Title: Universal Natural Shapes.
When: Tuesday, November 13, (2018), 12:00.
Place: Department of Theoretical Condensed Matter Physics, Faculty of Sciences, Module 5, Seminar Room (5th Floor).
Speaker: Johan Gielis, University of Antwerp, The Antenna Company, Belgium.

In the natural sciences, global anisotropies or (quasi-) periodic local deviations from isotropy or Euclidean perfection in many forms that occur in nature can be effectively dealt with by applying Gielis transformations to the basic forms that show up in Euclidean geometry, e.g. circle and spiral. Since their introduction in botany in 2003, Gielis curves, surfaces and transformations have been used in various fields of science and technology, including in nanotechnology. I will focus on 1) further generalizations and Pythagorean-compact representations, 2) Applications in biology and antennas, and 3) Generalized Möbius-Listing surfaces and bodies, in the context of possible further applications in nanotechnology and nanophotonics.
Ex ample of a nanophotonic system where organic molecules are strongly coupled to a plasmon mode (confined light mode) in the gap between two metallic nanoparticles, thus suppressing the photochemical reaction sketched in the inset.

Article: published in *Nature Communications* by Javier Galego, Francisco J. Garcia-Vidal and Johannes Feist, Department of Theoretical Condensed Matter Physics and IFIMAC researchers.

**Photoisomerization** is a change in chemical structure of a molecule after the absorption of a photon. It plays a crucial role in biological processes, for example in human vision, as well as for technological applications such as solar energy storage, optical memories, or molecular switches. However, photoisomerization can also have detrimental effects, for example as an important damage pathway of DNA, or as a limiting factor for the efficiency of organic solar cells. While photoisomerization can be avoided by shielding the system from light, this is of course not a viable approach for devices that rely on the interaction with external light (such as solar cells).

In a theoretical study published in *Nature Communications*, a group of researchers from the Departamento de Física Teórica de la Materia Condensada and the Condensed Matter Physics Center (IFIMAC) at the Universidad Autónoma de Madrid show how it is possible to take advantage of the phenomenon of strong light-matter coupling to significantly suppress photoisomerization and similar photochemical reactions. Strong light-matter coupling is a well-known concept in quantum electrodynamics that has received a lot of attention in recent years. A quantum emitter (for example an
organic molecule) and a light mode (a confined photon) become strongly coupled when
the molecule can repeatedly emit a photon into the confined mode and reabsorb it
before it is lost to the environment. The natural states of the system then become new
hybrid states with mixed light-matter properties, known as polaritons. Strong coupling is
chiefly achieved by exploiting the tools of nanophotonics and nanolasmonics, which
allow to create and design structures that can confine light to small spaces of only a few
nanometers, such as in the gap between two metallic nanoparticles as sketched in the
figure.

The researchers show that strong coupling in the molecule-photon system leads to a
change in the energy landscape of the reacting molecule, creating an energy barrier
that blocks the natural pathway from one isomer to the other. Under irradiation with an
external light source (such as sunlight or a laser), the excited light-molecule state
(polariton) then is significantly more stable than a molecule by itself.

Going beyond the single-molecule case, the researchers next studied the case of a
large group of molecules coupled to a single electromagnetic mode. In this situation,
the polariton is formed by distributing the excitation coherently over all of the
molecules, enhancing the effective light-matter coupling. This is the most common way
of achieving strong coupling experimentally. However, previous studies had found that
the collective enhancement does not apply for changes to the internal structure, such
that one could expect that the stabilization of the molecules would disappear in this
setting. In a surprising twist, the opposite turns out to be the case: The researchers
found that the stabilization effect becomes even more pronounced for a large number
of molecules. The reason for this lies exactly in the collective nature of the excitation:
Because it is distributed over many molecules, each molecule spends most of the time
in its chemically stable ground state, which does not undergo isomerization. This leads
to an additional collective protection of the polariton when many molecules are
involved.

The study thus shows that thanks to their hybrid light-matter nature, polariton modes
can be significantly more chemically stable than excitations in bare molecule, and even
more so in the common experimental case of collective strong coupling. This new kind
of collective protection could pave the way towards novel polaritonic materials for
devices such as solar cells. [Full article]