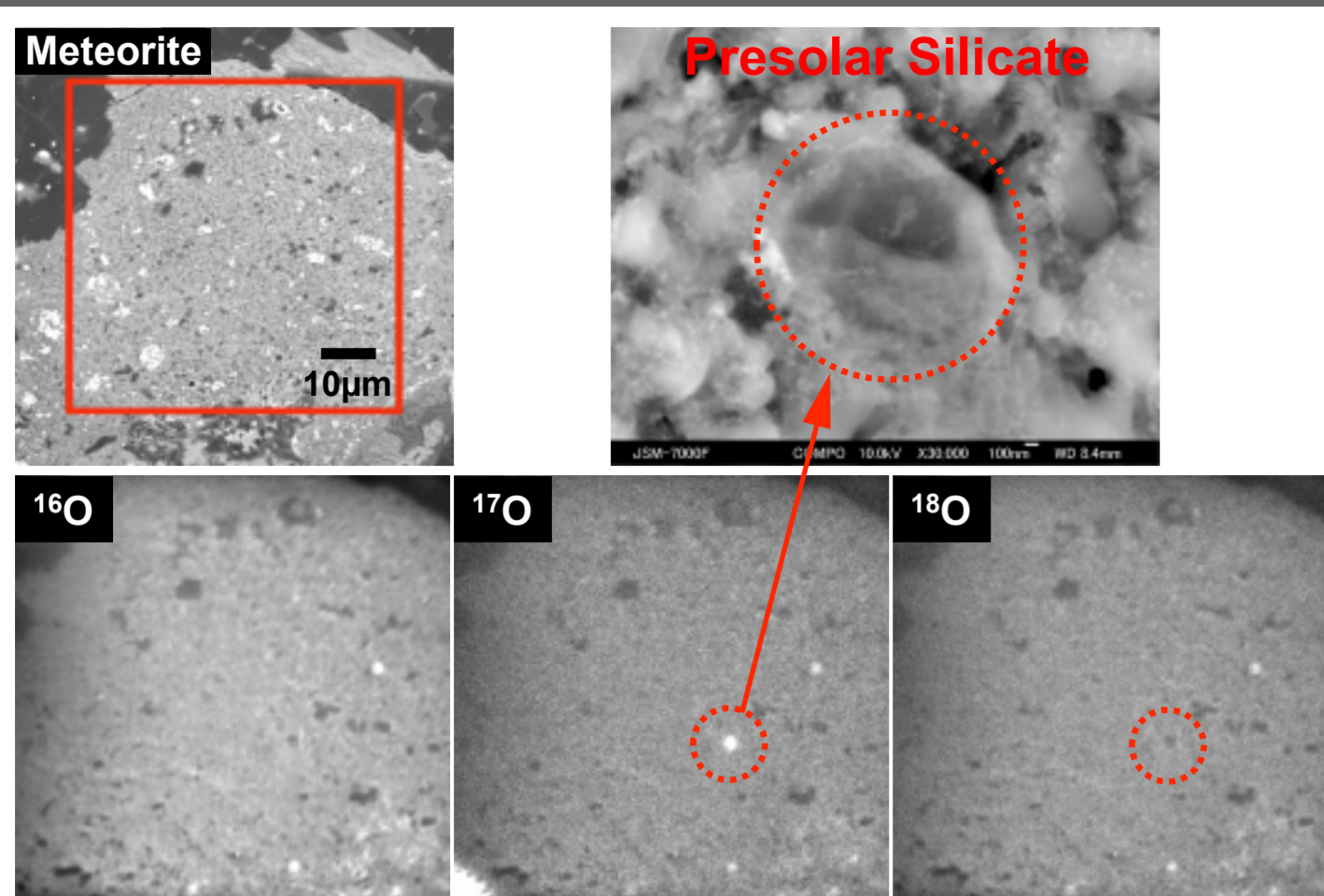


# Stigmatic Isotope Imaging Method for Biology and Cosmochemistry

Naoya Sakamoto and Hisayoshi Yurimoto

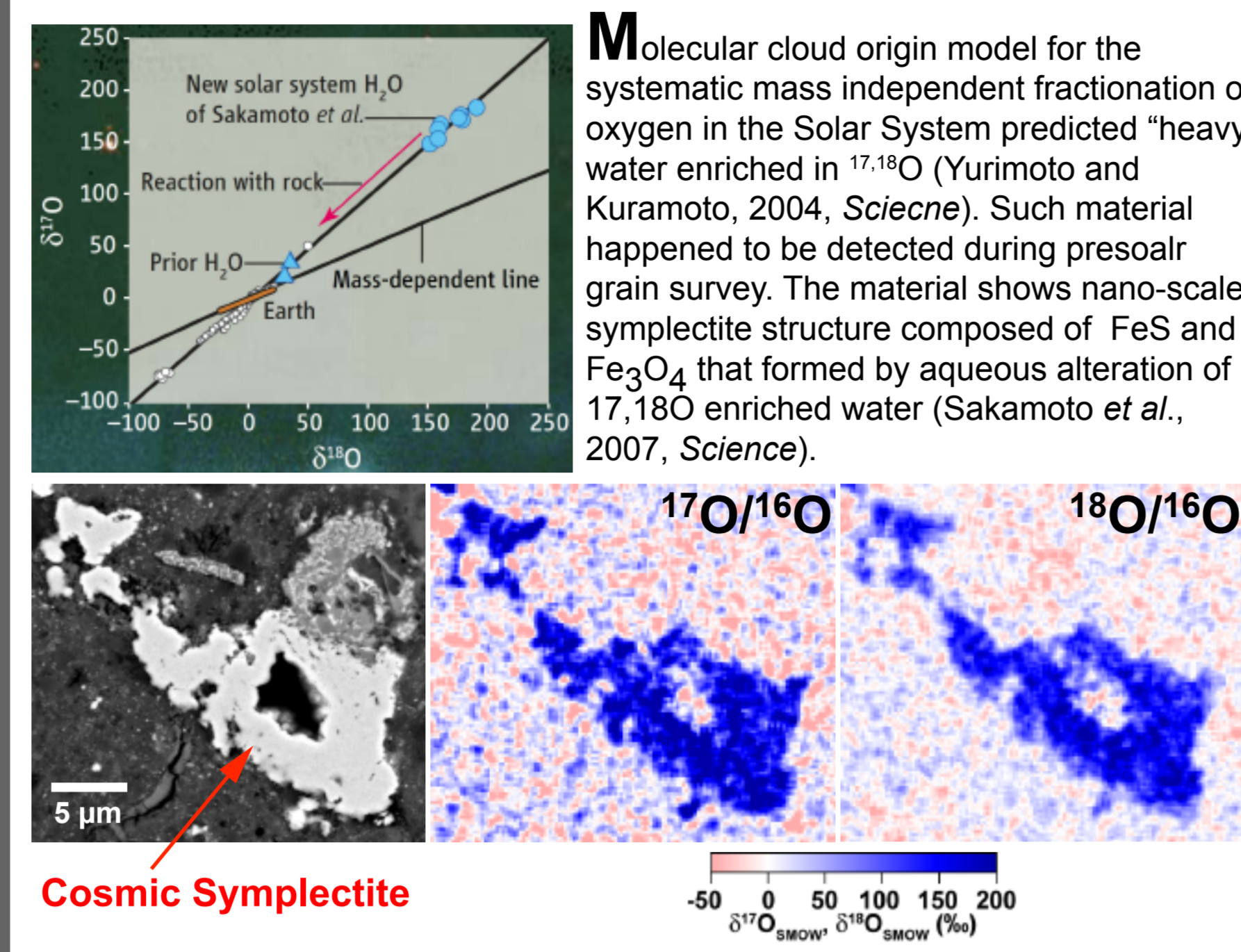
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## Presolar Grain



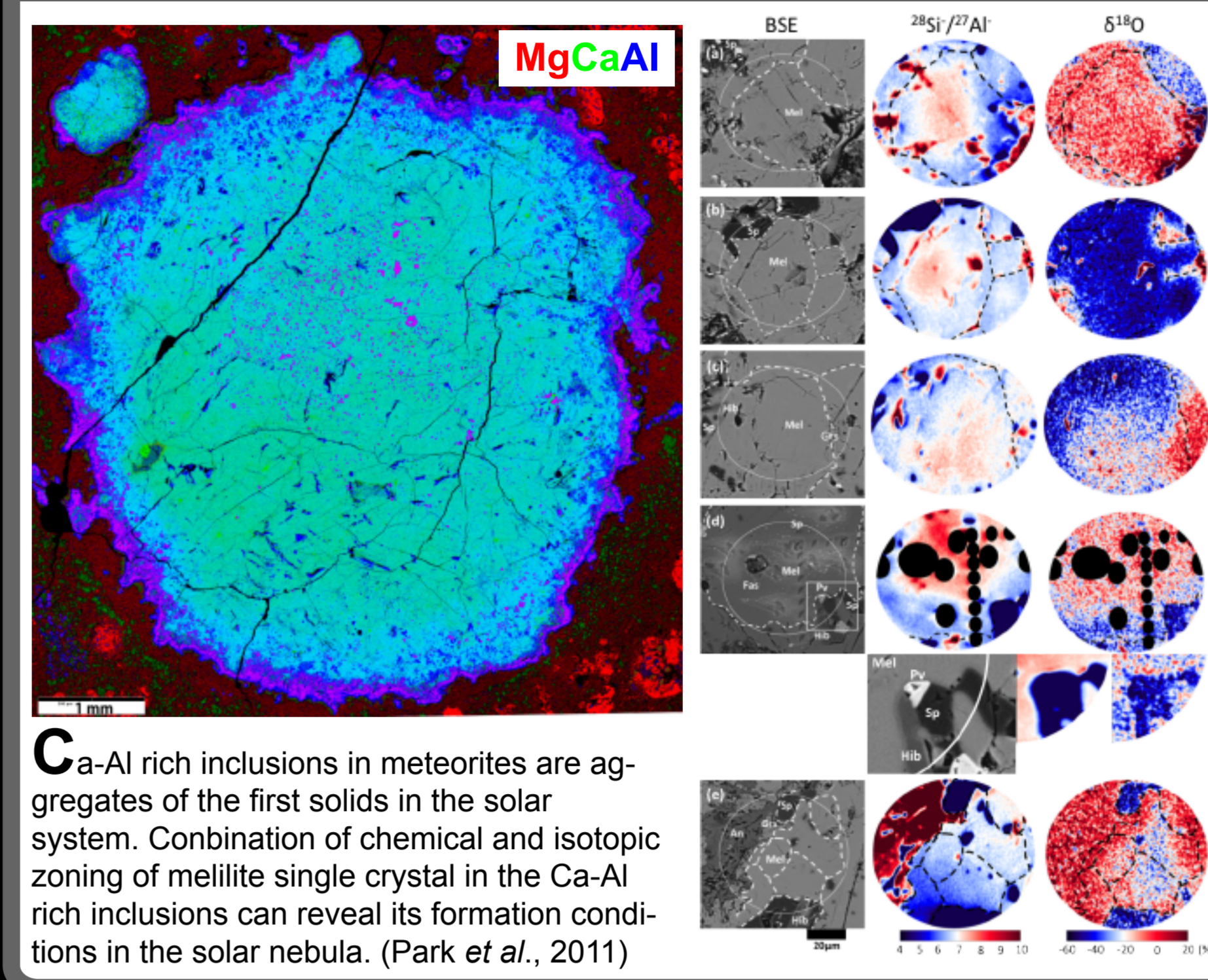
Meteorites contain isotopically anomalous grains thought to be of extrasolar origin. Stigmatic isotope imaging allows us to survey in broad area quickly. (Nagashima *et al.*, 2004, *Nature*)

## Molecular Cloud Water



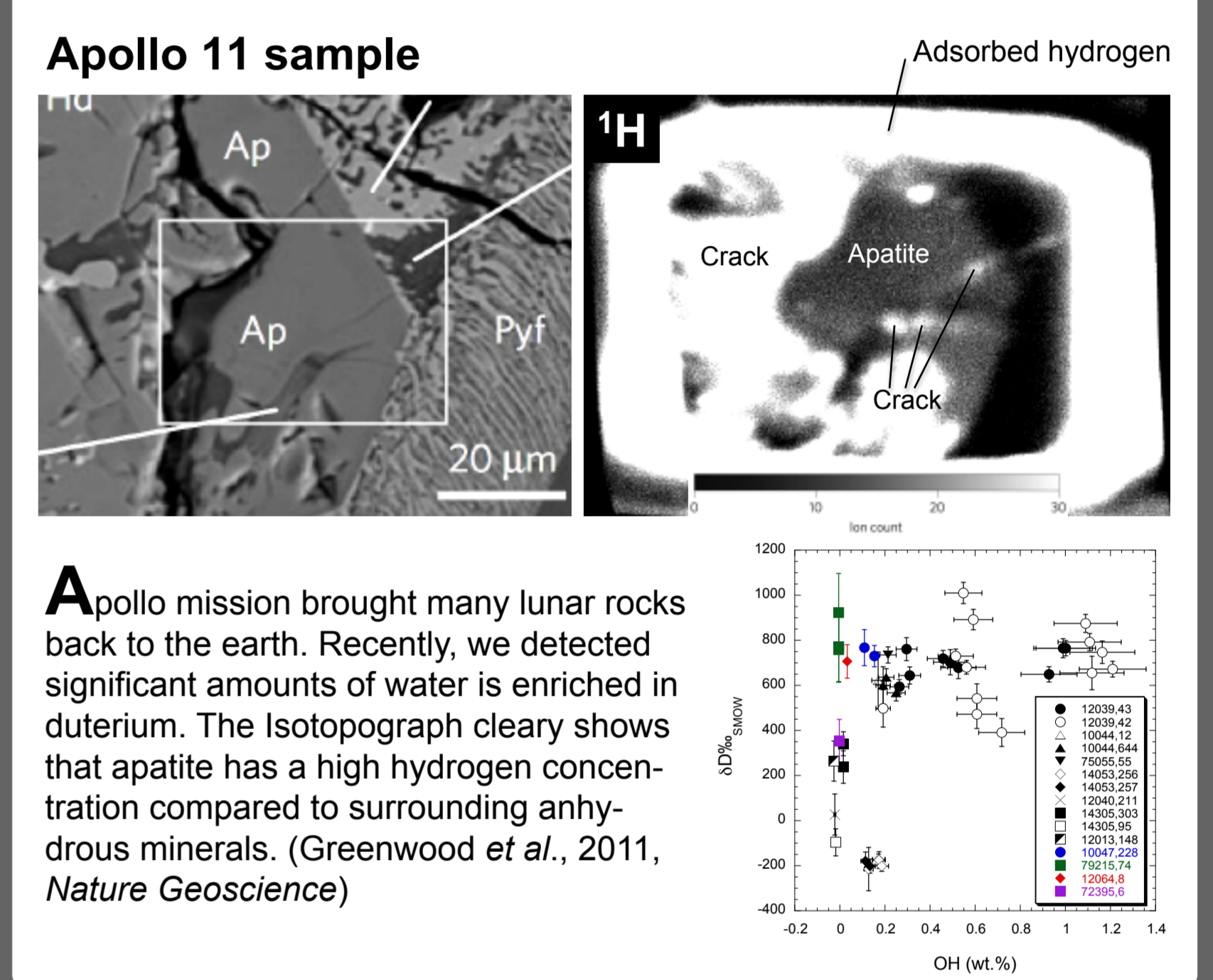
Cosmic Symplectite

## First Solid in the Solar System



Ca-Al rich inclusions in meteorites are aggregates of the first solids in the solar system. Combination of chemical and isotopic zoning of melilite single crystal in the Ca-Al rich inclusions can reveal its formation conditions in the solar nebula. (Park *et al.*, 2011)

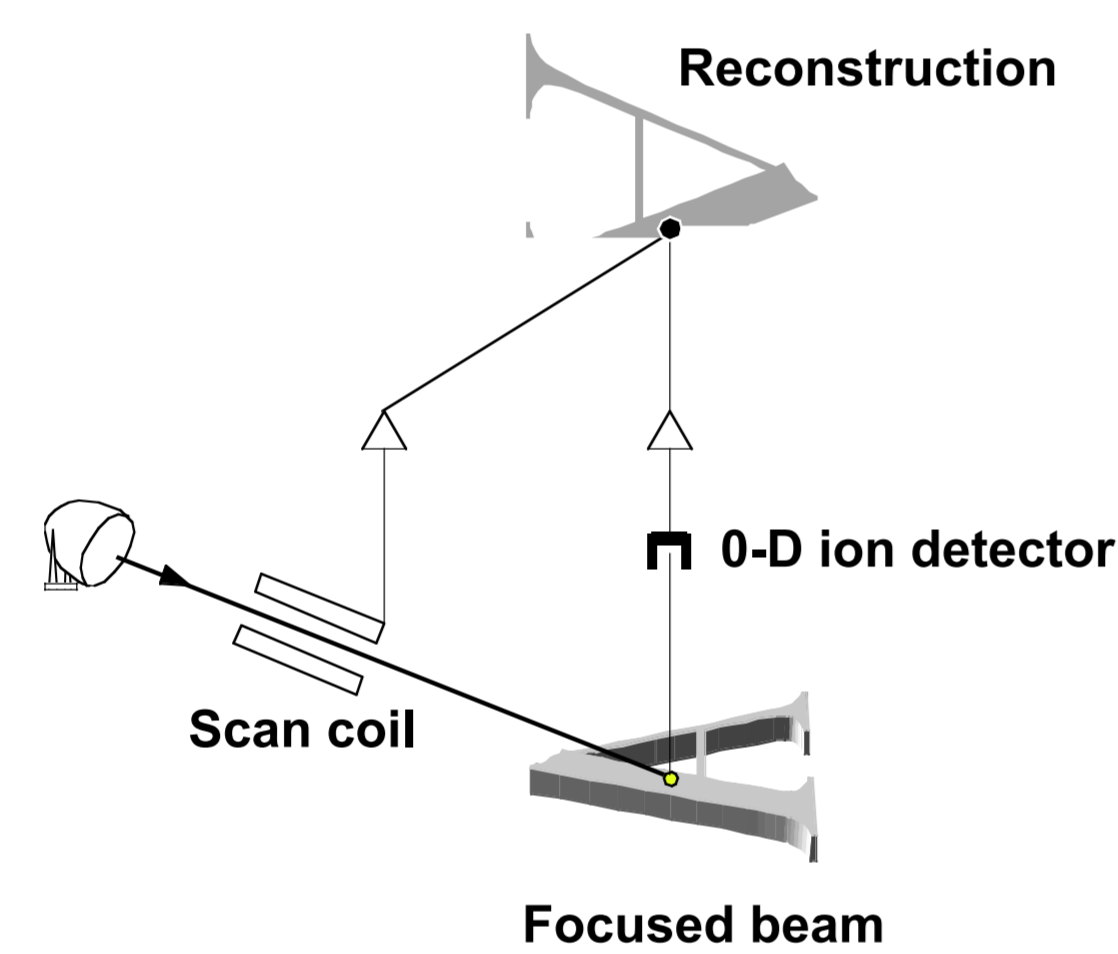
## Moon Water



Apollo mission brought many lunar rocks back to the earth. Recently, we detected significant amounts of water is enriched in deuterium. The isotopograph clearly shows that apatite has a high hydrogen concentration compared to surrounding anhydrous minerals. (Greenwood *et al.*, 2011, *Nature Geoscience*)

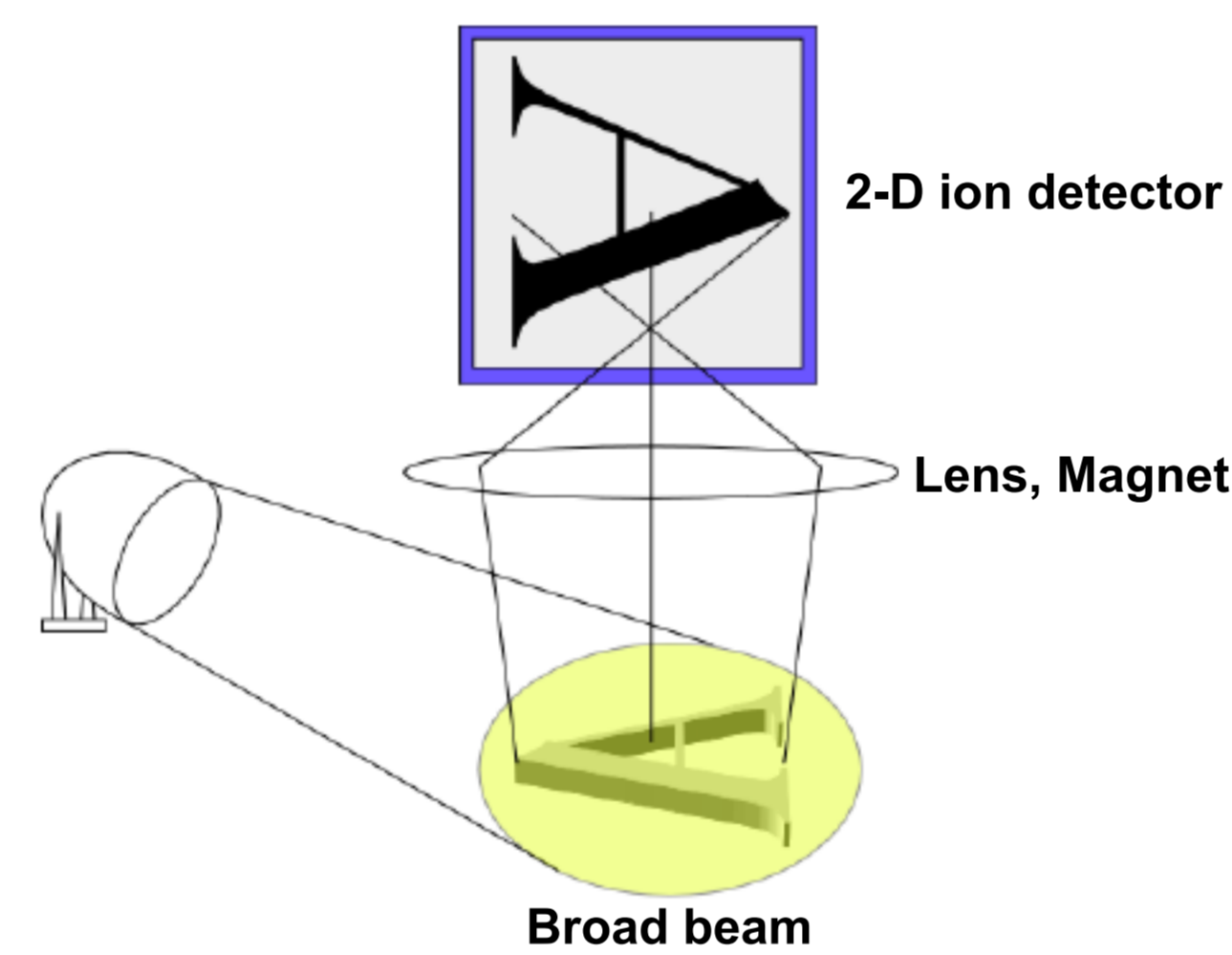
## Stigmatic Isotope Imaging

### Scanning



- High spatial resolution with a fine probe size
- Long measurement time for wide area
  - High precision analysis is difficult for wide area

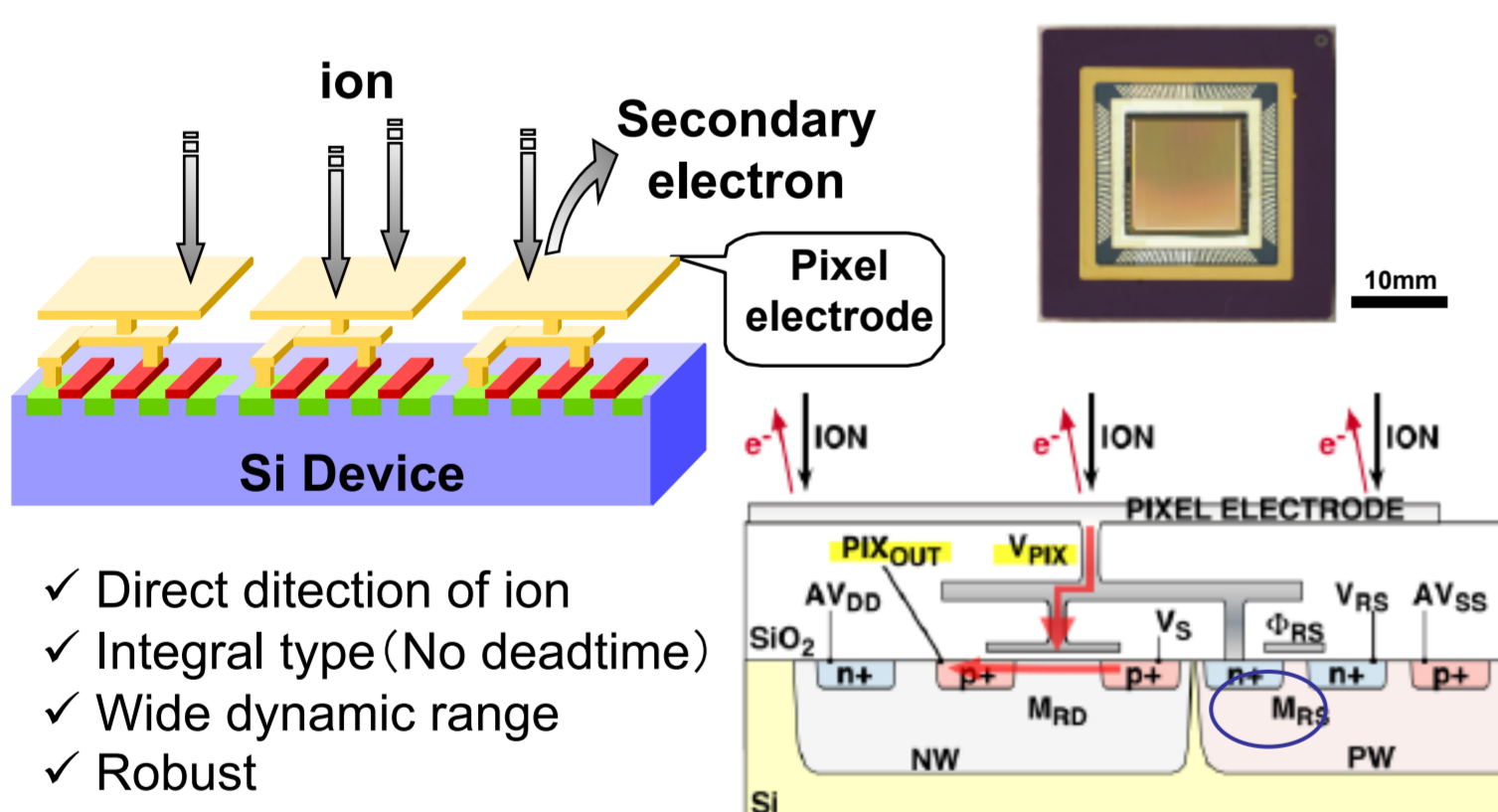
### Stigmatic



- Spatial resolution is limited by ion optics
- Wide area with high Intensity signals
  - High precision analysis

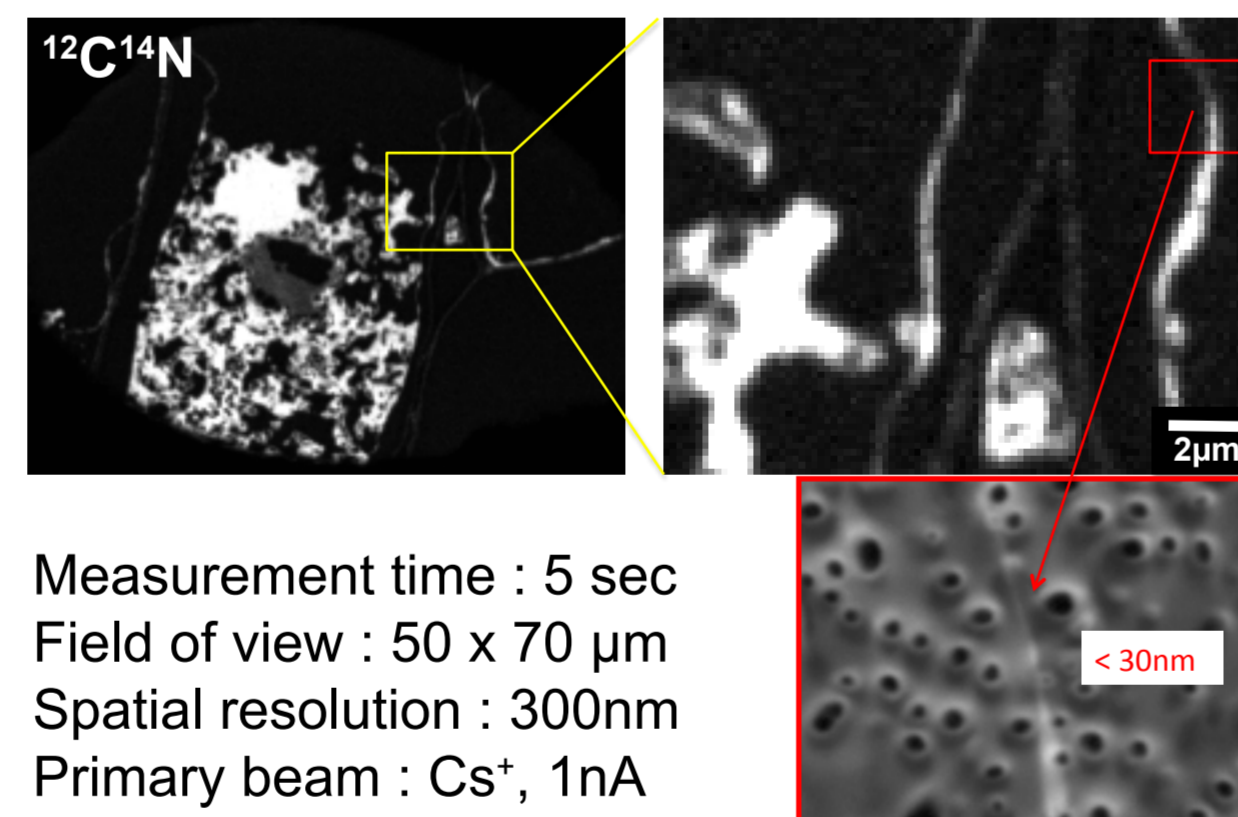
## 2-D Ion Detector "SCAPS"

### SCAPS (Stacked CMOS Active Pixel Sensor)



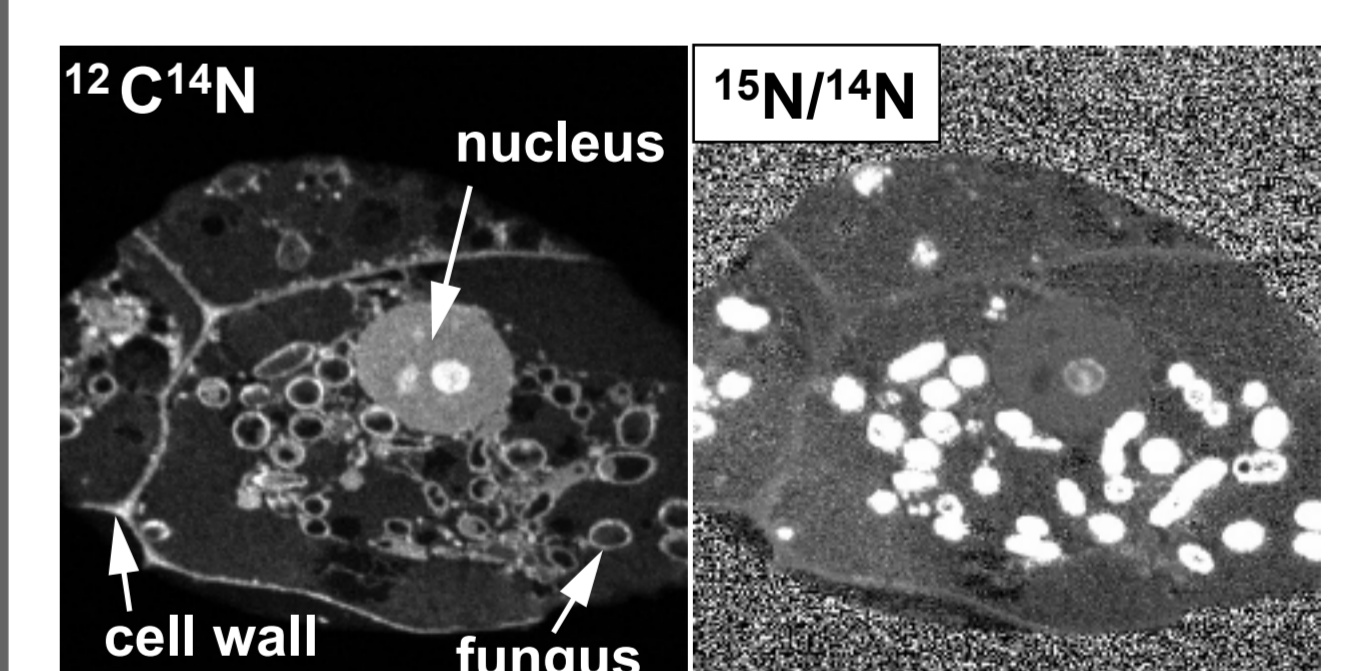
- ✓ Direct detection of ion
- ✓ Integral type (No deadtime)
- ✓ Wide dynamic range
- ✓ Robust

### Performance (in case of ims1270)



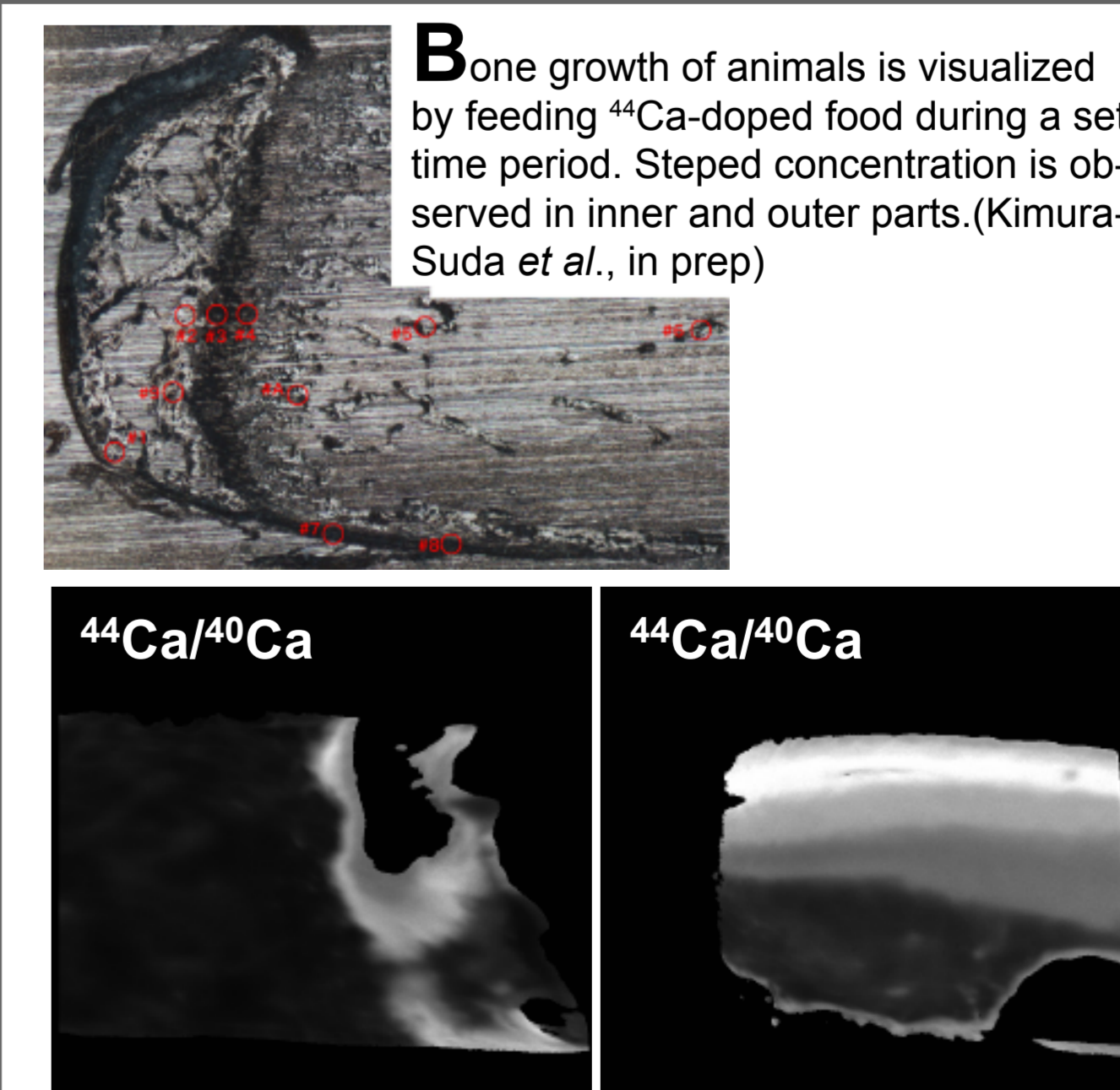
Measurement time : 5 sec  
Field of view : 50 x 70 μm  
Spatial resolution : 300nm  
Primary beam : Cs<sup>+</sup>, 1nA

## Mutualism in Plants



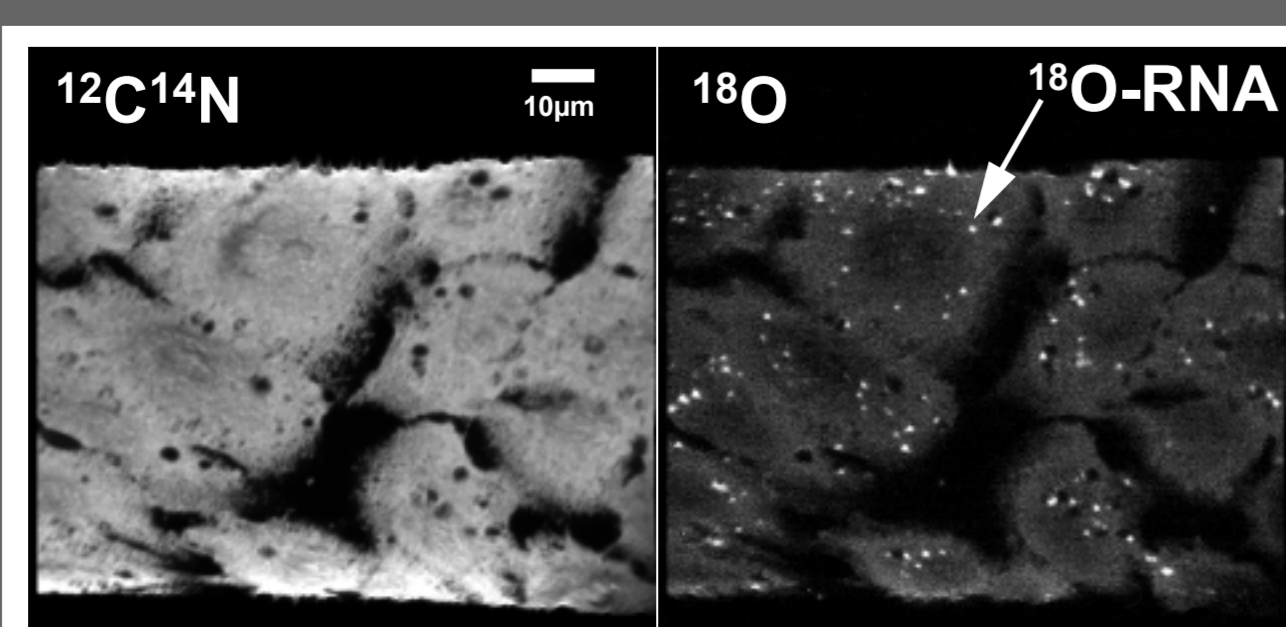
Fungus penetrates the cells of the roots of a vascular plant and interacts materially. Isotopographs show dynamical exchange of <sup>15</sup>N-doped fertilizer between a plant and arbuscular mycorrhiza. (Kuga *et al.*, in prep)

## Bone growth



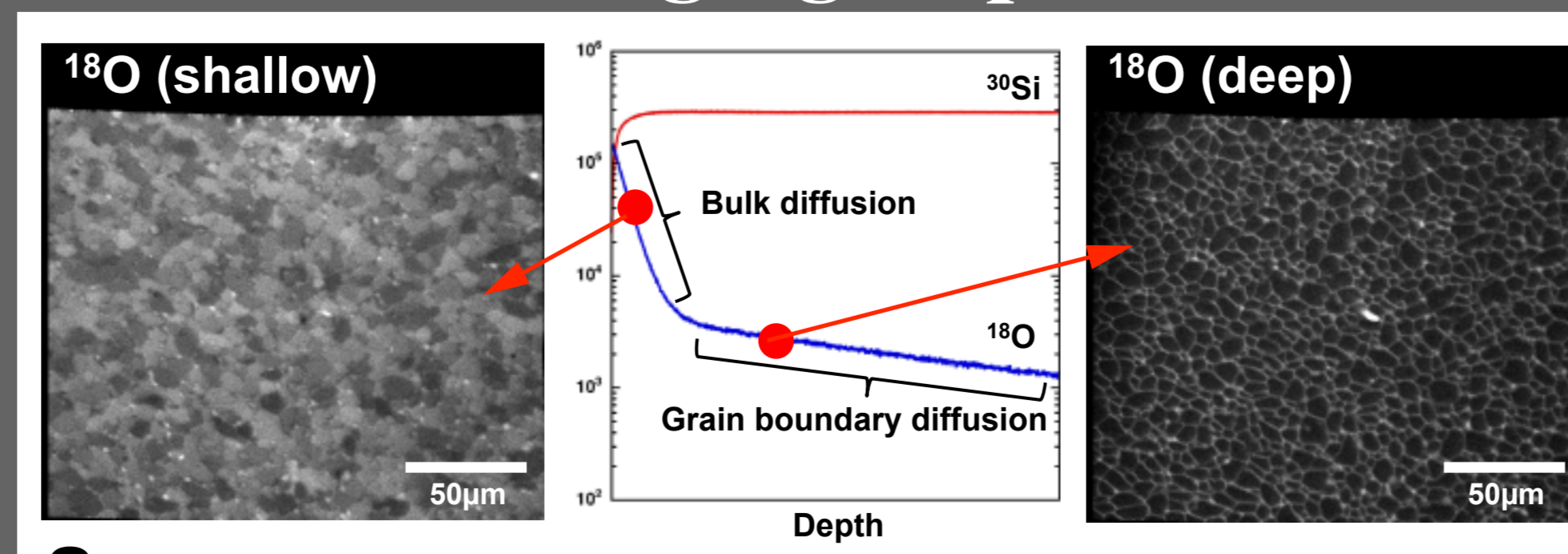
Bone growth of animals is visualized by feeding <sup>44</sup>Ca-doped food during a set time period. Stepped concentration is observed in inner and outer parts. (Kimura-Suda *et al.*, in prep)

## Gene



The demand of visualization methods without additional tracer disturbing the natural environments is increasing in the medical field. The isotopograph shows incorporation of <sup>18</sup>O-doped RNA into cells. (Hamasaki *et al.*, in prep).

## Imaging Depth



Stigmatic imaging method realizes practical imaging depth profiling because probe current can increase without degradation of spatial resolution. Figures show snapshots from <sup>18</sup>O imaging depth profiling for <sup>18</sup>O-diffused ZnO polycrystal (Sakaguchi *et al.*, in prep).