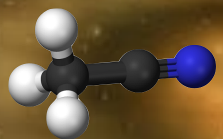
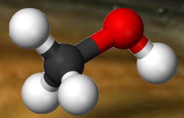
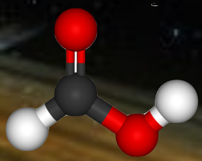






The chemistry of planet-forming disks with SKA: the inner 50 au

Linda Podio(1)

M. De Simone(2), E. Bianchi(2), C. Codella(1), C. Ceccarelli(2), B. Sbovoda(3), C.J. Chandler(3)

(1) INAF - Osservatorio di Arcetri, Italy

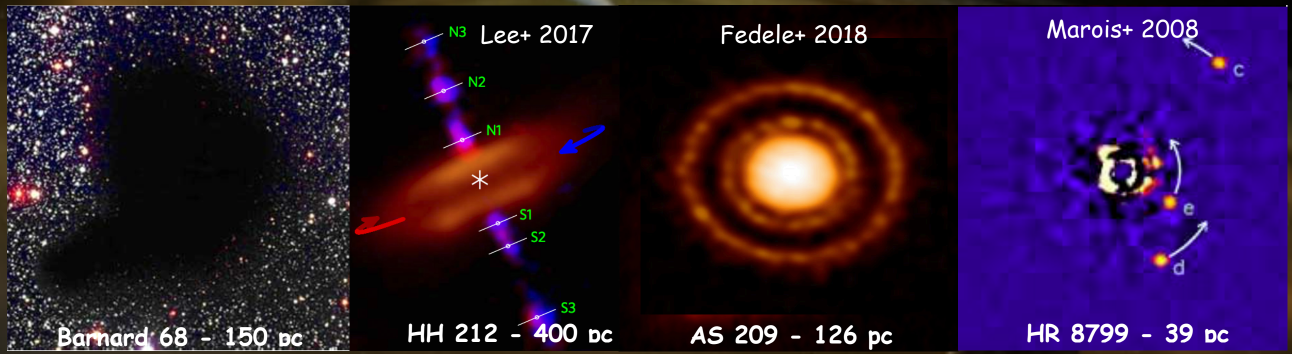
(2) IPAG, Grenoble, France

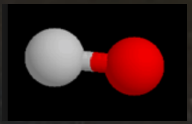
(3) NRAO, Socorro, USA

From a cloud to a SUN and its planets

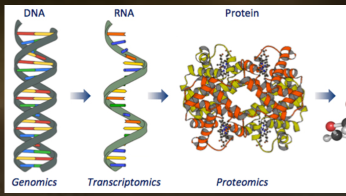
prestellar core | protostar | T Tauri star | main-sequence

from E. Bianchi PhD thesis





t=0 | 10^4—10^5 yrs | 10^6—10^7 yrs | >10^8 yrs

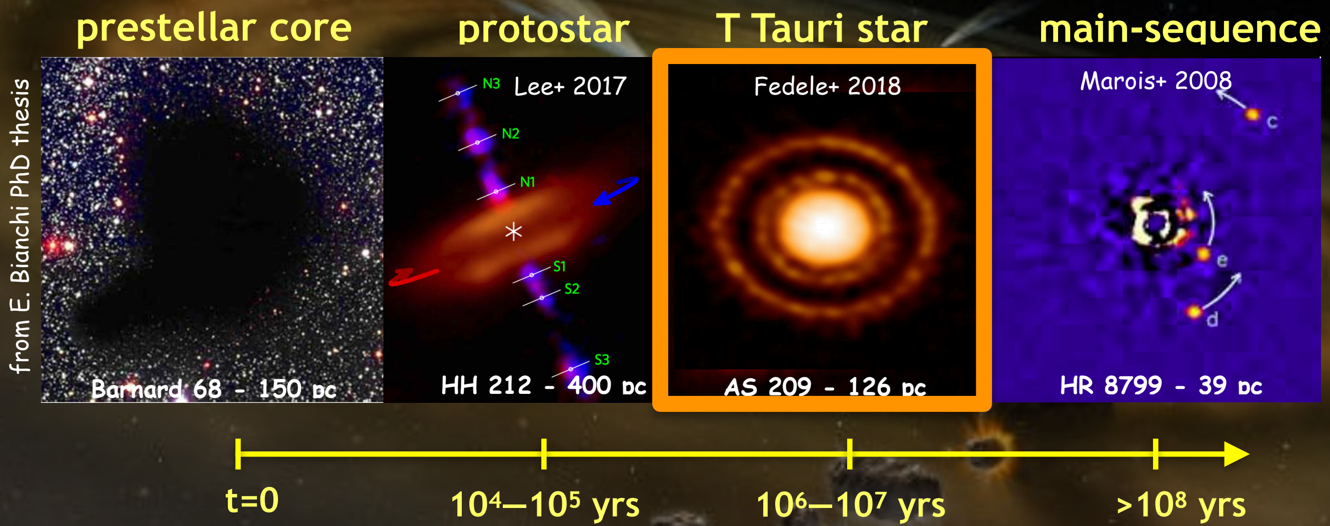


What about chemistry ?

How chemical complexity builds up from prestellar cores to planets ?

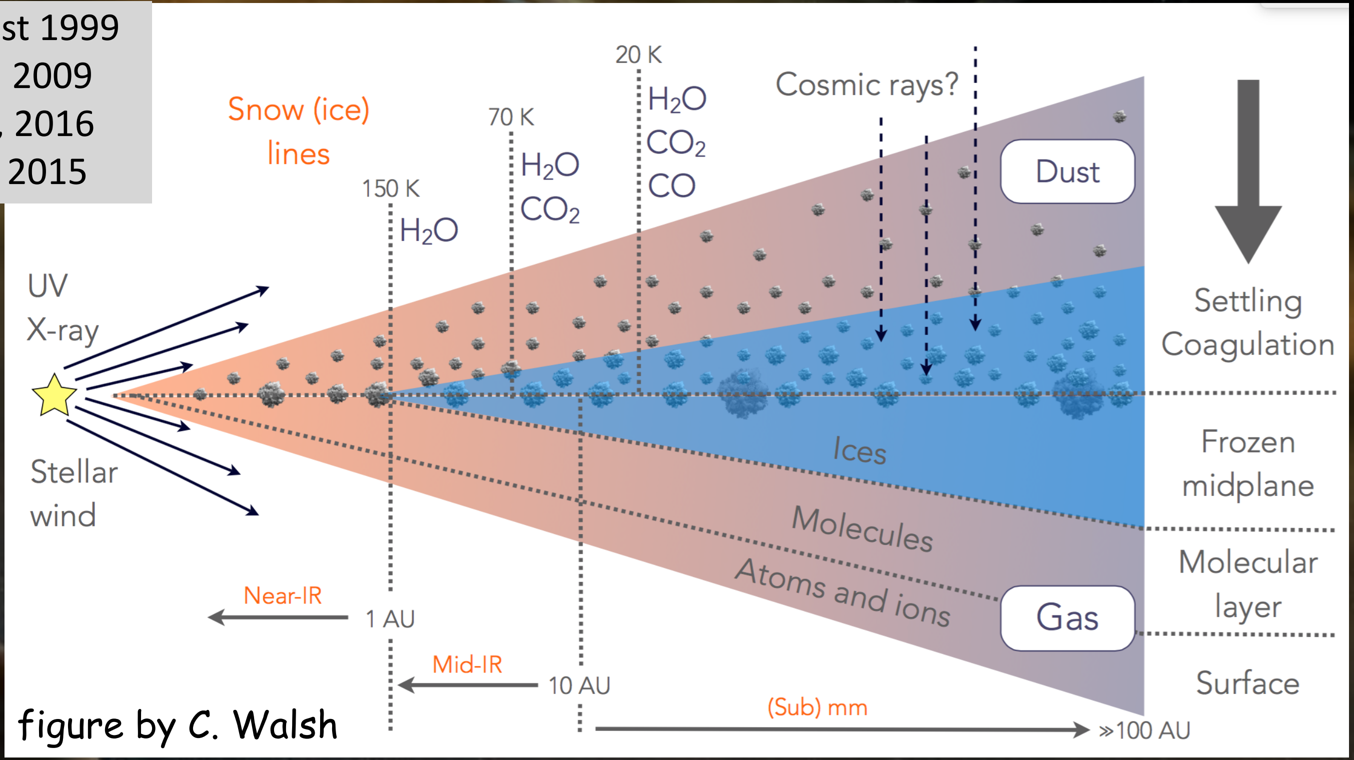
Planetary composition: disc **chemical reset** or **inheritance** ?

The missing link: the chemistry of planet-forming disks



The chemistry of disks: observational challenges

Aikawa & Herbst 1999
Wallacy et al. 2009
Walsh+ 2014, 2016
Loomis et al. 2015



Disks are small (~100 au) and their molecular content is hidden on ices

High angular resolution and sensitivity are needed!

ALMA-DOT ALMA chemical survey of Disk-Outflow sources in Taurus

PI: L. Podio

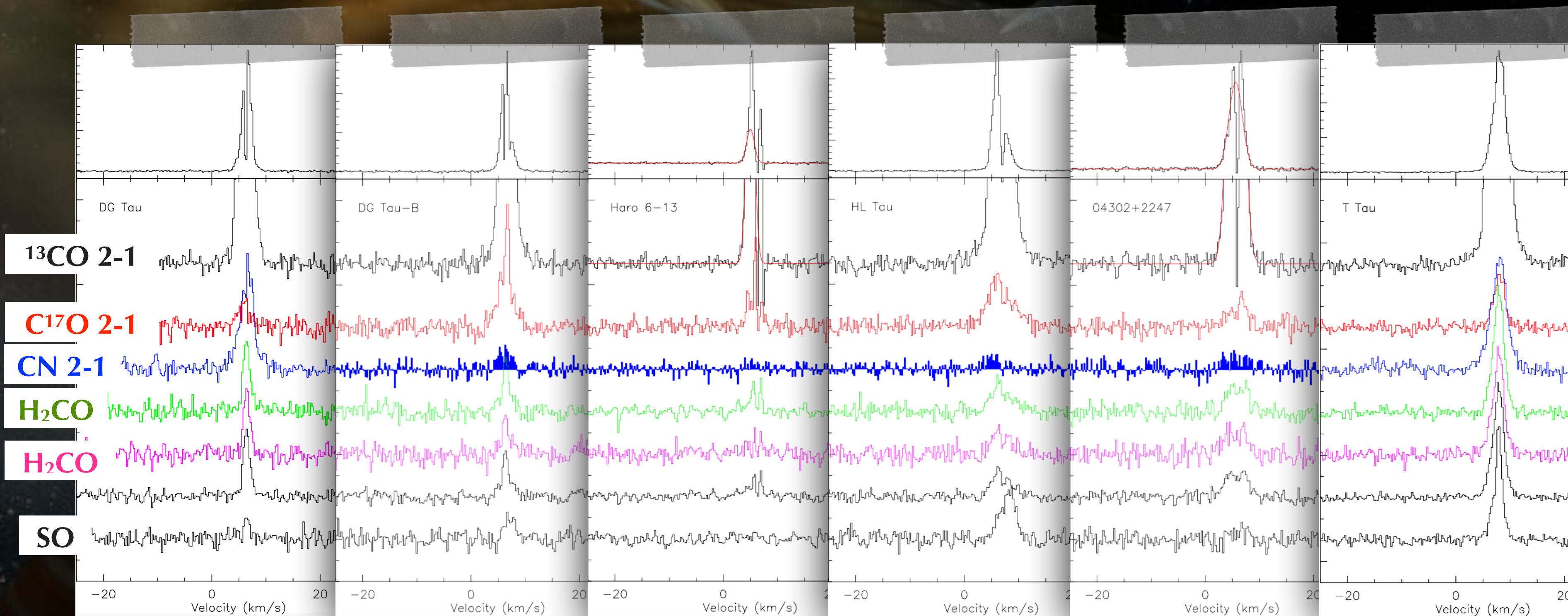
GOAL: to unveil the CHEMICAL CONTENT of YOUNG DISKS with ALMA

www.sites.google.com/view/alma-dot/

young disks around Class I-II:
DG Tau, DG Tau B, Haro 6-13, HL Tau, IRAS 04302+2247, T Tau

Molecules: CO, CS, CN, H_2CO, H_2CS, CH_3OH, SO, SO_2

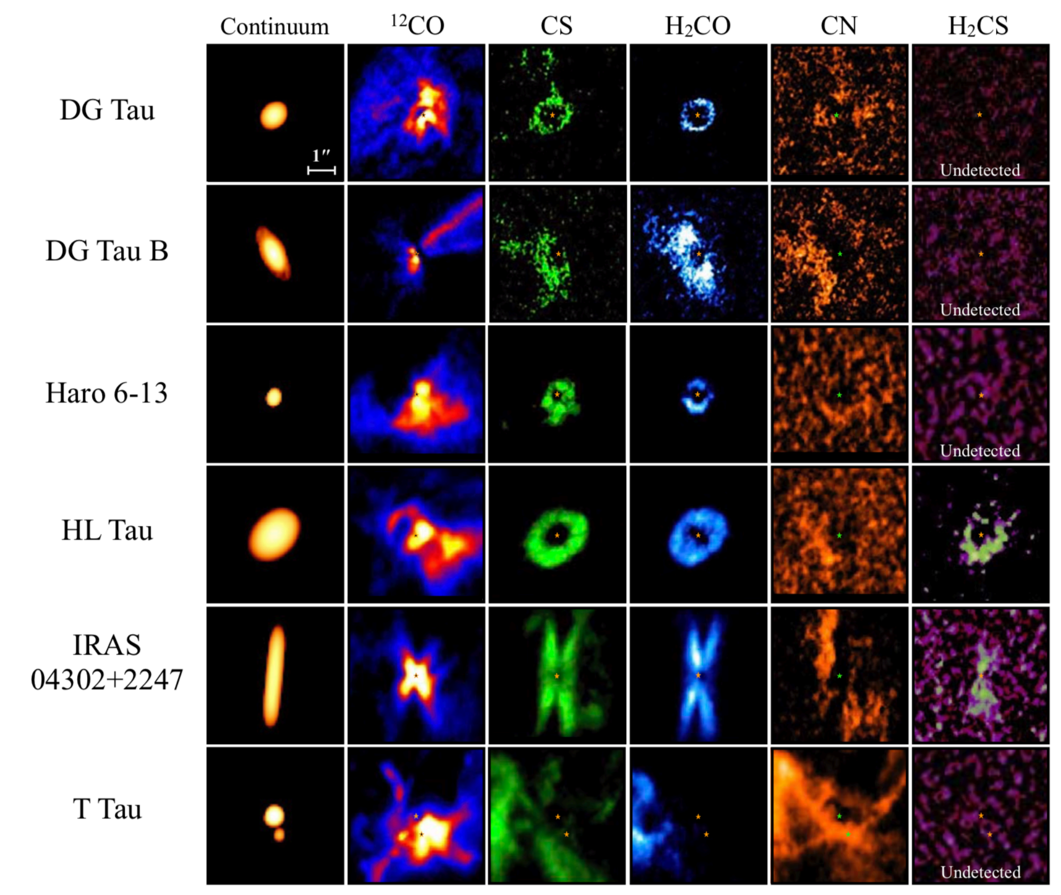
the disk chemistry before …



Molecules in protoplanetary disks in Taurus with IRAM-30m
Guilloteau et al. 2013

. . . and after ALMA-DOT

An overview of the molecular distribution and abundance in young disks

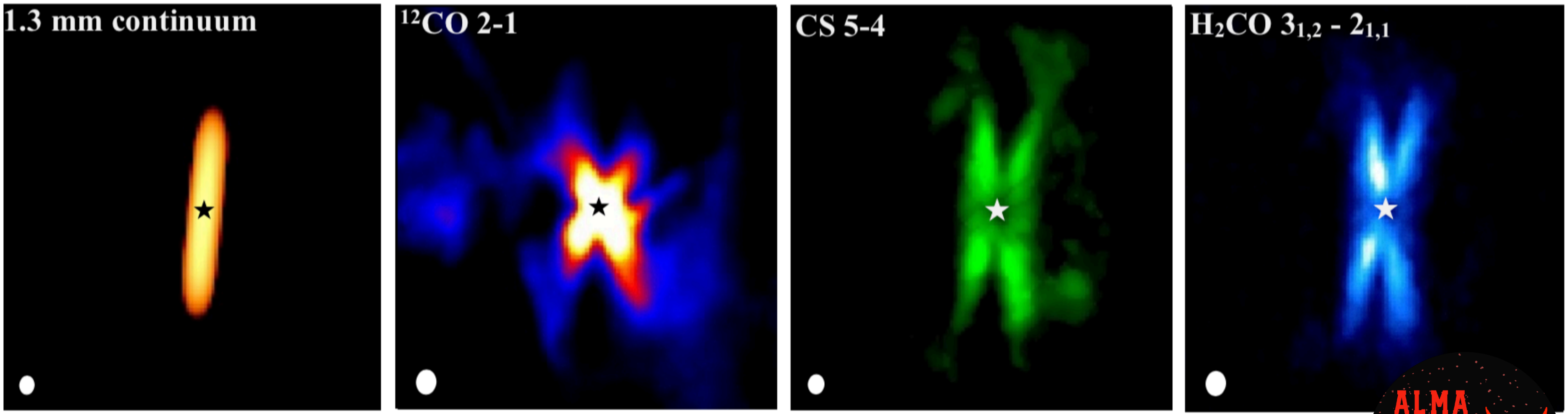


ALMA-DOT 0. Podio et al. 2019
ALMA-DOT I. Garufi et al. 2020
ALMA-DOT II. Podio et al. 2020a
ALMA-DOT III. Podio et al. 2020b
ALMA-DOT IV. Codella et al. 2020
ALMA-DOT V. Garufi et al. 2021
ALMA-DOT VI. Garufi et al. 2021
ALMA-DOT VII. Bacciotti et al. in prep

+ five more disks surveyed by the ALMA LP MAPS

Chemical stratification in the edge-on disk of IRAS 04302

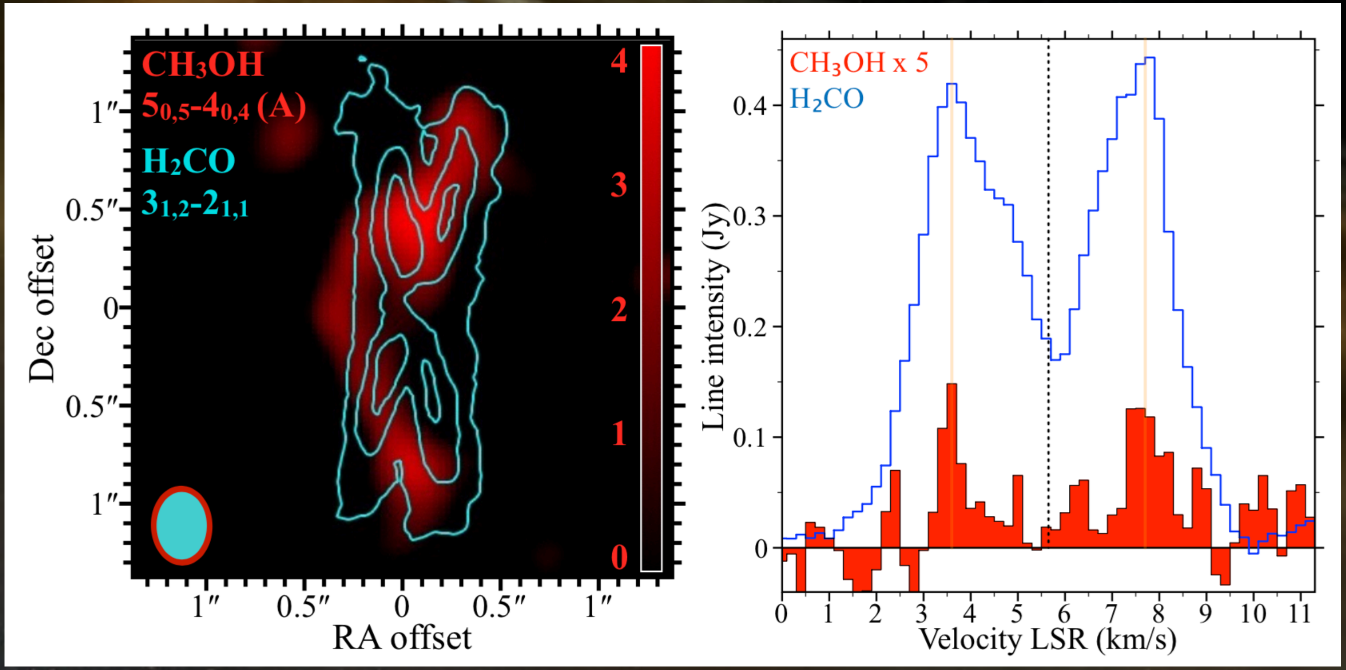
ALMA-DOT II. Podio et al. 2020a



MOLECULAR LAYER: probed by H_2CO, CS (z/r=0.21-0.25), and CO (0.41-0.45)

FREEZE-OUT LAYER: Molecular emission decreases at the disk mid plane due to freeze-out

ALMA-DOT: methanol in the Class I disk IRAS 04302



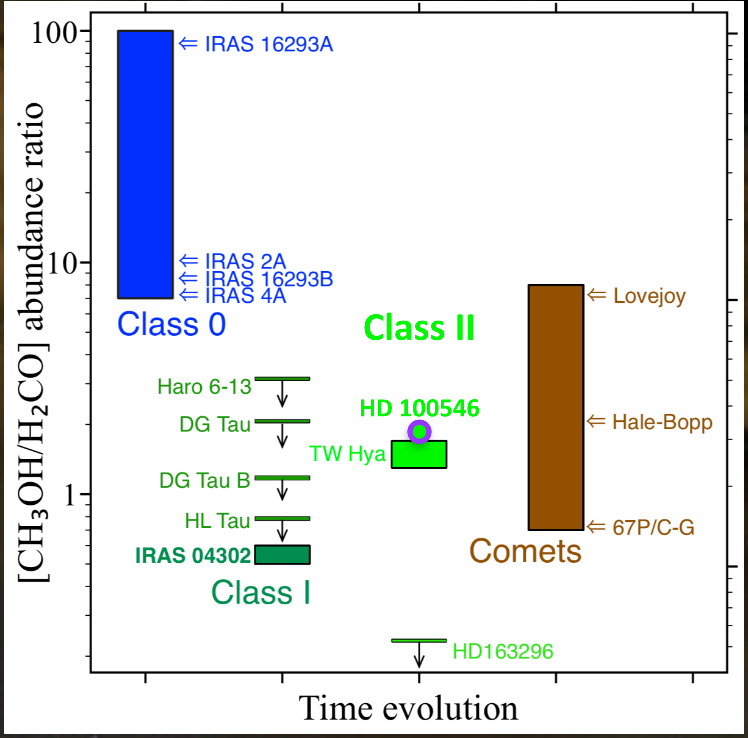
ALMA-DOT II. Podio et al. 2020a

METHANOL is a key molecule for iCOMs formation

METHANOL is only formed on ices hence it is a probe of ICES composition in disks

L. Podio — INAF - Arcetri

chemical evolution from PROTOSTARS to COMETS ?



ALMA-DOT II. Podio et al. 2020a
ALMA-DOT V. Garufi et al. 2021

CH_3OH/H_2CO in disks is in agreement with comets and ~10-100 times lower than in hot-corinos

disc chemical reset ?

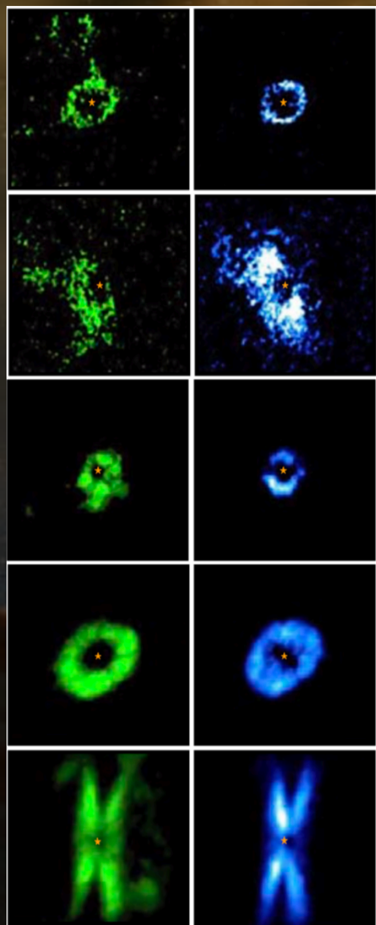
HOT-CORINOS IRAS 2A, IRAS 4A (Taquet+ 2015), IRAS16293 A&B (Jørgensen+ 2018, Persson+ 2018, Manigand+ 2020)

DISKS TW Hya, HD163296 (Walsh+ 2016, Carney+ 2017, 2019), Class I Taurus (ALMA-DOT), HD100546 (Booth+ 2021)

COMETS Hale-Bopp, Lovejoy (Biver+ 2015), 67/C-G (Rubin+ 2019)

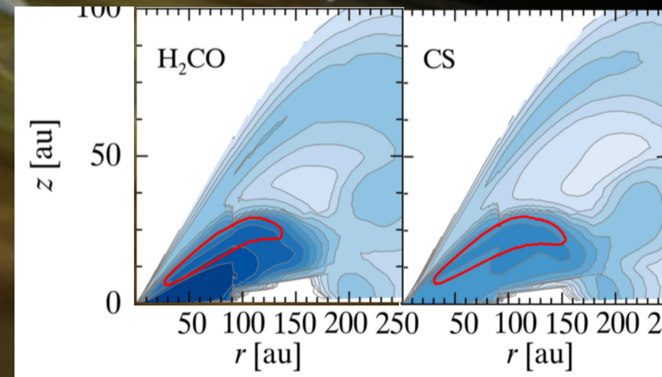
ALMA-DOT probes molecules in the OUTER DISK

ALMA-DOT disks



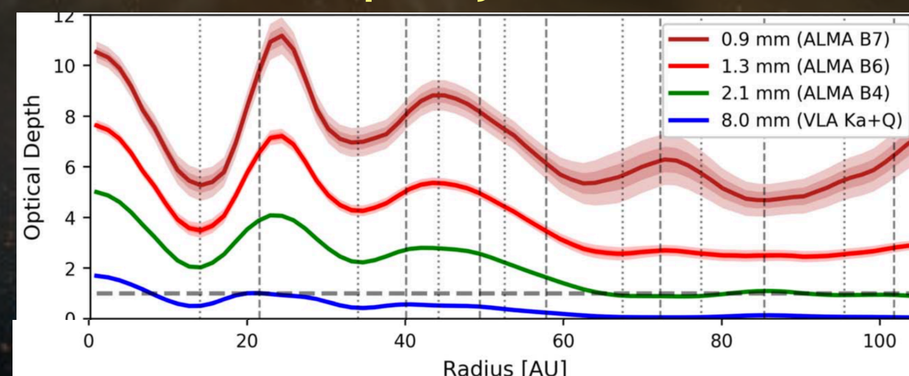
ALMA-DOT V. Garufi et al. 2021

Chemical ring ???



models of molecular emission
Fedele & Favre 2020

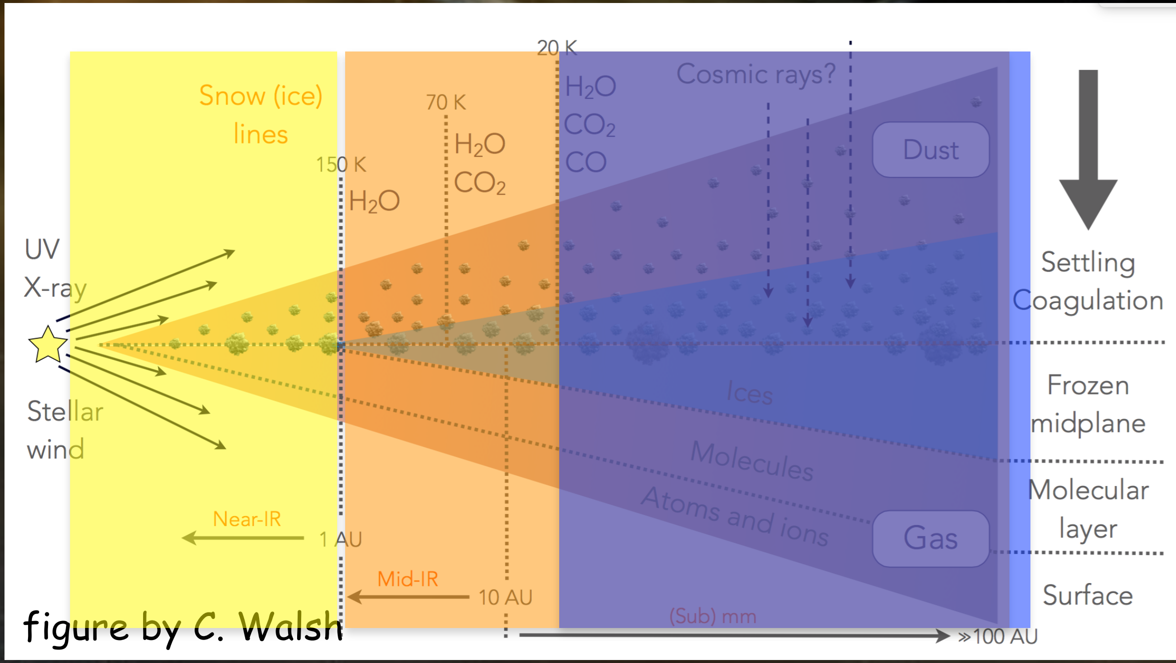
dust opacity @mm ???



HL Tau - ALMA & VLA obs
Carrasco Gonzalez et al. 2019

ALMA-DOT probes molecules in the OUTER DISK

methanol: the inner & outer reservoirs in disks

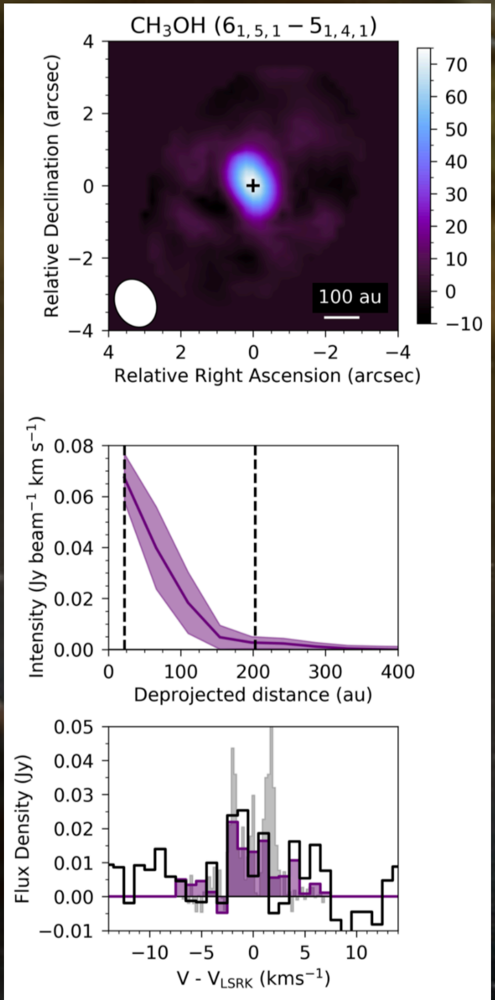


methanol
thermal desorption
inside the water (and COMs)
snowline

methanol
non-thermal desorption

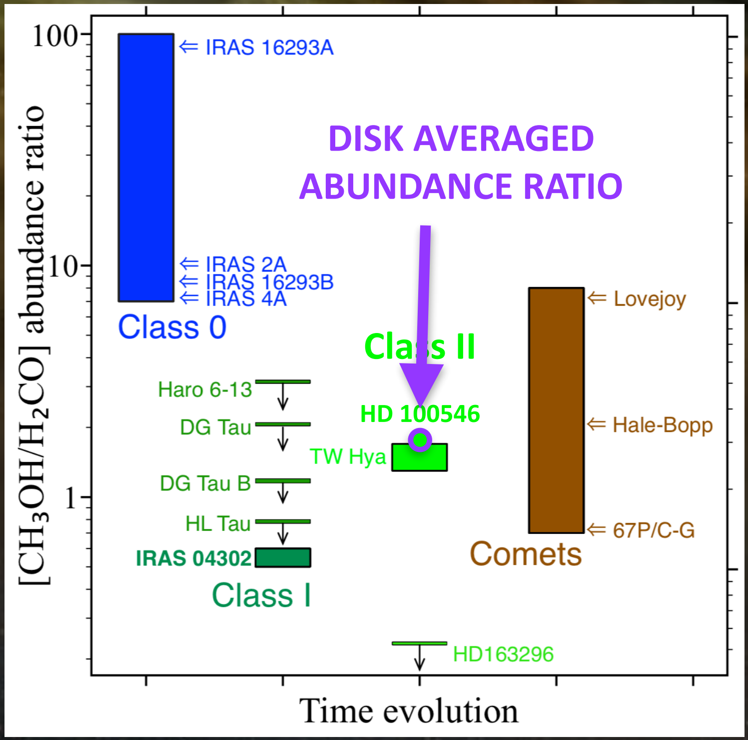
methanol
in-situ formation
on icy dust grains
outside the CO snowline

the first detection of CH_3OH in the disk of an Herbig star



HD 100546, 110 pc

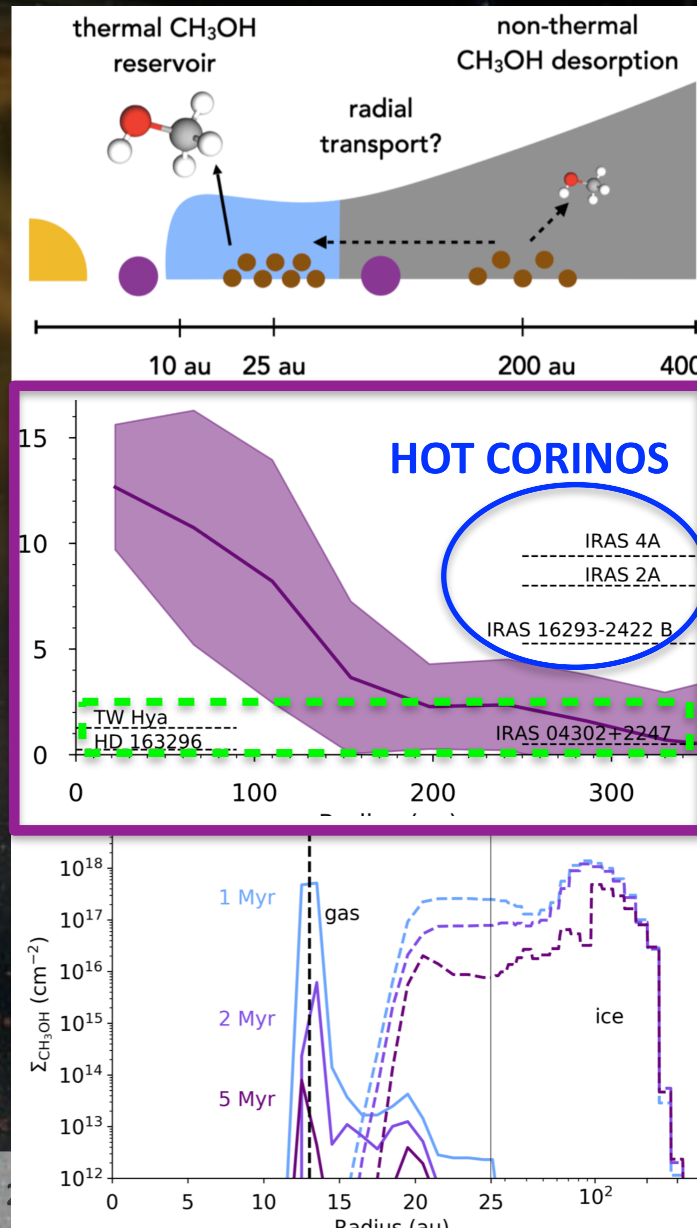
Booth et al. 2021



CH_3OH/H_2CO in the inner & outer disk

CH_3OH/H_2CO~10-15
in the INNER DISK
where molecules are
thermally released,
in agreement with the
ratios in HOT-CORINOS

CH_3OH/H_2CO ~0.2-2
in the OUTER DISK
where molecules are
non-thermally desorbed



SKETCH of the DISK

Booth et al. 2021

CH3OH/H2CO radial profile in HD 100546

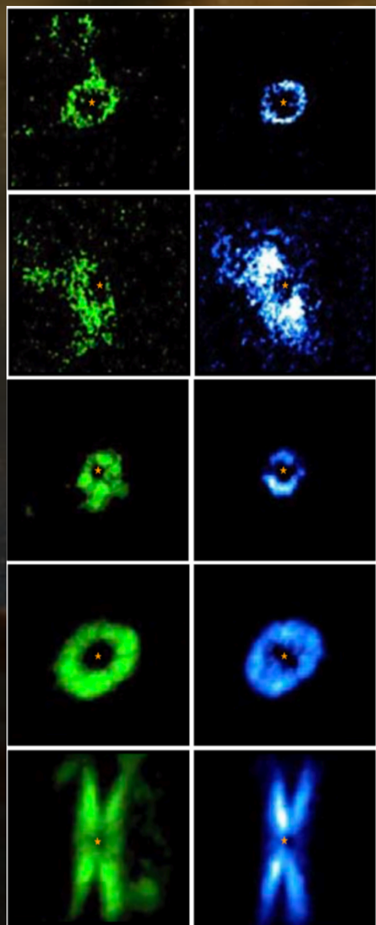
MODEL of CH3OH in GAS and ICES

how can we unveil molecules in the INNER DISK ?

if ALMA is BLIND due to dust opacity @mm
then observations @cm (dust optically thin)
may unveil the INNER DISK molecular reservoir

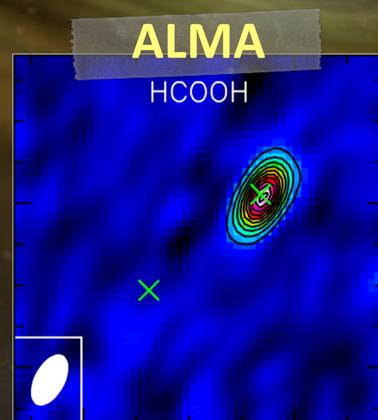
may VLA unveils simple organics in the INNER DISK ?

ALMA-DOT disks

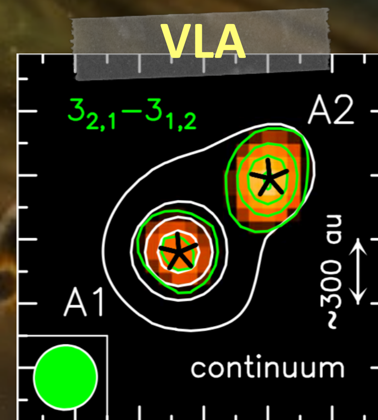


ALMA-DOT V. Garufi et al. 2021

ALMA & VLA observations of IRAS4A



Lopez-Sepulcre et al. 2017



De Simone et al. 2020

JVLA pilot project (PI: L. Podio)
to observe IRAS 04302
H2CO line @29 GHz @0.33" (~50 au)

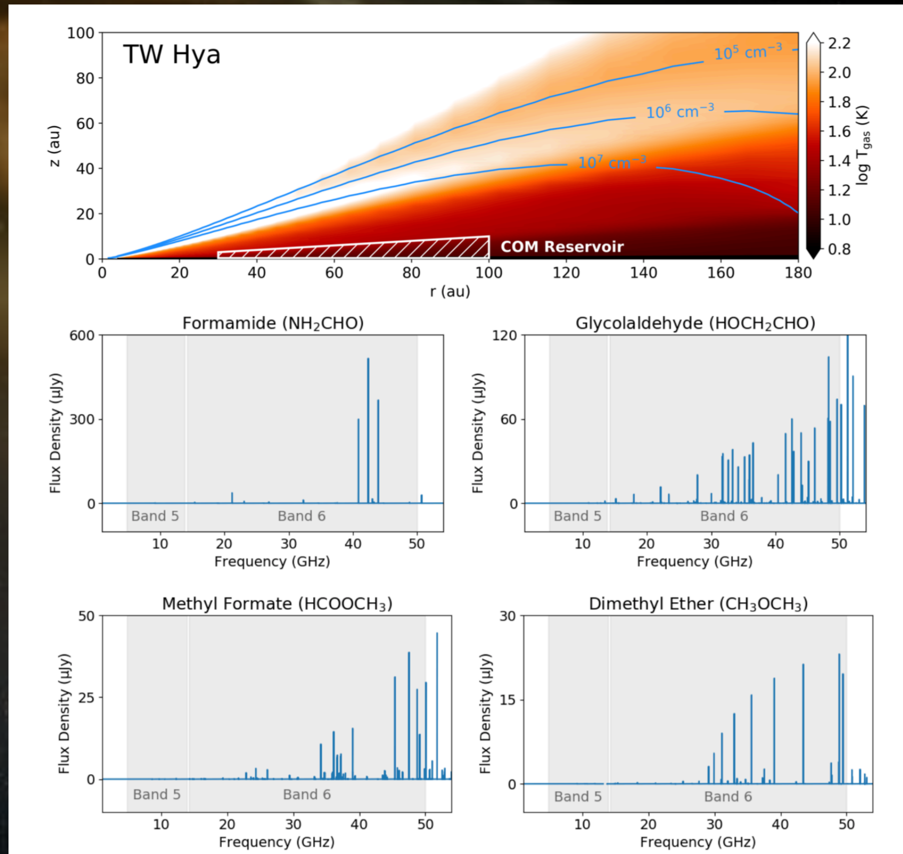
may SKA unveils COMs in the INNER 50 au of DISKs ?

advantages of observing COMs in disks @cm

- larger molecules preferentially emit at lower frequencies
- the spacing between rotational transitions increases as frequency decreases, reducing the effects of line blending or confusion.
- continuum opacities at 10’s of GHz (cm-wavelengths) are expected to be up to an order of magnitude lower than those in the millimetre regime

may SKA unveils COMs in the INNER 50 au of DISKs ?

Yes, but we need Band 6 !



Ilee et al. 2020
SKA1 Beyond 15GHz: The Science case for Band 6

Simulation of the disk-integrated line flux density under LTE in the disk of TW Hya (disk physical structure by Kama+ 2016, COMs abundance by Walsh+ 2014, 2016).

Key Science Project (KSP)
Cradle of Life
1000hr deep field integration of young cluster (Oph A).

The expected 3σ sensitivity of SKA1-MID in Band 6 (15–50GHz) would be 60–200μJy across a 1 km/s channel.