



# Formation Routes of Interstellar Molecules through Surface Reactions at Low Temperatures

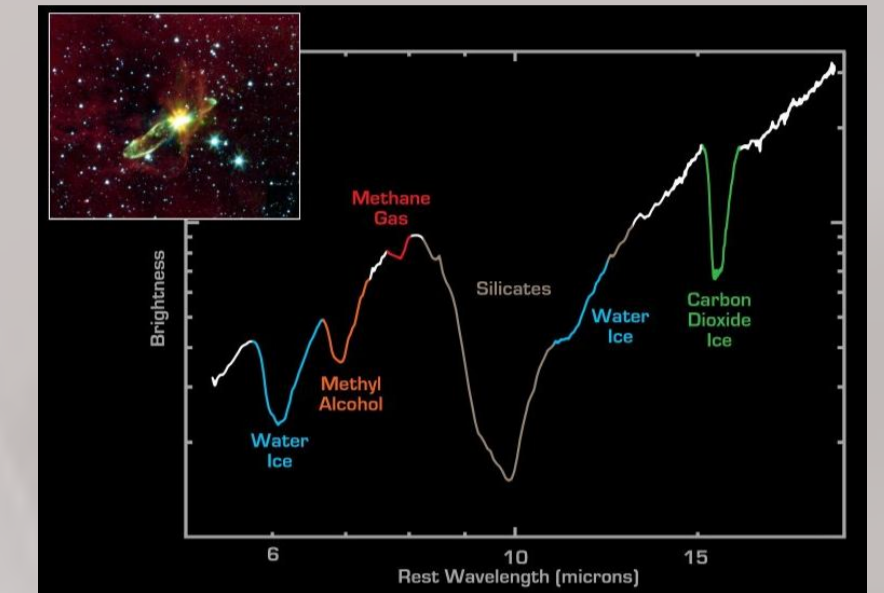


Gleb Fedoseev, Sergio Ioppolo, Harold Linnartz

Sackler Laboratory for Astrophysics, Leiden Observatory, University of Leiden, 2300 RA Leiden, NL

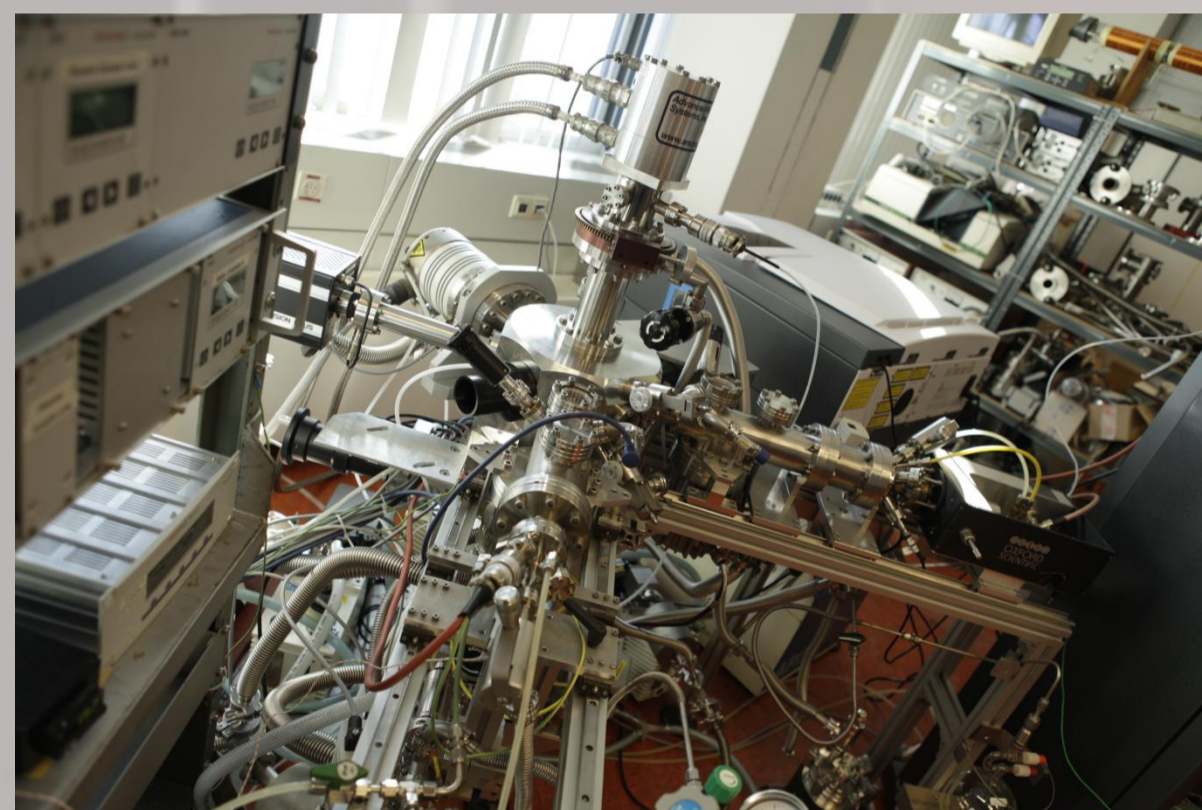
## Introduction

Although the interstellar medium (ISM) is a very dilute environment more than 150 different molecules have already been detected. Nowadays it is generally accepted that **solid state reactions** on **icy grains** play a significant role in the formation of several of the astronomically relevant molecules like H<sub>2</sub>O, CO<sub>2</sub>, HNC, H<sub>2</sub>CO, CH<sub>3</sub>OH and HCOOH. Due to progress in ultra-high vacuum (UHV) and cryogenic techniques solid state reaction pathways proposed in the past can now be experimentally investigated. **Systematic verification** of solid state reaction networks is highly required to explain observed abundances in ISM.



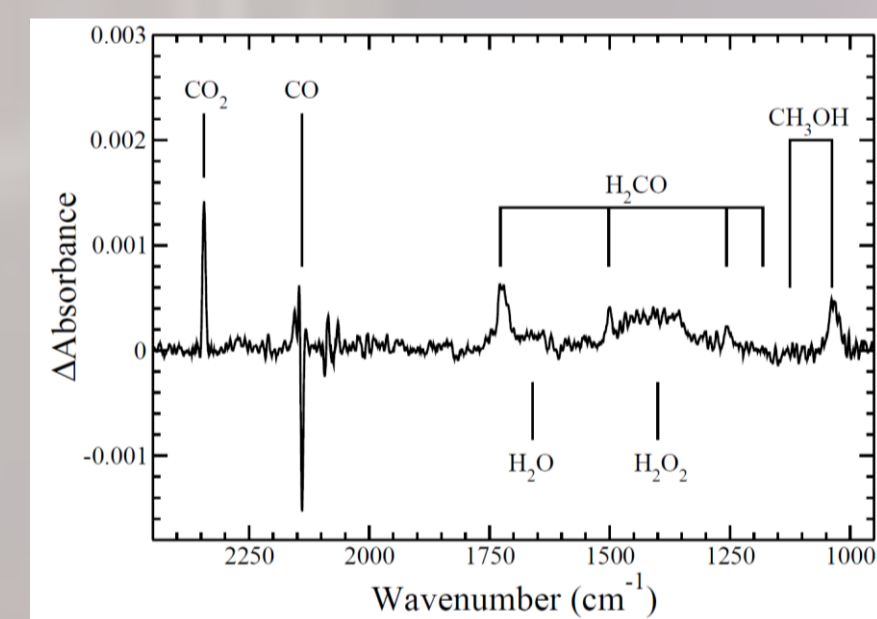
## Analysis and Methode

SURFRESIDE II UHV setup



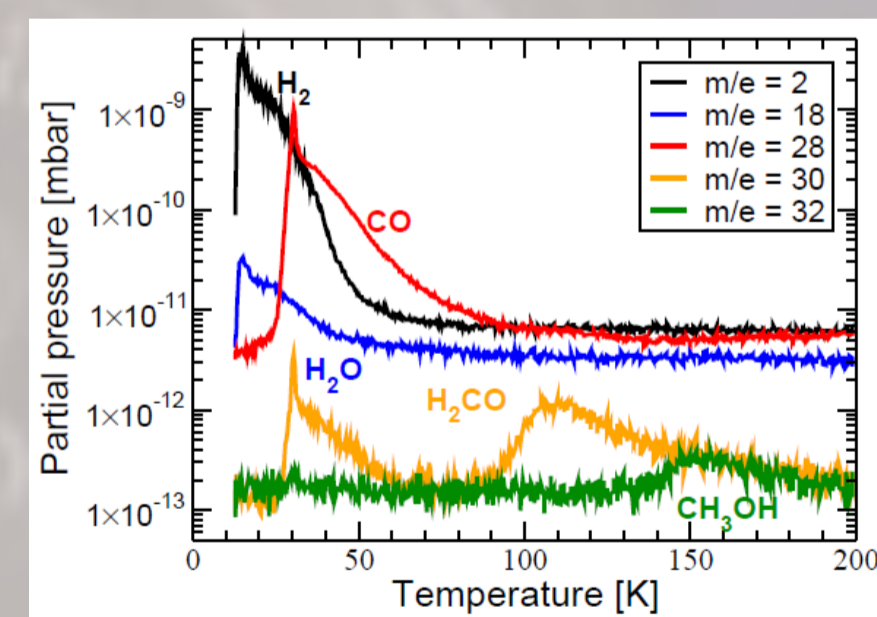
**Pressure:** ~ 10<sup>-10</sup> mbar  
**Temperature:** 12-300 K  
**Ice thicknesses:** 10-100 ML  
**H - fluxes:** 10<sup>12</sup> – 10<sup>14</sup> cm<sup>-2</sup>s<sup>-1</sup>  
**O-, N-, OH- fluxes:** > 10<sup>12</sup> cm<sup>-2</sup>s<sup>-1</sup>

SURFRESIDE II possessing two complementary analytic tools



### RAIRs

- in situ analysis
- does not damage the ice
- provides kinetic information
- low sensitivity



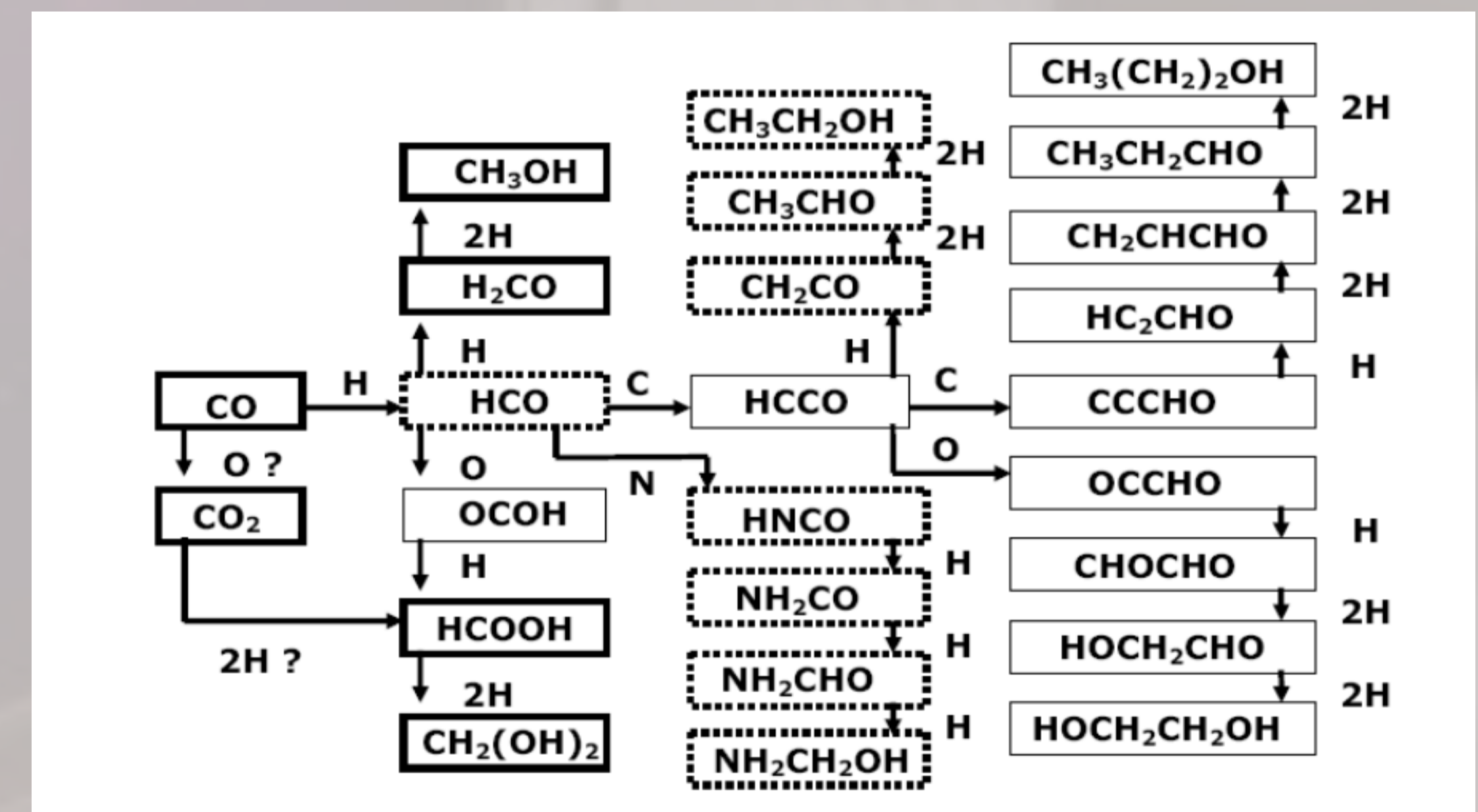
### QMS

- in situ gas phase composition analysis
- damages the ice
- high sensitivity

**Different experimental conditions**, i.e. temperature, ice thicknesses, co-deposition rates, and the use of a double atom beam line, provide information on both final and intermediate surface reaction products, unveiling **complex reaction networks** and **reaction branching ratios**.

## Goals

The focus is on the experimental investigation of H- O- N- **atom addition reactions** at low temperatures:



Charnley et al., A&A (2001)

The **Goal** is the qualitative and quantitative characterization of reaction pathways towards molecular complexity in space. The use of Monte Carlo simulations combined to experiments expands laboratory data to astronomical scales.



e-mail: fedoseev@strw.leidenuniv.nl