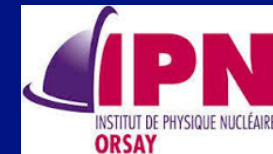# COSMIC RAYS ELECTRONIC SPUTTERING YIELD OF INTERSTELLAR H$_2$O ICE MANTLES

E. Dartois, ISMO, Orsay, France
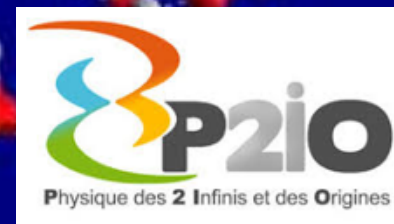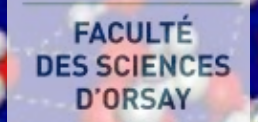*emmanuel.dartois@u-psud.fr*

October 19th 2018, P2IO, Orsay

M. Chabot
T. Id Barkach

A.N. Agnihotri
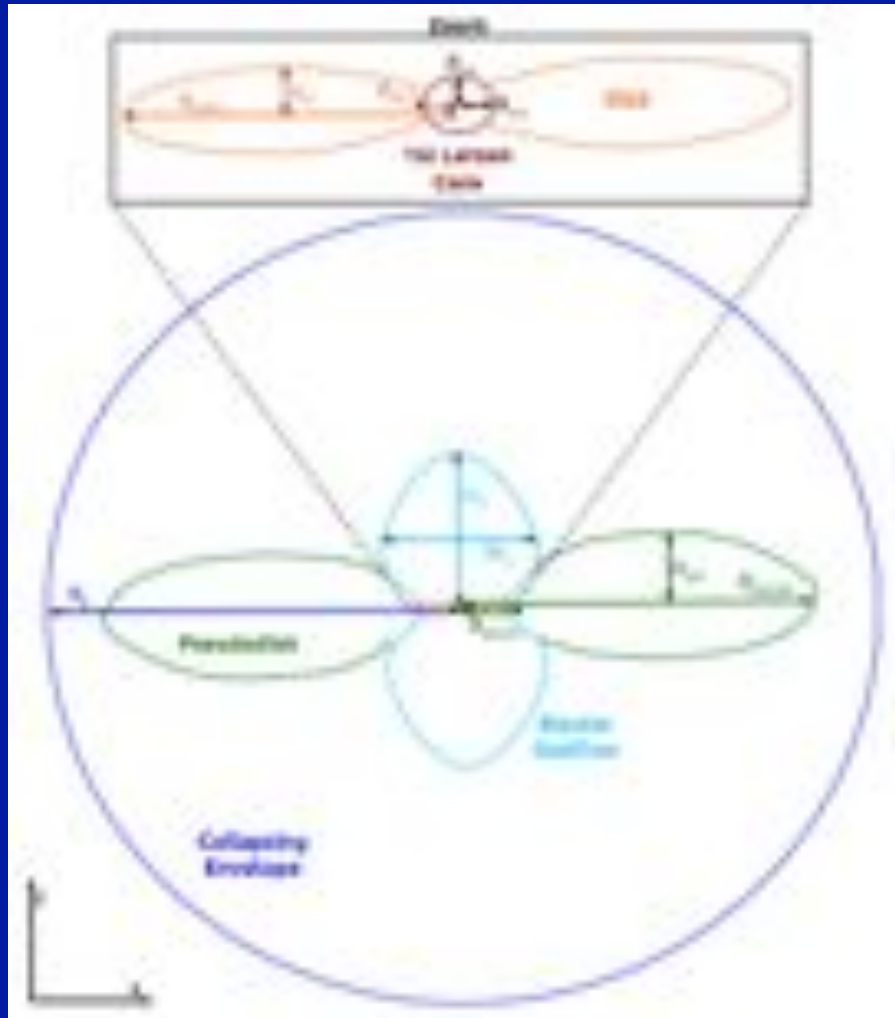P. Boduch
A. Domaracka
H. Rothard
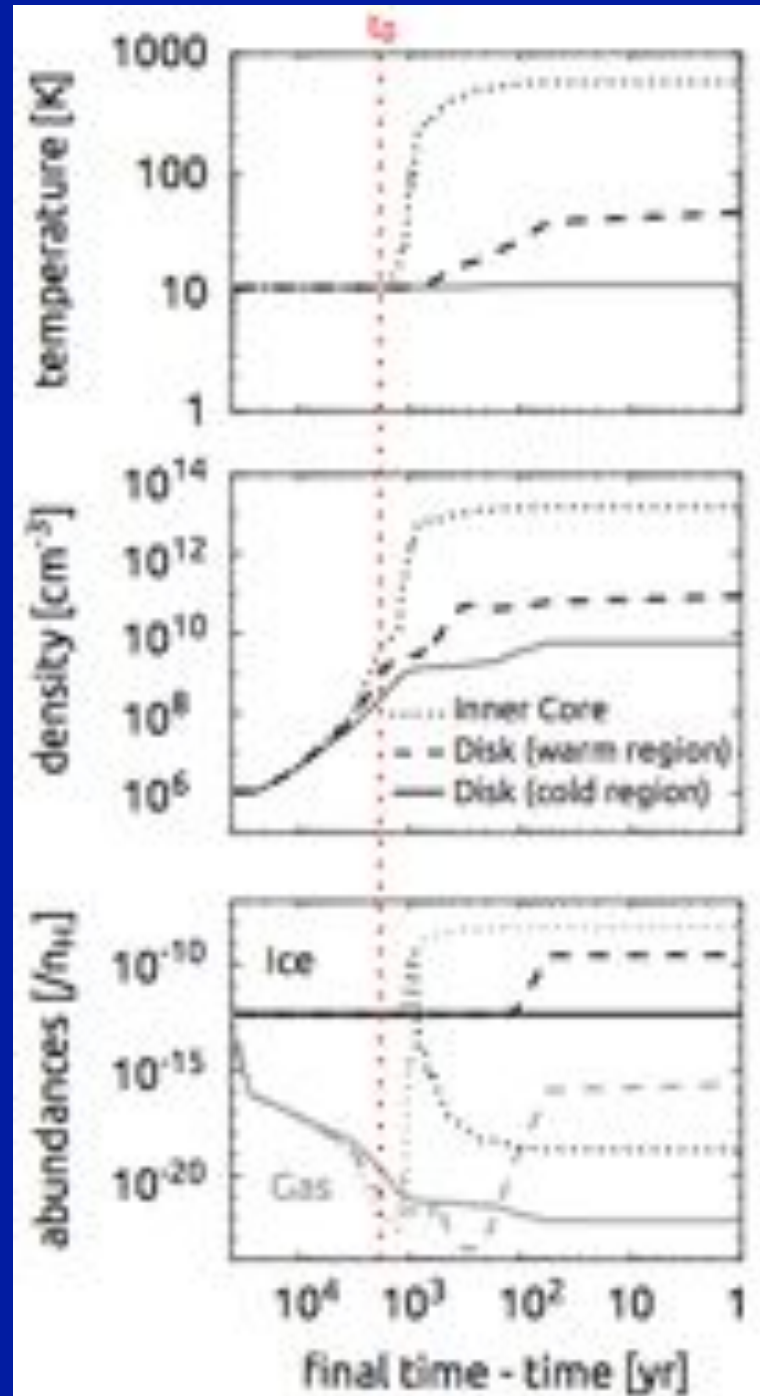
B. Augé

Sputtering in molecular clouds

Gas phase accretion timescale $\sim 10^9$ years / n_H

➡ everything should condense

- Sputtering is one mechanism (re-)injecting species in the gas phase (as well as stochastic heating and secondary photons)
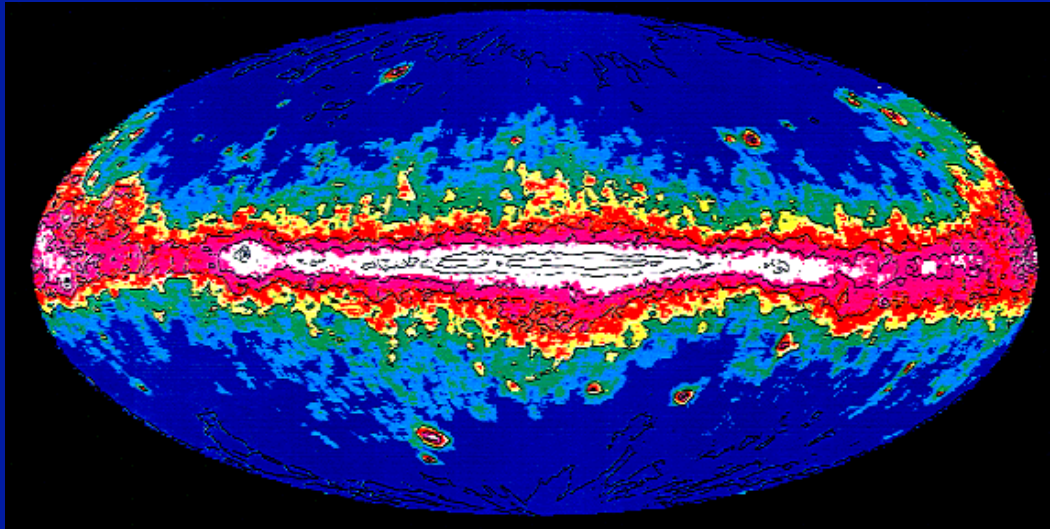
Lupus 3 dark cloud © ESO/F. Comeron

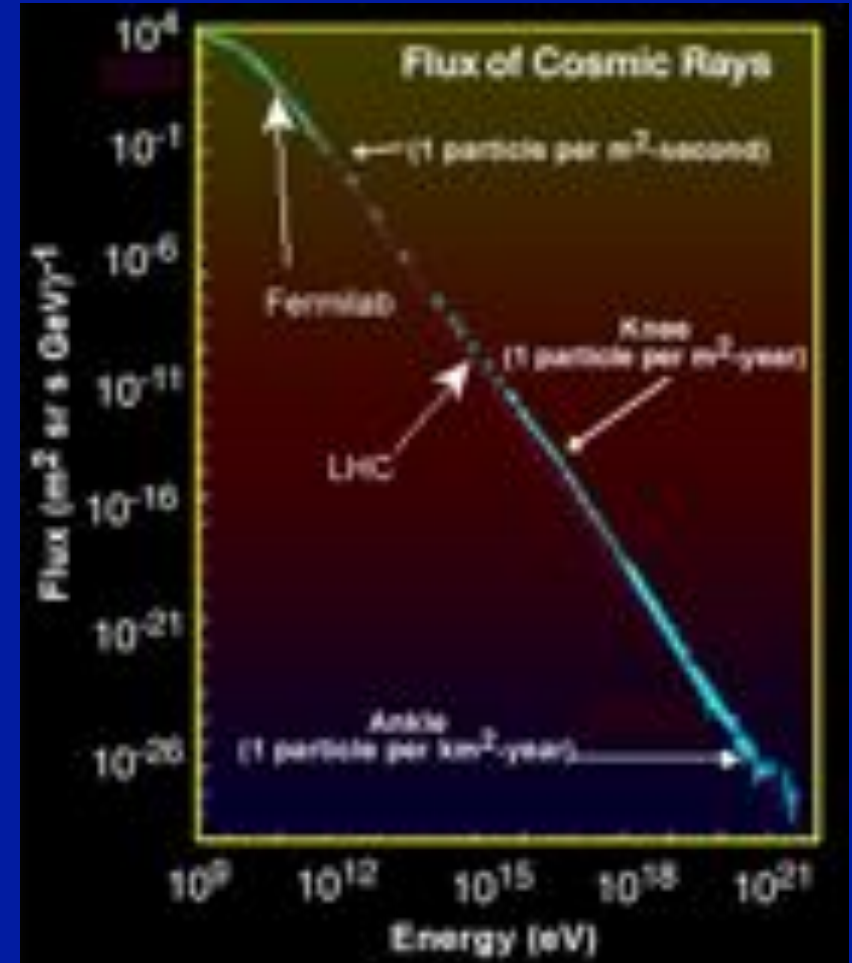# Sputtering in disks ?

Hincelin+ 2016

Influence of energetic cosmic rays ?
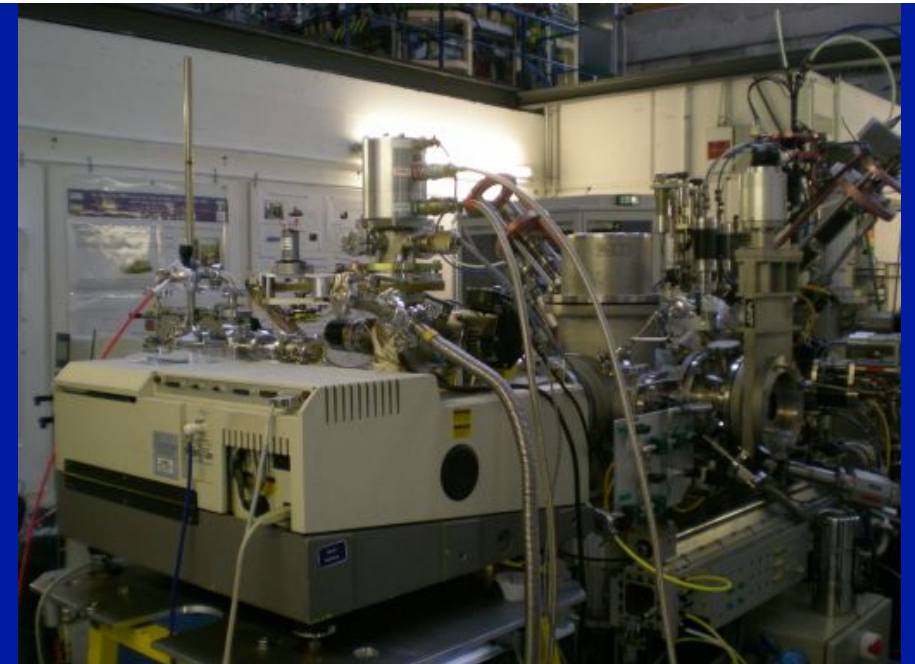

EGRET Gamma ray Galactic map

LPSC Grenoble

Measuring the CR sputtering yield with IR

^{58}Ni^{+11} 46 MeV
Fluences
[x10^{10} ions/cm^2]
— 0
— 0.03
— 0.16
— 1.5
— 14
— 140

OH-db

Peak red-shift
$\Delta\nu = \nu_0 - \nu_{eq}$

Band area variation
$\Delta S = S_p - S_0$
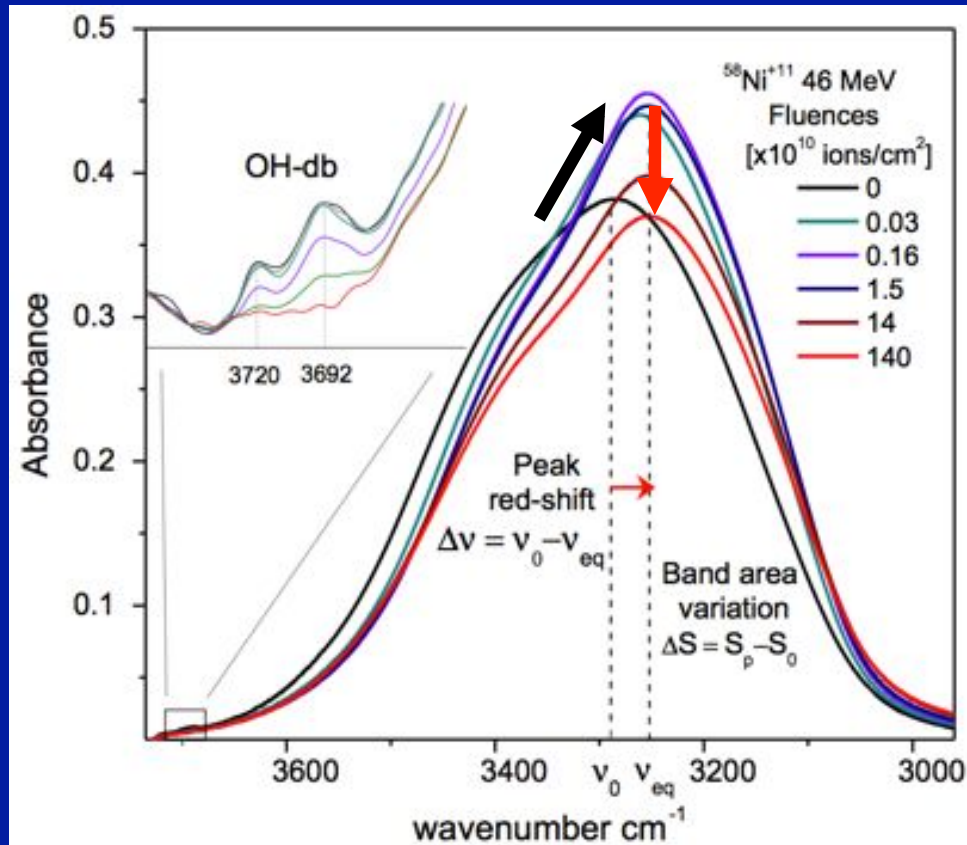
Mejia+2015, Dartois+2015, Rothard+2017

CASIMIR Setup/GANIL

GANIL

$S_0 - S_p$

Ni 46 MeV

E. Dartois – P2IO – October 2018
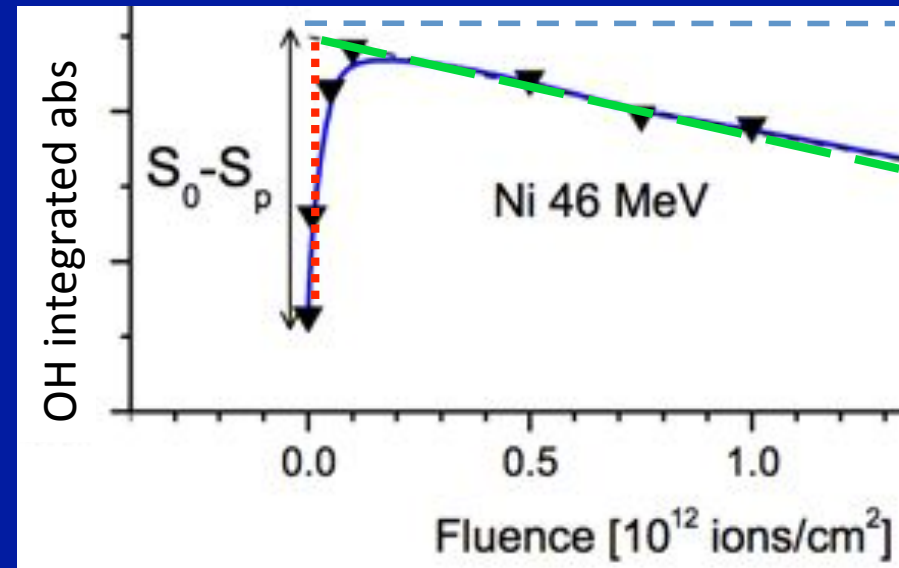
Measuring the sputtering with IR

$^{58}Ni^{11+}$ 0.793 MeV/u 13.6K
Crystalline water ice
7.10^{13} ions/cm^2
ν_2
ν_1
H_2O_2

Cryst. ice → C. Am. ice → Sputtering

Dartois et al. 2015

E. Dartois – P2IO – October 2018
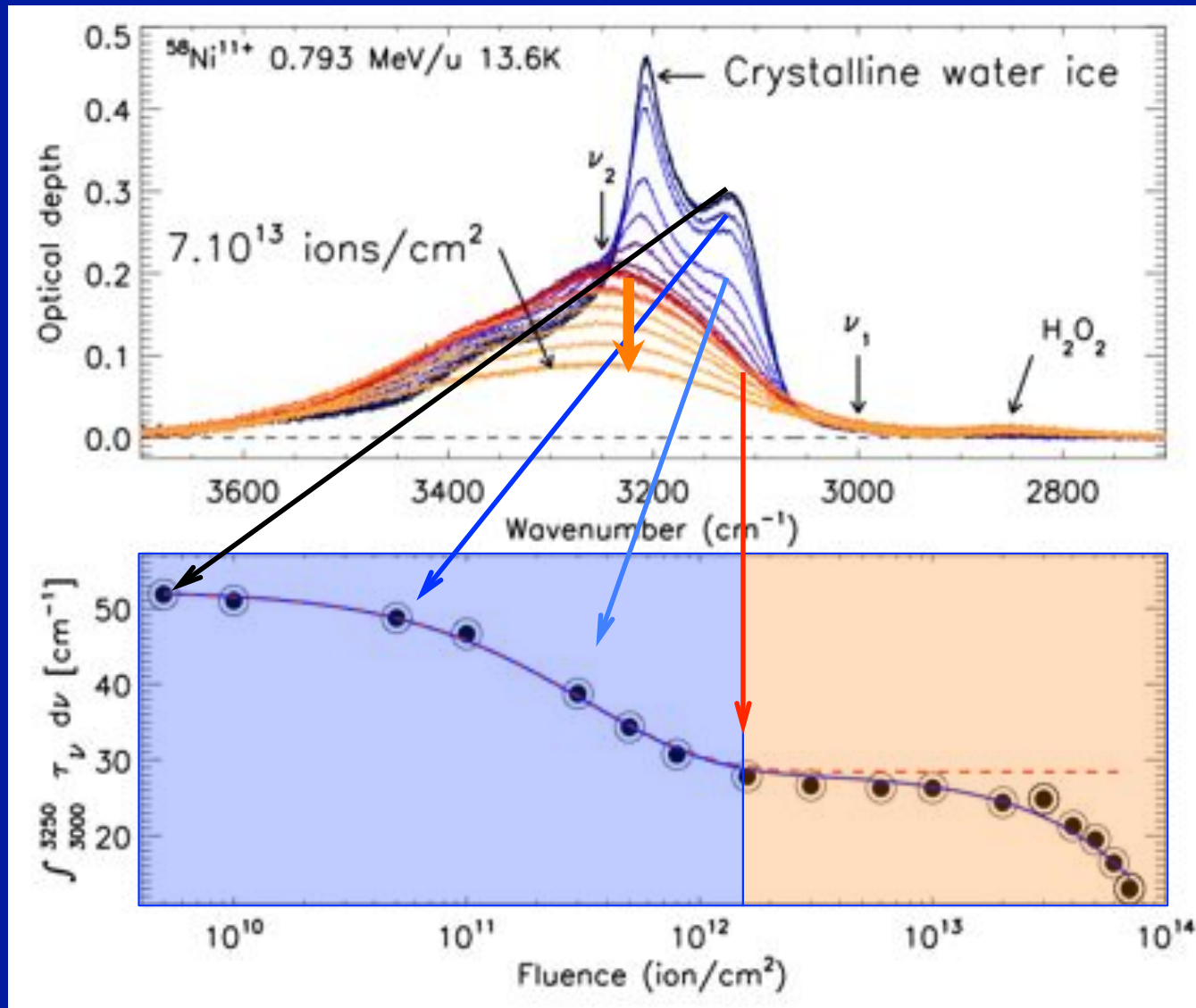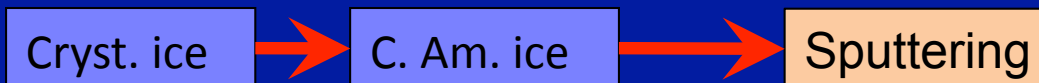
Semi-∞ sputtering yield

Previous measurements

GANIL

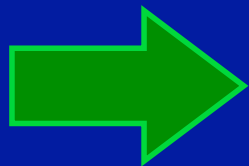$Y^\infty \approx Y_0 S_e^2$
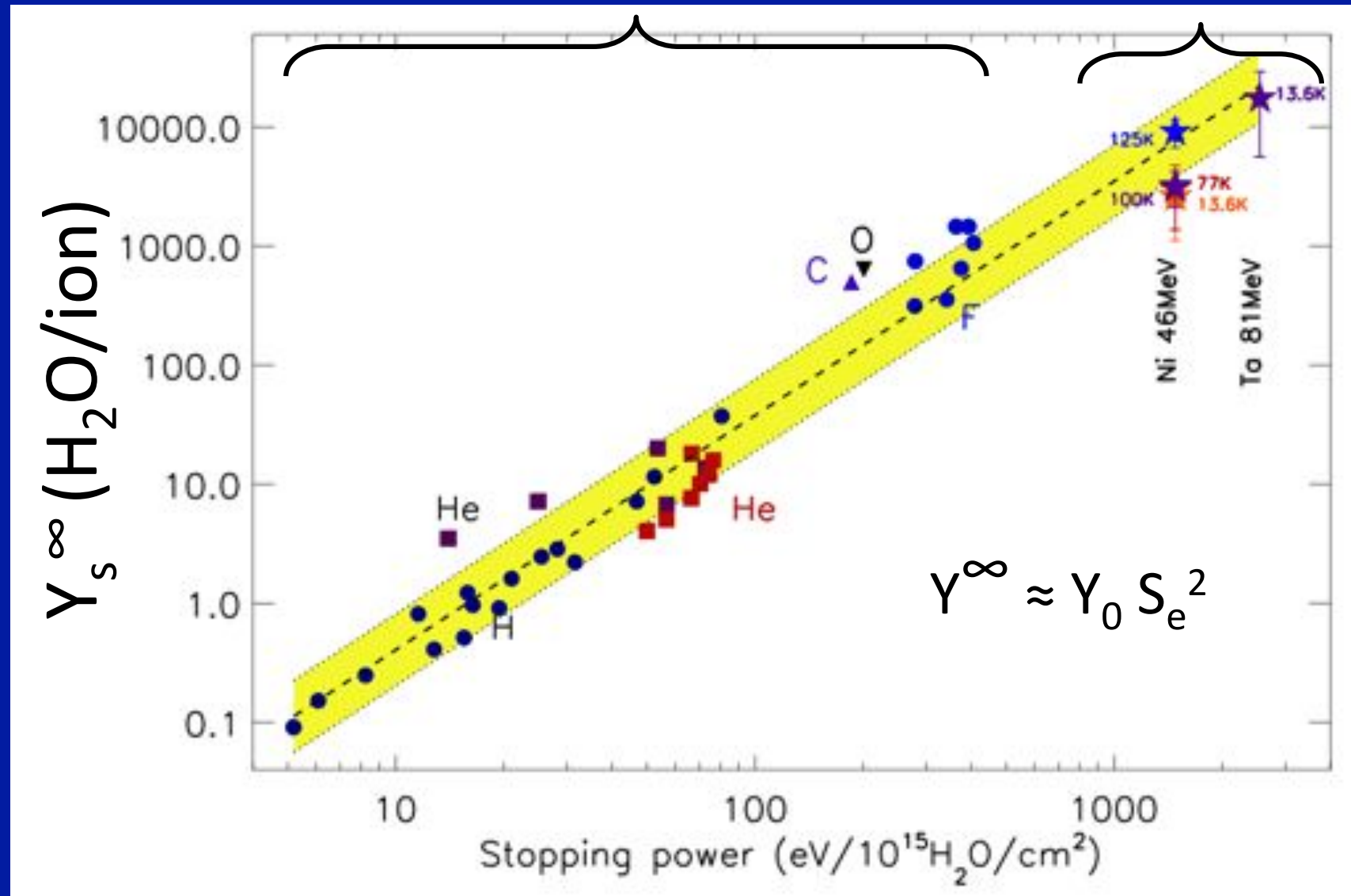
H₂O CR sputtering rate

$$\eta^{\infty}_{CR\ sputtering} \approx 8\ H_2O/cm^2/s \text{ for } \zeta = 10^{-16}s^{-1}$$
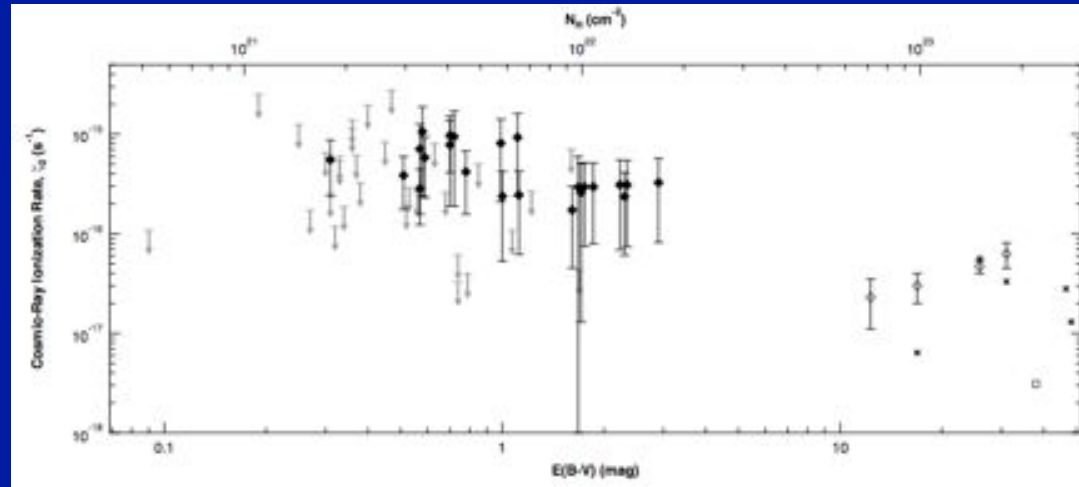
Indriolo+2012
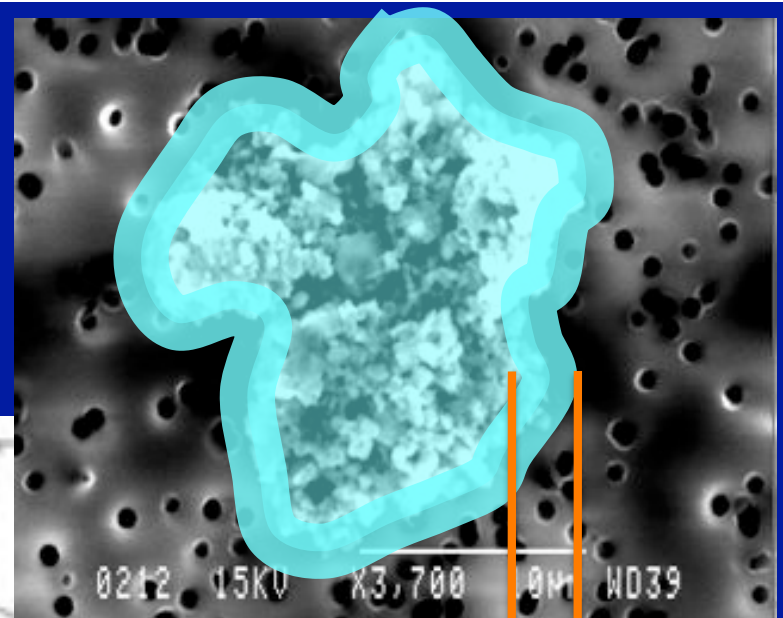
Under implementation in PDR codes
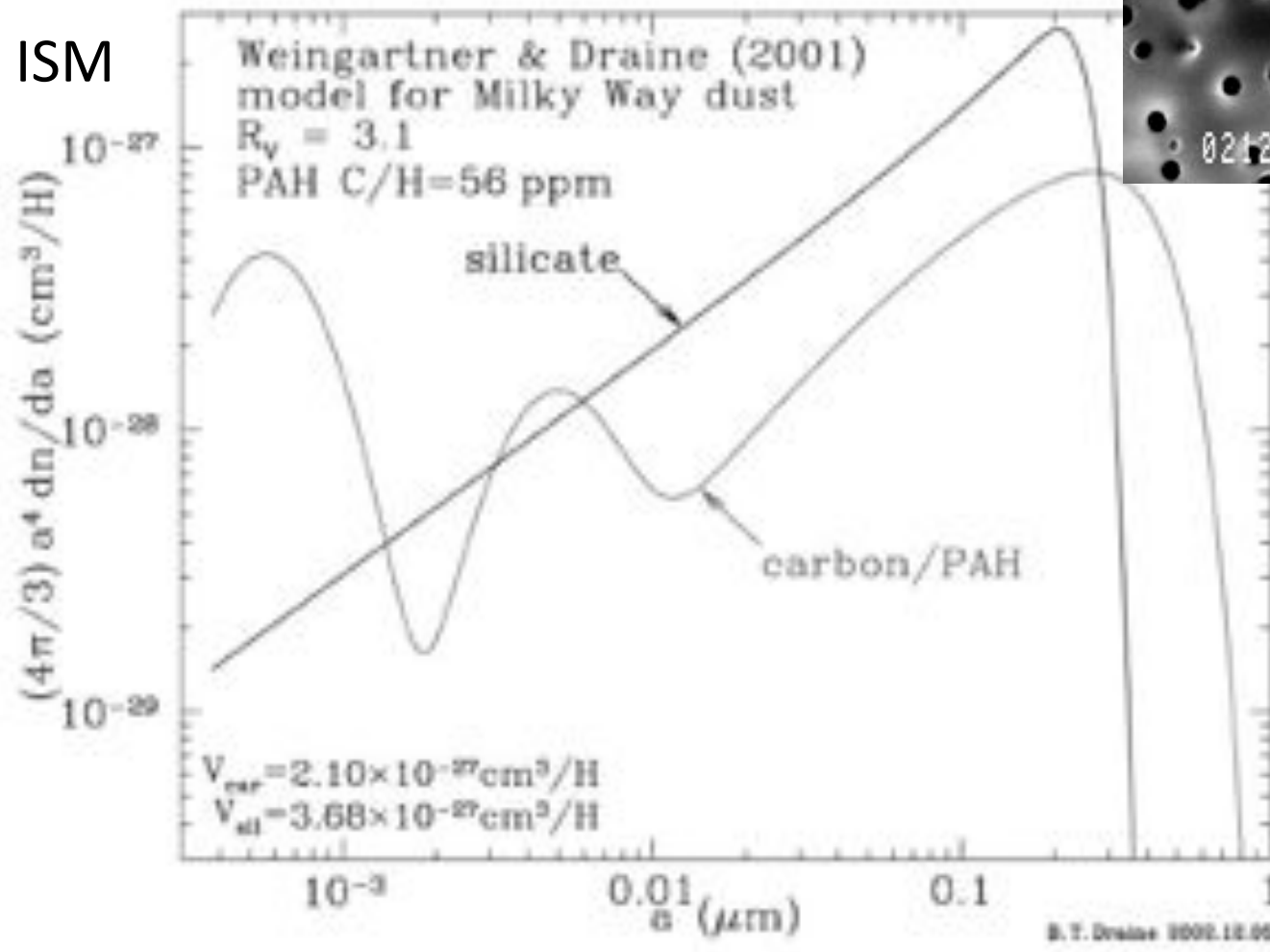
A mechanism to add to VUV photons photodesorption

$(n_{photodesorption} \approx 10\ H_2O/cm^2/s \text{ for } Y \approx 10^{-3})$

Cruz-Diaz+2017

Grain size distribution

ISM

Weingartner & Draine (2001)
model for Milky Way dust
$R_v = 3.1$
PAH C/H=56 ppm

silicate

carbon/PAH

$V_{car} = 2.10 \times 10^{-27} cm^3/H$
$V_{sil} = 3.68 \times 10^{-27} cm^3/H$

$(4\pi/3) a^4 dn/da$ (cm^3/H)

a (μm)

Δx

Ice mantle
thickness
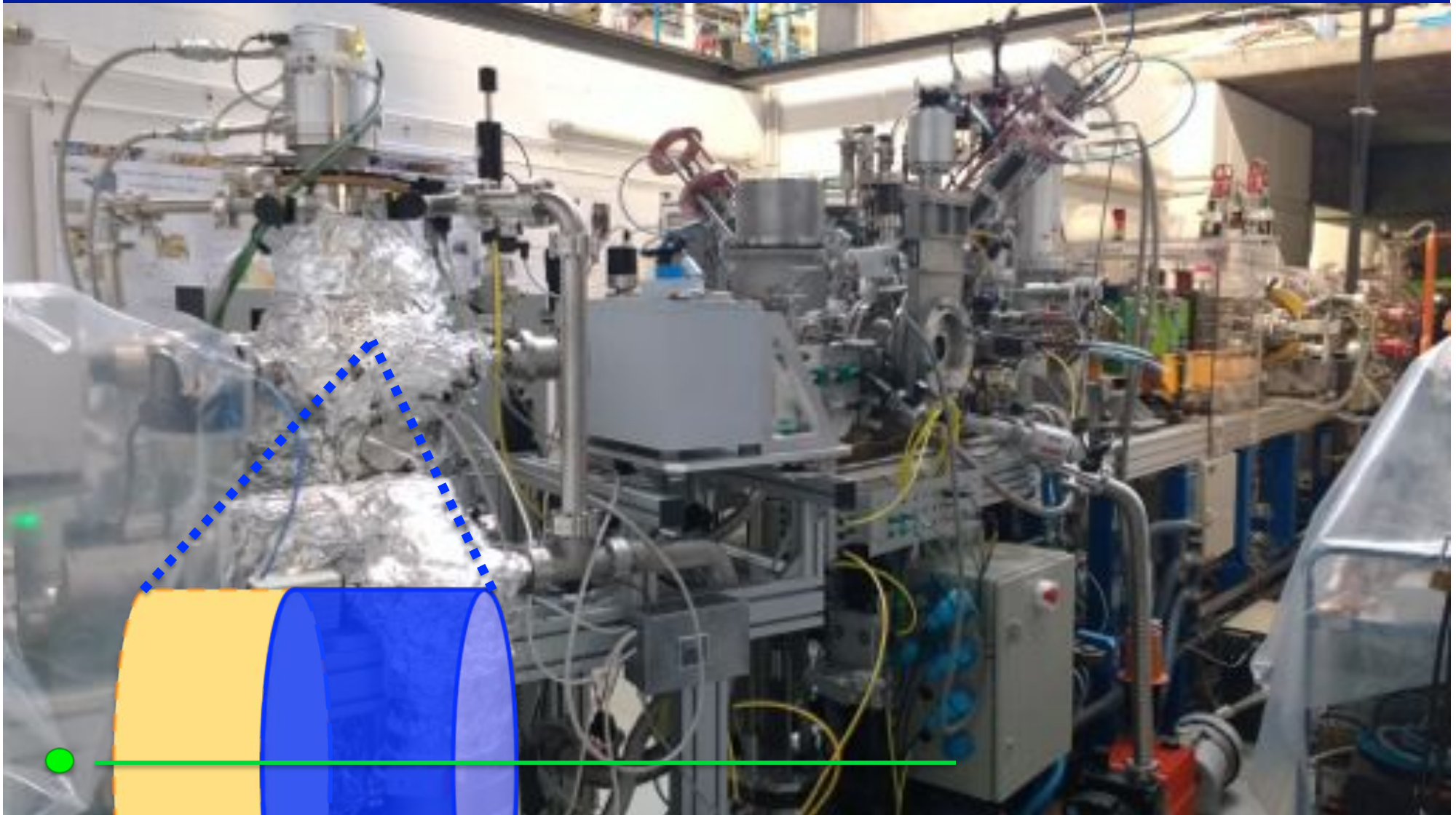
substrate   ice film

Ice infrared spectra evolution upon SHI irradiation

$^{136}Xe^{23+}$
@ 0.7 MeV/u

Dartois+2018, accepted

OH Stretch.
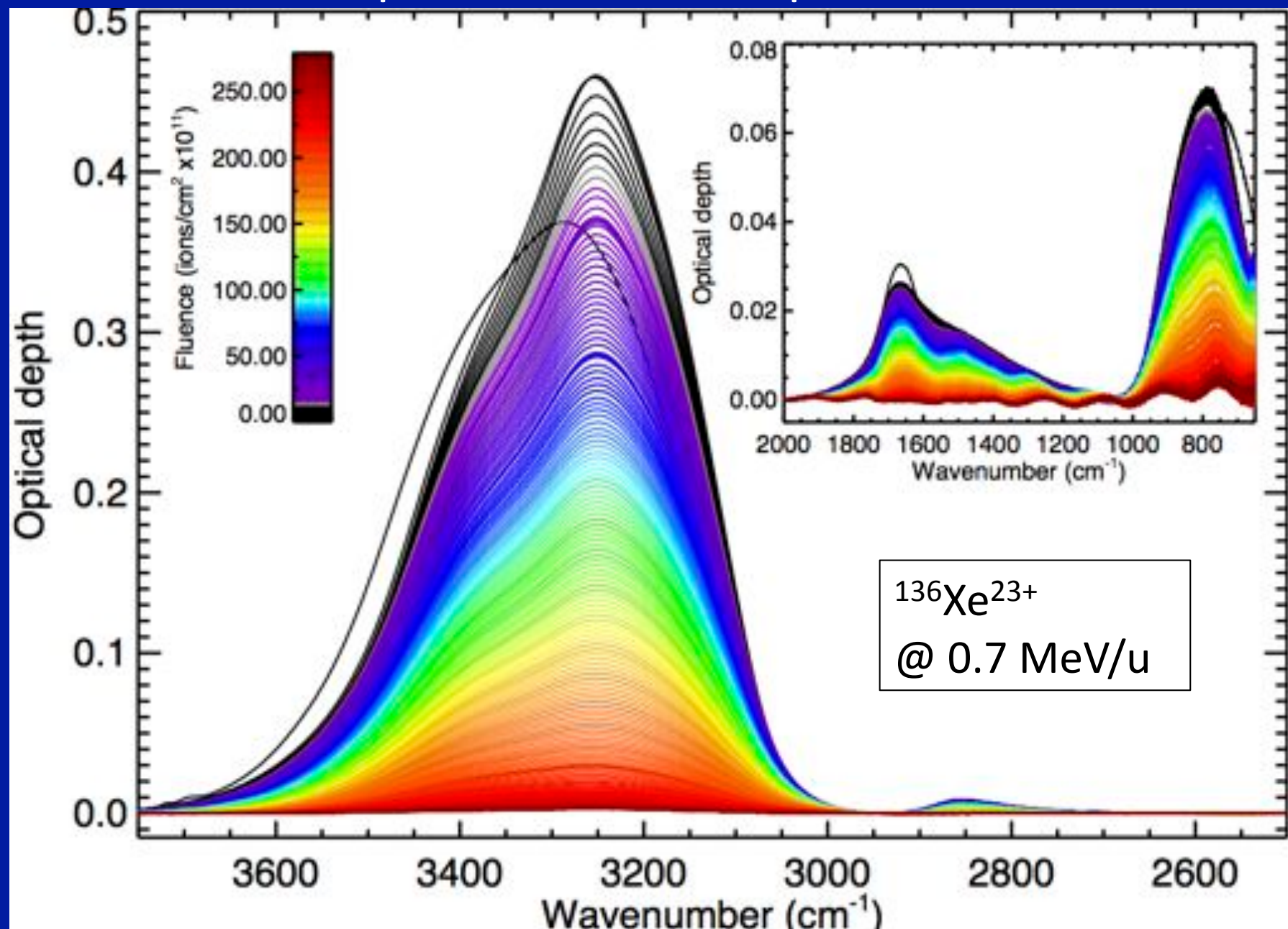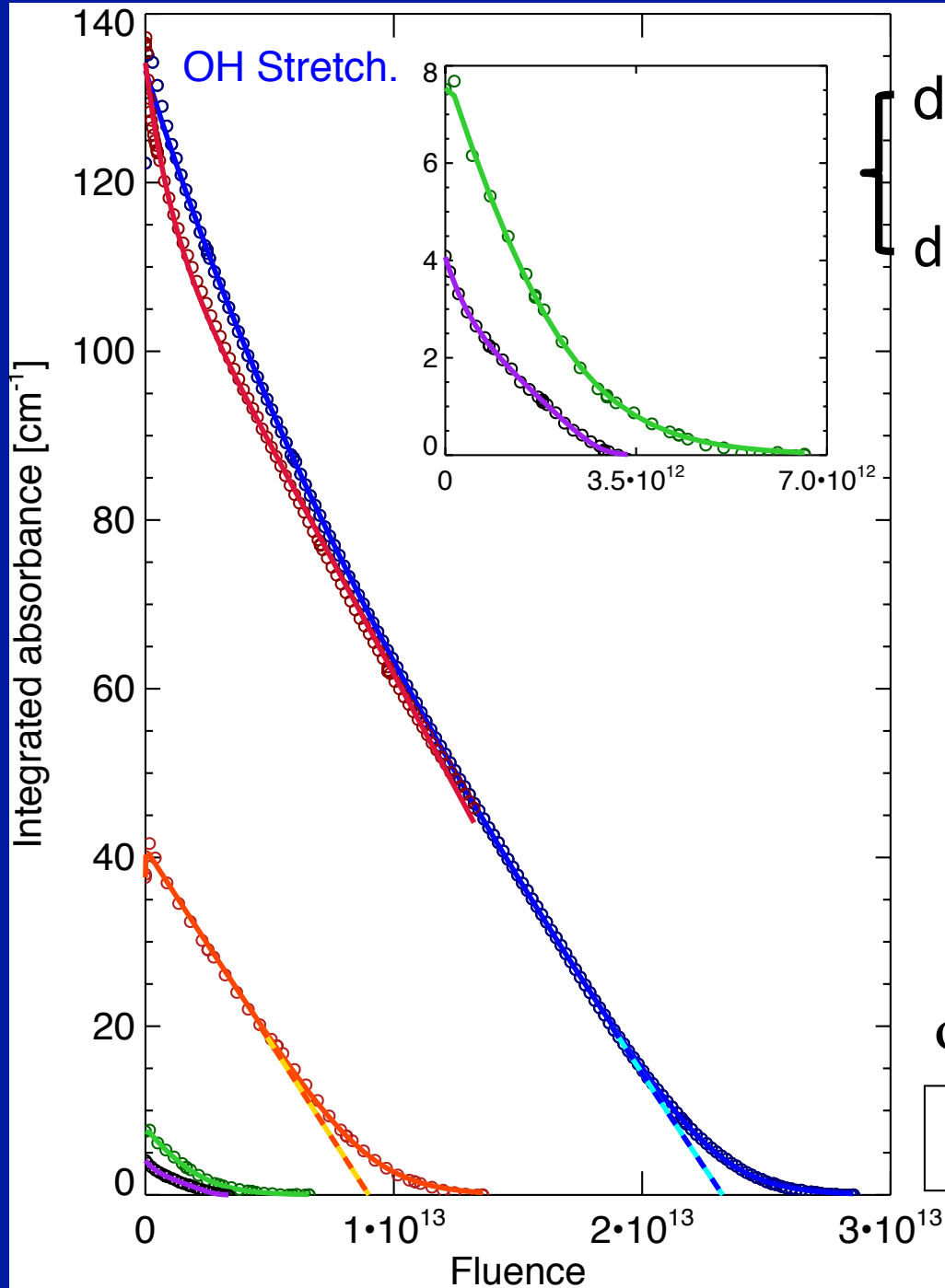
$$dN/dF = -\sigma_d N - Y_S^\infty (1 - e^{(-N/Nd)})$$

$$dWa/dF = -\sigma_c Wa$$
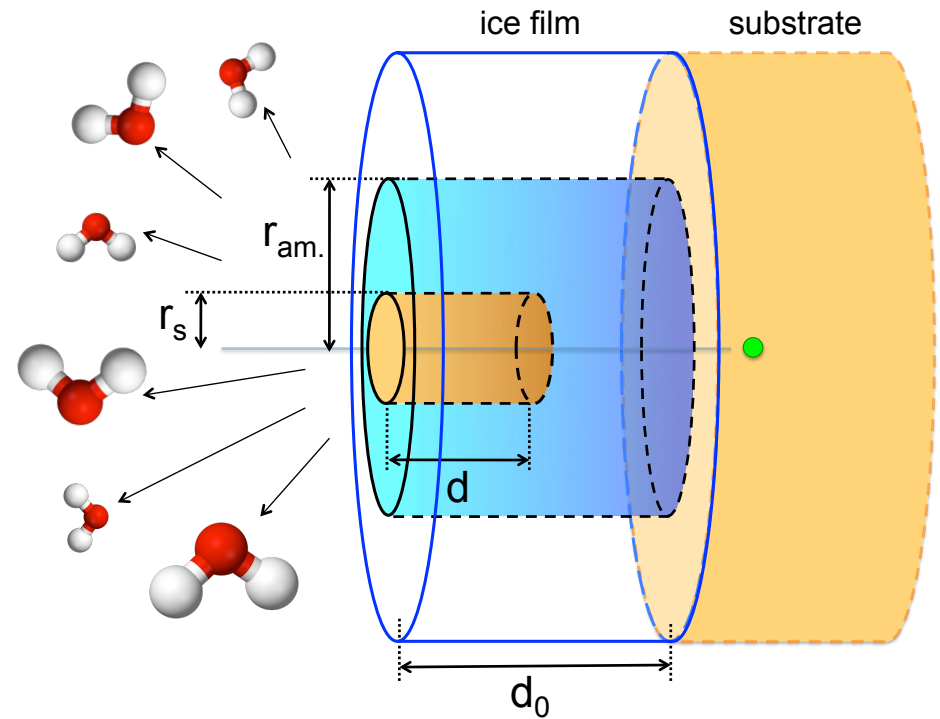
$$\sigma_d N \ll Y_S^\infty$$

$$dN/dF \approx -Y_S^\infty (1 - e^{(-N/Nd)})$$

QMS versus Infrared

Ice compaction
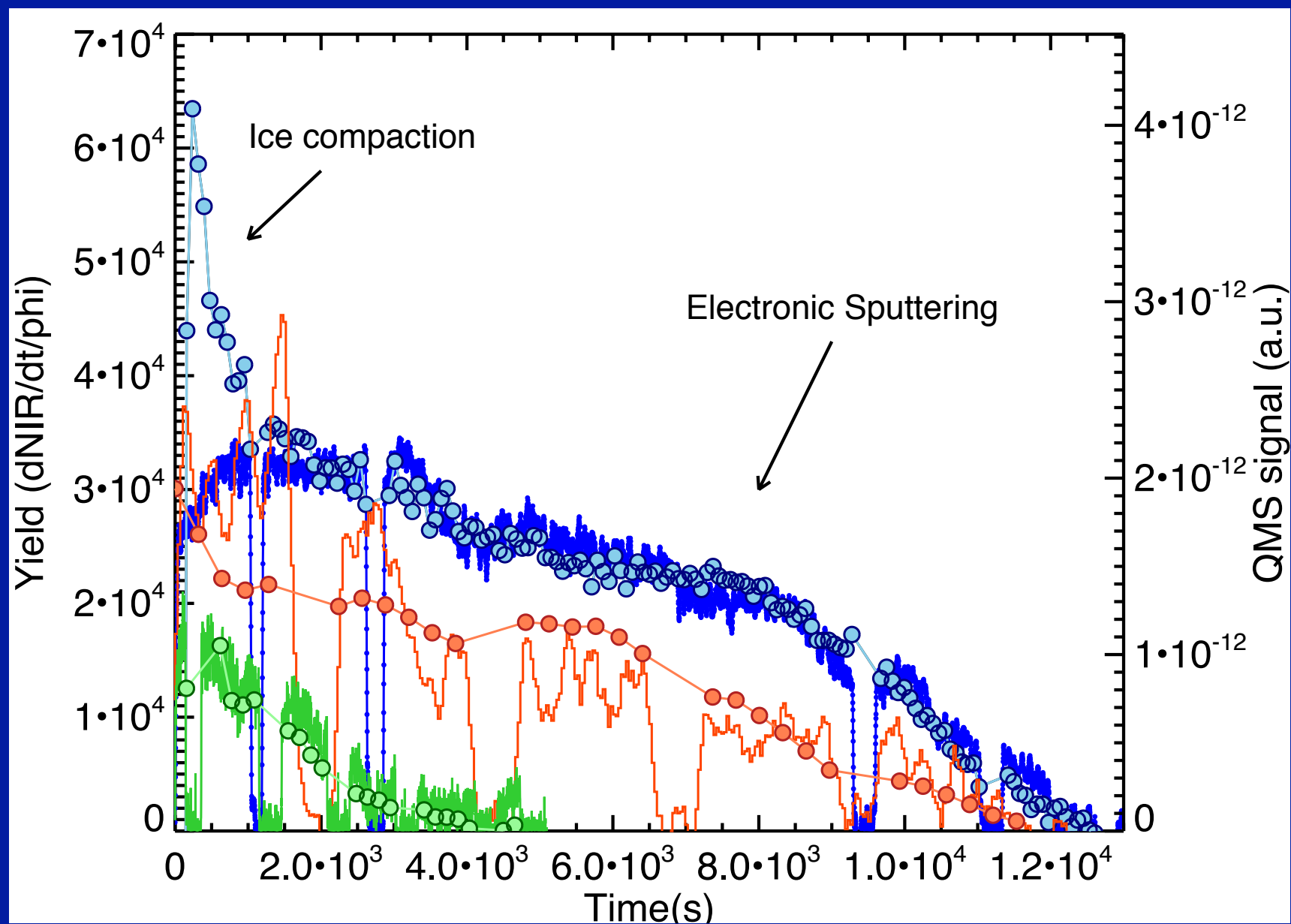
Electronic Sputtering

Yield thickness dependence $\approx -Y_S^\infty (1-e^{(-N/N_d)})$

Y_S^∞

N_D

Yield

2.0·10⁴ → $2.0\cdot10^4$

$1.5\cdot10^4$

$1.0\cdot10^4$

$5.0\cdot10^3$

0

10000

1000

10^{14} 10^{15} 10^{16} 10^{17}

0   $3.0\cdot10^{16}$ $6.0\cdot10^{16}$ $9.0\cdot10^{16}$ $1.2\cdot10^{17}$ $1.5\cdot10^{17}$
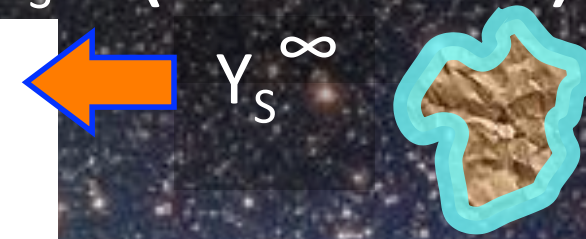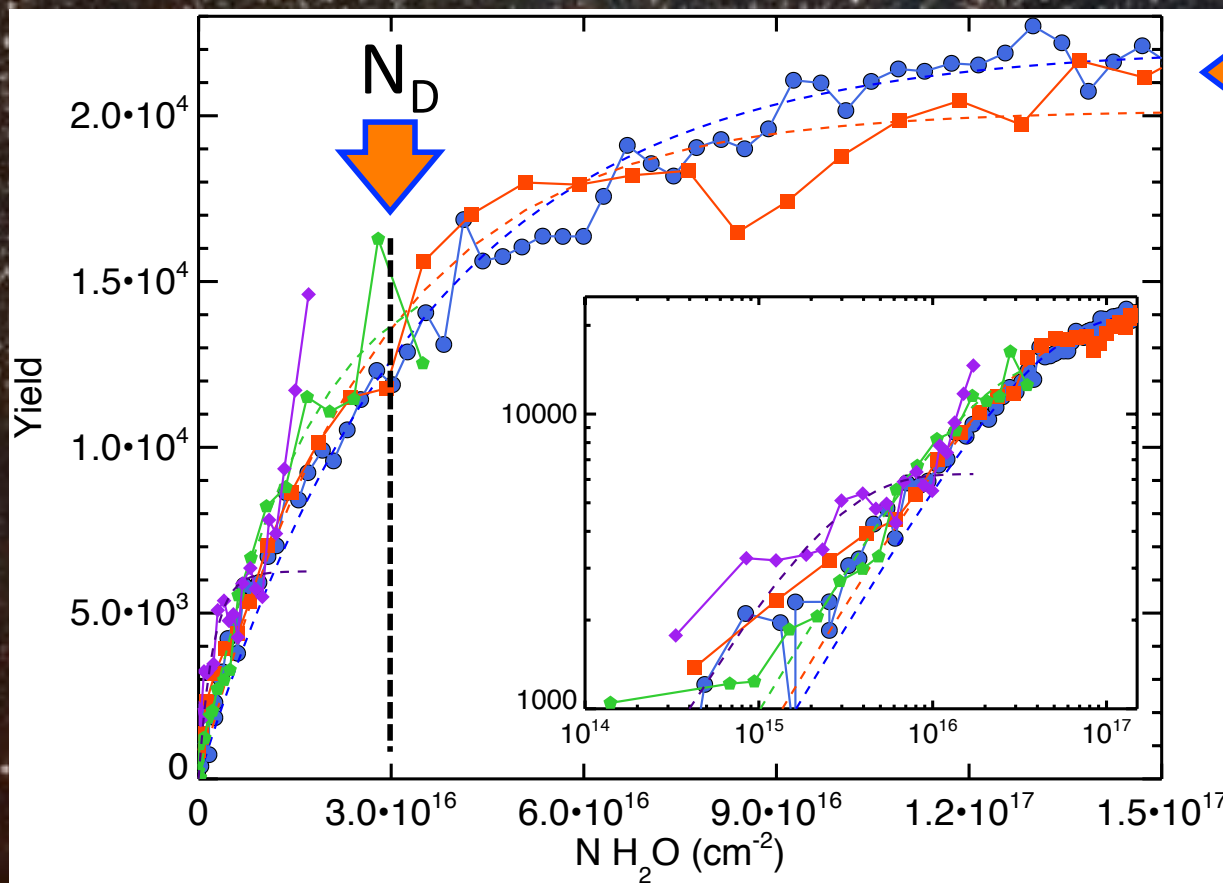
N H$_2$O (cm^{-2})

$Y_S^\infty \sim 2.10^4$ H$_2$O/ion

Nd $\sim 3.10^{16}$ H$_2$O/cm^2 , i.e. about 30 ml
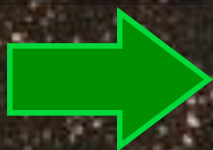
Provides Anchor point

Prescription (A.R.) of dependency with Se for astro

E. Dartois – P2IO – October 2018

Results and perspective

- SHI in CR, desp. low abundance, have a role to play

- Exp. SHI probe Se dependencies at high Se :
  better implementation in astrophysical models
  ice mantles thickness dependence (other ices measured)

- Measured yields : CRs participate to replenishing of dense
  gas phase, SHI e- sputtering ≥ photons

- Explore the effect on *complex organic molecules*:
  build astrophysical model chemistry networks