Some Early Results from the HIFI Instrument on the *Herschel Space Observatory*

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The Herschel Space Observatory was sent into orbit in May 2009 in order to study the sky in the submillimeter-wave and far infrared. The observatory is now orbiting the earth at the so-called second Lagrangian point (L2) of the Earth-Sun system. The 3.5-meter dish sends radiation to three detectors, one of which is a high spectral-resolution spectrometer known as HIFI (Heterodyne Instrument for the Far Infrared), while the other two – PACS (Photoconductor Array Camera and Spectrometer) and SPIRE (Spectral and Photometric Imaging Receiver) – are cameras and imaging spectrometers. HIFI operates in 6 bands, ranging from 480 GHz to over 1900 GHz in frequency. The first period of observations was devoted to 7 Key Programs, which had been selected before launch and involved many astronomers and astrochemists, such as myself. Currently, proposals have been submitted for the first open-time portion of the mission (OT1), with each proposal having a team of perhaps 10 people, far smaller than the make-up of the Key Program groups.

Molecular observations using HIFI consist of both emission and absorption line studies. At the higher frequencies accessible to HIFI, critical densities for emission can be very large, and so absorption becomes competitive as long as there is a continuum to absorb. Emission lines have been detected from the usual suspects, especially hot cores rich in weeds such as methyl formate. Interestingly though, the density of lines is lower than seen at millimeter-wave frequencies. Even in Orion KL, absorption can be seen against the quasi-continuum emission. The absorption lines include those of HF, and two most improbable ions OH^+ and H_2O^+, which are known to react with abundant H_2 on every collision. Models explaining their existence indicate that the matter is in a most violent state.

For continuum sources more distant than Orion, such as the galactic center, absorption is present both from cooler portions of the primary source and from diffuse matter in the spiral arms between the galactic center and us. In fact, there can be so many sources that the absorption spectra need not be resolved. Absorption studies of the spiral arm clouds show CH+, CH, CN, CCH, HCO+, HF, OH^+, H_2O^+, and H_3O^+; here, though, it is somewhat easier to understand the presence of the two strange ions if H >> H_2 in abundance. A new molecule detected is protonated HCl, or H_2Cl^+, although the density of its environment is unclear. Although water is a prosaic molecule, its detection and study are clearly important for astrobiological considerations. Deuterated isotopomers seen in the spiral arm clouds include ND and D_2O. Although detailed gas-grain PDR models have not yet been run, it is difficult to understand the high abundance of ammonia without including surface chemistry. From the measurement of diverse ortho/para ratios for H_2O, H_2O+, D_2O, and NH_3, astrochemists hope to understand the physical conditions better, although the analysis of ortho/para ratios is itself a source of much debate. These and other important studies in old stars and external galaxies will be discussed as time permits.