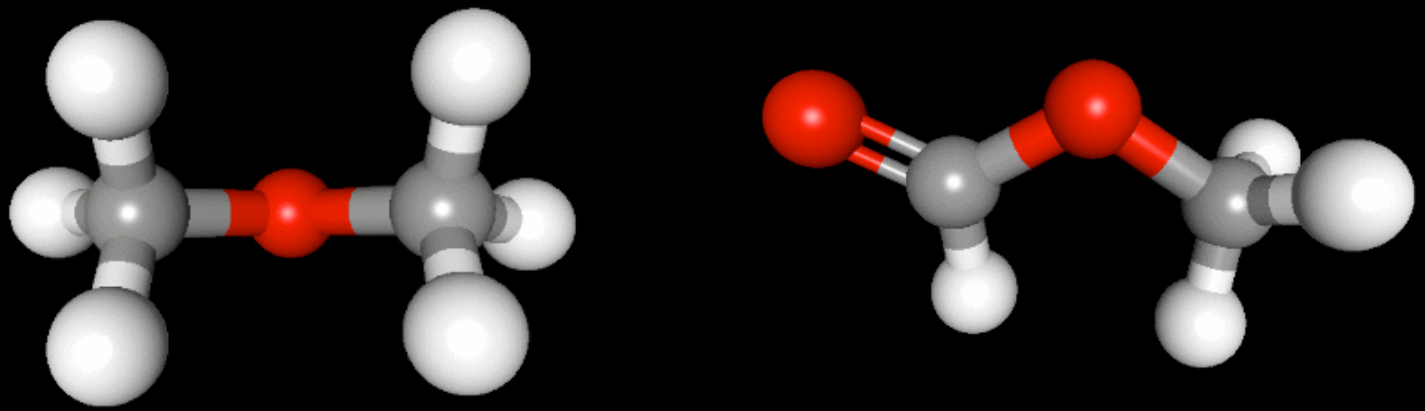
Dimethyl Ether and Methyl Formate (DME & MF)



Cecilia Ceccarelli
Institut de Planétologie et d'Astrophysique de Grenoble

With billions thanks to:
N.Balucani, E.Bianchi, C.Codella, A.Jaber, F.Fontani, C.Kahane, B.Lefloch, A.Lopez-Sepulcre, A.Rimola, V.Taquet, P.Ugliengo

Dimethyl Ether and Methyl Formate (DME & MF)
Mimì e Cocò: inseparable friends

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Institut de Planétologie et d'Astrophysique de Grenoble
With billions thanks to:
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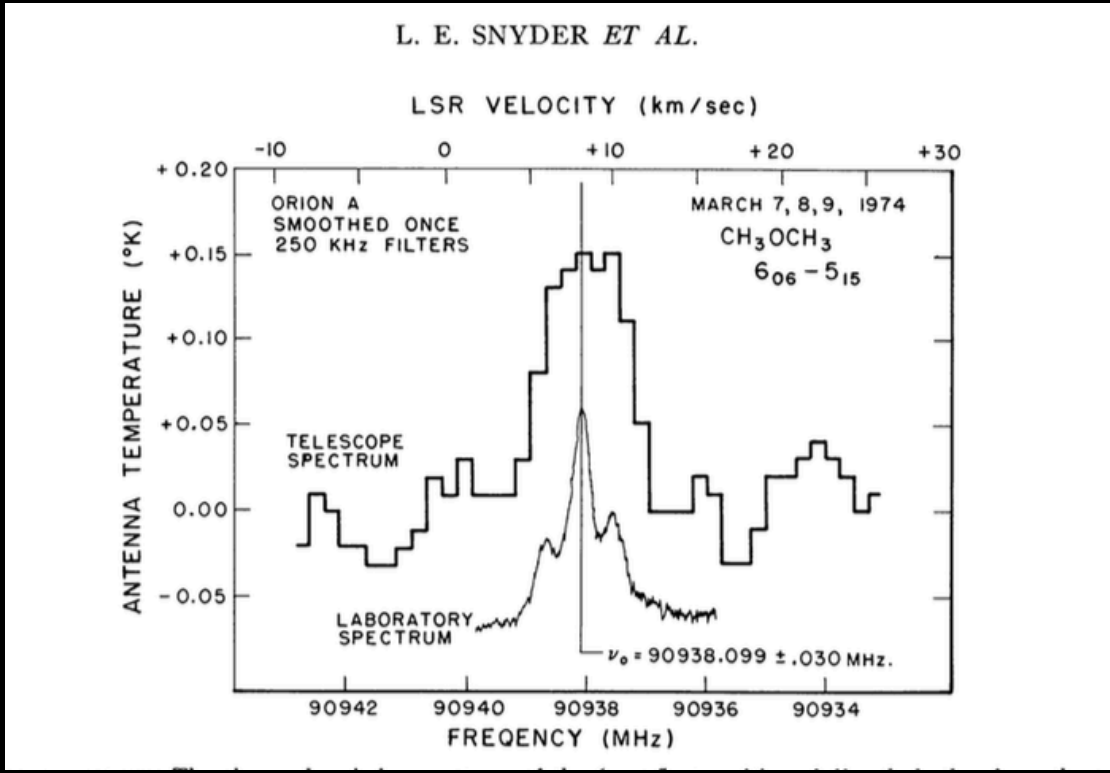
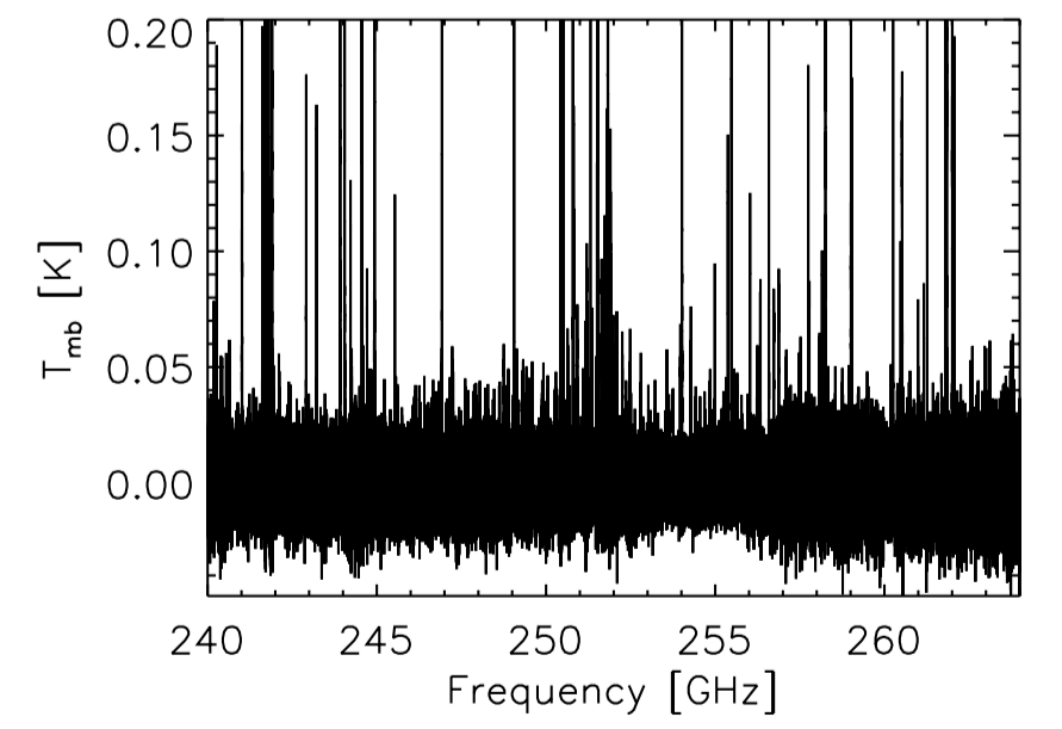
HISTORYCAL BACKGROUND: old days

➔ DME & MF HAVE BEEN DETECTED IN THE ISM ALREADY IN 1974… SO THEY ARE OLD FRIENDS OF ASTROCHEMISTS



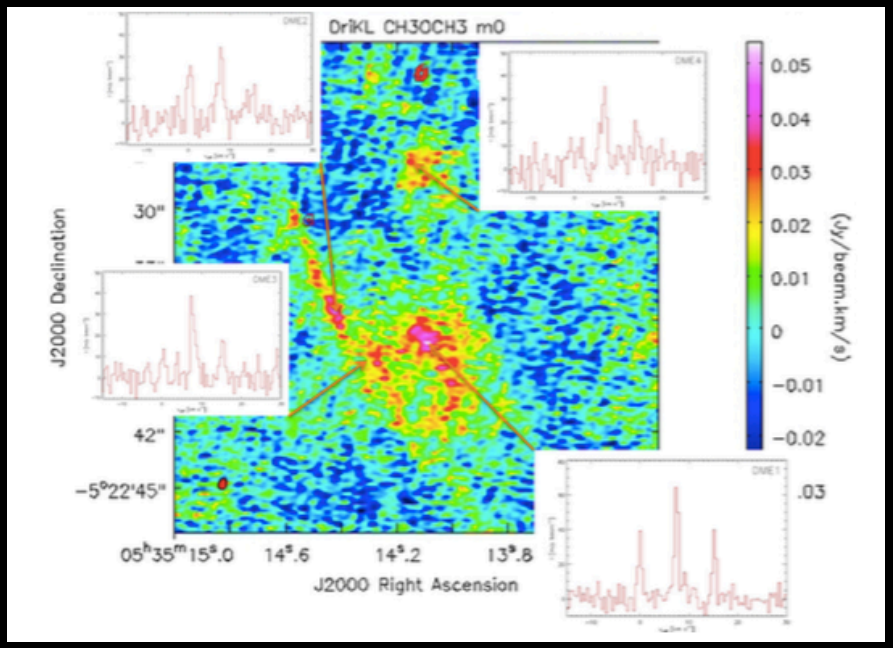
HISTORYCAL BACKGROUND: nowadays

➔ DME & MF HAVE BEEN DETECTED IN THE ISM ALREADY IN 1974… SO THEY ARE OLD FRIENDS OF ASTROCHEMISTS

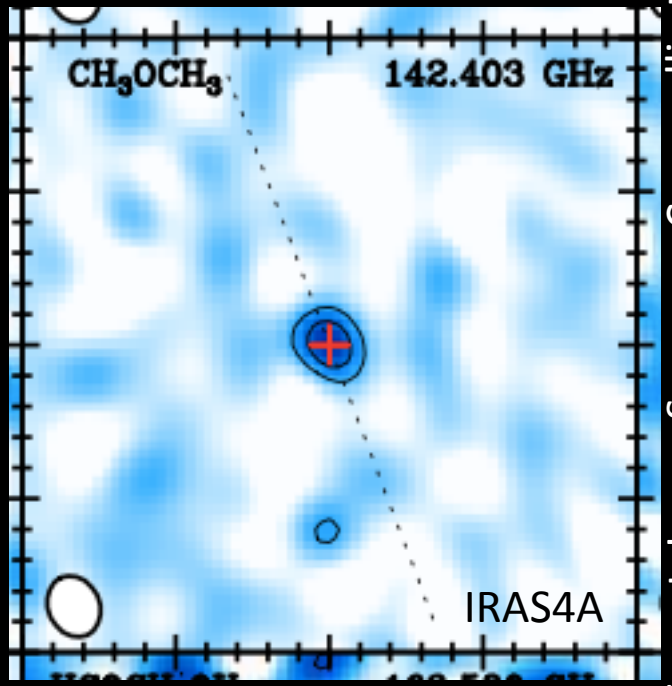


SINCE THEN MANY MORE SOURCES AND LINES: e.g. ASAI

INTERFEROMETRY STUDIES



Favre, Wootten, Remijan, et al 2011

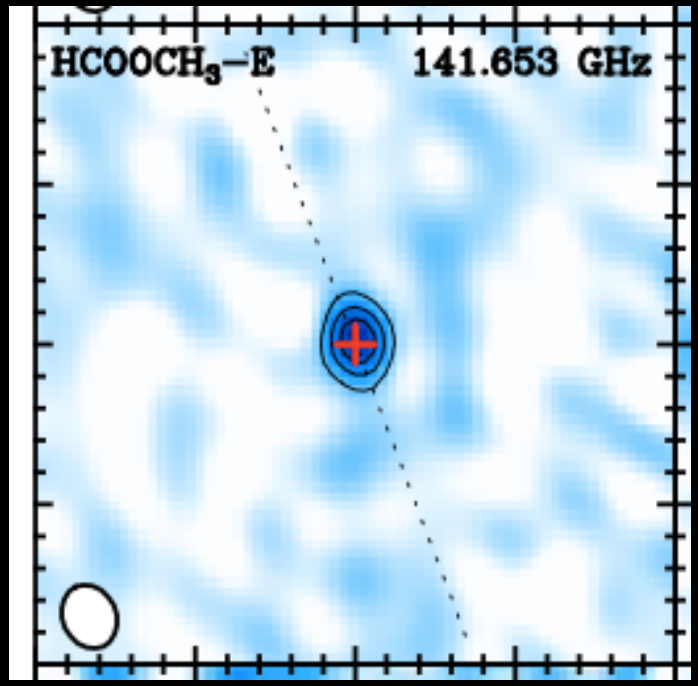


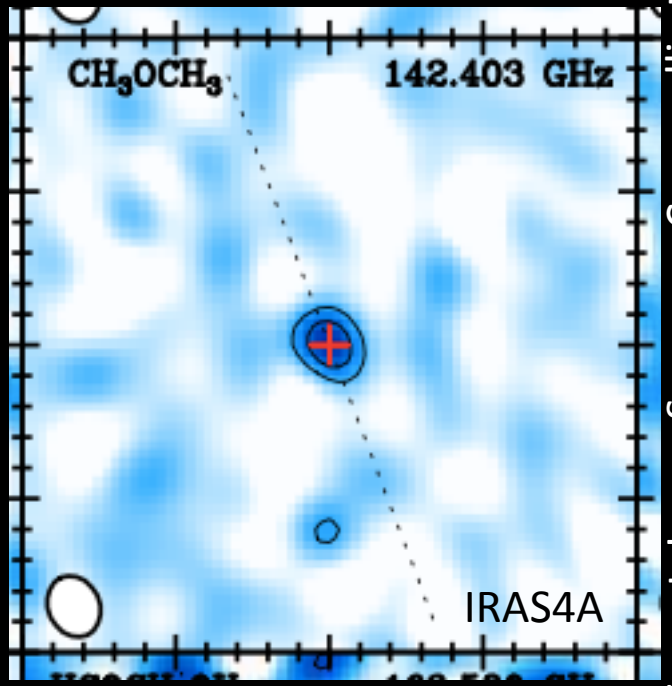
Taquet, Lopez-Sepucre, Ceccarelli et al 2015

ORION (and High-Mass Protostars) ARE COMPLICATED
(NOTE: DME & MF HAVE A SIMILAR SPATIAL DISTRIBUTION)

LOW-MASS PROTOSTARS ARE SIMPLER

LOW MASS IS SIMPLE & BEAUTIFUL

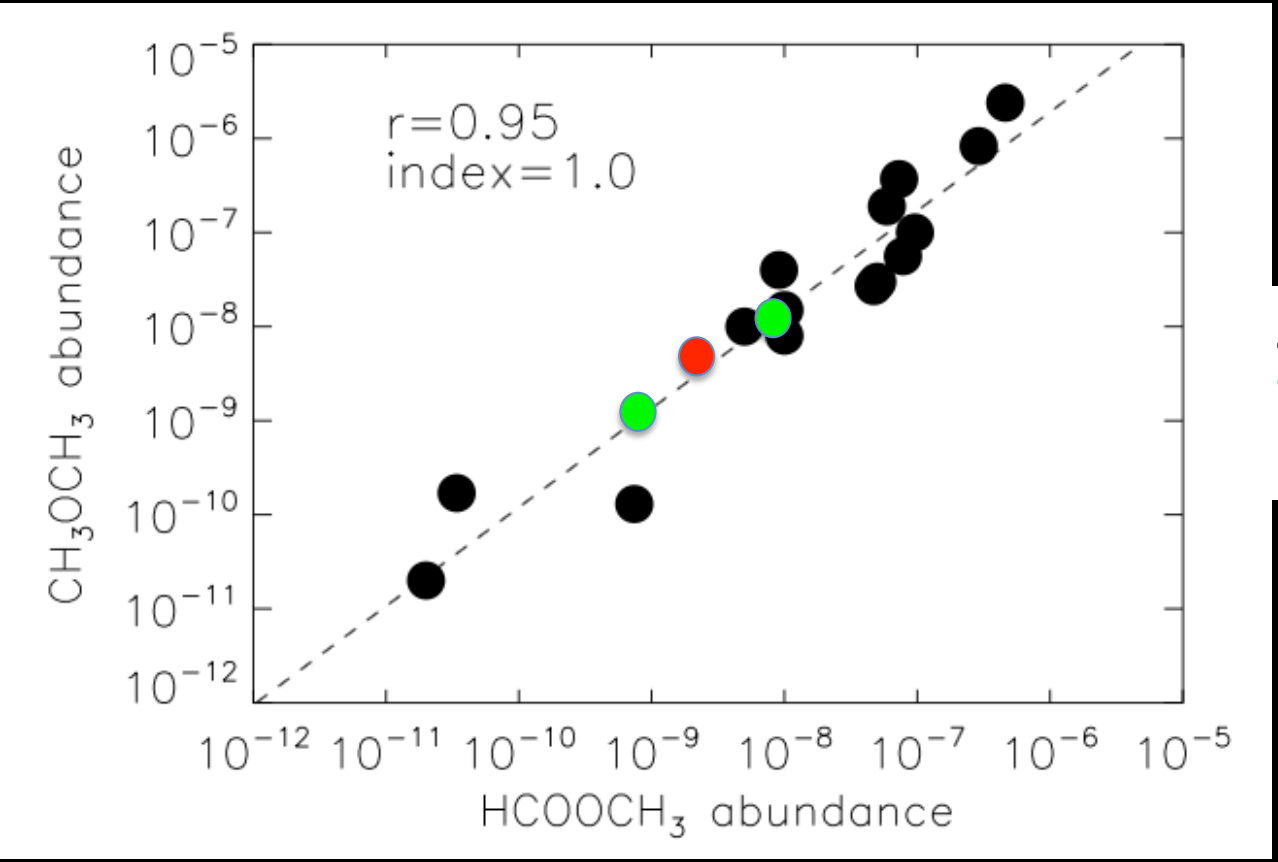




Taquet, Lopez-Sepucre, Ceccarelli et al 2015

DME & MF ORIGINATES FROM THE SAME REGION
(IN THIS CASE THE HOT CORINO OF IRAS4A)

DME & MF: MIMI & COCO



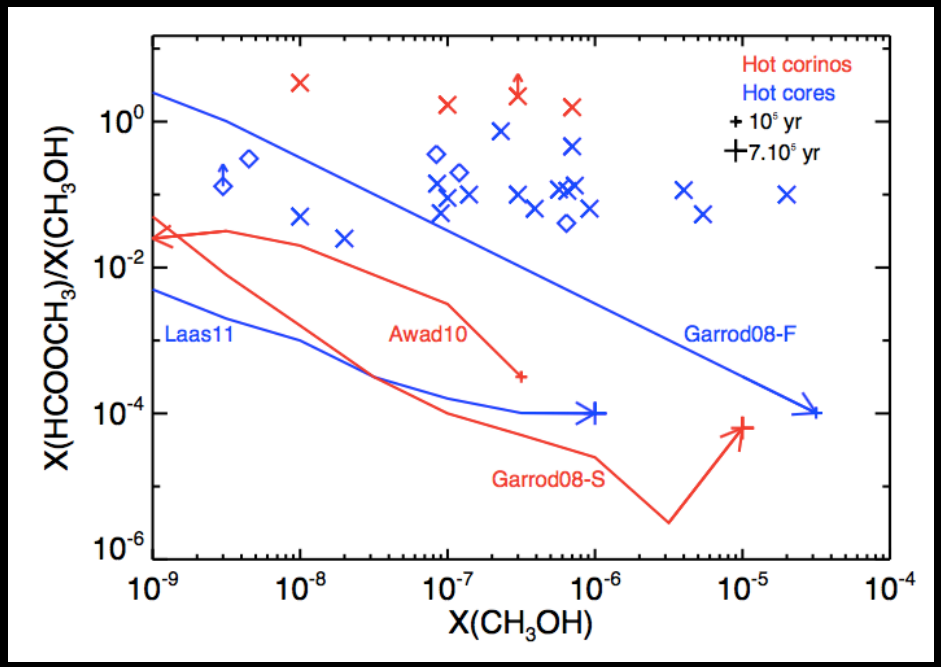
Jaber et al 2014
Taquet et al. 2015
Bianchi et al. 2016

THE DME & MF ABUNDANCES ARE ABOUT THE SAME OVER A LARGE RANGE OF ABUNDANCES (AND OBJECTS)

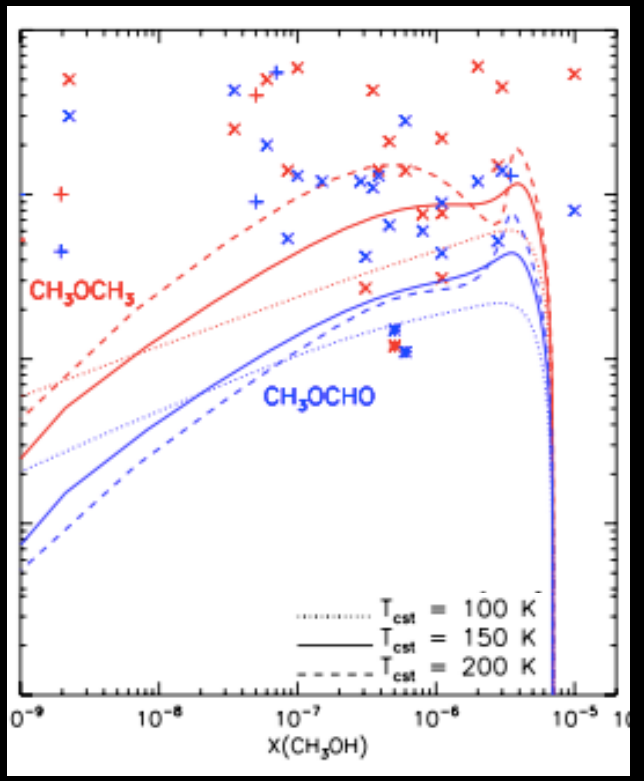
➔ SISTERS OR MOTHER-DAUGTHER RELATIONSHIP ➔

HOW DME & MF ARE SYNTHETISED?

ALTHOUGH KNOWN SINCE A LONG TIME, WE STILL DO NOT KNOW HOW DME & MF ARE SYNTHETISED IN THE ISM



Taquet, Ceccarelli, Kahane 2012



Taquet , Wirstrom, Charnley 2016

MODELS STILL UNABLE TO REPRODUCE THE OBSERVED ABUNDANCES

SYNTHESIS OF DME & MF: models

IN VOGUE UNTIL 2003/5

GAS PHASE

reactions in the gas phase, often started by the injection of hydrogenated molecules formed on the grain surfaces

IN VOGUE UNTIL 2012/3

GRAIN SURFACES

reactions on the grain surfaces between radicals during the warm-up of the dust; radicals are formed in the cold phase

Step 1	Step 2	Step 3
H_2CO CH_3OH NH_3	ice sublimation	$HCOCH_2OH$ CH_3OCH_3 NH_2CHO

Step 1	Step 2	Step 3
H_2CO CH_3OH NH_3	$HCOCH_2OH$ CH_3OCH_3 NH_2CHO	ice sublimation

TEMPERATURE

NOTE: IN BOTH SCHEMES MOLECULES ARE THERMALLY DESORBED FROM GRAIN MANTLES

SYNTHESIS OF DME & MF: models

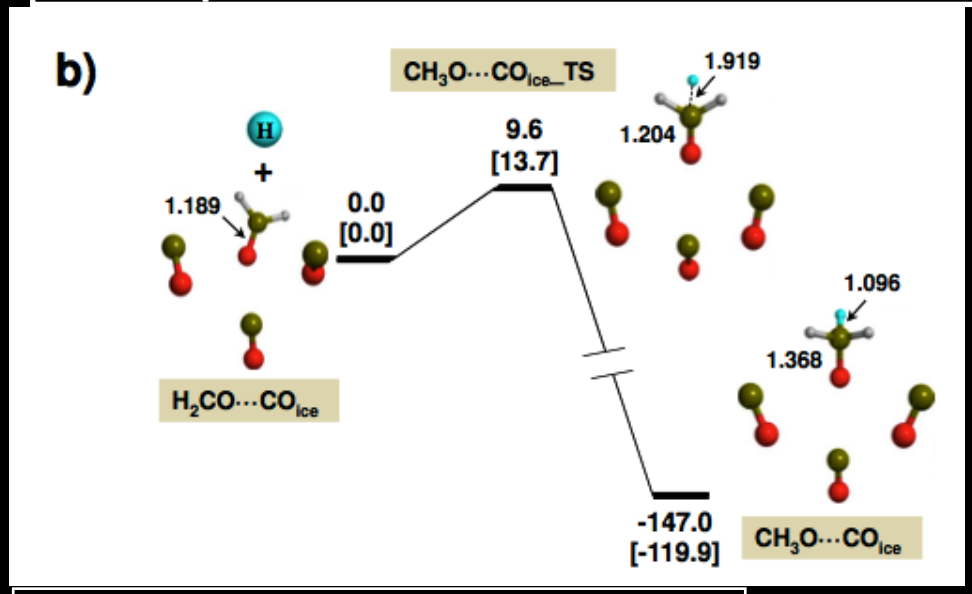
STEP 1. HYDROGENATION

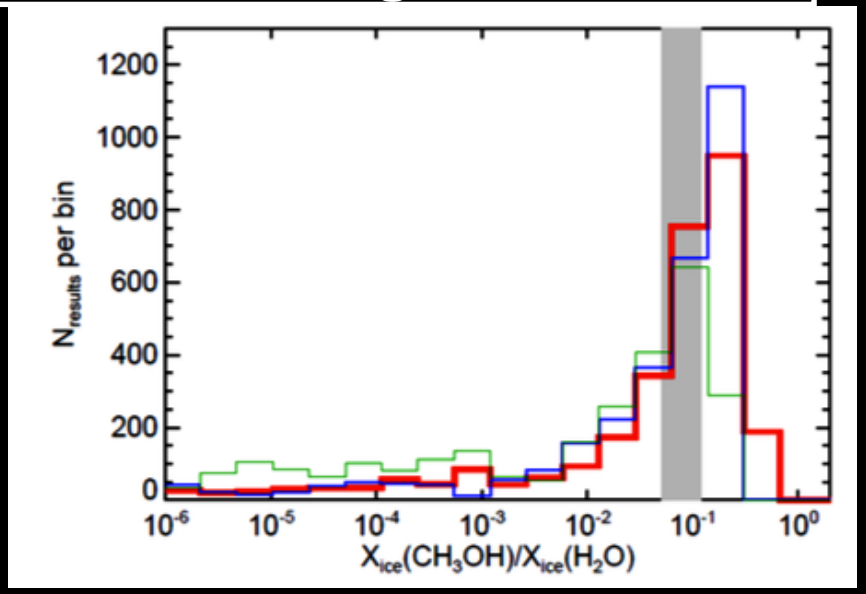
$E_{BARRIER}$ ➔ EXPERIMENTS SAY ~ 400K, THEORY SAYS ~1100K

➔ LABORATORY EXPERIMENTS + **THEORY**

ARE NECESSARY TO UNDERSTAND WHAT HAPPENS

Example of the methanol formation on the grain surfaces





Rimola, Taquet, Ugliengo et al. 2014

(TUNNELING IS DOING THE JOB)

SYNTHESIS OF DME & MF: models

IN VOGUE UNTIL 2012/3

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CH_3OH NH_3	CH_3OCH_3	sublimation
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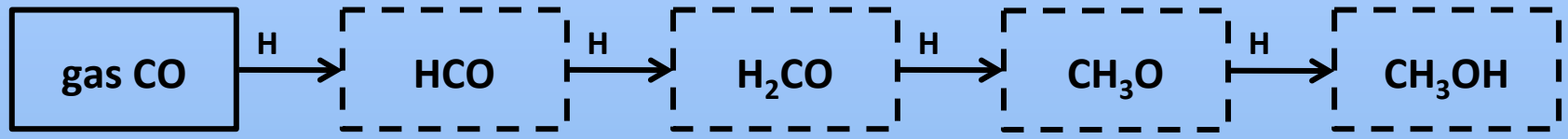
DME & MF: grain-surface formation

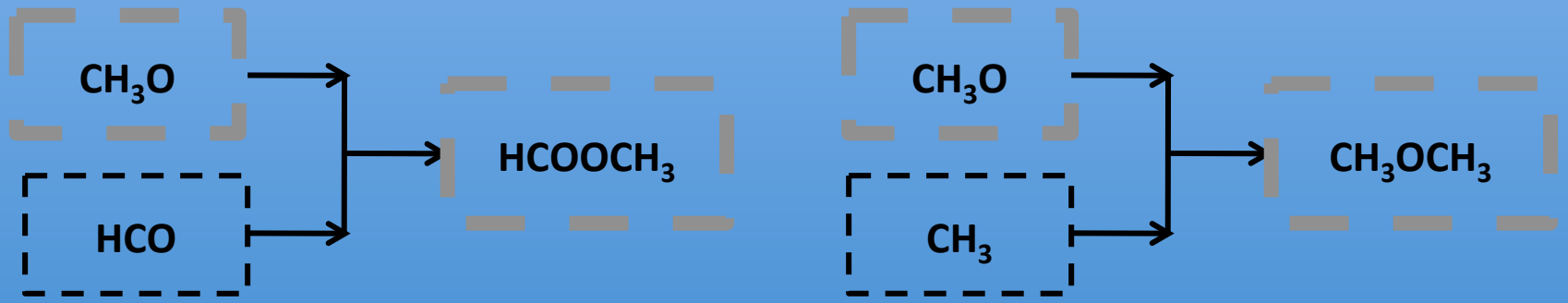
Garrod & Herbst 2006; Garrod et al. 2008; Oberg et al. 2009; Kalvans 2015

Phase I: hydrogenation



Phase II: (CR-induced) hydrolysis

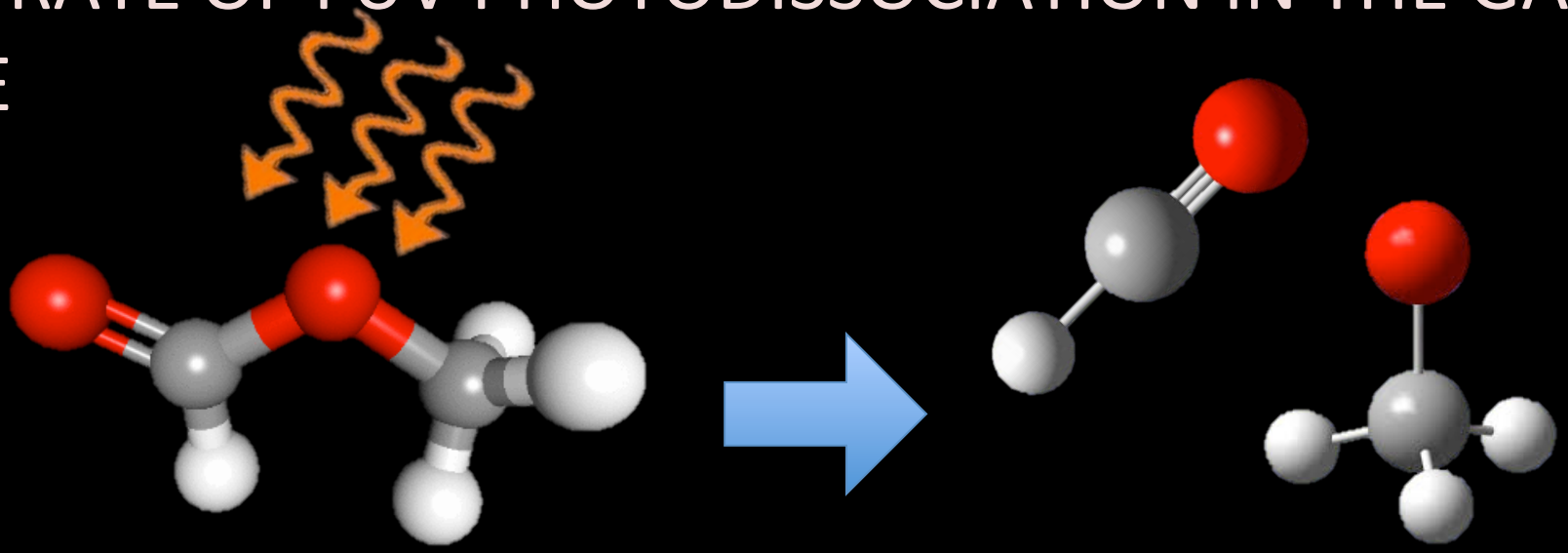
Phase III: warm-up



SYNTHESIS OF DME & MF: models

STEP 1b. RADICALS FORMATION ON THE ICY MANTLES FROM FUV SECONDARY PHOTONS

(DISCUTABLE) HYPOTHESIS: RADICALS CREATED AT THE SAME RATE OF FUV PHOTODISSOCIATION IN THE GAS PHASE

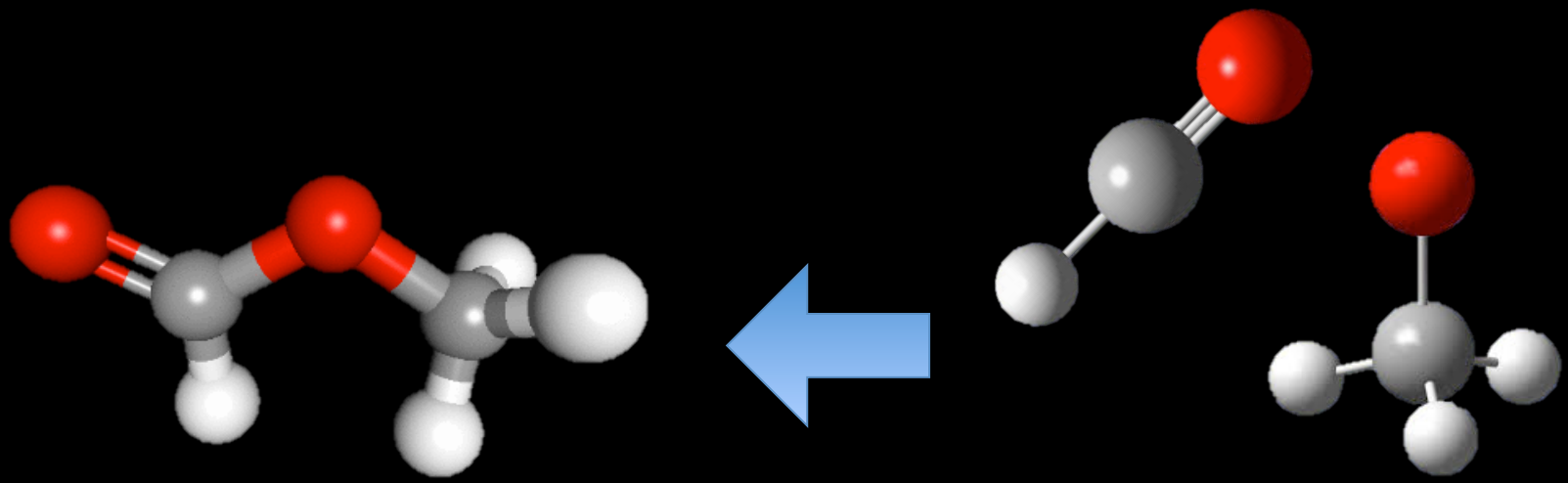


➔ LABORATORY EXPERIMENTS + **THEORY**
ARE NECESSARY TO UNDERSTAND WHAT HAPPENS

SYNTHESIS OF DME & MF: models

STEP 2. RADICAL S COMBINATION INTO ACOMs

(DISCUTABLE) HYPOTHESIS: RADICALS ACQUIRE MOBILITY AT T_{DUST}>30K AND RECOMBINE



SYNTHESIS OF DME & MF: models

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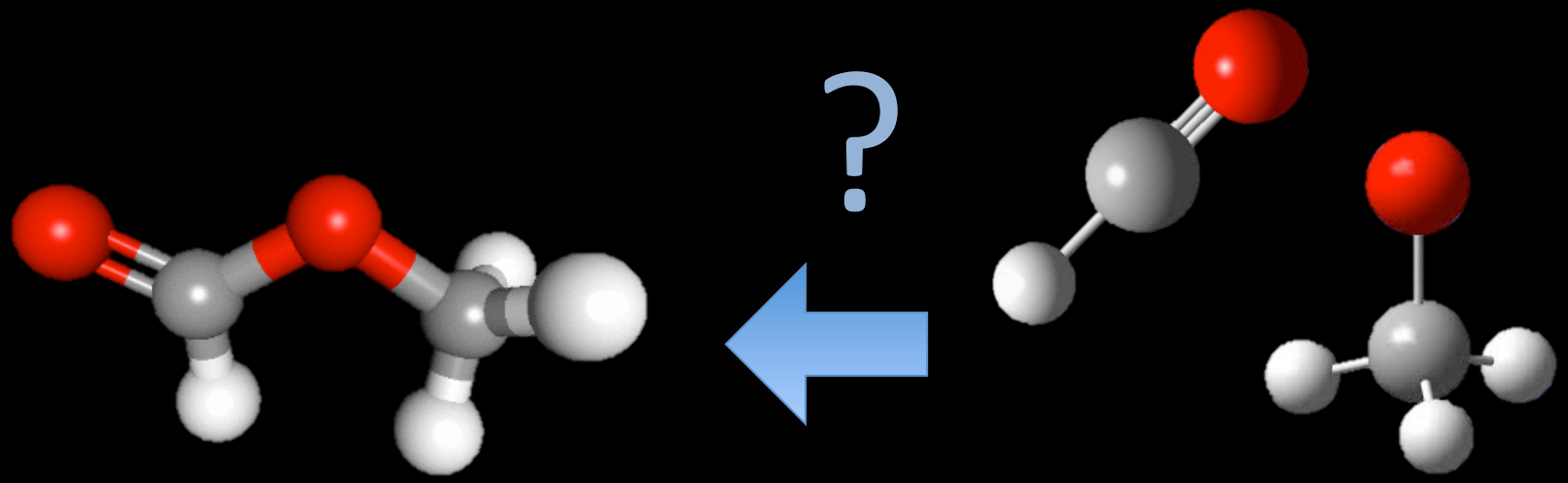

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SYNTHESIS OF DME & MF: models

STEP 2. RADICAL S COMBINATION INTO ACOMs

EXAMPLE OF ACETALDEHYDE

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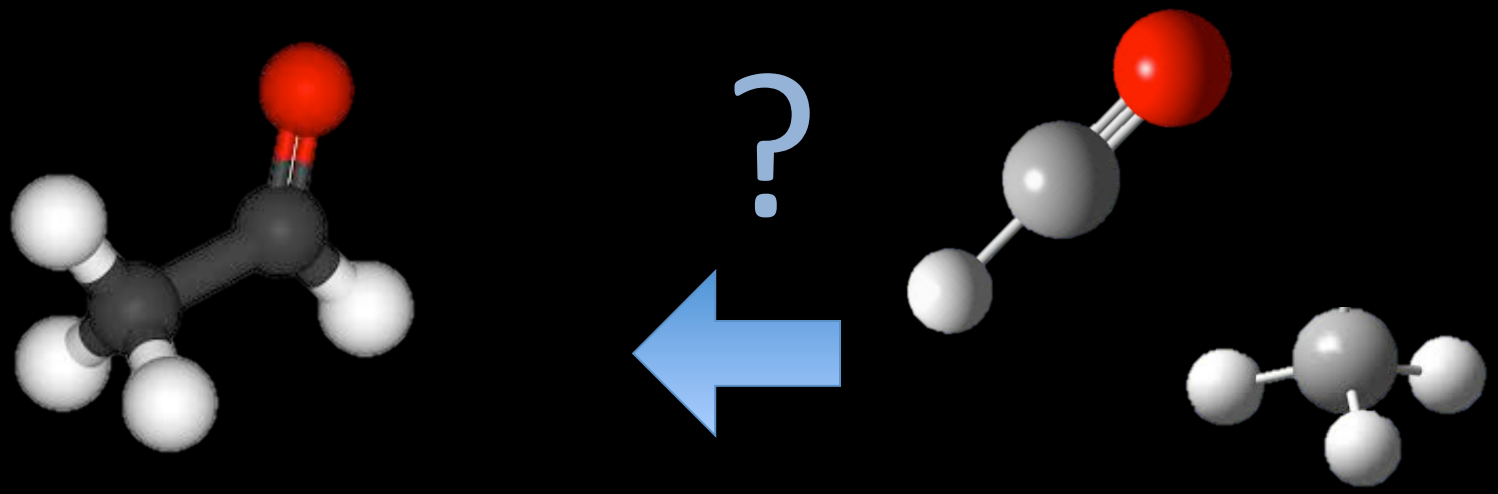

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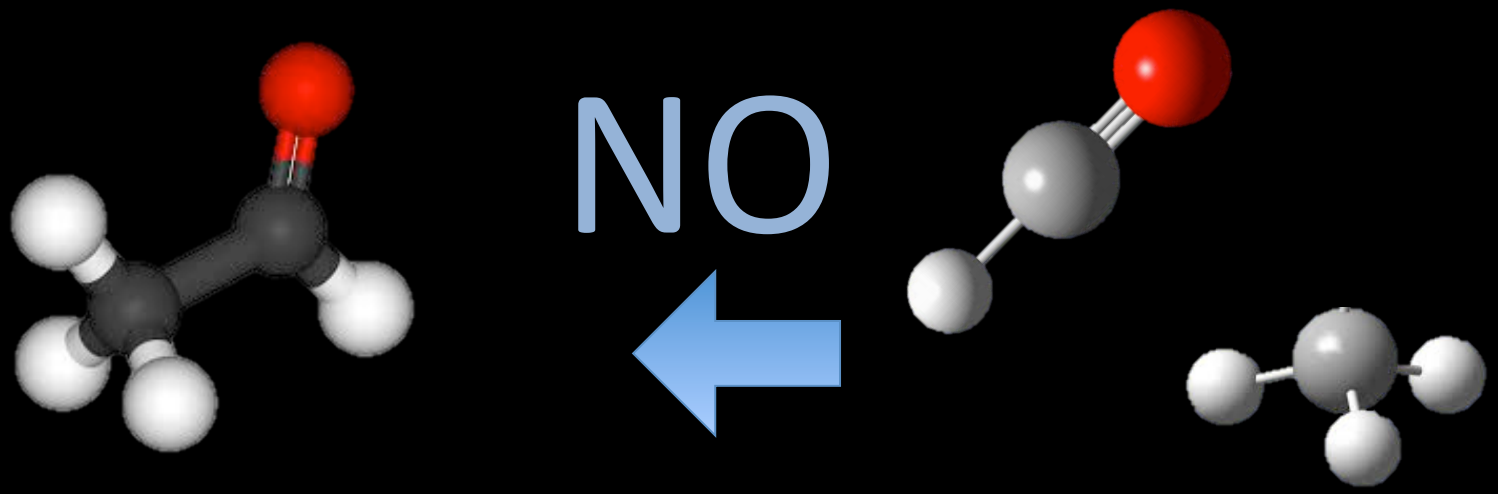

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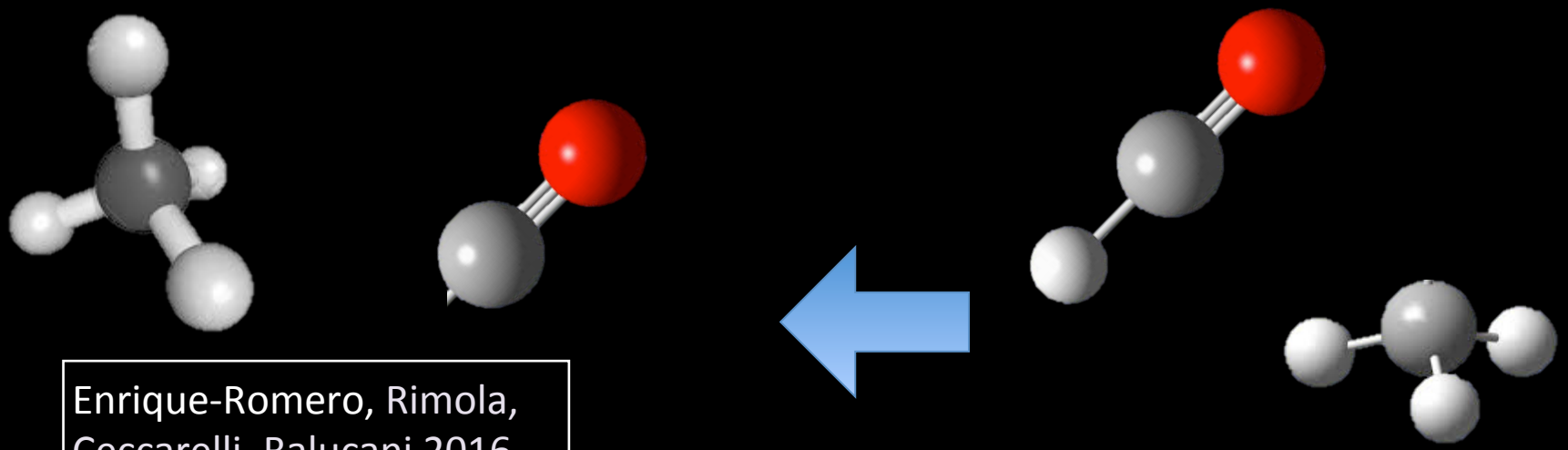

Enrique-Romero, Rimola, Ceccarelli, Balucani 2016

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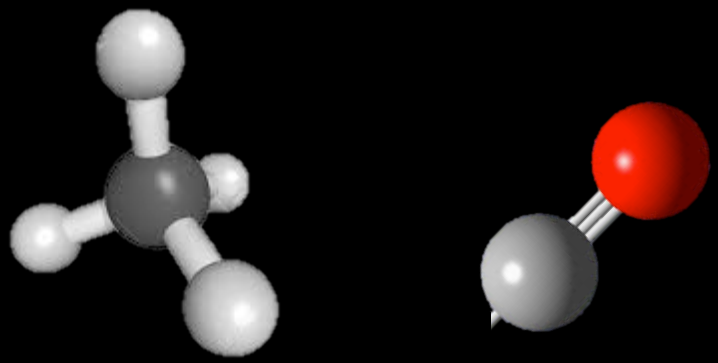
SYNTHESIS OF DME & MF: models

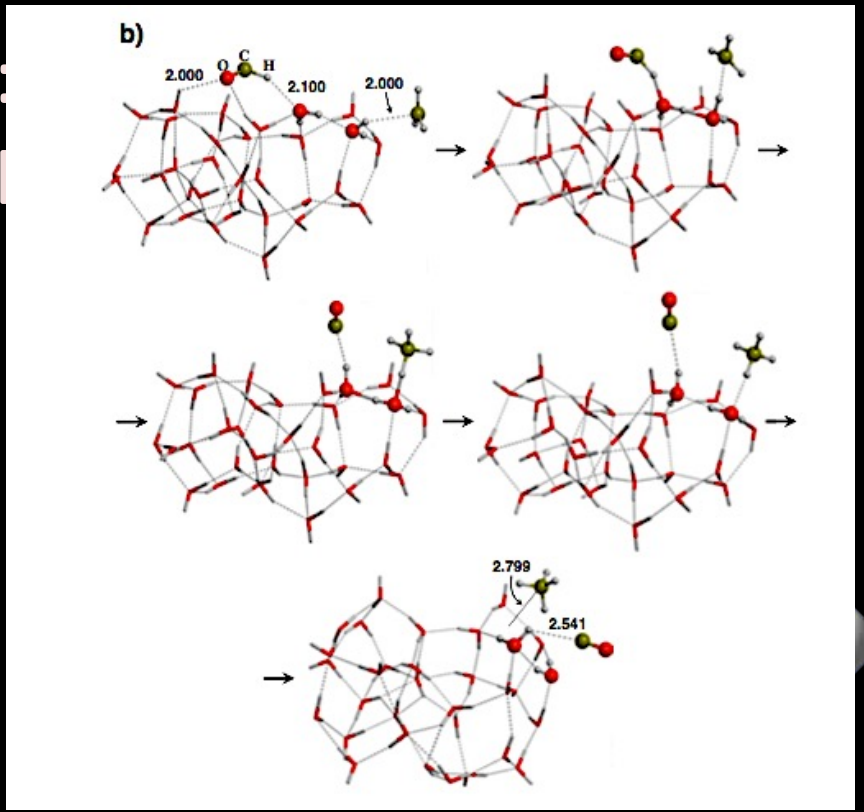
STEP 2. RADICAL S COMBINATION INTO ACOMs

EXAMPLE OF ACETALDEHYDE

(DISCUTABLE) HYPOTHESIS:
MOBILITY AT T_{DUST}>30K ANI



Enrique-Romero, Rimola, Ceccarelli, Balucani 2016



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SYNTHESIS OF DME & MF: models

IN VOGUE UNTIL 2003/5

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TEMPERATURE

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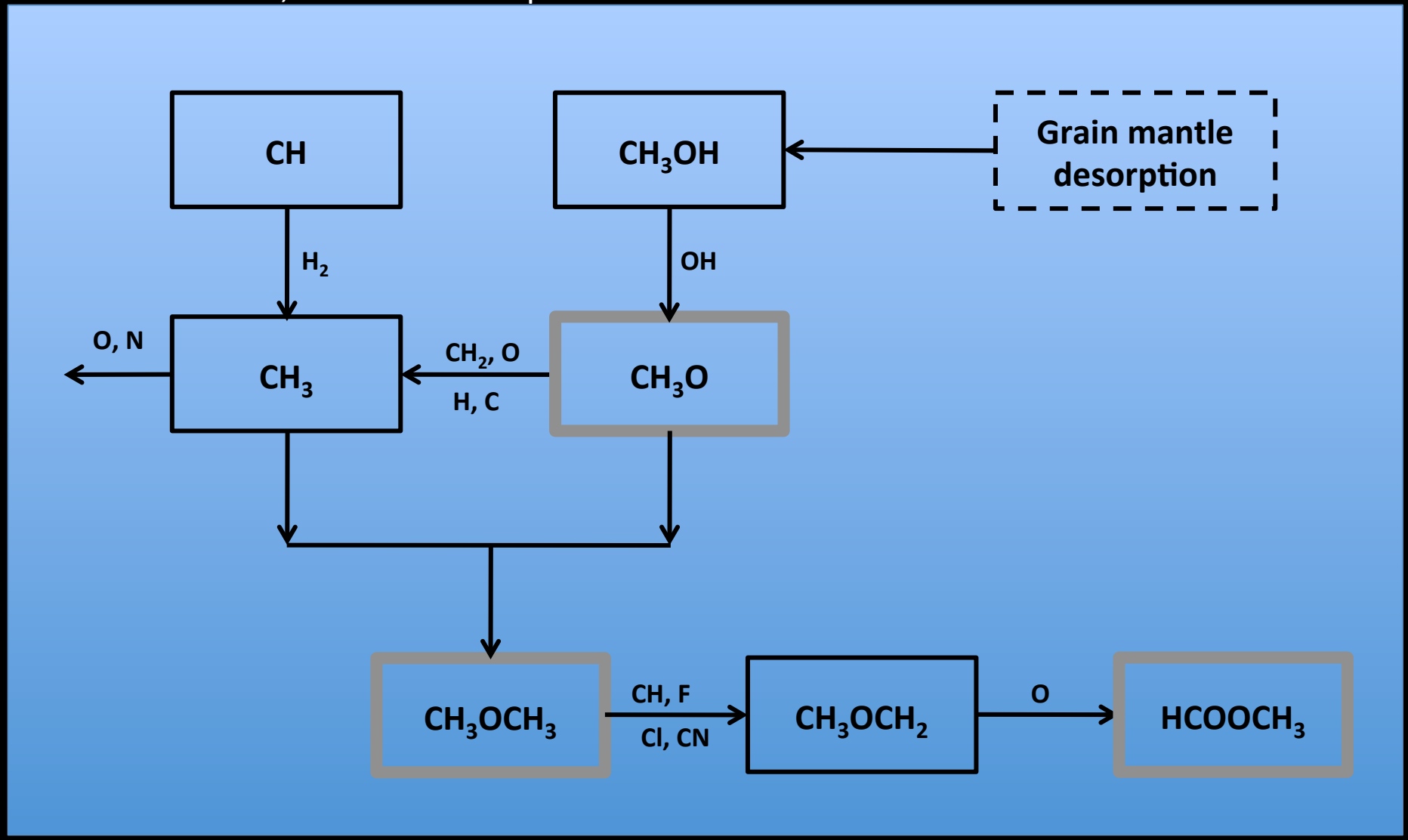
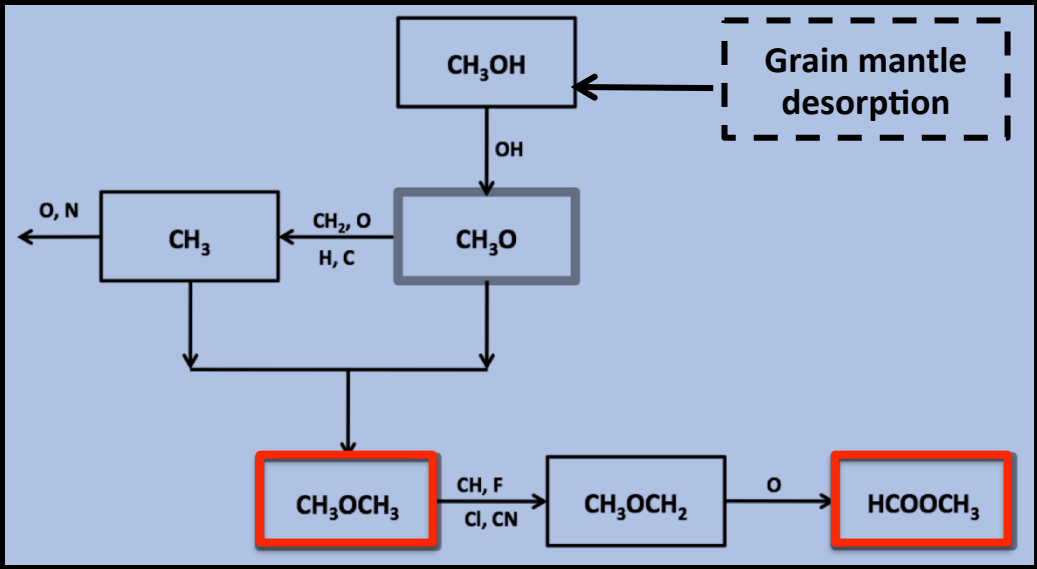
DME & MF: gas phase formation

Balucani, Ceccarelli & Taquet 2015

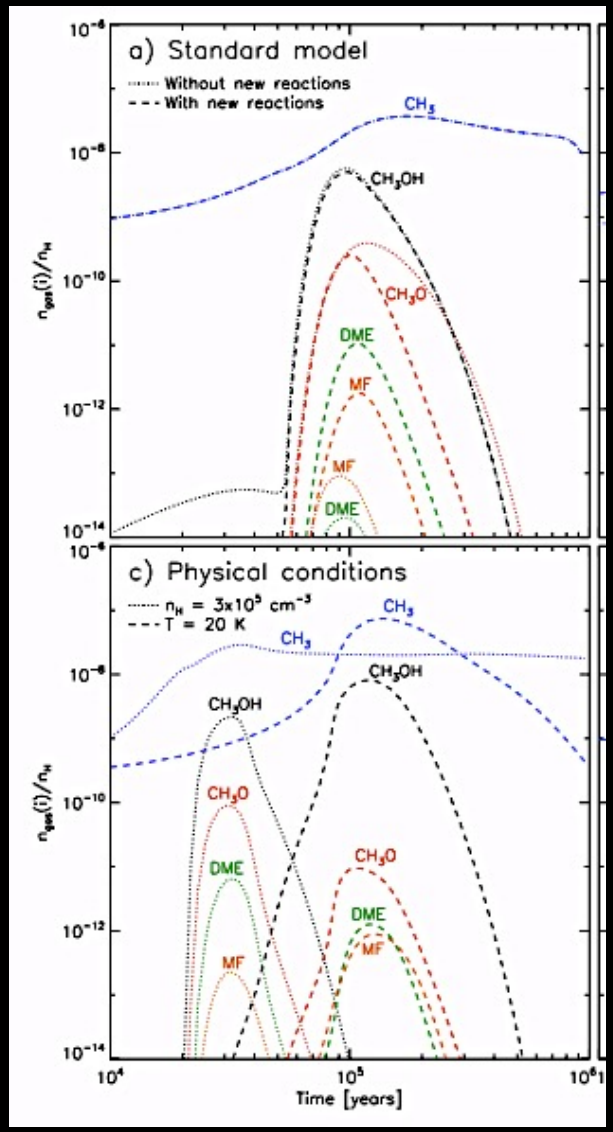


DME & MF: gas phase formation

- ALL CONSIDERED REACTIONS ARE EITHER COMPUTED OR MEASURED (EXCEPTION $CH_3 + CH_3O$)
- MF DAUGHTER OF DME -> NATURAL EXPLANATION OF OBSERVATIONS
- IT WORKS AT LOW TEMPERATURES



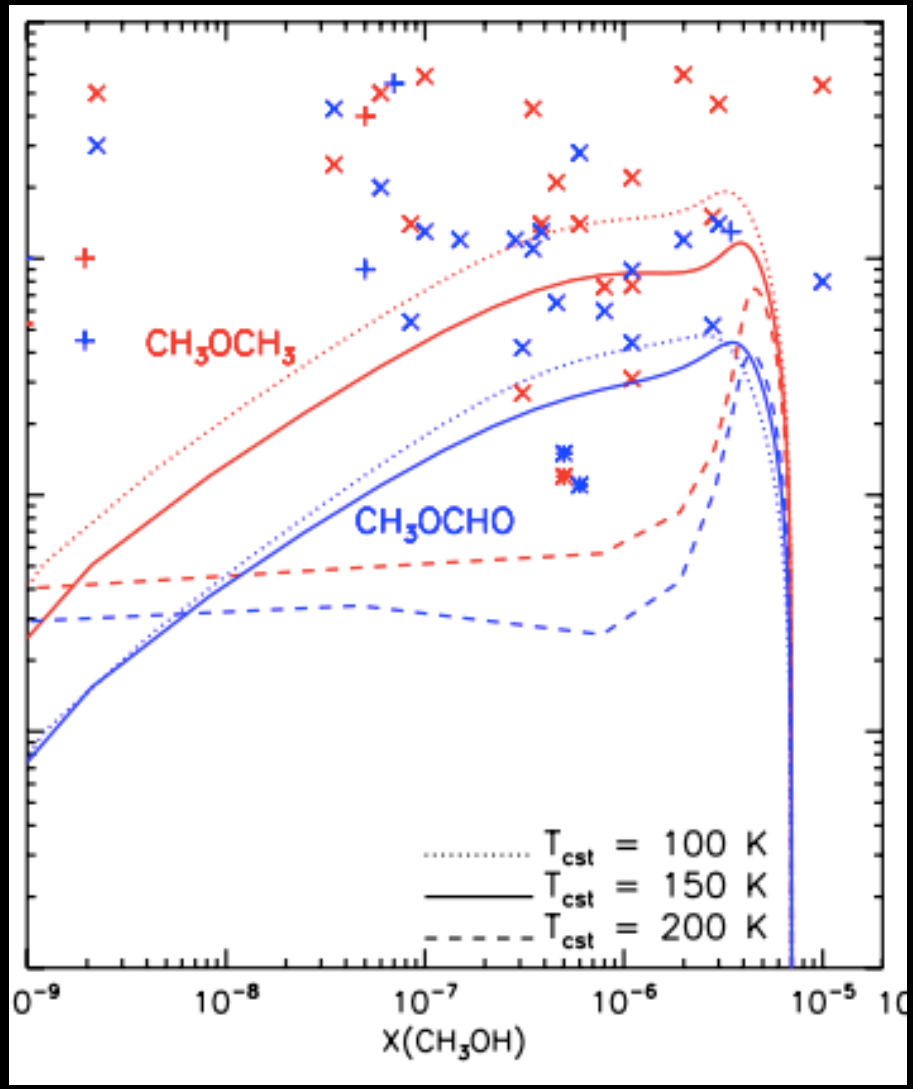
Balucani et al. 2015



DME & MF: gas phase formation

Taquet, Wirstrom, Charnley 2016

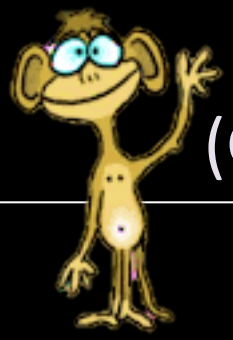
THE AMMONIA ROLE: BUILD UP COMs TAKING THE PROTON
(theoretical computations in Perugia going on to verify the rates and products)



WHAT NEXT (on our side) ?

MORE ASTROCHEMICAL MODELING
INCLUDING THE RESULTS FROM THE EXPERIMENTS OF THE TRENTO GROUP (Ascenzi, Cernuti, Tosi and Pirani)
ON THE DESTRUCTION OF DME & MF
AND TEH NEW COMPUTATIONS ON THE AMMONIA

➔ AND USE THE BID DATA APPROACH BY Serena Viti !



(GOODBYE STAMPS COLLECTION ERA)

WHAT NEXT (on our side) ?

IRAM NOEMA LARGE PROGRAM (interferometer):

ACOMs

PI: C.Ceccarelli & P.Caselli