SYLC 1: Light and Chirality: From Fundamentals to Applications

Time: Wednesday 14:30–16:30 Location: RW 1

Invited Talk SYLC 1.1 Wed 14:30 RW 1

Enantio-sensitive molecular compass — P. M. Flores[1], S. Carlstroem[1], S. Patchkovskii[1], M. Ivanov[1,2,3], V. Mujica[4], A. F. Ordonez[5], and •O. Smirnova[1,3,6] — [1]Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany — [2]Insitute of Physics, Humboldt University zu Berlin, Berlin 12489, Germany — [3]Technion - Israel Institute of Technology, Haifa, Israel — [4]School of Molecular Sciences, Arizona State University, Tempe, AZ 85287-1604, USA — [5]Department of Physics, Freie Universität Berlin, 14195 Berlin, Germany — [6]Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany

Chirality describes the asymmetry between an object and its mirror image and manifests itself in diverse functionalities across all scales of matter - from molecules and aggregates to thin films and bulk chiral materials. A particularly intriguing example is chirality-induced spin selectivity (CISS), where chiral structures orient electron spins enantio-sensitively. Despite extensive research, the fundamental origin of spin-chirality coupling, the unexpectedly large magnitude of the CISS effect, and the possible role of electromagnetic fields in it remain unclear.

We show [1] that any excited or photoionized chiral molecule behaves like an enantio-sensitive molecular compass. Its internal "compass axis" is locked to the molecular geometry itself – not to any external field. Remarkably, this compass effect arises even under isotropic illumination, where light provides no preferred direction. Just as a traditional compass needle aligns with Earth's magnetic field, the molecular compass aligns the electron spin with a built-in geometric direction inside the molecule – a direction defined by its handedness. In this way, the molecule generates its own "chiral north," guiding the electron spin without any magnetic interaction. In a single chiral molecule fixed in space, this compass causes the emitted or excited electron's spin to orient differently for left- and right-handed forms of the same molecule – exactly the kind of enantio-sensitive spin polarization observed in the CISS effect. In randomly oriented chiral molecules and under isotropic illumination the enantio-sensitive molecular compass enables a phenomenon central to CISS: locking of the photoelectron spin orientation to molecular geometry. It shows that chiral molecules can sustain time-odd correlations whereas achiral molecules cannot.

New spin-sensitive phenomena also arise in the interaction of chiral molecules with photon spin. We show that molecular chirality mediates the coupling between photon spin and electron spin in photoionization of randomly oriented molecules and induces a triple orientational lock, where molecular structure, electron and photon spin orientations are correlated in an enantio-sensitive way. Specifically, we identify a universal spin-torque mechanism in which the Berry curvature of a chiral molecule, activated by the photon spin of the incident light, exerts a torque on the photoelectron spin. This mechanism represents the second fundamental pathway of chiral spin-photon coupling, complementary to the enantio-sensitive molecular-compass effect. While enantio-sensitive molecular compass identifies a direction of spin-polarization of photoelectron imposed by chiral molecule, the spin torque rotates the photoelectron spin around the photon-spin direction and away from the compass axis. Our geometric framework connecting Berry curvature to electron spin polarization provides foundation for linking the CISS effect to topological properties of electron response.

[1] P. M. Flores et al, arxiv 2505.22433

Invited Talk SYLC 1.2 Wed 15:00 RW 1

Conjugation, chirality and optical activity — •Matthew Fuchter — Department of Chemistry, University of Oxford, Chemical Research Laboratory, 12 Mansfield Road, Oxford, OX1 3TA, United Kingdom

There has been a large growth in interest in the study of chiral conjugated organic materials, partly due to the rich optoelectronic behaviour of such systems and how these properties can enable multiple future technologies. This talk will bring together our work on chiral self-assembled conjugated polymers. Following the discovery that helicenes can induce large chiroptical activity in thin film polyfluorenes, we have extensively studied this fascinating material. We have assigned the giant chiroptical activity (circular dichroism and circularly polarised luminescence) displayed by polyfluorene blends to an intrinsic response of the chromophore, which is formed through assembly of individual polymer chains into a highly twisted architecture. We have subsequently shown that this same material results in a large anomalous chiroptical activity when employed as the emitter in an OLED. Finally, we have recently reported substantial magneto-optical activity (specifically Faraday rotation) when this material is placed in a magnetic field. Thus, it seems self-assembled polyfluorenes provide a useful platform to explore the origins of optical activity and a useful means to control chiroptic and magneto-optic responses in conjugated organic materials.

Invited Talk SYLC 1.3 Wed 15:30 RW 1

Gas-phase spectroscopy of chiral molecules — •Anne Zehnacker[1], Etienne Rouquet[1,2], Valéria Lepère[1], Gustavo Garcia[2], and Laurent Nahon[2] — [1]Institut des Sciences Moléculaires d'Orsay CNRS Université Paris Saclay — [2]Synchrotron Soleil

Molecular recognition is strongly influenced by several factors including chirality and molecular flexibility. Chirality indeed modifies the interactions at plays between molecules and flexibility allows them to mutually adapt their shape for optimising the interaction. We will describe here gas-phase studies that are sensitive to both chirality and conformation. In the first part, we will describe conformer-selective laser spectroscopy studies of weakly bound complexes, which allow assessing the influence of chirality of the sub-units on the structure of the complex, to understand the nature of the forces responsible for chiral recognition at the molecular level. The second part will be devoted to photoelectron circular dichroism (PECD). PECD is defined as a forward-backward asymmetry in the photoelectron angular distribution for randomly oriented chiral molecules photo-ionised by circularly polarised light (CPL). Like all the chiroptical spectroscopy methods, it is very sensitive to small differences in the molecular structure, including conformational isomerism. We recently developed a conformer-selective PECD scheme based on resonance-enhanced multiphoton ionisation (REMPI) that allows obtaining separately the PECD of each conformer of a chiral system.

Invited Talk SYLC 1.4 Wed 16:00 RW 1

Toward a low-energy test of the parity symmetry via precise mid-IR spectroscopy of cold chiral molecules — Agathe Bonifacio, Sahil Viel, Raphaël Hahn, Minh Nhut Ngo, Marylise Saffre, Yuhao Liu, Wenling Dong, Etienne Cantin, Olivier Lopez, Anne Amy-Klein, Mathieu Manceau, and •Benoît Darquié — LPL, CNRS-Uni Sorbonne Paris Nord, Villetaneuse, France

There is an increasing demand for precise molecular spectroscopy, in particular in the mid-IR, whether it be for modelling our atmosphere, interpreting astrophysical spectra or testing fundamental physics.

I will present our efforts towards building new-generation mid-IR spectrometers specifically designed for precision vibrational spectroscopy of complex species in the gas phase. This includes amongst other things producing gases of polyatomics cooled to a few kelvins in cryogenic buffer-gas cells, developing frequency stabilised mid-IR lasers calibrated to some of the world's best frequency standards and explore the opportunities offered by cutting-edge mid-IR photonics technologies. The proposed technologies are at the forefront of cold molecule research and frequency metrology and have allowed us to measure absolute frequencies of a variety of species of atmospheric, astrophysical or fundamental interest with record up to 12-digit accuracies.

This opens possibilities for using polyatomic molecules to improve tests of fundamental physics and precision measurements in general. I will in particular focus on our effort towards measuring the tiny energy difference between chiral enantiomers expected to result from electroweak interactions and to be a sensitive probe of dark matter.