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**OPTICS &
PHOTONICS**

UNIVERSITY OF NOTTINGHAM



Imaging the microstructure and elasticity of space rock

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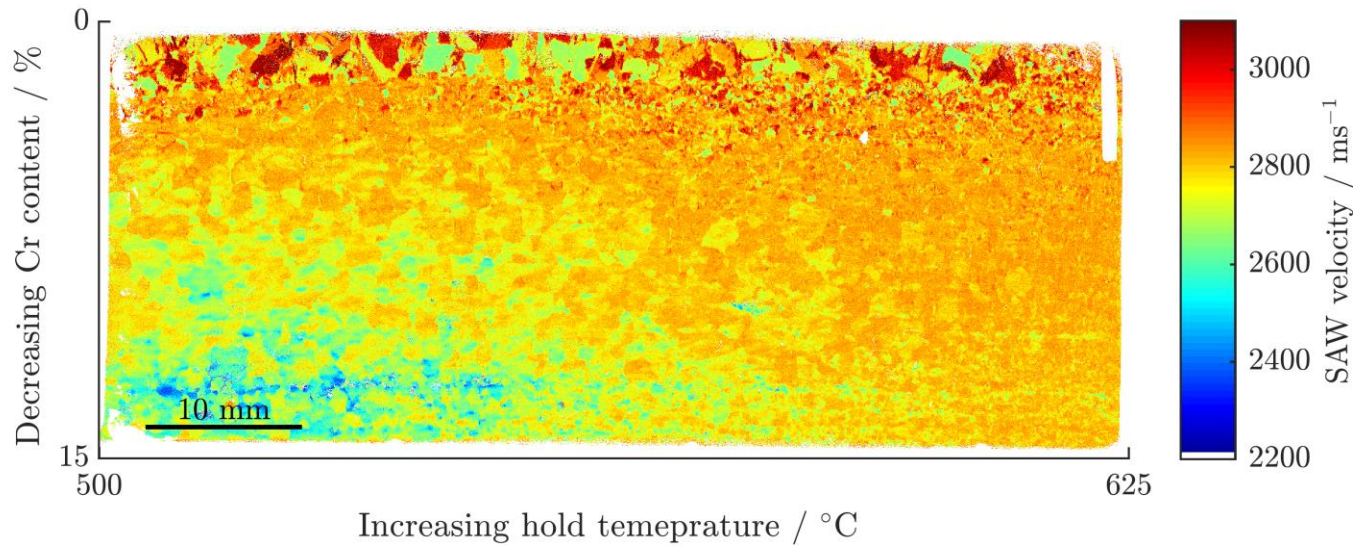
Optics and Photonics Research Group
University of Nottingham, UK



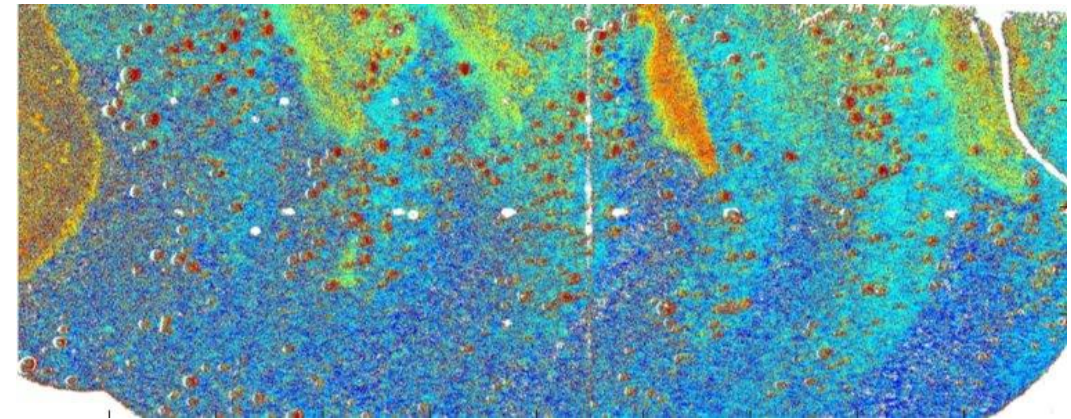


Opportunities and Challenges

Gradient Materials (Ti + Cr wt%)



Ti64 + tungsten carbide



Multi-material



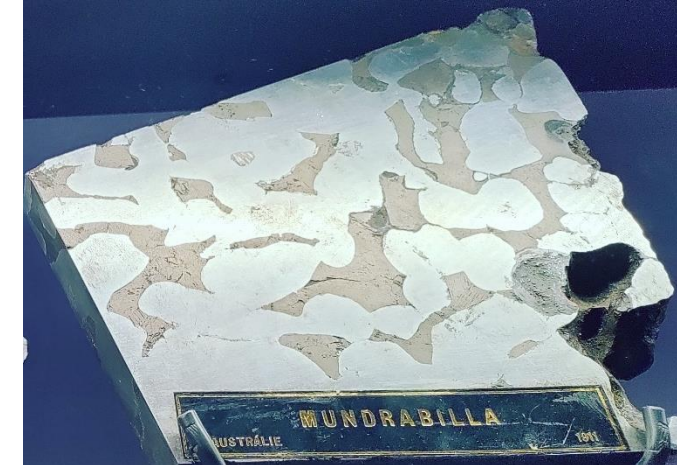
Space rocks!



Meteorites are space rocks that survives its trip through the atmosphere and hits the ground.

Types of meteorites are:

- iron meteorites
- stony-iron meteorites
- stony meteorites



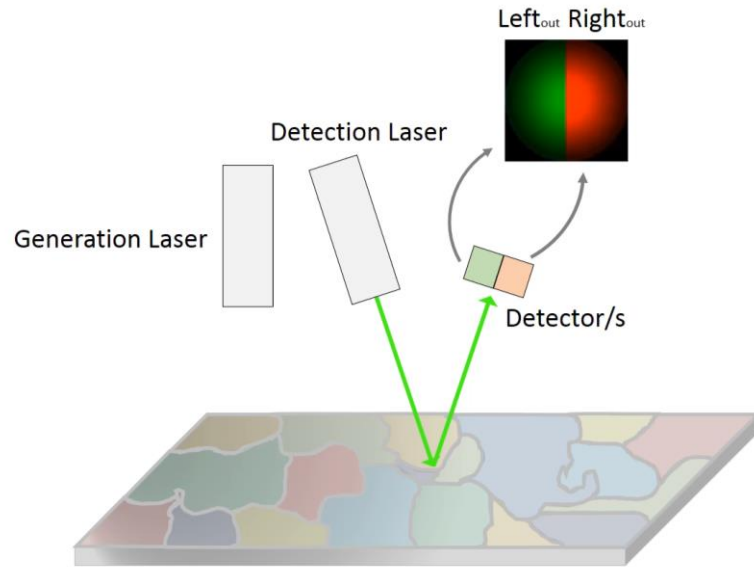


Spatially Resolved Acoustic Spectroscopy

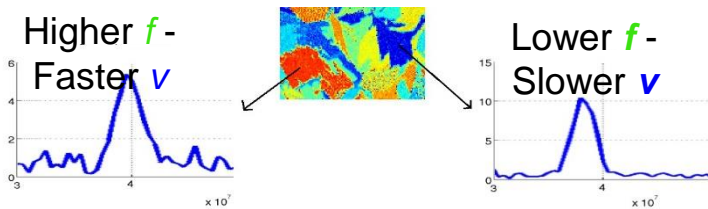
SRAS



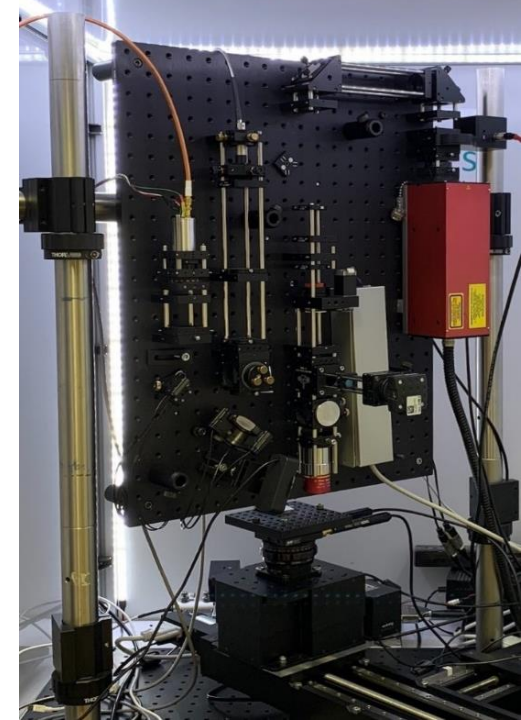
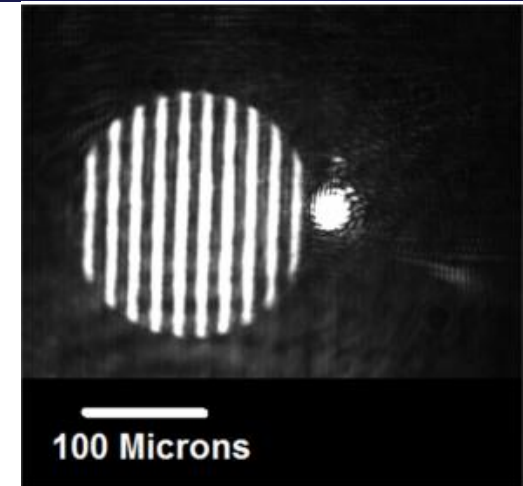
Spatially resolved acoustic spectroscopy



$$V_{\text{saw}} = f_{\text{sig}} * \lambda_{\text{gen}}$$

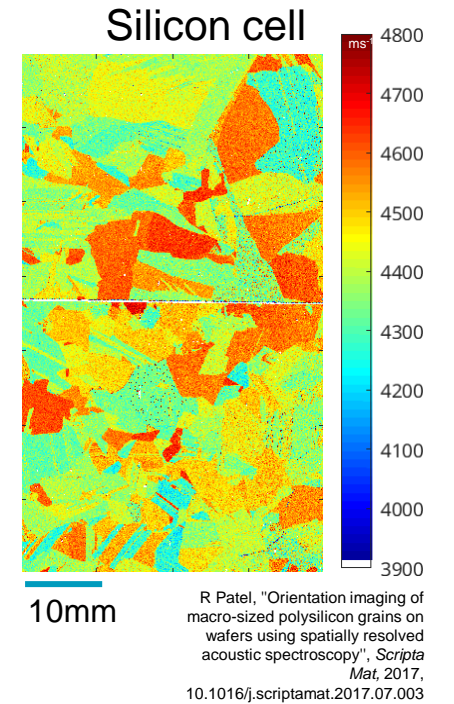
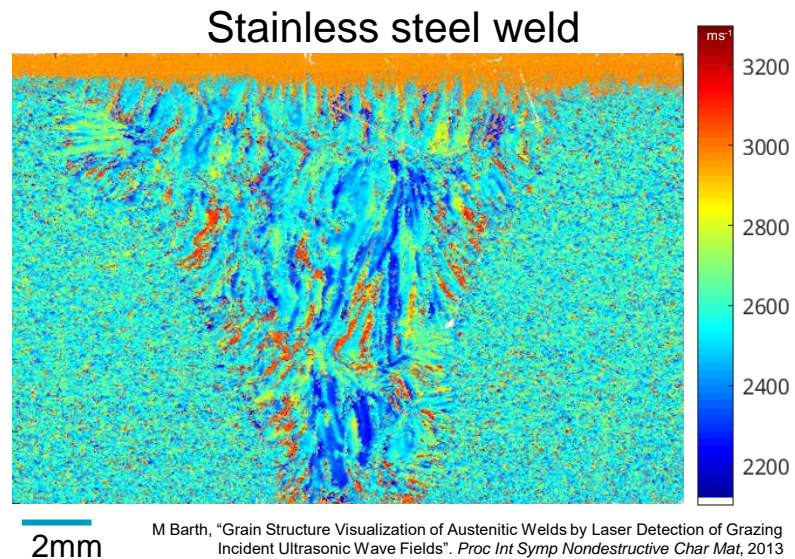
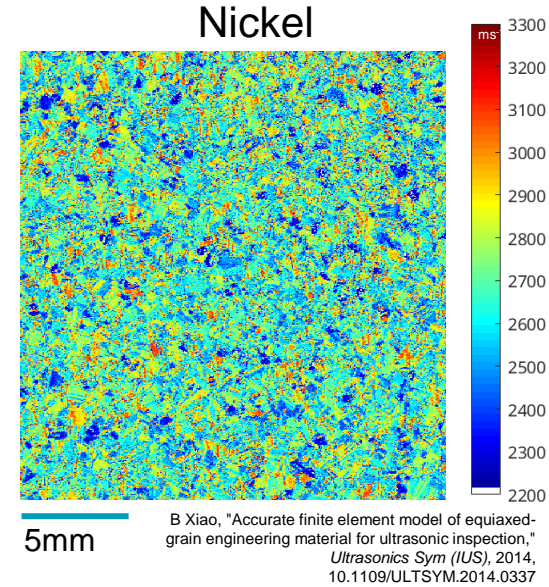
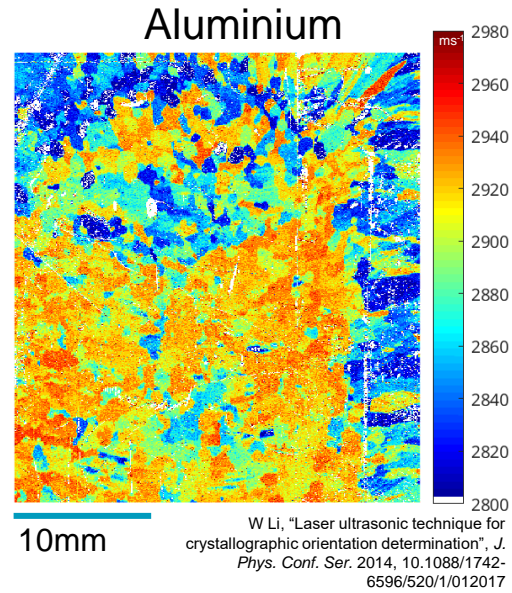
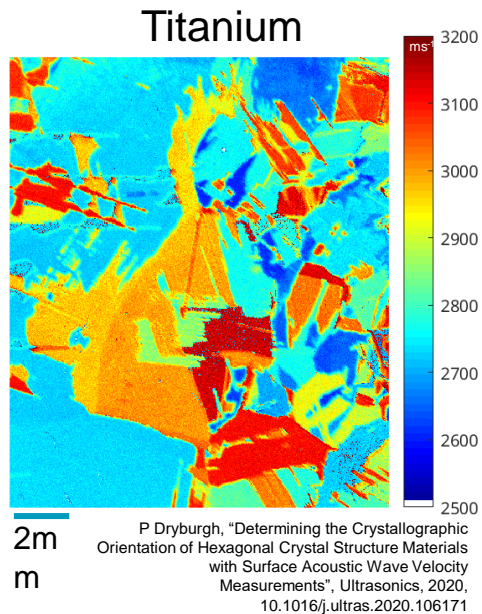


- Probe: Green – 532 nm. ~200mW after fibre
- Detector: Knife Edge
- Pump: IR – 1064 nm Broadband Q-Switched Pulsed, 50-150μJ, 1- 2 ns pulse width and 2 kHz repetition rate
- Scan speed: ~1000 points per second (due to scanning stages)
- Spatial Resolution: ~ 40 -100microns
- Sample state: Polished
- Max sample size: 300mmx300mm (limited by scanning stages range)



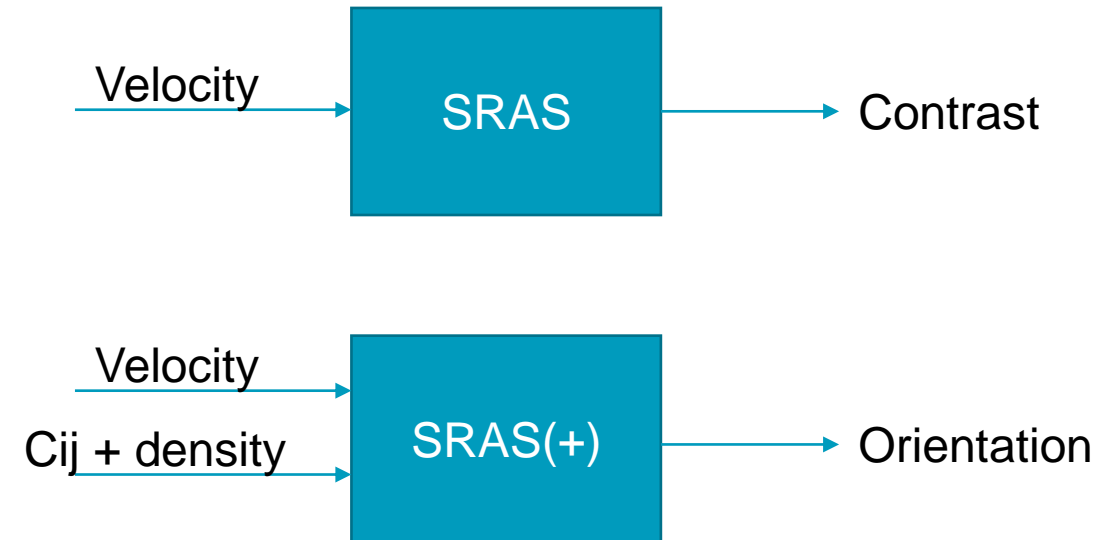
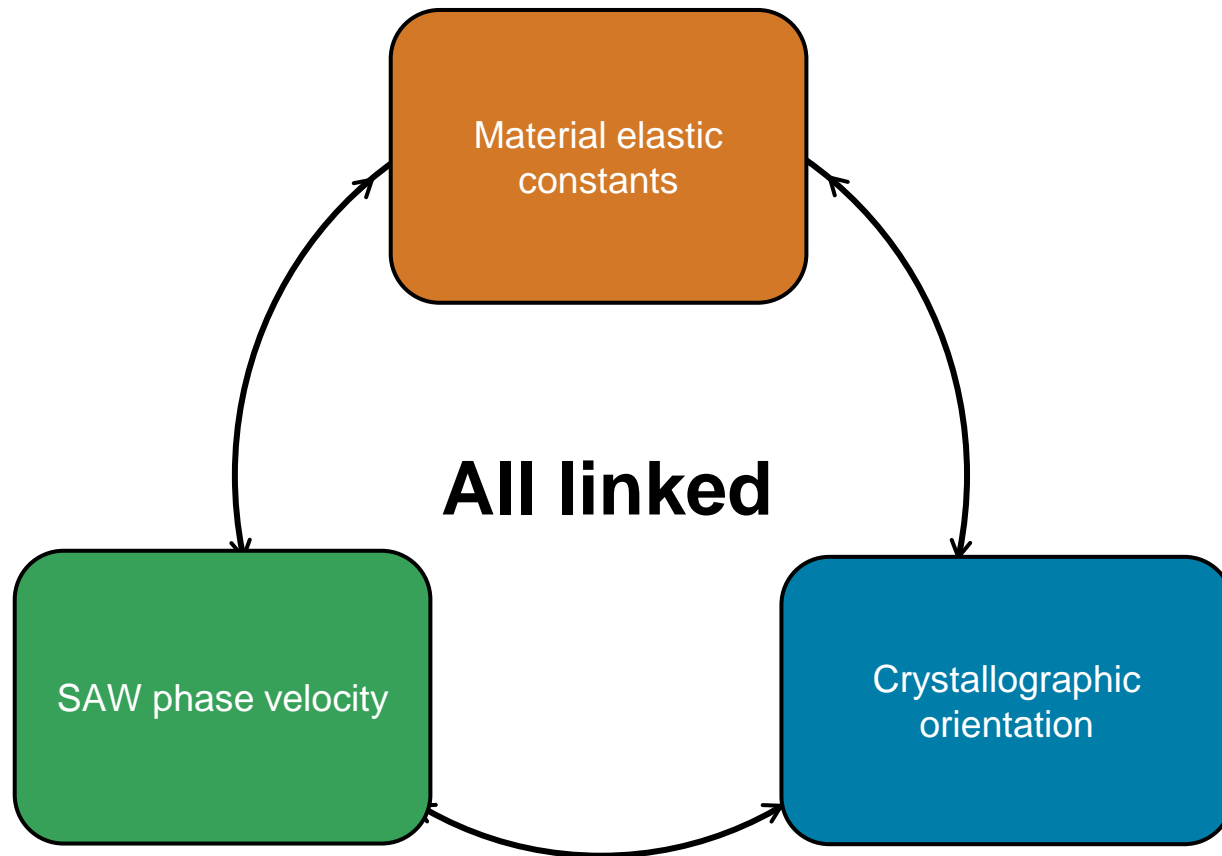


Multi-megapixel images of microstructure



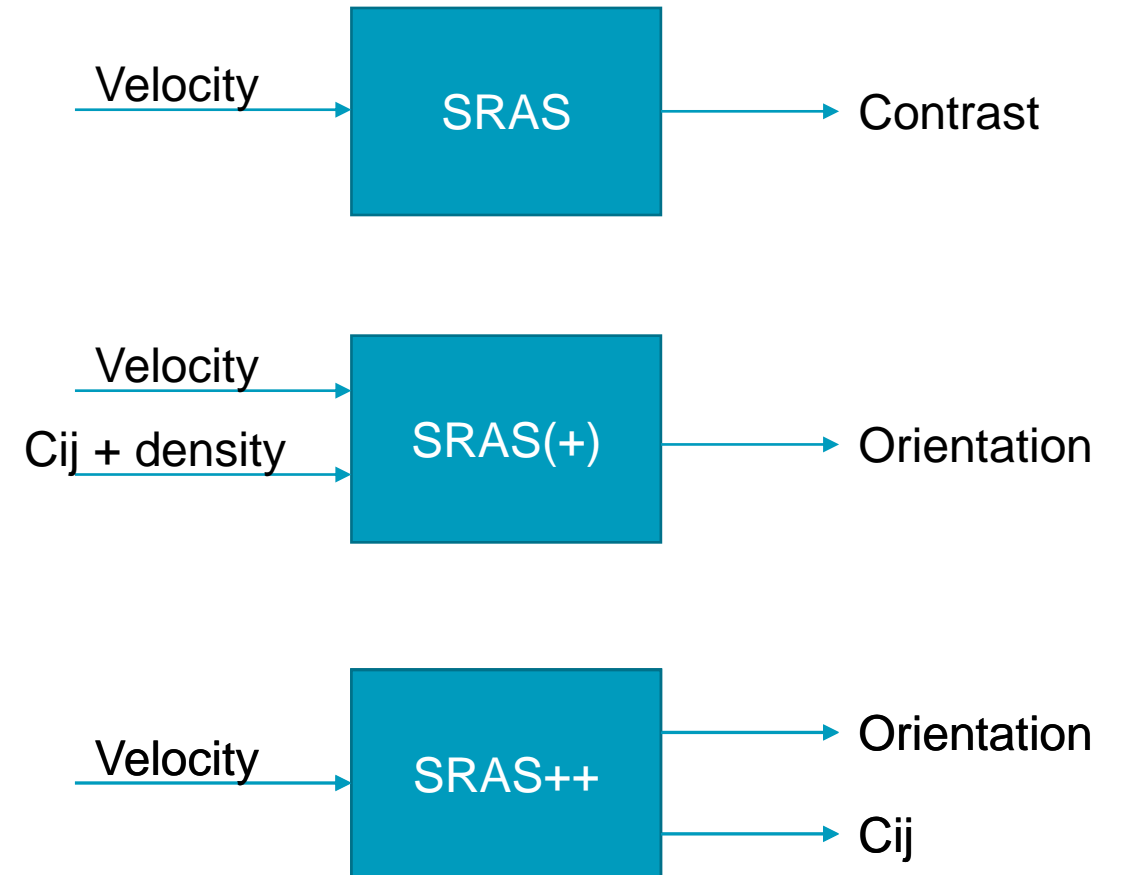
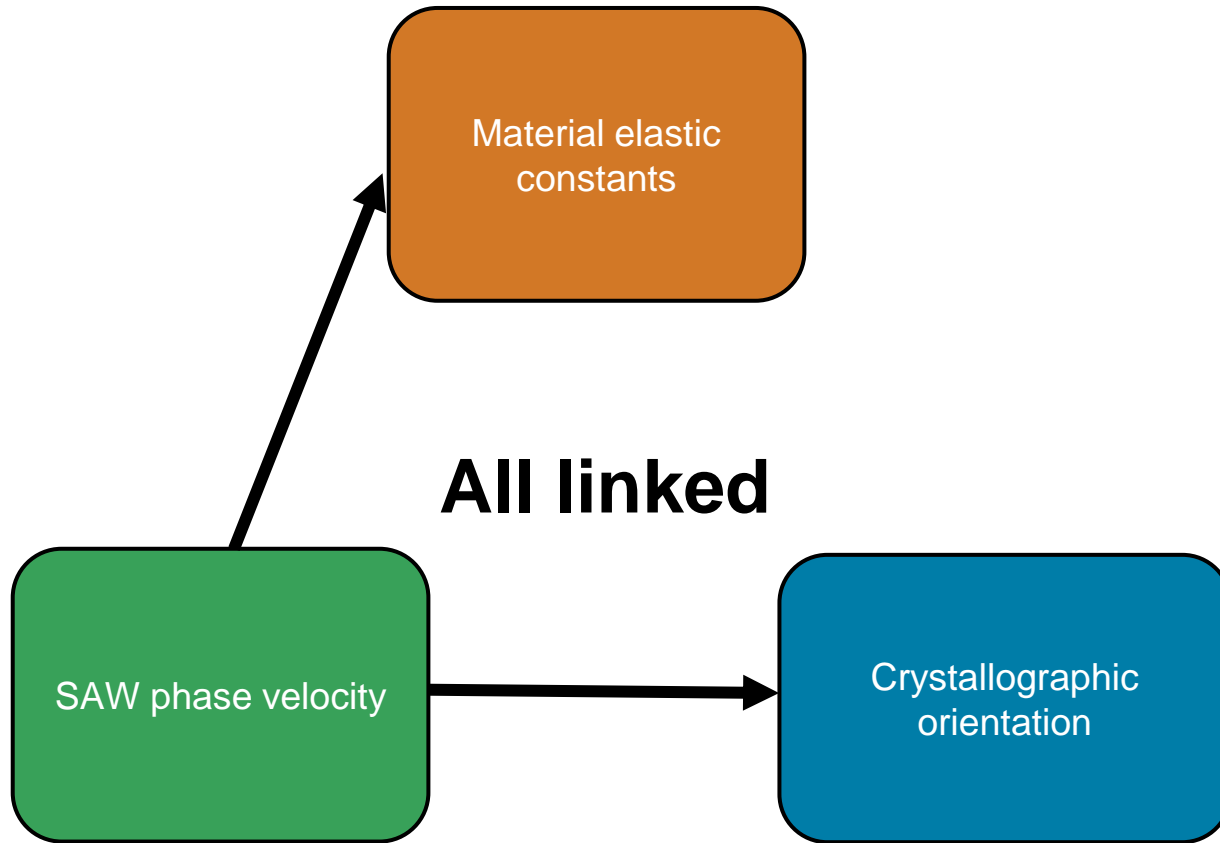


Relationship between SAW velocity and material





Relationship between SAW velocity and material



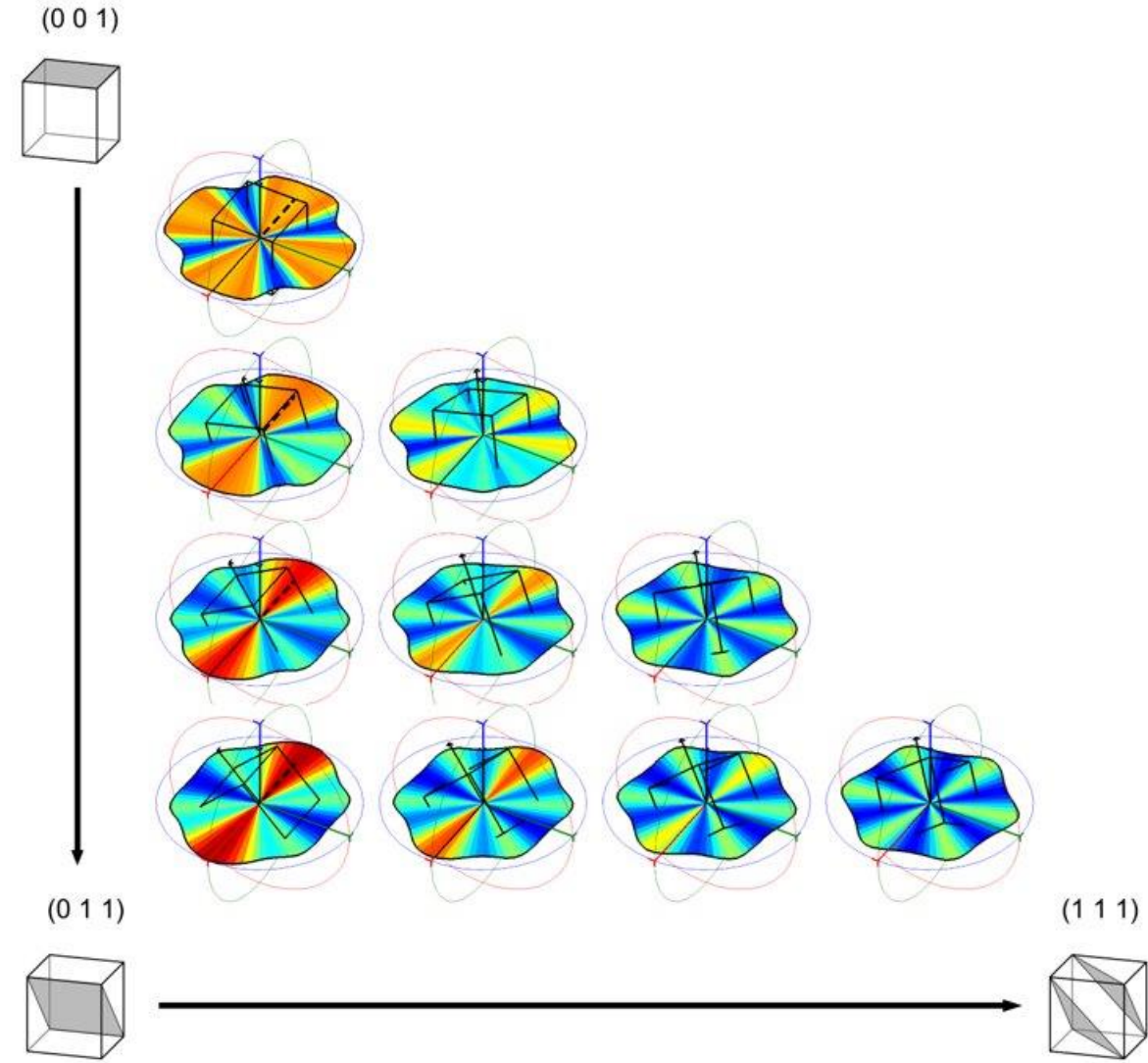
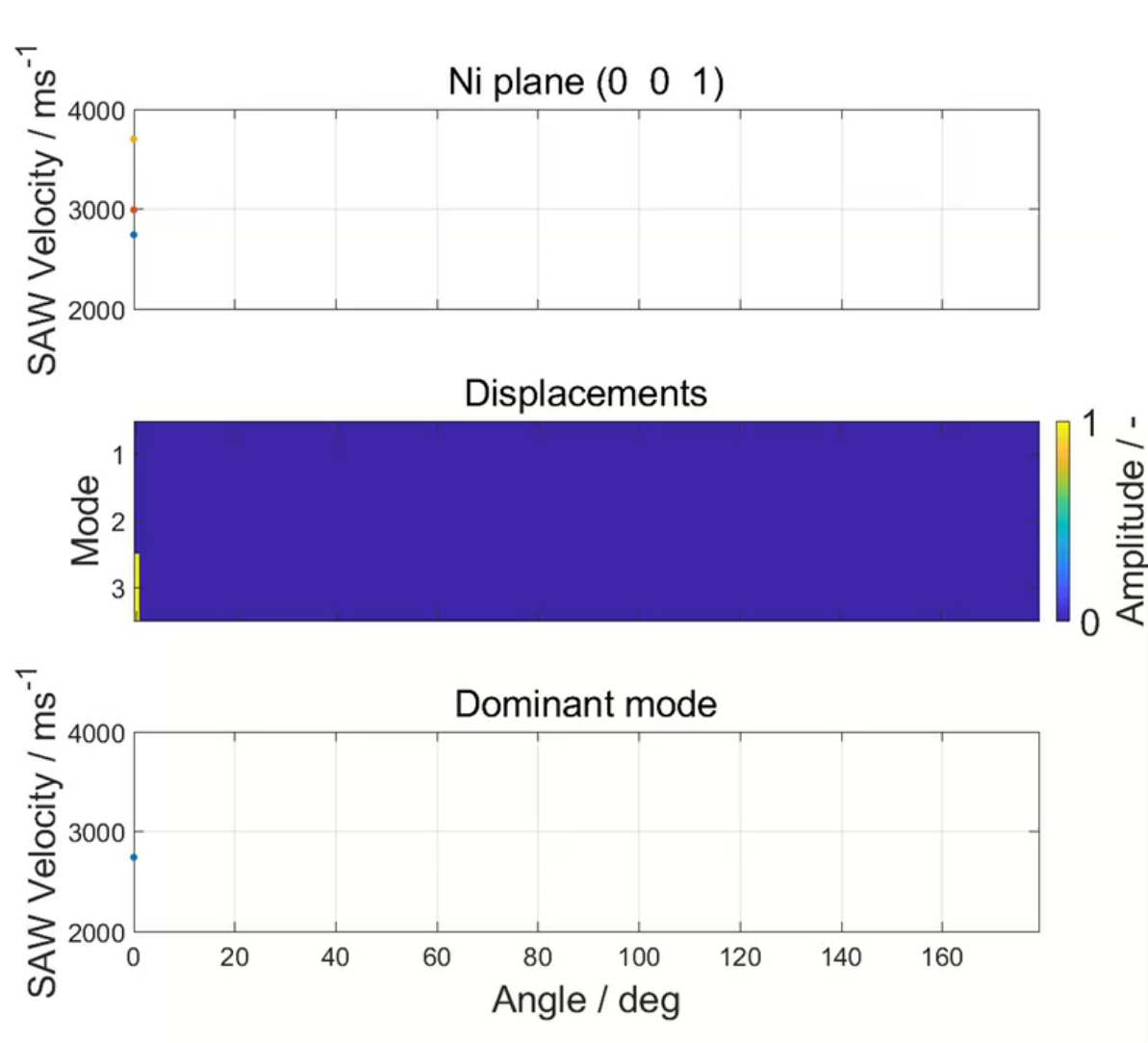


Spatially Resolved Acoustic Spectroscopy

SRAS+

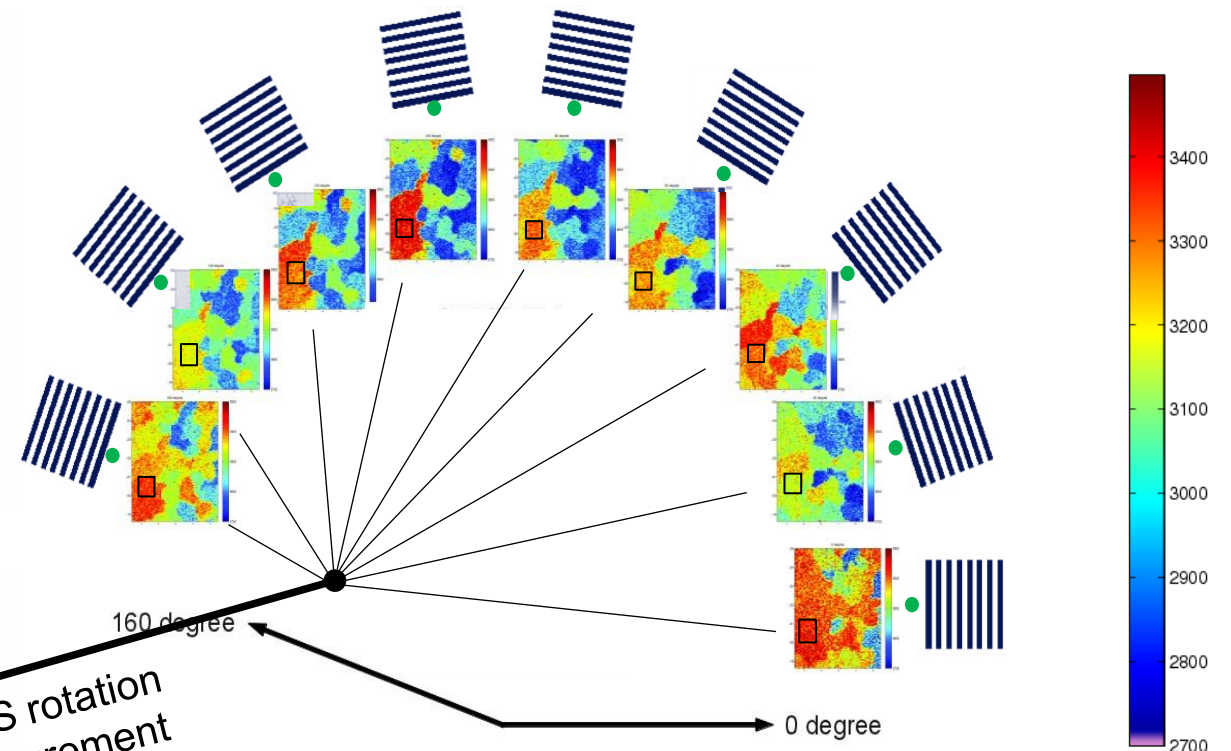
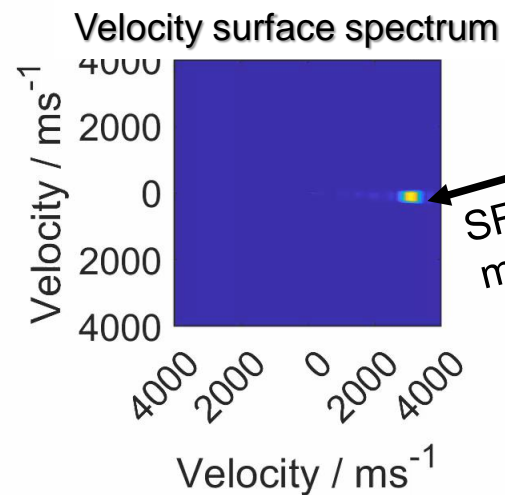
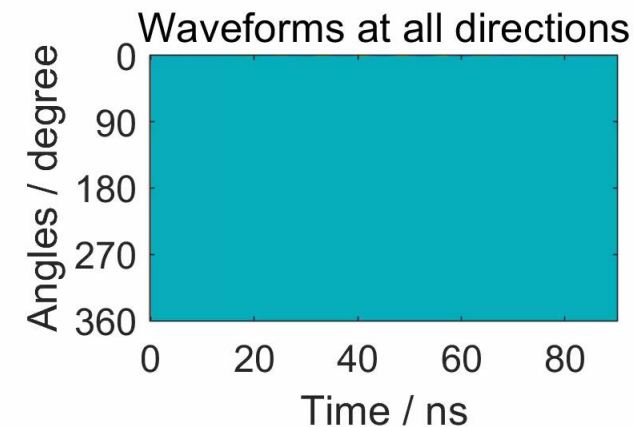
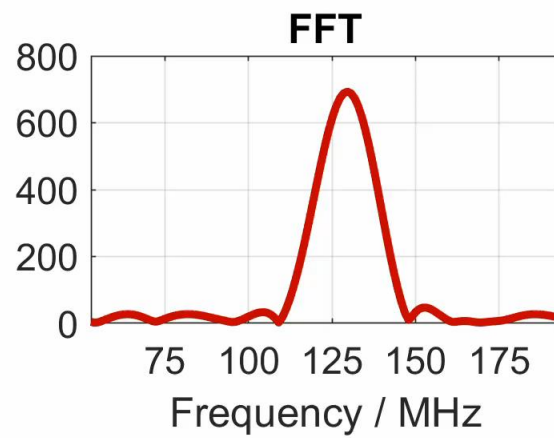
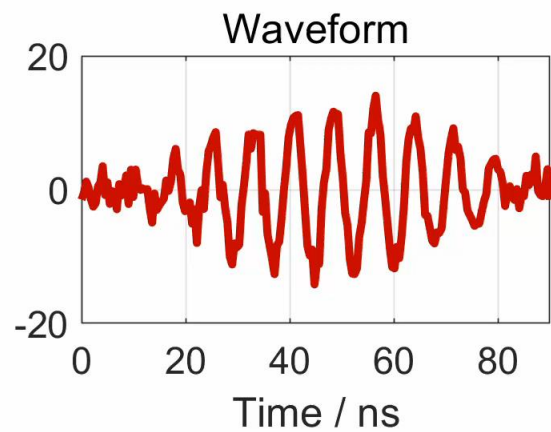


Solving the forward problem



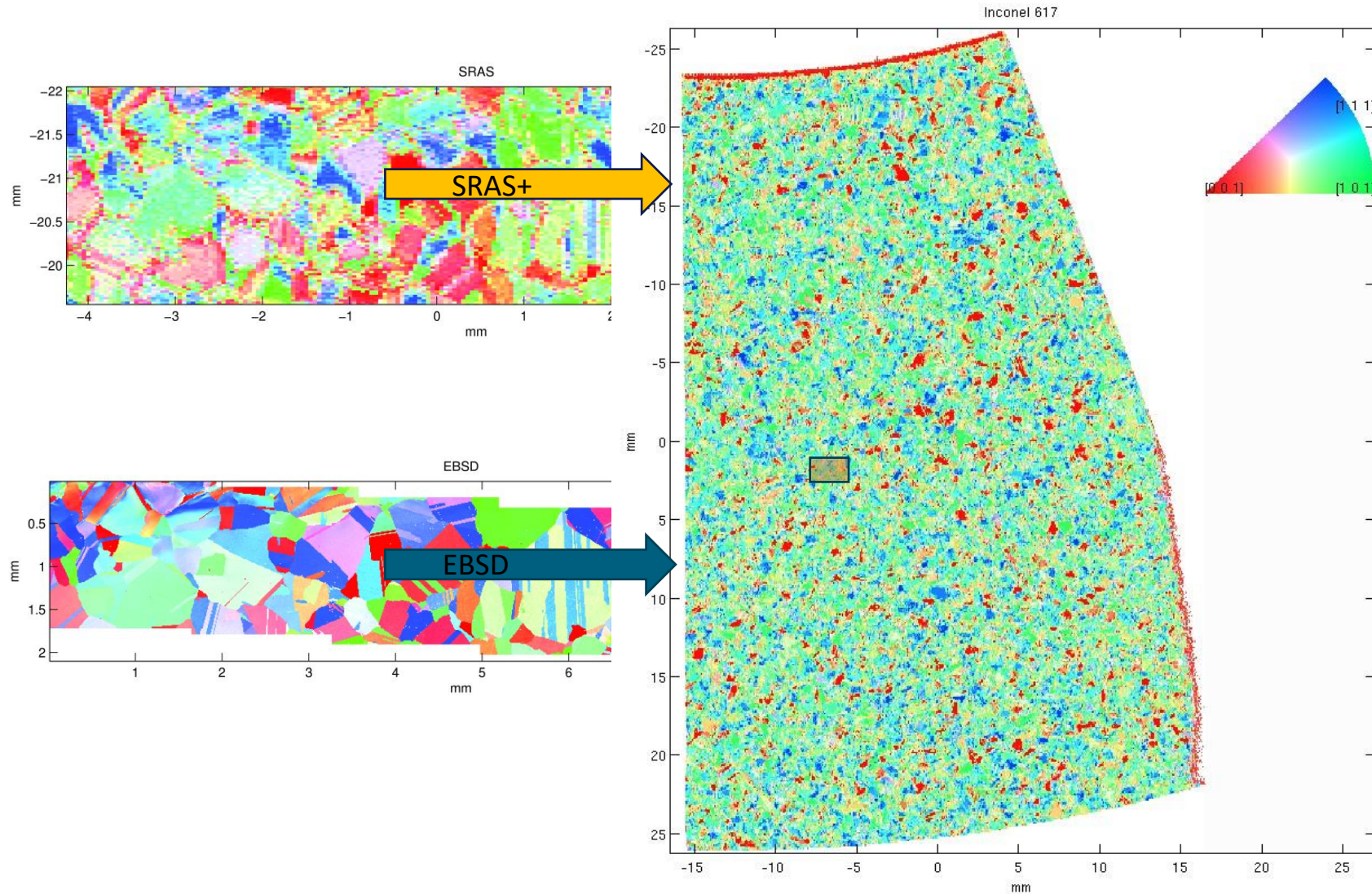


Collecting Experimental data





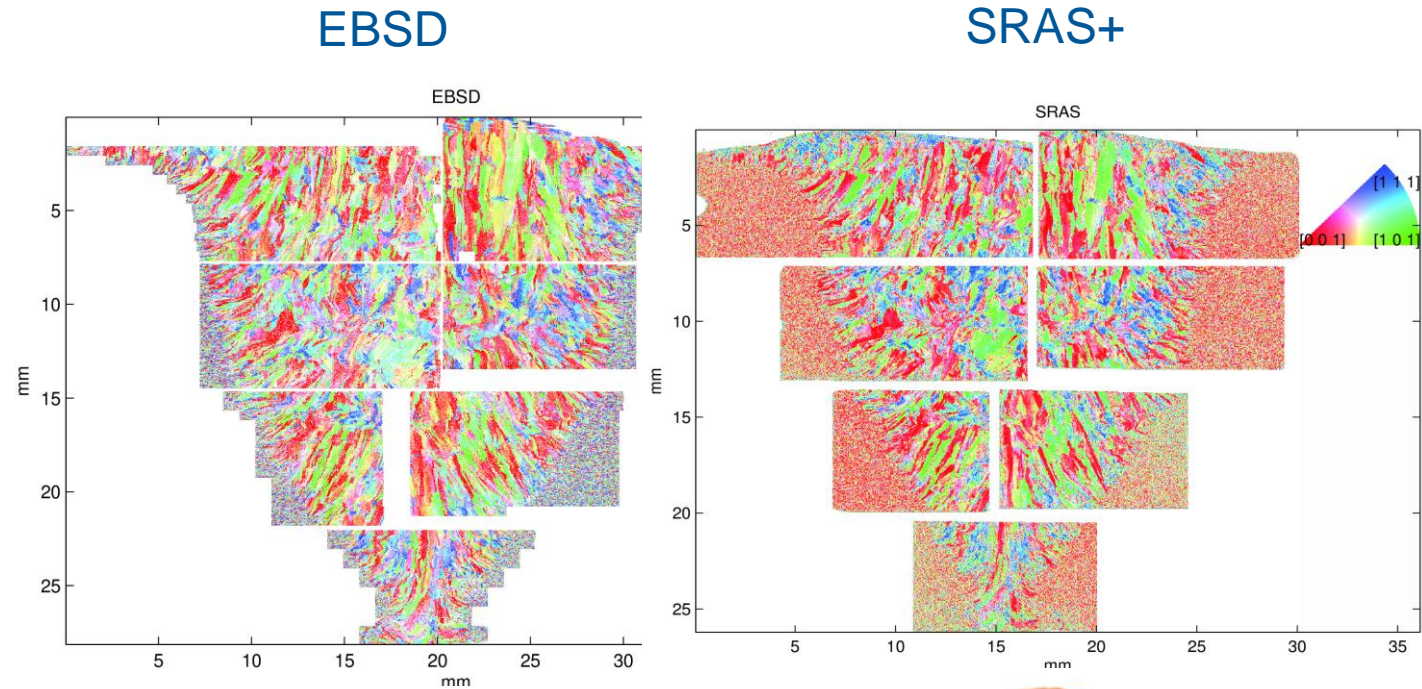
Large scale specimens





Inverse pole figures

Stainless Steel weld



Nickel superalloy



Dryburgh et al *Ultrasonics* 108 (1 December 2020): 106171.
<https://doi.org/10.1016/j.ultras.2020.106171>.
Li et al, *JASA*, 132, no. 2 (2012): 738–45.
<https://doi.org/10.1121/1.4731226>.

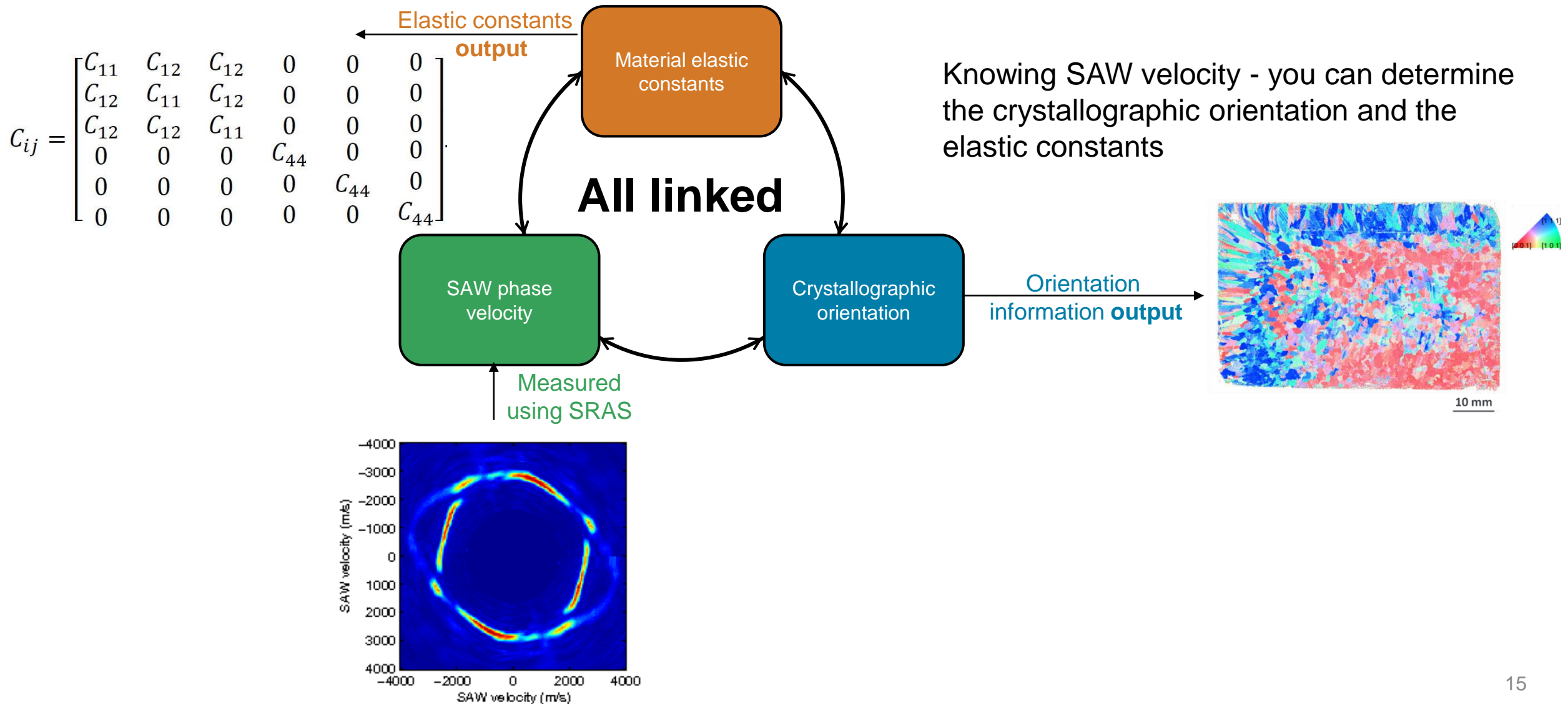


Spatially Resolved Acoustic Spectroscopy

SRAS++

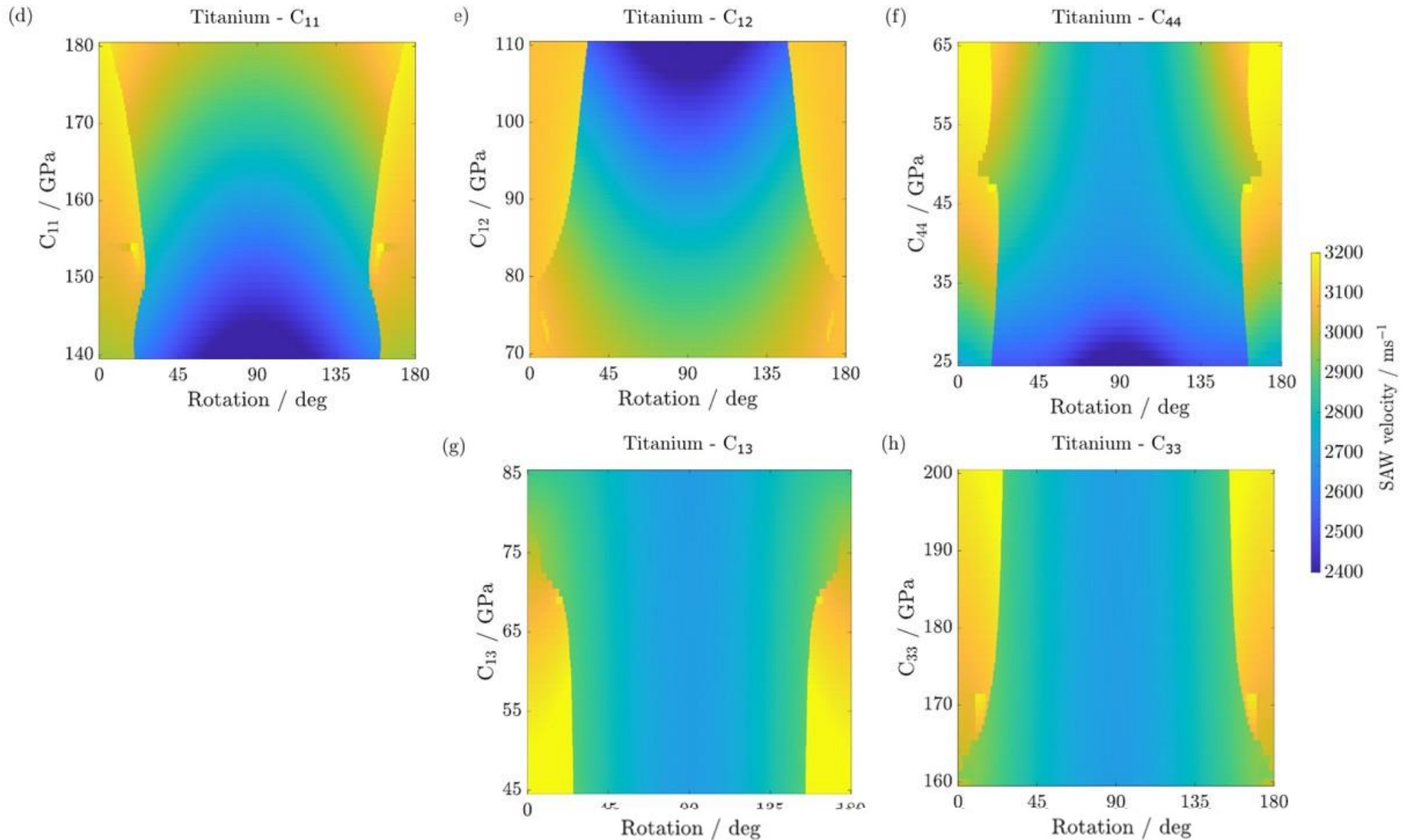


The inverse problem (SRAS++) or 'getting something from nothing'



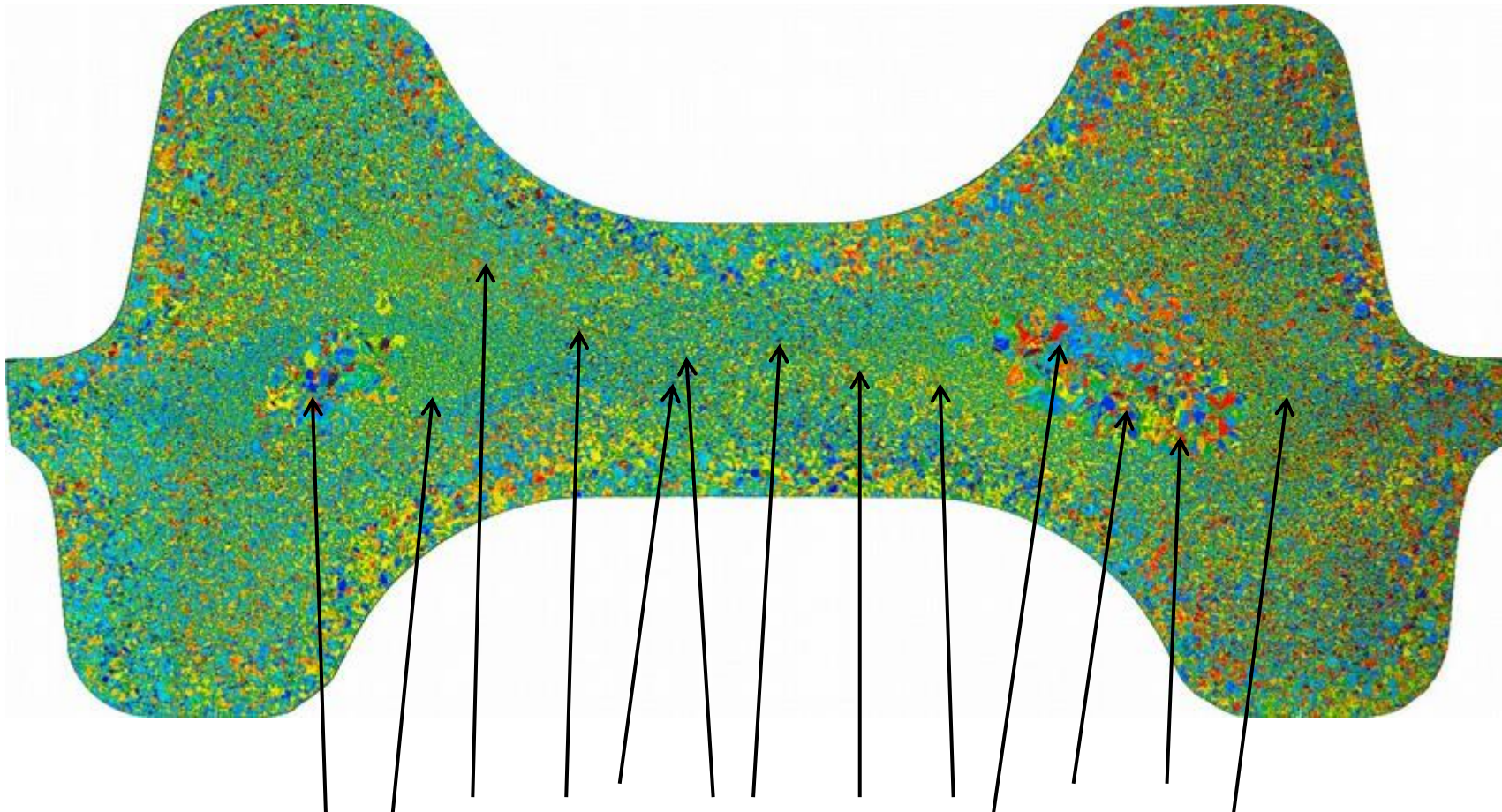


Cij sensitivity to SAW velocity





Using global elasticity as a shortcut



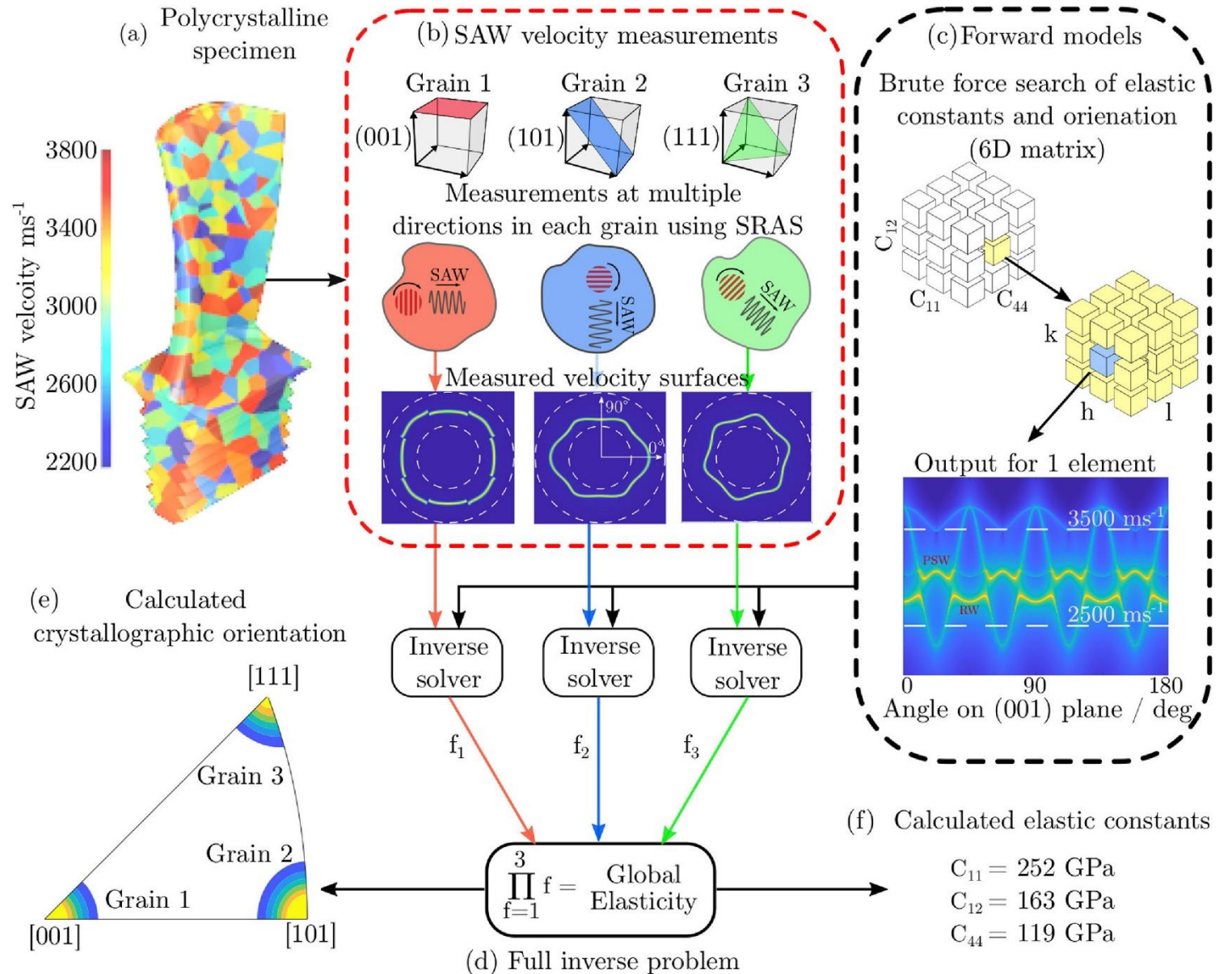
From SRAS we have *lots* of grains and *lots* of *random* orientations...

...but only one C_{ij}



SRAS++ in practice

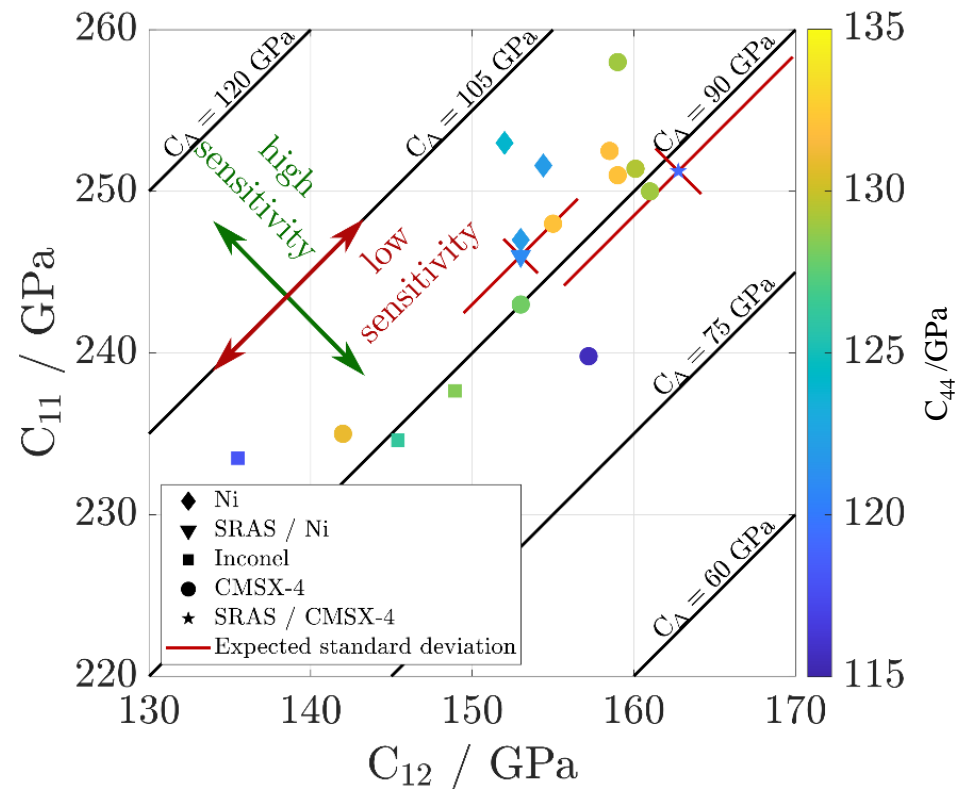
We can exploit the global nature of elasticity to the sample and combine measurements from multiple grains



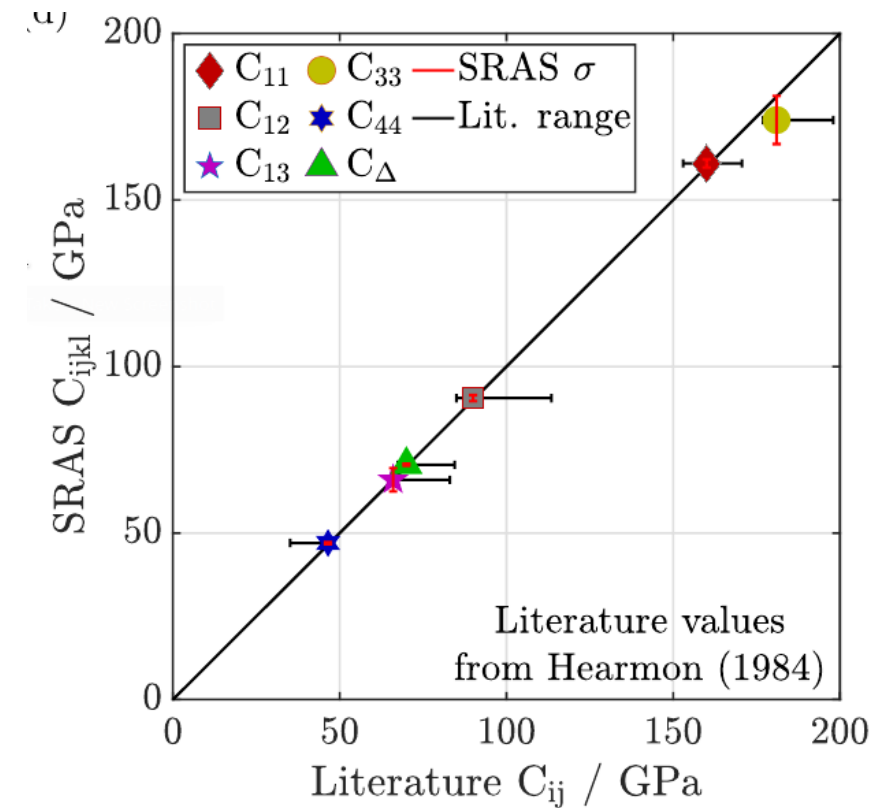


SRAS++ result: elastic constants output (published)

Nickel superalloy (cubic)



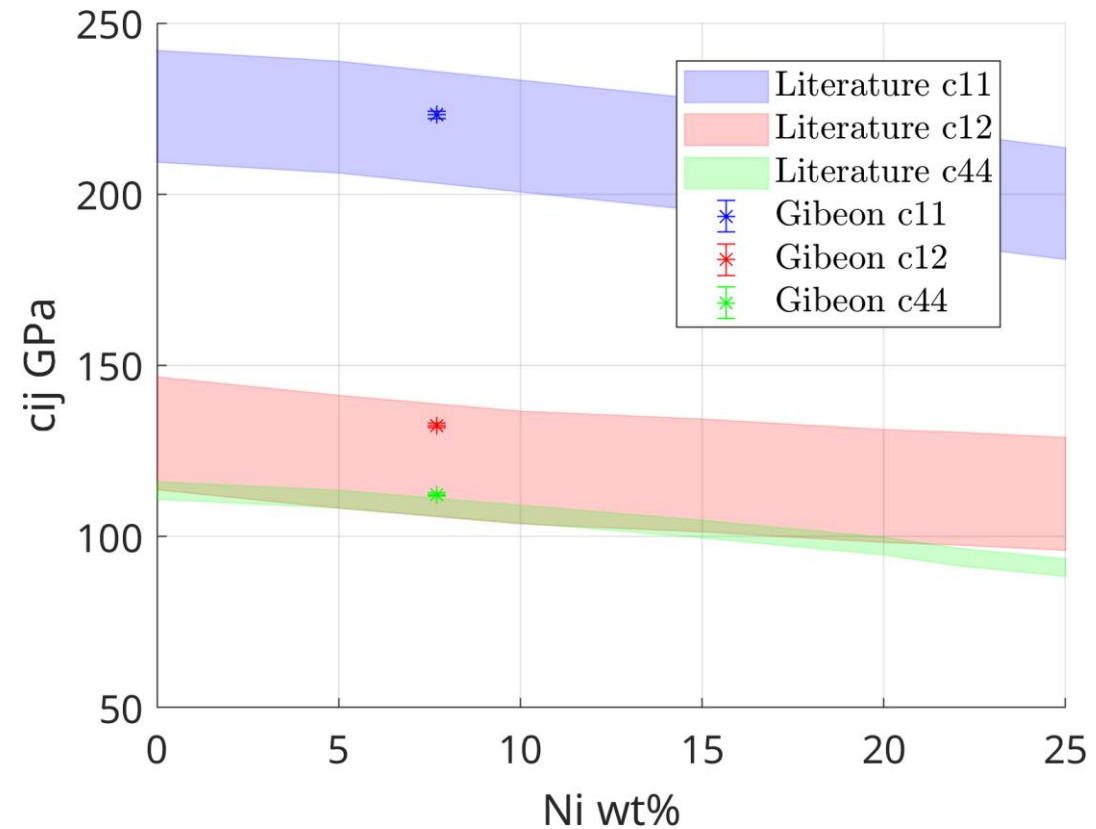
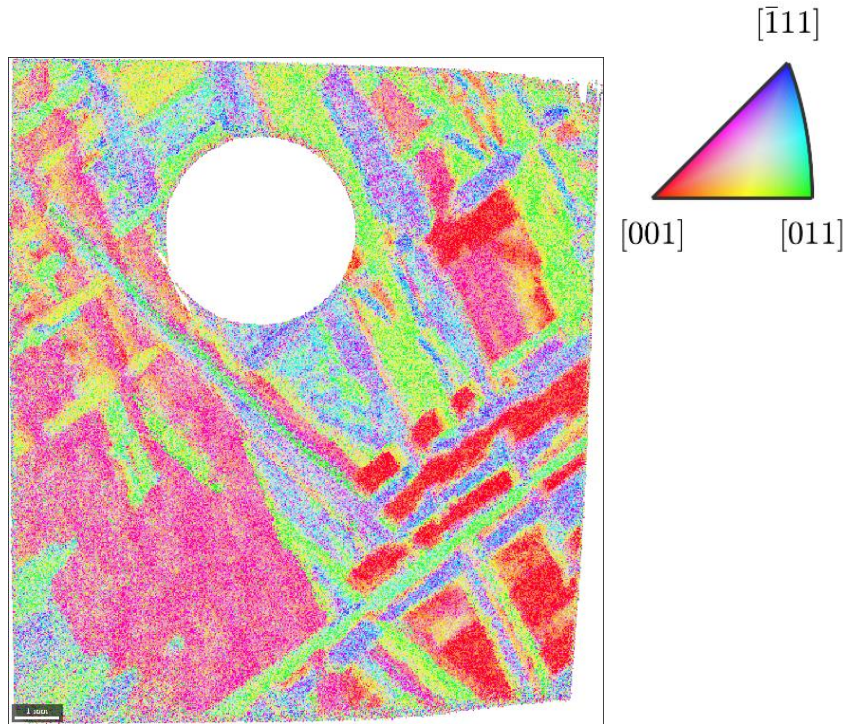
CP Titanium (hexagonal)





Space rock: Gibeon

Gibeon meteorite: 91.8% Fe; 7.7% Ni; 0.5% Co; 0.04% P; 2.4 ppm Ir; 1.97 ppm Ga; 0.111 ppm Ge.



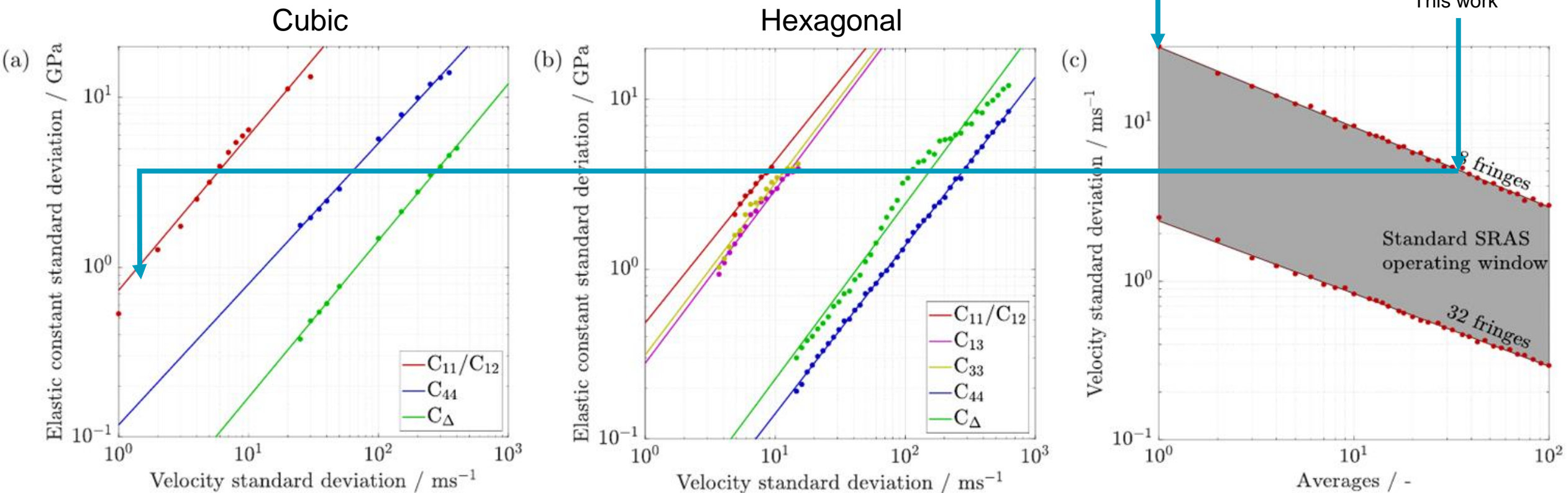
R. F. S. Hearmon, *The Elastic Constants of Anisotropic Materials*, Rev. Mod. Phys. 18, 409 – Published 1 July 1946

K.S. Alexandrov and T.V. Ryzhova, *Elastic properties of rock-forming minerals II. Layered silicates*, Bulletin. USSR Academy of Science, Geophysics., Vol. 9, 1961, pp. 165-1168.

C. Asker, L. Vitos, and I. A. Abrikosov, *Elastic constants and anisotropy in FeNi alloys at high pressures from first-principles calculations*, Phys. Rev. B 79, 214112 – Published 19 June 2009; Erratum Phys. Rev. B 81, 149901 (2010)



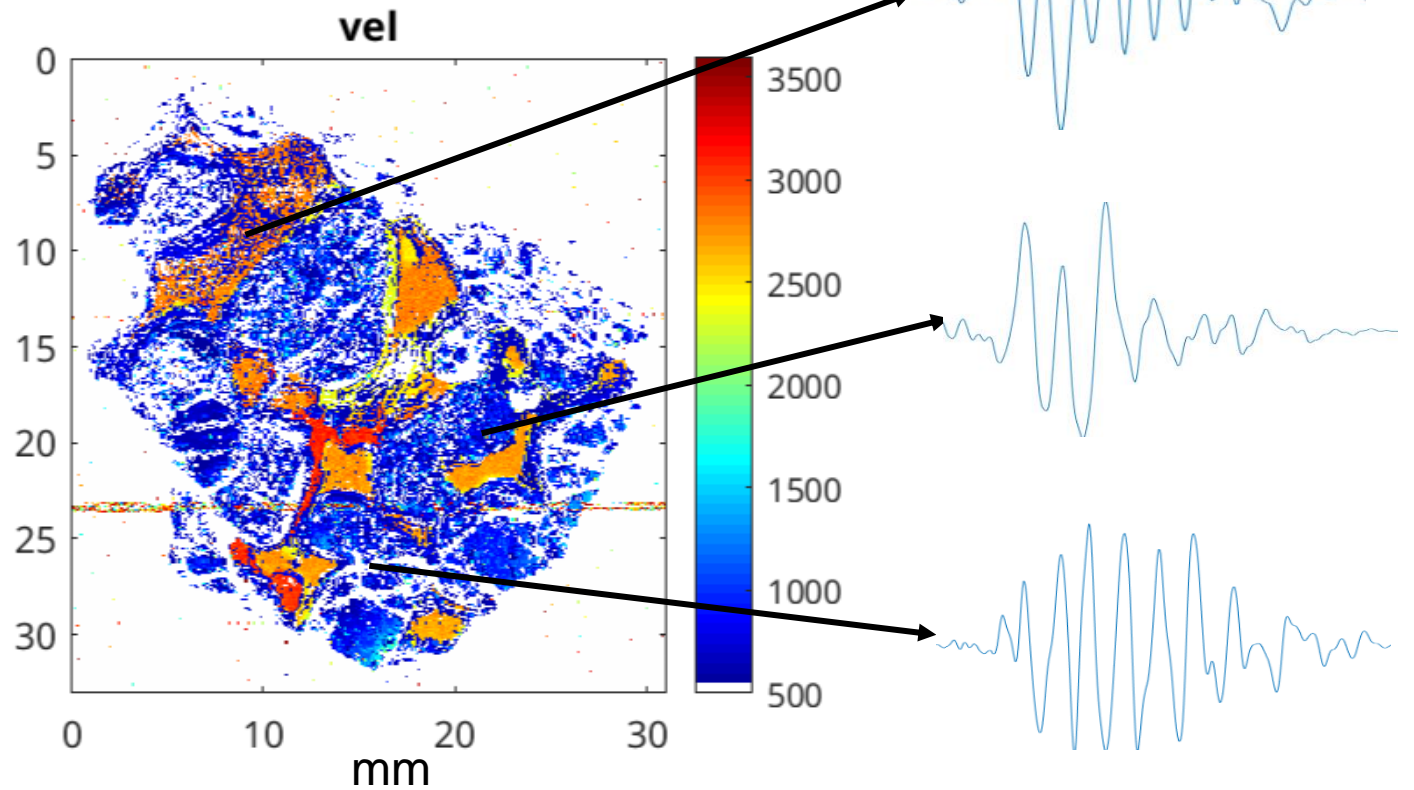
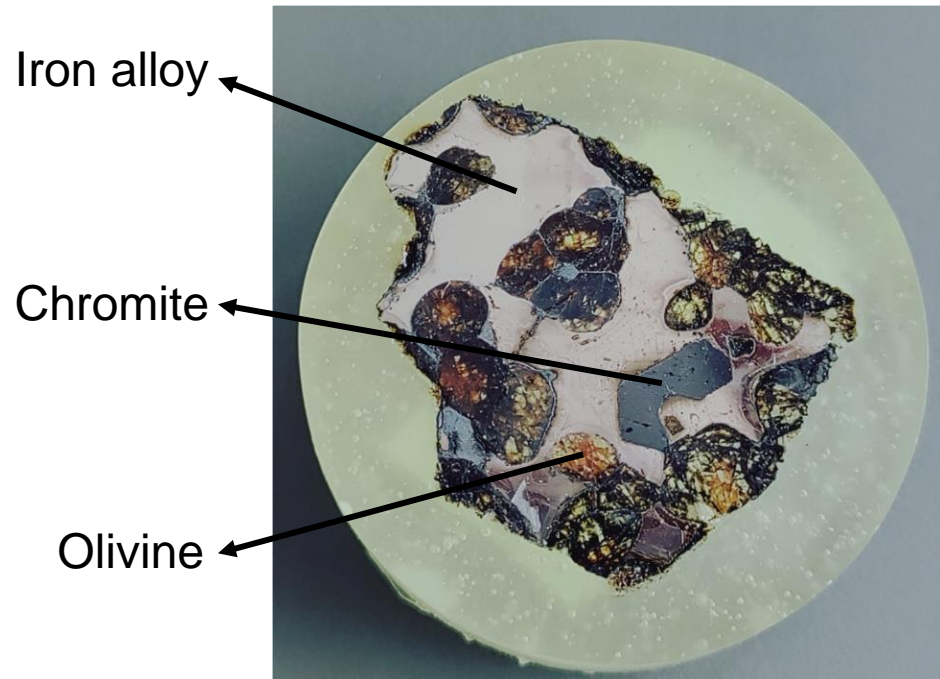
SRAS++ accuracy





Future work: more space rock!

Sericho pallasite meteorite: approximately 70 – 80% olivine.





optics.nottingham.ac.uk
en.wikipedia.org/wiki/SRAS



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