Série de Cours et Séminaires du Professeur Trevor Sears

Dans le cadre de son programme d'accueil de Professeurs Invités, la Communauté des Universités et Établissements Lille/Nord de France, en collaboration avec le Laboratoire de Physico-Chimie de l'Atmosphère (Université du Littoral, Côte d'Opale) et l'Université de Lille, accueillera le Professeur Trevor Sears pour une série de 4 cours et 2 séminaires du 7 au 21 Novembre.

Dates des Cours : les mardis et mercredis 8, 9, 15 et 16 Nov. à 8h30 en visio-conférence, dans le Bâtiment de Physique P5 (salle 172) à Lille 1, et en salle de visio de l'ULCO (Citadelle) à Dunkerque.

Dates des Séminaires : le jeudi 10 à 14h00 et le lundi 21 à 10h00 Nov. en visio-conférence, au CERLA à Lille, et dans l'amphi de la Citadelle à Dunkerque.

Trevor Sears est Professeur au Department de Chimie de Stony Brook University, NY, et Senior Chemist à Brookhaven National Laboratory, NY. Les cours et séminaires sont ouverts aux étudiants des Écoles Doctorales et aux Chercheurs.

Titre des Cours : **Angular momentum, symmetry and rotational energy levels.**

Titre des Séminaires **I : Old problems meet new techniques: Applications of frequency comb-referenced spectroscopy.**

II : Using precision spectroscopy of diatomic molecules to investigate fundamental physics: $^{207}Pb^{19}F$ hyperfine splittings.

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1 Lectures

1.1 Angular momentum, symmetry and rotational energy levels

These lectures will begin with a review of the matrix approach to the eigenvalue problem using the hyperfine structure of the hydrogen atom as an example. Then cover some details of angular momentum operators, spherical tensor formalism and Wigner-Eckart theorem. By the end, students should be familiar with methods to calculate matrix elements of different fine and hyperfine contributions to the molecular Hamiltonian. The final seminar will focus on use of the methods to compute the different energy contributions to the hyperfine split levels of $^{207}Pb^{19}F$ in its zero point level which is relevant to investigations of parity-violating effects.

1.2 Lecture 1

Introduction.
Motivation, near-term objectives.
Review of matrix approach to eigenvalue problem, example: hyperfine structure of the hydrogen atom.
Variational theorem, form of matrix solution.
Orbital angular momentum, spherical harmonics.

1.3 Lecture 2

Properties of spherical harmonics, coupling of angular momenta. Example Matlab plots of spherical harmonics.
Generalized angular momentum operators.
Vector model for angular momenta (classical).
Coupling of angular momenta: Clebsch-Gordon coefficients and 3-j symbols.
Coupled and uncoupled representations.
Term symbols and wavefunctions.

1.4 Lecture 3

Coupling of 3 and 4 angular momenta: 6-j and 9-j symbols.
Rotational operators, Euler angles, relation between rotation and angular momentum, Wigner rotation matrices.
Connection to group theory (brief).

1.5 Lecture 4

Spherical tensor operators, 0-rank, 1st-rank and 2nd-rank tensor operators.
Products of spherical tensor operators.
Wigner-Eckart theorem.
Matrix elements of tensor operators.
Spin-orbit interaction in an atom.
Examples for diatomic molecules: OH, PbF.

2 Seminars

2.1 Seminar 1

Old problems meet new techniques: Applications of frequency comb-referenced spectroscopy

Frequency comb technology has become widely available and relatively inexpensive, so that it is now practical to routinely measure optical spectra with accuracy and precision approaching a few parts in 10^{12}. This is some 4 orders of magnitude greater than can be achieved with wavelength-based measurement techniques. It opens up possibilities for the measurement of precise spectral splittings and line positions for fundamental spectroscopy, but also dramatically improves the accuracy with which we can measure spectral line shapes. Line shapes contain information on collisional processes within the sample and intermolecular potentials. Their knowledge is also centrally important in practical remote sensing measurements. In this talk, I will outline the frequency comb idea and spectroscopic techniques and illustrate the kinds on data attainable with examples from line shape and frequency measurements in the molecules C_2H_2 and NH_3. The figure below shows an example of the recent experimental data.

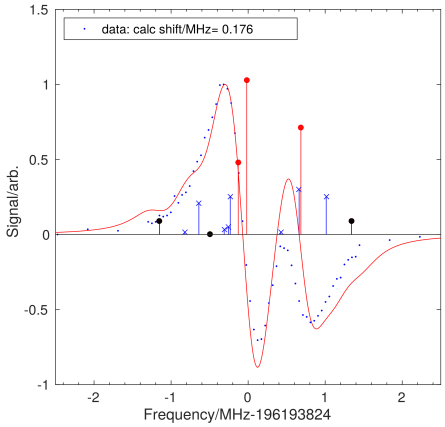

Figure 1: Quadrupole hyperfine split structure for the ${}^rP(3,0)_s$ transition of NH_3 in the $v_1 + v_3$ band at 196 193.824 176(30) GHz. The figure shows the saturation dip line shape (blue points) observed at a pressure of 5 mTorr and a one-way intra-cavity power of 100 mW. The red, black and blue stick spectra correspond to the strong (red), weaker (black) and crossover (blue $\times$) transitions contributing to the observed lines shape, plotted at the corresponding detunings from the hyperfine-free transition frequency, with heights proportional to the calculated intensities. The red line is the simulated spectrum, assuming transit-time broadening is dominant. The transition frequency ν_0 is adjusted to optimize the agreement of observed and simulated line profiles at the dominant zero crossing.

2.2 Seminar 2

Using precision spectroscopy of diatomic molecules to investigate fundamental physics: ${}^{207}Pb^{19}F$ hyperfine splittings

Recently, it has been realized that precision measurements of the spectra of certain small molecules containing a heavy atom can provide opportunities to investigate parity-violating effects and other fundamental interactions. This is because electrons in the molecules experience relativistic forces in the regions of their wavefunction that overlap the heavy nucleus. Examples include the recent upper-limit determination for the electron dipole moment and recent searches for nuclear anapole moments. One molecule that has received attention as a possible candidate for study of these effects is PbF and this lecture will build on the material in the earlier lectures and cover some aspects of the spectroscopy of the ground state that makes it attractive for these studies.