# Laboratory Studies of Energetic Processing in the Interstellar Medium

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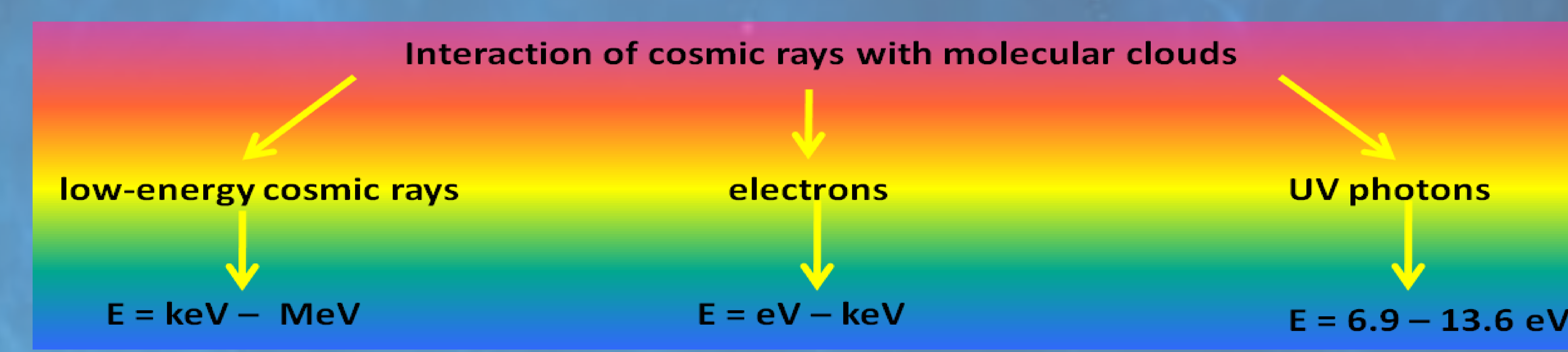
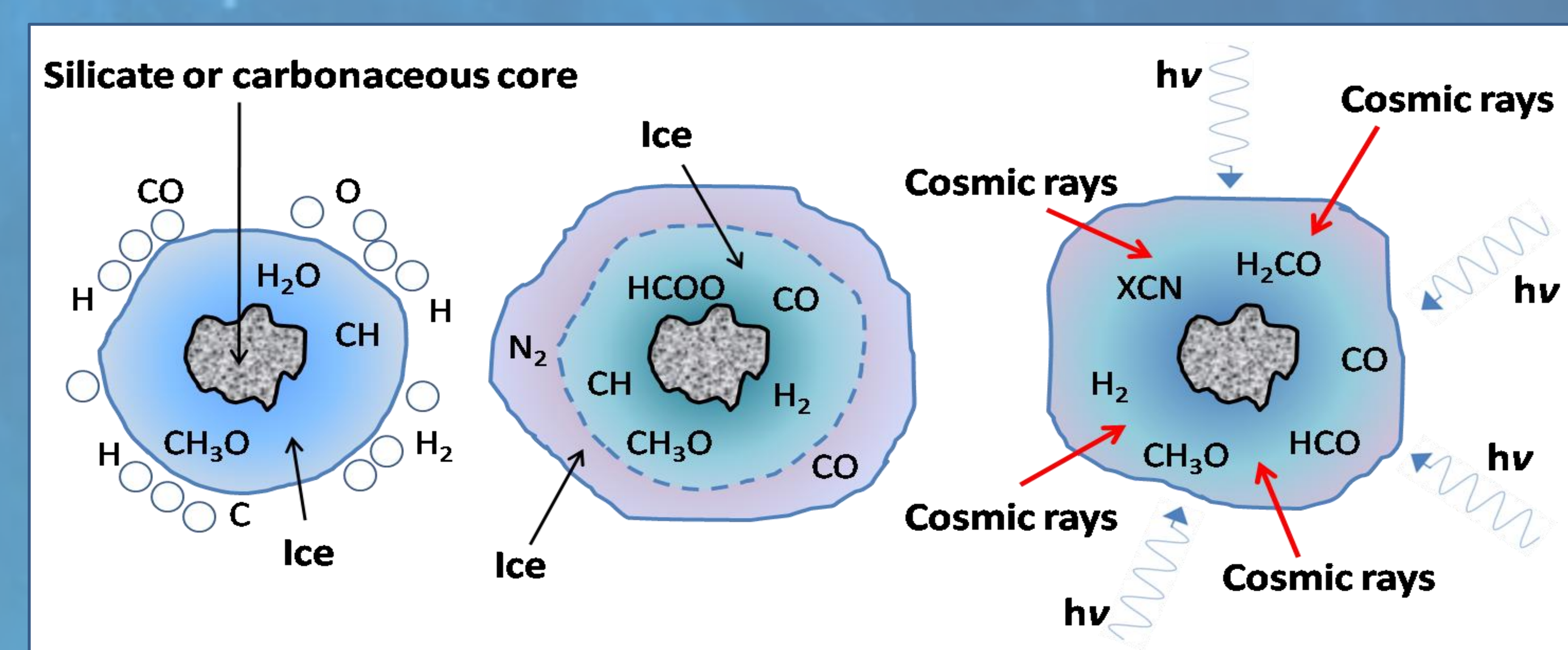
## Motivation

The key to interstellar chemistry lies with the formation of molecules on dust grain surfaces. These dust grains are thought to be silicate or carbonaceous in nature. In dense regions, such as in the interior dense molecular clouds, dust grains provide shielding from the destructive external galactic UV radiation field allowing the build up of icy mantles surrounding the dust grain. These ices are processed by the cosmic ray induced internal UV radiation present even in the deep interior of dense clouds and by particles of the galactic cosmic radiation field.

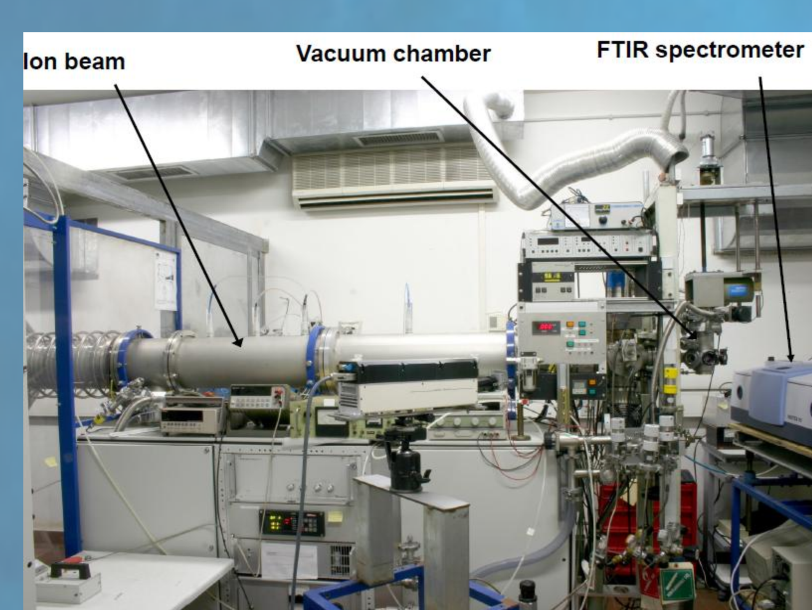
Fast ions passing through a molecular solid impart energy to the target material such that molecular bonds are broken along the trajectory of the ion. The molecular fragments recombine, leading to a rearrangement of the chemical structure and the formation of new molecular species not present before irradiation. In the case of UV irradiation, the energy is released to the target material through single photodissociations, photo-excitations or ionization events per incoming photon. Hence energetic processing via UV irradiation also gives rise to the formation of new molecular species. Molecules in the ice mantles can also desorb, thus directly affecting gas phase abundances.




## Aim of Project

To use a combination of experimental and observational methods to study ion and UV irradiation of interstellar and circumstellar ices and to understand both the gas and solid phase abundances of chemical species in interstellar clouds and circumstellar envelopes.




LASp

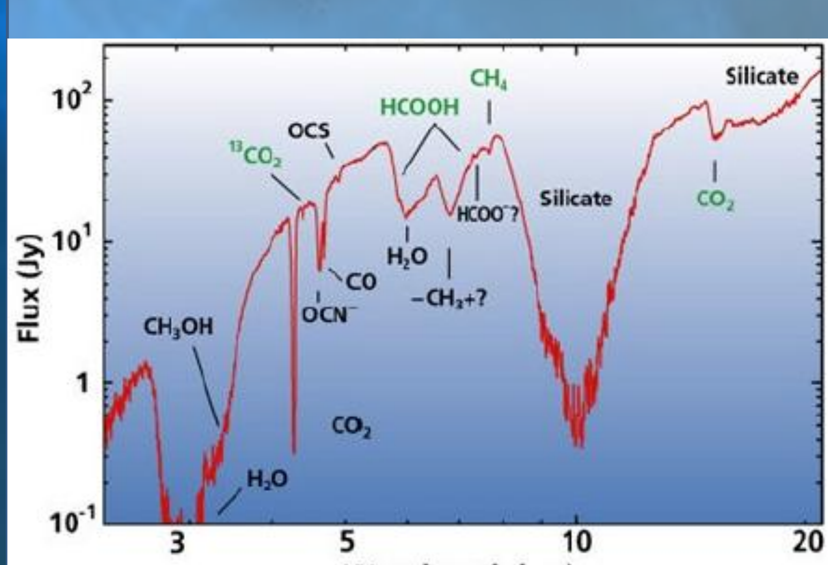
## The Laboratory

The "Laboratorio di Astrofisica Sperimentale" (LASp) is equipped with an ion beam production system with a maximum acceleration potential up to 200 kV. We conduct experiments using high vacuum chambers, facilities for the deposition of ice films, many spectrometers in the range from 190 nm up to 200 microns and also Raman spectrographs. The "in situ" techniques used to analyze the effects of irradiation are infrared, Raman and UV-VIS-NIR spectroscopy. Our group mainly investigates the effects induced by fast ions and UV Lyman-alpha photons in solids of astrophysical interest (e.g. frozen gases, carbonaceous materials and silicates).

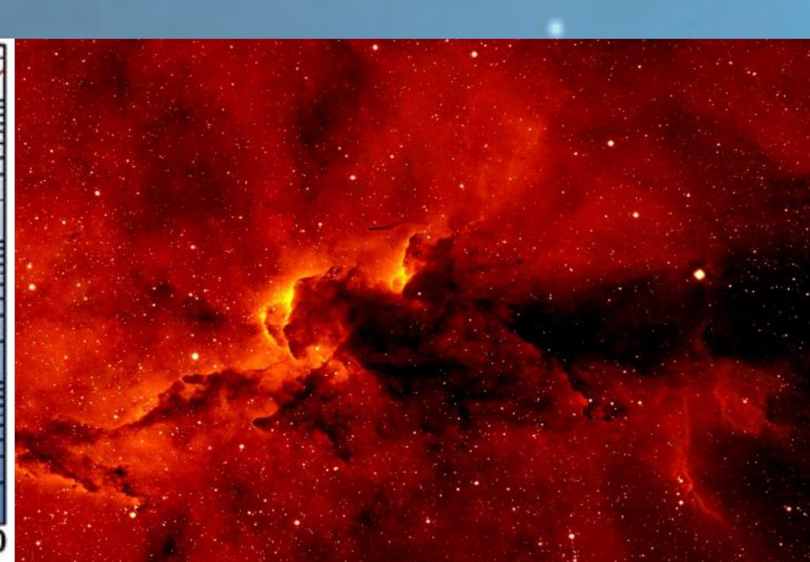
## Research Planned

**1) Synergy:**
Investigating the effect of combining both ion and UV irradiation in order to identify if synergy takes place. This study entails the analysis of experiments involving infrared spectroscopy of the simultaneous irradiation of $CH_3OH$:$N_2$ ice by $H^+$ ions and UV photons.

**2) Observational work:**
Compare laboratory spectra with ISO and Spitzer observations of molecules in the interstellar medium.




ISO-SWS spectrum of the protostar W33A
**Gibb et al. 2000, ApJ 536, 347**

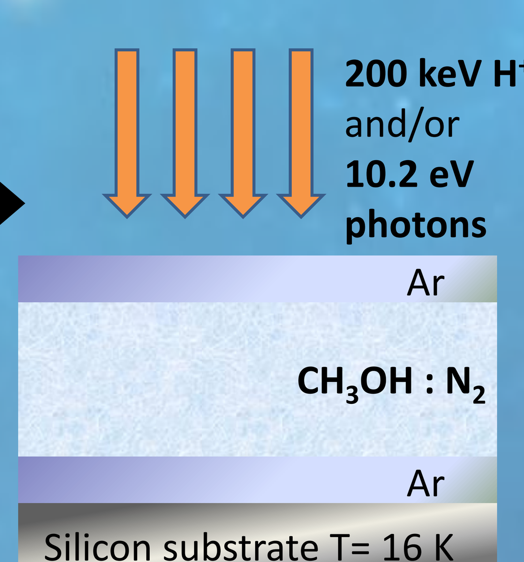


IC 1396 in the constellation Cepheus
**N. Wright (CfA), IPHAS collaboration**

**3) Industrial secondment**
Jan/Feb 2012 at **HITEC2000** - precision engineering, developing systems and equipment, advanced services and products in various hi-tech sectors, particularly manufacturing and testing processes in the cleanroom in microelectronics, pharmaceutical, scientific research and in all other high technology activities.

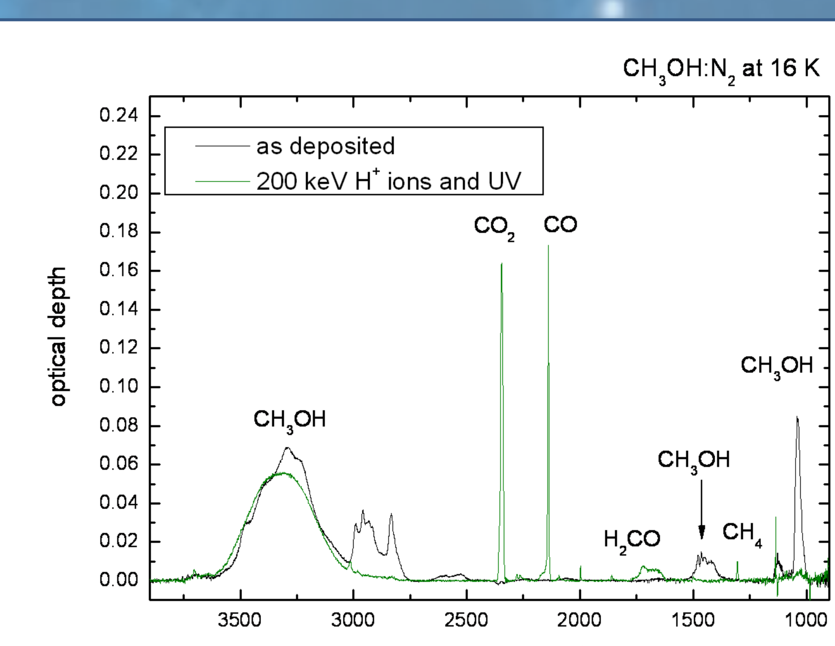
**4) Collaborations** with other member groups of LASSIE, e.g. An investigation of $CH_3CN$ with the group of Prof. Martin McCoustra (Heriot-Watt).

## Preliminary Results - Synergy

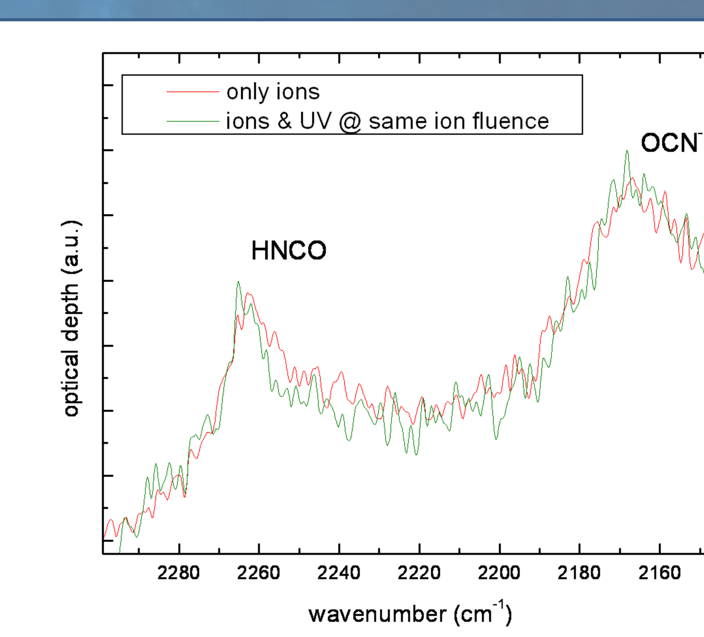



After ion bombardment only, species such as $CO_2$, CO, $H_2CO$, $CH_4$, $N_2O$, HNCO and $OCN^-$ are formed in the ice mixture. In contrast, after $CH_3OH$:$N_2$ ice is photolysed by UV only, species such as $CO_2$, CO, $H_2CO$ and $CH_4$ are formed but no N-bearing species are detected. Therefore, N-bearing species may be used to discriminate between the processes of ion bombardment and UV irradiation for $CH_3OH$:$N_2$ ice.

To investigate synergy, spectra of ices irradiated by both UV and ions were compared to spectra of ices bombarded only by ions. We find that at the same ion fluence, there are no differences in the band areas and band profiles of N-bearing species for the two types of experiment; thus, the addition of UV irradiation to ion bombardment does not affect the abundance of N-bearing species. Therefore, we conclude that no synergy takes place between ion and UV irradiation for $CH_3OH$:$N_2$ ice mixtures.




Spectra of $CH_3OH$:$N_2$ ice before and after irradiation with both ions and UV




Spectra of $CH_3OH$:$N_2$ ice irradiated with ions only and irradiated with both ions and UV, at the same ion fluence

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