



# *Beyond ALMA: SKA unveiling the gas composition of the midplane of protostellar disks on a Solar System scale*

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*On behalf of E. Bianchi, M. De Simone, L. Podio, C. Ceccarelli,  
C.-F. Lee, C.J. Chandler, B. Svoboda*

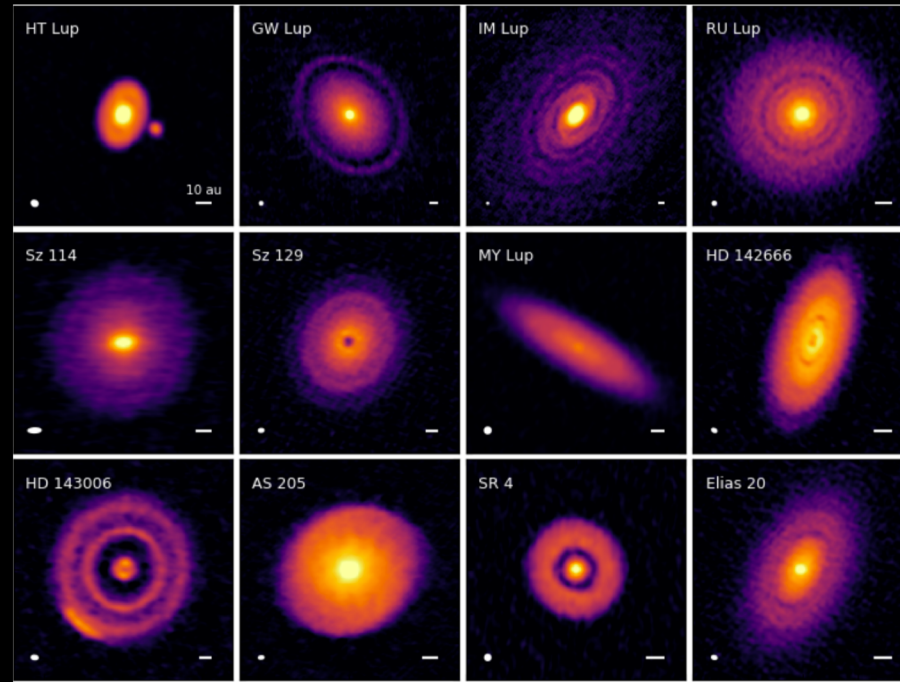


**observations**

**fundings**

# PLANET FORMATION STARTS EARLY

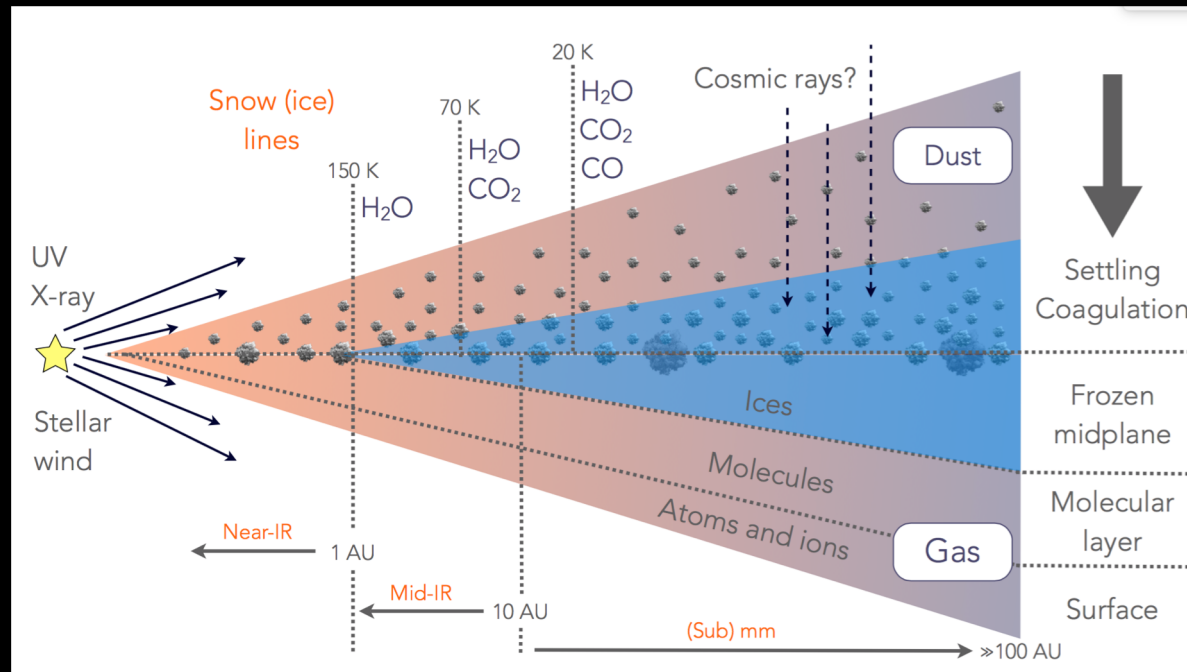
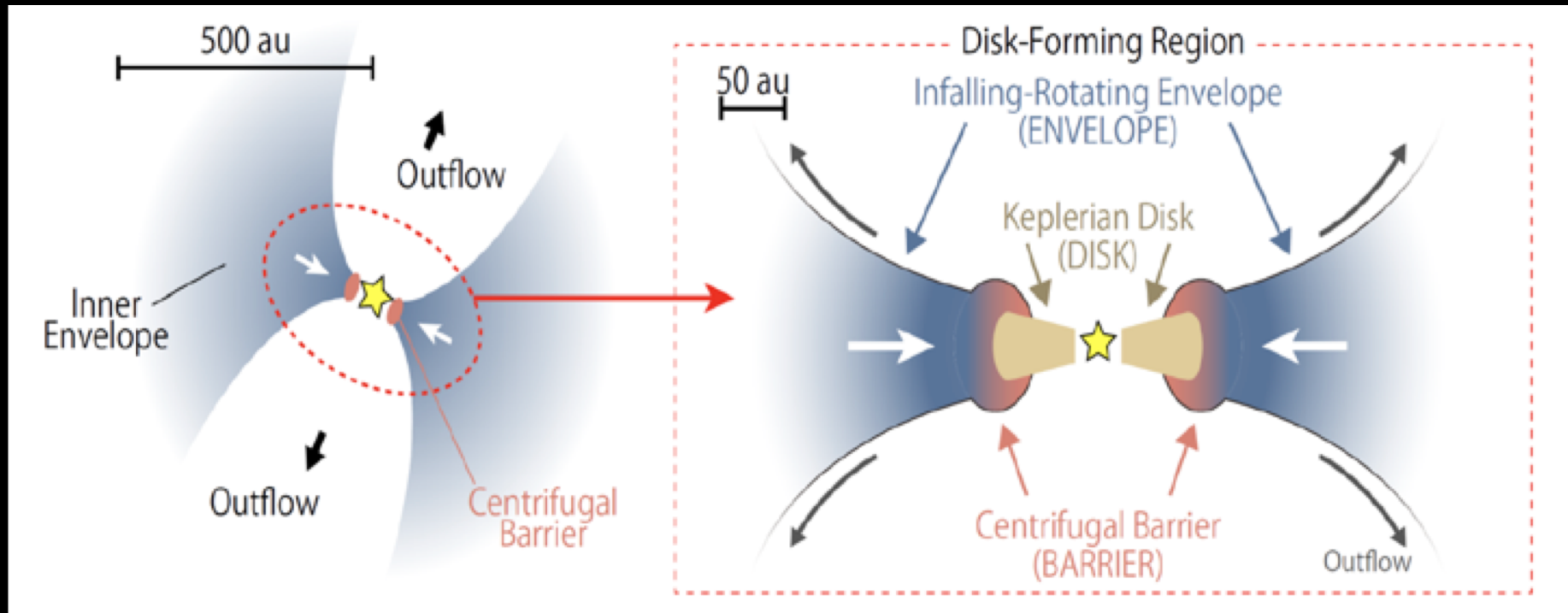
Rings and gaps in disks  
of less than 0.5 Myr



Segura-Cox et al. 2020; Tychoniec et al. 2021; DSHARP

All disks show RINGS and GAPS if observed at high resolution

*THE MISSING LINK:  
CHEMISTRY OF PLANET FORMING DISKS*





# GENESIS - SKA

PI C. Codella

## FOUR PILLARS



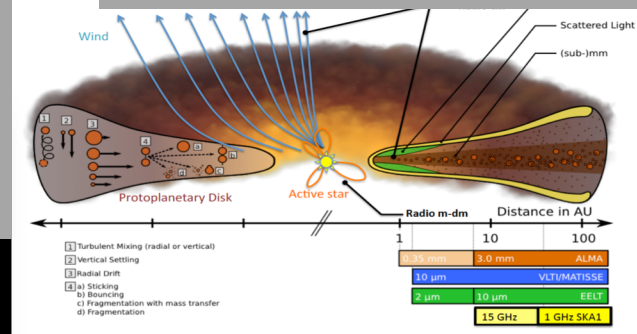
1. PLANET FORMATION:  
Models, simulations, &  
observations

2. VOLATILES EVOLUTION:  
Complex Organics as the  
building blocks of life  
(quantum-mechanical  
computations of gas reactions)

3. LABORATORY  
EXPERIMENTS

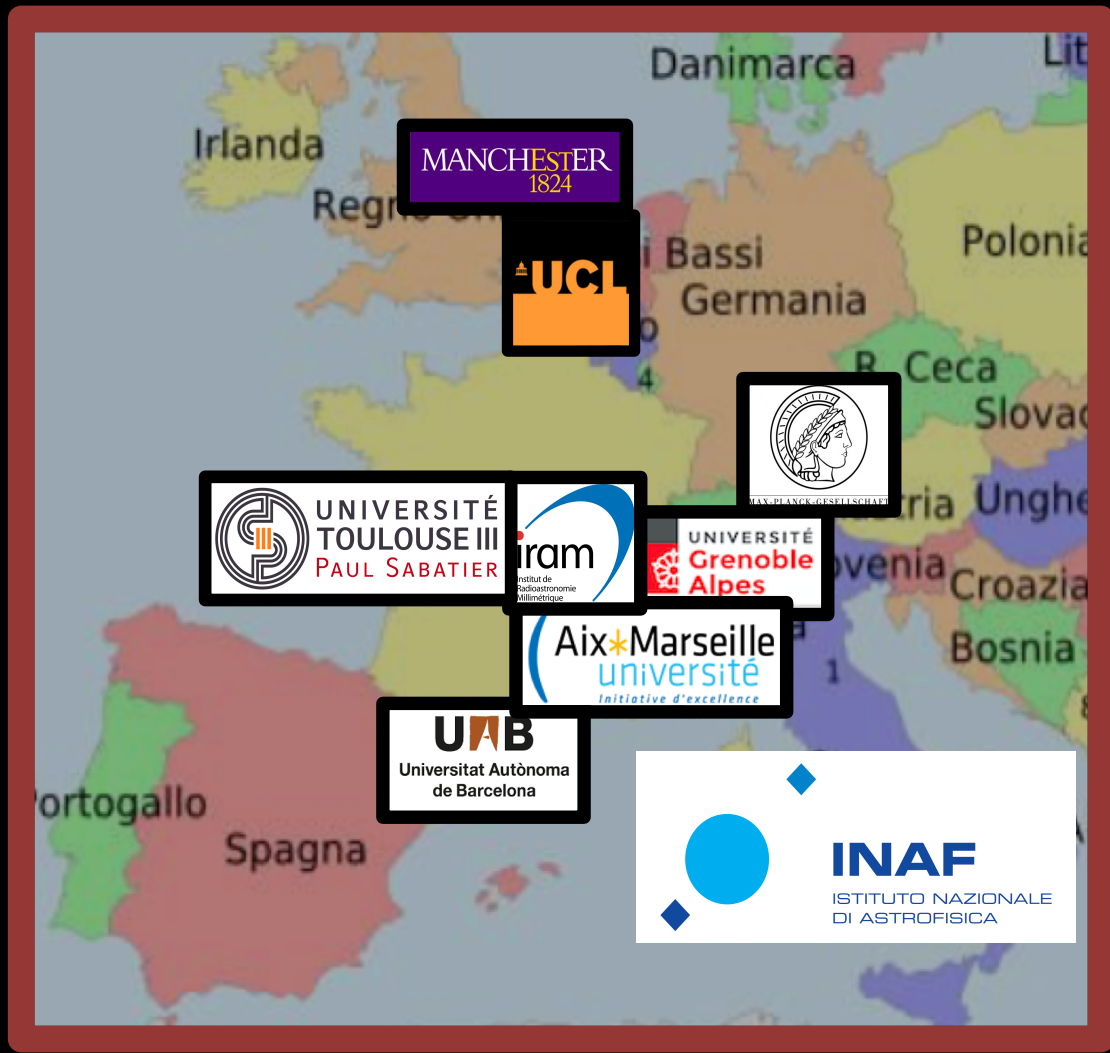
4. COMMUNICATION AND  
DISSEMINATION

[www.genesis.inaf.it](http://www.genesis.inaf.it)



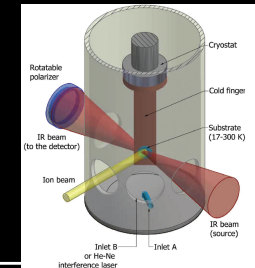
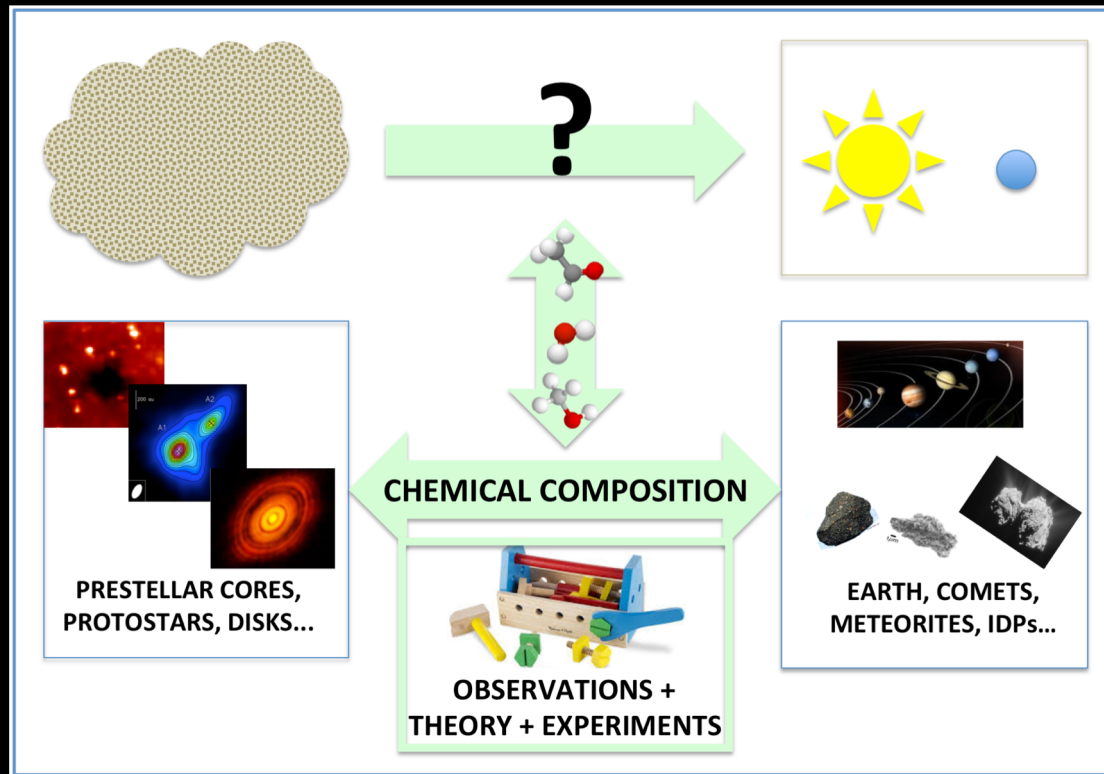


# AstroChemical Origins (ACO) H2020 EU Innovative Training Network

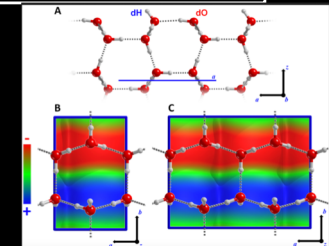
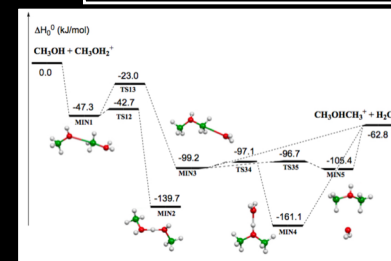


# Scientific goals

**USE THE CHEMICAL COMPOSITION AS A TOOL TO RECONSTRUCT THE EARLY PHASES OF THE SOLAR SYSTEM FORMATION**



- (i) laboratory outputs,
- (ii) surface simulations,
- (iii) quantum-mechanical computations



**→ OBSERVE THE CHEMICAL PROXIES LINKED TO THE SOLAR SYSTEM PRIMITIVE OBJECTS TOWARDS PRESTELLAR CORES, PROTOSTARS AND PROTOPLANETARY DISKS**

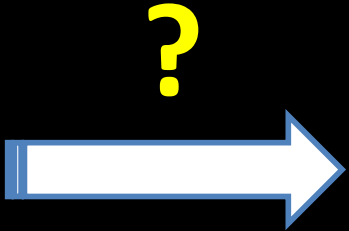
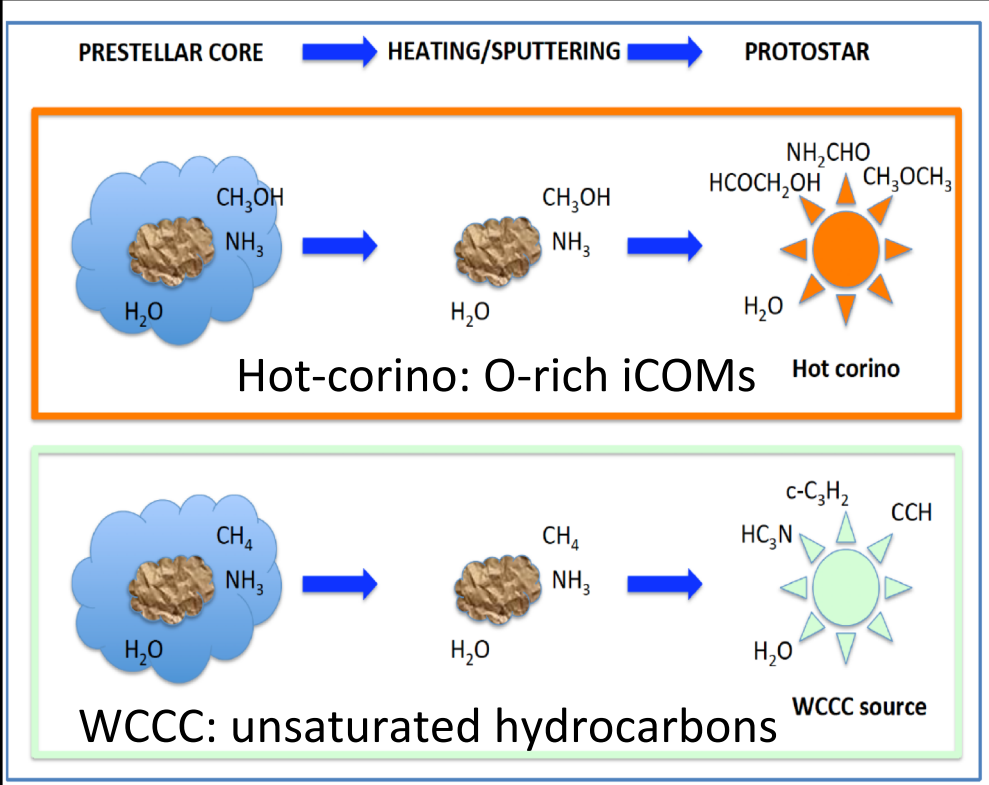
**→ AND INTERPRET THEM VIA ASTROCHEMICAL MODELS**

*BACK TO CM*  
*[from (sub-)mm]*



# QUESTION 1: Is every Sun-like protostar going through a hot corino phase ?

Compact (< 100 au), hot (> 100 K), dense (> 10<sup>7</sup> cm<sup>-3</sup>) regions enriched in iCOMs (e.g. Ceccarelli+ 2004, 2007)



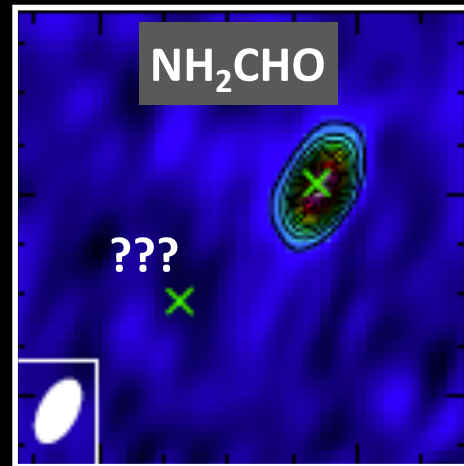
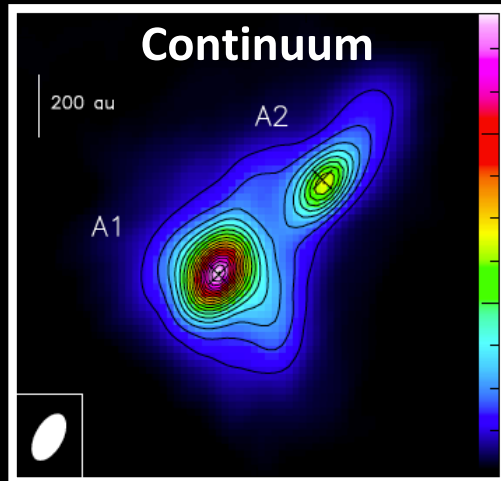
Tracing ice mantle history in Solar-type protostars

FAUST  
(Fifty AU Study of Sun-like protostellar systems)  
ALMA Large Program



# *ACO: ALMA and beyond: Hot-corinos at cm-wavelengths*

NGC1333-IRAS4A



López-Sepulcre+ 2017;

With ALMA:  
Hot corino in one of the  
two components

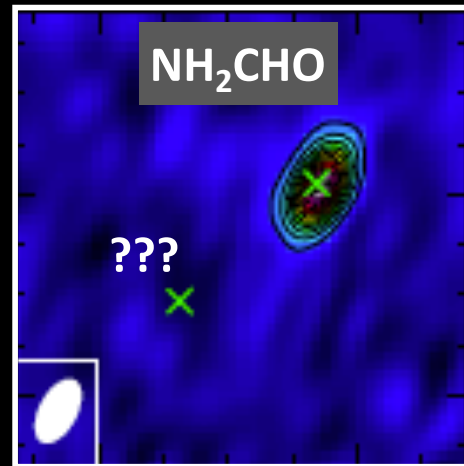
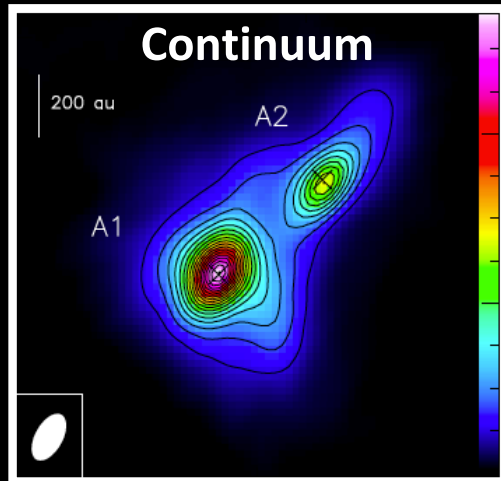
iCOMs abundances at  
mm-wavelengths can be  
underestimated

# ACO: ALMA and beyond: Hot-corinos at cm-wavelengths

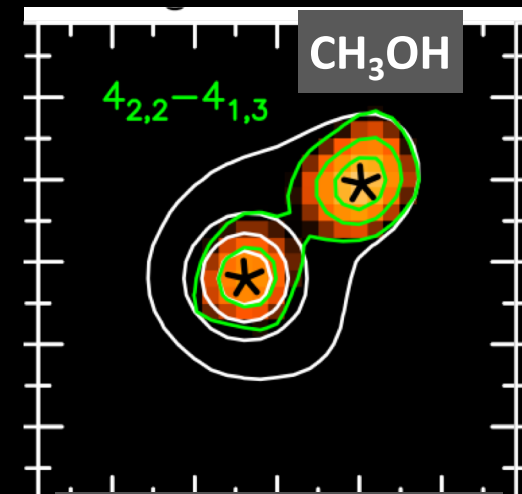


NGC1333-IRAS4A

See the talk by  
M. De Simone !



López-Sepulcre+ 2017;



De Simone+ 2020

With ALMA:  
Hot corino in one of the  
two components

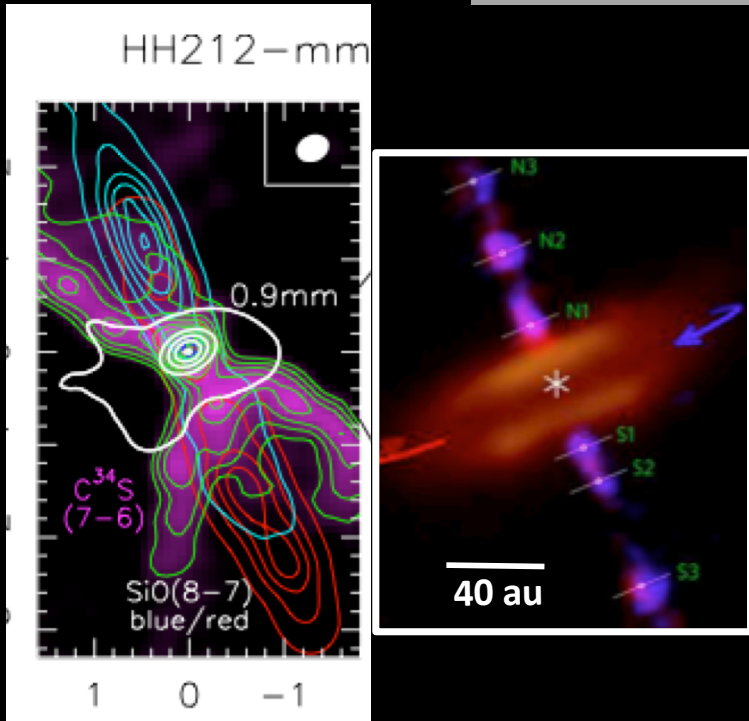
With VLA:  
Both IRAS4A1 and IRAS 4A2  
have a hot corino !

iCOMs abundances at  
mm-wavelengths can be  
underestimated

Food for SKA  
(WG Cradle of Life)

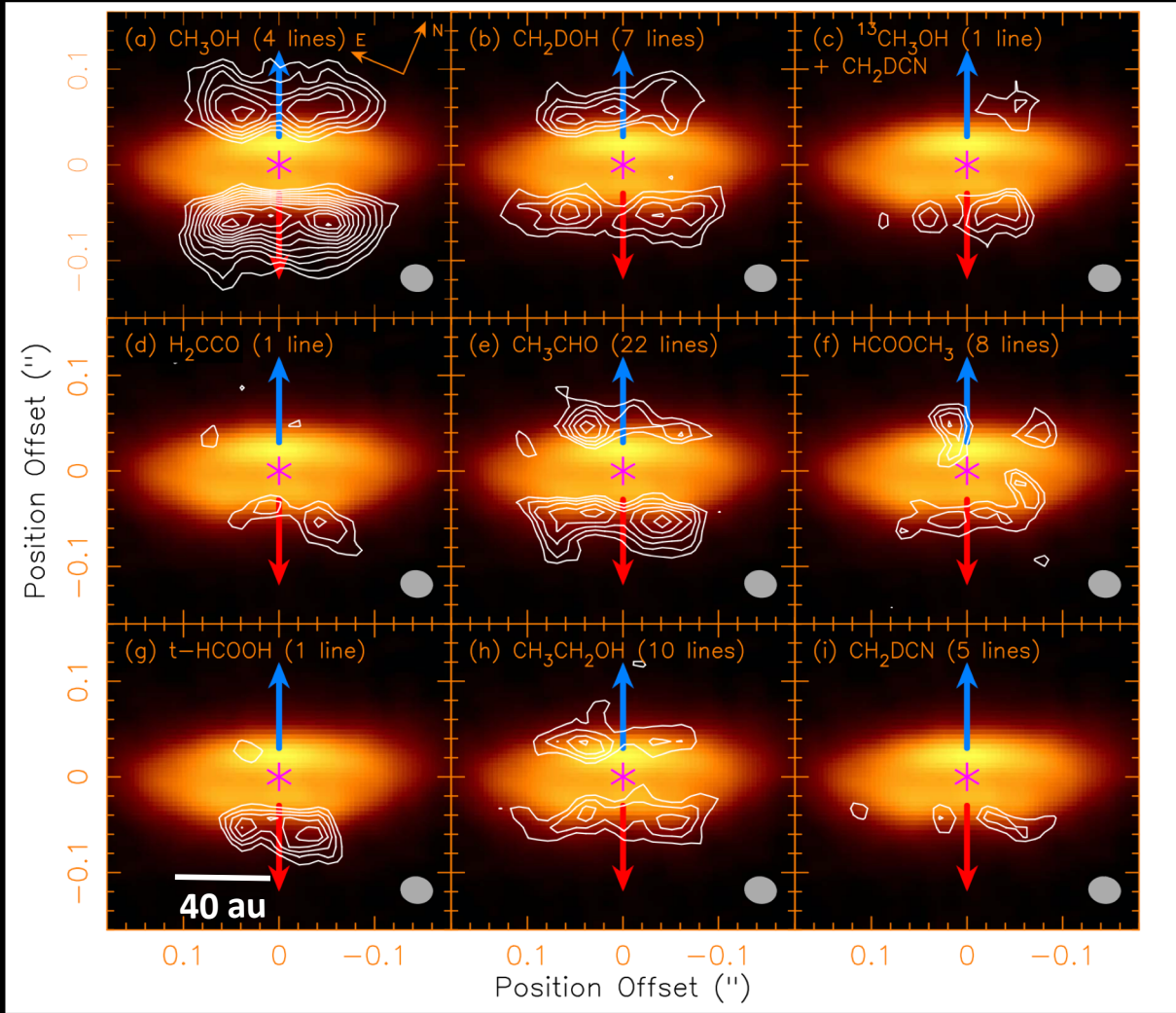


**QUESTION 2:**  
 What do we see if we image a jet/disk system down to a 10 au scale?



Lee et al. (2017, 2019)  
 Codella et al. (2014, 2018, 2019b)

**Chemically rich  
 disk rings**



Lee et al. (2019)

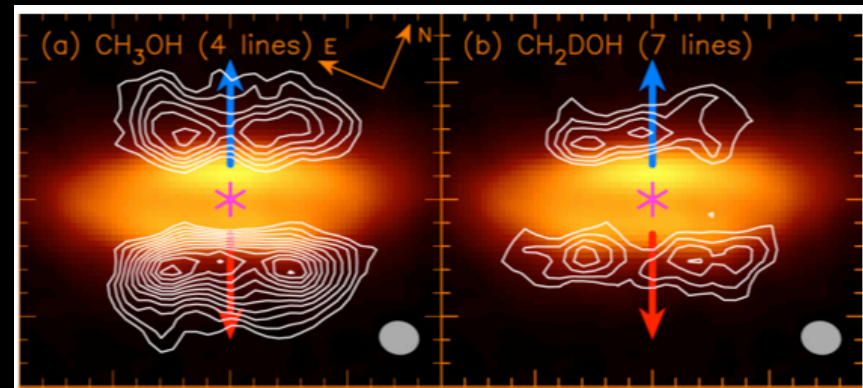
# *iCOMs associated with the disk*

Emission related with the extended rotating disk

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

Disk atmosphere ?

The disk midplane is optically thick in continuum and show no methanol (iCOMs) emission: lower abundance or opacity effect ?



Need (again) for cm-observations. In this case we need an angular resolution of 10 au.....

# Protoplanetary disks:

The disk midplane is optically thick in continuum and show No iCOMs emission: lower abundance or opacity effect ?

We need VLA observations at cm to probe the INNER MOLECULAR RESERVOIR of YOUNG DISKS



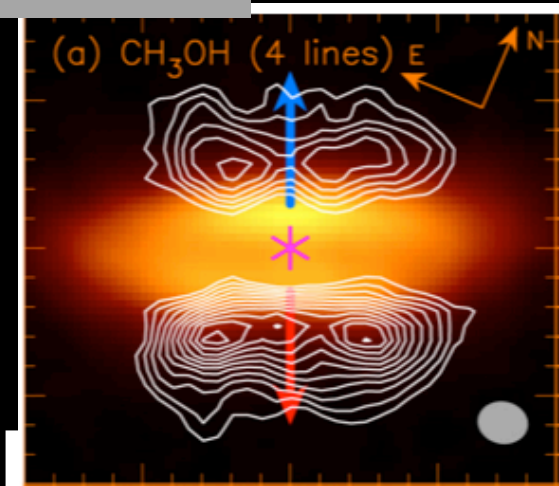
See the talk by L. Podio !

Food for SKA (WG Cradle of Life)

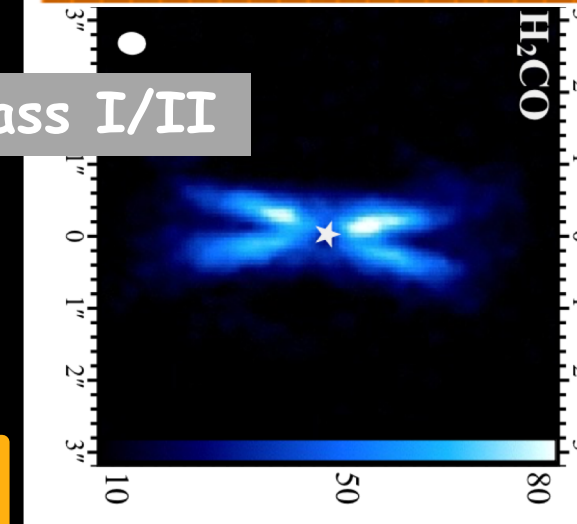


Class 0

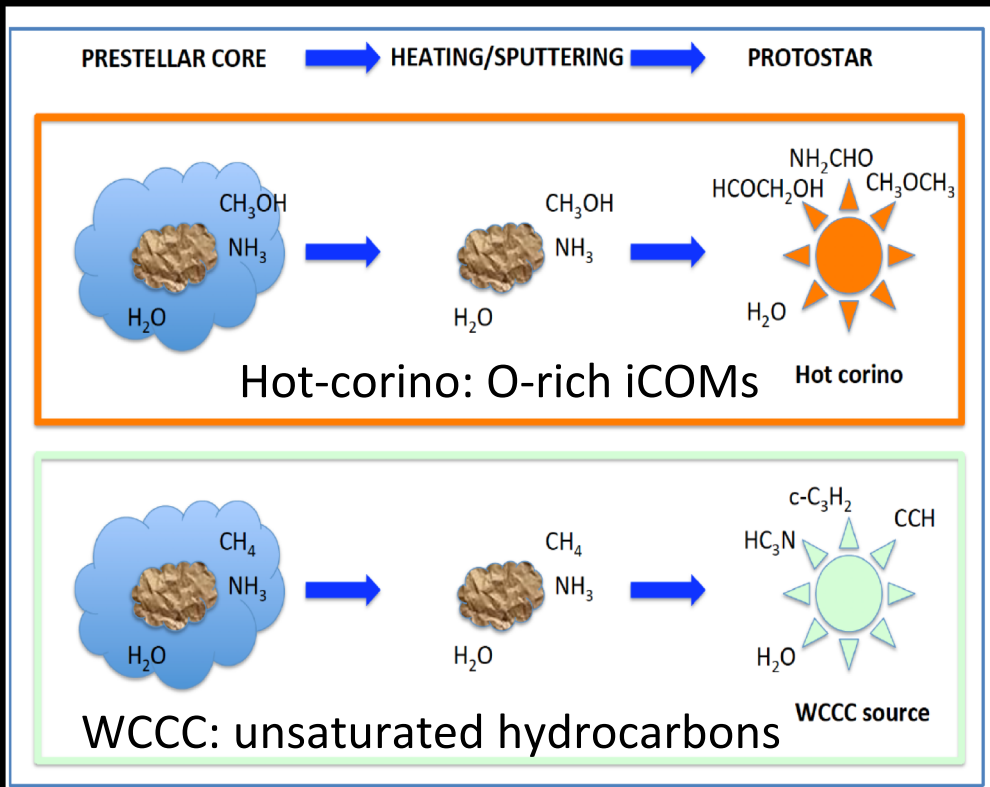
Lee+ 2019  
Codella+ 2019



Class I/II

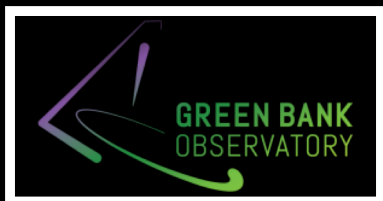


Podio+ 2020



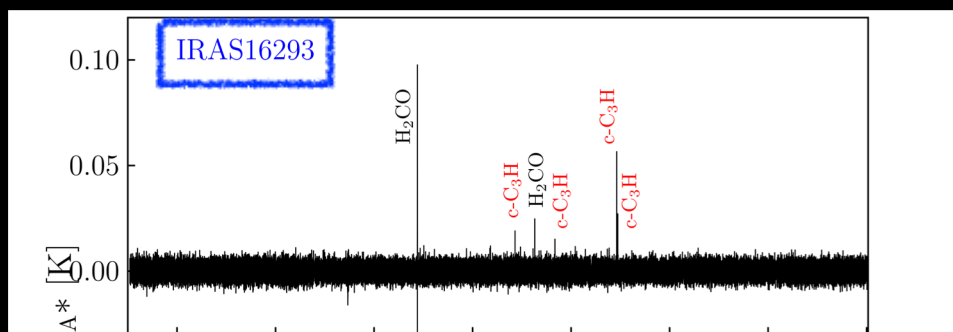
Tracing ice mantle history in Solar-type protostars

# Carbon chains hunt with GBT!

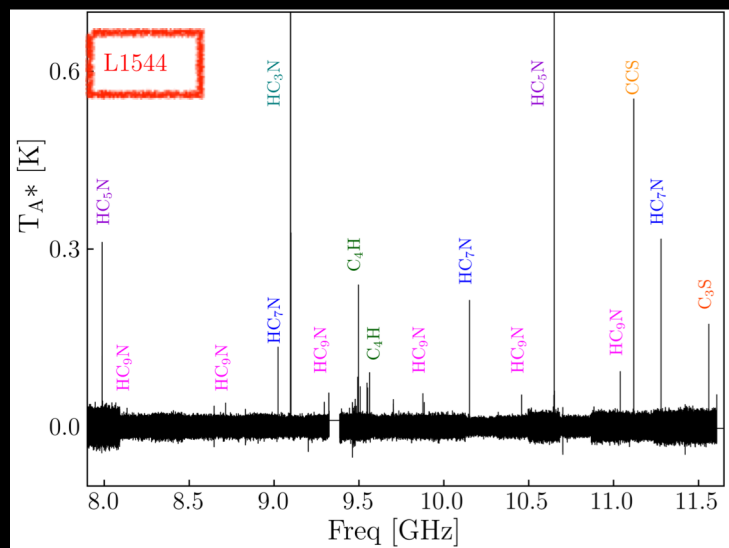


## GBT Pilot Project

See the talk by  
E. Bianchi !



Hot corino prototype IRAS16293 B  
 $c-C_3H$  envelope / parental cloud



## Prestellar prototype L1544

$c-C_3H$ ,  $C_4H$ ,  $C_6H$ ,  
 $HC_3N$ ,  $HC_5N$ ,  $HC_7N$ ,  $HC_9N$ ,  
 $CCS$ ,  $C_3S$

# SKA User Case

Food for SKA  
(WG Cradle of Life)



See the talk by  
E. Bianchi !



## 1.1 PROJECT NAME

PROJECT DETAILS	
Title	<b>SKA unveiling heavy carbon chains chemistry in OMC-2, the closest analogue to our Sun's birth environment</b>
Principal Investigator	<b>Eleonora Bianchi</b>
Co-Authors	<b>Cradle Of Life Team</b>
Time Request	~ 1000 hours

FACILITY		Preconditions
	SKA1-LOW	
x	SKA1-MID	Band 5b frequency coverage in 2 windows 2.5 GHz broad (9 -11.5 GHz and 13-15.5 GHz) + four narrower zoom windows on selected lines. Some aspects would benefit from Band 5+.



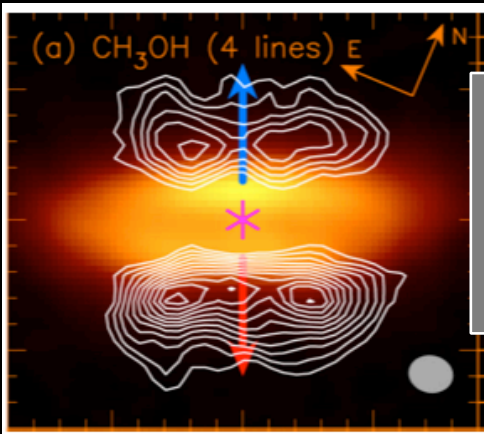
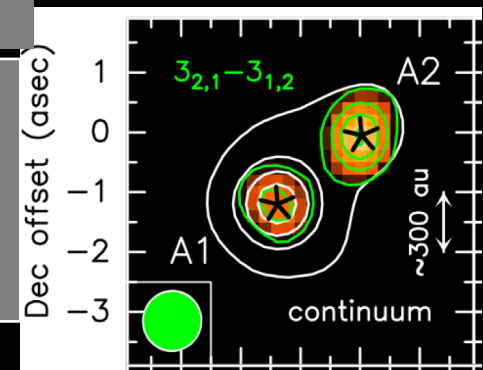


# Wrapping up.....



*Centimeter observations of hot corinos are CRUCIAL for their correct study*

*SKA will unveil the C-chemistry of Sun-like protostars on Solar System scale (by observing heavy C-species)*



*cm-surveys (SKA..) are a must to probe the chemical composition of the PROTOSTELLAR disk MIDPLANE*

*We need cm-observations to probe the INNER MOLECULAR RESERVOIR of Class I/II DISKS*

