30 Years of Photodissociation Regions:

A symposium to honor David Hollenbach's lifetime in science

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"Dark" Gas in Isolated Interstellar Clouds

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Far-infrared and gamma-ray surveys indicate there are significantly more nucleons in the diffuse interstellar medium than are traced by H I and CO emission. Using the $Planck$ far-infrared Arecibo GALFA 21-cm line surveys, we identified a set of isolated interstellar clouds and assessed their dust-to-gas ratios—taking into account only the atomic gas traced by the 21-cm line. Significant deviations from the standard dust-to-gas ratio are found both from cloud to cloud and within regions of individual clouds. The outskirts of the clouds are most similar to the truly diffuse ISM and the standard dust-to-gas ratio. Within the clouds, the dust per unit gas increases over 300% in many clouds.

We are engaged in a follow-up observing program to determine the reason for the enhanced apparent dust-to-gas ratio. The first (already widely accepted) hypothesis is that the extra dust is associated with molecular gas. Based on the dust-to-(atomic)gas enhancement, we predict detectable amounts of molecular gas. Results of a search for OH absorption toward radio sources in one cloud were, to our surprise negative, indicating relatively little molecular gas.

The second hypothesis is that the 21-cm line is underestimating the amount of atomic gas, so the apparent dust-to-gas ratio was overestimated. Cold gas would be optically thick in the 21-cm. We measured 21-cm absorption profiles toward one cloud, and have proposed to survey the others. Results to date indicate that the gas is in fact remarkably cold; however, the column density of cold atomic gas does not appear sufficient to explain the enhanced dust-to-gas ratio. There could also be warm or ionized gas; we have begin observations with SOFIA to measure the [C II] 157 μm line brightness to search for extra gas traced by ionized Carbon.

The third hypothesis is that the dust properties evolve inside of the clouds, so that the apparently enhanced dust-to-gas ratio is actually measuring different dust properties. There is already some indication of this from the $Planck$ data alone, which indicate the emissivity index changes at the same time as the dust temperature decreases in the cloud cores. The emission at frequency ν is $\nu^\beta B_\nu(T)$ where β is the emissivity index and $B_\nu(T)$ is the blackbody function at temperature T. It is qualitative expected that the grains will be colder in regions where starlight is more excluded, but the emissivity index is a property of the grains. If this hypothesis is the only one active, then there may be no 'dark gas' at all, but there is a critical new physical process that changes grain properties with the resultant effect on their ability to heat interstellar gas and coagulate into planets around forming stars.