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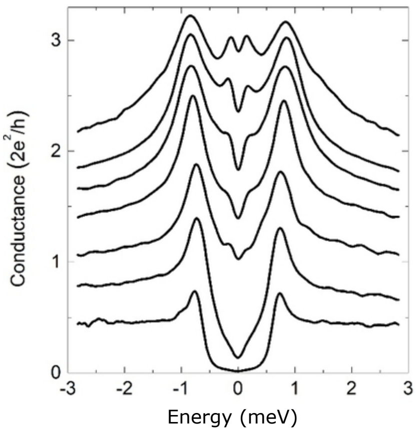
Two energies for a single phase transition

In a superconducting material, below the so-called critical temperature (T_c), the electrons are paired two by two. These pairs, called Cooper pairs, form a state described by the same quantum wave, the condensate. It is this condensed state that explains the superfluidity of electrical transport and in particular the strictly zero electrical resistance of these materials when they are cooled down to temperatures below T_c. In most superconductors, Cooper pairs form and condense simultaneously at T_c. But highly disordered superconductors deviate from this rule.

There is indeed a class of materials where, due to a major disorder (stacking defects, atomic impurities, etc...), and by confinement effects (thin layers of a few nm thick), electrons have difficulty to move above T_c. These materials are therefore close to a ***quantum transition*** to an insulating state, called an Anderson insulator, for which electrons remain localized at absolute zero temperature. Paradoxically, Cooper pairs switch matter between two opposite quantum states: from an Anderson insulator characterized by infinite electrical resistance to a superconductive state of zero resistance (see fact marking "An insulating superconductor"). However, their condensation is delayed by the effect of the disorder and once formed they only condense at a lower temperature.

This two-step superconducting transition is logically driven by two energy scales that researchers from the Irig's Quantum Photonics, Electronics and Engineering Laboratory have highlighted using a scanning tunneling microscope cooled at very low temperatures (50 mK). See Figure for more information.



Tunnel conductance spectra obtained at 50 mK on an amorphous Indium oxide film. The conductance (at – 3mV) is adjusted by varying the distance between the tip of the microscope and the sample.
Researchers at the Pheliqs laboratory recorded spectra for different conductance values. For low conductances (tunnel regime, bottom curve), only two peaks are visible in the spectrum. They characterize the "pseudogap" related to the formation of Cooper pairs (see highlight "What is hidden behind the pseudo-gap?"). On the other hand, for conductances higher than the conductance quantum (2 e^2/h, Andreev reflection regime), an additional pair of peaks emerges in the spectra at a lower energy. It corresponds to the condensation of the Cooper pairs into a superfluid collective state.

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REFERENCE

Dubouchet T, Sacépé B, Seidemann J, Shahar D, Sanquer M and Chapelier C. Collective energy gap of preformed Cooper pairs in disordered superconductors. *Nature Physics*, 2019

A ***quantum phase transition*** is a phase transition between different quantum states. Unlike classical phase transitions, quantum phase transitions are only accessible by varying a physical parameter such as the magnetic field or pressure at a temperature near absolute zero.

Inflammasome and intrauterine growth retardation

Intrauterine growth retardation (IUGR) is one of the main causes of pathological pregnancies that cause different disabilities in children (intellectual, motor, pulmonary...). IUGR also causes other diseases such as diabetes, obesity, hypertension that will develop later in adulthood. In the majority of cases, IUGR is related to a failure in the placenta that does not properly ensure the nutrients and gas exchanges between mother and the fetus. Since 2010, numerous deregulations have been reported in the function of cellular ***inflammasome*** in relation to IUGR.

In 2015, researchers in Cancer Biology and Infection from IRIG institute, were interested in the study of the member 7 of the inflammasome family, the ***NLRP7*** protein. Neither the expression profile nor the biological functions of NLRP7 were known in normal and in IUGR pregnancies. In collaboration with the University Hospital of Grenoble, the maternity hospital of Poissy-Saint-Germain-en-Laye and the Royal Women's Hospital of Melbourne, these researchers demonstrated that the NLRP7 protein is directly involved in the proliferation of placental cells and that it is regulated by ***hypoxia***, the causal parameter of placental insufficiency. They also demonstrated that NLRP7 could contribute to the defects in the establishment of feto-maternal circulation, defects often associated with IUGR. Indeed, the invalidation of the *NLRP7* gene at the ***trophoblast*** level increased the early invasion of trophoblast cells into the maternal endometrium (lining of the uterus). Analysis of sera and placental tissues from cohorts of normal pregnant women and women with IUGR showed an overexpression of NLRP7 and an increase in the inflammatory response.

This work reports for the first time a direct role of the NLRP7 member of the inflammasome family in the control of human pregnancy. Further experiments are needed to understand the potential role of this protein in the development of other pregnancy disorders.

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REFERENCE

Abi Nahed R, Reynaud D, Borg AJ, Traboulsi W, Wetzel A, Sapin V, Brouillet S, Dieudonné MN, Dakouane-Giudicelli M, Benharouga M, Murthi P and Alfaidy N. NLRP7 is increased in human idiopathic fetal growth restriction and plays a critical role in trophoblast differentiation. *Journal of Molecular Medicine* (Berlin), 2019

The ***inflammasome*** is an oligomeric protein complex involved in innate immunity.
NLRP7 is the inflammasome member the most commonly expressed in the placenta.
Placental ***hypoxia*** denotes the decrease in the oxygenation of the placenta.
The ***trophoblast*** is the functional unit of the placenta, responsible for the transfer of nutrients.

A technology licence put into orbit

The space environment is associated with specific constraints including the mechanical resistance related to rocket takeoff, lack of gravity and reliability that are among the most critical. In particular, the reliability constraint or the need of fault-free operation over durations typically from 5 to 10 years leads to the design of systems with non-frictional moving parts or even ideally no moving part at all. The Low Temperature Systems Department (DSBT) is developing ***pulse tube cryocoolers*** that are characterized by the absence of cold moving parts and of which ESA has financed a number of developments at DSBT.

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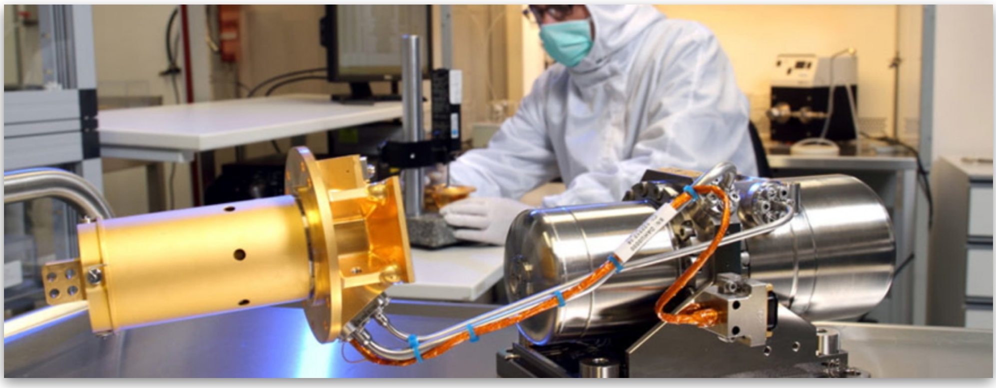
DSBT has been developing pulsed tube cryocoolers for many years. The technology developed at DSBT, very close to Stirling coolers, is characterized by the absence of moving parts in the ***cold part***. This makes this cooler more reliable and limits the level of exported mechanical disturbances (microvibrations) to the sensitive parts of the instruments that host them.

Between 2004 and 2006, a Large Pulse Tube Cooler (LPTC) was jointly developed with Air Liquide and Thales Cryogenics on behalf of ESA with the aim of cooling infrared detectors for earth observation missions. Its ability to generate about 2 watts of cooling power to 50K fits well with the cooling needs of infrared detector arrays with very good signal-to-noise ratio. The first engineering model, developed by the DSBT for the cryogenic cold finger was transferred to Air Liquide which qualified it for space applications. Many technological developments were necessary before the first model to go into orbit on an earth observation satellite. Twelve other models will join it soon in space on Meteosat Third Generation (MTG). These satellites will provide infrared images of the earth and sound the atmosphere to extract information on water vapor and temperature to improve weather forecasting.

Other developments on pulse tube cooler technology have lowered their operating temperature to about 10 K. These low temperature coolers are one of the essential building blocks for thermal architectures of future major astrophysical missions using detectors at very low temperatures.

Pulse tube cryocoolers are cryocooler used to produce temperatures up to 4 K (for ground applications). They consist of a compressor located at room temperature and a ***cold part*** (called cold finger) where the gas expansion takes place which produces the cooling effect. The advantage of pulse tube coolers over other conventional cryocoolers is the absence of a cold moving part, which results in a low level of exported vibration as well as a high reliability and a long life time. Pulse tube coolers are therefore mainly intended for applications where reliability and vibration are critical, such as space missions or the cooling of highly sensitive detectors.



Pulsed tube manufactured by Air Liquide under CEA license to cool the infrared detectors of MTG.

Prion Protein and pulmonary barrier

In 2016, 3,133,000 people were treated for chronic respiratory diseases (CKD), excluding cystic fibrosis. CKDs are characterized by an increase in the permeability of bronchial lumen to antigens and pro-inflammatory molecules. Understanding the pathophysiological causes of the deregulation of this permeability should lead to the development of new therapeutic approaches.

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Bronchial epithelial cells play a central role in maintaining a tight and selective physical barrier by setting up structures called "junction complexes" (JC; see figure), located between the cells. This barrier protects the respiratory tract against pollutants, allergens, fine particles and microorganisms. In infectious and inflammatory pneumopathies such as cystic fibrosis, excessive permeability of this pulmonary epithelium is observed. The molecular mechanisms underlying the increased permeability are poorly understood and deserved to be investigated.

During their study of the mechanisms involved in maintaining JC, researchers at the Irig's Chemistry and Metal Biology Laboratory identified normal cellular prion protein (***PrP^C***) as essential protein that control JC homeostasis. They demonstrated that, in addition to its interaction with JC proteins, ***PrP^C*** contributes to the maintenance of the epithelial barrier by protecting JC proteins from degradation induced by inflammation and copper associated oxidative stress.

These results provide new insight into the role of ***PrP^C*** in the pulmonary barrier defense. Hence, ***PrP^C*** protein should be ranked among proteins involved in the protection of the lung barrier in infectious and inflammatory pneumopathies.

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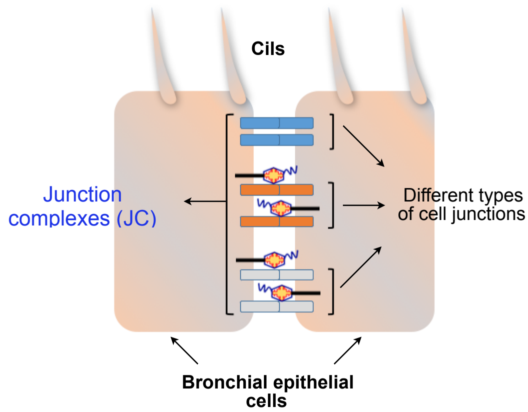

PrP^C is the cellular form of the prion protein which in its infectious form plays a key role in the transmission and pathogenesis of the transmissible spongiform encephalopathies diseases.

The Laboratories

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