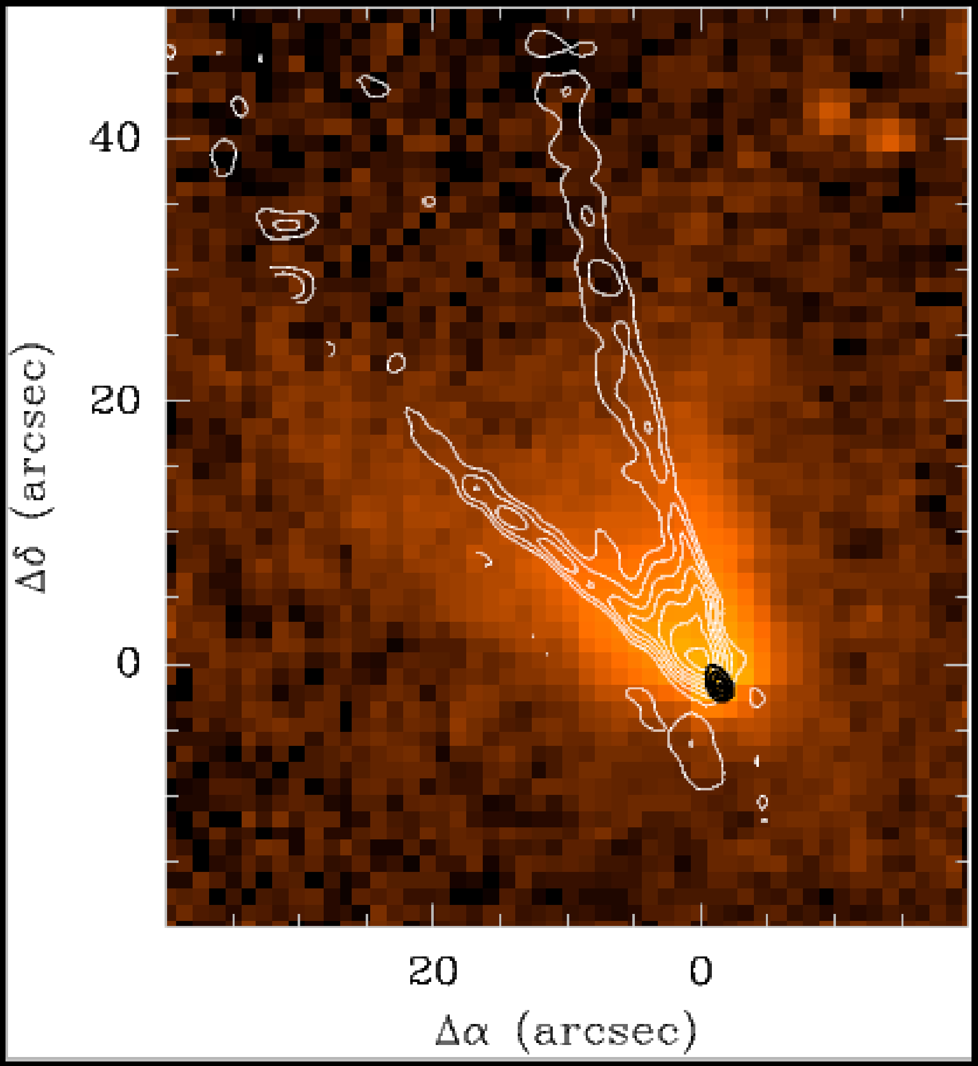
Tafalla et al. (2004)



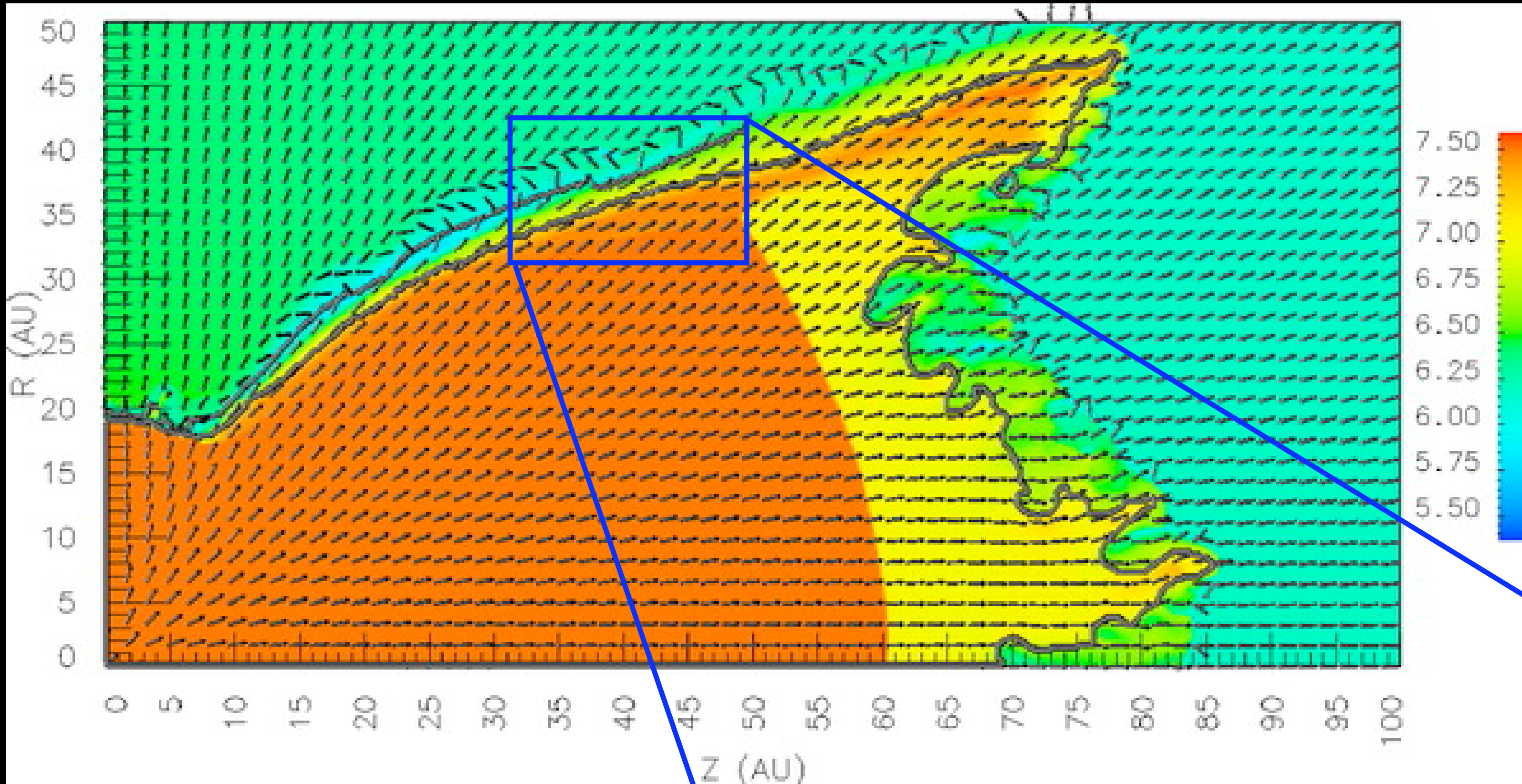
Santiago-Garcia et al. (2009)

outflow wings: gas shells

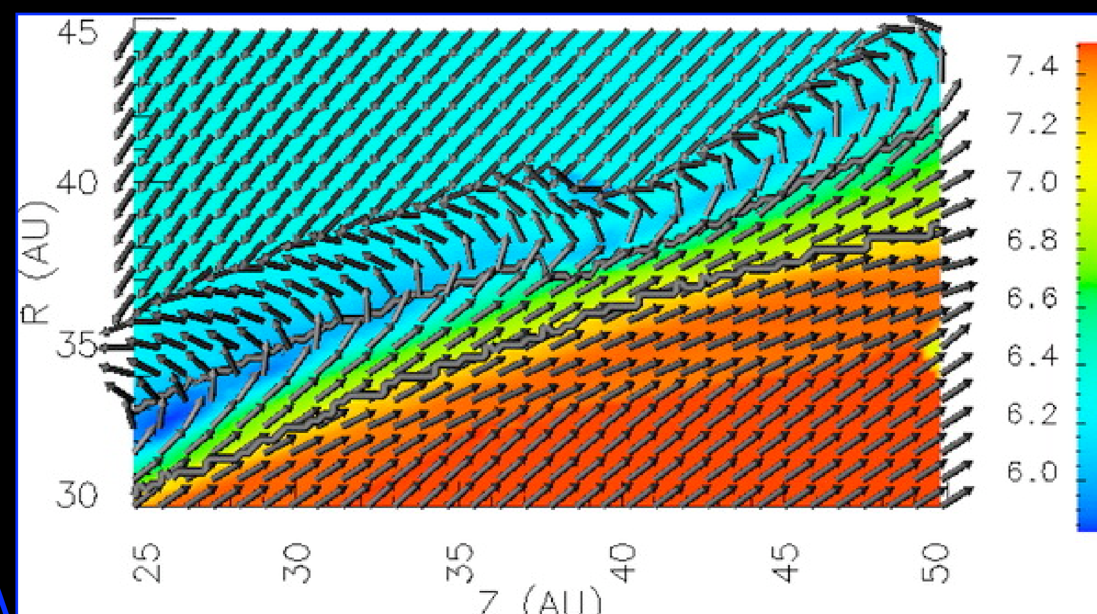
CO(2-1) & IRAC 3.6 mμ

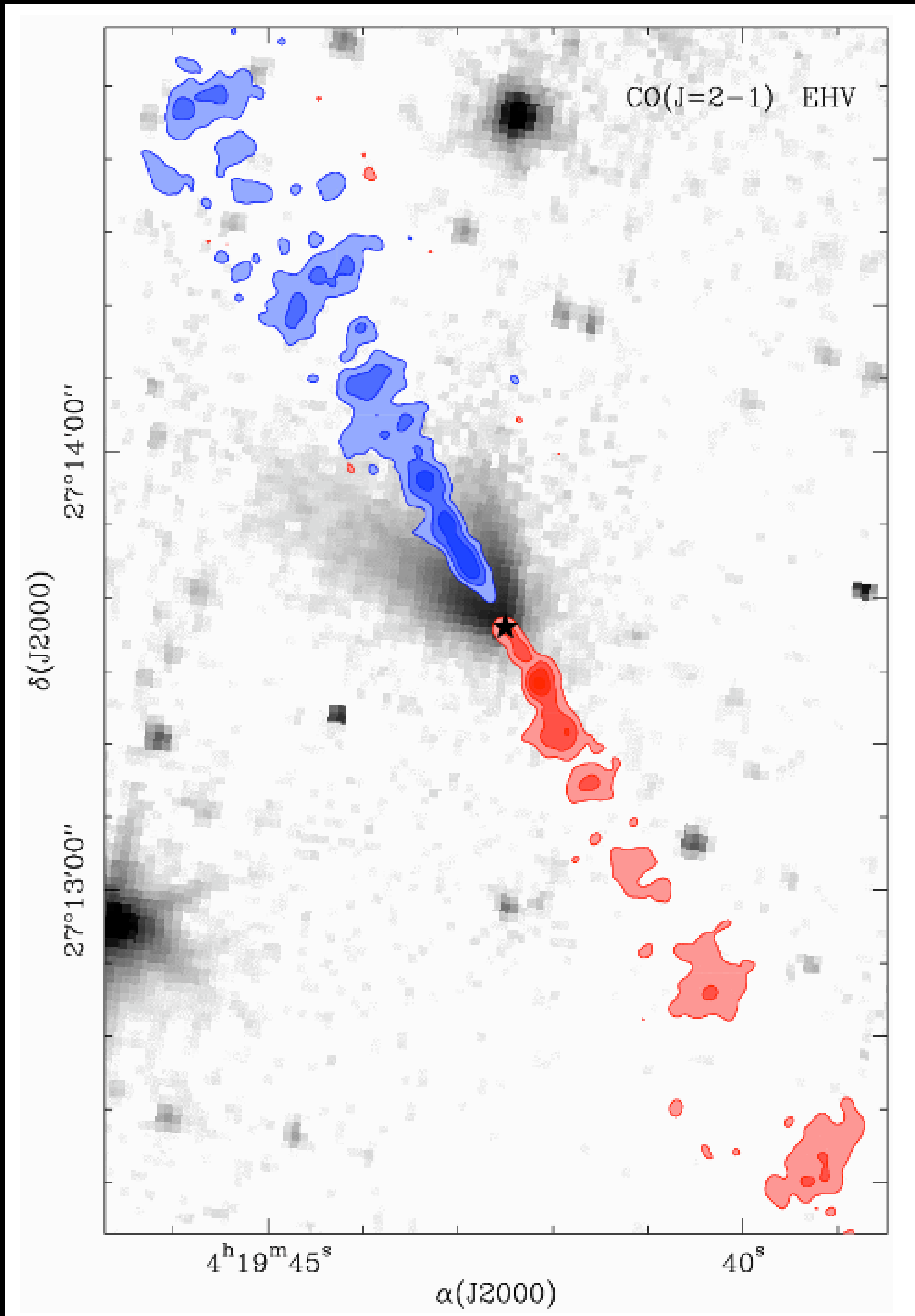


- Shells are evacuated cavities
- Wing: multiple velocities co-exist in thin layer. Shear?



Cunningham et al. (2004)

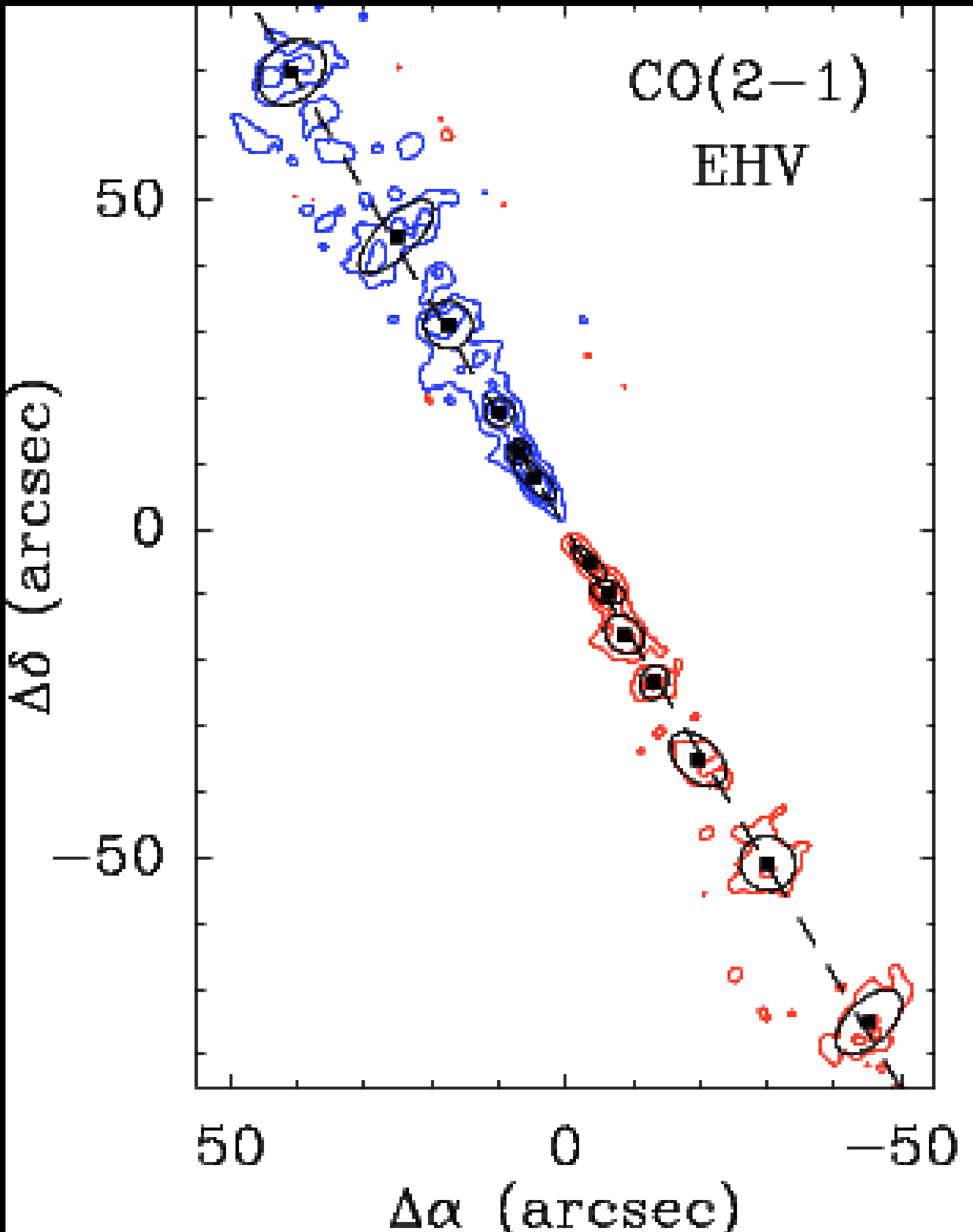




EHV gas

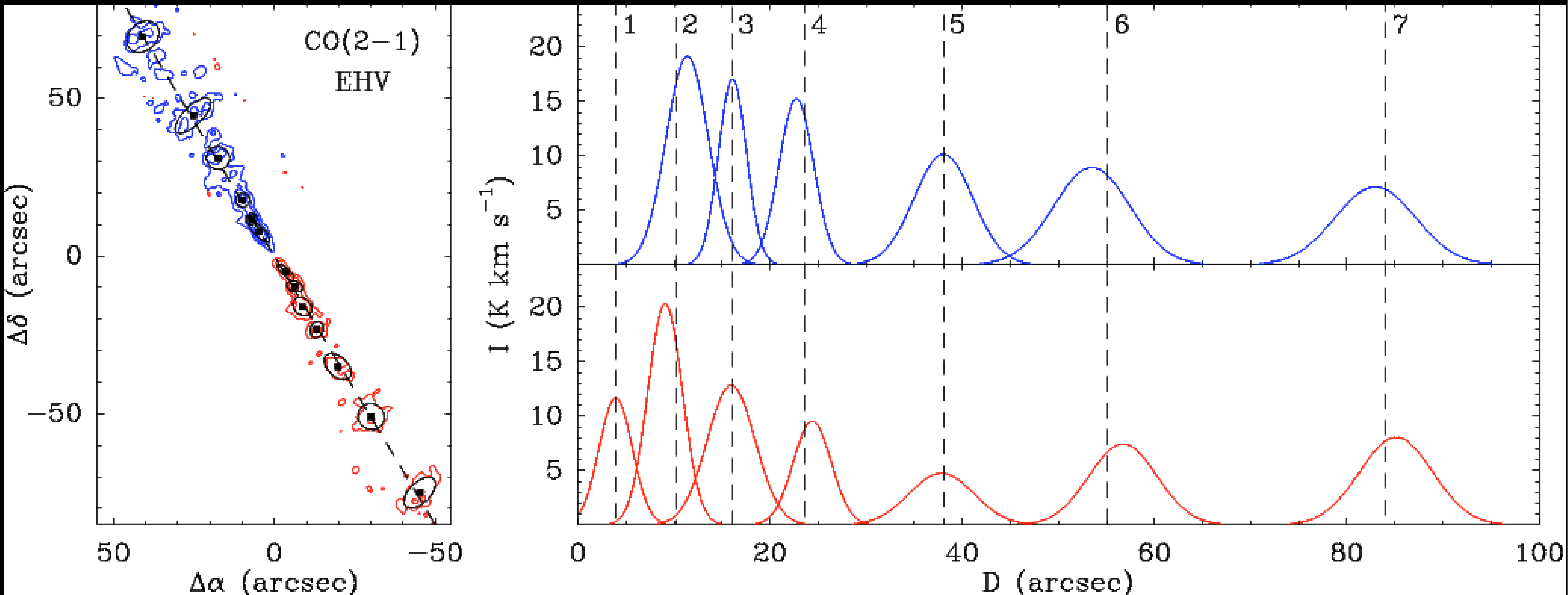
- Jet-like but fragmented
- High degree of symmetry wrt YSO

2D Gaussian fit to EHV peaks. I



- Precession angle of jet: < 1 degree
- Opening angle of emission: 10 deg

2D Gaussian fit to EHV peaks. II

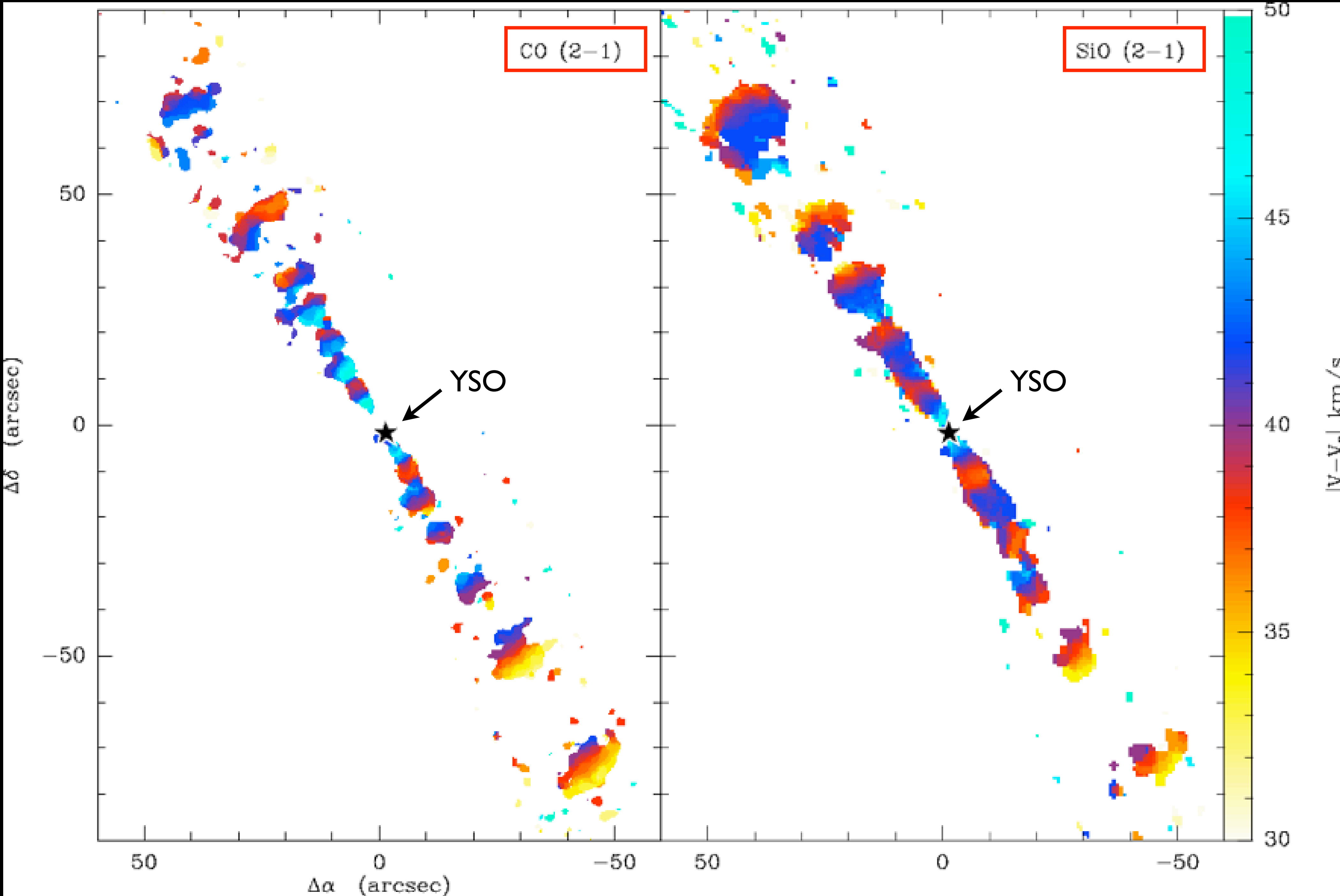


- Mean red-blue position difference: 2 arcsec

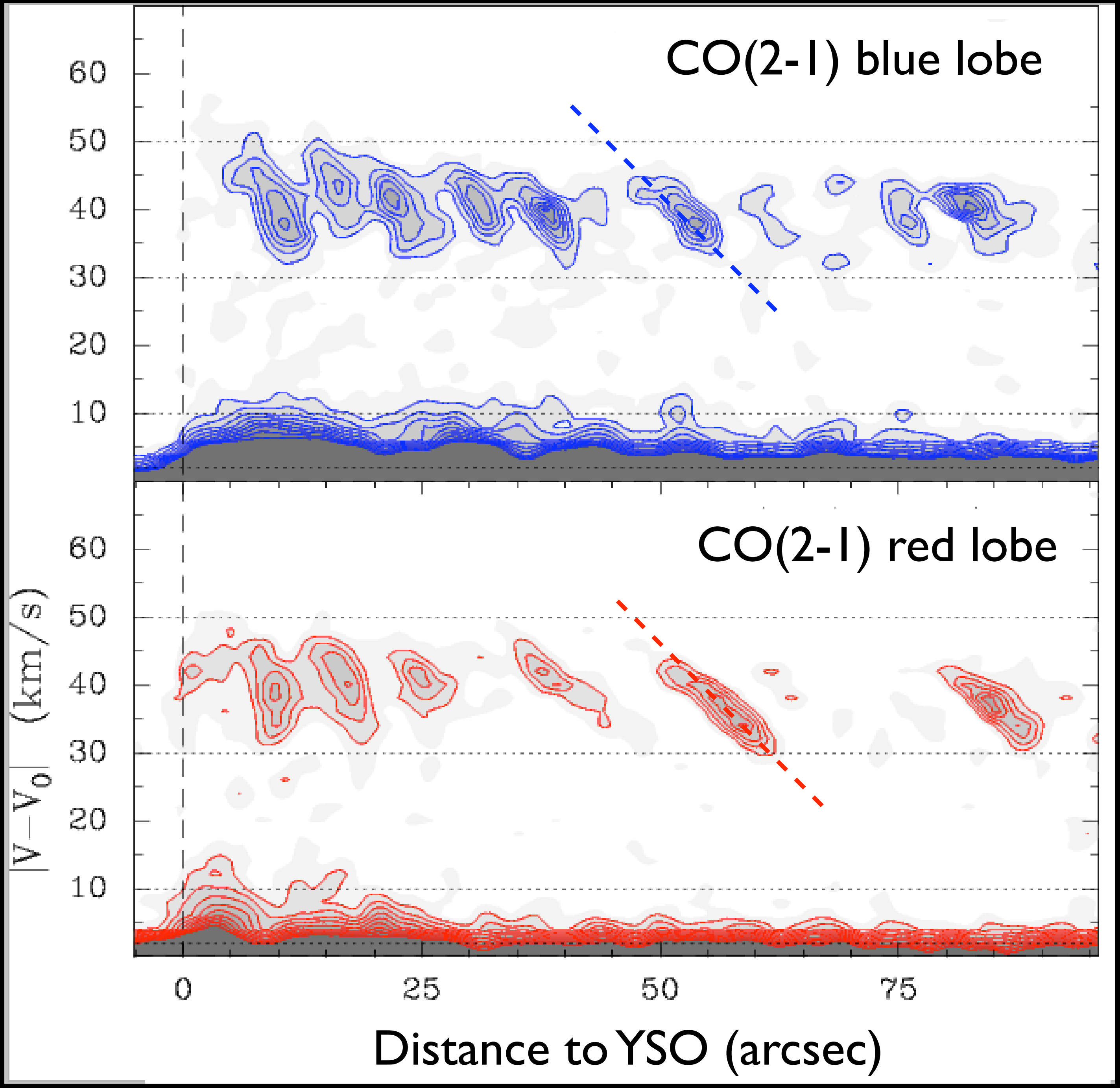
EHV peaks connected to events at YSO

- Time scale:
  - 100 yr inner peaks
  - 500-1,000 yr outer peaks
- Typical mass ≈ few 10^{-5} $M_{\odot}$
- Bullets?

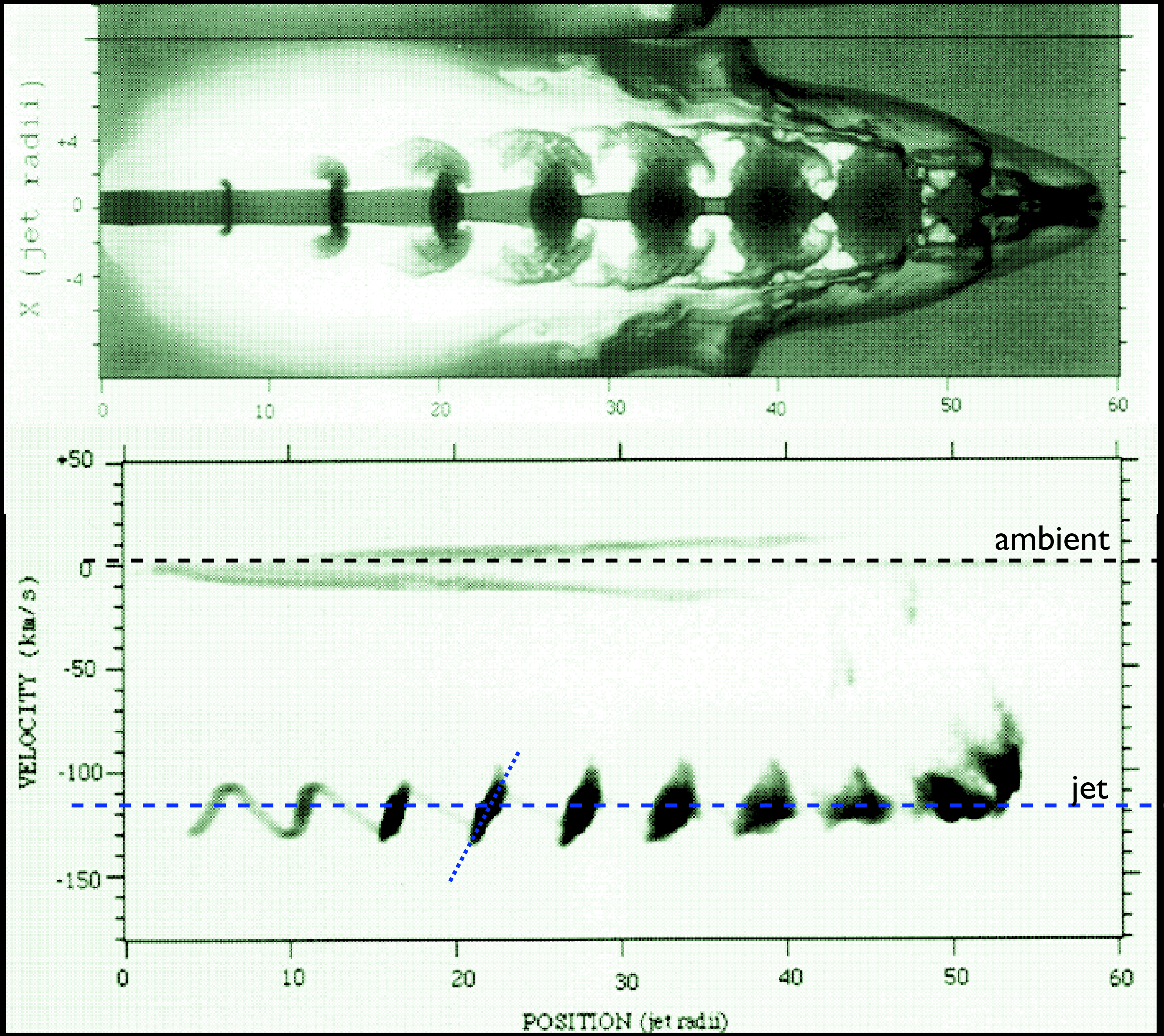
First moment of emission



Velocity gradients in the EHV gas

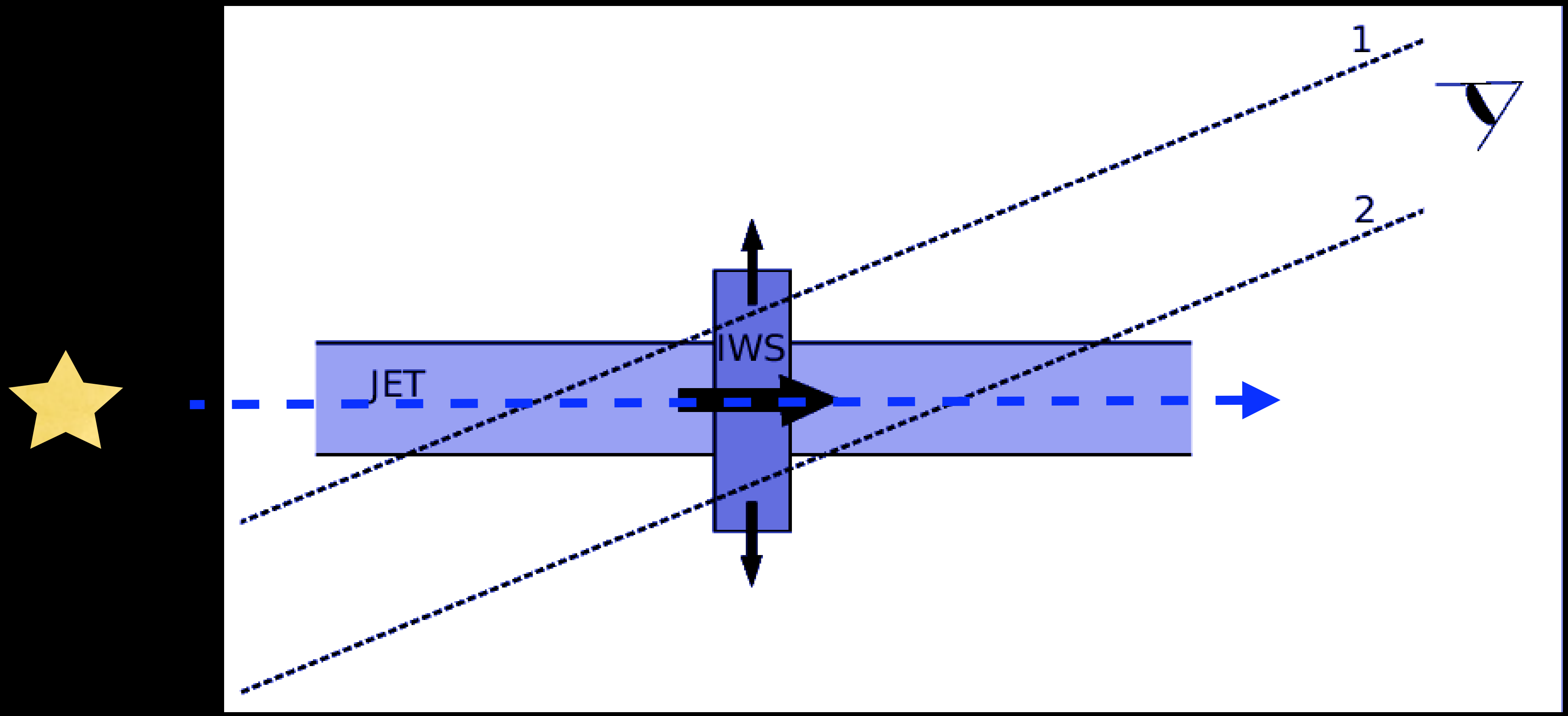


Simulation of pulsating jet



Stone & Norman (1993)

Internal working surface

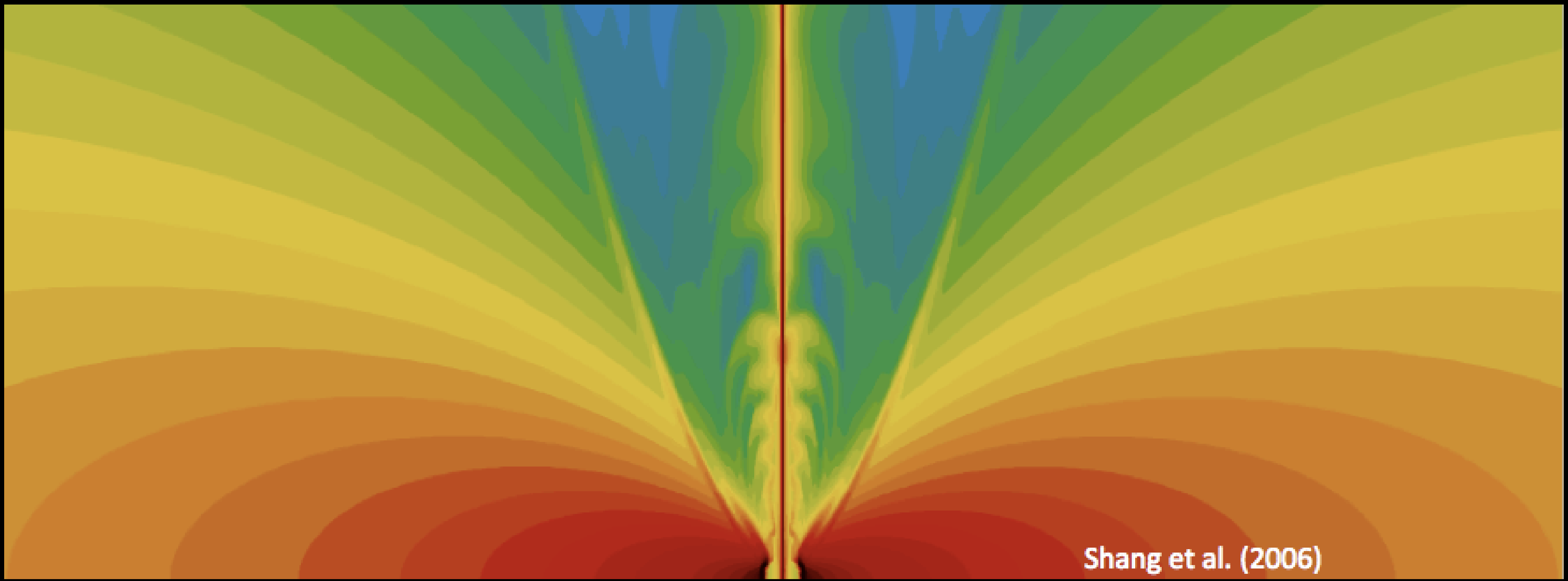


- Lateral ejection in internal shocks reproduces observed velocity pattern
- Similar physics to shocks in optical HH jets (Reipurth & Bally 2000)

Need for two outflow components

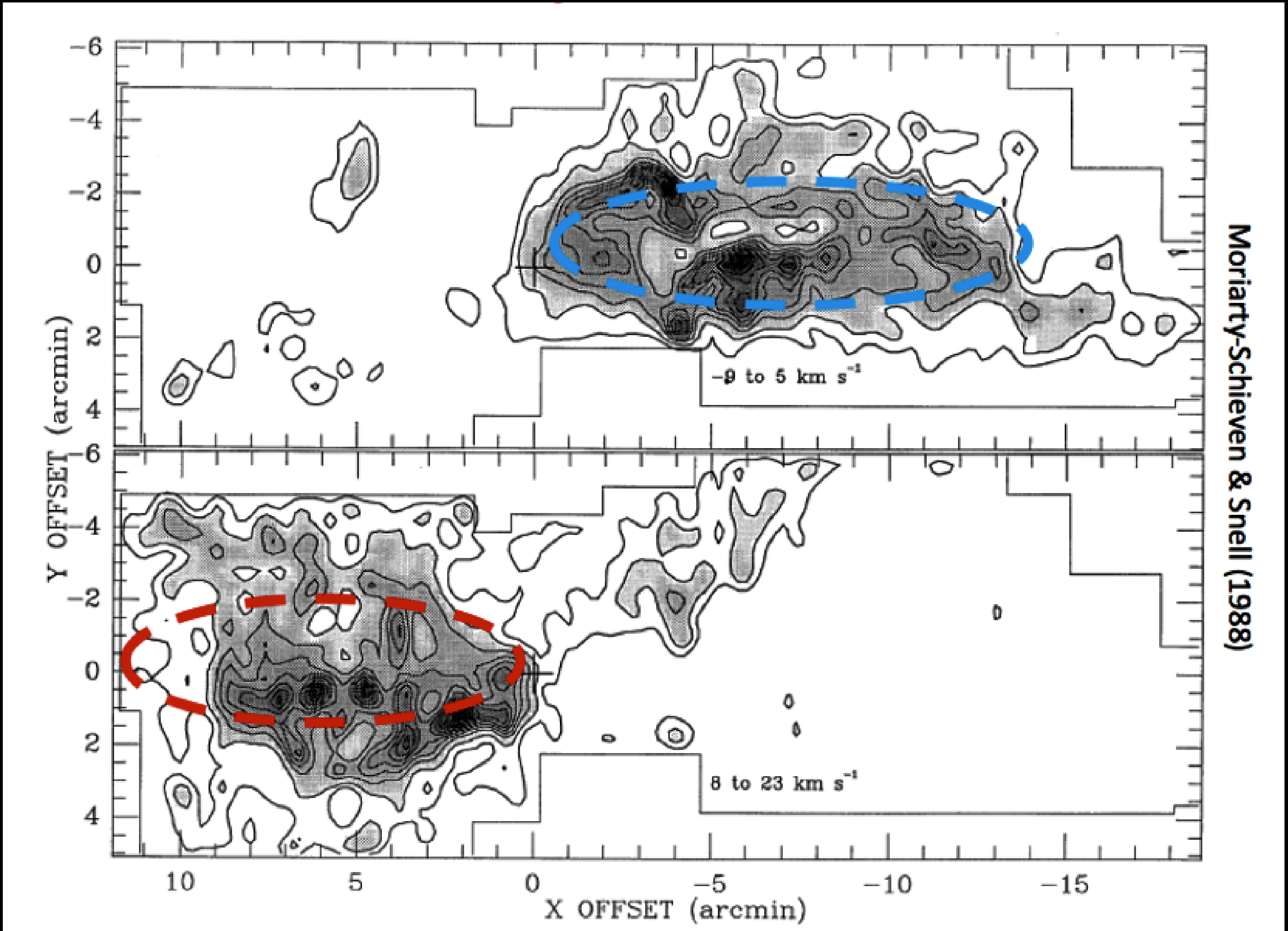
- Jets and shells occur simultaneously
  - no evolution transition
  - no cause and effect
- Unlikely for I04166 jet to create shells
  - No evidence for precession
  - Jet is not broad enough (10 deg vs 30 deg)
- Opening a shell with a jet requires too much sideways acceleration
- Shell and jet are two separate outflow components

"Unified" model (Shang et al. 2006)



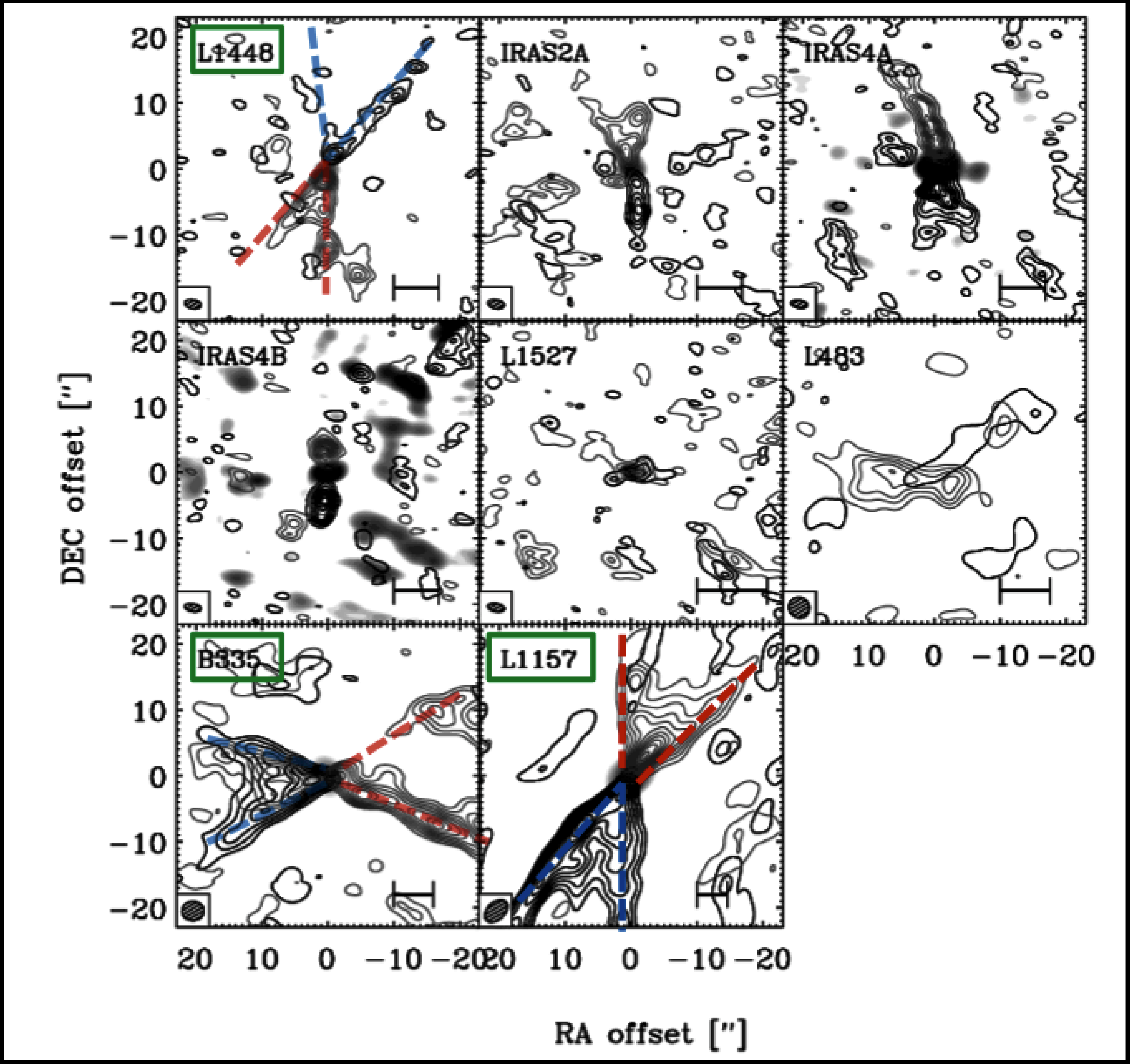
- Interaction X/disk wind with flattened core
  - central jet is densest part of wind
  - shells are shocked cavity walls

Shells in L1551 (Class I)



Moriarty-Schieven & Snell (1988)

Shells in young (Class 0) outflows

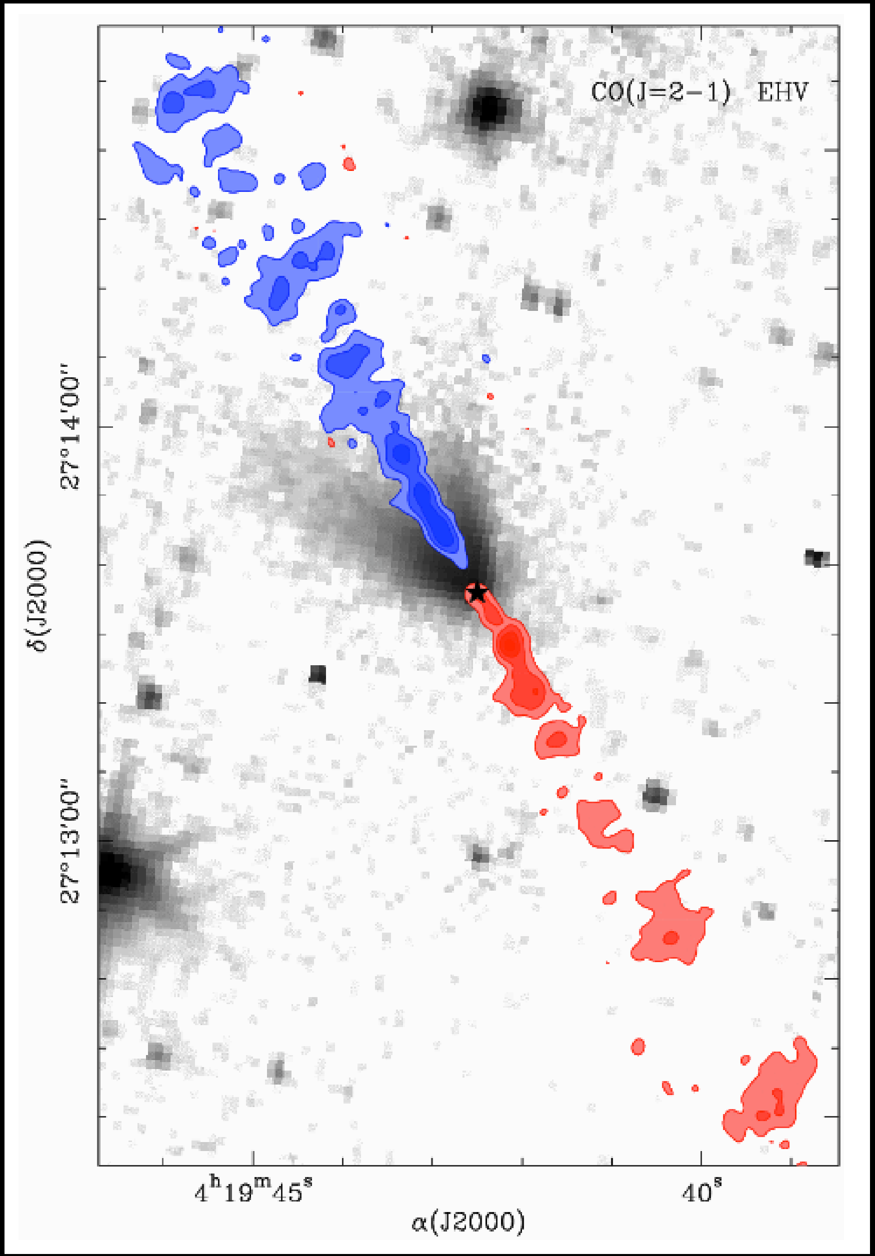


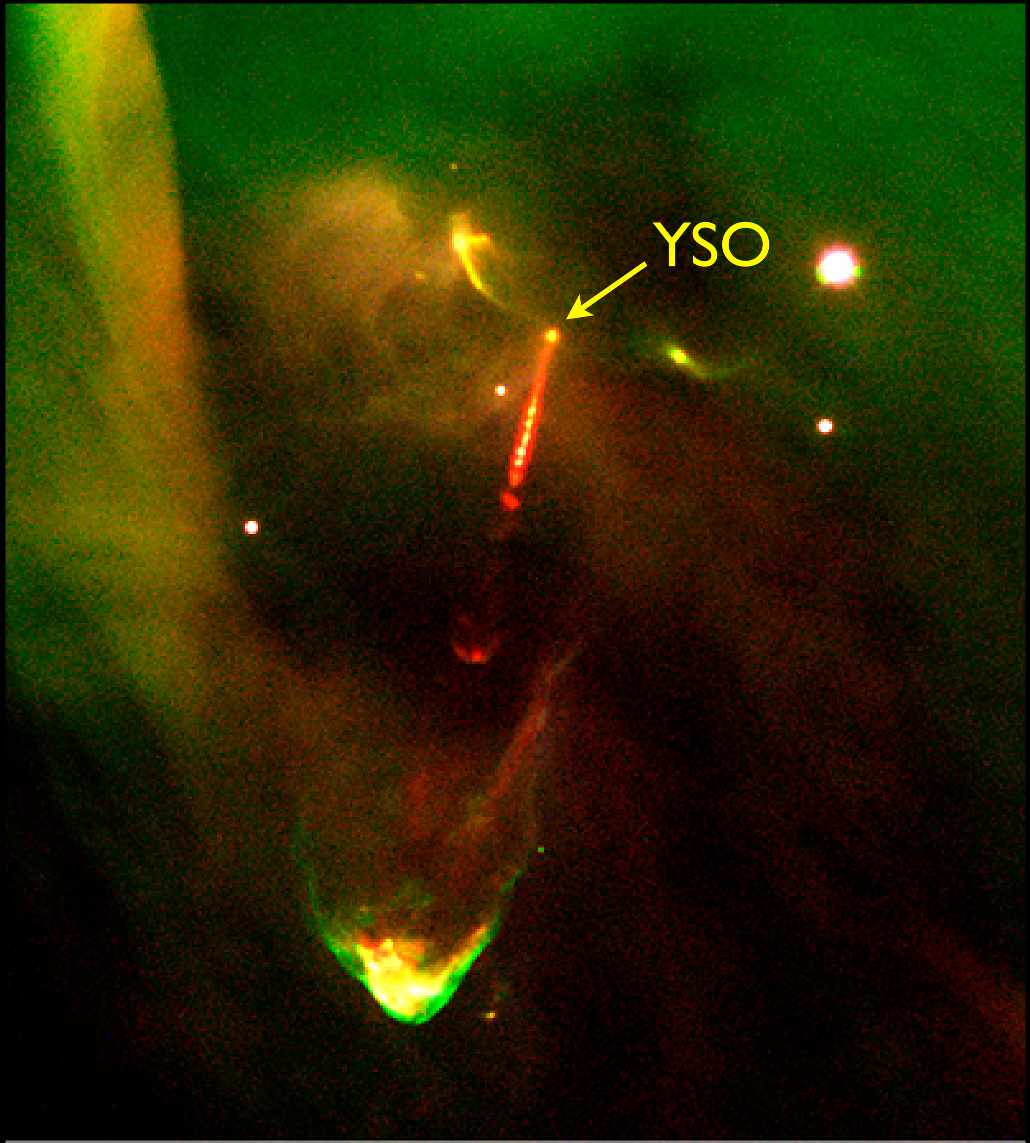
Jørgensen et al. (2007)

Why don't we see more jets?

- Jet is part of the wind itself
- Jets start atomic near YSO
- If dense enough, they become molecular (Glassgold et al. 1991)
  - Early Class 0.
- Evolved jets are not dense enough
  - Invisible (Class I)
- Jets can brighten in later phases due to internal shocks: HH jets

Jets: molecular and atomic

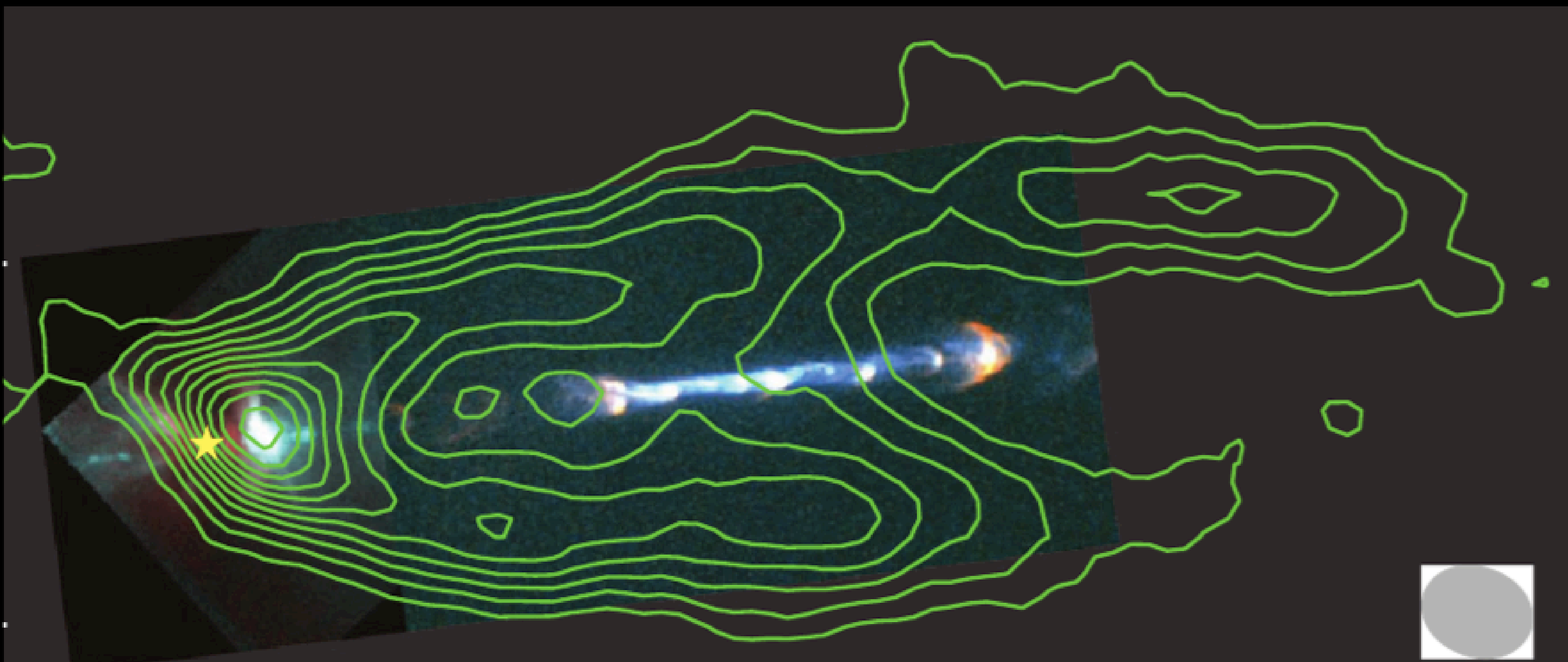




Protostar HH-34 in Orion (detail) (VLT KUEYEN + FORS2)

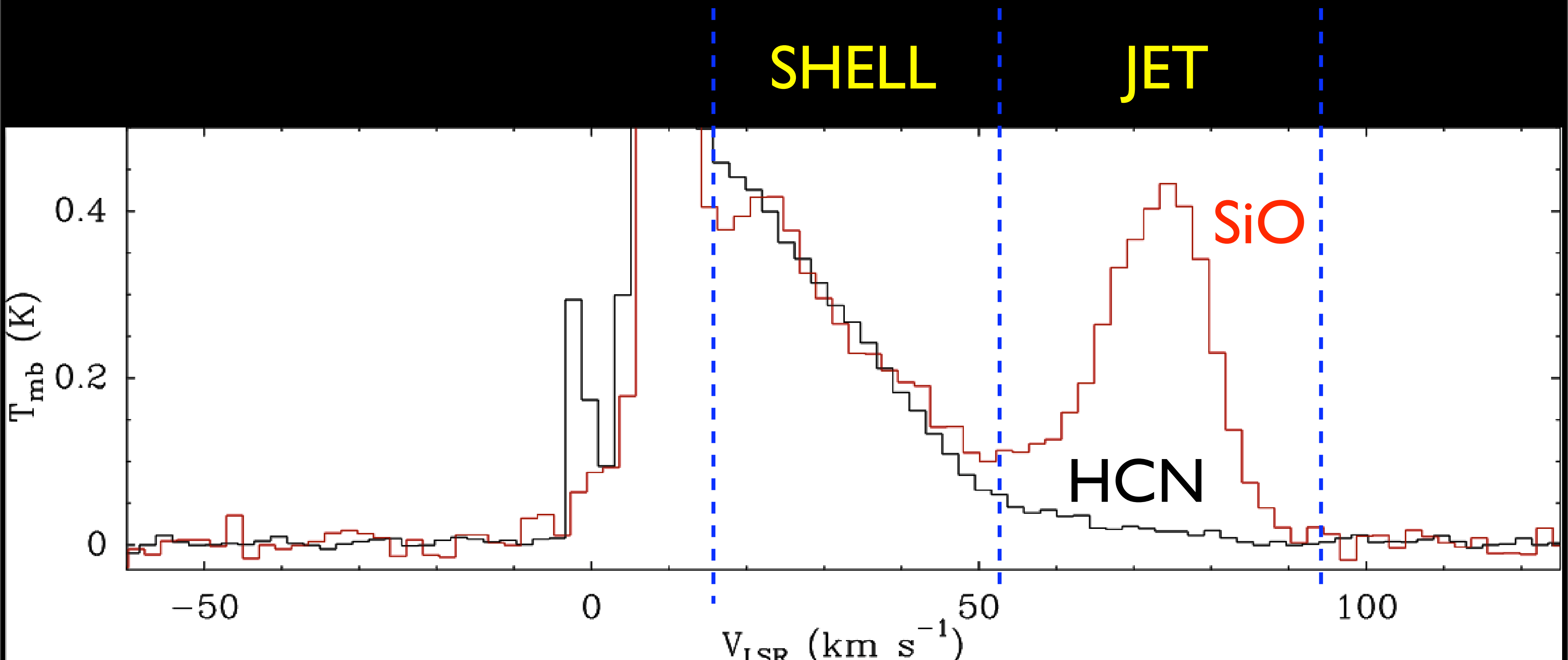
ESO PR Photo 40c/99 (17 November 1999)

B335 Gålfalk & Olofsson (2007)



HH111 Lee et al. (2007)

Jet chemistry



Tafalla et al. (A&A submitted)

- Jet material oxygen rich (little/no HCN, CS)

Conclusions

- Outflows contain two gas components of different origin
- Shells represent ambient material accelerated by wide angle wind (outflow wings)
- Jets represent inner, densest part of wind
  - molecular at earliest stages
  - atomic later on
- Jets are spectacular but feedback on cores dominated by wide angle wind
- Simulations needed to characterize interaction