SMA Imaging of the Chemical Segregation toward the AFGL2591 Massive Hot Core

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Massive Star Formation: Molecular Hot Cores

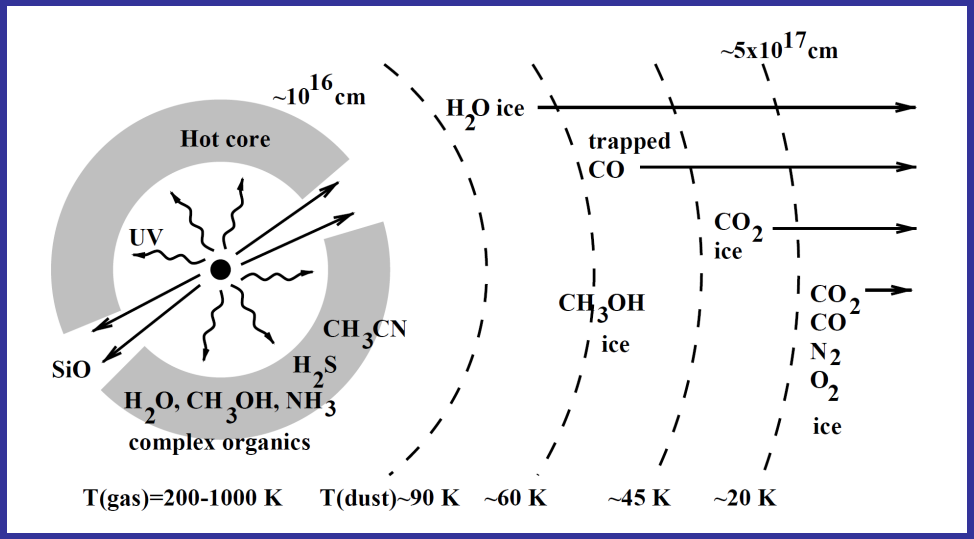
Compact (<0.01 pc), dense (>10^6 cm^{-3}) and hot (>100 K) condensations

One of the earliest stages of high-mass star formation

Very rich chemistry: i) Saturated molecules (H_2O, H_2S, NH_3, CH_3OH)

ii) COMs (C_2H_5OH, CH_3OCH_3, $HCOOCH_3$)

~1300 AU



van Dishoeck & Blake (1998)

Recent SMA examples:

Cepheus A HW2 (Brogan et al. 2007)

Orion KL (Zapata et al. 2010)

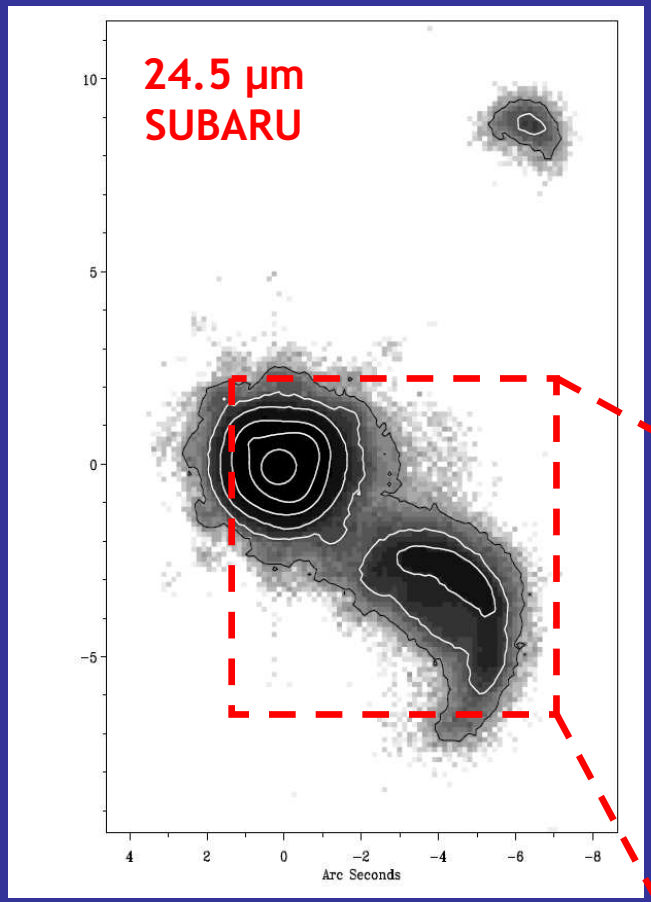
AFGL2591 (Bruderer et al. 2009)

Imaged at linear scales
> 1000 AU

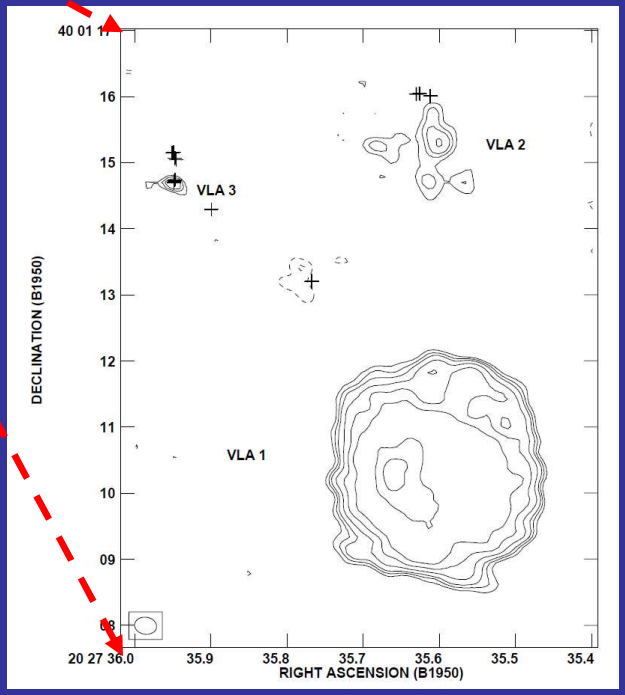
Chemical segregation within hot cores???

A Hot Core in the Making: AFGL2591

de Wit et al. 2009



Trinidad et al. 2003



Located in the Cygnus X region at d~1kpc

B0.5 ZAMS star with L_{bol}~2 10^4 Lo (van der Tak et al. 1999; Trinidad et al. 2003)

1'-size east-west outflow (Lada et al. 1984; Mitchell et al. 1992)

Cluster of B-type stars with 3 HII regions (Trinidad et al. 2003)

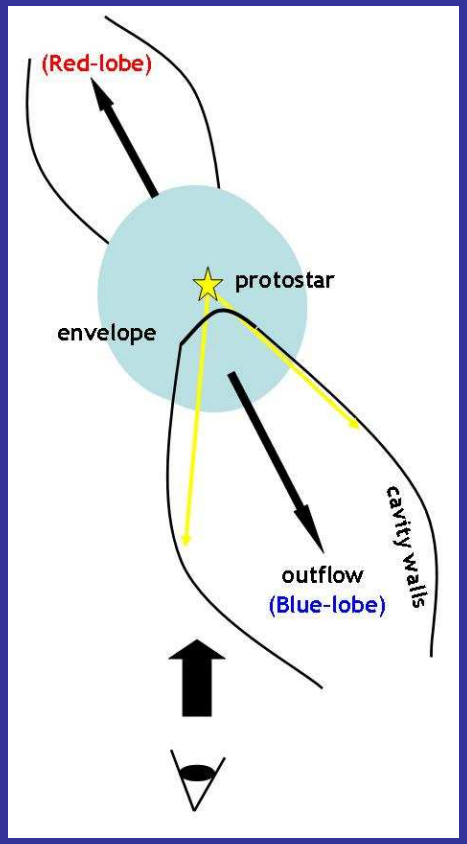
VLA3, the youngest source (t_{age}~5 10^4 yrs; Doty et al. 2002)

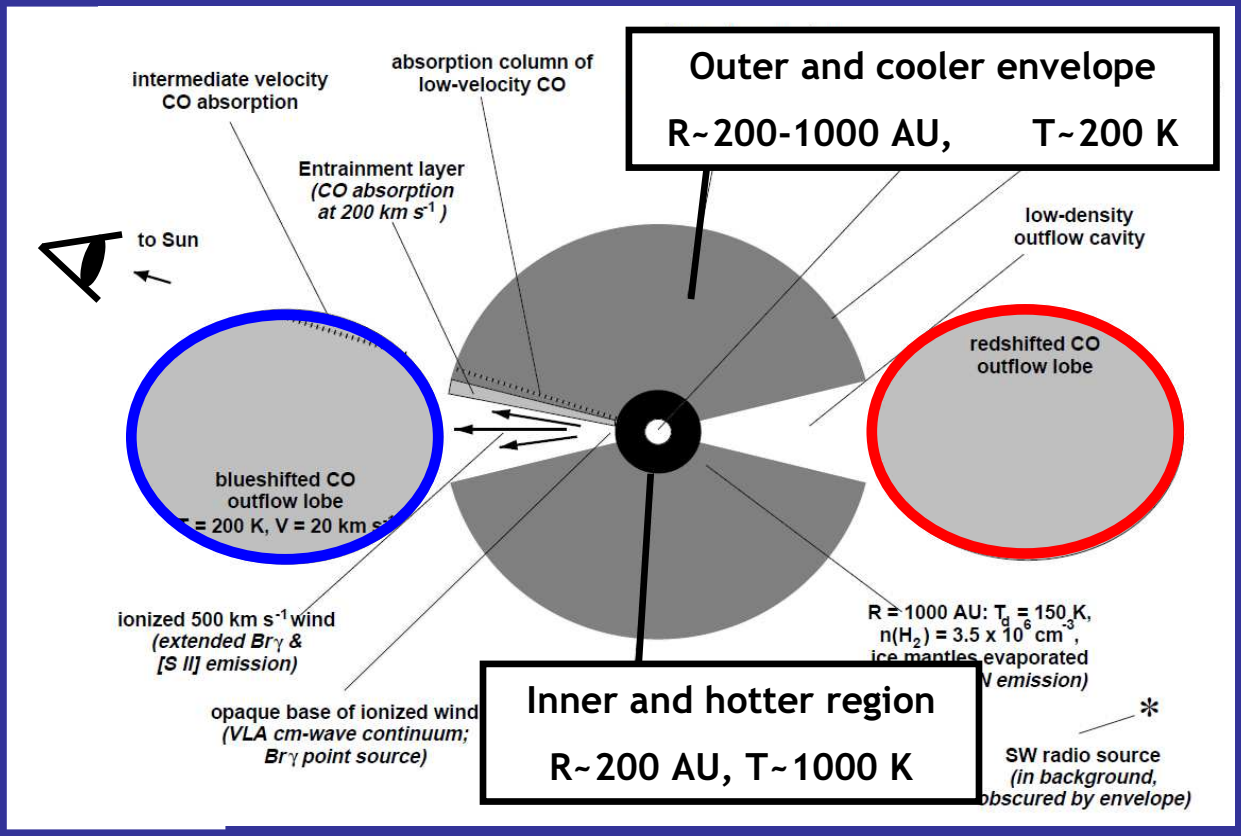
M_*~10 Mo & M_{env}~42 Mo

(van der Tak et al. 1999; Boonman et al. 2001)

AFGL2591-VLA3= Massive Hot Core

Physical Structure of the AFGL2591 Hot Core



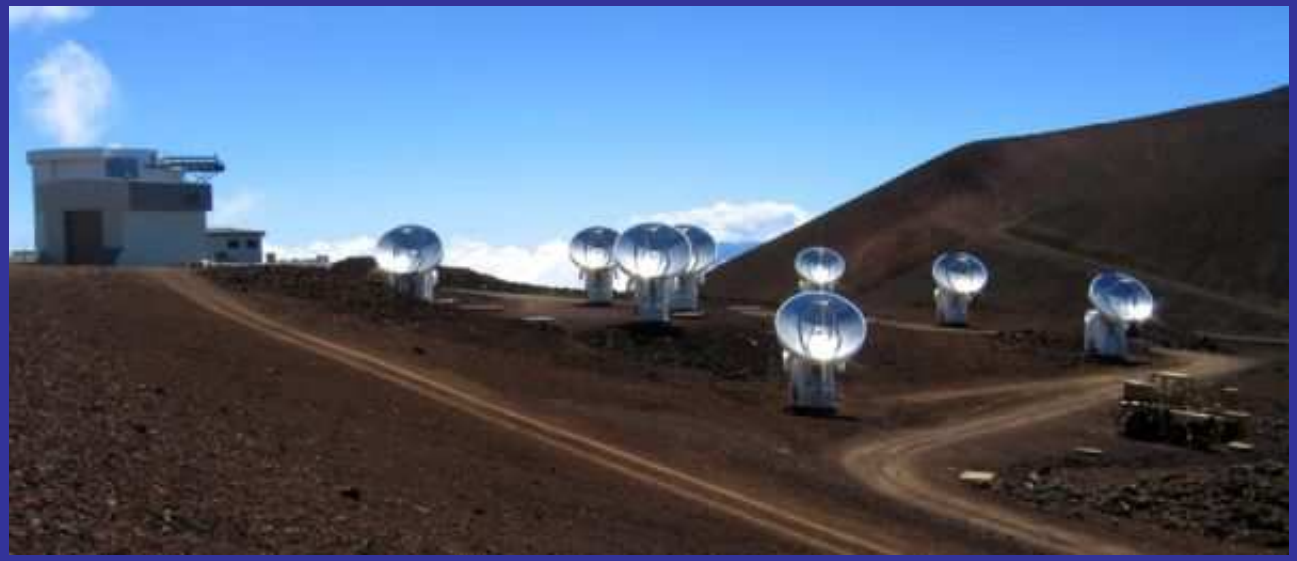


van der Tak et al. (1999), Boonman et al. (2001)

HOT CORE: an inner and hotter envelope + an outer and cooler region

Different chemical regimes at sub-arcsec scales!

SMA Observations



1 full track in VEX (beam of ~0.35", i.e. ~350 AU)

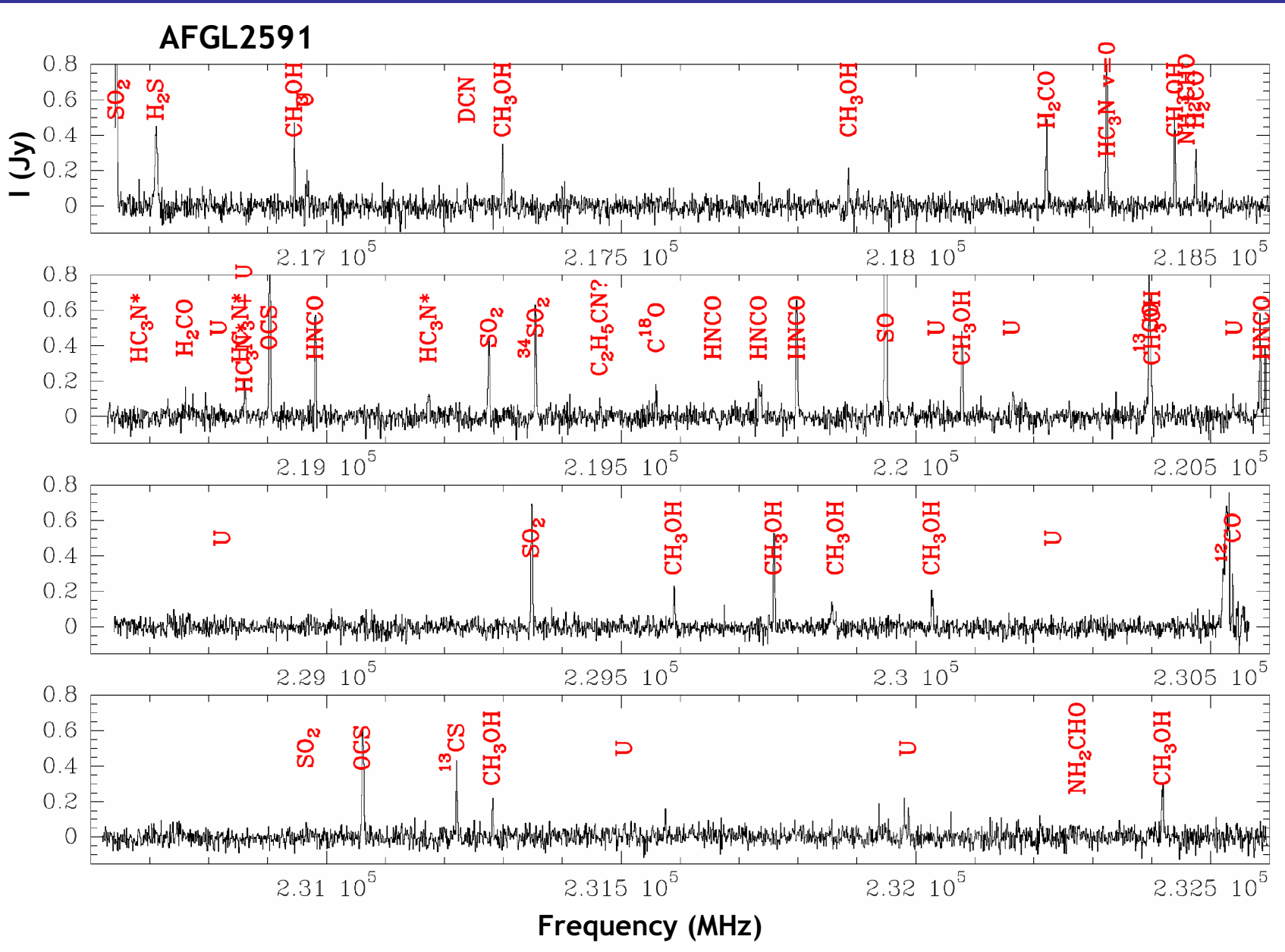
dopplerTrack -r 218.75 -l -s23

restartCorrelator -R l -s128, uniform velocity resolution of 1.1 kms^{-1}

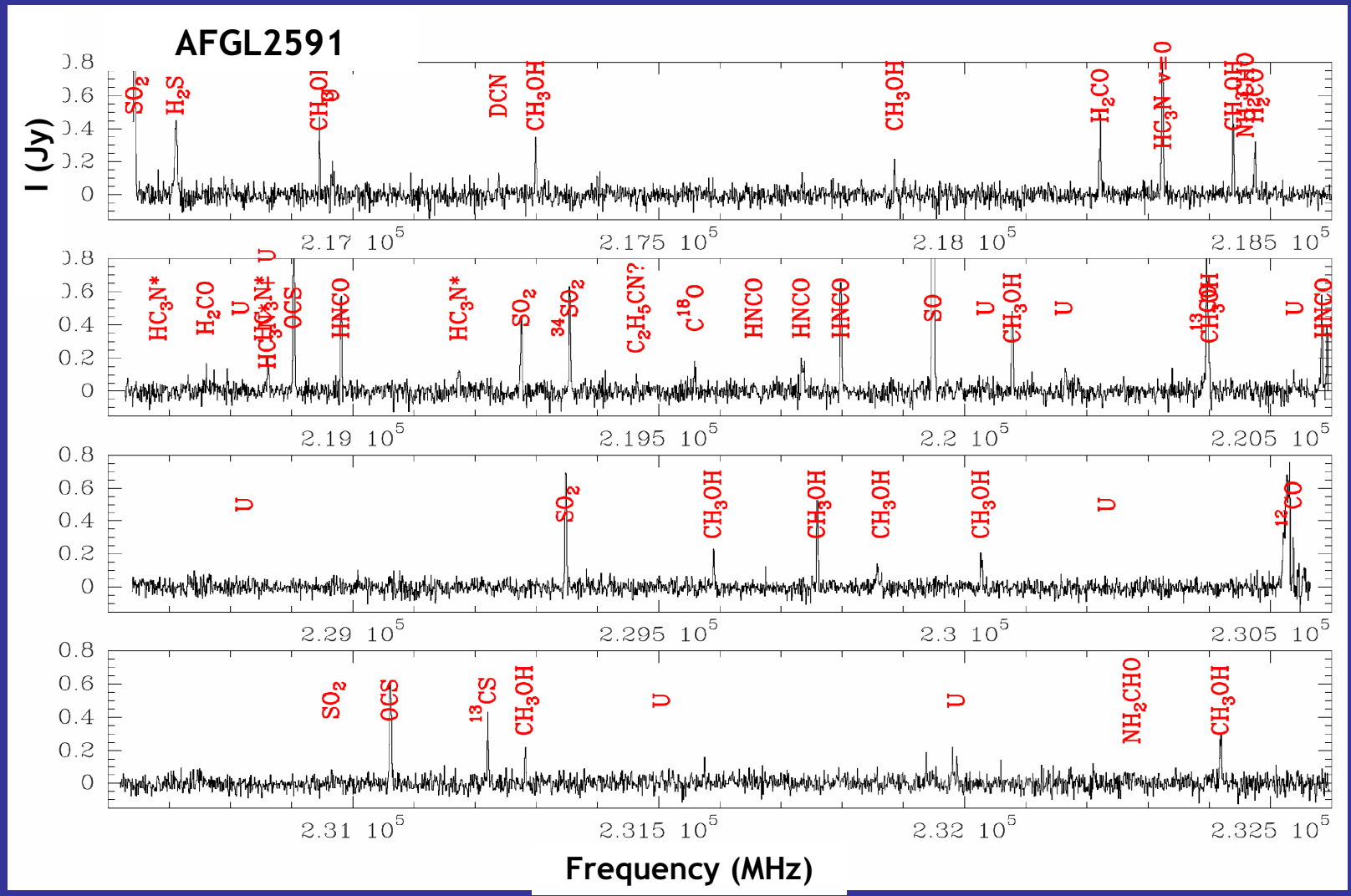
Observed molecules:

CO and isotopologues	O-bearing molecules	S-bearing molecules	N-bearing molecules
^{12}CO, ^{13}CO, $C^{18}O$	CH_3OH, H_2CO	H_2S, SO, SO_2, OCS, ^{13}CS	HC_3N(*), HNCO, DCN

SMA 8GHz Passband

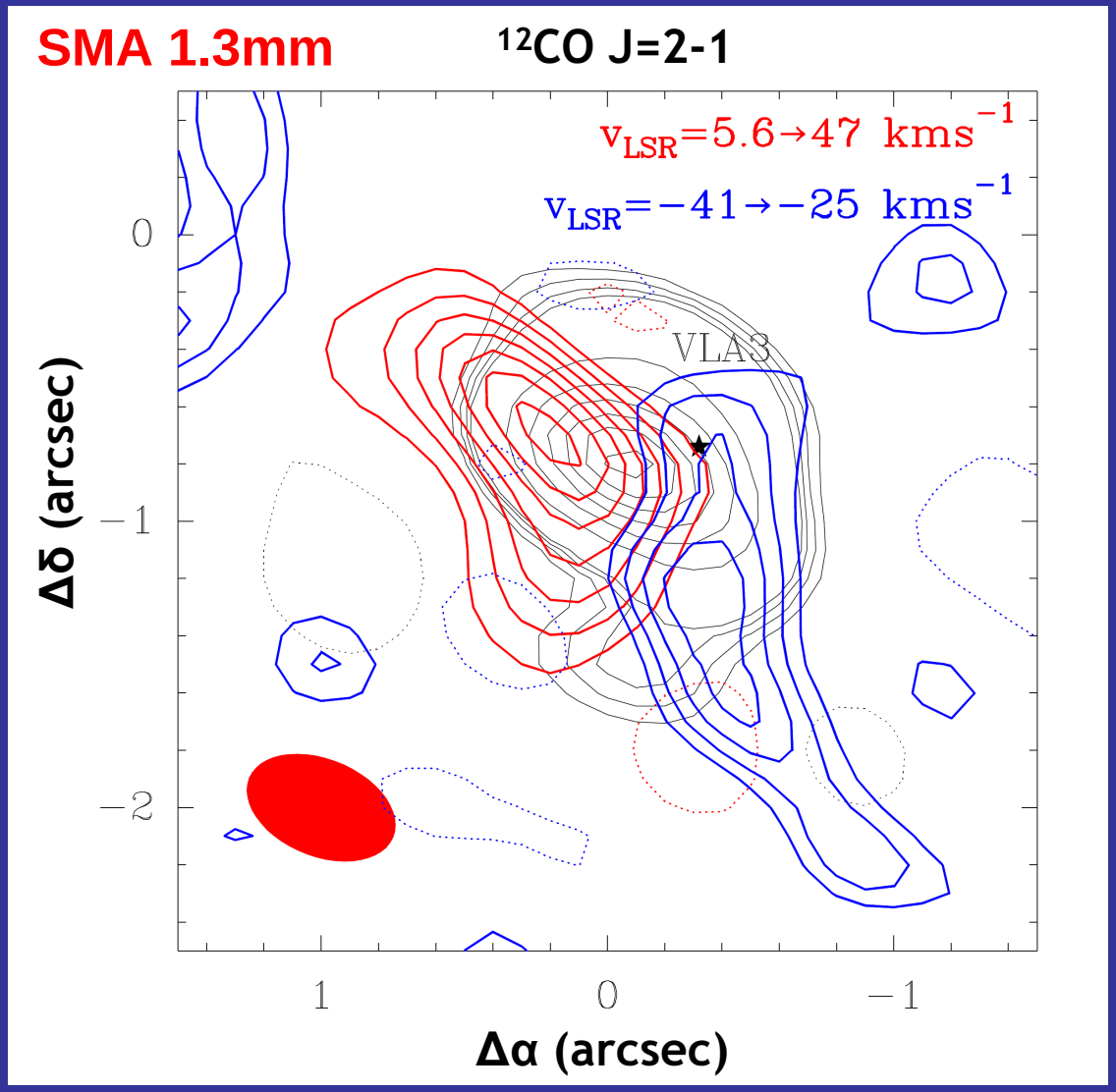


SMA 8GHz Passband



^{12}CO | CH_3OH | H_2S | SO | SO_2 | OCS | HC_3N

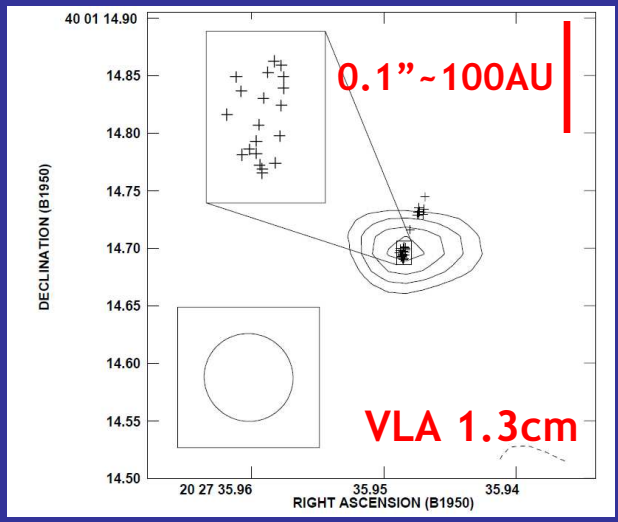
^{12}CO emission: Outflowing Gas



Jimenez-Serra et al., in preparation

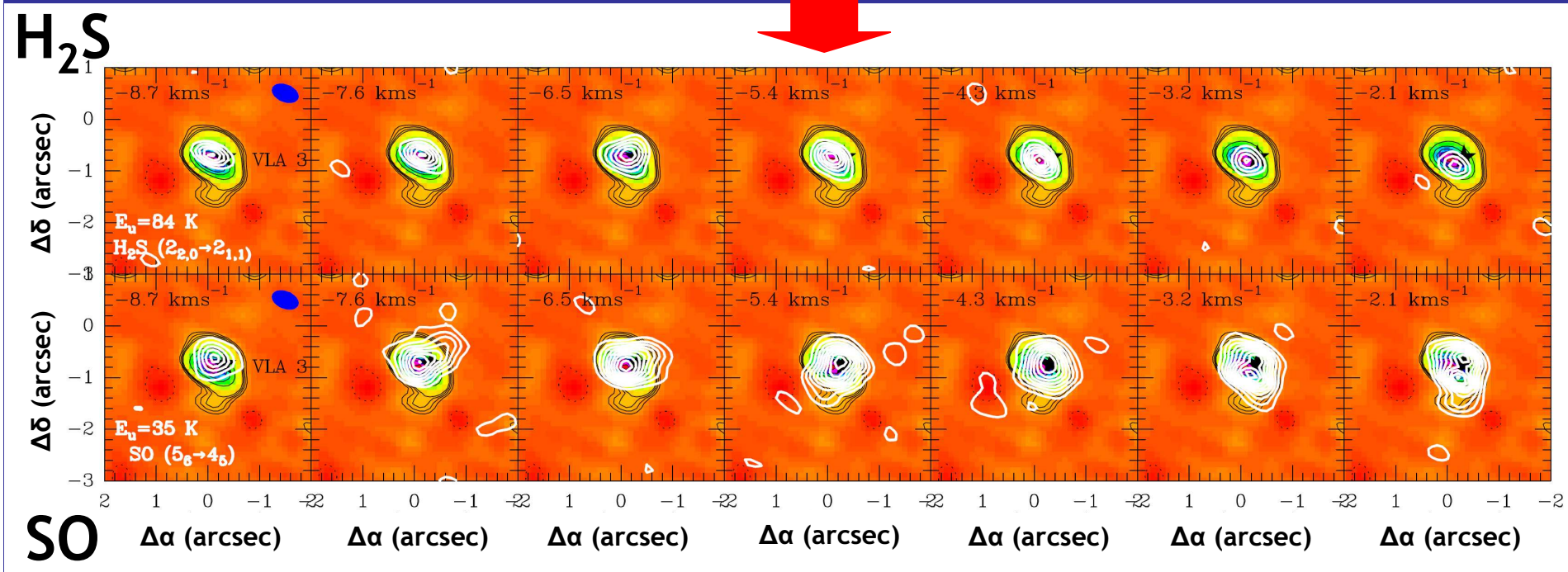
Bi-conical structure tracing the base of the large-scale east-west CO outflow.

Consistent with the elongation of VLA3 in the east-west direction (Trinidad et al. 2003).



Molecular emission in the Hot Core (I)

V_{LSR}~-5.5 kms^{-1}

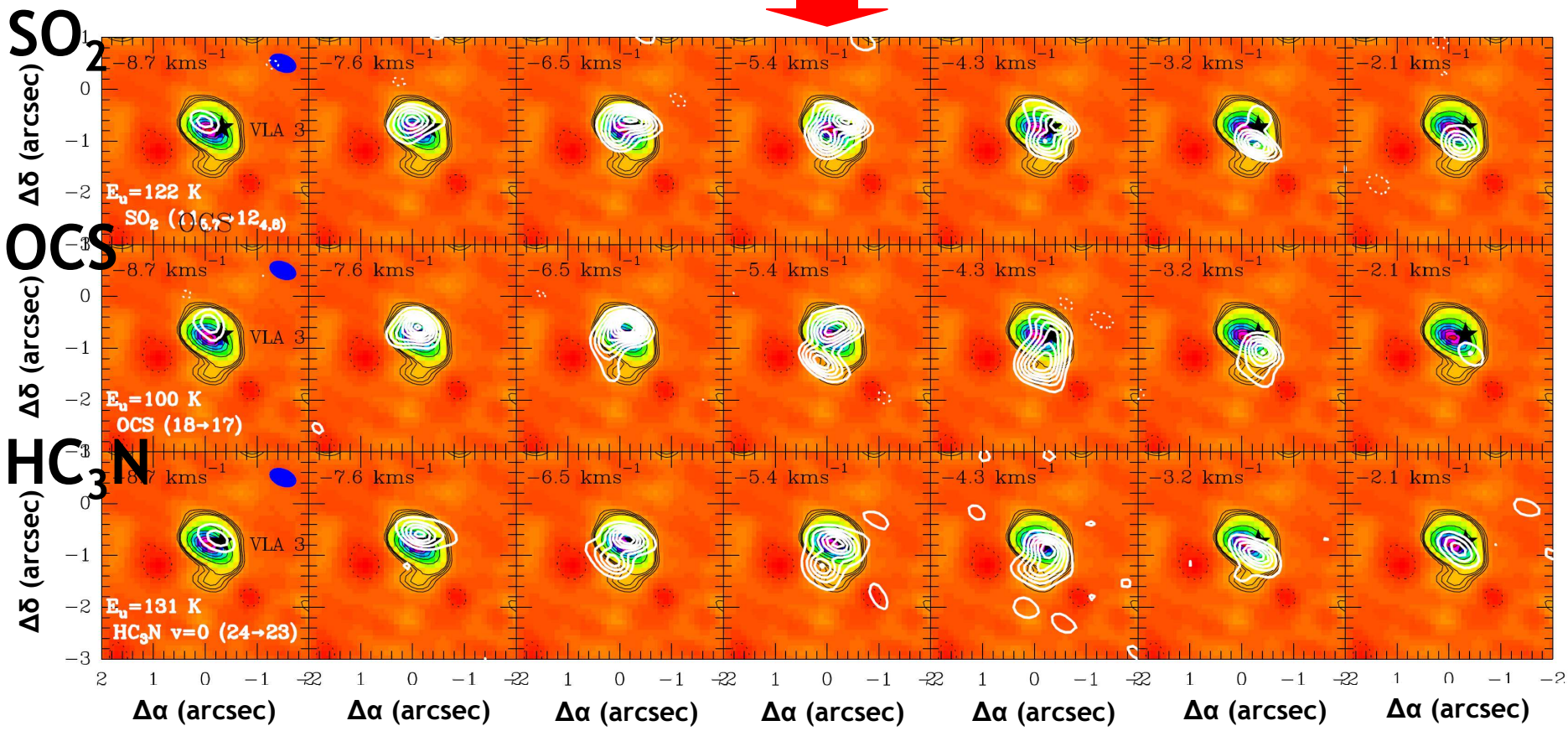


Jimenez-Serra et al., in preparation

i) H_2S and SO: single-peaked feature centered at the radiocontinuum

Molecular emission in the Hot Core (II)

V_{LSR}~-5.5 kms^{-1}

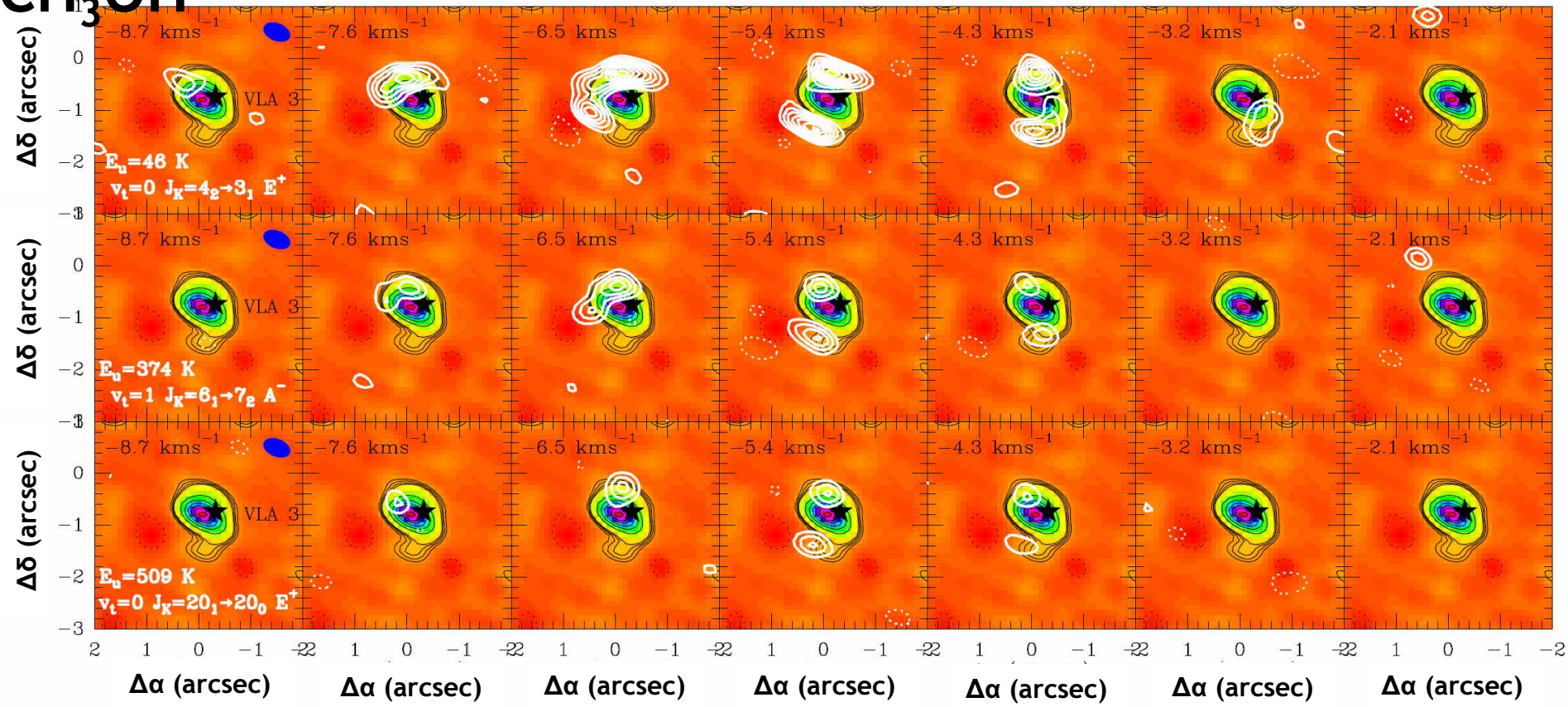


ii) SO_2, OCS and HC_3N: double-peaked structure circumventing the radiocontinuum peak

Molecular emission in the Hot Core (III)

V_{LSR}~-5.5 kms^{-1}

CH_3OH



iii) CH_3OH: Coherent ring-like structure surrounding the radiocontinuum emission

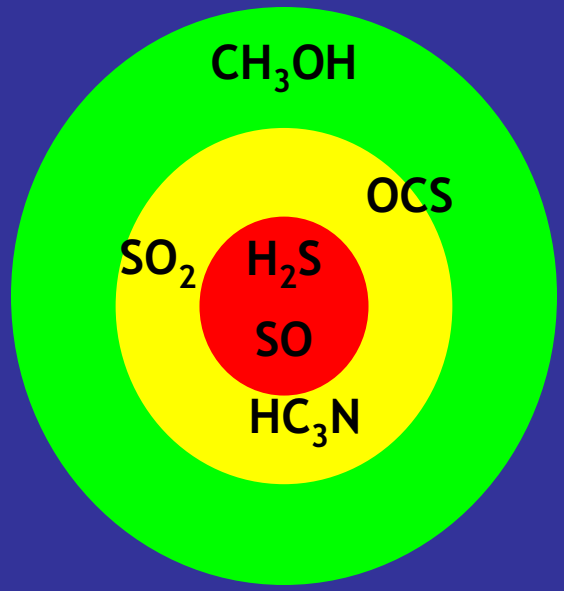
Chemical Segregation in AFGL2591

Molecules distributed in concentric shells with

H_2S and SO in an inner shell

SO_2, OCS and HC_3N in an intermediate envelope

CH_3OH in an outer shell



ANTAGONIST BEHAVIOR BETWEEN H_2S and CH_3OH!!!

Origin of the Chemical Segregation

Two different chemical effects:

i) strong UV-photodissociation: destruction of H_2S and CH_3OH

H_2S+ photon → HS + H

H_2S+ photon → S + H_2

CH_3OH+ photon → OH+ CH_3

CH_3OH+ photon → H_2+ H_2CO

ii) high-temperature gas-phase chemistry: formation of H_2S ONLY

H_2 + HS → H_2S + H Highly endothermic!!!

No gas-phase route to form CH_3OH!!!

Chemical Modelling of the AFGL2591 Hot Core

UCL_CHEM code (Viti et al. 2004)

# of reactions = 1874 (UMIST) # of species = 170 Grain surface + gas-phase reactions

Two step code = 1st Collapse (freeze-out)

2nd Increase of the Gas temperature + UV-photon illumination

Two point model:

(A) inner and hotter core

Radius~175 AU

$n(H_2)$~10^7 cm^{-3}

T~1000 K

A_v~18^m

(B) cooler outer envelope

Radius~400 AU

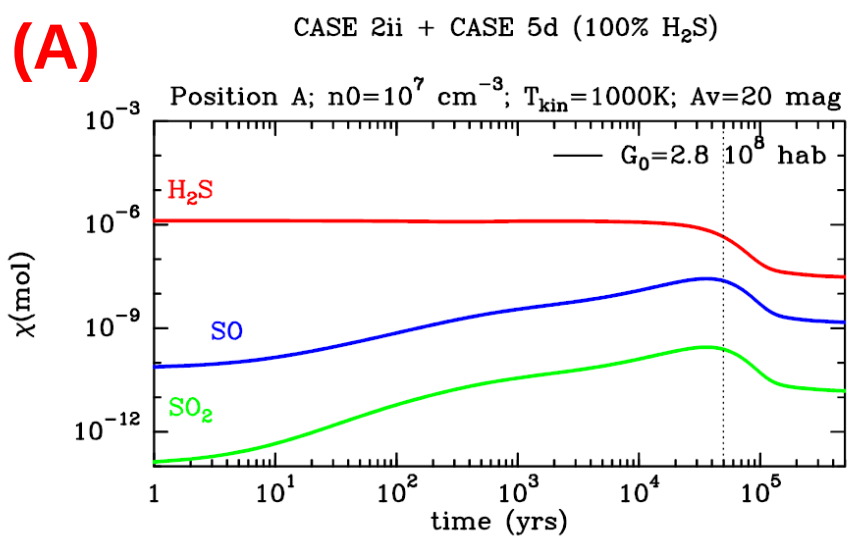
$n(H_2)$~3 10^6 cm^{-3}

T~200 K

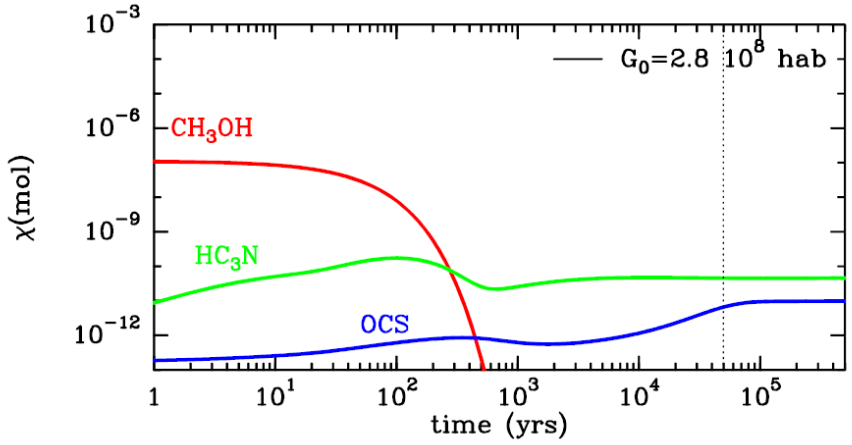
A_v~23^m

Chemical Modelling of the AFGL2591 Hot Core

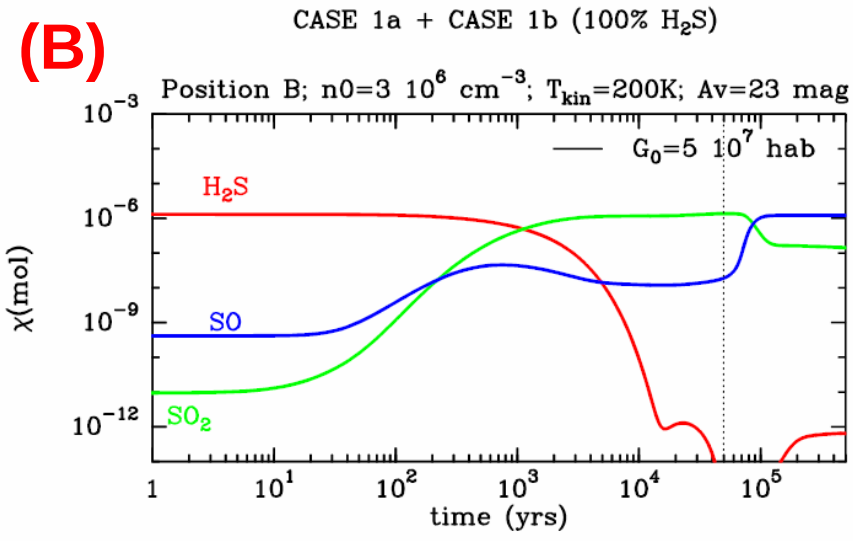
(A)



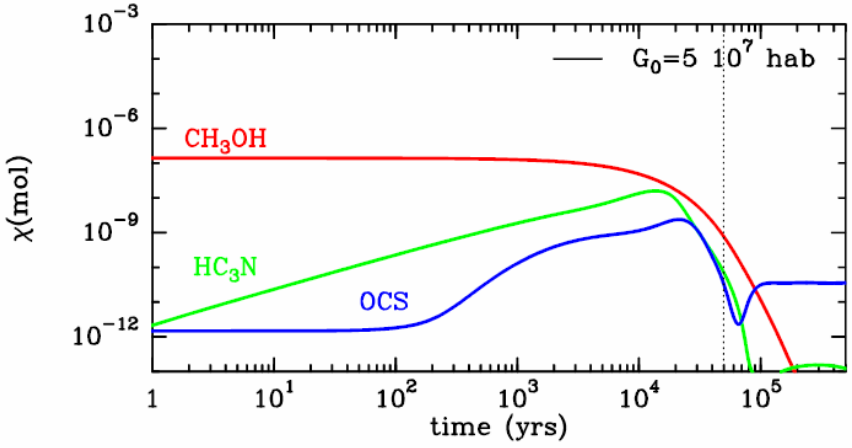
T=1000K, n=10^7 cm^{-3}, radius<200 AU, A_v=18^m



(B)



T=200K, n=3 10^6 cm^{-3}, radius=400 AU, A_v=23^m



Conclusions

First time that a complete chemical study of a massive hot core is carried out at angular resolutions down to ~350AU.

Chemical segregation in AFGL2591 produced by:

- i) UV-photo dissociation of the molecular gas
- ii) high-temperature gas-phase chemistry

Crucial to establish the physical structure of hot cores.

The high angular resolution + 8GHz bandwidth of the SMA make it a unique instrument to carry out comprehensive chemical studies toward high-mass star forming regions.