Evolution of the Solar System: The first ten million years

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The collapse of a rotating interstellar molecular gas and dust cloud, more than 4.5 billion years ago, led to the formation of the proto-Sun with a gas and dust envelope around it. Gravitational effects of the proto-Sun led to settling of gas and dust leading to the formation of a disk around the early sun. Astronomical observations of young sun-like stars confirm the validity of such a scenario. The initial temperature in this environment was very high and the first solar system solids to form will be highly refractory in nature, such as oxides of Al, Ca and Ti. Even though rare, such refractory grains are present in primitive meteorites.

To follow the evolution of the solar system, we need information on absolute and relative time scales of the various solar system events, starting from the formation of the first grain to the formation of the planets. In general, long-lived radionuclides (e.g. isotopes of Uranium and Thorium) present in solar system objects can serve as internal clocks and provide their absolute ages. However, they are not sensitive enough to precisely infer relatively small time differences of few million years between events taking place during the very early evolution of our solar system.

The discovery of fossil records of the now-extinct short-lived nuclide Iodine-129 (half-life ~16 million years) in a meteorite in 1960, opened up the possibility of inferring relative time scales of events in the early solar system and it was proposed that formation of various proto-planetary objects took place within fifty to hundred million years. Since then records of a good number of now-extinct short-lived nuclides (^{41}Ca, ^{36}Cl, ^{26}Al,^{10}Be, ^{135}Cs, ^{60}Fe, ^{107}Pd, ^{53}Mn, ^{182}Hf, ^{129}I) with half-life ranging from 0.1 Ma (^{41}Ca) to 15.7 Ma (^{129}I), have been found in early solar system objects that allow one to make more robust estimates of relative time scales of early solar system events and processes. Studies of fossil records of now-extinct nuclides in solar system objects suggest (i) a triggered collapse of the proto-solar cloud leading to the origin of our solar system, (ii) a very short duration of less than a million years for the formation of the first solar system grains, (iii) a rapid process of growth leading to formation of large objects such as primitive and differentiated asteroids, the parent bodies of various meteorites, in less than ten million years.

This view of evolution of the early solar system emerged from the results of isotopic studies of pristine early solar system solids done across the globe using mass spectrometry techniques. A summary of our current understanding, highlighting some of the work done in India that led to several important breakthroughs in the field, will be presented.