# The role of absorption and scattering in the changing shape of ice bands across protoplanetary disks

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Ices form in the cold regions of protoplanetary disks and are involved in many processes leading to planetary formation. They can facilitate the formation of complex organic molecules and are the reservoir of volatile species, playing a key role in the chemical evolution from the molecular cloud to the protoplanets. In particular, water ice plays a crucial role in the growth of grains and in planetary formation, however, its spatial distribution in protoplanetary disks is yet poorly constrained. The James Webb Space Telescope now enables the spectral study of ices with unprecedented sensitivity and angular resolution.

In preparation for future spectra observations by JWST, we studied the dependency of water-ice absorption bands of disk inclination and disk location from which spectra are extracted. Based on a standard protoplanetary disk model composed of a spatially homogeneous dust and amorphous water ice mixture around a T Tauri star, we used the radiative transfer code MCFOST to extract water-ice spectra and to characterize their properties in terms of depth, shape and central wavelength at different locations in the disk. These properties of ice bands in disks are generally used to constrain the properties of ices.

We found that the observed properties of water-ice bands depend on two parameters independently of the type of ice or the grain size distribution: inclination of the system as well as location within the disk. In particular, even with only amorphous water ice, the wavelength minimum of the bands can change by up to 0.17 $\mu$m, comparable to the difference expected between amorphous and crystalline ices assumed in previous studies. This phenomenon stems from a balance between absorption and scattering linked to a shift between absorption and scattering opacities curve and must be taken into account in detailed modeling of spatially resolved infrared spectroscopy of ices. We also predict the same phenomenon for CO and $CO_2$ based on the shift of their opacities curves.

## Acknowledgments

This project has received funding from the European Research Council (ERC) under the European Union's Horizon Europe research and innovation program (grant agreement No. 101053020, project Dust2Planets, PI: F. Ménard).