



The Cradle of Life

*From protostellar disks to
planetary atmospheres with SKA:
Back to cm-wavelengths with
new perspectives*

C. Codella (INAF, OA Arcetri)



The Origin of the Solar System

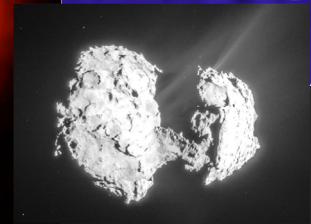
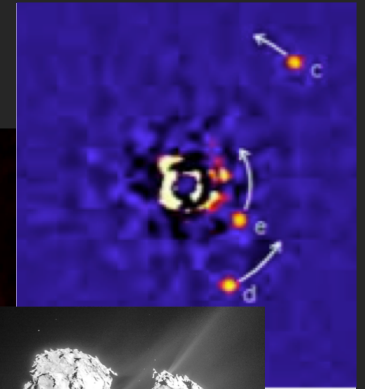
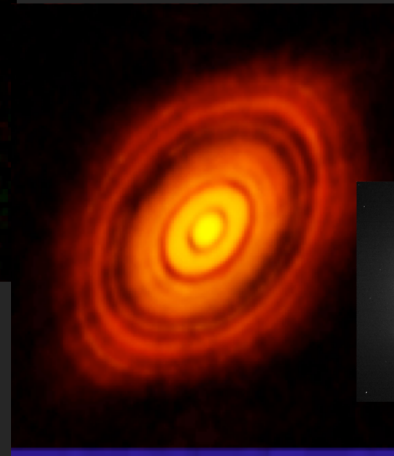
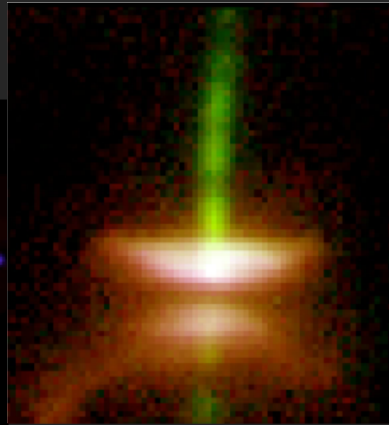
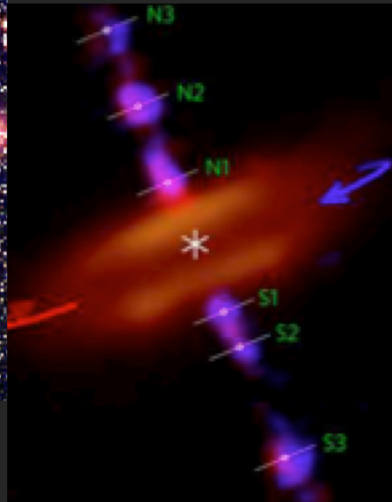
About 4.6 billions years ago, a small dense cloud of our Galaxy became the Solar System



What happened to that primordial cloud?



The formation of a Sun-like star



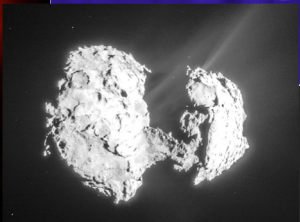
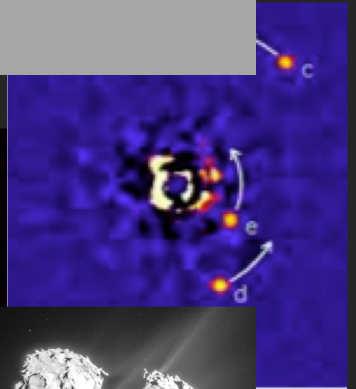
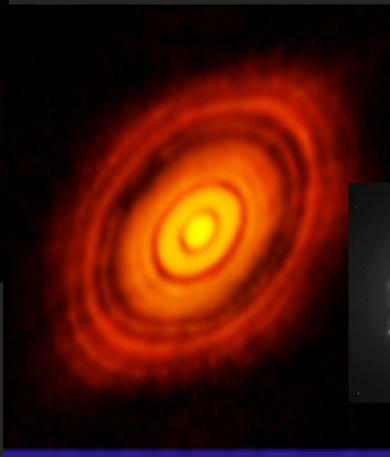
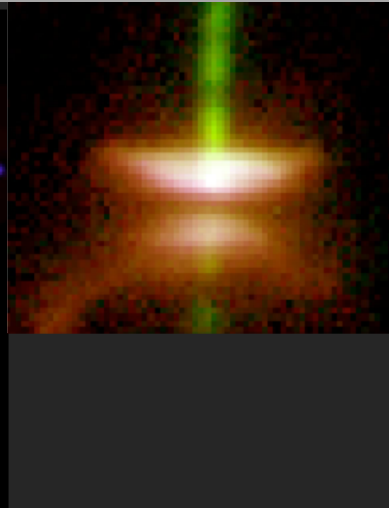
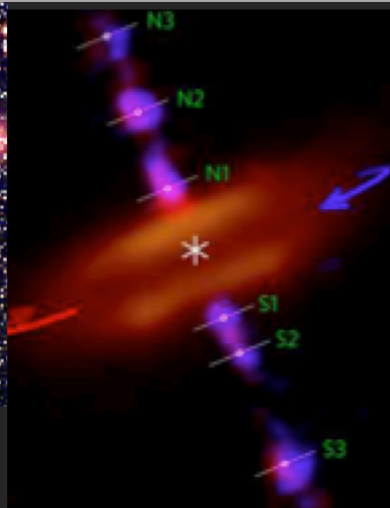
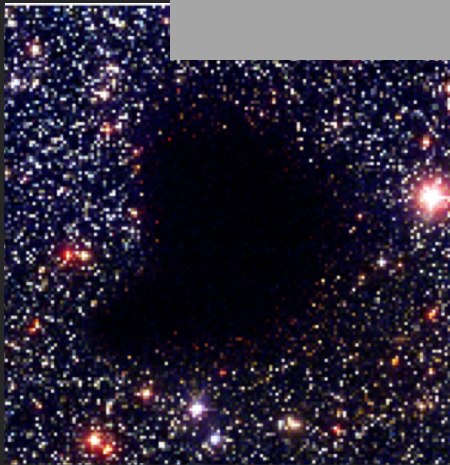
Time



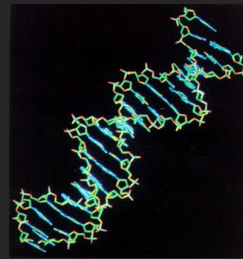
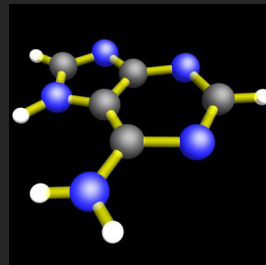
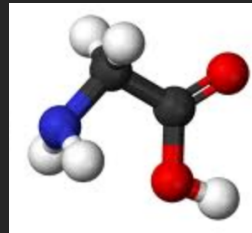
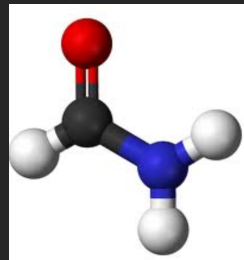
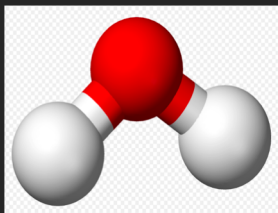


*The formation of a Sun-like star
The formation of a Solar System
The emergency of life*

Planetary composition: disk chemical reset
or inheritance ?



Time

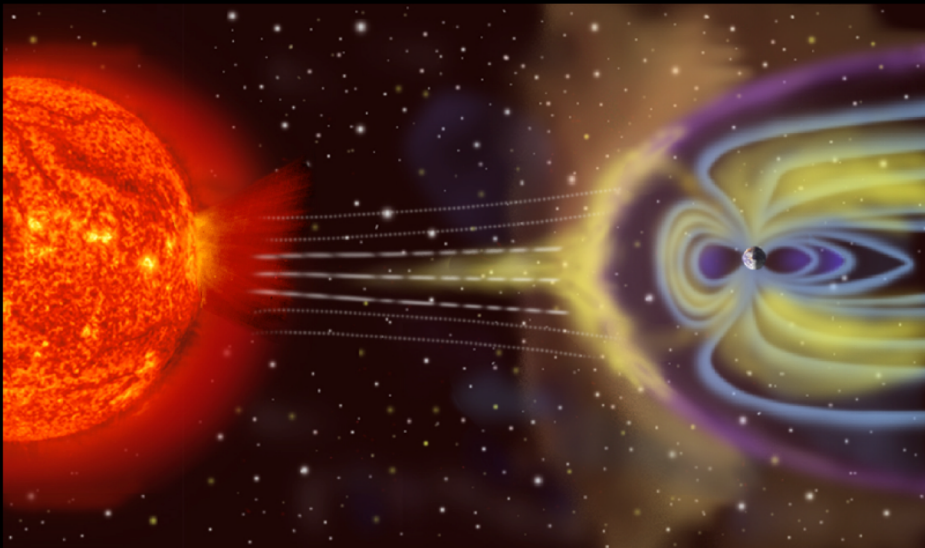
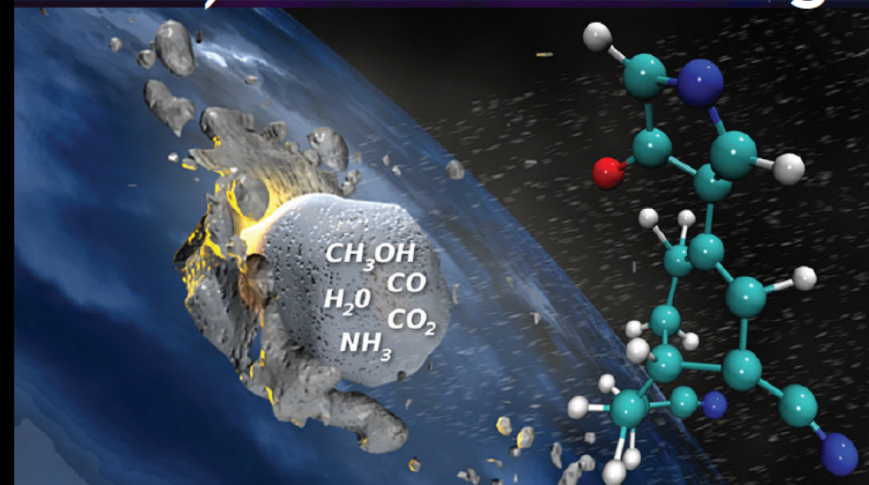


Cradle of Life Science Themes

1) How do rocky planets form?



2) How did life originate?



3) What are exoplanets like?

4) SETI project



Cradle of Life Science Themes

1) How do rocky planets form?

2) How did life originate?

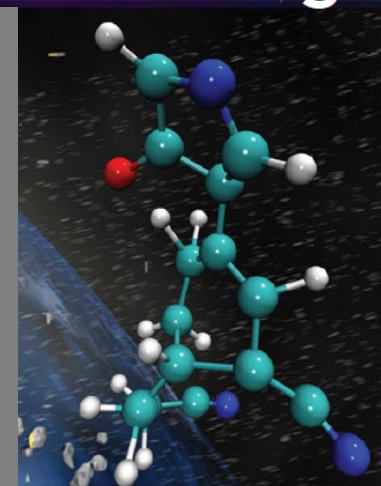
Co-chair:

I. Jiménez-Serra (CAB, Spain)

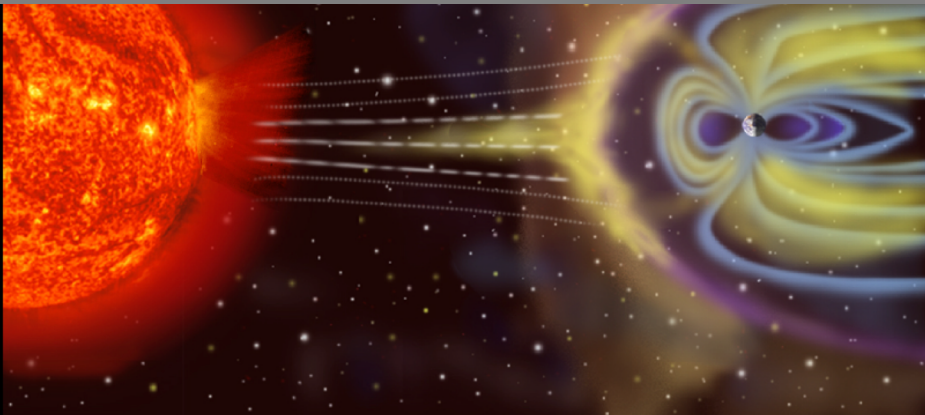
D. Johnstone (HIA, Canada)

+

~ 40 WG members



TI project



3) What are exoplanets like?

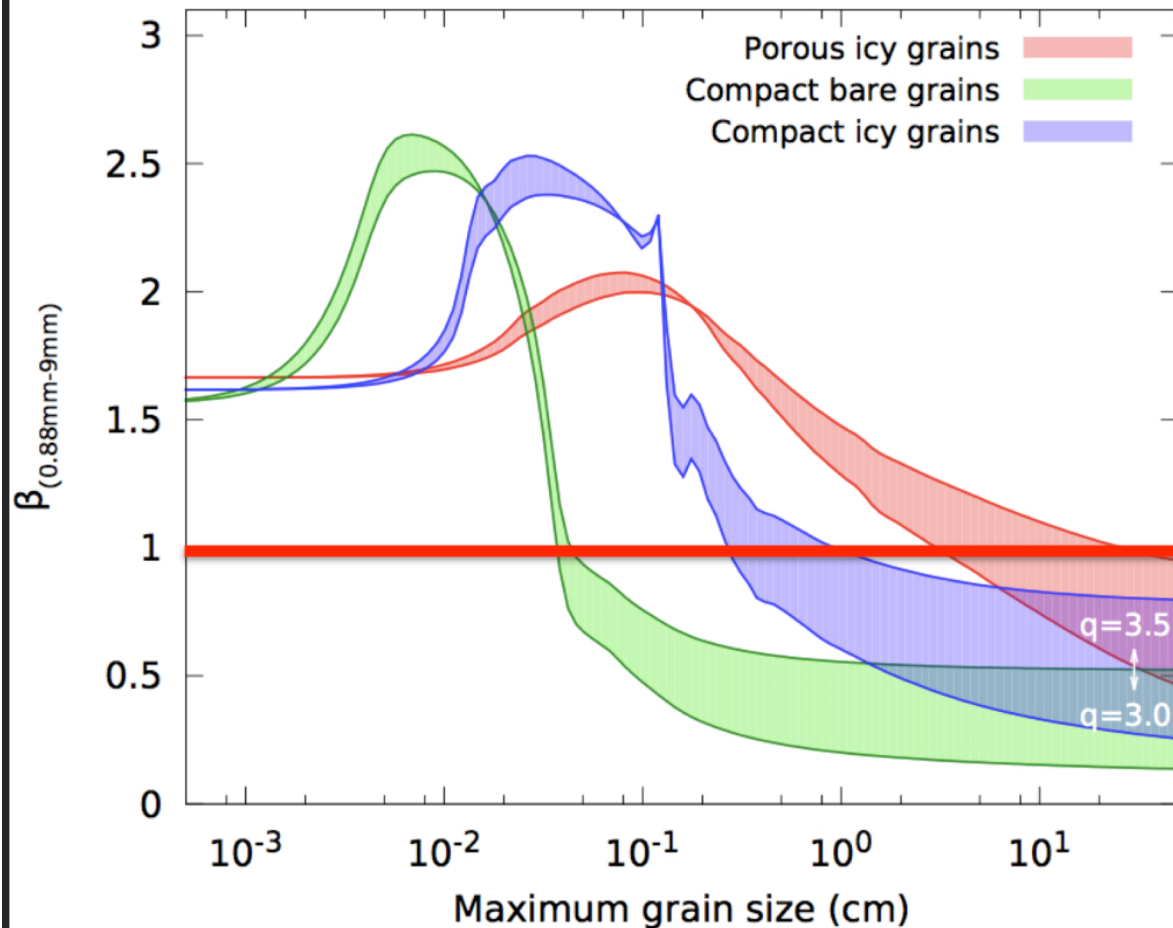


How do rocky planets form ?

Formation of rocky cores of planets → grain growth and dust settling

$$\kappa_V \propto \nu^\beta$$

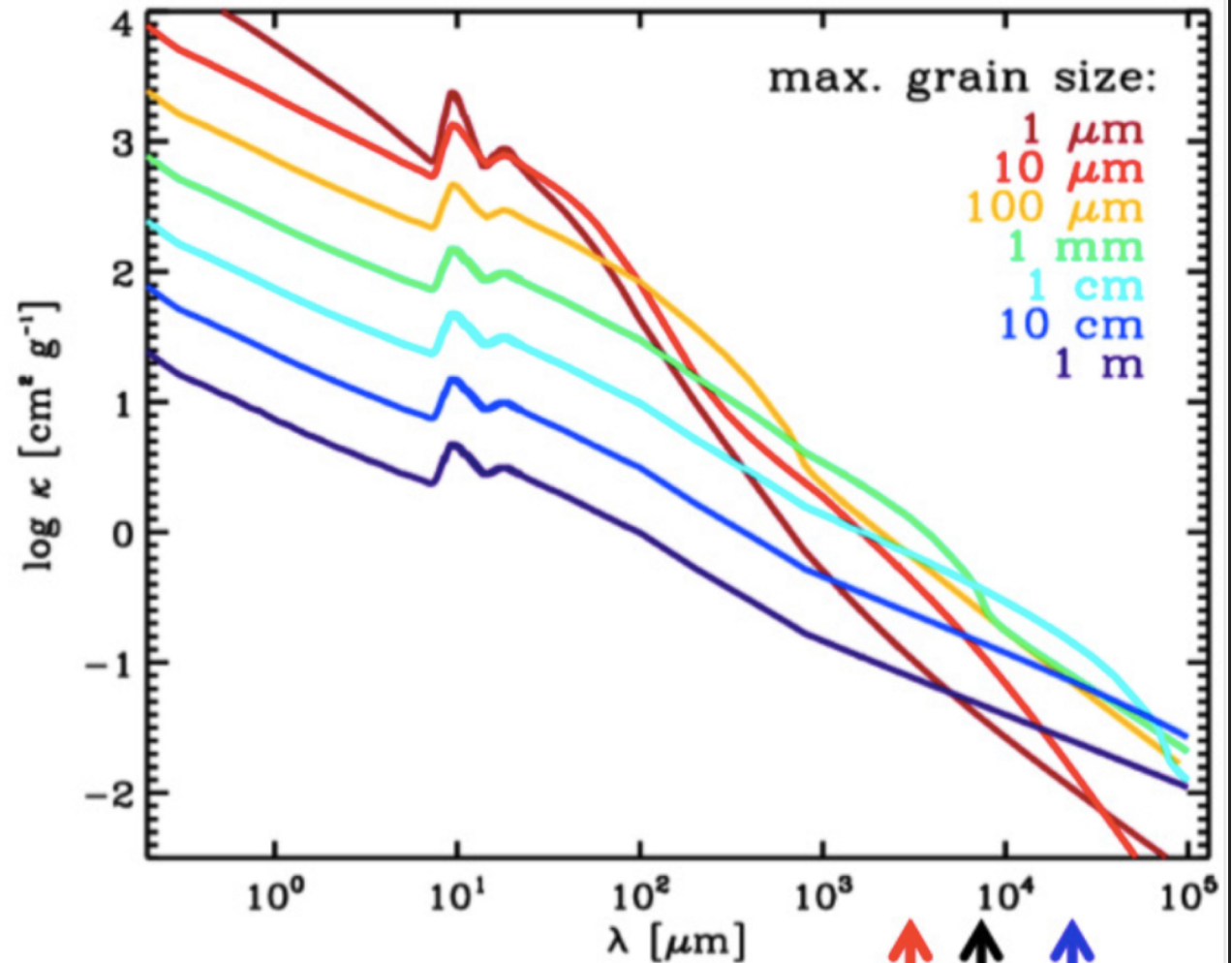
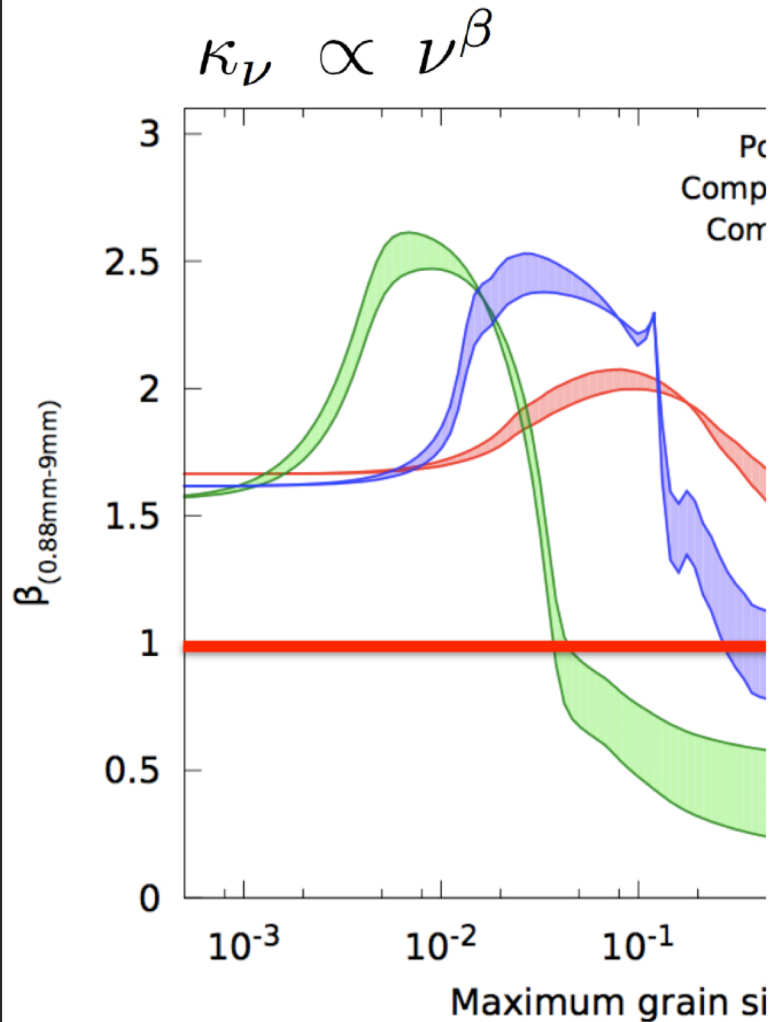
Testi et al. 2014



How do rocky planets form ?

Formation of rocky cores of planets → grain growth and dust settling

Hoare et al. 2015



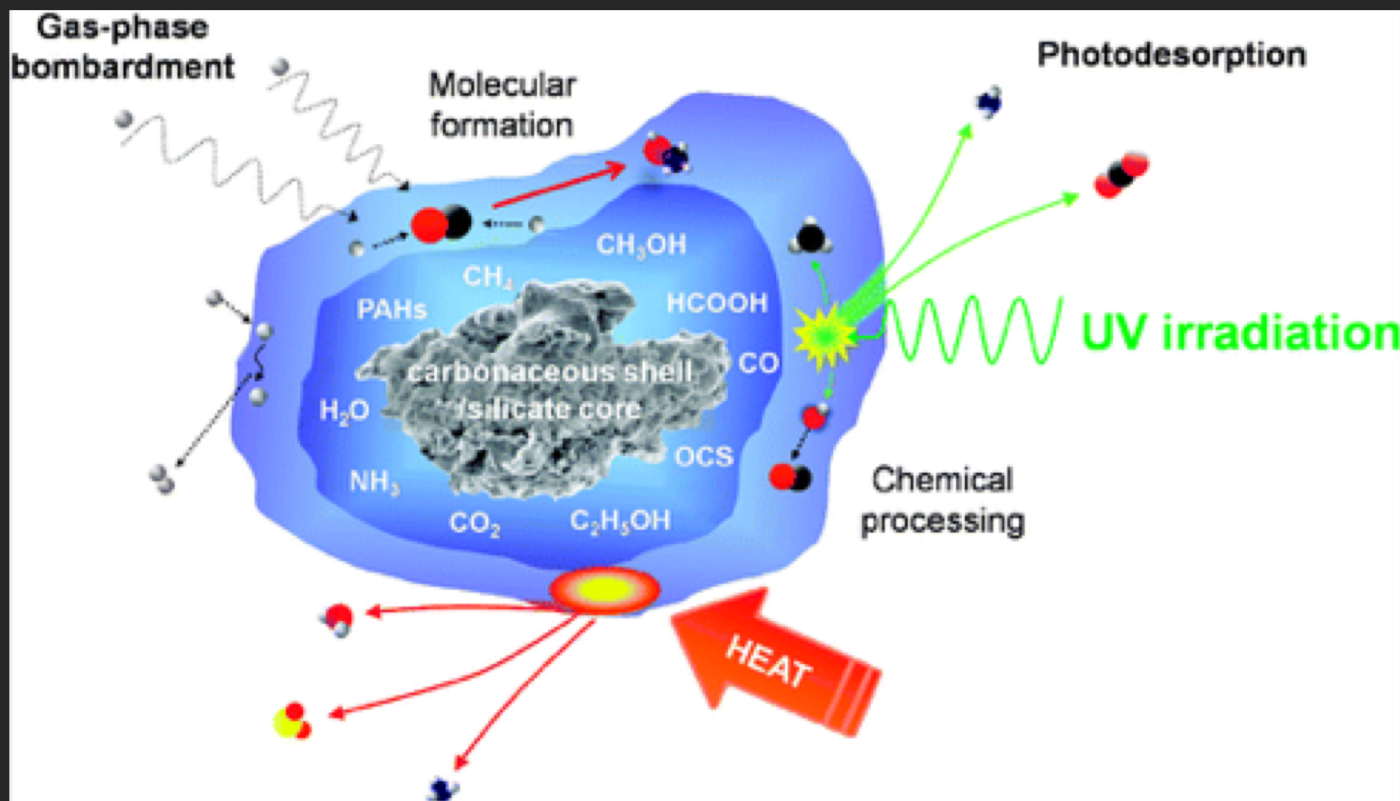
SKA covers the right λ 's to probe cm-sized grains

ALMA ↑
JVLA ↑
SKA1 ↑

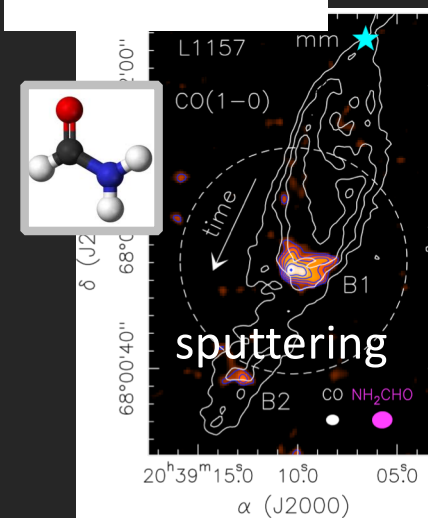
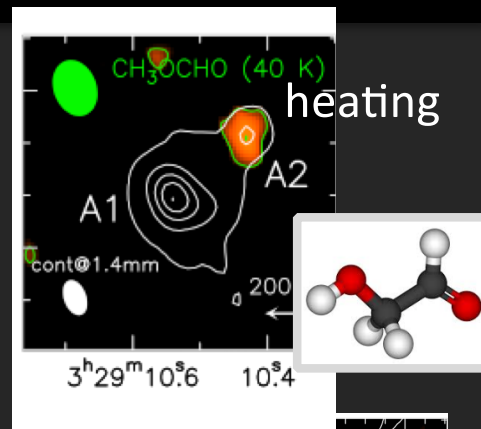
The formation of *i*COMs (interstellar Complex Organic Molecules)

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

and *C*-chains....

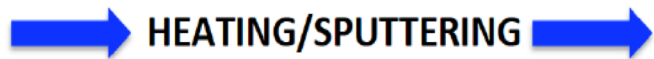


Or are daughter species, i.e. are formed in gas phase following the release of parent species such as methanol?



De Simone+ 2017
Codella+ 2017

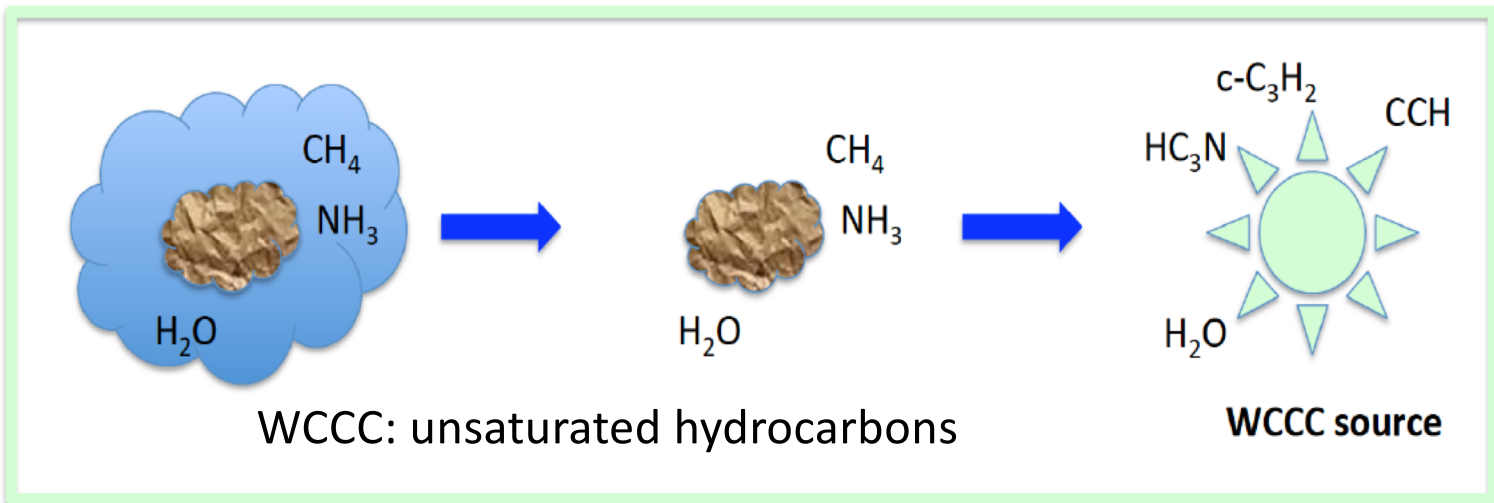
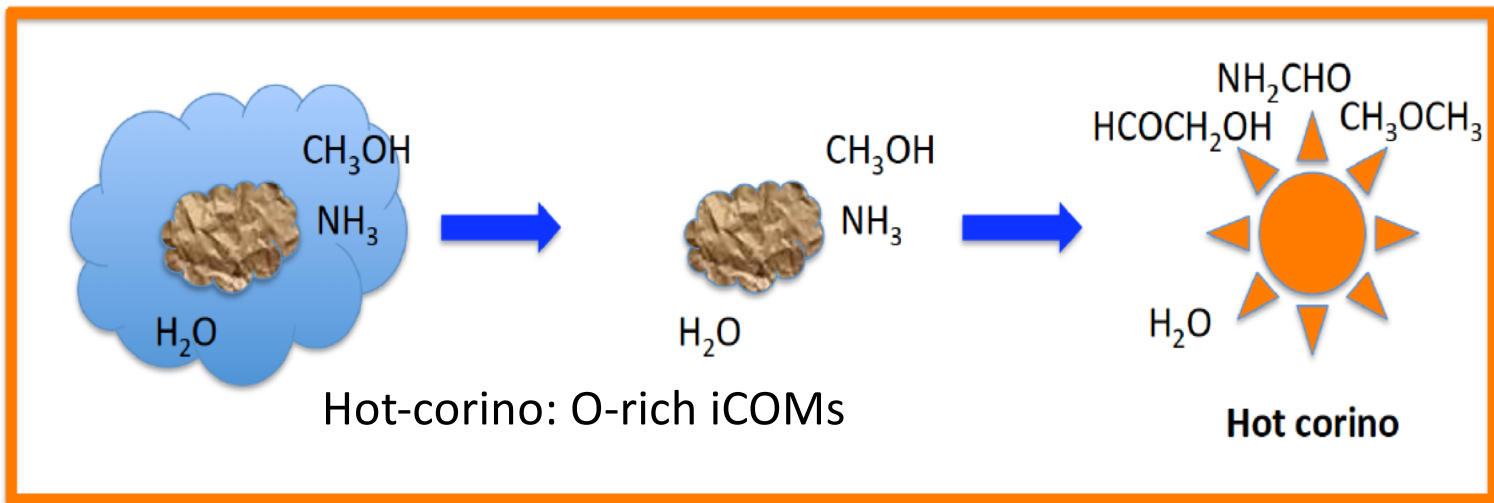
PRESTELLAR CORE

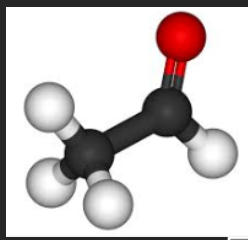
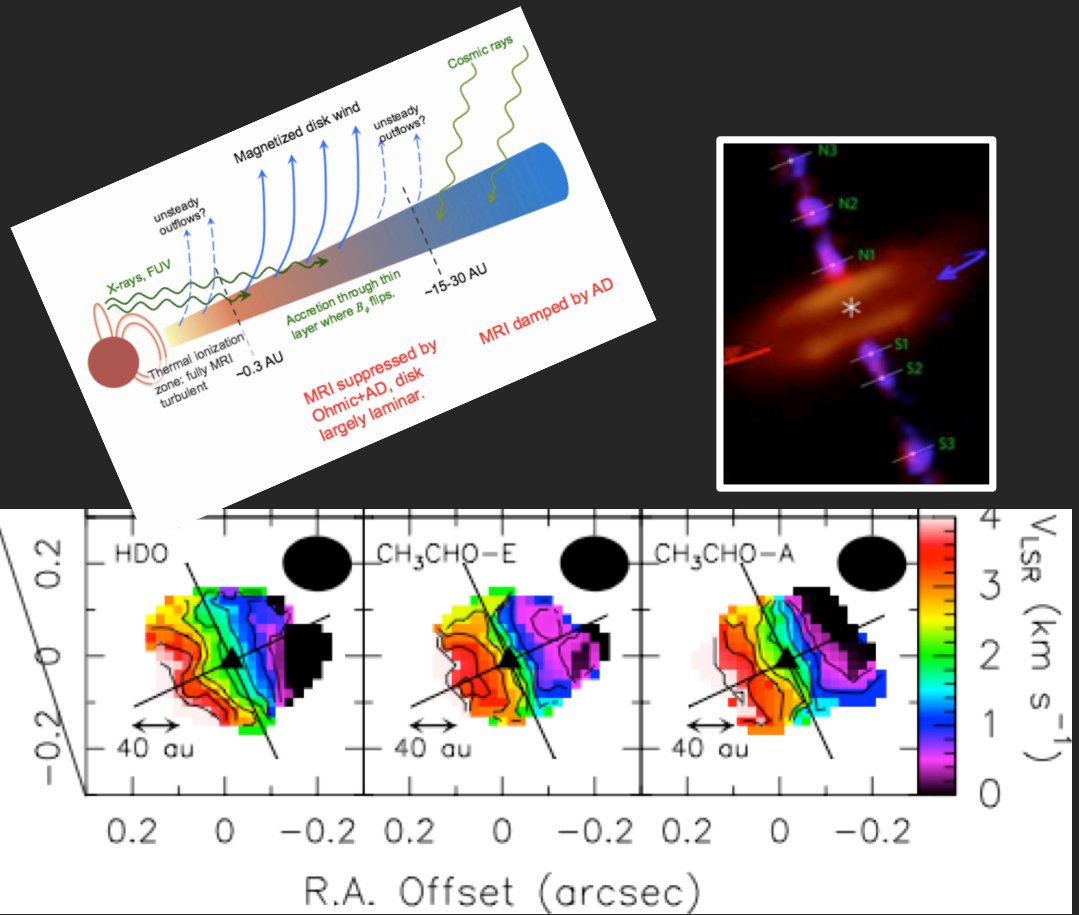
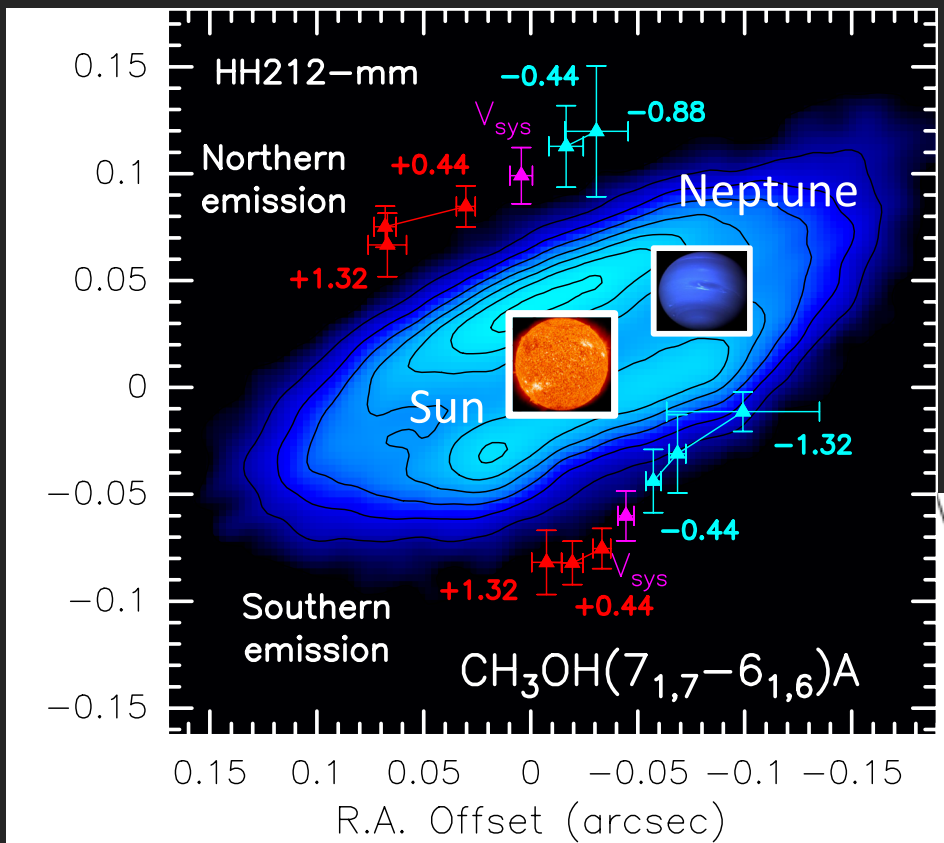


HEATING/SPUTTERING



PROTOSTAR





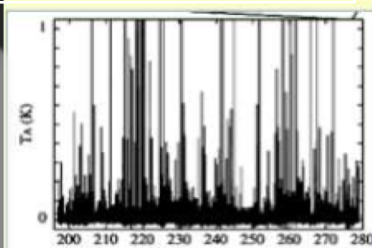
Codella et al. (2018), Lee et al. (2018)

Astrochemistry provides key tools to observe the fundamental processes (accretion, ejection) sculpting the cradle of a star (and its planetary system)

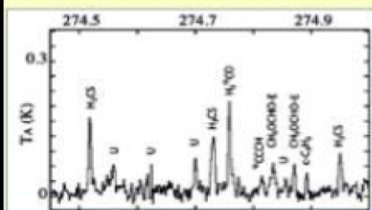


Volatiles evolution: Complex Organics as the building blocks of life

STARS IN THE CAOS



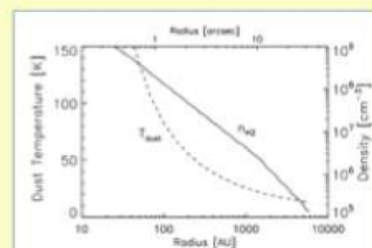
STEP 1: Observe the spectrum of the source.
Tool: telescope



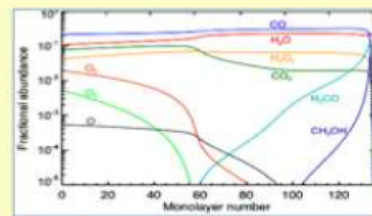
STEP 2: Identify the lines and species.
Tool: spectroscopic data



ASTROPHYSICAL OBJECT



STEP 3: Derive the physical and chemical structure.
Tool: collisional coefficients



STEP 4: Understand the chemical structure.
Tool: reaction pathways and rate coefficients

collaboration
SNS@Pisa - SOLIS@Arcetri,
Bologna (Ciamician) and
Perugia Universities
to model iCOMs in gas phase
PRIN-MIUR: STARS IN THE
CAOS
PRIN-INAF: GENESIS-SKA



1st Italian Workshop on Astrochemistry
Astronomical Complex Organic Molecules in different environments
Palazzo Strozzi
Firenze, Italy
March 10-11, 2016

2nd ITALIAN WORKSHOP ON ASTROCHEMISTRY
JUNE 13-16 : CHEMICAL EVOLUTION IN OUR GALAXY 2018 : Spectroscopy, Observations and Reactivity



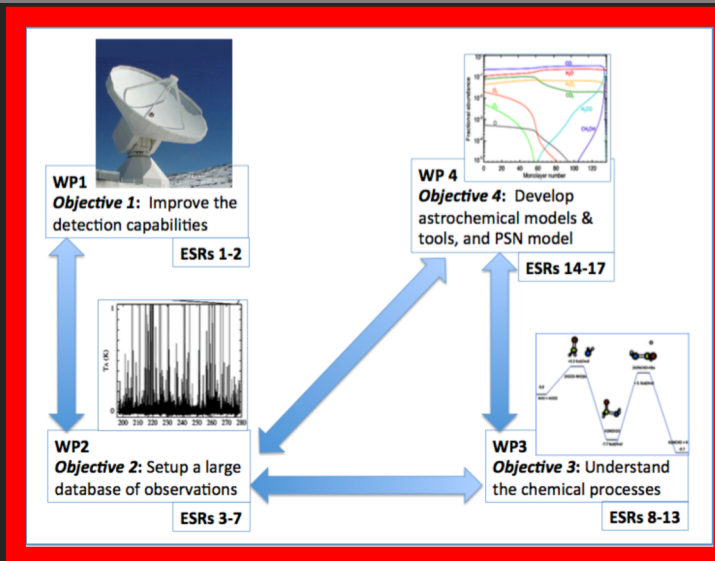
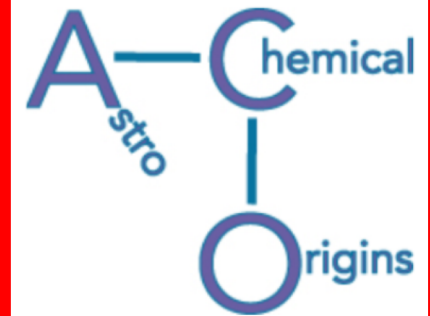
EU-ITN ACO: AstroChemical Origins



Marie Skłodowska-Curie
Innovative Training Networks

GOAL: to unveil the early history of the Solar System
by studying the chemical composition of young Solar analogs

METHODOLOGY: synergy between observers, chemists &
laboratory experiments



INAF: 2 PhD students + 400 kEuro

C. Ceccarelli (Université Grenoble)
C. Codella (INAF-Arcetri, I)
S. Viti (UCL, UK)
P. Ugliengo (UniTo, I)
A. Rimola (UBA, ES)
N. Balucani (UniPg, I)
L. Piccirillo (Manchester, UK)
C. Vastel (Toulouse, FR)
P. Theulé (AMU, FR)
D. Ascenzi (UniTn, I)

GENESIS-SKA: General conNditions in Early planetary Systems for the rISE of life with SKA

PRIN-SKA
INAF 2016
(480 kEuro
2 TD, 6 AR)

synergy between the
following INAF nodes:

Arcetri
Palermo
Catania
Capodimonte
IAPS
Monteporzio
Padova
Brera

C. Codella
(INAF – OAA)



The Cradle of Life

www.genesis.inaf.it





GENESIS - SKA

4 columns



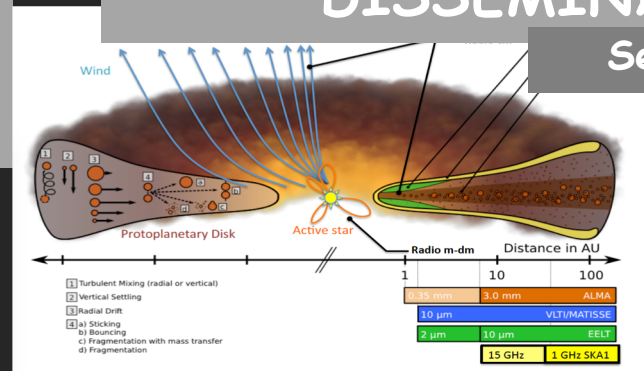
1. PLANET FORMATION:
Models, simulations, &
observations

2. VOLATILES EVOLUTION:
Complex Organics as the
building blocks of life

3. LABORATORY
EXPERIMENTS

4. COMMUNICATION AND
DISSEMINATION

See Boccato's talk



Tracing our chemical origins: Astrochemistry of forming Sun-like star



Herschel



IRAM 30-m

In less than 10 years:
 1 Premiale INAF
 5 Large Programs
 1 Astrofit
 1 PRIN-MIUR
 1 PRIN-INAF
 1 EU-ITN

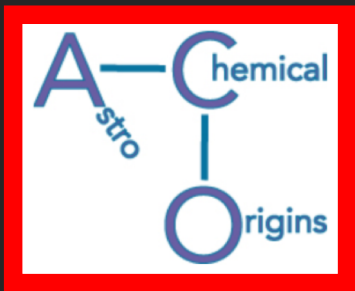
2009



IRAM PdBI



Time



IRAM NOEMA



ALMA

2018

The first ALMA LP on Astrochemistry

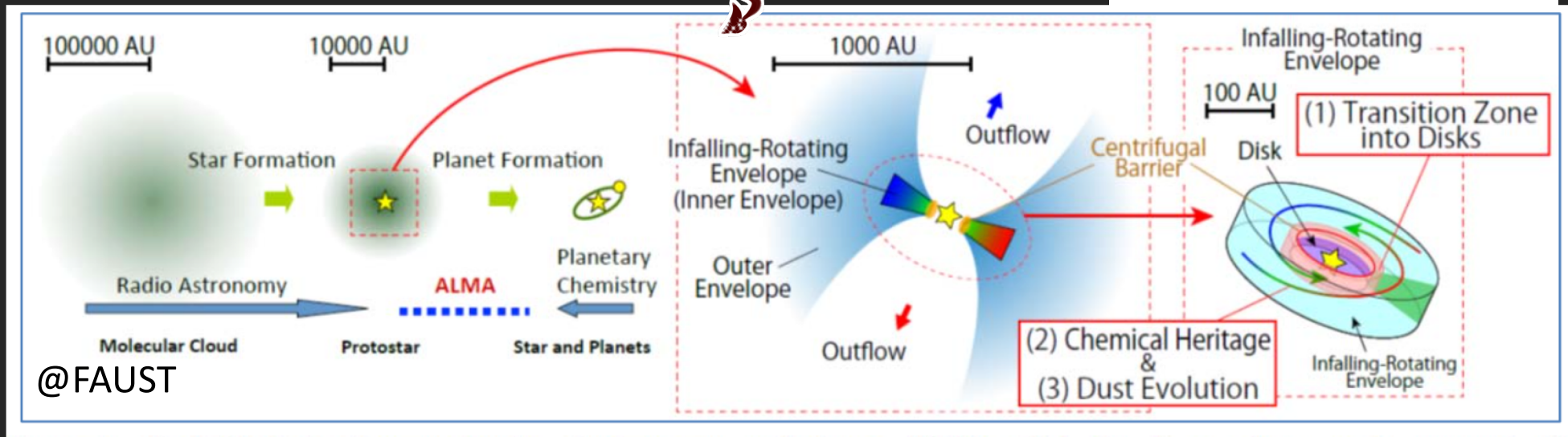
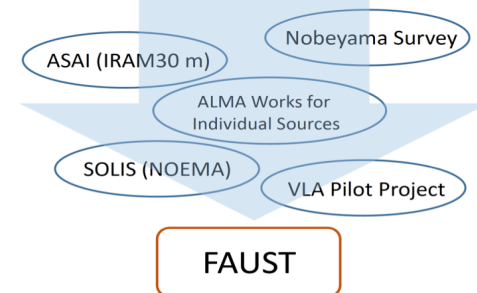
The FAUST synergy
 Fifty AU Study of Protosun Analogues
 ALMA Large Program + 2 pilot @VLA and @GBT



C. Codella (INAF-Arcetri)
 C. Ceccarelli (IPAG, Grenoble)

S. Yamamoto (Tokyo University)
 N. Sakai (RIKEN)

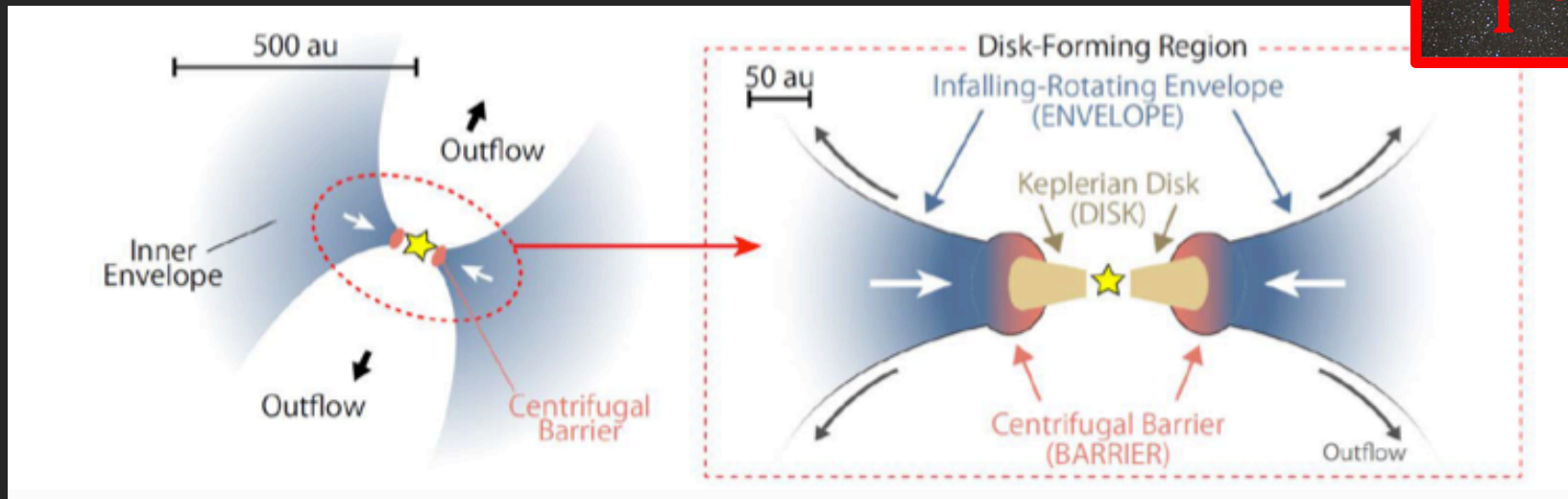
C. Chandler (NRAO)



GOALS:

Is the chemical diversity at a 1000 au scale also present in the inner envelope/disk system (50 au) ?

What molecules are passed from the envelope to the disk in which planets, asteroids, and comets form



- Zone Probes

Envelope: $c\text{-C}_3\text{H}_2$, CS, (C_2H , OCS)

Barrier: CH_3OH , SO, SiO, (SO_2 , COMs)

Disk: H_2CO , C^{18}O and HC_3N , (H_2CS)

- Molecular Complexity Probes

CH_3OH , NH_2CHO , CH_3CHO , CH_3OCH_3 , and HCOOCH_3

- Gas Ionization Probes

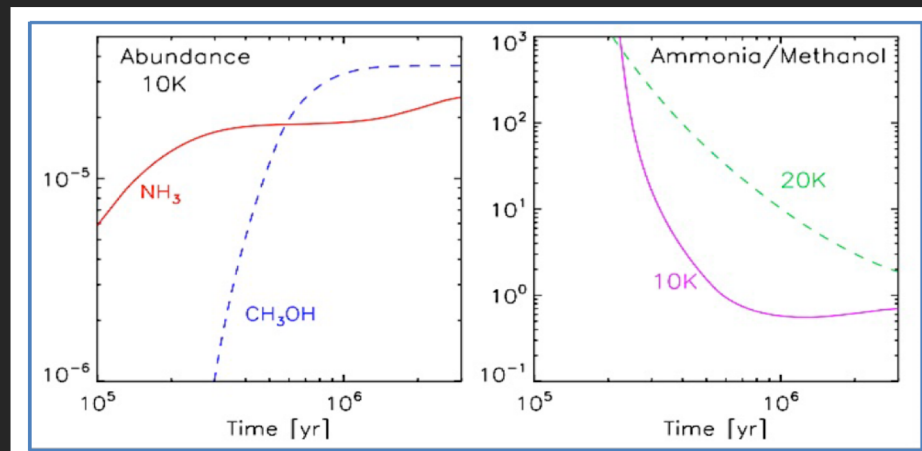
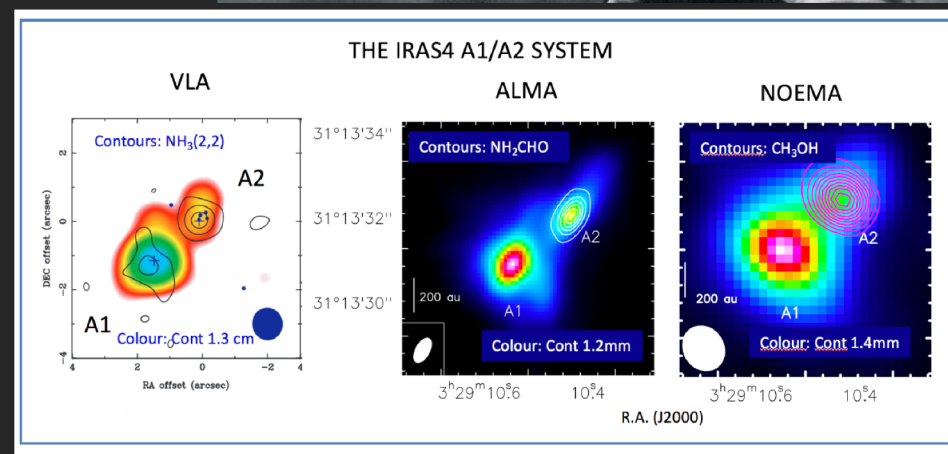
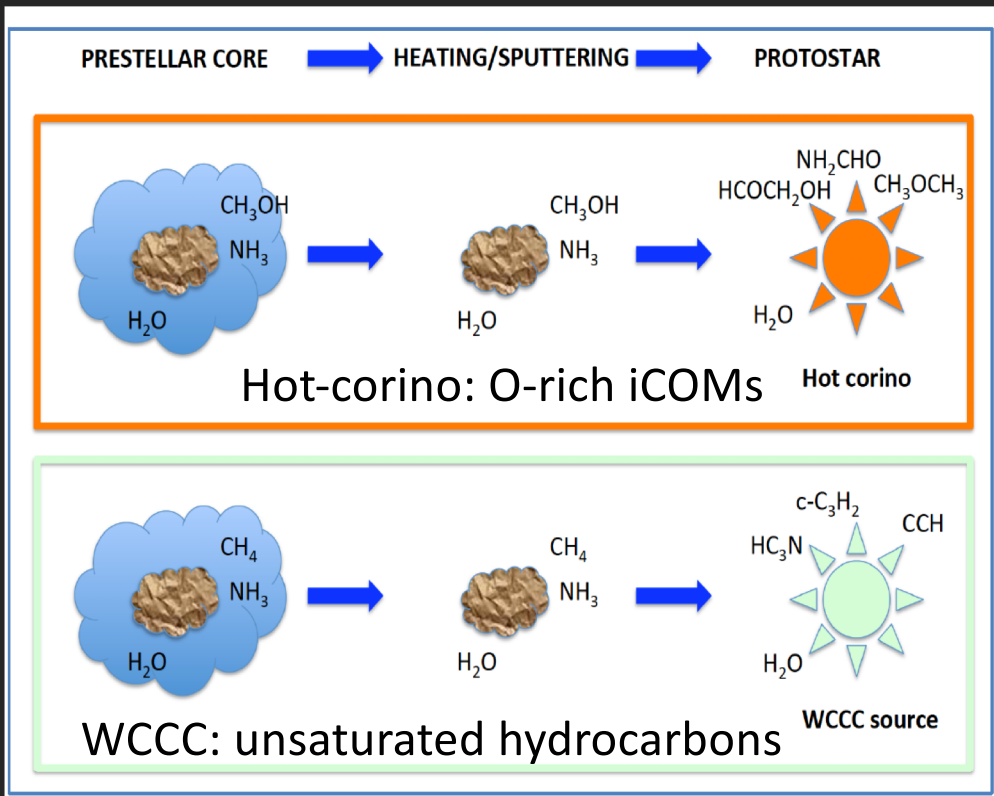
H^{13}CO^+ , DCO^+ and N_2H^+

- Deuterium-bearing Species

$c\text{-C}_3\text{HD}$, N_2D^+ , HDCO , D_2CO and CH_2DOH



Back to the cm-window with new perspectives (1/2)



Tracing ice mantle history in
Solar-type protostars



Large Program:
On-going Pilot project

(Examples of) Predictions in the grain mantles
(as a function of T and time)

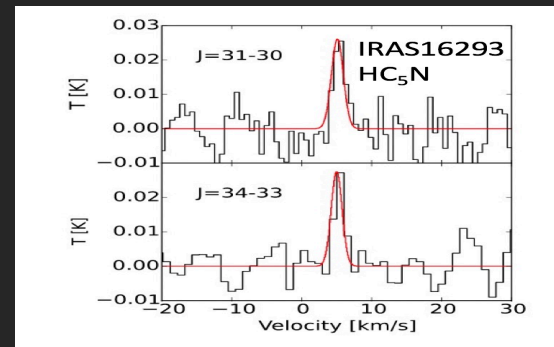
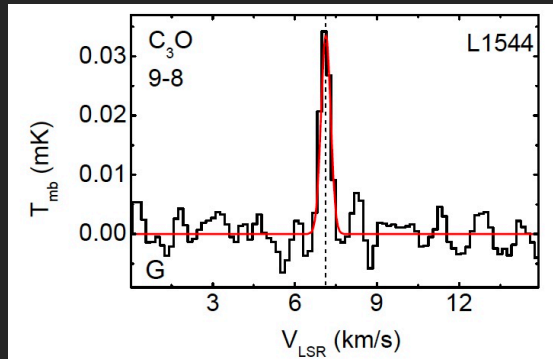
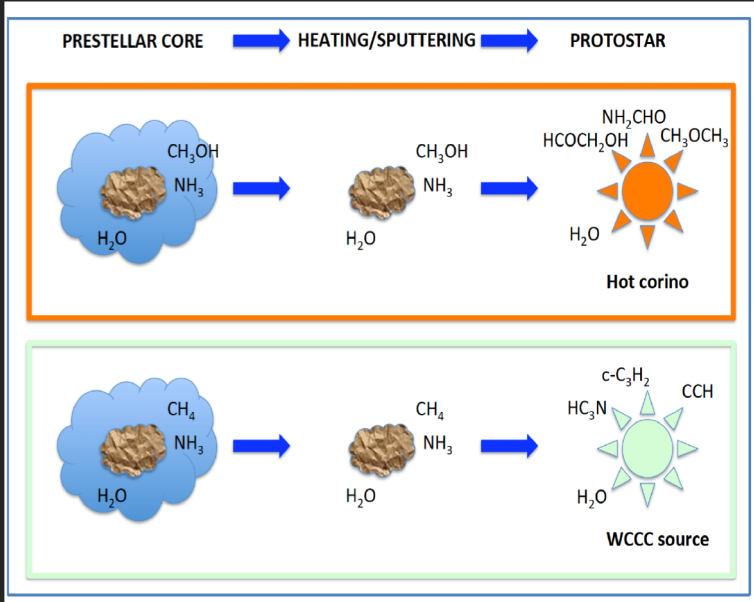


Back to the cm-window with new perspectives (2/2)

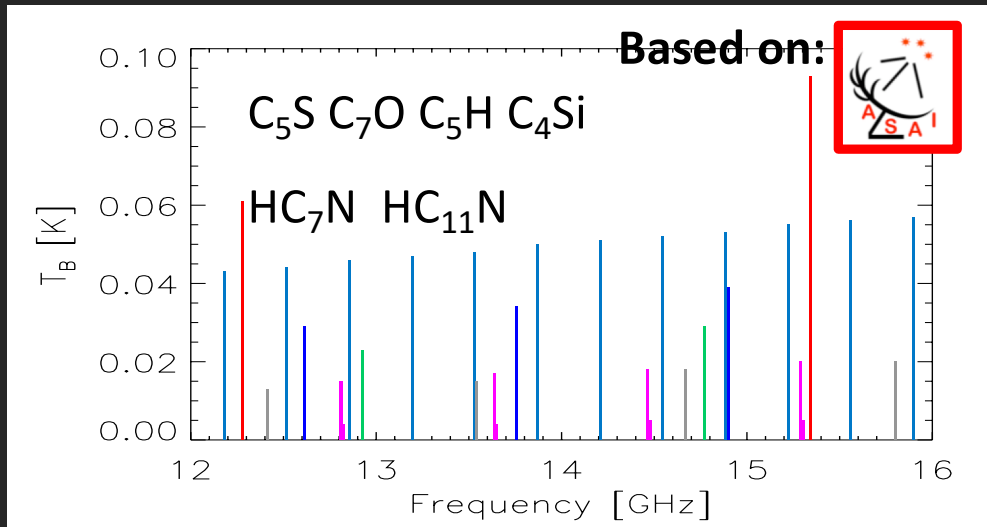


Hot-corino: O-rich iCOMs

The missing information on large carbon chains rs



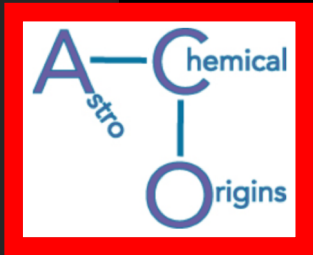
WCCC: unsaturated hydrocarbons



Large Program:
On-going Pilot project



Astrobiological context: cosmic-ray irradiation
(Ceccarelli+14; Fontani+17; Favre+18)



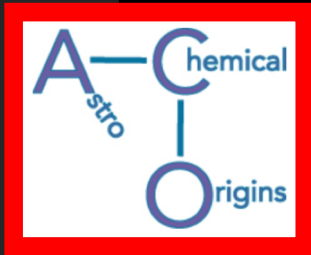
Conclusions (1/2)



Single-Dish

Interferometry

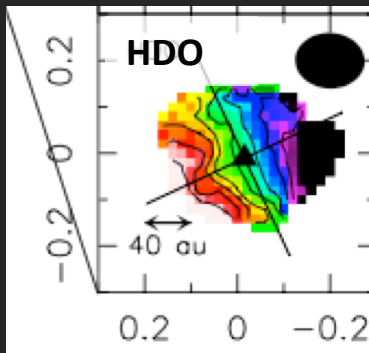
Wavelength



Conclusions (2/2)



Road to a Solar System



Bianchi+ 2017ab, 2018;
Codella+ 2018

