

## SHORT-LIVED RADIONUCLIDES IN THE FIRST SOLAR SYSTEM SOLIDS: CURRENT PARADIGM AND ON-GOING DEVELOPMENTS

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**Introduction:** Calcium-aluminium-rich inclusions (CAIs), the first solids to have condensed out of the gaseous nebula surrounding the nascent Sun, represent direct witnesses of the processes that set the initial architecture of our solar system. In particular, CAIs preserve evidence that short-lived radionuclides (SLRs; e.g., <sup>10</sup>Be, <sup>26</sup>Al, <sup>41</sup>Ca, <sup>60</sup>Fe) with half lives < 5Myr were present during the earliest phases of our solar system's build-up [1]. However, the source(s) of SLRs in the CAI-forming region, as well as the heterogeneous nature of their overall distribution across the solar system, remain highly uncertain. It is unclear whether the occurrence of SLRs in CAIs represent the inheritance of the long-term chemical evolution of the Galaxy, early injection into the solar system by a nearby supernova, and/or traces of early solar irradiation (e.g., [1-4]). These information are yet crucial for understanding the birth environment and formation timescales of the solar system, as well as the nature and extent of early solar irradiation processes. Fossil records of solar irradiation have the potential to inform us about the nature (gradual vs. impulsive flares) and magnitude of the young Sun's activity, the cosmolocation of the CAI factory, and the process(es) accounting for their efficient transport to the outer Solar System [5], where they were accreted into carbonaceous asteroids.

Among the SLRs whose former existence in the solar nebula has been demonstrated, <sup>26</sup>Al (decays to <sup>26</sup>Mg,  $t_{1/2} = 0.7$  Myr) and <sup>41</sup>Ca (decays to <sup>41</sup>K,  $t_{1/2} = 0.1$  Myr) have attracted increasing interest since the proposal of their correlated presence/absence in CV chondrite CAIs and CM chondrite refractory hibonite grains [6-8]. A synchronous decay between <sup>26</sup>Al and <sup>41</sup>Ca would indeed suggest that the two radionuclides were homogeneously distributed in the solar nebula, and that the Al-Mg and Ca-K systems can be used as chronometers. In 2012, the reanalysis of the Ca-K system with an advanced analytical technique however led to an order of magnitude revision of the initial <sup>41</sup>Ca/<sup>40</sup>Ca in the solar system [9]. Even then, the major interference of (<sup>40</sup>Ca<sup>42</sup>Ca)<sup>++</sup> at mass 41 could not be resolved under any available mass resolution ( $M/\Delta M = 34,000$  is needed) [9]. Recent <sup>41</sup>Ca-<sup>41</sup>K isotopic data acquired for two Type A CAIs from the Vigarano CV3 chondrite using this technique were combined with Al-Mg systematics to suggest that <sup>41</sup>Ca distribution was actually not homogeneous when <sup>26</sup>Al was widespread at the canonical level [10]. Such a <sup>41</sup>Ca heterogeneity could reflect the effect of *in-situ* charged particle irradiation by the protoSun in the solar nebula. High precision measurements of <sup>41</sup>Ca/<sup>40</sup>Ca in CAIs are clearly needed to shed light on the source(s) of <sup>41</sup>Ca in the early solar system, and determine whether or not the Ca-K system constitutes a reliable chronometer for early solar system formation.

**Research project:** We have carried out *in-situ* <sup>26</sup>Al-<sup>26</sup>Mg and <sup>41</sup>Ca-<sup>41</sup>K analyses in a series of coarse-grained CAIs from the Efremovka (including the well characterized CAI E101.1 [11]), Vigarano, and Allende (CAI 3529-Z [12]) CV3 chondrites, as well as a Forsterite-bearing Type B CAI (from Allende, bulk  $\Delta^{17}\text{O} = -12\%$ ) exhibiting remarkable internal zoning structures revealed by high-resolution cathodoluminescence imaging. This study takes advantage of the new generation Cameca 1280 HR2 SIMS (Nancy, France) recently equipped with a stable, high-density radio frequency primary ion source. In collaboration with the Cameca firm, we have recently developed new acquisition cards for faraday cups ( $10^{12} \Omega$ ) allowing for significantly higher sensitivity and stability during analysis. The unique equipment and design of the CRPG Cameca 1280 HR2 SIMS offers the possibility to perform high mass resolution ( $\geq 30,000$ ) measurements enabling, for the first time, resolution of the major interference of (<sup>40</sup>Ca<sup>42</sup>Ca)<sup>++</sup> at mass 41. We present our most recent analytical developments allowing for high precision <sup>41</sup>Ca/<sup>40</sup>Ca analyses of CAIs, which we interpret in combination with <sup>26</sup>Al-<sup>26</sup>Mg systematics to identify the source(s) of <sup>41</sup>Ca in the early solar system.

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