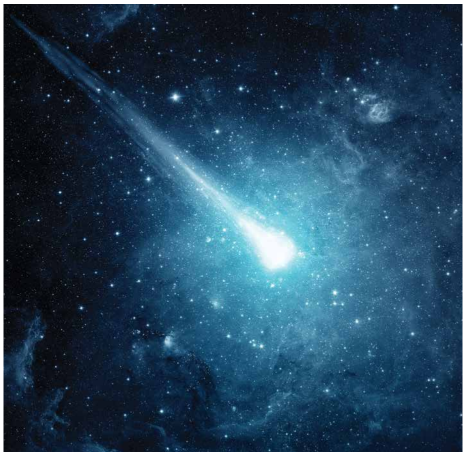
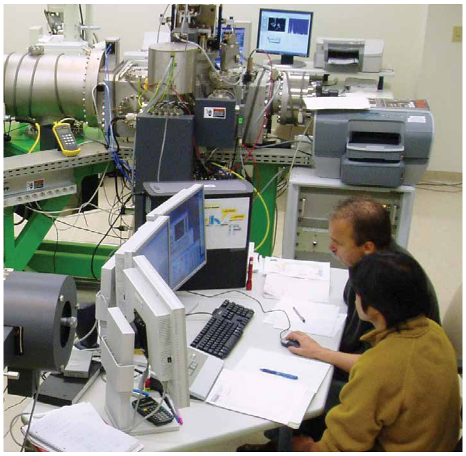
Probing cosmochemical conundrums with a CAMECA SIMS at the University of Hawai‘i

A SUCCESS STORY





CAMECA SIMS Advantages

- Ultra-high sensitivity magnetic sector SIMS
- In-situ microscale isotopic & elemental analyses

- Superior tunability
- Ensured stability
- Utmost versatility

- Cosmochemistry
- Geochronology
- Trace elements
- Environmental studies

The Challenge

What went on in the early Solar System? Almost all the evidence has been gone for billions of years. Can we ever know how and when our Sun and planets formed, and from what?

Gary Huss and his colleagues are determined to find out. A research professor and director of the W. M. Keck Cosmochemistry Laboratory in the Hawai‘i Institute of Geophysics and Planetology (HIGP) at the University of Hawai‘i, Dr. Huss facilitates a wide range of cosmochemical tasks and other projects at the lab, working with scientists worldwide.

One recent line of enquiry involved samples, from the Smithsonian Institution, of two already much-studied objects: the Kaba and Allende meteorites.

Some challenging questions remained: when did certain changes in these objects' composition take place? In the earliest stage of nebular cloud collapse? In the later accretion disk of gas and dust containing embryonic material for the Sun and planets? Or in an even later asteroid body from which the meteoritic material finally separated?

The Instrument

To conduct its investigation, the facility relied on its chief tool. “The core of our laboratory is our IMS 1280 ion microprobe,” states Professor Huss.

This large-geometry magnetic sector secondary ion mass spectrometer (SIMS) is made by CAMECA — the world's only supplier of this advanced technology. The HIGP's instrument features two ion sources (a cesium source and a newer Hyperion oxygen plasma source), multi-detection capability configurable via combinations of electron multipliers and Faraday cups, and a SCAPS solid-state imaging detector developed by lab manager Dr. Kazuhide Nagashima. (The HIGP team also plans to upgrade their IMS 1280 with a low-noise detector to share some advantages of the newest CAMECA SIMS model, the IMS 1300-HR^3.)

Prof. Huss has used CAMECA instruments since 1991, at Caltech and then Arizona State. In 2005, when asked to establish a new cosmochemistry lab at U. Hawai‘i, he raised extra funds to procure the IMS 1280.

"In 2 to 3 hours," he says, "we can tune this machine to measure almost any system we're interested in. It's also very stable. You set it up, and you don't have to worry about it.

"And it's extremely versatile. We can do high-precision spot measurements. We can use it for isotope mapping with direct ion imaging (using the SCAPS detector) at a high spatial resolution of about 1 micron. We can do scanning ion imaging — make a sub-micron beam, step it very precisely across the sample, and get an isotope map of about a 50-micron area. We can do concentration and isotope profiles. We can do multi-collection, measuring many isotopes of the same element at the same time. We can do depth profiles. We can do energy filtering, which allows us to measure trace elements. Because it's so flexible, we can measure almost all of the Periodic Table."

The Work

For these recent studies, small polished cross-sections from the Kaba and Allende carbonaceous chondrite meteorites were initially characterized for mineral content. The team then conducted a series of more precise measurements via the IMS 1280, using direct ion images, spot measurements, and other techniques.

"The problem is sorting out signals from different time periods," says Prof. Huss. "But by selecting the right sample and choosing the right way to measure it, everything collapses to a point on the diagram which tells you what the original material was before it was altered."

The Results

Findings showed that calcium aluminum-rich inclusions (CAIs) in Kaba are only slightly altered, with many measurements showing ^{16}O-rich oxygen like that of the Sun. Preliminary aluminum-magnesium dates indicate early formation. By contrast, oxygen isotopes in Allende CAIs scatter all along the mixing line between ^{16}O-rich Solar-like oxygen and ^{16}O-poor planetary disk compositions. Allende CAIs experienced significant metasomatic alteration, which changed their chemical composition, mineralogy, and texture. Such alteration occurred at moderately high temperature in the presence of water, probably on the parent asteroid. Like the Kaba CAIs, Allende CAIs are among the oldest objects in the solar system, although their asteroidal histories are very different.

These results suggest three distinct stages in CAI history: (1) formation during the first half-million years of the Solar System, (2) transport to the place where each meteorite parent body formed, and (3) different degrees of alteration on the parent bodies. The samples then came to Earth as meteorites.

"As this early series of events becomes clear, we can compare our Solar System with telescopic observations of other stellar systems," Prof. Huss says. "A key question outstanding is how to merge the sequence of events inferred from cosmochemistry with the sequence that telescopes show. We now have a real chance of solving this problem."

The Future

Soon a major focus for the lab should be materials coming from a pair of asteroid study and sample return space missions — the American OSIRIS-REx and the Japanese Hayabusa 2.

But actually, with the HIGP team's expertise (and the right instrument), the possibilities are boundless. "If it is scientifically of interest," says Prof. Huss, "we'll try anything. For example, if you want to understand what hydrogen is doing in the interior of the Moon, you have a good sample, and we can make a measurement that addresses your problem, we will do that."

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About the Lab

The W. M. Keck Cosmochemistry Laboratory, established in 2006 at the University of Hawai'i, Honolulu, is a catalyst for interdisciplinary research into the origin of the Solar System. The facility's cosmochemical work utilizes samples of meteorites and interplanetary dust particles (IDPs), as well as samples returned from the Moon, comet Wild 2, asteroid Itokawa, and even the Sun (solar wind) via missions operated by NASA, JAXA, and ESA. The Keck facility welcomes researchers from around the world for collaborative investigations.

www.higp.hawaii.edu/cosmochemistry

About CAMECA

CAMECA is a world-leading supplier of microanalytical and metrology instrumentation for research and process control. Our instruments measure elemental and isotopic composition in materials down to atomic resolution. Advanced CAMECA technologies include secondary ion mass spectrometry (SIMS), atom probe tomography (APT), electron probe microanalysis (EPMA), and low-energy electron-induced X-ray emission spectrometry (LEXES). We address challenging characterization needs in diverse markets, from cosmochemistry, geology, and life sciences to environmental, nuclear, materials, and semiconductor research.