MSRI
Mathematical Sciences Research Institute

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NOTETAKER CHECKLIST FORM

(Complete one for each talk.)

Name: Malgorzata Marciniak **Email/Phone:** mmarciniak@lagcc.cuny.edu 5734620411

Speaker's Name: Dilworth (Dula) Parkinson

Talk Title: Shape and structure challenges from users of the 3D micron-scale imaging beamline at the Advanced Light Source (Studying shapes with microCT)

Date: 10 /01 /2018 **Time:** 2 :00 **am / pm (circle one)**

Please summarize the lecture in 5 or fewer sentences:

Micro CT, known as X-rays, can be used for analyzing various micro structures. The talk focused on: flexible rocks (Packed Quartz Grains Separated by Voids), spider evolution (jaws and muscles that close them), analysis of hotter engines (crack structure and composites), flow through rocks (with capturing and storing of underground CO2), leaf porosity to understand how leaves optimize photosynthetic performance under a range of environmental conditions.

CHECK LIST

(This is **NOT** optional, we will **not pay** for **incomplete** forms)

- ☑ Introduce yourself to the speaker prior to the talk. Tell them that you will be the note taker, and that you will need to make copies of their notes and materials, if any.
- ☑ Obtain ALL presentation materials from speaker. This can be done before the talk is to begin or after the talk; please make arrangements with the speaker as to when you can do this. You may scan and send materials as a .pdf to yourself using the scanner on the 3rd floor.
  - **Computer Presentations**: Obtain a copy of their presentation
  - **Overhead**: Obtain a copy or use the originals and scan them
  - **Blackboard**: Take blackboard notes in black or blue **PEN**. We will **NOT** accept notes in pencil or in colored ink other than black or blue.
  - **Handouts**: Obtain copies of and scan all handouts
- ☑ For each talk, all materials must be saved in a single .pdf and named according to the naming convention on the "Materials Received" check list. To do this, compile all materials for a specific talk into one stack with this completed sheet on top and insert face up into the tray on the top of the scanner. Proceed to scan and email the file to yourself. Do this for the materials from each talk.
- ☑ When you have emailed all files to yourself, please save and re-name each file according to the naming convention listed below the talk title on the "Materials Received" check list. (*YYYY.MM.DD.TIME.SpeakerLastName*)
- ☑ Email the re-named files to notes@msri.org with the workshop name and your name in the subject line.

Studying shapes with microCT

Dula Parkinson

Advanced Light Source

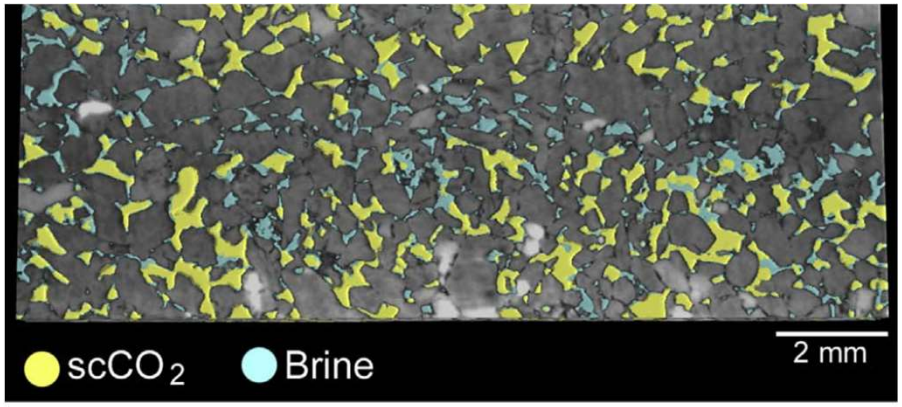
Center for Advanced Mathematics for Energy Research Applications (CAMERA)

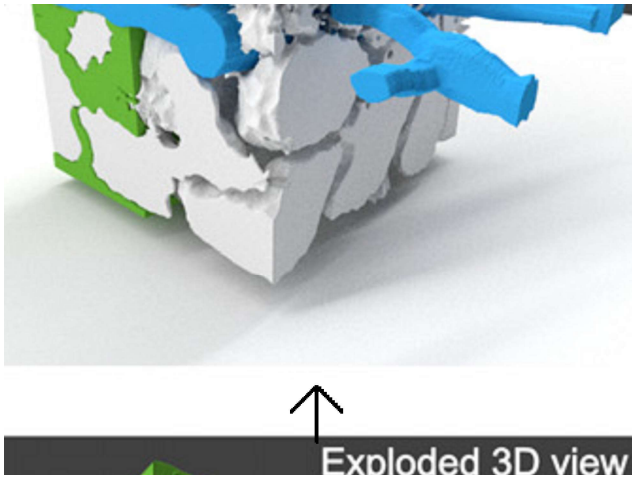
BERKELEY LAB

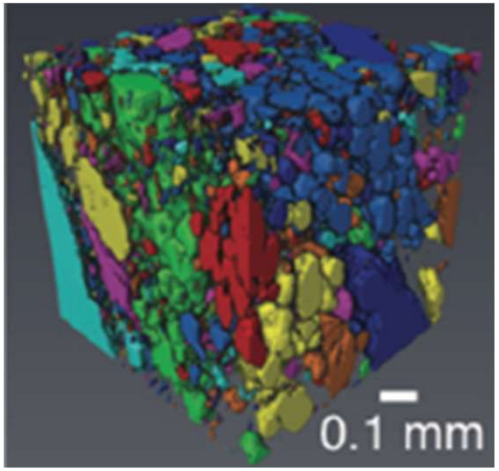
U.S. DEPARTMENT OF ENERGY | Office of Science

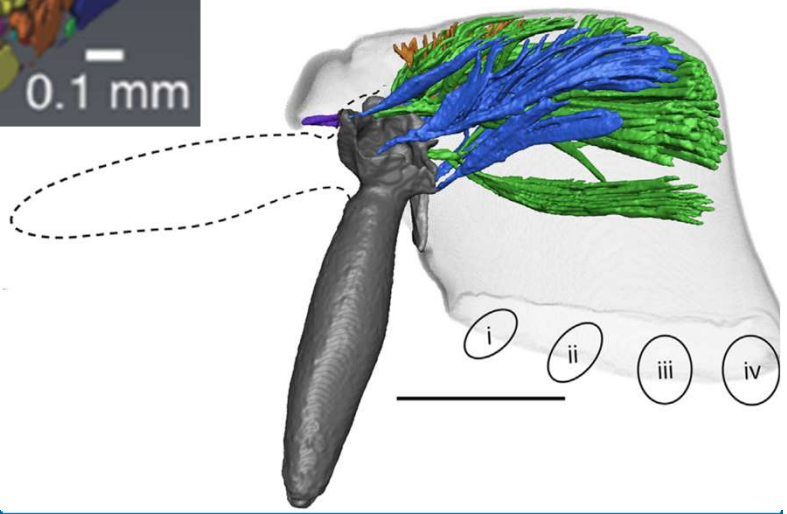
CAMERA Applied Math

ALS ADVANCED LIGHT SOURCE









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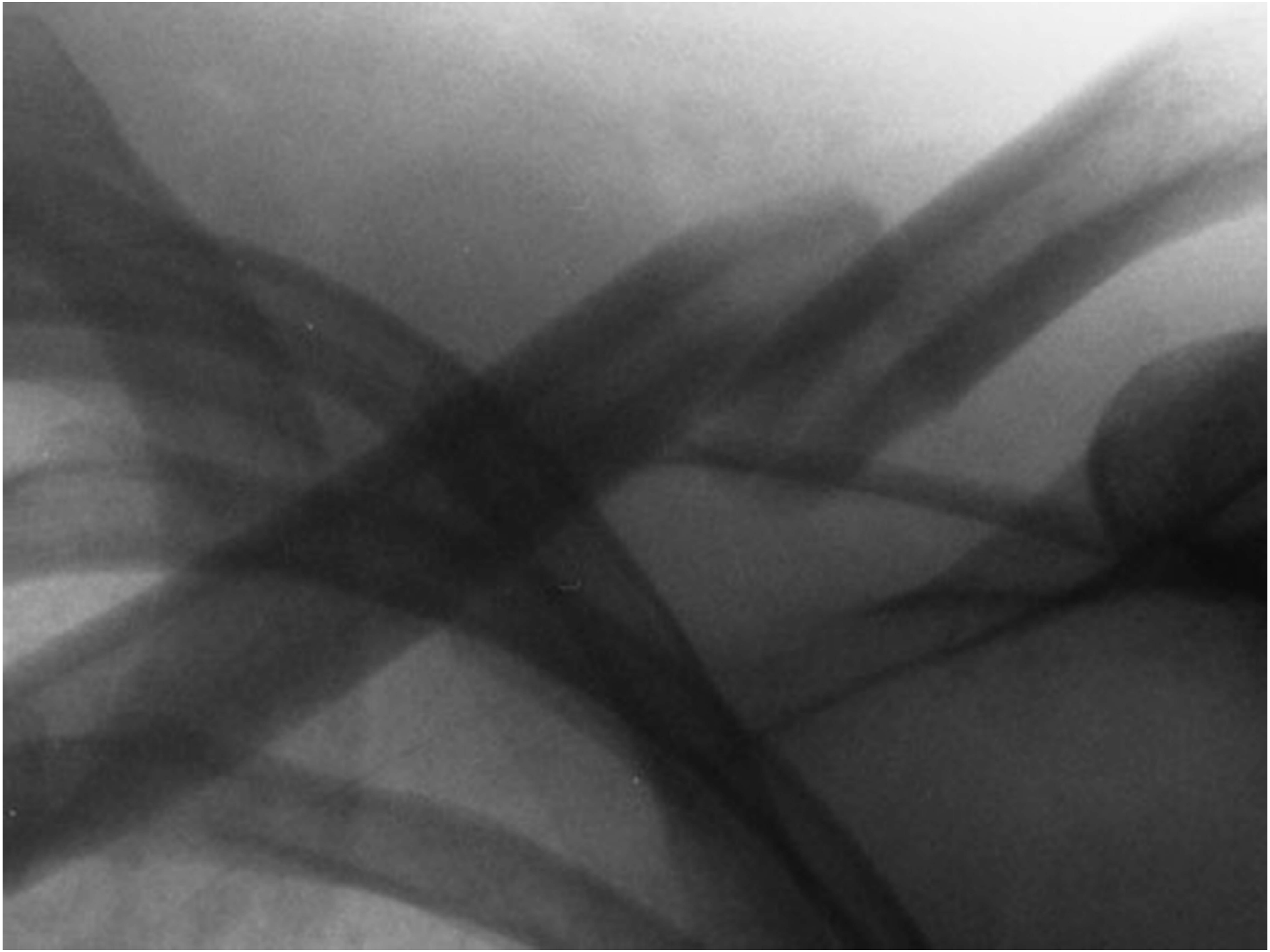
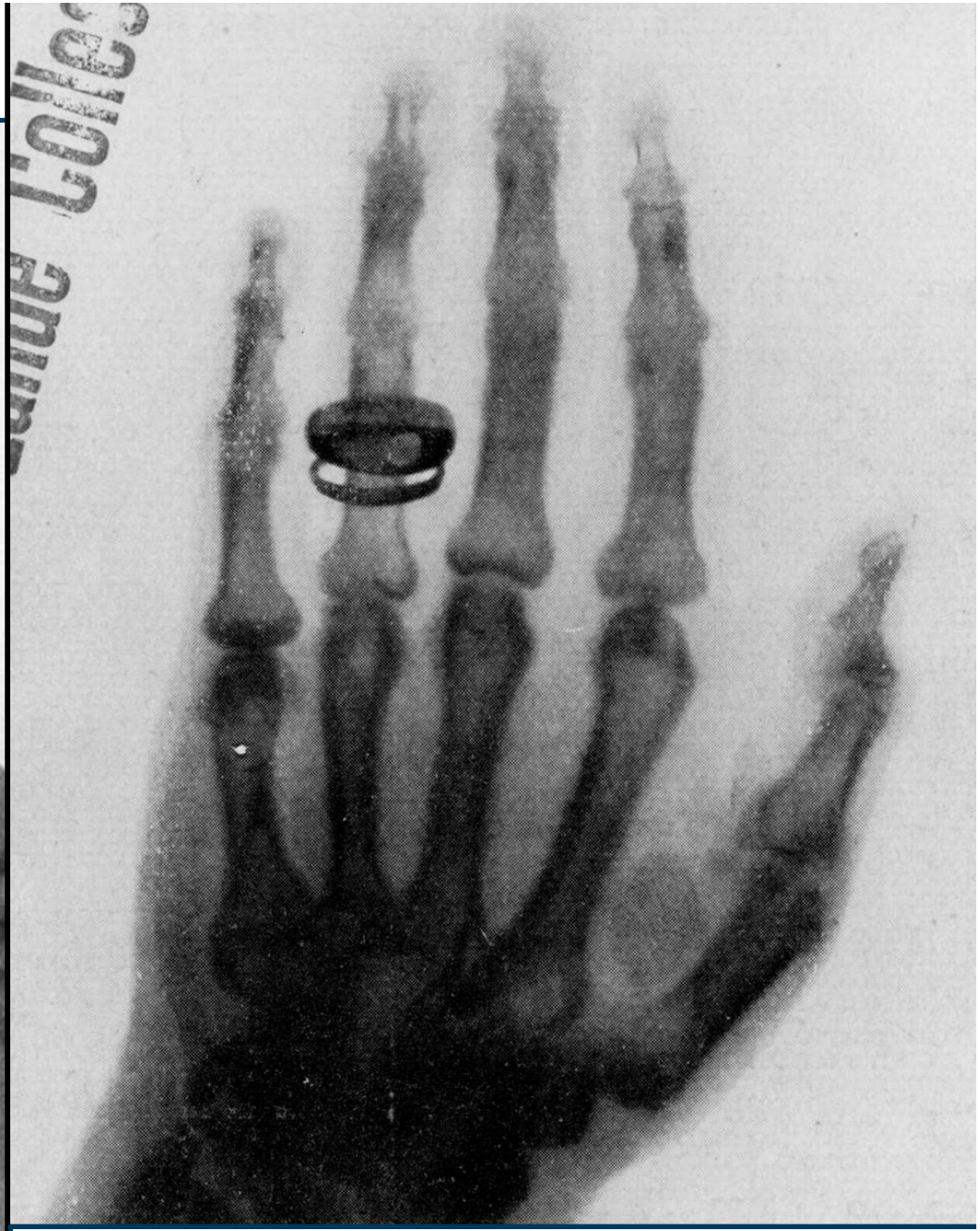
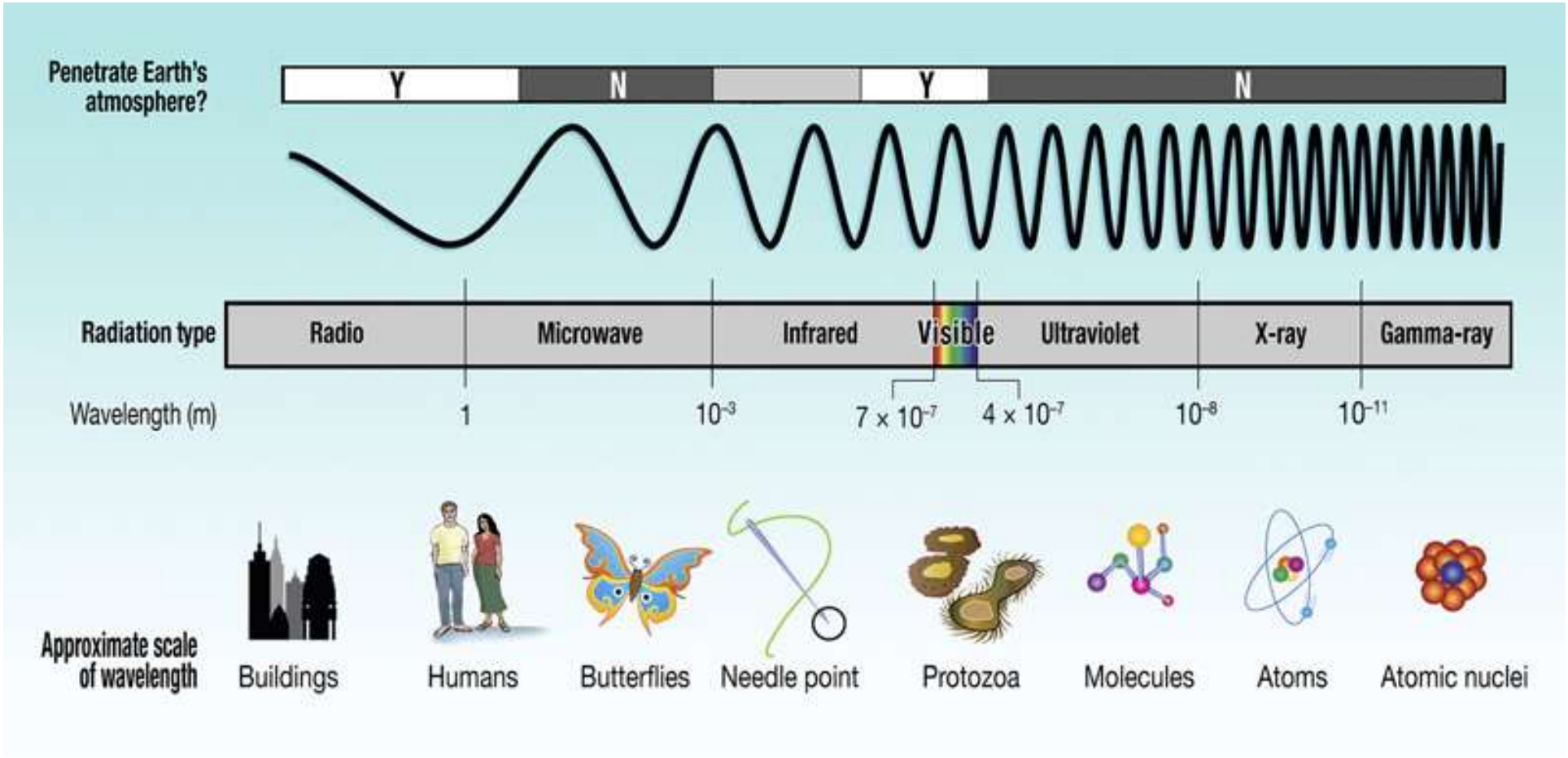
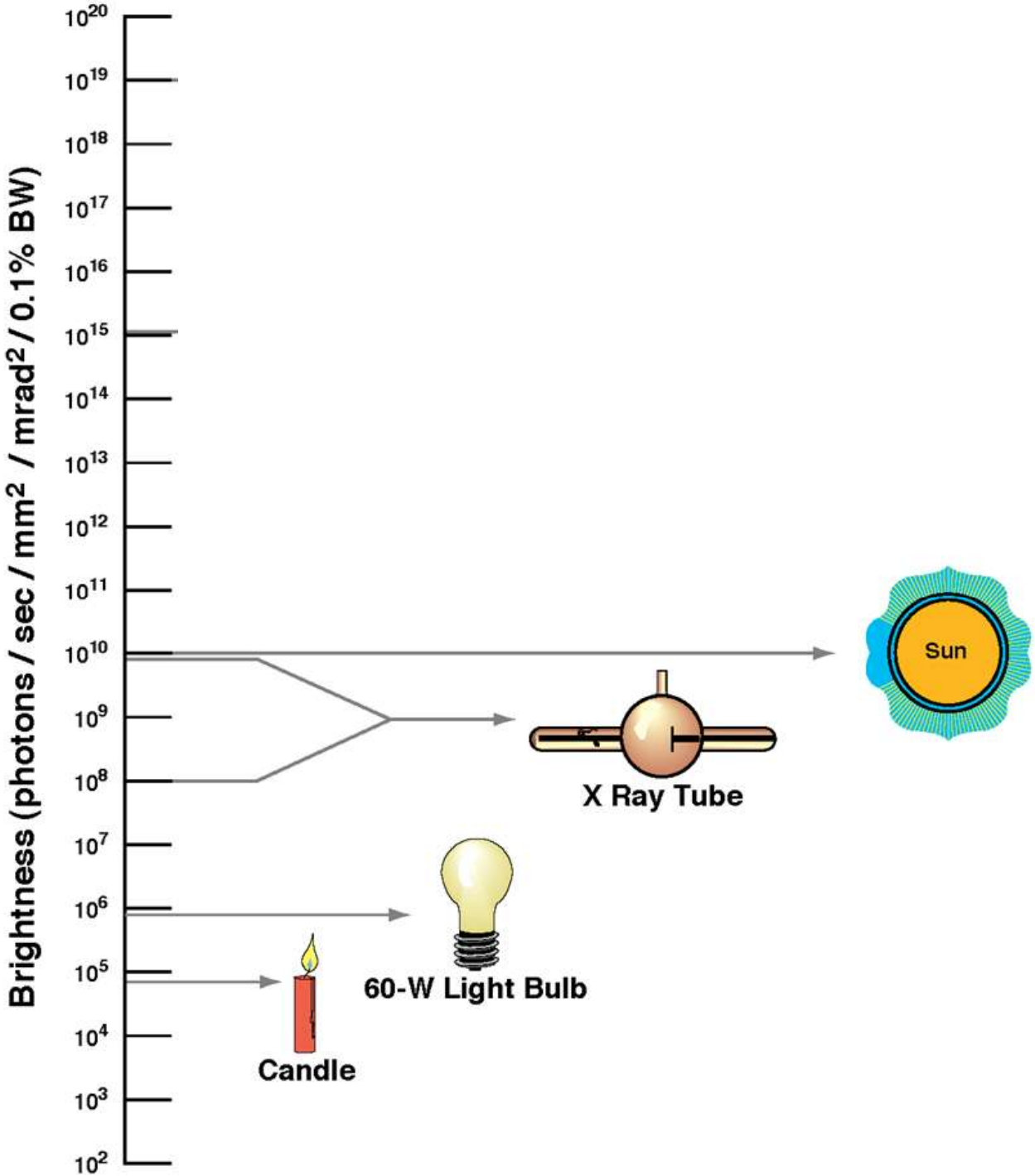


Wilhelm Conrad Roentgen
1845-1923



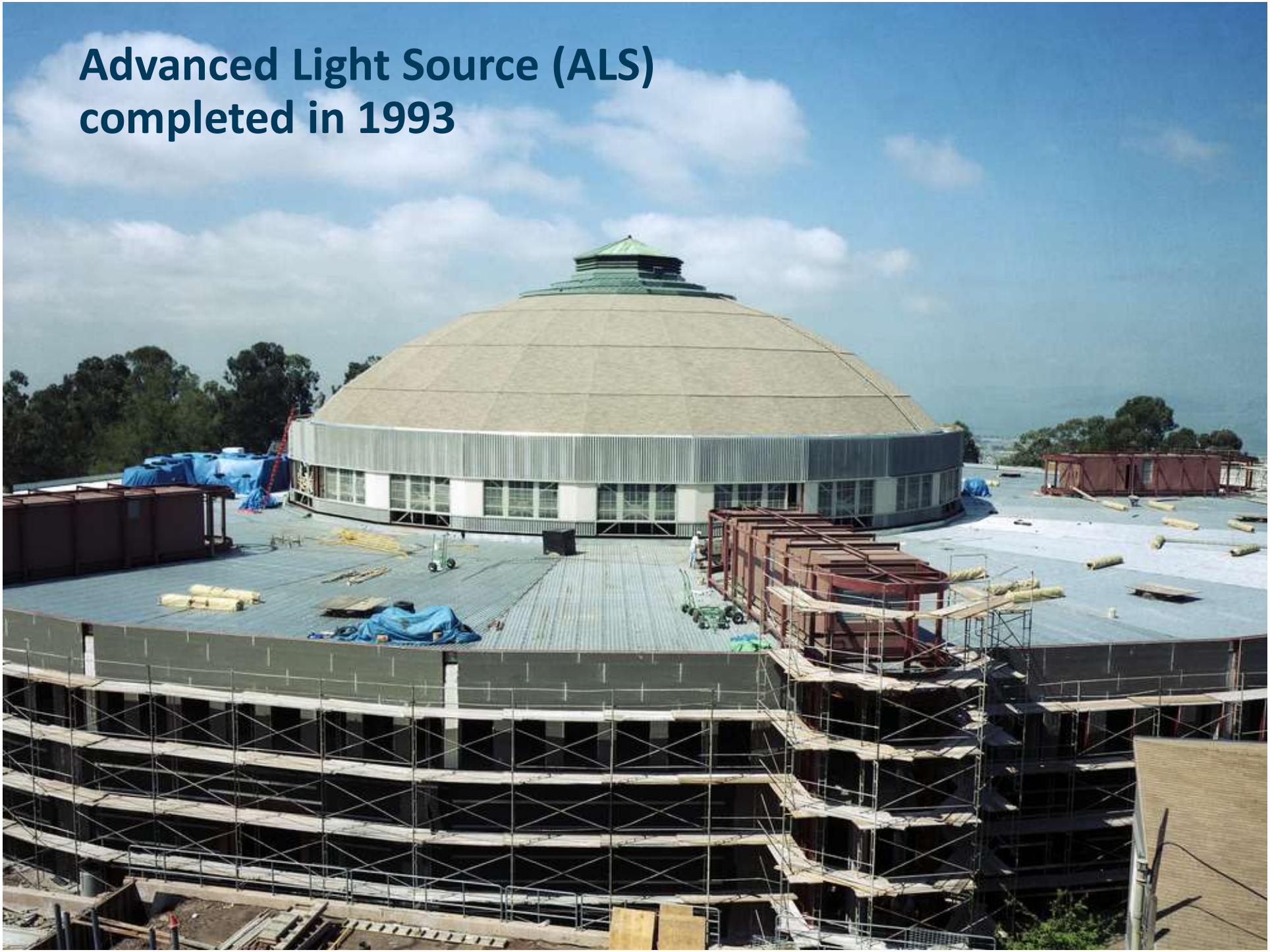
November 1895:
First ever X-ray Image, Anna Bertha Roentgen's hand


Penetrate Earth's atmosphere?
Y
N
Y
N
Radiation type
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma-ray
Wavelength (m)
1
10^{-3}
7×10^{-7}
4×10^{-7}
10^{-8}
10^{-11}
Approximate scale of wavelength
Buildings
Humans
Butterflies
Needle point
Protozoa
Molecules
Atoms
Atomic nuclei


Brightness (photons / sec / mm² / mrad² / 0.1% BW)
10²⁰
10¹⁹
10¹⁸
10¹⁷
10¹⁶
10¹⁵
10¹⁴
10¹³
10¹²
10¹¹
10¹⁰
10⁹
10⁸
10⁷
10⁶
10⁵
10⁴
10³
10²
Sun
X Ray Tube
60-W Light Bulb
Candle

Structure to house Lawrence's 184 inch cyclotron

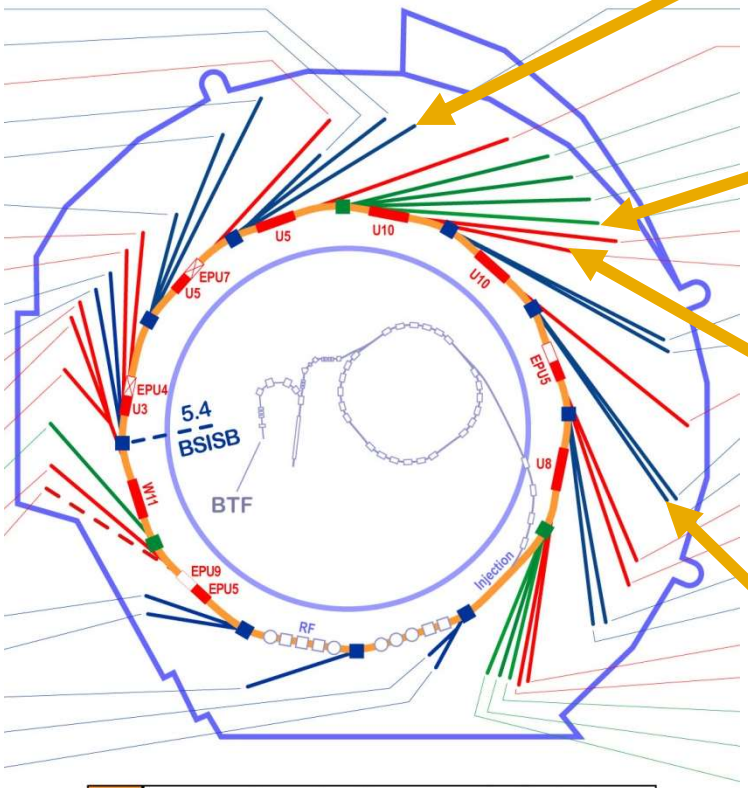
Advanced Light Source (ALS) completed in 1993




SR10 VC M4
SR10 HC M4
SE1009
INSIDE

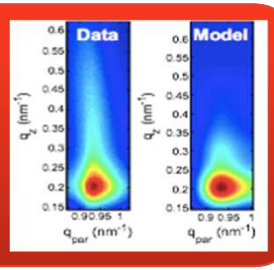
Lots of lead and concrete shielding help make it safe to work there!

ALS



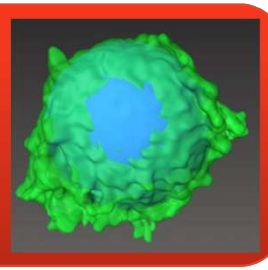
Reciprocal Space
(Scattering)

HipGISAXS/HipMC
parallel Scattering



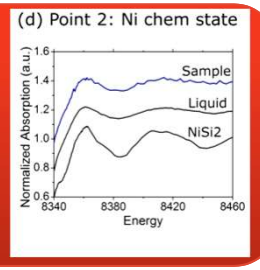
Real Space
(Tomography)

Arec3d, QuantCT,
CrunchFlow



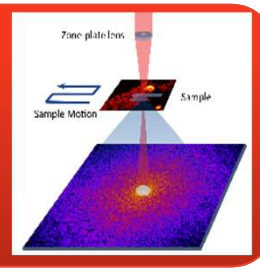
Spectroscopy
(MicroXas)

ShirleyXAS (MSD)
BerkeleyGW (NERSC)



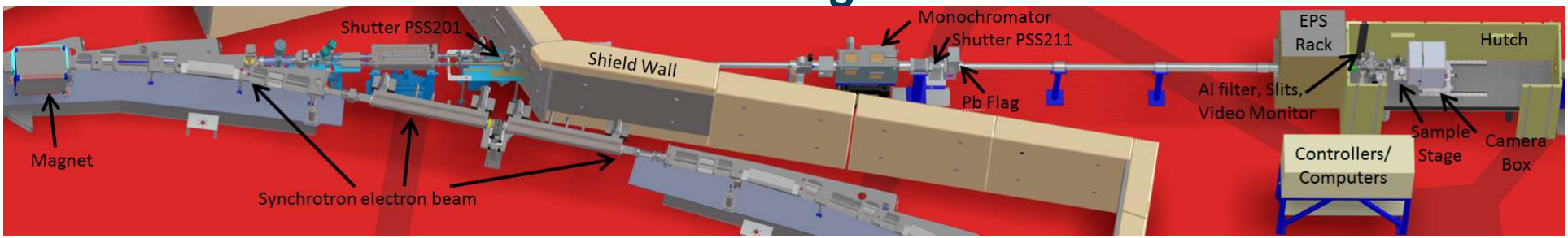
Hybrid
(COSMIC)

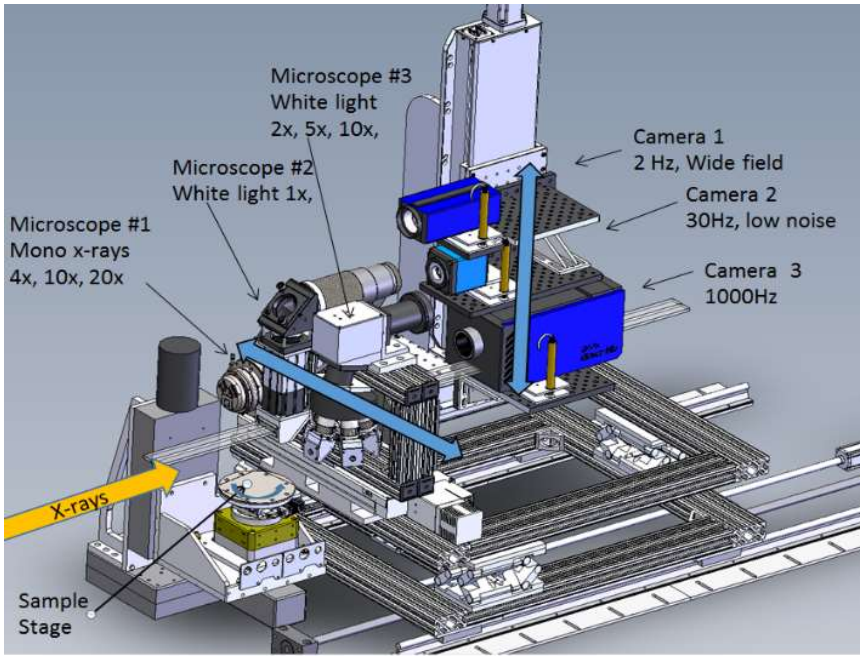
Ptychographic
reconstruction

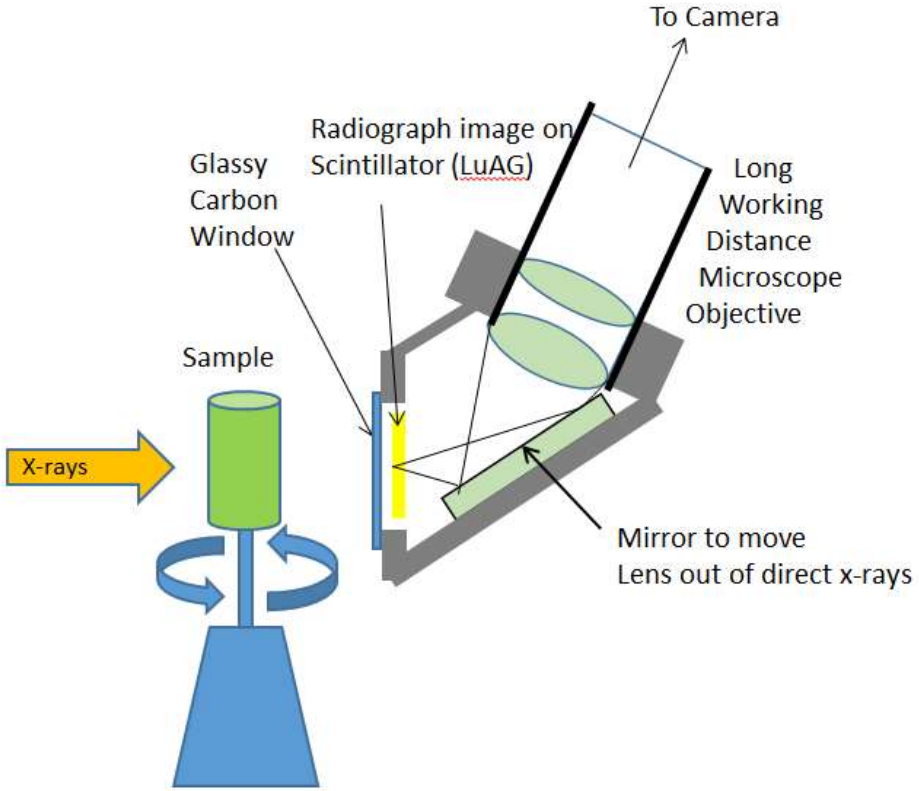


Microtomography Beamline & Optics

Beamline 8.3.2 at the Advanced Light Souce







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Applied Math ALS

Tomography Stage

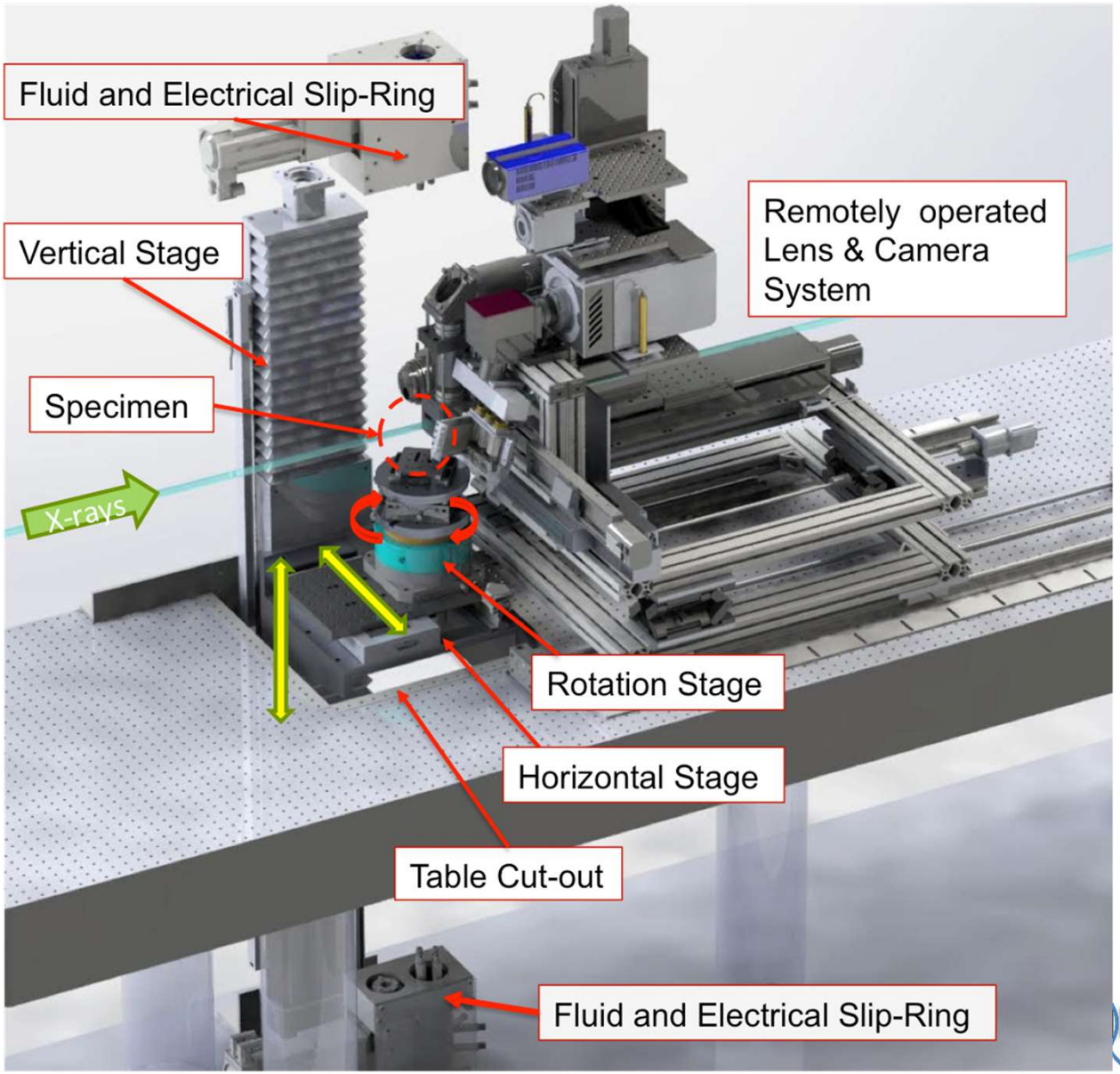
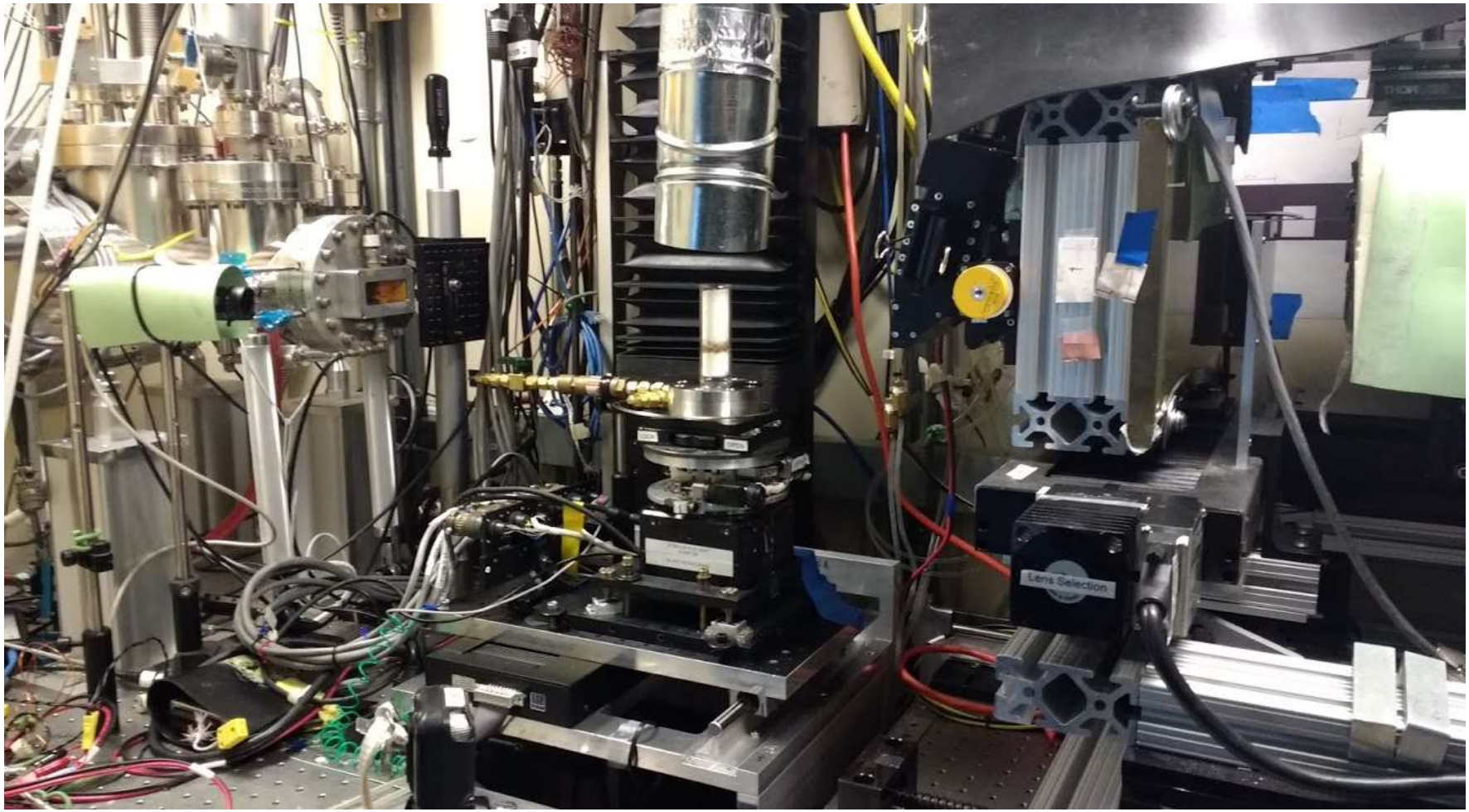
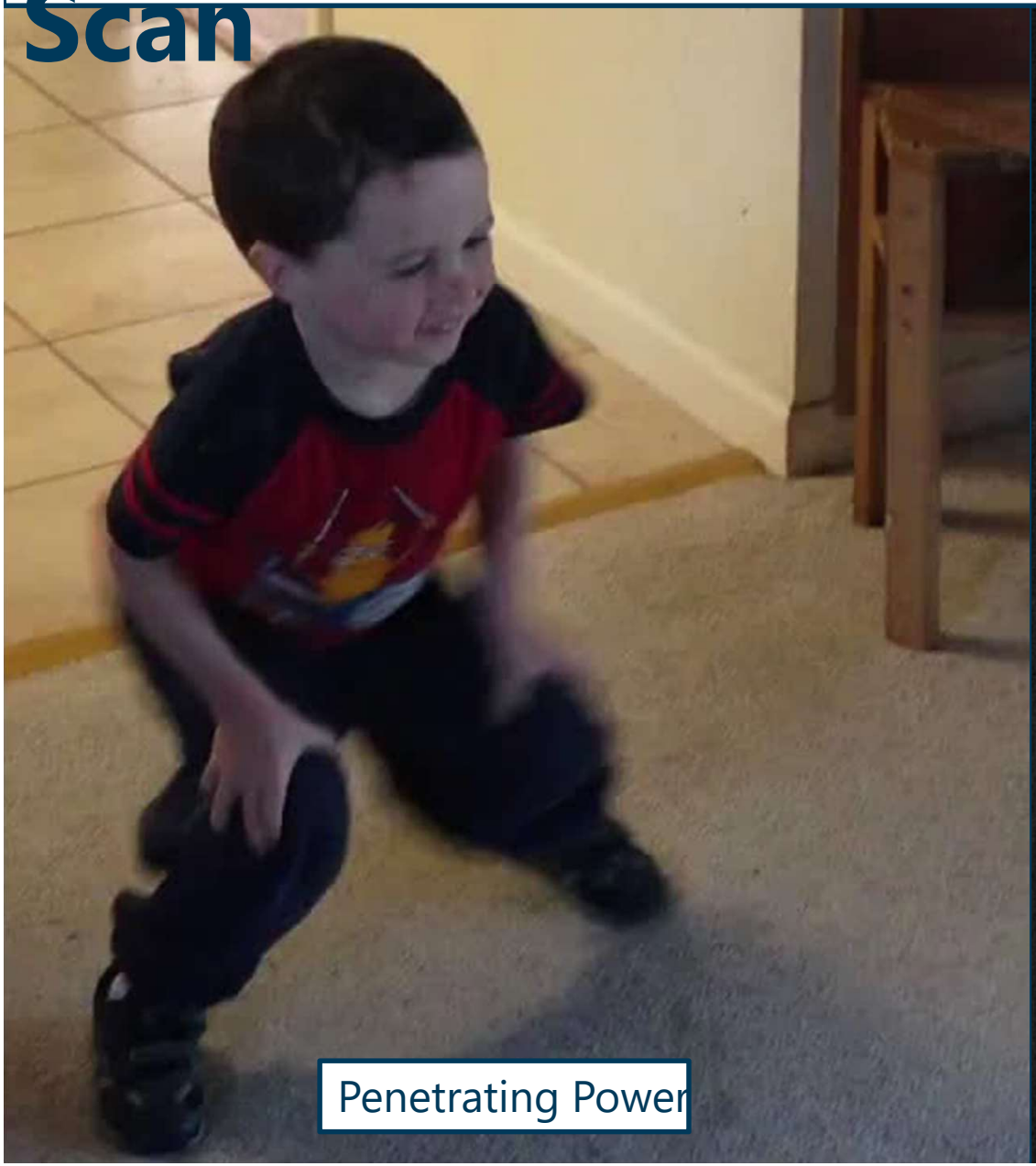
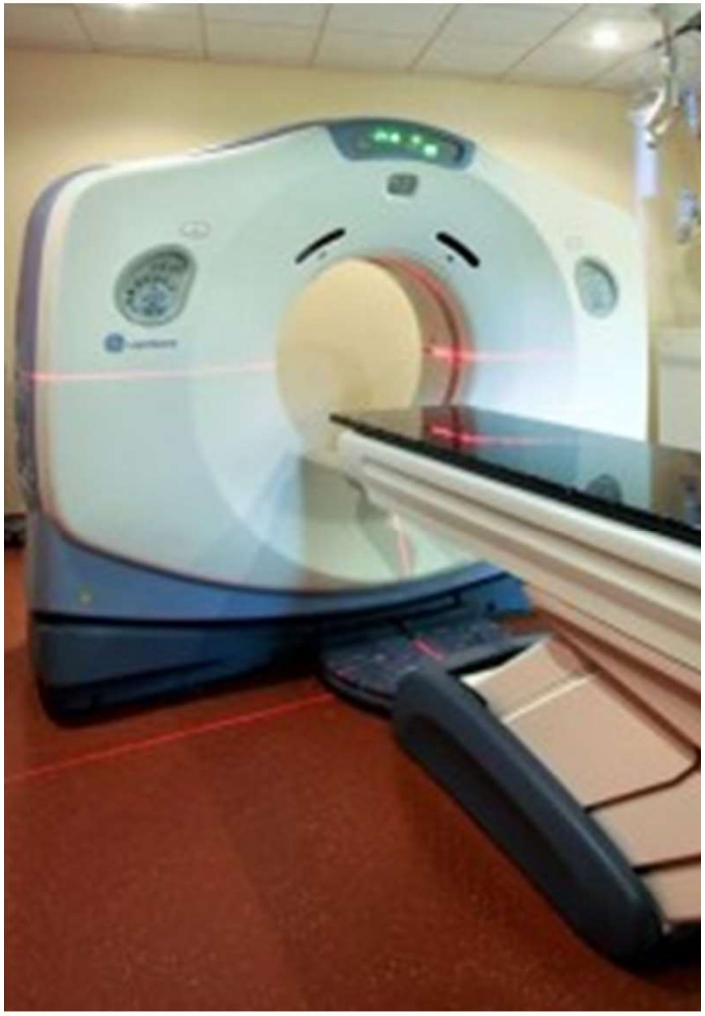


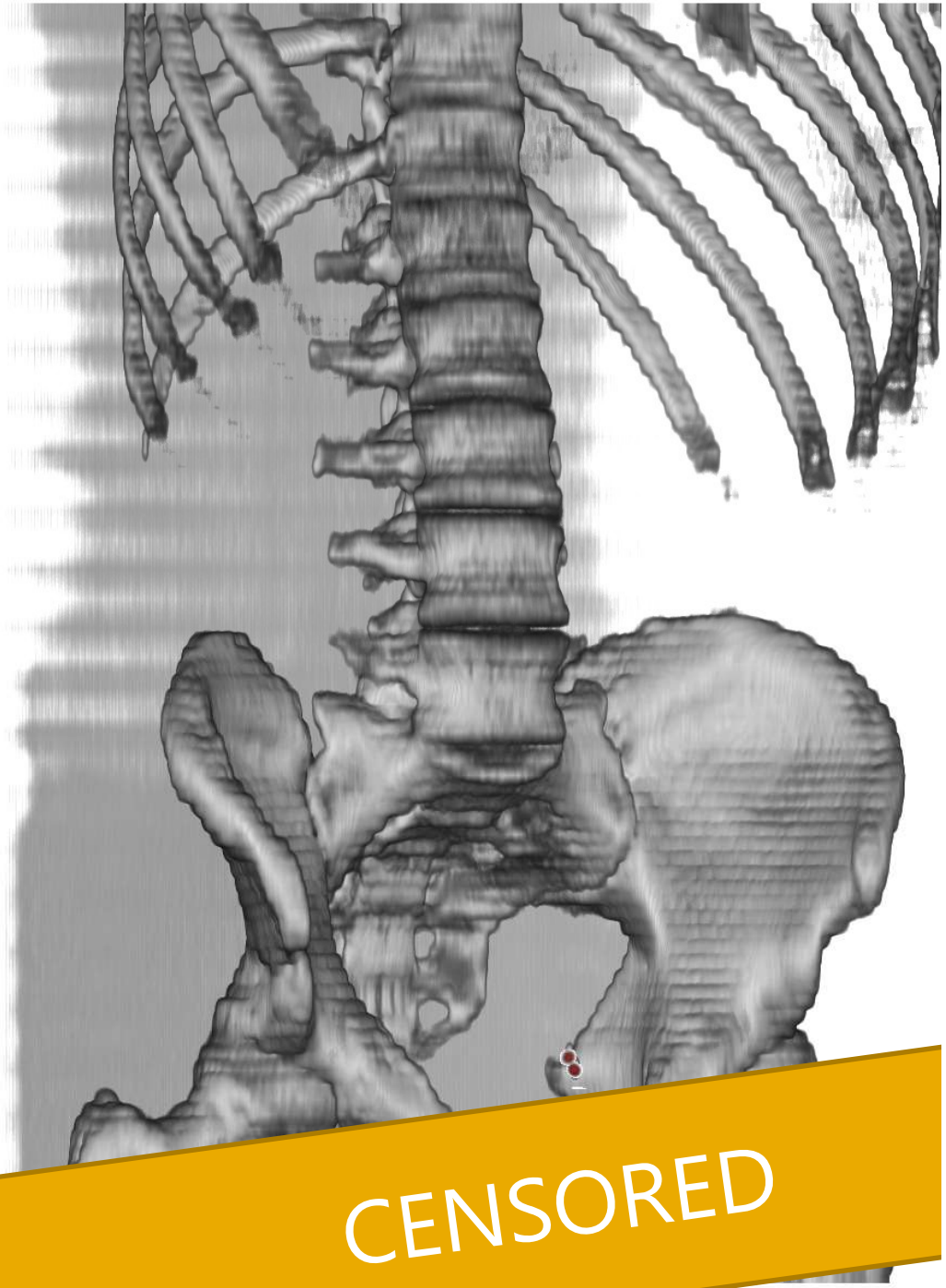
Photo: Tomography Setup



Computed Tomography = CT Scan







CENSORED

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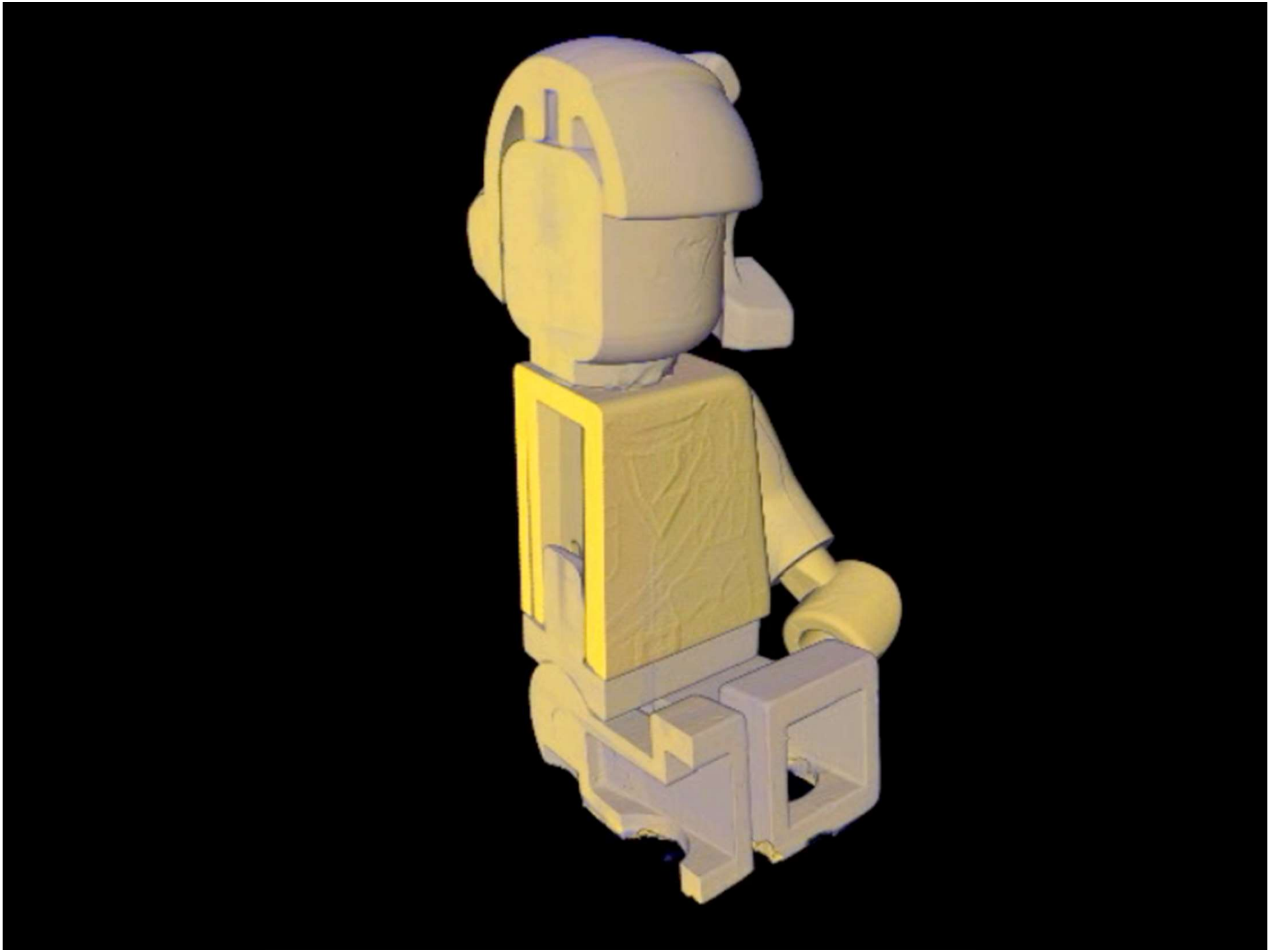
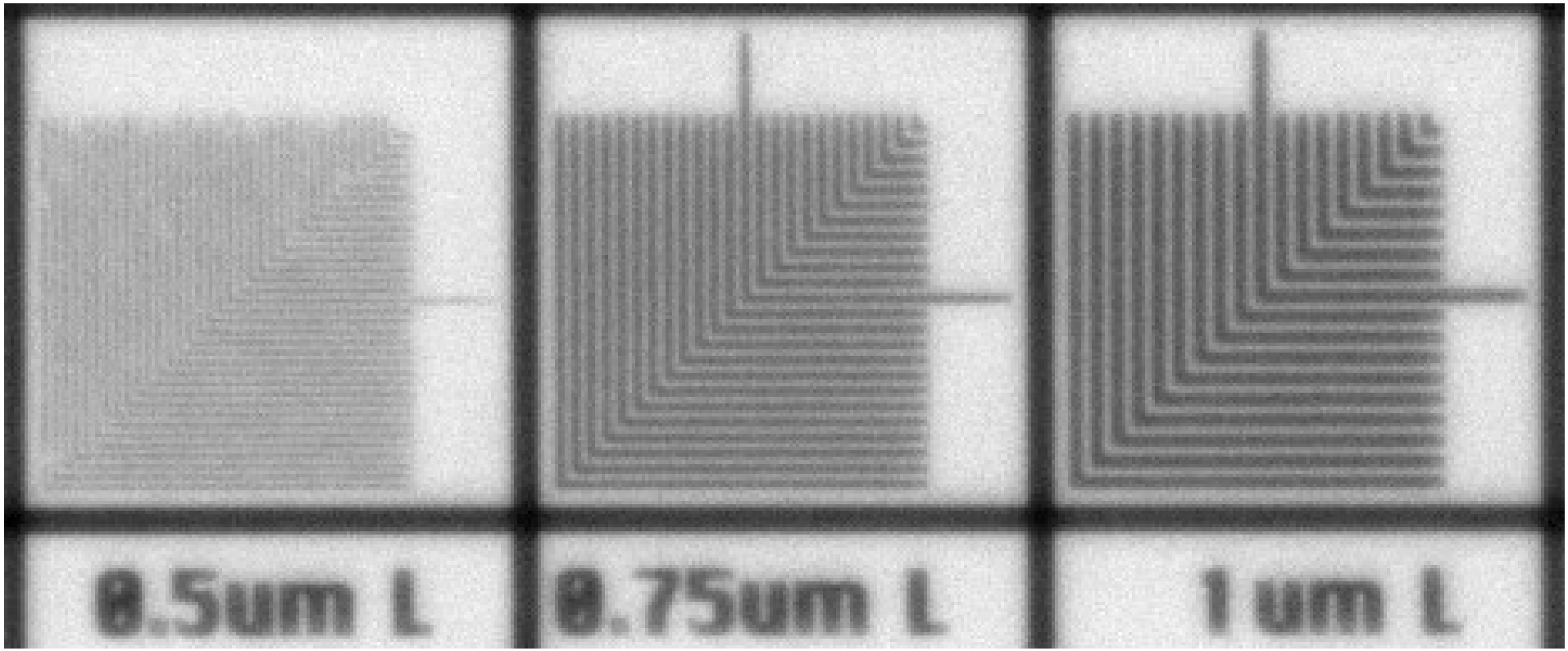
X-ray Camera View
Beamline 8.3.2: Hard X-ray Micro-CT

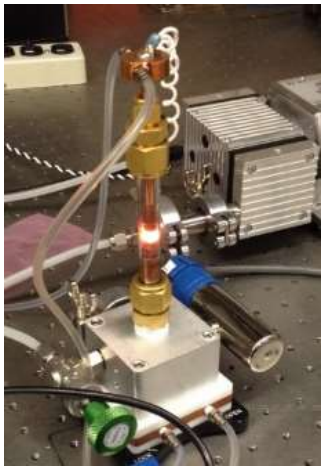


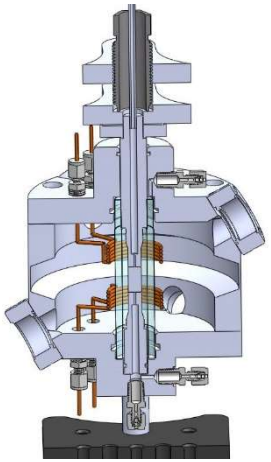
Micrometer Resolution

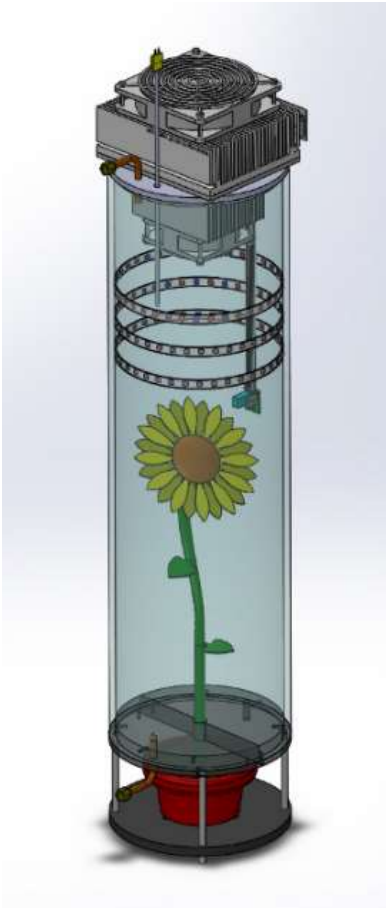


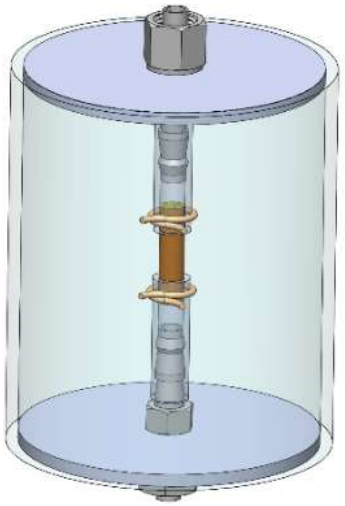
High flux + Fast Detectors = High speed

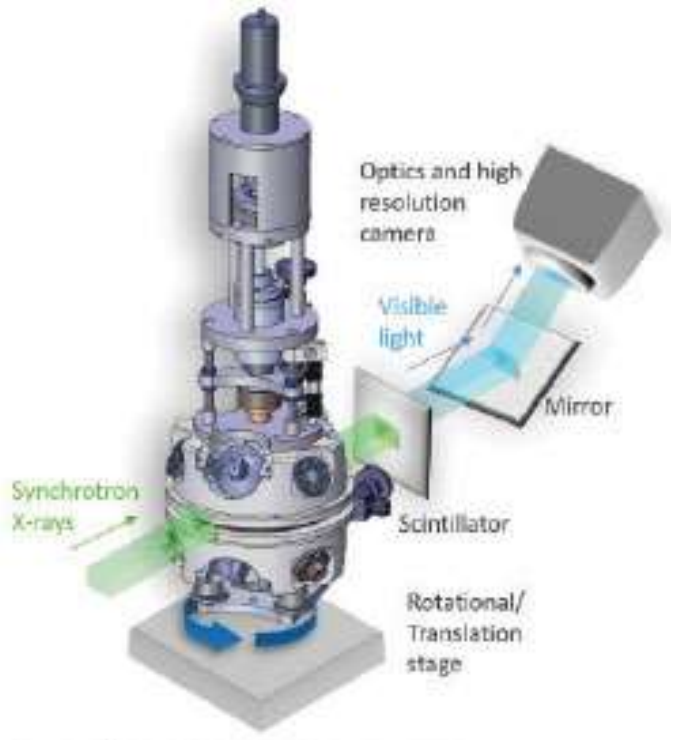
Sample Environments











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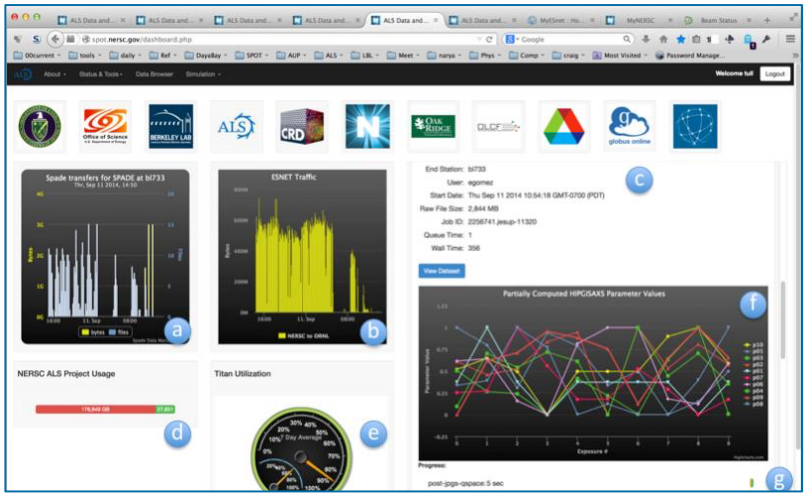
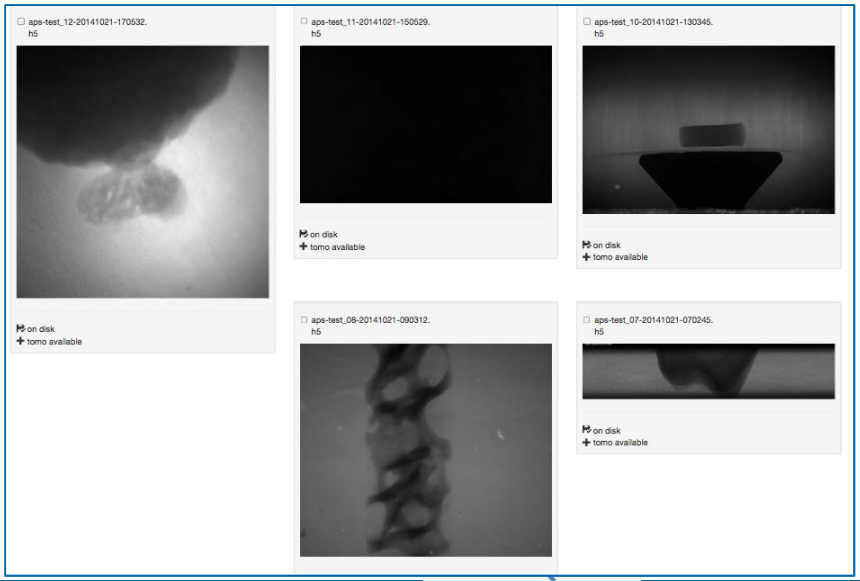
CAMERA Applied Math ALS

Database of Scans

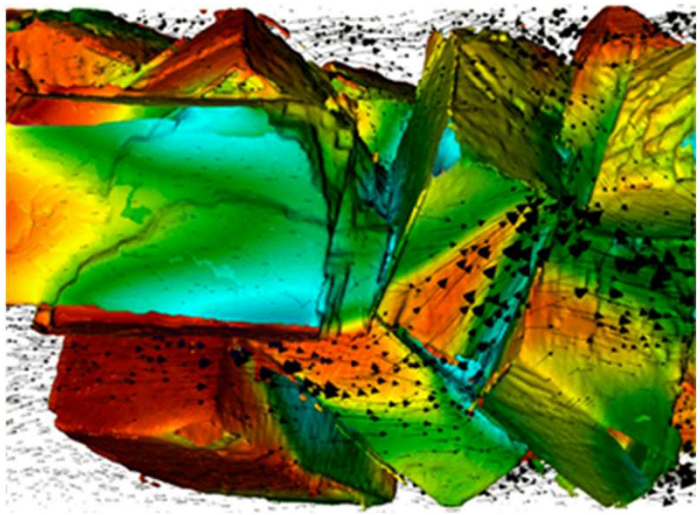
ALS repository at NERSC (3 beamlines)

- >400k data sets
- >3.0 PB
- >5 million jobs





David Trebotich, simulation produced >1 PB data



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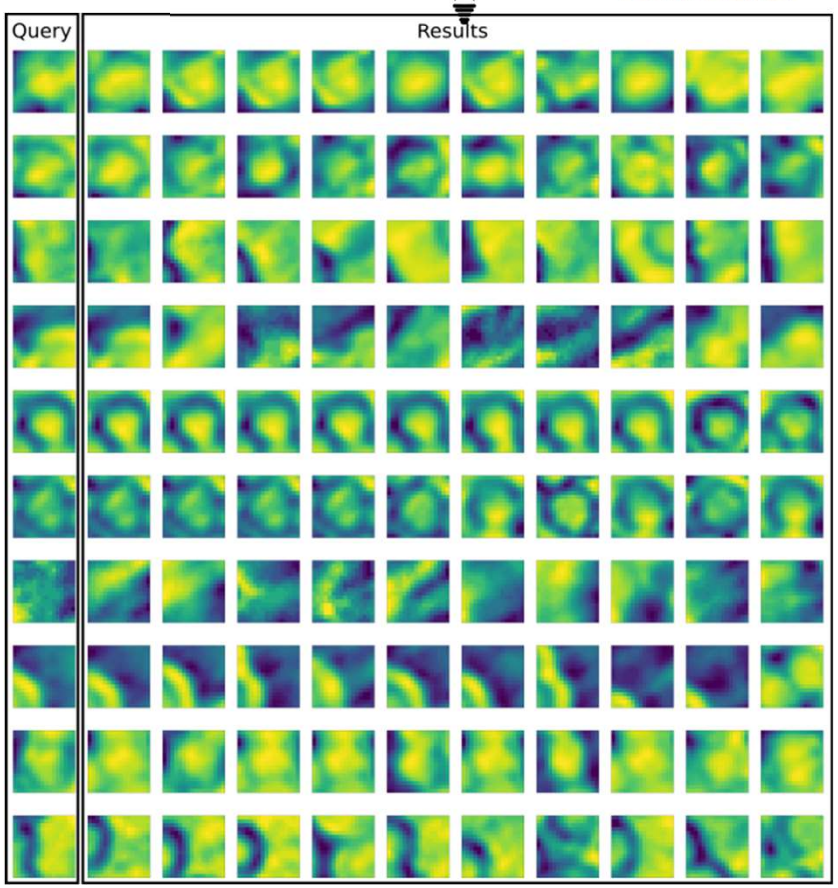
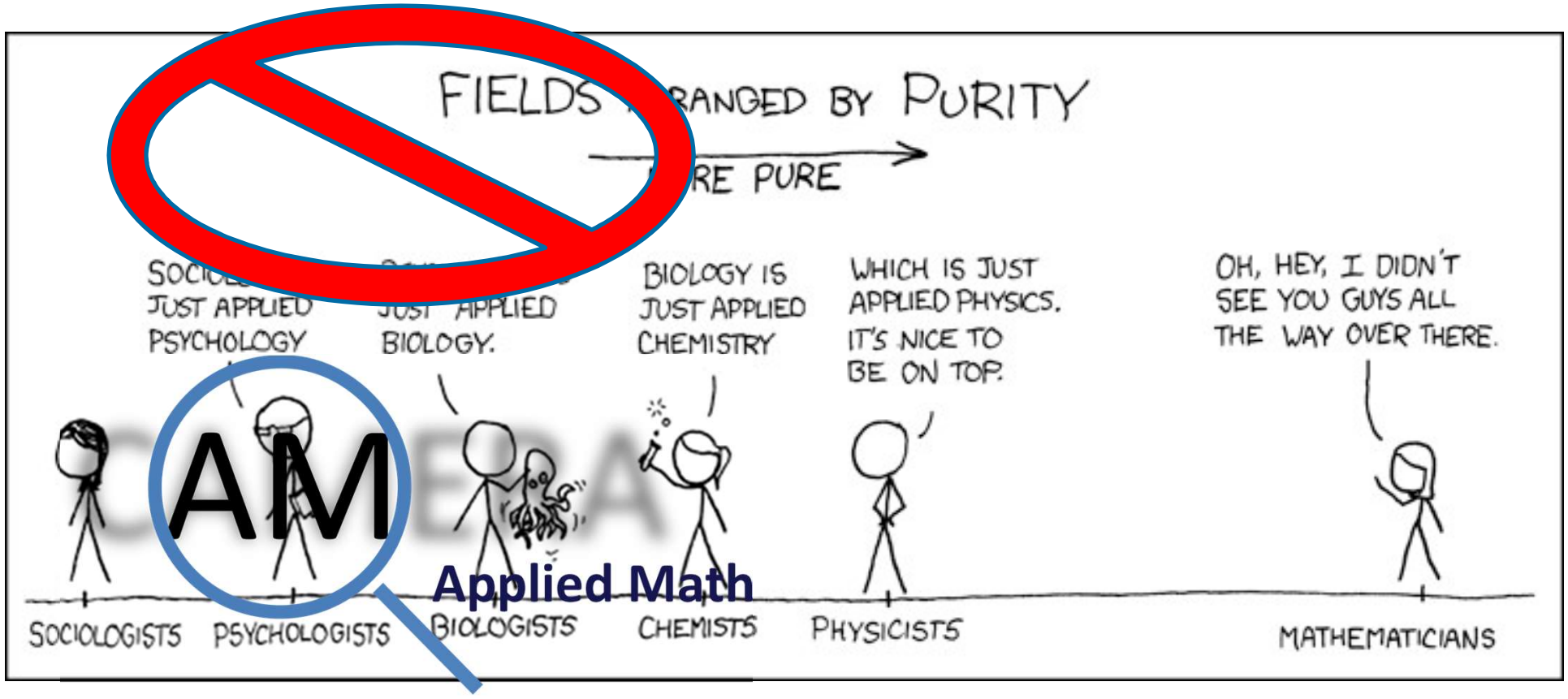
pyCBIR: Recommendation system for scientific images

- Visual search engine: image retrieval based on pictorial similarity
- Quantitative analytics to give confidence associated with each recommendation



Ushizima, Araujo, Romuere, "Searchable datasets in Python: images across domains, experiments, algorithms and learning – pyCBIR", pyData San Francisco 2016.
Araujo, Romuere, Ushizima, Medeiros,"Reverse Image Search for Scientific Images within and beyond the Visible Spectrum", IEEE Trans Imag Proc 2017 (under review).

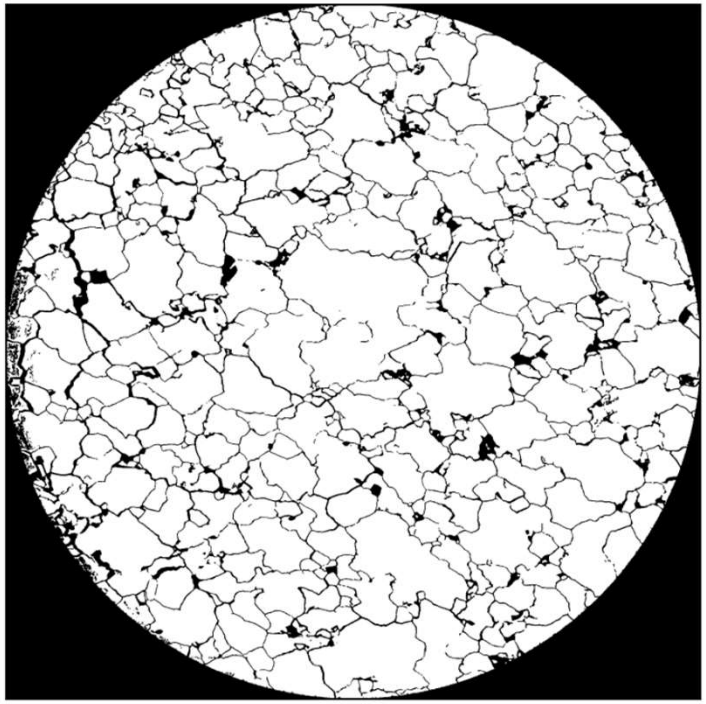
“Computational Imaging”



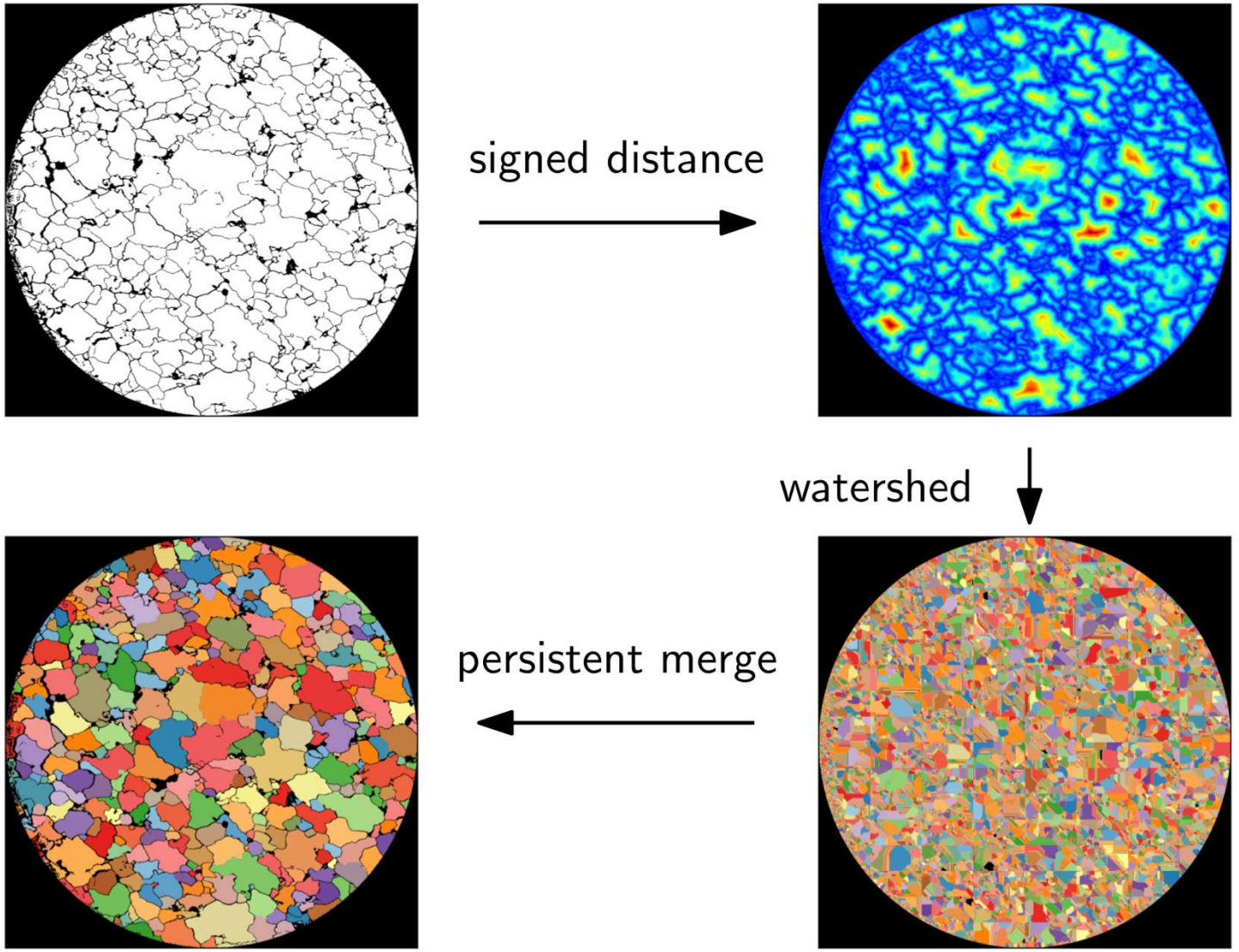
Flexible Rocks

- Work of **Dmitriy Morozov**, working with Patrick O'Neil and Michael Manga, Gunther Weber, Lawrence Berkeley National Laboratory

Composition: Packed Quartz Grains Separated by Voids



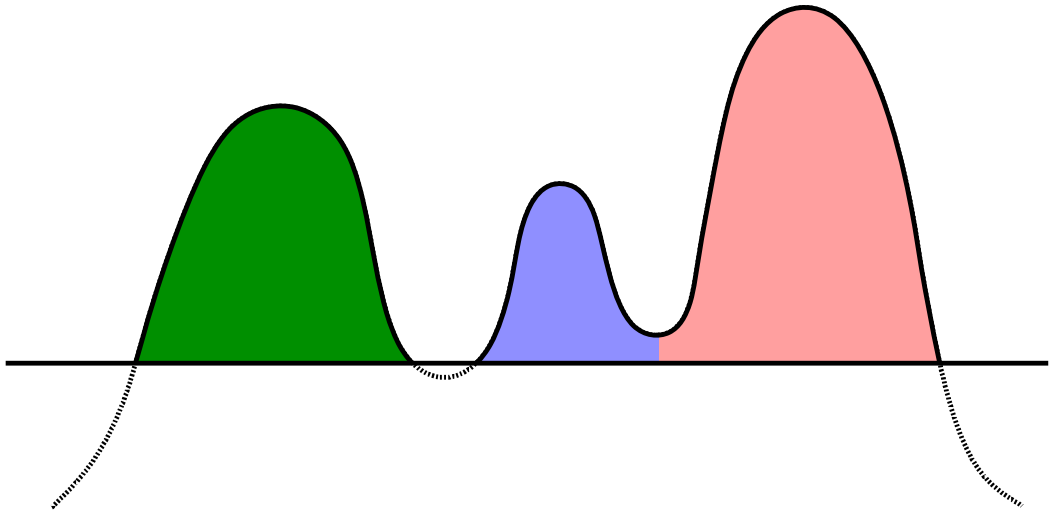
Segmentation of Individual Grains



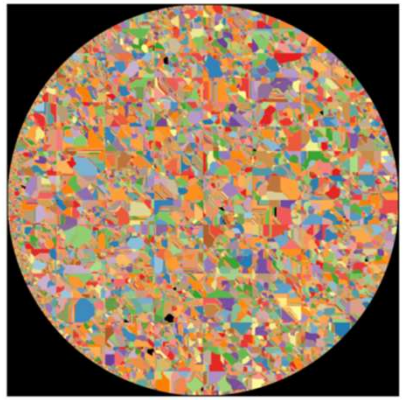
Watershed

Process vertices in the sorted order:

- at a maximum, start a new label
- otherwise, copy label from a neighbor
- if neighbors have different labels, mark as watershed



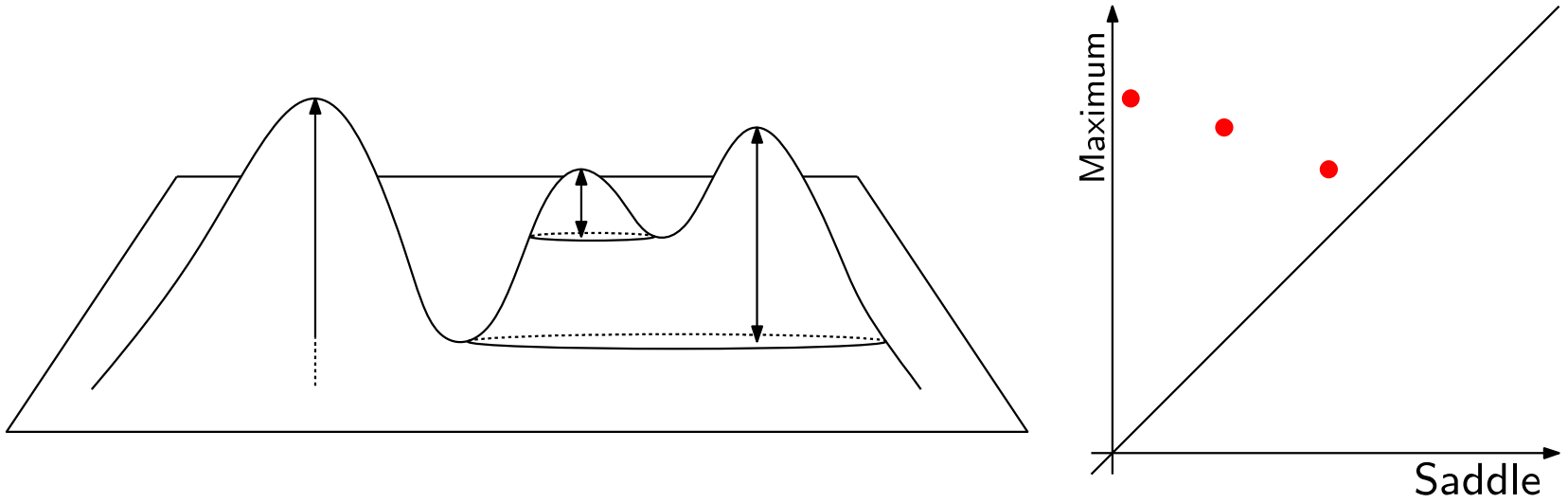
Initial result (too noisy):



Persistence

Persistence of a peak (local maximum) is the height of the peak's summit above the lowest contour line encircling it and no higher summit.

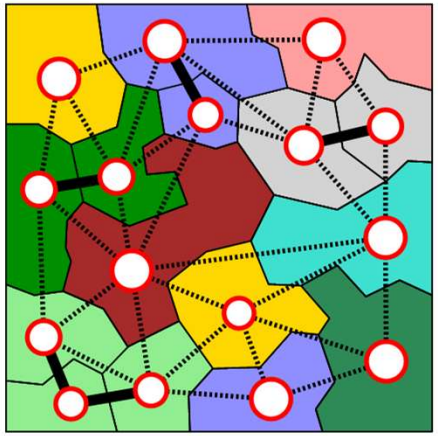
(known as topographic prominence in mountaineering)



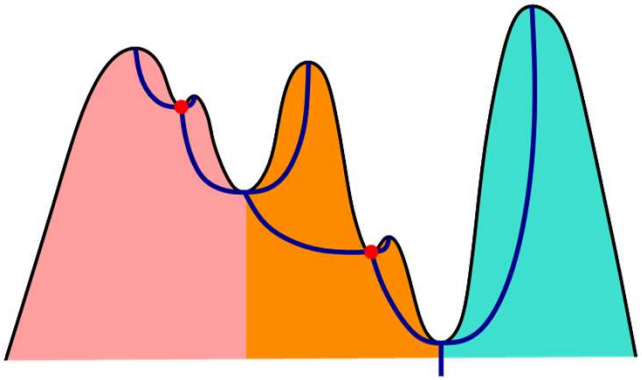
Persistence diagram records for each peak its value on the vertical axis, and the value of the saddle where it merges into a higher peak on the horizontal axis.

Persistence Merge

Dual graph:



Merge tree:



Merged result:

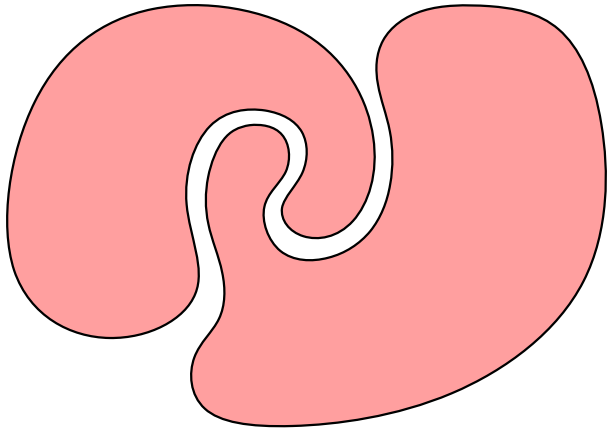
Mark saddles below a given persistence threshold
(⇒ subforest in the graph)

Merge the connected components (in dual graph)

NB: not the same as merging into the maxima
in the merge tree

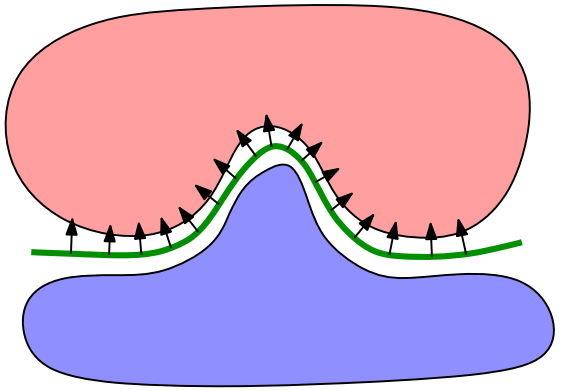
Dominant theory for bending

It is due to the porous character of the rock together with the interlocking junctions between the sand grains. The porosity allows interstitial movement, while the hinge-like joints by which the particles are connected hold them together in spite of the displacement. (– Wikipedia)



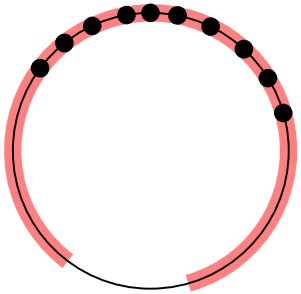
Examine adjacent pairs of grains:

- Construct the interface between the grains (subset of the medial axis)



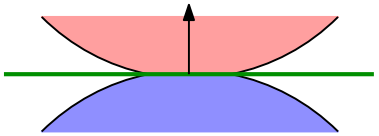
- Compute the normals along the interface

- Push each normal direction onto the sphere



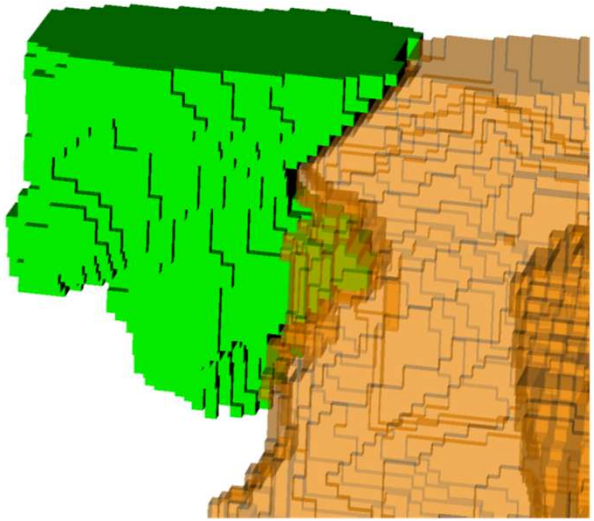
- Directions within $\pi/2$ cap of a normal are blocked

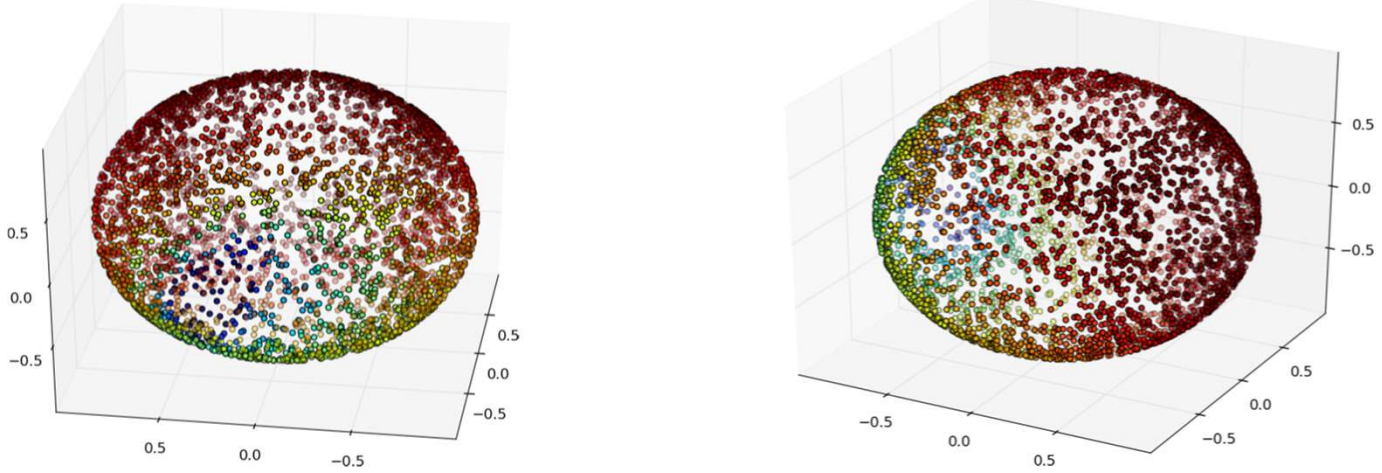
- Examine percentage of the sphere that is blocked



Neither necessary, nor sufficient for blocking. But a useful proxy.
Better ideas?

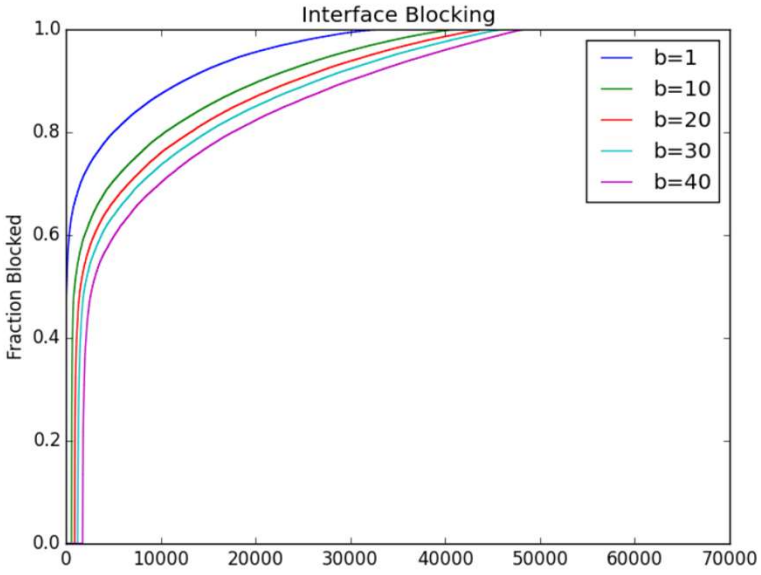
Blocked Directions



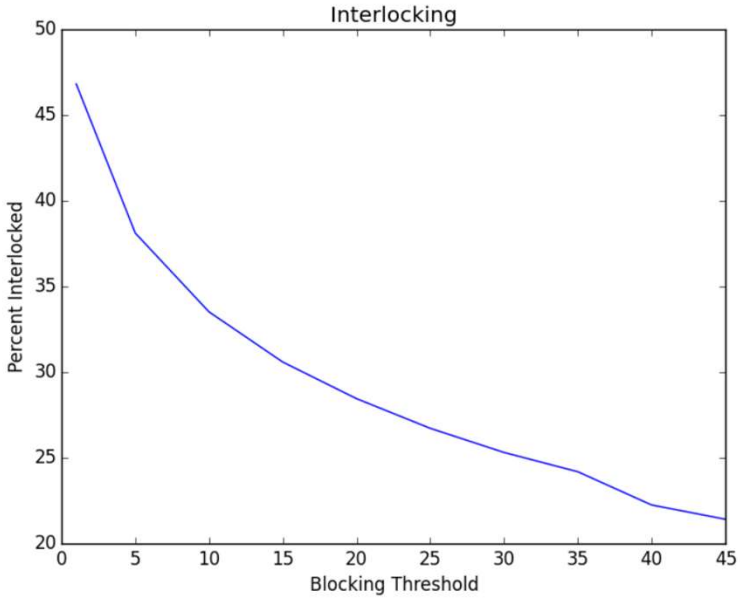


(Monte–Carlo sampling of directions on the sphere.)

Blocked Directions

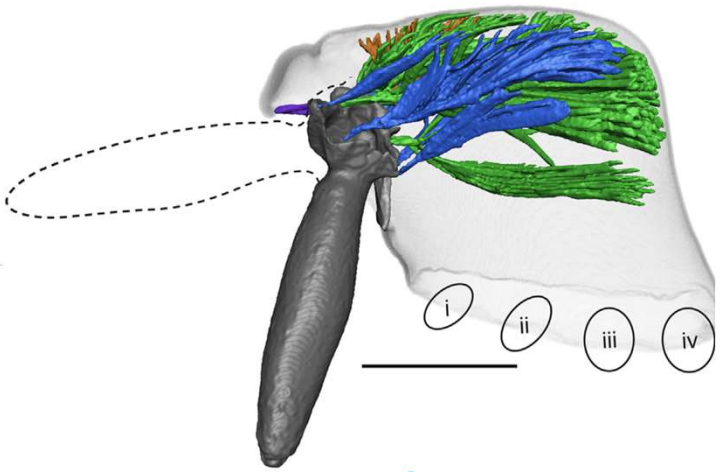


Interfaces sorted by how blocked they are.



Percentage of interface completely blocked (for various thresholds).

b = blocking threshold = how many normals have to block a direction before it's considered blocked.



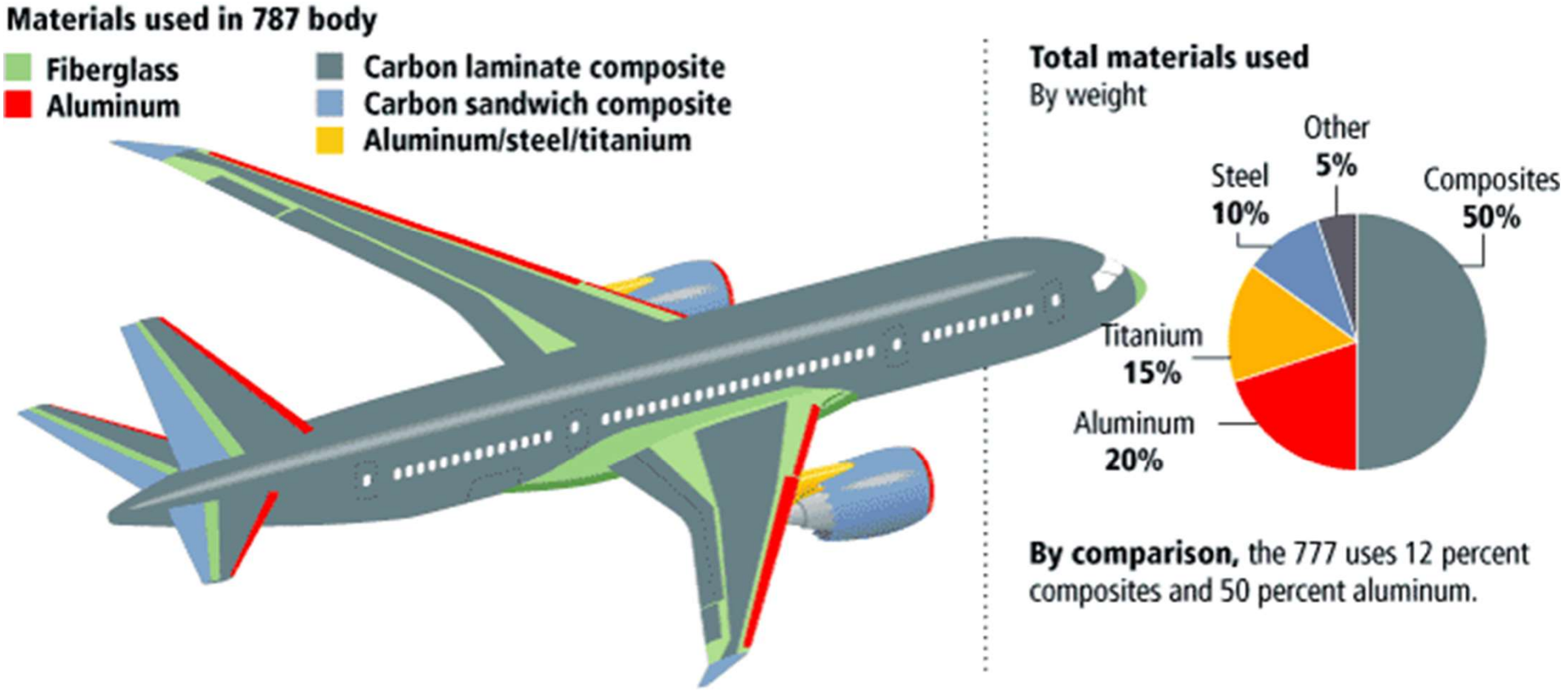
Spider Evolution

- **Hannah Wood**, Smithsonian

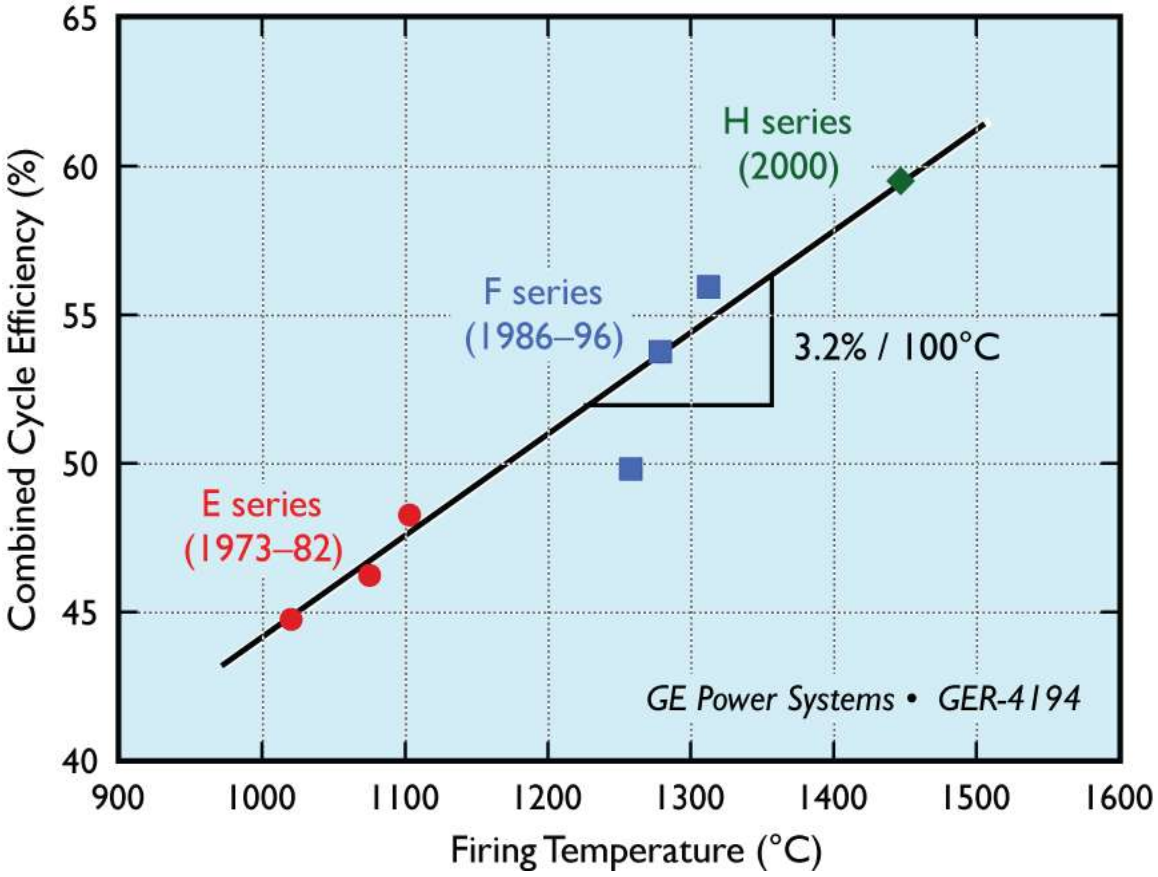
Crack Structure in Composites

- Natalie Larson, Frank Zok, UC Santa Barbara

Materials distribution for the Boeing 787 Dreamliner

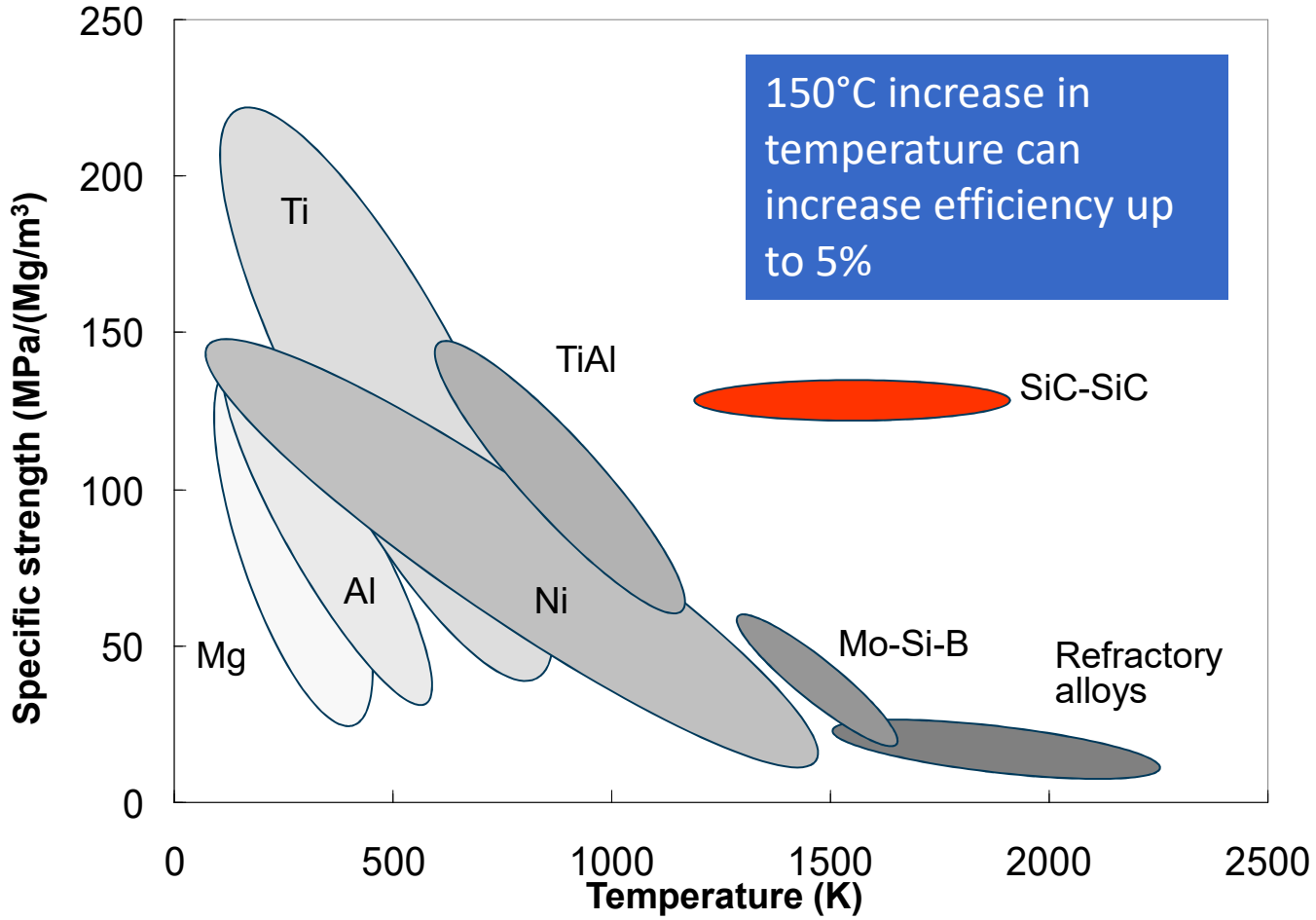


Hotter engines are more efficient



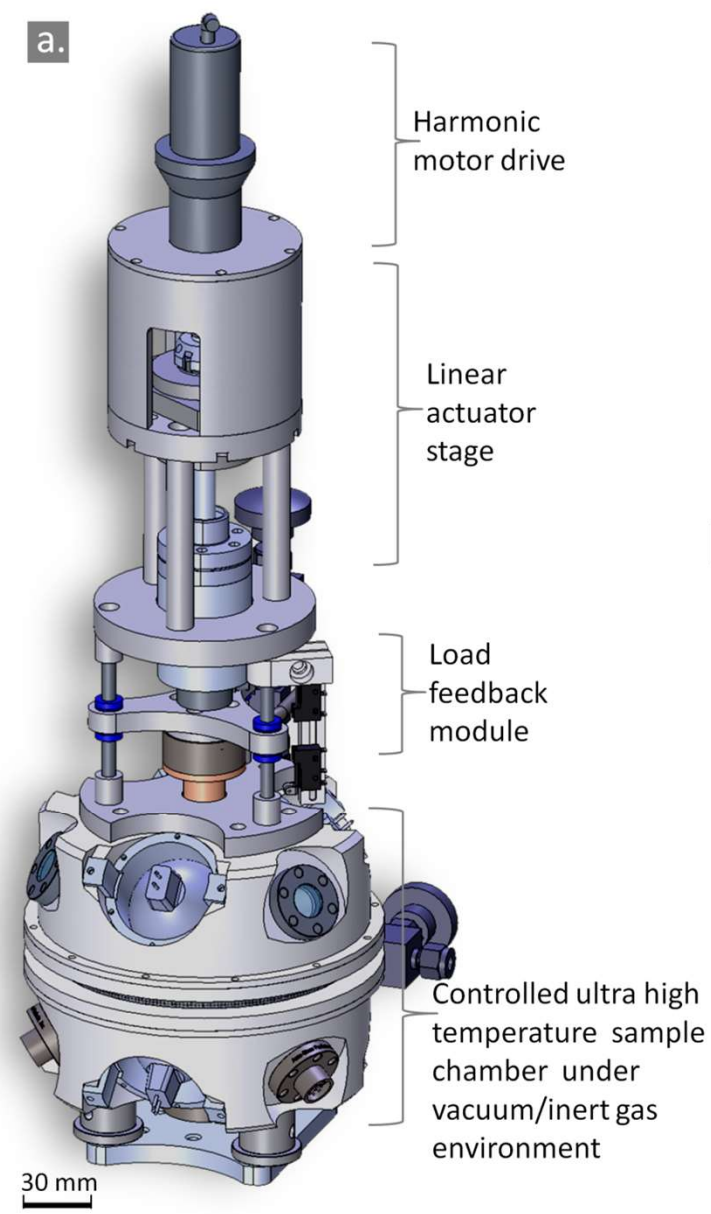
GE LEAP jet engine
www.geaviation.com

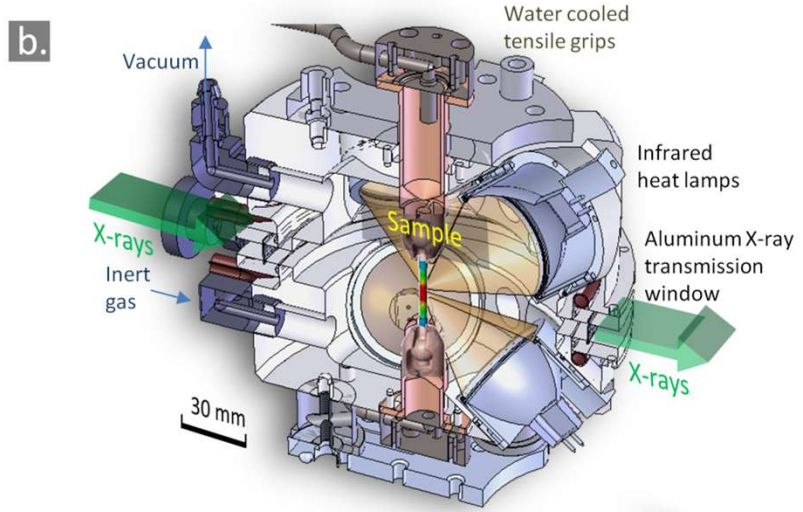
SiC/SiC CMCs for more efficient jet engines

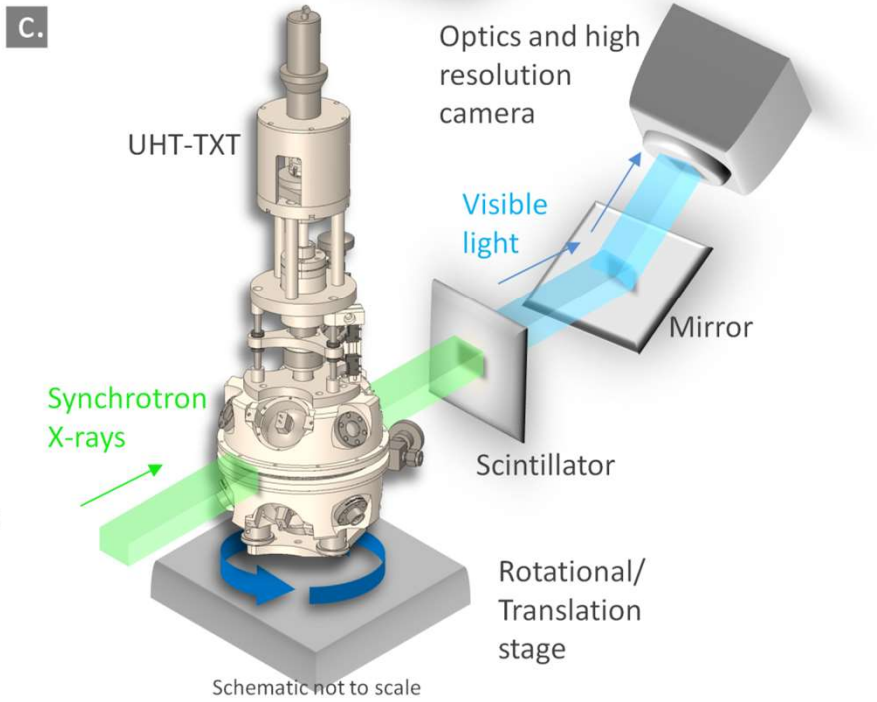


Marshall and Cox 2008

In Situ Ultrahigh-Temperature Rig for Micro-XCT

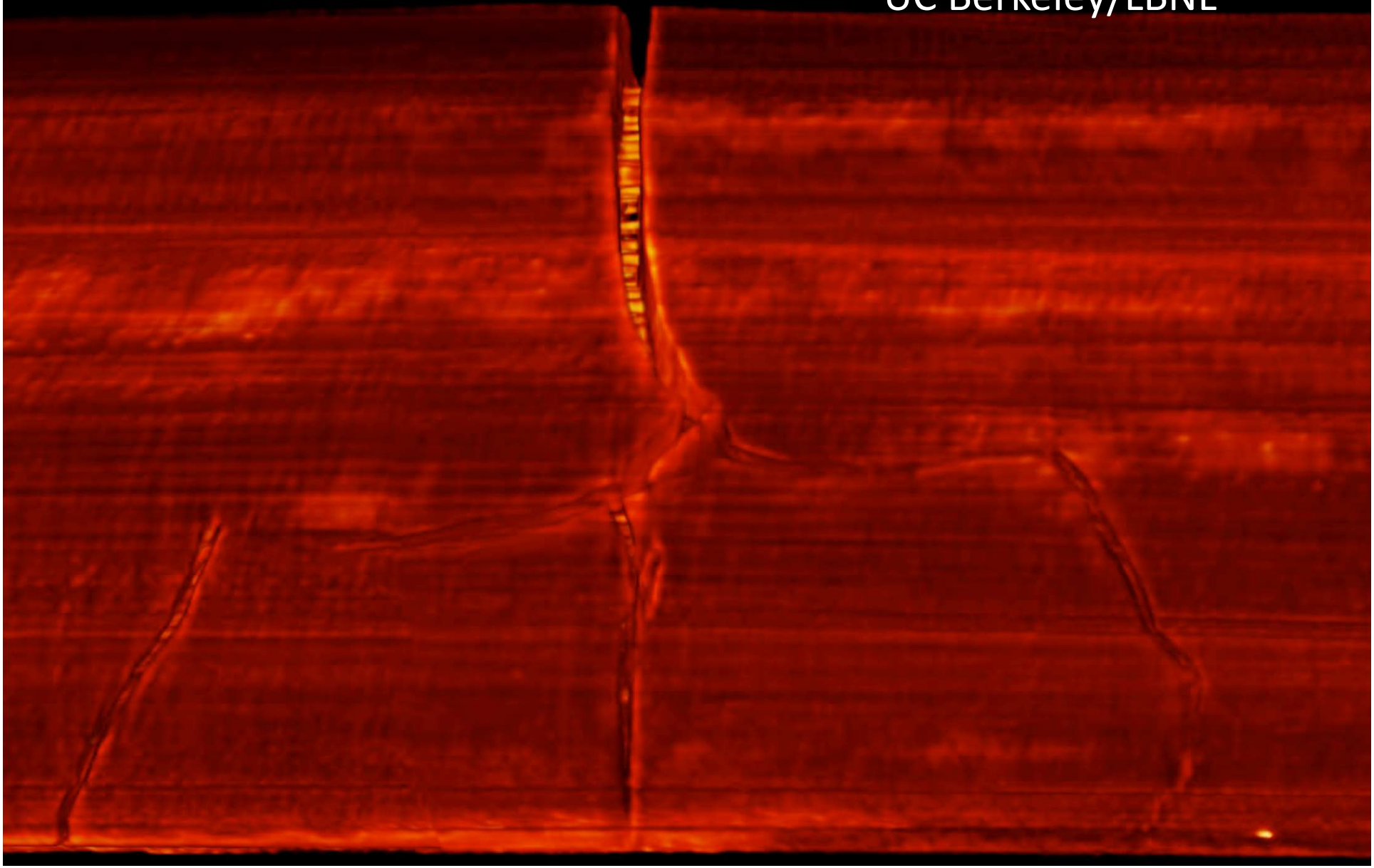


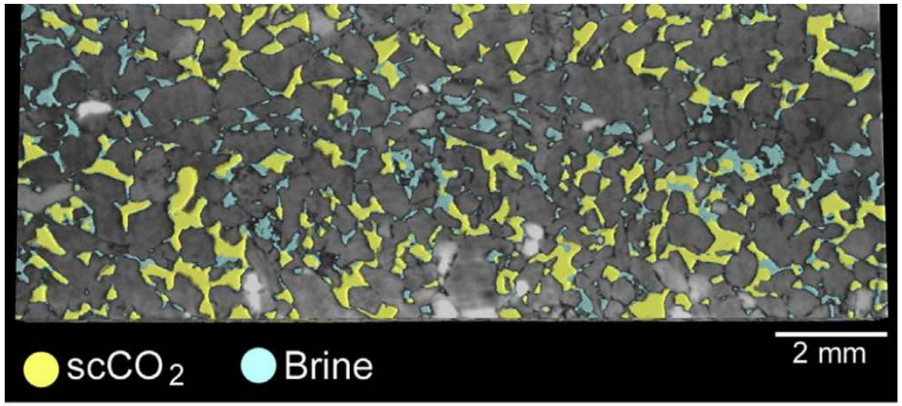




Ceramic Matrix Composites

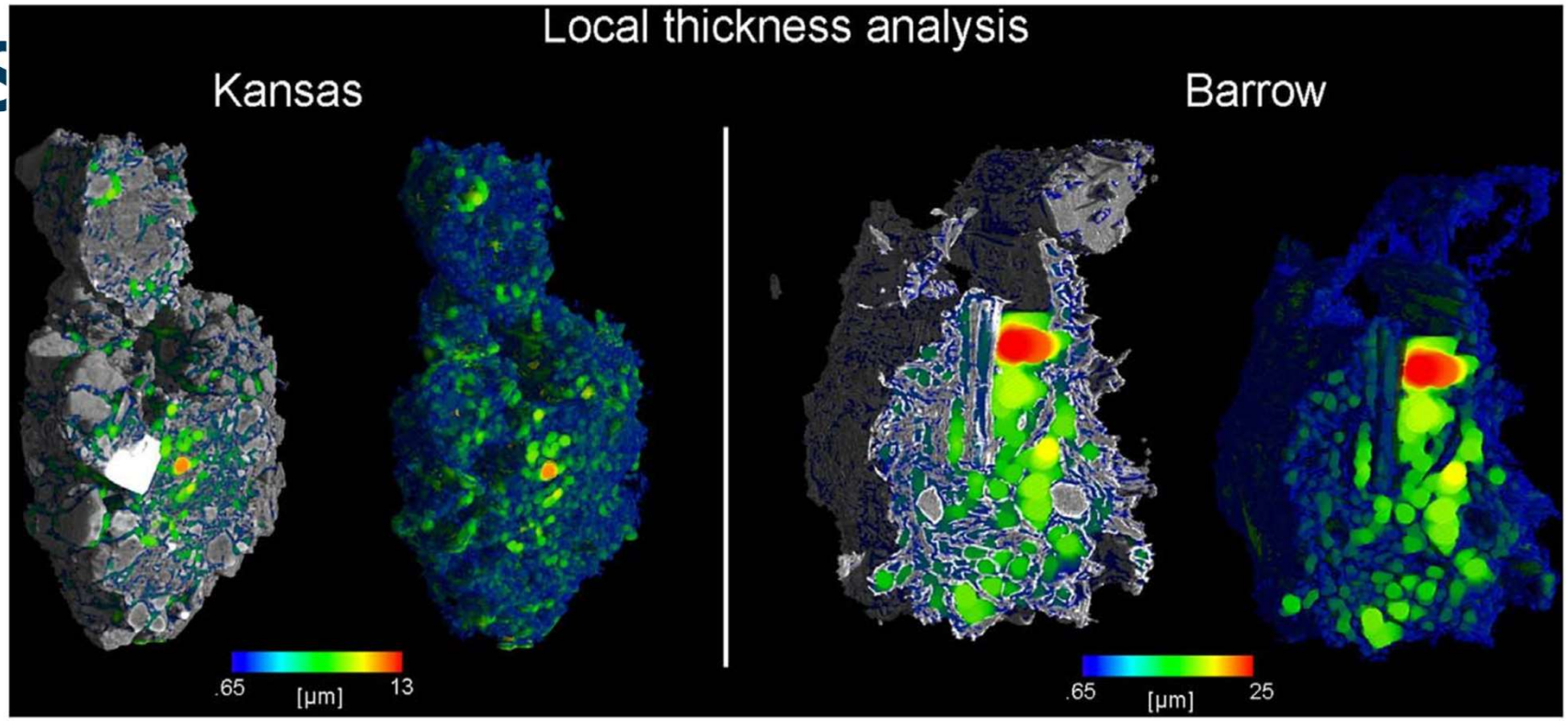
Data courtesy Rob Ritchie, Hrishi Bale, UC Berkeley/LBNL

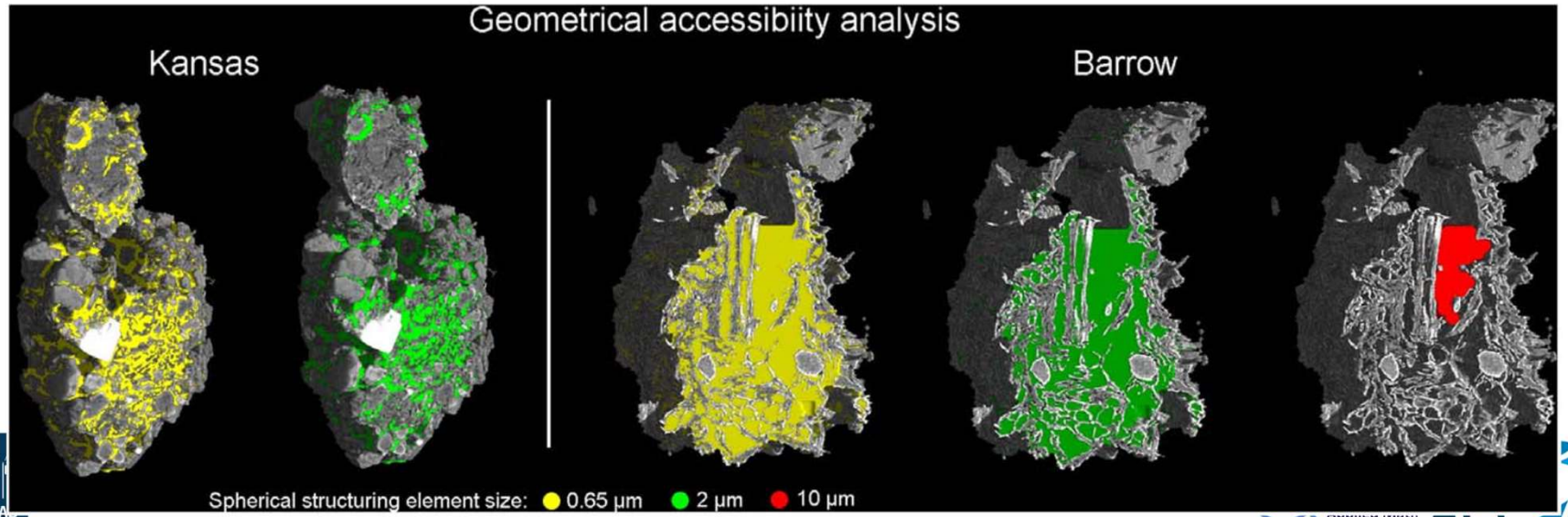




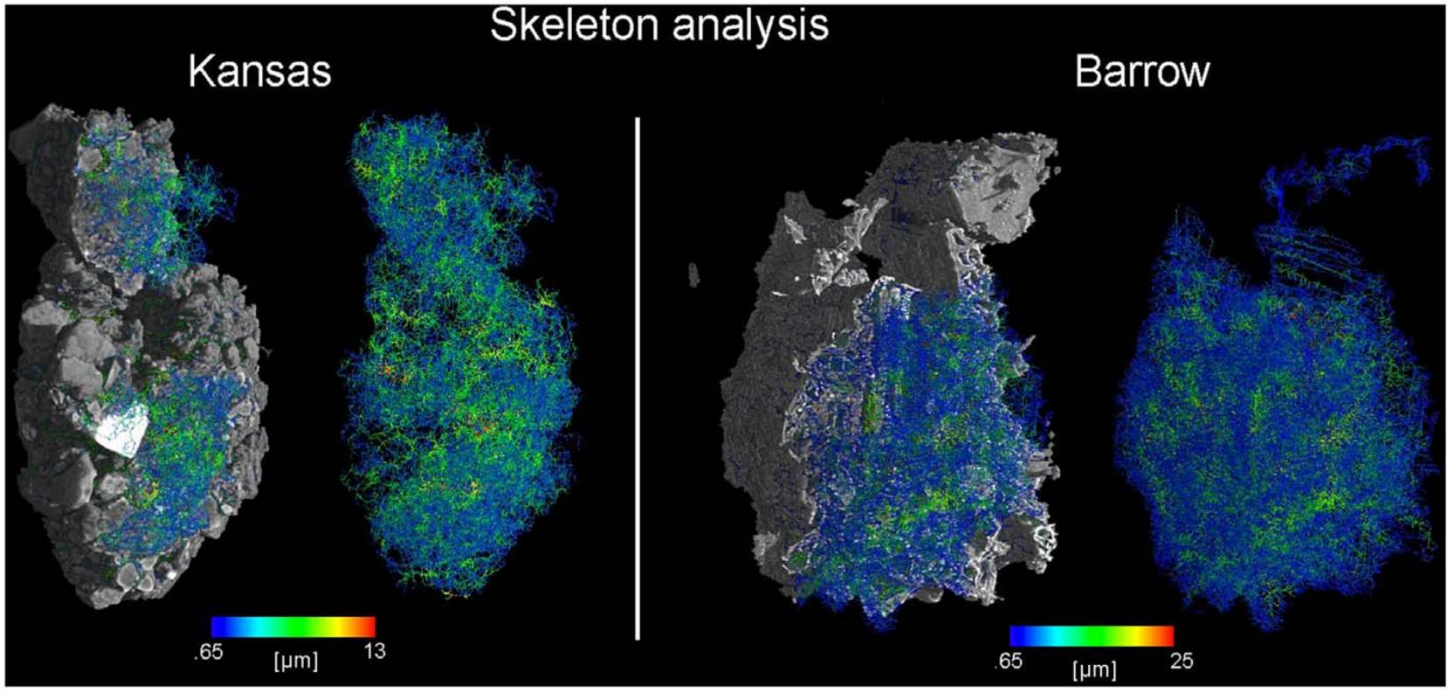
Flow through rocks

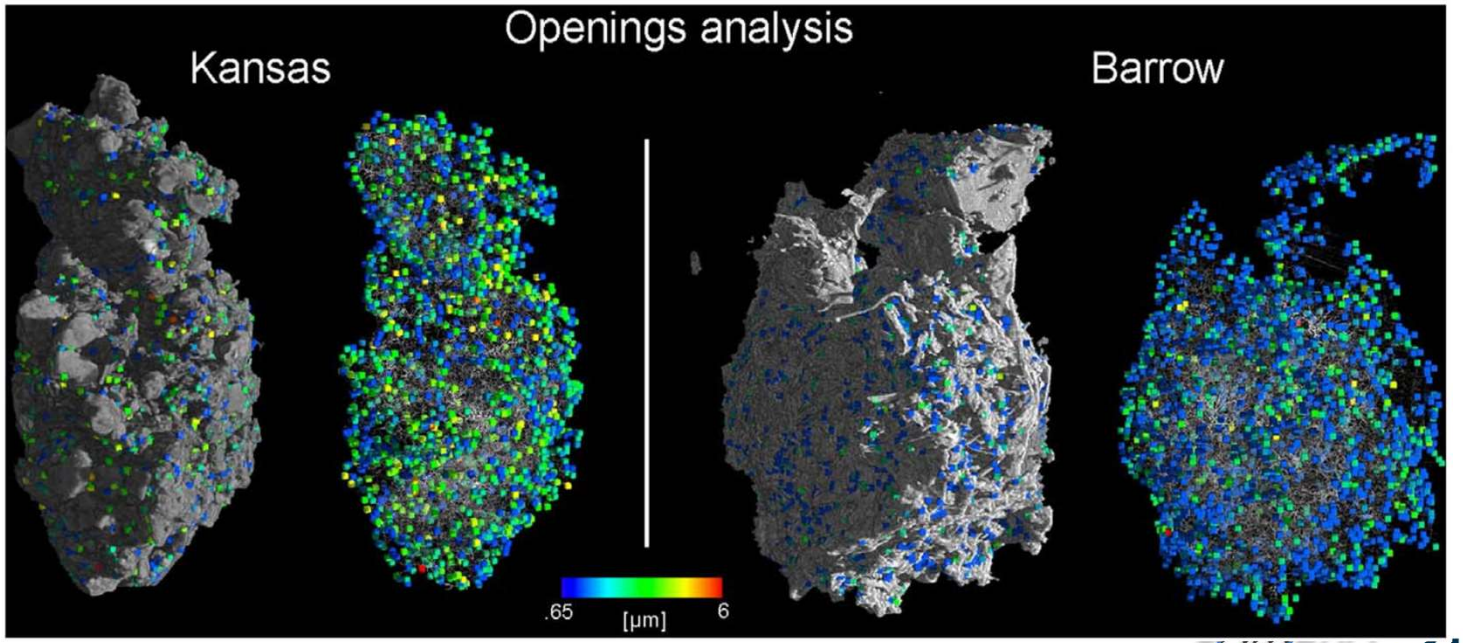
- Marco Voltolini, Jonathan Ajo-Franklin et al.
- (Geoderma 305 (2017) 382–393)


Local thickness analysis
Kansas
Barrow
.65
[µm]
13
.65
[µm]
25


Geometrical accessibiity analysis
Kansas
Barrow
Spherical structuring element size:
0.65 µm
2 µm
10 µm

Soil





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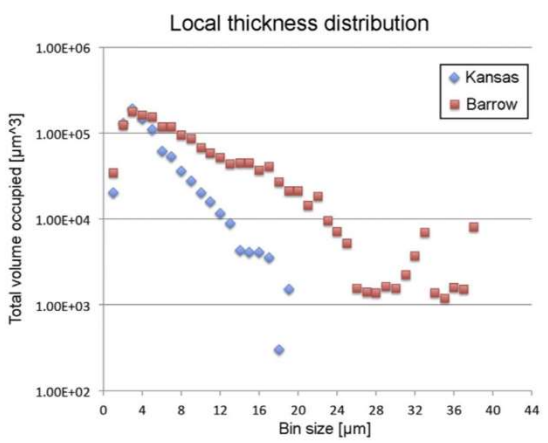
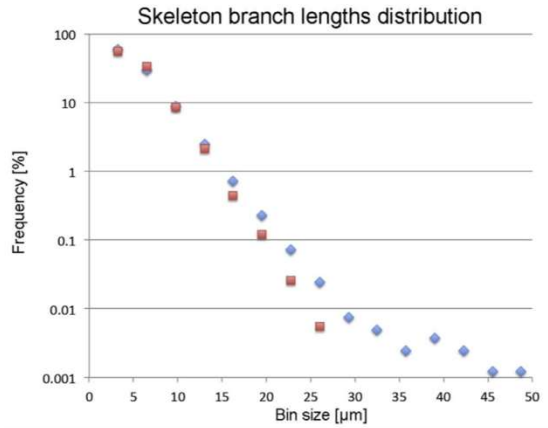
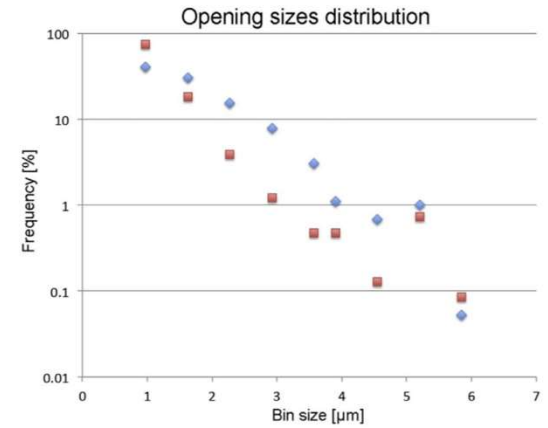
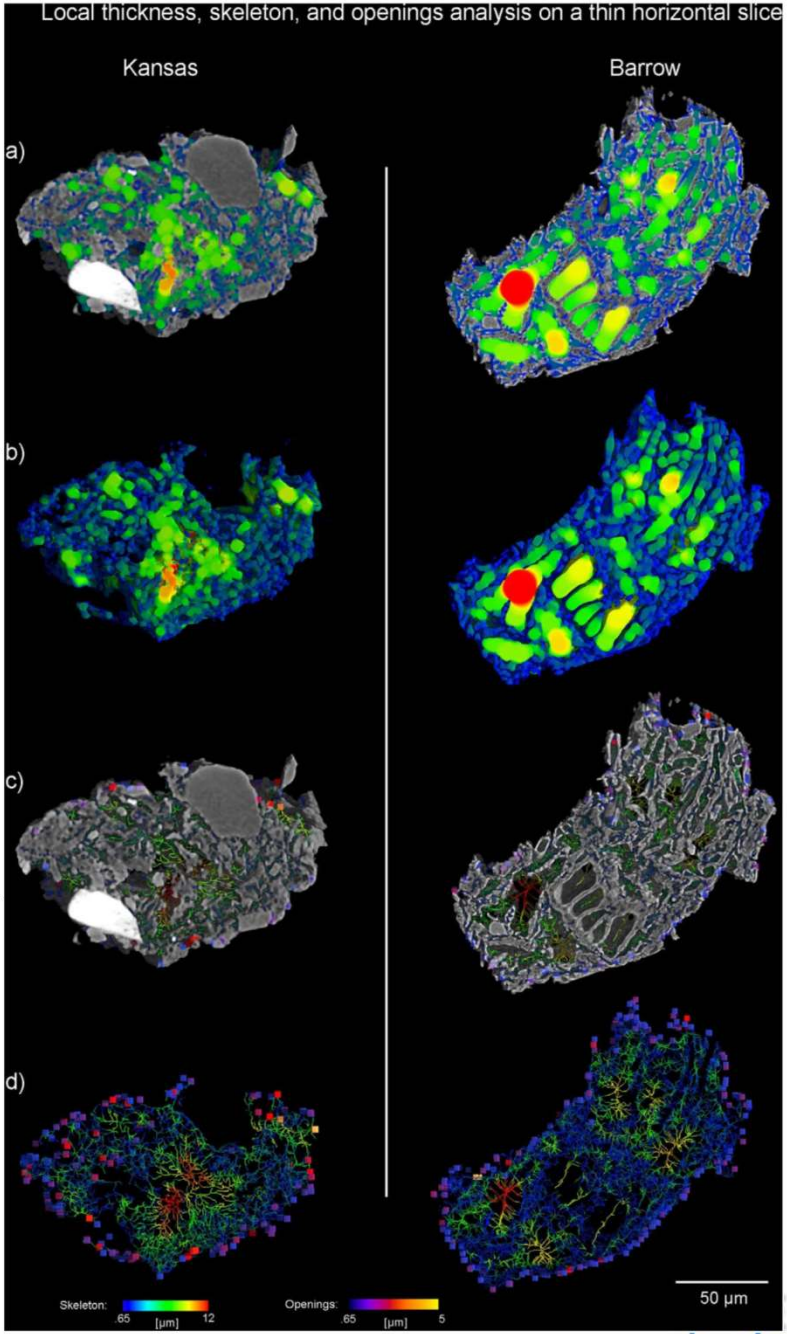
Applied Math ALS









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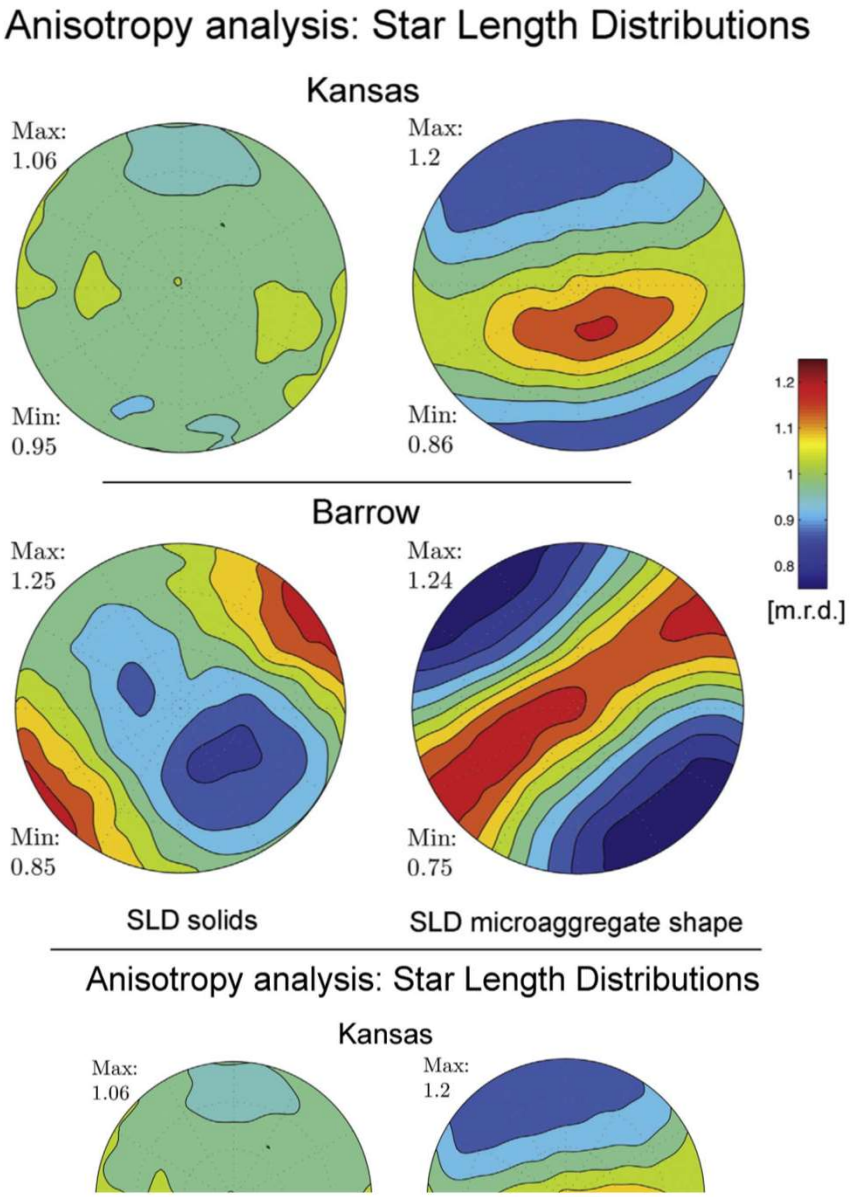
Applied Math

ALS

Soil Micro-Aggregates



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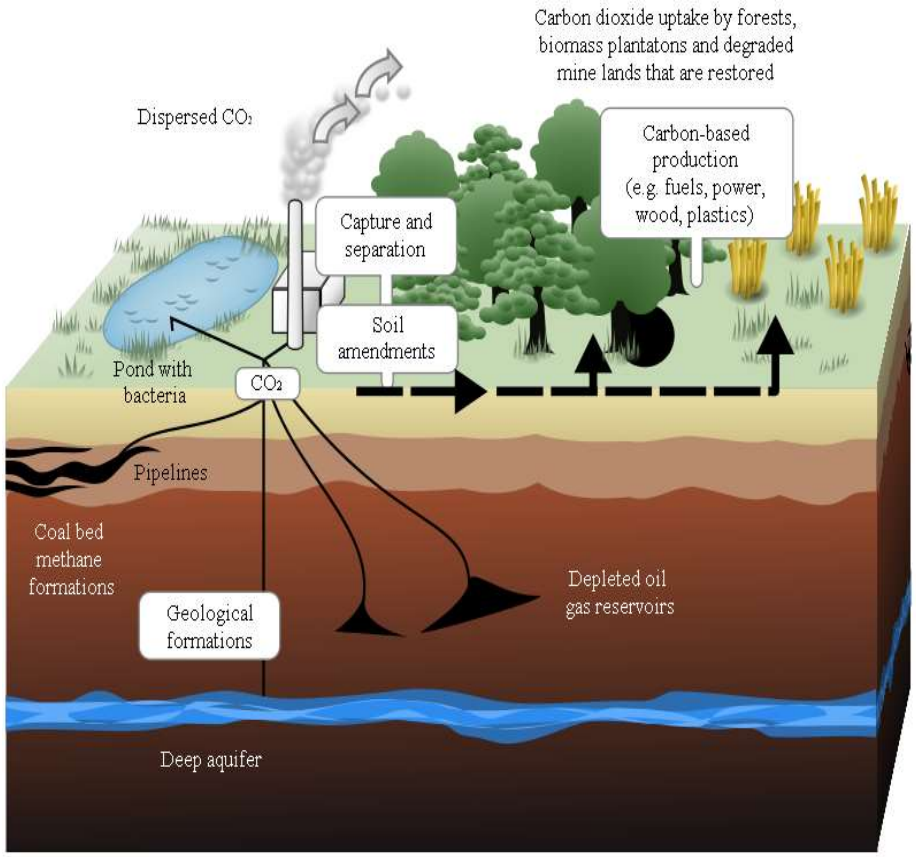
CAMERA Applied Math ALS

Capture and storage of underground CO2



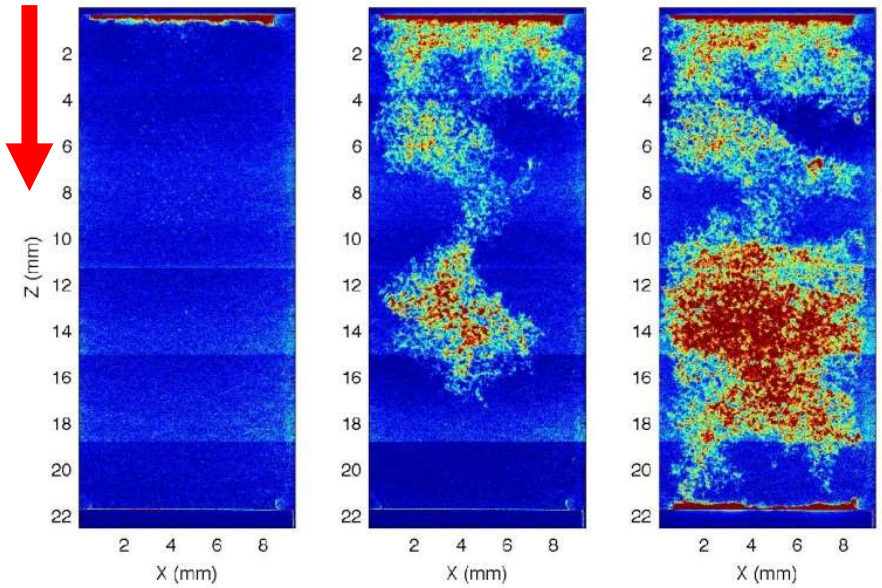
CO2 sequestration projects

Location of sites where geological storage of CO_2 and CO_2- enhanced oil and gas recovery takes place, from the IPCC Special Report on Carbon Dioxide Capture and Storage

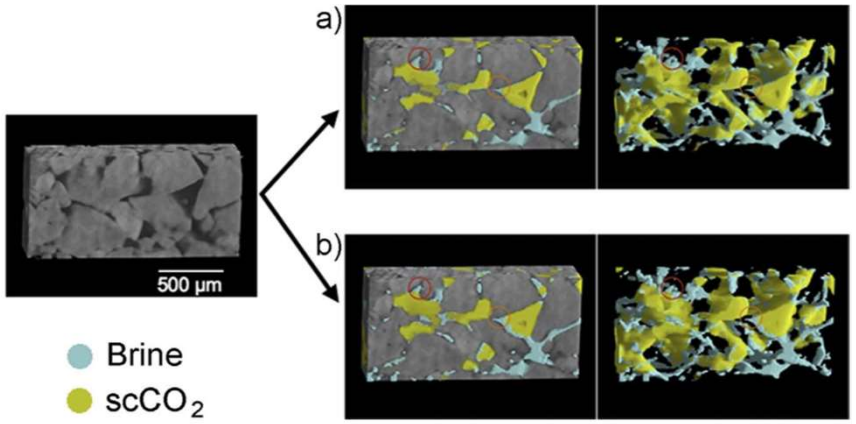
DOE spending ~$4B on CO2 sequestration projects

Carbon Sequestration Slides made with help from Jonathan Ajo-Franklin

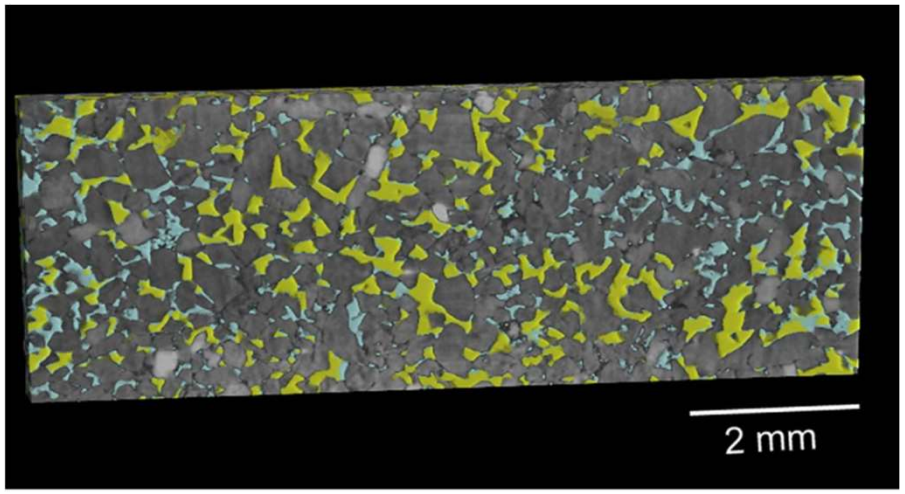
$scCO_2$ (displacing brine)



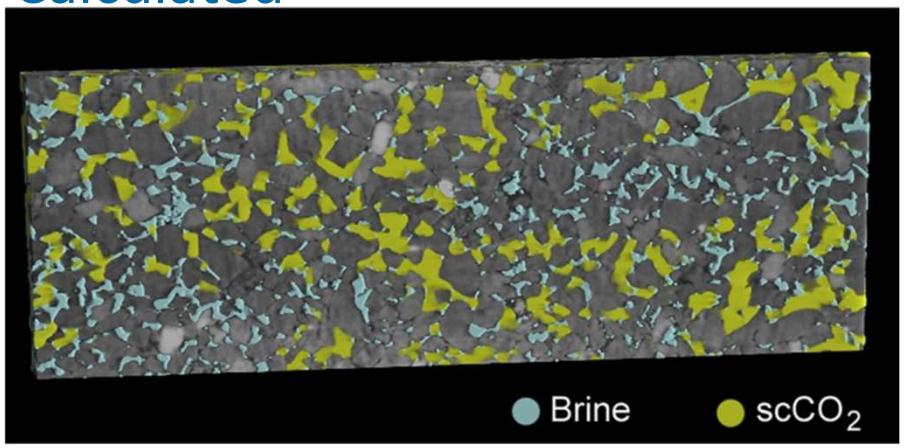
0 s 30 s 60 s



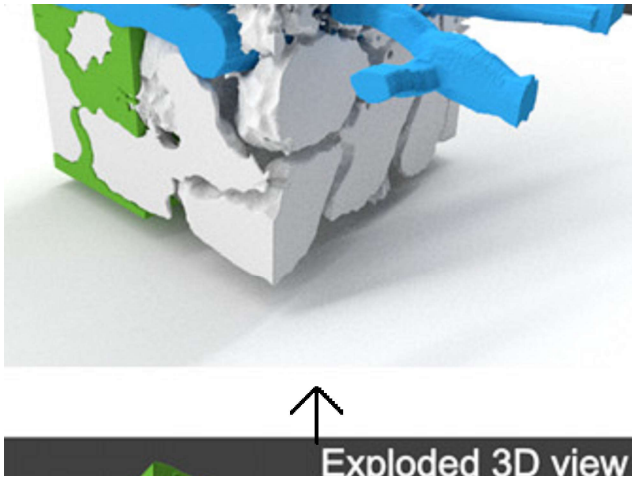
Measured



Calculated



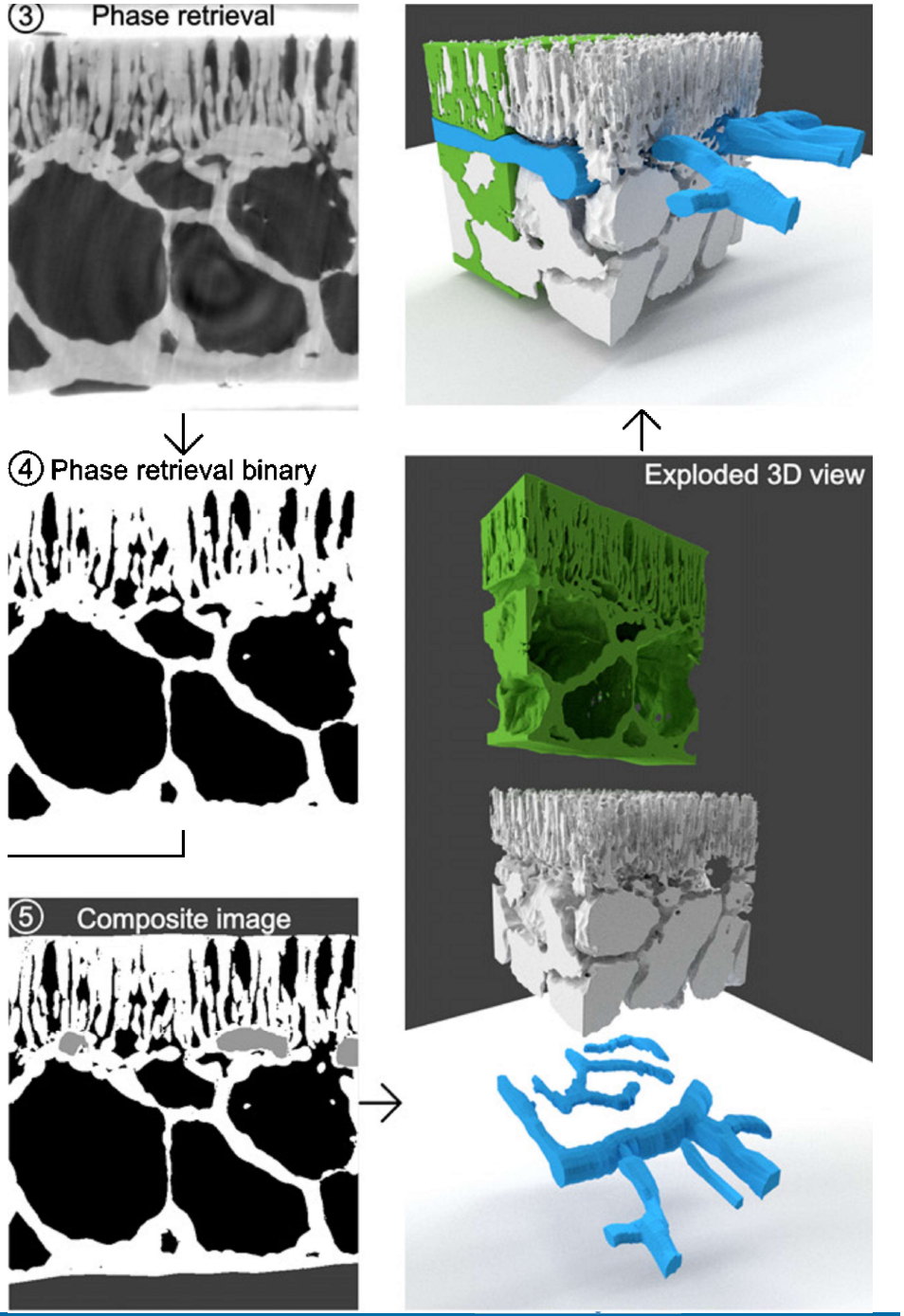
Leaf Internal Structure



Motivation

- Measure
  - Leaf porosity
  - Surface area of cells exposed to the air space inside the leaf
  - Pathlength for CO2 or H2O going in and out of a leaf.
- Understand how leaves optimize photosynthetic performance under a range of environmental conditions.

Leaf structure



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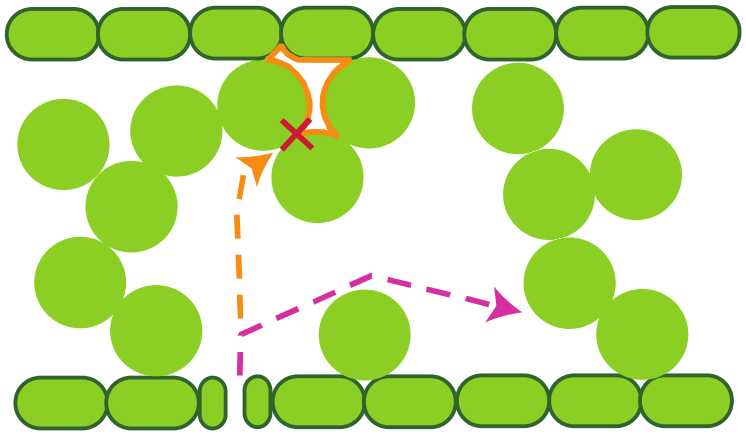
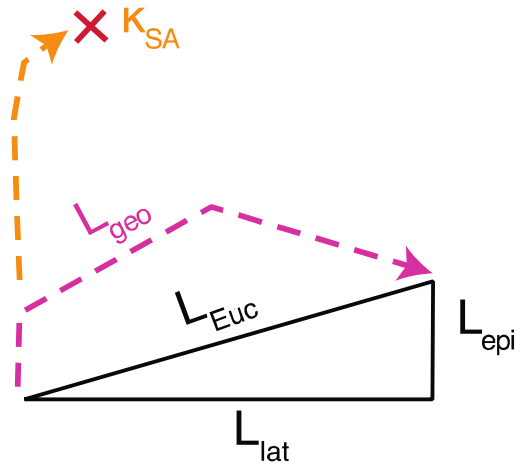
Tortuosity and Lateral Path Lengthening

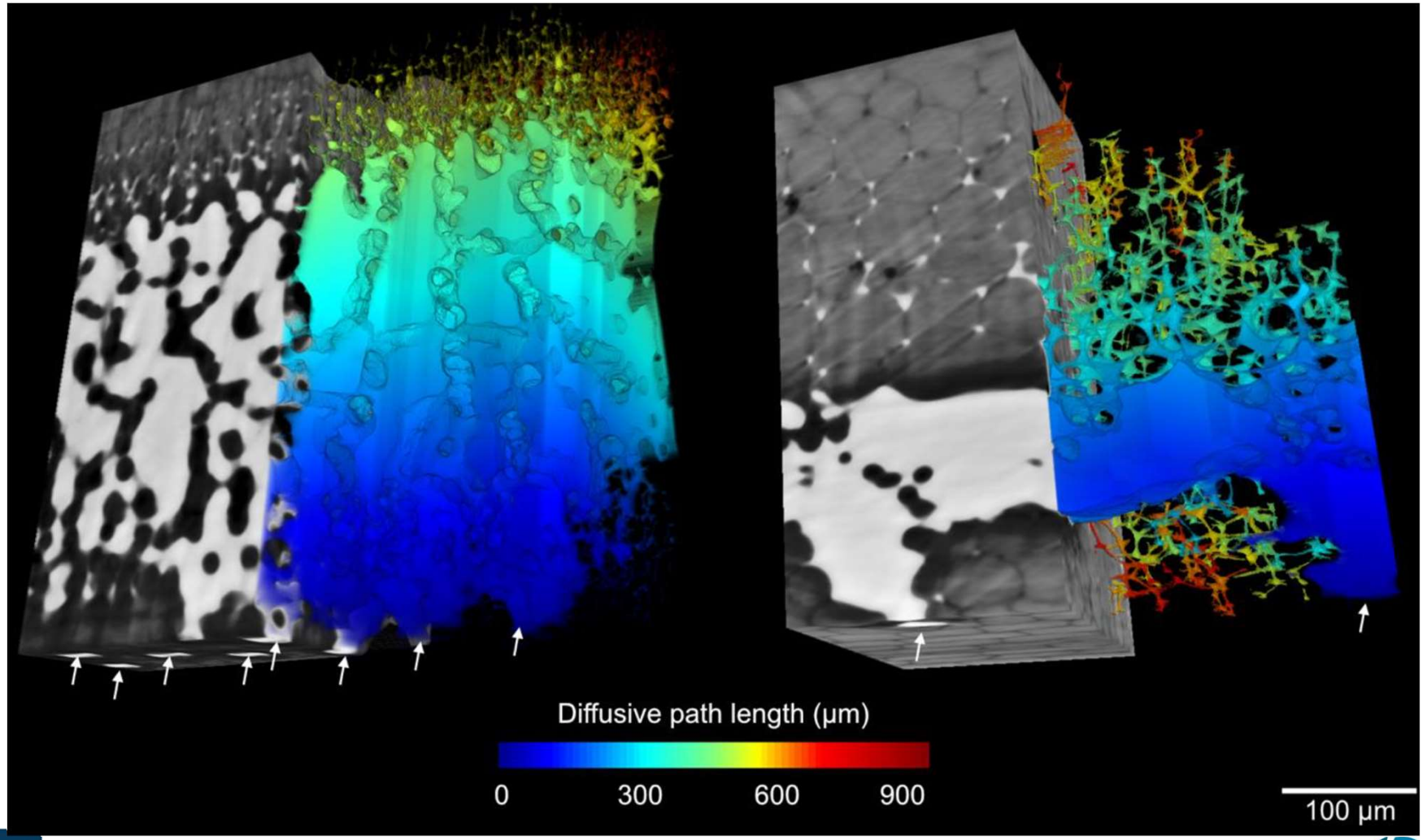




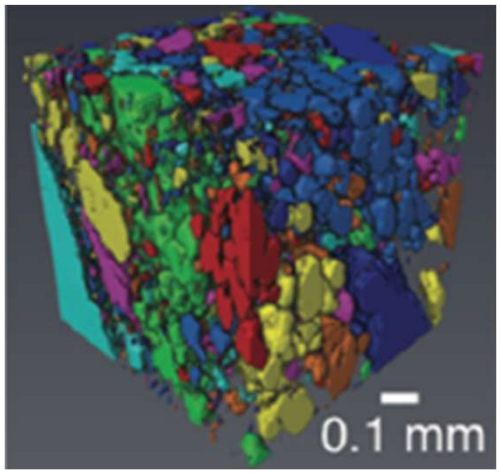
$$\lambda = \frac{L_{Euc}}{L_{epi}}$$

$$\tau = \frac{L_{geo}^2}{L_{Euc}^2}$$

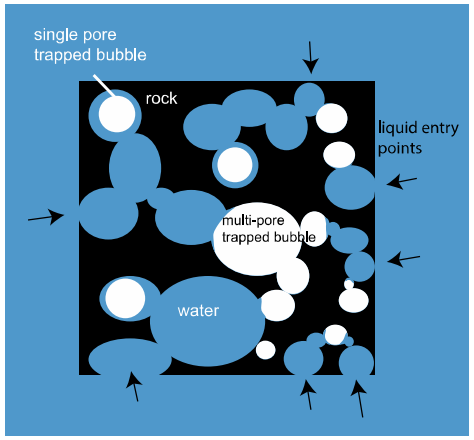
Diffusive air path length

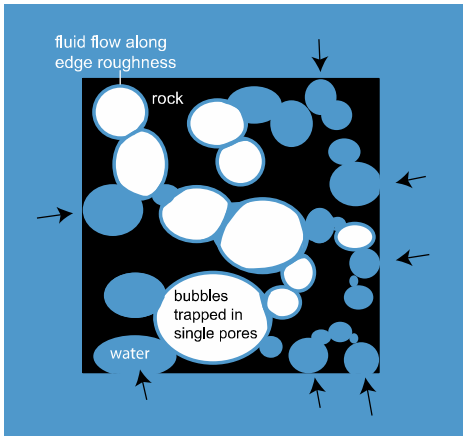


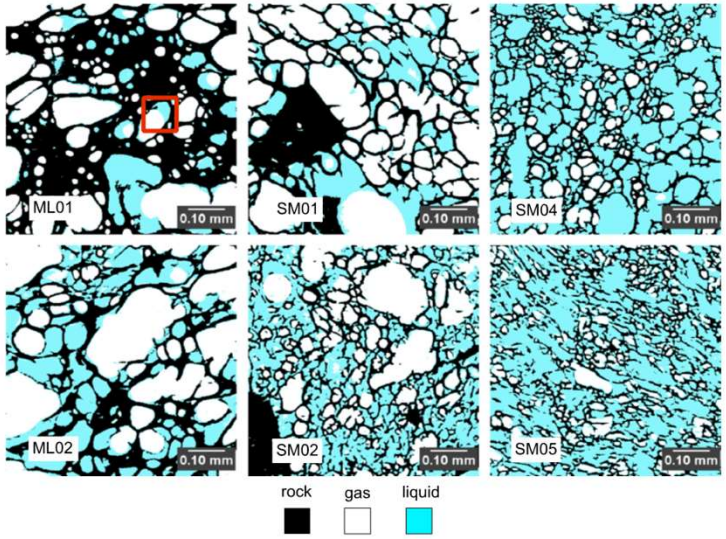
Floating Rocks



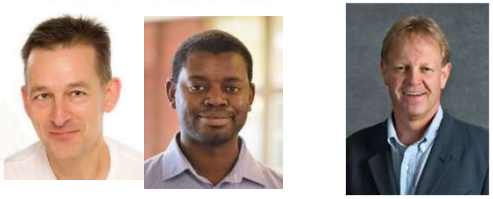
Pumice

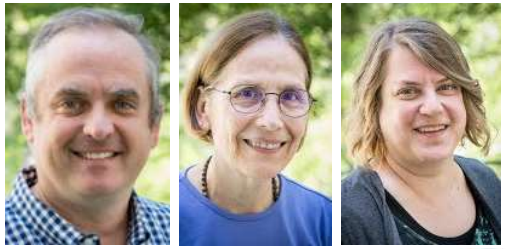

single pore
trapped bubble
rock
liquid entry
points
multi-pore
trapped bubble
water


fluid flow along
edge roughness
rock
bubbles
trapped in
single pores
water


ML01
SM01
SM04
ML02
SM02
SM05
0.10 mm
rock
gas
liquid

Thanks…





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