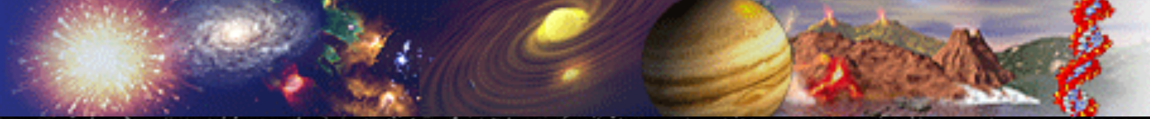
UNIVERSIDAD COMPLUTENSE MADRID

CENTRO DE ASTROBIOLOGÍA
ASOCIADO AL NASA ASTROBIOLOGY INSTITUTE

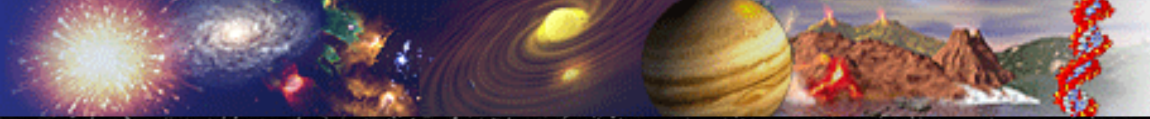
TESIS DOCTORAL
The cycle of matter in the interstellar medium:
Energetic processing of dust and ice

Rafael Martín Doménech[1]
Director: Guillermo M. Muñoz Caro[1]
Tutor: Jesús Gallego Maestro[2]
[1]Centro de Astrobiología (INTA-CSIC), Madrid, Spain
[2]Universidad Complutense de Madrid, Spain



1. Introduction

The cycle of matter in the interstellar medium (ISM)
10-15% of galactic matter

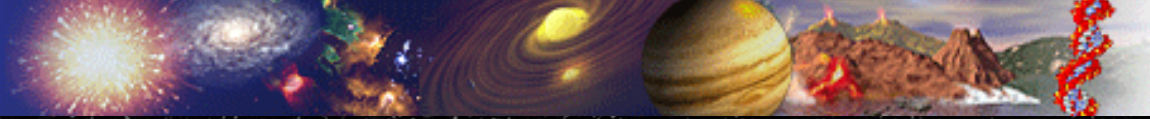


1. Introduction

The cycle of matter in the interstellar medium (ISM)
10-15% of galactic matter

ISM components

- **Ordinary matter**
  - Gaseous (mostly)
  - Solid (dust grains w/ ice mantles)

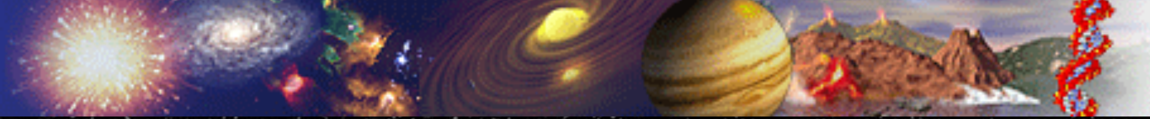


1. Introduction

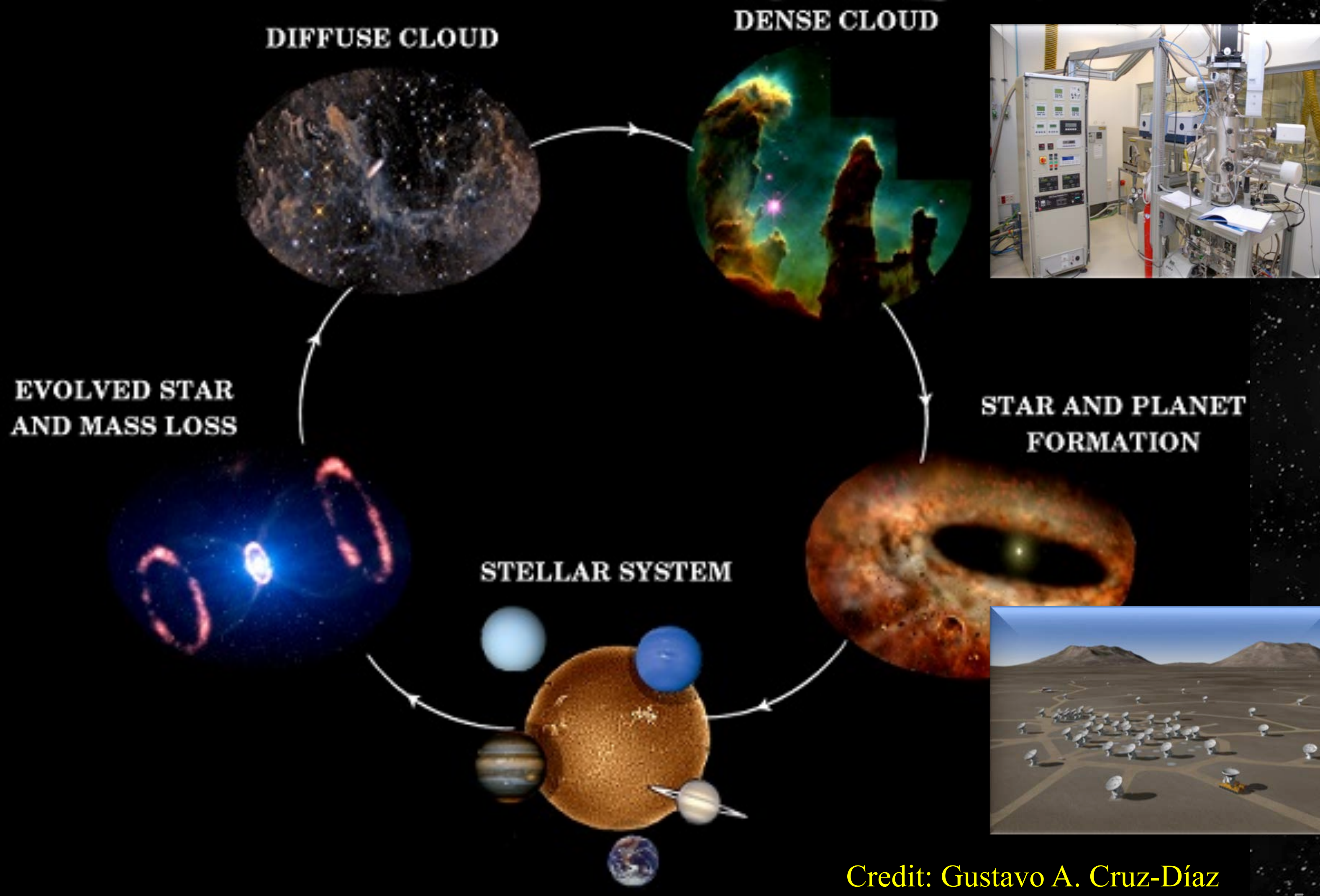
The cycle of matter in the interstellar medium (ISM)
10-15% of galactic matter

ISM components

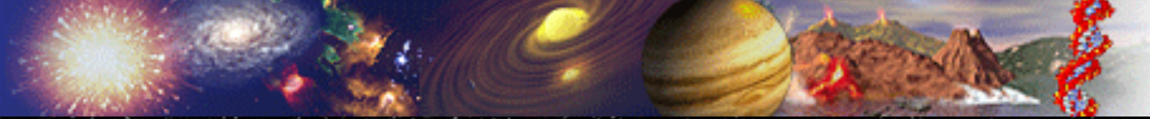
- **Ordinary matter**
  - Gaseous (mostly)
  - Solid (dust grains w/ ice mantles)
- Cosmic Rays
- Magnetic Fields



The cycle of matter in the interstellar medium (ISM)

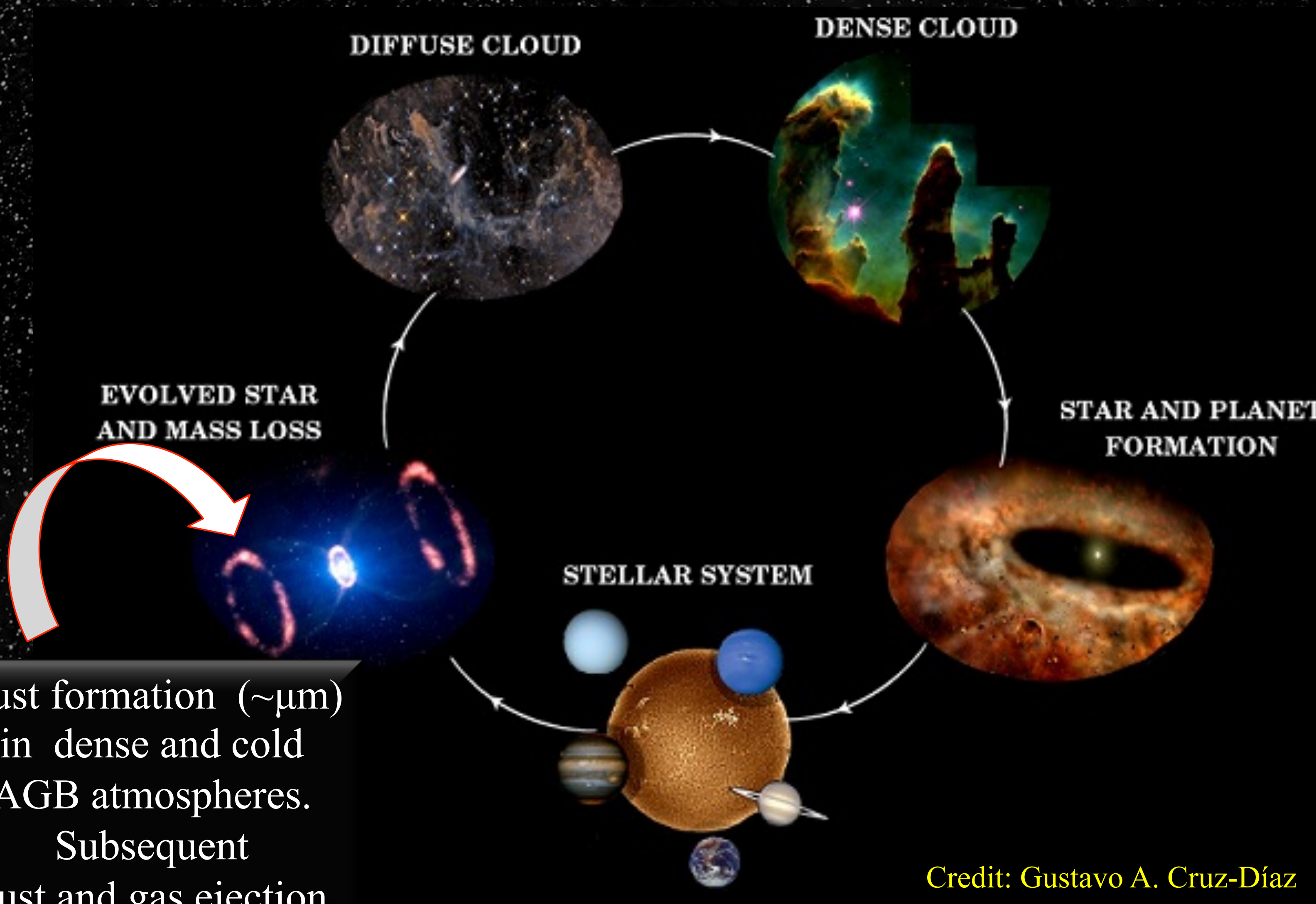


Credit: Gustavo A. Cruz-Díaz



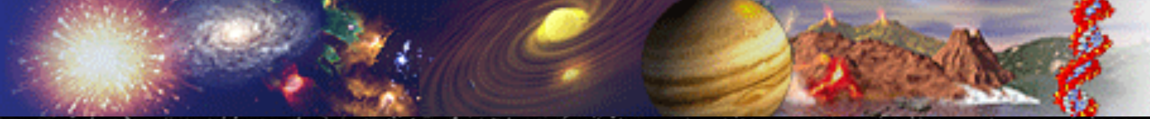
1. Introduction

The cycle of matter in the interstellar medium (ISM)



Dust formation (~µm) in dense and cold AGB atmospheres. Subsequent dust and gas ejection

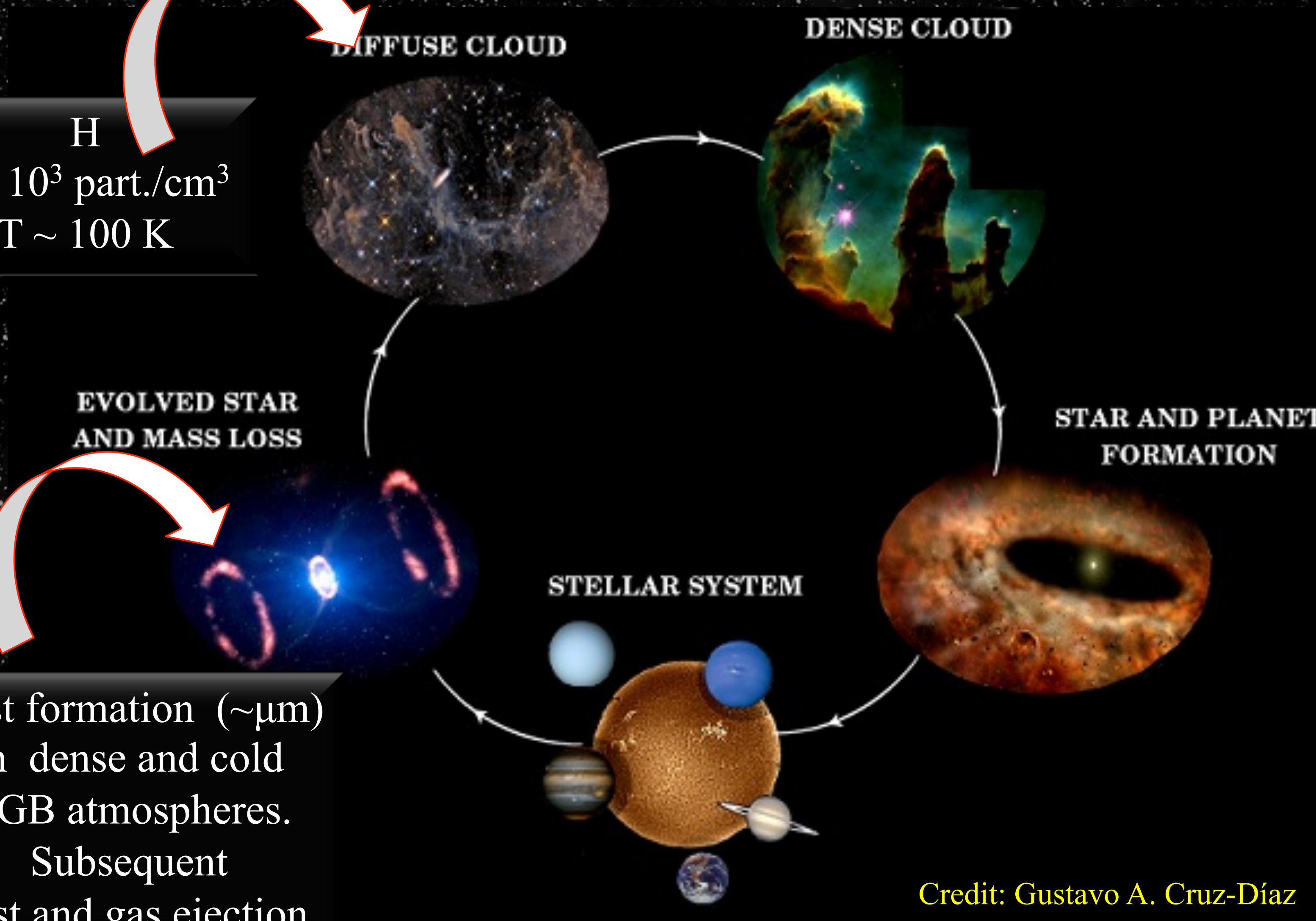
Credit: Gustavo A. Cruz-Díaz



1. Introduction

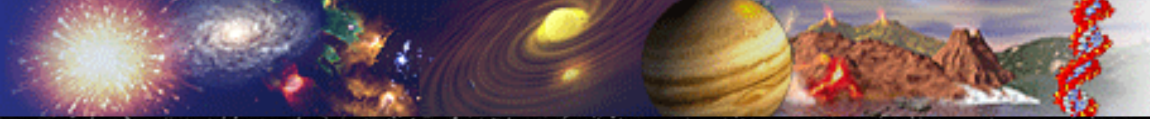
The cycle of matter in the interstellar medium (ISM)

H
$n \leq 10^3$ part./cm^3
T ~ 100 K



Dust formation (~µm) in dense and cold AGB atmospheres. Subsequent dust and gas ejection

Credit: Gustavo A. Cruz-Díaz

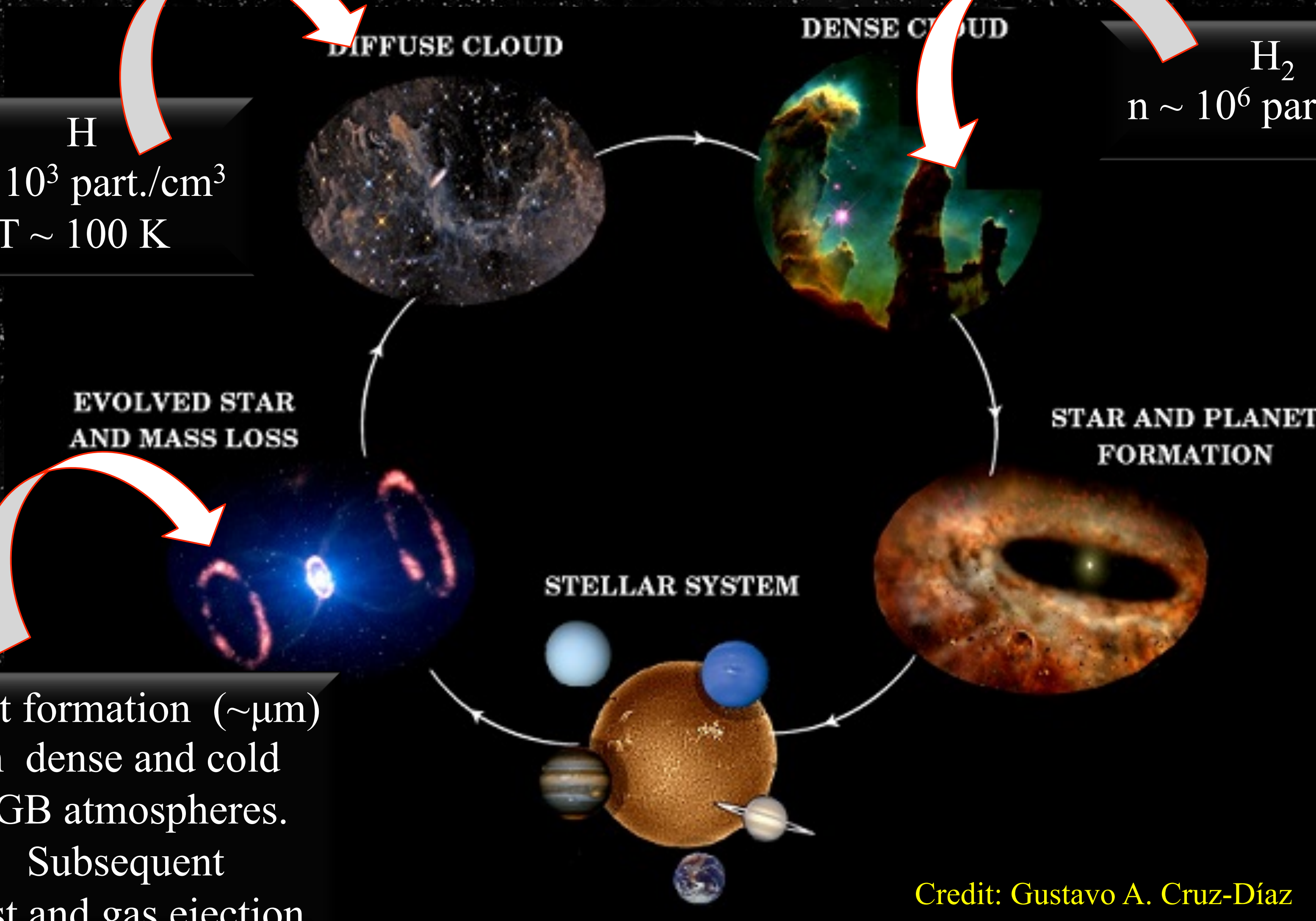


1. Introduction

The cycle of matter in the interstellar medium (ISM)

H
n ≤ 10^3 part./cm^3
T ~ 100 K

H_2
n ~ 10^6 part./cm^3

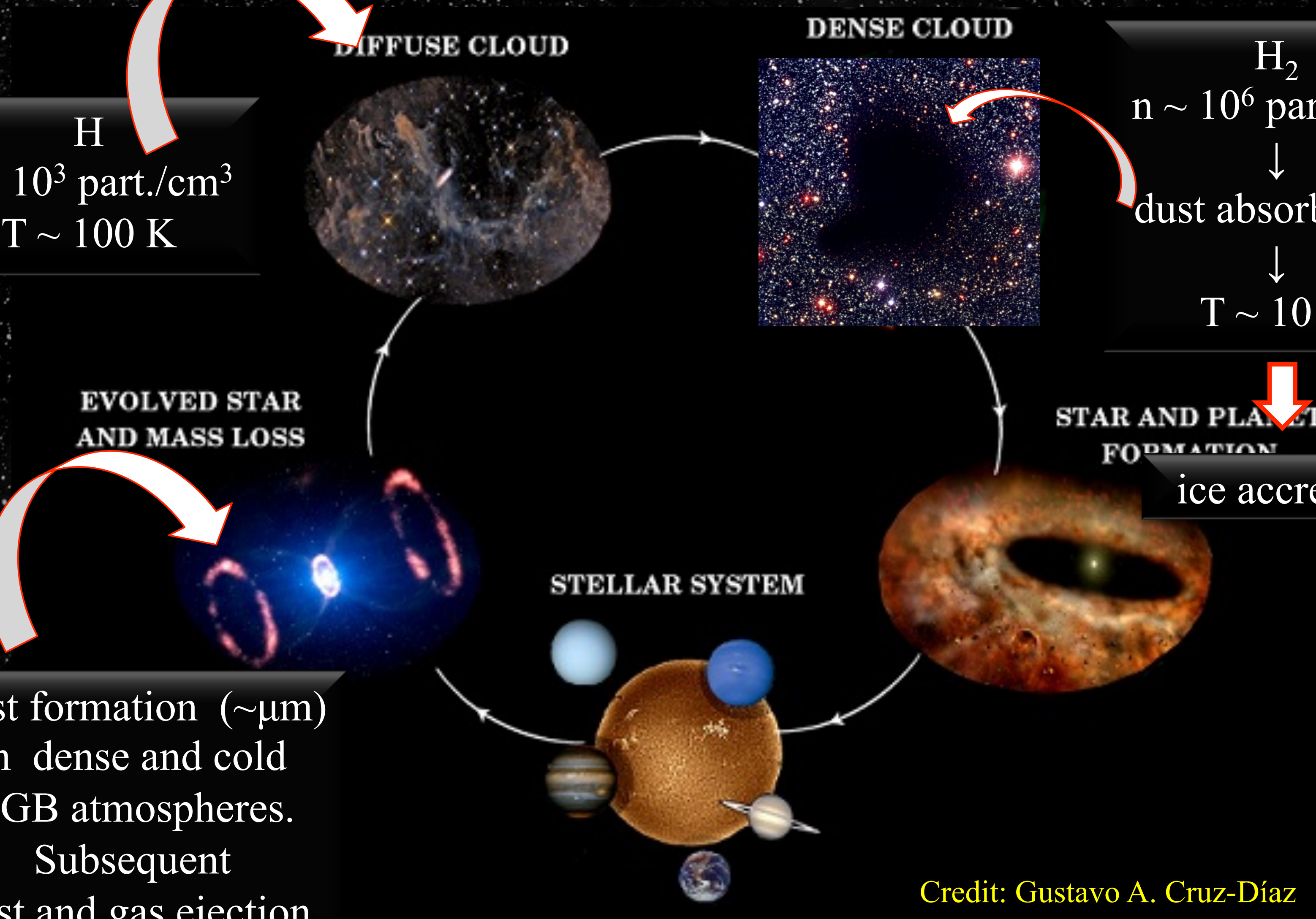


Dust formation (~μm) in dense and cold AGB atmospheres. Subsequent dust and gas ejection

Credit: Gustavo A. Cruz-Díaz

The cycle of matter in the interstellar medium (ISM)

H
$n \leq 10^3$ part./cm^3
T ~ 100 K

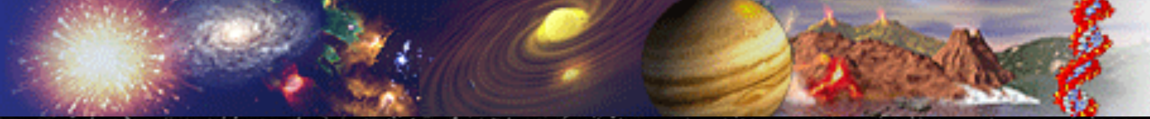


H_2
$n \sim 10^6$ part./cm^3
↓
dust absorbs UV
↓
T ~ 10 K

⇩ ice accretion

Dust formation (~µm)
in dense and cold
AGB atmospheres.
Subsequent
dust and gas ejection

Credit: Gustavo A. Cruz-Díaz

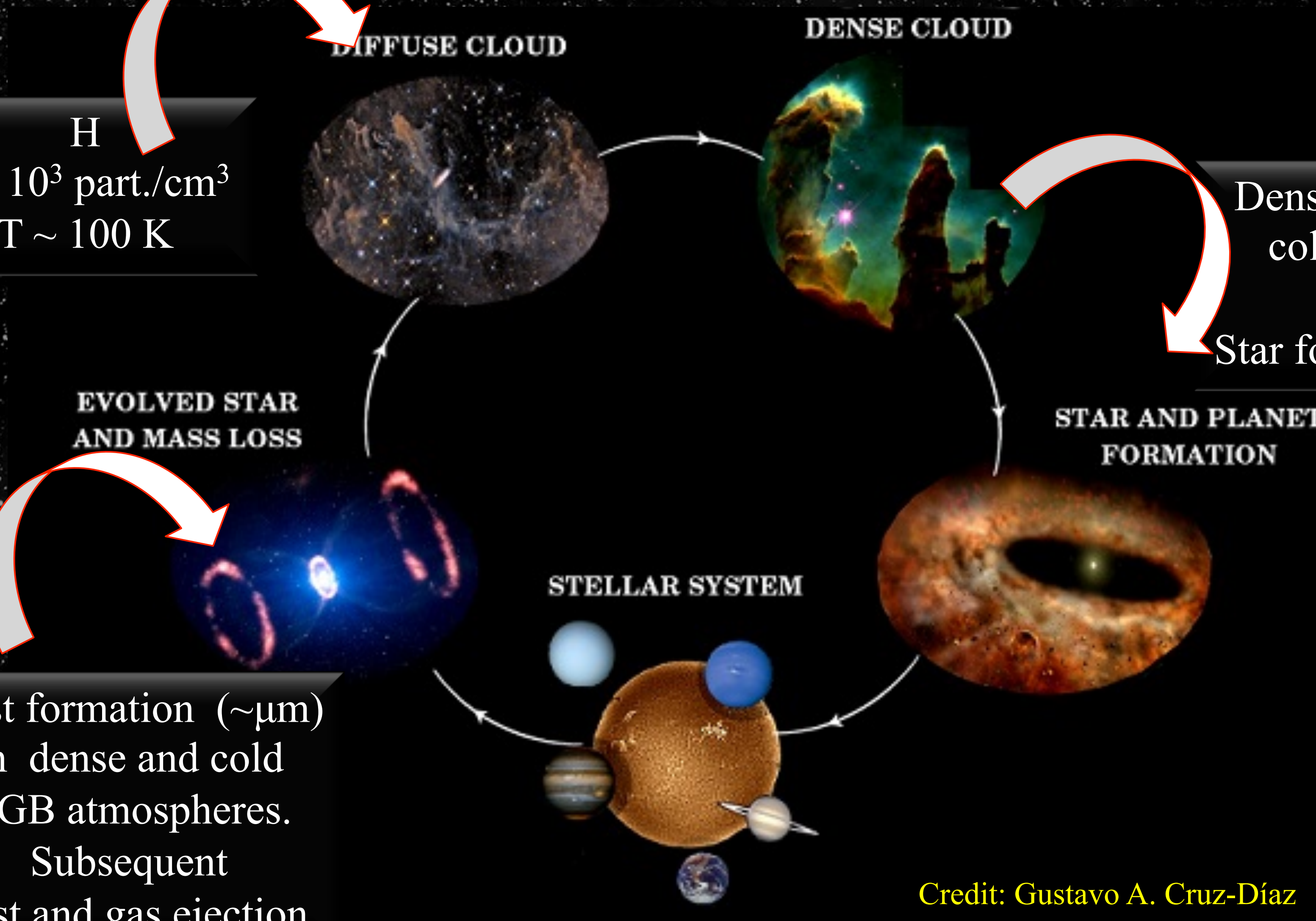


1. Introduction

The cycle of matter in the interstellar medium (ISM)

H
n ≤ 10^3 part./cm^3
T ~ 100 K

Dense cores collapse
↓
Star formation

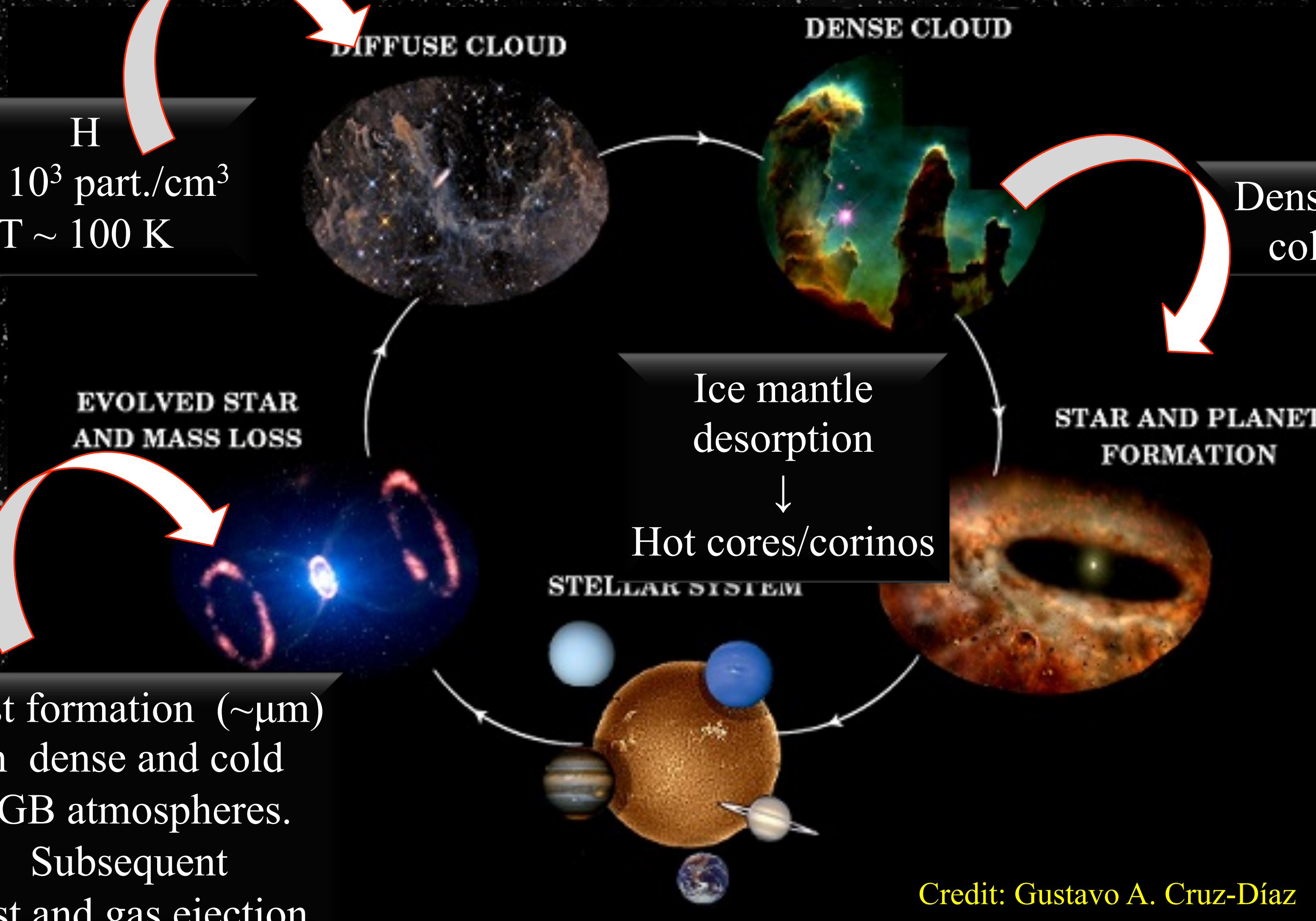


Dust formation (~µm) in dense and cold AGB atmospheres. Subsequent dust and gas ejection

Credit: Gustavo A. Cruz-Díaz

The cycle of matter in the interstellar medium (ISM)

H
$n \leq 10^3$ part./cm^3
T ~ 100 K



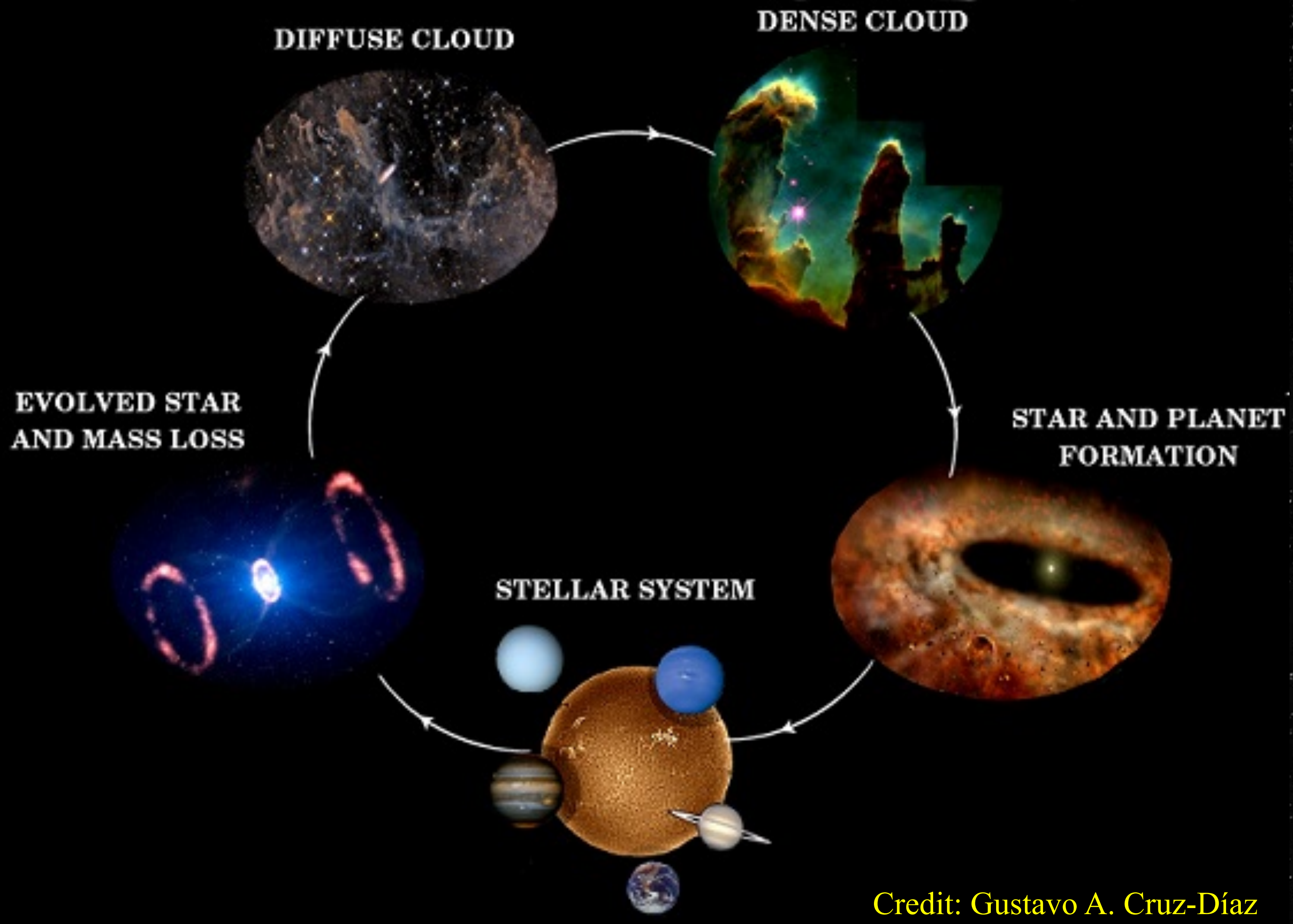
Dense cores collapse

Ice mantle desorption
↓
Hot cores/corinos

Dust formation (~µm) in dense and cold AGB atmospheres. Subsequent dust and gas ejection

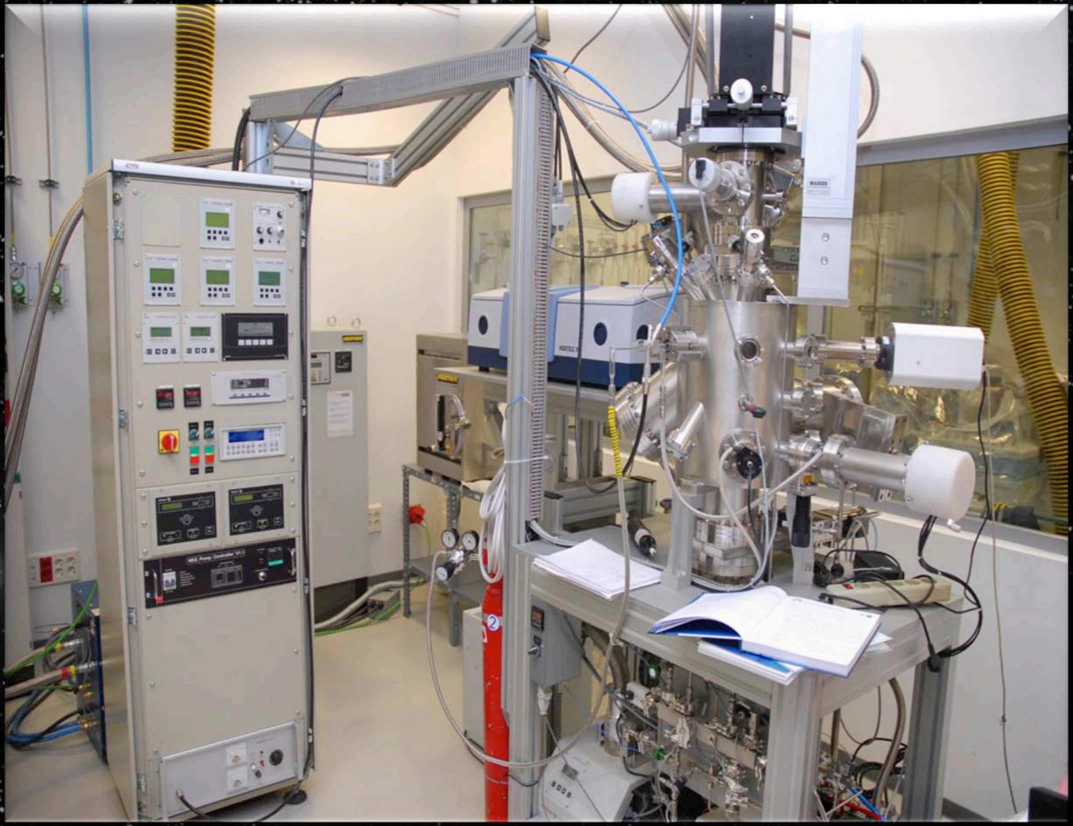
Credit: Gustavo A. Cruz-Díaz

The cycle of matter in the interstellar medium (ISM)

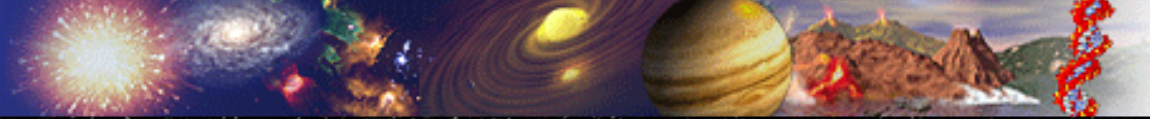


Credit: Gustavo A. Cruz-Díaz

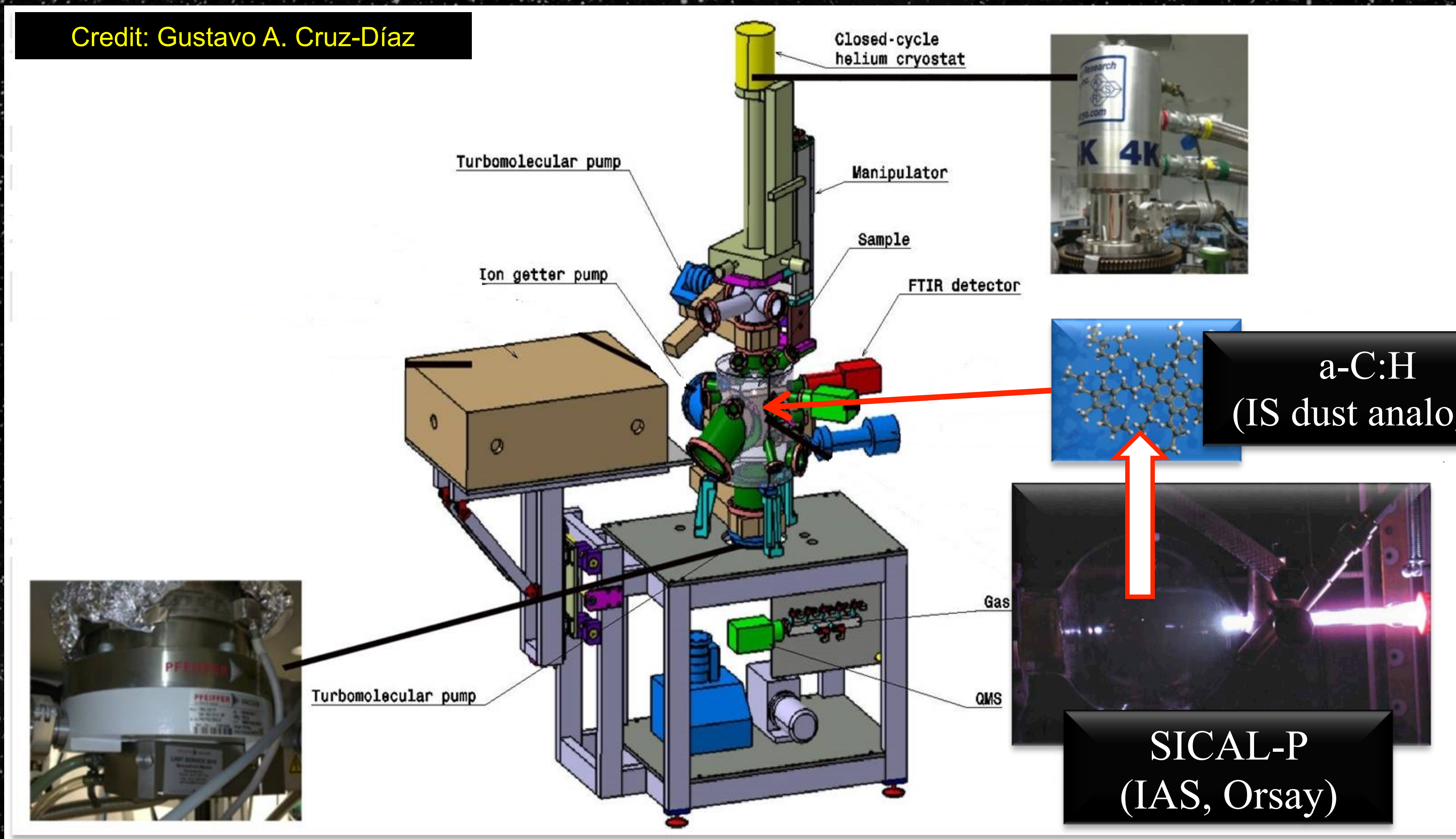
InterStellar Astrochemistry Chamber (ISAC)



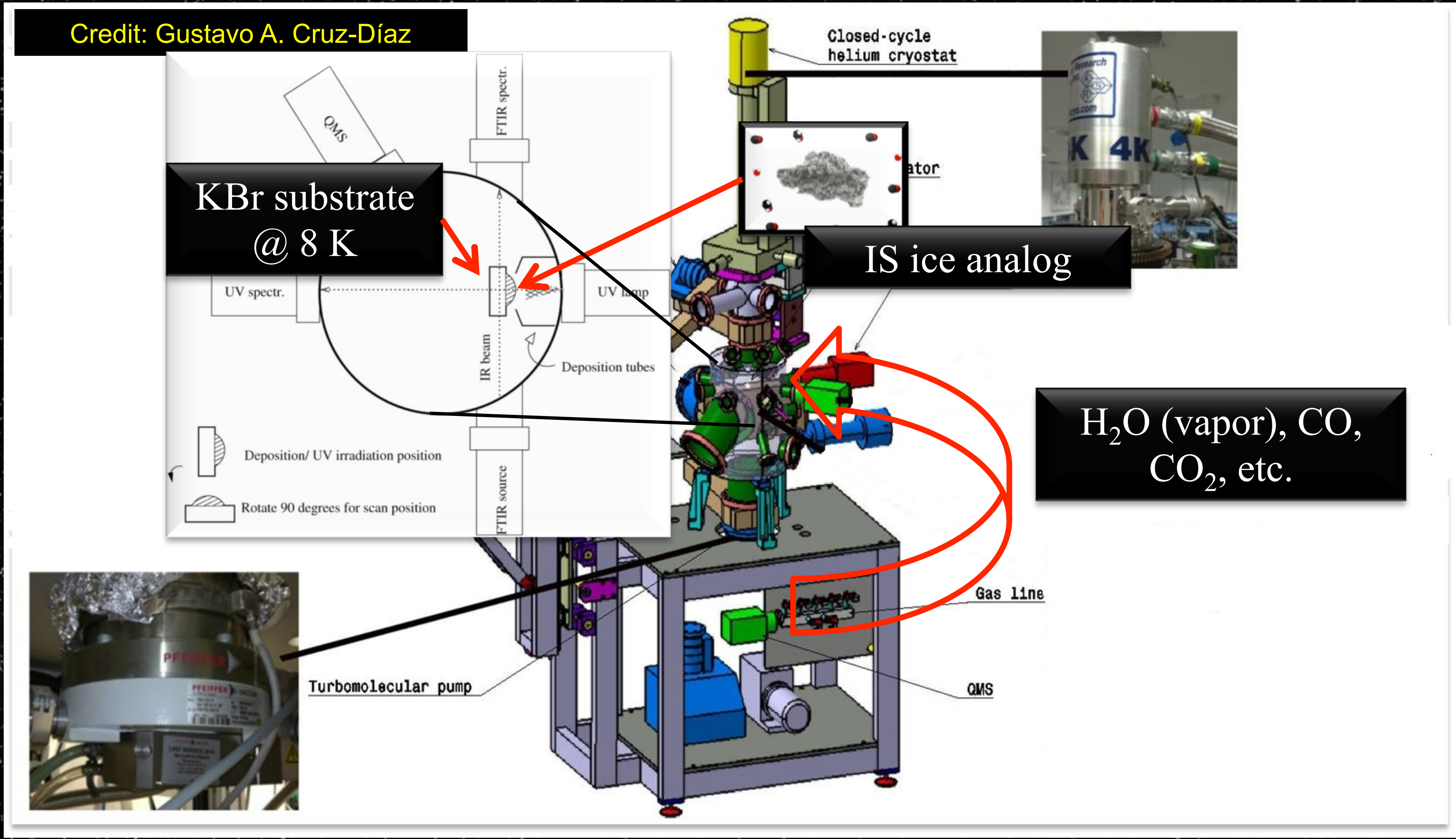
ISAC is an UHV chamber with P~4 10^{-11} mbar (dense clouds interiors)

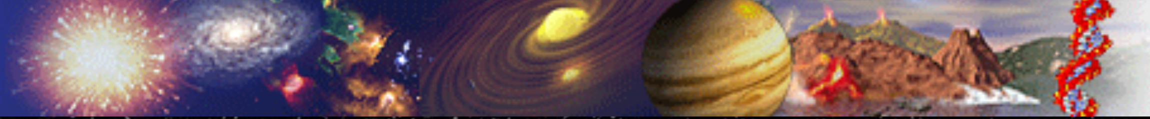


InterStellar Astrochemistry Chamber (ISAC)



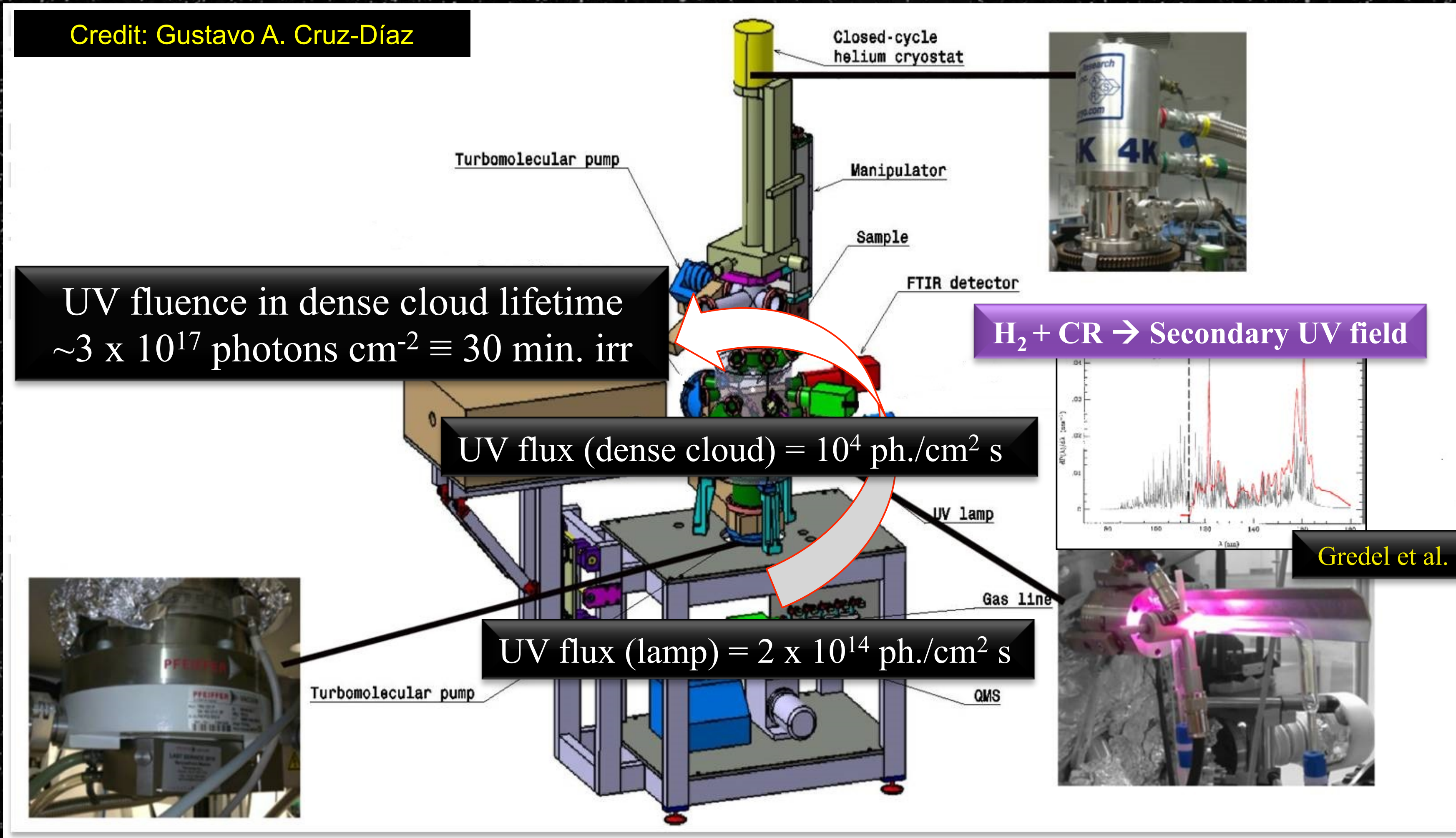
InterStellar Astrochemistry Chamber (ISAC)





2. Methods

InterStellar Astrochemistry Chamber (ISAC)



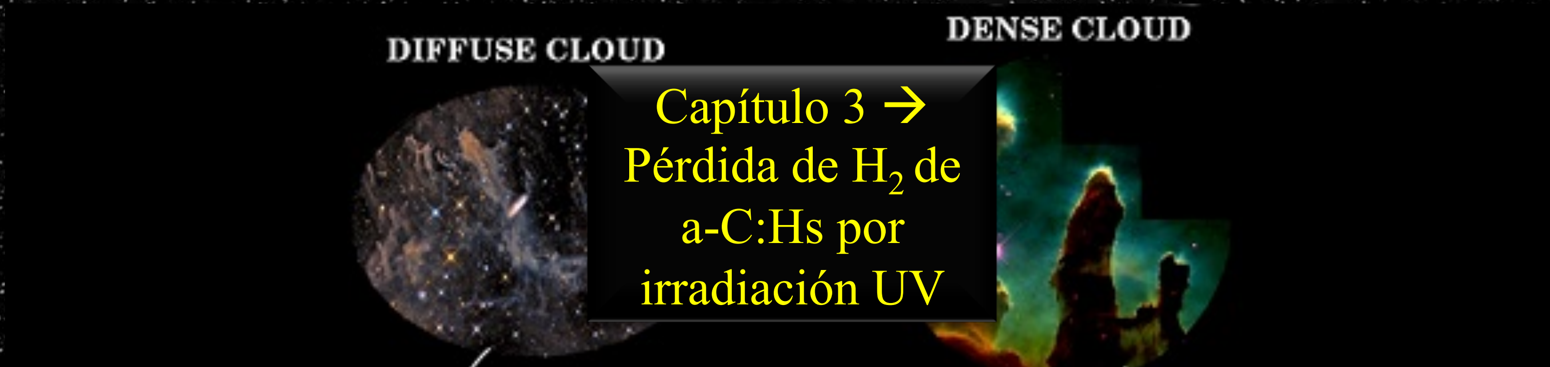
UV fluence in dense cloud lifetime
~3 x 10^{17} photons cm^{-2} ≡ 30 min. irr

H_2 + CR → Secondary UV field

UV flux (dense cloud) = 10^4 ph./cm^2 s

UV flux (lamp) = 2 x 10^{14} ph./cm^2 s

UV photoprocessing of a-C:H (IS dust grain analog)→ diffusion of H_2



Capítulo 3 →
Pérdida de H_2 de
a-C:Hs por
irradiación UV

A&A 591, A107 (2016)
DOI: 10.1051/0004-6361/201628500

Astronomy & Astrophysics

Vacuum ultraviolet photolysis of hydrogenated amorphous carbons

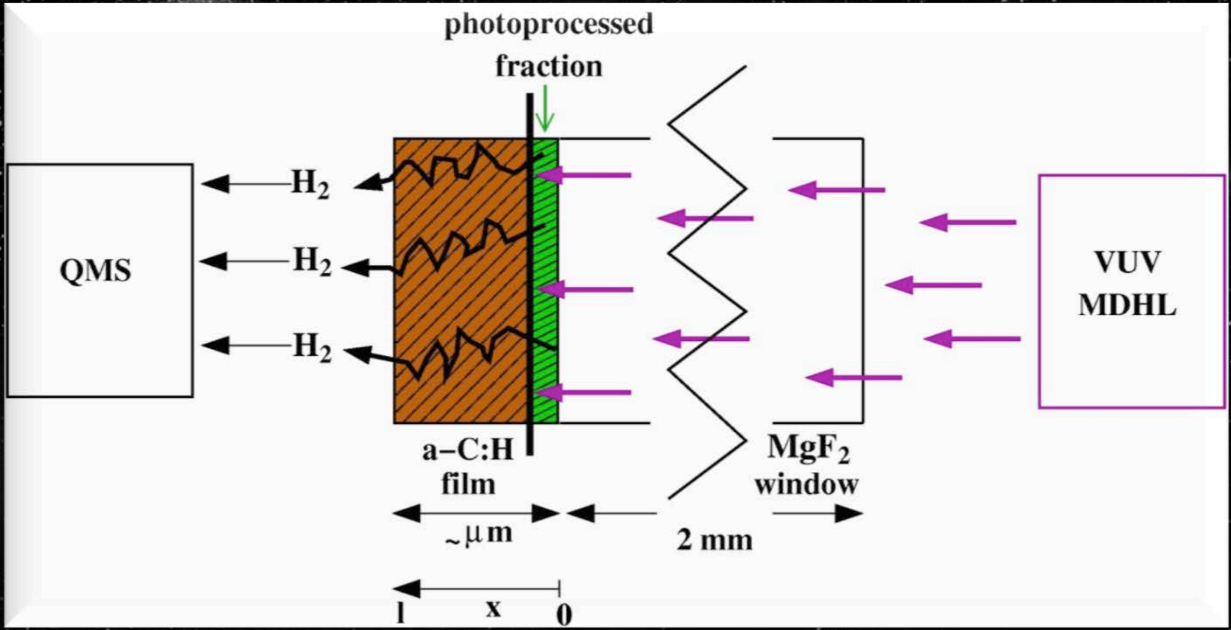
III. Diffusion of photo-produced H_2 as a function of temperature

R. Martín-Doménech[1], E. Dartois[2], and G. M. Muñoz Caro[1]

[1] Centro de Astrobiología, INTA-CSIC, Carretera de Ajalvir, km 4, Torrejón de Ardoz, 28850 Madrid, Spain
e-mail: rmartin@cab.inta-csic.es
[2] Institut d'Astrophysique Spatiale, UMR 8617, CNRS/Université Paris-Sud, Université Paris-Saclay, Université Paris-Sud, 91405 Orsay, France

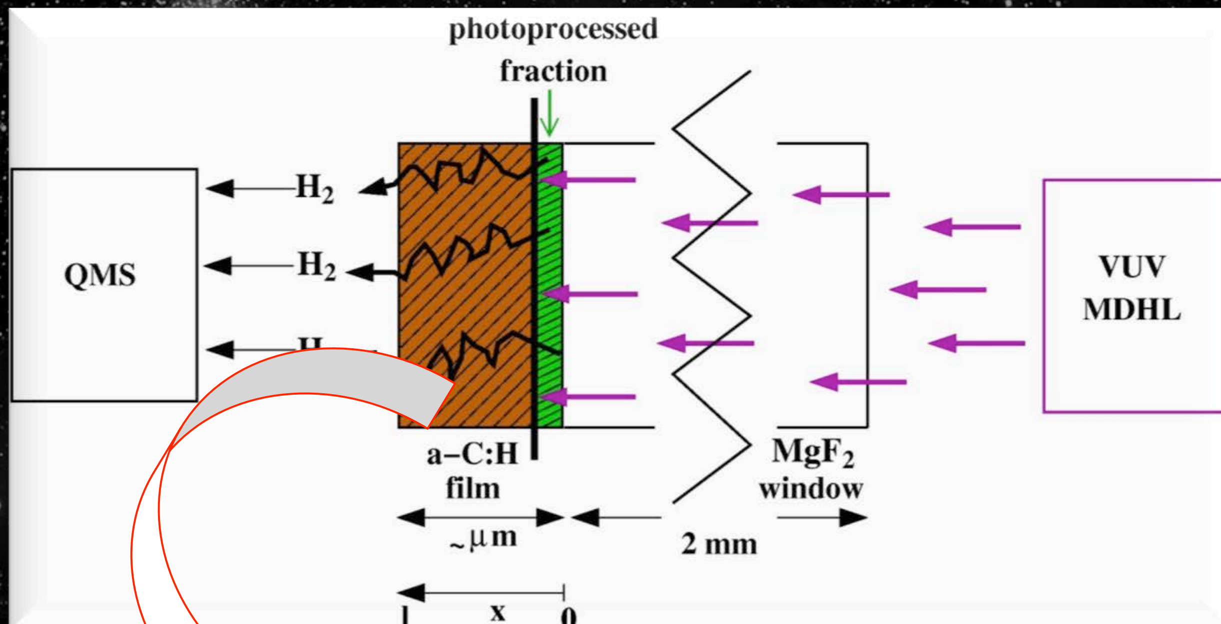
Received 12 March 2016 / Accepted 10 May 2016

UV photoprocessing of a-C:D (IS dust grain analog) ➔ diffusion of D_2



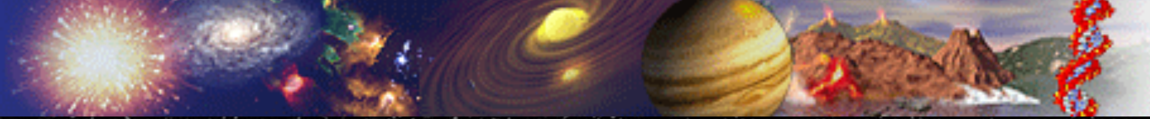
3. Results - Dust

UV photoprocessing of a-C:D (IS dust grain analog) → diffusion of D_2



$$F(x,t) = -D \cdot \frac{\partial C(x,t)}{\partial x}$$

$$D = D_0 \cdot e^{\frac{-E_D}{T}}$$

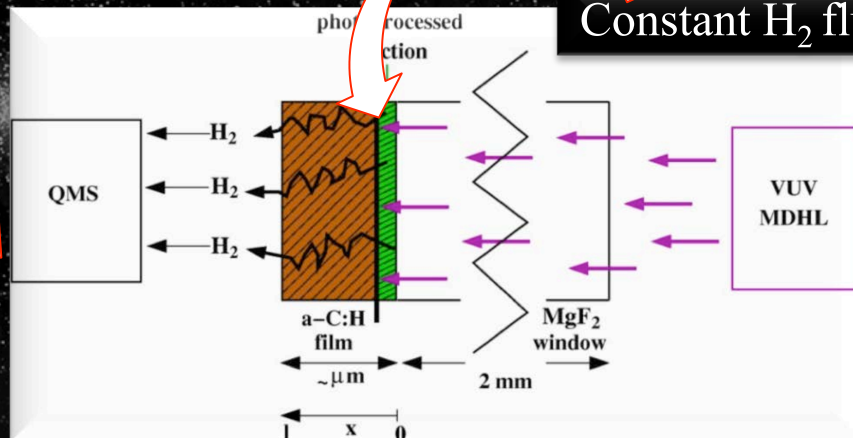


3. Results - Dust

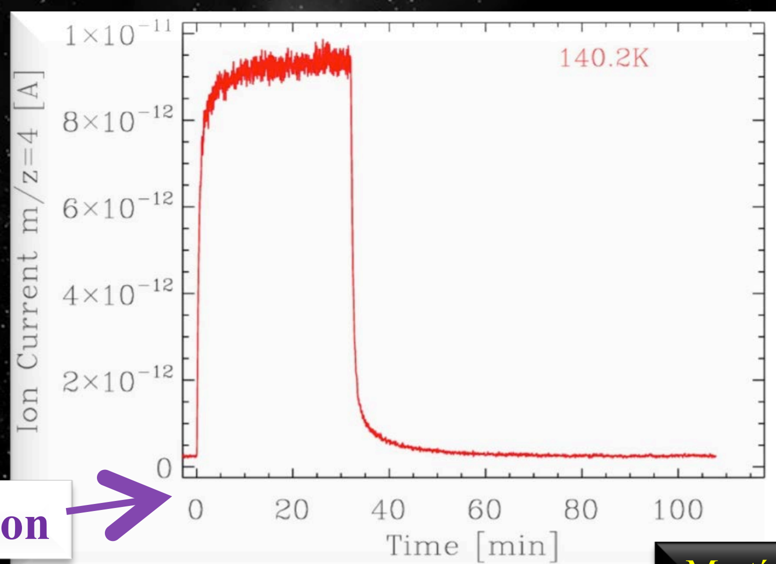
UV photoprocessing of a-C:D (IS dust grain analog) ➔ diffusion of D_2

Constant H_2 flux at surface x=0

UV on



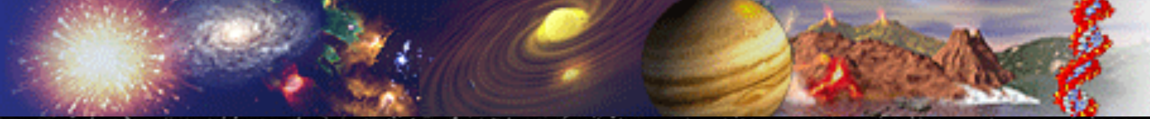
Ion current ≡ H_2 flux at surface x=l



UV on

l = 3.4 μm

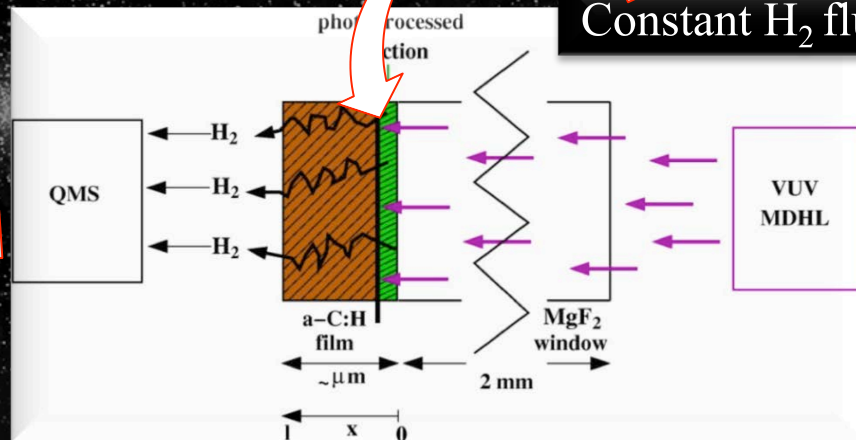
Martín-Doménech et al. 2016



3. Results - Dust

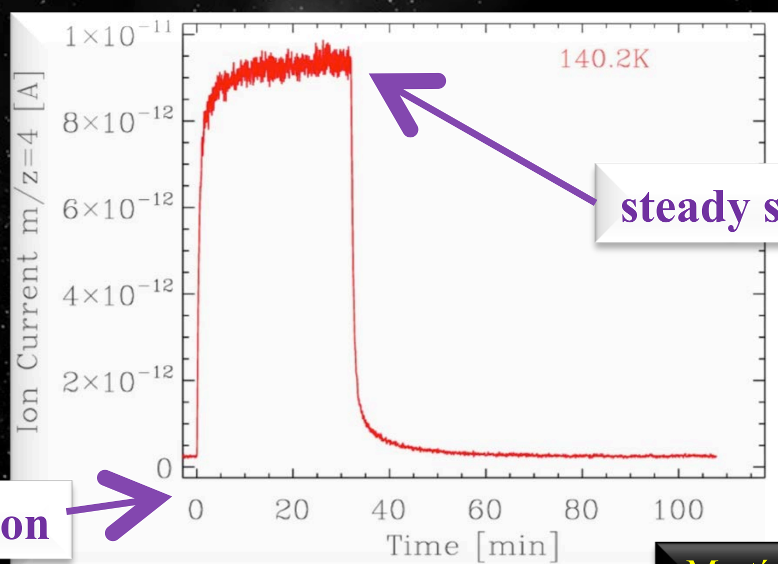
UV photoprocessing of a-C:D (IS dust grain analog) ➔ diffusion of D_2

Constant H_2 flux at surface x=0



UV on

Ion current ≡ H_2 flux at surface x=l

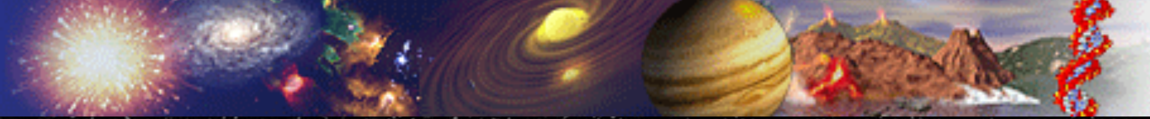


steady state

UV on

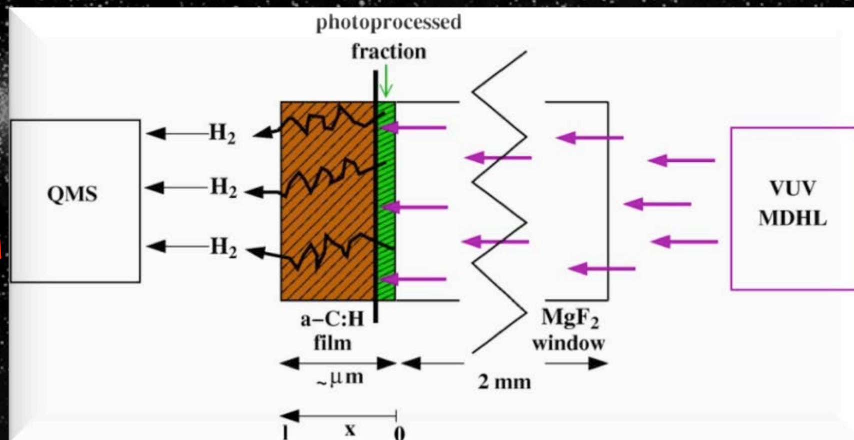
$l = 3.4\ \mu m$

Martín-Doménech et al. 2016

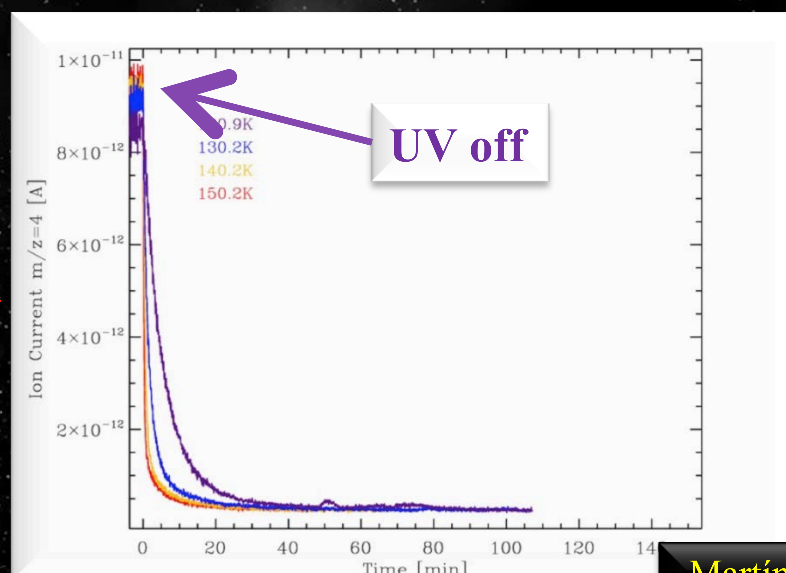


3. Results - Dust

UV photoprocessing of a-C:D (IS dust grain analog) ➔ diffusion of D_2



Ion current ≡
H_2 flux at surface x=l



$l = 3.4$ µm

↓T ➔ ↓D ➔ ↑t

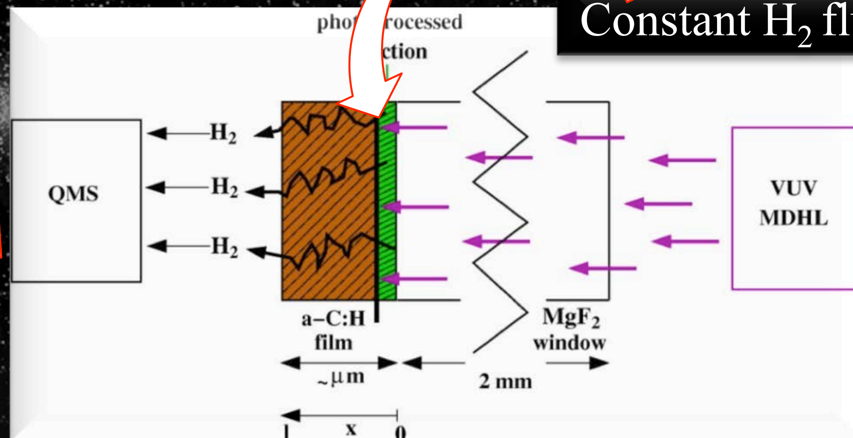
Martín-Doménech et al. 2016

3. Results - Dust

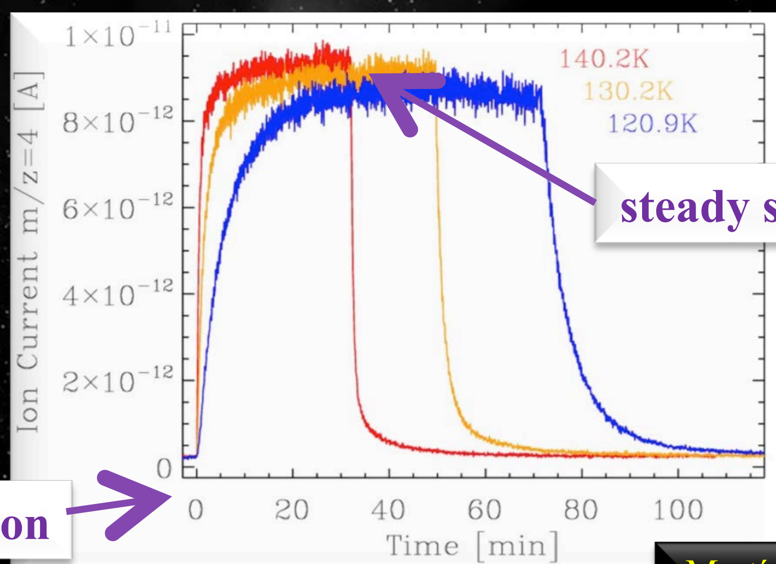
UV photoprocessing of a-C:D (IS dust grain analog) ➔ diffusion of D_2

Constant H_2 flux at surface x=0

UV on



Ion current ≡
H_2 flux at surface x=l



steady state

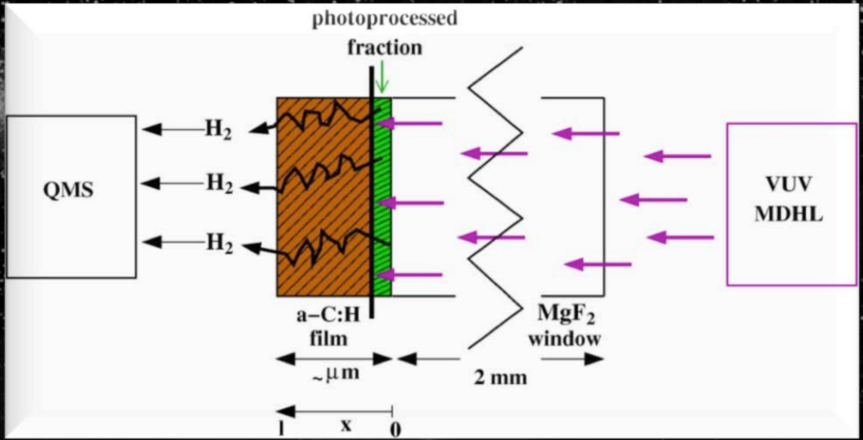
UV on

l = 3.4 µm

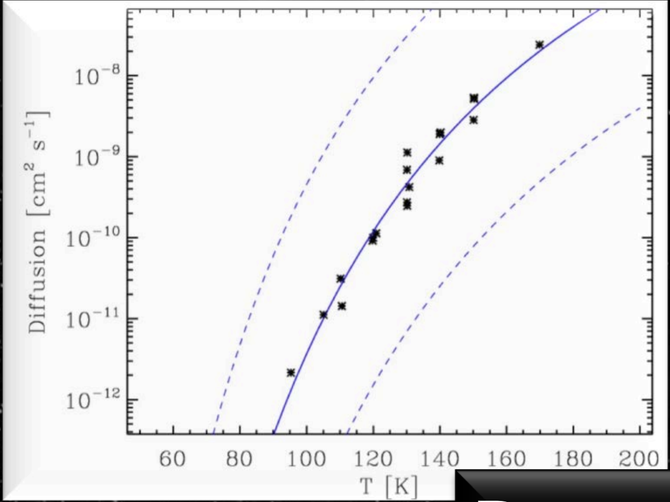
↓T ➔ ↓D ➔ ↑t

Martín-Doménech et al. 2016

UV photoprocessing of a-C:D (IS dust grain analog) → diffusion of D_2

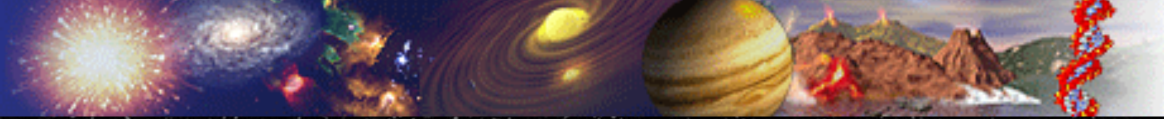


$$ln[D] = ln[D_0] - E_D \cdot \frac{1}{T}$$



$$D_0 = 0.0045^{+0.0050}_{-0.0023}\ cm^2\ s^{-1}$$
$$E_D = 2090 \pm 90\ K$$

D very sensitive to T variations



4. Results - Ice

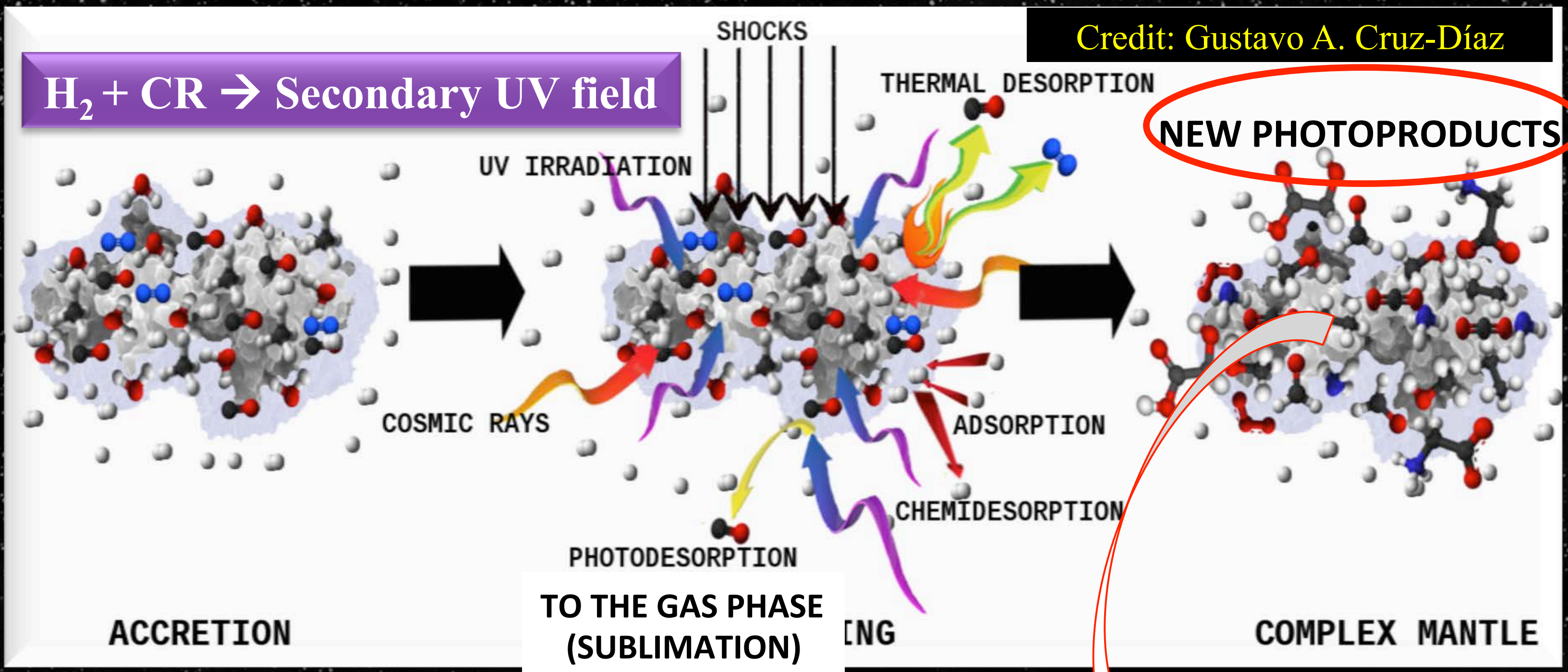
Capítulo 4 →
Acreción de CO sobre
hielo de H_2O

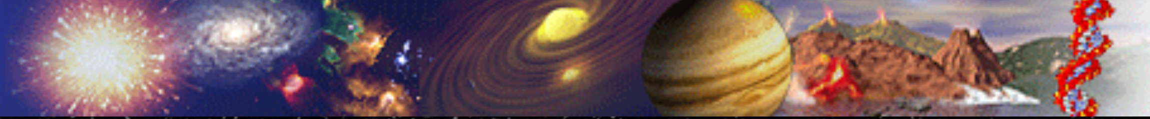
Capítulos 5-8 →
Irradiación UV de
análogos de hielo

Capítulo 9 →
Desorción térmica de
análogos de hielo

4. Results - Ice

UV photoprocessing of ices

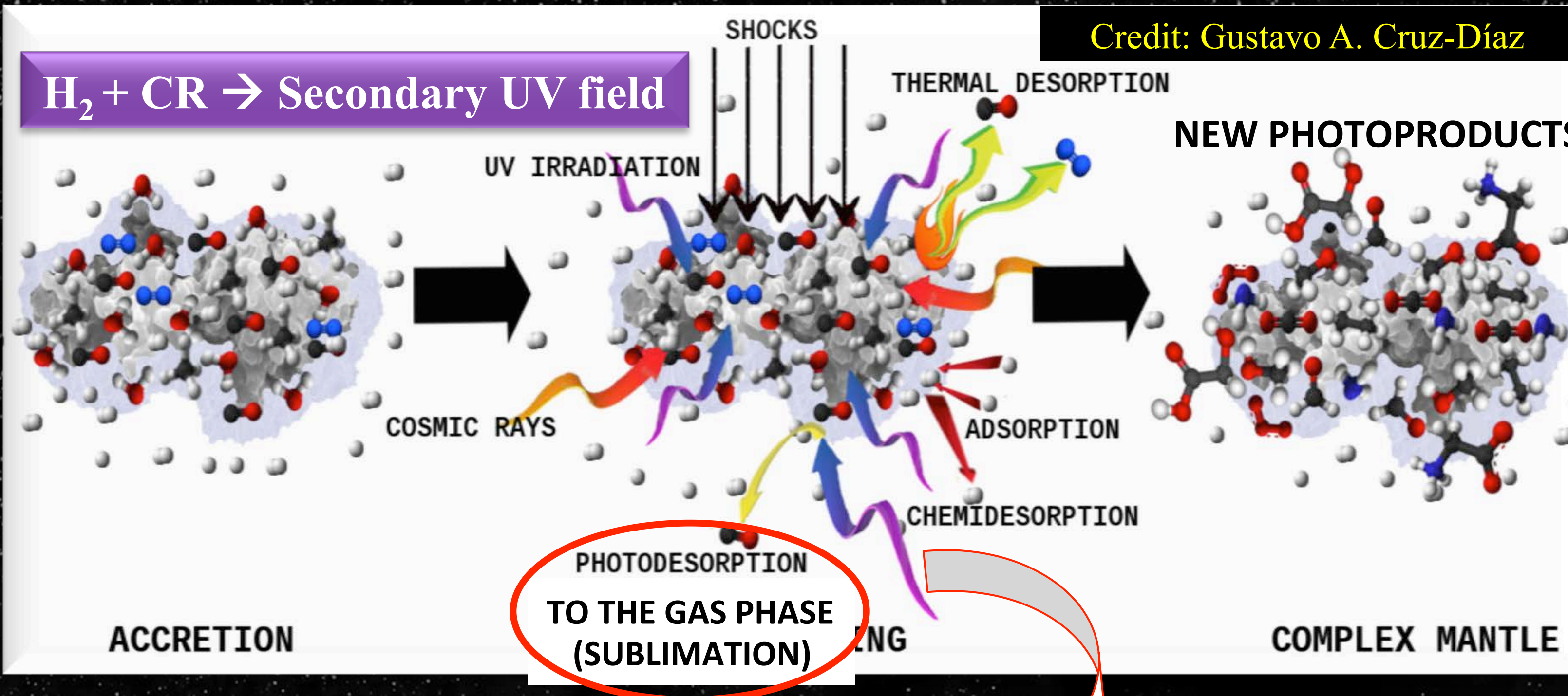




4. Results - Ice

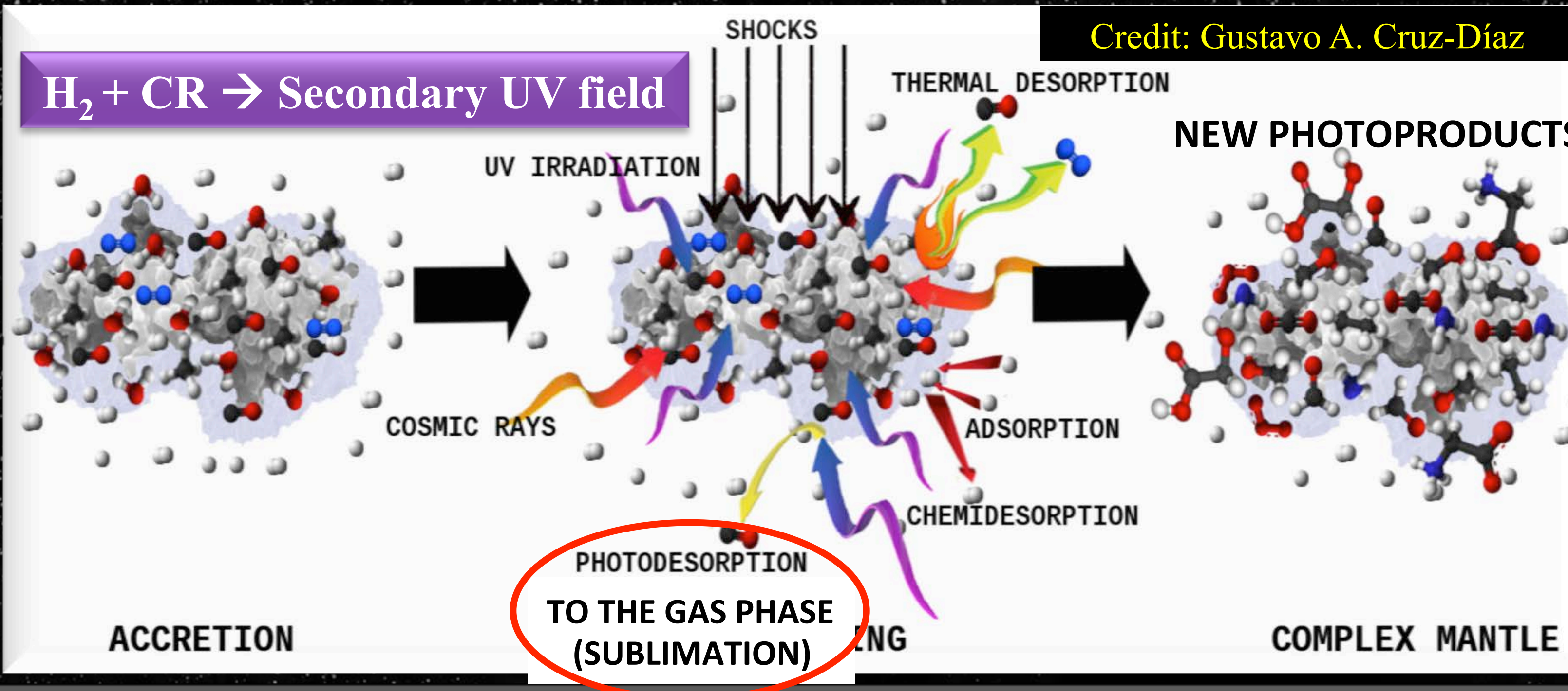
UV photoprocessing of ices

H_2 + CR → Secondary UV field



4. Results - Ice

UV photoprocessing of ices



Non-thermal desorption (sublimation) processes needed in cold regions to explain gas-phase presence (e.g., CH_3OH)

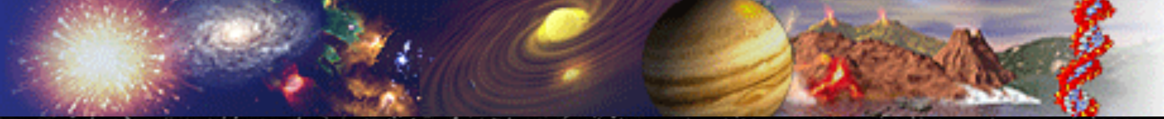
UV photodesorption of ices

Direct photodesorption

absorption + photodesorption

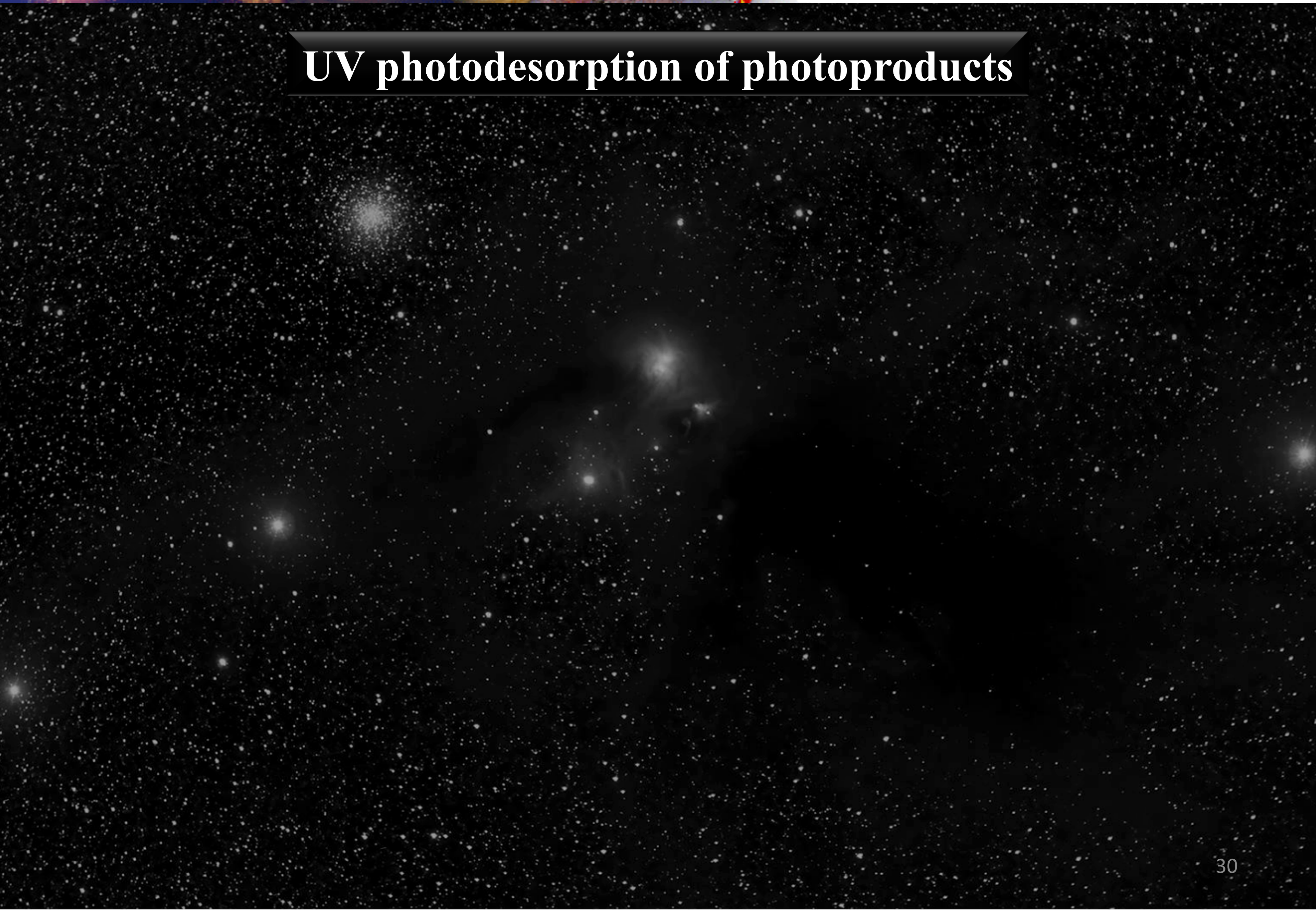
Photodesorption via energy transfer

absorption + energy transfer + photodesorption



4. Results - Ice

UV photodesorption of photoproducts



UV photodesorption of photoproducts

Direct photodesorption

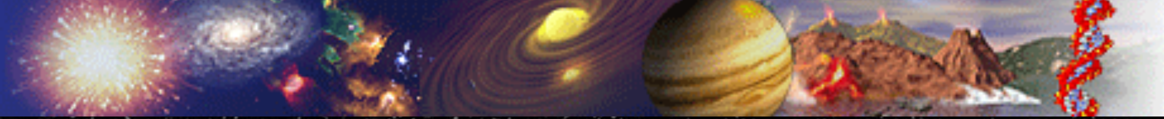
1 photon

absorption + photodesorption

Photodesorption via energy transfer

>1 photons

absorption + energy transfer + photodesorption



UV photodesorption of photoproducts

Direct photodesorption

Photoproducts formed on the ice surface (first photon)

- by photofragmentation
- by subsequent recombination of radicals

$$CH_3OH + h\nu \rightarrow \left\{ \begin{array}{c} CH_3 + OH \\ CH_2OH + H \end{array} \right\} \rightarrow CH_3 + H \rightarrow CH_4 \uparrow$$

(first photon)

CH_3OH ice surface

Cruz-Díaz et al. 2016

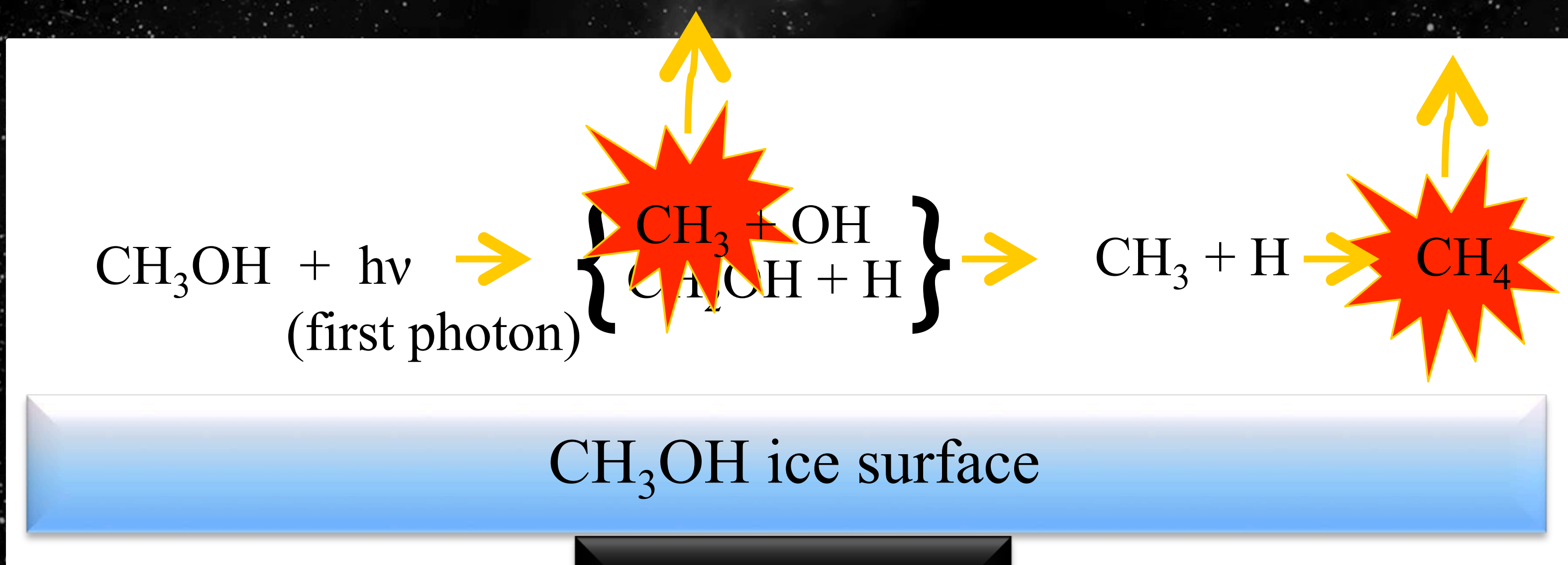
UV photodesorption of photoproducts

Direct photodesorption

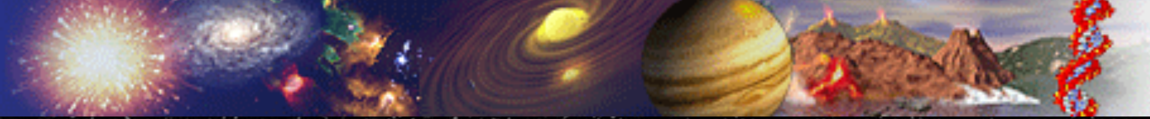
Photoproducts formed on the ice surface (first photon)
- by photofragmentation
- by subsequent recombination of radicals

can desorb INMEDIATELY because of the excess energy (no more photons needed)

Fayolle et al. 2013, Fillion et al. 2014



Cruz-Díaz et al. 2016



4. Results - Ice

UV photodesorption of photoproducts

photochemical desorption or photochemidesorption

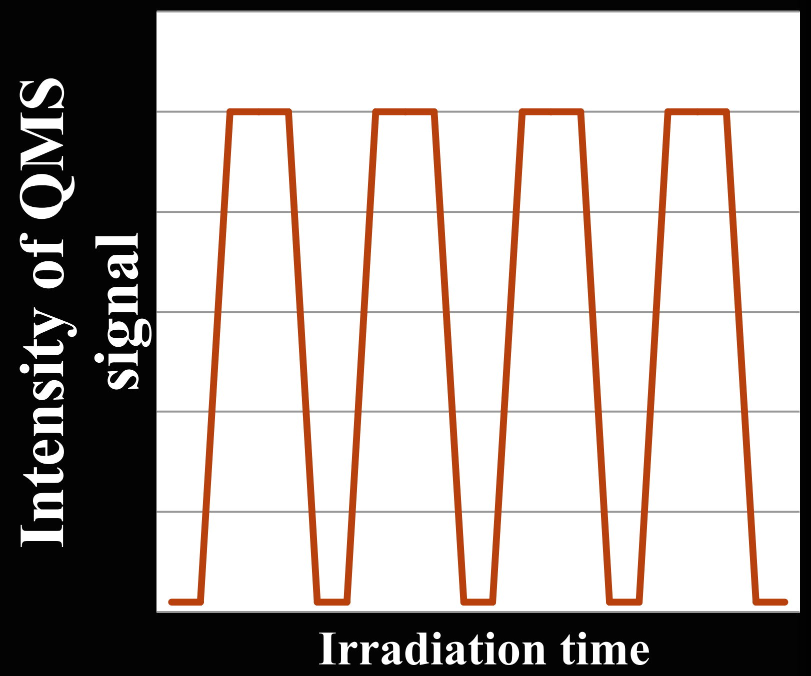
Photoproducts formed on the ice surface (first photon)

als

can desorb INMED

re photons needed)

Photochemidesorption ≡ constant yield



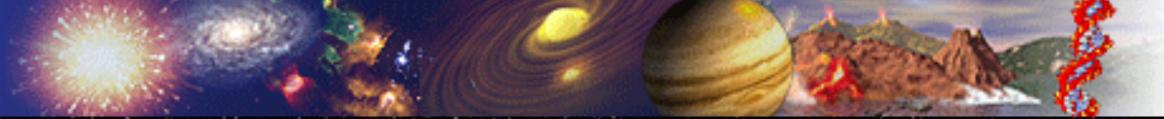
CH_3OH +

(fir

H

CH_4

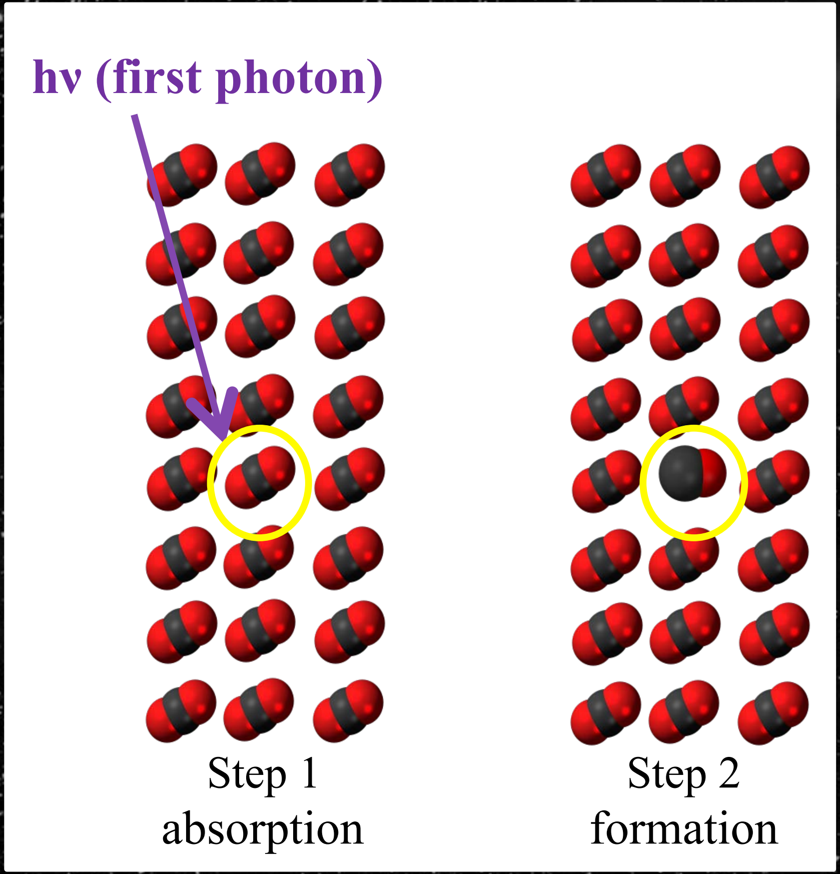
Cruz-Díaz et al. 2016

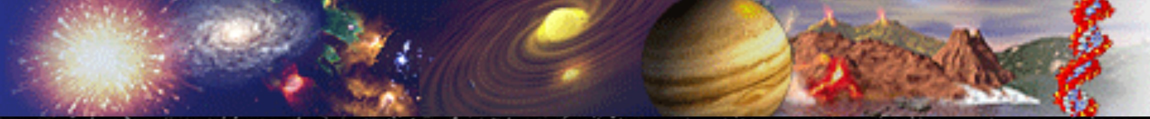


UV photodesorption of photoproducts

Photodesorption via energy transfer

Photoproducts formed in the ice bulk (first photon)





4. Results - Ice

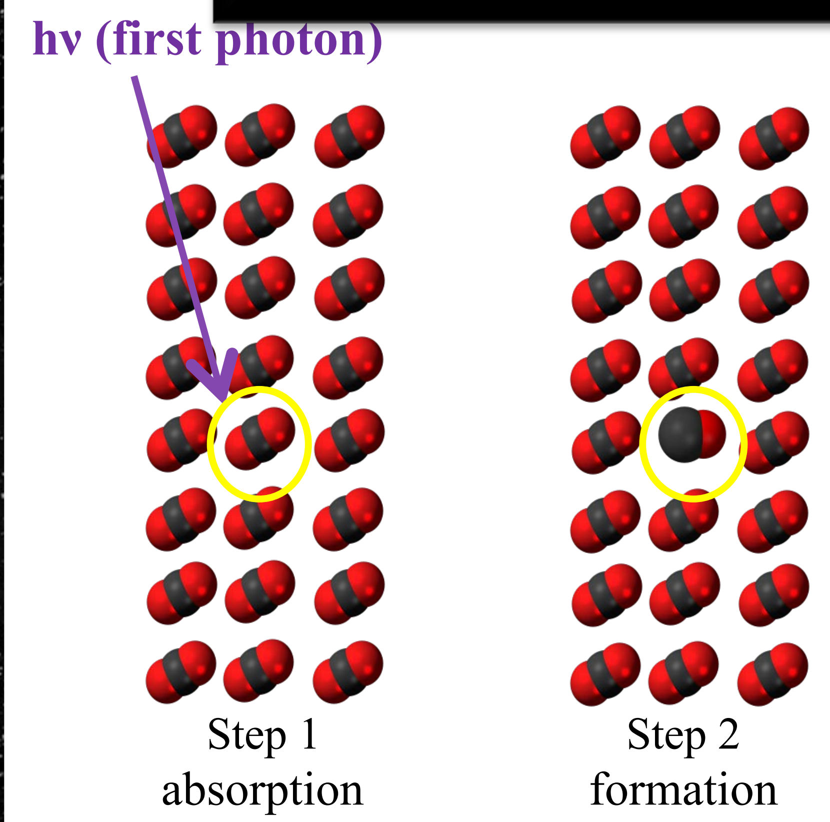
UV photodesorption of photoproducts

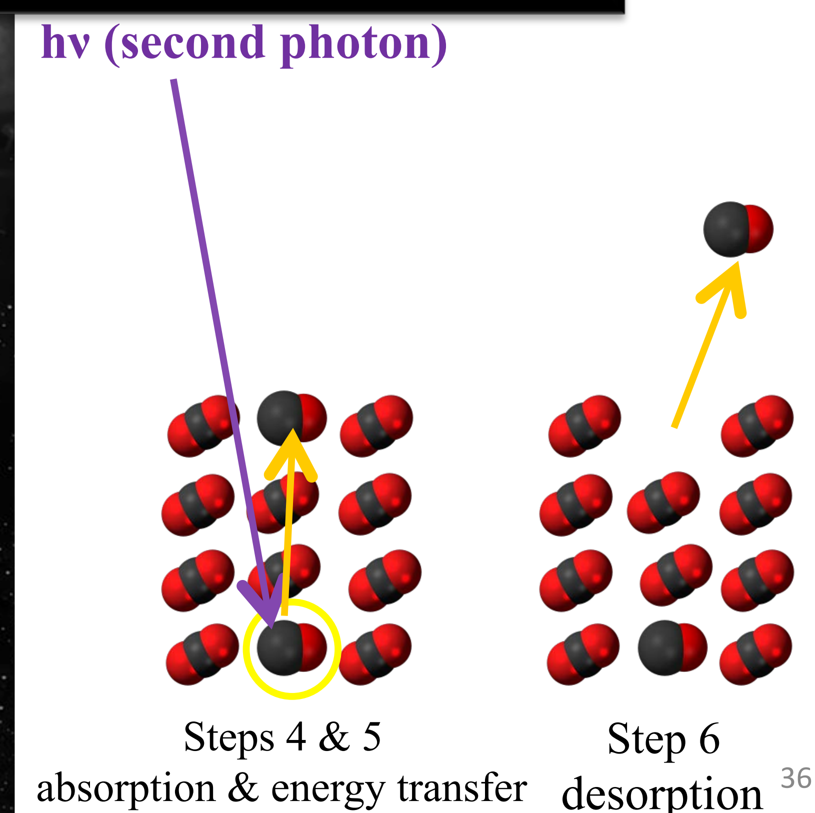
Photodesorption via energy transfer

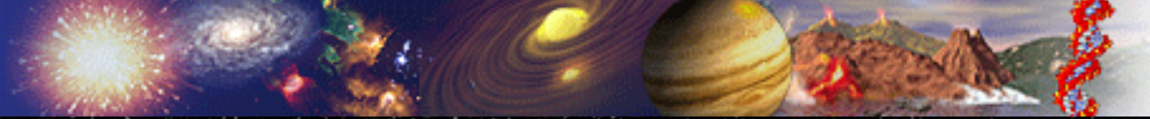
Photoproducts formed in the ice bulk (first photon)

can desorb LATER after energy transfer (second photon)

(Muñoz Caro et al. 2010, Fayolle et al. 2011, 2013, Bertin et al. 2012, 2014, Chen et al. 2014)







UV photodesorption of photoproducts

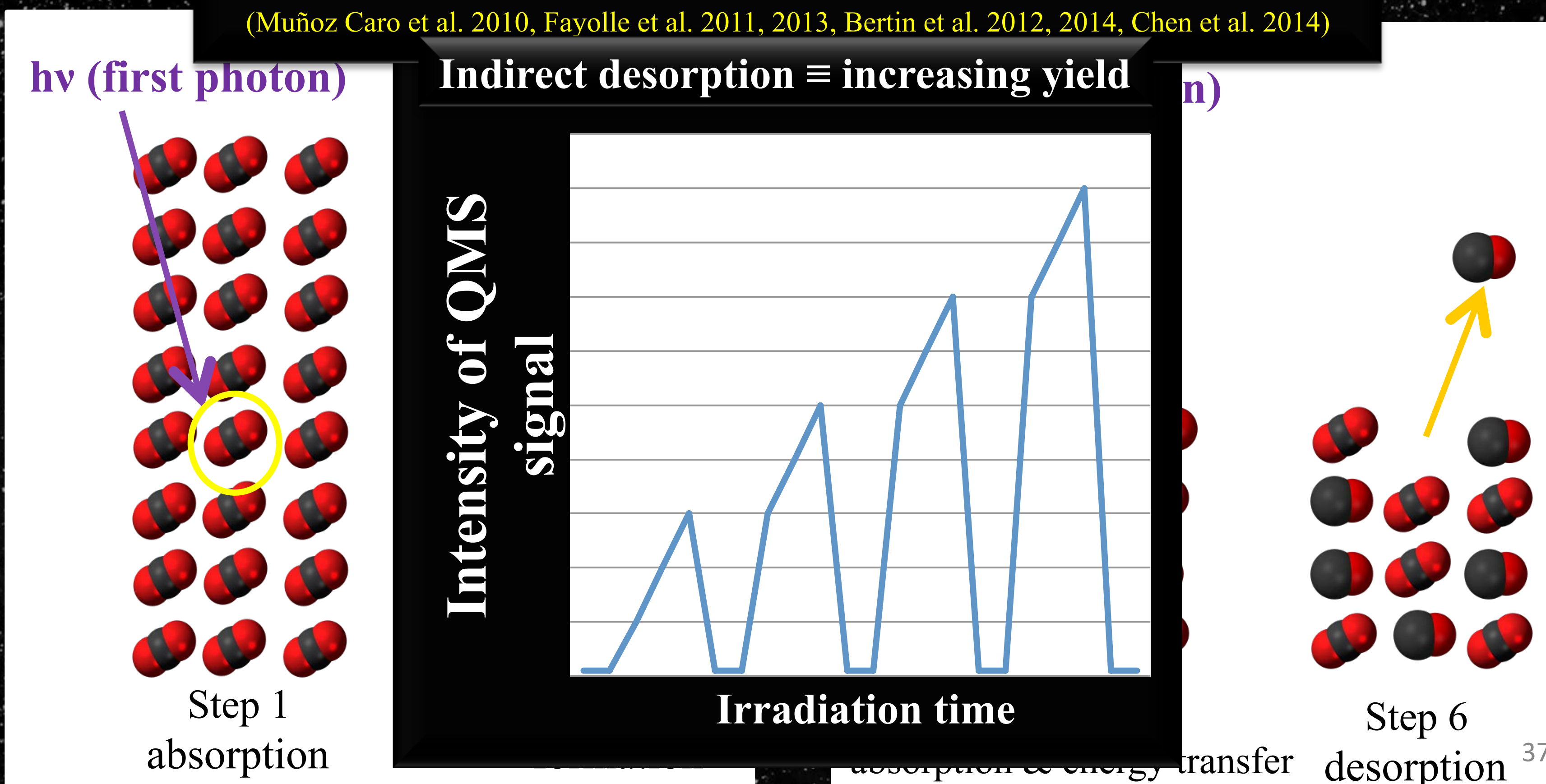
Photodesorption via energy transfer

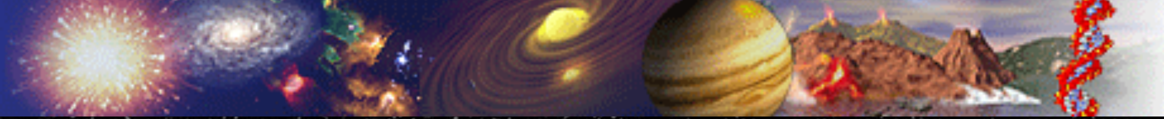
Photoproducts formed in the ice bulk (first photon)

can desorb LATER after energy transfer (second photon)

(Muñoz Caro et al. 2010, Fayolle et al. 2011, 2013, Bertin et al. 2012, 2014, Chen et al. 2014)

Indirect desorption ≡ increasing yield





UV photoprocessing of ices

UV photoprocessing of a pure CO_2 ice

A&A 584, A14 (2015)
DOI: 10.1051/0004-6361/201526003

Astronomy & Astrophysics

UV photoprocessing of CO_2 ice: a complete quantification of photochemistry and photon-induced desorption processes★

R. Martín-Doménech[1], J. Manzano-Santamaría[1], G. M. Muñoz Caro[1], G. A. Cruz-Díaz[1,2], Y.-J. Chen[3,4], V. J. Herrero[5], and I. Tanarro[5]

[1] Centro de Astrobiología (INTA-CSIC), Ctra. de Ajalvir, km 4, Torrejón de Ardoz, 28850 Madrid, Spain
e-mail: rmartin@cab.inta-csic.es
[2] Sackler Laboratory for Astrophysics, Leiden Observatory, University of Leiden, PO Box 9513, NL 2300 RA Leiden, The Netherlands
[3] Space Sciences Center and Department of Physics and Astronomy, University of Southern California, Los Angeles, CA90089-1341, USA
[4] Department of Physics, National Central University, Jhongli City, 32054 Taoyuan County, Taiwan
[5] Instituto de Estructura de la Materia-Consejo Superior de Investigaciones Científicas (IEM-CSIC), 28006 Madrid, Spain

Received 2 March 2015 / Accepted 7 September 2015

UV photoprocessing of a pure C_2H_5OH ice

UV photoprocessing of a H_2O:CH_4 (3:1) ice mixture

A&A 589, A107 (2016)
DOI: 10.1051/0004-6361/201528025

Astronomy & Astrophysics

Study of the photon-induced formation and subsequent desorption of CH_3OH and H_2CO in interstellar ice analogs

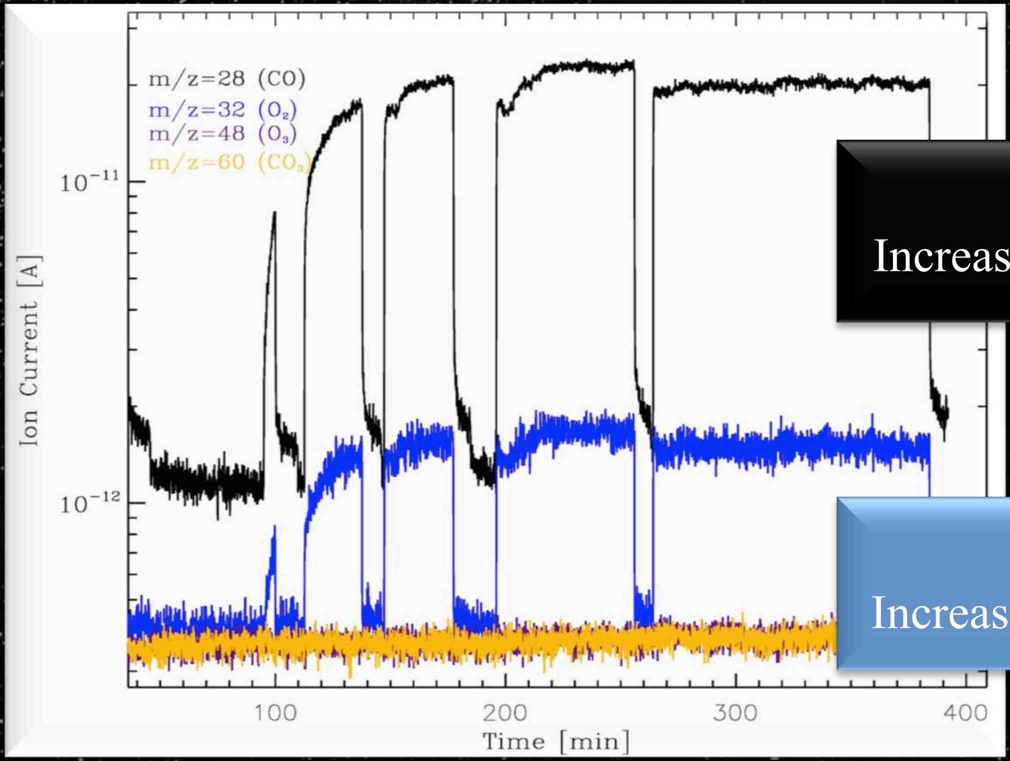
R. Martín-Doménech[1], G. M. Muñoz Caro[1], and G. A. Cruz-Díaz[1,2,3]

e Astrobiología (INTA-CSIC), Ctra. de Ajalvir, km 4, Torrejón de Ardoz, 28850 Madrid, Spain
martin@cab.inta-csic.es
Ames Research Center, Moffett Field, Mountain View, CA 94035, USA
a Environmental Research Institute, Petaluma, CA 94952, USA

1 December 2015 / Accepted 6 February 2016

UV photoprocessing of a pure CO_2 ice

Photodesorption of CO and O_2 observed by QMS



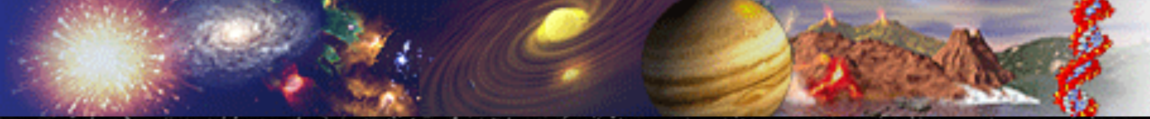
Martín-Doménech et al. 2015

CO

Increasing yield ≡ indirect photodesorption

O_2

Increasing yield ≡ indirect photodesorption



4. Results - Ice

UV photoprocessing of a pure C_2H_5OH ice

UV photoprocessing of a $H_2O{:}CH_4$ ice mixture

A&A 589, A107 (2016)
DOI: 10.1051/0004-6361/201528025

Astronomy & Astrophysics

Study of the photon-induced formation and subsequent desorption of CH_3OH and H_2CO in interstellar ice analogs

R. Martín-Doménech[1], G. M. Muñoz Caro[1], and G. A. Cruz-Díaz[1,2,3]

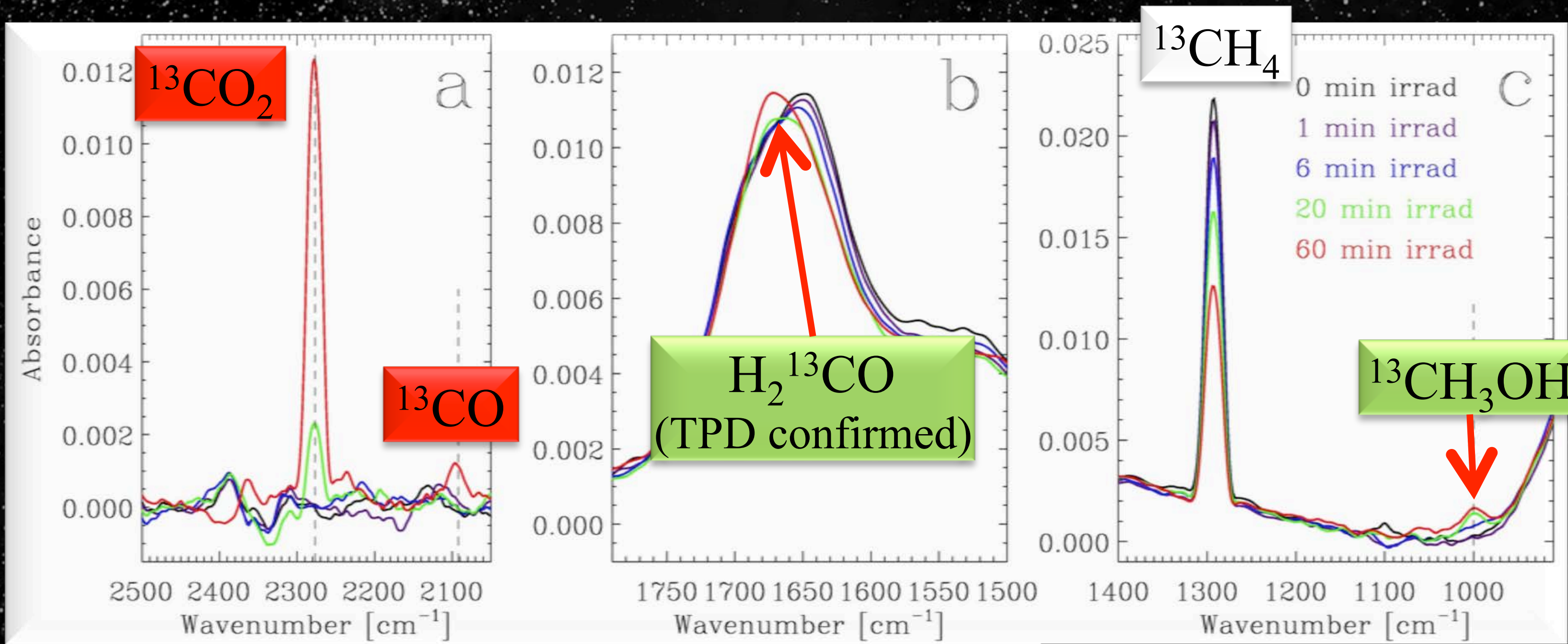
[1] Centro de Astrobiología (INTA-CSIC), Ctra. de Ajalvir, km 4, Torrejón de Ardoz, 28850 Madrid, Spain
e-mail: rmartin@cab.inta-csic.es
[2] NASA Ames Research Center, Moffett Field, Mountain View, CA 94035, USA
[3] Bay Area Environmental Research Institute, Petaluma, CA 94952, USA

Received 21 December 2015 / Accepted 6 February 2016

4. Results - Ice

UV photoprocessing of a $H_2O:CH_4$ (3:1) ice mixture

Formation of photoproducts → new IR bands during irradiation

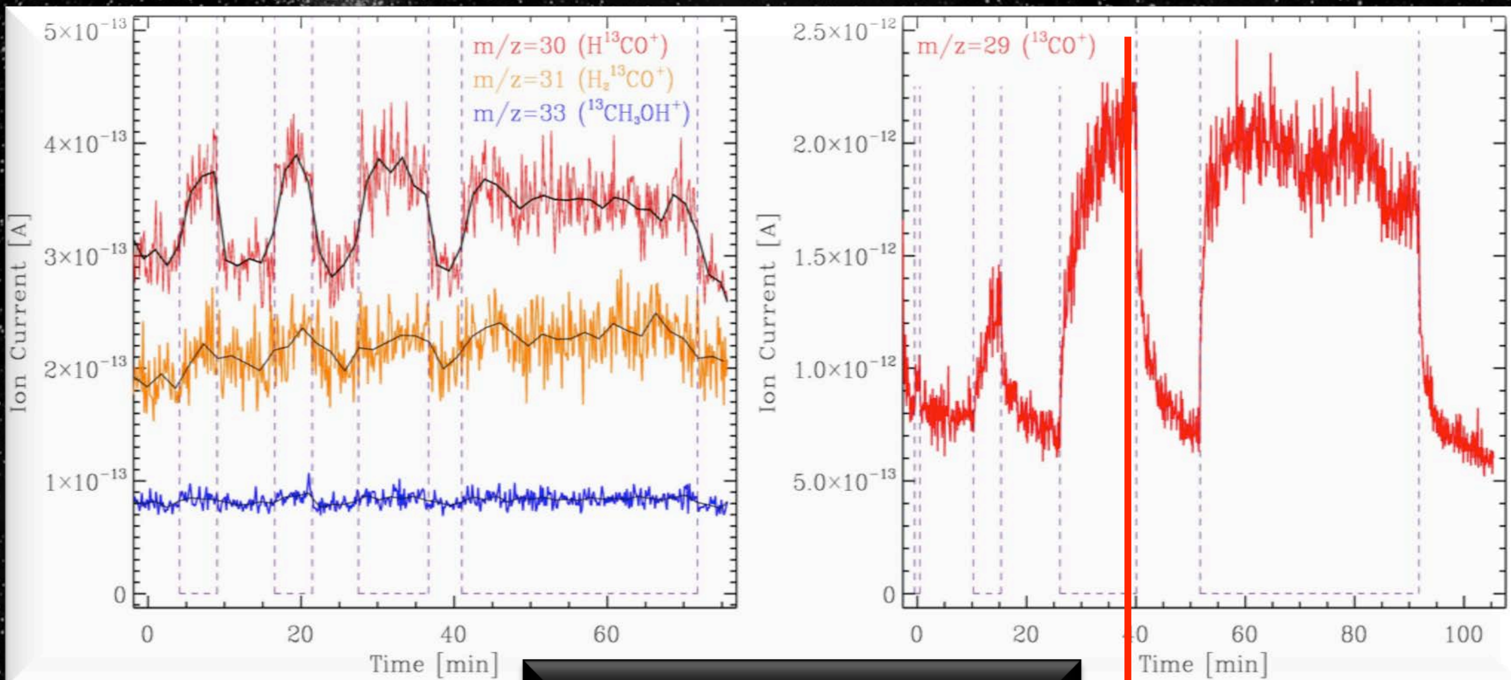


Martín-Doménech et al. 2016

For UV fluence 2x dense cloud lifetime
(~7.2 x 10^{17} photons cm^{-2} = 60 min. irr.)
↓
~4% of CH_3OH produced with respect to $N_i(CH_4)$

UV photoprocessing of a $H_2O:CH_4$ (3:1) ice mixture

Photodesorption of H_2CO and CO observed by QMS



Martín-Doménech et al. 2016

H_2CO

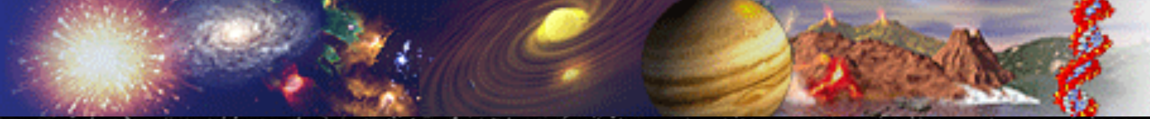
Y_{pd} (H_2CO) = 4.4 x 10^{-5} mol. / inc. ph.

photochemidesorption

CO

Y_{pd} (CO) = 1.5 x 10^{-4} mol. / inc. ph.

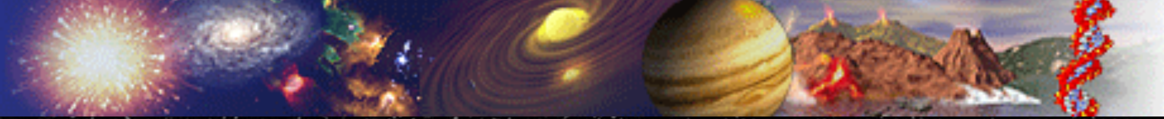
photodesorption **via energy transfer**



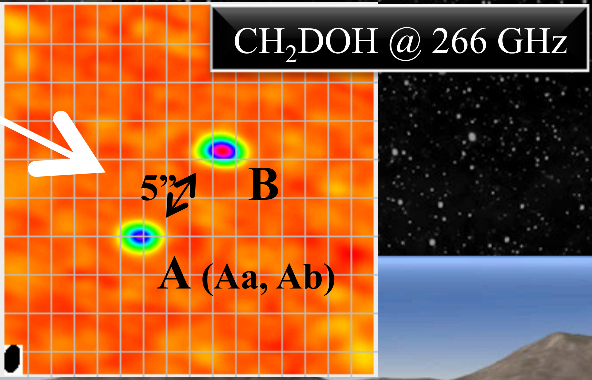
5. Results - Gas

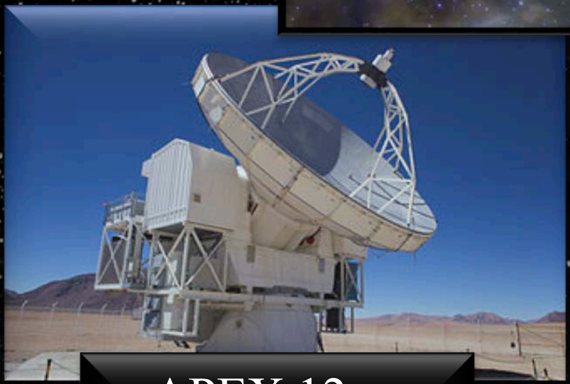
Capítulos 10 y 11 →
Observaciones del
hot corino
IRAS16293-2422

Credit: Gustavo A. Cruz-Díaz

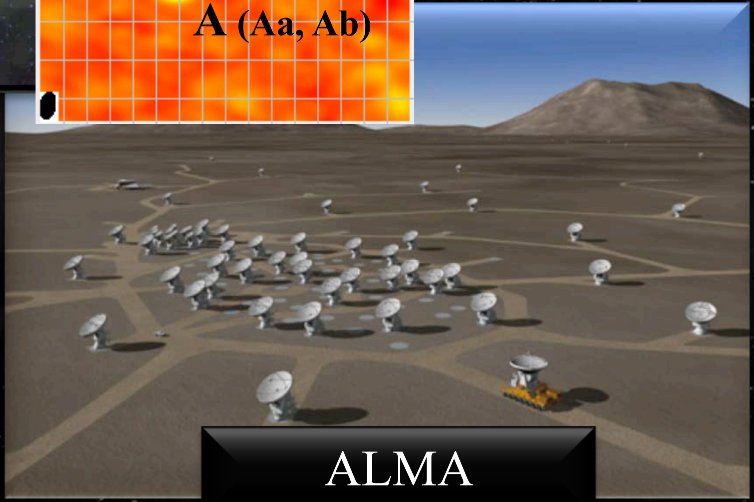


5. Results - Gas





E-092.C-0030A-2013 (PI)



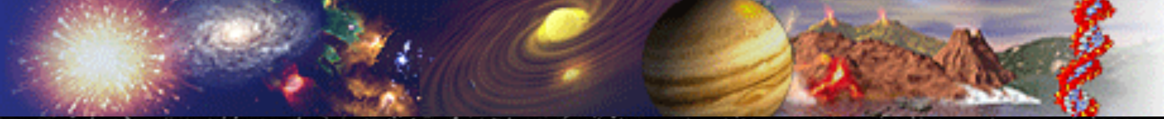
2013.1.00352.S (PI)

+

2013.1.0061.S

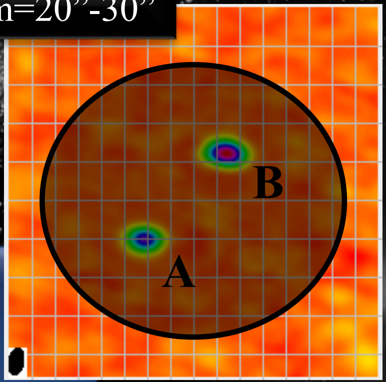
2012.1.0072.S

2011.0.00007.SV



Upper limits to the H_2S_2, HS_2, and S_2 abundances

beam=20”-30”



APEX 12-m

E-092.C-0030A-2013 (PI)

European Organisation for Astronomical Research in the Southern Hemisphere

OBSERVING PROGRAMMES OFFICE • Karl-Schwarzschild-Straße 2 • D-85748 Garching bei München • e-mail: opo@eso.org • Tel.: +49 89 320 06473

APPLICATION FOR OBSERVING TIME PERIOD: **92A**

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted.

1. Title Category: **C–2**

Sulfur depletion in circumstellar regions. First proposed observation of desorbing UV-photoproducts in H_2S-bearing ice mantles.

6. Principal Investigator: Rafael Martin-Domenech, rmartin@cab.inta-csic.es, E, Centro de Astrobiologia (CSIC-INTA)

6a. Co-investigators:

I.	Jiménez-Serra	ESO Headquarters Garching,ESO
H.	Mueller	I. Physikalisches Institut d... ...Koeln,D
G.M.	Muñoz Caro	Centro de Astrobiologia (C...
L.	Testi	ESO Headquarters Garchin...

- 1 -

A&A 585, A112 (2016)
DOI: 10.1051/0004-6361/201526271
© ESO 2016

Astronomy & Astrophysics

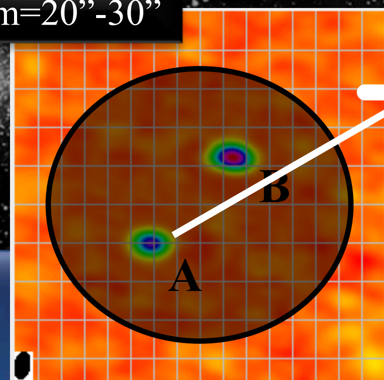
The sulfur depletion problem: upper limits on the H_2S_2, $HS_2^{\cdot}$, and S_2 gas-phase abundances toward the low-mass warm core IRAS 16293-2422★

R. Martín-Doménech[1], I. Jiménez-Serra[2,3], G. M. Muñoz Caro[1], H. S. P. Müller[4], A. Occhiogrosso[2], L. Testi[3], P. M. Woods[5], and S. Viti[2]

[1] Centro de Astrobiología (INTA-CSIC), Ctra. de Ajalvir, km 4, Torrejón de Ardoz, 28850 Madrid, Spain
e-mail: rmartin@cab.inta-csic.es
[2] University College London, 132 Hampstead Road, London NW1 2PS, UK
[3] European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching, Germany
[4] I. Physikalisches Institut, Universität zu Köln, Zülpicher. Str. 77, 50937 Köln, Germany
[5] Astrophysics Research Centre, Dept. of Mathematics & Physics, Queen's University Belfast, Belfast BT7 1NN, UK

Received 7 April 2015 / Accepted 22 November 2015

Upper limits to the H_2S_2, HS_2, and S_2 abundances

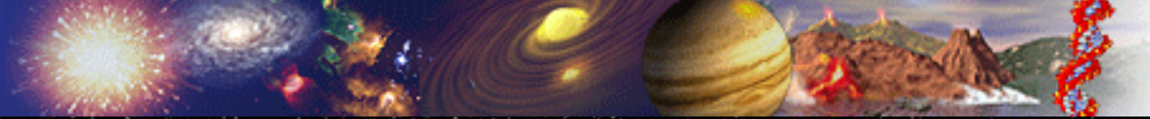


Very rich sulfur chemistry after thermal desorption of ices

$X(H_2S) = 5 \times 10^{-7}$ (Wakelam et al. 2004)

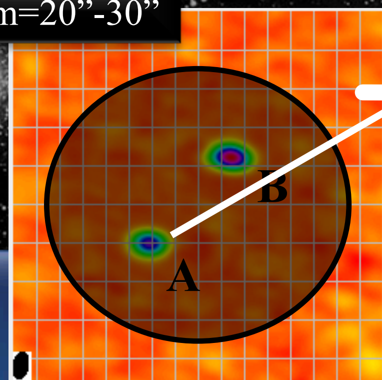
APEX 12-m

E-092.C-0030A-2013 (PI)



Upper limits to the H_2S_2, HS_2, and S_2 abundances

beam=20”-30”



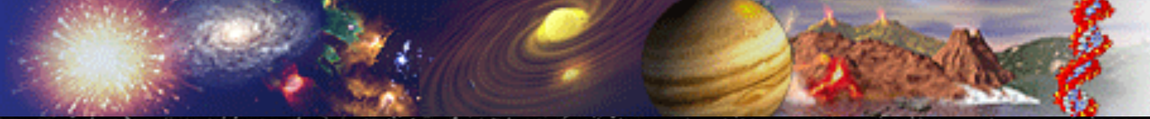
APEX 12-m

E-092.C-0030A-2013 (PI)

Very rich sulfur chemistry after thermal desorption of ices

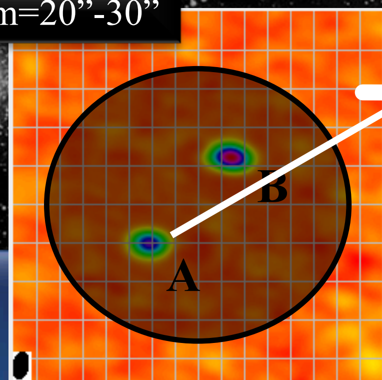
$X(H_2S) = 5 \times 10^{-7}$ (Wakelam et al. 2004)

H_2S_2, HS_2, and S_2??



Upper limits to the H_2S_2, HS_2, and S_2 abundances

beam=20”-30”



Very rich sulfur chemistry after thermal desorption of ices

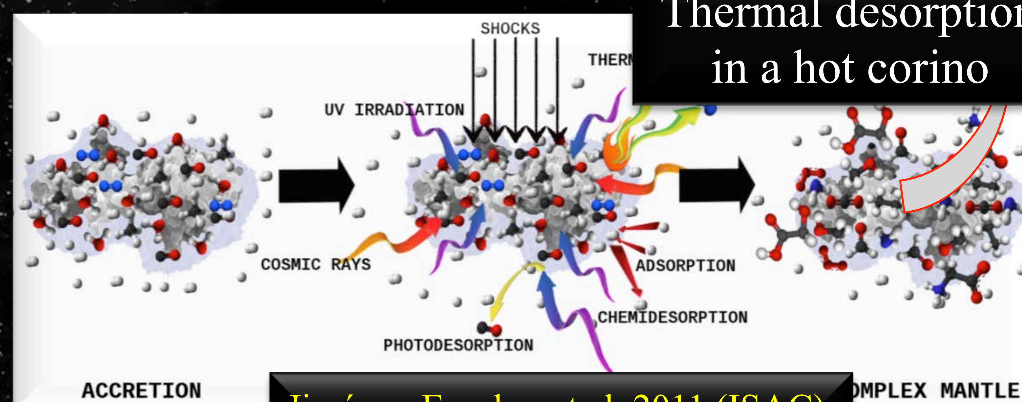
$X(H_2S) = 5 \times 10^{-7}$ (Wakelam et al. 2004)

H_2S_2, HS_2, and S_2??

APEX 12-m

E-092.C-0030A-2013 (PI)

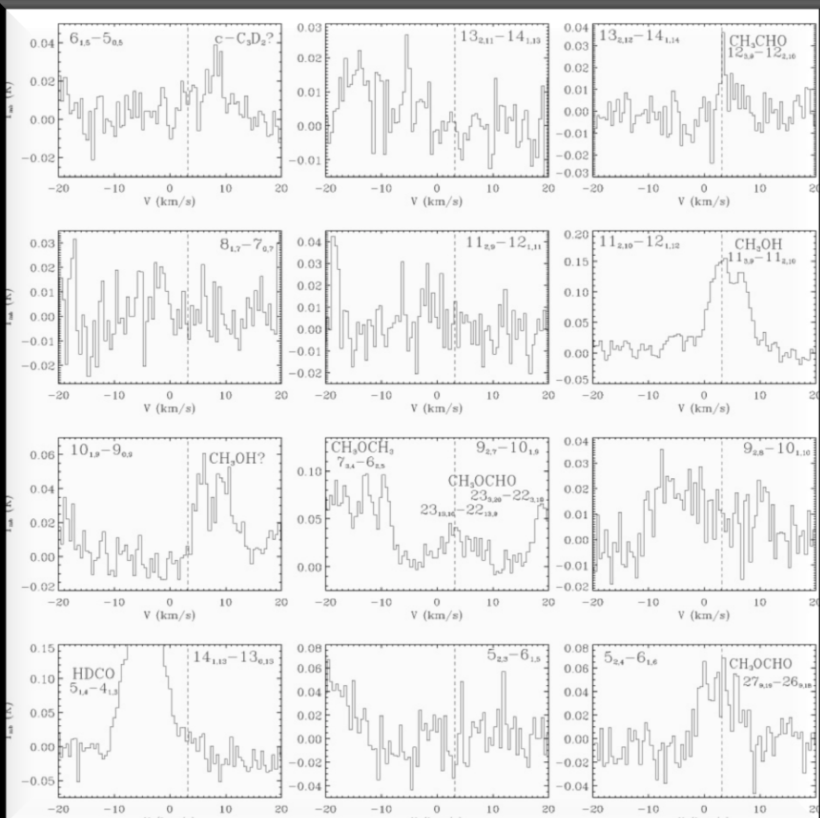
Thermal desorption in a hot corino



Jiménez-Escobar et al. 2011 (ISAC)

Upper limits to the H_2S_2, HS_2, and S_2 abundances

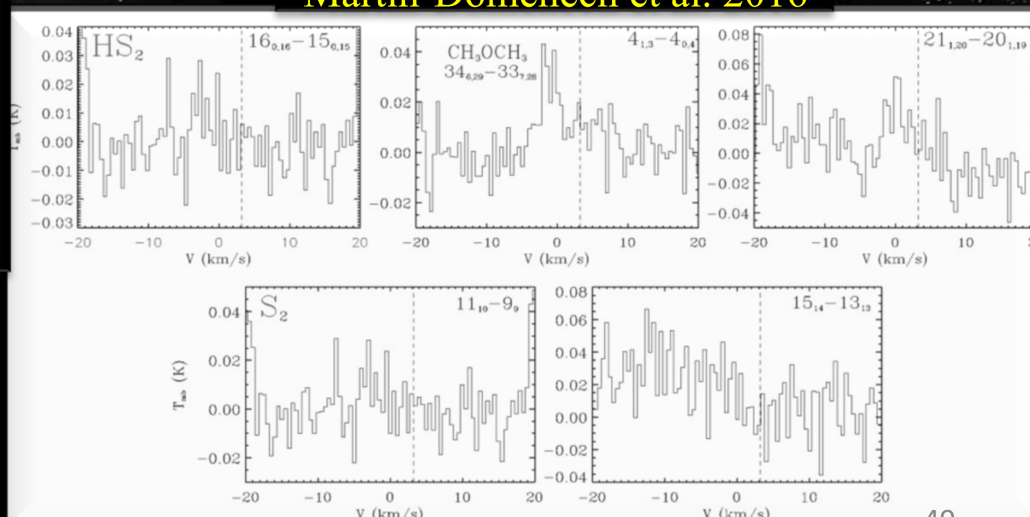
H_2S_2, HS_2, and S_2??

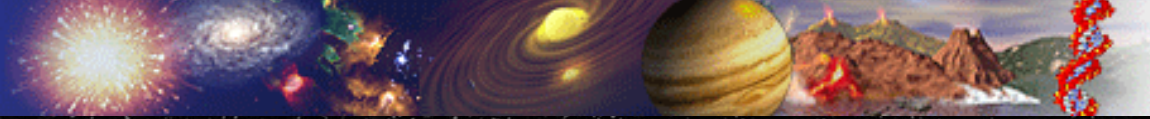


Martín-Doménech et al. 2016

$\Delta v = 0.5$ km/s
$V_{LSR} = 3.2$ km/s (source A)

Martín-Doménech et al. 2016

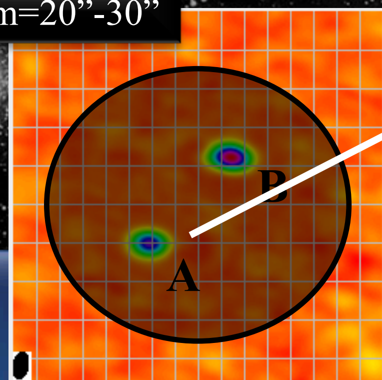




5. Results - Gas

Upper limits to the H_2S_2, HS_2, and S_2 abundances

beam=20”-30”



APEX 12-m

E-092.C-0030A-2013 (PI)

↓

16 GHz

in the 220-340 GHz range

H_2S_2, HS_2, and S_2??

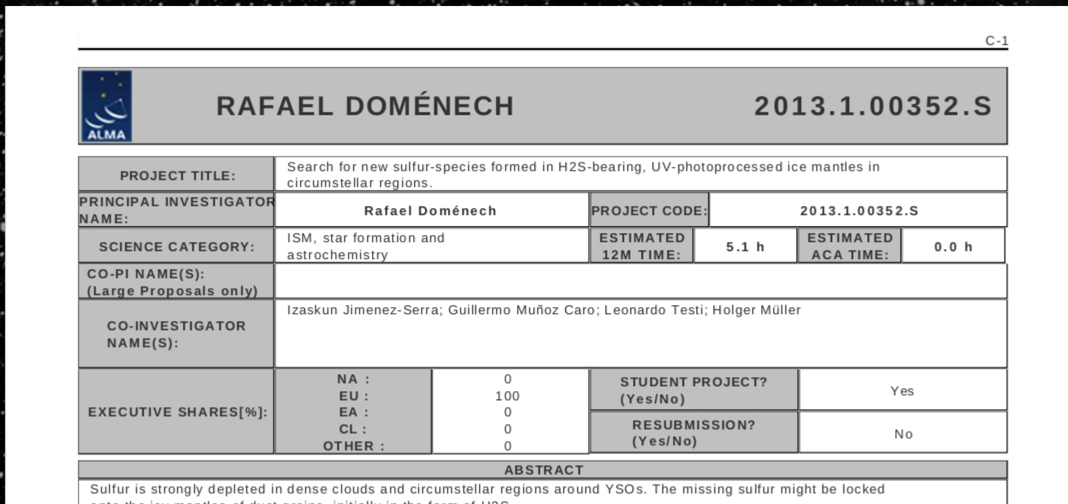
Molecule	Transition	Frequency (MHz)	rms [(1)] (K)	N (cm^{-2})
H_2S_2	$6_{1,5}$-$5_{0,5}$	223535.85	...	...[(2)]
H_2S_2	$13_{2,11}$-$14_{1,13}$	224367.15	0.0018	$\leq 1.7 \times 10^{15}$
H_2S_2	$13_{2,12}$-$14_{1,14}$	224657.47	...	...[(2)]
H_2S_2	$8_{1,7}$-$7_{0,7}$	251423.70	0.0026	$\leq 6.1 \times 10^{14}$
H_2S_2	$11_{2,9}$-$12_{1,11}$	252271.50	0.0025	$\leq 1.7 \times 10^{15}$
H_2S_2	$11_{2,10}$-$12_{1,12}$	252486.63	...	...[(2)]
H_2S_2	$10_{1,9}$-$9_{0,9}$	279312.25	...	...[(2)]
H_2S_2	$9_{2,7}$-$10_{1,9}$	280174.30	...	...[(2)]
H_2S_2	$9_{2,8}$-$10_{1,10}$	280325.68	0.0022	$\leq 3.7 \times 10^{15}$
H_2S_2	$14_{1,13}$-$13_{0,13}$	335087.32	...	...[(2)]
H_2S_2	$5_{2,3}$-$6_{1,5}$	335971.39	0.0036	$\leq 2.1 \times 10^{15}$
H_2S_2	$5_{2,4}$-$6_{1,6}$	336029.02	...	...[(2)]
HS_2	$16_{0,16,16,15}$-$15_{0,15,15,14}$	252270.66	0.0028	$\leq 8.0 \times 10^{14}$
HS_2	$16_{0,16,16,16}$-$15_{0,15,15,15}$	252270.71		
HS_2	$4_{1,3,5,4}$-$4_{0,4,5,4}$	280022.63	0.0027	$\leq 1.6 \times 10^{15}$
HS_2	$4_{1,3,5,5}$-$4_{0,4,5,5}$	280023.28		
HS_2	$21_{1,20,22,22}$-$20_{1,19,21,21}$	333247.58	0.0052	$\leq 1.3 \times 10^{15}$
HS_2	$21_{1,20,22,21}$-$20_{1,19,21,20}$	333247.67		
S_2	11_{10}-9_9	224301.13	0.0017	$\leq 2.2 \times 10^{16}$
S_2	15_{14}-13_{13}	333685.77	0.0039	$\leq 2.3 \times 10^{16}$

Martín-Doménech et al. 2016

Molecule	N_{mol} (cm^{-2})	$N_{mol}/N(H_2)$	$[N_{mol}/N(H_2S)]_{obs}$ (%)	$[N_{mol}/N(H_2S)_i]_{lab}$ [(1)] (%)
H_2S_2	$\leq 6.1 \times 10^{14}$	$\leq 8.1 \times 10^{-9}$	≤ 1.5	≤ 25.0 [(2)]
HS_2	$\leq 8.0 \times 10^{14}$	$\leq 1.1 \times 10^{-8}$	≤ 2.0	15.0
S_2	$\leq 2.2 \times 10^{16}$	$\leq 2.9 \times 10^{-7}$	≤ 55.0	...[(3)]

Corrected from beam dilution

Detection of CH_3NCO



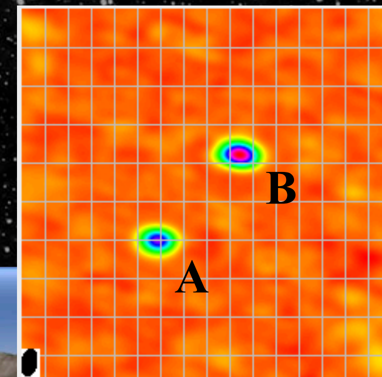
C-1

RAFAEL DOMÉNECH	2013.1.00352.S

PROJECT TITLE:	Search for new sulfur-species formed in H2S-bearing, UV-photoprocessed ice mantles in circumstellar regions.				
PRINCIPAL INVESTIGATOR NAME:	Rafael Doménech	PROJECT CODE:	2013.1.00352.S		
SCIENCE CATEGORY:	ISM, star formation and astrochemistry	ESTIMATED 12M TIME:	5.1 h	ESTIMATED ACA TIME:	0.0 h
CO-PI NAME(S): (Large Proposals only)					
CO-INVESTIGATOR NAME(S):	Izaskun Jimenez-Serra; Guillermo Muñoz Caro; Leonardo Testi; Holger Müller				
EXECUTIVE SHARES[%]:	NA : EU : EA : CL : OTHER :	0 100 0 0 0	STUDENT PROJECT? (Yes/No)	Yes	
			RESUBMISSION? (Yes/No)	No	

ABSTRACT

Sulfur is strongly depleted in dense clouds and circumstellar regions around YSOs. The missing sulfur might be locked onto the icy mantles of dust grains, initially in the form of H2S.

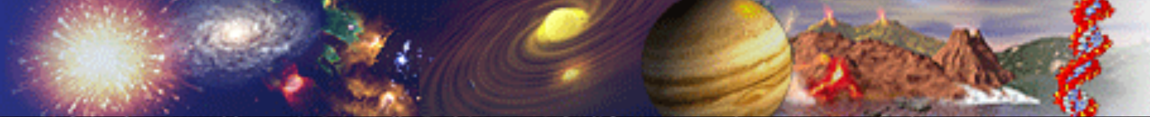


ALMA

2013.1.00352.S (PI)

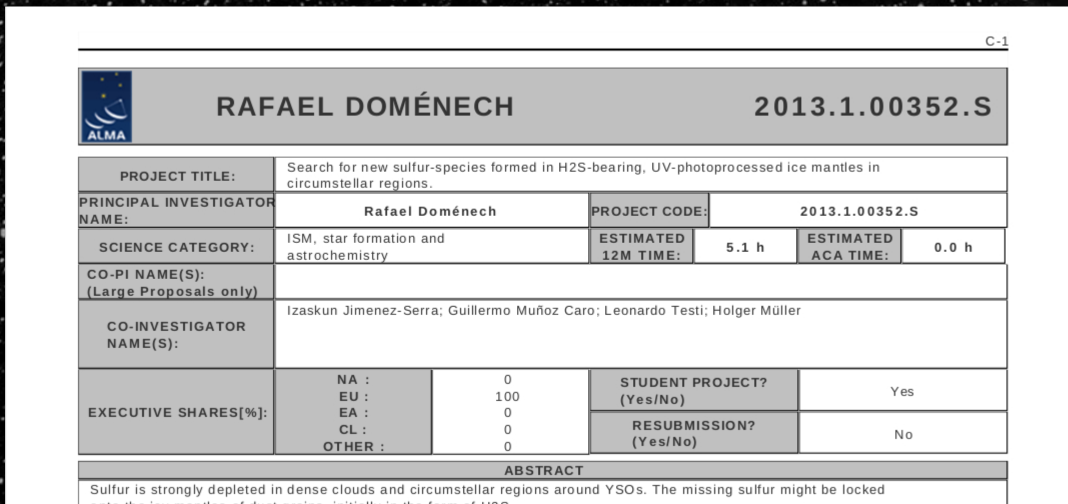
+

2013.1.0061.S
2012.1.0072.S
2011.0.00007.SV



5. Results - Gas

Detection of CH_3NCO

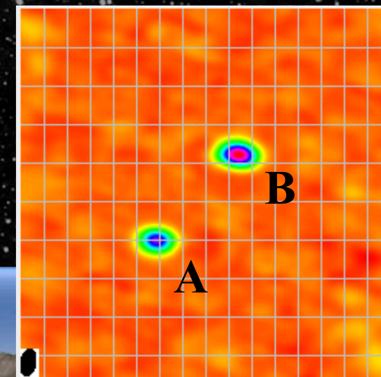


C-1

RAFAEL DOMÉNECH			2013.1.00352.S			
PROJECT TITLE:	Search for new sulfur-species formed in H2S-bearing, UV-photoprocessed ice mantles in circumstellar regions.					
PRINCIPAL INVESTIGATOR NAME:	Rafael Doménech		PROJECT CODE:	2013.1.00352.S		
SCIENCE CATEGORY:	ISM, star formation and astrochemistry		ESTIMATED 12M TIME:	5.1 h	ESTIMATED ACA TIME:	0.0 h
CO-PI NAME(S): (Large Proposals only)						
CO-INVESTIGATOR NAME(S):	Izaskun Jimenez-Serra; Guillermo Muñoz Caro; Leonardo Testi; Holger Müller					
EXECUTIVE SHARES[%]:	NA :	0	STUDENT PROJECT? (Yes/No)	Yes		
	EU :	100				
	EA :	0	RESUBMISSION? (Yes/No)	No		
	CL :	0				
	OTHER :	0				

ABSTRACT

Sulfur is strongly depleted in dense clouds and circumstellar regions around YSOs. The missing sulfur might be locked onto the icy mantles of dust grains, initially in the form of H2S.



ALMA

- Comet 67P/Churyumov-Gerasimenko
- Hot cores
  - Orion KL
  - SgrB2(N)
- Hot corinos?

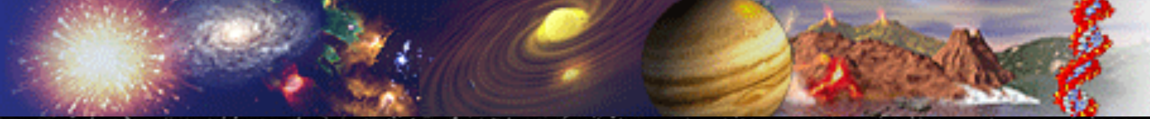
2013.1.00352.S (PI)

\+

2013.1.0061.S

2012.1.0072.S

2011.0.00007.SV

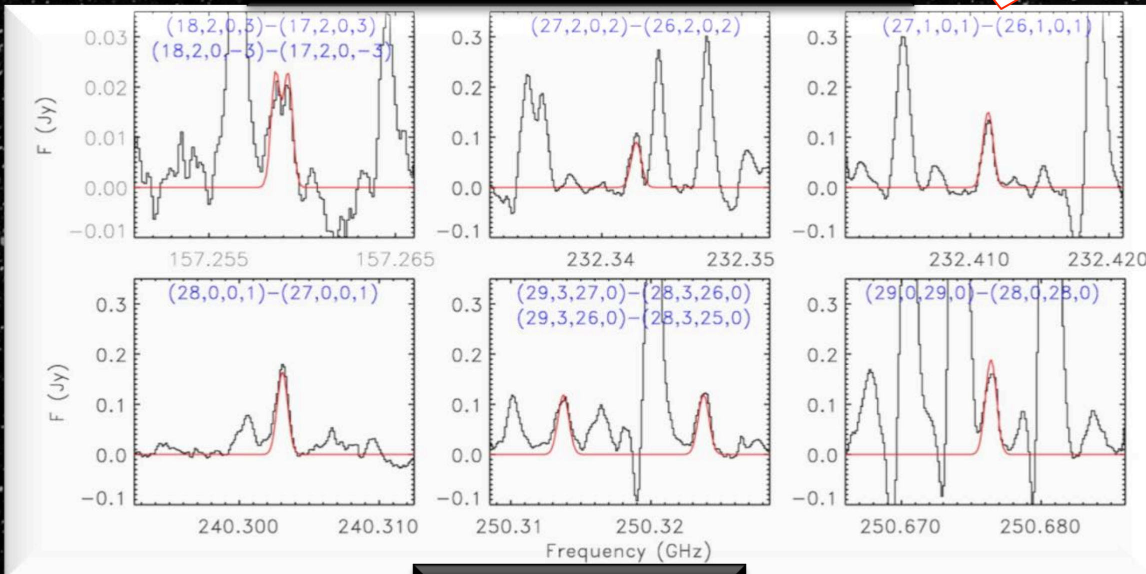


5. Results - Gas

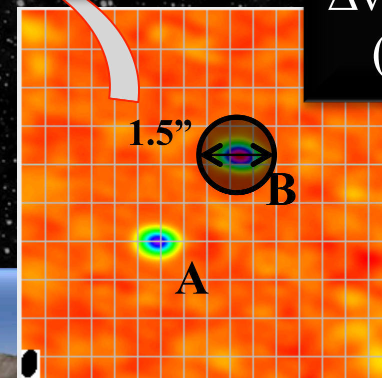
f CH_3N

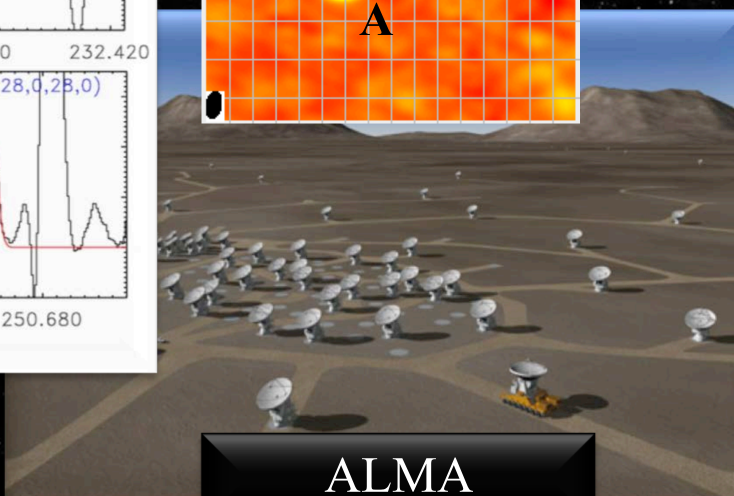
8 unblended lines detected (+14 blended)

MADCUBAIJ



$\Delta v = < 2$ km/s (source B)





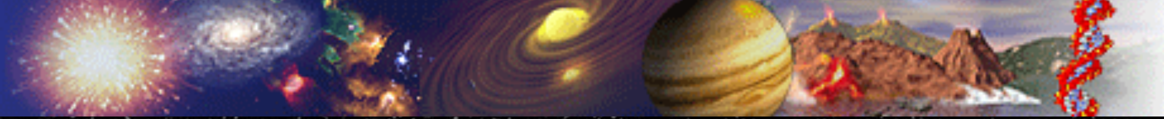
$\Delta v = 1.1$ km/s
$V_{LSR} = 2.7$ km/s

Frequency (GHz)	Transition	$\log A_{ul}$ (s^{-1})	E_u (K)	Integrated flux Jy km s^{-1}
157.258419	18,2,0,3–17,2,0,3	-3.75	210	0.028 ± 0.009
157.259087	18,2,0,-3–17,2,0,-3	-3.75	210	0.028 ± 0.009
232.342227	27,2,0,2–26,2,0,2	-3.22	234	0.12 ± 0.04
232.411044	27,1,0,1–26,1,0,1	-3.22	175	0.16 ± 0.06
240.302835	28,0,0,1–27,0,0,1	-3.17	181	0.18 ± 0.06
250.313498	29,3,27,0–28,3,26,0	-3.13	235	0.16 ± 0.05
250.323521	29,3,26,0–28,3,25,0	-3.13	235	0.16 ± 0.05
250.676140	29,0,29,0–28,0,28,0	-3.13	181	0.21 ± 0.07

Martín-Doménech et al. 2017, *submitted*

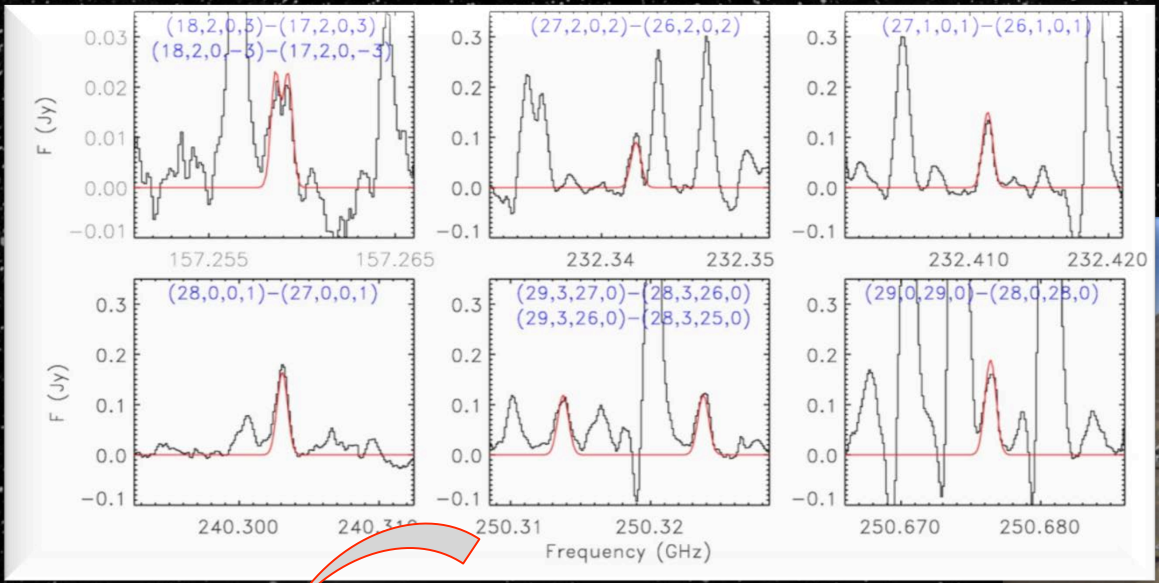
ALMA

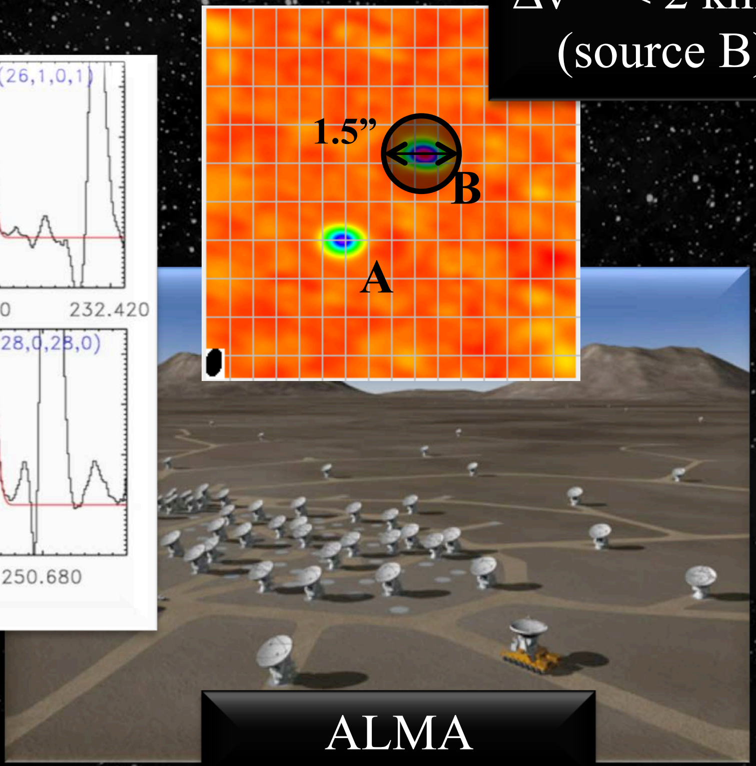
2013.1.00352.S (PI)
+
2013.1.0061.S
2012.1.0072.S
2011.0.00007.SV



5. Results - Gas

Detection of CH_3NCO





$\Delta v = < 2$ km/s (source B)

MADCUBAIJ (LTE)

$T_{ex} = 110 \pm 19$ K

$X(CH_3NCO) = (1.4 \pm 0.1) \times 10^{-10}$

ALMA

2013.1.00352.S (PI)
+
2013.1.0061.S
2012.1.0072.S
2011.0.00007.SV

Martín-Doménech et al. 2017, *submitted*

Gracias!