Bolometric luminosity of young binary system protostars, as measured from OCS line emission and binding energy

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The bolometric luminosity L_{bol} of a young protostar, a basic property of paramount importance, is usually obtained integrating its continuum Spectral Energy Distribution (SED) from millimeter (mm) to infrared (IR) wavelengths. While the mm/submm wavelength range can be observed with ground-based telescopes, IR observations require space-born facilities. Measurement of the luminosity of embedded protostars in binary (or multiple) systems can be challenging, where a high ($\geq$ sub-arcsec) spatial resolution is required, impossible to obtain at wavelengths smaller than submm.

The luminosity of a protostar is a very important parameter to characterize them. More the protostar emit photons, hotter the envelope will be close to the protostar. Ice mantle of the grain will start to melt, releasing by thermal desorption molecules trapped on the grain surface. It means that for a molecule formed on the grain, the gas phase abundance depends on the desorption from the grain if the desorption is mainly thermal.

Starting from this idea, we used ALMA observations of the proto-binary system NGC1333 IRAS4A — composed of A1 and A2, whose total $L_{bol} = 14.5 \pm 1.5\ L_{\odot}$ — from the ALMA large program FAUST (Fifty AU STudy of the chemistry in the disk/envelope systems of Solar-like protostars) with a very high spatial resolution (~50 au) to resolve the molecular emission around the protostars. The study focus on the carbonyl sulphide (OCS) emission, which is a molecule mainly formed on the grain surface and emitting rotational lines in the millimeter domain. The observed OCS emission arises from the gas in the walls excavated by the large scale outflows emanating from the two components A1 and A2 and the gas in the hot corino/inner envelope/disk of each source. While the OCS along the outflow cavities is due to the shocks that sputter and shatter the dust grains, the OCS abundance in the inner envelope is governed by the balance between the OCS thermal sublimation from and its absorption onto the grain icy mantles.

Using new quantum mechanicals calculation of the OCS binding energy distribution also presented in the study, it was possible to obtain a theoretical intensity profile based on an adsorption-desertion model of the OCS molecule from the grains depending on the protostar luminosity. By comparing it with the high resolution observations of the OCS molecule, it was possible to derive an estimate luminosity of the source based on the best fit with the theoretical intensity emission line.

This method shows how powerful is the combination of quantum chemical computation (in particular binding energy distribution computation), with astronomical lines observations to retrieve the luminosity of a protostar, and more importantly here, protostellar binaries. Our work demonstrates the power of astrochemistry in studies of star and planet formation, adding a novel application to the existing list: the measurement of the bolometric luminosity of young binary system protostars.