# ULTRA-LOW TEMPERATURE COOLER FOR VERY HOT PHOTONS

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**A**thena and other future space missions call for an extended lifetime and ultra-low temperature for some of their detectors. Cryogenic detectors, such as X-IFU on-board Athena, are essential for accomplishing their scientific objectives, offering unique advantages and unmatched performance.

**T**he direct transfer of ground cooling technology to space applications is hindered by at least three problems: the need to survive the launch, operation in zero gravity and finally, the requirement for multi-year missions leading to long-term reliability and, preferably, no consumables. The last requirement leads to the rule that a cooler should be simple, have no friction or better still have no moving parts.

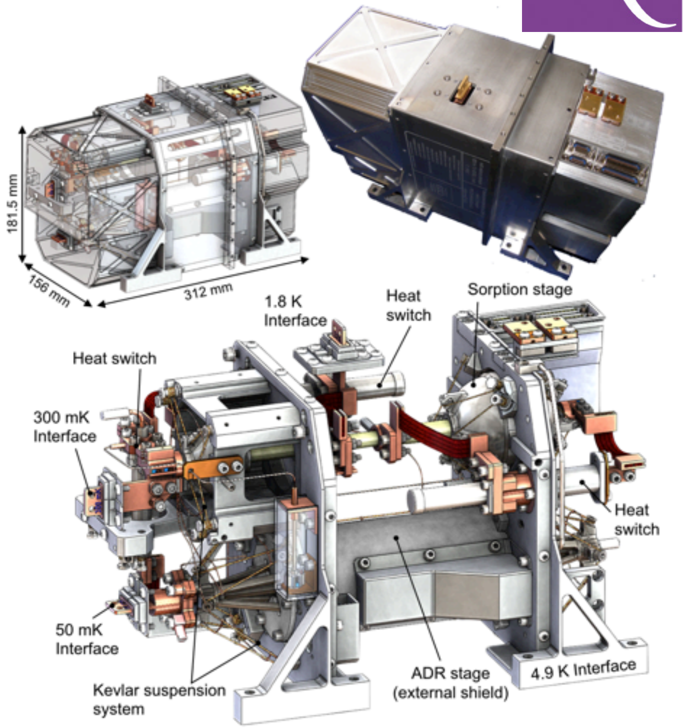
**A** new generation vibration-free hybrid cooler has been developed at CEA-SBT to provide ultra low temperature down to 20 mK while minimising mass, volume and power consumption. The cooler interfaces with the 1.8 K and 4.9 K heat sinks provided by the upper cryogenic chain featuring pulse tube and Joule-Thomson coolers. The hybrid cooler is self-contained, fits in 18x16x31 $cm^3$ and weighs about 5 kg, the lightest in its category. Mass is a critical driver and a clear objective is to maximise the amount of onboard science within the overall mass allocation.

**T**his hybrid cooler is a combination of an evaporative helium sorption stage and a miniature adiabatic demagnetization refrigerator (ADR), providing cooling at the two targeted temperatures for X-IFU, 300 mK and 50 mK.

**H**elium sorption cooling has earned worldwide renown, following its successful implementation for the SPIRE and PACS instruments, on board the Herschel space observatory. It relies on the capability of porous materials to adsorb or release a gas when cyclically cooled or heated. Using this physical process, compression and pumping can be combined to condense a liquid and then perform evaporative pumping on the liquid bath, namely helium 3, to reduce its temperature to 300 mK.

**F**rom this base temperature, a miniature ADR stage takes over to lower the ultimate temperature to 50 mK. A limited magnetic field (≈ 1 T) is used to force the electronic spins of the atoms of a paramagnetic salt to align, thereby transferring magnetic entropy to thermal entropy. Heat is dissipated to the 300 mK interface. Once the salt has been thermally isolated by means of an efficient gas-gap heat switch, the field is reduced producing a cooling effect through the inverse transfer of entropy. Both stages are one-shot systems: the operation is a succession of a recycling phase followed by a cold operating phase. They both can be recycled indefinitely. Duty cycles higher than 75-80% can be obtained depending on the available cooling power at the 1.8 and 4.9 K heat sinks mentioned above.

**T**he cooler features no moving parts and is cycled and controlled using only heaters, current wires and thermometers. It holds the required level of maturity for space applications having passed a stringent qualification program. X-IFU will benefit from these advantages to provide its outstanding science.




Engineering Model cooler developed for the SAFARI instrument on-board the SPICA satellite. The cooler has been qualified to TRL 6. 3D views: Credit F. Bancel (SBT)