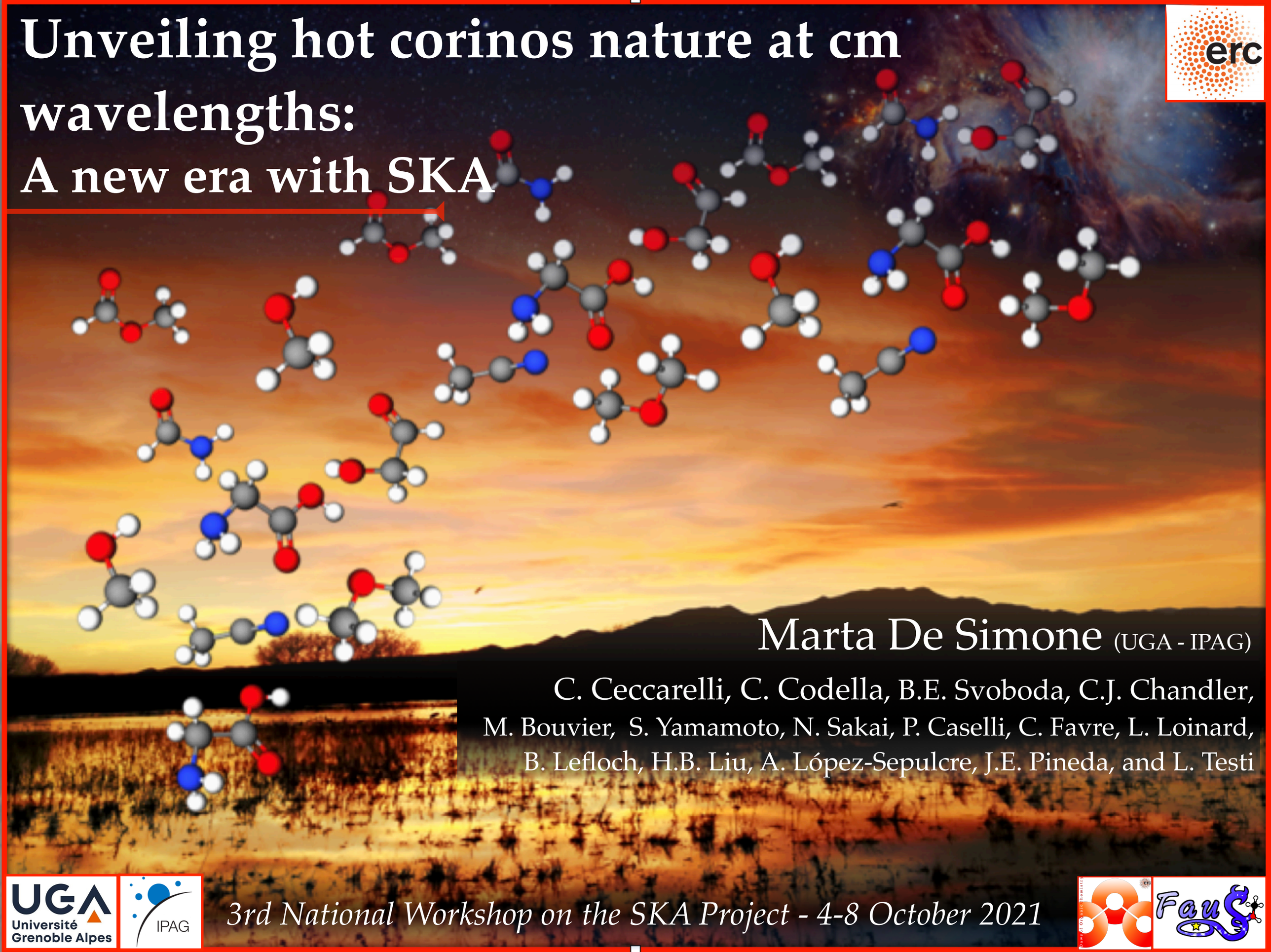
Unveiling hot corinos nature at cm wavelengths: A new era with SKA



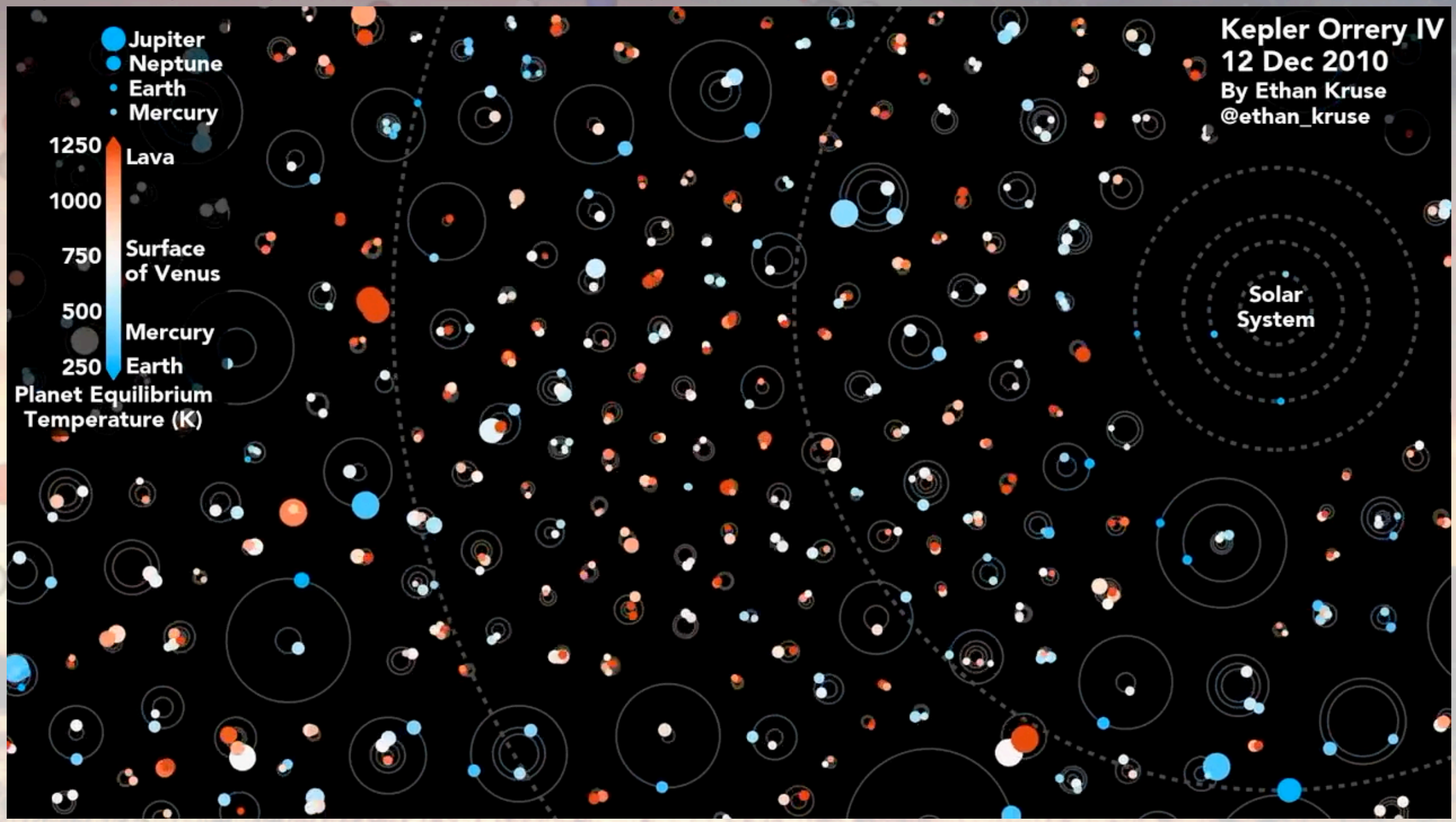
Marta De Simone (UGA - IPAG)

C. Ceccarelli, C. Codella, B.E. Svoboda, C.J. Chandler, M. Bouvier, S. Yamamoto, N. Sakai, P. Caselli, C. Favre, L. Loinard, B. Lefloch, H.B. Liu, A. López-Sepulcre, J.E. Pineda, and L. Testi

3rd National Workshop on the SKA Project - 4-8 October 2021

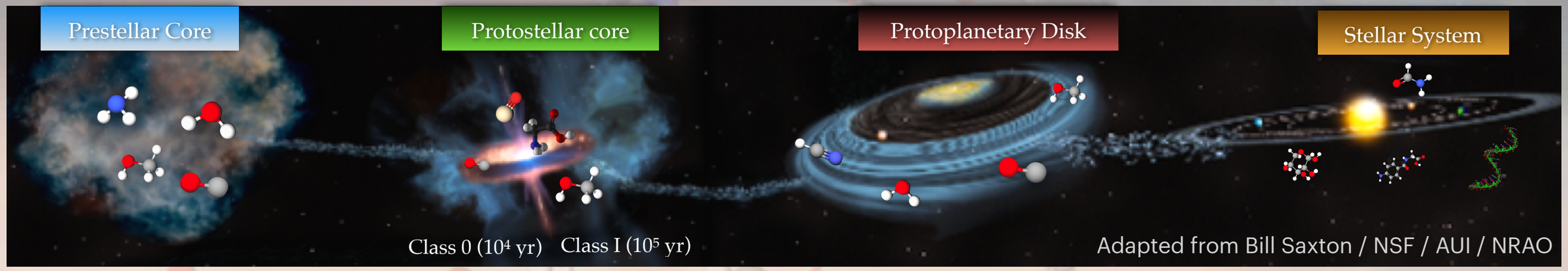
The origin of the diversity of planetary systems

Kepler multi-planet systems Nov2015 (Kepler Orrery IV) —> *https://www.youtube.com/watch?v=_DnDeBa0KFc*



Large variety of planetary systems all different from each other and from our Solar System

The importance of the early stages



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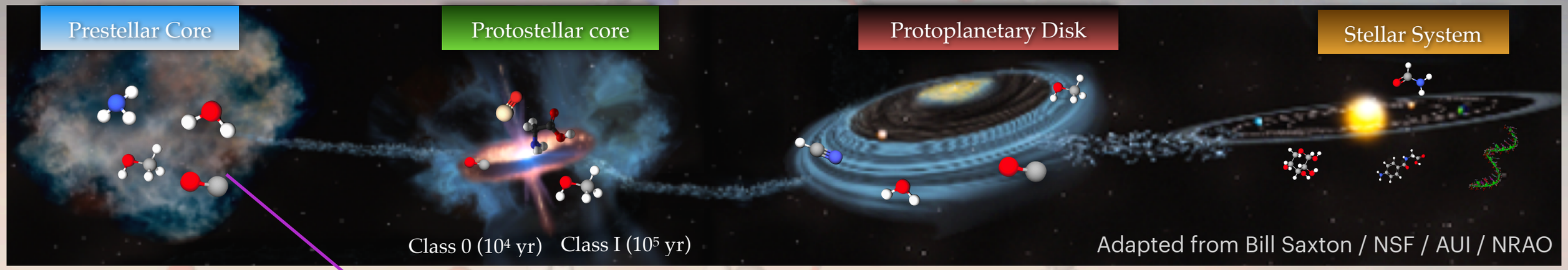
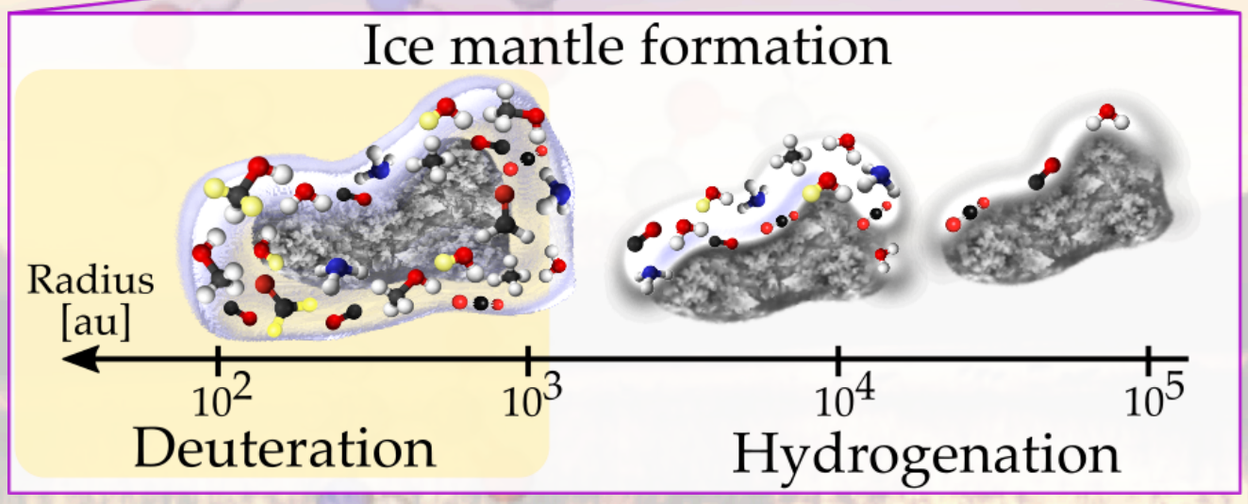
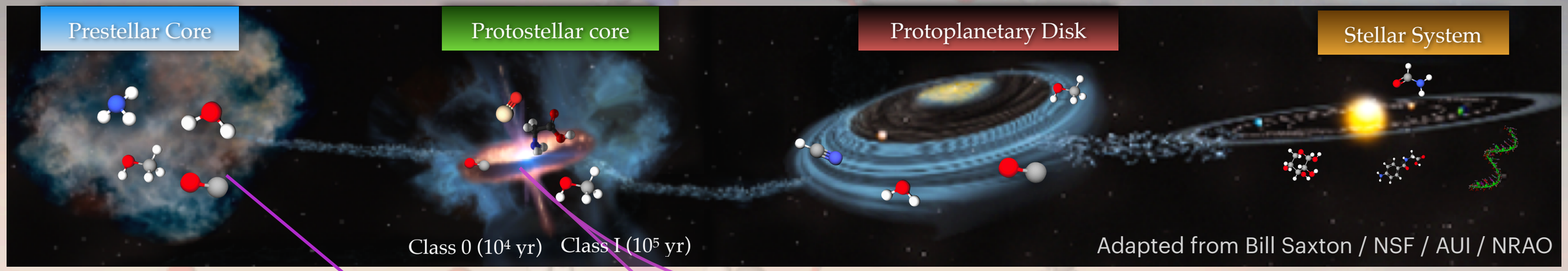
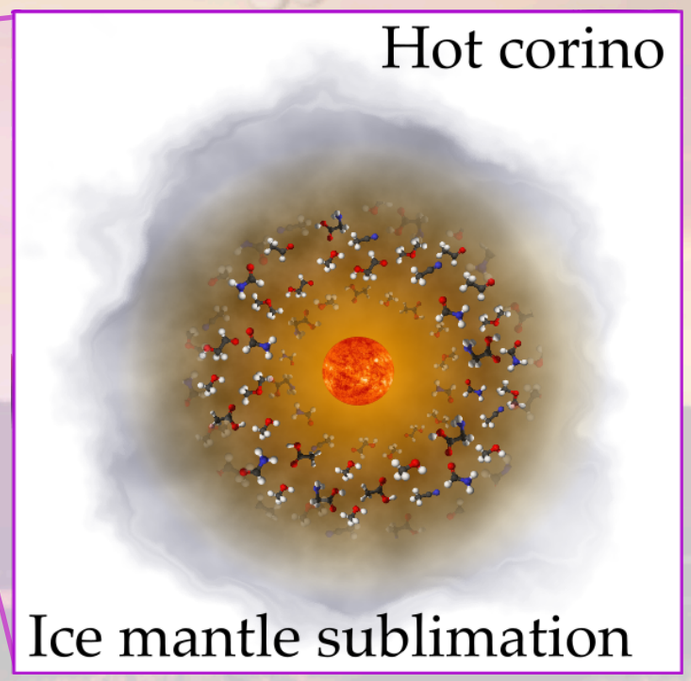




Formation of hydrogenated species

The importance of the early stages



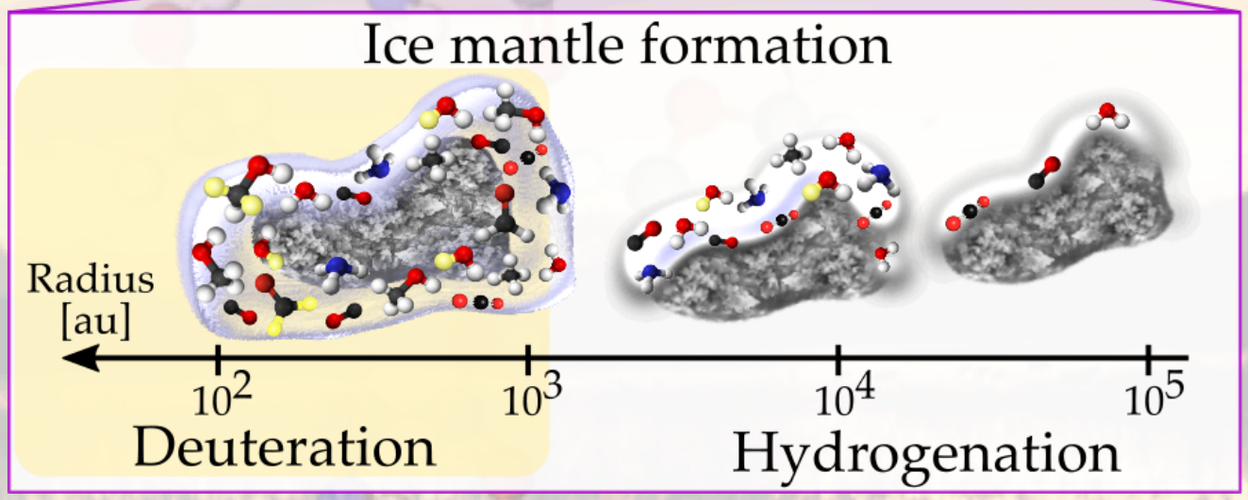


Envelope

Young protostar

iCOMs

Interstellar Complex Organic Molecules



Formation of hydrogenated species

Compact (<100 au), hot (>100 K), dense ($>10^7$ cm^{-3}) regions enriched in iCOMs

Ceccarelli 2004, Ceccarelli et al. 2007

On the origin of the chemical differentiation

APPARENT Diversity

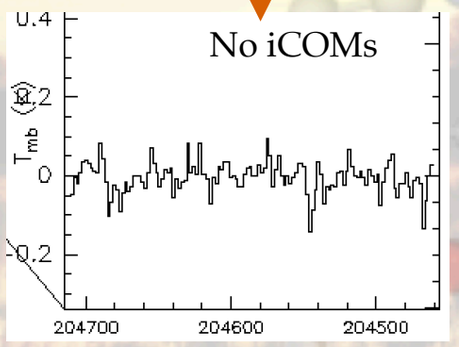
REAL Diversity

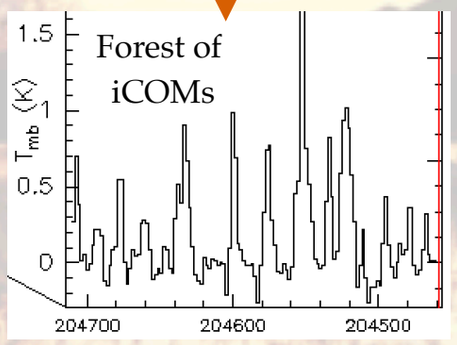
On the origin of the chemical differentiation

APPARENT Diversity

REAL Diversity

Optically thick dust absorb the lines

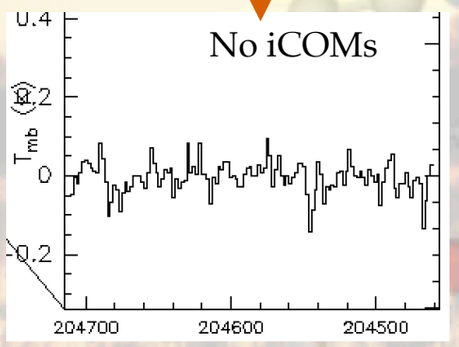


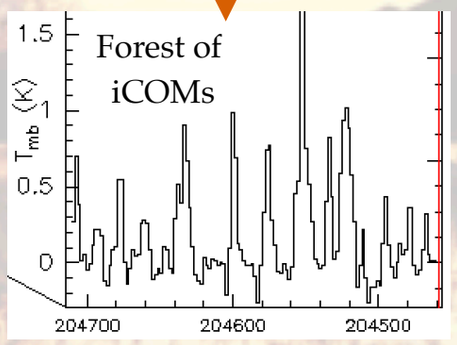


On the origin of the chemical differentiation

APPARENT Diversity

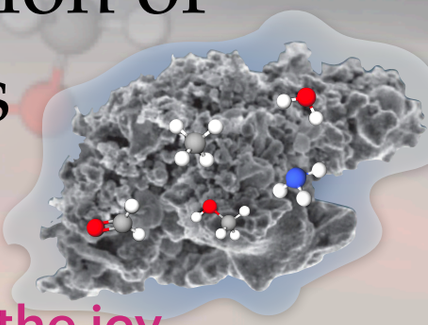
Optically thick dust absorb the lines





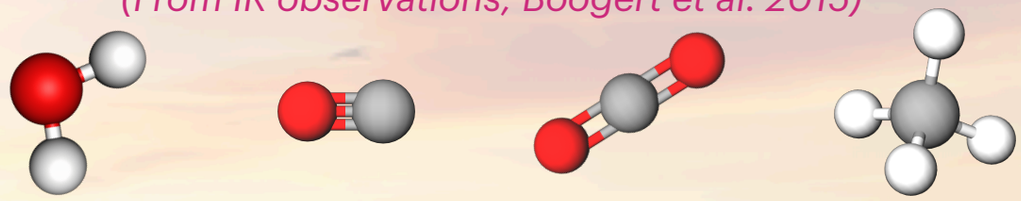
REAL Diversity

Different composition of grain mantles



Major components of the icy mantles of dust grains

(From IR observations, Boogert et al. 2015)



On the origin of the chemical differentiation

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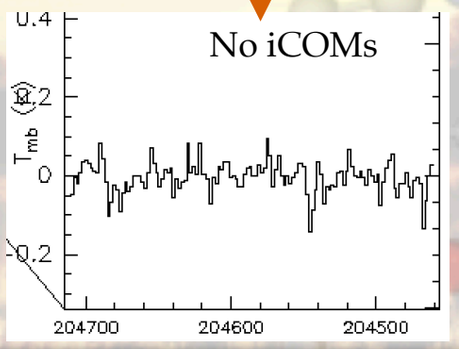

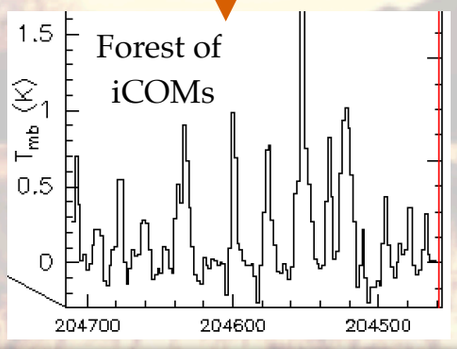

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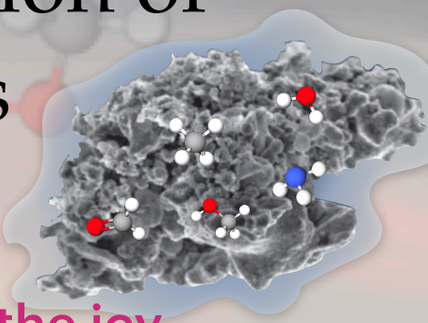

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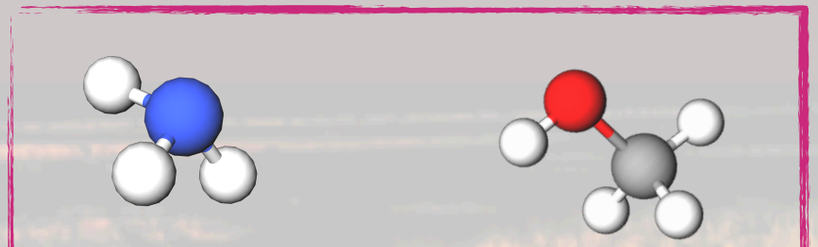
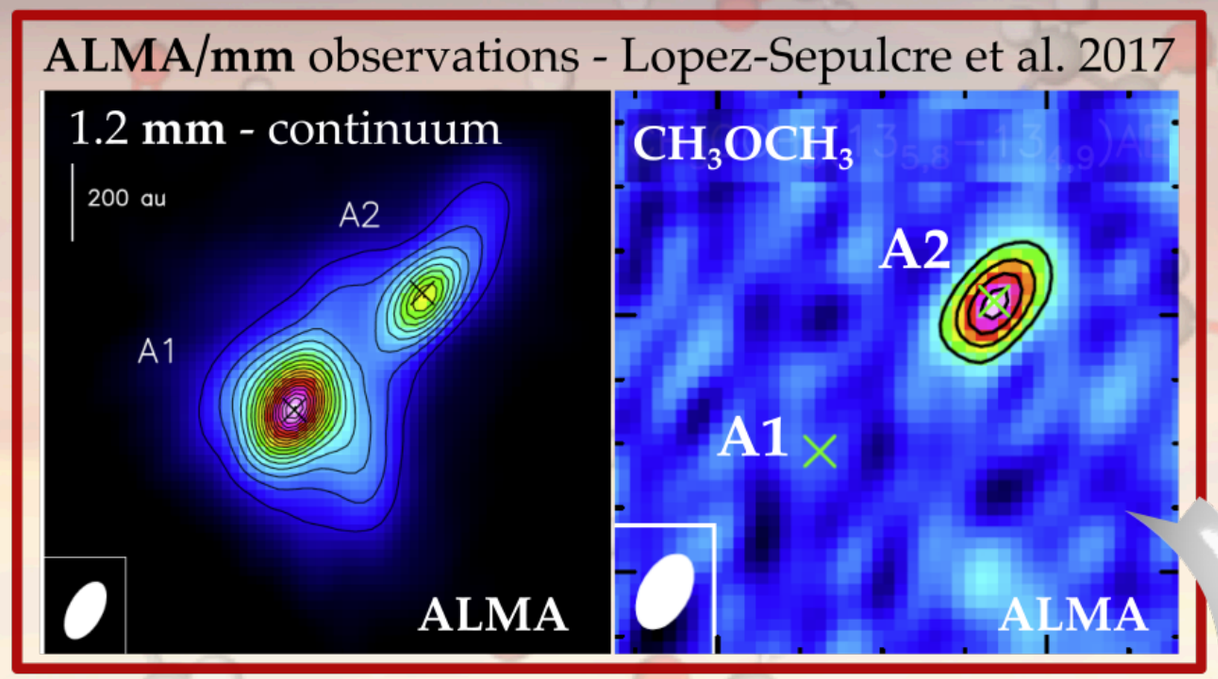


Cm interferometric observations are the **key**: NH_3 and CH_3OH are simultaneously observable and the dust is likely optically thin also at planet-formation scales

Observing at cm wavelengths:
The dust contribution

Check out *De Simone et al. 2020*

The IRAS 4A binary system



While IRAS 4A2 has a hot corino region, IRAS 4A1 does **not**.

Observing at cm wavelengths:
The dust contribution

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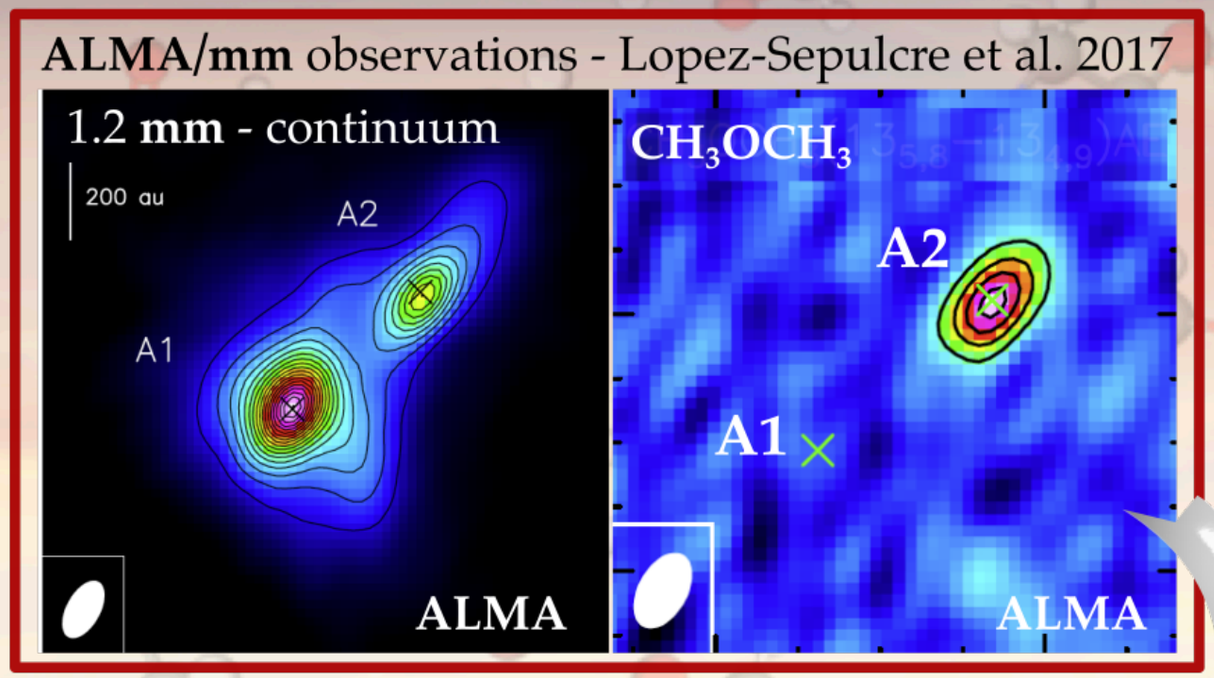

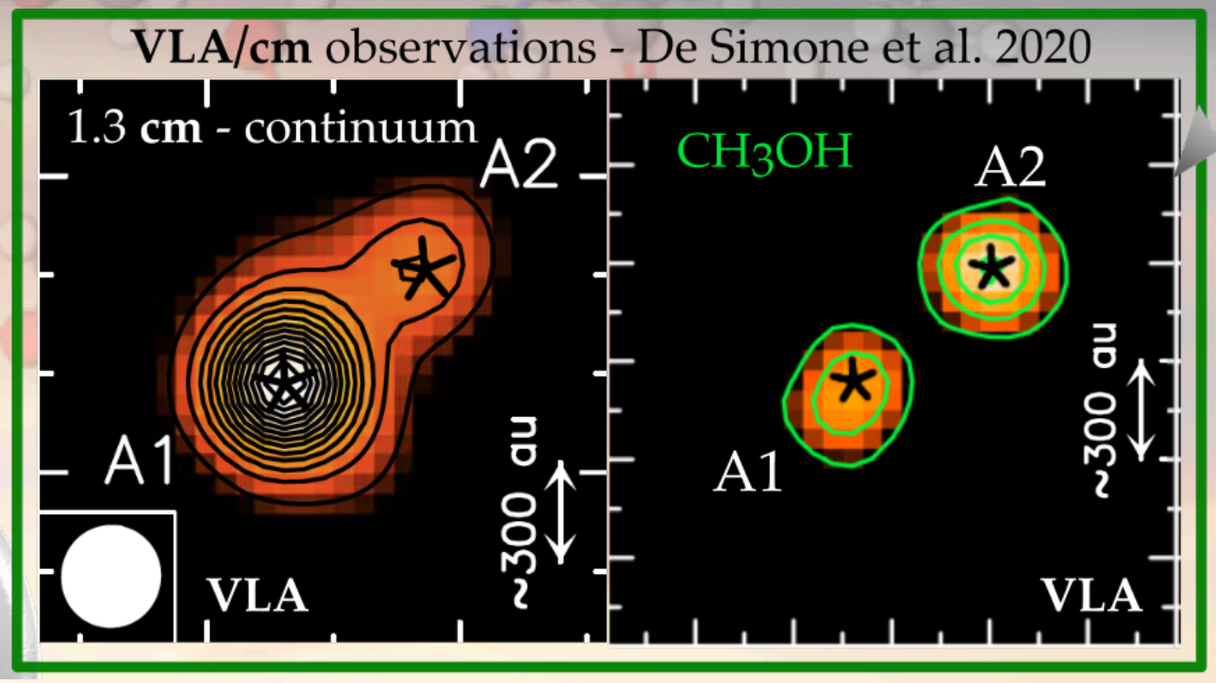

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Both IRAS 4A1 and IRAS 4A2 have a Hot Corino!

Observing at cm wavelengths:
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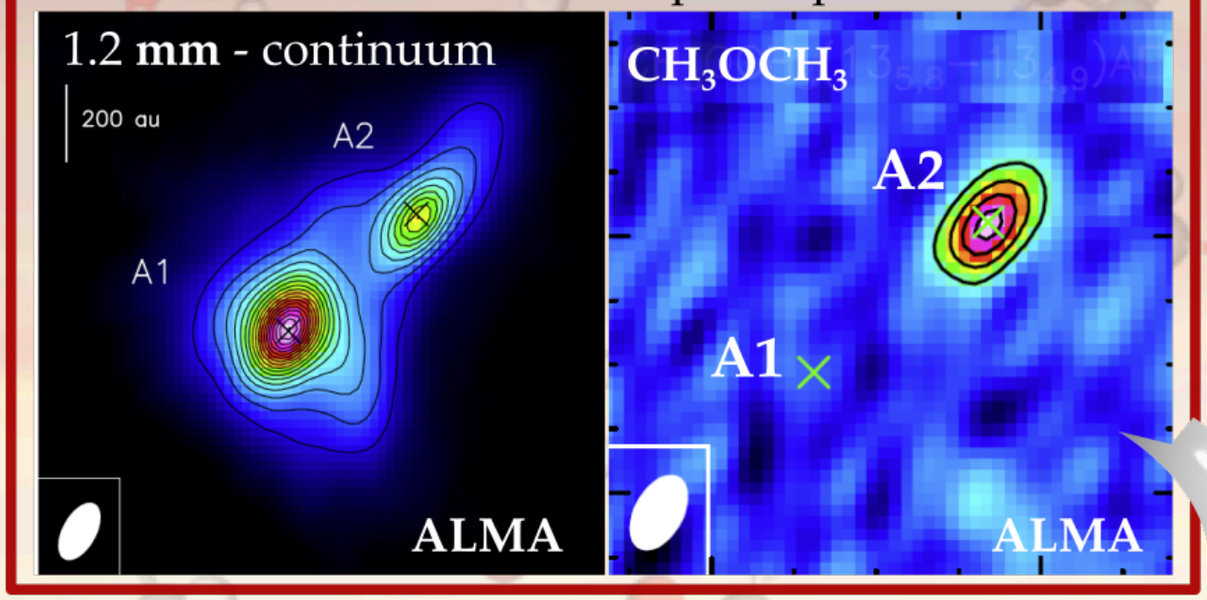
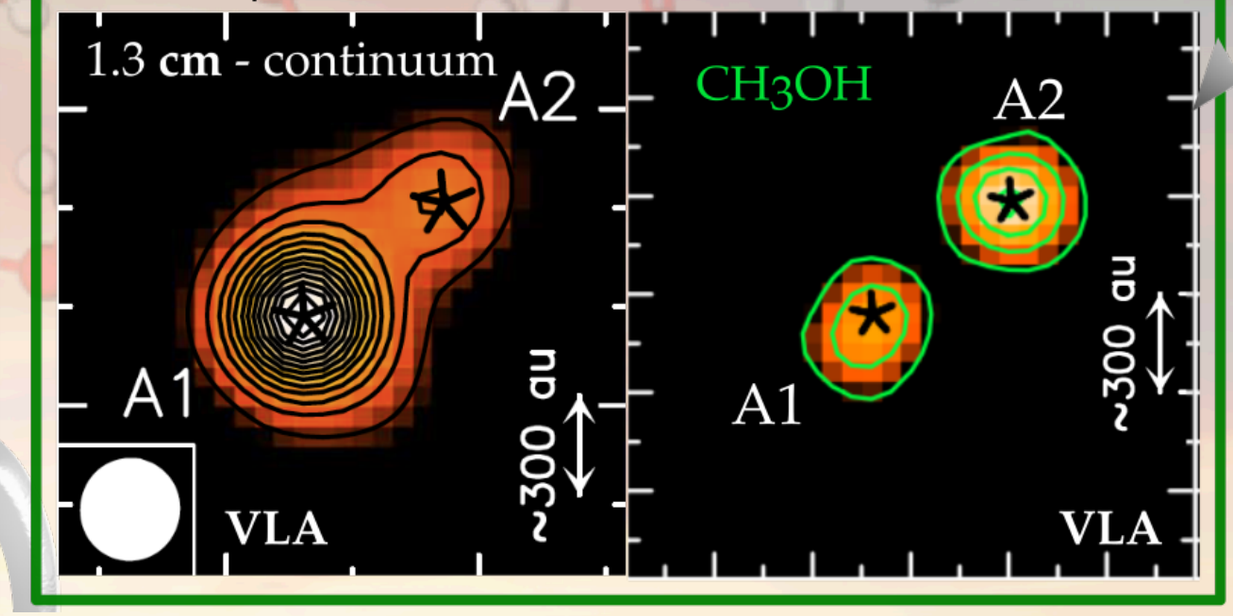
The IRAS 4A binary system

Check out *De Simone et al. 2020*

ALMA/mm observations - Lopez-Sepulcre et al. 2017



VLA/cm observations - De Simone et al. 2020



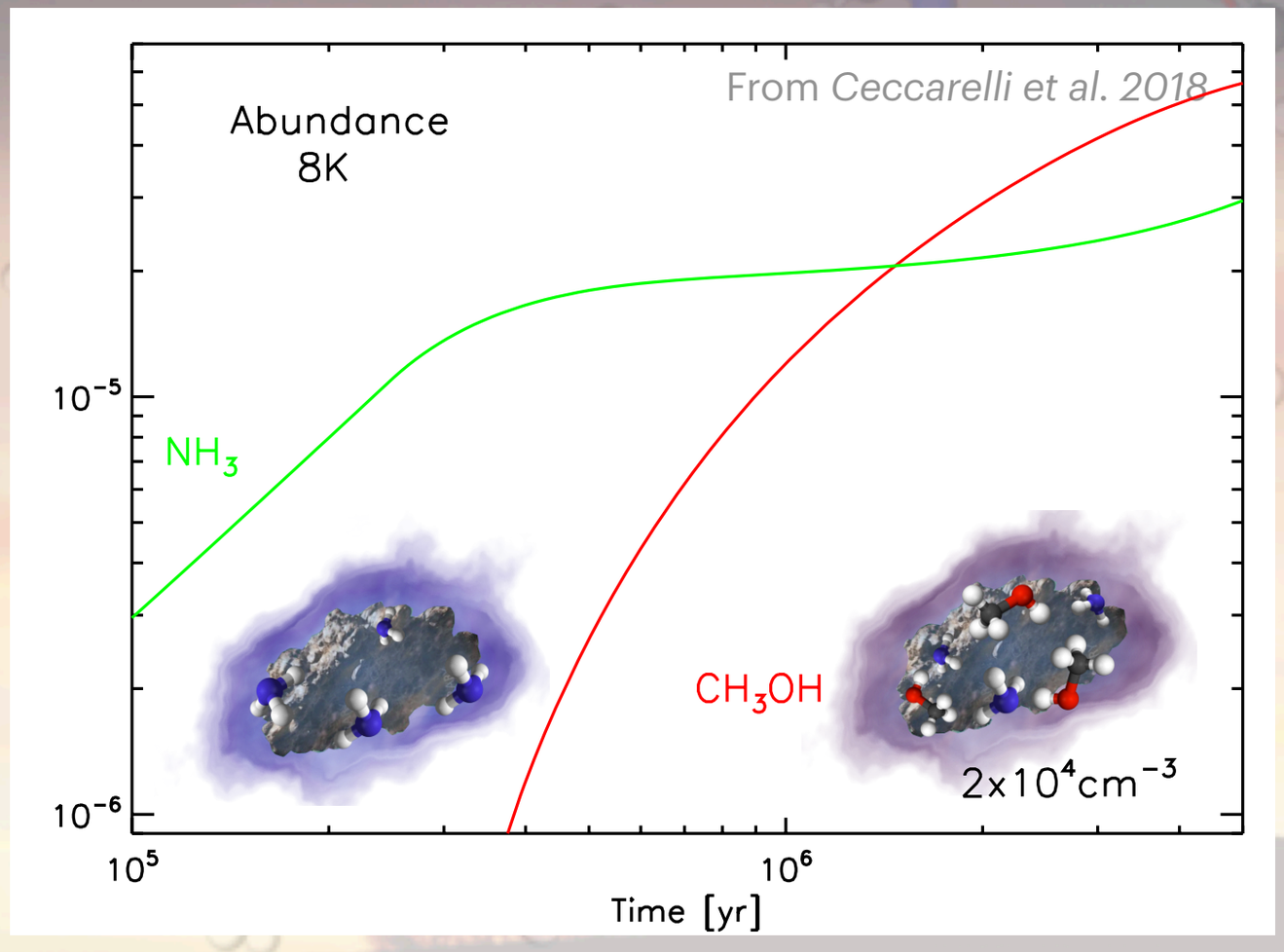
While IRAS 4A2 has a hot corino region, IRAS 4A1 does **not**.

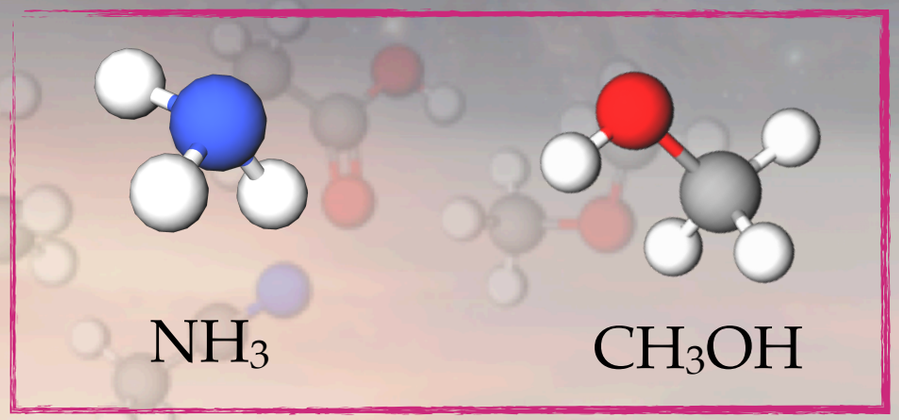
Both IRAS 4A1 and IRAS 4A2 have a Hot Corino!

4A1 and 4A2 are **not** chemically different

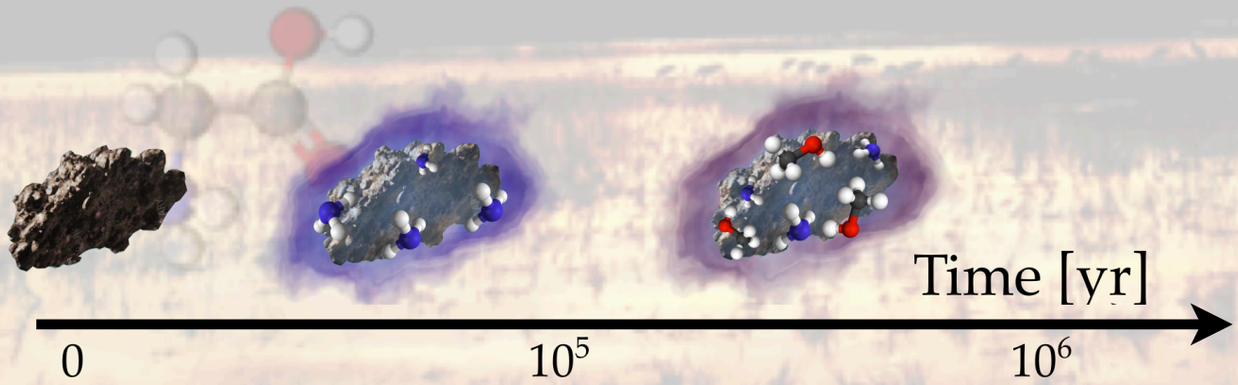
⚠ iCOMs abundances at millimeter wavelengths are underestimated

Observing at cm wavelengths:
The ice mantle history





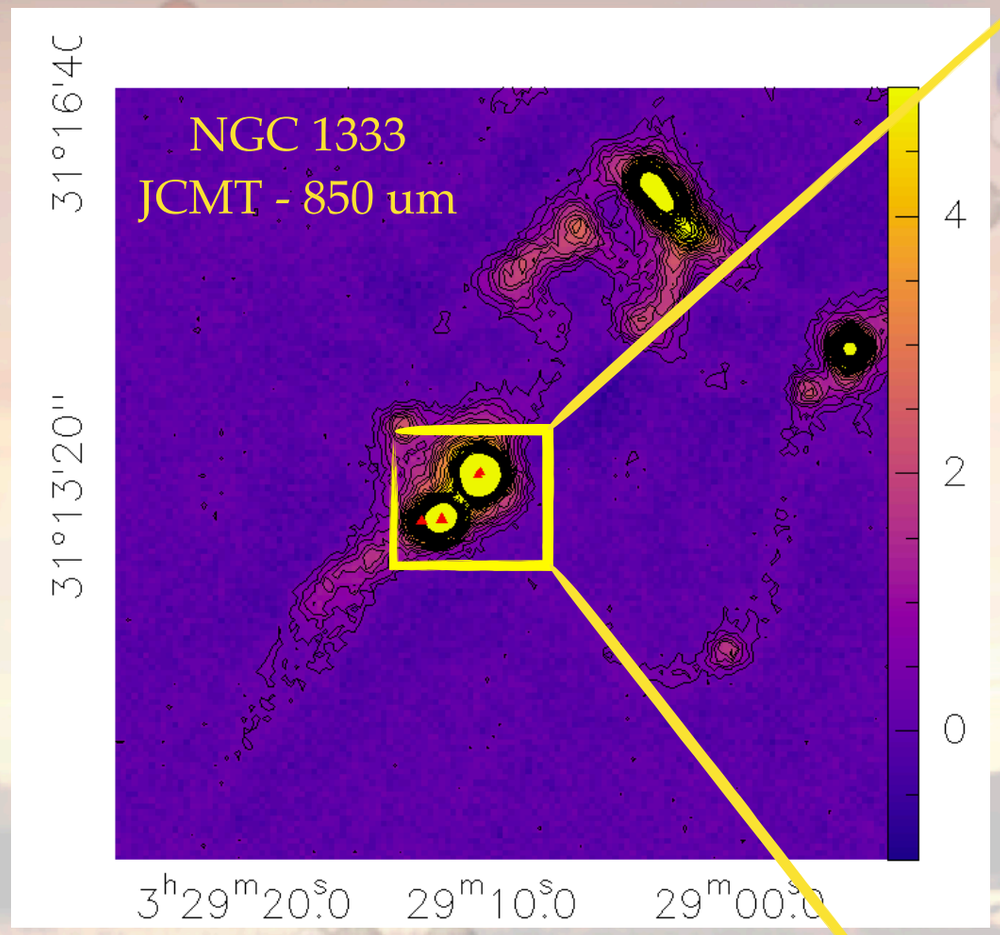
The NH_3 and CH_3OH relative abundance depends on the clump **temperature** and **density**, and the ice mantle formation **timescale**

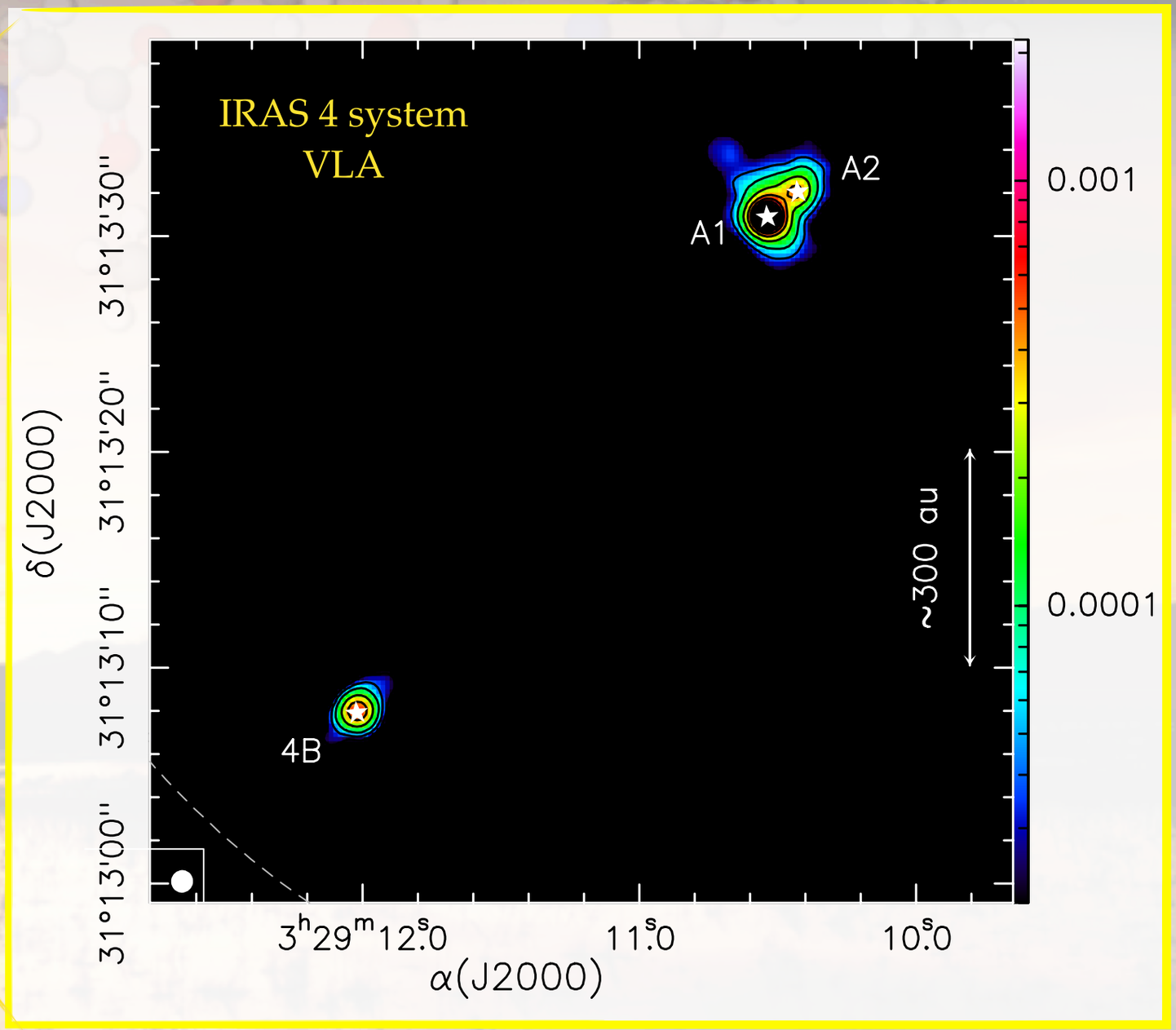


e.g, an old grain mantle would be likely enriched in CH_3OH

Observing at cm wavelengths:
The ice mantle history

Observing CH_3OH and NH_3 emission in three protostars in the NGC 1333 region





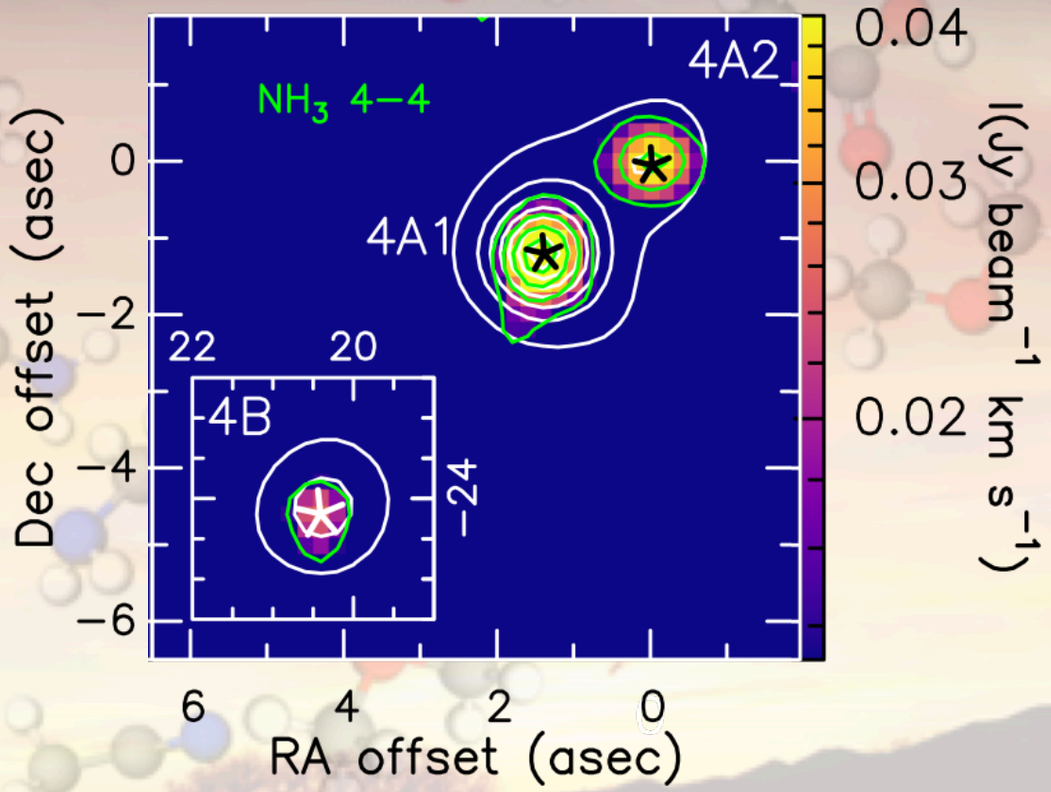
Continuum emission

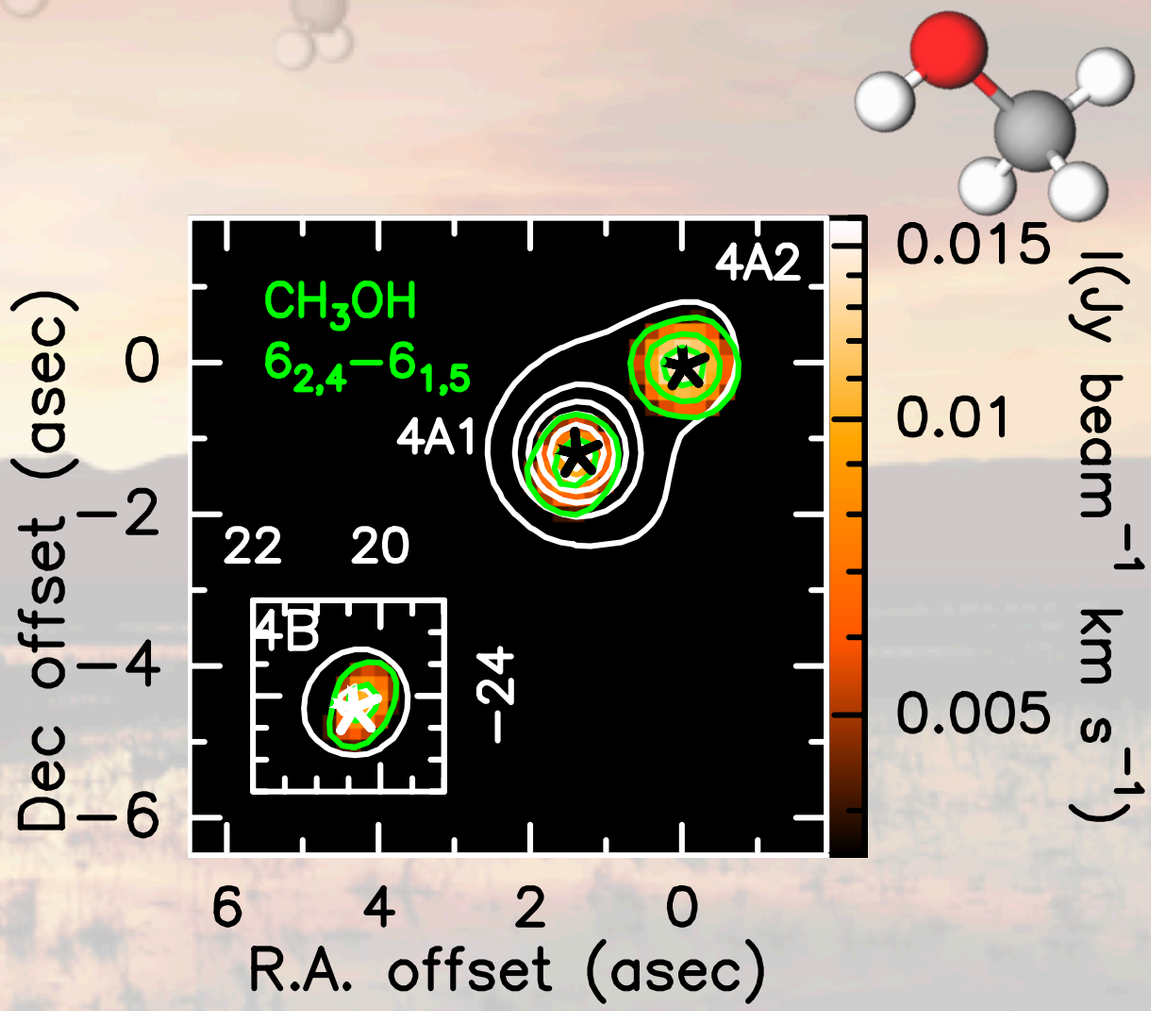
Observing at cm wavelengths:
The ice mantle history

Detection of compact CH_3OH and NH_3 emission in three protostars in the NGC 1333 region

De Simone et al. in submission

Line emission





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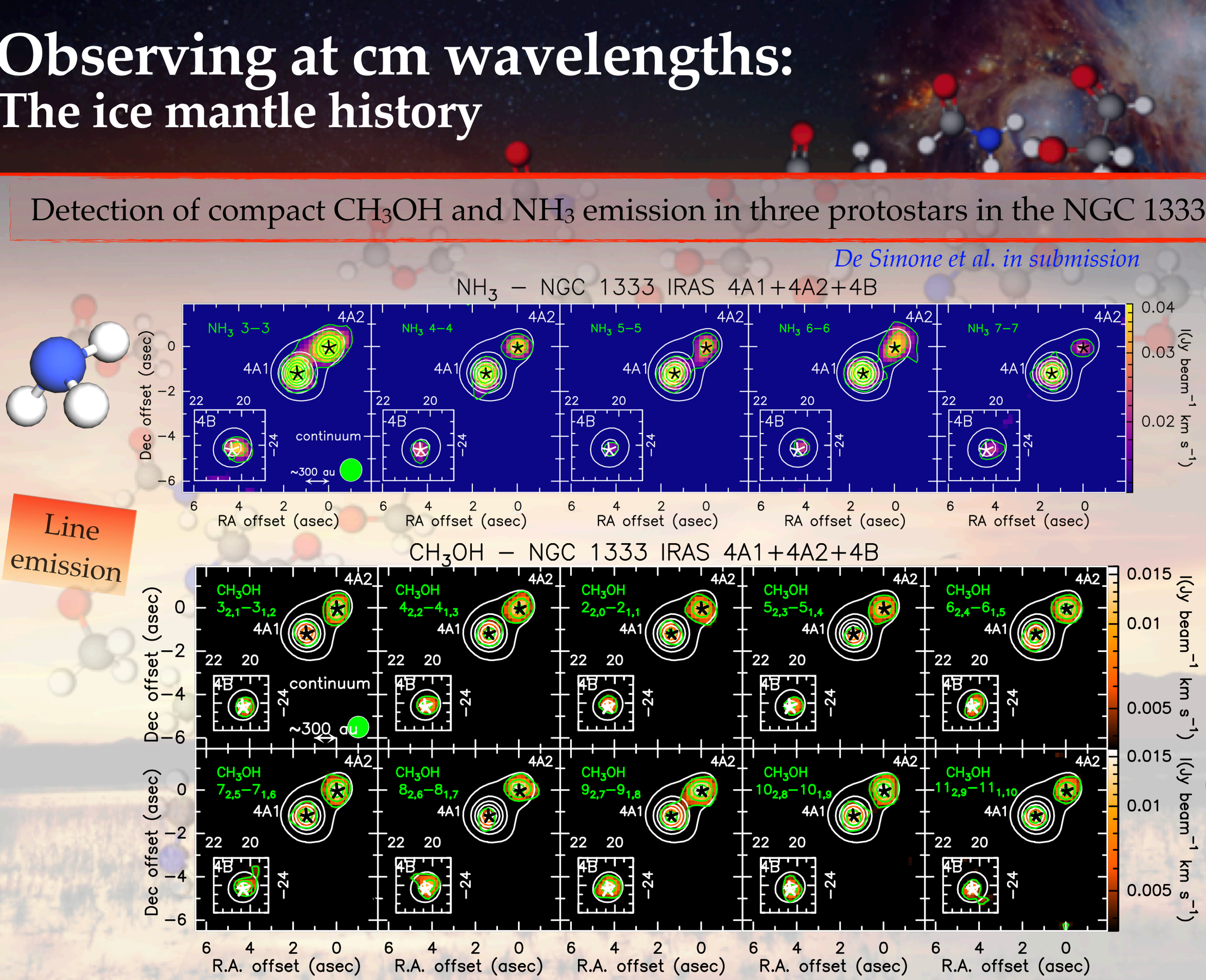

Line emission

Observing at cm wavelengths:
The ice mantle history

With a non-LTE LVG analysis we derived the abundance ratio —>

De Simone et al. in submission

IRAS 4A1

$$\frac{NH_3}{CH_3OH} < 0.5$$

IRAS 4A2

$$\frac{NH_3}{CH_3OH} < 3$$

IRAS 4B

$$\frac{NH_3}{CH_3OH} < 15$$

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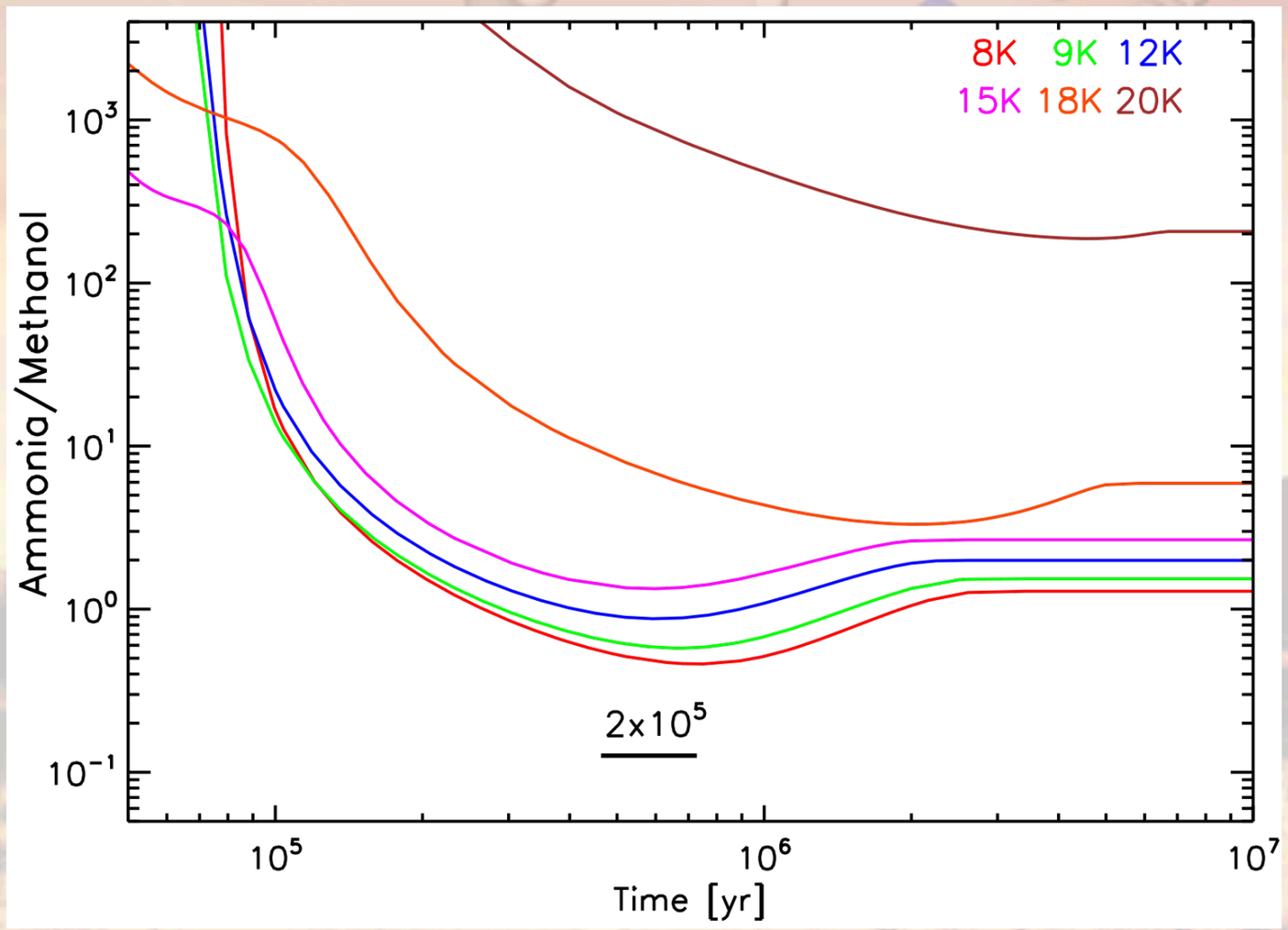

GRAINOBLE model
(*Taquet et al. 2012, 2013*)
Ceccarelli et al. 2018

How do the curves change varying the density?

Observing at cm wavelengths:
The ice mantle history

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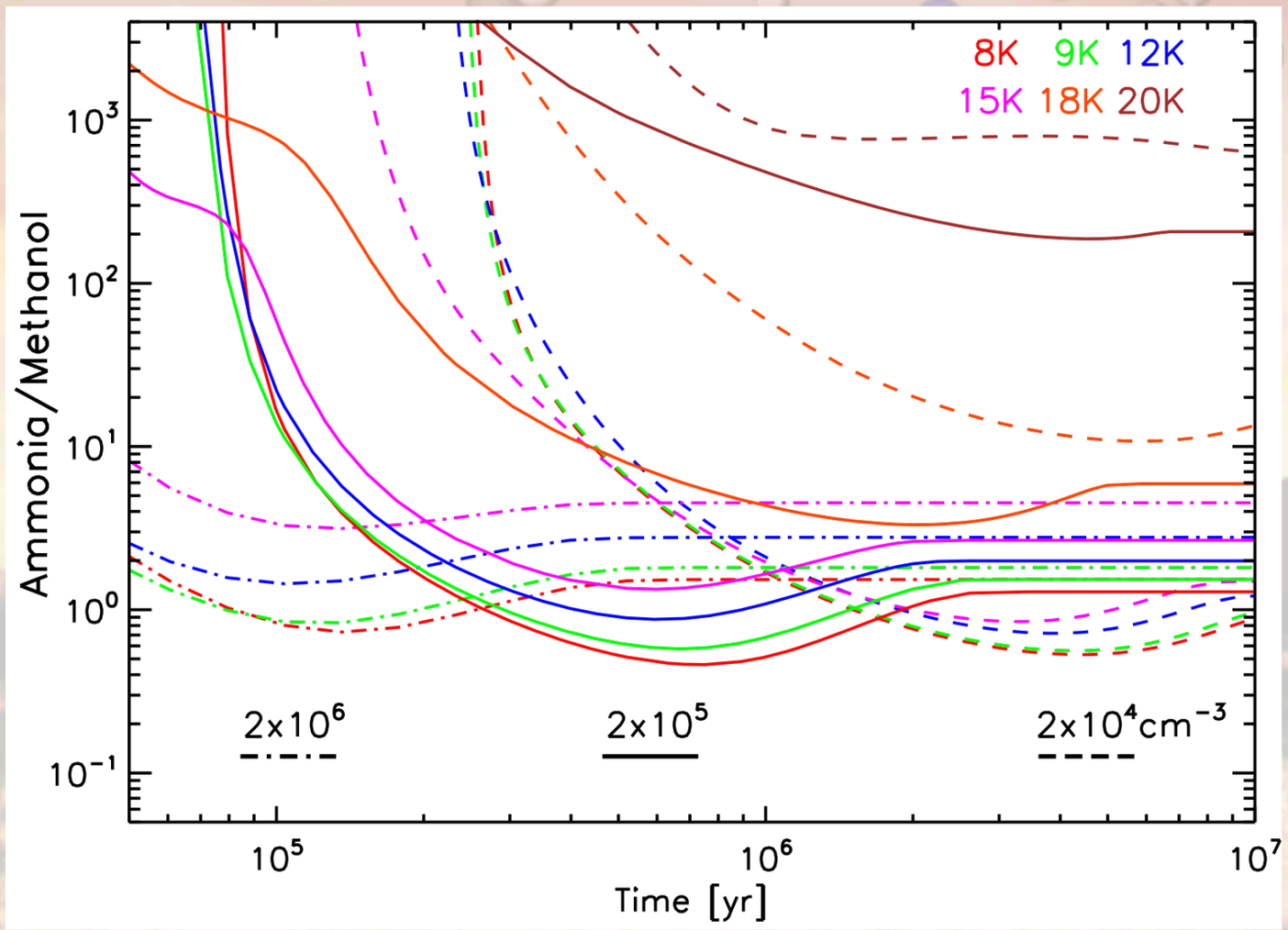

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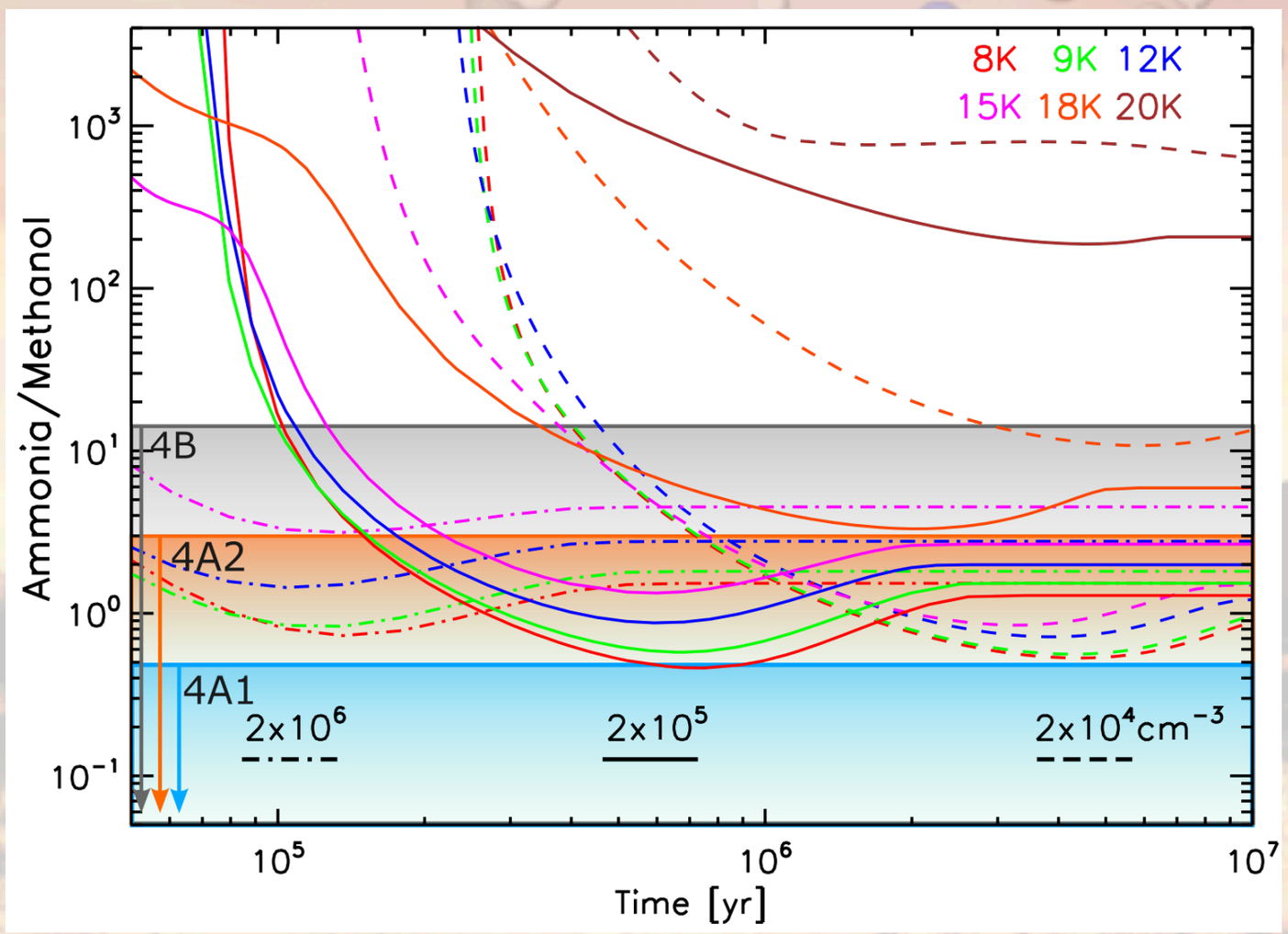

We can constrain the clump **temperature** for ALL the three protostars!

IRAS 4B —> $T \leq 18$ K

IRAS 4A2 —> $T \leq 12 - 15$ K

IRAS 4A1 —> $T \leq 8$ K

But…for IRAS 4A1
we can say something more…

Observing at cm wavelengths:
The ice mantle history

With a non-LTE LVG analysis we derived the abundance ratio —>

De Simone et al. in submission

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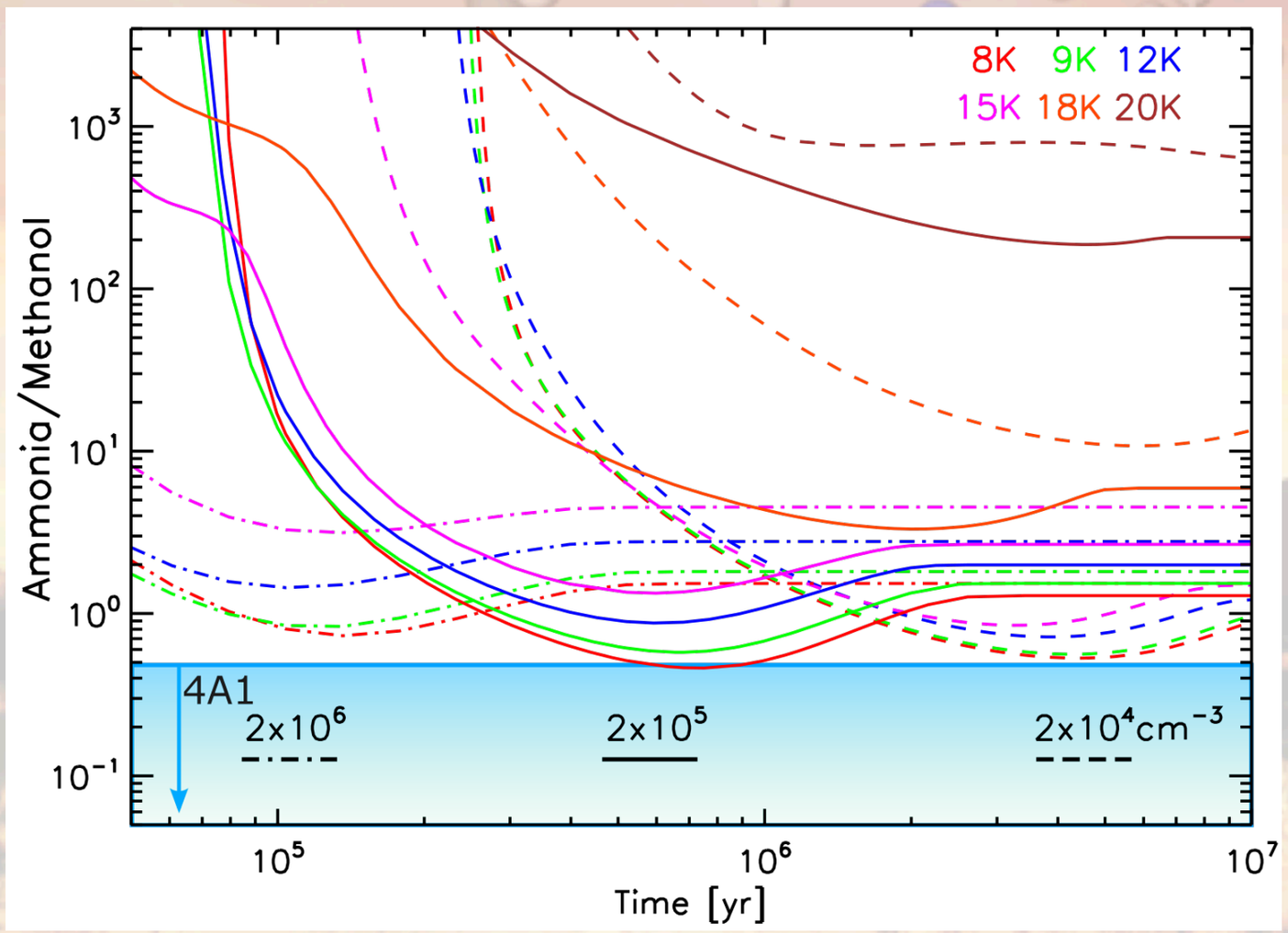


Indeed we can constrain ALSO the clump **density** and ice mantle formation **timescale**!

IRAS 4A1 pre-collapse clump

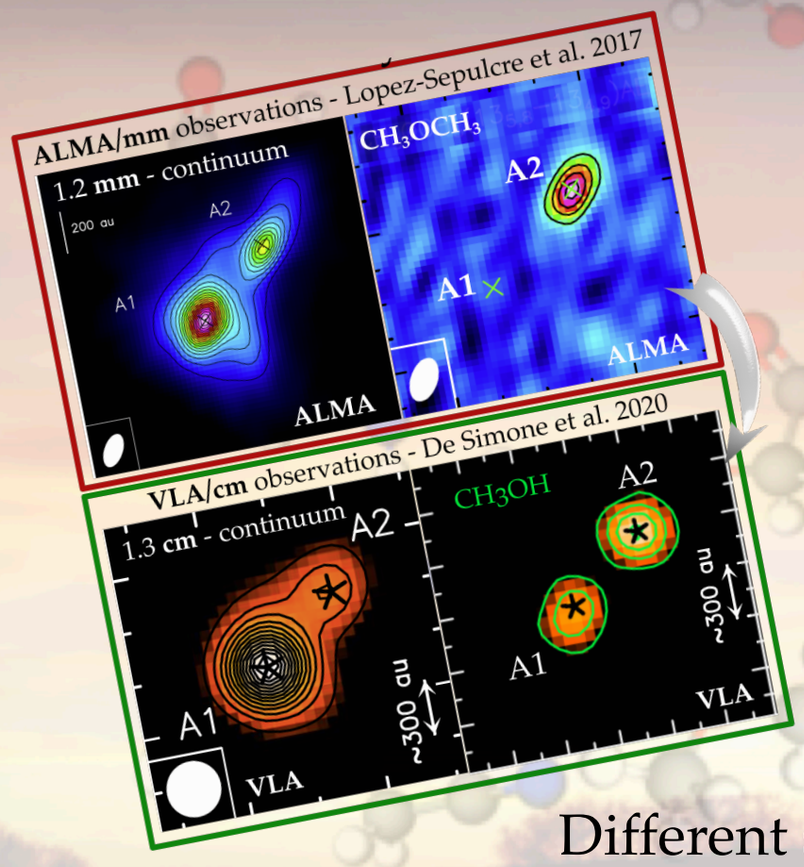
$T \leq 8$ K

$n_{H_2} \sim 10^5$ cm^{-3}

time $= 5 - 9 \times 10^5$ yr

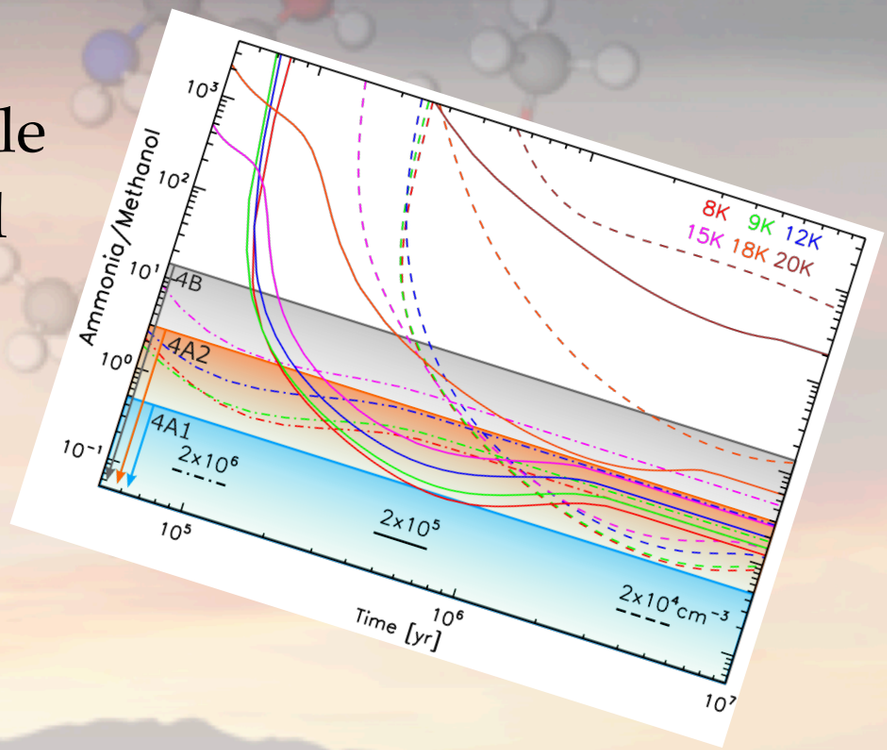
Take home messages looking to the future…

Centimeter observations of hot corinos are crucial for their correct study



We can constrain the ice mantle history without being biased by dust opacity effects

What do we need?



More sources;
Different star forming regions - different environments;
Complementarity of cm and mm observations!

These observations will serve as a testbed for future results that can be obtained with ngVLA and SKA.

SKA SQUARE KILOMETRE ARRAY

The unprecedented SKA sensitivity and resolution will be a breakthrough

Unveiling hot corinos nature at cm wavelengths

Marta De Simone (UGA - IPAG)

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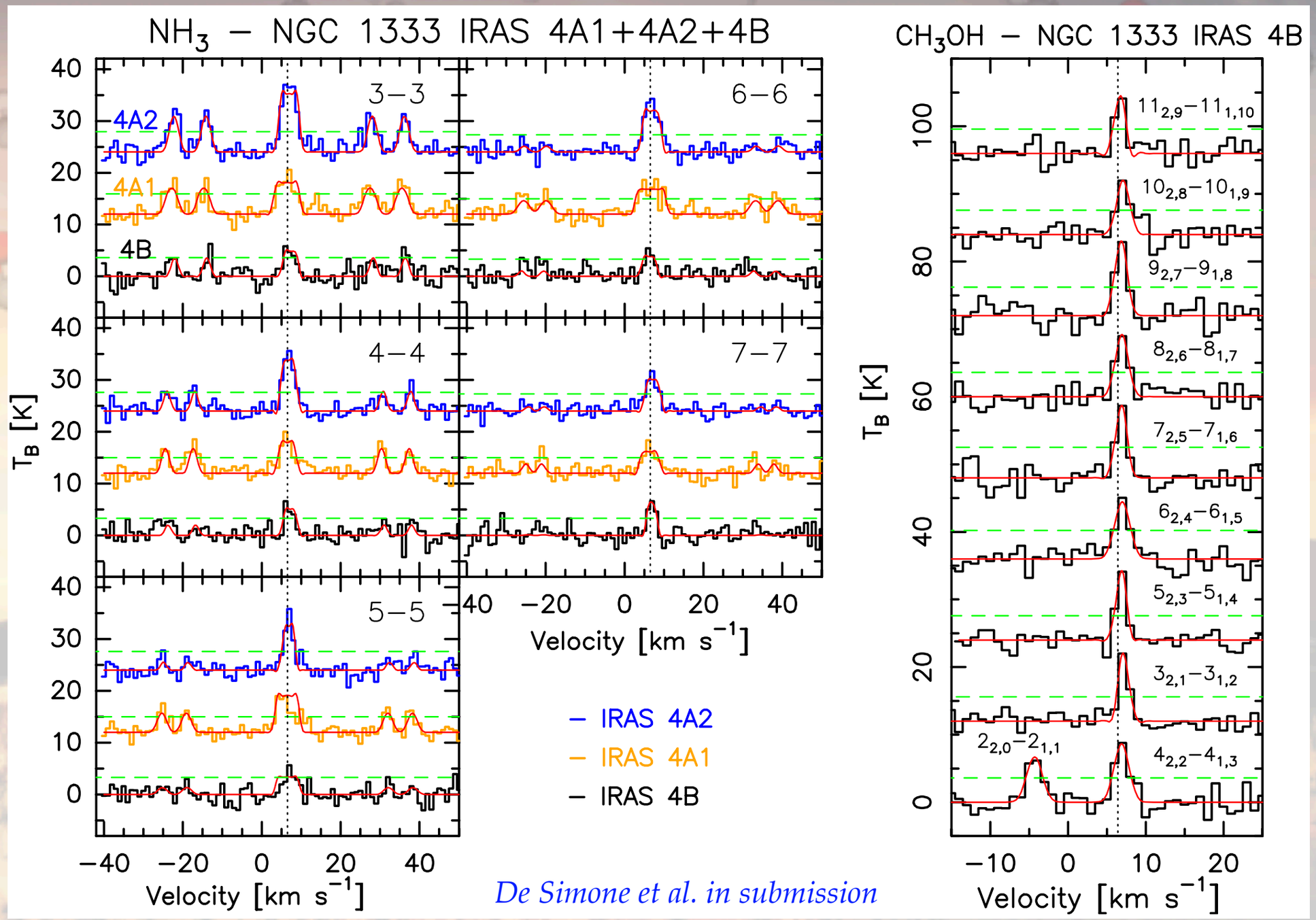
Astrobigné - INAF Arcetri - 28 September 2021

Observing at cm wavelengths:
The ice mantle history

CH_3OH and NH_3 spectra extracted at the continuum peak of the three protostars



De Simone et al. in submission