INTERSTELLAR AND LABORATORY SPECTROSCOPY IN THE TERAHERTZ REGION

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Since the identification of the Fraunhofer lines seen in the solar spectrum by the at that time new methods of spectral analysis introduced around 1860 by Kirchhoff and Bunsen, astrophysical and laboratory based spectroscopy have ever since enjoyed a special and fruitful relationship of mutual dependence. Many recent interstellar molecular assignments have become possible by the exacting test of matching frequencies from distant objects with spectral features measured and calculated in the laboratory. Spectroscopic observations are now possible throughout almost the entire electromagnetic spectrum. In particular recently the terahertz region has been opened, providing an overwhelming amount of new information. At Cologne both interstellar and laboratory heterodyne spectroscopy has been expanded towards the terahertz region by new developments, such as the production of SIS (superconductor-isolater-superconductor) Nb-based mixer junctions and superconducting diffusion cooled hot electron bolometers in our microstructure laboratory, both operational up to 900 GHz.

From Cologne we operate the KOSMA 3-m radiotelescope (Kölner Observatorium für Submillimeter Astronomie) located on the Gornergrat at an altitude of 3200 m near Zermatt, Switzerland. The telescope is mainly used for large scale molecular (CO, CN...) line mapping to reveal the star formation centers embedded deeply within the clouds, and the interface regions between neutral, atomic and ionized material. In collaboration with other observatories and airplane based observations detailed molecular line maps in selected galactic sources, such as Orion A and B, the Rosette Nebula, S140, IC 1396 demonstrate that the interstellar clouds are structured down to a level of solar system size, i.e. the smallest structures presently detectable. The fractal dimension of several molecular clouds has been determind. Recently we have performed a simultaneous measurement of the two fine structure lines of atomic carbon, i.e. at 492 and 810 GHz with a newly constructed Cologne dual channel receiver employing the German-American 10m Submillimeter Telescope near Tucson, Arizona. The Cologne group has detected both lines not only in galactic sources but also for the first time in the star burst galaxy M82. In addition to the mapping projects of molecular clouds, deep submillimeter line surveys, carried out with various telscopes around the world, have produced new and spectacular molecular identifications such as $^{33}SO_2$, ... revealing molecular abundances and thus useful clues to the evolutionary state of molecular clouds.

The astrophysical work is complemented by high resolution laboratory spectroscopy, which has been expanded into the terahertz region with Russian backward wave oscillators (BWOs) and successive frequency multiplication techniques. We have studied the spectra of many astrophysically interesting molecules and radicals up to 1.3 THz, some of which will be discussed, e.g. NH_3, CH_3OH, ... Special emphasis has been devoted to the investigation of molecular radicals SO, CN, SH, NH, and their various isotopomers. In addition we have detected the millimeter and submillimeter wave spectra of van der Waals complexes such as Ar-CO and the CO-CO dimer. The large power output of the frequency and phase stabilized BWOs can effectively be used for saturation spectroscopy and thus it opens the domain of sub-Doppler spectroscopy to the terahertz region. We have recently observed Lamb-dip spectra of various molecules such as NH_3, HCl, HSSH and CO with accuracies of 1 kHz. In addition tunable diode lasers have been employed to record the spectra of different van der Waals molecules and to use them as local oscillators for heterodyne detection of atmospheric constituents.

HIGH SENSITIVE SPECTROSCOPY OF SIMPLE MOLECULES IN THE INFRARED

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Recent developments on the rotational and vibrational overtone spectroscopy of simple molecules such as HCl and its isotopic substitutes and CO, are reported. In particular, as for the rotational spectroscopy, an improvement in sensitivity of the tunable FIR (TuFIR) spectrometer, based on nonlinear mixing of two lasers and microwaves on a MIM diode, has been obtained with a multiple pass White cell.
Vibrational overtone transitions are instead studied using distributed feedback (DFB) semiconductor diode lasers in combination with sensitive detection schemes, like two-tone modulation.