

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

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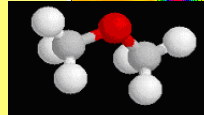
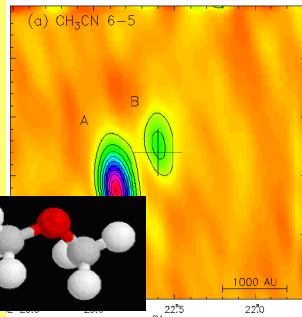
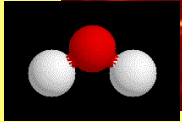
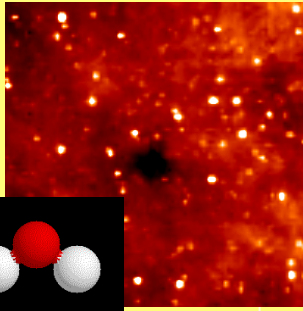


From a diffuse cloud to a planetary system

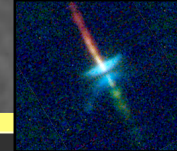
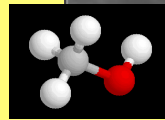
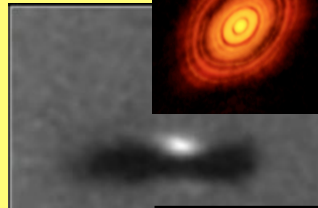
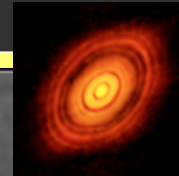
From atoms & simple molecules to life

1- PRE-STELLAR PHASE: cold and dense gas
FORMATION OF SIMPLE MOLECULES

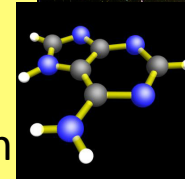
Caselli & Ceccarelli (2012)



2- PROTOSTELLAR PHASE: collapsing, warm dense gas
FORMATION OF COMPLEX MOLECULES

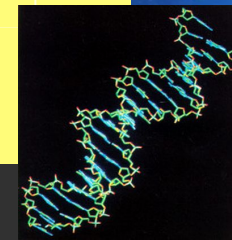


3- PROTOPLANETARY DISK PHASE:
cold and warm dense gas
SIMPLE & COMPLEX MOLECULES



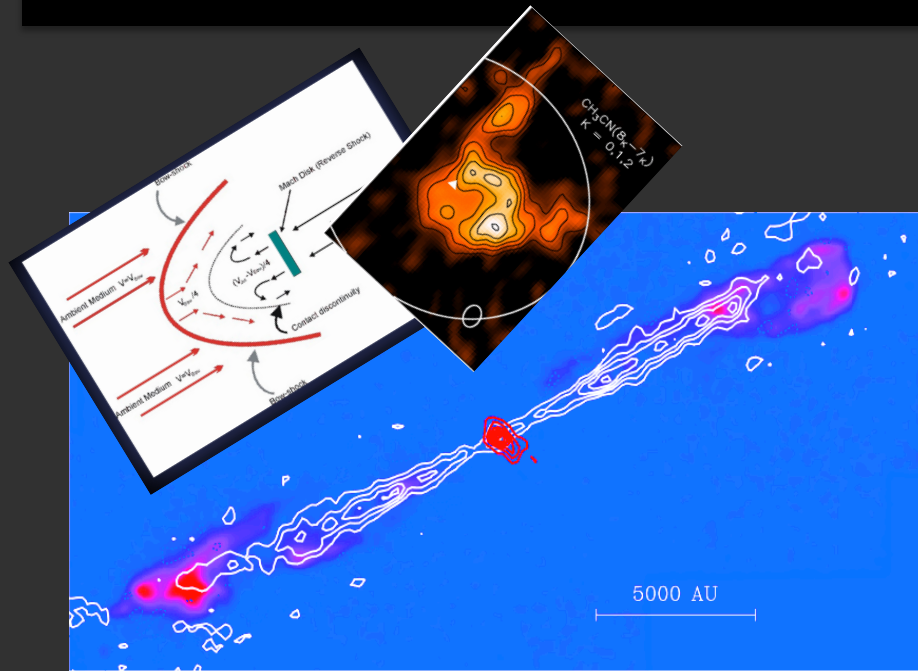
4- PLANETESIMALS FORMATION : grains agglomeration

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?

Ingredients for the Sun-like star formation recipe



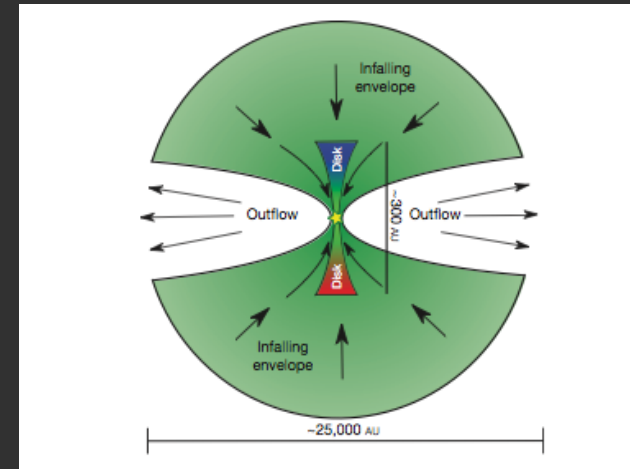
Gueth & Guilloteau (1992), Codella et al. (2009)

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

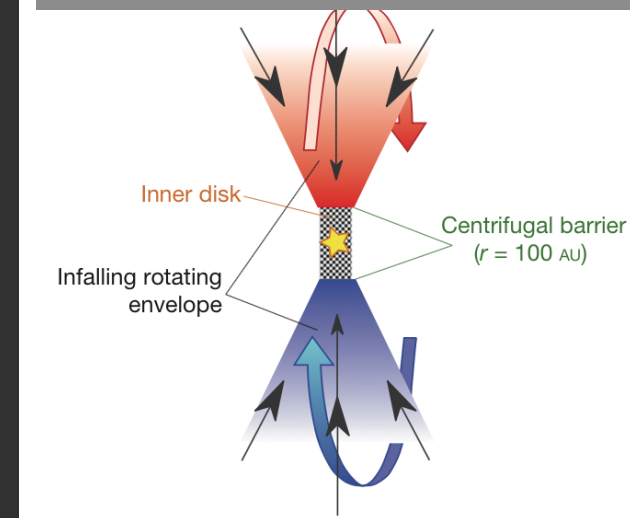
High-T chemistry: endothermic reactions

Ice sublimation & grain disruption

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



accretion shock
at disk-envelope interface

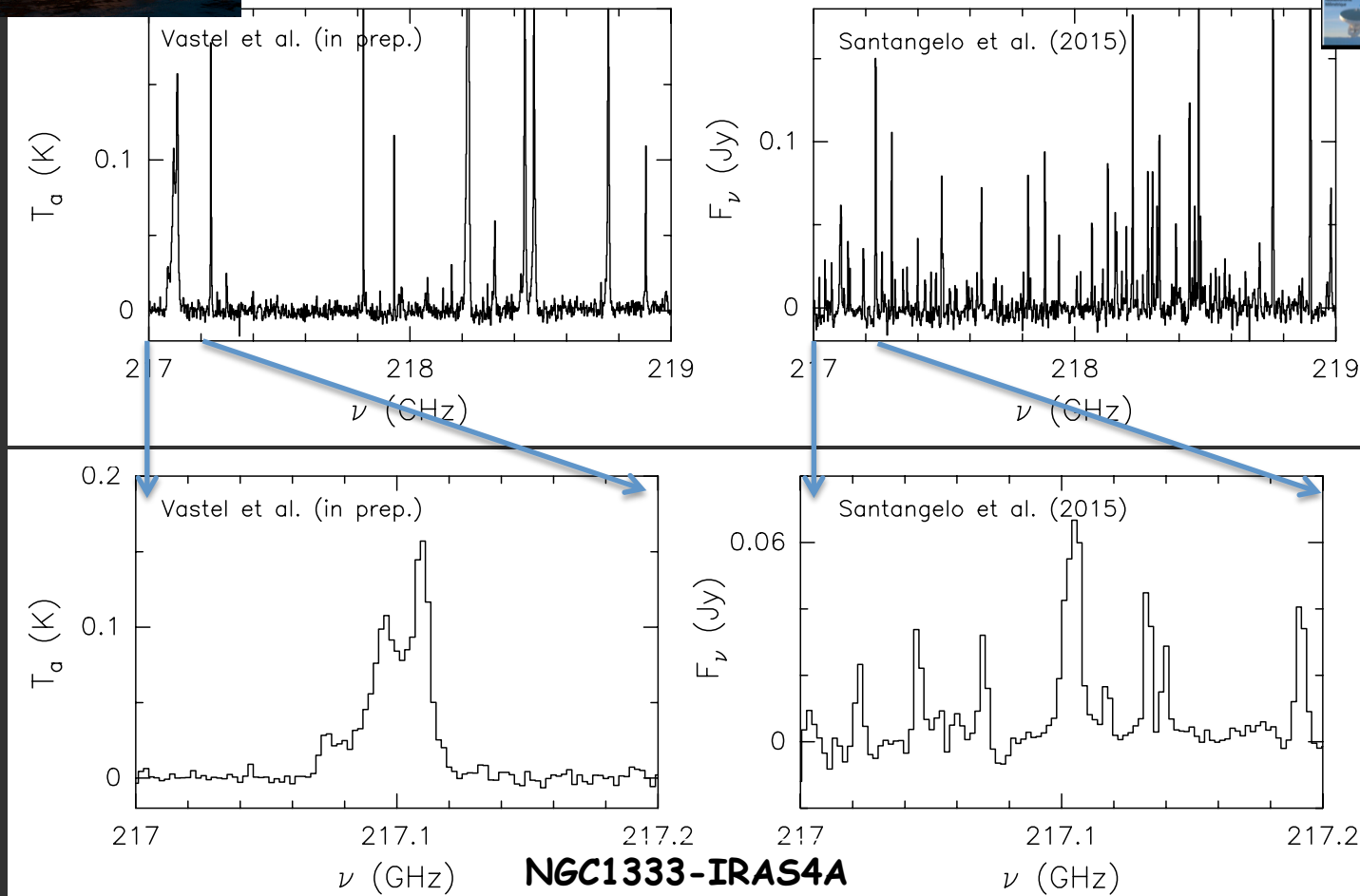
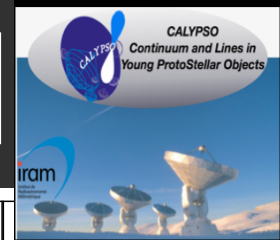


Lee et al. 2014, Sakai et al. 2014

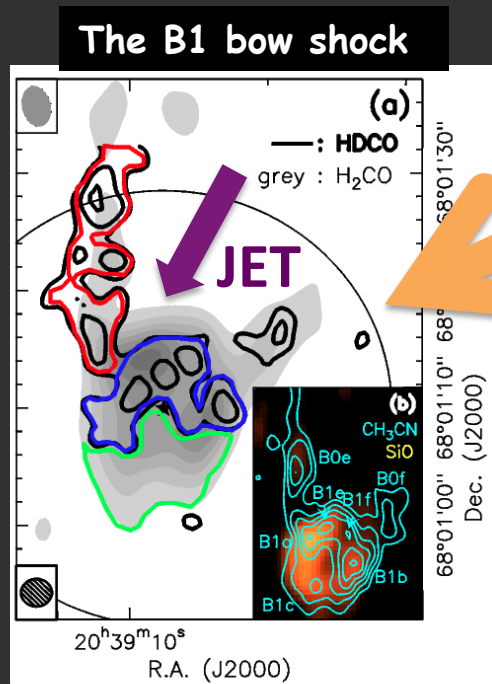
We need interferometry



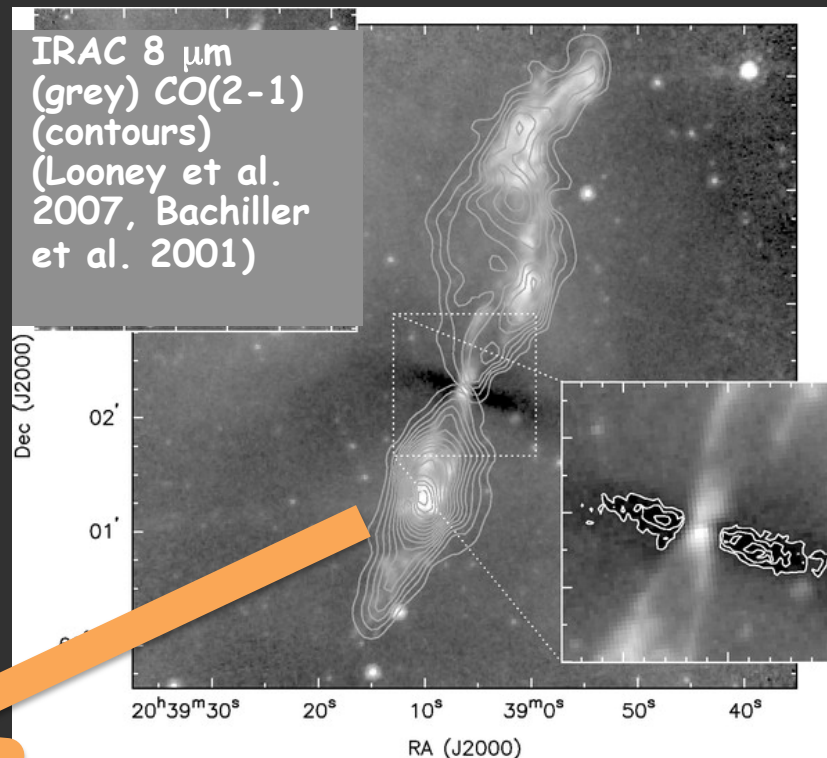
We need spatial resolutions of < 30 AU:
210 mas @ Taurus; 125 mas @ Perseus; 70 mas @ Orion



COMs in shocks: the L1157-B1 laboratory

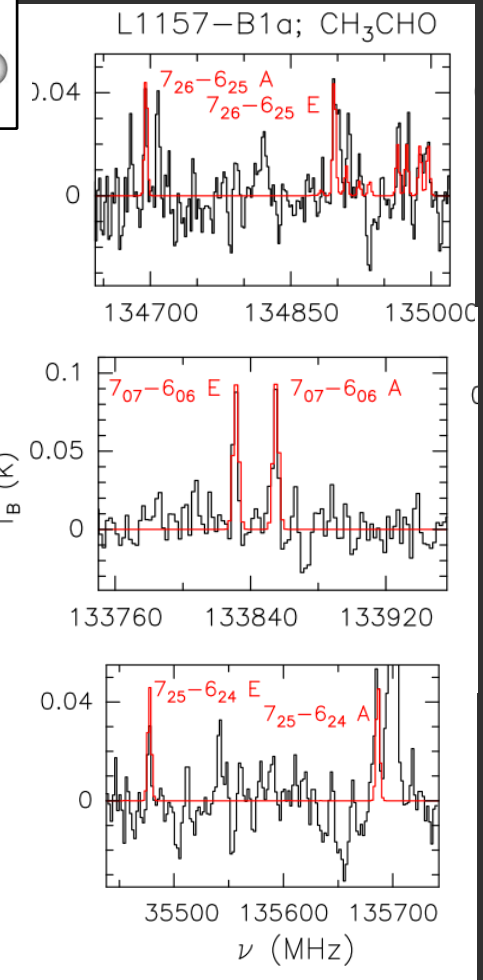
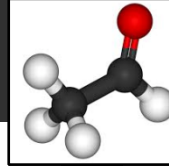
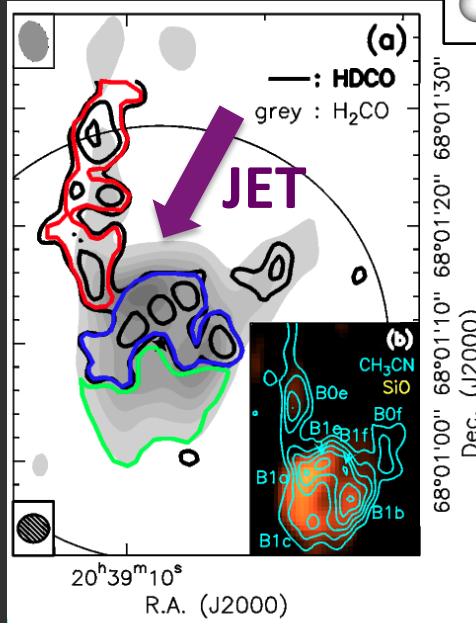
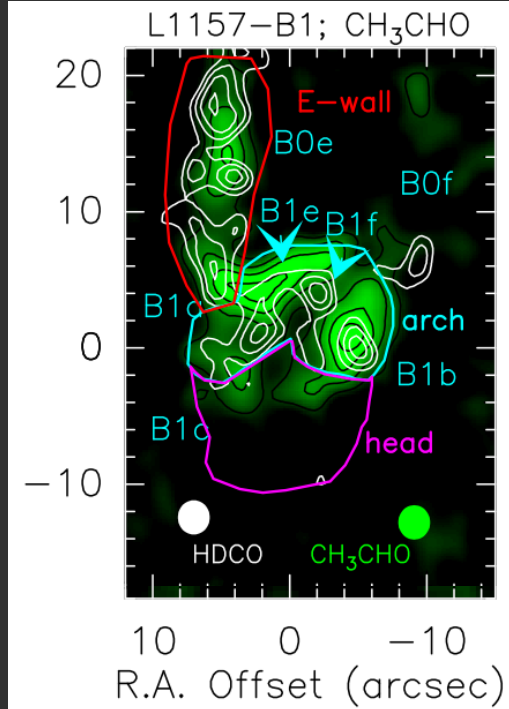


Fontani et al. (2014)



COMs in shocks: the L1157-B1 laboratory

Acetaldehyde (CH_3CHO)

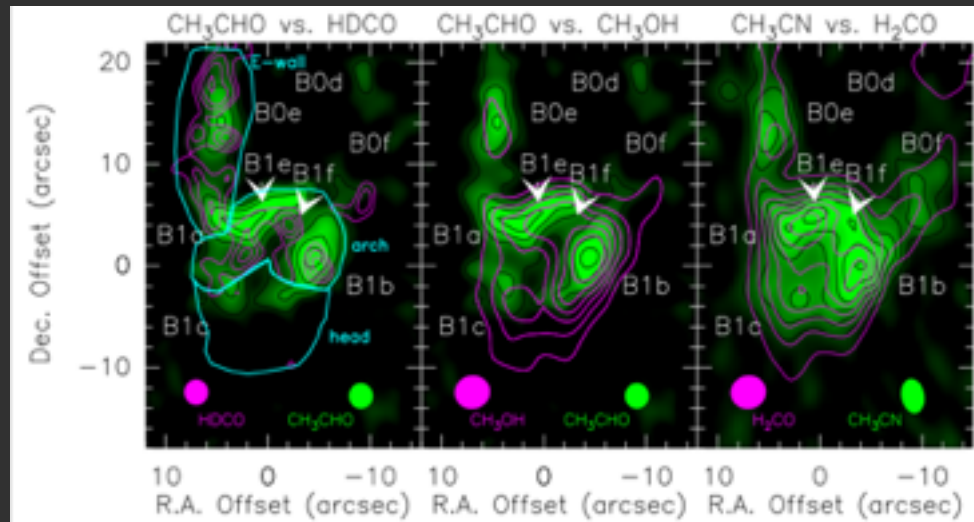


Fontani et al. (2014)
Codella et al. (2015)

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

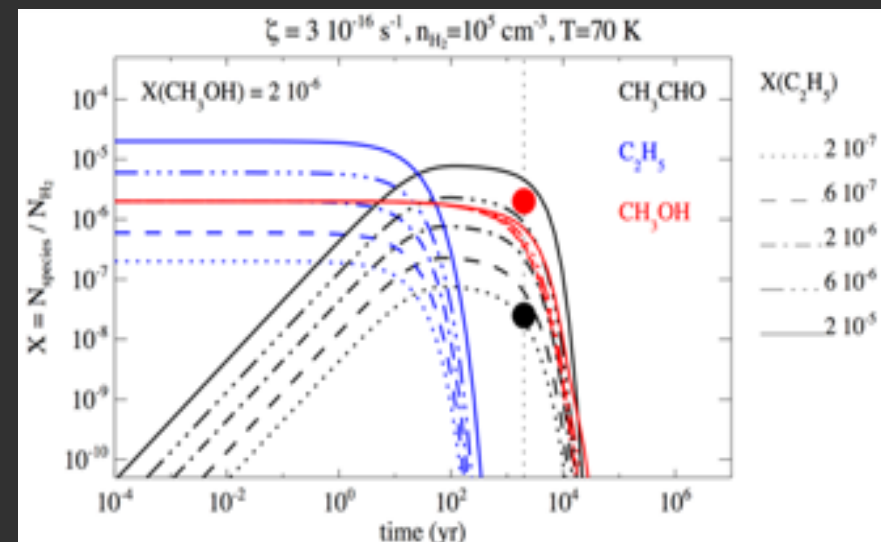
COMs in shocks: the L1157-B1 laboratory



Codella et al. (2015)

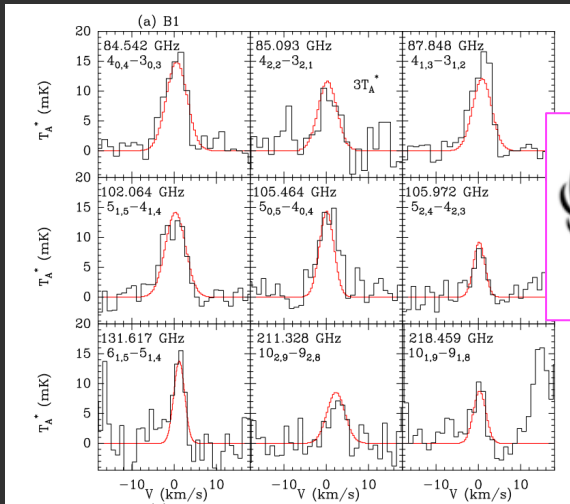
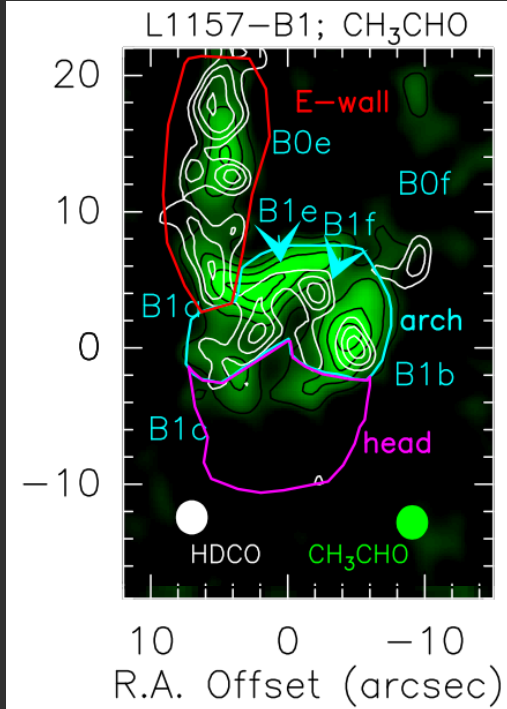
CH₃CHO formation on grains
 combination of CH₃ and HCO on the grain surface
 (Garrods & Herbst 2006)
 irradiation of iced CH₄, CO₂ and other iced
 species (Bennett et al. 2005)

CH₃CHO formation in gas-phase
 only if a large fraction of C (~0.1%)
 is locked into iced hydrocarbons
 (Charnley 1992, 2004, Vasyunin & Herbst 2013)

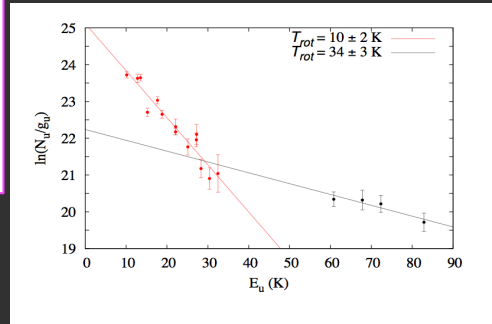


COMs in shocks: the L1157-B1 laboratory

Acetaldehyde (CH_3CHO)



Formamide (NH_2CHO)



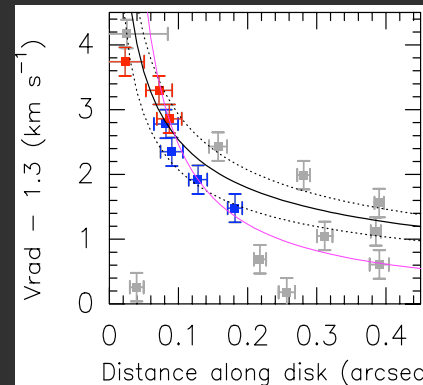
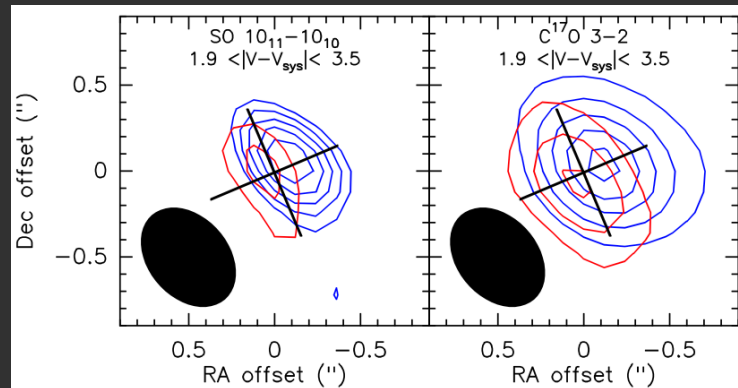
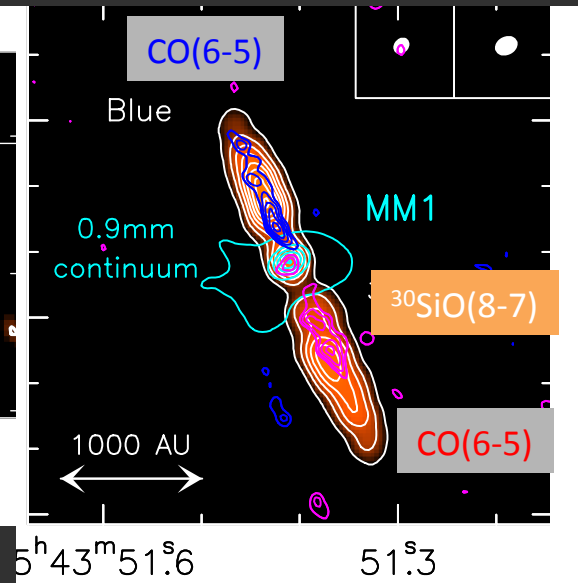
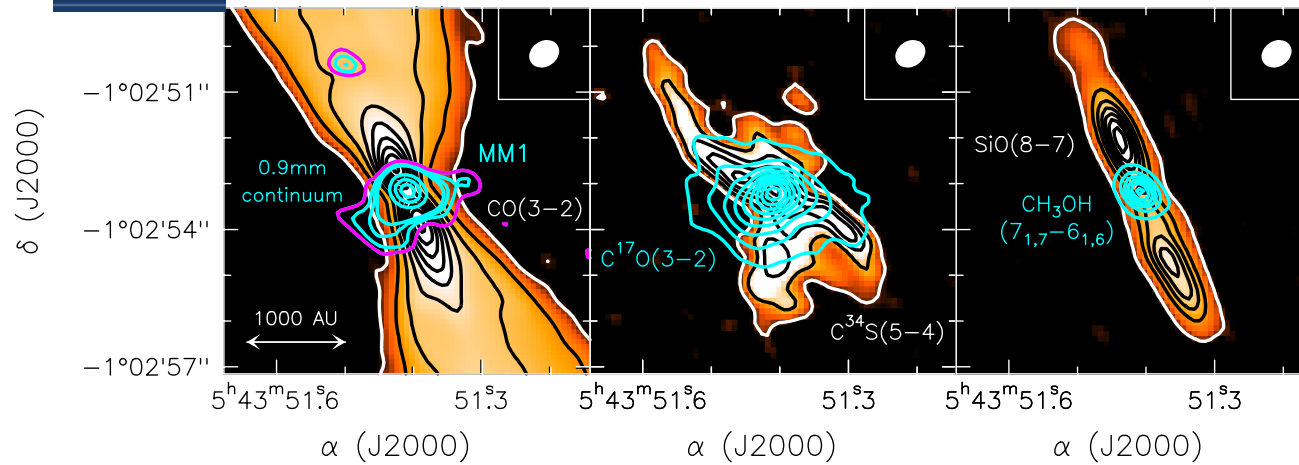
Mendoza et al. (2014)
 Codella et al. (2015)

SOLIS started:
 COMs in Sun
 precursors

The inner 100 AU: HH212-land



HH212 as observed with ALMA (Band 7)

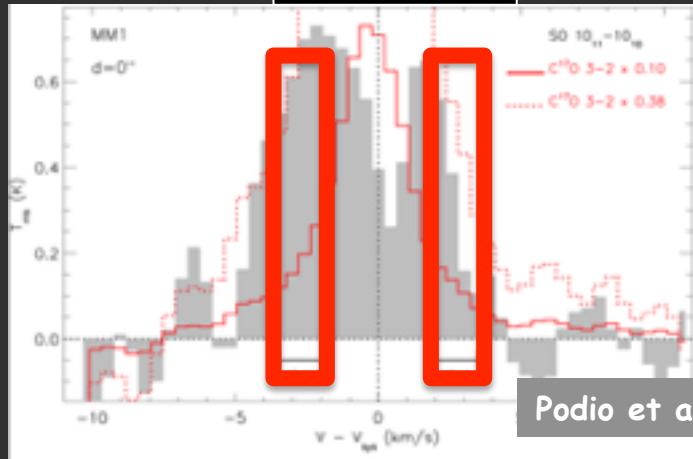


Codella et al. (2014),
Podio et al. (2015)
Gueth et al. (submitted)

These findings are consistent
with keplerian rotation out to
90 AU around a $0.3 \pm 0.1 M_{\odot}$

SO abundance in protostellar disks

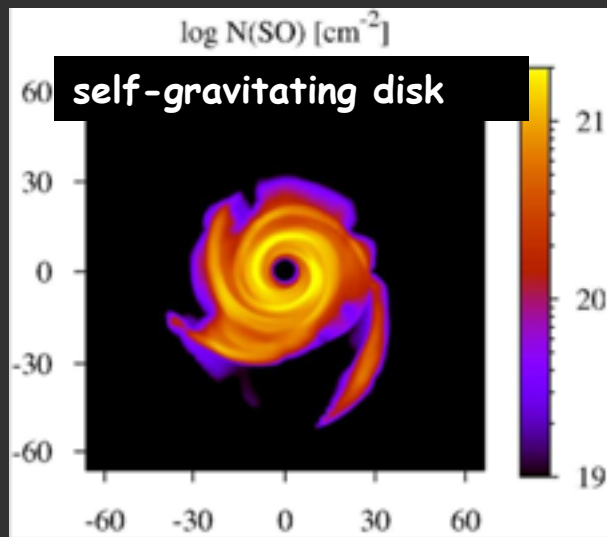
THE DISK



Podio et al. (2015)

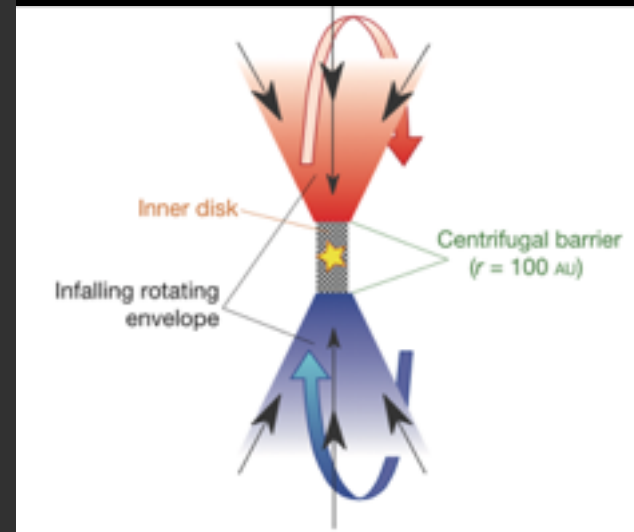
$X(\text{SO}) \sim 10^{-8} - 10^{-7}$
 much higher than in passively heated
 Class II disks
 (found $\leq 10^{-11}$)

Fuente et al. (2010)
 Dutrey et al. (2011)



Ilee et al. (2011)
 Douglas et al. (2013)

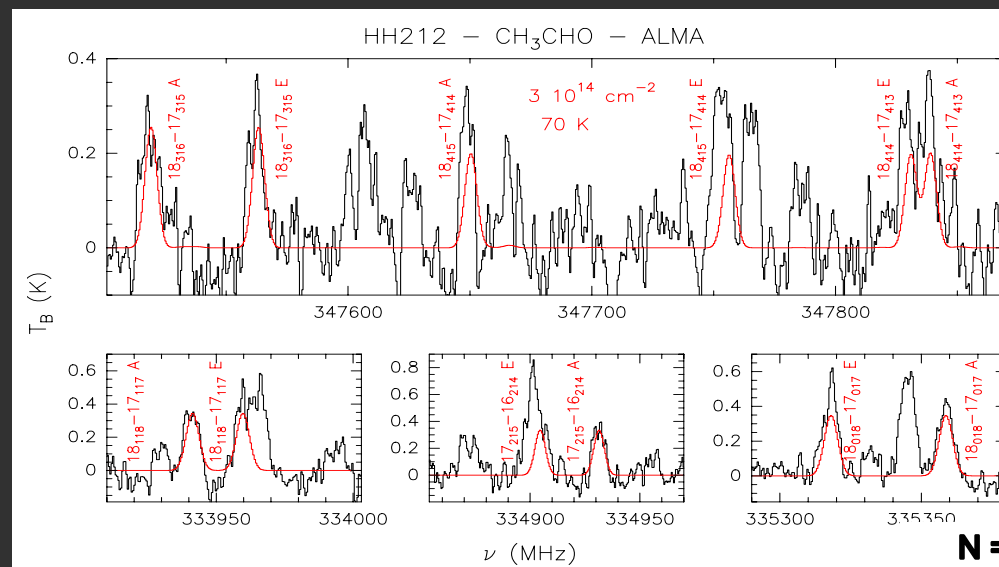
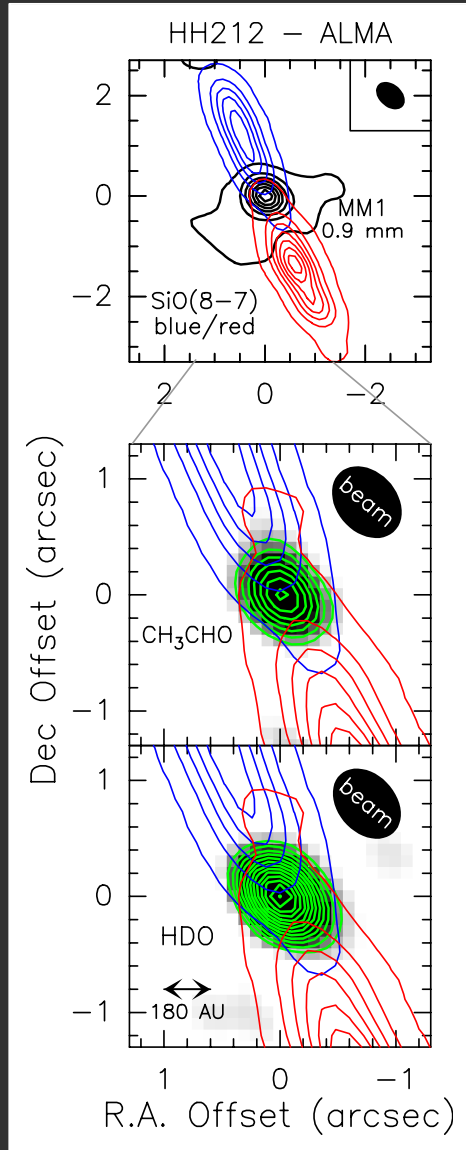
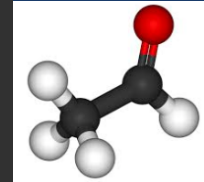
accretion shock at envelope-disk interface



Lee et al. (2014)
 Sakai et al. (2014)

What about COMs ?

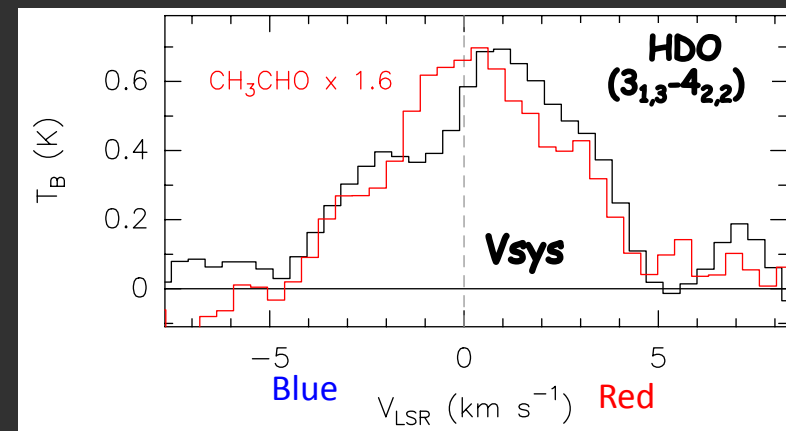
The inner 100 AU: The jet, the disk, and the wind



$$N = 3(2) \times 10^{14} \text{ cm}^{-2}$$

$$T_{\text{rot}} = 87(47) \text{ K}$$

$$X(\text{CH}_3\text{CHO}) = 10^{-9}-10^{-8}$$

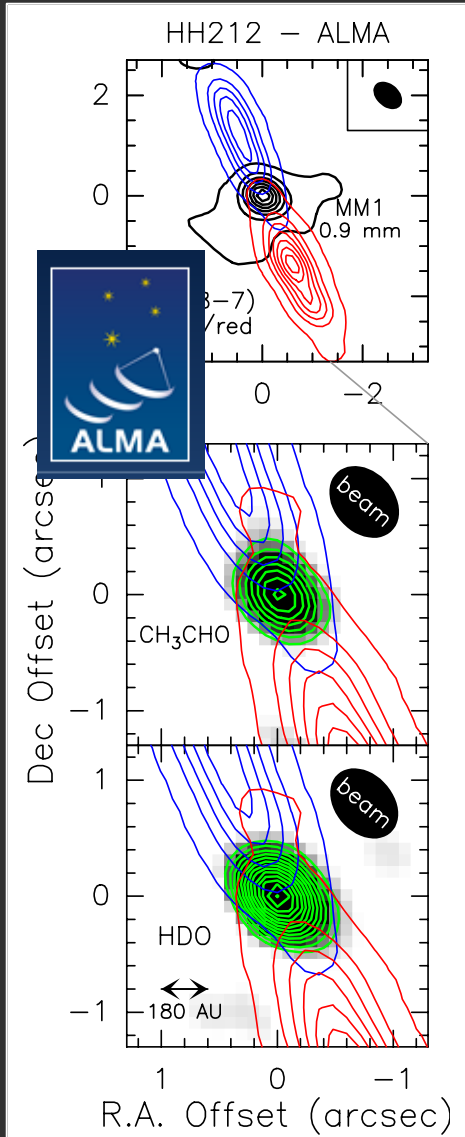


VERY High-Eu
(up to 335 K)
CH₃CHO and HDO
compact (< 100 AU)
emission;
T_{kin} > 100 K,
n_{H2} > 10⁷ cm⁻³

Codella et al. (2016)



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 precursors:
Stay tuned!

