Introduction

# From the dust cycle in the Galaxy to the importance of ice in space

Dust formation in stars outer shells and supernovae, dispersed into the diffuse ISM.

ISM various environment 🡪 Molecular clouds where grains are shielded from radiation, form seeds for ice to form 🡪 **Ice formation processes**, atomic deposition and water formation, desorption and readsorption (during early stage of stage formation) .

Complex Organic Molecules (COMs) in Molecular clouds (link with molecular diversity in planetary systems, comets - asteroids)

**Chemistry** within the ice 🡪 Different chemical processes (Rachel diagram)

Lab astronomy to mimic those processes 🡪 Amorphous Solid Water review

Challenges with ASW 🡪 **Porosity**, gas adsorption versus small angle neutron scattering

* Ice is very important but complex and still poorly understood

# Interplay between ice observations, models and experiment

## Dust / Ice Observation

### 2.1.a. Dust Emission

Thermal emission in sub-mm, cm domain 🡪 ALMA 🡪 Dust composition and size modify the SED (spectral energy distribution), peak shape, spectral index

SED is main Observational signature to study the different stages and processes within PPD 🡪 Limitations

Polarization function of scattering angle (dust grain properties) 🡪 Grain (ice?) shape/size 🡪 Extinction at certain wavelength

VLT

### 2.1.b. Ice absorption

Spitzer, Hershel, ISO 🡪 Vibrational transitions of molecules (0.6 – 300 µm)🡪 **Chemical compositions**

Absorption from material located between background source and observer (column density 🡪 not good for spatial resolution, particularly in the case of PPDs)

DIBs (Diffuse Interstellar Bands) and (AIBs) Aromatic Interstellar Bands 🡪 Link with experimental investigation, identification

Future 🡪 JWST

## Ice Experiment

### 2.2.a. Amorphous solid water

#### Bulk properties

ASW vapor deposition on a cold surface 🡪 Main focus of previous decades 🡪 IR investigation

Various deposition conditions leads to various ice structure 🡪 Deposition angle, Temperature, surface effect ?

Used as a substrate for chemistry (different molecular composition) and reactivity study.

Backed up with matrix isolation studies to characterize molecular interactions

Glass transition Tg, Desorption Temperature 🡪 TPD

Porosity

#### Surface properties

### 2.2.b. Water polyamorphism

6 different forms of Amorphous Solid water ice : ASW, HGW, LDA I, LDA II, HAD, vHDA

High density forms of particular interests for Icy moons, Europa, Enceladus.

Jenniskens misinterpretation of Interstellar Ice structure 🡪 HAD

#### Stacking disorder ice ?

## Ice Models

Different model for the water molecule (TIP4P …), each one reproducing well some water physical properties, but never all of them. 🡪 Geometry, charge distribution, Lennard Jones potential.

Which one to choose to model water ice ?

Model used to fit experimental Data 🡪 EPSR simulation from Neutron scattering data

## Discussion and challenges

# Planet formation in the context of stellar evolution

Different phases of stars and planet formation (Rachel diagrams) 🡪 Link with observational signatures

## Protoplanetary Disks

### Structure

Very complex, dust and gas.

Different observation techniques tracks different populations of grains

Crystalline Ice, ASW and water vapor detected 🡪 Snow line

### Dust processing

Gas in Keplerian rotation around newly formed star.

Dust and gas coupled for small dust grains 🡪 Grains grow through van der walls interaction

As grain grow start decoupling from gas 🡪 head wind

Relative velocity between different grain size is important for collision experiment.

## Dust aggregation : As found from laboratory experiments

Different dust grain population (carbonaceous, silicate, crystalline and amorphous ice) require various experiment to study collision behavior 🡪 Sticking, Bouncing, fragmentation

Collision between grains of similar sizes require very low velocity 🡪 Parabolic and sub-orbital flight, drop tower experiment.

Collision Physical parameters.

## Rocky Dust collisions

## Ice collision experiments

Crystalline ice but no ASW

Importance of surface properties 🡪 Diffuse surface interface

## Challenges in Planet formation

Bouncing barrier

# Challenges in laboratory experiments

## Water polyamorphism

# Discussion and evaluation