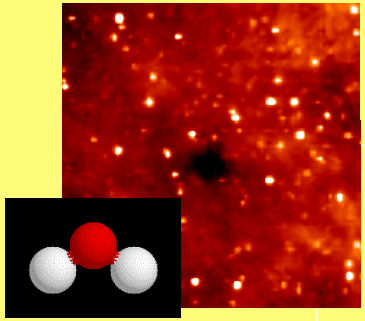
Pristine protostellar jet-disk systems: from darkness to the cradle of life

C. Codella (INAF, OA Arcetri)

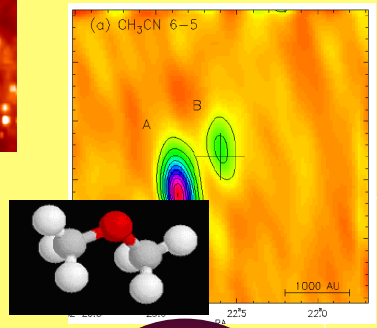
From a diffuse cloud to a planetary system
From atoms & simple molecules to life



1- PRE-STELLAR PHASE: cold and dense gas

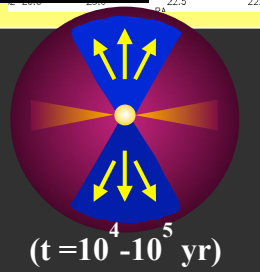
FORMATION OF SIMPLE MOLECULES

Caselli & Ceccarelli (2012)

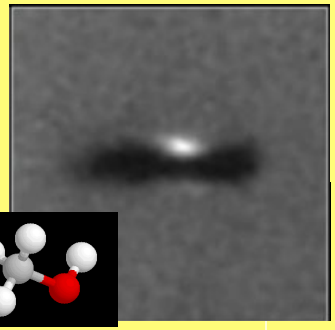


2- PROTOSTELLAR PHASE: collapsing, warm dense gas

FORMATION OF COMPLEX MOLECULES

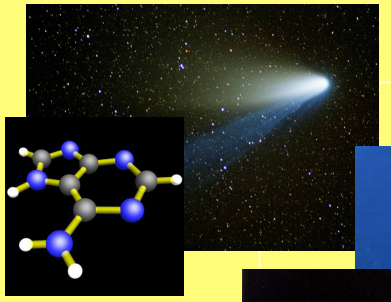


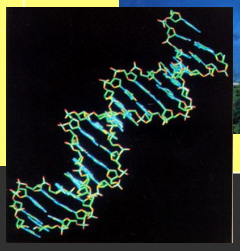
(t =10^4 -10^5 yr)



3- PROTOPLANETARY DISK PHASE:
cold and warm dense gas

SIMPLE & COMPLEX MOLECULES





4- PLANETESIMALS FORMATION : grains agglomeration

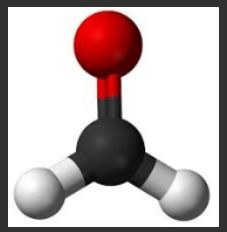
5- PLANETS FORMATION AND THE “COMETS/ASTEROIDES RAIN”

CONSERVATION AND DELIVERY OF OLD MOLECULES + LIFE

What is the role of the pre-solar chemistry in the present Solar System chemical composition?

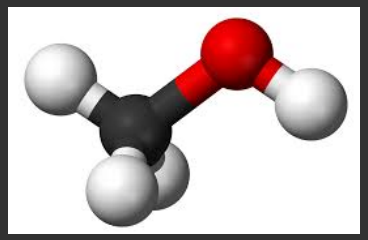
The ASTRONOMICAL COMs zoo

H_2CO



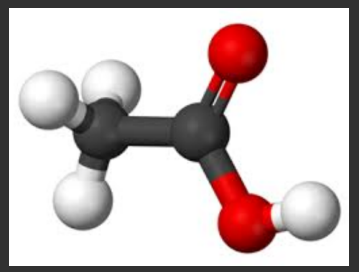
formaldehyde

CH_3OH



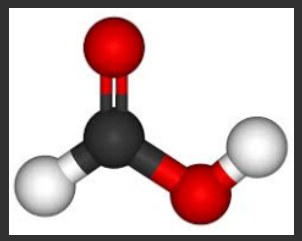
methanol

CH_3COOH



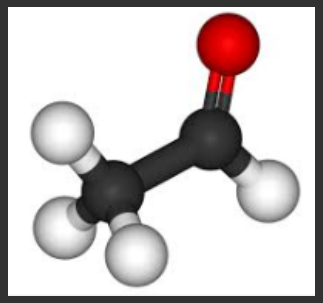
acetic acid

$HCOOH$



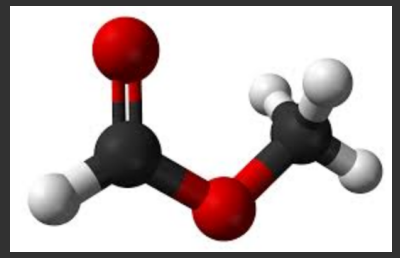
formic acid

CH_3CHO



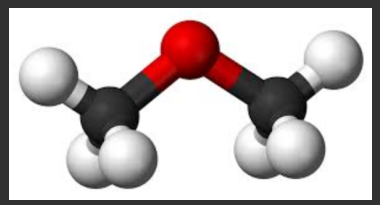
acetaldehyde

CH_3OCHO



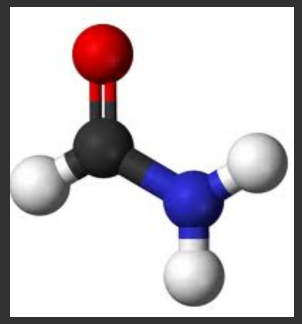
methyl formate

CH_3OCH_3



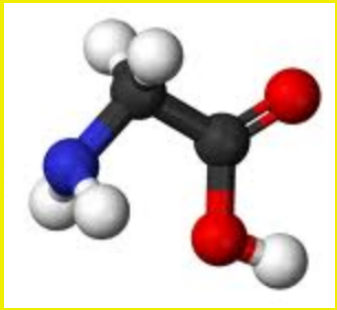
dimethyl ether

NH_2CHO



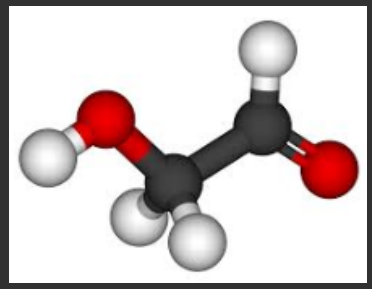
formamide

NH_2CH_2COOH



glycine
THE HOLY GRAIL....

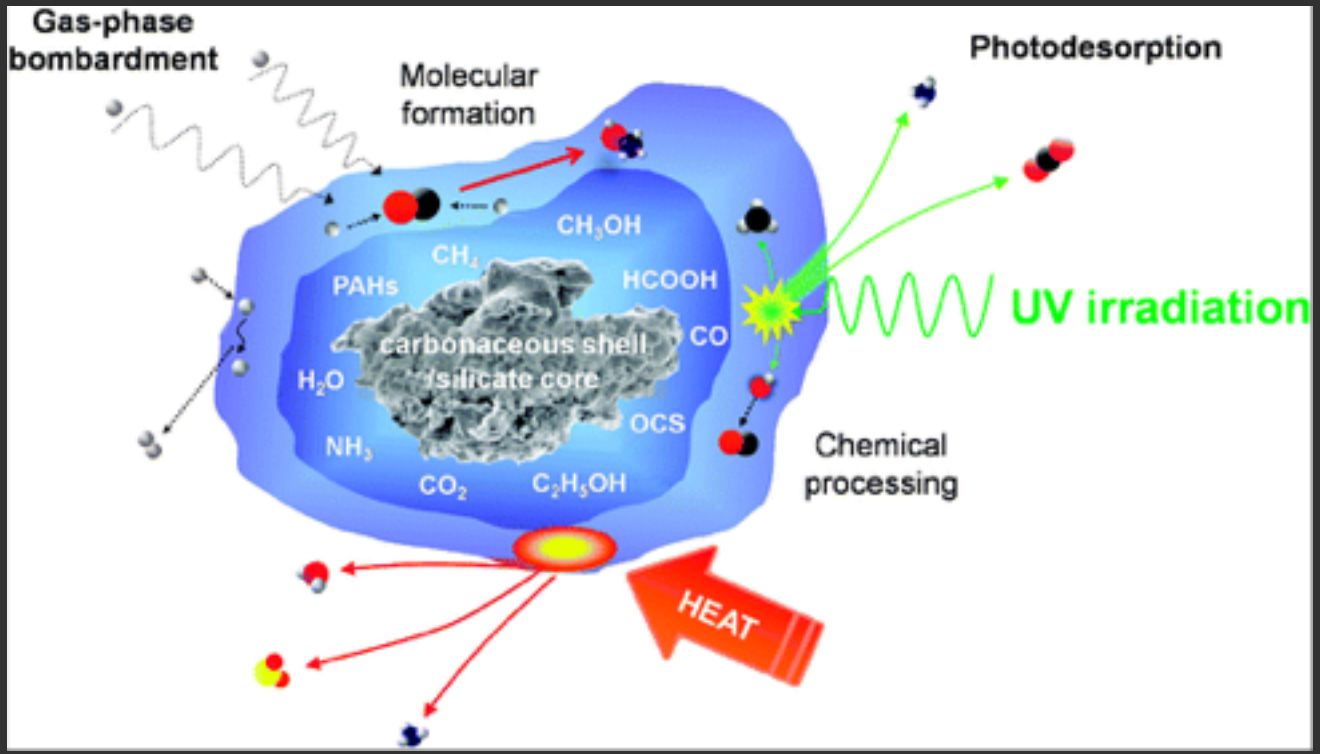
$HCOCH_2OH$



glycoaldehyde

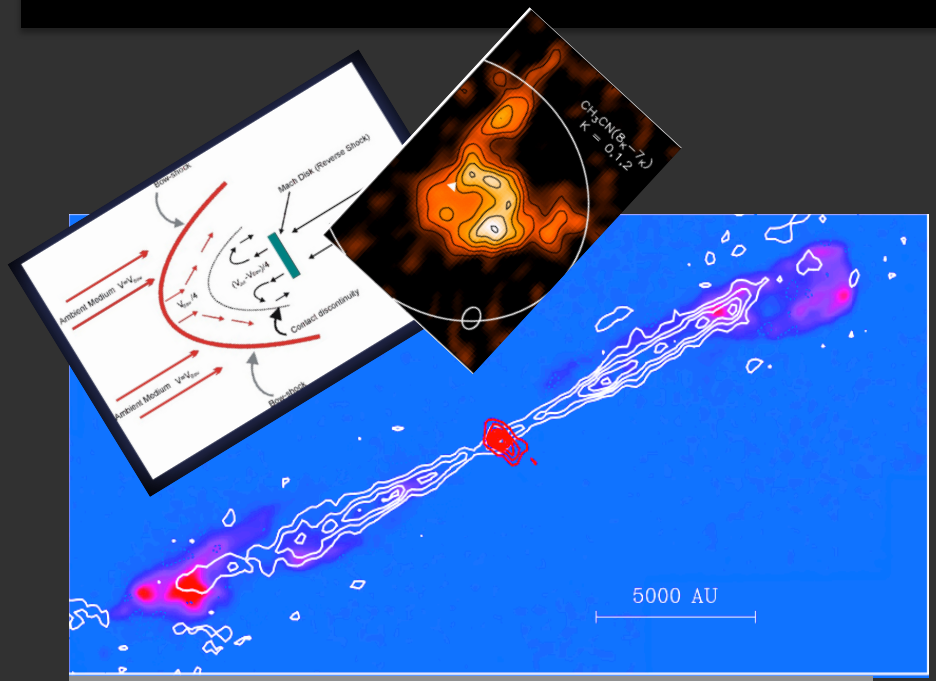
The formation of COMs

COMs are formed on ices and then released into the gas phase?



Or are daughter species, i.e. are formed in gas phase following the release of parent species such as methanol and formaldehyde?

Ingredients for the Sun-like star formation recipe



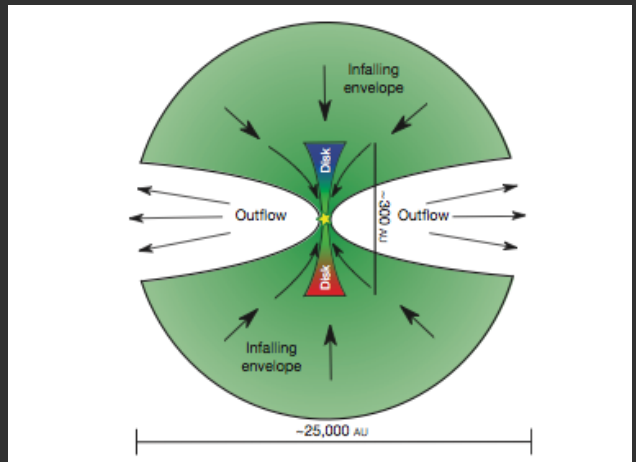
Gueth & Guilloteau (1992), Codella et al. (2009)

Rapid heating (from ~10 K to a few 1000 K) and compression of the gas → "Shock chemistry"

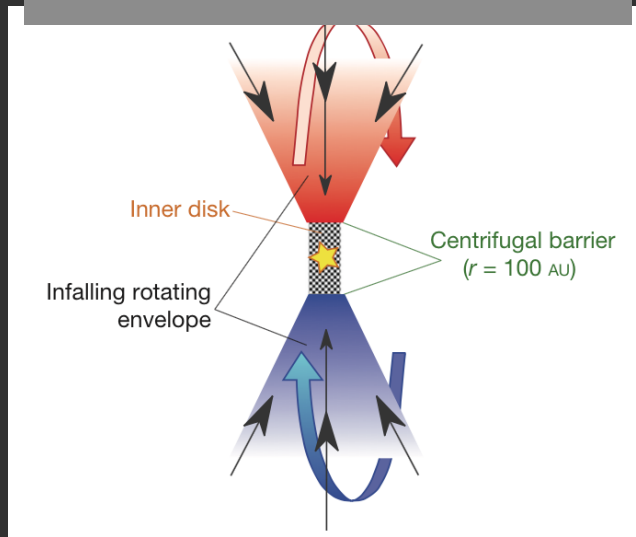
High-T chemistry: endothermic reactions

Ice sublimation & grain disruption

The gas acquires a chemical composition distinct from that of the unperturbed medium



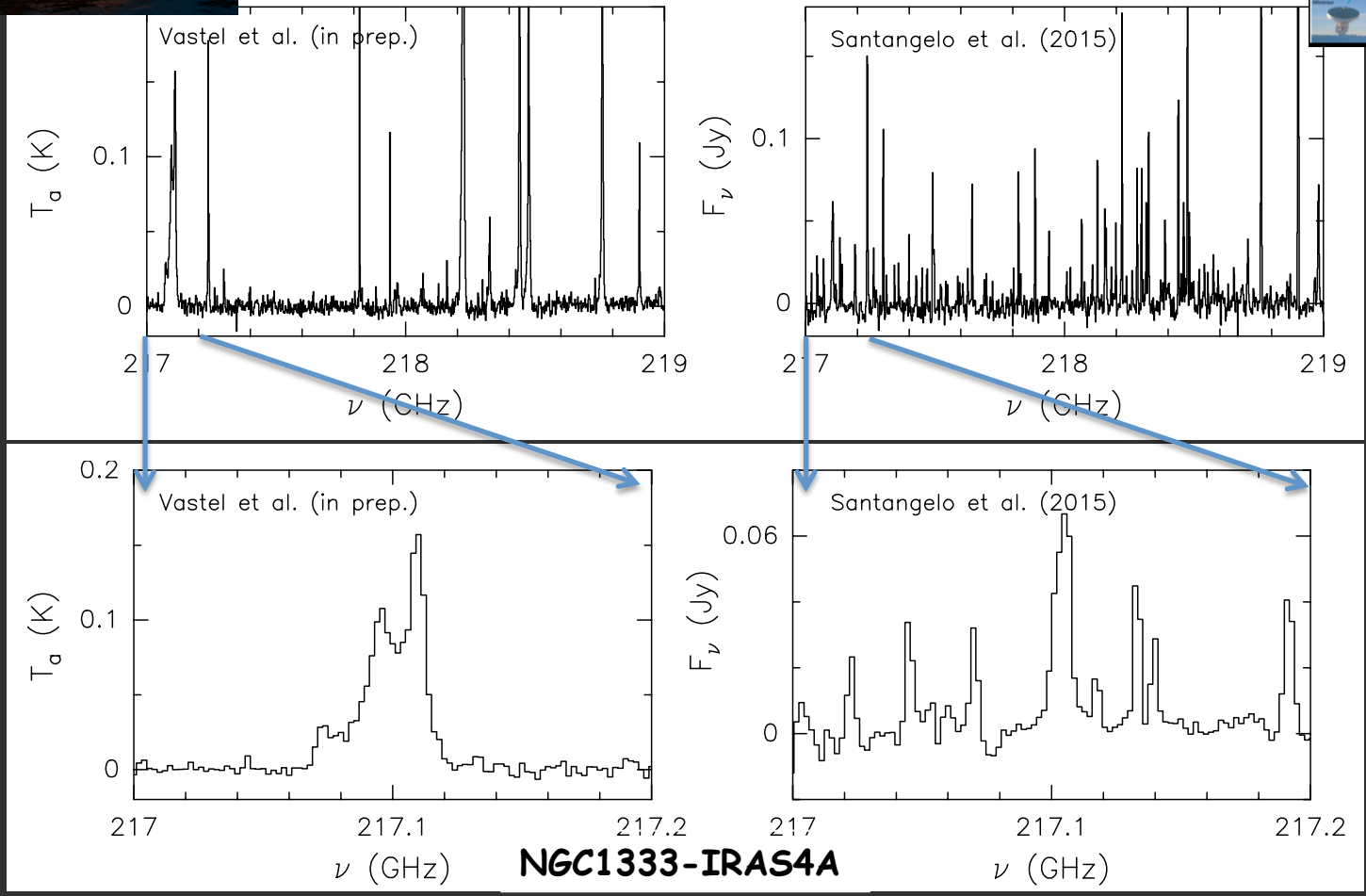
accretion shock
at disk-envelope interface



Lee et al. 2014, Sakai et al. 2014

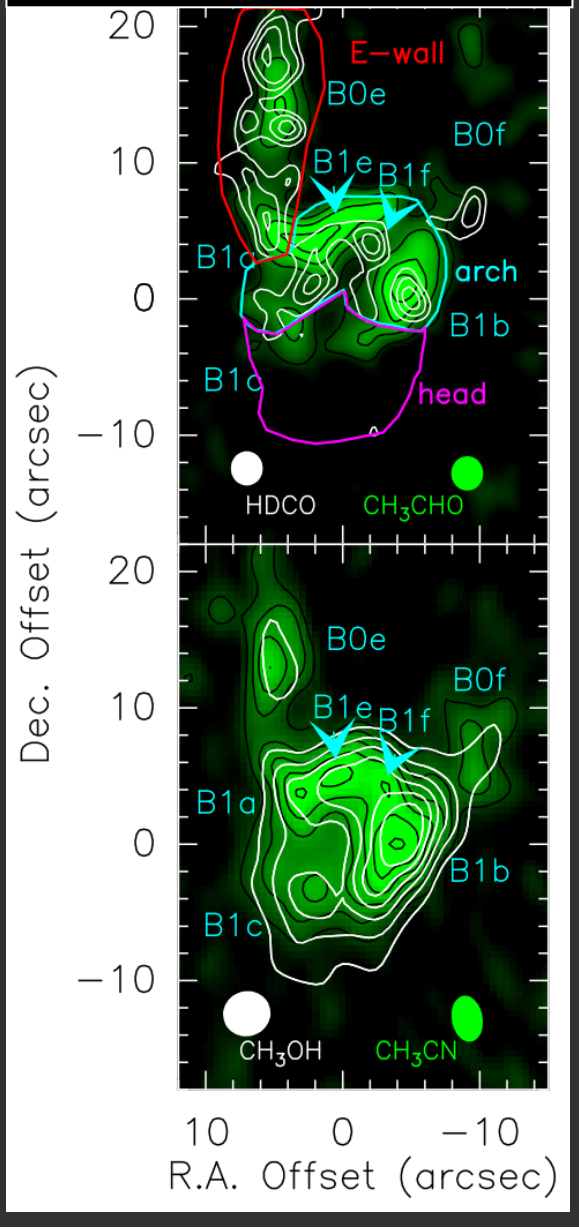
We need interferometry

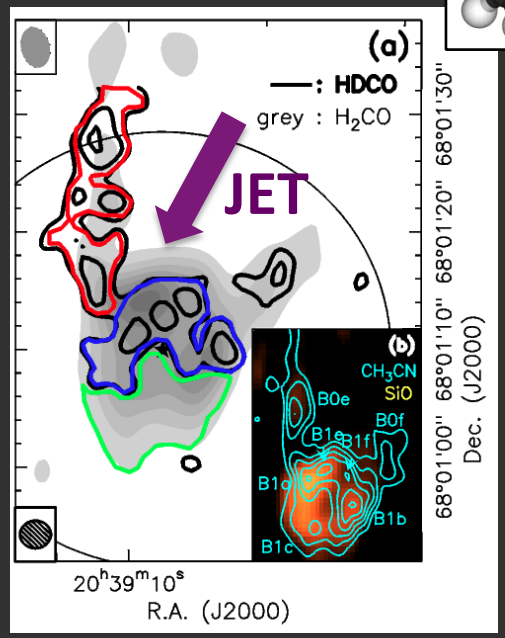
We need spatial resolutions of < 30 AU:
210 mas @ Taurus; 125 mas @ Perseus; 70 mas @ Orion

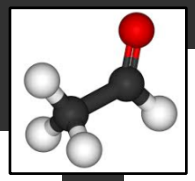


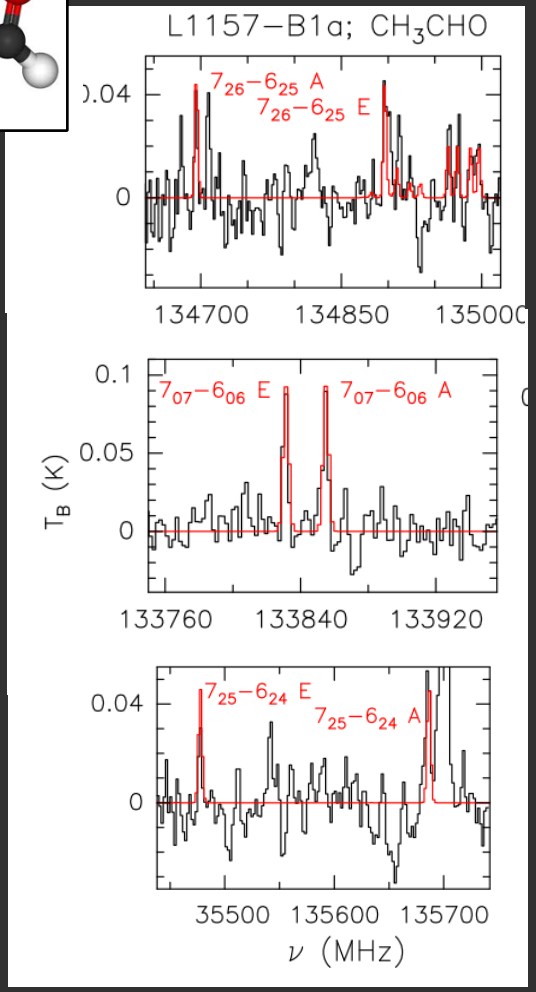
COMs in shocks

Acetaldehyde (CH_3CHO)









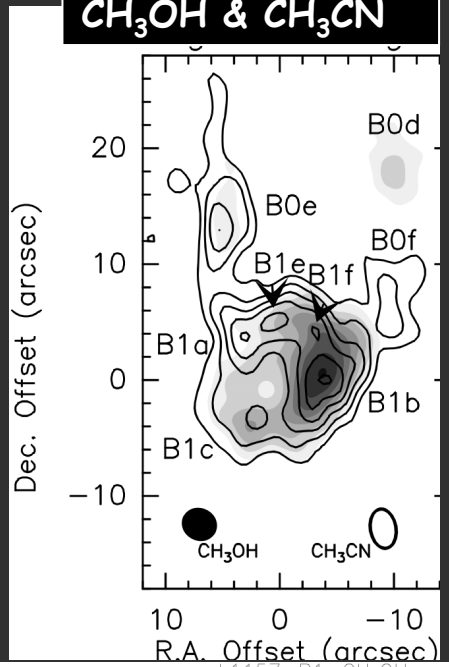
Fontani et al. (2014)
Codella et al. (2015)

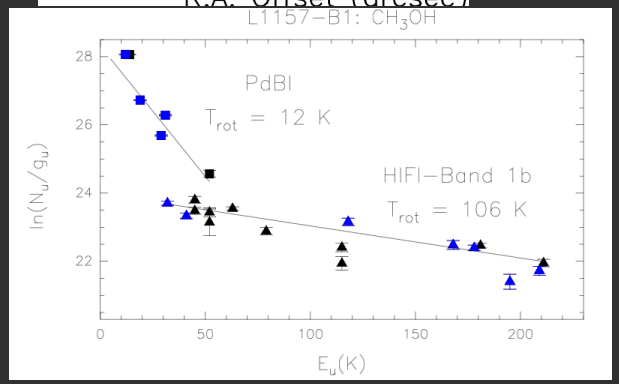
CH_3CHO spatial distribution follows the young (2000 yr) cavity produced by the impact of the jet with the ambient medium

COMs associated with the region enriched by iced species evaporated from dust mantles and released into the gas phase

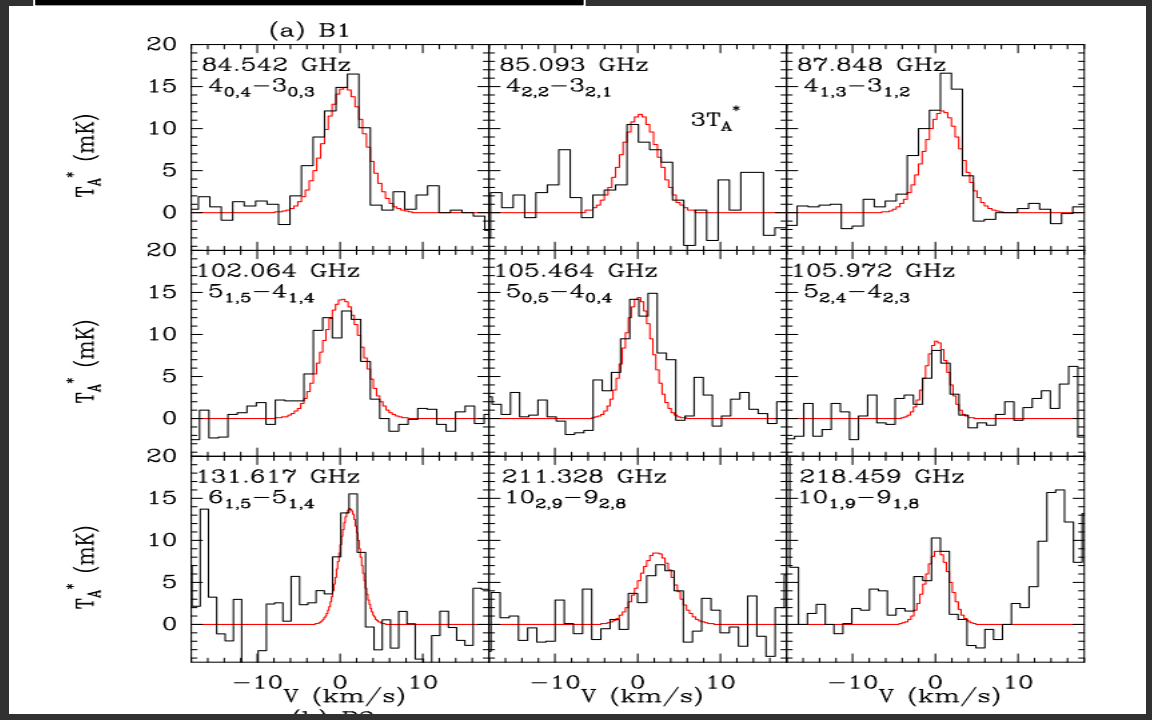
COMs in shocks

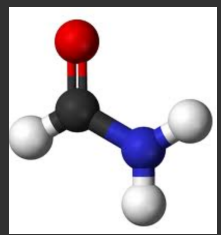
CH_3OH & CH_3CN

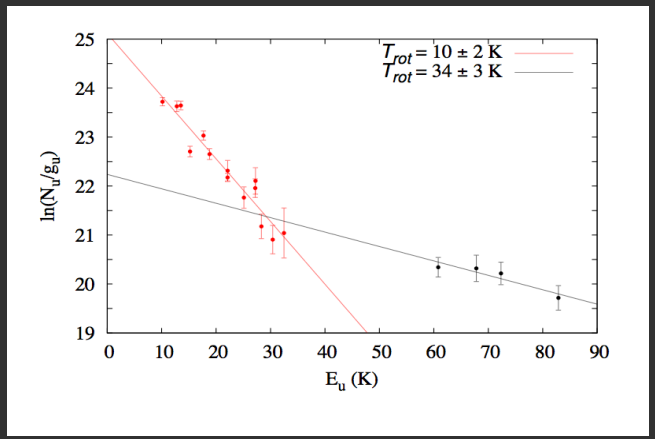




Formamide (NH_2COCH_3)



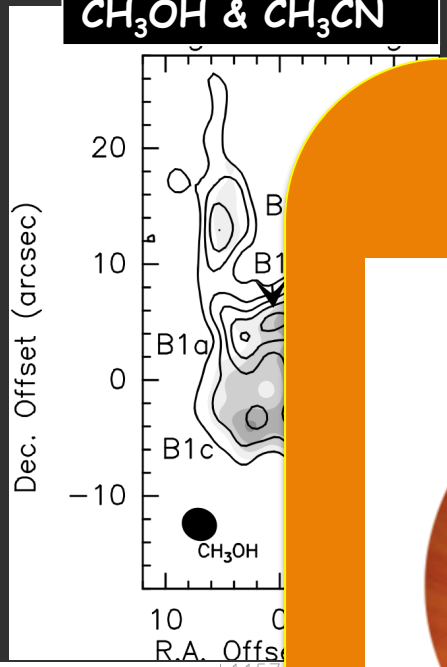


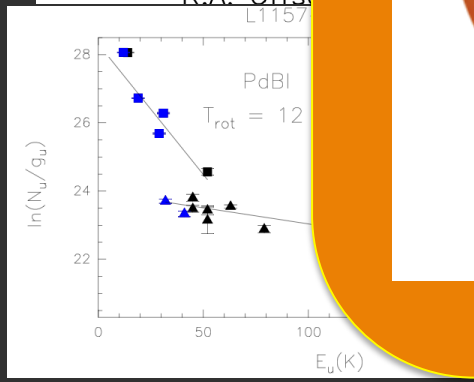


Codella et al. (2009,2010)
Mendoza et al. (2014)

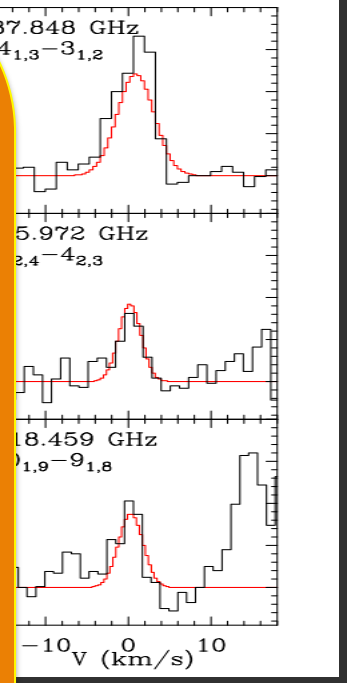
COMs in shocks

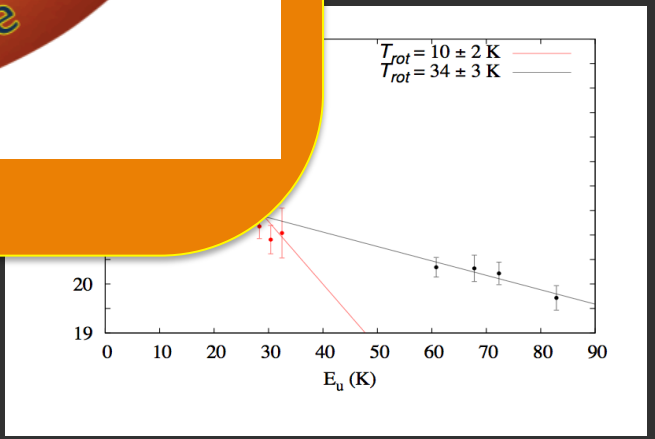
CH_3OH & CH_3CN





Formamide (NH_2COCH_3)



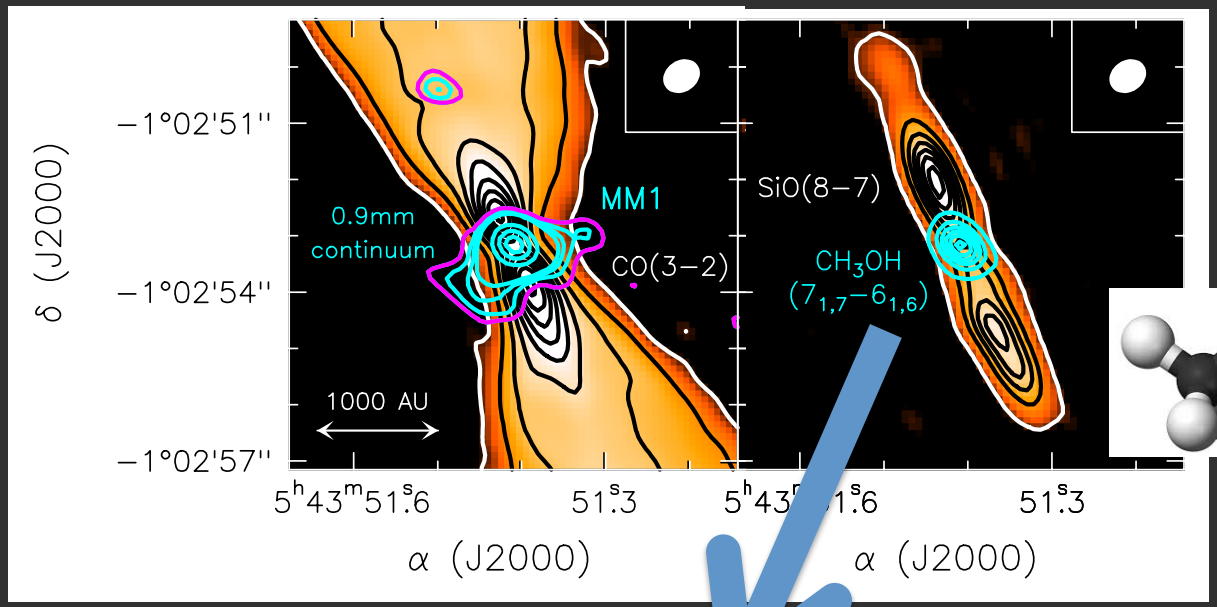


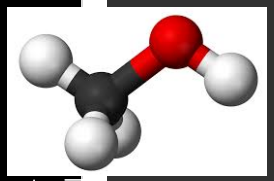
IRAM-NOEMA Large Program
SOLIS (Seeds Of Life in Space)
COMS in Sun precursors

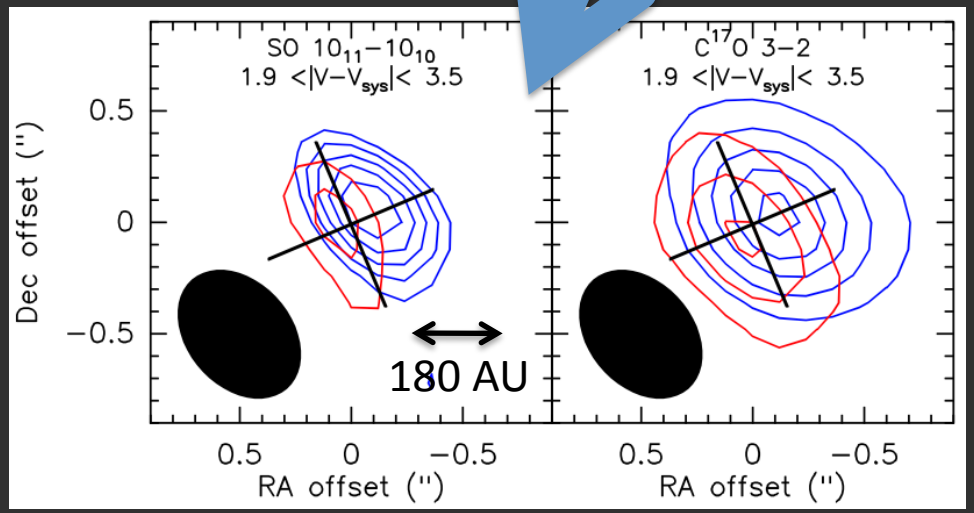
PI: Ceccarelli - Caselli

Codella et al. (2009,2010)
Mendoza et al. (2014)

The inner 100 AU: The jet, the disk, and the wind





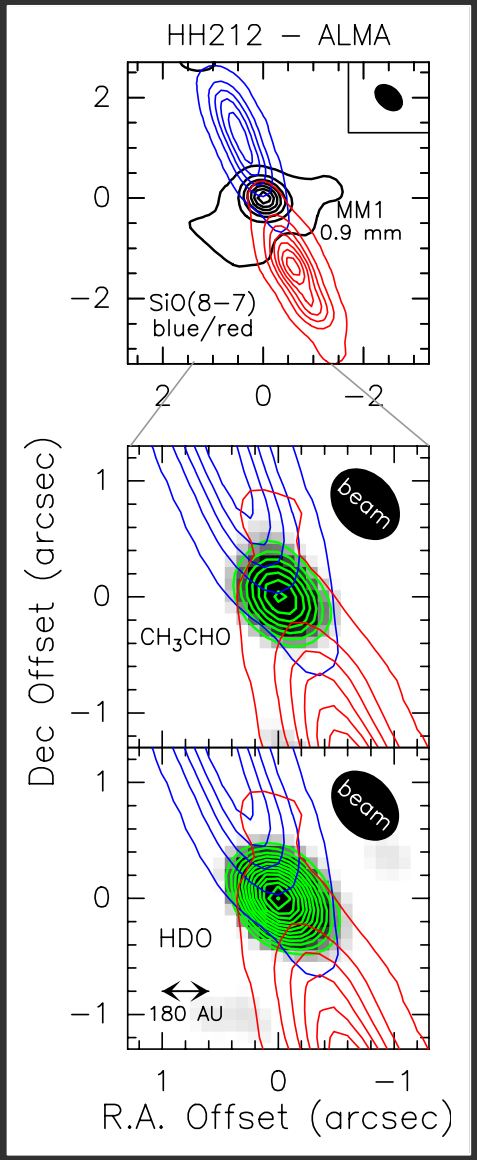


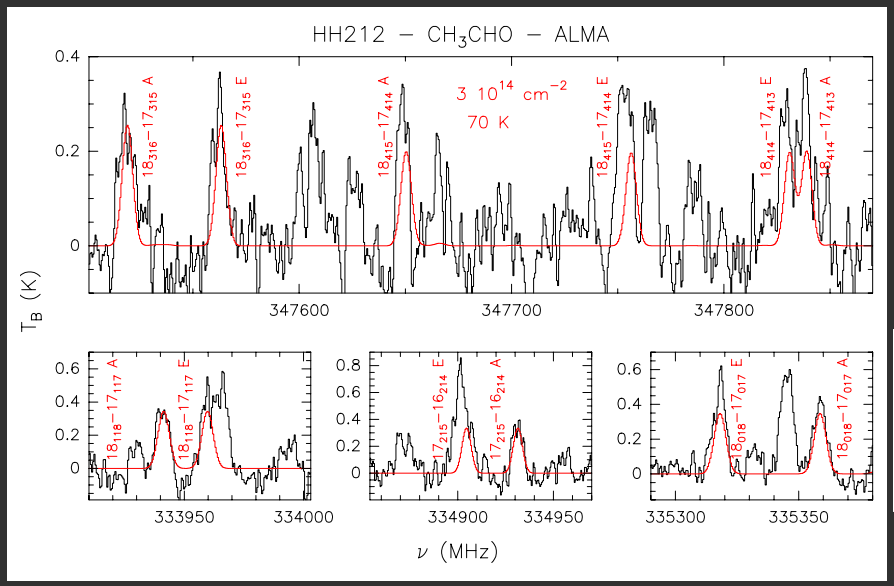
High-Eu (143 K) SO emission

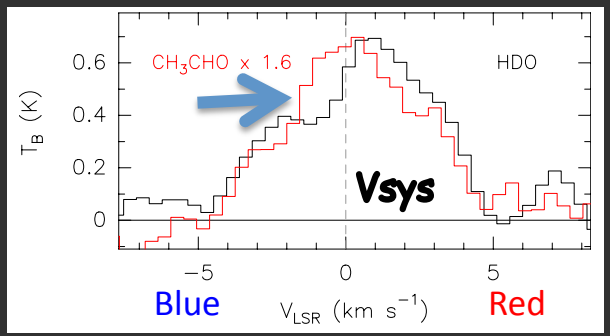
At low-velocity
blue & red peaks along disk axis
similar to $C^{17}O$
(Keplerian) rotating inner disk ?

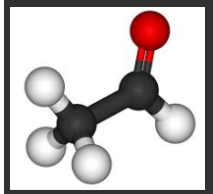
Codella et al. (2014),
Podio et al. (2015)

The inner 100 AU: The jet, the disk, and the wind







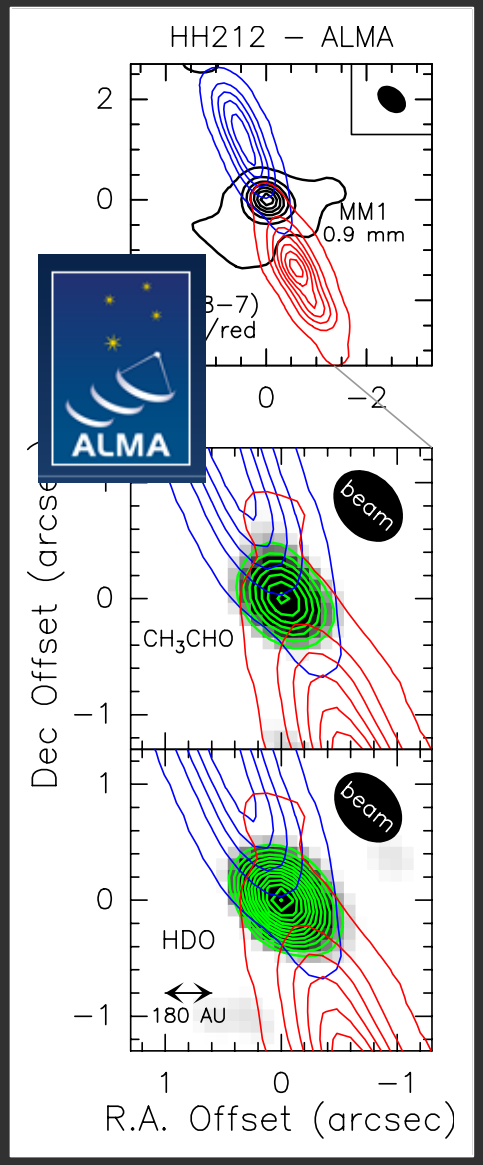


VERY High-Eu (up to 335 K) CH_3CHO and HDO emission

Asymmetric HDO profile indicating outflowing (and compact) gas: Evidence for a disk wind ?

Codella et al. (submitted)

Conclusions



COMs are key tools to observe the fundamental processes (accretion, ejection) sculpting the cradle where a star (and its planetary system) is going to form

….and viceversa….

The jet/disk protostellar system is the ideal place to understand when the seeds of life form

Interferometry (ALMA, NOEMA) is needed (as well as large bandwidths)

SOLIS started: COMs in Sun precursor

Be prepared to the advent of SKA !!