INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

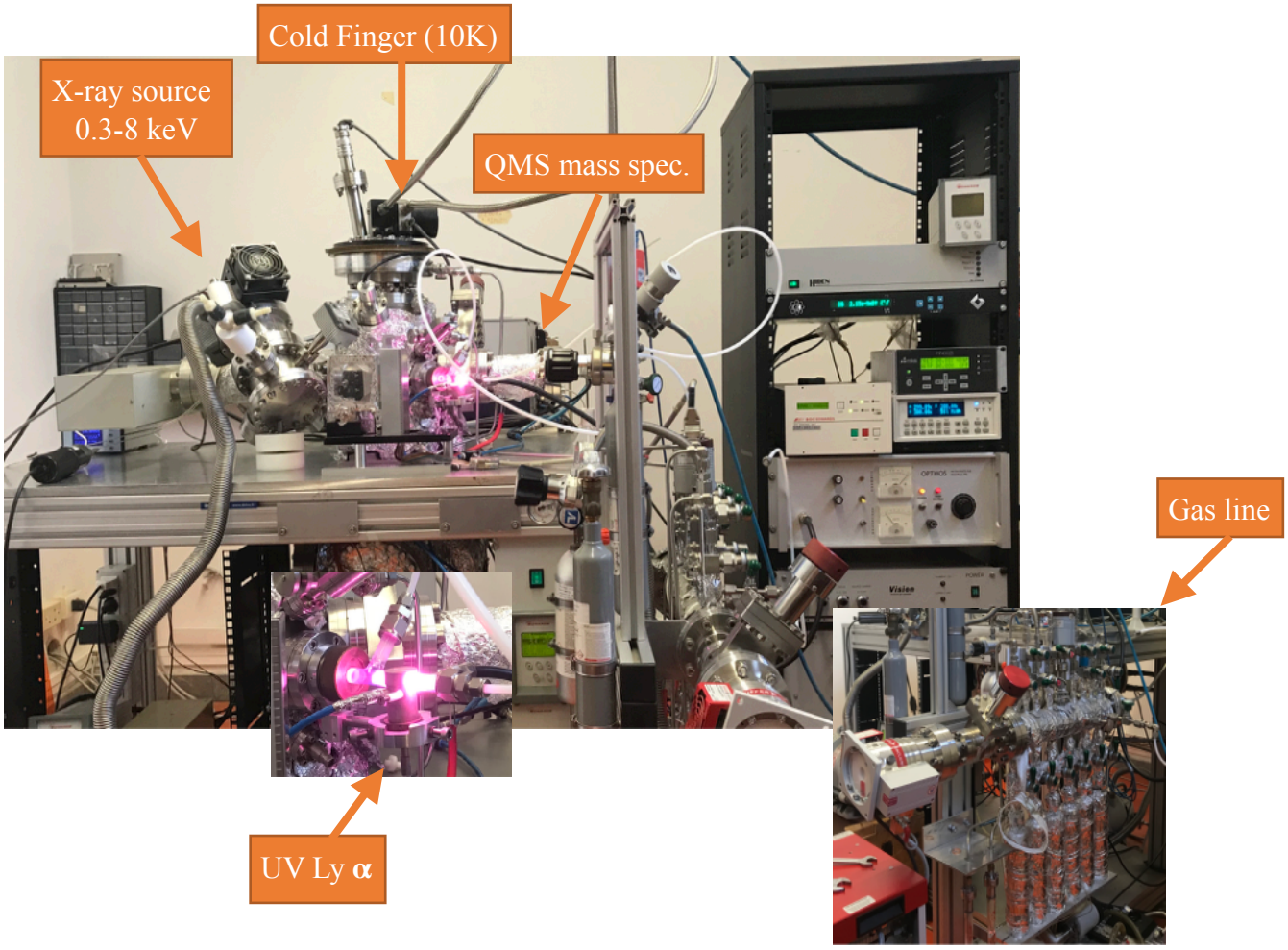
INAF - OSSERVATORIO ASTRONOMICO DI PALERMO
"Giuseppe Salvatore Vaiana"

Sur**F**ace **E**nhanced infra**R**ed spectroscopy for **A**strochemistry (**SFERA**)

Laboratori Spaziali

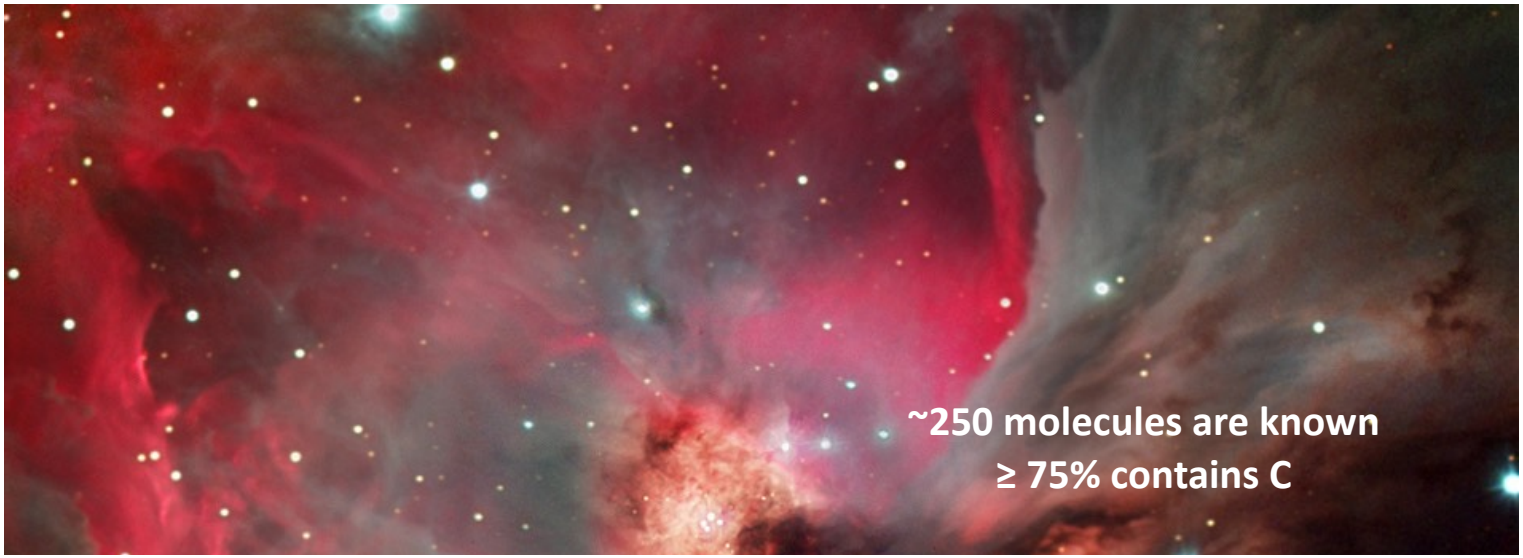
- Angela Ciaravella

Light Irradiation Facility for Exochemistry (LIFE)

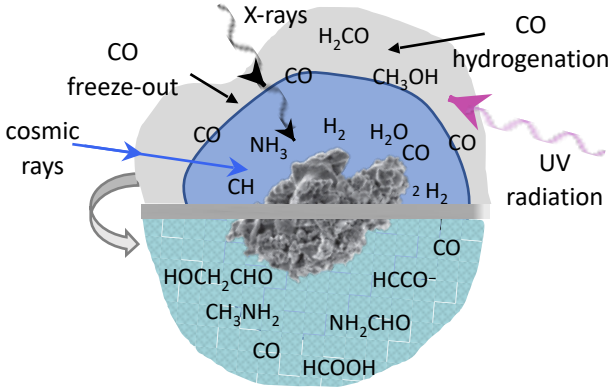


Ice analogs are studied under space-like conditions. The ices are grown onto low temperature (~ 10 K) substrates inside high or ultra-high (<10^{-8} mbar) vacuum chambers, and processed with radiative and not radiative sources to study their chemical evolution.

The interstellar medium is a rich environment where organic chemistry can reach a high level of complexity



- ✓ The inventory of molecular species in space is dominated by organic molecules ; e.g. acetonitrile NH_2CH_2CN, a species close to the simplest amino acid glycine.
- ✓ Are mainly detected in the gas phase, but gas-phase chemistry can only partially explain the observed species.
- ✓ Highly saturated molecules cannot be formed in gas phase, and they originate in icy mantles coating dust grains
- ✓ Chemical reactions in ices are induced by non-energetic (e. g. hydrogenation) and energetic (e. g. cosmic rays, VUV, X-rays) sources.
- ✓ The molecules formed into the icy mantles can then be released in the gas-phase by photo and/or thermal desorption.



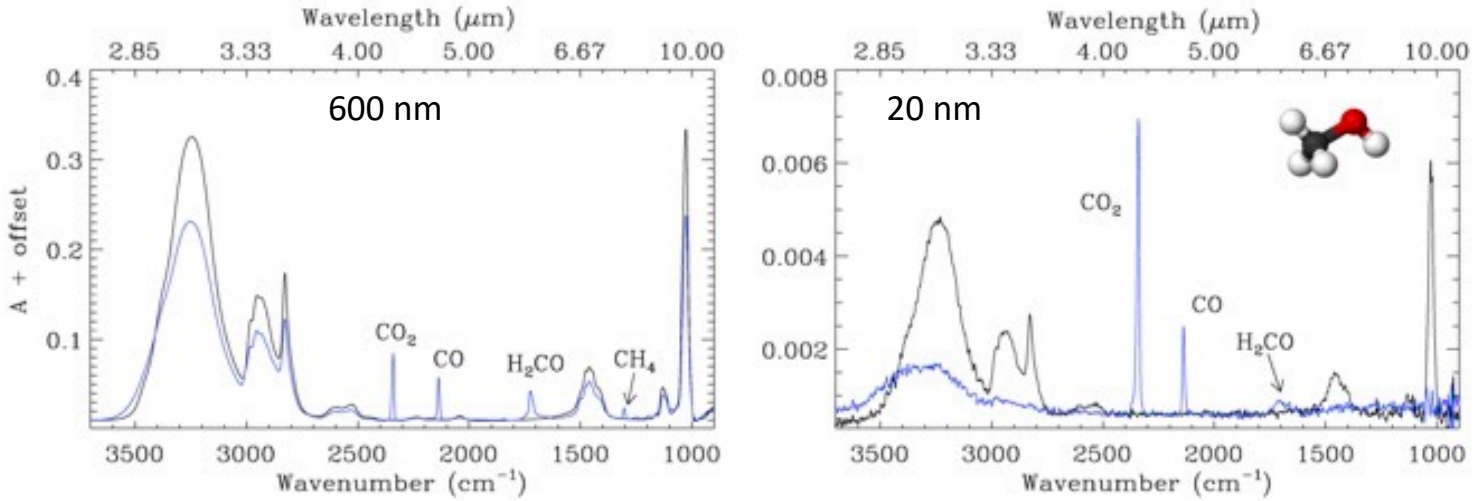
Laboratory studies of interstellar ice analogs are of invaluable relevance for the interpretation of the data

There are important limitations:

human being timescale is much shorter than the evolutionary lifetime of astronomical environments. To overcome such enormous time lag very high flux radiation sources are used:

UV flux inside an interstellar cloud is about 10^3 -10^4 photons cm^{-2} s^{-1},
in laboratory 10^{12} -10^{14} photons cm^{-2} s^{-1} about 10^9 - 10^{10} times higher!

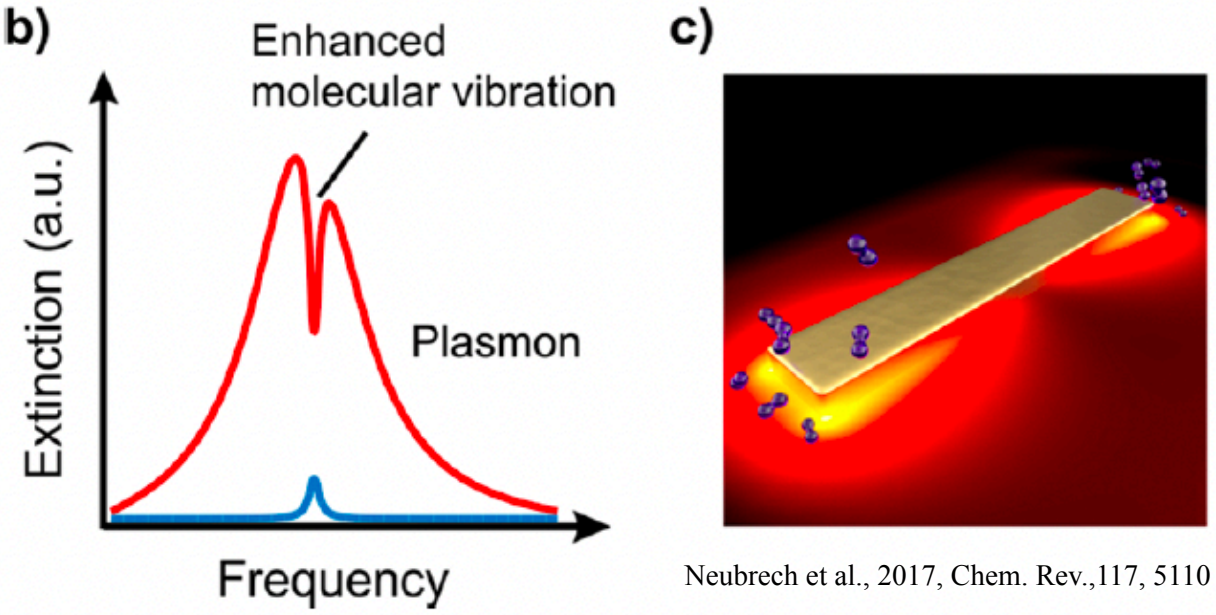
Even in these conditions:



many species, being products of secondary chemistry, are synthesized in small amounts, and therefore not easily detected e.g. through IR spectroscopy.

How can we make laboratory conditions closer to space environments?

As demonstrated in other **fields enhanced spectroscopies** are techniques able to amplify the optical signal, through the optical properties of either metallic or semiconductor nanostructures acting as nanoantennas for light.



Neubrech et al., 2017, Chem. Rev.,117, 5110

Infrared vibrations of molecules located in the enhanced electromagnetic near-field of a plasmonic nanostructure (nanoantenna) are enhanced if the plasmon (red) is resonantly matched to the molecular vibration (blue).

The IR vibrational signals of adsorbed molecules can be enhanced up to 10^4 - 10^5

The projected will be developed with the LIFE laboratory. The interdisciplinary team includes scientists belonging to astrophysics, chemistry, photonics, and enhanced spectroscopies.

Planned steps:

- ✓ Upgrading LIFE cryostat
- ✓ Design and Fabrication of the nanoantennas
  in collaboration with the CNR-IPFC (Messina) and Dr. Lucia Petti's group (Napoli)
- ✓ Test of the nanoantennas substrates on
  - probe molecules
  - pure ices of different thickness.
  - ice mixture
- ✓ Testing the substrate during irradiation
  - UV HI Lya
  - X-rays with low (2.2 x 10^9 photon cm^{-2} sec^{-1}) and high (NSRRC, Taiwan) intensity sources

Objective: deliver a performing technique for laboratory astrochemistry that will significantly improve sensitivity in analytic chemical analyses of samples and interpretation of astrophysical environments

The funds will be used for:

- ✓ A new cryostat.
  The LIFE laboratory was built with very limited amount of funds. The current cryostat it was adapted from an old cryopump and no longer works properly. It does not reach low temperatures (10 K) and it does not keep a constant temperature during the experiments. The latter malfunction. is severe in long duration experiments.

- ✓ Consumables - Consumables include all the samples, high purity gases and isotopes, gaskets, and supplies for running the laboratories. Material needed by the CNR collaborators for the construction of the nanoantennas substrates.

- ✓ Travels & Publications – including experiments at the National Synchrotron Radiation Research Center (NSRRC, Taiwan) where our group has allocated time to X-rays and EUV beamlines.