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Formation and composition of the Galilean Moons

C. Serpollier (1), U. Marboeuf (1), Y. Alibert (1,2), M. Ogihara (3), S. Ida (4), and P. Wurz (1);
(1) Physikalisches Institut, Universität Bern, 3012, Bern, Switzerland (clea.serpollier@space.unibe.ch)
(2) Observatoire de Besançon, 41 avenue de l'Observatoire, 25000, Besançon, France
(3) Observatoire de la Côte d'Azur Boulevard de l'Observatoire, 06304 Nice Cedex 4, France
(4) Department of Earth and Planetary Sciences, Tokyo Institut of Technology, Ookayama, Menguro-ku, Tokyo 152-8551, Japan

Abstract

During the formation of the Jupiter Galilean moons in a gas circumplanetary disk, satellitesimals undergo several physico-chemical processes. The present work combines models of satellite formation [6] and cometary nucleus [4] to study their physico-chemical evolution in the disk.

1. Introduction

The first large-class mission in ESA's Cosmic Vision 2015-2025 programme JUICE (JUpiter ICy moons Explorer) is planned for 3.5 years exploration of the Jovian system. The spacecraft will have a special focus on Europa, Ganymede and Callisto. Among its many tasks, it will characterise their surfaces composition and chemistry [2]. For instance, among the scientific instruments on the JUICE mission is the Particle Environment Package (PEP) with a neutral gas mass spectrometer for the in situ measurement of the exospheres of the moons. From the chemical composition of the exosphere the surface composition will be derived [2]. To better understand the relation between the galilean moons formation and their actual composition we combine models of moon's formation [6] and cometary nuclei [4] which allow us to study the physico-chemical evolution of satellitesimals before their incorporation in moons. We establish a complete model of moon formation and therefore a relation between the galilean moons formation processes and their composition.

2. Method

We use two models: the first one, that provides the thermodynamic conditions of moons formation, is a N-body simulation giving birth to moons around giant planets in a gas-starved circumplanetary disk, fed by a flow of gas and solid coming from the circumstellar disk [6]. The second one allows us to study the physico-chemical evolution of satellitesimals during the process of moons formation. It describes the composition's evolution of a 1D cometary nucleus composed of all water ice structure (amorphous, crystalline, clathrate hydrates or a mixture of the three ones), several volatile molecules and dust grains [4].

2.1 Disk model

The Galilean Moons are believed to have been formed during the end-stage formation of Jupiter, in a gas starved disk [1], in a scale time of about 10^6 years. During Jupiter formation, a gap is formed in the circumstellar disk at the orbit of the planet, but there is still an incoming flow of materials falling onto the planet (see Fig.4 in [3]). They computed the N-body evolution on satellitesimals accreted in the circumjovian disk, and showed that they could reproduce some of the characteristics of galilean moons, in particuar their orbital configuration. Ogihara and Ida 2012 [6] modelised a circumjovian disk fed by a flux coming from the circumstellar disk, of gas and solid in the region of 30 R_J around the forming planet.

2.2 Satellitesimal nucleus model

Considering that planetesimals (that will be named satellitesimal once in the circumplanetary disk) are formed from ices in cold area in the solar nebula and should have conserved its chemical composition [5], we modelized spherical bodies composed of water ice, volatiles molecules (H_2O, CO_2 and CO) in both solid and gas phase, and dust grains [4, 5]. The model computes the composition of the bodies evolving with time in the solar planetary disk, taking into account the following processes: heat and gas diffusion, changes of phase of volatile species (sublimation/condensation, trapping/release), latent heat exchanges, gas and dust release, and dust mantle formation at the surface of the nuclei.

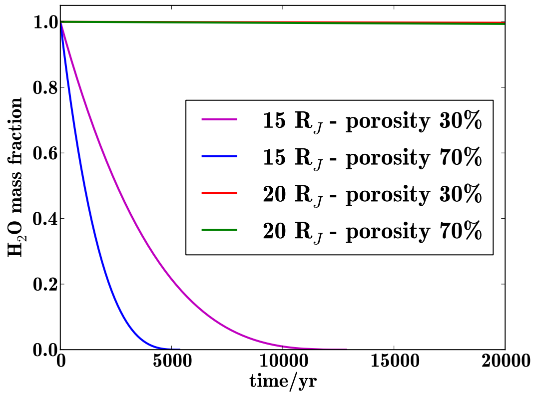

Figure 1: H_2O mass fraction evolution with time at 15 and 20 R_J for a 30% and 70% porous bodies, of a radius of 100 km. In those simulations, the planetesimals do not form a mantle at their surfaces. At 20 R_J, the green curve (70% porous body) is slightly below the red one (30% porous body).

3. Results

We study different chemical compositions of satellitesimals based on the composition of planetesimals in the solar nebula in the actual location of Jupiter at 5.2 AU, computed by Marboeuf et. al 2014 and Thiabaud et. al 2014 [5, 7]. We find that planetesimals undergo large physico-chemical processes near Jupiter inside 15 R_J of the central planet, where the temperature is between 190 and 220 K. Satellitesimals of 100 km in radius fully disappear in less than 13000 years when they are made only of H_2O ices and dust, without a mantle formation and with a porosity of 30%. With a higher porosity of 70%, they are sublimated more rapidly in less than 5500 years. Farther, around 20 R_J, planetesimals are not so much affected (with and without the formation of a mantle) because of a lower temperature between 110 and 160 K of the gas disk. The sharp decrease of the water mass fraction at 15 R_J is shown on Fig.1. At 20 R_J this diminution is very low, and the H_2O mass fraction stays close to 1 for both porosities. The more porous the bodies are the more rapidly they loose water. We currently compute the physico-chemical evolution of satellitesimals made of dust, H_2O, CO and CO_2 ices.

Acknowledgements

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