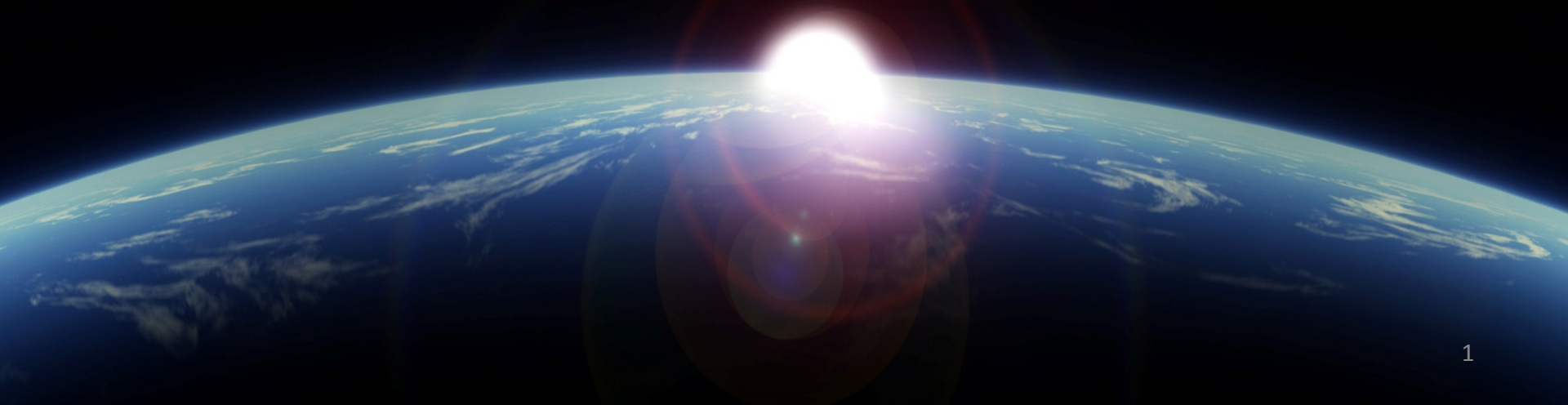
Etude de la photostabilité de composés organiques à partir d'expériences en laboratoire et en orbite terrestre basse.

K. Saïagh, P. Coll, H. Cottin, N. Carrasco, D. Chaput, N. Fray , Y.Y. Guan, F. Raulin, F. Stalport, C.Szopa, D. Khalaf, M. Jerome, J.M. Polienor,



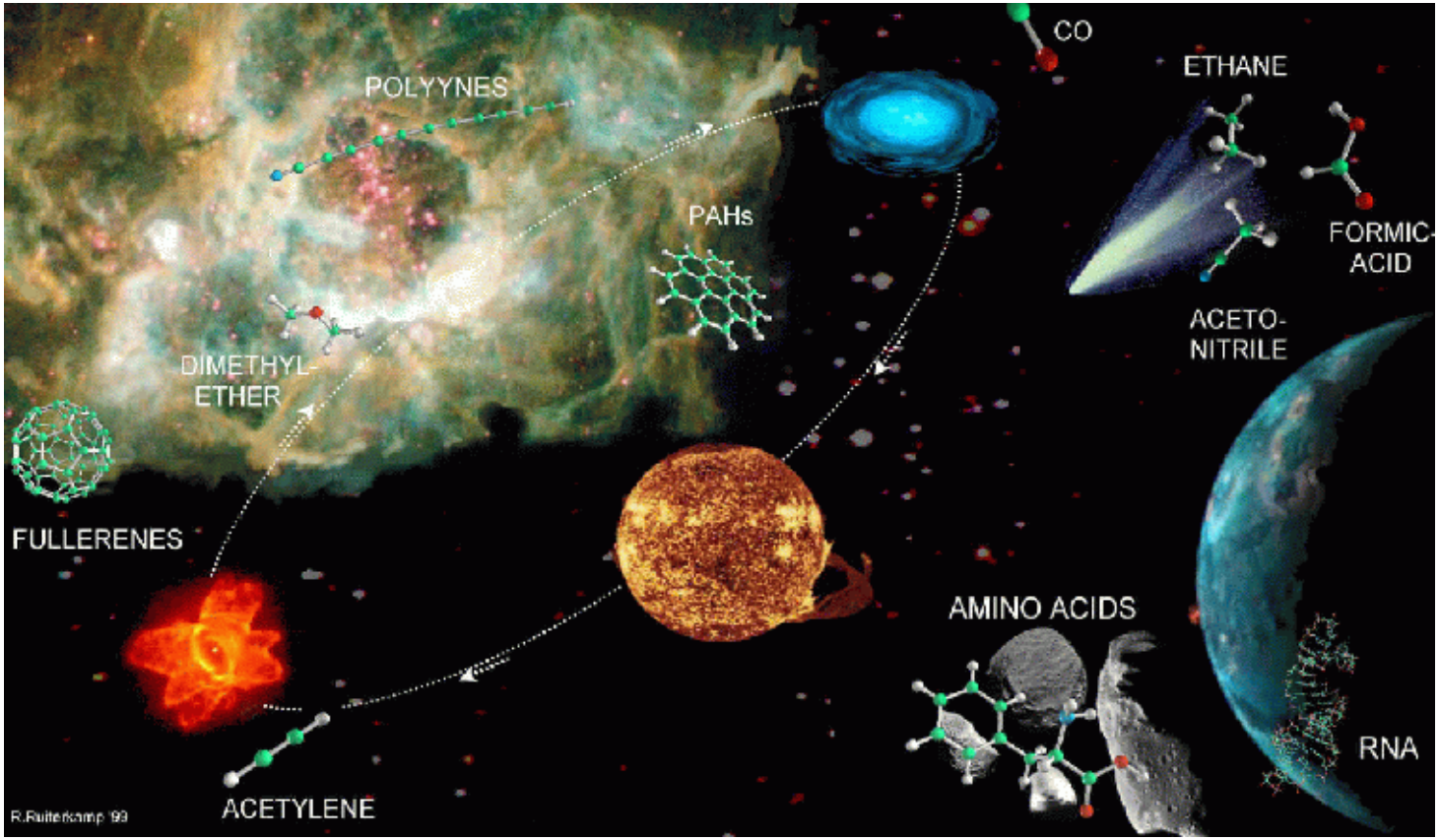
Plan

1. Contexte général.
2. Expériences de photochimie: méthodologie.
   2.1. En laboratoire.
   2.2. En orbite basse terrestre.
3. Quelques résultats.
4. Limites et perspectives.
5. Conclusions.

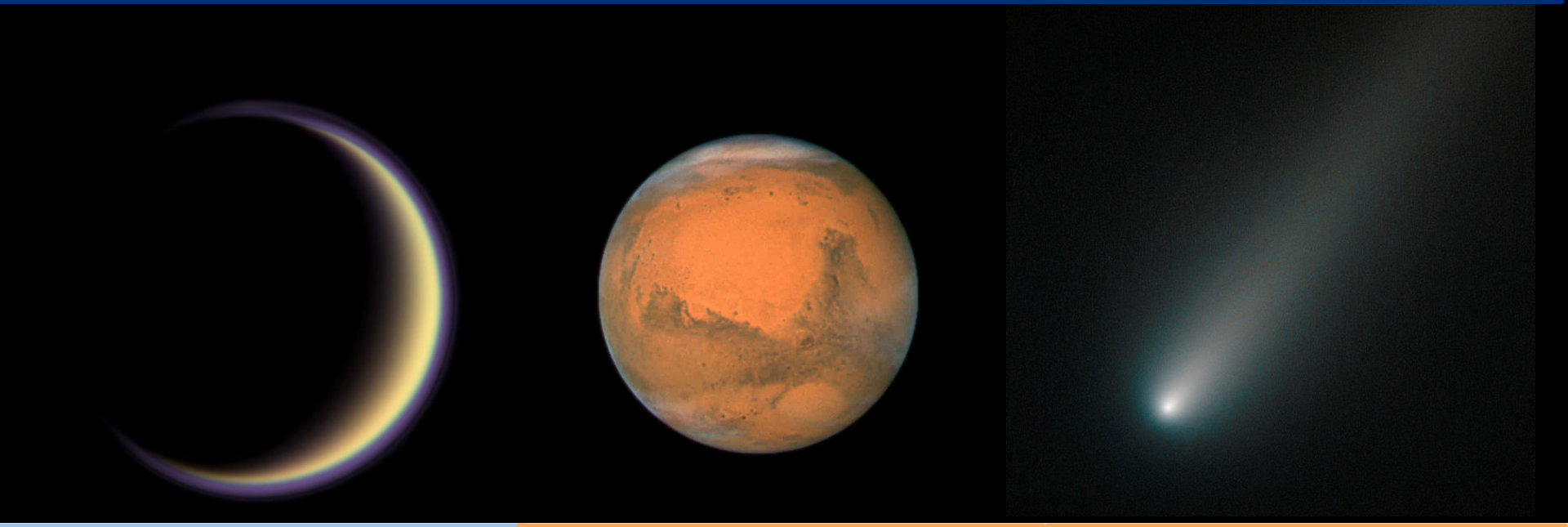
1.Contexte

EXOBIOLOGIE

Etude des conditions et des processus qui ont permis l'émergence du vivant sur notre planète



1. Contexte



- Atmosphère dense: N_2 (94%), CH_4 (3%), hydrocarbures , nitriles.

- Cycle du méthane de l'éthane?

- Ecoulements et lac d'hydrocarbures.

→ **Réacteur de chimie organique de type prébiotique à l'échelle planétaire**

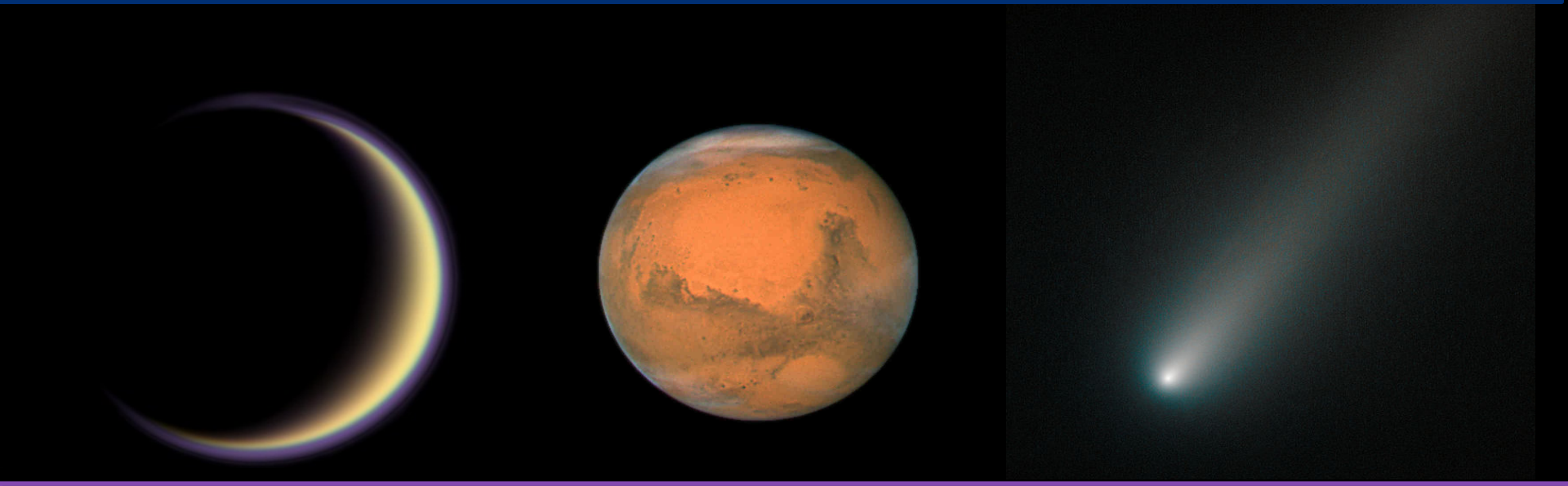
- Présence d'eau liquide dans le passé + matière organique apportée par les petits corps : VIE?

→ **Recherche de traces d'une vie éventuelle passée.**

→ **Source exogène de matière organique sur la terre primitive**

→ **Paramètres physico-chimiques régnant dans la nébuleuse solaire primitive.**

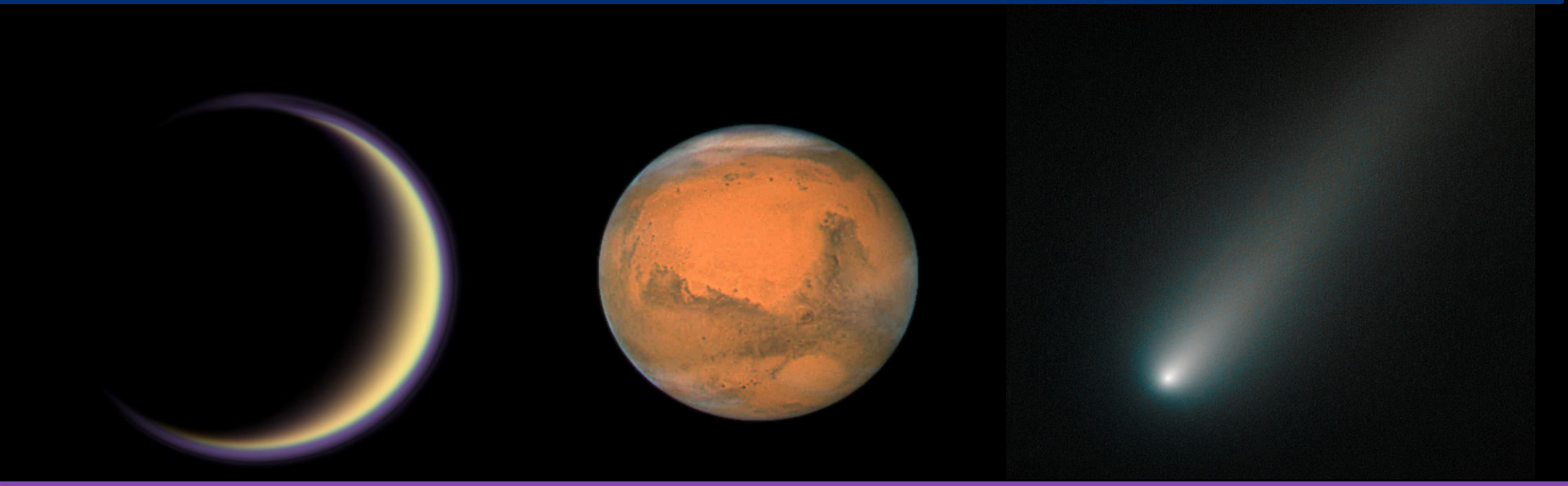
Problématique



VUV/UV

Photostabilité de ces composés organiques ?

Molécules cibles



VUV/UV

→ Evolution de la structure des aérosols et de leurs propriétés optiques?

→ Photochimie du méthane dans l'atmosphère de Titan.

Mélanges gazeux N_2/CH_4
Tholins

→ Stabilité photochimique à la surface de Mars de composés organiques purs ou mélangés à un analogue de sol martien ?

→ Détectabilité? .

Acides aminés
Bases azotées
Acides carboxyliques

→ Stabilité des molécules organiques à la surface d'un grain éjecté du noyau cométaire.

→ Dégradation de ces molécules à l'origine des sources distribuées dans l'atmosphère cométaire?

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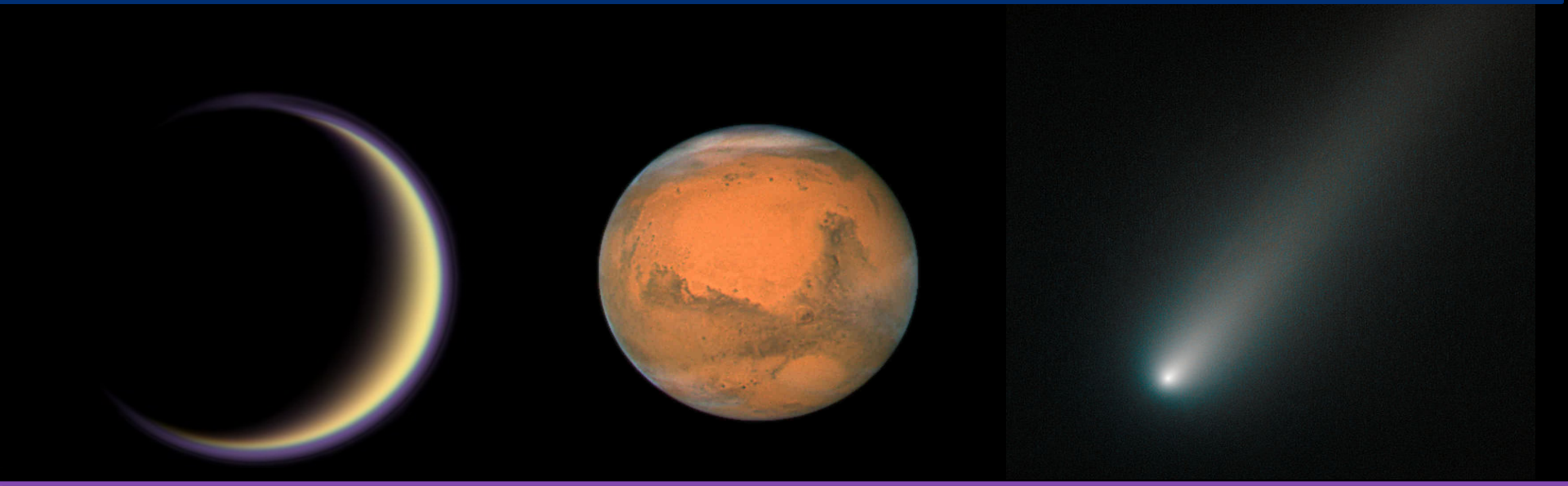

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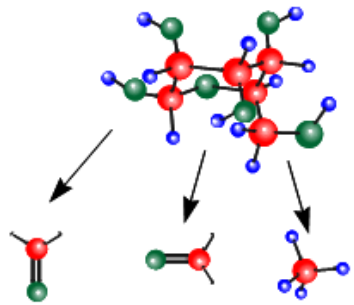
Photolyse

VUV/UV

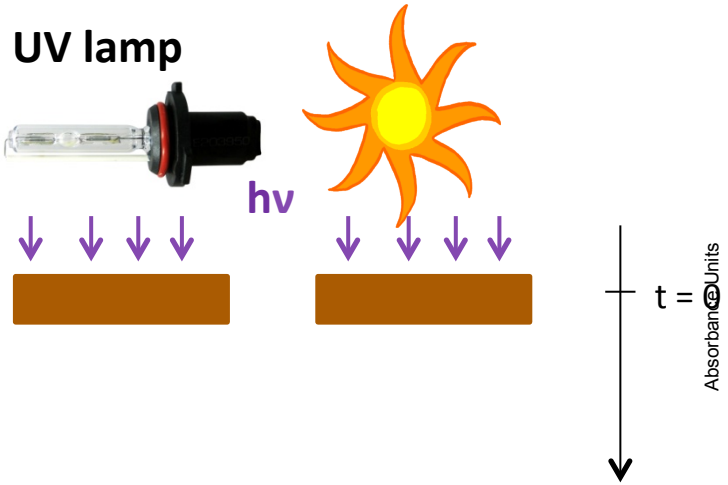


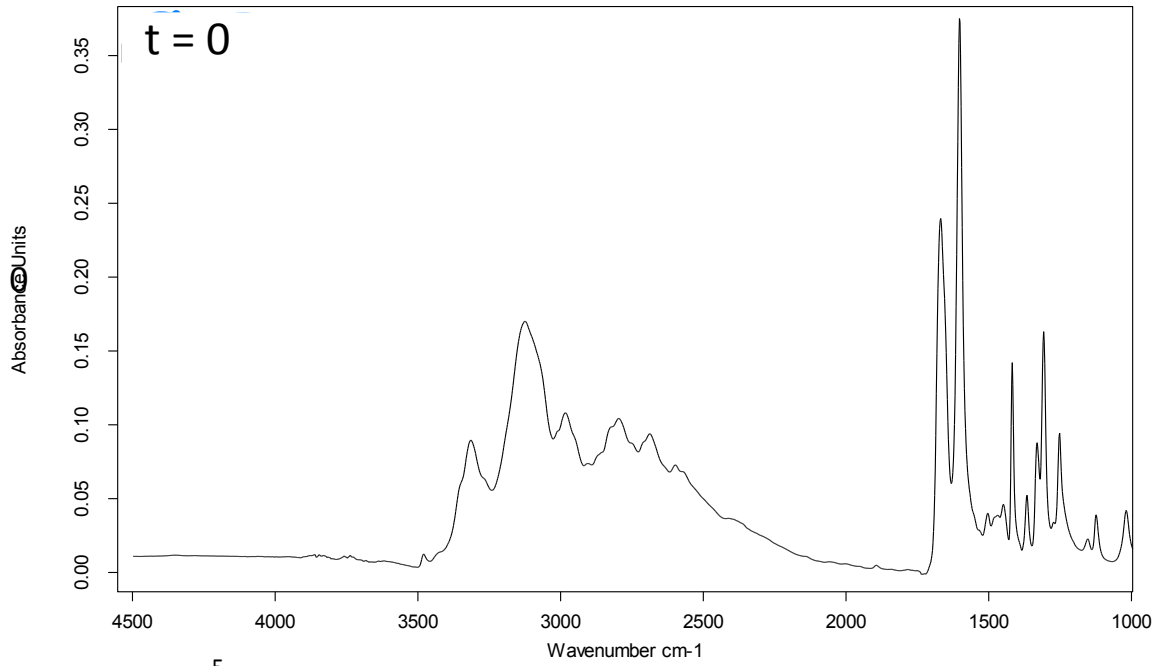
$$AB + h\nu \xrightarrow{J} A\bullet + B\bullet$$

$$J = \int_{\lambda} \sigma_{\lambda} I_{\lambda} \Phi_{\lambda} d_{\lambda}$$

σ(λ) = absorption cross section (cm^2)
I(λ) = solar flux ($photon.cm^{-2}.s^{-1}.nm^{-1}$)
ϕ(λ) = quantum yield

2. Expériences de photochimie: méthodologie.





$$AB + h\nu \xrightarrow{J} A\bullet + B\bullet$$

$$\frac{d[A]}{dt} = -J[A]$$

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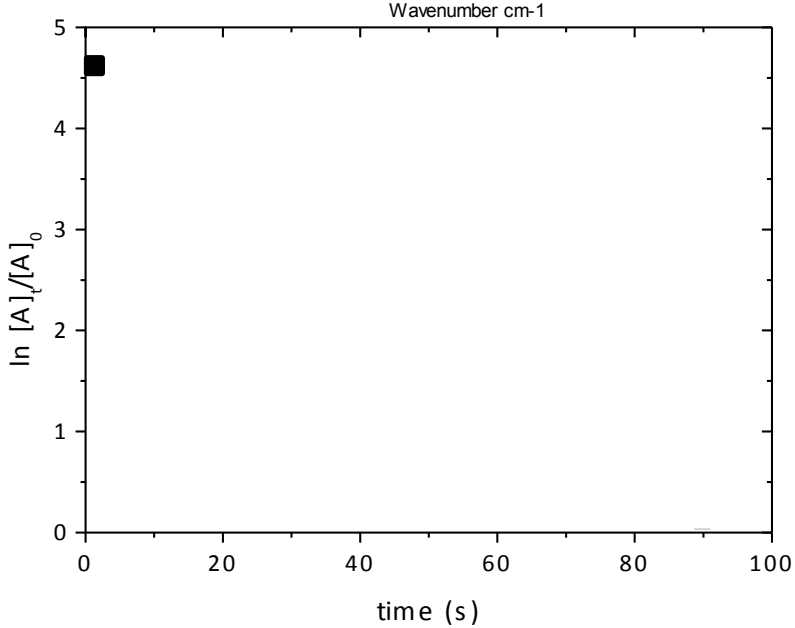

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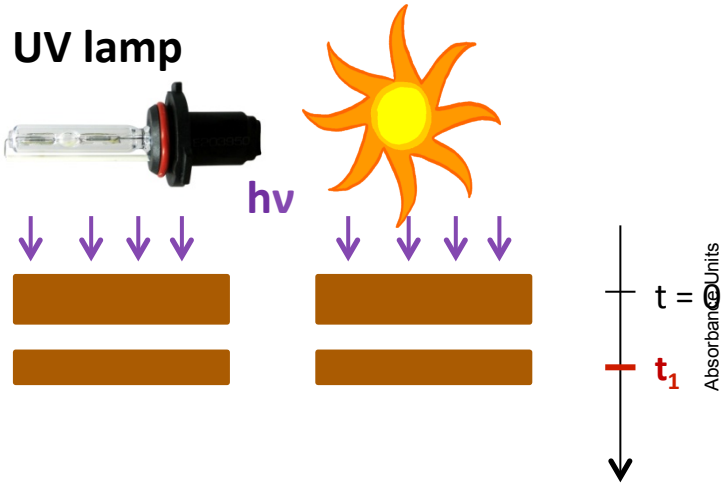

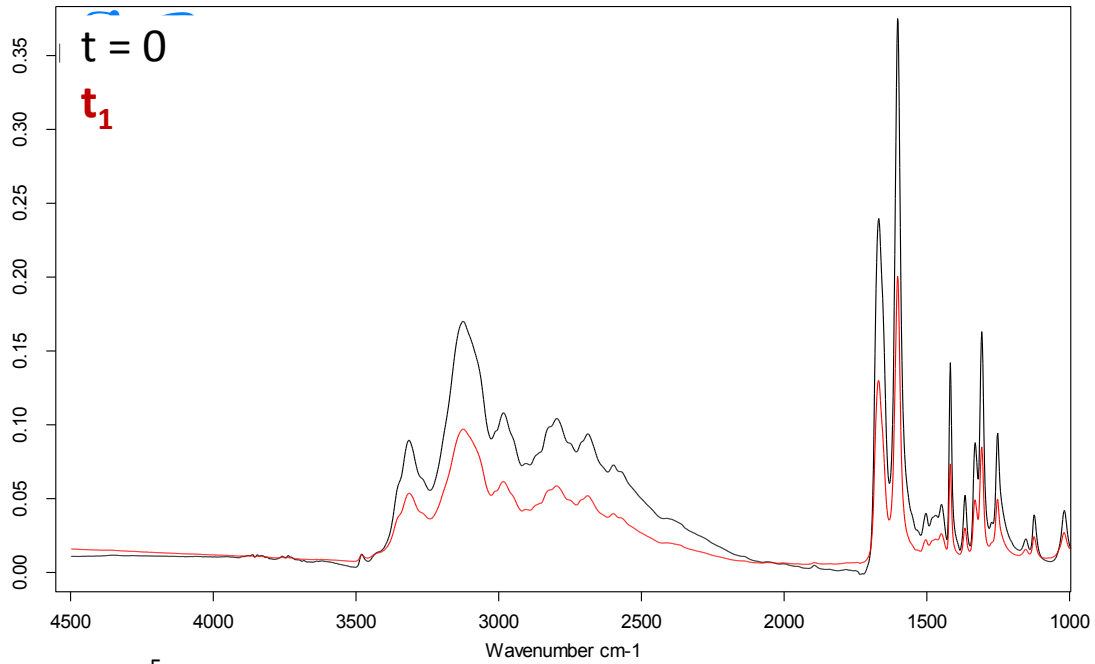

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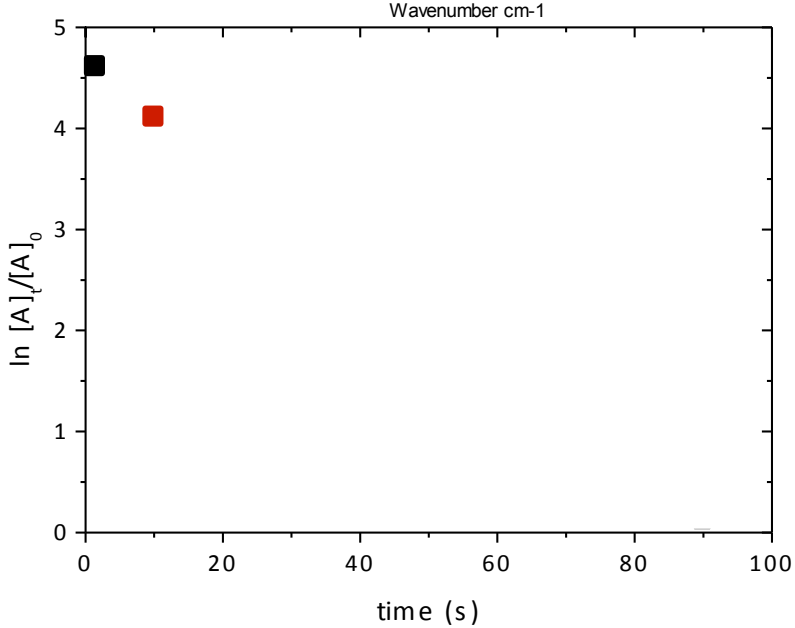

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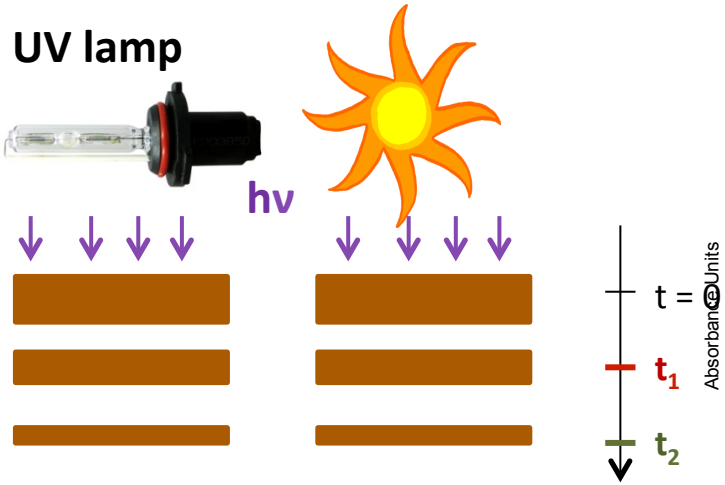

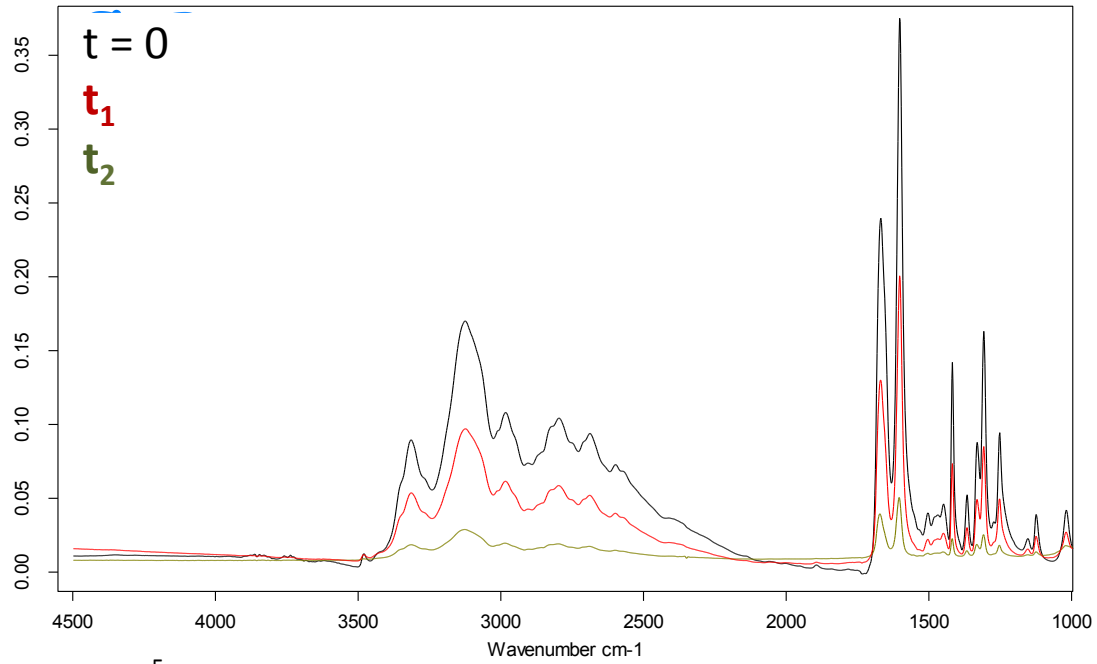

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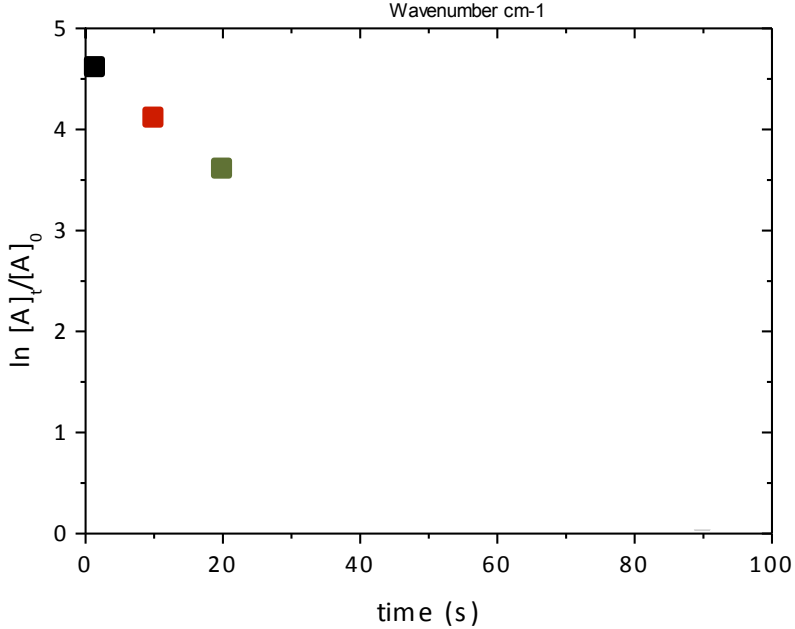

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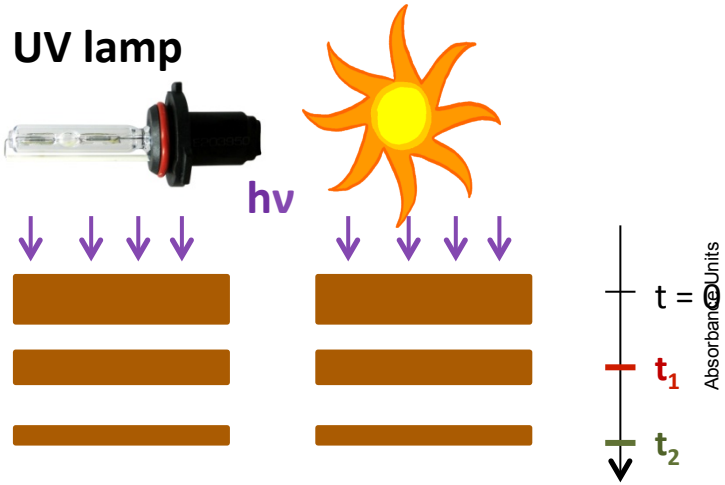

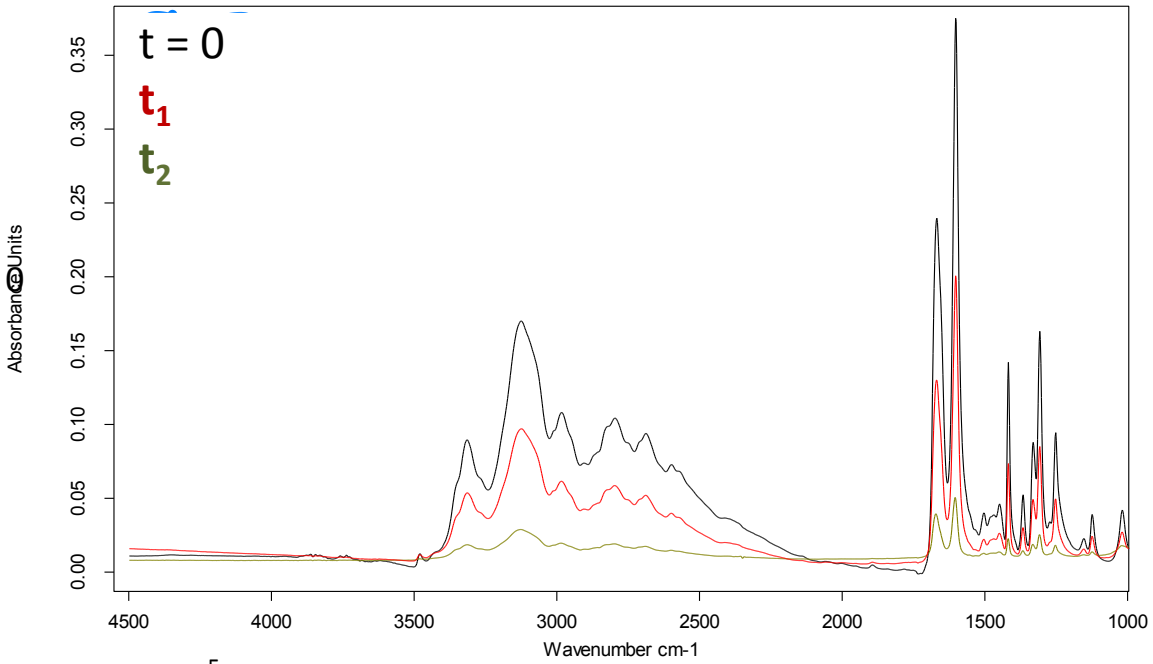

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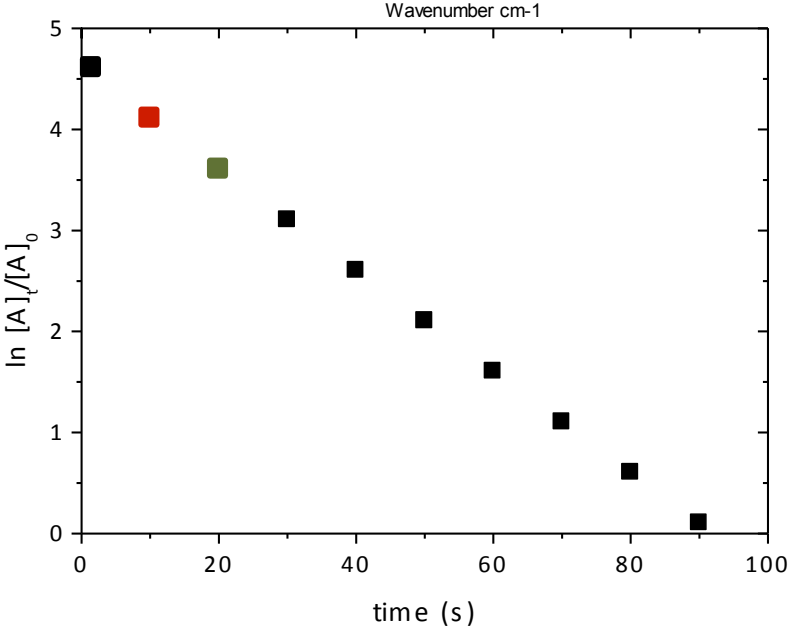

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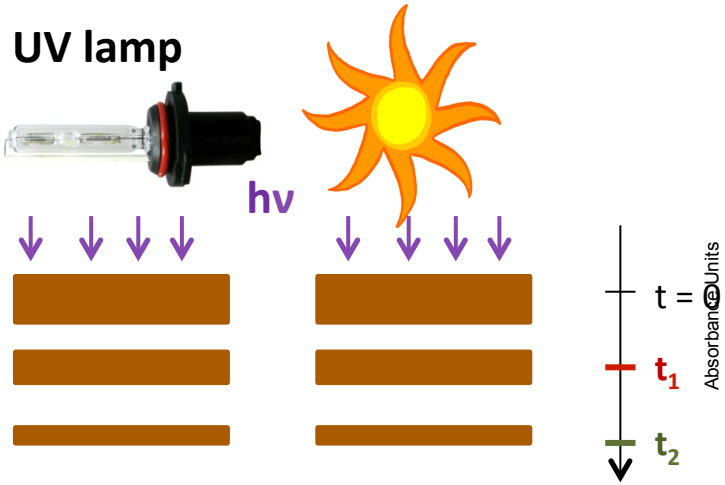

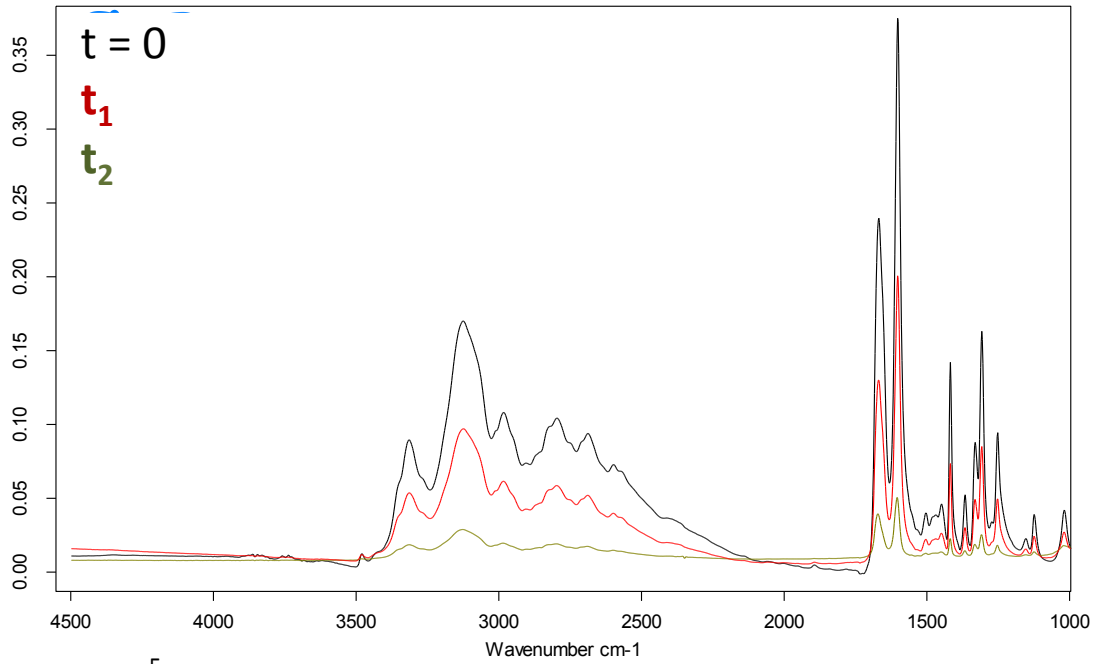

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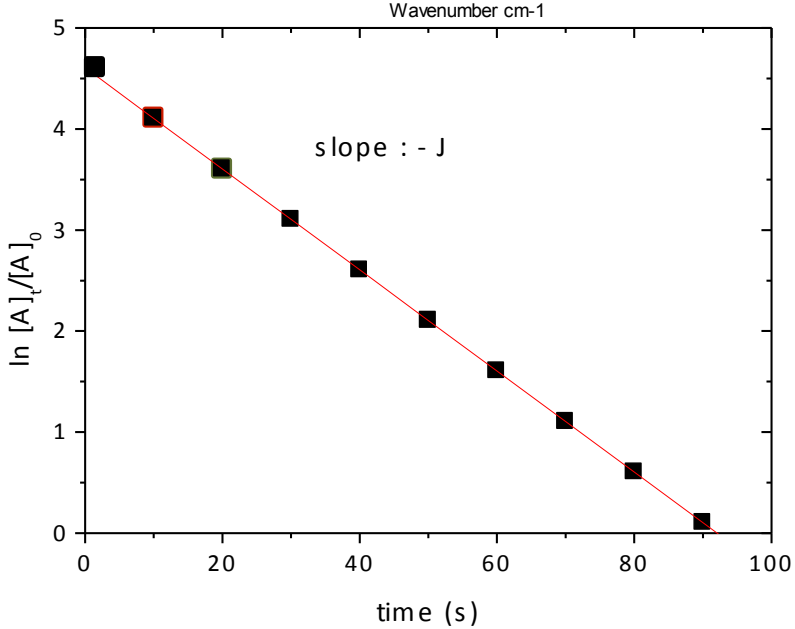

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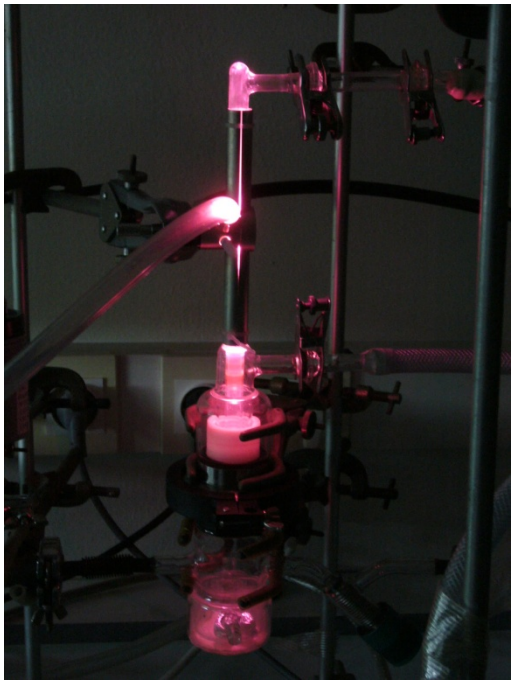
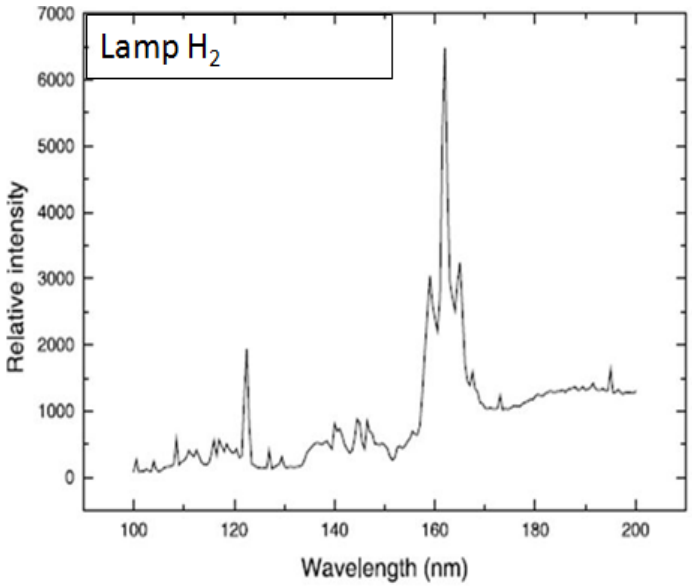
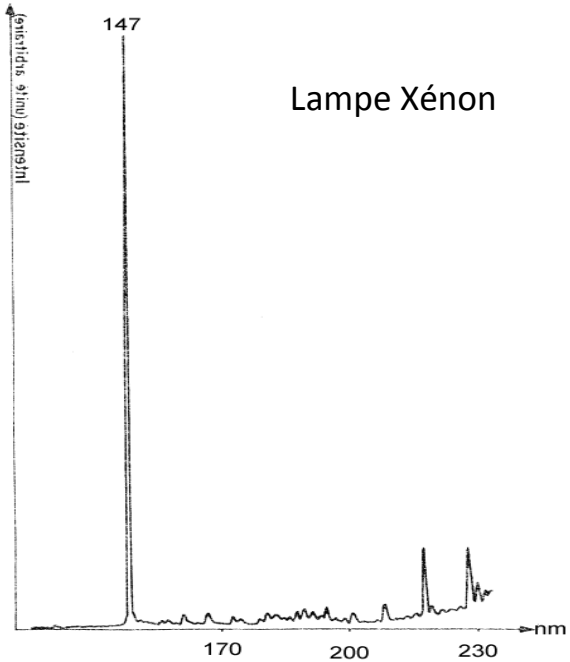
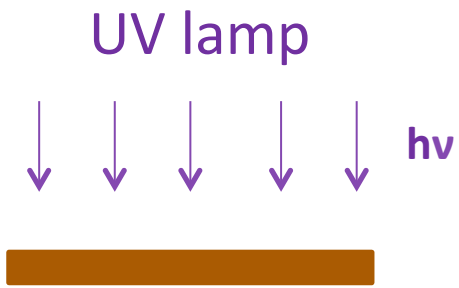
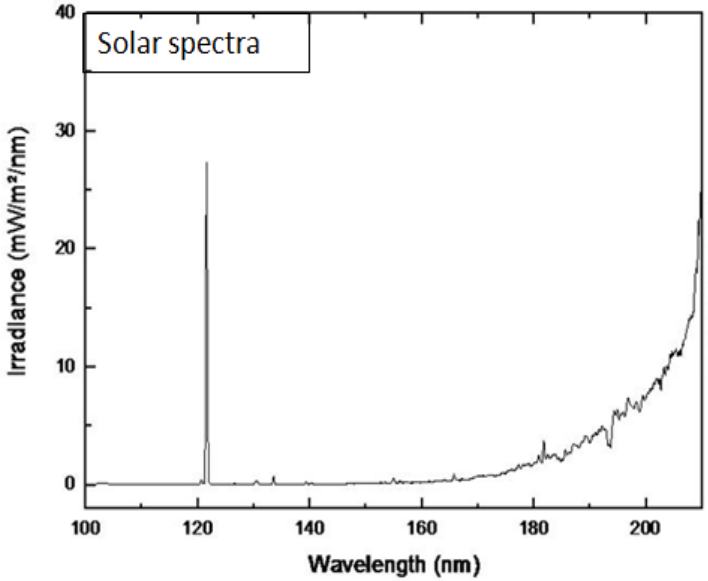


En laboratoire



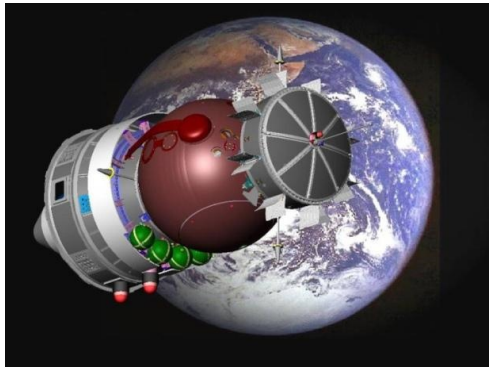






2. Expériences de photochimie

En orbite terrestre



UVolution

14 jours

Guan et al. 2008
Stalport et al. 2009
Stalport et al. 2010

PROCESS, AMINO

1 an et demi à 2 ans.

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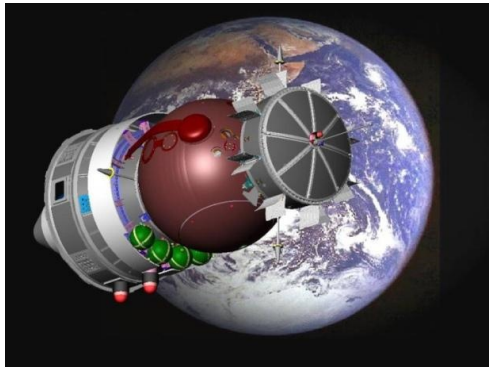

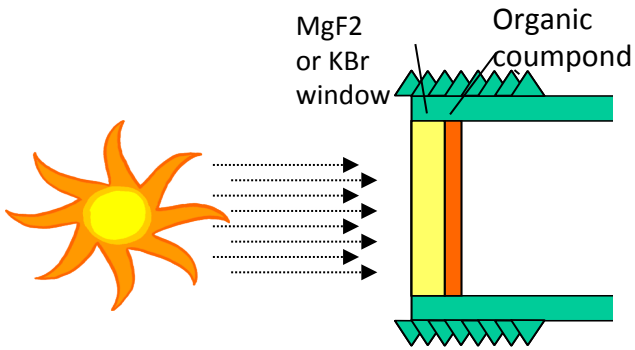

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2. Expériences de photochimie: matériel.

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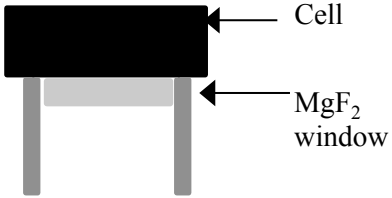

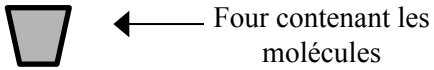

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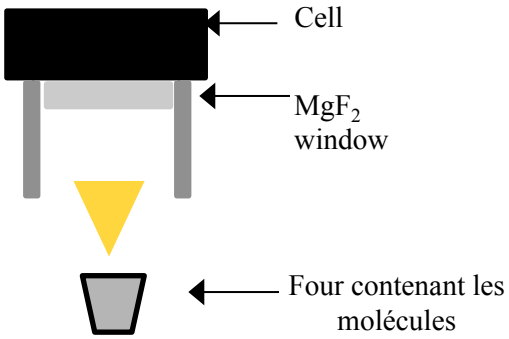

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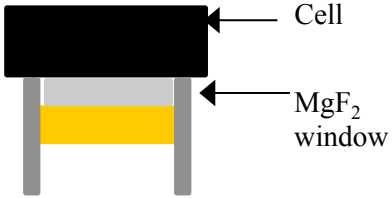

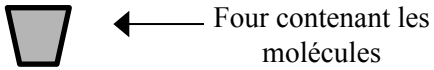

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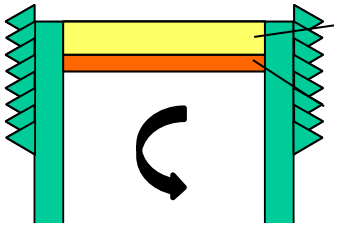
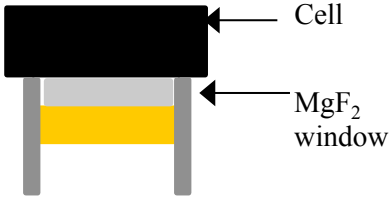
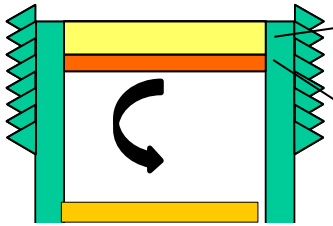




Four contenant les molécules



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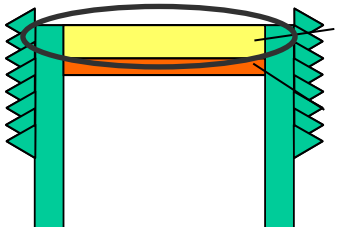

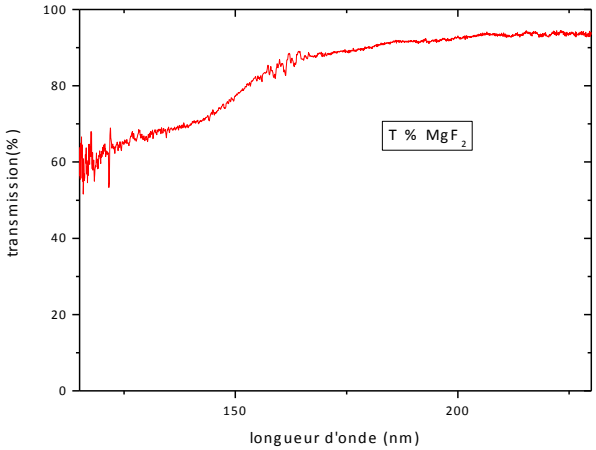

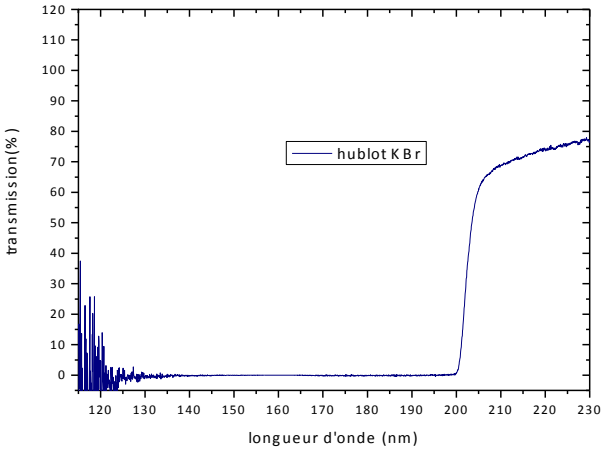

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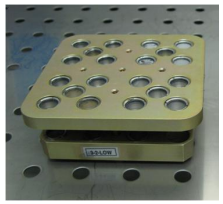

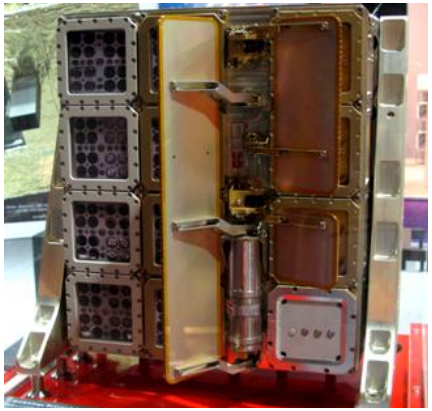

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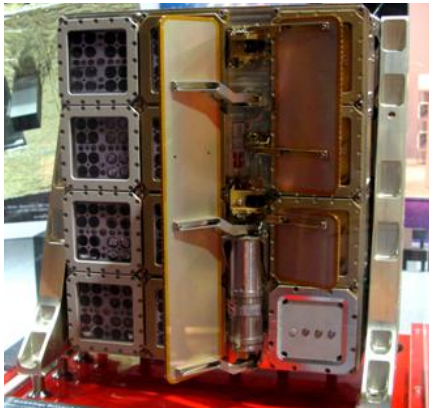
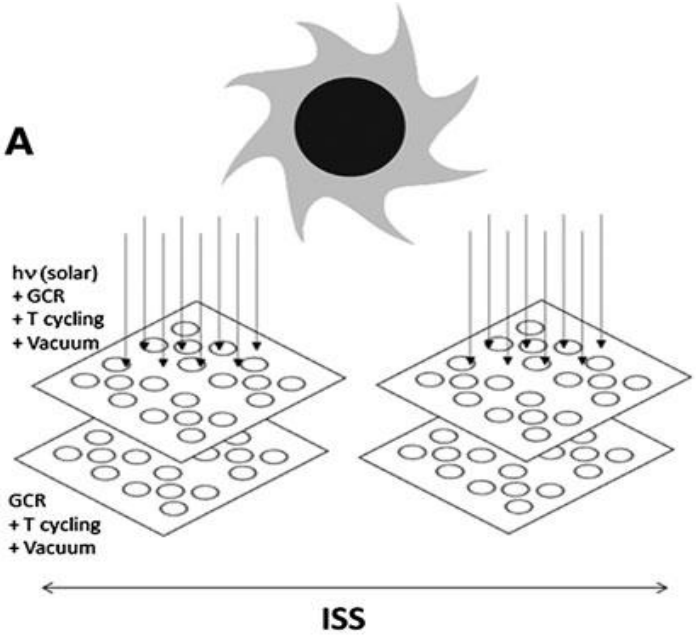
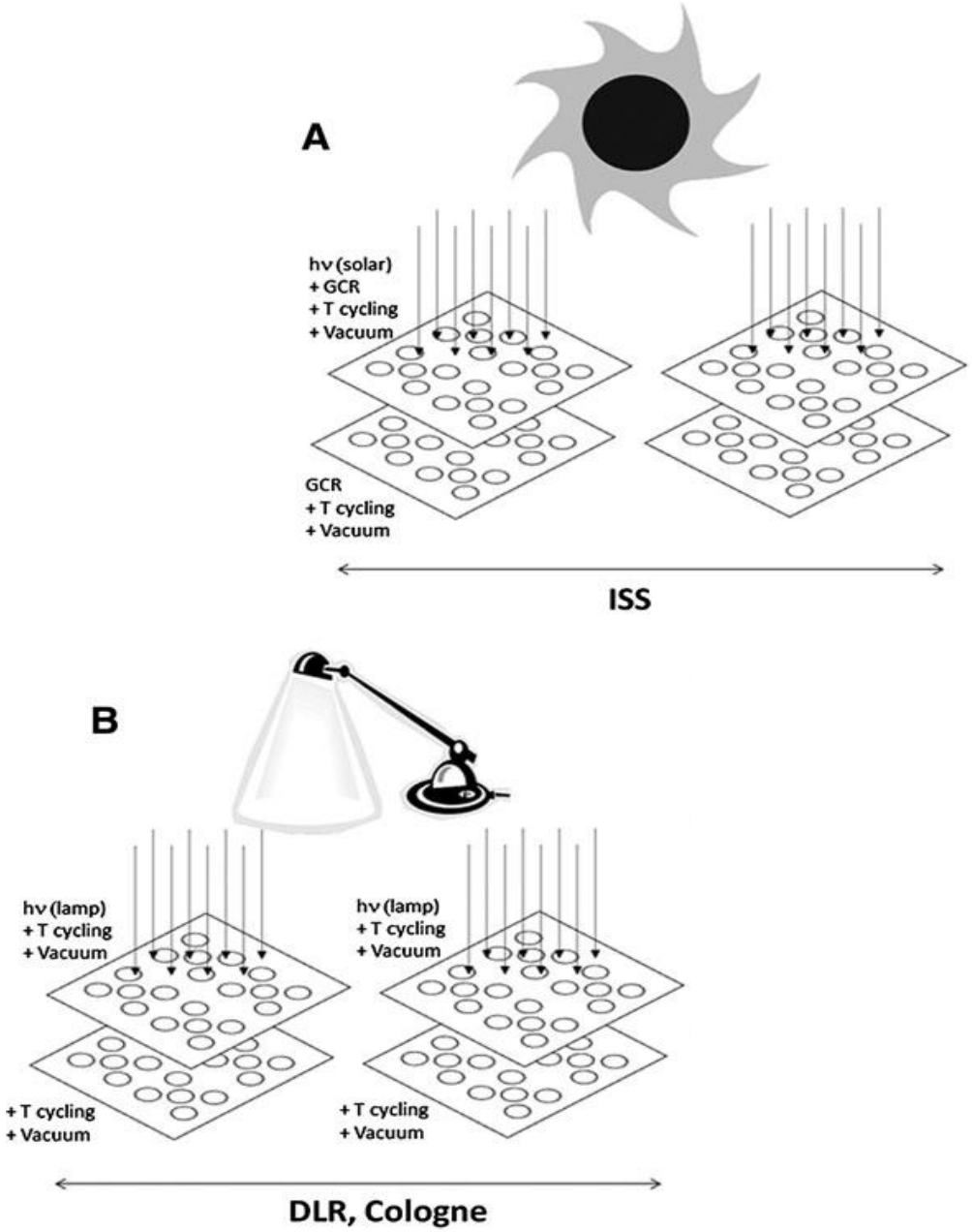




2. Expériences de photochimie: matériel.



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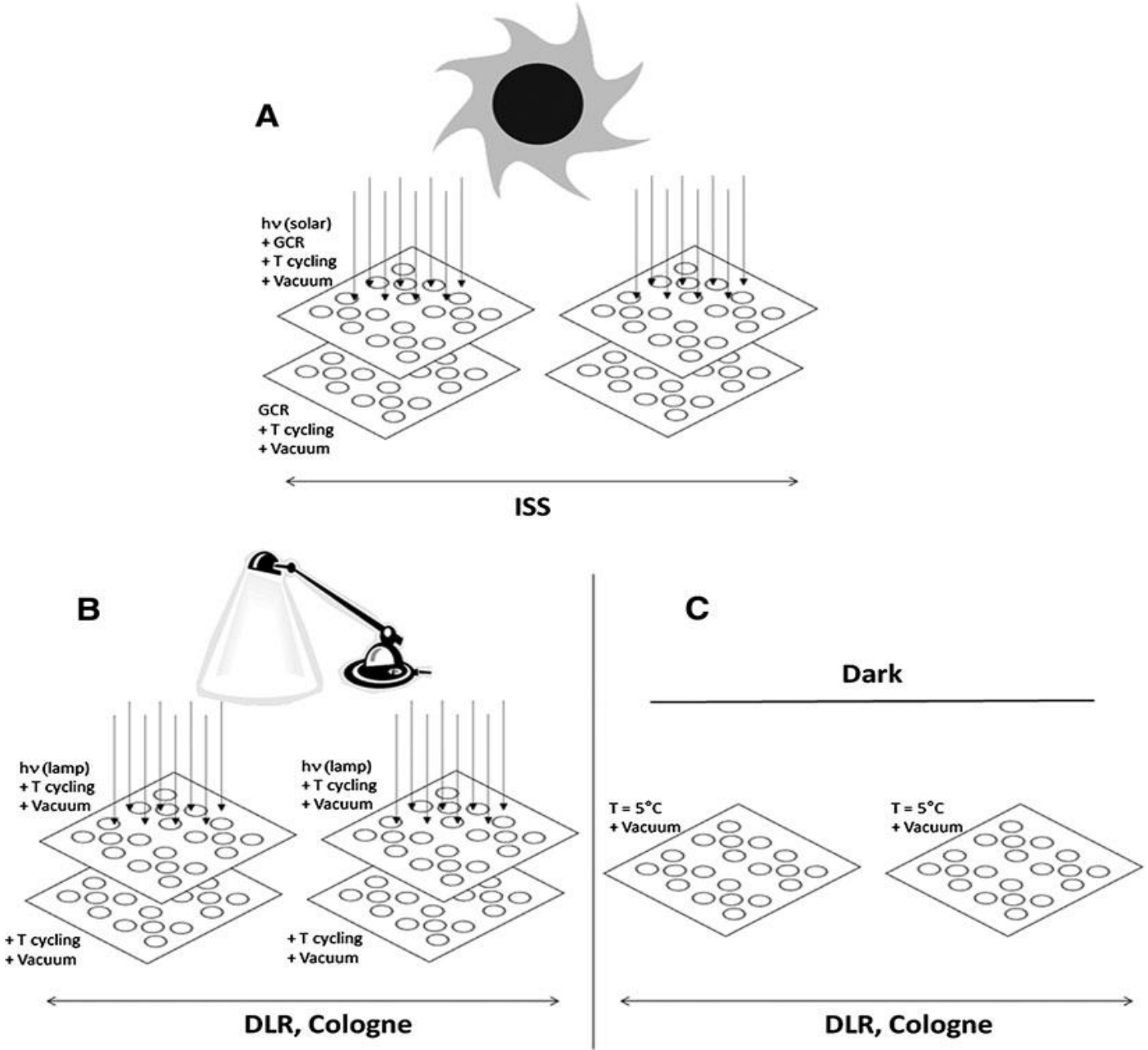
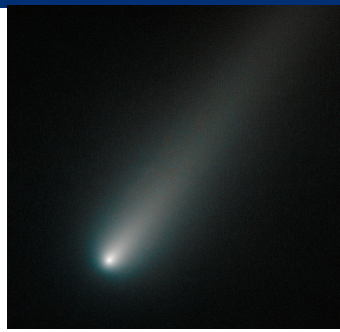


3. Quelques résultats

UVolution

Guan et al. 2008
Stalport et al. 2009
Stalport et al. 2010



Molecule	J measured in space (s-1)	J' measured in the lab. (s-1)
glycine	1,0E-06	$8,6\ 10^{-6}$
adenine	< 1,9E-7	$2,7\ 10^{-7}$
guanine	< 1,9E-7	$< 2,7\ 10^{-7}$
xanthine	5,0E-07	$1,3\ 10^{-6}$
hypoxanthine	< 1,9E-7	$3,7\ 10^{-6}$
urea	< 1,9E-7	$< 2,7\ 10^{-7}$
C3O2 polymer(*)	1,3E-06	$1,3\ 10^{-5}$
polyHCN	8,0E-07	$2,0\ 10^{-6}$

(*) CN band

Guan et al., PSS, 2010.

3. Quelques résultats

UVolution

Guan et al. 2008
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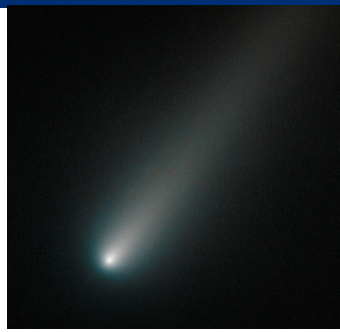


Molecule	J measured in space (s-1)	J' measured in the lab. (s-1)	J' extrapolated at 1 AU (s-1) (lyman α)	Ratio (space/lab.) (lyman α)
glycine	1,0E-06	$8{,}6\ 10^{-6}$	6E-09	167
adenine	< 1,9E-7	$2{,}7\ 10^{-7}$	8E-10	< 238
guanine	< 1,9E-7	$< 2{,}7\ 10^{-7}$	$< 8{,}2\ 10^{-10}$	--
xanthine	5,0E-07	$1{,}3\ 10^{-6}$	4E-09	125
hypoxanthine	< 1,9E-7	$3{,}7\ 10^{-6}$	1,1E-08	< 17
urea	< 1,9E-7	$< 2{,}7\ 10^{-7}$	$< 8{,}2\ 10^{-10}$	--
C3O2 polymer(*)	1,3E-06	$1{,}3\ 10^{-5}$	1,1E-08	118
polyHCN	8,0E-07	$2{,}0\ 10^{-6}$	2E-09	400

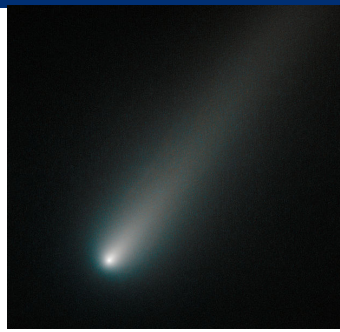
(*) CN band

Guan et al., PSS, 2010.

3. Quelques résultats

UVolution

Guan et al. 2008
Stalport et al. 2009
Stalport et al. 2010



Molecule	J measured in space (s-1)	J' measured in the lab. (s-1)	J' extrapolated at 1 AU (s-1) (lyman α)	Ratio (space/lab.) (lyman α)	J' extrapolated at 1 AU (s-1) (115-200 nm)	Ratio (space/lab.) (115-200 nm)
glycine	1,0E-06	8,6 10^{-6}	6E-09	167	1E-07	10
adenine	< 1,9E-7	2,7 10^{-7}	8E-10	< 238	1,5E-08	< 13
guanine	< 1,9E-7	< 2,7 10^{-7}	< 8,2 10^{-10}	--	< 8,2 10^{-10}	--
xanthine	5,0E-07	1,3 10^{-6}	4E-09	125	7E-08	7
hypoxanthine	< 1,9E-7	3,7 10^{-6}	1,1E-08	< 17	2E-07	< 1
urea	< 1,9E-7	< 2,7 10^{-7}	< 8,2 10^{-10}	--	< 8,2 10^{-10}	--
C3O2 polymer(*)	1,3E-06	1,3 10^{-5}	1,1E-08	118	2E-07	6,5
polyHCN	8,0E-07	2,0 10^{-6}	2E-09	400	3,5E-08	23

(*) CN band

Guan et al., PSS, 2010.

3. Quelques résultats

UVolution

Guan et al. 2008
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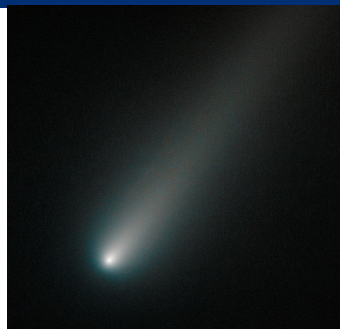


Molecule	J measured in space (s-1)	J' measured in the lab. (s-1)	J' extrapolated at 1 AU (s-1) (lyman α)	Ratio (space/lab.) (lyman α)	J' extrapolated at 1 AU (s-1) (115-200 nm)	Ratio (space/lab.) (115-200 nm)
glycine	1,0E-06	8,6 10^{-6}	6E-09	167	1E-07	10
adenine	< 1,9E-7	2,7 10^{-7}	8E-10	< 238	1,5E-08	< 13
guanine	< 1,9E-7	< 2,7 10^{-7}	< 8,2 10^{-10}	--	< 8,2 10^{-10}	--
xanthine	5,0E-07	1,3 10^{-6}	4E-09	125	7E-08	7
hypoxanthine	< 1,9E-7	3,7 10^{-6}	1,1E-08	< 17	2E-07	< 1
urea	< 1,9E-7	< 2,7 10^{-7}	< 8,2 10^{-10}	--	< 8,2 10^{-10}	--
C3O2 polymer(*)	1,3E-06	1,3 10^{-5}	1,1E-08	118	2E-07	6,5
polyHCN	8,0E-07	2,0 10^{-6}	2E-09	400	3,5E-08	23

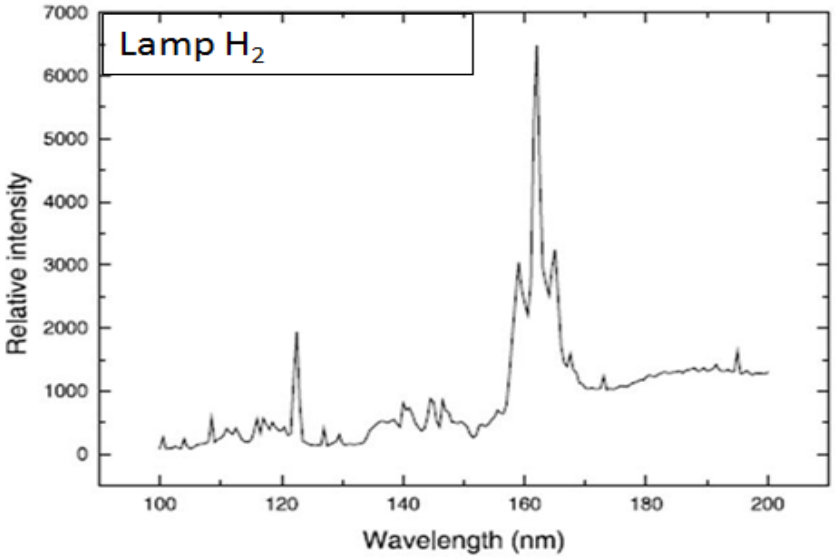
(*) CN band

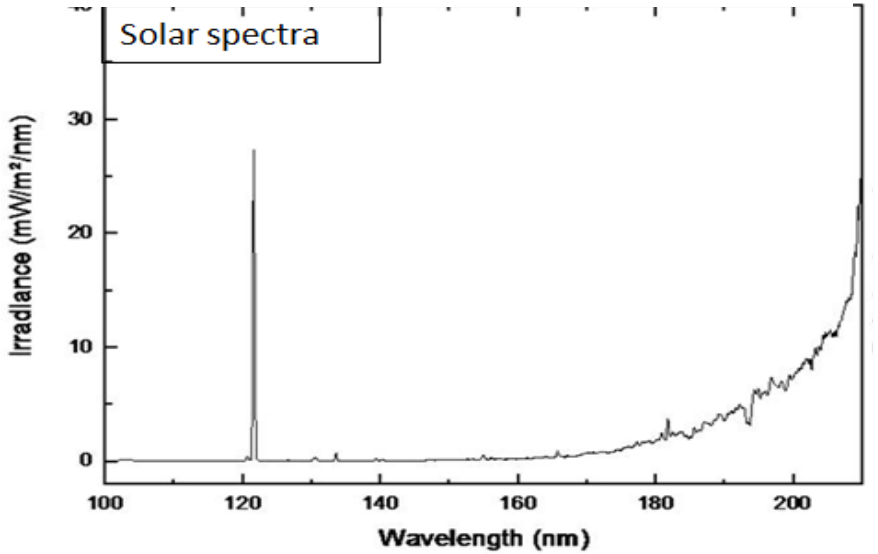
→ **Mesures de laboratoire difficilement extrapolables**

Guan et al., PSS, 2010.

4. Limites et perspectives

En laboratoire

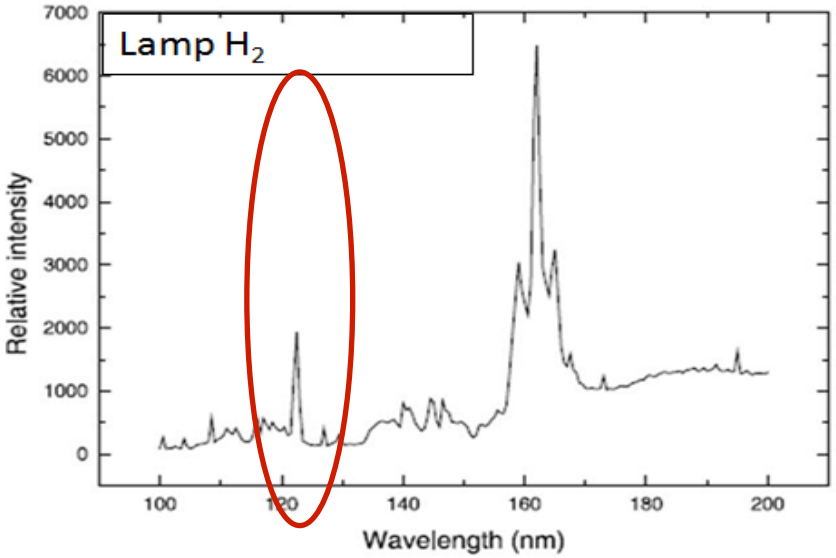


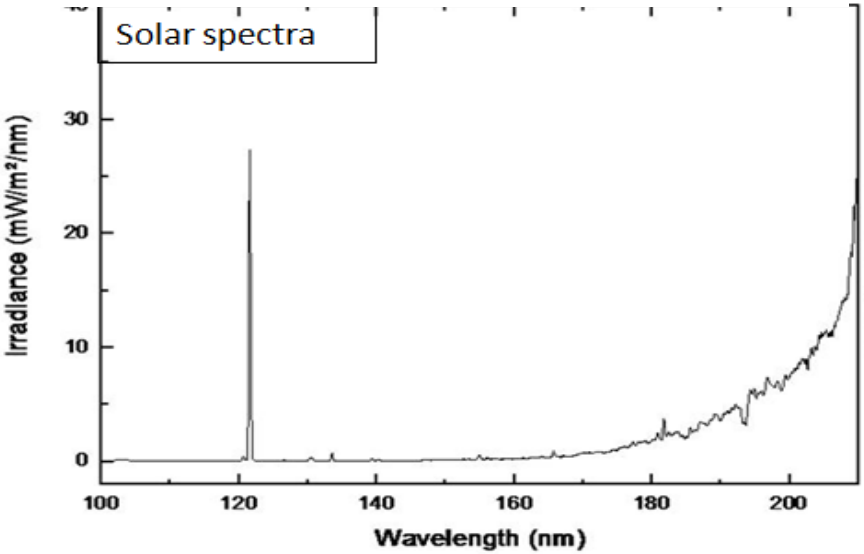


Travail sur la représentativité des lampes de laboratoire.

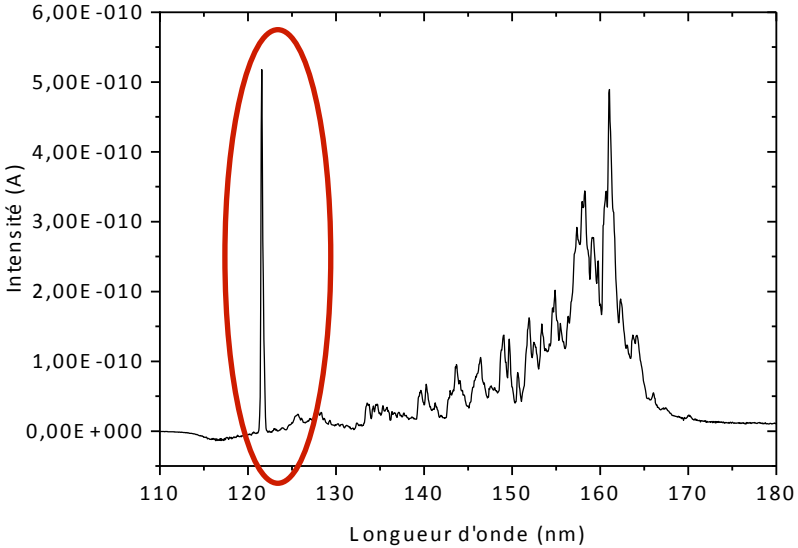
4. Limites et perspectives

En laboratoire





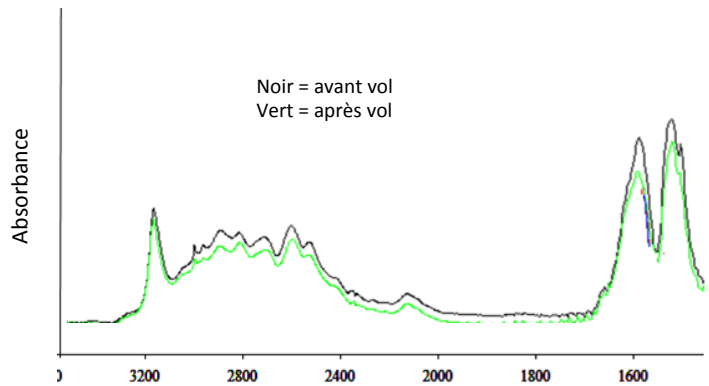
Travail sur la représentativité des lampes de laboratoire.

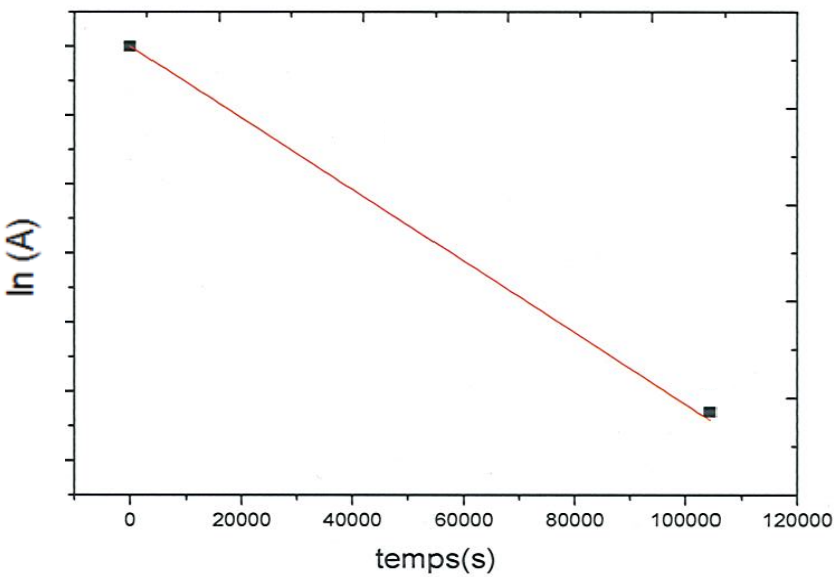


Bouilloud M., 2012, rapport de M2.

4. Limites et perspectives

En orbite terrestre



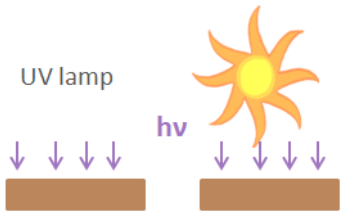


mesures in situ

Projet VITRINE
(CNES)
20XX ?

Limites et perspectives

En laboratoire ET en orbite



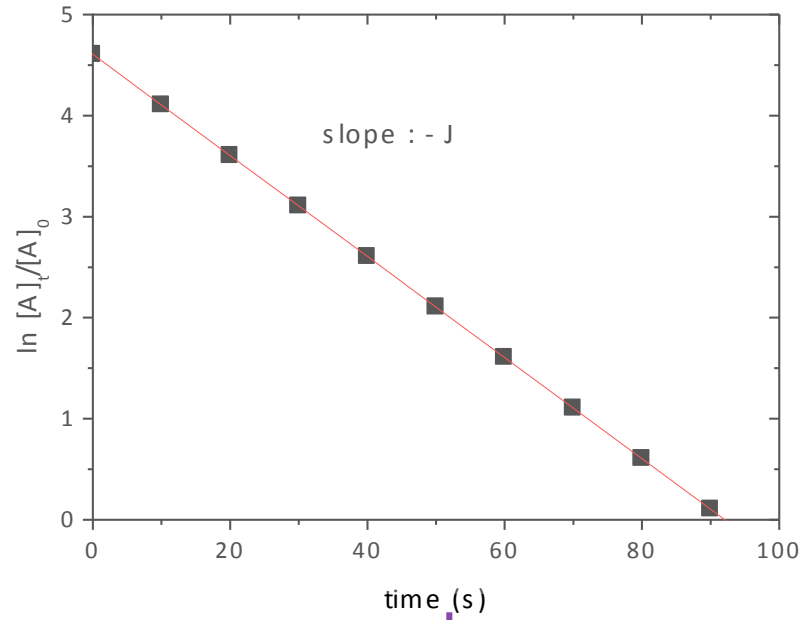
$$AB + h\nu \xrightarrow{J} A\bullet + B\bullet$$

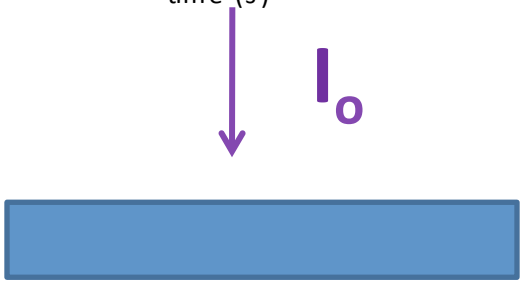
$$\frac{d[A]}{dt} = -J[A]$$

$$\ln[A] = \ln[A]_0 - J \times t$$

First kinetic order

Sample optically thin

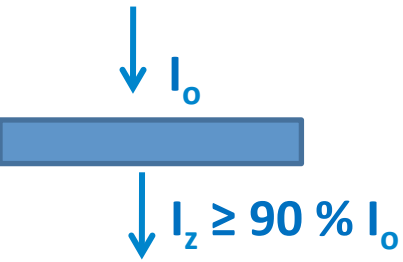




I_o

$I_z \geq 90\ \%\ I_o$

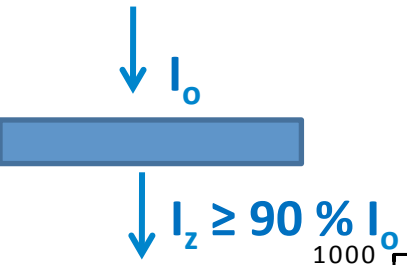
Sample optically thin



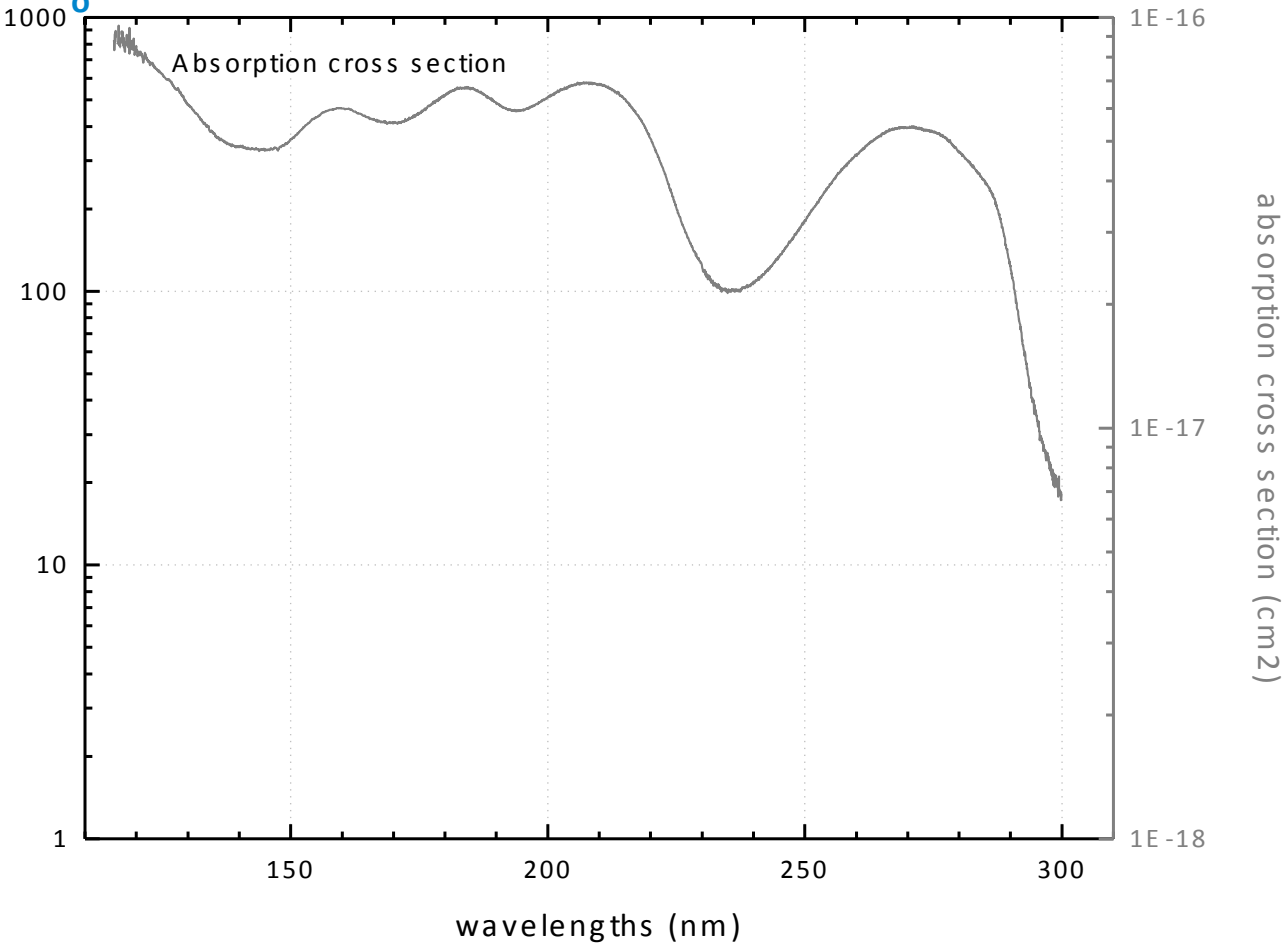
$$z = Ln\left(\frac{Io}{90\%Io}\right) \times \frac{M}{\sigma \times \rho \times N_a}$$

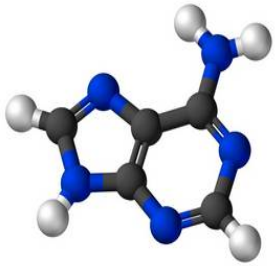
?

Sample optically thin



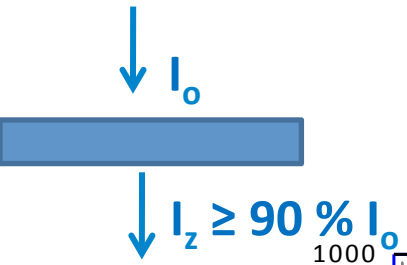
$$z = Ln\left(\frac{Io}{90\%Io}\right) \times \frac{M}{\sigma \times \rho \times N_a}$$



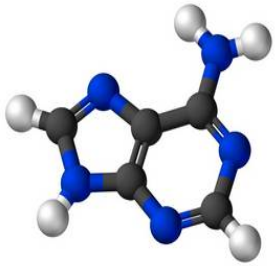


Adenine

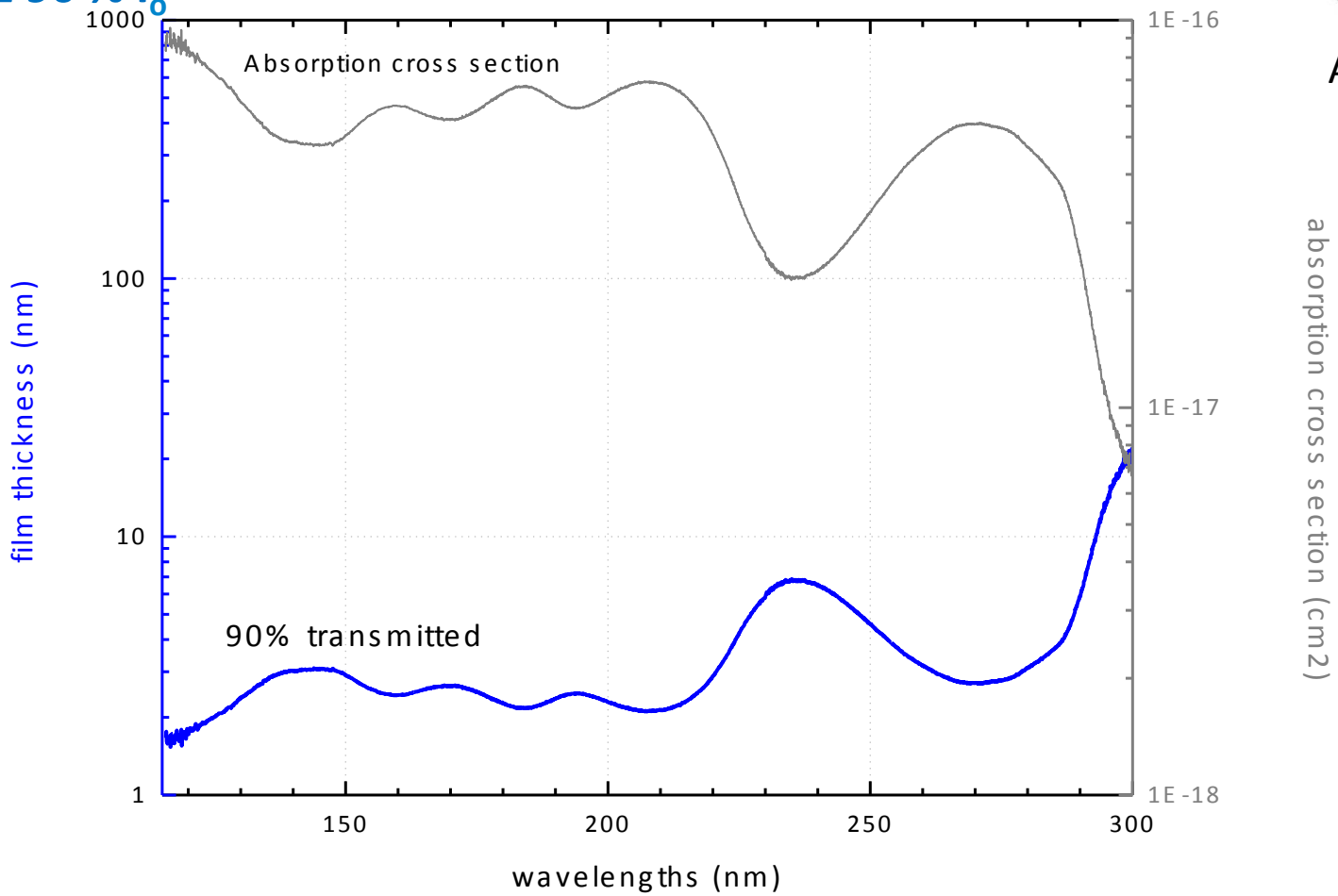
Sample optically thin



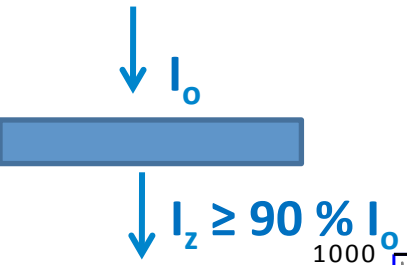
$$z = Ln\left(\frac{Io}{90\%Io}\right) \times \frac{M}{\sigma \times \rho \times N_a}$$



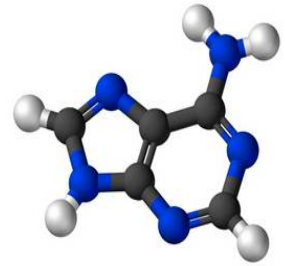
Adenine



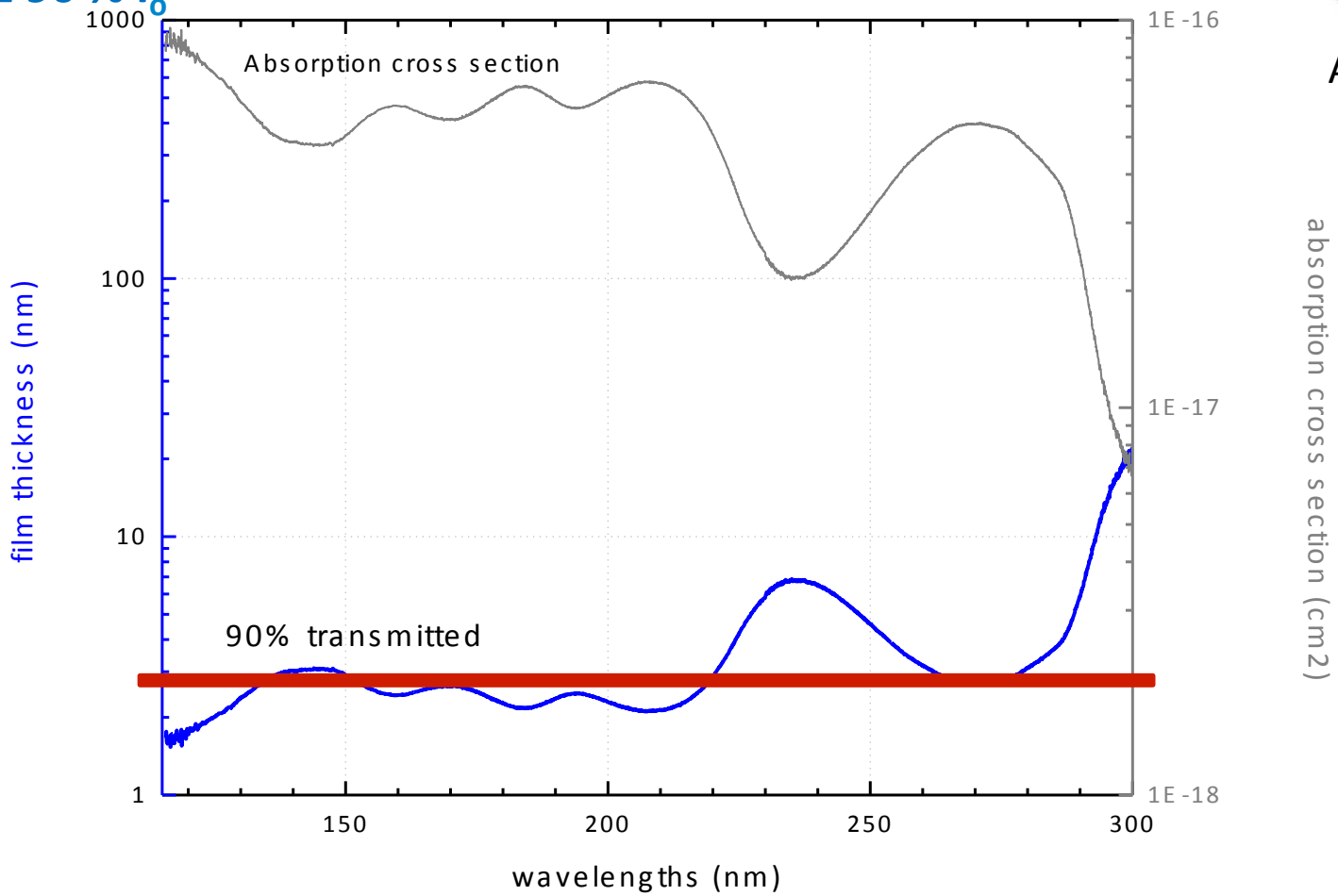
Sample optically thin



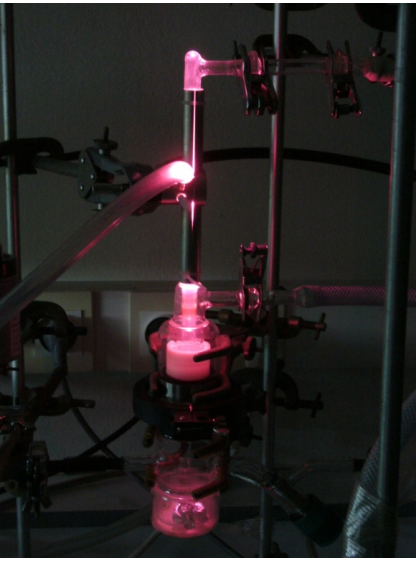
$$z = Ln\left(\frac{Io}{90\%Io}\right) \times \frac{M}{\sigma \times \rho \times N_a}$$

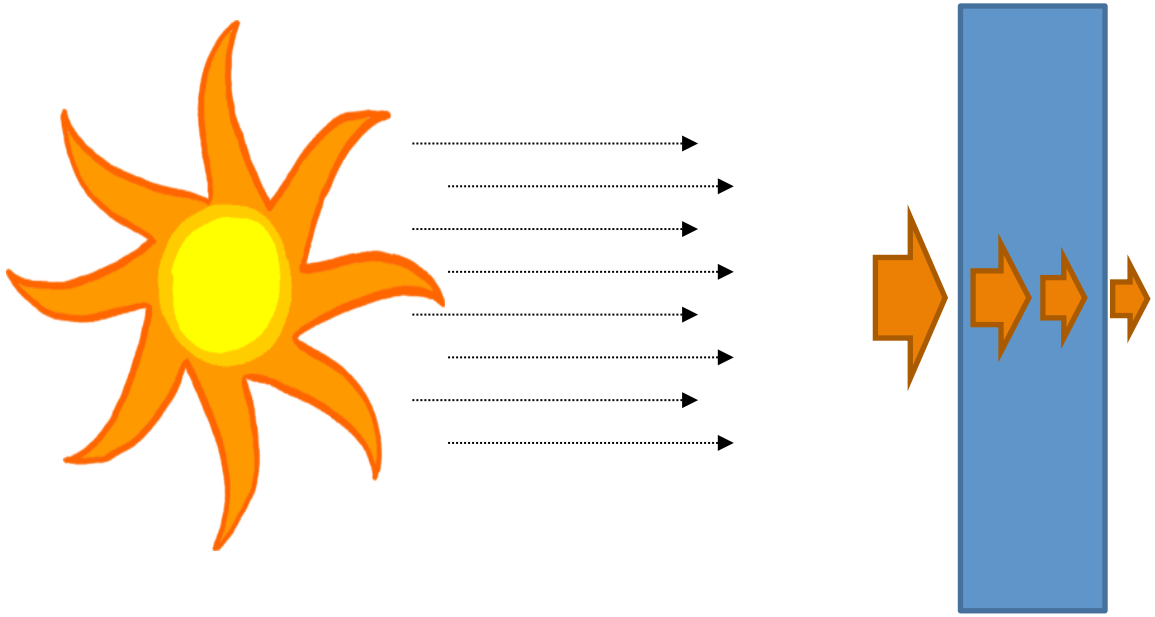


Adenine

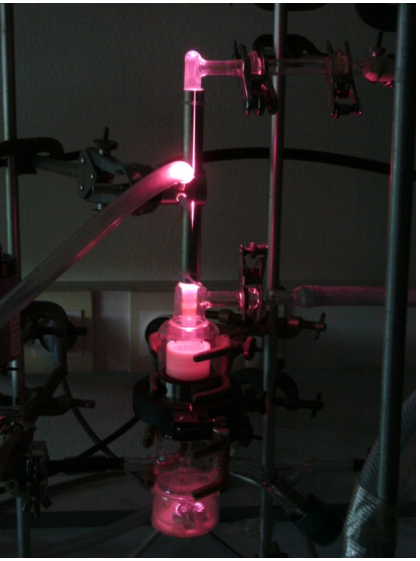


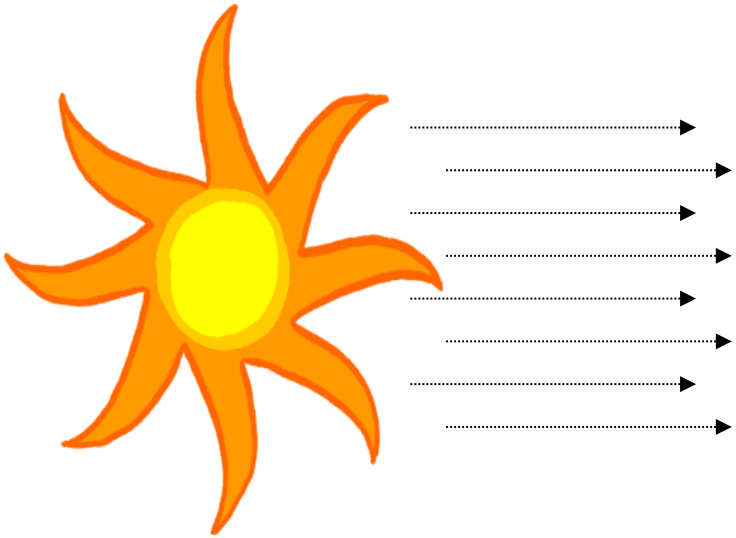
Limites et perspectives

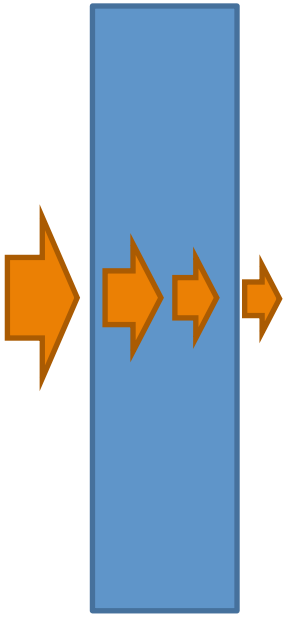




Limites et perspectives





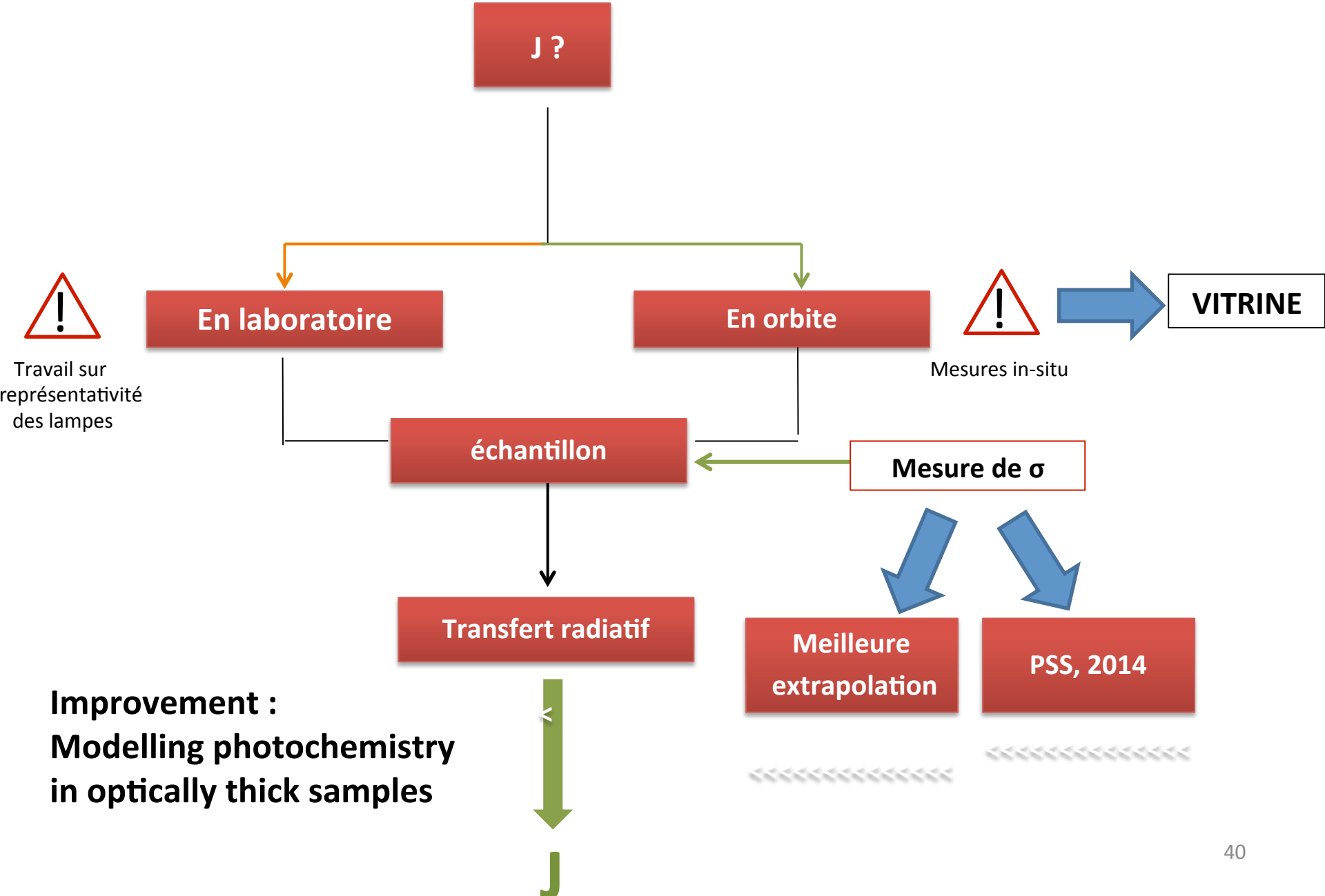


200 nm

temps de vie sous-estimé.

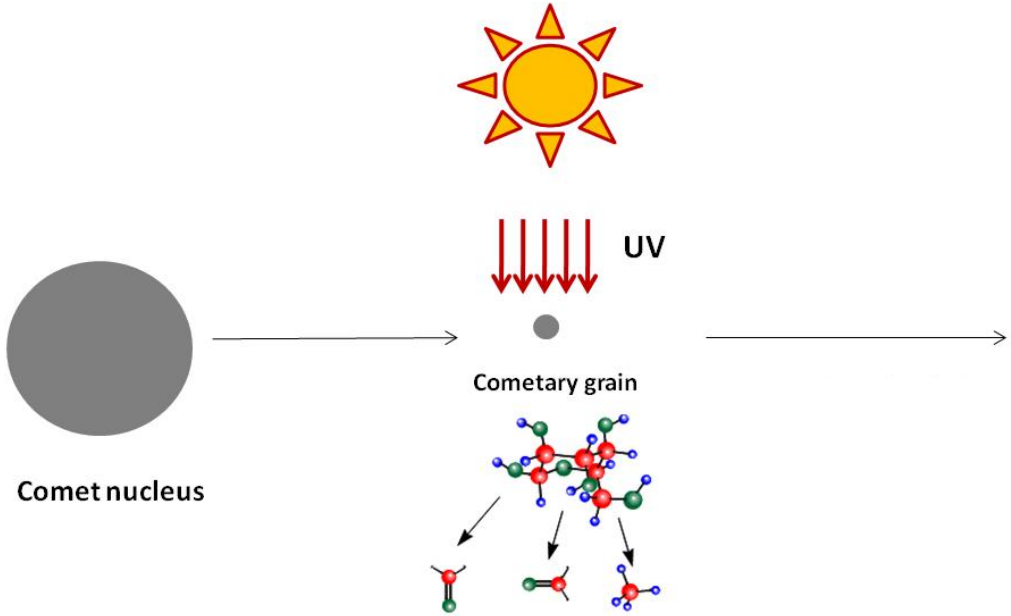
Transfert radiatif

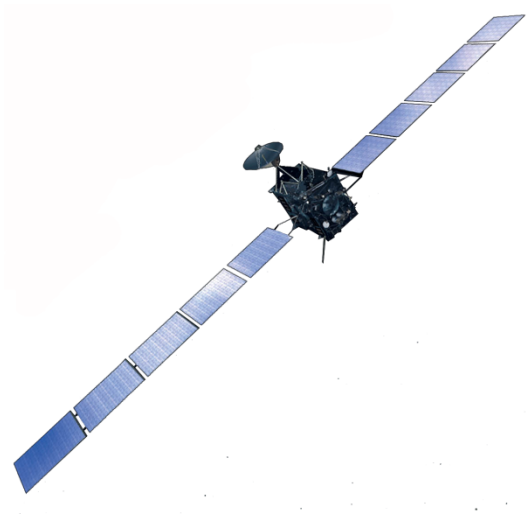
Conclusions



Improvement :
Modelling photochemistry in optically thick samples

Exemple d'application : ROSETTA





<u>Analyse des grains</u>
Quelques minutes à quelques heures après éjection

Quelle est la fraction de molécules organiques détruite sur un grain entre le moment de son éjection et son analyse?