Imaging signatures of infall motions in the G31.41 hot molecular core

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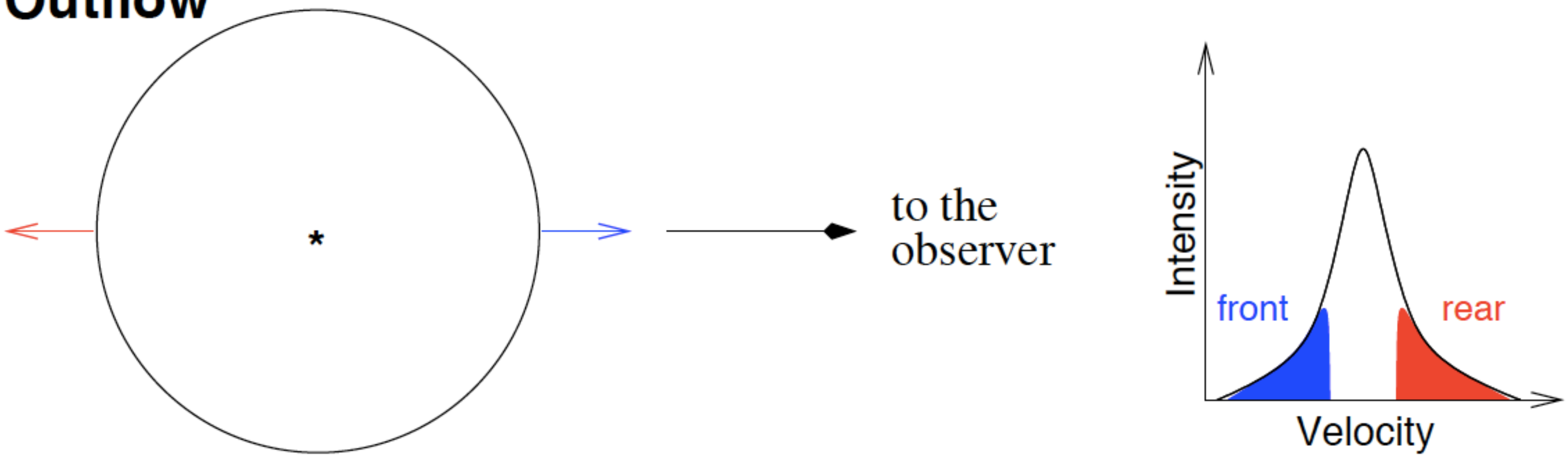
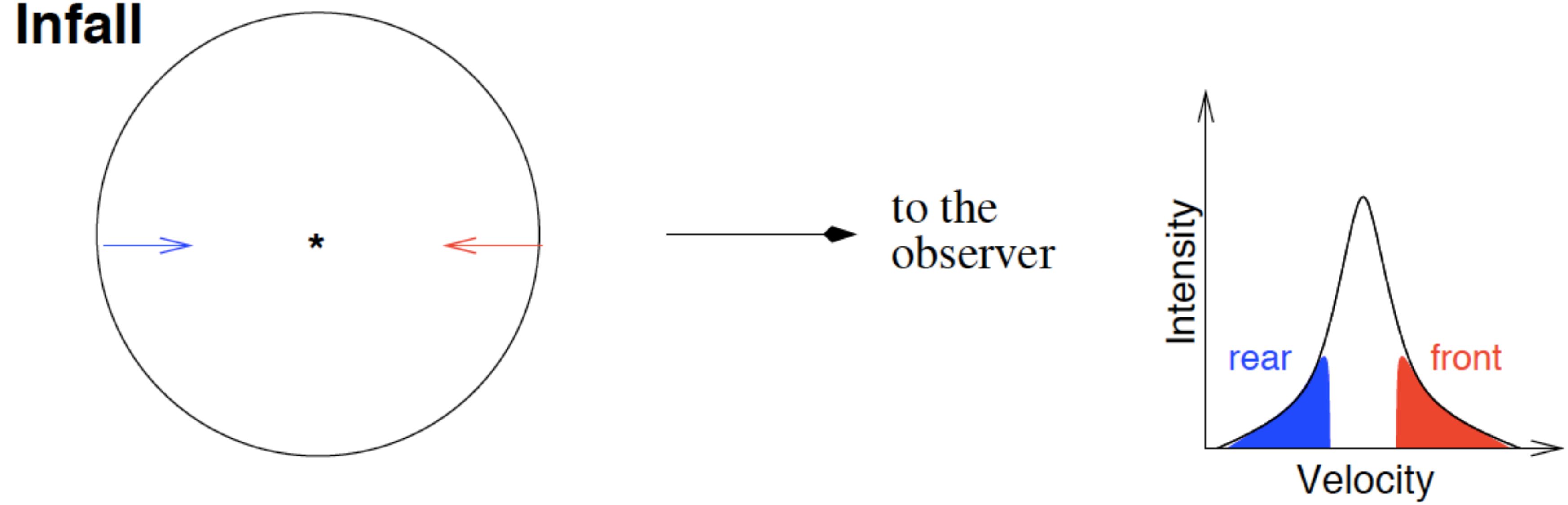
Outflow vs infall in optically thin symmetric sources

Outflow



Infall



Blue asymmetries in line Profiles as tracers of infall

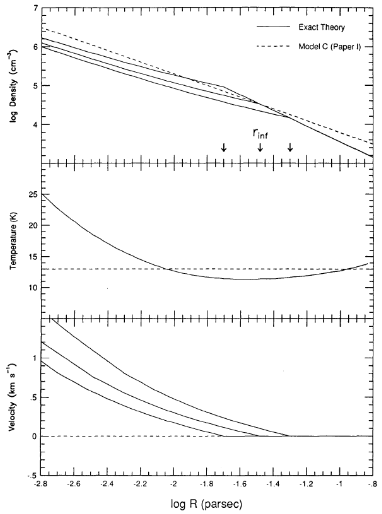
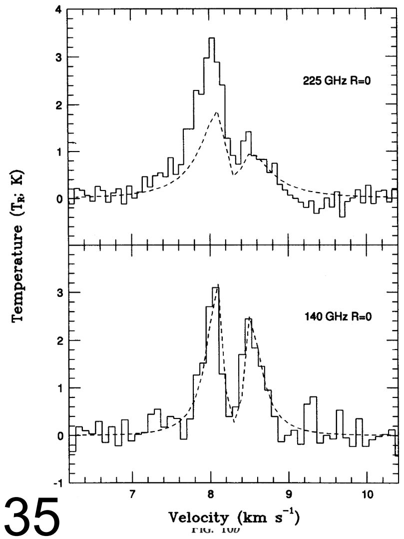
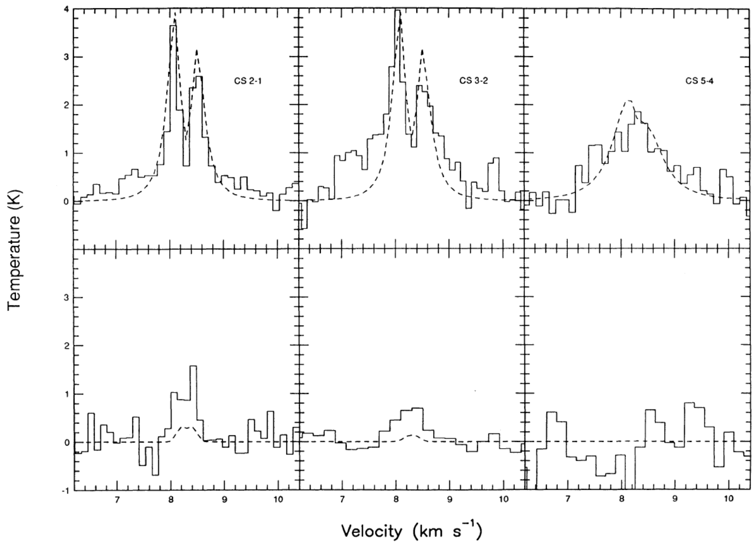


Fig. 10a



B335



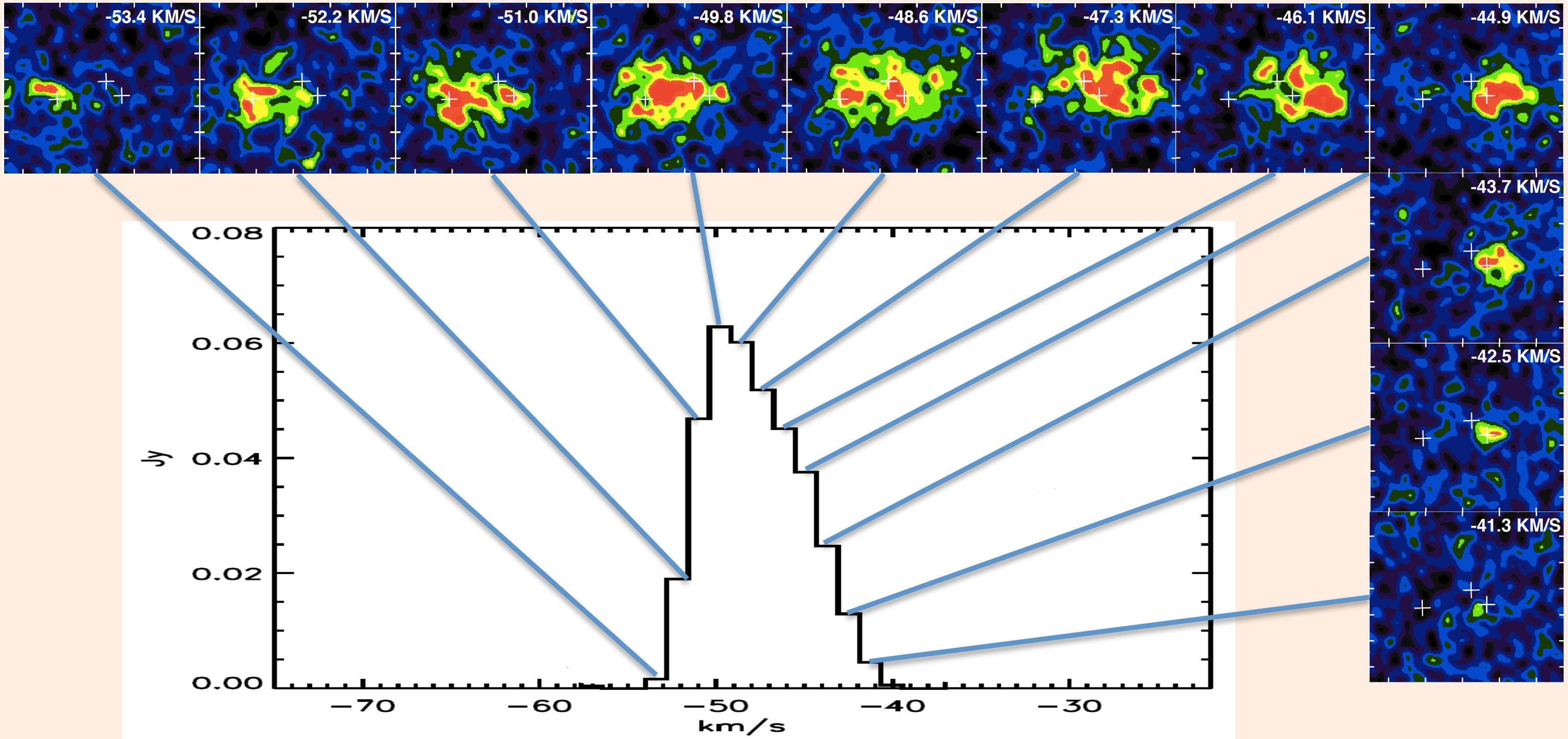
(Zhou et al. 1993)

Asymmetries in line profiles have been widely used to study infall.

However, there are possible ambiguities because: sources can be intrinsically asymmetric, the central region of the line is affected by the ambient cloud emission/absorption and by the angular resolution, uncertainties in the rest frequency of the line...

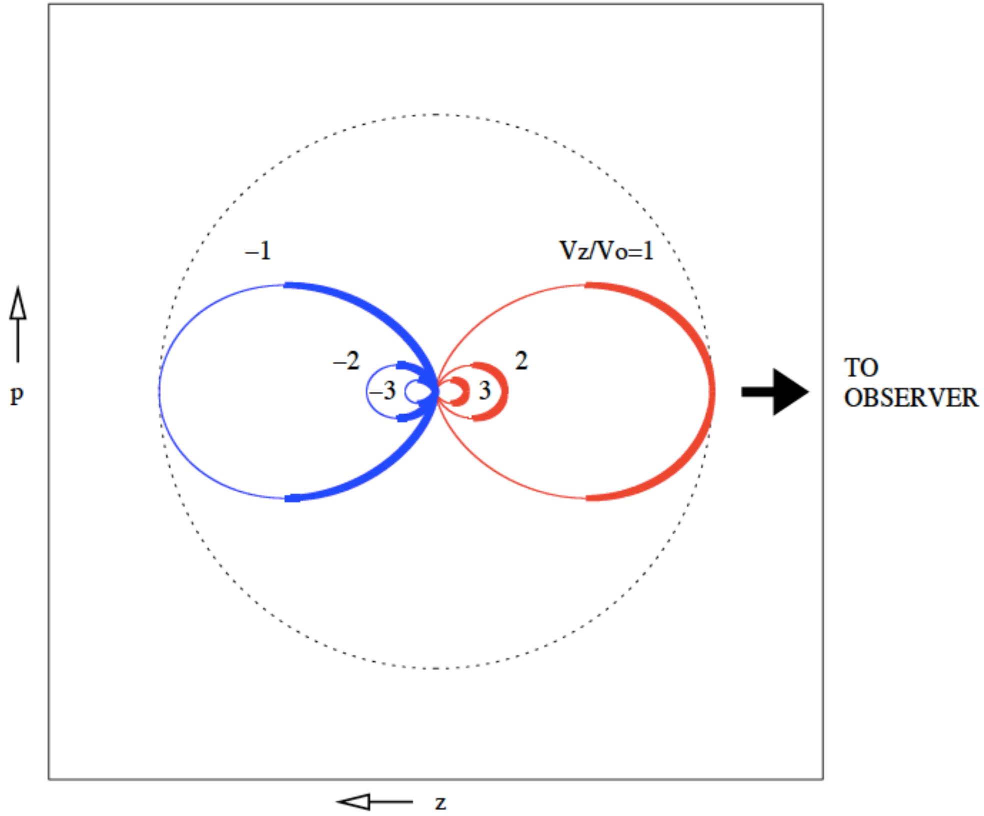
Images (cubes of channel maps) provide much more information than line profiles

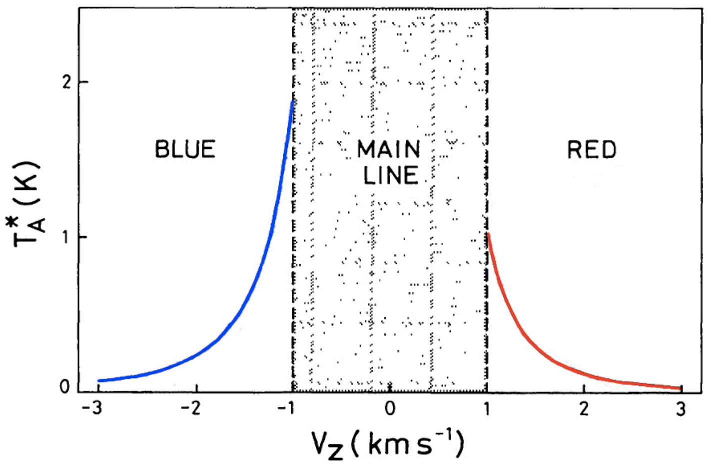
but require much more sensitive observations



INFALL SIGNATURES IN LINE PROFILES
(unresolved sources)

Anglada et al. (1987)





If protostellar infall dominates kinematics:
V increases when r→ 0 (acceleration)
T increases when r→ 0 (central heating)

Optically thick line:

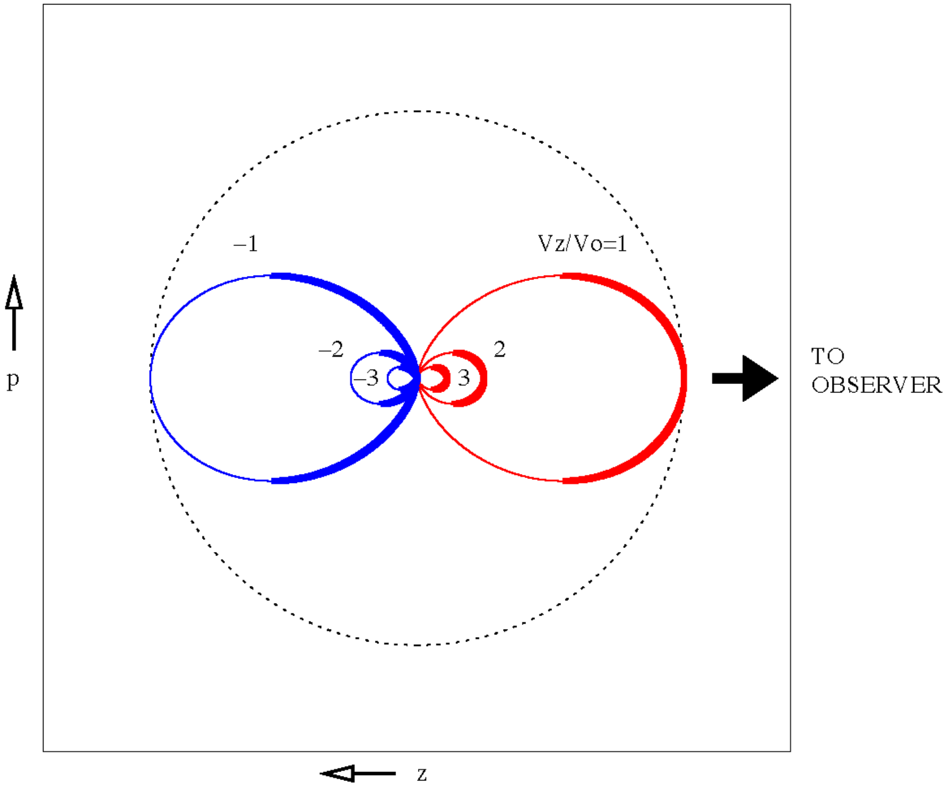
Gravitational infall signature:
Blue side stronger than red side

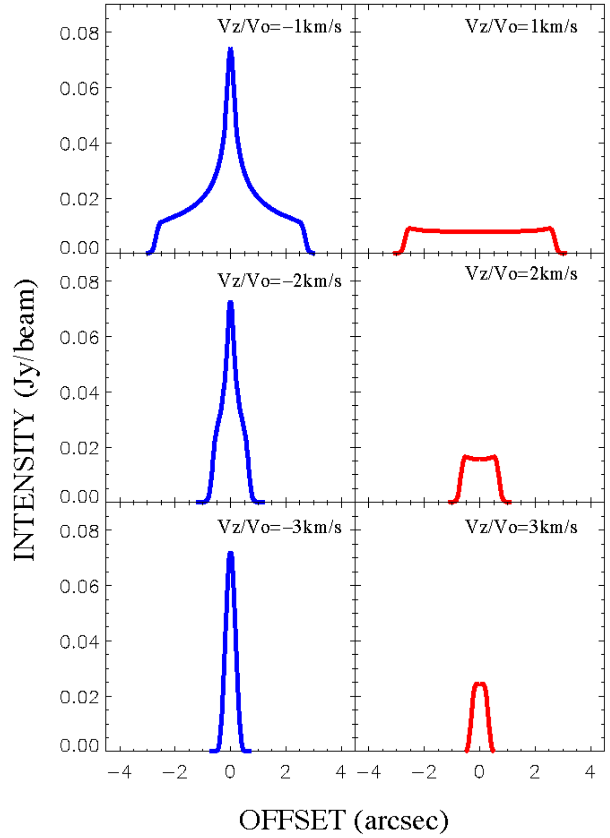
However, there is no spatial information in the line profile

INFALL SIGNATURES IN IMAGES (CHANNEL MAPS)

(angularly resolved sources)

Anglada et al. (1991)



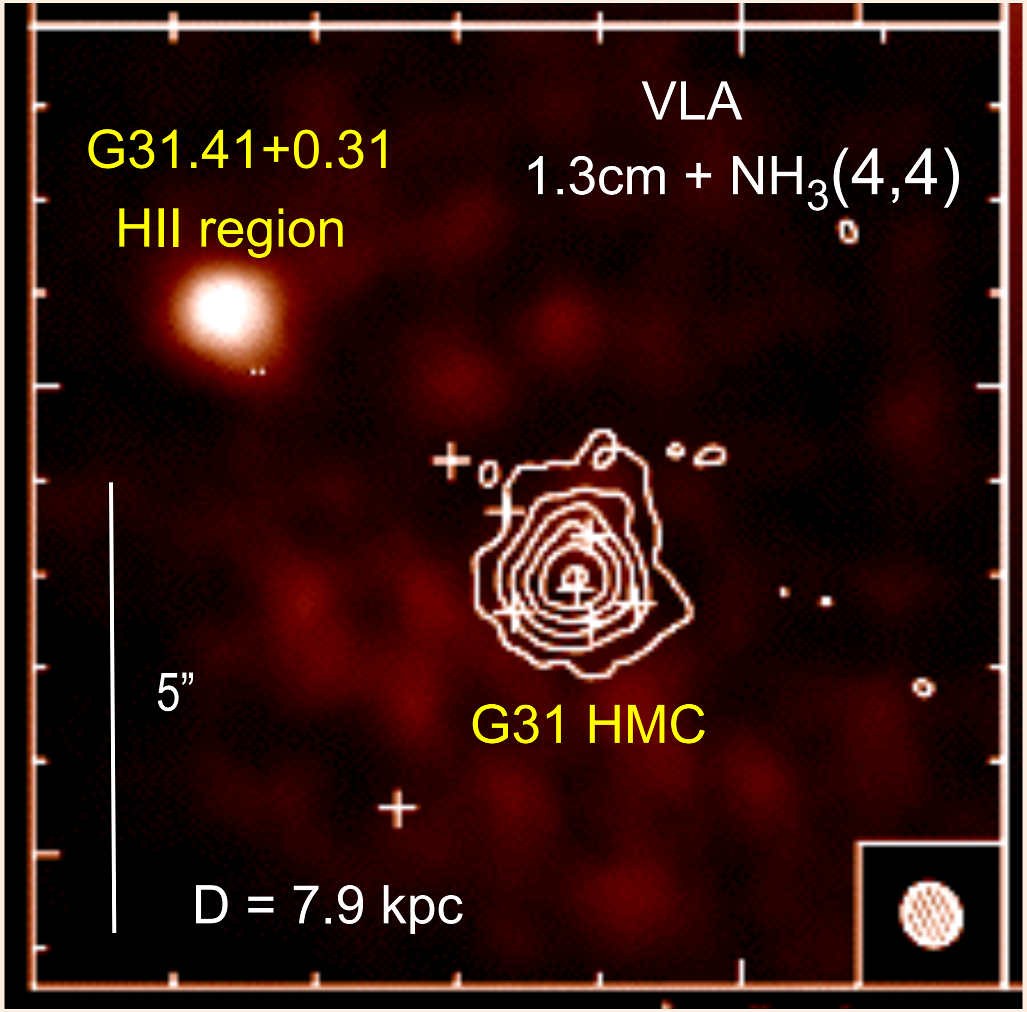


Gravitational infall signatures in channel maps:

- Asymmetry: Blue channel stronger and sharper, Red channel flatter
- Source size decreases with increasing velocity

Channel maps provide spatial information

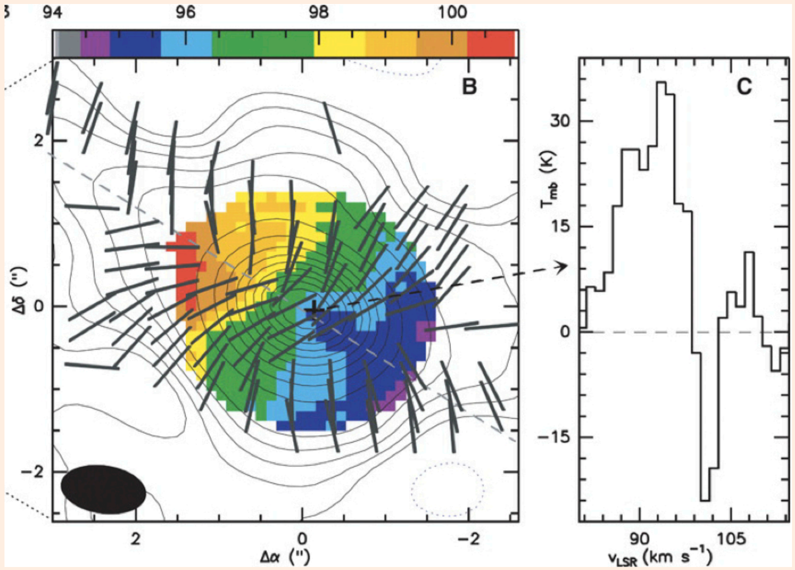
The G31.41+0.31 Region



(Cesaroni et al. 1998)

Signs of infalling core

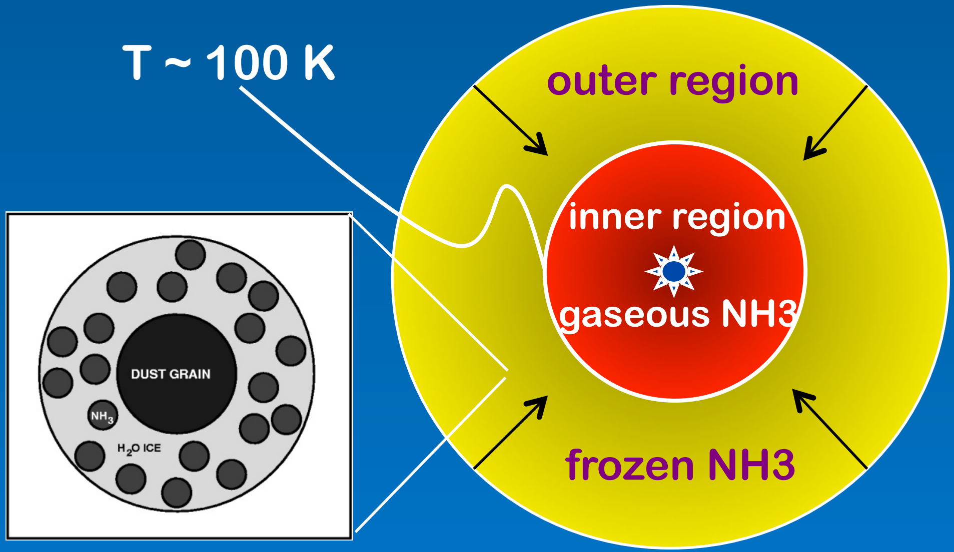
- Hourglass shape of the magnetic field
- Inverse P-Cygni line profile

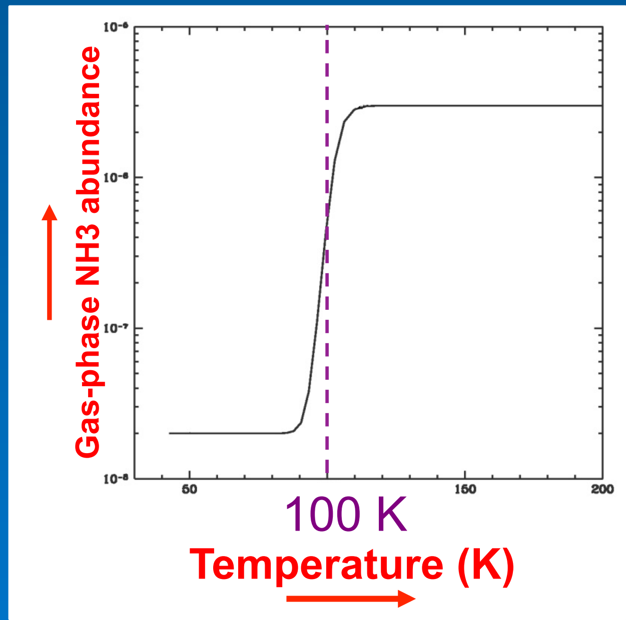


(Girart et al. 2009)

Modeling of G31.41+0.31 HMC
(Osorio, Anglada, Lizano & D'Alessio 2009)

G31 HMC was modeled as an infalling singular logatropic sphere (SLS) heated by a central protostar. The SED and ammonia spectra were fitted. The NH3 emission was fitted by using a variable gas-phase abundance resulting from the sublimation of ammonia molecules trapped on water ice grain mantles.



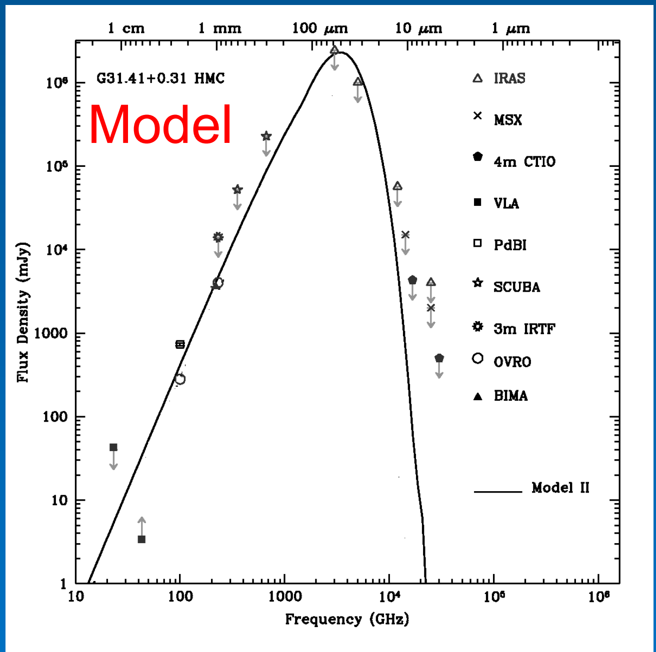


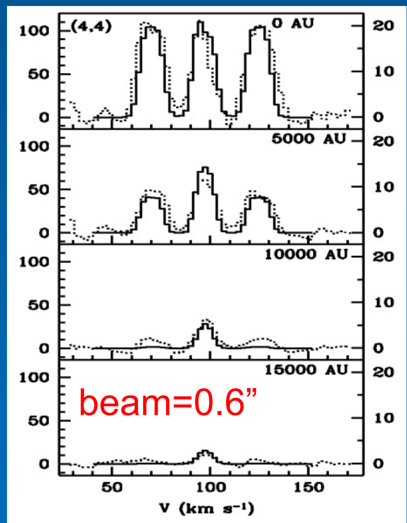
Outer regions (T<Tsub) ⟶ ammonia frozen ⟶ low abundance

Inner regions (T>Tsub) ⟶ ammonia sublimated ⟶ high abundance

Fitting of the SED and NH3(4,4) Emission of G31 HMC

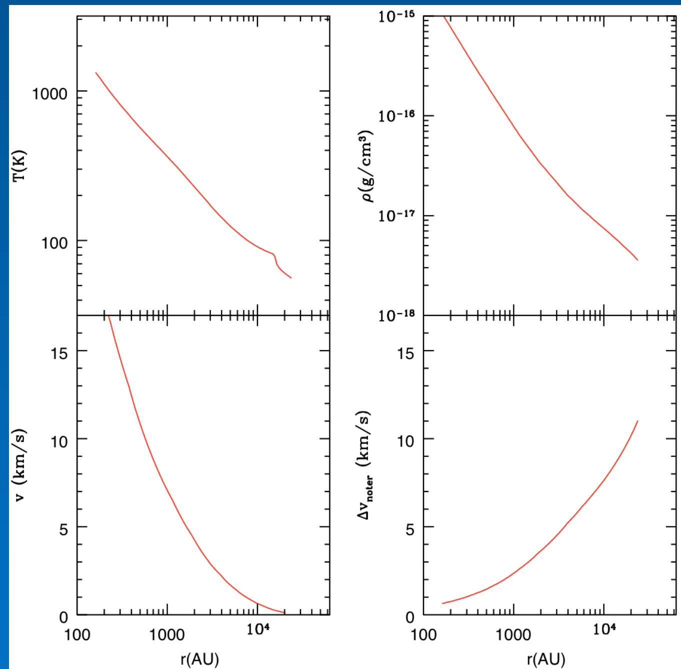
The same set of parameters were used to fit both the SED and the VLA NH_3(4,4) spectra of Cesaroni et al. 1998. As a result, the physical parameters of the core: Temperature, Density, Velocity, and Velocity Dispersion were obtained as a function of radius.





$[NH_3/H_2]_{max}$=3x10^{-6}

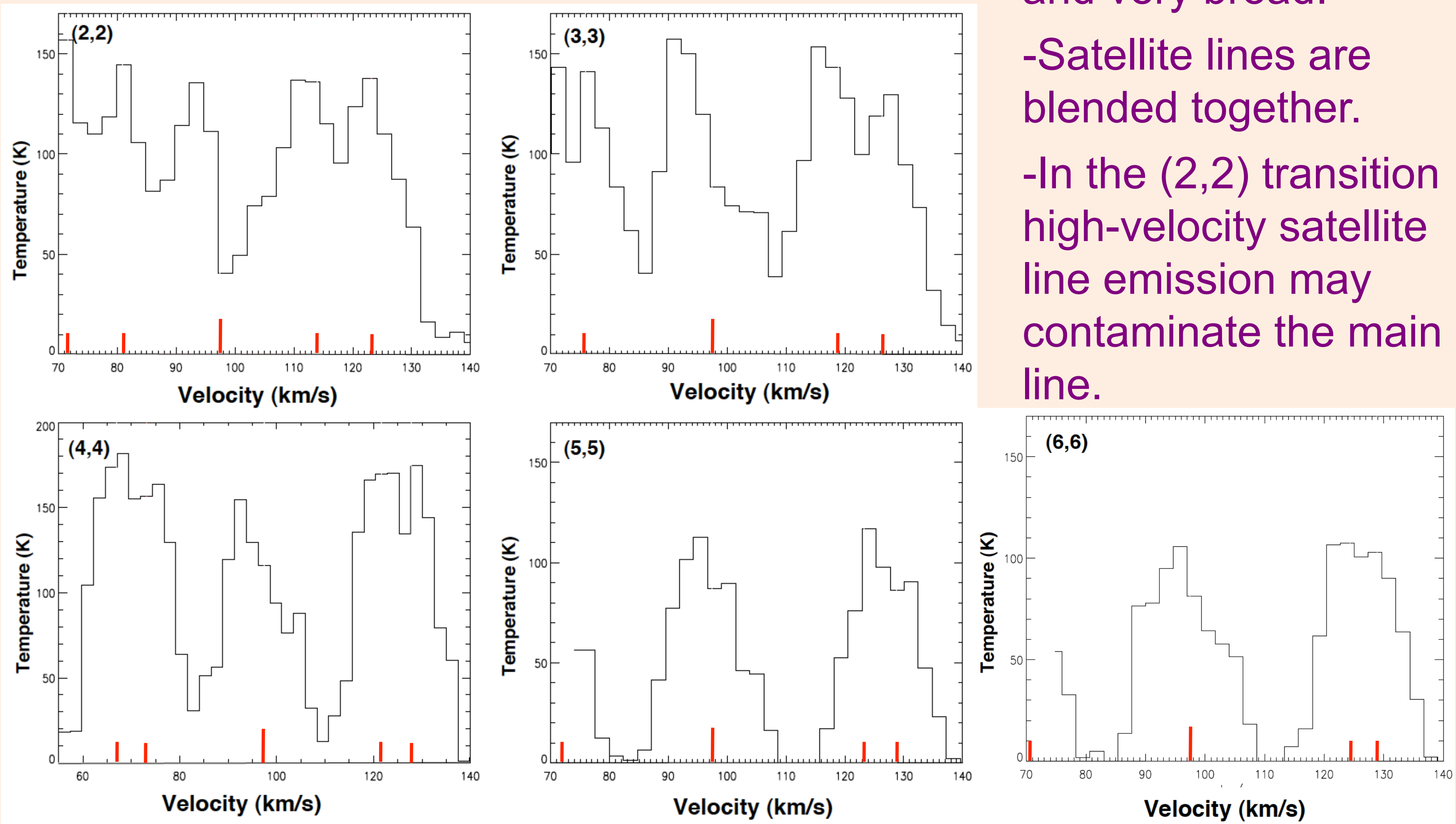
$[NH_3/H_2]_{min}$=2x10^{-8}



(Osorio, Anglada, Lizano, D'Alessio 2009)

VLA ammonia observations towards G31 HMC

Ammonia spectra



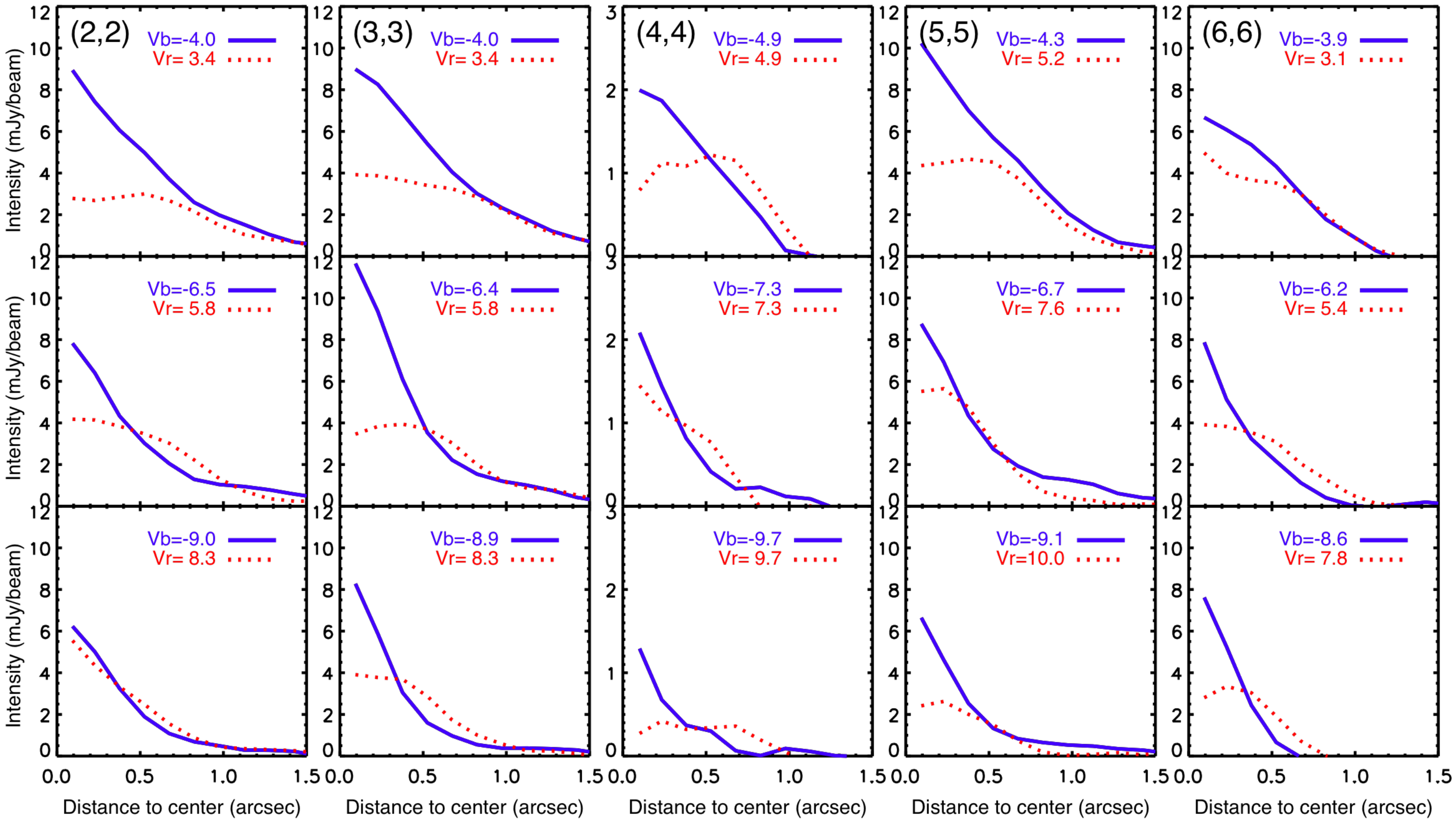
-Lines are very opaque and very broad.

-Satellite lines are blended together.

-In the (2,2) transition high-velocity satellite line emission may contaminate the main line.

(Mayen-Gijon et al. 2014)

INFALL SIGNATURES IN RADIAL INTENSITY PROFILES
(VLA Ammonia Observations)



Azimuthally-averaged intensity vs radius

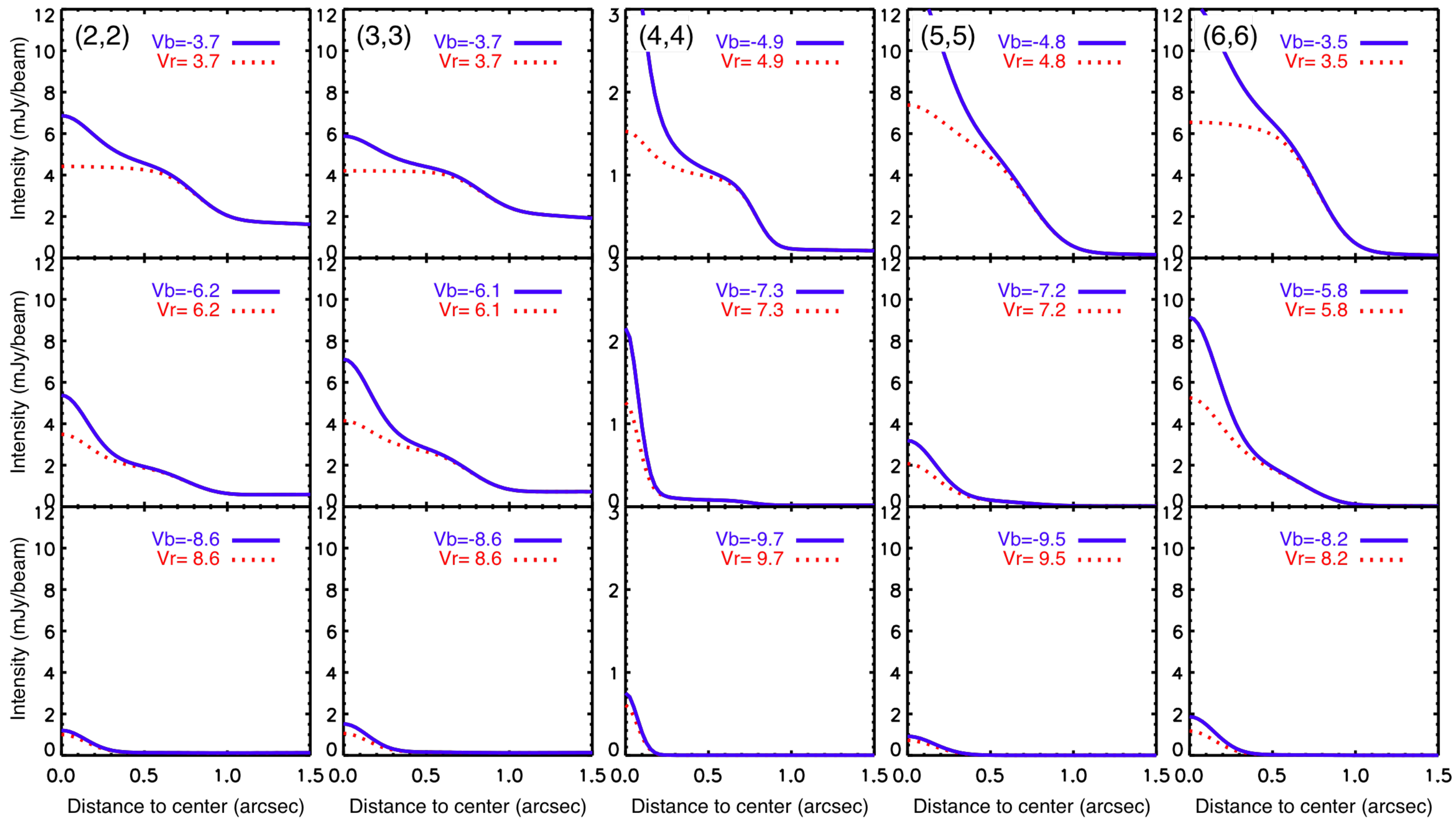
(Mayen-Gijon et al. 2014)

beam=0.3” (B config)

beam=0.16” (A config; NH_3(4,4), Cesaroni et al. 2010)

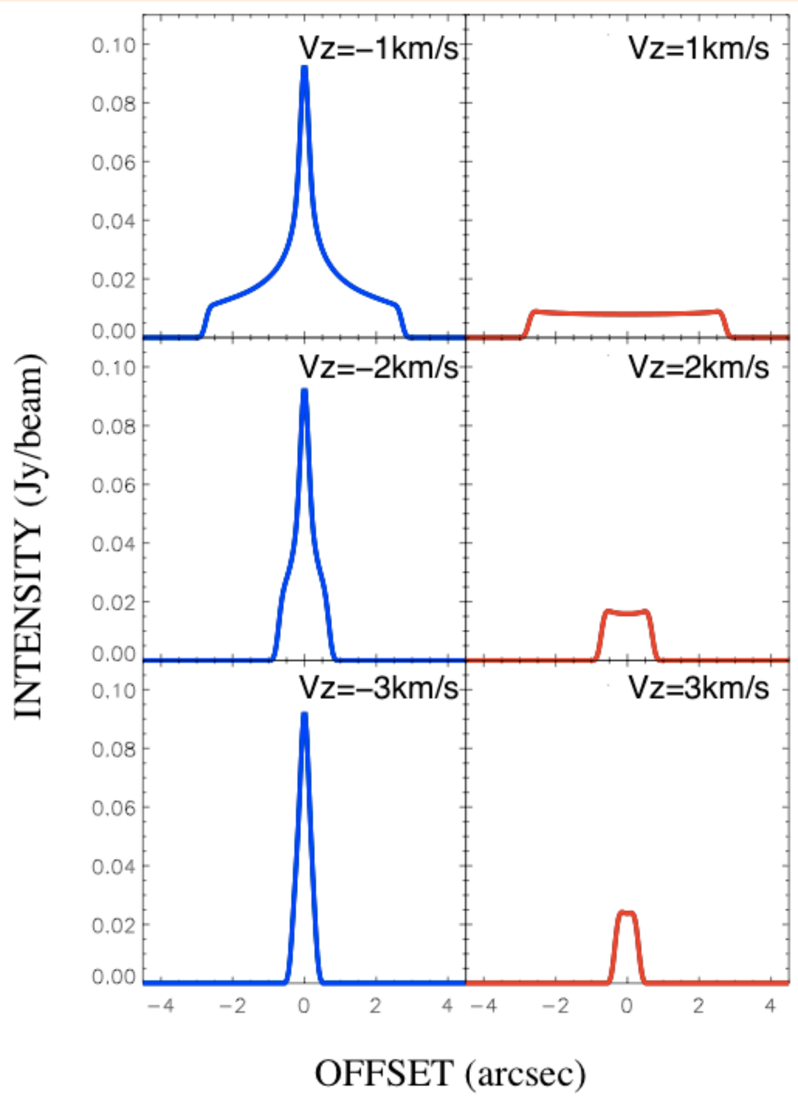
INFALL SIGNATURES IN RADIAL INTENSITY PROFILES

(Osorio et al. 2009 Ammonia Model Predictions)

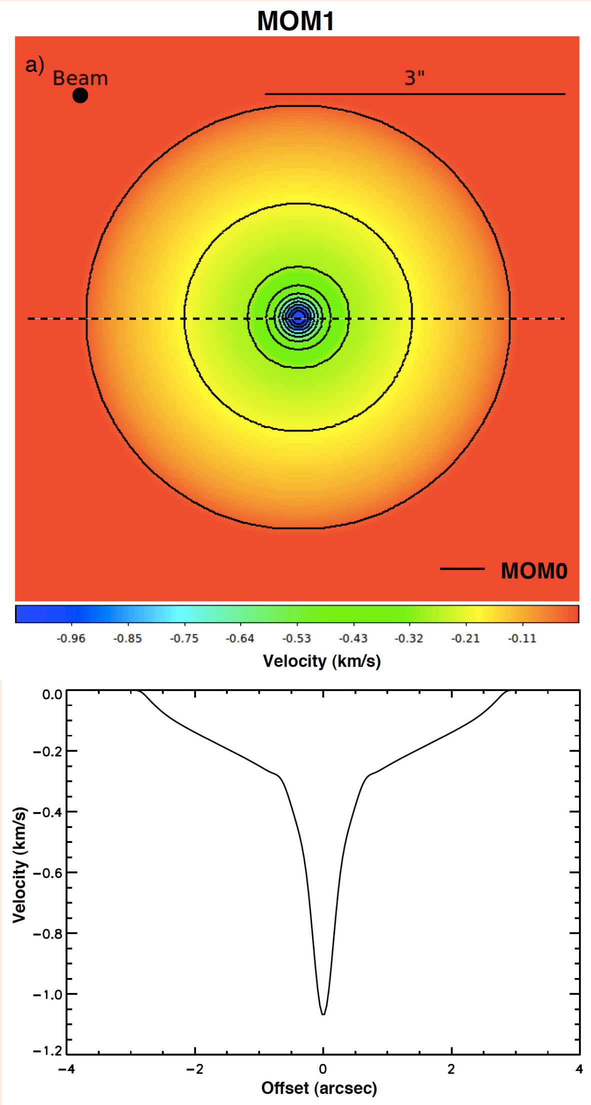


(Mayen-Gijon et al. 2014)

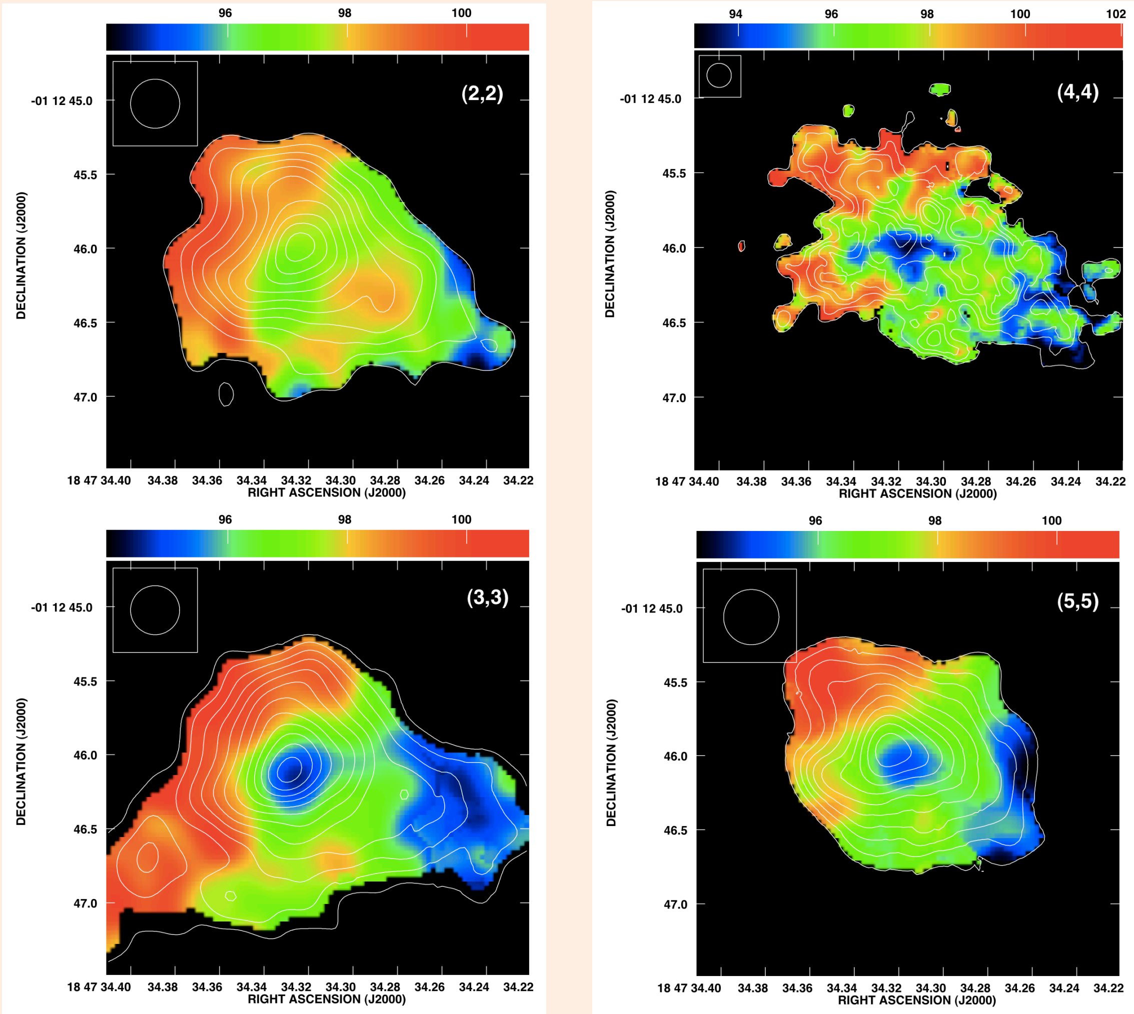
The “central blue spot” infall signature



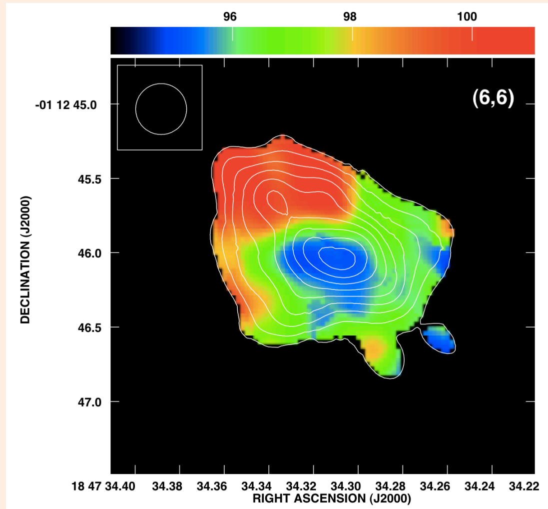
FIRST-ORDER MOMENT



The central blue spot in G31 HMC

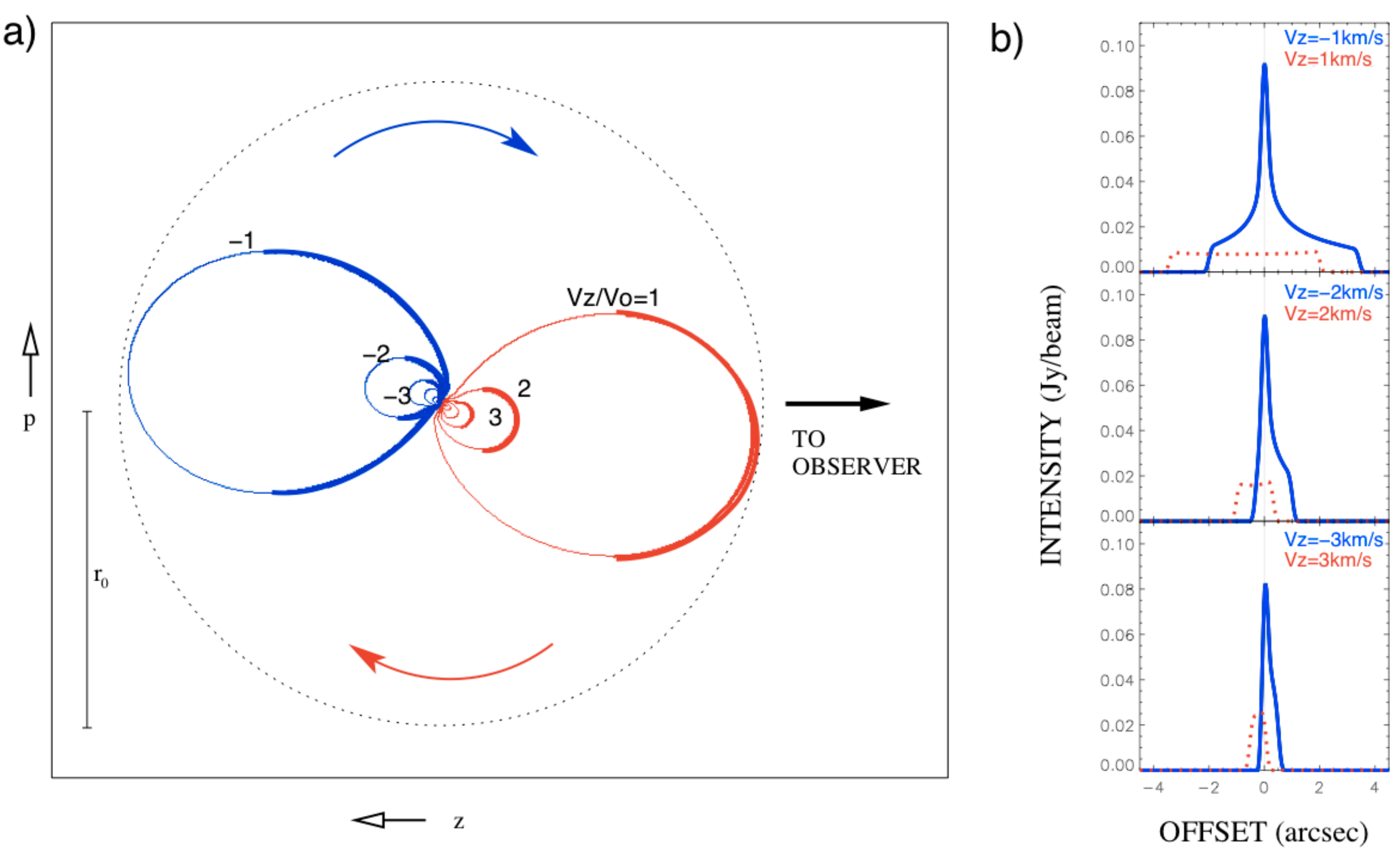


First-order moments



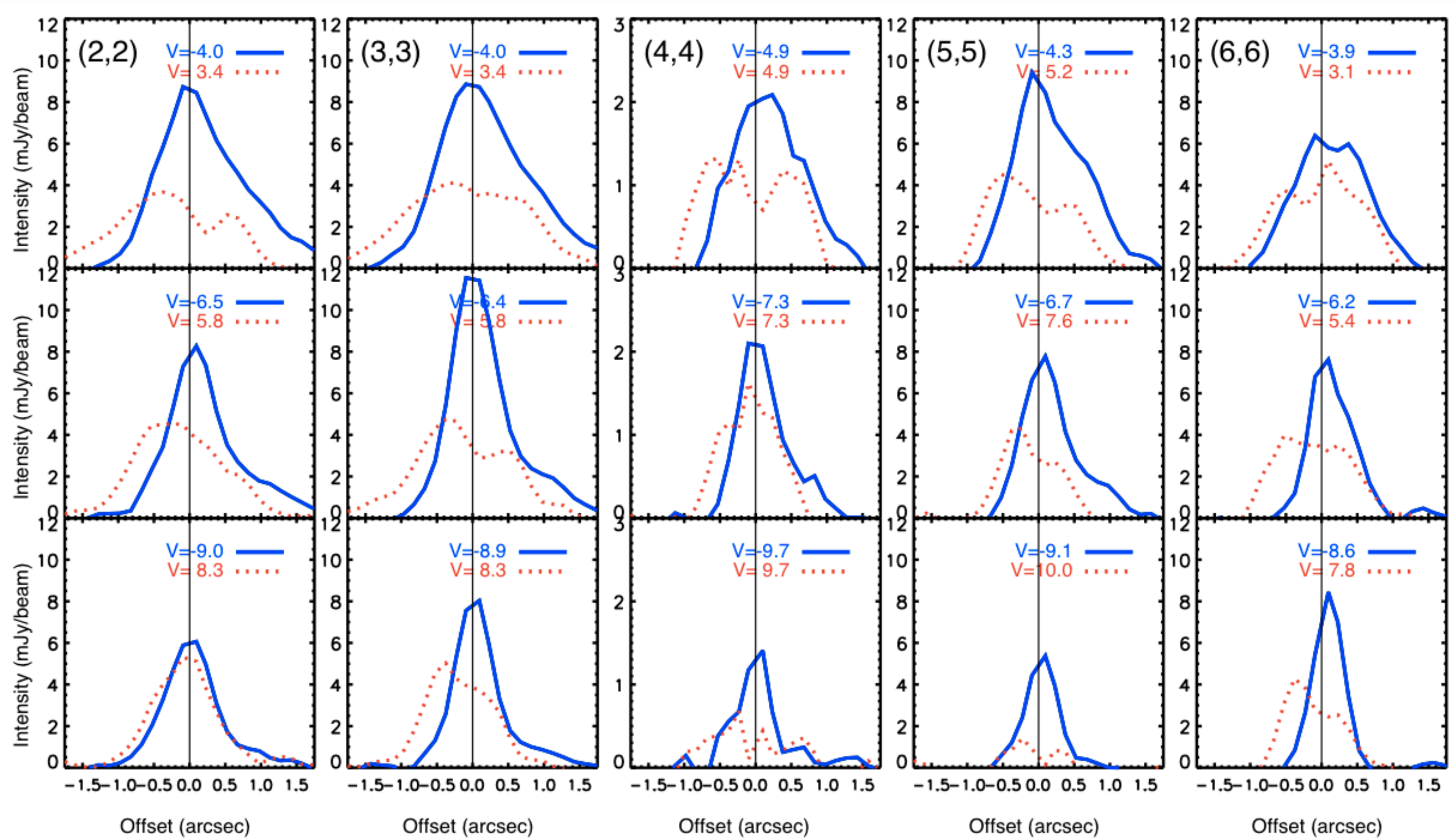
(Mayen-Gijon et al. 2014)

Infall + Rotation



Infall and rotation signatures in intensity profiles are independent.
Infall signatures persist.

Infall + Rotation Signatures in G31 HMC



Averaged over half-rings

negative offsets: -30 < PA < 150 deg

positive offsets: 150 < PA < 330 deg

(Mayen-Gijon et al. 2014)

Conclusions

The VLA channel maps of the NH3(2,2) to NH3(6,6) transitions in G31 HMC show the expected signatures of protostellar gravitational infall:

-Radial intensity profiles of redshifted channels are flat while those of blueshifted channels are centrally peaked (indicates central heating).
-The emission becomes more compact as the (relative) velocity increases (indicates gravitational acceleration).

The results are in quantitative agreement with the predictions of a previous model of the core (Osorio et al. 2009).

The first-order moment maps show the “central blue spot” infall signature.

Rotation produces an independent signature in the image intensity profiles, in qualitative agreement with what is observed in G31 HMC.

G31 HMC is an exceptionally strong source that allowed us to identify all these kinematical signatures. With the advent of new, ultrasensitive high-angular resolution facilities similar studies will become possible for many sources.

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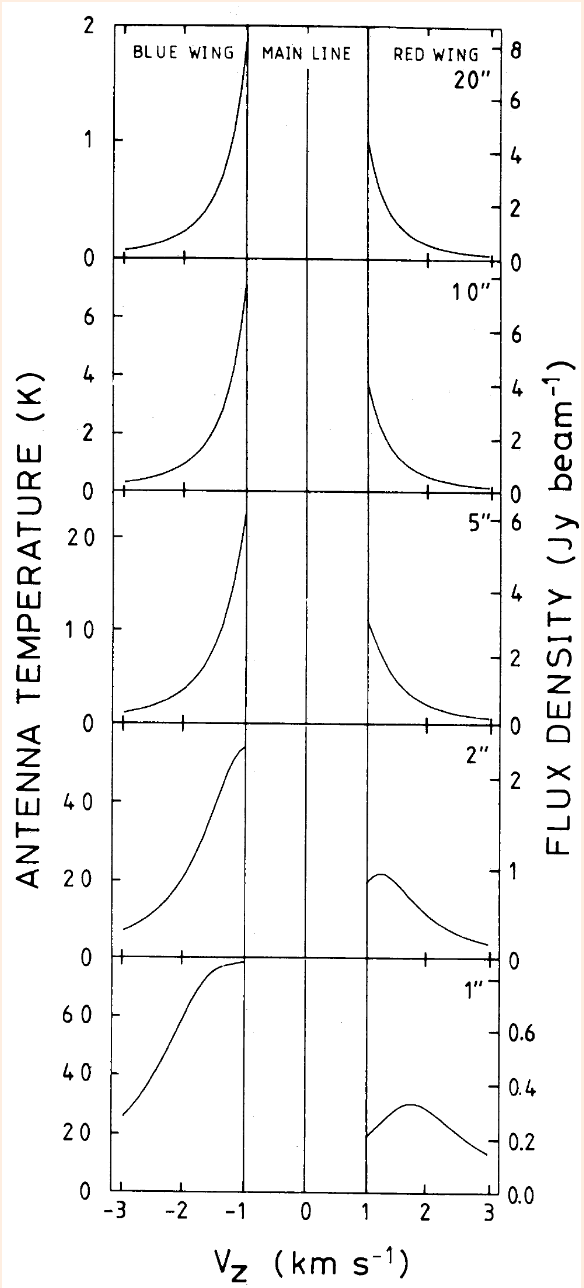
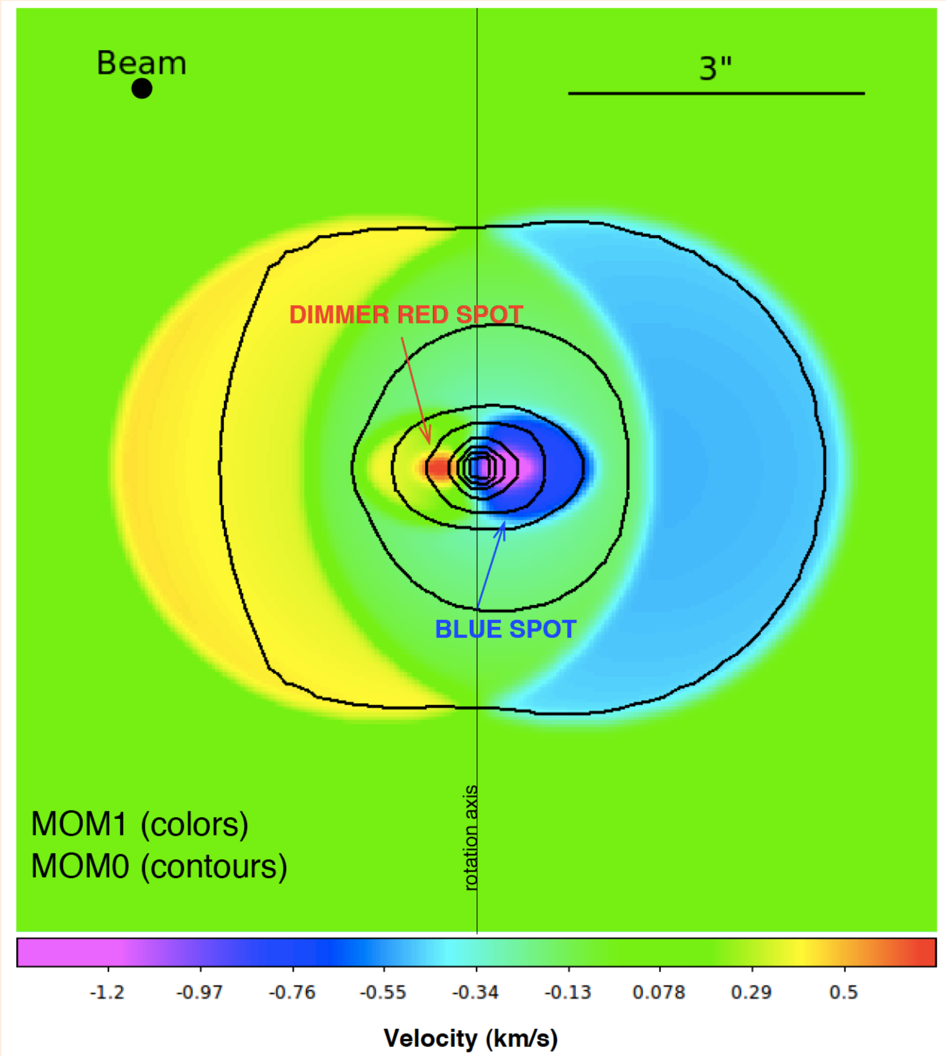


A dip appears when the source becomes angularly resolved

INFALL + ROTATION



A pair of (strong) blue / (dimmer) red spots.