Dynamics in pre-stellar cores : fast infall in L1689B

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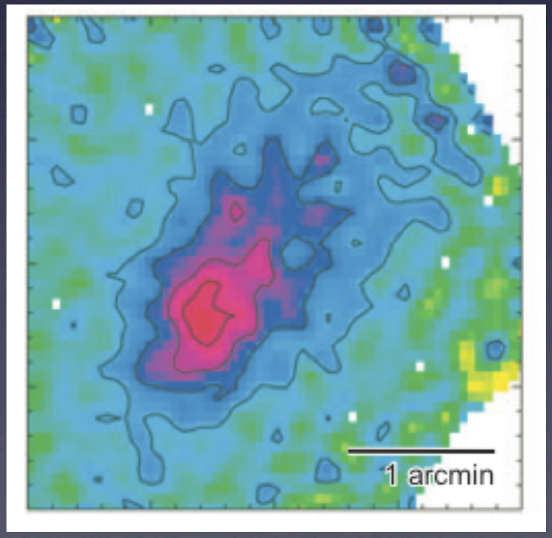
Motivation

- Critical influence of initial conditions on SF
- No clear understanding of dominant physical processes
- Density profile well characterised and not very discriminating
- Gravitational collapse key process, much less well characterised

Alves et al.

Oscillations: Lada et al. 2003

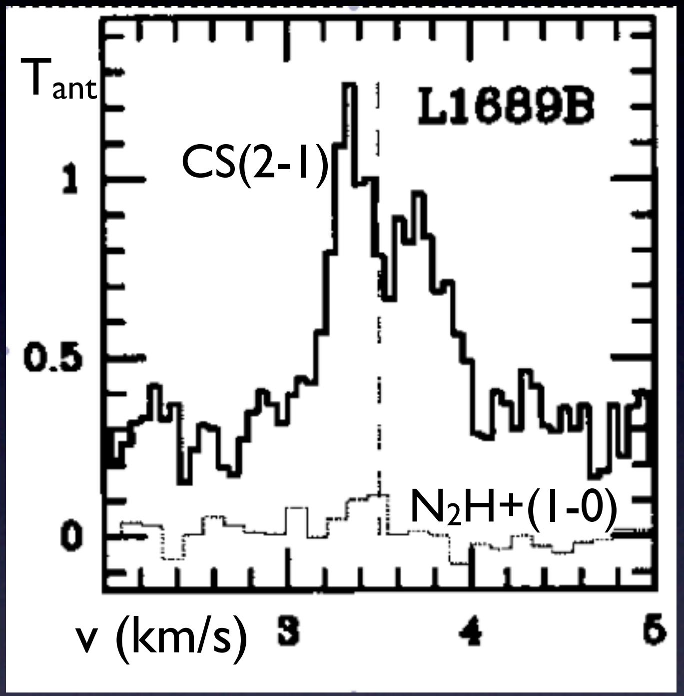
Ward-Thompson et al.



Extended infall: Tafalla et al. 1998
Williams et al. 1998

Characterising infall: modelling approach

Lee et al. 1999



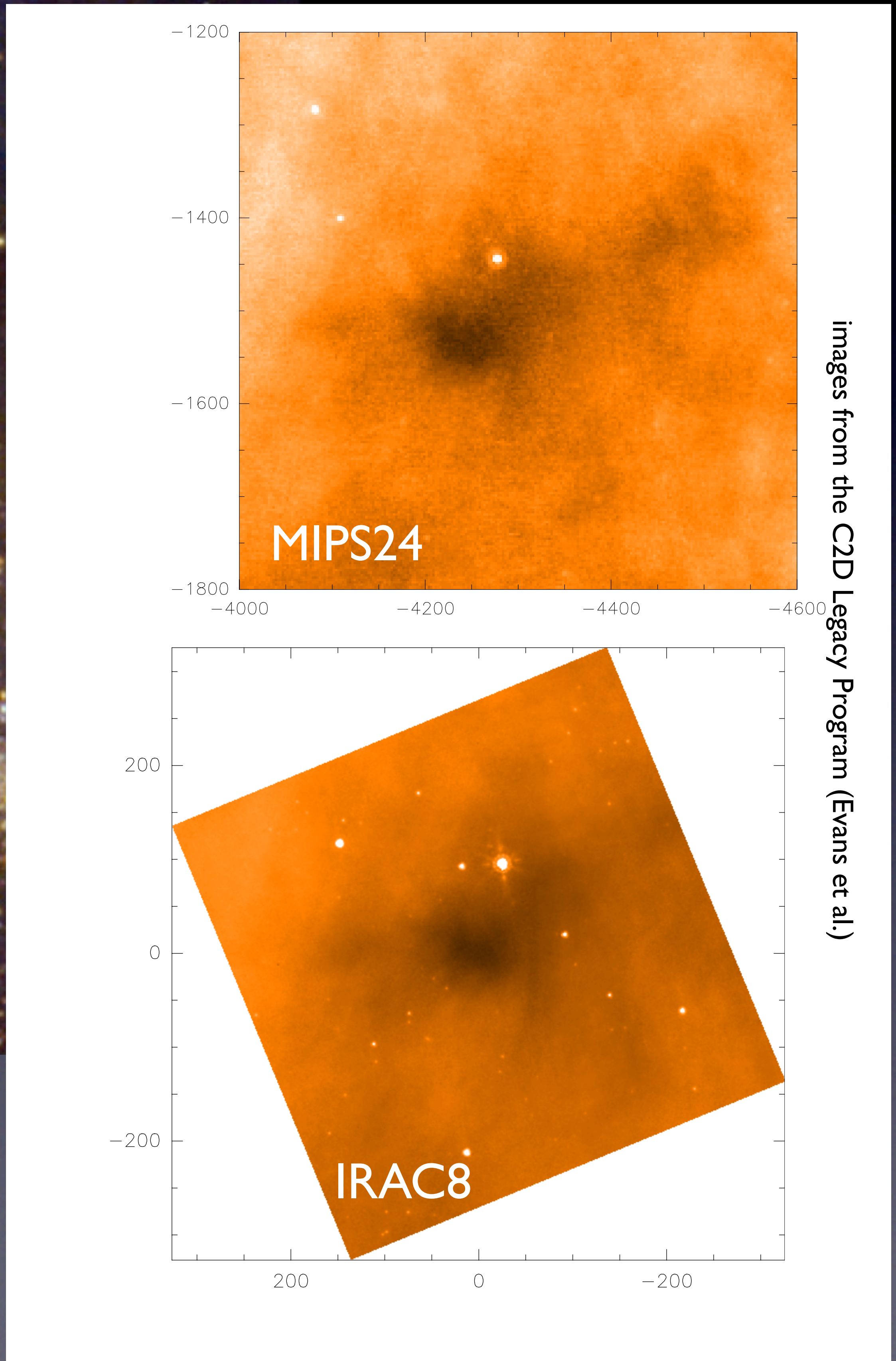
- First type of approach: quantifying line asymmetry (e.g. Lee et al. 1999, 2001, Sohn et al. 2007)
    - advantage : quick analysis of many cores
    - drawback : no detailed characterisation of velocity field
- Second type of approach: detailed radiative transfer modelling of line profiles (e.g. Belloche et al. 2002, Keto et al. 2004, Lee et al. 2007)
    - advantage : velocity profiles are determined
    - drawback : analysis takes somewhat more time...

Our approach

- Mapping of cores in N_2H+(1-0) and N_2H+(3-2)
    - N_2H+ not very depleted at core centers (Pagani et al. 2007, Bergin et al. 2002, Walmsley et al. 2004)
      → good tracer of *inner* core kinematics
    - less degenerate information (column density/temperature) with 2 rotational transitions of species with hyperfine components
      (Keto et al. 2004)
- Detailed fitting of line profiles with NLTE code (Pagani et al. 2007) using N_2H+ collisional coefficients by Daniel et al. (2005) and taking line overlap into account

L1689B

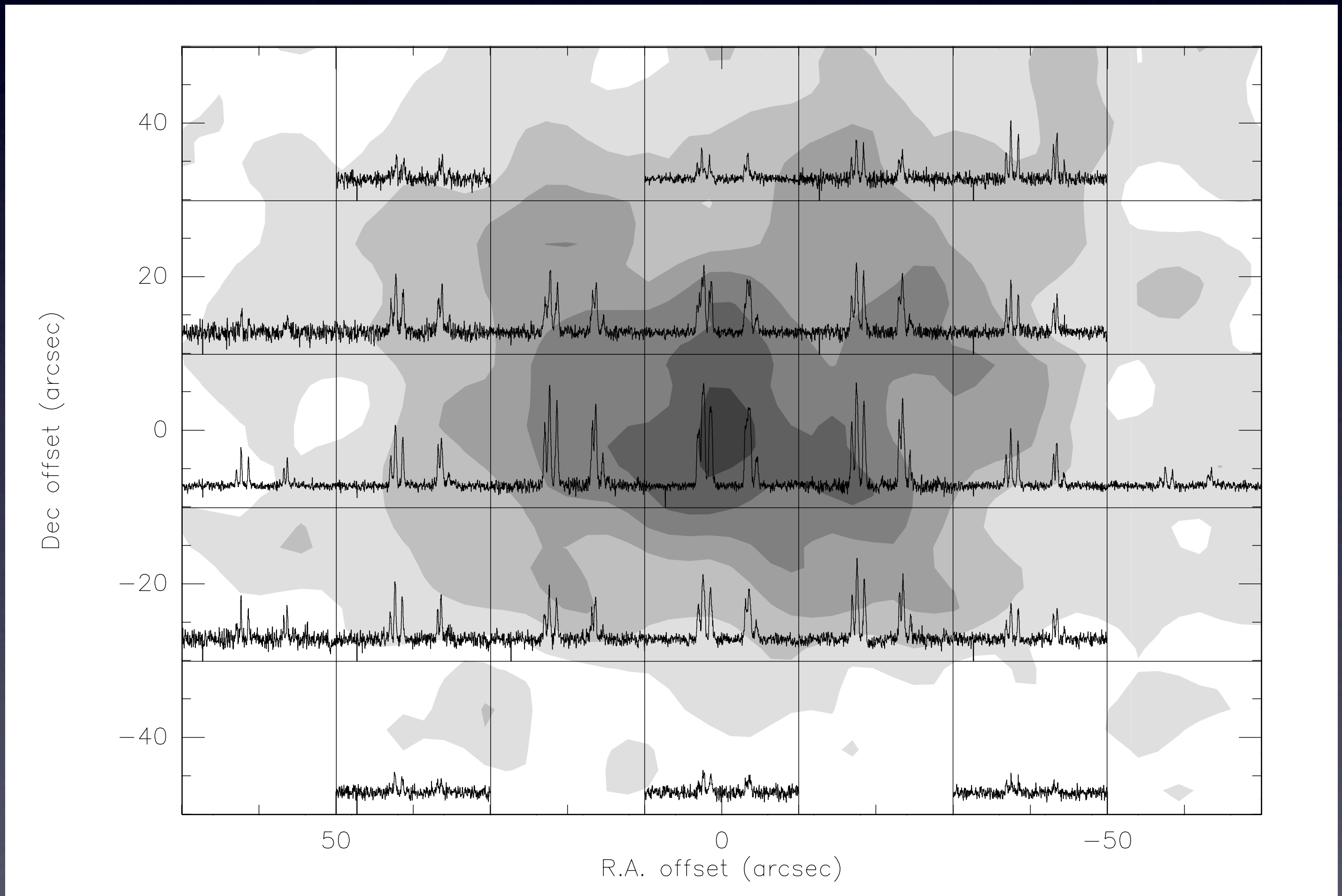
- starless (no star detected even with Spitzer), no outflow
- not very chemically evolved (cf. Shirley et al. 2005): low CO depletion factor and deuterium fractionation (Bacmann et al. 2002, 2003)
- A probable infall candidate (Lee et al. 1999, Sohn et al. 2007)



Observations

- N_2H+(1-0) map: high S/N (around 10) and high spectral resolution (30 m/s) in order to fit line profile
- central point in N_2H+(3-2)
- central point + (20,0) offset N_2D+(1-0) and N_2D+(2-1)

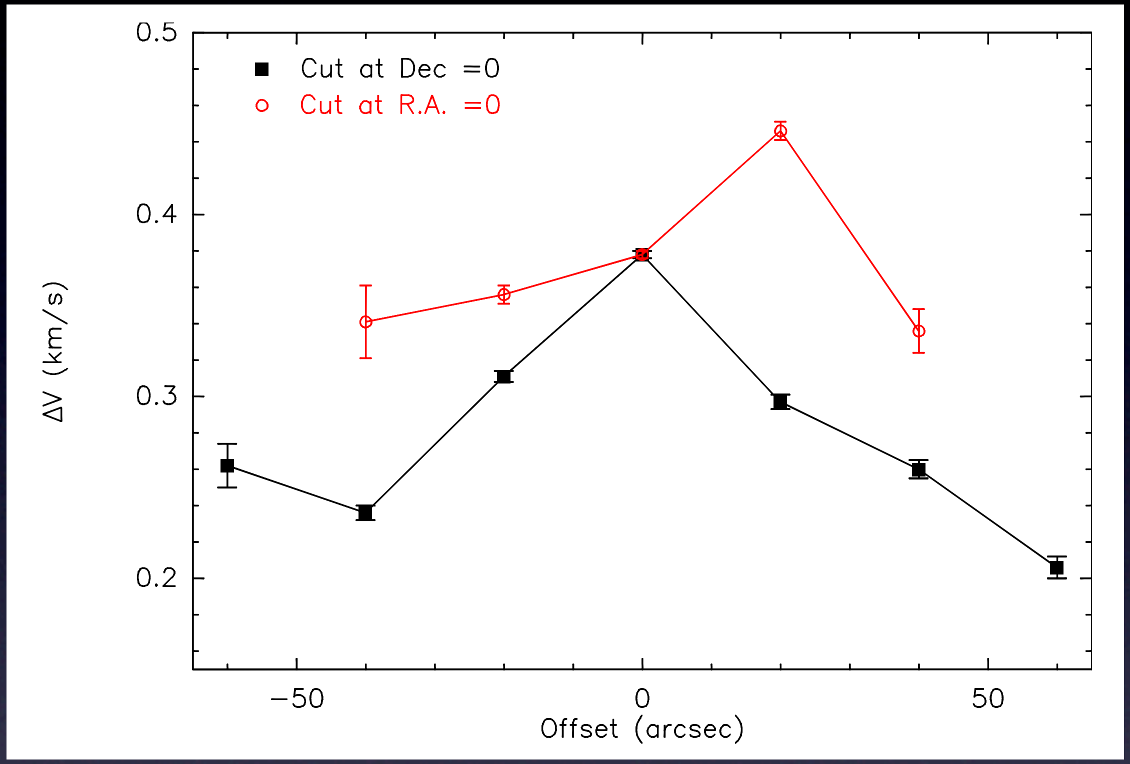
Data from the IRAM 30m telescope

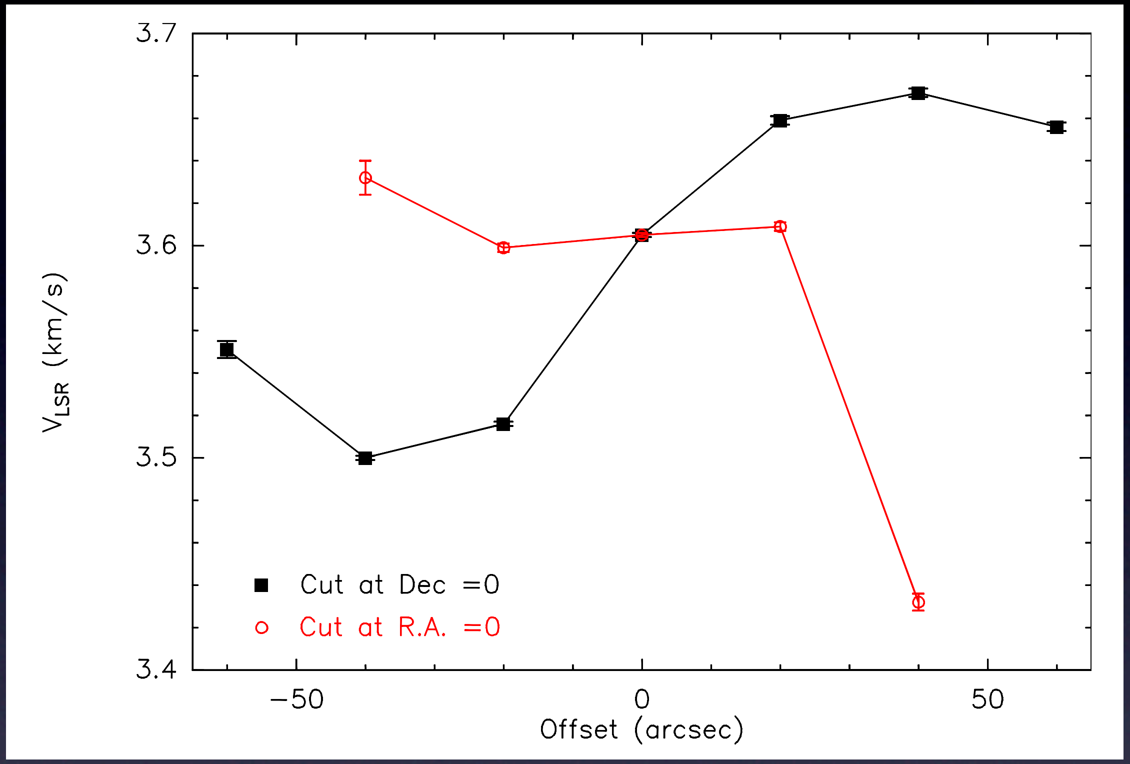


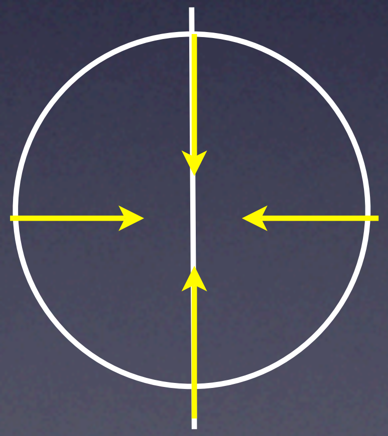
1.3 mm continuum map from André et al. (1996)

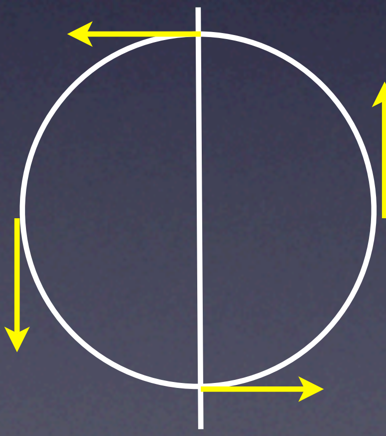
Spatial resolution ~ 28 arcsec for N_2H+(1-0), 9 arcsec for N_2H+(3-2)

Linewidths and line shifts





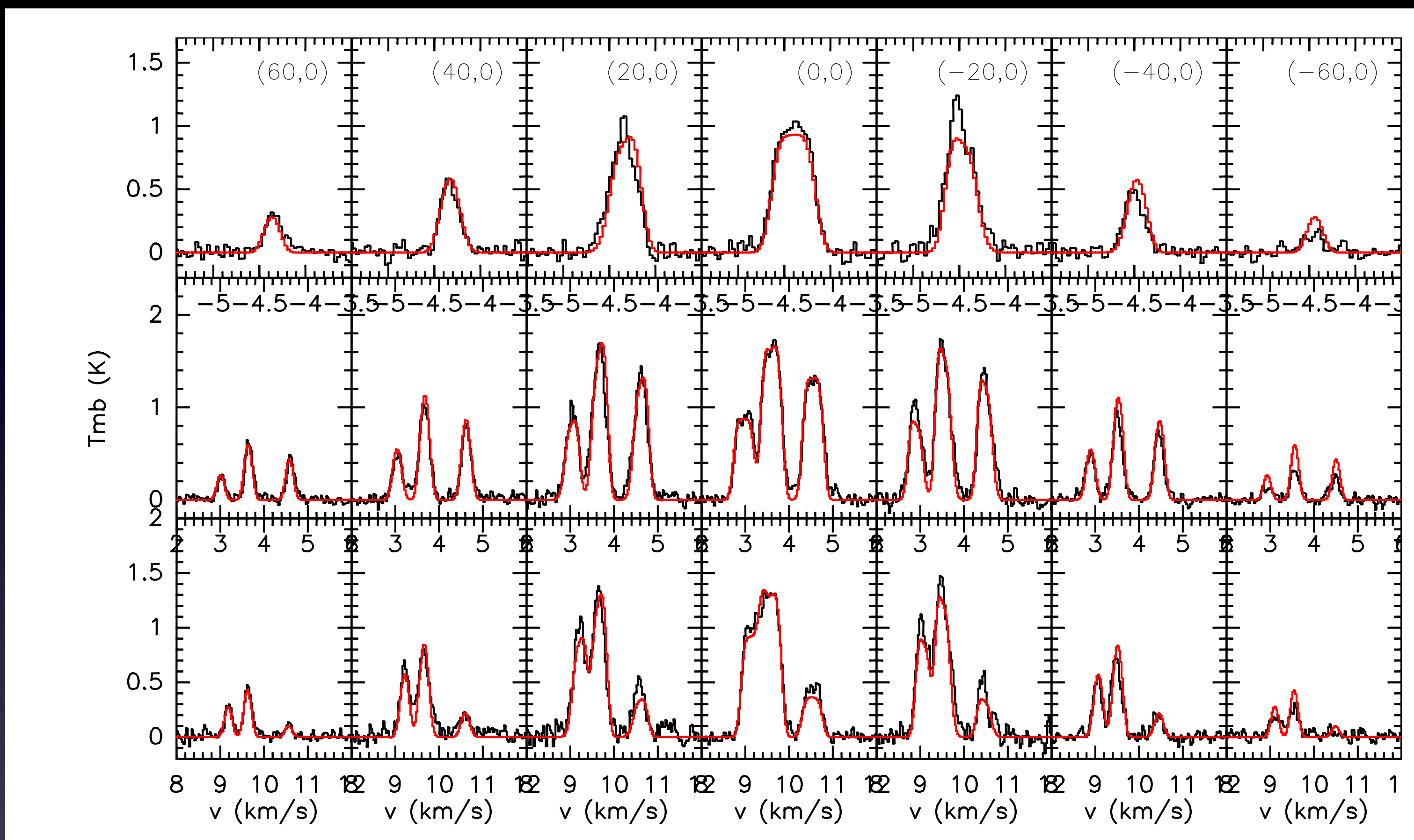




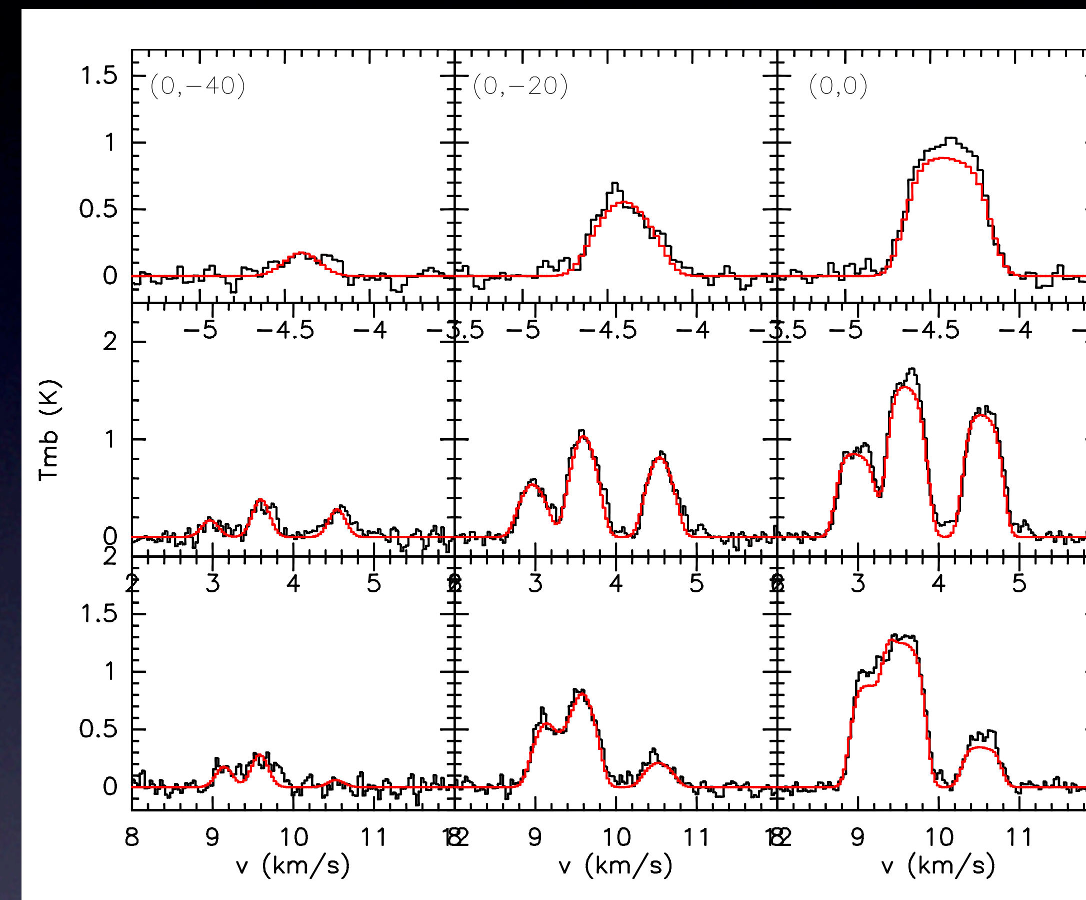
- one direction stands out : rotation axis = declination axis (see core geometry)
- indicative of both infall (left Fig.) and rotation (right Fig.)

N_2H+ Fitting results

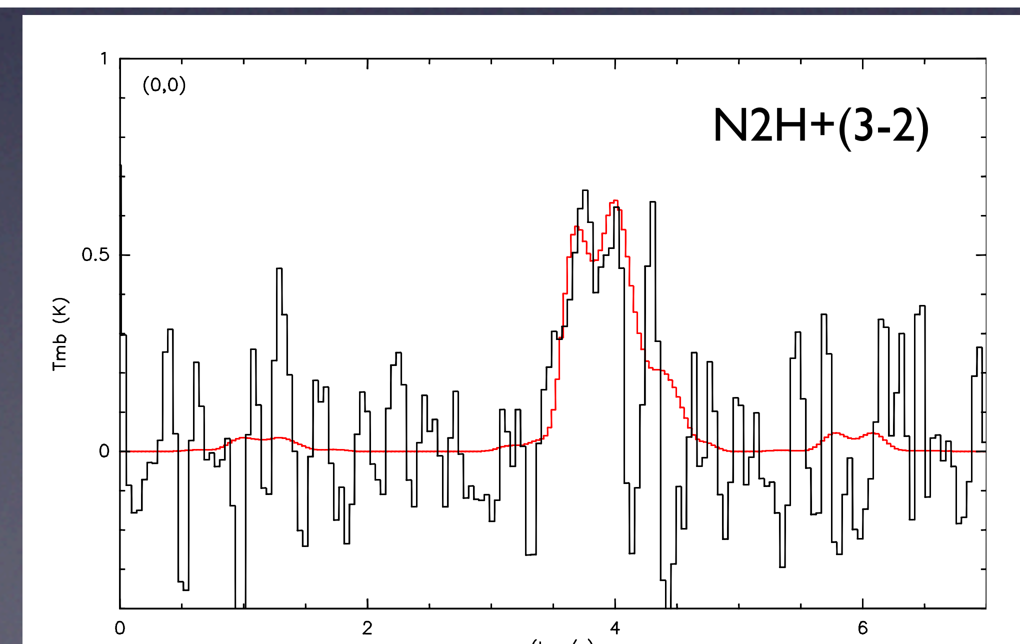
$N_2H+(1\text{-}0)$ East-West profile



$N_2H+(1\text{-}0)$ South profile

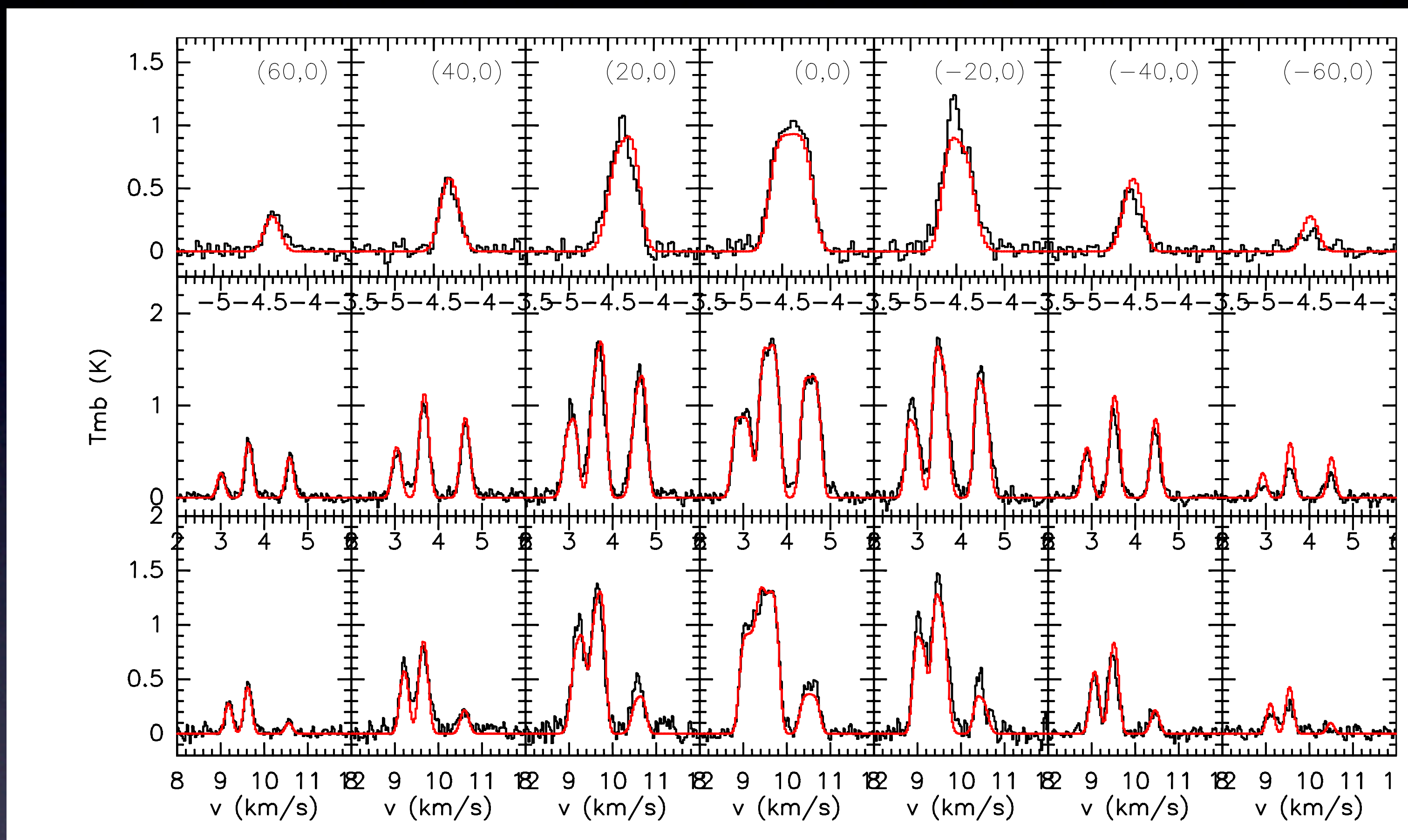


- Fitted parameters: N_2H+ abundance, gas temperature, radial velocity, rotation velocity in 10 concentric shells
- density profile derived from 1.3mm continuum observations (fixed)
- 40+ parameters



N_2H+ Fitting results

N_2H+(1-0) East-West profile



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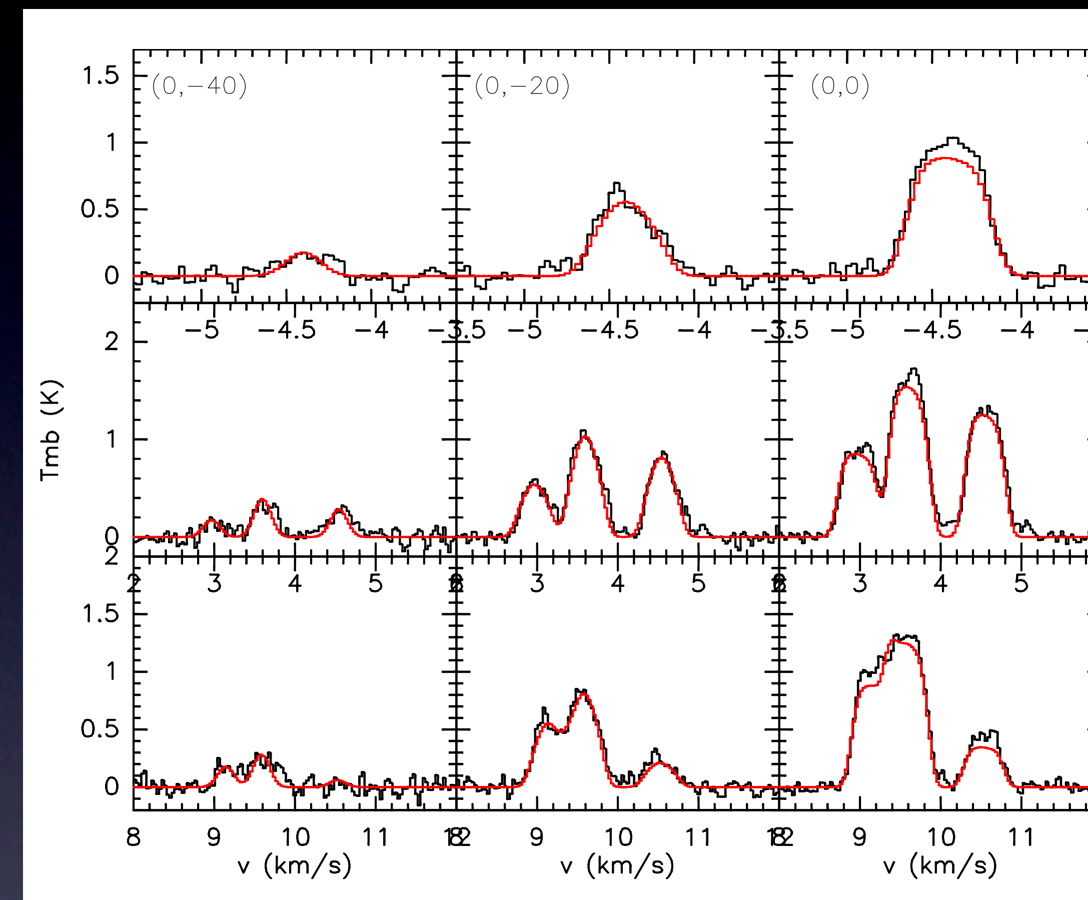

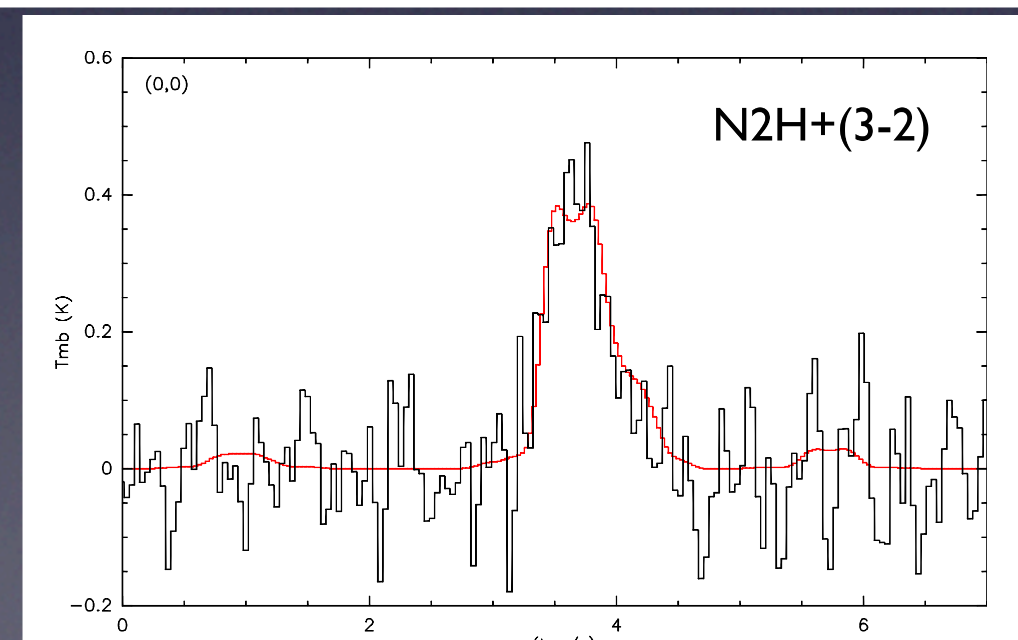

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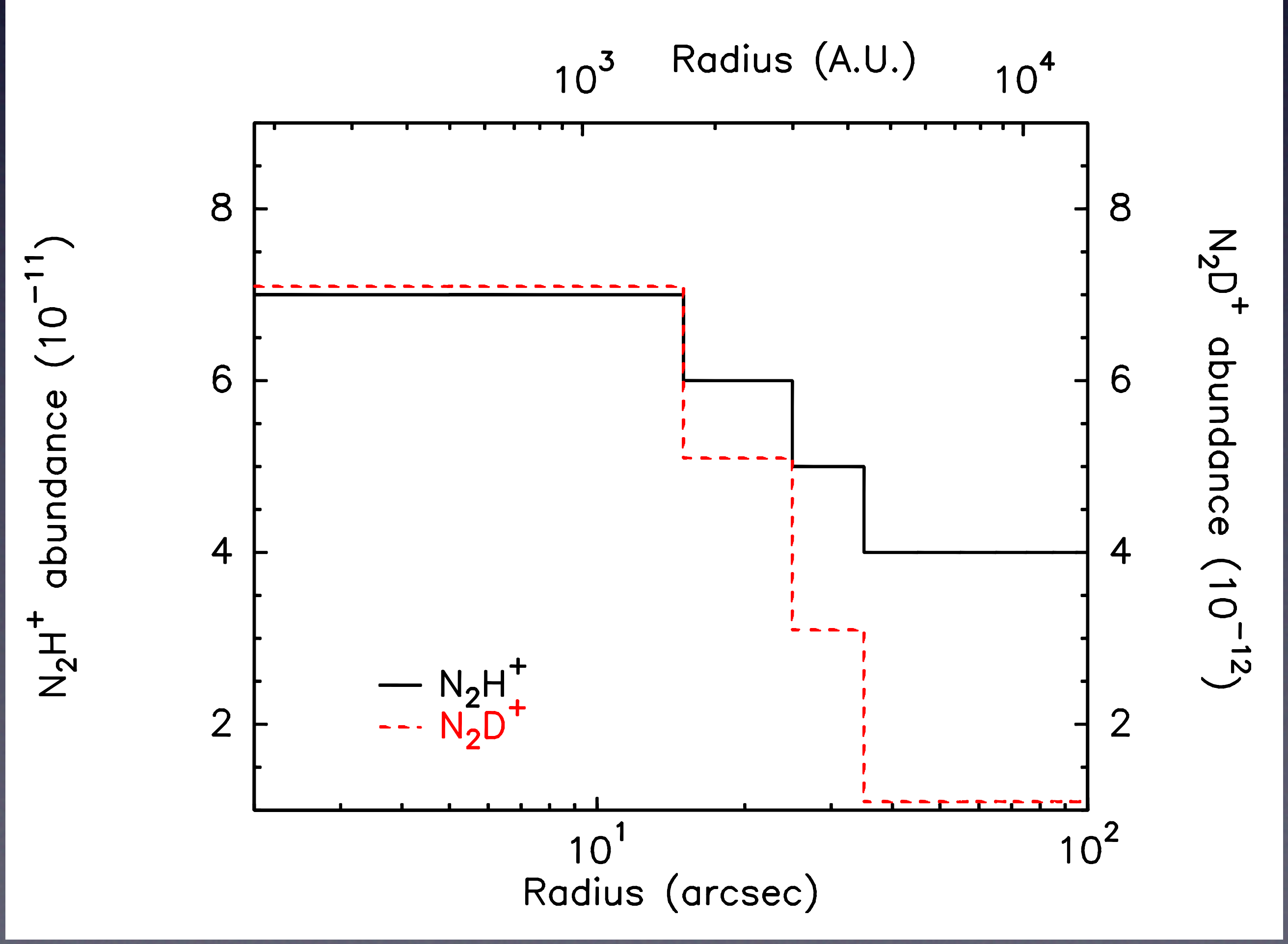
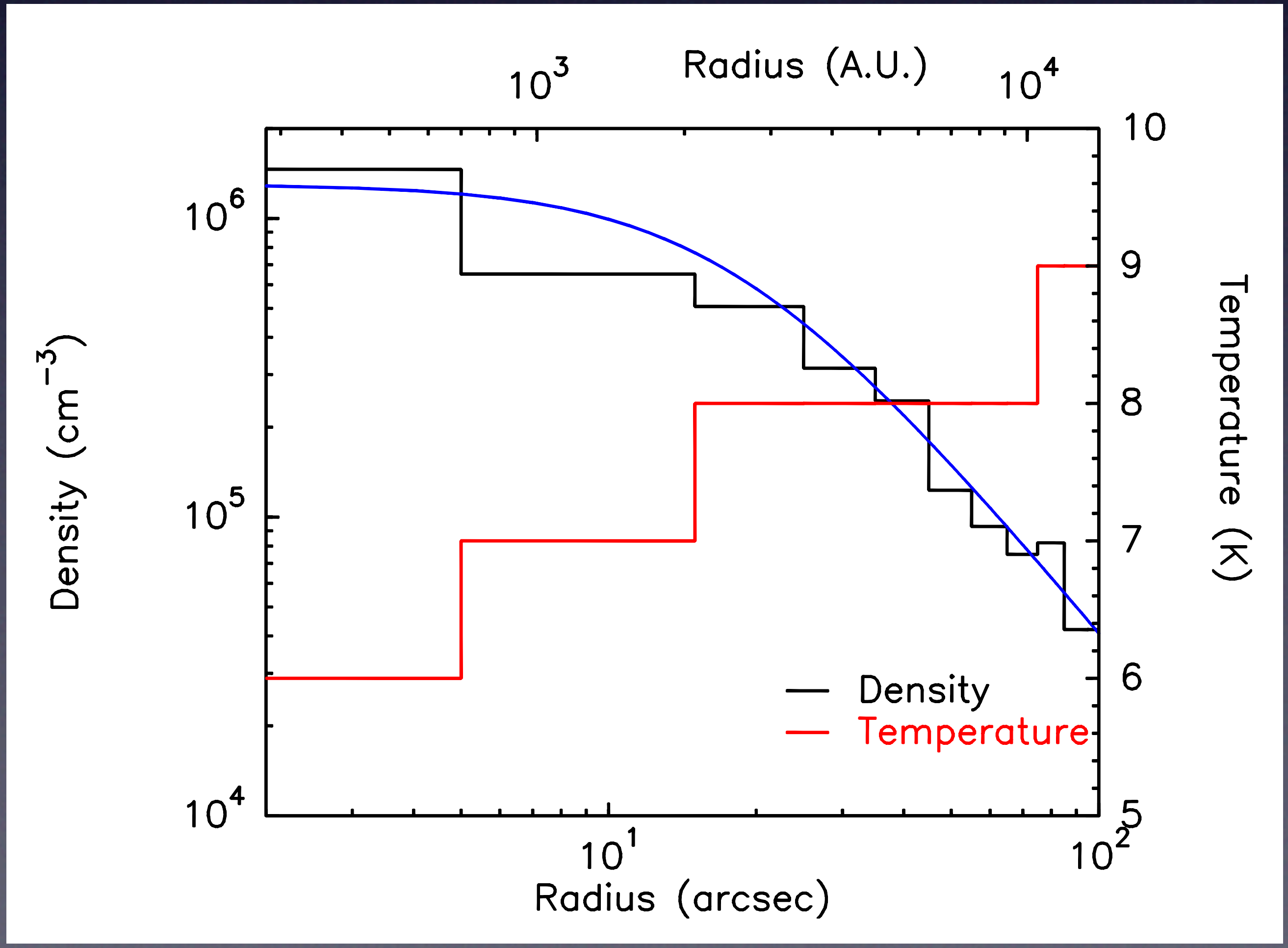
Abundance and temperature profiles

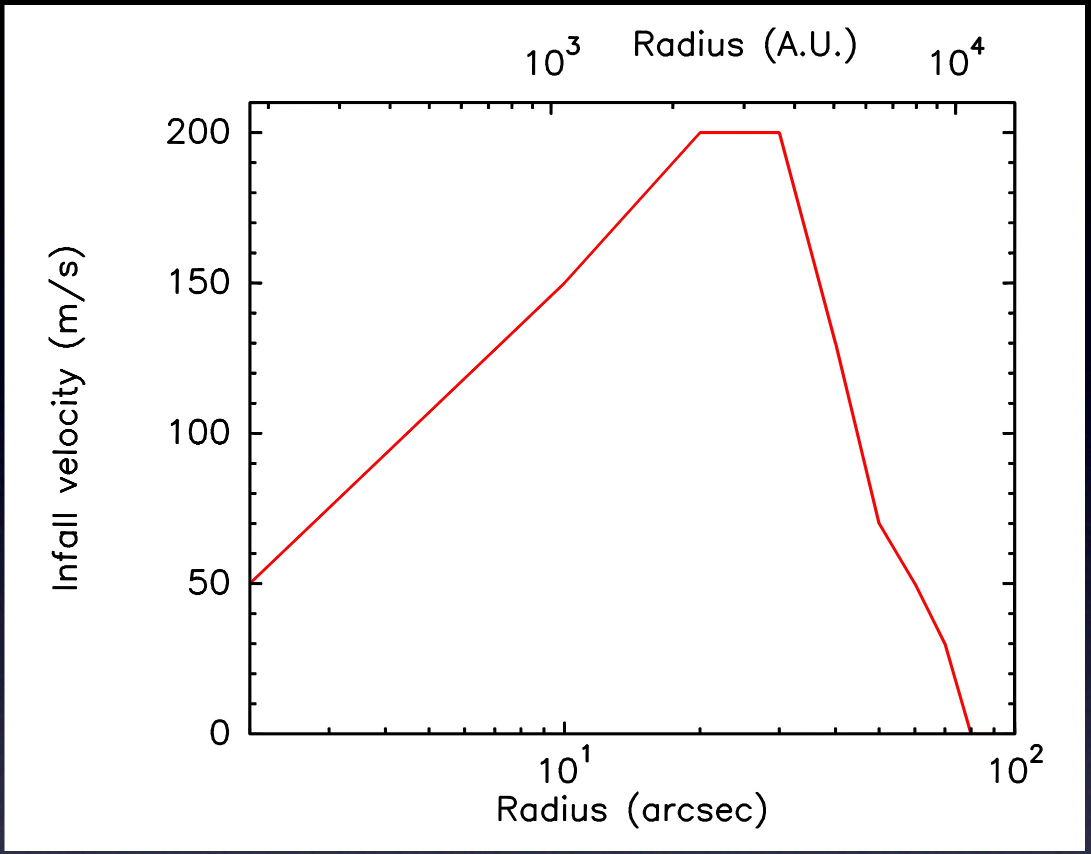
- same model for N_2D+. $N_2D+/N_2H+ \sim 10$ %
- temperature/density degenerate because of low S/N of $N_2H+(3\text{-}2)$
- derived gas temperature consistent with inferred dust temperature from Evans et al. (2001)
- density well reproduced by $n = \rho_c/[1+(r/r_f)^\alpha]$ with $r_f \sim 3000$ A.U. (see Tafalla et al 2002)

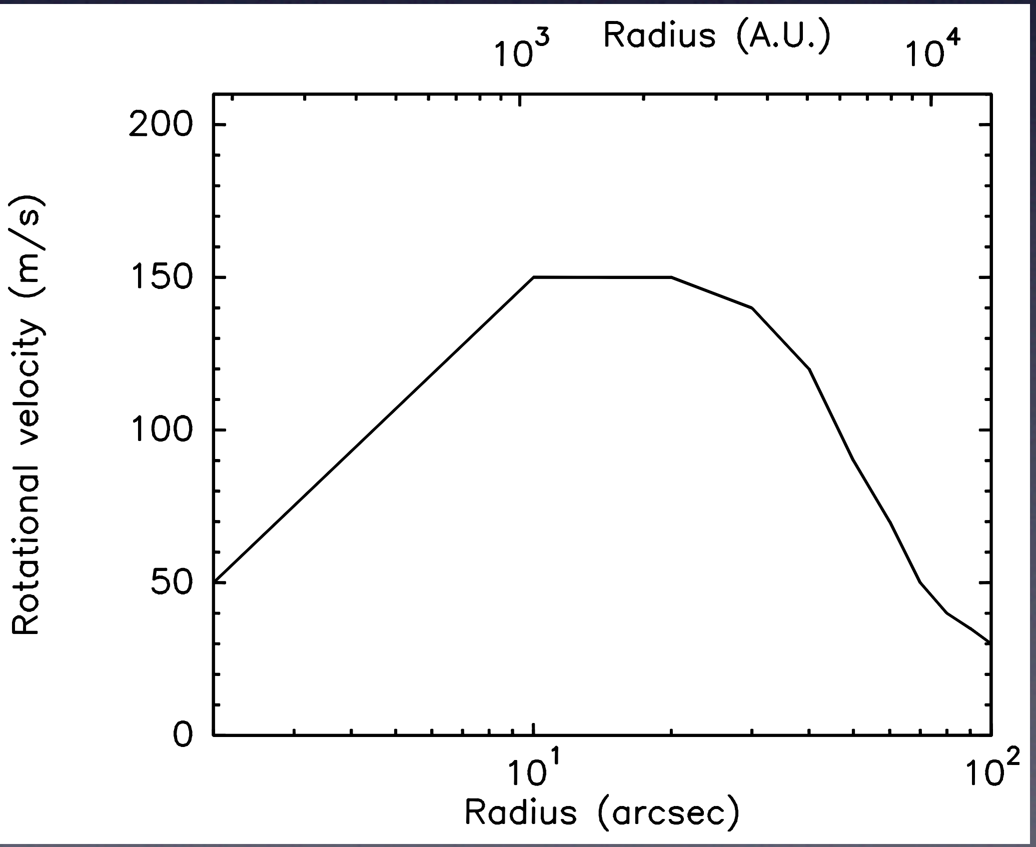




Velocity profiles

- need high velocity (~ 200 m/s) to reproduce linwidths of central spectrum
- sound speed ~ 170 m/s
- profile not completely constrained but looks Λ-shaped





- rotation also needed to reproduce profiles
- fast differential rotation
- profile similar to that of IRAM04191 (Belloche et al 2002): $v \sim r^{-1.5}$

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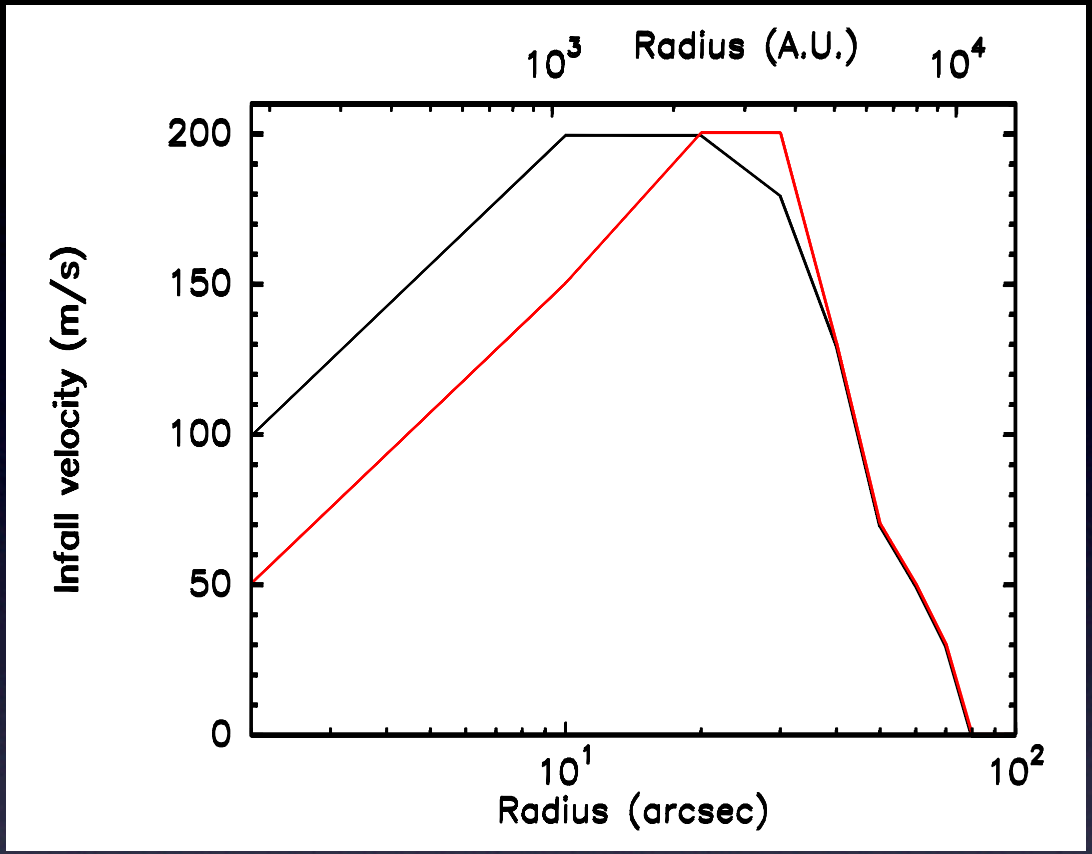

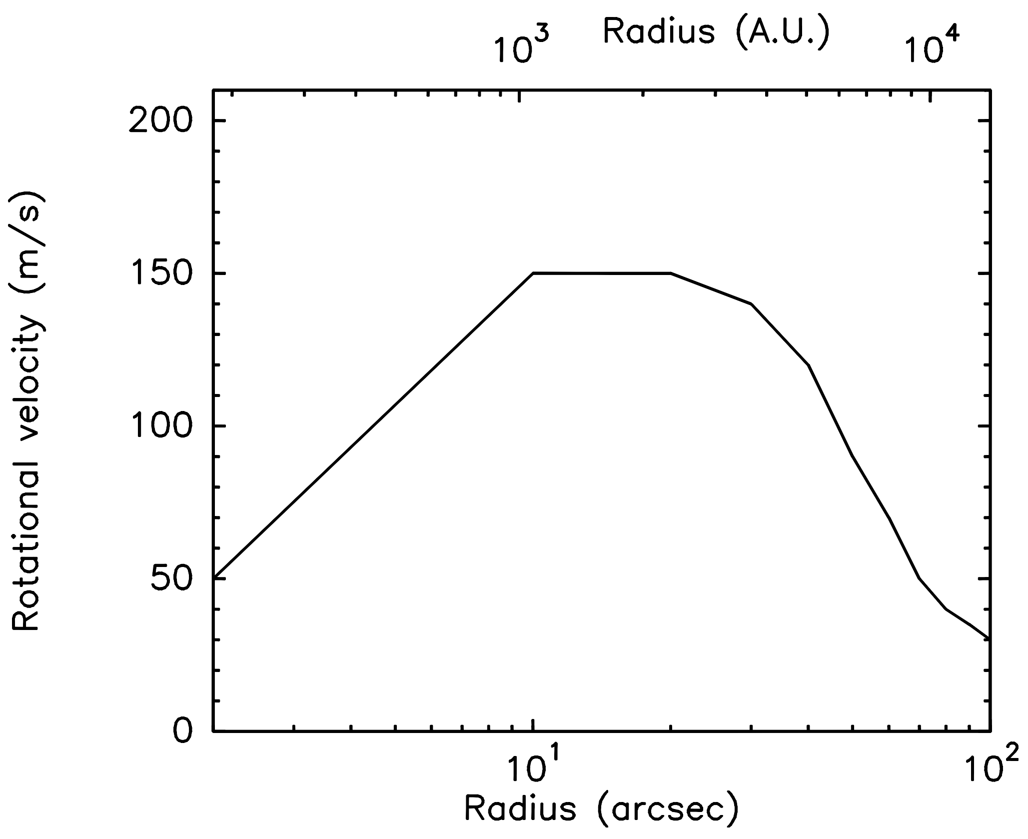

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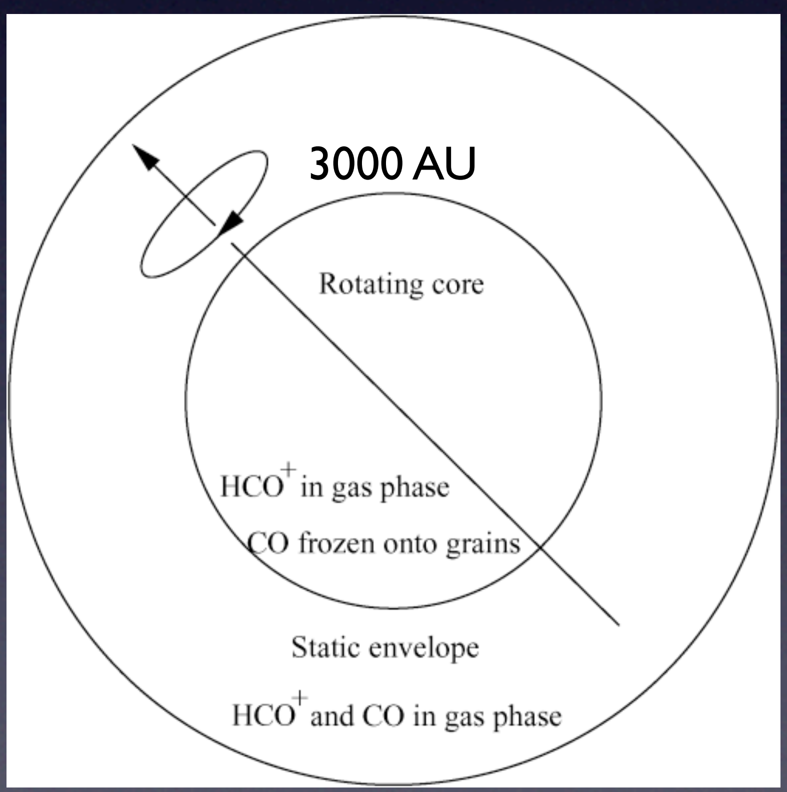
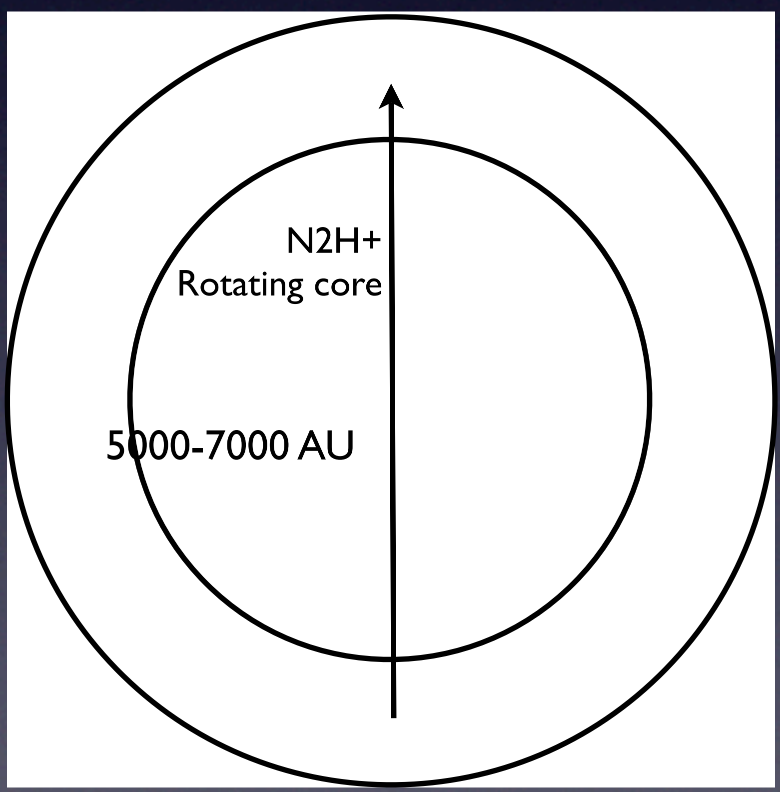
Comparison with other models of L1689B

- Redman et al. 2004: non-LTE radiative transfer modelling of HCO+(3-2) line profiles in L1689B
- differences due to HCO+ depletion ?



Redman et al. 2004

No infall necessary



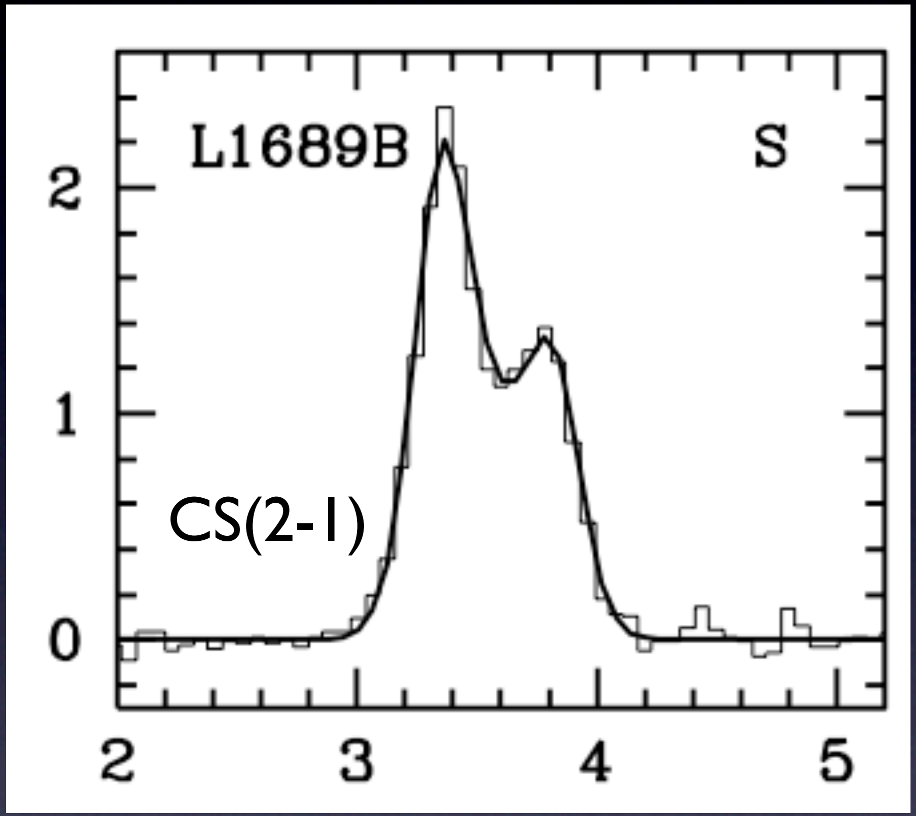
our model

infall necessary

model not sensitive beyond 7000 AU

Comparison with other models of L1689B

Lee et al. 2001



- mapping observations of CS(2-1) and $N_2H+(1-0)$
- extended infall asymmetry seen in CS lines: ~ 0.18 pc
- model of 2 contracting layers (Myers et al. 1996) → infall speed ~ 0.05 km/s

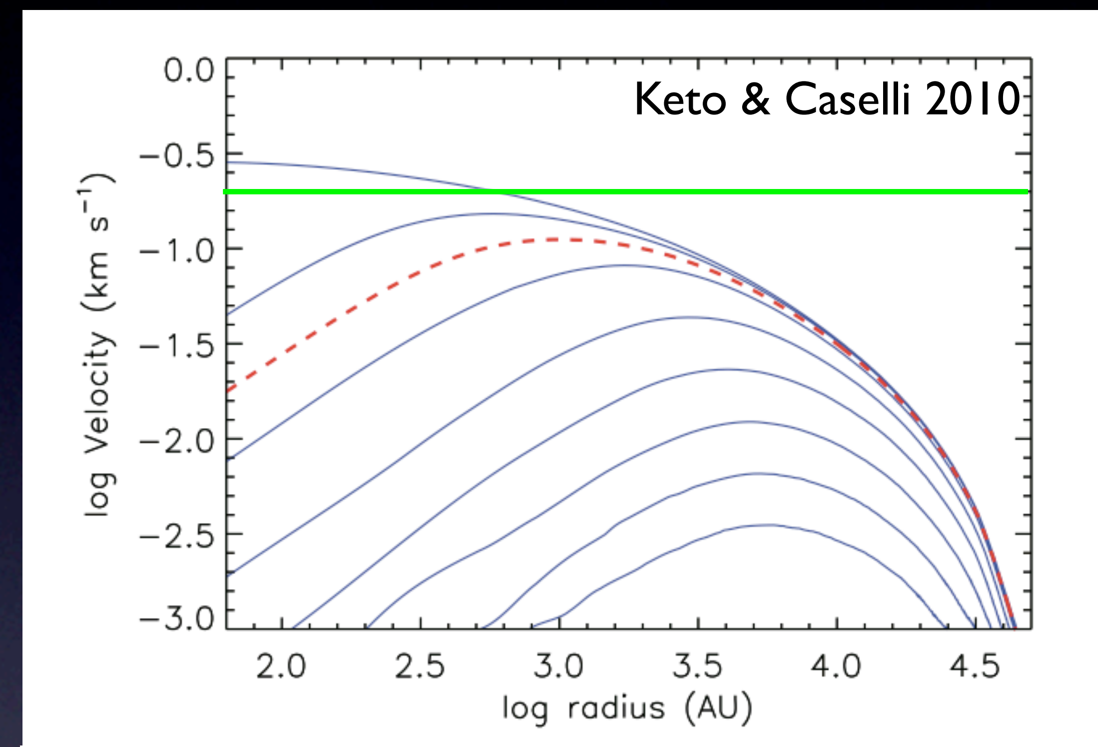
Not inconsistent with our results since:

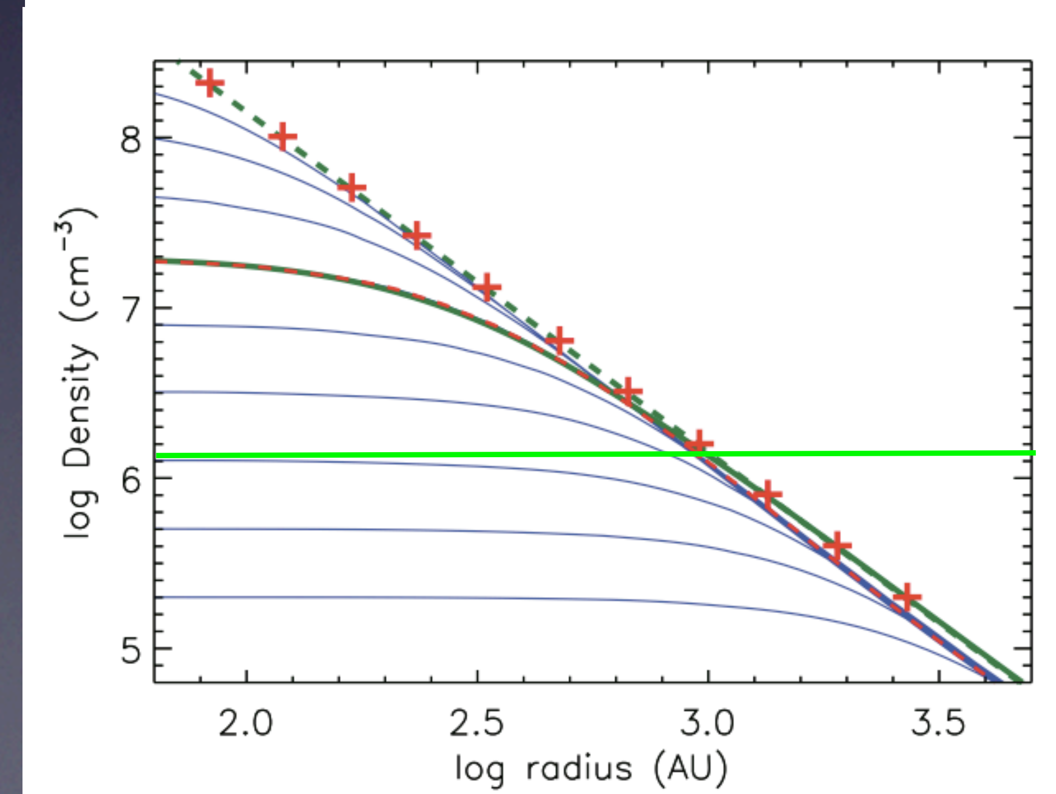
- N2H+ emission more compact (more central)
- CS depleted in the center

→ trace infall in different zones.

Comparison with dynamical models collapse of Bonnor-Ebert sphere

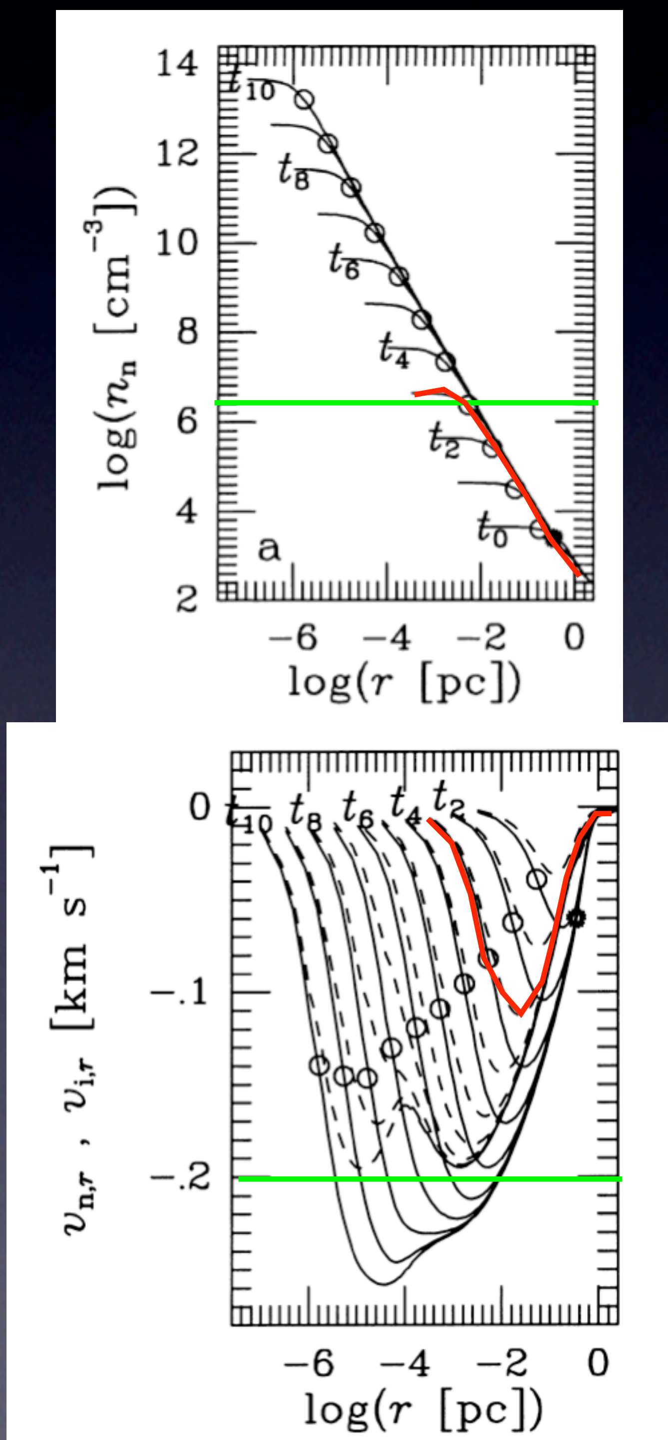
- profile overall consistent in shape with models of collapse of BE spheres (e.g. Keto & Caselli 2010, Myers 2005)
- max infall speed at ~ r_f
- nearly supersonic infall velocity implies core which is dynamically evolved - more than L1544, although less centrally concentrated
- role of environment ? L1689B not (completely) isolated
- chemistry less evolved than in L1544





Comparison with models ambipolar diffusion

Ciolek & Basu 2000



- Ciolek & Basu (2000) model fitting L1544
- similar type of profiles - uncertainty in data does not allow more detailed comparison
- density profile corresponds to moderately evolved core
- velocity profile corresponds to that of a core which is 2 orders of mag denser

Conclusions (1)

- Modelling of N_2H+ map of L1689B confirms L1689B as an infall candidate (Lee et al. 1999, Sohn et al. 2007)
- Fast infall (close to sound speed) necessary to reproduce spectra
- maximum velocity around edge of flat inner parts, in agreement with BE sphere collapse models (Keto & Caselli 2010)
- Models are unable to account for relatively “low” central density and fast infall
- Is the core more evolved or less than L1544 ?

Conclusions (2)

- on the observational/technical point of view: need to have maps (of several rotational transitions) with
  - very good S/N
  - very good spectral resolution
- profiles not really asymmetric despite fast infall
- N_2H+(1-0) not optically thin (opt. depth ~ 2 for isolated component), N_2H+(3-2) optically thin
- N_2H+ reasonably abundant in the centre: traces inner velocity field (but not the outer one)