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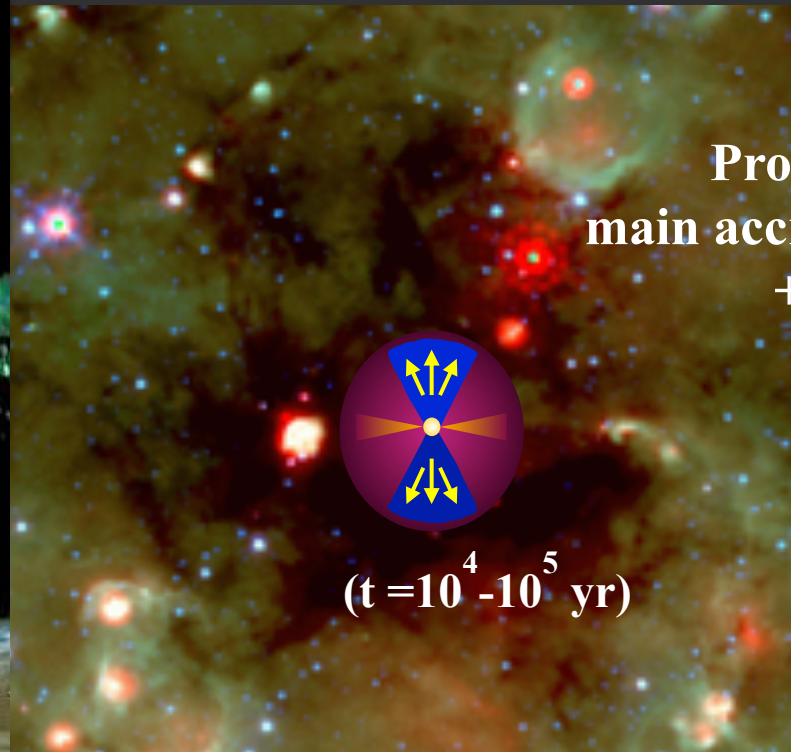


The chemistry of protostellar jet-disk systems

C. Codella (INAF, OA Arcetri)



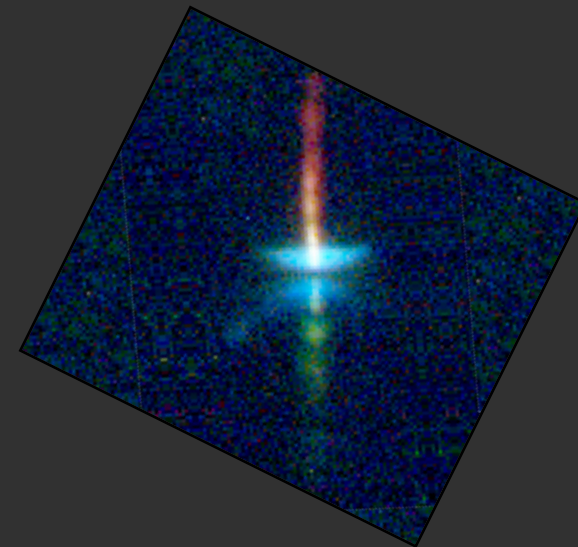
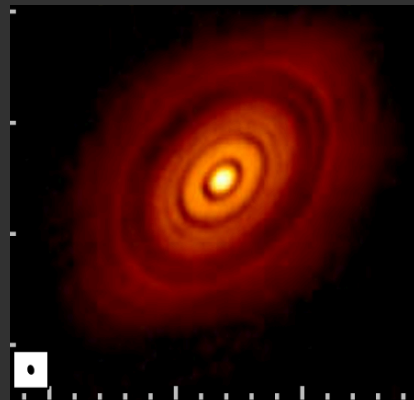
Heart of Darkness



Protostar:
main accretion phase
+ jet

$(t = 10^4 - 10^5 \text{ yr})$

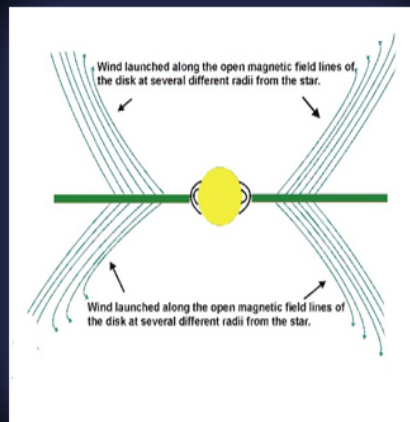
T-Tauri Star:
accretion disk + jet
 $(t = 10^6 - 10^7 \text{ yr})$



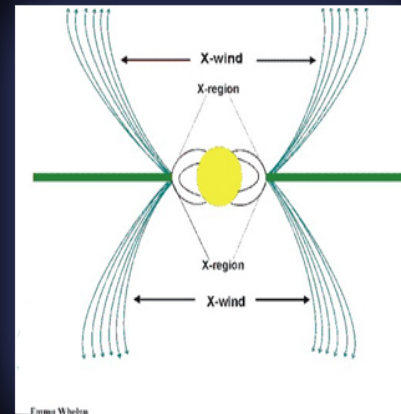
The launching and collimation of jets

MHD models predict that jets extract excess angular momentum from the star/disk system

D-wind



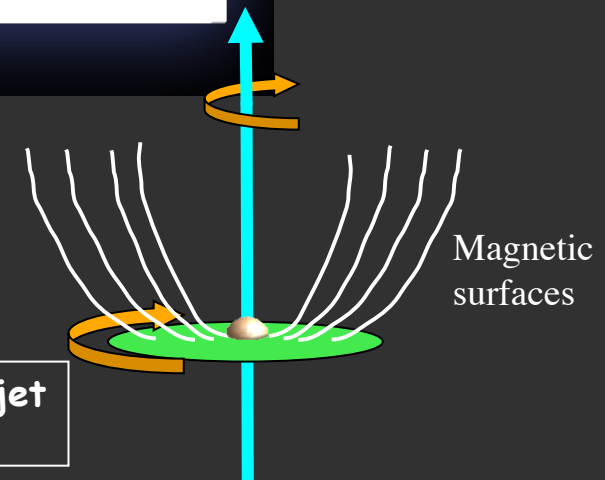
X-wind



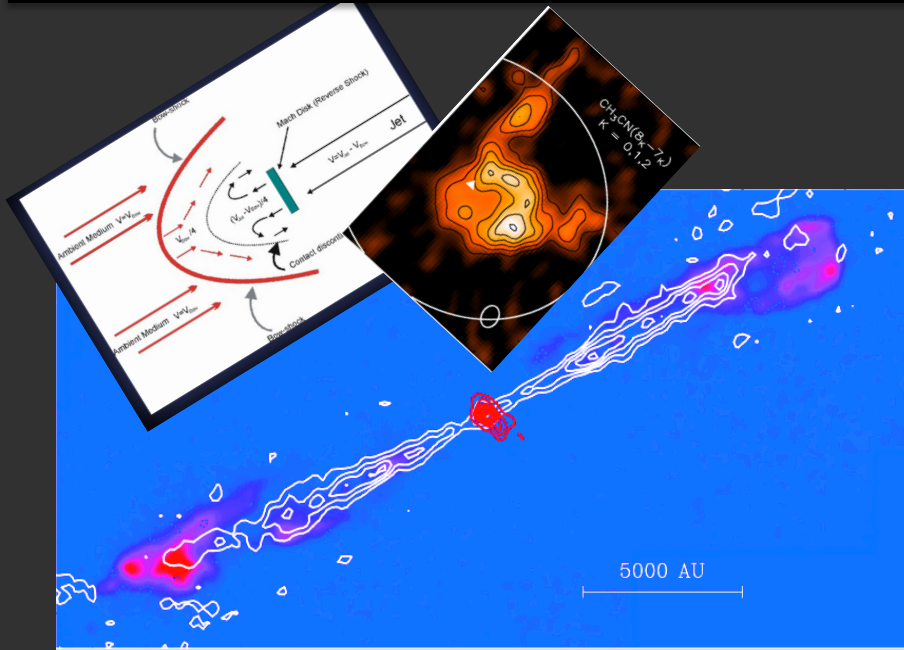
Origin of the jet in the disk plane: 0.03 to a few AU
Acceleration and collimation of jet: within 20-100 AU above the disk

PPVI: Li et al.; Frank et al.

Rotation is transferred to the jet from the disk



Ingredients for the Sun-like star formation recipe



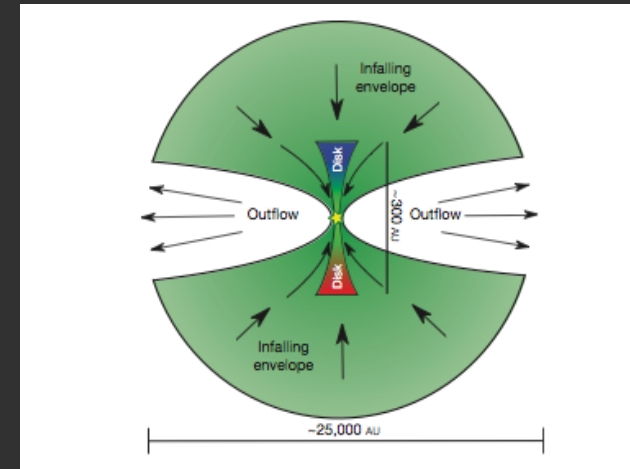
Gueth & Guilloteau (1992), Codella et al. (2009)

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

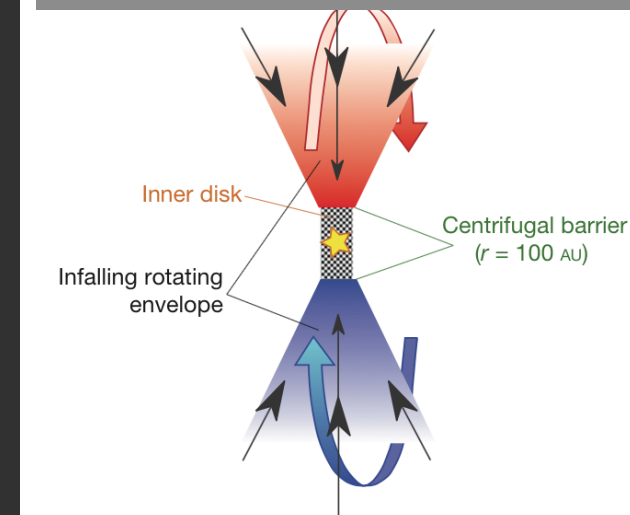
High-T chemistry: endothermic reactions

Ice sublimation & grain disruption

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

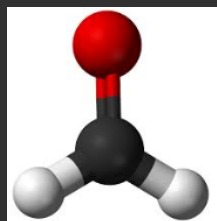


accretion shock
at disk-envelope interface

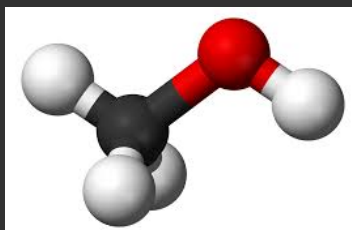


Lee et al. 2014, Sakai et al. 2014

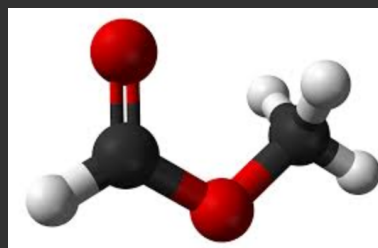
The interstellar complex organic molecules (iCOMs) zoo



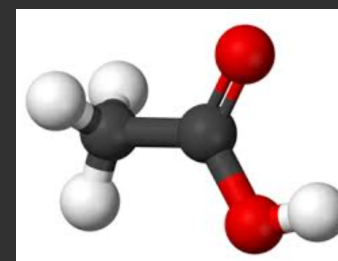
formaldehyde



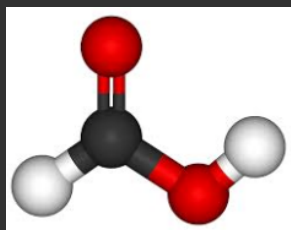
methanol



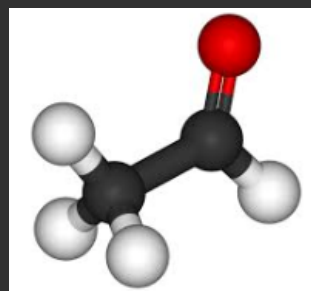
methyl formate



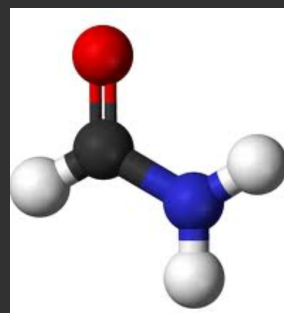
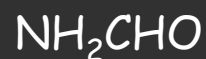
acetic acid



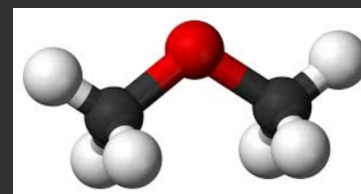
formic acid



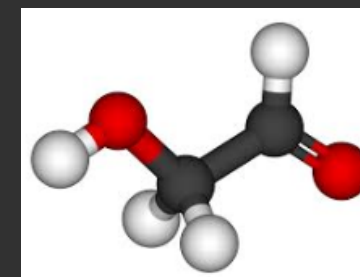
acetaldehyde



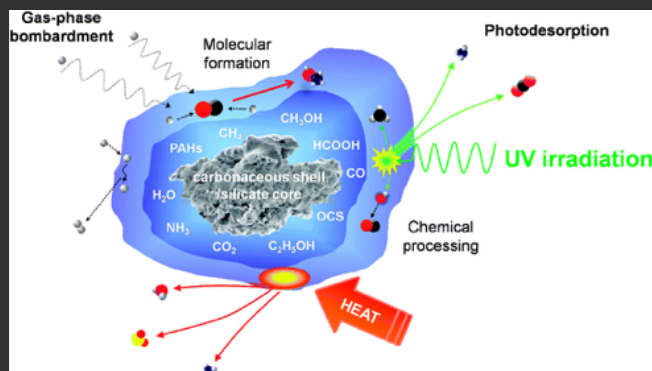
formamide



dimethyl ether



glycoaldehyde

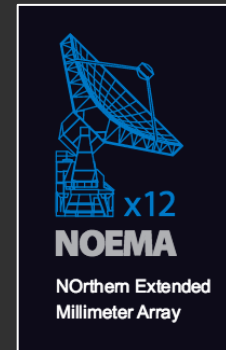
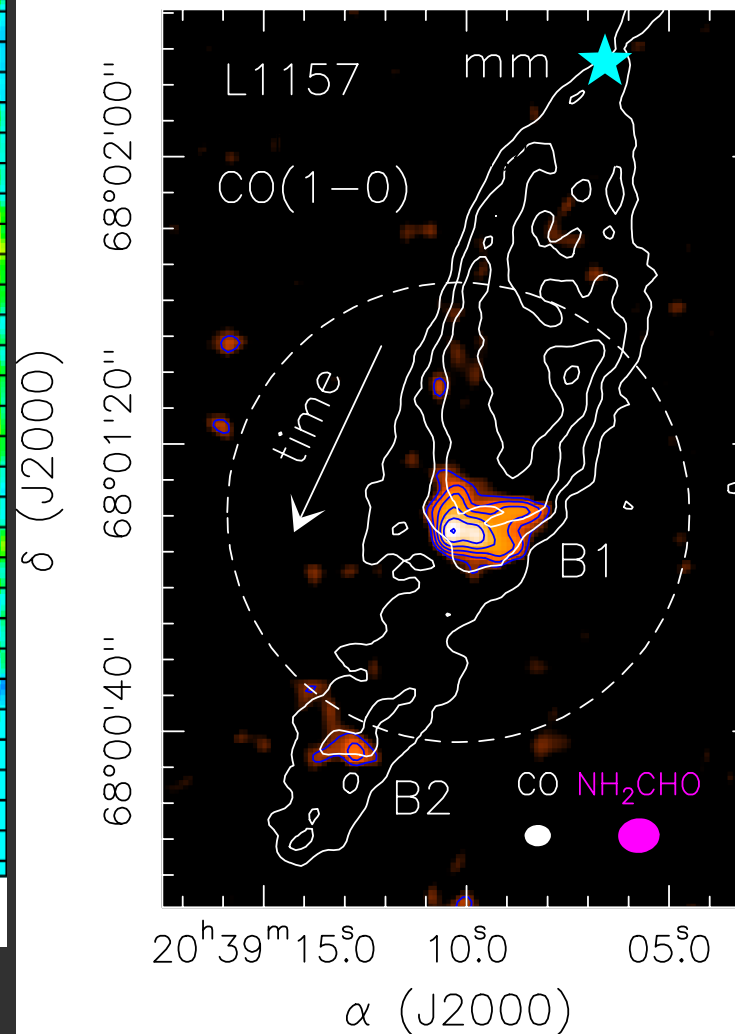
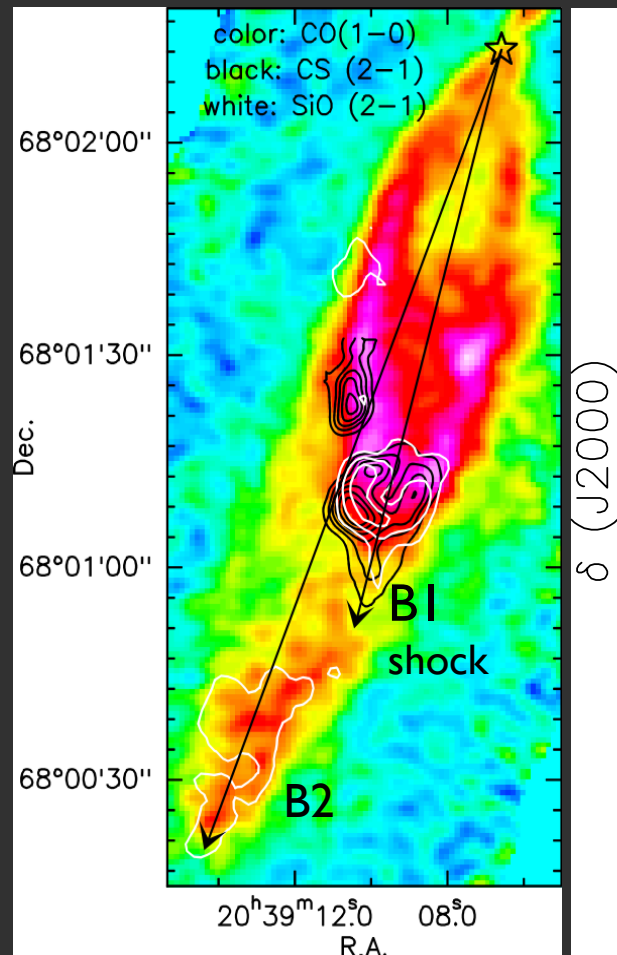


Gas phase or
surface chemistry ?

*Outflows/Jets shocks as chemical laboratories
(as seen by NOEMA)*



NH_2CHO (colour scale) detected towards the B1 bow structure....



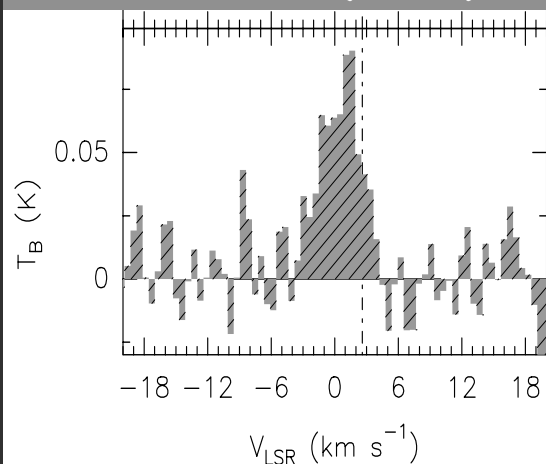
Podio et al. (2016)
Codella et al. (2017a)
Feng et al. (2017)

.....Surprise surprise....

NH_2CHO looks anticorrelated wrt CH_3CHO

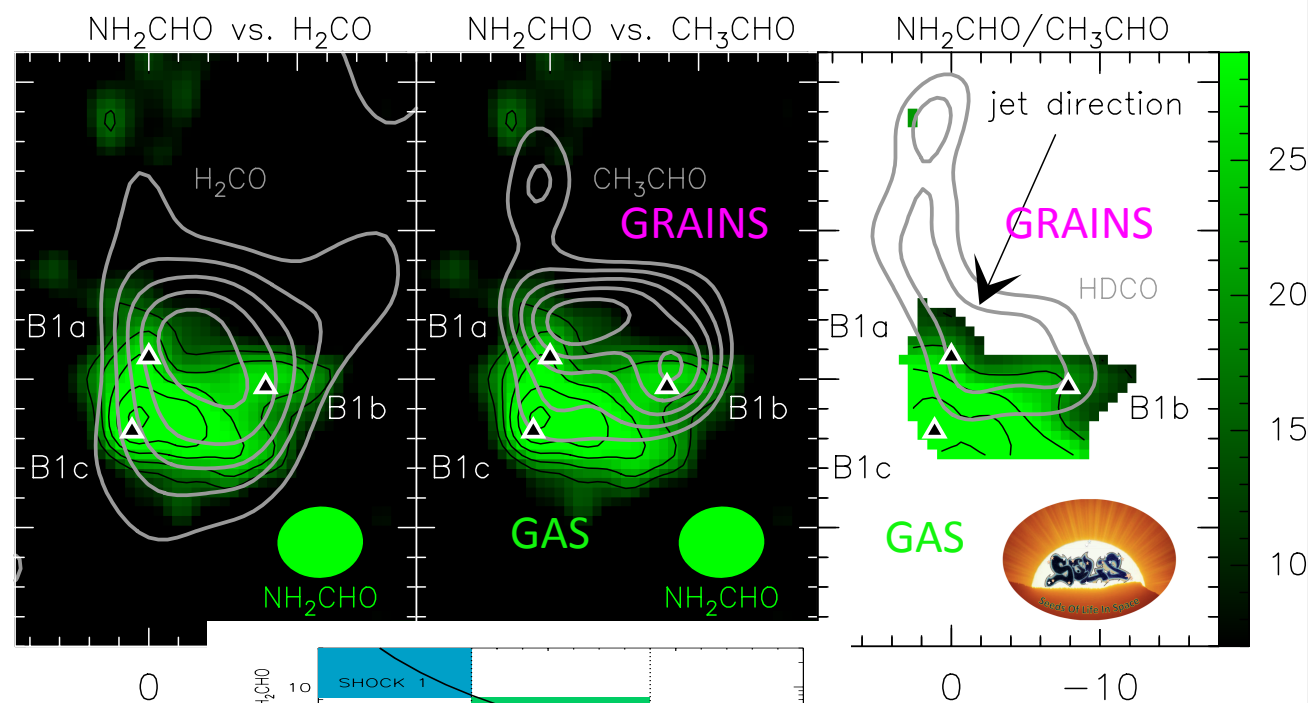


Codella et al. (2017a)

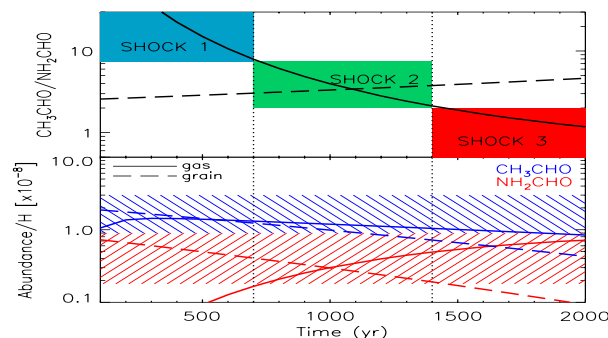


Dec.

-10



The smoking gun
of gas-phase at work



*How ALMA can reveal a pristine jet/disk
protostellar system*

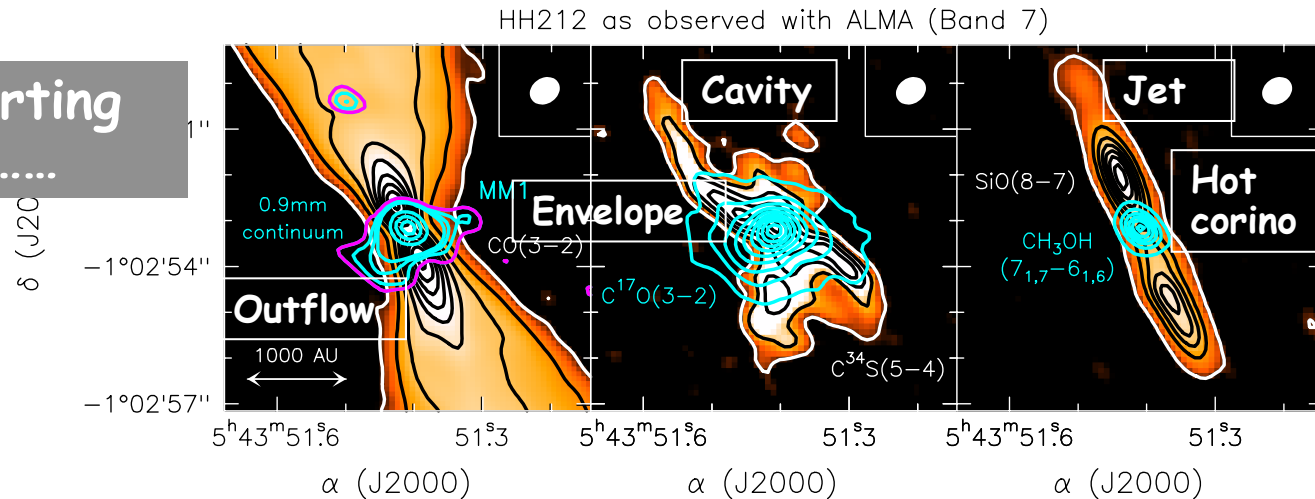




The inner 50 AU of a Sun-like protostar, as seen by ALMA



The starting point.....



All the ingredients of the Sun-like star formation recipe imaged with a single spectral set-up:

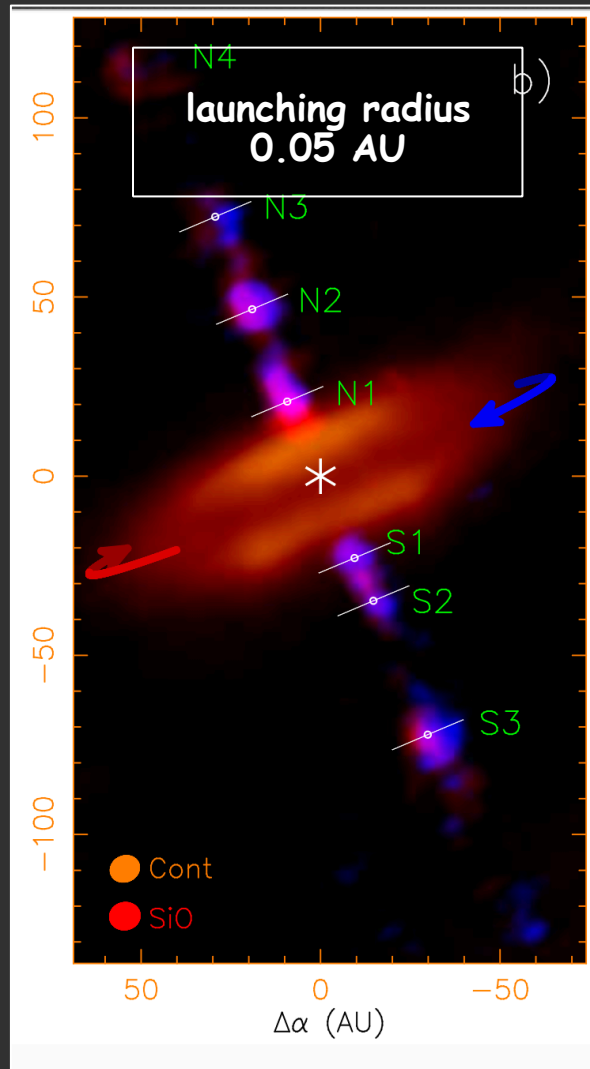
1. The flattened (dust & molecules) envelope
2. The hot-corino (iCOMs) heated by the protostar
3. The forming disk
4. The hot and fast collimated jet
5. The cold, slow, and extended swept-up outflow
6. The cavity as interface between outflow and static cloud

See
Bianchi et al.
POSTER !

Codella et al. (2014, 2016, 2017),
Podio et al. (2015), Leurini et al. (2016),
Bianchi et al. (2017), Tabone et al. (2017)

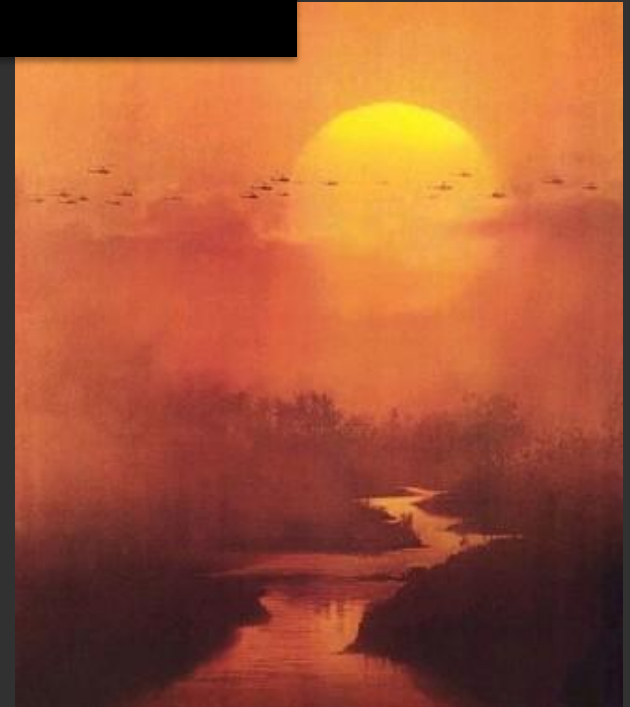


Upriver toward the launching radius

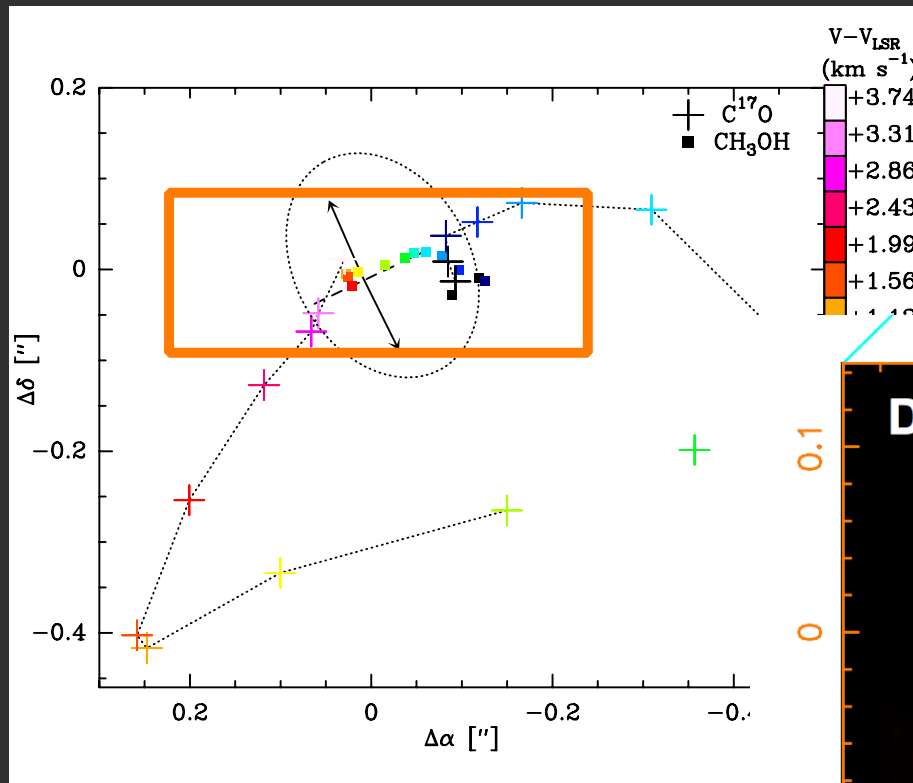


Lee et al. (2017ab)

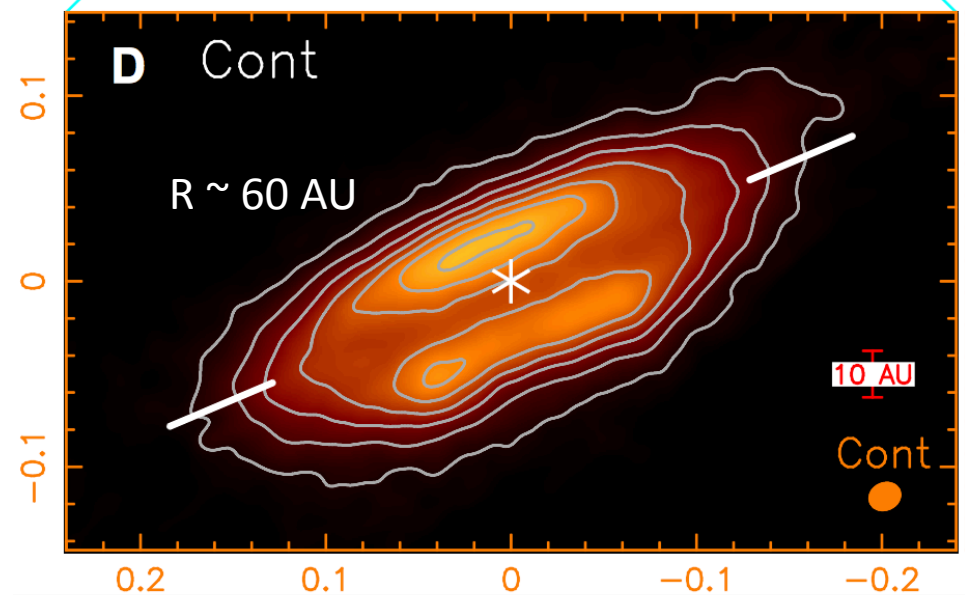
Where is the
disk wind ?



We need to explore the inner 50 AU....

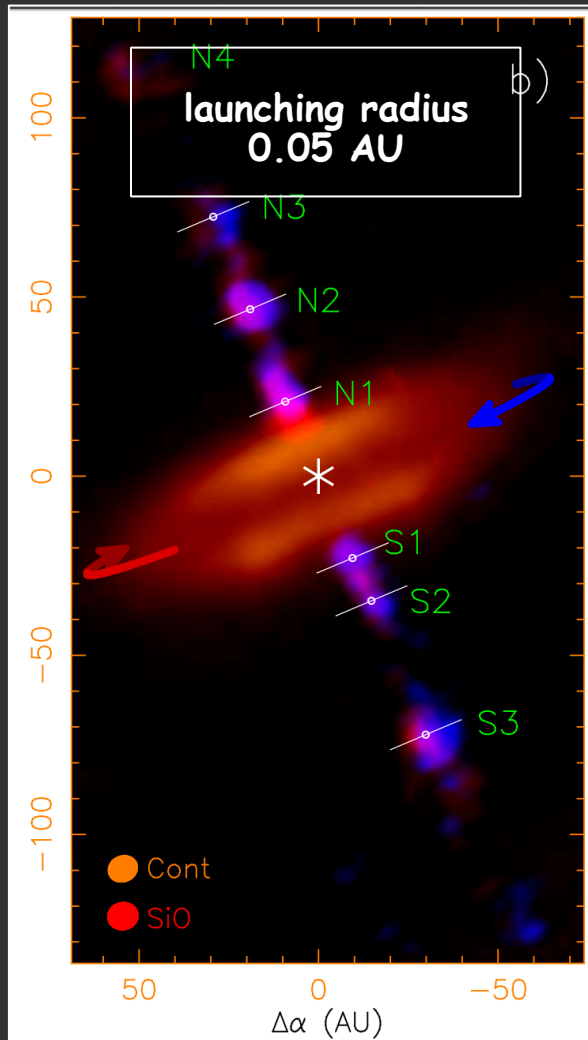


Leurini et al. (2016)

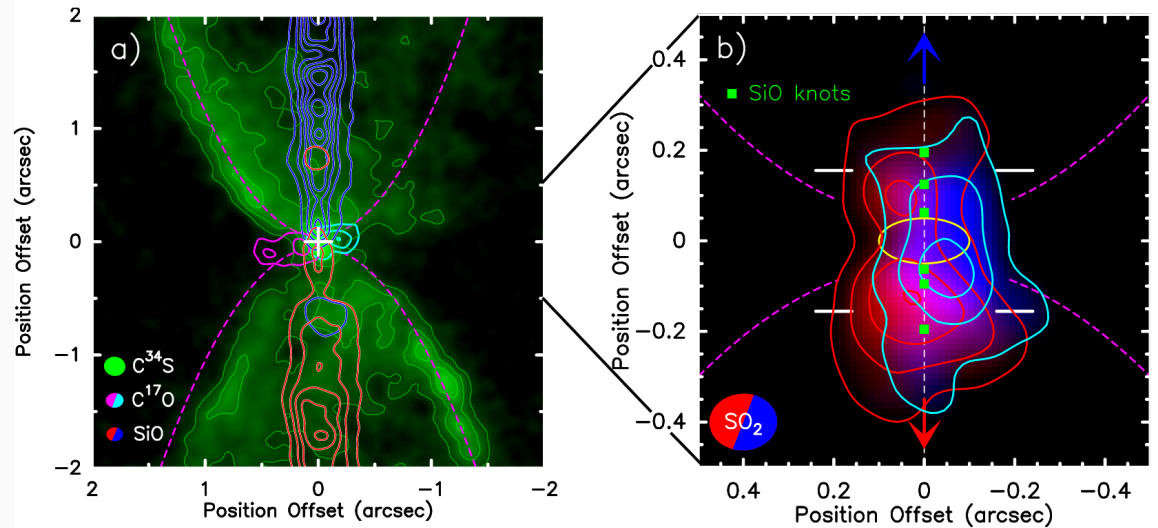


Lee et al. (2017)

Upriver toward the launching radius

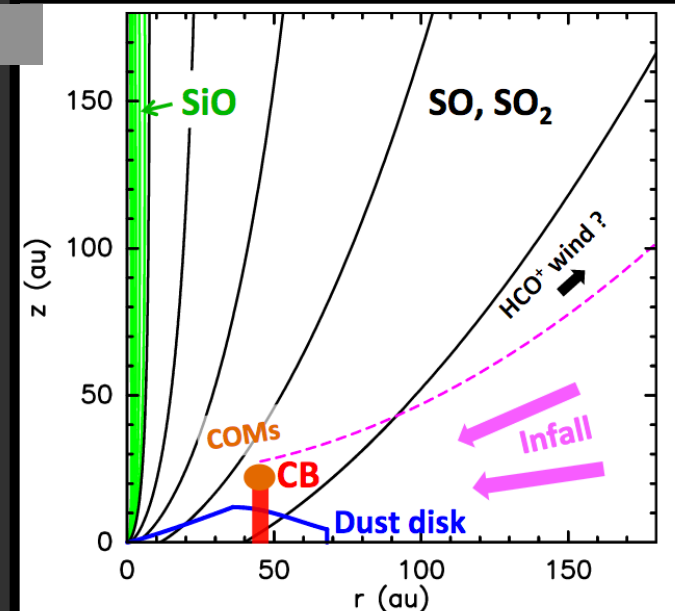


Lee et al. (2017ab)



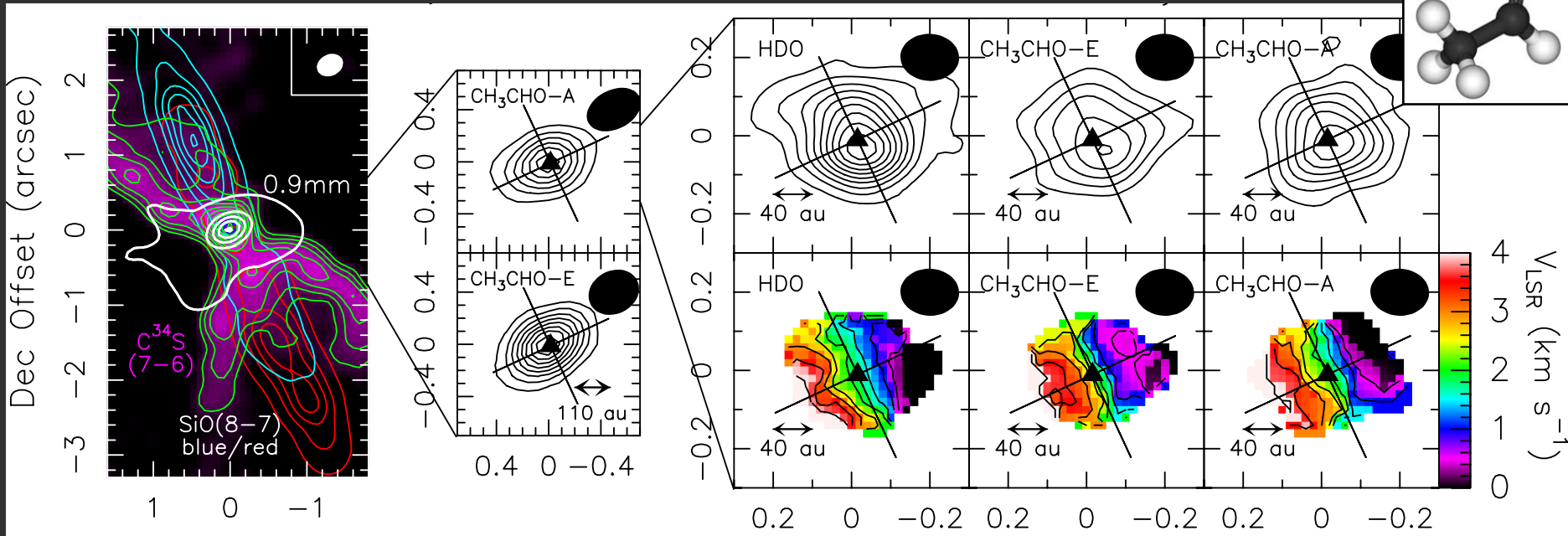
Tabone et al. (2017)

Rotating flow in
SO and SO₂



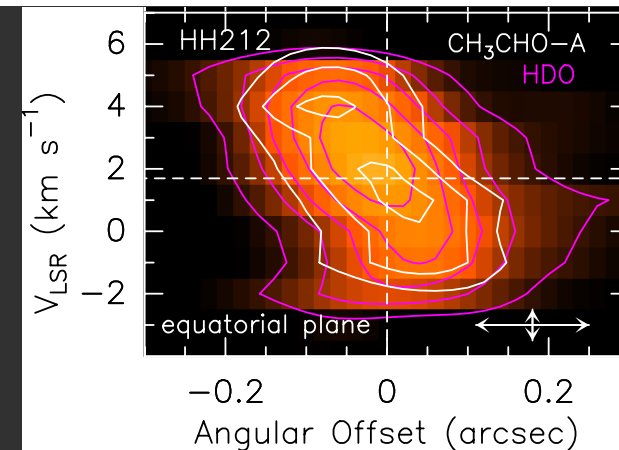
icOMs associated with

Emission related with the extended rotating disk

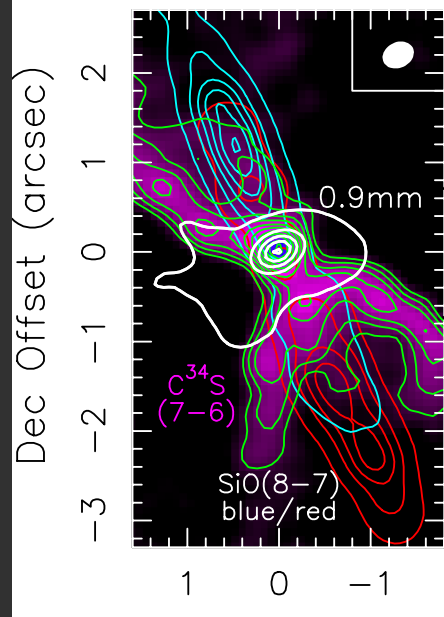
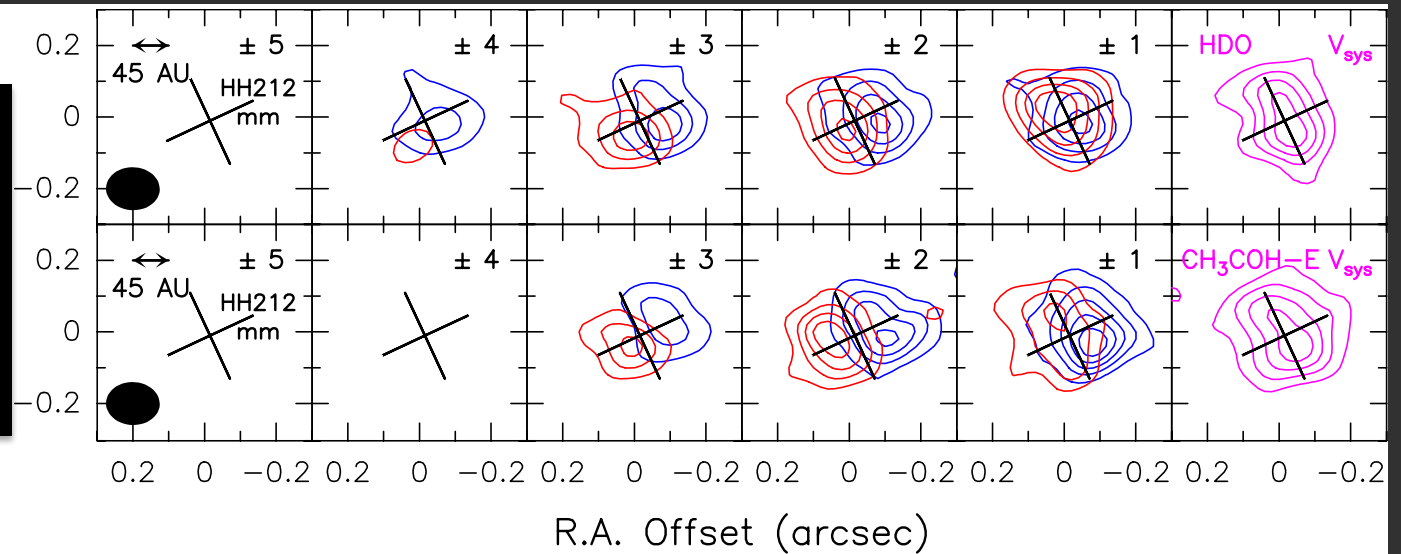


Codella et al. (2017b)
Lee et al. (2017)

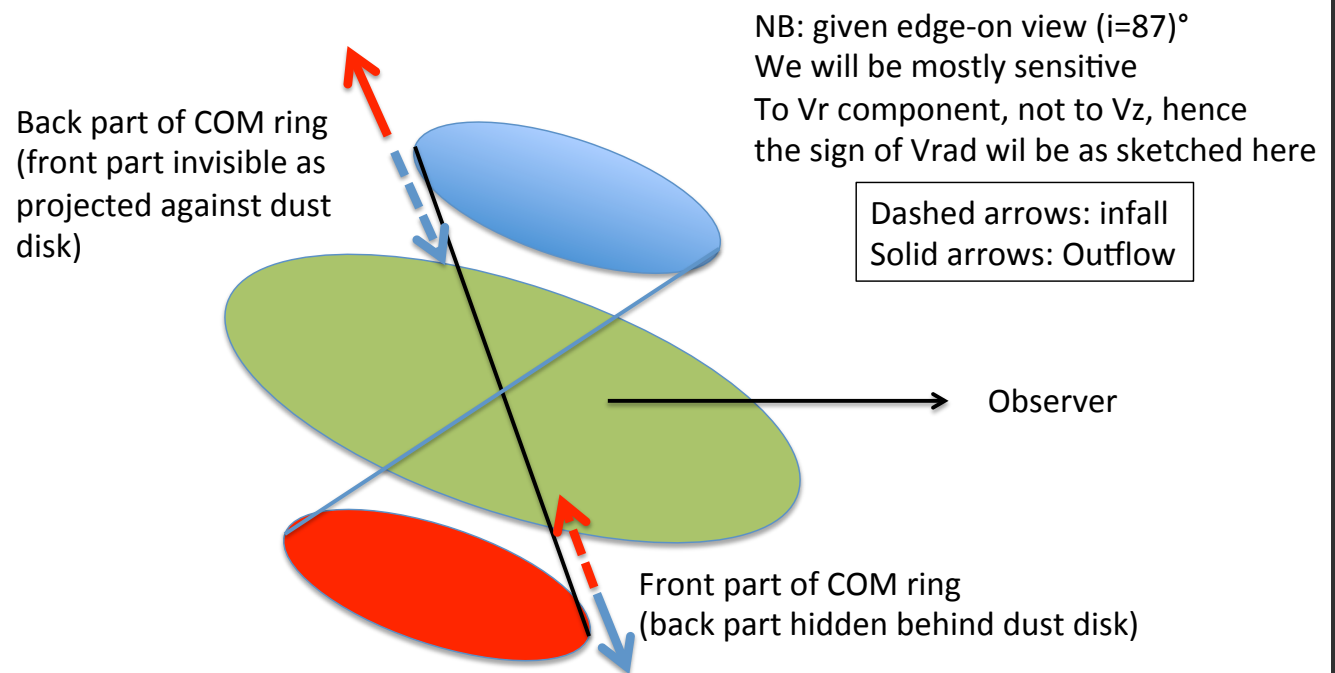
Rotating structure extending up to
50 AU from the jet axis and
elongated by 90 AU along the jet



*iCOMs
associated
with ...*



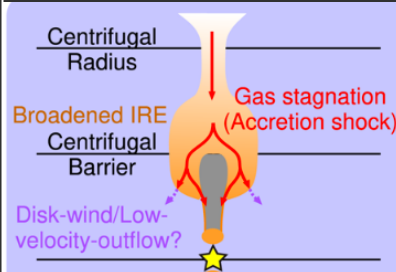
Codella et al. (2017b)
Lee et al. (2017)
Tabone et al. (2017)



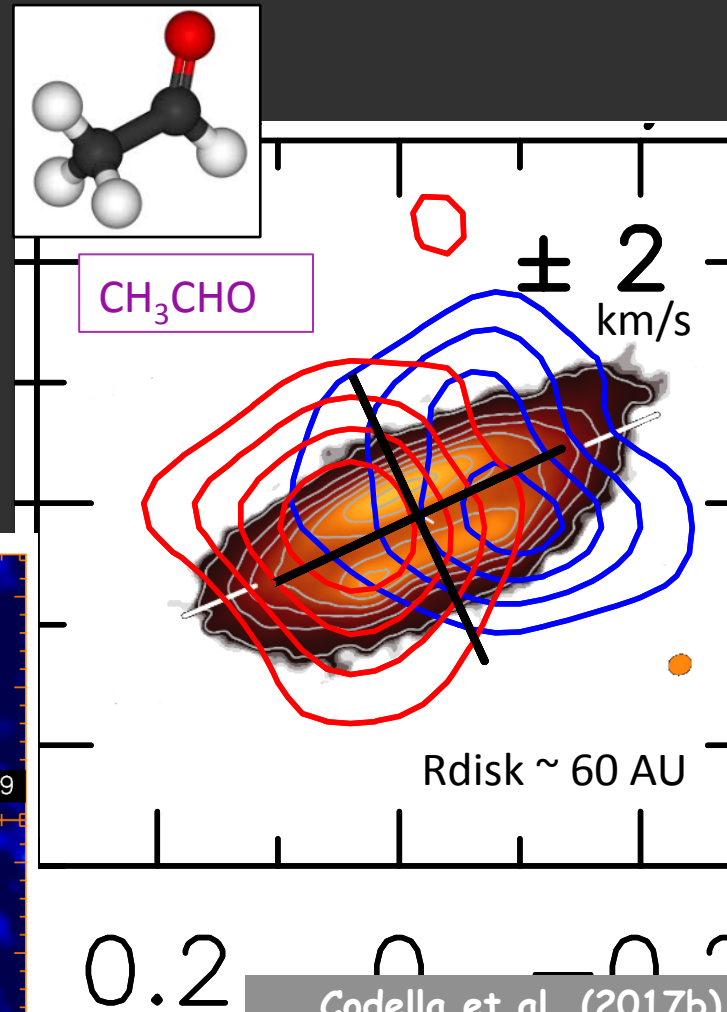
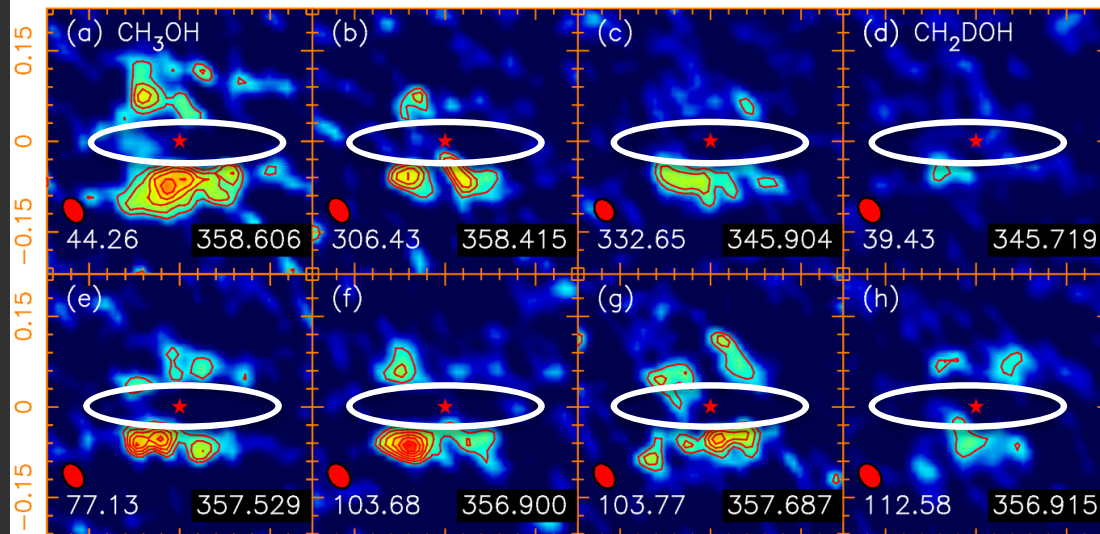
iCOMs associated with the disk

Emission related with the extended rotating disk

Gas launched by
the centrifugal
barrier ?
(Sakai et al. 2017)



Disk atmosphere ? (Lee et al. 2017)



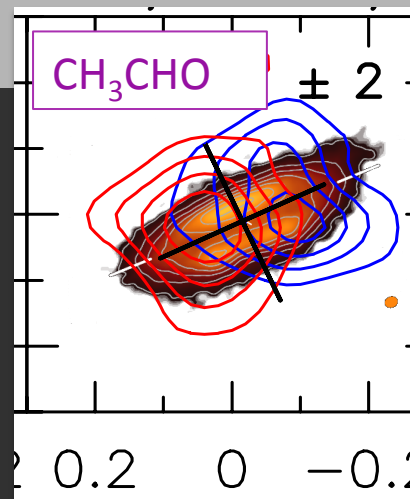
Codella et al. (2017b)
Lee et al. (2017)
Bianchi et al. (2017)

Conclusions

iCOMs ARE KEY TOOLS TO OBSERVE FUNDAMENTAL PROCESSES (ACCRETION, EJECTION) SCULPTING THE CRADLE WHERE A STAR (AND ITS PLANETARY SYSTEM) IS GOING TO FORM



*Multiple (excitation) components;
We need (unbiased) spectral
surveys;
(sub-mm)
Large Programs needed....*



*The use of interferometers is a must:
e.g. ALMA, NOEMA.*