End of workshop Report

**Workshop Title:** Advances in synchrotron-based research towards understanding the structure, evolution, and dynamics of Earth and planetary interiors

**Duration:** 3 Days (August 31, 2021 – September 2, 2021)

**Workshop Organizers:**

Vitali Prakapenka (GSECARS/Univ. Chicago)
Yanbin Wang (GSECARS/Univ. Chicago)
Donald Weidner (Stony Brook University)
Quentin Williams (University of California Santa Cruz)
Anat Shahar (The Carnegie Institution for Science)
Susannah Dorfman (Michigan State University)
Ercan Alp (Argonne National Laboratory)

**Workshop Local Coordinator:**

Stella Chariton (GSECARS/Univ. Chicago)

**Brief Overview of topics that were addressed:**

- Current state-of-the-art synchrotron capabilities for studies of Earth and planetary materials at elevated conditions, from crust to the core and beyond.
- Novel technological developments and capabilities that will boost Earth and planetary sciences research, especially in view of recent and planned upgrades to US synchrotron facilities.
- New approaches to foster engagement and expansion of the user community, including to traditionally underrepresented constituencies.
- User community needs for cyberinfrastructure and data services.

**Last Revised Document:**

1 October 2021
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# 1. Agenda and Recordings

<table>
<thead>
<tr>
<th>Time (CDT)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00</td>
<td>Welcome</td>
</tr>
<tr>
<td>10:10</td>
<td>Progress towards a new organization for synchrotron-based geoscience research</td>
</tr>
<tr>
<td>10:20</td>
<td>DAC program at GSECARS: A Unique Probe into the Deep Earth</td>
</tr>
<tr>
<td>10:50</td>
<td>High Pressure Research at the ALS: Recent Developments and Opportunities</td>
</tr>
<tr>
<td>11:20</td>
<td>Partnership for eXtreme Xtallography (PX^2): frontier extreme conditions research facility at GSECARS</td>
</tr>
<tr>
<td>11:50</td>
<td>Nuclear Resonant Scattering at the APS-U era: What does it mean for geosciences and high pressure research?</td>
</tr>
<tr>
<td>12:20</td>
<td>Synchrotron Radiation and Geoscience: From Terahertz to Gigayears</td>
</tr>
<tr>
<td>12:50</td>
<td>Lunch</td>
</tr>
<tr>
<td>13:10</td>
<td>Earth science research at PETRA III and VI: Making optimal use of x-ray properties of 3rd and future 4th generation light sources.</td>
</tr>
<tr>
<td>13:30</td>
<td>New opportunities for high pressure science at the new beamline ID27 on the ESRF extremely brilliant source</td>
</tr>
<tr>
<td>13:50</td>
<td>New high-pressure techniques for the study of Earth and planetary materials at the PSICHE beamline, synchrotron SOLEIL</td>
</tr>
<tr>
<td>14:10</td>
<td>Current status and future plans of BL04B1/SPring-8</td>
</tr>
<tr>
<td>14:30</td>
<td>High Pressure Collaborative Access Team (HPCAT) facility at APS – Current and Future Direction</td>
</tr>
<tr>
<td>14:50</td>
<td>Coffee break</td>
</tr>
<tr>
<td>15:00</td>
<td>NSF program update</td>
</tr>
</tbody>
</table>

**Table 1.1. Day 1 – Tuesday, August 31st**

<table>
<thead>
<tr>
<th>Time (CDT)</th>
<th>Title</th>
<th>Speaker</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00</td>
<td>Welcome</td>
<td>Vitali Prakapenka</td>
<td>The University of Chicago</td>
</tr>
<tr>
<td>10:10</td>
<td>Progress towards a new organization for synchrotron-based geoscience research</td>
<td>Thomas Duffy</td>
<td>Princeton University</td>
</tr>
<tr>
<td>10:20</td>
<td>DAC program at GSECARS: A Unique Probe into the Deep Earth</td>
<td>Vitali Prakapenka</td>
<td>The University of Chicago</td>
</tr>
<tr>
<td>10:50</td>
<td>High Pressure Research at the ALS: Recent Developments and Opportunities</td>
<td>Quentin Williams</td>
<td>University of California Santa Cruz</td>
</tr>
<tr>
<td>11:20</td>
<td>Partnership for eXtreme Xtallography (PX^2): frontier extreme conditions research facility at GSECARS</td>
<td>Przemyslaw Dera</td>
<td>University of Hawaii</td>
</tr>
<tr>
<td>11:50</td>
<td>Nuclear Resonant Scattering at the APS-U era: What does it mean for geosciences and high pressure research?</td>
<td>Ercan Alp</td>
<td>The Advanced Photon Source at Argonne National Laboratory</td>
</tr>
<tr>
<td>12:20</td>
<td>Synchrotron Radiation and Geoscience: From Terahertz to Gigayears</td>
<td>Russell Hemley</td>
<td>University of Illinois at Chicago</td>
</tr>
<tr>
<td>12:50</td>
<td>Lunch</td>
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<tr>
<td>13:10</td>
<td>Earth science research at PETRA III and VI: Making optimal use of x-ray properties of 3rd and future 4th generation light sources.</td>
<td>Hans-Peter Liermann</td>
<td>Petra III, Germany</td>
</tr>
<tr>
<td>13:30</td>
<td>New opportunities for high pressure science at the new beamline ID27 on the ESRF extremely brilliant source</td>
<td>Mohamed Mezouar</td>
<td>ESRF, France</td>
</tr>
<tr>
<td>13:50</td>
<td>New high-pressure techniques for the study of Earth and planetary materials at the PSICHE beamline, synchrotron SOLEIL</td>
<td>Nicolas Guignot</td>
<td>SOLEIL, France</td>
</tr>
<tr>
<td>14:10</td>
<td>Current status and future plans of BL04B1/SPring-8</td>
<td>Yuji Higo</td>
<td>Spring-8, Japan</td>
</tr>
<tr>
<td>14:30</td>
<td>High Pressure Collaborative Access Team (HPCAT) facility at APS – Current and Future Direction</td>
<td>Nenad Velisavljevic and HPCAT staff</td>
<td>HPCAT, Argonne National Laboratory</td>
</tr>
<tr>
<td>14:50</td>
<td>Coffee break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15:00</td>
<td>NSF program update</td>
<td>Russ Kelz</td>
<td>The National Science Foundation</td>
</tr>
</tbody>
</table>
### NSF supported GSECARS and COMPRES LVP programs

Session chair: Tony Yu (The University of Chicago)

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Speaker</th>
<th>Institution</th>
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</thead>
<tbody>
<tr>
<td>15:20</td>
<td>COMPRES LVP Program</td>
<td>Donald Weidner</td>
<td>Stony Brook University</td>
</tr>
<tr>
<td>15:50</td>
<td>LVP facilities at GSECARS</td>
<td>Yanbin Wang</td>
<td>The University of Chicago</td>
</tr>
<tr>
<td>16:20</td>
<td>Current and future opportunities for non-ambient condition Earth Science experiments at the ALS</td>
<td>Kurt Leinenweber</td>
<td>Arizona State University</td>
</tr>
<tr>
<td>16:50</td>
<td>APS-U: New Opportunities for High Pressure Earth Science</td>
<td>Mark Rivers</td>
<td>The University of Chicago</td>
</tr>
<tr>
<td>17:10</td>
<td>Current and future opportunities for non-ambient condition Earth Science experiments at the ALS</td>
<td>Martin Kunz</td>
<td>The Advanced Light Source at Lawrence Berkeley National Laboratory</td>
</tr>
<tr>
<td>17:30-18:00</td>
<td>Open discussion</td>
<td>Moderators: Vitali Prakapenka and Quentin Williams</td>
<td></td>
</tr>
</tbody>
</table>

### Table 1.2. Day 2 – Wednesday, September 1st

<table>
<thead>
<tr>
<th>Time (CDT)</th>
<th>Title</th>
<th>Speaker</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00</td>
<td>Introduction</td>
<td>Quentin Williams</td>
<td>University of California Santa Cruz</td>
</tr>
<tr>
<td>10:05</td>
<td>Impediments to progress in our understanding of the dynamics and evolution of planetary interior</td>
<td>Bruce Buffet</td>
<td>UC Berkeley</td>
</tr>
<tr>
<td>10:40</td>
<td>Quantitative mineral physics and geochemistry of deep Earth and planetary interiors</td>
<td>Leonid Dubrovinsky</td>
<td>BGI, Germany</td>
</tr>
<tr>
<td>11:10</td>
<td>Axial and radial diffraction studies of Mg2SiO4 and Fe-Si(–Ni) alloys</td>
<td>Rebeca Fischer</td>
<td>Harvard University</td>
</tr>
<tr>
<td>11:40</td>
<td>An integrated approach to advance our understanding of the Earth’s core</td>
<td>Yingwei Fei,</td>
<td>Carnegie Institution for Science</td>
</tr>
<tr>
<td>12:10</td>
<td>Laser heated diamond anvil cell and synchrotron radiation to investigate planetary interiors. The example of the Fe-Si-C ternary system</td>
<td>Francesca Miozzi</td>
<td>Carnegie Institution for Science</td>
</tr>
<tr>
<td>12:40</td>
<td>Lunch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td>How can synchrotron facilities support experimental petrology for the deep mantle and core</td>
<td>Susannah Dorfman</td>
<td>Michigan State University</td>
</tr>
<tr>
<td>13:30-13:50</td>
<td>Open discussion</td>
<td>Moderators: Andrew Campbell and Thomas Duffy</td>
<td></td>
</tr>
<tr>
<td>14:00</td>
<td>Introduction</td>
<td>Thomas Duffy</td>
<td>Princeton University</td>
</tr>
<tr>
<td>Time (CDT)</td>
<td>Title</td>
<td>Speaker</td>
<td>Institution</td>
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</tr>
<tr>
<td>14:05</td>
<td>Synchrotron in-situ experiments and their relevance to mantle rheology and earthquakes</td>
<td>Shun-Icho Karato</td>
<td>Yale University</td>
</tr>
<tr>
<td></td>
<td><strong>Rheology at extremes</strong></td>
<td></td>
<td><strong>Session chair: Anat Shahar (Carnegie Institution for Science)</strong></td>
</tr>
<tr>
<td>14:40</td>
<td>In-situ texture and stress characterization in earth materials</td>
<td>Lowell Miyagi</td>
<td>University of Utah</td>
</tr>
<tr>
<td>15:10</td>
<td>Effects of foliation orientation on melt interconnectivity and rock viscosity during synedformational partial melting</td>
<td>Caleb Holyoke</td>
<td>University of Akron</td>
</tr>
<tr>
<td>15:40</td>
<td>In-Situ Measurements of Deforming Materials: Synchrotron X-Ray Diffraction and Radiography combined with Ultrasonic Interferometry</td>
<td>Taryn Traylor and Pamela Burnley</td>
<td>University of Nevada</td>
</tr>
<tr>
<td>16:10</td>
<td>Synchrotron High-Pressure Deformation Applications To Answer Some Of Earth Sciences Outstanding Questions</td>
<td>Jennifer Girard</td>
<td>Yale University</td>
</tr>
<tr>
<td>16:40</td>
<td>Introduction</td>
<td>Yanbin Wang</td>
<td>The University of Chicago</td>
</tr>
<tr>
<td>16:45</td>
<td>Recent Developments in In-situ Rock Deformation Research</td>
<td>Wenlu Zhu</td>
<td>University of Maryland</td>
</tr>
<tr>
<td><strong>17:40-18:00</strong></td>
<td>Open discussion</td>
<td></td>
<td><strong>Moderators: Susannah Dorfman and Donald Weidner</strong></td>
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</tbody>
</table>

**Table 1.3. Day 3 – Thursday, September 2nd**

<table>
<thead>
<tr>
<th>Time (CDT)</th>
<th>Title</th>
<th>Speaker</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00</td>
<td>Perspective for Brillouin Scattering in Earth Sciences</td>
<td>Zhu Mao</td>
<td>U of Sci.&amp;Techn., China</td>
</tr>
<tr>
<td>10:30</td>
<td>Study of the thermo-elastic properties of hydrated wadsleyite (β-Mg2SiO4) by ultrasonic Interferometry with synchrotron X-radiation</td>
<td>Gabriel Gwanmesia</td>
<td>Delaware State University</td>
</tr>
<tr>
<td>11:00</td>
<td>Constraining the large temperature and composition variations in the Mantle Transition Zone</td>
<td>Jin Zhang</td>
<td>University of New Mexico</td>
</tr>
<tr>
<td>10:30</td>
<td>Understanding planetary dynamos by synchrotron X-ray and laser spectroscopic techniques</td>
<td>Jung-Fu &quot;Afu&quot; Lin</td>
<td>University of Texas at Austin</td>
</tr>
<tr>
<td>12:00</td>
<td>Integrative deep Earth science through advances in x-ray spectroscopy</td>
<td>Jennifer Jackson</td>
<td>California Institute of Technology</td>
</tr>
<tr>
<td>12:30</td>
<td>Applications of synchrotron Mössbauer spectroscopy in high pressure research</td>
<td>Wenli Bi</td>
<td>The University of Alabama</td>
</tr>
<tr>
<td>Time</td>
<td>Session</td>
<td>Speaker/Institution</td>
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</tr>
<tr>
<td>13:00-</td>
<td>Open discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:30</td>
<td>Introduction</td>
<td>Donald Weidner, SUNY, Stony Brook</td>
<td></td>
</tr>
<tr>
<td>13:35</td>
<td>Computational mineral physics: challenges and opportunities ahead</td>
<td>Renata Wentzcovitch, Columbia University</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Earth’s deep interior</strong></td>
<td></td>
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<tr>
<td></td>
<td><em>Session chair: Susannah Dorfman (Michigan State University)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:50</td>
<td>Structural and electronic transitions in liquid FeO</td>
<td>Guillaume Morard, Institut des Sciences de la Terre, France</td>
<td></td>
</tr>
<tr>
<td>14:20</td>
<td>Structure, composition, and transport properties of deep planetary materials at extreme pressure and temperature</td>
<td>Alex Goncharov, Carnegie Institution for Science</td>
<td></td>
</tr>
<tr>
<td>14:50</td>
<td>A Geophysics Wish List for Synchrotron</td>
<td>Dan Shim, Arizona State University</td>
<td></td>
</tr>
<tr>
<td>15:40</td>
<td>SNS</td>
<td>Chris Tulk, ORNL</td>
<td></td>
</tr>
<tr>
<td>15:10</td>
<td>Synchrotron and XFEL studies of Earth’s deep interior</td>
<td>Wendy Mao, Stanford University</td>
<td></td>
</tr>
<tr>
<td>16:40</td>
<td>Light-source diffraction studies of geologic materials under dynamic loading</td>
<td>Sally June Tracy, Carnegie Institution for Science</td>
<td></td>
</tr>
<tr>
<td>17:00</td>
<td>Overview of Lightsources.org and prize award</td>
<td>Silvana Westbury, Lightsources.org</td>
<td></td>
</tr>
<tr>
<td>17:15-</td>
<td>Open discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18:00</td>
<td>Adjourn</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recordings of the workshop can be viewed on YouTube using the link below:

https://www.youtube.com/watch?v=rcPFKspuyjiU&list=PLj86dx7VA1soNQSyox6EEmJWbZjubSP0

Check the workshop’s website for the latest updates:

2. Participation

2.1. Registration & Zoom participants

*Table 2.1. Number of registrants and Zoom participants for each day of the workshop (unique participants = joined the meeting at least once; overall participants = joined the meeting multiple times per day)*

<table>
<thead>
<tr>
<th>Number of Registrations</th>
<th>331</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique participants Day 1</td>
<td>264</td>
</tr>
<tr>
<td>Overall Participants Day 1</td>
<td>550</td>
</tr>
<tr>
<td>Unique participants Day 2</td>
<td>219</td>
</tr>
<tr>
<td>Overall participants Day 2</td>
<td>424</td>
</tr>
<tr>
<td>Unique participants Day 3</td>
<td>197</td>
</tr>
<tr>
<td>Overall participants Day 3</td>
<td>385</td>
</tr>
</tbody>
</table>

*Figure 2.1. The distribution of the number of attendees over time for each of the three workshop days. The yellow highlighted region indicates the Open Discussion Sessions.*
2.2. Registration demographics (location, career status, synchrotron usage etc...)

**Figure 2.2.** Geographic distribution of the 331 workshop registrants across the world map.

**Figure 2.3.** Geographic distribution of the 216 workshop registrants across the USA.
The registrants who have never made use of a synchrotron facility in the past, but who are eager to try to become a user in the future, were asked what type of experiments they would be interested to perform. Below are some of their replies (sample of 49, 12 replies):

- “XANES, XPS, XRF, Mössbauer spectroscopy, Fe-XANES, FTIR, X-ray Absorption Fine Structure (XAFS), Diffraction Anomalous Fine Structure (DAFS), X-ray Resonant and Magnetic Scattering, X-ray Magnetic Circular Dichroism (XMCD)”
- “synchrotron-based techniques use in high temperature and high pressure and petrology
- “To understand the deformation mechanism, CPO and the effect of water on quartz under dislocation creep regime.”
- “13IDD beamline…”, “Sector 16 beamline at APS”, “APS”
- “Since I have never used synchrotron-based techniques before, I would like to learn about the different techniques and their application/s in the study of the Earth mantle materials to know which one of them may be more useful for my research in the future.”
**Figure 2.6.** Response of the synchrotron-user registrants when asked to name all the light sources where they have performed experiments at (sample=275, multiple choice question).

**Figure 2.7.** Count of the number of synchrotrons that a registrant has visited in total (sample=275). For example, 4 registrants have performed experiments at 7 different light sources, while the vast majority has visited only one synchrotron.
Figure 2.8. Response of all workshop's participants when asked to identify their current career stage (sample=331).

Figure 2.9. Count of the science division or other agency that the registrants are affiliated with (sample=331).
3. Open Discussions

Several roundtable discussions took place throughout the duration of the workshop. The participation during those sessions is highlighted in Fig. 2.1 and the live recordings can be found online (see end of Section 1 above). Live mini surveys were used to initiate conversation, the results of which are presented below along with the main bullet points that were discussed.

3.1. Day 1

Main topic: What synchrotron/high pressure techniques are available, future plans and updates
Moderators: Vitali Prakapenka and Quentin Williams
Main bullet points:
- What are the most critical/impactful current capabilities?
- What new capabilities are most needed?
- What suggestions you may have to improve interactions between synchrotron users’ office, beamline staff and users?
- Are there any issues with proposal system: submission, review process, rating, feedback or beamtime allocation procedure?
- Are there other issues/improvements that could facilitate your usage of synchrotrons?

Mini survey:

Figure 3.1. Participants’ responses when asked if they are satisfied with the existing synchrotron capabilities (sample=51).
3.2. Day 2

3.2.1. Discussion #1

Main topic: *What are the unsolved problems in planetary interiors, their dynamics; how do synchrotron techniques address these problems?*

Moderators: Andrew Campbell and Thomas Duffy

Main bullet points:

- *What are the most important/relevant questions of the NSF “Earth in Time” report for our community?*
- *What additional questions are of equal importance?*
- *What capabilities are needed to address these questions?*

Mini survey:

![Survey Results](image)

**Figure 3.2.** Participants’ responses when presented with the 12 science priority questions of the NSF “Earth in Time” report and asked to select those which they feel that are addressed by the high-pressure community (sample=56, multiple choice question).

![Survey Results](image)

**Figure 3.3.** Following the survey above (Fig. 3.2.), the participants were asked to comment on whether this list reflects all the important questions to be addressed? (sample=56).
3.2.2. Discussion #2

Main topic: Properties of rocks that control dynamics on planetary timescales, how do synchrotron techniques address these problems?

Moderators: Susannah Dorfman and Donald Weidner

Main bullet points:
- Do you have a pressing scientific project that you need to discuss with beamline staff regarding feasibility?
- New approaches to foster engagement and expansion of the user community and to bring new technology
- How can we include and engage underrepresented constituencies?

Mini survey:

Figure 3.4. Participants’ responses when presented with the 12 science priority questions of the NSF “Earth in Time” report and asked to select those which they feel that are addressed by the high-pressure community (sample=56, multiple choice question, *free response option was available).
3.3. Day 3

3.3.1. Discussion #1

**Main topic:** Mineral elasticity and composition of the Earth’s interior

**Moderators:** Anat Shahar and Jin Zhang

**Main bullet points:**

- What combination of x-ray techniques you would like to have in one station (e.g. XRD, EXRD, sXRD, dXRD, rXRD, TXS, XES, XAFS, IXS, CMT, coherent scattering, imaging etc.)?
- Which on-line, not x-ray, capabilities are needed? (e.g., resistive/laser heating, time domain modes, laser spectroscopy (BS, Raman, fluorescence etc), cryostat, ultrasonic, conductivity etc.)

**Mini survey:**

<table>
<thead>
<tr>
<th>Technique/Multitude</th>
<th>Are currently using</th>
<th>Would like to use in the future</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray Diffraction (XRD)</td>
<td></td>
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<tr>
<td>Energy Dispersive X-ray Diffraction (EXRD)</td>
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<td>Single-crystal X-ray Diffraction (SCXRD)</td>
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<tr>
<td>Dynamic Compression X-ray diffraction (dXRD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radial X-ray Diffraction (rXRD)</td>
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<td></td>
</tr>
<tr>
<td>Total X-ray Scattering (TXS)</td>
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<tr>
<td>X-ray Emission Spectroscopy (XES)</td>
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<tr>
<td>X-ray Absorption Fine Structure (XAFS)</td>
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<td>Inelastic X-ray Scattering (IXS)</td>
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<td>Coherent Scattering</td>
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<td>Syncrotron Mössbauer spectroscopy</td>
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<td>*Synchrotron Infrared spectroscopy (SIR)</td>
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<td>*Nuclear Resonance Inelastic X-ray Scattering (NRIXS)</td>
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<td>*Laue Diffraction</td>
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*Figure 3.5.* Participants’ responses when asked to select the synchrotron techniques that they have used as well as those that they plan to use in the future (sample=50, multiple choice question, *free response option was available*).
3.3.1. Discussion #1

Main topic: Core Composition. Dynamics of planetary materials at impact timescales, and hydrogen

Moderators: Vitali Prakapenka, Yanbin Wang and Stella Chariton

Main bullet points:
• What capabilities and new approaches are needed to address key science questions?
• What are user community needs for cyberinfrastructure and data services?
• What should the facilities do to reach out more users, students, and enhance BAJEDI in our community?
• What are your preferred ways to enhance community interaction/communication - annual meetings, email lists, website forums, others?

Mini survey:

Figure 3.6. Participants’ responses when asked if they would like to contribute/volunteer services and/or ideas to the new organization? (sample=41).

Figure 3.7. Participant’s responses when asked to select the type of activities that they would like to be involved in (sample=41, multiple choice question).
The discussion participants’ were finally asked to suggest any new technological developments and capabilities that may help the community boost the Earth and planetary sciences research. Below are some of their replies (sample of 41, 10 replies) (visit the live recordings for further participants’ suggestions):

- “Coupling laser heating with either opto-elastic techniques or IXS/NRIXS with X-ray diffraction for high P-T sound velocity measurement”
- “Brillouin spectroscopy + Laser Heating; Additional laser heating beam time for XRD”
- “Data storage and the access to it from different places”
- “Expansion of free electron laser facility”
- “Spectroscopy in a large volume press”
- “XPCS and combination of techniques”
- “Single crystal XRD + laser heating”
- “Diffraction tomography”
- “Optical spectroscopy”

Figure 3.8. Participant’s responses when asked to select the ways that they would like to be informed (sample=41). A list of e-mails and names was provided to the organizers.

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4. Large Survey Results

A large survey was conducted in an effort to address future opportunities to advance geomaterials at extreme conditions research at U.S. synchrotron light sources that covered a variety of topics, such as, synchrotron usage, availability of resources, type of techniques most commonly used, funding information, and other demographics. About one quarter (82 out of 331) of the workshop’s registrants filled out this survey anonymously and provided valuable feedback. The paragraphs that follow summarize the results of this survey.

4.1. Synchrotron usage

Figure 4.1. Survey’s participants’ responses when asked if they have ever used a synchrotron facility (sample/#responses=82/82). See related figure in section 2 (Fig. 2.4).

Figure 4.2. Survey’s participants’ responses when asked if they have ever used a synchrotron facility (sample/#responses=82/77). The participants were asked to base their responses on pre-COVID19-pandemic facility use.
The survey’s participants were asked to comment on whether they have a preferred light source and if yes then which on and why. Below are some of their replies (sample/#responses=82/37):

- “Yes, depending on the measurements”
- “PETRA, because of the nearest one”
- “PETRA”, “NSLS-II”, “APS”, “ESRF”, “HSLS-II”, “No preference”, “16 BMD, APS”
- “NSLS and APS – location and accessibility”
- “LCLS, photon number in very short pulses”
- “I use the DDIA apparatus with white x-rays so my preferred source is 6BMB at APS”
- “I have found APS the most useful for my experiments due to its capabilities for nuclear resonant inelastic x ray scattering”
- “ESRF, closer to home, great beam”
- “ESRF and APS. ID27 and 13IDD respectively have the optimal setup and characteristic of the beam to collect reliable data in the multimegabar pressure range”
- “APS; it provides great quality of beam, and is close to home”
- “APS: quality of facilities, location”
- “APS. Location, techniques available, flux”
- “APS. It has the DDIA”
- “APS. Everything I need is there. Excellent Staff”
- “APS. Established collaboration and familiarity with the facility”
- “APS, very high quality”
- “APS, nice people”
- “APS, because of type of experiments we do”
• “APS The beamline capabilities are awesome”
• “APS or NSLS. Beamline scientist support, travel costs, instrument reliability”
• “APS for the best support and collaborative opportunities. Petra III is also very preferable and competitive”
• “APS due to the particularly great high-pressure beamline staff that doesn’t turn over often and smooth beamline operation procedures, communication, good specs for LHDAC XRD; NSLS-II for IR measurements again due to specs and staff”
• “APS because it is in the US and has a higher flux and smaller size of focused beam compared to NSLS and ALS”
• “APS as I am based in the Midwest and GSECARS and HPCAT are great!”
• “APS (I am ANL employee, so it is very local for me)”
• “APS - reliability and performance”
• “APS - it provides high-brightness, hard x-rays that I need for my experiments, and it is close to home”
• “ALS--Excellent support and easy usage”
• “ALS. Ease of access; flexibility of facility”

Rate the importance of the following factors when selecting a synchrotron/beamline for your experiments

- Synchrotron/Beamline’s popularity in my research area
- Accessibility (e.g. beamtime request system, usual amount of beamtime awarded, accommodation facilities, etc.)
- Beamline staffs’ expertise / close collaborations
- Beamline uniqueness
- Ring’s characteristics
- Distance from my location

![Graph showing ratings](image)

**Figure 4.4.** The survey’s participants were asked to rate the importance of several factors when selecting a synchrotron/beamline for their experiments (sample/#responses=82/82).

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20
Among different analytical techniques you employ for high-pressure experiments, where do you rank synchrotron methods in your research?

Figure 4.5. The survey’s participants were asked to rate the importance of several factors when selecting a synchrotron/beamline for their experiments (sample/#responses=82/82).

4.2. Availability of resources

Is sufficient beam time available at the synchrotron facilities you use for your team to complete the experiments that are most important to you?

Figure 4.6. The survey’s participants were asked if there is sufficient beamtime available at synchrotron facilities for their team to complete their experiments (sample/#responses=82/76).
Do you think your Earth-science focused research is able to compete favorably for beamtime at the beamlines to which you apply?

![Pie chart showing responses to the question.](image)

**Figure 4.7.** Responses of the survey’s participants’ when asked if their Earth-Science research can compete favorably for beamtime at the beamlines to which they apply (sample/#responses=82/75).

Do the facilities you use strike a good balance between cutting-edge capabilities and more established techniques?

![Pie chart showing responses to the question.](image)

- Some of them
- N/A
- I am not sure

**Figure 4.8.** The survey’s participants shared their opinions on whether there is a good balance between cutting-edge capabilities and more established techniques at the facilities they use (sample/#responses=82/75).
Do you consider synchrotron access to be equitably distributed by the current proposal-driven allocation systems?

- **Yes**: 50
- **No**: 17
- **Other**: 5

- Not always, depends on the case
- Unsure
- Mostly. The proposal system tends to favor a certain type of research
- I don't know! We don't have access to breakdowns of who gets time where and how often, broken down by various demographic categories.
- Too much to physicists and chemists!

**Figure 4.9.** The survey’s participants were asked if they consider synchrotron access to be equitably distributed by the current proposal-driven allocation systems (sample/#responses=82/72).

Do you consider assistance at beamlines to be equitably accessible to all users?

- **Yes**: 59
- **No**: 11
- **Other**: 4

- Not always, depends for my work this is not relevant
- I can’t judge for other beam lines.
- I can’t speak for all the users but I have always found great assistance. Assistance is very beam line driven and not uniform.
- I don’t know! We don't have access to breakdowns of who gets time where and how often, broken down by various demographic categories, but my assumption is yes.

**Figure 4.10.** Responses of participants when asked whether they consider assistance at the beamlines to be equitably accessible to all users (sample/#responses=82/74).
The survey’s participants were asked to comment on whether they have experienced major challenges or limitations in using synchrotron methods. Below are their replies (sample/#responses=82/21):

- “No”, “N/A”
- “No, but sometimes wish it were easier to get beamtime”
- “Size and intensity of the beam”
- “Ability to combine different techniques on the same sample; beam size”
- “Challenges : being allocated enough beamtime each run”
- “Limited time, long gaps between experiment access, and competition High stress on users Beamline staff are also stressed”
- “Dealing with the quantity of data we gather in a single beam time. We lack good software for processing our data. We have built some but I think it would be better of the beam line/community could put more effort into creating and maintaining user friendly software”
- “The cost of travel and scheduling constraints for undergrads who are less able to miss weekday classes”
- “Limitations are usually related to beam quality, but this is constantly improving. User-friendliness of the beamline and ease of data collection is another important factor.”
- “There is limited ability for time-resolved temperature measurements.”
- “Yes, many of our experiments are coupled with high pressure and low temperature and/or external magnetic field, but due to travel restriction for COVID, many of these experiments have to be done remotely, which is not effective and difficult to train new graduate students.”
- “Covid obviously”
- “In situ high pressure and high temperature”
- “I wish there was more beamtime awarded each run, enough to finish a project, rather than splitting it into multiple runs which causes many delays and results in extra traveling”

The survey’s participants were asked to share any further comments on the availability of beamtime and other resources. Below are some of their replies (sample/#responses=82/10):

- “N/A”, “No, any more”
- “Beamline scientists should play more role in beamtime assignment”
- more beamtime per proposal should be allocated even at the expense of running fewer proposals each run.”
- “Beamtime has potential to be more accessible to a wider community than other lab techniques. Users can carry out state of the art experiments without building an extensive home laboratory. On the other hand, in a competitive environment, beamtime resources continue to be limited, and there is a perception that established people with connections have advantages in getting access.”
- “Access to lab prep space is essential for non-R1 scientists with limited sample prep spaces.”
- “The pandemic showed that we can successfully conduct remote operations if technology cooperates, and we need to invest in ironing our remote operations given likely future public health crises. As Earth scientists, it is also our duty to lead on cutting down on carbon footprints from travel.”
- “Access to newer beamlines like the dynamic compression sector is not user-friendly, they could take some lessons from GSECARS and other DAC beamlines”
• Sometimes it feels like I am in a constant hunt for beamtime; the competition is just too high nowadays, which on one hand is great because it means more and more scientists recognize the great advantages of a synchrotron-based research, but on the other hand it becomes very frustrating when your entire scientific career/research/thesis is literally hanging from whether you get beamtime or not. I am not sure what the answer on this problem can be - more beamlines? - decrease the maintenance/shutdown times and offer more beam for user operations?"
Figure 4.13. The participants were asked to rate the importance of the various spectroscopic techniques that are commonly available (sample = 82).

Figure 4.14. The participants were asked to rate the importance of the various X-ray imaging techniques that are commonly available (sample = 82).
The survey's participants were asked to list any other techniques which were not mentioned in Fig. 14.12-15, that are important to their research. Below are their replies (sample/#responses=82/21):

- “None”, “N/A”
- “Surface science methods: CTR, X-ray reflectivity, grazing incidence spectroscopies”
- “Combinations of the above-mentioned techniques on the same sample (e.g. XRD and micro imaging) is vital”
- “Dynamic compression and time-resolved methods (potential)”
- “Gas gun”
- “In-situ Ultrasonic measurements, High-Energy X-ray Diffraction Microscopy”
- “X-ray photon correlation spectroscopy”
- “X-ray Raman and X-ray emission”
- “TEM”

*Figure 4.15. The participants were asked to rate the importance of the various X-ray scattering techniques that are commonly available (sample = 82).*
4.4. Training and communication

In which of the following have you participated?

- COMPRES Workshops
- ** Annual User Meeting at any synchrotron facility
- National School on Neutron and X-ray Scattering (Oak Ridge and APS)
- Synchrotron Environmental Science (SES) Meeting
- Ultrafast X-ray Summer School (CFEL and SLAC)
- SSRL Summer School on Synchrotron X-ray Absorption Spectroscopy
- APS/IIT Summer XAFS School
- *Neutron School in Munich
- *RACIRI Summer school
- *Hercules Synchrotron school
- *IUCr meetings

** Annual user meetings at synchrotron facilities include the following (#counts) = APS (9), NSLS & NSLS-II (4), ESRF (2), SSRL (2), CHESS (1), DESY (1), Beijing SRF (1), SOLEIL (1), CLS (1), LCLS (1), Not defined (5)

Figure 4.16. The participants were asked to list few of commonly advertised educational programs, such as user meetings, workshops and summer schools (sample/#responses=82/60, multiple choice question, *free response option was available).

Are there sufficient training opportunities available for novice users, either through workshops and summer schools or one-on-one support from experts?

- Yes
- No
- Other

- Not sure
- I don't know
- Enough for some techniques, not all, and training opportunities may not reach everyone who needs them
- Probably we need to do better in reaching out to people who don't even know that there are synchrotron techniques that would be useful for them

Figure 4.17. Responses of participants on whether they see sufficient training opportunities available for novice users through workshops, summer schools or one-on-one support experts (sample/#responses=82/70).
The survey’s participants were asked to share any further comments on the topic of training and communication. Below are some of their replies (sample/#responses=82/9):

- “Targeted workshops are useful”
- “Summer schools delayed due to covid”
- “More hands-on training at a beamline would be very useful”
- “We can do more to foster community among trainees in synchrotron techniques, especially when we have no opportunities to meet in person at the beamline”
- “Regarding above, I get enough information by aggressively pursuing it”
- “I would like to see more workshops on analysis procedures, since synchrotron facility staff are often those making the biggest improvements and using the most cutting-edge software”
- “From a staff perspective, I wish some PIs would take a more active role in training”
- “One of the good things that the COVID pandemic revealed to us is how quickly and well we can adapt into the virtual world and how many new opportunities to education and outreach this can allow. Training for new synchrotron/beamline users and analysis software can be done remotely without all the travel and fund limitations. So many more people can be given the opportunity to have a glimpse inside the exciting science that happens at the beamline if only some effort is put into organizing virtual labs/experiments/tours/workshops. It is a lot of work to set those up but once they are established, just imagine all the possibilities that the new generation will have!”
- “I would like to attend them if possible”
4.5. GSECARS beamlines

The GSECARS beamlines are located at APS and are the following:

- 13-BM-D
- 13-ID-E
- 13-ID-C
- 13-ID-D

**Figure 4.19.** Responses of participants when asked if they have ever used the GSECARS beamlines for their experiments (sample/#responses=82/79).

**Figure 4.20.** Responses of participants when asked to list the benefits that GSECARS provide to users (sample/#responses=82/48, multiple choice question, *free response option was available).
The survey’s participants were asked to share those capabilities that are available at the GSECARS beamlines which have been valuable for their research. Below are their responses (sample/#responses = 82/25):

- “Laser heated DAC powder XRD”
- “Extremely high competence of the beam-line stuff”
- “CTR, X-ray reflectivity, grazing incidence spectrosocopies”
- “Large volume press, tomography, X-ray powder diffraction”
- “Combined XRD, laser heating, low T capabilities, Raman spectroscopy”
- “High spatial resolution XANES spectroscopy profile analysis”
- “Raman Lab”
- “Large volume press”
- “Combined diffraction and Brillouin spectroscopy”
- “Single crystal, Crysallis, non-rotational methods, quick changes in energy, gas membrane”
- “Single-crystal and powder XRD, laser heated diamond anvil cell, gas loading”
- “Excellent beamline support staff”
- “XRD”
- “Sample prep lab, Raman spectroscopy, CW and pulsed laser heating”
- “Multi-Anvil press”
- “Online double-sided laser-heating system / offline Raman system”
- “Single crystal X-ray diffraction, Laser heating in the diamond anvil cell”
- “XANES”
- “The membrane system for pressure control has been particularly useful”
- “LHDAC setup”
- “Single crystal XRD”
- “XRD, gas loading system”
- “Reliable, collaborative, and communicative laser heating, beamline staff”
- “XRD single-crystal and powder, Brillouin, high T, high P”
- “Laser heated DAC, Raman lab and knowledgeable/friendly staff”

4.6. COMPRES beamlines

The COMPRES beamlines are located at various synchrotron facilities as listed below:

- 6-BM-B (APS)
- 13-BM-C (APS)
- 3-ID (APS)
- 12.2.2 (ALS)
- 28-ID-2-D (NSLS-II)
Are you a user at COMPRES supported beamlines?

- Yes: 45
- No: 33

**Figure 4.21.** Responses of participants when asked if they have ever used any of the COMPRES supported beamlines for their experiments (sample/#responses=82/78).

What benefits does COMPRES provide to members and users of COMPRES beamlines?

- Knowledgeable beamline staff: 40
- Support for data analysis and interpretation: 30
- *Unique technical capabilities: 20
- Educational opportunities: 10
- Community outreach: 5

* Few of the unique technical capabilities that the participants specified = Development of radial DAC XRD; DDIA; there is more support for data analysis and interpretation, but COMPRES doesn't really support this, the support comes from Stony Brook; West coast HP synchrotron facility / double-sided laser heating in radial geometry; MAP design; Shutter system at 3-ID of APS, high-resolution forward scattering;

**Figure 4.22.** Responses of participants when asked to list the benefits that COMPRES provides to members and users of the COMPRES beamlines (sample/#responses=82/45, multiple choice question, *free response option was available).
The survey’s participants were asked to share those capabilities that are available at COMPRES supported beamlines which have been valuable for their research. Below are their responses (sample/#responses = 82/18):

- “Radial XRD in DAC, with/without laser heating, IR spectroscopy”
- “NRIXS”
- “Opportunity to showcase my research results at the COMPRES Annual Meeting”
- “Single-crystal XRD. Sector 3 facilities as well”
- “DDIA (NSLS and APS) and FTIR (NSLS only)”
- “DDIA & DIASCOPE”
- “FTIR, gas-loading”
- “Other than APS beamlines, many are not so good.”
- “APS 3-ID NRS”
- “HP SXD, in-situ laser heating in radial and axial geometry”
- “Gas loading system @ GSECARS”
- “White X-ray diffraction beamline coupled with Large volume for Deformation experiment”
- “Synchrotron FTIR spectroscopy”
- “XRD and gas loading system”
- “Laser heating, data analysis tool development”
- “XRD high T and high P, NRIXS and Mossbauer at Sector 3”

4.7. Future of geoscience research at extreme conditions using synchrotron facilities

The survey’s participants were first informed that the workshop will close with a roundtable discussion on the future of the high-pressure research at U.S. synchrotron light sources and were then asked if they planned to join this discussion. The 79 responses received in the survey indicated the following answers: Yes (31 counts); Maybe (43 counts); No (5 counts). The final participation is demonstrated in Fig.2.1.

The participants were then asked to list up to 3 immediate synchrotron-based needs for their research. Below are their responses (sample/#responses = 82/28):

- “More access to laser heating techniques (more beamlines?)”
- “Beam size 0.5 μm without tales; diffractometer with confusing sphere less than 1 μm; on-line optical spectroscopy”
- “Combined XRD, spectroscopy, imaging; low-temperature capabilities; on site Raman of high quality”
- “SCXRD, powder XRD”
- “Funding, funding, funding”
- “Powder diffraction from heated (resistive and laser) DACs”
- “Single crystal collection, powder collection, high energies/microdiffraction”
- “Laser heated diamond anvil cell, improved data analysis and processing software; dynamic compression capabilities”
The participants were asked to list up to long-term synchrotron-based needs for their research. Below are their responses (sample/#responses = 82/26):

- “More techniques for in situ high PT and/or more education on techniques currently available”
- “Laser heating for in situ single crystal diffraction in DACs”
- “Thermal conductivity measurements combined with XRD and imaging probes”
- “Funding for research assistance in the form of graduate students and postdocs”
- “Time resolved x-ray phase contrast imaging in DACs would be of interest”
- “Laser heating while collecting single crystal diffraction”
- “Tomography during experiments and torsional strain”
- “Dynamic-DAC, designer anvils, access to beamtime during shutdown”
- “Access to new imaging and diffraction techniques currently developed for metals at ambient pressure”
- “Thermal transport properties at high P-T”
- “LHDAC, single-crystal XRD, Synchrotron Mossbauer Spectroscopy”
- “Sustained access”
- “LVP experiments”
- “More LVP-beamlines”
- “I don’t have long-term needs yet”
- “NFS, IXS, XRS”
- “FTIR capabilities”
- “Imaging in laser heated diamond anvil cell”
- “Time-resolved temperature measurement”
The participants were asked to list the opportunities for improvement or growth that they see in synchrotron-based high-pressure Earth and planetary research. Below are their responses (sample/#responses = 82/20):

- “Coupling techniques in novel ways”
- “Access of pressure range over 500 GPa and study of light elements compounds”
- “Single crystal XRD and time domain XRD combined with pulsed laser heating”
- “New emphasis in synchrotron facility upgrades”
- “Improved sample preparation facilities: better gas loader at APS, better glove boxes, clearer ways to ship materials”
- “Laser heating while collecting single crystal diffraction”
- “More cooperative, accessible, inclusive”
- “More crustal work”
- “Access to larger sample volumes, improved temperature measurements”
- “Undergraduate support”
- “Nanofocus beam, high-resolution XRD and laser-heating in the DAC for ultra-high-pressure research, Energy-domain Synchrotron Mossbauer Spectroscopy”
- “Laser heating associated to X-ray Raman”
- “Synchrotron-based research provide access to details on the behavior of matter that are pivotal to understand planetary interiors. Overcoming technical limitation will provide the means to pass the first layer of knowledge and investigate more complex questions that involve also the dynamic aspects at extreme conditions”
- “Upgrades, strong communities and networks”
- “More multi-crystal diffraction experiments combined with easier-to-use analysis tools”
- “More tools to identify chemical gradients after heating a DAC sample -- XRF, XANES, and/or the XRD technique where the X-ray energy is tuned (a) below and (b) above the K-edge of an element of interest”
- “Advancements in in-situ determination of high temperatures (e.g., laser heating)”
- “Pushing to higher pressures and temperatures”
- “Quantitative measurement techniques are needed”
- “In-situ laser heated single-crystal X-ray diffraction, smaller and cleaner beam to study sample at multi-mbar conditions in the DAC”
- “To know the recent techniques”
Upcoming facility upgrades inherently mean change, and in some cases may require the retirement of certain programs. The participants were asked if they are concerned about threats to synchrotron research capabilities that are important to them. Below are their responses (sample/#responses = 82/26):

- “Yes”, “No”, “Yes! Of course”, “Sure”, “Not yet”
- “Not to me, but certainly for my colleagues”
- “For the time being no”
- “No, because I am open to new techniques to apply to my research”
- “Yes, closure of facilities seen as "routine" would be devastating, and disproportionately to groups with fewer resources. Only a select few labs have enough funding and space to build their own gas loading, laser heating, etc.”
- “Yes, especially the impact it will have on synchrotron Mossbauer techniques”
- “Mossbauer Spectroscopy”
- “I am somewhat concerned about the fate of GSECARS and beamlines which mostly support earth science research although admittedly I have not been much involved in this discussion as a graduate student. Myself and others in the group have relied heavily on the capabilities at GSECARS for our high-pressure powder diffraction work”
- “Synchrotron Mössbauer Spectroscopy”
- “Techniques that require specific ring timing modes, e.g. nuclear inelastic scattering and others may be severely affected from certain upgrade projects and this is worrisome, because such techniques provide unique information not obtainable otherwise”

The participants were asked to list the combination of experimental techniques (synchrotron-based or not) that would serve best for their research purposes. Below are their responses (sample/#responses = 82/21):

- High PT with in situ X-ray techniques, maybe more offline analytical techniques like electron microprobe (WDS)”
- “Thermal conductivity measurements combined with XRD and imaging probes”
- “I would like more education / information / workshops in what current and new experimental techniques could be used in my research”
- “Single crystal + powder diffraction at high P-T”
- “Laser-heated diamond anvil cell”
- “I am quite invested in using the DDIA with ultrasonics”
- “FTIR, single crystal XRD, and NRIXS in DACs”
- “X-ray diffraction at non-ambient conditions - beyond DACs”
- “Large volume”
- “PXRD + FIB + XAS/ASEM/other (basically be able to perform chemical analysis in-situ at high-pressure AND/OR be able to conduct a synchrotron experiment and immediately after be able to perform textural and chemical analysis on recovered samples”
- “5000t LVP”
- “Laser heating + inelastic scattering”
“Dominantly X-ray diffraction and Mössbauer spectroscopy”
“LHDAC and tomography”
“Imaging and XRD”
“Powder, single-, and poor-crystal x-ray diffraction”
“Synchrotron x-ray diffraction and FTIR”
“High P-T DACs and LVPs with high-brilliance X-rays”
“XRD, imaging”
“Micromotography and X-ray diffraction in the DAC or diamond inclusions, Mossbauer spectroscopy and X-ray diffraction in the laser-heated DAC”
“Analytical STEM with EDS and EELS”

Finally, the participants were asked to share any additional topics that they would like to have covered at the Discussion Sessions. Below are their responses (sample/#responses = 82/6):

“More flexible beamtime scheduling”
“Funding, plans for increasing diversity in STEM fields, help with recruitment of new students and postdocs”
“Currently, what is the typical division of labor between a PhD student, their PhD advisor, and the synchrotron staff? More specifically, how much assistance are synchrotron staff prepared to provide in sample preparation and in data analysis? Are more resources needed to facilitate high-quality sample preparation and data analysis?”
“How to reach out and spread the news to colleagues that are not aware of all the capabilities one can find in synchrotrons or those who are confused by the system on how to apply and get beamtime thus feel discouraged to do so. Are workshops like this enough? New users bring new ideas and shape the future of the synchrotron-based research so they deserve our time and best efforts to introduce more and more of them in the great world of synchrotron.”

4.8. Funding sources

![National Science Foundation](image.png)

**Figure 4.23.** Responses of participants when asked to list the NSF programs that support their synchrotron-based research (sample/#responses=82/43, multiple choice question).
Figure 4.24. Responses of participants when asked to list the DOE programs that support their synchrotron-based research (sample/#responses=82/27, multiple choice question).

Figure 4.25. Responses of participants when asked to list other US government programs that support their synchrotron-based research (sample/#responses=82/11, multiple choice question).

Figure 4.26. Responses of participants when asked to list other than the aforementioned funding sources that support their synchrotron-based research (sample/#responses=82/21, multiple choice question). Specified entries indicate funding from one of the following (#counts): university fundings (2); DFG, BMBF (3); KAKENHI (1), FAPESP, Serrapileira (1), ERC (1), CNRS, ANR (1), DOD (1), Korean Ministry of science and education (1).
4.9. Other demographics

![Pie chart showing country distribution](chart.png)

*Other countries (#counts) = Brazil (1); China (1); India (1); South Korea (1); Spain (1); Sweden (1);

**Figure 4.27.** The survey’s participants were asked to indicate their country location (sample/#responses=82/79). See related figure in section 2 (Fig. 2.2)

![Bar chart showing state distribution in the United States](chart.png)

**Figure 4.28.** Those who replied “USA” in the Fig. 4.27. were asked to specify the state (sample/#responses=60/53). See related figure in section 2 (Fig. 2.3)
Figure 4.28. The survey’s participants were asked of their age (sample/#responses=82/78).

Figure 4.29. The survey’s participants were of their gender (sample/#responses=82/77).

Figure 4.30. The survey’s participants were asked of their ethnicity (sample/#responses=82/65).

Figure 4.31. The survey’s participants were asked of their race (sample/#responses=82/71).
Figure 4.32. The survey’s participants were asked of their career stage (sample/#responses=82/80). See related figure in section 2 (Fig. 2.8)