PECAS: A NEW SIMULATION CHAMBER FOR STUDYING PLANETARY ENVIRONMENTS.

CENTRO DE ASTROBIOLOGÍA
INTA- CSIC

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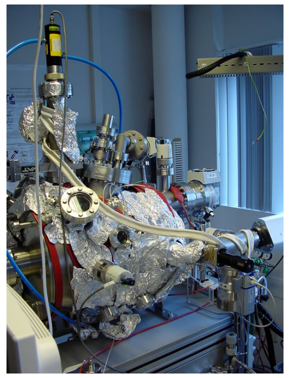
We present a versatile planetary simulation chamber able to reproduce atmosphere and sample temperature for most of the planetary objects. It has been especially developed to make feasible in-situ irradiation and characterization of the sample

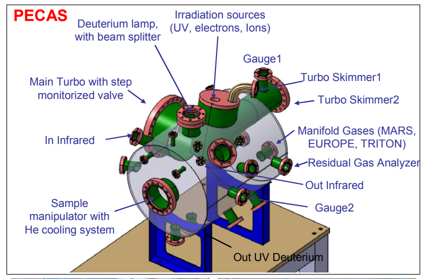
We have built a **versatile planetary simulation chamber** able to computer-control gas composition in the atmosphere and sample temperature for most of the solar system planetary objects. Our equipment has been especially developed to make feasible *in-situ* irradiation and characterization of the sample. Therefore, it allows for studying **chemical changes in a given sample upon gas environment, temperature and radiation dose**. For this purpose we include irradiation sources as UV-photons, ions and electrons, and the implementation of analytical techniques as Infrared and Ultra-Violet spectroccopies.

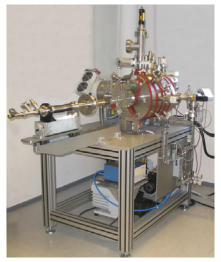
Summary of the technical specifications

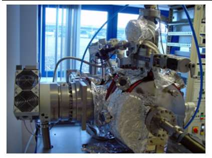
- **Total pressure ranges from 5 mbar to 5x10-9 mbar. Partial pressure of the gasses can be set with this precision.**
- **Temperature ranges from 4K to 325K. It can be computer programmed.**
- **Gas composition is regulated via a residual gas analyzer with ca ppm precision**
- **Sample size ranges from 5 to 35mm wide and 1 to 6mm height**
- **Available irradiation sources: up to 5 KV-ions (ions) 5 KV-electrons, Deuterium UV lamp and noble-gas discharge UV**
- **Analysis in-situ techniques: UV spectroscopy, infrared spectroscopy (future)**

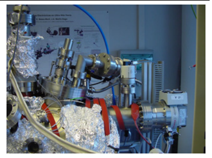
The system we have built consists of an ultra-high vacuum (UHV) chamber 500 mm long by 400 mm diameter with standard CF flanges and fittings. Several flanges have been left available for future developments. The desired gases are mixed in a manifold to the required proportion, controlled each by individual fluxmeters. Gas composition is constantly monitorized by a residual gas analyzer spectrometer, which fixes the desired partial pressure of a particular gas by acting on its corresponding fluxmeter. Temperature at the sample is regulated by a Helium cooling system connected to the sample holder. Irradiation by different sources can be performed at Mars pressures (mbar range) by means of a performance differential pumping stage, which assure the correct working conditions at the irradiation source. A water partial pressure can be also set and regulated. Samples are mounted horizontally in order to allow the study of low cohesive material. Crystals, soils, rocks and minerals are among the possible samples that can be introduced.

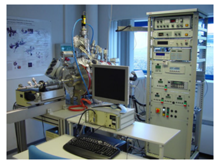


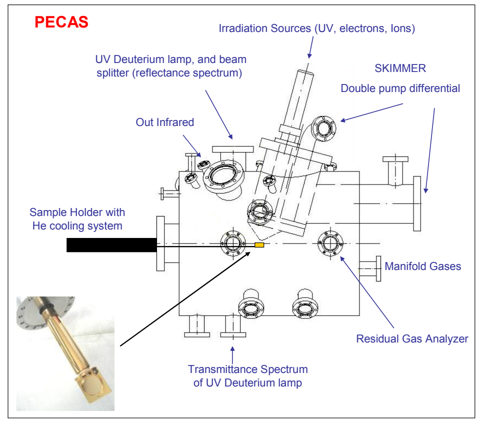








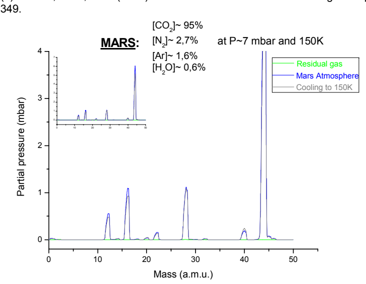




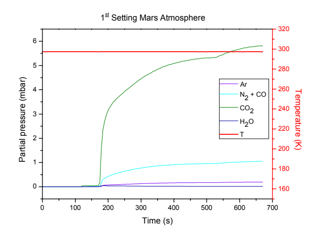
MARS

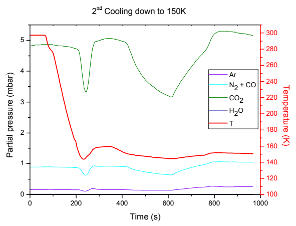
The exploration of Mars, starting in the 70's, has revealed some of the atmospheric and surface properties of this planet (1, 2), for instance their major constituents and the UV radiation environment (3), which are important constraints to life.

(1) Owen, T. C. (1992). The composition and early history of the atmosphere of Mars. In: Mars. Kieffer, H. H. et al. (Eds.),818-835. University of Arizona Press.
(2) Zurek, R. W. et al. (1992). Dynamics of the atmosphere of Mars. In: Mars. Kieffer, H. H. et al. (Eds.),835-934. University of Arizona Press.
(3) Cockell, C. S., et al. (2000). The UV environment of Mars: Biological implications. Past, present and future. Icarus 146, 343-349.



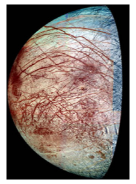
7 mbars are used as the average atmospheric pressure of the planet, temperature cycles can be programmed from 150 to 280K. To reach these values we set first the partial pressures of the gasses in order to have 95%CO_2, 2,7% N_2, 1.6% Ar and 0.6% H_2O with a total pressure of 7 mbars. This process takes around 5 minutes. Once the gases are stabilized we cool down to 150K. We get stable temperature after 15 minutes.





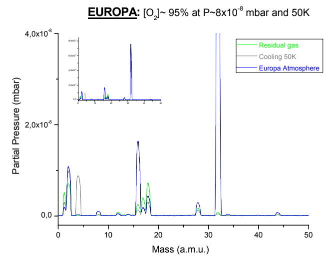
Attenuation of electronic and ionic irradiation depends on the electron and ion free-mean path, which is a function of the total gas pressure of the atmosphere and the energy of the incident particle. Minimum irradiation has been found for particle energies of about 100-200 eV. In the case of Mars, the presence of atmospheric gases absorbs the incoming radiation and very little electrons and ions are arriving to the surface in the experimentally available range of energies. This scenario is different when we talk about UV radiation. In this case the attenuation strongly depends on the atmosphere composition, the radiation wavelength and total pressure. We have *in-situ* recorded absorption curves both for Deuterium radiation in the range of 200-400 nm, and strong monochromatic HeI radiation at 58 nm.

EUROPA



The satellite of Jupiter, Europa, is an interesting planetary object from both geological and astrobiological points of view. Its most attractive characteristic is the possible presence of a harbour ocean at its interior. Voyager and Galileo missions have obtained some data about the physics, chemistry, and geology of this satellite, including the temperature distribution (4) and the radiation environment at surface (5). Besides, observations from earth has determined the existence of an atmosphere (6).

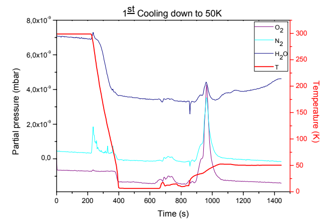
(4) Spencer, J. R., et al. (1999). Temperatures on Europa from PPR: Night time thermal anomalies. Science 284, 1514-1516.
(5) Cooper, J. F., et al. (2001).Energetic Ion and Electron Irradiation of the Icy Galilean Satellites *Icarus, Volume 149, Issue 1, 133-159.*
(6) Hall, D. T., et al. (1995). Detection of an oxygen atmosphere on Jupiter's moon, Europa. Nature 373, 677-679.

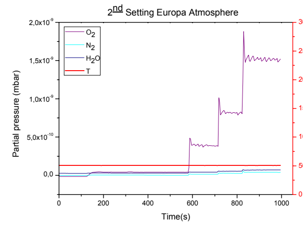


For studies on the surface of the satellite Europa,the base pressure of the chamber should be reduced as much as possible. For this, the chamber should be baked-out. The residual pressure is on the low 10^{-9} mbar range. The experimental protocol consist of:

1. cooling the sample at 50K. To get this temperature stable on the sample takes about 20 minutes. Once the temperature is stable we can dose the to the desired pressure.
2. Oxygen is dosed until measuring in the mass spectrometer the required pressure.

Oxygen concentration remains stable at the desired pressure.



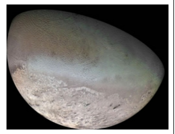


The radiation environment is reproduced including ion and electron sources.

Due to the low total pressure (10^{-8} mbar) in Europa, electronic and ionic irradiation plays an important role in the surface chemistry. Therefore, this seems to be an important parameter to take into account when describing the geological process of the satellite. We are able to irradiate with electrons a dose of about 5 μA /cm², and with ions of about 10 μA/cm². The electron and ionic energy can be set by the user, ranging from 0.1 to 5 kV

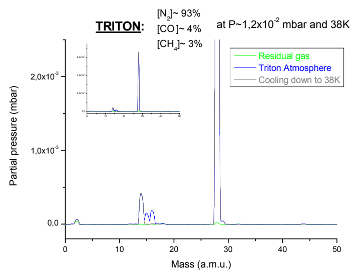
Photo of sample irradiated with electrons

TRITON

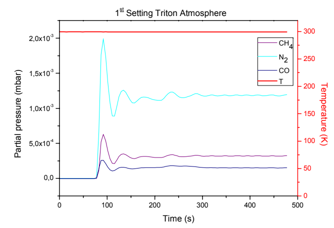


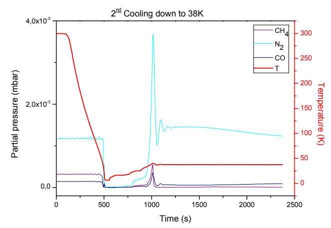
Voyager 2 spacecraft has shown the current activity of the Neptunian satellite, Triton. Geological processes, like cryovolcanism occur in this extremely low environment, in which even nitrogen is seasonally solid. Interactions between the atmosphere and the surface has been observed, such as geysers ejecting gases. Once in the atmosphere, some materials are photolytical destroyed (7).

(7) Yelle, R. V. et al. (1995). Lower atmospheric structure and surface atmosphere interaction on Triton. In: Neptune and Triton. Cruikshank, D. P. (Ed.), 1031-1107.University of Arizona Press.



Triton conditions have also been developed as one technically extreme environment because the circumstance of relative low pressure (10^{-2} mbar, from 93% N_2, 4%CO and 3% CH_4) and very low temperatures. Although Triton does not have any evident interest for astrobiology, it deserves attention from a geological point of view. To reproduce Triton in this machine we set first the gas composition, which is stable after 5 minutes. Then we decrease temperature up to 38 K. Note that at a slightly smaller temperature CO, CH_4 and N_2 condensate, and therefore extreme control on the surface temperature should be attained. Stable triton conditions are reach after 20 minutes.





Triton presents a pressure lower than mars and higher than Europe, therefore electronic and ionic irradiation is strongly reduced by absorption in the atmosphere but could be not neglected. We have detected about 0.1 μA /cm², and with ions of about 1 μA/cm². Also UV irradiation deserve special interest, and both UV-De lamp and noble gas discharge lamp are available in the experimental chamber.

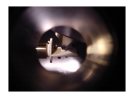
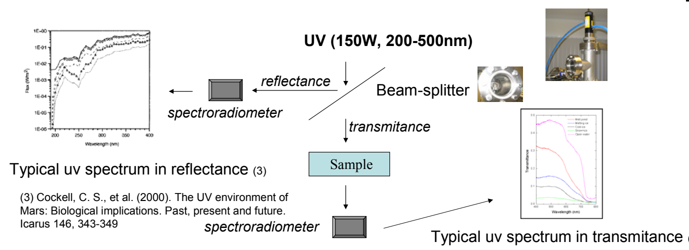


Photo of a sample in Triton Atmosphere. The white features corresponds to frozen methane

Irradiation by Deuterium lamp



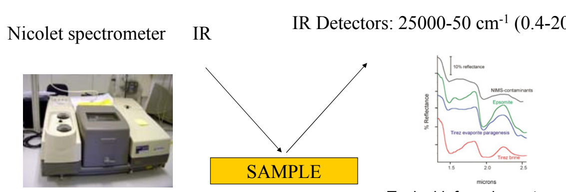
Typical uv spectrum in reflectance (3)

(3) Cockell, C. S., et al. (2000). The UV environment of Mars: Biological implications. Past, present and future. Icarus 146, 343-349

Typical uv spectrum in transmitance (8)

(8) D.K. Perovich, T.C. Grenfell, B. Light, J.A. Richter-Menge, M. Sturm, W.B. Tucker III, H. Eicken, G.A. Maykut National Science Foundation Arctic System Science Program and the Office of Naval Research High Latitude Program.

In-situ characterization by Infrared spectroscopy



Typical infrared spectrum (9)

(9) Prieto-Ballesteros O, Rodriguez N, Kargel JS, Kessler CG, Amils R, Remolar DF(2003). Tirez lake as a terrestrial analog of Europa ASTROBIOLOGY 3 (4): 863-877.

Summary: The flexibility of this simulation chamber to reach different planetary conditions (partial pressure and temperature) and the possibility to adapt different in-situ irradiation sources and analytical techniques results in a unique instrument for Astrobiological and Planetary studies, that will be open for applications to the whole scientific community.

http://www.cab.inta.es/~XPS/index.html