

# Prospective de l'IN2P3 GT12 – Thème 4- Strasbourg2020

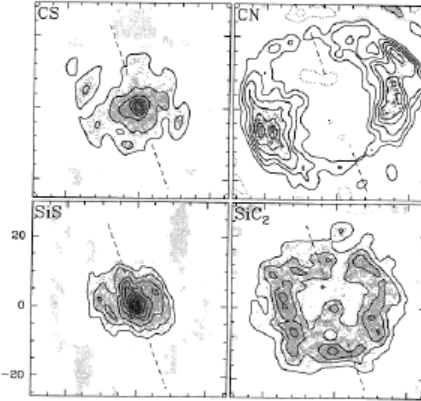
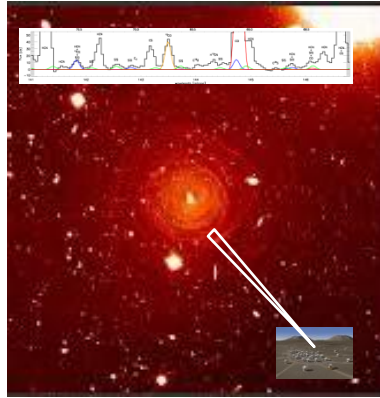
Marin Chabot

# Plan

- AGAT (IJCLab, ISMO, LAB, LAP)
- INGMAR (IJCLab, ISMO, IAS)
- Nano-CR (IJCLab, ISMO, NIMBE-CEA)

# AGAT motivations

Observations give a number of molecule by cm<sup>2</sup>....



With models (and/or other observations) the density of molecular specie (cm<sup>3</sup>) is derived and the abundance relatively to the H number too.

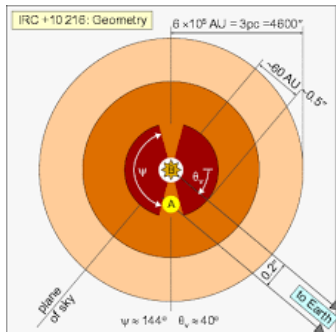
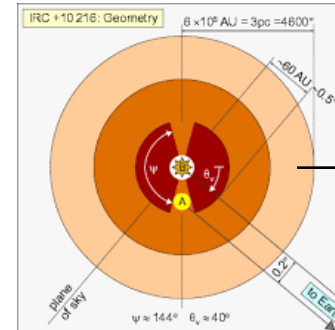


Table 10. Molecular abundances in the inner layers of IRC +10216

Molecule	Abundance relative to H <sub>2</sub>		Reference
	1-5 R <sub>*</sub>	2 × 10 <sup>15</sup> cm	
CS	4 × 10 <sup>-6</sup>	7 × 10 <sup>-7</sup>	(1)
SiO	...	1.8 × 10 <sup>-7</sup>	(1)
SiS	3 × 10 <sup>-6</sup>	1.3 × 10 <sup>-6</sup>	(1)
NaCl <sup>a</sup>	...	1.8 × 10 <sup>-9</sup>	(1)
KCl <sup>a</sup>	7 × 10 <sup>-10</sup>	5 × 10 <sup>-10</sup>	(1)
AlCl <sup>a</sup>	...	7 × 10 <sup>-8</sup>	(1)
AlF	...	1 × 10 <sup>-8</sup>	(1)
NaCN <sup>a</sup>	...	3 × 10 <sup>-9</sup>	(1)
CO	...	6 × 10 <sup>-4</sup>	(1)
C <sub>2</sub> H <sub>2</sub>	...	8 × 10 <sup>-5</sup>	(2)

Chemical model



T, d, Av, CR

...

Chemical net

$$\frac{dy_i(t)}{dt} = \sum_j \tau_{crea}^j \times y_j(t) - \left( \sum_j \tau_{dest}^j \right) \times y_i(t)$$

Calculated  
abundance at t

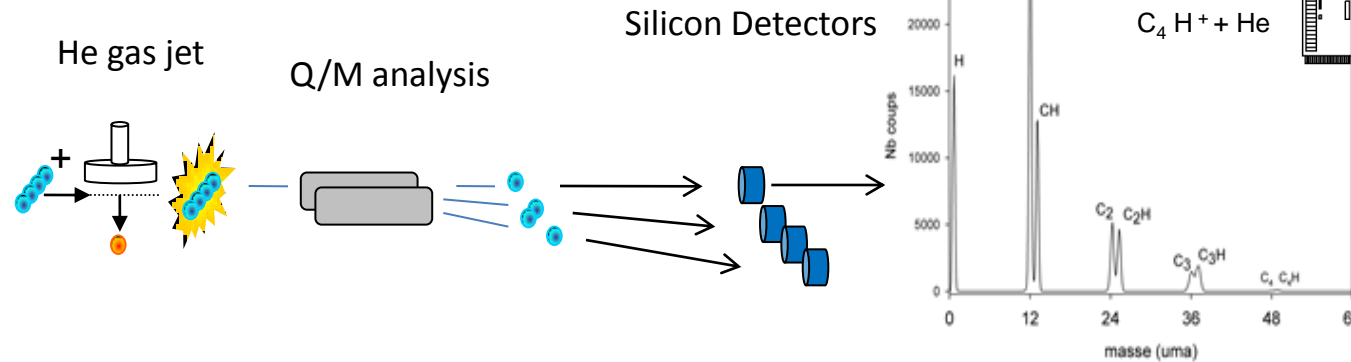
Kinetic data

KIDA | KINETIC DATABASE  
FOR ASTROCHEMISTRY

The AGAT job is to give Branching Ratios (BR) of chemical reactions for database.

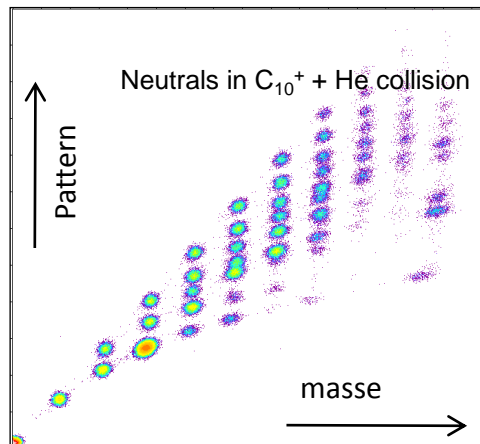
# AGAT : an experiment to retrieve a full set of BRs.

MeV Molecular beams with  
the Orsay Tandem

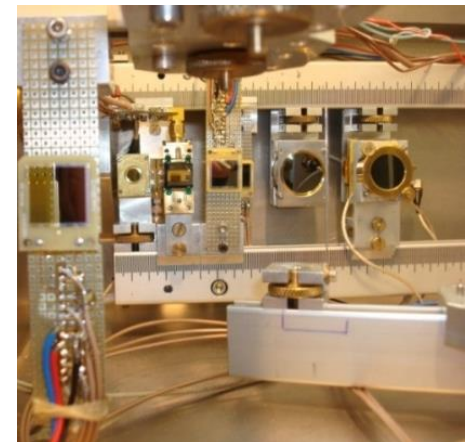


- . Intermediate complex excited and/or ionized is formed in a high velocity collision between cationic beams and He atom
- . The detection combine charge over mass electrostatic analysis and kinetic energy measurement with silicon detector.

**C<sub>7</sub><sup>+</sup>**

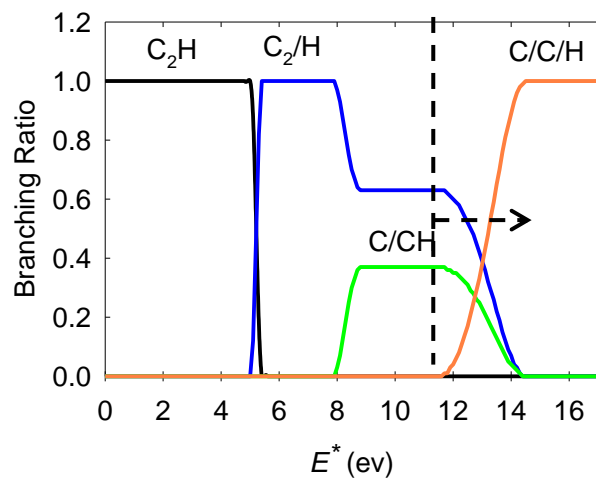


Channel	BR	$E_{\text{diss}}$	Channel	BR	$E_{\text{diss}}$
$\text{C}_6^+/\text{C}$	1.8(0.2)	7.5	$\text{C}_4^+/\text{C}_3$	18.5 (0)	7.7
$\text{C}_4^+/\text{C}_3$	2.5(0.3)	8.4	$\text{C}_5^+/\text{C}_2$	6.7(0.5)	8.5
$\text{C}_5^+/\text{C}_2$	0.2(0.1)	8.8	$\text{C}_6^+/\text{C}$	0.1(0.1)	8.9
$2\text{C}_3/\text{C}^+$	5.1(0.4)	13.3	$\text{C}_3^+/\text{C}_3/\text{C}$	15.5(1.0)	13.8
$\text{C}_5/\text{C}^+/\text{C}$	0.4(0.1)	14.5	$\text{C}_5^+/\text{C}_2\text{C}$	3.0(0.3)	14.6
$\text{C}_3/\text{C}_2^+/\text{C}_2$	2.9(0.3)	15.2	$\text{C}_4^+/\text{C}_2/\text{C}$	4.5(0.4)	15.3
$\text{C}_3^+/\text{C}_2\text{C}_2$	6.7(0.5)	15.3	$\text{C}_4/\text{C}_2/\text{C}^+$	1.0(0.1)	15.6
$\text{C}_4/\text{C}_2^+/\text{C}$	0.5(0.1)	15.9	$\text{C}_3/\text{C}_2/\text{C}^+/\text{C}$	7.6(0.5)	20.9
$\text{C}_3/\text{C}_2^+/\text{C}_2\text{C}$	2.5(0.2)	21.3	$\text{C}_4^+/\text{C}_3\text{C}$	1.1(0.1)	21.4
$\text{C}_3^+/\text{C}_2/\text{C}_2\text{C}$	7.1(0.3)	21.4	$\text{C}_4/\text{C}^+/\text{C}_2\text{C}$	0.3(0.1)	21.6
$3\text{C}_2/\text{C}^+$	0.8(0.1)	22.4	$\text{C}_2^+/\text{C}_2\text{C}_2/\text{C}$	1.9(0.2)	22.8
$\text{C}_3/\text{C}^+/\text{C}_3\text{C}$	2.1(0.2)	27.0	$\text{C}_3^+/\text{C}_4\text{C}$	1.2(0.1)	27.5
$2\text{C}_2/\text{C}^+/\text{C}_2\text{C}$	2.7(0.3)	28.5	$\text{C}_2^+/\text{C}_2/\text{C}_3\text{C}$	1.6(0.2)	28.8
$\text{C}_2/\text{C}^+/\text{C}_4\text{C}$	1.6(0.2)	34.6	$\text{C}_2^+/\text{C}_5\text{C}$	0.3(0.1)	34.9
$\text{C}^+/\text{C}_6\text{C}$	0.3(0.1)	40.7			



# Semi empirical BRs

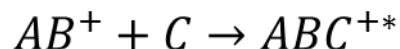
In micro canonical dissociation Branching Ratios for a particular internal energy is given by *Break Down Curves*.



**Table 3**  
Branching Ratios for the Dissociative Electronic Recombination (DR)  
Reactions of  $C_nH^+$  Molecules

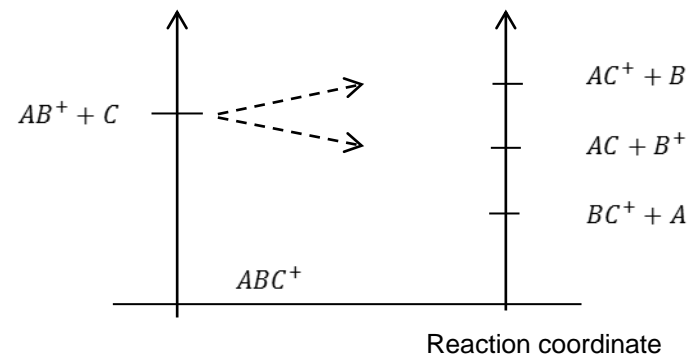
Reaction	Model	KIDA	OSU	UDfA	IP/ $\Delta E$
$C_2H^+ + e^- \rightarrow$					<b>11.6</b>
$C_2/H$	0.58( $\pm 0.05$ )	<u>0.43</u>	0.43	0.44	6.59
$C/CH$	0.34( $\pm 0.04$ )	<u>0.39</u>	0.39	0.56	3.74
$C/C/H$	0.08( $\pm 0.05$ )	<u>0.18</u>	0.18		0.1

If a reaction occurs an intermediate complex is formed.



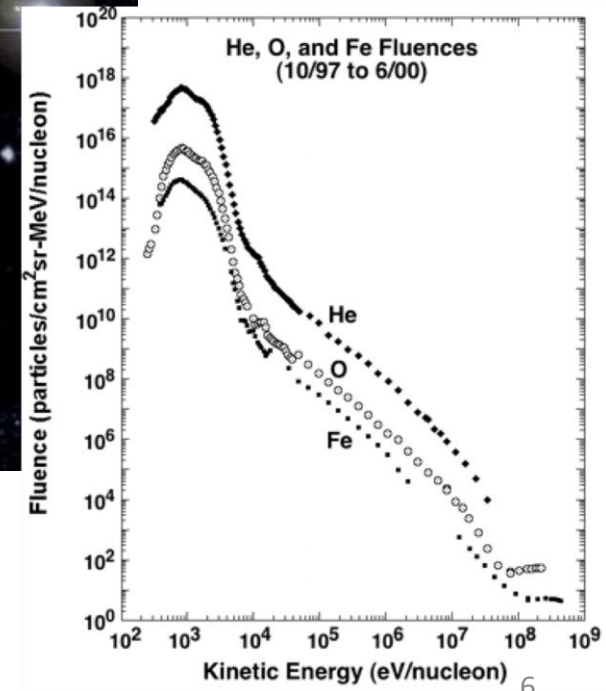
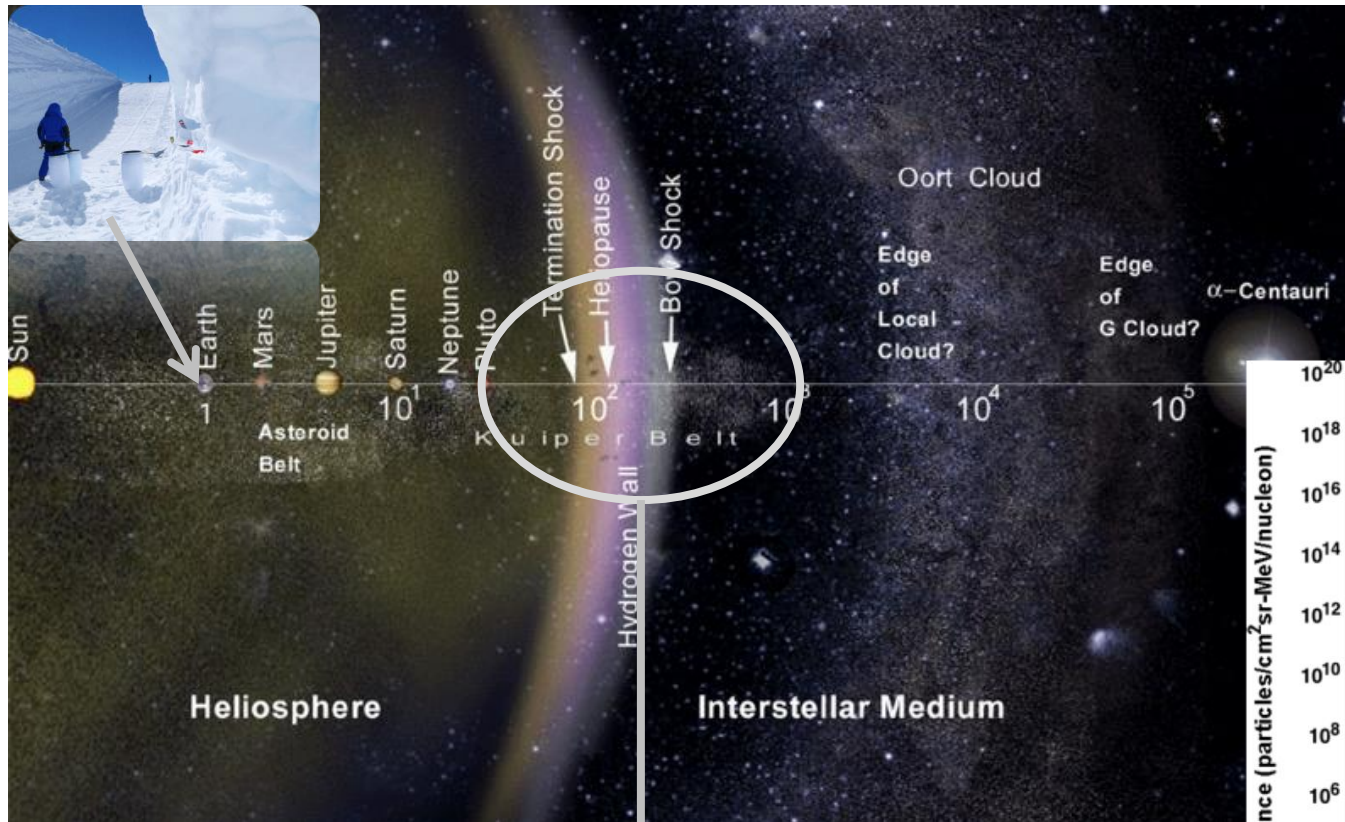
The internal energy at 0 K is :

$$E^* = \Delta H_{AB^+}^f + \Delta H_C^f - \Delta H_{ACB^+}^f$$



# INGMAR: Irradiation d'analogues de matière organique cométaire.

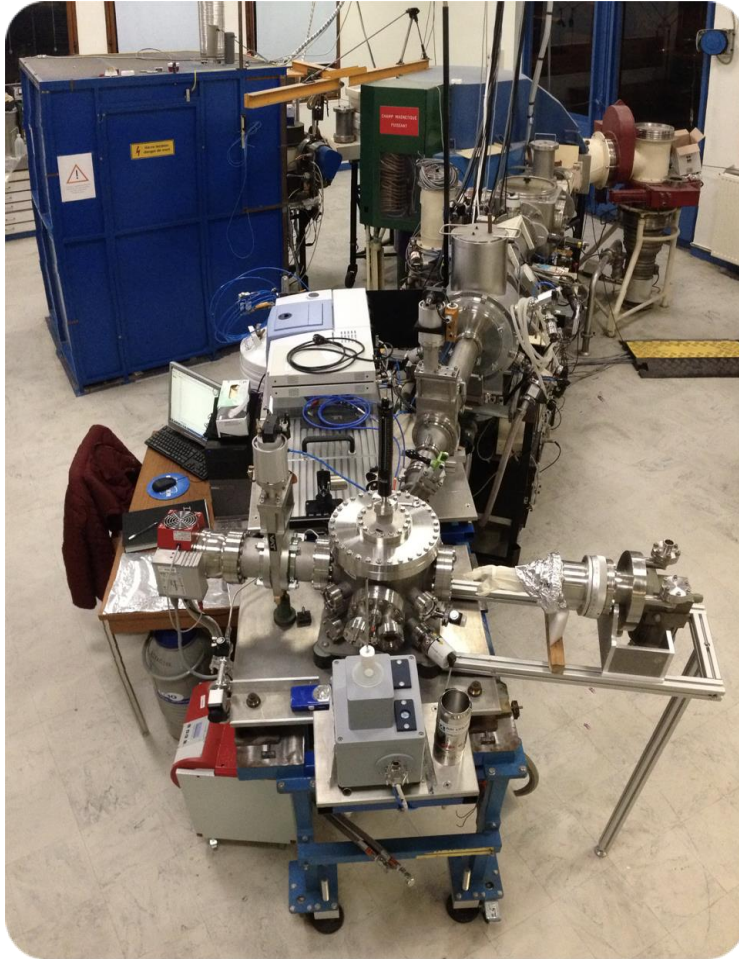
Comment l'irradiation par les particules solaires modifie les matériaux voyageant des régions externes du système solaire aux régions internes ( la terre) ?



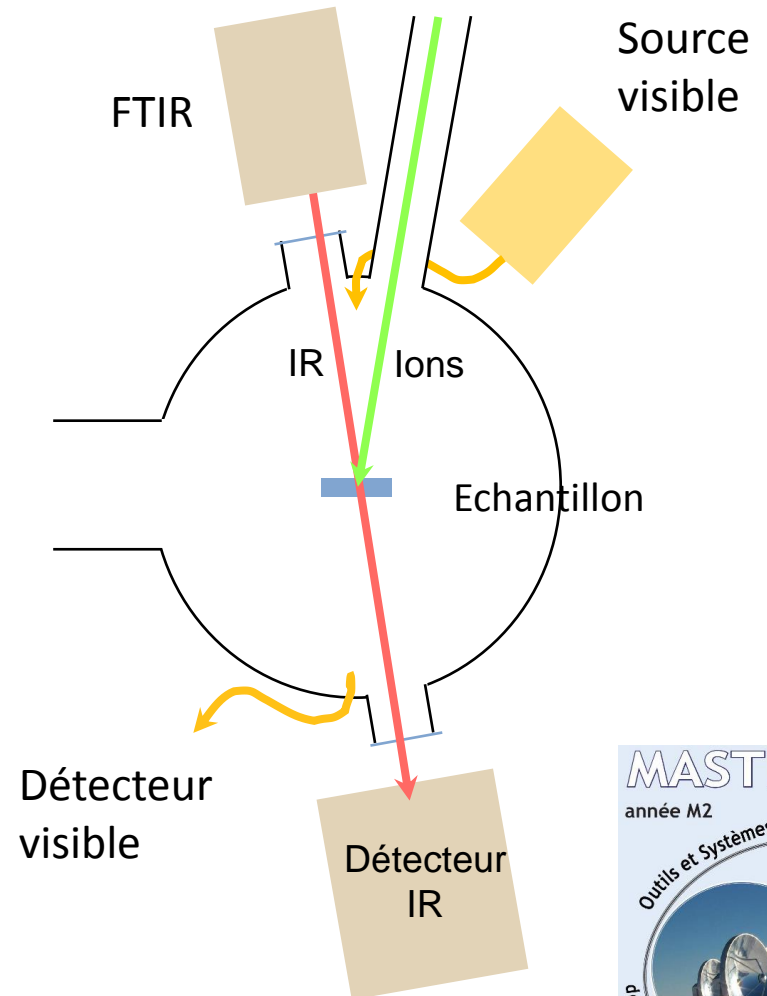
Formation par irradiation des glaces



# Dispositif expérimental (104-IJCLab)

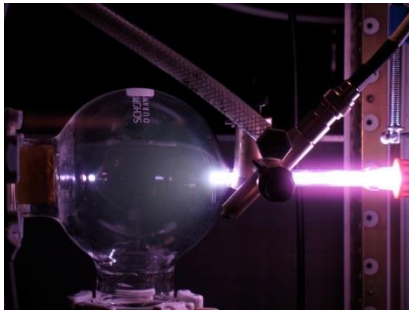


*Sidonie(0-50 keV)*

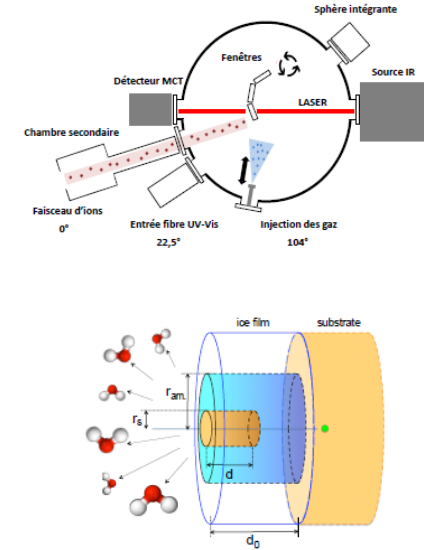
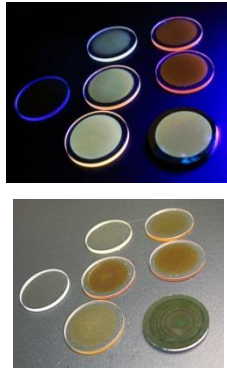


# Principe des mesures

## 1- Fabrication d'analogues.



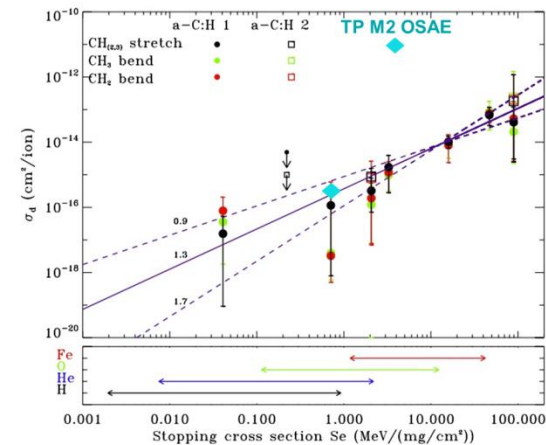
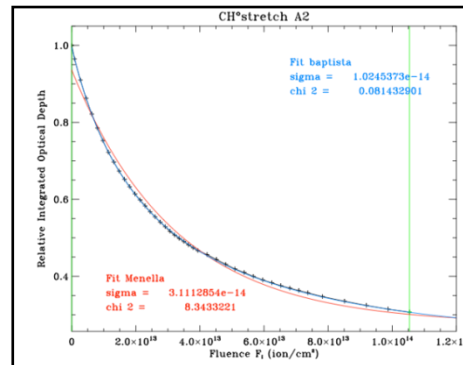
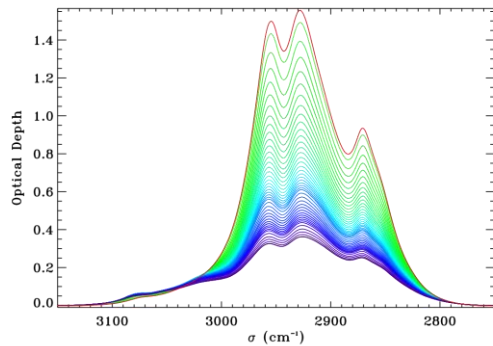
Dépôt plasma (ISMO)



Irradiation de glace ( UV, Ganil/CIMAP,...) + processus thermique

## 2- Mesure des Sections efficaces de destruction/création des signature spectrale.

$\alpha$ -CH Élongation  $\text{CH}_{3,2}$



3- convolution  
avec les fluences.

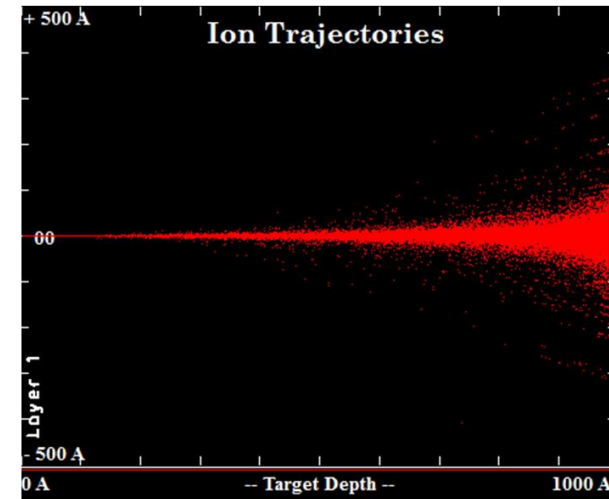
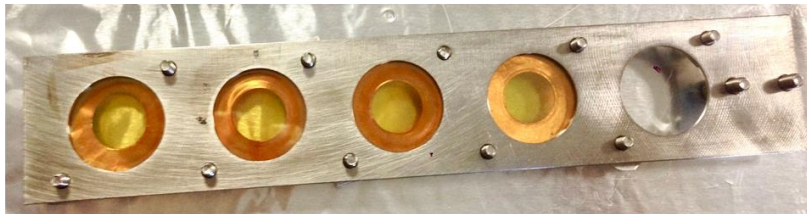


# INGMAR : Irradiation d'analogues des précurseurs d'UCAMMs

## Echantillons :

Film d'a-CN:H (solide amorphe composé de C, N, H) produit par plasma sur une fenêtre de ZnSe

Epaisseur ~ 100-300 nm



## Expérience :

INGMAR

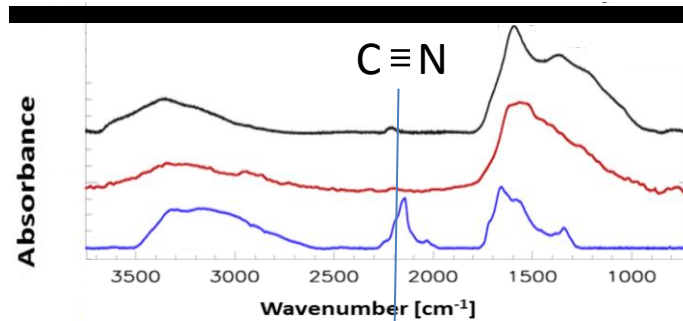
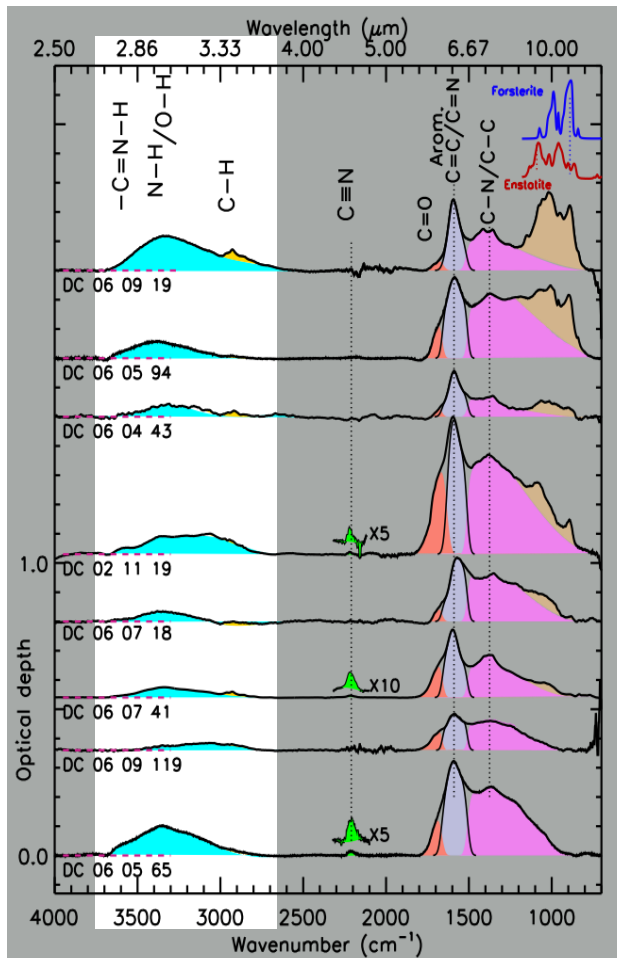
Mesure IR in situ en fonction de la fluence

## Ions : Sidonie

Ions	Energie	Stopping power Se	Stopping power Sn	Fluence atteinte	Flux
H <sup>+</sup>	50 keV	10,69 eV/Angstrom	0,03 eV/Angstrom	3,3 10 <sup>16</sup> ions/cm <sup>2</sup>	2-2,2 10 <sup>12</sup> ions/cm <sup>2</sup> /s
He <sup>+</sup>	50 keV	12,35 eV/Angstrom	0,35 eV/Angstrom	0,3 10 <sup>16</sup> ions/cm <sup>2</sup>	1-1,5 10 <sup>12</sup> ions/cm <sup>2</sup> /s
He <sup>+</sup>	50 keV	12,35 eV/Angstrom	0,35 eV/Angstrom	1,4 10 <sup>16</sup> ions/cm <sup>2</sup>	1-2 10 <sup>12</sup> ions/cm <sup>2</sup> /s
Ne <sup>2+</sup>	100 keV	24,95 eV/Angstrom	11,2 eV/Angstrom	0,9 10 <sup>16</sup> ions/cm <sup>2</sup>	0,5-1 10 <sup>12</sup> ions/cm <sup>2</sup> /s

⇒ Effet du dépôt d'énergie par les ions, pas d'implantation

# La question du jour:



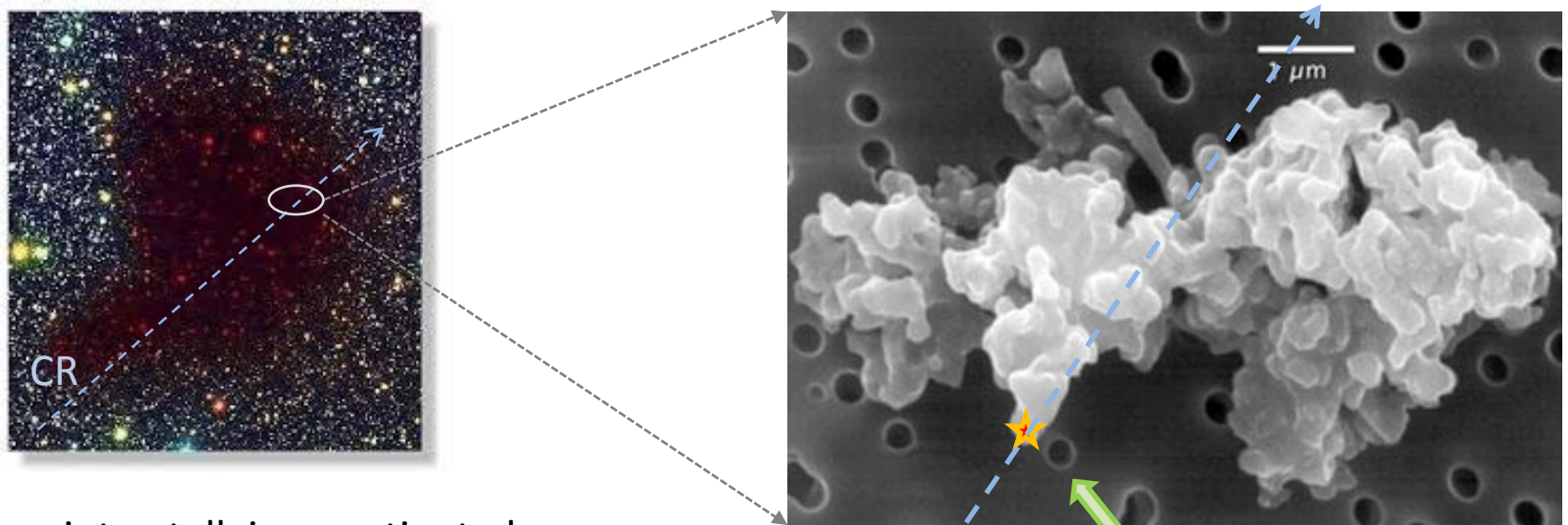
UCAMM

+ température

Ice irradiation

Quel est le rôle des irradiations par vent solaire sur la liaison C-N ?

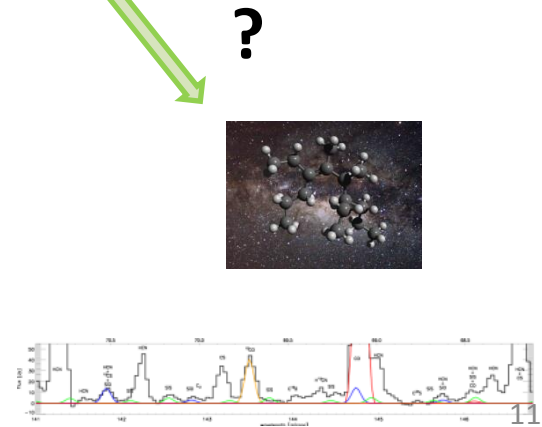
# Nano poussières versus rayons cosmiques (NanoCR)



Le milieu interstellaire contient des poussières. Dans les nuages denses, les rayons cosmiques sont les principaux vecteurs du chauffage et de l'ionisation. Comment les rayons cosmiques modifient la structure de la population des grains ayant une taille nanométrique, est le sujet

06/02/2020

M. Chabot -GT12 -Thème 4 -Strasbourg



# NanoCR – Faisabilité-

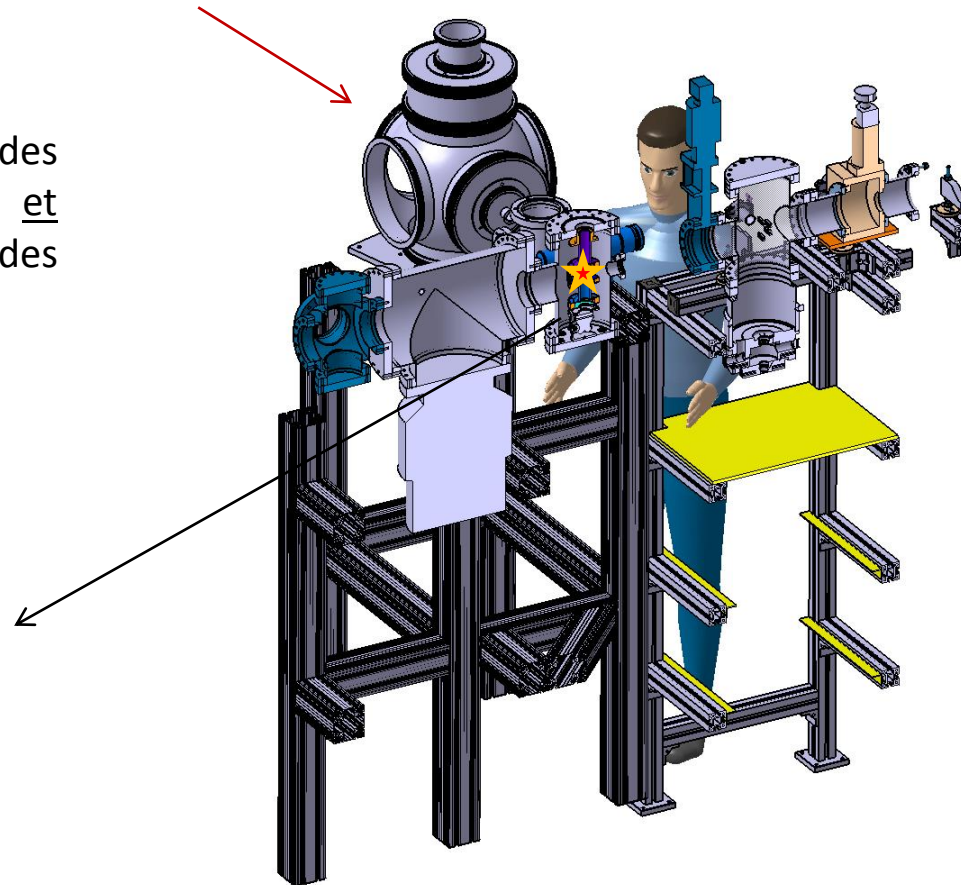
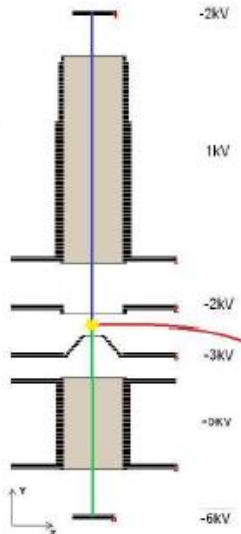
$P = \text{mBar}$



Lentille aérodynamique (CEA)

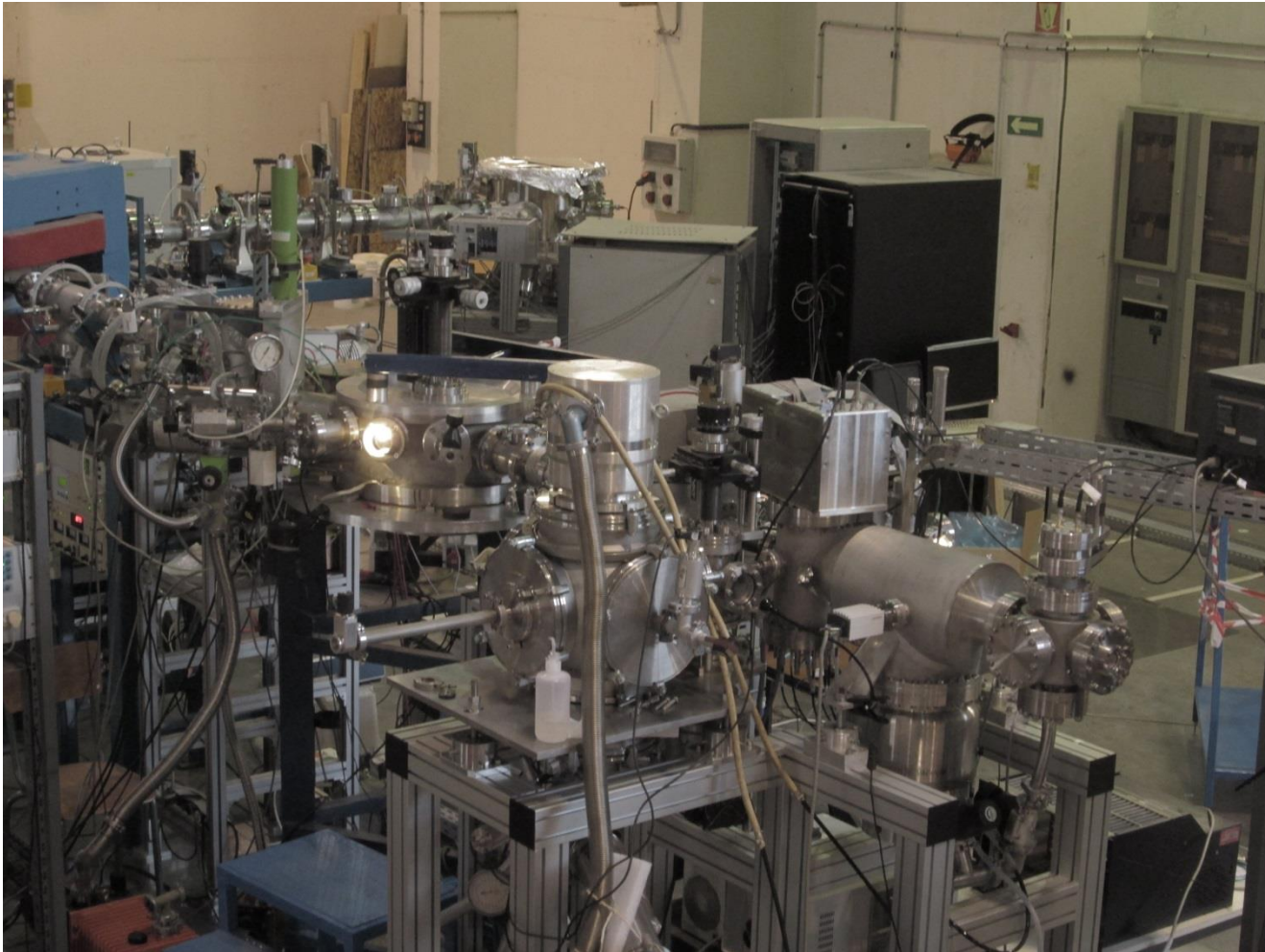
Andromède  
(IJClab)

Détection des ions et des électrons en coïncidence et analyse électrostatique des nano.





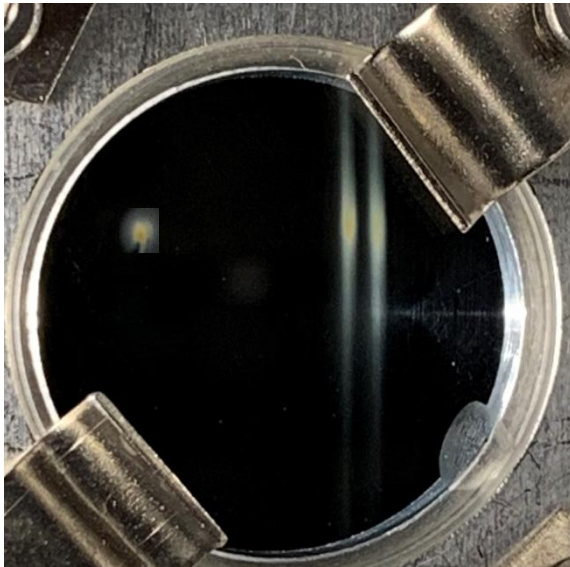
## Nano-CR@ANDROMEDE – 01/2020



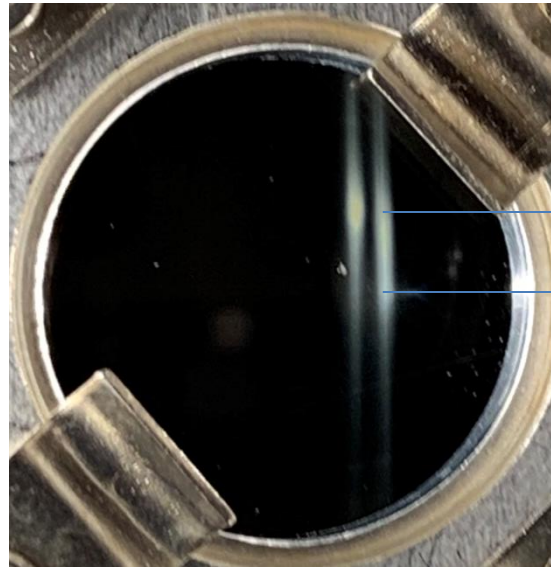


# Irradiation de Silicium 100 nm par de l' Argon 4+ à 12 MeV.

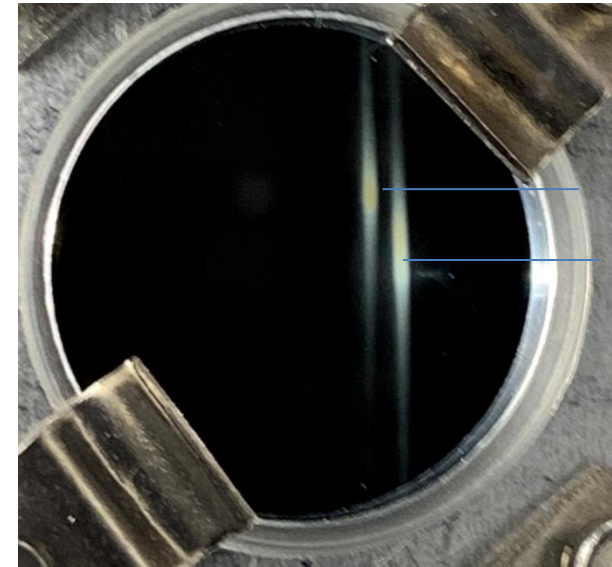
Initial & 10 nAmp



Initial & 50 nAmp

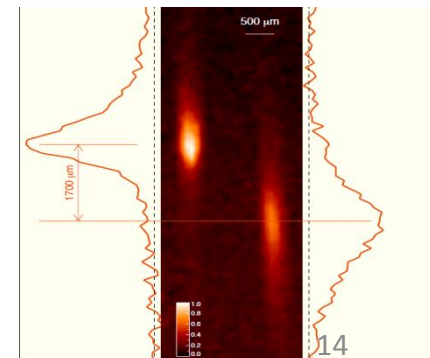


Initial & 100 nAmp



La faisabilité d'expériences en cinématique inverse sur des nano objets ionisés par impact ionique est montrée. Une nouvelle expérience est programmée en septembre 2020 avec un dispositif légèrement amélioré (suppression des espèces chargées avant la zone de collision, collimation du faisceau d'ion, conservation et post traitement des échantillons...).

AFMIR ( Si/SiO<sub>2</sub> )



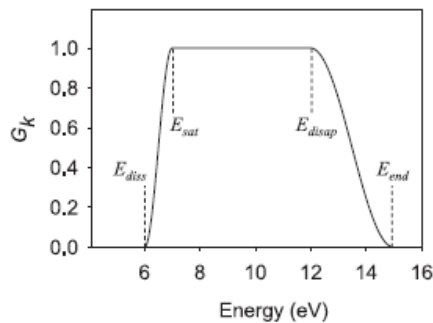
Merci

# Semi empirical Breakdown curves construction

$$BR_j = \int_0^{+\infty} BDC_j(E) \times f(E) dE,$$

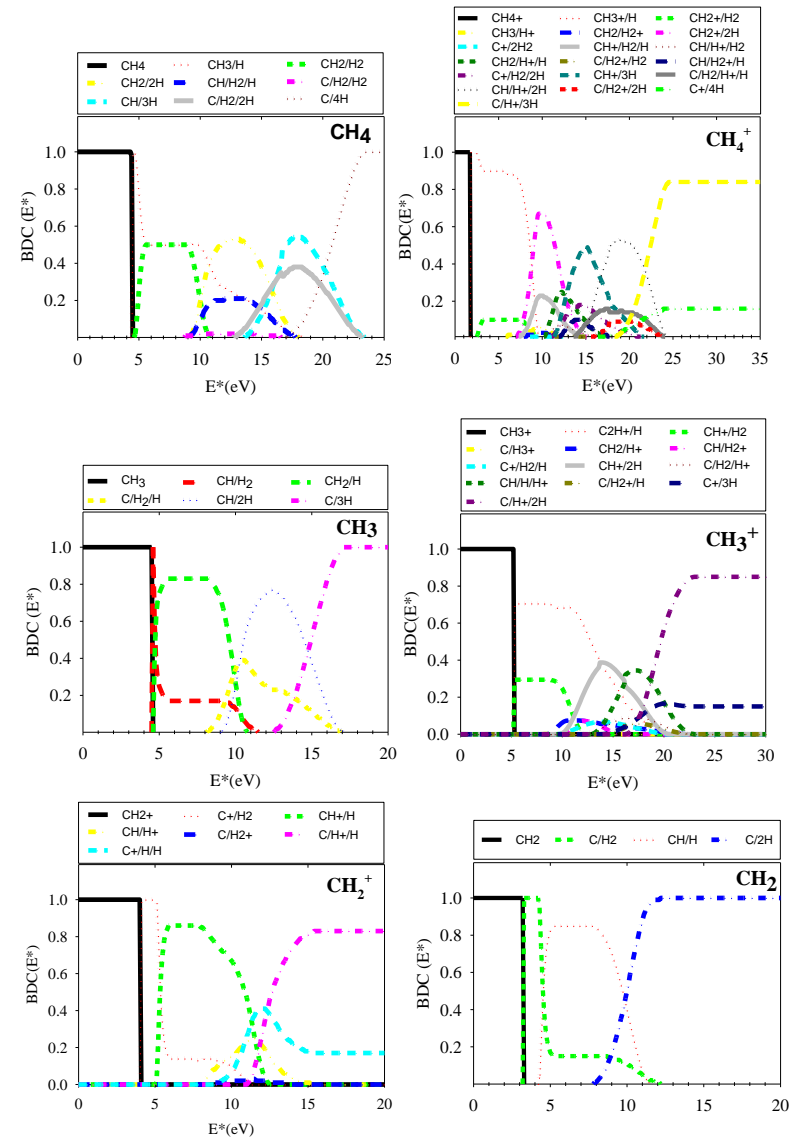
## Paramétrisation micro canonique

$$\text{BDC}_j(E) = \frac{a_j \times G_j(E)}{\sum_j a_j \times G_j(E)},$$



Minimization of :  $\sum_j \|BR_j^{exp} - BR_j^{s.emp}\|^2$

2-  $a_j$ : adjustment on experimental  $BR$  and for an experimental internal energy distribution  $f(E)$ .



# Chemical reactions in ISM



Interstellar medium is every thing except stars and planets

Elementary composition : H(90%),He(9%),Others(1%)

Density: 10 to 108 H/cm<sup>3</sup>, T=10 to 1000 K

UV field : very few ( $A_V > 100$ ) to ambient ( $A_V = 0$ ) (or more)

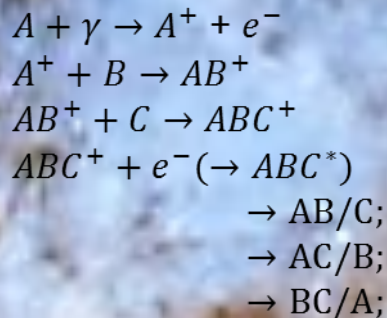
Ionizing particle field (CR) : 10-1000 MeV/u

Magnetic field : ISM is plasma !

## Diffuse medium

( $N_H = 10 - 500/\text{cc}$ ,  $T = (1-3)00\text{K}$ ,  $A_V = 0$ )

*Ion molecule chemistry:*



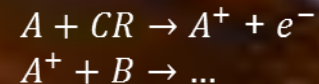
(PDR)



## Dense medium

( $N_H = \text{few } 10^4/\text{cc}$ ,  $T = 10-30\text{ K}$ ,  $A_V = 100$ )

*Ion - molecule :*



*Neutral-neutral:*



Interstellar medium is full of grains and/or ices injecting in the chemical  
« reactor » molecules !